EE-464 STATIC POWER CONVERSION-II

Magnetic Design for Power Electronics

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Review of Magnetic Circuits

Review of Magnetic Circuits

- [Magnetic Materials]
- [EE564-Transformer Design]

Transformer Design

References:

- [Mohan, Design of Magnetic Components]
- [Erickson, Inductor Design]
- [Erickson, Transformer Design]
- [Hurley, Magnetic Design]

Inductor Design

Inductor Design

- Magnetic Design: Calculating B, H, magnetic energy

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- Electrical Design: Choosing number of turns, copper size, wire type, current density

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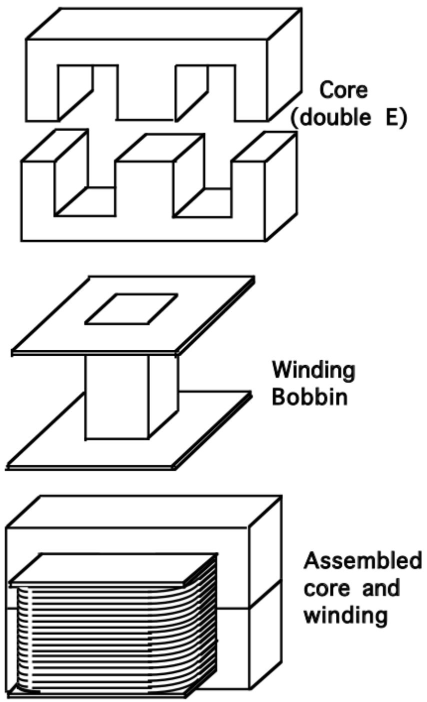
Inductor Design

- Magnetic Design: Calculating B, H, magnetic energy
- Electrical Design: Choosing number of turns, copper size, wire type, current density
- Parameter Estimation: Inductance, Leakage, Resistance
- Thermal: Losses, Efficiency

Typical Core



Core Types

- U, I Core
- E Core
- Toroid Core
- Pot Core

Core Materials

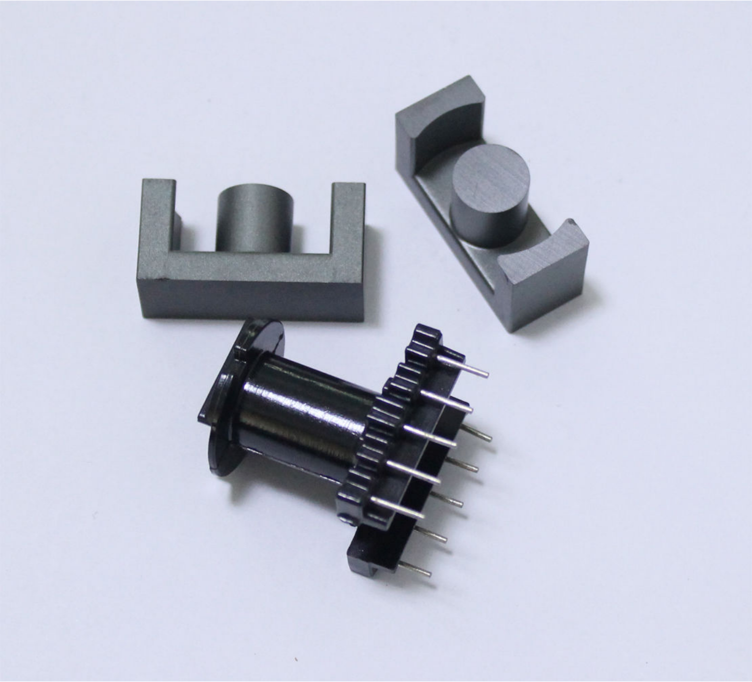
- Ferrites
- Laminated Electrical Sheets
- Kool Mu Powder
- Metglass
- Powdered Iron

Core Bobbin

[Karkas Çeşitleri]

[Coil Winding], [toroidal winding]

E-Core



[Nüve Çeşitleri]

Pot Core

Inductor Fundamentals

Review of Magnetic Circuits

- EE361-Inductors
- EE361-Practical Transformers
- Magnetic Materials
- EE564-Transformer Design

Winding Design

Winding Design

- Winding area, copper area

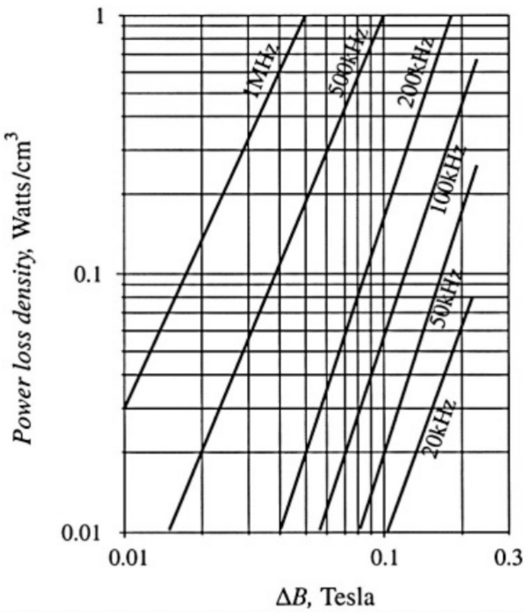
Winding Design

- Winding area, copper area
- Fill Factor (k_{cu})

Winding Design

- Winding area, copper area
- Fill Factor (k_{cu})
- $k_{cu} = 0.3$ for Litz wire
- $k_{cu} = 0.6$ for round wire
- $k_{cu} = 0.7 - 0.8$ for rectangular wire

Core Loss



Typical core loss for a power ferrite

Core Loss

Steinmetz's Equation

Core Loss

Steinmetz's Equation

$$P_{fe} = K_{fe} f^{\alpha} (\Delta B)^{\beta} A_c l_c$$

Usually the constants are given in the datasheet

Alternatively core loss graphs can be available

Skin Effect

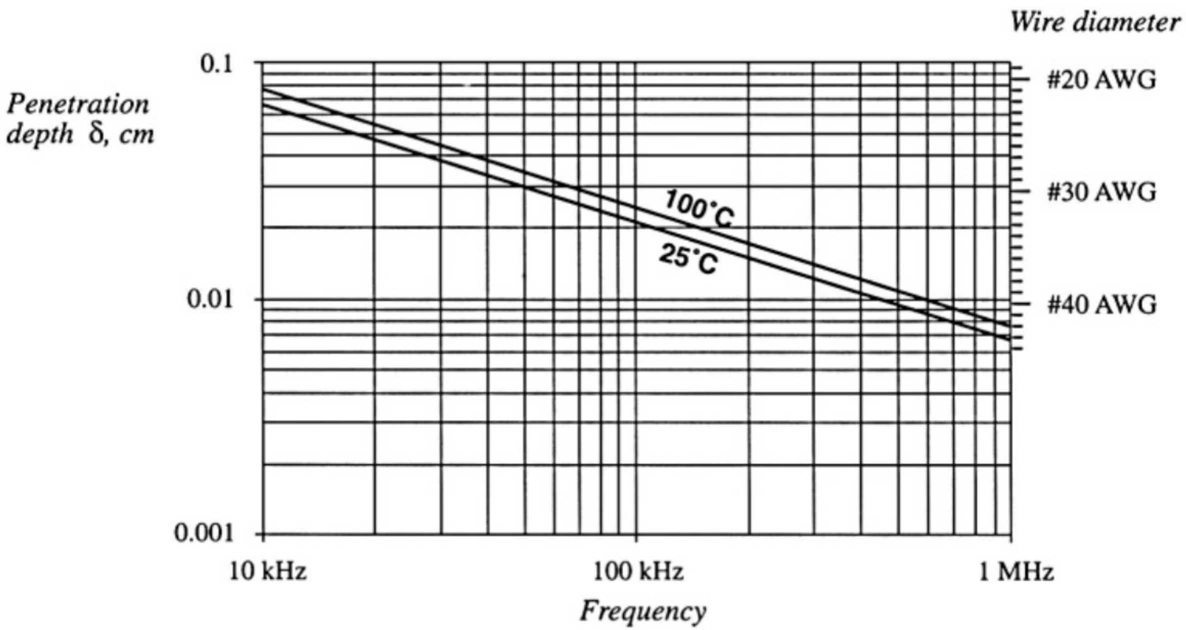
For 100 C copper resistivity:

Skin Effect

For 100 C copper resistivity:

$$\delta = \frac{7.5}{\sqrt{f}}\,\text{cm}$$

Skin Depth



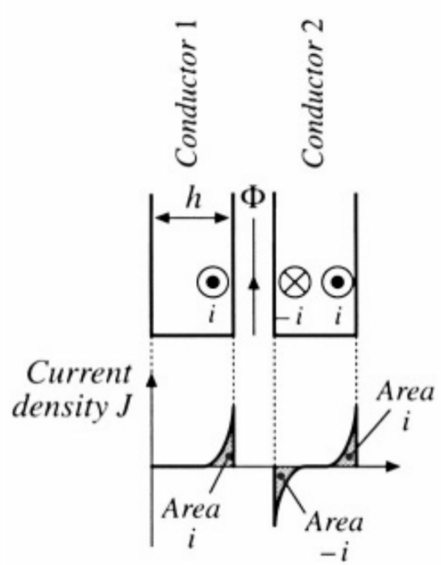
Wire diameter
0.1
0.01
0.001
Penetration depth δ, cm
#20 AWG
#30 AWG
#40 AWG
100°C
25°C
10 kHz
100 kHz
1 MHz
Frequency

Proximity Effect

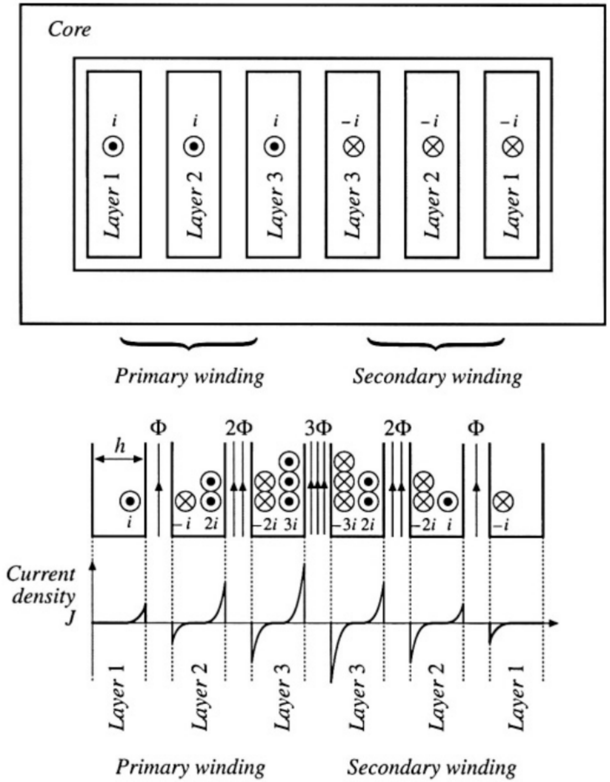
Current loss induced by adjacent coils

Proximity Effect

Current loss induced by adjacent coils



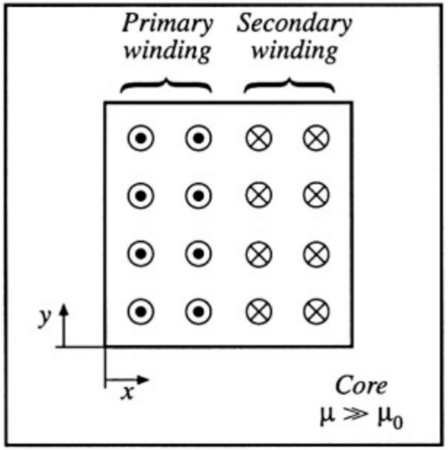
Coil-1 carries a high frequency current, Coil-2 open circuited.

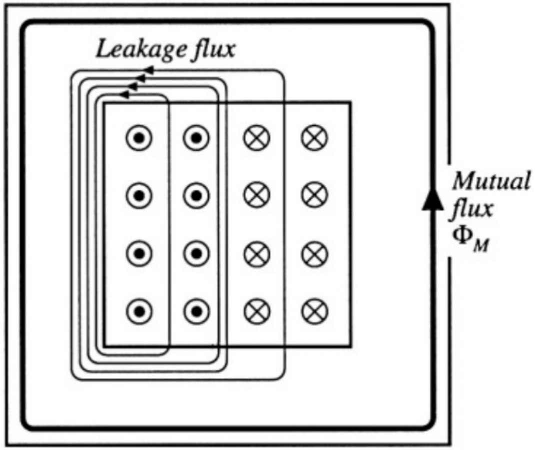


Increased copper loss

Leakage Flux

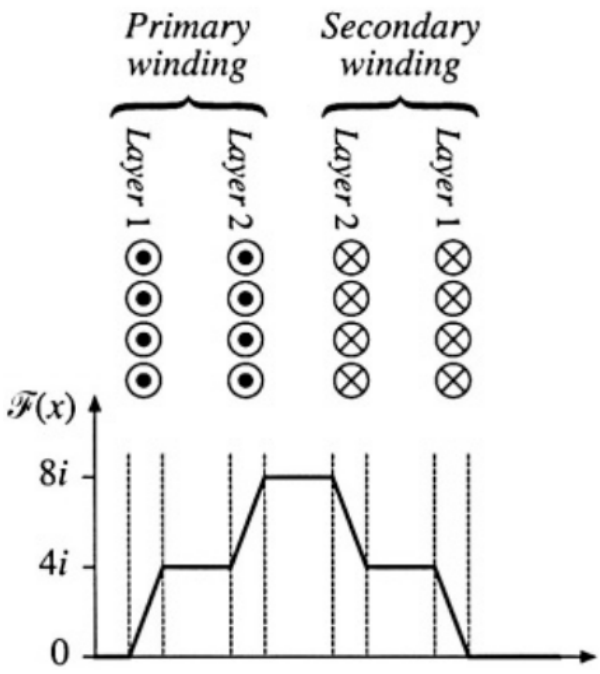
Leakage Flux





Leakage Flux

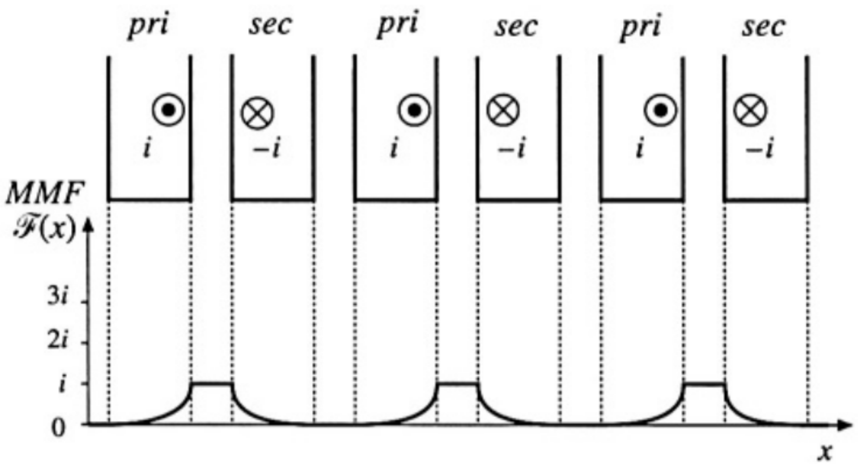
MMF Distribution



Interleaving Windings

Interleaving Windings

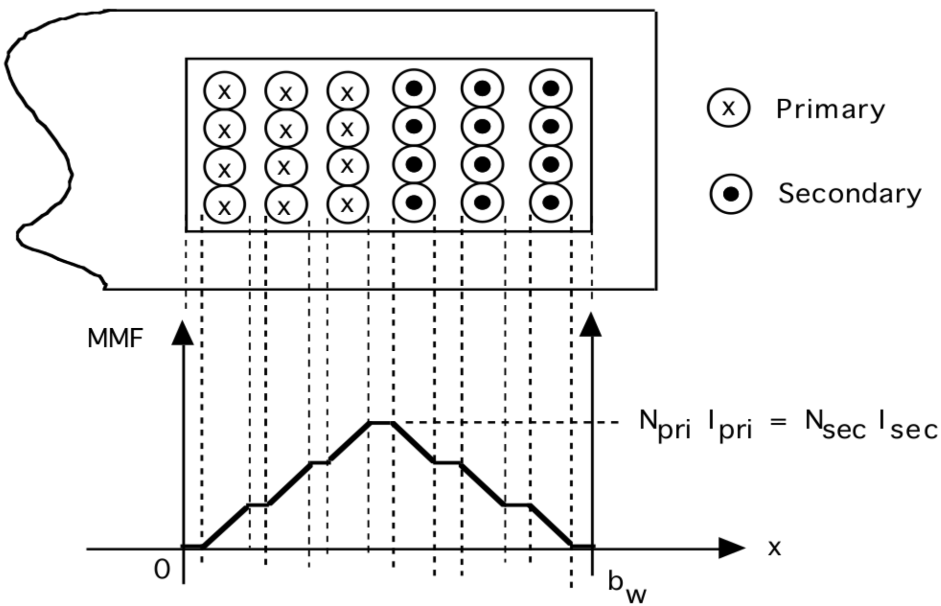
Can help to reduce proximity effect and leakage



Interleaving Windings

Interleaving Windings

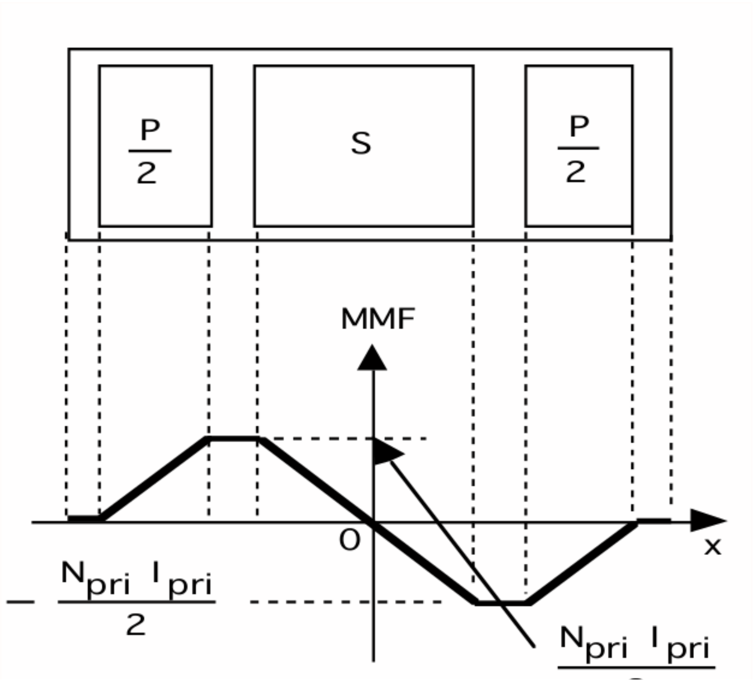
Worst Case



Interleaving Windings

Interleaving Windings

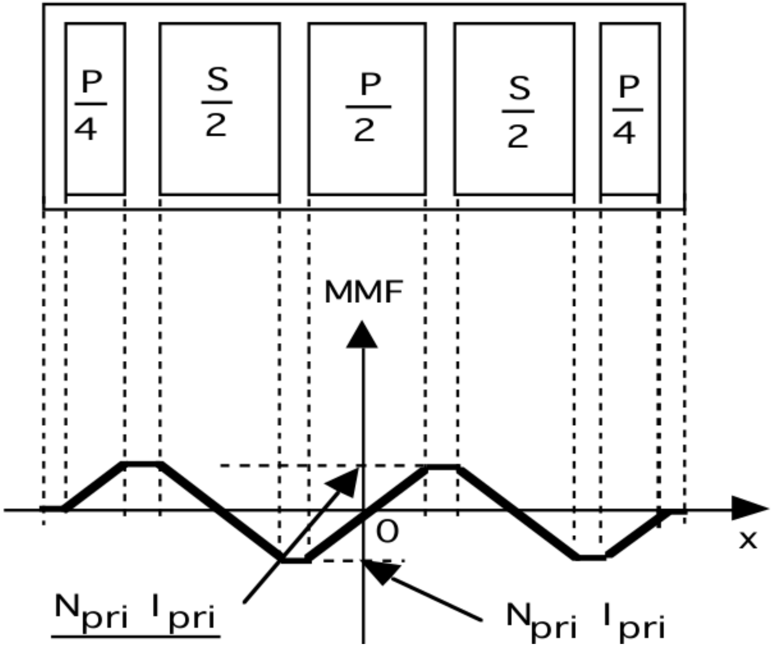
Better Case



Interleaving Windings

Interleaving Windings

Best Case



How to use an RLC Meter?

How to use an RLC Meter?

- [Hioki, IM3533](#)

How to use an RLC Meter?

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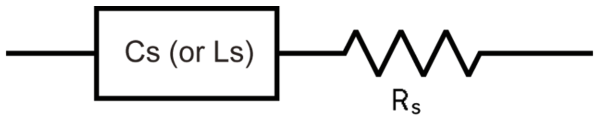
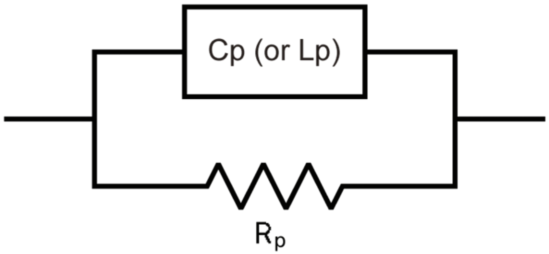
[Equivalent Circuit Models]()

How to use an RLC Meter?

[Equivalent Circuit Models]



Series equivalent circuit

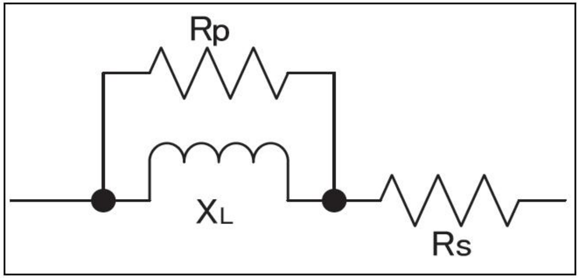


Parallel equivalent circuit

Equivalent Circuit Models

	10Hz	1kHz	100kHz	5MHz	300MHz
100mH	6.3Ω	630Ω	63kΩ	3.1MΩ	
10mH	630mΩ	63Ω	6.3kΩ	310kΩ	
1mH	63mΩ	6.3Ω	630Ω	31kΩ	
100uH	6.3mΩ	630mΩ	63Ω	3.1kΩ	
10uH		63mΩ	6.3Ω	310Ω	
1uH		6.3mΩ	630mΩ	31Ω	1.9kΩ
100nH			63mΩ	3.1Ω	190Ω
10nH			6.3mΩ	310mΩ	19Ω
1nH					1.9Ω

Choose Lp
Depends on the case
Choose Ls



How to use an RLC Meter?

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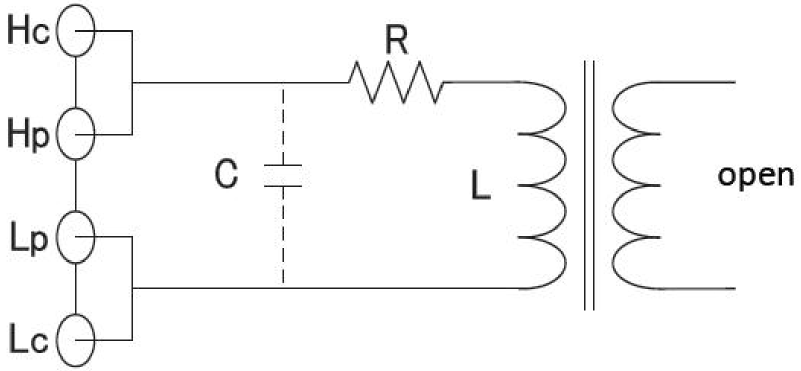
Primary and Secondary Inductance Measurement

[Measure Primary Inductance with Osciloscope]



Measuring circuit for primary and secondary inductance

How to use an RLC Meter?

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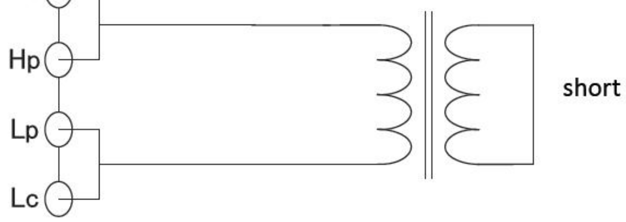
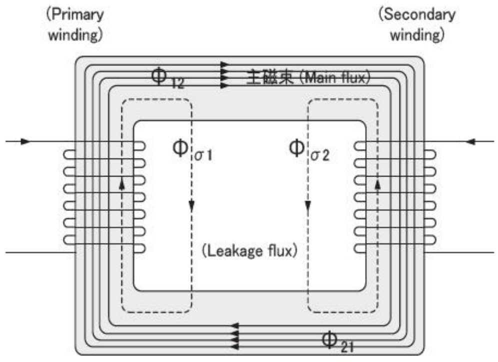
Leakage Inductance Measurement

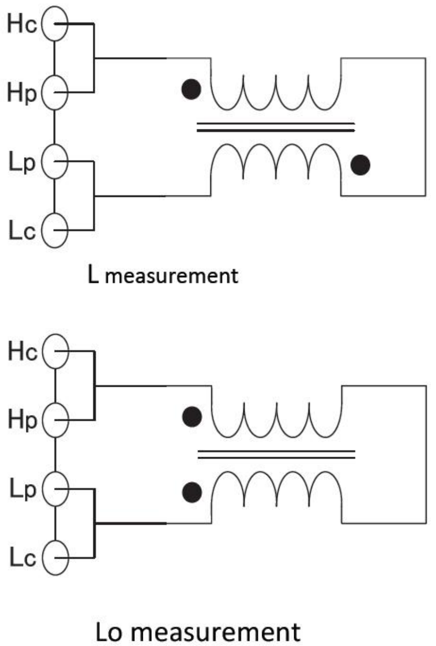


Measuring circuit for leakage inductance



Leakage flux

Mutual Inductance Measurement: $L_m = (L_a - L_o)/4$



Measuring circuit for mutual inductance between coils

How to use an RLC Meter?

How to use an RLC Meter?

[Turns Ratio Measurement]

Application Notes:

- Coil Craft Application Notes
- Selecting the Best Inductor
- Structured Design off Switching Power Transformers

Application Notes:

- OnSemi-Transformer Design Consideration for Flyback
- Transformers and Inductors for Power Electronics: Theory, Design and Applications
- Power Transformer Design
- Flyback Transformer Design
- Fuji, Flyback Transformer Design

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