Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes

Metric prefixes you'll need to know ...

1 Giga (G) = 1 billion = 1,000,000,000
1 Mega (M) = 1 million = 1,000,000
1 kilo (k) = 1 thousand = 1,000
1 centi (c) = 1 one-hundredth = 0.01
1 milli (m) = 1 one-thousandth = 0.001
1 micro (u) = 1 one-millionth = 0.000001
1 pico (p) = 1 one-trillionth = 0.000000000001

... and a few you might want to know ...

1 Tera (T) = 1trillion = 1,000,000,000,000
1 hecto (h) = ten = 10
1 deci (d) = 1 tenth = 0.1
1 nano (n) = 1 one-billionth = 0.000000001

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes

The prefix enables us to reduce the amount of zeros that are used in writing out large numbers.

For example... instead of saying that the frequency of my signal is 1,000,000 Hz (Hertz or cycles per second) I can say that it is 1,000 kilohertz (kHz) or even 1 Megahertz (MHz). The prefix enables us to write the number in a shorter form. This especially becomes useful when we need to measure VERY large or VERY small numbers.

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes Mega- (one million; 1,000,000)

Just to make certain that this stuff makes sense, lets go back and look at large frequencies again.

1,000 Hz = 1 kHz

"One thousand Hertz equals one kilohertz"

1,000,000 Hz = 1 Mhz

"One million Hertz equal one megahertz"

So how many kilohertz are in one megahertz? 1000 kHz = 1 MHz

"One thousand kilohertz equals one megahertz"

So if your radio was tuned to 7125 kHz, how would you express that same frequency in megahertz?

1000 kHz = 1 MHz || 7125 kHz = 7.125 MHz

(It takes 1000 kilohertz to equal 1 megahertz, so 7125 kilohertz would equal 7.125 megahertz.)

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes Mega- (one million; 1,000,000)

Lets do another frequency problem. This time, your dial reads 3525 kHz. What is the same frequency when expressed in Hertz? This should be simple...

1 kHz = 1000 Hz || 3525 kHz = 3,525,000 Hz

(Notice that since we have to add three zeros to go from 1 kHz to 1000 Hz, we must also do the same to go from 3525 kHz to 3,525,000 Hz.)

Now, let's work another frequency problem, except we're going to do it backwards. Your displays shows a frequency of 3.525 MHz. What is that same frequency in kilohertz?

1 MHz = 1000 kHz || 3.525 MHz = 3525 kHz

(See how the 1 became 1000? To go from megahertz to kilohertz, you multiply by 1000. Try multiplying 3.525 MHz by 1000 to get your frequency in kilohertz.)

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes   Giga- (one billion; 1,000,000,000)

Now we're going to deal with an even larger frequency. Remember, kilo equals one thousand, and mega equals one million. What equals one billion? There is a prefix for one billion - Giga. One billion Hertz is one gigahertz (GHz). What if you were transmitting on 1.265 GHz? What would your frequency be in megahertz? How many millions equals one billion? 1 billion is 1000 millions, so 1 gigahertz (GHz) is 1000 megahertz (MHz).

1 GHz = 1000 MHz || 1.265 GHz = 1265 MHz

As you begin to see how these metric prefixes relate to each other, it will become easier to express these large and small numbers commonly used in radio and electronics.

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes Milli- (one one-thousandth; 0.001)

If you were to take an ammeter (a meter that measures current) marked in amperes and measure a 3,000 milliampere current, what would your ammeter read?

First, what does milli- mean? Milli might be familiar to those of you who were already familiar with the ever popular centimeter.

The millimeter is the next smallest measurement. There are 100 centimeters in 1 meter... there are also 1000 millimeters in 1 meter.

So milli must mean 1 one-thousandth.

If your circuit has 3,000 milliamps (mA), how many amps (A) is that?

1,000 mA = 1 A || 3,000 mA = 3 A

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes

Now lets say, on a different circuit, you were using a voltmeter marked in volts (V), and you were measuring a voltage of 3,500 millivolts (mV). How many volts would your meter read?

1,000 mV = 1 V || 3,500 mV = 3.5 V

How about one of those new pocket sized, micro handheld radio you're itching to buy once you get your license? One manufacturer says that their radio puts out 500 milliwatts (mW) , while the other manufacturer's radio will put out 250 milliwatts (mW). How many watts (W) do these radios really put out?

1000 mW = 1 W || 500 mW = 0.5 W

1000 mW = 1 W || 250 mW = 0.25 W

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes Pico- (one one-trillionth; 0.000000000001)

Capacitors are devices that usually have very small values. A one farad capacitor is seldom ever used in commercial electronics (however I understand that they are sometimes used when a lot of stored up energy is needed for an instant).

Usually, your run of the mill capacitor will have a value of 1 thousandth of a farad to 1 trillionth of a farad.

This is the other end of the scale compared with kilo, mega, and giga. Now we'll learn about micro and pico.

If you had a capacitor which had a value of 500,000 microfarads, how many farads would that be?

Since it takes one million microfarads to equal one farad...

1,000,000 uF = 1 F || 500,000 uF = 0.5 F

Basic Electronics & Theory

Lesson 5

5.1 Metric Prefixes   Pico- (one one-trillionth; 0.000000000001)

What if we had a capacitor with a value of 1,000,000 picofarads? Pico is a very, very small number, so to have 1 million pico farads is saying that the value is just very small instead of very, very small. One picofarad is one trillionth of a farad. One picofarad is also one millionth of a microfarad. So it takes one million picofarads (pF) to equal one microfarad (uF)...

1,000,000 pF = 1 uF

By the way, just so you get a grasp of just how small a picofarad really is, remember, it would take one trillion (i.e. one million-million) picofarads (pF) to equal one farad (F), or...

1,000,000,000,000 pF = 1 F

Basic Electronics & Theory

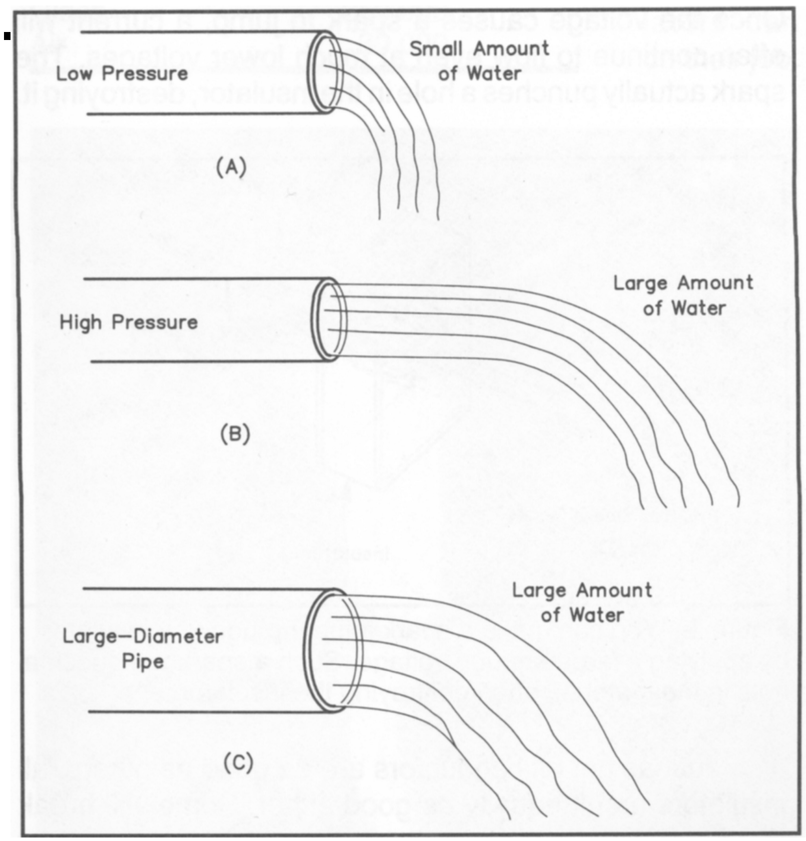
Lesson 5

5.2 Concepts of Current, Voltage, Conductor, Insulator, Resistance Current

Water flowing through a hose is a good way to imagine electricity **Water** is like **Electrons** in a wire (flowing electrons are called **Current**)

Pressure is the force pushing water through a hose – **Voltage** is the force pushing electrons through a wire

Friction against the holes walls slows the flow of water – **Resistance** is an impediment that slows the flow of electrons



Basic Electronics & Theory

Lesson 5

- There are 2 types of current
  - The form is determined by the directions the current flows through a conductor
- **Direct Current** (**DC**)
  - Flows in only one direction from negative toward positive pole of source
- **Alternating Current** (**AC**)
  - Flows back and forth because the poles of the source alternate between positive and negative

Basic Electronics & Theory

Lesson 5

5.2 Concepts of Current, Voltage, Conductor, Insulator, Resistance

Conductors and Insulators

There are some materials that electricity flows through easily. These materials are called conductors. Most conductors are metals.

Four good electrical conductors are gold, silver, aluminum and copper.

Insulators are materials that do not let electricity flow through them.

Four good insulators are glass, air, plastic, and porcelain.

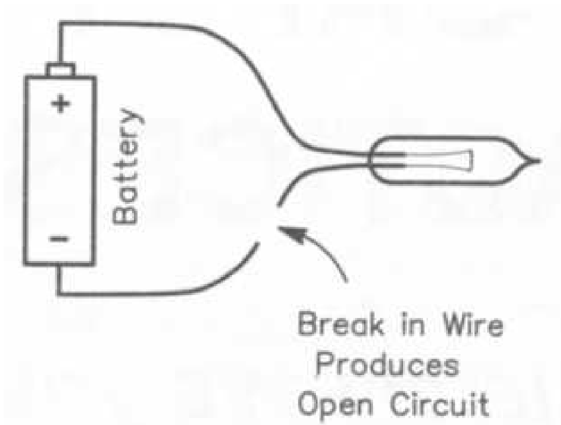
Basic Electronics & Theory

Lesson 5

5.3 Concepts of Energy & Power, Open & Short Circuits

The Open Circuit

The open circuit is a very basic circuit that we should all be very familiar with. It is the circuit in which no current flows because there is an open in the circuit that does not allow current to flow. A good example is a light switch. When the light is turned off, the switch creates an opening in the circuit, and current can no longer flow.



You probably figured that since there are "open circuits" that there are probably also "closed circuits". Well, a closed circuit is when the switch is closed and current is allowed to flow through the circuit.

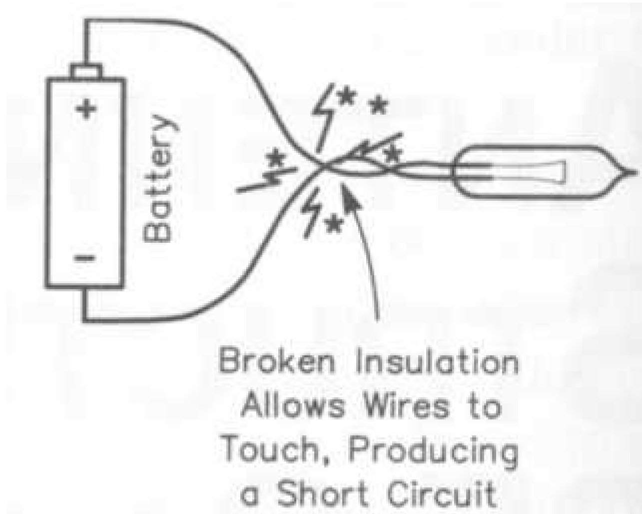
A fuse is a device that is used to create an open circuit when too much current is flowing.

Basic Electronics & Theory

Lesson 5

5.3 Concepts of Energy & Power, Open & Short Circuits

The Short Circuit



A short circuit can be caused by incoming power wires (wires that are normally insulated and kept separate) coming in contact with each other. Since a circuit usually has resistance, and the power wires that "short out" have very little resistance, the current will tend to flow through the path of least resistance... the short. Less resistance at the same amount of voltage will result in more current to flow.

Therefore a short circuit will have too much current flowing through it. What's the best way to stop a short circuit from doing damage (because it is drawing too much power from the source)? By using a fuse. Fuses are designed to work up to a certain amount of current (e.g. 1 amp, 15 amps, ...). When that maximum current is exceeded, then the wire within the fuse burns up from the heat of the current flow. With the fuse burnt up, there is now an "open circuit" and no more current flows.

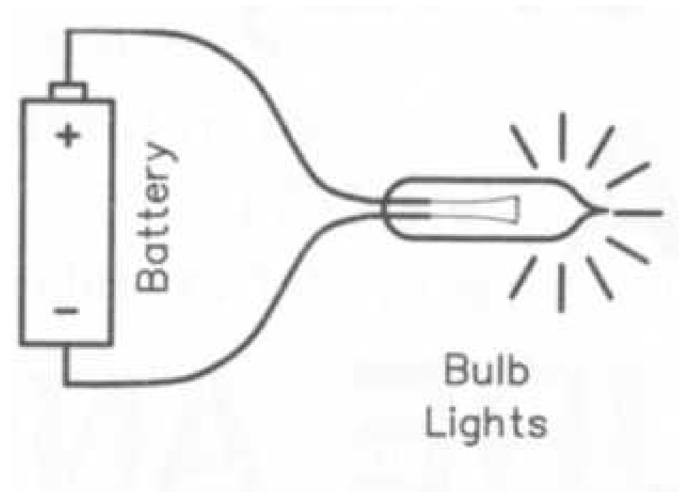
Basic Electronics & Theory

Lesson 5

5.3 Concepts of Energy & Power, Open & Short Circuits

Power

Every circuit uses a certain amount of power. Power describes how fast electrical energy is used. A good example is the light bulbs used in each circuit of your home. When you turn on a light bulb, light (and heat) are produced. This is because of the current flowing through a resistor built into the bulb. The resistance turns the electrical power into primarily heat, and secondarily light (assuming an incandescent bulb).

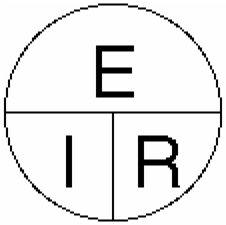


Each light bulb is rated at a certain power rating. This is how much power the bulb will use in a normal 110 Volt house circuit. Three of the most popular power values for inside light bulbs are 60, 75, and 100 Watts (Power is measured in Watts). Which of these light bulbs uses the most power? The 100 Watt bulb uses the most power.

Basic Electronics & Theory

- **5.4 Ohm's Law**

- E = electromotive force (a.k.a. Voltage)
- I = *intensity* (French term for Current)
- R = resistance



- **Voltage:** E = I x R *(Volts)*
- **Current:** I = E / R *(Amps)*
- **Resistance:** R = E / I *(Ohms)*

Basic Electronics & Theory

Lesson 5

5.4 Ohm’s Law Calculating Voltage and Current and Resistance

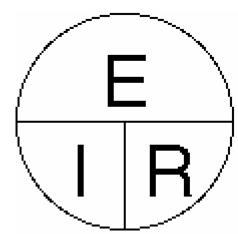
Current?

There is a very easy way to determine how much current will flow through a circuit when the voltage and resistance is known. This relationship is expressed in a simple equation (don't let the word scare you... this is going to be easy as "pie"...

Let's start with the "pie"...

This circle will help you to know how to figure out the answer to these electrical problems. The three letters stand for...

E = electromotive force (a.k.a. Voltage)
I = *intensity* (French term for Current)
R = resistance



Basic Electronics & Theory

Lesson 5

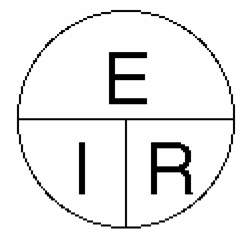
5.4 Ohm's Law **Calculating Voltage and Current and Resistance**

Current?

Lets say you have 200Volts hooked up to a circuit with 100 Ohms of resistance.
How much current would flow?

Since our "unknown" value in this problem is the current, then we put our finger over the "I". What you see is "E over R". This means you take the Voltage and divide it by the Resistance. This is 200 Volts divided by 100 Ohms. The result is 2 Amps.

E = electromotive force (a.k.a. Voltage)
I = *intensity* (French term for Current)
R = resistance



Basic Electronics & Theory

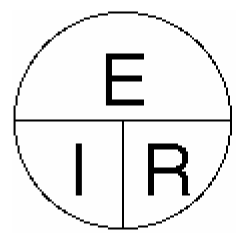
Lesson 5

5.4 Ohm's Law **Calculating Voltage and Current and Resistance**

Voltage?

What if we wanted to find out the voltage in a circuit when we know the current and resistance? Go back to the "pie" and cover up the E. You're now left with I times R. How much voltage would you need in a circuit with 50 ohms and 2 amps? E=IxR... E=2x50... E=100 Volts.

E = electromotive force (a.k.a. Voltage)
I = *intensity* (French term for Current)
R = resistance



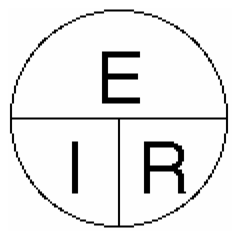
Basic Electronics & Theory

Lesson 5

5.4 Ohm's Law   Calculating Voltage and Current and Resistance

Resistance?

Finally, if you had a circuit with 90 Volts and 3 amps, and you needed to find the resistance, you could cover up the R... the result is E over I (Volts divided by Current). R=E/I... R=90/3... R=30 Ohms. This circuit would have 30 Ohms of resistance if it was hooked up to 90 Volts and 3 amps flowed through the circuit.



Ohm's Law

This relationship between voltage, current, and resistance is known as Ohm's Law. This is in honour of the man who discovered this direct relationship (his last name was Ohm). The relationship described in Ohm's Law is used when working with almost any electronic circuit.

Basic Electronics & Theory

Memorizing Ohm's law

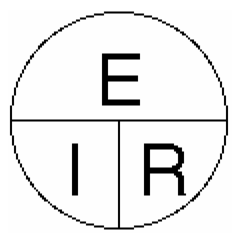
Memorizing Ohm's law may sound like a time consuming and daunting task, but if remember this little story you'll have it committed to memory for life within a few minutes!

An old Indian was walking across the plains one day and he saw an eagle soaring high in the sky over a rabbit.

Now, picture things from the Indian's stand point - he sees the Eagle flying over the Rabbit:

Say to yourself Indian equals Eagle over Rabbit.

Now just use the first letter of each word: I = E over R, which is this formula:



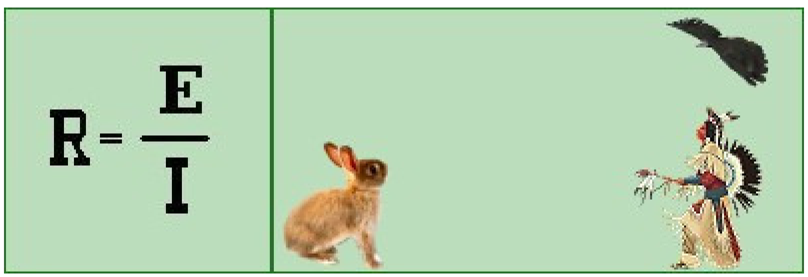
Voltage: E = I x R *(Volts)*
Current: I = E / R *(Amps)*
Resistance: R = E / I *(Ohms)*

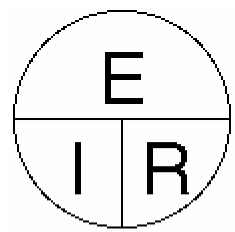
Basic Electronics & Theory

Memorizing Ohm's law

However, from the Rabbit's point of view, he sees things a little differently. The Rabbit looks out and sees the Eagle flying over the Indian.

Say to yourself Rabbit equals Eagle over Indian.
Now just use the first letter of each word: R = E over I, which is this formula:





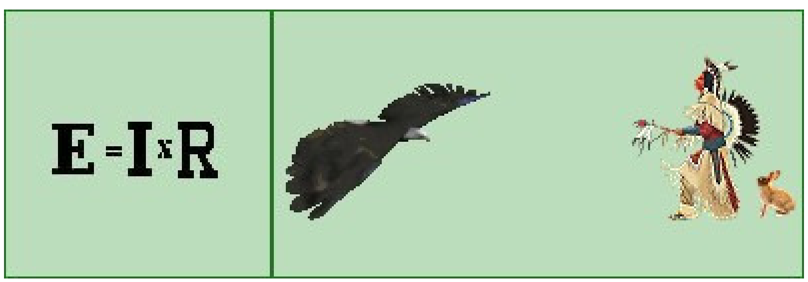
Voltage: E = I x R *(Volts)*
Current: I = E / R *(Amps)*
Resistance: R = E / I *(Ohms)*

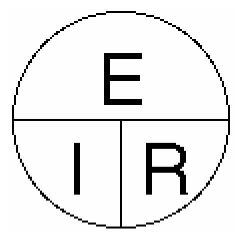
Basic Electronics & Theory

Memorizing Ohm's law

Finally, the Eagle up in the sky sees both the Indian and the Rabbit standing on the ground together.

Say to yourself Eagle equals Indian and Rabbit together.
Now just use the first letter of each word: E = IxR, which is this formula:





Voltage: E = I x R *(Volts)*
Current: I = E / R *(Amps)*
Resistance: R = E / I *(Ohms)*

Now if you simply remember the story of the Indian, Eagle and Rabbit, you will have memorized all three formulae!

Basic Electronics & Theory

Memorizing Ohm's law

So now we have 3 different ways that we can algebraically express Ohm's Law.

$E = I \times R$ or $I = \dfrac{E}{R}$ or $R = \dfrac{E}{I}$

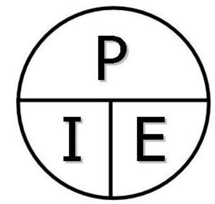
Voltage: E = I x R *(Volts)*
Current: I = E / R *(Amps)*
Resistance: R = E / I *(Ohms)*

But of what significance is it? Here is the gist of it. If we know 2 out of the 3 factors of the equation, we can figure out the third. Let's say we know we have a 3 Volt battery. We also know we are going to put a 100 W resistor in circuit with it. How much current can we expect will flow through the circuit?

Without Ohm's Law, we would be at a loss. But because we have Ohm's Law, we can calculate the unknown current, based upon the Voltage and Resistance.

$$I = \frac{3 \text{ Volts}}{100\ \Omega} = .03 \text{ Amperes}$$

Power calculations



- The unit used to describe electrical *power* is the **Watt.**

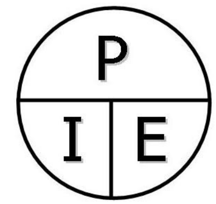
- The formula: Power (P) equals voltage (E) multiplied by current (I).

$P = I \times E$

Basic Electronics & Theory

Lesson 5

- **Power calculations (cont)**



  - How much power is represented by a voltage of 13.8 volts DC and a current of 10 amperes.
    - **P = I x E** P = 10 x 13.8 = ***138 watts***
  - How much power is being used in a circuit when the voltage is 120 volts DC and the current is 2.5 amperes.
    - **P = I x E** P = 2.5 x 120 = ***300 watts***

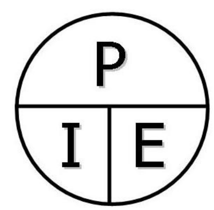
Basic Electronics & Theory

Lesson 5

➢ **Power calculations (cont)**

- You can you determine how many watts are being drawn [consumed] by your transceiver when you are transmitting by measuring the DC voltage **at** the transceiver and multiplying by the current drawn when you transmit.

- How many amperes is flowing in a circuit when the applied voltage is 120 volts DC and the load is 1200 watts.
  - **I = P/E** I = 1200/120 = ***10 amperes***.



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Memorizing Ohm's law

Power Formula P= I x E

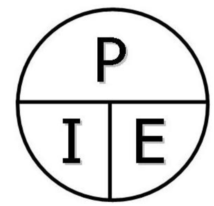
Lets try some examples we are familiar with;

P= 60 watt light bulb
E=120 volts
I= .5 amps

P=100 watt light bulb
E=120 volts
I=.83 amps

Electric Kettle consumes
P=900 watts
E=120 volts
I= 7.5 amps

Electric Toaster
P= 1200 watts
E=120 volts
I=10 amps



Power: P = I x E *(Watts)*
Current: I = P / E *(Amps)*
Voltage: E = P/ I *(Volts)*

E = Electromotive Force aka Volts
I = Intensity aka Current

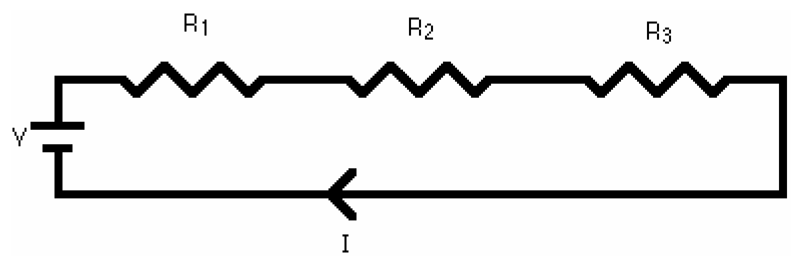
Basic Electronics & Theory

Lesson 5

5.5 Series & Parallel Resistors

Series circuits

A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take. The current is the same through each resistor. The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors: equivalent resistance of resistors in series : **R = R1 + R2 + R3 + ...**

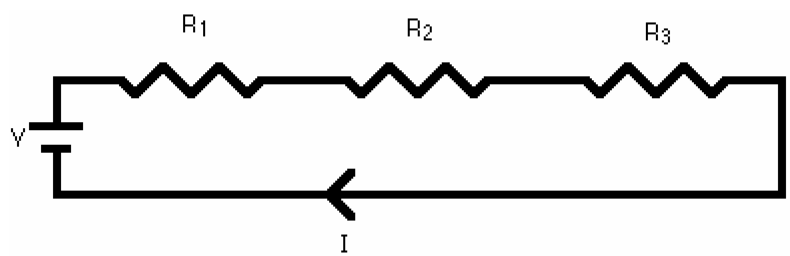


Basic Electronics & Theory

Lesson 5

5.5 Series & Parallel Resistors

Series circuits



A series circuit is shown in the diagram above. The current flows through each resistor in turn. If the values of the three resistors are:

$R_1 = 8\ \Omega$, $R_2 = 8\ \Omega$, and $R_3 = 4\ \Omega$, the total resistance is $8 + 8 + 4 = 20\ \Omega$.

With a 10 V battery, by V = I R the total current in the circuit is:
I = V / R = 10 / 20 = 0.5 A. The current through each resistor would be 0.5 A.

Basic Electronics & Theory

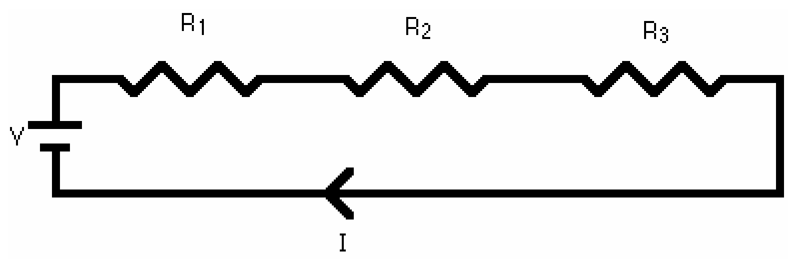
Lesson 5

5.5 Series & Parallel Resistors

Series circuits

R = R1 + R2 + R3 + ...

R1=100 ohms
R2=150 ohms
R3=370 ohms
RT= ? ohms



Basic Electronics & Theory

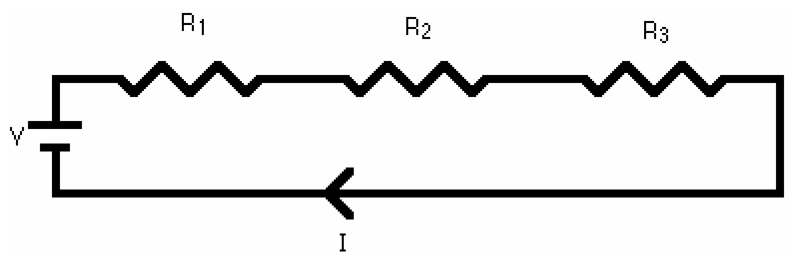
Lesson 5

5.5 Series & Parallel Resistors

Series circuits

R = R1 + R2 + R3 + ...

R1=100 ohms
R2=150 ohms
R3=370 ohms
RT= 620 ohms



Basic Electronics & Theory

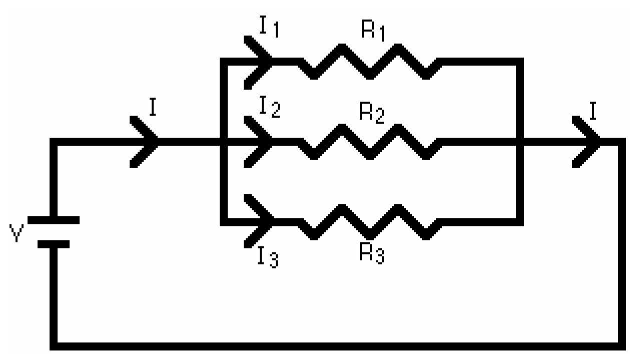
Lesson 5

5.5 Series & Parallel Resistors

Parallel circuits

A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together. The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same.

The total resistance of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total: equivalent resistance of resistors in parallel: 1 / R = 1 / R1 + 1 / R2 + 1 / R3 +...



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Lesson 5

5.5 Series & Parallel Resistors

Parallel circuits

A parallel circuit is shown in the diagram above. In this case the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance. If the values of the three resistors are:

$R_1 = 8\ \Omega$, $R_2 = 8\ \Omega$, and $R_3 = 4\ \Omega$, the total resistance is found by:

$1 / R = 1 / 8 + 1 / 8 + 1 / 4 = 1 / 2$. This gives $R = 2\ \Omega$.

With a 10 V battery, by V = I R the total current in the circuit is: I = V / R = 10 / 2 = 5 A.

The individual currents can also be found using I = V / R. The voltage across each resistor is 10 V, so:
I1 = 10 / 8 = 1.25 A
I2 = 10 / 8 = 1.25 A
I3=10 / 4 = 2.5 A

Note that the currents add together to 5A, the total current.

Basic Electronics & Theory

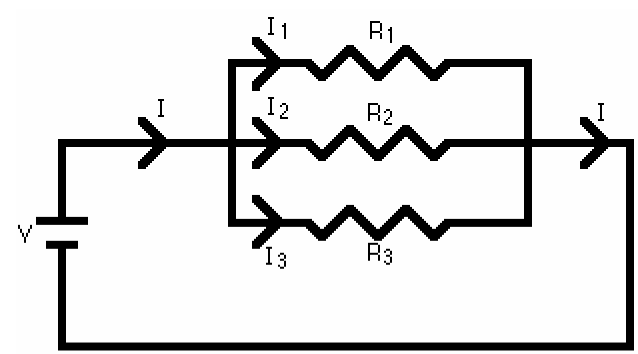
Lesson 5

5.5 Series & Parallel Resistors

Parallel circuits

1 / R = 1 / R1 + 1 / R2 + 1 / R3 +...

R1=100 ohms
R2=100 ohms
R3=100 ohms
RT= ? Ohms



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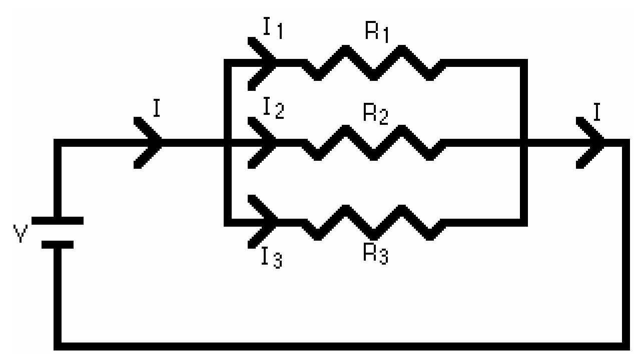
Lesson 5

5.5 Series & Parallel Resistors

Parallel circuits

1 / R = 1 / R1 + 1 / R2 + 1 / R3 +...

R1=100 ohms
R2=100 ohms
R3=100 ohms
RT= ? Ohms



1/100 + 1/100 + 1/100 =

.01 + 01 + .01 = .03

1/.03= 33.33 ohms

Basic Electronics & Theory

Lesson 5

5.5 Series & Parallel Resistors

A parallel resistor short-cut

If the resistors in parallel are identical, it can be very easy to work out the equivalent resistance. In this case the equivalent resistance of N identical resistors is the resistance of one resistor divided by N, the number of resistors. So, two 40-ohm resistors in parallel are equivalent to one 20-ohm resistor; five 50-ohm resistors in parallel are equivalent to one 10-ohm resistor, etc.

When calculating the equivalent resistance of a set of parallel resistors, people often forget to flip the 1/R upside down, putting 1/5 of an ohm instead of 5 ohms, for instance. Here's a way to check your answer. If you have two or more resistors in parallel, look for the one with the smallest resistance. The equivalent resistance will always be between the smallest resistance divided by the number of resistors, and the smallest resistance. Here's an example.

You have three resistors in parallel, with values 6 ohms, 9 ohms, and 18 ohms. The smallest resistance is 6 ohms, so the equivalent resistance must be between 2 ohms and 6 ohms (2 = 6 /3, where 3 is the number of resistors).

Doing the calculation gives 1/6 + 1/12 + 1/18 = 6/18. Flipping this upside down gives 18/6 = 3 ohms, which is certainly between 2 and 6.

Basic Electronics & Theory

Lesson 5

5.5 Series & Parallel Resistors

Circuits with series and parallel components

Many circuits have a combination of series and parallel resistors. Generally, the total resistance in a circuit like this is found by reducing the different series and parallel combinations step-by step to end up with a single equivalent resistance for the circuit. This allows the current to be determined easily. The current flowing through each resistor can then be found by undoing the reduction process.

General rules for doing the reduction process include:
Two (or more) resistors with their heads directly connected together and their tails directly connected together are in parallel, and they can be reduced to one resistor using the equivalent resistance equation for resistors in parallel.

Two resistors connected together so that the tail of one is connected to the head of the next, with no other path for the current to take along the line connecting them, are in series and can be reduced to one equivalent resistor.

Finally, remember that for resistors in series, the current is the same for each resistor, and for resistors in parallel, the voltage is the same for each one

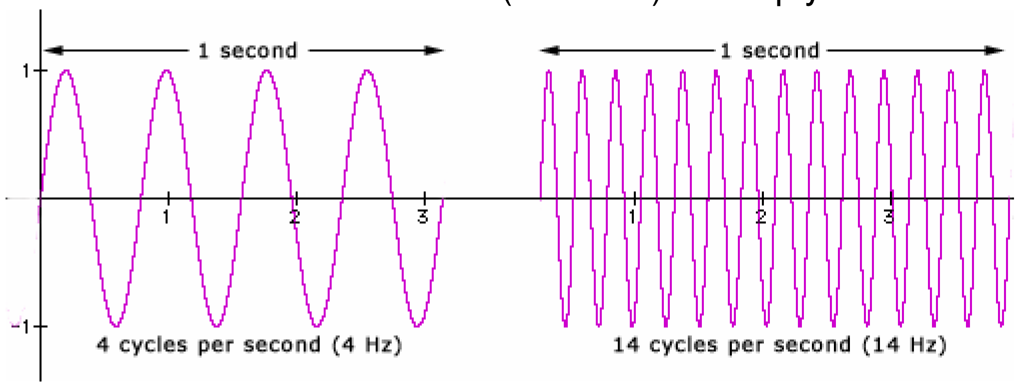
Basic Electronics & Theory

Lesson 5

5.7 AC, Sinewave, Frequency, Frequency Units

What is frequency?

The number of cycles per unit of time is called the **frequency**. For convenience, frequency is most often measured in **cycles per second (cps)** or the interchangeable **Hertz (Hz)** (60 cps = 60 Hz), 1000 Hz is often referred to as 1 kHz (kilohertz) or simply '1k' in studio parlance.

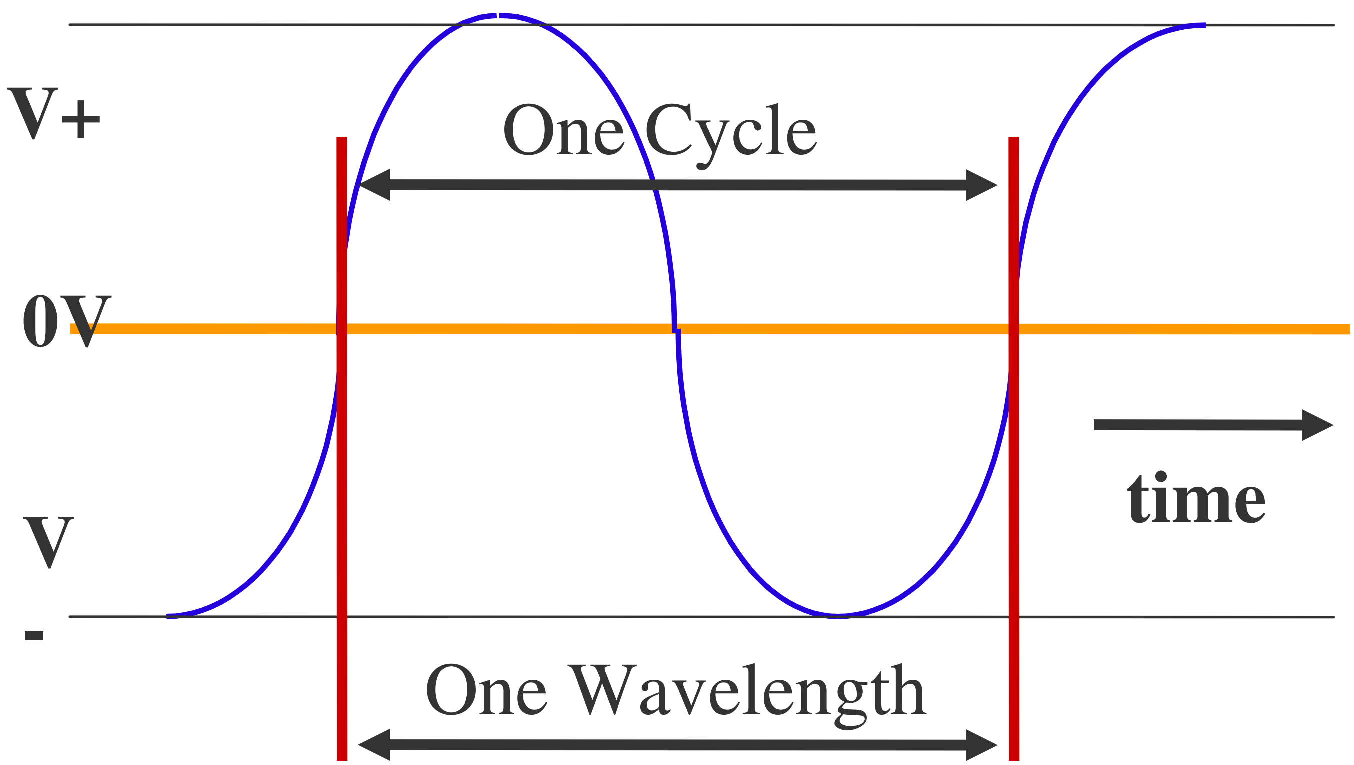


The range of human hearing in the young is approximately 20 Hz to 20 kHz—the higher number tends to decrease with age (as do many other things). It may be quite normal for a 60-year-old to hear a maximum of 16,000 Hz.

We call signals in the range of 20 Hz to 20,000 Hz audio frequencies because the human ear can sense sounds in this range

The Relationship of Frequency and Wavelength

The distance a radio wave travels in one cycle is called wavelength.



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Lesson 5

Names of frequency ranges, types of waves

- Voice frequencies are ***Sound waves*** in the range between 300 and 3000 Hertz.

- *Electromagnetic waves* that oscillate more than 20,000 times per second as they travel through space are generally referred to as ***Radio waves***.

Basic Electronics & Theory

Lesson 5

Relationship between frequency and wavelength

- Frequency describes number of times AC flows back and forth per second
- Wavelength is distance a radio wave travels during one complete cycle
- The wavelength gets shorter as the frequency increases.
- Wavelength in meters equals 300 divided by frequency in megahertz.
- A radio wave travels through space at the speed of light.

Basic Electronics & Theory

Lesson 5

Identification of bands

The property of a radio wave often used to *identify* the different *bands* amateur radio operators use is the *physical length* of the wave.

The frequency range of the **2-meter band** in Canada is **144 to 148 MHz**.

The frequency range of the **6-meter band** in Canada is **50 to 54 MHz**.

The frequency range of the **70-centimeter band** in Canada is **420 to 450 MHz**.

Basic Electronics & Theory

Lesson 5

5.8 Decibels

The decibel is used rather than arithmetic ratios or percentages because when certain types of circuits, such as amplifiers and attenuators, are connected in series, expressions of power level in decibels may be arithmetically added and subtracted.

In radio electronics and telecommunications, the decibel is used to describe the ratio between two measurements of electrical power

Decibels are used to account for the gains and losses of a signal from a transmitter to a receiver through some medium (free space, wave guides, coax, fiber optics, etc.)

Basic Electronics & Theory

Lesson 5

5.8 Decibels

-A two-time increase in power results in a change of 3dB higher

-You can decrease your transmitter's power by 3dB by dividing the original power by 2

-You can increase your transmitter's power by 6dB by multiplying the original power by 4

Basic Electronics & Theory

Lesson 5

5.8 Decibels

If a signal-strength report is “10dB over S9” , if the transmitter power is reduced from 1500 watts to 150 watts, the report should now be S9

If a signal-strength report is “20dB over S9”, if the transmitter power is reduced from 1500 watts to 150 watts the report should now be S9 plus 10dB

The power output from a transmitter increases from 1 watt to 2 watts. This is a dB increase of 3.3

The power output from a transmitter increases form 5 watts to 50 watts by a linear amplifier. The power gain would be 10 dB.

Basic Electronics & Theory

Lesson 5

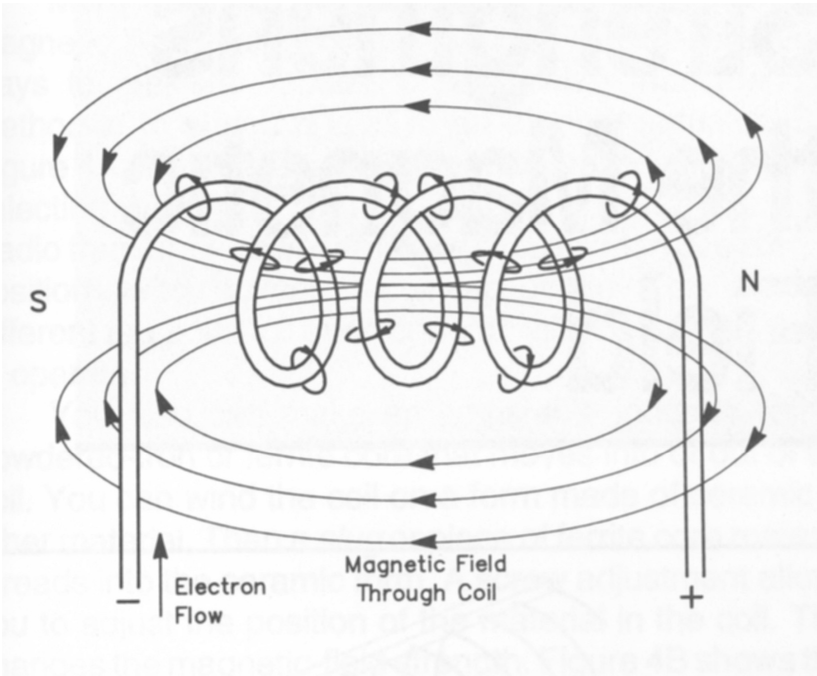
5.9 Inductance

The Inductor

- There are two fundamental principles of electromagnetics:
  1. Moving electrons create a magnetic field.
  2. Moving or changing magnetic fields cause electrons to move.
- An inductor is a coil of wire through which electrons move, and energy is stored in the resulting magnetic field.

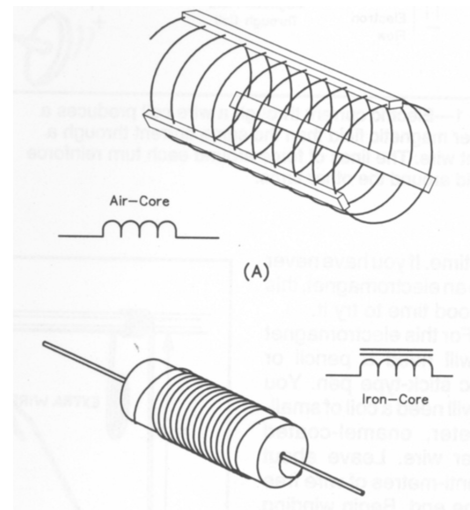
The Inductor

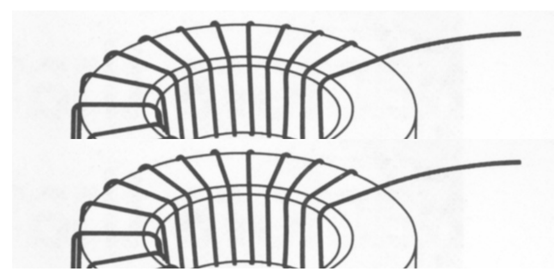
- Like capacitors, inductors temporarily store energy.
- Unlike capacitors:
  - Inductors store energy in a magnetic field, not an electric field.
  - The magnetic field is proportional to the current. When the current drops to zero the magnetic field also goes to zero.



The Inductor

- 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)



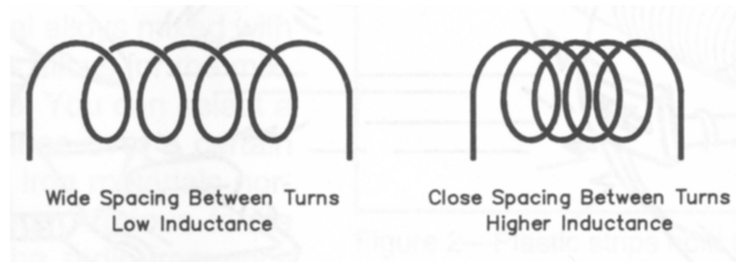


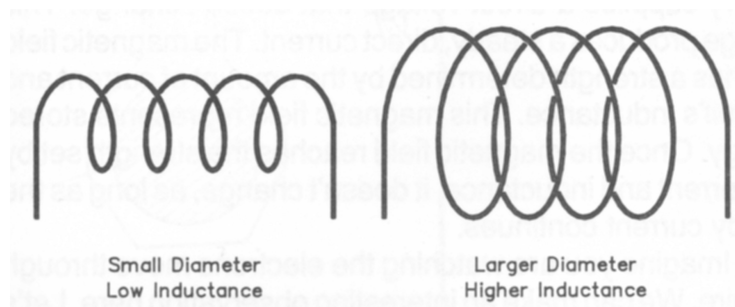
The Inductor

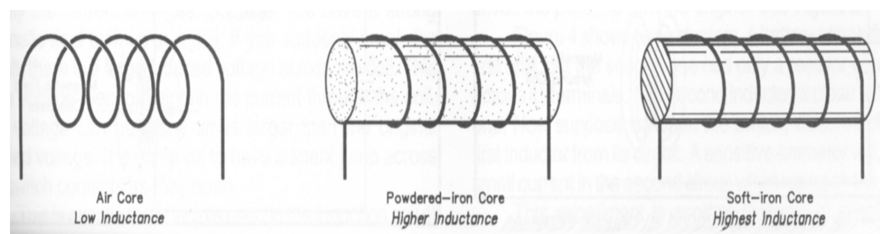
- The rate at which current through an inductor changes is proportional to the voltage across it.
- A coil (or inductor) has a property called its inductance. The larger the inductance, slower the rate at which the current changes.
- The unit that measures the size of the inductance is the Henry.
- Typical inductor values used in electronics are in the range of several Henrys down to microhenrys (1/1.000,000 Henry)

The Inductor

- 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.







Inductor Performance With DC Currents

- When a DC voltage is applied to an inductor the current starts to build. The increasing current produces an increasing magnetic field that causes a (back) EMF that opposes the applied voltage .
- "In a real inductor the wires (and, perhaps the voltage source) have resistance. Ultimately, this resistance prevents the current from rising any higher.
- In an ideal inductor (one where the wires have no resistance) the current would flow round and round forever. In order to cause the current to slow down and stop, a voltage in the opposite direction would have to be applied.
- If the circuit is actually broken (a switch is opened) the current is forced to stop immediately. Since the current does not 'want' to stop suddenly, a large voltage will be generated, often with the production of a spark.

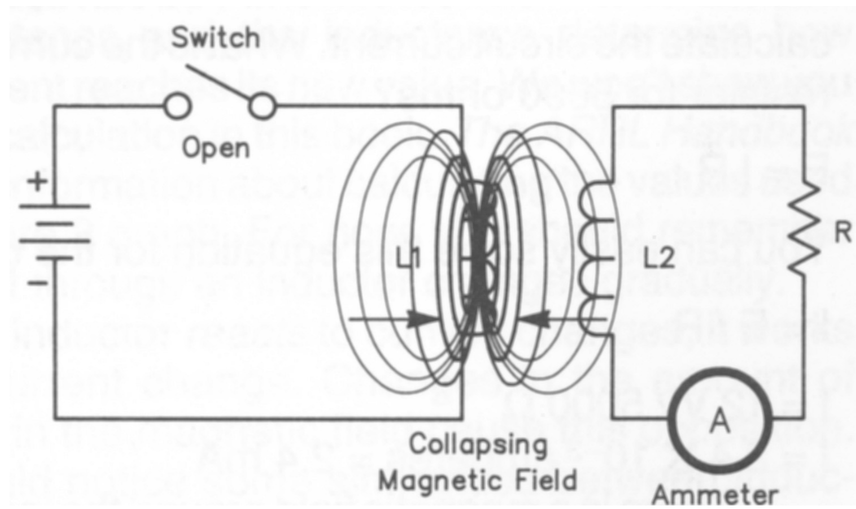
Inductor Performance With AC Currents

- When AC voltage is applied to an inductor the current rises when the voltage is positive; it holds constant when the voltage is zero, and it decreases when the voltage is negative. This gives rise to the rather counter-intuitive situation that, for part of the cycle, a negative current will be associated with a positive voltage – and vice versa.

- Unlike the case of a resistor, the current does not follow lock-step along with the voltage. Although the AC current does tend to do the same thing as the voltage, it doesn't do it at the same time; it does it later in the cycle.

The Inductor

- 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 … the basis of transformers

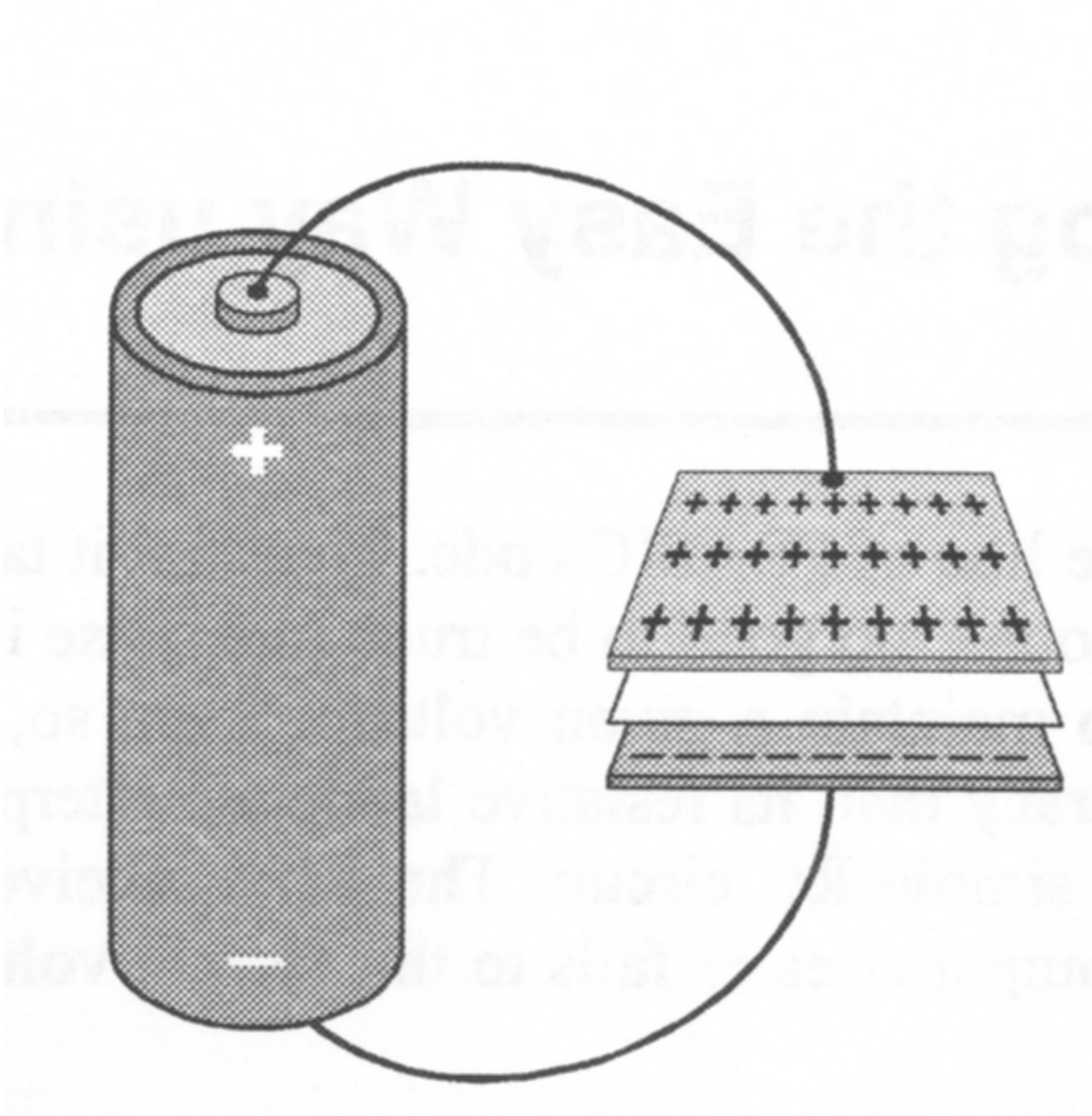


Basic Electronics & Theory

Lesson 5

5.9 Capacitance

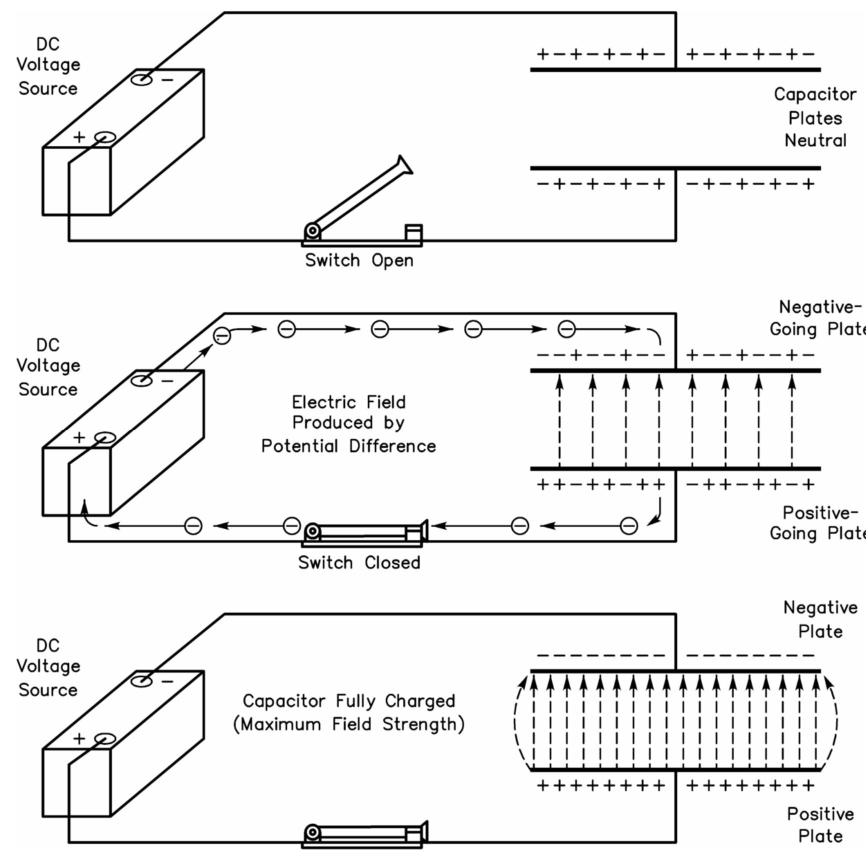
The Capacitor



The Capacitor

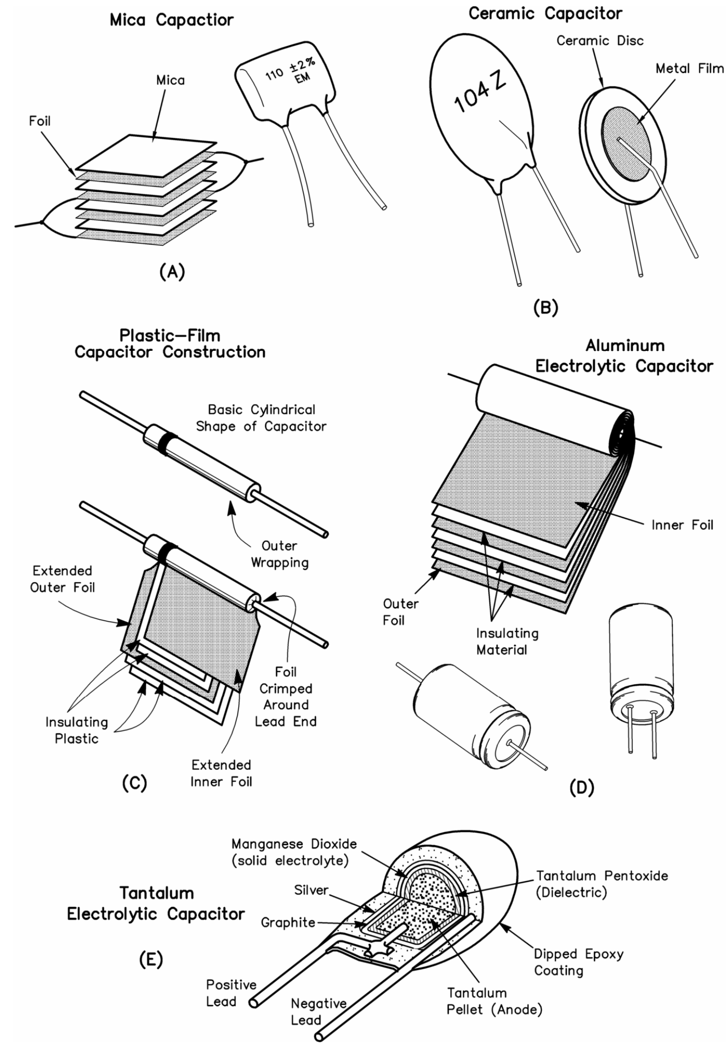
Defined

- A device that stores energy in electric field.
- Two conductive plates separated by a non conductive material.
- Electrons accumulate on one plate forcing electrons away from the other plate leaving a net positive charge.
- Think of a capacitor as very small, temporary storage battery.



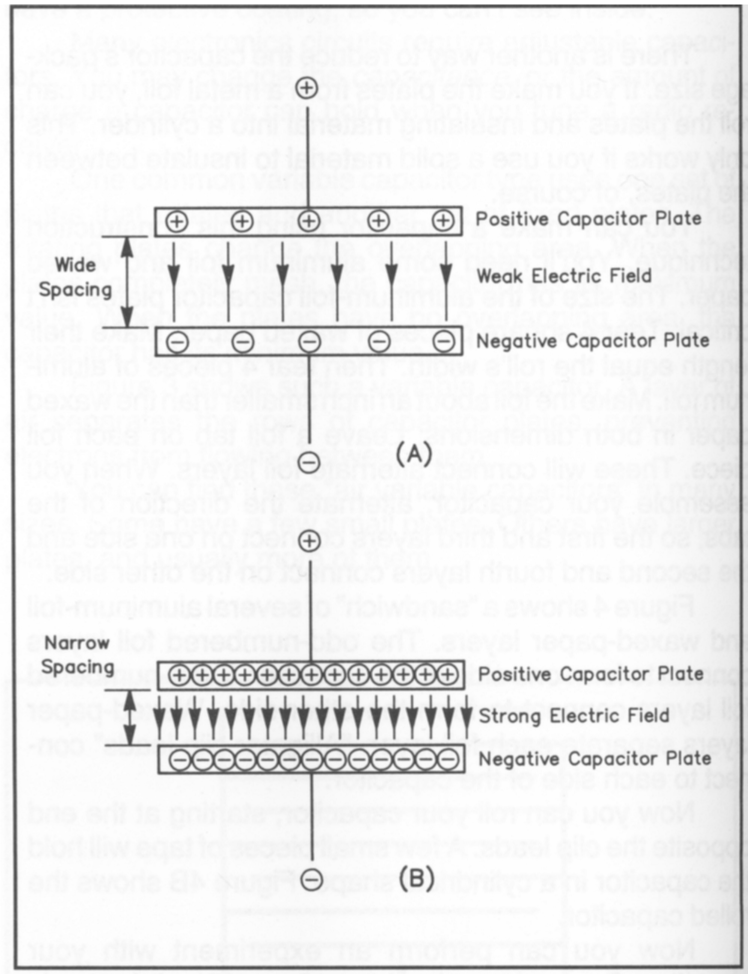
The Capacitor
Physical Construction

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

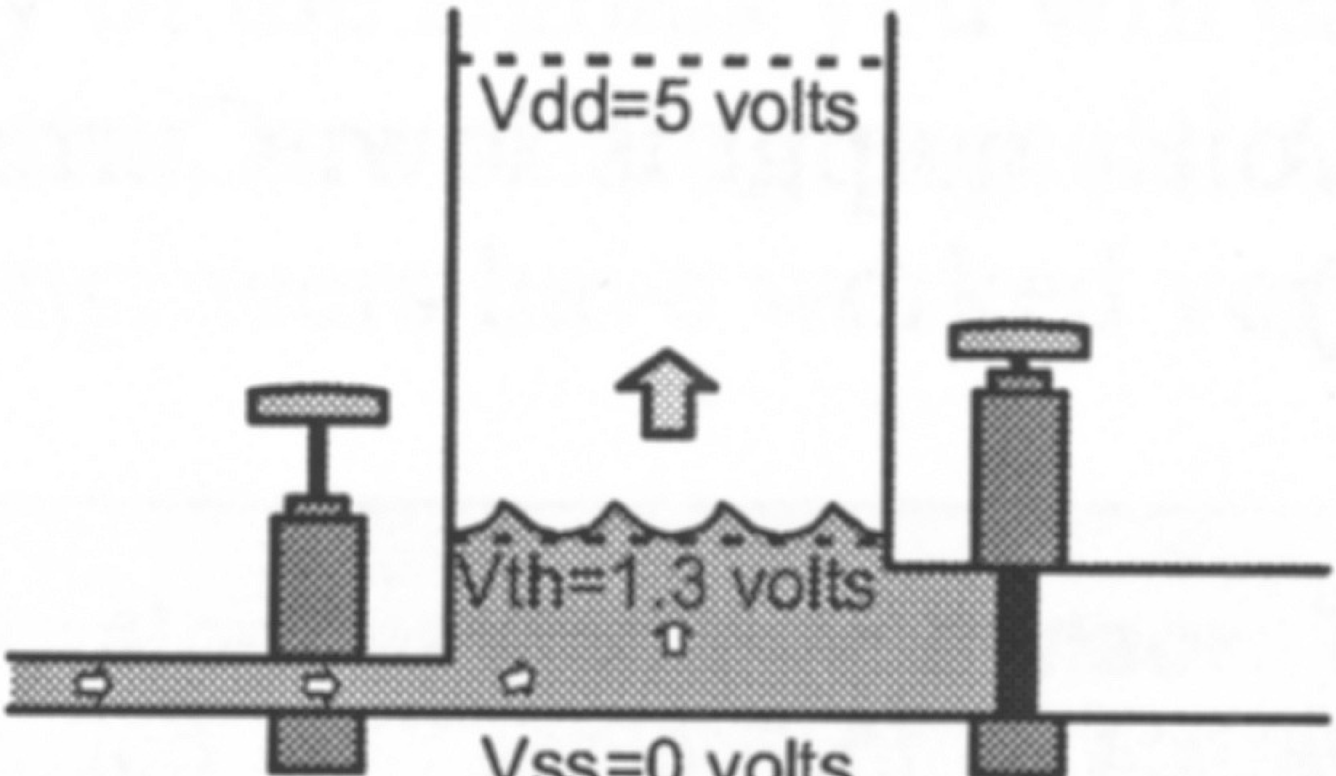


The Capacitor
Ability to Hold a Charge

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



Charging a Capacitor



The Capacitor
Behavior in DC

- 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.

The Capacitor
Behavior in AC

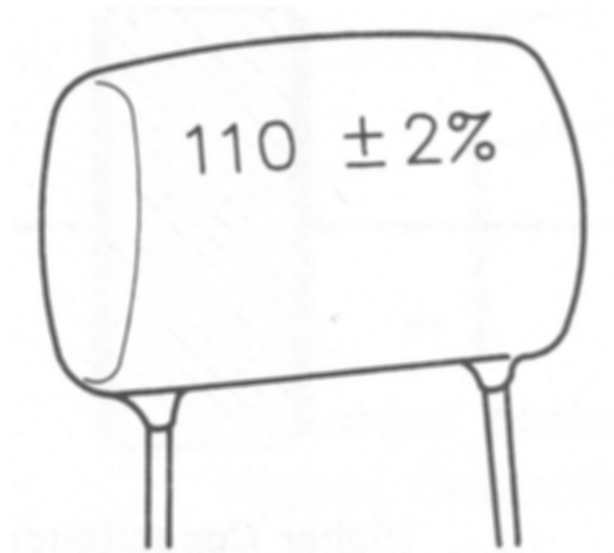
- When AC voltage is applied, during one half of the cycle the capacitor accepts a charge in one direction.
- During the next half of the cycle, the capacitor is discharged then recharged in the reverse direction.
- During the next half cycle the pattern reverses.
- It acts as if AC current passes through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

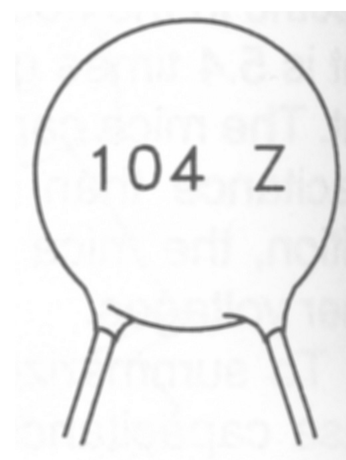
The Capacitor
Capacitance Value

- 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}

The Capacitor
Capacitance Value

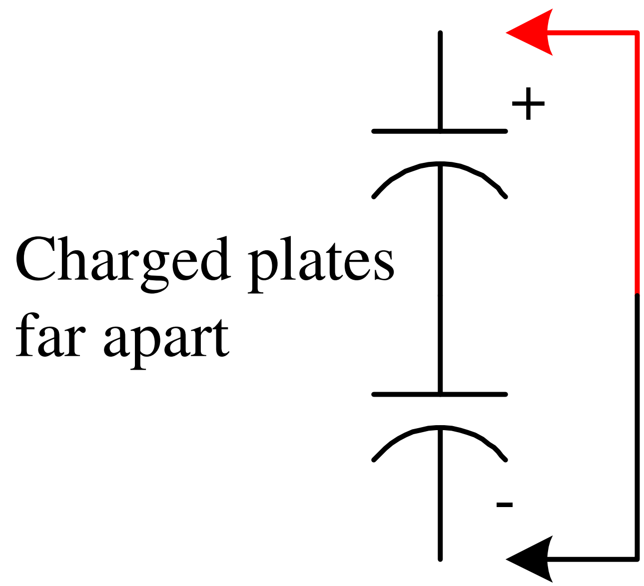
- Capacitor identification depends on the capacitor type.
- Could be color bands, dots, or numbers.
- Wise to keep capacitors organized and identified to prevent a lot of work trying to re-identify the values.





Capacitors in Circuits

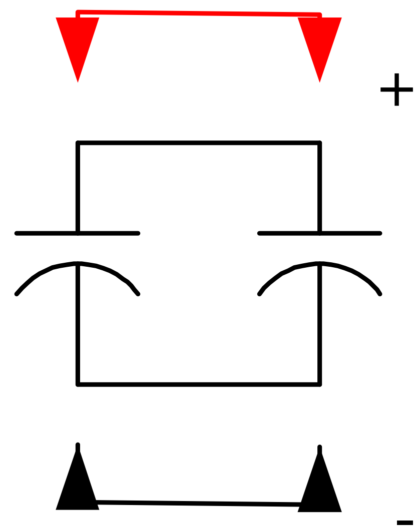
- Three physical factors affect capacitance values.
  - Plate spacing
  - Plate surface area
  - Dielectric material
- In series, plates are far apart making capacitance less



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

Capacitors in Circuits

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



$$C_E = C_1 + C_2$$

5.11 Magnetics & Transformers

The transformer is essentially just two (or more) inductors, sharing a common magnetic path. Any two inductors placed reasonably close to each other will work as a transformer, and 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, although this would be a very long article indeed if

I were to cover all the magnetic field devices that exist.
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 differing permeabilities. Some are optimised 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.

Basic Electronics & Theory

Lesson 5

5.11 Magnetics & Transformers (Continued)

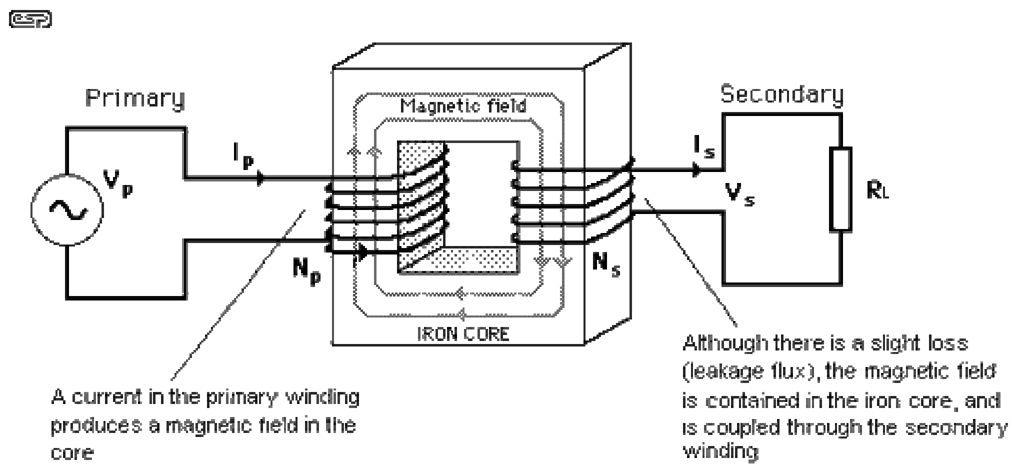


Figure 1.1 - Essential Workings of a Transformer

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.

Basic Electronics & Theory

Lesson 5

5.11 Magnetics & Transformers (Continued)

How a Transformer Works At no load, an ideal transformer draws virtually no current from the mains, since it is simply a large inductance. The whole 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! It is this characteristic that allows any inductor to function as expected, and 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 <u>effectively</u> in the same phase as) the applied EMF.

When you apply a load 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.

Basic Electronics & Theory

Lesson 5

Multimeters will measure Voltage, Current and Resistance.

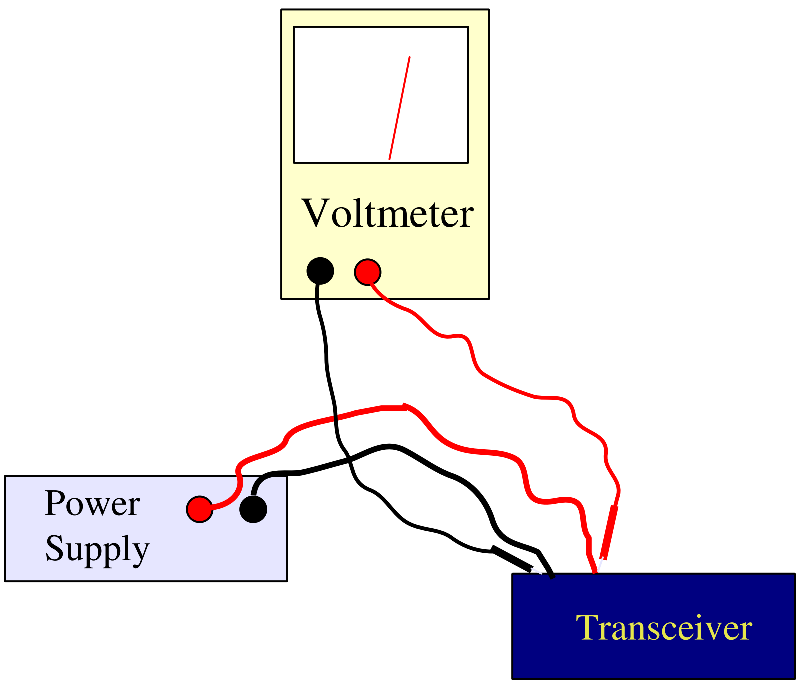
Be sure it is set properly to read what is being measured.

If it is set to the ohms setting and voltage is measured the meter could be damaged!

Basic Electronics & Theory

Lesson 5

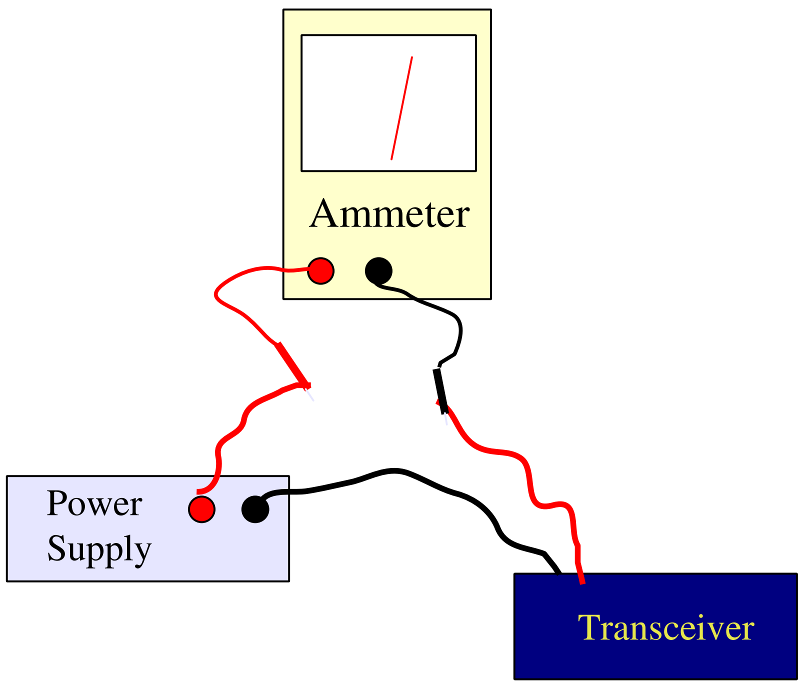
Potential difference (voltage) is measured with a voltmeter, the voltmeter is connected to a circuit under test **in parallel with the circuit.**



Basic Electronics & Theory

Lesson 5

The instrument to measure the flow of electrical current is the ammeter. An ammeter is connected to a circuit under test **in series with the circuit**



Radio and electronic fundamentals T4A

The instrument to measure resistance is the ohmmeter. An ohmmeter is connected to a circuit under test **in parallel with the circuit.**