AutoTap

TECHNICAL ARTICLE

# UNDERSTANDING MULTI-COIL IGNITION SYSTEMS

Distributorless Ignition Systems (DIS) have been around for more than two decades, but in recent years the trend has been to multi-coil systems such as Coil-On-Plug (COP) or Coil-Per-Cylinder (CPC) ignition systems, and Coil-Near-Plug (CNP) ignition systems.

Coil On Plug systems have become the hot setup for a number of packaging, performance, emissions and maintenance reasons. Placing individual ignition coils directly over each spark plug eliminates the need for long, bulky (and expensive) high voltage spark plug cables. This reduces radio frequency interference, eliminates potential misfire problems caused by burned, chaffed or loose cables, and reduces resistance along the path between the coil and plug. Consequently, each coil can be smaller, lighter and use less energy to fire its spark plug.

From a performance standpoint, having a separate coil for each cylinder gives each coil more time to recharge between cylinder firings. With single coil distributor systems, the coil must fire twice every revolution of the crankshaft in a four cylinder engine, and four times in a V8. With a multi-coil system, each coil only has to fire once every other revolution of the crankshaft. This provides more saturation time for a hotter spark, especially at higher rpm when firing times are greatly reduced. The result is fewer misfires, cleaner combustion and better fuel economy.

According to the original equipment supplies who make multi-coil ignition systems, having a separate coil for each cylinder also improves the engine's ability to handle more exhaust gas recirculation to reduce oxides of nitrogen emissions (important with today's low emission vehicle standards). A hotter spark also makes spark plugs more resistant to fouling and helps 100,000 mile plugs go the distance. A multi-coil ignition system also improves idle stability and idle emissions, too.

The typical multiple coil ignition system may have one of several different configurations. On Chrysler, Toyota and many other imports, the coils are mounted directly over the spark plugs. Many of these are the thin "pencil" style coils that extend down into recessed wells in the engine's valve covers. On other applications, such as GM's Quad 2.2L Four, the individual coils are mounted in a cassette or carrier that positions the coils over the spark plugs. On late model Corvette, Camero and other V8s, a Coil-Near-Plug (CNP) setup is used because the spark plugs protrude from the side of the cylinder head and there isn't room to mount a coil on the end of each plug. Here, the individual coils are mounted on the valve cover and attached to the plugs by short plug wires.

In most of the older DIS ignition systems, an electronic module was part of the coil pack assembly and controlled the switching of the coils on and off. On most of the newer systems, the switching function is handled by the powertrain control module, though there may some additional electronics and diodes built into the top of each coil. The PCM receives a basic timing signal from the crankshaft position sensor and sometimes a camshaft position sensor to determine engine speed, firing order and timing. It then looks at inputs from the throttle position sensor, airflow sensor, coolant sensor, MAP sensor and even the transmission to determine how much timing advance to give each plug. Most of today's multi-coil ignition systems are capable of making timing adjustments between cylinder firings which makes these systems very responsive and quick to adapt to changing engine loads and driving conditions.

## COIL TECH

All coils are essentially transformers that consist of an iron core surrounded by primary and secondary windings. The primary windings are a much larger diameter wire than the secondary windings, but have fewer turns around the core. The ratio of turns between the primary and secondary windings determines the coil's output potential (the higher the ratio, the higher the maximum output voltage). Most coils have about 10 times as many secondary windings as primary windings. High performance coils have more.

Conventional canister or can style coils used with older distributor ignition systems usually have a common primary and secondary ground connection. High energy coils may use a similar design or have isolated primary and secondary windings. DIS coils may have isolated primary and secondary windings (typical of the waste spark systems), or a common primary circuit with an isolated secondary circuit. COP and CNP coils usually have a common primary and secondary ground junction.

With all types of coils, the primary and secondary windings are insulated from one another and do not touch. The resistance of the primary winding is typically very low, usually less than a couple of ohms and as low as 0.6 to 0.7 ohms on some individual coils. The resistance of the secondary windings, by comparison, is quite high. Segmented bobbin designs are usually in the 5,500 ohm range while serial bobbin designs usually fall in the 10,000 to 14,000 ohm range. Always look up the resistance specifications for the coils you are testing because the numbers vary considerably depending on the application.

So how does a coil actually fire a spark plug? When battery voltage from the ignition circuit, ignition module or PCM flows through the coil's primary windings, the iron core becomes a strong electromagnet. This forms lines of magnetic force that surround the core and envelop the secondary windings. When the ignition module switches off the primary voltage to the coil, the magnetic field collapses. As the lines of magnetic force contract and rush back towards the core, they push along the electrons in the secondary windings and induce a high voltage surge in the coil. The voltage then passes from the coil to the spark plug and creates a spark that ignites the air/fuel mixture.

## COIL DIAGNOSIS

Though coils are very reliable, they sometimes fail. Coils run hot because of the voltage that is constantly surging through them. Over time, the combination of heat and voltage may break down the insulation between the windings, coil housing or tower. If a coil problem is suspected, the coil's primary and secondary resistance can be measured with an ohmmeter. If either is out of specifications, the coil needs to be replaced.

A short or lower than normal resistance in the primary windings allows excessive current to flow through the coil, which can quickly damage the ignition module. This may also reduce the coil's voltage output resulting in a weak spark, hard starting and hesitation or misfire under load or when accelerating.

An open or high resistance in the coil primary windings will not usually damage the ignition module or PCM driver circuit right away but may cause the module to run hot and shorten its life. With this condition, coil output will be low or non-existent (weak spark or no spark).

A short or low resistance in the coil's secondary windings will result in a weak spark, but will not damage the module or PCM driver circuit.

An open or high resistance in the coil's secondary windings will also cause a weak spark or no spark, and may also damage the ignition module due to feedback induction through the primary circuit.

An important point to keep in mind with respect to all types of ignition coils is that when the magnetic field collapses, the high voltage surge has to go someplace. If it can't go to the spark plug, it will find another path to ground -- which may be back through the ignition module, PCM driver circuit or through the insulation inside the coil itself. This can be very damaging to these parts. So never disconnect a plug wire or COP coil while the engine is running. It can be very damaging as well as dangerous to you should you become the path to ground.

When a coil failure occurs on a distributor ignition system, it affects all the cylinders. The engine may not start or it may misfire badly when under load. But with multi-coil ignition systems, a single coil failure will only affect one cylinder (or paired cylinders in the case of waste spark DIS systems).

On 1996 and newer vehicles, the OBD II system should detect coil problems as well as misfires and generate a fault codes that identify the problem coil or cylinder. A misfire code P0301, for example, would indicate a misfire problem in cylinder #1. Of course, misfires can be caused by a lot of things. It could be a worn or fouled spark plug, a weak coil, a bad plug wire or connection in the case of a DIS or CNP system, a dirty or dead fuel injector, or a loss of compression (burned exhaust valve or leaky head gasket). Further diagnosis is always needed to isolate and identify the cause -- which creates a problem on multi-coil systems that do not have spark plug wires because you can't observe the secondary ignition pattern unless you use some type of adapters or inductive pickups that fit on the coils themselves.



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## HANDY TOOLS FOR COIL DIAGNOSIS

A variety of aftermarket tool suppliers sell inductive pickup adapters that can be attached directly to the coils on various COP systems to gather secondary ignition information. Most of these adapters cost less than $50 each and allow you to observe secondary ignition data for each coil on a scope or scan tool that can display ignition patterns. In most applications, the coils do not have to be removed to connect the adapter (it fits over the top of the coil and uses induction to pick up coil voltage).

COP adapters are available for various BMW models, Chrysler 2.7L, 3.2L and 3.5L engines (Dodge Intrepid, Chrysler Concorde LHS and 300M), Ford 3.4L Taurus SHO, 4.6L Town Car and Mark VIII, Mustang, Crown Victoria and Grand Marquis, and F-Series and E-Series trucks with 5.4L and 6.8L engines, Acura SLX, Honda Passport, Isuzu Amigo, Rodeo and Trooper, Mercedes with M112 and M113 engines, Toyota and Lexus with with 1UZ-FE and 2UZ-FE engines, Audi A4 1.8L turbo and A8 4.2L, Volkswagen Passat 1.8L turbo, Volvo 960 and 9000.

Another handy tool that can be used to quickly find a dead or misbehaving coil is an inductive ignition probe. This hand-held tool sells for less than $100 and is simple to use. It has an inductive paddle that is placed over the coil to detect coil activity. A super bright LED strobe flashes every time the coil fires and produces sufficient kV. A green indicator LED also flashes when the presence of adequate spark duration is detected. This tool eliminates the need to back-probe connectors and to disassemble and test each coil at its connectors.

## COIL REPLACEMENT

Replacement coils must always be the same basic type as the original and have the same primary resistance as the original. Using the wrong coil may damage other ignition components or cause the new coil to fail.

If an engine is experiencing repeated coil failures, the coil may be working too hard. The underlying cause is usually high secondary resistance (bad spark plug wire or spark plugs), or in some cases a lean fuel condition (dirty injectors, vacuum leak or leaky EGR valve).

Future coil problems can often be avoided by cleaning the connectors and terminals when the new coil is installed. Corrosion can cause intermittent operation and loss of continuity, which may contribute to component failure. Applying dielectric grease to these connections can help prevent corrosion and assure a good connection.

On high mileage engines with distributors or DIS ignition systems, the spark plug wires should also be replaced following a coil failure to assure a good hot spark. New plugs should also be installed if the original plugs are fouled or are at or near their service limit (45,000 miles for conventional plugs, 100,000 miles for long life plugs).



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