ASE 8 - Engine Performance

Module 10
Powertrain Control Module Processing
Acknowledgements

General Motors, the IAGMASEP Association Board of Directors, and Raytheon Professional Services, GM’s training partner for GM’s Service Technical College wish to thank all of the people who contributed to the GM ASEP/BSEP curriculum development project 2002-3. This project would not have been possible without the tireless efforts of many people. We acknowledge:

• The IAGMASEP Association members for agreeing to tackle this large project to create the curriculum for the GM ASEP/BSEP schools.
• The IAGMASEP Curriculum team for leading the members to a single vision and implementation.
• Direct contributors within Raytheon Professional Services for their support of translating a good idea into reality. Specifically, we thank:
  – Chris Mason and Vince Williams, for their leadership, guidance, and support.
  – Media and Graphics department under Mary McClain and in particular, Cheryl Squicciarini, Diana Pajewski, Lesley McCowey, Jeremy Pawelek, & Nancy DeSantis.
  – For their help on the Engine Performance curriculum volume, Subject Matter Experts, John Beggs and Stephen Scrivner, for their wealth of knowledge.

Finally, we wish to recognize the individual instructors and staffs of the GM ASEP/BSEP Colleges for their contribution for reformatting existing General Motors training material, adding critical technical content and the sharing of their expertise in the GM product. Separate committees worked on each of the eight curriculum areas. For the work on this volume, we thank the members of the Engine Performance committee:

  – Jamie Decato, New Hampshire Community Technical College
  – Lorenza Dickerson, J. Sargeant Reynolds Community College
  – Marvin Johnson, Brookhaven College
  – Jeff Rehkopf, Florida Community College at Jacksonville
  – David Rodriguez, College of Southern Idaho
  – Paul Tucker, Brookdale Community College
  – Kelly Smith, University of Alaska
  – Ray Winiecki, Oklahoma State University - Okmulgee
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Introduction

NATEF Standards

VIII. ENGINE PERFORMANCE

B. Computerized Engine Controls Diagnosis and Repair
   2. Retrieve and record stored OBD II diagnostic trouble codes; clear codes. P-1
   3. Diagnose the causes of emissions or driveability concerns resulting from malfunctions in the computerized engine control system with stored diagnostic trouble codes. P-1
   5. Check for module communication errors using a scan tool. P-2

STC Standards

ALL Competencies for Electrical Stage 3 18043.03 W

B. Automotive Computers
   1. Identify the characteristics of processors
   2. Identify the characteristics of integrated circuits
   3. Identify the characteristics of automotive microprocessor communications
   4. Identify types of computer input signals

A-8 Competencies for GM Powertrain Performance 16044.10 W/D/H

F. PCM Engine Control Management
   1. Identify and list the sensors that provide PCM inputs
   2. Describe each sensors that provides PCM inputs

Objectives

Upon successful completion of engine performance module 10, the ASEP student will be able to:

• Describe computer voltage signals
• Describe computer components
• Describe PCM communication types
• Explain PCM modes of operation
• Describe PCM Interfaces
• Explain PCM adaptive learning
**PCM Components and Function**

GM vehicles use on-board computers for powertrain management, on-board diagnostics, and a variety of other control systems. These are referred to as control modules.

A computer control module is any device that can take incoming information, perform a set of instructions, and then generate specific outputs.

GM powertrain control modules receive input data from a variety of sensors and switches. Based on the information received, the PCM makes the necessary calculations and then issues operating commands to various systems and components. The computer performs specific output functions. Typical outputs include: metering fuel, controlling AIR system switching, adjusting timing, and control transmission shifting.

![Figure 10-1, PCM Control](image-url)
The engine control module used is dependent on the application. In most applications, the powertrain control module, or PCM controls both the engine and transmission functions. However, in some applications, there is an engine control module, or ECM, which works in conjunction with a transmission control module, or TCM, to control transmission functions. The vehicle control module, or VCM, incorporates the transmission and engine control functions of the PCM with the control of the anti-lock brake system, or ABS. For the purposes of this course, we will refer to the vehicle's control module as the PCM, since this is the most commonly used engine control module.

On some earlier model vehicles, plug-in modules in the PCM are vehicle specific. When replacing the PCM on these vehicles, remove the plug-in modules from the old PCM and place it in the new PCM. For example, the knock sensor module is unique to the engine and must be moved to the new PCM.
Computer Voltage Signals

Computers use voltage to communicate with input and output devices, and to communicate with other computers. There are two basic types of voltage signals used for this communication: analog and digital.

![Signal Types](image)

An analog signal is often described as continuous and variable. If these voltages were placed on a graph, it would look like a wave. A digital signal, on the other hand, has only two voltage levels: ON and OFF. The only kind of voltage signal that the automotive computer understands is digital. Therefore, any analog signal coming into the computer must be converted into a digital format.

Inside the PCM

The PCM is arranged in a logical manner. Some of the components are easily recognized such as resistors, capacitors, integrated circuits and other electronic components. These are all soldered to a Printed Circuit Board, or PCB.

One of the chips is usually a clock circuit that regulates how many instructions are processed each second. One of the bigger chips is the microprocessor unit, which may also be called the Central Processing Unit, or CPU.
Input Interface

An input interface transforms sensor signals into a signal the microprocessor can read. Many sensors, such as the Vehicle Speed Sensor (VSS), generate an AC voltage or analog signal. The input interface transforms this analog signal into a digital voltage signal that can be read by the microprocessor. The digital signal is produced in a series of on and off pulses.

The input interface may also act as an amplifier. Sensors that generate their own voltage, such as the 100mv to 900mv signal generated by the Oxygen (O2) Sensor, are amplified by the input interface so that they can be read by the microprocessor.

![Figure 10-3, Integrated Circuits](image)

Microprocessor

The microprocessor makes logical decisions based on information from sensors and other parts of the computer. It is the thinking or calculating part of the computer. Most microprocessors cannot store information. Instead, the microprocessor reads information from storage sections of the computer called memory. In addition, the microprocessor can change information in memory by adding new information.

Memory, input interface and output interface, all components of the computer, support the microprocessor.
Types of Memory

Computers have different types of memory, all of which work together to allow it to function for a specific purpose. Some memory is programmed in permanently. Other memory is volatile, meaning it changes under various conditions.

Random Access Memory (RAM)

Random Access Memory, or RAM, is the non-permanent type of memory. It stores temporary data. When power is removed from the PCM all of the stored data is erased. This is called volatile memory. When power is disconnected for 30 seconds, memory is cleared. Diagnostic trouble codes, as well as other vehicle parameters that change often, are stored in RAM.

Read Only Memory (ROM)

Read Only Memory, or ROM, has all of the attributes and features of RAM except two. It cannot be erased or changed, only read. Also, any data written to it from the factory is permanent. Data can be randomly accessed from a specific location. The manufacturer programs this type of chip. Once it is programmed, the data cannot be erased or changed. ROM contains the low level instructions that allow the computer to perform the tasks of managing the engine. ROM does not need applied power to store its data. This is why when a vehicle is shut down for the day or the battery is disconnected for some type of service work, the PCM can still function when power is restored. Its instructions are stored in memory that is non-volatile.

Programmable Read Only Memory (PROM)

Programmable Read Only Memory, or PROM, is a type of ROM that retains the ability to be randomly accessed and is non-volatile. When a PROM is manufactured, all of the memory locations are empty. When the chip arrives at the PCM manufacturer, its programs can be electronically written in. Data or information that is specific to a particular application or type of vehicle is put into a PROM. Many of the parameters between vehicles are different due to features such as engine size and type, final drive or rear axle ratio, type of transmission, and A/C. Many PROMs are socketed components, instead of being soldered to the PCM board. The advantage is that if an improvement is developed at a later date, it can be added by just replacing the PROM in a vehicle’s PCM, thereby updating it to the latest calibration specifications.
A newer form of PROM is being used on GM vehicles today. Electronically Erasable Programmable Read Only Memory, or EEPROM, is an input circuit that is permanently soldered to the PCM circuit boards. When calibrations need to be changed, the EEPROM can be reprogrammed using a Techline scan tool and a Techline terminal. This is known as the Service Programming System procedure.

**Output Interface**

The PCM uses a variety of output interfaces to control output devices. Output interfaces also protect the microprocessor from the high voltage or high current found in some circuits.

**PCM Communication**

As with any computer, the PCM relies on external communication to obtain sensor information on vehicle operating conditions, to cause control components to improve operation, and to provide data to service technicians for diagnosis.

**Serial Data**

Serial data is a string of information transmitted in sequence, one item at a time, in what is called a data stream. In electrical terms, it consists of voltage signals changing from high to low, or "ON" to "OFF." Each individual signal is known as a "bit." A series of eight bits makes up a "byte," also called a "word." Various components in an electronic system communicate by means of a serial data stream. The wire or wires that carry the serial data messages are called the "Data Buss."

**Data Buss**

The data buss is the communication line between the various vehicle control modules and the scan tool. It handles the transfer of serial data for control module communication. Besides allowing control modules to communicate with each other, the data bus allows the technician to run system diagnostics via the data link connector, or DLC.
Baud Rate

The bits of a serial data stream are transmitted at exact intervals. The speed at which bits are transmitted is called the baud rate, which is how many bits are transmitted per second. Early ECMs had a baud rate of 160. Starting with the 1986 model year, ECMs with a baud rate of 8192 were introduced, which is a much higher serial data transmission speed. GM OBD II vehicles use a data stream with a baud rate of 10.4 K, or 10,400 bits per second, also known as "GM Class 2" data stream.

Figure 10-4, DLC Terminal Identification
Serial Data Circuits

The two most common types of serial data in use are UART and Class 2.

UART

Universal Asynchronous Receive and Transmit, or UART, communication was used prior to OBD II for communication between the PCM, off-board equipment and other control modules. UART serial data circuit is a five-volt data line that toggles the voltage to ground at a fixed bit pulse width during communication. UART transmits data at the rate of 8192 kilobits per second. Some OBD II compliant vehicles still use UART. For most GM vehicles, powertrain related communication with the off-board diagnostic equipment would be handled on the Class 2 data line.

Class 2

OBD II requires more sophisticated communications between the PCM, other control modules and the scan tool. Class 2 serial data was designed to meet this need. The Class 2 data line transfers information by toggling the line from zero volts to seven volts. The data line at rest is zero volts. The information can be transferred in short or long pulse widths.
PCM Modes of Operation

For engine management the PCM controls several operating modes of the engine.

Starting Mode

The first of these is the "Starting" mode. When the ignition is first turned "On", the PCM powers up and sends 12v to the fuel pump relay for two seconds. This pressurizes the fuel system in preparation to start cranking. Before engine cranking, the PCM receives readings for coolant temperature, intake air temperature, atmospheric pressure, and throttle position to determine the initial air-fuel ratio. During cranking, the PCM delivers one injector pulse for each RPM reference pulse. The lower the coolant temperature, the longer the pulse width and the richer the air fuel ratio. As coolant temperature goes up, the pulse width becomes shorter and the air fuel ratio becomes leaner. Cranking mode air fuel ratios determined by the PCM may range from 1.5:1, to 14.7:1, depending on temperature.

Note:
Normal starting mode fuel delivery follows the description above as long as the throttle angle is zero percent. If the throttle is open, the air fuel ratio changes.

Figure 10-5, Cranking/Starting Mode
Clear Flood

Next is the "Clear Flood" mode. If the engine becomes flooded, the driver can depress the accelerator pedal to the 80% or greater open position to activate the "Clear Flood" mode. In most cases the instructions simply require pressing the accelerator pedal to the floor for wide-open throttle.

With the throttle wide open and cranking RPM below 600, the PCM issues injector pulses at a rate that would be equal to an air fuel ratio of 20:1. In some applications, fuel is cut off completely, with no injector pulses from the PCM.

Run Mode

In the "Run" mode there are two conditions: Open Loop and Closed Loop.

Open Loop

When the engine is first started, the system is in "Open Loop." In open loop, the PCM does not use the oxygen sensor signal. Instead, it calculates the air fuel mixture ratio from the throttle position sensor, engine coolant temperature sensor, manifold absolute pressure or mass airflow sensor, inlet air temperature sensor, and CKP sensors.

The system will stay in open loop until the oxygen sensor is hot enough to operate properly, engine coolant temperature is above a specified temperature, or a specific amount of time has elapsed after start-up. These specific values are stored in the PCM's memory calibration, which is calibrated to individual vehicle specifications.
Closed Loop

When the oxygen sensor, coolant temperature, and time conditions are met, the system goes into "Closed Loop". "Closed Loop" means the PCM corrects the air fuel mixture based on varying voltage signals from the O2 sensor.

An O2 signal below 450 mv causes the PCM to increase injector pulse width. When the O2 signal rises above 450 mv, sensing a rich mixture, the PCM reduces the injector pulse width.

By constantly sensing the oxygen content of the exhaust, the PCM can maintain an air fuel mixture ratio close to the ideal 14.7:1. This is the point where the catalytic converter is most efficient.

Figure 10-8, Closed Loop
**Acceleration Enrichment**

When the throttle is opened rapidly or the vehicle is accelerated, the opening of the throttle causes a simultaneous increase in manifold absolute pressure and throttle angle. The amount of fuel must be increased to compensate for the extra air.

In response to the changes in TP and MAP signals, the PCM supplies longer injector pulses and additional pulses timed between the base synchronous pulses. Because the extra pulses are not synchronized to crankshaft position, they are called asynchronous pulses. This provides the extra fuel needed to prevent the engine from stumbling during hard acceleration due to a mixture that is too lean.

*Figure 10-9, Acceleration Enrichment*

**Deceleration Enleanment**

When the engine is required to decelerate, a leaner air fuel mixture is required to reduce the emission of hydrocarbons and carbon monoxide and to prevent deceleration backfire. To adjust injector "on" time, the PCM uses the decrease in MAP and the decrease in throttle position to calculate the decrease in pulse width.

Deceleration may be either partial or full. That is, the driver may have simply backed off the throttle or may have allowed the throttle valve to return all the way to the idle position. Under light-throttle deceleration, the PCM reduces fuel flow by shortening injector "on" time. Under closed throttle deceleration, the PCM senses that the driver intends the engine to return to idle speed. Fuel delivery may be cut off entirely. As desired idle speed is approached, fuel delivery and idle air control come into play to maintain the desired idle.
Fuel Cut-Off

One purpose of fuel cut-off is to remove fuel from the engine during extreme deceleration conditions.

The PCM may also be programmed to shut off fuel flow for safety reasons when the vehicle reaches a predetermined maximum speed. Fuel flow is also shut off on some engines if RPM reaches a predetermined maximum. These values, maximum MPH and maximum RPM, vary from vehicle to vehicle.

Fuel cut-off also occurs when the ignition is turned "Off." Without operating voltage and without ignition reference pulses, the PCM does not trigger the injectors, and no fuel is delivered. This prevents dieseling or run-on.

Check Mode

Check Mode can be used to increase the ability of the powertrain control module to detect engine control system malfunctions. The PCM can be requested to operate in Check Mode by using the Output Controls feature of the scan tool. While in Check Mode operation, the PCM will turn ON the MIL and record freeze frame data, even on the first failure of a B type DTC. Not all engine control system diagnostics will be enhanced by Check Mode operation. The Check Mode service bay test can be performed while driving the vehicle in order to duplicate the customer concern. Those diagnostics most commonly known to benefit from Check Mode operation will be specified in the diagnostic procedure.

PCM Interfaces

In order to maintain control of various vehicle systems, the PCM must interface with other control systems.

Theft Deterrent

The PCM interfaces with the theft deterrent system. The theft deterrent fuel enable signal is an input from the vehicle theft deterrent module. It signals the PCM to enable the fuel injectors. If the vehicle theft deterrent control module does not send the correct theft deterrent fuel enable signal to the PCM, the fuel system may be disabled. On some vehicles, this signal is a direct input to the PCM. Other applications use Class 2 serial data to transmit this message. Be sure to refer to vehicle theft deterrent diagnosis in the appropriate service information.
Traction Control

Another system that can affect engine management is the Traction Control Desired Torque Request system. On vehicles with traction control, there is constant communication between the Electronic Brake Traction Control Module and the PCM. The traction control desired torque request is a pwm signal that ranges from 0 to 100%. The EBTCM reduces the pulse width of the traction control desired torque request when a drive wheel slippage is detected. Depending on vehicle application, the PCM reduces wheel slippage by retarding spark timing; closing the throttle; decreasing the boost solenoid "On" time, or Pulse Width Modulation; or disabling the fuel injectors.

Transmission Control

The PCM controls certain transmission transaxle controls, including the torque converter clutch apply solenoid, shift solenoids, downshift solenoids, and pressure control solenoid, in order to create improved shift timing and feel.
Adaptive Learning

Idle Learn

Anytime the powertrain control module or the battery is disconnected, the PCM loses power, or the PCM is reprogrammed, the PCM's learned idle is lost. The engine idle is unstable when the learned idle is lost. When this happens the technician must perform the Idle Learn procedure. Refer to the service information for specific instructions.

Shift Adapt

The purpose of the Adapt function is to automatically compensate the shift quality for the various vehicle shift control systems. It is a continuous process that will help to maintain optimal shift quality throughout the life of the vehicle.

In order for the PCM to perform a "shift adapt," it must first identify if an upshift is acceptable to analyze. When an upshift is initiated, a number of contingencies are checked in order to determine if the actual shift time is valid to compare to a calibrated desired shift time. If all the contingencies are met during the entire shift, then the shift is considered valid and the Adapt function may be utilized.

Once an adaptable shift is identified, the PCM compares the actual shift time to the desired shift time, calculates the difference between them. This difference is known as the shift error.

The actual shift time is determined from the time that the PCM commands the shift to the start of the engine RPM drop initiated by the shift. If the actual shift time is longer than the calibrated desired shift time then the PCM decreases current to the Pressure Control, or PC solenoid, in order to increase line pressure for the next upshift under identical conditions. If the actual shift time is shorter than the calibrated desired shift time, the PCM increases current to the PC solenoid in order to decrease line pressure for the next upshift under identical conditions.
Crankshaft Position Variation Learn
The Crankshaft Position System Variation Learn Procedure should be performed if any of the following conditions are true:

• DTC P1336 is set
• The PCM has been replaced
• The engine has been replaced
• The crankshaft has been replaced
• The crankshaft harmonic balancer has been replaced, or
• The crankshaft position sensor has been replaced.

The "Crankshaft Position System Variation Learn" function will be inhibited if engine coolant temperature is less than 70 degrees Celsius. Allow the engine to warm to this temperature before attempting the "Crankshaft Position System Variation Learn" procedure.

The "Crankshaft Position System Variation Learn" function will be inhibited if any powertrain DTCs other than D C P1336 are set before or during the "Crankshaft Position System Variation Learn Procedure." Diagnose and repair any DTCs, if set.

The "Crankshaft Position System Variation Learn" function will be inhibited if the PCM detects a malfunction involving the camshaft position signal circuit, the 3 X reference circuit, or the 18 X reference circuit.