CHAPTER 16

IGNITION SYSTEM OPERATION AND DIAGNOSIS

OBJECTIVES

After studying Chapter 16, the reader will be able to:

1. Prepare for Engine Repair (A1) ASE certification test content area "E" (Fuel, Electrical, Ignition, and Exhaust Systems Inspection and Service).
2. Explain how ignition coils create 40,000 volts.
3. Discuss crankshaft position sensor and pickup coil operation.
4. Describe the operation of waste-spark or coil-on-plug ignition systems.

KEY TERMS

Automatic Shutdown (ASD) (p. 269)
Base Timing (p. 277)
Coil-By-Plug (p. 267)
Coil-Near-Plug (p. 267)
Coil-On-Plug (COP) Ignition (p. 267)
Coil-Over-Plug (p. 267)
Distributor Ignition (DI) (p. 256)
Distributorless Ignition System (DIS) (p. 264)
E Coil (p. 256)
Electromagnetic Interference (EMI) (p. 267)
Electronic Control Unit (ECU) (p. 264)
Electronic Ignition (EI) (p. 256)
Electronic Ignition Module (or Igniter) (p. 257)
Electronic Ignition System (EIS) (p. 264)
Firing Order (p. 273)
High Energy Ignition (HEI) (p. 256)
Ignition Coil (p. 256)
Inductive Reactance (p. 257)
LED (p. 261)
Magnetic Pulse Generator (p. 258)
Mutual Induction (p. 257)
Polarity (p. 257)
Primary Coil Windings (p. 256)
Primary Ignition Circuit (p. 257)
Saturation (p. 257)
Secondary Coil Windings (p. 256)
Secondary Ignition Circuit (p. 257)
Self-Induction (p. 257)
Spark Tester (p. 268)
Thick-Film Integration (TFI) (p. 263)
Track (p. 270)
Transistor (p. 258)
Waste-Spark Ignition (p. 264)

The ignition system includes those parts and wiring required to generate and distribute a high voltage to the spark plugs. A fault anywhere in the primary (low-voltage) ignition circuit can cause a no-start condition. A fault anywhere in the secondary (high-voltage) ignition circuit can cause engine missing, hesitation, stalling, or excessive exhaust emissions.

IGNITION SYSTEM OPERATION

The ignition system includes components and wiring necessary to create and distribute a high voltage (up to 40,000 volts or more). All ignition systems apply voltage close to battery voltage to the positive side of the ignition coil and pulse the negative side to ground. When the coil negative lead is grounded, the primary (low-voltage) circuit of the coil is complete and a magnetic field is created by the coil windings. When the circuit is opened, the magnetic field collapses and induces a high-voltage spark from the secondary winding of the ignition coil. Early ignition systems used a mechanically opened set of contact points to make and break the electrical connection to ground. Electronic ignition uses a sensor such as a pickup coil or trigger to signal an electronic module that makes and breaks the primary connection of the ignition coil.

NOTE: 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.

IGNITION COILS

The heart of any ignition system is the **ignition coil.** The coil creates a high-voltage spark by electromagnetic induction. 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 16-1.

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. Surrounding the laminated core are approximately 20,000 turns of fine wire (approximately 42 gauge). These windings are called the **secondary coil windings.** Surrounding the secondary windings are approximately 150 turns of heavy wire (approximately 21 gauge). These windings are called the **primary coil windings.** The secondary winding has about 100 times the number of turns of the primary winding, referred to as the turn ratio (approximately 100:1). In many coils, these windings are surrounded with a thin metal shield and insulating paper and placed into a metal

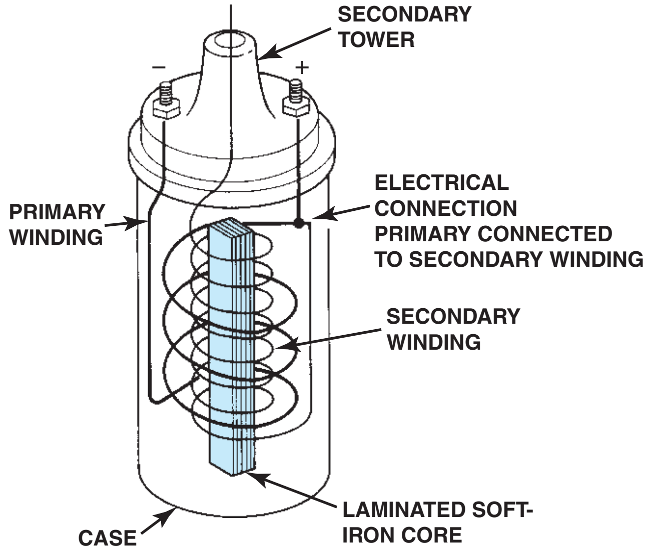


FIGURE 16-1 Internal construction of an oil-cooled ignition coil. Notice that the primary winding is electrically connected to the secondary winding. The polarity (positive or negative) of a coil is determined by the direction in which the coil is wound.

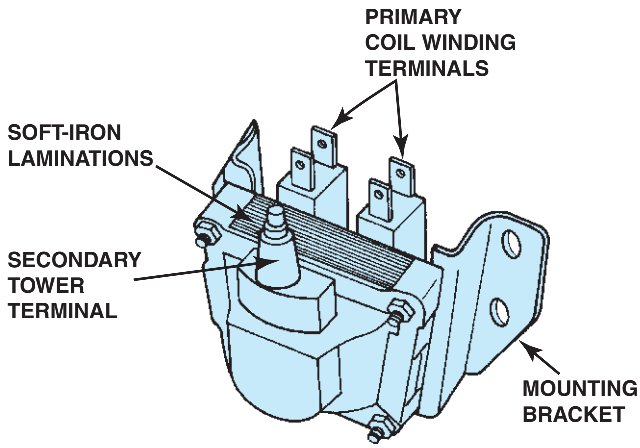


FIGURE 16-2 Typical air-cooled epoxy-filled E coil.

container. The metal container and shield help retain the magnetic field produced in the coil windings. The primary and secondary windings produce heat because of the electrical resistance in the turns of wire. Many coils contain oil to help cool the ignition coil. Other coil designs, such as those used on GM's **high energy ignition (HEI)** systems, 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 16-2 and 16-3.

The primary windings of the coil extend through the case of the coil and are labeled as positive and negative. The positive

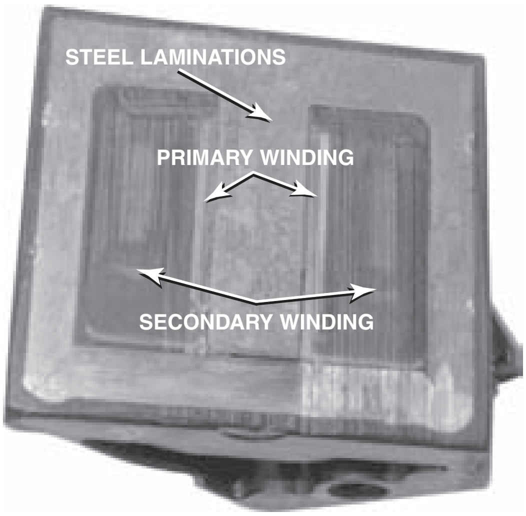


FIGURE 16-3 Cutaway of a General Motors Type II distributorless ignition coil. Note that the primary windings are inside of the secondary windings.

terminal of the coil attaches to the ignition switch, which supplies current from the positive battery terminal. The negative terminal is attached to an **electronic ignition module (or igniter),** which opens and closes the primary ignition circuit by opening or closing the ground return path of the circuit. When the ignition switch is on, current should be available at *both* the positive terminal and the negative terminal of the coil if the primary windings of the coil have continuity. The labeling of positive (+) and negative (–) of the coil indicates that the positive terminal is *more* positive (closer to the positive terminal of the battery) than the negative terminal of the coil. This condition is called the coil **polarity.** The polarity of the coil must be correct to ensure that electrons will flow from the hot center electrode of the spark plug. *The polarity of an ignition coil is determined by the direction of rotation of the coil windings.* The correct polarity is then indicated on the primary terminals of the coil. If the coil primary leads are reversed, the voltage required to fire the spark plugs is increased by 40%. The coil output voltage is directly proportional to the ratio of primary to secondary turns of wire used in the coil.

Self-Induction

When current starts to flow into a coil, an opposing current is created in the windings of the coil. This opposing current generation is caused by **self-induction** and is called **inductive reactance.** Inductive reactance is similar to resistance because it opposes any increase in current flow in a coil. Therefore, when an ignition coil is first energized, there is a slight delay of approximately 0.01 second before the ignition coil reaches its maximum magnetic field strength. The point at which a coil's maximum magnetic field strength is reached is called **saturation.**

Mutual Induction

In an ignition coil there are two windings, a primary and a secondary winding. When a *change* occurs in the magnetic field of one coil winding, a change also occurs in the other coil winding. Therefore, if the current is stopped from flowing (circuit is opened), the collapsing magnetic field cuts across the turns of the secondary winding and creates a high voltage in the secondary winding. This generation of an electric current in both coil windings is called **mutual induction.** The collapsing magnetic field also creates a voltage of up to 250 volts in the primary winding.

How Ignition Coils Create 40,000 Volts

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. The magnetic field in an ignition coil is produced by current flowing through the primary windings of the coil. The current for the primary winding is supplied through the ignition switch to the positive terminal of the ignition coil. The negative terminal is connected to the ground return through an electronic ignition module (igniter).

If the primary circuit is completed, current (approximately 2 to 6 A) can flow through the primary coil windings. This flow creates a strong magnetic field inside the coil. When the primary coil winding ground return path connection is opened, the magnetic field collapses and induces a voltage of from 250 to 400 volts in the primary winding of the coil and a high-voltage (20,000 to 40,000 volts) low-amperage (20 to 80 mA) current in the secondary coil windings. This high-voltage pulse flows through the coil wire (if the vehicle is so equipped), distributor cap, rotor, and spark plug wires to the spark plugs. For each spark that occurs, the coil must be charged with a magnetic field and then discharged. The ignition components that regulate the current in the coil primary winding by turning it on and off are known collectively as the **primary ignition circuit.** 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 16-4. These circuits include the following components.

Primary Ignition Circuit

1. Battery
2. Ignition switch
3. Primary windings of coil
4. Pickup coil (crankshaft position sensor)
5. Ignition module (igniter)

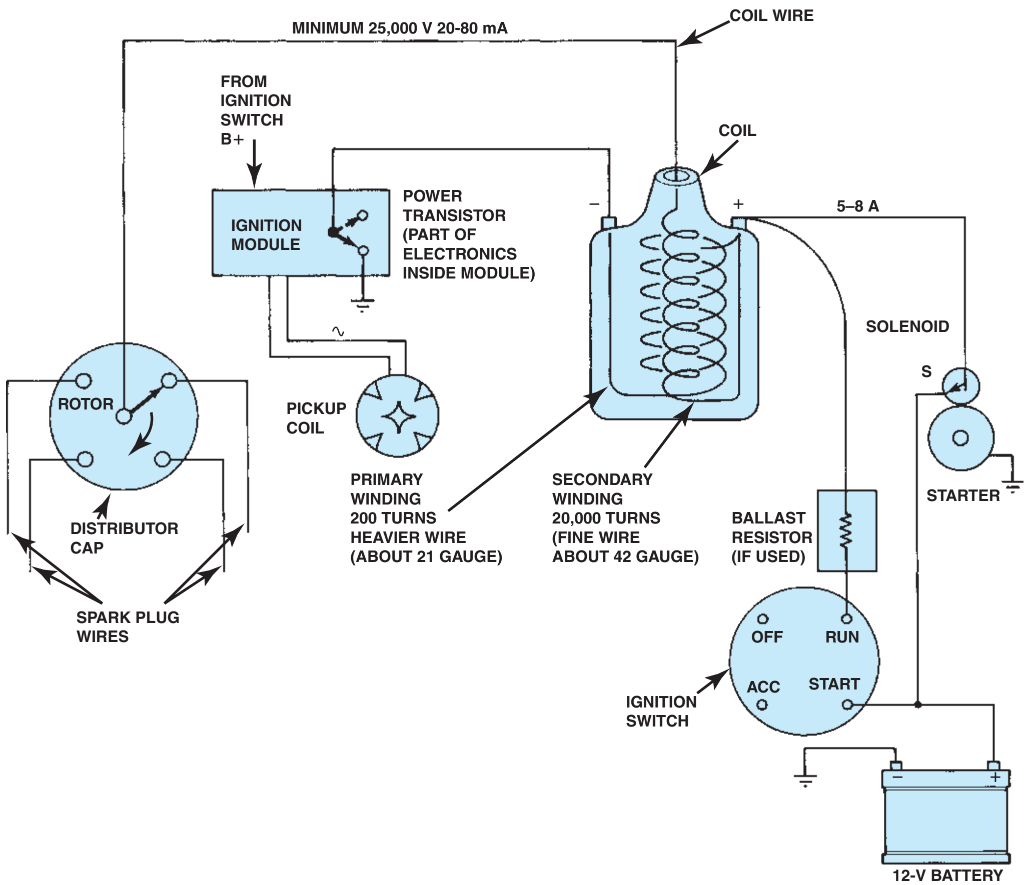


FIGURE 16-4 Typical primary and secondary electronic ignition using a ballast resistor and a distributor. To protect the ignition coil from overheating at lower engine speeds, many electronic ignitions do not use a ballast resistor, but use electronic circuits within the module.

Secondary Ignition Circuit

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

Primary Circuit Operation

To get a spark out of an ignition coil, the primary coil circuit must be turned on and off. This primary circuit current is controlled by a **transistor** (electronic switch) inside the ignition module or igniter that in turn is controlled by one of several devices, including:

- **Pickup coil (pulse generator)—**A simple and common ignition electronic switching device is the magnetic pulse generator system used in distributor ignition systems. Most manufacturers use the rotation of the distributor shaft to time the voltage pulses. The **magnetic pulse generator** 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). See Figures 16-5 and 16-6.
- **Hall-effect switch—**This switch also uses a stationary sensor and rotating trigger wheel (shutter). See Figure 16-7. Unlike the magnetic pulse generator, the Hall-effect switch requires a small input voltage to generate an output or signal voltage. Hall-effect is the ability to generate a voltage signal in semiconductor material (gallium arsenate crystal) by passing 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 in distributors have a Hall element or device, a permanent magnet, and a rotating ring of metal blades (shutters) similar to a trigger wheel (another method uses a stationary sensor with a rotating magnet). Some blades, typically found in Bosch and Chrysler systems, are designed to hang down; others, typically found

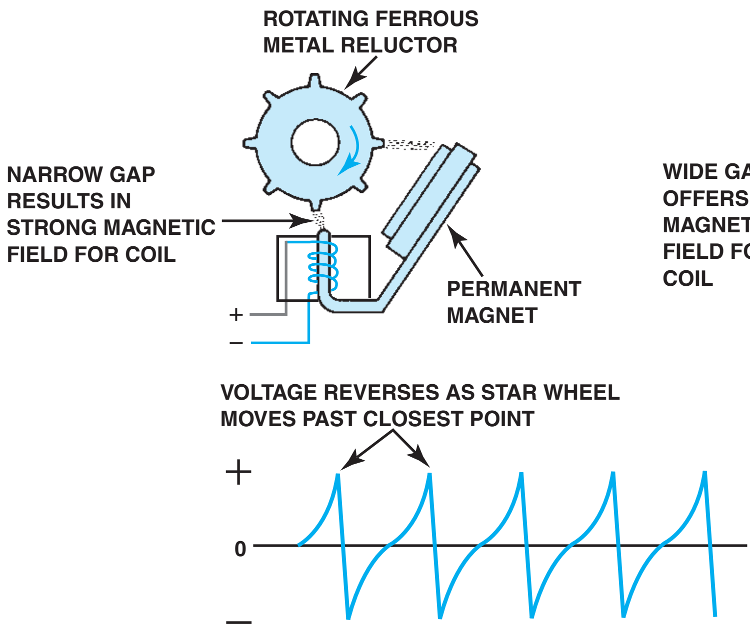


FIGURE 16-5 Operation of a typical pulse generator (pickup coil). At the bottom is a line drawing of a typical scope pattern of the output voltage of a pickup coil. The module receives this voltage from the pickup coil and opens the ground circuit to the ignition coil when the voltage starts down from its peak (just as the reluctor teeth start moving away from the pickup coil).

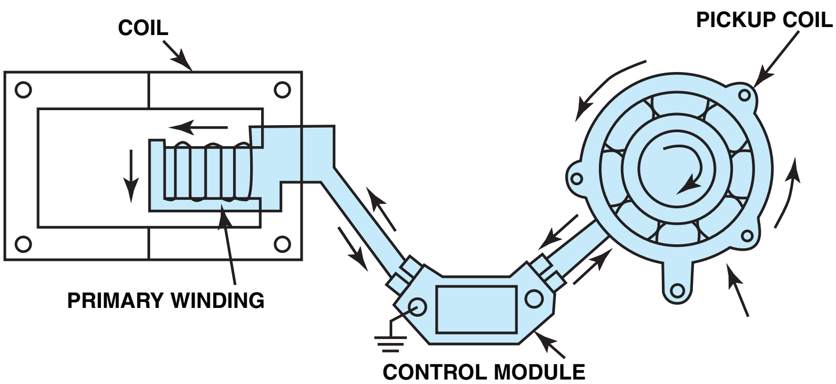


FIGURE 16-6 The varying voltage signal from the pickup coil triggers the ignition module. The ignition module grounds and ungrounds the primary winding of the ignition coil, creating a high-voltage spark.

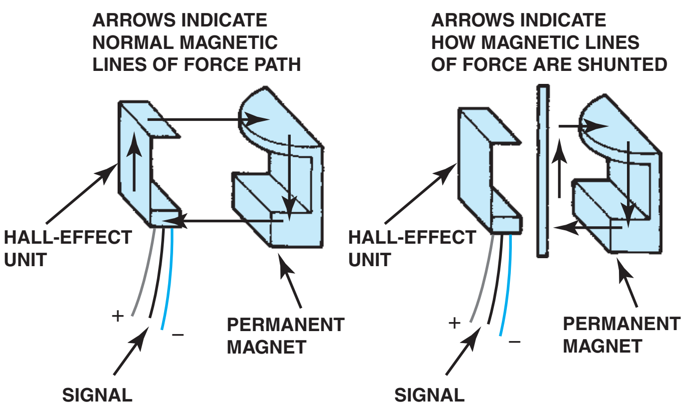


FIGURE 16-7 Hall-effect switches use metallic shutters to shunt magnetic lines of force away from a silicon chip and related circuits. All Hall-effect switches produce a square wave output for every accurate triggering.

in GM and Ford Hall-effect distributors, may be on a separate ring on the distributor shaft. 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, thereby creating an analog voltage signal. The Hall element contains a logic gate that converts the analog signal into a digital voltage signal, which triggers the switching transistor. The transistor transmits a digital square waveform at varying frequency to the ignition module or onboard computer. See Figure 16-8.

- **Magnetic crankshaft position sensors**—This sensor uses the changing strength of the magnetic field surrounding a coil of wire to signal the module and computer. This signal is used by the electronics in the module and computer as to piston position and engine speed (RPM). See Figure 16-9.

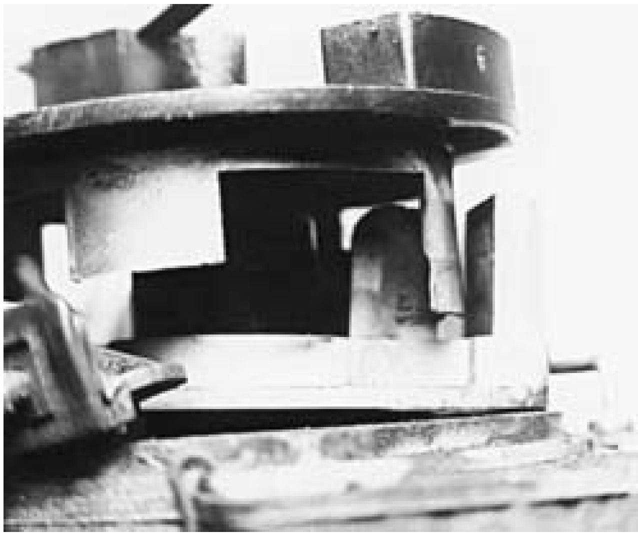


FIGURE 16-8 Shutter blade of a rotor as it passes between the sensing silicon chip and the permanent magnet.

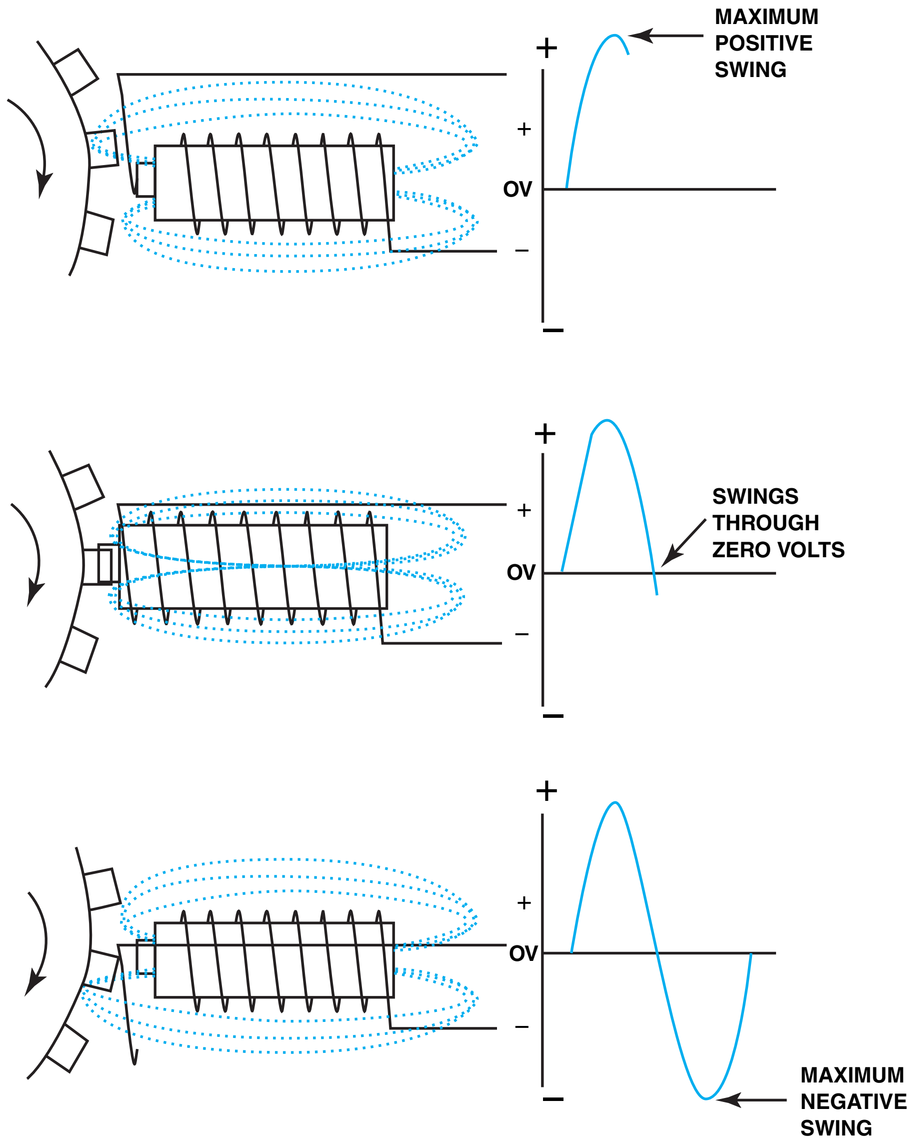


FIGURE 16-9 A magnetic sensor uses a permanent magnet surrounded by a coil of wire. The notches of the crankshaft (or camshaft) create a variable magnetic field strength around the coil. When a metallic section is close to the sensor, the magnetic field is stronger because metal is a better conductor of magnetic lines of force than air.

- **Optical sensors—**These use light from a **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. See Figure 16-10.

DISTRIBUTOR IGNITION

General Motors HEI Electronic Ignition

As mentioned, high energy ignition (HEI) has been the standard equipment DI system on General Motors vehicles since the 1975 model year. Most V-6 and V-8 models use an ignition coil inside the distributor cap. Some V-6, inline 6-cylinder, and 4- to 6-cylinder models use an externally mounted 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 arc 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 16-11. 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.

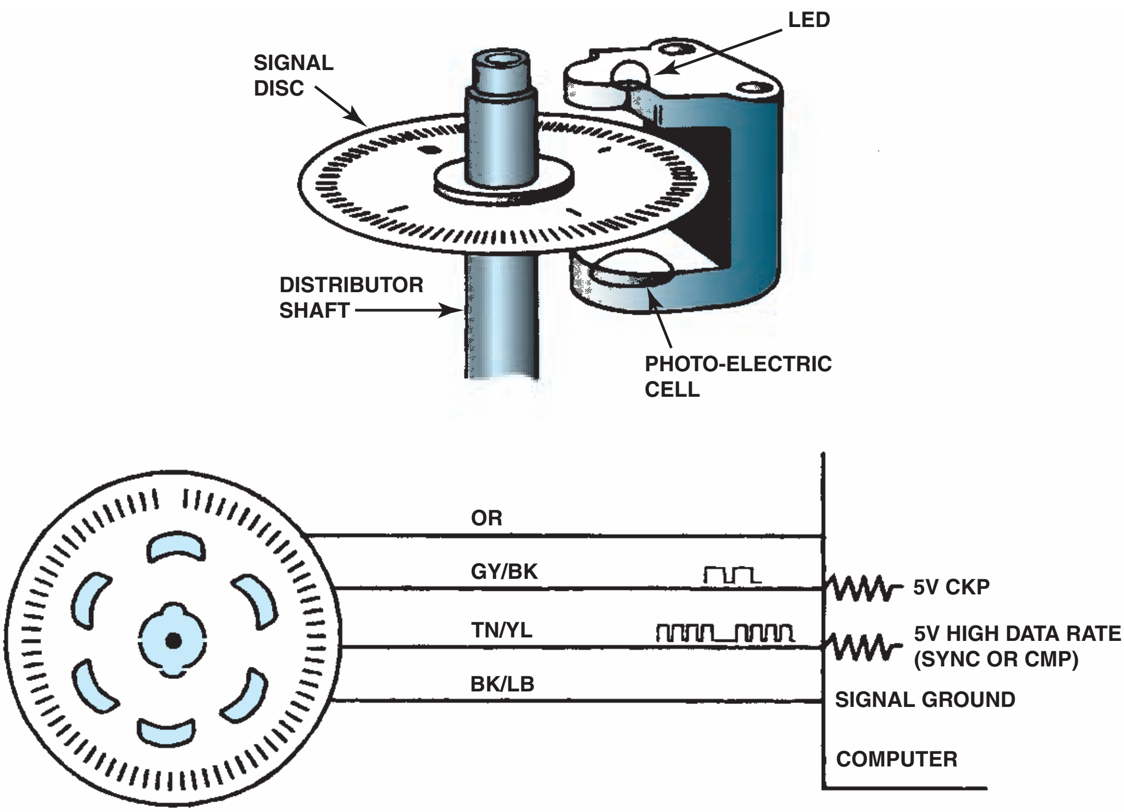
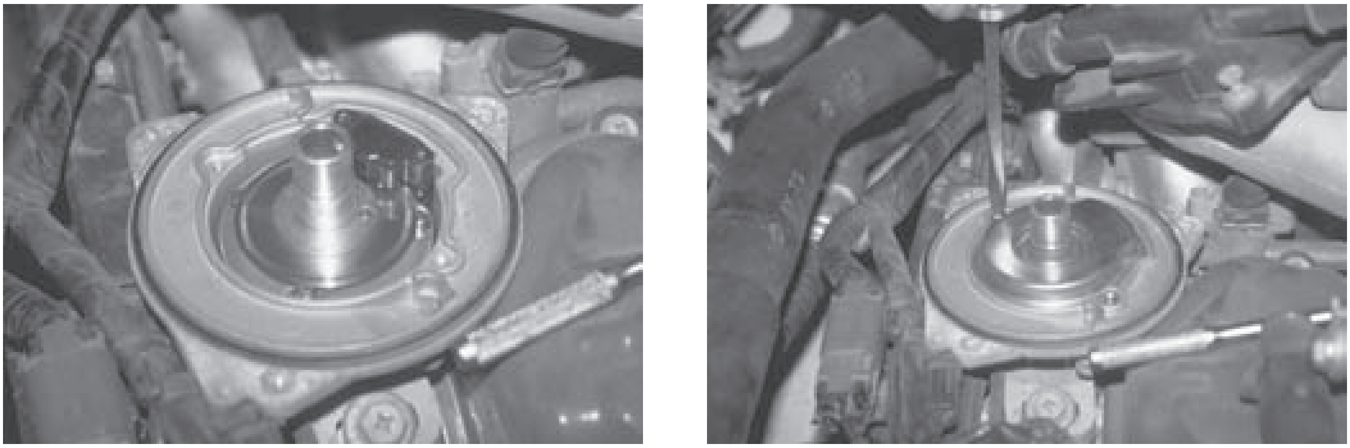


FIGURE 16-10 The small holes (slots) in the signal disc create a high-data rate used for ignition timing. The larger slots represent crankshaft position top dead center for each of the cylinders on a V-6 engine.



(a) (b)

FIGURE 16-11 (a) An optical distributor on a Nissan 3.0 liter V-6 shown with the light shield removed. (b) A light shield being installed before the rotor is attached.

TECH TIP

THE TACHOMETER TRICK

When diagnosing a no-start or intermediate missing 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 sensor
- Ignition module (igniter)
- Coil primary wiring

If the vehicle is not equipped with a tachometer, connect a handheld tachometer to the negative terminal of the coil. Remember the following:

- No tachometer reading means the problem is in the primary ignition circuit.
- A tachometer reading okay means the problem is in the secondary ignition circuit or is a fuel-related problem.

coil. See Figure 16-12. The operation of both styles is similar. The large-diameter distributor cap provides additional space between the spark plug connections to help prevent crossfire. Most HEI distributors also use 8-mm-diameter spark plug wires that use female connections to the distributor cap towers. HEI coils must be replaced (if defective) with the exact replacement style. HEI

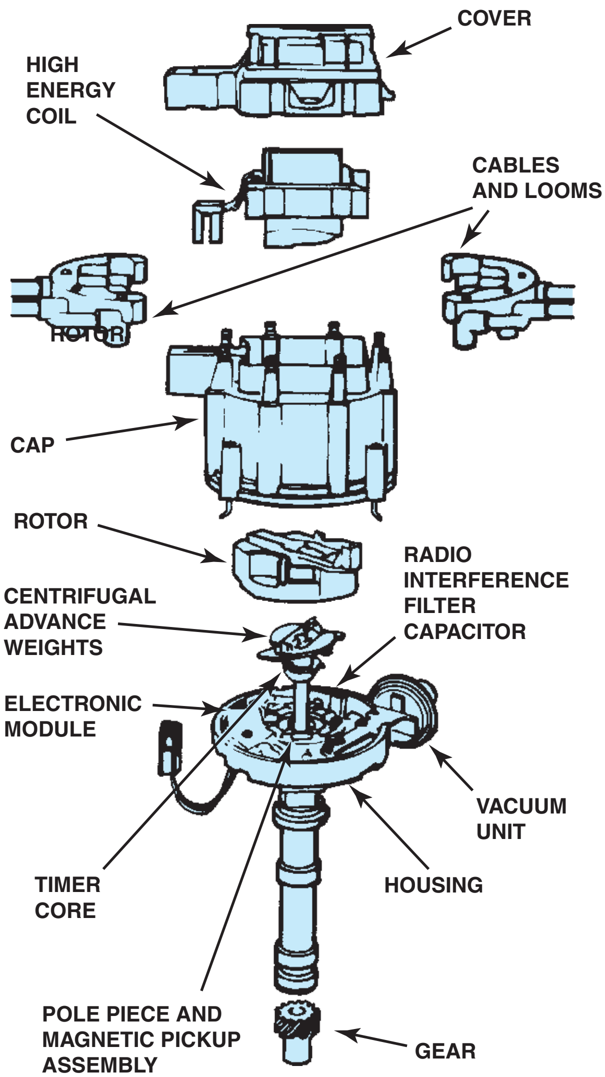


FIGURE 16-12 An HEI distributor.

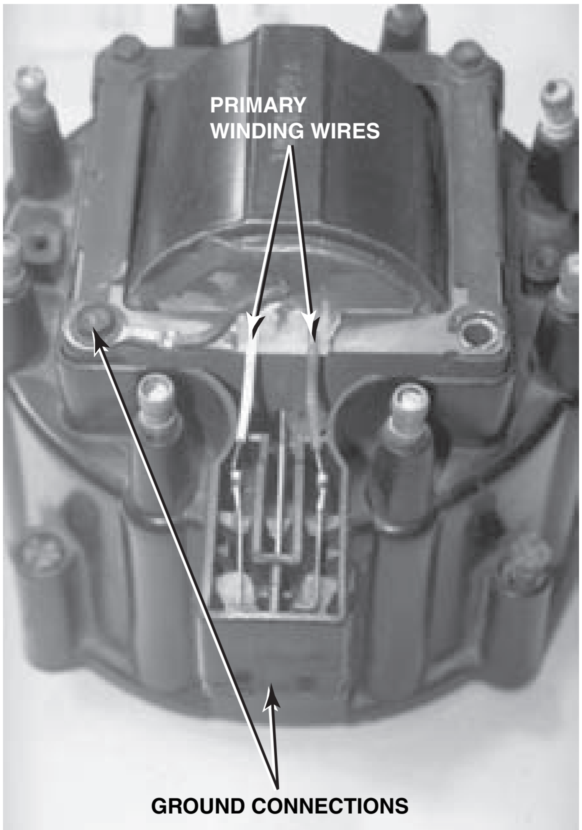


FIGURE 16-13 A typical General Motors HEI coil installed in the distributor cap. When the coil or distributor cap is replaced, check that the ground clip is transferred from the old distributor cap to the new. Without proper grounding, coil damage is likely. There are two designs of HEI coils. One uses red and white wire and the other design, which has reversed polarity, uses red and yellow wire for the primary coil.

coils differ and can be identified by the colors of the primary leads. The primary coil leads can be either white and red or yellow and red. The correct color of lead coil must be used for replacement. The colors of the leads indicate the direction in which the coil is wound, and therefore its polarity. See Figure 16-13.

Ford Electronic Ignition

Ford electronic ignition systems all function similarly, even though the name for the Ford EI system has changed many times since 1974. See Figure 16-14.

Ford Thick-Film-Integrated Ignition

The EEC IV system uses the **thick-film-integration (TFI)** ignition system. This system uses a smaller control module attached to the distributor and uses an air-cooled epoxy E coil. Thick-film integration means that all electronics are manufactured on small layers built up to form a thick film. Construction includes using pastes of different electrical resistances that are deposited on a thin, flat ceramic material by a process similar to silk-screen printing. These resistors are connected by tracks of palladium silver paste. Then the chips that form the capacitors, diodes, and integrated circuits are soldered directly to the palladium silver tracks. The thick-film manufacturing process is highly automated.

Operation of Ford Electronic Ignition

Ford EI systems function in basically the same way regardless of year and name (Duraspark, EEC, etc.). Under the distributor cap and rotor is a magnetic pickup assembly. This assembly produces a small alternating electrical pulse (approximately 1.5 volts) when the distributor armature rotates past the pickup assembly (stator). This low-voltage pulse is sent to the ignition module. The ignition module then switches (through transistors) off the primary ignition coil current. When the ignition coil primary current is stopped quickly, a high-voltage "spike" discharges from the coil secondary winding. Some Ford EI systems use a ballast resistor to help control the primary current through the ignition coil in the run mode (position); other Ford systems do not use a ballast resistor. The coil current is controlled in the module circuits by decreasing dwell (coil-charging time) depending on various factors determined by operating conditions. See Figure 16-15 on page 265.

TECH TIP

IF IT'S SOFT, THROW IT AWAY

Ford used a Hall-effect sensor in the distributor on most TFI module-equipped engines. The sensors were originally coated in a black plastic that would often become soft with age and break down electrically. The soft plastic sensor would also prevent proper connection to the TFI module, as shown in Figure 16-16 on page 266. If a no-start or rough engine operation occurs, always check the Hall-effect sensor and the connections to the module. The original Hall-effect units were black plastic and more prone to failure. Ozone formed by the high-voltage arcing in the distributor cap is highly corrosive, and it chemically attaches to the plastic. The plastic then becomes soft, pliable, and similar to tar in feel and texture. If the sensor is soft like tar, replace the Hall-effect switch assembly. Later production units use a more chemically stable white plastic material that is soft but not sticky.

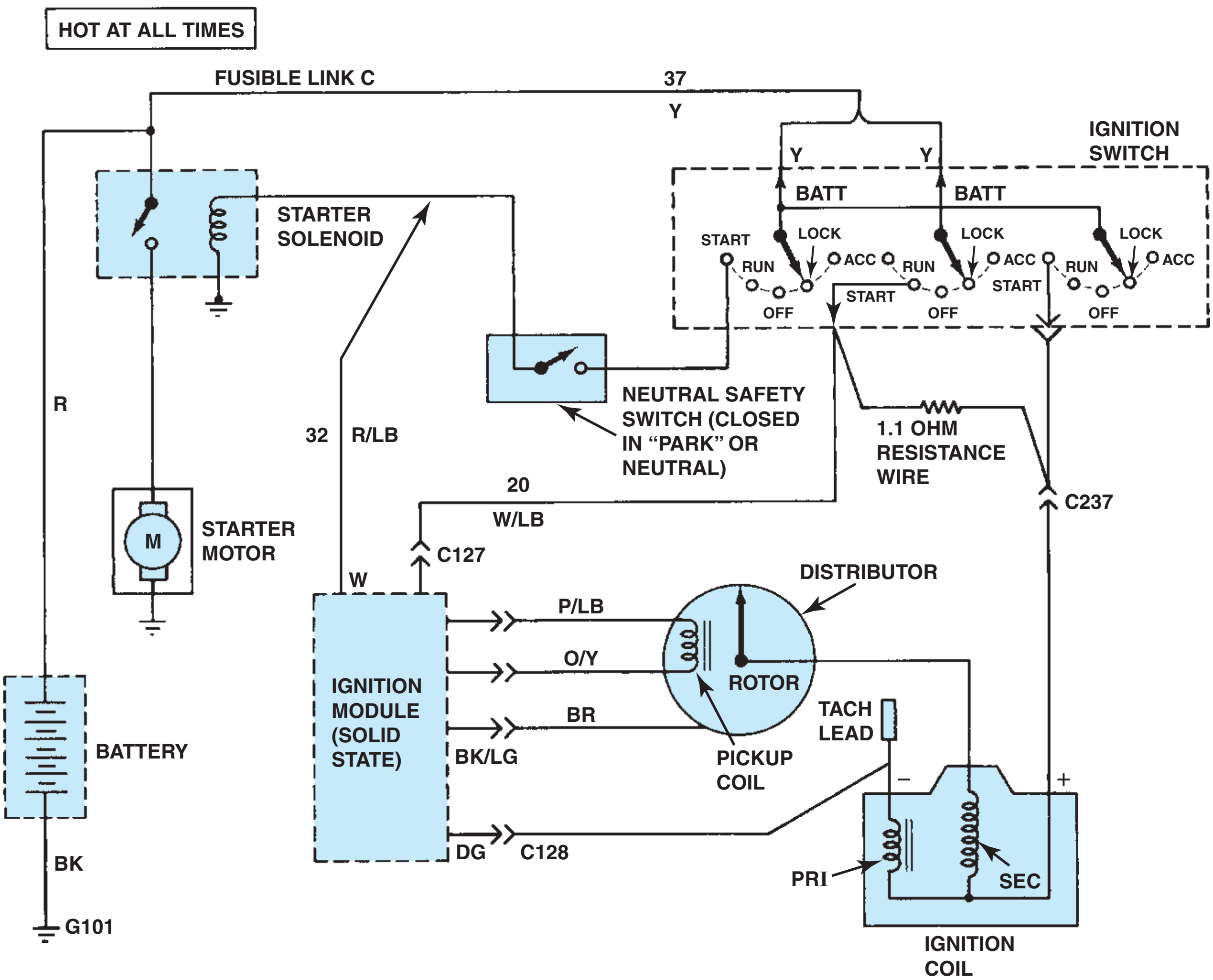


FIGURE 16-14 Wiring diagram of a typical Ford electronic ignition.

Chrysler Electronic Ignition

Chrysler was the first domestic manufacturer to produce electronic ignition as standard equipment. The Chrysler system consists of a pulse generator unit in the distributor (pickup coil and reluctor). Chrysler's name for their electronic ignition is **electronic ignition system (EIS),** and the control unit (module) is called the **electronic control unit (ECU).**

The pickup coil in the distributor (pulse generator) generates the signal to open and close the primary coil circuit. See Figure 16-17 on page 266.

WASTE-SPARK IGNITION SYSTEMS

Waste-spark ignition is another name for **distributorless ignition system (DIS)** or **electronic ignition (EI).** Waste-spark ignition was introduced in the mid-1980s and uses the onboard computer to fire the ignition coils. These systems were first used on some Saabs and General Motors engines. Some 4-cylinder engines use four coils, but usually a 4-cylinder engine uses two ignition coils and a 6-cylinder engine uses three ignition coils. Each coil is a true transformer in which the primary winding and secondary winding are not electrically connected. Each end of the secondary winding is connected to a cylinder exactly opposite the other in the firing order. See Figure 16-18 on page 266. This means that *both* spark plugs fire at the same time! When one cylinder (for example, 6) is on the compression stroke, the other cylinder (3) is on the exhaust stroke. This 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 and provides the *ground circuit* for the secondary coil

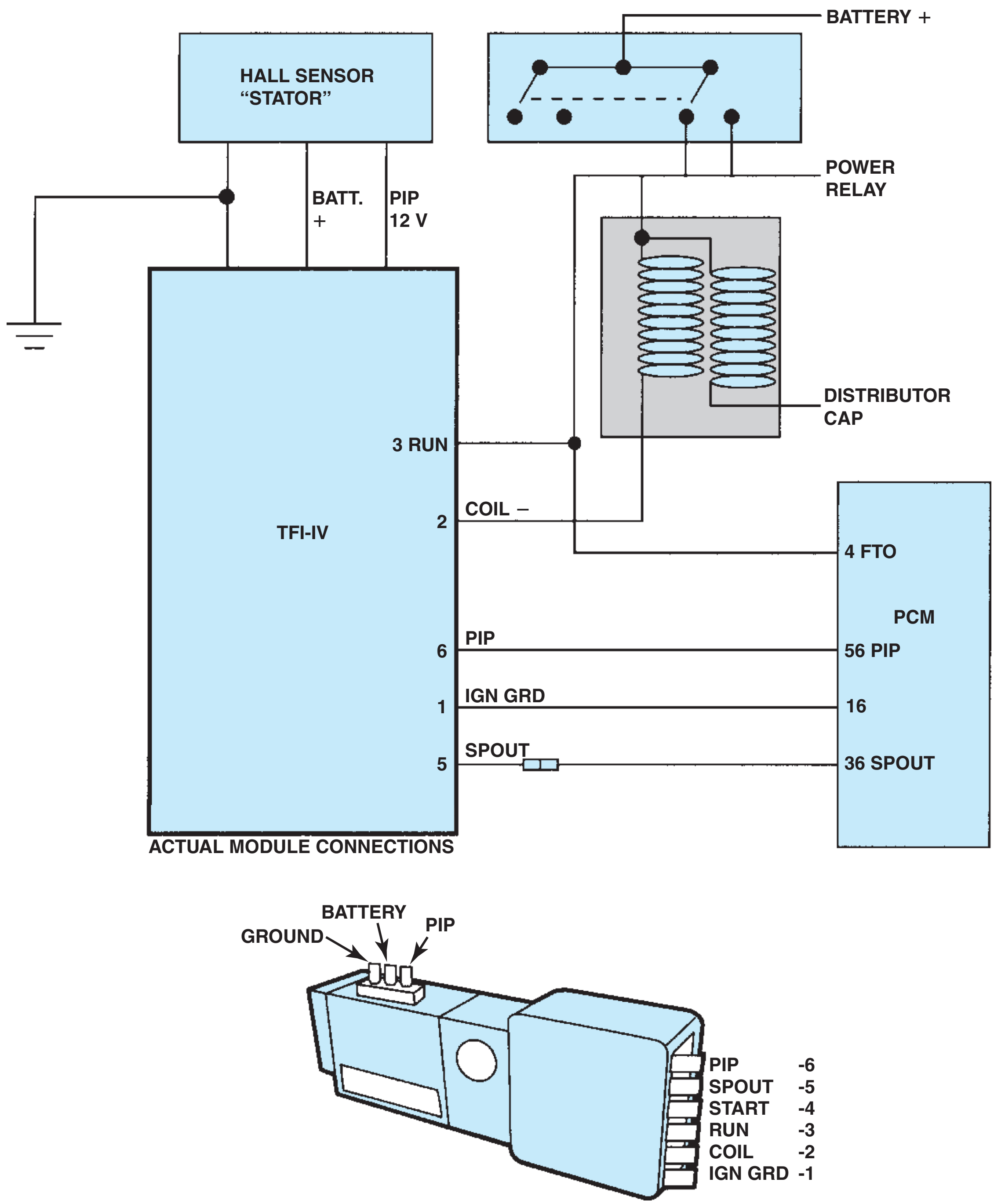


FIGURE 16-15 Schematic of a Ford TFI-IV ignition system. The SPOUT connector is unplugged when ignition timing is being set.

circuit. The remaining coil energy is used by the cylinder on the compression stroke. One spark plug of each pair fires straight polarity and the other cylinder fires reverse polarity. 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.

NOTE: With a distributor-type ignition system, the coil has two air gaps to fire: one between the rotor tip and the distributor insert (not under compression forces) and the other in the gap at the firing tip of the spark plug (under compression forces). A DIS also fires two gaps: one under compression (compression stroke plug) and one not under compression (exhaust stroke plug).

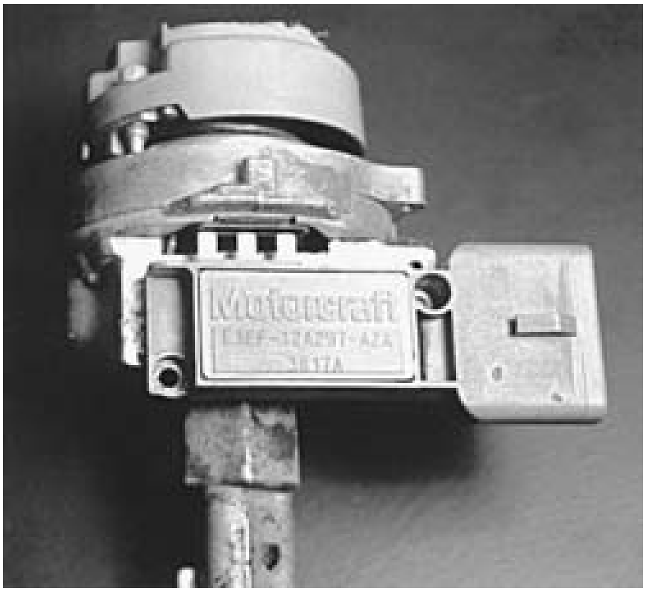


FIGURE 16-16 Thick-film-integrated type of Ford EI. Note how the module plugs into the Hall-effect switch inside the distributor. Heat-conductive silicone grease should be used between the module and the distributor mounting pad to help keep the electronic circuits inside the module cool.

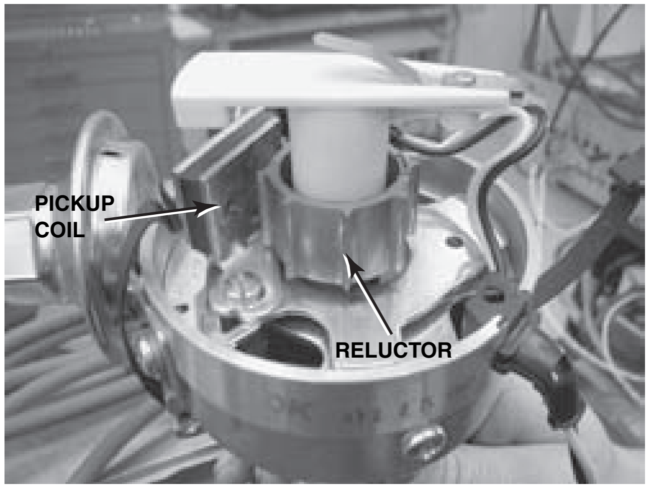


FIGURE 16-17 A Chrysler electronic ignition distributor. This unit is equipped with a vacuum advance mechanism that advances the ignition timing under light engine load conditions.

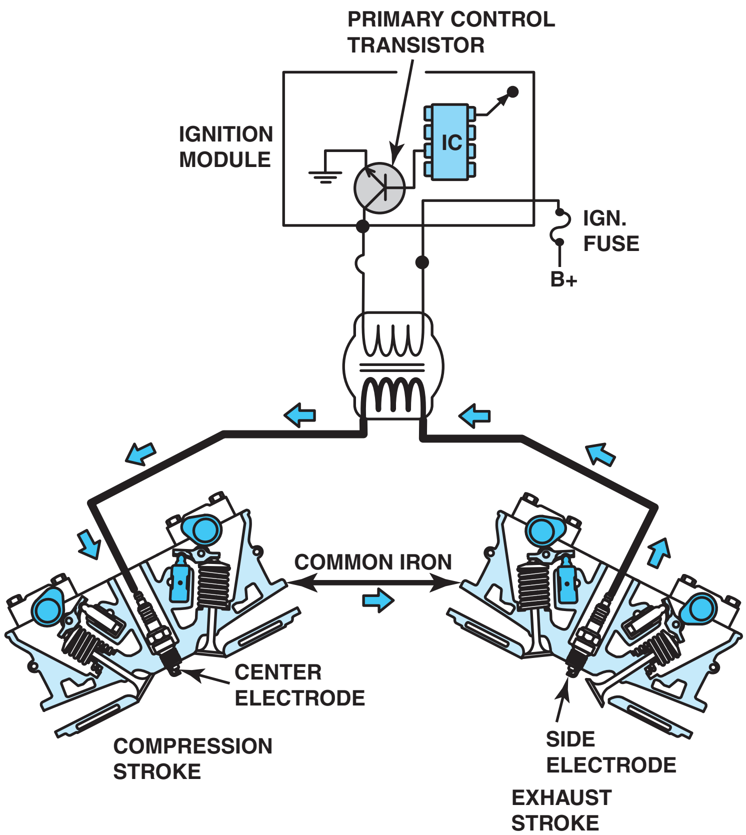


FIGURE 16-18 A waste-spark system fires one cylinder while its piston is on the compression stroke and into paired or companion cylinders while it is on the exhaust stroke. In a typical engine, it requires only about 2 to 3 kV to fire the cylinder on the exhaust strokes. The remaining coil energy is available to fire the spark plug under compression (typically about 8 to 12 kV).

Waste-spark ignitions require a sensor (usually a crankshaft sensor) to trigger the coils at the correct time. See Figure 16-19. The crankshaft sensor cannot be moved to adjust ignition timing. 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. Some engines do not use a camshaft position sensor, but rather double Hall-effect

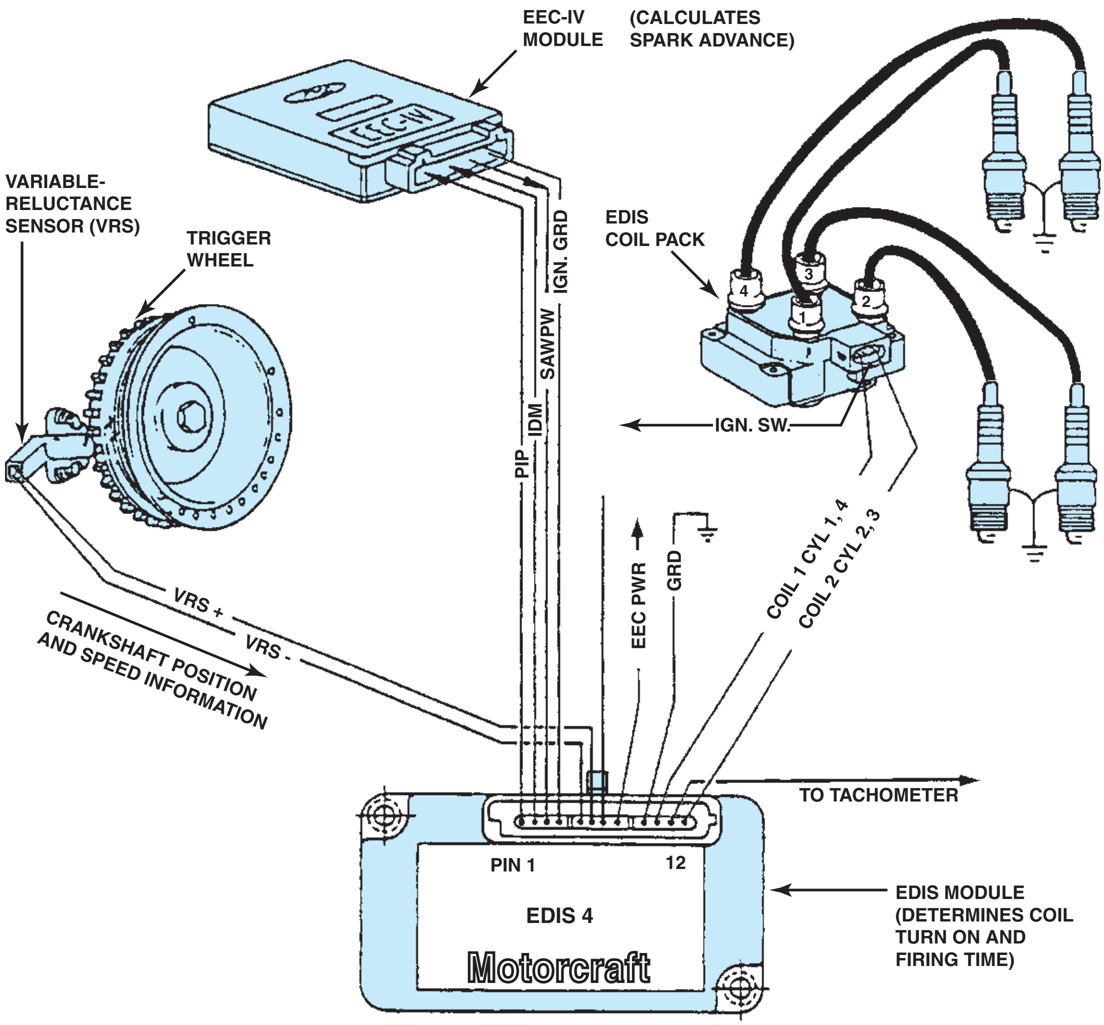


FIGURE 16-19 Typical Ford EDIS 4-cylinder ignition system. The crankshaft sensor, called a variable-reluctance sensor (VRS), sends crankshaft position and speed information to the EDIS module. A modified signal is sent to the computer as a profile ignition pickup (PIP) signal. The PIP is used by the computer to calculate ignition timing, and the computer sends a signal back to the EDIS module as to when to fire the spark plug. This return signal is called the spark angle word (SAW) signal.

crankshaft sensors and, again, ignition timing is not adjustable. See Figure 16-20.

COIL-ON-PLUG IGNITION

Coil-on-plug (COP) ignition uses one ignition for each spark plug. This system is also called **coil-by-plug, coil-near-plug,** or **coil-over-plug** ignition. The coil-on-plug system eliminates the spark plug wires which are often sources of **electromagnetic interference (EMI)** that can cause problems to some computer signals. The vehicle computer pulses the ground terminal of each coil at the proper time. Ignition timing also can be changed (retarded or advanced) on a cylinder-by-cylinder basis for maximum performance and to respond to knock sensor signals. See Figure 16-21.

General Motors vehicles use a variety of coil-on-plug-type ignition systems. Many V-8 engines use a coil-near-plug system with individual coils and modules for each individual cylinder that are 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.

Most newer Chrysler 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.

CHECKING FOR SPARK

In the event of a no-start condition, the first step should be to check for secondary voltage out of the ignition coil or to the

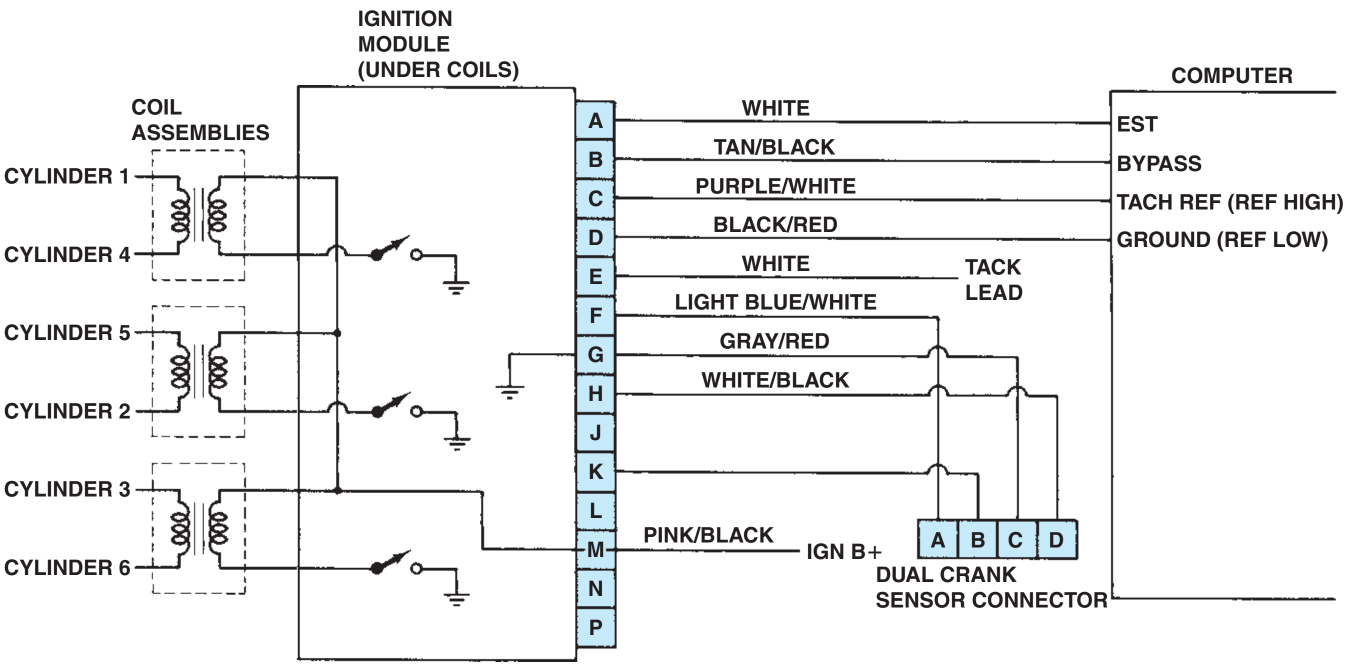


FIGURE 16-20 Typical wiring diagram of a V-6 distributorless (direct fire) ignition system.

FIGURE 16-21 Individual coils with modules shown on the General Motors 4.2 L inline 6-cylinder light truck engine. Note the aluminum cooling fins (heat sink) on top of each assembly.

spark plugs. If the engine is equipped with a separate ignition coil, remove the coil wire from the center of the distributor cap, install a **spark tester,** and crank the engine. See the Tech Tip "Always Use a Spark Tester." A good coil and ignition system should produce a blue spark at the spark tester. See Figure 16-22.

If the ignition system being tested does not have a separate ignition coil, disconnect any spark plug wire from a spark plug and, while cranking the engine, test for spark available at the spark plug wire, again using a spark tester.

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.

NOTE: An intermittent spark should be considered a no-spark condition.

Typical causes of a no-spark (intermittent spark) condition include the following:

1. Weak ignition coil
2. Low or no voltage to the primary (positive) side of the coil
3. High resistance or open coil wire, or spark plug wire

FIGURE 16-22 Using a spark tester on an engine with direct-fire (distributorless) ignition. The spark tester is grounded to the rocker cover stud. This is the recommended type of spark tester, with the center electrode recessed into the center insulator.

4. Negative side of the coil not being pulsed by the ignition module
5. Defective pickup coil
6. Defective module

ELECTRONIC IGNITION TROUBLESHOOTING PROCEDURE

When troubleshooting any electronic ignition system for no spark, follow these steps to help pinpoint the exact cause of the problem:

1. Turn the ignition on (engine off) and, using either a voltmeter or a test light, test for battery voltage available at the positive terminal of the ignition coil. If the voltage is not available, check for an open circuit at the ignition switch or wiring. Also check the condition of the ignition fuse (if used).

   NOTE: Many Chrysler products use an **automatic shutdown (ASD)** relay to power the ignition coil. The ASD relay will not supply voltage to the coil unless the engine is cranking and the computer senses a crankshaft sensor signal. This little fact has fooled many technicians.

TECH TIP

ALWAYS USE A SPARK TESTER

A spark tester looks like a spark plug without a side electrode, with a gap between the center electrode and the grounded shell. The tester commonly has an alligator clip attached to the shell so that it can be clamped on a good ground connection on the engine. A good ignition system should be able to cause a spark to jump this wide gap at atmospheric pressure. Without a spark tester, a technician might assume that the ignition system is okay, because it can spark across a normal, grounded spark plug. The voltage required to fire a standard spark plug when it is out of the engine and not under pressure is about 3,000 volts or less. An electronic ignition spark tester requires a minimum of 25,000 volts to jump the 3/4-in. gap. Therefore, never assume that the ignition system is okay because it fires a spark plug—always use a spark tester. *Remember that an intermittent spark across a spark tester should be interpreted as a no-spark condition.*

2. Connect the voltmeter or test light to the negative side of the coil and crank the engine. The voltmeter should fluctuate or the test light should blink, indicating that the primary coil current is being turned on and off. If there is no pulsing of the negative side of the coil, then the problem is a defective pickup, electronic control module, or wiring.

IGNITION COIL TESTING USING AN OHMMETER

If an ignition coil is suspected of being defective, a simple ohmmeter check can be performed to test the resistance of the primary and secondary winding inside the coil. For accurate resistance measurements, the wiring to the coil should be removed before testing. To test the primary coil winding resistance, take the following steps:

1. Set the meter to read low ohms.
2. Measure the resistance between the positive terminal and the negative terminal of the ignition coil. Most coils will give a reading between 1 and 3 ohms; however, some coils should indicate less than 1 ohm. Check the manufacturer's specifications for the exact resistance values.

To test the secondary coil winding resistance, follow these steps:

1. Set the meter to read kilohms (kΩ).
2. Measure the resistance between either primary terminal and the secondary coil tower. The normal resistance of most coils ranges between 6,000 and 30,000 ohms. Check the manufacturer's specifications for the exact resistance values.

NOTE: Many ignition coils use a screw that is inside the secondary tower of the ignition coil. If this screw is loose, an intermittent engine miss could occur. The secondary coil would also indicate high resistance if this screw was loose.

PICKUP COIL TESTING

The pickup coil, located under the distributor cap on many electronic ignition engines, can cause a no-spark condition if defective. The pickup coil must generate an AC voltage pulse to the ignition module so that the module can pulse the ignition coil.

A pickup coil contains a coil of wire, and the resistance of this coil should be within the range specified by the manufacturer. See Figure 16-23. Some common specifications include the following:

Manufacturer	*Pickup Coil Resistance (ohms)*
General Motors	500–1,500 (white and green leads)
Ford	400–1,000 (orange and purple leads)
Chrysler	150–900 (orange and black leads)

If the pickup coil resistance is not within the specified range, replace the pickup coil assembly.

FIGURE 16-23 Measuring the resistance of an HEI pickup coil using a digital multimeter set to the ohms position. The reading on the face of the meter is 0.796 KΩ or 796 ohms right in the middle of the 500 to 1500 ohm specifications.

The pickup coil can also be tested for proper voltage output. During cranking, most pickup coils should produce a minimum of 0.25 volt AC. This can be tested with the distributor out of the vehicle by rotating the distributor drive gear by hand.

TESTING MAGNETIC SENSORS

First of all, magnetic sensors must be magnetic. If the permanent magnet inside the sensor has cracked, the result is two weak magnets.

If the sensor is removed from the engine, hold a metal (steel) object against the end of the sensor. It should exert a strong magnetic pull on the steel object. If not, replace the

TECH TIP

BAD WIRE? REPLACE THE COIL!

When performing engine testing (such as a compression test), always ground the coil wire. Never allow the coil to discharge without a path to ground for the spark. High-energy electronic ignition systems can produce 40,000 volts or more of electrical pressure. If the spark cannot spark to ground, the coil energy can (and usually does) arc inside the coil itself, creating a low-resistance path to the primary windings or the steel laminations of the coil. See Figure 16-24. This low-resistance path is called a **track** and could cause an engine miss under load even though all of the remaining component parts of the ignition system are functioning correctly. Often these tracks do not show up on any coil test, including most scopes. Because the track is a lower-resistance path to ground than normal, it requires that the ignition system be put under a load for it to be detected, and even then, the problem (engine missing) may be intermittent.

Therefore, when disabling an ignition system, perform one of the following procedures to prevent possible ignition coil damage:

1. Remove the power source wire from the ignition system to prevent any ignition operation.
2. On distributor-equipped engines, remove the secondary coil wire from the center of the distributor cap and connect a jumper wire between the disconnected coil wire and a good engine ground. This ensures that the secondary coil energy will be safely grounded and prevents high-voltage coil damage.

sensor. Second, the sensor can be tested using a digital meter set to read AC volts.

TESTING HALL-EFFECT SENSORS

As with any other sensor, the output of the Hall-effect sensor should be tested first. Using a digital voltmeter, check for the presence of an AC voltage when the engine is being cranked. The best test is to use an oscilloscope and observe the waveform.

TESTING OPTICAL SENSORS

Optical sensors will not operate if dirty or covered in oil. Perform a thorough visual inspection looking for an oil leak that could cause dirty oil to get on the LED or phototransistor. Also be sure that the light shield is securely fastened and that the seal is lightproof. An optical sensor can also be checked using an oscilloscope or a digital multimeter set to read AC volts.

IGNITION SYSTEM DIAGNOSIS USING VISUAL INSPECTION

One of the first steps in the diagnosis process is to perform a thorough visual inspection of the ignition system, including the following items:

- Check all spark plug wires for proper routing. All plug wires should be in the factory wiring separator and be clear of any metallic object that could cause damage to the insulation and cause a short-to-ground fault. See Figure 16-25.
- Check that all spark plug wires are securely attached to the spark plugs and to the distributor cap or ignition coil(s).
- Check that all spark plug wires are clean and free from excessive dirt or oil. Check that all protective covers normally covering the coil and/or distributor cap are in place and not damaged.
- Remove the distributor cap and carefully check the cap and distributor rotor for faults. See Figures 16-26 and 16-27.
- Remove the spark plugs and check for excessive wear or other visible faults. Replace if needed.

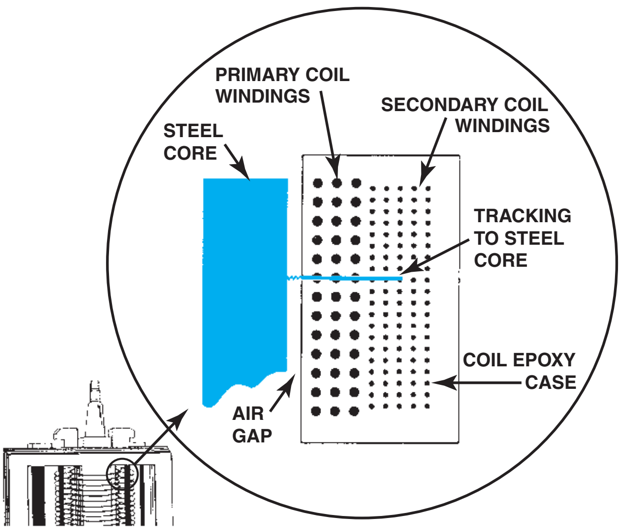


FIGURE 16-24 A track inside an ignition coil is not a short, but rather a low-resistance path or hole that has been burned through from the secondary wiring to the steel core.

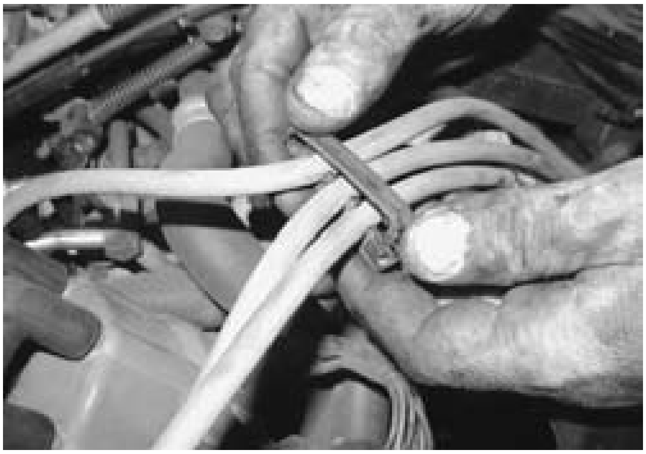


FIGURE 16-25 Always take the time to install spark plug wires back into the original holding brackets (wiring combs).

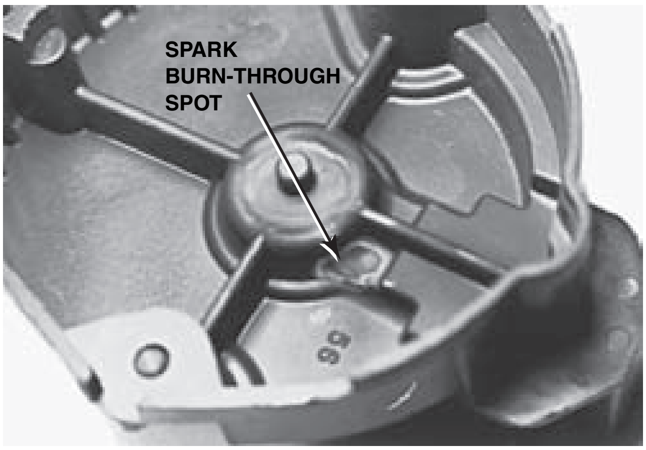


FIGURE 16-26 Note where the high voltage spark jumped through the plastic rotor to arc into the distributor shaft. Always check for a defective spark plug(s) whenever a defective distributor cap or rotor is discovered. If a spark cannot jump to a spark plug, then it tries to find a ground path wherever it can.

FIGURE 16-27 This distributor cap came off a GM V-8 engine that was starting and running okay. The only problem seemed to be a "snapping" noise heard in the distributor.

NOTE: According to research conducted by General Motors, about one-fifth (20%) of all faults are detected during a *thorough visual inspection!*

TESTING FOR POOR PERFORMANCE

Many diagnostic equipment manufacturers offer methods for testing distributorless ignition systems on an oscilloscope. If using this type of equipment, follow the manufacturer's recommended procedures and interpretation of the specific test results.

A simple method of testing distributorless (waste-spark systems) ignition with the engine off involves removing the spark plug wires (or connectors) from the spark plugs (or coils or distributor cap) and installing short lengths (2 in.) of rubber vacuum hose in series.

NOTE: For best results, use rubber hose that is electrically conductive. Measure the vacuum hose with an ohmmeter. Suitable vacuum hose should give a reading of less than 10,000 ohms (10 kΩ) for a length of about 2 in. See Figure 16-28.

1. Start the engine and ground out each cylinder one at a time by touching the tip of a grounded test light to the rubber vacuum hose. Even though the computer will increase idle speed and fuel delivery to compensate for the grounded spark plug wire, a technician should watch for a change in the operation of the engine. If no change is observed or heard, the cylinder being grounded is obviously weak or defective. Check the spark plug wire or connector with an ohmmeter to be certain of continuity.

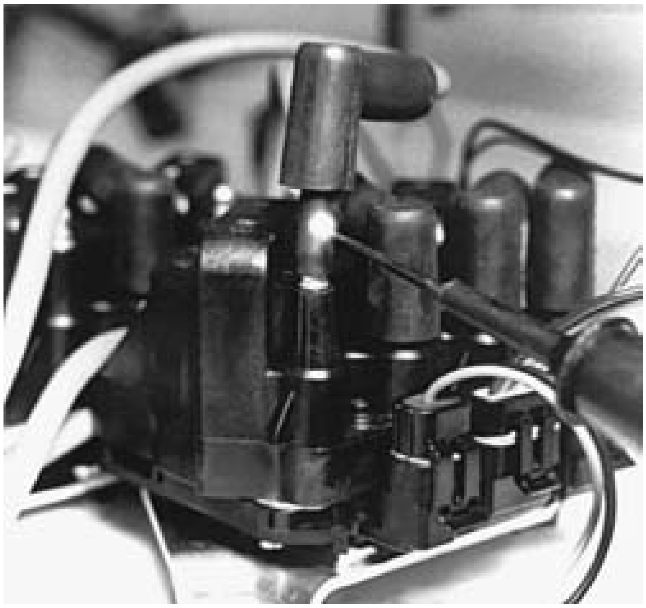


FIGURE 16-28 Using a vacuum hose and a grounded test light to ground one cylinder at a time on a DIS. This works on all types of ignition systems and provides a method for grounding out one cylinder at a time without fear of damaging any component.

2. Check all cylinders by grounding them out one at a time. If one weak cylinder is found, check the other cylinder using the same ignition coil (except on engines that use an individual coil for each cylinder). If both cylinders are affected, the problem could be an open spark plug wire, defective spark plug, or defective ignition coil.
3. To help eliminate other possible problems and determine exactly what is wrong, switch the suspected ignition coil to another position (if possible).
   - If the problem now affects the other cylinders, the ignition coil is defective and must be replaced.
   - If the problem does not "change positions," the control module affecting the suspected coil or either cylinder's spark plug or spark plug wire could be defective.

TESTING FOR A NO-START CONDITION

A no-start condition (with normal engine cranking speed) can be the result of either no spark or no fuel delivery.

Computerized engine control systems use the ignition primary pulses as a signal to inject fuel—a port or throttle-body injection (TBI) style of fuel-injection system. If there is no pulse, then there is no squirt of fuel. To determine exactly what is wrong, follow these steps:

1. Test the output signal from the crankshaft sensor. Most computerized engines with distributorless ignitions use a

crankshaft position sensor. These sensors are either the Hall-effect type or the magnetic type. The sensors must be able to produce a variable (either sine or digital) signal. A meter set on AC volts should read a voltage across the sensor leads when the engine is being cranked. If there is no AC voltage output, replace the sensor.

2. If the sensor tests okay in step 1, check for a changing AC voltage signal at the ignition module.

NOTE: Step 2 checks the wiring between the crankshaft position sensor and the ignition control module.

3. If the ignition control module is receiving a changing signal from the crankshaft position sensor, it must be capable of switching the power to the ignition coils on and off. Remove a coil or coil package, and with the ignition switched to on (run), check for voltage at the positive terminal of the coil(s).

NOTE: **Several manufacturers program the current to the coils to be turned off within several seconds of the ignition being switched to on if no pulse is received by the computer. This circuit design helps prevent ignition coil damage in the event of a failure in the control circuit or driver error, by keeping the ignition switch on (run) without operating the starter (start position). Some Chrysler engines do not supply power to the positive (+) side of the coil until a crank pulse is received by the computer.**

If the module is not pulsing the negative side of the coil or not supplying battery voltage to the positive side of the coil, replace the ignition control module.

NOTE: **Before replacing the ignition control module, be certain that it is properly grounded (where applicable) and that the module is receiving ignition power from the ignition circuit.**

CAUTION: **Most distributorless (waste spark) ignition systems can produce 40,000 volts or more, with energy levels high enough to cause personal injury. Do not open the circuit of an electronic ignition secondary wire, because damage to the system (or to you) can occur.**

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 design. The firing order is determined by 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, as shown in Figure 16-29. Most service manuals also show the firing order and the direction of the distributor rotor rotation, as well as the location of the spark plug wires on the distributor cap.

FIGURE 16-29 The firing order is cast or stamped on the intake manifold on most engines that have a distributor ignition.

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-6s 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.**

Firing order is also important for waste-spark-type distributorless (direct-fire) ignition systems. The spark plug wire can often be installed on the wrong coil pack that can create a no-start condition or poor engine operation.

SPARK PLUG WIRE INSPECTION

Spark plug wires should be visually inspected for cuts or defective insulation and checked for resistance with an ohmmeter. Good spark plug wires should measure less than 10,000 ohms per foot of length. See Figure 16-30. Faulty spark plug wire insulation can cause hard starting or no starting in damp weather conditions.

SPARK PLUG SERVICE

Spark plugs should be inspected when an engine performance problem occurs and should be replaced regularly to ensure proper ignition system performance. Many spark plugs have a service life of over 20,000 miles (32,000 kilometers). Platinum-tipped original equipment spark plugs have a typical service life of 60,000 to 100,000 miles (100,000 to 160,000 kilometers). Used spark plugs should *not* be cleaned and reused unless

TECH TIP

SPARK PLUG WIRE PLIERS ARE A GOOD INVESTMENT

Spark plug wires are often difficult to remove. Using good-quality spark plug wire pliers, such as shown in Figure 16-31, saves time and reduces the chance of harming the wire during removal.

FIGURE 16-30 Measuring the resistance of a spark plug wire with a multimeter set to the ohms position. The reading of 16.03 kΩ (16,030 ohms) is okay because the wire is about 2 ft long. Maximum allowable resistance for a spark plug wire this long would be 20 kΩ (20,000 ohms).

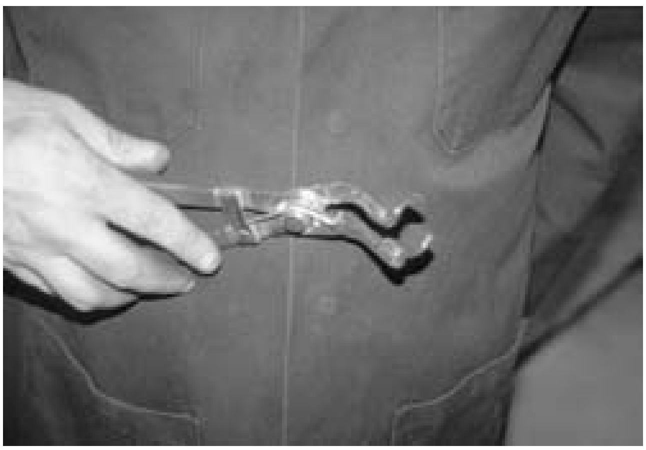


FIGURE 16-31 Spark plug wire boot pliers are a handy addition to any toolbox.

absolutely necessary. The labor required to remove and replace (R & R) spark plugs is the same whether the spark plugs are replaced or cleaned. Although cleaning spark plugs often restores proper engine operation, the service life of cleaned spark plugs is definitely shorter than that of new spark plugs. *Platinum-tipped spark plugs should not be regapped!* Using a gapping tool can break the platinum after it has been used in an engine.

Be certain that the engine is cool before removing spark plugs, especially on engines with aluminum cylinder heads. To help prevent dirt from getting into the cylinder of an engine while removing a spark plug, use compressed air or a brush to remove dirt from around the spark plug before removal. See Figures 16-32 and 16-33.

Spark Plug Inspection

Spark plugs are the windows to the inside of the combustion chamber. A thorough visual inspection of the spark plugs can often lead to the root cause of an engine performance problem. Two indications and their possible root causes include the following:

1. **Carbon fouling.** If the spark plug(s) has *dry black carbon* (soot), the usual causes include:

FIGURE 16-32 When removing spark plugs, it is wise to arrange them so that they can be compared and any problem be identified with a particular cylinder.

FIGURE 16-33 A spark plug thread chaser is a low-cost tool that hopefully will not be used often, but is necessary to use to clean the threads before new spark plugs are installed.

- Excessive idling
- Slow-speed driving under light loads that keeps the spark plug temperatures too low to burn off the deposits
- Overrich air–fuel mixture
- Weak ignition system output

2. **Oil fouling.** If the spark plug has *wet, oily* deposits with little electrode wear, oil may be getting into the combustion chamber from the following:
   - Worn or broken piston rings
   - Defective or missing valve stem seals

NOTE: If the deposits are heavier on the plug facing the intake valve, the cause is usually due to excessive valve stem clearance or defective intake valve stem seals.

When removing spark plugs, place them in order so that they can be inspected to check for engine problems that might affect one or more cylinders. All spark plugs should be in the same condition, and the color of the center insulator should be light tan or gray. If all the spark plugs are black or dark, the engine should be checked for conditions that could cause an overly rich air–fuel mixture or possible oil burning. If only one or a few spark plugs are black, check those cylinders for proper firing (possible defective spark plug wire) or an engine condition affecting only those particular cylinders. See Figures 16-34 and 16-35.

If all spark plugs are white, check for possible overadvanced ignition timing or a vacuum leak causing a lean air–fuel mixture. If only one or a few spark plugs are white, check for a vacuum leak affecting the fuel mixture only to those particular cylinders.

NOTE: The engine computer "senses" rich or lean air–fuel ratios by means of input from the oxygen sensor. If one cylinder is lean, the computer may make all other cylinders richer to compensate.

Inspect all spark plugs for wear by first checking the condition of the center electrode. As a spark plug wears, the center electrode becomes rounded. If the center electrode is rounded, higher ignition system voltage is required to fire the spark plug. When installing spark plugs, always use the correct tightening torque to ensure proper heat transfer from the spark plug shell to the cylinder head. See the following table.

TECH TIP

TWO-FINGER TRICK

To help prevent overtightening a spark plug when a torque wrench is not available, simply use two fingers on the ratchet handle. Even the strongest service technician cannot overtighten a spark plug by using two fingers.

FIGURE 16-34 Typical worn spark plug. Notice the rounded center electrode. The deposits indicate a possible oil usage problem.

FIGURE 16-35 New spark plug that was fouled by a too-rich air–fuel mixture. The engine from which this spark plug came had a defective (stuck partially open) injector on this one cylinder only.

	Torque with Torque Wrench (in lb-ft)		Torque without Torque Wrench (in turns)	
Spark Plug	**Cast-Iron Head**	**Aluminum Head**	**Cast-Iron Head**	**Aluminum Head**
Gasket				
14 mm	26–30	18–22	1/4	1/4
18 mm	32–38	28–34	1/4	1/4
Tapered seat				
14 mm	7–15	7–15	1/16 (snug)	1/16 (snug)
18 mm	15–20	15–20	1/16 (snug)	1/16 (snug)

TECH TIP

USE ORIGINAL EQUIPMENT MANUFACTURER'S SPARK PLUGS

A technician at an independent service center replaced the spark plugs in a Pontiac with new Champion brand spark plugs of the correct size, reach, and heat range. When the customer returned to pay the bill, he inquired as to the brand name of the replacement parts used for the tune-up. When told that Champion spark plugs were used, he stopped signing his name on the check he was writing. He said that he owned 1,000 shares of General Motors stock and he owned two General Motors vehicles and he expected to have General Motors parts used in his General Motors vehicles. The service manager had the technician replace the spark plugs with AC brand spark plugs because this brand was used in the engine when the vehicle was new. Even though most spark plug manufacturers produce spark plugs that are correct for use in almost any engine, many customers prefer that original equipment manufacturer (OEM) spark plugs be used in their engines.

NOTE: General Motors does not recommend the use of antiseize compound on the threads of spark plugs being installed in an aluminum cylinder head, because the spark plug will be overtightened. This excessive tightening torque places the threaded portion of the spark plug too far into the combustion chamber where carbon can accumulate and result in the spark plugs being difficult to remove. If antiseize compound is used on spark plug threads, reduce the tightening torque by 40%. Always follow the vehicle manufacturer's recommendations.

QUICK AND EASY SECONDARY IGNITION TESTS

Most engine running problems are caused by defective or out-of-adjustment ignition components. Many ignition problems involve the high-voltage secondary ignition circuit. Following are some quick and easy secondary ignition tests.

Test 1. If there is a crack in a distributor cap, coil, or spark plug, or a defective spark plug wire, a spark may be visible at night. Because the highest voltage is required during partial throttle acceleration, the technician's assistant should accelerate the engine slightly with the gear selector in drive or second gear (if manual transmission) and the brake firmly applied. If any spark is visible, the location should be closely inspected and the defective parts replaced. A blue glow or "corona" around the shell of the spark plug is normal and not an indication of a defective spark plug.

Test 2. For intermittent problems, use a spray bottle to apply a water mist to the spark plugs, distributor cap, and spark plug wires. See Figure 16-36. With the engine running, the water may cause an arc through any weak insulating materials and cause the engine to miss or stall.

NOTE: Adding a little salt or liquid soap to the water makes the water more conductive, and also makes it easier to find those hard-to-diagnose intermittent ignition faults.

Test 3. To determine if the rough engine operation is due to secondary ignition problems, connect a 6- to 12-volt test light to the negative side (sometimes labeled "tach") of the coil. Connect the other lead of the test light to the positive lead of the coil. With the engine running, the test light should be dim and steady in brightness. If there is high resistance in the secondary circuit (such as that caused by a defective spark plug wire), the test light will pulse brightly at times. If the test light varies noticeably, this indicates that the secondary voltage cannot find ground easily and is feeding back through the primary windings of the coil. This feedback causes the test light to become brighter.

FIGURE 16-36 A water spray bottle is an excellent diagnostic tool to help find an intermittent engine miss caused by a break in a secondary ignition circuit component.

IGNITION TIMING

Ignition timing should be checked and adjusted according to the manufacturer's specifications and procedures for best fuel economy and performance, as well as lowest exhaust emissions. Generally, for testing, engines must be at idle with computer engine controls put into **base timing,** the timing of the spark before the computer advances the timing. To be assured of the proper ignition timing, follow exactly the timing procedure indicated on the underhood emission decal. See Figure 16-37 for a typical ignition timing plate and timing mark.

NOTE: Most older engines equipped with a vacuum advance must have the vacuum hose removed and plugged before it is checked for timing.

If the ignition timing is too far *advanced,* for example, if it is set at 12 degrees before top dead center (BTDC) instead of 8 degrees BTDC, the following symptoms may occur:

1. Engine ping or spark knock may be heard, especially while driving up a hill or during acceleration.
2. Cranking (starting) may be slow and jerky, especially when the engine is warm.
3. The engine may overheat if the ignition timing is too far advanced.

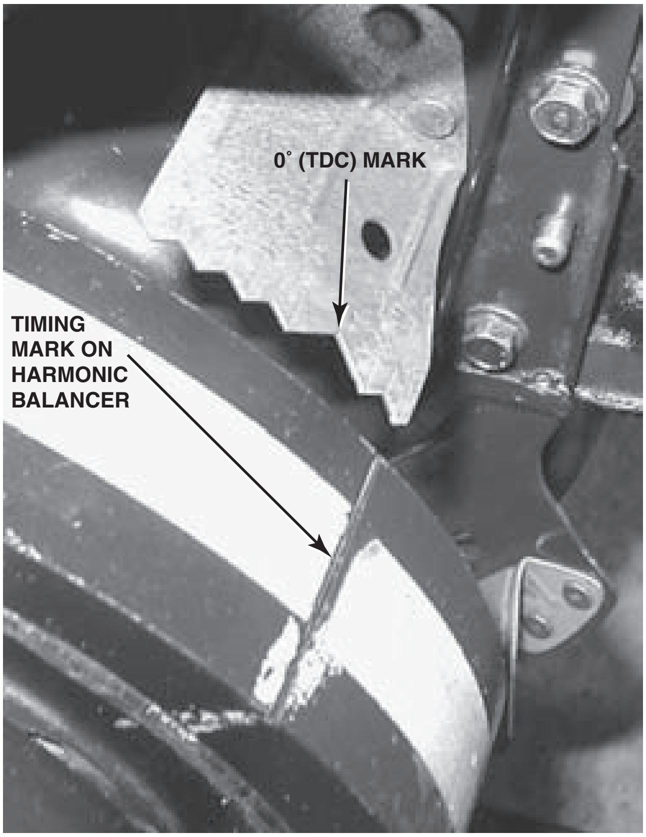


FIGURE 16-37 Typical timing marks. The degree numbers are on the stationary plate and the notch is on the harmonic balancer.

If the ignition timing is too far *retarded,* for example, if it is set at 4 degrees BTDC instead of 8 degrees BTDC, the following symptoms may occur:

1. The engine may lack in power and performance.
2. The engine may require a long period of starter cranking before starting.
3. Poor fuel economy may result from retarded ignition timing.
4. The engine may overheat if the ignition timing is too far retarded.

Pretiming Checks

Before the ignition timing is checked or adjusted, the following items should be checked to ensure accurate timing results:

1. The engine should be at normal operating temperature (the upper radiator hose should be hot and pressurized).
2. The engine should be at the correct timing RPM (check the specifications).
3. The vacuum hoses should be removed, and the hose from the vacuum advance unit on the distributor (if the vehicle is so equipped) should be plugged unless otherwise specified.

4. If the engine is computer equipped, check the timing procedure specified by the manufacturer. This may include disconnecting a "set timing" connector wire, grounding a diagnostic terminal, disconnecting a four-wire connector, or similar procedure.

NOTE: **General Motors specifies 10 different pretiming procedures depending on the engine, type of fuel system, and type of ignition system. For example, many 4-cylinder engines use the *average* of the timing for cylinder 1 and cylinder 4! Always consult the emission decal under the hood for the exact procedure to follow.**

Timing Light Connections

For checking or adjusting ignition timing, make the timing light connections as follows:

1. Connect the timing light battery leads to the vehicle battery: the red to the positive terminal and the black to the negative terminal.
2. Connect the timing light high-tension lead to spark plug cable 1.

Determining Cylinder I

The following will help in determining cylinder 1.

1. **Four- or 6-cylinder engines.** On all inline 4- and 6-cylinder engines, cylinder 1 is the *most forward* cylinder.

TECH TIP

"TURN THE KEY" TEST

If the ignition timing is correct, a warm engine should start immediately when the ignition key is turned to the start position. If the engine cranks a long time before starting, the ignition timing may be retarded. If the engine cranks slowly, the ignition timing may be too far advanced. However, if the engine starts immediately, the ignition timing, although it may not be exactly set according to specification, is usually adjusted fairly close to specifications. When a starting problem is experienced, check the ignition timing first, before checking the fuel system or the cranking system for a possible problem. This procedure can be used to help diagnose a possible ignition timing problem quickly without tools or equipment.

2. **V-6 or V-8 engines.** Most V-type engines use the left front (driver's side) cylinder as cylinder 1, except for Ford engines and some Cadillacs, which use the right front (passenger's side) cylinder.
3. **Sideways (transverse) engines.** Most front-wheel-drive vehicles with engines installed sideways use the cylinder to the far right (passenger's side) as cylinder 1 (plug wire closest to the drive belt[s]).

Follow this rule of thumb: If cylinder 1 is unknown for a given type of engine, it is the *most forward* cylinder as viewed from above (except in Pontiac V-8 engines). See Figure 16-38 for typical cylinder 1 locations.

NOTE: **Some engines are not timed off of cylinder 1. For example, Jaguar inline 6-cylinder engines before 1988 used cylinder 6, but the cylinders were numbered from the firewall (bulkhead) forward. Therefore, cylinder 6 was the most forward cylinder. Always check for the specifications and procedures for the vehicle being tested.**

NOTE: **If cylinder 1 is difficult to reach, such as up against the bulkhead (firewall) or close to an exhaust manifold, simply use the opposite cylinder in the firing order (paired cylinder). The timing light will not know the difference and will indicate the correct position of the timing mark in relation to the pointer or degree mark.**

Checking or Adjusting Ignition Timing

Use the following steps for checking or adjusting ignition timing:

1. Start the engine and adjust the speed to that specified for ignition timing.
2. With the timing light aimed at the stationary timing pointer, observe the position of the timing mark with the light flashing. Refer to the manufacturer's specifications on the underhood decal for the correct setting. See Figure 16-39.

   NOTE: If the timing mark appears ahead of the pointer, in relation to the direction of crankshaft rotation, the timing is advanced. If the timing mark appears behind the pointer, in relation to the direction of crankshaft rotation, the timing is retarded.

3. To adjust timing, loosen the distributor locking bolt or nut and turn the distributor housing until the timing mark is in correct alignment. Turn the distributor housing

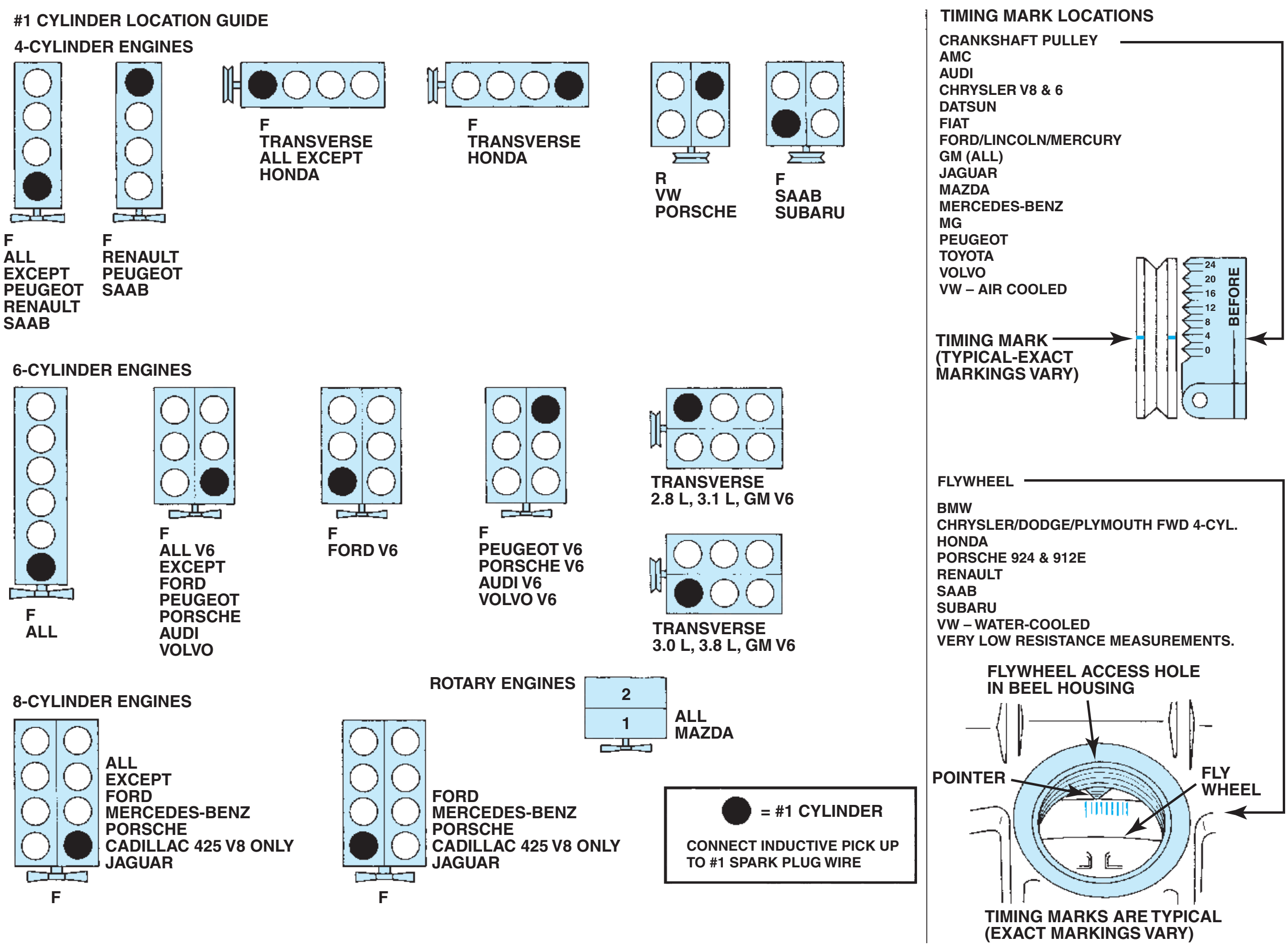
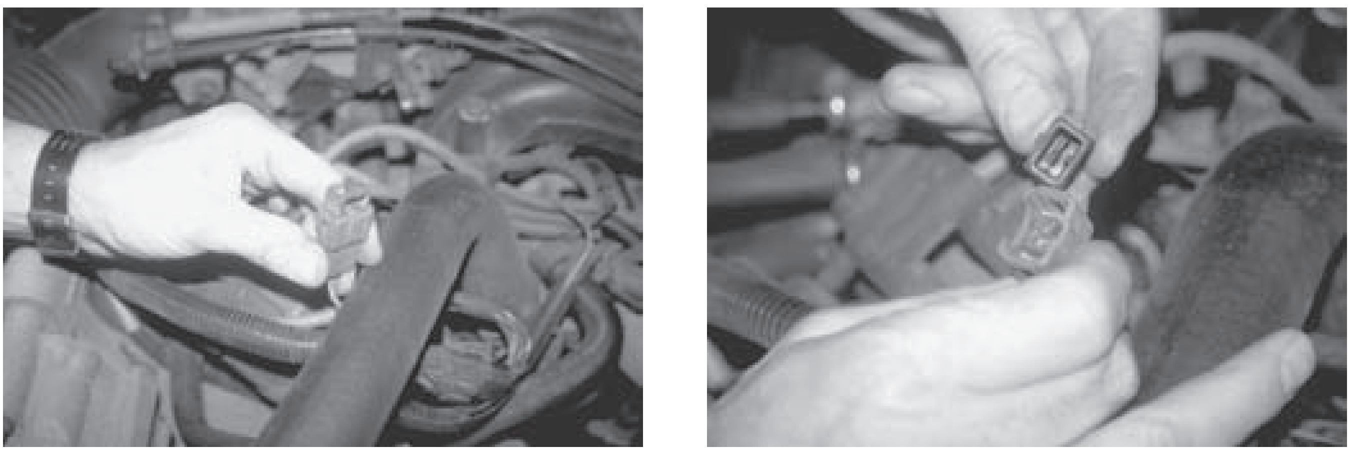


FIGURE 16-38 Cylinder 1 and timing mark location guide.



(a) (b)

FIGURE 16-39 (a) Typical SPOUT connector as used on many Ford engines equipped with distributor ignition (DI). (b) The connector must be opened (disconnected) to check and/or adjust the ignition timing. On DIS/EDIS systems, the connector is called SPOUT/SAW (spark output/spark angle word).

TECH TIP

TWO MARKS ARE THE KEY TO SUCCESS

When a distributor is removed from an engine, always mark the direction the rotor is pointing to ensure that the distributor is reinstalled in the correct position. Because of the helical cut on the distributor drive gear, the rotor rotates as the distributor is being removed from the engine. To help reinstall a distributor without any problems, simply make another mark where the rotor is pointing just as the distributor is lifted out of the engine. Then, to reinstall, simply line up the rotor to the second mark and lower the distributor into the engine. The rotor should then line up with the original mark as a double-check. See Figure 16-40.

in the direction of rotor rotation to retard the timing and against rotor rotation to advance the timing.

4. After adjusting the timing to specifications, carefully tighten the distributor locking bolt. It is sometimes necessary to readjust the timing after the initial setting because the distributor may rotate slightly when the hold-down bolt is tightened.

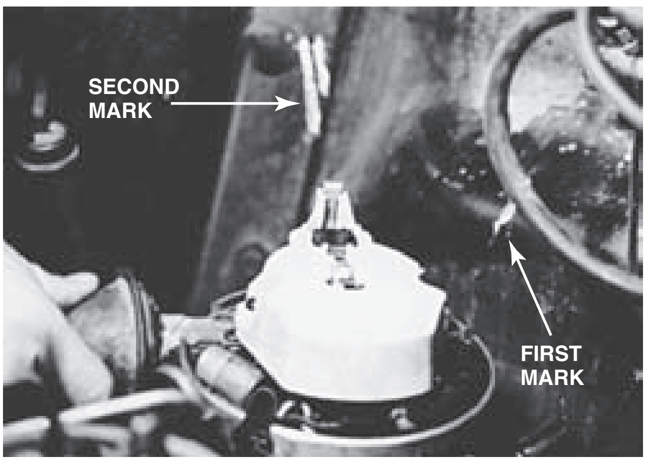


FIGURE 16-40 The first mark indicates the direction the rotor is pointing when the distributor is in the engine. The second mark indicates where the rotor is pointing just as it is pulled from the engine.

IGNITION SYSTEM TROUBLESHOOTING GUIDE

The following list will assist technicians in troubleshooting ignition system problems.

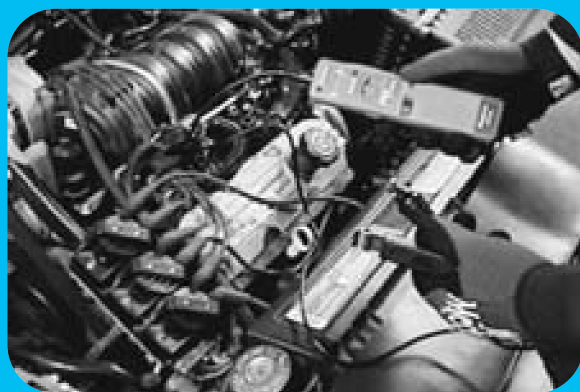
Problem	*Possible Causes and/ or Solutions*
No spark out of the coil	Possible open in the ignition switch circuit Possible defective ignition module (if electronic ignition coil) Possible defective pickup coil or Hall-effect switch (if electronic ignition) Possible shorted condenser
Weak spark out of the coil	Possible high-resistance coil wire or spark plug wire Possible poor ground between the distributor or module and the engine block
Engine missing	Possible defective (open) spark plug wire Possible worn or fouled spark plugs Possible defective pickup coil Possible defective module Possible poor electrical connections at the pickup coil and/or module

IGNITION SYSTEM DIAGNOSIS Step-by-Step

STEP 1 The tools and supplies needed to test for a fault in the secondary ignition system.

STEP 2 Using a spark plug wire boot removal tool, carefully remove the spark plug wire from the spark plug.

STEP 3 Attach a spark tester to the end of the spark plug wire and then clip the spark tester to a good engine ground. Start the engine and observe the spark tester. A spark should consistently jump the gap indicating that the system is capable of supplying at least 25,000 volts (25 kV).



STEP 4 Engine faults as well as ignition system faults can often be detected by using a tester capable of measuring spark plug firing voltage such as this unit from Snap-On tools.

STEP 5 Start the engine and rotate the thumb wheel until the red light emitting diode (LED) just flickers off and then read the firing voltage on the display. This cylinder shows about 12–13 kV with conventional firing.

STEP 6 This cylinder is firing in the opposite polarity of the other cylinder (inverted). The firing voltage indicates a possible narrow gap or fouled spark plug.

(continued)

IGNITION SYSTEM DIAGNOSIS continued

STEP 7 Another tester that can be used is one from OTC tools. To use this tester, connect the ground clip to a good engine ground and connect the test probe around a spark plug wire.

STEP 8 This is the voltage required to fire the spark plugs; this display indicates 16.4 kV. This is higher than normal and could be due to a high-resistance spark plug wire or a wide gap spark plug.

STEP 9 Move the selector to read "burn kV." The reading indicates 1.9 kV. This is the voltage necessary to keep the spark firing after it has been started. It should be less than 2 kV for most vehicles.

STEP 10 Move the selector to "burn time." The reading is 1.2 mS (milliseconds). This is the duration of the spark and it should be between 1 and 2 mS.

STEP 11 Ground out a cylinder one at a time and observe if the engine speed or idle quality is affected. Insert 2-inch lengths of vacuum hose between the coil tower and the spark plug wires.

STEP 12 Use a grounded test light and touch the section of rubber hose with the tip. The high voltage will travel through the test light to ground and not fire the spark plug.

SUMMARY

1. All inductive ignition systems supply battery voltage to the positive side of the ignition coil and pulse the negative side of the coil on and off to ground to create a high-voltage spark.
2. If an ignition system uses a distributor, it is a distributor ignition (DI) system.
3. If an ignition system does not use a distributor, it is called an electronic ignition (EI) system.
4. A waste-spark ignition system fires two spark plugs at the same time.
5. A coil-on-plug ignition system uses an ignition coil for each spark plug.

REVIEW QUESTIONS

1. How can 12 volts from a battery be changed to 40,000 volts for ignition?
2. How does a magnetic sensor work?
3. How does a Hall-effect sensor work?
4. How does a waste spark ignition system work?
5. Why should a spark tester be used to check for spark rather than a standard spark plug?
6. What harm can occur if the engine is cranked or run with an open (defective) spark plug wire?

CHAPTER QUIZ

1. Coil polarity is determined by the _____.
   - **a.** Direction of rotation of the coil windings
   - **b.** Turn ratio
   - **c.** Direction of laminations
   - **d.** Saturation direction
2. The pulse generator _____.
   - **a.** Fires the spark plug directly
   - **b.** Signals the electronic control unit (module)
   - **c.** Signals the computer that fires the spark plug directly
   - **d.** Is used as a tachometer reference signal by the computer and has no other function
3. Two technicians are discussing distributor ignition. Technician A says that the pickup coil or optical sensor in the distributor is used to pulse the ignition module (igniter). Technician B says that some distributor ignition systems have the ignition coil inside the distributor cap. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
4. A waste-spark-type ignition system _____.
   - **a.** Fires two spark plugs at the same time
   - **b.** Fires one spark plug with reverse polarity
   - **c.** Fires one spark plug with straight polarity
   - **d.** All of the above
5. Technician A says that a defective crankshaft position sensor can cause a no-spark condition. Technician B says that a faulty ignition control module can cause a no-spark condition. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
6. Technician A says that a pickup coil (pulse generator) can be tested with an ohmmeter. Technician B says that ignition coils can be tested with an ohmmeter. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B

7. Technician A says that a defective spark plug wire can cause an engine miss. Technician B says that a defective pickup coil wire can cause an engine miss. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B
8. Typical primary coil resistance specifications usually range from _____ ohms.
   - **a.** 100 to 450
   - **b.** 500 to 1,500
   - **c.** 1 to 3
   - **d.** 6,000 to 30,000
9. Typical secondary coil resistance specifications usually range from _____ ohms.
   - **a.** 100 to 450
   - **b.** 500 to 1,500
   - **c.** 1 to 3
   - **d.** 6,000 to 30,000
10. Technician A says that an engine will not start and run if the ignition coil is tracked. Technician B says that one wire of any pickup coil must be grounded. Which technician is correct?
   - **a.** Technician A only
   - **b.** Technician B only
   - **c.** Both Technicians A and B
   - **d.** Neither Technician A nor B