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EMI & Common-Mode Magnetics: The Selection Reference (Pillar)

Impedance curves, core materials, winding structure and validation — one map for CM chokes

Item	Detail
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Document	EMI & Common-Mode Magnetics — Selection Reference (Pillar)
Scope	Common-mode chokes & EMI magnetics across SMPS, EV, PV/ESS, datacenter
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Summary & key takeaways

Bottom line

A common-mode choke exists to insert high impedance into the common-mode noise path while staying nearly transparent to differential (working) current. Selection is three steps: (1) define the noise band and limit (conducted EMI 150 kHz–30 MHz) → (2) pick the core material by band (MnZn ferrite strong low-mid, nanocrystalline extremely strong at low frequency in a small size, NiZn for >10 MHz) → (3) size the winding by current and rise (flat wire for high current; leakage doubles as DM filtering but must be checked for saturation). Read the impedance-frequency curve and half the selection is done.

Key takeaways:

- **CM vs DM:** common-mode flows in phase on both lines to ground; differential flows line-to-line. The choke is high-Z to CM and ideally zero to DM — which is why working current does not saturate it.
- **The impedance curve is the selection language:** check Z-f in your failing band; one part rarely covers the whole band — two stages or mixed materials are common.
- **Materials split by band:** nanocrystalline (low-frequency, few turns, compact), MnZn ferrite (mid-band, economical), NiZn (>10 MHz).
- **Leakage cuts both ways:** it doubles as DM filtering but saturates with working current and heats up — control it at high current.
- **High through-current is the trend:** EV/PV/datacenter chokes carry tens to hundreds of amps — flat wire plus thermal design is becoming standard.
- **Two-stage integration saves space:** asymmetric wire gauges and dual cores integrated in one part (see the two-stage article).

Note A ProMagTech engineering reference (not an official standard); the third selection pillar, sister to the 800 V and Solar/ESS references.

1. What this reference is and how to use it

ProMagTech's third selection pillar: it unifies common-mode choke selection — noise mechanism, impedance curves, materials, windings, validation — in one place, linking the three CM deep-dives and cross-cutting methodology. Three steps: sort CM vs DM in §2; pick material by band and winding by current in §3–4; set the DVP from §6, going deeper via §9.

2. First, separate the noise: common-mode vs differential

Dimension	Common-mode (CM)	Differential (DM)
Path	both lines in phase → ground (via parasitic C)	out one line, back the other
Source	switch-node dv/dt through parasitic capacitance	switching current ripple
Fix	CM choke + Y capacitors	DM inductor + X capacitors
Band (typical)	hundreds of kHz–30 MHz and above	150 kHz–a few MHz

Table 1 — CM vs DM (conducted EMI test range 150 kHz–30 MHz)

How the choke works: the two windings are wound so working (DM) current fluxes cancel — hence no saturation from load current; CM current fluxes add and meet high inductive impedance. That asymmetry — transparent to DM, high-Z to CM — is its entire value.

3. Impedance curves and core materials: divide the band

The selection language is the impedance-frequency (Z-f) curve: is impedance high enough in your failing band. Every material's Z-f peaks somewhere, so materials divide the band:

Material	Strong band	Traits	Typical use
Nanocrystalline	10 kHz–1 MHz	very high μ, few turns, compact, high Bsat	EV OBC, PV/ESS high-current CM
MnZn ferrite	100 kHz–2 MHz	economical, widely sourced	general SMPS input filters
NiZn ferrite	>10 MHz	good HF impedance	HF fill-in, radiated fixes
Amorphous	10 kHz–500 kHz	nanocrystalline-like, slightly cheaper	industrial supplies

Table 2 — CM core materials by band (typical magnitudes; per measured curves)

> CM impedance: $Z(CM) \approx 2\pi \cdot f \cdot L(CM)$ (low band; at HF winding parasitic C takes over)
> HF roll-off: inter-turn C(p) resonates with L(CM); above resonance Z falls → sectioned winding / fewer turns / two-stage

> **Key** The HF impedance collapse is caused by winding parasitic capacitance, not the material — sectioned windings, fewer turns, or adding a small HF stage beat changing material.

4. Winding and structure: the high-current era

- **Flat-wire windings:** EV/PV/datacenter chokes carry tens to hundreds of amps; flat wire cuts DCR and rise — now standard for high-current CM.
- **Using and controlling leakage:** leakage doubles as the DM inductor and saves a part; but its flux path saturates with load current and heats locally — check at worst-case current.
- **Creepage and insulation:** between windings per safety standards (barriers/separators); reinforced insulation at high voltage (800 V).

- **Two-stage integration:** a low-frequency stage (nanocrystalline, high L) plus an HF stage (ferrite, small L) in one part, asymmetric gauges optimizing the window.
- **Audible noise:** CM current with audio content excites magnetostriction; fix with material choice, varnish/potting and control strategy.

5. Application quick-reference

Application	Typical configuration	Axis focus
General SMPS input (<2 kW)	MnZn single stage	impedance coverage, cost
EV OBC / on-board (11–22 kW)	nanocrystalline + flat wire, or two-stage	through-current, automotive, rise
PV inverter / ESS PCS	nanocrystalline high-current CM + HF stage	current, outdoors, efficiency
Datacenter power (PSU/rack)	nanocrystalline/ferrite two-stage	density, low profile, rise
DC-side CM (PV/ESS)	nanocrystalline (large DC through-current)	impedance retention under bias
Radiated-emission fixes	NiZn rings/clamps + layout	targeted HF fill-in

Table 3 — Application—configuration—axis quick reference

6. Validation & quality baseline (DVP)

Validation item	Method / instrument	Acceptance (example)
CM impedance curve	impedance analyzer	Z ≥ spec in target band
CM inductance L(CM)	LCR	target ± spec %
Leakage L(leak)	LCR (other side shorted)	target ± spec %, saturation checked
DCR / temperature rise	micro-ohm meter / ΔDCR	≤ spec / ≤ limit
Insulation / hi-pot	hi-pot (winding-to-winding)	per safety class
Impedance under current	biased impedance test	Z holds at working current
System EMI verification	EMI receiver (conducted 150 kHz–30 MHz)	passes limit (e.g. CISPR 32/25)
Batch consistency	sampling	spread < ±spec %

Table 4 — Common validation baseline for CM chokes (acceptance per project)

> **Reminder** The final verdict on a CM choke is the system EMI scan, not component parameters — the component DVP is necessary, the system pass is sufficient. Involve the system EMI engineer from the design stage.

7. Frequently asked questions (FAQ)

Q Why doesn't load current saturate a CM choke?

A The two windings carry working (DM) current with opposing, cancelling fluxes, so net core flux is near zero. What actually saturates it is CM current and the leakage flux — which is why leakage saturation must be checked at high current.

Q Nanocrystalline or ferrite?

A By band and current: for low-band impedance or compact high-current parts → nanocrystalline; mid-band and cost-sensitive → MnZn ferrite; >10 MHz fill-in → NiZn. The EV/PV high-current trend is nanocrystalline + flat wire.

Q Why does impedance collapse at high frequency?

A Winding inter-turn capacitance resonates with the CM inductance; above resonance the part turns capacitive. Fixes: sectioned windings, fewer turns, or add a small HF stage — not simply a different material.

Q What's the cost of using leakage as the DM inductor?

A It saves a part, but the leakage flux path saturates with load current and adds local heating and radiation. Check leakage saturation and rise at worst-case current, or use a separate DM inductor.

Q Do CM chokes make audible noise?

A They can: audio-band CM current excites magnetostriction. Fixes: low-magnetostriction material/process, varnish/potting, and control strategies that avoid the audio band.

Q Component passes, system still fails EMI — now what?

A The choke is one link: Y-cap placement, grounding, layout parasitics and shielding all matter. Work backward from the failing band — low-band failures point to CM inductance, high-band to parasitics and layout — then decide between part and layout changes.

Q What can ProMagTech deliver in CM?

A MnZn/nanocrystalline chokes, high-current flat-wire CM, two-stage integrated CM; DVP data including impedance curves, leakage, rise and impedance-under-bias, plus joint debugging support for system EMI.

8. Glossary

- **Common-mode noise (CM) —** Noise flowing in phase on both lines, returning via ground parasitics.
- **Differential-mode noise (DM) —** Noise flowing line-to-line, sharing the working-current path.
- **Impedance-frequency curve —** The choke's CM impedance vs frequency — the core selection evidence.
- **Leakage inductance —** The uncoupled part of the windings; doubles as DM filtering but can saturate.
- **Nanocrystalline —** Ultra-high-permeability soft magnetic material; strong low-band CM impedance in small size.
- **Parasitic capacitance —** Inter-turn/layer capacitance setting the HF impedance collapse point.
- **Conducted EMI —** Interference conducted along power lines; tested 150 kHz–30 MHz.
- **CISPR 32 / CISPR 25 —** EMI standards for multimedia equipment / vehicle environments.

- **Y capacitor —** Line-to-ground safety capacitor working with the CM choke as the CM filter.

9. Further reading (deep-dives)

This page is the hub of the EMI/CM magnetics set; the spokes below are clickable:

A. Common-mode topics

- Common-mode choke selection: impedance curves & core materials
- Two-stage integrated common-mode choke (EV / AI server / inverter)
- Common-mode inductor design guide: improving EMI performance

B. Methodology (cross-cutting)

- Flat wire vs round wire inductors
- Thermal design & temperature-rise testing for high-current magnetics

C. Sister pillars

- 800 V Power Magnetics Selection Reference (EV & AI datacenter)
- Solar & Energy-Storage Magnetics Selection Reference

10. About ProMagTech

SHENZHEN PROMAGTECH CO.,LTD (founded 2013, Shenzhen) designs and manufactures common-mode chokes, flat-wire inductors, planar transformers and PFC inductors for SMPS, 800 V EV OBC, PV inverters, energy-storage PCS, AI-datacenter power and industrial power.

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