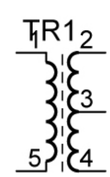
Cornerstone Electronics Technology and Robotics Week 31
Inductance and RL Circuits

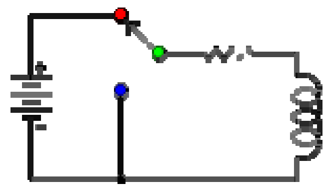
- Administration:
  - Prayer
  - Turn in quiz
  - Oral presentations
- Electricity and Electronics, **Section 14.1**, Inductance in DC Conditions:
  - Introduction: The study of electronics revolves around resistance, inductance, capacitance, and the combination of these in series and parallel circuits. We have already covered resistance in Chapter 3 and capacitance in Chapter 15, now we will study inductance in this chapter.
  - *Inductance* is the property in electrical circuits that resists a change in *current*. Don't confuse inductance with *capacitance* which is the property in electrical circuits that resists a change in *voltage*.
  - An inductor is an electronic component that is used to produce inductance in a circuit.
  - This opposition to a change in *current* is the result of the energy stored within the *magnetic field* of the *inductor*. Remember that a *capacitor* opposes a change in *voltage* by storing its energy in an *electric field*.
  - Inductance is symbolized by the letter L, measured in henrys (H). Usually, in electronics smaller values of henrys are used like mH (millihenry).
  - Most inductors have a low dc resistance since they are wound from copper wire.
  - Except for some radio circuits, inductors are not used in modern electronic circuits as often as resistors and capacitors.
  - Other names:
    - Coil
    - Reactor
    - Choke
  - Types:
    - Chokes
    - Tuning Coil
    - Toroidal Coil
  - Symbol:

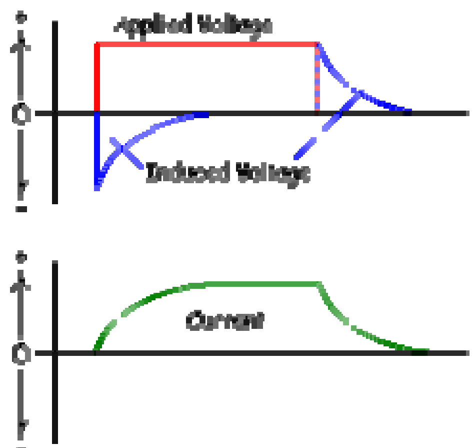
Inductor



Transformer

- o Counter emf:
  - When current through an inductor is increased or decreased, the inductor "resists" the *change* in current by producing a voltage between its leads in opposing polarity to the *change*.
  - View http://www.williamson-labs.com/480_rlc-l.htm#top
  - This phenomenon exhibits a more general principle known as *Lenz's Law*, which states that an induced effect will always be opposed to the cause producing it.



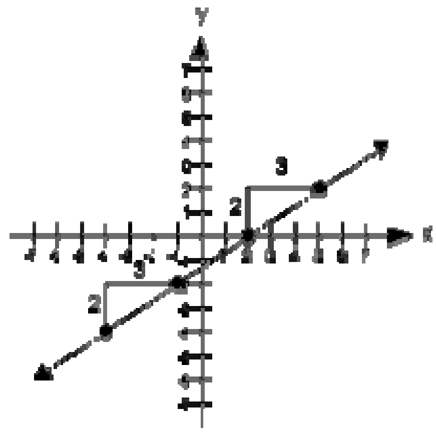


From: http://www.williamson-labs.com/480_rlc-l.htm#top

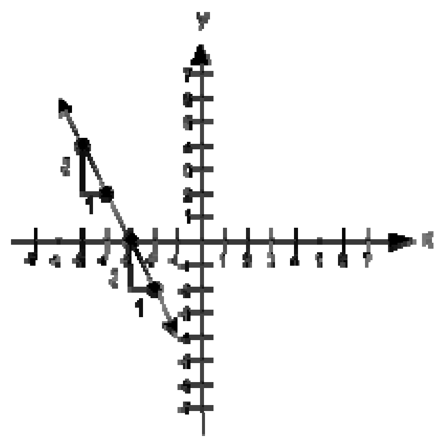
- o Other References:
  - http://www.allaboutcircuits.com/vol_1/chpt_15/2.html
  - http://www.allaboutcircuits.com/vol_1/chpt_15/1.html

- Slopes:
  - o The slope of a line measures the steepness of the line.
  - o Slope may be described as “rise” over “run”.
    - Rise means how many units you move up or down from point to point. On a graph, it would be the change in the y-value.
    - Run on the other hand means how many units you move left or right from point to point. On a graph, it would be the change in the x-value.

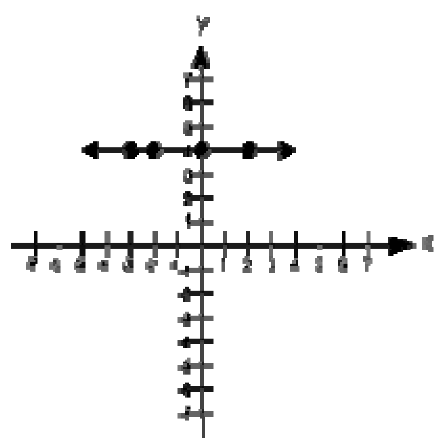
- Examples of slope:



$$slope = \frac{rise}{run} = \frac{2}{3}$$



$$slope = \frac{rise}{run} = \frac{-2}{1} = -2$$



slope = 0

Graph different slopes, then the values of the slopes on another graph.

Slope Formula:

Slope Formula Given Two Points

Given two points (x_1, y_1) and (x_2, y_2)

$$m = \frac{rise}{run} = \frac{change\ in\ y}{change\ in\ x} = \frac{y_2 - y_1}{x_2 - x_1}$$

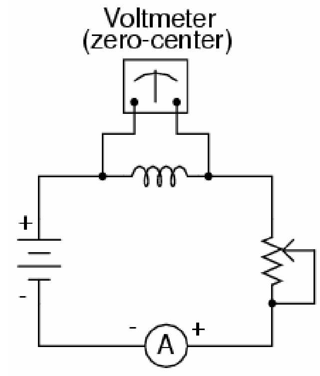
- Current/voltage behavior ("Ohm's Law for an Inductor"):

$$V_L = L \times \Delta I/\Delta t$$

Where,

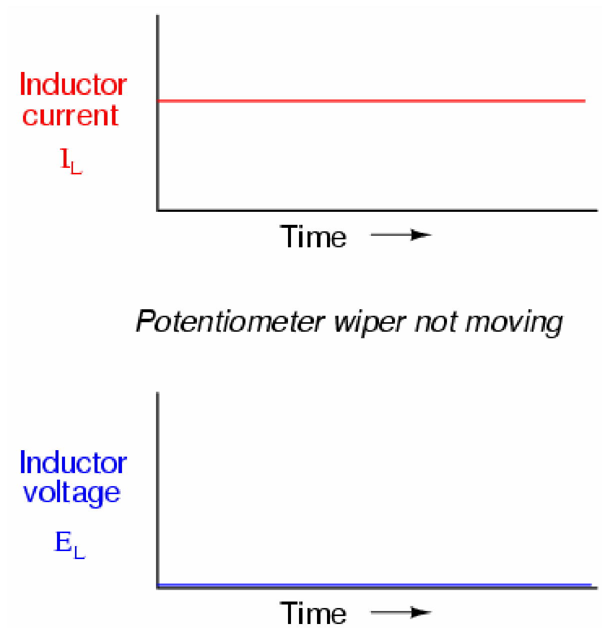
V_L or E_L = Instantaneous voltage across the inductor in volts
L = Inductance in henrys
$\Delta I/\Delta t$ = Instantaneous rate of current change

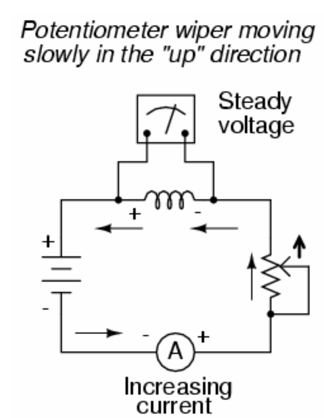
The equation relates one variable (in this case, inductor voltage drop, V_L) to a *rate of change* of another variable (in this case, the rate of change of inductor current, $\Delta I/\Delta t$).



Circuit conditions for Example 1

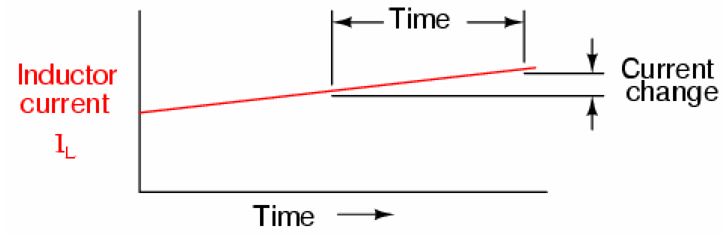
Example 1:



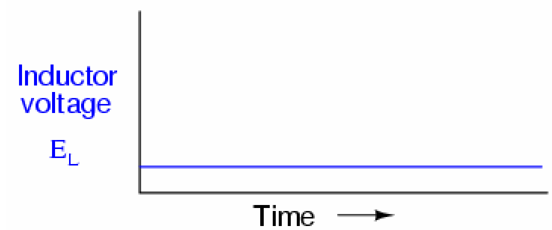


Circuit conditions for Example 2

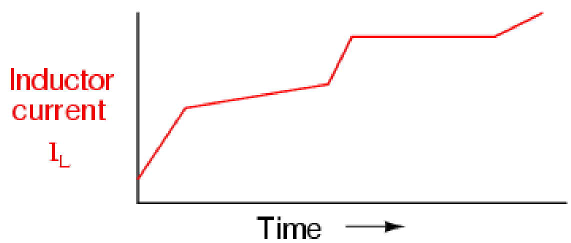
Example 2:



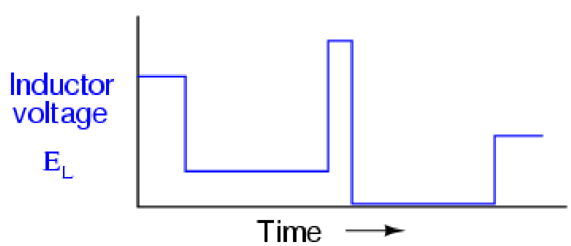
Potentiometer wiper moving slowly "up"



Example 3:



Potentiometer wiper moving "up" at different rates



From: **http://www.allaboutcircuits.com/vol_1/chpt_15/2.html**

- Resistor/Inductor (R/L) Circuit:
  - L/R Time Constant:
    - Pg 48 pract elect
    - Formula:

$$\tau = L/R$$

Where:

τ = Time in seconds for the current to increase to 63.2 % of its maximum value,
L = Inductance in henrys, and
R = Resistance in ohms

- Electricity and Electronics, **Section 14.2**, Inductance in AC Circuits:
  - Inductance like capacitance is an ac phenomenon.
    - Inductance is frequency sensitive.
    - Signals of different frequencies respond to inductors differently.
  - Inductors ac resistance is called inductive reactance. Another way of saying it is inductors oppose the flow of ac current; this opposition is called inductive reactance.
    - Formula:

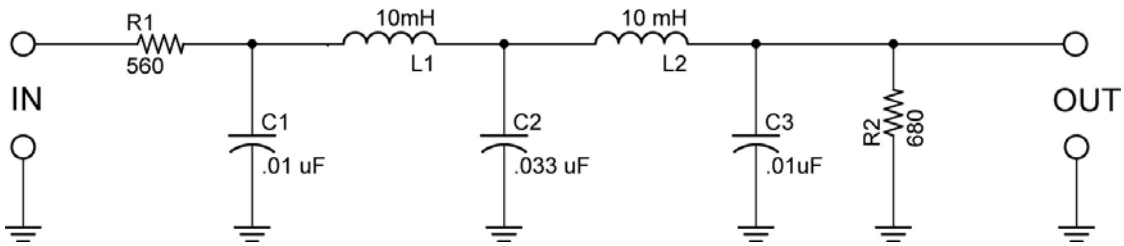
$$X_L = 2\Pi fL$$

Where:

X_L = Inductive reactance in ohms,
f = Frequency in hertz, and
L = inductance in henrys

    - Reactance increases with frequency and as the value of the inductance increases.
    - The effect that an inductance has on impeding current flow is analogous to the effect of resistance on impeding current flow in a dc circuit. However, in this case inductive reactance (X_L) measured in ohms.

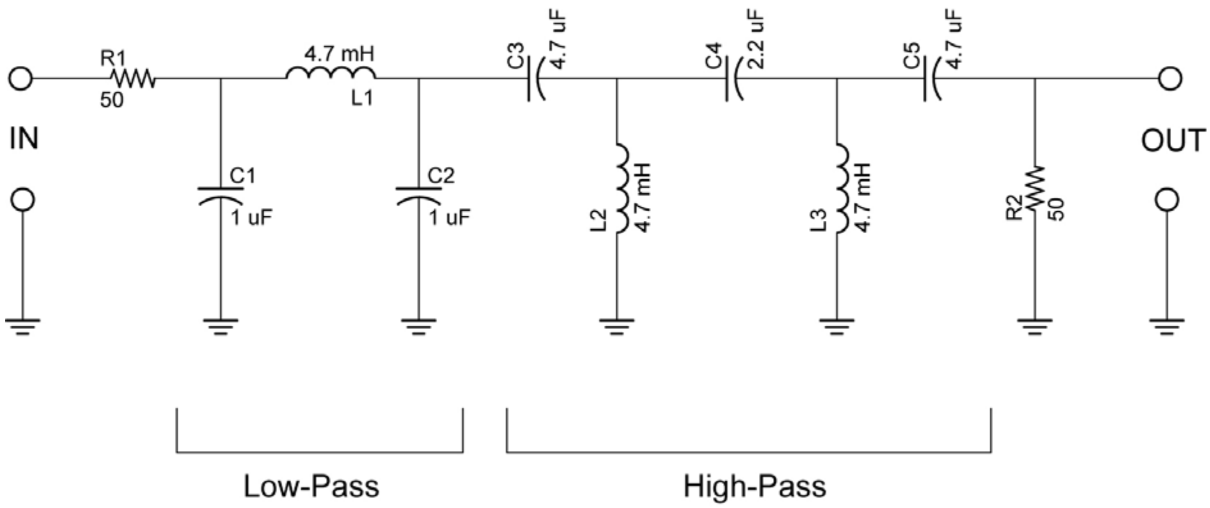
- Applications:
  - o LC Low Pass Filter:
    - The circuit below permits lower frequencies to pass through while cutting off higher frequencies.
    - Connect a function generator to the input and an oscilloscope to the output and observe the frequency response of the circuit.
    - Plot the voltage vs. the frequency.



5-Pole Butterworth Low-Pass Filter

From: *Student Manual for The Art of Electronics* by Thomas Hayes and Paul Horowitz

  - o Bandpass Filter:
    - The following circuit allows a band of frequencies to pass through while suppressing frequencies below and above that band. The approach to a bandpass filters is to combine a low-pass and a high-pass filter.
    - Connect a function generator to the input and an oscilloscope to the output and observe the frequency response of the circuit.
    - Plot the voltage vs. the frequency.



Wide-Band Bandpass Filter

From *Practical Electronics for Inventors* by Paul Scherz