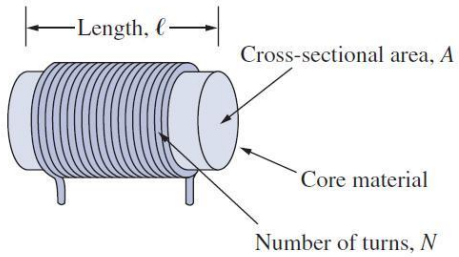
Introduction

Electrical & Electronic Circuits and Elements

Embedded Systems & Embedded Programming

Fundamentals of Electric Circuits (Inductor)

- Is a passive element that **stores energy** in its **magnetic field**
- Is used in power supplies, transformers, radios, radars, electric motors and etc.
- Any conductor of electric current has inductive properties and may be regarded as an inductor
- To enhance the inductive effect, a practical inductor consists of a **coil of conducting wire**
- **Inductance** is the property that an inductor shows opposition to the change of current
  - Measured in henrys (**H**)
  - Depends on the physical dimension and construction of the inductor
  - Represented by **L**

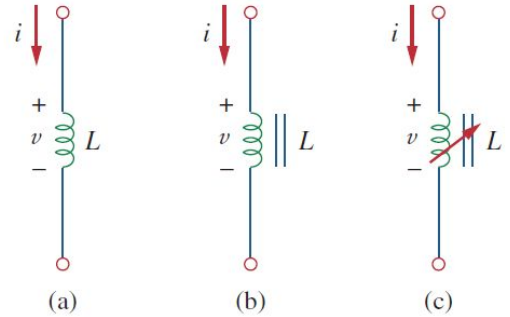


Typical form of an inductor

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

μ is the permeability of the core

μ for air is 1.257 x 10^{-6} H/m



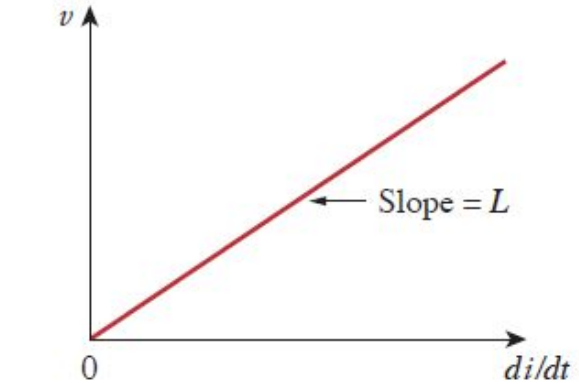
Circuit symbols for inductors: (a) air-core, (b) iron-core, (c) variable iron-core.

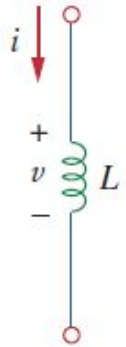
Fundamentals of Electric Circuits (Inductor)

- The voltage across an inductor is directly proportional to the time rate of change of the current
- An inductor acts like a short circuit to dc current
  - ➢ The voltage across an inductor is zero when the current is constant
- The current through an inductor cannot change instantaneously
  - ➢ Discontinuous change in the current requires an infinite voltage

Inductors and Inductance

$$v = L\frac{di}{dt}$$





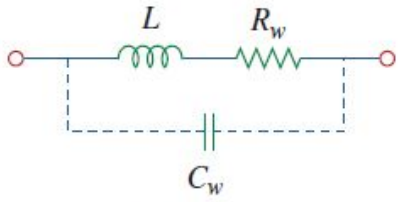
$$w = \frac{1}{2}Li^2$$

Stored energy

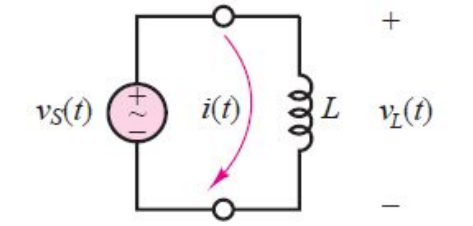
Voltage-current relationship of an inductor.

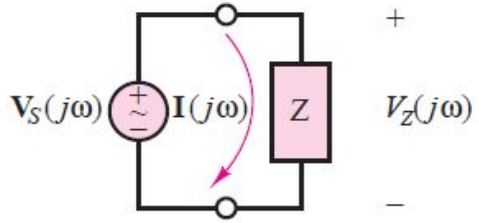
Fundamentals of Electric Circuits (Inductor)

- An ideal inductor does not dissipate energy
  - It takes power from the circuit when storing energy
  - Delivers power to the circuit when returning previously stored energy
- A practical inductor has significant:
  - Resistance because of the
    - Conducting material
  - Capacitance because of the
    - Capacitive coupling between the conducting coils



Circuit model for a practical inductor.

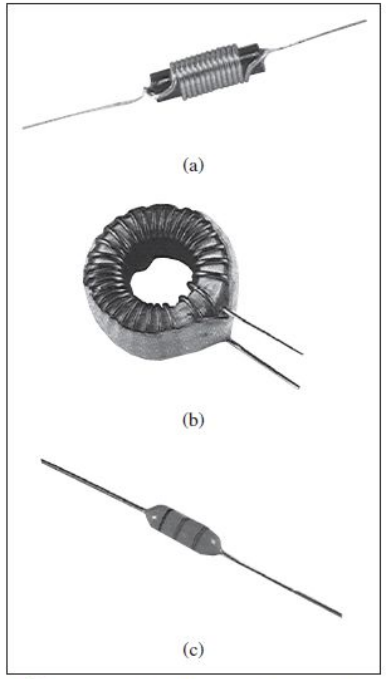




- Impedance of an inductor is ***sL*** where
  - ***s*** is the complex frequency of the source signal
  - ***s*** for a **DC** signal is **0** and for a **sinusoidal AC** signal is ***jω***
  - $\omega = 2\pi f$ where f is the frequency of the signal

Fundamentals of Electric Circuits (Inductor)

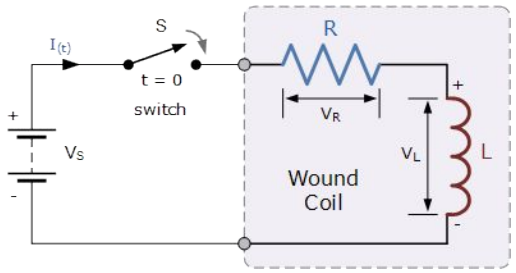
- Measured by
  - Online Calculator
  - Inductance meter
  - By text or color marking on the inductor
- Some useful links
  - The Inductor
  - Inductance of a Coil
  - Mutual Inductance
  - Inductors in Series
  - Inductors in Parallel

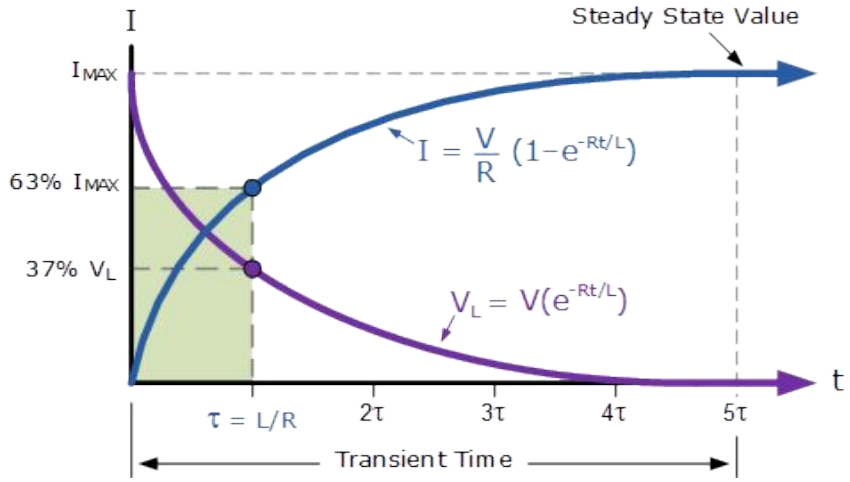


Various types of inductors: (a) solenoidal wound inductor, (b) toroidal inductor, (c) chip inductor.

Fundamentals of Electric Circuits (Inductor)

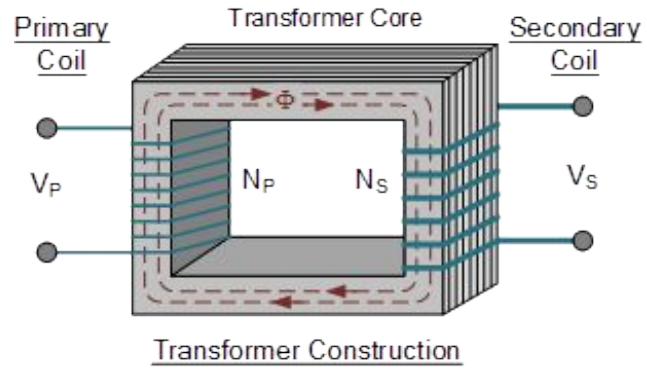
- Store and release energy
  - ➢ LR Series Circuit
- AC, puls and etc. responses
- Applications
  - ➢ Filters
  - ➢ Transformers

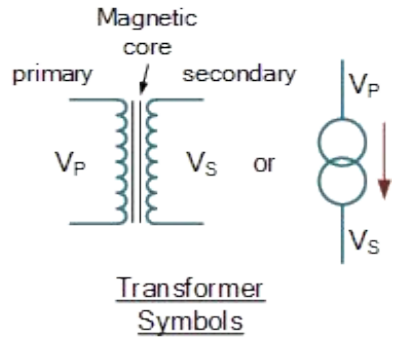




$$\frac{N_P}{N_S} = \frac{V_P}{V_S} = n = \text{Turns Ratio}$$

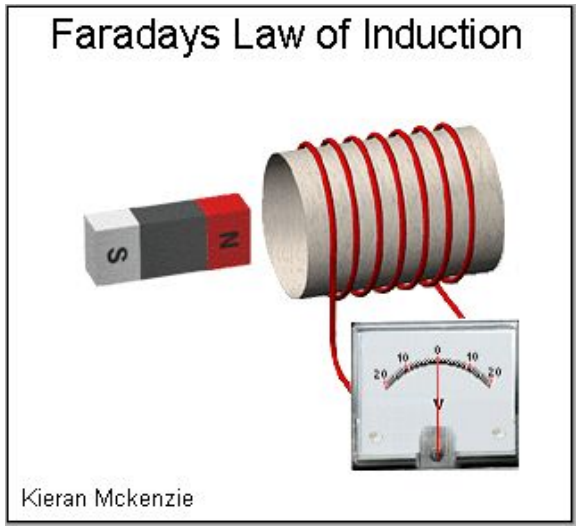
$$\text{Power}_{Primary} = \text{Power}_{Secondary}$$

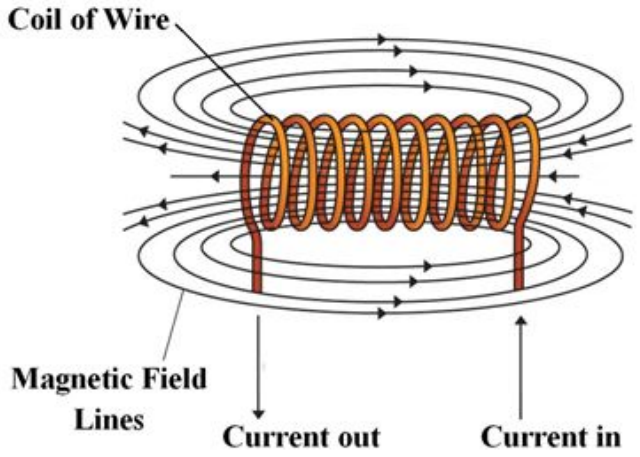


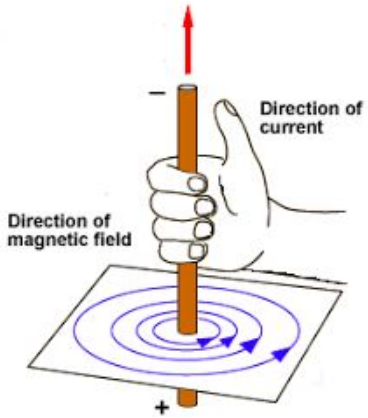


Fundamentals of Electric Circuits (Electromagnetism)

- A moving electric charge (**current**) generates a **magnetic field**
- A **magnetic field** induces electric charge movement (**current**)
- Electricity and magnetism are two related phenomena produced by the **electromagnetic** force
- In an electromagnetic wave, the electric and magnetic fields are perpendicular to each other

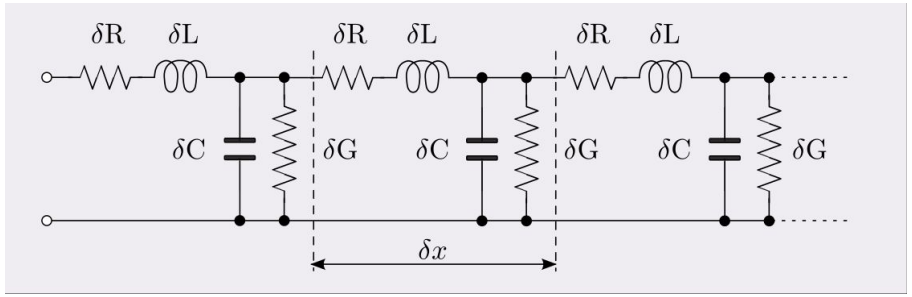


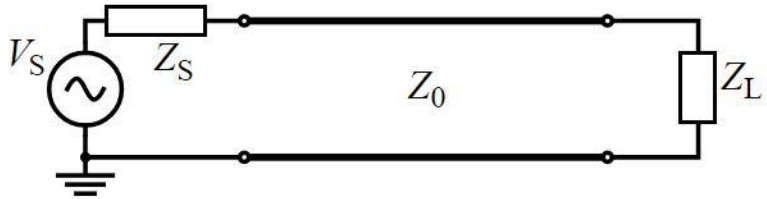




Fundamentals of Electric Circuits (Transmission Line)

- To deliver power, connection of two wires between the source and the load is required
- At low frequencies, power is delivered to the load in electric fields
- At higher frequencies, power is delivered in electric and magnetic fields
- Transmission line is a material structure that transfers energy in form of electromagnetic field
- If the impedance of the load and the transmission line are not matched
  - Some part of the power will be reflected to the source
  - The reflection coefficient at the load is $\Gamma_L = \frac{Z_L - Z_o}{Z_L + Z_o}$



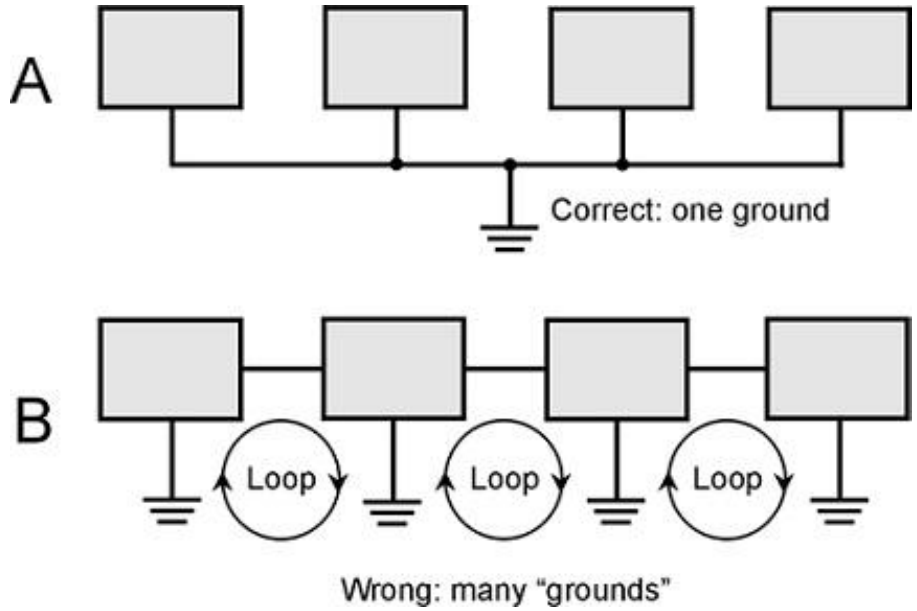


Transmission Lines - Signal Transmission and Reflection

Fundamentals of Electric Circuits (Ground Loops)

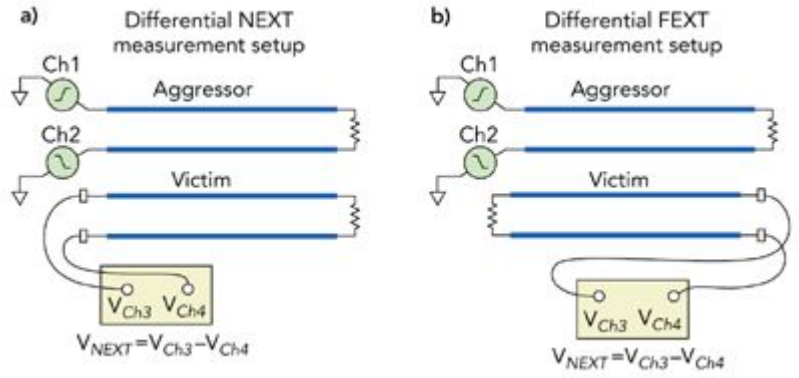
- Ground loop exists when an electrical system is connected through more than one path to the ground
- Ideally, all grounded points of an electrical system should be at the same potential
- The ground loop forms a large loop antenna that picks up interference currents easily
- The larger the loop the more interference (EMI)
- Result: The ground is no longer stable

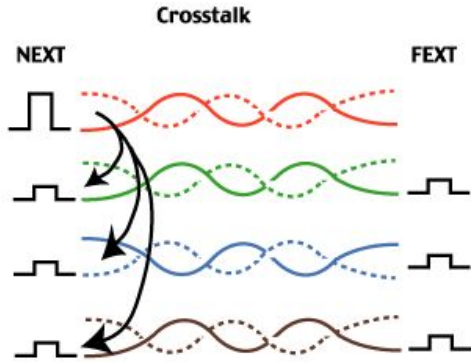
- Ground Loops: Avoid Them!
- Grounding and Shielding of electric circuits
- Galvanic Isolation: Purpose and Methodologies



Fundamentals of Electric Circuits (Crosstalk)

- Electromagnetic (EM) Crosstalk is an unwanted interference
- It is caused by the electric and magnetic fields of one or more signals affecting another signal
- Crosstalk occurs via two mechanisms
  - Capacitive crosstalk caused by the electrical field
  - Inductive crosstalk caused by the magnetic field
- Some solutions
  - Shielding
  - Increase the distance between lines
  - Using twisted pair wires
- Crosstalk (electronics)
- CrossTalk





Fundamentals of Electric Circuits

- References
  - Fundamentals of Electric Circuits, 5th Edition, Charles K. Alexander and Matthew N.O. Sadiku, ISBN 978-0-07-338057-5
  - Fundamentals of Electrical Engineering, First Edition, Giorgio Rizzoni, ISBN 978-0–07–338037–7
  - ***Some of the images have been copied from these two books***
- Some useful links
  - Electronic Basics #12: Coils / Inductors (Part 1)
  - Inductance basics
  - Do Volts or Amps Kill You? Voltage, Current and Resistance
  - How does an Antenna work? | ICT #4
  - Electromagnetic interferences
  - What is Hall Effect and How Hall Effect Sensors Work

The SI prefixes.

Multiplier	Prefix	Symbol
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a