Electrical Engineering Technology

Inductor Introduction

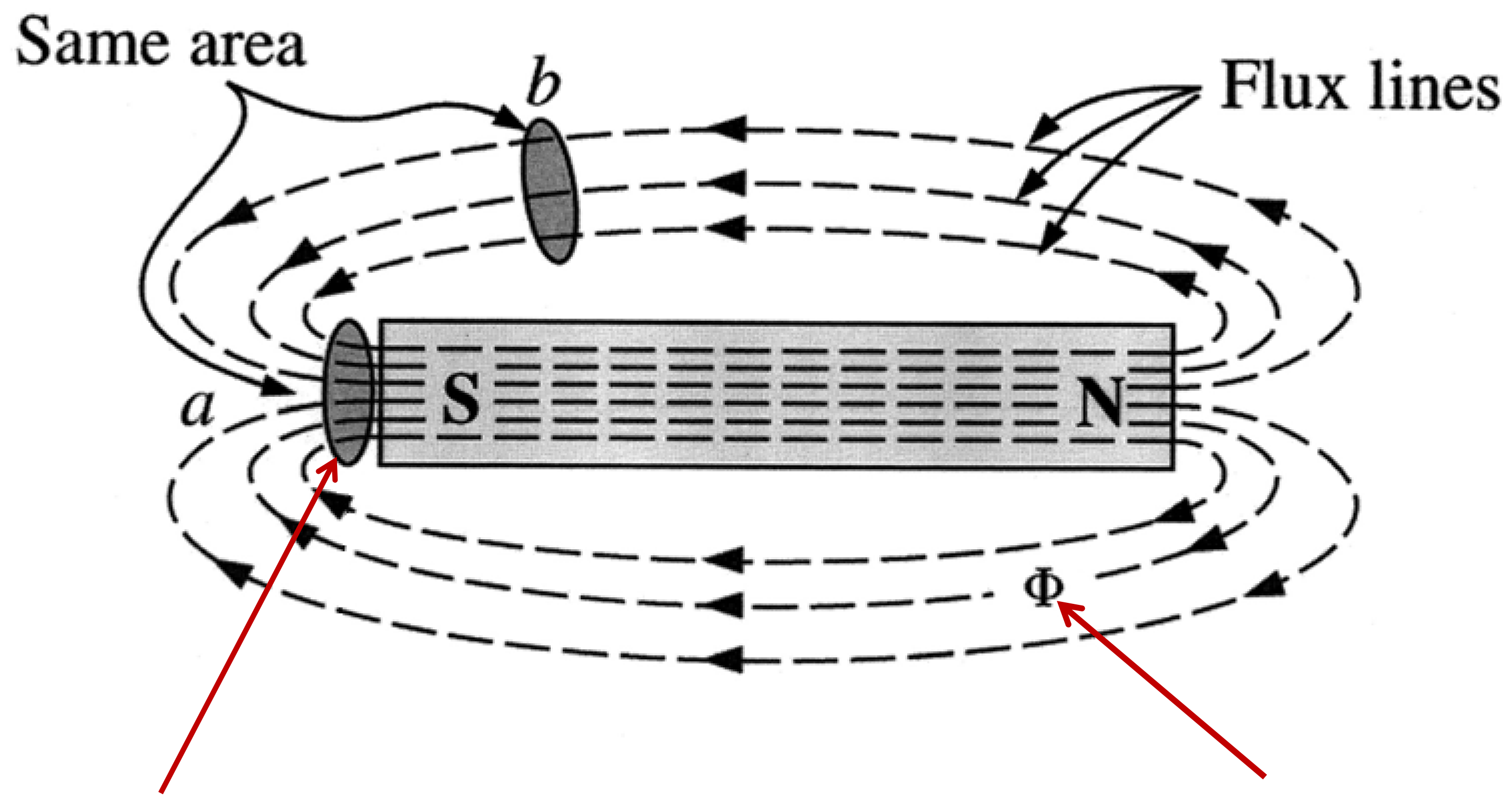
Inductors vs. Capacitors

- Capacitors store potential energy in an electric field
  - The applied voltage determines total energy stored
  - We can't change the voltage across a capacitor instantly
- Inductors store kinetic energy in a magnetic field
  - The applied current determines the total energy stored
  - We can't change the current through an inductor instantly

Inductors vs. Capacitors

- By definition, you can’t “store” kinetic energy, it must remain in motion
- Thus, the current through an inductor must not stop
- If you attempt to stop it instantly, the inductor will generate whatever voltage is necessary to maintain current flow

Flux

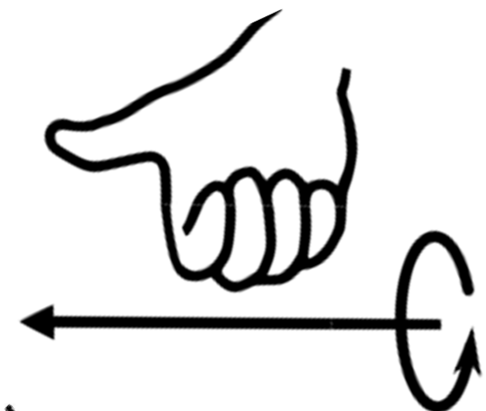


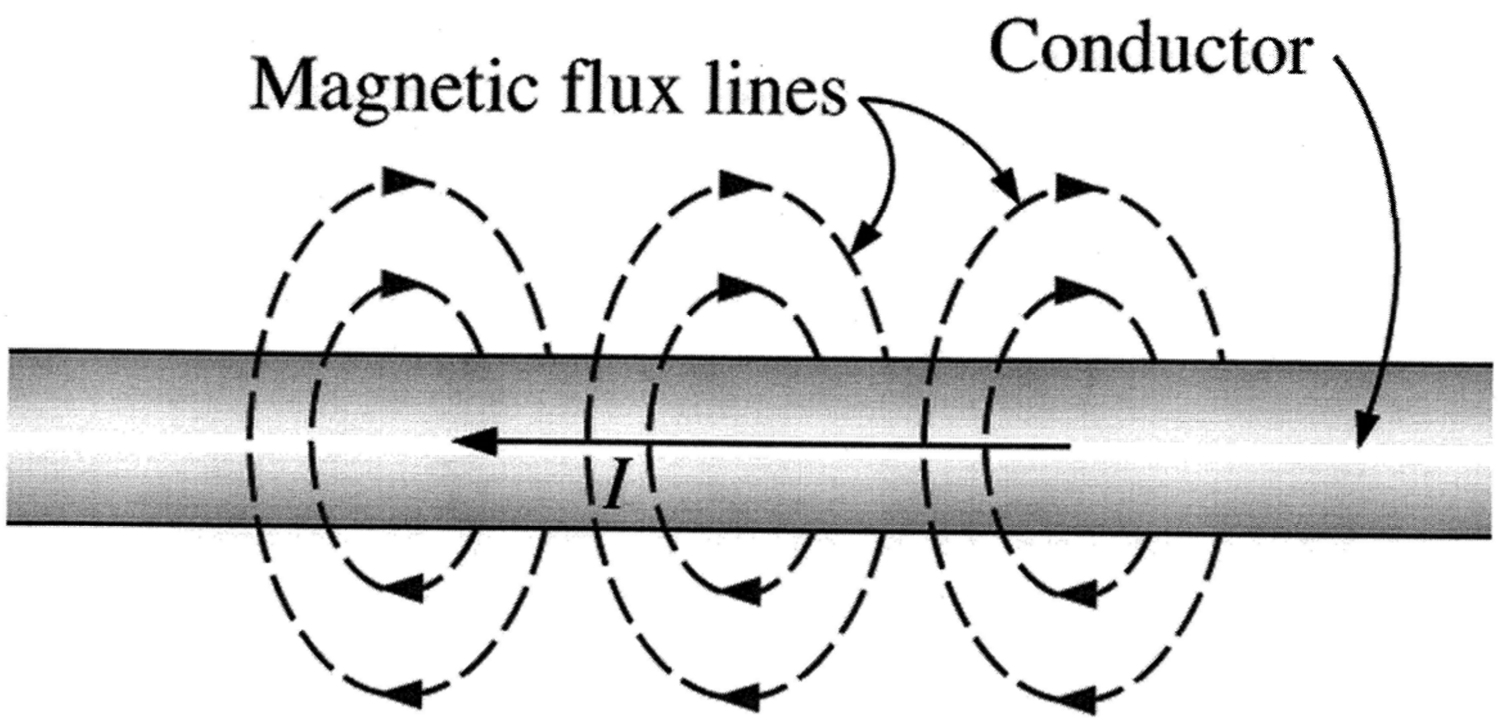
Stronger field here than at area B

Magnetic flux symbol (Webers)

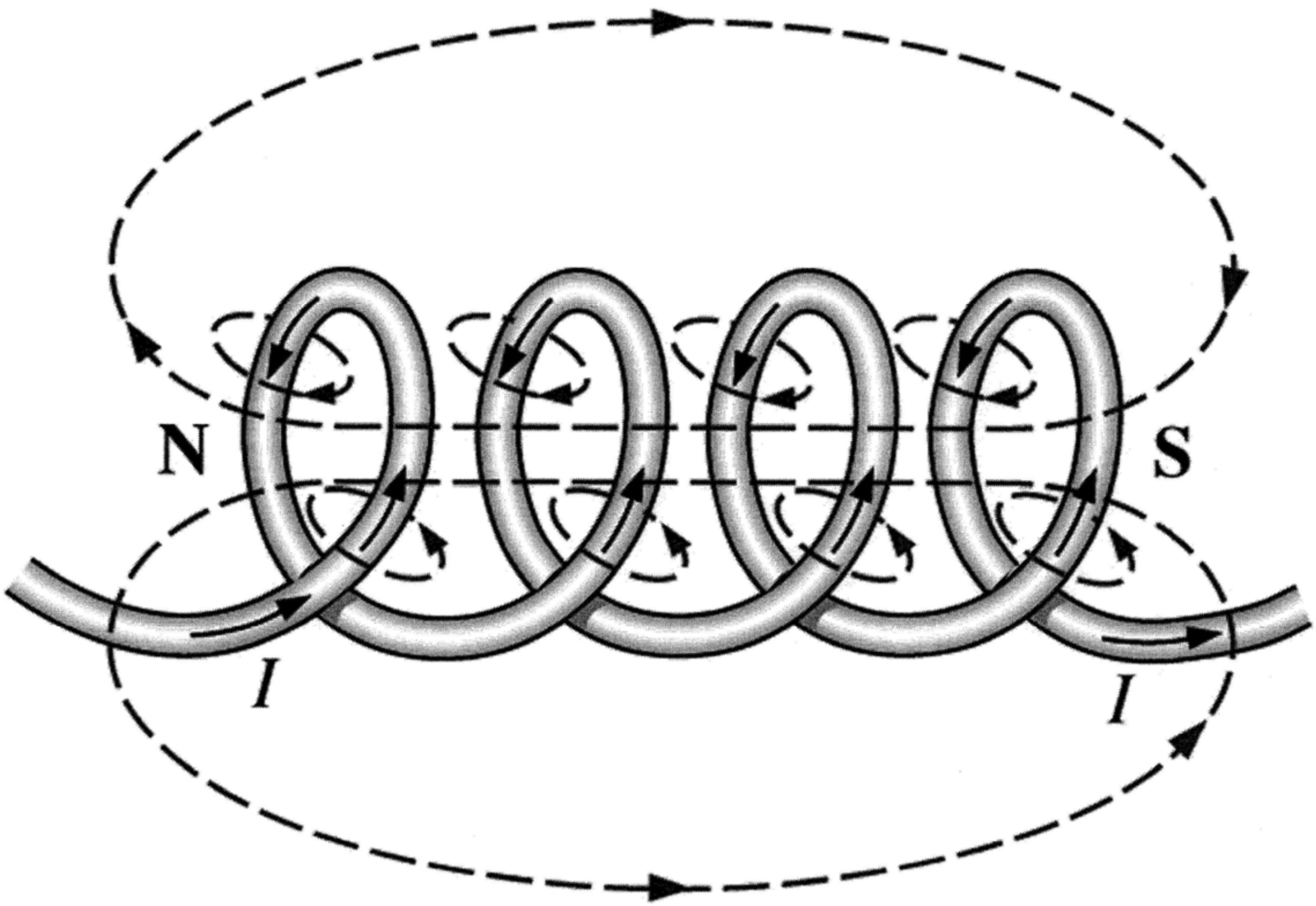
Right-hand rule

- Thumb points in direction of current flow
- Fingers curl in direction of flux
- Valid for conventional current





Flux in a coil



Self-Inductance

- The ability of a coil to oppose any change in current is a measure of self-inductance "L", measured in Henries (H)

$$H = \frac{Wb}{A}$$ ← *units*

$$L = \frac{N^2 \mu A}{l}$$

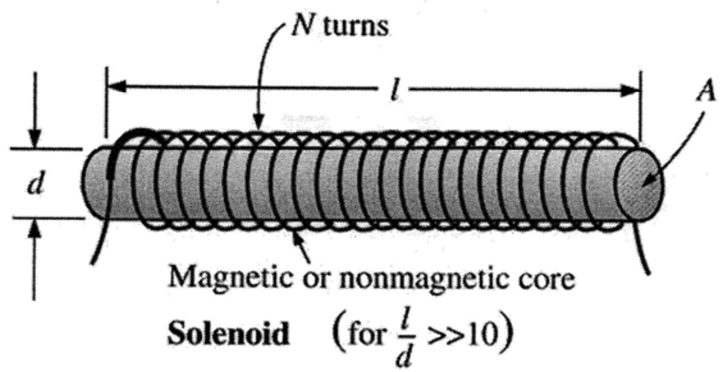
N : Number of turns
μ : Permeability of the core, $\mu_0 \bullet \mu_r$, $\frac{Wb}{A \cdot m}$
A : Area of the core, m^2
l : Mean length of the core, m

Good low-frequency approximation (DC is 0 frequency)

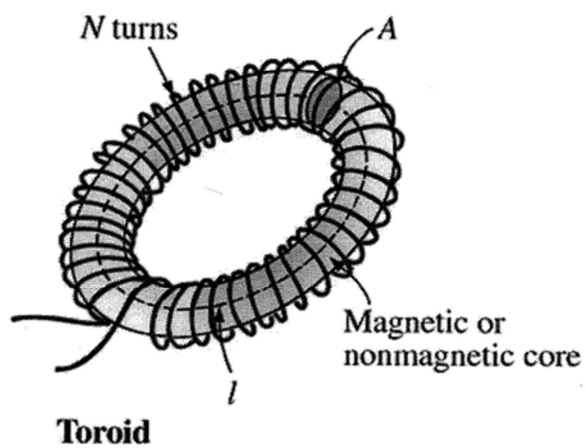
$$L = \mu_r \frac{N^2 \mu_0 A}{l}$$

$$L = \mu_r (L_0)$$ *L_0 = Inductance with an air core*

Core shapes



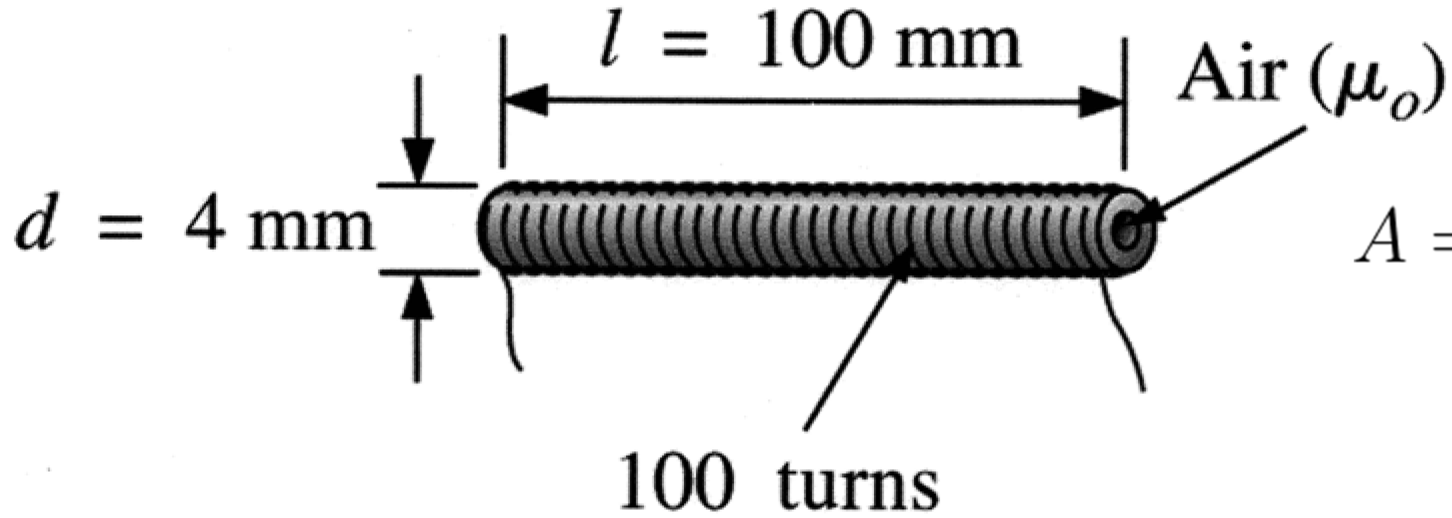
(a)



(b)

Example

- Find L in Henries



$$A = \pi r^2 = \frac{\pi d^2}{4}$$

$$L = \mu_r L_0$$

$$L_0 = \frac{N^2 \mu_0 A}{l}$$

$$N = 100$$

$$\mu_0 = 4\pi \cdot 10^{-7} \frac{Wb}{A \cdot m}$$

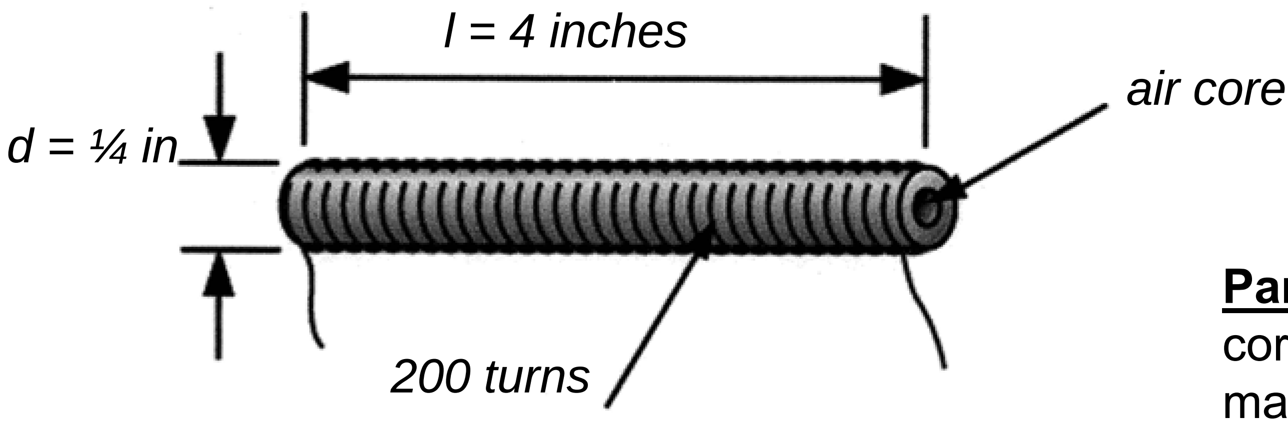
$$A = \frac{\pi d^2}{4} = \frac{\pi\left(4 \cdot 10^{-3} m\right)^2}{4} = 12.57 \cdot 10^{-6} m^2$$

$$l = 100 \cdot 10^{-3} m$$

$$L_0 = \frac{(100)^2\left(4\pi \cdot 10^{-7} \frac{Wb}{A \cdot m}\right)\left(12.57 \cdot 10^{-6} m^2\right)}{100 \cdot 10^{-3} m} = \boxed{1.58 \mu H}$$

ICP

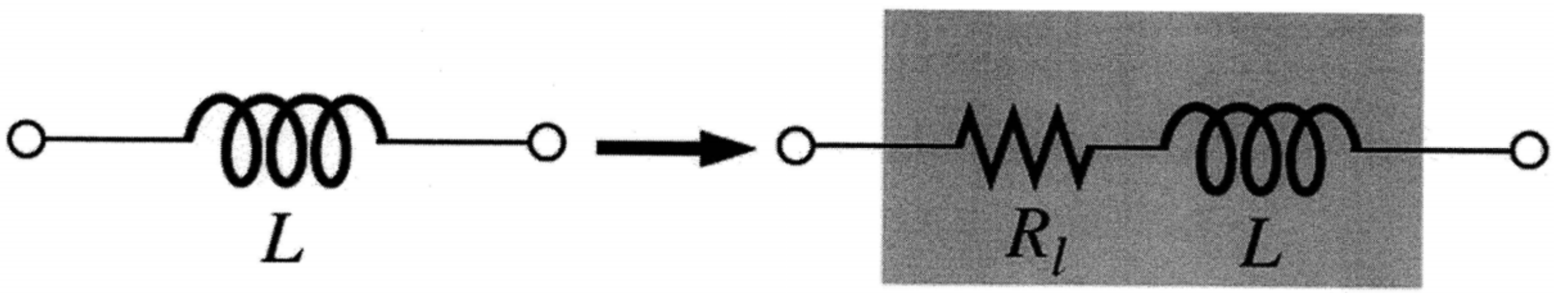
- Find L in Henries



Part II : Find L if the core was a magnetic material with $\mu_r = 125$

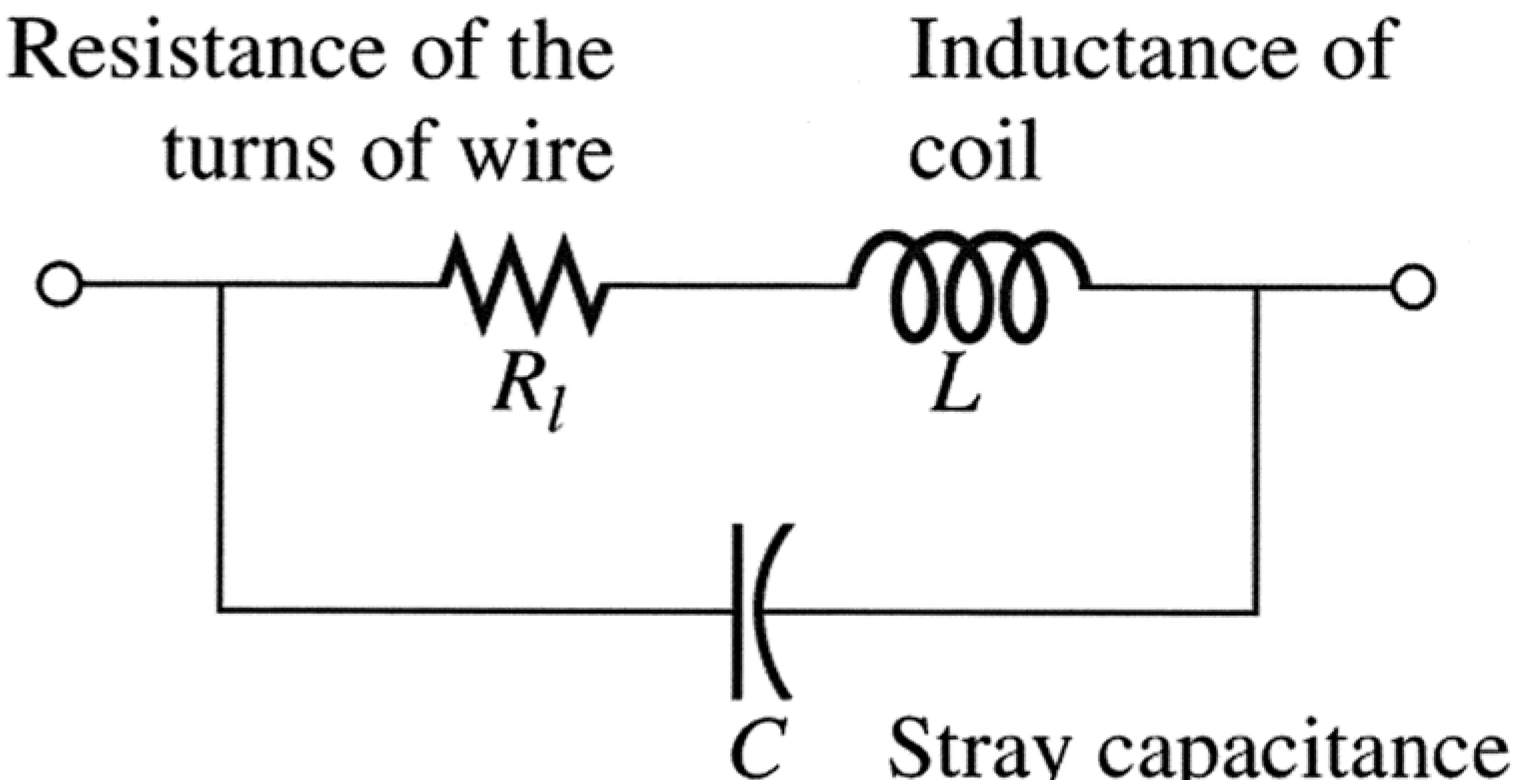
Practical Model

- Valid for low frequencies

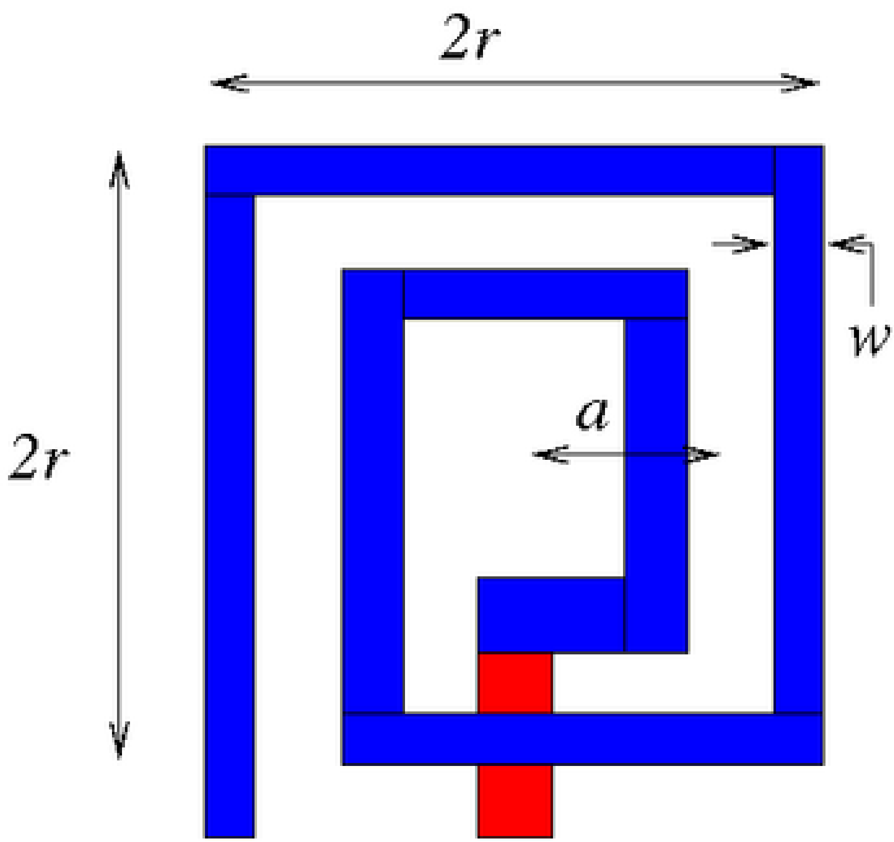


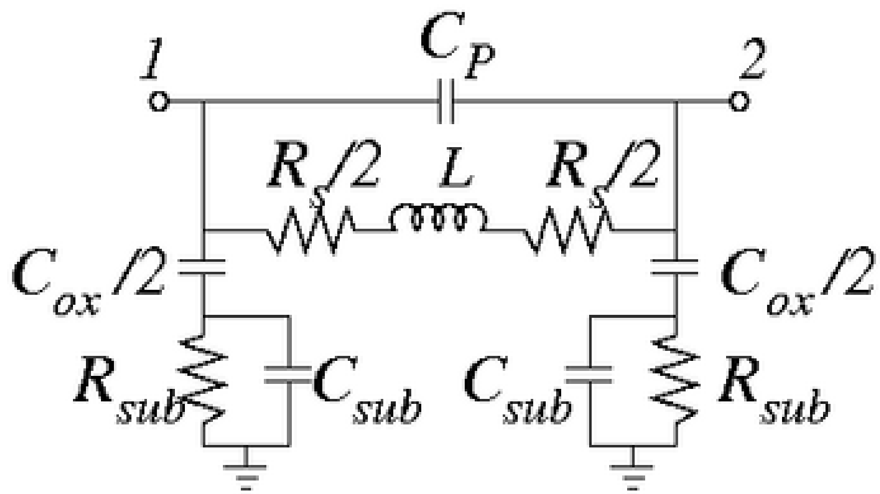
Practical Model

- Slightly better (includes parasitic capacitance)



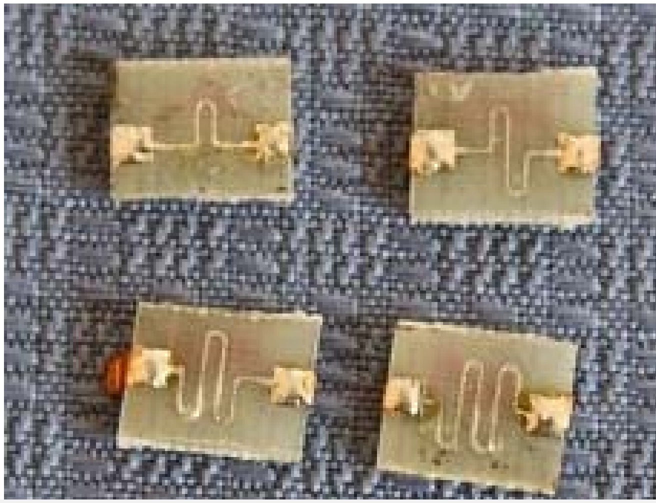
Spiral PCB Trace Inductor

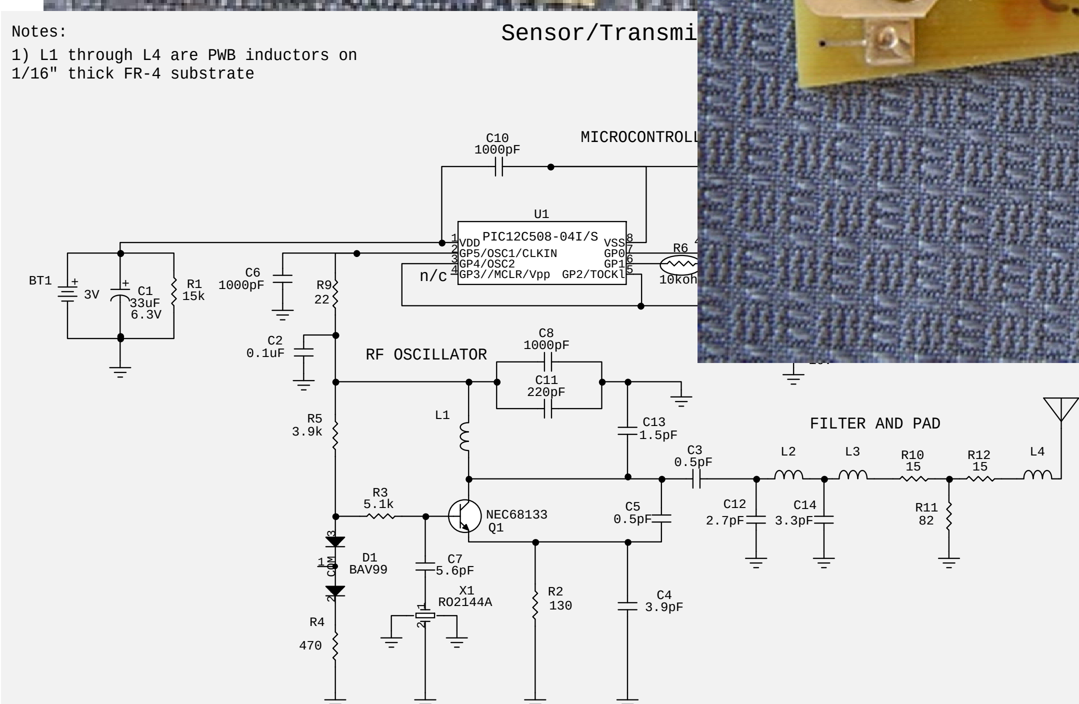


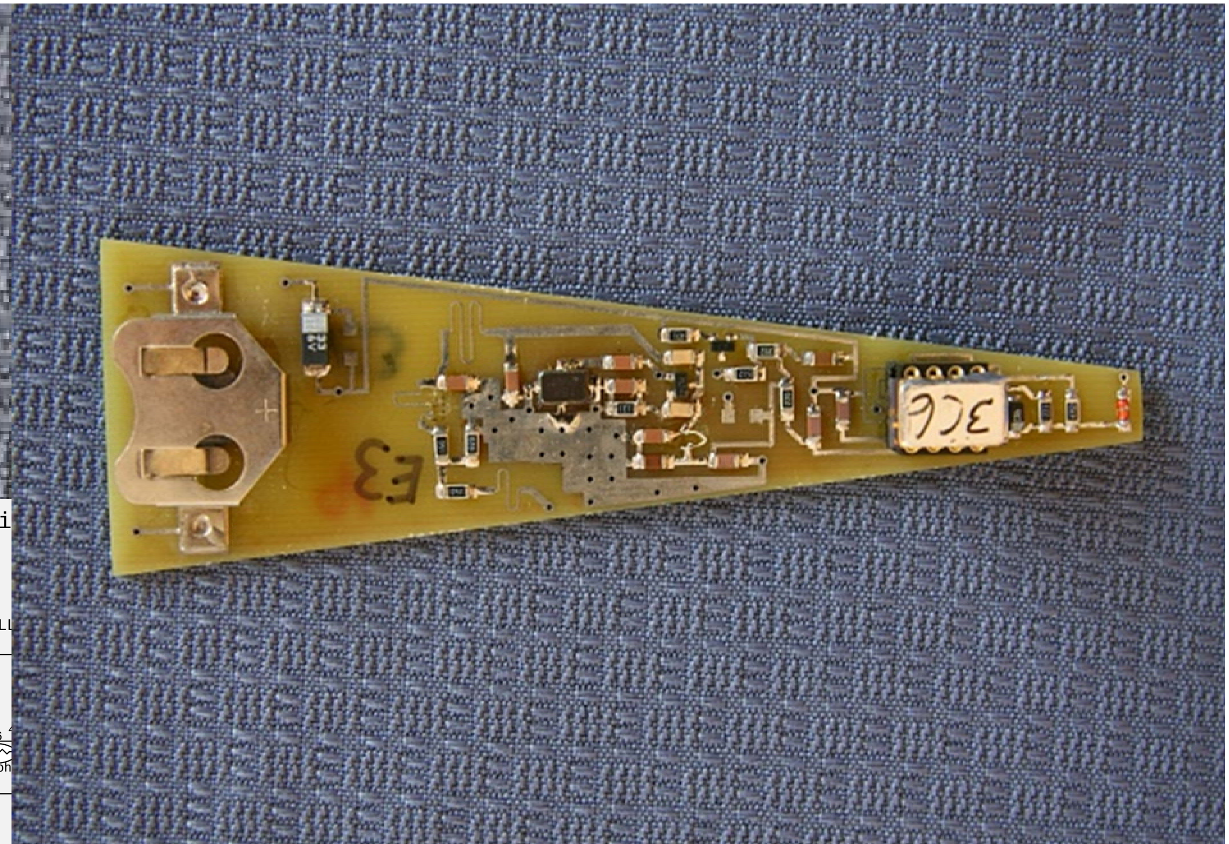


http://bmf.ece.queensu.ca/mediawiki/index.php/Spiral_Inductor_Design

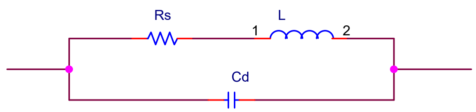
Example - PCB Trace Inductors







MEMS Design – RF Inductors

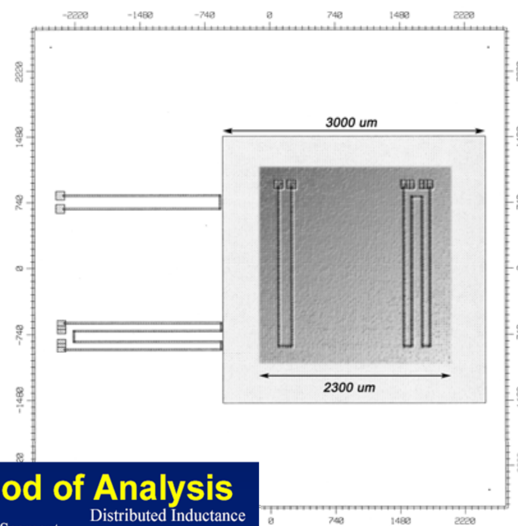


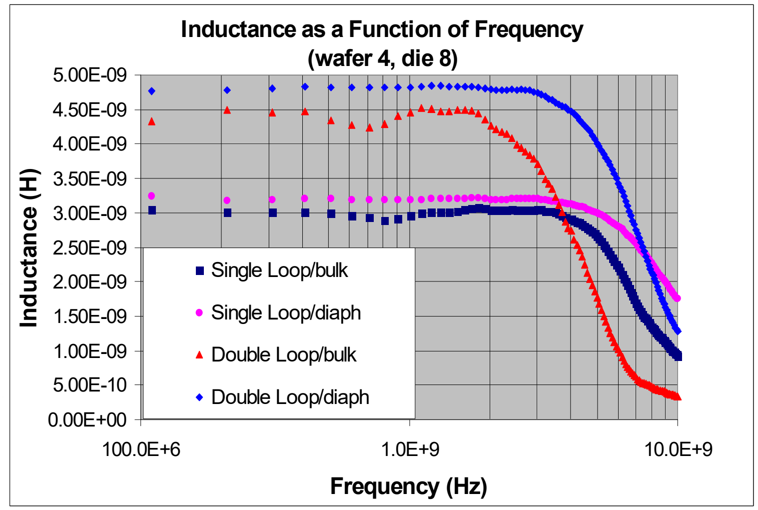
$$Y(jw) = j \cdot w \cdot Cd + \frac{1}{Rs + j \cdot w \cdot L}$$

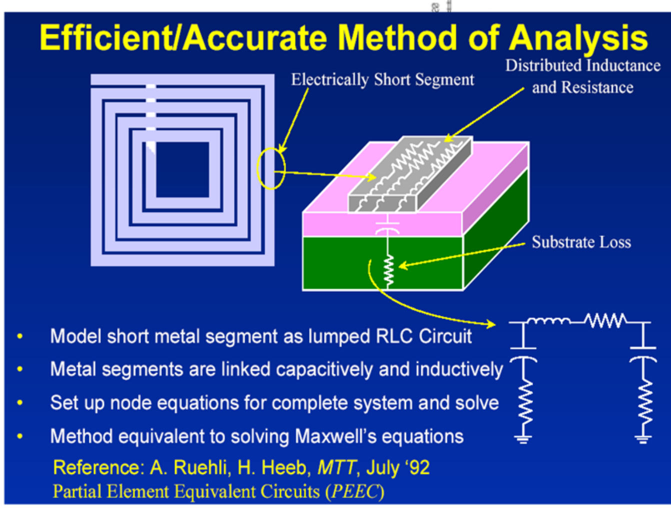
$$Y(jw) = \frac{Rs}{Rs^2 + w^2 \cdot L^2} + j \cdot \left(w \cdot Cd - \frac{w \cdot L}{Rs^2 + w^2 \cdot L^2} \right)$$

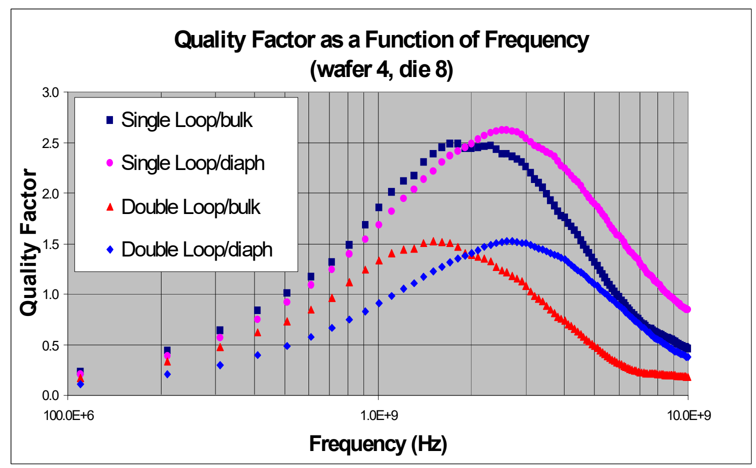
$$w_0 = \sqrt{\frac{1}{L \cdot Cd} - \left(\frac{Rs}{L} \right)^2}$$

$$Q \equiv \frac{X}{Rs} \approx \frac{X_L}{Rs} \text{ at low frequencies}$$

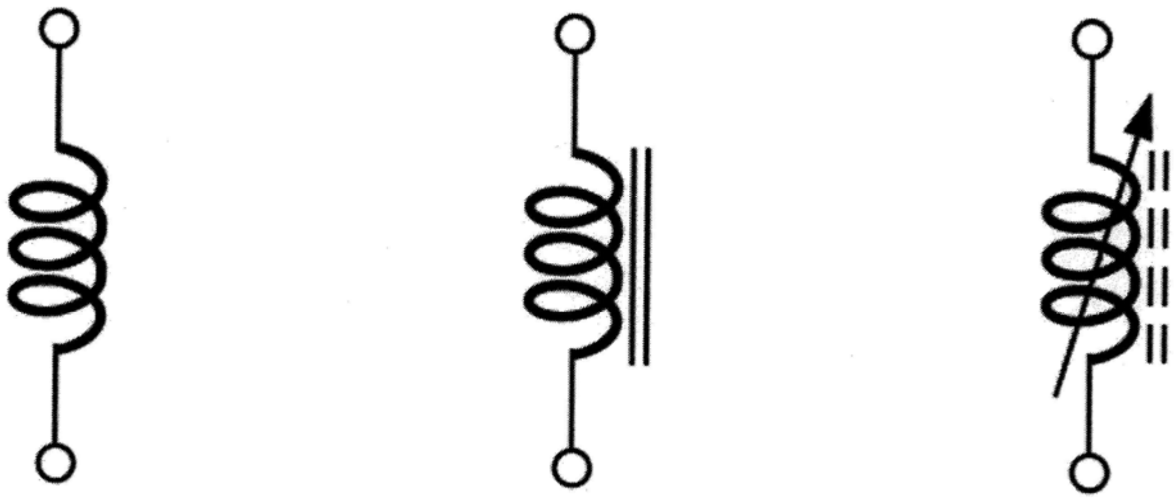








Schematic Symbols

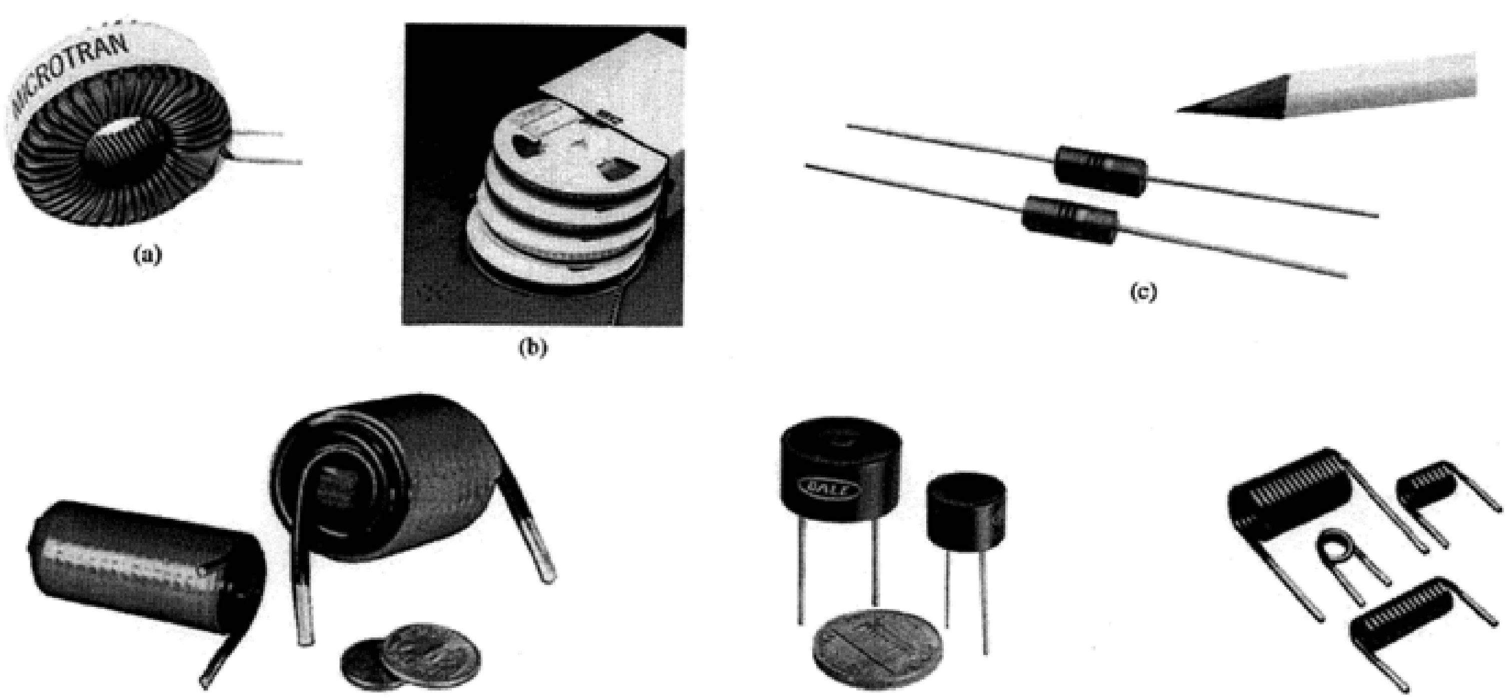


Air-core

Iron-core

Variable (permeability-tuned)

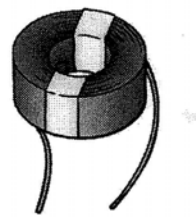
Types of Inductors



(a) (b) (c) (d) (e) (f)

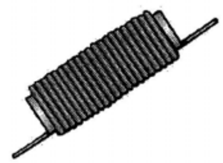
Types of Inductors/Applications

Type: Open Core Coil
Typical Values: 3 mH to 40 mH
Applications: Used in low-pass filter circuits. Found in speaker crossover networks.

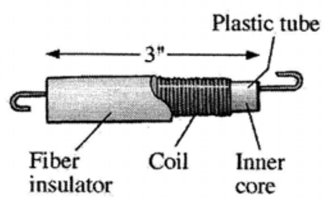


Type: Toroid Coil
Typical Values: 1 mH to 30 mH
Applications: Used as a choke in AC power lines circuits to filter transient and reduce EMI interference. This coil is found in many electronic appliances.

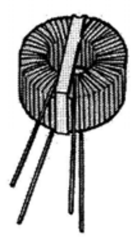
Type: Hash Choke Coil
Typical Values: 3 μH to 1 mH
Applications: Used in AC supply lines that deliver high currents.



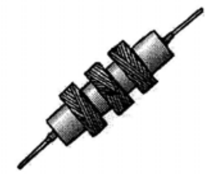
Type: Delay Line Coil
Typical Values: 10 μH to 50 μH
Applications: Used in color televisions to correct for timing differences between the color signal and black and white signal.



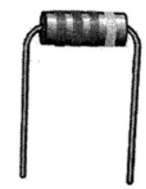
Type: Common Mode Choke Coil
Typical Values: 0.6 mH to 50 mH
Applications: Used in AC line filters, switching power supplies, battery charges and other electronic equipment.



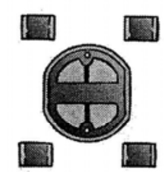
Type: RF Chokes
Typical Values: 10 μH to 50 μH
Applications: Used in radio, television, and communication circuits. Found in AM, FM, and UHF circuits.



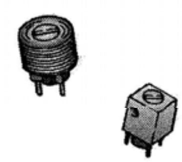
Type: Moiled Coils
Typical Values: 0.1 μH to 100 μH
Applications: Used in a wide variety of circuit such as oscillators, filters, pass-band filters, and others.



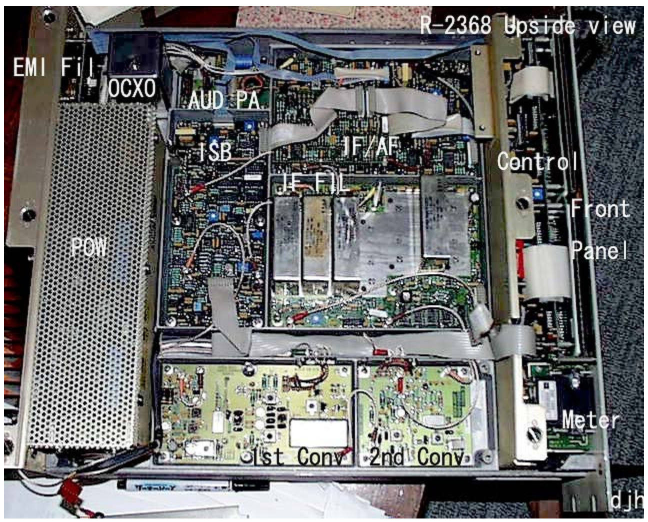
Type: Surface Mounted Inductors
Typical Values: 0.01 μH to 100 μH
Applications: Found in many electronic circuits that require miniature components on multilayered PCB.

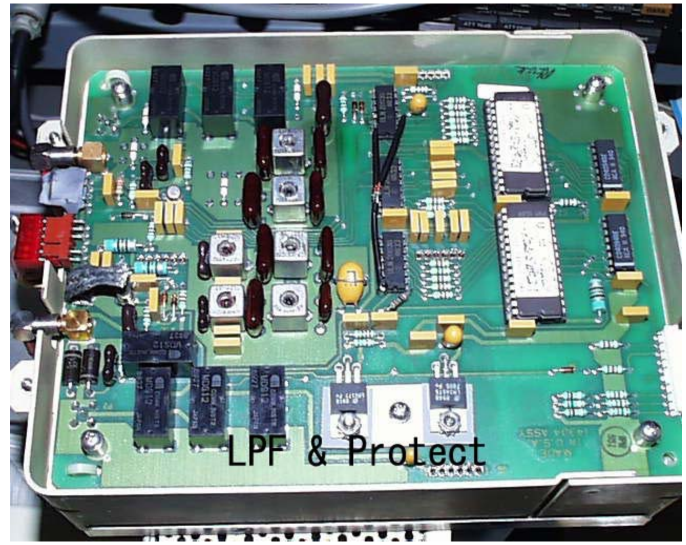


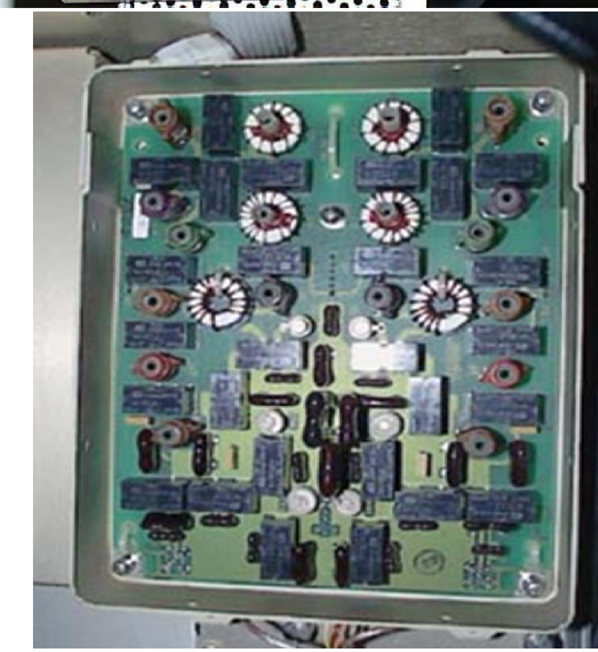
Type: Adjustable RF Coil
Typical Values: 1 μH to 100 μH
Applications: Variable inductor used in oscillators and various RF circuits such as CB transceivers, televisions, and radios.



Through-Hole Inductor Example (RF Filters)







Surface Mount Inductor Example (RF Filter)