

CHAPTER 4

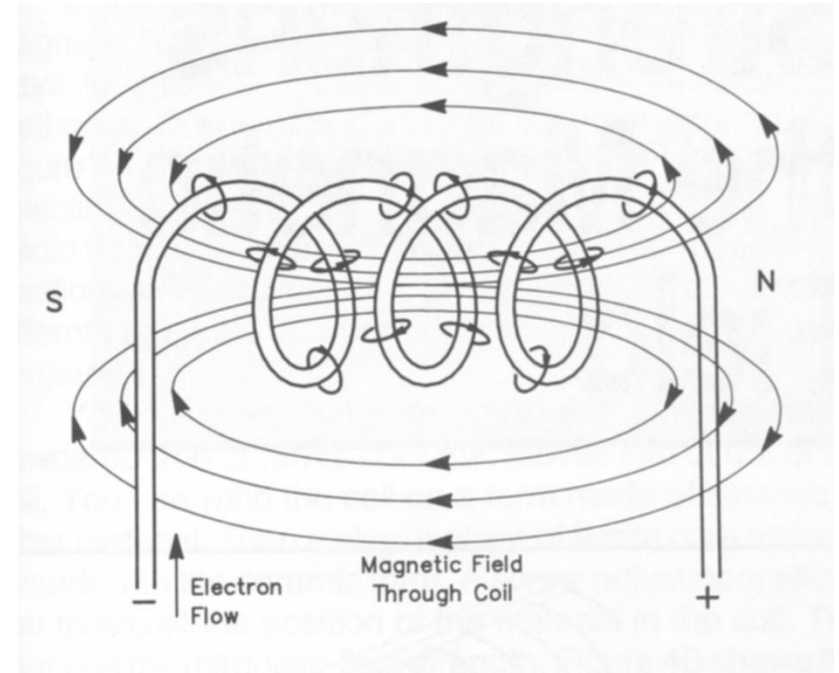
INDUCTORS & CAPACITORS

Inductance and Inductors

- Two fundamental principles of electromagnetics:
 1. Moving electrons create a magnetic field
 2. Change in a magnetic field causes electrons to move... it induces a current
- An inductor is a coil of wire through which electrons move, and energy is stored in the resulting magnetic field

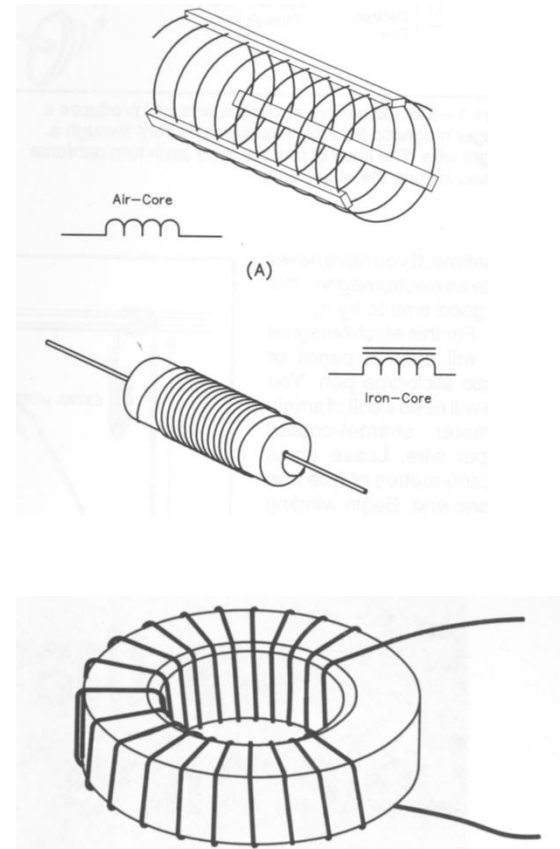
Inductors

- Like capacitors, inductors temporarily store energy
- Unlike capacitors:
 - Inductors store energy in a magnetic field, not an electric field
 - When the source of electrons is removed, the magnetic field collapses immediately



Inductors

- Inductors are simply coils of wire
 - Can be air wound (just air in the middle of the coil)
 - Can be wound around a permeable material (material that concentrates magnetic fields)
 - Can be wound around a circular form (toroid)

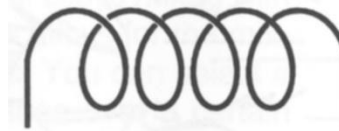


Inductors

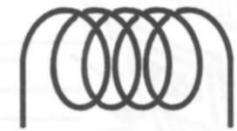
- Inductance is measured in Henrys
- A Henry is a measure of the intensity of the magnetic field that is produced
- Typical inductor values used in electronics are in the range of millihenry (1/1000 Henry) and microhenry (1/1,000,000 Henry)

Inductors

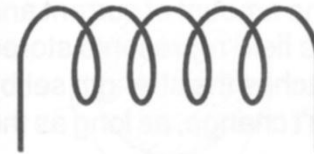
- The amount of inductance is influenced by a number of factors:
 - Number of coil turns
 - Diameter of coil
 - Spacing between turns
 - Size of the wire used
 - Type of material inside the coil



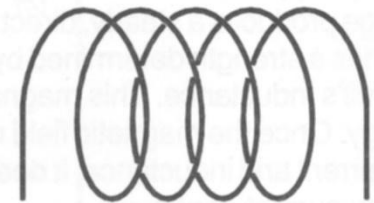
Wide Spacing Between Turns
Low Inductance



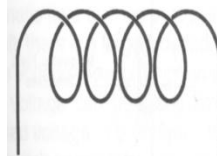
Close Spacing Between Turns
Higher Inductance



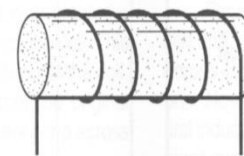
Small Diameter
Low Inductance



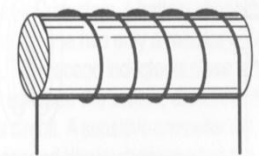
Larger Diameter
Higher Inductance



Air Core
Low Inductance



Powdered-Iron Core
Higher Inductance



Soft-Iron Core
Highest Inductance

Inductor Performance With DC Currents

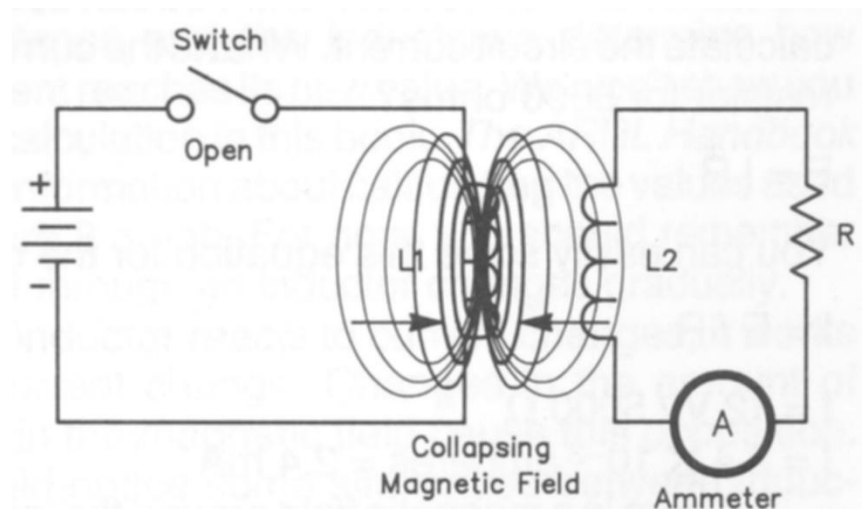
- When a DC current is first applied to an inductor, the increasing magnetic field opposes current flow - current flow is at a minimum
- Eventually (milliseconds) the magnetic field achieves its maximum and current flows, maintaining the field
- As soon as the current source is removed, the magnetic field begins to collapse and creates a rush of current in the other direction, sometimes at very high voltage

Inductor Performance With AC Currents

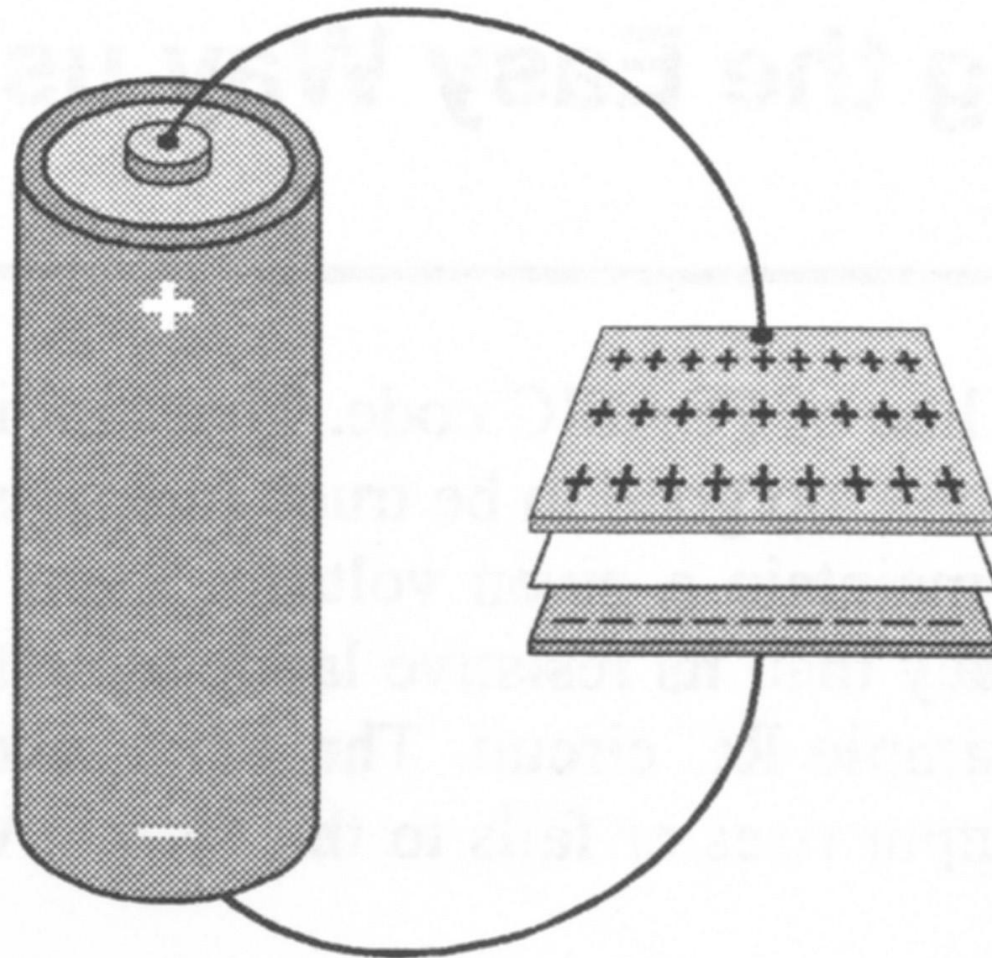
- When AC current is applied to an inductor, during the first half of the cycle, the magnetic field builds as if it were a DC current
- During the next half of the cycle, the current is reversed and the magnetic field decreases the reverse polarity in step with the changing current
- These forces can work against each other resulting in a lower current flow

Inductors

- Because the magnetic field surrounding an inductor can cut across another inductor in close proximity, the changing magnetic field in one can cause current to flow in the other.
- This is the basis of transformers

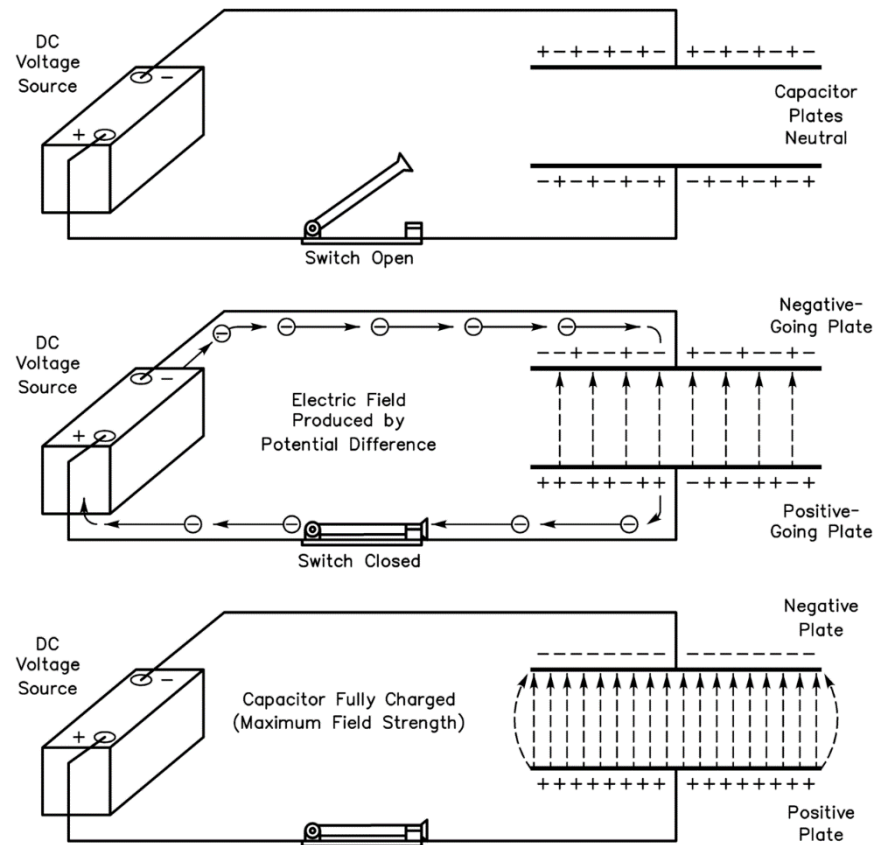


Capacitors



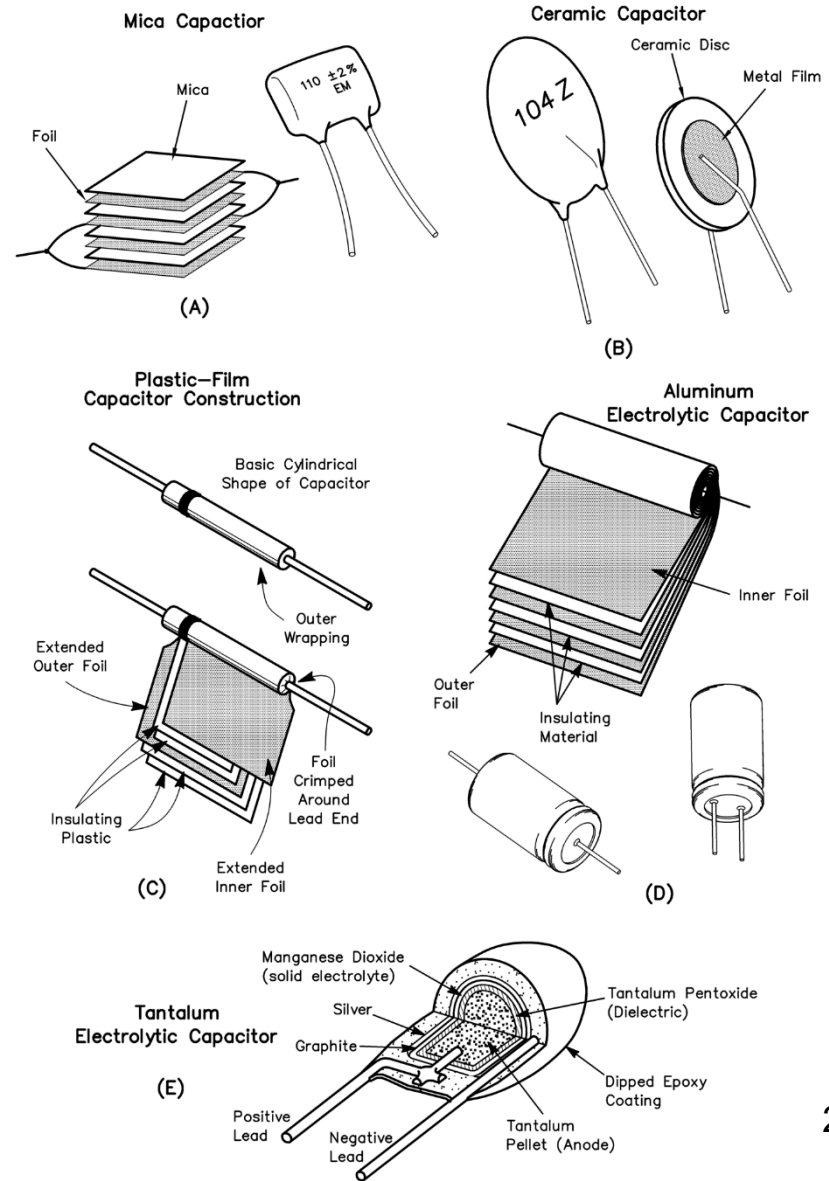
Capacitors

- Devices that store energy in an electric field
- Two conductive plates separated by a non-conductive material
- Electrons accumulate on one plate, forcing electrons away from the other plate and leaving a net positive charge
- Think of capacitors as small temporary storage batteries



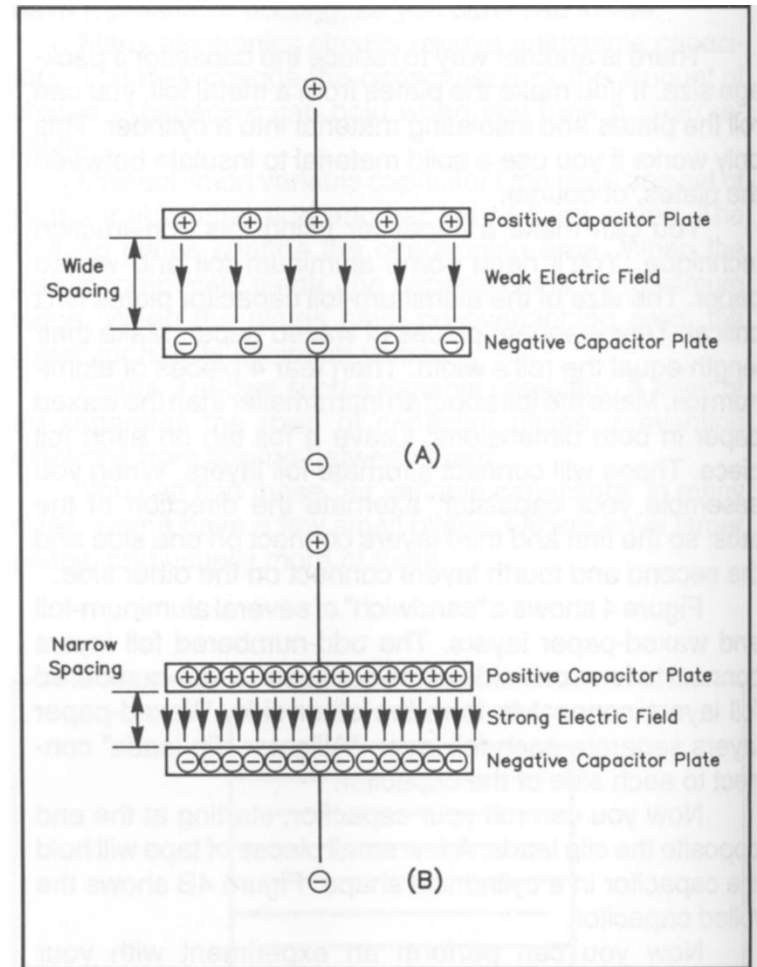
Capacitors

- Capacitors are rated by:
 - Amount of charge that can be held
 - Voltage handling capabilities
 - Insulating material between plates

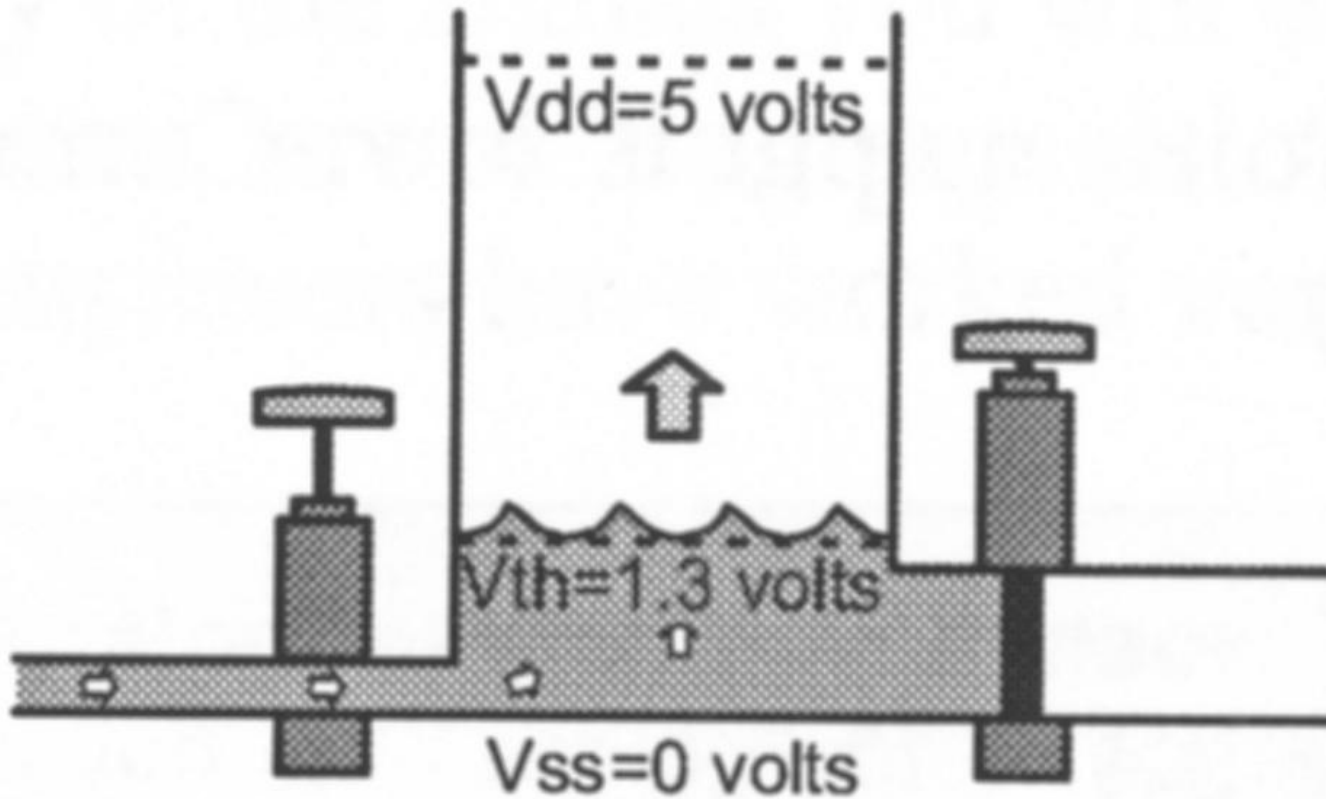


Capacitors

- Ability to hold a charge depends on:
 - Conductive plate surface area
 - Space between plates
 - Material between plates



Charging a Capacitor



Capacitors

- When connected to a DC source, the capacitor charges and holds the charge as long as the DC voltage is applied
- The capacitor essentially blocks DC current from passing through

Capacitors

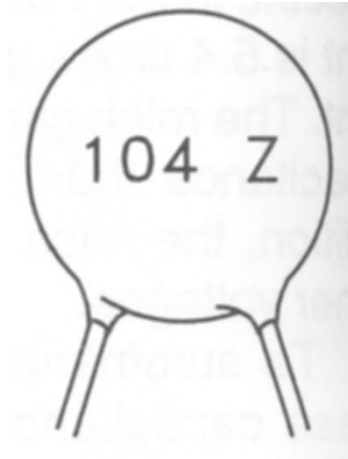
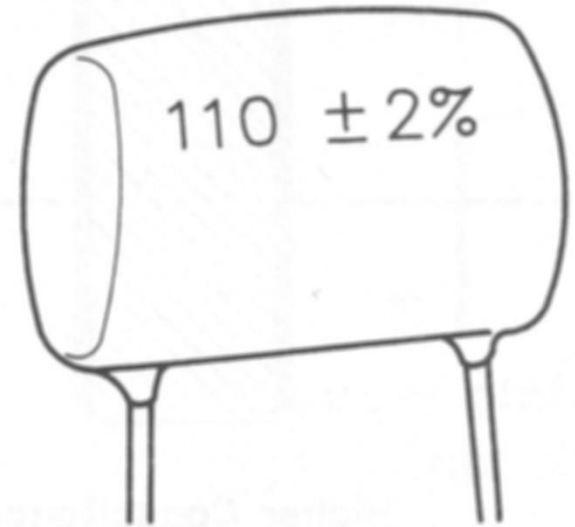
- When AC voltage is applied, during one half of the cycle the capacitor accepts a charge in one direction
- During the next half of the cycle, the capacitor is discharged then recharged in the reverse direction
- During the next half cycle the pattern reverses
- It acts as if AC current passes through a capacitor

Capacitors

- The unit of capacitance is the farad
 - A single farad is a huge amount of capacitance
 - Most electronic devices use capacitors that are a very tiny fraction of a farad
- Common capacitance ranges are:
 - Micro μ 10^{-6}
 - Nano n 10^{-9}
 - Pico p 10^{-12}

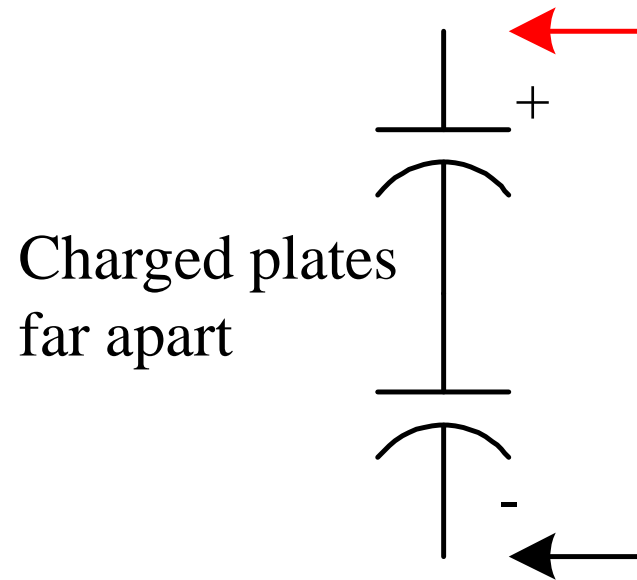
Capacitors

- Capacitor value identification depends on the capacitor type
- Could be color bands, dots, or numbers
- Wise to keep capacitors organized and identified to prevent a lot of work trying to re-identify the values



Capacitors in Circuits

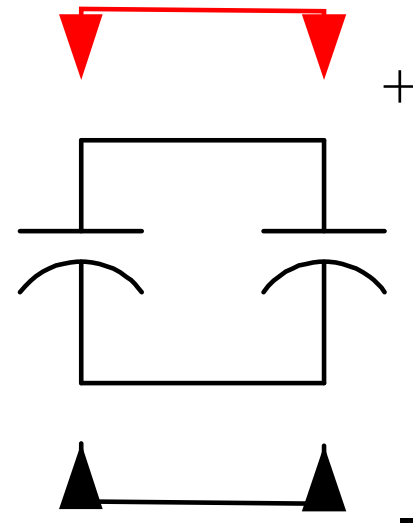
- Three physical factors affect capacitance values
 - Plate spacing
 - Plate surface area
 - Dielectric material
- In series, plates are far apart making capacitance less



$$C_E = \frac{C_1 C_2}{C_1 + C_2}$$

Capacitors in Circuits

- In parallel, the surface area of the plates add up to be greater
- This makes the total capacitance higher



$$C_E = C_1 + C_2$$

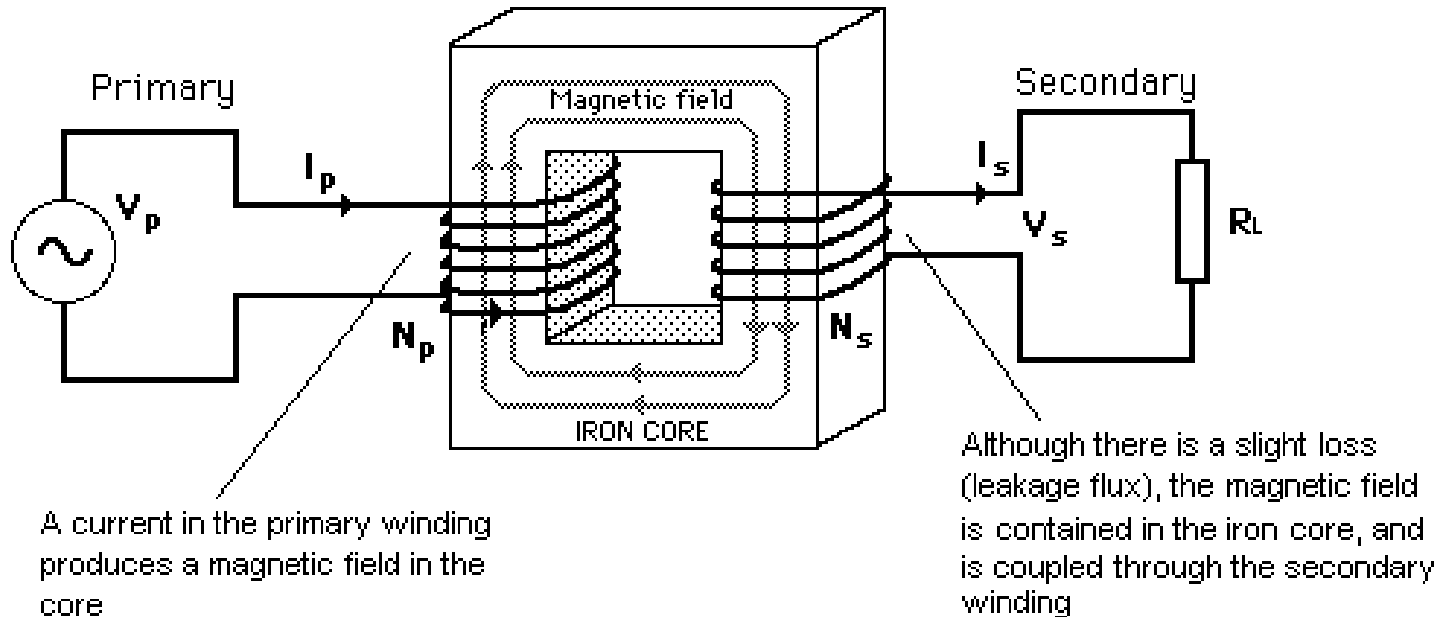
Magnetics & Transformers

- A transformer is just two (or more) inductors sharing a common magnetic path
- Any two inductors placed reasonably close to each other will work as a transformer
- The more closely they are coupled magnetically, the more efficient they become.
- When a changing magnetic field is in the vicinity of a coil of wire (an inductor), a voltage is induced into the coil which is in sympathy with the applied magnetic field.
- A static magnetic field has no effect, and generates no output.
- Many of the same principles apply to generators, alternators, electric motors and loudspeakers

Magnetics & Transformers

- When an electric current is passed through a coil of wire, a magnetic field is created - this works with AC or DC, but with DC, the magnetic field is obviously static. For this reason, transformers cannot be used directly with DC, for although a magnetic field exists, it must be changing to induce a voltage into the other coil
- The ability of a substance to carry a magnetic field is called **permeability**, and different materials have different permeability. Some are optimized in specific ways for a particular requirement - for example the cores used for a switching transformer are very different from those used for normal 50/60Hz mains transformers

Magnetics & Transformers



Essential Workings of a Transformer

Figure 1.1 shows the basics of all transformers. A coil (the primary) is connected to an AC voltage source - typically the mains for power transformers. The flux induced into the core is coupled through to the secondary, a voltage is induced into the winding, and a current is produced through the load.

Magnetics & Transformers

- At no load, an ideal transformer draws virtually no current from the mains, since it is simply a large inductance.
- The principle of operation is based on induced magnetic flux, which not only creates a voltage (and current) in the secondary, but the primary as well
- The voltage generated in the primary is called a "back EMF" (electromotive force). The magnitude of this voltage is such that it almost equals (and is effectively in the same phase as) the applied EMF.
- When a load is applied to the output (secondary) winding, a current is drawn by the load, and this is reflected through the transformer to the primary.
- As a result, the primary must now draw more current from the mains. Somewhat intriguingly perhaps, the more current that is drawn from the secondary, the original 90 degree phase shift becomes less and less as the transformer approaches full power.
- The power factor of an unloaded transformer is very low, meaning that although there are volts and amps, there is relatively little power. The power factor improves as loading increases, and at full load will be close to unity (the ideal).
- Transformers are usually designed based on the power required, and this determines the core size for a given core material. From this, the required "turns per volt" figure can be determined, based on the maximum flux density that the core material can support. Again, this varies widely with core materials.