Magnetics 101

Rock River Valley IEEE-EMCS

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Maxwell's Equations: Differential Form -- MKS Units

$$\nabla \cdot \mathbf{D} = \rho$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

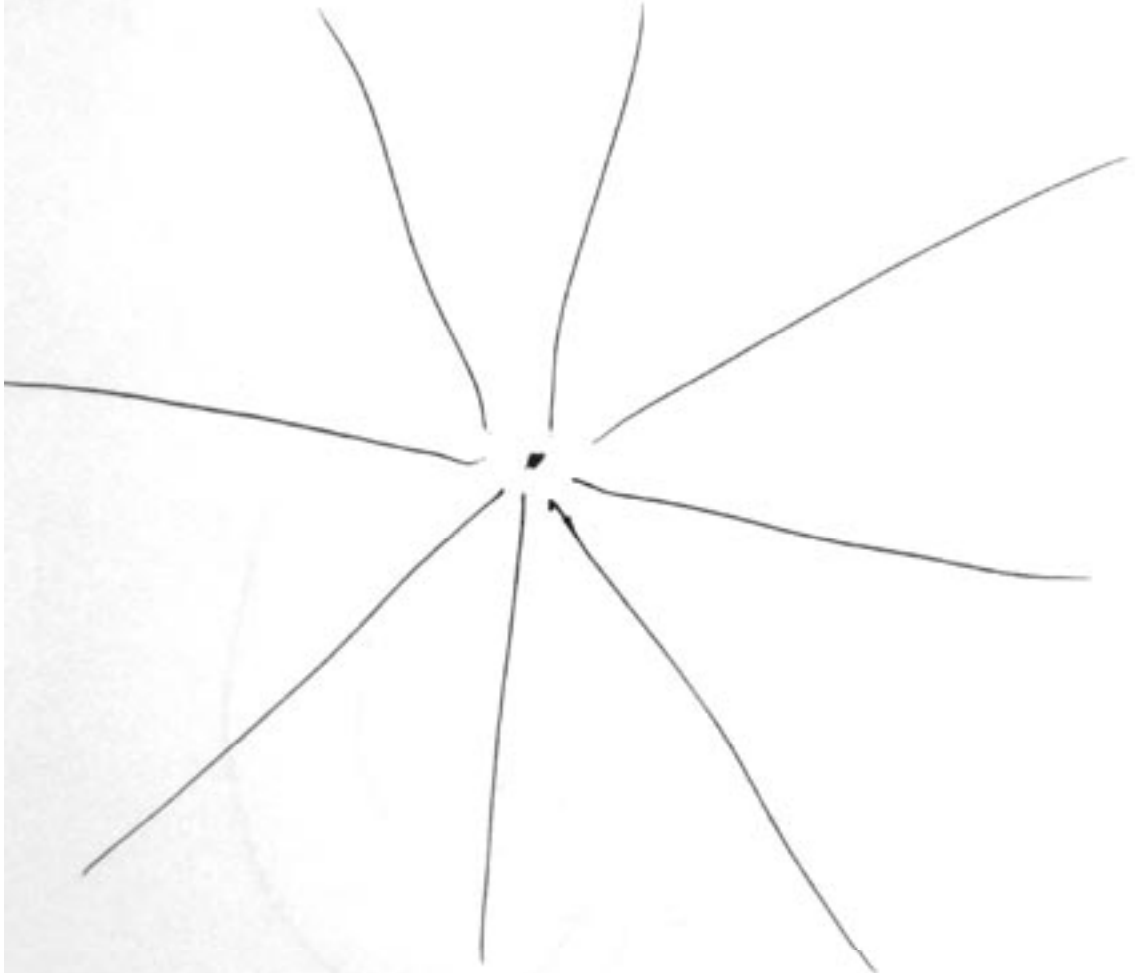
$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{H} = \frac{\partial \mathbf{D}}{\partial t} + \mathbf{J}$$

FIELDS

TWO KINDS: Electric
Magnetic

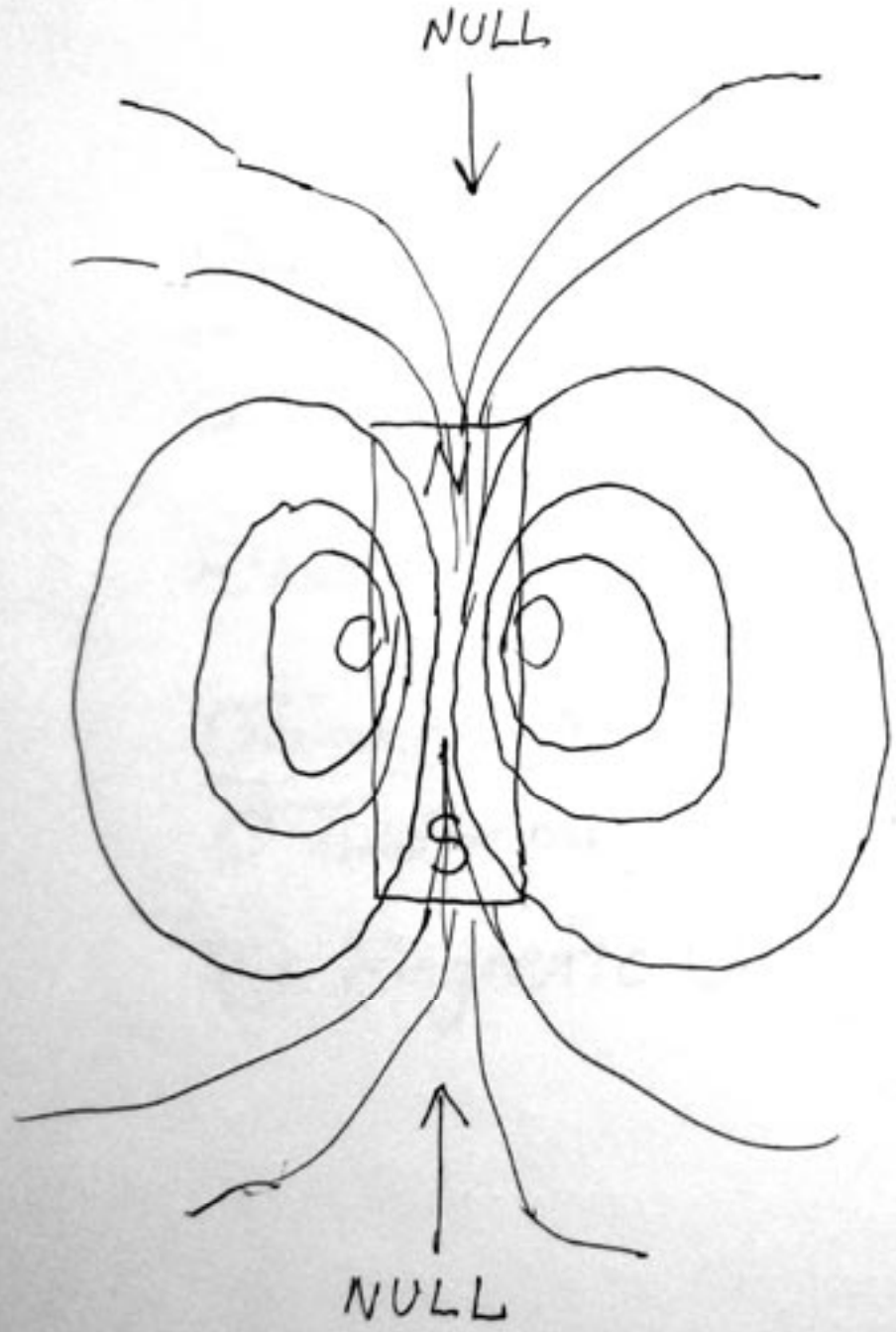
TWO Forms: Divergent [charge]
Curled [closed loop flux]



Divergence has a source (or sink)

For EM, it is a manifestation of CHARGE

Field is conservative
KVL applies



Curl-derived fields form closed loops.

No charge is involved.

Flux Circuits

Source 1: flow of charge $\vec{J}_e$ ($\vec{J}_m$)

Source 2: conversion via flux change

$$\nabla \times E = -\frac{\partial B}{\partial t} \qquad \nabla \times H = \frac{\partial D}{\partial t} + J$$

Vacuum has flux conductivities

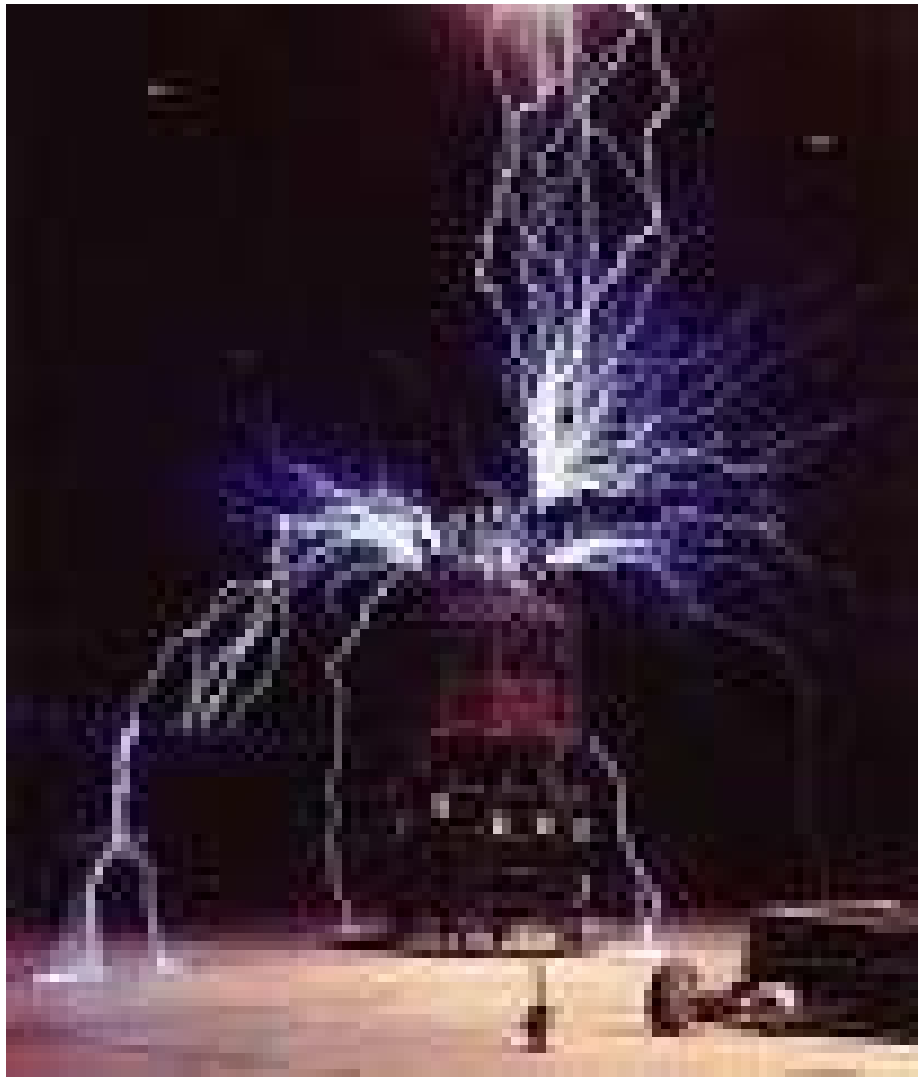
$$\epsilon_0 \approx 8.854E-12$$

$$\mu_0 = 4\pi E-7$$

$$c = (\epsilon_0 \mu_0)^{-\frac{1}{2}}$$

$$= 299\,792\,458 \text{ m/s}$$

Bob Golka’s Tesla Coil



Playing with magnets

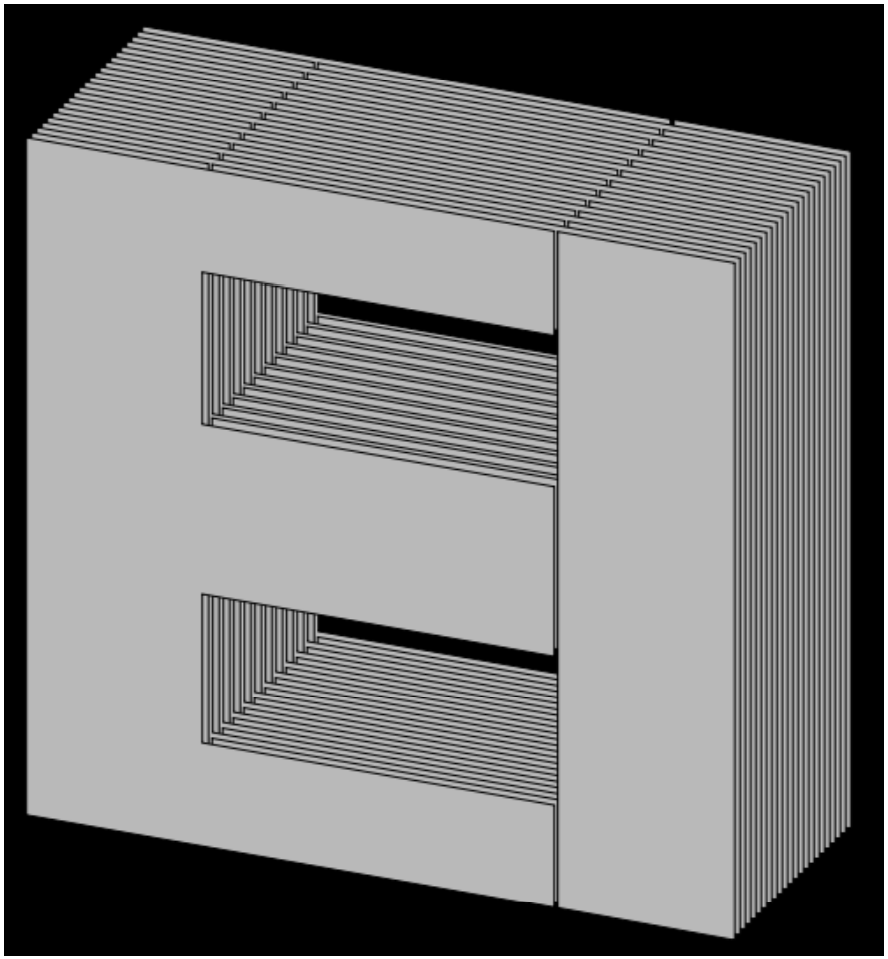
Like poles repel

Opposite poles attract

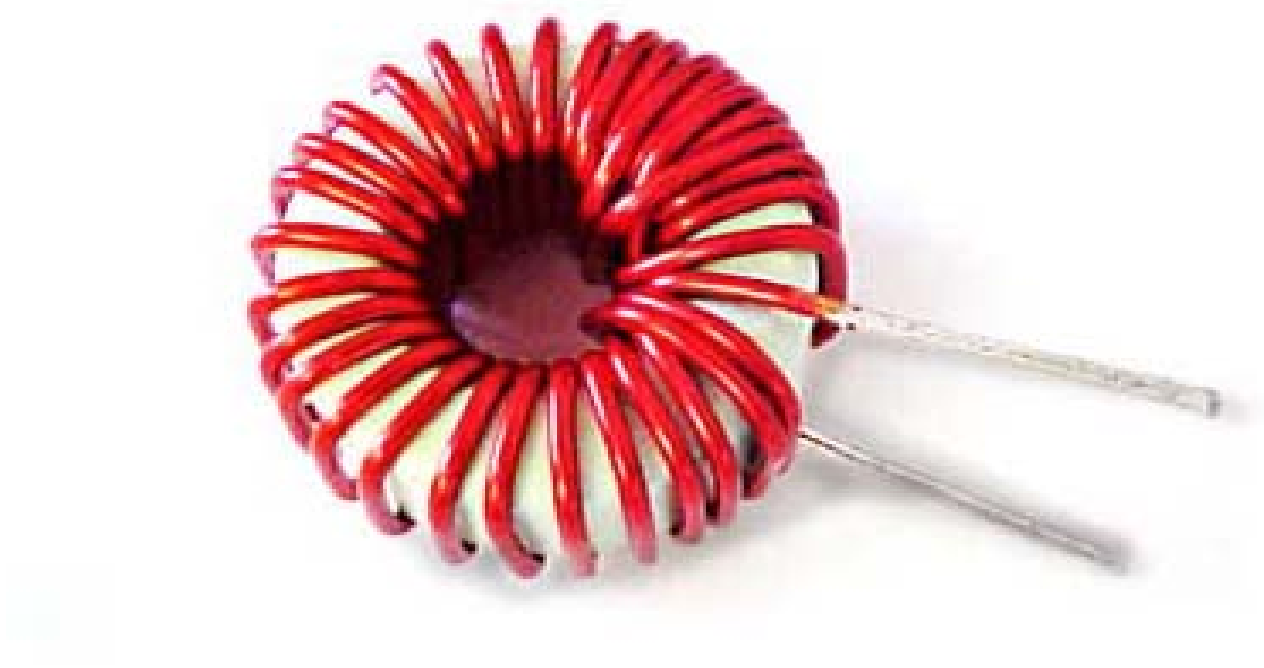
AC Levitation: No Connection but Plenty of Induced Current!

Pot Core

Laminated Cores



Toroid Winding

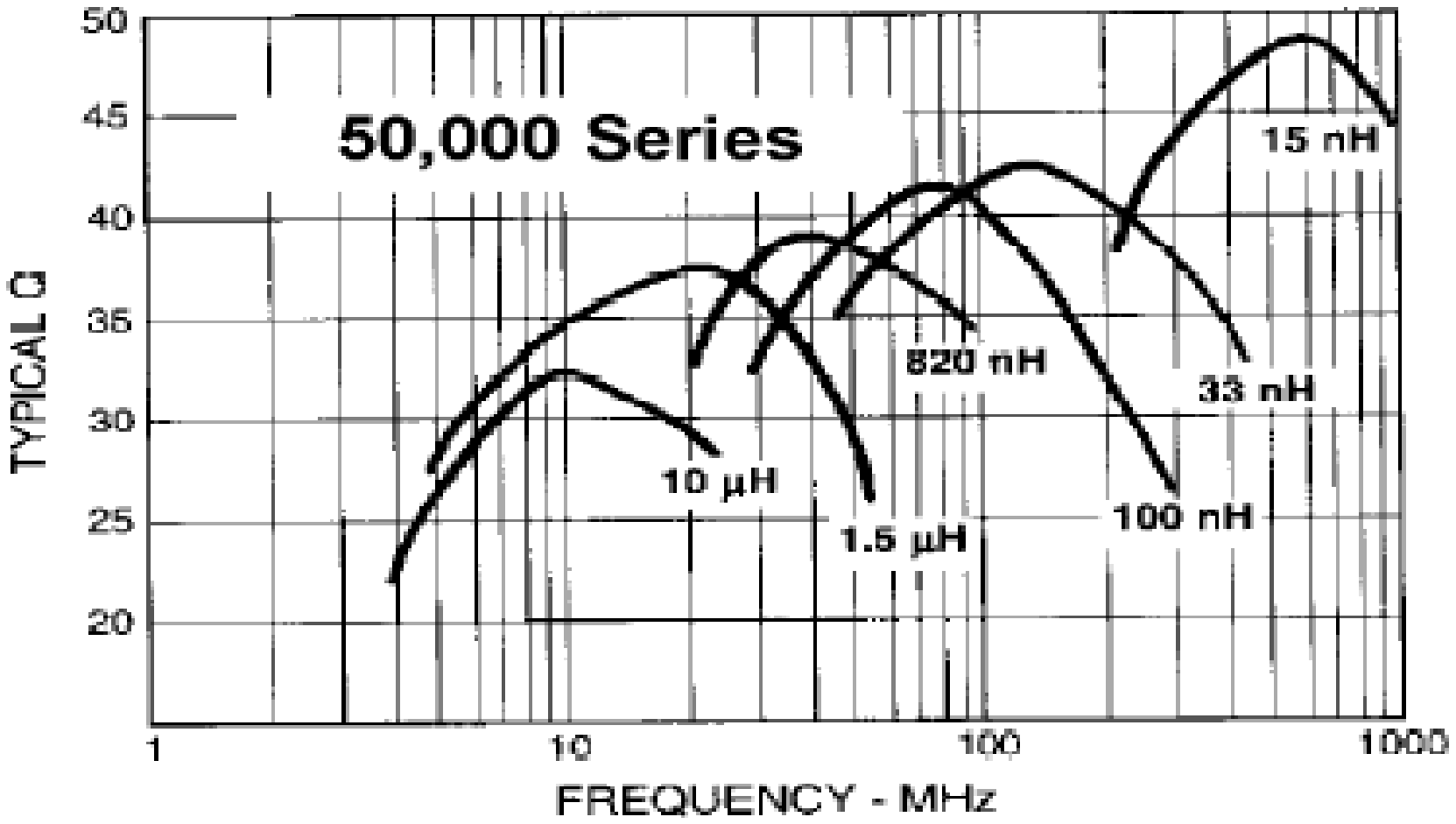


Cut Cores

Inductors

- Inductor self resonance is parallel (high Z)
- Above self resonance, Z is capacitive and lossy
- Single layer coils have highest SRF for a given L
- Minimum Z is DCR
- Q can range from >100 to <5, has peak

Q Curve Example

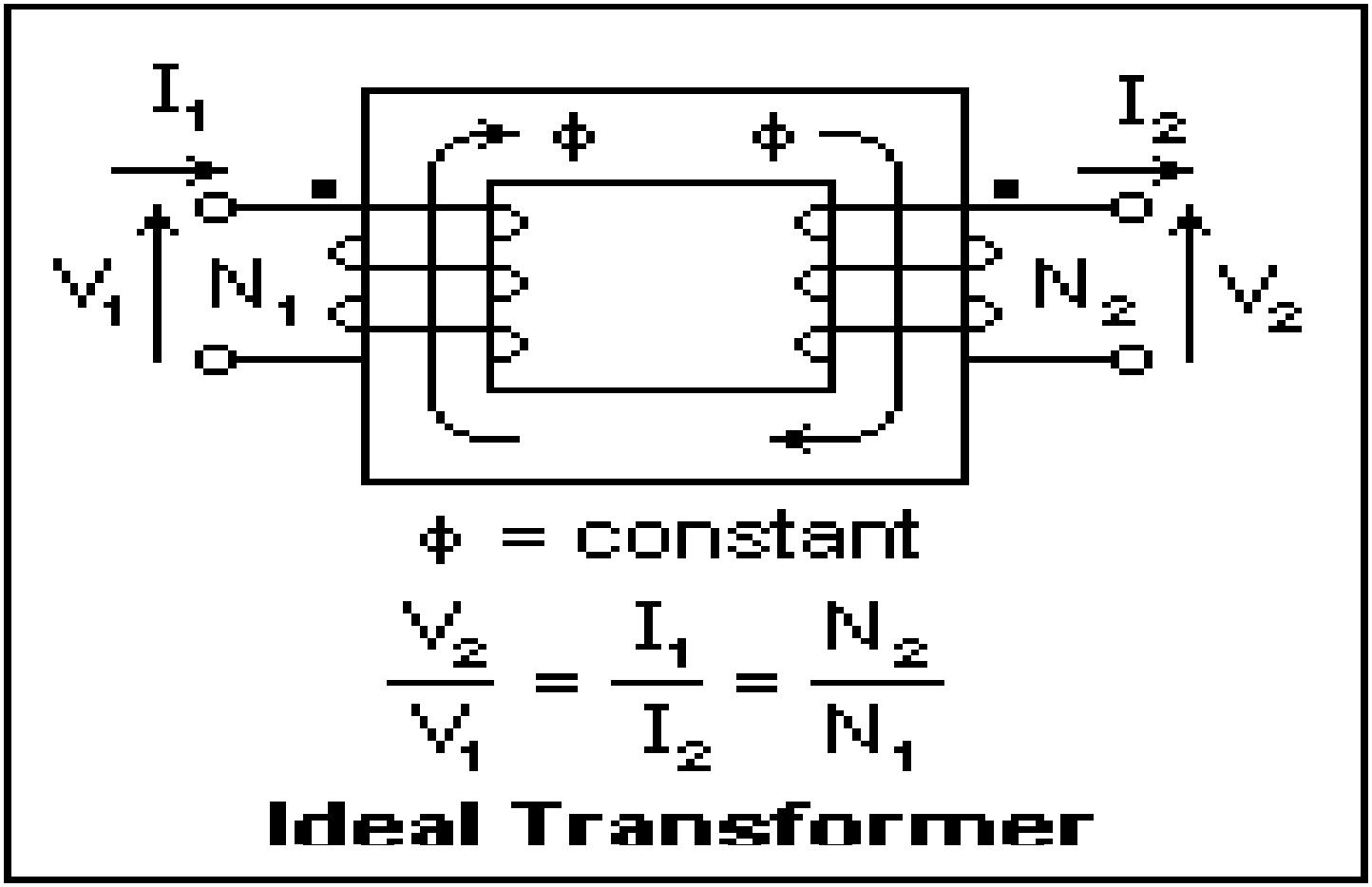


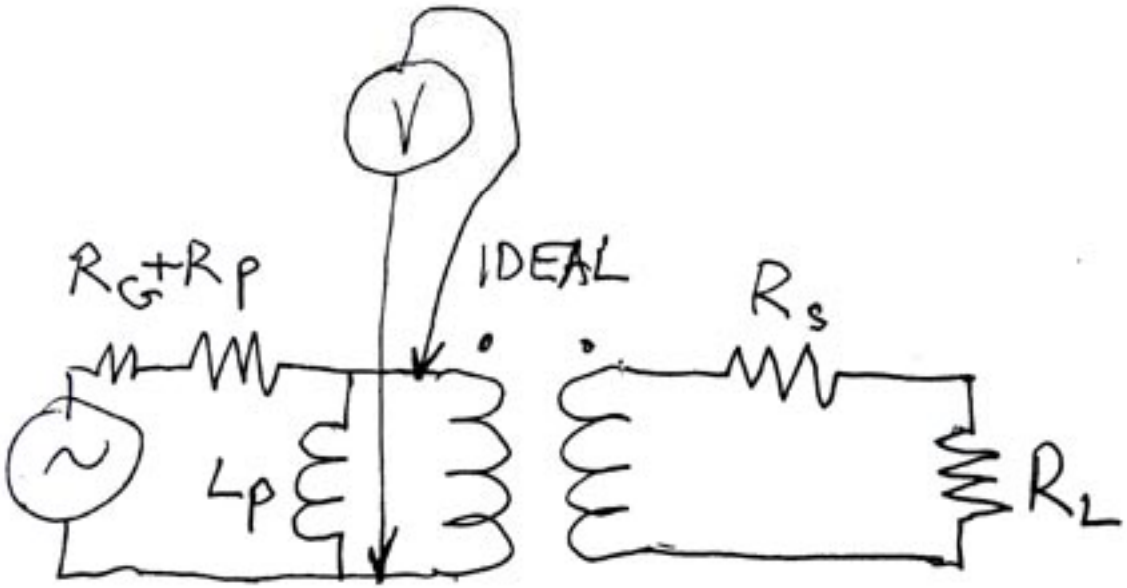
Rod Core Inductor

Transformer Uses

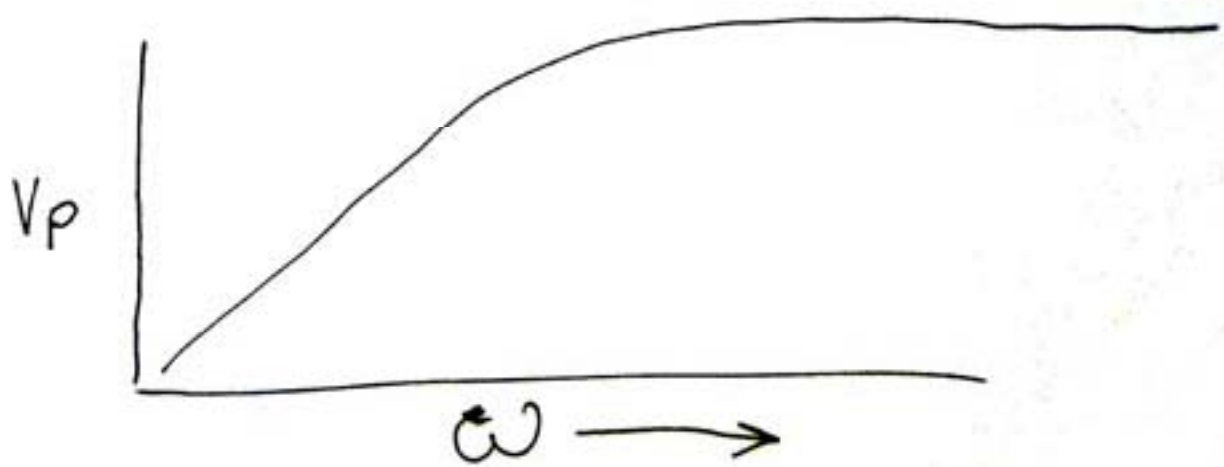
- Voltage Transformer
- Current Transformer
- Isolation Transformer
- Impedance Conversion
- Mode Conversion (Balun)
- Mode Chokes
- Phase & Balance mgmt.

Ideal Transformer

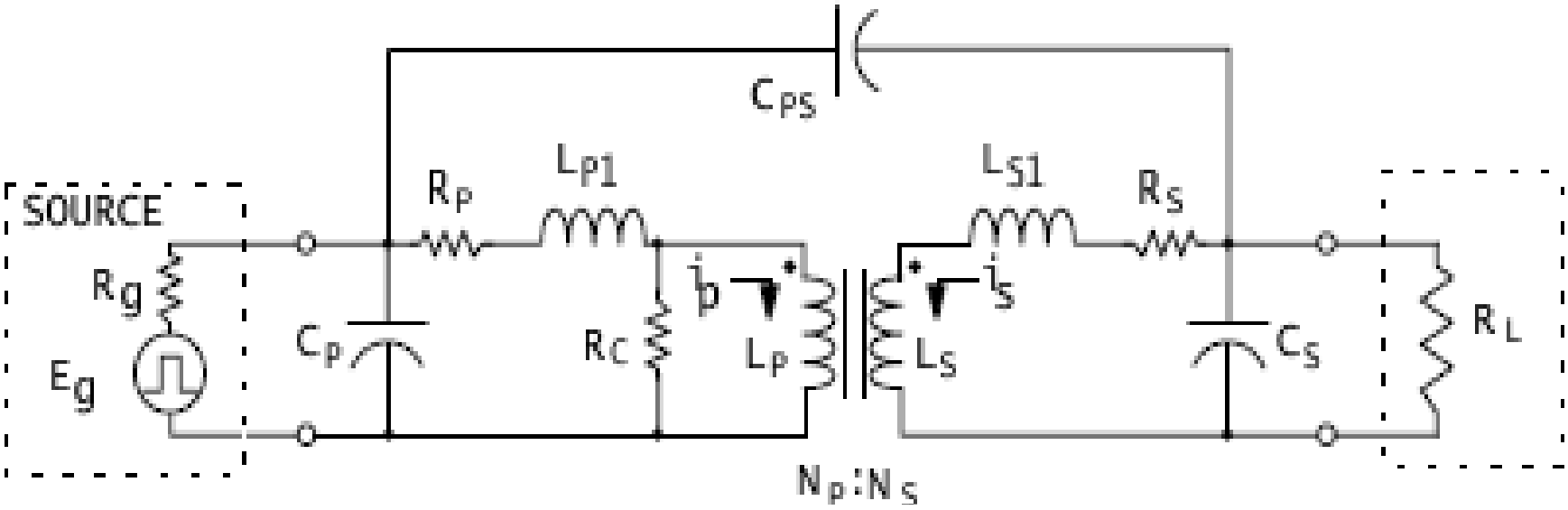




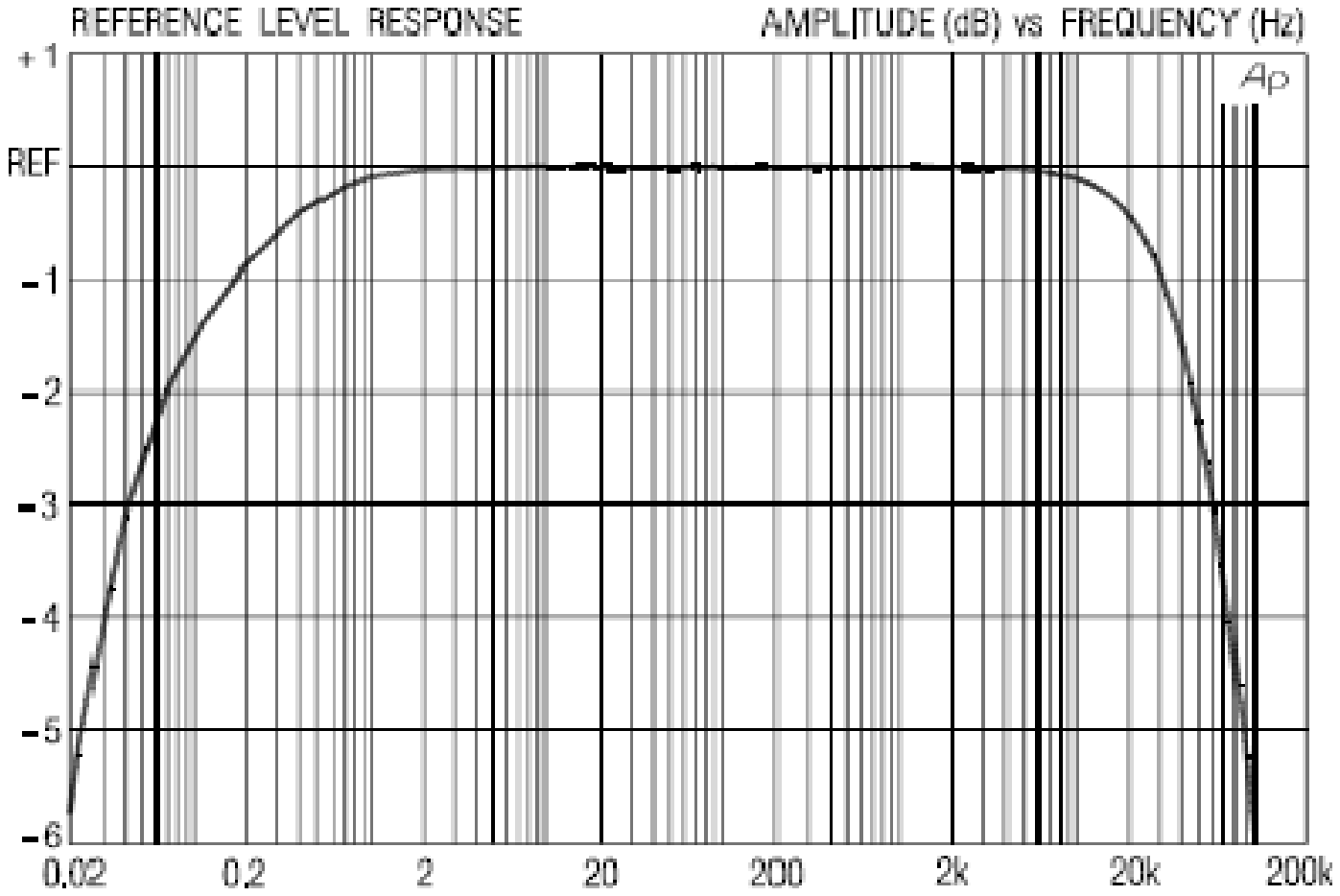
SIMPLIFIED LF MODEL



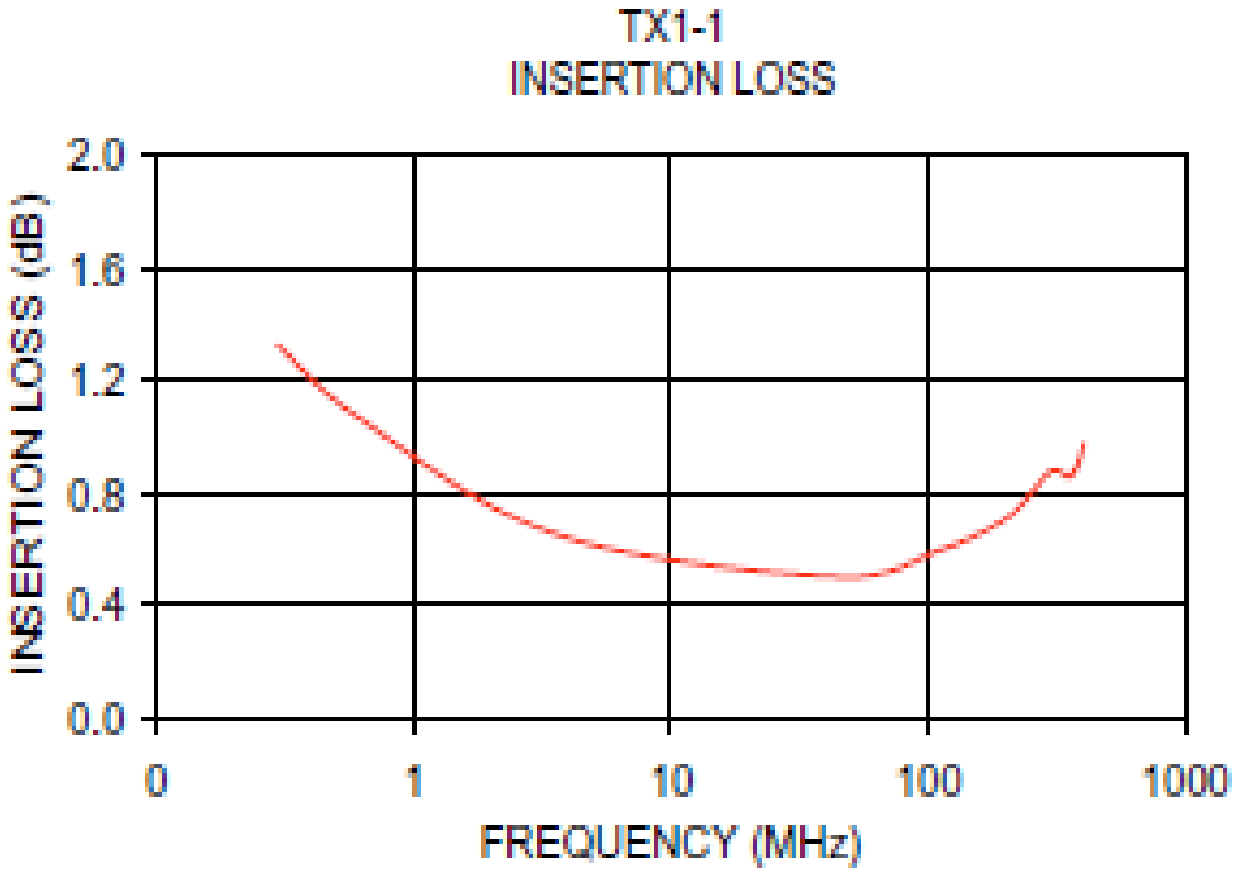
Equivalent Circuit of a Real Xfmr



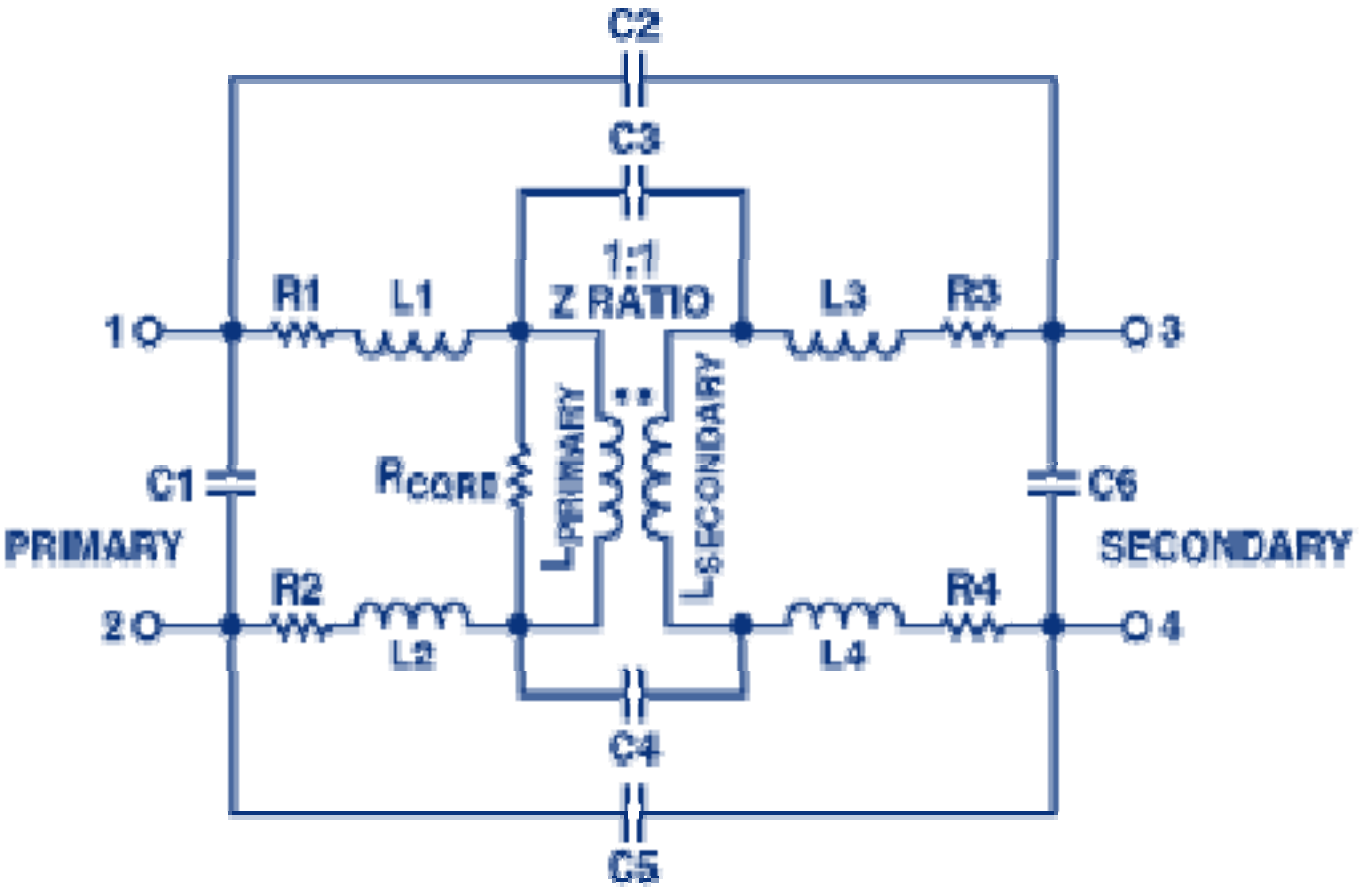
Transformer Frequency Response



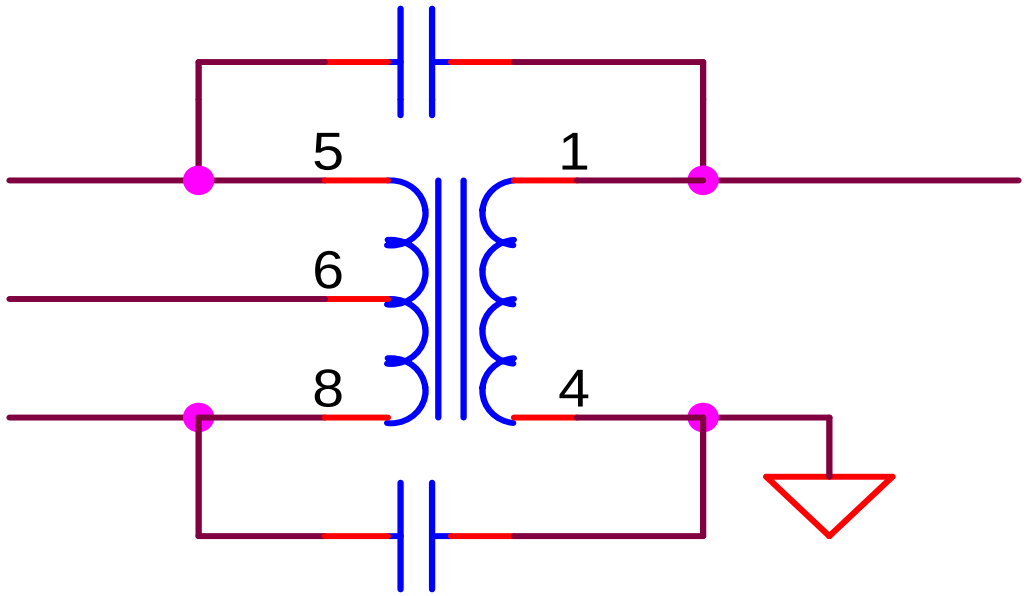
Response as Insertion Loss



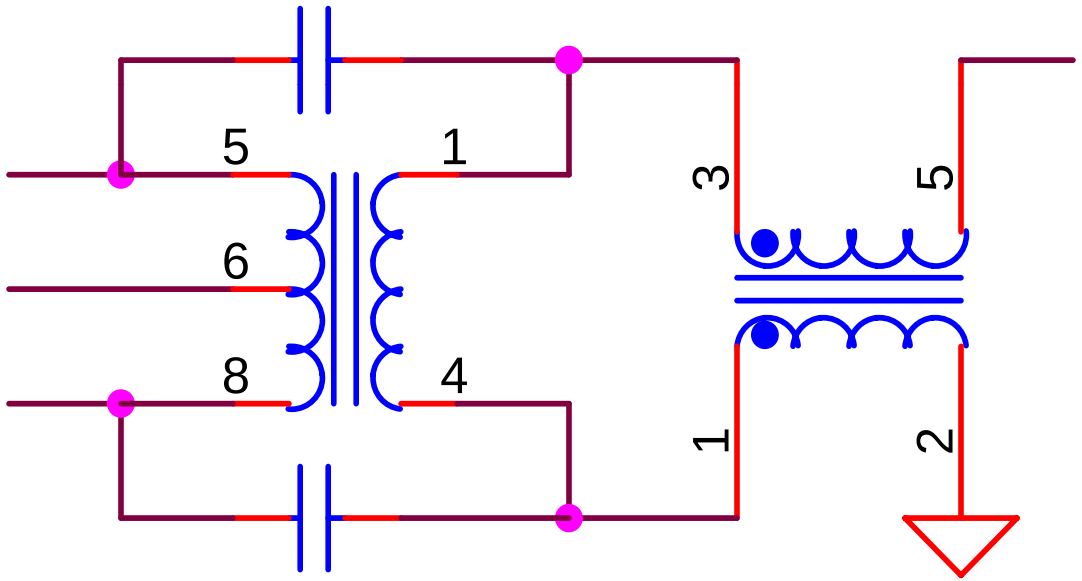
Balanced Model



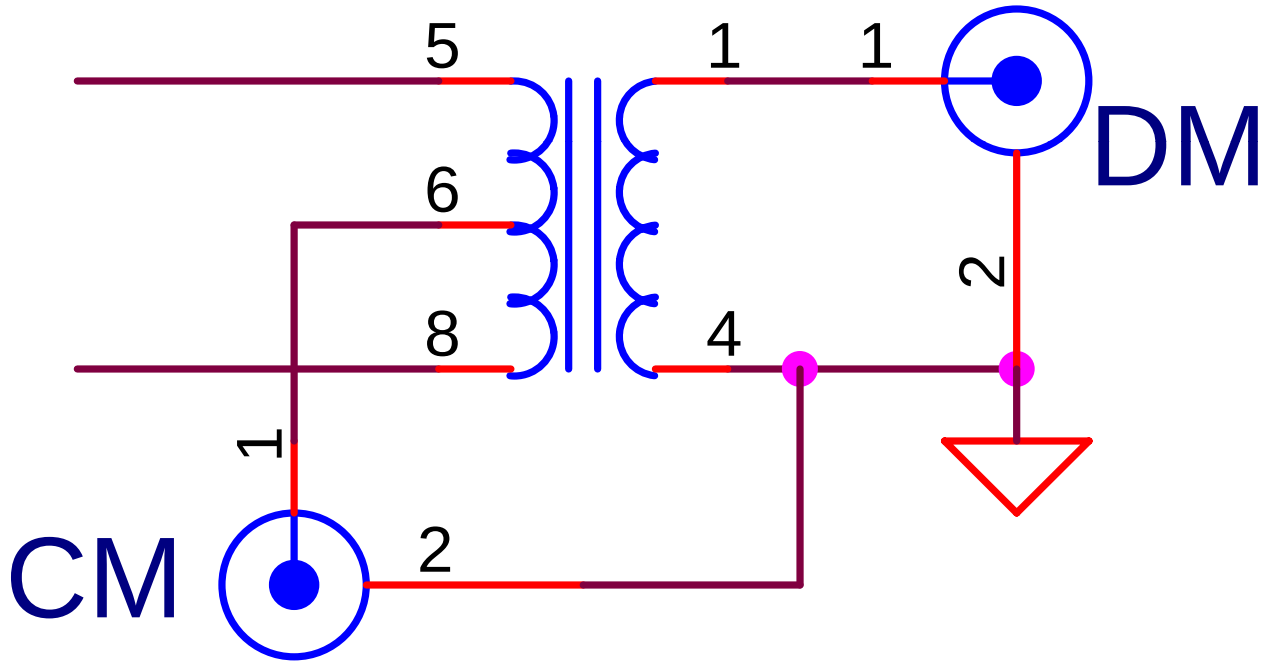
Transformer Stray Capacitance



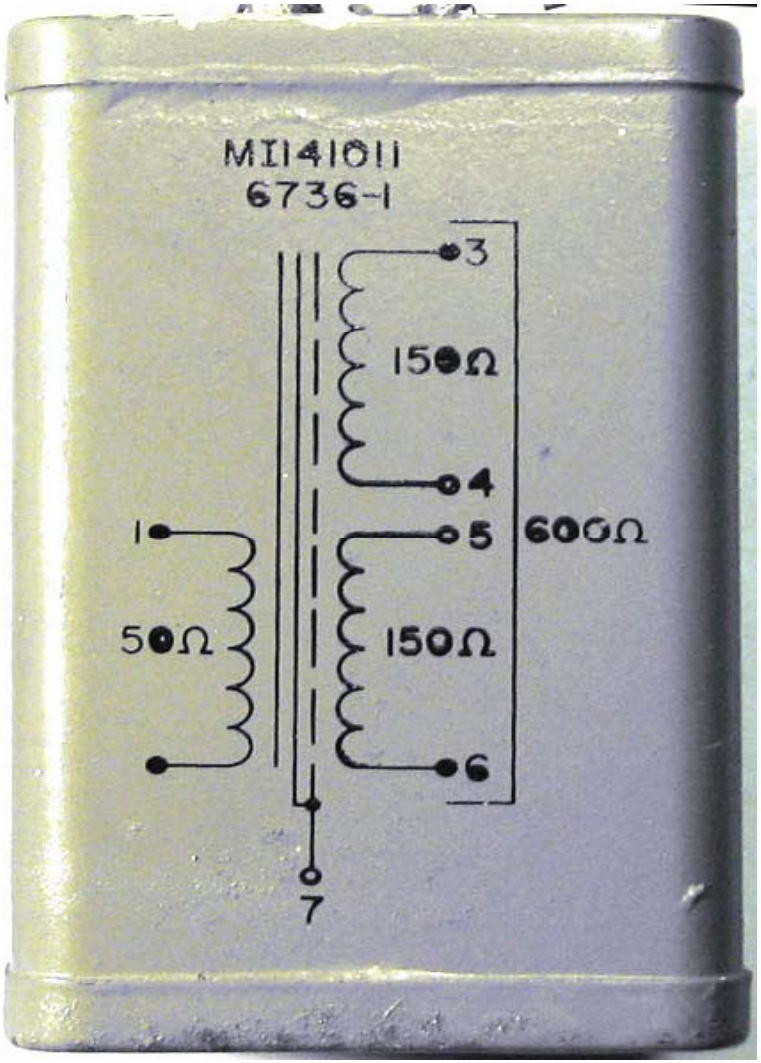
Transformer + CM Choke

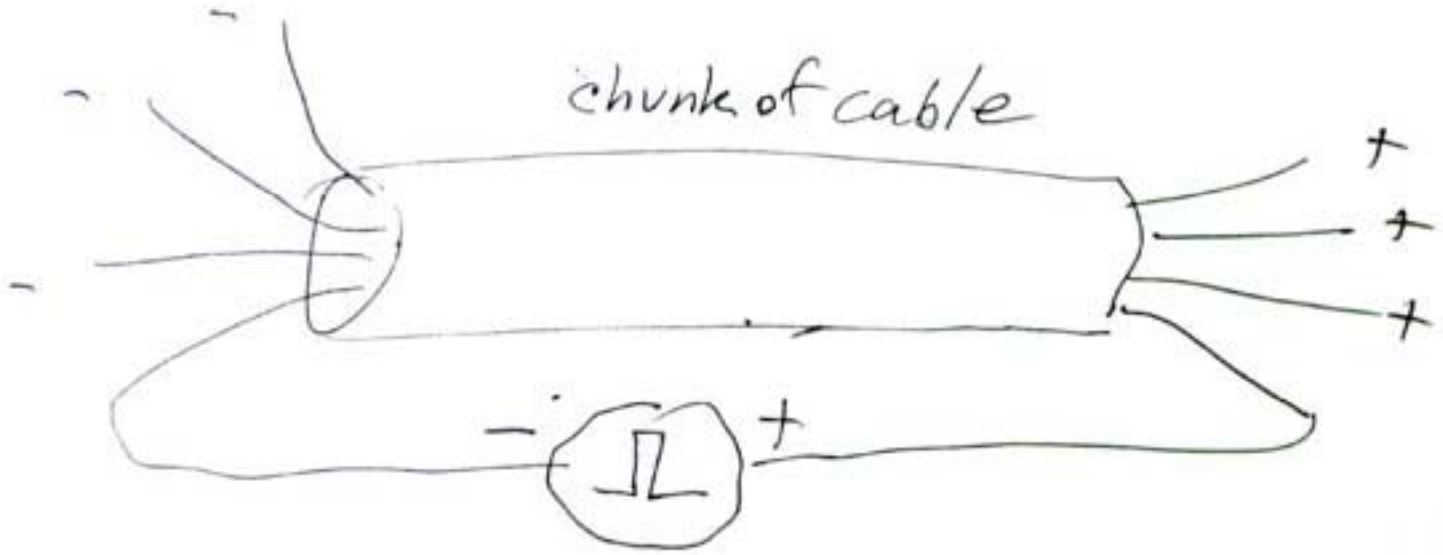


Separating CM & DM

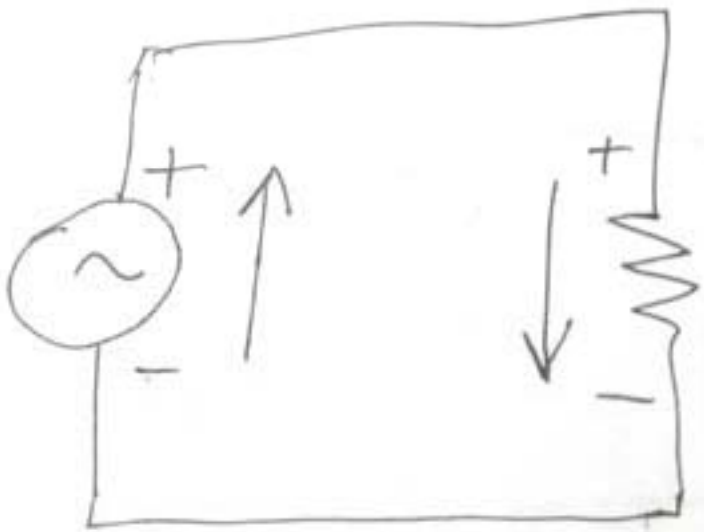


Audio Coupling Xfmr

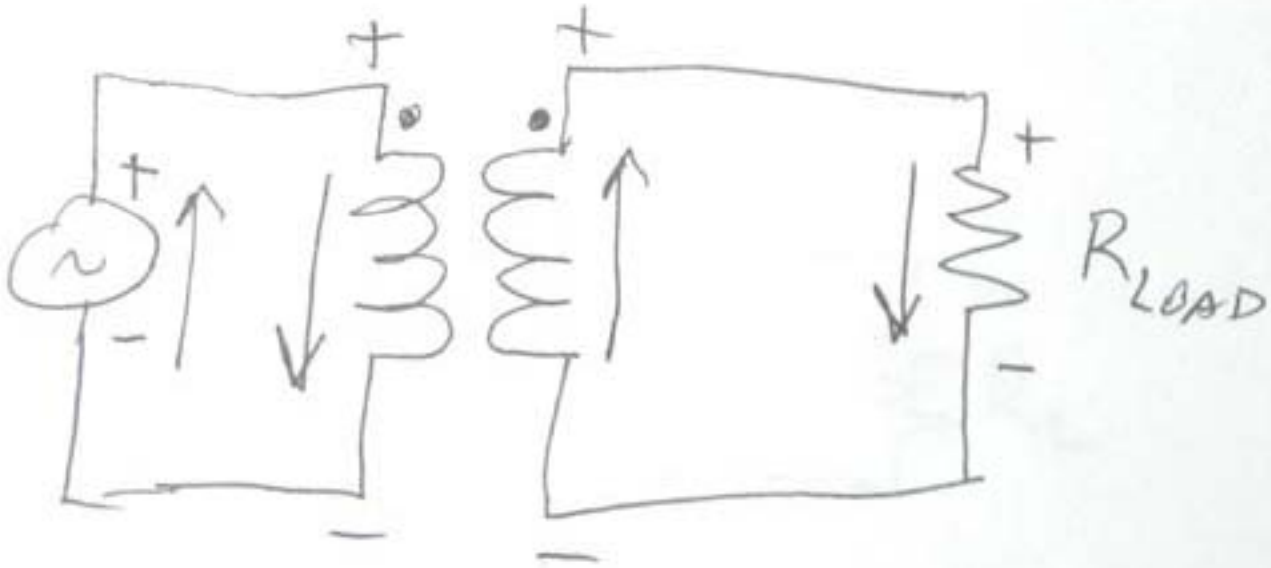




INSTANTANEOUS POLARITY



Current Direction Opposite
Between Source and Sink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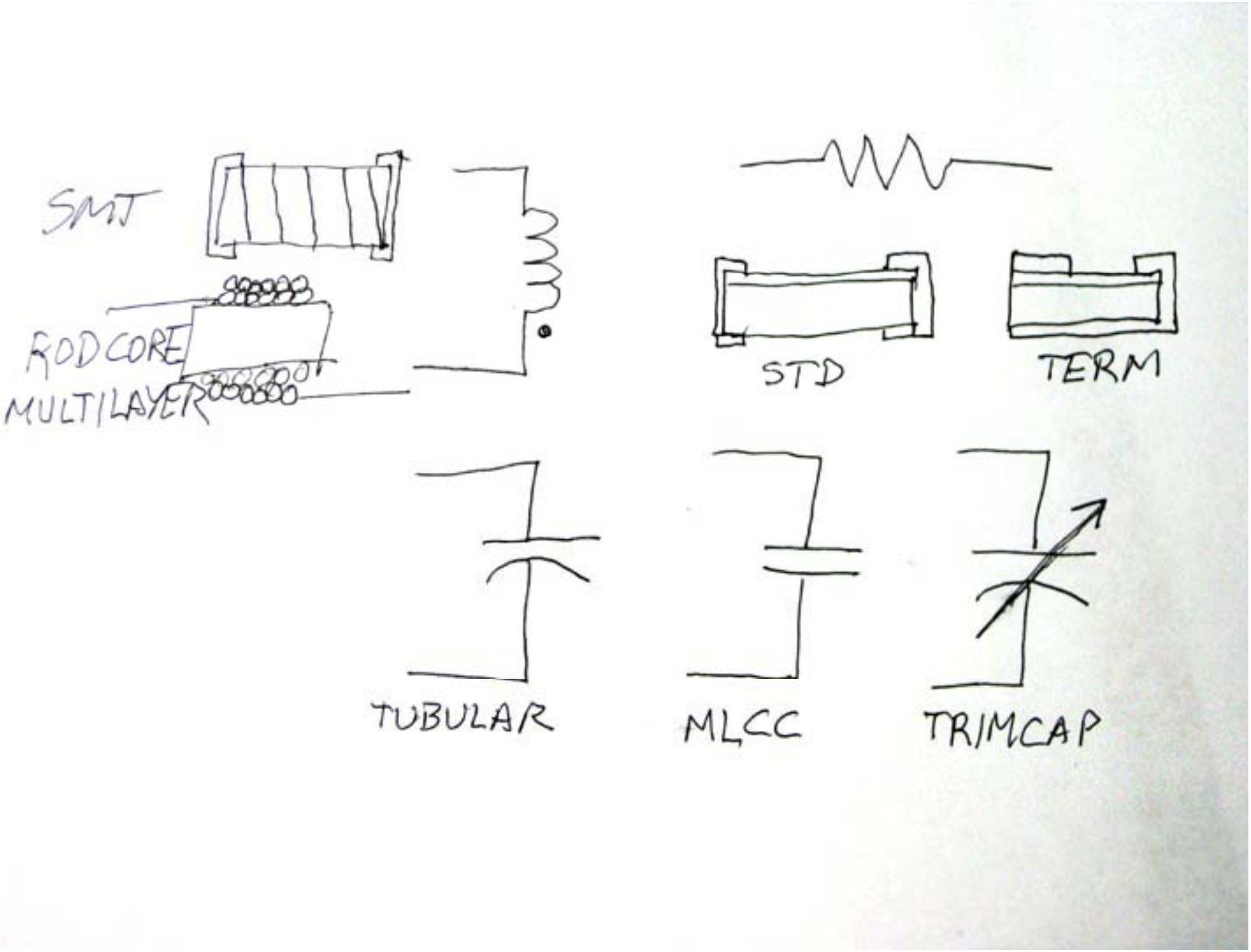
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Thank You For Coming

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