IGNITION SYSTEM

PURPOSE AND FUNCTION The ignition system includes components and wiring necessary to create and distribute a high voltage (up to 40,000 volts or more) and send to the spark plug at the correct time. A high-voltage arc occurs across the gap of a spark plug inside the combustion chamber. The spark raises the temperature of the air-fuel mixture and starts the combustion process inside the cylinder.

BACKGROUND All ignition systems apply battery voltage (close to 12 volts) to the positive side of the ignition coil(s) and pulse the negative side to ground on and off.

- **Early ignition systems.** Before the mid-1970s, ignition systems used a mechanically opened set of contact points to make and break the electrical connection to ground. A cam lobe, located in and driven by the distributor, opened the points. There was one lobe for each cylinder. The points used a rubbing block that was lubricated by applying a thin layer of grease on the cam lobe at each service interval. Each time the points opened, a spark was created in the ignition coil. The high-voltage spark then traveled to each spark plug through the distributor cap and rotor and the spark plug wires. The distributor was used twice in the creation of the spark.
  - First, it connected to the camshaft that rotated the distributor cam causing the points to open and close.
  - Second, it used a rotor to direct the high-voltage spark from the coil entering the center of the distributor cap to inserts connected to spark plug wires to each cylinder.

  ● **SEE FIGURE 69–1.**
- **Electronic ignition.** Since the mid-1970s, ignition systems have used sensors, such as a pickup coil and reluctor (trigger wheel), to trigger or signal an electronic module that switches the primary ground circuit of the ignition coil. **Distributor ignition (DI)** is the term specified by the Society of Automotive Engineers (SAE) for an ignition system that uses a distributor. **Electronic ignition (EI)** is the term specified by the SAE for an ignition system that does not use a distributor. Types of EI systems include:
  1. **Waste-spark system.** This type of system uses one ignition coil to fire the spark plugs for two cylinders at the same time.
  2. **Coil-on-plug system.** This type of system uses a single ignition coil for each cylinder with the coil placed above or near the spark plug.

IGNITION COIL OPERATION In an ignition coil there are two windings:

- Primary winding
- Secondary winding

All ignition systems use electromagnetic induction to produce a high-voltage spark from the ignition coil. Electromagnetic induction means that a current can be created in a conductor (coil winding) by a moving magnetic field. Current flowing through the primary winding of the coil produces the magnetic field in an ignition coil. An ignition coil is able to increase battery voltage to 40,000 volts or more in the following way.

- Battery voltage is applied to the primary winding.
- A ground is provided to the primary winding by the ignition control module (ICM), igniter, or powertrain control module (PCM).

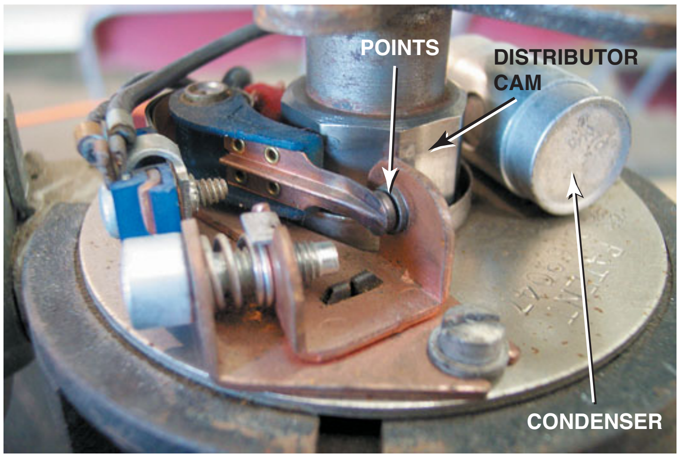

FIGURE 69–1 A point-type distributor from a hot rod being tested on a distributor machine.

- Current (approximately 2 to 6 amperes) flows in the primary coil creating a magnetic field.
- When the ground is opened by the ICM, the primary circuit is turned off and the built-up magnetic field in the secondary winding collapses.
- The movement of the collapsing magnetic field induces a voltage of 250 to 400 volts in the primary winding and 20,000 to 40,000 volts or more in the secondary winding with a current of 0.02 to 0.08 amperes (20 to 80 mA).
- The high voltage created in the secondary winding is high enough to jump the air gap at the spark plug.
- The electrical arc at the spark plug ignites the air-fuel mixture in the combustion chamber of the engine.
- For each spark that occurs, the coil must be charged with a magnetic field and then discharged.

WARNING

The spark from an ignition coil is strong enough to cause physical injury. Always follow the exact service procedure and avoid placing hands near the secondary ignition components when the engine is running.

The ignition components in the coil primary winding are known collectively as the primary ignition circuit.

- When the primary circuit is carrying current, the secondary circuit is off.
- When the primary circuit is turned off, the secondary circuit has high voltage.
- The components necessary to create and distribute the high voltage produced in the secondary windings of the coil are called the secondary ignition circuit. ● **SEE FIGURE 69–2.**

  These circuits include the following components.
- Primary ignition circuit
  1. Battery
  2. Ignition switch
  3. Primary winding of coil
  4. Pickup coil (if distributor ignition)

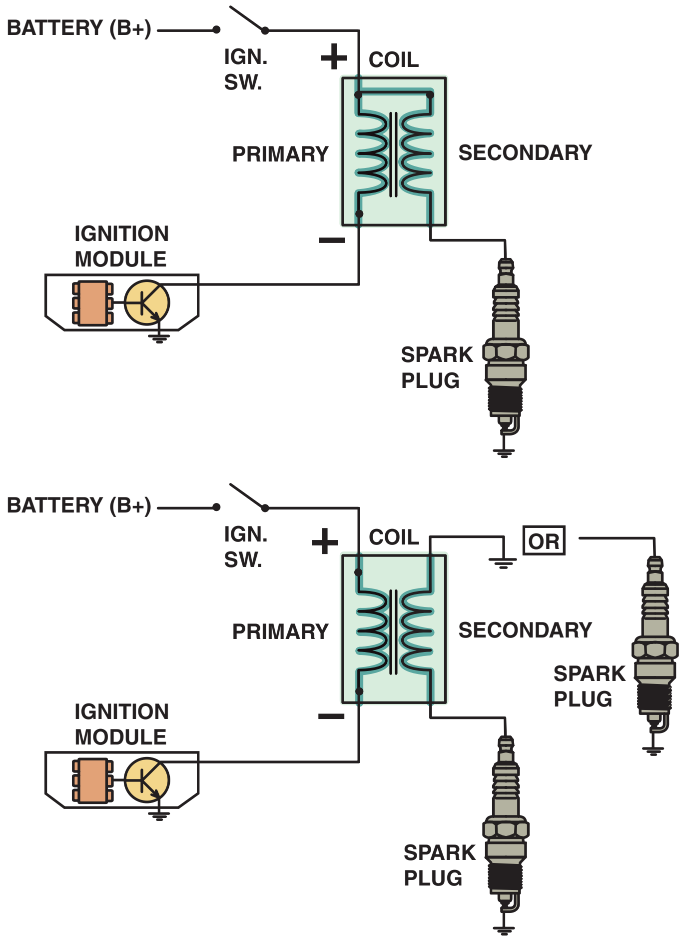

FIGURE 69–2 The primary ignition system is used to trigger and therefore create the secondary (high-voltage) spark from the ignition coil. Some ignition coils are electrically connected, called married (top figure) whereas others use separated primary and secondary windings, called divorced (lower figure).

5. Crankshaft position sensor (CKP)
6. Ignition control module (ICM) or igniter

- Secondary ignition circuit
    1. Secondary winding of coil
    2. Distributor cap and rotor (if the vehicle is so equipped)
    3. Spark plug wires
    4. Spark plugs

IGNITION COIL CONSTRUCTION Many ignition coils contain two separate but electrically connected windings of copper wire. Other coils are true transformers in which the primary and secondary windings are not electrically connected. ● **SEE FIGURE 69–3.**

The center of an ignition coil contains a core of laminated soft iron (thin strips of soft iron). This core increases the magnetic strength of the coil.

- **Secondary winding.** Surrounding the laminated core are approximately 20,000 turns of fine wire (approximately 42 gauge), which is smaller than a human hair. The winding is called the **secondary** coil winding.
- **Primary winding.** Surrounding the secondary windings are approximately 150 turns of heavy wire (approximately 21 gauge), which is about 0.028 inch in diameter. The winding is called the **primary** coil winding. The secondary winding has about 100 times the number of turns of the primary winding, referred to as the **turns ratio** (approximately 100:1).

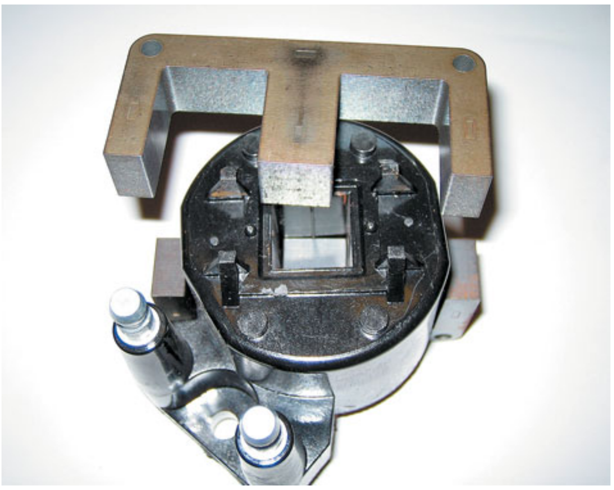

FIGURE 69–3 The steel laminations used in an E coil helps increase the magnetic field strength, which helps the coil produce higher energy output for a more complete combustion in the cylinders.

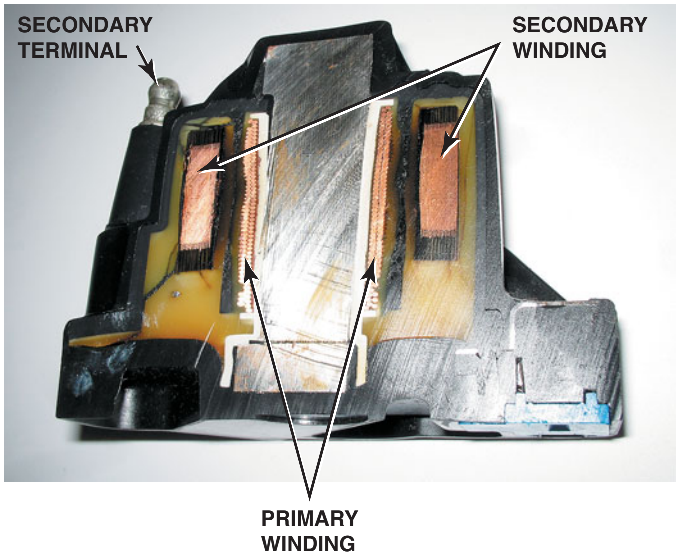

FIGURE 69–4 The primary windings are inside the secondary windings on this General Motors coil.

In older coils, these windings are surrounded with a thin metal shield and insulating paper and placed into a metal container filled with transformer oil to help cool the coil windings. Other coil designs use an air-cooled, epoxy-sealed E coil. The *E coil* is so named because the laminated, soft iron core is E shaped, with the coil wire turns wrapped around the center "finger" of the E and the primary winding wrapped inside the secondary winding. ● **SEE FIGURES 69–4 AND 69–5.**

IGNITION SWITCHING AND TRIGGERING

SWITCHING For any ignition system to function, the primary current must be turned on to charge the coil and off to allow the coil to discharge, creating a high-voltage spark. This turning on and off of the primary circuit is called **switching.** The unit that does the switching is an electronic switch, such as a power transistor. This power transistor can be located in either of the following locations.

- In the ICM or igniter
- In the PCM (computer)

NOTE: On some coil-on-plug systems, the ICM is part of the ignition coil itself and is serviced as an assembly.

PRIMARY CIRCUIT OPERATION The device that signals the switching of the coil on and off or just on in most instances is called the **trigger.** A trigger is typically a pickup coil in some distributor-type ignitions and a crankshaft position sensor (CKP) on electronic systems (waste-spark and coil-on-plug systems). To get a spark out of an ignition coil, the primary coil circuit must be turned on and off.

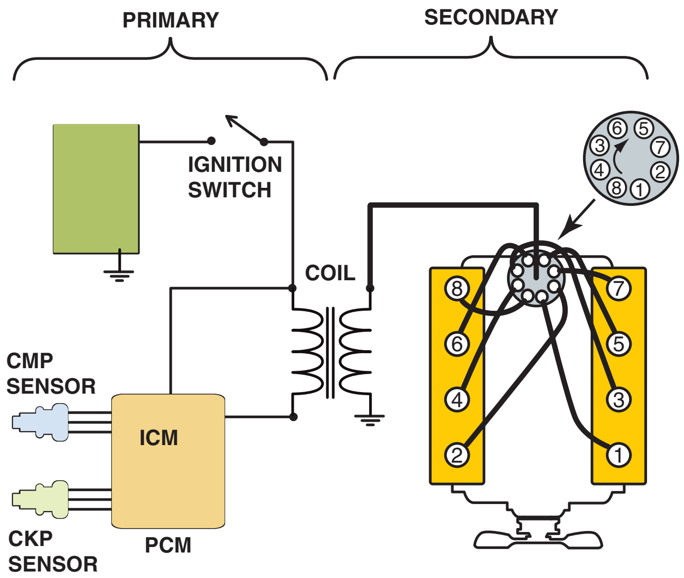

FIGURE 69–5 The primary ignition system is used to trigger and therefore create the secondary (high-voltage) spark from the ignition coil.

The primary circuit current switching is controlled by a **transistor** (electronic switch) inside the ignition module or igniter, and is controlled by one of the following devices.

- **Magnetic sensor.** A simple and common ignition electronic switching device is the magnetic pulse generator system. This type of magnetic sensor is often called a magnetic **pulse generator** or **pickup coil,** and is installed in the distributor housing. The pulse generator consists of a trigger wheel (reluctor) and a pickup coil. The pickup coil consists of an iron core wrapped with fine wire, in a coil at one end and attached to a permanent magnet at the other end. The center of the coil is called the pole piece. The pickup coil signal triggers the transistor inside the module and is also used by the computer for piston position information and engine speed (RPM). The reluctor is shaped so that the magnetic strength changes enough to create a usable varying signal for use by the module to trigger the coil. A magnetic pickup coil produces an analog AC signal. ● **SEE FIGURE 69–6.**

  Magnetic crankshaft position sensors use the changing strength of the magnetic field surrounding a coil of wire to signal the ICM and PCM. This signal is used by the electronics in the ignition module and computer to determine piston position and engine speed (RPM). This sensor operates similarly to the distributor magnetic pickup coil. The crankshaft position sensor uses the strength of the magnetic field surrounding a coil of wire to signal the ICM. The rotating crankshaft has notches cut into it that trigger the magnetic position sensor, which change the strength of the magnetic field as the notches pass by the position sensor, creating an AC analog signal. ● **SEE FIGURE 69–7.**
- **Hall-effect switch.** This switch also uses a stationary sensor and rotating trigger wheel (shutter). Unlike the magnetic pulse generator, the Hall-effect switch requires a small input voltage to generate an output or signal voltage. **Hall effect** has the ability to generate a voltage signal in semiconductor material (gallium arsenate crystal) by passing

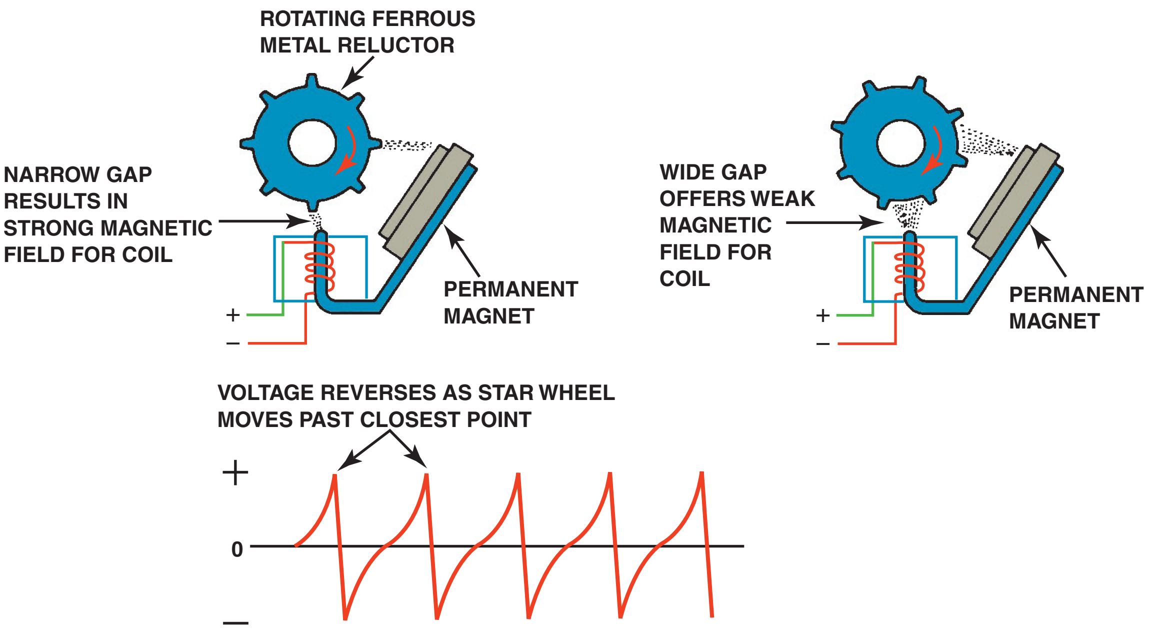

FIGURE 69–6 Operation of a typical pulse generator (pickup coil). At the bottom is a line drawing of a typical scope pattern of the output voltage of a pickup coil. The ICM receives this voltage from the pickup coil and opens the ground circuit to the ignition coil when the voltage starts down from its peak (just as the reluctor teeth start moving away from the pickup coil).

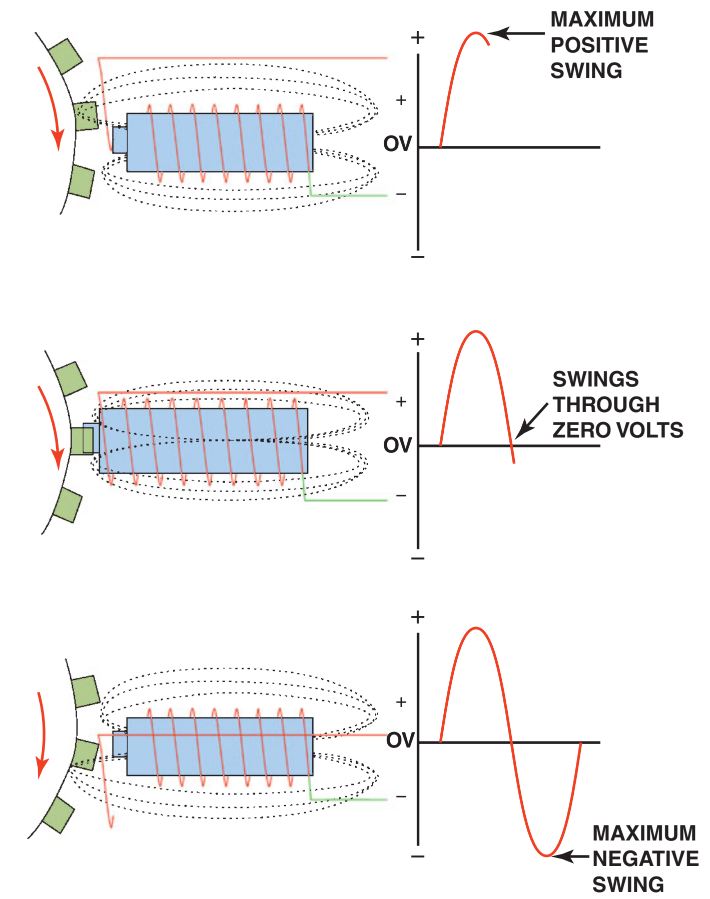

FIGURE 69–7 A magnetic sensor uses a permanent magnet surrounded by a coil of wire. The notches of the crankshaft (or camshaft) create a variable magnetic field strength around the coil. When a metallic section is close to the sensor, the magnetic field is stronger because metal is a better conductor of magnetic lines of force than air.

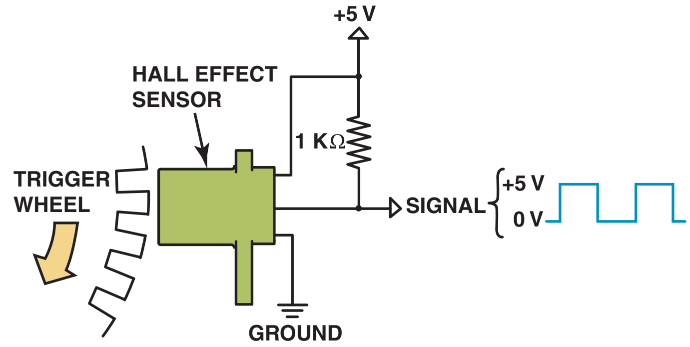

FIGURE 69–8 A Hall-effect sensor produces an on-off voltage signal whether it is used with a blade or a notched wheel.

current through it in one direction and applying a magnetic field to it at a right angle to its surface. If the input current is held steady and the magnetic field fluctuates, an output voltage is produced that changes in proportion to field strength. Most Hall-effect switches used in distributors have the following:

1. Hall element or device
2. Permanent magnet
3. Rotating ring of metal blades (shutters) similar to a trigger wheel (Another method uses a stationary sensor with a rotating magnet.) ● **SEE FIGURE 69–8**.

Some blades are designed to hang down, typically found in Bosch and Chrysler systems; others may be on a separate ring on the distributor shaft, typically found in General Motors and Ford Hall-effect distributors.

- When the shutter blade enters the gap between the magnet and the Hall element, it creates a magnetic shunt that changes the field strength through the Hall element.
- This analog signal is sent to a **Schmitt trigger** inside the sensor itself, which converts the analog signal into a digital signal. A digital (on or off) voltage signal is created at a varying frequency to the ignition module or onboard computer. ● **SEE FIGURE 69–9.**
- **Optical sensors.** This type of sensor uses light from an LED and a phototransistor to signal the computer. An interrupter disc between the LED and the phototransistor has slits that allow the light from the LED to trigger the phototransistor on the other side of the disc. Most optical sensors (usually located inside the distributor) use two rows of slits to provide individual cylinder recognition (low-resolution) and precise distributor angle recognition (high-resolution) signals that are used for cylinder misfire detection. ● **SEE FIGURE 69–10.**

TECH TIP

The Tachometer Trick

When diagnosing a no-start or intermediate misfiring condition, check the operation of the tachometer. If the tachometer does not indicate engine speed (no-start condition) or drops toward zero (engine missing), then the problem is due to a defect in the *primary* ignition circuit. The tachometer gets its signal from the pulsing of the primary winding of the ignition coil. The following components in the primary circuit could cause the tachometer to not work when the engine is cranking.

- Pickup coil
- Crankshaft position (CKP) sensor
- Ignition control module (ICM) or igniter
- Coil primary wiring

If the vehicle is not equipped with a tachometer, use a scan tool to look at engine RPM. Results:

- No or an unstable engine RPM reading means the problem is in the primary ignition circuit.
- A steady engine RPM reading means the problem is in the secondary ignition circuit or is a fuel-related problem.

DISTRIBUTOR IGNITION

PURPOSE AND FUNCTION The purpose of a distributor is to distribute the high-voltage spark from the secondary terminal of the ignition coil to the spark plugs for each cylinder. A gear or shaft that is part of the distributor is meshed with a gear on the camshaft. The distributor is driven at camshaft speed (one-half of crankshaft speed).

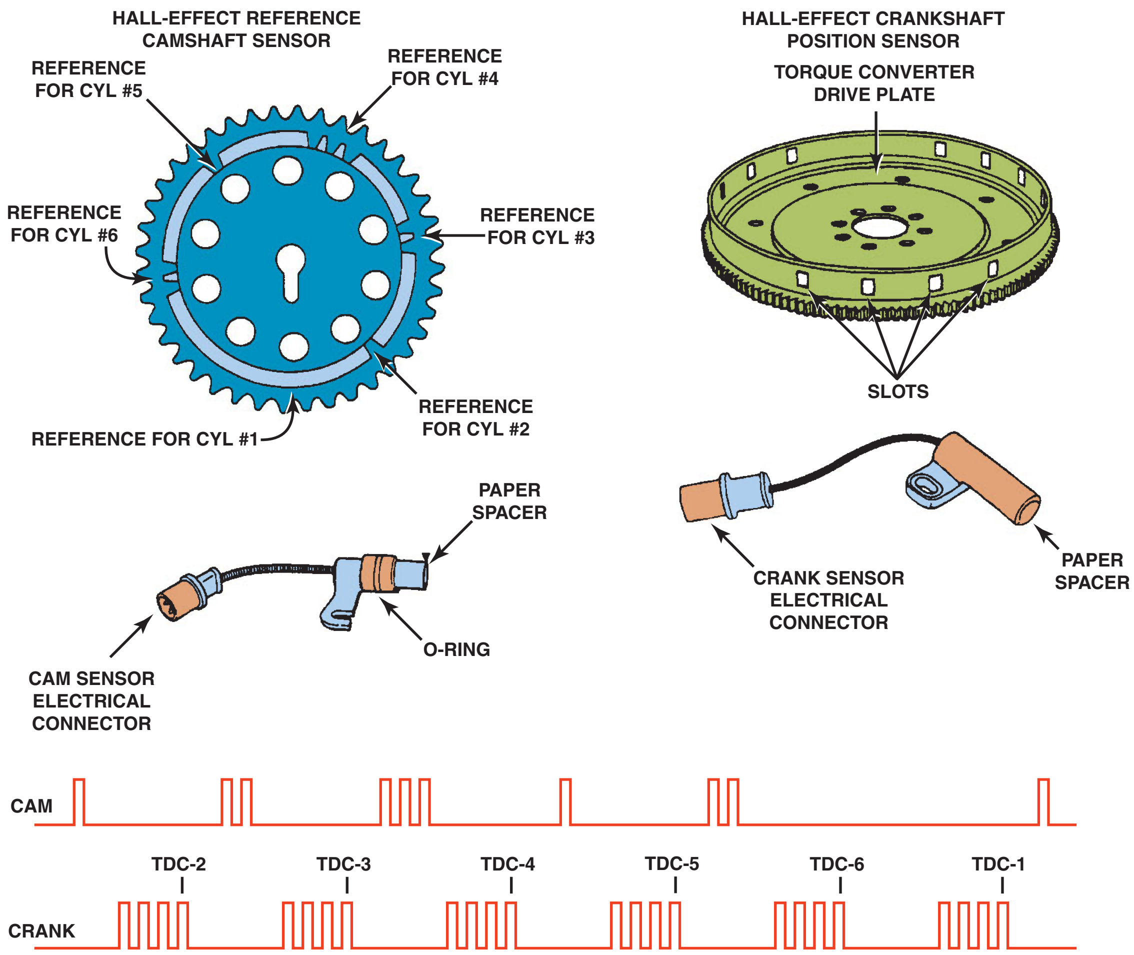

FIGURE 69–9 Some Hall-effect sensors look like magnetic sensors. This Hall-effect camshaft reference sensor and crankshaft position sensor have an electronic circuit built in that creates a 0 to 5 volt signal as shown at the bottom. These Hall-effect sensors have three wires: a power supply (8 volts) from the computer (controller), a signal (0 to 5 volts), and a signal ground.

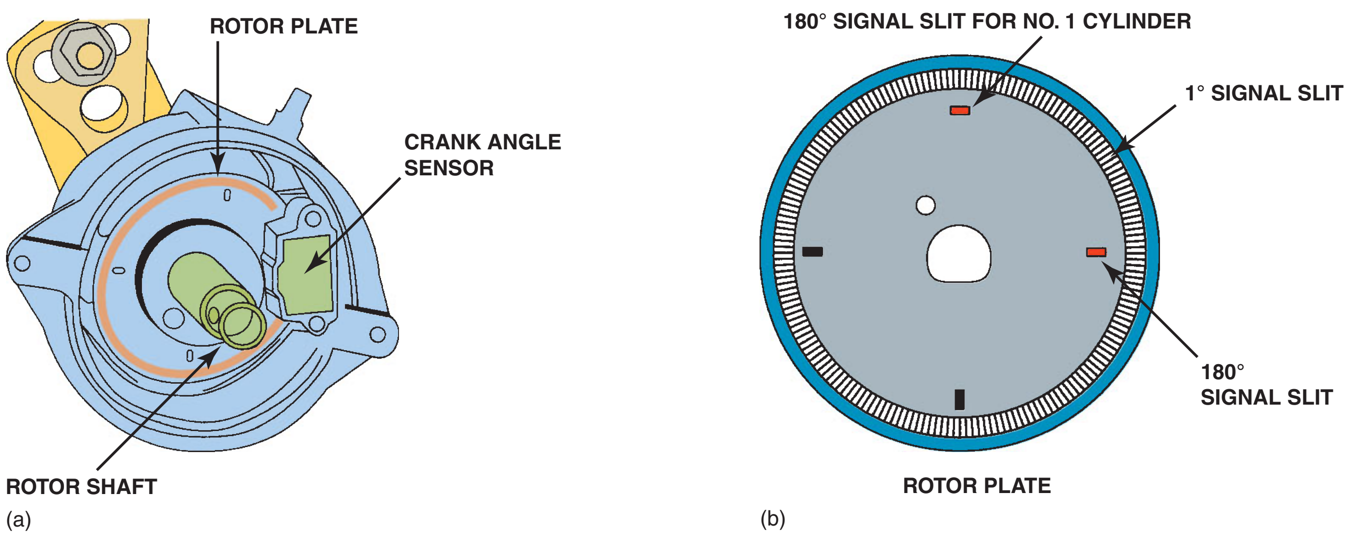

FIGURE 69–10 (a) Typical optical distributor. (b) Cylinder I slit signals the computer the piston position for cylinder I. The 1-degree slits provide accurate engine speed information to the PCM.

Most distributor ignition systems also use a sensor to trigger the ignition control module.

OPERATION OF DISTRIBUTOR IGNITION The distributor is used twice in most ignition systems that use one.

- The first time is when the **low voltage** triggers the ignition control module (ICM) by the use of the rotating distributor shaft.
- The second time is when the **high voltage** is directed by rotating the rotor to distribute the high-voltage spark to the individual spark plugs.

FIRING ORDER **Firing order** means the order that the spark is distributed to the correct spark plug at the right time. The firing order of an engine is determined by crankshaft and camshaft

FIGURE 69–11 A light shield being installed before the rotor is attached.

FIGURE 69–12 The firing order is cast or stamped on the intake manifold on most engines that have a distributor ignition.

TECH TIP

Optical Distributors Do Not Like Light

Optical distributors use the light emitted from LEDs to trigger phototransistors. Most optical distributors use a shield between the distributor rotor and the optical interrupter ring. Sparks jump the gap from the rotor tip to the distributor cap inserts. This shield blocks the light from the electrical arcs from interfering with the detection of the light from the LEDs.

If this shield is not replaced during service, the light signals are reduced and the engine may not operate correctly. ● **SEE FIGURE 69–11.**

This can be difficult to detect because nothing looks wrong during a visual inspection. Remember that all optical distributors must be shielded between the rotor and the interrupter ring.

design and the location of the spark plug wires in the distributor cap of an engine equipped with a distributor. The firing order is often cast into the intake manifold for easy reference. ● **SEE FIGURE 69–12.**

Service information also shows the firing order and the direction of the distributor rotor rotation, engine cylinder numbering, and the location of the spark plug wires on the distributor cap.

CAUTION: Ford V-8s use two different firing orders depending on whether the engine is high output (HO) or standard. Using the incorrect firing order can cause the engine to backfire and could cause engine damage or personal injury. General Motors V-6 engines use different firing orders and different locations for cylinder 1 between the 60-degree V-6 and the 90-degree V-6. Using the incorrect firing order or cylinder number location chart could result in poor engine operation or a no-start condition. Firing order is also important for waste-spark-type ignition systems. The spark plug wire can often be installed on the wrong coil pack which can create a no-start condition or poor engine operation.

WASTE-SPARK IGNITION SYSTEMS

PARTS INVOLVED Waste-spark ignition is another name for the **distributorless ignition system (DIS)** or electronic ignition (EI). Waste-spark ignition was introduced in the mid-1980s and uses the ignition control module (ICM) and/or the powertrain control module (PCM) to fire the ignition coils. A 4-cylinder engine uses two ignition coils and a 6-cylinder engine uses three ignition coils. Each coil is a true transformer because the primary winding and secondary winding are not electrically connected. A waste-spark coil has four terminals:

- Two primary (Bat + and − to ICM)
- Two secondary (each connected to a spark plug)

Each end of the secondary winding is connected to the spark plug of the cylinder exactly opposite the other in the firing order, called a **companion (paired) cylinder.** ● **SEE FIGURE 69–13.**

WASTE-SPARK SYSTEM OPERATION *Both* spark plugs fire at the same time (within nanoseconds of each other).

- When one cylinder (for example, cylinder number 6) is on the compression stroke, the other cylinder (number 3) is on the exhaust stroke.
- The spark that occurs on the exhaust stroke is called the waste spark, because it does no useful work and is only used as a ground path for the secondary winding of the ignition coil. The voltage required to jump the spark plug gap on cylinder 3 (the exhaust stroke) is only 2 to 3 kV.
- The cylinder on the compression stroke uses the remaining coil energy.
- One spark plug of each pair always fires straight polarity (from the center electrode to the ground electrode of the spark plug) and the other cylinder always fires reverse polarity (from the ground electrode to the center electrode of the spark plug). Spark plug life is not greatly affected by the reverse polarity. If there is only one defective spark plug wire or spark plug, two cylinders may be affected.

The coil polarity is determined by the direction the coil is wound (left-hand rule for conventional current flow) and cannot be changed.

For example, if a V-6 engine has a firing order of 165432 when one cylinder is on compression, such as cylinder number 1, then the paired cylinder (number 4) is on the exhaust stroke. During the next

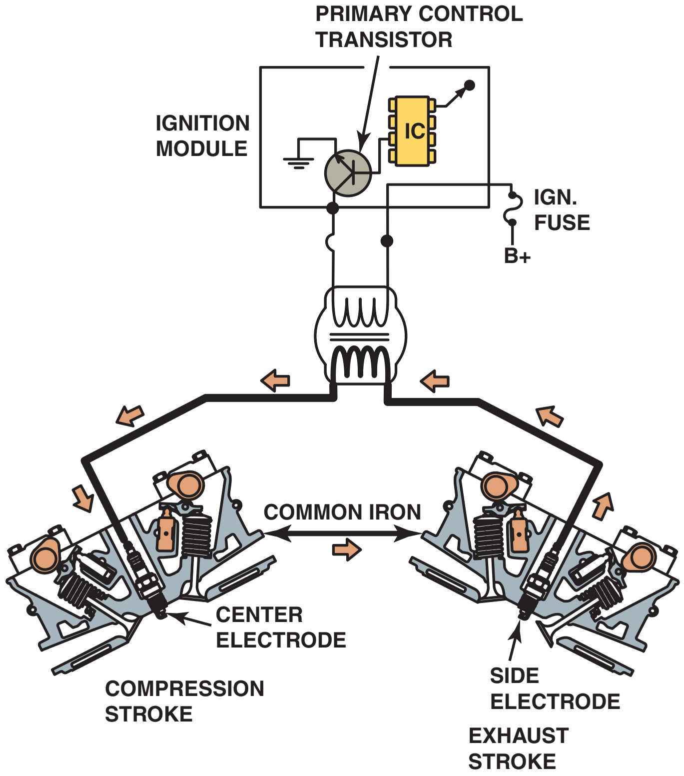

FIGURE 69–13 A waste-spark system fires one cylinder while its piston is on the compression stroke and into paired or companion cylinders while it is on the exhaust stroke. In a typical engine, it requires only about 2 to 3 kV to fire the cylinder on the exhaust stroke. The remaining coil energy is available to fire the spark plug under compression (typically about 8 to 12 kV).

rotation of the crankshaft, cylinder number 4 is on the compression stroke and cylinder number 1 is on the exhaust stroke.

Cylinder 1. Always fires straight polarity (from the center electrode to the ground electrode), one time requiring 10 to 12 kV, and one time requiring 3 to 4 kV.

Cylinder 4. Always fires reverse polarity (from the ground electrode to the center electrode), one time requiring 10 to 12 kV, and one time requiring 3 to 4 kV.

Waste-spark ignitions require a sensor (usually a crankshaft sensor) to trigger the coils at the correct time. ● **SEE FIGURE 69–14.**

The crankshaft sensor cannot be moved to adjust ignition timing, because ignition timing is not adjustable. The slight adjustment of the crankshaft sensor is designed to position the sensor exactly in the middle of the rotating metal disc for maximum clearance.

COMPRESSION-SENSING WASTE-SPARK IGNITION Some waste-spark ignition systems, such as on Saturns and others, use the voltage required to fire the cylinders to determine cylinder position. It requires a higher voltage to fire a spark plug under compression than it does when the spark plug is being fired on the exhaust stroke. The electronics in the coil and the PCM can detect which of the two companion (paired) cylinders that are fired at the same time requires the higher voltage, which indicates the cylinder that is on the compression stroke. For example, a typical 4-cylinder engine equipped with a waste-spark ignition system will fire both cylinders 1 and 4. If cylinder number 4 requires a higher voltage to fire, as determined by the electronics connected to the coil, then the PCM assumes that cylinder number 4 is on the compression stroke. Engines equipped with **compression-sensing ignition** systems do not require the use of a camshaft position sensor to determine specific cylinder numbers. ● **SEE FIGURE 69–15.**

FREQUENTLY ASKED QUESTION

How Can You Determine the Companion Cylinder?

Companion cylinders are two cylinders in the same engine that both reach top dead center at the same time.

- One cylinder is on the compression stroke.
- The other cylinder is on the exhaust stroke.

To determine which two cylinders are companion cylinders in the engine, follow these steps:

STEP 1 Determine the firing order (such as 165432 for a typical V-6 engine).

STEP 2 Write the firing order and then place the second half under the first half.

165
432

STEP 3 The cylinder numbers above and below each other are companion or paired cylinders.

In this case, 1 and 4, 6 and 3, and 5 and 2 are companion cylinders.

TECH TIP

Odds Fire Straight

Waste-spark ignition systems fire two spark plugs at the same time. Most vehicle manufacturers use a waste-spark system that fires the odd number cylinders (1, 3, and 5) by straight polarity (current flow from the top of the spark plug through the gap and to the ground electrode). The even number cylinders (2, 4, and 6) are fired reverse polarity, meaning that the spark jumps from the side electrode to the center electrode. Some vehicle manufacturers equip their vehicles with platinum plugs, with the expensive platinum alloy only on one electrode as follows:

- On odd number cylinders (1, 3, 5), the platinum is on the center electrode.
- On even number cylinders (2, 4, 6), the platinum is on the ground electrode.

Replacement spark plugs use platinum on both electrodes (double platinum) and, therefore, can be placed in any cylinder location.

COIL-ON-PLUG IGNITION

TERMINOLOGY **Coil-on-plug (COP) ignition** uses one ignition coil for each spark plug. This system is also called *coil-by-plug, coil-near-plug,* or *coil-over-plug* ignition. ● **SEE FIGURES 69–16 AND 69–17.**

ADVANTAGES The coil-on-plug system eliminates the spark plug wires that are often the source of **electromagnetic interference (EMI)** that can cause problems to some computer signals. The vehicle computer controls the timing of the spark. Ignition

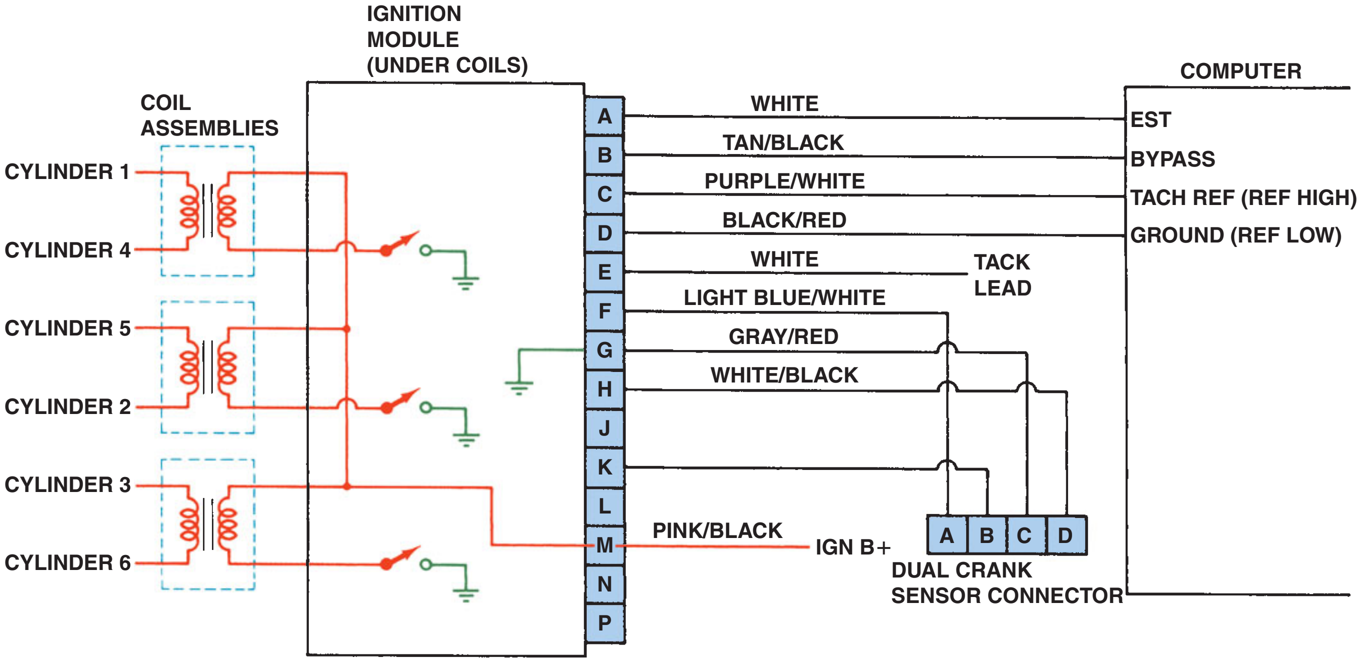

FIGURE 69–14 Typical wiring diagram of a V-6 waste-spark ignition system. The computer (PCM) is in control of the ignition timing based on information from various engine sensors including engine speed (RPM), MAP and engine coolant temperature (ECT). The timing signal is sent to the module through the electronic spark timing (EST) wire in this example.

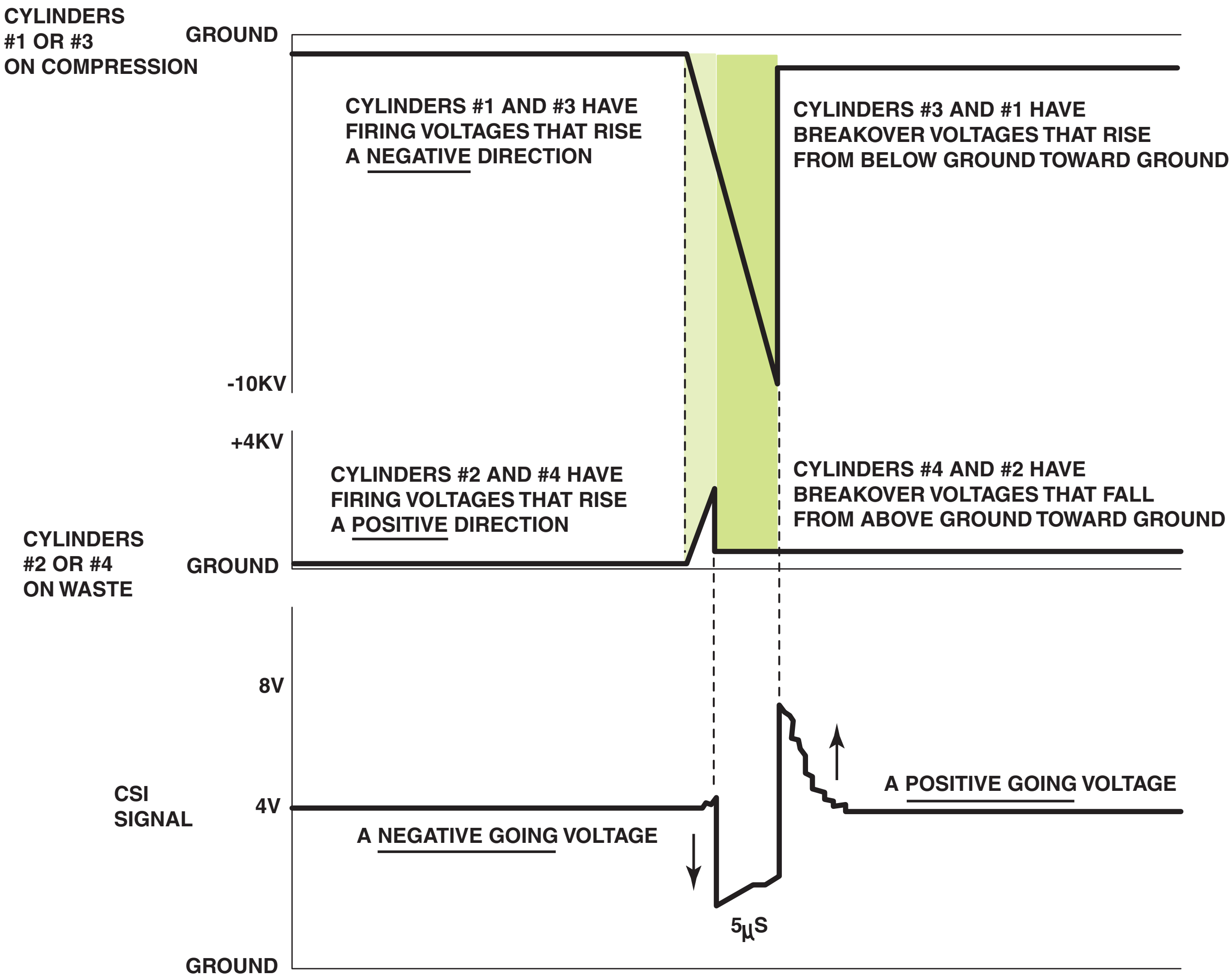

FIGURE 69–15 The slight (5 microsecond) difference in the firing of the companion cylinders is enough time to allow the PCM to determine which cylinder is firing on the compression stroke. The compression sensing ignition (CSI) signal is then processed by the PCM which then determines which cylinder is on the compression stroke.

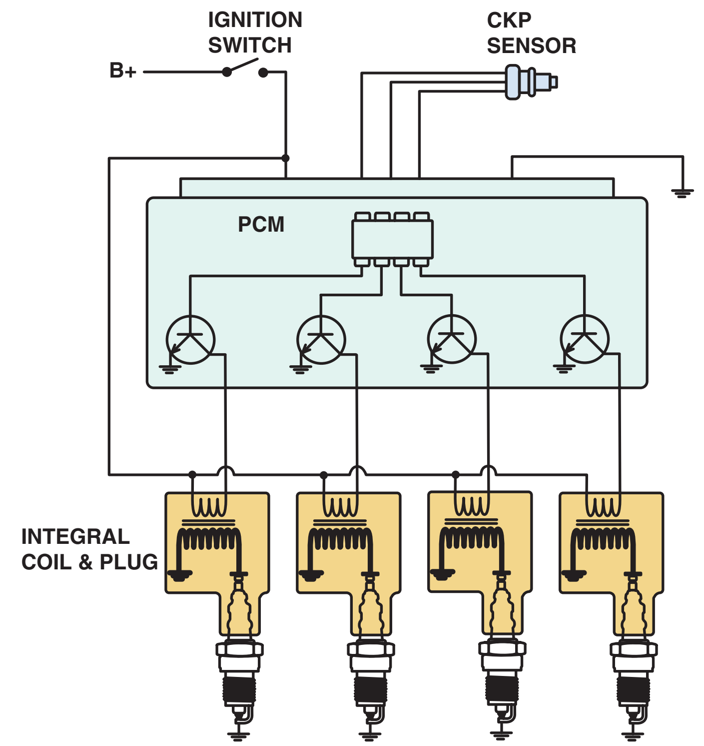

FIGURE 69–16 A typical coil-on-plug ignition system showing the triggering and the switching being performed by the PCM via input from the crankshaft position sensor.

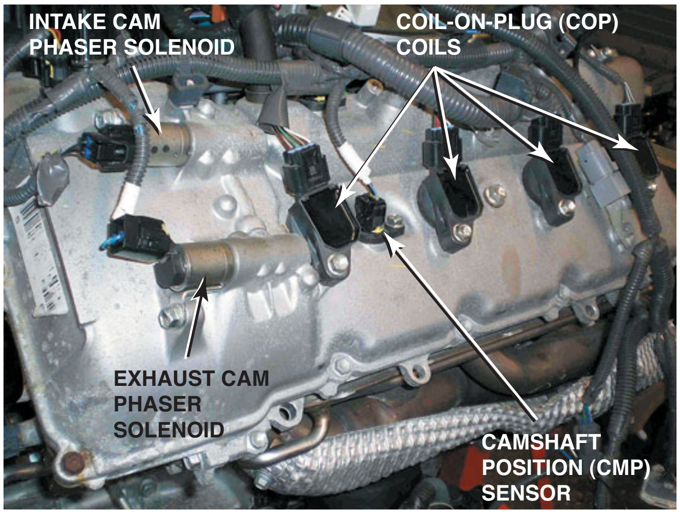

FIGURE 69–17 An overhead camshaft engine equipped with variable valve timing on both the intake and exhaust camshafts and the coil-on-plug ignition.

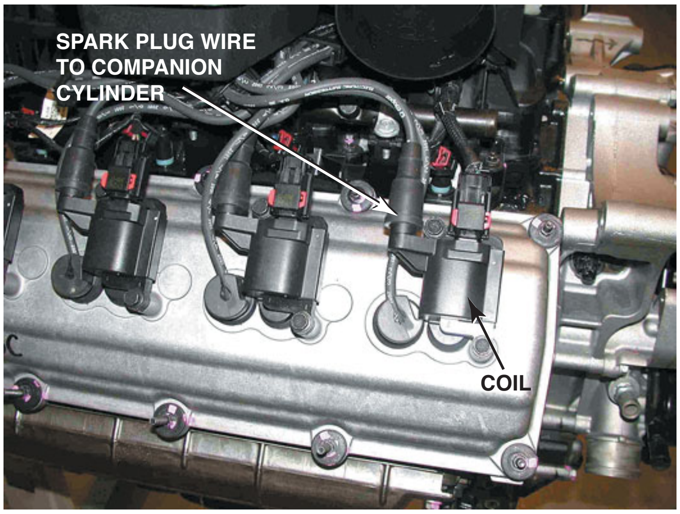

FIGURE 69–18 A Chrysler Hemi V-8 that has two spark plugs per cylinder. The coil on top of one spark plug fires that plug and, through a spark plug wire, fires a plug in the companion cylinder.

SAFETY TIP

Never Disconnect a Spark Plug Wire When the Engine Is Running!

Ignition systems produce a high-voltage pulse necessary to ignite a lean air-fuel mixture. If you disconnect a spark plug wire when the engine is running, this high-voltage spark could cause personal injury or damage to the ignition coil and/or ignition module.

timing also can be changed (retarded or advanced) on a cylinder-by-cylinder basis for maximum performance and to respond to knock sensor signals.

TYPES OF COP SYSTEMS There are two basic types of coil-on-plug ignition.

- **Two primary wires.** This design uses the vehicle computer to control the firing of the ignition coil. The two wires include ignition voltage feed and the pulse ground wire, which is controlled by the PCM. The ignition control module (ICM) is located in the PCM, which handles all ignition timing and coil on-time control.
- **Three primary wires.** This design includes an ignition module at each coil. The three wires include:
  - Ignition voltage
  - Ground
  - Pulse from the PCM to the built-in ignition module

Vehicles use a variety of coil-on-plug-type ignition systems, such as the following:

- Many General Motors V-8 engines use a coil-near-plug system with individual coils and modules for each individual cylinder placed on the valve covers. Short secondary ignition spark plug wires are used to connect the output terminal of the ignition coil to the spark plug, which explains why this system is called a *coil-near-plug* system.
- A combination of coil-on-plug and waste-spark systems fires a spark plug attached to the coil and uses a spark plug wire attached to the other secondary terminal of the coil to fire another spark plug of the companion cylinder. This type of system is used in some Chrysler Hemi V-8 and Toyota V-6 engines. ● **SEE FIGURE 69–18.**

Most new engines use coil-over-plug-type ignition systems. Each coil is controlled by the PCM, which can vary the ignition timing separately for each cylinder based on signals the PCM receives from the knock sensor(s). For example, if the knock sensor detects that a spark knock has occurred after firing cylinder 3, then the PCM will continue to monitor cylinder 3 and retard timing on just this one cylinder if necessary to prevent engine damaging detonation.

ION-SENSING IGNITION In an **ion-sensing ignition** system, the spark plug itself becomes a sensor. An ion-sensing ignition uses

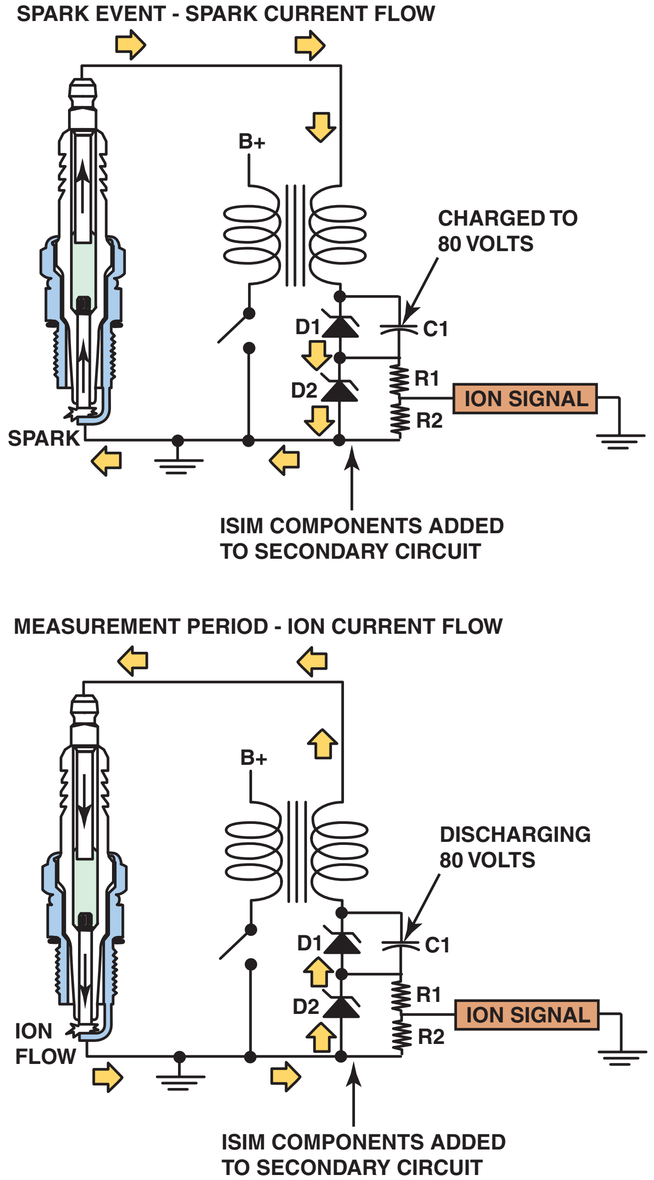

FIGURE 69–19 A DC voltage is applied across the spark plug gap after the plug fires and the circuit can determine if the correct air-fuel ratio was present in the cylinder and if knock occurred. The applied voltage for ion sensing does not jump the spark plug gap but rather determines the conductivity of the ionized gases left over from the combustion process.

a coil-on-plug design where the **ignition control module (ICM)** applies a DC voltage across the spark plug gap *after* the ignition event to sense the ionized gases (called plasma) inside the cylinder. Ion-sensing ignition is used in the General Motors EcoTec 4-cylinder engines. ● **SEE FIGURE 69–19.**

The secondary coil discharge voltage (10 to 15 kV) is electrically isolated from the ion-sensing circuit. The combustion flame is ionized and will conduct some electricity, which can be accurately measured at the spark plug gap. The purpose of this circuit includes:

- Misfire detection (required by OBD-II regulations)
- Knock detection (eliminates the need for a knock sensor)
- Ignition timing control (to achieve the best spark timing for maximum power with lowest exhaust emissions)
- Exhaust gas recirculation (EGR) control
- Air-fuel ratio control on an individual cylinder basis

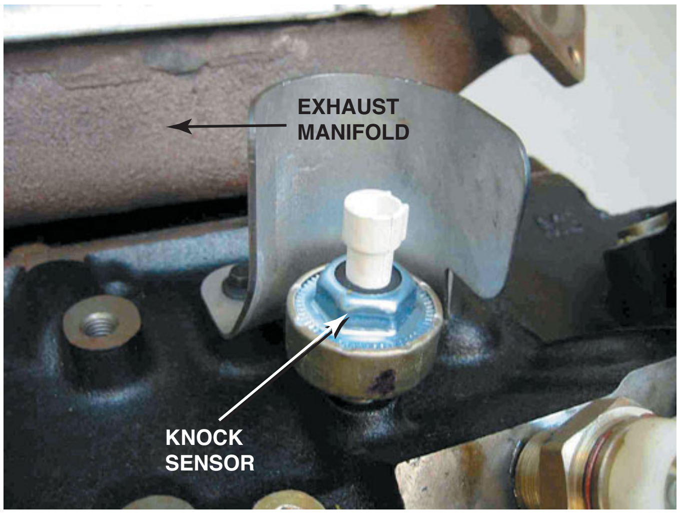

FIGURE 69–20 A typical knock sensor on the side of the block. Some are located in the "V" of a V-type engine and are not noticeable until the intake manifold has been removed.

Ion-sensing ignition systems still function the same as conventional coil-on-plug designs, but the engine does not need to be equipped with a camshaft position sensor for misfire detection or a knock sensor, because both of these faults are achieved using the electronics inside the ignition control circuits.

KNOCK SENSORS

PURPOSE AND FUNCTION **Knock sensors (KS)** are used to detect abnormal combustion, often called **ping, spark knock,** or **detonation.** Whenever abnormal combustion occurs, a rapid pressure increase occurs in the cylinder, creating a vibration in the engine block. It is this vibration that is detected by the knock sensor. The signal from the knock sensor is used by the PCM to retard the ignition timing until the knock is eliminated, thereby reducing the damaging effects of the abnormal combustion on pistons and other engine parts.

Inside the knock sensor is a piezoelectric element which is a type of crystal that produces a voltage when pressure or a vibration is applied to the unit. The knock sensor is tuned to the engine knock frequency, in a range from 5 to 10 kHz depending on the engine design. The voltage signal from the knock sensor is sent to the PCM, which then retards the ignition timing until the knocking stops. ● **SEE FIGURE 69–20.**

DIAGNOSING THE KNOCK SENSOR If a knock sensor diagnostic trouble code (DTC) is present, follow the specified testing procedure in the service information. A scan tool can be used to check the operation of the knock sensor, using the following procedure.

STEP 1 Start the engine and connect a scan tool to monitor ignition timing and/or knock sensor activity.

STEP 2 Create a simulated engine knocking sound by tapping on the engine block or cylinder head with a soft faced mallet or small ball peen hammer.

STEP 3 Observe the scan tool display. The vibration from the tapping should have been interpreted by the knock sensor as a knock, resulting in a knock sensor signal and a reduction in the spark advance.

A knock sensor also can be tested using a digital storage oscilloscope. ● **SEE FIGURE 69–21.**

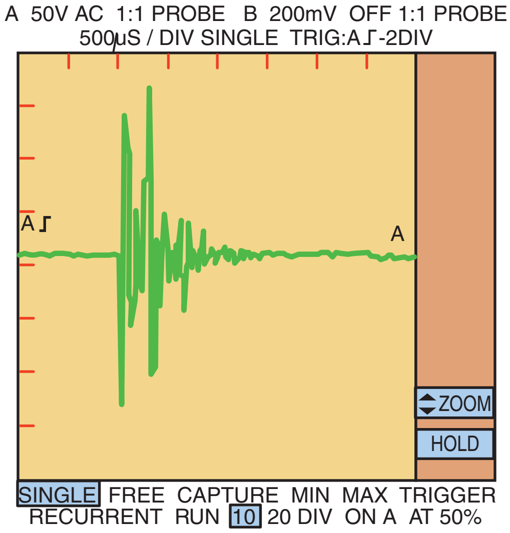

FIGURE 69–21 A typical waveform from a knock sensor during a spark knock event. This signal is sent to the computer which in turn retards the ignition timing. This timing retard is accomplished by an output command from the computer to either a spark advance control unit or directly to the ignition module.

? REAL WORLD FIX

The Low Power Toyota

A technician talked about the driver of a Toyota who complained about poor performance and low fuel economy. The technician checked everything, and even replaced all secondary ignition components. Then the technician connected a scan tool and noticed that the knock sensor was commanding the timing to be retarded. Careful visual inspection revealed a "chunk" missing from the serpentine belt, causing a "noise" similar to a spark knock. Apparently the knock sensor was "hearing" the accessory drive belt noise and kept retarding the ignition timing. After replacing the accessory drive belt, a test drive confirmed that normal engine power was restored.

Other items that can fool the knock sensor to retard the ignition timing include:

- Loose valve lifter adjustment
- Engine knocks
- Loose accessory brackets such as the air-conditioning compressor, power steering pumps, or alternator.

NOTE: Some engine computers are programmed to ignore knock sensor signals when the engine is at idle speed, to avoid having the noise from a loose accessory drive belt or other accessory interpreted as engine knock. Always follow the vehicle manufacturer's recommended testing procedure.

REPLACING A KNOCK SENSOR If replacing a knock sensor, be sure to purchase the exact replacement needed, because they often look the same, but the frequency range can vary according to engine design and location on the engine. Many engines also use two knock sensors, so check service information for exact details and locations of the sensors for the engine being serviced. Always tighten the knock sensor using a torque wrench and tighten to the specified torque to avoid causing damage to the piezoelectric element inside the sensor.

FIGURE 69–22 A SPOUT connector on a Ford that is equipped with a distributor ignition. This connector has to be disconnected to separate the PCM in order to set base ignition timing.

TERMINOLOGY **Ignition control (IC)** is the OBD-II terminology for the output signal from the PCM to the ignition system that controls engine timing. Previously, each manufacturer used a different term to describe this signal. For instance, Ford referred to this signal as **spark output (SPOUT)** and General Motors referred to this signal as **electronic spark timing (EST).** This signal is now referred to as the ignition control (IC) signal. The ignition control signal is usually a digital output that is sent to the ignition system as a timing signal. If the ignition system is equipped with an ignition module, then this signal is used by the ignition module to vary the timing as engine speed and load change. If the PCM directly controls the coils, such as most coil-on-plug ignition systems, then this IC signal directly controls the coil primary and there is a separate IC signal for each ignition coil. The IC signal controls the time that the coil fires and it can also either advance or retard the ignition timing. On many systems, this signal controls the duration of the primary current flow in the coil, referred to as the **dwell.** ● **SEE FIGURE 69–22.**

BYPASS IGNITION CONTROL SYSTEM With **bypass ignition** control, the engine starts using the ignition module for timing control and then switches to the PCM for timing control after the engine starts. A bypass ignition is commonly used on General Motors engines equipped with distributor ignition (DI), as well as those equipped with waste-spark ignition.

The bypass circuit includes four wires.

- The *tach reference (purple/white)* wire comes from the ignition control (IC) module and is used by the PCM as engine speed information.
- The *ground (black/white)* wire is used to ensure that both the PCM and the ignition control module share the same ground.