

Planar Transformer Core Selection Complete Guide: Material, Geometry & Parameter Calculation

For Switch-Mode Power Supplies, Motor Drives, Server Power Units, Automotive OBC, PV & Energy-Storage Power Modules.

Planar transformers deliver ultra-low profile, high power density, and native PCB-integrated winding capability, making them a mainstream solution for fast chargers, modular power supplies, motor drive converters, on-board chargers (OBC), and photovoltaic energy-storage equipment.

Core selection is the most critical step in planar transformer design. Poor core material choice brings excessive high-frequency core loss and abnormal temperature rise. Improper mechanical geometry wastes enclosure space, raises leakage inductance, and violates system height constraints. Missing parameter validation may trigger magnetic saturation and catastrophic hardware failure.



Many hardware engineers face repeated design iterations due to incorrect core selection: over-temperature at full-load, unexpected saturation under worst-case duty cycle, higher-than-target leakage inductance, or mechanical stack-up conflict with enclosure limits.

This practical, production-oriented guide provides a step-by-step workflow for planar transformer core selection, covering material matching, core geometry comparison, and parameter validation. It serves as reference for both power design engineers and component purchasing engineers working on industrial, automotive, data-center and renewable-energy projects.

1. Magnetic Core Material Selection: Match by Operating Frequency & Power Rating

Core material determines maximum usable frequency, core-loss performance, thermal resistance, and achievable power density. Material grade shall be confirmed **before selecting core mechanical dimensions**.

1.1 MnZn Ferrite – General-Purpose Workhorse for SMPS

Operating Frequency Range: 10kHz ~500kHz

Typical commercial grades:



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- PC40: Optimized for conventional 100 kHz switching power supplies
- PC95 / PC98: High-frequency grades for 200 kHz up to 1 MHz operation

Key advantages: Low high-frequency core loss, stable batch-to-batch consistency, mature mass-production supply chain, excellent cost-performance.

Typical Applications: Low-to-medium-power systems within 2 kW, including flyback, LLC resonant, forward converter topologies; server auxiliary power, industrial motor auxiliary power supply.

1.2 Nanocrystalline Alloy – Preferred for High-Frequency High-Reliability High-Power Designs

Operating Frequency Range: 1 kHz~500 kHz

Key advantages: Wide frequency bandwidth, outstanding high-temperature stability, smaller footprint at equal power throughput, lower power loss compared with ferrite solutions.

Typical Applications: Automotive on-board charger(OBC), charging station power stages, photovoltaic inverters, heavy-duty industrial power supplies, high-power energy-storage modules.

1.3 NiZn Ferrite – Specialized for Ultra-High-Frequency Small-Signal Circuits

Operating Frequency Range: 500 kHz~10 MHz+

Key advantages: Stable ultra-high-frequency magnetic performance, excellent EMI suppression capability.

Typical Applications: RF circuits, wireless power transfer assemblies, high-frequency EMI filter cores.

1.4 Planar-Optimized Custom Ferrite

Custom-formulated for low-profile hardware requirements. Ultra-low stacking height enables seamless stack integration with multi-layer PCB windings.

Typical applications: Slim fast-charging adapters, low-profile modular power supplies, end products with strict total height constraints.



Core Material	Operating Frequency	Key Benefits	Primary Limitations	Representative Use Cases
MnZn Ferrite	10k ~ 500kHz	Low high-frequency loss, cost-effective, proven mass-production	Moderate high-temperature threshold	General-purpose SMPS, LLC / flyback / forward converters, server auxiliary power
Nanocrystalline Alloy	1 k ~500kHz	Compact footprint, superior high-temperature performance, excellent high-power capability	Higher unit material cost	Automotive OBC, charging infrastructure, PV inverter, high-power energy-storage modules
NiZn Ferrite	500k~ 10MHz+	Stable ultra-high-frequency response, strong EMI suppression	Poor power-handling capacity	RF circuitry, wireless power transfer, high-frequency EMI filters
Planar-Optimized Ferrite	10k ~ 500kHz	Ultra-low stack height, compatible with PCB winding stack-up	Custom grade may increase lead-time	Slim fast-chargers, height-limited compact power modules

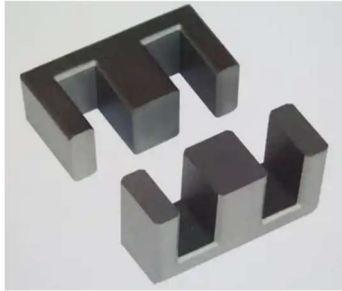
2. Magnetic Core Geometry Selection: Match by Power Output, Mechanical Constraints & Leakage-Inductance Target

Once material grade is locked-in, select core geometry based on output power, enclosure dimension, maximum allowable assembly height, and target leakage inductance

Important note for planar magnetics: Total stack-up height, winding window area (A_w) , effective cross-sectional area (A_e) are three non-negotiable geometry indicators for PCB-winding transformers.

2.1 EE / EI / E-Type Cores

Characteristics: Large winding window area, good thermal dissipation, lowest overall component cost, broad general-purpose compatibility.



Limitations: Moderate magnetic shielding performance; relatively higher leakage inductance.

Best-fit scenarios: Low-to-medium-power, high-current switching power supplies, motor drive auxiliary power.

2.2 RM Pot-Style Cores

Characteristics: Round centre leg shortens winding turn length and reduces copper loss; partial inherent magnetic shielding, relatively low leakage inductance.

Limitations: Relatively small winding window area.

Best-fit scenarios: Medium-to-high-power systems with low-voltage high-current requirements; energy-storage converter modules.

2.3 ER / ETD-Type Cores



Characteristics: Combine spacious winding window of E-type cores and low-loss round centre leg of RM-style cores; versatile for high power-density design.

Best-fit scenarios: Medium-to-high-power systems with low-voltage high-current requirements; energy-storage converter modules.

2.4 PQ-Type Cores

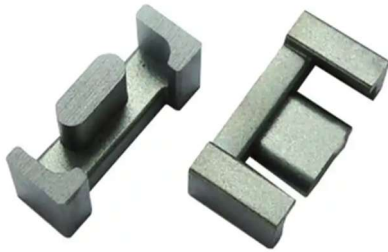


Characteristics: Deliver extreme power density and high window-utilization ratio within compact footprint.

Limitations: Higher component cost.

Best-fit scenarios: Premium compact high-power power-conversion hardware, high-density server power modules.

2.5 EEL / EPC Planar Cores



Characteristics: Extremely flattened, ultra-low-height geometry purpose-built for planar transformers; fully compatible with multi-layer PCB winding stacking workflow.

Best-fit scenarios: All slim height-restricted precision power systems, fast-charger adapters, low-profile data-center power units.

Core Model	Core Characteristics	Optimal Application Scenarios
EE/EI/E-Type	Large winding window, good heat dissipation, cost-efficient	General-purpose low-to-medium-power high-current power supplies, motor drive auxiliary power
RM-Type	Low leakage inductance, partial self-shielding, minimized copper loss	Compact multi-output low-to-medium-power SMT power supplies
ER/ETD-Type	Balanced winding window capacity and low-loss performance	Medium-to-high-power, low-voltage high-current energy-storage & industrial converters
PQ-Type	Outstanding power density, compact mechanical outline	Premium compact high-power server & industrial power-conversion hardware
EEL/EPC Planar	Low-profile planar-optimized geometry, PCB-stack-friendly	Height-constrained slim modules, fast-charging adapters, low-profile data-center power

3. Critical Parameter Calculation & Validation (Must-Do Before Final Core Specification Freeze)

Correct material and geometry alone are insufficient. Rigorous parameter validation prevents magnetic saturation, thermal runaway and insufficient inductance performance, especially critical for planar transformers with fixed PCB winding layout (hard to modify after PCB release).

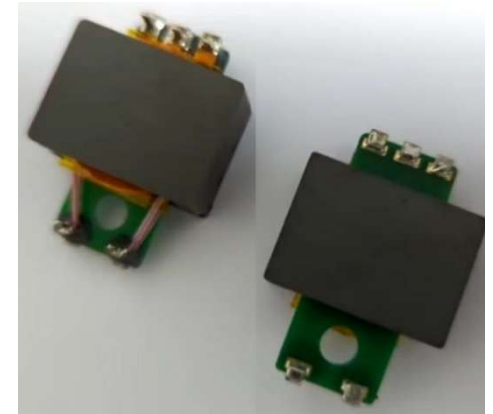
3.1 Area-Product (AP) Method for Core Power Capability Evaluation

Formula: $AP = A_e \times A_w$

- A_e : Effective magnetic cross-sectional area of the core
- A_w : Winding window area

AP value quantifies theoretical power-handling capability of a magnetic core. Cross-reference AP value with operating frequency, peak flux density (B_m) , and winding current density to guarantee sufficient saturation margin under full-load and worst-case operating conditions.

Practical engineer tip: Never select core purely by physical size. Same outline dimension with different material grades may deliver very different actual power capacity.



3.2 Magnetic Flux Density & Temperature-Rise Verification

1. Refer to official core-loss curves corresponding to your switching frequency to calculate working peak flux density B_m .

Reserve adequate saturation margin under maximum duty-cycle, input-voltage corner conditions.

2. Design target: **maximum temperature rise $\leq 50\text{ K}$** , to mitigate long-term reliability risk introduced by high-frequency core loss. Common failure root-cause: Engineers only check room-temperature saturation flux density while ignoring core loss induced temperature drift.

3.3 Stack-Up Height Mechanical Verification (Planar-Specific Check Item)

For planar transformer assemblies, height tolerance is extremely critical.

Total assembled height = Core thickness + PCB winding stack thickness + insulating clearance gap



Confirm the calculated total stack-up height satisfies mechanical height limit of system enclosure. Stack-up conflict will force PCB revision or core re-selection in later project phase.

4. Practical Core-Selection Decision Framework

Use this framework for preliminary short-listing core options:

- i. **Cost-sensitive low-to-medium-power projects: MnZn ferrite material + E-type or ER-type core geometry**
- ii. **High-power, high-temperature, high-reliability deployments (OBC / energy-storage / industrial): Nanocrystalline alloy + RM or ETD-type core geometry**
- iii. **Ultra-high-frequency small-signal filtering: NiZn ferrite cores**
- iv. **Slim height-limited hardware with PCB-integrated windings (fast-charger, slim server PSU): Prioritize EEL / EPC dedicated planar cores**

Important Note after preliminary selection: Perform final cross-checking against converter topology (LLC, flyback, forward), flux swing amplitude, duty-cycle range, target inductance, and leakage-inductance specification before freezing BOM part-number.

5. Frequently Asked Questions (FAQ)

Q1: Can I directly replace wire-wound transformer core with planar core of same AP value?

A: Not recommended. Planar transformers adopt PCB windings with different window-utilization factor, copper AC loss and thermal path. Re-run flux density and temperature-rise validation even for same AP value.

Q2: What is the most frequent mistake in planar core selection?

A: Ignoring mechanical stack-up height and insufficient saturation margin at worst-case corner conditions. PCB winding cannot be easily adjusted like traditional enameled wire windings, mistake leads to costly PCB re-spin.

Q3: Nanocrystalline alloy vs MnZn ferrite for OBC planar transformer, how to trade-off?

A: Nanocrystalline delivers better high-temperature performance and smaller size but higher BOM cost. MnZn high-grade ferrite (PC98 equivalent) works well for cost-constrained OBC projects within reasonable power range.



Q4: How much temperature-rise margin should I reserve for energy-storage planar transformer?

A: Target temperature rise ≤ 50 K under full-load. For energy-storage applications with long-duration continuous operation, extra thermal margin is strongly advised.

6. Core-Selection Key Takeaway

The logical three-stage workflow for planar transformer core selection:

1. **Material definition:** Select core material grade driven by operating frequency and target power rating.
2. **Geometry screening:** Pick core shape according to available physical space, stack-up height, leakage-inductance and thermal requirement.
3. **Final validation:** Confirm core part-number via AP calculation, magnetic saturation check, thermal simulation and mechanical stack-up verification.

Improper core selection will bring heavy redesign cost in hardware projects. For custom planar transformer specification support, you may reach out to our magnetic component engineering team.