

## **Key Ignition Concepts to Know**

### **Voltage**

This is a term of electrical pressure, named after Alessandro Volta. It specifies how much force is trying to push electrons (the basic unit of electrical flow) through a circuit. It is similar to water pressure in a hose.

### **Current**

Current is a measurement of the flow rate of electrons in a circuit, and is measured in amps, short for amperes, named after Andre-Marie Ampere. It corresponds to a flow rate like gallons per minute in a water line.

### **Resistance**

Resistance is measured in Ohms, named after Georg Ohm. It specifies the opposition to the flow of electrons in a circuit, kind of like squeezing the water hose so it is harder for water to get through!

### **Inductance**

Inductance is the property of an electric circuit that tends to resist change in the rate of current flow, but doesn't interfere with a steady flow of current. Inductors are measured in Henries, named after Joseph Henry. In our work with coils, we also use millihenries which are 1/1000th of a Henry, and microhenries, which are 1/1,000,000th of a Henry. Inductors can store electrical energy in the form of a magnetic field. We do this by using a lower voltage, operating over a longer period of time to store the energy, then we release it much more quickly, which causes the output voltage to be much higher. That's how we get a good spark from a standard ignition system.

### **Capacitance**

Capacitance is another form of energy storage, kind of the opposite of inductance, because a capacitor transfers a change in current, but will not allow a steady flow to pass through. Capacitance is measured in Farads, named after Michael Faraday. In most circuits, a farad is much too large to be practical, so we typically use microfarads, which are 1/1,000,000th of a farad.

### **Power and Energy**

Power and energy are sometimes used interchangeably, but they are two different things. Power is measured in Watts, after James Watt, and is calculated by multiplying voltage times current. For example, if a power supply is set for 12 volts, and is sending 3 amps to a circuit, it is supplying 36 watts. Energy is power delivered over a period of time. For example, most people are familiar with kilowatt-hours, because that's how we buy our electricity. A kilowatt-hour is

equivalent to 1000 watts over a 1 hour period. You could also get the same from 500 watts for 2 hours, or 2000 watts for ½ hour. In ignition systems, we use a smaller unit of energy called a Joule, named after James Joule. In electrical terms, a Joule is the amount of energy delivered by supplying 1 watt for period of one second, and is also called a watt-second. In ignition systems, a joule is typically too large, so we use the millijoule, which is 1/1000th of a joule.

## **Time**

Time is typically measured in seconds, milliseconds (1/1000th of a second) and microseconds (1/1,000,000th of a second) and specifies the duration of an event.

## **Understanding Ignition Coils**

Ignition coils are, at the simplest, a special type of electrical transformer. Transformers are electromagnetic devices that couple AC energy from one circuit to another. A transformer cannot transfer DC power. When used in an automotive ignition system, a transformer (or coil) can be used in one of two ways – as a simple transformer only, or as a combination energy storage/transformer.

The first way is most commonly seen when using a CD ignition system. The ignition energy is developed within the CD ignition, and the coil merely "transforms" the energy to a form that will fire the plug.

The second way of using a coil is the way that conventional point/electronic ignitions work. The coil primary stores energy in the form of a magnetic field, then transforms it to a spark-plug suitable form when required.

The two ways of using a coil determine what characteristics are important when selecting a coil for a particular application. Coils have several characteristics that have an effect on their output, and the importance of these characteristics change depending upon the ignition system used. The major characteristics are primary inductance, primary resistance, turns ratio, secondary resistance, and core configuration.

### **Primary Inductance**

Primary inductance determines several things, in a non-CD ignition, it determines the amount of stored energy for a given amount of primary current, the usable RPM range of the ignition, and it has a significant effect upon the risetime of the spark voltage. A higher inductance means more energy, but a slower risetime.

In a CD ignition, it determines mainly the peak primary current (and ultimately the secondary current) and the risetime of the spark voltage. A lower inductance means higher primary peak current and quicker risetime.

### **Primary Resistance**

Primary resistance has an effect upon the maximum current realizable in a non-CD ignition. The greater the primary resistance, the lower the current (and available energy). In a CD ignition, the resistance is not nearly as important, but contributes to the parasitic losses as the peak current goes up. Primary resistance is a combination of two things: the coil's primary winding resistance and the external ballast resistance (if used). Coils are sometimes built with a relatively high primary resistance (motorcycle coils are a good example of this type) that limits the primary current automatically. Most automotive applications that require controlled primary resistance use a ballast resistor (which is a low value, high wattage resistor) in series with the coil primary. The advantages of the high primary resistance coil (sometimes called self-ballasted) are simplified installation and a bit more consistent output as the coil temperature changes. The externally ballasted circuit allows the finer tuning of primary resistance, and also allows the circuit to be designed so that, during cranking, the full battery voltage is placed on the coil "+" terminal, making more energy at low engine speeds

### **Turns Ratio**

Turns ratio, which is the ratio between the number of secondary turns and the number of primary turns, affects the maximum peak output voltage (the greater the turns ratio, the higher the voltage), the maximum spark current (the lower the turns ratio, the greater the spark gap current), and indirectly, the risetime (generally, the higher the turns ratio, the slower the risetime). A "turn" of wire is one complete 360 degree wrap around the coil magnetic core.

### **Secondary Resistance**

Secondary resistance affects risetime somewhat, secondary current, and overall efficiency. The greater the secondary resistance, the slower the risetime, the lower the maximum spark gap current, and the lower the overall efficiency.

### **Core Configuration**

Core configuration is the way the magnetic path in the coil is designed. The most common for many years was the "I", or rod core. Most coils made now use some kind of continuous magnetic path, either an E-I configuration (sometimes referred to as "E-core") or a double "C" core. The advantage to the E-core or C-core design is that more of the primary energy gets transferred to the secondary. Also, it allows the coil designer to be able to use fewer turns in both windings, thus lowering the resistances.

### **Coils 201 - Advanced Coil Talk**

A commonly asked question is, "What is the best coil for my application?" Another similar question is, "Will this coil work for my application?" The answer to both of these questions is, annoyingly, "It depends."

Here's how it works out: non-CD (or inductive storage) ignitions use the coil primary to store energy in a magnetic field. The amount of stored energy is a function of the square of the primary current. This means that, for example, if you double the primary current, you quadruple

the primary energy. Because of this, the primary inductance and resistance are critical items. However, in answer to the obvious question of, "Why not make all coils for conventional ignitions with high primary inductance?" we have to deal with the fact that as the inductance goes up, the longer time it takes for current to rise when the points or transistor switch are "on". This means that at low speeds, you may have plenty of time to reach maximum current, but as the RPM goes up, you have less and less time available.

In contrast, a lower inductance coil may have less energy at the same current rating, but will allow more current to build up at the higher engine speeds, and actually have more energy than the high inductance coil would. All inductive storage ignitions require some kind of current limiting to make sure that the primary current is not excessive at low speeds. In older point and electronic ignitions, a high-wattage ballast resistor was commonly used to do this. Typical values are .5 to 2 ohms. More modern systems often use some kind of electronic current limiting in the coil driver device itself to limit the current. The disadvantage of this is that, if the current is allowed to reach the limit, there is a lot of heat developed.

CD ignition systems have a different operating condition. A CD system uses an internal DC to DC converter to step the battery voltage up to the 400-600 volt region. This energy is stored in an electronic component called a capacitor. When the trigger signal occurs, the stored energy is transferred to the coil, and the transformer action of the coil steps the voltage up high enough to fire the spark plug. This allows us to make the coil design relatively independent of the engine RPM range. However, the coil characteristics still affect the "quality" of the spark. Turns ratio still determines the open circuit maximum voltage. Since CD ignitions typically have primary voltages higher than inductive storage ignitions, the system maximum voltage is also higher (with the same coil). The turns ratio also affects the spark gap current in the same way, and the coil inductances and resistances also affect the risetime similarly. With a CD system, we can tailor the coil to match what we need more exactly.