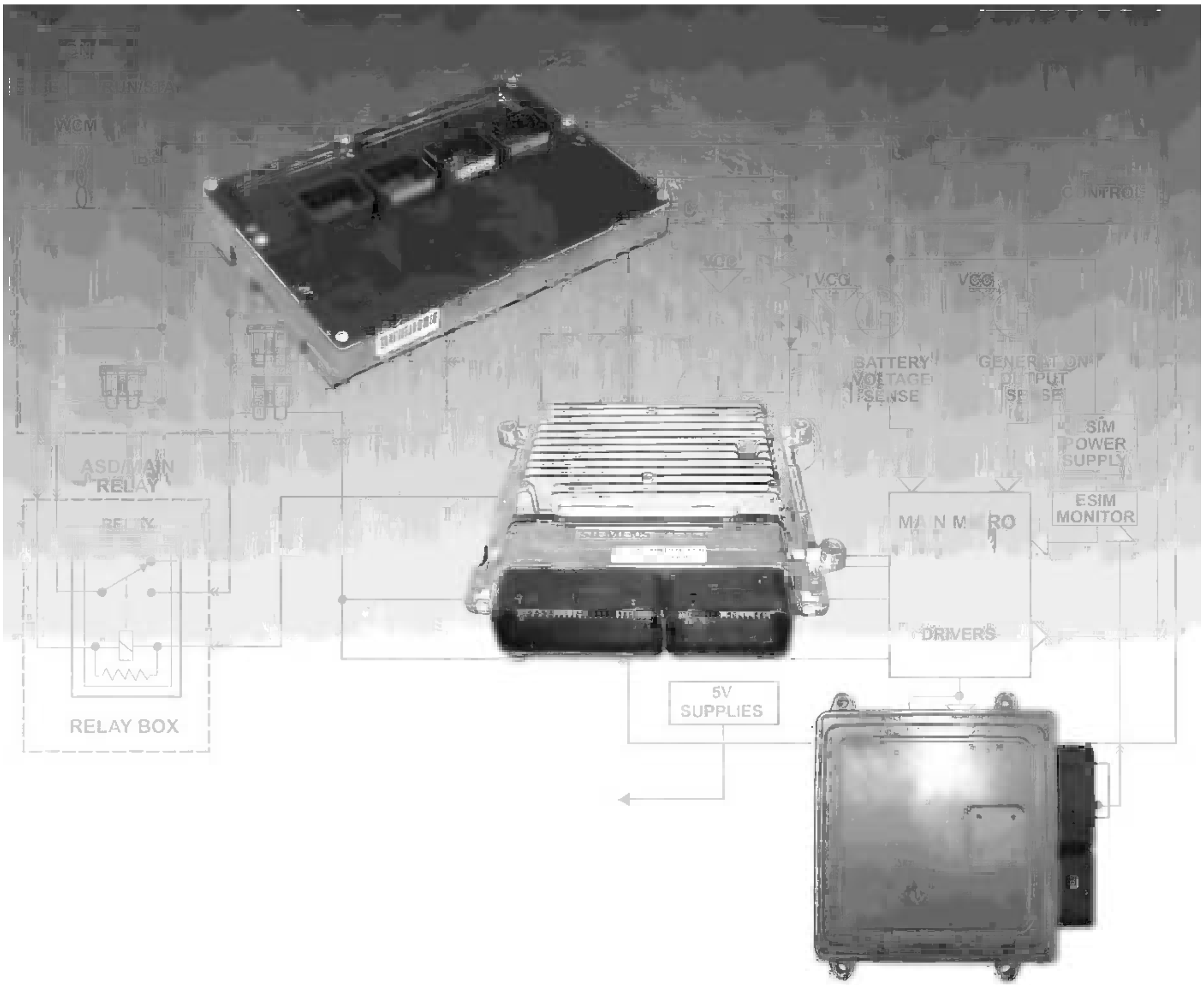
NGC and GPEC Speed Density Fuel Systems



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NGC and GPEC Speed Density Fuel Systems

INTRODUCTION

This publication contains information regarding the Speed Density fuel systems used on most Chrysler Group vehicles. The emphasis is on NGC and GPEC engine management systems. The NGC controller replaced the JTEC and SBEC controllers in most gasoline-powered vehicles by the 2005 model year, and the GPEC controller is used by World Engine Family vehicles.

The fuel injection system for all of these engines is sequential multiport with an in-tank fuel pump module. Ignition systems are direct coil-on-plug.

A brief review of basic electrical principles will help your understanding of PCM operation, PCM inputs and outputs. This course will discuss the Speed Density Equation, which describes how the PCM determines the correct fuel quantity. Fuel adaptives and electronic throttle control are also included.

COURSE OBJECTIVES

Upon completion of this course, you should be able to:

- Have a general understanding of PCM operation.
- Locate and test the components of the wet side of the speed density fuel system.
- Locate and test PCM power and ground circuits.
- Apply the speed density equation to both NGC and GPEC controllers.
- Identify PCM inputs and diagnose a faulty PCM input.
- Identify PCM outputs and diagnose a faulty PCM output.
- Describe the operation of the ETC/APPS systems, and diagnose a fault in the system.

ACRONYMS

The acronyms listed here are used throughout this course.

- APPS Accelerator Pedal Position Sensor
- ASD Auto Shutdown Relay
- BARO Barometric Pressure Sensor
- BCM Body Control Module
- BTS Battery Temperature Sensor
- CAN Controller Area Network
- CKP Crankshaft Position Sensor
- CMP Camshaft Position Sensor
- COP(S) Coil On Plugs Ignition
- DHSS Dual High Side Switch
- DIS Distributorless Ignition System
- DLC Data Link Connector
- DMM Digital Multimeter
- DRBIII ® Diagnostic Readout Box – 3rd Generation
- DTC Diagnostic Trouble Code
- EATX Electronic Automatic Transmission Controller
- ECT Engine Coolant Temperature Sensor
- EGR Exhaust Gas Recirculation
- EMI Electromagnetic Interference
- ESIM Evaporative System Integrity Monitor
- ETC Electronic Throttle Control
- GPEC Global Powertrain Engine Controller
- IAC Idle Air Control
- IAT Intake Air Temperature Sensor
- JTEC Jeep/Truck Engine Controller
- KOEO Key On Engine Off
- KOER Key On Engine Running

- LDP Leak Detection Pump
- LEV Low Emission Vehicle
- LIN Local Interconnect Network
- LSIAC Linear Solenoid Idle Air Control Valve
- LTFT Long Term Fuel Trim
- MAP Manifold Absolute Pressure Sensor
- MIC Mechanical Instrument Cluster
- MIL Malfunction Indicator Lamp
- MTV Manifold Tuning Valve
- MUX Multiplex
- NC Normally Closed (switch state)
- NGC Next Generation Controller
- NO Normally Open (switch state)
- NTC Negative Temperature Coefficient
- NVLD Natural Vacuum Leak Detection
- OBD II On-Board Diagnostics – 2nd Generation
- ORVR On-Board Refueling Vapor Recovery
- PCI Programmable Communication Interface Bus (J1850)
- PCM Powertrain Control Module
- PCV Positive Crankcase Ventilation Valve
- PDC Power Distribution Center
- PEP Peripheral Expansion Port
- PPS Proportional Purge Solenoid
- PTC Positive Temperature Coefficient
- PWM Pulse Width Modulated
- QHSS Quad High Side Switch
- RAM Random Access Memory
- RFI Radio Frequency Interference
- RPM Revolutions Per Minute
- SBEC Single Board Engine Controller

•	SC	Speed Control
•	SCI	Serial Communication Interface Bus
•	SKIM	Sentry Key Immobilizer Module
•	SKREEM	Sentry Key Remote Entry Module
•	SKIS	Sentry Key Immobilizer System
•	SPIO	Serial Peripheral Interface/Output Circuit
•	SRTV	Short Runner Tuning Valve
•	STFT	Short Term Fuel Trim
•	TCM	Transmission Control Module
•	TDC	Top Dead Center
•	TIP	Throttle Inlet Pressure Sensor
•	TIPM	Totally Integrated Power Module
•	T-MAP	Throttle MAP (calculated MAP value)
•	TPS	Throttle Position Sensor
•	ULEV	Ultra Low Emission Vehicle
•	VDC	Variable Displacement Compressor
•	VSS	Vehicle Speed Signal
•	VVT	Variable Valve Timing
•	WCM	Wireless Control Module
•	WOT	Wide Open Throttle

MODULE 1 BASIC ELECTRICITY

The basic principles of electricity are essential to understanding PCM circuit operation. Let's review several concepts.

The circuit shown is a simple series circuit with a battery, a bulb and a switch. As shown, the switch is open and no current is flowing. The bulb is the load and it is not illuminated. There is no voltage drop when no current flows, so voltage on the ground side of the bulb (point 2) measures 12V.

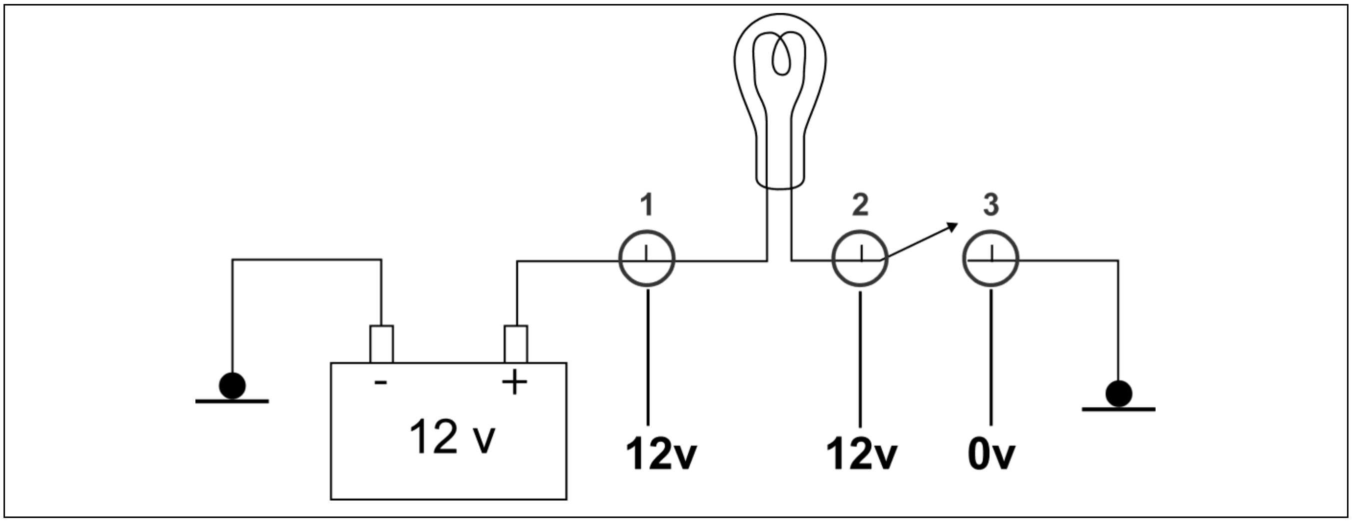


Figure 1 Open Series Circuit

When the switch closes, the circuit is complete and current flows (voltage drops across the bulb). The ground side of the bulb now measures 0V, and the bulb is illuminated.

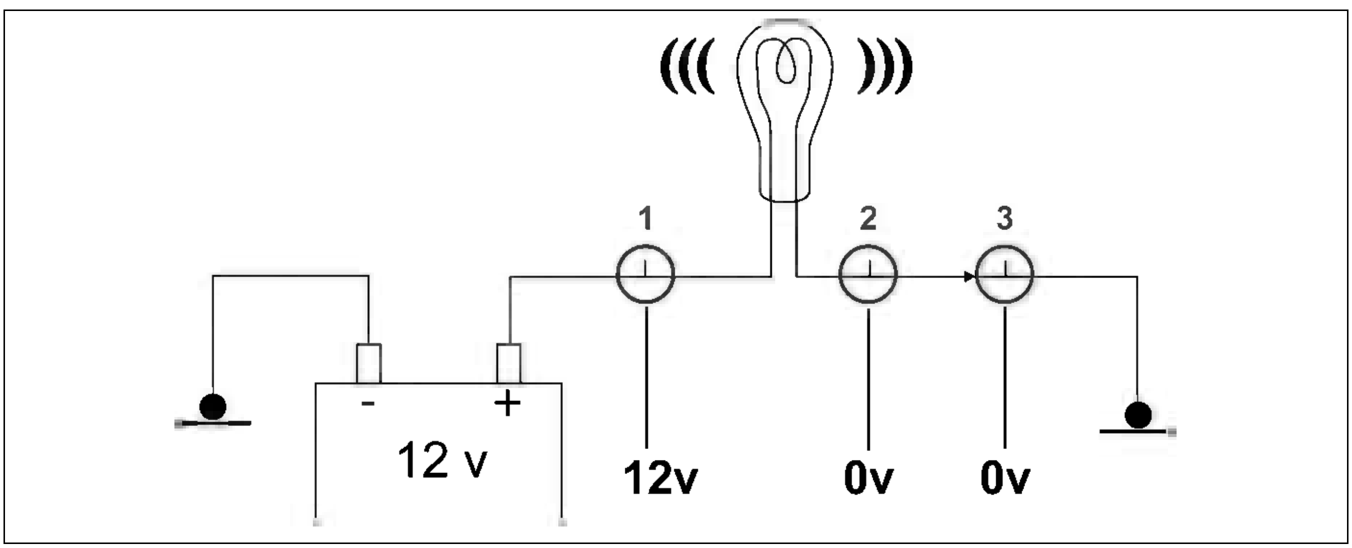


Figure 2 Closed Series Circuit

We have replaced the switch with a variable resistor. On a low-ohm setting, the resistance of the variable resistor is low, the voltage at point 2 is close to 0V and the bulb is bright (Fig. 3). On a high-ohm setting, the resistance of the variable resistor is increased, the voltage at point 2 is also increased, and the bulb is dimmer (Fig. 4).

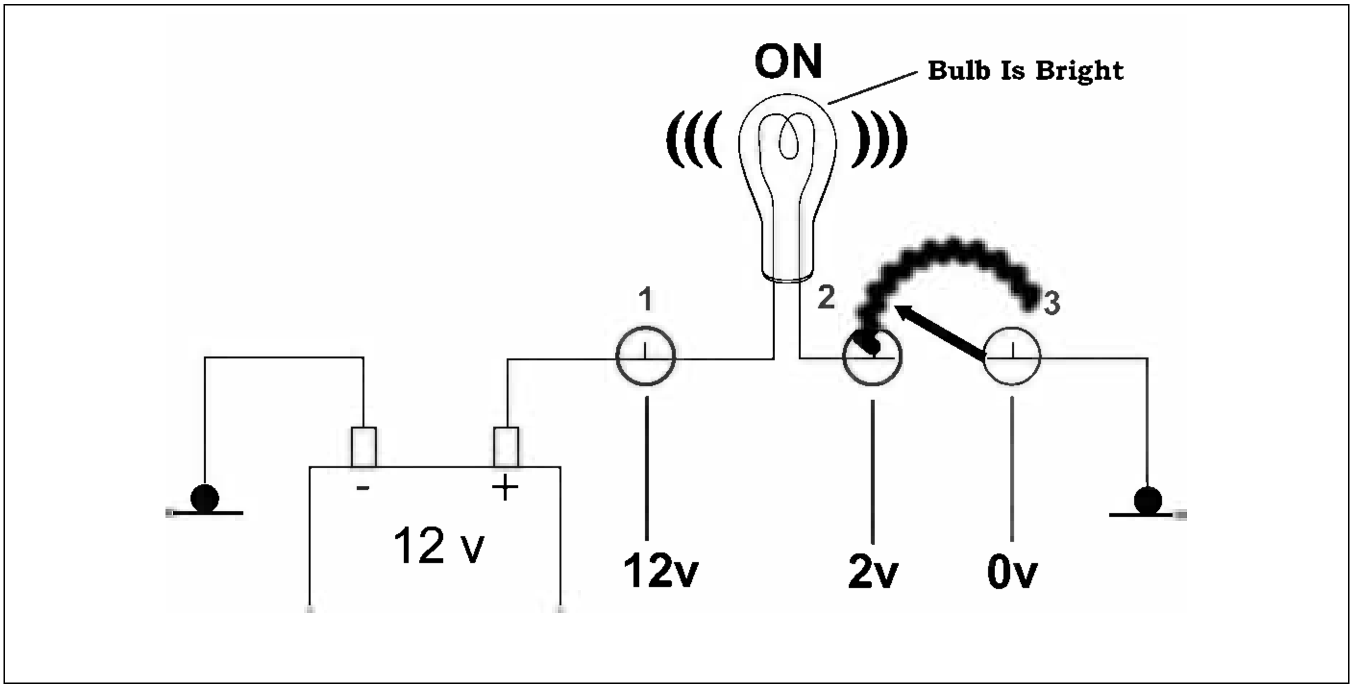


Figure 3 Variable Resistor, Low Ohm Setting

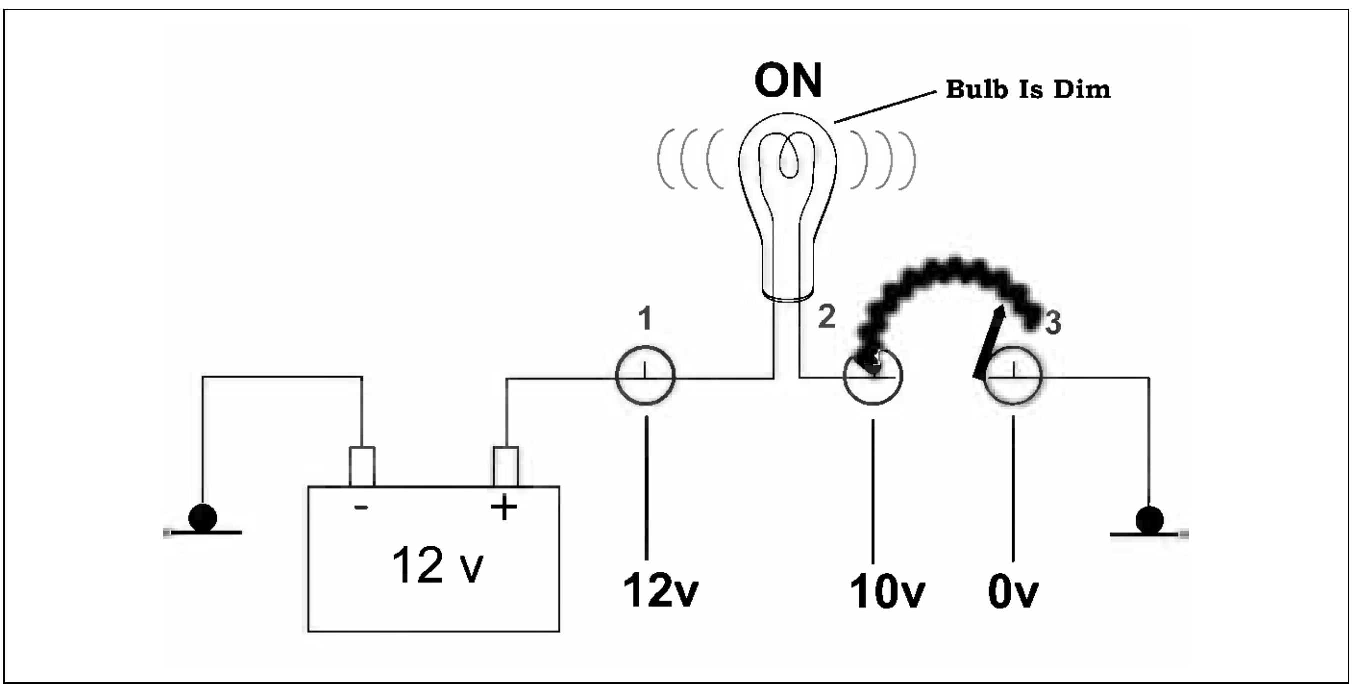


Figure 4 Variable Resistor, High Ohm Setting

PCM TWO-STATE INPUT CIRCUIT

Let's apply these concepts to a PCM Two-State Input circuit. The PCM has a 12V reference voltage and an internal pull-up resistor. PCM sensor reference voltages typically are 12V or 5V.

In the next figure, the switch is open (Fig.5). The PCM voltmeter circuit sees the voltage at point 2. The PCM sees a high voltage when the circuit is open. No current is flowing, and there is no voltage drop across the pull-up resistor, so the full reference voltage is at point 2.

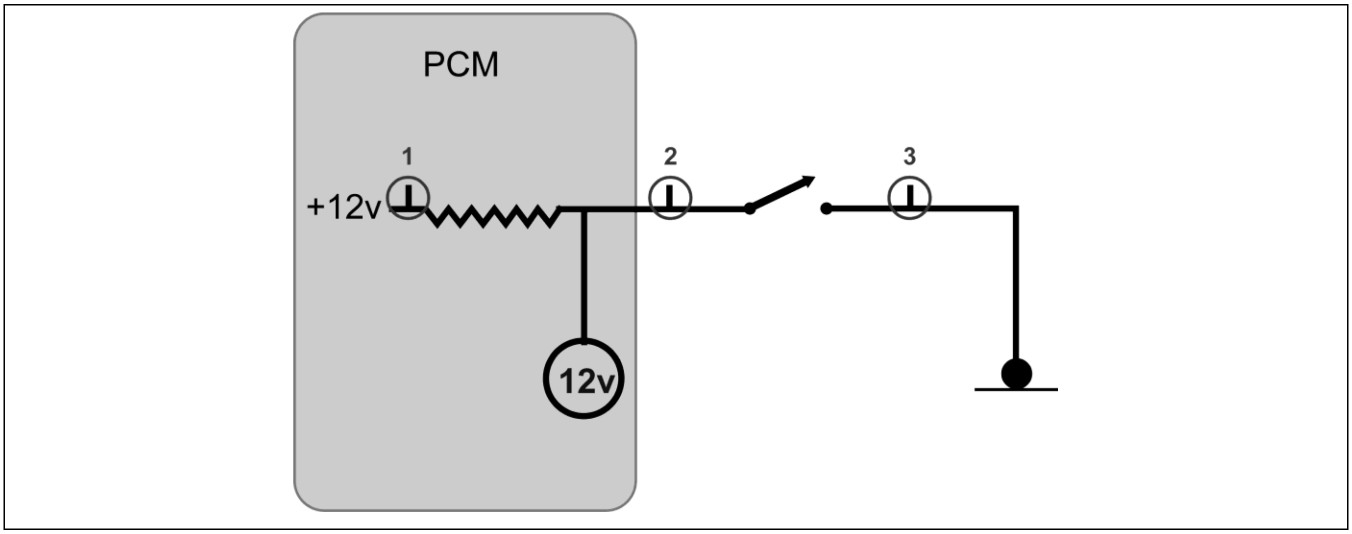


Figure 5 PCM Circuit, High Input

In the figure below, the Two-State Input circuit switch is closed (Fig. 6). The PCM now sees 0V when the circuit is closed. Current is flowing and the voltage drop across the pull-up resistor pulls voltage low on the ground side.

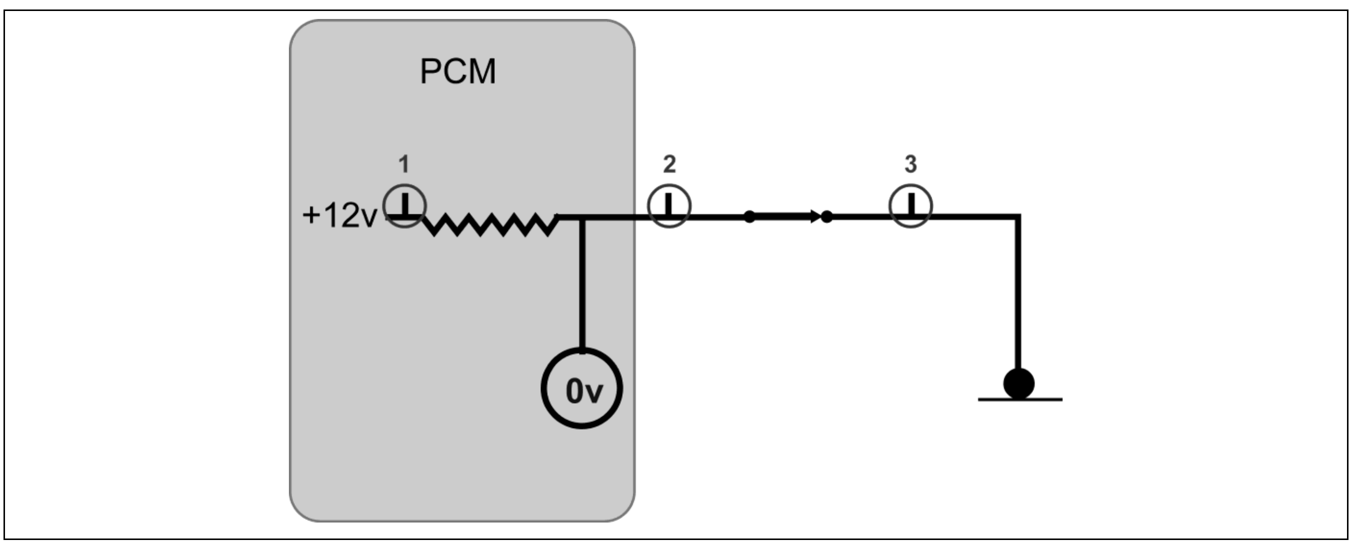


Figure 6 PCM Circuit, Low Input

In the figure below, the PCM is monitoring an Engine Coolant Temperature (ECT) Sensor (Fig. 7). This sensor is a Negative Temperature Coefficient (NTC) thermistor. Note that the sensor reference voltage in this example is 5V.

Because the ECT is a NTC sensor, sensor resistance decreases as temperature increases. As the sensor resistance decreases, the signal voltage also decreases. This sensor provides an analog signal which varies continuously with changes in temperature.

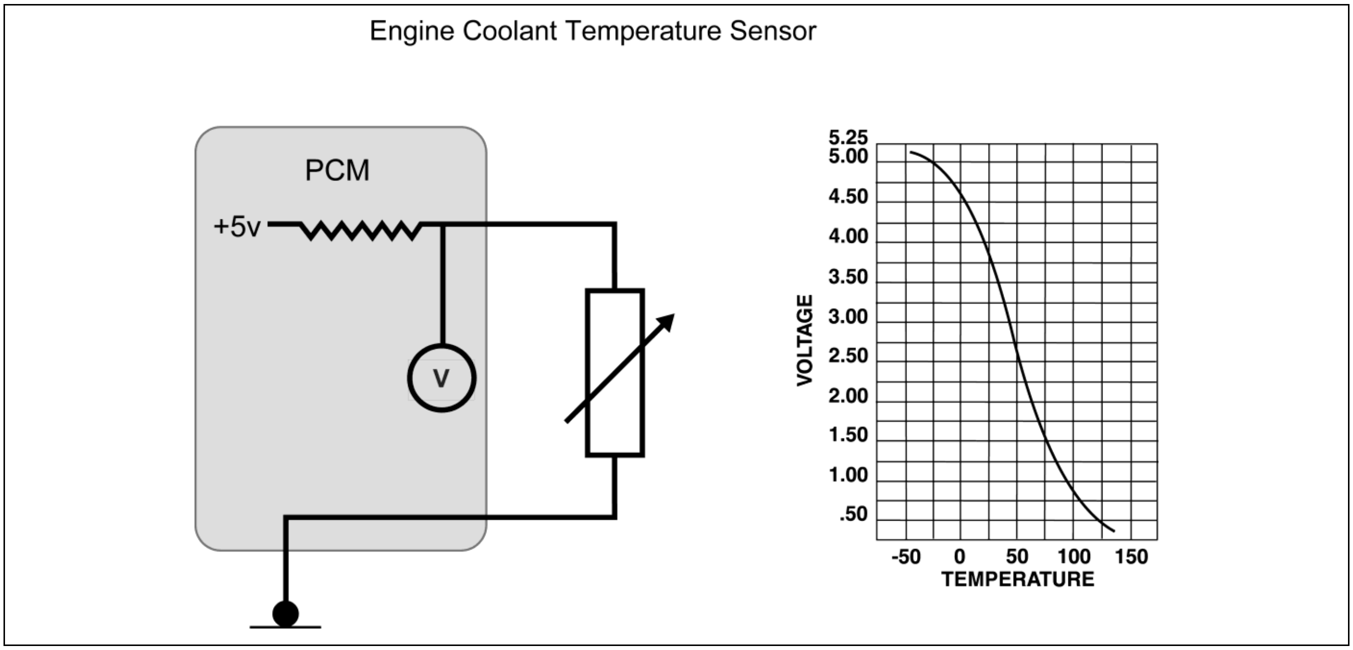


Figure 7 PCM Circuit, Variable Input

PCM FAULT RECOGNITION

The PCM monitors sensor voltage signals and will set a DTC when an abnormal condition occurs. There are three basic types of faults that the PCM can recognize:

- Short to Ground
- Open Circuit
- Short to Positive

SHORT TO GROUND

In the next figure, there is a short to ground in the sensor circuit. The PCM sensor signal voltage now reads 0V, and the PCM interprets this voltage as a fault (Fig. 8).

The PCM stores DTC P0117-ECT SENSOR CIRCUIT LOW and illuminates the MIL lamp.

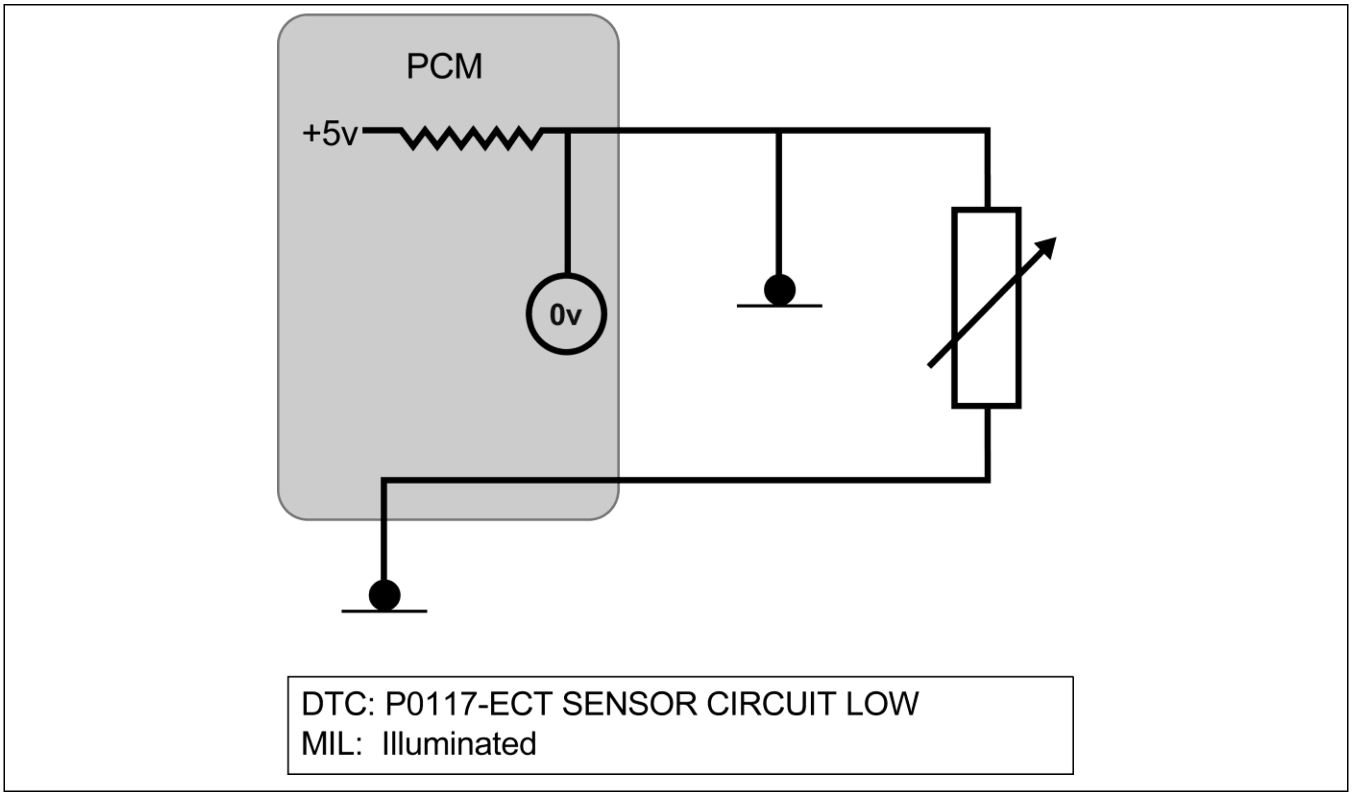


Figure 8 PCM Circuit, Short to Ground

OPEN CIRCUIT

In the figure below, there is an open in the sensor circuit. The PCM sensor signal voltage now reads the full reference voltage, 5V, and the PCM interprets this voltage as a fault (Fig. 9).

The PCM stores DTC P0118-ECT SENSOR CIRCUIT HIGH and illuminates the MIL lamp.

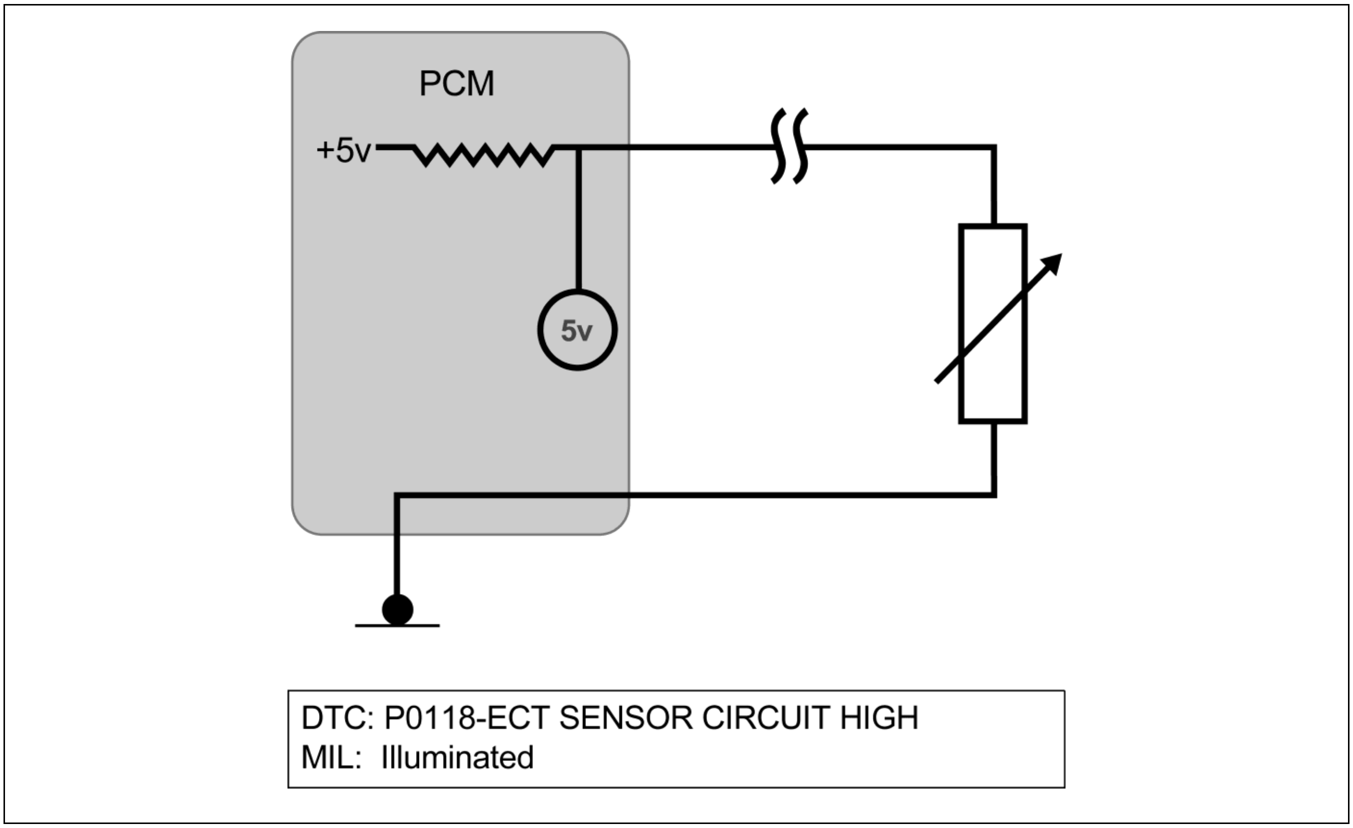


Figure 9 PCM Circuit, Open Circuit

SHORT TO POSITIVE

In the next figure, there is a short to positive in the sensor circuit (Fig. 10). The PCM sensor signal voltage again reads 5V, and the PCM interprets this voltage as a fault.

The PCM stores DTC P0118-ECT SENSOR CIRCUIT HIGH and illuminates the MIL lamp.

Note that an open circuit or a short to positive will generate the same DTC.

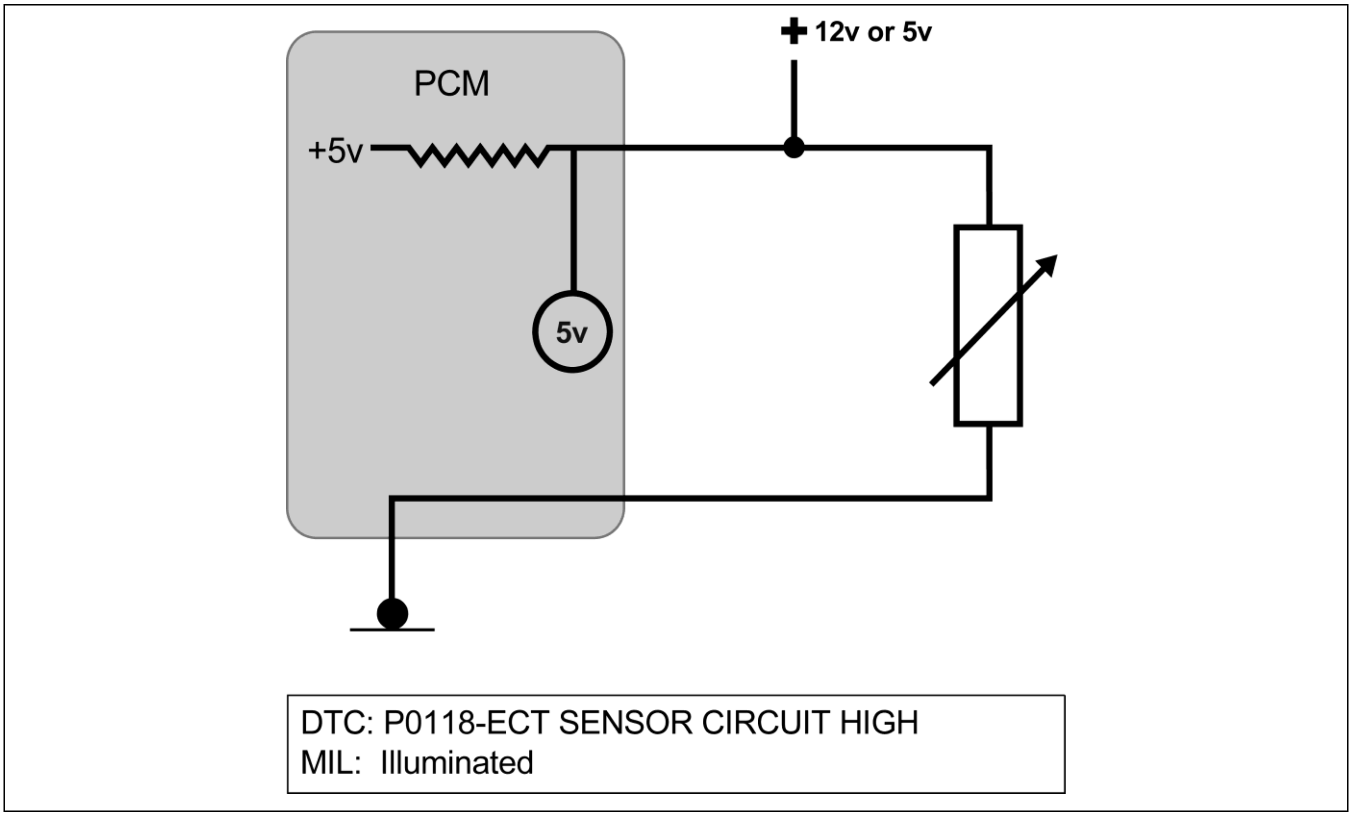


Figure 10 Short to Positive

Notes:

MODULE 2 SPEED DENSITY FUEL SYSTEM

FUEL DELIVERY SYSTEM

The fuel delivery system is returnless. All fuel leaving the fuel tank and pump is used by the engine. There is no fuel return line so no fuel returns to the tank.

An in-tank pump module pressurizes the fuel system. In vehicles without the Totally Integrated Power Module (TIPM), the PCM controls the operation of the fuel system by providing battery voltage to the fuel pump through the fuel pump relay. In vehicles with TIPM, the TIPM controls the fuel pump relay. The PCM requires only three inputs and a good ground to operate the fuel pump relay. The three inputs are:

- Ignition voltage
- Crankshaft position (CKP) sensor
- NGC:
  - Camshaft position (CMP) sensor
- GPEC:
  - Intake camshaft position sensor (CMP1/1)
  - Exhaust camshaft position sensor (CMP1/2)

Most passenger cars use a high-density polyethylene fuel tank. Since 1998, all fuel systems are returnless to minimize heat in the fuel tank, which leads to excessive hydrocarbon vapors.

The fuel delivery system components include:

- Fuel pump module
- Fuel filter/Fuel pressure regulator
- Check valve
- Fuel level sensor
- Lines and hoses
- Fuel rail and injectors

Fuel Pump Module

The in-tank fuel pump module contains the 12V electric fuel pump, fuel level sensor and pressure regulator. The pump is a positive displacement, gearotor, immersible pump with a permanent magnet electric motor. The pump is serviced only as part of the fuel pump module. Most fuel pump modules are retained by a “Mason Jar” flange ring on top of the fuel tank.

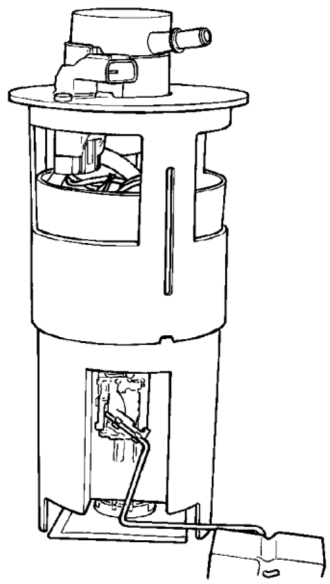


Figure 11 Typical Fuel Pump Module

Fuel Filter/Fuel Pressure Regulator

A combination fuel filter and fuel pressure regulator is currently used on all gas powered engines. It is located on the side of the fuel pump module in the fuel tank.

The pressure regulator is a mechanical device that is not controlled by the PCM. On NGC and GPEC vehicles, the regulator controls fuel pressure to a constant 58 psi (400 kPa). Consult Service Information for vehicle-specific information.

The PCM uses a special formula utilizing MAP sensor information to adjust injector pulse width based on the pressure differential across the injector.

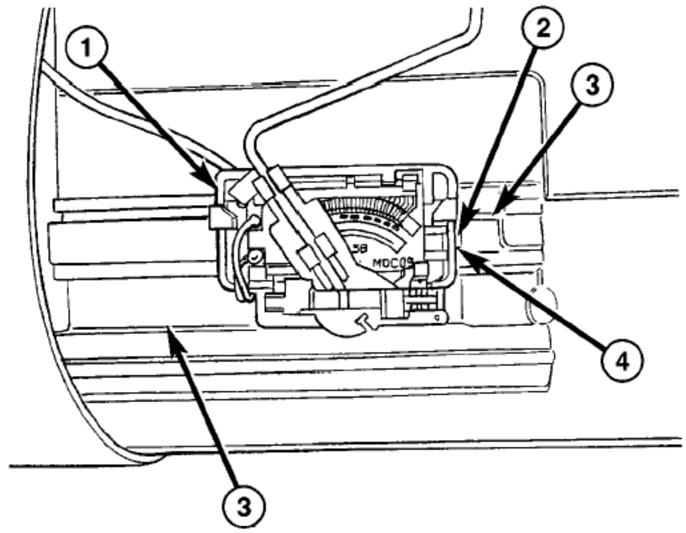
Some fuel filter and pressure regulator assemblies are replaceable separately. Consult Service Information for vehicle-specific information.

Check Valve

The fuel pump outlet contains a one-way check valve to prevent fuel return back into the tank when the pump is not running. With engine OFF, fuel pressure may drop to 0 psi (0 kPa) as the fuel cools, but the fuel supply line between the check valve and the fuel injectors will remain full of fuel. This is normal. When the fuel pump is activated, fuel pressure should immediately rise to specification.

Fuel Level Sensor

A fuel gauge level sending unit is attached to the fuel pump module. The resistance of the sensor rheostat changes with the amount of fuel in the tank. The sensor float arm moves as the fuel level changes.



1	Sending Unit
2	Lock Tab
3	Tracks
4	Notch

Figure 12 Typical Fuel Level Sending Unit

Some vehicles have a non-contact type of sensor which uses a magnet.

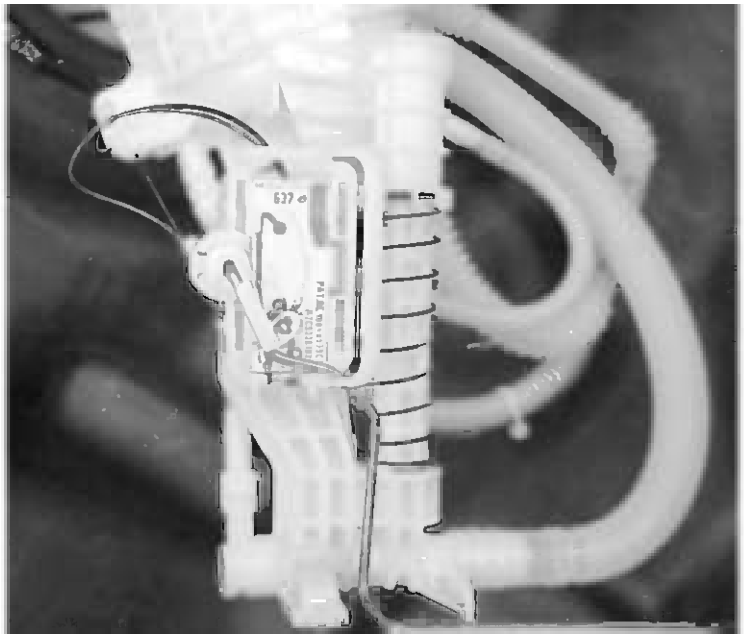


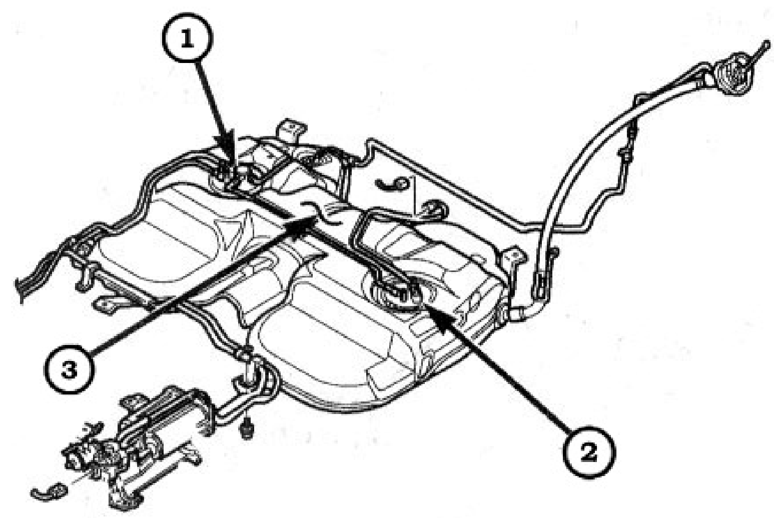
Figure 13 Magnet type fuel sending unit

The interior of the sensor contains 52 flexible metal fingers. The lever moved by the float is attached to a magnet. When the tank is full, the float is on top along with the magnet. As the fuel level falls, the float drops and the position of the magnet changes. The magnet is so close to the sensor that it attracts the closest metal finger. The fingers contact a metal strip. Different contact sites on the strip produce different resistances, which the system uses to measure fuel level.

Because of its enclosed design, this type of sensor does not wear as fast as the typical sending unit.

Dual Fuel Level Sensor

On vehicles which have a saddle-type fuel tank, there are two fuel level sensors. The two sensor signals are averaged by the appropriate body control module, depending on the vehicle package, to determine fuel level.



1	Fuel Pump Module and Fuel Level Sensor 1
2	Fuel Level Sensor 2
3	Fuel Tank

Figure 14 Dual Fuel Level Sending Units

Saddle-type fuel tanks are typically used in all wheel drive applications where a traditional single cavity style tank would not fit. The tank has reservoirs on both sides of the car that are connected by a “saddle” section above the driveshaft and exhaust. The fuel pump is in the primary side of the tank; the other side contains a regulator. When the engine is running, a venturi in the secondary side siphons fuel to the pump side. As the fuel is used, the side opposite the pump will be drained and only the pump side will have fuel. To provide an accurate fuel gauge reading, both fuel level sensors are combined to create a single output.

Lines and Hoses

The high pressure lines from the tank to the engine can be rubber, plastic or steel lines. The lines and hoses are of a special construction due to the higher fuel pressures and the possibility of contaminated fuel in this system. Use only replacement lines marked EFM/EFI.

Caution: Always follow procedures found in the Service Manual when removing fuel system components. Always lube the O-rings in the quick connect fittings with engine oil before reassembly.

Fuel Rail and Injectors

The fuel rail supplies fuel to each individual fuel injector and is mounted to the intake manifold. A fuel pressure test port is provided on the fuel rail for some applications.

FUEL DELIVERY SYSTEM DIAGNOSTICS

The fuel level input is used as an input for OBD II. If the fuel level is below 15% or above 85% of total tank capacity, several monitors are disabled.

The fuel pump has a maximum pressure output of approximately 130 psi (880 kPa).

Recommended test procedures may include line pressure test, pump volume test, and pump current draw test.

Caution: Pump volume testing must be completed within the specified time to prevent pumping all fuel from the pump well.

Fuel Quality Testing

Fuel quality is an old problem. The current main concern is alcohol and water contamination.

Adding any alcohol to gasoline increases the volatility (boiling point and vapor pressure) of the fuel, leading to possible driveability concerns such as vapor lock. Too much alcohol in fuel can make a vehicle difficult to start in colder weather. In addition, ethanol (the alcohol in E85) can corrode metal parts and damage plastics and nonmetallic fuel system parts. It can also wash out deposits in the fuel system leading to fuel filter clogging. Any of these issues can also lead to the setting of an OBDII code.

Alcohol contamination can be caused by:

- Fuel producers putting too much alcohol into fuel while producing 10% alcohol fuel (“gasohol”)
- Consumers mistakenly adding E85 to a non-flexfuel vehicle

If the contamination is serious enough, the fuel system should be flushed and the fuel tank cleaned. Refer to the appropriate Service Information.

Notes:

Notes:

MODULE 3 PCM

PCM OPERATION

The PCM controls the operation of the following fuel-related systems:

- Fuel delivery
- Emission controls
- Charging voltage
- Idle speed
- Radiator fan
- Air conditioning
- Speed control system
- Variable valve timing (GPEC)

The PCM receives information from input sensors, switches and the data bus that monitor specific operating conditions. The PCM processes this information in order to operate outputs that regulate engine performance. Outputs include the following:

- Ignition system
- Fuel injectors
- Generator field
- Air conditioning compressor
- Radiator fans
- Speed control servos

NEXT GENERATION CONTROLLER (NGC) PCM

The Next Generation Controller (NGC) replaced the SBEC and JTEC PCMs for most Chrysler group products as well as EATX III and EATX IV Transmission Control Modules (TCMs). The JTEC is still used on 10 cylinder applications. The NGC PCM first appeared on 2002 LH vehicles and 2002 ½ DN vehicles with the 4.7L engine.

Typically, NGC controllers house both the PCM and TCM.

NGC controllers:

- Require less under hood space due to the integration of the PCM and TCM
- Eliminate many external wiring circuits because of the ability of the PCM and TCM to share information
- Provide cleaner emissions, better fuel economy, drivability, and idle quality, as a result of a "model-based" fuel injection strategy. This strategy works on all engine applications, regardless of displacement.
- Have improved resistance against radio frequency interference (RFI) and electromagnetic induction (EMI)
- Improve fault detection and circuit protection through the use of Smart Drivers and enhanced diagnostics
- Provide faster computational speed

Differences Between NGC3 and NGC4

On NGC3 controllers, internal communications between the PCM and TCM microprocessors takes place via the Dual-Port RAM chip. This integrated circuit allows the two microprocessors to directly share high-speed digital information internally without having to rely on the PCI Bus for all communications. NGC4 (2007+ MY) instead uses a single board with a single processor.

There are other notable differences between NGC3 and NGC4:

- TIPM inputs to and controls of previous NGC functions
- New signals over the CAN bus
- Voltage regulator strategy
- Connector I/O differences
- Transmission-only module to support diesel applications
- Processor bandwidth and speed:
- NGC3: 32 bit/32 MHz engine processor, 16 bit/16 MHz transmission processor
- NGC4: 32 bit/80MHz processor for both engine and transmission

Figure 15 NGC4 PCM

Four 38-pin connectors are used on the NGC PCM. The connectors are identified by color:

- C1 (black)
- C2 (orange)
- C3 (white)
- C4 (green)

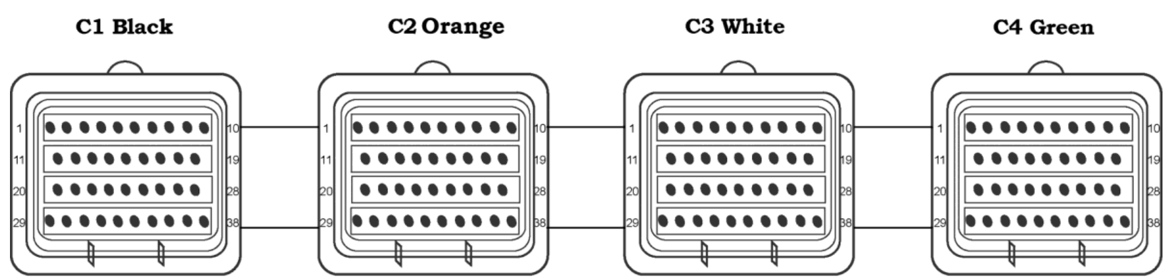


Figure 16 NGC PCM Connectors

Connector C4 is dedicated to transmission signals. If C4 is not populated with pins, the TCM will be found separately. Consult Service Information for vehicle-specific information.

When performing wiring harness diagnostics, it is important to not probe or back probe the connector. Connector damage will occur if this procedure is not followed. Two special tools have been designed for these connectors. The first is a pin-out box (Miller #8815) and adaptor cable (Miller #8815-1) combination that allows you to perform wiring harness tests, and the other is a pin removal tool (Miller #8638), which is used to remove the terminal end from the connector.

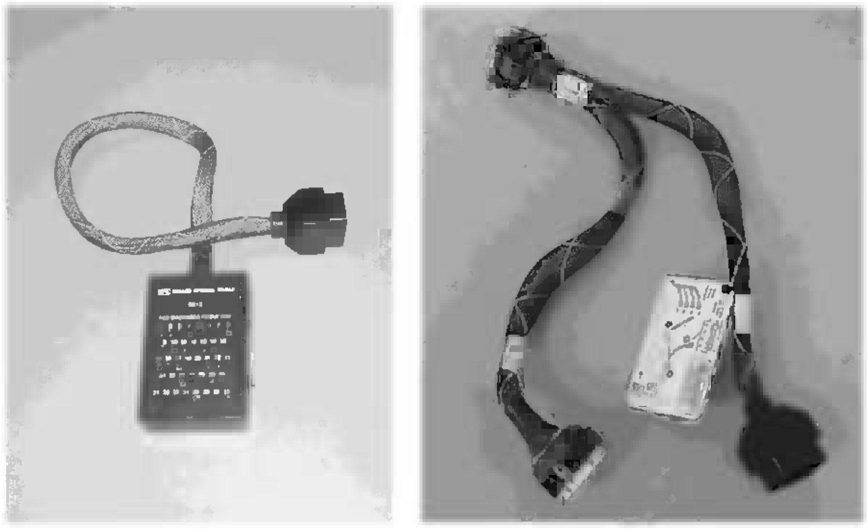


Figure 17 Miller #8815 Breakout Box and Miller #8815-1 PCM Breakout Box Adapter

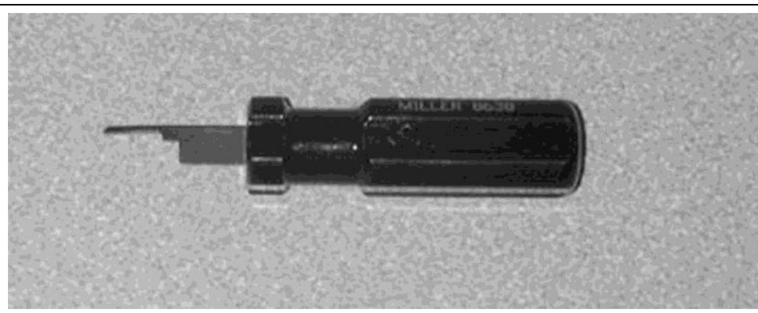


Figure 18 Miller #8638 Pin Removal Tool – NGC

GLOBAL POWERTRAIN ENGINE CONTROLLER (GPEC) PCM

The Global Powertrain Electronic Controller (GPEC) is used on vehicles equipped with the World Engine. These engines are 1.8L, 2.0L, and 2.4L I4 engines designed as a joint venture between DaimlerChrysler, Mitsubishi Motors, and Hyundai Motor Company. GPEC's first applications are the 2007 PM (Dodge Caliber) and 2007 MK (Jeep Compass).

Figure 19 GPEC PCM

GPEC does not control the transmission in the PM and MK, but will do so in future applications beginning with the 2007 JS (Sebring) equipped with the World Engine.

Two connectors are used on the GPEC PCM, one with 58 pins (C1) and one with 96 pins (C2). Connector C1 is dedicated to body or vehicle circuits (for example, brake switch state and vehicle speed), while connector C2 is dedicated to engine circuits (such as engine coolant temperature and camshaft position).

There is currently no breakout box or pin removal tool for the GPEC PCM.

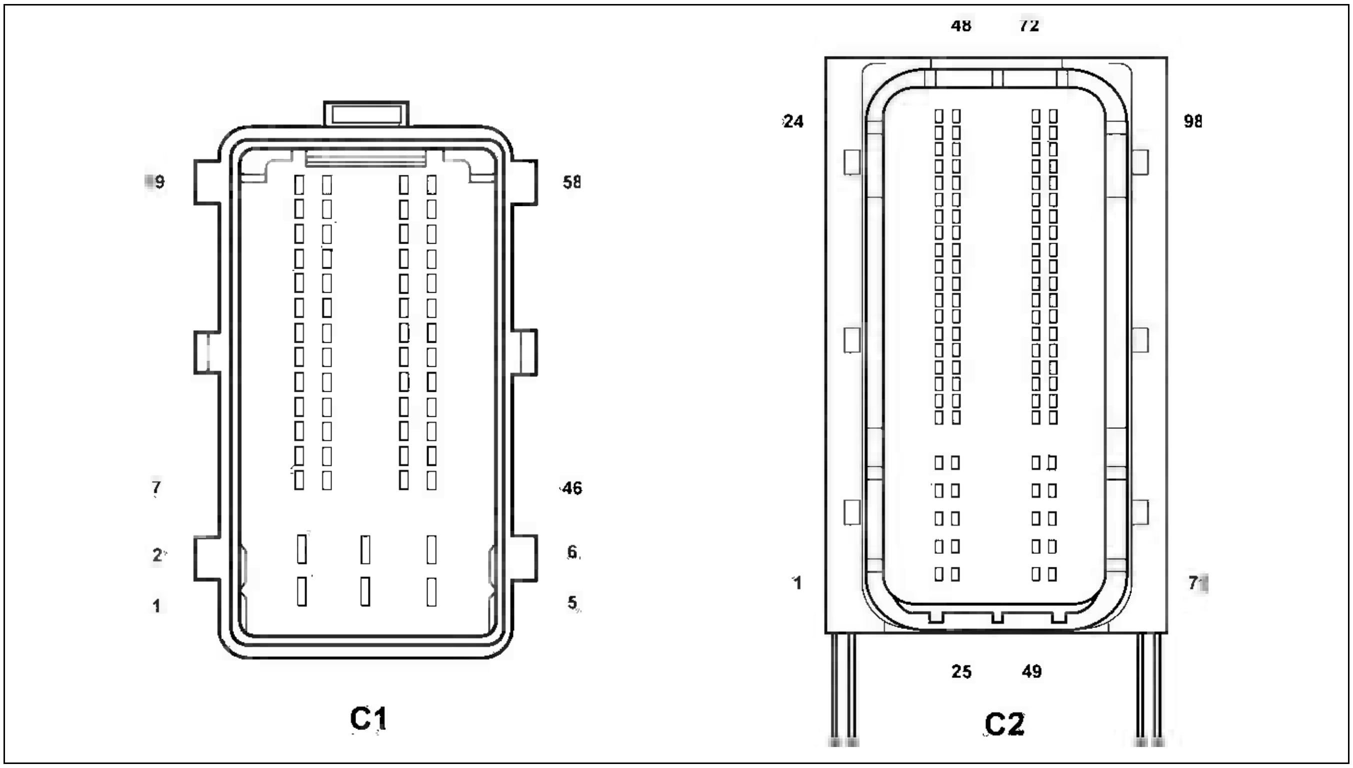


Figure 20 GPEC connectors

COMMUNICATION PROTOCOLS

PCI Bus (J1850)

Beginning in 1998, many vehicles used a single wire Programmable Controller Interface (PCI) Data Bus, also known as the J1850 Bus, for communication between the PCM and its shared inputs and outputs.

The PCI Bus was used for communication between the PCM and other modules. This single-wire communication protocol was also used by the DRBIII scan tool to communicate with the engine control microprocessor in the PCM while in the Generic Tool Mode using the J1979 protocol.

The PCI bus has been superseded by the CAN bus. Currently, only 2007 MY RS/RG minivan applications use the PCI. PCI will be 100% phased-out in 2008 MY, to be replaced by the Controller Area Network (CAN). Since the DRBIII can only be used with the PCI, it can only be used on older vehicles.

SCI Bus

The Serial Communication Interface (SCI) Bus is the communication protocol used to enable two-way communications between the engine control microprocessor and the scan tool while in Standalone Mode. SCI Transmit (SCI Tx) is also used to record engine and/or transmission events while Data Recording. SCI Receive (SCI Rx) is used for flash programming either the PCM or TCM.

The SCI bus is being phased out, to be replaced with the CAN bus system.

CAN Bus

Controller Area Network (CAN) is a serial bus system developed by Bosch in the early 1980s. It was first introduced on the Grand Cherokee export with MB supplied engine and transmission and on Ram trucks with the Cummins Diesel. Beginning with the 2007 model year, all vehicles with the exception of RS/RG minivan use the CAN bus instead of the PCI bus.

The CAN bus is a twisted two-wire communications system for transferring data between all of the vehicle's control modules. In addition to the CAN bus, some nodes may use a dedicated Serial Controller Interface (SCI) or a Local Interface Network (LIN) data bus. CAN Bus allows sensors to be wired to the closest module and share data with other modules. This is possible with increased data transfer speed and no lost messages.

The CAN bus system typically consists of three networks: CAN B (which operates at 83.3 kbps) or Interior High Speed Bus (IHS)(which operates at 125 kbps), CAN C, and Diagnostic CAN C. CAN C (which operates at 500 kbps) is faster than CAN B and is used for fast communications between critical powertrain and chassis modules. CAN B or IHS are used for communications between body and interior modules. Diagnostic CAN C carries diagnostic information between the Central GateWay module and a scan tool connected to the Data Link Connector (DLC). These Central GateWay modules physically and electrically isolate the CAN busses from each other, and coordinate message transfer between them.

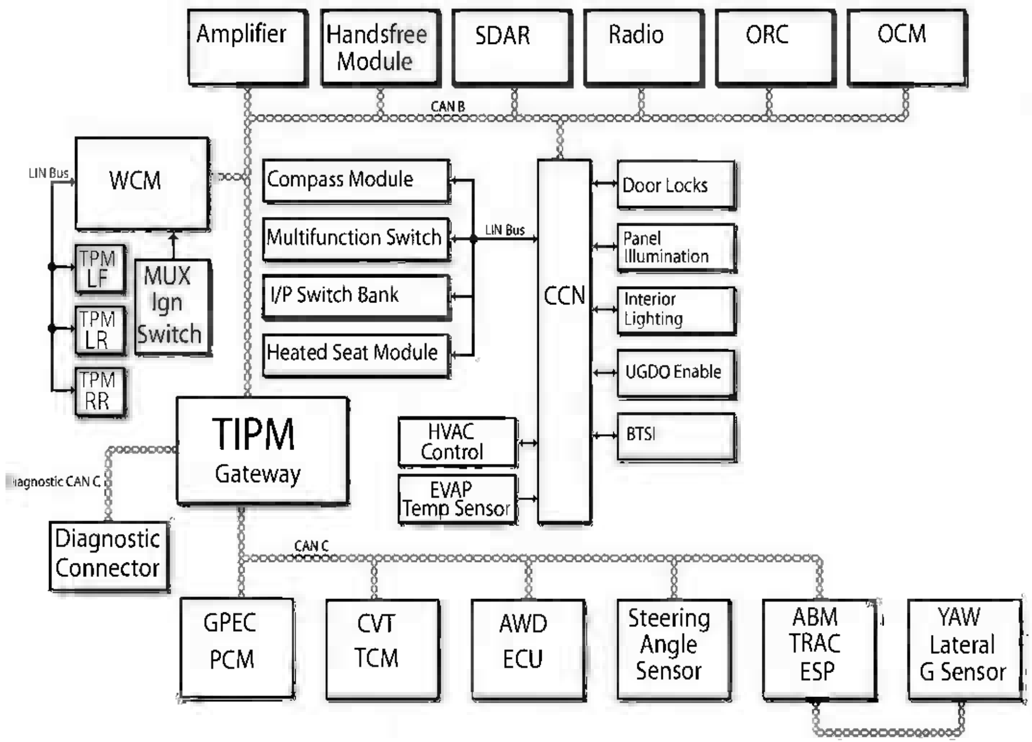
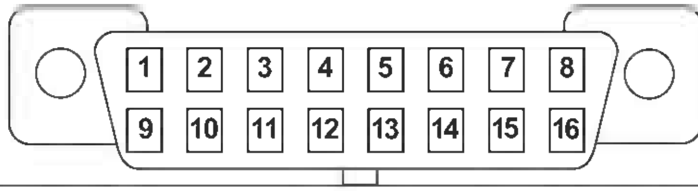


Figure 21 GPEC CAN bus

J1962 Data Link Connector (DLC) Connector

The PCM maintains communication with scan tools through the vehicle Data Link Connector (DLC). The DLC connector is located under the instrument panel, near the steering column.

Beginning with 2002 LH, AN, DN and DR models, Chrysler Group vehicles switched over to a new J1962 DLC connector layout to comply with a revised SAE specification. This was required for the introduction of the Controller Area Network (CAN) Bus. Pins 6 and 14 were originally designated as "manufacturer specific" by SAE, but were recalled to be used for the CAN Bus. This forced a relocation of the SCI Bus circuits that were previously assigned to these terminals. Refer to the appropriate Service Information.



TERMINAL ASSIGNMENT & FUNCTION			
		DaimlerChrysler Corporation	
PIN	**SAE/ ISO**	**A (1994MY - 2002MY+)**	**B (2002MY+)**
1	Manufacturer Discretionary	RKE Programming Input	not used
2	SAE J1850 (+)	SAE J1850 10.4 Kbps	SAE J1850 10.4 Kbps
3	Manufacturer Discretionary	CCD (+)	not used
4	Chassis Ground	Power Ground	Power Ground
5	Signal Ground	Signal Ground	Signal Ground
6	ISO 15765-4 CAN-C (+)	SCI A Rx (Receive) (*Engine*)	ISO 15765-4 CAN-C (+)
7	ISO 9141-2 K-line ISO 1423-4 K-line	ISO 9141-2 K-line/ SCI Tx (Transmit) (*Engine/ Transmission*)	SCI Tx (Transmit) (*Engine*)
8	Manufacturer Discretionary	A/D Signal Output/Switched Ignition	Switched Ignition
9	Manufacturer Discretionary	SCI B Rx (Receive)/ J1850 Flash Enable	SCI Rx (Receive) (*Trans.*)/ J1850 Flash Enable
10	SAE J1850 (-)	Reserved	Reserved
11	Manufacturer Discretionary	CCD (-)	not used
12	Manufacturer Discretionary	SCI C Rx (Receive)	SCI Rx (Receive) (*Engine*)
13	Manufacturer Discretionary	Lo-Driver/SCI Tx (Transmit) (*Body/ Chassis*)	not used
14	ISO 1565-4 CAN-C (-)	SCI D Rx (Receive) (*Transmission*)	ISO 15765-4 CAN-C (-)
15	ISO 9141-2 L-line/ ISO 14230-4 L-line	Inverted SCI Tx (Transmit)	SCI Tx Transmit (*Trans.*)
16	Unswitched Battery Voltage	Battery Voltage	Battery Voltage

Figure 22 Data Link Connector Pin Assignment

PCM REPLACEMENT

Replacement PCMs now require programming with a scan tool. The PCM will not operate until programmed and a DTC will be set "Not Programmed". See the latest applicable "Generic Powertrain Control Module (PCM) Procedure" TSB for the procedure to program the generic PCM.

Caution: Always verify before programming (flashing) a PCM that the correct software for the vehicle configuration and PCM is being used. Flashing a PCM with incorrect software may prevent some vehicle features from operating and in some cases may cause damage.

Note: Many PCMs are replaced incorrectly because of scan tool issues or problems with communication between the scan tool and the PCM.

When replacing the PCM, follow the procedure in the Service or Diagnostic Procedure Manuals.

WARNING: VEHICLES EQUIPPED WITH WCM REQUIRE A SPECIFIC PROCEDURE FOR WRITING THE VIN IN THE PCM. IF THE PROPER PROCEDURE IS NOT FOLLOWED, PCM AND SKIM MODULE DAMAGE COULD OCCUR.

FLASH PROGRAMMING

When the Module Display screen is accessed on the scan tool, the software year that is displayed is not programmed directly into the PCM, but is actually determined from the VIN number that has been programmed into the vehicle's controllers. Also, note that the last two digits following the part number refer to the software year of the module. Be aware that the vehicle year may not always match the actual software year in the module.

Notes:

Notes:

MODULE 4 PCM POWER FEEDS AND GROUNDS

NGC POWER FEEDS AND GROUNDS

Caution: In order to avoid damage to the PCM, always turn the key OFF befor disconnecting any PCM related circuits or connectors.

NGC Unswitched Battery Feeds

The Power Distribution Center (PDC) provides one or more direct B+ battery feeds to the NGC PCM. It is used by the PCM to retain DTCs and OBD II data after the vehicle has been turned off. Direct B+ battery feeds are also used to supply power to low voltage components and the internal power supply that is used for power and biasing the sensors.

The PCM monitors the direct battery feed input to determine charging rate, control the injector pulse width, and back–up RAM used to store DTC functions. Direct battery feed is also used to perform key-off diagnostics and to supply working voltage to the controller. This is called Sensed Battery Voltage.

NGC Switched Ignition Feeds

The PCM also receives switched voltage from the ignition switch while in the RUN and START positions. In the RUN positions, the ignition feed is a “wake-up” signal to the PCM and a source of B+ power. This signals the microprocessor to turn on the 5V power supply. In the START position, the ignition feed signals the TCM to prohibit diagnostics on certain circuits in order to prevent errors that may occur because of voltage fluctuations.

NGC Sensor Grounds

The PCM uses three engine grounds. The grounds include an RFI/EMI filter to supply an electrically clean, common ground for all sensors except oxygen sensors, knock sensors and transmission input and output shaft speed sensors. The oxygen sensors do not use a “sensor ground” for the return side of their circuits. The return (ground) side is biased to supply 2.5V on the sensor return side of the circuit, instead of having a direct path to ground.

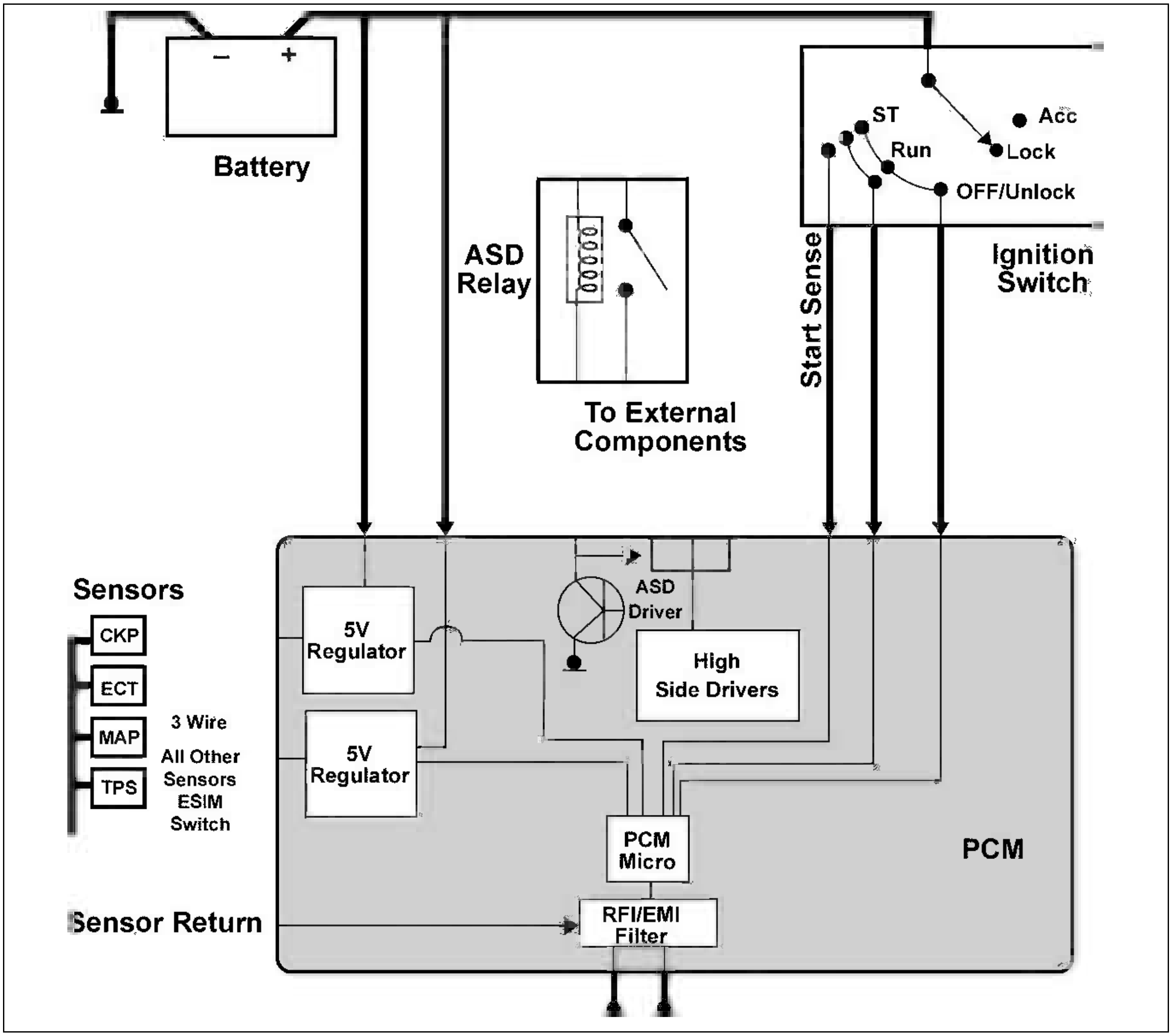


Figure 23 NGC Power and Grounds

NGC Auto Shutdown (ASD) Relay

When energized by the PCM, the Auto Shutdown (ASD) Relay will supply voltage to various circuits including:

- PCM
- Fuel injectors
- Ignition coils
- Short runner valve
- Manifold tuning valve

The ASD relay outputs two or three voltage feeds to the PCM. Just as in previous controllers, this information is used by the PCM as a confirmation that the output side of the ASD relay is operating correctly. Unlike previous systems, these voltage feeds are used:

- To power the high-side driver circuits
- To allow the engine to keep running in the event direct battery power is lost

Note: The vehicle will not start without a direct battery feed to the PCM.

NGC 5 Volt Regulated Power Supply

The NGC PCM utilizes the direct 12V battery feed to power 5V regulators, which supply the Primary, and Secondary voltage feeds. These 5V circuits supply power to the various three-wire sensors and transducers utilized. The application of the primary and secondary 5 Volt power supplies is vehicle and power train specific. Internally the 5V regulators also bias the sensor input circuits. On NGC PCMs while in sleep mode, a 5V power source and some memory will stay alive to monitor the NVLD or ESIM switch for closure. This will be discussed in detail in the OBD II course.

NGC Testing and Diagnosis

The vehicle will not start without a direct battery feed to the PCM.

It is important that the sensors be properly connected to the sensor return (ground) circuit, and that the sensor return circuit is not directly connected to Ground. Bypassing the sensor return (ground) may bypass RFI/EMI filter circuitry and may introduce problems. For example, the PCM may see blips in the TPS signal and assume that the throttle is opening.

The PCM stores diagnostic information in battery–backed RAM. Once the technician reads a DTC, it can be erased from RAM by using the scan tool (the recommended method), or by running three Good Trips and 40 Warm-Up Cycles. DTCs can also be erased by disconnecting the battery for several seconds, but this method is not recommended since it erases other information (such as long term fuel trim values) that is kept in battery-backed RAM.

GPEC POWER FEEDS AND GROUNDS

GPEC Unswitched Battery Feeds

The GPEC receives three 12-volt power feeds. One feed comes directly from the battery; the other two are from the main relay. Unlike the NGC, the voltage feed from the main relay is the primary source of power for the GPEC. The direct 12-volt battery feed is only used to keep the GPEC alive to conduct OBD II monitor tests after the vehicle is shut off.

GPEC Switched Ignition Feeds

The ignition switch is hardwired to the Wireless Control Module (WCM). The WCM busses the switch position information to the TIPM, which sends voltage to the GPEC PCM through a high side driver.

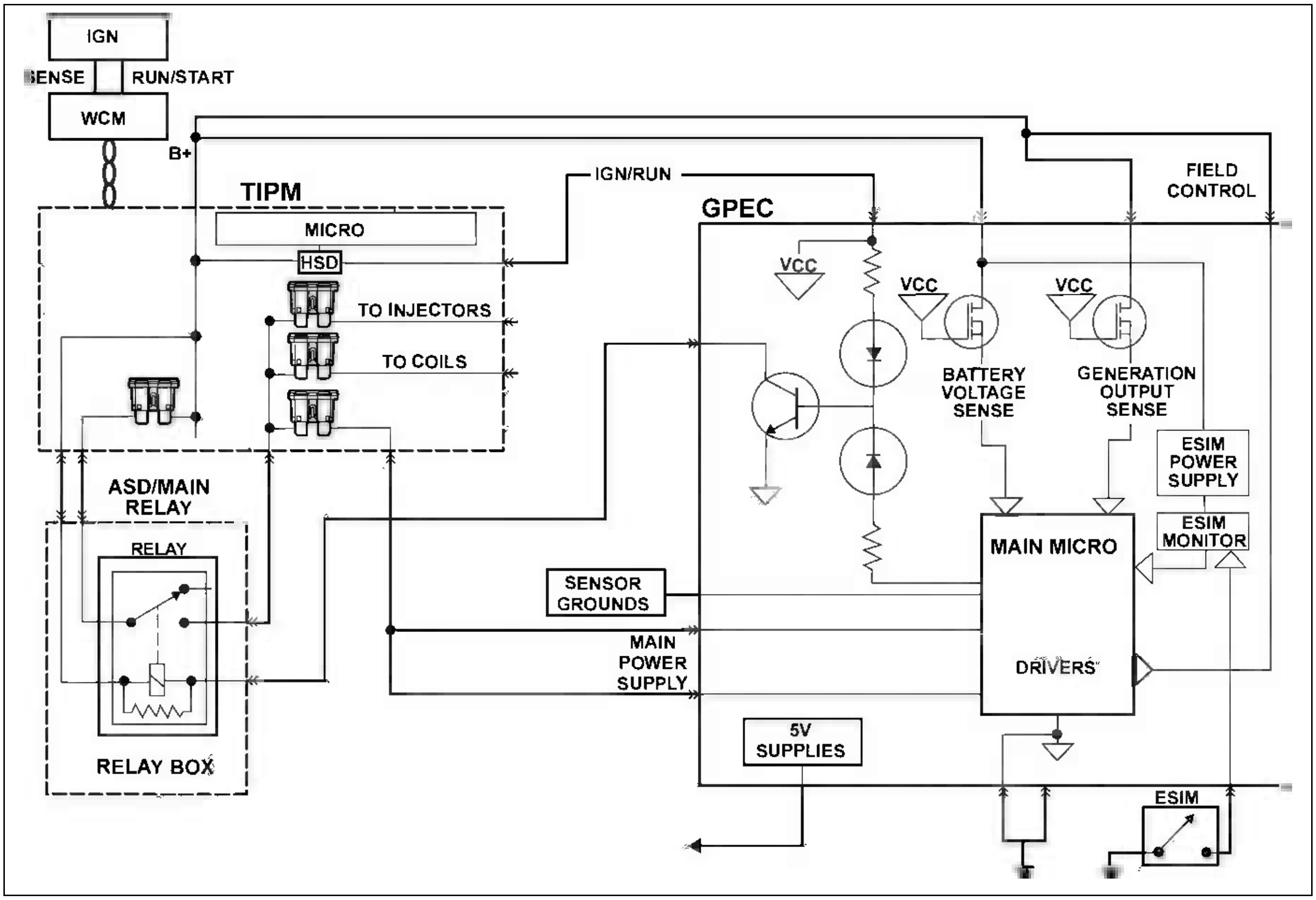


Figure 24 GPEC Feeds and Grounds

GPEC Main Relay

The main relay is located under the hood. Like the ASD relay used with the NGC, the main relay supplies voltage to the ignition coils, fuel injectors, and high side drivers. The main relay also provides the voltage to power-up the GPEC. If the main relay is bad, the GPEC will not power-up.

The main relay is energized when the ignition switch is in the RUN/START switch position. The GPEC grounds out the main relay control energizing the main relay coil. This circuit allows the relay to remain energized for approximately seven to ten seconds after the vehicle is shut off. During this time the GPEC performs various shutdown functions.

Reverse voltage protection for the GPEC is provided by the main relay. During a reverse voltage condition, the main relay is deactivated and therefore does not provide power to the GPEC.

GPEC 5 Volt Regulated Power Supply

The GPEC supplies voltage to four 5V supplies. Internally, the 5V regulators operate in a similar fashion as the NGC. One supplies the primary voltage feed, one supplies the main secondary voltage feed, and the other two supply the other secondary voltage feeds.

The primary 5V supply provides power to:

- Throttle position sensor (TPS)
- Exhaust camshaft sensor (CMP1/2)
- Crankshaft sensor (CKP)

The secondary 5V supplies provide power to:

- Accelerator pedal position sensor 1 (APP1)
- Vehicle speed sensor (VSS)
- Manifold flow valves
- Intake camshaft sensor (CMP1/1)
- Manifold air pressure sensor (MAP)
- Accelerator pedal position sensor 2 (APP2)

GPEC Testing and Diagnosis

The vehicle will not start without a direct battery feed to the PCM.

It is important that the sensors be properly connected to the sensor return (ground) circuit, and that the sensor return circuit is not directly connected to Ground. Bypassing the sensor return (ground) may bypass RFI/EMI filter circuitry and may introduce problems. For example, the PCM may see blips in the TPS signal and assume that the throttle is opening.

The vehicle will also not start without input from the exhaust camshaft sensor (CMP2) or the crankshaft sensor (CKP).

The GPEC PCM stores diagnostic information in nonvolatile memory, which, unlike earlier PCMs, cannot be erased by a battery, disconnect. It can only be erased by a scan tool or by running three Good Trips followed by 40 Warm-Up Cycles.

Totally Integrated Power Module (TIPM)

The Totally Integrated Power Module, or TIPM, and the PCM share the responsibility to power many devices on vehicles that use the TIPM.

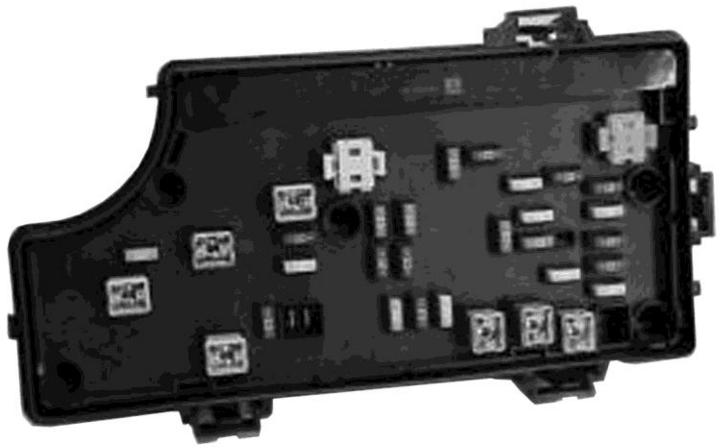


Figure 25 TIPM

The TIPM performs many functions traditionally relegated to the engine controller. It is the gateway of the communication network. It processes bussed messages from the PCM and other controllers and provides power and logic control for various systems.

The TIPM contains solid-state high and low side drivers as well as fuses for critical systems. Some outputs that require TIPM processing include:

- Starter relay
- Radiator fan relay
- Fuel pump high side driver

The high side driver for the starter is located inside the TIPM. The PCM busses starter information to the TIPM, which then supplies voltage directly to the starter assembly.

The radiator fan relay is hard-wired to the TIPM. The TIPM receives information regarding fan operation through the CAN bus, then sends the signal to activate the fan relay. If the CAN bus fails, the fans turn on.

The high side driver for the fuel pump is also located inside the TIPM.

Notes:

Notes:

MODULE 5 SPEED DENSITY EQUATION

Chrysler Group vehicles have used the Speed Density Equation since the introduction of fuel injection in the early 1980s. The formula demonstrates how the PCM uses these inputs to modify fuel injector pulse width in order to maintain the stoichiometric air/fuel ratio of 14.7:1.

When the air/fuel ratio is rich (lower than 14.7:1, low oxygen content), HC and CO emissions increase. When the air/fuel ratio is lean (higher than 14.7:1, high oxygen content), NOx emissions increase.

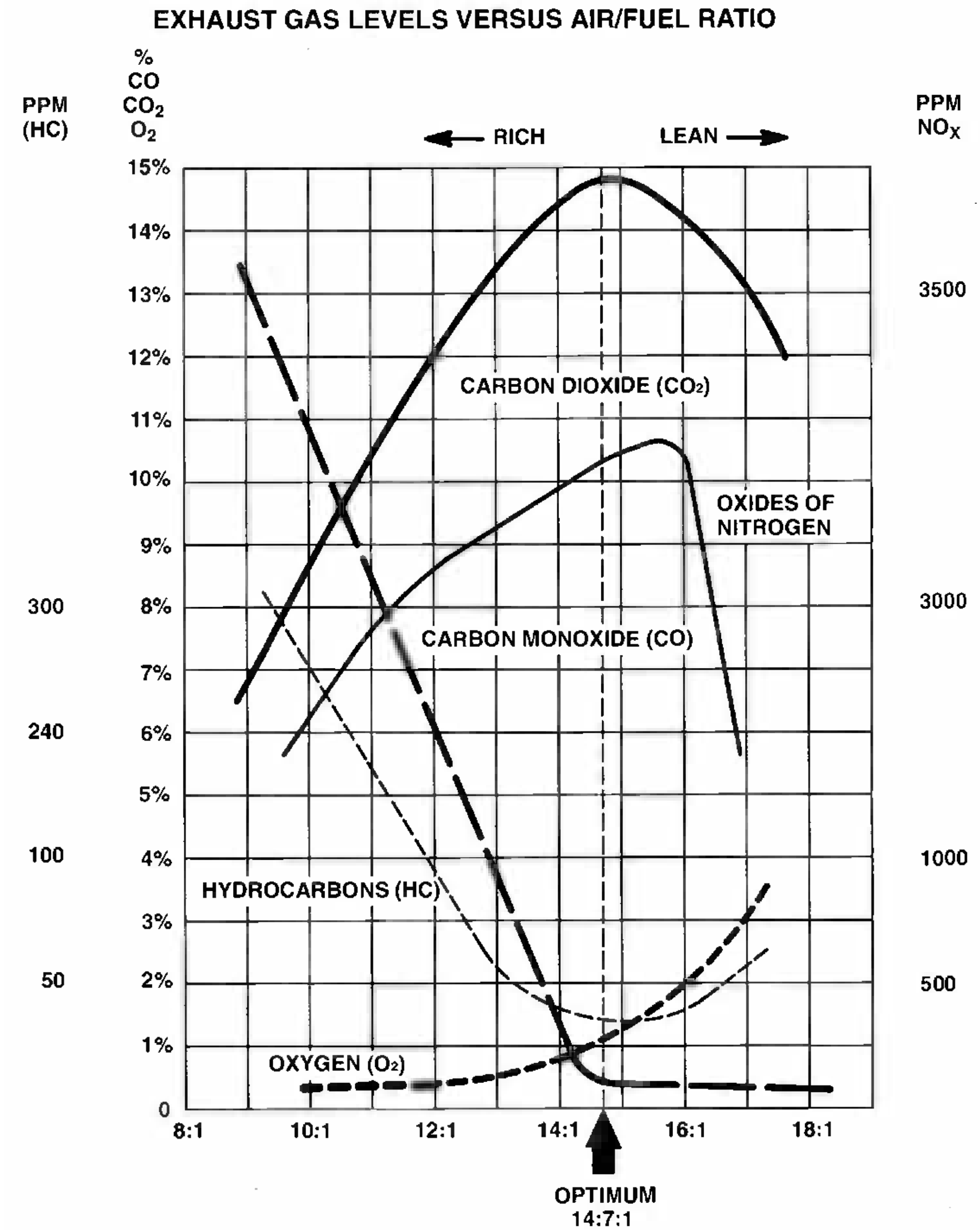


Figure 26 Exhaust Emissions vs. Air/Fuel Ratio

SPEED DENSITY MODEL

Older PCMs were unable to allow for the extra fuel and air that are fed into the engine when EGR and purge are active, and then had to use short and long term fuel trims to compensate. Because of the increased capabilities of NGC, EGR flow and extra fuel from EVAP purge are also part of the equation now.

Air Flow	Fuel Modifiers	Feedback Input	Adaptives	P.W.
RPM / Max RPM (X) MAP / Baro (X) EGR Flow*	(X) TPS (X) ECT (X) IAT (X) Sensed B+	(X) Up O2	(X) ST (X) LT (X) Purge Vapor Ratio*	= Pulse Width

*Where Equipped

Figure 27 NGC Speed Density Equation

Air Flow	Fuel Modifiers	Feedback Input	Adaptives	P.W.
RPM / Max RPM (X) MAP / Baro (X) Calculated EGR	(X) TPS (X) ECT (X) IAT (X) Sensed B+	(X) Up 02	(X) ST (X) LT (X) Purge Vapor Ratio	= Pulse Width

Figure 28 GPEC Speed Density Equation

The following explains how the PCM derives each multiplier in the Speed Density Model:

Air Flow

The PCM calculates engine RPM from the Crankshaft Position (CKP) Sensor signal. The sensor is a Hall-effect sensor that detects notches in a pulse ring machined into the crankshaft on some engines or slots in the flywheel or flex plate on other engines. The high-low digital signals allow the PCM to determine crankshaft RPM. The Camshaft Position Sensor (CMP) sensor determines which of the two companion cylinders should receive fuel and spark. Basic airflow requirements are determined by dividing the current engine RPM value by the theoretical maximum (rated) RPM. The Speed Density Equation allows the PCM to determine the percentage of the maximum possible airflow currently entering the engine.

To determine the level of engine load, the Manifold Absolute Pressure (MAP) Sensor measures the level of pressure (vacuum) in the intake manifold. This measurement is compared with atmospheric (barometric) pressure. On non-turbo vehicles, during startup and at WOT, the MAP sensor reading is assumed to be atmospheric pressure and is stored as a BARO value. This is accomplished with a separate sensor on turbo vehicles. The Speed Density Equation divides MAP by BARO to determine the level of engine load. The MAP value approaches BARO at higher loads.

There is always a slight lag in response from the MAP sensor itself. Therefore, the PCM calculates the expected MAP value based on inputs for throttle position, barometric pressure and IAC position. This is part of the "Model-Based Fuel Strategy" and this calculated value is called "T-MAP". MAP sensor input validates this calculated value. Whenever a MAP DTC is set or a MAP problem occurs, the PCM will use the T-MAP value. T-MAP values will appear on the scan tool as "real" MAP values.

Exhaust Gas Recirculation (EGR) is used for control of NOx emissions and to improve fuel economy. During EGR, exhaust gases from the exhaust manifold are metered through a valve and fed into the intake manifold. These gases are mostly inert carbon dioxide and nitrogen, and in the engine cylinder they displace a percentage of the incoming mixture. Because EGR gases effectively reduce the size of the combustion chamber, there is less room for air/fuel mixture. Less oxygen is drawn in and therefore less fuel is required.

In the GPEC PCM, camshaft overlap and modeled exhaust gas temperature are used to more accurately predict the amount of air in the engine and the amount of calculated or "internal" EGR (combustion products still present in the cylinder at the moment that the exhaust valves close). There is no EGR valve.

Fuel Modifiers

The Speed Density Equation uses Throttle Position Sensor (TPS) input to inform the PCM of certain operating conditions such as idle (Min TPS), wide open throttle (WOT), decel and the rate of throttle opening. These conditions can affect engine fuel requirements and the fuel injection pulse width calculation: acceleration enrichment, decel fuel shutoff, WOT indicating open loop while running or fuel injector shutoff (clear-flood) while cranking.

Engine temperature affects fuel requirements, therefore input from the Engine Coolant Temperature (ECT) Sensor is part of the Speed Density Equation. A cold engine requires enrichment compensation. Fuel does not vaporize well when cold and can puddle in the intake. The ECT is monitored to determine initial cranking injector pulse width and also temperature compensation while the engine is running.

The World Engine controlled by the GPEC PCM currently has two ECT sensors, one in the cylinder head and one in the cylinder block. The ECT input in the Speed Density Equation comes from the sensor in the head.

Air density changes as a factor of air temperature and altitude. Denser air requires more fuel to maintain a stoichiometric air/fuel ratio. The Intake Air Temperature (IAT) Sensor assists the PCM in calculating the density of the incoming air and modifies the Speed Density calculation accordingly.

The voltage applied to the fuel injectors affects how rapidly and how far the injector pintle opens. The quantity of fuel injected in a given amount of time changes with variations in voltage. Sensed B+ or sensed system voltage is monitored and used by the PCM to correct injector pulse width.

Feedback Input

The oxygen sensor measures oxygen levels in the exhaust and provides the PCM with a feedback signal. The PCM infers air/fuel ratio from this signal to see how well the Speed Density calculation has predicted fuel requirements for current engine speed, load and other conditions.

When the air/fuel ratio is at stoichiometry, the oxygen sensor signal switches above and below a predetermined switching point (goal voltage). When the oxygen sensor stops switching and the signal is consistently high or low, the PCM responds by changing injector pulse width until the O_2 sensor switches again. It does this through the Short Term Adaptive, Long Term Adaptive and Purge Adaptives.

Short Term Adaptive (Short Term Fuel Trim or STFT), is an immediate correction to fuel injector pulse width. It is an immediate response to an O_2 sensor signal that is not switching or is consistently high or low. Short Term Adaptive begins functioning shortly after the vehicle has started, as soon as the oxygen sensor is heated to operating temperature. Short Term Adaptive values change very quickly and are not stored when ignition is OFF.

After the vehicle has reached full operating temperature, the correction factors generated by Short Term Adaptive will be stored in Long Term Adaptive (Long Term Fuel Trim or LTFT) memory cells. These long term values allow the Short Term Adaptive value to be brought back to near zero. Once this correction factor is stored in memory, it will be used by the PCM under all operating conditions, open loop and closed-loop.

The final correction in the Speed Density Equation is the Purge Adaptive. This is the proportion or concentration of fuel (Hydrocarbon) vapors in the EVAP system purge flow. If purge flow contains a high ratio of HC vapors, less fuel from the injectors is required. During purge operation, Long Term Adaptive values are not updated, and necessary fuel adjustments are accomplished through changes in Purge Adaptive.

Notes:

MODULE 6 PCM INPUTS

The PCM receives inputs from sensors and switches that inform the PCM about physical conditions such as temperatures, speeds and the position of various components. This information influences the PCMs output decisions. Inputs can be either a sensor (analog) input, or a switch (digital) input. A sensor or analog input will generate or modify a varying voltage signal that is sent to the PCM, whereas a switch or digital input will send a HIGH/LOW or ON/OFF signal to the PCM.

PCM DIGITAL INPUTS

Hall-effect devices are frequently used for digital PCM inputs where accuracy and fast response are important. Hall-effect devices provide the PCM with digital inputs that do not need analog to digital conversion.

The PCM supplies 5V to the Hall-effect sensor. This voltage powers the Hall-effect chip and the electronics in the sensor. A ground for the sensor is provided through the sensor ground circuit. The signal to the PCM is on a 5V reference circuit. The Hall-effect sensor contains a powerful magnet. As the magnetic field passes over the dense portion of a counterweight, flex plate or trigger wheel, the 5V signal is pulled low to approx. 0.3V through a transistor in the sensor. When the magnetic field passes over the notches in the crankshaft counterweight, flex plate or trigger wheel, the magnetic field is lost, turning OFF the transistor in the sensor and supplying the PCM with a 5V signal. The PCM identifies crankshaft position by registering the change from 5V to 0V, as signaled from the crankshaft position sensor (CKP).

NGC Crankshaft Position (CKP) and Camshaft Position (CMP) Sensors

The CKP and CMP sensors are Hall-effect switch inputs to the PCM. Hall-effect devices toggle the 5V reference from the PCM ON and OFF.

Each Hall-effect switch is a three-wire sensor. One wire is the 5V power supply. This feed powers the internal electronics. Each sensor will share a common sensor ground wire. The remaining wire on each sensor is an individual signal wire.

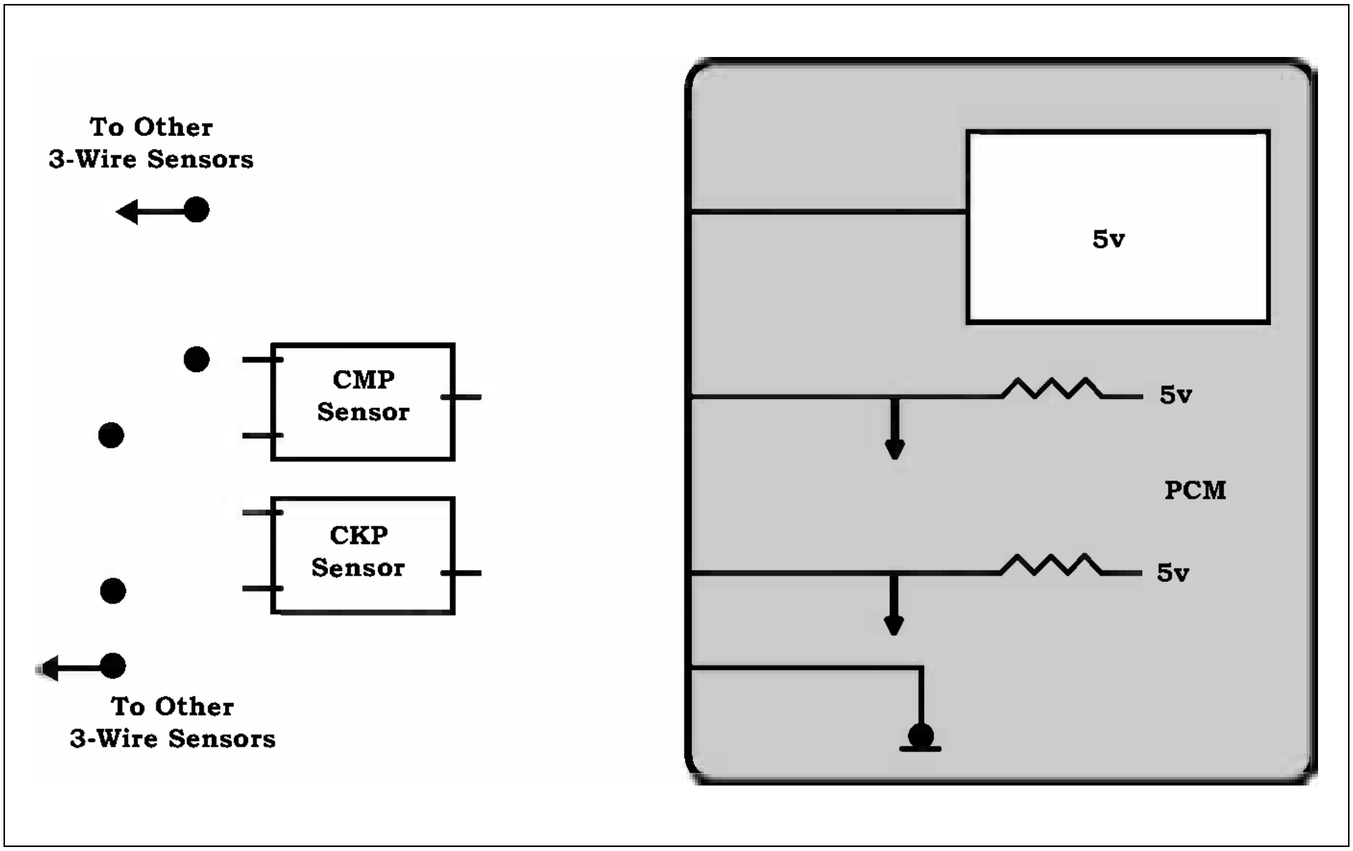


Figure 29 NGC CMP and CKP Sensors (Completed by Student)

One of the goals of NGC is commonality among all vehicle lines. Achieving this requires benchmarks that would be used for all applications. One example of this is the signals generated by the CMP and CKP sensors. All vehicles, regardless of the number of cylinders, will generate exactly the same CKP signal. The triggering device, whether a flex plate or a tone wheel, will have a tooth or notch every 10 degrees of crankshaft rotation, with two missing notches and two fused notches 180° apart.

Figure 30 Typical NGC CKP Trigger

Figure 31 Typical NGC CKP Scope Pattern

CMP sensor triggers are also benchmarked. However, four, six and eight cylinder engines each need a specific trigger to determine cylinder location. The result is three separate trigger patterns, specific to the number of cylinders. All four-cylinder engines will generate the same scope pattern, all six-cylinder engines will generate the same pattern, and all eight cylinder triggers will generate the same pattern.

Figure 32 Typical 6 Cylinder NGC CMP Triggers

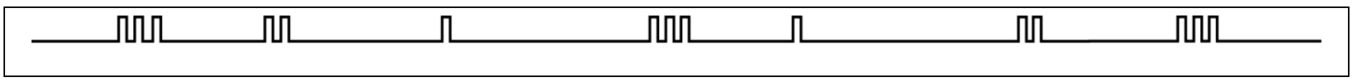


Figure 33 Typical 6 Cylinder NGC CMP Scope Pattern

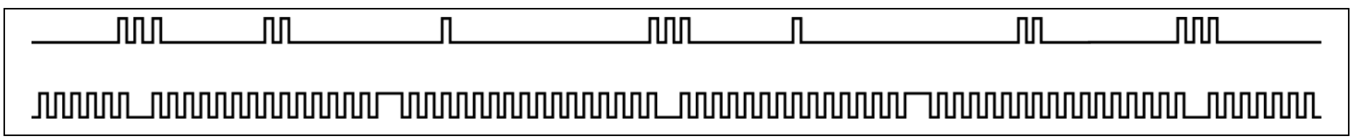


Figure 34 Typical NGC CMP / CKP Scope Patterns Superimposed

NGC Crankshaft Position (CKP) and Camshaft Position (CMP) Sensor Diagnostics

The engine will start even if one of these two sensors fails. The PCM will eventually sort out engine position and start the vehicle on just one of these two inputs. However, there will be a slight delay in starting until the PCM can establish sync.

A DTC is set and the MIL will illuminate if either or both CKP and CMP signals are not present during engine cranking.

When performing oscilloscope diagnosis, all NGC CKP sensor patterns will be identical for all vehicles and engines. It is important that the correct components are installed in an NGC vehicle.

GPEC Crankshaft Position (CKP) and Camshaft Position (CMP) Sensors

On GPEC vehicles, the crankshaft sensor senses crankshaft position based on the position of a tone wheel that has 60 minus 2 teeth. When the gap created by the missing teeth passes by the sensor, a signal is produced that indicates the number one piston is at Top Dead Center (TDC).

Figure 35 GPEC CKP Tone Wheel

Figure 36 GPEC CKP Scope Pattern

Currently, there is both an intake and an exhaust camshaft sensor on GPEC vehicles. The variable valve timing (VVT) system used on World Engines requires the exact position of both the intake and exhaust camshaft. The GPEC uses crankshaft sensor data along with camshaft sensor data to determine the actual position of the camshafts.

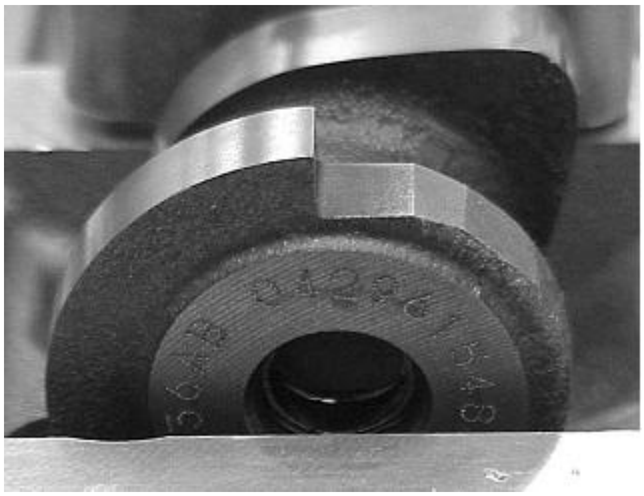


Figure 37 GPEC World Engine CMP Tone Wheel

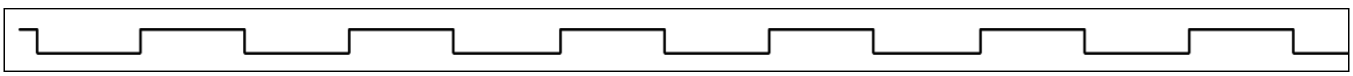


Figure 38 GPEC CMP Scope Pattern

Notes:

PCM ANALOG INPUTS – THREE WIRE

Analog inputs to the PCM provide a variable voltage signal which varies with the changes to the condition monitored. Analog inputs typically are three-wire sensors with a common 5V power source, a 5V bias signal, and a common sensor ground.

All analog input voltages from the sensors are measured relative to the sensor bias voltage internally in the PCM. Since all three-wire sensors are fed by the same power supply, a short to ground or an open circuit at a common location will result in a no-start.

Manifold Absolute Pressure (MAP) Sensor

The MAP sensor measures the level of pressure or vacuum existing in the intake manifold. The MAP sensor also determines ambient barometric pressure. The PCM needs this information to know if the vehicle is at or above sea level because air density changes with altitude. The MAP sensor also helps to correct for varying weather conditions.

The MAP sensor is supplied 5V from the PCM and varies a voltage signal to the PCM in proportion to manifold pressure (vacuum). The 5V power supply to the MAP sensor may be shared with other sensors. The MAP sensor operating range is typically from approximately 0.45V (high vacuum) to 4.8V (low vacuum). Like the cam and crank sensors, ground is provided through the sensor ground circuit.

The MAP sensor has the most authority for determining injector pulse width. The MAP sensor also influences spark advance, ETC throttle plate position and deceleration fuel shutoff.

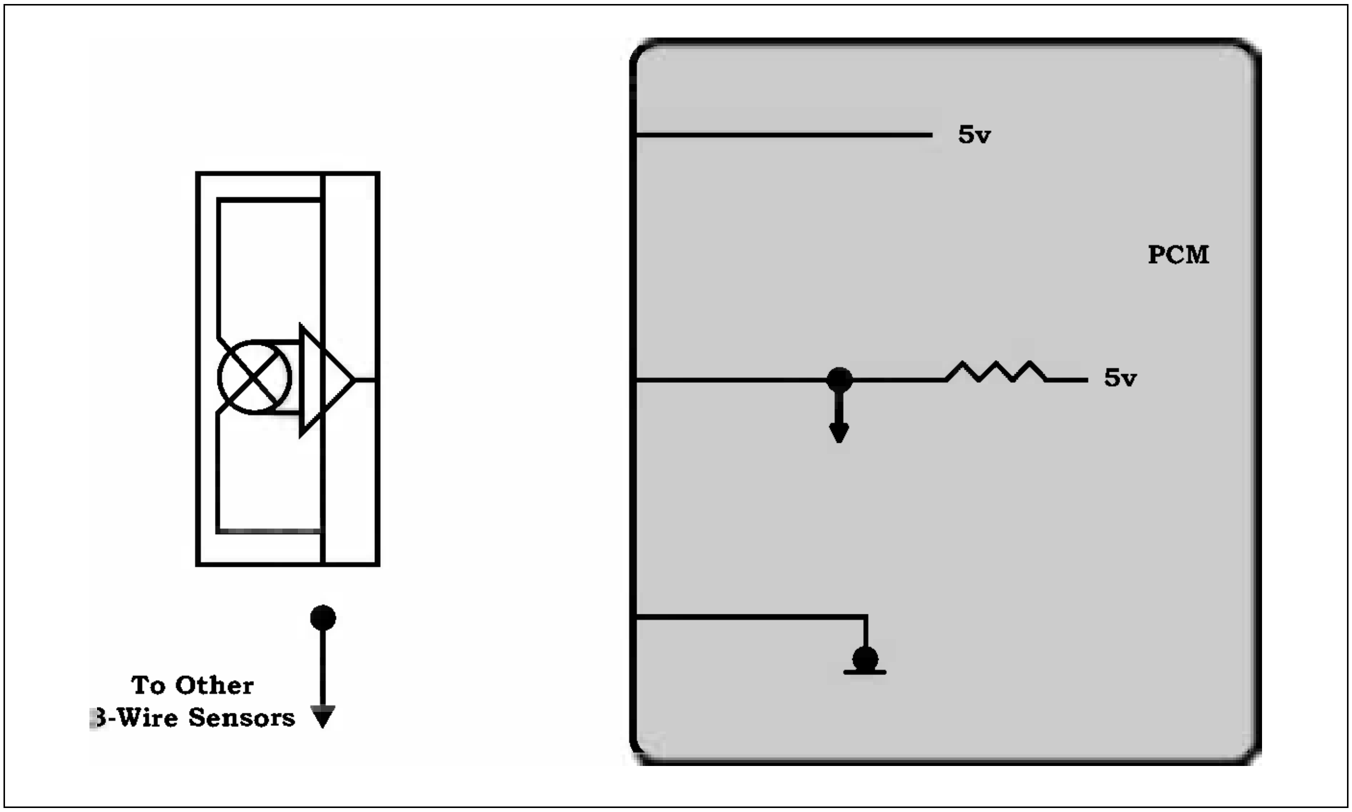


Figure 39 MAP Sensor (Completed by Student)

Table 1 Typical MAP Sensor Signal vs. Pressure

MAP Sensor Voltage	Barometer Reading	Altitude
4.43V	29.92 in. Hg	Sea Level
4.36V	29.42 in. Hg	500 ft.
4.29V	28.92 in. Hg	1000 ft.
4.22V	28.42 in. Hg	1500 ft.
4.15V	27.92 in. Hg	2000 ft.
4.08V	27.42 in. Hg	2500 ft.
4.01V	26.92 in. Hg	3000 ft.
3.94V	26.42 in. Hg	3500 ft.
3.87V	25.92 in. Hg	4000 ft.
3.80V	25.42 in. Hg	4500 ft.
3.73V	24.92 in. Hg	5000 ft.

MAP Sensors on Turbocharged Vehicles

Turbocharged vehicles have MAP Sensors that are calibrated to measure positive as well as negative pressures in the intake manifold. These vehicles have a second sensor called the Throttle Inlet Pressure/Baro Sensor. This sensor is just like a MAP sensor and measures two different conditions: barometric (atmospheric) pressure and also inlet boost pressure. Inlet boost pressure is sensed in the pipe after the charge air cooler and before the throttle body. The Throttle Inlet Pressure/Baro Solenoid is switched by the PCM to allow the TIP/Baro Sensor to sense throttle inlet pressure 95% of the time, and barometric pressure 5% of the time.

Table 2 Typical Turbo MAP Sensor Signal vs. Pressure

MAP Sensor Voltage	Barometer Reading	Manifold Vacuum/Pressure
4.46V	60.46 in. Hg	15 lb (boost)
4.01V	54.35 in. Hg	12 lb (boost)
3.56V	48.24 in. Hg	9 lb (boost)
3.11V	42.14 in. Hg	6 lb (boost)
2.66V	36.03 in. Hg	3 lb (boost)
2.21V	29.92 in. Hg (Sea Level)	0 lb (boost)
2.11V	28.7 in. Hg	1.2 in. Hg
2.02V	27.42 in. Hg	2.5 in. Hg
1.91V	25.92 in. Hg	4.0 in. Hg
1.76V	23.92 in. Hg	6.0 in. Hg
1.62V	21.9 in. Hg	8.0 in. Hg
1.40V	18.9 in. Hg	11.0 in. Hg
1.25V	16.9 in. Hg	13.0 in. Hg
1.03V	13.9 in. Hg	16.0 in. Hg
0.88V	11.9 in. Hg	18.0 in. Hg

(Voltage values will vary with changes in altitude and atmospheric pressure)

Manifold Absolute Pressure (MAP) Sensor Diagnostics

There are typically five MAP Sensor diagnostic routines:

- MAP voltage high
- MAP voltage low
- No change in MAP voltage at START to RUN transfer (vacuum)
- MAP/TPS correlation (TPS values do not agree with MAP signals)
- MAP/TPS correlation (high flow, vacuum leak)

Whenever a MAP DTC is set or a MAP problem occurs, the PCM enters "limp-in" and uses the T-MAP value. T-MAP values will appear on the scan tool as "real" MAP values.

Note: If you are attempting to generate the opposite code while performing diagnostics, it is important to remember the PCM does not perform diagnostics unless the engine is within the specified rpm range (the vehicle must be running).

Note: Make sure the ignition is OFF, prior to unplugging the MAP sensor, or MAP sensor damage will occur.

Some NGC scan tool screens do not update with a new or second condition until the key is cycled. As a result, a condition may exist, but the corresponding code will not appear until the key is cycled.

Notes:

Throttle Position Sensor (TPS)

The Throttle Position Sensor is a three wire potentiometer mounted on the side of the throttle body. The TPS is responsible for determining idle position (Min TPS), acceleration, wide open throttle (open loop and clear-flood mode) and influencing fuel injector pulse width and ignition timing according to these changing requirements:

- Idle: With key ON and engine running, the PCM assumes that the lowest voltage signal value received, above the fault threshold, must be where the throttle blade hits the idle stop. This voltage signal (typically 0.5–1.0V) is recorded by the PCM as “idle”, or “minimum TPS”.
- Off–Idle: Once the throttle is opened and the TPS signal value is approximately 0.04 volt over minimum TPS, the PCM moves into its off–idle program. Spark–scatter advance idle control is shut off and the IAC is set to act as a dashpot to prevent stalling from sudden deceleration.
- Acceleration: A rapid rise in TPS voltage within a specified time causes the injector pulse–width to increase. The amount of PW increase is determined by the rate of TPS voltage rise.
- Wide Open Throttle (WOT): The PCM is programmed to go into open loop whenever TPS voltage exceeds a programmed value, typically 2.5–2.7V above minimum TPS voltage. This enables the PCM to increase pulse width at WOT to improve full throttle performance.
- Deceleration: If the TPS is closed and manifold vacuum is high while the vehicle is in motion (as indicated by the VSS), the PCM narrows the injector pulse width to reduce emissions. Under some conditions, the injector pulse width may be zero.
- WOT fuel cutoff during cranking: In case of flooding, the driver can depress the accelerator pedal to WOT so that the PCM will de-energize all injectors. This program is enabled only during cranking and when TPS voltage indicates WOT.

Hall-Effect Throttle Position Sensor

Some vehicles use a Hall-effect TPS. These Hall-effect sensors output an analog signal voltage similar to conventional TPS sensors, but the connector pin assignments are different. Consult Service Information for vehicle-specific information.

Throttle Position Sensor (TPS) Diagnostics

There are three TPS diagnostic routines:

- TPS voltage too high (signal open or short to power).
- TPS voltage too low (signal shorted to ground or no 5V supply).
- TPS voltage does not agree with MAP (rationality fault).

When the TPS signal voltage is too high, too low or not believable, the PCM sets a DTC. When the DTC is set, the MIL is illuminated and the PCM moves into limp–in mode. Limp–in for TPS is divided into three categories:

- Idle
- Part–throttle
- Wide open throttle (WOT)

When observing the Calculated TPS value on the scan tool while in limp-in mode, the TPS display will change as if there were no problem with the circuit. In limp-in mode, the TPS calculation will be based on RPM and MAP values, and the T-MAP value may appear unusual.

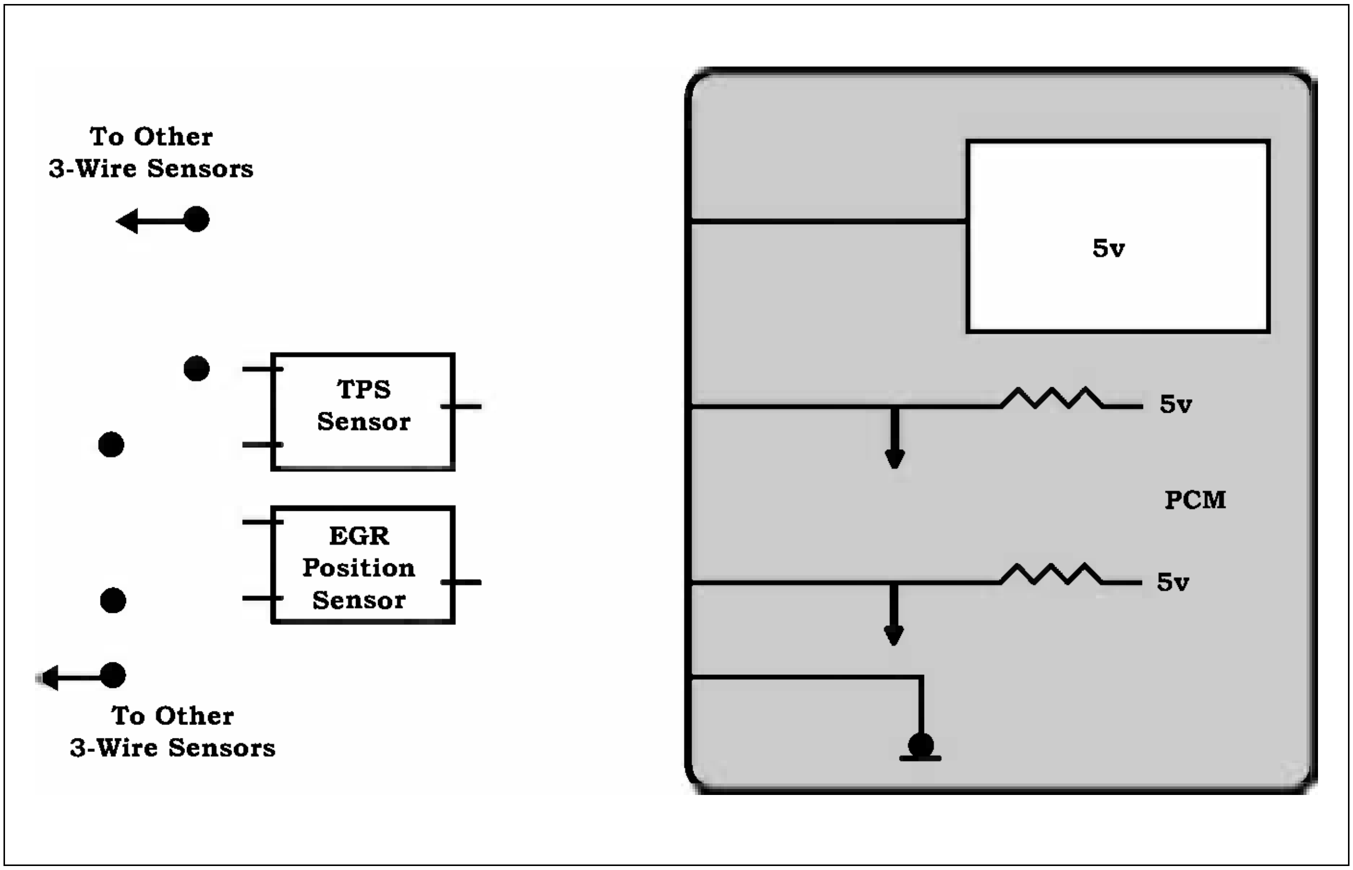


Figure 40 TPS and EGR Position Sensors (Completed by Student)

Notes:

EGR POSITION SENSOR

The EGR position sensor is a three wire linear potentiometer providing feedback to the PCM for EGR valve position. This allows for more precise control over EGR flow for better NOx control. The EGR position sensor signal is an input to the Speed Density Equation.

The EGR position sensor shares the same feed as MAP, TPS and A/C pressure sensor (except in packages where the TIPM processes the A/C pressure sensor input), and works similar to the TPS. This sensor is part of the Linear EGR Valve assembly, and is carried over from previous models.

EGR Position Sensor Diagnostics

- EGR Rationality Fault is set when flow or valve movement is not what is expected.
- EGR Position Sensor Too Low is set when the signal is less than 0.157V.
- EGR Position Sensor Too High is set when the signal is greater than 4.9V for 6 seconds.

PCM ANALOG INPUTS – TWO WIRE

All two wire sensors receive a 5V bias signal from the PCM and have a common sensor ground. On NGC vehicles, the only two-wire sensors that do not use the same sensor return are the knock sensor and oxygen sensors. The knock sensor has its own dedicated ground. The oxygen sensors do not use ground at all for the sensor return. Their sensor return circuits are biased to 2.5V. GPEC vehicles have multiple sensor grounds.

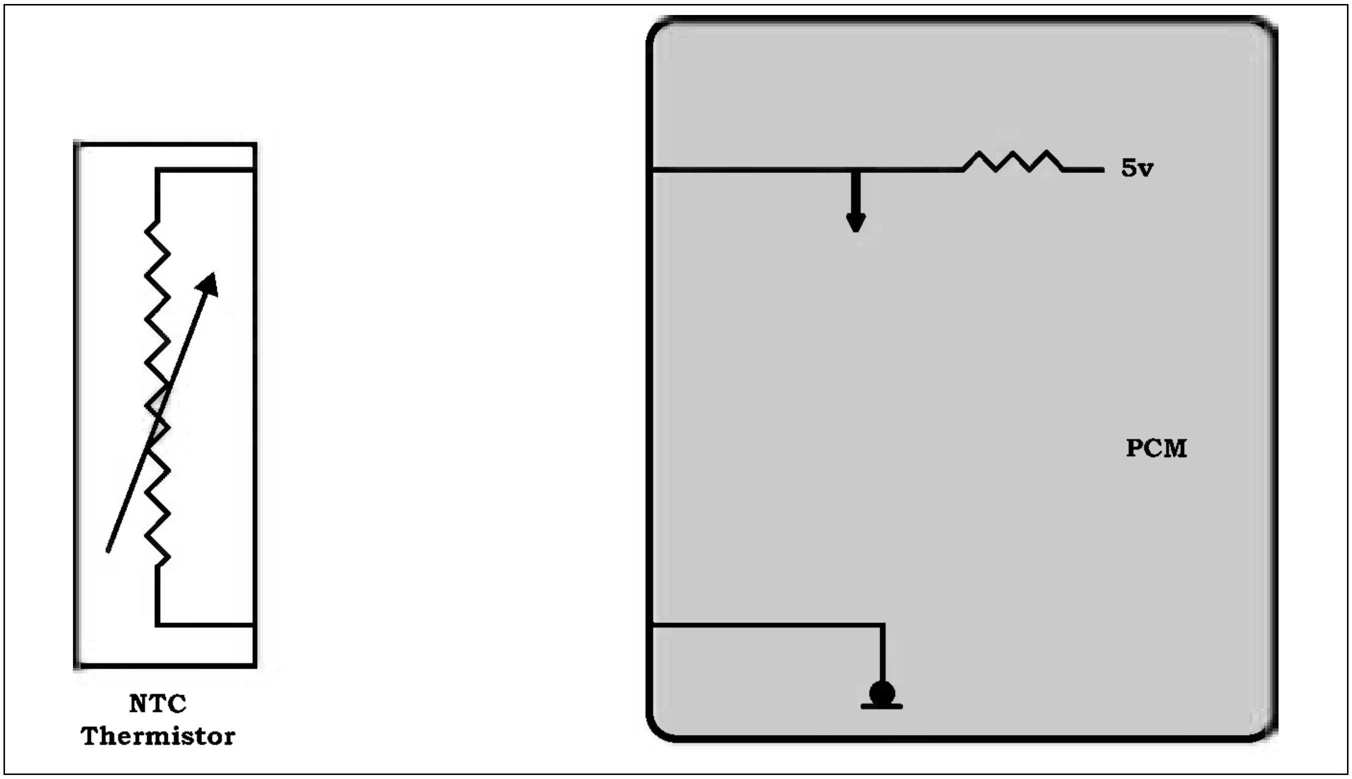


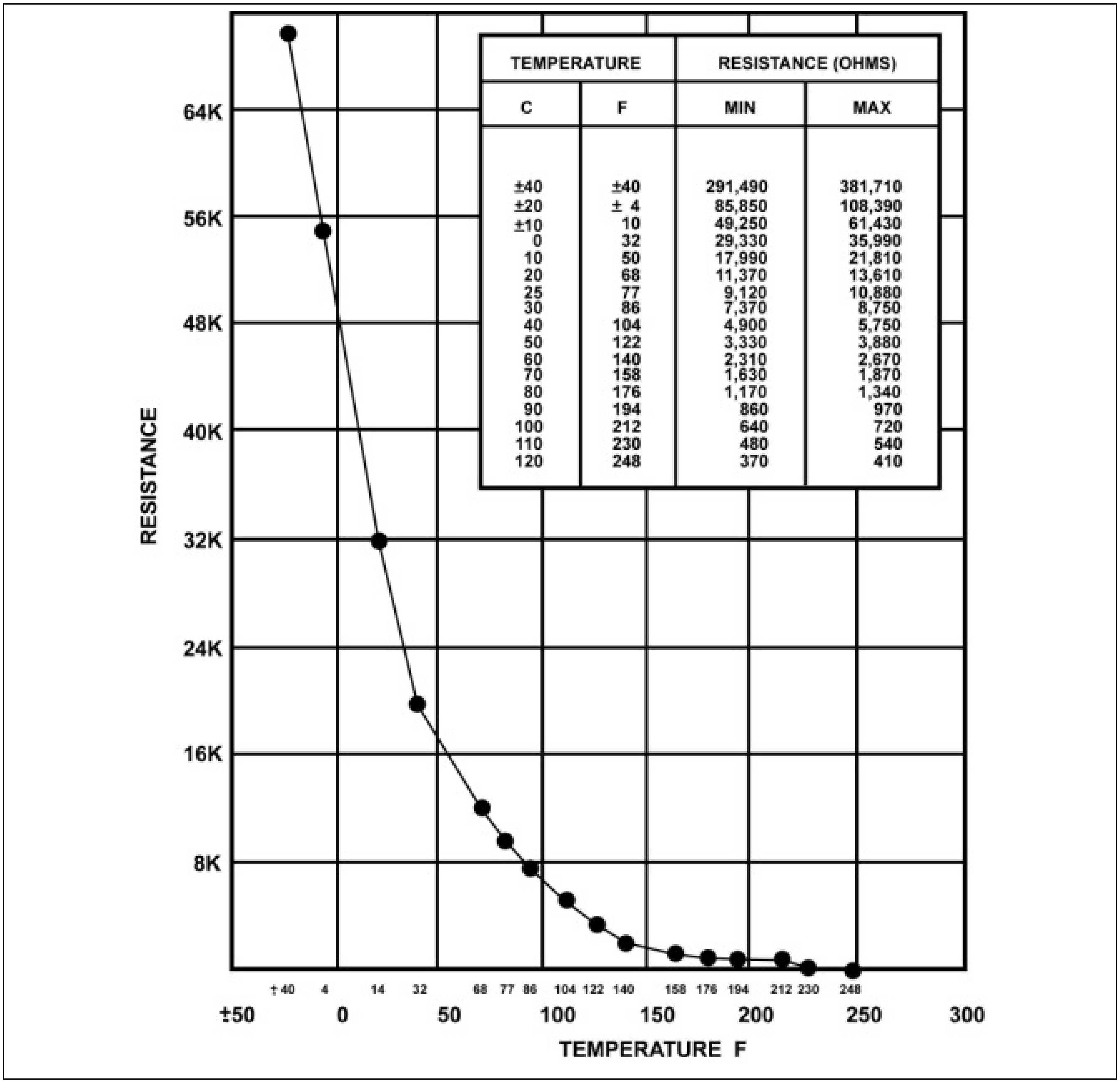
Figure 41 Typical NTC Thermistor Circuit (Completed by Student)

NTC Thermistors

Temperature sensors are thermistors, resistors that significantly change resistance value with changes in temperature. All of the temperature sensors listed below are Negative Temperature Coefficient (NTC) thermistors. This means that their resistance changes inversely with temperature. They have high resistance when cold and low resistance when hot.

The PCM sends 5V through a fixed resistor to each sensor and measures the voltage drop to sensor ground through the thermistor. When the sensor is cold, its resistance is high and voltage sensed on the feed side remains high. As the temperature increases, sensor resistance drops and the signal voltage gets pulled low.

NTC thermistors use a single-range PCM circuit.



TEMPERATURE		RESISTANCE (OHMS)	
C	F	MIN	MAX
±40	±40	291,490	381,710
±20	± 4	85,850	108,390
±10	10	49,250	61,430
0	32	29,330	35,990
10	50	17,990	21,810
20	68	11,370	13,610
25	77	9,120	10,880
30	86	7,370	8,750
40	104	4,900	5,750
50	122	3,330	3,880
60	140	2,310	2,670
70	158	1,630	1,870
80	176	1,170	1,340
90	194	860	970
100	212	640	720
110	230	480	540
120	248	370	410

Figure 42 Typical NTC Thermistor Temperature-Resistance Curve

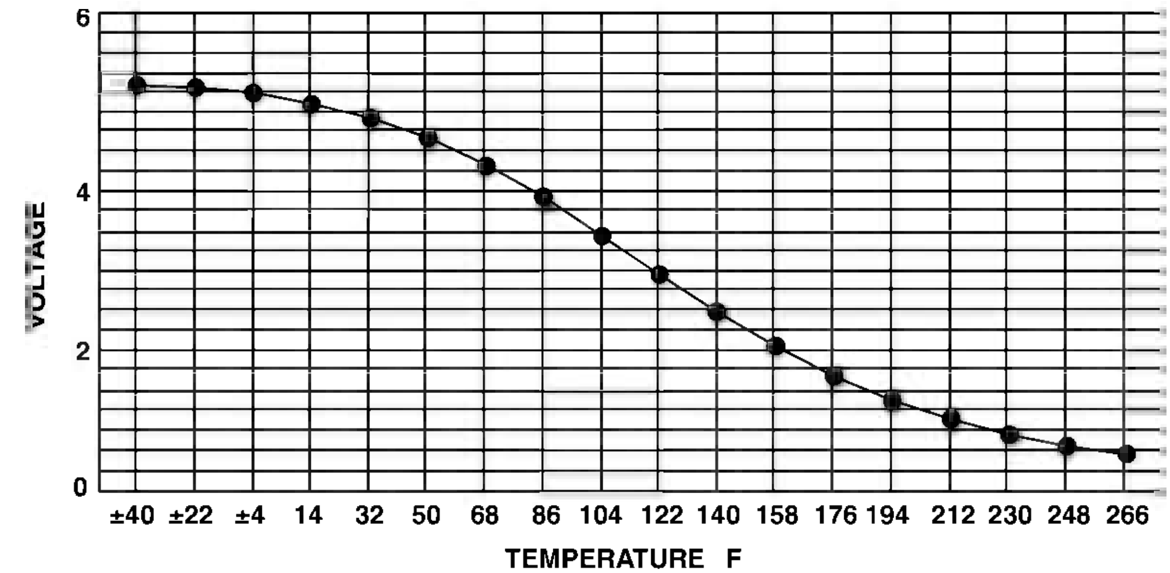


Figure 43 Typical NTC Thermistor Temperature-Voltage Curve

Engine Coolant Temperature (ECT) Sensor

The ECT modifies injector pulse width, enables OBDII monitors and controls cooling fan operation. Its biggest influence on pulse width occurs with cold engine, key-on to determine cranking pulse width. After the vehicle has reached operating temperature, the PCM uses the ECT value to aid in calculating air density. ECT only has the authority to increase the base calculated pulse width. For example, in a cold engine, poor fuel atomization can require increased pulse width.

The ECT also affects spark advance curves, engine idle speed, cooling fan, A/C, transmission, and purge solenoid operation.

GPEC World Engine ECT Sensors

Currently, the World Engine has two ECT sensors, one located in the cylinder head and the second located in the cylinder block. The GPEC PCM uses the cylinder head ECT sensor as its primary sensor, with the cylinder block sensor as a backup.

Engine Coolant Temperature (ECT) Sensor Diagnostics

There are four ECT Sensor diagnostic routines:

- ECT Sensor voltage too high (signal open)
- ECT Sensor voltage too low (signal shorted to ground)
- ECT Sensor too cold too long (rationality)
- Closed loop temperature not reached (rationality)

The limp–in mode for the ECT Sensor is initially the IAT value (then uses a timer and ramps up value with run time) and the radiator fans operate at high speed.

Notes:

INTAKE AIR TEMPERATURE (IAT) SENSOR

Air density changes as a factor of air temperature. The PCM uses the IAT signal to calculate the density of the incoming air. The IAT's greatest influence on pulse width occurs during extremely cold intake air temperatures with wide-open throttle conditions. The PCM may retard ignition timing to prevent spark knock at high intake air temperatures.

The IAT is typically located in the air tube instead of the intake manifold.

The IAT is also used as a backup to ECT. Typically, the resistance specifications for the ECT and IAT Sensors are the same.

Intake Air Temperature (IAT) Sensor Diagnostics

There are two IAT Sensor diagnostic routines:

- Voltage Too Low (near 0V)
- Voltage Too High (near 5V)

When the IAT Sensor indicates a voltage that is too high or too low, the PCM moves into limp–in mode. In case of IAT failure, the PCM uses Ambient/Battery temperature for a limp-in value. The PCM uses the Ambient/Battery Temperature Sensor information as long as this information is believed to be accurate.

Notes:

OTHER PCM INPUTS

Sensed B+ Battery Voltage

The direct battery feed to the PCM is used as a reference to sense battery voltage.

Fuel injectors are rated for operation at a specific voltage. If voltage increases, the plunger will open faster and farther and conversely, if voltage is low, the injector will be slow to open and will not open as far. If sensed battery voltage drops, the PCM increases injector pulse width to maintain the same volume of fuel through the injector.

If the charging voltage is too high, check resistance in the Sensed B+ circuit.

The GPEC PCM has a circuit which measures the output of the alternator. It compares sensed B+ and the alternator output. If the signals are inconsistent, it will shut down battery charging to protect the components.

If a loose connection in the B+ circuit is suspected, check the DTC # of starts since the counts were cleared.

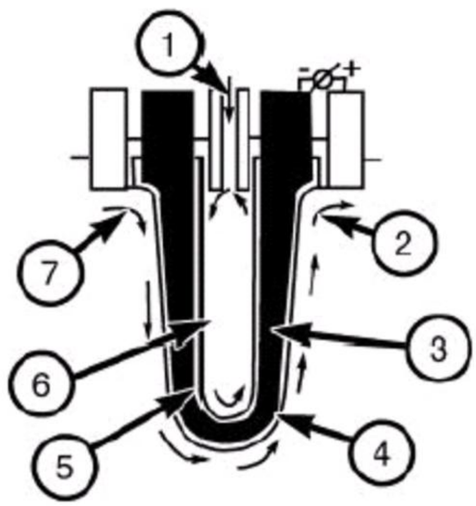
Oxygen (O_2) Sensors

The heated O2 sensors are four-wire zirconium dioxide sensors placed in the exhaust system to measure oxygen content in the exhaust stream.

When hot, the O2 sensor becomes a galvanic battery that typically generates a voltage signal between 0.0 - 1.0V. When the O_2 sensor signal is monitored using a scan tool or a voltmeter, you will see 2.5 - 3.5V. This is because the sensor return is biased 2.5V to prevent O2 sensor voltages from inverting and going below 0V, which would result in a possible open-loop condition that could occur under the following conditions:

- Sensor contamination
- O2 air inlet clogged (preventing oxygen from being drawn into the sensor via the wiring harness)
- High-load, extreme heat conditions (trailer tow up a mountain in the desert)

The PCM infers air/fuel ratio from this information on oxygen content. The PCM then adjusts injector pulse width in order to achieve optimum air/fuel ratio, proper engine operation, and control emissions.



1	Outside Air	5	Inner Electrode
2	Exhaust Oxygen	6	Ambient Oxygen
3	Solid Electrolyte	7	Exhaust Oxygen
4	Outer Electrode		

Figure 44 Oxygen Sensor Operation

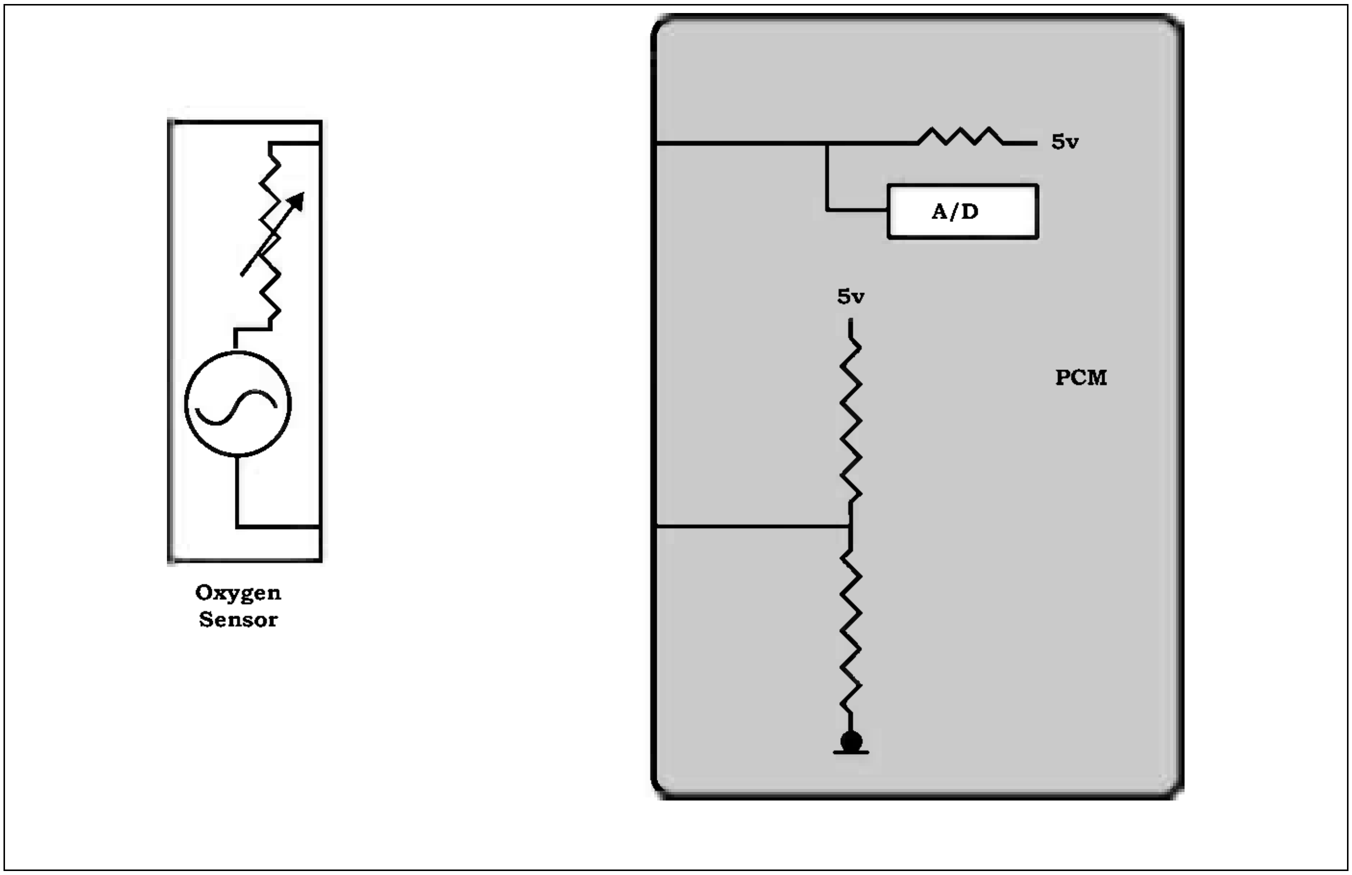
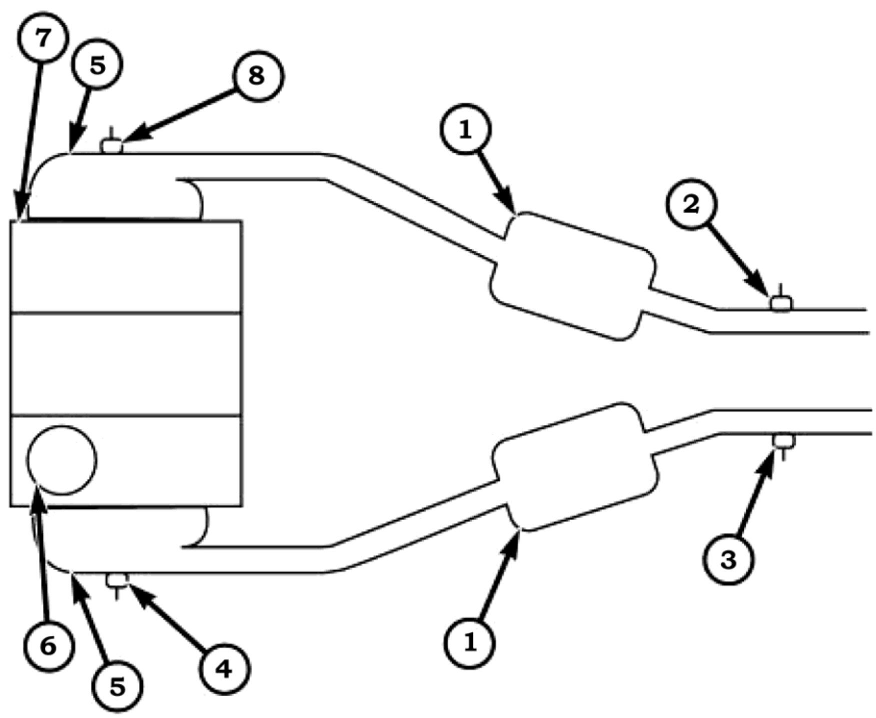


Figure 45 Oxygen Sensor Signal Circuit (Completed by Student)

Oxygen Sensor Locations and Naming

Starting in 1996, all vehicles use at least one upstream and one downstream oxygen sensor. O_2 sensors are typically named 1/1, 1/2, 1/3, 2/1, etc. The first digit indicates the bank of the engine served by the O_2 sensor. A first digit "1" indicates the O_2 sensor is on the same bank as number 1 cylinder. A first digit "2" represents a location on the bank opposite number 1 cylinder. The second digit represents upstream (1), downstream (2) or mid-catalyst (3) locations. As an example, 1/2 would represent an O_2 sensor located downstream, on the bank with number 1 cylinder. Upstream and downstream sensors operate in a similar way but may not be interchangeable due to physical differences.



1	Catalytic Converter	5	Exhaust Manifold
2	Oxygen Sensor (2/2)	6	Cylinder #1
3	Oxygen Sensor (1/2)	7	Engine
4	Oxygen Sensor (1/1)	8	Oxygen Sensor (2/1)

Figure 46 Oxygen Sensor Naming Conventions

Open Loop Operation

The PCM is in Open Loop mode during a cold start when the O_2 sensors are below 660°F (349°C), and also when the engine is operated at wide open throttle (WOT). In Open Loop, the PCM ignores the O_2 sensors and performs air/fuel ratio adjustments based on pre-programmed values and inputs from other sensors.

A heater element heats the O_2 sensor in order to bring it to operating temperature and into Closed Loop operation quickly. Typical conditions for closed loop operation are:

- Engine temperature above 35°F (2°C)
- O_2 sensor temperature above 660°F (349°C)
- All timers have timed out following the START–TO–RUN transfer (timer lengths vary, based on engine temperature at key ON). The O_2 sensor must read either greater than 3.245V or less than 2.6V.

Table 3 Typical Time to Closed Loop Operation*

Engine Temperature (°F)	Time to Closed Loop Operations
35	41 Seconds
50	36 Seconds
70	19 Seconds
167	11 Seconds

**These times and temperatures may vary for each engine package.*

Closed Loop Operation

In Closed Loop operation, the PCM monitors oxygen levels in the exhaust and makes air/fuel ratio adjustments based on O_2 sensor feedback. The upstream O_2 sensor voltage signal verifies that the fuel system is operating at the 14.7:1 stoichiometric ratio. All tailpipe emissions, HC, CO and NOx are at their lowest points simultaneously when this fuel ratio is maintained.

There are two types of Closed Loop operation:

Short-Term: Immediate corrections are made to the pulse-width in response to the oxygen sensor, but these values are not stored in memory. The parameters are:

- Engine temperature exceeds 30 - 35°F (-1 - 2°C)
- O_2 sensor is switching
- All timers have timed-out following the START-to-RUN transfer (the timer lengths vary, based upon engine temperature at key-on)

Long-Term: Values are stored in non-volatile memory based on short-term corrective values. The parameters are:

- Full operating temperature
- All timers have expired

Note: Times and temperatures may vary for each engine package.

At 14.7:1, the O2 sensor voltage will fluctuate between 2.5V and 3.5V. When the O2 sensor detects excess oxygen, the signal voltage will be closer to 2.5V. A lack of oxygen will result in a voltage signal closer to 3.5V.

Zirconia O_2 sensors do not respond in a linear way. The voltage generated by the sensor is consistently high at air/fuel ratios richer than ideal (low O2), and the voltage generated is consistently low at air/fuel ratios leaner than ideal (high O2). The sensor signal voltage switches dramatically at stoichiometry and is relatively unchanging at all other air/fuel ratios. This means that the oxygen sensor signal can tell the PCM that the air/fuel ratio is leaner or richer than stoichiometry, but it can't tell the PCM how rich or how lean the mixture is.

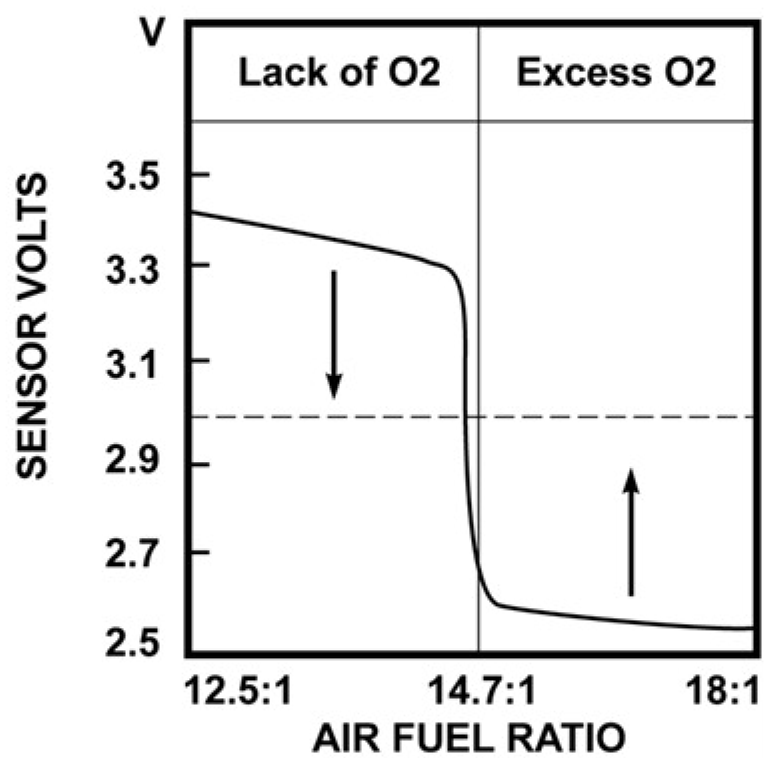


Figure 47 Oxygen Sensor Signal

When voltage exceeds preset high or low thresholds, called Switch Points, the PCM begins to add or remove fuel until the change in oxygen content causes the sensor to reach its opposite preset threshold. The process then repeats itself in the opposite direction.

O_2 Sensor Diagnostics

The O_2 sensor must have a source of oxygen from outside the exhaust stream for comparison. O_2 sensors receive their fresh oxygen supply through the wire harness. Never solder an O_2 sensor connector or pack the connector with grease.

Exhaust system leaks ahead of the O_2 sensor can allow false air to be drawn into the exhaust stream. The sensor will report this extra oxygen to the PCM, and the PCM may incorrectly add extra fuel to compensate.

If the O2 sensor heater performance is poor, the 5V heater diagnostic voltage can cause the PCM to think that the mixture is rich. The PCM will then respond with negative Adaptives.

Notes:

DOWNSTREAM O_2 SENSOR

Depending on the vehicle's emission calibration, it may be equipped with multiple upstream and downstream O2 sensors. Downstream sensors were first used in 1996 and have two functions.

The first function is to measure catalyst efficiency to meet OBD II requirements. If the catalytic converter is working properly, the oxygen content of the exhaust gases at the converter outlet fluctuates significantly less than at the converter inlet. The PCM compares the switching rates of both downstream and upstream O_2 sensors under specific operating conditions to determine if the catalyst is functioning properly. Any time the upstream to downstream switching ratio exceeds a calibrated value, a catalyst efficiency fault will be stored.

The second function is downstream fuel control. This function adjusts the upstream O_2 Goal Voltage within the range of operation of the upstream O_2 sensor. The upstream Goal Voltage is used to ensure long catalytic converter life by allowing the PCM to control the amount of air and fuel that is supplied to the catalytic converter.

Before 1996, the Goal Voltage was a pre-programmed fixed value based upon where it was believed the catalyst was most efficient. While the upstream O_2 sensor input was used to maintain the 14.7:1 air/fuel ratio, variations in engines, exhaust systems and catalytic converter ageing can cause this ratio to be less than ideal for a given vehicle. If gases leaving the catalyst contain too much oxygen, the mixture is too lean. The PCM responds by raising the upstream O_2 Goal Voltage. This increases fuel quantity and reduces excess oxygen. Conversely, if the gasses leaving the catalyst do not contain enough oxygen, the PCM lowers the upstream O_2 Goal Voltage. This reduces fuel quantity and increases excess oxygen. This function is active only during downstream closed loop operation.

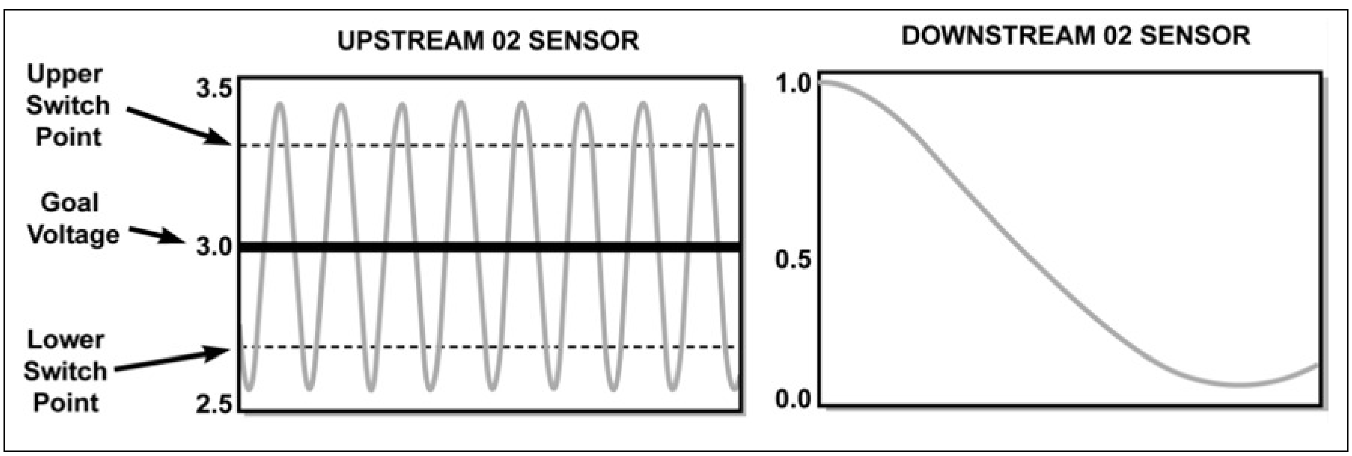


Figure 48 Upstream and Downstream O_2 Signal with Efficient Catalyst

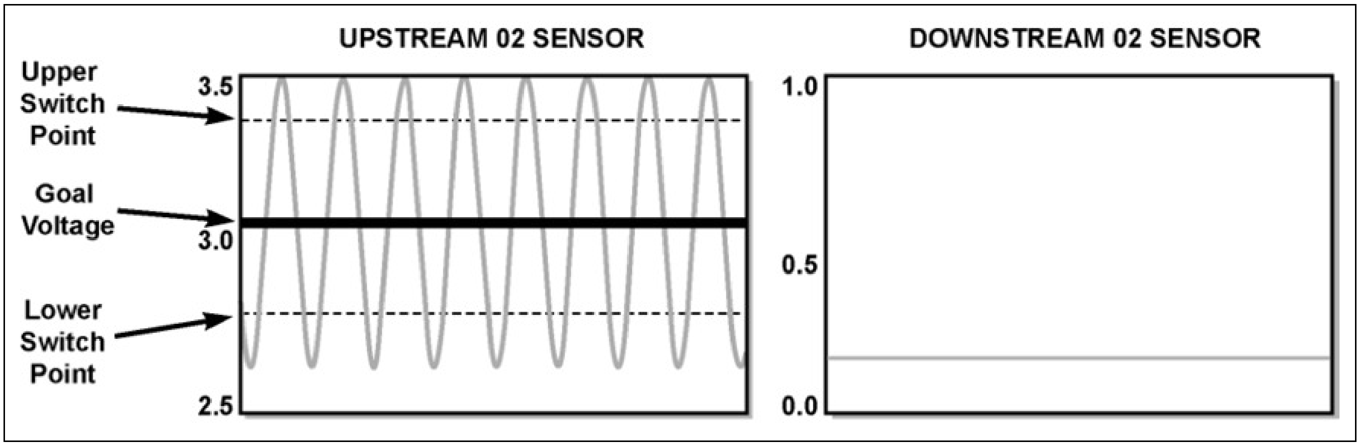


Figure 49 Goal Voltage and Switch Points Shift to Reduce High O_2 Content

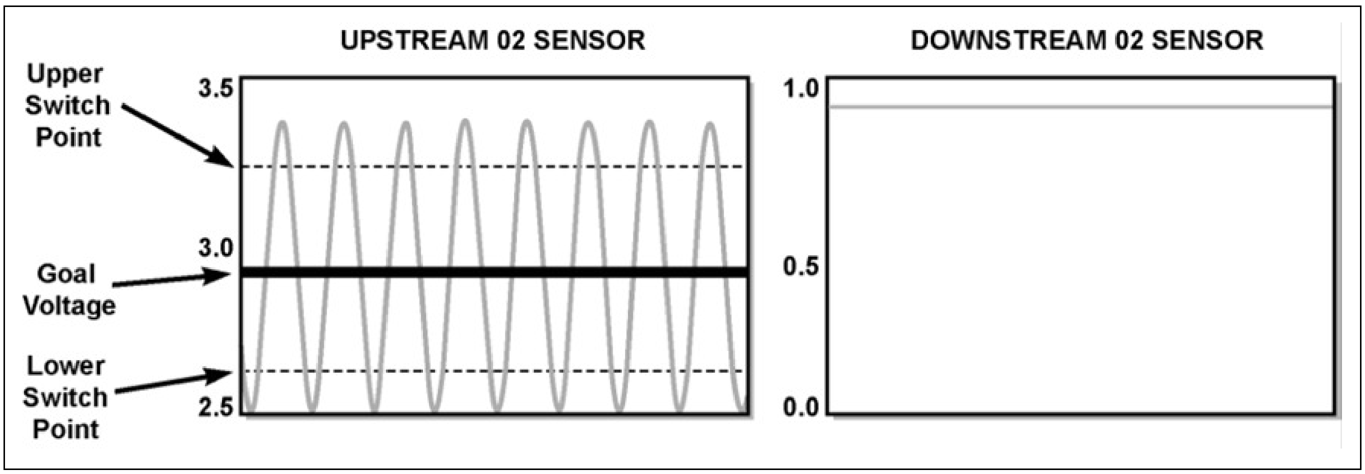


Figure 50 Goal Voltage and Switch Points Shift to Increase Low O_2 Content

Oxygen Sensor Heaters

The oxygen sensor heaters are controlled using a PWM high-side driver. The resistance of the sensor heaters is constantly monitored by the PCM. This information is used to verify proper operation of the heater circuit, and to indirectly determine the temperature of the O_2 sensor.

Some of the advantages of the PWM heaters are:

- Meet tighter LEV and ULEV emissions regulations
- Allow closed loop operation as early as 5 - 10 seconds after start
- Delays activation after an overnight soak to allow moisture to burn off to prevent cracking of the thimble

In the GPEC, PWM duty cycle is modified in response to heater temperature in order to achieve a desired temperature target. The heater temperature is measured by passing current through a resistor connected in series with each heater element. The voltage across the resistor is used to calculate the current and the temperature.

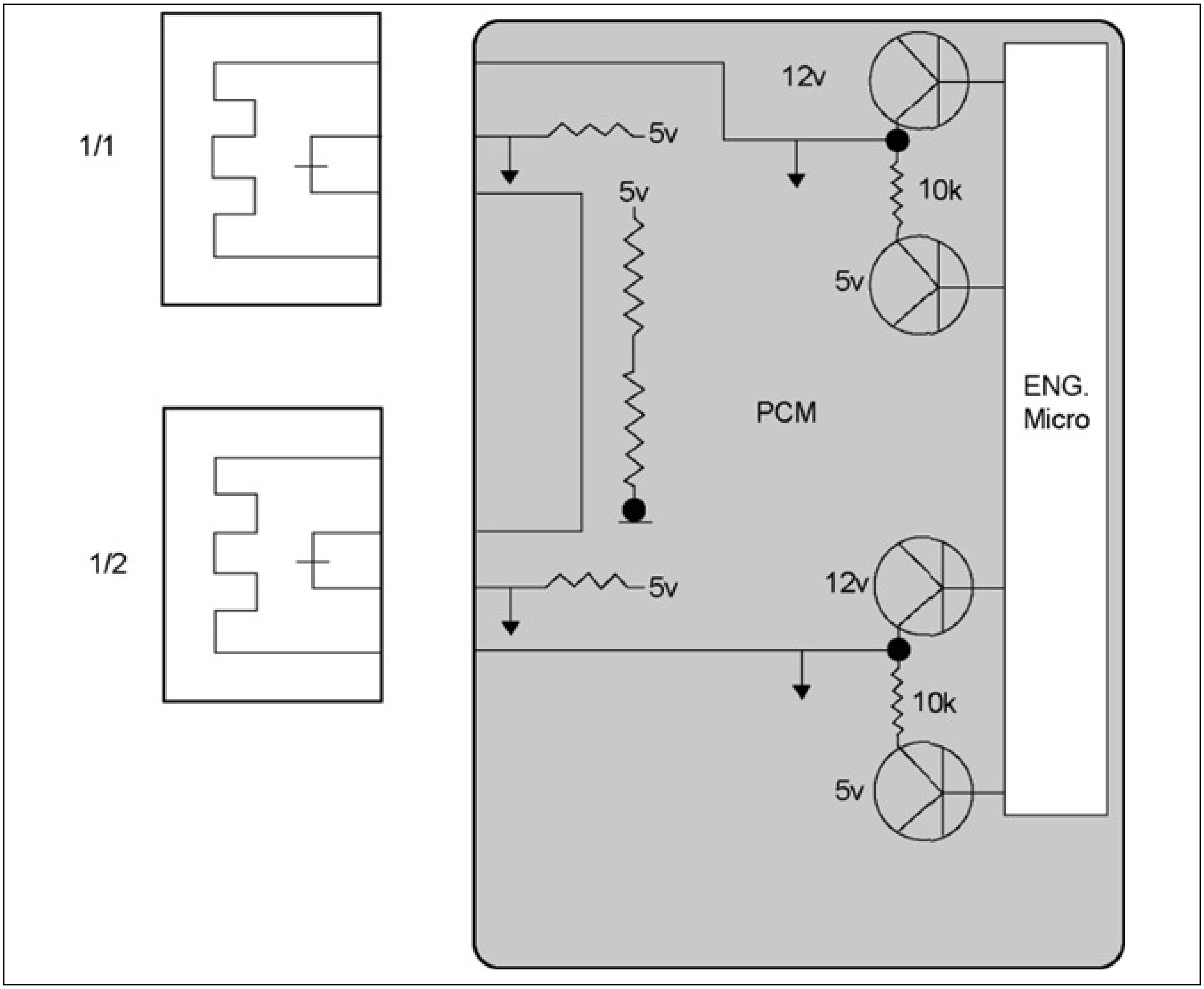


Figure 51 NGC O_2 Sensor Heater Circuits (Completed by Student)

Notes:

MODULE 7 ADAPTIVES

OXYGEN SENSOR FEEDBACK

The PCM uses the Speed Density Equation to calculate the base pulse width required for the specific operating conditions. The goal is to maintain the stoichiometric air/fuel ratio of 14.7:1. At this ratio, all vehicle tailpipe emissions are at their lowest point possible and the catalytic converter is also getting what it needs to be efficient.

The upstream oxygen sensor signal should be switching between 0 – 1.0V if the PCM's calculation is correct and if the vehicle is operating with a 14.7:1 air/fuel ratio. The PCM then adds a 2.5V bias voltage to the oxygen sensor return circuit. On a scan tool, the oxygen sensor signal may be 2.5 – 3.5V.

When the fuel system goes into closed loop operation, there are two adaptive memory programs that begin to operate. The PCM operates these two fuel correction programs to modify fuel delivery based on oxygen sensor feedback. These two programs are:

- Short Term Adaptive
- Long Term Adaptive

SHORT TERM ADAPTIVE

During closed loop operation, Short Term Adaptive makes immediate adjustments to fuel delivery in direct response to the signal from the upstream O_2 sensor. The PCM infers air/fuel ratio by monitoring oxygen content measured by the upstream O_2 sensor.

If the upstream oxygen sensor voltage is not switching between 2.5 -3.5V, the PCM knows that the base pulse width calculation needs to be modified by adjusting the injector pulse width until a switching O_2 sensor voltage is achieved. This immediate correction is known as Short Term Adaptive, or Short Term Fuel Trim (STFT), and begins functioning shortly after the vehicle has started. STFT is only kept alive by ignition voltage.

The need to adjust the injector pulse width may be a result of vehicle operating conditions, vehicle wear, fuel quality, etc. The maximum range of authority for Short Term Adaptive is ±33%.

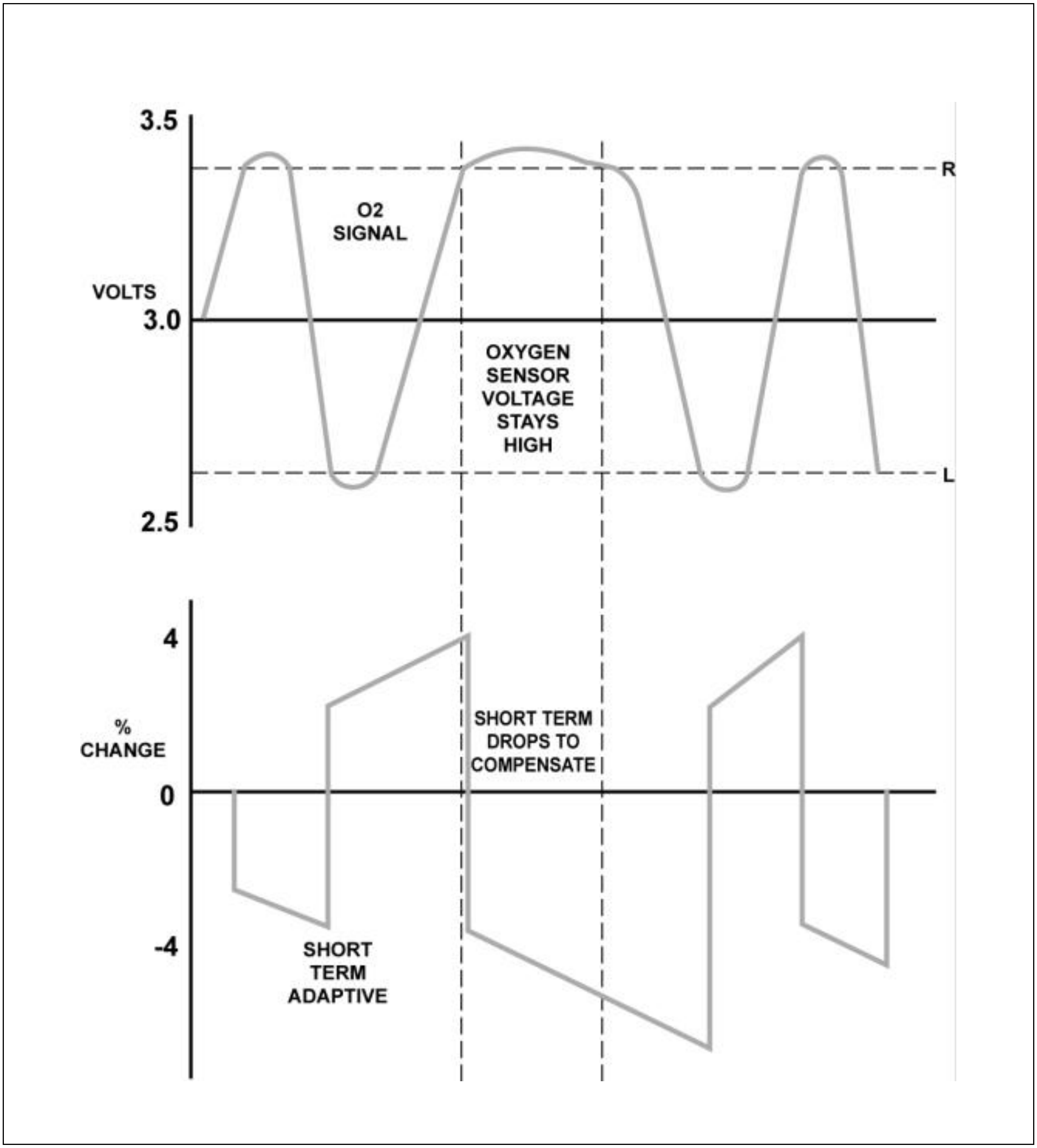


Figure 52 Short Term Adaptive vs. O_2 Sensor Voltage

LONG TERM ADAPTIVE

The values shown in the figure below are for example only (Fig. 53). The main function of Long Term Adaptive is to make fuel corrections that allow Short Term Adaptive to hover around zero. In order to maintain correct emissions throughout all operating ranges of the engine, a cell structure based on engine rpm and load (MAP) is used.

There are 26 cells. Two of the cells are used only during idle, as determined by TPS and Park/Neutral switch inputs. The other cells each represent specific off-idle manifold pressure and rpm ranges.

After the vehicle has reached full operating temperature, short term correction factors will be stored in Long Term Adaptive memory cells based on vehicle load (RPM/MAP) to allow the Short Term Adaptive value to be brought back to near zero. Once this correction factor is stored in memory, it will be used by the PCM under all operating conditions, open loop and closed-loop. However, the values stored in Long-term are updated only after the vehicle has entered long-term closed loop at full operating temperature. This is done to prevent any transition temperature or start–up compensation from corrupting long term fuel correction.

Long Term and Short Term Adaptive can each change the pulse width by as much as ±33% for a maximum total correction of ±66% from the base pulse width calculation.

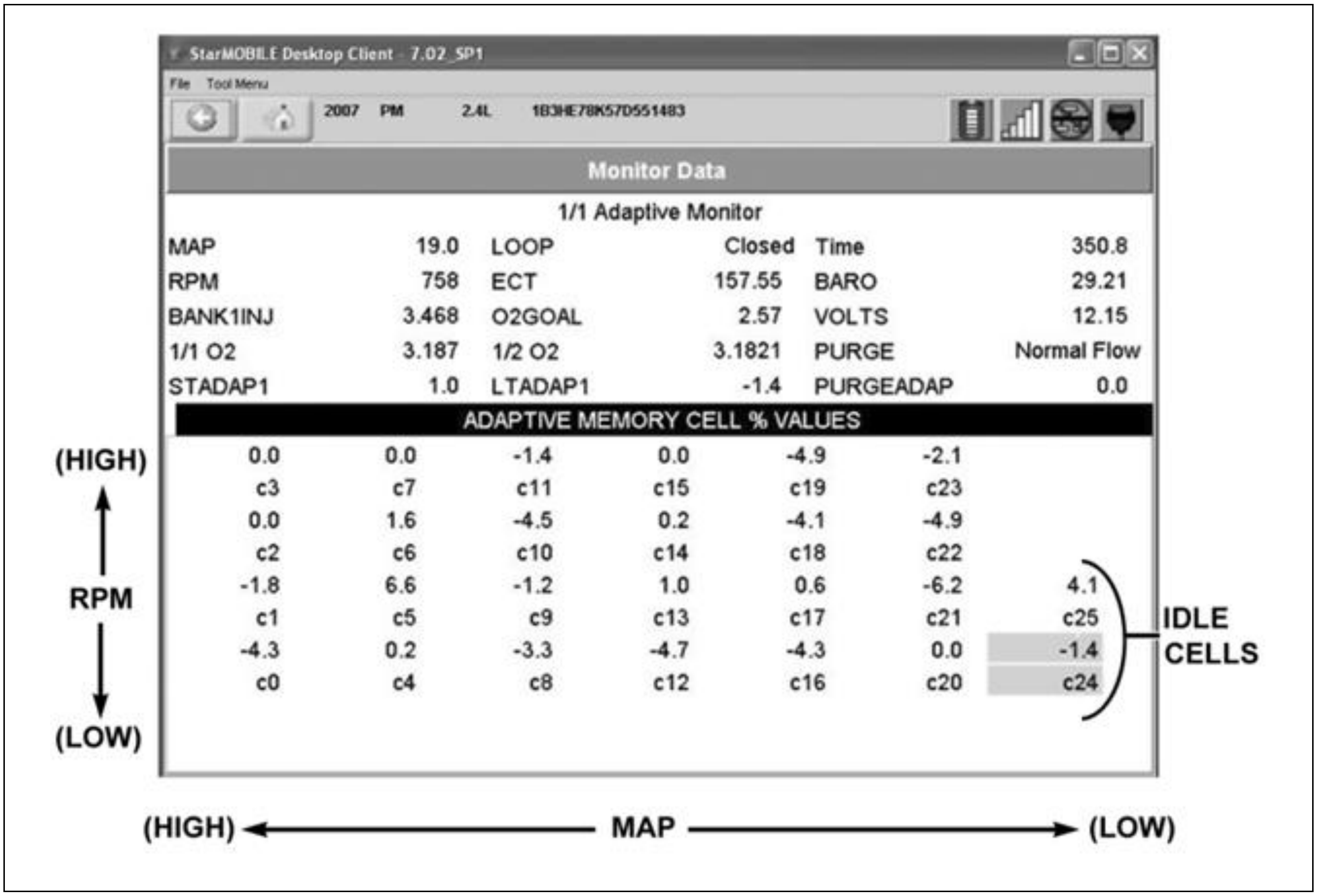


Figure 53 Adaptive Fuel Monitor Screen

The cell structure is a matrix based on RPM and MAP characteristics that is calibrated for each power train package. Each row represents a different RPM range and each column represents a different range of MAP values.

In an NGC PCM, Long Term Adaptive is maintained in memory by battery voltage; a battery disconnect will cause it to be erased. This may lead to driveability issues until the memory cells have matured again. In a GPEC PCM, Long Term Adaptive is stored in nonvolatile memory. Disconnecting the battery will have no effect on the values.

Note: Whenever components that affect engine operation are replaced, the Adaptive Memory should be reset. If this is not done, when the engine is started and runs in Open Loop, it will use the Long Term Adaptive values stored while the component was malfunctioning. This could cause rough operation during warm-up after repairs.

PURGE VAPOR RATIO

Canister purge is part of the Speed Density Equation. The PCM learns the HC content within the components of the EVAP system, which allows it to predict the effect of purge flow on the final pulse width. Purge Vapor Ratio is learned on every start through O_2 feedback and Short Term Adaptive shift. The PCM operates in three different modes to learn how purge fits into this equation:

- **OFF (Mode 0) –** This occurs shortly after the vehicle has been started and has entered short-term closed loop. During Mode 0, purge is disabled while the PCM learns what it takes to operate the vehicle at stoichiometry without the extra load of purge vapors. This is when Long Term Adaptive memory values are allowed to update.
- **LEARN (Mode 1) -** Once the PCM has learned the engine's fuel requirements, Long Term Adaptive memory values are locked, and purge flow slowly starts to ramp-in. The objective of Mode 1 is to learn the HC loading of the fuel tank and the vapor canister. This is accomplished by monitoring the effects of purge on Short Term Adaptive and comparing the results against the data accumulated during Mode 0. Once purge loading has been learned, the vehicle enters Mode 2 operation.
- **NORMAL (Mode 2) –** During this mode of operation, Long Term Adaptive memory values remain locked, and purge flow is increased to normal high-flow levels required to deplete the EVAP system of HC vapors. The PCM adjusts the injector pulse width to automatically compensate for this extra source of fuel. Remember that the PCM learned during Modes 0 and 1 what the effect of the additional HC from purge is. It can therefore adjust the pulse width in anticipation of what will occur once purge is ramped-up to normal levels.

Proper purge flow is achieved by adjusting the flow through the Proportional Purge Solenoid. The PPS is monitored by the PCM on the ground side of the circuit. The PCM uses this data to regulate the opening of the solenoid to ensure proper purge flow under changing operating conditions. This is monitored by the PCM and displayed on the scan tool as "P-Ad" or Purge Adaptive.

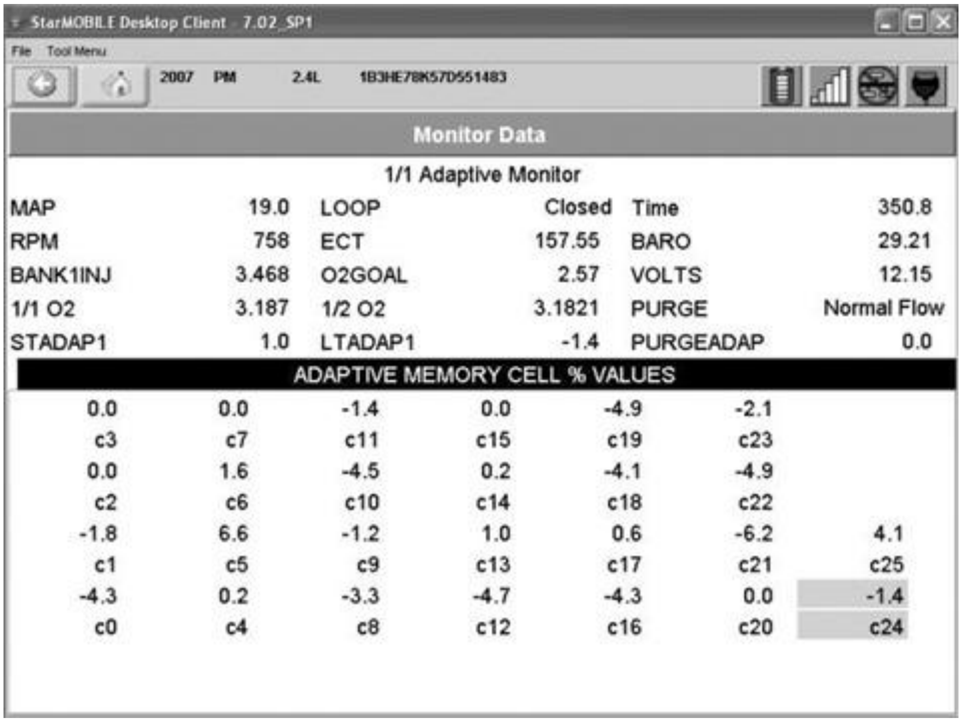


Figure 54 Adaptive Fuel Monitor Screen

If the PCM determines that the HC level in the charcoal canister is below a calibrated amount by monitoring the Purge Vapor Ratio, purge operation will be turned OFF. Periodically the PCM will re-enter the LEARN Mode to determine whether there is sufficient HC in the EVAP system to again initiate purge flow. These events can occur on the same key-cycle.

In other words, purge vapor content is learned shortly after short-term closed loop operation begins and is factored into the Speed Density Equation. All long-term cells represent fuel correction without purge flow. In other words, all long-term cells are purge-free cells.

Notes:

Notes:

MODULE 8 PCM OUTPUTS

PCM CONTROLLED OUTPUT DEVICES

PCMs may use either high-side or low-side drivers to control output devices.

NGC LOW-SIDE CONTROLLED DEVICES

The NGC controller contains two latching (always-on) drivers to control various low-current devices such as relays and solenoids. Each IC chip is capable of controlling eight low-side controlled devices.

Typical NGC low-side outputs:

- Double Start Override (starter) Relay
- Fuel Pump Relay
- S/C Vent Solenoid
- Low and High Speed Radiator Fans
- ASD Relay
- A/C Clutch Relay
- S/C Vacuum Solenoid

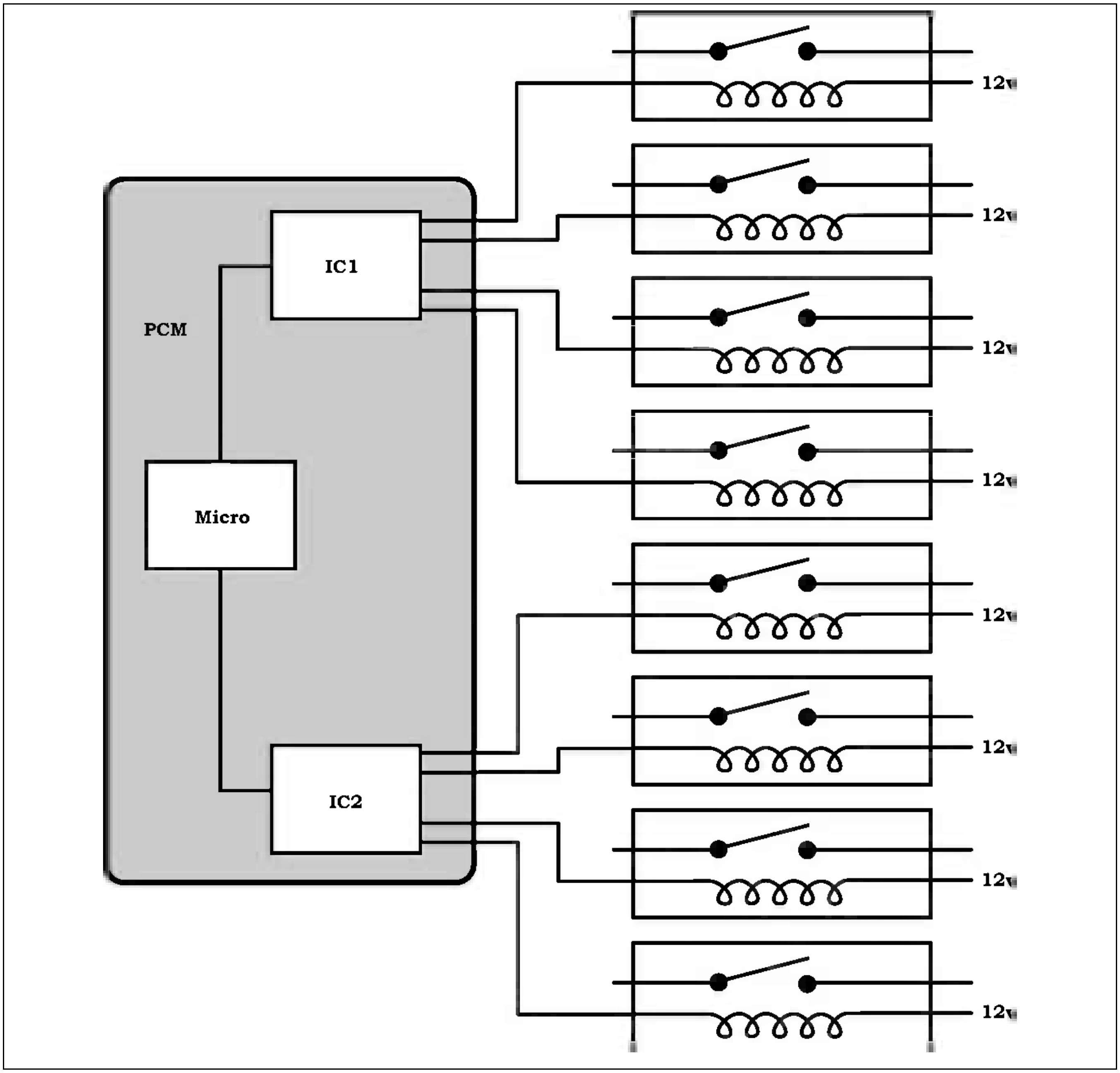


Figure 55 Low Side Output Control

NGC HIGH-SIDE CONTROLLED DEVICES

On NGC vehicles, high-side drivers are used to control high-current devices. Although low-side drivers can control high-current devices, it is difficult and expensive to place these drivers onto one integrated circuit chip. NGC controllers use either a Dual High Side Switch (DHSS) or a Quad High Side Switch (QHSS) to control all high-side controlled devices.

The difference between the two is the way they are packaged. A DHSS integrates two high-side drivers into one chip (dual), where as a QHSS integrates four drivers onto each chip (quad).

Variable output devices, such as the Linear Solenoid Idle Air Control (LSIAC) Valve and Proportional Purge Solenoid (PPS) have their ground connection made through the PCM. In these cases, the PCM is capable of monitoring the ground circuit to determine the position of the device.

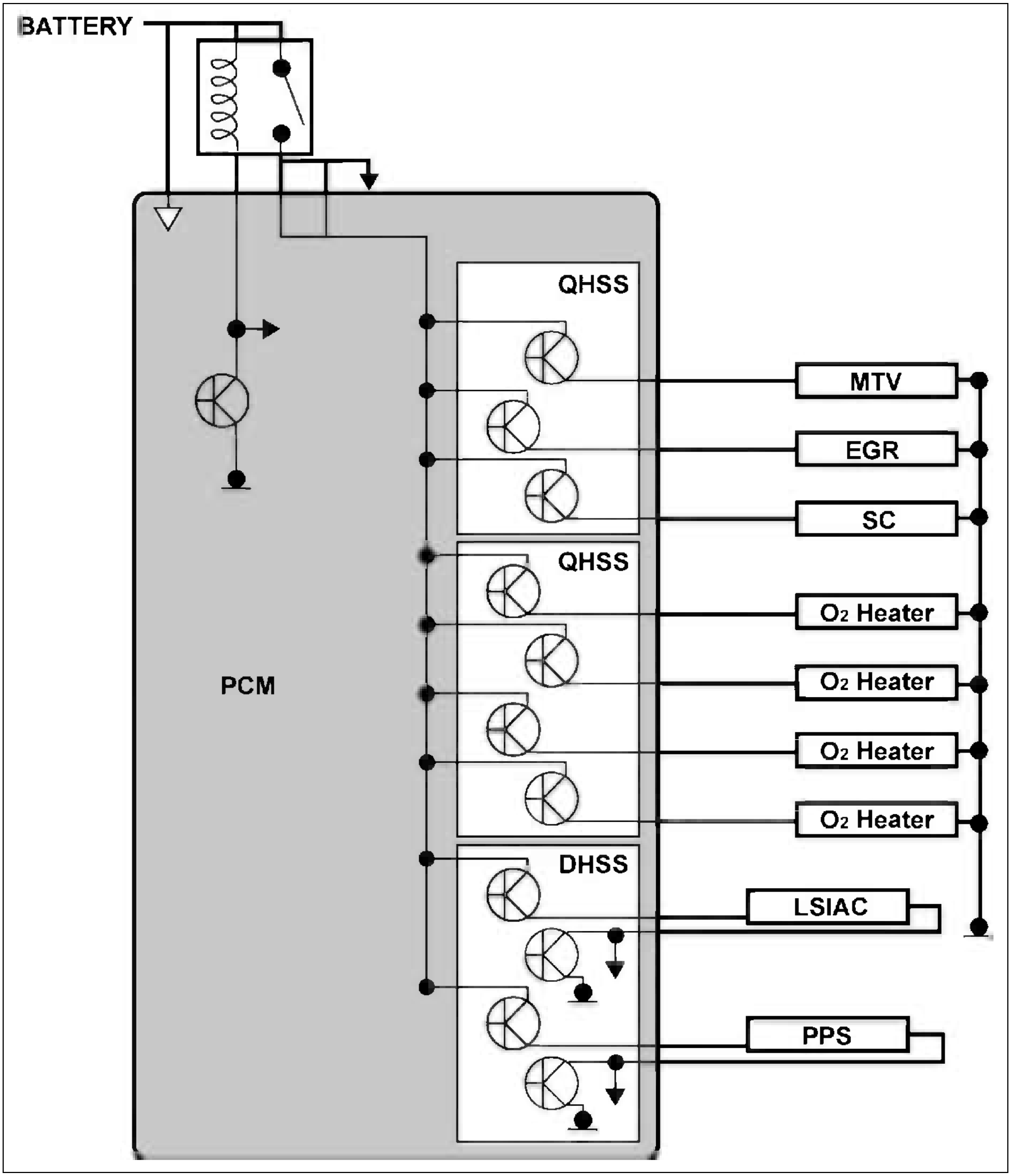


Figure 56 NGC High Side Output Control

GPEC LOW-SIDE CONTROLLED DEVICES

Similarly to the NGC, the GPEC PCM contains a low-side driver which controls various low-current outputs. These outputs are:

- Main relay
- Intake and exhaust VVT solenoids

GPEC HIGH-SIDE CONTROLLED DEVICES

The GPEC high-side driver controls medium and high-current outputs such as:

- Oxygen sensor heaters
- Electronic throttle control (ETC)
- Proportional Purge Solenoid (PPS)
- Variable displacement A/C
- Flow control valve

NGC AUTOMATIC SHUTDOWN RELAY (ASD)

When energized, the ASD Relay provides power to operate the injectors and ignition coils. The relay provides a sense circuit to the PCM for diagnostic purposes.

The PCM energizes the ASD:

- For approximately 2.0 seconds during initial key–ON cycle.
- Whenever the Crankshaft Position Sensor signal exceeds a certain value.

The ASD Relay coil is fed battery voltage and the PCM provides the ground. The ASD output may be distributed to the PCM and other components.

Consult Service Information for vehicle-specific information.

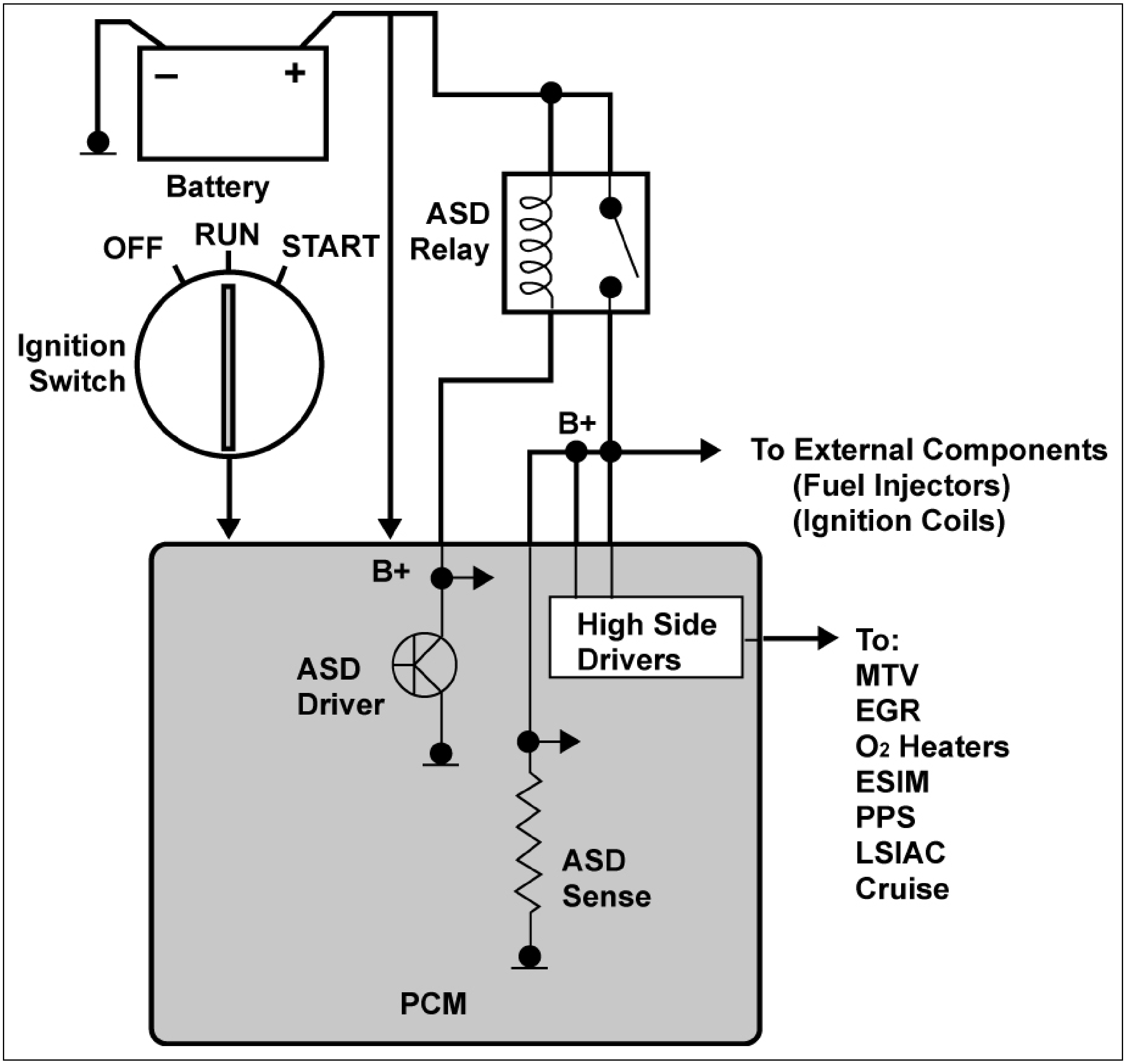


Figure 57 NGC ASD Relay

GPEC MAIN RELAY

The main relay is located under the hood, in a secondary power distribution box with the radiator fan relays. Like the ASD relay used with the NGC, the main relay supplies voltage to the ignition coils, fuel injectors, and high side drivers. The main relay also provides the voltage to power-up the GPEC.

The main relay is energized when the ignition switch is turned to RUN/START. There is also a feedback circuit from the GPEC to the groundside of the main relay coil. This circuit allows the relay to remain energized for approximately seven to ten seconds after the vehicle is shut off. During this time the GPEC performs various shutdown functions.

Reverse voltage protection for the GPEC is provided by the main relay. During a reverse voltage condition, the main relay is deactivated and therefore does not provide power to the GPEC.

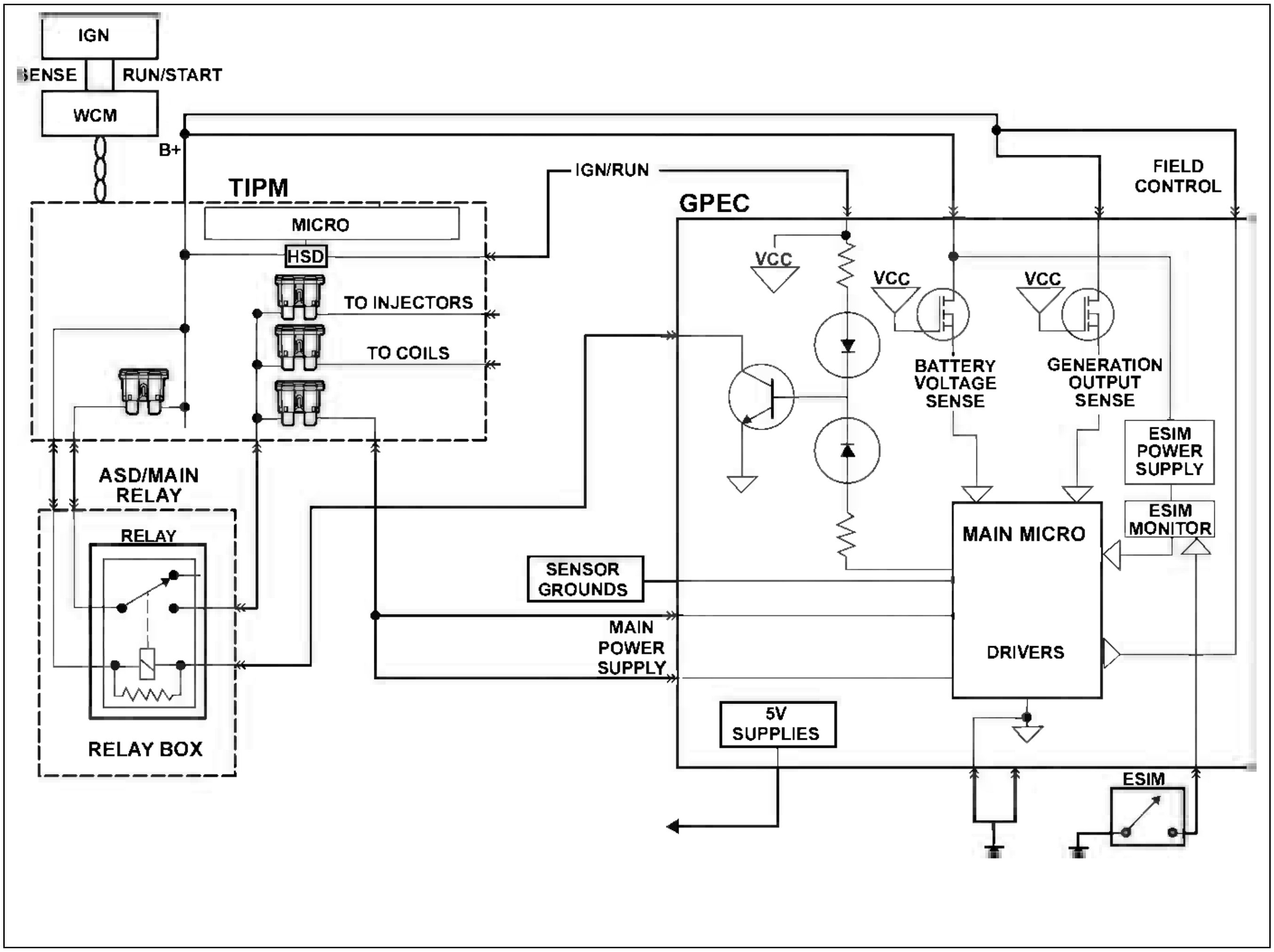
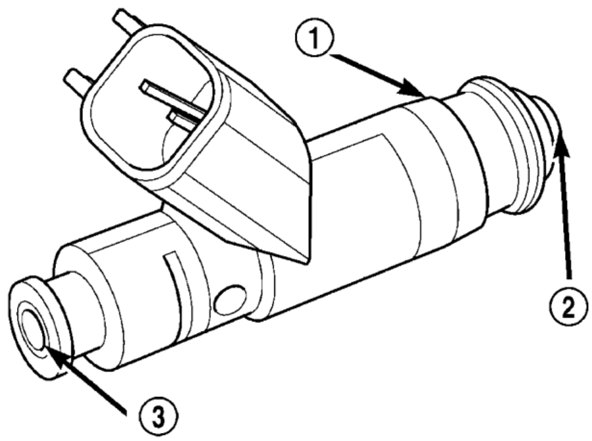


Figure 58 GPEC Main Relay

Fuel Injector Control

All engines use 12 ohm, top feed injectors. The ASD relay or Main relay supplies voltage to the injectors, and the PCM controls the injectors using a low side, pulse width modulated driver. All injector circuits are clamped to 62V to prevent damage from inductive kicks.



1	Fuel Injector
2	Discharge Nozzle
3	Fuel Inlet

Figure 59 Fuel Injector

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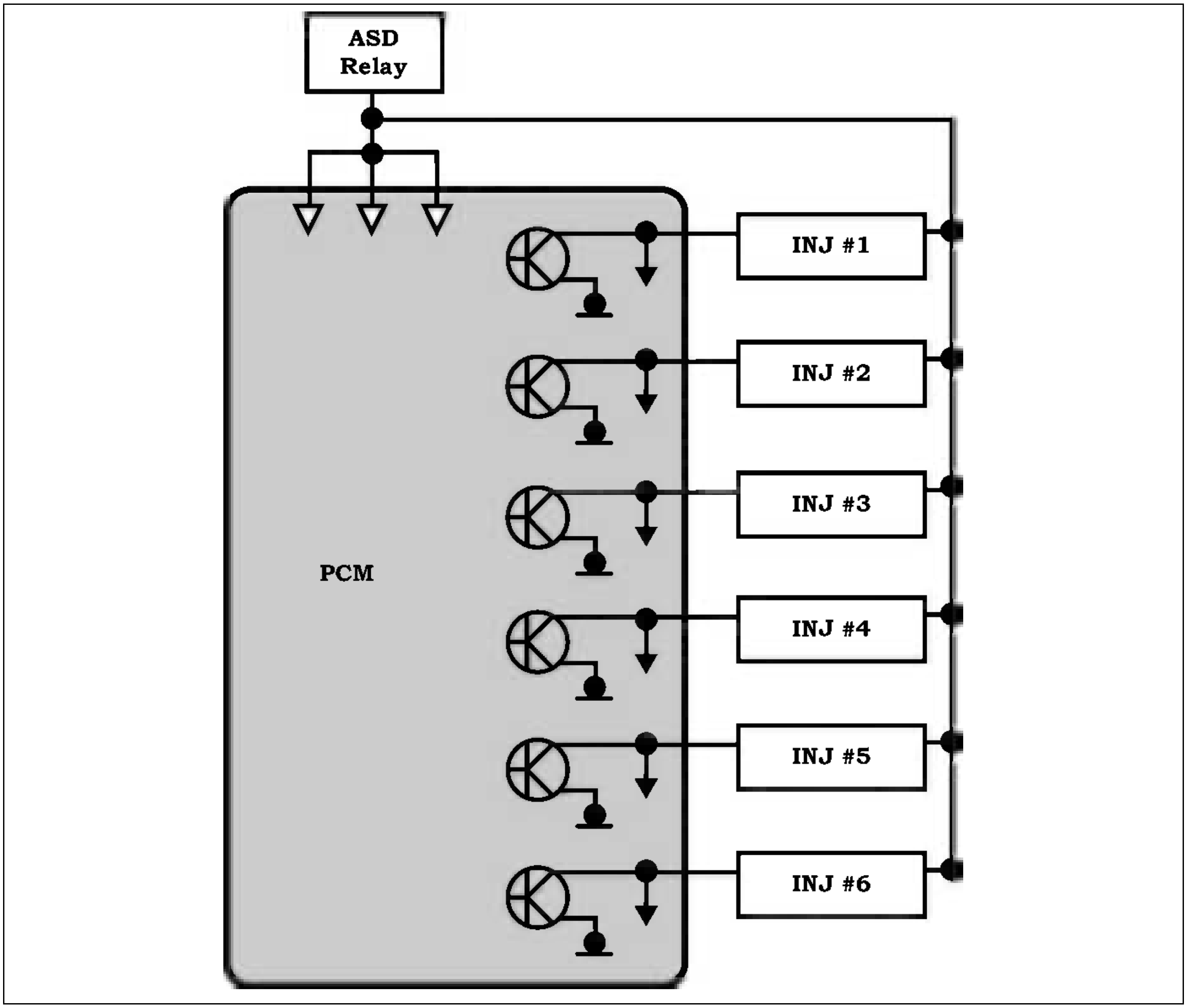


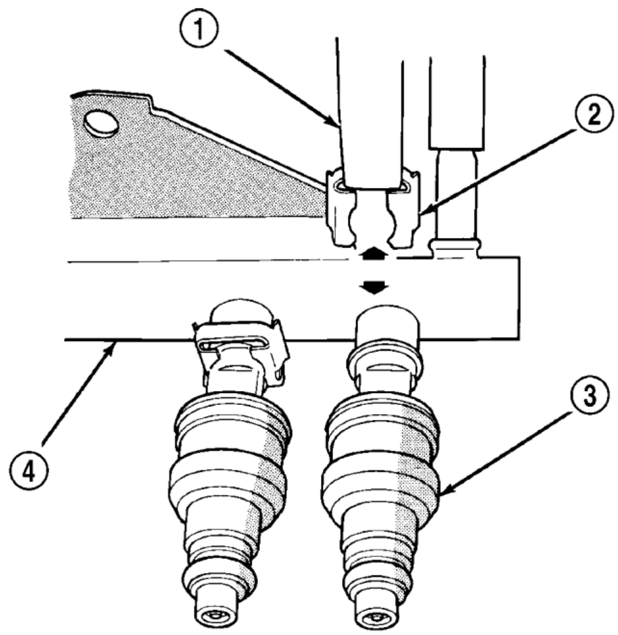
Figure 60 NGC Fuel Injector Control Circuit

Fuel Injector Diagnostics

The PCM monitors the continuity of the circuit as well as the voltage spike (inductive kick) created by the collapse of the magnetic field in the injector coil. The inductive kick is typically above 60V. Any condition that reduces the maximum current flow or the magnitude of the kick can set a DTC (Injector Peak Current Not Reached).

WARNING: FUEL SYSTEM PRESSURE MUST BE RELEASED BEFORE SERVICING CERTAIN FUEL SYSTEM COMPONENTS. ALWAYS FOLLOW PROCEDURES IN SERVICE INFORMATION. SERVICE VEHICLES AND FUEL SYSTEM COMPONENTS IN WELL VENTILATED AREAS. AVOID SPARKS, FLAMES, AND OTHER IGNITION SOURCES. NEVER SMOKE WHILE SERVICING THE VEHICLE'S FUEL SYSTEM.

WARNING: FUEL INJECTOR CLIPS ARE FOR ASSEMBLY PURPOSES. THE FUEL RAIL SHOULD NOT BE PRESSURIZED WHEN NOT PROPERLY INSTALLED ON THE ENGINE.



1	Pliers (tool)
2	Clip
3	Fuel Injector - Typical
4	Fuel Rail - Typical

Figure 61 Fuel Injector Clips

IGNITION SYSTEMS

Ignition System Operation

The ignition system creates the high voltage spark that ignites the air/fuel mixture in the engine cylinder to begin the power stroke. To accomplish this, the ignition system does three jobs:

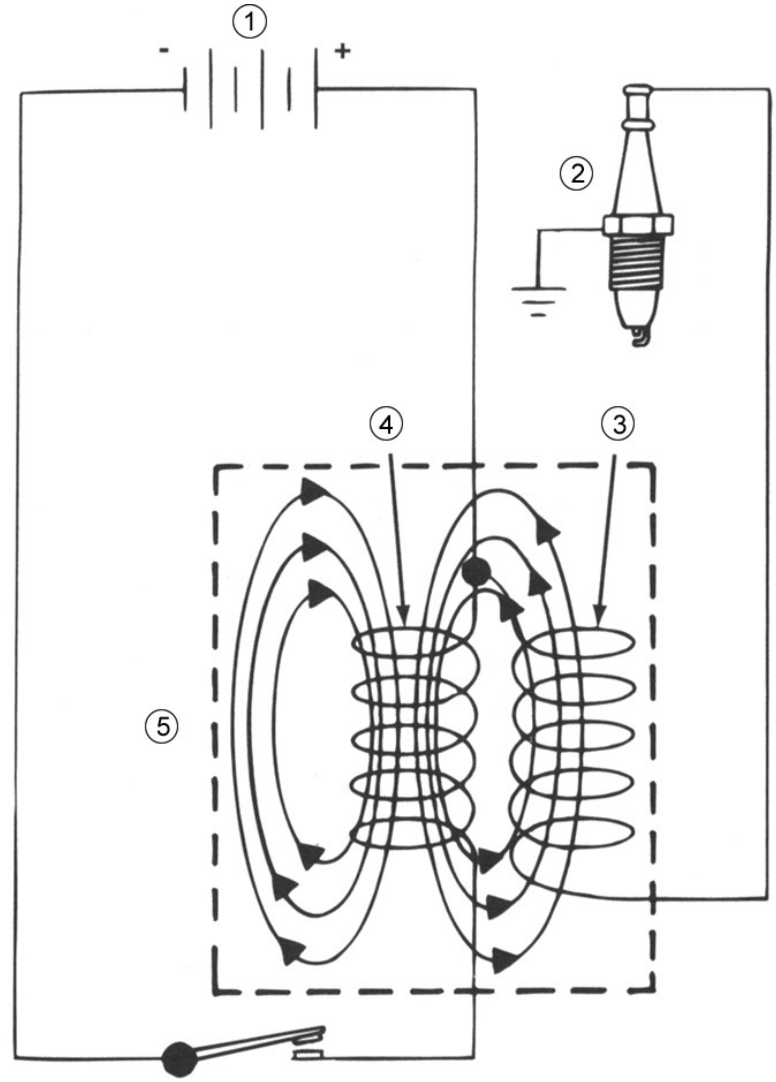
- Generates a high voltage pulse
- Decides which spark plug and cylinder will receive the high voltage
- Decides when in the cycle the high voltage is sent to the spark plug

In the past, these jobs were performed by electromechanical components. Today, these tasks are managed electronically by the PCM, sensors and actuators.

The ignition coil generates the high voltage needed to create a spark across the spark plug electrodes. The coil contains two windings, the Primary and the Secondary. The primary winding typically has about 200 turns of copper wire, and the secondary typically has about 100 times as many turns or about 20000 turns. The ratio of the number of turns of wire is the Turns Ratio.

Voltage is induced in the coil by a process called Magnetic Induction. When a current flows through a wire, a magnetic field exists around that wire. Conversely, if a wire is moved through a magnetic field, a voltage will be induced in the wire. You can move either the wire or the magnetic field. As long as there is relative motion between the two, a voltage will be induced in the wire.

When current flows through the primary coil windings, a magnetic field builds in the coil. When the primary current is quickly interrupted, this magnetic field collapses rapidly. The magnetic lines of force pass through the primary and secondary coil windings, inducing several hundred volts in the primary and thousands of volts in the secondary. This secondary voltage is sent to fire the correct spark plug.



1	Battery	4	Primary Winding
2	Spark Plug	5	Ignition Coil
3	Secondary Winding		

Figure 62 Basic Ignition System

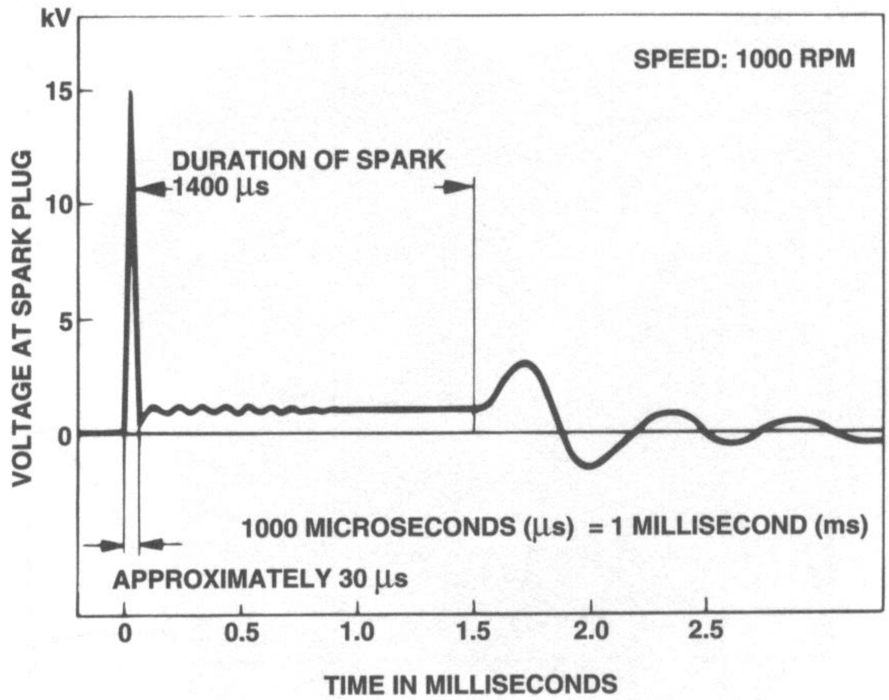


Figure 63 Secondary Ignition Voltages

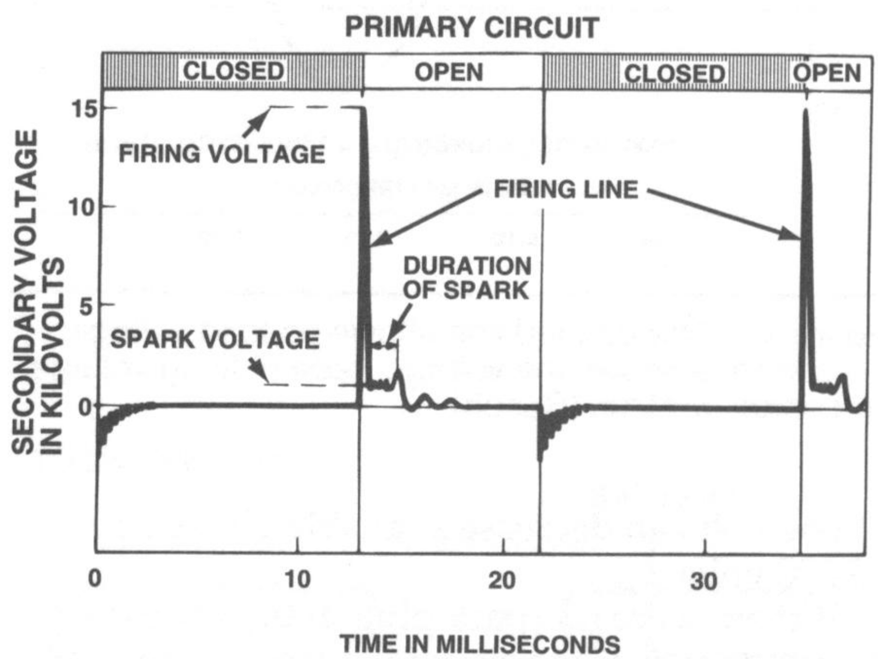
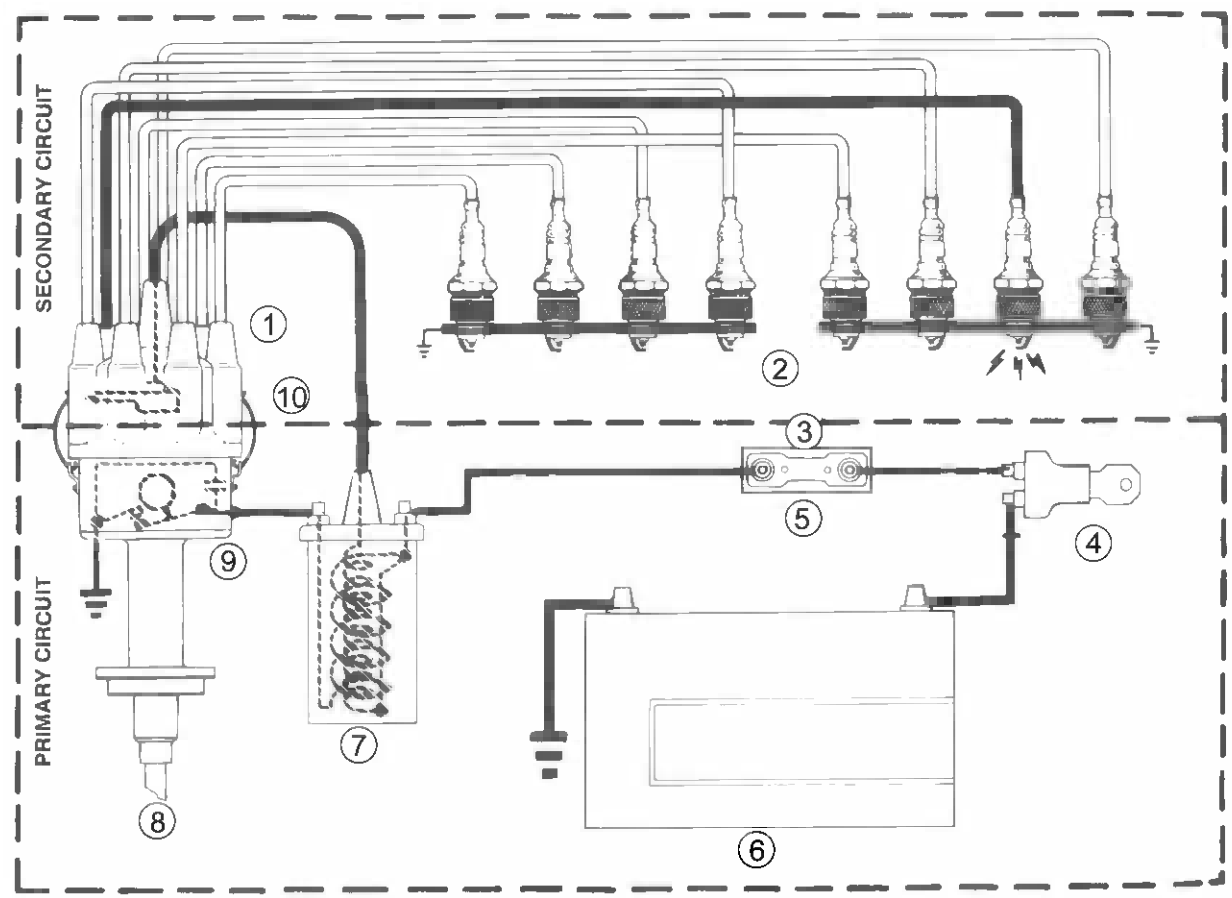


Figure 64 Primary and Secondary Circuits

In older vehicles with distributor-type ignition, one coil is used to generate a high voltage for every cylinder in the engine. The rotor inside the distributor cap is a rotating selector switch that sends the high voltage to the correct cylinder.



1	Cap	6	Battery
2	Spark Plugs	7	Coil
3	Primary Resistor	8	Distributor
4	Ignition Switch	9	Switching Device
5	Resistor Wire or Ballast Resistor	10	Rotor

Figure 65 Distributor Type Ignition System

The correct firing sequence is the same as the engine firing order. For example, the firing order for the 2.4L four-cylinder engine is 1-3-4-2, and the firing order for the 3.3L six-cylinder engine is 1-2-3-4-5-6.

NGC Ignition Systems

NGC-equipped vehicles utilize Coil-On-Plug (COP) direct ignition systems. Spark timing and cylinder selection are controlled by the PCM. Other engines continue to use Distributorless (DIS) Waste Spark ignition systems. Spark timing and cylinder selection are controlled by the PCM.

With COP ignition, each spark plug fires once every two revolutions of the crankshaft. Engines with DIS Waste Spark ignition fire each spark plug every revolution of the crankshaft. The 5.7L engine has a Waste Spark system with two spark plugs per cylinder.

Each individual ignition coil is supplied voltage by the Automatic Shutdown (ASD) Relay. A low side pulse width modulated driver controls each coil. A capacitor may be wired in parallel with the circuit to prevent RFI.

NGC PCMs in passenger cars are capable of varying dwell and current to meet the engine's changing requirements. Cold engines, lean fuel mixtures, EGR flow and engine idle conditions require a hotter spark to maintain combustion stability and achieve smooth idle. Under high speeds and heavy engine loads, the engine has more inertia and is more stable, so the hotter spark is no longer required. Current flow is limited to 7-11 amps in low current mode, and 11-15.8 amps in high current mode.

GPEC Ignition System

GPEC-equipped vehicles also use Coil-On-Plug direct ignition systems. Current flow is typically 7 amps and is limited to 10 amps maximum.

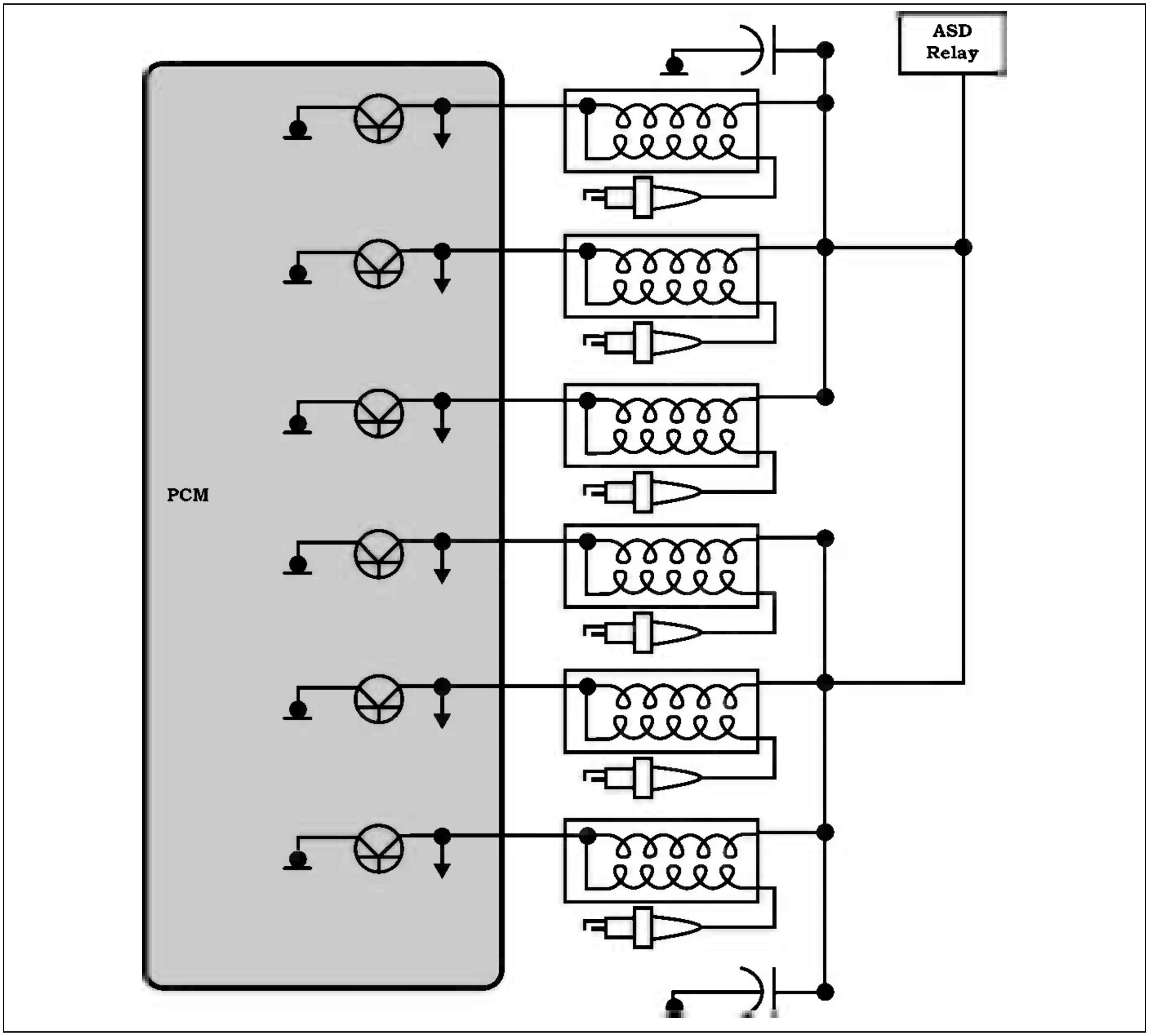


Figure 66 NGC COP Ignition Coil Circuit

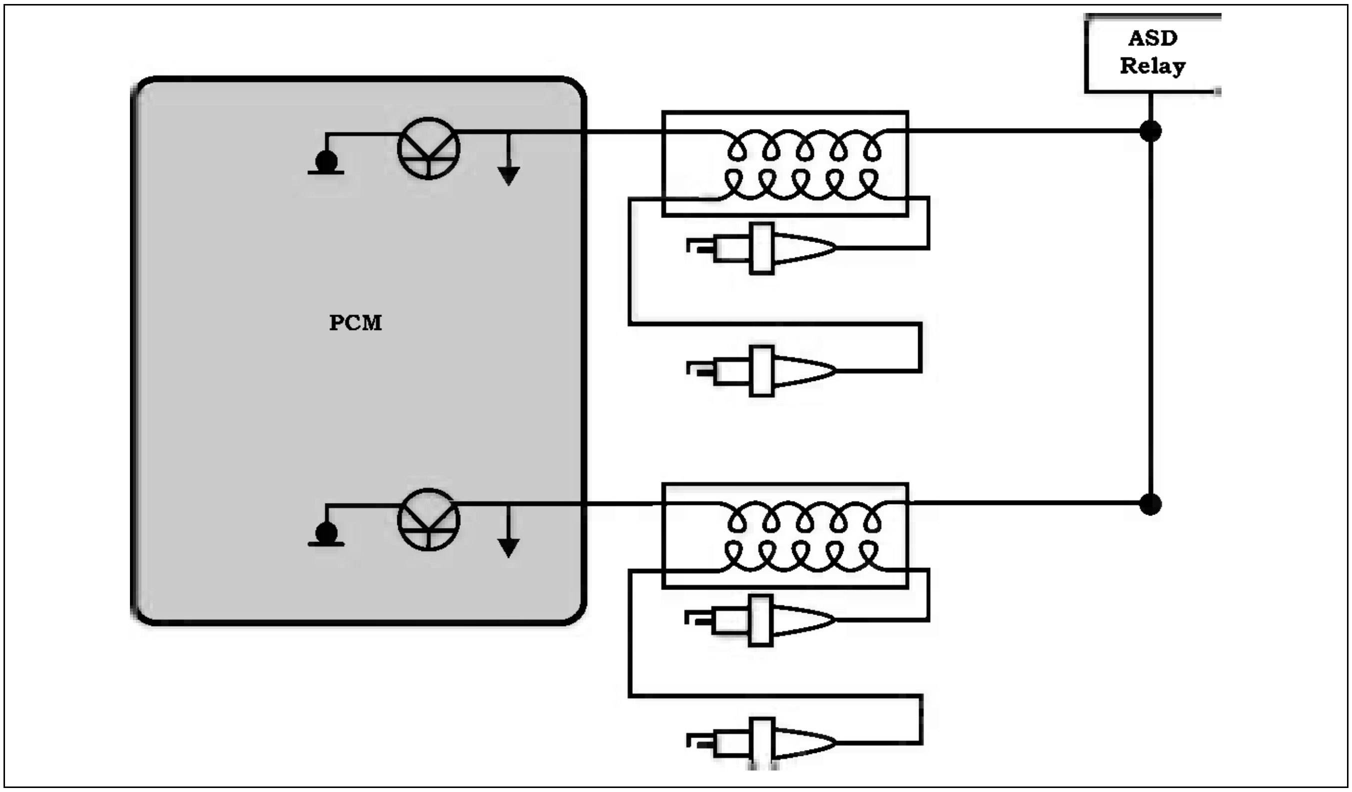
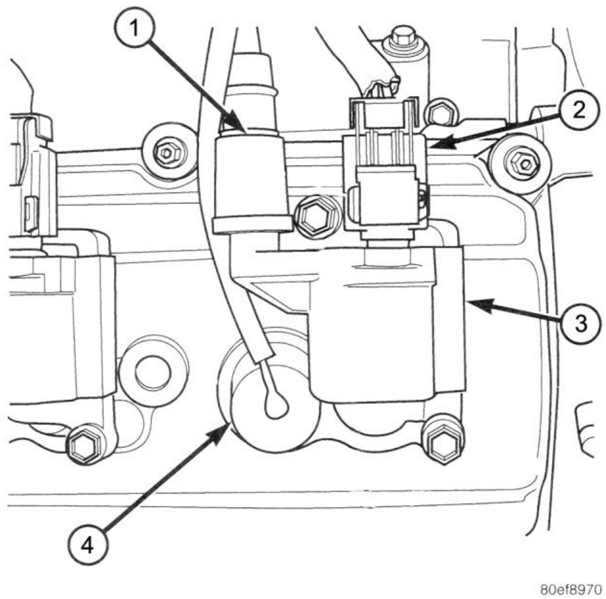


Figure 67 NGC DIS (Waste Spark) Ignition Coil Circuit

NGC 5.7L Engine (Early 5.7L only)

The early builds of the 5.7L engine used a Waste Spark ignition system and two spark plugs per cylinder. Each coil is connected to two spark plugs, one directly under the coil and one in the companion cylinder. In this engine, every coil and every spark plug fires with every revolution of the crankshaft. When a coil is firing its COP fired spark plug on the compression stroke to begin the power stroke event, at the same time it fires the remote fired spark plug in the companion cylinder on the exhaust stroke for the Waste Spark event. During the next revolution of the crankshaft, the same coil fires again, but this time it fires its remote fired spark plug on the compression stroke and the COP fired spark plug on the exhaust stroke. Both spark plugs in a cylinder fire at the same time, but different coils fire them.



1	Spark Plug Cable (to remote fired spark plug in companion cylinder)	3	Ignition Coil
2	Electrical Connector	4	Spark Plug Cable (from ignition coil in companion cylinder)

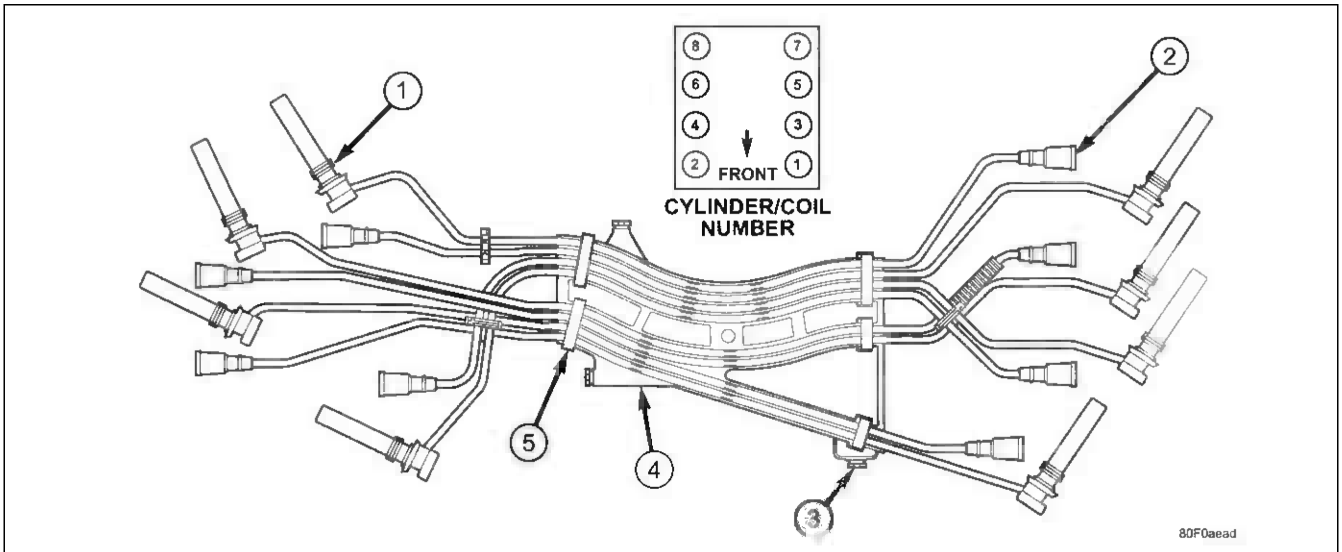
Figure 68 Early 5.7L Ignition Coil Installation

A plastic cable tray holds the secondary cables in position to prevent crossfire. Before removing any spark plug cables, note their original position. Remove cables one at a time.

Both the secondary cables and the cable tray are marked with cylinder numbers to help routing. The cables and the cable tray are replaced as an assembly. At this time, the cables are not available separately.

Before installing spark plug cables, apply dielectric grease to the inside of the terminal boots.

Caution: The cables MUST be properly positioned in the tray to prevent crossfire. Cable retention clips must also be securely locked.



1	Secondary Cable Spark Plug Connector (typical)
2	Secondary Cable Coil Connector (typical)
3	Clips (tray–to–manifold retention)
4	Cable Tray
5	Clips (Spark Plug Cable–to–tray retention)

Figure 69 Early 5.7L Spark Plug Cable Routing and Cable Tray

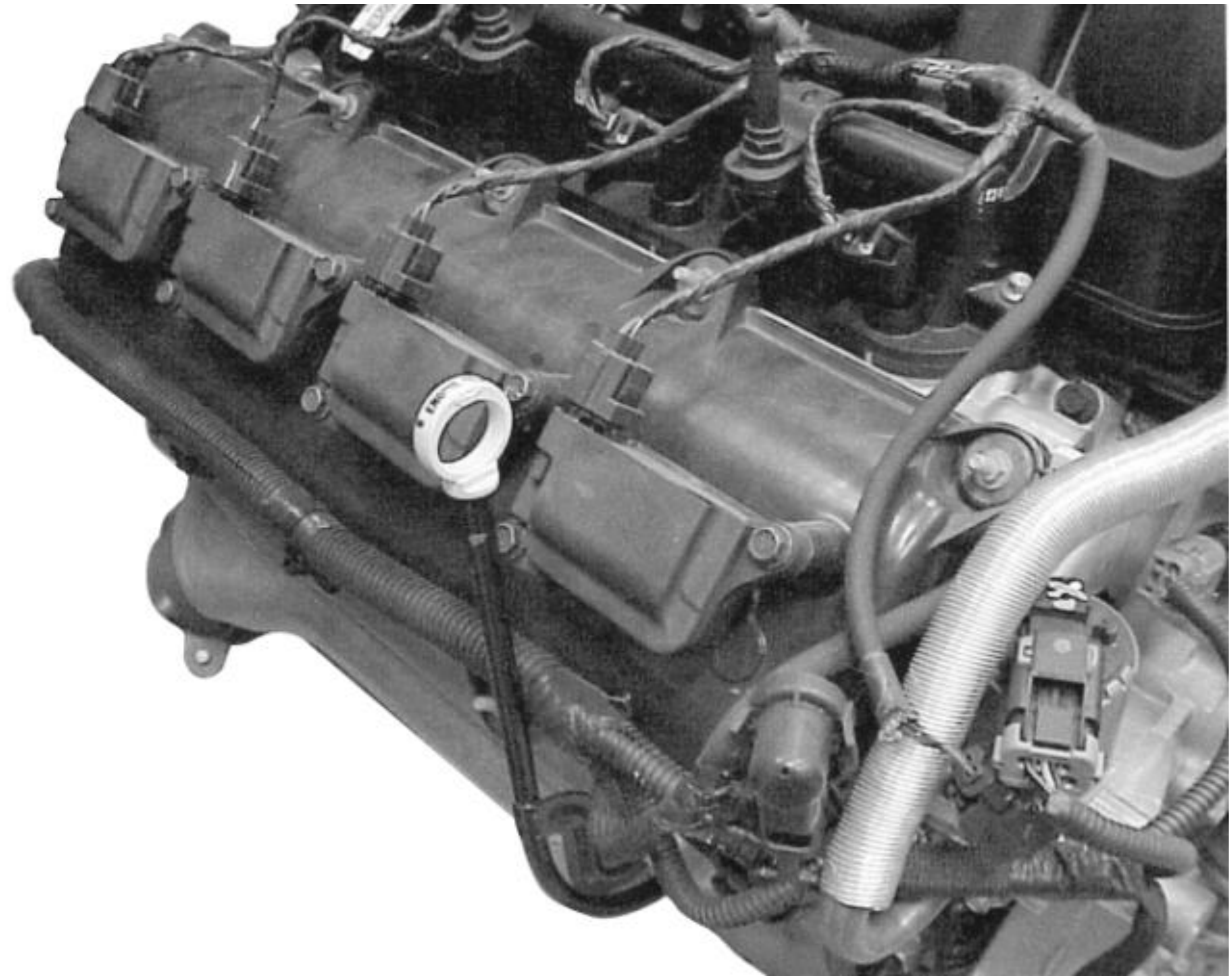


Figure 70 Current 5.7L Ignition System

Ignition System Diagnostics

In vehicles with DIS Waste Spark ignition, an open ignition secondary circuit may affect one or both spark plugs in the circuit depending upon engine load. Under light load, only one spark plug may misfire, and the capacitive effect of the open circuit may fire the second plug. Under heavy load, both spark plugs may misfire.

The PCM may monitor spark plug ionization (burn time) and may set a DTC if an out-of-range condition is detected. If the spark duration (primary circuit firing line) is above or below specifications, a fault will be stored. This is accomplished by monitoring the coil's primary circuit current flow.

WARNING: DURING DIAGNOSIS AND TESTING, IT IS IMPORTANT TO USE A SPARK TESTER WHEN TESTING FOR SPARK OR CYLINDER MISFIRE. DO NOT ALLOW COILS TO FIRE OPEN CIRCUIT. PCM DRIVER FAILURE WILL RESULT!

LINEAR SOLENOID IDLE AIR CONTROL VALVE (LSIAC)

The Linear Solenoid Idle Air Control (LSIAC) Valve is a two-wire air bypass solenoid controlled by the PCM. It was first used on the 2001 RS and PL. The PCM uses a high-side driver to regulate current flow to the LSIAC with a duty cycle of 10 - 90% at 1.5 - 2.5 kHz.

The biggest advantage to the LSIAC valve is quick response: 20 ms from closed to full open. This results in more accurate idle air control and less tendency for idle undershoot.

The PCM also provides a path to ground. Current flow on this ground circuit is monitored to determine the position of the LSIAC. The PCM compares the target current flow against the actual current flow to determine LSIAC position, rather than counting "steps" as in the old style IAC motor.

Table 4 Typical LSIAC Values

LSIAC Condition	LSIAC Current (ma)
Fully Closed	180-200
Engine Idle	300-450
Engine at Light Cruise	500-700
Fully Open	900-950

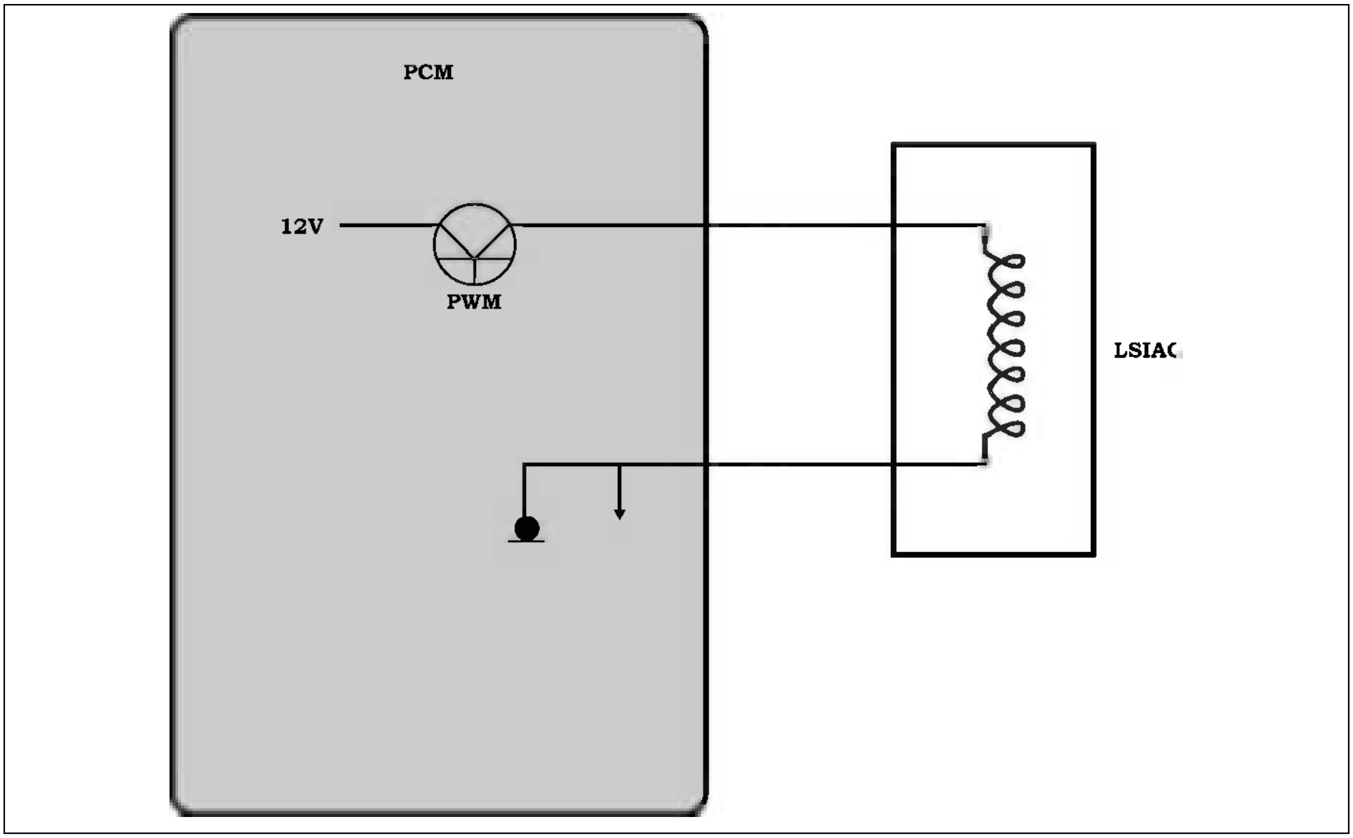


Figure 71 Linear Solenoid Idle Air Control Valve

LSIAC AND IAC AIR FLOW MANAGEMENT

Target Idle speed is mainly determined by the following inputs:

- TPS
- ECT sensor
- Gear position (P/N Switch)

Other factors affecting Target Idle speed may include:

- Battery voltage
- Ambient/Battery temperature sensor
- VSS
- MAP sensor

When engine rpm is above idle speed, the LSIAC and IAC are used for the following functions:

- Off–idle dashpot
- Deceleration air flow control

Under all engine operating conditions, the PCM will compensate for A/C compressor load by opening the passage slightly before the compressor is engaged so that engine rpm does not dip down when the compressor engages.

MINIMUM IDLE AIR FLOW

Minimum air flow is the volume of air flowing past the throttle plate at idle, plus any other components that might allow air to flow into the intake manifold at idle, such as the PCV valve. Minimum air flow specifications aid in engine diagnostics. Worn or out of adjustment components, exhaust restrictions and other items can have an effect on minimum air flow. All fuel, ignition, emission and engine mechanical components must be checked "good" before a minimum air flow check can be done. When performing the minimum air flow check, all other components that load the engine must be OFF or not operating during the airflow check. Consult Service Information for vehicle-specific procedures.

LINEAR EGR VALVE

The Linear EGR Valve was first used on 1998 LH models. The Linear EGR Valve controls the metering of exhaust gases into the intake manifold. The PCM uses a high-side driver to control the Linear EGR Valve solenoid. The PCM controls the valve position by varying the duty-cycle supplied to the solenoid. The circuit is grounded externally.

The linear EGR valve assembly also contains a three-wire potentiometer that provides feedback to the PCM on valve position.

Figure 72 Linear EGR Valve

SHORT RUNNER TUNING VALVE (SRTV)

The Short Runner Tuning Valve (SRTV) is used on vehicles equipped with an active intake manifold. It optimizes the intake runner length to increase horsepower at high RPM. It accomplishes this by opening passageways that shorten the path between the air inlet and cylinders. The SRTV is supplied power by the ASD Relay and is controlled by the PCM via a latching, low-side driver. This circuit is either full ON or full OFF. The SRTV is actuated by an electric motor.

MANIFOLD TUNING VALVE (MTV)

Like the SRTV, the Manifold Tuning Valve (MTV) is used on vehicles equipped with an active intake manifold. Its purpose is to vary the intake manifold runner configuration to optimize torque over a wider RPM range. It is a two-state device that electrically opens and closes a passageway that connects two separate plenums within the intake manifold. A high-side driver controls the circuit, and there is an external ground.

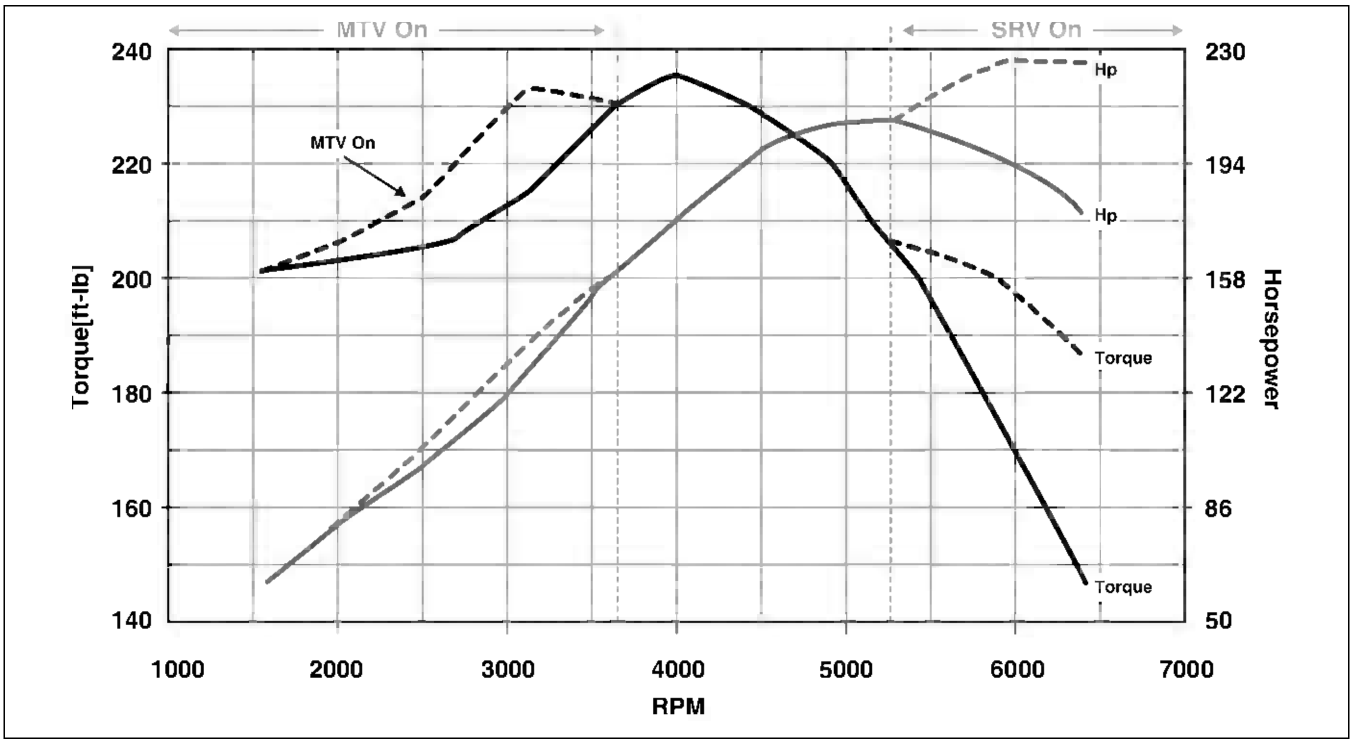
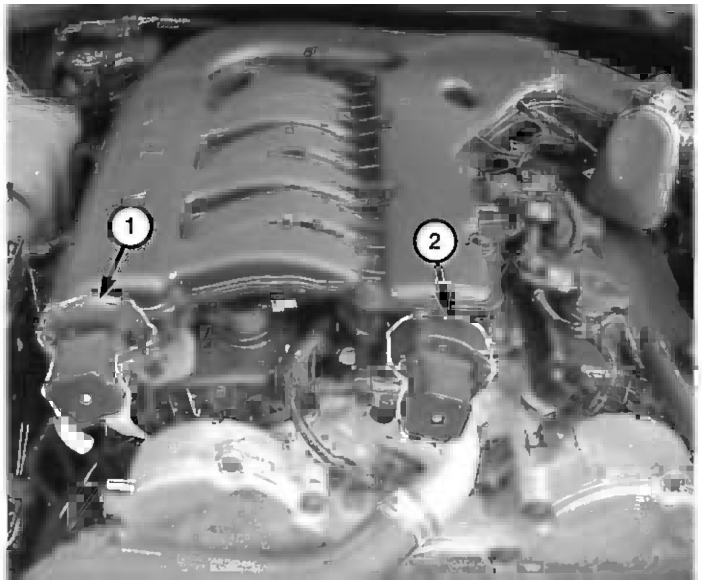


Figure 73 MTV and SRTV Benefits



1	Short Runner Valve
2	Manifold Tuning Valve

Figure 74 LX 3.5L Showing SRTV and MTV

WORLD ENGINE FLOW CONTROL VALVE

Manifold flow control valves are unique to Chrysler World Engine vehicles. They are designed to promote maximum air/fuel atomization. The valve restricts airflow, causing it to tumble or swirl. The tumbling action helps ensure that the fuel and air mix thoroughly and burn faster. The intake manifold flow control valve and variable valve timing work together to improve fuel economy, idle stability, and emissions.

The electrically controlled intake manifold flow control valve is located in the intake manifold at the cylinder head.

Figure 75 World Engine Flow Control Valves

The intake manifold is constructed of composite material and divided into equal length runners. At the end of each runner is an intake manifold flow control valve flap. The intake manifold flow control valve actuator controls the flaps through a common shaft.

The intake manifold flow control valve actuator is a two-position torque motor that is pulse width driven by the GPEC. The actuator is either energized to move the flaps out of the way to the wide-open position, or de-energized to move the flaps up to a restricted position.

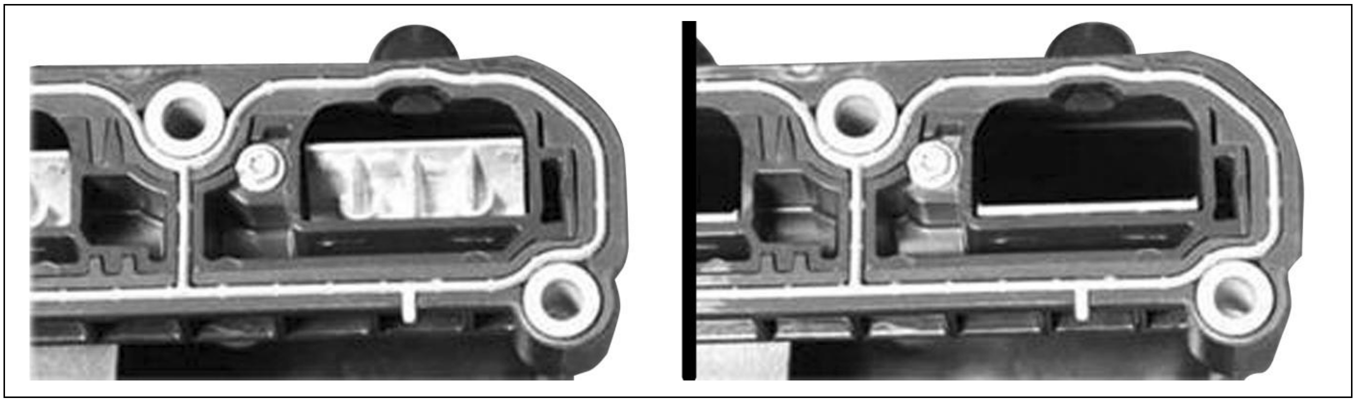


Figure 76 World Engine Flow Control Flaps Closed and Open

The intake manifold flow control valve actuator also contains a potentiometer feedback system to aid in diagnosis.

The potentiometer circuit reports the actual position of the intake manifold flow control valve flaps. The GPEC compares the actual position with the desired position to ensure that the system is functioning correctly.

The valve actuator is energized to open the flaps at higher engine speeds (greater than 3600 rpm for the 1.8L and 2.0L or 4000 rpm for the 2.4L) or at wide-open throttle. The actuator is deenergized when the engine is at lower speeds than noted above, and at closed- or partially open-throttle.

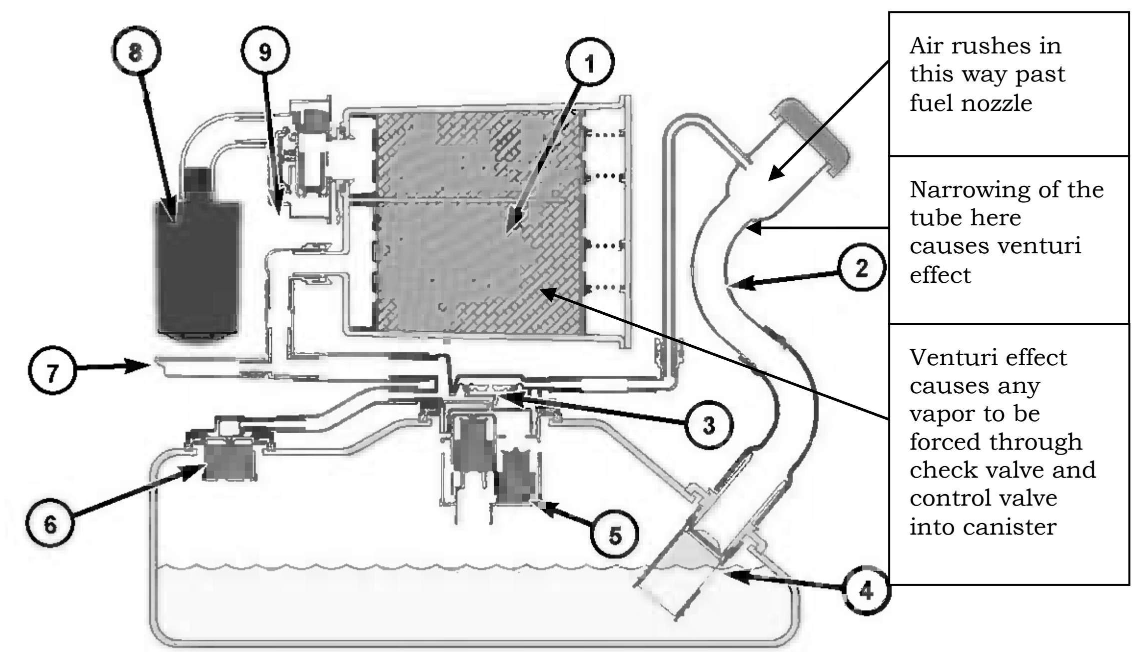
EVAPORATIVE EMISSIONS (EVAP) SYSTEM

Onboard Refueling Vapor Recovery (ORVR)

Previous EVAP systems vented fuel vapor (HC) emissions during refueling. The Onboard Refueling Vapor Recovery (ORVR) system greatly reduces these HC emissions. ORVR was first introduced on some 1998 passenger vehicles.

Fuel flowing into the small-diameter tank filler tube (approx. 1" I.D.) creates a venturi effect which draws air into the fill tube. During refueling, the fuel tank is vented to the charcoal canister to capture HC vapors. With air flowing into the filler tube, no fuel vapors escape to the atmosphere.

Once the HC vapors from refueling are captured by the canister, the vehicle's computer-controlled EVAP purge system draws the HC out of the canister for the engine to burn. The vapor flow is metered by the purge solenoid so that there is minimal impact on driveability or on tailpipe emissions.



1	Charcoal Canister	6	Grade Vent Valve
2	Filler Tube	7	To Purge Solenoid
3	0.100" Orifice	8	Fresh Air Filter
4	Inlet Check Valve	9	ESIM
5	Control Valve		

Figure 77 Onboard Refueling Vapor Recovery (ORVR) System

PROPORTIONAL PURGE SOLENOID (PPS)

The Proportional Purge Solenoid (PPS) controls the purge rate of HC vapors from the vapor canister and fuel tank to the intake manifold. The PCM uses a high-side driver to control the PPS. The PCM regulates the current flow with a duty-cycle of 0-60% at 200 Hz. This 200 Hz frequency is twice that of the previous Duty Cycle Purge Solenoid.

The PCM also provides a ground path for the circuit. Current flow on this ground circuit is monitored to determine the position of the PPS. The PCM compares the target current flow against the actual current flow to determine PPS position.

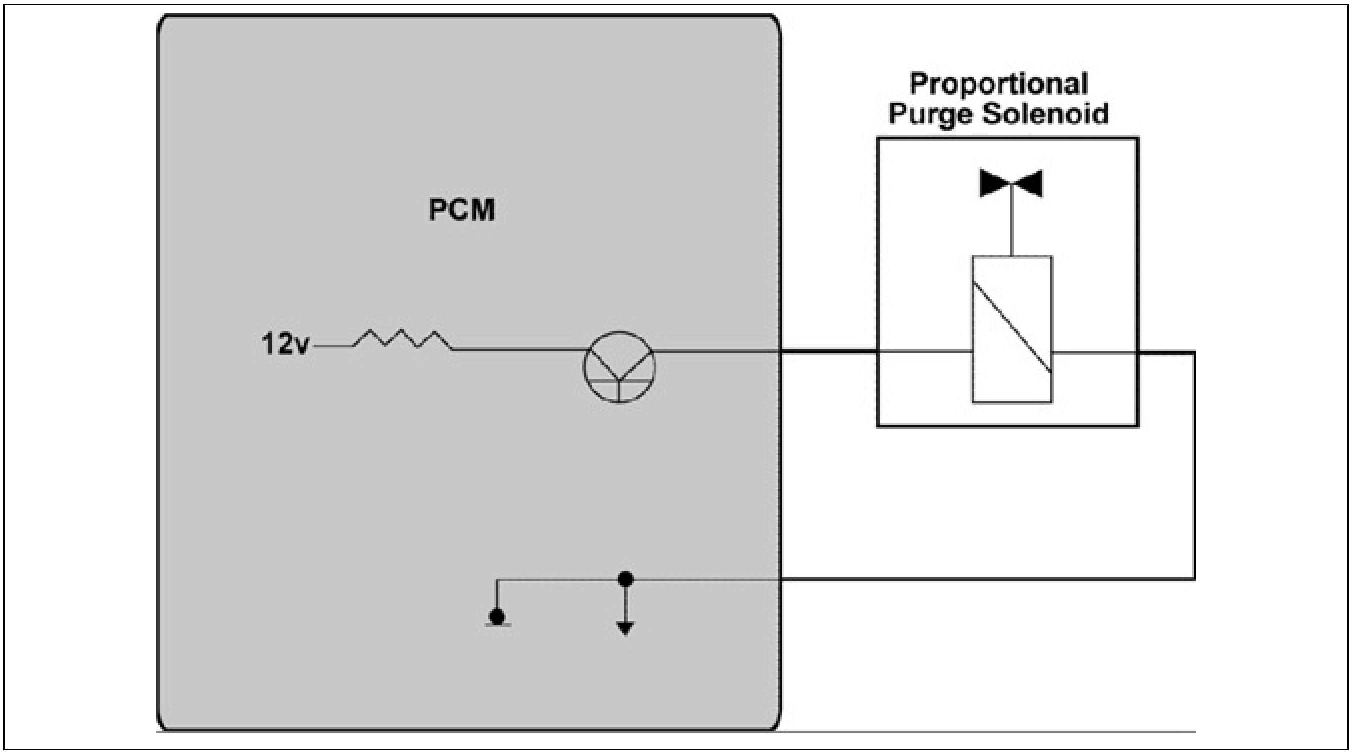


Figure 78 Proportional Purge Solenoid

Proportional Purge Solenoid Diagnostics

A DTC is set when the PCM determines that the actual state of the solenoid does not match the intended state. The PCM monitors the EVAP System and the following DTCs may set if a fault is detected:

- P0441 EVAP PURGE SYSTEM PERFORMANCE – This fault is set when the PCM does not see the NVLD or ESIM switch state change as expected or the PCM does not see a Short Term Adaptive shift as expected.
- P0443 EVAP PURGE SOLENOID CIRCUIT - This fault is set when the commanded state of the solenoid does not agree with the monitored state of the solenoid.

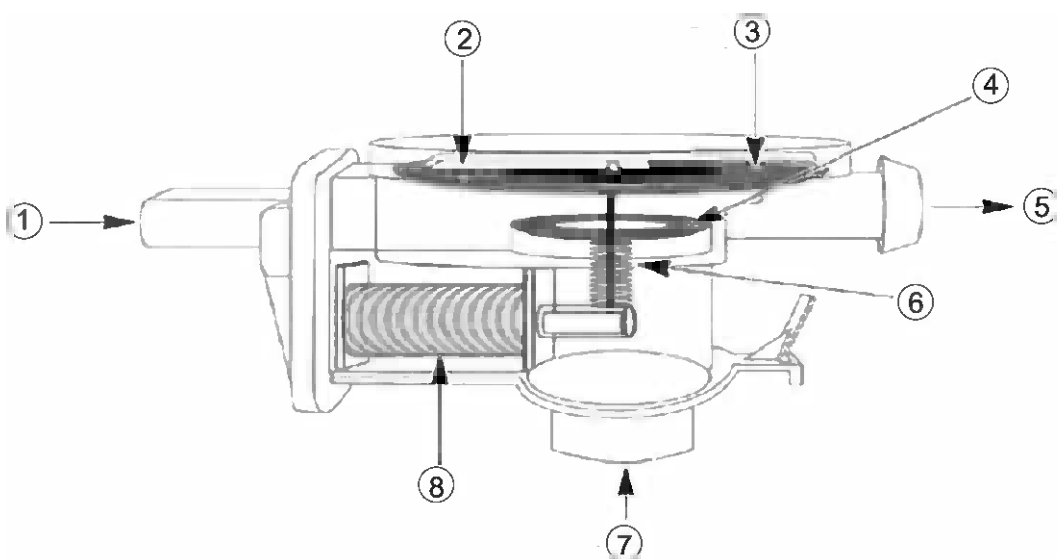
NGC NATURAL VACUUM LEAK DETECTION SOLENOID (NVLD) (PRE-2007 MY)

Note: The NVLD is no longer used and has been replaced by the Evaporative System Integrity Monitor (ESIM)

The Natural Vacuum Leak Detection (NVLD) system replaced the EVAP Leak Detection Pump used on JTEC and SBEC vehicles. The NVLD assembly contains a solenoid, a switch and a pressure operated diaphragm.

The NVLD solenoid is controlled by a PCM high-side driver, and is grounded externally. The solenoid actuates a normally-closed valve to open the EVAP system vent while the engine is running to allow fresh air to enter the system during purge. The solenoid will be de-energized to close the vent during the medium and large leak tests. A switch in the NVLD assembly has normally-open contacts which will close when a vacuum equal to or greater than 1 in. H_2O is present.

The NVLD assembly has three wires: switch sense, solenoid driver and a shared ground.



1	Electrical Connector	5	To Remote Filter
2	Vacuum Switch	6	Spring and Plunger
3	Diaphragm	7	To Canister
4	Pressure/Vacuum Relief Valve	8	Solenoid

Figure 79 NVLD Assembly

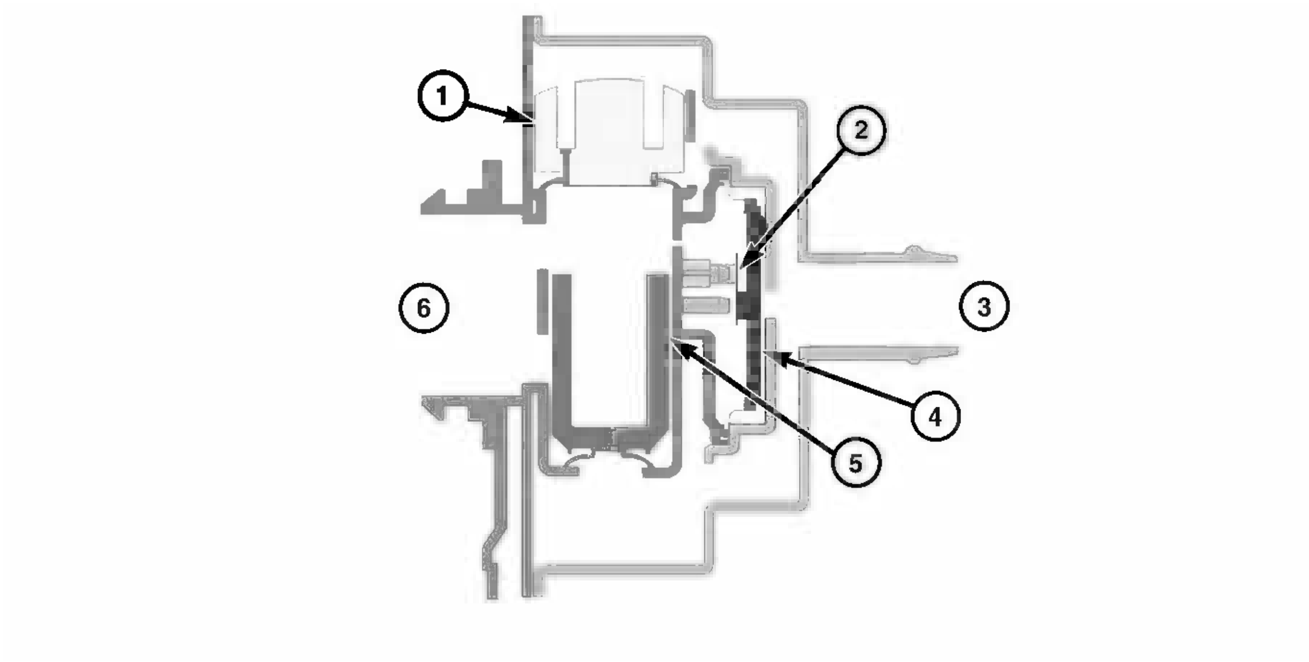
GPEC EVAPORATIVE SYSTEM INTEGRITY MONITOR (ESIM) (2007+ MY)

The Evaporative System Integrity Monitor (ESIM) replaces the Natural Vacuum Leak Detection (NVLD) system. The monitor is very similar to the NVLD system, but is much simpler since it does not use a solenoid.

The ESIM mounts directly to the canister, eliminating the need for a mounting bracket.

Figure 80 ESIM mounted on canister

The ESIM consists of a housing, a small purge weight and a large refueling weight that serve as check valves, a diaphragm, and a switch.



1	Refueling Weight	4	Diaphragm
2	Switch	5	Purge Weight
3	To Fresh Air Filter	6	To Charcoal Canister

Figure 81 Cross section of ESIM

The central feature of ESIM is a diaphragm-operated switch that closes at a calibrated vacuum. The switch is mounted in a chamber ported to the inside of the fuel tank, thus measuring the vacuum there. Reaching the level of vacuum required to close the switch and holding it verifies that the system is intact and meets regulatory requirements. The mechanism also includes a check valve that opens to let air into the tank when vacuum exceeds the required level. This prevents the tank from collapsing.

The ESIM cover has different configurations depending on the application:

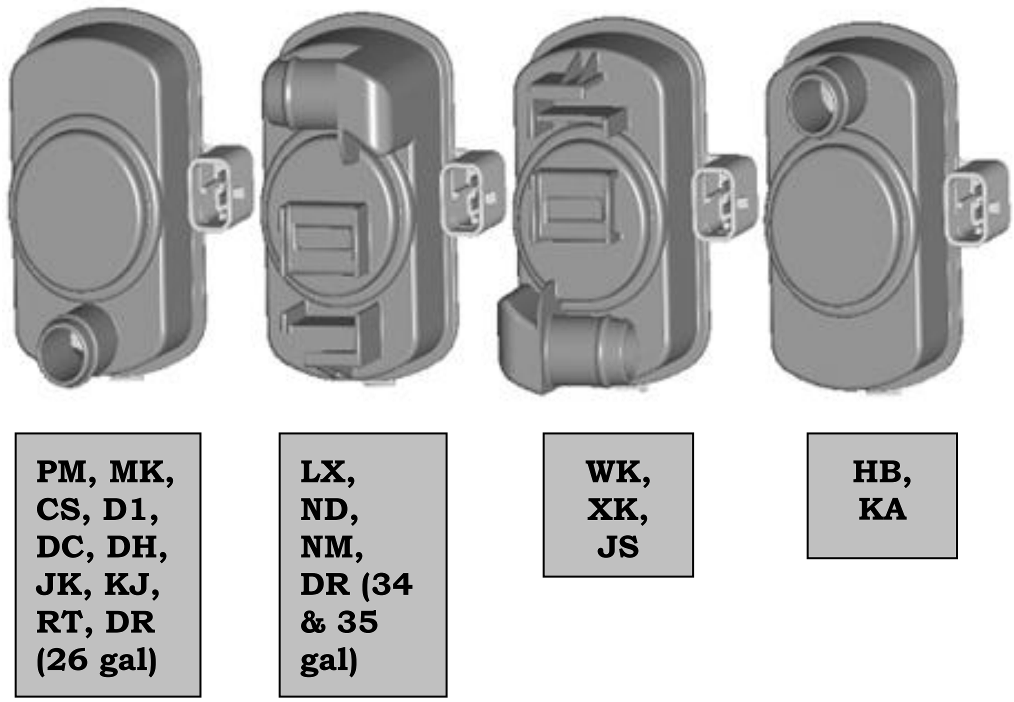


Figure 82 Evaporative System Integrity Monitor (ESIM) Configurations

Operation of the ESIM and the Evap Leak Monitor will be covered in detail in the OBD II course.

FUEL CAP OFF TEST

The PCM also uses the ESIM to detect a loose or missing fuel cap. ESIM and NVLD logic is very similar when it comes to monitoring for a loose or missing gas cap. The PCM looks for a significant change in fuel level. If a large leak (greater than .090 inches) is detected on a number of consecutive cold start trips (three for GPEC, two for NGC), a “Loose Gas Cap Light” illuminates and a P0457 trouble code is set. One good trip turns off the MIL.

Figure 83 Fuel Cap Light

MALFUNCTION INDICATOR LAMP (MIL)

The MIL is controlled by the PCM. It illuminates for a 3-second bulb test each time the ignition is turned to ON and remains continuously illuminated when an emissions component fails, or when the vehicle enters limp-in mode. The MIL flashes if the onboard diagnostic system detects engine misfire severe enough to damage the catalytic converter.

After the PCM performs a bulb check at Key-On, the lamp stays illuminated until the vehicle is started. In addition, with Key-On-Engine-Off for approximately ten seconds, the MIL lamp flashes ON and OFF if the CARB Readiness Indicator does not indicate that all “Once per Trip” monitors have been successfully completed. This has been integrated into the software to address the IM240 states that require all "Once per Trip” monitors be completed prior to an IM test.

Notes:

Notes:

MODULE 9 ELECTRONIC THROTTLE CONTROL SYSTEM

The Electronic Throttle Control (ETC) system moves the throttle by an electric motor under PCM control and the throttle is no longer mechanically connected to the accelerator pedal. Accelerator pedal position is one of several inputs that determine throttle position.

The PCM receives inputs from sensors, calculates the desired torque request and outputs control signals to the throttle motor, ignition and fuel injectors. In this system, the PCM manages intake airflow, ignition timing and fuel quantity control. ETC also handles speed control function and engine idle speed. No separate speed control unit or processor or IAC motor are necessary.

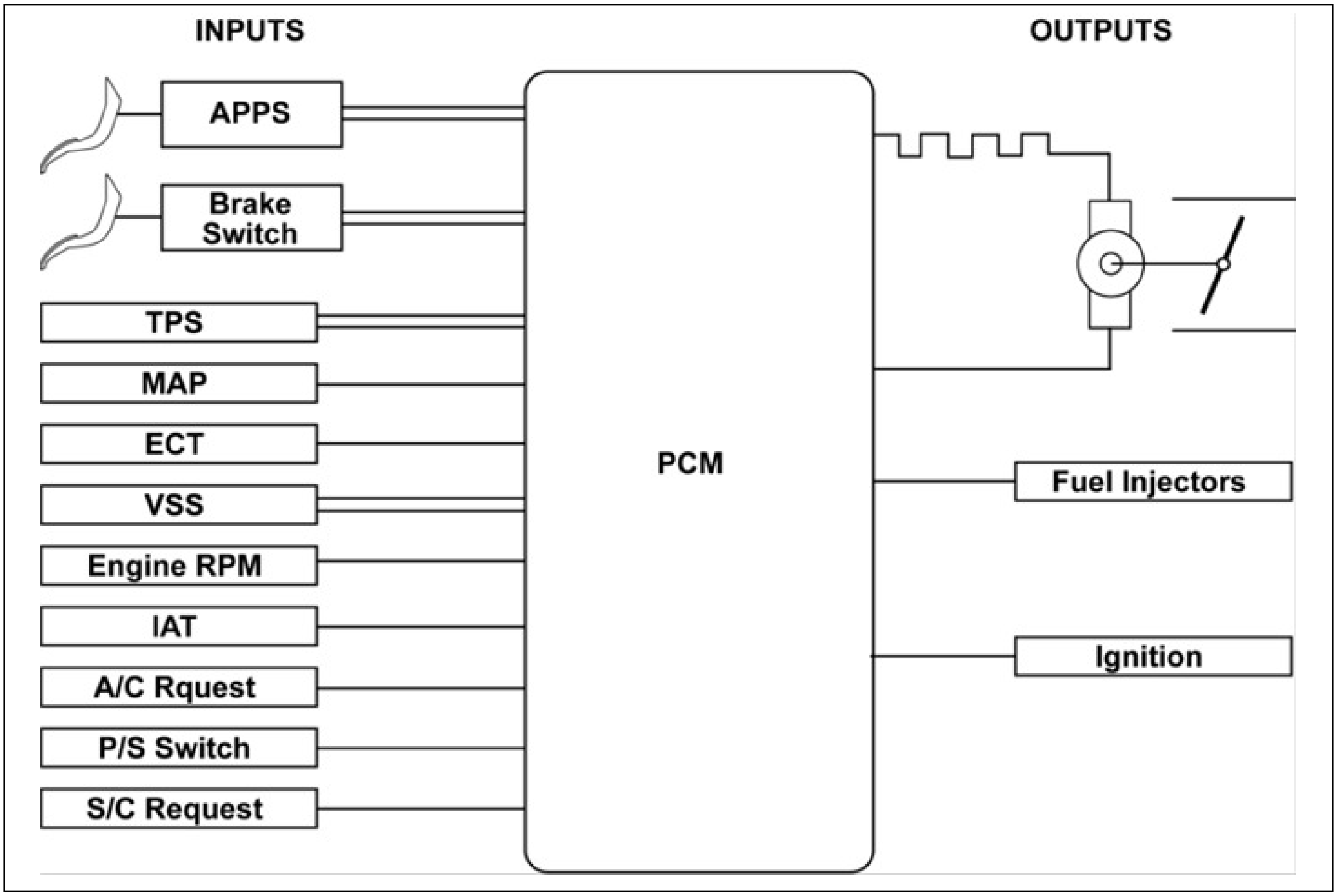


Figure 84 PCM Inputs and Outputs used by ETC

ACCELERATOR PEDAL POSITION SENSORS (APPS)

Two Accelerator Pedal Position Sensors (APPS) input the driver's torque-demand signal to the PCM.

Two sensors are in one housing. The sensors are on the accelerator pedal.

Figure 85 Accelerator Pedal Position Sensors With Accelerator Pedal

The sensors are two three-wire linear Hall-effect sensors that provide the PCM with two voltage signals in proportion to accelerator pedal position. Redundant sensors are used because of their critical function.

The signals from the two sensors are not identical. As the throttle opens, the signal from one sensor increases at about twice the rate of the signal from the other sensor. The two sensors have completely separate circuits, with separate 5V references, signals and grounds.

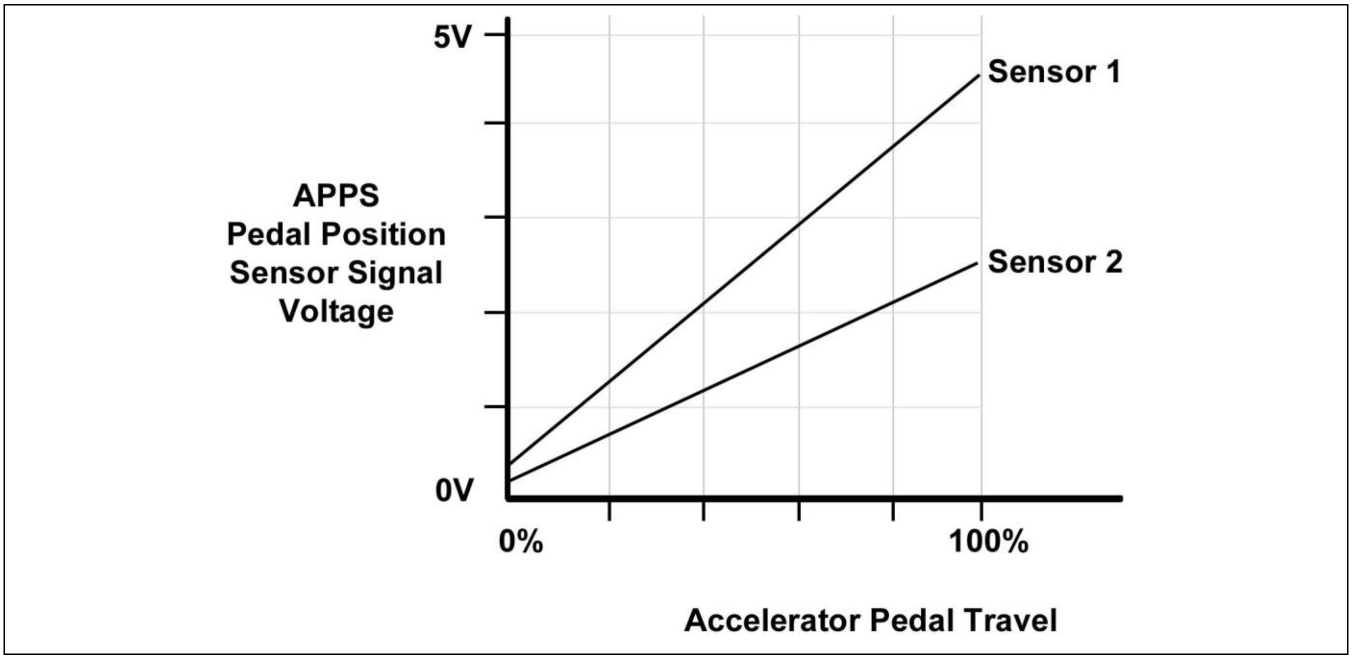


Figure 86 APPS Signal Voltages vs. Accelerator Pedal Travel

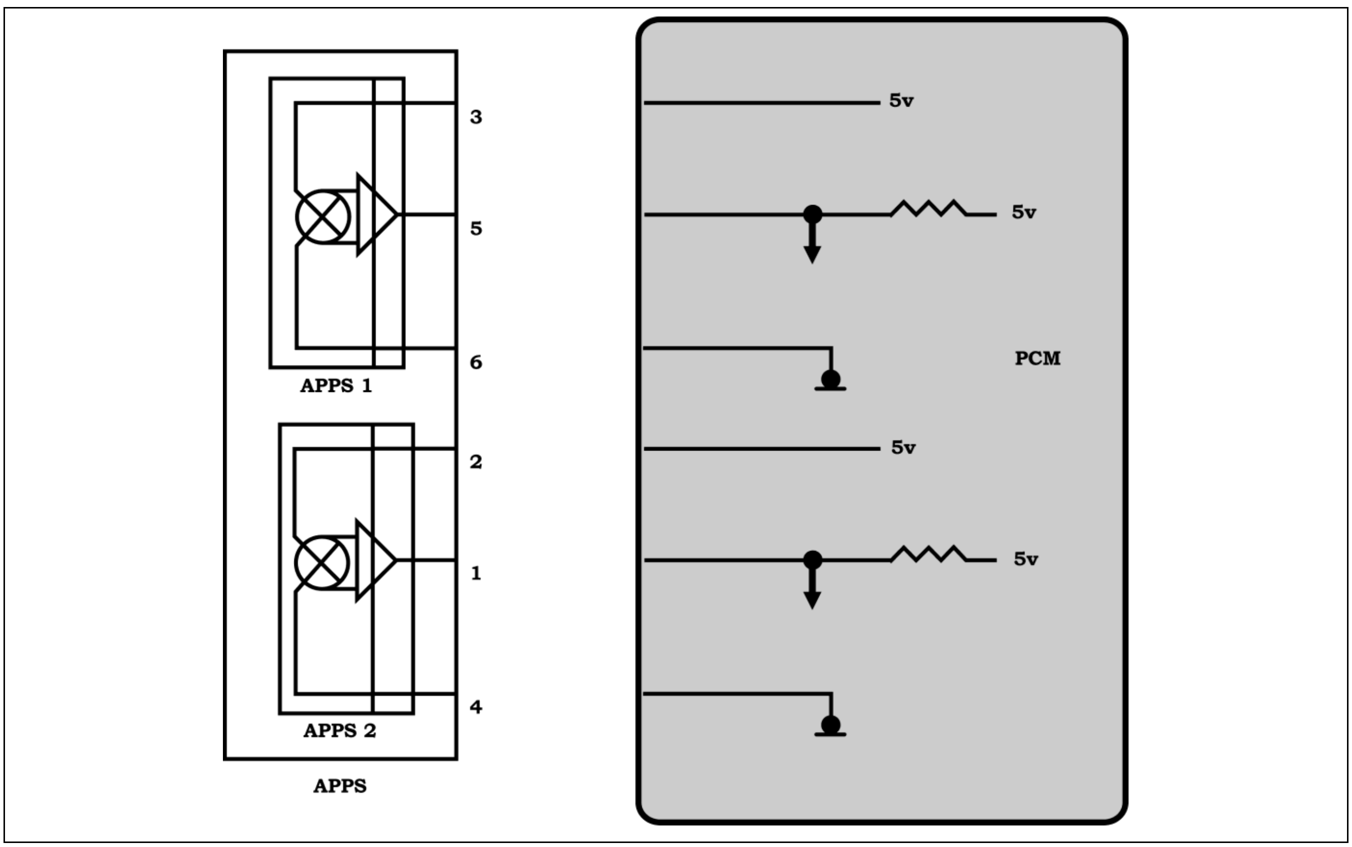


Figure 87 APPS Circuit (Completed by Student)

ETC THROTTLE BODY

The ETC throttle body houses the throttle plate, electric actuator motor, dual throttle position sensors, gears and a spring.

The throttle actuator motor is controlled by a duty-cycle signal from the PCM. A concentric clockspring works to close the throttle plate when it is opened beyond a nearly-closed position. If electric power is lost, the spring will close the throttle to this default position. The spring also tries to open the throttle plate when it is fully closed.

Figure 88 ETC Throttle Body

THROTTLE PLATE MOTOR CIRCUIT

The motor circuit reverses polarity to drive the throttle plate either open or closed. ETC connector Pin 5 is the Pulse Width Modulated side of the motor circuit. The motor circuit is completed through Pin 3. Most of the time, circuit polarity causes the actuator motor to either open the throttle plate or hold the throttle plate open against spring tension. To do this, Pin 3 is grounded and Pin 5 is powered. To reverse the motor and rapidly close the throttle, the circuit reverses polarity. Pin 3 supplies 12V and Pin 5 is grounded. Regardless of polarity, the motor circuit is always PWM on Pin 5 (Fig. 89 and Fig. 90).

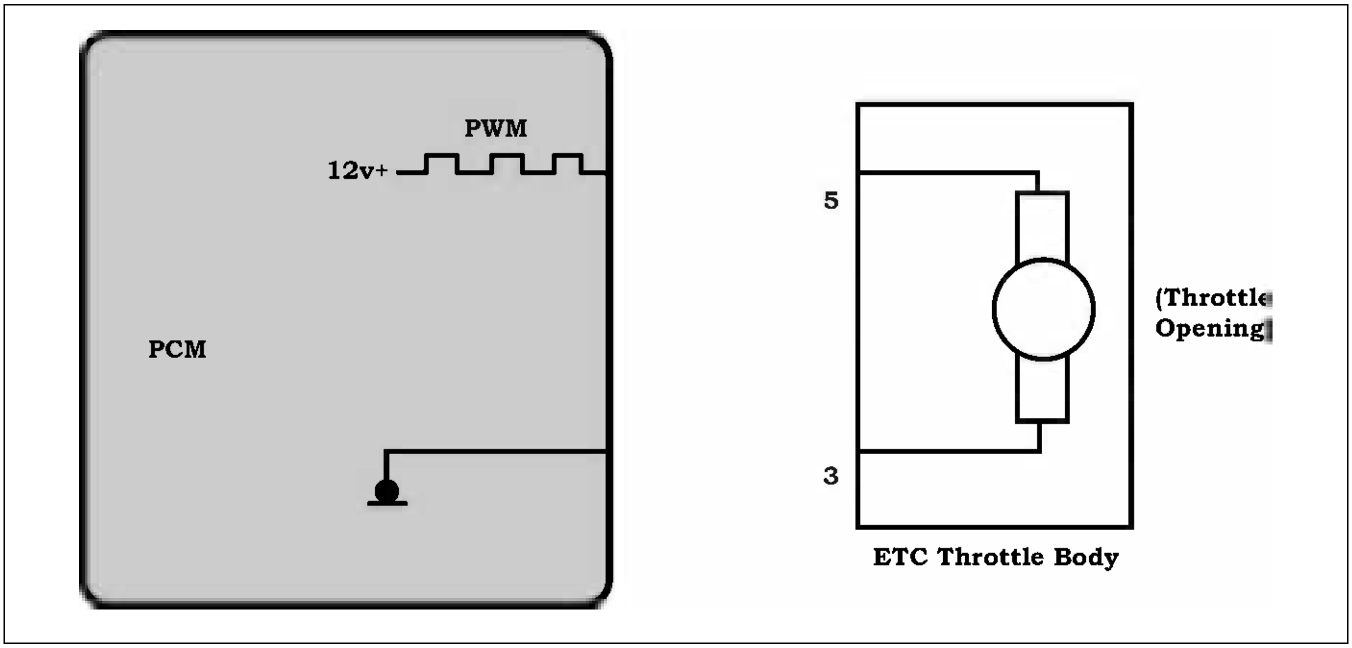


Figure 89 ETC Motor Polarity with Throttle Opening (Completed by Student)

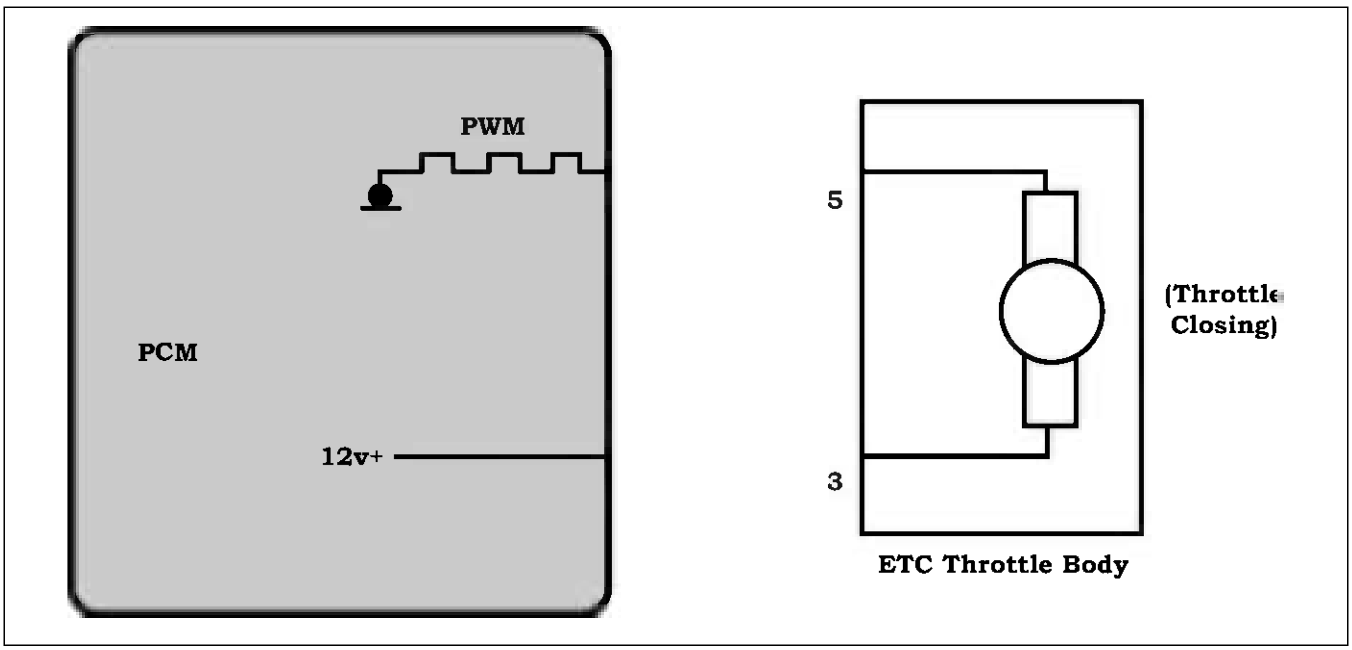
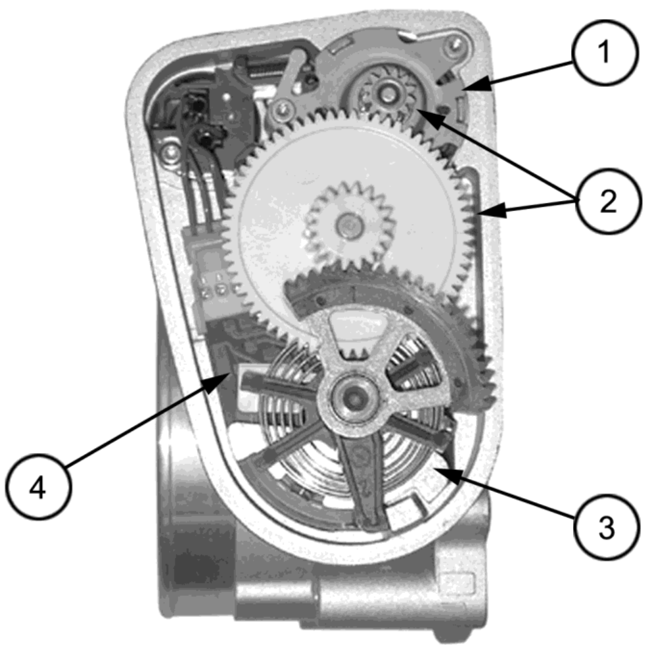


Figure 90 ETC Motor Polarity with Throttle Closing Completed by Student)

THROTTLE POSITION SENSOR (TPS)

Two Throttle Position Sensors (TPS) are built into the ETC throttle body and provide two throttle position signals to the PCM. Two sensors are used for fail-safe redundancy and error checking. The sensors output analog signals to inform the PCM that the throttle plate moves as expected.



1	Throttle Actuator Motor	3	Spring
2	Gears	4	Throttle Position Sensors (2)

Figure 91 ETC Throttle Actuator Motor, TPS, Spring and Gears

Two three-wire potentiometer sensors are used. The sensors use a common 5V reference and sensor return. Each sensor outputs an analog signal in proportion to throttle plate position, but one sensor uses reverse logic. As the throttle plate opens, the signal voltage from TPS#1 increases, and the signal voltage from TPS#2 decreases. The sum of the two TPS signal voltages should always equal approx. 5V. The PCM monitors this value to check system integrity.

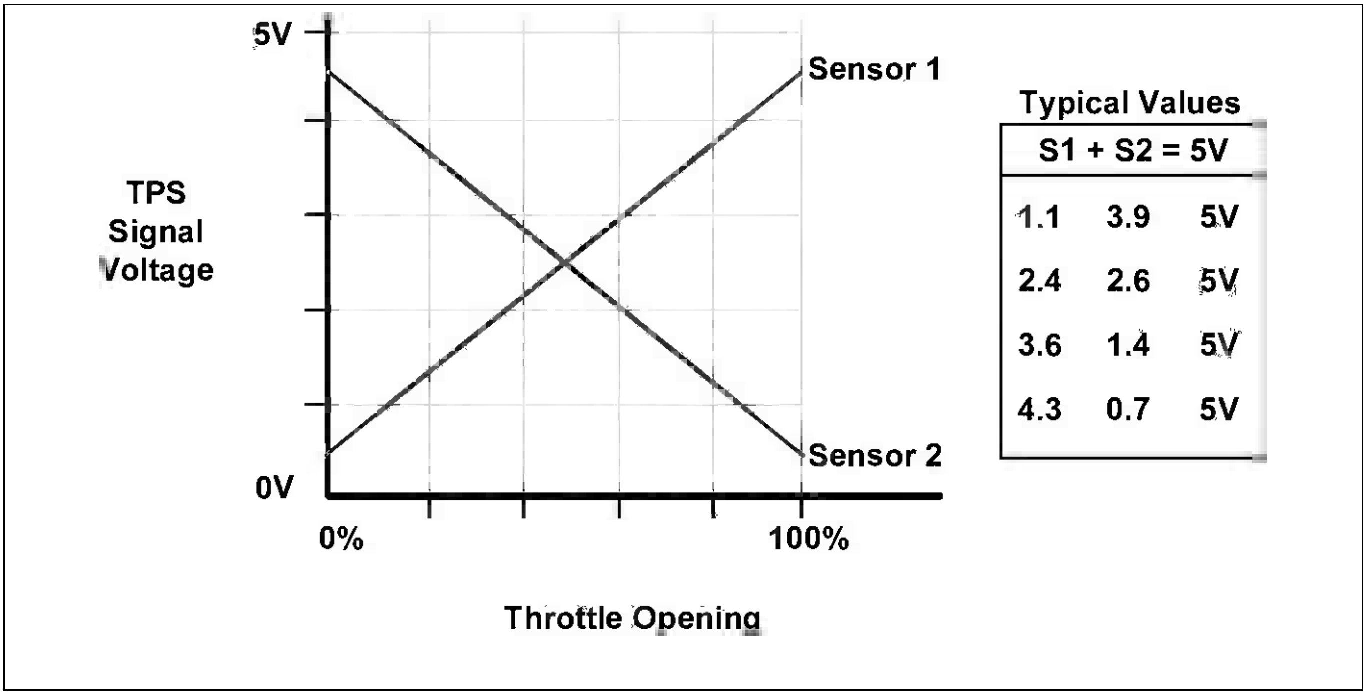


Figure 92 TPS Signal Voltages vs. Throttle Plate Position

The ETC throttle body has a six-pin connector for the throttle plate actuator motor and the two TPS.

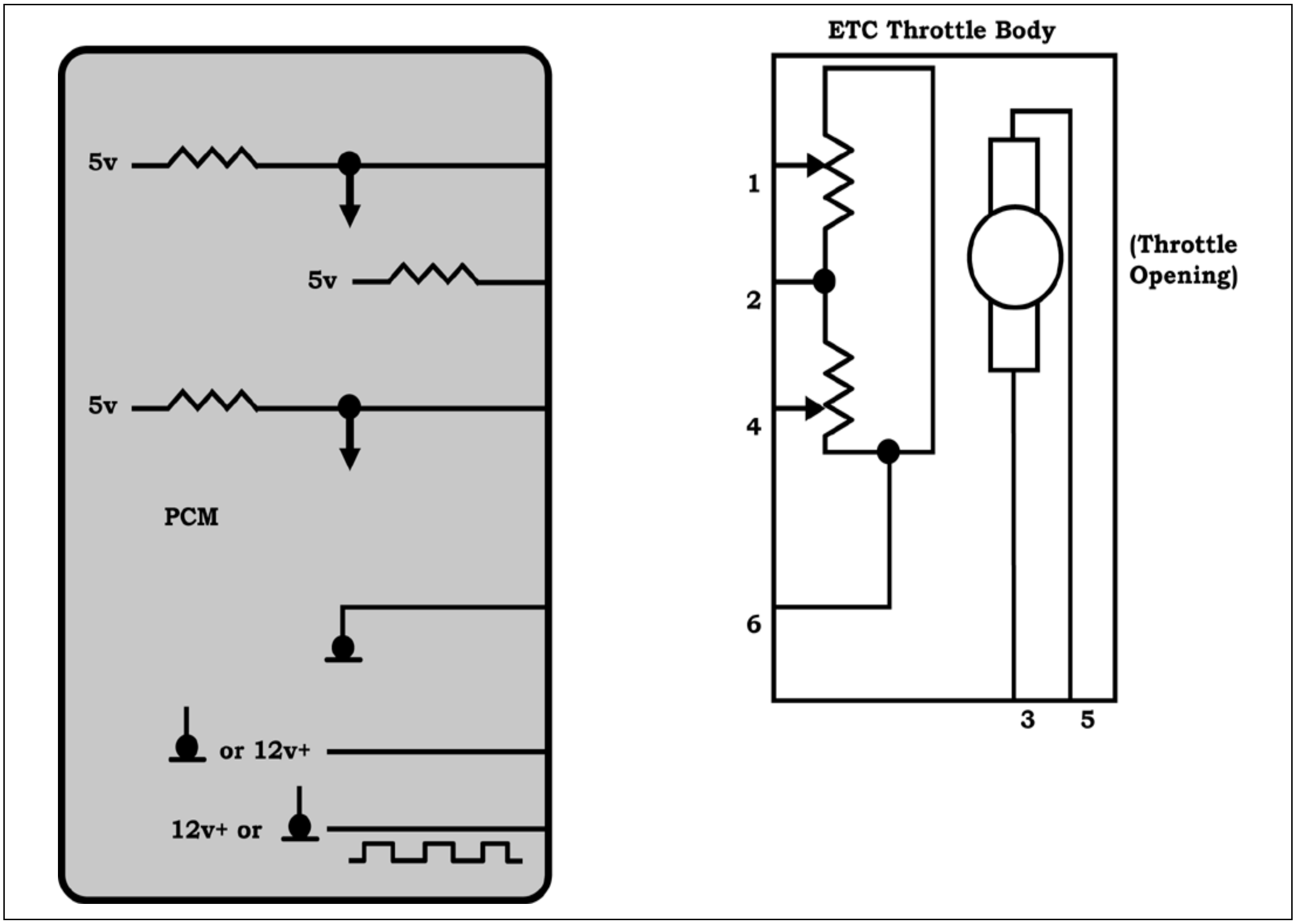


Figure 93 Electronic Throttle Control Circuit (Completed by Student)

OTHER INPUTS

Vehicle speed input comes from both the front and rear wheel speed sensors.

Two brake switch inputs are also used. The switches are in a common housing near the brake pedal.

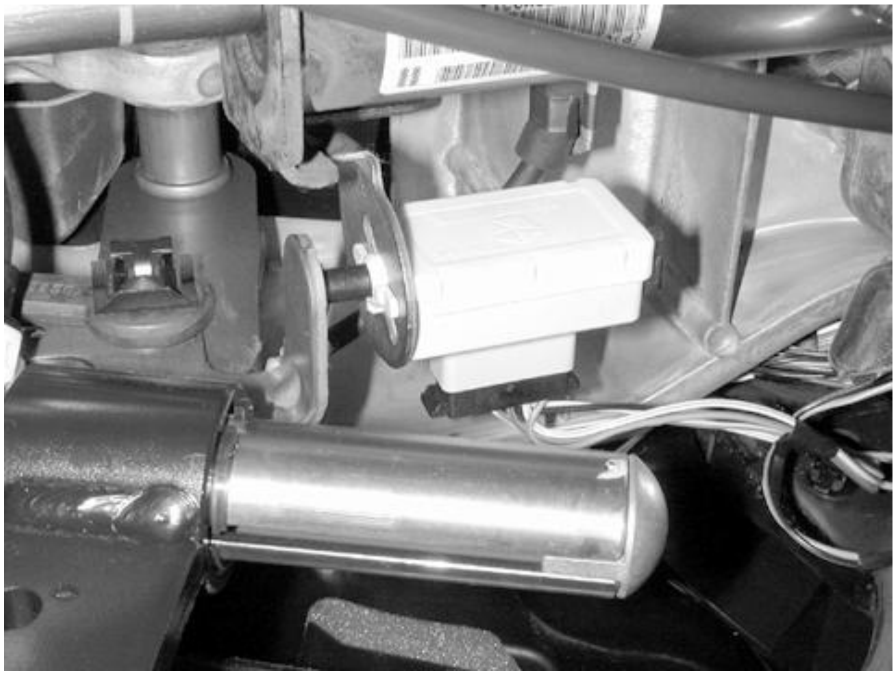


Figure 94 Typical Brake Switch

The PCM busses brake switch information over CAN C for use by the Antilock Brake System (ABS) and Electronic Stability Program (ESP) systems.

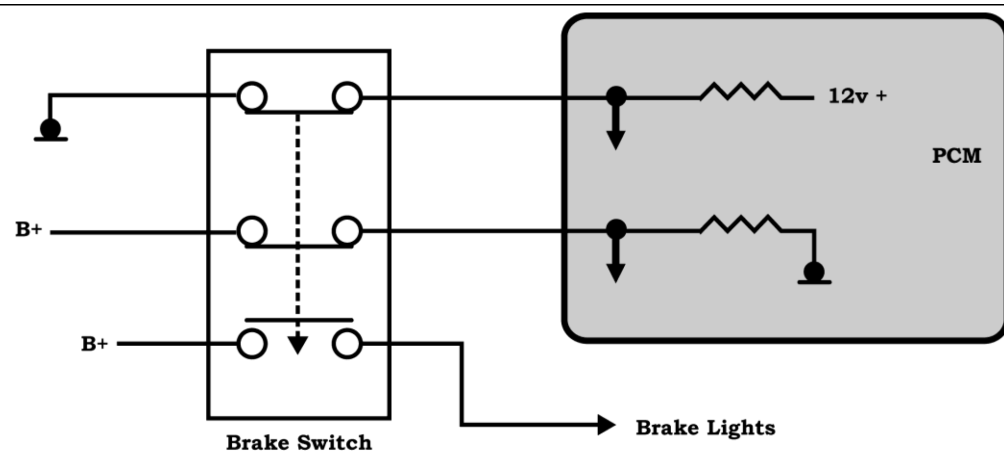


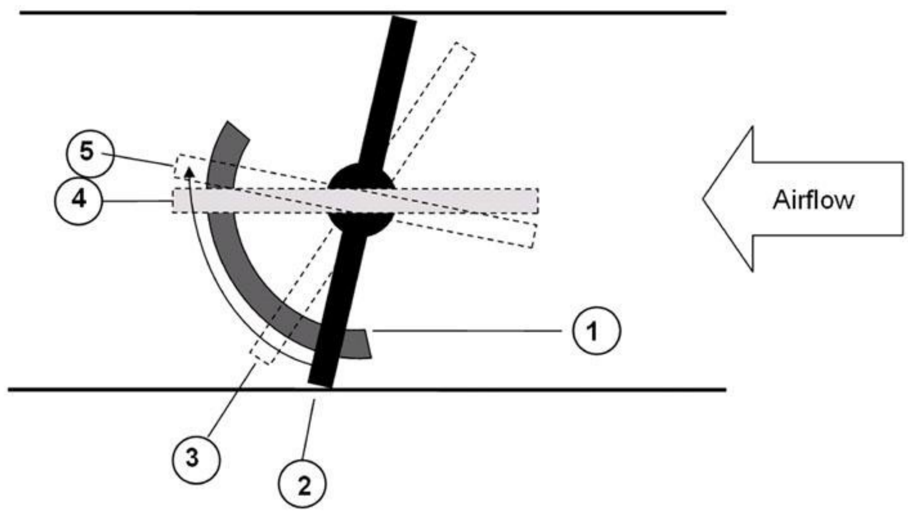
Figure 95 Brake Switch Circuit

ETC RESPONSE TO NORMAL AND ABNORMAL CONDITIONS

The PCM looks at the accelerator pedal sensor signals (and many other inputs) and determines throttle plate position. If all is OK, then the driver will get the requested torque. If not, then the PCM will take some other course of action (reduced power, power-free, zero RPM, etc.)

Starting a Vehicle with ETC

Starter engagement may be delayed briefly every start-up while the PCM conducts an ETC Spring Test. The throttle plate is quickly driven open, then completely closed. The delay is approx. 1 sec. and the driver may or may not notice this delay. On some applications the delay is more noticeable than others. Throttle plate movement can make noises that are unfamiliar to the driver. The throttle plate has a full range of travel that is greater than the normal operating range.



1	Position sensor range (~105°)	4	Wide Open Throttle
2	Lower Mech. Stop (DELTHR = 0.0V)	5	Upper Mech. Stop
3	Mechanical Limp-Home (default) position. Defined by platform, adjusted by supplier.		

Figure 96 Typical ETC Throttle Plate Stops

This start-up delay may be noticed only if the driver goes directly from the Lock position to the Start position. In rare cases, the delay can be up to 2 sec. before starter engagement is allowed. This will only happen if all of the following are true:

- The battery has been disconnected.
- Both engine coolant and ambient temperature sensors indicate that no ice may be present.
- The ETC Throttle learned Limp-In values don't match the actual Limp-In values (this would most likely happen if the entire Throttle Body Assembly is replaced).

If the above conditions are all true, then the PCM will do an entire throttle plate range sweep (min. to WOT and closed again) which takes place before starter engagement is allowed. This may last up to 2 sec. The scan tool displays when the starter was last disabled with "ETC STARTER INHIBIT: Miles".

The PCM may decide to abort the ETC Spring Test if the key is turned rapidly to the start position.

Normal Operation

Regardless of accelerator pedal position, the PCM has the ability to reduce maximum engine rpm. For example, on DR models with 5.7L engine, in-gear, maximum rpm at WOT request is approx. 5900 rpm. If the WOT request is maintained, maximum rpm drops to approx. 5600 rpm. The In-Neutral Rev Limiter holds rpm to approx. 3,500 rpm.

Note: The throttle plate will not open with accelerator pedal input if the engine is not running, even with the key ON.

GPEC THROTTLE LEARN AND INJECTOR OFF TEST CONDITIONS

The World Engine ETC strategy is very similar to the NGC ETC, but the World Engine strategy has two new features:

- Throttle learn strategy
- Throttle strategy during injector off test

Throttle Learn Strategy

The GPEC has the ability to learn maximum and minimum throttle plate and accelerator pedal position values. These values are important to GPEC calculations and can vary due to build tolerances.

Unlike NGC vehicles, learned values are not lost when the battery is disconnected.

Similar to NGC vehicles, the values must be relearned when a new GPEC controller, throttle body assembly, or accelerator pedal assembly is installed.

Certain enable conditions must be met before the throttle plate and accelerator pedal position values can be learned:

- Battery voltage must be greater than 9.95V
- Engine speed must be less than 192 rpm
- The inlet air temperature must be greater than 41° F (5° C)
- The coolant temperature must be between 41° and 230° F (5° and 110° C)
- There must be no throttle errors

After the enable conditions are met, the Learn ETC Misc Function can be run on the scan tool. This function allows the GPEC to learn maximum and minimum throttle plate and accelerator pedal position values.

Fuel is disabled during learning.

Injector Off Test

The GPEC ETC throttle strategy during an injector off test differs slightly from an NGC ETC system. Instead of holding idle speed during the test, the GPEC commands the ETC system to a fixed throttle position.

FAILURE MODES

Fail-Safe Mode

Loss of one input will cause the PCM to start the Fail-Safe mode. The ETC system will limit throttle opening, slow the response to the accelerator pedal, drop engine speed to idle with brake application and disable the speed control function. A DTC will be set and the ETC warning light will illuminate.

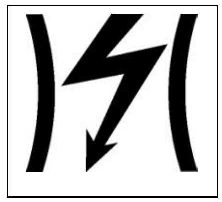


Figure 97 ETC Warning Light

Limp-In Mode

More serious faults will cause the system to enter the Limp-In mode. In this mode, the ETC light flashes, a DTC will be set and the MIL illuminates. The engine will run but the vehicle can be driven with severe restrictions. Speed control operation is not permitted. In the Limp-In mode, accelerator pedal position has no effect on throttle plate opening or engine speed. The engine runs at two different rpms, with engine speed controlled by the action of the brake pedal. When the brakes are applied, engine speed is controlled at approx. 800 rpm. With brakes released, engine speed slowly increases to 1200-1500 rpm. The PCM controls engine speed by controlling the ETC motor, spark timing and fuel. If the PCM cannot control throttle blade position, the PCM attempts to control rpm with spark timing and fuel.

Below are reasons for the ETC system to enter the Limp-In mode:

- Low battery voltage
- ASD Relay OFF
- ETC throttle adaptation routine Limp-In learning
- PCM failure
- Auxiliary 5V supply failed (Not Primary)
- One TPS and the MAP sensor have failed
- Both TPS have failed
- ETC actuator motor failure
- Spring test open or close failure
- APPS internal signal failure
- One brake switch and one APPS failure

VACUUM LEAKS

The ETC system can compensate for some vacuum leaks. A vacuum leak in the intake manifold will allow air into the manifold that has not come through the throttle body, but this air is not unmeasured air, since there is no mass airflow sensor. There is no Idle Air Control system, so the ETC system will simply adjust throttle plate opening to compensate for the leak.

APPS SENSOR FAILURE

Loss of one APPS signal will initiate the Fail-Safe mode.

Loss of both APPS signals will cause the system to enter the Limp-In mode.

THROTTLE BODY AND TPS FAILURES

A blocked or sticking throttle plate will cause an out-of-range duty cycle response in the ETC motor circuit. The PCM compares TPS signals and actuator motor circuit duty cycle, and if it senses a disparity, it will remove power to the motor and enter the Limp-In mode.

Failure of one TPS will initiate the Fail-Safe mode. Loss of both TPS signals will cause the system to enter the Limp-In mode.

WARNING: THE THROTTLE BODY CANNOT BE CLEANED. DO NOT USE SPRAY (CARBURETOR) CLEANERS OR SILICONE LUBRICANTS ON ANY PART OF THE THROTTLE BODY.

The throttle body has no serviceable components and is replaced as a unit. Disconnect the battery before replacing the throttle body. After replacement, the new throttle body must be adapted. A typical procedure is below, refer to the latest service information for specific procedures.

- Disconnect the battery negative cable and leave disconnected for at least 90 seconds.
- Reconnect the negative cable.
- Turn the ignition key to the KOEO position, do not crank.
- Leave the ignition switch ON for at least ten seconds. The PCM will adapt to the throttle body.

This procedure will be performed whenever the battery has been disconnected. The PCM will move the throttle plate through its full travel.

DIAGNOSTIC PROCEDURES

To assist in diagnosis, use the Throttle Follower Test on the Scan Tool. In this mode, depressing the accelerator pedal will cause the PCM to actuate the throttle plate motor. With this test, you can verify throttle plate movement with accelerator pedal input. This Throttle Follower Test must be performed with KOEO.

ETC System Test allows you to actuate the throttle plate directly with the Scan Tool. See service information for complete testing information.

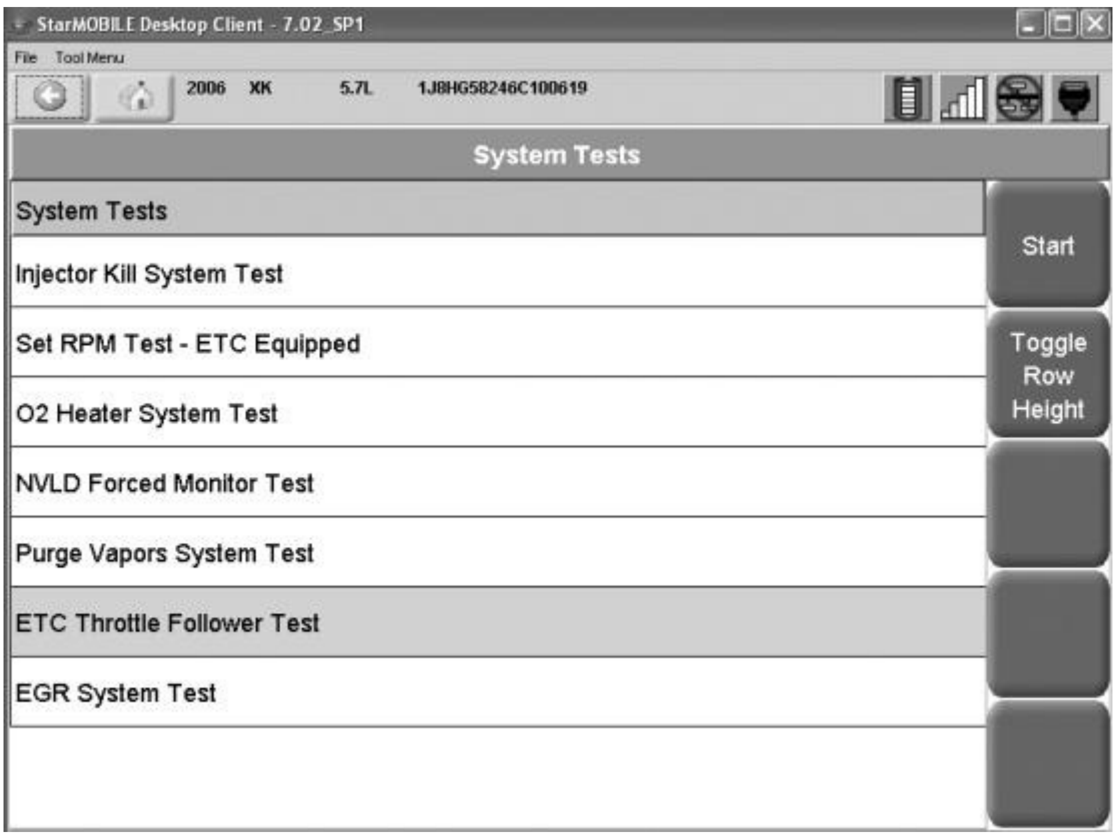


Figure 98 ETC Throttle Follower Test

Notes:

MODULE 10 VARIABLE VALVE TIMING (VVT)

Conventional camshafts are permanently positioned and synchronized with the engine's crankshaft. With this system, optimum low speed valve timing does not necessarily result in optimum high speed performance. With a conventional camshaft, a balance must be struck between idle stability, low speed torque and high speed performance.

Dual-camshaft variable valve timing (VVT) is a feature of GPEC and the World Engine Family. VVT gives an engine the flexibility to provide peak power and torque along with a smooth idle and better fuel economy by allowing precise valve timing.

It works by advancing and retarding valve timing by rotating the position of both the intake and exhaust camshafts. With this system, both the intake valve opening can vary from 80 to 120 crankshaft degrees after Top Dead Center. The VVT system is electronically controlled and hydraulically operated.

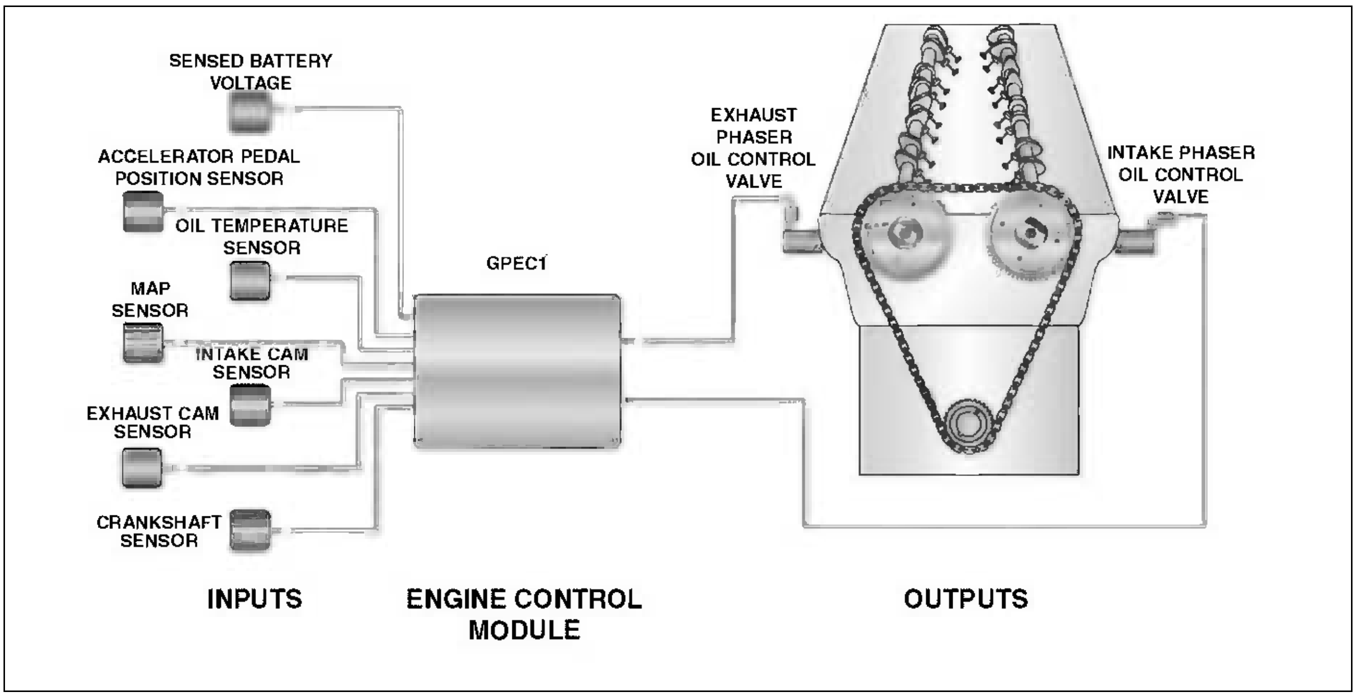


Figure 99 Variable Valve Timing

The GPEC receives information from several sensors to determine the optimum valve timing. It then pulse width modulates oil control valves which direct oil to the cam phasers. The cam phasers use oil pressure to rotate the intake and exhaust camshafts. The rotation of the camshafts is referred to as cam phasing.

Several conditions must be met before the GPEC can command camshaft phasing:

- Engine oil temperature must be at least 20° F
- Oil control valve coil temperature must be less than 280° F
- Engine speed must be at least 600 rpm
- Battery voltage must be at least 10V
- No camshaft or crankshaft sensor faults, engine timing faults, or oil control valve faults

Since oil is used to control camshaft movement, oil temperature and viscosity have an impact on the operation of the system. The wrong oil viscosity may cause the VVT to malfunction and trouble codes to set. The correct oil viscosity for this system is 5W20.

SENSORS USED IN VVT

The GPEC uses information from several sensors. They are:

- Oil temperature
- Accelerator pedal position sensor (APPS)
- Manifold air pressure (MAP)
- Crankshaft position (CKP)
- Intake and exhaust camshaft position (CMP1/1 and CMP1/2)
- Sensed battery voltage

The accelerator pedal position sensor indicates how far the driver wants to open the throttle plate. The GPEC calculates an initial camshaft set point based on whether the accelerator pedal is at part throttle or wide open throttle.

The MAP sensor provides information about engine load. This information allows the GPEC to adjust camshaft timing to produce better fuel economy, better engine performance, or a combination of the two.

The crankshaft position sensor feeds information about engine speed and timing information to the GPEC. The camshaft position sensors return information about the position of the intake and exhaust camshafts. Together, the crankshaft and camshaft position sensors are used by the GPEC to calculate crankshaft position.

Sensed battery voltage is used to check that the system has enough voltage for the oil control valves to function properly.

PCM-CONTROLLED OUTPUTS

Figure 100 Oil Control Valve

Oil Control Valves

There are two oil control valves. One valve directs oil to the intake cam phaser, the other to the exhaust cam phaser. The outer casing of each oil valve has five oil passages, a passage for pressurized supply oil, a passage to the advance chamber of the cam phaser, and two passages for oil return. Oil flows through the passages and applies pressure to the cam phasers to change cam timing.

The GPEC individually controls each valve. It sends a pulse width modulated signal to move a spool within the outer casing of the valve. Depending upon spool movement, oil is directed through the passages to advance or retard cam timing.

The oil control valve also uses a special cleaning strategy at key-on, called "debris-crush mode". At key-on the GPEC cycles the oil control valve on and off several times to crush any debris in the oil control valve and to prevent the spool valve from sticking.

Notes: