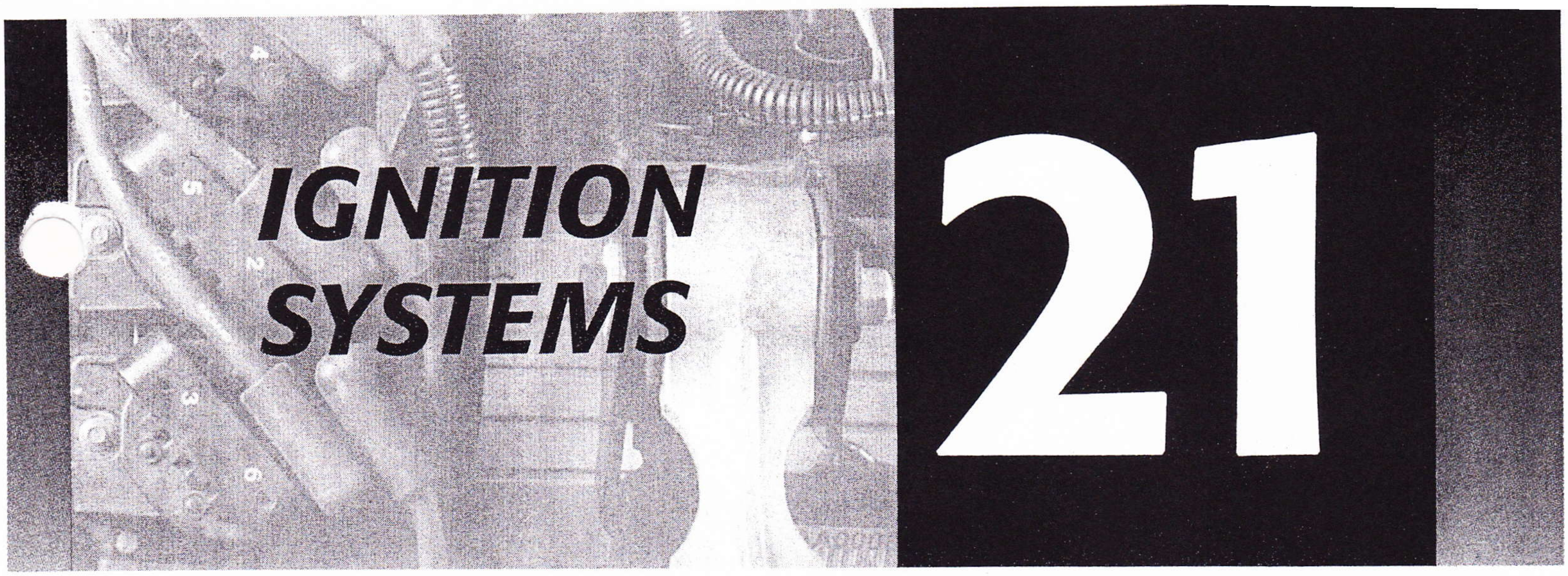
Ignition Systems



IGNITION SYSTEMS 21

OBJECTIVES

◆ Describe the three major functions of an ignition system. ◆ Name the operating conditions of an engine that affect ignition timing. ◆ Name the two major electrical circuits used in ignition systems and their common components. ◆ Describe the operation of ignition coils, spark plugs, and ignition cables. ◆ Describe the various types of spark timing systems, including electronic switching systems and their related engine position sensors. ◆ Describe the operation of distributor-based ignition systems. ◆ Describe the operation of distributorless ignition systems.

One of the requirements for an efficient engine is the correct amount of heat shock, delivered at the right time. This requirement is the responsibility of the ignition system. The ignition system supplies properly timed, high-voltage surges to the spark plugs. These voltage surges cause combustion inside the cylinder. For each cylinder in an engine, the ignition system has three main jobs. First, it must generate an electrical spark that has enough heat to ignite the air/fuel mixture in the combustion chamber. Secondly, it must maintain that spark long enough to allow for the combustion of all the air and fuel in the cylinders. Lastly, it must deliver the spark to each cylinder so combustion can begin at the right time during the compression stroke of each cylinder.

When the combustion process is completed, a very high pressure is exerted against the top of the piston. This pressure pushes the piston down on its power stroke. This pressure is the force that gives the engine power. For an engine to produce the maximum amount of power it can, the maximum pressure from combustion should be present when the piston is at 10 to 23 degrees after top dead center (ATDC). Because combustion of the air/fuel mixture within a cylinder takes a short period of time, usually measured in thousandths of a second (milliseconds), the combustion process must begin before the piston is on its power stroke. Therefore, the delivery of the spark must be timed to arrive at some point before the piston reaches top dead center.

Determining how much before TDC the spark should begin gets complicated by the fact that as the speed of the piston as it moves from its compression stroke to its power stroke increases, the time needed for combustion stays about the same. This means the spark should be delivered earlier as the engine's speed increases (Figure 21–1). However, as the engine has to provide more power to do more work, the load on the crankshaft tends to slow down the acceleration of the piston and the spark should be somewhat delayed.

Figuring out when the spark should begin gets more complicated with the fact that the rate of combustion varies according to certain factors. Higher compression pressures tend to speed up combustion. Higher octane gasolines ignite less easily and require more burning time. Increased vaporization and turbulence tend to decrease combustion times. Other factors, including intake air temperature, humidity, and barometric pressure, also affect combustion. Because of all of these complications, delivering the spark at the right time is a difficult task.

IGNITION TIMING

Ignition timing refers to the precise time spark occurs. Ignition timing is specified by referring to the position of the #1 piston relation to crankshaft rotation. Ignition timing reference timing marks can be located on engine parts and on a pulley or flywheel to indicate the position of the #1 piston (Figure 21–2). Vehicle manufacturers specify initial or **basic ignition timing**.

When the marks are aligned at TDC, or 0, the piston in cylinder #1 is at TDC of its compression

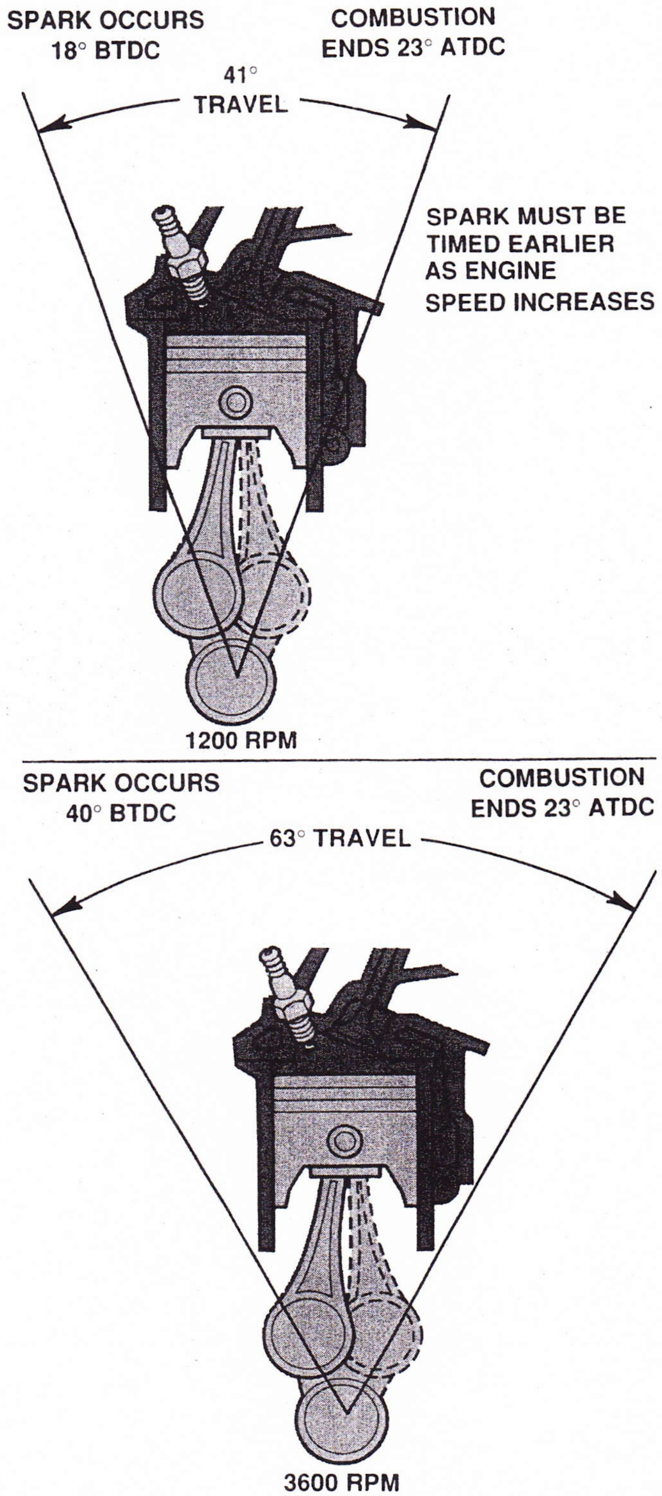


FIGURE 21–1 Ignition must begin earlier as engine speed increases. *Courtesy of Ford Motor Company*

stroke. Additional numbers on a scale indicate the number of degrees of crankshaft rotation before TDC (**BTDC**) or after TDC (**ATDC**). In a majority of engines, the initial timing is specified at a point between TDC and 20 degrees BTDC. A few manufacturers specified initial timing from 1 to 5 degrees ATDC for vehicles built during the 1970s.

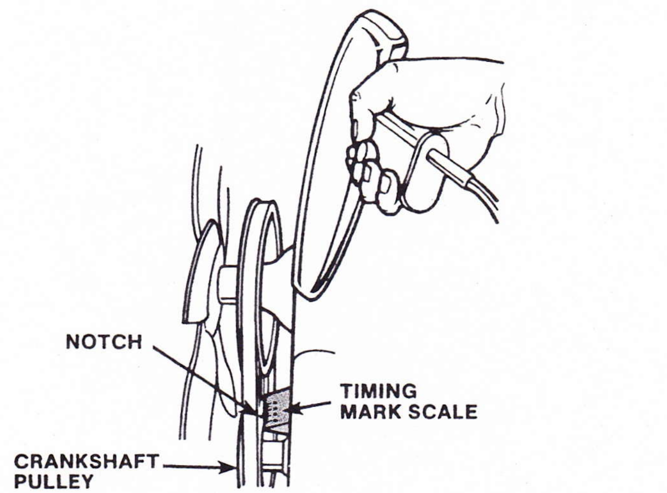


FIGURE 21–2 Reading ignition timing marks using a timing light.

If optimum engine performance is to be maintained, the ignition timing of the engine must change as the operating conditions of the engine change. Ignition systems allow for these necessary changes in many ways; these are covered in greater detail later in this chapter. All the different operating conditions affect the speed of the engine and the load on the engine. All ignition timing changes are made in response to these primary factors.

Engine RPM

At higher rpms, the crankshaft turns through more degrees in a given period of time. If combustion is to be completed by 10 degrees ATDC, ignition timing must occur sooner or be advanced.

However, air/fuel mixture turbulence (**swirling**) increases with rpm. This causes the mixture inside the cylinder to turn faster. Increased turbulence requires that ignition must occur slightly later or be slightly retarded.

These two factors must be balanced for best engine performance. Therefore, while the ignition timing must be advanced as engine speed increases, the amount of advance must be decreased some to compensate for the increased turbulence.

Engine Load

The load on an engine is related to the work it must do. Driving up hills or pulling extra weight increases engine load. Under load, the pistons move slower and the engine runs less efficiently. A good indication of engine load is the amount of vacuum formed during the intake stroke.

Under light loads and with the throttle plate(s) partially opened, a high vacuum exists in the intake manifold. The amount of air/fuel mixture drawn into the manifold and cylinders is small. On compression, this thin mixture produces less combustion pressure and combustion time is slow. To complete combustion by 10 degrees ATDC, ignition timing must be advanced.

Under heavy loads, when the throttle is opened fully, a larger mass of air/fuel mixture can be drawn in, and the vacuum in the manifold is low. High combustion pressure and rapid burning results. In such a case, the ignition timing must be retarded to prevent complete burning from occurring before 10 degrees ATDC.

Firing Order

Up to this point, the primary focus of discussion has been ignition timing as it relates to any one cylinder. However, the function of the ignition system extends beyond timing the arrival of a spark to a single cylinder. It must perform this task for each cylinder of the engine in a specific sequence.

Each cylinder of an engine must produce power once in every 720 degrees of crankshaft rotation. Each cylinder must have a power stroke at its own appropriate time during the rotation. To make this possible, the pistons and rods are arranged in a precise fashion. This is called the engine's **firing order**. The firing order is arranged to reduce rocking and unbalance problems. Because the potential for this rocking is determined by the design and construction of the engine, the firing order varies from engine to engine. Vehicle manufacturers simplify cylinder identification by numbering each cylinder (Figure 21–3). Regardless of the particular firing order used, the number 1 cylinder always starts the firing order, with the rest of the cylinders following in a fixed sequence.

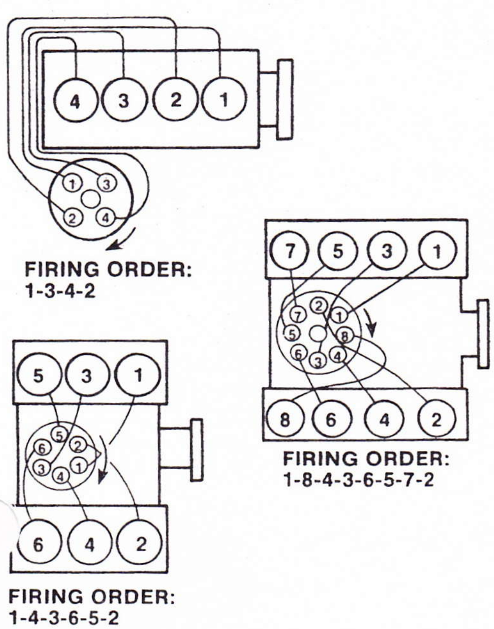


FIGURE 21–3 Examples of typical firing orders.

The ignition system must be able to monitor the rotation of the crankshaft and the relative position of each piston to determine which piston is on its compression stroke. It must also be able to deliver a high-voltage surge to each cylinder at the proper time during its compression stroke. How the ignition system does these things depends on the design of the system.

BASIC CIRCUITRY

All ignition systems consist of two interconnected electrical circuits: a **primary** (low voltage) **circuit** and a **secondary** (high voltage) **circuit** (Figure 21–4).

Depending on the exact type of ignition system, components in the primary circuit include the following.

- Battery
- Ignition switch
- Ballast resistor or resistance wire (some systems)
- Starting by-pass (some systems)
- Ignition coil primary winding
- Triggering device
- Switching device or control module

The secondary circuit includes these components.

- Ignition coil secondary winding
- Distributor cap and rotor (some systems)
- Ignition cables
- Spark plugs

Primary Circuit Operation

When the ignition switch is on, current from the battery flows through the ignition switch and primary circuit resistor to the primary winding of the ignition coil. From here it passes through some type of switching device and back to ground. The switching device can be electronically or mechanically controlled by the triggering device. The current flow in the ignition coil's primary winding creates a magnetic field. The switching device or control module interrupts this current flow at predetermined times. When it does, the magnetic field in the primary winding collapses. This collapse generates a high-voltage surge in the secondary winding of the ignition coil. The secondary circuit of the system begins at this point.

Secondary Circuit Operation

The secondary circuit in the ignition system carries high voltage to the spark plugs. The exact manner in which the secondary circuit delivers these high-voltage surges depends on the system design. Until 1984 all ignition systems used some type of **distributor** to accomplish this job. However, in an effort to reduce emissions, improve fuel economy, and boost compo-

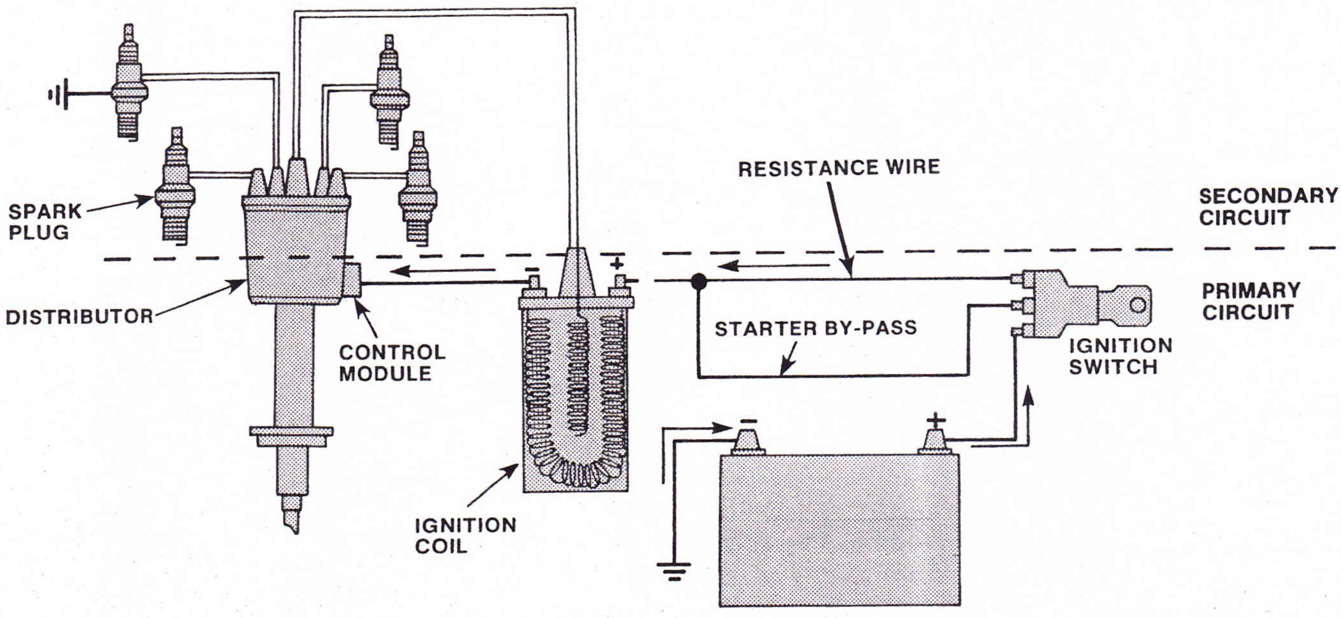


FIGURE 21–4 Ignition systems have a primary and secondary (high voltage) circuit.

nent reliability, many auto manufacturers are using distributorless systems.

In a system using a distributor, such as that shown in Figure 21–4, high voltage from the secondary winding passes through an ignition cable running from the coil to the distributor. The distributor then distributes the high voltage to the individual spark plugs through a set of ignition cables. The cables are arranged in the distributor cap according to the firing order of the engine. A **rotor**, which is driven by the distributor shaft, rotates and completes the electrical path from the secondary winding of the coil to the individual spark plugs. The distributor delivers the spark to match the compression stroke of the piston. The distributor assembly may also have the capability of advancing or retarding ignition timing.

Distributorless or **direct ignitions** have no distributor, rather spark distribution is controlled by the vehicle's computer. Instead of a single ignition coil for all cylinders, each cylinder may have its own ignition coil, or two cylinders may share one coil. The coils are wired directly to the spark plug they control. An ignition control module, tied into the vehicle's computer control system, controls the firing order and the spark timing and advance. This module is typically located under the coil assembly. It may also be integrated into a special housing that contains most of the system's ignition parts.

IGNITION COMPONENTS

All ignition systems share a number of common components. Some, such as the battery and ignition switch, perform simple functions. The battery supplies low-voltage current to the ignition primary circuit. The current flows when the ignition switch is in the start or run position. Full-battery voltage is always present at the ignition switch, as if it were directly connected to the battery.

Ignition Coils

To generate a spark to begin combustion, the ignition system must deliver high voltage to the spark plugs. Vehicles manufactured in recent years may require a voltage level between 30,000 and 60,000 volts to force a spark across the air gap of a spark plug. Since the battery typically delivers only 10 to 12 volts, a method of stepping up the voltage must be used. Multiplying battery voltage is the job of a coil.

The ignition coil is a **pulse transformer**. It transforms battery voltage into short bursts of high voltage. As explained previously, when a wire is moved through a magnetic field, voltage is induced in the wire. The inverse of this principle is also true—when a magnetic field moves across a wire, voltage is induced in the wire.

If a wire is bent into loops forming a coil and a magnetic field is passed through the coil, an equal amount of voltage is generated in each loop of wire. The more loops of wire in the coil, the greater the total voltage induced.

Also, the faster the magnetic field moves through the coil, the higher the voltage induced in the coil. If the speed of the magnetic field is doubled, the voltage output doubles.

An ignition coil uses these principles and has two coils of wire wrapped around an iron core. An iron or steel core is used because it has low **inductive reluctance**. In other words, iron freely expands or strengthens the magnetic field around the windings. The first, or primary, coil is normally composed of 100 to 200 turns of 20-gauge wire. This coil of wire conducts battery current. When a current is passing through the primary coil, it magnetizes the iron core. The strength of the magnet depends directly on the number of wire loops and the amount of current flowing through those loops. The secondary coil of wires may consist of 15,000 to 25,000, or more, turns of very fine copper wire.

Because of the effects of counter EMF on the current flowing through the primary winding, it takes some time for the coil to become fully magnetized or saturated. The CEMF that opposes current flow in the winding is called **inductive reactance**. Therefore, primary current flow is present for some time between firings of the spark plugs. When the primary coil circuit is suddenly opened, the magnetic field instantly collapses. The sudden collapsing of the magnetic field produces a very high voltage in the secondary windings. This high voltage is used to push current across the gap of the spark plug. Figure 21–5 simplistically shows the coil's primary and secondary circuits.

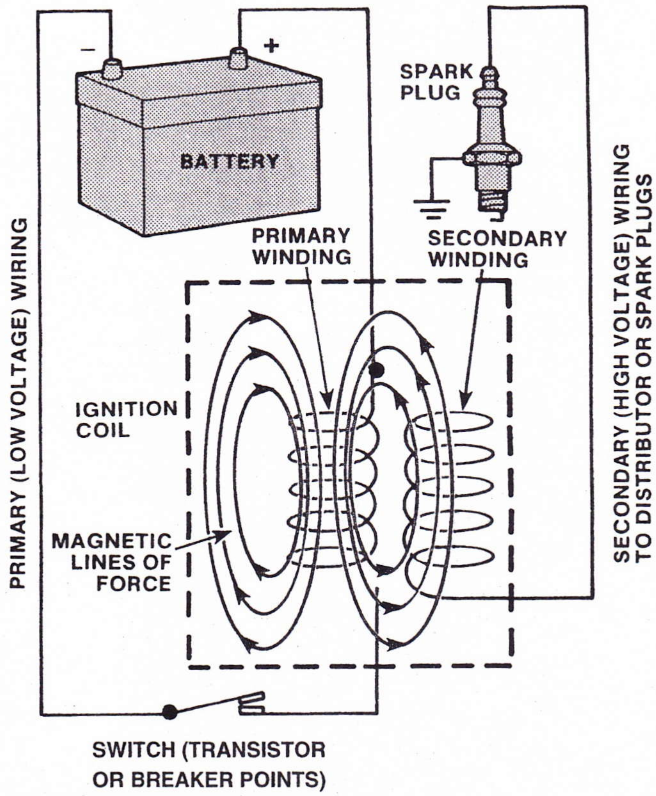


FIGURE 21–5 Current passing through the coil's primary winding creates magnetic lines of force that cut across and induce voltage in the secondary windings.

The number of ignition coils used in an ignition system varies depending on the type of ignition system found on a vehicle. In most ignition systems with a distributor, only one ignition coil is used. Figure 21–6 shows a cutaway view of the type of ignition coil used in these systems. The high voltage of the secondary winding is directed, by the distributor, to the various spark plugs in the system. Therefore, there is one secondary circuit with a continually changing path.

While distributor systems have a single secondary circuit with a continually changing path, distributorless (**DIS**) systems have several secondary circuits, each with an unchanging path.

Spark Plugs

Every type of ignition system uses spark plugs. The spark plugs provide the crucial air gap across which the high voltage from the coil flows in the form of an arc. The three main parts of a spark plug are the steel core, the ceramic core, or insulator, which acts as a heat conductor; and a pair of electrodes, one insulated in the core and the other grounded on the shell. The shell holds the ceramic core and electrodes in a gas-tight assembly and has the threads needed for plug installation in the engine (Figure 21–7). An ignition cable connects the secondary to the top of the plug. Current flows through the center of the plug and arcs from the tip of the center (or side) electrode to the ground electrode. The resulting spark ignites the air/fuel mixture in the combustion chamber. Most automotive spark plugs also have a resistor between the top terminal and the center electrode. This resistor reduces the amount of current and, therefore, reduces the amount of radio interference caused by the spark plug. The resistor, like all other

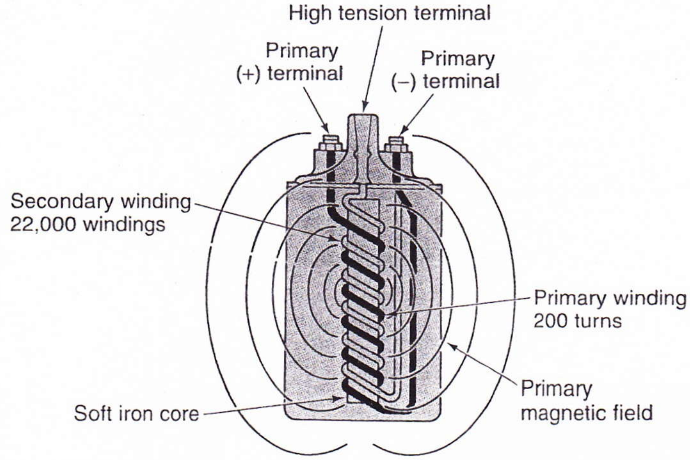


FIGURE 21–6 Ignition coil design. *Courtesy of Chrysler Corporation*

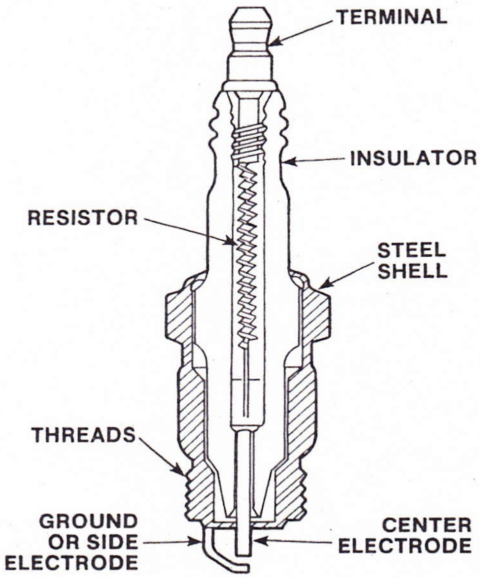


FIGURE 21–7 Components of a typical spark plug.

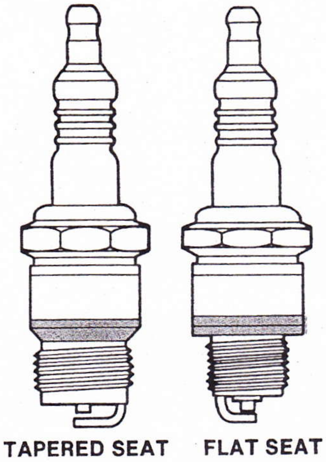


FIGURE 21–8 Spark plug seats: tapered versus flat.

resistances in the secondary, increases the voltage needed to jump the gap of the spark plug.

Spark plugs come in many different sizes and designs to accommodate different engines. To fit properly, spark plugs must be of the proper size and reach. Another design factor that determines the usefulness of a spark plug for a specific application is its **heat range**. The desired heat range depends on the design of the engine and on the type of driving conditions the vehicle is subject to. Once a technician selects a spark plug with the correct size, reach, and heat range for a particular application, there is one more spark plug characteristic that must be checked and adjusted—the spark plug **air gap**. Although the size, reach, and heat range of a spark plug are already determined by the manufacturer, the technician has the responsibility to properly gap the plug.

Size Automotive spark plugs are available in either 14- or 18-millimeter diameters. All 18-millimeter plugs feature tapered seats that match similar seats in the cylinder head and need no gaskets. The 14-millimeter variety can have either a flat seat that requires a gasket or a tapered seat that does not (Figure 21–8). The latter is the most commonly used. All spark plugs have a hex-shaped shell that accommodates a socket wrench for installation and removal. The 14-millimeter, tapered seat plugs have shells with a 5/8-inch hex; 14-millimeter gasketed and 18-millimeter tapered seat plugs have shells with a 13/16-inch hex.

Reach One of the most important design characteristics of spark plugs is the **reach** (Figure 21–9). This refers to the length of the shell from the contact surface at the seat to the bottom of the shell, including both threaded and nonthreaded sections. Reach is crucial. The plug's air gap must be properly placed in the combustion chamber so it can produce the correct amount of heat. Installing plugs with too short a reach means the electrodes are in a pocket and the arc is not able to adequately ignite the air/fuel mixture. In addition, the exposed threads in the cylinder head will accumulate carbon deposits. If the reach is too long, the exposed plug threads can get so hot they will ignite the air/fuel mixture at the wrong time, causing **preignition**. Preignition is a term used to describe abnormal combustion, which is caused by something other than the heat of the spark.

Heat Range Spark plugs are available in different heat ranges. A heat range indicates how well a spark plug can conduct heat away from its tip. A cooler plug transfers heat rapidly, resulting in lower tip temperatures. A hotter plug transfers heat slowly, resulting in higher tip temperatures (Figure 21–10). The shape of the porcelain insulator and its point of contact with the outer metal shell determines spark plug heat range. A spark plug's heat is transferred from the core to the shell to the cylinder head to the engine's coolant, which moves the heat away from the head.

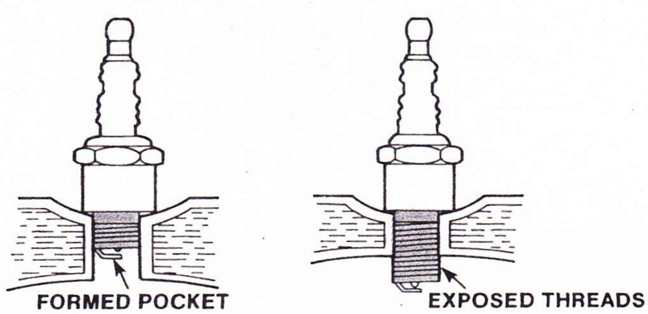


FIGURE 21–9 Spark plug reach: long versus short.

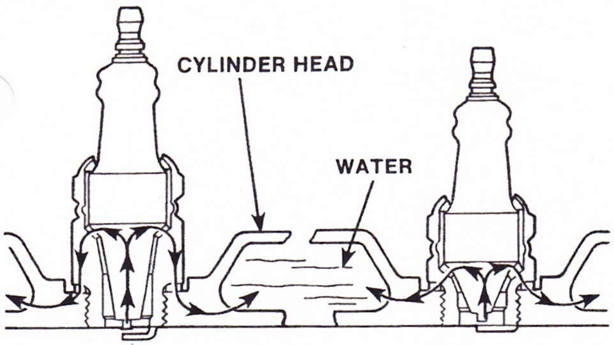


FIGURE 21–10 Spark plug heat range: hot versus cold.

Installing a plug with the correct heat range is important because the plug must remain hot enough to burn away fouling deposits while the engine is idling, yet cool enough at higher speed to prevent preignition and electrode wear. The heat range is indicated by a code imprinted on the side of the plug, usually on the porcelain insulator.

SHOP TALK

When spark plugs must be replaced, follow the recommendations for plug type as specified by the engine and plug manufacturers. These are recommendations only. For example, continuous heavy driving demands a much cooler plug than if the vehicle does a lot of stop-and-go driving. However, until you know more about the engine and its operating conditions than the manufacturers, follow their recommendations. ■

Spark Plug Air Gap The correct spark plug air gap is essential to achieve optimum engine performance and long plug life. A gap that is too wide (Figure 21–11) requires higher voltage to jump the gap. If the required voltage is greater than what is available, the result is **misfiring**. Misfiring results from the inability of the ignition to jump the gap or the inability to maintain the spark. On the other hand, a gap

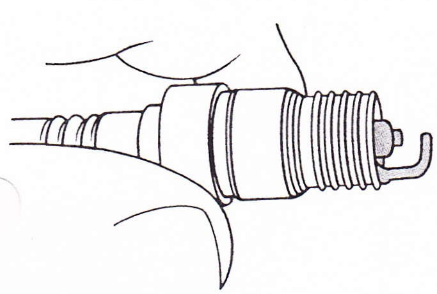


FIGURE 21–11 It is difficult for current to jump a gap this wide.

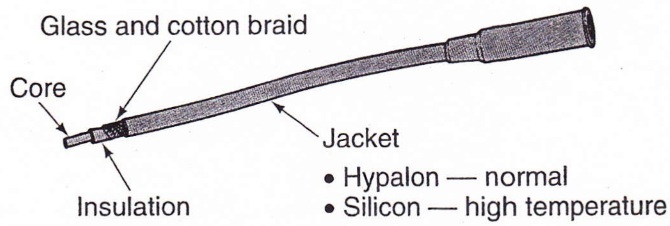


FIGURE 21–12 Spark plug cable construction. *Courtesy of Chrysler Corporation*

that is too narrow requires lower voltages, which leads to rough idle and prematurely burned electrodes, due to higher current flow. Always set the gap according to the manufacturer's specifications. New electronic ignition systems call for wider air gaps than older systems due to higher available voltages and leaner air/fuel mixtures.

Ignition Cables

Spark plug, or ignition cables make up the secondary wiring. These cables carry the high voltage from the distributor or the multiple coils (DIS systems) to the spark plugs. The cables are not solid wire, rather they contain fiber cores that act as resistors in the secondary circuit (Figure 21–12). They cut down on radio and television interference, increase firing voltages, and reduce spark plug wear by decreasing current. Insulated boots on the ends of the cables strengthen the connections as well as prevent dust and water infiltration and voltage loss.

SPARK TIMING SYSTEMS

To better understand the operation of current ignition systems, it is helpful to first review how older, fully mechanical distributor systems worked.

Breaker Point Ignition

Breaker point ignition systems were used on vehicles for more than 60 years but were abandoned many years ago as engineers looked for ways to decrease emissions and increase fuel efficiency. The breaker point system had three major functions.

SWITCHING DEVICE The distributor assembly acted as a mechanical switch to turn the primary circuit on and off. The distributor's shaft, cam, breaker points, and condenser performed this function.

As shown in Figure 21–13, mechanical breaker, or **contact**, **points**, are used as the primary circuit triggering and switching device. The breaker point assembly, which was mounted on the **breaker plate** inside the distributor, consisted of a fixed contact, movable contact, movable arm, rubbing block, pivot, and spring. The fixed contact was grounded through the distribu-

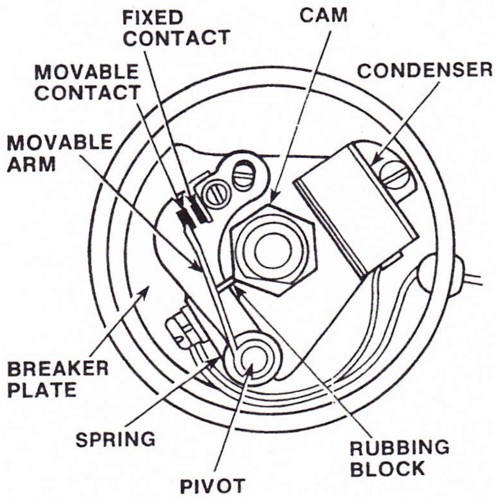


FIGURE 21–13 Older ignition systems used breaker points as the switching device in the primary circuit.

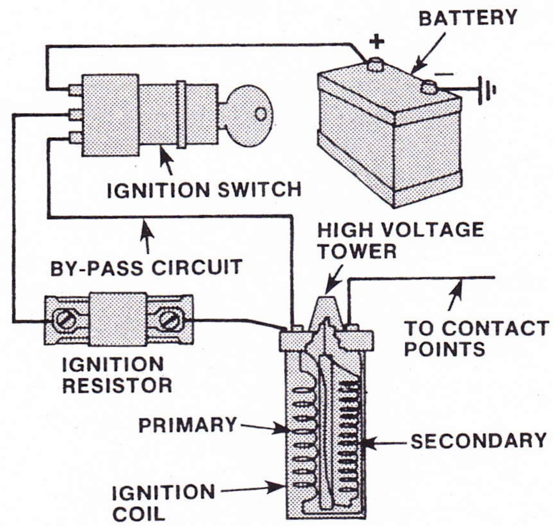


FIGURE 21–15 Ignition resistor by-pass circuit controlled by the ignition switch.

tor housing, and the movable contact was connected to the negative terminal of the coil's primary winding. As the cam was turned by the camshaft, the movable arm opened and closed, which opened and closed the primary circuit in the coil. When the points were closed, primary current flow attempted to saturate the coil. When the points opened, primary current stopped and the magnetic field collapsed causing high voltage to be induced in the secondary. The firing of the plug was the result of opening the points.

Because voltage was still present at the movable arm when the breaker arms opened, current could continue to arc across the open point gap, which could damage the points. To prevent this, a condenser (Figure 21–14) was attached to the movable arm. In this way, the voltage at the movable arm was retained by the condenser instead of arcing across the gap.

A primary or **ballast resistor** was located in series between the battery and the primary coil winding and was responsible for keeping the primary voltage at the desired level (about 9 or 10 volts). This prevented the contact points from burning due to high voltage. The ballast resistor could be either a separate unit or a specially made wire. During starting, the ballast resistor was bypassed to provide maximum current flow to the primary circuit (Figure 21–15).

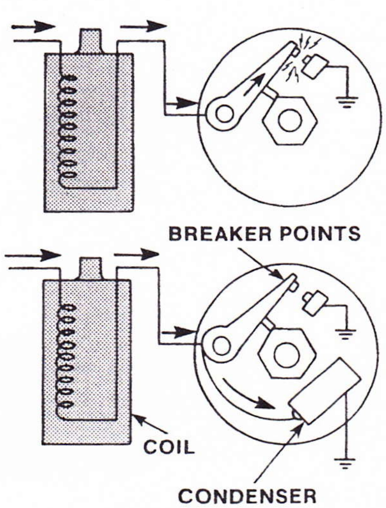


FIGURE 21–14 A condenser prevents current from jumping across the open point gap.

TIMING ADJUSTER The distributor also mechanically adjusted the time the spark arrived at the cylinder through the use of two mechanisms: the centrifugal advance and the vacuum advance units. This improved engine performance, fuel efficiency, and emission levels.

SPARK DISTRIBUTION As its name implies, the distributor mechanically distributed the spark so it arrived at the right time during the compression stroke of each cylinder. The distributor's shaft, rotor, and cap performed this function.

Electronic or Solid State Ignition

From the fully mechanical breaker point system, ignition technology progressed to basic electronic or solid state ignitions (Figure 21-16). Breaker points were replaced with electronic triggering and switching devices. The electronic switching components are normally inside a separate housing known as a **control module** or control unit. The original (solid state) electronic ignitions still relied on mechanical and vacuum advance mechanisms in the distributor.

As technology advanced, many manufacturers expanded the ability of the ignition control modules. For example, by tying a manifold vacuum sensor into the ignition module circuitry, the module could now detect when the engine was under heavy load and retard the timing automatically. Similar add-on sen-

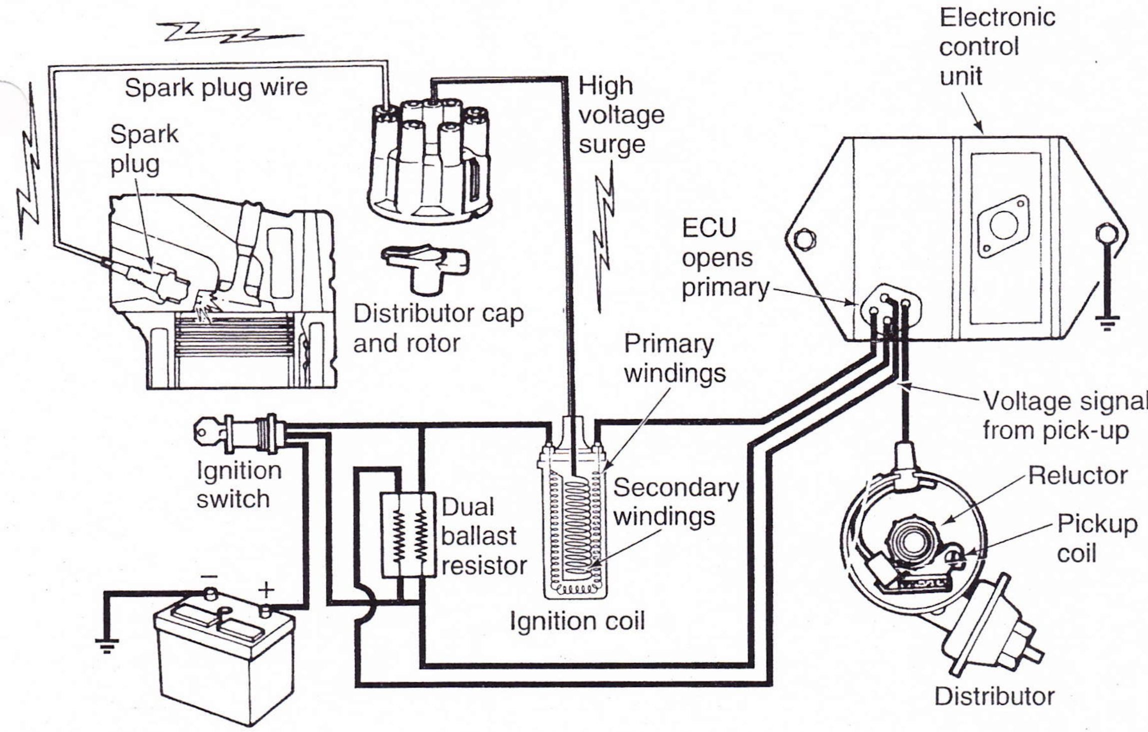


FIGURE 21–16 Typical solid-state ignition system. *Courtesy of Chrysler Corporation*

sors and circuits were designed to control spark knock, start-up emissions, and altitude compensation.

Computer-Controlled Electronic Ignition

Computer-controlled ignition systems offer continuous spark timing control through a network of engine sensors and a central microprocessor. Based on the inputs it receives, the central microprocessor or computer makes decisions regarding spark timing and sends signals to the ignition module to fire the spark plugs according to those inputs and the programs in its memory.

Computer-controlled ignition systems may or may not use a distributor to distribute secondary voltage to the spark plugs. As mentioned earlier, distributorless systems use multiple coils and modules to provide and distribute high secondary voltages directly from the coil to the plug.

ADVANTAGES OF ELECTRONIC IGNITION

Electronic ignition systems have many advantages over breaker point ignition systems.

High Secondary Voltages

Electronic ignition systems can carry the increased primary current needed to produce the higher secondary system voltages needed to ignite leaner air/fuel mixtures.

The primary circuit in most breaker point systems carried 3.5 to 4.0 amperes. When the breaker points opened, this current tried to arc across the points. Point arcing caused electrolysis and corrosion on the metal surface of the contacts. When primary current increases above 4 amperes, point life begins to decrease at an increased rate, resulting in very limited point life. Faster wearing points require extra maintenance and result in an ever-decreasing **dwell** period, which in turn decreases the potential voltage induced in the secondary system. Dwell is the period of time that current flows through the primary circuit.

Better High-Speed Performance

Another handicap of the old breaker point system was that as engine speed increased, the dwell time decreased. This, in turn, decreases the output of the coil. For the ignition coil to generate maximum secondary voltage, maximum primary current flow must be flowing through the primary winding before the field is collapsed. In a breaker point system, the length of time the primary circuit is closed is controlled by the speed of the breaker cam. This period of time is called a dwell angle and is expressed in a number of degrees of distributor shaft rotation. For example, many V-8 engines have a dwell angle of 30 degrees during which time the points are closed and current builds in the primary winding. This dwell angle remains constant regardless of engine speed; but as engine rpm increases, the actual time, in seconds, the

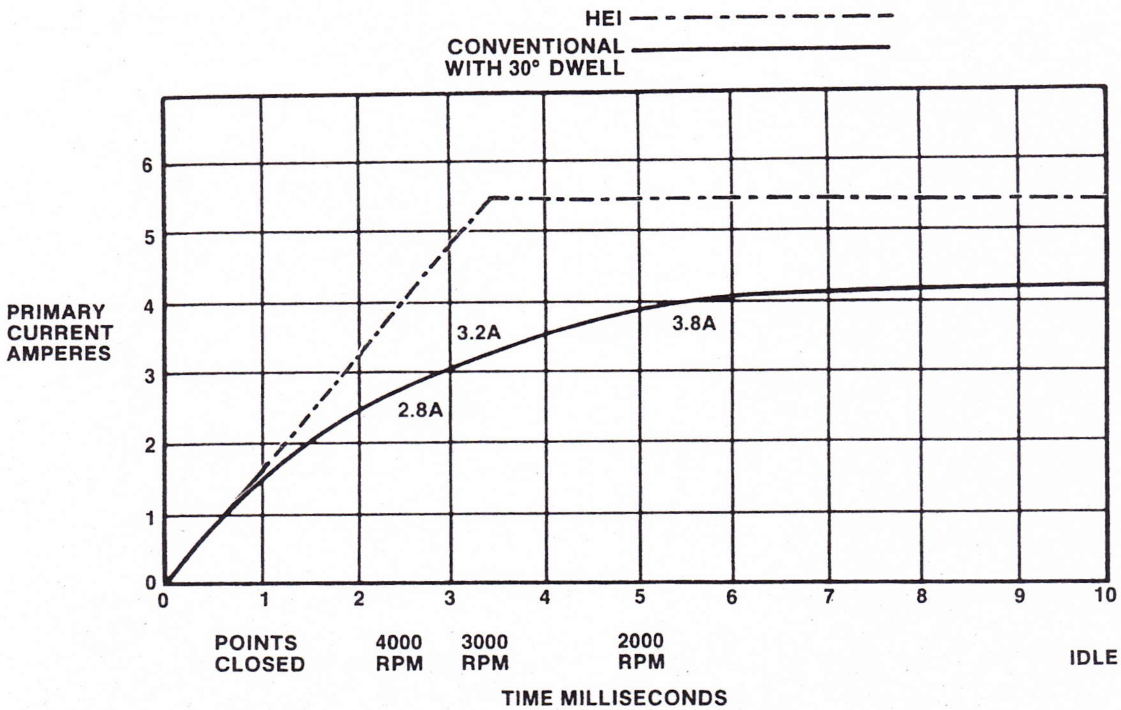


FIGURE 21–17 Current levels of General Motors' high-energy ignition system remain higher over a longer range of engine speeds when compared to breaker point systems.

points are closed decreases. Any increase in engine speed above a specific rpm reduces the saturation time of the ignition coil, causing the available voltage to decrease.

This phenomenon is due to the fact that the current in the coil does not instantaneously reach its maximum value when the contact points close. Current in the coil must build for several milliseconds for this value to be reached. At 1,000 rpm, the distributor shaft rotates once every 0.12 second. Of this time, the points are closed for 0.10 second, or 10 milliseconds, for every cylinder of an 8-cylinder engine. This is sufficient time for saturation of the primary winding. This time versus current relationship is shown in Figure 21–17.

When the engine speed increases to 2,000 rpm, the time that the points are closed for each plug firing is reduced to 5 milliseconds. A dwell period of 5 milliseconds allows the primary current to build to 3.8 amperes. At 3,000 rpm, the dwell period drops to 3.3 milliseconds and the current drops to 3.2 amperes. The reduced saturation time lowers the available secondary voltage. This can result in a misfire as there may be less voltage available than is needed to fire the plug. This increases exhaust emissions and decreases fuel economy and engine performance.

An electronic ignition system, however, is not limited by a fixed dwell angle. The system's control unit can vary the on-time of the primary circuit based on engine speed, load, and temperature. As the chart in Figure 21–17 shows, GM's high-energy ignition (HEI) system maintains a constant voltage level until the engine reaches 3,000 rpm. Because coil primary current levels are not limited by breaker points, low-resistance coils are used in the electronic ignition system. By decreasing the resistance in the primary circuit, the required saturation time of the coil is greatly reduced. It takes 10 milliseconds for the current to reach maximum saturation in a coil with a resistance of 2.6 ohms. In a coil used in electronic ignition systems, the primary winding can have a resistance as low as 0.5 ohm. This allows full current to be reached in about 3.4 milliseconds. Because it takes less time to reach full current, coil saturation can be obtained at much higher engine speeds. For example, the HEI system developed by General Motors in 1974 is able to generate 35,000 volts at engine speeds above 3,000 rpm. A typical breaker point system, on the other hand, developed a maximum of 20,000 volts at 1,000 rpm. Above this speed, the voltage dropped off.

ELECTRONIC SWITCHING SYSTEMS

Electronic ignition systems control the primary circuit, using an NPN transistor instead of breaker contact points. The transistor's emitter is connected to ground and takes the place of the fixed contact point.

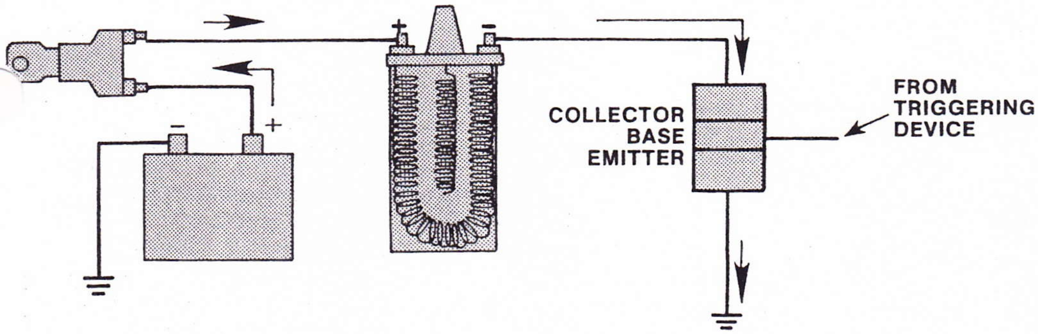


FIGURE 21–18 When the triggering device supplies a small amount of current to the transistor's base, the primary coil circuit is closed and current flows.

The collector is connected to the negative (–) terminal of the coil, taking the place of the movable contact point. When the triggering device supplies a small amount of current to the base of the switching transistor, the collector and emitter act as if they are closed contact points (a conductor), allowing current to build up in the coil primary circuit. When the current to the base is interrupted by the switching device, the collector and emitter act as an open contact (an insulator), interrupting the coil primary current. An example of how this works is shown in Figure 21–18, which is a simplified diagram of an electronic ignition system.

Engine Position Sensors

The time when the primary circuit must be opened and closed is related to the position of the pistons and the crankshaft. Therefore, the position of the crankshaft is used to control the flow of current to the base of the switching transistor.

A number of different types of sensors are used to monitor the position of the crankshaft and control the flow of current to the base of the transistor. These engine position sensors and generators serve as triggering devices and include magnetic pulse generators, metal detection sensors, Hall-effect sensors, and photoelectric sensors.

The mounting location of these sensors depends on the design of the ignition system. All four types of sensors can be mounted in the distributor, which is turned by the camshaft.

Magnetic pulse generators and Hall-effect sensors can also be located on the crankshaft (Figures 21-19 and Figure 21–20). These sensors are also commonly used on DIS ignition systems. Both Hall-effect sensors and magnetic pulse generators can also be used as camshaft reference sensors to identify which cylinder is the next one to fire.

Magnetic Pulse Generator

Basically, a magnetic pulse generator consists of two parts: a timing disc and a pick-up coil. The timing disc may also be called a reluctor, trigger wheel, pulse ring, armature, or timing core. The pick-up coil, which consists of a length of wire wound around a weak permanent magnet, may also be called a stator,

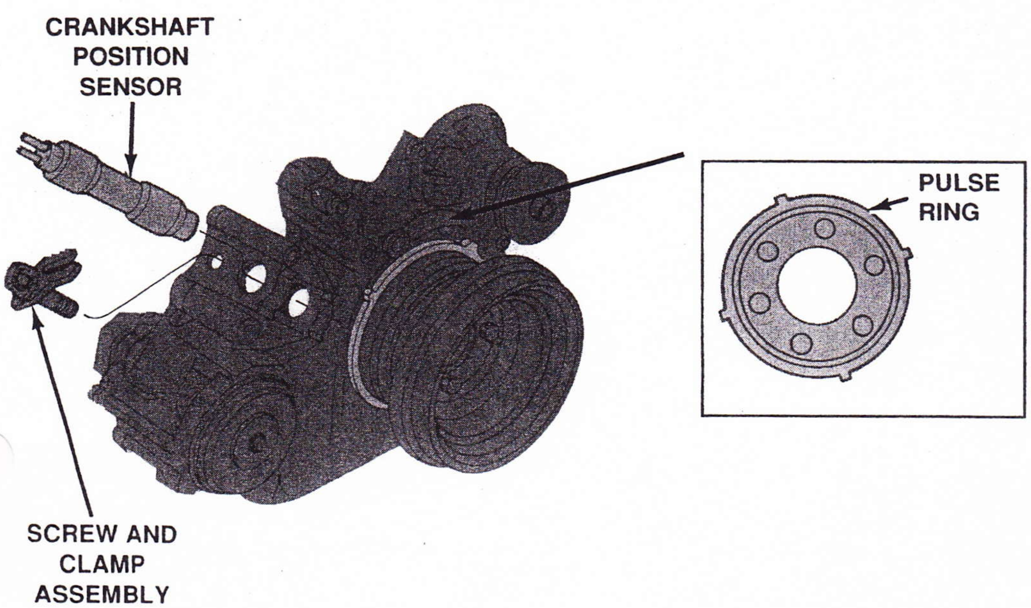


FIGURE 21–19 Crankshaft position sensor. *Courtesy of Ford Motor Company*

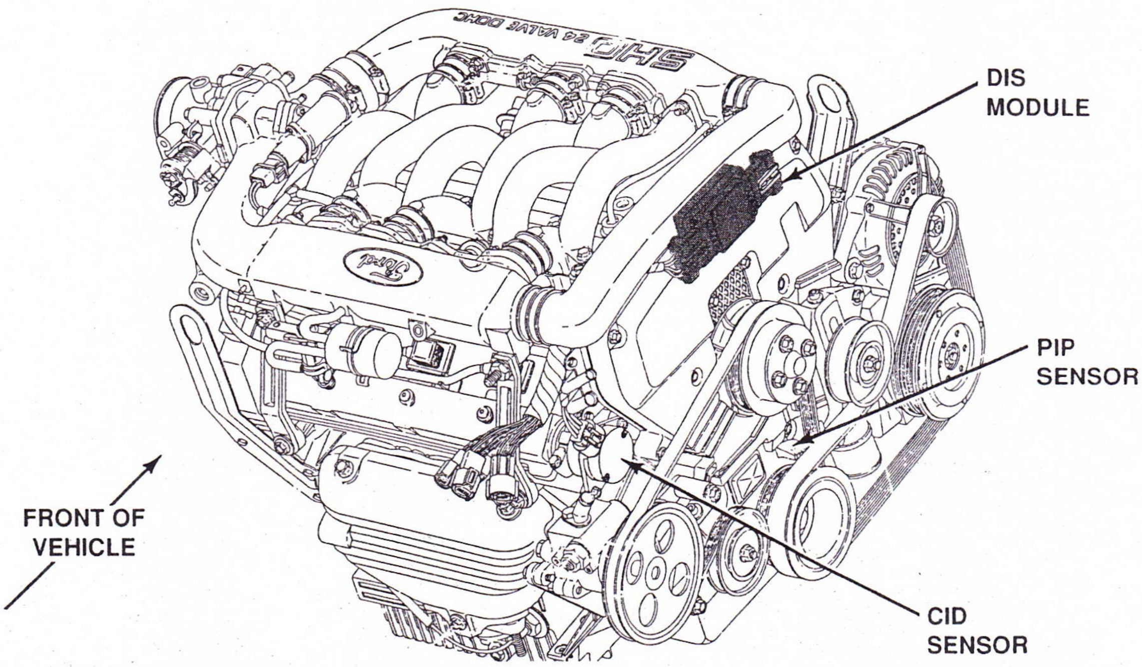


FIGURE 21–20 DIS system with Hall-effect switches for camshaft (CID) and crankshaft (PIP) rotation. *Courtesy of Ford Motor Company*

sensor, or pole piece. Depending on the type of ignition system used, the timing disc may be mounted on the distributor shaft (Figure 21–21), at the rear of the crankshaft (Figure 21–22), or on the crankshaft vibration damper (Figure 21–23).

The magnetic pulse or PM generator operates on basic electromagnetic principles. Remember that a voltage can only be induced when a conductor moves through a magnetic field. The magnetic field is provided by the pick-up unit and the rotating timing disc provides the movement through the magnetic field needed to induce voltage.

As the disc teeth approach the pick-up coil, they repel the magnetic field, forcing it to concentrate around the pick-up coil (Figure 21–24A). Once the tooth passes by the pick-up coil, the magnetic field is free to expand or unconcentrate (Figure 21–24B), until the next tooth on the disc approaches. Approaching teeth concentrate the magnetic lines of force, while passing teeth allow them to expand. This pulsation of the magnetic field causes the lines of magnetic force to cut across the winding in the pick-up coil, inducing a small amount of AC voltage that is sent to the switching device in the primary circuit.

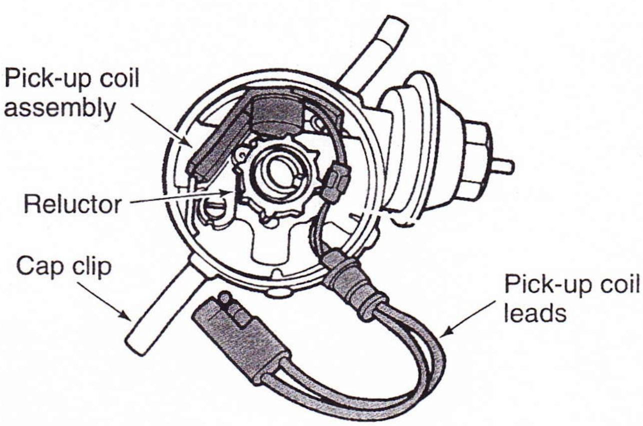


FIGURE 21–21 Magnetic pulse generator located inside a distributor. *Courtesy of Chrysler Corporation*

When a disc tooth is directly in line with the pick-up coil, the magnetic field is not expanding or contracting. Since there is no movement or change in the field, voltage at this precise moment drops to zero. At this point, the switching device inside the ignition module reacts to the zero voltage signal by turning the ignition's primary circuit current off. As explained earlier, this forces the magnetic field in the primary coil to collapse, discharging a secondary voltage to the distributor or directly to the spark plug.

As soon as the tooth rotates past the pick-up coil, the magnetic field expands again and another voltage signal is induced. The only difference is that the polarity of the charge is reversed. Negative becomes positive or positive becomes negative. Upon sensing this change in voltage, the switching device turns the primary circuit back on and the process begins all over.

The slotted disc is mounted on the crankshaft, vibration damper, or distributor shaft in a very precise manner. When the disc teeth align with the pick-up coil, this corresponds to the exact time certain pis-

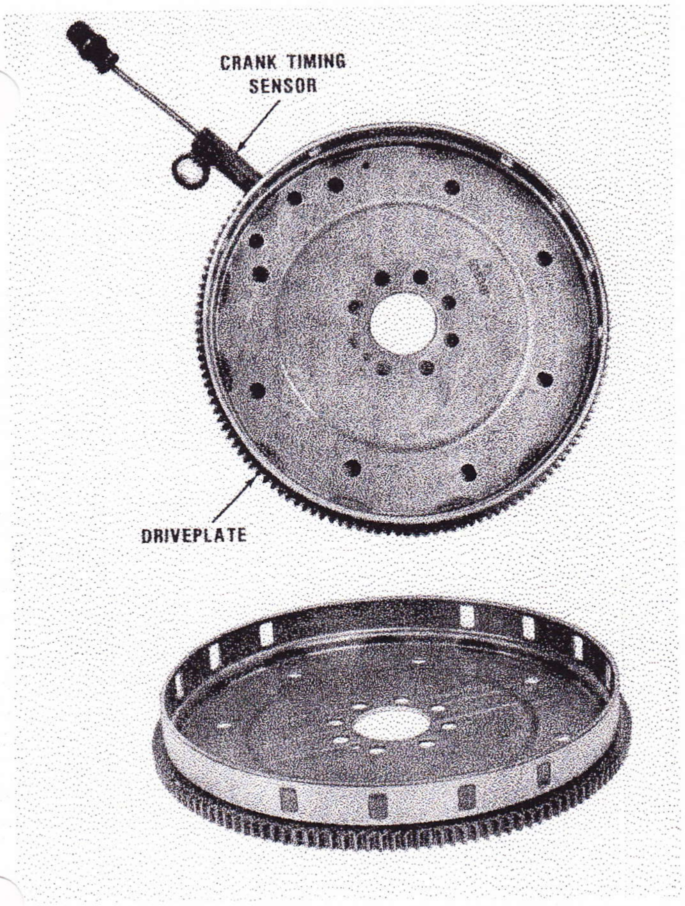


FIGURE 21–22 Magnetic pulse generator positioned to sense flywheel rotation. *Courtesy of Chrysler Corporation*

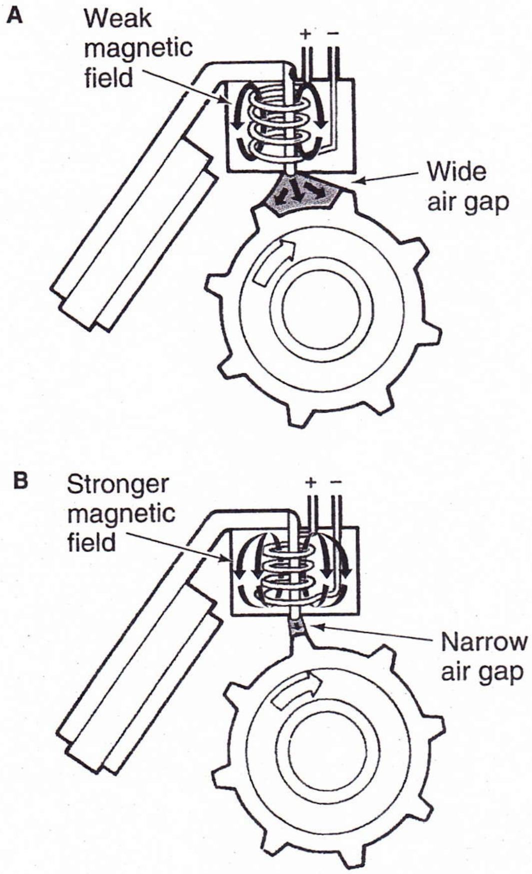


FIGURE 21–24 (A) Wide gap produces a weak magnetic signal. (B) Narrow gap produces a strong magnetic field. *Courtesy of Chrysler Corporation*

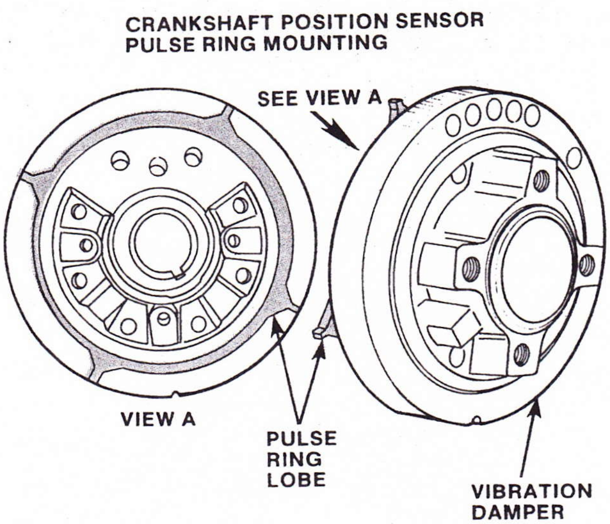


FIGURE 21–23 Pulse ring location on the vibration damper.

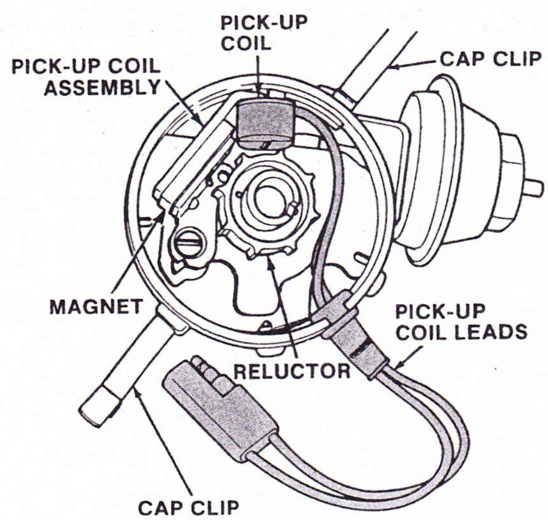


FIGURE 21–25 Magnetic pulse generator (pick-up coil) used on early Chrysler electronic ignition systems.

tons are nearing TDC. This means the zero voltage signal needed to trigger the secondary circuit occurs at precisely the correct time.

The pick-up coil might have only one pole as shown as Figure 21–25. Other magnetic pulse generators have pick-up coils with two or more poles. The one shown in Figure 21–26 has as many poles as it has trigger teeth.

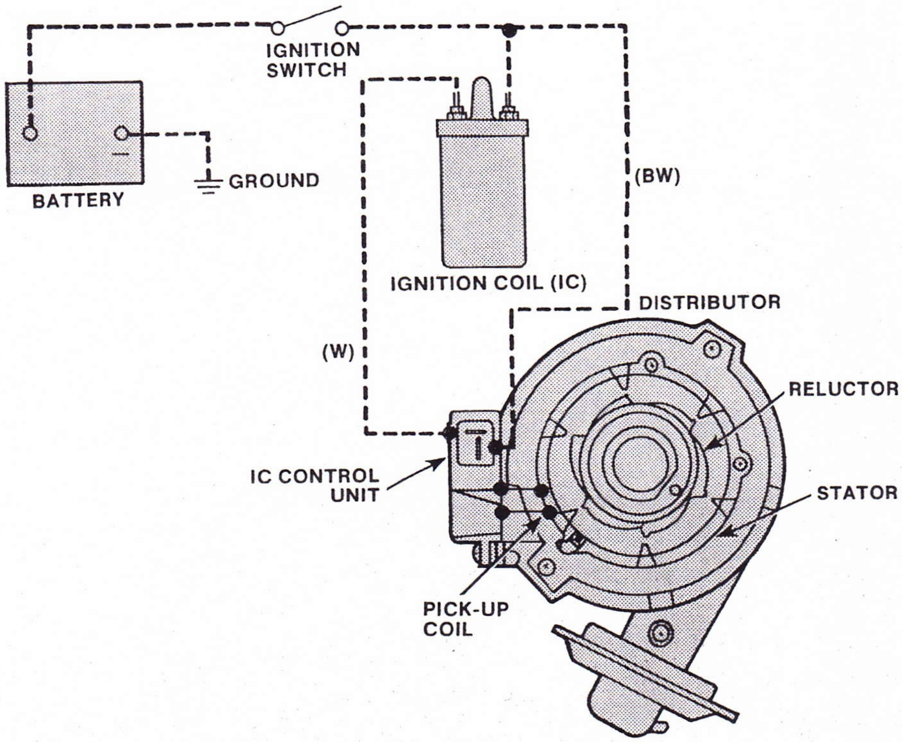


FIGURE 21–26 Magnetic pulse generator used in early Datsun electronic ignition systems. *Courtesy of Nissan Motors*

Metal Detection Sensors

Metal detection sensors are found on many early electronic ignition systems. They work much like a magnetic pulse generator with one major difference.

A trigger wheel is pressed over the distributor shaft and a pick-up coil detects the passing of the trigger teeth as the distributor shaft rotates. However, unlike a magnetic pulse generator, the pick-up coil of a metal detection sensor does not have a permanent magnet. Instead, the pick-up coil is an electromagnet. A low level of current is supplied to the coil by an electronic control unit, inducing a weak magnetic field around the coil. As the reluctor on the distributor shaft rotates, the trigger teeth pass very close to the coil (Figure 21–27). As the teeth pass in and out of the coil's magnetic field, the magnetic field builds and collapses, producing a corresponding change in the coil's voltage. The voltage changes are monitored by the control unit to determine crankshaft position.

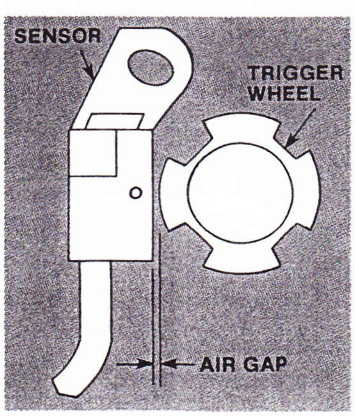


FIGURE 21–27 In a metal detecting sensor, the revolving trigger wheel teeth alter the magnetic field produced by the electromagnet in the pick-up coil.

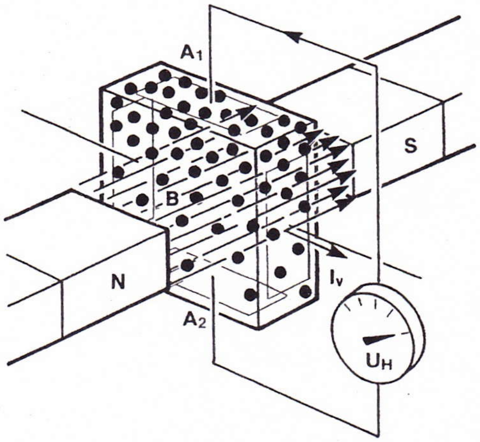
Hall-Effect Sensor

Introduced in early 1982, the Hall-effect sensor or switch is now the most commonly used engine position sensor. There are several good reasons for this. Unlike a magnetic pulse generator, the Hall-effect sensor produces an accurate voltage signal throughout the entire rpm range of the engine. Furthermore, a Hall-effect switch produces a square wave signal that is more compatible with the digital signals required by on-board computers.

Functionally, a Hall switch performs the same tasks as a magnetic pulse generator. But the Hall switch's method of generating voltage is quite unique. It is based on the Hall-effect principle, which states: If a current is allowed to flow through a thin conducting material, and that material is exposed to a magnetic field, voltage is produced.

The heart of the Hall generator is a thin semiconductor layer (Hall layer) derived from a gallium arsenate crystal. Attached to it are two terminals—one positive and the other negative—that are used to provide the source current for the Hall transformation.

Directly across from this semiconductor element is a permanent magnet. It's positioned so its lines of flux bisect the Hall layer at right angles to the direc-



UH = HALL VOLTAGE
B = MAGNETIC FIELD (FLUX DENSITY)
Iv = CONSTANT SUPPLY CURRENT
A1, A2 = HALL LAYER

FIGURE 21–28 In a Hall-effect sensor, the electrons move perpendicular to the lines of magnetic flux and electrical current.

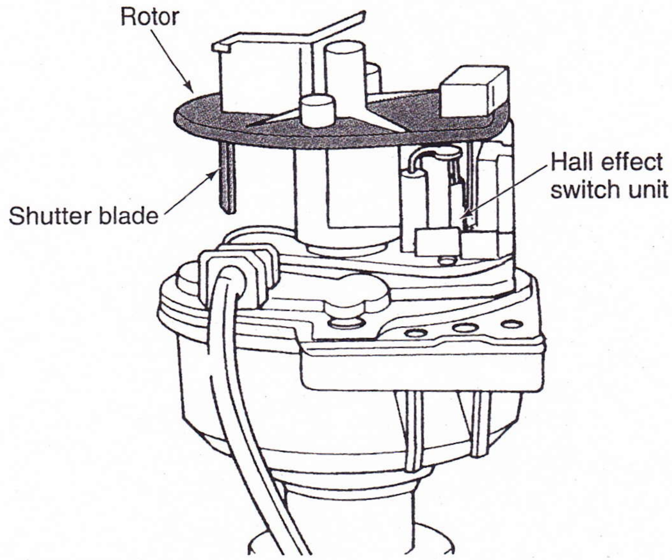


FIGURE 21–29 Hall-effect switch mounted inside a distributor. *Courtesy of Chrysler Corporation*

tion of current flow. Two additional terminals, located on either side of the Hall layer, form the signal output circuit.

When current is passed through the Hall layer, a voltage is produced perpendicular to the direction of current flow and magnetic flux. The signal voltage produced is the direct result of the magnetic field's effect on electron flow. As the magnetic lines of force collide with the electrons in the supply current, current flow in the crystals is distorted and, as a result, electrons are deflected toward what becomes the negative Hall voltage terminals (Figure 21–28). It is this creation of an electron surplus at the Hall voltage terminal that results in the production of a weak voltage potential.

The Hall switch is described as being on any time the Hall layer is exposed to a magnetic field and a Hall voltage is being produced. However, before this signal voltage can be of any use, it has to be modified. After leaving the Hall layer, the signal is routed to an amplifier where it is strengthened and inverted so the signal reads high when it is actually coming in low and vice versa. Once it has been inverted, the signal goes through a pulse-shaping device called the Schmitt trigger where it is turned into a clean square wave signal. After conditioning, the signal is sent to the base of a switching transistor that is designed to turn on and off in response to the signals generated by the Hall switch assembly.

The shutter wheel is the last major component of the Hall switch. The shutter wheel consists of a series of alternating windows and vanes that pass between the Hall layer and magnet. The shutter wheel may be part of the distributor rotor (Figure 21–29) or be separate from the rotor.

The shutter wheel performs the same function as the timing disc on magnetic pulse generators. The only difference is with a Hall switch there is no electromagnetic induction. Instead, the shutter wheel creates a magnetic shunt that changes the field strength through the Hall element. When a vane of the shutter wheel is positioned between the magnet and Hall element, the metallic vane blocks the magnetic field and keeps it from permeating the Hall layer. As a result, only a few residual electrons are deflected in the layer and Hall output voltage is low (Figure 21–30). Conversely, when a window rotates into the air gap, the magnetic field is able to penetrate the Hall layer, which in turn pushes the Hall voltage to its maximum range.

The points where the shutter vane begins to enter and begins to leave the air gap are directly related to primary circuit control. As the leading edge of a vane enters the air gap, the magnetic field is deflected away from the Hall layer; Hall voltage decreases. When that happens, the modified Hall output signal increases abruptly and turns on the switching transistor. Once the transistor is turned on, the primary circuit closes and the coil's energy storage cycle begins.

Primary current continues to flow as long as the vane is in the air gap. As the vane starts to leave the gap, however, the reforming Hall voltage signal prompts a parallel decline in the modified output signal. When the output signal goes low, the bias of the transistor changes. Primary current flow stops.

In summary, the ignition module supplies current to the coil's primary winding as long as the shutter wheel's vane is in the air gap. As soon as the shutter wheel moves away and the Hall voltage is produced,

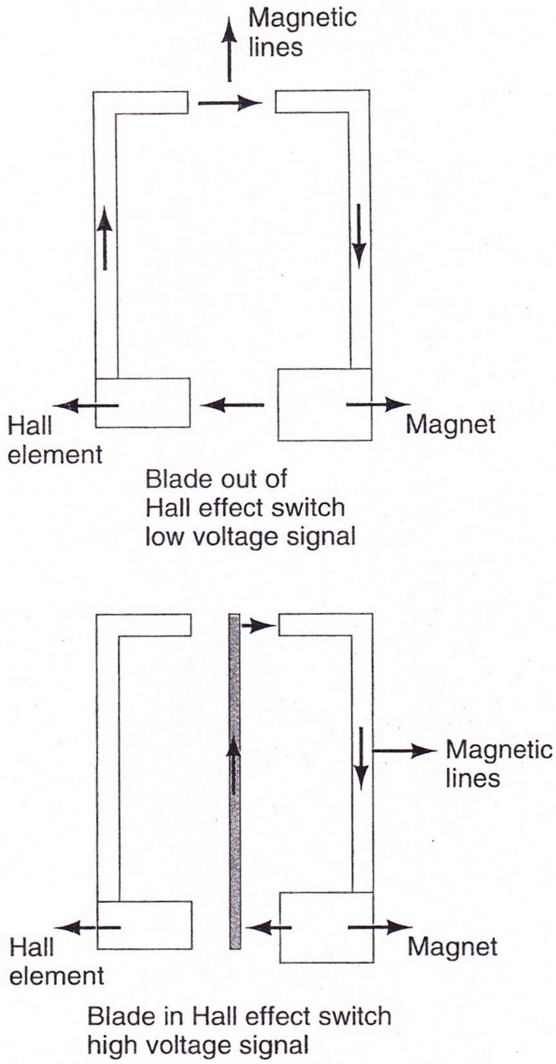


FIGURE 21–30 Blade and magnetic field action in a Hall-effect switch.

the control unit stops primary circuit current, high secondary voltage is induced, and ignition occurs.

In addition to ignition control, a Hall switch can also be used to generate precise rpm signals (by determining the frequency at which the voltage rises and falls) and provide the sync pulse for sequential fuel ignition operation.

Photoelectric Sensor

A fifth type of crankshaft position sensor is the **photoelectric sensor**. The parts of this sensor include a light-emitting diode (LED), a light-sensitive phototransistor (photo cell), and a slotted disc called a light beam interrupter (Figure 21–31).

The slotted disc is attached to the distributor shaft. The LED and the photo cell are situated over and under the disc opposite each other. As the slotted disc rotates between the LED and photo cell, light from the LED shines through the slots. The intermittent flashes of light are translated into voltage pulses

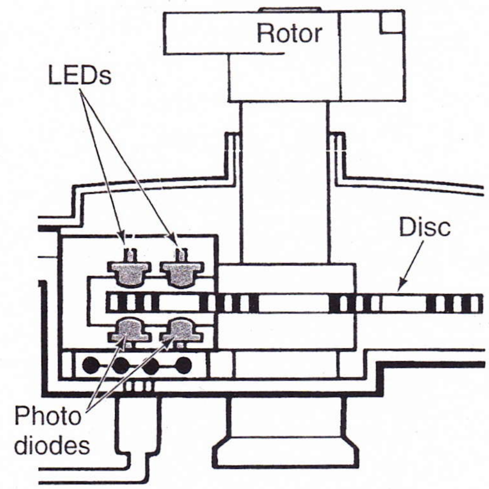


FIGURE 21–31 Distributor with optical-type pick-ups. *Courtesy of Chrysler Corporation*

by the photo cell. When the voltage signal occurs, the control unit turns on the primary system. When the disc interrupts the light and the voltage signal ceases, the control unit turns the primary system off, causing the magnetic field in the coil to collapse and sending a surge of voltage to a spark plug.

The photoelectric sensor sends a very reliable signal to the control unit, especially at low engine speeds. These units have been primarily used on Chrysler and Mitsubishi engines. Some Nissan and General Motors products have used them as well.

ELECTRONIC IGNITION SYSTEM OPERATION

The primary circuit of an electronic ignition system is controlled electronically by one of the sensors just described and an electronic control unit (module) that contains some type of switching device.

Primary Circuit Control

Figure 21–32 shows a basic electronic ignition system. The system consists of a distributor with a magnetic pulse pick-up unit and reluctor, an electronic control module, and a ballast resistor. As described earlier, when the tooth of the reluctor passes the pick-up, an electrical impulse is sent to the electronic module, which contains the switching transistor. The pulse signals the transistor to open the primary circuit, firing the plug. Once the plug stops firing, the transistor closes the primary coil circuit. The length of time the transistor allows current flow in the primary ignition circuit is determined by the electronic circuitry in the control module. Some systems used a dual ballast resistor. The ceramic ballast resistor assembly is mounted on the fire wall and has a ballast resistor for primary current flow and an auxiliary resistor for the control module.

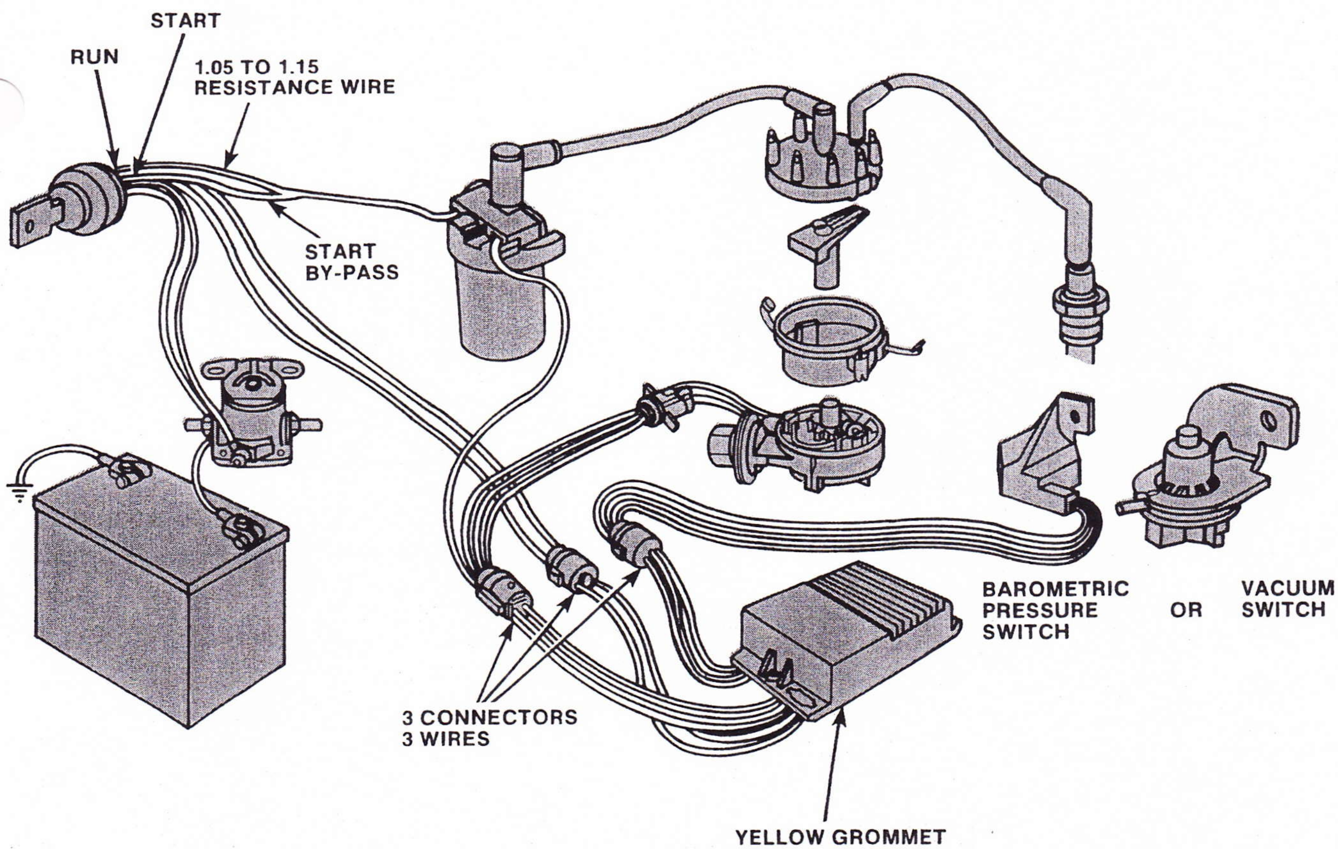


FIGURE 21–32 Dura Spark II electronic ignition system. *Courtesy of Ford Motor Company*

The ballast resistor has a 0.5-ohm resistance that maintains a constant primary current. The auxiliary ballast resistor uses a 5-ohm resistance to limit voltage to the electronic control unit.

There are some electronic ignition systems that do not require a ballast resistor. For instance, some control units directly regulate the current flow through the primary of the coil. Hall-effect systems do not require ballast resistors either. The signal voltage is not changed by the speed of the distributor as it is in an inductive magnetic signal generating system.

Some systems can be enhanced with additional sensors that increase the capabilities of the control module. The module shown in Figure 21–32 can be equipped with either a barometric pressure switch or vacuum switch. The **barometric pressure switch** enables the module to retard the ignition timing 3 to 6 degrees when the vehicle is operating at low elevations. The vacuum switch does the same, when the engine is under hard acceleration or heavy load. Other modules have the ability to retard ignition timing during start-up or when engine knock is detected.

Timing Advance

As stated, early electronic ignition systems changed the timing mechanically just like breaker point systems.

CENTRIFUGAL ADVANCE At idle, the firing of the spark plug usually occurs just before the piston reaches top dead center. At higher engine rpms, however, the spark must be delivered to the cylinder much earlier in the cycle to achieve maximum power from the air/fuel mixture since the engine is moving through the cycle more quickly. To change the timing of the spark in relation to rpm, the **centrifugal advance** mechanism is used (Figure 21–33).

This mechanism consists of a set of weights and springs connected to the distributor shaft and a distributor armature assembly. During idle speeds, the springs keep the weights in place and the armature and distributor shaft rotate as one assembly. When speed increases, centrifugal force causes the weights to slowly move out against the tension of the springs. This allows the armature assembly to move ahead in relation to the distributor shaft rotation. The ignition's triggering device is mounted to the armature assembly. Therefore, as the assembly moves ahead, ignition timing becomes more advanced.

VACUUM ADVANCE During part-throttle engine operation, high vacuum is present in the intake manifold. To get the most power and the best fuel economy from the engine, the plugs must fire even earlier

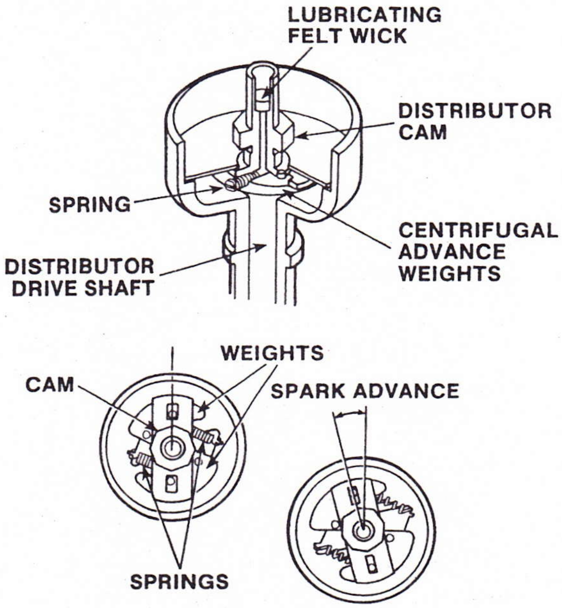


FIGURE 21–33 Typical centrifugal advance mechanism.

during the compression stroke than is provided by a centrifugal advance mechanism.

The heart of the vacuum advance mechanism (Figure 21–34) is the spring-loaded diaphragm, which fits inside a metal housing and connects to a movable plate on which the pick-up coil is mounted. Vacuum is applied to one side of the diaphragm in the housing chamber while the other side of the diaphragm is open to the atmosphere. Any increase in vacuum allows atmospheric pressure to push the diaphragm. In turn, this causes the movable plate to rotate. The more vacuum present on one side of the diaphragm, the more atmospheric pressure is able to cause a

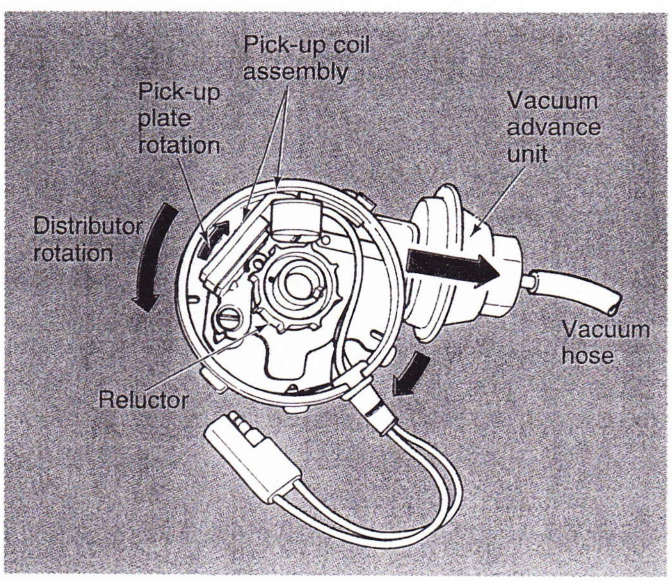


FIGURE 21–34 Typical vacuum advance unit operation. *Courtesy of Chrysler Corporation*

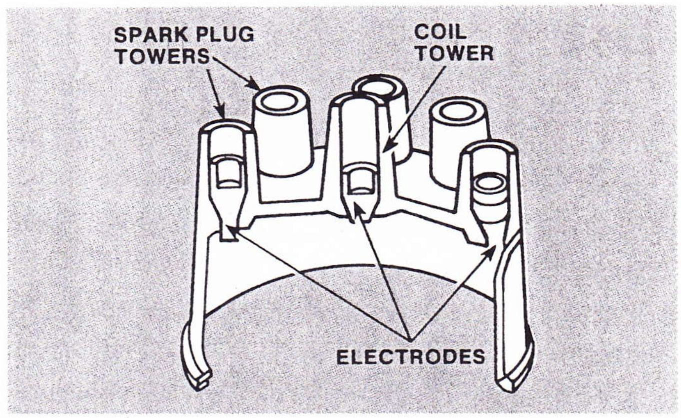


FIGURE 21–35 Cutaway view of a distributor cap.

change in timing. The rotation of the movable plate moves the pick-up coil so the armature develops a signal earlier. These units are also equipped with a spring that retards the timing as vacuum decreases.

Spark Distribution

The distributor cap and rotor receive the high voltage from the secondary winding via a high-tension wire. The voltage enters the distributor cap through the coil tower, or center terminal. The rotor then sends the voltage from the coil tower to the spark plug electrodes inside the distributor cap. The rotor mounts on the upper portion of the distributor shaft and rotates with it.

The distributor cap (Figure 21–35) is made from silicone plastic or similar material that offers protection from chemical attack. It is attached to the distributor housing with screws or spring-loaded clips. The coil tower contains a carbon insert that carries the voltage from the high-tension coil lead to the raised portion of the electrode on the rotor. Spaced evenly around the coil tower are the spark plug electrodes and towers for each spark plug.

An air gap of a few thousandths of an inch exists between the tip of the rotor electrode and the spark plug electrode inside the cap. This gap is necessary to prevent the two electrodes from making contact. If they did make contact, both would wear out rapidly. This gap cannot be measured when the distributor is assembled; therefore, the gap is usually described in terms of the voltage needed to create an arc between the electrodes.

COMPUTER-CONTROLLED IGNITION SYSTEM OPERATION

Computer-controlled ignition systems (Figure 21–36) control the primary circuit and distribute the firing voltages in the same manner as other types of electronic ignition systems. The main difference between

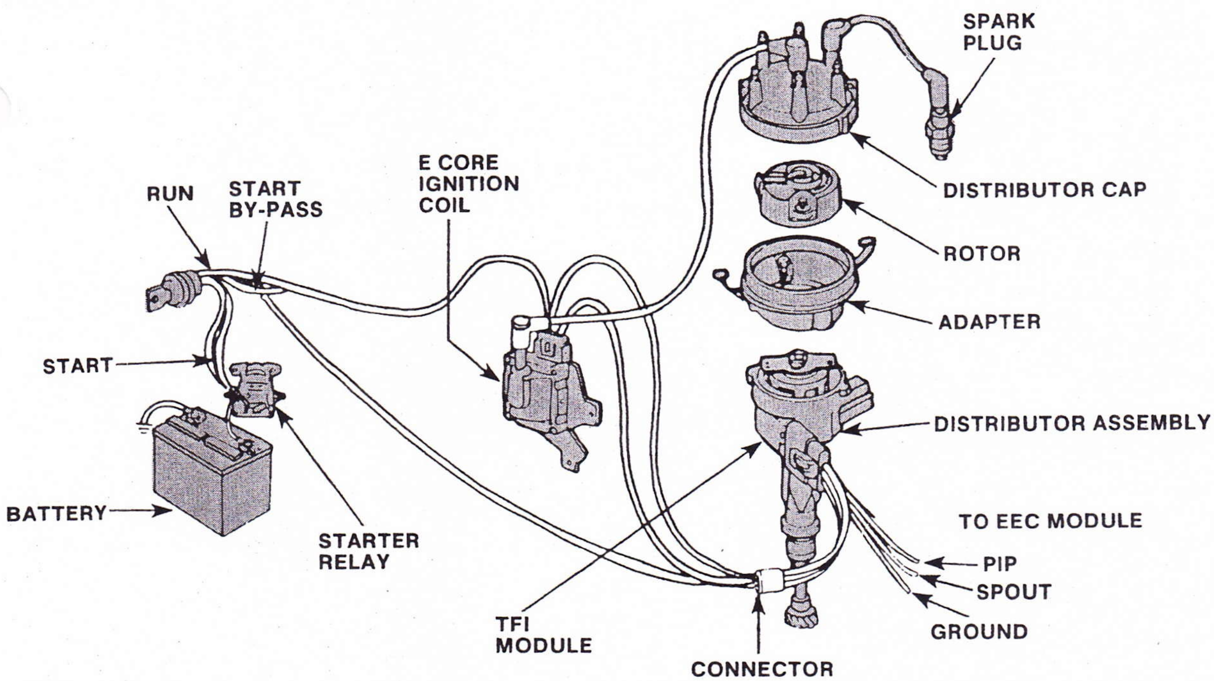


FIGURE 21–36 TFI-IV computer-controlled ignition system. *Courtesy of Ford Motor Company*

the systems is the elimination of any mechanical or vacuum advance devices from the distributor in the computer-controlled systems. In these systems, the distributor's sole purpose is to generate the primary circuit's switching signal and distribute the secondary voltage to the spark plugs. Timing advance is controlled by a microprocessor, or computer. In fact, some of these systems have even removed the primary switching function from the distributor by using a crankshaft position sensor. The distributor's only job is to distribute secondary voltage to the spark plugs.

Spark timing on these systems is controlled by a computer that continuously varies ignition timing to obtain optimum air/fuel combustion. The computer monitors the engine operating parameters with sensors. Based on this input, the computer signals an ignition module to collapse the primary circuit, allowing the secondary circuit to fire the spark plugs (Figure 21–37).

Timing control is selected by the computer's program. During engine starting, computer control is bypassed and the mechanical setting of the distributor controls spark timing. Once the engine is started and running, spark timing is controlled by the computer. This scheme or **strategy** allows the engine to start regardless of whether the electronic control system is functioning properly or not.

The goal of computerized spark timing is to produce maximum engine power, top fuel efficiency, and minimum emission levels during all types of operating conditions. The computer does this by continuously adjusting ignition timing. The computer deter-

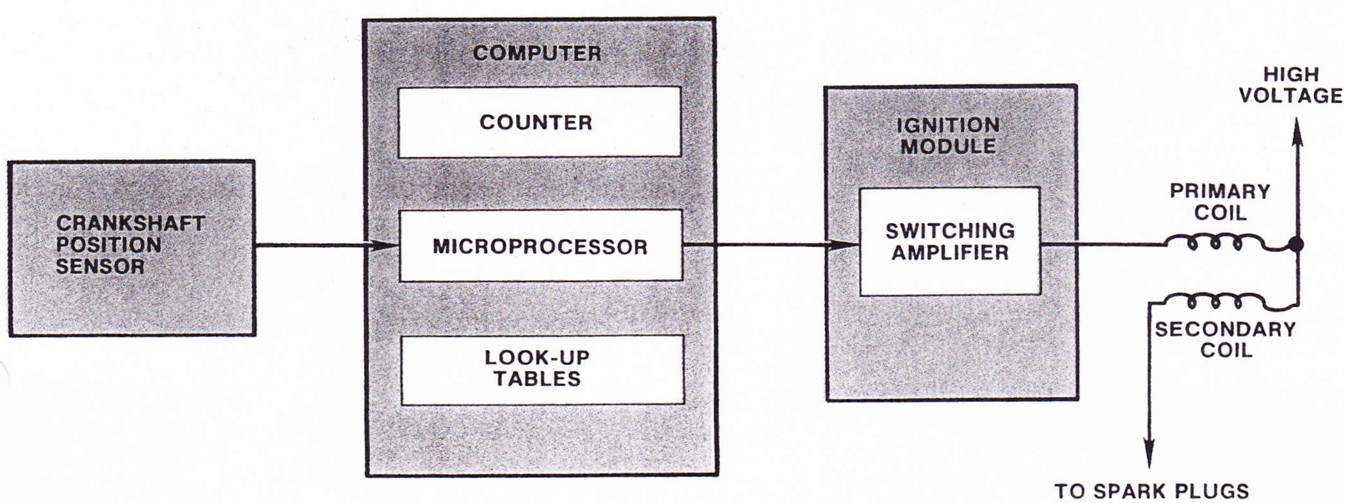


FIGURE 21–37 Typical engine timing control.

mines the best spark timing based on certain engine operating conditions such as crankshaft position, engine speed, throttle position, engine coolant temperature, and initial and operating manifold or barometric pressure. Once the computer receives input from these and other sensors, it compares the existing operating conditions to information permanently stored or programmed into its memory. The computer matches the existing conditions to a set of conditions stored in its memory, determines proper timing setting, and sends a signal to the ignition module to fire the plugs.

The computer continuously monitors existing conditions, adjusting timing to match what its memory tells it is the ideal setting for those conditions. It can do this very quickly, making thousands of decisions in a single second. The control computer typically has the following types of information permanently programmed into it.

- Speed-related spark advance. As engine speed increases to a particular point, there is a need for more advanced timing. As the engine slows, the timing should be retarded or have less advance. The computer bases speed related spark advance decisions on engine speed and signals from the TPS.
- Load-related spark advance. This is used to improve power and fuel economy during acceleration and heavy load conditions. The computer defines the load and the ideal spark advance by processing information from the TPS, MAP, and engine speed sensors. Typically, the more load on an engine, the less spark advance is needed.
- Warm-up spark advance. This is used when the engine is cold, since a greater amount of advance is required while the engine warms up.
- Special spark advance. This is used to improve fuel economy during steady driving conditions. During constant speed and load conditions, the engine will be more efficient with much advance timing.
- Spark advance due to barometric pressure. This is used when barometric pressure exceeds a preset calibrated value.

All this information is looked at by the computer to determine the ideal spark timing for all conditions. The calibrated or programmed information in the computer is contained in what is called software **look-up tables**.

Ignition timing can also work in conjunction with the electronic fuel control system to provide emission control, optimum fuel economy, and improved driveability. They are all dependent on spark advance.

Many computer-controlled ignition systems have a self-diagnostic capability that aids in troubleshooting.

DISTRIBUTORLESS IGNITION SYSTEM OPERATION

Distributorless ignition systems (Figure 21–38) electronically perform the functions of a distributor. They control spark timing and advance in the same manner as the computer-controlled ignition systems. Yet the DIS is a step beyond the computer-controlled system because it also distributes spark electronically instead of mechanically. The distributor is completely eliminated from these systems.

The computer, ignition module, and position sensors combine to control spark timing and advance. The computer collects and processes information to determine the ideal amount of spark advance for the operating conditions. The ignition module uses crank/cam sensor data to control the timing of the primary circuit in the coils. Remember that there is more than one coil in a distributorless ignition system. The ignition module synchronizes the coils' firing sequence in relation to crankshaft position and firing order of the engine. Therefore, the ignition module takes the place of the distributor.

The ignition module also adjusts spark timing below 400 rpm (for starting) and when the vehicle's control computer by-pass circuit becomes open or grounded. Depending on the exact DIS system, the ignition coils can be serviced as a complete unit or separately. The coil assembly is typically called a **coil pack** and is comprised of two or more individual coils.

On those DIS systems that use one coil per spark plug, the electronic ignition module determines when each spark plug should fire and controls the on/off time of each plug's coil.

The systems with a coil for every two spark plugs also use an electronic ignition module, but they use the **waste spark** method of spark distribution. Each end of the coil's secondary winding is attached to a spark plug. Each coil is connected to a pair of spark plugs in cylinders whose pistons rise and fall together. When the field collapses in the coil, voltage is sent to both spark plugs that are attached to the coil. In all V-6s, the paired cylinders are 1 and 4, 2 and 5, and 3 and 6 (or 4 and 1 and 3 and 2 on 4-cylinder engines). With this arrangement, one cylinder of each pair is on its compression stroke while the other is on the exhaust stroke. Both cylinders get spark simultaneously, but only one spark generates power while the other is wasted out the exhaust. During the next revolution, the roles are reversed.

Due to the way the secondary coils are wired, when the induced voltage cuts across the primary and secondary windings of the coil, one plug fires in the normal direction—positive center electrode to

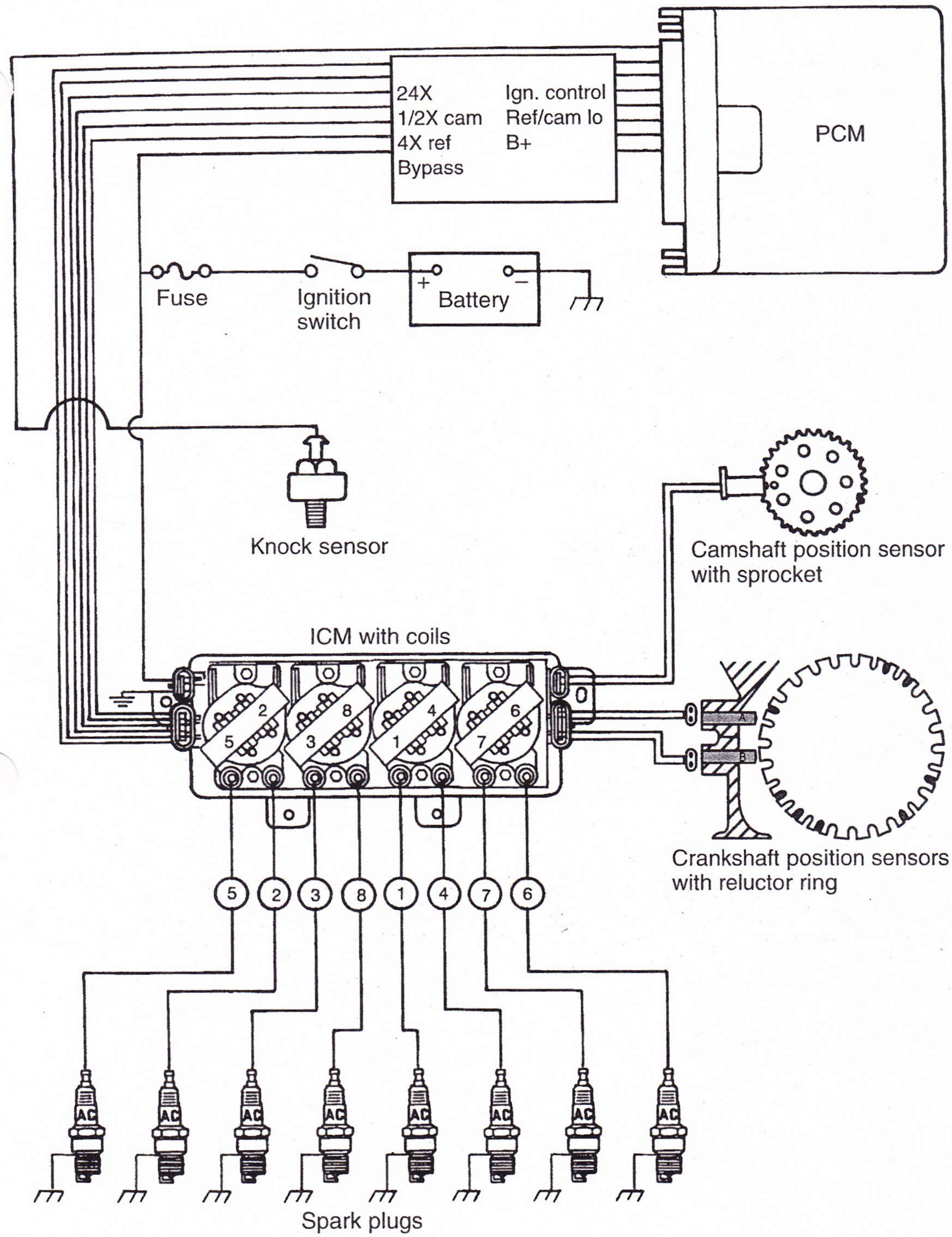


FIGURE 21–38 Distributorless ignition system with two crankshaft position sensors and one camshaft position sensor. *Courtesy of Cadillac Motor Car Division, General Motors Corporation*

negative side electrode—and the other plug fires just the reverse side to center electrode (Figure 21–39). As shown in Figure 21–40, both plugs fire simultaneously, completing the series circuit. Each plug always fires the same way on both the exhaust and compression strokes.

The coil is able to overcome the increased voltage requirements caused by reversed polarity and still fire two plugs simultaneously because each coil is capable of producing up to 100,000 volts. There is very little resistance across the plug gap on exhaust, so the plug requires very little voltage to fire, thereby pro-

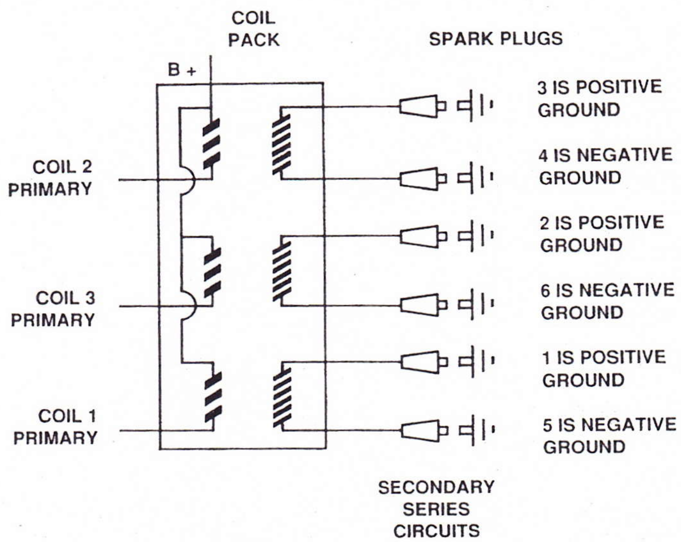


FIGURE 21–39 Polarity of spark plugs in a DIS system. *Courtesy of Ford Motor Company*

viding its mate (the plug that is on compression) with plenty of available voltage.

Figure 21–41 shows a waste spark system in which the coils are mounted directly over the spark plugs so no wiring between the coils and plugs is nec-

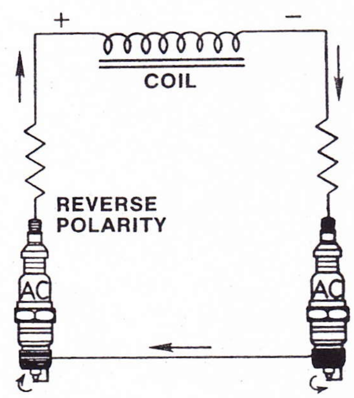


FIGURE 21–40 The manner in which two spark plugs are fired by a single-ignition coil in DIS ignition system circuits.

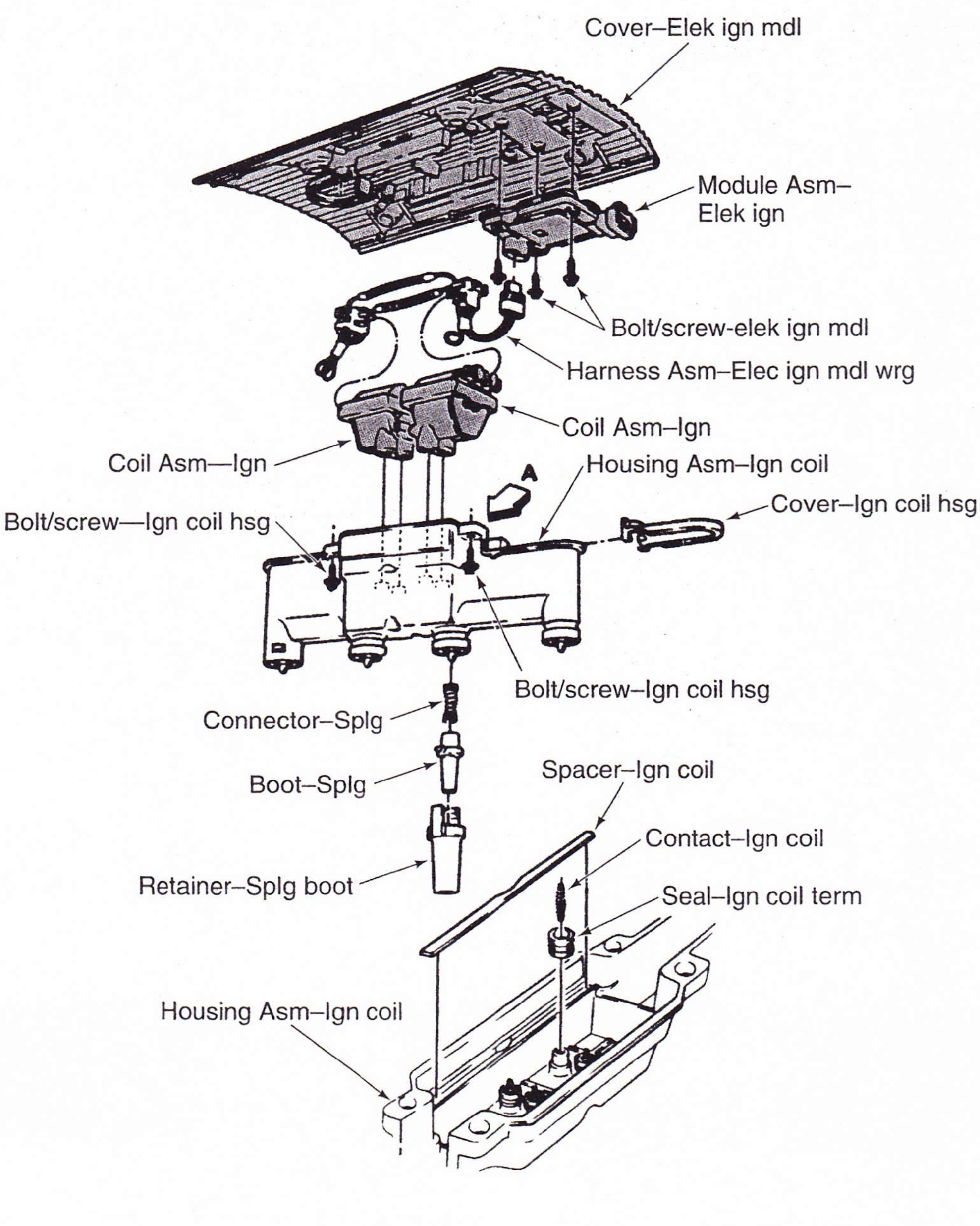


FIGURE 21–41 Cableless DIS system. *Courtesy of Oldsmobile Division, General Motors Corporation*

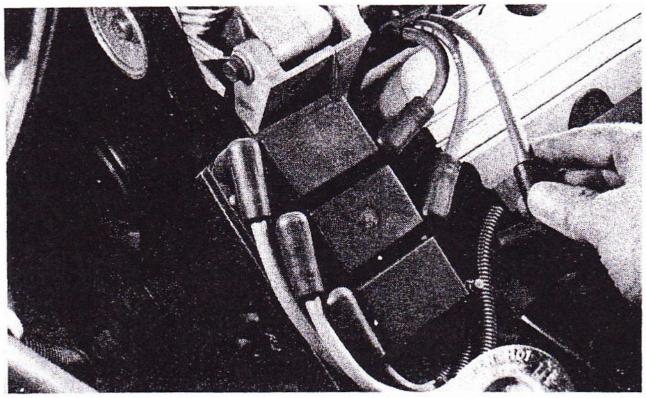


FIGURE 21–42 Coil pack for a V-6 engine. Each coil fires two spark plugs.

essary. On other systems, the coil packs are mounted remote from the spark plugs. High-tension secondary wires carry high-voltage current from the coils to the plugs (Figures 21–42 and 21–43).

A few DIS systems have one coil per cylinder with two spark plugs per cylinder. During starting only one plug is fired. Once the engine is running the other plug also fires. One spark plug is located on the intake side of the combustion chamber while the other is located on the exhaust side. Two coil packs are used, one for the plugs on the intake side and the other for the plugs on the exhaust side. These systems are called **dual plug** systems (Figure 21–44). During dual plug operation, the two coil packs are synchronized so each cylinder's two plugs fire at the same time. The coils fire two spark plugs at the same

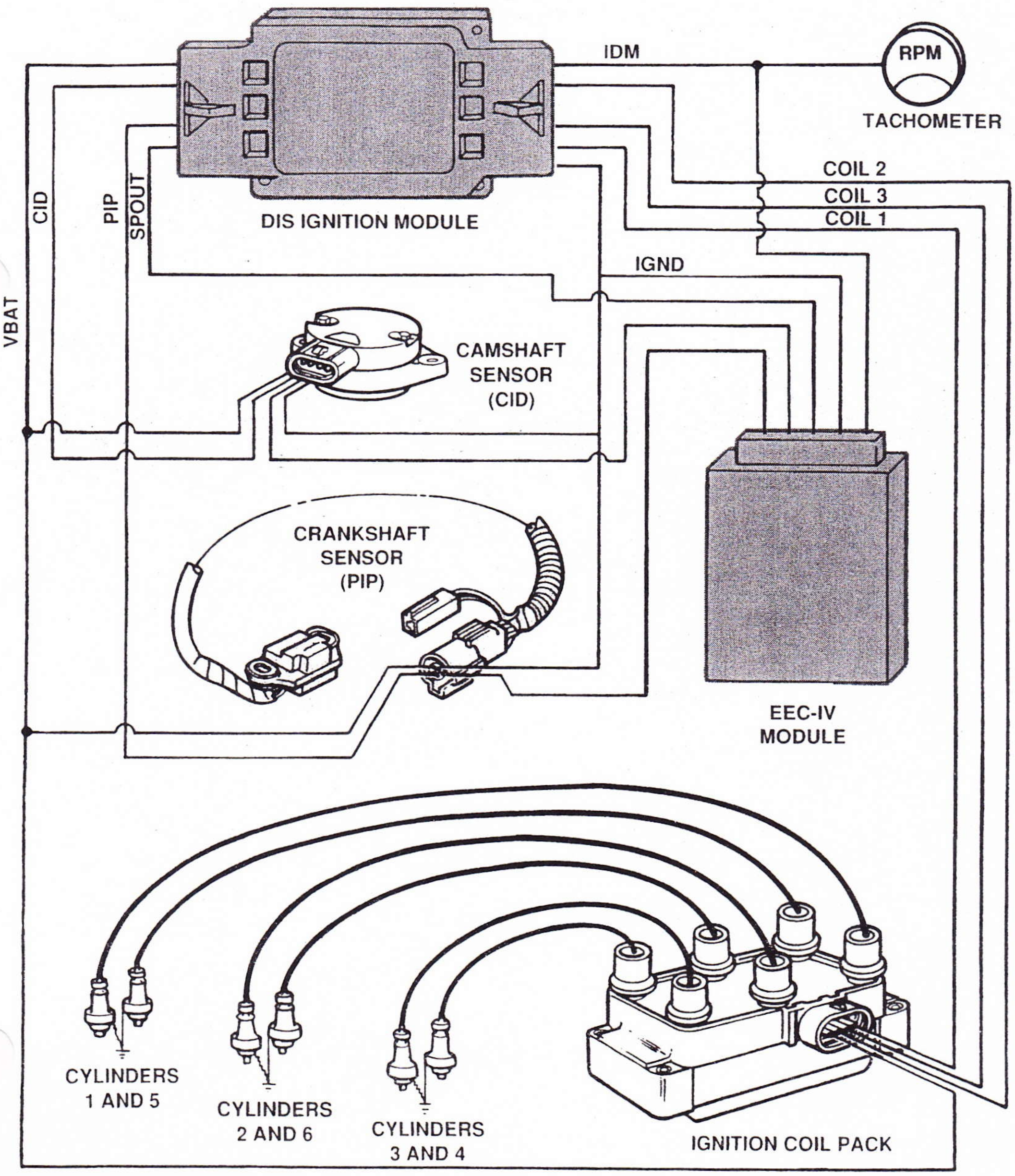


FIGURE 21–43 6-cylinder distributorless ignition system. *Courtesy of Ford Motor Company*

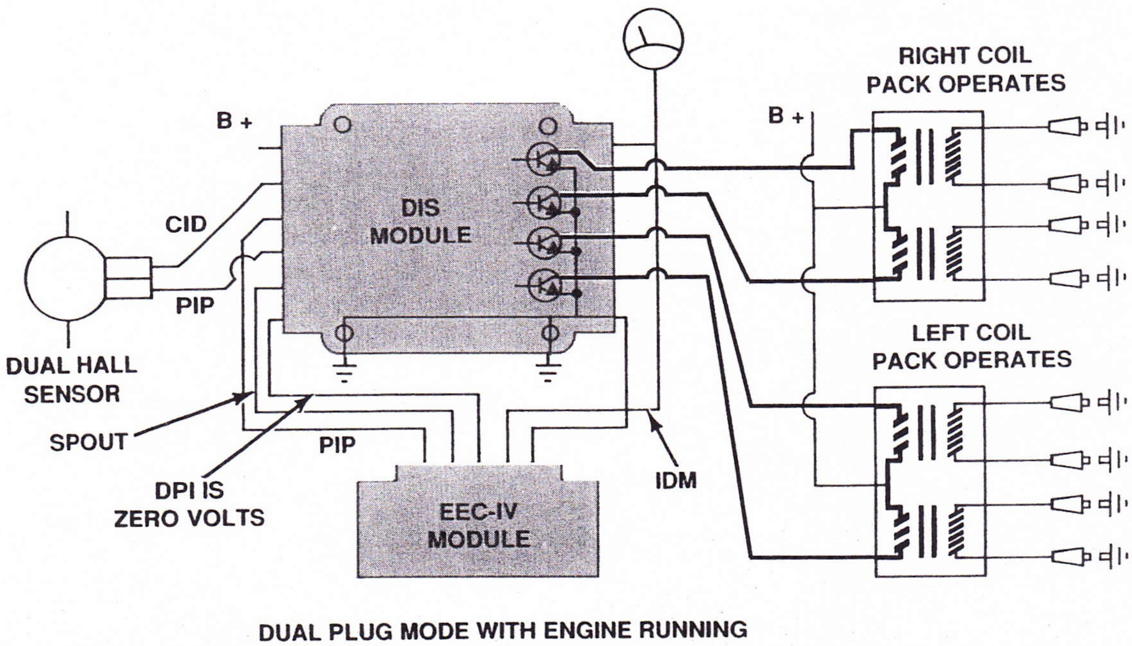


FIGURE 21–44 Dual plug system for a 4-cylinder engine. *Courtesy of Ford Motor Company*

time. Therefore, on a four-cylinder engine, four spark plugs are fired at a time: two during the compression stroke of the cylinder and two during the exhaust stroke of another cylinder.

Timing References

From a general operating standpoint, most distributorless ignition systems are similar. However, there are variations in the way different distributorless systems obtain a timing reference in regard to crankshaft and camshaft position.

Some engines use separate Hall-effect sensors to monitor crankshaft (Figure 21–45) and camshaft (Figure 21–46) position for the control of ignition and fuel injection firing orders. The camshaft sensor helps the computer determine when the number one piston is at TDC on the compression stroke.

Other systems use a dual Hall-effect sensor. One sensor generates three signals per crankshaft rotation, at 120 degree intervals. The other sensor generates one signal per revolution, which tells the computer when the number one cylinder is on TDC. From these signals, the computer can calculate the position of the camshaft, as well as know the position of the crankshaft.

Many different designs of DIS are possible. The **Fast-Start** electronic ignition system used in GM's Northstar system uses two crankshaft positions. A reluctor ring with twenty-four evenly spaced notches and eight unevenly spaced notches is cast onto the center of the crankshaft (Figure 21–47).

When the reluctor ring rotates past the magnetic-type sensors, each sensor produces thirty-two high

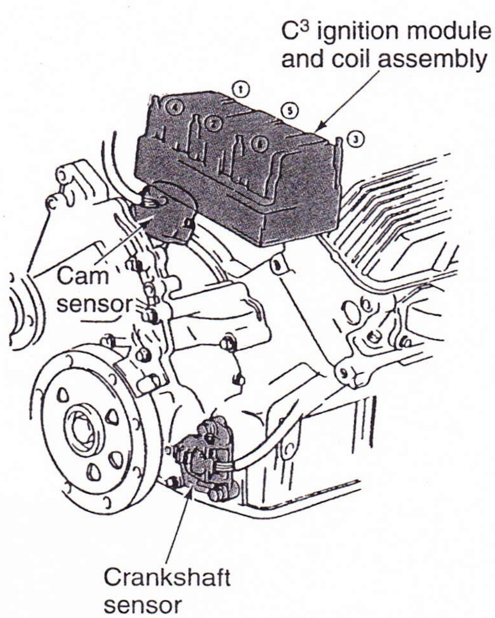


FIGURE 21–45 DIS system with a camshaft and crankshaft sensor. *Courtesy of Buick Motor Division, General Motors Corporation*

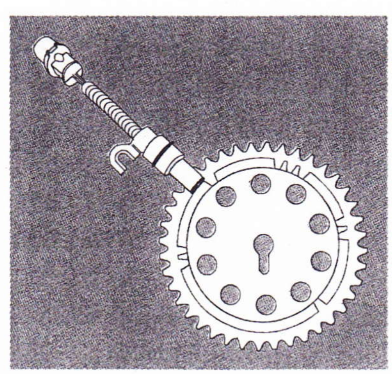


FIGURE 21–46 Notched ring on camshaft gears. *Courtesy of Chrysler Corporation*

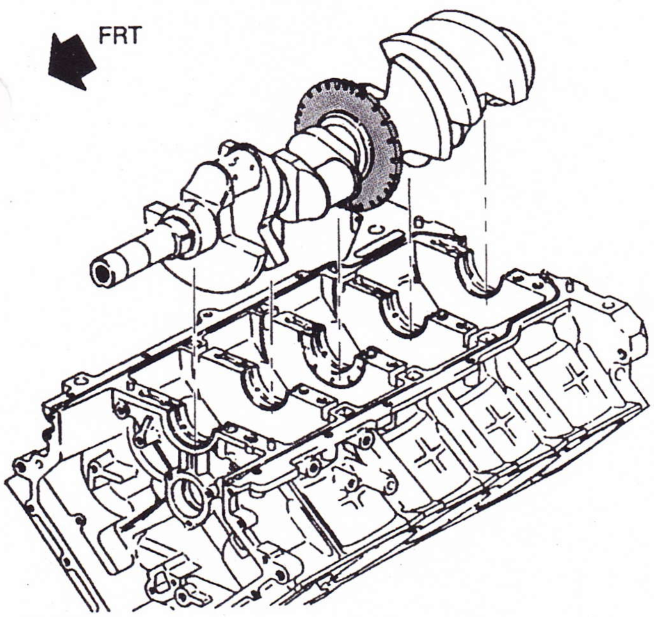


FIGURE 21–47 Crankshaft reluctor ring in a Northstar engine. *Courtesy of Cadillac Motor Car Division, General Motors Corporation*

and low voltage signals per crankshaft revolution. The "A" sensor is positioned in the upper crankcase, and the "B" sensor is positioned in the lower crankcase. Since the A sensor is above the B sensor, the signal from the A sensor occurs 27 degrees before the B sensor signal (Figure 21–48).

The signals from the two sensors are sent to the ignition control module. This module counts the number of B sensor signals between the A sensor signals to sequence the ignition coils properly. There can be zero, one, or two B sensor signals between the A signals. When starting the engine, the module begins counting B sensor signals between the A signals as soon as the module senses zero B signals between sensor signals. After the module senses four B signals, the module sequences the coils properly. This allows the ignition system to begin firing the spark plugs within 180 degrees of crankshaft rotation while starting the engine. This system allows for much quicker starting than other DIS systems, which required the crankshaft to rotate one or two times before the coils were sequenced.

Finally, some engines use a magnetic pulse generator. The timing wheel is cast on the crankshaft and has machined slots on it. If the engine is a six-cylinder, there will be seven slots, six of which are spaced exactly 60 degrees apart and the seventh—located 10 degrees from the number six notch—is used to synchronize the coil firing sequence in relation to crankshaft position (Figure 21–49). The same triggering wheel can be and is used on four-cylinder engines. The computer needs only to be programmed to interpret the signals differently than on a six-cylinder.

The magnetic sensor, which protrudes into the side of the block to within 0.050 in. (±0.020 in.) of the crankshaft reluctor, generates a small AC voltage each time one of the machined slots passes by.

By counting the time between pulses, the ignition module picks out the unevenly spaced seventh slot, which starts the calculation of the ignition coil sequencing. Once its counting is synchronized with the crankshaft, the module is programmed to accept the AC voltage signals of the select notches for firing purposes.

When the system is working properly, there is no base timing to adjust and there are no moving parts to wear.

The development and spreading popularity of DIS is the result of reduced emissions, improved fuel economy, and increased component reliability brought about by these systems.

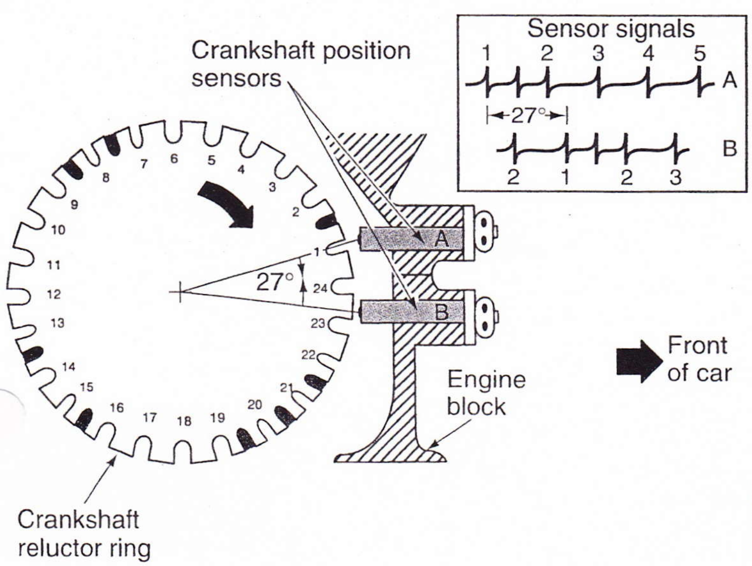


FIGURE 21–48 A and B crankshaft sensors in a Northstar engine. *Courtesy of Cadillac Motor Car Division, General Motors Corporation*

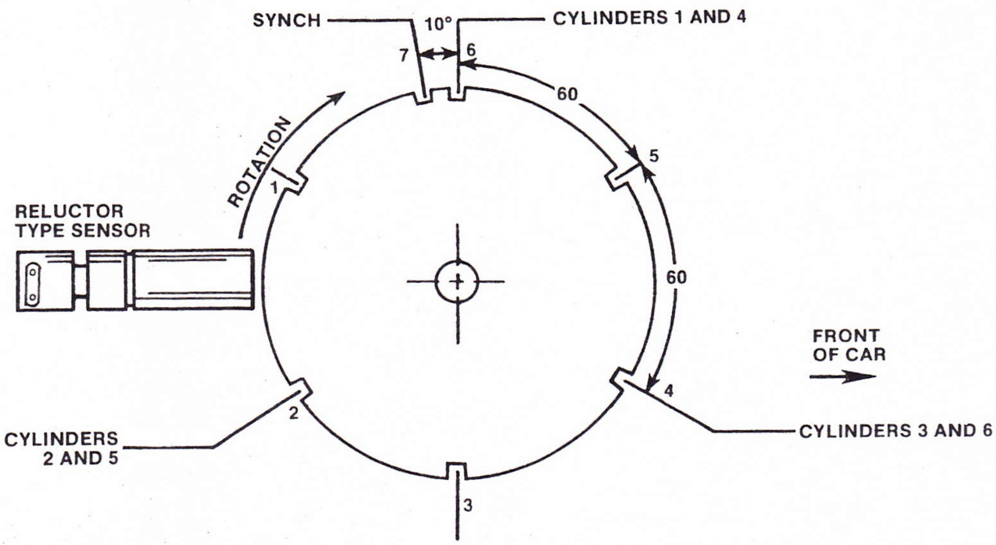


FIGURE 21–49 In a typical system, the AC voltage signal produced each time the magnetic pulse sensor passes notches 2, 4, and 6 triggers firing. The seventh notch references the coil firing sequence to the crankshaft position.

DIS offers advantages in production costs and maintenance considerations. By removing the distributor, the manufacturers realize a substantial savings in ignition parts and related machining costs. Also, by eliminating the distributor, they also do away with cracked caps, eroded carbon buttons, burned-through rotors, moisture misfiring, base timing adjustments, and the like.

CASE STUDY

A vehicle equipped with an early electronic ignition system is experiencing spark detonation (knocking) and erratic spark advance problems. The vehicle has 82,000 miles on it.

The technician checks the engine's base timing and finds it to be 5 degrees out of adjustment. The technician makes the adjustment, but it does not seem to hold steady. In fact, the problem still occurs on the test drive made immediately after the timing adjustment is made.

The technician then removes the distributor for closer inspection. The centrifugal advance mechanism appears to be in good order, but the technician notices shiny worn areas on the tangs of the distributor shaft's drive coupling. Wear on the tangs could mean the distributor shaft is not in proper mesh with the camshaft. The technician replaces the worn drive coupling and reinstalls the distributor. After resetting initial timing, the problem of erratic advance disappears.

KEY TERMS

Air gap
ATDC
Ballast resistor
Barometric pressure switch
Basic ignition timing
Breaker plate
Breaker point
BTDC
Centrifugal advance
Coil pack
Contact points
Control module
Direct ignition
DIS
Distributor
Dual plug
Dwell
Fast-Start
Firing order
Heat range
Ignition timing
Inductive reactance
Inductive reluctance
Look-up tables
Misfire
Photoelectric sensor
Preignition
Primary circuit
Pulse transformer
Reach
Rotor
Secondary circuit
Strategy
Swirling
Waste spark

SUMMARY

- The ignition system supplies high voltage to the spark plugs to ignite the air/fuel mixture in the combustion chambers.
- The arrival of the spark is timed to coincide with the compression stroke of the piston. This basic timing can be advanced or retarded under certain conditions, such as high engine rpm or extremely light or heavy engine loads.
- The ignition system has two interconnected electrical circuits: a primary circuit and a secondary circuit.

- The primary circuit supplies low voltage to the primary winding of the ignition coil. This creates a magnetic field in the coil.
- A switching device interrupts primary current flow, collapsing the magnetic field and creating a high-voltage surge in the ignition coil secondary winding.
- The switching device used in electronic systems is an NPN transistor. Old ignitions use mechanical breaker point switching.
- The secondary circuit carries high voltage surges to the spark plugs. On some systems, the circuit runs from the ignition coil, through a distributor, to the spark plugs.
- The distributor may house the switching device plus centrifugal or vacuum timing advance mechanisms. Some systems locate the switching device outside the distributor housing.
- Ignition timing is directly related to the position of the crankshaft. Magnetic pulse generators and Hall-effect sensors are the most widely used engine position sensors. They generate an electrical signal at certain times during crankshaft rotation. This signal triggers the electronic switching device to control ignition timing.
- Direct ignition systems eliminate the distributor. Each spark plug, or in some cases, pair of spark plugs, has its (their) own ignition coil. Primary circuit switching and timing control is done using a special ignition module tied into the vehicle control computer.
- Computer-controlled ignition eliminates centrifugal and vacuum timing mechanisms. The computer receives input from numerous sensors. Based on this data, the computer determines the optimum firing time and signals an ignition module to activate the secondary circuit at the precise time needed.

TECH MANUAL

The following procedures are included in Chapter 21 of the Tech Manual that accompanies this book:

1. *Set ignition timing dynamically.*
2. *Check the resistance of primary circuit components.*
3. *Test spark plug firing voltages.*
4. *Test secondary circuit insulation.*

REVIEW QUESTIONS

1. Under what condition is the ballast resistor in an ignition system's primary circuit bypassed?
2. Under light loads, what must be done to complete air/fuel combustion in the combustion chamber by the time the piston reaches 10 degrees ATDC?
3. At high engine rpm, what must be done to complete air/fuel combustion in the combustion chamber by the time the piston reaches 10 degrees ATDC?
4. How do DIS ignition systems differ from conventional electronic ignition systems?
5. Explain the components and operation of a magnetic pulse generator.
6. What happens when the low-voltage current flow in the coil primary winding is interrupted by the switching device?
   - **a.** The magnetic filed collapses.
   - **b.** A high-voltage surge is induced in the coil secondary winding.
   - **c.** Both a and b.
   - **d.** Neither a nor b.
7. Which of the following is a function of all ignition systems?
   - **a.** to generate sufficient voltage to force a spark across the spark plug gap
   - **b.** to time the arrival of the spark to coincide with the movement of the engine's pistons
   - **c.** to vary the spark arrival time based on varying operating conditions
   - **d.** all of the above
8. Reach, heat range, and air gap are all characteristics that affect the performance of which ignition system component?
   - **a.** ignition coils
   - **b.** ignition cables
   - **c.** spark plugs
   - **d.** breaker points