Ignition System

There are several different types of ignition systems in use on modern cars.
They are:

- Distributed spark using a single coil and a distributor for all cylinders.
- Wasted spark using one coil for two cylinders.
- Direct Fire using one coil on plug of each cylinder.

Distributed Spark

Distributed spark systems have been around the longest. As the name implies, the spark is distributed to the plugs via a coil output to a rotor, then through the distributor cap to the appropriate plug via a high-tension (HT) lead. This is the most complex system because of the relationship that has to be maintained between the firing point, rotor to cap terminal angle, and engine position. Distributed spark systems also rely on a mechanical link between the engine and ignition output, which adds another dimension of unreliability-and to a minor extent-inaccuracy in timing. In addition to these problems, distributed spark systems typically produce the least intense spark of all ignition systems. The time to achieve full charge diminishes as engine speed increases; therefore the coil charge is reduced as a function of RPM. In spite of the potential problems with distributed spark systems, they have been used successfully for many years on high-performance engines. Distributed spark ignition systems respond well to spark amplification within their design limits.

Wasted Spark

Wasted spark systems employ one coil for two cylinders. The term “wasted spark” comes from the fact that each plug fires every engine revolution. On a 4-cycle engine, the piston is at Top Dead Center (TDC) two times for every cycle; once for firing and again during the overlap phase. The wasted spark coil fires one plug Before Top Dead center (BTDC) and another plug just before the overlap phase (at the latest part of the exhaust stroke before the exhaust valve closes). Wasted spark systems have a higher potential for spark intensity because the duty of charging and discharging is split between the coils, which allows for more charge time per coil. Additionally, wasted spark systems build up less heat in the coil, making it more reliable. Wasted spark systems have been in use since the mid 80’s on GM cars and on motorcycles for considerably longer than that. There are no moving parts, no complicated relationships with a cap and rotor to maintain, and they deliver very accurate spark timing. Furthermore, multi-channel spark amplification systems to enhance spark duration or intensity are available for wasted spark ignition systems.

Direct Fire

Direct fire systems employ one coil on each spark plug and is the most reliable system used today, (this type of system is used on most modern cars). Each coil fires sequentially in the cylinder firing order. The charge time for each coil is twice as long as those of a wasted spark system, which allows direct-fire, coil manufacturers to build compact, lightweight coils that retain sufficient spark energy. There are no moving parts to wear out and no HT leads that will deteriorate. The lack of HT leads in direct fire systems is a major advantage for an EFI-equipped car because there is a very low incidence of noise due to leaking or improperly routed wires. There have been incidences of the terminal from a direct-fire coil (that attaches to the spark plug) cracking and subsequently causing Radio Frequency Interference (RFI) or “noise” to the ECU. This will cause engine operation problems, but it should be noted that these cases are extremely rare.

Amplifying Spark Energy

There are several ways to amplify the spark. This can be accomplished either by making the spark duration longer or by increasing the intensity of the spark. Firing the plugs multiple times on each cycle increases Spark duration. Spark intensity is increased by shortening the duration of the spark and increasing voltage at the plug. It is necessary to amplify the spark on engines with high cylinder pressures, such as forced-induction or nitrous oxide applications. On engines that utilize bolt-on modifications with no internal engine modifications, an enhanced ignition system is rarely needed. The AEM system is compatible with most stock and aftermarket ignition systems.

We have found that in many instances where there is some type of misfire associated with high RPM, the ignition system is at fault. The total ignition system must be in perfect working order to fire at the high cylinder pressures commonly used in high performance or racing engines. The reference to "total" ignition system refers to the point of signal generation to the ECU to the spark discharge at the spark plug.

Engine Position and Ignition Sequence

Each cylinder of a four-cycle engine undergoes four phases for every "engine cycle": intake, compression, power, and exhaust. This cycle takes two revolutions of the crankshaft to complete. **(For an outstanding demonstration on the four-cycles of an engine please go to:** http://www.howstuffworks.com/engine.html). The piston is at Top Dead Center (TDC) two times during the cycle (once between the compression/power cycle and once between the exhaust/intake cycles). When the piston in a cylinder is at TDC between the compression/power cycles, both the intake and exhaust valves are closed to contain the rapidly expanding gas caused by the combustion of the mixture. When the piston is at TDC between the exhaust/intake cycle there is no combustion being performed and both the intake and exhaust valves are slightly open. This is the "overlap" phase of the engine cycle (there are several reasons for the overlap phase of engine operation but it is beyond the scope of this instruction manual to discuss them). In the following discussion keep in mind that the cam angle sensor determines "engine position" and tells the ECU what the cam angle is in relation to the TDC firing (between compression/power cycles) position.

1. Signal generation to the ECU

a. The ECU must receive an electronic signal at the proper time to process information on crank angle (degrees before or after TDC) and output a signal to fire the ignition coil at the proper time in relation to crank angle (ignition timing) and firing position of the engine (TDC firing position). This signal is generated from a mechanical link between the engine and the computer. Usually a sensor is placed on the engine block adjacent to a "trigger wheel" on the crankshaft. The trigger wheel has multiple teeth that are a factor of the number of cylinders of the engine. For example, if our six-cylinder engine that we mentioned previously has a trigger wheel with 24 teeth, which means the engine will fire every eighth tooth (1,9 & 17). Remember, - the crank goes around two times for every CYCLE (720 degrees of rotation), therefore our 6 cylinder engine fires every 120 degrees of rotation (120 degree firing interval X 6 cylinders = 720 degrees/cycle).

b. Sometimes the crank angle sensor is mounted to the camshaft. This is possible because of the mechanical link between the cam(s) and crank. Using our six cylinder engine as an example, if the cam turns at ½ the engine speed, then on the same 24-tooth wheel mounted to the cam there would be a firing event every 4th tooth (1,5,9,13,17 & 21). A complete cycle for the cam is one revolution (two crank revolutions), so the number of degrees for every firing event is halved.

c. A cam angle sensor is used to determine when the engine is at the TDC firing position. This is accomplished via a sensor mounted adjacent to the camshaft with a single tooth trigger mounted to the camshaft. The angle between the cam in the firing position and the sensor trigger position determines the sequencing of the injectors for sequential operation. On distributed spark or direct fire systems, it determines how to initiate the ignition firing order.

2. Signal Processing in the ECU

a. Once the ECU receives the signals from the crank and cam angle sensors, it processes the data through predetermined tables in the ECU program. Based on the timing map and any modifications to timing due to various other input information it receives, the ECU sends a signal to the appropriate coil or igniter, depending on what type of ignition system is used. Because time is required to process the signals being received by the ECU and to deliver the output signal to the ignition, the cam and crank angle sensor pulse relative to TDC is well in advance of the actual event of TDC. The calculation of TDC is mathematically derived from a value entered by a programmer.

b. Modifications to the timing output signal may include a reduction in timing due to high engine temperature or inlet air charge. These modifiers are usually some factor of the base timing map that are corrected for a specific engine operating condition such as engine temperature or excessive knocking.

c. On distributed systems, the order in which the HT leads are positioned on the distributor cap determines the firing sequence of the plugs. With this type of system, the output signal from the ECU usually is not strong enough to trigger the coil directly; therefore an igniter is used to amplify the signal from the ECU to the coil(s). The sequencing of the coil discharge in wasted spark or direct fire systems is controlled in the software of the ECU.

Noise

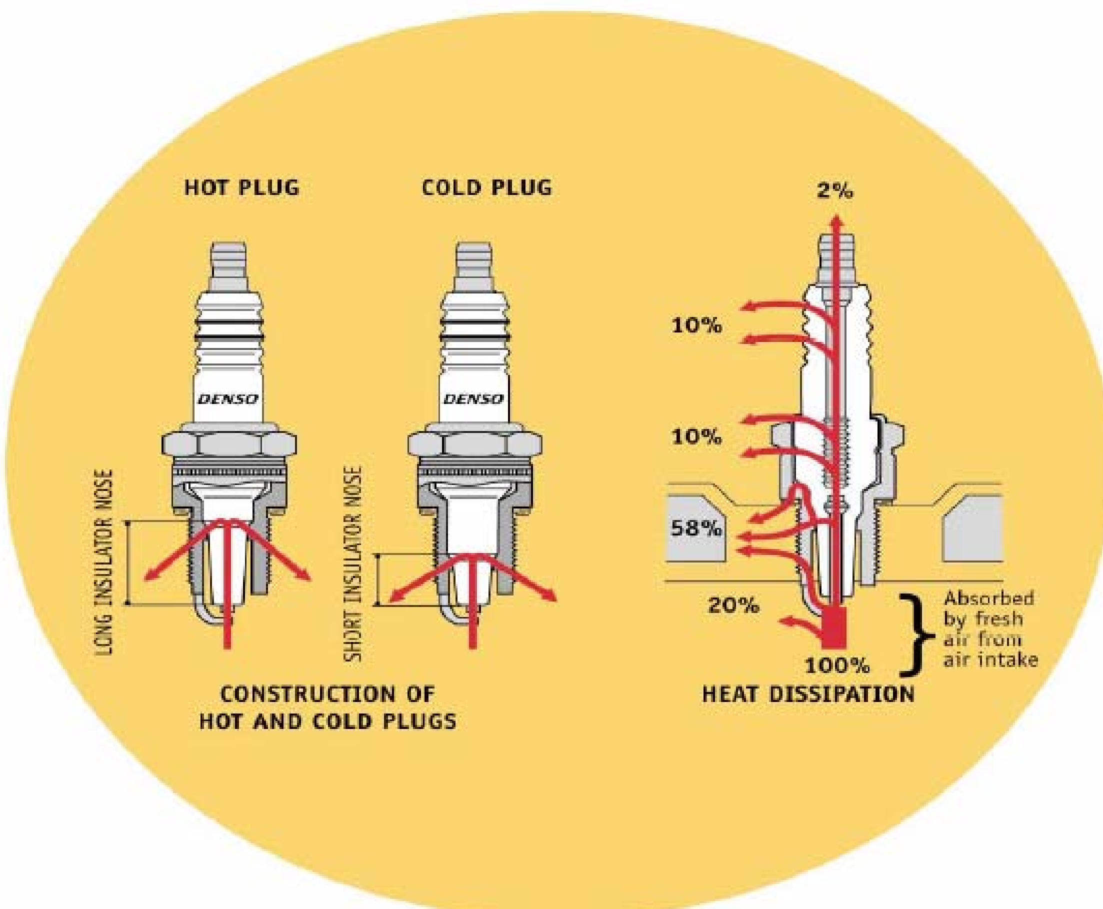
Misfire caused by “noise,” (commonly referred to as radio frequency interference {RFI}, or electro magnetic interference {EMI}), is usually due to routing the input signal leads in close proximity of the HT leads. Typically, spark plug wires cause RFI or primary ignition wires arcing to an engine component, which causes a frequency that interferes with the ECU. Routing two wires that carry high current parallel to each other cause EMI. The strength of current necessary to incur “noise” is dependent on the sensitivity of the device the wires are connected to. A common preventative measure for eliminating “noise” is to twist the wires together to minimize the electromagnetic field near the wires.

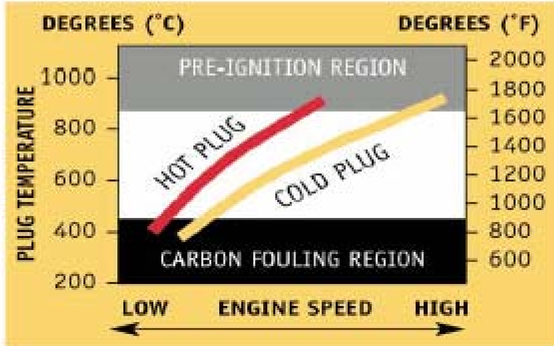
On any EFI system, resistive spark plug leads are REQUIRED to suppress noise! Common resistive spark plug leads include those with a carbon impregnated fiberglass core or spiral wound filament around a carbon core wire.

Another source of noise that can cause a misfire is an electrical “leak” in a plug wire or boot. Even a very small pinhole in a spark plug insulator or boot will allow electricity to arc to the cylinder head and interfere with the ECU signal.

Spark Plugs

Spark plug selection affects engine performance. On forced induction engines, it is critical that the proper heat range and gap is used. Heat range refers to the ability of the spark plug to conduct heat away from the electrode to the engine. A plug that has high thermal conductivity has a short insulator that comes in contact with a large portion of the metallic plug shell. This large area allows the combustion heat to be carried through the plug shell to the cooling jacket of the cylinder head. In the case of a hot plug, the insulator is recessed deeply into the plug shell with minimal contact to the shell. The plug has low thermal conductivity due to the lack of contact with the shell. The nose of the insulator should operate at between 400 – 850 degrees C. Temperatures above 400 degrees C are desirable because at higher temperatures deposits from carbon, lead or soot are burnt off. Temperatures of 850 degrees C and over should not be exceeded because this is typically the point where detonation or auto ignition can occur. Lower heat range plugs have a higher resistance to auto ignition while higher heat range plugs have less tendency to foul.





TEMPERATURE CURVES OF HOT AND COLD PLUGS

The spark plug gap on forced induction engines should be reduced REGARDLESS of the type of ignition system. We have read many instruction manuals for aftermarket ignition systems that recommend that the plug gap be opened up for better flame propagation. Although this recommendation may have had some merit when vehicles had carburetors, it does not apply to modern engines with electronic engine management systems. The smaller gap on forced-induction engines requires less spark energy to arc across the ground and the electrode and has a lesser tendency to misfire under the extreme pressures of a racing engine combustion chamber. Also there are spark plugs made with exotic fine wire highly conductive center electrodes that require less energy to fire such as the Denso Iridium that are well suited to racing conditions. The following is a chart of gap sizes for various engines on gasoline:

Naturally Aspirated up to 11.0:1 CR 1.1mm (.044”)

Naturally Aspirated 11.0:1 to 14.0: 1.8mm (.032”)

Forced Induction to 20-PSI .7mm (.028”)

Forced Induction to 40-PSI .6mm (.022”)

The color or condition of the spark plug is a general indicator of how rich or lean the engine is running and also if the engine is exhibiting signs of detonation if it is not audible. This is a plug color chart (supplied courtesy of Denso) of plug conditions.


Normal
Carbon Fouling
Over Heating
Pre-Ignition
Oil Fouling
Torched-Seat
Mechanical Damage
Broken Insulator
DENSO
Courtesy of:
IRIDIUM POWER