

Basic Electronics Part 14
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When electrons move through a wire they produce a magnetic field. The magnetic field extends outward from the wire. The field is stronger close to the wire and it gets weaker as you move away from the wire. Larger currents produce stronger magnetic fields. If the wire is bent into several circles next to each other, the magnetic field around each piece of wire adds to the force of the pieces on either side creating a stronger magnetic field. The magnetic force lines wrap through the center of the cylinder of wire and around the outside. A coil of wire used in an electronics circuit is called an inductor. An electric current through an inductor creates a magnetic field.

An inductor may consist of coils of wire that are stiff enough that they remain in the coiled position. Such inductors are called air-core. Some inductors consist of coils of wire wrapped around a piece of iron or a rod containing powdered iron. This is called an iron-core inductor. If we have an air-core inductor and an iron-core inductor with the same number of turns of wire and the same current, the iron-core inductor will produce a stronger magnetic field than the air-core inductor.

Many electronic circuits use a special type of inductor core called a toroid. A toroid is an inductor wound on a core that curves into a donut shape. Toroid cores are available in many powdered-iron and ferrite core materials. Remember the magnetic field produced by an inductor goes through the center of the coil. The magnetic field from a straight coil curves back around outside the core, because magnetic-field lines form a closed loop. A magnetic field inside a toroid core doesn't have to loop around outside the core since the toroid forms a donut. In this case, because the donut closes back on itself, the field stays completely inside the core. This is one of the advantages of using a toroid inductor.

Some electronic circuits require an inductor with a magnetic field that can be changed. If we have an air-core inductor, we can change the magnetic field by attaching a lead to the inductor at a turn that is not at the end of the inductor. This is called tapping the inductor. We can attach leads to any point in the coil and in some circuits we can have multiple taps that are accessed using a multi-position switch. This is common in antenna tuners or in radio frequency amplifiers. We can also make an adjustable inductor with a powdered-iron or ferrite core that moves in to or out of the center of the coil. We can wind the coil on a form made of ceramic or other material. Then a slug or piece of ferrite core material is threaded into the ceramic form. A screw adjustment allows us to adjust the position of the material in the coil. This changes the magnetic-field strength.

The inductance of a coil is a property that relates to the magnetic-field strength produced by the coil. Inductance is represented by a capital L. The basic unit of inductance is the henry, abbreviated H. A 1-henry inductor is physically very large so we use the millihenry (mH) which is 10^{-3} H or the microhenry (μ H) which is 10^{-6} H in most electronic circuits.

Four main factors help determine a coil's inductance. These are as follows:

1. Number of turns,
2. Spacing between turns,
3. Coil diameter, and
4. Type of core material.

If we wind more turns in a coil, we increase the inductance. If we space the coils further apart, we decrease the inductance. If we wind a coil with a larger diameter, we increase the inductance. The fourth factor affecting inductance is the type of core material in the center of the coil. Permeability is a measure of how easily a magnetic field goes through a material. Permeability also tells us how much stronger the magnetic field will be with that material inside the coil. Permeability is usually given as relative permeability. This means the value compares the material with the permeability of air. If a ferrite material has a relative permeability of 50, then a coil with that material as a core will have 50 times more inductance than a similar coil that is air-core.

We now come to the question of the purpose a magnetic field has in an electronics circuit. Suppose we place an inductor, a battery, and a switch in a circuit, as in Fig. 1.

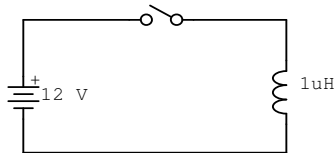


Fig. 1

When we close the switch, current begins to flow in the circuit and this flow of electrons causes a magnetic field to build around the inductor. This magnetic field will reach the strength set by the current and inductance, and it will not change as long as the steady current continues. If we open the switch, breaking the circuit, the magnetic field collapses. This collapsing magnetic field induces a voltage across the inductor, trying to maintain the current. As a matter of fact, as the magnetic field was increasing, there was also an induced voltage that tries to oppose the current. That is why the current increases gradually when we first close the switch. In general, the induced voltage of a collapsing magnetic field has the opposite polarity to the applied voltage when the magnetic field was increasing. The magnitude of the induced voltage depends on how rapidly the current changes. If we have a strong magnetic field built up in an inductor and we suddenly break the circuit, there is a large induced voltage across the inductor. This large voltage tries to maintain the current through the inductor. This induced voltage can be many times larger than the original applied voltage. It could be so large that we have a spark jump across the switch contacts as they open. This can be seen if we use a knife switch in the circuit.

Now consider the circuit in Fig. 2.

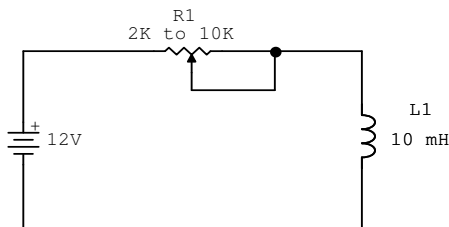


Fig. 2

The inductor is a piece of wire so it has very little resistance to this direct current. We can use Ohm's Law to calculate the circuit current. If we set the resistance to 5K ohms, then $E = IR$, and we can solve this for the current.

$$I = \frac{E}{R} = \frac{12}{5000}$$

Therefore, $I = 2.4 \times 10^{-3} \text{ A} = 2.4 \text{ mA}$. There is a magnetic field around the inductor with this current through the circuit. If the current doesn't change, the magnetic field remains constant. If we adjust the resistor to increase the resistance, the current begins to decrease. The inductor reacts to this change by returning some of the energy stored in its magnetic field. This returned energy produces a voltage across the inductor that tries to keep the same current flowing through it. The current does decrease, however, as the magnetic-field strength decreases. The inductor prevents the change from occurring instantly. The new current maintains a smaller magnetic field. If the resistance is increased to 10K ohms, the current decreases to 1.2 mA. How do we know this? What would happen if we decreased the resistance to 2K ohms?