



***ADVANCED
ENGINE PERFORMANCE
SPECIALIST TEST (L1)***

***COMPOSITE VEHICLE TYPE 3
REFERENCE BOOKLET***

This booklet is intended only for reference when preparing for and taking the ASE Advanced Engine Performance Specialist Test. The composite vehicle type 3 powertrain control system is based on designs common to many vehicle manufacturers, but is not identical to any actual production vehicle.

GENERAL DESCRIPTION

This generic four cycle, V6 engine has four overhead chain-driven camshafts, 24 valves, distributorless ignition, and a mass airflow-type closed-loop sequential multiport fuel injection system. The Engine Control Module (ECM) receives input from sensors, calculates ignition and fuel requirements, and controls engine actuators to provide the desired driveability, fuel economy, and emissions control. The ECM also controls the vehicle's charging system. The powertrain control system has OBD II-compatible sensors and diagnostic capabilities. The ECM receives power from the battery and ignition switch and provides a regulated 5 volt supply for most of the engine sensors. The engine is equipped with a single exhaust system and a three-way catalytic converter, without any secondary air injection. Engine control features include variable valve timing, electronic throttle actuator control (TAC), a data communications bus, a vehicle anti-theft immobilizer system, and on-board refueling vapor recovery (ORVR) EVAP components. The control system software and OBD II diagnostic procedures stored in the ECM can be updated using factory supplied calibration files and PC-based interface software, along with a reprogramming device or scan tool that connects the PC to the vehicle's data link connector (DLC).

AUTOMATIC TRANSMISSION

- Four-speed automatic overdrive transaxle, with shifting controlled by a transmission control module (TCM). The TCM communicates with the ECM and other modules through the data bus.
- The TCM provides its own regulated 5 volt supply, performs all OBD II transaxle diagnostic routines, and stores transaxle diagnostic trouble codes (DTCs). The control system software and OBD II diagnostic procedures stored in the TCM can be updated in the same way as the ECM.
- Failures that result in a pending or confirmed DTC related to any of the following components will cause the TCM to default to fail-safe mode: range switch, shift solenoids, turbine shaft speed sensor, and the vehicle speed sensor. The TCM will also default to fail-safe mode if it is unable to communicate with the ECM.
- When in fail-safe mode, maximum line pressure will be commanded, the transmission will default to 2nd gear, and the torque converter clutch will be disabled.

FUEL SYSTEM

- Sequential Multiport Fuel Injection (SFI)
- Returnless Fuel Supply with electric fuel pump mounted inside the fuel tank
- Fuel pressure is regulated to a constant 50 psi (345 kPa) by a mechanical regulator in the fuel tank. Minimum acceptable fuel pressure is 45 psi (310 kPa). The fuel system should maintain a minimum of 45 psi (310 kPa) for two minutes after the engine is turned off.

IGNITION SYSTEM

- Distributorless Ignition (EI) with six ignition coils (coil-on-plug)
- Firing Order: 1-2-3-4-5-6
- Cylinders 1, 3, and 5 are on Bank 1, Cylinders 2, 4, and 6 are on Bank 2
- Ignition timing is not adjustable
- Timing is determined by the ECM using the crankshaft position (CKP) sensor signal
- The ignition coil drivers are integrated into the ECM

VARIABLE VALVE TIMING

- Intake camshaft timing is continuously variable using a hydraulic actuator attached to the end of each intake camshaft. Engine oil flow to each hydraulic actuator is controlled by a camshaft position actuator control solenoid. Exhaust camshaft timing is fixed.

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- A single timing chain drives both exhaust camshafts and both intake camshaft hydraulic actuators. While valve overlap is variable, valve lift and duration are fixed.
 - Cam timing is determined by the ECM using the crankshaft position (CKP) sensor and camshaft position sensor (CMP 1 and CMP 2) signals. At idle, the intake camshafts are fully retarded and valve overlap is zero degrees. At higher speeds and loads, the intake camshafts can be advanced up to 40 crankshaft degrees.
 - Each intake camshaft has a separate camshaft position sensor, hydraulic actuator, and control solenoid. If little or no oil pressure is received by a hydraulic actuator (typically at engine startup, at idle speed, or during a fault condition), it is designed to mechanically default to the fully retarded position (zero valve overlap), and is held in that position by a spring-loaded locking pin.

ELECTRONIC THROTTLE CONTROL

- The vehicle does not have a mechanical throttle cable, a cruise control throttle actuator, or an idle air control (IAC) valve. Throttle opening at all engine speeds and loads is controlled directly by a throttle actuator control (TAC) motor mounted on the throttle body housing.
- Dual accelerator pedal position (APP) sensors provide input from the vehicle operator, while the actual throttle angle is determined using dual throttle position (TP) sensors.
- If one APP sensor or one TP sensor fails, the ECM will turn on the malfunction indicator lamp (MIL) and limit the maximum throttle opening to 35%. If any two (or more) of the four sensors fail, the ECM will turn on the MIL and disable the electronic throttle control.
- In case of failure of the electronic throttle control system, the system will default to limp-in operation. In limp-in mode, the spring-loaded throttle plate will return to a default position of 15% throttle opening, and the TAC value on the scan tool will indicate 15%. This default position will provide a fast idle speed of 1400 to 1500 rpm, with no load and all accessories off.
- Normal no-load idle range is 850 to 900 rpm at 5% to 10% throttle opening.
- No idle relearn procedure is required after component replacement or a dead battery.

DATA COMMUNICATIONS BUS

- The serial data bus is a high-speed, non-fault tolerant, two wire twisted pair communications network. It allows peer-to-peer communications between various electronic modules, including the engine control module (ECM), transmission control module (TCM), instrument cluster (including the MIL), immobilizer control module, and a scan tool connected to the data link connector (DLC).
- The Data-High circuit switches between 2.5 (rest state) and 3.5 volts (active state), and the Data-Low circuit switches between 2.5 (rest state) and 1.5 volts (active state). The data bus has two 120 ohm terminating resistors: one inside the instrument cluster, and another one inside the ECM.
- Any of the following conditions will cause the data communications bus to fail and result in the storage of network DTCs: either data line shorted to power, to ground, or to the other data line.
- The data bus will remain operational when one of the two modules containing a terminating resistor is not connected to the network. The data bus will fail when both terminating resistors are not connected to the network.
- Data communication failures do not prevent the ECM from providing ignition and fuel control.

IMMOBILIZER ANTI-THEFT SYSTEM

- When the ignition switch is turned on, the immobilizer control module sends a challenge signal through the antenna around the ignition switch to the transponder chip in the ignition key. The transponder key responds with an encrypted key code. The immobilizer control module then decodes the key code and compares it to the list of registered keys.
- When the engine is started, the ECM sends a request to the immobilizer control module over the data bus to verify the key validity. If the key is valid, the immobilizer control module responds with

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- a “valid key” message to the ECM to continue normal engine operation.
 - If an attempt is made to start the vehicle with an invalid ignition key, the immobilizer control module sends a message over the data bus to the instrument cluster to flash the anti-theft indicator lamp. If the ECM does not receive a “valid key” message from the immobilizer control module within 2 seconds of engine startup, the ECM will disable the fuel injectors to kill the engine. Cycling the key off and cranking the engine again will result in engine restart and stall.
 - The immobilizer control module and ECM each have their own unique internal ID numbers used to encrypt their messages, and are programmed at the factory to recognize each other. If either module is replaced, the scan tool must be used to program the replacement module, using the VIN, the date, and a factory-assigned PIN number.
 - Up to eight keys can be registered in the immobilizer control module. Each key has its own unique internal key code. If only one valid key is available, or if all keys have been lost, the scan tool can be used to delete lost keys and register new keys. This procedure also requires the VIN, the date, and a factory-assigned PIN number.
 - Neither the ECM, TCM, nor the immobilizer control module prevent operation of the starter motor for anti-theft purposes.

ON-BOARD REFUELING VAPOR RECOVERY (ORVR) EVAP SYSTEM

- The on-board refueling vapor recovery EVAP system causes fuel tank vapors to be directed to the EVAP charcoal canister during refueling, so that HC vapors do not escape into the atmosphere.
- The following components have been added to the traditional EVAP system for ORVR capability: a one inch I.D. fill pipe, a one-way check valve at the bottom of the fill pipe, a fuel vapor control valve inside the fuel tank, and a ½ inch I.D. vent hose from the vapor control valve to the canister.
- The fuel vapor control valve has a float that rises to seal the vent hose when the fuel tank is full. It also prevents liquid fuel from reaching the canister and blocks fuel from leaking in the event of a vehicle roll-over.

SENSORS

• MASS AIRFLOW (MAF) SENSOR

Senses airflow into the intake manifold. The sensor reading varies from 0.2 volts (0 gm/sec) at key-on, engine-off, to 4.8 volts (175 gm/sec) at maximum airflow. At sea level, no-load idle (850 rpm), the sensor reading is 0.7 volts (2.0 gm/sec). Located on the air cleaner housing.

• MANIFOLD ABSOLUTE PRESSURE (MAP) SENSOR

Senses intake manifold absolute pressure. The MAP sensor signal is used by the ECM for OBD II diagnostics only. The sensor reading varies from 4.5 volts at 0 in. Hg vacuum / 101 kPa pressure (key on, engine off, at sea level), to 0.5 volts at 24 in. Hg vacuum / 20.1 kPa pressure. At sea level, no-load idle with 18 in. Hg vacuum (40.4 kPa absolute pressure), the sensor reading is 1.5 volts. Located on the intake manifold.

• ENGINE COOLANT TEMPERATURE (ECT) SENSOR

A negative temperature coefficient (NTC) thermistor that senses engine coolant temperature. The sensor values range from -40°F to 248°F (-40°C to 120°C). At 212°F (100°C), the sensor reading is 0.46 volts. Located in the engine block water jacket.

• INTAKE AIR TEMPERATURE (IAT) SENSOR

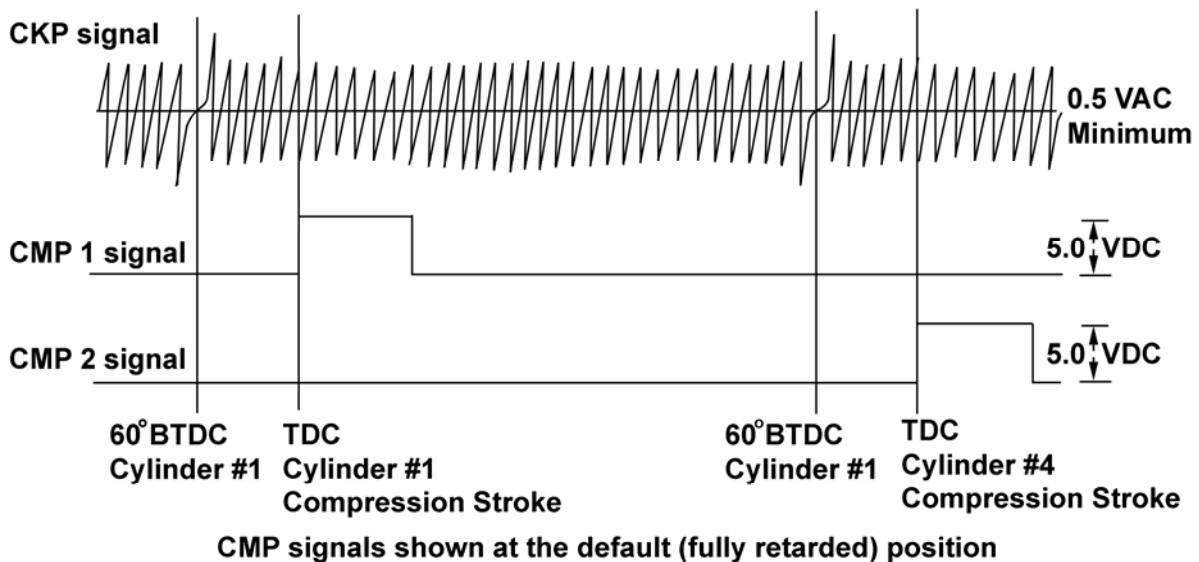
A negative temperature coefficient (NTC) thermistor that senses air temperature. The sensor values range from -40°F to 248°F (-40°C to 120°C). At 86°F (30°C), the sensor reading is 2.6 volts. Located in the air cleaner housing.

- **CRANKSHAFT POSITION (CKP) SENSOR**

A magnetic-type sensor that generates 35 pulses for each crankshaft revolution. It is located on the front engine cover, with a 35-tooth reluctor wheel mounted on the crankshaft just behind the balancer pulley. Each tooth is ten crankshaft degrees apart, with one space for a “missing tooth” located at 60 degrees before top dead center of cylinder number 1.

- **CAMSHAFT POSITION SENSORS (CMP 1 AND CMP 2)**

A pair of three-wire solid state (Hall-effect or optical-type) sensors that generate a signal once per intake camshaft revolution. The leading edge of the bank 1 CMP signal occurs on the cylinder 1 compression stroke, and the leading edge of the bank 2 CMP signal occurs on the cylinder 4 compression stroke. When the intake camshafts are fully retarded (zero valve overlap), the signals switch at top dead center of cylinders 1 and 4. When the intake camshafts are fully advanced (maximum valve overlap), the signals switch at 40 crankshaft degrees before top dead center. These signals allow the ECM to determine fuel injector and ignition coil sequence, as well as the actual intake valve timing. Loss of one CMP signal will set a DTC, and valve timing will be held at the fully retarded position (zero valve overlap). If neither CMP signal is detected during cranking, the ECM will store a DTC and disable the fuel injectors, resulting in a no-start condition. Located at the rear of each valve cover, with an interrupter mounted on the intake camshafts to generate the signal. The following diagram shows the CKP and CMP sensor signal waveforms with the camshafts at the default (fully retarded) position.



- **THROTTLE POSITION (TP 1 AND TP 2) SENSORS**

A pair of redundant non-adjustable potentiometers that sense throttle position. The TP 1 sensor signal varies from 4.5 volts at closed throttle to 0.5 volts at maximum throttle opening (decreasing voltage with increasing throttle position). The TP 2 sensor signal varies from 0.5 volts at closed throttle to 4.5 volts at maximum throttle opening (increasing voltage with increasing throttle position). Failure of one TP sensor will set a DTC and the ECM will limit the maximum throttle opening to 35%. Failure of both TP sensors will set a DTC and cause the throttle actuator control to be disabled, and the spring-loaded throttle plate will return to the default 15% position (fast idle). Located on the throttle body.

- **ACCELERATOR PEDAL POSITION (APP 1 AND APP 2) SENSORS**

A pair of redundant non-adjustable potentiometers that sense accelerator pedal position. The APP 1 sensor signal varies from 0.5 volts at the released pedal position to 3.5 volts at maximum pedal depression (increasing voltage with increasing pedal position). The APP 2 sensor signal varies from 1.5 volts at the released pedal position to 4.5 volts at maximum pedal depression (increasing voltage with increasing pedal position, offset from the APP 1 sensor signal by 1.0 volt). The ECM interprets an accelerator pedal position of 80% or greater as a request for wide open throttle. Failure of one APP sensor will set a DTC and the ECM will limit the maximum throttle opening to 35%. Failure of both APP sensors will set a DTC and cause the throttle actuator control to be disabled, and the spring-loaded throttle plate will return to the default 15% position (fast idle). Located on the accelerator pedal assembly.

- **EGR VALVE POSITION SENSOR**

A three-wire non-adjustable potentiometer that senses the position of the EGR valve pintle. The sensor reading varies from 0.50 volts when the valve is fully closed to 4.50 volts when the valve is fully opened. Located on top of the EGR valve.

- **KNOCK SENSOR**

A two-wire piezoelectric sensor that generates an AC voltage spike when engine vibrations within a specified frequency range are present, indicating spark knock. The signal is used by the ECM to retard ignition timing when spark knock is detected. The sensor signal circuit normally measures 2.5 volts DC with the sensor connected. Located in the engine block.

- **HEATED OXYGEN SENSORS (HO2S 1/1, HO2S 2/1, AND HO2S 1/2)**

Electrically heated zirconia sensors that measure oxygen content in the exhaust stream. Sensor 1/1 is located on the Bank 1 exhaust manifold (cylinders 1, 3 and 5). Sensor 2/1 is located on the Bank 2 exhaust manifold (cylinders 2, 4, and 6). Both upstream sensor signals are used for closed loop fuel control and OBD II monitoring. Sensor 1/2 is mounted in the exhaust pipe after the catalytic converter (downstream). Its signal is used for OBD II monitoring of catalytic converter operation. The sensor outputs vary from 0.0 to 1.0 volt. When a sensor reading is less than 0.45 volts, oxygen content around the sensor is high; when a sensor reading is more than 0.45 volts, oxygen content around the sensor is low. No bias voltage is applied to the sensor signal circuits by the ECM. With the key on and engine off, the sensor readings are zero volts. Battery voltage is continuously supplied to the oxygen sensor heaters whenever the ignition switch is on. The ECM will provide the ground for both of the upstream oxygen sensor heaters as soon as the engine starts. Once the engine is started, the ECM will then provide the ground for the downstream oxygen sensor heater after two minutes of continuous engine operation.

- **POWER STEERING PRESSURE (PSP) SWITCH**

A switch that closes when high pressure is detected in the power steering system. The signal is used by the ECM to adjust throttle position to compensate for the added engine load from the power steering pump. Located on the P/S high pressure hose.

- **BRAKE PEDAL POSITION (BPP) SWITCH**

A switch that closes when the brake pedal is depressed (brakes applied). The signal is used by the TCM to release the torque converter clutch. Located on the brake pedal.

- **A/C ON/OFF REQUEST SWITCH**

A switch that is closed by the vehicle operator to request A/C compressor operation. Located in the climate control unit on the instrument panel.

- **A/C PRESSURE SENSOR**

A three-wire solid-state sensor for A/C system high-side pressure. The sensor reading varies from 0.25 volts at 25 psi to 4.50 volts at 450 psi. The signal is used by the ECM to control the A/C compressor clutch, radiator fan, and to adjust throttle position to compensate for the added engine load from the A/C compressor. The ECM will also disable compressor operation if the pressure is below 40 psi or above 420 psi. Located on the A/C high side vapor line.

- **FUEL LEVEL SENSOR**

A potentiometer that is used to determine the fuel level. The reading varies from 0.5 volts / 0% with an empty tank to 4.5 volts / 100% with a full tank. When the fuel tank is $\frac{1}{4}$ full, the sensor reading is 1.5 volts. When the fuel tank is $\frac{3}{4}$ full, the sensor reading is 3.5 volts. Used by the ECM when testing the evaporative emission (EVAP) system. Located in the fuel tank.

- **FUEL TANK (EVAP) PRESSURE SENSOR**

Senses vapor pressure or vacuum in the evaporative emission (EVAP) system compared to atmospheric pressure. The sensor reading varies from 0.5 volts at 1/2 psi (14 in. H₂O) **vacuum** to 4.5 volts at 1/2 psi (14 in. H₂O) **pressure**. With no pressure or vacuum in the fuel tank (gas cap removed), the sensor output is 2.5 volts. Used by the ECM for OBD II evaporative emission system diagnostics only. Located on top of the fuel tank.

- **VEHICLE SPEED SENSOR (VSS)**

A magnetic-type sensor that senses rotation of the final drive and generates a signal that increases in frequency as vehicle speed increases. The TCM uses the VSS signal to control upshifts, downshifts, and the torque converter clutch. The TCM communicates the VSS signal over the data communications bus to the ECM to control high-speed fuel cutoff, and to the Instrument Cluster for speedometer operation. The signal is displayed on the scan tool in miles per hour and kilometers per hour. Located on the transaxle housing.

- **TRANSMISSION FLUID TEMPERATURE (TFT) SENSOR**

A negative temperature coefficient (NTC) thermistor that senses transmission fluid temperature. The sensor values range from -40°F to 248°F (-40°C to 120°C). At 212°F (100°C), the sensor reading is 0.46 volts. This signal is used by the TCM to delay shifting when the fluid is cold, and control torque converter clutch operation when the fluid is hot. Located in the transaxle oil pan.

- **TRANSMISSION TURBINE SHAFT SPEED (TSS) SENSOR**

A magnetic-type sensor that senses rotation of the torque converter turbine shaft (input / mainshaft) and generates a signal that increases in frequency as transmission input speed increases. Used by the TCM to control torque converter clutch operation and sense transmission slippage. Located on the transaxle housing.

- **TRANSMISSION RANGE (TR) SWITCH**

A six-position switch that indicates the position of the transaxle manual select lever: Park/Neutral, Reverse, Manual Low (1), Second (2), Drive (3), or Overdrive (OD). Used by the TCM to control line pressure, upshifting, and downshifting. The TR switch is NOT used to enable or disable starter motor operation. Located on the transaxle housing.

ACTUATORS

● FAN CONTROL (FC) RELAY

When energized, provides battery voltage (B+) to the radiator/condenser cooling fan motor. The ECM will turn the fan on when engine coolant temperature reaches 210°F (99°C) and off when coolant temperature drops to 195°F (90°C). The ECM will also turn the fan on when the A/C high side pressure reaches 300 psi and off when the pressure drops to 250 psi. The relay coil resistance spec is 48 ± 6 ohms.

● FUEL PUMP (FP) RELAY

When energized, supplies battery voltage (B+) to the fuel pump. The relay coil resistance spec is 48 ± 6 ohms.

● A/C CLUTCH RELAY

When energized, provides battery voltage (B+) to the A/C compressor clutch coil. The relay coil resistance spec is 48 ± 6 ohms.

● THROTTLE ACTUATOR CONTROL (TAC) MOTOR

A bidirectional pulse-width modulated DC motor that controls the position of the throttle plate. A scan tool data value of 0% indicates an ECM command to fully close throttle plate, and a value of 100% indicates an ECM command to fully open the throttle plate (wide open throttle). Any throttle control actuator motor circuit fault will set a DTC and cause the throttle actuator control to be disabled, and the spring-loaded throttle plate will return to the default 15% position (fast idle). When disabled, the TAC value on the scan tool will indicate 15%.

● MALFUNCTION INDICATOR LAMP (MIL)

The MIL is part of the instrument cluster and receives commands from the ECM and TCM over the data communications bus. If the instrument cluster fails to communicate with the ECM and TCM, the MIL is continuously lit by default. Under normal conditions, when the ignition switch is turned on the lamp remains lit for 15 seconds for a bulb check. Afterward, the MIL will light only for emissions related concerns. Whenever an engine misfire severe enough to damage the catalytic converter is detected, the MIL will flash on and off.

● CAMSHAFT POSITION ACTUATOR CONTROL SOLENOIDS

A pair of duty cycle controlled solenoid valves that increase or decrease timing advance of the intake camshafts by controlling engine oil flow to the camshaft position actuators. When the duty cycle is greater than 50%, the oil flow from the solenoid causes the actuator to advance the camshaft position. When the duty cycle is less than 50%, the oil flow from the solenoid causes the actuator to retard the camshaft position. When the ECM determines that the desired camshaft position has been achieved, the duty cycle is commanded to 50% to hold the actuator so that the adjusted camshaft position is maintained. The solenoid winding resistance spec is 12 ± 2 ohms.

● EXHAUST GAS RECIRCULATION (EGR) VALVE

A duty cycle controlled solenoid that, when energized, lifts the spring-loaded EGR valve pintle to open the valve. A value of 0% indicates an ECM command to fully close the EGR valve, and a value of 100% indicates an ECM command to fully open the EGR valve. The solenoid is enabled when the engine coolant temperature reaches 150°F (66°C) and the throttle is not closed or wide open. The solenoid winding resistance spec is 12 ± 2 ohms.

- **FUEL INJECTORS**

Electro-mechanical devices used to deliver fuel to the intake manifold at each cylinder. Each injector is individually energized once per camshaft revolution, in time with its cylinder's intake stroke. The injector winding resistance spec is 12 ± 2 ohms.

- **IGNITION COILS**

These six coils, mounted above the spark plugs, generate a high voltage to create a spark at each cylinder individually. Timing and dwell are controlled by the ECM. The coil primary resistance spec is $1 \pm .5$ ohms. The coil secondary resistance spec is $10K \pm 2K$ ohms.

- **GENERATOR FIELD**

The ECM supplies this variable-duty cycle signal to ground the field winding of the generator (alternator), without the use of a separate voltage regulator. Increasing the duty cycle results in a higher field current and greater generator (alternator) output.

- **EVAPORATIVE EMISSION (EVAP) CANISTER PURGE SOLENOID**

A duty cycle controlled solenoid that regulates the flow of vapors stored in the canister to the intake manifold. The solenoid is enabled when the engine coolant temperature reaches 150°F (66°C). A duty cycle of 0% blocks vapor flow, and a duty cycle of 100% allows maximum vapor flow. The duty cycle is determined by the ECM, based on engine speed and load. The solenoid is also used for OBD II testing of the evaporative emission (EVAP) system. The solenoid winding resistance spec is 48 ± 6 ohms. There is also a service port with a schrader valve and cap installed on the hose between the purge solenoid and the canister.

- **EVAPORATIVE EMISSION (EVAP) CANISTER VENT SOLENOID**

When energized, the fresh air supply hose to the canister is blocked. The solenoid is only energized for OBD II testing of the evaporative emission (EVAP) system. The solenoid winding resistance spec is 48 ± 6 ohms.

- **TORQUE CONVERTER CLUTCH (TCC) SOLENOID VALVE**

A duty cycle controlled solenoid valve that applies the torque converter clutch by redirecting hydraulic pressure in the transaxle. With a duty cycle of 0%, the TCC is released. When torque converter clutch application is desired, the pulse width is increased until the clutch is fully applied. The solenoid will then maintain a 100% duty cycle until clutch disengagement is commanded. Then the pulse width is decreased back to 0%. If the brake pedal position switch closes, the duty cycle is cut to 0% immediately. The solenoid is enabled when the engine coolant temperature reaches 150°F (66°C), the brake switch is open, the transmission is in 3rd or 4th gear, and the vehicle is at cruise (steady throttle) above 40 mph. In addition, whenever the transmission fluid temperature is 248°F (120°C) or more, the TCM will command TCC lockup. The solenoid winding resistance spec is 12 ± 2 ohms.

- **TRANSMISSION PRESSURE CONTROL (PC) SOLENOID**

This duty cycle controlled solenoid controls fluid in the transmission valve body that is routed to the pressure regulator valve. By varying the duty cycle of the solenoid, the TCM can vary the line pressure of the transmission to control shift feel and slippage. When the duty cycle is minimum (10%), the line pressure will be maximized. When the duty cycle is maximum (90%), the line pressure will be minimized. The solenoid winding resistance spec is 6 ± 1 ohms.

- **TRANSMISSION SHIFT SOLENOIDS (SS 1 AND SS 2)**

These solenoids control fluid in the transmission valve body that is routed to the 1-2, 2-3, and 3-4 shift valves. By energizing or de-energizing the solenoids, the TCM can enable a gear change. The solenoid winding resistance spec is 24 ± 4 ohms.

Gear	SS 1	SS 2
P, N, R, or 1	On	Off
2	Off	Off
3	Off	On
4 (OD)	On	On

SFI SYSTEM OPERATION AND COMPONENT FUNCTIONS

- **STARTING MODE**

When the ignition switch is turned on, the ECM energizes the fuel pump relay for 2 seconds, allowing the fuel pump to build up pressure in the fuel system. Unless the engine is cranked within this two-second period, the fuel pump relay is de-energized to turn off the pump. The fuel pump relay will remain energized as long as the engine speed (CKP) signal to the ECM is 100 rpm or more.

- **CLEAR FLOOD MODE**

When the accelerator pedal is fully depressed (pedal position of 80% or greater) and the engine speed is below 400 rpm, the ECM turns off the fuel injectors.

- **RUN MODE: OPEN AND CLOSED LOOP**

- **OPEN LOOP**

When the engine is first started and running above 400 rpm, the system operates in open loop. In open loop, the ECM does not use the oxygen sensor signals. Instead, it calculates the fuel injector pulse width from the throttle position sensors, the coolant and intake air temperature sensors, the MAF sensor, and the CKP sensor.

The system will stay in open loop until all of these conditions are met:

- Both upstream heated oxygen sensors (HO2S 1/1 and HO2S 2/1) are sending varying signals to the ECM.
- The engine coolant temperature is above 68°F (20°C).
- Ten seconds have elapsed since start-up.
- Throttle position is less than 80%.

- **CLOSED LOOP**

When the oxygen sensor, engine coolant temperature sensor, and time conditions are met, and the throttle opening is less than 80%, the system goes into closed loop. Closed loop means that the ECM adjusts the fuel injector pulse widths for Bank 1 and Bank 2 based on the varying voltage signals from the upstream oxygen sensors. An oxygen sensor signal below 0.45 volts causes the ECM to increase injector pulse width. When the oxygen sensor signal rises above 0.45 volts in response to the richer mixture, the ECM reduces injector pulse width. This feedback trims the fuel control program that is based on the other sensor signals.

- **ACCELERATION ENRICHMENT MODE**

During acceleration, the ECM uses the increase in mass airflow and the rate of change in throttle position to calculate increased fuel injector pulse width. During wide open throttle operation, the control system goes into open loop mode.

- **DECELERATION ENLEANMENT MODE**

During deceleration, the ECM uses the decrease in mass airflow, the vehicle speed value, and the rate of change in throttle position to calculate decreased fuel injector pulse width.

- **FUEL CUT-OFF MODE**

The ECM will turn off the fuel injectors, for safety reasons, when the vehicle speed reaches 110 mph, or if the engine speed exceeds 6000 rpm.

OBD II SYSTEM OPERATION

- **COMPREHENSIVE COMPONENT MONITOR**

The OBD II diagnostic system continuously monitors all engine and transmission sensors and actuators for shorts, opens, and out-of-range values, as well as values that do not logically fit with other powertrain data (rationality). On the first trip during which the Comprehensive Component Monitor detects a failure that will result in emissions exceeding a predetermined level, the ECM or TCM will store a diagnostic trouble code (DTC), illuminate the malfunction indicator lamp (MIL), and store a freeze frame.

- **SYSTEM MONITORS**

The OBD II diagnostic system also actively tests some systems for proper operation while the vehicle is being driven. Fuel control and engine misfire are checked continuously. Oxygen sensor response, oxygen sensor heater operation, catalyst efficiency, EGR operation, EVAP integrity, variable valve timing, and thermostat operation are tested once or more per trip. When any of the System Monitors detects a failure that will result in emissions exceeding a predetermined level on two consecutive trips, the ECM will store a diagnostic trouble code (DTC) and illuminate the malfunction indicator lamp (MIL). Freeze frame data captured during the first of the two consecutive failures is also stored.

- **Fuel Control** - This monitor will set a DTC if the system fails to enter Closed Loop mode within 5 minutes of startup, or the Long Term Fuel Trim is excessively high or low anytime after the engine is warmed up, indicating the loss of fuel control. This is always the case when the Long Term Fuel Trim reaches its limit (+30% or -30%).

- **Engine Misfire** - This monitor uses the CKP sensor signal to continuously detect engine misfires, both severe and non-severe. If the misfire is severe enough to cause catalytic converter damage, the MIL will blink as long as the severe misfire is detected.

- **Oxygen Sensors** - This monitor checks the maximum and minimum output voltage, as well as switching and response times for all oxygen sensors. If an oxygen sensor signal remains too low or too high, switches too slowly, or not at all, a DTC is set.
- **Oxygen Sensor Heaters** - This monitor checks the current flow through each oxygen sensor heater. If the current flow is too high or too low, a DTC is set. Battery voltage is continuously supplied to the oxygen sensor heaters whenever the ignition switch is on. The heaters are grounded through the ECM.
- **Catalytic Converter** - This monitor compares the signals of the two upstream heated oxygen sensors to the signal from the downstream heated oxygen sensor to determine the ability of catalyst to store free oxygen. If the catalyst's oxygen storage capacity is sufficiently degraded, a DTC is set. This monitor will only run after the oxygen sensor heater and oxygen sensor monitors have run and passed for all three oxygen sensors.
- **EGR System** - This monitor uses the MAP sensor signal to detect changes in intake manifold pressure as the EGR valve is commanded open and closed. If the pressure changes too little or too much, a DTC is set.
- **EVAP System** - This monitor first turns on the EVAP vent solenoid to block the fresh air supply to the EVAP canister. Next, the EVAP purge solenoid is turned on to draw a slight vacuum on the entire EVAP system, including the fuel tank. Then the EVAP purge solenoid is turned off to seal the system. The monitor uses the Fuel Tank (EVAP) Pressure Sensor signal to determine if the EVAP system has any leaks. After the leak testing is completed, the EVAP vent solenoid is turned off to relieve the vacuum. If sufficient vacuum is not created, or decays too rapidly, or does not decay quickly at the conclusion of the leak test, a DTC is set. In order to run this monitor, the engine must be cold (below 86°F / 30°C) and the fuel level must be between $\frac{1}{4}$ and $\frac{3}{4}$ full.
- **Variable Valve Timing** - This monitor compares the desired valve timing with the actual timing indicated by the CMP sensors. If the timing is in error, or takes too long to reach the desired value, a DTC is set.
- **Engine Thermostat** - This monitor confirms that the engine warms up fully within a reasonable amount of time. If the coolant temperature remains too low for too long, a DTC is set.

• MONITOR READINESS STATUS

The monitor readiness status indicates whether or not a particular OBD II diagnostic monitor has been run since the last time that DTCs were cleared from ECM and TCM memory. If the monitor has not yet run, the status will display on the Scan Tool as "Not Complete". If the monitor has been run, the status will display on the scan tool as "Complete". This does not mean that no faults were found, only that the diagnostic monitor has been run. Whenever DTCs are cleared from memory or the battery is disconnected, all monitor readiness status indicators are reset to "Not Complete". Monitor readiness status indicators are not needed for the Comprehensive Component, Fuel Control, and Engine Misfire monitors because they run continuously. The readiness status of the following system monitors can be read on the scan tool:

Oxygen Sensors	Oxygen Sensor Heaters	Catalytic Converter	EGR System
EVAP System	Variable Valve Timing	Engine Thermostat	

- **WARM UP CYCLE**

Warm Up Cycles are used by the ECM and TCM for automatic clearing of DTCs and Freeze Frame data as described below. To complete one warm up cycle, the engine coolant temperature must rise at least 40°F (22°C) and reach a minimum of 160°F (71°C).

- **TRIP**

A trip is a key-on cycle in which all enable criteria for a particular diagnostic monitor are met and the diagnostic monitor is run. The trip is completed when the ignition switch is turned off.

- **DRIVE CYCLE**

Most OBD II diagnostic monitors will run at some time during normal operation of the vehicle. However, to satisfy all of the different Trip enable criteria and run all of the OBD II diagnostic monitors, the vehicle must be driven under a variety of conditions. The following drive cycle will allow all monitors to run on this vehicle.

1. Ensure that the fuel tank is between $\frac{1}{4}$ and $\frac{3}{4}$ full.
2. Start cold (below 86°F / 30°C) and warm up until engine coolant temperature is at least 160°F (71°C).
3. Accelerate to 40-55 mph at 25% throttle and maintain speed for five minutes.
4. Decelerate without using the brake (coast down) to 20 mph or less, and then stop the vehicle. Allow the engine to idle for 10 seconds, turn the key off, and wait one minute.
5. Restart and accelerate to 40-55 mph at 25% throttle and maintain speed for two minutes.
6. Decelerate without using the brake (coast down) to 20 mph or less, and then stop the vehicle. Allow the engine to idle for 10 seconds, turn the key off, and wait one minute.

- **FREEZE FRAME DATA**

A Freeze Frame is a miniature “snapshot” (one frame of data) that is automatically stored in the ECM/TCM memory when an emissions-related DTC is first stored. If a DTC for fuel control or engine misfire is stored at a later time, the newest data are stored and the earlier data is lost. All parameter ID (PID) values listed under “Scan Tool Data” are stored in freeze frame data. The ECM/TCM stores only one single freeze frame record.

- **STORING AND CLEARING DTCs & FREEZE FRAME DATA, TURNING THE MIL ON & OFF**

- **One Trip Monitors:** A failure on the first trip of a “one trip” emissions diagnostic monitor causes the ECM or TCM to immediately store a confirmed DTC and Freeze Frame data, and turn on the MIL. All Comprehensive Component Monitor faults set a confirmed DTC on one trip.
- **Two Trip Monitors:** A failure on the first trip of a “two trip” emissions diagnostic monitor causes the ECM to store a pending DTC and Freeze Frame data. For all monitors, if the failure recurs on the next trip during which the monitor runs, regardless of the engine conditions, the ECM will store a confirmed DTC and turn on the MIL. In addition, for the misfire and fuel control monitors, if the failure recurs on the next trip during which the monitor runs and where conditions are similar to those experienced when the fault first occurred (engine speed within 375 rpm, engine load within 20%, and same hot/cold warm-up status), the ECM will store a confirmed DTC and turn on the MIL. If the second failure does not recur as described above, the pending DTC and Freeze Frame data are cleared from memory. All of the System Monitors are two trip monitors. Engine misfire which is severe enough to damage the catalytic converter is a two trip monitor. However, the MIL will always blink when the severe misfire is occurring.

- **Automatic Clearing:** When the vehicle completes three consecutive good/passing trips (three consecutive trips in which the monitor that set the DTC is run and passes), the MIL will be turned off, but the confirmed DTC and Freeze Frame will remain stored in ECM/TCM memory. For misfire and fuel control monitor faults, the three consecutive good/passing trips must take place under similar engine conditions (engine speed, load, and warm up condition) as the initial fault for the MIL to be turned off. If the vehicle completes 40 Warm Up cycles without the same fault recurring, the DTC and Freeze Frame are automatically cleared from the ECM/TCM memory.

- **Manual Clearing:** Any stored DTCs and Freeze Frame data can be erased using the scan tool, and the MIL (if lit) will be turned off. Although it is not the recommended method, DTCs and Freeze Frame data will also be cleared if the B+ power supply for the ECM/TCM is lost, or the battery is disconnected.

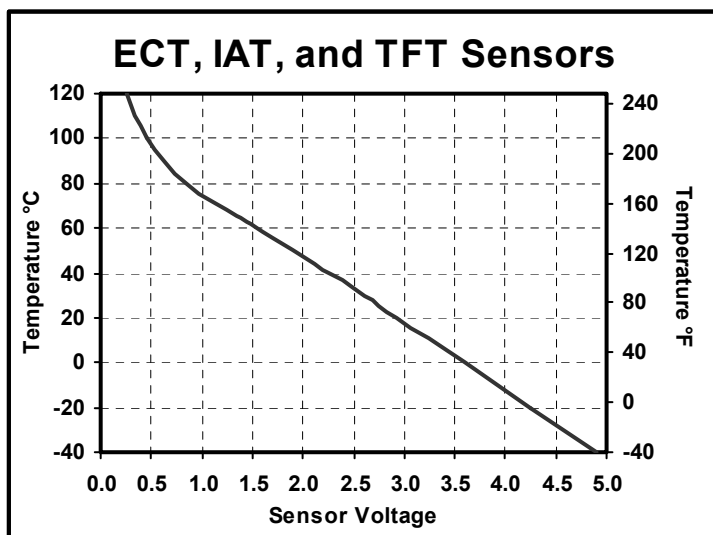
• SCAN TOOL DATA

These are different values and the minimum-to-maximum ranges for each data parameter that the OBD II scan tool is capable of displaying:

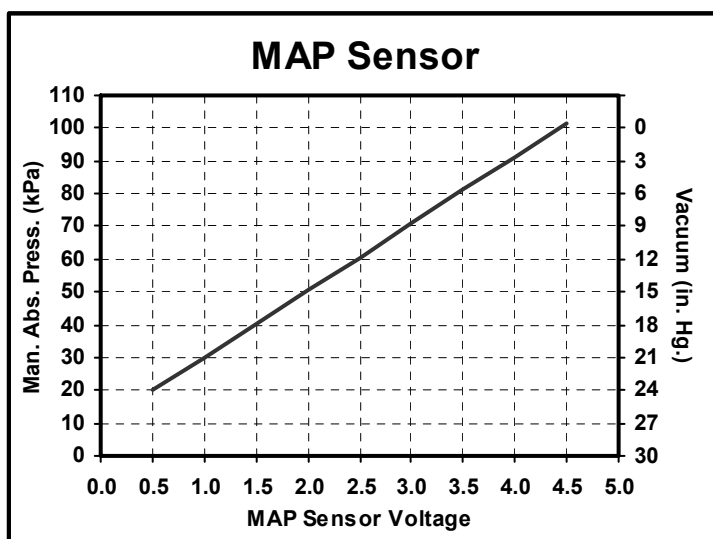
ECT: 248 to -40°F / 120 to -40°C / 0.0 to 5.0 v.
 IAT: 248 to -40°F / 120 to -40°C / 0.0 to 5.0 v.
 MAP/BARO: 20 to 101 kPa pressure /
 24 to 0 in.Hg. vacuum / 0.0 to 5.0 v.
 MAF: 0 to 175 gm/sec / 0.0 to 5.0 volts
 TP 1: 0 to 100% / 0.0 to 5.0 v.
 TP 2: 0 to 100% / 0.0 to 5.0 v.
 APP 1: 0 to 100% / 0.0 to 5.0 v.
 APP 2: 0 to 100% / 0.0 to 5.0 v.
 CKP (engine speed): 0 to 6000 rpm
 Calculated Load Value: 0 to 100%
 HO2S 1/1: 0.00 to 2.00 v.
 HO2S 2/1: 0.00 to 2.00 v.
 HO2S 1/2: 0.00 to 2.00 v.
 Loop: Open / Closed
 Valid Ignition Key: Yes / No
 Fuel Enable: Yes / No
 Bank 1 Injector Pulse Width: 0 to 15 ms
 Bank 2 Injector Pulse Width: 0 to 15 ms
 Bank 1 Long Term Fuel Trim: -30% to +30%
 Bank 1 Short Term Fuel Trim: -30% to +30%
 Bank 2 Long Term Fuel Trim: -30% to +30%
 Bank 2 Short Term Fuel Trim: -30% to +30%
 Ignition Timing Advance: 0 to 60° BTDC
 Knock Sensor knock detected: Yes / No
 Throttle Actuator Control: 0 to 100%
 Battery Voltage: 0 to 18 v.
 Generator Field: 0 to 100%
 Intake Cam 1 Desired Advance: 0 to 40°
 Intake Cam 2 Desired Advance: 0 to 40°
 CMP 1: 0 to 40°
 CMP 2: 0 to 40°
 EGR Valve Opening Desired: 0 to 100%
 EGR Position Sensor: 0 to 100% / 0.0 to 5.0 v.

Evap Purge Solenoid: 0 to 100%
 Evap Vent Solenoid: On / Off
 Fuel Tank (EVAP) Pressure: -14.0 to +14.0
 in.H₂O / -0.5 psi to 0.5 psi / 0.0 to 5.0 v.
 Fuel Tank Level: 0 to 100% / 0.0 to 5.0 v.
 P/S Switch: On / Off
 Brake Switch: On / Off
 A/C Request: On / Off
 A/C Pressure: 25 to 450 psi / 0.0 to 5.0 v.
 A/C Clutch: On / Off
 Fan Control: On / Off
 Fuel Pump: On / Off
 TR: P/N, R, 1, 2, 3, OD
 TFT: 248 to -40°F / 120 to -40°C / 0.0 to 5.0 v.
 VSS: 0 to 110 mph
 TSS: 0 to 6000 rpm
 SS 1: On / Off
 SS 2: On / Off
 TCC: 0 to 100%
 PC: 0 to 100%
 MIL: On / Off / Flashing
 Confirmed DTCs: P####, U####, etc.
 Pending DTCs: P####, U####, etc.
 Monitor Status for this trip: Disabled /
 Not Complete / Complete
 Time elapsed since engine start: hh:mm:ss
 Distance traveled with MIL on: ##### miles/km
 Distance traveled since DTCs cleared:
 ##### miles/km
 Number of warm-up cycles since DTCs
 cleared: ###
 Software Calibration ID # (CAL ID)
 Software Verification Number (CVN)
 Vehicle Identification Number (VIN)

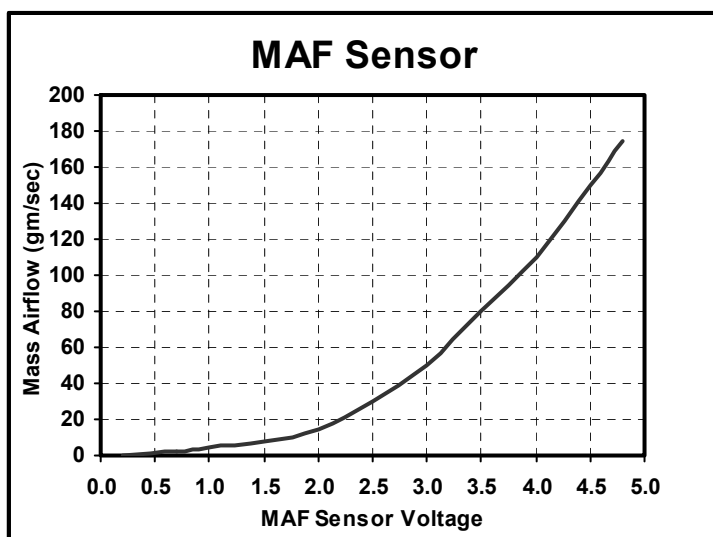
Temperature °F	Temperature °C	Sensor Voltage
248	120	0.25
212	100	0.46
176	80	0.84
150	66	1.34
140	60	1.55
104	40	2.27
86	30	2.60
68	20	2.93
32	0	3.59
-4	-20	4.24
-40	-40	4.90



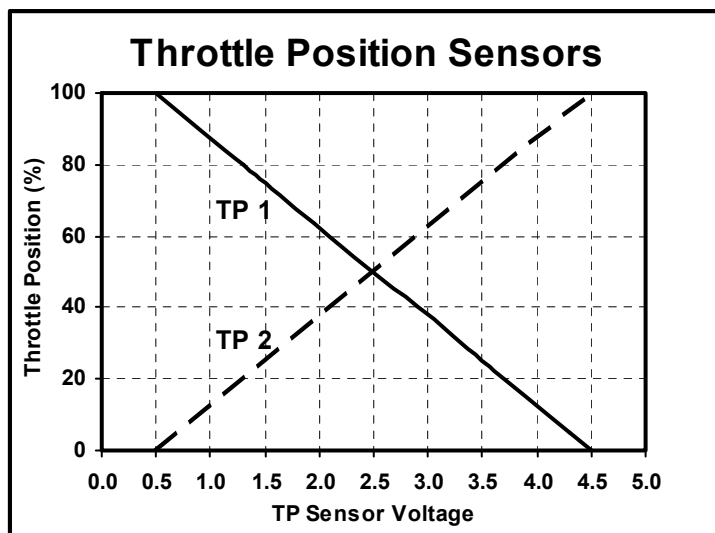
Vacuum at sea level (in. Hg.)	Manifold Absolute Press. (kPa)	Sensor Voltage
0	101.3	4.50
3	91.2	4.00
6	81.0	3.50
9	70.8	3.00
12	60.7	2.50
15	50.5	2.00
18	40.4	1.50
21	30.2	1.00
24	20.1	0.50



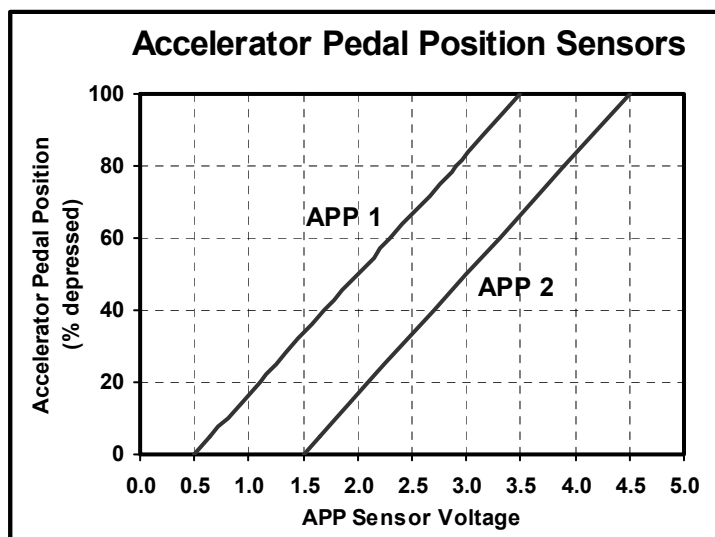
Mass Airflow (gm/sec)	Sensor Voltage
0	0.20
2	0.70
4	1.00
8	1.50
15	2.00
30	2.50
50	3.00
80	3.50
110	4.00
150	4.50
175	4.80



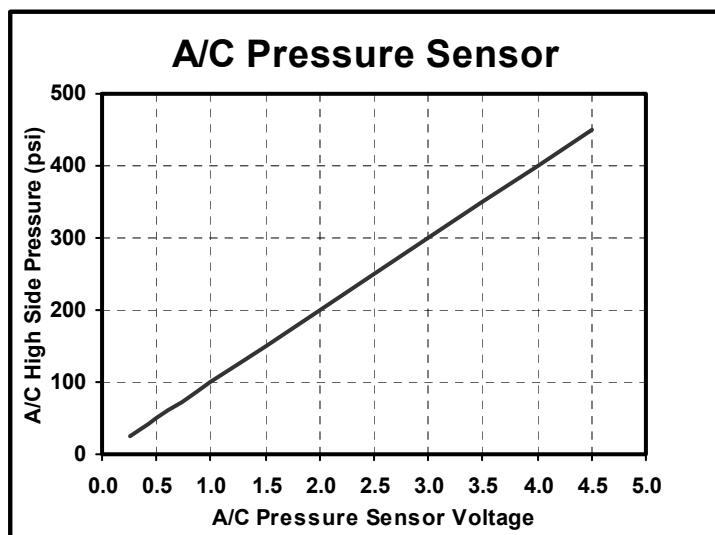
Throttle Position (% open)	TP 1 Sensor Voltage	TP 2 Sensor Voltage
0	4.50	0.50
5	4.30	0.70
10	4.10	0.90
15	3.90	1.10
20	3.70	1.30
25	3.50	1.50
40	2.90	2.10
50	2.50	2.50
60	2.10	2.90
75	1.50	3.50
80	1.30	3.70
100	0.50	4.50



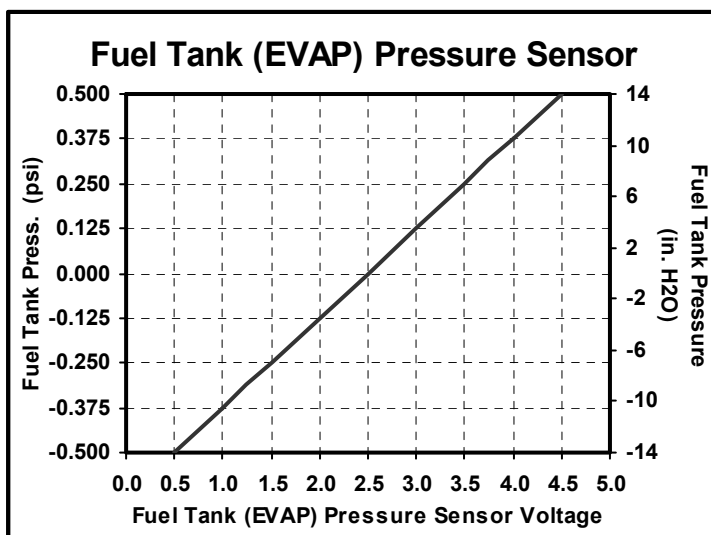
Accelerator Pedal Pos'n (% depressed)	APP 1 Sensor Voltage	APP 2 Sensor Voltage
0	0.50	1.50
5	0.65	1.65
10	0.80	1.80
15	0.95	1.95
20	1.10	2.10
25	1.25	2.25
40	1.70	2.70
50	2.00	3.00
60	2.30	3.30
75	2.75	3.75
80	2.90	3.90
100	3.50	4.50



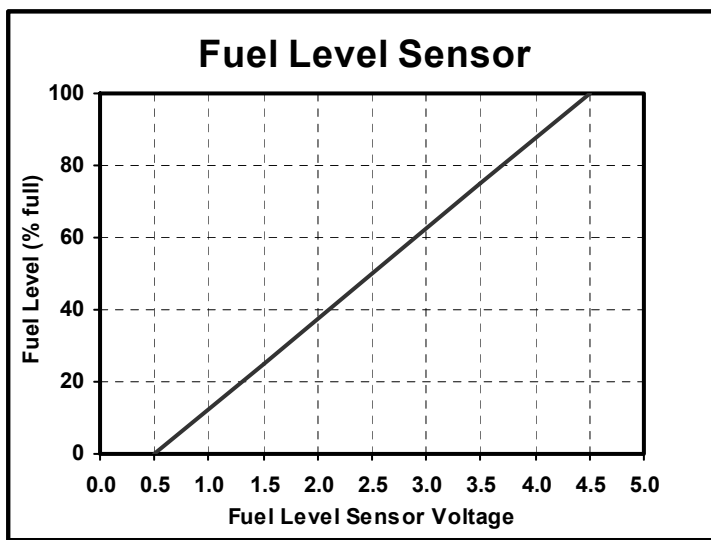
A/C High Side Pressure (psi)	Sensor Voltage
25	0.25
50	0.50
100	1.00
150	1.50
200	2.00
250	2.50
300	3.00
350	3.50
400	4.00
450	4.50



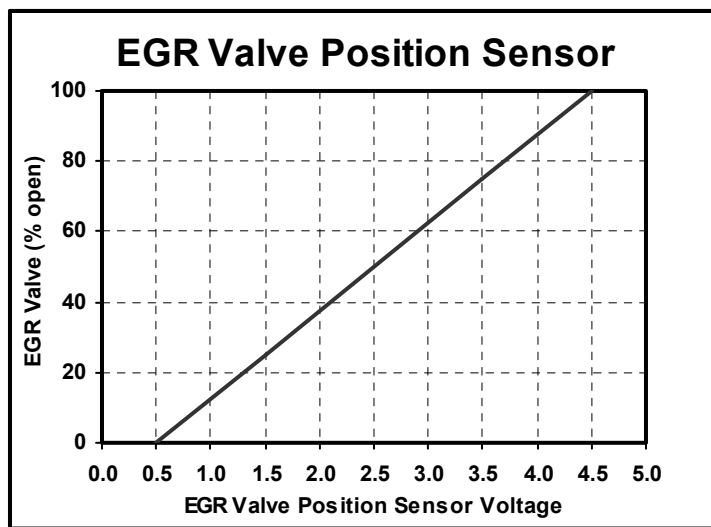
Fuel Tank (EVAP) Pressure (in. H ₂ O)	Sensor Voltage	
-14.0	-0.500	0.50
-10.5	-0.375	1.00
-7.0	-0.250	1.50
-3.5	-0.125	2.00
0.0	0.000	2.50
3.5	0.125	3.00
7.0	0.250	3.50
10.5	0.375	4.00
14.0	0.500	4.50



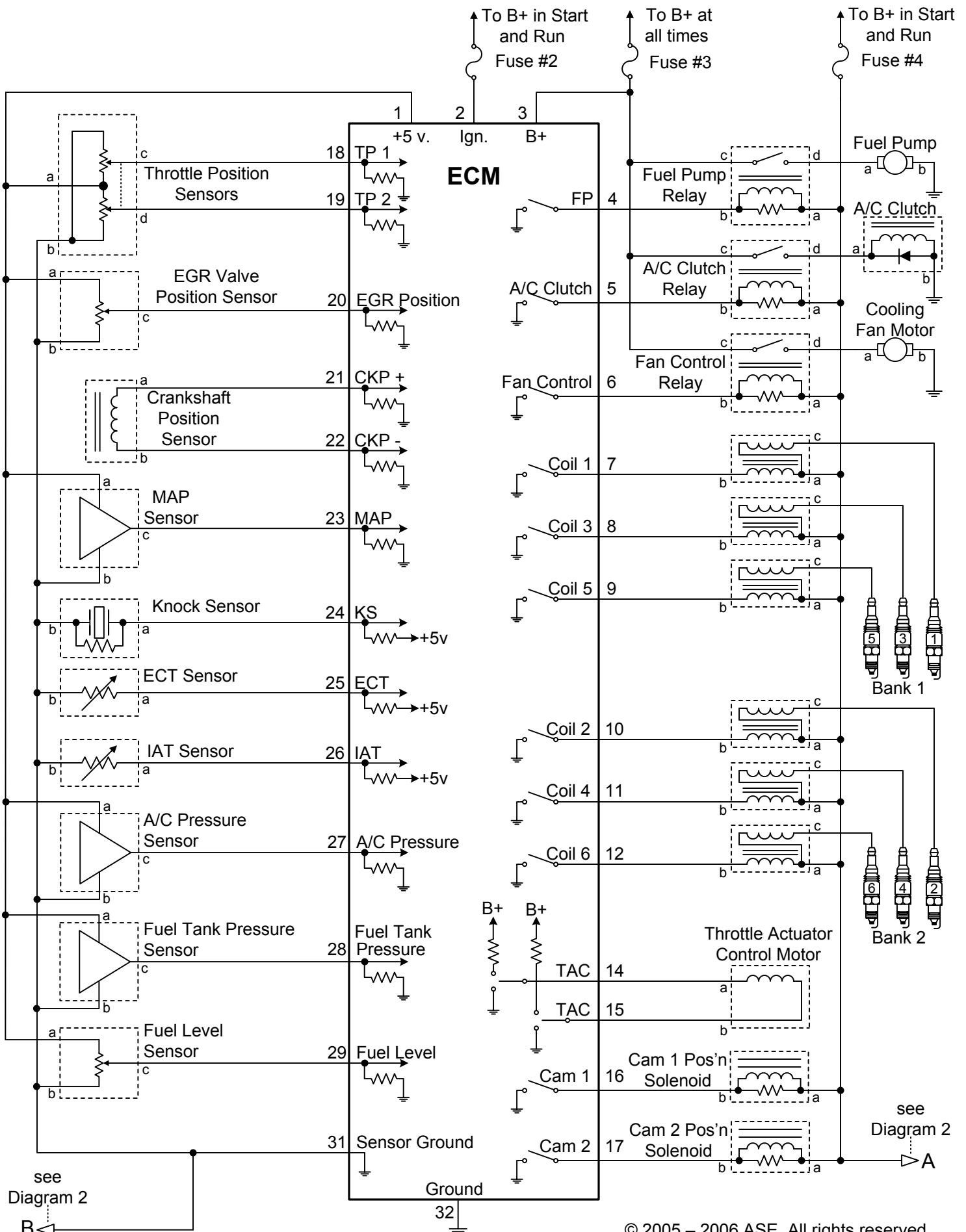
Fuel Level (% full)	Sensor Voltage
0	0.50
25	1.50
50	2.50
75	3.50
100	4.50



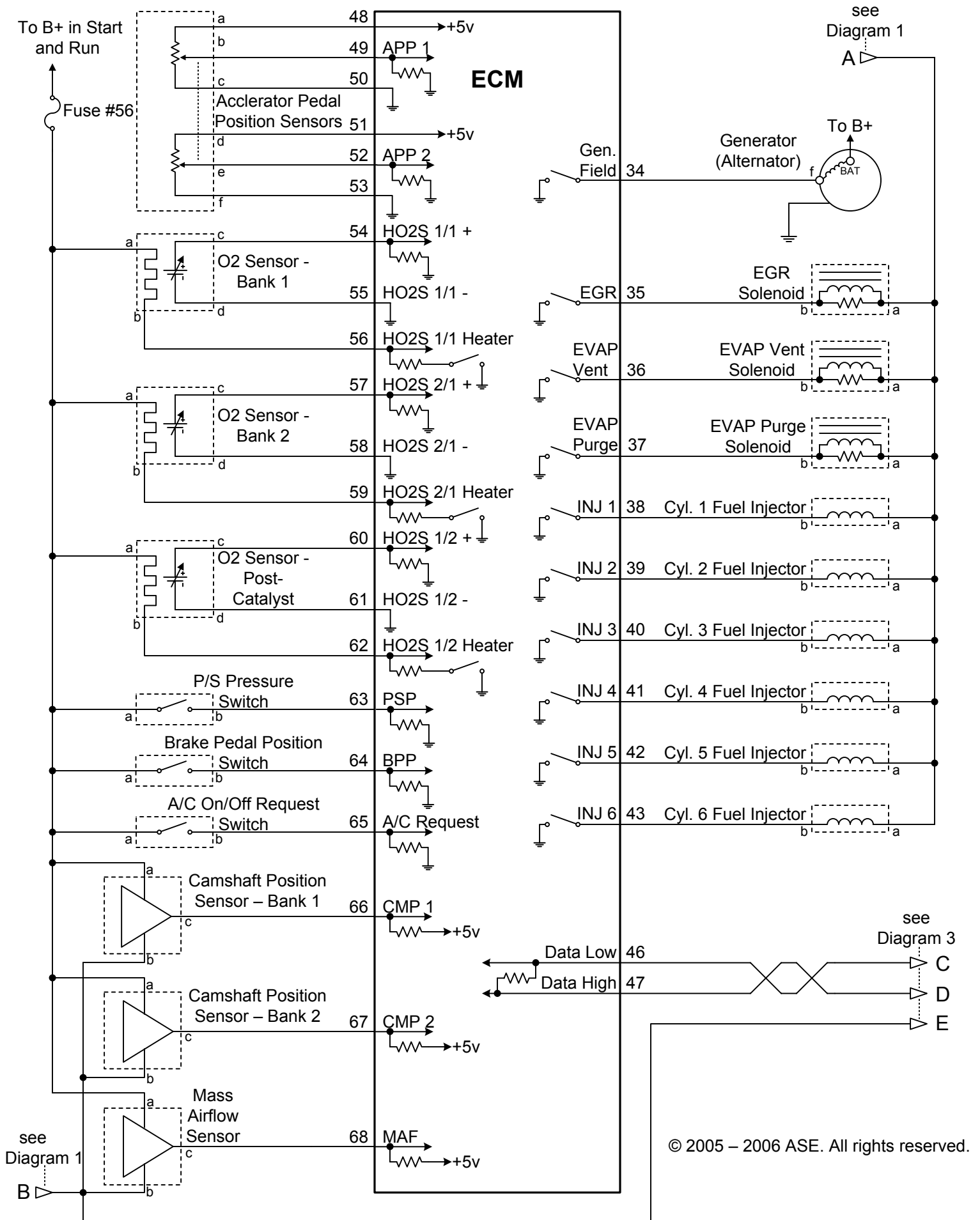
EGR Valve (% open)	Sensor Voltage
0	0.50
25	1.50
50	2.50
75	3.50
100	4.50



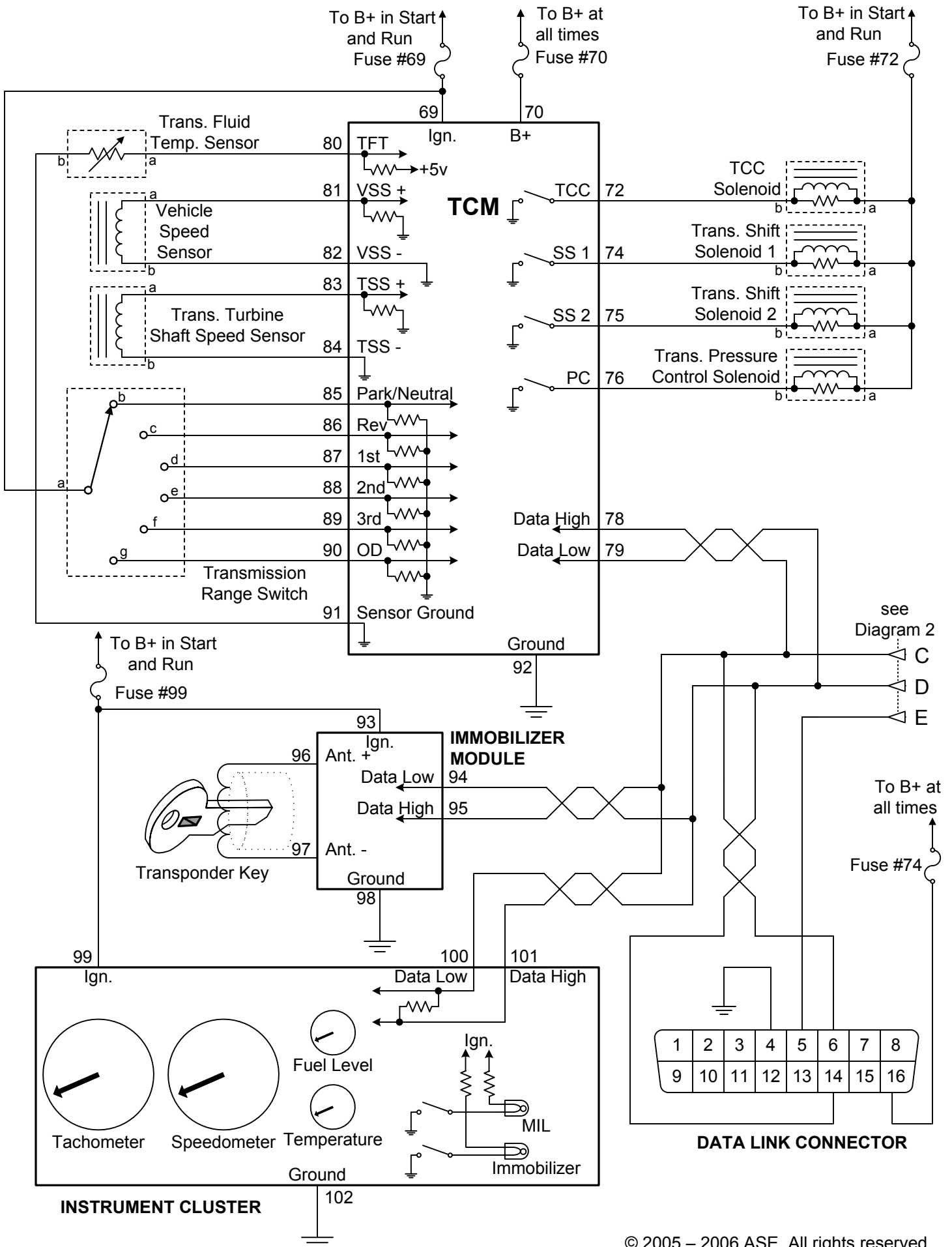
Electrical Diagram 1 of 3

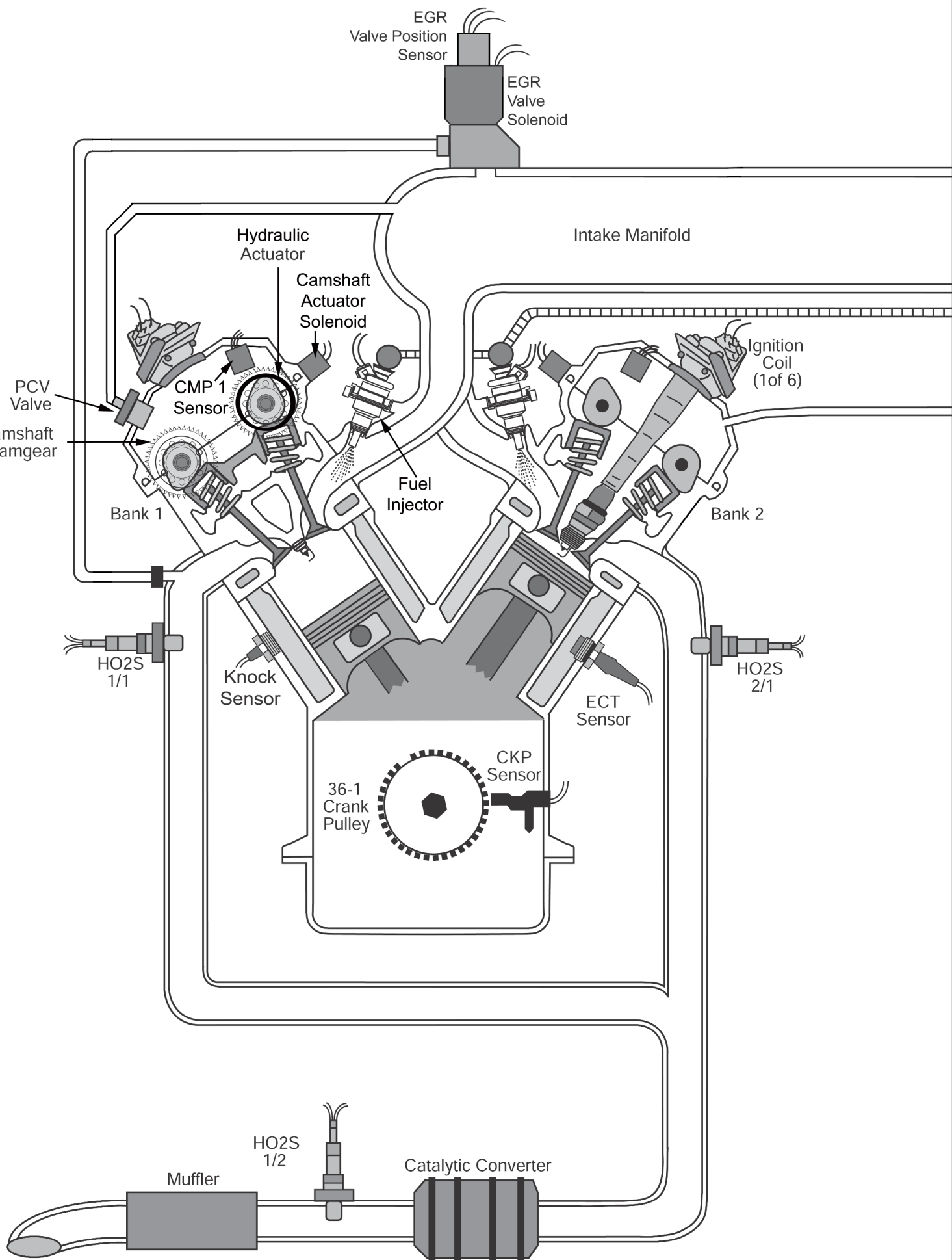


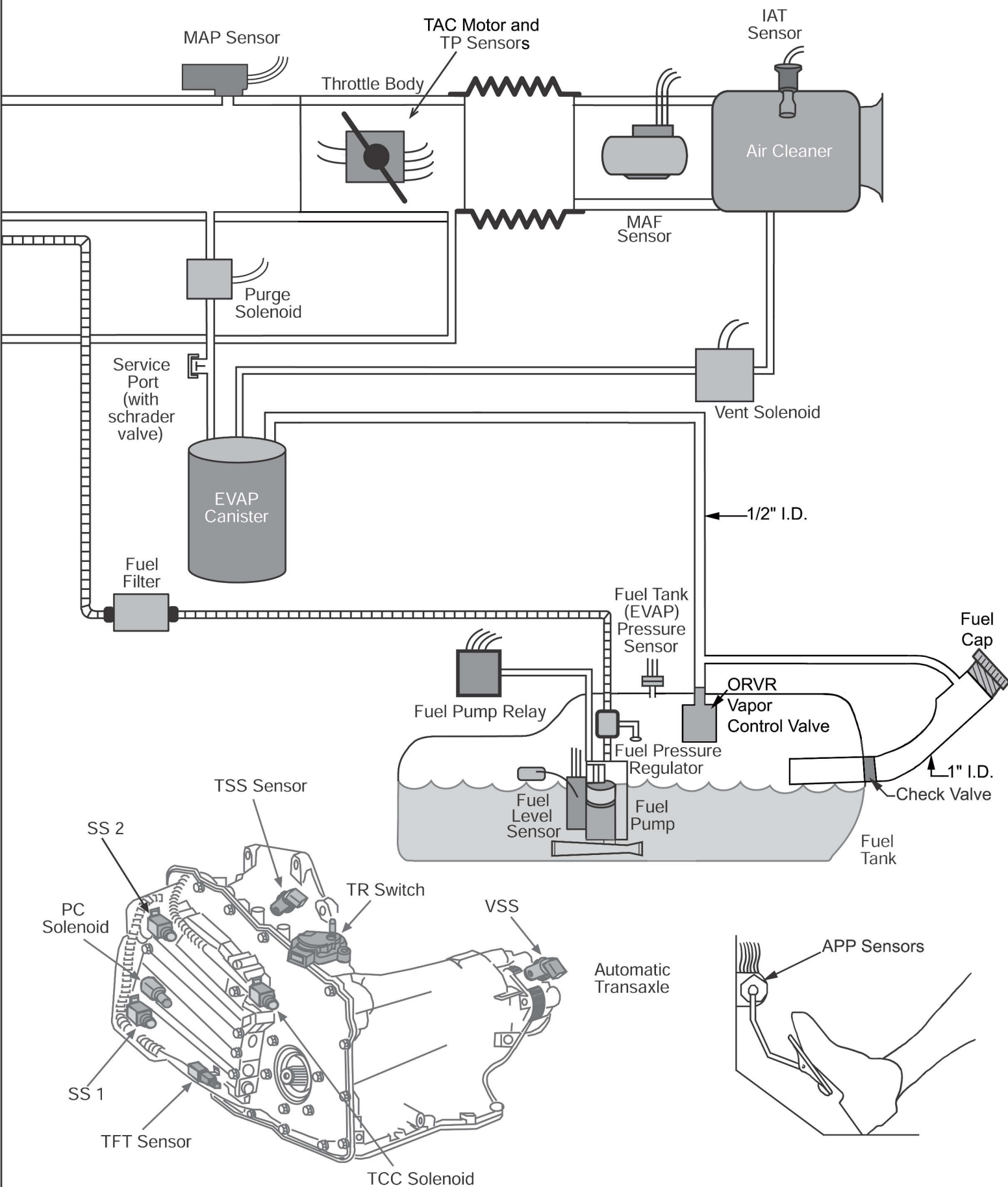
Electrical Diagram 2 of 3



Electrical Diagram 3 of 3









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101 Blue Seal Dr. S.E., Suite 101, Leesburg, VA 20175 * (703) 669-6600 * www.ase.com
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