

# IDENTIFYING EMISSIONS PROBLEMS ON COMPUTERIZED VEHICLES



Vehicle Emissions Inspection

## STUDENT STUDY GUIDE

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# COURSE PREREQUISITES

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**Students attending this two day course should have certain skills and knowledge relating to basic automotive functions and emissions testing. Students should:**

- Have basic knowledge of the ADEQ Emissions Testing Program.
  
- Know how to operate basic emissions testing equipment:
  - I/R Analyzer
  
  - Scan-Tool (As defined in the Fleet Inspector Handbook).
  
  - Have a working knowledge of a digital volt/ohmmeter (DVOM).

## COURSE OBJECTIVE

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Upon completion of this two day course, students should be able to identify emissions-related engine problems, and make or recommend the proper corrective repairs on vehicles.

# USING THIS STUDY GUIDE

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The Student Study Guide is designed for use during the Certification Training Program for Fleet Vehicle Emissions Inspectors in Arizona. It contains pertinent information to the Training Program, as well as information that can be useful in the student's daily work. In general, the type of information found throughout this Study Guide includes:

1. **Informational Sections** – provide a brief discussion or summary of important topics presented by the instructor. **Important information appears as bold text.** This helps make studying the information easier, and serves as a good review of the type of information likely to be included in the Certification Test. The student can make any additional notes or highlight other information as necessary. A section for notes is provided at various points throughout the study guide, and at the end of some sections.
2. **Self-Check Sections** – contain a series of questions that relate to the material being presented. After presentation or discussion of a subject, the student will be directed to a "Self-Check Section" to answer some questions about the material presented. The Self-Check questions are to help the student determine understanding of the material.
3. **Figures and Illustrations** – It has often been said that "a picture is worth a thousand words". For that reason, some graphics have been included in this Study Guide to facilitate your understanding of the subject matter.



# **HC / CO BASICS**

# HC / CO BASICS

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**The improvement of air quality is the goal of Arizona's Emissions Testing Program.** Phoenix and Tucson experience serious air pollution problems. The pollution created can obscure vision and cause itchy or burning eyes. Several serious health problems can be attributed to smog. The most common complaints are; headaches, reduced alertness, and breathing problems for those with respiratory and heart ailments. Long term exposures to some elements of smog are known carcinogens.

The automobile is a major contributor to Arizona's pollution problems in the larger metropolitan areas. The major problem is improper or poor vehicle maintenance. Periodic emissions inspections serve to identify vehicles that are polluting excessively, and require corrective action be taken to reduce emissions.

Arizona's Emissions Testing Program checks **for three primary pollutant gases – hydrocarbons (HC), carbon monoxide (CO), and oxides of nitrogen (NO<sub>x</sub>)** on vehicles 1967 through 1995 model years with a gross vehicle weight rating (GVWR) of 8500 or less (light-duty), and also, on all heavy-duty vehicles (GVWR 8501 and greater). The concern is when these pollutants exceed the Environmental Protection Agency's (EPA) federal standards.

**Note: in Pima County, NO<sub>x</sub> are not currently measured.**

These gases are invisible and are not detectable by simple observation. Special testing devices, such as infra-red exhaust gas analyzers (I/R analyzer), and/or Constant Volume Sampling (CVS) Systems, are used to measure the levels of HC, CO and NO<sub>x</sub> in a vehicle's exhaust.

Measuring the levels of HC and CO in a vehicle's exhaust not only detects whether the vehicle is emitting excessive pollution, but also serves as a diagnostic tool for troubleshooting problems with certain vehicles when they fail an emissions inspection.

If the automotive technician has a good understanding of the basic theory and operation of the internal combustion engine, the Infra-Red (I/R) analyzer can be used to improve diagnostic accuracy and shorten diagnostic time. The result is a vehicle that emits less pollution, has better fuel economy and, in many cases, improved performance. However, the I/R analyzer does have limitations as a diagnostic tool. It cannot be used to identify all possible problems on all vehicles. It should be used in conjunction with other test equipment, such as; an electronic scope, a tachometer, timing light, scan equipment, and a dynamometer to ensure proper engine diagnosis.

**Hydrocarbons (HC)** are the primary elements in gasoline, and the "fuel" that burns during engine combustion. During combustion in an engine cylinder, not all of the hydrocarbons present can be used. Those not burned are discharged in the exhaust and into the atmosphere. **HC readings on an I/R analyzer indicate the amount of unburned or raw gasoline vapor in the vehicle's exhaust. As more unburned fuel is left after combustion, HC levels in the exhaust will increase/go up.** Hydrocarbons are generally measured in "parts per million" (ppm).

**Basic causes of high HC readings (too much unburned/raw fuel) include:**

1. **Combustion failing to occur in one or more cylinders** (fouled spark plugs, faulty ignition components, disconnected or shorted ignition wire).

**NOTE: on a computerized/ OBD vehicle, this will cause an increase in both HC & CO.**

2. **Combustion occurring at the wrong time** (improper ignition timing adjustment, such as over advanced timing or improper vacuum advance).
3. **Combustion not being properly contained** (mechanical failures, such as a burned valve). **Vehicle may display blue-grey smoke out tailpipe.**
4. **Combustion not hot enough** (engine running too rich).
5. **Combustion is weak** (due to worn cam lobes on one or more cylinders, the normal amount of air/fuel mixture are not being drawn into the cylinders).
6. **Lean Air/Fuel Mixture** (too much air not enough fuel causing a periodic misfire).

7. **Rich Air/Fuel Mixture** (too much fuel not enough air causing left over hydrocarbons).

Although high HC readings may be caused by problems other than those mentioned, they are still the result of too much **unburned or raw fuel** in the vehicle's exhaust.

**Carbon Monoxide (CO) is an odorless and colorless gas. It results from fuel that is only partially burned during the combustion process** and is directly related to the air/fuel mixture being burned in the cylinders. **CO is formed in the cylinders when not enough oxygen is present to burn all of the fuel during combustion.** Since CO emissions relate to the air/fuel mixture being partially burned, it is often easier to diagnose than HC failures. CO is generally measured with an I/R analyzer as a percentage of the vehicle's exhaust.

**Basic causes of high CO readings include:**

1. **Rich air/fuel mixture** (internal carburetor problems, improper carburetor adjustment, or other fuel delivery system malfunctions such as fuel pumps, fuel injectors, and fuel pressure regulators).
2. **Restriction of the air intake** (clogged air filters or other airway obstructions).
3. **Enrichment effects** (insufficient crankcase ventilation or oil diluted with fuel).
4. **Canister purge system** (blocked or other malfunction).

High CO readings are caused by rich air/fuel mixtures (a high amount of fuel for a given amount of oxygen), but problems other than those specifically mentioned may also cause high CO readings.

When attempting to diagnose HC and CO emissions failures, there are two important points that must be kept in mind:

1. **HIGH HC READINGS INDICATE UNBURNED OR RAW FUEL** (several possible causes, such as lean misfire or ignition problems)

**2. HIGH CO READINGS INDICATE PARTIALLY BURNED FUEL** (rich air/fuel mixture, or more fuel is present than required)

**Oxides of Nitrogen (NO<sub>x</sub>)** – Air is made up of both nitrogen and oxygen and, under normal conditions, they do not chemically combine. However, when heated above 2500° F, they begin to unite and form a group of compounds called “oxides of nitrogen”. These NO<sub>x</sub> compounds form during combustion and also contribute to air quality pollution problems. **Excessive NO<sub>x</sub> emissions are caused by lean air/fuel mixtures, high compression ratios, and high combustion temperatures.** Many vehicles feature a three-way type catalytic converter that serves to reduce NO<sub>x</sub> emissions, as well as HC and CO; some vehicles use an Exhaust Gas Recirculation (EGR) valve to help control NO<sub>x</sub>.

At present, an internal combustion engine that emits **no** pollution has not been designed. However, an engine that is properly tuned and adjusted, as well as being mechanically sound, will emit only small amounts of pollutants. When HC (unburned fuel) and/or CO (partially burned fuel) exceed a normal level for a particular model year and engine type, it is usually an indication that the engine may be in need of a tune-up, mechanical repairs, or perhaps only proper adjustments.

The point at which HC and CO are considered excessive depends on many factors. The year, make, engine type/size and emissions control devices on a particular vehicle all affect the amount of pollution that is emitted.

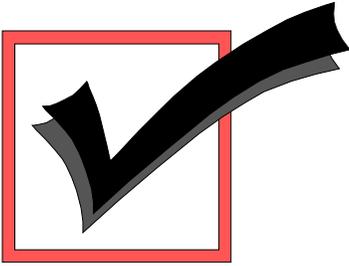
IMPORTANT NOTE!! – All vehicle adjustments and settings should be made to the manufacturer's specifications!! DO NOT make adjustments or settings to the State of Arizona maximum allowable limits!! The technician is not doing the environment or the customers any favors by adjusting a vehicle simply to meet emissions test limits. This can actually cause increased emissions and/or poor fuel economy at highway speed.

In 1975, vehicle manufacturers began equipping vehicles with Catalytic Converters. A catalytic converter that is functioning efficiently can significantly reduce emissions.

On 1996 model year vehicles and newer light-duty (GVWR 8500 or less); Arizona's Emissions Testing Program follows Environmental Protection Agency's federal guidelines and administers an On Board Diagnostic (OBD) Test. These systems will continually check emissions on the vehicle, and will trigger the check engine light to "ON" when anything within the system causes an increase in emissions by one and one half times (1.5) the new car standard.

## **NOTES**

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## SELF – CHECK

### HC / CO BASICS

Mark or fill-in the correct answer. Check your answers in Appendix “A” at the back of the Study Guide.

1. \_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_ are the three primary pollutants in a vehicle’s exhaust.
2. Fuel that partially burns during combustion is responsible for causing what type of emissions?
  - A. CO<sub>2</sub>
  - B. CO
  - C. HC
  - D. NO<sub>x</sub>
3. **TRUE or FALSE** – Hydrocarbons are the result of unburned fuel left after combustion.
4. **Causes of excessive or high HC readings are:**
  - A. Combustion failing to occur in one or more cylinder
  - B. Combustion not being properly contained
  - C. Enrichment effects
  - D. Both A and B above
5. **TRUE or FALSE** – Regardless of the actual problem, excessive CO readings are caused by not enough oxygen (or too much fuel) present during combustion, resulting in partially burnt fuel in the exhaust.

## SELF – CHECK (cont.)

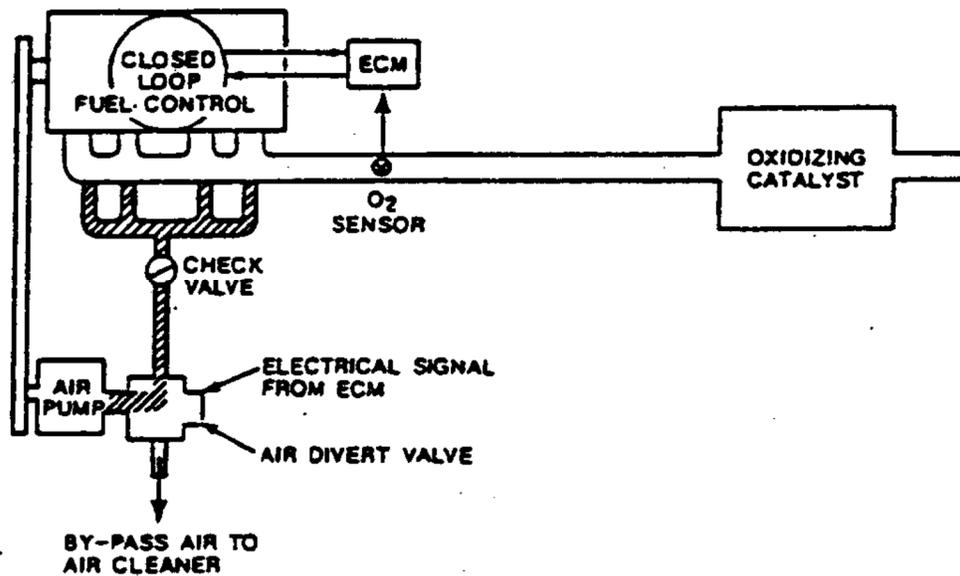
6. **Causes of excessive or high CO readings are:**
- A. Canister purge system
  - B. Enrichment effects
  - C. Lean air/fuel mixture
  - D. Both A and B above
7. **You see blue-grey exhaust smoke coming from the tail-pipe of a vehicle being emissions tested. The I/R analyzer indicates high HC readings. Which is most likely the cause of the problem?**
- A. Lean air/fuel mixture
  - B. Mechanical/compression
  - C. Crankcase dilution
  - D. Leaking Injector
8. **Which of the conditions listed below will most likely cause an engine misfire?**
- A. Faulty ignition components
  - B. PCV valve stuck in the low flow position
  - C. Faulty evaporative canister
  - D. Rich air/fuel mixture
9. **A fouled or missing spark plug on an OBD vehicle will cause an increase in what type of tailpipe emissions?**
- A. HC
  - B. CO
  - C. NO<sub>x</sub>
  - D. HC and CO

# **EMISSIONS REDUCTION DEVICES**

# CATALYTIC CONVERTERS

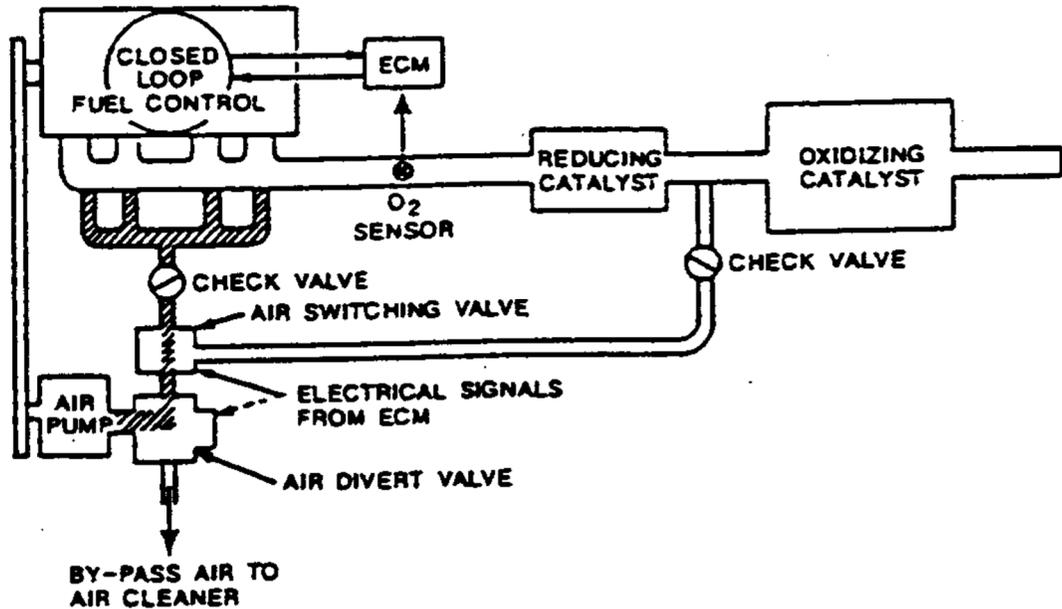
The catalytic converter (CAT) serves as a “trimmer” to reduce already low emissions to near zero. It contains special materials, called catalysts, in either a pellet or honeycombed form, which causes a low temperature oxidation of HC and CO elements in exhaust gas. Catalytic converters also reduce the nitrogen oxide (NO<sub>x</sub>) content of the exhaust. Common types of catalytic converters are:

1. **Single-bed, Two-way** – mid to late 1970's; all material are contained in a single chamber; burns (oxidizes) only HC and CO.
2. **Single-bed, Three-way** – late 1970's to present; all catalytic materials are in a single chamber; burns (oxidizes) HC, CO and reduces NO<sub>x</sub>.



Single-Bed Catalytic Converter System

3. **Dual-bed, Three-way** – late 1970's to present; separate reducing chamber for breaking down NO<sub>x</sub>; separate oxidizing chamber for HC and CO conversion.



Dual-Bed, Three-way CAT System

The amount of oxygen present in the exhaust has a significant effect on the three-way CAT's ability to reduce NO<sub>x</sub> and oxidize HC and CO at the same time. Too much oxygen inhibits NO<sub>x</sub> reduction, while too little oxygen inhibits the burning of HC and CO. Very tight mixture control is necessary for best CAT performance.

## CANISTER PURGE SYSTEM

**The purpose of the canister purge system is to capture and store fuel vapors emitted from the fuel tank.** These vapors are continually being stored in the carbon canister and are “purged” during vehicle operation. Depending on the type of vehicle, various controls are used to control both vapor storage and purging. Most systems use a solenoid canister purge control valve, which is energized by computer commands. If the canister purge system allows stored vapors to flow into the intake manifold at idle, an emissions failure and probable poor idle quality will result.

A quick way to check the canister purge system for proper operation is to pinch off the purge hose (or remove it and cap off its' entry to manifold vacuum). If a large change in idle quality or speed is noted, you have found a problem. If the system under test has idle speed control, it may attempt to compensate for the extra “unintended” fuel. With a vacuum-controlled diaphragm valve, failure of the diaphragm allows direct leakage into the vacuum signal hose. This affects the idle mixture and will cause a CO failure at idle. Pinching off the control hose to the manifold vacuum source will confirm this problem with an RPM change. A technician should also check to see if the charcoal canister has a removable filter. The filter may be contaminated to the point that it is causing a higher CO reading.

## POSITIVE CRANKCASE VENTILATION (PCV) SYSTEM

The purpose of the positive crankcase ventilation (**PCV**) system is to **control “blow-by” vapors that escape from the cylinders into the crankcase during combustion.** These vapors are primarily HC and CO. PCV systems on computerized vehicles are similar, if not identical to those used on earlier model vehicles. The same test procedures should be used to verify proper operation, with one important difference; computerized vehicles use an oxygen sensor to monitor oxygen content in the exhaust gas. PCV conditions which cause HC/CO failures on older vehicles differ from computerized vehicles only to the extent that the O<sub>2</sub> sensor and computer are able to adjust the air/fuel mixture to compensate for the unburned fuel from crankcase sources.

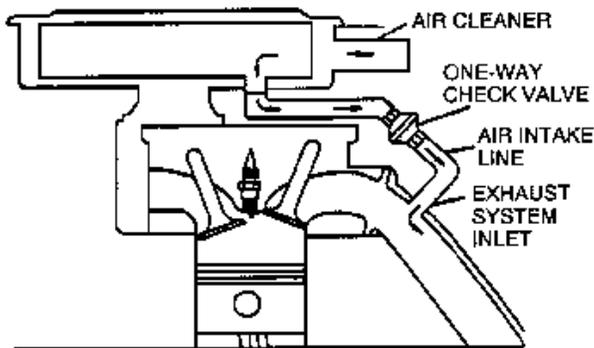
# AIR INJECTION SYSTEMS

The automobile industry has used air injection systems to reduce exhaust emissions since the mid to late 1960's to current model year.

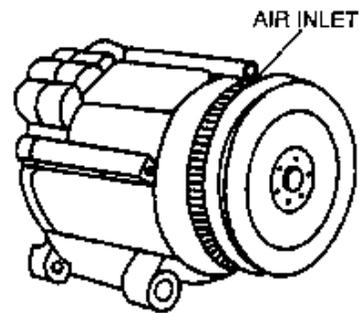
The two types of air injection systems used on vehicles are:

1. Pulse Type – Reed Valve (Suction)
2. Pump Type – Forced Air

**The Pulse Type** air injection system (Aspirator Air System) relies on the negative pressure that occurs in the exhaust system when the exhaust valve closes. The negative pulse creates a momentary low pressure (vacuum) that draws fresh air into the exhaust through a sensitive reed valve. When exhaust pressure increases, the reed valve is forced closed to prevent exhaust flow in the opposite direction.



Pulse Air Type



Pump Type

Air Systems

**The Pump Type** air injection systems use a low pressure high volume pump to supply air to the exhaust. In the earlier designs most air injection pumps were driven by an accessory drive belt. Most late model vehicles are using an electrically operated pump that is activated by the vehicle's computer.

The pump type system delivers air under greater than atmospheric pressure; therefore, delivery must be controlled. Prior to computerized feedback systems, a control valve was installed in series with the air injection pump to regulate pressure and direct air into the exhaust system or to atmosphere.

Properly directing the air requires a control mechanism known as a diverter valve, bypass valve, or anti-backfire valve. This valve is used to direct air to the appropriate place. The valve is usually controlled by a vacuum signal. In most cases, exhaust is diverted from the exhaust to atmosphere during deceleration to prevent backfire. Other systems prevent air from being injected into the exhaust during periods of extended idle.

With feedback systems, some air injection systems utilized two types of valves. From the pump air is directed to the diverter or bypass valve. This valve either bypasses air to atmosphere, or to the air control valve. The air control valve is used to direct air upstream to the exhaust manifold, or downstream to the catalytic converter, depending on vehicle operating condition. Some manufacturers incorporate both valves into a single valve assembly called an air management valve.

During engine warm-up, air is directed upstream to promote afterburning in the exhaust manifold. **This upstream afterburning reduces the oxygen sensor and catalytic converter warm-up time and allows the vehicle to go into closed loop much quicker.**

**During normal operating condition, air is shifted downstream to the catalytic converter. With oxygen being injected to the rear (oxidation) bed of a dual bed three-way catalytic converter, HC and CO reduction is improved.**

Some computerized feedback engines use the air injection solely to assist in oxygen sensor and catalyst warm-up. Once achieved, air is bypassed to the atmosphere or air cleaner.

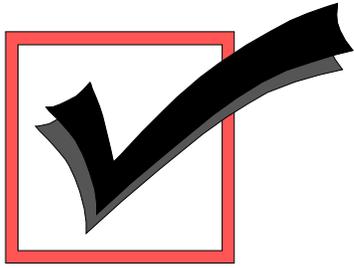
# Exhaust Gas Recirculation System (EGR)

**EGR is designed to reduce NO<sub>x</sub> emissions** created by an increase in cylinder temperature, high compression ratios, and lean air/fuel mixture ratios.

The EGR valve will recirculate exhaust into the intake stream, lowering the combustion chamber temperatures. Since the exhaust has already been burned, it will not need to be burned again by the engine, it is referred to as inert (non-combustible) exhaust gas. This procedure will chemically slow and cool the combustion process by several hundred degrees; reducing NO<sub>x</sub> formation.

## NOTES

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## SELF-CHECK

### EMISSIONS REDUCTION DEVICES

Mark or fill-in the correct answer. Check your answers in Appendix "A" at the back of the Study Guide.

1. **Which emissions control system is designed to temporarily store vapors put out/emitted by the fuel tank and fuel delivery system?**
  - A. Positive Crankcase Ventilation (PCV) System
  - B. Air Injection System
  - C. Evaporative Emissions Control system (Canister Purge)
  - D. Exhaust Gas Recirculation System
  
2. **The function of the air management system on most computerized vehicle is \_\_\_\_\_.**
  - A. To help bring the O<sub>2</sub> sensor to operating temperature rapidly
  - B. To direct the air either overboard (atmosphere) or downstream (catalytic converter) after warm-up
  - C. To assist the catalytic converter to better oxidize both HC and CO
  - D. All of the above
  
3. **Which is the most correct statement about the catalytic converter?**
  - A. I/R analyzer readings for CAT and NON-CAT vehicles are nearly the same
  - B. It helps reduce emissions by restricting exhaust flow
  - C. It acts as a trimmer device to reduce already low emissions to near zero
  - D. If the vehicle has a catalytic converter, it won't fail an emissions test
  
4. **TRUE or FALSE**-The EGR system will reduce NO<sub>x</sub> emissions

# **BASIC ELECTRONICS**

# BASIC ELECTRONICS

It is necessary to know some **basic** information of electronics and the types of devices used as sensors in order to understand **how** the sensor communicates information to the computer.

**Voltage** is measured in “volts.” Voltage can be considered a rating on **how much “force” is present in the electricity to carry current.**

**Current** is best described as a measure of electrical flow. Current is measured in “amperes,” or “amps.”

**Circuit** is the path for electricity to flow between two points. Amperes are used to measure how much electricity is moving past a given point in a circuit, for a given amount of time.

**Resistance** – Resistance is best described as opposition to the flow of electricity (**Restriction**). It is measured in units called “ohms.” As the ohms rating of an electronic device increases, less current is able to flow through it, with a given force.

**Alternating Current (AC)** – Alternating current is electricity that cycles (or changes direction of flow). It is the type of electricity that is present at most wall-outlets, as well as the type of electricity that is produced by a vehicle’s alternator before it is rectified by the diodes. It is not suitable for use in most electronic applications unless it has been changed, or processed into a form which is more readable by the computer, because it cycles, or changes from positive to negative.

**Direct Current (DC)** – Direct current does not cycle and flows in only one direction. Therefore it is considered stable and the type of electricity used in most electronic applications. Direct current is produced by batteries, or from alternating current that has been rectified and filtered into direct current.

**Reference Voltage** – is an electrical signal of a predetermined or set value that is used as a standard when making measurements in an electronic circuit.

In most automotive applications, a **reference voltage of 5 volts DC** is supplied to the sensors by the computer. However, some manufacturers are using 8 volts, while others are using 2.7 volts or 3.5 volts. Take the time to verify the reference voltage being used by the manufacturer of the vehicle you are checking.

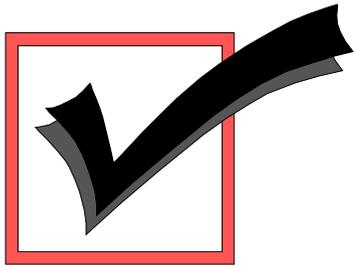
The computer determines the difference between the reference voltage signal it provided and the actual voltage being returned from the sensor. It then uses the measurement to make a decision and commands the appropriate actuator to make the required adjustment.

**Diodes** – Although diodes are not used specifically as sensors, they are an important part of many sensors and actuator circuits. Diodes **permit current to flow through it in only one direction**. Diodes control the direction of current flow; therefore, they are used to protect the computer from sudden voltage surges (spikes). Diodes also serve as rectifying devices in other automotive circuits. Diodes are commonly used as a “one-way valve” on vehicle alternators.

**When testing with an Digital Volt Ohm Meter (DVOM) or an audible diode checker the technician should; connect the test meter leads; the meter beeps, the technician then reverses the leads; the meter beeps again. This is an indication of a bad diode.**

## NOTES

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## SELF-CHECK

### BASIC ELECTRONICS

Mark or fill-in the correct answer. Check your answers in Appendix "A" at the back of the Study Guide.

1. **With the exception of some Ford computerized systems, what should reference voltage be for most computerized systems?**
  - A. 12 volts
  - B. 24 volts
  - C. 15 volts
  - D. 5 volts
  
2. **The property of an electronic device to oppose/restrict the flow current through it is called \_\_\_\_\_.**
  - A. Voltage
  - B. Resistance
  - C. Amps
  - D. Feedback
  
3. **You are using a DVOM that has an audible diode test feature to test a diode. After properly setting your meter and connecting the leads, your DVOM beeps once. You then switch leads (place the red one where the black one was, and vice-versa) and your meter beeps again. What does this indicate?**
  - A. The diode is good
  - B. The diode is bad
  - C. Nothing not a valid test

# **CLOSED LOOP SYSTEM OPERATION**

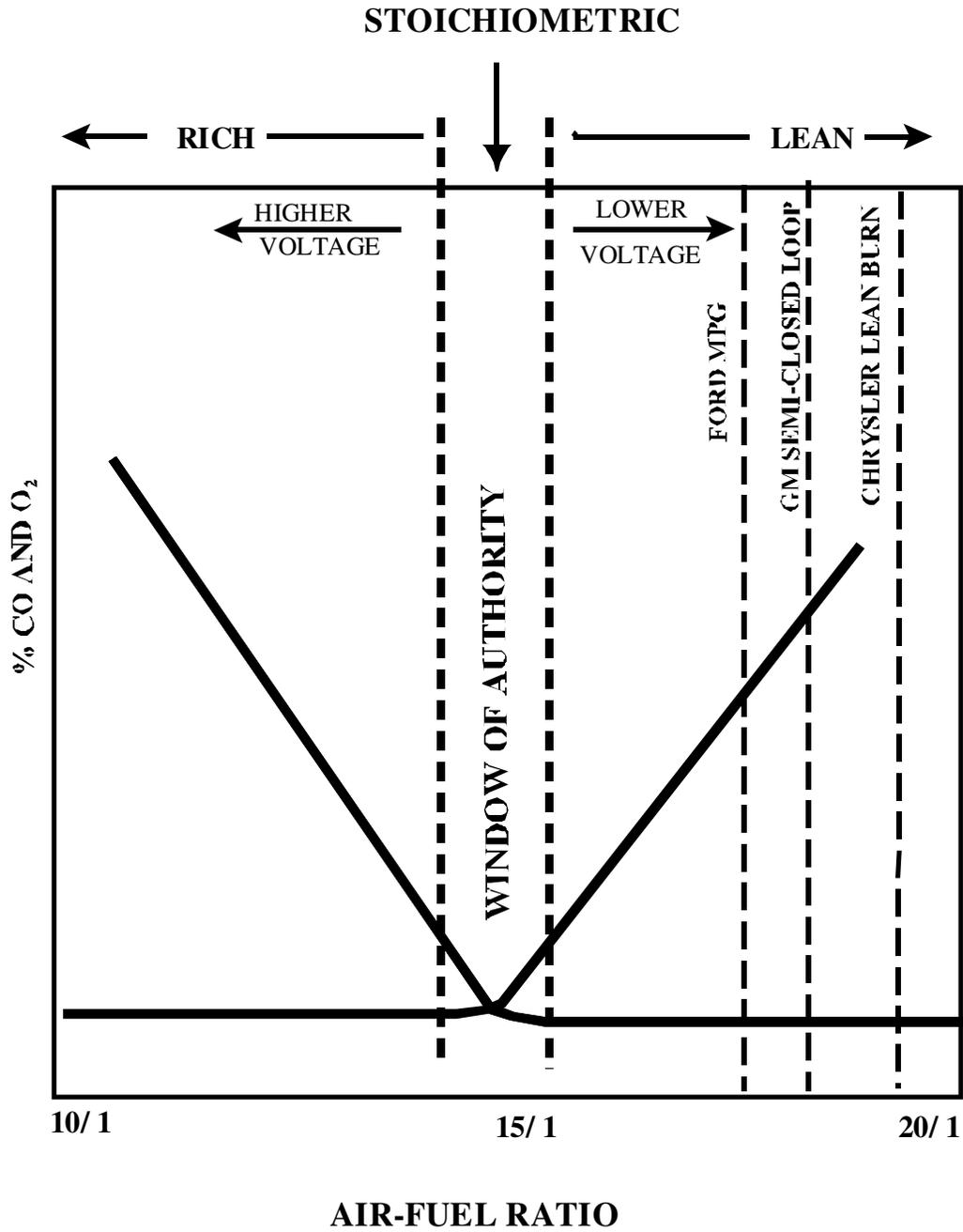
## CLOSED LOOP SYSTEMS

To effectively identify emissions failures on computerized vehicles, it is important to understand some basic functions of the system. One of the most common methods to control emissions in computerized vehicles is called "closed loop operation"

The purpose of the closed loop system is to control engine emissions by regulating the air/fuel mixture and ignition timing, while maintaining satisfactory fuel economy and performance/drivability. Regulating the air/fuel mixture and controlling ignition timing allows the engine to "adjust" to a variety of driving conditions, such as heavy loads, operation at different altitudes, and normal highway cruise mode.

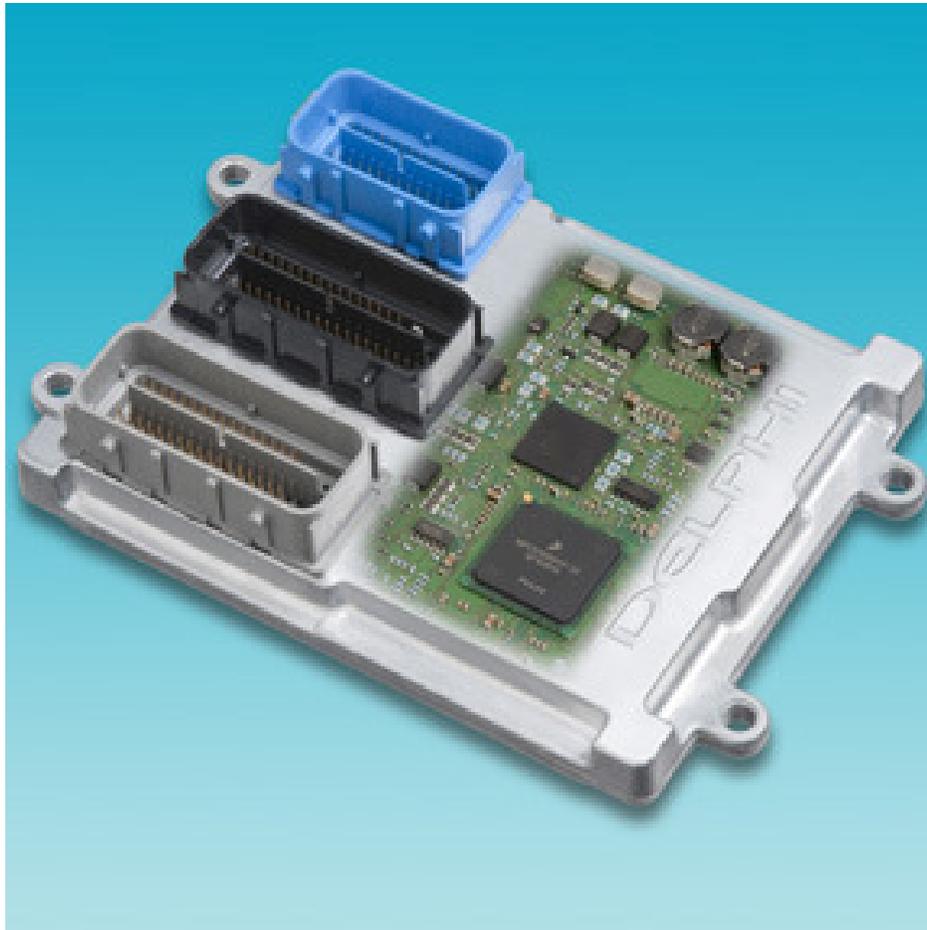
## STOICHIOMETRIC AIR/FUEL RATIO

The air/fuel mixture burned during combustion produces HC if not enough fuel is burned, and CO if not enough oxygen is present for complete burning. There must be an "ideal" air/fuel mixture that will provide the right amount of fuel and oxygen for a complete, clean burn during combustion. This "ideal" mixture would produce very small amounts of HC or CO, since all of the fuel mixture would burn completely. **The "ideal" air/fuel mixture is referred to as "Stoichiometric air/fuel ratio and consist of approximately 14.7 lbs. of air to 1 lb. fuel, or a 14.7:1 ratio. A Stoichiometric air/fuel ratio provides a complete burn during combustion and keeps HC and CO emissions at a minimum, while providing acceptable performance, drivability, and fuel economy.** While a Stoichiometric air/fuel mixture provides low emissions; it is not necessarily the best ratio for engine power or fuel economy. Richer mixtures (more fuel, less oxygen) at a ratio of about 13.9:1 provide more power, while leaner mixtures (more oxygen, less fuel) at a ratio of about 16:1 provide better fuel economy. As the air/fuel mixture moves either richer or leaner away from Stoichiometric, some emissions increase accordingly. This is due to the change in combustion and because most catalytic converters were designed to function at Stoichiometric. As the air/fuel mixture becomes richer or leaner, the catalytic converter is not as effective at reducing all emissions.



Stoichiometric Air/Fuel Ratio vs. Emissions

# THE COMPUTER



Automotive Computer

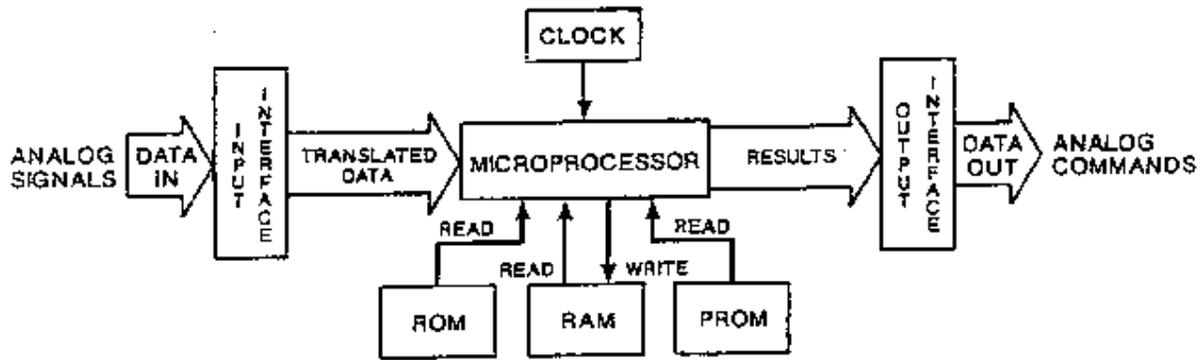
The computer's **basic function is to control the air/fuel mixture, ignition timing and other engine operations.** Different manufacturers refer to the computer by a variety of names, some of the names commonly used are:

**PCM** – Power Control Module – 1996 and newer OBD II

**ECM** – Electronic Control Module – GM

**ECU** – Electronic Control Unit – Bosch

**Major Computer Elements** – Regardless of the manufacturer or sophistication of the computer module used in the system, there are a few basic elements that need to be understood to properly identify emissions related failures.



Block Diagram of Computer Module

**Internal Timer** – The internal timer acts like an alarm clock. When the engine is first started, the timer is activated and the computer uses preset commands, instead of sensor information to control engine functions. This allows the vehicle's systems to warm-up before the computer relies on information from the various sensors. Once the timer runs out (5 seconds to 5 minutes), the computer then starts using sensor information to make engine control decisions.

**Microprocessor** – The microprocessor does all the “work” in the computer. It performs all the calculations, makes all the decisions, and handles the communications. Components such as the analog-to-digital converters change the signals received from a component into a form the microprocessor can understand. High-level digital outputs are used to command the actuators and many other components used in the microprocessor to control different functions.

**Three Part Memory** – The computer's memory consist of three main sections, with each serving a specific purpose.

1. **RAM – Random Access Memory – RAM is a temporary memory, or “scratchpad,” that works only while the vehicle’s ignition is switched on.** The computer stores information from the sensors in RAM until it can be used. When the vehicle's ignition is switched off, all information in RAM is cleared.
2. **ROM – Read Only Memory – ROM contains a set of permanent instructions that tell the computer what it is capable of doing.** The instructions are programmed into ROM by the vehicle's manufacturer and cannot be changed. The ROM instructions remain regardless of whether or not the vehicle is running.
3. **PROM – Programmable Read Only Memory – PROM is a type of computer chip or device that contains special instructions and allows manufacturers to adopt basic computers to specific makes and models of vehicles.** Like in ROM, the instructions contained on a PROM are permanent. They may also contain specific reference information that the computer uses to make decisions. Since PROM is designed to make the computer work on a specific type of vehicle, it is sometimes changeable for upgrade purposes.

**EPROM & EEPROMS** – These are the same as a PROM; except that EPROMS and EEPROMS are reprogrammable. A re-flash or reprogramming can be done.

## NOTES

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Most automotive computer systems consist of three main elements:

1. **SENSORS – detect (or sense) various engine operating conditions** and relay the information to the computer in the form of electronic signals.
2. **COMPUTER – monitors the inputs from the sensors, makes decisions** based on program information contained in memory, **then sends commands to adjust engine functions.**
3. **ACTUATORS – perform engine adjustments, based on commands from the computer.**

### **SENSORS**

The sensors generate signals of varying voltage, frequency or resistance. The **analog** signals indicating different operating conditions of the engine are monitored by the computer. The computer checks the information against a stored program and decides the conditions needed for change or adjustment. The computer issues a **command** to the appropriate actuator to perform the adjustment.

### **COMPUTER**

The computer is checking the inputs from the sensors hundreds of times per second. It analyzes the information and compares it to a program stored in memory. When the computer decides that a condition needs change, it sends a command to the actuator responsible for that function. The actuator then makes the adjustment. This allows the computer to adjust the engine and keep it operating efficiently (or as close to Stoichiometric as possible) through all driving conditions.

### **ACTUATORS**

The actuators depend on current to operate. Most are coiled devices, such as solenoids, relays or motors. A coiled device acts like an ignition coil primary winding when actuated. Current is present at the device, when provided a ground path. The current energizes the coil and produces a “spike” of high voltage. If this spike is not suppressed (limited, or held down) by a resistor or de-spiker diode, it can “feedback” into the power transistor which controls the actuator and may destroy it.

Most **actuators** have current supplied to them while the ignition is in the "RUN" position, connecting or disconnecting them with power "ON" can destroy a power driver transistor in the computer. Actuator current flow ranges from 250 milliamps for a small solenoid to several amps for a low resistance injector.

If you should determine that a computer is bad and requires replacement, be certain to check the actuators, relays and wiring for possible shorts and correct winding resistance prior to replacement.

## **CLOSED-LOOP VS OPEN-LOOP**

**When the computer is using inputs from the oxygen sensor to control engine functions, the system is operating in "closed-loop."** During closed loop operation, the computer keeps the engine operating as close to Stoichiometric as possible. Before the computer can use the oxygen sensor inputs and **attain** closed loop operation, certain conditions must be met:

1. **The computer's internal timer must run out before closed-loop operation can begin.** Although some models can begin closed loop immediately if the engine is already warm, many computers have an internal timer that begins when the engine is first started, and expires within a set time frame (15 seconds to 5 minutes, depending on the type of system).
2. **The engine must reach normal operating temperature.** Upon starting the engine, the computer monitors the signal from the **coolant temperature sensor**. This is considered the most important, or "**dominant**" **sensor at start up**. Closed-loop will not usually take place until the engine warms up.

3. **The oxygen sensor must reach operating temperature (about 600° F) and begin sending a varying voltage signal to the computer.** Once the coolant temperature sensor signal indicates to the computer that the engine has reached normal operating temperature, the oxygen sensor is monitored by the computer as the “dominant” sensor. Engine functions are then controlled according to the varying voltage output of the sensor tracking exhaust oxygen content.
4. **All other sensors are sending signals within their normal ranges.**

“Open loop” operation is when the computer is not using the inputs from the oxygen sensor to control engine operations. The computer cannot maintain the air/fuel mixture adjustment as close to Stoichiometric as needed, and emissions are likely to increase, when operating in open loop.

#### **OPERATING CONDITIONS THAT CAN AFFECT CLOSED LOOP:**

During closed loop, the computer monitors the output of the oxygen sensor and sends commands to maintain the air/fuel mixture adjustment to as close to Stoichiometric as possible. Closed loop operation cannot be maintained under all driving conditions. When a driver presses the accelerator pedal to the floor (wide open throttle or WOT), the computer senses that more power is required and adjusts for a richer air/fuel mixture. During this period of acceleration, the system may drop into open-loop.

Some manufacturers have programmed a “semi-closed-loop” mode into the computer for fuel economy purposes. As a driver enters the “cruise mode” (either cruise control setting or maintaining a specific speed for a set amount of time), the computer automatically shifts to cruise mode operation and adjusts the air/fuel mixture to be lean (as high as 18:1). This increases fuel economy.

Other operating conditions and/or problems within the system can also cause open loop operation. An important part of identifying emissions related failures is confirming that the system can achieve closed loop operation.

A computerized control system is operating in closed-loop when it is using the output of various sensors to control engine functions, such as air/fuel mixture. A basic understanding of the types of devices used as sensors; how they work; and their purpose is needed to accurately identify emissions related problems.

## **NOTES**

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# ELECTRONIC DEVICES USED AS SENSORS

There are many types of electronic devices used in automotive applications. How the device “reacts,” or conducts electricity in response to a specific condition determines its suitability as a sensor. There are a number of different conditions to be considered – heat, cold, movement, pressure, etc...

**Thermistors – function like variable resistors; as temperature changes, the thermistors’ resistance changes.** Most thermistors are manufactured to change resistance at a set rate. For example, a 10 degree change in temperature may cause resistance to change by 1000 ohms. There are two types of thermistors: negative temperature co-efficient (NTC) and positive temperature co-efficient (PTC). The only difference is whether the resistance **increases or decreases** as temperature rises. **NTC thermistors decrease** in resistance as temperature rises, while **PTC thermistors increase** in resistance as temperature rises. This predictable change in resistance causes a corresponding change in circuit current flow. Thermistors are used to sense such things as; **engine coolant temperature, air temperature** and **battery temperature**.

**Potentiometers** – Potentiometers are commonly referred to as “pots” or “variable resistors.” **They provide a varying voltage output in response to motion.** In the center of a pot is a movable contact called a “wiper.” The wiper senses voltage between two sides of set resistance. As the wiper travels between the two sides, a potentiometer’s resistance changes, causing a varying voltage drop, or output. Pots are used to sense the movement of the throttle being opened or an EGR valve opening or closing. To check potentiometers, a technician will need a Digital Volt Ohm Meter (DVOM). A technician can use either the voltmeter function if current is flowing or the ohmmeter function if no current is applied. A smooth transition of voltage or ohm’s should be the results; there should be no jumps in the readings.

**Switches** – There are various types of switches, such as mechanical, magnetic, and thermal. Switches provide a steady voltage or no voltage (0 volts or 12 volts) to the computer. **The voltage is used to indicate whether a function is on or off, or if a specific condition does or does not exist.** The signal a switch provides is steady; non-varying. A switch cannot be used to detect a rate of change.

**Inductive Pick-Ups** – are **sensitive to movements of magnetic fields.** A magnetic field is created when current flows through the circuit. As the polarity of the current changes, the magnetic field expands and collapses. When current goes positive the magnetic field expands, and as current goes negative it collapses.

A magnetic field is normally sensed by a sensor. When the field is temporarily broken or blocked by an object passing through it, a voltage signal is sent to the computer. **Inductive pick-ups are commonly used in electronic ignition systems to control ignition timing by sensing crankshaft position.**

**Piezoelectric Devices** – **contain a crystal which responds to specific frequencies, or certain pressures.** When vibration or pressure within a preset range is detected, the crystal produces a signal that is transmitted to the computer. The computer then sends the appropriate commands to control the engine. Piezoelectric devices are commonly used in engine Knock Sensors, Manifold Absolute Pressure (MAP) Sensors, and Barometric Pressure (BARO) Sensors. **These sensors use a piezoresistive diaphragm, spread across two separate chambers. The diaphragm changes resistance as it flexes.** One chamber is sealed with specific reference pressure, while the other is connected to the pressure being sensed. For example; the MAP sensor is connected by a vacuum hose to the intake manifold. Manifold vacuum changes as engine load changes. This causes the diaphragm to flex with the differences in pressure between the chambers; and a varying voltage to be sent to the computer.

# COMMON ENGINE SENSORS

Common sensors found in closed-loop systems are used as references. Since it is impractical to detail each manufacturer's variation of a particular sensor; only the most commonly used types are detailed. **A technician should consult the manufacturers' or other suitable reference manual to determine what devices exist for a specific year, make, and model of vehicle.**

## OXYGEN SENSORS

Oxygen Sensors ( $O_2$ ) sense the amount of oxygen in the exhaust and send a voltage signal back to the computer indicating whether the air/fuel mixture is rich or lean from Stoichiometric (14.7:1 air/fuel mixture ratio).

The fuel control computer monitors the oxygen sensor output signal and uses the information for closed loop operation. **If the voltage signal from the  $O_2$  sensor is varying somewhere between .2 to .9 volts (200mv to 900mv) a technician can conclude that closed loop operation is being used.** If the voltage signal is a fixed voltage, the system is operating in open loop.

The Coolant Temperature Sensor (CTS), Throttle Position Sensor (TPS), Manifold Absolute Pressure Sensor (MAP) or Mass Air Flow Sensor (MAF) and Air Charge Temperature Sensor (ACT) are used by the vehicle's computer to set the air/fuel mixture ratio as close to 14.7:1 as possible. **Then the computer will monitor the  $O_2$  sensor and "trim" the air/fuel mixture ratio to maintain 14.7:1 under as many driving conditions as possible.**

### CONDITIONS THAT AFFECT THE OXYGEN SENSOR

Several conditions can affect the output of oxygen sensors, causing the system to operate incorrectly or go into open-loop.

Contamination can come from such things as engine coolant, excessive oil consumption, additives used in sealants, or the wrong fuel additives in gasoline.

A contaminated oxygen sensor will not produce the proper voltage, nor will it be able to switch properly. When only lightly contaminated it is called a "lazy" oxygen sensor because of the extended length of time to switch from rich to lean and or lean to rich.

Important points about oxygen sensors include:

1. **The oxygen sensor must reach its operating temperature and begin sending a voltage signal.**
2. The oxygen sensor's output must vary from .2 to .9 volts for the system to stay in closed loop.
3. **As the oxygen content of the exhaust increases (air/fuel mixture becomes leaner), output voltage decreases.**

As the oxygen content of the exhaust decreases (air/fuel mixture becomes richer), output voltage increases.

4. The computer monitors the output of the O<sub>2</sub> sensor and adjusts the air/fuel mixture based on received voltage signals.

**ZIRCONIA OXYGEN SENSORS** (narrow range oxygen sensor) –**there are two basic types of zirconia oxygen sensors that are commonly used in automotive applications; heated and unheated.** Sensors that are not heated are one or two wire sensors. Heated sensors may have three or four wires. Heated sensors reach operating temperature much quicker than unheated sensors. Regardless of which type is used, the purpose remains the same – **to sense the amount of oxygen present in the exhaust gas and relay that information to the computer.** The amount of oxygen present in the exhaust is directly related to the air/fuel ratio being burned in the engine. The O<sub>2</sub> sensor is usually located on the exhaust manifold or upper exhaust pipe of the engine. The inner part of the sensor is constructed of a special material called zirconium dioxide, which generates voltage when the sensor is heated to above 600° F and low concentrations of oxygen are present in the exhaust. The O<sub>2</sub> sensor is the only sensor on a computerized vehicle whose signal cannot be seen by the computer until it reaches operating temperature. The oxygen sensor produces its own voltage potential; all other sensors use reference voltage.

**The output voltage of the O<sub>2</sub> sensor ranges between .2 to .9 volts.** The computer recognizes a specific voltage, called “**set-point**” as the ideal air/fuel mixture ratio (normally between .45 volts to .5 volts).

**The amount of voltage produced by the O<sub>2</sub> sensor increases as the mixture becomes richer.** As the amount of oxygen in the exhaust increases, or **as the mixture becomes leaner, the voltage output drops.**

**The computer must see a varying voltage signal from the O<sub>2</sub> sensor to stay in closed-loop.** As voltage from the O<sub>2</sub> sensor drops, the computer signals for a richer mixture. If voltage rises, the computer signals for a leaner mixture.

**If the O<sub>2</sub> signal does not vary or does not reach any higher than .5 volts, the computer may go into open-loop.**

**TITANIA OXYGEN SENSORS** – Titania oxygen sensors were used on very limited models of vehicles in the late 1980s and early 1990s.

Titania oxygen sensors accomplish the same task as the zirconia oxygen sensors. However, Titania sensors work like a coolant temperature sensor. The sensor changes resistance as the air/fuel ratio changes from rich to lean, lean to rich. Instead of a gradual change; the Titania oxygen sensor switches very rapidly from low resistance when the mixture is rich, to high resistance when the mixture is lean.

The computer sends a reference voltage to the sensor, and depending on the oxygen content in the exhaust, the sensor sends back a portion of the reference voltage which the computer will use to make adjustment to the air/fuel mixture ratio.

**AIR/FUEL RATIO (A/F) SENSOR** – Although it may appear similar to the narrow range oxygen sensor, it is made differently and has different operating characteristics. The A/F sensor is commonly referred to as a wide range or wide ratio sensor because of its ability to sense air/fuel over a wide range. The advantage of using the A/F sensor is that the ECM can much more accurately monitor and meter the fuel, reducing emissions. To make this happen, the A/F sensor operates at a much hotter temperature than the oxygen sensor; approximately 1220° F and changes its current (amperage) output in relation to the amount of oxygen in the exhaust.

The A/F sensor is designed so that at stoichiometric, there is no current flow and the voltage put out by the detection circuit is 3.3 volts. A rich mixture produces a negative current flow. The detection circuit will produce a voltage below 3.3 volts. A lean mixture produces a positive current flow. The detection circuit will now produce a voltage signal above 3.3 volts.

The A/F sensor voltage output is opposite from that of the narrow range oxygen sensor. Voltage output through the detection circuit goes up as the mixture becomes leaner. This will let the ECM more accurately calculate air/fuel ratio in a much wider range of conditions and respond more quickly to adjust the amount of fuel to stoichiometric.

**COOLANT TEMPERATURE SENSOR (CTS)** – The Coolant Temperature Sensor is usually a type of thermistor. The computer monitors the difference between the reference voltage and the actual voltage returned by the CTS. The computer compares the returned voltage to reference values within its program to determine the current operating temperature of the engine. **The CTS is the dominate sensor at engine start-up, since the engine must receive cold enrichment mixtures for starting and cold drive-away performance.** The computer monitors the CTS primarily to issue mixture commands. After the CTS signal indicates warm-up and the internal timer runs out, the computer begins to monitor the O<sub>2</sub> sensor to control air/fuel mixture. Common CTS (and related) problems include:

1. If the CTS non-functioning or functioning incorrectly; the system may not go into closed loop. Depending on testing conditions, this may cause an emissions failure. A DVOM or scanner can be used to monitor either the voltage or resistance of the CTS at start-up. Other factors that affect the output of the CTS include the following:
  - A. Proper coolant mixture – 50/50 coolant/water mixture is the ideal.
  - B. Coolant level – sensor must be surrounded by coolant.
  - C. **Thermostat operation (critical)** – if the thermostat is not present, or has been replaced with one of lower opening value than specified, the engine may not reach proper temperature. Also, if the thermostat should stick closed; overheating problems may occur. **Original Equipment Manufacturer (OEM) thermostats are highly recommended.**
  - D. Cooling Fan or Fan Clutch operation – non-functioning or even an intermittent problem can cause engine overheating problems.
2. Faulty CTS emissions indications are likely to be:
  - A. High CO readings: The engine may not reach operating temperature, causing cooler combustion and partially burned fuel to be exhausted; increasing CO.

- B. High HC readings: If the computer does not sense the engine reaching operating temperature, it may keep the air/fuel mixture adjusted for cold enrichment needed at start-up. This rich mixture causes unburned fuel to be exhausted and increases both HC and CO.



Coolant Temperature Sensor (CTS)

**MANIFOLD ABSOLUTE PRESSURE SENSORS (MAP) – Most MAP sensors are piezoresistive devices used to give the computer an indication of engine load depending on throttle opening.** MAP locations vary depending on the type of vehicle, but are most commonly mounted on the firewall or fender well. MAP sensors may look identical to, and be located with the Barometric Pressure Sensor (BARO). The MAP sensor compares the intake manifold vacuum to specific or “absolute” pressure. As the manifold vacuum on the variable side of the sensor decreases, the output voltage increases. The computer responds by adjusting for a richer mixture to meet the demand for more power.

Common MAP sensor problems include:

1. MAP sensor does not hold vacuum –there may be an internal leak and the unit should be replaced. Drivability symptoms could include loss of power or sluggish response to increased load or possible ping.

2. MAP sensor signal out of spec – The computer sees this as a false signal and adjusts the timing; causing a rich mixture and retarded timing. This will cause a ping under a load to occur.
3. MAP sensor does not receive vacuum – This may be due to a kinked or broken hose from the manifold.

**MASS AIR FLOW (MAF) SENSORS** –MAF sensors perform the same job as MAP sensors but carry it out differently. The three most common types are; the hot wire type, grid type, and the Karman Vortex type.

MAF sensors are not interchangeable and the correct type must be used for the specific engine application. The hot wire and grid type sensors are capable of compensating for altitude and humidity. They measure the electrical power that is required to maintain the sensing element at 75° C above the temperature of the incoming air. The power required to maintain the 75° C differential is a measure of mass air flow.

There are two types of Karmon Vortex MAF sensors. One type measures mass air flow by sensing ultrasonic waveforms, the other uses optical vibrations.

**BAROMETRIC SENSOR (BARO)** – The barometric sensor is also a piezoresistive device that often looks and functions much like the MAP sensor. **The purpose of the BARO sensor is to provide the computer with an input of the operating altitude of the vehicle.** This is important, since air becomes less dense at higher altitudes. The BARO sensor provides the computer with the necessary input to compensate for altitude differences for adjusting the air/fuel mixture and ignition timing. One chamber of the BARO sensor contains a reference pressure (usually sea level), while the other chamber is exposed to the current atmosphere. The piezoresistive diaphragm flexes with differences between the two pressures, sending a varying voltage signal to the computer.

The BARO sensor is likely to fail by not responding to changes in applied vacuum. A hand-held vacuum pump can be used to test the BARO sensor.

**THROTTLE POSITION SENSOR (TPS)** – The Throttle Position Sensor is usually a type of potentiometer. **Its purpose is to indicate the angle of throttle opening to the computer.** It is normally part of fuel injection system. As the accelerator is opened or closed, the center wiper of the TPS moves. This causes a change in resistance and allows either more or less reference voltage to be returned to the computer. At wide open throttle (WOT), about 85% or more of the reference voltage is returned to the computer.



Throttle Position Sensor and TPS Schematic Symbol

A common TPS problem is; **a dirty center wiper; the transition from idle to WOT and back, should be a smooth increase and decrease in signal voltage when monitored with a DVOM. If the transition is not smooth (or jumps in voltage are noticed), then the TPS should be replaced.** If the computer is not receiving accurate signals from the TPS, it cannot properly adjust the air/fuel; mixture for the actual driving conditions.

**CRANKSHAFT POSITION SENSOR (CPS)** - **the purpose is to control ignition timing by monitoring the rotational position of the crankshaft.** The CPS is a type of inductive pickup or Hall-effect cell that senses the motion of the crankshaft. The sensor's location varies with different vehicles; but is most commonly found near the crankshaft. In some cases, the engine may not be able to run without a signal from the crankshaft position sensor. If the signal is weak or incorrect; improper ignition timing may be noticed. Excessive knocks and pinging along with hesitation and other drivability problems may result as the computer tries to adjust the ignition timing for the conditions being sensed. Emissions indications are likely to be excessive HC.

**CAMSHAFT POSITION SENSOR** – the purpose is to communicate the position of the camshaft to the control module. This information is then used to synchronize the pulsing of sequential fuel injectors to match the firing order of the engine. On some applications input from the sensor is also needed for ignition timing.

**KNOCK SENSOR** – The knock sensor is a piezoelectric type sensor that responds to certain frequencies. **Its purpose is to send a voltage signal to the computer indicating that engine knock is taking place.** The computer responds to this signal by adjusting ignition timing to reduce the knock. **When the computer receives a signal from the knock sensor it will retard ignition timing in small increments until pre-ignition is reduced or eliminated.**

**SWITCHES** –Switches are used to indicate that a condition is present for which the computer may need to adjust engine operation.

The types of switches used to monitor different conditions may include:

1. **Park/Neutral Switch** – Signals the computer to indicate whether or not the transmission is in gear. With some systems, the computer may control engine idle speed and will not advance timing unless the transmission is in gear.
2. **Air conditioning (A/C) Switch** – Signals the computer if the A/C is in use, so that the engine can be adjusted for the extra load.
3. **Idle Speed Control Switch** – On some systems, a switch sends a signal to the computer indicating when the throttle is in the closed position. The computer then controls the idle speed.
4. **Transmission Switches** – Most transmissions have hydraulic or mechanical switches to tell the computer what gear the transmission is currently operating in. The computer locks up the torque converter, then adjust engine settings for the most effective operation, such as cruise mode in 4<sup>th</sup> gear.
5. **EGR Switch** – The EGR switch is monitored by the computer to advance ignition timing and for diagnostic purposes. It signals whether the vacuum controlled EGR valve is open or closed.

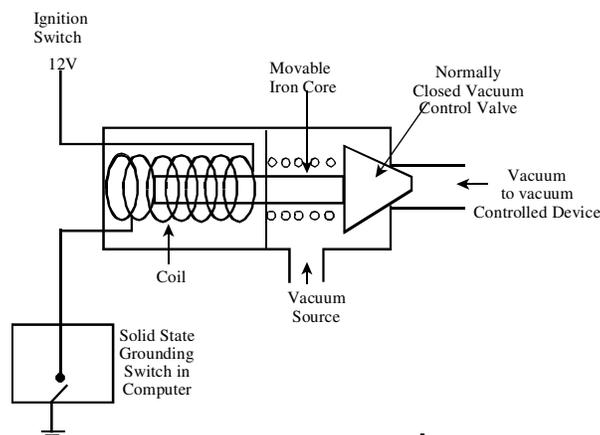
# ACTUATORS

**Actuators are the devices that make adjustments to engine control systems.** All actuators have one thing in common; they don't "act" until they are directed to do so by the computer. A good example is electronic timing controls. Most computerized vehicles have preset timing to aid engine starting. After proper warm-up, the computer decides where to set ignition timing, based on information it senses about RPM, engine load, and etc... It signals the actuator to "act," or make adjustments as needed, advancing or retarding the timing in milliseconds.

**Most actuators are "current-controlled" devices. They depend on a specific current flow, rather than voltage, to operate.** The current flow to the actuator may be regulated by a relay that is controlled by the computer. The actuator draws less than .5 amps and is controlled by a power transistor within the computer.

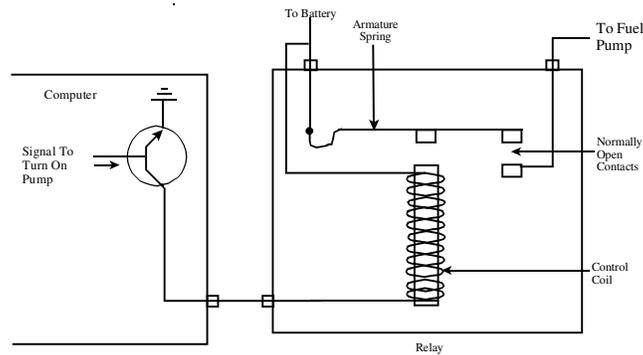
**Actuator Types** – There are three types of devices commonly used as actuators in automotive systems:

1. **Solenoids** – This is the most common type of actuator. It uses a magnetic field created by a coil of wire to move an iron center core or armature. Solenoids are commonly connected to valves to control engine functions, such as vacuum, fuel mixture, or EGR. Fuel injectors and relays are other examples of common solenoid devices.



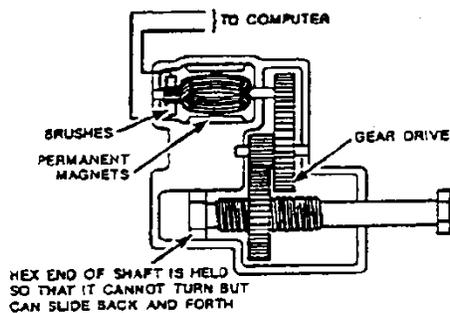
Solenoid Diagram

2. **Power Relays** – These are remote control switches that allow a light duty switch, such as the ignition or computer power transistor, to control a device that requires a heavier current to operate. Relays also have a coil of wire that creates a magnetic field to open or break a set of contacts that control the heavier current flow. The most common use of a relay in a vehicle is the starter. The starter motor requires a high current to turn over (initially start) the engine. The relay makes the connection from the starter to the battery when the ignition key is turned, allowing the starter to draw needed current, which may range from 150 to 400 amperes. Other types of relays are used to energize current dependent devices, without passing those loads through the ignition system.



Relay Diagram

3. **Motors** – Both simple DC and stepper motors are used to control engine functions. The motor contains a coil winding, which drives a shaft as it receives direct current or electric pulses. The direction the shaft turns is controlled by the polarity (positive or negative) applied to the coil windings; making most motors reversible. A motor is commonly used to control the idle speed, and in some case, the air/fuel in computerized vehicles.



Typical Motor

A coil may fail in one of four ways that may be detected with a DVOM or Scanner:

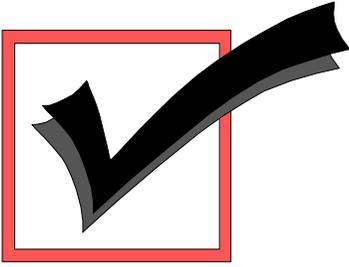
1. Open – The wire windings have been damaged and are broken.
2. Partially Shorted – Some of the windings may be shorted to ground or to each other, causing a low resistance.
3. Totally Shorted – Windings corroded or damaged, causing a total short and no resistance readings at all.
4. Intermittent Short or Open – This is due to heat, causing intermittent failures. An actuator coil that is partially shorted can cause a power transistor failure in the computer, due to the excessive current draw.

#### **NOTES**

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## SELF-CHECK

### CLOSED LOOP SYSTEM OPERATION



Mark or fill-in the correct answer. Check your answers in Appendix "A" at the back of the Study Guide.

1. **TRUE or FALSE** – The purpose of the closed loop system is to control emissions by regulating ignition timing and air/fuel mixture, while maintaining the acceptable performance/drivability and fuel economy.
  
2. **Inductive pick-ups are commonly used in computerized engine control systems to\_\_\_\_\_.**
  - A. Indicate EGR valve position
  - B. Detect engine knock
  - C. Provide crankshaft position for ignition timing
  - D. Indicate coolant Temperature
  
3. **Which sensor on an OBD equipped vehicle has to be heated before it will begin sending a signal to the computer?**
  - A. Oxygen Sensor (O<sub>2</sub>)
  - B. Throttle Position Sensor (TPS)
  - C. Manifold Absolute Pressure Sensor (MAP)
  - D. Thermistor Style Coolant Temperature Sensor (CTS)
  
4. **The device/chip which contains specific instructions for the computer and allows auto manufacturers to use the same computer in different models of vehicles is called\_\_\_\_\_.**
  - A. Read Only Memory (ROM)
  - B. Random Access Memory (RAM)
  - C. Programmable Read Only Memory (PROM)
  - D. Keep Alive Memory (KAM)

## SELF – CHECK (cont.)

5. **As the oxygen level of the exhaust gas goes down/decreases, the O<sub>2</sub> sensor voltage should\_\_\_\_\_.**
- A. go up/increase
  - B. go down/decrease
  - C. show no significant change
  - D. None of the above
6. **The “ideal” air/fuel mixture for emissions, referred to as “Stoichiometric “Air/Fuel ratio is approximately \_\_\_\_\_.**
- A. 13.5:1 A/F ratio
  - B. 14.7:1 A/F ratio
  - C. 15.1:1A/F ratio
  - D. None of the above
7. **You are using a DVOM to monitor a Throttle Position Sensor (TPS). As you slowly open the throttle, you *first* observe a slow steady increase in voltage. As you approach mid-throttle range, the voltage suddenly decreases by almost a full volt. What does this indicate?**
- A. Normal TPS operation
  - B. Defective Digital Volt Ohm Meter (DVOM)
  - C. Defective TPS, repair or replace
8. **The components used to perform engine adjustments as commanded by the computer are referred to as\_\_\_\_\_.**
- A. Switches
  - B. Actuators
  - C. Sensors
  - D. Diodes
9. **While monitoring the output of a known good oxygen sensor with a DVOM. The readings remain fixed at about 0.75 volts. What does this indicate?**
- A. Normal exhaust condition
  - B. Rich exhaust condition
  - C. Lean exhaust condition

## SELF – CHECK (cont.)

10. **The part of the computer's memory which temporarily stores information is called**
- A. Random Access Memory (RAM)
  - B. Programmable Read Only Memory (PROM)
  - C. Central Processing Unit (CPU)
  - D. Read Only Memory (ROM)
11. **When the computer receives a signal from the knock sensor, it is likely to respond by sending a command to\_\_\_\_\_.**
- A. Retard ignition timing
  - B. Advance ignition timing
  - C. Adjust base timing
  - D. To make Air/Fuel mixture richer
12. **The computer is able to adjust the engine for operation at different altitudes by monitoring which sensor?**
- A. Coolant Temperature Sensor (CTS)
  - B. Air Conditioning Sensor (ACS)
  - C. Oxygen Sensor (O<sub>2</sub>)
  - D. Barometric Pressure Sensor (BARO)
13. **Which sensor is monitored by the computer as the dominate sensor at engine start-up most computerized automotive systems?**
- A. Throttle Position Sensor (TPS)
  - B. Manifold Absolute Pressure Sensor (MAP)
  - C. Coolant Temperature Sensor (CTS)
  - D. Oxygen Sensor (O<sub>2</sub>)

## SELF-CHECK (CONT.)

14. **What factors can most likely affect Coolant Temperature Sensor (CTS) output?**
- A. Potentiometer positioning
  - B. Thermostat operation
  - C. Engine load
  - D. None of the above
15. **On computerized systems the MAP tells the computer\_\_\_\_\_.**
- A. To change dwell on the mixture control
  - B. About engine load
  - C. When to advance or retard timing
  - D. About engine temperature
16. **You are monitoring the output of a known good oxygen sensor with a DVOM. The output voltage seems to fluctuate between about 0.2 volts and 0.9 volts. From this, you can conclude that\_\_\_\_\_.**
- A. The system is operating in open loop
  - B. The vehicle has an emissions problem
  - C. The system is operating in closed loop

# **ON-BOARD DIAGNOSTICS**

# ON-BOARD DIAGNOSTICS

The OBD system uses **Diagnostic Trouble Codes (DTCs)** to help technicians isolate a problem, and a **Malfunction Indicator Light (MIL)** to alert the driver that there is an emissions system problem with the vehicle.

The first OBD system was referred to as OBD I and was required to monitor the oxygen sensor (O<sub>2</sub>), exhaust gas recirculation (EGR) system, fuel delivery system, and power-train control module (PCM). OBD I monitors were designed to detect system and component electrical failures.

## OBD II

**All light-duty vehicles beginning with the 1996 model year are required to have OBDII diagnostic systems. The purpose of OBD II is to make sure every vehicle's emissions system works properly for the life of the vehicle.** To accomplish this, the diagnostic system monitors emissions control systems and components for performance and failure.

Every OBD II diagnostic system must be capable of:

- identifying failure or malfunction of emissions components which can result in the vehicle's failure to comply with federal emissions standards
- alerting the vehicle operator of the need to maintain and/or repair emissions related components and/or system
- storing trouble codes and providing access to vehicle on-board information

OBD II monitors the performance of emissions systems and components as well as electrical failures. **The MIL will be activated/illuminated and a DTC will be set by the OBD II system if the system detects an emissions system failure on two consecutive drive cycles (most systems). The MIL will be turned off by the OBD II system when it detects three consecutive trips (drive cycles) without the problem reoccurring.**

**There are two types of Readiness Monitors, Continuous and Non-continuous.**

**Continuous Monitors are:**

- misfire
- fuel trim/fuel delivery system
- Engine Misfire
- comprehensive components (sensors and actuators)

These monitors are continuously checked by the OBD II system and **are NOT to be considered in the readiness monitor determination.**

**Non-continuous monitors (efficiency monitors) are:**

- Comprehensive Component Monitoring (emissions related inputs and outputs)
- Oxygen Sensor System (HO<sub>2</sub>S)
- Oxygen Sensor Heater System (HO<sub>2</sub>S Heater)
- Catalytic Converter Efficiency
- Heated Catalyst Monitoring (if equipped)
- Evaporative Emissions Control System (EECS)
- Exhaust Gas Recirculation System (EGR)
- Secondary Air Injection (AIR)

**These monitors are to be considered in the readiness monitor determination.**

**OBD II systems include an emissions monitor. Before any of the vehicles emissions rise to more than 1.5 times the Federal Test Procedure cut-points/new car standard, the system turns the MIL “ON”, warning the driver that there is a problem causing the higher than normal emission levels.**

**After repairs and/or battery service, replacement or disconnection, it is recommended that the vehicle be driven through the drive cycles; then re-checked to ensure monitor readiness before returning for a retest.**

EPA approved OBD II standards, beginning with some models years as early as 1994, with full compliance for gasoline powered vehicles by 1996.

In addition, factory only alternative fuel vehicles were required to adopt OBD II standards.

In 1998, CARB and the Society of Automotive Engineers (SAE) developed a new set of standards for vehicle control systems requiring a common:

- ✓ set of terms and definitions (J1939)
- ✓ set of diagnostic trouble codes and definitions (J2012)
- ✓ diagnostic connector and connector location (J1962)
- ✓ diagnostic scan tool (J1978)
- ✓ set of diagnostic test modes (J1979 and J2190)
- ✓ way for technicians to get service information (J2008)
- ✓ SAE-recommended serial data communication system (J1850)
- ✓ International serial data communication system (ISO 9141)

All manufacturers are required to use the same diagnostic link connector (DLC) and each DLC must be wired the same way, and use the same type of software packages. One scan tool should be able to provide some information on every vehicle that comes through the shop.

All OBD II connectors must be compatible with one generic scan tool. Manufacturers are required to make their OBD II DLCs adapt to a generic scan tool. There is a minimum amount of information that every manufacturer must provide through the OBD II compatible scan tool. The standard also provides minimum requirements that the generic scan tool protocol must meet for the manufacturer to claim that it is OBD II compatible.

**Among these requirements is the retrieval of:**

- **Diagnostic Trouble Codes**
- **Sensor Parameter Values**
- **Freeze Frame Data**

The generic scan tool protocol may also read serial data and perform diagnostic test modes. OBD II standard J1979 requires certain serial data be available to the scan tool and that certain diagnostic test capabilities be part of the on-board computer design.

**Standard test modes include:**

- **Diagnostic test modes**
- **Diagnostic test results**
- **Retrieving trouble codes**
- **Clearing trouble codes**

One of the features of OBD II is a "Trip." During a trip, the computer performs a specific series of tests and monitors while the vehicle is driven through a specific series of conditions. **These driving conditions are called an OBD II Drive Cycle.**

**OBD II systems provide adaptive learning. OBD II systems sense specific conditions during a drive cycle, and adjust to compensate for those conditions.**

# ENGINE COOLANT TEMPERATURE (ECT) SENSOR DIAGNOSTICS

The computer provides a 5-volt reference voltage signal to the sensor. The sensor provides a high resistance when the engine is cold. The computer measures this resistance as a high voltage drop across the sensor.

As the sensor warms-up, its resistance decreases/goes down and the computer measures a lower voltage drop across the sensor. The OBD II system requires that the ECT sensor be monitored for performance deterioration.

The engine coolant temperature sensor diagnostics include several tests:

- ✓ ECT Sensor voltage out of range
- ✓ ECT Sensor input failed to enable closed loop

The diagnostics also test for intermittent circuit activity. The computer monitors temperature readings from the ECT sensor in 100 millisecond intervals. For a fixed time period, the diagnostics count the number of engine coolant temperature sensor readings outside of the sensors expected range. If the number of engine coolant temperature sensor readings in the high or low range exceeds a calibrated threshold, the sensor shows a high or low failure.

The diagnostics for closed loop enable monitors the engine run time required for the engine coolant temperature sensor to reach the closed loop enable threshold. This diagnostic is to identify an engine coolant temperature sensor reading that is delaying or preventing closed loop operation, but has not failed out of range yet.

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## NOTES

# HEATED OXYGEN SENSOR MONITOR

The purpose of the heated oxygen sensor used for fuel control, is to provide the computer with information on the amount of oxygen in the exhaust stream to allow proper fueling and maintain emissions within the mandated levels. After the O<sub>2</sub> sensor reaches operating temperature, it will generate a DC voltage potential of up to 1-volt. The voltage is opposite to the amount of oxygen present in the exhaust stream (high voltage = low oxygen). The computer uses the signal from the heated O<sub>2</sub> sensors in closed loop mode to adjust fuel injector pulse width. While the fuel control system is operating in closed loop fuel control, the computer can adjust fuel delivery to maintain an air/fuel ratio that allows the best combination of emissions control and drivability.

**The Oxygen Sensor Monitor is designed to monitor the upstream heated oxygen sensor(s).**

**The Monitor looks for the following conditions:**

- **Heater performance (time to operating temperature on a cold engine)**
- **Heated Oxygen Sensor slow response time**
- **Inactive signal (voltage steady at bias of 450mv)**
- **Heated Oxygen Sensor signal fixed high or low**

**Possible causes of Oxygen Sensor Heater Monitor faults:**

- **Open heater elements**
- **Faulty heated oxygen sensor**
- **Backed out terminals, damaged connectors or wiring**

During the drive cycle the OBD II system monitors the oxygen sensor after warm-up, during a steady speed cruise, between 20 and 45 MPH, for about 20 seconds.

# CATALYST EFFICIENCY

The OBD II system monitors the catalytic converter system for efficiency by checking two oxygen sensors, one before the converter, and one after. **The system compares the oxygen levels coming in and going out of the converter.** If the system is operating properly the oxygen sensor before the converter should be switching back and forth, within its full voltage range. The oxygen sensor after the converter should not have a switching rate equal to the oxygen sensor before the converter, and should be fairly constant.

As the catalytic converter becomes less efficient, the oxygen level downstream of the converter will begin to fluctuate until it appears almost the same as the upstream oxygen sensor levels. **When the computer sees that both oxygen sensor readings are similar, it sets a code that catalyst efficiency may be reduced.**

Inputs for various sensors are required to allow the Catalyst Monitor to run.

- Crankshaft Position Sensor(CPS)
- Engine Coolant Temperature (ECT) Sensor
- Intake Air Temperature (IAT) Sensor
- Throttle Position Sensor (TPS)
- Vehicle Speed Sensor (VSS)

Also required, a specific amount of time has to have expired since engine startup, and closed loop operation must be enabled. During the test, the switching frequency of the downstream oxygen sensor (HO<sub>2</sub>S<sub>2</sub>) is evaluated and compared to the upstream oxygen sensor switching frequency.

**The slower the switching frequency of the downstream HO<sub>2</sub>S<sub>2</sub> oxygen sensor; the more efficient the converter.**

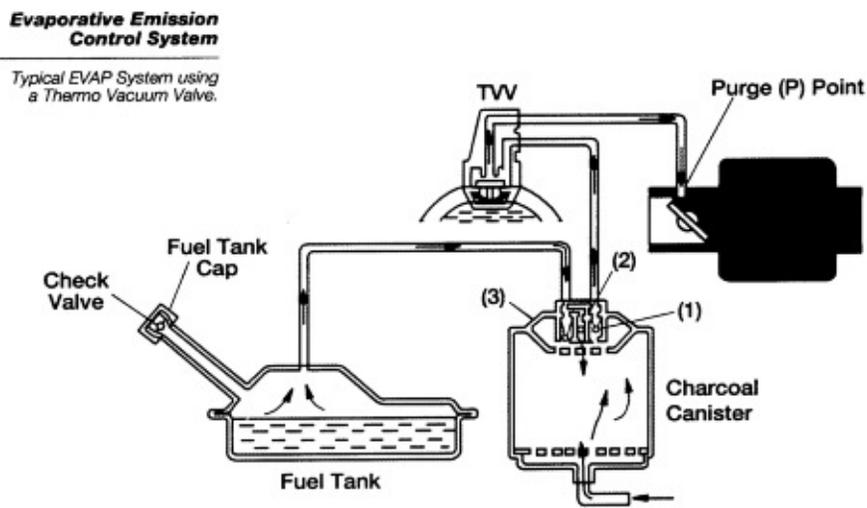
During the drive cycle the OBD II system monitors the oxygen levels in the exhaust before and after the catalytic converter, to determine its oxygen storage capabilities. This test requires a steady speed cruise, between 40 and 60 MPH, for a little over a minute.

#### **NOTES**

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# EVAP SYSTEM MONITOR

The EVAP System Monitor is designed to test for correct operation of the Evaporative Emissions System **by checking the operation of its components and its ability to flow fuel vapors (HC) to the engine**. The EVAP Monitor **also detects leaks by performing a vacuum check of the complete EVAP system**.



EVAP System

The EVAP Monitor strategy is to allow vacuum flow to the EVAP system and then monitor for a leak. At the correct time, engine vacuum is used to create a small vacuum on the EVAP system which has been sealed off. When a calculated vacuum is achieved, the vacuum source is turned off and the system is sealed.

The Vacuum Monitor looks for vacuum leaks by observing vacuum level changes over a measured period of time.

Possible causes of EVAP System problems are:

- **Vacuum hoses cracked, leaking, cut, or disconnected**
- **Plugged hose from solenoid to canister or throttle body**
- **Plastic connector to EVAP Canister Purge Solenoid cracked**
- **Connectors or wiring damage**
- **EVAP Canister Purge Solenoid fault or computer defective**
- **Faulty fuel cap**

#### **NOTES**

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# EGR SYSTEM MONITOR

The Exhaust Gas Recirculation (EGR) System Monitor is an on-board monitor designed to test the integrity and flow features of the EGR system. It checks the EGR system for abnormally low or high flow-rate faults and sets a code if it detects an EGR system component fault, or a change in EGR flow rate that could result in the vehicle emissions exceeding 1.5 times federal test procedure cut-points/new car standard for the vehicle.

Possible causes of an EGR System Monitor fault:

- **Open or blocked vacuum supply (hoses) to the EGR valve**
- **Blocked exhaust transfer tubes to the intake manifold**
- **Blocked backpressure tube to the transducer**
- **Failed EGR valve or EGR transducer**
- **Backed-out or damaged connector terminals**

The OBD II system monitors the EGR system operation during a series of idles and accelerations.

# MISFIRE MONITOR

The Misfire Monitor is designed to monitor engine misfires and identify the specific cylinder in which the misfire occurred. In order for the Misfire Monitor to work, certain base engine conditions must be met.

Inputs from the following are required to enable the Misfire Monitor:

- Crankshaft Position Sensor (CKP or CPS)
- Engine Coolant Temperature (ECT) Sensor
- Mass Air Flow(MAF) Sensor

Possible causes of misfire faults are:

- **Engine mechanical faults, restricted exhaust**
- **Fuel pump faults or a plugged or restricted fuel filter**
- **EGR or EVAP system faults**
- **Dirty or faulty injectors, damaged injector connectors**
- **Vehicle low on or out of fuel**
- **Intake system restriction**
- **PCM power or ground circuit faults, a faulty PCM**
- **Ignition defects**
- **Fouled or malfunctioning spark plugs or bad plug wires**

# FUEL SYSTEM MONITOR

**The Fuel System Monitor is designed to measure the averages of short term and long term fuel system values.** The fuel trim diagnostic compares the average values of short term and long term fuel trim values to rich to lean tolerances. Provided that both values are within range the fuel system passes the monitor test. If both values are out of range a rich or lean diagnostic trouble code is set.

**Short Term & Long Term Fuel Trim** – Short Term and Long Term Fuel trim work together. **If the oxygen sensor used for air/fuel mixture control indicates a rich exhaust condition, the computer moves short term fuel trim to a negative range to correct the rich exhaust condition. If after a calibrated period of time the short term fuel trim is still correcting for the rich exhaust condition, the computer learns this and changes long term fuel trim into the negative range to correct the rich exhaust condition.** This allows short term fuel trim to return to a value of zero percent. Signals from the Engine Coolant Temperature (ECT) sensor, Incoming Air Temperature sensor (IAT) and Mass Air Flow sensor (MAF) are used to make changes to the adaptive fuel control system.

Possible causes of fuel system monitor faults:

- **IAT Sensor faults, MAP Sensor faults, O<sub>2</sub> Sensor or computer faults**
- **EGR faults, fuel or ignition system faults**
- **Worn engine parts, a defective catalytic converter**

## **Misfire, Comprehensive Component and Fuel System**

During a drive cycle, the OBD II system begins performing these monitors at the beginning of the drive cycle. These monitors can end any time during the trip.

# SECONDARY AIR MONITOR

Vehicles that are equipped with a secondary air injection pump must be monitored for the presence of air flow in the exhaust, as well as functional monitoring of the air pump and any related valves.

With the Secondary Air System "on", air will flow into the exhaust system causing the HO<sub>2</sub>S1 voltage to drop. The HO<sub>2</sub>S1 voltage and/or short term fuel trim value are monitored for a response. The monitor tests the HO<sub>2</sub>S1 voltage after startup and before closed loop operation. The pump is normally "on" at this time to clear exhaust emissions. The monitor will indicate a pass if the HO<sub>2</sub>S1 voltage indicates a lean condition before it goes into closed loop operation.

If this test fails, an active test is started. The air pump is turned on when the fuel system is in closed loop operations. The monitor will indicate pass or fail based on the HO<sub>2</sub>S1 and "Short Term Fuel Trim" values. A low HO<sub>2</sub>S1 voltage signal with increased short term fuel trim value indicates the air system is operational

## NOTES

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## **MANIFOLD ABSOLUTE PRESSURE (MAP) DIAGNOSTICS**

The Manifold Absolute Pressure (MAP) sensor measures changes in intake manifold pressure. Manifold Absolute Pressure sensor readings are shown in both kilopascals (kPa) and voltage. Kilopascals are a measure of pressure.

Intake manifold pressure changes are the result of engine load and speed changes. To measure these changes the MAP sensor varies resistance. The computer sends a 5-volt reference voltage and then decreases the voltage according to the pressure in the intake manifold. A high voltage potential indicates high pressure, and high pressure indicates the engine is under a heavy load. Low pressure indicates the engine is under a light load.

The MAP signal is used to measure barometric pressure changes in linear EGR flow and changes in manifold pressure during certain diagnostic testing.

The Manifold Absolute Pressure sensor (MAP) Monitoring Diagnostics will monitor for voltages outside of the normal calibrated range. The computer also measures actual manifold absolute pressure output to calculated values to determine sensor performance failure. The calculated values are based on throttle position and various engine load factors.

# OBD II EMISSIONS INSPECTION

The test consists of verifying the operation of the malfunction indicator lamp (MIL); confirming that the appropriate readiness monitors are set; visually inspecting the diagnostic link connector (DLC); determining if the MIL is commanded "ON"; recording diagnostic trouble codes (DTC).

The process is as follows:

1. The vehicle's ignition is turned to "Key On Engine Off" (KOEO) and the MIL is observed; the MIL must be lit. This portion of the test verifies MIL operation and is commonly known as the **"bulb check"**.

**On = pass**

Off = fail

2. The DLC is located and inspected for tampering (missing, loose, or damaged).  
**If the DLC is tampered (missing, loose, or damaged), the vehicle fails the inspection.**

3. The vehicle's DLC is connected to the scan tool. The vehicle's ignition is turned "Key On Engine Running" (KOER) and the MIL is observed. The MIL should light and then go out during this phase.

If the MIL stays on; the vehicle fails.

**If the MIL goes off the vehicle passes.**

4. **The scan tool used must be in the generic OBD mode**, and the following is then determined:

## **Readiness Monitor Status:**

1996 through 2000 model year vehicles are allowed two or fewer unset readiness monitors for a valid test.

**2001 and newer model year** vehicles are allowed **one or less unset readiness monitors for a valid test. If monitor requirements are not met, the vehicle must be driven through a drive cycle until required monitors are set.**

The MIL status is then checked to determine if the vehicle's computer is commanding the MIL to be on or off.

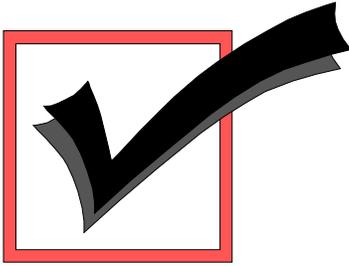
**MIL commanded off = pass**

MIL commanded on = fail

5. The functional gas cap test is performed.

## NOTES

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## SELF-CHECK

### ON-BOARD DIAGNOSTICS OBD – II

Mark or fill-in the correct answer. Check your answers in Appendix "A" at the back of the Study Guide.

- 1. The slower the switching frequency of the downstream oxygen sensor (HO<sub>2</sub>S<sub>2</sub>), the more efficient the catalytic converter?**
  - A. True
  - B. False
- 2. All light-duty vehicles beginning with what model year are required to have OBD II diagnostic systems.**
  - A. 1995
  - B. 1996
  - C. 1997
  - D. 2000
- 3. The scan tool used to perform or duplicate the official Arizona OBD test must be set to \_\_\_\_\_.**
  - A. Generic mode
  - B. It really doesn't matter what the setting is
  - C. Manufacturer specific mode
  - D. None of the Above
- 4. The purpose of OBD II was to make sure every new vehicle's emission system \_\_\_\_.**
  - A. Tells technicians when to replace emission components
  - B. Operates properly for the life of the vehicle
  - C. Shuts the engine off when a problem occur
  - D. None of the above

## SELF-CHECK (CONT.)

5. **The Oxygen Sensor Monitor is designed to monitor the upstream heated oxygen sensor (s). The monitor not only looks for a heated oxygen sensor signal fixed high or low but also for\_\_\_\_\_.**
- A. Heated Oxygen Sensor slow response time
  - B. Heater performance (time to reach operating temp on a cold engine)
  - C. Inactive signal (voltage steady at bias of around 450 mv)
  - D. All of the above
6. **The OBD system uses Diagnostic Trouble Codes (DTC's) to\_\_\_\_\_.**
- A. Help the techs isolate a problem
  - B. Tell the techs what component to replace
  - C. Annoy the vehicle owner by turning the light on
  - D. None of the above
7. **One of the features of OBD II is a "TRIP". During a trip, the computer performs a specific series of test and monitors while driving the vehicle through a specific series of conditions. These driving conditions are referred to as\_\_\_\_\_.**
- A. OBD II Data Stream Cycle
  - B. Emissions System Test Cycle
  - C. OBD II Drive Cycle
  - D. Get It Ready Cycle
8. **On an OBD II Catalytic Converter system, the MIL is activated when a fault is detected on\_\_\_\_\_ consecutive drive cycles.**
- A. 4
  - B. 2
  - C. 1
  - D. 3

## SELF-CHECK (CONT.)

9. **The Malfunction Indicator Light (MIL) is lit and a Diagnostic Trouble Code (DTC) is stored, when one or more of the vehicles emissions systems signals increases more than\_\_\_\_\_.**
- A. One and one half (1.5) times the new car standard for the vehicle being tested
  - B. Two (2) times the new car standard for the vehicle being tested
  - C. Four (4) times the new car standard for the vehicle being tested
  - D. One half (0.5) times the new car standard for the vehicle being tested
10. **The purpose of the OBD II evaporative system monitor is to\_\_\_\_\_.**
- A. Test the integrity of the system components.
  - B. To detect a leak in the system.
  - C. Both A and B
  - D. None of the above
11. **Possible causes of an EGR System Monitor Fault are\_\_\_\_\_.**
- A. Blocked exhaust transfer tubes to the intake manifold
  - B. Failed EGR valve or EGR transducer
  - C. Open or blocked vacuum supply (hoses) to the EGR valve
  - D. All of the above
12. **The Catalyst Efficiency Monitor measures the amount of \_\_\_\_\_ before and after the catalyst to determine catalyst efficiency.**
- A. Hydrocarbons (HC)
  - B. Oxygen (O<sub>2</sub>)
  - C. Carbon Monoxide (CO)
  - D. Carbon Dioxide (CO<sub>2</sub>)

## SELF-CHECK (CONT.)

13. **Which of the conditions listed below will most likely cause an engine misfire, or a misfire DTC to be set?**
- A. Faulty ignition components
  - B. PCV valve stuck in the low flow position
  - C. Faulty evaporative canister
  - D. Rich air/fuel mixture
14. **2001 and newer model year vehicles are allowed \_\_\_\_\_ or less unset readiness monitors for a valid test.**
- A. Three
  - B. One
  - C. Two
  - D. Zero
15. **If the oxygen sensor used for air/fuel mixture control (HO<sub>2</sub>S1) indicates a rich exhaust condition, the computer responds by moving\_\_\_\_\_.**
- A. Short Term Fuel Trim to a negative range first, and if the problem persist then Long Term Fuel Trim is moved to a negative range
  - B. Long Term Fuel Trim to a positive range
  - C. Short Term Fuel Trim to a positive range
  - D. Short Term Fuel Trim to a positive range first, and if the problem persist then Long Term Fuel Trim to a positive range

# **GLOSSARY**

# GLOSSARY OF TERMS AND ACRONYMS

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## A

**ACCELERATOR** – Pedal (or other type of control) used to regulate the revolutions per minute (RPM) of an engine or the speed of a vehicle.

**ACTUATOR** – A device (solenoid, relay, or motor) that is used to adjust an engine function, such as idle speed, air/fuel mixture or ignition timing.

**ADDITIVES** – Substances added to gasoline or motor oil.

**AIR/FUEL RATIO** – The mixture of air and gasoline (or other fuel) in specific quantities.

**ALTERNATING CURRENT (AC)** – Electricity that cycles from positive to negative.

**ALTERNATOR** – A device that generates electricity (alternating current).

**AMPERE (AMPS)**– A unit of measure for electrical current.

**ANALOG** – relating to a mechanism that represents data by measurement of a continuous physical variable, as voltage or pressure.

## B

**BACK PRESSURE** – Pressure created as a result of a restriction of flow, i.e., a restricted catalytic converter causes exhaust back pressure, since the exhaust gas cannot pass freely through it.

**BATTERY** – Cell which stores an electrical charge.

**BAROMETRIC PRESSURE SENSOR (BARO)** – a component used to measure atmospheric pressure changes.

**BOOST** – A measure of air pressurization above normal atmospheric pressure, usually associated with turbo – or supercharging of engines.

## C

**CALIBRATION** – A setting or adjustment of a device (test equipment, fuel injection systems, etc...) to a precise, measurable standard.

**CAMSHAFT** – An engine component consisting of shaped lobes that operate intake and exhaust valves at a specific rate.

## C

**CANISTER** – A component of an emissions control system used to store excessive fuel vapors.

**CARBON** – Black substance which is created by the incomplete burning of fuel.

**CARBON MONOXIDE (CO)** – Odorless, colorless gas created by the incomplete burning of fuel.

**CARBURETOR** – An ancient device used on older vehicles for controlling the mixture of air and fuel for an engine.

**CATALYTIC CONVERTER (CAT)** – A component of an emissions control system that reduces emissions by oxidizing/burning off pollutants in exhaust gas.

**CIRCUIT** – Path for the flow of electricity.

**CLOSED LOOP** – The operating condition of a computer controlled engine that is using inputs from the sensors to control engine functions.

**COMBUSTION** – The high temperature burning of fuel when it reacts to an oxidant.

**COMPRESSION** – Increasing the pressure of a gas by reducing its volume.

**CONDENSATION** – A gas vapor converting to its liquid form.

**COOLANT** – Liquid circulated through engine to absorb, and disperse the heat created by combustion.

**CRANKSHAFT POSITION SENSOR (CPS)** – An electronic device used to monitor the position of the crankshaft for engine timing reference.

**CRANKCASE** – The bottom portion of the engine that houses the crankshaft and lubricating oil.

**CRANKSHAFT** – An engine component that transforms the up and down motion of the pistons into rotary motion, or produces useable inertia, energy, etc...

**COLLANT TEMPERATURE SENSOR (CTS)** – used to measure temperature of the engine coolant.

**CYLINDER** – The space in which a piston travels.

## D

**DETERIORATION** – The break down of matter into simpler substances, either naturally or by other agents.

**DIAGNOSIS** – Using available tests, test equipment, observation and reasoning to determine the cause of a particular malfunction or failure.

**DIAPHRAGM** – Flexible partition which separates two chambers.

**DILUTION** – The breakdown of a substance by adding another substance.

**DIODE** – An electronic device that permits current to flow through it in one direction only.

**DIRECT CURRENT (DC)** – Electricity that does not cycle and flows in one direction only.

**DIGITAL VOLT/OHM METER (DVOM)** – used to make measurements in a circuit

## **E**

**EXHAUST GAS RECIRCULATION (EGR)** – The routing of some of the exhaust gas to the intake manifold.

**EXHAUST GAS ANALYZER** – An instrument used to measure the amount of specific gases in a vehicle's exhaust.

## **F**

## **G**

**GASKET** – Cork, rubber or other material used as a seal between two metal surfaces.

## **H**

**HO<sub>2</sub>S1**-Heated oxygen sensor before the catalytic converter.

**HO<sub>2</sub>S2**- Heated oxygen sensor after the catalytic converter.

**HEAT RISER** – Passage between the exhaust and intake manifold used to aid fuel vaporization during engine warm up.

**HYDROCARBON** – Particles composed of hydrogen and carbon. Produced when fuel is left unburned/raw after combustion.

## **I**

**IDLE** – Engine running at lowest speed, not in gear.

**IGNITION** – The start of combustion, usually induced by a spark.

**IGNITION SYSTEM** – The parts of an engine used to control when ignition takes place, such as the coil, distributor, wiring and spark plugs.

**IMPEDANCE** – A circuit's total resistance to current.

**INDUCTIVE PICK-UP** – Electronic device sensitive to movements of magnetic fields.

**INTAKE MANIFOLD** – A component of an engine that channels the air/fuel mixture from the mixing device to the cylinders.

**INTAKE VALVE** – Part of an engine which allows the air/fuel mixture to enter the cylinder.

**INTEGRATED CIRCUITS** – A variety of devices and/or circuits that have been miniaturized and assembled in a single package to save space.

**INFRA-RED ANALYZER (I/R)** – Test instrument used to measure Emissions in automotive exhaust.

## L

**LEAN** – Used to describe an air/fuel mixture with an excess of air and lack of fuel.

## M

**MANIFOLD VACUUM** – low pressure produced in the engine's intake manifold as air is being drawn into the cylinders.

**MANIFOLD ABSOLUTE PRESSURE SENSOR (MAP)** – tells the computer about engine load.

**MEMORY** – Part of a computer used to store information.

**MICROPROCESSOR** –used to perform calculations of the information received by the sensors.

**MISFIRE** – Used to describe an ignition system that is sending a spark to a cylinder(s) at the incorrect time.

## O

**OHM** – Unit of measure for resistance.

**ON-BOARD DIAGNOSTICS** – Refers to self-diagnosing capability of automotive computers, which store codes to indicate problems and can be retrieved to assist in troubleshooting.

**OPEN CIRCUIT** – A break or other disruption that stops the flow of electricity in a circuit.

**OXIDES of NITROGEN (NO<sub>x</sub>)** – Chemical compound of oxygen and nitrogen produced during combustion.

**OXIDIZE** – To change the form of an element by combining it with oxygen. Burning off.

## **P**

**PIEZOELECTRIC** – Electronic device that contains a crystal which produces a voltage in response to frequency or pressure.

**POLARITY** – Positive or negative terminal of a battery, or reference to current flow in an electrical circuit.

**POTENTIOMETER** – Electronic device used to give a variable output in response to motion.

**PROPANE** – A flammable gas used as a fuel, also called LP gas.

## **R**

**RANDOM ACCESS MEMORY (RAM)** – temporary memory in the vehicle's computer.

**REFERENCE VOLTAGE** – A set voltage provided by the computer and used as a standard to measure rate of change information.

**REGULATOR** – A device used to reduce or control the flow of current, liquid or air.

**RELAY** – Low current device which controls current flow to high current devices.

**RESISTOR** – Electronic device used to limit the flow of current.

**READ ONLY MEMORY (ROM)** – permanent information in the vehicle's computer.

## **S**

**SCANNER** – A test instrument used to monitor digital codes or other engine functions.

**SPARK** – Electrical charge created by a difference in potential (positive and negative) between two points.

**SPIKES** – Sudden electrical surges in a circuit.

**STOICHIOMETRIC** – Term used to refer to the ideal air/fuel mixture for complete, clean combustion, generally considered to be 14.7 to 1 air/fuel ratio.

## T

**THERMISTOR** – Electronic device which changes its resistance in response to temperature changes.

**THERMOSTAT** – A valve that opens and closes to control the flow of coolant in an engine.

**TUNE-UP** – The adjustment or replacement of parts to obtain maximum engine performance and low Emissions.

## V

**VACUUM** – Pressure lower than atmospheric.

**VAPORIZATION** – The change of a liquid into its gaseous form.

**VAPOR LOCK** – Created when fuel in the system begins to boil, inhibiting flow.

**VOLT** – Unit of measure for electricity, the electrical force required to cause one amp to flow through one ohm of resistance.

# **APPENDIX A**

## **ANSWERS TO SELF CHECK QUESTIONS**

# **APPENDIX A – ANSWERS TO SELF-CHECK QUESTIONS**

## **HC/CO BASICS**

1. HYDROCARBONS (HC), CARBON MONOXIDE (CO) OXIDES OF NITROGEN (NO<sub>x</sub>)
2. B.
3. TRUE
4. D.
5. TRUE
6. D.
7. B.
8. A.
9. D.

## **EMISSIONS REDUCTION DEVICES**

1. C.
2. D.
3. C.
4. TRUE

## **BASIC ELECTRONICS**

1. D.
2. B.
3. B.

# APPENDIX A – ANSWERS TO SELF-CHECK QUESTIONS

## CONT...

### CLOSED LOOP SYSTEMS OPERATION

1. TRUE
2. C.
3. A.
4. C.
5. A.
6. B.
7. C.
8. B.
9. B.
10. A.
11. A.
12. D.
13. C.
14. B.
15. B.
16. C.

# APPENDIX A – ANSWERS TO SELF-CHECK QUESTIONS

## CONT...

### ON-BOARD DIAGNOSTICS OBD II

1. A.
2. B.
3. A.
4. B.
5. D.
6. A.
7. C.
8. B.
9. A.
10. C.
11. D.
12. B.
13. A.
14. B.
15. A.

