# Core Materials

# Core Materials & Properties

The core material of an inductor dramatically affects its performance. Choosing the right core is essential for achieving the desired inductance, Q factor, and frequency response in VIC applications.

## Why Use a Core?

A magnetic core increases inductance by providing a low-reluctance path for magnetic flux:

```
L = ????N²A/l
```

The relative permeability ($\mu_r$) of the core multiplies the inductance compared to an air core.

## Core Material Comparison

| Material | $\mu_r$ (typical) | Frequency Range | Saturation | Cost |
|---|---|---|---|---|
| Air | 1 | Any | N/A | Free |
| Iron Powder | 10-100 | 1 kHz - 100 MHz | High (0.5-1.5T) | Low |
| Ferrite (MnZn) | 1000-10000 | 1 kHz - 1 MHz | Low (0.3-0.5T) | Medium |
| Ferrite (NiZn) | 50-1500 | 100 kHz - 500 MHz | Low (0.3-0.4T) | Medium |
| Laminated Silicon Steel | 2000-6000 | 50 Hz - 10 kHz | High (1.5-2.0T) | Low |
| Amorphous Metal | 10000-100000 | 50 Hz - 100 kHz | High (1.5T) | High |
| Nanocrystalline | 15000-100000 | 1 kHz - 1 MHz | High (1.2T) | High |

## Core Losses

All magnetic cores dissipate energy through two mechanisms:

## 1. Hysteresis Loss

Energy lost each time the core is magnetized and demagnetized.

$P_h$ ? $f \times B_{max}^n$ (n ? 1.6-2.5)

Proportional to frequency and flux density.

## 2. Eddy Current Loss

Circulating currents induced in the core material.

$P_e$ ? $f^2 \times B_{max}^2$

Proportional to frequency squared - dominates at high frequencies.

## Steinmetz Equation

$P_{core} = k \times f^? \times B^? \times Volume$

Where k, α, β are material-specific constants from datasheets.

# Ferrite Materials for VIC

Ferrites are the most common choice for VIC frequencies (1-50 kHz):

| Material | $\mu_i$ | Optimal Frequency | Application |
| --- | --- | --- | --- |
| 3C90 (TDK) | 2300 | 25-200 kHz | Power transformers |
| N87 (EPCOS) | 2200 | 25-500 kHz | General purpose |
| N97 (EPCOS) | 2300 | 25-150 kHz | Low loss |
| 3F3 (Ferroxcube) | 2000 | 100-500 kHz | Higher frequency |
| 77 Material (Fair-Rite) | 2000 | Up to 1 MHz | EMI/RFI suppression |

# Iron Powder Cores

Micrometals and Amidon iron powder cores are popular for their:

- High saturation flux density
- Gradual saturation (soft saturation)
- Good temperature stability
- Self-gapping (distributed gap)

## Common Iron Powder Mixes

| Mix | μ | Color | Frequency Range |
|---|---|---|---|
| Mix 26 | 75 | Yellow/White | DC - 1 MHz |
| Mix 52 | 75 | Green/Blue | DC - 3 MHz |
| Mix 2 | 10 | Red/Clear | 1 - 30 MHz |
| Mix 6 | 8 | Yellow | 10 - 50 MHz |

# Core Shapes

## Toroidal

Doughnut shape with closed magnetic path. Excellent flux containment, low EMI. Harder to wind but very efficient.

## E-Core / EI-Core

E-shaped halves that mate together. Easy to wind on bobbin. Can add air gap easily.

## Pot Core

Cylindrical with center post. Shields winding from external fields. Good for sensitive applications.

## Rod Core

Simple cylindrical rod. Open magnetic path, lower inductance per turn but no saturation issues.

# Core Saturation

When the magnetic flux density exceeds the saturation limit:

- Permeability drops dramatically

- Inductance decreases
- Current increases rapidly
- Core heating increases

## Avoiding Saturation:

$B_{peak} = (L \times I_{peak}) / (N \times A_e) < B_{sat}$

Always check that peak flux density stays below saturation limit of your core material.

# Recommendations for VIC

| Frequency Range | Recommended Core | Notes |
|---|---|---|
| 1-10 kHz | N97/3C90 ferrite or iron powder | Low loss at these frequencies |
| 10-50 kHz | N87/3F3 ferrite | Good balance of µ and loss |
| 50-200 kHz | 3F3/3F4 ferrite or Mix 26 powder | Lower permeability, lower loss |
| >200 kHz | NiZn ferrite or Mix 2 powder | Designed for high frequency |

**VIC Matrix Calculator:** The Choke Design module includes a core database with $A_L$ values and frequency recommendations. Select your core and it will calculate the required turns for your target inductance.

*Next: Wire Gauge & Material Selection →*

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