SAFETY

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles as well as the personal safety of the individual doing the repair. There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This module cannot possibly anticipate all such variations and provide advice or caution to each. Accordingly, anyone who departs from the instruction provided in this module must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools, or parts. The following list contains general warnings that should always be followed while working on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires underbody work.
- Be sure ignition switch is always off unless otherwise specified by a procedure.
- Set the parking brake when working on the vehicle.
- Operate the engine only in a well ventilated area.
- Keep clear of moving parts when engine is running.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on a vehicle.
# OBD-II

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Introduction

Course Goal

The goal of this OBD-II course is to provide the technician with in-depth knowledge of KIA vehicle OBD II system operation, diagnosis and repair. The Hi-Scan Pro Scan Tool, Break Out Box, Oscilloscope, Five-Gas Analyzer and DVOM Multimeter will be utilized by the technician to understand and diagnose failures related to system interaction, system authority, fuel trim adaptation and vehicle emissions.

Critical thinking skills and a logical diagnostic approach will be encouraged to help the technician improve the speed and accuracy of diagnosis and repairs.

Approximately 60% of the course content is presented in Guided Practices.

Performance Objectives

Upon completion of this OBD-II course, the technician will be able to demonstrate the following competencies:

- Use the following test equipment with industry-acceptable accuracy and speed: Hi-Scan Pro Scan Tool, Break Out Box, Oscilloscope, Five-Gas Analyzer and DVOM Multimeter

- Apply the Kia Five-Step diagnostic approach when diagnosing customer complaints

- Apply knowledge of system interaction, system authority, fuel trim adaptation and emissions to correctly diagnose and repair vehicle problems

- Correctly test two types of Kia vehicle EVAP systems

- Demonstrate knowledge of current OBD II emissions laws and requirements, CARB regulations and the progression from OBD I to OBD II systems.
KIA OBD-II
Pretest Answer Sheet

Name: ____________________________ Date: _________

Record the answers to the questions by blackening the letter of your choice for each question.
Fill in blanks where appropriate.
DO NOT CIRCLE THE LETTERS!

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

The negative effects of the internal combustion engine on the environment and air quality have been a concern for many years. Today, more than 6.3 billion vehicle miles are driven every day. Emissions from mobile internal combustion engines (automobiles and light trucks) are mostly Water Vapor and Carbon Dioxide, but these engines also have produced over 50% of the air pollution in our atmosphere. About half of the ozone and nearly all of the Carbon Monoxide are attributed to these mobile sources. A typical vehicle emits about a half ton of pollutants annually, and a vehicle with defects or in poor condition emits many times that amount. Direct health consequences caused by vehicle pollutants include increased levels of carcinogens and irritants to eyes and respiratory and cardiovascular systems. In addition to concerns about pollution, there are also good reasons to conserve petroleum resources. The United States has less than 5% of the world’s population, yet we consume more than 40% of the world’s petroleum. Tuning, maintaining and repairing vehicles will not only reduce levels of pollutants but will also improve fuel economy and stretch petroleum reserves.

Pollutants emitted by gasoline powered vehicles include:

**Carbon Monoxide (CO)** is a colorless, odorless, poisonous gas that is produced by combustion in gasoline engines. It can cause dizziness, headaches, impaired judgment, and in large concentrations, death from oxygen starvation.

**Hydrocarbons (HC)** are unburned fuel molecules that either exit the tailpipe (leftover from incomplete combustion) or evaporate from the vehicle fuel supply or gas pump nozzle. Emissions during refueling have become a more significant source of HC as tailpipe emissions have been reduced. HC combines with Oxides of Nitrogen (NOx) in the presence of sunlight to form Photochemical Smog, which creates a brownish haze and contributes to respiratory problems and eye irritation.

**Oxides of Nitrogen (NOx)** are compounds that are produced when combustion temperatures in the engine’s cylinders exceeds 1400 degrees C (approx. 2500 degrees F). Above these temperatures, normally inert Nitrogen (N₂) combines with Oxygen (O₂) to form several different compounds which again contribute to Smog, respiratory problems and eye irritation.

**Sulfur Dioxide (SO₂)** is a colorless gas with a pungent rotten egg odor. High sulfur content in the gasoline leads to SO₂ production in the catalytic converter. It can cause respiratory irritation, heart problems, and increased risk of asthma.

**Carbon Dioxide (CO₂)** is not toxic and not a pollutant, but it is considered a greenhouse gas and a major contributor to global warming. Much of the CO₂ increase in the atmosphere is a result of burning gasoline in internal combustion engines - for every gallon of gasoline burned, about twenty pounds of CO₂ are emitted to the atmosphere.

**Toxins (Benzene, Formaldehyde, Butadiene and others):** Are emitted by motor vehicles and are known carcinogens and toxic in low concentrations.
CARB

The California Air Resources Board (CARB) has led the effort to reduce all types of motor vehicle emissions nationwide. In addition to reducing vehicle emissions, CARB rulings have driven the introduction of innovations such as the standardized On Board Diagnostics (OBD I and OBD II) systems in use today. In 1961, the predecessor of the California Air Resources Board (CARB) mandated the use of PCV systems in the state. This was the first auto emission control standard in effect in the country. In 1971 California adopted the first oxides of nitrogen reduction standards in the nation. In the early 1980s CARB began developing regulations that would require all vehicles sold in that state to have onboard diagnostic capabilities by 1988.

Emissions control efforts are working. While the number of automobile registrations has risen sharply, fuel consumption has risen only slightly. Today, passenger vehicles account for less than 24% of the smog in major cities, compared to 40% in 1970. These findings are more promising when we realize that the number of miles driven per year has increased to 2½ times the amount driven in 1970, and that light truck/SUV registrations have nearly doubled during the past 5 years.

Half of all automobile pollution is generated by only 10% of the vehicles on the road - those vehicles in the worst running condition. Modern emissions control standards ensure that today’s automobiles run cleaner, but today’s well-trained technicians are needed to ensure that the percentage of gross polluters will continue to decline. The quality of our environment in the future depends upon this.

OBD I

The advent of improved integrated circuit electronics and integrated engine management systems in the early 1980s enabled the development of systems that could self-diagnose engine problems. OBD I refers to a requirement for vehicles sold in California, starting with the 1988 model year, to standardize these diagnostics.

In addition to far better management of the engine’s fuel delivery and the air/fuel ratio, the OBD I requirement stated that a partial or a complete malfunction that caused exhaust emissions to exceed a specified level had to be detected. This would illuminate a Malfunction Indicator Light (MIL) to alert the driver of the possible problem, and also the system would store an identification code or trouble code assigned to each malfunction detected. The trouble code could be retrieved either by using a Scan Tool or by commanding the MIL to blink-out the code numbers (Flash Codes). Monitored systems included fuel metering, exhaust gas recirculation (EGR), and emissions related electrical/electronic components. The intent of these regulations was to warn the driver, assist technicians in diagnosis and reduce emissions.
One weakness of OBD I systems was the handling of intermittent problems. If the problem were not continuous, the MIL might not remain illuminated and the trouble code erased from the computer memory. This might result in the problem being ignored by the driver and if the vehicle were serviced, no trouble code would be present to help the technician. Another weakness was the inability of the vehicle's engine management system to monitor component performance and condition. A vehicle, therefore, might severely pollute for a long time before a problem is detected.

Other drawbacks include the lack of standardization in test connector design and location and the lack of uniform and consistent trouble code definitions and code numbers. There is no standard criteria to illuminate the MIL and each manufacturer required a unique Scan Tool to retrieve diagnostic information.

Emissions reductions brought about as a result of OBD I technology evolved into the next generation of on board diagnostics, OBD II. As the graph shows, the major automotive pollutants (Hydrocarbons (HC), Carbon Monoxide (CO), and Oxides of Nitrogen (NOx)) have been dramatically reduced in California due to the effects of CARB-sponsored legislation.

**Note:**

References are made throughout this course referring to ECM and PCM engine management computers. They differ as follows. An ECM or Engine Control Module is responsible for controlling the engine management system only. Electronic transmission functions must be controlled by another computer module. A PCM or Powertrain Control Module is capable of managing both engine and transmission functions in one integrated "box." Kia uses both ECM and PCM systems, see Model / ECM / Sensor / Actuator Matrix in Appendix for listings. In this course, references to the ECM are taken to mean either ECM or PCM.
OBD II

Beginning with the 1996 model year, the EPA (Environmental Protection Agency) has mandated that all passenger vehicles be equipped to meet the new OBD II diagnostic standard. OBD II is a refinement of OBD I and overcame drawbacks inherent in the earlier regulations. OBD II requires the vehicle's engine management system to actively monitor and test emissions-related components and systems. If the vehicle's computer determines that a failed or deteriorating component or condition might cause emissions to exceed 1.5 times the allowable standard, the MIL must illuminate to warn the driver and the computer records a Diagnostic Trouble Code (DTC). If the fault is intermittent, the MIL remains illuminated for a defined period of time (typically three trips) and will go out only if the problem does not recur.

OBD II requirements also created industry standards and greatly simplified diagnosis. Earlier OBD I system communication protocols (how the on-board computer talks to the testing equipment), connector types, connector locations and trouble code definitions were all separately designed and defined by each manufacturer. There was no common standard and technicians had to learn manufacturer-specific information for every different make vehicle. OBD II standardization of these features has made the job much easier. Note that in addition to the standardized OBD II connector under-dash, Kia continues to include its proprietary test connector in the engine compartment for most models. This connector is capable of providing OBD II data, and also must be used to retrieve ABS and SRS data, which is not available at the OBD II connector.

The new standards encompass more than engine operating parameters alone. Additional engine management components, engine and fuel systems, and non-engine systems are also monitored as part of the OBD II system.

A functional test of the MIL circuit is required. Turning the ignition switch "On" will cause the MIL to illuminate steadily and remain on. This is to ensure that the MIL lamp and circuit are OK. On some makes, the MIL will remain on for only about five seconds, then go off. This is considered normal.
OBD II standards include:

- Standardized diagnostic connector design and location near the driver
- Standardized criteria for illuminating Malfunction Indicator Light (MIL)
- Standardized (generic) Diagnostic Trouble Codes (DTCs) for all manufacturers (Note that manufacturer-specific DTCs can also exist)
- Retrieval of DTCs and the live datastream by commercially available diagnostic equipment (generic scan tools)
- Retention of operating conditions present during a monitored malfunction (Freeze Frame)
- Standards governing when and how a DTC for a monitored malfunction must be displayed
- Standardized names for components and systems

With the set of standards as a framework, a set of objectives was developed to provide the basis for system operation. The objectives include:

- Operational monitoring of all components that have an influence or effect on exhaust emissions
- Catalytic Converter monitoring and warning of possible catalyst damage
- Visual display within driver's view (Malfunction Indicator Light) to signal malfunctions in emissions-relevant components
- On-board fault memory to store standardized Diagnostic Trouble Codes (DTCs)
- Storage of Freeze Frame Data which describes vehicle operating conditions when the DTC was set
- Diagnosis capability
History of Vehicle Emissions

OBD II Connectors

Kia vehicles typically have two Diagnostic Connectors installed:

**OBD II Connector** - Conforms to standard SAE J1962, which defines requirements for the connector location, design, terminal assignments and electrical interface requirements. The connector has sixteen pins and is located in the passenger compartment on the driver’s side of the dash under the knee pad. Power to the Scan Tool is continuously provided by pin 16. The Kia Hi-Scan Pro Scan Tool DLC Cable 16 (P/N 09900-21100) will mate with this connector. For all Kia OBD II compliant vehicles, engine and transmission data are available at this connector. ABS, Traction Control System and SRS data are also available at this connector on some newer models, such as 2001 Optima (for earlier models like 2000 Sephia, this data must be retrieved from the Kia Diagnostic Connector underhood).

<table>
<thead>
<tr>
<th>Cavity</th>
<th>SAE Assignment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IGN. Control</td>
</tr>
<tr>
<td>2</td>
<td>BUS (+) SCP</td>
</tr>
<tr>
<td>3</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>4</td>
<td>Chassis Ground</td>
</tr>
<tr>
<td>5</td>
<td>Signal Ground</td>
</tr>
<tr>
<td>6</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>7</td>
<td>“K” Line (ISO 9141)</td>
</tr>
<tr>
<td>8</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>9</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>10</td>
<td>BUS (-) SCP</td>
</tr>
<tr>
<td>11</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>12</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>13</td>
<td>PEPS (Flash EEPROM)</td>
</tr>
<tr>
<td>14</td>
<td>Not Assigned</td>
</tr>
<tr>
<td>15</td>
<td>“L” Line (ISO 9141)</td>
</tr>
<tr>
<td>16</td>
<td>Battery Power (B+)</td>
</tr>
</tbody>
</table>

**Kia 20-pin Diagnostic Connector** - Most Kia vehicles have this Kia-specific connector, which is located in the engine compartment. The Scan Tool requires DLC Cable Adapter (P/N 09900-29020) to connect. OBD II engine and transmission data are available at this connector. On some Kia vehicles, this connector provides the only access to ABS, Traction Control System and SRS data. On some vehicles, data from those systems are also available at the OBD II connector, but the underhood connector does have testing circuits and capabilities that the OBD II connector does not have. Relays, keyless entry and the fuel pump circuit can also be accessed here.
Kia 10-pin Diagnostic Connector - This Kia-specific connector is supplied on all Optima vehicles, and is located under the dash near the OBD II connector. Keyless entry functions are available at this connector. Adapter cable P/N 09900-21300 is required.

OBD II Data Communication Protocols

The law also requires that the vehicle manufacturer design the diagnostic system in a manner that permits retrieval of OBD II data in a standard format using any available generic scan tool using one of four data transfer protocols:

- **SAE J1850 VPW**
  - (Used by GM, 10.4k Baud data transfer rate)

- **SAE J1830 PWM**
  - (Used by Ford, 41.7k Baud data transfer rate)

- **ISO 9141-2 CARB**
  - (Used by most Kia, and other European and Asian, 10.4k Baud data transfer rate)

- **ISO 14230-4 KWP 2000**
  - (Used by 2001 Kia Optima V6, 19.2-115.2K Baud data transfer rate)

For example, the 2001 Sephia uses the ISO 9141-2 CARB communication protocol, and the 2001 Optima V6 utilizes ISO 14230-4 KWP 2000. Either the Kia Hi-Scan Pro Scan Tool or a generic scan tool can be plugged into the OBD II connector and the required communication initiated using the scan tool manufacturer's instructions.
Diagnostic Trouble Codes

Information about detected faults is stored in the form of Diagnostic Trouble Codes (DTCs). Each code number defines a specific condition or component failure. When retrieved from the vehicle’s engine management computer (ECM) memory, the codes can assist the technician in pinpointing which system or component might be at fault. OBD II DTCs are five-digit alphanumeric codes that are stored in the ECM whenever it detects a failed or deteriorating component or condition.

The required threshold for setting a DTC is the determination that the detected condition might cause emissions to exceed 1.5 times the allowable standard. Diagnostic Trouble Codes are required by law to be structured and defined in a manner that is consistent with SAE standard J2012. This standard uses the following logic:

**Diagnostic Trouble Codes**

- **B** - Body
- **C** - Chassis
- **P** - Powertrain
- **U** - Network

00-99 - Specific fault designation

**P 0150** (O₂ Sensor circuit problem)

- 0 - Generic (SAE universal codes - same definitions for all manufacturers)
- 1 - Manufacturer’s specific codes - not standardized

1 - Fuel and Air metering
2 - Fuel and Air metering
3 - Ignition system or Misfire
4 - Auxiliary emission controls
5 - Vehicle speed and idle regulation
6 - Control module and output signals
7 - Transmission
8 - Transmission
9 - Control modules, input and output signals
Diagnostic Trouble Code Strategy

Faults that cause DTCs to set can be either Continuous Faults or Intermittent Faults.

Continuous Faults are any type of failure that is always present, such as an open or short or failed catalytic converter. The fault is always present and may be continuously detected.

Intermittent Faults occur randomly and may not always be present. This type of fault might be caused by a loose connector or Ground or a component sensitive to vibration or temperature. One of the major improvements made by OBD II requirements is the ability to record and remember both Trouble Codes and Freeze Frame Data for conditions occurring during an intermittent problem. This gives the technician relevant information even if the problem is not present when the vehicle is in the shop.

False Trouble Codes sometimes occur. DTCs which are set and illuminate the MIL when there is no failed component or out of range condition are False Trouble Codes. The cause can be design or manufacturing issues such as component tolerance stackup or high sensitivity to sensed conditions. This can be compounded by the fact that many faults are not detected directly but rather are inferred and are measured indirectly. Misfire, for example, is not detected by means of a direct measurement of cylinder pressure or some other monitoring of combustion in the cylinder. Rather, the ECM watches the Crankshaft Position Sensor (CKP) signal waveform.

Misfire Monitoring

As power strokes occur, the crankshaft is accelerated (receives a kick) from combustion pressures of up to 700 PSI acting on the piston. Between power strokes, the crankshaft coasts. Since all Kia engines are even-firing, the power strokes are evenly spaced and the crankshaft should be evenly accelerated as it rotates. Four cylinder engines have two power pulses per crankshaft revolution, six cylinder engines have three per revolution. If there is no misfire, the frequency of the CKP signal waveform will not vary significantly as the crankshaft rotates. If misfire occurs, the crankshaft coasts or slows down when it should be accelerating and the resultant instantaneous decrease in CKP signal frequency is detected by the ECM. If this change in frequency occurs often enough, the computer infers that misfire has taken place.

Misfire monitoring begins as soon as 2.9 to 50 ignitions pass after engine start. The misfire threshold is determined by counting the number of misfire events in a given number of crankshaft revolutions. Kia uses two different algorithms which sample either 200 or 1000 revolutions. The 1000 revolution sample determines Emissions-Relevant Misfire. If misfire occurs more frequently than 2% or 20 times in 1000 revolutions, then an Emissions-Relevant Misfire DTC is set (after the second consecutive occurrence or second trip, see below) and the MIL will illuminate. The 200 revolution sample consults a stored load/RPM map and detects severe misfire which can cause catalytic converter damage. If detected, this fault will immediately cause the MIL to flash to warn the driver of potential catalyst damage.

If the detected misfire is generalized and cannot be attributed to a specific cylinder, code P0300 will be stored. If the misfire does occur in a specific cylinder, then the cylinder-specific code P0301, P0302, P0303, P0304, P0305 or P0306 will be set.
**History of Vehicle Emissions**

**Rough road conditions** are known to sometimes cause false misfire codes to be set. The engine crankshaft is a heavy component with considerable inertia and its rotation is affected by rough road conditions. Also, misfire detection is a Continuous Monitor and checks for misfire at all times. To reduce the possibility of a false misfire code, Kia has used two methods: **Chassis Acceleration Sensors** and **Wheel Speed Sensors**. Both methods look for acceleration changes in either sprung or unsprung components. The Chassis Acceleration Sensor looks for rapid vertical displacement of the chassis. The Wheel Speed Sensor watches for large frequency variations in the rotation of one wheel. With both approaches, when rough road conditions are detected, the ECM will disregard any misfire sensed by the Crankshaft Sensor and thereby reduce the possibility of a false misfire DTC. Kia vehicles with Melco PCMs do not use either of the above methods.

To further reduce the number of false Trouble Codes, many faults must be detected twice, and they must be detected on consecutive trips in order for a DTC to be set and the MIL illuminated. This is called **Two Trip Logic** and it works like this. If a fault is detected on the first trip, the ECM places the DTC in memory as a pending DTC. The MIL is not illuminated. If the same fault is detected on the next trip, then the ECM knows that the same problem has occurred on consecutive trips and assumes that the problem is not false or random. It then makes the DTC a confirmed code, illuminates the MIL and records Freeze Frame Data.

If a fault is detected on the first trip, is not detected on the second trip but is again detected on the third trip, the Soft or Pending code will not become a Mature or Hard code. Although the fault has been detected twice, the two occurrences were not during consecutive trips.

Both **Soft (Pending) Codes** and **Hard (Mature) Codes** can be displayed by the Scan Tool.

DTCs are stored in ECM memory (along with Freeze Frame Data) as long as battery power is supplied. This "Keep Alive Memory" (KAM) is volatile Random Access Memory (RAM) which must be continuously powered and will be erased if power is interrupted. DTCs therefore can be erased by disconnecting the battery, or also by means of the Scan Tool.

The MIL Lamp is turned off and Trouble Codes are automatically erased by the ECM under some conditions. If the problem that set a DTC is no longer detected, the PCM will turn off the MIL Lamp after three consecutive good Drive Cycles without the problem recurring. Typically, if the problem is not detected after 40 Drive Cycles, the Trouble Code is then erased from KAM (Fuel Trim and Misfire DTCs are erased after 80 Drive Cycles).

**OBD II Monitors and Fault Detection**

Monitors are fault detection circuits built into the ECM. Earlier OBD I systems verified the normal operation of Sensors and Actuators (inputs and outputs) by simply measuring voltage drop across the component. This technique for confirmation of operation is known as Component Monitoring and only check for shorts and opens. A sensor or circuit may have excessive resistance, a bad sensor, exhibit dropouts or other range or plausibility problems, but if the signal is not open or shorted, no fault is identified. OBD I Monitors perform these tests:

- Short circuits to positive
- Short circuits to Ground
- Open circuits
OBD II Monitors are capable of detecting more systems, types of faults, and can make more subtle distinctions. OBD II Monitors are capable of performing these tests:

- Short circuits to positive
- Short circuits to Ground
- Open circuits
- Plausibility of signals and components of emissions-related functions
- Functions not completely monitored previously
- Systems not monitored previously

OBD II Monitors can be grouped by function:

- Component Monitors: the ECM looks at the operation of individual parts of the system.
- System Monitors: the ECM operates a component (or multiple components) to verify system operation.

OBD II Monitors can also be grouped by how often they check or test:

**Continuous (Comprehensive Components) Monitors:**

A comprehensive component is any input or output component that can affect emissions, and any component that monitors another component or system.

Examples of this are:

- Fuel trim
- Engine misfire detection
- All sensors, components, and inputs associated with the ECM

**Non-Continuous Monitors** (check or test once per trip or Drive Cycle):

- Catalytic converter efficiency
- Oxygen sensors - signal circuit
- Oxygen sensors - heater circuit
- Evaporative emissions control and system integrity
- Secondary air injection (if equipped)
- Exhaust gas recirculation (if equipped)
- Thermostat monitoring (if equipped)

An example of a non-continuous monitor is the **Catalyst System Monitor**.

When vehicles equipped with front and rear oxygen sensors are operating in “closed loop,” the ECM/PCM compares the signals from the front and rear sensors to evaluate the efficiency of the catalytic converter.

Notice in the graphic that when the front oxygen sensor is operating properly, the oxygen levels downstream of the cat are more constant, resulting in a flatter rear oxygen sensor signal. As the converter’s efficiency degrades, the rear oxygen sensor signal begins to resemble the front oxygen sensor signal.
Another example of a non-continuous monitor is **Thermostat Monitoring (2000 and later Sephia and Spectra, 2001 Rio)**.

In order to properly control exhaust emissions, the engine must rapidly warm-up to normal operating temperature. In a normally operating cooling system, as the coolant temperature increases to normal operating temperature, the thermostat should open, causing a decrease in coolant temperature. The thermostat monitoring system is used to calculate this temperature drop when the thermostat is supposed to open. To do this, the ECM stores the maximum coolant temperature after start-up. After a specified length of time (usually 3-5 minutes, which varies with outside temperature), the ECM calculates the difference between the maximum coolant temperature and the current coolant temperature. If the temperature decrease is not within a calibrated threshold while all enabling conditions have been met for a specified length of time, the ECM will set DTC P0128. If the condition is repeated on the next consecutive drive cycle (trip), the ECM turns on the MIL.

The ECM will perform thermostat monitoring if all of the following conditions are met:
- The engine is not in fuel cutoff.
- There are no ECT, IAC or VSS related DTCs.
- Vehicle speed is higher than specified vehicle speed.
- Intake air temperature is within calibrated range
- Engine speed is higher than specified vehicle speed.
- The coolant temperature at start-up is within specified range.
- Mass air flow is greater than calibrated value.

### Setting Monitor Readiness

In all OBD II compliant vehicles, Monitors are capable of detecting faults only when in the active or "Ready" state. There are three Continuous Monitors: Fuel Trim, Misfire and Comprehensive Components, and in most vehicles they are Ready as soon as the vehicle is started and are always checking their respective circuits. Therefore, a fault can occur at any time and under any conditions, and if it is in a continuously monitored circuit, a DTC will be set.

**Note:**

An exception to the readiness state of Continuous Monitors is the 2001 V6 Optima model with Siemens ECM. On this vehicle, all three Continuous Monitors MAY NOT immediately become Ready when the engine is started, but will during a short trip).

All other Monitors are Non-Continuous and must be set to the Ready state before they begin to check circuits.

Non-Continuous Monitors are made Ready and begin to actively test their respective systems when the vehicle is driven in such a way to satisfy the conditions of a Drive Cycle. If Drive Cycle conditions are satisfied, then the appropriate operational test is run and found to be within specifications (for the duration of the test).
Malfunctions in the system that occur later will record a DTC but will not change the readiness status of the Monitors. However, when the fault is repaired and the DTC is erased, the Non-Continuous Monitor responsible for detecting that specific fault will be reset to Not-Ready and a Drive Cycle must be repeated. When the vehicle battery is disconnected, all Non-Continuous Monitors are set to the “Not Ready” state and the vehicle must be driven through at least one Drive Cycle to again set the Monitors to “Ready.” At times, conditions may not permit a Monitor to run and Several Drive Cycles may be required to set all Monitors to “Ready.”

A Drive Cycle is NOT completed by simply allowing the vehicle to run in a shop. As the illustration shows, the ECM must see road speed, a sufficient rise in engine temperature and various gearshifts. The different Monitors run their tests at different points in the Drive Cycle, so each becomes Ready at a different time. Sometimes the vehicle must complete several Drive Cycles for all monitors to be made Ready.

Some states are performing OBD II checks as part of a state vehicle inspection procedure. MIL function, DTCs and Monitor Readiness are typically checked. If Monitors are “Not Ready,” the vehicle will not pass, even in the absence of any Trouble Codes in memory.

Some Monitors are not applicable to the particular vehicle being tested due to variations in engine management systems and how they are equipped. A vehicle without EGR, for example, does not require an EGR Monitor.
**History of Vehicle Emissions**

### OBD-II DRIVING CYCLE

**SPORTAGE / SEPHIA 1998 / 1999 MY**

**May take up to 17 minutes to start Evap. Leak test**

<table>
<thead>
<tr>
<th>Driving Instruction</th>
<th>Start &amp; warm-engine (ECT &lt; 150˚ F)</th>
<th>MT - 5th gear</th>
<th>MT - 5th gear</th>
<th>Idle</th>
<th>Idle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A/C off</td>
<td>AT - Overdrive</td>
<td>AT - Overdrive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steady Throttle</td>
<td>Steady Throttle</td>
<td>Steady Throttle</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MT - 5th gear</td>
<td>AT - Overdrive</td>
<td>AT - Overdrive</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Steady state Cruise 50-85mph</td>
<td>Steady state Cruise 35-45mph</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accelerate to 50mph</td>
<td><strong>NO UPHILL OR DOWNHILL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>At least 5 min.</td>
<td>Stop Engine</td>
<td>Stop Engine</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Road Condition**

- NO UPHILL OR DOWNHILL

**Monitor Test Sequence**

- Misfire /Fuel trim
- ECT sensor
- 02 Sensor
- 02 Sensor Heater
- Circuit continuity
- MAF, TPS, CKP, CMP, Injectors, IAC, FTPS
- Misfire /Fuel trim
- 02 Sensor aging
- Catalyst
- Misfire /Fuel trim
- Catalyst
- Fuel trim
- Evap. Leak**
- IAC valve
- Ch. Accel. Sensor
- Can close valve
- Veh. speed sensor
- Knock sensor
- AT/MT codification
Diagnostic Tool Review

Break Out Box

The Break Out Box (BOB) permits access to all ECM Sensor and Actuator circuits. The BOB is connected in series with the vehicle wiring harness and ECM and provides easy circuit access and test points. Separate adapters and harnesses are provided to mate with the various ECM connector styles from four different manufacturers: Bosch, Siemens, Melco and Nippondenso. While circuit access can be made easy with the Kia T-Connector when used at harness connectors, sometimes the connector design or location makes this impossible. (See page 20 for description of T-Connector). Use of the BOB lessens the possibility of wire harness, insulation or connector damage. It is never advisable to pierce wire insulation to make contact as this will promote corrosion.

On some vehicles, the ECM location allows in-place access to harnesses, on others the computer must be unbolted to remove connectors and install the BOB. Always be sure that the Ignition Switch is OFF or the Battery disconnected before removing harnesses from the ECM.

Functionally, the Break Out Box (along with the appropriate system Adapter and harness) is installed in series between the vehicle wiring harness and the ECM. There are test points for up to 140 circuits. Overlays are available for specific vehicles to identify circuits (pinout lists). Once the BOB is installed, testing can be performed KOER or KOEO. Voltage and resistance measurements can be made and oscilloscope patterns obtained with appropriate testers. Resistance measurements should be made with the ECM disconnected. The ECM circuitry may cause inaccurate results if connected. Current measurements are not recommended since the BOB test points are wired in parallel.
Measurements taken at BOB test points are an accurate reflection of real time and are UNPROCESSED OR RAW DATA being sent to or from the computer. Keep this in mind, as data viewed on the Scan Tool is DATA PROCESSED BY THE ECM and may NOT be accurate!

ECM’s and PCM’s have multiple Ground connections. When testing Sensors, use care in selecting the circuit Ground. Choosing the wrong Ground connection can skew values significantly and lead to incorrect diagnosis.

Normal Vehicle Operation

Testing With Break Out Box

Test Meter

Break Out Box

BOB is in series with vehicle wiring and ECM.

Provides easy circuit access.

Functional schematic only. Actual connections require use of ECM/PCM specific adapter.

The Kia T-Connector tool provides circuit test points quickly and easily. A sensor or actuator can be tested by unplugging its connector and inserting the T-Connector in series. The T-Connector has eight pairs of color coded leads and eight test sockets. Each pair of leads ends in one male and one female connector. Three T-Connector models are available and differ in connector pin size. T Connectors allow for pi-to-pin readings at the source condition.
Kia Hi-Scan Pro Scan Tool

The Kia Hi-Scan Pro Scan Tool meets SAE J1978 OBD II Scan Tool requirements. It is a full-featured tool and has both Kia-specific enhanced OBD II and generic CARB OBD II capabilities. The tool can communicate bi-directionally by means of any one of the four Communications Protocols, per SAE J1830 PWM, SAE J1850 VPW, ISO 9141-2 CARB or ISO 14230-4 KWP 2000.

There are two PCMCIA slots on the right hand side of the tool. The Program Card is installed in the upper slot, and a Memory Expansion Card can be installed in the lower slot. The Scan Tool Software is upgradeable through an RS232 communications port. The following are the available tool functions:

- Diagnostic Trouble Codes (DTCs) - Displaying / Clearing
- Freeze Frame Data Display
- Current Data Display
- System Monitors / Monitor Readiness Status
- Flight Record
- Multimeter (DVOM) (requires separate test leads)
- Digital Storage Oscilloscope (requires separate test leads)
- EVAP Leakage Test
- Sensor Simulator
- Actuator Driving Tests
- Dual Display (permits both DTCs and Current Data to be displayed simultaneously)
- Troubleshooting Pack

Unless otherwise noted, the above functions are available through the OBD II connector, making hookup quick and easy. Some functions, such as Multimeter and Oscilloscope require use of separate test leads which attach to BNC connectors for Channel A and/or Channel B on the top of the tool.
Diagnostic Trouble Codes (DTCs)

Diagnostic Trouble Codes (DTCs) can be displayed and cleared by the Scan Tool. The DTC screen is accessed several ways. Using up-down arrow keys and the ENTER key, navigate to:

01 Kia Vehicle Diagnosis (Select model and year)
02 Engine Control (Select engine)
01 DTCs

or

03 Carb OBD II Diagnosis
03 DTCs

The DTC screen displays any Pending or Mature Trouble Codes. Pending Codes are noted by the letter "P." Pressing F4 will show Freeze Frame Data, see below.

DTCs are cleared from memory by pressing F2. Remember that the system Monitor that detected the fault will be set to "Not-Ready" and a Drive Cycle must take place for the Monitor to again become Ready. No fault can be detected when Monitors are Not-Ready.

Pressing F6 displays testing suggestions and reference waveforms. For Optima V6, pressing F5 provides troubleshooting information.

Current Data

The Current Data display is a word-form datastream of the PID's (Parameter ID's) or Sensor and Actuator values in real time. Different OBD II communications protocols have faster or slower data transmission rates (Baud rates) and this affects the rate of update or refresh rate. (See OBD II Data Communication Protocols, page 11).

The refresh rate can be accelerated by reducing the list and selecting only a few line items. Pressing F1 "Fixes" or selects a line item. Up to eight items can be Fixed. To access the Current Data screen, navigate to:

01 Kia Vehicle Diagnosis (Select model and year)
02 Engine Control (Select engine)
03 Current Data

or

03 Carb OBD II Diagnosis
02 Current Data

The Carb OBD II choice permits communication with any make OBD II compliant vehicle. Functionality is limited and meets SAE standards.
Freeze Frame Data Display

Freeze Frame Data is a "snapshot" of Current Data values that existed the moment that a DTC was set. If there are more than one DTC in memory, then the Freeze Frame Data is recorded by the FIRST DTC set.

Note: Freeze Frame Data is recorded and stored in the vehicle ECM. Flight Record is a Scan Tool function. Flight Record data is Current Data recorded over a time interval and stored in the Scan Tool's internal memory.

To access the Freeze Frame Data screen, navigate to:

01 Kia Vehicle Diagnosis (Select model and year)
02 Engine Control (Select engine)
02 Freeze Frame

or

03 Carb OBD II Diagnosis
04 Freeze Frame

In vehicles with a separate Transmission Control Module, the TCM does not have the ability to store Freeze Frame data. All Freeze Frames are stored in the ECM or PCM. In Optima V6 models, trouble code P1624 will set to indicate a TCM or automatic transaxle problem.
System Monitors / Readiness Status

The Kia Hi-Scan Pro Scan Tool is capable of displaying the Monitor Readiness Status (sometimes called Readiness Flags) of all system Monitors. Monitors can be displayed on the Scan Tool two ways by navigating either of these paths:

01 Kia Vehicle Diagnosis (Select model and year)
02 Engine Control (Select engine)
04 Monitoring Test Results
01 Readiness Tests

or

03 Carb OBD II Diagnosis
01 Readiness Tests

The display lists all Monitors for this vehicle, and indicates Monitor Status (Readiness Flags). Monitors are capable of detecting faults ONLY when READY. The first three Monitors: MISFIRE, FUEL SYSTEM (or Fuel Trim), and COMPREHENSIVE COMPONENTS are continuous, and are ready and actively monitoring at all times when the engine is running. The Scan Tool display should read "Completed" or "Supported" for these three Monitors.

All other Monitors are non-continuous, and must be MADE-READY or flagged COMPLETED in order to become active. The vehicle must experience at least one Drive Cycle in order for all non-continuous monitors to become active and ready to detect faults. When a Monitor is ready, the display will read "Completed." NO faults can be detected and no DTCs set unless a Monitor is "Ready" or "Completed."

The Scan Tool display indicates whether Readiness Tests have been completed and if a fault is found. After emissions system repairs, proper operation of the repair can be confirmed by checking Monitor Readiness after executing a Drive Cycle and setting Monitors to Ready. If no DTC is set once the Monitor test has "Completed" and the Monitor has again become Ready, then the repair is probably successful. Note: Disconnecting the vehicle battery will set all non-continuous Monitors to the Not-Ready state. Clearing DTCs will set the relevant Monitor (the Monitor that found the fault and set the DTC) to the Not-Ready state. A Drive Cycle then must be completed to again set the monitors to Ready. Sometimes more than one Drive Cycle must be completed to set all Monitors to Ready.

Some Monitors are not applicable to the particular vehicle being tested due to variations in engine management systems. A vehicle without EGR, for example, does not require or have an EGR Monitor. For those systems not installed on a vehicle, the Kia Scan Tool displays "Not Applic."
Flight Record

This mode allows recording Current Data over a time interval for storage and future playback. All Current Data line items may be recorded, or a shortened user-select list of parameters may be created (by "Fixing" desired items with F1 key). Flight record can also be accessed using Manual Scope.

There are three possible Trigger choices which permit start of recording with any DTC, a specific DTC or manually initiated. There are four Memory Locations in which to store recorded data. Selecting a location with previously recorded data will cause the new data to overwrite the old. To navigate to the Flight Record menu:

01 Kia Vehicle Diagnosis (Select model and year)
02 Engine Control (Select engine)
09 Flight Record

Trigger Choices:
01 Auto Trigger (Any DTC)
02 Auto Trigger (Single DTC)
03 Manual Trigger
04 Flight Record Data Review

Pressing ENTER starts the Flight Record function. To STOP recording session, press ESC.

To replay a recording, press "04 Flight Record Data Review." Select the memory location holding the recording to replay and press ENTER to begin playback. Display is in Current Data text format. L-R Arrow Keys scroll Data time scale. The Time Interval is shown in brackets at bottom of screen.

Recorded Data playback can also be graphed. Using L-R Arrow Keys, select desired time interval and press F1. Two graphs of the first two fixed Data items are displayed. The item in the upper graph is Fixed. Up-Down Arrows scroll list of available (Fixed) items. L-R Arrows move cursor along time scale. Values at point in time of cursor displayed at left.
Multimeter (DVOM) and Simu-Scan

Digital Multimeter functions are available on the Scan Tool allowing Voltage, Current, Frequency, Resistance, Temperature and Pressure measurements. Additional harnesses and adapters are required for Temperature and Pressure measurements. Diagnostic Test Leads are used to probe circuits for all Multimeter functions. The Leads are connected to the BNC connectors for either Channel A or Channel B on the top of the Scan Tool. (Note: The Scan Tool often prompts which channel to use; Channel A is on top left, B on top right of tool). Often, the Break Out Box simplifies and speeds circuit access.

The Multimeter screen can be opened two ways:

0 Initial Screen
01 KIA Vehicle Diagnostics (Select model and year)
02 Engine Control (Select engine)
12 Simu-Scan

or

0 Initial Screen
02 Vehicle Scope Meter
03 Meter

The Simu-Scan function (see page 27) creates a split screen, with Current Data in the upper half and either Multimeter or Simulator functions in the lower half.

When used as a Multimeter or Simulator, the Scan Tool must be powered externally. Power choices include the OBD-II connector, vehicle battery and power transformer.

Digital Storage Oscilloscope

The Hi-Scan Pro Scan Tool Oscilloscope has both automatic and manual modes. In the Kia Vehicle Auto Scope mode, oscilloscope setup is automatic, and sample waveforms and Flight Record functions are available. Sensors and actuators are selected from a list, and the oscilloscope is automatically configured based on the chosen component. Only one channel at a time displays in this mode. To access the Kia Vehicle Auto Scope mode, navigate to:

02 Vehicle Scope Meter
01 Kia Vehicle Auto Scope
(Select model)
01 Engine
(Select Sensor or Actuator from list)

In the Manual Scope mode, the oscilloscope is manually set by the user and two waveforms may be on screen simultaneously. In this mode the oscilloscope has more user-settable trigger features, but Flight Record and Sample Waveforms are not available. To access the Manual Scope mode, navigate to:

02 Vehicle Scope Meter
02 Manual Scope

In the Manual Scope mode, the user must manually select Channel, Time, Voltage, Ground, Trigger and Slope settings. Diagnostic Test Leads must be used to access circuits for all oscilloscope functions. The leads are connected to the BNC connectors on the top of the Scan Tool for either Channel A or Channel B. (Note: The Scan Tool often prompts which channel to use; Channel A is on top left, B on top right). In the oscilloscope mode, the Scan Tool must be powered externally. Power choices include the OBD-II connector, vehicle battery and power transformer.
**EVAP Leakage Test**

Evaporative Emissions Systems (EVAP) Leak Tests can be run by the Scan Tool. Both types of EVAP Systems (systems with and without leak detection pumps) can be tested. To perform this test, navigate to:

- 0 Initial Screen
- 01 Kia Vehicle Diagnosis (select model and year)
- 02 Engine Control
- 05 Evap Leakage Test

The tests are automated and provide either a pass-fail result or directions to check for DTCs.

**Sensor Simulator**

The Sensor Simulator function permits the Scan Tool to output a signal that simulates a Sensor's characteristics. Voltage, frequency and duty cycle can be defined. Wiring harness continuity and integrity can be tested while the engine runs. To access the Sensor Simulator mode, navigate to:

- 0 Initial Screen
- 02 Vehicle Scope Meter
- 05 Sensor Simulator

**Monitoring Test Results**

This feature permits analysis of all readiness tests available for the selected vehicle. It also allows in-depth analysis of HO2S and OBD II monitoring.

**Actuator Driving Tests**

The actuator driving function permits the Scan Tool to drive actuators such as the Idle Air Control (IAC) Valve with a predefined signal frequency and duty cycle. Components tested include Fuel Injectors, the MIL Lamp, Purge Solenoid Valve, Idle Air Control Valve, Ignition Coils, Relays and Cooling Fans. For some components, the engine must be running, for others the test condition is KOEO. To perform this test, navigate to:

- 0 Initial Screen
- 02 Vehicle Scope Meter
- 04 Actuator Driving
  - or
- 0 Initial Screen
- 01 Kia Vehicle Diagnosis (select model and year)
- 02 Engine Control
- 06 Actuation Tests

**Dual Display**

The Dual Display function permits both Diagnostic Trouble Codes and Current Data to be displayed simultaneously. This choice can reduce navigation and key-presses needed to view needed information. To navigate to the Dual Display menu:

- 0 Initial Screen
- 01 Kia Vehicle Diagnosis (select model and year)
- 02 Engine Control
- 11 Dual Display

**SIMU-SCAN**

This function (option 09) splits the screen so both multimeter values (raw data) and current data (processed data) can be viewed simultaneously.
Diagnostic Approach

Back to the Basics

To review just a bit, an internal combustion engine requires the proper ratio of air and fuel, a properly timed spark and good compression for efficient operation. The overall mechanical condition of the engine directly influences combustion efficiency, and this in turn affects horsepower, torque and the levels of exhaust emissions. An engine with mechanical or electrical defects or deficiencies such as intake or exhaust vacuum leak, intake or exhaust restriction, low compression, incorrect valve timing or valve train problems will probably not run well and will pollute excessively.

No amount of engine management system sophistication or electronics will compensate for an inherent mechanical problem. Troubleshooting should begin with confirmation that the engine is mechanically sound and in good condition.

While the engine is running, the engine management system delivers fuel in the right quantity and spark at the right time to match the airflow and load demands of the engine. At 3000 RPM, the crankshaft turns two revolutions and each piston completes the four stroke cycle in 0.040 sec. That permits only 0.010 sec. for completion of each stroke or 180 degrees of crankshaft rotation. Valve duration typically allows less than 0.015 sec. for intake and exhaust events to take place. Fuel injection typically requires 0.002-0.005 sec. duration "On" time and once the spark plug ignites the air-fuel mixture, the combustion burn time is about 0.003 sec. Since peak combustion pressures are desired at 10 degrees ATDC, ignition timing must vary to start the burn sooner at higher engine speeds, since it takes the same 0.003 sec. to build pressure in the cylinder regardless of engine speed. Things are happening quickly and with precision, and there is little margin for degradation in today's engines.
Conditions affecting an engine's combustion efficiency, power and emissions:

- Camshaft and valve timing
- Defective valves or valvetrain (bad camshaft, broken springs, etc.)
- Low compression
- Oil pressure
- Vacuum leak in intake or exhaust systems
- Restrictions in intake or exhaust systems
- Spark plug or ignition problems (electrical or mechanical)

**Vacuum Gauge**

The Vacuum Gauge is a useful and frequently overlooked tool. It is able to provide an excellent overview of basic engine condition. The gas engine is a pump, and Intake Manifold Vacuum is a good measure of its efficiency as a pump. Gas engines are air-throttled by means of a Throttle Plate. At low engine speeds and loads, the Throttle Plate is nearly closed and creates a restriction. The pumping action of the pistons must work against this restriction.

Conditions affecting the engine as a whole, such as incorrect valve timing, restricted exhaust, restricted intake and conditions affecting only one cylinder, such as a burned valve, can be seen. A complete vacuum test would include cranking vacuum as well as manifold vacuum at idle and high speed. Note the vacuum reading and also how much the needle fluctuates. A rapidly bouncing needle can indicate a problem in one cylinder only. Typically, cranking vacuum measures 3-6 in. Hg. Manifold Vacuum at idle is 16-18 in. Hg. and decreases with load and throttle opening.

**Compression Test**

The compression test can be useful in evaluating the condition of the pistons and rings, head gasket, valve sealing ability and valve timing when used in conjunction with other diagnostic tests. When performed properly, it is a reliable, but not infallible indicator. Be sure to follow good practice: Block throttle open to permit unrestricted airflow. Disable fuel injection to prevent flooding. Be sure that cranking RPM is sufficient (approx. 150-250 RPM) and repair the cranking circuit if not OK. (Higher than normal cranking speed can indicate incorrect valve timing). Rapid pressure rise is desired on first strokes. Maximum pressures cylinder to cylinder should meet specifications and vary less than 20%. See service manual for specific test procedure.

**Cylinder Leakdown Test**

A cylinder leakdown test measures the ability of each cylinder to hold air pressure with the piston at TDC of compression. It is especially useful to identify sources of cylinder leakage.

For example, a hissing sound heard at the tailpipe while the test is being performed would indicate a possible leaking exhaust valve. With a piston at TDC of compression, shop air is connected to the tester and fed by the tester into the spark plug hole and the percentage of leakage is noted. <10% leakage is excellent. >30% leakage indicates a definite problem. Perform test on hot engine if possible. Areas of potential leakage are the head gasket, valves, pistons, rings, cracked castings. Any leak into the cooling system will create bubbles in the coolant, remove filler cap to check. Also listen for air escaping from crankcase, intake and exhaust.
Electrical Faults

Once it has been verified that the engine is sound mechanically, but that there is a fault, the MIL is illuminated and DTCs have been set, further troubleshooting will require testing of electrical and electronic circuits and components.

Recall from the earlier discussion about how OBD Monitors are fault detection circuits built into the ECM that set Diagnostic Trouble Codes. Monitors are capable of locating four basic types of faults:

- Open/short circuit faults
- Drive cycle faults
- Implausible signal and Range/performance faults
- Adaptation faults

Understanding the characteristics of these fault types and how they are detected can help improve your troubleshooting ability.

Diagnostic Trouble Codes can be Continuous or Intermittent.

Continuous Faults are any type of failure that is always present, such as a broken wire or failed oxygen sensor heater. The fault is always present and may be continuously detected.

Intermittent Faults occur randomly and may not always be present. This type of fault might be caused by a loose connector or Ground or a component sensitive to vibration or temperature. When diagnosing an intermittent code it is important to understand what the conditions were when the fault was set. Refer to Electrical TSB #003 Volume 1 regarding using Stabilant 22 on intermittent faults.

Did the problem occur during warm-up after a cold start or when a normal operating temperature? Did ambient temperature or humidity or moisture (rain, etc.) contribute? Were road conditions a factor, rough road vibration? Can the DTC be duplicated by wiggling wires, hoses, spraying water, etc? Attempting to duplicate the conditions present when the trouble occurred can often help.

Open/Short Circuit Faults

To locate Open or Short Circuit Faults, the ECM measures the voltage drop across Sensors and Actuators. Typically, a Sensor is a Variable Resistor or Potentiometer that is provided a 5V Reference Voltage. It modifies that Reference Voltage and sends the Signal or Return back to the computer.

If the voltage drop across the Sensor is out of specification, the ECM will set a DTC. Range extremes (0V and 5V) are reserved for error detection. For example, if the ECM measures 0V drop, the Sensor may be shorted to Ground. Measuring 5V drop can indicate an open circuit in the Sensor or wiring. The fault can also be in the ECM. Circuit voltage drop for a 5V computer circuit should not exceed 50-60 mV.

Drive cycle faults

Specific vehicle systems are tested only once per Drive Cycle. For this type of fault to be detected, it must occur during the test. For example, the Drive Cycle for 1999 Sportage and Sephia states that Misfire, Fuel Trim, Oxygen Sensor and Catalyst Efficiency Monitors run during steady state cruise conditions, with vehicle speed <50 MPH and the transmission in 5th gear (M/T) or O/D (A/T). Time under these conditions must exceed three minutes. If these conditions are not met then the tests will not run and these systems will not be tested.
Implausible and Range/Performance faults

OBD II Monitors are capable of determining not only if a Signal is within an accepted range but also whether the Signal is plausible for the given conditions. When the ECM determines that a Sensor's Signal does not make sense when compared with other Signals, it assigns an Implausible Signal Fault. For example, if the voltage drop across the ECT does not change after the vehicle has been running for a period of time, then the ECM determines the signal to be implausible.

Range/Performance faults occur when signals from multiple related components provide conflicting data. For example, if the MAF shows low airflow, but the Throttle Valve Position Sensor shows the throttle plate is open, a Range/Performance fault will occur.

Adaptation faults

Adaptation faults are set when a failure in the system causes an adaptation value to go beyond a specified limit. For example, vacuum leaks or low fuel pressure can cause Short Term Fuel Trim to adapt in the positive direction. If the STFT value remains with an extreme positive shift for too long, a "System too lean" fault is set.

Understanding the types of faults and how faults are detected can improve your troubleshooting ability and speed.
Formulating a Sound Diagnostic Plan

A planned, deliberate approach to diagnosis is vital if repairs are to be accurate and cost effective for both the customer and the shop. Vehicle systems are far too complex today to permit hit-or-miss random guessing. While experience may point to a specific component fault, systematic verification of both the fault's cause and correction are the only way to ensure accurate and complete repairs.

The engine's mechanical and electrical / electronic systems must all work together to draw the combustible mixture into the cylinder, to compress it, to extract maximum power from combustion and to expel what remains after the combustion process.

Do not forget to verify mechanical operating condition of the engine before troubleshooting an apparent problem in the engine management system.

OBD II does NOT check everything. There can be malfunctions that will not be detected and will not set a DTC or illuminate the MIL. Example: low fuel pressure, plugged air filter.

The Kia Diagnostic Plan

Effective diagnosis requires knowledge of how a system functions in order to accurately determine when it is not operating correctly. It is equally true that your "approach" to diagnosis and troubleshooting greatly affects the accuracy and timeliness of troubleshooting. You should be familiar with the following steps:

- **Verify the problem**
  - Determine what has gone wrong - the symptoms
  - Determine when the problem occurs - under what operating conditions
  - Understand how the affected system works and related component interaction
  - Determine that the problem is not an operator issue.

- **Analyze the problem**
  - Create a Diagnostic Plan
  - Make preliminary checks of basic engine condition

- **Locate the cause**

- **Check easiest and most likely components**

- **Repair the problem**

- **Check the repair**
Engine Management Systems
Overview

Engines produced today which comply with OBD II requirements are usually equipped with one of two types of Engine Management Systems:

- Speed / Density Type, which uses the MAP Sensor + engine RPM as the primary inputs to determine fuel injection quantity (not used by Kia)
- Mass Airflow Type, which uses a Hot Film, Hot Wire or Karmann Vortex Mass Airflow Sensor.

All current Kia vehicles are equipped with the Mass Airflow type of system and use either Hot Film or Hot Wire Mass Airflow Sensors. Kia vehicles use Engine Management Systems from four manufacturers, and there are similarities and differences in those systems. All systems use sequential fuel injection with individually controlled fuel injectors and distributorless Waste Spark ignition.

Some systems employ a PCM (Powertrain Control Module) alone, which integrates all major engine and transmission control functions into one unit. Others use separate computers for engine and transmission control, and these systems have ECM + TCM (Engine Control Module + Transmission Control Module) arrangements. We will look at these systems and their similarities and differences in more detail.

Nippondenso systems were last used on 1997 Sephia models.

All engines are equipped with at least two Catalytic Converters, a small Main Catalytic Converter located close to the engine and exhaust manifold, and a Post or Cleanup Catalytic Converter located downstream under the vehicle floorpan. V6 engines, which have two cylinder banks, require two main cats, one for each cylinder bank. The two-into-one exhaust systems allow one clean-up cat.

All Kia vehicles except Optima V6 models use conventional Zirconium Dioxide (or Zirconia) Oxygen Sensors. The Optima uses Titanium Dioxide (Titania) Oxygen Sensors. Both types of sensor provide similar a analog feedback signal but work on different principles. They are described in the next section.

All current Kia vehicles use Hall Effect CMP Sensors (Camshaft Position Sensors) which provide a synchronization signal. However, Kia CKP Sensors (Crankshaft Position Sensors) may be either Hall Effect or Magnetic Pulse type, with the Hall Effect type more common. 1998-2001 Sephia (Bosch ECM) and 1996-97 Sephia (Nippondenso PCM) use the Magnetic Pulse type CKP Sensor.

The following pages list current system applications.
Optima 2.5L V6 DOHC
Siemens ECM and TCM
KWP2000 OBD II Protocol
OBD-II 16-pin Connector

Sensors

- MAF (Hot Film)
- IAT
- ECT
- TPS
- CMP (Hall Effect)
- CKP (Hall Effect)
- KNK
- HO2SB1S1 (Titania)
- HO2SB1S2 (Titania)
- WSS (Wheel Speed Sensor)
- Rough Road-Misfire Detect
- Disable and Vehicle Speed (Magnetic Pulse)
- EVAP FTPS (Fuel Tank Pressure Sensor)
- PSP Switch (Power Steering Pressure)
- Inhibitor Switch (Park/Neutral Switch)
- A/C Switch

Actuators

- ECM
- Injectors-Sequential
- Ignition-Waste Spark
- EVAP (no pump) Detects 0.5mm (0.020 in. dia.) leak
- EVAP CCV (Canister Close Valve)
- EVAP PSV (Purge Solenoid Valve)

Engine Management Systems Overview
Engine Management Systems Overview

Rio 1.5L L4 A5D DOHC

Siemens ECM and Bosch TCM
ISO 9141-2 OBD II Protocol
OBD-II 16-pin Connector
Kia 20-pin DLC in Engine Compartment

Sensors

- MAF (Hot Film)
- IAT
- ECT
- TPS
- CMP (Hall Effect)
- CKP (Hall Effect)
- KNK
- HO2SB1S1 (Zirconia)
- HO2SB1S2 (Zirconia)
- WSS (Wheel Speed Sensor)
- Rough Road-Misfire Detect
- Disable and Vehicle Speed (Magnetic Pulse)
- PSP Switch (Power Steering Pressure)
- EVAP FTPS (Fuel Tank Pressure Sensor)
- A/C Switch

Actuators

- ECM
- ISC
- Injectors-Sequential
- Ignition-Waste Spark
- EVAP (no pump) Detects 0.5mm (0.020 in. dia.) leak
- EVAP CCV (Canister Close Valve)
- EVAP PSV (Purge Solenoid Valve)
Engine Management Systems Overview

**Sensors**

- MAF (Hot Film)
- IAT
- ECT
- TPS
- CMP (Hall Effect)
- CKP (Magnetic Pulse)
- KNK
- VSS (Hall Effect)
- HO2SB1S1 (Zirconia)
- HO2SB1S2 (Zirconia)
- Chassis Accelerator Sensor
- Inhibitor Switch (Park/Neutral Switch)
- A/C Switch

**Actuators**

- ISC
- Injectors-Sequential
- Ignition-Waste Spark
- EVAP Leak Detection Pump (2000 3-Wire 2001 4-Wire with Heater)
  Detects 0.5mm (0.020 in. dia.) leak
- EVAP Leak Detection Module Changeover Valve
- EVAP PSV (Purge Solenoid Valve)

**Spectra 1.8L L4 T8 DOHC**

Bosch ECM and TCM
ISO 9141-2 OBD II Protocol
OBD-II 16-pin Connector (Sephia Model Also)
Kia 20-pin DLC in Engine Compartment

**KIA 1.8L L4 T8 DOHC**

- Spectra 1.8L L4 T8 DOHC
- Bosch ECM and TCM
- ISO 9141-2 OBD II Protocol
- OBD-II 16-pin Connector (Sephia Model Also)
- Kia 20-pin DLC in Engine Compartment

**KIA**
Sensors

- MAF (Hot Film)
- IAT
- ECT
- TPS
- CMP (Hall Effect)
- CKP (Magnetic Pulse)
- KNK
- VSS (Hall Effect)
- HO2SB1S1 (Zirconia)
- HO2SB1S2 (Zirconia)
- Chassis Accelerator Sensor
- Inhibitor Switch (Park/Neutral Switch)
- A/C Switch
- EVAP FTPS (Fuel Tank Pressure Sensor)

Actuators

- ISC
- Injectors-Sequential
- Ignition-Waste Spark
- EVAP (no pump) Detects 1.0mm (0.040 in. dia.) leak
- EVAP CCV (Canister Close Valve)
- EVAP PSV (Purge Solenoid Valve)

Sportage 2.0L L4 FE DOHC

Bosch ECM and Aisin Warner TCM
ISO 9141-2 OBD II Protocol
OBD-II 16-pin Connector
Kia 20-pin DLC in Engine Compartment

Engine Management Systems Overview
Engine Management Systems Overview

Sedona 3.5L V6
SIGMA DOHC
Melco PCM
ISO 9141-2 OBD II Protocol
OBD-II 16-pin Connector
Kia 20-pin DLC in Engine Compartment

Sensors
- MAF (Hot Film)
- MAP
- IAT
- ECT
- TPS
- CMP (Hall Effect)
- CKP (Hall Effect)
- KNK
- VSS
- HO2SB1S1 (Zirconia)
- HO2SB1S2 (Zirconia)
- PSP Switch (Power Steering Pressure)
- IFS (Ignition Failure Sensor)
- EVAP FTPS (Fuel Tank Pressure Sensor)
- FTS (Fuel Temperature Sensor)
- FLS (Fuel Level Sensor)

Actuators
- ISC
- Injectors-Sequential
- Ignition-Waste Spark
- EVAP (no pump) Detects 0.5mm (0.020 in. dia.) leak
- EVAP CCV (Canister Close Valve)
- EVAP PSV (Purge Solenoid Valve)
- VIS (Variable Intake Motor)

PCM

Engine Management Systems Overview
Component Functionality Review

All Kia electronic engine management systems, regardless of manufacturer, have computers which receive input signals from sensors. The sensors are transducers, which produce a changing electrical signal based on changing physical conditions. The conditions sensed may be temperature, pressure, physical motion or oxygen concentration. The computer processes and stores the information and then provides output signals to actuators, which are transducers that convert the electrical signal to physical motion.

Electrical signals can be either Digital or Analog. It is important to understand the difference between them and how they are used. Digital signals are either ON or OFF, with nothing in between. A switch is the simplest type of digital signal. In most cases a digital signal is ON when the ECM or control device provides a ground to a constant voltage source, and is OFF when the ECM or control device removes the ground.

Analog signals are continuous, and vary in exact proportion to a measured quantity such as pressure, temperature, speed, etc. Notice in the graphic that the voltage signal increases proportionally to the speed of the vehicle. In most analog circuits, the ECM provides a reference signal (usually 5-volts), then compares the sensor’s output signal to it.

There are three main types of sensors used by the ECM. They include voltage generating sensors, resistive sensors and switch sensors. When diagnosing a circuit it is important to know what type of sensor is installed.

A voltage generating sensor produces its own voltage signal from the mechanical condition that it monitors. The signal is relayed to the control module for use in system control. Knock sensors (piezo-electric), oxygen sensors and magnetic inductance sensors (crankshaft and camshaft position) are examples of voltage generating sensors.

A resistive sensor changes its resistance in response to changes in mechanical conditions or temperature. The ECM provides a 5 Volt reference voltage to the sensor, and then measures the voltage drop across the sensor. The throttle position sensor (potentiometer), engine coolant temperature sensor (thermister), and fuel tank pressure sensor (piezo resistive) are all examples of resistive sensors.

A switch sensor supplies a digital (ON/OFF) voltage signal to the ECM. An example of a switch sensor would be the brake pedal switch.

The following pages list and describe sensors and actuators used in KIA vehicles.
Sensor Descriptions

IAT - Intake Air Temperature Sensor

The IAT senses the temperature of incoming air in the intake system. The sensor may be integrated into the Mass Airflow sensor, or it may be a separate component mounted in the air cleaner housing or tapped into the intake manifold casting. It is a Negative Temperature Coefficient Thermistor - its resistance varies inversely with changes in temperature. As air temperature rises, the resistance value of the Sensor falls. The sensor is supplied a 5V Reference Voltage by the ECM. As the sensor resistance drops, the Voltage Drop across the Sensor also drops, producing a reduced Signal Voltage. The sensor is an Analog device, so its resistance value varies continuously, not in discrete steps, and in a linear fashion. For Optima, the IAT sensor signal ranges from 3.3-3.7V @ 0°C (32°F) to 0.5-0.9V @ 80°C (176°F).

ECT - Engine Coolant Temperature Sensor

The ECT is another Negative Temperature Coefficient Thermistor, and is very similar to the IAT Sensor. The ECT resistance again varies inversely with changes in temperature - as coolant temperature rises, the resistance value of the Sensor falls. This Sensor is located in a coolant passage and is supplied a 5V Reference Voltage by the ECM. As the Sensor resistance drops, the Voltage Drop across it also drops, producing a reduced Signal Voltage. The Sensor is an Analog device, so its resistance value varies continuously, not in discrete steps, and in a linear fashion. For Optima, the ECT Sensor Signal ranges from 4.05V @ 0°C (32°F) to 1.25V @ 80°C (176°F).
MAF - Mass Air Flow Sensor

All Kia vehicles currently use either Hot Wire or Hot Film Mass Airflow sensors and both types function in a similar way. The sensor is placed in an intake air passage between the Air Filter and the Throttle Plate. The sensor element is either a heated wire or heated integrated circuit chip which is exposed to the flow of incoming air. This airflow has a cooling effect on the heated element. Internal circuitry in the sensor is powered by Battery Voltage and keeps the heated element at a consistent temperature above ambient by varying current flow through the Hot Wire or Hot Film.

As incoming airflow increases with increased engine load and throttle opening, there is an increased cooling effect on the Hot Wire or Hot Film. A Bridge Circuit increases current flow to keep the temperature of the element constant.

The Signal to the computer is an Analog voltage in proportion to the current to the element. For Optima, the MAF Sensor Signal ranges from 0.5V @ idle to 1.0V @ 2000 RPM. For Spectra, the MAF sensor Signal ranges from 0.9-1.1V @ idle to 1.7V @ 3000 RPM. If a fault is suspected, check for a correct Signal Voltage with an oscilloscope. Be sure to compare the Signal with specifications, as a small shift alone can mean trouble. Look for dropouts and opens, faulty connectors and wiring.
TPS - Throttle Position Sensor

The TPS is a Potentiometer or Variable Resistor that receives a 5V Reference Voltage from the ECM and outputs an Analog Signal Voltage in proportion to throttle opening. This Signal is used as a load signal for both engine management calculations and automatic transmission shifting. The Signal to the computer is an Analog voltage in proportion to throttle opening. For V6 Optima, the TPS sensor signal ranges from 0.2-0.8V @ idle to 4.25-4.7V @ WOT.
**Chassis Acceleration Sensor**

This sensor is attached to the chassis and responds to vertical acceleration of the vehicle. Its purpose is to reduce false misfire Trouble Codes by informing the ECM of rough road conditions. When excessive chassis movement is sensed, inferring rough road, the computer disregards any misfire signal it detects from the Crankshaft Position sensor. As most indications of misfire would be false under these conditions, this reduces the frequency of false misfire Trouble Codes. The Chassis Acceleration sensor is a Piezo device and outputs an AC waveform when triggered and is used only on vehicles with Bosch ECMs.

**VSS - Vehicle Speed Sensor**

The VSS is a transmission mounted Hall Effect sensor and outputs a pulsed digital Signal. The signal frequency is in proportion to vehicle speed, and is used as a signal input for engine management calculations and automatic transmission shifting.
All Kia engines in current production, with one exception, use conventional Narrow Range Zirconium Dioxide (or Zirconia) Oxygen sensors. Zirconia Oxygen sensors are generators, producing a signal voltage between 0-1V in response to the oxygen level measured in the exhaust stream. A measured high oxygen level will result in low Oxygen sensor signal voltage output. This can indicate a mixture leaner than the ideal 14.7:1 air-fuel-ratio (Stoichiometry). This condition can also be caused by other problems: exhaust manifold leak (false air), ignition misfire, etc. A low oxygen level (richer than 14.7:1) will result in high Oxygen sensor signal voltage output. The sensor must respond rapidly to changing conditions if low emissions standards are to be met.

Narrow Range Oxygen Sensors do not respond to changes in exhaust oxygen content in a linear way. Rather, the sensor's voltage output goes sharply higher to around 850 mV when little oxygen is sensed (indicating a mixture richer than Stoichiometry), and conversely the voltage output goes sharply lower to around 175 mV when much oxygen is sensed (indicating a mixture leaner than Stoichiometry). Since the computer cannot tell HOW rich or lean the mixture is, it constantly corrects the mixture lean-rich-lean-rich, striving for equal rich and lean swings on either side of the ideal air/fuel ratio. The Oxygen sensors' sine wave oscillations are not a characteristic of the sensor itself, but the result of the computer constantly changing the air/fuel ratio toward rich and lean so that the AVERAGE air/fuel ratio is 14.7:1.

For Zirconia type sensors the maximum Signal Voltage should be > 850 mV and the minimum Signal Voltage should be < 175 mV. The Switch Time between the high and low swings should be no more than 100 mS.
All Oxygen sensors must be hot to provide a reliable signal and to permit the ECM to go into Closed Loop operation. Also it is desirable for the system to switch to Closed Loop operation quickly after a cold start. Exhaust heat is not sufficient to heat the sensors quickly or to keep them hot during slow driving, so Oxygen sensors are heated by internal electric heating elements to over 300°C (572°F) in seconds.

Kia uses Titanium Dioxide (or Titania) Oxygen sensors in place of Zirconia sensors in the Optima V6 engine (2.5 L/2.7 L with Siemens ECM). Titania sensors are also Narrow Range sensors and provide oscilloscope waveforms very similar to Zirconia sensors. Two are used upstream, and two are used downstream. Titania sensors, however, are not generators, but are variable resistors and are supplied a 5 V reference voltage. For Titania type sensors, the maximum Signal Voltage should be > 4.0 V and the minimum Signal Voltage should be < 0.5 V (voltage output range = 0 to 5 Volts).

Broadband or Wide Range Oxygen sensors do exist and are more linear in their response, but Kia is not presently using them.
**CKP - Crankshaft Position Sensor**

This sensor can be either a Magnetic Pulse or Hall Effect type sensor and provides engine RPM and also misfire detection information to the computer. The Magnetic Pulse type is a two-wire device (coil and permanent magnet) which generates a voltage and outputs an Analog Sine Wave Signal.

The Signal varies in both amplitude (voltage generated) and frequency with changing RPM. There may be a missing tooth on the Trigger Wheel or Reluctor which provides a reference cylinder no.1. Magnetic Pulse Signal Voltage ranges from approx. 6V @ idle to approx. 10V @ 2000 RPM. Bosch and Nippondenso systems use magnetic pulse sensors.

The Hall Effect type CKP sensor is a three-wire device which receives Battery Voltage and outputs a 5V Digital Pulsed Wave signal. This Signal varies in frequency with changing RPM. Kia vehicles with Siemens and Melco systems use Hall Effect CKP sensors.

**Magnetic Pulse type sensor**

**Hall Effect type sensor**
**CMP - Camshaft Position Sensor**

The CMP sensor is always a Hall Effect device on OBD II certified Kia vehicles. It is a three-wire device which receives Battery Voltage and outputs a 5V Digital Pulsed Wave Signal. This Signal varies in frequency with changing RPM. The sensor provides cylinder no.1 reference information (a synchronization signal) to the ECM for injector timing purposes.

**KNK - Knock Sensor**

The Knock sensor is provided to alert the computer to engine knock or detonation. This condition is caused by overly advanced spark timing, lean mixtures, hot spots, excessive carbon buildup, etc., and can dramatically raise cylinder temperatures and pressures and can cause severe internal damage. The Knock sensor has a Piezo element that is tuned to respond to the specific frequency of vibration in the block created when knock occurs. When the ECM sees this signal, it progressively retards spark timing until the knock disappears. Knock sensors are very sensitive to the tightness or torque of their mounting bolts. Incorrect torque can shift the sensor response to a different frequency and render it ineffective.

**Engine Management Systems Overview**
**FTPS - Fuel Tank Pressure Sensor**

This is a sensor used in Evaporative Systems (EVAP Systems) without Leak Detection Pumps. It is a differential pressure sensor with a Piezo element which senses small pressure differences between fuel tank and atmospheric pressure. The sensor is supplied a 5V Reference Voltage and outputs an Analog Signal Voltage in proportion to fuel tank pressure.

Leak detection in systems without a pump is accomplished by what is called a Pressure Gradient Test. Fuel system pressure is permitted to rise and fall, and the rate of pressure changes is monitored. A leak is assumed if the change in pressure is too rapid. The sensor may be mounted on top of the fuel tank or under the vehicle near the tank.

**MAP - Manifold Absolute Pressure Sensor**

A MAP sensor is installed on Kia vehicles only if EGR is used and only functions as an EGR System Monitor. To detect EGR flow, the computer looks for changes in intake manifold vacuum while opening and closing the EGR Valve. The sensor is supplied a 5V Reference Voltage and outputs an Analog Signal Voltage in proportion to increasing manifold pressure (decreasing vacuum). For the V6 Optima, the MAP sensor signal ranges from 0.8V @ idle to 2.4V when throttle is snapped open.

**PSP - Power Steering Pressure Switch**

This switch senses power steering system line pressure and provides a Digital signal to the ECM indicating high line pressure. This indicates increased engine load, and in response the computer may increase engine idle speed.
**A/C Switch**

This switch provides a Digital (On-Off) signal to the ECM when occupants request A/C. The signal is an indicator of increased engine load and in response the ECM may increase idle speed.

**A/C Relay and A/C Cut Relay (Sportage)**

On the Sportage, the A/C Relay and the A/C Cut Relay are located below the right side of the instrument panel, behind the glove box.

When the ignition is in the *ON* position, battery voltage is applied to the contacts (load side) of the A/C Cut Relay and the coil (control side) of the A/C Relay. When both the A/C switch and the blower switch are turned to the *ON* position, a ground path is provided by the blower circuit to the coil of the A/C Relay and to the ECM. With the A/C Relay energized, battery voltage is applied to the condenser fan motor, allowing it to run. If all conditions for A/C engagement are met (thermocon and dual pressure switch both closed), a ground signal will be applied to the coil side of the A/C Cut Relay, allowing A/C Compressor engagement.

On 2000 and later Sportages, the condenser fan will run continuously if the ignition, A/C and blower switches are in the *ON* position.

**Cooling Fan Relay (Sephia, Spectra and Rio)**

The cooling fan relay is located in the engine compartment fuse/relay box. When the ECT senses that the engine coolant temperature has reached 196°F (91°C), or if the A/C is turned on, the cooling fan relay will be energized, energizing the fan motor until the temperature decreases to 182°F (83°C) or until the A/C cycles or is turned off.

**A/C Relay (Sephia, Spectra and Rio)**

The A/C Relay on the Sephia is located in the engine compartment fuse/relay box. Power is continuously applied to it.

Refer to the graphic below. If all operating parameters are correct, the ECM will provide a ground to the coil side of the A/C Relay. The relay is then energized and can apply battery voltage to the A/C compressor clutch through its closed contacts. Under certain acceleration conditions, engine load, or excessive coolant temperature, the ECM will cut off the A/C compressor magnetic clutch to improve engine performance, or to allow the engine to cool down if overheated.
Actuators

Fuel Injectors

All Kia engines use electronic multiport fuel injection systems with solenoid type fuel injectors, one per each cylinder. Each Injector is individually Ground-side controlled by the ECM and the Injectors are fired sequentially in the firing order, once each per cycle. Air/fuel ratio is controlled and maintained by computer management of the injector Pulse Width or "On" time. Injectors typically have approx. 12 Ohms resistance and draw about one Amp current. Kia uses Saturated Switch Type (voltage controlled) Injectors.

IAC - Idle Air Control Valve

The Idle Air Control valve (IAC) regulates engine idle speed by controlling the amount of air allowed to bypass the throttle plate. Two valve designs are used. The valve in all models except Sedona has two coils which are pulsed on a duty cycle by the ECM. The pulse width determines the valve bias and idle air passage opening. Sedona models only use a stepper motor valve design. Sedona models also have a separate Fast Idle Air valve (FIAV). This valve opens or closes in response to the temperature of the engine coolant. It is purely mechanical and employs a wax pellet temperature sensor (refer to page 54 for more information).
PSV - EVAP Purge Solenoid Valve

Both types of EVAP Systems (with and without pump) use a Purge Solenoid Valve. The valve is mounted in the line connecting the Charcoal Canister with the engine Intake Manifold. The valve is opened during the EVAP System Purge Cycle, when Hydrocarbon vapors stored in the Canister are purged. The valve is normally closed and is opened by a Pulse Width Modulated signal from the ECM. This Duty Cycle or percentage of "On" time determines the flow rate. Since the valve is a solenoid similar to a fuel injector, an oscilloscope pattern will appear similar to an Injector pattern. This course will discuss EVAP System functioning and testing in detail later.

CCV - EVAP Canister Close Valve

EVAP Systems without Leak Detection Pumps use this Normally Open Valve during the Pressure Gradient Leak Test. The CCV controls the fresh air inlet/outlet of the Canister and during part of the leak test, the CCV is closed on a signal from the ECM, sealing the fuel system. Pressure changes are monitored during different phases of leak testing to detect small and large leaks. This course will discuss EVAP System functioning and testing in detail later.

Located near the EVAP canister, left-rear quarter panel, behind the rear wheel (Optima).
Engine Management Systems Overview

EVAP Leak Detection Pump Assembly

This unit (sometimes called DM-TL or Diagnostic Module for Tank Leakage) consists of an electric Pump, a Calibrated Orifice and a Changeover Valve. The Pump motor runs only during leak testing and is controlled by the ECM. Pump Current Draw is monitored during leak testing to determine the presence of leaks as small as 0.5 mm (0.020 in.) dia. The Changeover Valve is also computer controlled and is actuated only during one phase of the leak test. This course will discuss EVAP System functioning and testing in detail later. The latest versions add a heater circuit for stabilization in high humidity and low temperature conditions.

Fuel Pump Relay

The fuel pump relay is located in the engine compartment fuse relay box on all Kia vehicles. Fuel pump operation is controlled by the ECM through the fuel pump relay. Battery voltage from the INJ fuse is present on the switch (load) side of the fuel pump relay continuously.

With the ignition in the ON position, battery voltage is applied to the coil side of the relay. The ground side of the circuit is controlled by the ECM. When the ECM provides the ground for the relay to operate, the current from the INJ fuse flows through the relay to the fuel pump.

Ignition Control (in ECM)

Kia engines use Distributorless Waste Spark ignition Systems. In this type of ignition, there is one Ignition Coil for each Companion Cylinder Pair. The Spark Plugs in these pairs are fired every revolution of the crankshaft. Companion Cylinders are cylinders in which the position of the pistons is the same at every point in the cycle. In other words, both pistons are at TDC at the same time, but one cylinder is at TDC of compression and the other is at TDC of the exhaust stroke. The ECM must determine not only ignition timing, but also which Ignition Coil to fire. The computer also controls Dwell, or Primary Current "On" time.

Vehicle Specific Sensors and Actuators

Ignition Failure Sensor (Optima 2.4L/Sedona 3.5L)

The Ignition Failure sensor is located in the engine compartment, on the driver’s side of the cylinder head (Optima 2.4L), or the thermostat housing (Sedona). Used to detect ignition system malfunctions (P0350), the coil primary circuits are wired through the ignition failure sensor. Signals are sent from the sensor to the ECM and tachometer. On the Sedona EX, signals are also sent to the trip computer. A sensor failure can cause crank/no start conditions.

Wheel Speed Sensor (Optima 2.5L/2.7L)

The Wheel Speed sensor is found on the RF knuckle, and is used for calculating vehicle speed as seen by the ECM/TCM (analog signal), and to detect rough road conditions. Signals are transmitted directly to the ECM on non-ABS vehicles, and to the ABS ECU on ABS equipped vehicles (signal shared through the Controller Area Network (CAN)).
Wheel Speed Sensor (Rio)

The Rio Wheel Speed sensor is also found on the RF knuckle, and is used to detect rough road conditions, and to update the “Distance after MIL” parameter on the current data of the High Scan Pro. Signals are transmitted directly to the ECM. ABS equipped vehicles have two wheel speed sensors on the RF knuckle.

Idle Speed Control/Fast Idle Air Valve (Sedona 3.5L)

The ISC motor is PCM controlled, and is mounted to the throttle body. ISC STEP data can be seen using the current data function of the Hi-Scan Pro. The FIAV is also mounted to the throttle body, and opens/closes based on temperature of coolant passing through throttle body (not PCM controlled).

Cooling Fan/Condenser Fan Control (Optima)

Three fan relays for the cooling fan, and three fan relays for the condenser fan are located in the engine compartment fuse box 3. Two diodes are located in the engine compartment fuse relay box, and are wired into the low speed fan circuits. The ECM/PCM controls fan speed (low, medium, high) based on coolant temperature, vehicle speed, and A/C switch position. Fans will default to high-speed operation upon ECT or VSS failure.

Cooling Fan/Condenser Fan Control (Sedona)

The Radiator/Condenser fans have high and low speed functions, and are PCM controlled through a series of 3 fan relays. The PCM determines fan operation based on ECT, VSS, and A/C operation (A/C switch on instrument panel and pressure switch inputs are evaluated by PCM).

EGR (Optima 2.4L)

The EGR is a diaphragm type valve controlled by the PCM, and is used to introduce exhaust gas into the combustion chamber, lowering combustion temperatures and reducing oxides of nitrogen. The PCM monitors the EGR performance using a MAP sensor once per trip (complies with OBD II regulations). At idle, MAP output should be .8 to 2.4 Volts, and should rise with decreased engine vacuum.

Variable Intake Manifold (Sedona 3.5L)

Used to boost low to medium speed torque, the variable intake manifold is controlled by the PCM via a variable intake motor. Shutters within the manifold change position (steps) based on engine RPM (9 steps possible). Two Hall effect sensors supplied with a 5 Volt reference send shutter position information back to PCM. The motor is active between 3750 and 4750 RPM without regard to vehicle speed.

Controller Area Network (CAN)
(Optima 2.5L/2.7L)

The ECM, TCM and ABS (if equipped) share signals over two common data lines. This differs from the serial communication we are used to, where each signal must have separate wiring.

With the CAN, data is transmitted in digital format at a rate of 500 K bit/sec. Serial communication occurs at 15.625 Kbit/sec.
**System Authority**

All components in the engine management system work together to provide the optimum air/fuel mixture under all conditions. Understanding what components have the greatest influence during specific operating conditions can aid the technician in diagnosing a vehicle problem. The following table describes various operating conditions and lists the sensors that have influence during those conditions. Fill in the table during class discussion.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Loop: Open/Closed</th>
<th>Base Timing and Injector Duration</th>
<th>Greatest Influence</th>
<th>Some Influence</th>
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<tbody>
<tr>
<td>Cold Start</td>
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<td>Warm-up</td>
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<td>Warm Idle</td>
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<td>Deceleration</td>
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</table>
Air-Fuel-Ratio and Stoichiometry

The optimum air/fuel ratio is known as the Stoichiometric ratio, and for gasoline it is 14.7 parts air to 1 part fuel by mass. If measured by volume, the proportions would be 9000:1, or 9000 l of air per 1 l fuel. At Stoichiometry, fuel and air are in exact proportion and there is just enough oxygen to combine with fuel molecules when combustion takes place. Leaner mixtures have excess oxygen, richer mixtures insufficient oxygen.

Another measure of Stoichiometry is the Lambda Ratio, which is a comparison of the actual quantity of air vs the theoretically correct quantity of air. If the air/fuel ratio is 14.7:1 or Stoichiometric, the Lambda Ratio is 1:1. Lambda values greater than 1.0 indicate leaner mixtures with excess air, and Lambda values less than 1.0 indicate richer mixtures with insufficient air.

Engines do not necessarily run best or pollute the least if continuously fed a Stoichiometric mixture. Engine mechanical conditions, operating conditions and emissions considerations affect and modify the air/fuel ratio requirements. The range of operating ratios will vary between approximately 14.2:1 and 16.2:1 depending on the engine and engine operating conditions. During a cold start, poor fuel atomization and increased quench due to cold cylinder, piston and head temperatures necessitate a richer mixture. Peak power also requires enrichment. Leaner mixtures provide better economy and lower HC and CO emissions but raise NOx emissions.

The Feedback Loop

OBD II Three-way catalytic converters promote both oxidation and reduction reactions within the catalyst beds in order to reduce quantities of all three major pollutants: HC (Hydrocarbons), CO (Carbon Monoxide) and NOx (Oxides of Nitrogen). The HC and CO are oxidized to form Water Vapor (H2O) and Carbon Dioxide (CO2) in the presence of Oxygen. The NOx is reduced to Nitrogen (N2) and CO2 in the presence of CO. In order for conditions to be favorable for both reactions to take place in the catalytic converter, Engine-Out Gases (Catalyst Feed Gases) must contain both O2 and CO. This is accomplished by maintaining the engine's air/fuel ratio at or near Stoichiometry. The engine's Air/fuel ratio is constantly being monitored by the feedback loop using input from the Oxygen Sensors and is adjusted by the engine management system.

It is the Front Oxygen sensors that provide a feedback signal to the ECM for air/fuel ratio control. Rear Oxygen sensors only check Catalytic Converter efficiency). In Kia, the Front Oxygen Sensors are located near the engine exhaust manifold and head, in a location to sample Engine-Out exhaust gases before being treated by a Catalytic Converter.

Zirconia (narrow range) Oxygen sensors are generators, producing a signal voltage between 0-1V in response to the oxygen level measured in the exhaust stream. A measured high oxygen level will result in low Oxygen sensor signal voltage output. This can indicate a mixture leaner than the ideal 14.7:1 air-fuel-ratio (stoichiometry). This condition can also be caused by other problems: exhaust manifold (false air) leak, ignition misfire, etc.
A low oxygen level (richer than 14.7:1) will result in high Oxygen Sensor signal voltage output. The sensor must respond rapidly to changing conditions if low emissions standards are to be met.

Oxygen Sensors must be hot in order to generate a reliable signal and allow the system to enter Closed Loop operation. As exhaust heat is not sufficient to quickly heat the Sensors or to keep them hot during slow driving, Oxygen Sensors are heated by internal electric heating elements to over 300°C (572°F) in seconds. During a cold start, the ECM runs in Open Loop mode until it receives reliable Signals from the Main Oxygen Sensors.

### Fuel Injection Calculation

Kia fuel systems use one of two types of fuel feed and fuel pressure regulation configurations. The system used affects how much "work" the ECM must do in order to determine the quantity of fuel injected.

Kia engines with Return-Type (Loop Type) Fuel Systems have vacuum-sensing fuel pressure regulators mounted on the engine fuel rail. In these systems, fuel line pressure to the injectors is permitted to vary in proportion to changes in intake manifold vacuum. In these systems, the pressure drop across the injectors (the difference between fuel pressure and manifold vacuum) is nearly constant. Therefore, fuel injection quantity is dependent entirely on injector "On" time. Raising fuel line pressure as manifold vacuum decreases tends to richen the mixture. It also reduces lag as the throttle is opened.

Kia vehicles with Returnless Fuel Systems use pressure regulators mounted in-tank which do not sense intake manifold vacuum and fuel line pressure is regulated at a constant value. In these systems, the pressure drop across the injectors is not constant but varies with changes in manifold vacuum. The injection pulse width calculation is a bit more complex in this case.

In all OBD II compliant vehicles, the injectors are sequentially and individually controlled. The computer has a Driver or controlling transistor for each individual injector enabling the computer to control each injector’s duration individually. The injectors are Ground-side controlled and receive battery voltage continuously with ignition switch "On."
The ECM determines the quantity of fuel injected per cycle by first calculating the Base Fuel Injection Duration. This value sets the basic fuel injector Pulse Width or injector "On" Time for the given conditions. Again, the quantity of fuel injected is directly proportional to how long the injectors are permitted to remain open (injector "On" time).

To determine the Base Fuel Injection Calculation, the ECM receives Input Signals from the Mass Airflow Sensor (engine load), engine RPM and Engine Coolant Temperature Sensor. In addition, the computer also considers any Long Term Fuel Trim adaptation (Short Term and Long Term Fuel Trim are described below). Based on the above inputs, the computer consults a Lookup Table for the desired fuel injection duration value. A Lookup Table is a map or matrix of injector duration values stored in, and accessed by the ECM. These values are stored in nonvolatile Read-Only-Memory or ROM.

On some makes, these values can be changed or updated by either reprogramming EEPROM chips (integrated circuits) or chip replacement. At present, Kia does not use reprogrammable ROM or utilize replaceable integrated circuits. Lookup tables are also used by the ECM for mapping ignition spark timing values.

When the engine is operating in Open Loop (as during warmup), and before the Front Oxygen Sensor heats and generates a feedback signal, the fuel injection duration calculation is the Base Fuel Injection Duration value. No further calculation takes place to alter injection quantity and the ECM does not receive any feedback information regarding how closely its calculations came to the engine’s actual fuel requirements.

In Closed Loop operation which occurs during most driving, the ECM does receive a feedback signal from the Main or Upper Oxygen Sensor indicating oxygen content in the exhaust stream. This signal gives the computer guidance regarding how closely it has estimated fuel requirements and allows it to fine tune or trim fuel delivery to maintain the air/fuel ratio at Stoichiometry.

For an analogy to help your understanding of Open Loop and Closed Loop operation, consider a person blindfolded in a room with one doorway. If the task is to locate the door, Open Loop operation is similar to having the blindfolded person locate the door with no coaching (no feedback) from anyone. Eventually, the person will probably find the door after some trial and error, but it might take a while. If that person is coached or receives verbal clues "more to the right, etc.," he or she will most likely find the doorway more quickly. The feedback helps to find the target sooner.

In the vehicle, the feedback from the Oxygen Sensor also tells the ECM how close it is to the target Air/fuel ratio and allows much closer control.
Fuel Trim

Short Term and Long Term Fuel Trim

Short Term and Long Term Fuel Trim are adaptations to the calculated fuel injection duration for the purpose of maintaining the air/fuel ratio at or near Stoichiometry (14.7:1). These adaptations or changes are made by the ECM in response to the Main or Upper Oxygen Sensor Feedback Signal.

Fuel Trim adaptations are needed for several reasons. It is not possible to set and adjust the fuel injection quantity at the factory to precisely meter the exact fuel requirements under all conditions. And even if that were possible, with time and miles, parts wear, signals shift and the quantity of fuel delivered will change. Variations in sensor and engine component tolerance and wear can cause signal shifts and can change engine fuel requirements in order to keep the air fuel ratio at Stoichiometry (14.7:1).

Short Term Fuel Trim (STFT) is an instantaneous response to Oxygen Sensor input, but is active during Closed Loop operation only. This adaptation starts at "zero," or no trim state with every engine start. Short Term Fuel Trim can be considered the "fine adjustment." It can instantly respond and increase or decrease the quantity of fuel delivered by ± 25%. The system is designed to work best with Short Term Fuel Trim hovering around "zero" or no trim, however. If an ongoing or long term, continuous adaptation is required for conditions, then Long Term Fuel Trim steps in.

Long Term Fuel Trim (LTFT) responds more slowly than Short Term Fuel Trim, but its changes are more permanent. Shifts in Long Term Fuel Trim allow Short Term Fuel Trim to return back to the "zero" trim state. Long Term Fuel Trim is active in both Open Loop and Closed Loop conditions and its adaptation value is kept in memory in the Key Off condition. Therefore, when the vehicle is restarted, the Long Term Fuel Trim value immediately modifies the fuel injection quantity. Long Term Fuel Trim can be considered the "coarse adjustment."

The ideal is to have both Short Term and Long Term Fuel Trim values 'zero', with no adaptation required. Short and Long Term Fuel Trim values on Kia vehicles can vary as much as ± 25%, although the value usually remains within ±10%. If Fuel Trim values are at maximum limits for a defined period, a DTC will be set. Fuel trim is continuously monitored for faults at all times.

<table>
<thead>
<tr>
<th>1.3 CURRENT DATA</th>
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<tbody>
<tr>
<td>ST FUEL TRIM (B1)</td>
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<tr>
<td>LT FUEL TRIM (B1)</td>
</tr>
<tr>
<td>INJECTION TIME #1</td>
</tr>
<tr>
<td>FUEL SYS. 1 STATUS</td>
</tr>
<tr>
<td>MIL STATUS</td>
</tr>
</tbody>
</table>

HOLD | TIME | VOLT | RCRD | GND | WAVE


Emissions

5-Gas Analysis

5-Gas analysis is an effective tool which can assist in the diagnosis of engine problems. Engine wear, broken or out-of-specification components and problems with the electronic engine management system can all contribute to high levels of emissions and drivability problems and can set Trouble Codes.

Hydrocarbons (HC) are unburned fuel molecules. High Hydrocarbons (HC) are generally caused by either partial or total misfire. Any problem contributing to the mixture not burning or the flame propagation being quenched will raise levels of HC. This includes:

- Excessively rich mixture - Insufficient O₂ is present to support the burning (oxidation) of all fuel molecules. The excess fuel also has a cooling effect. Richer mixtures do burn faster than lean mixtures, however. The fuel molecules are closer together and the flame front propagates faster. This is why ignition timing is retarded on acceleration during power enrichment. If gas analysis shows high HC emissions, also note CO levels. If CO is also high, this indicates excessively rich mixture.

- Excessively lean mixture - With too little fuel and excess O₂, the fuel molecules are too far apart to reliably support flame propagation. Misfire or partial misfire occurs and the fire goes out, leaving the remaining unburned fuel. Ignition requirements have become more critical as mixtures have leaned, and ignition systems must provide higher voltages and longer duration spark to reliably ignite the mixture. If gas analysis shows high HC emissions, but low CO levels, suspect lean misfire.

- Ignition problems - Any problem with the ignition primary or secondary circuit that prevents the spark plug from firing causes complete misfire. HC levels will be very high.

- Engine mechanical problems - Mechanical problems such as low compression, burned valves, late valve timing, reduce engine efficiency. If the engine is using conventional mineral oil for lubrication, excessive oil bypassing piston rings can be detected by the gas analyzer and will increase measured HC at the tailpipe. The mechanical cause must be repaired to lower these HC emissions.

- Engine design - Large quench or "squish" areas, such as the wedge combustion chamber. Also combustion chambers with a high surface-to-volume ratio. Hemispherical or pent-roof shaped combustion chambers have particularly favorable surface-to-volume ratios. Obviously this is not a condition easily altered, but it does help explain why older vehicles pollute more.
Carbon Monoxide (CO) is a colorless, odorless, poisonous gas that is produced when gasoline is burned with insufficient O\textsubscript{2}. High CO is generally caused by excessively rich mixtures with excess fuel and insufficient O\textsubscript{2} available for complete combustion. (Total Misfire will LOWER levels of CO, since no combustion at all has taken place). CO is a good indicator of a rich mixture. Air/fuel ratios richer than 14.7:1 lack sufficient Oxygen for complete combustion (and formation of CO\textsubscript{2}), so some CO results. At ratios leaner than 14.7:1 there is excess Oxygen available and little CO is formed.

- Excessively rich mixture - Insufficient O\textsubscript{2} is present to combine with HC and form CO\textsubscript{2}, so CO is formed instead. If gas analysis shows high CO emissions, also note HC levels. If HC is also high, this indicates excessively rich mixture.

Oxides of Nitrogen (NO\textsubscript{x}) are compounds that are produced when combustion temperatures in the engine's cylinders exceeds 1400 degrees C (approx. 2500 degrees F). Above these temperatures, normally inert Nitrogen (N\textsubscript{2}) combines with Oxygen (O\textsubscript{2}) to form several different compounds which contribute to Smog, respiratory problems and eye irritation. Efficient engine combustion raises the average flame temperature, as does an air-fuel-ratio at or near Stoichiometry (14.7:1). Therefore, efficient combustion that lowers HC and CO emissions tends to raise levels of NO\textsubscript{x}. Three-Way Catalytic Converters reduce NO\textsubscript{x} to acceptable levels.

In addition, engine modifications also help. Exhaust Gas Recirculation (EGR) Systems are sometimes employed to direct a small percentage of exhaust gases (which are essentially inert) back to the intake system. The intake air/fuel charge is diluted with up to 10% exhaust gases. This dilution takes the place of burnable fuel molecules, so less fuel is available. The exhaust gases also force the fewer fuel molecules farther apart. Both effects reduce the peak combustion temperatures below the 1400 degrees C (approx. 2500 degrees F) threshold above which large quantities of NO\textsubscript{x} are formed. Excessive engine knock or pinging can indicate a failed EGR system. Engines with variable valve timing can use the increased valve overlap to create what can be called "natural EGR." With high overlap, on the exhaust stroke some exhaust can backflow into the intake manifold and then be introduced into the cylinder with the next charge. Generally, engines with variable valve timing systems do not need separate EGR systems. If NO\textsubscript{x} values are high, suspect:

- EGR System problem - Any defect that reduces the desired EGR flow will raise peak combustion temperatures and raise NO\textsubscript{x} levels. EGR valves can stick, passages can clog, or there can be vacuum or electrical/electronic problems. Knock or pinging can be present. Note that EGR systems never allow flow at idle.

- High engine compression - Carbon buildup in the cylinder can raise effective compression ratio and raise peak combustion temperatures. Carbon removal procedures may be necessary.

- Overly advanced ignition timing - Advanced timing can raise combustion and cylinder temperatures. Ignition should be timed to allow the spark to ignite the mixture so that peak pressure occurs when the piston is at 10 degrees ATDC. If the spark occurs too early then high cylinder pressure may occur before the piston passes TDC. Severe damage may result. With ECM controlled ignition timing there are usually no timing adjustments possible.
Excessively lean mixture - With too little fuel and excess O₂, the cooling effect of excess fuel is not present and combustion temperatures can rise. If gas analysis also shows high HC emissions and low CO levels, suspect a lean condition.

**Carbon Dioxide (CO₂)** is an indicator of efficient combustion. The more completely and efficiently the fuel is burned, the higher the percentage of CO₂. Levels can be as high as around 16%. Any reduction in engine efficiency will reduce the percentage of CO₂.

- Excessively rich mixture
- Excessively lean mixture
- Engine mechanical problems

**High Oxygen (O₂)** levels are an indicator of mixtures leaner than 14.7:1, where excess Oxygen remains after combustion. Since the ECM is maintaining the air/fuel ratio at Stoichiometry (14.7:1), gas analysis should show both O₂ and CO levels low and values similar, about 0.5%. Low Oxygen levels usually indicate excess fuel.

**Emissions Inspection**

Because of the great environmental risk exhaust gases pose to our environment, Federal and State motor vehicle emissions regulations are getting stricter every year. To comply with these regulations KIA uses various emissions-related controls, such as Exhaust Gas Recirculation, Evaporative Emissions, On Board Vapor Recovery (ORVR) and Leak Detection (with and without pump).

All of these systems are designed to reduce one or more of the following byproducts of combustion:

- Carbon Monoxide (CO)
- Carbon Dioxide (CO₂)
- Hydrocarbons (HC)
- Oxides of Nitrogen (NOₓ)

In the past, emissions inspections for vehicles registered in the United States sampled tailpipe emissions with the test vehicle at idle. This made it possible for vehicles that were gross polluters on the road (i.e. while the engine is under load) to pass the emissions inspection. To reduce this risk, enhanced emissions testing has been implemented utilizes a chassis dynamometer.

The IM240 driving cycle is such a test. It is a 240 second long test representing a 1.96 mile route with a 29.4 mile per hour average speed and a maximum speed of 56.7 miles per hour.

By understanding during which part of the driving cycle the vehicle exceeded allowable emissions, the technician may gain a clue as to what system is malfunctioning. For example, if the vehicle fails around the 90 second point, the problem is occurring during deceleration. This can be particularly helpful in diagnosing emissions failures on pre-OBD II cars, which, due to their fewer sensors and reduced self-diagnostic capabilities, can be more difficult to diagnose.
Catalytic Converters

Catalytic Converters were first used to reduce exhaust emissions in 1975. The first ones contained Two-Way Catalysts which promoted only the Oxidation reaction and reduced HC (Hydrocarbons) and CO (Carbon Monoxide) to form H₂O (water) and CO₂ (Carbon Dioxide). Levels of Oxides of Nitrogen (NOₓ) were not reduced or affected by these early Catalysts. Catalytic Converters are constructed of a high-temperature resistant housing with a monolithic ceramic core. The core which thousands of honeycomb passages and enormous surface area, and is coated with the Catalyst agents, Platinum and Palladium which promote Oxidation.

Since 1996, OBD II Catalytic Converters have Three-Way Catalysts which promote both Oxidation and Reduction Reactions within the catalyst beds in order to reduce quantities of all three major pollutants: HC, CO and NOₓ. The HC and CO are oxidized to form Water Vapor (H₂O) and Carbon Dioxide (CO₂) in the presence of Oxygen, the same as in the older Two-Way Converter. But now, the NOₓ is also reduced to Nitrogen (N₂) and CO₂ in the presence of CO. In order for conditions to be favorable for both reactions to take place in the catalytic converter, Engine-Out Gases (Catalyst Feed Gases) must contain both O₂ and CO. This is accomplished by maintaining the engine's air/fuel ratio at or near Stoichiometry. The engine's Air/fuel ratio is constantly being monitored by the feedback loop using input from the Oxygen Sensors and is adjusted by the engine management system.

Three-Way Catalysts have two ceramic cores or beds, the first for the Reduction Reaction and the second for Oxidation. The Catalysts for the Reduction side is Rhodium. Cerium is present to promote Oxygen storage.

Catalytic Converters must reach a bed temperature of approx. 600°F (315°C) before they "light-off" and promote the catalytic reactions, and this can take several minutes of running. Once working, the Converter works most efficiently if the engine air/fuel ratio is held close to Stoichiometry or 14.7:1. Then both Oxygen and Carbon Monoxide are available to promote both oxidation and reduction reactions. The Rear or Down Oxygen Sensor is placed to monitor Catalytic Converter efficiency, and it does so by watching the Converter's ability to store Oxygen.

When working correctly, the Catalytic Converter either uses or holds onto the available Oxygen and very little O₂ exits. The Rear Oxygen Sensor sees very little Oxygen and therefore its oscilloscope pattern is a flat line at about 0.7V. If the Converter begins to fail, it loses its ability to store Oxygen and the scope pattern for the Rear Oxygen Sensor begins to oscillate similar to the Front Sensor. If the patterns become too similar, the Monitor will set a Catalyst Efficiency DTC.

For a quick test of Converter function, use an infrared pyrometer which can measure temperatures quickly and without contact. Measure the temperatures of both Converter inlet and outlet. If the outlet temperature is at least 10% greater than the inlet temperature, then the Catalytic Converter is working.

Catalytic Converters can be damaged by overheating. Excess fuel in the feed gases from excessively rich mixture or especially misfire can melt the ceramic core. This is why misfire is considered a serious fault. If misfire is detected, the MIL will immediately flash as a warning to the driver.
Emissions

Exhaust Gas Recirculation

The Exhaust Gas Recirculation or EGR System is designed to reduce NOx (Oxides of Nitrogen) emissions. Since NOx is formed in significant amounts when peak combustion temperatures exceed 2500°F, NOx can be controlled and reduced by lowering that peak temperature. The EGR System works by introducing some exhaust gases back into the engine intake manifold where the gases flow with the incoming intake air/fuel charge into the cylinder. About 10% maximum dilution of the intake charge is permitted.

Adding exhaust gases to the combustible air/fuel mixture accomplishes several things. First, the exhaust gases are essentially inert and do not burn again. Also, these exhaust gases occupy the space that would have been taken by air/fuel mixture, so there is less burnable mixture in the cylinder. EGR flow is not needed at idle, as peak temperatures and pressures are low. Also, any EGR flow at idle can cause rough running and stalling.

Kia Optima models with 2.4l four cylinder engines have EGR. The EGR Valve is a vacuum operated valve which, when open, allows exhaust gases to pass from the exhaust manifold to the intake manifold. The EGR Valve is opened by manifold vacuum which is controlled by an EGR Solenoid Valve. This valve is normally closed and EGR flow rate is determined by a duty cycle.

Problems that can be caused by the EGR System include pinging or knock, rough running or stalling and high NOx emissions.

If the EGR flow is reduced for any reason, pinging or knocking can occur. Insufficient EGR flow reduces the dilution effect and higher cylinder temperatures can cause preignition and knocking. Problem areas can be the EGR Valve, EGR Solenoid Valve, vacuum leaks and ECM circuits and controls. Passages can clog and reduce flow. Reduced flow can also raise levels of NOx when the engine is under load.

Stalling or rough idling can be caused by too much EGR flow, or EGR flow when not desired. EGR Valves can stick open. Also check the Solenoid Valve.
**EVAP Evaporative Emissions Systems**

Evaporative Emissions (EVAP) Systems are designed to reduce Hydrocarbon (HC) emissions by capturing and storing fuel vapors emitted from the vehicle fuel tank and related lines. The vapors are adsorbed onto charcoal granules inside the EVAP Charcoal Canister and stored. A Purge Cycle allows fresh airflow to pick up the HC in a controlled flow to the running engine’s intake manifold where it adds to the incoming air/fuel mixture. The rate and timing of the purge flow must be controlled in order to avoid upsetting the air/fuel ratio and smooth running of the engine.

Pre-OBD II EVAP Systems were mechanical, and the rate of EVAP Purge flow was controlled by throttle body ported vacuum. During cold engine operation, EVAP Purge was disabled by a coolant temperature operated Vacuum Switch. In these systems, EVAP flow rates were not well controlled.

In Kia OBD II ECM-controlled EVAP systems, Purge Flow is managed more precisely by a duty-cycle-controlled Purge Solenoid Valve. Onboard Refueling Vapor Recovery (ORVR) Systems add the ability to recover and store fuel vapors (HC) during refueling. These systems check for leaks by sealing the system and monitoring both pressure increase due to fuel tank vapor pressure and also pressure drop when connected to engine manifold vacuum. The rate of pressure increase and decrease is evaluated as an indicator of system integrity. Leaks as small as 1 mm (0.040 in. dia.), or in some vehicles 0.5 mm (0.020 in. dia.), can be detected. The EVAP Monitor conducts this Pressure Gradient Leak Test with KOER, vehicle stopped, engine at idle.

The latest Kia OBD II ECM-controlled EVAP systems use a Leak Detection Pump to check for leaks and monitor system integrity. The Pump’s current draw is monitored while it pressurizes the EVAP system. This current value is compared to a baseline value obtained during a calibrated reference leak test using an orifice representing a leak measuring 0.5 mm (0.020 in. dia.). The ECM EVAP Monitor runs this leak test five hours or more after the end of a trip, key-off.
Systems without a Leak Detection Pump

Most KIA ECM-controlled EVAP systems check for leaks with a Pressure Gradient Leak Test. This test seals the system and monitors both pressure increase due to fuel tank vapor pressure and also pressure drop when connected to engine manifold vacuum. The rate of pressure increase and decrease is evaluated as an indicator of system integrity. Leaks as small as 1 mm (0.040 in. dia.), or in some vehicles 0.5 mm (0.020 in. dia.), can be detected. The EVAP Monitor conducts this Pressure Gradient Leak Test with KOER, vehicle stopped, engine at idle.

EVAP Leak Test (without pump)

*See next page for test mode descriptions
Leak Test functional description

**NOTE:**

*Paragraph Numbers below refer to numbers keyed on Fig.: EVAP Leak Test diagram)*

1. **COMPENSATION GRADIENT MODE:** Both Canister Close Valve (CCV) and Canister Purge Solenoid Valve (PSV) CLOSE. System pressure rises due to fuel vapor pressure.

   Threshold values to set DTC P0440:

   - Fuel tank pressure: <-1.46 hPa in 4 Sec. (= -0.146 kPa = 0.043 in.Hg)
   - Fuel tank pressure: <-14.89 hPa in 25 Sec. (= -1.489 kPa = 0.439 in.Hg)
   - Fuel tank pressure variation: > 4.88 hPa in 20 Sec. (= 0.488 kPa = 0.07 PSI)

2. **BUILDING VACUUM:** Both Canister Close Valve (CCV) and Canister Purge Solenoid Valve (PSV) OPEN. The PSV Duty Cycle is increased to 100% (fully opening the valve). Engine intake manifold vacuum causes system pressure to drop below atmospheric pressure (vacuum builds).

   Threshold values to set DTC P0440:

   - Fuel tank pressure drop: <-1.95 hPa in 1.5 Sec. (= -0.195 kPa = 0.058 in.Hg)

3. **GROSS LEAK DETECTION MODE:** The Canister Close Valve (CCV) CLOSES, the Canister Purge Solenoid Valve (PSV) REMAINS OPEN and engine manifold vacuum causes EVAP system pressure to continue to drop. The RATE OF PRESSURE DROP is monitored to detect LARGE LEAKS.

   Threshold values to set DTC P0440:

   - Fuel tank pressure variation: > 0.24 hPa in 2 Sec. (= 0.024 kPa = 0.0035 PSI)
   - Fuel tank pressure: >-7.08 hPa in 9 Sec. (= -0.708 kPa = 0.209 in.Hg)
   - Gradient of fuel tank pressure: <0.55 hPa / Sec. (= 0.055 kPa/Sec. = 0.008 PSI/Sec.)

4. **SMALL LEAK DETECTION MODE:** Both Canister Close Valve (CCV) and Canister Purge Solenoid Valve (PSV) CLOSE when maximum vacuum level is reached. System is monitored for RATE OF PRESSURE RISE to detect small leaks.

   Fuel tank pressure: <-15.14 hPa (= -1.514 kPa = 0.447 in.Hg)
**EVAP Canister Purge Solenoid Valve (PSV)**

Valve is DUTY CYCLE CONTROLLED, is normally closed (NC) and opened when energized with system voltage (12V nominal). Testing: Disconnect vacuum hoses for testing. Remove electrical connector, valve should be closed (no air flow). Apply 12V, valve should open. In operation, valve is controlled by ECM duty cycle.

**EVAP Canister Close Valve (CCV)**

Valve is normally open (NO) and is closed when energized with system voltage (12V nominal). Testing: Measure CCV Resistance: 24 Ohms (±4 Ohms at 68 degrees F. (or) Disconnect vacuum hoses for testing. Remove electrical connector, valve should be open and permit flow. Apply 12V, valve should close. In operation, valve is closed by a signal from the ECM. (2001 Optima manual: A thin sheet if paper can be used to sense airflow into canister port when CCV is OPEN, engine idling, NOT.

**EVAP Fuel Tank Pressure Sensor (FTPS)**

Measures pressure differential between atmospheric pressure and tank pressure. Monitors pressure during EVAP Leak Test cycle.

**EVAP System Leak Test (Without Leak Detection Pump)**

Enabling Criteria:

- Runs Once per Drive Cycle
- Vehicle speed: 0
- Engine speed: idle
- ECT at startup: <= 150 degrees F
- IAT > 10.4 degrees F
- Battery Voltage > 10.9 V
- Time after startup: > 1015 Seconds (16.92 Min.) or Long Term Fuel Trim has stabilized and idle control system has passed diagnostic tests.
- Fuel tank pressure: < 15.14 hPa (= 1.514 kPa = 0.447 in.Hg = 0.2196 PSI)
- Fuel System Status: Closed Loop
### Emissions

<table>
<thead>
<tr>
<th>NORMAL OPERATION (NOT LEAK TESTING):</th>
<th>Purge Solenoid Valve (PSV)</th>
<th>Canister Close Valve (CCV)</th>
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<tbody>
<tr>
<td>Normal Mode</td>
<td>OFF (CLOSED)</td>
<td>OFF (OPEN to Fresh Air)</td>
</tr>
<tr>
<td>Purge Mode</td>
<td>ON (OPEN)</td>
<td>OFF (OPEN to Fresh Air)</td>
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<thead>
<tr>
<th>DURING LEAK TEST:</th>
<th>Purge Solenoid Valve (PSV)</th>
<th>Canister Close Valve (CCV)</th>
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</thead>
<tbody>
<tr>
<td>Compensation Gradient Mode (1*)</td>
<td>OFF (CLOSED)</td>
<td>ON (CLOSED)</td>
</tr>
<tr>
<td>Building Vacuum (2*)</td>
<td>ON (OPEN - DUTY CYCLE)</td>
<td>OFF (OPEN to Fresh Air)</td>
</tr>
<tr>
<td>Gross Leak Detection Mode (3*)</td>
<td>ON (OPEN)</td>
<td>ON (CLOSED)</td>
</tr>
<tr>
<td>Small Leak Detection Mode (4*)</td>
<td>OFF (CLOSED)</td>
<td>ON (CLOSED)</td>
</tr>
</tbody>
</table>

### DURING EVAP LEAK TEST:

1* COMPENSATION GRADIENT MODE - System pressure rises due to fuel vapor pressure.

2* BUILDING VACUUM - Engine intake manifold vacuum causes system pressure to drop below atmospheric pressure (vacuum builds).

3* GROSS LEAK DETECTION MODE - Engine manifold vacuum causes EVAP system pressure to continue to drop. The RATE OF PRESSURE DROP is monitored to detect LARGE LEAKS.

4* SMALL LEAK DETECTION MODE - Both Canister Close Valve (CCV) and Canister Purge Solenoid Valve (PSV) CLOSE when maximum vacuum level is reached. System is monitored for RATE OF PRESSURE RISE to detect small leaks.
**Systems with a Leak Detection Pump**

The latest KIA ECM-controlled EVAP systems use a Leak Detection Pump to monitor system integrity and check for leaks. The Pump pressurizes the EVAP system while its current draw is monitored. This value is compared to a baseline current value obtained during a calibrated reference leak test (using an orifice representing a leak measuring 0.5 mm (0.020 in. dia.). The ECM EVAP Monitor runs this leak test five hours after the end of a trip, key-off.

---

**EVAP Leak Test (with pump)**

- **Purge Solenoid Valve (PSV)** (normally closed)
- **Change-Over Valve** (normally open to fresh air)
- **Leak Detection Pump**

- **Reference Mode**
  - **Leak Detection Pump current draw**: 0 mA
  - **Pressurization Mode**
    - **(Open to fresh air)**
    - **(Closed to fresh air)**
    - **(On)**
    - **(Off)**

- **Current draw greater than reference mode.**
  - **No leak**
  - **Leak detected**

---

**Open** on duty cycle when purging (otherwise closed)

**Test ends**

**Leak detected**

Pump current draw less than or equal to reference mode.
When NOT running Leak Test:

In the **Normal Mode**, no voltage is applied to the Leak Test Air Pump, the Change-Over Valve or the Purge Solenoid Valve (PSV). The pump does not operate. The Change-Over Valve is OFF and allows fresh filtered air to enter or leave the Charcoal Canister as required. The PSV is OFF and CLOSED and no purge takes place.

During the **Purge Mode**, no voltage is applied to either the Leak Test Air Pump or Change-Over Valve. Voltage is applied to the Purge Solenoid Valve (PSV) and it is ON and OPEN on a DUTY CYCLE. Engine manifold vacuum draws in fresh filtered air through the Charcoal Canister to purge HC. This flow is controlled by the PSV duty cycle. The Change-Over Valve is OFF and allows fresh filtered air to enter the Charcoal Canister as required.

When RUNNING Leak Test:

During the **Reference Mode** and **System Pressurization Mode**, the Canister Purge Solenoid Valve (PSV) remains OFF and CLOSED throughout the entire Leak Test.

During the Reference Mode, no voltage is applied to the Change-Over Valve or the Purge Solenoid Valve (PSV). The Change-Over Valve is OFF (not powered) and OPEN. The Purge Solenoid Valve (PSV) is OFF and CLOSED. The Leak Detection Pump runs. Filtered air is drawn in and pumped through a 0.020 in. orifice. Pump current draw is monitored and stored as a baseline for comparison.

During the System Pressurization Mode, voltage is now applied to the Change-Over Valve and it is ON and CLOSED. The Purge Solenoid Valve (PSV) is OFF and CLOSED. The Leak Detection Pump continues to run. The Pump now pressurizes the closed EVAP System and Pump current draw is again monitored. If Pump current draw is equal to or less than measured during the Reference Mode, a leak equal to or greater than 0.020 in. (depending upon model) is assumed and the applicable DTC will be stored. Two trip logic applies.

**Note:**

See "KIA EVAP with Pump - System Modes & Component Status" chart.

**EVAP Canister Purge Solenoid Valve (PSV)**

Valve is DUTY CYCLE CONTROLLED, is normally closed (NC) and opened when energized with system voltage (12V nominal). Testing: Disconnect vacuum hoses for testing. Remove electrical connector, valve should be closed (no air flow). Apply 12V, valve should open. In operation, valve is controlled by ECM duty cycle.

**Diagnostic Module for Tank Leakage (DM-TL)**

Replaces the Canister Close Valve (CCV) and Fuel Tank Pressure Sensor (FTPS).

DM-TL consists of the following components: Leak Test Air Pump (electric), Change-Over Valve, Reference Orifice (0.020 in. dia.)
## EVAP System Leak Test (With Leak Detection Pump)

**Enabling Criteria:**

- Leak test runs no sooner than five hours after end of trip
- Engine ON time during last Drive Cycle: >20 min.
- Key OFF
- Vehicle speed: 0
- Engine speed: 0
- Fuel level: 15-85% of capacity
- Ambient air temp: 39-95 degrees F.
- Battery voltage: 11.5-14.5V
- Altitude: <8000 ft (=2500 m)
- Test is aborted if fuel level changes more than 1.3 gal. during test
- Test duration: 2.5-5 minutes

1* Normal vehicle operation - KOER, EVAP not purging. Same with key OFF.

2* Normal vehicle operation - KOER, EVAP purging.

3* EVAP Leak Test (Reference Mode) - Leak Detection Pump runs. Filtered air is drawn in and pumped through a 0.020 in. orifice. Pump current draw is monitored and stored as a baseline for comparison.

4* EVAP Leak Test (System Pressurization Mode) - Leak Detection Pump runs and pressurizes closed EVAP system. Pump current draw is measured and compared with baseline value.

<table>
<thead>
<tr>
<th>Normal Operation (NOT LEAK TESTING):</th>
<th>Normal Mode (1*)</th>
<th>Purge Mode (2*)</th>
<th>Reference Mode (3*)</th>
<th>System Pressurization Mode (4*)</th>
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</thead>
<tbody>
<tr>
<td>Purge Solenoid Valve</td>
<td>OFF (CLOSED)</td>
<td>OFF (OPEN to Fresh Air)</td>
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</tr>
<tr>
<td>Change-Over Valve</td>
<td>OFF (CLOSED)</td>
<td>OFF (OPEN to Fresh Air)</td>
<td>OFF (CLOSED)</td>
<td>OFF (CLOSED to Fresh Air)</td>
</tr>
<tr>
<td>Leak Detection Pump</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>ON</td>
</tr>
</tbody>
</table>
Electronic control of the throttle plate, or "fly by wire" systems are produced by several manufacturers and have several benefits. Electronic Throttle Systems can combine the capabilities of several discrete systems and can allow a reduction in component count. For example, a separate Idle Air Control (IAC) system can be eliminated as the ECM can manage idle speed directly with changes in throttle plate position. A separate Cruise Control system can also be eliminated as vehicle speed can be directly controlled by the ECM by means of throttle position. Traction and Stability Control Systems can also be integrated.

General Motors, Honda, Toyota, Mercedes, BMW, Saab, Jaguar, Volkswagen, Audi and Porsche are some of the manufacturers with electronic throttle control systems now in production. The Bosch ME 7 system used by several of these companies is a torque-based engine management system that uses Electronic Throttle Control. In this system, an Accelerator Pedal Position Sensor is used to provide torque demand input to the engine management computer. Since the ECM's control output to the throttle (and other actuators) is not necessarily linear, driveability and power can be improved for a given accelerator pedal position.
Variable Valve Mechanisms

Intake and exhaust events in a four-stroke gasoline engine do not take place continuously. Instead, gases must stop and start motion in order to flow into and out of the cylinder during the Intake and Exhaust Strokes. Since these processes must occur very rapidly at all engine speeds, the laws of physics and inertia become important and losses occur (at 3000 RPM, intake and exhaust events typically take place in less than 0.015 sec.). Valve overlap (having both intake and exhaust valves open simultaneously) is designed into most valve mechanisms to take advantage of the inertia of these gases.

In normally aspirated engines with fixed valve mechanisms, the valve timing, lift and duration do not vary over the engine’s RPM range and therefore Volumetric Efficiency (the ratio of the amount of air inducted vs the cylinder swept volume) can be optimized only for a very narrow RPM range. For optimized breathing at all engine speeds, the valve timing and duration must be varied.

Another source of inefficiency in gasoline engines is caused by pumping losses. Gas engines are air-throttled; engine speed is controlled by the opening of the throttle plate. In normal operation, the throttle plate is partially open and creates a restriction that reduces airflow. This effect creates manifold vacuum and the engine must work against this restriction.
To solve the above problems, there are engines now manufactured with variable valve timing and also more complex systems with variable timing, duration and lift. At higher engine RPM, longer duration and higher lift improve volumetric efficiency. The simplest systems vary only intake valve phasing or timing. Duration is not changed, but the camshaft is advanced or retarded relative to the crankshaft. Varying overlap allows for a "natural" EGR effect and eliminates the need for a separate EGR valve.

Manufacturers of engines with variable valve timing mechanisms include:

**Audi V8** - inlet, 2-stage discrete

**BMW Double Vanos** - inlet and exhaust, continuous

**Ferrari 360 Modena** - exhaust, 2-stage discrete

**Fiat (Alfa) SUPER FIRE** - inlet, 2-stage discrete

**Ford Puma 1.7 Zetec SE** - inlet, 2-stage discrete

**Jaguar AJ-V6 and updated AJ-V8** - inlet, continuous

**Lamborghini Diablo SV engine** - inlet, 2-stage discrete

**Porsche Variocam** - inlet, 3-stage discrete

**Renault 2.0-litre** - inlet, 2-stage discrete

**Toyota VVT-i** - inlet, continuous

**Volvo 4 / 5 / 6-cylinder modular engines** - inlet, continuous

BMW will be the first manufacturer to eliminate the throttle plate in a production engine. Production of the Valvetronic system is beginning in mid 2001 with the 316ti engine for the new 3 Series model. This system features infinitely variable intake valve duration and lift and entirely eliminates the need for a throttle plate. A second follower is placed between the conventional camshaft and valve actuator finger. By moving or repositioning the second follower, intake valve lift and duration can be greatly modified. Valve lift can vary between 0 - 9.7 mm in order to control the quantity of air inducted and engine speed. The engine is still air throttled, but its speed is now controlled by the intake valve lift and there is no manifold vacuum created.
**Electronic Valve Actuation**

After mechanically variable valve mechanisms, the next improvement in valve trains will be the elimination of the traditional camshaft and the introduction of Electronically Controlled Valve Systems. 36/42 Volt electrical systems will provide sufficient power to make solenoid valve actuation practical. These systems will at last remove the limitations of mechanical valve actuation and permit infinitely variable valve timing, duration and lift. Valve action can be ECM controlled for the specific operating conditions and the throttle plate can be eliminated, and valve action in each cylinder can be individually monitored and adjusted. Siemens currently has test engines running with electronically controlled valves.

**Electronic EGR**

Exhaust Gas Recirculation systems have been in use for more than three decades in an effort to reduce Oxides of Nitrogen emissions. Early systems were entirely mechanical using ported manifold vacuum to control the opening of the EGR valve. Frequently the only additional control was a Thermal Vacuum Switch which denied vacuum to the EGR valve during cold engine operation. Exhaust backpressure monitoring on a few systems allowed some tailoring of EGR flow rates to engine load, but these were still crude.

Hybrid EGR systems have been produced which still use manifold vacuum to operate the EGR valve but the ECM controls the vacuum signal to the valve. A solenoid operating on a duty cycle controls the magnitude of the vacuum signal to the valve and therefore the percentage of valve opening. Full electronic control of solenoid operated EGR valves will permit very close control of valve opening and EGR flow rates independent of variations in manifold vacuum.
36/42 Volt Electrical Systems

The increasing number of electronic and electrical controls and systems is driving the need for more available power or wattage. Presently automotive electrical systems are limited to under approximately 3000 watts of power. Increasing system voltage allows a proportional reduction in current requirements. Ohm's Law tells us that by tripling the voltage, current (amperage) is reduced by 2/3 if the power (wattage) remains the same. Vehicle weight can potentially be reduced with smaller gauge wire, as the current carried by the conductor determines the necessary wire gauge. Electric motors, fuel injectors and other solenoid-type components can be made smaller also. Electromagnetic valvetrains, integrated brushless flywheel mounted starter/generators, heated catalytic converters, electronic steering and brakes and electric coolant pumps will all be possible. Voltages under 60 volts are not expected to cause increased health risks, but battery terminal protection is essential to ensure that reverse polarity voltage cannot be applied.

Opel, Mercedes, BMW, PSA (Citroen & Peugeot), and Renault already have plans for 42-volt systems in vehicles as soon as 2003. Dual voltage systems and dual batteries (or a step-down circuit) will be used initially, as some components such as lighting work better with 12/14 Volts. Since the power to generate this voltage ultimately comes from the vehicle's fuel, these higher electrical outputs and requirements will reduce mileage.
**Variable Induction Systems**

Variable Intake or Induction Systems can have benefits similar to variable valve timing but at lower cost. Again, the inertia of the intake gases flowing in the intake manifold comes into play. These gases stop and start in the manifold as the intake valve opens and closes. A tuned or specific length manifold passage can use the natural frequency of the gas to improve and increase the amount of air inducted into the cylinder. Increasing or decreasing engine RPM changes the required effective length of the passages. Systems in production have two or more paths or lengths to deal with different engine speeds.

The 2002 Kia Sedona 3.5 liter Sigma V6 engine is equipped with a Variable Intake System (VIS). The PCM controls a Variable Intake Motor which positions a Shutter in the intake manifold. The Shutter has ten possible steps or positions depending on engine RPM. Intake air is provided a longer path at low RPM and a shorter path at high RPM. The Shutter begins to step at 3750 RPM and completes movement at 4750 RPM to boost low to medium speed torque.
New Technology

Gasoline Direct Injection

Recently introduced in some markets, the Gasoline Direct Injection engine design increases power and efficiency by injecting the fuel under extremely high pressure directly into the combustion chamber during the intake stroke. This timed, direct injection increases charge turbulence and swirl, improving mixture distribution. The high fuel system injection pressure results in finer atomization of the fuel promoting more complete vaporization prior to ignition. In-cylinder charge cooling reduces octane requirements, allowing a higher compression ratio to be used. Direct injection yields stratified charge combustion which is very tolerant of exhaust gas recirculation (EGR) and can result in ultra-lean burn mixtures under light load conditions. Overall benefits include increased efficiency and reduced fuel consumption and emissions.

Volvo's S40 series is now available with 1.8l direct Injection engines, the first European manufacturer to market. The 4-cylinder engine has been adapted from the Mitsubishi GDI engine which has been available for some time. This system switches between the ultra-lean combustion mode, with injection during the compression stroke, and a high output mode, with injection during the intake stroke. Mixtures as lean as 40:1 are claimed along with up to 20% decrease in fuel consumption and carbon dioxide emissions.
Broadband or Wide Range Oxygen Sensor

All OBD II vehicles use Oxygen Sensors for two purposes. Main (or Upper or Front) Oxygen Sensors provide a feedback signal to the ECM for air/fuel ratio control. Sub (or Down or Rear) Oxygen Sensors are used to check Catalytic Converter efficiency.

All Kia engines in current production, with one exception, use conventional Narrow Range Zirconium Dioxide (or Zirconia) Oxygen Sensors in both locations. Zirconia Oxygen Sensors are generators, producing a signal voltage between 0-1V in response to the oxygen level measured in the exhaust stream. A measured high oxygen level (which can indicate a mixture leaner than the ideal 14.7:1 air-fuel-ratio or Stoichiometry) will result in low Oxygen Sensor signal voltage output. A low oxygen level (richer than 14.7:1) will result in high Oxygen Sensor signal voltage output.

Narrow Range Oxygen Sensors do not output a linear response to changes in exhaust oxygen content. Rather, the Sensor’s voltage output goes sharply higher (to around 850 mV) when little oxygen is sensed (indicating a mixture richer than Stoichiometry), and conversely the voltage output goes sharply lower (to around 175 mV) when much oxygen is sensed (indicating a mixture leaner than Stoichiometry). Since the computer cannot tell HOW rich or lean the mixture is, it constantly corrects the mixture lean-rich-lean-rich, striving for equal rich and lean swings on either side of the ideal air/fuel ratio. These are sometimes referred to as “jump” sensors due to this jump in voltage.
Kia uses Titanium Dioxide (or Titania) Oxygen Sensors in place of Zirconia Sensors in the 2001 Optima 2.5l V6 engine (with Siemens ECM). Titania Sensors are also Narrow Range Sensors and provide oscilloscope waveforms very similar to Zirconia Sensors. Titania Sensors, however, are not generators, but are variable resistors and are supplied a 5 V reference voltage. For Titania type sensors, the maximum Signal Voltage should be > 4.0 V and the minimum Signal Voltage should be < 0.5 V.

The Broadband Heated Oxygen Sensor is a new generation of oxygen sensor which is used "upstream" from the catalytic converter for air-fuel ratio control. As the mixture richens or leans, the change in oxygen content in the exhaust causes the broadband oxygen sensor to modify an ECM-supplied current. This change in current flow is almost linear and can be used by the ECM to identify the oxygen content and therefore the air-fuel ratio. Inside the sensor, this current is used to pump exhaust gas across a sensing cell and allows the oxygen content value to be measured over a larger range of air-fuel mixtures.

A conventional Narrow Range Oxygen Sensor is still used "downstream" from the catalytic converter to check catalyst efficiency.
Conventional Narrow Range Oxygen Sensor

The key element is a ceramic body which is coated on both sides, creating a Nernst Cell. This coating takes over the function of electrodes, where one electrode layer comes into contact with external air and the other with the exhaust. A voltage difference is established between the electrodes by differing concentrations of oxygen in the external air and the exhaust. This voltage will be evaluated for determination of the lambda value in the engine control unit.

Wide Range or Broadband Oxygen Sensor

The Wide Range or Broadband Sensor also produces a voltage difference with the help of two electrodes, which are also in contact with external air and with the exhaust. This Sensor differs in that the voltage of the electrodes is kept constant by the ECM. This process is carried out by a miniature pump (pump cell) which supplies the electrodes on the exhaust side with enough oxygen to ensure that the voltage between the electrodes remains a constant 450 mV. The current consumption of the pump is interpreted by the ECM into an air-fuel ratio value.
New Technology

Electronically Mapped Cooling Systems

Traditional cooling systems use a heat-sensing mechanical thermostat to control coolant flow and maintain a specific coolant operating temperature. However, optimum engine operating temperature can vary depending on the engine design and operating conditions. Higher cooling system operating temperatures reduce emissions and increase engine efficiency during low load/part throttle conditions, while lower cooling system temperatures are desirable during high load/full throttle. Also, all mechanical thermostat designs respond "after the fact" in reaction to a change in coolant temperature that has already occurred.

In an electronic or "mapped" cooling system, the thermostat is replaced by an electronic flow control valve managed by the ECM. The ECM monitors parameters such as throttle opening and ambient temperature and then consults Look-Up Tables or Maps to correctly position the flow control valve. Mapped cooling systems can "forecast" the onset of rising coolant temperature and reposition the control valve rather than simply reacting to a change in coolant temperature.

Mapped cooling can also vary the "optimum temperature" based upon instantaneous operating conditions. Under light load conditions such as urban driving, for example, mapped cooling allows the engine to heat up faster, reducing emissions, increasing fuel efficiency and heating the passenger compartment more quickly in cold weather.
Continuously Variable Transmission (CVT)

In today's typical gasoline powered vehicle, the transmission must perform several jobs. Both manual and automatic transmissions provide gear reduction ratios to allow the wheels turn much more slowly than the engine at low road speeds, and they must multiply torque to improve vehicle performance and acceleration. Engines have a rather narrow useful RPM range of operation for both long engine life and reasonable torque. A typical engine's useful RPM range might only be 2000-4000 RPM, but the vehicle may be designed for road speeds ranging from zero to well over one hundred miles per hour. Therefore, the transmission must change the engine's (or transmission input) speed to match the requirements for the driveline (or transmission output) speed.

Gear ratios provided in conventional manual and automatic transmissions provide a finite number of ratios in discrete steps or increments. The number of ratios has typically varied from two to six, depending upon transmission type, age and cost. More ratios in the transmission can provide smaller steps and a smaller change in engine RPM when the shift occurs, allowing the engine to operate in its optimum RPM range more of the time, but the engine RPM still changes quickly and drastically when a shift occurs. Emissions can be significantly reduced by running the engine as close as possible to constant speed and load.

A Continuously Variable Transmission (CVT) changes ratios infinitely and without steps. One common design employs variable width pulleys and a link type chain or belt. When the input pulley diameter gradually decreases and the output pulley diameter increases, the transmission gradually "upshifts" from high reduction starting ratios to direct or overdrive cruising ratios. Reduced emissions, better economy and smoother operation result.
**Glossary**

**Actuator**
A device which converts an electrical signal (output) from the ECM to perform a mechanical action. Example: fuel injector, idle air control valve.

**A/D Converter**
Analog-to-Digital converter; an electronic circuit that converts analog input signals to digital signals that are compatible with computer circuitry.

**Air/Fuel Ratio**
The quantity of air inducted in the engine as compared with the quantity of fuel. See Stoichiometry.

**Ambient Temperature**
The temperature of the surrounding air.

**Analog Circuit**
An electronic circuit that alters a voltage reference to produce a continuously variable voltage signal in response to a changing physical condition.

**Bottom Dead Center**
In an engine, when the piston is at its lowest point of travel in the cylinder, abbreviated BDC.

**Break Out Box**
A test interface that connects between the vehicle ECM and chassis wiring harness. Once installed it permits easily accessible test points for all major engine management system circuits.

**CAFE**
Corporate Average Fuel Economy; the annual model year fuel economy average for all automobiles produced by a manufacturer.

**CARB**
California Air Resources Board; has led efforts to control and reduce levels of air pollution. CARB rulings created OBD and OBD II standards.

**Catalyst**
A material which promotes or accelerates a chemical reaction without being significantly altered or used up in that reaction.

**Catalytic Converter**
A device which reduces pollution in engine exhaust gases by promoting oxidation and/or reduction reactions.

**CKP**
Crankshaft Position sensor; provides a signal to the ECM for engine RPM and misfire detection.

**Closed Loop Control**
A mode of operation during which the ECM receives a feedback signal from an oxygen sensor as a reference for air-fuel ratio control.
CMP
Camshaft Position sensor; provides a signal to the ECM for cylinder no.1 reference and synchronization.

Combustion
The controlled burning of the air-fuel mixture in the engine cylinder.

Compression Ratio
In an engine, the ratio of BDC cylinder volume to TDC cylinder volume.

CO
Carbon Monoxide; a byproduct of incomplete combustion in an internal combustion engine. It is odorless and can cause suffocation by displacing oxygen. In an engine, high levels of CO can indicate a rich mixture.

CO2
Carbon Dioxide; in an engine, high levels of CO2 can indicate efficient combustion.

Communication Protocol
The communications standards or language used to permit the ECM and Scan Tool to communicate. Currently there are four OBD II communications protocols: VPW, PWM, ISO 9141-2 and KWP. Kia vehicles use either ISO 9141-2 or KWP.

CPU
Central Processing Unit; the section of a computer where calculations take place.

Current Data
Scan tool display of engine management system parameters in real time.

Detonation
In an engine, a condition where the air-fuel mixture does not burn normally and progressively, but explodes uncontrolled. This condition creates very high pressures and temperatures and can cause serious damage.

Digital Circuit
An electronic circuit that alters a voltage reference to produce a voltage signal in discrete steps in response to a changing physical condition.

Displacement
A measure of engine size; the swept volume of all cylinders or the volume of the space defined between the piston TDC and BDC positions times the number of cylinders.

DLC
Data Link Connector; common name for a diagnostic connector.

Drive Cycle
Specific driving requirements (speeds, time, temperature, gears, etc.) necessary in order to set OBD II system monitors to the ready state.

DTC
Diagnostic Trouble Code; information stored in the vehicle ECM which defines a possible fault to help in diagnosis.
Duty Cycle
The period of time that a component is switched on or activated, expressed in percent.

ECM
Engine Control Module; the computer responsible for engine management and control decisions. The ECM usually controls fuel delivery, idle speed and ignition timing and possibly other systems.

ECT
Engine Coolant Temperature sensor; usually a negative temperature coefficient sensor providing an analog signal which varies with changes in engine coolant temperature.

EGR
Exhaust Gas Recirculation; the introduction of a controlled quantity of engine exhaust gases back into the intake system to dilute the incoming air-fuel mixture. EGR helps reduce NOx emissions.

Evaporative Emissions
Hydrocarbons (unburned fuel or HC) which evaporates from the fuel tank and system into the atmosphere. These emissions are reduced by the vehicle EVAP system.

False Trouble Codes
A diagnostic trouble code that is set when a non-existent fault is detected.

Freeze Frame
A snapshot of system conditions present at the instant that a trouble code is set. Freeze frame data is stored in the vehicle ECM.

Fuel Injector (Electronic)
A solenoid-type actuator which is controlled by the ECM to deliver the correct quantity of finely atomized fuel with the incoming air charge.

Generic Codes
Standardized OBD II diagnostic trouble codes that have uniform definitions and numbers by law. These DTCs can be identified by “0” in the second digit. See Manufacturers Specific Codes.

Hall Effect Sensor
A magnetically switched solid state integrated circuit which modifies a reference voltage and outputs a digital signal. The signal strength of a Hall sensor does not vary with changing RPM or speed.

Hard Code
A trouble code in ECM memory that illuminates the MIL. Also known as a Mature Code.

HC
Hydrocarbons; unburned fuel. In an engine, high HC can indicate the presence of misfire or excessively rich or lean mixture. HC contributes to photochemical smog, respiratory and eye problems and irritation.

IAT
Intake Air Temperature sensor; usually a Negative Temperature Coefficient sensor providing an analog signal which varies with changes in intake air temperature.
**Ignition Timing**
The firing of the spark plug relative to the position of the crankshaft and piston on the cycle (also known as Spark Timing).

**KAM**
Keep Alive Memory; computer RAM which is continuously powered to maintain memory. If power is interrupted any adaptations or data stored in KAM will be erased.

**KNK**
Knock sensor; detects engine knocking, ping or detonation. ECM retards ignition timing in response to prevent internal damage.

**KOER**
The key on engine running condition.

**KOEO**
The key on engine off condition.

**Long Term Fuel Trim or LTFT**
A system adaptation to the calculated fuel delivery by the ECM. LTFT is a slow response to the oxygen sensor input and is only active at all times. LTFT shifts in order to allow Short Term Fuel Trim to return to near-zero adaptation.

**Look Up Table**
A matrix of stored values in ROM which are referenced by the ECM to control actuators.

**MAF**
Mass Airflow sensor; a sensor that can measure the mass of incoming air in the engine’s intake system. MAF sensors are self-compensating for variations in altitude and air density. Hot wire, hot film and Karman vortex sensors are MAF types.

**Magnetic Pulse Sensor**
A two wire device which generates a small voltage signal through electromagnetic induction. The signal is analog and varies with changing RPM or speed.

**Main or Up Oxygen Sensor**
Oxygen sensor placed ahead of the catalytic converters to provide feedback information to the ECM for air/fuel ratio control.

**Manufacturers Specific Codes**
Non-standardized OBD II diagnostic trouble codes that are individually assigned and defined by each vehicle manufacturer. These DTCs do not have uniform definitions and code numbers and are identified by a “1” in the second digit. See Generic Codes.

**MAP**
Manifold Absolute Pressure; the absolute pressure in the intake manifold, or pressure compared to a pure vacuum. Absolute atmospheric pressure at sea level = 14.7 psi = 101 kPa = 1 bar.

**Mature Code**
A trouble code in ECM memory that illuminates the MIL. Also known as a Hard Code.
MIL
Malfunction Indicator Light or check engine light. The dash indicator that illuminates to warn the driver of the presence of a DTC and possible emissions related failure.

Misfire
An engine condition in which the air/fuel charge in the cylinder does not burn. This event raises pollution levels, especially HC, and can cause catalytic converter damage.

Monitors
OBD II fault detection circuits which verify correct operation of sensors and actuators.

Negative Temperature Coefficient or NTC
In electricity, a conductor has a negative temperature coefficient when its resistance varies inversely with its temperature. See PTC.

NOT
Normal operating temperature; the stabilized warm operating temperature of an engine.

NOx
Oxides of Nitrogen; produced when combustion temperatures in the cylinder exceed 2500 degrees F. NOx contributes to photochemical smog, respiratory and eye problems and irritation.

OBD
On Board Diagnostics; a legislated standard for engine management systems that provides for self-diagnosis capability, fault warning to the driver and storage of diagnostic information. OBD II is a refinement and was a requirement for all 1996 and newer passenger automobiles.

Open Loop Control
A mode of operation during which the ECM does not receive a feedback signal from an oxygen sensor as a reference for air-fuel ratio control. In this mode, the ECM manages air-fuel ratio with stored values.

Oxygen Sensor
Sensors placed in the exhaust stream and sense oxygen content in the engine exhaust. See Main or Up Oxygen sensor and Sub or Down Oxygen sensor.

Pending Code
A two-trip logic trouble code stored in ECM memory temporarily after the first occurrence. The ECM waits to see if the same fault is detected on the next trip. If it is detected, the code becomes a Hard code and the MIL is illuminated. Also known as a Soft Code.

Preignition
In an engine, the ignition of the air-fuel charge in the cylinder before the spark plug fires. Preignition can lead to detonation.

PCM
Powertrain Control Module; the computer responsible for engine and drivetrain management and control decisions. The ECM usually controls fuel delivery, idle speed, ignition timing and transmission shifting and possibly other systems.
Positive Temperature Coefficient or PTC
In electricity, a conductor has a positive temperature coefficient when its resistance varies directly with its temperature. See NTC.

RAM
Random Access Memory; a type of read/write memory in the ECM that is volatile or non-permanent. RAM is erased when power is interrupted.

ROM
Read Only Memory; permanent type of computer memory used to store programs or instructions or look up table data.

SAE J1930
Society of Automotive Engineers standard defining the OBD II terms, definitions and acronyms.

SAE J1962
Society of Automotive Engineers standard defining the OBD II connector design, location, terminal assignments and electronic interface requirements.

SAE J2012
Society of Automotive Engineers standard defining OBD II diagnostic trouble code definitions and structure.

Scan Tool
A tester capable of two-way communications with the vehicle ECM and which can perform all required OBD II functions.

Sensor
A device which sends an electrical signal to the ECM in response to a physical condition. Example: throttle position sensor, intake air temperature sensor.

Short Term Fuel Trim or STFT
A system adaptation to the calculated fuel delivery by the ECM. STFT is an instantaneous response to the oxygen sensor input, and STFT is only active during closed loop operation.

SO2
Sulfur Dioxide; a colorless gas with a rotten egg odor, created when sulfur in gasoline combines with oxygen in the catalytic converter.

Soft Code
A two-trip logic trouble code stored in ECM memory temporarily after the first occurrence. The ECM waits to see if the same fault is detected on the next trip. If it is detected, the code becomes a Hard code and the MIL is illuminated. Also known as a Pending Code.

Spark Timing
The firing of the spark plug relative to the position of the crankshaft and piston on the cycle (also Ignition Timing).

Speed Density
A type of fuel injection system which uses engine RPM and manifold vacuum (or pressure) as the main inputs to determine fuel quantity.
**Stoichiometry**
The theoretically correct proportion or amount of air for a given quantity of fuel for complete combustion with no excess air or fuel remaining. For gasoline, stoichiometry = 14.7 parts air to 1 part fuel by weight, or 9000 parts air to 1 part fuel by volume.

**Sub or Down Oxygen Sensor**
Oxygen sensor placed after the catalytic converters to monitor catalyst efficiency.

**System Authority**
The hierarchy of sensor influence on the engine management system decisions for a given set of operating conditions.

**Titania Oxygen Sensor**
Oxygen sensor using a titanium dioxide element. A variable resistor, modifying a reference voltage in response to exhaust oxygen content.

**Top Dead Center**
In an engine, when the piston is at its highest point of travel in the cylinder, abbreviated TDC.

**TPS**
Throttle Position sensor; provides throttle opening signal to the ECM, and may also provide closed-throttle and/or WOT information to the ECM.

**Trip**
Vehicle operation after an engine-off period that is long enough so that all components and systems are monitored.

**Two Trip Logic**
Trouble codes that illuminate the MIL only if the defect is detected on two consecutive trips.

**Volumetric Efficiency**
The engine’s pumping efficiency, or the quantity of air drawn into the cylinder compared to the theoretical maximum amount (engine displacement).

**VSS**
Vehicle Speed sensor; provides a signal to the ECM for vehicle road speed. Used for both engine management and automatic transmission shift functions.

**WOT**
Wide open throttle.

**Zirconia Oxygen Sensor**
Oxygen sensor using a zirconium dioxide element. A generator, producing a signal 0-1V which varies with exhaust oxygen content.
# KIA OBD-II

## Posttest Answer Sheet

**Name:** ____________________________  **Date:** __________

Record the answers to the questions by blackening the letter of your choice for each question. Fill in blanks where appropriate. DO NOT CIRCLE THE LETTERS!

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