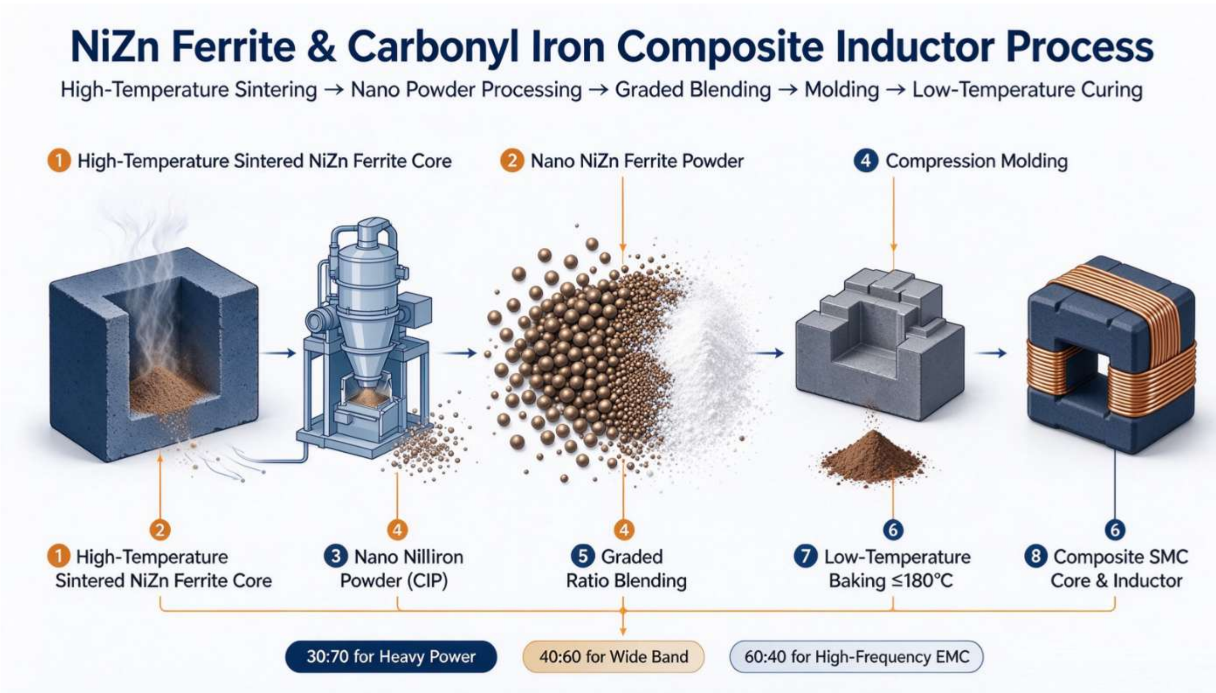
Optimized NiZn Ferrite & Carbonyl Iron Composite Inductors: — Performance & Applications

Manufacturing Process Overview

Production workflow: High-temperature sintered Ni-Zn ferrite blocks → Jet milling & classification to produce nano-scale Ni-Zn ferrite powder; High-purity spherical carbonyl iron powder (CIP). Three mass ratios are adopted for differentiated working conditions: 30wt% NiZn:70wt% CIP, 40wt% NiZn:60wt% CIP, 60wt% NiZn:40wt% CIP. The mixed powder is blended homogeneously with organic insulating binder, compression molded and cured under low temperature (≤180℃) to form SMC composite cores, then wound with flat enameled wire to manufacture integrated power & EMC composite inductors. The original 50:50 equal ratio suffers compromised performance on both low & high frequency sides with concentrated defects. The below graded ratios mitigate inherent drawbacks and realize scenario-oriented balanced electromagnetic performance.



A. Pros & Cons of Three Graded Composite Core Inductor Formulas

Grade 1: Heavy-Duty High Power Scenario – 30wt% Nano NiZn Ferrite : 70wt% Carbonyl Iron Powder

Core Advantages

1. Superior saturation flux density & DC bias resistance: High CIP proportion delivers Bs = 1.1～1.3T, permeability retention ≥82% under 100Oe DC bias, eliminating severe saturation of pure NiZn cores under heavy DC superposition. For identical inductance, footprint is reduced by 25% vs 50:50 ratio; winding turns cut by 20%～35% with drastically lower DC winding resistance.

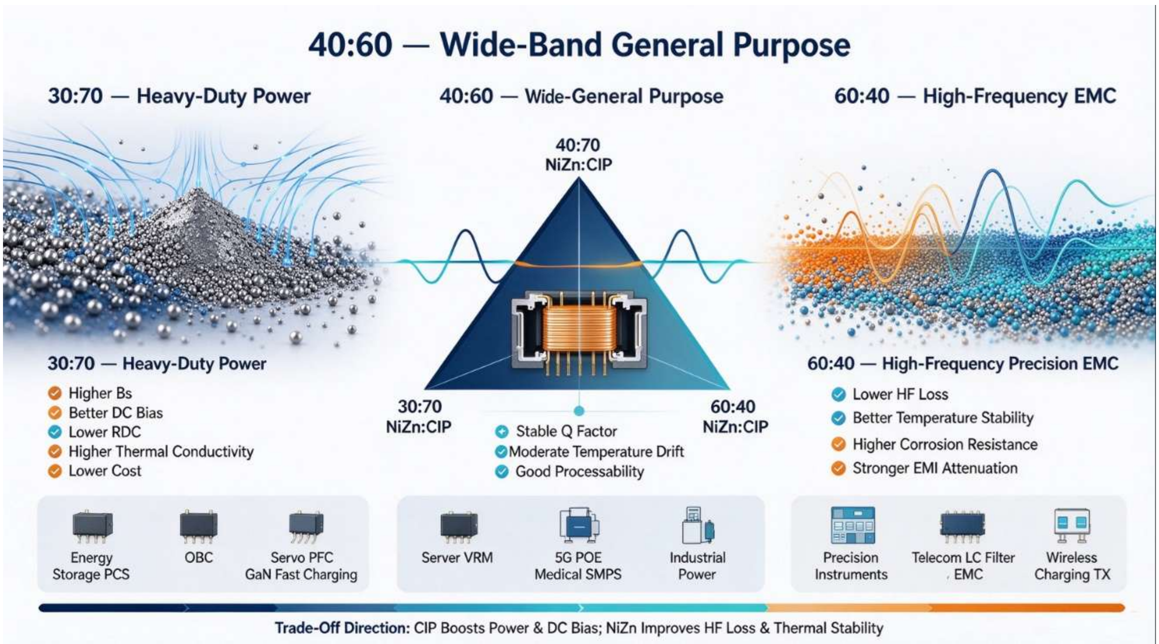
2. Improved thermal conductivity & mechanical robustness: Low content of brittle ceramic ferrite boosts impact & drop resistance by 45%. Continuous metallic flux & heat conduction channels suppress thermal accumulation under 30~50A full load; temperature rise drops 12～18℃ without auxiliary heat sinks.
3. Optimized mass production cost: Nano NiZn ultrafine powder bears high processing cost; 30% dosage cuts total material cost by 22%～28% compared to 50:50 blend, ideal for mass power supply manufacturing.
4. Basic wideband EMI compatibility: Nano NiZn uniformly coats metal particles to build insulating barriers, suppressing eddy current loss from 10kHz to 120MHz vs pure carbonyl iron cores. It integrates low-frequency energy storage & mid-band noise attenuation, replacing discrete power inductor + filter ferrite ring to simplify PCB layout and BOM count.
5. Stable environmental reliability: Ceramic phase isolates moisture & oxygen, delivering oxidation & salt-spray resistance superior to all-metallic SMC cores within -40℃～130℃ operating range.

Inherent Drawbacks

1. Elevated core loss above 120MHz: Excessive metallic powder triggers severe spin resonance & eddy current loss beyond 200MHz, unsuitable for RF high-frequency filtering.
2. Moderate permeability temperature drift: Low NiZn content leads to larger inductance fluctuation under medium-high temperature than 60:40 formula, requiring simple temperaturecompensation for precision temperature-controlled equipment.
3. Weaker high-frequency EMI attenuation vs high-NiZn ratios: Noise suppression above 100MHz is inferior to 40wt% & 60wt% NiZn systems.

Target Applications

Portable outdoor energy storage PCS, 48V automotive OBC on-board charger, micro solar inverter, industrial servo PFC inductors, ≥200W GaN high-power PD molded inductors, forklift low-voltage DC-DC buck-boost inductors.



Grade 2: Wide-Band General Industrial & Telecom Scenario – 40wt% Nano NiZn Ferrite : 60wt% Carbonyl Iron Powder

Core Advantages

1. Optimal balanced all-around performance: Combines high saturation flux of metallic phase and low high-frequency loss of ceramic phase. Effective permeability μe ranges 25～72, covering full low-to-medium current power levels with flat loss curve & stable Q factor across 10kHz～150MHz.
2. Triple balance of cost, heat dissipation & temperature drift: Material cost reduced by 12%～18% vs 50:50 ratio; temperature rise drops 10～15℃ under 10～30A mid-current; permeability temperature coefficient lowered by 30% vs 30:70 formula, eliminating compensation circuits for most industrial & telecom power supplies.
3. Integrated EMC power solution: 40% high-resistivity nano NiZn suppresses MHz-band eddy current loss, supporting simultaneous low-frequency current limiting & conducted noise attenuation below 150MHz, compatible with high-density SMD packaging for server & 5G hardware.
4. High molding process compatibility: Low-temperature curing avoids thermal deformation, supporting ultra-thin SMD, through-hole & flat high-current packages with higher mass yield than extreme high/low NiZn ratios.
5. Excellent humidity & heat resistance: Complete ceramic insulation layer coats metal particles, free of oxidation degradation under long-term humid server & automotive operating conditions.

Inherent Drawbacks

1. Inferior extreme high-current performance vs 30:70 blend: Permeability degradation & higher temperature rise under continuous load over 50A.
2. Higher ultra-high frequency loss (>200MHz) than 60:40 ratio: Suboptimal for RF & precision high-frequency filtering components.
3. Limited maximum permeability vs all-metallic SMC: Unable to design ultra-high inductance cores with μe＞75, restricted selection for low-frequency high-inductance inductors.

Target Applications

Server VRM step-down inductors, 5G base station POE power inductors, high-frequency medical SMPS, wide-input industrial control power supplies, network switch EMC composite filter inductors, small energy storage bidirectional converters.

Grade 3: High-Frequency Precision EMC & Test Instrument Scenario – 60wt% Nano NiZn Ferrite : 40wt% Carbonyl Iron Powder

Core Advantages

1. Ultra-low loss at ultra-high frequency: 60% high-resistivity nano NiZn forms multi-layer insulation network, cutting core loss by over 40% at 150～200MHz compared to 50:50 blend, drastically suppressing eddy current & spin resonance loss to resolve high-frequency loss defect of pure metallic cores.

2. Outstanding temperature stability: Increased ceramic phase reduces permeability temperature drift coefficient by 50%; inductance fluctuation controlled within ±5% from -40℃ to 130℃, fully compliant with precision measurement instruments.
3. Top-tier corrosion & oxidation resistance: Dense NiZn ceramic matrix isolates air and moisture, maintaining stable performance for long-term outdoor communication & railway salt-spray environments.
4. Maxed-out EMI filtering capability: Superior high-frequency noise attenuation vs 30:70 & 40:60 ratios, simplifying LC filter circuit design at equipment power inlet and reducing filter component count.

Inherent Drawbacks

1. Degraded DC saturation performance:Only 40% carbonyl iron leads to Bs = 0.8～1.0T; permeability retention merely 55%～65% at 100Oe DC bias, not applicable for continuous current over 15A.
2. Low maximum permeability: μe limited to 10～45; more winding turns required for target inductance, resulting in elevated DC resistance and minor system conduction loss.
3. High raw material cost:Large dosage of nano NiZn powder raises unit cost by 25%～32% vs 30:70 blend, poor cost performance for high-power equipment.
4. Weak mechanical strength: Brittle ceramic phase dominates the matrix, with the worst drop & shock resistance; structural reinforcement required for ultra-small thin components.

Target Applications

Precision test & measurement instrument power supplies, LC composite filter inductors for telecom power inlet, railway conducted interference suppression magnetic components, mid-low power wireless charging transmitter cores, RF front-end low-frequency chokes.

B. Universal Shared Advantages of All Three Graded Ratio Inductors

1. Flexible integrated molding process: Low-temperature curing ≤180℃ eliminates sintering deformation, supporting coil pre-embedded one-shot molding for ultra-thin miniaturized SMD packages, reducing overall device size by over 30% vs discrete ferrite + metal magnetic rings.
2. Synergized soft magnetic performance: Nano NiZn delivers high-frequency insulation & low loss while carbonyl iron provides high saturation energy storage. Single component realizes both power transmission and EMI noise suppression, simplifying PCB layout and cutting BOM parts count.
3. Integrated powder insulation without secondary coating: Nano NiZn naturally encapsulates carbonyl iron particles during blending, eliminating phosphating or silane insulation coating procedures, shortening production lines and lowering process defect rate.
4. Broader frequency bandwidth than single magnetic material: Stable operation from 10kHz to 150MHz (up to 200MHz for 60:40 ratio), covering mainstream working frequencies of energy storage, automotive, telecom & industrial power supplies.

5. Sufficient customized tuning range: Yetcoil adjusts NiZn proportion within 30～60wt%, together with molding density and binder content, to target core loss, DC bias and temperature drift per client requirements.

C. Universal Shared Inherent Disadvantages of All Three Graded Ratio Inductors

1. Lower maximum permeability than all-metallic SMC cores: Ceramic phase dilutes permeability; all formulas have lower μe ceiling than FeSiAl & High-Flux pure metal cores, limiting selection for low-frequency ultra-high inductance inductors.
2. Higher base cost than single carbonyl iron powder cores: Dual-powder batching and nano-powder preparation raise process complexity, not cost-effective for entry-level low-cost chargers & adapters.
3. Inferior thermal conductivity vs 100% carbonyl iron cores: Poor heat conduction of ceramic phase disables continuous operation above 50A without dedicated heat dissipation.
4. Intrinsic mechanical brittleness boundary: Drop & shock resistance degraded vs all-metallic powder cores; shell reinforcement mandatory for vehicle vibration & heavy outdoor impact scenarios.
5. Suboptimal performance for dedicated ultra-high frequency RF devices: Loss performance above 200MHz millimeter wave & RF filters remains worse than 100% pure nano NiZn ferrite toroids.

D. Expert Conclusion & Yetcoil Service CTA

The original 50:50 equal-mass blending ratio lacks scenario targeting, compromising both low-frequency power and high-frequency filtering performance, and has been fully replaced by the three graded optimized formulas:

1. High-power energy storage, heavy-load automotive & fast charging → 30%NiZn+70%CIP, prioritizing saturation, heat dissipation and cost optimization;
2. Servers, 5G telecom & general industrial power supplies → 40%NiZn+60%CIP, balanced core loss, DC bias and temperature stability;
3. Precision instruments, high-frequency EMC filters & railway outdoor equipment → 60%NiZn+40%CIP, optimized ultra-high frequency loss & wide-temperature performance.

Changsha Yuyang Magnetics Co., Ltd. (Yetcoil) owns full industrial chains including self-developed nano NiZn powder jet milling, graded powder blending and integrated molded inductor mass production. We customize composite inductors with matched powder ratios per client’s current, frequency, dimension and temperature drift specifications, supplying complete core loss & DC bias test datasets and official technical selection guides.