Cam and Crank Sensors

Camshaft and crankshaft sensors are critical inputs, providing important real-time information to the PCM concerning ignition timing, sequential injector firing, and valve train position.

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In the early days of the automotive engine, engine speed was monitored by the triggering of the coil. This provided a revolutions per minute (RPM) signal that was mainly used for dash-mounted tachometers. With the evolution to electronic ignition and computer-controlled fuel systems, the need for precise crankshaft position and speed inputs was realized. As engine control systems continued to evolve, the addition of camshaft position sensors provided control that is even more precise.

The Need For Sensors
The crankshaft angle sensor (more commonly known as a crankshaft position [CKP] sensor, or crank sensor for short), converts the mechanical physical movement of the engine’s crankshaft to an electrical signal. The signal provides position and rotational speed of the crankshaft to the powertrain control module (PCM). The electrical signal can be analog or digital.

The crank sensor can be used in conjunction with one or more camshaft position (CMP) sensors (or cam sensor, for short), which informs the PCM what valves are open and closed in the valve train. In simple terms, the crank sensor reports the crank position to the PCM and that a piston is approaching top dead center (TDC). The cam sensor reports the camshaft position to the PCM and is used to determine which piston is approaching TDC.

Used together, the cam and crank sensor(s) provide real-time information relating to the relationship of all the important mechanical movement within the engine to the PCM. This information is critical for ignition and sequential fuel injector timing, as well as variable valve timing (VVT) verification. The cam and crank sensors are among the most important on the engine; if these sensors do not produce the proper electrical signal(s) to the PCM, in most cases the engine will not start.

The CKP and CMP sensors provide precise position and speed information to the PCM.
The history of modern camshaft and crankshaft sensors goes back to early electronic fuel injection and ignition systems. One of the most noteworthy changes in automotive ignition systems was the introduction of General Motors first direct ignition (DI) system, called the computer controlled coil ignition (C3I).

The C3I distributorless ignition system was first mass produced on turbocharged, fuel injected, 3.8L V6 Buick engines in 1984. The C3I system used a CMP sensor and two CKP sensors, providing signals directly to the system ignition module. One of the CKP sensor inputs provides a low resolution 3x signal used by the ignition module to fire the correct coil, at the correct time during cranking and starting, along with base timing advance built-in. The outer ring sends a high resolution 18x signal, marking every 20 degrees of crankshaft rotation.

This waste spark system fires two spark plugs on companion cylinders, both of which are at TDC at the same time, one on the compression stroke and one on the exhaust stroke. On this system, fuel injection command occurs while the intake valve is closed, just prior to intake valve opening. This means there is no fuel present in the exhaust during the waste spark event, before TDC of the exhaust stroke. There were several advantages to this type of system, the most notable being the elimination of the distributor. Distributor caps and rotors are wear items, similar to brake pads. The fact that the workload of the ignition system was spread out over 3 separate coils instead of only one coil meant that the coils had more time to cool between charging and firing events. Modern coil-on-plug systems have expounded on these concepts, some 25 to 30 years later.

Today, several GM vehicles are on the road with C3I technology under the hood. Many other DI systems, developed by other manufacturers are also used today, all with camshaft and crankshaft position sensors providing vital triggering data.

Sensor Types
There are several different types of camshaft and crankshaft position sensors. The most common include; Hall-effect, magnetic pulse generator, and variable reluctance designs. Typically, the three (3) wire sensor produces a digital square wave pattern, and the two (2) wire pulse generator type sensor produces an analog alternating current (AC) signal that cycles above and below zero (0) volts (or system ground level). The quality of the electrical signal generated by these sensors is critical for proper engine performance. The best way to know if the signal from a crankshaft or camshaft sensor is good is with the use of an automotive digital storage oscilloscope (DSO), or a lab scope. In fact, if you or your technicians in your shop are not using a lab scope of some kind when diagnosing these sensors, quite frankly, you’re guessing as to the quality of the component and the quality of the circuit which connects the sensor to the PCM.

Sensor Signals
The crank sensor, crank sensor ground point, voltage amplitude, sensor signal polarity, and sensor to trigger wheel air gap, are all critical to proper operation. Some engines will start with only a crank sensor signal without a good cam sensor signal, while some will not. A good rule of thumb on this issue is whether or not the crank sensor has some type of signature pulse, or missing tooth pattern that clearly defines a specific point during the rotation of the crankshaft. If the CKP waveform does not have a signature pulse, the engine likely requires both the cam and the crank signals to start.

A common misconception, when viewing crank sensor waveforms, is that the signature pulse or missing tooth portion of the waveform identifies TDC for cylinder one (1). The fact is the PCM needs to know the position of the crankshaft well before firing that specific cylinder. Ford, for example, typically uses the missing tooth signal of the waveform to mark 50° before TDC on V8 applications. This gives the PCM time to fire the injector, charge the ignition coil, and fire the spark plug. During engine starting, synchronizing of the spark firing and injector events can happen within two (2) crankshaft revolutions after receiving the proper voltage amplitude from the crank sensor.

Another important oddity to the Ford AC pulse crank sensor that use a signature pulse signal is the fact that the voltage levels are offset by 1.5 volts positive. The 1.5 volt bias on the ground side of this sensor prevents induced noise from the starter’s magnetic field from affecting the pattern to the PCM during cranking.

Some engines use more than one crank and cam sensor signal. For example, several Cadillac engine applications...
used two (2) high data rate crank sensors that are positioned 27 degrees apart from one another. The trigger wheel has a total of 32 notches. Of these, 24 are evenly spaced and 8 are not. The ignition module recreates the 24 evenly spaced notches and makes a 24x signal to send to the PCM. It also generates a 4x signal to the PCM.

This gives the ignition module two locations on the crankshaft to provide for faster starting. Each sensor generates its own AC voltage that is sent to the ignition module. The ignition module then generates a digital output signal to the PCM. Later models used DC square wave 3 wire sensors and reported directly to the PCM for faster data analysis and misfire detection.

The digital signal provides a square wave pattern. Typically, a Hall-effect sensor is used to generate the digital signal. Although referred to as a sensor, the three wire Hall-effect is actually a switch that produces an on/off signal. The Hall-effect switch operates on the principle that if a current is allowed to flow through a thin conducting material that is exposed to a magnetic field, another voltage is produced. It contains a permanent magnet, a thin semiconductor layer made of gallium arsenate crystal (Hall layer), and a trigger wheel. The signal voltage leaves the Hall layer as a weak analog signal that is amplified, inverted, and then converted to a digital signal by a transistor (Schmitt trigger).

The Hall layer is supplied a steady voltage. Depending on manufacturer and system, the typical voltages are 12, 8-9, 6, and 5 volts. A signal wire that is biased to 5 volts (typically however some use 6 or 12 volts) is applied to the collector of the transistor. The third circuit is the sensor return from the transistor’s emitter to a filtered ground. As the magnetic field passes over the dense portion of the trigger wheel, the Hall layer output voltage is directed to the base leg of the transistor and “turns on” the transistor. Signal voltage is pulled to ground (0.3 volts) through the transistor. When the magnetic field passes over the notches in the trigger wheel, the magnetic field is lost removing the voltage to the base leg and “turning off” the transistor. This causes the controller to register the 5-volt signal.

Lab scope testing of the Hall-effect sensor allows you to “see” the condition of the signal. The scan tool only reports that the signal is present and a voltmeter will not read fast enough to provide accurate voltage readings. Check the waveform for proper amplitude, ground, excessive noise, and glitches. In addition, the lab scope provides a quick method to check camshaft to crankshaft timing, ignition timing, and the condition of the trigger wheel.

Something else to consider when viewing patterns on your scope’s display is mechanical wear factors, such as worn or stretched timing chains. Another common fault dealing with signal position could be that the trigger wheel could be worn or out of position due to some sort of timing component failure. A common failure on several 4.2L V6 Ford engines is wear of the harmonic balancer where the crankshaft keyway makes contact with the balancer. This wear causes the crank sensor to trigger at the incorrect time and drastically affects ignition timing.

Sensor Air Gap

Any sensor that uses the interaction of a magnetic field must have the correct air gap between the sensor and the trigger wheel in order to provide an accurate signal to the PCM. Rust formation on the trigger wheel can result in clearance issues and cause improper sensor signal inputs. Sensor air gap can be a serious hindrance to proper operation for the sensor.

Failure to replace the plastic timing cover on some GM V6 applications could cause the sensor to be either too close, or too far away from the trigger wheel inside the cover. Some GM cam sensor codes are actually being caused by excessive air gap between the cam gear/trigger wheel and the sensor caused by excessive wear between the cam gear/trigger wheel and the sensor.

Some Chrysler sensors have adjustable air gap, and come with an oil-soluble paper spacer. If the air gap isn’t correct, camshaft and crankshaft sensor synchronization will be offset and the vehicle could experience drivability issues, and/or the setting of a trouble code.

Excessive air gap of a Hall-effect type sensor can be identified on the lab scope waveform by a more pitched shape to the rising and falling edges of the pattern.

Sensor Polarity

When examining waveforms, it is imperative you know how the sensor works and what the waveform should look like. The polarity of the sensor is determined by the direction the coil is wound and/or the orientation of the magnet’s north and south poles. For example, GM sensors will first increase in voltage, then drop below zero. Many sensors used on Ford and Asian vehicles will first drop the voltage below zero, and then increase. There are instances where some low cost, inferior replacement crank sensors have produced a reversed polarity. These sensor windings are
terminated incorrectly inside the sensor housing, causing an upside-down waveform, which is useless to the PCM. The improper polarity can cause a no-start condition, or severely affect ignition timing.

Some Nissan three wire cam sensors would reverse polarity internally, setting cam sensor fault codes. These same Nissan vehicles also had crank sensor issues, where the voltage amplitude would change causing a logic fault to the PCM. These vehicles have a Technical Service Bulletin (TSB) that addresses these concerns with new design cam and crank sensors. These new design sensors are available at your local NAPA store.

Sensor Noise

Proper charging system operation, as well as good vehicle ground connections, is critical to the quality of the waveforms produced by the cam and crank sensors. A faulty alternator diode can cause the waveform to have extra AC pulses in the pattern. This can cause the PCM to get confused on which signal to use as reference, the pattern produced by the sensor, or the extra AC pulses from a faulty alternator. This is a common problem on several Ford vehicles where a false P0340-Cam Sensor Signal Fault code is set. The root cause is a faulty alternator, not the sensor.

Excessive electrical noise on the vehicle’s ground circuits, or a poor ground connection, can cause the sensor voltage to rise above ground. This can result in the setting of fault codes, or even a no start condition.

If you have a question about a cam or crank sensor waveform, your NAPA Autotech instructors are available to help. The best on-line resource for automotive waveforms is the International Automotive Technician’s Network (IATN), which is a NAPA industry partner, and can be found at the domain address: www.iatn.net.

Review Questions

1. Technician A says a Hall-effect sensor provides an analog signal to the PCM. Technician B says a pulse generator type sensor provides a digital signal to the PCM. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B

2. Which of the following is NOT a true statement?
   a. The sensor voltage can have a bias voltage above ground.
   b. Some engine applications use more than one CKP sensor.
   c. The signature pulse from the CKP sensor indicates TDC.
   d. The best method for determining CKP and CMP signal quality is by a lab scope.

3. Technician A says electrical noise can be caused by poor ground connections. Technician B says electrical noise can be caused by a faulty alternator diode. Who is correct?
   a. Technician A
   b. Technician B
   c. Both Technician A and Technician B
   d. Neither Technician A nor Technician B

Answers: 1. d, 2. c, 3. a.