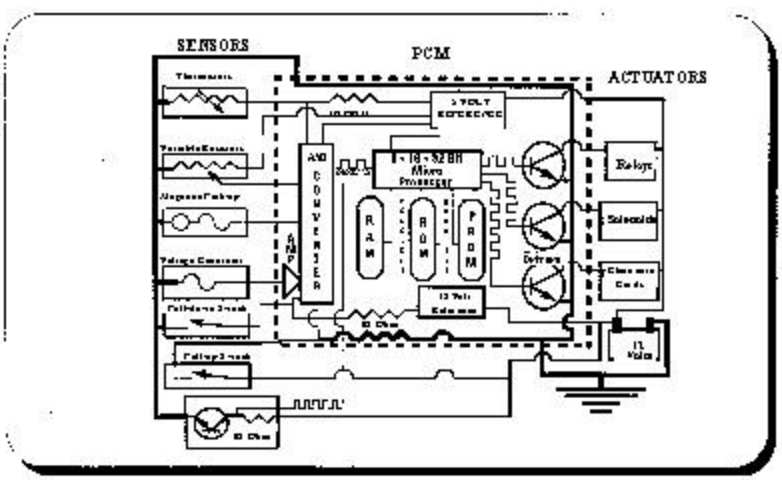
# Sensors

# &

# Actuators

## PCM




**Notes:**

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The PCM is the on-board computer which receives input from various sensors and, with this information, controls various engine & emissions control actuators.

The PCM has various “memories” within it. These are: RAM, random access memory, KAM, keep alive memory (part of RAM), ROM, read only memory and PROM, programmable read only memory.

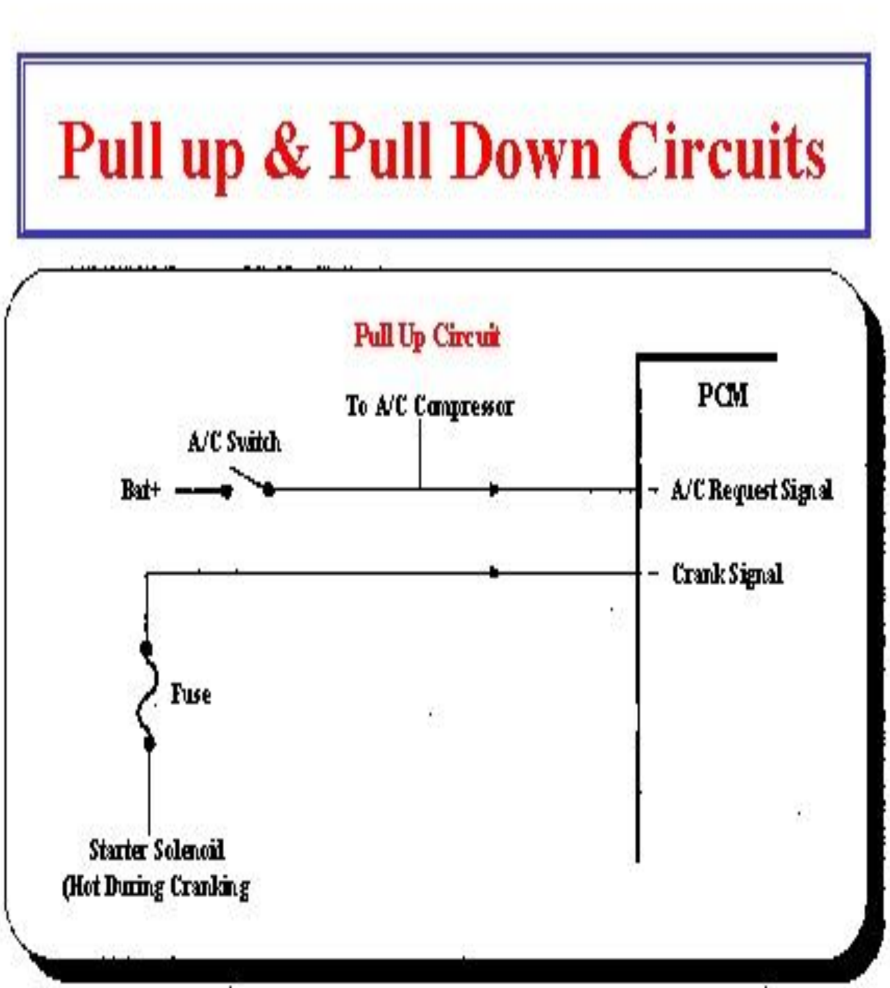
RAM is lost whenever the ignition is turned off. KAM is where some data is retained after the ignition is turned off. KAM is where trouble codes are stored. It is also where odometer readings are stored.

ROM is programmed into the PCM at the factory and cannot be changed. This is where the various lookup tables are stored.

All input signals that are analog must be converted to digital. This is accomplished in the circuitry of the PCM. The PCM cannot process analog signals thus the need for an A/D converter.

In the above illustration the PCM is shown with input sensors on the left side and the actuators on the right side.

The technician should be encouraged to study the diagram of the PCM and rationalize the various subunits within.

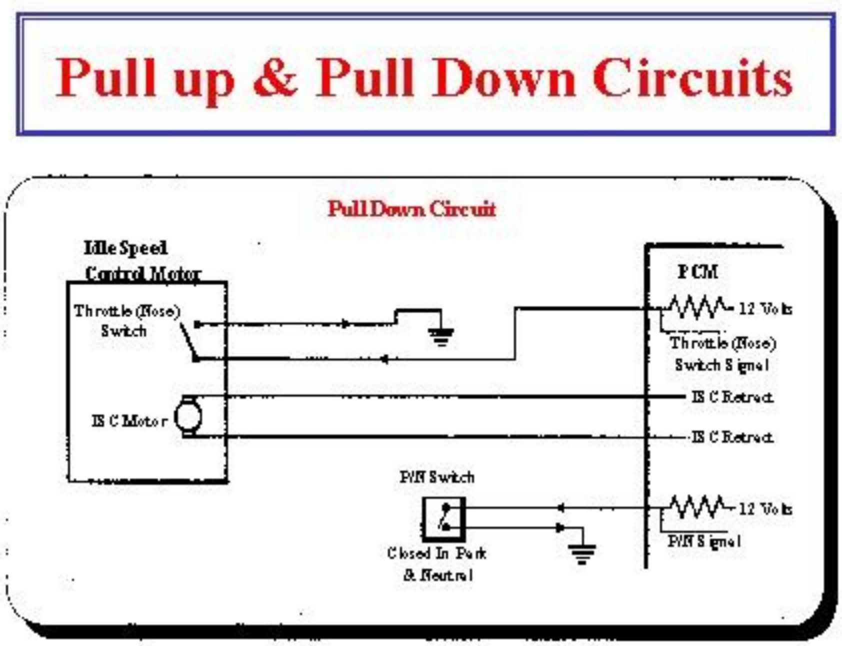


## Notes:

The term “pull up circuit” is applied to a switch controlled circuit where the PCM detects an increase in voltage when the switch is closed. In the above circuit the power is supplied by the vehicle battery. When the switch is closed, a voltage is applied to both the PCM and the A/C compressor clutch circuit. These circuits are always grounded and the circuit is completed through the switch and the vehicle battery voltage.

Another system which uses the “pull up circuit” is the starter circuit. When the ignition switch is in the start position, the voltage is sensed by the PCM indicating the engine is being cranked. This will have an effect on timing and air/fuel ratio.

This type of circuit differs from the “pull down circuit” which is described in the next slide.



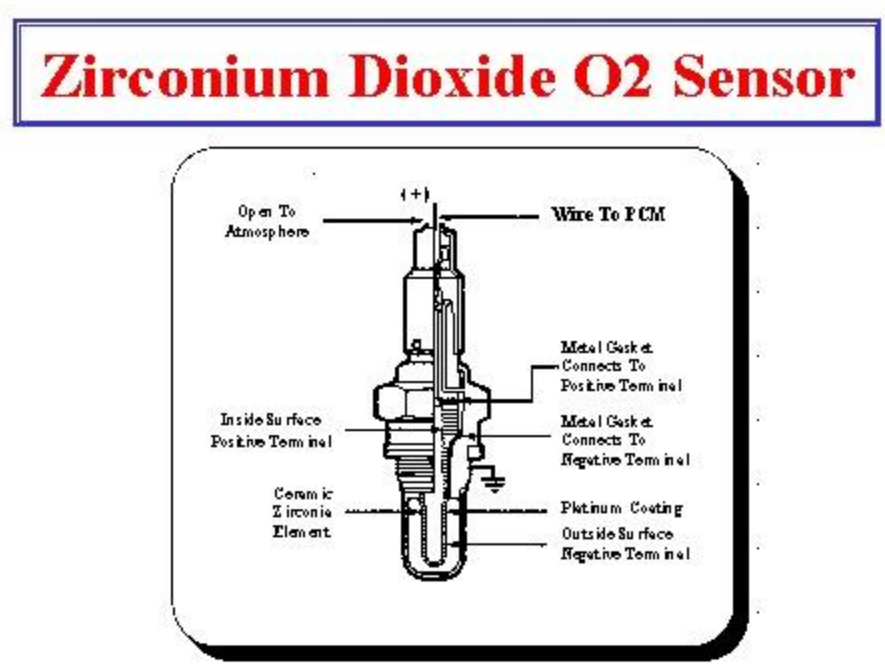

## Notes:

The above slide shows two “pull down circuits”. These circuits differ from the “pull up circuits” in that the PCM supplies the power and the switch completes the circuit to ground.

The first of these circuits, shown in the slide, is the throttle switch controlled circuit. Here the PCM supplies 12 volts to the circuit. There is a fixed resister (non-variable) inside the PCM. When the throttle switch is closed, the 12 volts are dropped across the fixed resister. The PCM then detects a “0” volt reading and it determines the throttle switch is closed.

The second “pull down circuit” shown in the slide is the park/neutral switch. Here again the PCM supplies the 12 volts to the circuit. When the park/neutral switch is closed the

PCM senses a "0" volt reading. The PCM then determines the circuit is complete and will enable or disable the starter circuit. The PCM uses this signal for other controls of various systems.




**Notes:**

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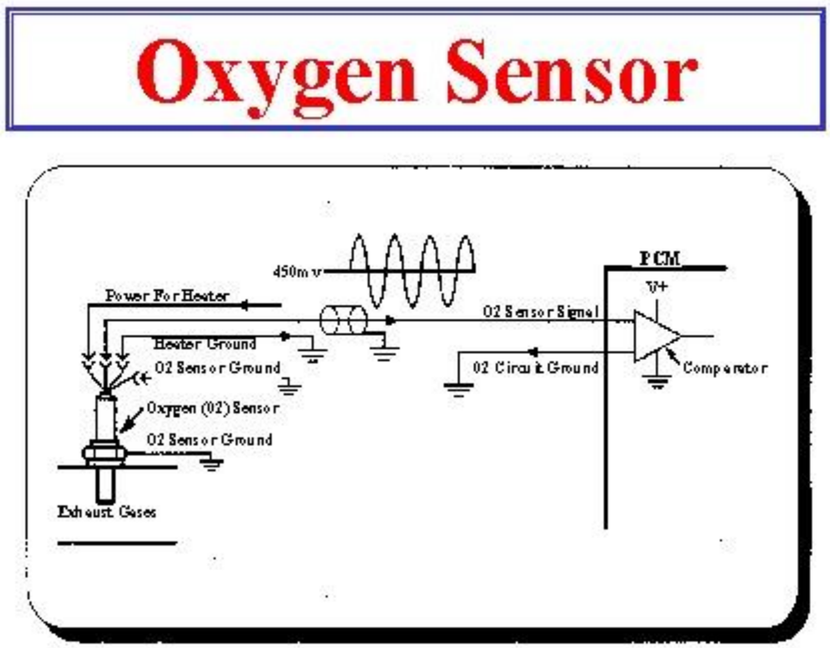
This sensor is used to detect the amount of oxygen left in the exhaust stream after the combustion process. If the mixture is too lean, there will be excess oxygen in the exhaust stream. This will generate a voltage below .5 volts. If the mixture is too rich there will be a lack of oxygen in the exhaust stream. This will generate a voltage above .5 volts.
The normal running engine will show an oscillating signal between .1volts and .9 volts. It is important to determine is the sensor is either biased or slow. Either of these conditions will affect the production of emissions and will reduce the efficiency of the catalytic converter.
To test the O2 sensor run the engine until at normal operating temperature. Slowly add propane to the induction system until there is a reduction in engine speed (rich mixture). With a DSO monitoring the O2 sensor signal, remove the propane. When the trace has reached its lowest level, snap accelerate the engine. At this point "freeze" the DSO screen. Next measure the amount of time taken to switch from a lean signal to a rich signal. This should be no more than 80m/s. Also observe the lowest and highest voltage level. The highest should be no less than 800m/v. The lowest should be no higher than 175m/v.
These sensors are one wire (grounded to the exhaust manifold), two wire (signal and sensor ground), Three wire (signal, ground and heater) and four wire (signal, ground, heater with ground).

The main function of this sensor is to fine tune the air/fuel mixture. If the sensor is not functioning properly, emissions and drivability will be effected




**Notes:**

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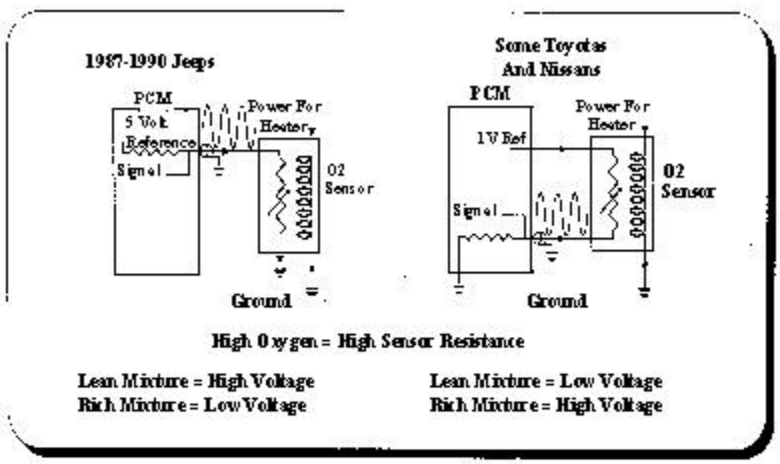
This slide shows the schematic for a four wire zirconium oxygen sensor. It should be noted the signal wire is shown as a shielded wire. This is true of some sensors but not all. The technician should note the metallic ground used on this sensor. In some cases, the manifold is used as the sensor ground. The reason for the metallic ground is to provide a “cleaner” signal to the PCM. If the sensor uses the manifold as a ground, voltage spikes will be picked up by the signal from the voltage “noise” in the ground return to the battery.

The PCM uses a comparator circuit to determine the actual voltage signal being generated by the sensor.

It should be noted the heater for the sensor also uses a metallic ground. This again prevents any “noise” being generated to the sensor signal.

The only true test of the functioning of this type of sensor is the DSO (digital storage oscilloscope). The use of a DVOM will not test the sensors bias or reaction time

# Titania Oxygen Sensor




## Notes:

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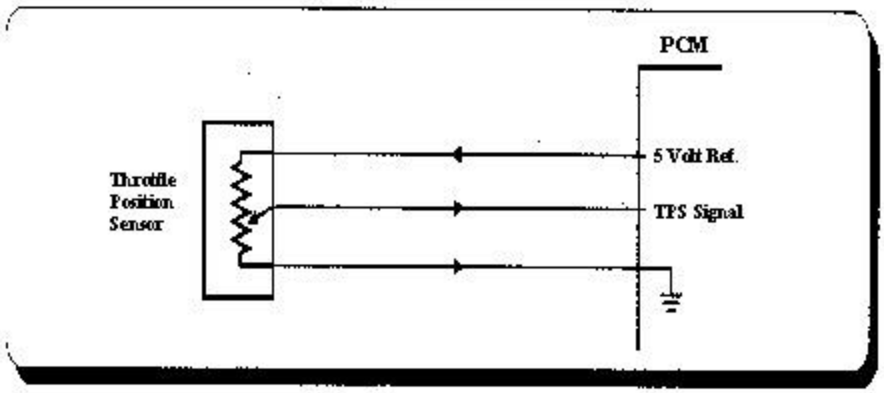
The Titania oxygen sensor operates differently than the Zirconium oxygen sensor. The Titania sensor must have a reference voltage applied to it in order to function. The first to be described will the one used on the Jeep vehicles. This is the one shown on the left of the above slide. It requires a 5-volt reference supplied by the PCM. It should be noted the signal is taken before the variable resister which completes the circuit to ground. As the variable resister increases in resistance, the signal voltage increases. This is because when the resistance increases the amperage decreases. With this decrease in amperage, the voltage drop across the fixed resister in the PCM will be less. Thus the signal voltage will increase. When the mixture is lean the variable resistance increases. The signal voltage will then increase. The reverse is also true, when the mixture is rich (low O2) the variable resistance decreases with a decrease in signal voltage. Rich mixture=low signal voltage, Lean mixture=high signal voltage.

The second type of Titania sensor is used on some Nissans and Toyotas. This sensor is shown on the right side of the slide. This uses a 1-volt reference. The signal is taken after the variable resister and before the fixed resister. The result is an opposite reading for the same O2 content in the exhaust. With a high O2 content the variable resister increases in resistance. The voltage drop across this resister is higher thus less voltage is available to the signal voltage line. Lean mixture=low signal voltage. Rich mixture=high signal voltage. The technician should understand this concept completely. It will help the technician diagnose a faulty Titania sensor.

# Throttle Position Sensor




## Notes:

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Most throttle position sensors are potentiometers. This type of sensor converts a variable voltage signal into % throttle opening. The PCM uses this signal to determine fuel delivery, spark timing and transmission shifting.

This sensor is usually a three wire sensor. One wire supplies the reference voltage. The second wire conducts the signal to the PCM. The third wire is used for sensor ground.

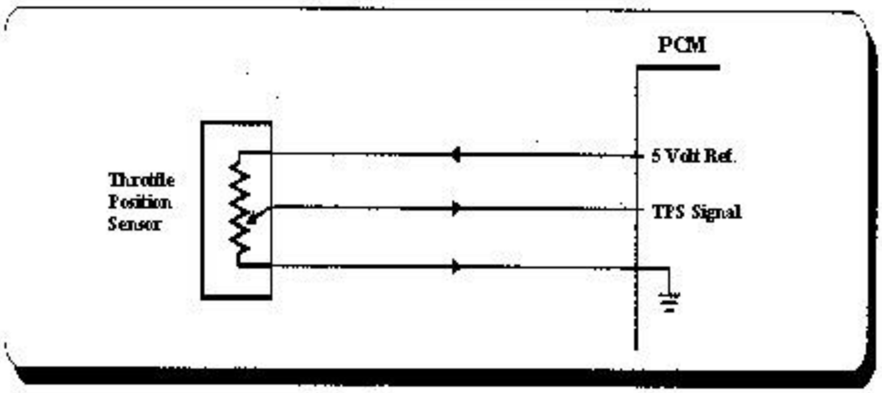
As the wiper is moved across the resister, the signal voltage changes to reflect the throttle angle. The PCM uses this information along with the RPM signal to help determine the proper air/fuel ratio and ignition timing.

If the PCM "sees" a signal voltage of 80% throttle opening it considers the throttle to be in the "wide open" position. Should the PCM see this type of signal, from the TPS, during cranking of the engine, the result could be a "no start" condition. The reason for this is the PCM would set the system into a "clear flood" mode. This would shut down the injectors completely or to a very short duration.

If the signal from the TPS "drops out" while the wiper is moved across the resister, the result will be a hesitation. The reason for this is the PCM interprets this drop out as a deceleration signal and will shut down the injectors.

The best tool to diagnose the TPS is the DSO. With the scope hooked up to the signal wire and ground, the TPS should be opened to WOT and allowed to return to an idle position. The trace on the scope should be a smooth transition from a low voltage signal to a high voltage signal and a smooth return to a low voltage signal.

# Throttle Position Sensor




## Notes:

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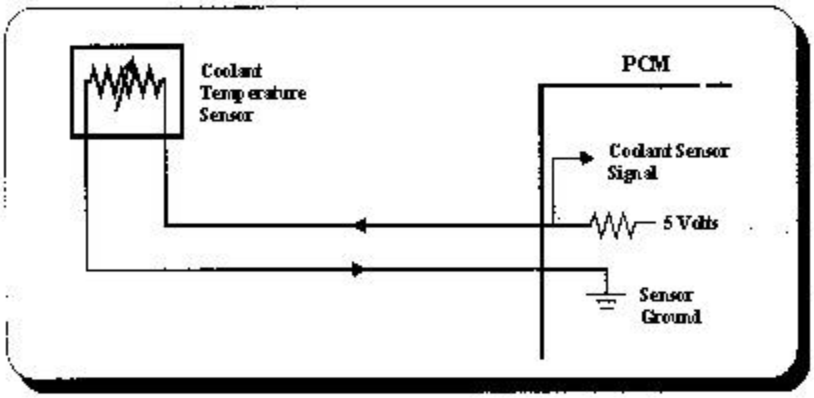
The types of TPS shown in the above slide communicates to the PCM whether the throttle is in the WOT position or closed throttle.
It should be noted there is a difference between the two types of TPSs using this type of communication with the PCM. The one on the left supplies the reference voltage to the "wiper" of the sensor while the sensor shown on the right side of the slide sends the reference voltage to the WOT and idle contacts. The circuit will be closed when either the WOT contact or the idle contact are closed with the wiper contact.
Some models using this type of TPS (like Toyota) must sense a closed throttle condition when the base timing is adjusted. If the electrical connection is not made by the TPS when the throttle is closed, any base timing adjustment made under these conditions would be inaccurate.

# Temperature Sensors




**Notes:**

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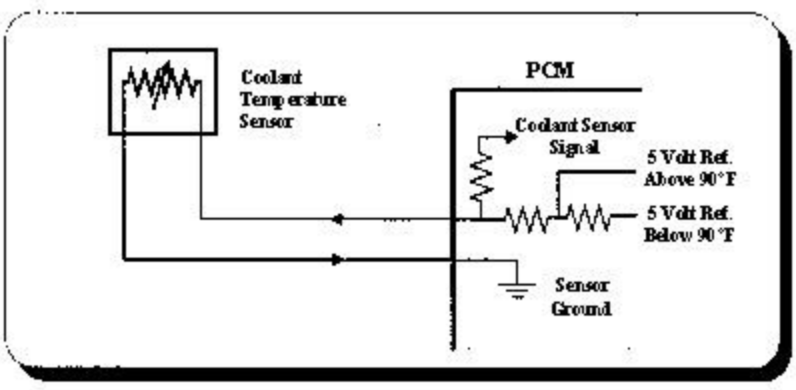
These types of sensors are called a “thermistor”. This simply means that as the temperature changes the voltage signal changes. Most thermistor type sensors are of the NTC type. NTC means “negative temperature coefficient”. This means that as the temperature of the sensor increases, the electrical resistance decreases. There are a “few” PTC type temperature sensors which increase in electrical resistance as the temperature of the sensor increases.

A reference voltage is applied through a fixed resister in the PCM. As the resistance of the sensor changes the amperage in the circuit changes. With the change in amperage, the amount of voltage drops across the fixed resister changes. It should be noted the PCM measures the voltage available after the fixed resister.

On an NTC type of sensor, if the amperage increases (lower resistance in the sensor) the voltage drop across the fixed resister increases. The result would be a lower available voltage sensed by the PCM. This would be interpreted by the PCM as a higher temperature.

# Temperature Sensors




**Notes:**

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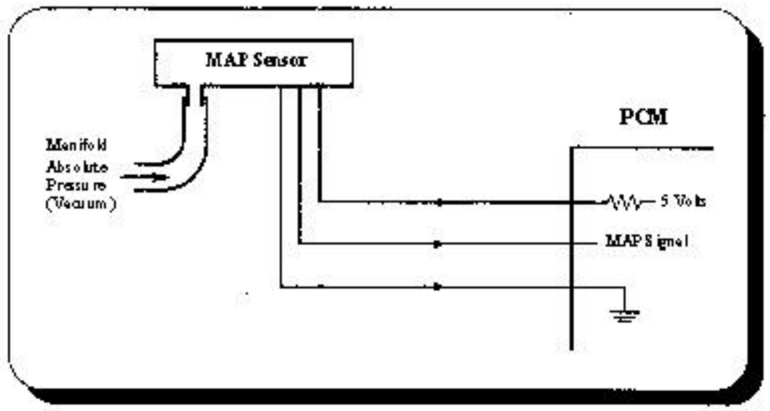
The temperature sensor shown in the above slide is an ECT (engine coolant temperature) sensor. It functions the same as the sensor discussed in the previous slide. The only difference is the circuitry inside the PCM associated with this sensor.
It should be noted the 5-volt reference voltage is applied in one of two locations of the circuit, depending on the current temperature of the coolant. One manufacturer that used this concept was GM.
If the technician is looking at the voltage signal of this sensor, it should be noted what actual temperature the coolant is at. As can be seen, the application of the reference voltage, to the circuit changes with the change in temperature of the coolant. It should be noted the change occurs at 90 def. The signal voltage will be high when the coolant is cold and will degrease as the temperature approaches 90 deg. F. At 90 def. the reference voltage is applied to the circuit with less fixed resistance. The result is a more accurate reading of the temperature at normal operating temperature.

# MAP Sensor




## Notes:

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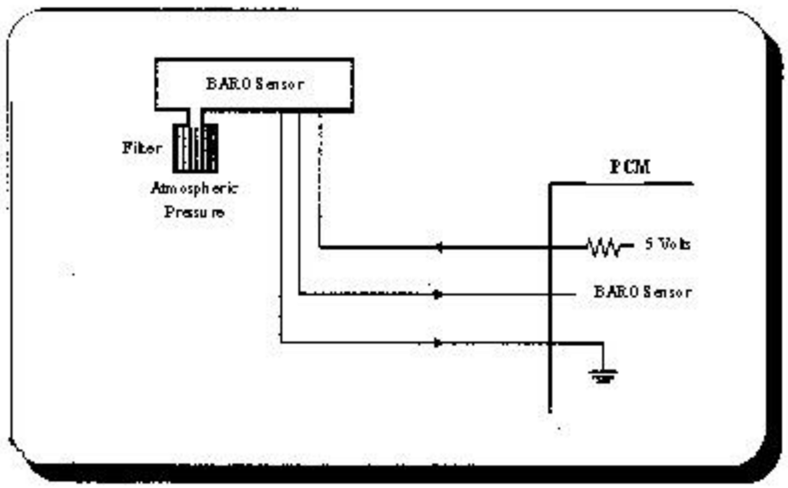
RPM sensors convert engine RPM into a voltage signal which the PCM uses for RPM, ignition timing, injector timing and over rev control. RPM sensors are also used to trigger the module when controlling the primary ignition.

There are basically three types of RPM sensors, the Permanent Magnetic generator, Hall-effect, and Optical (LED) types. The magnetic type generates an A/C analog signal as the reflector moves past the sensor which changes the magnetic field. Two wires are use on these sensors, but a third wire may be used with a grounded shield to protect against electrical interference.

A p.m. generator does not need a reference voltage to work, but some manufactures will send a small bias voltage to the sensor. The ignition module will convert this AC signal to a digital DC signal so it can be used by the module and the PCM.

Testing Sensor Signal -Attach AC voltmeter or lab-scope leads to the two sensor wires to check the signal. Check for proper waveform or voltage reading from the sensor while turning the engine or distributor. Attach Ohmmeter leads to the Magnetic generator sensor to test for continuity and resistance of the coil. Refer with your reference material for specs.

# BARO Sensor




**Notes:**

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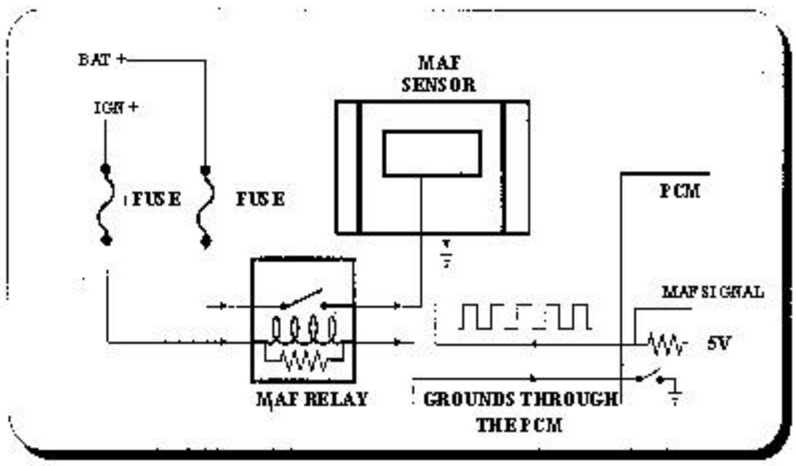
A BARO sensor is basically the same as a MAP sensor but is used to monitor barometric pressure only. In many cases the MAP sensor will take a reading of the barometric pressure as the engine is started. This reading is usually stored by the PCM until the key is turned off. Some systems will update the Baro reading during certain driving conditions. When testing an intermittent problem try lightly tapping on the sensor to show up the fault.
LOW PRESSURE HIGH PRESSURE
HIGH VACUUM LOW VACUUM
MAP SENSOR LOW VOLTAGE HIGH VOLTAGE
VACUUM SENSOR HIGH VOL TAGE LOW VOL TAGE
FORD SENSOR 100-110 Hz IDLE 159 Hz +-3 NO VACUUM (at sea level)
Testing Sensor Signal- Attach the positive lead of a DVOM or lab-scope to the signal wire. The voltage or frequency should change in relation to the pressure as vacuum is applied to the sensor. Check your reference material for specs on voltage or frequency reading at a given pressure.
Ford's MAP sensor signal can no.to be tested with a volt meter, a frequency meter (counter) can be used but a lab-scope is the best tool.
Testing Reference Voltage -Attach the positive lead of a DVOM or lab-scope to the signal wire. Most systems have a 5-volt reference voltage supplied to the sensor.
Testing Ground Circuit -Attach the positive lead of a DVOM or lab-scope to the ground wire. There should be less than 0.05 volts with the key in the run position.

# MAF Sensor




## Notes:

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MAF sensors convert the intake air flow and air mass into an electrical signal. This information can be used by the PCM for fuel delivery and spark timing. MAF sensors will send either a digital or an analog signal depending on the type and the manufacture. Most sensors use a hot wire or a heated element to measure the air flow. As the air flows past the heated element (or wire) the element is cooled. This cooling changes the resistance, and thus, the current flow in the element.

Some manufactures use the Karmon Vortex (ultra-sonic) or the Photo Diode types. Whatever type sensor is used, the signal is either an analog or digital. Most sensors also have an air temperature sensor included in the MAF. In some cases, this thermistor is called a Cold Wire.

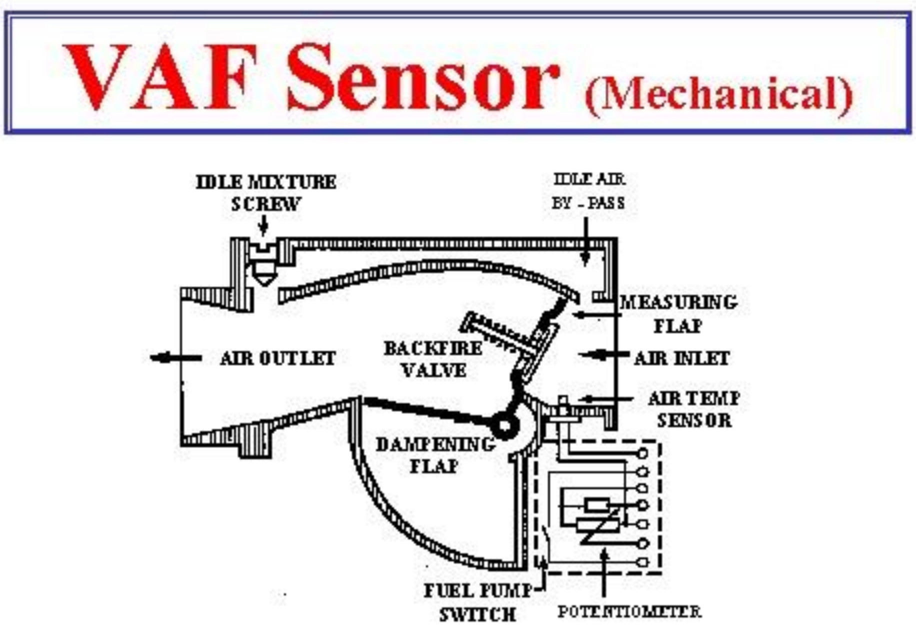
Some hot wire sensors use a burn-off relay to feed the wire for a few seconds when the engine is turned off. This heats up the wire to burn off contaminates. Some sensors only measure a sample of the total air rather than all of the air entering the engine. When testing an intermittent problem try lightly tapping on the sensor and tug lightly on the wires to show up the fault.

Testing The Power Feed -Attach the positive lead of a DVOM or lab-scope to the feed wire. Most sensors use system voltage to power up the sensor.

Testing Sensor Signal- Attach the positive lead of a DVOM or lab-scope to the signal wire. With the circuit complete and operating, the sensor wire voltage or frequency should vary with the change in airflow. Check your reference material for specs on voltage or frequency readings at different grams of air-flow.

Testing Reference Voltage -With the signal circuit open, attach the positive lead of a DVOM or lab- scope to the signal wire. The voltage on the sensor wire should be reference voltage. Most systems have a reference voltage supplied to the sensor.

Testing Ground Circuit -With a DVOM or a lab-scope, check for less than 0.2 volts with the key in the run position.




## Notes:

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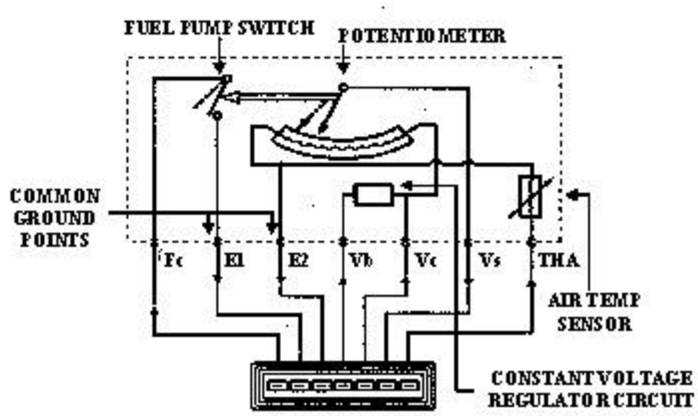
Vane Air Flow Meters use a potentiometer to convert the intake air flow into an electrical signal. This information can be used by the PCM for fuel delivery and spark timing.
Air flow moves a door (or vane) in the sensor which in turn moves a wiper on the potentiometer. Use your reference material to identify the signal wire for the sensor you are testing. Most Air-Flow meters have an air temperature sensor incorporated in the sensor.
Many Vane Air-Flow meters also have a fuel pump switch to cut off the fuel pump when no air flow is measured. On sensors with a "0" shaped plastic cover the potentiometer can be checked with an Ohm meter. The sensors with a square cover have a resistor parallel to the potentiometer and cannot be checked with an Ohmmeter.
Testing Sensor Signal -Attach the positive lead of a DVOM or lab-scope to the signal wire. The voltage should move in relation to the air flow (or vane movement). Check your reference material for specs
and testing procedures. Some volt meters may be too slow to properly test this sensor.
Testing Reference Voltage -Attach the positive lead of a DVOM or lab-scope to the reference wire. Most systems use a 5-volt reference voltage to the sensor with key in the run position.
Testing Ground Circuit -With a DVOM or a lab-scope there should be less than 0.05 volts with the key in the run position.

# VAF Sensor (Electrical)




AIRFLOW METER DIAGRAM

## Notes:

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MAF sensors convert the intake air flow and air mass into an electrical signal. This information can be used by the PCM for fuel delivery and spark timing. MAF sensors will send either a digital or an analog signal depending on the type and the manufacture. Most sensors use a hot wire or a heated element to measure the air flow. As the air flows past the heated element (or wire) the element is cooled. This cooling changes the resistance, and thus, the current flow in the element. Some manufactures use the Karmon Vortex (ultra-sonic) or the Photo Diode types.

Whatever type sensor is used, the signal is either an analog or digital. Most sensors also have an air temperature sensor included in the MAF. In some cases, this thermistor is called a Cold Wire. Some hot wire sensors use a burn-off relay to feed the wire for a few seconds when the engine is turned off. This heats up the wire to burn off contaminates. Some sensors only measure a sample of the total air rather than all of the air entering the engine. When testing an intermittent problem try lightly tapping on the sensor and tug lightly on the wires to show up the fault.

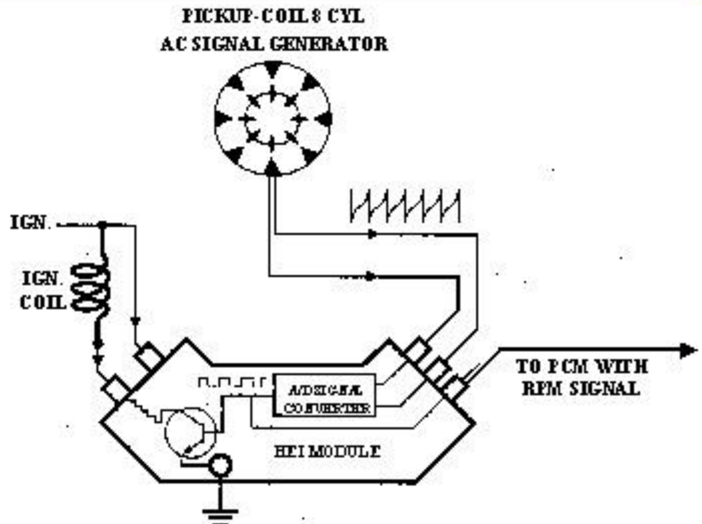
Testing The Power Feed -Attach the positive lead of a DVOM or lab-scope to the feed wire. Most sensors use system voltage to power up the sensor.

Testing Sensor Signal -Attach the positive lead of a DVOM or lab-scope to the signal wire. With the circuit complete and operating, the sensor wire voltage or frequency should vary with the change in airflow. Check your reference material for specs on voltage or frequency readings at different grams of air-flow.

Testing Reference Voltage -With the signal circuit open, attach the positive lead of a DVOM or lab- scope to the signal wire. The voltage on the sensor wire should be reference voltage. Most systems have a 5-volt reference voltage supplied to the sensor.

Testing Ground Circuit -With a DVOM or a lab-scope, check for less than 0.05 volts with the key in the run position.

# TACH Sensors




## Notes:

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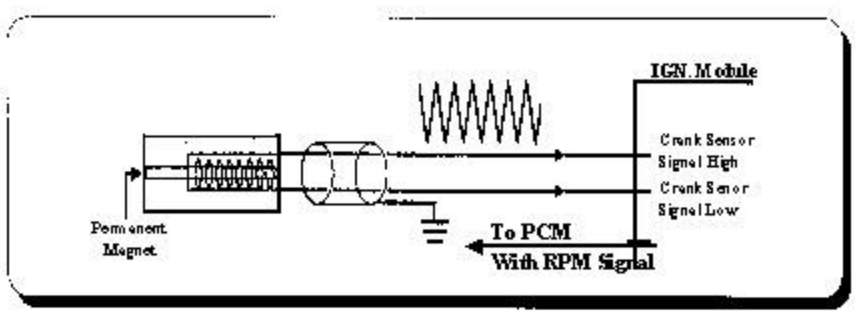
RPM sensors convert engine RPM into a voltage signal which the PCM uses for RPM, ignition timing, injector timing and over rev control. RPM sensors are also used to trigger the module when controlling the primary ignition.
There are basically three types of RPM sensors, the Permanent Magnetic generator, Hall-effect, and Optical (LED) types.
The magnetic type generates an A/C analog signal as the reflector moves past the sensor which changes the magnetic field. Two wires are use on these sensors, but a third wire may be used with a grounded shield to protect against electrical interference. A p.m. (permanent Magnet) generator does not need a reference voltage to work, but some manufactures will send a small bias voltage to the sensor. The ignition module will convert this AC signal to a digital DC signal so it can be used by the module and the PCM.
Testing Sensor Signal -Attach AC voltmeter or lab-scope leads to the two sensor wires to check the signal. Check for proper waveform or voltage reading from the sensor while turning the engine or distributor. Attach Ohmmeter leads to the Magnetic generator sensor to test for continuity and resistance of the coil. Refer with your reference material for specs.

# Tach Sensors




## Notes:

RPM sensors convert engine RPM into a voltage signal which the ECM uses for RPM, ignition timing, injector timing and over rev control. RPM sensors are also used to trigger the module when controlling the primary ignition.

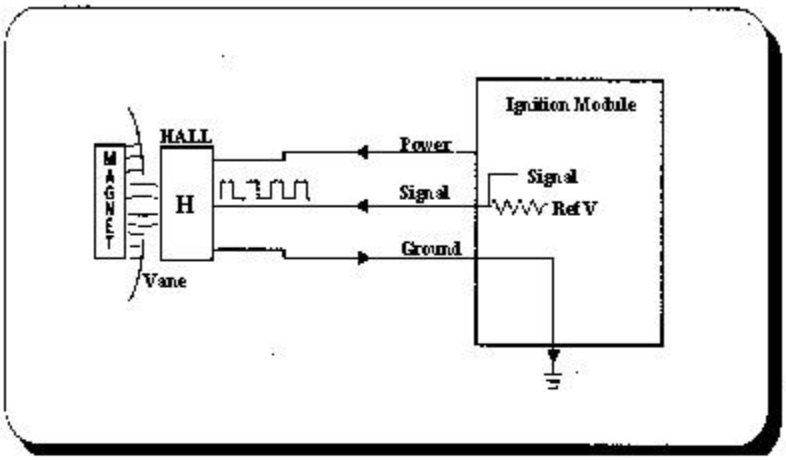
There are basically three types of RPM sensors, the Permanent Magnetic generator, Hall-effect, and Optical (LED) types. The Hall Effect and the Optical sensors are covered on other slides

The magnetic type generates an A/C analog signal as the reflector moves past the sensor which changes the magnetic field. Two wires are use on these sensors, but a third wire may be used with a grounded shield to protect against electrical interference. A p.m. (permanent magnet) generator does not need a reference voltage to work, but some manufactures will send a small bias voltage to the sensor.

The ignition module will convert this AC signal to a digital DC signal so it can be used by the module and the PCM.

Testing Sensor Signal -Attach AC voltmeter or lab-scope leads to the two sensor wires to check the signal. Check for proper waveform or voltage reading from the sensor while turning the engine or distributor. Attach Ohmmeter leads to the Magnetic generator sensor to test for continuity and resistance of the coil. Refer with your reference material for specs.

# Hall Effect RPM Sensor




**Notes:**

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RPM sensors convert engine RPM into a voltage signal which the PCM uses for RPM, ignition timing, injector timing and over rev control. RPM sensors are also used to trigger the module when controlling the primary ignition.

The Hall-effect switch uses a magnetic field to turn the Hall device on or off. Usually a series of blades are used to block the magnetic field from the Hall Effect device. Some systems will move the magnet away from the Hall Effect unit. As the blades alternately block or allow the magnetic field to reach the Hall Effect device, the signal is switched high and low.

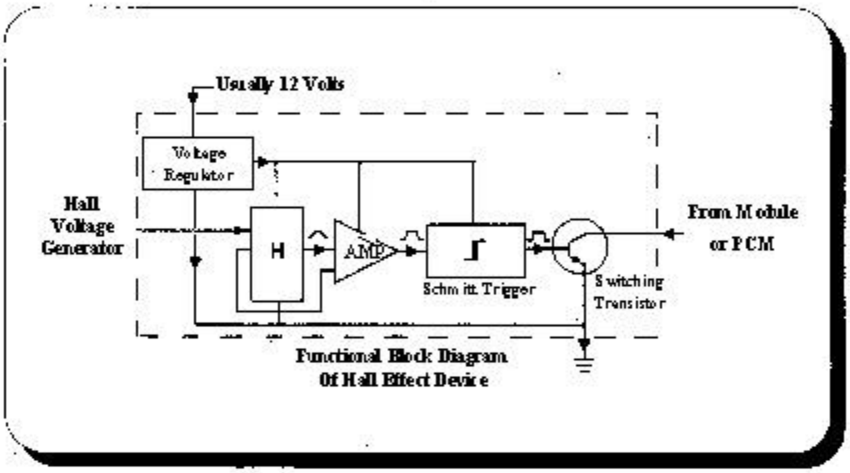
The Hall effect switch has three wires, power, signal and ground. Usually system voltage is used to power the Hall Effect device and 5 to 12 volts is used for the signal. These sensors are also used as camshaft sensors or vehicle speed sensors on some vehicles.

Testing Sensor Signal- Attach lab-scope or DC voltmeter pos. lead to the signal lead. Check for proper waveform or voltage reading from the sensor.

Testing Reference and Power Voltage -Use a DC voltmeter or lab-scope to test reference and power circuits. Check reference material for proper voltage.

Testing Ground Circuit -With a DVOM or a lab-scope, there should be less than 0.05 volts with the key in the run position.

# RPM – Hall Effect




## Notes:

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RPM sensors convert engine RPM into a voltage signal which the ECM uses for RPM, ignition timing, injector timing and over rev control. RPM sensors are also used to trigger the module when controlling the primary ignition.

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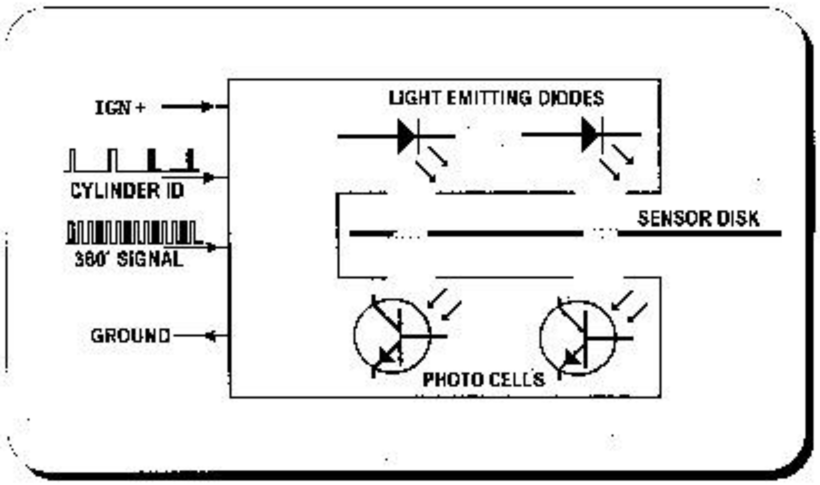
Testing Sensor Signal- Attach lab-scope or DC voltmeter pos. lead to the signal lead. Check for proper waveform or voltage reading from the sensor.

Testing Reference and Power Voltage -Use a DC voltmeter or lab-scope to test reference and power circuits. Check reference material for proper voltage.

Testing Ground Circuit -With a DVOM or a lab-scope, there should be less than 0.05 volts with the key in the run position.

# Light Emitting Diodes




## Notes:

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RPM sensors convert engine RPM into a voltage signal which the PCM uses for RPM, ignition timing, injector timing and over rev control. RPM sensors are also used to trigger the module when controlling the primary ignition.

Some distributors have Optical (LED) sensing devices in them to give cylinder ID and RPM signals. In the distributor is a thin disk which usually has two rings of small slots cut into it. Generally, the outer ring has 360 slots (one for every degree of rotation) and the inner ring of slots has one for each cylinder. Some systems will have a wider slot for number one cylinder to show engine position.

GM's L T1 engine is equipped with an optical ignition system which has 8-cylinder ID slots. 4 of the slots (every other) are wider, and the 4 slots are all different sizes. This allows the PCM to identify cylinder location within 180 degrees of crankshaft rotation.

They use Light Emitting Diodes (LED) on one side of the disk and Photo Transistors on the other side. As the light reaches the photo transistors a signal is produced and sent to the ignition module or the PCM. The signals are usually known as "High Res" (Resolution) for the 360-degree signal and "Low Res" for the cylinder ID signal. These distributors usually have 4 wires, system voltage to power it up, a ground, and one wire for each signal.

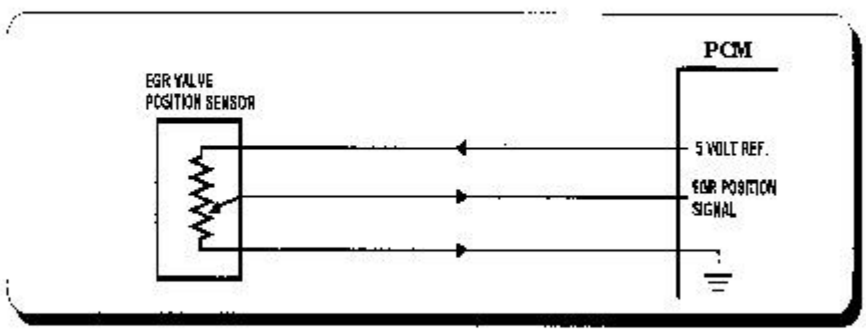
The PCM or ignition module sends a reference voltage to the optical sensor for both the high and low res. signals. The sensor will pull the signal low to produce the digital signal.

Testing Sensor Signals -Use a lab-scope to check the signal. The signal should be a DC waveform and usually a digital square wave. Some signals may look more like a P.M. Generator signal tapering toward the top and bottom.

Testing Input Power -Use a DVOM and look for close to system voltage with the key in the run position.

Testing Ground Circuit -Use a DVOM or a lab-scope and look for near "0" volts with the key in the run position.

# EGR Sensors




## Notes:

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The EGR valve sensor changes the valve pintle movement or exhaust flow into a voltage signal. which the PCM can use for fuel delivery and spark timing calculations. EGR valve position sensors are usually a potentiometer type sensor. There are usually three wires in the circuit, a reference voltage, a ground circuit and the signal wire. Current flows from the reference through the resistor in the sensor and on to ground. As the voltage drops through the resistor, a wiper (moved by the EGR pintle) senses the voltage at that point. That signal is sent to the PCM by the sensor wire. On most systems, a low voltage signal (.5 to 1.3v) will indicate a closed EGR valve.

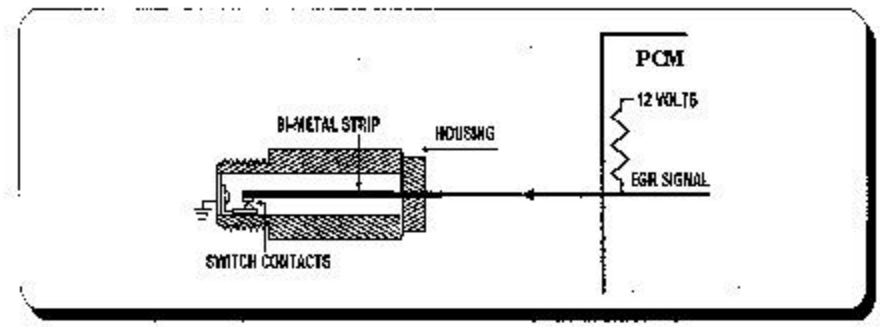
Some manufactures are using thermistors or thermal switches to monitor EGR flow by looking at the temperature of the gases flowing through the EGR valve. If a thermistor is used, check it the same as you would check a coolant temperature sensor circuit. A thermal switch will open or close the circuit depending on the temperature.

Some systems monitor MAP and Fuel Trim while operating the EGR valve. This allows the PCM to see the effect on engine operation, thus operation of the EGR system. Testing Sensor Signal -Attach the positive lead of a DVOM volt meter or lab-scope to the signal wire. The voltage should move up smoothly to near 5 volts as the EGR valve is opened slowly (about 20 seconds) and the voltage should move down smoothly as the valve is closed slowly. Most volt meters are too slow to properly test the sensor signal.

Testing Reference Voltage -Attach the positive lead of a DVOM or lab-scope to the signal wire. Most systems have a 5-volt reference voltage supplied to the sensor.

Testing Ground Circuit -With a DVOM or lab-scope there should be less than 0.05 volts on the ground line with the key in the run position.

# EGR Sensors

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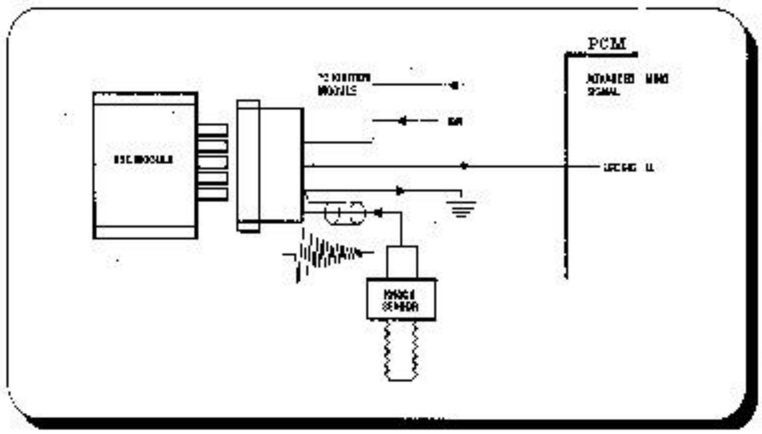
# Knock Sensors




## Notes:

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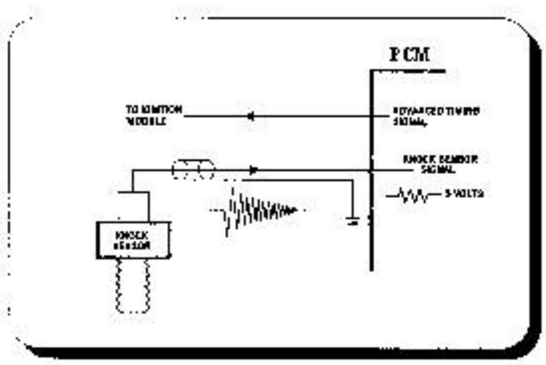
Knock sensors convert engine pinging (or vibration) into a voltage signal. The PCM uses this information to retard the spark timing to control spark knock. It is possible for the sensor to pick up engine or component noise which can retard ignition timing too far.
Most knock sensors are piezoelectric type sensors. They have a piezoelectric crystal that generates an A/C signal with a frequency and voltage proportional to the engine vibration it senses. Most sensors use one wire; the circuit is completed (grounded) through the mounting of the sensor. In many cases the knock signal will be sent to an Electronic Spark Control (ESC) module to be processed before being sent on to the PCM.
Most knock sensors use a shielded signal wire to eliminate magnetic interference from inducing a voltage on the signal line. If the shielded wire is damaged or the wire is routed too close to a magnetic field (like ignition coils) it may result is a knock signal when no knock is occurring. Some systems will send a bias voltage to the sensor. The AC signal generated by the sensor will then vary the bias voltage.
Some systems use a piezo resistive type sensor which changes resistance to vary a reference voltage.
Testing Sensor Signal- Attach the positive lead of a digital AC volt meter or lab-scope to the signal wire. The signal will vary as the sensor senses engine vibration. Tap on the engine block near the sensor and monitor the signal or check the ignition timing with a timing light. The amount of timing retard can sometimes be seen on a Scanner.
Testing Sensor Ground -Usually the sensor is grounded through the mounting. Use an Ohm meter to check resistance between the sensor and ground.
Testing ECM Response -Disconnect wire going to knock sensor. Attach one end of a 1Ox multiplier to the wire leading to the ECM (i.e. the 1Ox multiplier is in place of the knock sensor) leave the other end of the 1Ox multiplier unattached. Lay the 1Ox multiplier near

the distributor cap, coil, or coil packs. With a Scanner or a timing light, monitor ECM response to the knock signal.

# Knock Sensors

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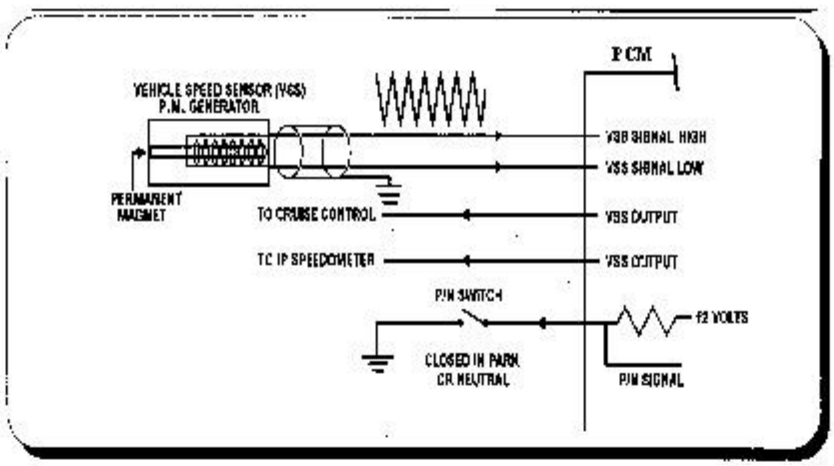
# VSS Sensor




**Notes:**

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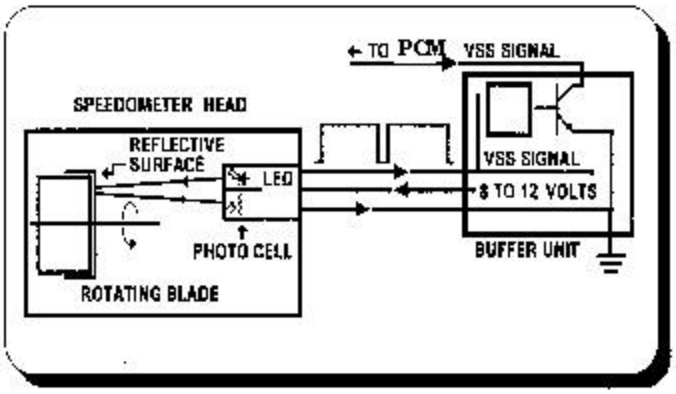
Vehicle speed sensors convert vehicle speed into a digital or analog signal that is sent to the PCM. This information can be used by the PCM for transmission shifting, cruise control, and over-speed control. Vehicle speed sensors can be a Permanent Magnet Generator, a Hall Effect switch, LED photo or a reed switch.
Most Vehicle speed sensors are mounted in the transmission and run off of the output shaft. Sometimes the VSS signal is routed through a buffer to digitalize the signal before it is sent to the PCM. VSS signals can also be used for the cruise control and electronic speedometers. Most of these circuits also have shielded leads to eliminate interference.
The PM generator produces an A/C voltage while the Hall Effect and reed switches give a digital signal.
Testing Sensor Signal- Magnetic generator type -attach AC voltmeter or lab-scope leads to the two sensor wires to check the signal. Check for proper waveform or voltage reading from the sensor. Attach Ohm meter leads to the Magnetic generator sensor to test for continuity and resistance of the coil. Refer with your reference material for specs.
When testing the signal from Hall, photo or reed switches, use a DVOM or lab-scope. On a reed switch, the voltage drop across the switch should not exceed 0.2 volts.

# VSS Sensors

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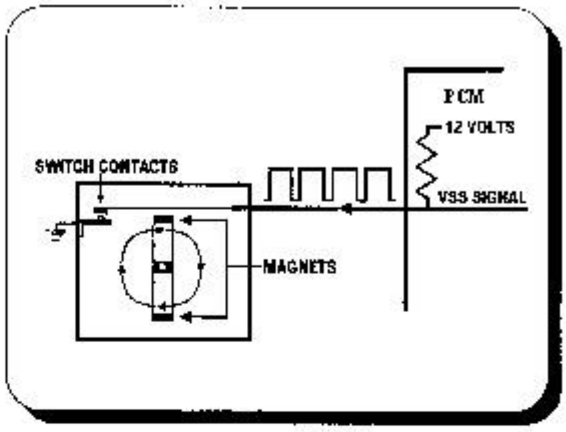


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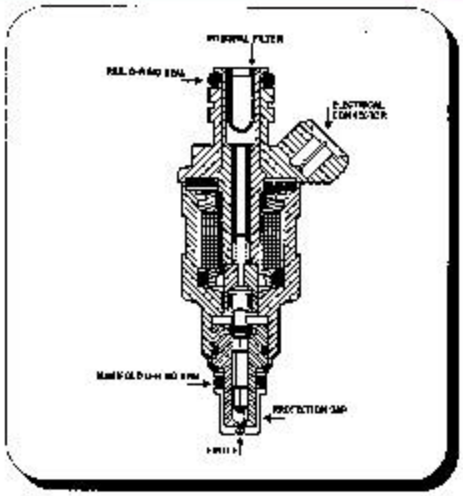
# Electronic Fuel Injector




**Notes:**

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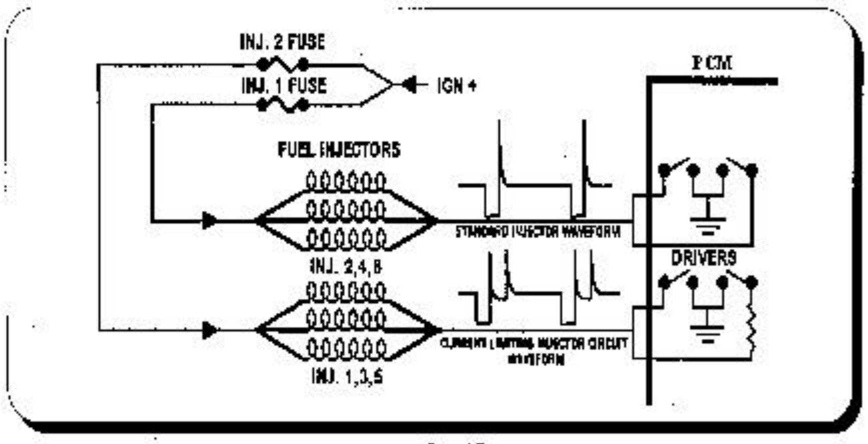
Fuel injectors are a Solenoid used to deliver fuel and are pulsed on to control the air fuel mixture. Injectors are usually energized for 1.5 to 3 milliseconds at idle. An on time of more than 5 MS usually indicates a rich command.
The injector has two wires, usually one supplies system voltage (key on) to the injector and the circuit is completed (grounded) through the other wire via the PCM. The PCM completes the circuit to energize the solenoid. On a few systems the PCM will control system voltage to the injector and the ground circuit is grounded all of the time.
When the solenoid is energized fuel flows through the injector. The PCM can increase or decrease the "on-time" of the injector to control the air fuel mixture.
The PCM needs an RPM signal before it will pulse the fuel injectors. Some systems will use two drivers to control injector circuits. They can use two drivers in order to handle more current in each circuit. The more injectors in a parallel circuit the more current flow through the drivers.
Some systems use one driver to pull the injector on and one driver to hold the injector on. This is generally called a "Current Limiting “type of injector circuit.
Testing The Injector -Attach the leads of a DVOM to test the resistance of the injector windings. Check your reference materials for specs on the injector resistance.
Testing Feed Circuit -Attach the positive lead of a DVOM or lab-scope to the feed wire. Check for system voltage supplied to the injector.

# Injector Control

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The PCM completes the circuit to energize the solenoid. On a few systems the PCM will control system voltage to the injector and the ground circuit is grounded all of the time. When the solenoid is energized fuel flows through the injector. The PCM can increase or decrease the "on-time" of the injector to control the air fuel mixture.

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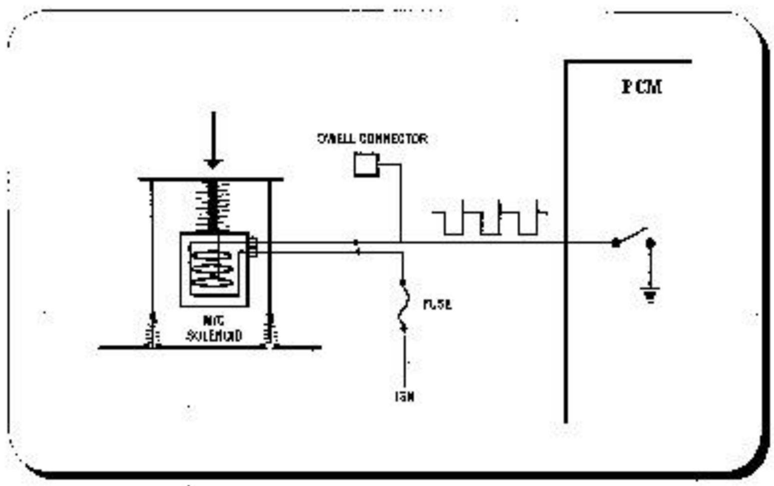
Testing The Injector -Attach the leads of a DVOM to test the resistance of the injector windings. Check your reference materials for specs on the injector resistance.

Testing Feed Circuit -Attach the positive lead of a DVOM or lab-scope to the feed wire. Check for system voltage supplied to the injector. Testing The Ground Circuit -The circuit is only grounded when the PCM wants the injector energized.

The best way to check the resistance of this circuit is to attach a lab-scope to the ground side of the injector. As the PCM grounds the circuit the voltage should be close to 0.

# Mixture Control Solenoid




**Notes:**

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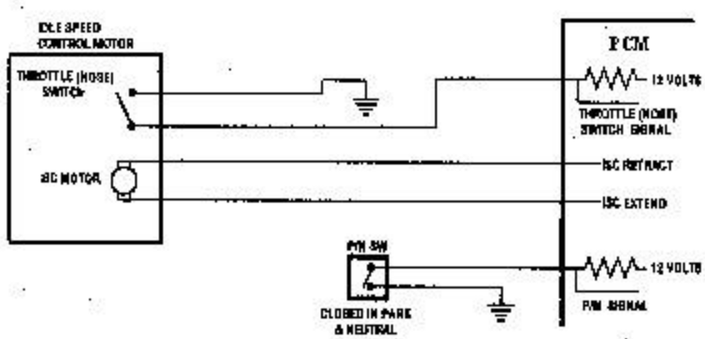
This Solenoid is used to control the air fuel mixture on most PCM controlled carburetors. The solenoid has two wires, one supplies 12 volt (key on) and the circuit is completed through the other wire via the PCM. The PCM completes the circuit to energize the solenoid and most systems will pulse the solenoid on and off ten times a second. The longer the solenoid is energized, the leaner the Air/Fuel mixture. The percentage of solenoid "on time" verses "off time" determines whether the mixture is rich or lean. The higher the percentage of time the solenoid is energized the leaner the mixture.
RICH_COMMAND LEAN_COMMAND
VOLT METER HIGHVOLTAGE LOW VOLTAGE
DWELL METER LOW DWELL HIGH DWELL
DUTY METER LOW DUTY CYCLE HIGH DUTY CYCLE
Testing The Solenoid -Attach the leads of a DVOM to the solenoid wires to test the resistance of the solenoid. Check your reference material for specs on the resistance. Usually above 15 Ohms.
Testing Feed Circuit -Attach the positive lead of a DVOM volt meter or lab-scope to the feed wire. Check for system voltage supplied to the solenoid.
Testing The Ground Circuit -The circuit is only grounded when the ECM want the solenoid energized. The best way to check the resistance of this circuit is to attach a lab-scope to the ground side of the solenoid. As the PCM grounds the circuit the voltage should be close to 0.

# Idle Speed Control




## Notes:

Most systems use a device, controlled by the PCM, to adjust the engine idle speed. There are three basic types of idle speed controls, DC motor, stepper-motor and solenoid. The systems using a DC motor will reverse the polarity (current flow) through the motor to position the plunger. Two wires are generally used on these motors, although two additional wires may be used for a nose switch. circuit. Usually these systems will not control the idle speed until the nose switch indicates that the throttle is closed. On the stepper-motor systems, the stepper motor has two separate windings in the motor. The PCM will energize each winding separately and will reverse the polarity to control the position of the plunger. These systems have four wires attached to the motor, two for each winding (circuit) in the motor. Some of the early systems used a solenoid as a throttle stop to set idle RPM. These solenoids are energized whenever the key is on, (not computer controlled).

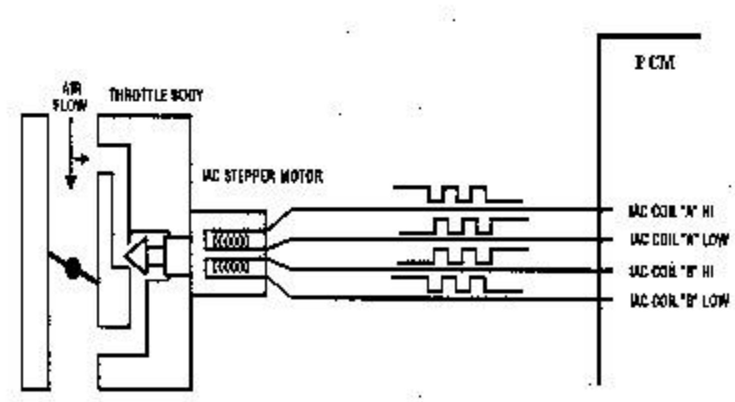
There is another type of RPM control that uses a solenoid. This solenoid opens and closes an orifice in which intake air flows around the throttle plate. The PCM controls the ground circuit of the solenoid and pulses the solenoid many times a second.

On many Ford systems, the ECM pulses the solenoid continually to control the idle speed. They vary the voltage more than the frequency which controls the current flowing through the solenoid. This means that the solenoid is held open (part way), depending on the current flow. Many systems use changes in ignition timing to make small changes in idle speed. The idle speed control motor may not be called to action until the PCM wants at least a 50 RPM change.

Testing The Solenoid or Motor -Use a DVOM to test the resistance of the solenoid or the stepper-motor windings. Check your reference material for specs.

Testing Feed Circuit -Use a DVOM or a lab-scope to check for system voltage supplied to the solenoid or motor. In some cases, the circuit will be powered up only when the PCM commands the motor to move.
Testing The Ground Circuit -The circuit is only grounded when the PCM want the solenoid energized. Use a lab-scope on solenoid and Stepper motors systems. The voltage should be close to 0 when the system is grounded. Remember, this is the command given to the actuator, it does not mean the motor or solenoid is moving.

# Idle Speed Control

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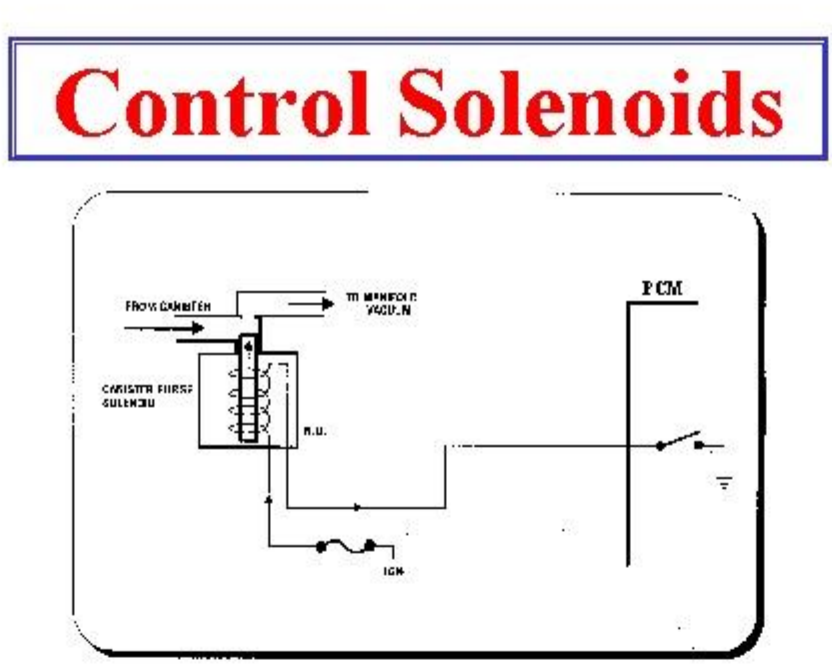


**Notes:**

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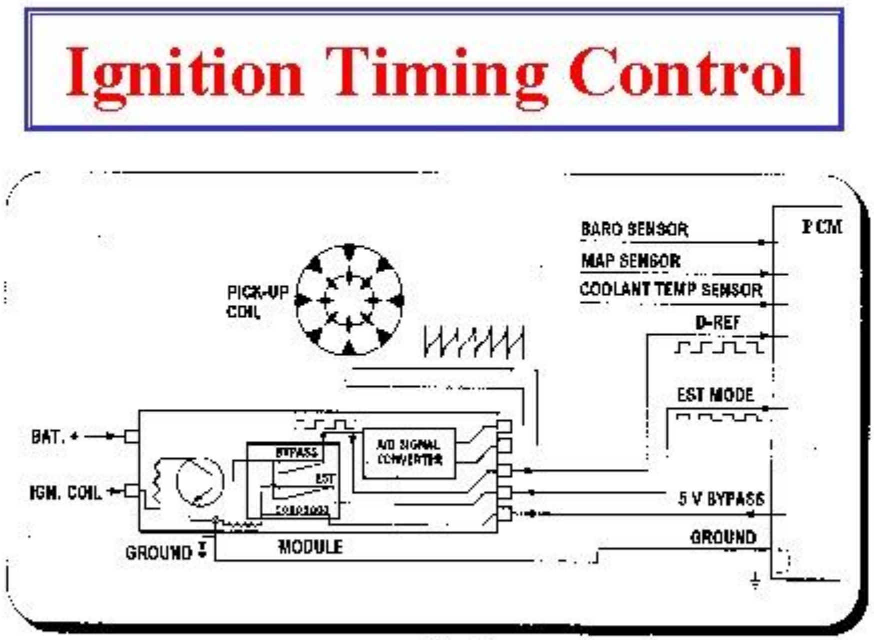
There are many systems such as EGR valves and Air Management Systems that use PCM controlled solenoids for better control. The solenoids have two wires, one supplies system voltage (key on) to the solenoid and the circuit is completed (grounded) through the other wire via the PCM. The PCM completes the circuit to energize the solenoid.

The PCM can increase or decrease the "on-time" of the solenoid to control the system.

Some solenoids may have a diode or resistor across the coil to protect the PCM from an inductive voltage spike as the circuit is opened.

Testing The Solenoid -Use a DVOM to test the resistance of the solenoid. Check your reference material for specs on the solenoid resistance.
Testing Feed Circuit -Attach the positive lead of a DVOM or lab-scope to the feed wire. Check for system voltage supplied to the injector. Testing The Ground Circuit -The circuit is only grounded when the PCM want the solenoid energized. The best way to check the resistance of this circuit is to attach a lab-scope to the ground side of the solenoid. As the PCM grounds the circuit the voltage should be close to 0.




**Notes:**

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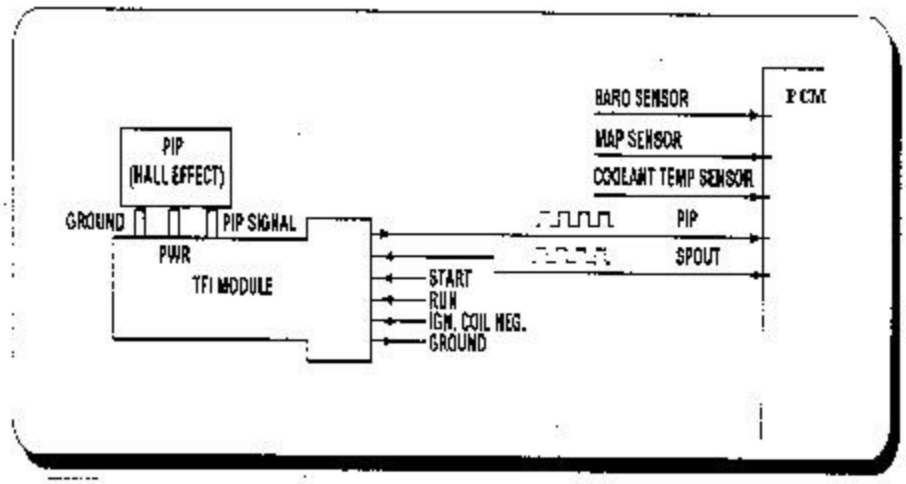
Most computer controlled systems use the PCM to control the ignition timing. Some ignition timing advance can be programmed in the ignition module, but most of the timing advance is processed through the PCM.
General Motors uses the D-REF (dist. reference) and EST (electronic spark timing) circuits to accomplish this, while Ford uses the PIP (profile ignition pick-up) and SPOUT (spark out) circuits.
The PCM calculates the amount of advance required depending on sensor inputs. Then the PCM modifies (advances) the distributor reference signal and sends the signal back to the ignition module. The module in-turn uses this signal to control the primary ignition circuit.
Testing The RPM and Computed Timing Signal -Use a DVOM or a lab-scope to check for a RPM signal to the PCM.
Testing The GM by: -pass Circuit -Use a DVOM or a lab-scope to check for a 5-volt signal to the module.

# Ignition Timing Control

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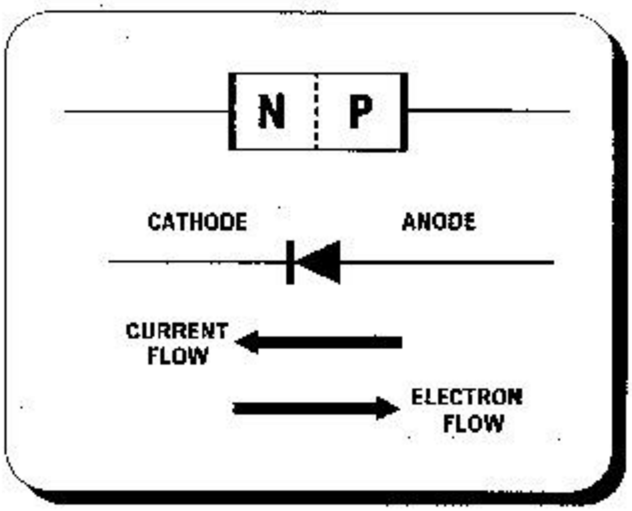
# Diode




**Notes:**

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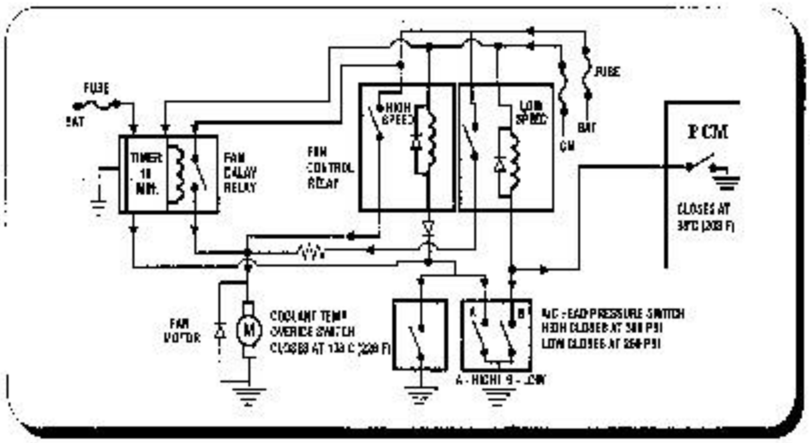
Diodes are a semiconductor designed to allow current flow in one direction only. Some vehicle manufactures use diodes within some circuits to restrict current flow to one direction only. Diodes also are used across some solenoids and relays to protect the PCM from inductive voltage spikes. Some motors, such as cooling fan motor, have diodes in them to reduce the A/C voltage that is produced within the motor.
Another type of diode that may be used is a. Zener diode. A Zener diode will allow reverse current flow when the voltage reaches a specific value.
When testing a diode, the circuit must be open and no system voltage applied to the diode. Most DVOMs have a DIODE test that will allow an ohm test of the diode with enough voltage to bias the diode. The ohm setting may not be able to bias the diode.
Testing The Diode -Confirm that the circuit, with the diode, is OPEN and that no voltage is applied to the diode. Set your meter to "DIODE TEST" and attach the leads to each side of the diode. Note the reading, then reverse the leads on the diode. The diode should have high resistance in one direction and low resistance in the other. Some meters will display a voltage instead of a resistance. The voltage shown is the voltage needed to bias the diode.

# Diodes in Circuits

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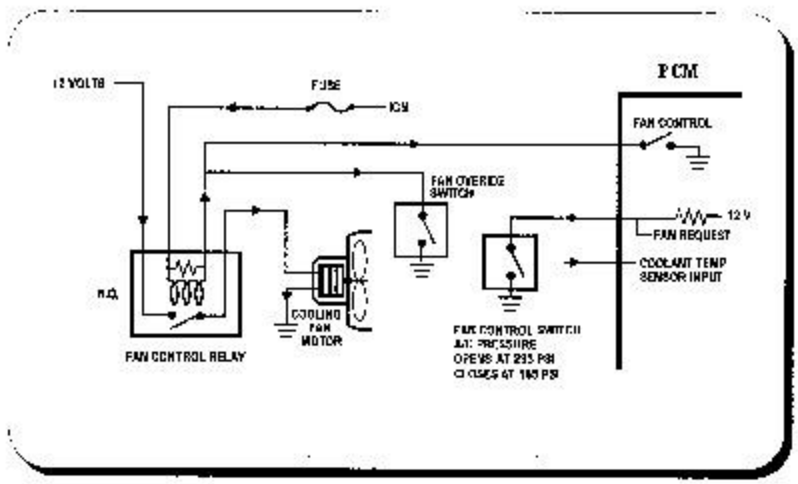
Testing The Diode -Confirm that the circuit, with the diode, is OPEN and that no voltage is applied to the diode. Set your meter to "DIODE TEST" and attach the leads to each side of the diode. Note the reading, then reverse the leads on the diode. The diode should have high resistance in one direction and low resistance in the other. Some meters will display a voltage instead of a resistance. The voltage shown is the voltage needed to bias the diode.

# Control Relays




**Notes:**

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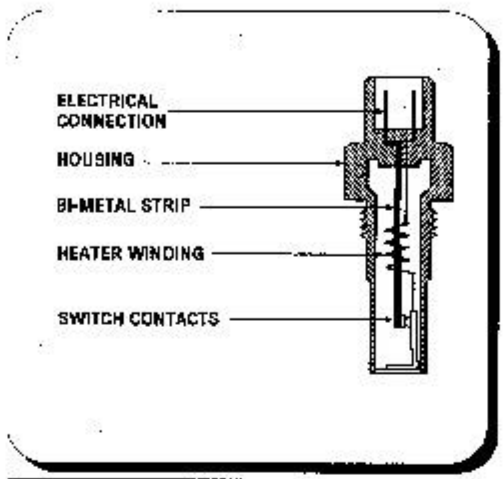
Relays are used to control circuits which require more current than the PCM can handle. The relay uses a low current circuit to control a higher current circuit such as a cooling fan or fuel pump. Relays use an electric magnet to pull high current contacts together or apart, depending on the application.
Usually the PCM controls the system by completing the ground circuit for the control portion (low current) of the relay. The relay usually has system voltage supplied to both high and low current circuits. When the PCM completes the low current circuit, the high current contacts will either be pulled together or apart depending on the application.
NOTE: Most relays have a diode or resisters across the coil to protect the ECM from inductive voltage spike as the circuit is opened.
Testing The Relay Coil -Use a DVOM to test the resistance of the coil. Check your reference material for specs on the relay coil resistance. Testing Feed Circuit -Use a DVOM or lab-scope to check for system voltage supplied to the relay coil and the high current circuit.
Testing The Ground Circuit -The circuit is only grounded when the PCM want the relay energized. The best way to check the resistance of this circuit is to attach a lab-scope to the ground side of the relay. As the PCM grounds the circuit the voltage should be close to 0.

# Thermo Time Switch




## Notes:

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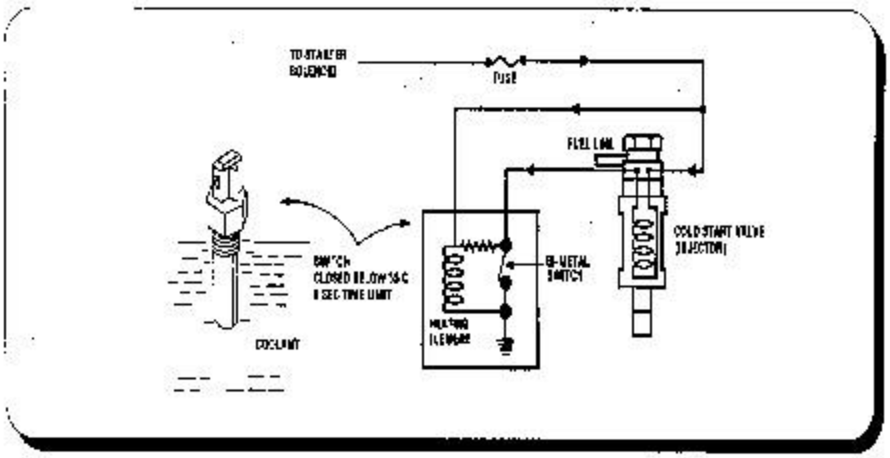
Some manufactures use a cold start injector to enrich the air fuel mixture during cold start-ups. These injectors are not controlled by the PCM. They use a thermo-time switch to complete the ground circuit for the cold start injector.

The thermo-time switch has a set of contact points mounted on a bi-metallic strip and a heater. In most cases, this circuit is only fed voltage during the engine cranking mode. With a cold engine the contact points will ground the injector circuit and fuel will flow through the cold start injector while cranking the engine. Within a number of seconds, the heater will heat-up the bi-metal strip, the contacts will pull apart, and the injector will shut off. With a warm engine the contact points would not complete the circuit and the injector would not be energized.

Testing The Thermo- Time Switch -Use a DVOM to perform a voltage drop across the switch. There should be no more than 0.2 volts while current is flowing in the circuit.

Testing The Feed Circuit -Use a DVOM to check for system voltage supplied to the injector and the Thermo-time switch. Remember the circuit is only live during the cranking mode.

# Thermo Time Switch



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