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Introduction

NATEF Area VIII. Engine Performance

B. Computerized Engine Controls Diagnosis and Repair

6. Inspect and test computerized engine control system sensors, powertrain control module (PCM), actuators, and circuits using a graphing multimeter (GMM)/digital storage oscilloscope (DSO); perform necessary action. P-1

7. Obtain and interpret scan tool data. P-1

8. Access and use service information to perform step-by-step diagnosis. P-1

9. Diagnose driveability and emissions problems resulting from malfunctions of interrelated systems (cruise control, security alarms, suspension controls, traction controls, A/C, automatic transmissions, non-OEM-installed accessories, or similar systems); determine necessary action. P-3

STC Standards

ALL Competencies for Electrical Stage 3 18043.03 W

B. Automotive Computers

7 Identify types of computer output signals

8 Identify types of actuators used

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

F. PCM Engine Control Management

3 Describe PCM outputs which control engine performance

Objectives

Upon successful completion of engine performance Module 12, the ASEP student will be able to:

• Define output circuit terms

• Identify output circuit components

• Explain output circuit operation

• Perform output circuit test
Output Devices

There are two types of output devices. They are relays and solenoids. Relays are used to control high current draw components with the PCM controlling the low current armature circuit. Solenoids are controlled directly by the PCM.

Control Circuits

Discrete Circuit

Most electrically operated devices are controlled by the PCM simply by turning them ON and OFF, often providing and removing ground.

Pulse Width Modulation Circuit

Turning a circuit ON and OFF very rapidly or pulsing it can achieve a varying range. Controlling the voltage in this manner is referred to as "Pulse Width Modulation," or PWM. Pulse means turning ON and OFF. Width means the amount of time the voltage is ON compared with the amount it is OFF. Finally, modulation refers to the fact that the circuit is being controlled or modulated over an operating range.

![Figure 12-1, Pulse Width Modulation Circuit](image)
**Driver Circuits**

There are several types of quad drivers. Carbureted vehicles built in the early 1980s were equipped with a fusible quad driver, or QDR, in the PCM. The fusible driver was unprotected and failed when exposed to a high amperage load, or when subjected to an amperage load at or near its limit for a prolonged period of time.

A Quad Driver 2, or QDR2, is protected. All new and some reconditioned PCMs are updated with current limiting quad drivers. When this type of quad driver is overloaded, it limits circuit current to protect itself. If the current to a solenoid or relay is being limited because of a shorted circuit or coil, the amperage may be too low to allow the component to function. If sufficient heat builds up, the quad driver may cease functioning due to thermal shut down. When this happens, all the components controlled by the QDR will stop functioning.

Quad driver modules, or QDMs, work like QDR2s, incorporating protection against circuit faults. They may also contain a fault line to provide a feedback signal to the PCM. The signal allows the PCM to help the service technician to locate an output fault by setting diagnostic trouble codes through readouts on the data stream.

![Figure 12-2, Quad Driver Circuits](image)

Another type of driver is the Output driver Module, or ODM. The ODM is the latest in output driver technology and can control seven outputs of varying currents. ODMs offer circuit protection and data bus communications with the central processor to specify which output is at fault.
Output Commands
There are a number of commands given by the PCM as outputs.

Malfunction Indicator Lamp (MIL)
The Malfunction Indicator Lamp, or MIL, comes on when the ignition key is turned to the on position, with the engine not running. This position serves as a bulb check. In some newer systems the light comes on for three seconds and then goes out.

With the engine running, the MIL is normally off. If a trouble code stores or the PCM goes into backup mode, the MIL comes on. If the condition changes and the trouble no longer exist the light may go off but the diagnostic trouble code, or DTC, remains stored in the PCM memory. In OBD II compliant vehicles, the MIL stays on for three passing trips after the fault is no longer present.

Up-shift Light
On manual transmission vehicles, the upshift light on the instrument panel indicates when it is appropriate to shift to the next higher gear to obtain optimum fuel economy while maintaining comparable vehicle performance. The PCM uses information from the ECT, TP, VSS, MAP or MAF sensor, and Engine RPM in determining when to illuminate the upshift light.

The PCM uses the indicated RPM and vehicle speed to calculate what gear the transmission is in. Airflow, RPM, and throttle position indicate engine load.

Temp Warning Light
Some vehicles have a "Temp" Warning Light in the instrument cluster, controlled by the PCM. The "Temp" warning light is activated by the PCM, which provides a ground path. On some models, for example, the light is illuminated when coolant temperature exceeds two-hundred fifty three degrees Fahrenheit, or one hundred thirteen degrees Celsius, and no engine coolant temperature DTCs have been set.
Exhaust Gas Recirculation Valve (EGR)

The Exhaust Gas Recirculation, or EGR, system is used to lower Oxides of Nitrogen emission levels caused by high combustion temperatures. It does this by decreasing combustion temperatures.

The main element of the system is the EGR valve. The EGR valve feeds small amounts of exhaust gas back into the combustion chamber. With the air fuel mixture displaced, combustion temperatures are reduced. EGR is usually activated during warm engine operation and above idle speeds.

In order to calculate EGR flow, the PCM looks at readings from ECT, TP, MAP or MAF, Ignition reference, and vehicle speed.

Linear EGR Valve

Many GM applications currently use a linear EGR valve as part of emissions control. EGR is used to lower combustion temperatures to help limit Nitrides of Oxygen, or NOX, emissions.

The PCM monitors the position of the EGR valve through a feedback signal. The PCM supplies a 5v reference and a ground to the EGR pintle position sensor. A voltage signal representing the EGR valve pintle position is sent to the PCM from the EGR valve. A high side driver using pulse-width modulation positions the EGR solenoid.

Unlike other system outputs, the PCM supplies voltage and ground to the EGR valve.

The feedback signal can be monitored on a scan tool and is the actual position of the EGR pintle. The Actual EGR Position should always be near the commanded or Desired EGR Position.

The linear EGR valve is designed to accurately supply EGR to an engine independent of intake manifold vacuum. The valve controls EGR flow from the exhaust to the intake manifold through an orifice. The PCM controls the pintle position by varying the magnetic field of the coil through pulse-width modulation. During operation, the PCM adjusts pintle position by monitoring the pintle position feedback signal. The linear system provides improvements in flow accuracy and diagnostic capabilities.
**Idle Air Control (IAC)**

The Idle Air Control, or IAC, valve is located in the throttle body of both TBI and MFI systems. It consists of a movable pintle, driven by a small electric motor called a stepper motor. The PCM uses the IAC valve to control idle RPM. It does this by changing the pintle position in the idle air passage of the throttle body. This varies the airflow around the throttle plate when the throttle is closed.

The stepper motor is capable of moving in exact, measured amounts called steps. Currents are reversed in the stators. Reversing the current will change the stator polarity, causing the rotor to rotate. Because the IAC valve is controlled by the PCM, it can make continuous precise changes in airflow to maintain proper idle speed under varying conditions.

During closed throttle, the PCM constantly compares actual idle RPM with the programmed desired idle RPM, and adjusts the IAC valve accordingly to achieve the desired idle. In some engines, the PCM also adjusts ignition timing to control idle speed even more precisely.

To determine the desired position of the IAC pintle at idle or during deceleration, indicated by closed throttle position or zero percent throttle angle, the PCM refers to the Battery voltage, ECT, TP sensor, Engine RPM, vehicle speed, and engine load, which includes MAP or MAF sensor, AC compressor, PSP switch, and PNP switch.

The pintle is moved OUT, or away, from the seat to increase airflow and RPM, and IN, or toward, the seat to decrease airflow and RPM.

During each ignition key cycle, the PCM commands the IAC valve to seat itself and then to move away from the seat a calibrated number of steps. This establishes a correct reference for operation when the engine is restarted. It also provides the exact amount of air for start-up, because the throttle plate remains closed during engine cranking.

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*Figure 12-4, Idle Air Control System*
Valve Designs

Three styles of IAC valve pintles have been used on GM fuel injection systems. One type has a single-taper, the second has a dual-taper, and the third has a blunt tip. Always replace an IAC valve with one having the same pintle shape and diameter.

If the IAC valve has to be replaced, be sure to observe all precautions and follow procedures exactly as provided in the service manual.

Ignition Control

Each ignition control module has a power feed circuit, a chassis ground circuit, ignition control circuits, and a reference low circuit. The PCM causes spark to occur by pulsing the IC circuit, which signals the module to trigger the coil and fire a spark plug. The PCM and ignition modules are circuit protected against shorts to power and ground on the IC circuits.
Fuel Control

Fuel Pump Control

Because the fuel pump draws high current, it is not directly controlled by the PCM. Instead, the PCM controls a fuel pump relay that provides system voltage to the fuel pump.

When the ignition is turned ON, before the starter is engaged, the PCM energizes the fuel pump relay by providing system voltage. If the PCM does not receive ignition reference pulses within 2 seconds, it will shut off the fuel pump relay. The PCM powers the relay circuit as long as it receives ignition reference pulses.

On some models, the oil pressure switch provides a backup circuit to the fuel pump relay. If the fuel pump relay fails to supply power to the fuel pump, it will receive power from this circuit. This may result in extended crank times.

This circuit is unique in that the PCM is supplying power instead of ground. This is done for safety reasons. If the fuel pump relay was configured like the other outputs, a short to ground would cause the pump to continue to operate even when the engine was not running.

An inoperative fuel pump will cause a no-start condition. A defective relay can result in long engine cranking times or a "no-start" condition if the vehicle is not equipped with an oil pressure switch backup circuit.
Fuel Injectors

Fuel is delivered by the fuel injector, which is controlled by the PCM. The fuel injector is provided a continuous supply of pressurized fuel by the electric fuel pump. The PCM controls fuel flow by pulse width modulation of the injector, or ON time. The ON time of the injector is determined by Engine temperature, intake air temperature, engine RPM, throttle position, manifold pressure or mass airflow, the oxygen sensor, engine load, and system voltage.

When fuel requirements increase, the injector on time increases, producing a richer air fuel mixture. When fuel requirements decrease, the injector on time decreases, producing a leaner mixture.

A fuel injector is an electromagnetic device. The precision mechanical components are controlled by means of the solenoid in the injector, and the solenoid is energized through an injector driver in the PCM. The injector is triggered based on ignition reference pulses.

Although engine RPM determines when an injector opens, the PCM determines how long to leave the injector open. How long the injector is open determines how much fuel is delivered; in other words, how rich or lean the air fuel mixture is. The duration of this on time is called the pulse width.
The PCM driver circuit controls the on time of the solenoid by providing a ground. When the injector driver opens the circuit to the solenoid again and turns it off, return spring tension closes the ball or pintle on its seat and shuts off fuel flow. There are two principal types of injector drivers: saturated switch and peak-and-hold.

A saturated switch drive circuit is used with injectors having relatively high resistance, generally twelve to sixteen ohms. The circuit resistance limits maximum current. There is no separate current limiting function. With this type of driver, the injector coil takes longer to build and collapse its magnetic field. When the injector driver opens the circuit to the injector's solenoid, return spring tension closes the ball or pintle on its seat and shuts off fuel flow.

A peak-and-hold injector drive circuit is used in conjunction with relatively low resistance injectors, one to two ohms. It incorporates a current limiting device to prevent overheating of the injector coil. The current limiting circuit monitors the current flow through the injectors. When current reaches the maximum level, it is reduced to avoid damage to the injector solenoid. Current is then maintained at a level sufficient to hold the valve off the seat for the required injection period. With this type of driver, the injector opens and closes more quickly, giving more precise fuel control over a very broad operating range. Peak-and-hold injector drivers are used in both TBI, and bottom feed, and MFI, or top feed, injectors.
**Enhanced Evaporative System**

The Enhanced Evaporative, or EVAP, Emission system used on OBD II vehicles consists of an Evaporative system canister, a Fuel tank pressure sensor, Canister purge valve, Canister vent valve, Fuel level sensor, Fuel tank, Fuel cap, and Service port.

EVAP canister purge occurs when the engine runs for a specified time, coolant temperature is above a specified value, and the vehicle speed above a specified MPH or throttle is off-idle.

When energized, the evaporative canister purge valve allows fuel vapor to flow from the canister to the engine. The normally closed valve is pulse width modulated by the control module to precisely control vapor flow. The valve is opened during the enhanced evaporative diagnostic tests to create a vacuum in the fuel tank and then closed to seal the system.

The evaporative canister vent valve replaces the fresh air vent used on past canisters. The normally open vent valve now not only allows fresh outside air to the canister during purge modes, but also allows the diagnostic to pull a vacuum on the fuel tank by closing the vent valve.
Secondary Air Injection System
The Secondary Air Injection system consists of an air pump, control valves for switching and or diverting, check valves, and necessary plumbing. In many applications, a belt drives the air pump on the front of the engine. In the other applications the air pump is electric, which reduces the load on the engine.

On cold start-up, oxygen is pumped into the exhaust manifold to continue combustion after the exhaust gases leave the combustion chamber. During cold operation, hydrocarbon, or HC, and Carbon Monoxide, or CO, output can be high. Extending combustion reduces HC and CO emissions in the exhaust. On some systems, air is switched to the catalytic converter after warm-up. The catalytic converter is used to control HC and CO emissions through oxidation. The AIR system provides additional oxygen to help lower HC and CO levels in the exhaust gases even further.

![Diagram of Secondary Air Injection System](image)

*Figure 12-11, Secondary Air Injection System*

The PCM turns the AIR pump OFF after a set time or under certain engine operating conditions. At the same time, the integral stop valve is de-energized, so no air is directed to the exhaust ports. The AIR system will shut OFF when the system goes into closed loop, when the AIR pump has been "ON" for a set time, when the air fuel mixture is too rich, engine parameters are out of range, when the catalytic converter is over temperature, the PCM recognizes a problem and sets a diagnostic trouble code.
**Throttle Actuator Control**

Since 1997, many engines are equipped with a Throttle Actuator Control, or TAC, system. The TAC system is a throttle by wire system that uses an actuator to move the throttle blade in unison with the accelerator pedal in the vehicle.

Proper engine operation requires that the PCM and TAC module to work together via the serial data line. There are two identical data lines between the TAC module and the PCM to decrease the likelihood of a failure.

![Figure 12-12, Throttle Actuator](image)

An accelerator pedal position, or APP, sensor tells the TAC module that the driver has selected a certain throttle position. The TAC and the PCM communicate back and forth. The PCM requests that the TAC module position the throttle blade via the throttle actuator control motor. This position is verified for the PCM by the TP sensor through the TAC module.

Cruise control functions are integrated into the TAC system.

**Note:**

Some TAC systems may have minor operating differences. For example, the 2002 four point two liter engine has the TAC module integrated into the PCM. Please refer to service information for your specific application.
Engine Cooling Fans

The engine cooling system may use a single fan or dual electric fans to cool the radiator and/or the AC condenser under certain conditions. On many applications the fan is controlled by the PCM via a cooling fan relay. The PCM grounds the cooling fan relay, providing system voltage to the cooling fan motor under some or all of the following conditions.

- The vehicle is at a specified speed,
- During an AC System request, or
- When AC is on and the vehicle is below a specified RPM.

![Figure 12-13, Engine Cooling Fans](image)
**A/C Clutch Control**

To improve idle quality and Wide Open Throttle performance, the PCM controls engagement of the AC clutch on some systems. At idle, the PCM first commands the IAC valve to increase engine idle slightly, then grounds the AC relay. This minimizes poor idle quality or stalling. The PCM will interrupt AC operation at wide-open throttle, when maximum engine performance is desired. When the power steering pressure, or PSP, switch signals high power steering pressure at low engine speed, the PCM removes the ground from the AC clutch relay to prevent stalling caused by the compressor load on the engine. If the coolant temperature sensor indicates that the engine cooling system is overheating, AC operation is interrupted.

**Transmission and Transaxle Control**

On all GM electronically controlled transmissions and transaxles, two shift solenoids work in tandem to provide the four forward gears. They are an ON/OFF design, similar to the TCC solenoid. When energized, the solenoids are closed and prevent fluid from passing through them. When the solenoid is de-energized, the fluid is allowed to exhaust back inside the case.

**Torque Converter Clutch**

The torque converter clutch, or TCC, is located inside the torque converter. The TCC provides a direct mechanical coupling between the engine output and the input shaft of the transmission. Slippage in the converter is reduced, thereby increasing fuel economy.

The PCM controls the TCC operation by providing a ground for an apply solenoid in the transmission. The solenoid controls the hydraulic fluid necessary for TCC actuation. In order to command the TCC ON, the PCM evaluates inputs from such sensors as the ECT, VSS, MAP or MAF, gear selector, and the transmission fluid temperature sensor.
Shift Pattern Control

For each specific gear, the 4T65-E solenoids operate as follows:

- In first gear, both solenoids are ON
- In second gear, the 1-2 shift solenoid goes OFF and the 2-3 shift solenoid remains ON
- For third gear, both solenoids are OFF, and
- In fourth gear, the 1-2 shift solenoid goes ON while the 2-3 shift solenoid remains OFF.

Both the 1-2 and 2-3 shift solenoids receive power from the Trans fuse whenever the ignition is ON. The PCM controls operation by providing the ground. The PCM determines shift points using the TP sensor, VSS and RPM. Other transmissions, such as the 4L80 E, will have a different ON/OFF combination.

*Figure 12-14, Transmission Control Components*
A 3/2 downshift control solenoid can also be found on the 4L60 E electronic automatic transmission. The 3/2 downshift control solenoid is pulse-width modulated and allows the PCM to control timing of 3/4 clutch release and 2/4 band apply based upon VSS and TP sensor signals. The PCM operates the 3/2 downshift control solenoid at 50 Hertz. A higher duty cycle from the PCM results in increased 3/2 signal fluid pressure. This increased pressure delays the downshift between third and second gears at higher speeds. As a result, the driver feels a smoother shift transition

![Figure 12-15, 3/2 Downshift Control Solenoid](image)

**Shift Quality Control**

Many electronic automatic transmissions, such as the 4L60 E, 4L80 E, and 4T80 E feature a line Pressure Control Solenoid, or PCS. Similar to the PWM solenoid for TCC, the PCS modulates fluid in the torque signal hydraulic circuit for applying components. The PCM primarily looks at throttle position to determine the PCS duty cycle. At minimum throttle, a maximum duty cycle of about forty percent is commanded, and torque signal fluid pressure and line pressure are minimized. At the higher throttle openings, the PCM uses a near zero percent duty cycle to provide maximum signal fluid and line pressure in the transmission.

This solenoid is part of the Adaptive Learning function in the PCM for transmission control. With Adaptive Learning, the PCM can compensate for component wear by varying torque signal fluid and line pressures to maintain originally calibrated shift timing.

![Figure 12-16, Pressure Control Solenoid](image)