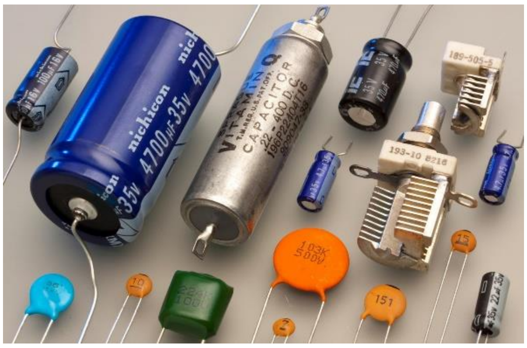
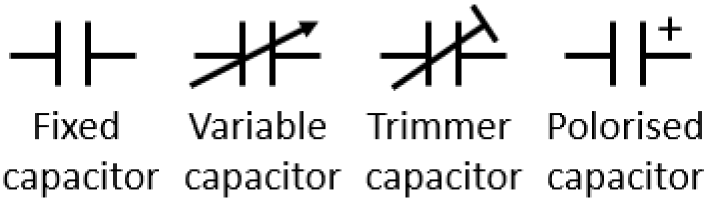
Lesson 6

Capacitors

Energy can be stored in an electrostatic field. This is called capacitance and the device is a capacitor. Capacitor symbols are shown below. Capacitors are measured in Farads.





A capacitor is comprised of two conducting plates parallel to each other. These plates are separated by a non-conducting material called a dielectric. If a voltage potential is placed across these plates, the plates will achieve the same voltage as the power source. If the voltage source is removed. The capacitor will retain the charge and discharge over time. A capacitor blocks DC current,

The capacitance is dependant on the plate sizes, the separation of the plates and the dielectric material between the plates. Dielectrics can be any material such as paper, air, plastic, etc. These all impact the capacitance of the product.

$$C=\varepsilon r \ \varepsilon 0 \ A / d$$

C = capacitance in Farads
εr = relative permittivity for the dielectric
ε0 = permittivity of space and it is equal to 8.854x10-12 F/m
A = the area of one plate in square metres
d = distance between the two plates in metres

Example: What is the capacitance of a device with plates 500 mm square, 5 mm apart and permittivity of 1.

C = 1 x 8.854x10-12 x 0.25 / 0.005

C = 1 x 8.854x10-12 x 50

C = 442 pF

Capacitor sizes

Prefix Name	Abbreviation	Weight	Equivalent Farads
Picofarad	pF	10-12	0.000000000001 F
Nanofarad	nF	10-9	0.000000001 F
Microfarad	μF	10-6	0.000001 F
Milifarad	mF	10-3	0.001 F
Kilofarad	kF	103	1000 F

Voltage and Current

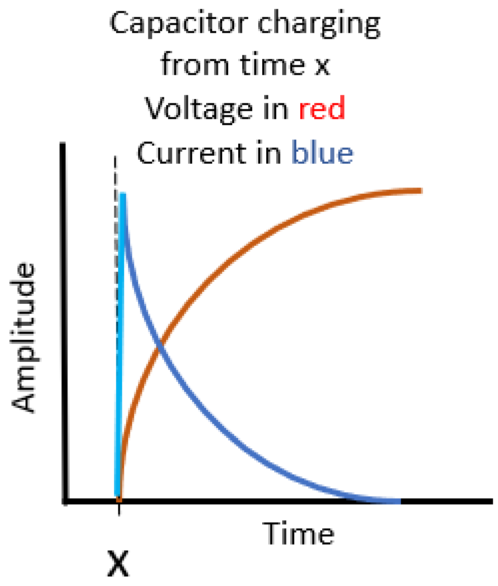


Figure 5

Figure 5 show how a capacitor charges when a voltage power source is connected at time x. The voltage, in red, rises over time and reaches the same potential as the voltage source. The current, in blue, rises rapidly then tapers off to zero as the source voltage potential is reached.

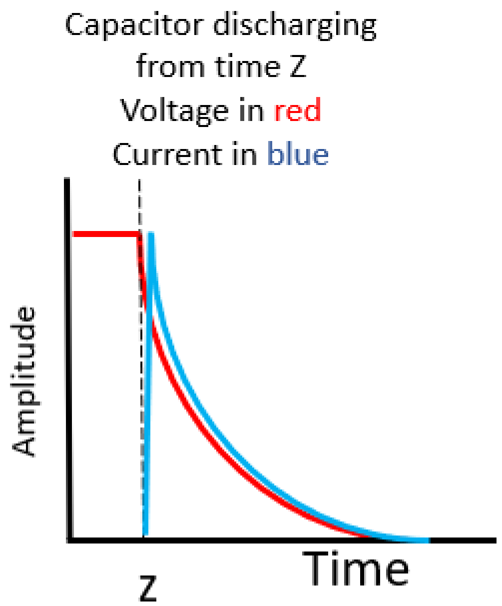


Figure 6.

When a charged capacitor is connected to a circuit at time Z, the current flow rises rapidly and tapers off to zero as the capacitor discharges.

Charge

The charge and discharge times are dependent on the resistance and reactance in the circuit.

The charge on the capacitor is proportional to the voltage applied.

Q = C x E

Q = Charge in coulombs (1Q = 1A x 1 second. Lesson 2)
C = Capacitance in Farads
E = voltage applied

Example: What is the charge on a 1 mF capacitor connected to 12 V

Q = 0.001 x 12 = 12 mQ

Energy

The energy stored in a capacitor is a function of capacitance and voltage.

$$W = \frac{E^2 x\ C}{2}$$

W = Joules (A joule is the heat dissipated when an electric current of one ampere passes through a resistance of one ohm for one second. Lesson 2)
E = Voltage
C = Capacitance in Farads

Example: The energy in a 1 mF capacitor connected to 12 V
W = ((12 x 12) x .001) / 2 = (144 x 0.001) / 2 = 0.144 / 2 = 72mJ

Types of capacitors

Ceramic capacitors –	The dielectric is ceramic and the plates are metal.
Electrolytic capacitors -	Electrolytic capacitors are polarized and must be connected to the voltage supply correctly.
Film capacitors -	Most common capacitor and are non-polarized.
Variable capacitors -	The capacitance is variable through a defined range,

Capacitor in series

Capacitors in series are treated the same way as resistors in parallel.

$$\frac{1}{Ct} = \frac{1}{C1} + \frac{1}{C2} + \frac{1}{C3} \dots n$$

Example: The capacitors in series are 3mF, 6mF and 9 mF what is the total capacitance?
1/CT = 1 / 0.003 + 1 / 0.006 + 1/ 0.009
1/CT = 333.33 + 166.66 + 111.11
1/CT = 611.1
CT = 0.0016 F or 1.6 mF

Capacitors in parallel

Capacitors in parallel are treated the same way as resistors in series

$$Ct = C1 + C2 + C3 \ldots n.$$

Example: The capacitors in parallel are 3mF, 6mF and 9 mF what is the total capacitance?
CT = 0.003 +0.006 + 0.009
CT = 0.18 F or 180 mF

Inductors

A coil can store electrical energy in a magnetic field and the device is an inductor, also called a coil, choke, or reactor. The inductance (L) of the device is measured in Henries (H). An inductor inhibits AC current.

The inductance of a coil depends on several factors.

- Coil diameter
- Cross sectional area
- Number of turns
- Magnetic density
- Type of material at the core.

$$H = \frac{0.4\ x\ \pi\ x\ N\ x\ I}{\varepsilon}$$

H = inductance in Henries
π = Pi = 3.141
N = number of turns
I = Current in amperes
Ɛ = mean magnetic path length in cm.

Example: Coil with 20 turns, 0.5 A and length of 5 cm, what is the inductance?

H = (0.4 x 3.141 x 20 x 0.5) / 5
H = 12.564 / 5
H = 2.51 H

Energy

The energy stored in an inductor is measured in Joules.

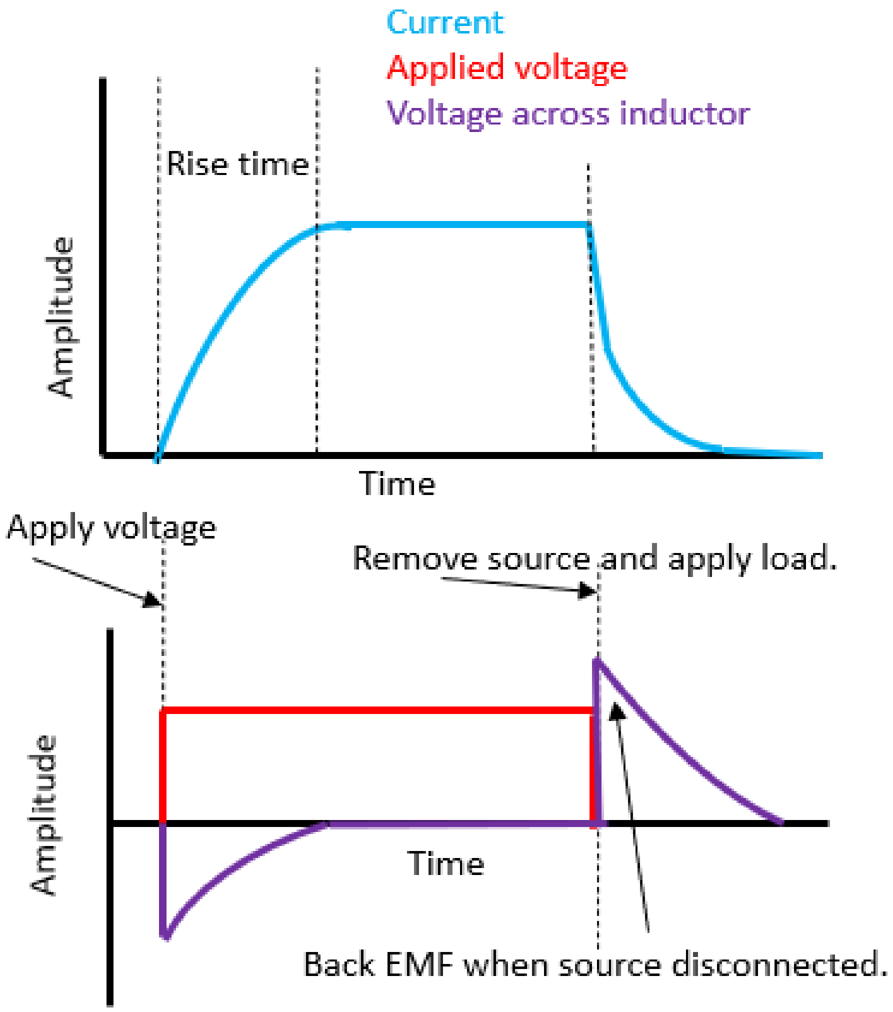
$$W = \frac{I^2\ x\ L}{2}$$

W = Energy in Joules
I = current in amperes
L = inductance in Henries

Example: How much energy is stored in a 5F capacitor fed by 2 A,

W = ((2 x 2) x 5) / 2
W = 20 / 2
W = 10 Joules

Voltage and Current

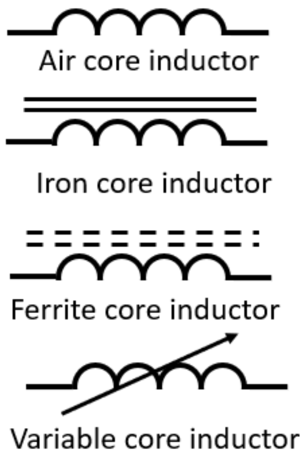


An inductor will resist the change as voltage is applied. This is due to the build up of the magnet field. This is termed self-inductance and is the ability of a coil to resist changes in current. Once the voltage across the inductor is steady, there is no potential across the inductor.

When the voltage source is removed and a load applied, the magnet field collapses induce a reverse current called a back emf. The back emf can be larger than the applied voltage. This feature is utilised in car ignition coils.

Symbols

Inductor symbols are shown below.



Inductor in Series

Inductors in series are the same as resistors in series.

$$\boldsymbol{Lt = L1 + L2 + L3 \ldots n}$$

Example: Three inductors in series. 3mH, 5 mH and 10 mH. What is the total inductance?
LT = 3 + 5 + 10
LT = 18 mH

Inductors in Parallel

Inductors in parallel are the same as resistors in parallel

$$\frac{1}{Lt} = \frac{1}{L1} + \frac{1}{L2} + \frac{1}{L3} \ldots n$$

. **Example:** Three inductors in parallel. 3mH, 5 mH and 10 mH. What is the total inductance?

1/LT = 1/3 + 1/5 + 1/10
1/LT = 0.33 + 0.2 + 0.1
1/LT = 0.63
LT = 1.58 H

Go to Lesson 6 questions.

Have fun and stay safe.