Cam & Crank Position Sensors Technical Editorial

Camshaft and crankshaft (also simply referred to as “Cam and Crank”) position sensors are some of the most crucial engine management devices on vehicles today. These controls have been present on modern vehicles for the better part of three decades and provide precision information needed for proper drivability. The vehicle’s onboard engine computer relies on these sensors to provide precise engine timing to ensure proper fueling, ignition, and internal engine operations. Without properly functioning camshaft and crankshaft position sensors, vehicles will notice significant loss in fuel economy, performance, and even catastrophic engine damage. For these reasons, the camshaft and crankshaft engine sensors are critical failure components that require proper diagnostics and repair.

While their purpose is understood to be crucial in the vehicle’s operation, their functions and internal workings may not be as well known. Walker Products is a global leader in camshaft and crankshaft position sensors and provides detailed insight on the operation of these components to educate the installers and technicians. Walker offers their “Pro Tips” on the basic electrical designs of today’s cam and crank sensors. With this information, we can better understand the sensors in question and how to properly diagnose common issues.

Camshaft & Crankshaft Position Sensors

To begin, it is important to understand the basic types of camshaft and crankshaft position sensors. There are two different styles of cam and crank position sensors: the hall effect and magnetic type sensor. In this issue, we will study both types and how they are used within the vehicle and registered by the onboard engine computer.

Hall Effect Sensors/Switches

First, let’s discuss the hall effect type sensors/switches. The hall effect switch consists of a permanent magnet, a gallium arsenate crystal, its related circuitry and an interrupter blade. ***(Figure 1)***

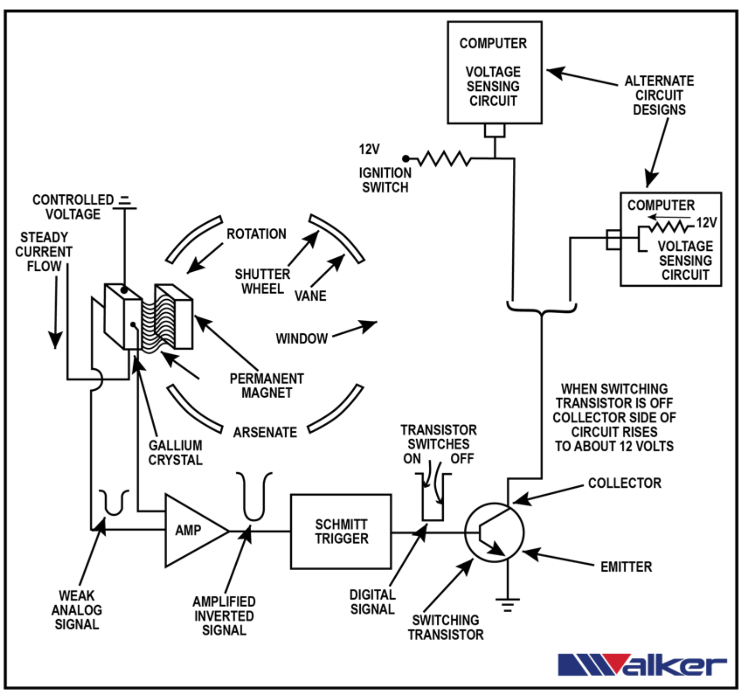

FIGURE 1

When the vehicle is running, the gallium arsenate crystal will have a steady current being passed through it from one end to the other. When the interrupter blade is not in between the magnet and the crystal, the magnetic lines of force invade the crystal. These magnetic lines of force distort the current that is flowing through the crystal, which causes a voltage potential at the top and bottom surfaces of the crystal. When the interrupter blade is in between the magnet and the crystal, the magnetic lines of force cannot invade the crystal, which results in a very low voltage signal. Therefore, the voltage will fluctuate between a low point (when the interrupter is in between the magnet and crystal) and high point (when the interrupter blade is not in between the magnet and the crystal).

This voltage is then amplified and inverted by a device called a Schmitt trigger which changes the analog signal to a digital signal. The digital signal is then sent to a switching transistor that turns the transistor on and off. The transistor is on when the interrupter blade is not in between the crystal and the magnet and off when it is in between them.

Vehicle Electronics – Walker Pro Tips 101

Diodes are important electronic components used in the automotive industry. When discussing diodes, it is important to familiarize yourself with the correct terminology.

> **Insulators:** An insulator is a material through which electrical current flows poorly or not at all.
>
> **Conductors:** A conductor is a material through which electrical current can flow easily.
>
> **Semiconductors:** Lastly, a semiconductor is a crystalline material that falls somewhere between the characteristics of insulators and conductors. The semiconductor will not inhibit electrical current as effectively as an insulator. However, it will not allow electrical current to flow as easily as a conductor.

Semiconductors are usually made from silicon, which is mixed with impurities to give it special characteristics – we refer to this process as doping. There are two different ways of doping, and each will provide different materials and types of semiconductors.

First, when phosphorus or arsenic is mixed with silicon it will have an excess of free electrons in its crystalline structure. This type of semiconductor is called *N-material*.

Second, when boron or gallium are mixed with silicon it will have a shortage of free electrons. This shortage of free electrons leaves spaces in the crystalline structure known as holes. This type of semiconductor is called a *P-material*.

The joining of an *N* and a *P* type material together in proximity is what makes a diode. The P side of the diode is called the anode and the N side is called the cathode.

The place where the P and N materials join is called the *PN junction*. At the PN junction some of the free electrons from the N material side will cross the PN junction to fill the shortage of electrons or holes on the P material side***.*** ***(Figure 2)*** This process forms what is known as the depletion region, because it is depleted of holes and free electrons. ***(Figure 3)***

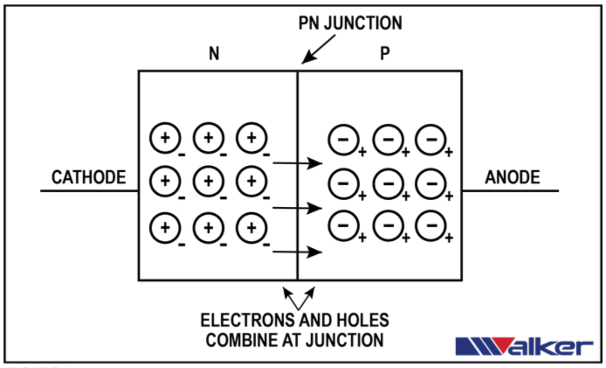

FIGURE 2

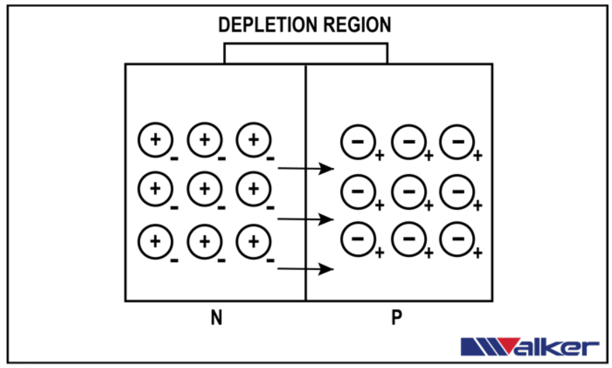

FIGURE 3

As a result of the loss of electrons, a net positive charge exists near the junction on the N side and the extra electrons on the P side create a net negative charge. These opposite charges result in a potential difference.

At a certain point, however, the electrical charge buildup in the P material will form a repulsive force barrier, which will inhibit the further flow of electrons. This potential difference is called the barrier voltage (which is typically measured at 0.7 volts for silicon). ***(Figure 4)*** This barrier voltage is not directly measurable but rather becomes apparent when an external voltage is applied to the diode.

If a voltage of 0.7 volts or greater is supplied, by connecting the positive terminal to the P material side and the negative terminal to the N material side, we will have current flow. This happens because the negative battery terminal repels the free electrons on the N side towards the junction where they will neutralize the positive charges in the barrier. At the same time, the positive battery terminal attracts the free electrons from the P material side of the barrier. This neutralizes the positive and negative charges which formed the barrier voltage. Therefore, there is no barrier voltage to stop the flow of charges and the diode will support current flow. This flow of current is known as forward bias. ***(Figure 5)*** It is important to note here that this action will only occur if the battery voltage is greater than the barrier voltage.

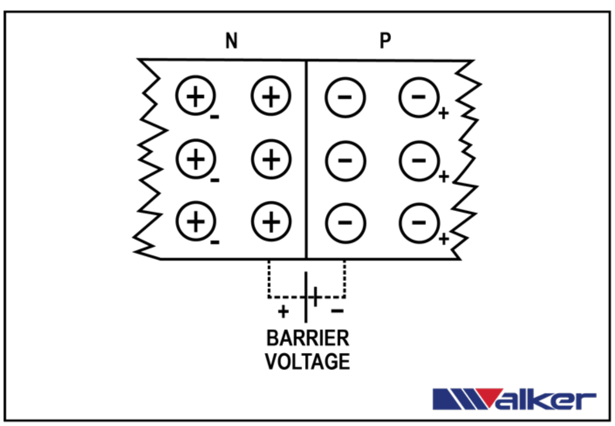

FIGURE 4

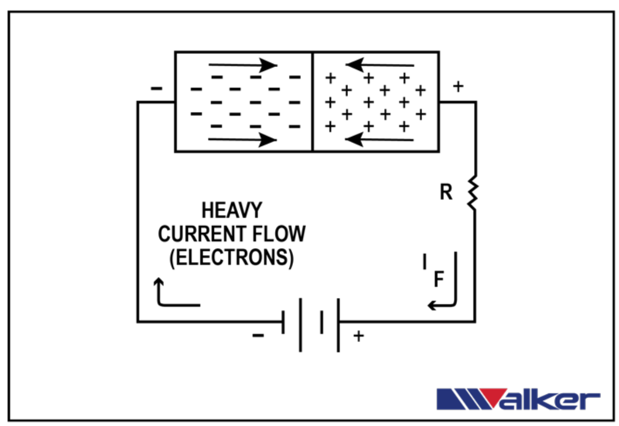

FIGURE 5

If the positive battery terminal gets connected to the N material side and the negative battery terminal to the P material side, no current will flow. This happens because the positive terminal attracts the free electrons away from the junction. At the same time, the negative terminal is attracting the positively charged particles, or holes, away from the junction, which effectively increasing the depletion region. This inhibits current flow and is known as reverse bias***. (Figure 6)*** Therefore, current will flow only one way through a diode.

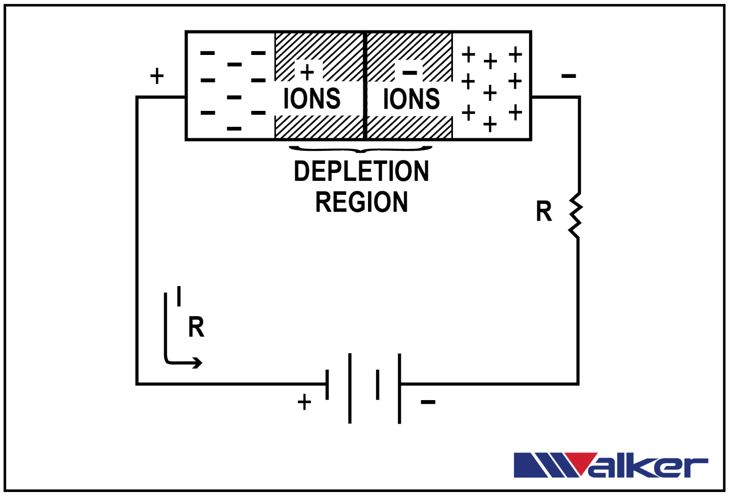

FIGURE 6

Magnetic Type Sensors

Now that we have covered the hall effect type sensors/switches, let's move to the second version: magnetic type position sensors. The magnetic position sensor consists of a permanent magnet with a coil of wire wrapped around it. The ends of the wire are attached to a control module or to the computer. In the case of a crankshaft position sensor, there is also a steel disc located on the crankshaft with protruding tabs on it.

This type of magnetic sensor is called a variable reluctance sensor. This means that the sensor has a magnetic field that can be varied. The magnetic field is varied by passing a ferromagnetic or steel material through the magnetic flux lines of the permanent magnet. When the steel tab is across from the magnet, the magnetic flux lines are increased. This in turn increases the strength of the magnetic field. It is important to remember that a voltage is only induced when there is a variance or change in the magnetic field.

As one of the tabs approaches the magnetic sensor, the strength of the magnetic field begins to increase. This change in magnetic field strength induces a voltage across the coil of wire. When one of the tabs is located directly across from the magnetic sensor, although the magnetic field is strongest at this point, there is no change in the magnetic field. Therefore, no voltage is induced in the coil of wire. As the tab begins to move away from the magnetic sensor, the magnetic field begins to decrease in strength. This change in the magnetic field results in a voltage of opposite polarity being induced in the coil of wire.

Vehicle Electronics – Walker Pro Tips 101

Small signal diodes can be used to multiply voltage, perform logic, and absorb voltage spikes. The most common use of small signal diodes is to convert alternating current (AC) into direct current (DC). This process is known as rectification.

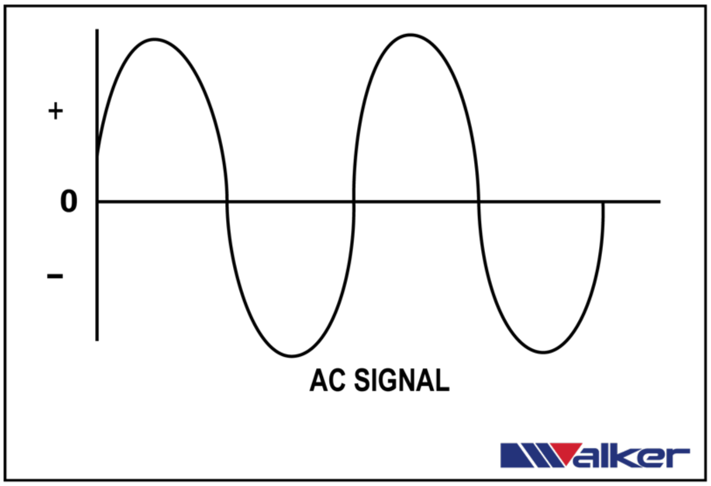

FIGURE 7

Half-Wave Rectification:

One type of rectification is called half-wave rectification. This type of rectification causes an AC signal to be converted to a single polarity DC signal. Let's follow through the steps to see how this works.

An AC signal is an alternating current whose polarity is constantly changing from positive to negative. ***(Figure 7)*** When we apply this AC current to a circuit with a diode in it, the current flowing with the positive polarity (the upper portion of the wave), causes the diode to become forward biased. Current then flows in the circuit, allowing the positive voltage portion of the AC wave to flow through the circuit. ***(Figure 8)***

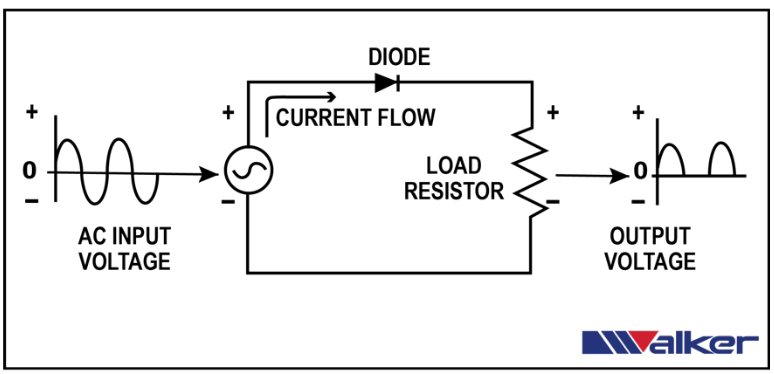

FIGURE 8

When the polarity of the AC current is negative (the lower portion of the wave) the diode becomes reversed biased. Therefore, no current will flow. The result is that just the top halves, or positive portions, of the wave can come through the diode. ***(Figure 9)***

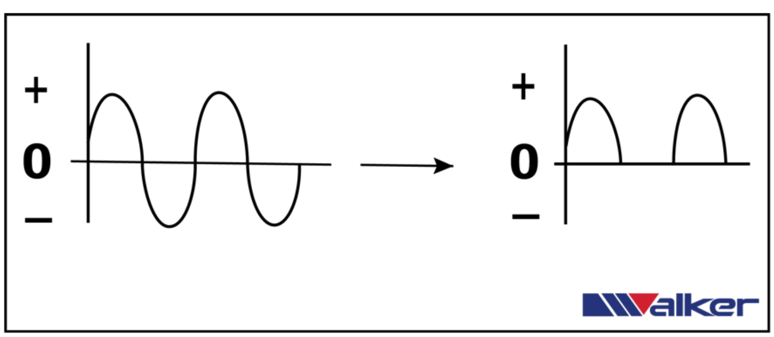

FIGURE 9

Full-Wave Rectification:

Another type of rectification is called full-wave rectification. This type of rectification converts both the positive and negative halves of the AC signal into a DC signal. This is accomplished by using a series of diodes. Following along with the illustrations we can see how this happens.

When the AC signal is positive, diodes D1 and D3 are forward biased, and diodes D2 and D4 are reversed biased. This allows current to flow as shown in ***Figure 10***. This represents the positive half of the AC signal.

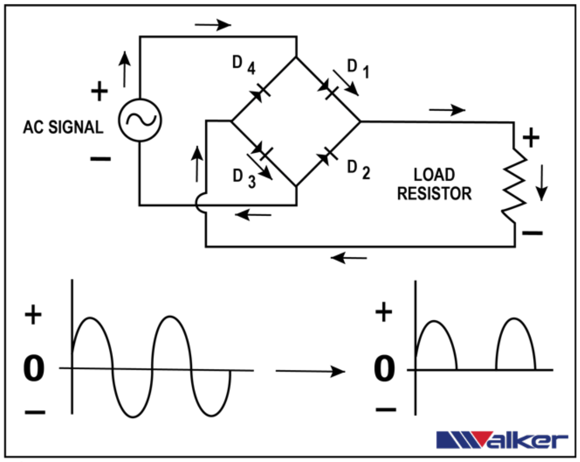

FIGURE 10

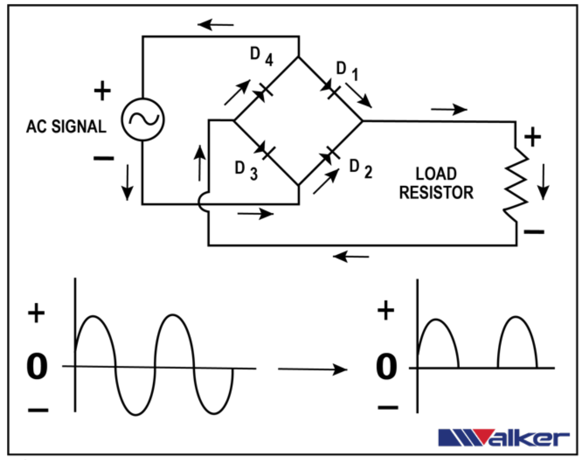

FIGURE 11

When the AC signal is negative, diodes D2 and D4 are forward biased, and diodes D1 and D3 are reversed biased. This allows current to flow as shown in ***Figure 11***. This represents the negative half of the AC signal.

As we follow the direction of the current flow in ***Figure 6***, we see that as far as the load resistor is concerned, the current flow is the same as when the AC signal is positive. Therefore, the voltage across the load is positive. The net result is the circuit inverted the negative half of the AC input signal to make it positive.

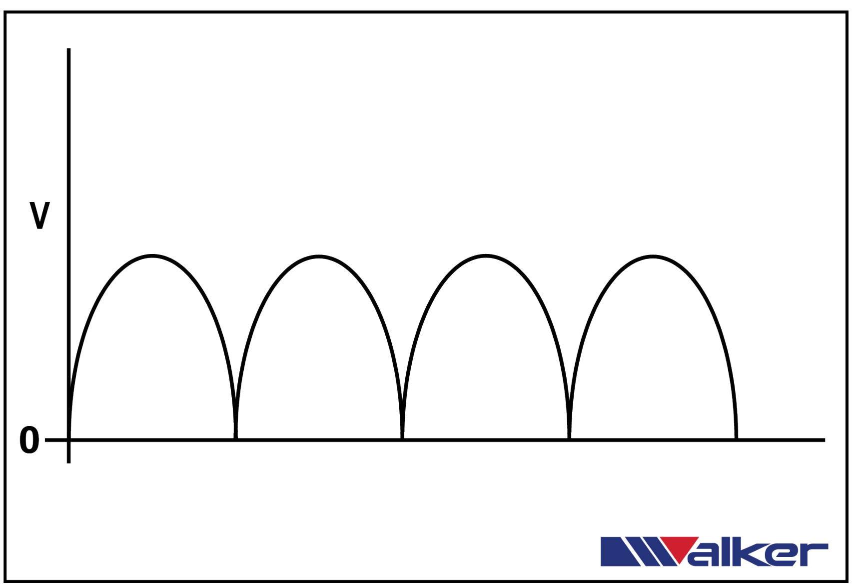

FIGURE 12

Therefore, a full-wave rectifier output voltage will be a series of successive half cycles as shown in ***Figure 12***. The positive portion of the AC signal is reproduced exactly, while the negative portion of the AC signal is inverted and made positive.

This is the same process used in today's alternators. If you have ever scoped an alternator, the pattern in ***Figure 12*** will look familiar to you.

When the gap between the tabs is across from the magnetic sensor, there is no change in the magnetic field, therefore there is no voltage induced in the coil of wire.

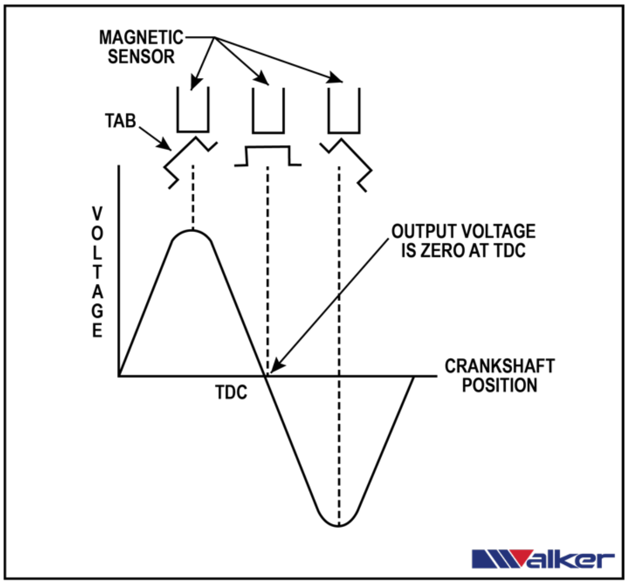

FIGURE 13

On a crankshaft position sensor each of these tabs correspond to the top dead center (TDC) position of a cylinder on its compression stroke. The computer uses these signals as a reference for crankshaft position and speed.

This type of magnetic position sensor produces a modified sine wave signal. This signal pattern can be seen on an oscilloscope. ***Figure 13*** is a representation of what a normal signal should look like.

The oscilloscope pattern can be helpful in diagnosing position sensor problems. If there is increased resistance in the position sensor circuit, some of the voltage will be dropped across this resistance. This will result in lower than normal voltage peaks in the sine wave pattern on the oscilloscope.

This same condition can occur if the sensor is misadjusted. If the sensor is located too far away from the steel tabs the magnetic field will not be as strong. Since the magnetic field is weaker there will also be a smaller change in the magnetic field. This will result in a smaller voltage being produced and hence a lower voltage sine wave pattern will be displayed on the oscilloscope. ***(Figure 14)***

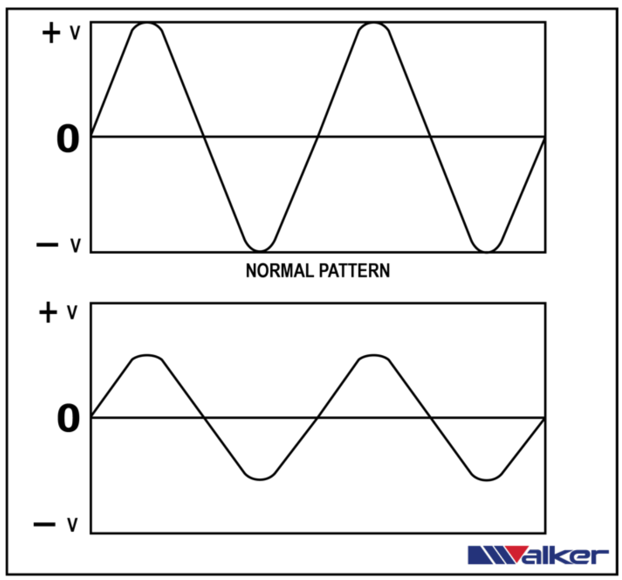

FIGURE 14

The fact of the matter is, when you break down the specific functions and internal workings of the cam and crank sensors, their duty on the vehicle remains justified. When diagnosing or troubleshooting a vehicle showing the signs of faulty engine sensors, it is always important to understand the underlying design of the system. These ***Walker Pro Tips*** can help save time by getting the job done right the first time.

Walker Products continues to lead the industry in automotive engine management, fuel delivery, and emissions control devices around the globe. Their facilities in Toluca, Mexico offer regional support throughout Mexico, Latin America, and South America for sales, distribution, technical assistance, and customer service inquires. For additional information regarding Walker Products and any of their product offerings, please visit www.walkerproducts.com or call 636-257-1700.