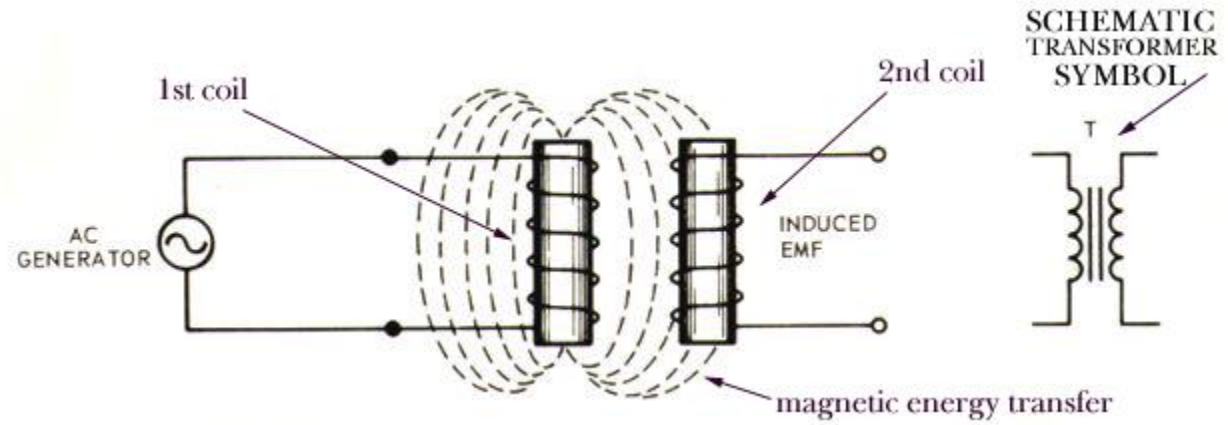
Chapter 7

Here I will try to explain to you how **TRANSFORMERS** work. Again, let me stress the importance of knowing the basics in this hobby. A lot of people can't wait to learn the basics and jump right into building things, later they wonder why they fail to work.

TRANSFORMERS use induction to work, something that I covered in Chapter 6, and you can always visit the local library to learn more about them if you like.



A term that you should be familiar with that plays an important role in understanding transformers is called **MUTUAL INDUCTANCE**. Mutual inductance is when you take two coils as described in Chapter 6, apply current to one coil only, don't matter which one as long as it is A/C current, and then place close together both coils (as long as they don't touch each other) and mutual inductance will take place. This is where the expanding and collapsing flux magnetic fields of the first coil with the current will cut across the winding of the second coil without the current, and voltage will be induced in the second coil.

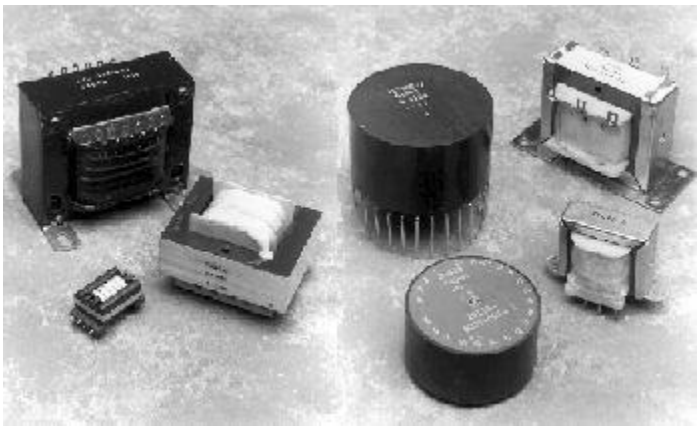
Energy will be transferred through AIR, these two coils never touch each other and electricity is transformed through INDUCTION through the AIR and the connection between these two coils is made by magnetic field only!

Interesting isn't it ? and if you didn't know what induction is, you might not fully understand this, now could you ?

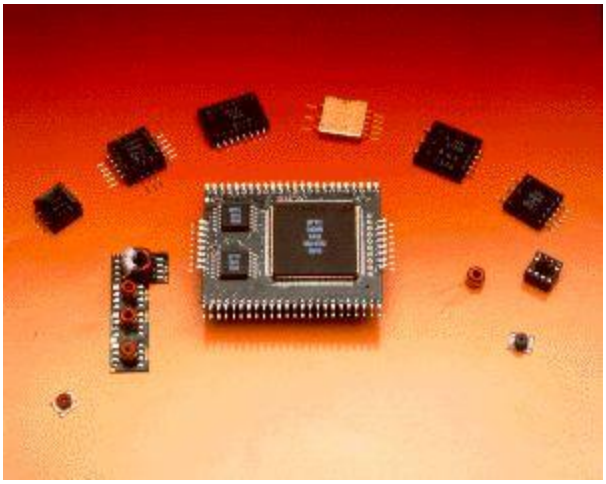
Ok, so...

The full assembly of these two coils is called a TRANSFORMER.

You might have seen transformers that may have looked like one of these:



these are POWER Transformers, but have you ever seen ones like these ?



these are surface mount transformers. Do you see the BIG difference ? they can come in many different shapes and sizes.

If you want to get more familiar with different types of transformers that are available and description of each I recommend that you visit this company:

http://www.bttc-beta.com/ they manufacture many different transformers and are experts in this field.

More about transformers:

There are many different types of transformers, some won't even look like transformers, and it takes time to get familiar with the vast majority that are out there. It took me some time to learn many of them and so too it will take you.

Looking at the picture above of a simple transformer here is some more information about it. The simple assembly of the coils goes as follows; The INPUT coil (this means the one where A/C is introduced into the first coil, and on that picture above, this is the one on the left side) is called the **PRIMARY** winding and the output coil is called the **SECONDARY** winding.

A transformers job by what is called the technical definition is to transfer electrical energy from one circuit to another by means of varying the magnetic field and transformer setup.

Don't forget that mutual induction works because of self-induction which I covered in chapter 6. If you don't know what self-induction is of a single coil while connected to a varying power supply, then you won't understand the above.

Anyways, all this conduction stuff is measured in electronics using a standard, and this magic word is called HENRY or measured in **HENRYS**.

It is said that if a primary coil induces a minimum one volt transfer into the secondary coil when the applied current to the primary coil is changing at a rate of ONE AMPERE per second, a mutual inductance of 1 HENRY takes place or inductance is ONE HENRY. The letter M represents Mutual inductance or HENRY. The complete formula is:

$$M\,(\text{in henrys}) = \frac{e}{\triangle i / \triangle t}$$

(SECONDARY voltage)

(ROC or rate of change)

where:

e = how many volts in CEMF.

i = change of current in amperes

t = change of time in seconds

Here is a quick example of how to use this formula. Suppose you are given this information to find out the mutual inductance of a transformer.

The current applied to the primary coil changes at 2 amperes per second and it in turn induces 20 volts in the secondary coil (remember coils do not touch each other, the electricity is transferred through the air only, no electrical connection of any kind is attached between the coils), **What is the mutual induction ?**

You really don't even need to understand this to solve it, it's very simple, if you know the formula, anyone with very basic math skills can do this, it's a matter to fill in the blanks for corresponding info.

the 20 volts goes to = e

the 2 amperes goes to = i

and t gets 1, why 1 ? because we are told that it alternates 2 amperes every 1 second and t stand for time, so t gets a value of 1.

so M = 2/1 = 2 and 20/2 = 10, so the answer is 10 henrys. And what is 10 henrys again ? the answer lies in the question, but to be nice I'll tell you.

If a primary coil induces 20 volts in the secondary coil when the current in the primary coil is changing at the rate of two amperes per second, the mutual induction is 10 HENRYS.

And yet more information, **What is COUPLING ?**

While the word coupling might sound complicated, it is not. Coupling is a unit of measurement that is used in transformer technology to measure the effect of the position of the individual coils and how their position effect induction in the transformer circuit.

Let me give you an example. As you already might know by now, and I hope that you do, transformers work because of induction, and so the induction will be greater if the two coils are positioned closer together, right ? because the many magnetic lines will cut across the secondary coils with a greater force and a greater secondary voltage will be induced.

Yes, the opposite is true, if the coils are spread farther apart from each other, less of the magnetic energy will be transferred and so the induction in the secondary coil will decrease. Understand ? I hope so.

And so the effect of the PRIMARY and SECONDARY coils to each other based on their respective distance position from each other is called COUPLING. That's all coupling is.

If all the lines of the primary coils windings cut exactly perfect across the secondary, it is said that the COUPLING is at 1 or is UNITY COUPLING with a value of 1.

If the two coils are separated so that only half the magnetic energy is transferred from the primary to the secondary, the COUPLING is .5 The decimal point in the .5 indicates the number of flux lines available for mutual induction or the percentage, and in this case 50% and is called the **COEFFICIENT OF COUPLING** and is assigned a letter of ***k.***

Also know what the angle of the two coils and their respective positions, how that will affect their mutual induction. For a maximum mutual induction to take place, the right angles must be used. And right angles means that both coils are parallel to each other. If you turn one coil so that there is an angular different like by 45 or 90 degrees, the mutual induction will be decreased.

Ok, now for another formula. If you know the coupling or the coefficient of coupling and the inductance of each coil, you can find out what the mutual inductance is by following this equation or formula:

$$M = k \sqrt{L_1 \quad L_2} = \text{mutual induction}$$

So here is an example of this formula. **EXAMPLE:** Each of the two coils in the transformer are 8H and have a coupling of .5 **What is their mutual inductance ?**

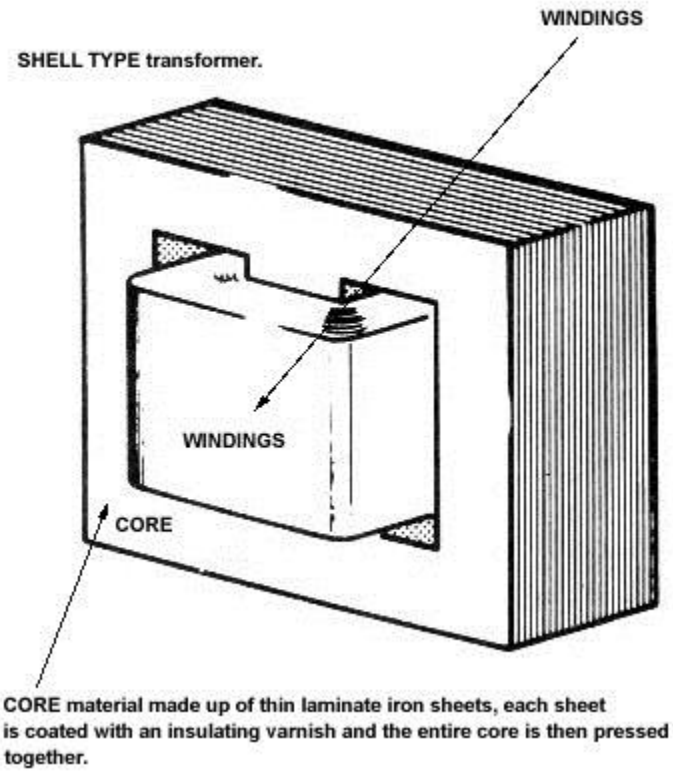
So the first L1 represents one of the coils in the transformer and the L2 the other, the example says that each coil has 8H, so 8 x 8 = 64 and what is then the square root of 64 ? 8 and then, k = .5, so 8 x .5 = 4 henrys.

How do transformers work in real life ?

One of the best ways to start out my transformer explanation is to introduce you to the power transformer first, because it is the most visible transformer type that you have probably in one time or another already seen even if you don't know how it works.

Basically there are two major types of POWER transformers out there, don't forget that power transformers are designed to work at power frequencies of between 30 to 500 Hz. The two major types are the CORE TYPE and the SHELL type:

The SHELL type which is the more popular model is shown below:

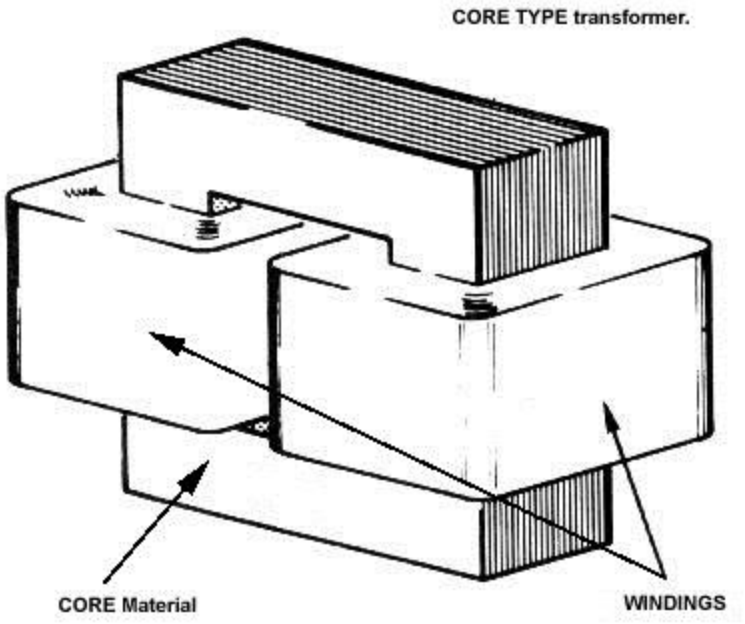


CORE material made up of thin laminate iron sheets, each sheet is coated with an insulating varnish and the entire core is then pressed together.

In the Shell type the windings are wound in layers and fit over the center of the core section.

The CORE type is the next model below:

www.electronics2000.com



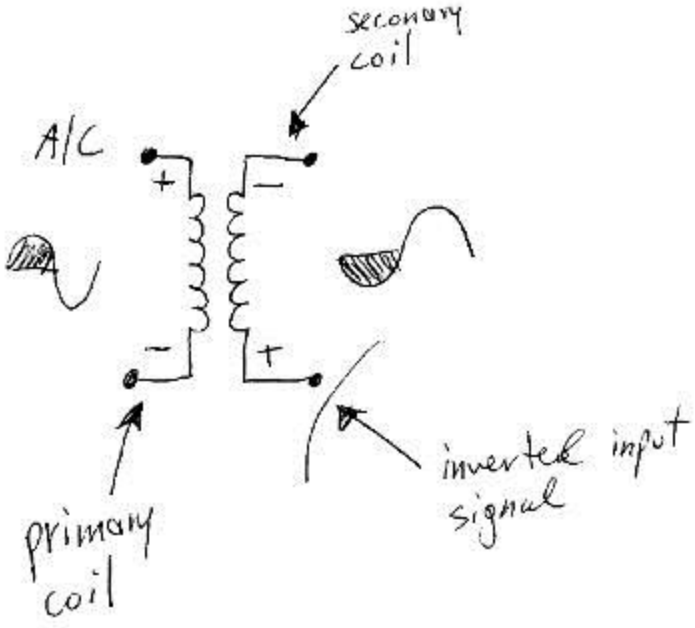
In the Core type the primary and secondary windings are placed on each side of the core.

Many other power transformers exist, and they may have more then one primary or secondary windings.

Power Transformer Theory:

When an A/C current/voltage is introduced to the primary winding of the transformer and the secondary winding is OPEN (that means no A/C current/voltage is applied to it), a magnetic field will be created in the primary coil or winding that will establish the magnetic fields necessary for transformer operation. The magnetized current in the primary coil depends on the A/C current/voltage applied and how many number of turns you wind around the coil. (I x N), I means current, N means number of turns on the winding/coil. The more is applied, the larger magnetic energy can be created in the primary coil/winding.

Now the expanding and collapsing magnetic fields of the primary coil cut across the secondary coil/winding and in turn induce a voltage in the secondary coil. The polarity outcome of the secondary coil will depend on the direction of the secondary coil winding and the external connections. Most of the time transformers invert the magnetic energy in the opposite direction to the secondary coil (see illustration below):



Hopefully you can read my hand writing. Inverted means made opposite, like inverting a picture, from a positive to a negative image. So it means that the + and - terminal location on the secondary side is reversed that from the positive input side.

Many of todays transformers are made in a way, especially the SHELL type transformers, where the unity coupling that exist between the primary and the secondary is at UNITY or very close to a COUPLING of 1. So therefore, since both the cores are wind closely together and the unit yis at almost a perfect 1 and are mounted on a common CORE, the available flux for the secondary coil is almost the same as for the primary.

Anyways, if the number of turns on the secondary coil are more then on the primary, this will increase the secondary voltage as it passes from the primary in the form of magnetic energy, but decrease current or AMPS. The opposite is also true. **THIS IS CALLED a STEP-UP transformer.** If the secondary has less turns in the coil then the primary, the secondary coil's voltage will decrease and the current or AMPS will increase. **This is called a STEP-DOWN transformer.**