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Choosing a Powder Core: Fe-Si · Sendust · High Flux · MPP

An engineer's decision guide: properties, trade-offs, selection map and sizing procedure

Item	Detail
Document	Powder Core Selection Guide — Fe-Si / Sendust / High Flux / MPP
Scope	Distributed-gap powder cores for PFC, high-current, filter and resonant inductors
Audience	Power inductor design & sourcing engineers
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Values are typical, per grade/vendor datasheet; confirmed by sample test per project. Trade names belong to their owners.

Summary & key takeaways

Bottom line

The four mainstream powder cores — Fe-Si, Sendust, High Flux and MPP — are fundamentally a trade-off across four axes: saturation flux (Bsat), core loss, DC-bias capability and cost. Higher Bsat holds inductance better under DC bias, but usually means higher core loss. One rule of thumb: Fe-Si takes the most bias and is cheapest but lossy; MPP has the lowest loss and is priciest; Sendust is the best-balanced general choice; High Flux gives the best DC bias in a compact size.

The bottom line up front — quick-pick table:

Material	Trade name	Bsat(T)	Position	Rel. cost
Fe-Si	XFlux / MegaFlux	~1.6	high Bsat, high loss, low cost	low
Sendust	Kool Mμ	~1.05	low loss, quiet, best all-rounder	low-mid
High Flux	High Flux	~1.5	best DC bias in compact size	mid-high
MPP	MPP	~0.75	lowest loss, best temp stability	high

Table 1 — Quick-pick table (typical values, per datasheet)

Key takeaways:

- **Four trade-off axes:** Bsat, core loss, DC bias, cost — there is no all-round material, only the best match to your operating point.
- **Bsat drives DC bias:** higher Bsat loses less inductance at the same current. Fe-Si ≈ High Flux hold bias best; MPP rolls off first.
- **Loss is inverse to Bsat:** core loss low→high: MPP < Sendust < High Flux < Fe-Si. For low loss, move toward MPP.
- **Cost low→high:** Fe-Si < Sendust < High Flux < MPP (more nickel, more cost).
- **Distributed gap:** powder cores have a built-in distributed gap and soft saturation — no external gap needed as with ferrite.

Note Values are typical; grades/vendors/permeabilities vary widely, so always confirm against the chosen grade's datasheet and sample test. Trade names (XFlux, Kool Mμ, etc.) belong to their owners.

1. Why powder cores matter: distributed gap and soft saturation

A powder core is made from insulated, compacted ferromagnetic alloy powder. The countless micro-gaps between particles form a 'distributed gap' that gives two engineering-critical traits: soft saturation — inductance rolls off gradually under DC current rather than dropping sharply like ferrite + a lumped gap; and no external gap needed, so the flux path is more uniform with less fringing loss and localized heating.

That is why any inductor carrying large DC bias (PFC boost, high-current storage, output filter) defaults to a powder core. All the selection effort is the trade-off among the four materials.

2. The four materials, one by one

Fe-Si (iron-silicon; trade names XFlux / MegaFlux)

An iron-silicon alloy, permeability roughly 26–60. Its standout trait is the highest Bsat (~1.6 T), so DC-bias capability is excellent and it takes high current; it contains no nickel, so it is the cheapest. The trade-off is the highest core loss of the four. Good for cost-sensitive, high-DC-bias designs where loss is not the first constraint — high-current storage inductors and some PFC.

Sendust (iron-silicon-aluminum; trade name Kool Mμ)

An Fe-Si-Al alloy, permeability roughly 26–125. Bsat is ~1.05 T, core loss is clearly lower than Fe-Si, DC bias and temperature stability are both good, and magnetostriction is near zero (quiet, no audible buzz). Nickel-free, so low-to-mid cost. It is the best-balanced all-rounder and the default for most general PFC and filter inductors.

High Flux (nickel-iron 50/50)

A ~50% nickel-iron alloy, permeability roughly 14–160. Bsat is ~1.5 T, giving the best DC-bias capability of the four (high Bsat plus stable permeability); core loss sits between Sendust and Fe-Si, and the nickel raises cost. Ideal where a compact inductor must take heavy DC bias.

MPP (molypermalloy)

A nickel-iron-molybdenum alloy with the widest permeability range (~14–550). Bsat is the lowest (~0.75 T), but core loss is the lowest, Q the highest, and temperature stability the best. Moly and nickel make it the priciest. Best for HF filtering, resonant inductors, high Q and wide temperature — where loss and stability are demanding and DC bias is not extreme.

3. Five-dimension comparison

Fig. 2 Five-dimension comparison of the four powder-core families (relative, 1-5)

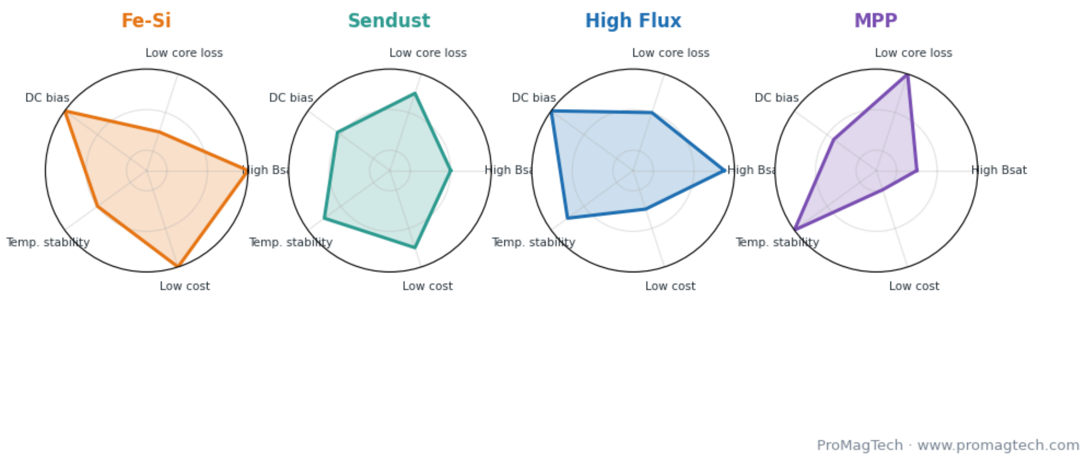

Fig. 2 — Five-dimension comparison of the four families (relative, larger is better).

Material	Bsat	Core loss (low=good)	DC bias	Temp. stab.	Rel. cost
Fe-Si	highest	high	very good	medium	low
Sendust	medium	low	good	good	low-mid
High Flux	high	medium	best	good	mid-high
MPP	low	lowest	medium	best	high

Table 2 — Five-dimension comparison (relative/qualitative; values per datasheet)

4. DC bias is the core: read the inductance-retention curve

An inductor's worst failure is losing inductance at rated current. A powder core's DC-bias behavior is usually given as '% of initial permeability vs DC magnetizing force H' — the slower it falls, the better inductance holds at high current. The rule: higher Bsat, longer the curve holds.

Fig. 1 Inductance retention under DC bias — higher Bsat holds inductance longer

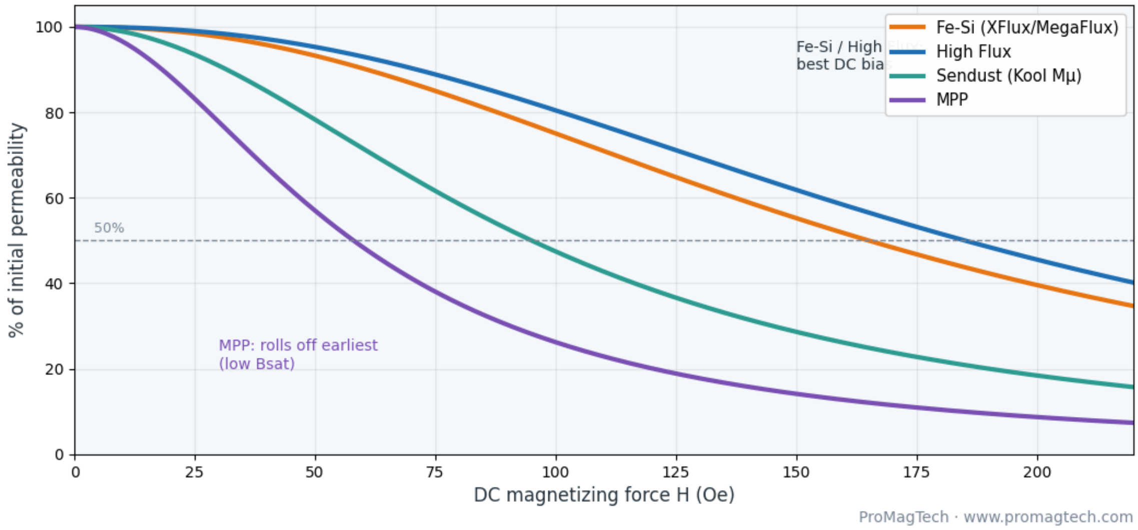

Fig. 1 — Inductance retention under DC bias: higher Bsat holds longer (illustrative; per datasheet).

How to use it Find the H for your rated/peak current, read how much permeability the material still has at that H, and multiply that percentage back onto the initial inductance — that is what you actually get. Never size turns from the initial inductance, or you will fall short under load.

5. Selection map and choosing by application

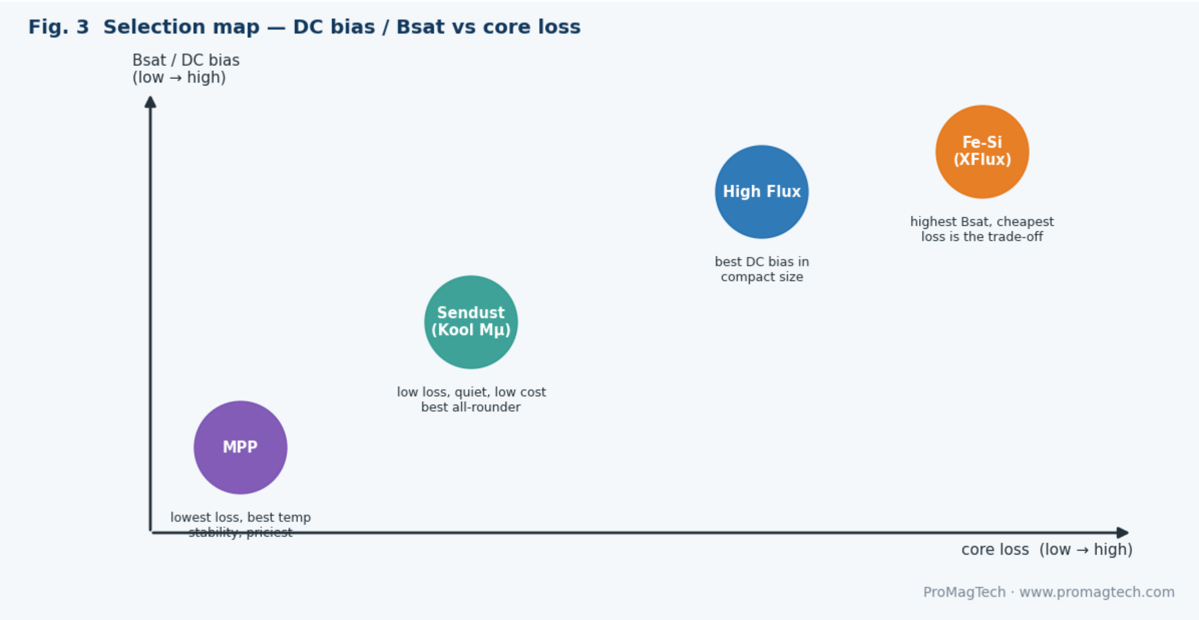

Fig. 3 — Powder-core selection map: DC bias / Bsat vs core loss.

Match material to application:

Application	First choice	Alternate	Reason
PFC boost (general)	Sendust	High Flux	low loss + balanced; High Flux for compact high bias
PFC (max cost / current)	Fe-Si	Sendust	cheapest, highest Bsat, takes big bias
Storage / high-current inductor	Fe-Si	High Flux	high Bsat for large DC
Compact high-DC-bias inductor	High Flux	Fe-Si	high Bsat + stable permeability
Output / filter inductor	MPP	Sendust	low loss, high Q
Resonant inductor / high Q	MPP	—	lowest loss, best stability
Wide temperature / automotive-leaning	MPP / Sendust	—	good temperature stability

Table 3 — Application-to-material guide (verify against real operating point & datasheet)

6. How an engineer sizes it: the selection procedure

An eight-step procedure you can follow directly; each step maps to a calculable quantity.

1. **Define requirements:** inductance L, rated/peak current I(dc/pk), ripple ΔI, switching frequency fs, temperature-rise and size limits.
2. **Energy & core size:** size the core from stored energy E (energy density sets volume).
3. **Material + permeability μ:** pick one of the four and μ from DC-bias need (Fig. 1) and loss need (Fig. 3).

4. **Turns N:** use the biased AL, not the initial AL, to avoid falling short under load.
5. **Check DC bias:** compute the operating H, read the remaining permeability from the curve, back out the actual inductance.
6. **Check core loss:** estimate loss from the material loss curve/Steinmetz at operating ΔB and fs.
7. **Check temperature rise:** copper + core loss ÷ cooling area → ΔT; if over, return to step 2/3.
8. **Iterate:** if anything fails, adjust size/material/μ/turns and recompute.

Common formulas:

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Stored energy:  E = ½ · L · Ipk²
Field strength: H(Oe) = 0.4π · N · I / le(cm)   (SI: H = N·I / le)
Inductance:     L = AL · N²    (AL = biased value)
Flux swing:    ΔB = L · ΔI /(N · Ae)
Core loss:     Pcore = k · fs^α · ΔB^β   (k,α,β from datasheet)
```

The most common trap Sizing turns from the initial AL — then inductance comes in well under target once current flows. Always use the biased effective AL (or compute H → read %μ → correct) to set turns.

7. Common mistakes

- **Judging by initial permeability:** high initial μ does not mean high inductance under load — look at the DC-bias curve.
- **Using Fe-Si just because it's cheap:** its high loss can run temperature away at high frequency or with limited cooling.
- **Adding an external gap to a powder core:** the distributed gap is built in; an extra lumped gap usually just adds fringing loss.
- **Ignoring magnetostriction noise:** for quiet designs, Sendust (near-zero magnetostriction) beats some high-bias materials.

8. Validation & quality baseline (DVP)

Validation item	Method / instrument	Acceptance (example)
Inductance & DC bias	LCR + DC bias source	L ≥ spec at rated current
Saturation current Isat	bias sweep	current before roll-off threshold OK
Core loss / temp rise	power analyzer / IR	rise ≤ limit at operating point
DCR	micro-ohm meter	≤ spec
Batch consistency	sampling statistics	spread < ±spec%
Wide temperature	chamber + LCR	L / loss OK across temp range

Table 4 — Common validation baseline for powder-core inductors (acceptance per project; values by test)

9. Frequently asked questions (FAQ)

Q Powder core or ferrite + gap — how to choose?

A For high DC bias, wide current and soft saturation → powder core; for very low loss, HF low current and cost sensitivity → ferrite + gap. Wide-current PFC inductors are usually powder core; HF transformers/resonant tanks use ferrite.

Q Why do PFC inductors mostly use powder cores?

A PFC inductors run at high DC bias over a wide current range and need soft saturation to hold inductance. Powder cores' soft saturation fits; ferrite + gap hard-saturates and does not.

Q Are Sendust and Kool Mμ the same thing?

A Yes. Kool Mμ is Magnetics' trade name for Fe-Si-Al (Sendust) material; other vendors have equivalent Sendust/Fe-Si-Al grades in the same family.

Q High Flux and MPP both contain nickel — what's the difference?

A High Flux is nickel-iron (~50% Ni) with high Bsat (~1.5 T), strong DC bias but higher loss; MPP adds molybdenum (Ni-Fe-Mo) with low Bsat (~0.75 T) but the lowest loss, highest Q and best temperature stability. Choose High Flux for bias, MPP for low loss.

Q Does a powder core need an external air gap?

A Usually not. The distributed gap is built into the material; an extra lumped gap adds fringing loss and is generally unnecessary.

Q How do I quickly estimate inductance under DC bias?

A Compute the operating field H = 0.4π·N·I/le, read the remaining permeability percentage from the material's %μ–H curve, and multiply it back onto the initial inductance.

Q Does high temperature affect powder cores?

A Apart from legacy iron powder (which thermally ages), Fe-Si/Sendust/High Flux/MPP are thermally stable, MPP the best; but core loss varies with temperature and frequency, so verify against the datasheet's temperature curves for wide-temperature designs.

Q Same permeability μ — which material?

A Depends on your main constraint: big bias → Fe-Si/High Flux; low loss → MPP/Sendust; cost → Fe-Si/Sendust; quiet → Sendust. Equal μ does not mean interchangeable — DC bias and loss differ a lot.

10. Glossary

- **Powder core —** A core of insulated, compacted ferromagnetic alloy powder with a built-in distributed gap and soft saturation.
- **Distributed gap —** Countless micro-gaps between powder particles, giving soft saturation with no external lumped gap.
- **Bsat (saturation flux) —** The maximum flux density a material sustains; higher resists DC bias better.
- **DC bias —** The roll-off of inductance under DC current.
- **Soft / hard saturation —** Inductance falling gradually / dropping sharply at a point.
- **Permeability μ —** A material's ability to conduct flux; powder cores commonly μ 14–550.
- **AL value —** Inductance per turn squared, $L = AL \cdot N^2$; use the biased AL.
- **Steinmetz equation —** Empirical core loss Pcore = k·f^α·B^β, coefficients from the datasheet.

- **Magnetostriction —** Micro-deformation from magnetization, the source of inductor buzz; near-zero in Sendust.

11. Further reading

This guide is part of the ProMagTech 800 V Power Magnetics Selection Reference; related deep-dives:

- 800 V Power Magnetics Selection Reference (the pillar map)
- OBC PFC boost inductor selection (powder core in PFC)
- AIDC / energy-storage PCS high-current inductor design
- 20–60 kW PFC inductor selection & design guide
- Flat wire vs round wire inductors (winding side)

12. About ProMagTech

SHENZHEN PROMAGTECH CO.,LTD (founded 2013, Shenzhen) designs and manufactures flat-wire inductors, planar transformers, common-mode chokes and PFC inductors for 800 V EV OBC and DC charging, AI-datacenter power, energy-storage PCS, solar inverters and industrial power. We select the powder-core material/permeability to your operating point and validate DC bias and temperature rise by samples.

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