Engine Performance

Engine Repair

Steering & Suspension

Electrical Systems

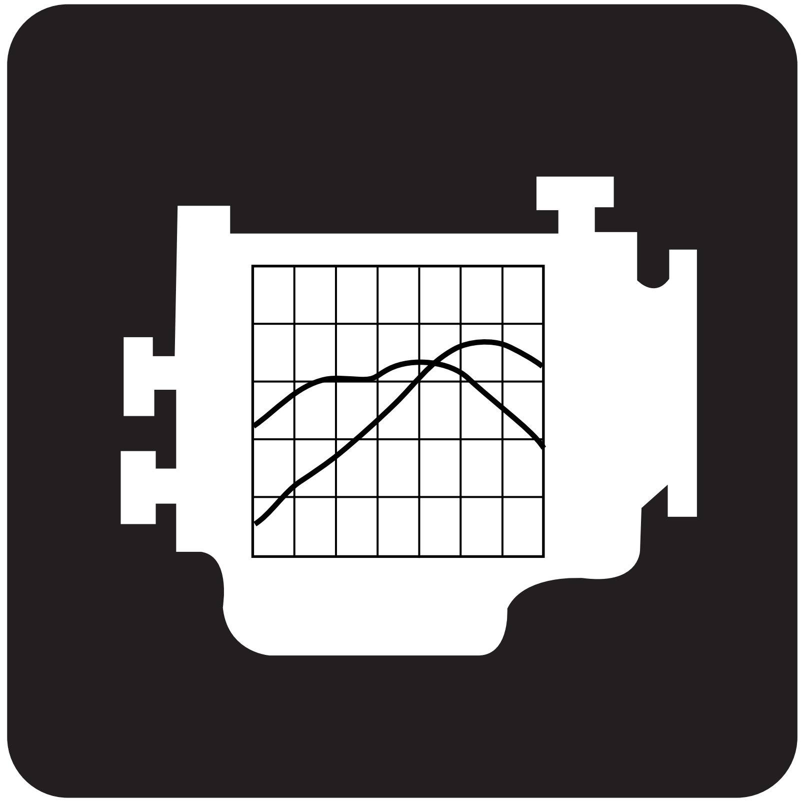
Climate Control

Manual Transmission

Automatic Transmission

Brakes

diesel engine performance



diesel engine electronics

self-study

COURSE CODE: 51S02S0
ORDER NUMBER: FCS-13005-REF

STST
Service Technician Specialty Training
Ford Customer Service Division
Technical Training

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, and WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind your head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design, or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents, if available, may be used. The right is reserved to make changes at any time without notice.

WARNING: Many brake linings contain asbestos fibers. When working on brake components, avoid breathing the dust. Breathing the asbestos dust can cause asbestosis and cancer.

Breathing asbestos dust is harmful to your health.

Dust and dirt present on car wheel brake and clutch assemblies may contain asbestos fibers that are hazardous to your health when made airborne by cleaning with compressed air or by dry brushing.

Wheel brake assemblies and clutch facings should be cleaned using a vacuum cleaner recommended for use with asbestos fibers. Dust and dirt should be disposed of in a manner that prevents dust exposure, such as sealed bags. The bag must be labeled per OSHA instructions and the trash hauler notified as to the contents of the bag.

If a vacuum bag suitable for asbestos is not available, cleaning should be done wet. If dust generation is still possible, technicians should wear government approved toxic dust purifying respirators.

OSHA requires areas where asbestos dust generation is possible to be isolated and posted with warning signs. Only technicians concerned with performing brake or clutch service should be present in the area.

Produced and Coordinated by
Technical Service Support Operations
Ford Customer Service Division

October, 1999

NOTES

The Diesel Engine Electronic Self-Study is the second course in the Diesel Engine Performance Curriculum. The first course to be completed should be Diesel Engine Operation Self-Study. It is important that the Diesel Engine Operation Self-Study be completed first since it will establish the building blocks for the other courses in this curriculum. Additionally making sure that all prerequisite courses are completed prior to taking this self-study will lead to a better understanding of the material presented.

This course has two main goals. The first goal is to introduce you to the engine electronics used on Ford diesel powered vehicles. As you learn new information, try to relate the new knowledge to diesel engine electronic systems as a whole. Think about the cause-and-effect relationships between the subsystems and components. Understanding the cause-and-effect relationships will help you in diagnosis. This course includes information related to the diesel engine electronic systems. Some of the topics that are covered in this course include the following:

- Electronic Engine Controls Overview
- Electronic Engine Controls Subsystem Overview
- Electronic Subsystem Input and Output Components and Operation
- Control and Failure Strategies
- PCM Self-Tests
- Parameter Identification (PID)
- Re-Programming the PCM

Although you may be familiar with some of these topics, it is essential that you, as a professional diesel engine technician, have a thorough understanding and mastery of this information. You will find that mastery learning is necessary to diagnose and repair the latest diesel engine systems.

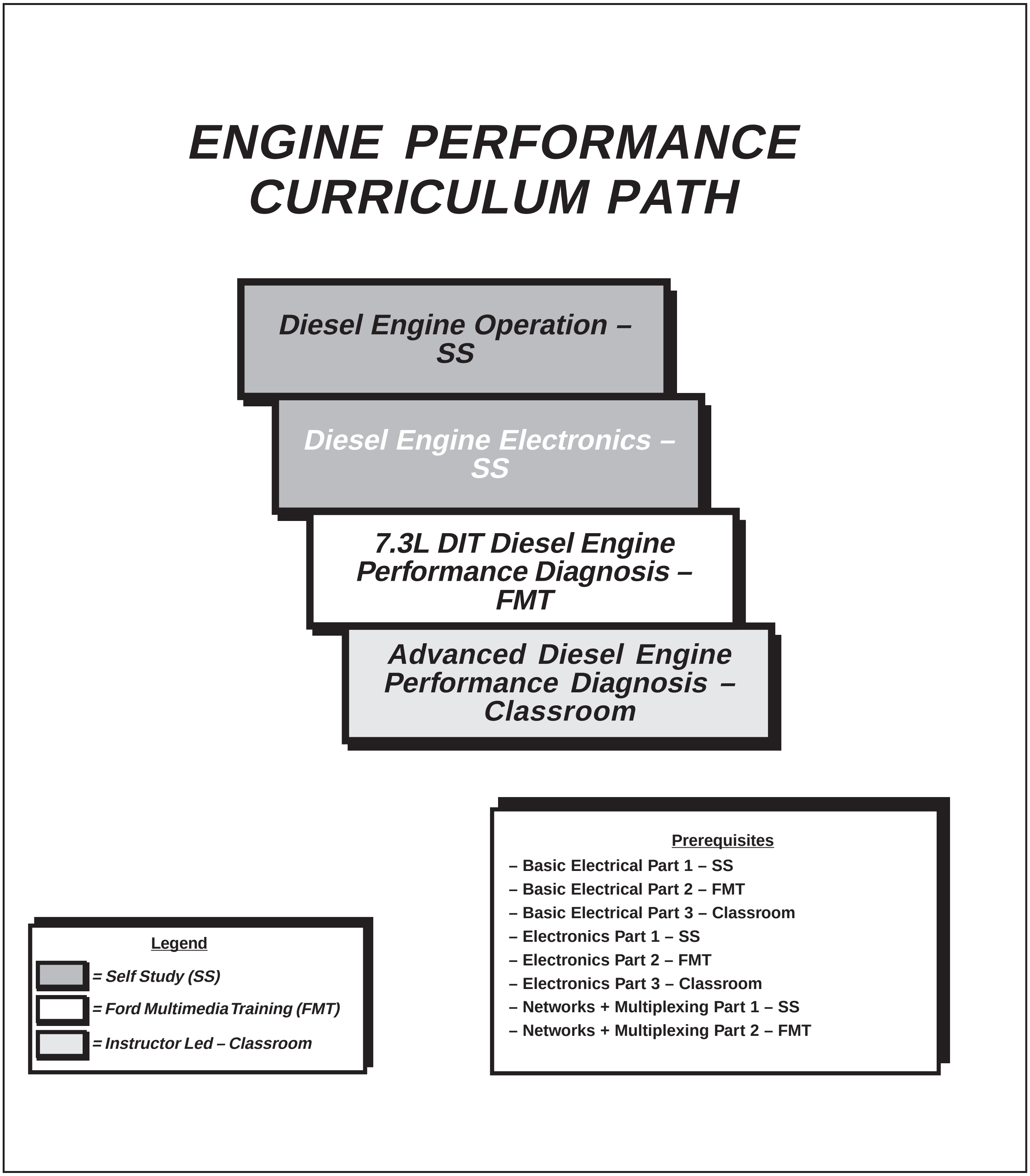
CURRICULUM DESCRIPTION

Diesel Engine Electronics Curriculum

Each course found in the Diesel Engine Performance Curriculum is one of the following types:

- Self-Study – This type of course is a self-paced program. The technician is responsible for learning the material at his or her own pace. The training material consists of a reference book and an accompanying videotape. The videotape is designed to support the material in the reference book and should not be used on its own.
- Ford Multimedia Training (FMT) – This type of course is also self-paced. The multimedia course allows the technician to interact with the training materials. The multimedia course allows the technician to utilize the knowledge gained in the self-study course. The FMT course concentrates on diagnosis and testing procedures.
- Classroom – The classroom course allows for a practical, real-world application of skills and knowledge learned in the other courses.

There are 4 courses in the Diesel Engine Performance Curriculum. Please refer to the Diesel Engine Performance Curriculum Training Pathway that follows.



Curriculum Training Pathway

Course Codes

These courses may be found in the STARS planner using the following course codes:

Engine Performance

- Diesel Engine Operation – Self-Study .... Course code: 51S01S0
- Diesel Engine Electronics – Self-Study .... Course code: 51S02S0
- 7.3L Direct Injection Turbocharged (DIT) Diesel Engine Performance Diagnosis – FMT .... Course code: 51S03M0
- Advanced Diesel Engine Diagnosis – Classroom .... Course code: 51S04T0

COURSE PURPOSE

Technician Course Objectives

Upon completion of this course, you will be able to describe:

- The purpose and operation of electronic control systems for the diesel engine.
- The purpose and operation of the powertrain control system for the diesel engine.
- The control and failure strategies used by the powertrain control module (PCM) and injector driver module (IDM).
- The purpose and procedures for carrying out PCM self-tests for diesel engines.
- The use of parameter identification (PID) data monitoring as it relates to the diesel engine.
- Re-programming of the PCM.
- The function and location of the Auxiliary Powertrain Control (APC) module (option).

Why Training?

1. Customers bring vehicles to the dealership because they want the best repair and maintenance work possible. They believe that no other technician besides you, a Ford trained technician, could know their vehicle better.
2. Customers expect a dealership to “Fix It Right The First Time, On Time.”

So, how do you live up to the customer’s expectations? The answer is continuous training. Training allows you to gain efficiency. Efficiency makes you an asset to the customer, the dealer, and yourself. Training promotes job security and allows you to learn the “latest and greatest” technology and repair procedures.

COURSE DESCRIPTION AND FORMAT

Course Description for Self-Study Learners

This Student Reference Book is designed for use as part of a self-study training course, which means you can allow yourself as much time as you need to learn the information in each section. A videotape has been developed to accompany this book. The videotape provides information that can best be presented through visual means.

Lesson Review Questions are provided throughout this book to help evaluate your individual learning needs. Answers to the Lesson Review Questions are provided with page references to help you determine your strengths and weaknesses. If you have difficulty answering certain questions, review the material until you feel confident that you understand the information.

Take as much time as you need to master the material. You may not answer the questions 100% correctly the first time around. With study, you will quickly master those areas with which you may have difficulty.

Evaluation Strategy

The final evaluation questions for this self-study course are on the 7.3L DIT Diesel Engine Performances Diagnosis FMT CD-ROM. You must pass this test and the test for the Diesel Engine Operations Self-Study before you can begin the FMT course.

NOTES

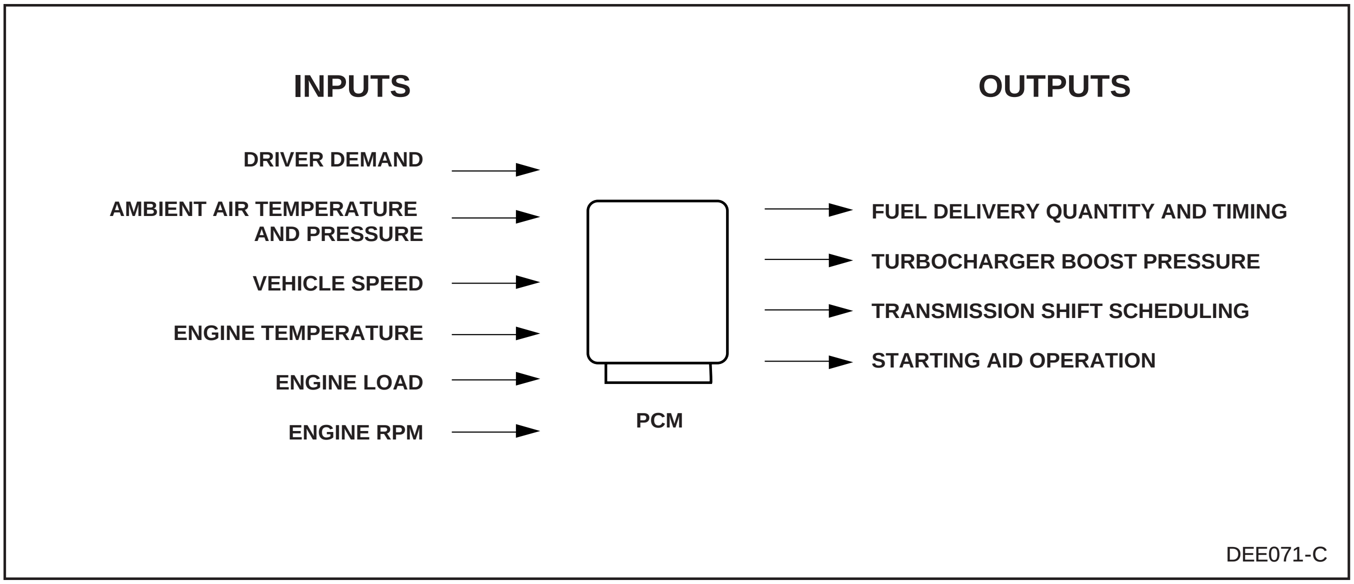
LESSON 1: DIESEL ENGINE CONCEPTS AND CHARACTERISTICS

TECHNICIAN OBJECTIVES

- Describe the operation of the engine control subsystem for the diesel engine.
- Describe the operation of the glow plug control subsystem.
- Describe the operation of the exhaust back pressure control subsystem.
- Describe the operation of the electric fuel supply subsystem.
- Describe the operation of the speed control subsystem.
- Describe the operation of the transmission/ PTO control subsystem.
- Describe the operation of the dual generator subsystem.

CONTENTS

OVERVIEW OF THE ELECTRONIC CONTROL SYSTEM



Electronic Control System (EEC) Inputs and Outputs

The purpose of an Electronic Engine Control (EEC) system is to use electrical and electronic components to control powertrain performance through a wide range of vehicle operating modes. This allows for higher power output during all driving conditions while maintaining acceptable emissions levels and fuel economy. Through a combination of inputs, outputs, control modules and strategies, powertrain operation is controlled to maintain the highest possible output and efficiency.

On vehicles equipped with the 7.3L DIT (Direct Injection Turbo) engine, the Electronic Engine Control system can be divided into seven subsystems. These subsystems work in conjunction with each other to accomplish precise powertrain control.

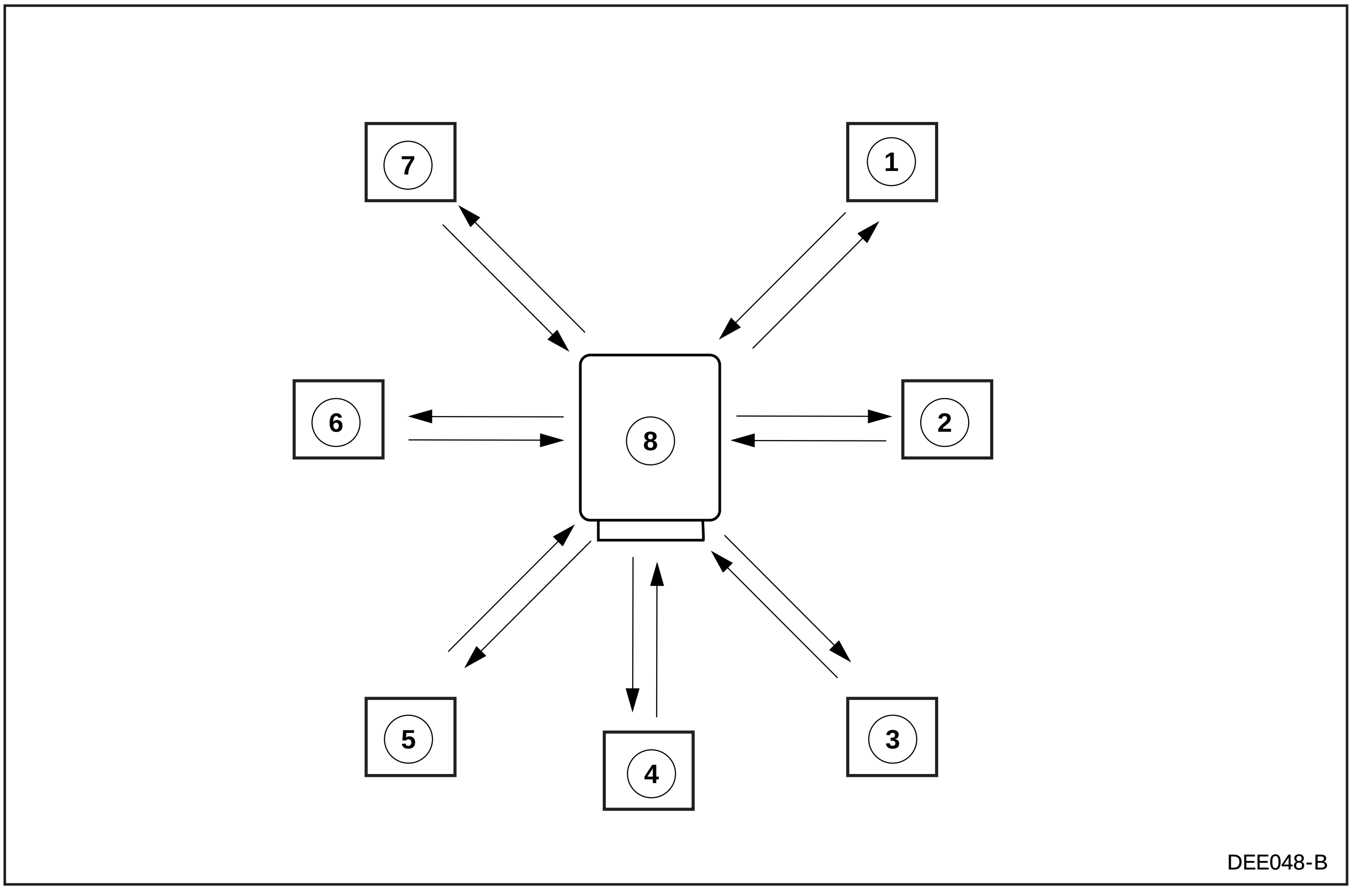
Within the seven subsystems inputs provide information on:

- Driver demand.
- Air temperature and pressure.
- Vehicle speed.
- Engine temperature.
- Engine load.
- Engine rpm.

This information is sent to a processor and is used to determine processor control of various outputs within the subsystems. Some of the outputs controlled are:

- Fuel delivery quantity and timing.
- Turbocharger boost pressure.
- Transmission shift scheduling.
- Starting aid operation.

Electronic Control Subsystems



Electronic Control Subsystems

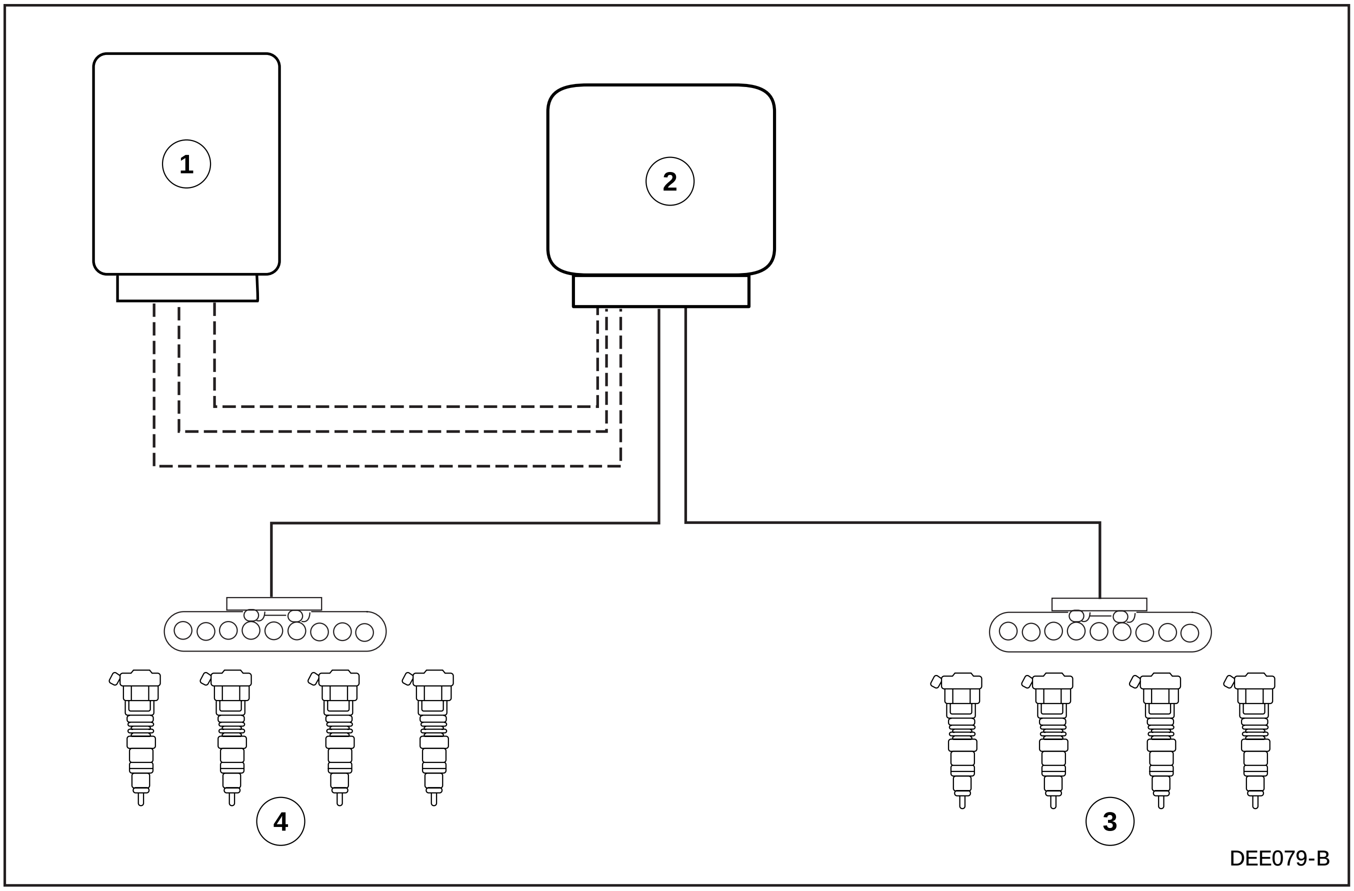
Item	Description
1	Engine Control Subsystem – Fuel Injector – High-Pressure Oil Control – Wastegate Control
2	Glow Plug Control Subsystem
3	Exhaust Backpressure Control Subsystem

Item	Description
4	Electric Fuel Supply Subsystem
5	Speed Control Subsystem
6	Transmission/PTO Control Subsystem
7	Dual Generator Subsystem
8	Powertrain Control Module (PCM)

The electronic engine control system used on the 7.3L DIT diesel engine consists of seven subsystems comprised of inputs and outputs managed by the powertrain control module. These subsystems are shown above.

In addition to these seven subsystems, other auxiliary subsystems and strategies may exist, such as the intake air heater which is used to reduce white smoke during cold engine operation.

Engine Control Subsystem



Engine Control Subsystem

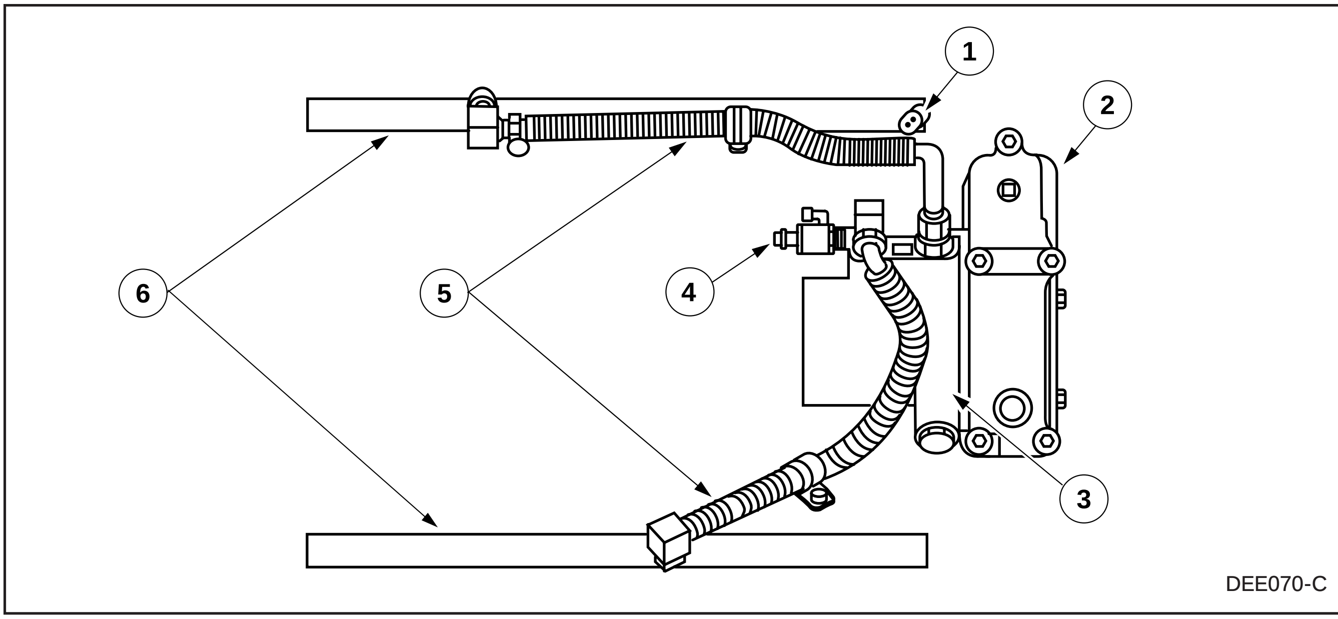
Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)

Item	Description
3	HEUI Injector Bank (RH)
4	HEUI Injector Bank (LH)

The engine control subsystem includes fuel injector control, high-pressure oil control, and wastegate control. Fuel injector and high-pressure oil control are both used to control fuel delivery quantity and timing. Wastegate control is used to manage turbo boost pressure.

- **Fuel Injector Control Subsystem**

  Consists of a Powertrain Control Module (PCM), Injector Driver Module (IDM), and hydraulically actuated Electronically controlled unit injectors (HEUI). The PCM and IDM are used to regulate fuel delivery by controlling the fuel injectors. The PCM receives signals indicating engine rpm and the position of cylinders numbers 1 and 4. It then sends signals to the IDM indicating when and how long to actuate the injector. The IDM uses this information to send command signals through a high-voltage circuit to control the HEUI fuel injectors.



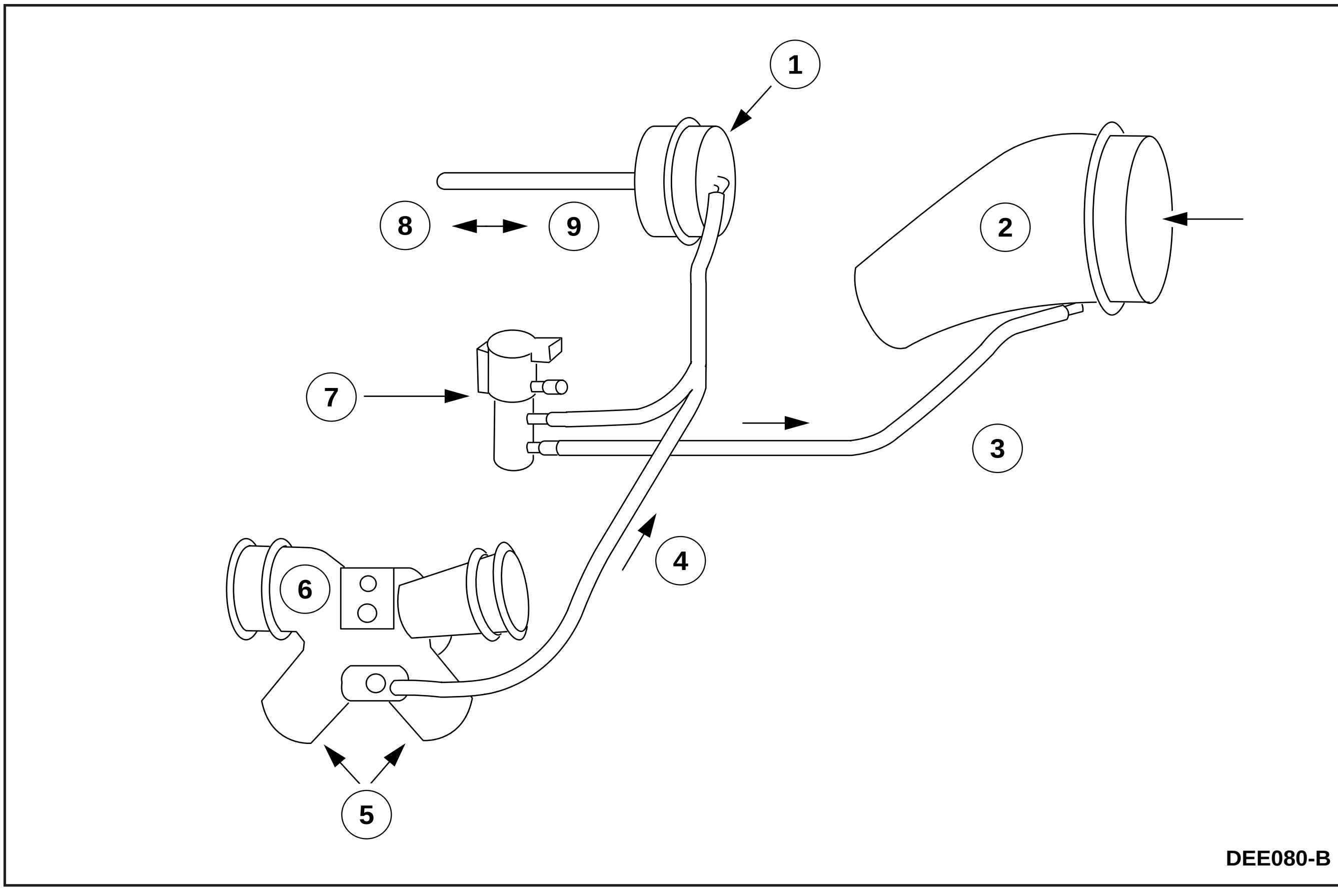
High-Pressure Oil Control System

Item	Description
1	Injection Control Pressure (ICP) Sensor
2	High-Pressure Oil Reservoir
3	High-Pressure Oil Pump
4	Injection Control Pressure Regulator

Item	Description
5	High-Pressure Oil Hoses
6	High-Pressure Oil Rails (Integral With Cylinder Head)

- **High-Pressure Oil Control Subsystem (Injection Control Pressure)**

  Consists of the high-pressure oil reservoir, high-pressure oil pump, injection control pressure regulator, injection control pressure sensor, high-pressure hoses, and oil rails in the cylinder heads. The high-pressure oil system is used to actuate the HEUI fuel injectors. The PCM controls an electronic pressure regulator to regulate the oil pressure supplied to the injectors. The high-pressure oil flow within the fuel injectors is controlled by a solenoid located on top of the injectors. Oil pressure supplies the force needed to pressurize the fuel in the injector to initiate fuel injection.



Wastegate Control System

Item	Description
1	Wastegate Control (WGC) Actuator
2	Air Inlet (To Turbocharger)
3	Bleed To Air Inlet
4	Intake Manifold Pressure
5	To Cylinder Heads

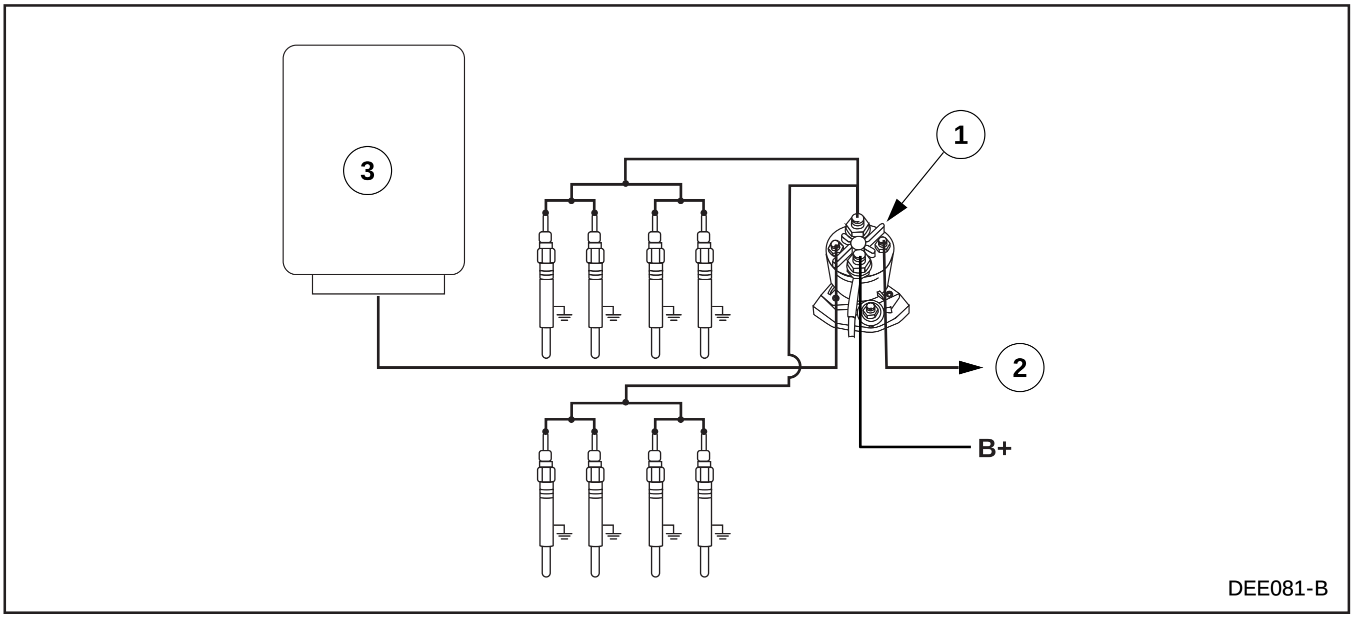
Item	Description
6	Charge Air Cooler (CAC) Housing
7	Wastegate Control (WGC) Solenoid
8	Wastegate Open
9	Wastegate Closed

- **Wastegate Control Subsystem**

Consists of the turbocharger, wastegate assembly and solenoid. The wastegate controls turbo boost pressure within the intake system. The PCM regulates wastegate operation by controlling a wastegate solenoid that bleeds intake manifold pressure from the wastegate actuator to the air inlet.

NOTE: Wastegate used only on vehicles with Charge Air Cooler (CAC) system.

GLOW PLUG CONTROL SUBSYSTEM



Glow Plug Control Subsystem

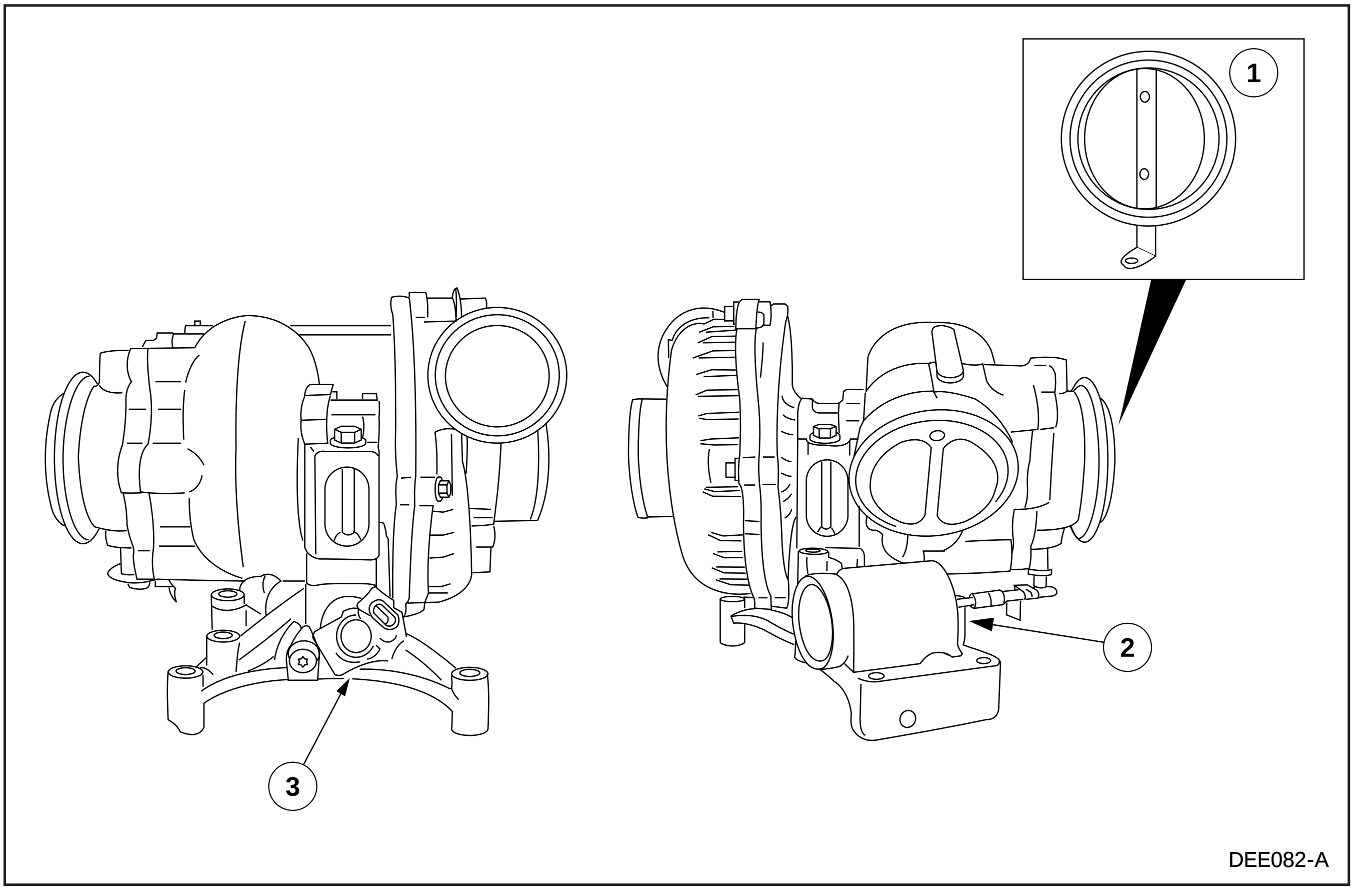
Item	Description
1	Glow Plug Relay
2	B^+ from EEC Power Relay

Item	Description
3	Powertrain Control Module (PCM)

- **Glow Plug Control Subsystem**

The glow plug subsystem is used to improve cold startability and reduce white smoke during cold engine operation. This is accomplished by using glow plugs to heat the air intake combustion chambers prior to starting the engine. When the ignition switch is turned to the ON position and conditions are correct, the PCM activates the glow plug relay and the WAIT TO START light for a predetermined period of time. After a period of time, the WAIT TO START lamp is turned off. This informs the driver that the engine is ready to be started. After the engine has started, the glow plug circuit may continue to operate to help reduce white smoke from the exhaust.

EXHAUST BACKPRESSURE CONTROL SUBSYSTEM



Exhaust Backpressure Control Subsystem

Item	Description
1	Exhaust Backpressure Butterfly Valve
2	Exhaust Backpressure Actuator
3	Exhaust Backpressure (EPR) Regulator

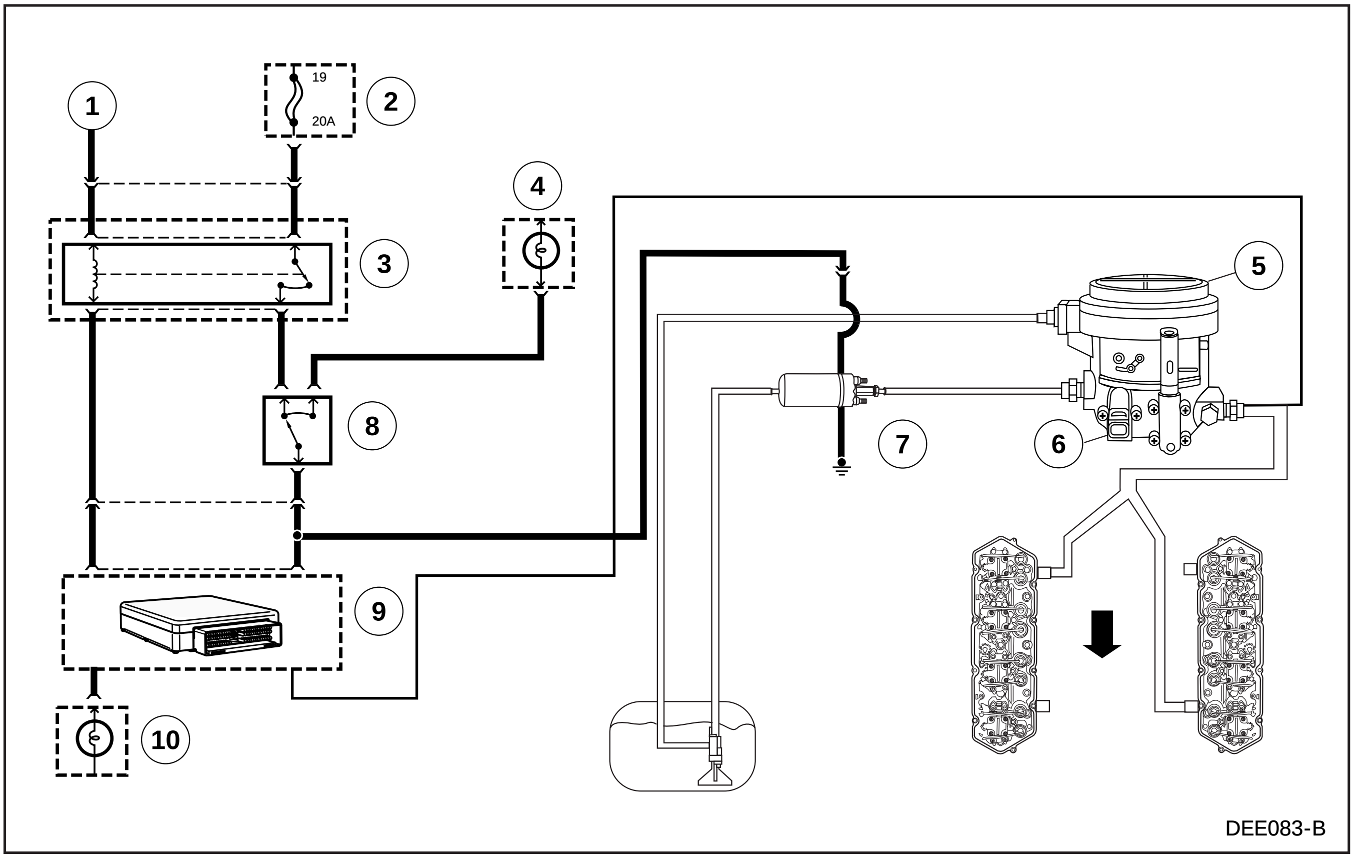
- **Exhaust Backpressure Control Subsystem**

The exhaust backpressure system restricts the flow of exhaust gasses to elevate engine temperature. The exhaust backpressure device is initiated during cold ambient and cold engine conditions, and when the engine is operated at low load and low rpm. During high load or high rpm conditions, the backpressure device is disabled to allow better exhaust flow from the engine.

The backpressure control system consists of a butterfly-type valve, solenoid and sensor. This valve closes to restrict the exhaust flow from the engine, raising cylinder wall temperatures and transferring heat to the engine coolant.

NOTE: Some vehicles may not be equipped with an exhaust back pressure system.

ELECTRIC FUEL SUPPLY SUBSYSTEM



Electric Fuel Supply Subsystem

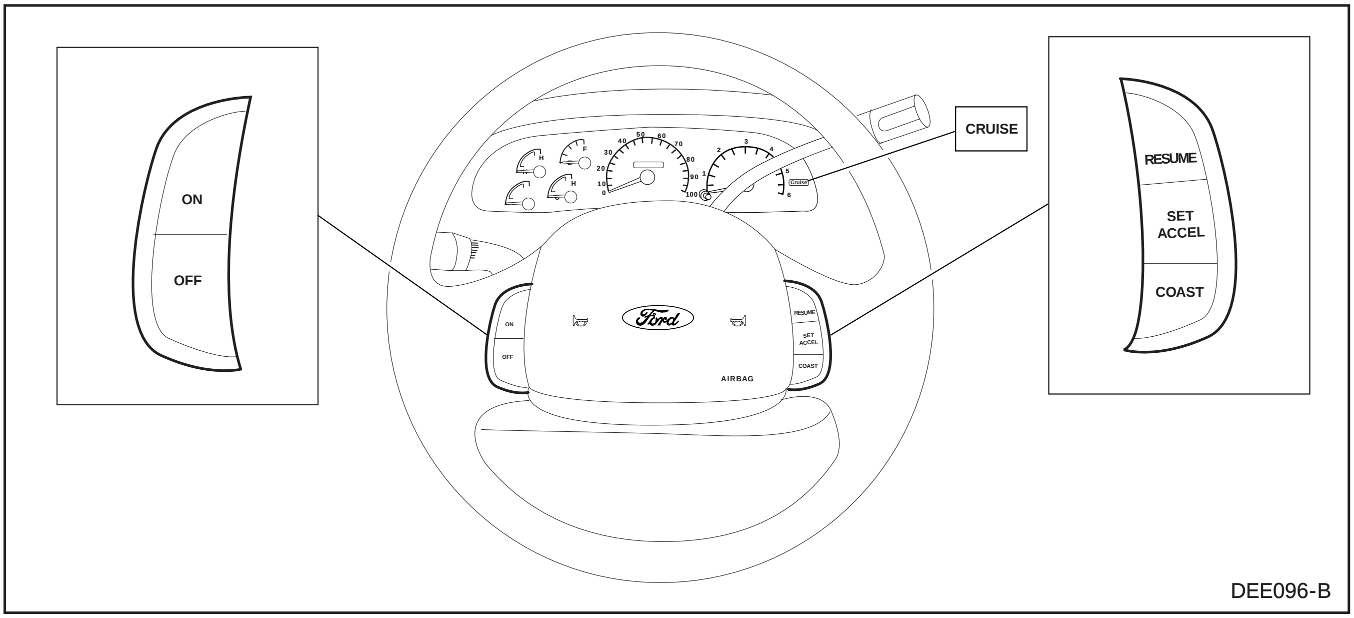
Item	Description
1	Switched Power
2	Fuel Pump Relay Fuse (Hot At All Times)
3	Fuel Pump Relay (FPR)
4	Fuel Reset Indicator Lamp
5	Fuel Filter Housing

Item	Description
6	Fuel Heater and Water in Fuel Sensor
7	Electric Fuel Pump (FP)
8	Fuel Pump Inertia Shut-Off Switch
9	Powertrain Control Module (PCM)
10	Water in Fuel Indicator Lamp

- **Electric Fuel Supply Subsystem**

The Electric Fuel Supply subsystem is responsible for moving the fuel through the fuel system while supplying the necessary fuel to the HEUI injectors for engine operation. The PCM controls a relay that supplies current to the electric fuel pump based on information that it receives indicating that the engine is running. This system also provides a way to notify the driver of the presence of water in the fuel by illuminating an indicator lamp on the instrument panel when water is detected by a sensor in the fuel filter housing. An inertia switch is also incorporated into the system. The inertia switch opens the circuit to the electric fuel pump, turning the fuel pump off, in the event of an accident to prevent unwanted delivery of fuel from the fuel tank.

SPEED CONTROL SUBSYSTEM



Speed Control Subsystem

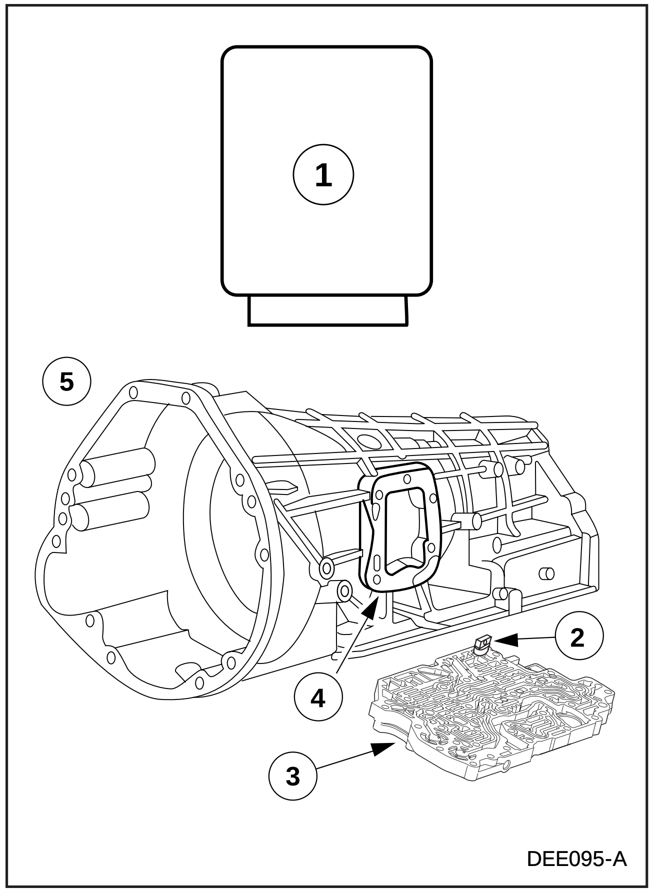
- **Speed Control Subsystem**

The speed control subsystem allows the driver to select and maintain a specific vehicle speed. The PCM controls vehicle speed by regulating fuel delivery. By monitoring various driver operated controls and vehicle speed the PCM controls system operation.

TRANSMISSION/PTO CONTROL SUBSYSTEM

On vehicles equipped with automatic transmissions, shift scheduling, line pressure, and torque converter application are controlled by the PCM.

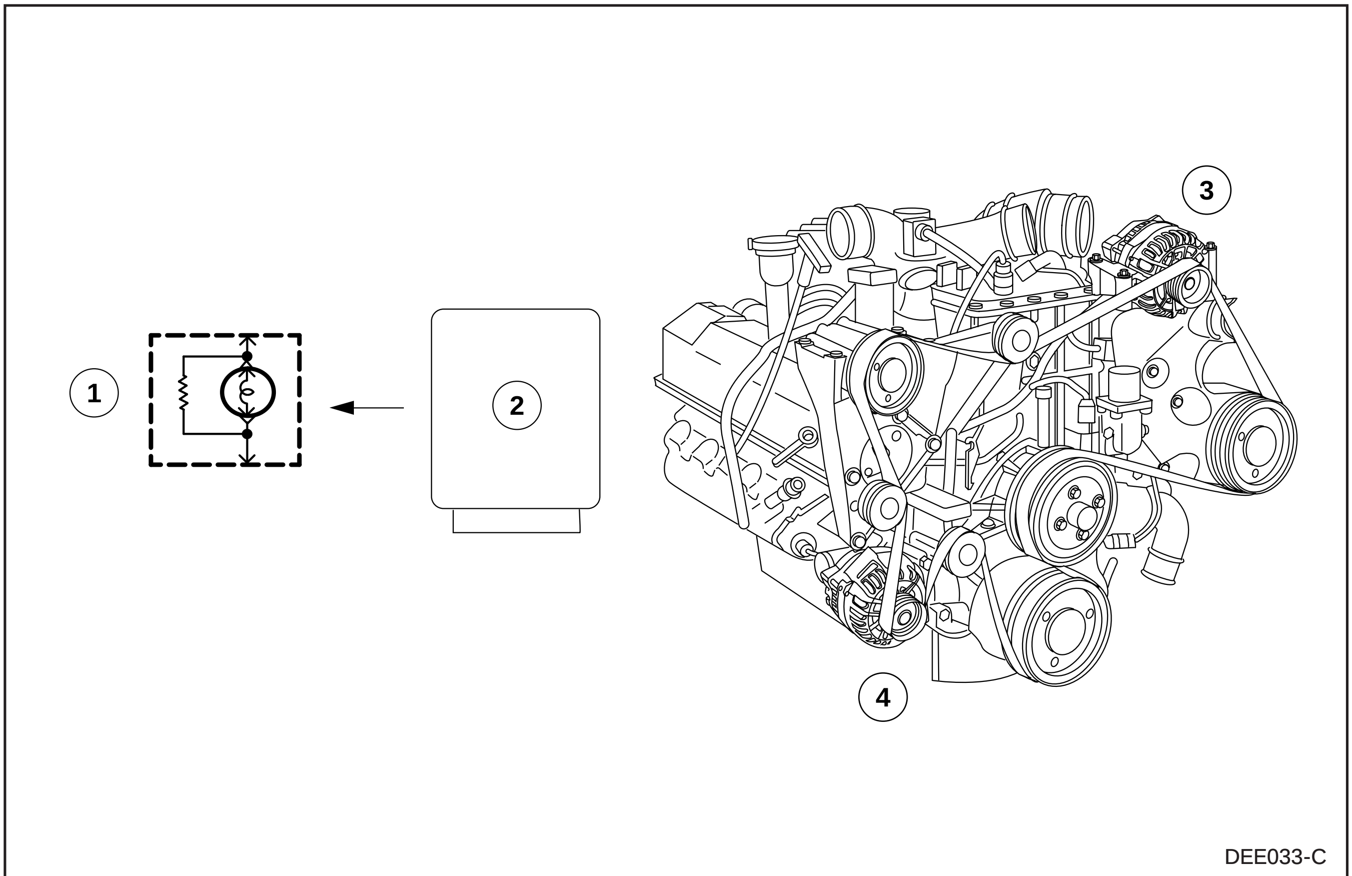
A Power Take-Off (PTO) is an auxiliary drive unit powered at the transmission and used to drive add-on systems, such as a hydraulic pump or winch assembly. During PTO operation, the PCM controls automatic transmission functions to provide power to an auxiliary drive unit.



Transmission/PTO Control Subsystem

Item	Description
1	Powertrain Control Module (PCM)
2	Solenoid Body
3	Valve Body
4	PTO Provision
5	Automatic Transmission Case

DUAL GENERATOR SUBSYSTEM



Dual Generator Subsystem

Item	Description
1	Warning Indicator Lamp
2	Powertrain Control Module (PCM)

Item	Description
3	Primary Generator
4	Secondary Generator

The charging system provides electrical current for battery charging and vehicle operation. Some vehicles, because of heavy use or special applications (wrecker or ambulance), may be ordered with a secondary generator. During glow plug operation, the PCM disables the secondary generator to limit available voltage to the glow plugs. High voltage could cause damage to the glow plugs.

REVIEW QUESTIONS

1. The 7.3L DIT electronic engine control system is divided into how many subsystems?
   A. three
   B. seven
   C. five
   D. ten
2. Which of the following is not an electronic engine control output?
   A. Turbocharger boost pressure control
   B. Transmission shift scheduling
   C. Starting aid operation
   D. Engine load
3. The ________________ and ________________ systems are responsible for controlling fuel timing and delivery.
4. The High-Pressure Oil system is used to:
   A. supply lube oil the crankshaft.
   B. lubricate the turbocharger.
   C. actuate the HEUI fuel injectors.
   D. operate the exhaust backpressure valve.
5. The system that has the greatest affect on assisting with cold starts is the:
   A. engine control subsystem.
   B. electronic fuel supply subsystem.
   C. glow plug control subsystem.
   D. none of the above.

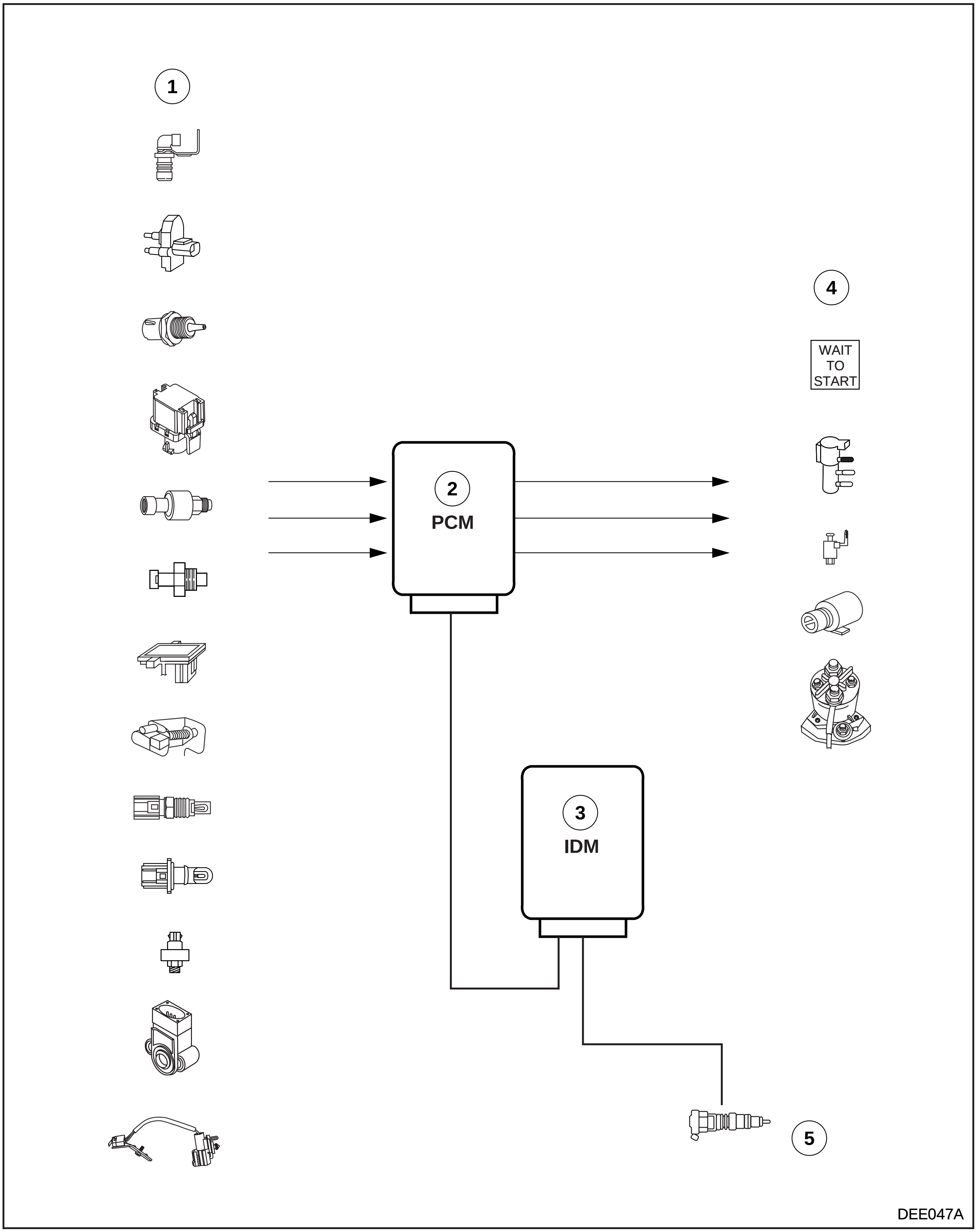
NOTES

TECHNICIAN OBJECTIVES

- Describe the function of the PCM.
- Describe the function of the IDM.
- Describe the inputs and outputs in the engine control subsystem.
- Describe the relationship between the inputs and outputs in the engine control subsystem.
- Describe the inputs and outputs in the glow plug control subsystem.
- Describe the relationship between the inputs and outputs in the glow plug control subsystem.
- Describe the inputs and outputs in the exhaust backpressure control subsystem.
- Describe the relationship between the inputs and outputs in the exhaust backpressure control subsystem.
- Describe the inputs and outputs in the electric fuel supply subsystem.
- Describe the relationship between the inputs and outputs in the electric fuel supply subsystem.
- Describe the inputs and outputs in the speed control subsystem.
- Describe the relationship between the inputs and outputs in the speed control subsystem.
- Describe the inputs and outputs in the transmission/PTO control subsystem.
- Describe the relationship between the inputs and outputs in the transmission/PTO control subsystem.
- Describe the inputs and outputs in the dual generator subsystem.
- Describe the relationship between the inputs and outputs in the dual generator subsystem.

CONTENTS

ELECTRONIC CONTROL SUBSYSTEM MODULES, INPUTS AND OUTPUTS



Electronic Control Subsystem Inputs and Outputs

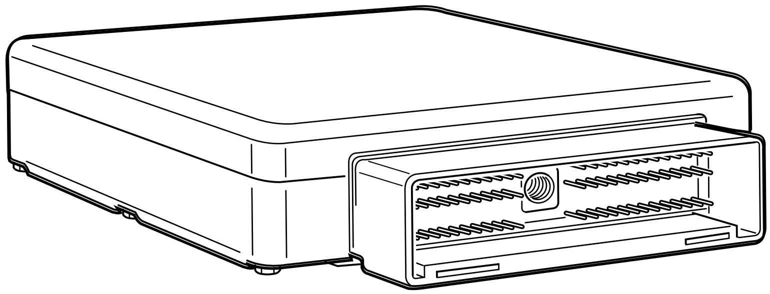
Item	Description
1	Inputs
2	Powetrain Control Module (PCM)
3	Injector Driver Module (IDM)

Item	Description
4	Outputs
5	Fuel Injector

The seven electronic control subsystems have a number of inputs and outputs associated with them. Each subsystem uses inputs to communicate with the PCM or the Injector Driver Module (IDM). Some of these subsystems share input signals. The PCM or IDM actuate outputs that manage these subsystems utilizing information obtained from the inputs, subsequently enhancing engine performance and reducing emissions. The seven subsystems and their inputs and outputs are explained in detail in this lesson.

The inputs within these subsystems send signals or information to the processor or Powertrain Control Module (PCM). The processor in turn uses this information to actuate outputs for engine performance management. On Board Diagnostic (OBD) strategies within the PCM are used to manage faults within the subsystems and allow the engine to operate at the highest efficiency level possible. This subsystem management allows for cleaner engine emissions and better performance.

Powertrain Control Module



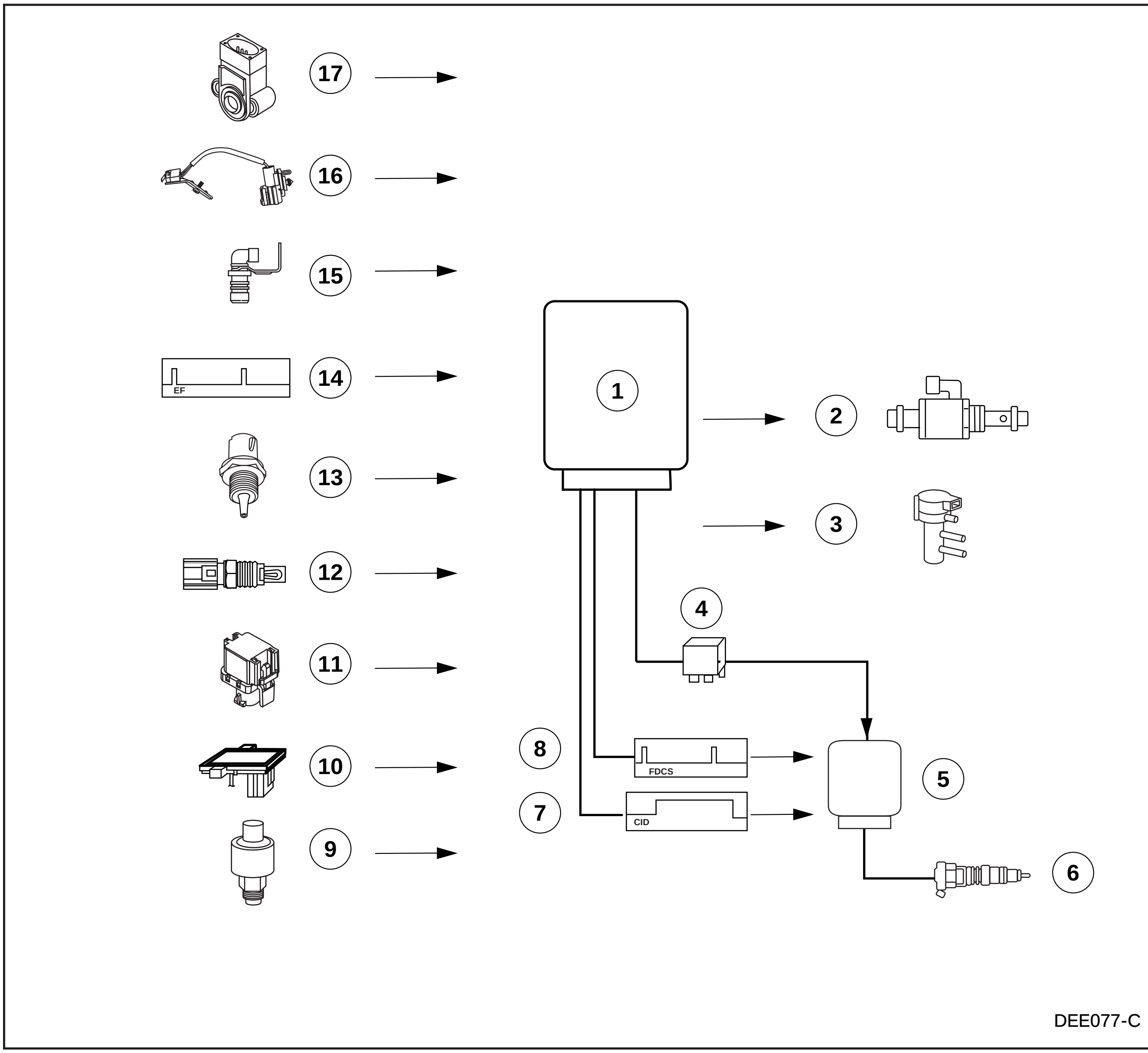
Powertrain Control Module

The EEC-V, 104-pin PCM is the heart of the electronic engine control system on the 7.3L DIT diesel engine. It monitors and controls powertrain operation to make sure maximum performance and emissions standards are met. The PCM is also used to monitor and control other vehicle features, such as speed control and shift patterns.

The PCM contains computer logic and programming to control engine and vehicle functions. The PCM receives input from sensors, processes the information and controls outputs such as the Injection Control Pressure Regulator (IPR). The PCM supplies a 5-volt reference voltage to some sensors and receives a signal that indicates an operating condition.

NOTES

Engine Control (Subsystem)



Engine Control (Subsystem) Inputs and Outputs

Item	Description
1	Powertrain Control Module (PCM)
2	Injection Control Pressure Regulator (IPR)
3	Wastegate Control (WCG) Solenoid
4	IDM Enable
5	Injector Driver Module (IDM)
6	Fuel Injector
7	Cylinder Identification (CID) Signal
8	Fuel Delivery Control Signal (FDCS)
9	Injection Control Pressure (ICP) Sensor

Item	Description
10	Manifold Absolute Pressure (MAP) Sensor
11	Barometric Pressure (BARO) Sensor
12	Manifold Air Temperature (MAT) Sensor
13	Engine Oil Temperature (EOT) Sensor
14	Electronic Feedback (EF) Signal
15	Camshaft Position (CMP) Sensor
16	Idle Validation Switch (IVS)
17	Accelerator Pedal (AP) Switch

Introduction to the Engine Control Subsystem

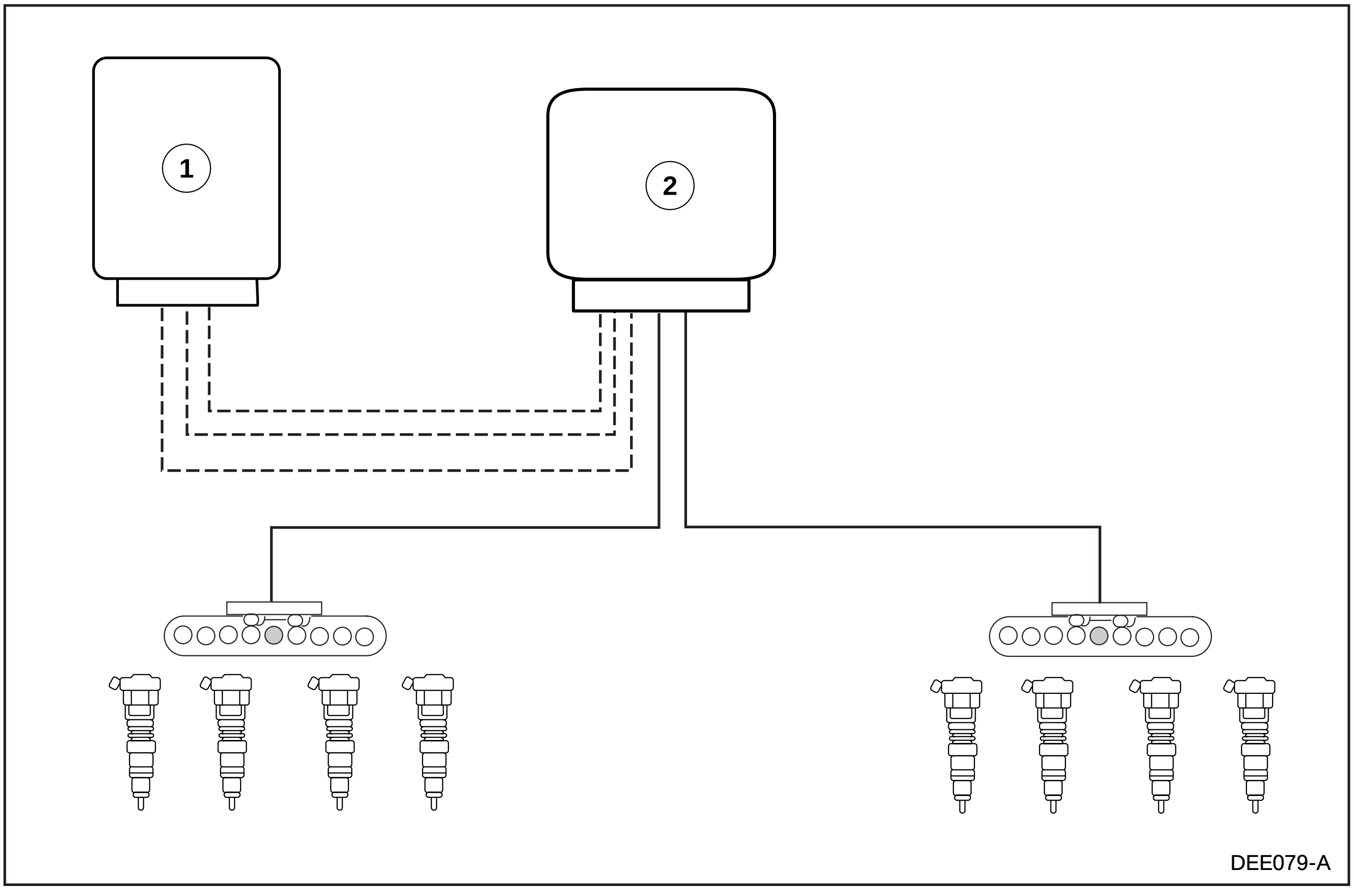
The engine control subsystem is the largest information processor of all the subsystems. Its responsibilities include fuel delivery, high oil pressure system control, and boost pressure control. The engine control subsystem can actually be broken down into three individual systems that work together. They are the fuel injection control and injection control pressure systems, both used for fuel timing and delivery, and the wastegate control system used to manage turbo boost pressure. Following is a list of all the inputs and outputs used for these three systems.

The engine control subsystem utilizes these inputs and outputs for operation by the PCM and IDM:

- Inputs
  - **Fuel Injection Control**
    - Accelerator Pedal (AP) sensor
    - Idle Validation Switch (IVS)
    - Camshaft Position (CMP) sensor
    - Electronic Feedback (EF) signal
    - Engine Oil Temperature (EOT) sensor
    - Manifold Air Temperature (MAT) sensor
    - Barometric Pressure (BARO) sensor
    - Manifold Absolute Pressure (MAP) sensor
  - **Injection Control Pressure**
    - Injection Control Pressure (ICP) sensor
  - **Wastegate Control**
    - Manifold Absolute Pressure sensor (MAP)
- Outputs
  - **Fuel Injection Control**
    - Injector Driver Module (IDM) and HEUI injectors
      - Fuel Delivery Control Signal (FDCS)
      - Cylinder Identification (CID) signal
    - IDM Enable (IDM_EN)
  - **Injection Control Pressure**
    - Injection Control Pressure Regulator (IPR)
  - **Wastegate Control**
    - Wastegate Control (WGC) solenoid

Fuel Injection Control

Introduction to the Fuel Injection Control Subsystem



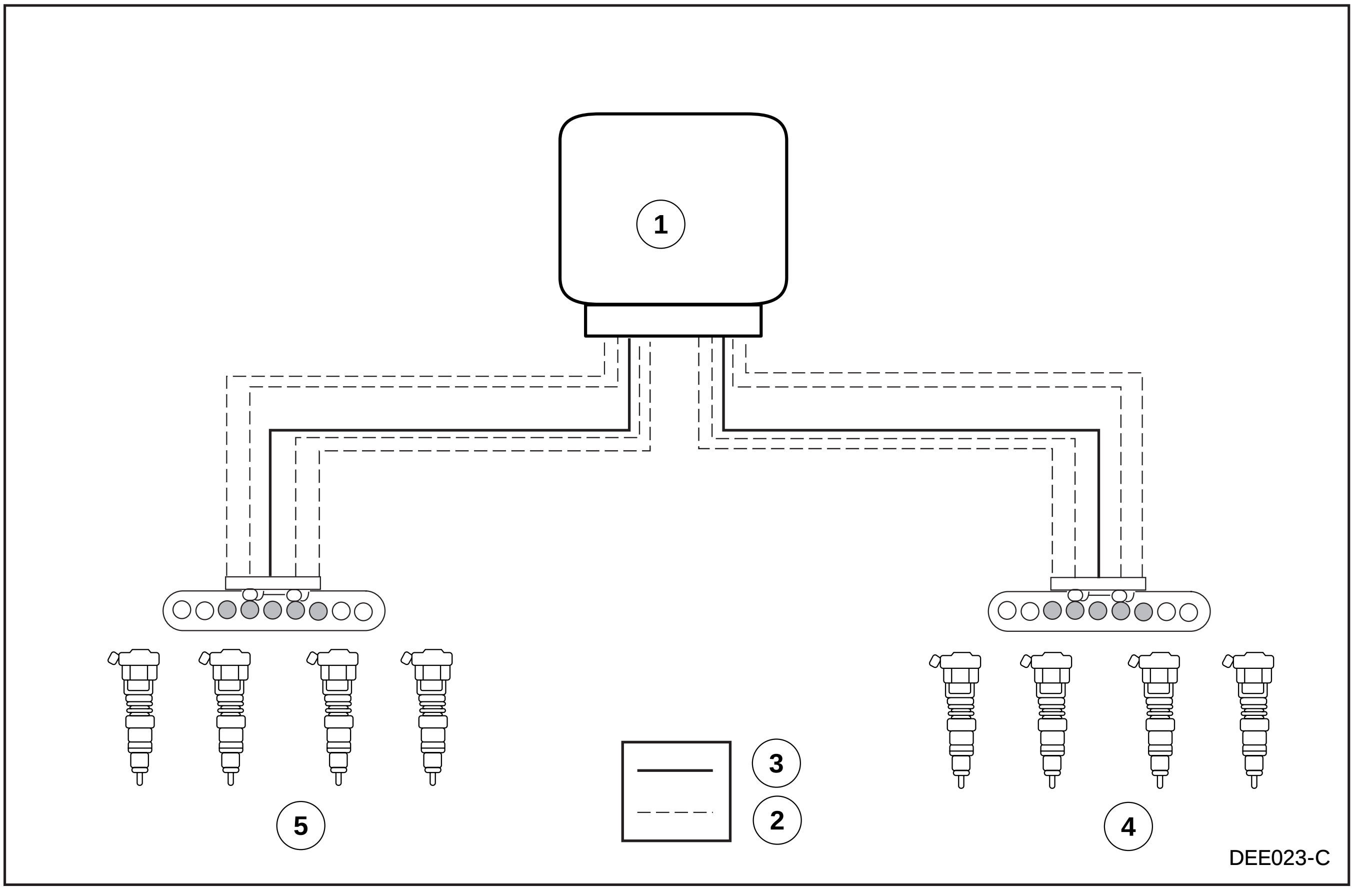
Fuel Injection Control Subsystem

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)

Precise delivery of fuel in a diesel engine is critical to correct operation. The Fuel Injection Control Subsystem is used to control this critical activity. This system controls both the timing and quantity of fuel delivered. The fuel injection control system consists of two modules: the PCM, IDM and fuel injector. The PCM receives inputs to indicate accelerator pedal position. Engine rpm and camshaft position information are also required. In addition, the PCM receives signals that indicate engine temperature and intake manifold temperature, as well as barometric pressure.

The PCM uses this information to control the IDM. The IDM then supplies the current required to energize the injectors at the correct time for precise fuel timing and delivery.

Function of the Injector Driver Module (IDM)



Injector Driver Module (IDM)

Item	Description
1	Injector Driver Module (IDM)
2	Injector Ground Circuit
3	Power Circuit to Injector (115V)

Item	Description
4	RH Fuel Injectors
5	LH Fuel Injectors

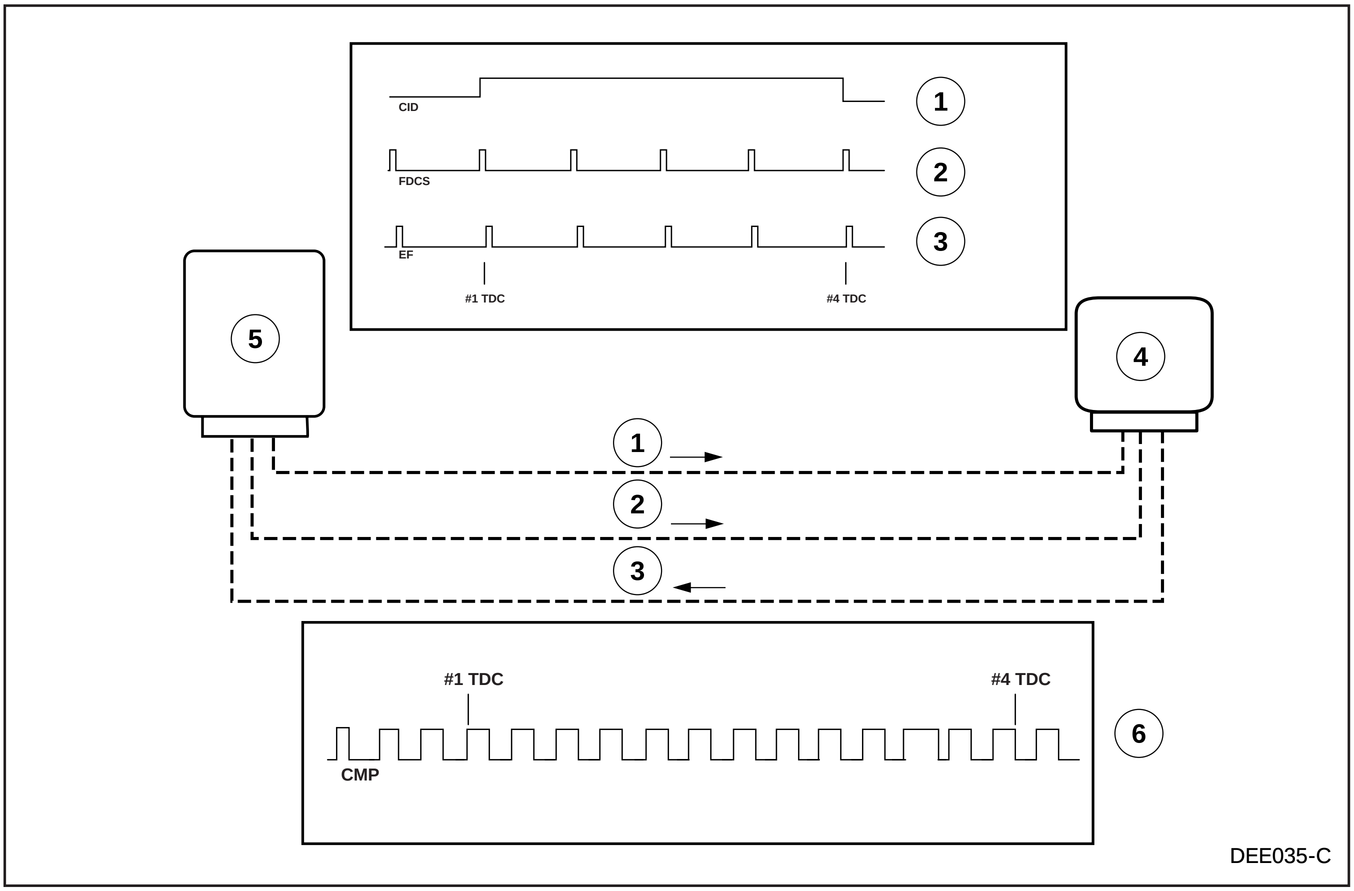
The IDM is a high-energy power supply that controls the fuel injectors. The IDM contains a step-up transformer that boosts the supply voltage up to approximately 115 volts DC. The IDM contains solid-state components, so there are no user repairable parts or adjustments.

There are two high side drivers, one for each cylinder bank; and eight low side drivers, one for each injector. The function of the high side driver is to supply 115 volts DC to the injectors. The low side drivers provide a ground for each individual injector. To actuate an injector, the IDM grounds the circuit from the injector, which energizes the injector solenoid.

The injector driver module enable is an output of the PCM that is used to energize the IDM relay which will provide power to the IDM.

WARNING: DO NOT CARRY OUT ANY VOLTAGE CHECKS WITH THE ENGINE RUNNING. 115 VOLTS DC AT 7-15 AMPS IS PRESENT ON INJECTION CIRCUITS. DO NOT PIERCE THE HARNESS; SEVERE ELECTRICAL SHOCK MAY OCCUR. FOLLOW THE WORKSHOP MANUAL PROCEDURES. SHIELDED WIRES IN THE RED-STRIPED HARNESS ARE HIGH VOLTAGE AND SHOULD NOT BE PROBED.

Communication Signals Between the PCM and IDM



Injector Driver Module (IDM)

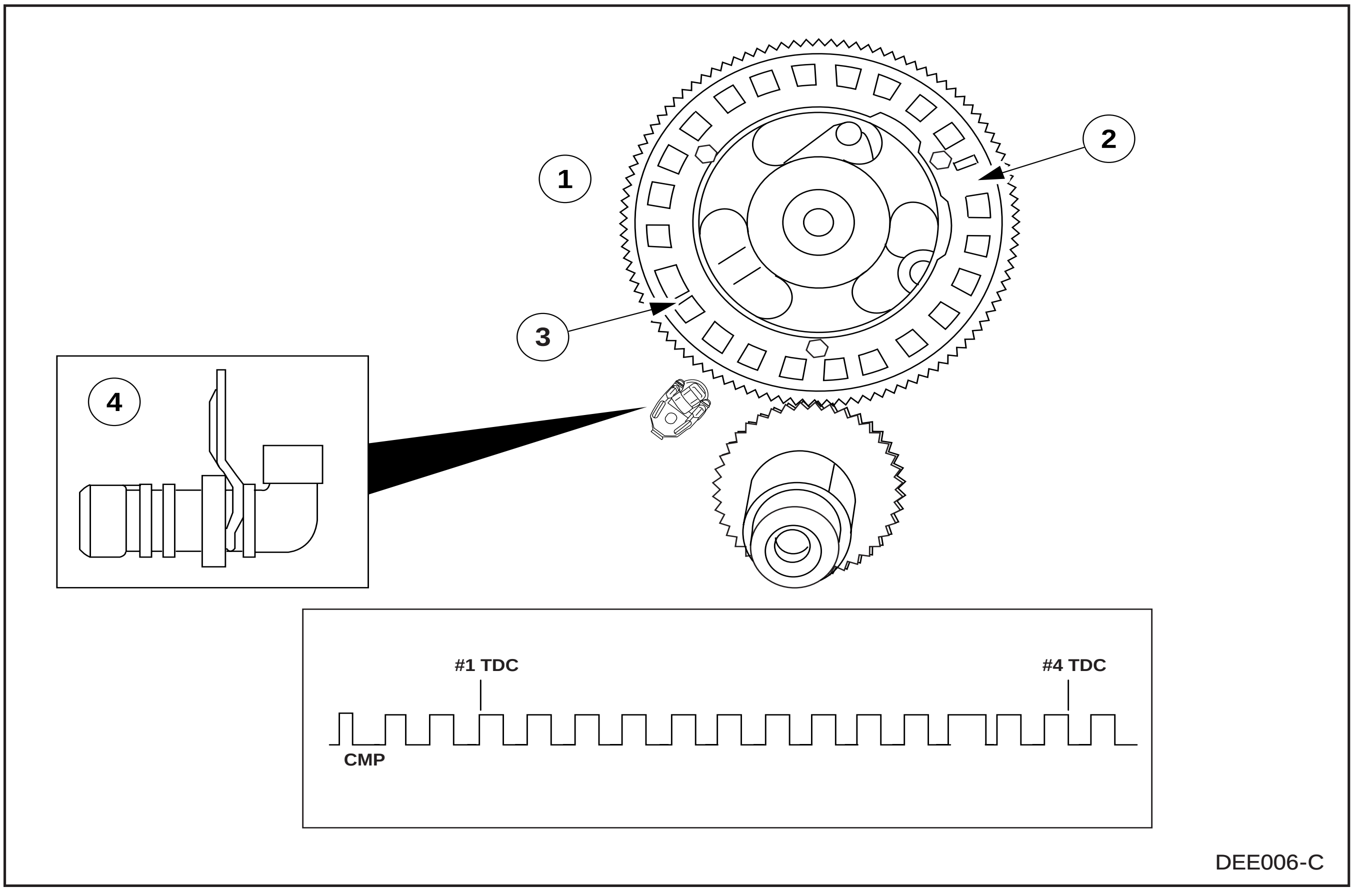
Item	Description
1	Cylinder Identification (CID) Signal
2	Fuel Delivery Control Signal (FDCS)
3	Electronic Feedback (EF) Signal

Item	Description
4	Injector Driver Module (IDM)
5	Powertrain Control Module (PCM)
6	Camshaft Position (CMP) Signal

The Injector Driver Module (IDM) controls power to the fuel injectors based on information received from the PCM. The IDM receives two digital control signals from the PCM: the Fuel Delivery Control Signal (FDCS) and the Cylinder Identification (CID) signal. The FDCS indicates engine rpm and is used by the IDM to control injection timing and injection duration. The CID signal provides synchronization to the engine's first and the fifth injector (firing order, cylinders one and four). The Electronic Feedback (EF) signal is used to send DTC information about the IDM and injectors (electrical portion) to the PCM.

The Camshaft Position (CMP) sensor signal is used by the PCM to generate both the CID and the FDCS signals.

Camshaft Position (CMP) Sensor



Camshaft Position (CMP) Sensor

Item	Description
1	Trigger Wheel
2	Wide Vane

Item	Description
3	Narrow Vane
4	Camshaft Position (CMP) Sensor

The Camshaft Position (CMP) sensor is a Hall-effect sensor, located in the front of the engine on the timing gear cover. The CMP generates a digital frequency as vanes in a trigger wheel pass through a magnetic field. The trigger wheel is located on the camshaft drive gear. The frequency of the vanes passing by the sensor indicates engine speed. The position of cylinder number one is indicated by a narrow vane on the trigger wheel, and the number four cylinder (fifth in firing order) is indicated by a wide vane on the trigger wheel. This information is used by the PCM to generate the CID signal.

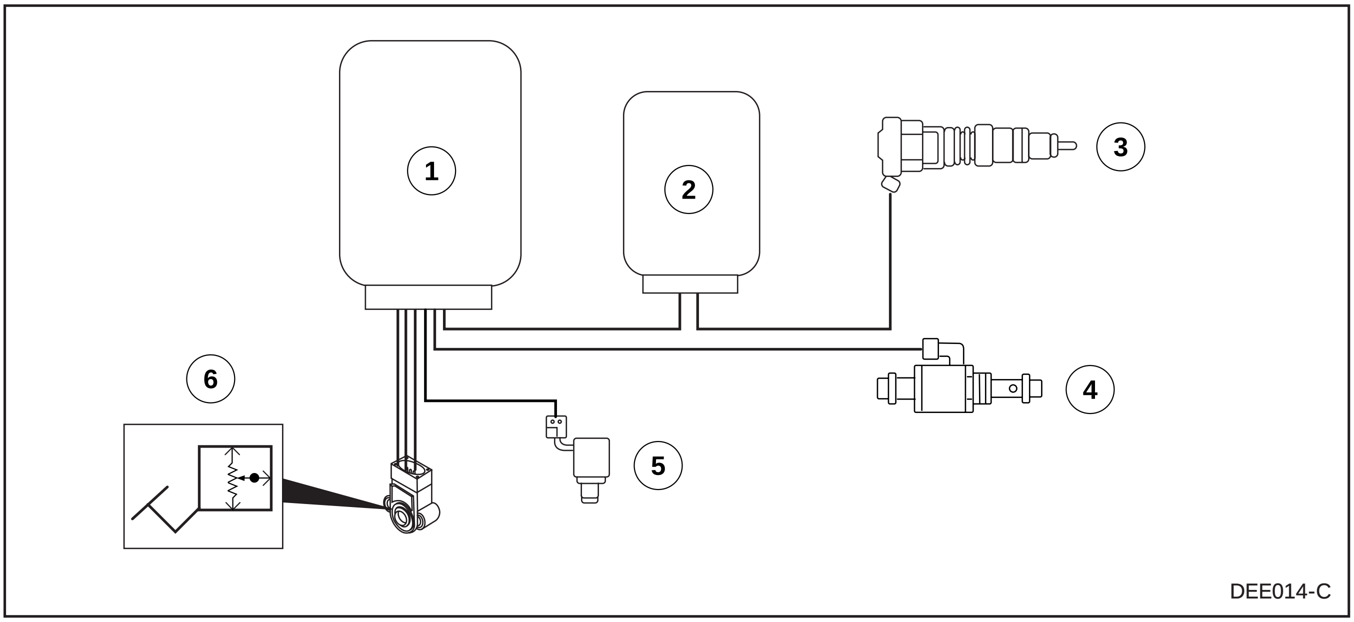
The CMP sensor provides engine speed and camshaft position information to the PCM. The PCM uses this information to control injection pressure, injection timing and fuel quantity. The CMP signal is also used by the PCM to provide an output to the exhaust backpressure subsystem and the instrument cluster mounted tachometer .

Gold-Plated Pins

Some engine control hardware components, such as the CMP, have gold-plated pins on the connector terminals and mating harness terminals to improve electrical stability for low current draw circuits and to reduce corrosion of the connections.

⚠ **CAUTION: Damaged gold-plated terminals should only be replaced with new gold-plated terminals. Do not mix gold- and tin-plated terminals as accelerated corrosion may cause excessive resistance at the connector due to corrosion.**

Accelerator Pedal (AP) Sensor



Accelerator Pedal (AP) Sensor

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Drier Module (IDM)
3	Fuel Injector
4	Injection Control Pressure (ICP) Regulator
5	Exhaust Backpressure (EBP) Regulator
6	Accelerator Pedal (AP) Position Sensor

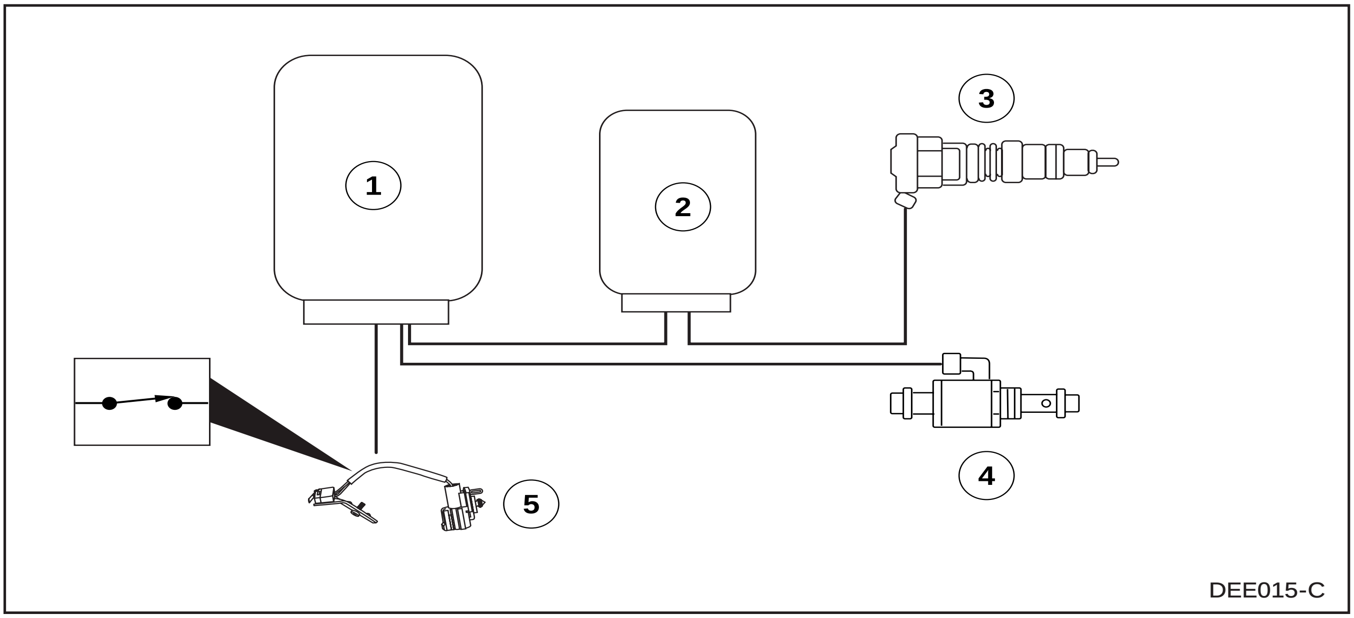
The Accelerator Pedal (AP) position sensor is a potentiometer, attached to the accelerator pedal assembly. The AP sensor detects the position of the accelerator pedal assembly and sends this information to the PCM as a varying analog voltage signal.

The 7.3L DIT diesel engine does not use any mechanical linkages or cables from the accelerator pedal to control engine speed. Instead, control is accomplished through electronic signals from the AP sensor to the PCM.

The PCM uses the AP sensor information to detect the driver demand for power. The AP sensor signal is used by the PCM to help calculate and control desired fuel quantity, injector timing, and injection control pressure.

The AP sensor signal is also used as an input for the exhaust backpressure subsystem.

Idle Validation Switch (IVS)



Idle Validation Switch (IVS)

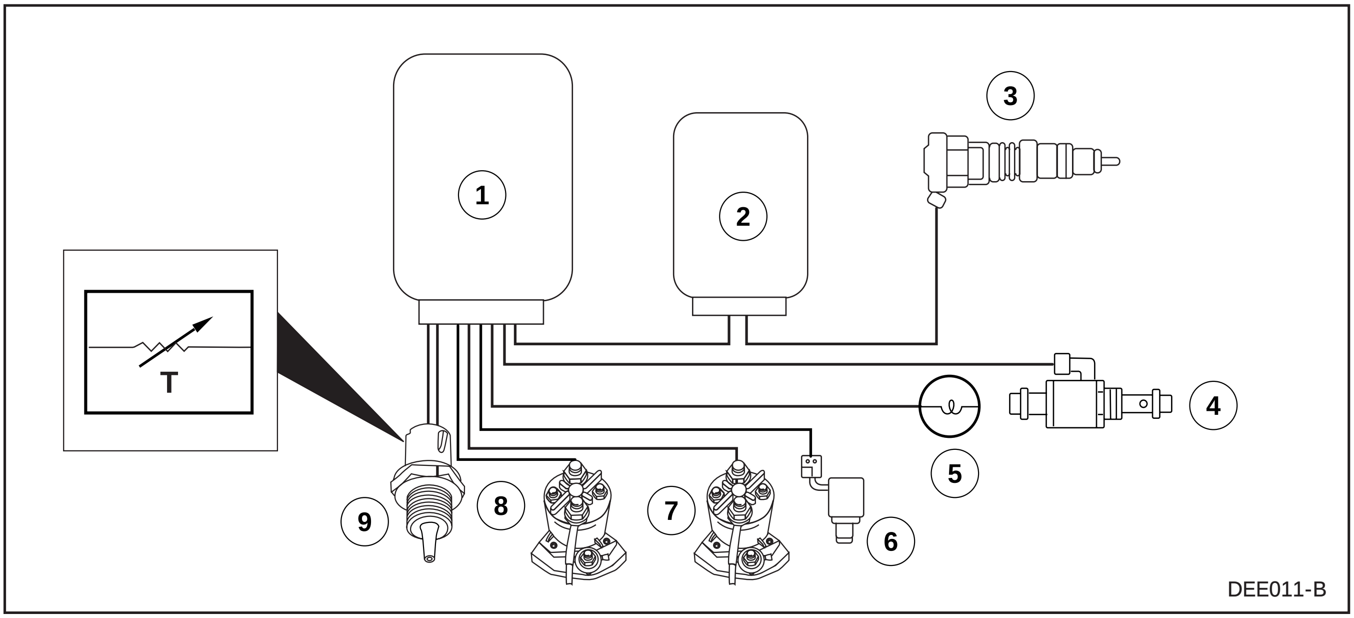
Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)
3	Fuel Injector

Item	Description
4	Injection Pressure Regulator (IPR)
5	Idle Validation Switch (IVS)

The Idle Validation Switch (IVS) is a power-side switch, located on the accelerator pedal assembly. The IVS provides the PCM with a redundant signal.

The PCM uses the IVS signal to verify when the accelerator pedal is either in the idle (switch is open), or off idle (switch is closed) position, and to detect in-range failure of the AP sensor. If a disagreement of IVS and AP sensor is detected by the PCM, the engine will be allowed to operate only at idle.

Engine Oil Temperature (EOT) Sensor



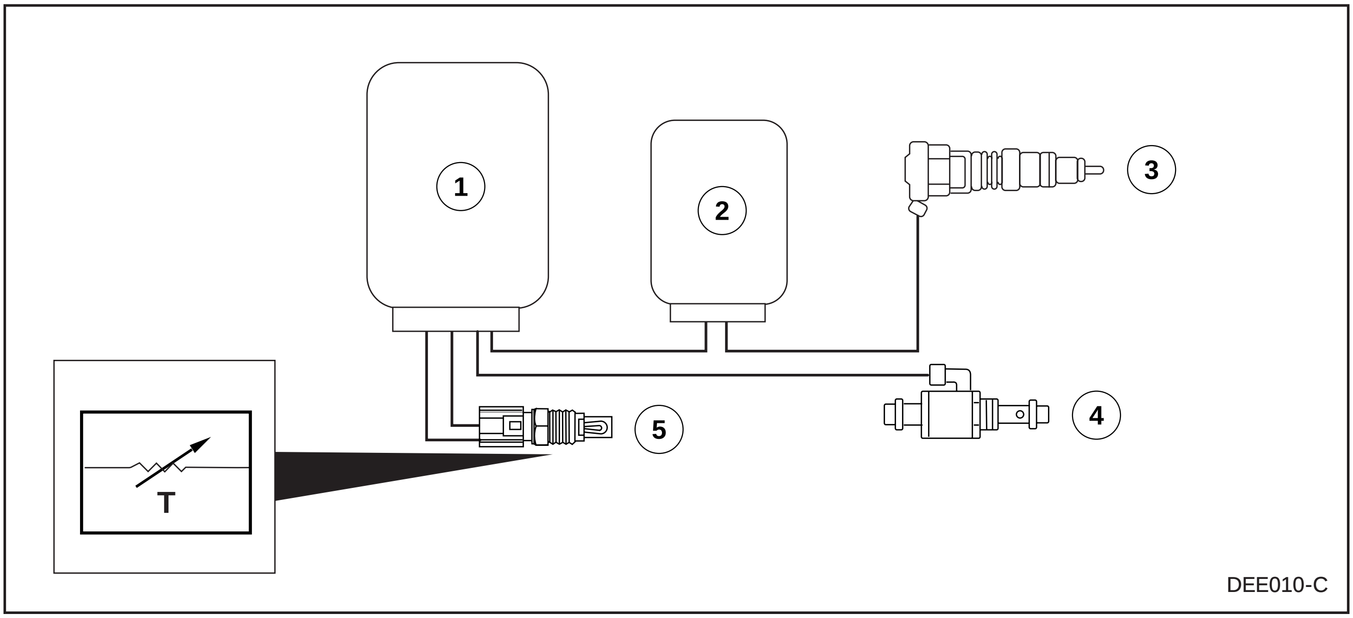
Engine Oil Temperature (EOT) Sensor

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)
3	Injector
4	Injection Control Pressure (IPR) Regulator

Item	Description
5	Glow Plug Lamp
6	Exhaust Backpressure (EBP) Regulator
7	Intake Air Heater Relay
8	Glow Plug Relay (GPR)
9	Engine Oil Temperature (EOT) Sensor

The engine oil temperature (EOT) sensor is a thermistor, mounted to the high-pressure oil reservoir. It sends an analog signal to the PCM to indicate engine oil temperature. As oil temperature increases, signal voltage will decrease. The EOT signal is used by the PCM to calculate fuel quantity and injection timing. The EOT signal is also used to calculate glow plug, and wait to start lamp on time, as well as the need to initiate intake air heater relay, and exhaust backpressure subsystem operation.

Manifold Air Temperature (MAT) Sensor



Manifold Air Temperature (MAT) Sensor

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)
3	Injector

Item	Description
4	Injection Control Pressure (IPR) Regulator
5	Manifold Air Temperature (MAT) Sensor

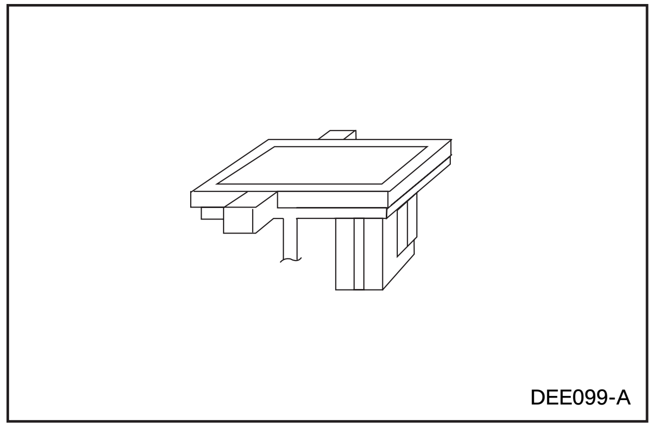
The Manifold Air Temperature (MAT) sensor is a thermistor, located in the charge air cooler housing. The MAT sensor measures intake air temperature after passing through the charge air cooler.

The information provided by the MAT is used by the PCM to calculate air density. The PCM uses this information to adjust fuel quantity and injection timing. The MAT sensor is only found on vehicles equipped with a charge air cooler because of a greater variance in air temperature.

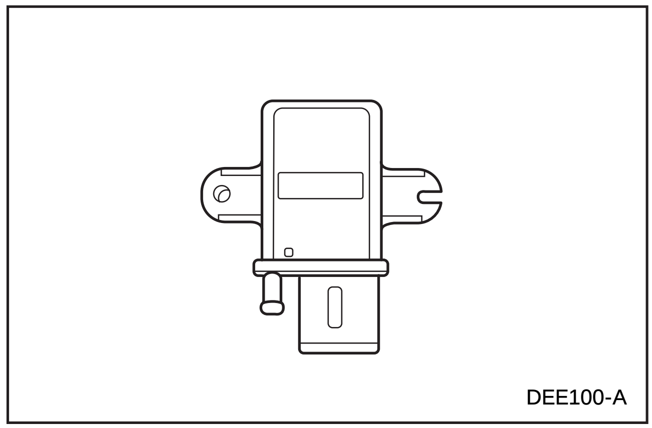
The Manifold Absolute Pressure (MAP) sensor is used to measure intake manifold pressure. There are two different types of MAP sensors for the 7.3L DIT: digital and analog. The digital sensor generates a variable frequency, and the analog sensor produces a variable voltage signal. These two types are not interchangeable. The MAP sensor is commonly located in the cowl area under the hood and has a hose attached to the intake manifold.

Information supplied by the MAP sensor is used by the PCM to control fuel quantity, and injector timing. The MAP sensor signal is also used to control turbocharger boost pressure.

The MAP sensor signal also controls smoke from the exhaust by limiting fuel quantity during acceleration, until a specific boost pressure is obtained.

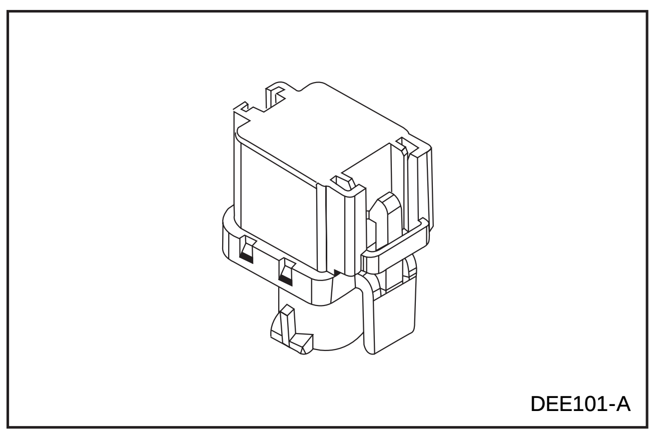


Analog Manifold Absolute Pressure (MAP) Sensor



Digital Manifold Absolute Pressure (MAP) Sensor

The Barometric Pressure (BARO) sensor is a variable capacitance sensor located inside the vehicle. On 99½ and newer vehicles, the BARO sensor is incorporated in the PCM. The BARO produces an analog signal proportional to atmospheric pressure. The PCM uses the BARO sensor to adjust fuel timing and delivery based on altitude. The BARO sensor signal is also used to control the glow plug subsystem.



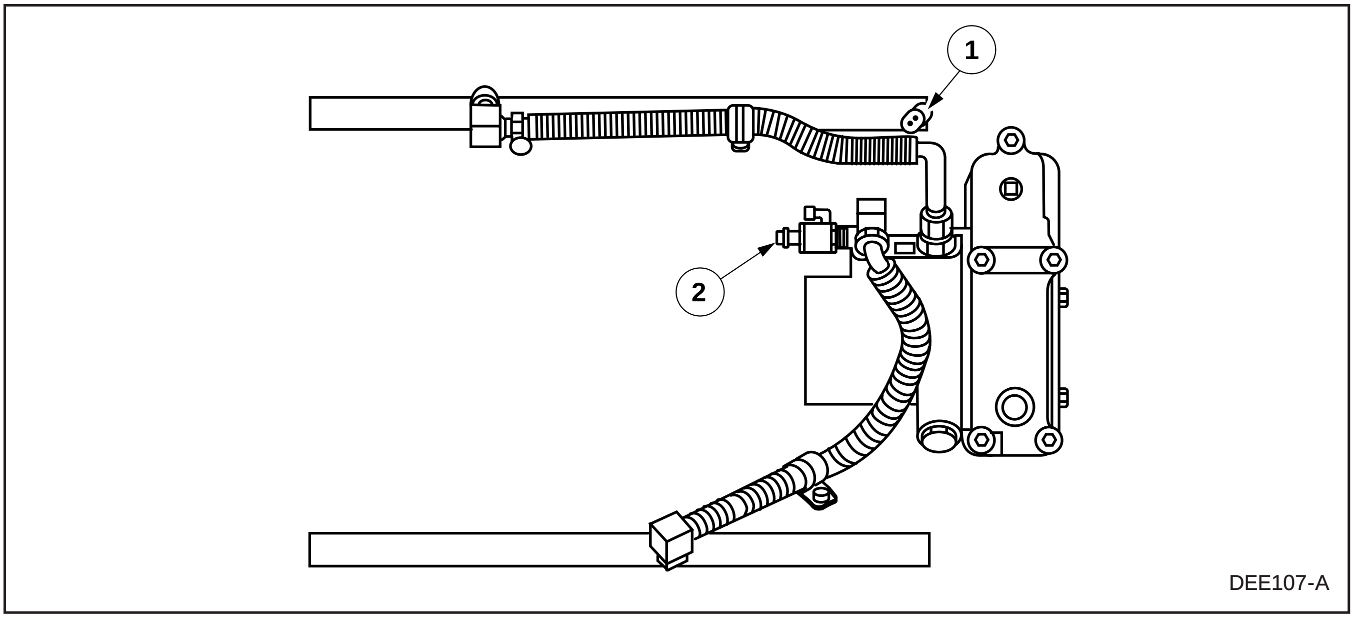
Barometric Pressure (BARO) Sensor

Fuel Injection Control Subsystem Summary

The AP signal allows the PCM to determine the driver request for more power when the accelerator pedal is depressed down. The PCM uses this information to deliver more fuel. This is accomplished by increasing ICP pressure and injector pulse width. The CMP signal is received by the PCM and allows it to then send the FDCS and CID signals to the IDM for precise fuel control. Because the amount of fuel required would vary based on temperature and air pressure, the PCM needs to make the necessary adjustments for these variables also. The EOT, MAT, MAP and BARO are used to provide input for those calculations. If a fault is detected in the IDM, or an electrical part of an HEUI injector, a DTC will be sent to the PCM by the IDM through the electronic feedback (EF) signal.

Injection Control Pressure (Subsystem)

Introduction to the Injection Control Pressure Subsystem



Injection Control Pressure (Subsystem)

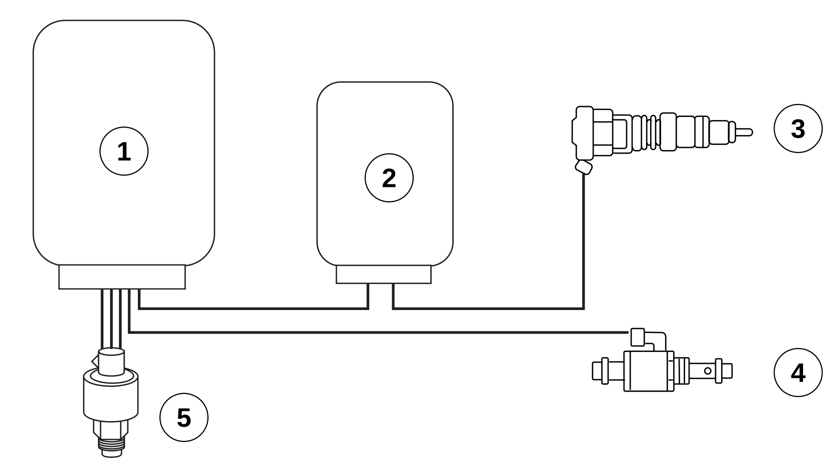
Item	Description
1	Injection Control Pressure (ICP) Sensor
2	Injector Pressure Regulator (IPR)

High-pressure oil is used to control fuel injection pressure. The Injection Control Pressure Subsystem carries out the task of controlling the high-pressure oil to the injectors. A sensor is used to measure the pressure within the high-pressure oil rails. A variable position control valve located on the high-pressure pump is used to manage oil pressure within the system.

This is known as a closed loop system because a sensor constantly monitors the output and adjustments are made based on this feedback. This is done to maintain the required amount of oil pressure within the high-pressure oil system for correct operation of the HEUI injectors.

NOTES

Injector Pressure Regulator (IPR)



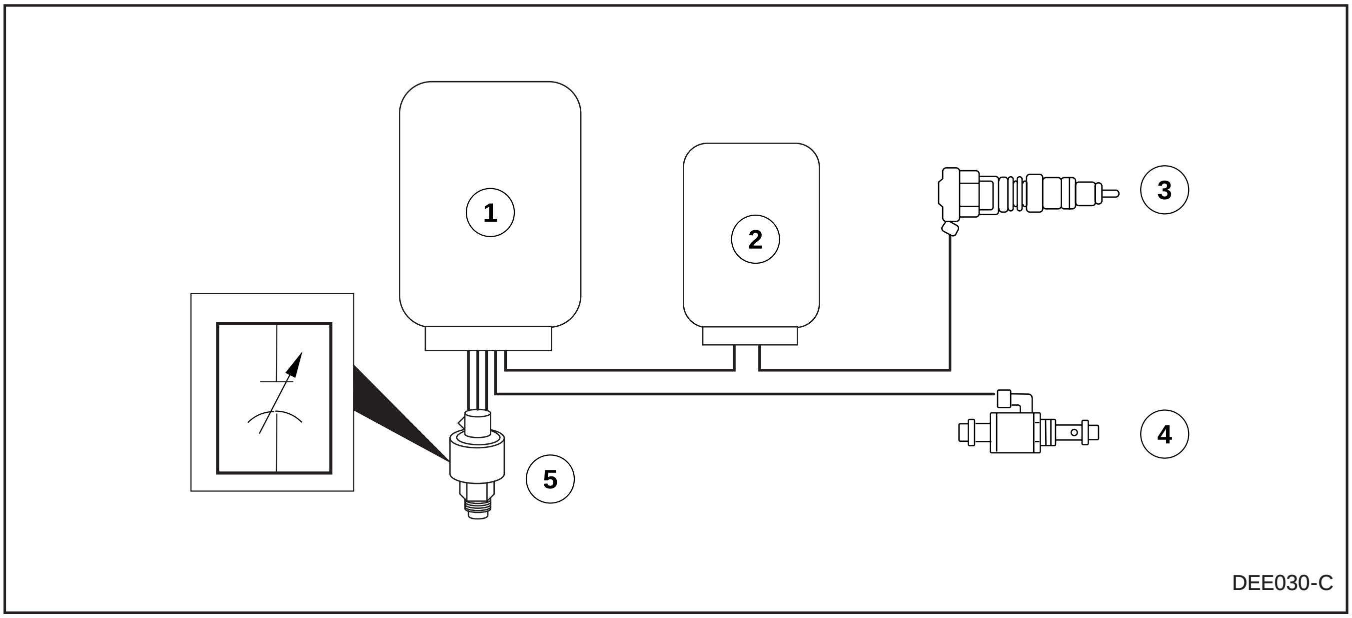
Injector Pressure Regulator (IPR)

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)
3	Injector

Item	Description
4	Injection Control Pressure Regulator (IPR)
5	Injection Control Pressure (ICP) Sensor

The Injection Pressure Regulator (IPR) is a variable force solenoid located on the high-pressure oil pump. The solenoid is used to control high-pressure oil delivery to the injectors. High-pressure oil is regulated by redirecting oil to the sump, rather than delivering it to the injectors. The PCM regulates current to control valve position. As IPR percentage (current) is increased, the amount of injection control pressure delivered to the injectors is also increased. Together the ICP and the IPR form a closed loop system.

Injection Control Pressure (ICP) Sensor



Injection Control Pressure (ICP) Sensor

Item	Description
1	Powertrain Control Module (PCM)
2	Injection Control Pressure (ICP) Sensor
3	Injector

Item	Description
4	Injection Control Pressure Regulator (IPR)
5	Injection Control Pressure (ICP) Sensor

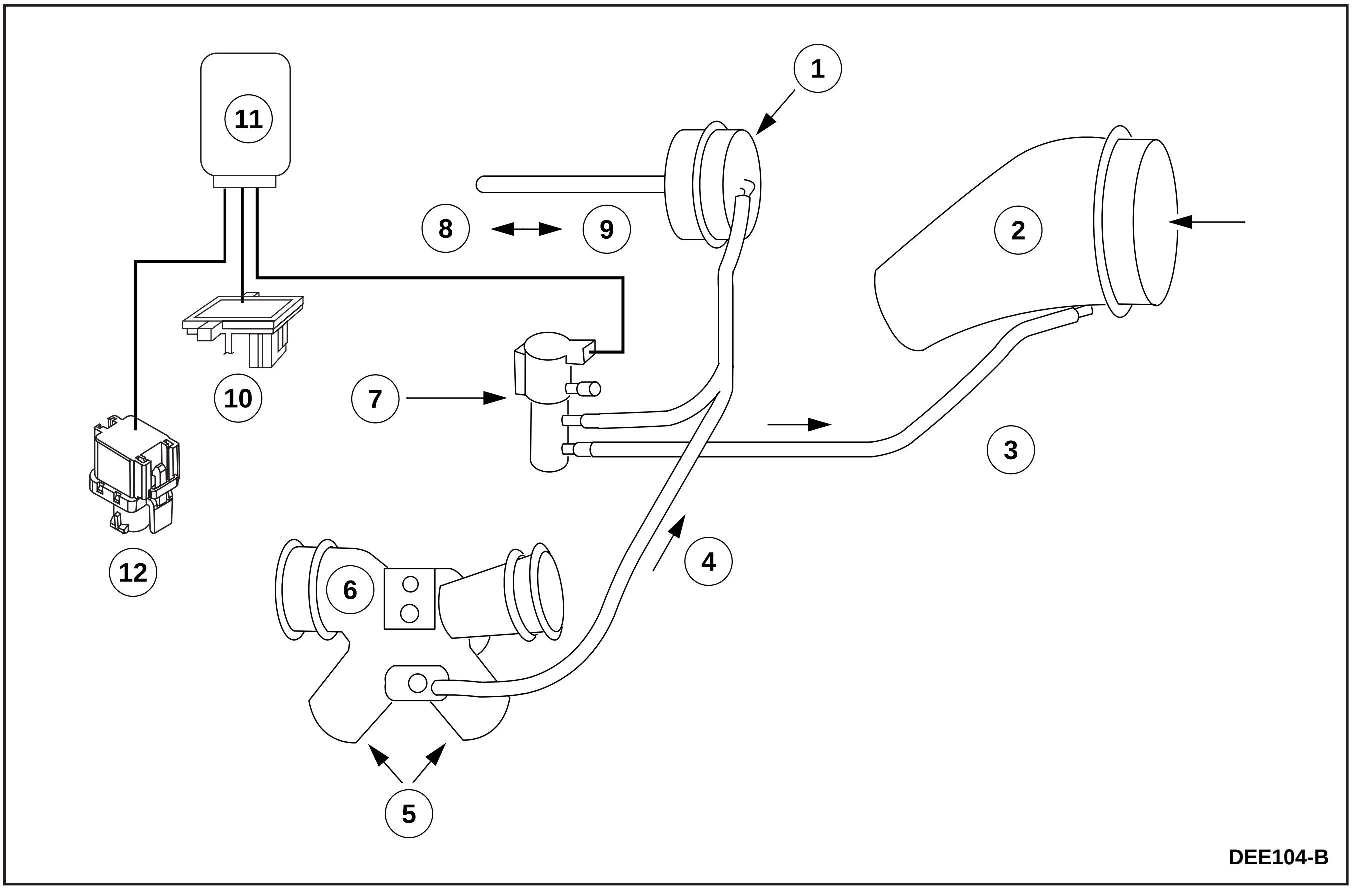
The Injection Control Pressure (ICP) sensor is a variable capacitance sensor that is threaded into the left cylinder head. It produces an analog signal proportional to the pressure in the left-hand high-pressure oil rail. The PCM uses this information to determine injection control pressure.

Injection Control Pressure Subsystem Summary

The PCM uses the signal from the ICP sensor to determine the need to increase or decrease oil pressure in the rails of the cylinder heads. Normal operating pressures can vary from approximately 3,103 kPa to 20,685 kPa (450 to 3,000 psi), based on fuel system requirements. This is accomplished by increasing or decreasing current to the IPR through a pulse width modulated signal from the PCM. The IPR duty cycle percentage can range from 0 to 65%, based on the oil pressure needed to meet fuel system demands. An increase in injector control pressure results in an increase in fuel volume, with little or no change in injector pulse width.

Wastegate Control (Subsystem)

Introduction to the Wastegate Control Subsystem



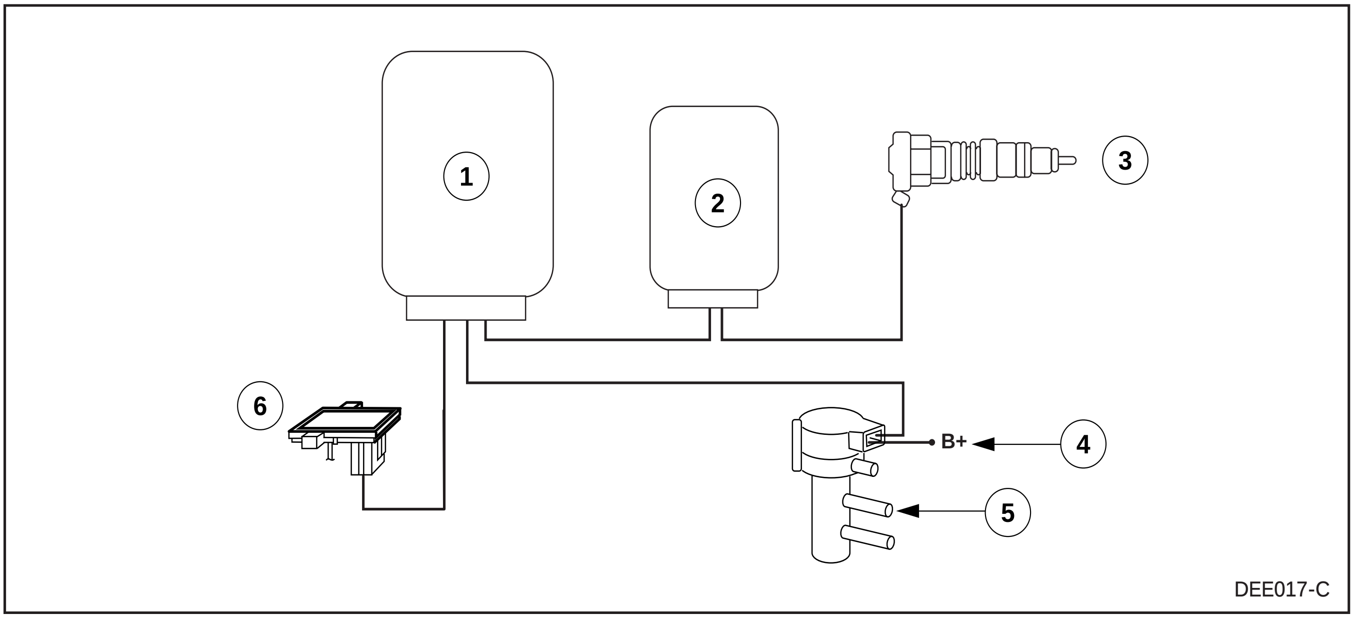
Wastegate Control System

Item	Description
1	Wastegate Control (WGC) Actuator
2	Air Inlet (To Turbocharger)
3	Bleed To Air Inlet
4	Intake Manifold Pressure
5	To Cylinder Heads
6	Charge Air Cooler (CAC) Housing
7	Wastegate Control (WGC) Solenoid

Item	Description
8	Wastegate Open
9	Wastegate Closed
10	Manifold Absolute Pressure (MAP) Sensor
11	Powertrain Control Module (PCM)
12	Barometric Pressure (BARO) Sensor

On vehicles equipped with a turbocharger, a wastegate may be used to control boost pressure. The wastegate is a small valve located in the turbine side of the turbocharger housing. When boost pressure reaches its maximum limit, the wastegate is opened to control the speed of the turbine and compressor wheels, thereby optimizing boost pressure. An actuator and a solenoid control the wastegate. The PCM controls the wastegate control solenoid, which is used to allow boost pressure to be applied to or diverted from the actuator. Manifold pressure is measured to indicate boost pressure to the PCM.

Wastegate Control (WGC) Solenoid



Wastegate Control (WGC) Solenoid

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)
3	Injector
4	Battery Voltage

Item	Description
5	Wastegate Control (WGC) Solenoid
6	Manifold Absolute Pressure (MAP) Sensor

Turbocharger boost pressure is controlled by a wastegate. The wastegate is controlled by a solenoid and a WGC actuator. The PCM uses a duty cycle to control the wastegate solenoid. When boost pressure is too high, the PCM sends a low percentage duty cycle to the wastegate solenoid to open the wastegate and reduce boost pressure. When the duty cycle is increased, boost pressure is bled from the WGC actuator, spring tension closes the wastegate, and the turbocharger is once again allowed to build boost.

Wastegate Control Subsystem Summary

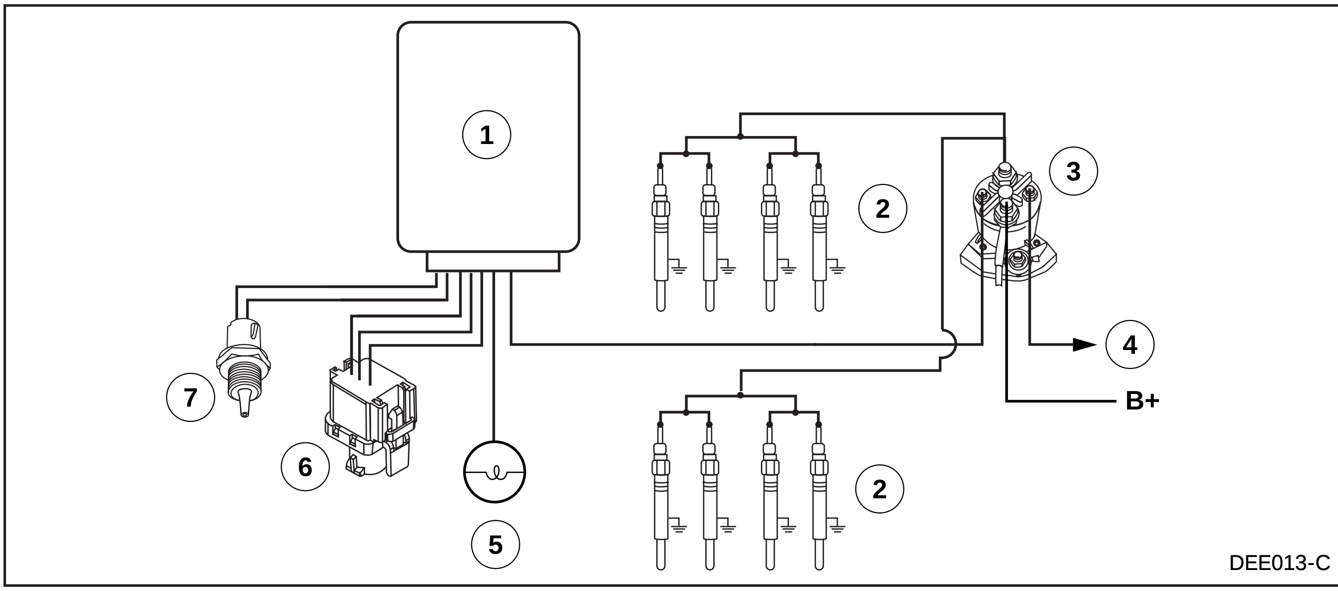
The MAP sensor signal is used by the PCM to determine turbocharger boost pressure. When boost pressure reaches its maximum levels, 104.8-124.1 kPa (15-18 psi), the PCM sends a duty cycle signal to the WGC solenoid to apply boost pressure to the wastegate actuator. At approximately 34.5 kPa (5 psi), spring pressure in the wastegate actuator is overcome, and the wastegate is opened. As boost pressure decreases, the WGC solenoid allows boost pressure to bleed back into the air inlet. This allows the wastegate to close, and boost pressure to develop again.

The MAP sensor reads absolute pressure; as a result MAP sensor readings will indicate both atmospheric pressure plus boost pressure.

Engine Control Subsystem Summary

Let’s look at an example of how all these systems work together. While driving down the road, the driver approaches a hill and presses on the accelerator pedal to maintain vehicle speed. The voltage signal from the AP sensor is increased. The voltage increase signals the demand for more power. In order to meet the demand the PCM will need to increase the amount of fuel being injected into the engine without increasing the levels of emissions. The PCM determines how much ICP will need to be increased based upon strategies programmed into its memory, and monitors the ICP to determine if the desired pressure has been achieved. Based on the ICP sensor reading, the PCM determines how much injection control pressure will need to be increased this increased pressure will allow the injectors to supply more fuel. The manifold temperature signal from the MAT sensor and the engine oil temperature signal from the EOT sensor are monitored by the PCM and assist in the calculation of fuel delivery. The CMP sensor information allows the PCM to send the FDCS and CID signals to the IDM to adjust the fuel pulse width for the rpm increase. As the load increases while starting up the hill, turbocharger boost pressure within the intake manifold increases. This is a result of more fuel being supplied, increasing the exhaust temperature and volume, thus causing the turbine and compressor wheels to spin faster. The PCM detects this increase in boost through the MAP sensor. The MAP sensor input may also be used for fuel timing and delivery. As boost pressure reaches its maximum level, 104.8-124.1 kPa (15-18 psi), the PCM decreases the duty cycle to the WGC solenoid. This allows boost pressure to be applied to the wastegate actuator, which opens the wastegate and permits the turbo to run at peak speed without restricting exhaust flow. All these events are taking place at the same time within the engine control subsystem. The PCM is constantly monitoring inputs and adjusting outputs to achieve peak performance.

Introduction to the Glow Plug Control Subsystem



Glow Plug Control (Subsystem)

Item	Description
1	Powertrain Control Module (PCM)
2	Glow Plugs
3	Glow Plug Relay (GPR)
4	To Ignition Switch

Item	Description
5	Glow Plug Lamp (GPL)
6	Barometric Pressure (BARO) Sensor
7	Engine Oil Temperature (EOT) Sensor

The Glow Plug control Subsystem is used to improve cold start characteristics and reduce white smoke during cold engine operation. This is accomplished by using glow plugs to heat the combustion chambers prior to starting the engine. The glow plugs are located in the cylinder heads under the valve covers and are supplied with current from the Glow Plug Relay (GPR). The PCM reads the EOT and BARO sensor signals to determine glow plug on time and then energizes the relay up to 120 seconds. The colder the engine oil, the longer the glow plugs will need to heat the combustion chambers. The PCM also reads battery voltage to protect the glow plugs from being damaged if battery voltage is abnormally high. The PCM illuminates the Glow Plug Lamp (GPL) for up to 10 seconds when the ignition key is turned to the ON position. After the lamp goes out, the vehicle is ready to be started. GPL illumination time is independent of glow plug relay on time. The glow plugs may continue to be energized after the vehicle is started, to reduce white smoke.

The glow plug control system utilizes these inputs and outputs for operation by the PCM:

- Inputs
  - Barometric Pressure (BARO) sensor
  - Engine Oil Temperature (EOT) sensor
  - Battery voltage (B+)
- Outputs
  - Glow Plug Relay (GPR)
  - Glow Plug Lamp (GPL)

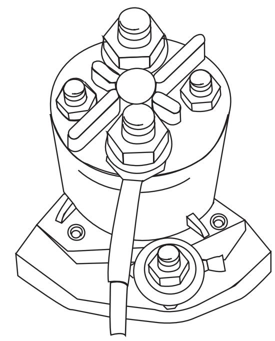
Glow Plug Relay (GPR)

The PCM uses the Glow Plug Relay (GPR) to control current flow to the glow plugs. The PCM controls the on time of the glow plugs based on engine oil temperature, barometric pressure, and battery voltage. On time normally varies between 1 and 120 seconds. The glow plugs may stay on after the engine has started to improve cold engine idle and reduce white smoke.

The glow plugs are self-limiting, which prevents overheating. As a result, they do not require cycling on and off. The glow plug relay will cycle on and off repeatedly only when system voltage is greater than 14.5 volts, due to an over-charging condition.

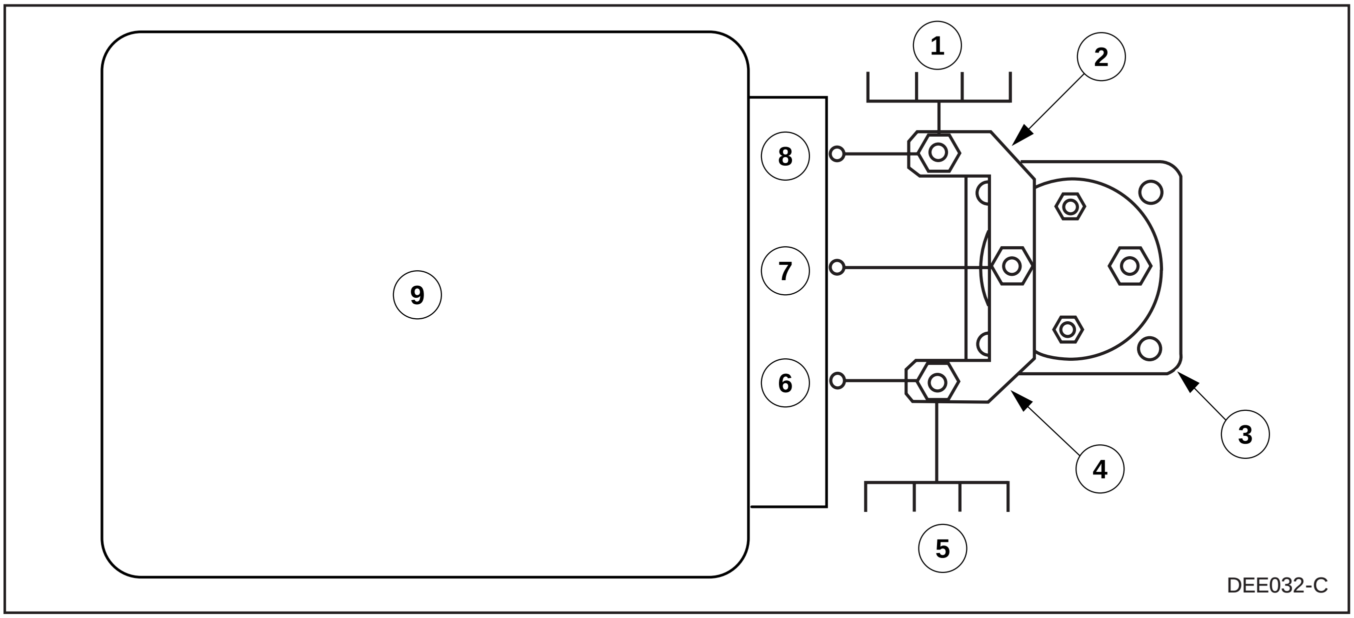
Glow Plug Lamp (GPL)

The Glow Plug Lamp (GPL), or WAIT TO START lamp is located on the instrument panel. The light comes on every time the ignition key is turned ON. On time normally varies between 2 and 10 seconds. When the lamp turns OFF, the engine is ready to be started. The WAIT TO START lamp on time is independent from the glow plug relay on time.



Glow Plug Relay (GPR)

Glow Plug Monitor



Glow Plug Monitor

Item	Description
1	Glow Plugs (Right Bank)
2	Glow Plug Monitor Shunt (Right Bank)
3	Glow Plug Relay (GPR)
4	Glow Plug Monitor Shunt (Left Bank)
5	Glow Plugs (Left Bank)

Item	Description
6	Glow Plug Sensor Circuit (Left Bank)
7	Glow Plug Sensor Circuit (Center/Both Banks)
8	Glow Plug Sensor Circuit (Right Bank)
9	Powertrain Control Module (PCM)

The Glow Plug Monitor (GPM) system is used to indicate failed glow plugs or glow plug circuits. The GPM system is only used on 1997 and newer California vehicles with a gross combined vehicle weight of less than 6,577.2 kg (14,500 lbs). The PCM monitors the glow plug system by using two low resistance shunts located on the Glow Plug Relay (GPR), which is mounted on the top of the engine. One shunt conducts current to the glow plugs in the left cylinder head, the other shunt conducts current for the right cylinder head.

Sensing wires measure the voltage drops across the shunts when the glow plugs are operating. The voltage drops are measured after the glow plug current stabilizes (approximately 30 to 40 seconds). This system only checks glow plug operation when oil temperature and/or altitude conditions cause the glow plugs to stay on for 30 seconds or more, and system voltage is between 11.8 and 14.0 volts.

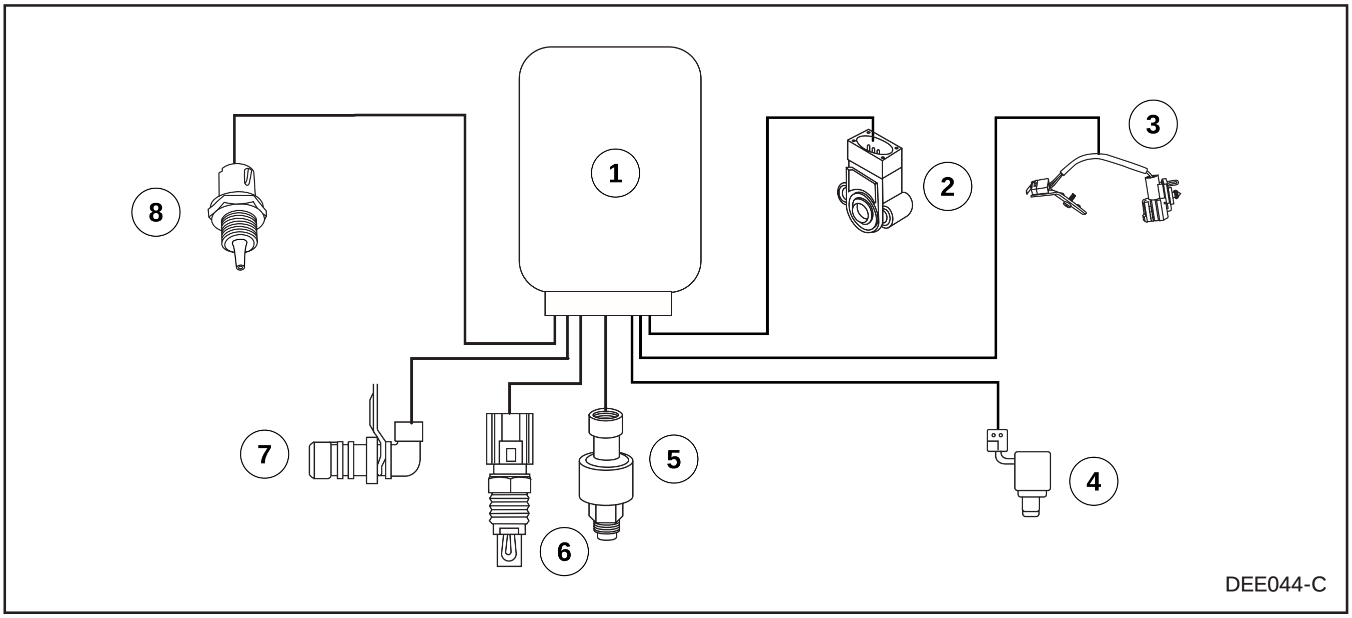
The GPM will monitor the current presented to both banks of glow plugs to determine a possible fault. If fault is found in either or both banks, the PCM will set a DTC and illuminate the MIL. The GPL and the glow plugs will stay active for the amount of time prescribed by the PCM.

Glow Plug Control Subsystem Summary

When the ignition key is turned to the ON position, the PCM reads the EOT and BARO sensors to determine glow plug on time. On time will vary from 1-120 seconds, based on engine oil temperature. If engine oil temperature is above 55°C (131°F), the glow plug relay will not be energized, but the PCM will bulb check the GPL. The PCM then reads battery voltage to protect the glow plugs from over-current by only energizing them for short periods of time if battery voltage is abnormally high. If conditions are correct, the glow plug relay will be energized and the glow plugs will warm the combustion chambers. After the glow plugs have been on the specified amount of time, the GPL lamp will go out and the driver may start the vehicle. After the vehicle is started, the glow plugs may continue to operate to reduce white smoke.

NOTES

Exhaust Backpressure Control (Subsystem)



Exhaust Backpressure Control (Subsystem) Inputs and Outputs

Item	Description
1	Powertrain Control Module (PCM)
2	Accelerator Pedal (AP) Position Sensor
3	Idle Validation Switch (IVS)
4	Exhaust Backpressure (EPR) Regulator

Item	Description
5	Exhaust Backpressure (EBP) Sensor
6	Intake Air Temperature (IAT) Sensor
7	Camshaft Position (CMP) Sensor
8	Engine Oil Temperature (EOT) Sensor

Introduction to the Exhaust Backpressure Control Subsystem

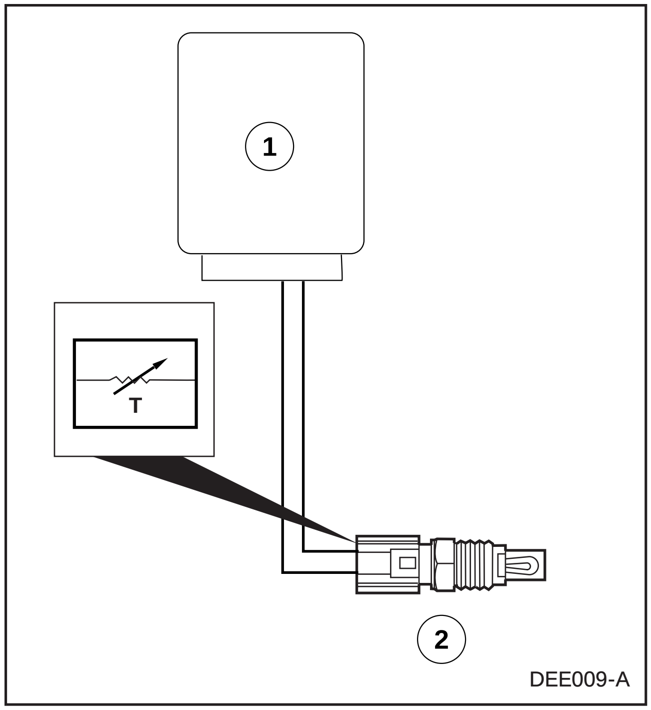
Exhaust backpressure is controlled to increase coolant temperature quickly after start up or to maintain coolant temperature during extended idle in cold ambient conditions. This system decreases the amount of time needed to effectively begin to use the defrost control functions. Exhaust backpressure is controlled by a butterfly valve located at the exhaust side of turbocharger housing. The butterfly valve is attached to an actuator that is fed turbocharger lube oil from a gallery in the rear of the engine. Oil flow to the actuator is controlled by a solenoid. Both the actuator and the solenoid are located in the turbocharger pedestal. A sensor attached to a feed tube that leads to the right exhaust manifold monitors exhaust backpressure. This information is used by the PCM to adjust the position of the butterfly valve. Engine temperature and intake air temperature sensors are used to determine the need for exhaust backpressure valve operation. The PCM also uses the AP, IVS and CMP sensors to determine engine load and speed. The system is only activated during low load, low rpm operation. At high load, high speed conditions the backpressure system is disabled.

The exhaust backpressure control system utilizes these inputs and outputs for operation by the PCM:

- Inputs
  - Exhaust Backpressure (EBP) sensor
  - Intake Air Temperature (IAT) sensor
  - Accelerator Pedal (AP) sensor
  - Idle Validation Switch (IVS)
  - Camshaft Position (CMP) sensor
  - Engine Oil Temperature (EOT)
- Outputs
  - Exhaust Pressure Regulator (EPR)

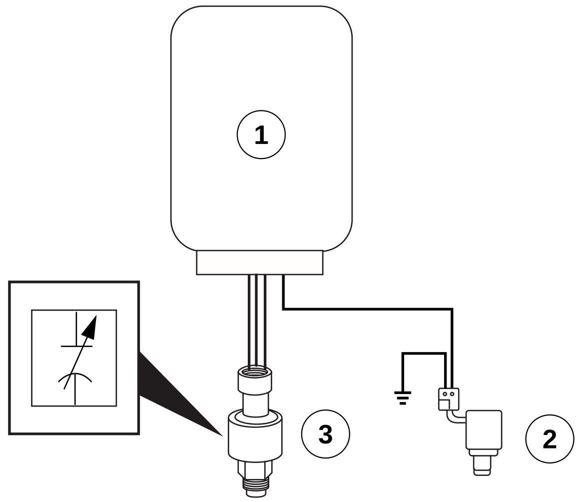
Intake Air Temperature (IAT) Sensor

The Intake Air Temperature (IAT) sensor is a thermistor, mounted on the air cleaner. The IAT sensor function is to provide ambient air temperature information to the PCM. The PCM uses IAT sensor information to determine whether to enable exhaust backpressure control or PCM strategies that compensate for cold ambient temperatures.



Intake Air Temperature (IAT) Sensor

Item	Description
1	Powertrain Control Module (PCM)
2	Intake Air Temperature (IAT) Sensor



Exhaust Backpressure Regulator (EPR)/Exhaust Backpressure (EBP)

Item	Description
1	Powertrain Control Module (PCM)
2	Exhaust Backpressure (EBR) Regulator
3	Exhaust Backpressure (EBP) Sensor

Exhaust Backpressure (EBP) Sensor

The Exhaust Backpressure (EBP) sensor is a variable capacitance sensor, located where it can measure pressure in the right-hand exhaust manifold. It produces a variable voltage signal proportional to exhaust backpressure.

The EBP sensor is used in conjunction with the Exhaust Backpressure Regulator (EPR) to form a closed-loop exhaust backpressure control system. The exhaust backpressure system is used to elevate and maintain engine temperature during cold ambient operation.

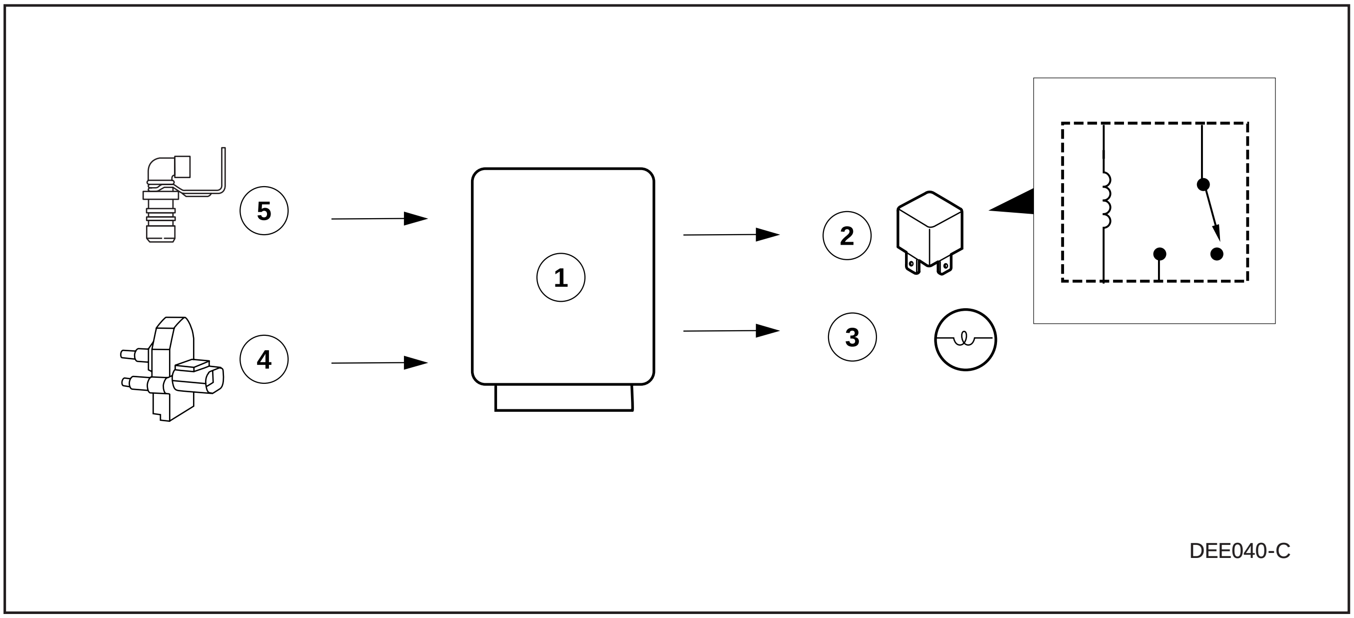
Exhaust Backpressure Regulator (EPR)

The Exhaust Backpressure Regulator (EPR) is a variable force, power side, switched solenoid. The EBP solenoid controls the flow of pressurized oil which moves an actuator piston. The EPR solenoid is located in the turbocharger pedestal. The EPR solenoid is controlled by the PCM by regulating the current provided. As EPR percentage (current) is increased, a higher amount of exhaust backpressure is achieved.

Exhaust Backpressure Subsystem Summary

With inputs to the PCM from the EOT, IAT, AP, IVS and CMP sensors, the PCM determines the need for exhaust backpressure system operation. If engine oil temperature is between –10ºC (15ºF) and 83ºC (182ºF), intake air temperature is below 5ºC (40ºF) and rpm are low enough, the PCM will send a duty cycle signal to the EPR to allow the backpressure valve to close. The on/off time is dependent upon the signal from the EBP sensor. The IAT sensor input is a “snapshot” read by the PCM when the key is turned to the ON position.

Electronic Fuel Supply (Subsystem)



Electronic Fuel Supply (Subsystem) Inputs and Outputs

Item	Description
1	Powertrain Control Module (PCM)
2	Fuel Pump Relay (FPR)
3	Water In Fuel Indicator Lamp (WIFIL)

Item	Description
4	Water In Fuel (WIF) sensor
5	Camshaft Position (CMP) sensor

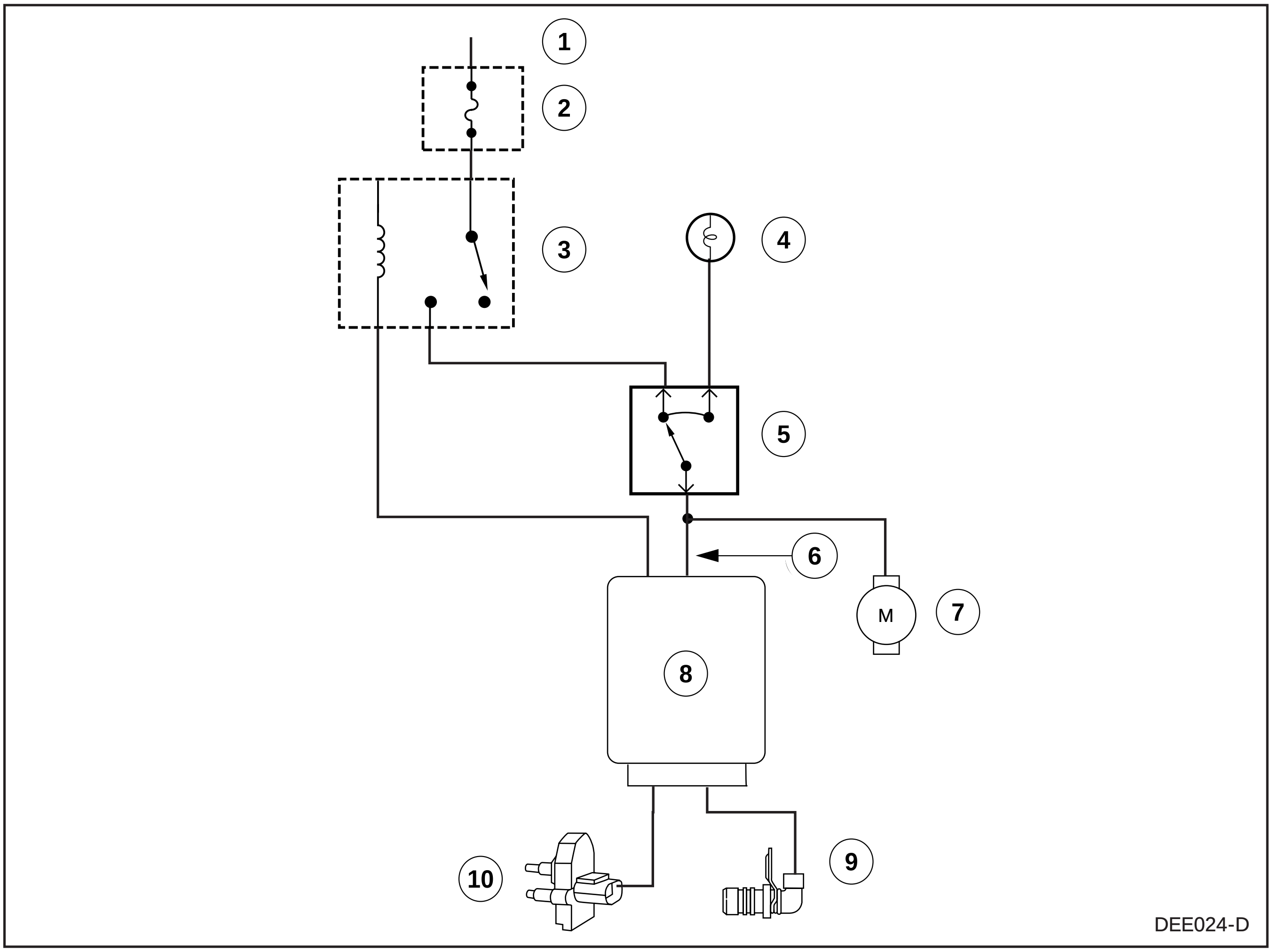
Introduction to the Electronic Fuel Supply Subsystem

Clean fuel is critical to the operation of the HEUI injectors and the performance of a diesel engine. The electronic fuel supply subsystem is used to control an electric fuel pump, which transfers fuel from the tank to the fuel injection system. The PCM uses a relay to control the operation of the electric fuel pump. The PCM monitors voltage to the electric fuel pump through the fuel pump monitor circuit. A Water In Fuel (WIF) sensor is used by the PCM to determine if there is water in the fuel. If water is present, the PCM will illuminate the Water In Fuel Indicator Lamp (WIFIL) notifying the driver to drain the filter housing.

The electronic fuel system utilizes these inputs and outputs for operation by the PCM:

- Inputs
  - Camshaft Position (CMP) sensor
  - Fuel Pump Monitor (FPM)
  - Water In Fuel (WIF) sensor
- Outputs
  - Fuel Pump Relay (FPR)
  - Water In fuel Indicator Lamp (WIFIL)

Fuel Pump Monitor (FPM)



Fuel Pump Monitor (FPM) 1999 F-Series Shown

Item	Description
1	Switched Power
2	Fuse
3	Fuel Pump Relay
4	Fuel Pump Reset Indicator
5	Inertia Switch

Item	Description
6	Fuel Pump Monitor (Pin 40 of PCM)
7	Electric Fuel Pump
8	Powertrain Control Module (PCM)
9	Camshaft Position (CMP) Sensor
10	Water In Fuel (WIF) Sensor

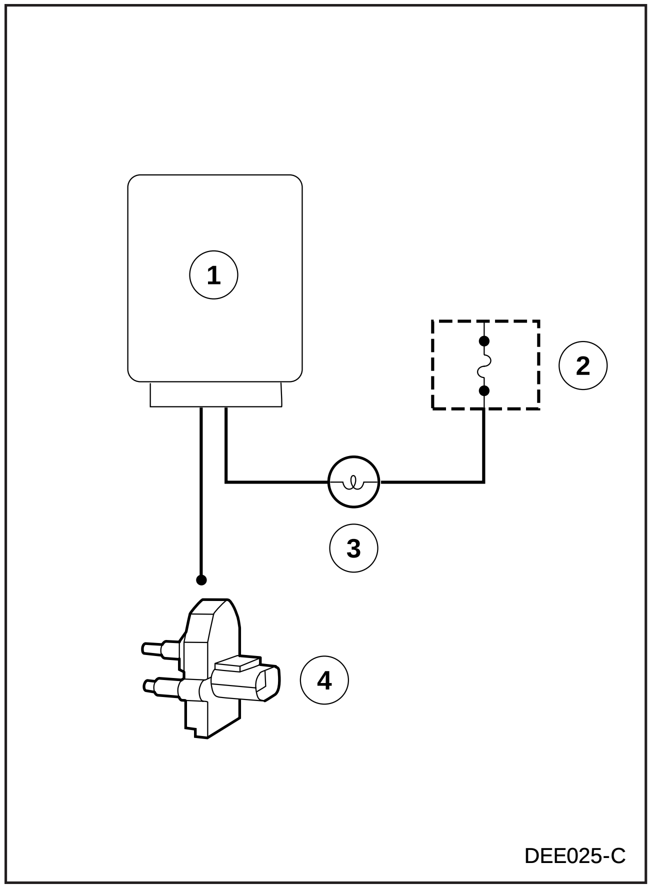
The Fuel Pump Monitor (FPM) circuit is between the inertia switch and the fuel pump, and is used by the PCM to monitor voltage on the fuel pump power circuit. These circuits are monitored to detect circuit malfunctions, including intermittent failures.

Water In Fuel (WIF) Sensor

The Water In Fuel (WIF) sensor is a ground-side switch, located in the fuel filter housing. The WIF is used to detect water in the fuel system. Water that has settled at the bottom of the fuel filter housing is used as a conductor to complete the WIF sensor circuit.

WATER IN FUEL Indicator Lamp (WIFIL)

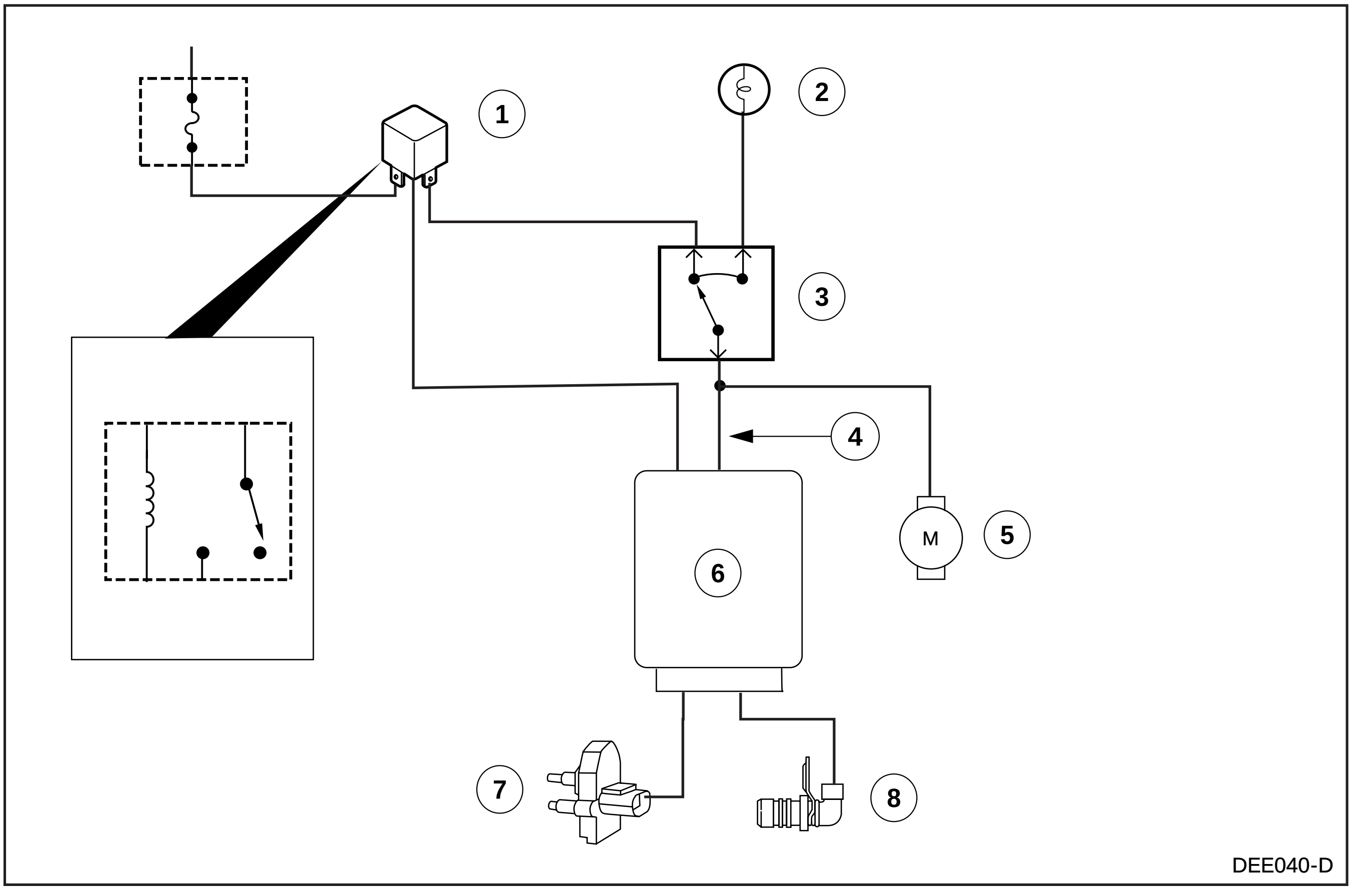
The WATER IN FUEL indicator lamp (WIFIL) is used to alert the driver when excessive water is present in the fuel filter housing. The lamp is located on the instrument panel. On 1998 ½ and newer vehicles, the PCM turns on the WIFIL in addition to setting a DTC. On 1998 and earlier vehicles, a water in fuel module turns on the WIFIL.



Water In Fuel (WIF) Sensor

Item	Description
1	Powertrain Control Module (PCM)
2	Fuse – Water in Fuel (Hot in START and RUN)
3	Water In Fuel Indicator Lamp (WIFIL)
4	Water In Fuel (WIF) Sensor

Fuel Pump Relay (FPR)



Fuel Pump Relay (FPR)

Item	Description
1	Fuel Pump Relay
2	Fuel Pump Reset Indicator Lamp
3	Inertia Switch
4	Fuel Pump Monitor (Pin 40 of PCM)

Item	Description
5	Electrical Fuel Pump
6	Powertrain Control Module (PCM)
7	Water In Fuel (WIF) Sensor
8	Camshaft Position (CMP) Sensor

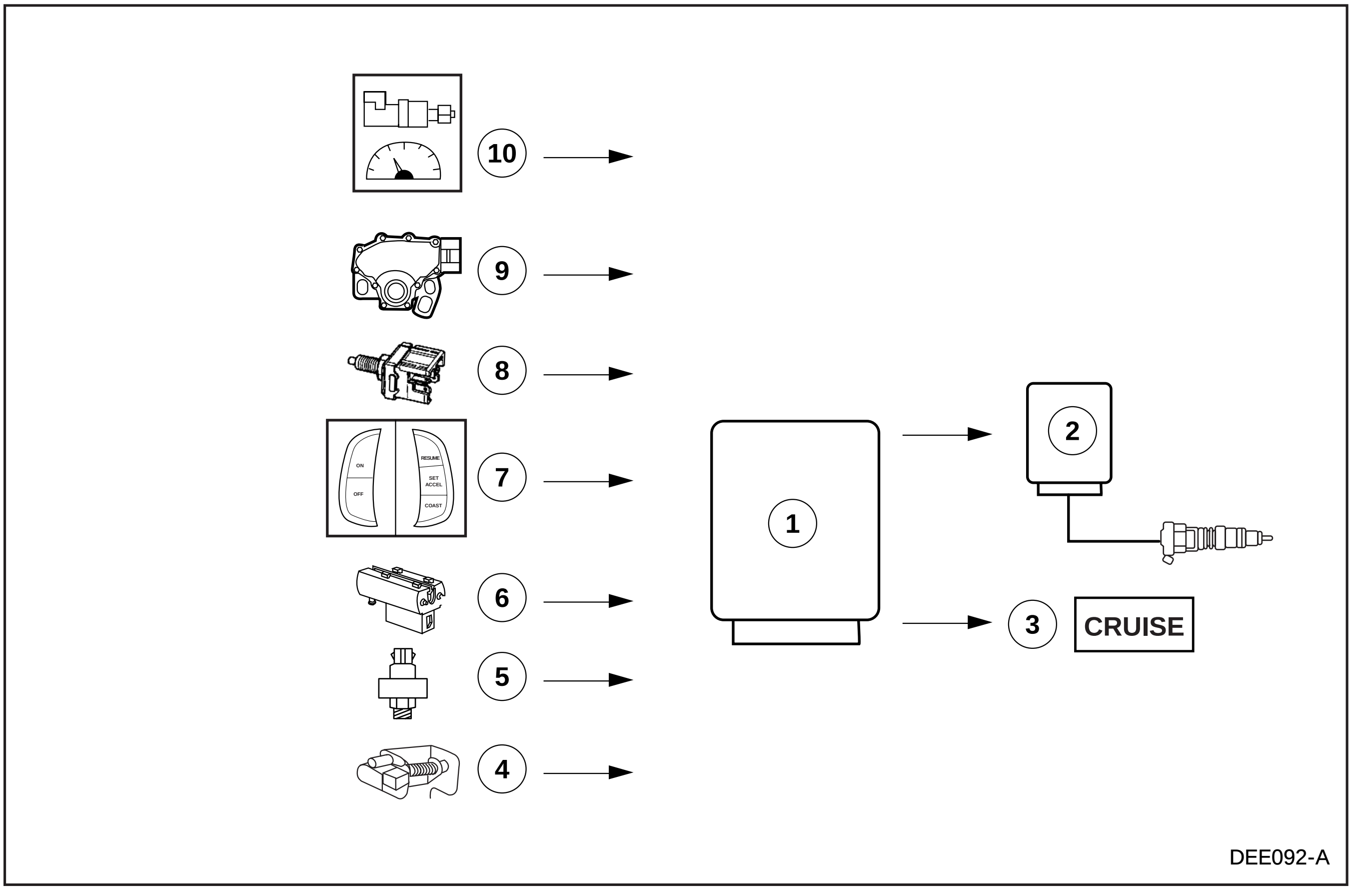
The fuel pump is controlled by the PCM through the Fuel Pump Relay (FPR). At key ON engine OFF, the PCM energizes the FPR for 20 seconds to prime the fuel system. If an engine rpm signal is not detected within 20 seconds, the FPR is de-energized until an rpm signal is received.

Electronic Fuel Supply Subsystem Summary

When the driver turns the key to the ON position, the FPR is energized and current is supplied to the electric fuel pump. This pressurizes the fuel system to 206.9 – 551.6 kPa (30-80 psi). If an rpm signal is not detected within 20 seconds after the key is turned on, the PCM will de-energize the FPR and the fuel pump will stop running. If an rpm signal is received within or after the 20 seconds, the PCM will re-energize the fuel pump relay and fuel pump operation will continue. If the WIF sensor detects water in the fuel during key ON, for more than five seconds. The PCM will set a continuous DTC and turn on the WATER IN FUEL indicator lamp (WIFIL).

NOTES

Speed Control (Subsystem)



Speed Control (Subsystem) Inputs and Outputs

Item	Description
1	Powertrain Control Module (PCM)
2	Injector Driver Module (IDM)
3	Cruise Indicator Lamp
4	Parking Brake Applied (PBA) Switch
5	Brake Pressure Applied (BPA) Switch
6	Clutch Pedal Position (CPP) Sensor

Item	Description
7	Speed Control Command Switches (SCCS)
8	Brake ON/OFF (BOO) Switch
9	Transmission Range (TR) Sensor
10	Vehicle Speed Sensor (VSS)

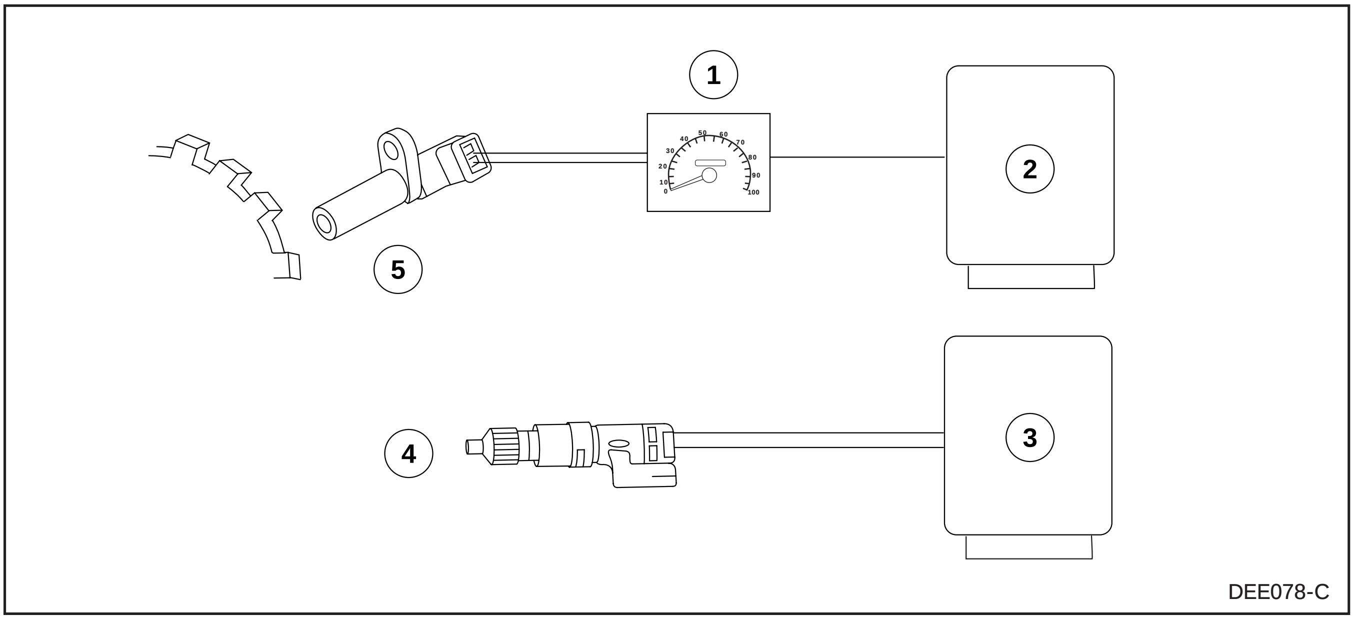
Introduction to the Speed Control Subsystem

The speed control system is used to allow the driver to select and maintain a specific vehicle speed without use of the accelerator pedal. Because there is no throttle plate or cable on the DIT diesel engine, speed control is accomplished by controlling fuel timing and delivery. The speed control uses multiple inputs to accomplish its job. The driver commands speed control function through the Speed Control Command Switches (SCCS). The SCCS are momentary contact switches that send a signal to the PCM when pressed by the driver. When speed control is commanded, the PCM reads the Vehicle Speed Signal (VSS) to determine the speed that the driver wishes to maintain. During speed control operation, the PCM monitors for inputs from the SCCS, Brake ON/OFF (BOO), Brake Pedal Applied (BPA), and Parking Brake Applied (PBA) switches, as well as the Clutch Pedal Position (CPP) switch for a manual transmission vehicle, to determine if the speed control needs to be disabled. The outputs that control speed control include fuel control strategy that is sent to the IDM from the PCM, and the signals from the IDM that control fuel timing and delivery.

The speed control system utilizes these inputs and outputs for operation by the PCM:

- Inputs
  - Vehicle Speed Signal (VSS)
  - Brake ON/OFF (BOO) switch
  - Speed Control Command switches (SCCS)
  - Clutch Pedal Position (CPP) sensor
  - Brake Pressure Applied (BPA) switch
  - Parking Brake Applied (PBA) switch
  - Transmission Range (TR) sensor
- Outputs
  - Fuel Control Strategy (FCS)
  - Injector Driver Module (IDM)
  - Cruise Indicator Lamp (CIL)

Vehicle Speed Signal (VSS)



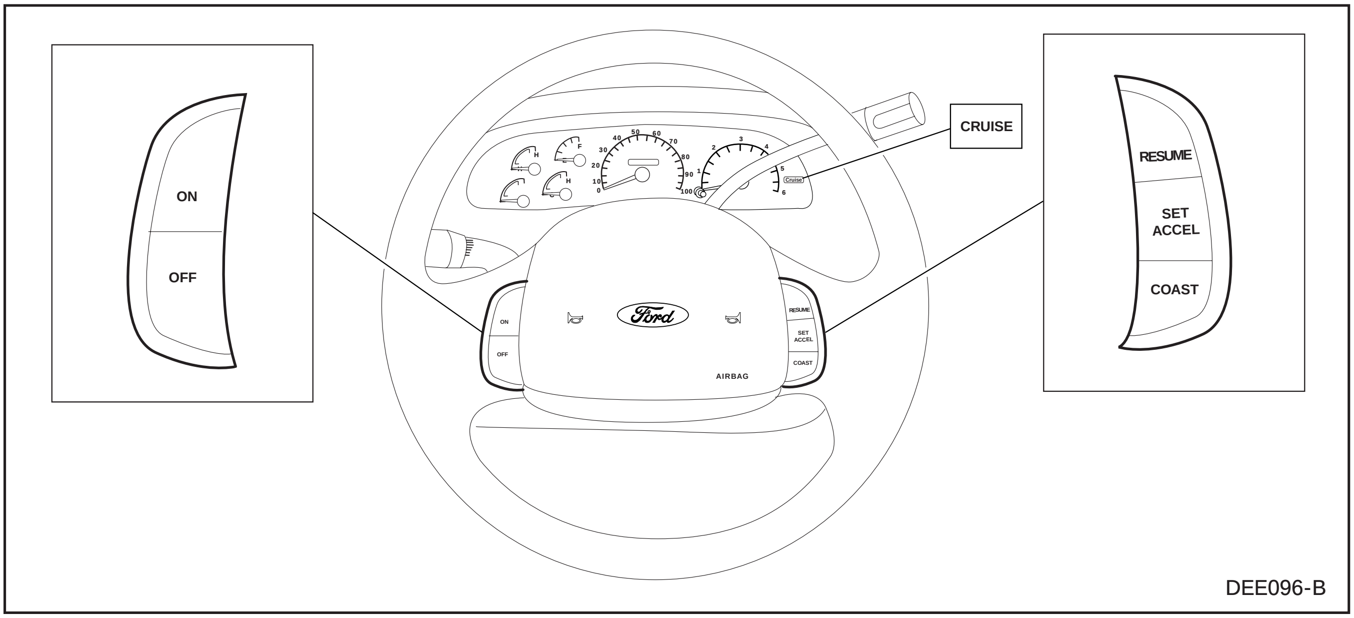
Vehicle Speed Signal (VSS)

Item	Description
1	Speedometer
2	Powertrain Control Module (PCM)
3	Powertrain Control Module (PCM)

Item	Description
4	E-Series Vehicle Speed Signal (VSS)
5	F-Series Vehicle Speed Signal (VSS)

The Vehicle Speed Signal (VSS) is produced by a variable reluctance sensor. This sensor can be part of a variety of systems and can be located in different areas of the vehicle. The VSS signal may come directly from a sensor or may be redirected through another module.

Speed Control Command Switches (SCCS)



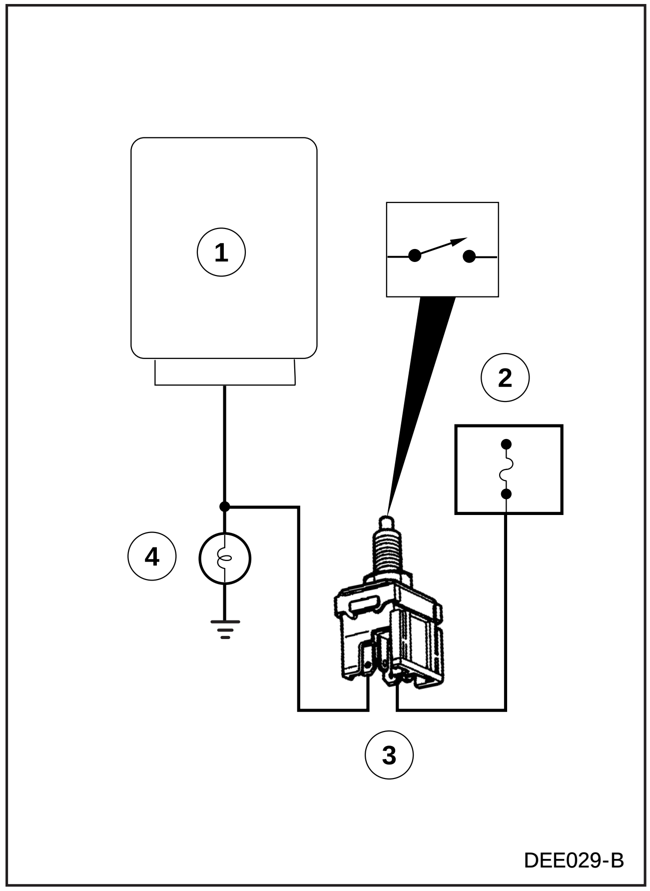
Speed Control Command Switches (SCCS)

The Speed Control Command Switches (SCCS) are multifunction momentary contact switches, located on the face of the steering wheel. There is one switch assembly that contains one ON/OFF toggle switch and another switch assembly that contains SET/ACCEL-COAST-RESUME switches. When these switches are depressed, one of several resistance values is selected, which creates a specific voltage value. The voltage value is sent to the PCM to select speed control functions.

Brake ON/OFF (BOO) Switch

The Brake ON/OFF (BOO) switch is a normally open, power-side switch, located on the brake pedal assembly. The BOO switch is wired to the stoplamp circuit. It informs the PCM when the brake is applied.

The PCM uses the BOO signal to disengage the speed control.



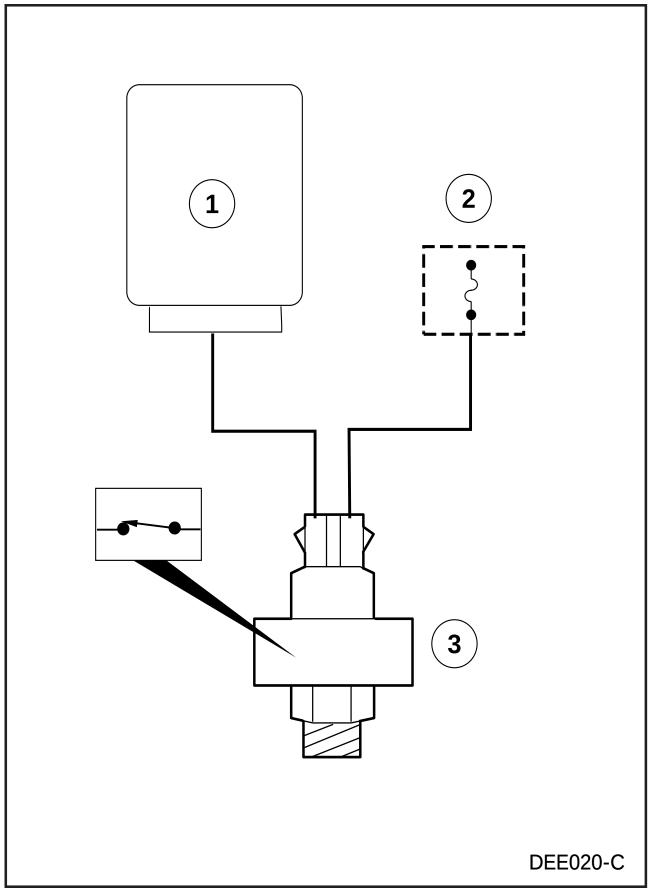
Brake ON/OFF (BOO) Switch

Item	Description
1	Powertrain Control Module (PCM)
2	Fuse (HOT AT ALL TIMES)
3	Brake ON/OFF (BOO) Switch
4	Brake Lamp

Brake Pressure Applied (BPA) Switch

The Brake Pressure Applied (BPA) switch is a normally closed power-side switch, hydraulically activated pressure switch. The BPA is located on the master cylinder and senses brake apply pressure. When the brake pedal is depressed, the switch is open. When the pedal is released, the switch is closed.

The PCM uses BPA information to deactivate speed control in the event of a BOO switch failure. The BPA also provides a backup to the brake ON/OFF switch in the event of a failure.



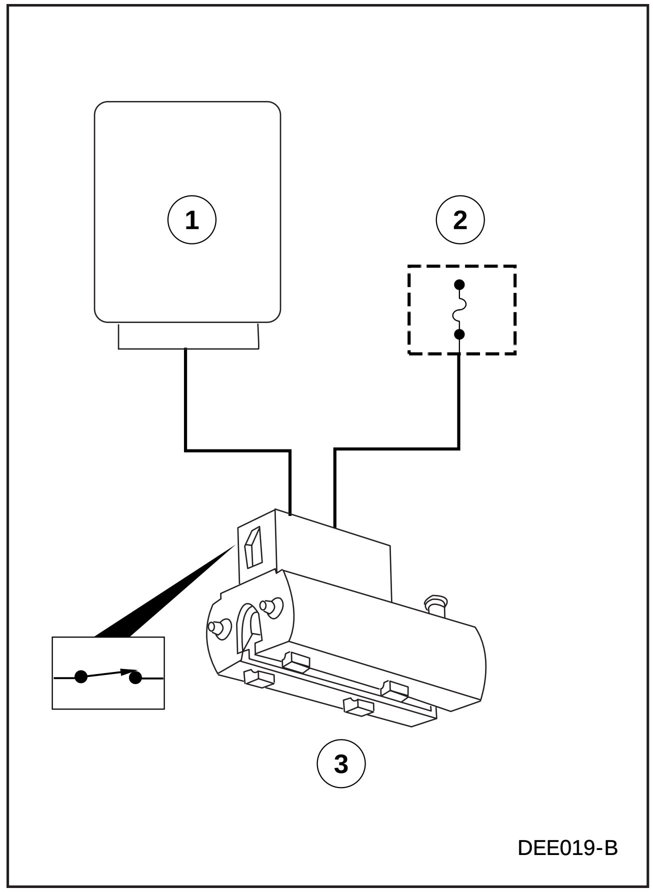
Brake Pressure Applied (BPA) Switch

Item	Description
1	Powertrain Control Module (PCM)
2	Fuse (HOT IN START AND RUN)
3	Brake Pressure Applied (BPA) Switch

Clutch Pedal Position (CPP) Switch

The Clutch Pedal Position (CPP) switch is a normally closed, power-side switch mounted on the clutch pedal assembly. The CPP switch is an input to the PCM, indicating clutch pedal position. When the clutch pedal is applied (foot on the pedal), the switch is open. When the clutch pedal is released (foot off the pedal), the switch is closed.

The PCM uses this signal to disable the speed control when the clutch pedal is applied.



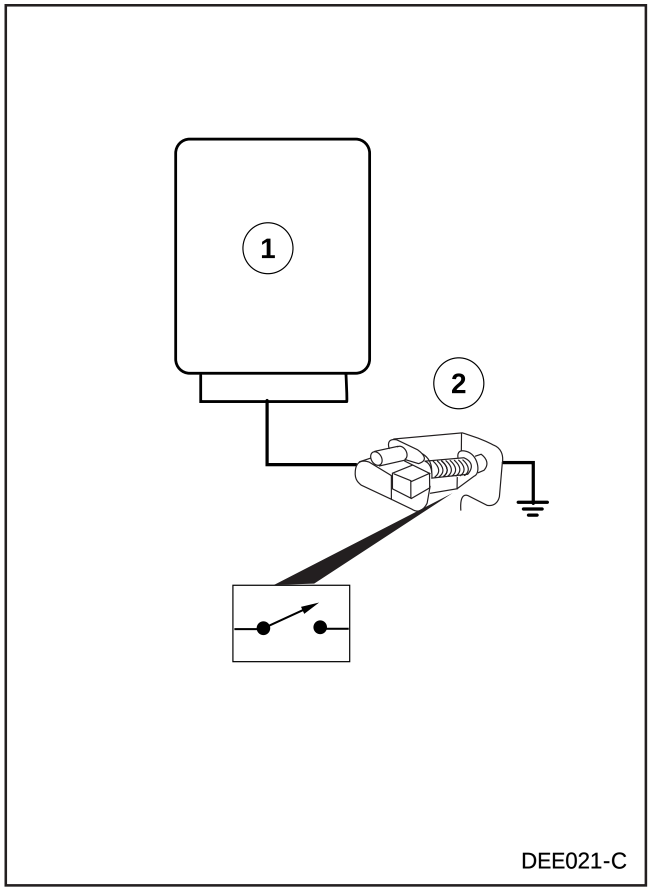
Clutch Pedal Position (CPP) Switch

Item	Description
1	Powertrain Control Module (PCM)
2	Fuse (HOT IN START AND RUN)
3	Clutch Pedal Position (CPP) Switch

Parking Brake Applied (PBA) Switch

The Parking Brake Applied (PBA) switch is a normally open ground-side switch, located on the parking brake pedal, under the instrument panel. The PBA switch detects when the parking brake is applied and sends this signal to the PCM.

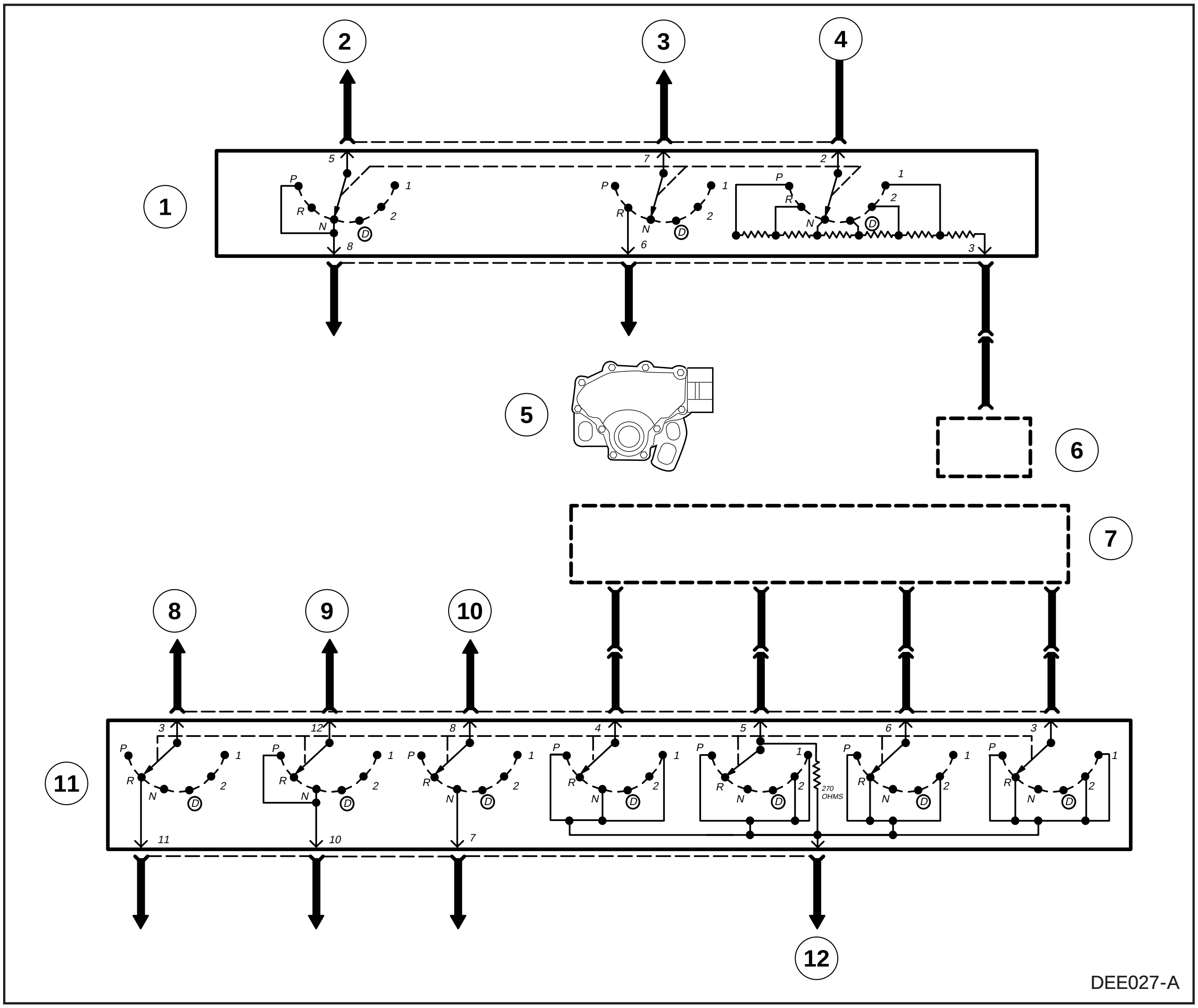
The PCM will deactivate speed control if the parking brake is applied during speed control operation.



Parking Brake Applied (PBA) Switch

Item	Description
1	Powertrain Control Module (PCM)
2	Parking Brake Applied (PBA)

Transmission Range (TR) Sensor



Transmission Range (TR) Sensor

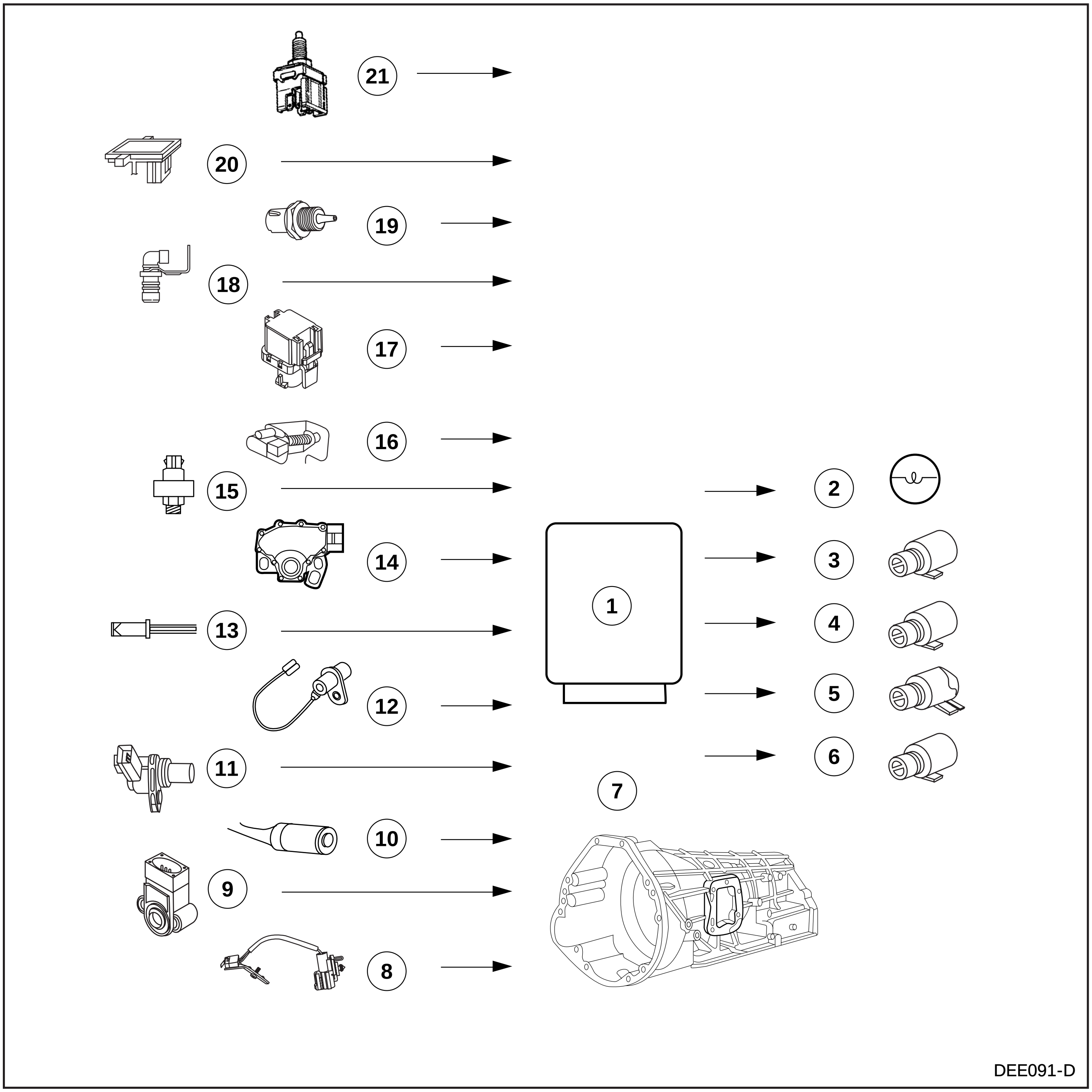
Item	Description
1	Analog TR Sensor Circuit
2	P/N Safety
3	Reverse Lights
4	Powertrain Control Module (PCM)
5	Transmission Range (TR) Sensor
6	Powertrain Control Module (PCM)
7	Powertrain Control Module (PCM)
8	Reverse Lights
9	P/N Safety
10	4x4 Low Input
11	Digital TR Sensor Circuit
12	Powertrain Control Module (PCM)

The Transmission Range (TR) sensor is a multifunction switch located on the left-hand side of the automatic transmission at the gear selector shaft. This sensor provides information to the PCM to detect specific gear selections. In addition, it contains a neutral safety switch for starter operation, a reverse light switch, and a neutral switch for four wheel drive. There are two types of TR sensor assemblies: analog and digital.

Speed Control Subsystem Summary

The driver, through the SCCS, commands speed control system operation. When the driver depresses a SCCS switch, a signal is sent to the PCM. If the command is to maintain a certain speed, the PCM uses the vehicle speed input to determine what speed the driver would like to maintain. The PCM then sends command signals to the IDM to maintain, increase, or decrease fuel delivery to sustain the desired speed. Unlike most gasoline engines, diesel speed control systems contain no mechanical linkage. Speed control is accomplished through electronic adjustments to fuel delivery. The SCCS can also command coasting, acceleration, resume and system-off functions based on driver input. When signals indicating that the vehicle hydraulic or parking brake systems are applied, speed control system operation will discontinue.

Transmission/PTO Control (Subsystem)



Transmission/PTO Control (Subsystem) Inputs and Outputs

Item	Description
1	Powertrain Control Module (PCM)
2	Transmission Control Indicator Lamp (TCIL)
3	Shift Solenoid (SS)
4	Electronic Pressure Control (EPC)
5	Torque Converter Clutch (TCC)
6	Coast Clutch Solenoid (CCS)
7	Transmission Case
8	Idle Validation Switch (IVS)
9	Accelerator Pedal (AP) Position Sensor
10	Transmission Control Switch (TCS)
11	Output Shaft Speed (OSS) Sensor

Item	Description
12	Turbine Shaft Speed (TSS) Sensor
13	Transmission Fluid Temperature (TFT) Sensor
14	Transmission Range (TR) Sensor
15	Brake Pressure Applied (BPA) Switch
16	Parking Brake Applied (PBA)
17	Barometric Pressure (BARO) Sensor
18	Camshaft Position (CMP) Sensor
19	Engine Oil Temperature (EOT) Sensor
20	Manifold Absolute Pressure (MAP)
21	Brake ON/OFF (BOO) Switch

Introduction to the Transmission/PTO Subsystem

The PCM is used to control shift scheduling, line pressure, and torque converter application for the automatic transmission and use of a Power Take Off (PTO) unit. The PCM monitors driver input for gear selection, transmission fluid temperature, transmission input shaft and output shaft speed. This information is used to control Shift Solenoids (SS), a Coast Clutch Solenoid (CCS), an Electronic Pressure Control (EPC) solenoid, and the Torque Converter Clutch (TCC). Other sensors are also monitored to provide information about driver demand engine speed, engine temperature, as well as barometric and manifold pressure. These inputs are used to fine tune shift scheduling.

If the driver depresses the Transmission Control Switch (TCS), the Transmission Control Indicator Lamp (TCIL) will be illuminated, and overdrive will be canceled. The TCIL lamp will also be illuminated for some circuit or sensor failures within the transmission.

If equipped with a Power Take Off (PTO) unit, the PCM provides the necessary transmission functions to apply power to the auxiliary drive unit. The PCM may also increase engine speed during PTO operation to meet the demand of the load being placed on the engine during PTO operation.

The transmission/PTO control system utilizes these inputs and outputs for operation by the PCM:

- Inputs
  - Transmission Range (TR) sensor
  - Transmission Fluid Temperature (TFT) sensor
  - Turbine Shaft Speed (TSS) sensor
  - Output Shaft Speed (OSS) sensor
  - Transmission Control Switch (TCS)
  - Accelerator Pedal (AP) position sensor
  - Idle Validation Switch (IVS)
  - Brake Pressure Applied (BPA) switch
  - Parking Brake Applied (PBA) switch
  - Barometric Pressure (BARO) sensor
  - Camshaft Position (CMP) sensor
  - Engine Oil Temperature (EOT) sensor
  - Manifold Absolute Pressure (MAP) sensor
  - Brake On/Off (BOO) Switch
- Outputs
  - Transmission Control Indicator Lamp (TCIL)
  - Shift Solenoid (SS)
  - Electronic Pressure Control (EPC)
  - Torque Converter Clutch (TCC)
  - Coast Clutch Solenoid (CCS)

Transmission Fluid Temperature (TFT) Sensor

The Transmission Fluid Temperature (TFT) sensor is a thermistor, located in the internal transmission wiring harness. The TFT varies a voltage signal proportional to temperature.

The PCM uses the TFT signal to determine shift schedules and control Torque Converter Clutch (TCC) operation.

Turbine Shaft Speed (TSS) Sensor

The Turbine Shaft Speed (TSS) sensor is a variable reluctance sensor located toward the front of the transmission on the outside of the housing. The TSS sensor measures transmission input shaft speed.

The PCM uses the TSS signal to determine transmission operating strategies and Power Take Off (PTO) control.

Output Shaft Speed (OSS) Sensor

The Output Shaft Speed (OSS) sensor is a variable reluctance sensor located toward the rear of the transmission on the outside of the housing. The OSS sensor measures the transmission output shaft speed.

The PCM uses the OSS signal to determine transmission operating strategies and Power Take Off (PTO) control.

Transmission Control Switch (TCS)

The Transmission Control Switch (TCS) is a momentary contact switch, located on the shift lever.
The TCS allows the driver to cancel the Overdrive gear operation.

Transmission Control Indicator Lamp (TCIL)

The Transmission Control Indicator Lamp (TCIL) illuminates to inform the driver that overdrive has been cancelled and is located in the instrument cluster or on the end of the transmission range selector lever.
The TCIL may flash when the PCM has detected a sensor or actuator failure in the transmission control system.

Shift Solenoids 1, 2, 3 (SS1)

The Shift Solenoids (SS) are on/off solenoids, located inside the transmission on the main valve body.
The PCM controls these solenoids in various combinations to achieve different gears.

Electronic Pressure Control (EPC) Solenoid

The Electronic Pressure Control (EPC) solenoid is a variable force solenoid located inside the transmission on the main valve body. The PCM modulates the EPC solenoid to control transmission fluid line pressure.

Torque Converter Clutch (TCC) Solenoid

The Torque Converter Clutch (TCC) solenoid is a pulse width modulated variable force solenoid, located inside the transmission on the main valve body assembly. The PCM modulates the solenoid to apply the torque converter clutch.

Coast Clutch Solenoid (CCS)

The Coast Clutch Solenoid (CCS) is an on/off solenoid, located inside the transmission on the main valve body.
The PCM energizes the CCS when the transmission Control Indicator Lamp (TCIL) is on, and Overdrive operation is cancelled.

Transmission/PTO Subsystem Summary

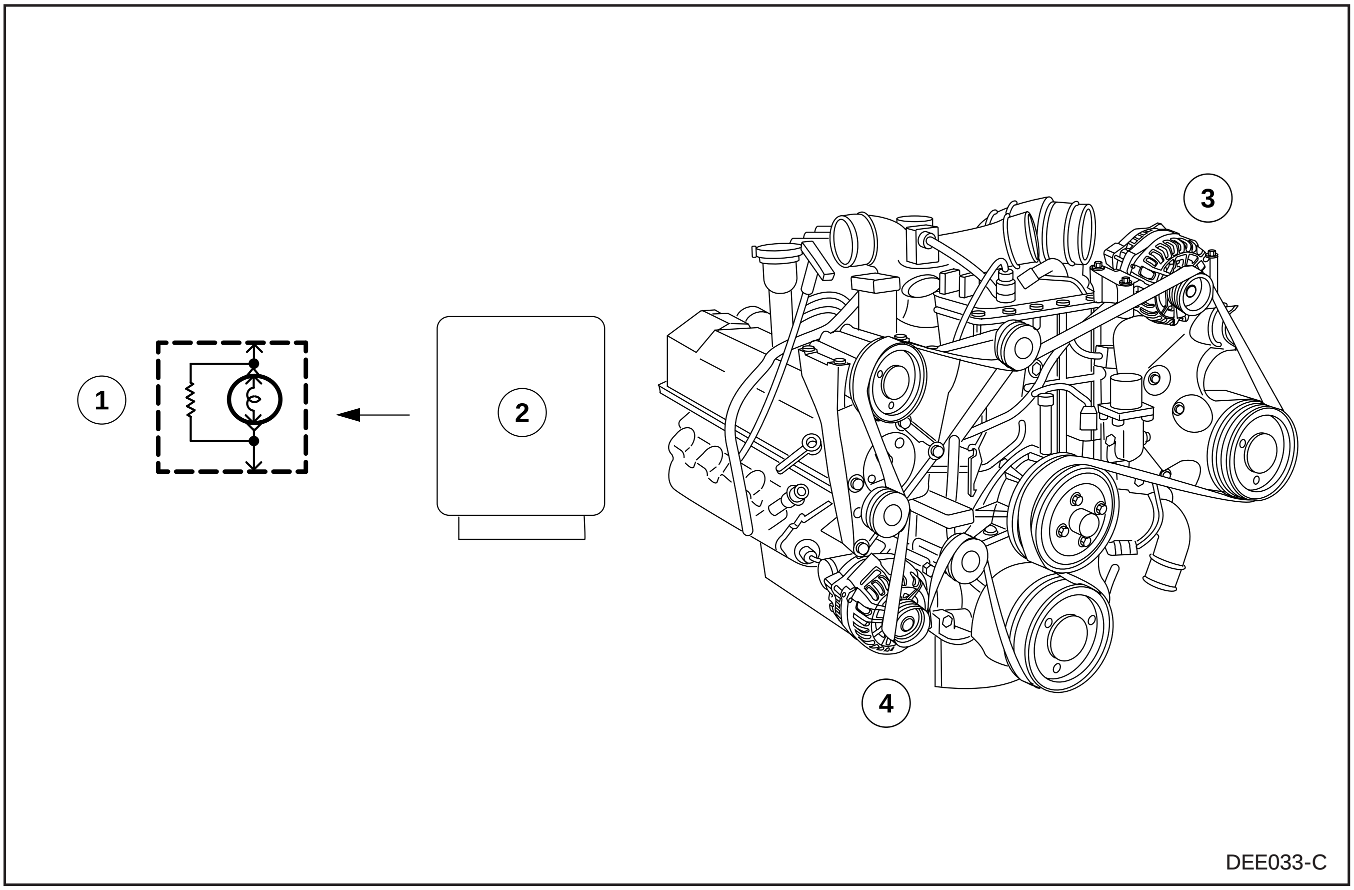
During automatic transmission operation, the PCM will receive a signal from the TR sensor to determine which gear selector position the driver has chosen, and from the TCS to determine if Overdrive will be allowed and if engine braking will be provided. These two inputs help the PCM determine shift strategy for given conditions. With that, signals are received from the TFT, TSS, OSS, AP, and IVS. With these inputs the PCM can send output signals to control shift solenoids, the EPC solenoid, TCC and CCS. The PCM also uses inputs from the BARO, CMP, EOT, and MAP sensors to trim line pressure through modulation of the EPC solenoid for optimum transmission performance. When commanding these outputs, the PCM adjusts shift points and shift firmness, while controlling Overdrive operation and torque converter lock-up. If the driver chooses not to allow the PCM to command Overdrive by pressing the TCS, the TCIL will be illuminated, the CCS will be energized, and engine braking will be provided. The TCIL can also be illuminated, and will flash, in the event that there is an electrical circuit fault of a sensor, actuator or the EPC solenoid.

The PTO system, on vehicles that are equipped with it, functions through PCM control of automatic transmission functions. When a 12-volt signal to the PCM is received by a driver activated switch, PTO operation is commanded. For PTO operation to occur, the TR sensor must indicate P, R, OD, 2 or 1 position, and the transmission fluid temperature must be less than maximum allowed, as indicated by the signal from the TFT sensor. When conditions are met that allow for PTO operation, the PCM increases the EPC solenoid duty cycle to a specific line pressure and illuminates the TCIL signifying that overdrive is canceled and fourth gear will not be allowed by activating the CCS. These events occur for both stationary and mobile PTO operation.

During stationary use of the PTO, the PCM commands engine idle to 1,200 rpm and engages the TCC after 1,200 rpm is achieved. If 1,200 rpm is not achieved within 5 minutes when in PARK, the PCM will cease PTO operation. Before 1,200 rpm can be achieved for stationary operation, the PCM must receive a signal from the PBA switch and TR sensor and no signal from the BPA switch. If a signal is sent from the BPA switch, PTO operation will be discontinued. The PCM must also see that the AP sensor is at idle position and that vehicle speed is at 0 km/h (0 mph). During mobile operation, the PCM allows the transmission to operate only in gears 1-3 and adjusts the shift schedule to provide slightly firmer and earlier shifts. It is important to remember that during PTO operation on-board diagnostics will be disabled. However, circuit checks will still be made by the PCM. The 12-volt signal to the PCM and the PTO unit itself are not factory equipment, and are installed with aftermarket accessories. The provision on the transmission case is the only factory supplied part for the installation of a PTO.

NOTES

Dual Generator (Subsystem)



Dual Generator (Subsystem) Inputs and Outputs

Item	Description
1	Charging Indicator Lamp
2	Powertrain Control Module (PCM)

Item	Description
3	Primary Generator
4	Secondary Generator

Introduction to the Dual Generator Subsystem

The 7.3L DIT diesel engine application offers a dual generator option for vehicles that have heavy electrical demands, such as an ambulance. When equipped with the dual generators, the generator mounted higher on the engine is called the primary or upper generator, while the generator mounted low on the engine is called the secondary or lower generator.

The charging system utilizes these inputs and outputs for operation by the PCM:

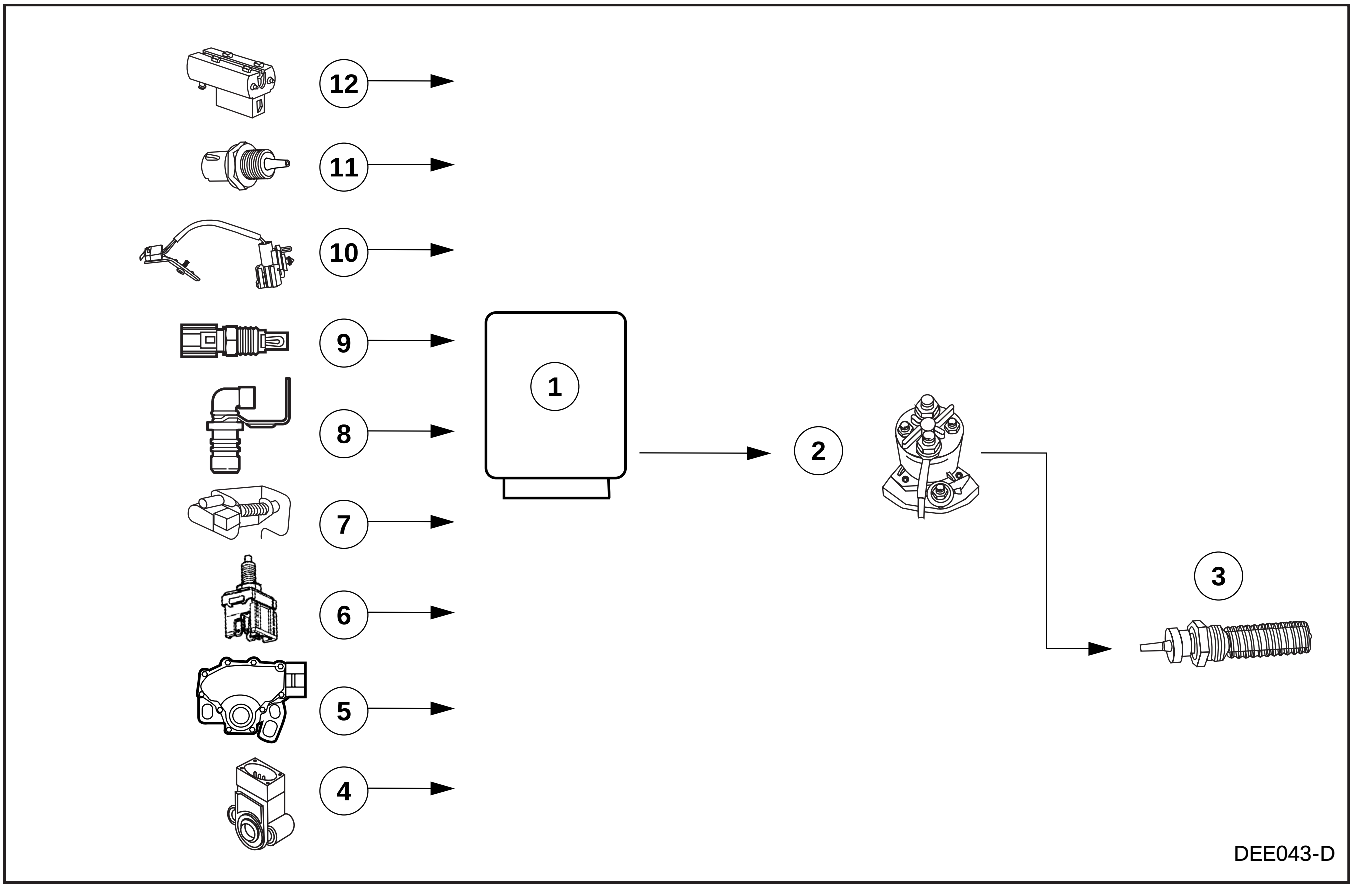
- Inputs
  - Primary generator regulator (I-circuit)
  - Secondary generator regulator (I-circuit)
- Outputs
  - Primary generator regulator (I-circuit)
  - Secondary generator regulator (I-circuit)
  - Charge indicator lamp

Dual Generator Subsystem Summary

The generators regulator "I" circuit is both an input and an output. The PCM turns on each regulator by supplying an electrical current to each "I" circuit. If the regulator detects a failed generator, the regulator grounds out the "I" circuit. When the PCM senses the grounded circuit, it turns on the charge indicator. The PCM controls the secondary generator by disabling the regulator to limit charging system voltage during glow plug operation to avoid possible glow plug damage due to excessive current.

COLD WEATHER ENGINE OPERATION

Intake Air Heater Control



Intake Air Heater Control Inputs and Outputs

Item	Description
1	Powertrain Control Module (PCM)
2	Intake Air Heater Relay
3	Intake Air Heater Element
4	Accelerator Pedal (AP) Position Sensor
5	Transmission Range (TR) Sensor
6	Brake ON/OFF (BOO) Switch

Item	Description
7	Parking Brake Applied (PBA) Switch
8	Camshaft Position (CMP) Sensor
9	Intake Air Temperature (IAT) Sensor
10	Idle Validation Switch (IVS)
11	Engine Oil Temperature (EOT) Sensor
12	Clutch Pedal Position (CPP) Sensor

The purpose of the intake air heater is to raise the temperature of the intake air before it reaches the combustion chambers, and reduce white smoke during cold engine operation. An electrical heating element located in the CAC crossover is used to warm the air before it reaches the intake manifolds. The intake air heater is only used on selected vehicles without a catalytic converter, and is controlled through a relay (similar to the glow plug relay) by the PCM. The intake air heater is only activated once during a key cycle and may function only at low idle when ambient air, and engine oil temperatures are low, and the glow plugs are off.

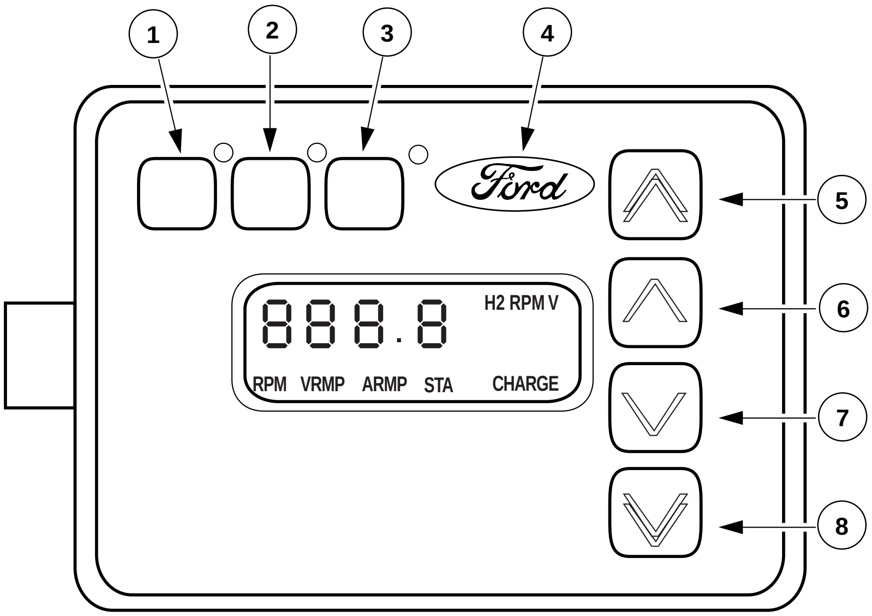
The intake air heater can stay active for up to thirty minutes but will be deactivated if the PCM receives indication of low battery voltage, movement of the brake pedal, clutch pedal, or the accelerator pedal.

The intake air heater utilizes these inputs and outputs for operation by the PCM:

- Inputs
  - Engine Oil Temperature (EOT) sensor
  - Intake Air Temperature (IAT) sensor
  - Camshaft Position (CMP) sensor
  - Brake Pressure Applied (BPA) switch
  - Brake ON/OFF (BOO) switch
  - Accelerator Pedal (AP)
  - Idle Validation Switch (IVS)
  - Transmission Range (TR) sensor
  - Clutch Pedal Position (CPP) sensor
- Outputs
  - Intake air heater relay

NOTE: Intake air heater used on 99½ model year when catalytic converter is not used.

FUNCTION AND LOCATION OF THE AUXILIARY POWERTRAIN CONTROL (APC) MODULE (OPTIONAL)



Auxiliary Powertrain Control Module and Key Pad

Item	Description
1	RPM Control (Engine Speed Mode Select Key)
2	CHARGE PROTECT (System Voltage Mode Select Key)
3	POWER (Module ON/OFF KEY)
4	FORD (Activate/Deactive KEY)
5	RPM Memory #1 and Fast Engine Speed Increase Key
6	RPM Memory #2 and Fast Engine Speed Increase Key
7	RPM Memory #3 and Fast Engine Speed Increase Key
8	RPM Memory #4 and Fast Engine Speed Increase Key

The Auxiliary Powertrain Control (APC) module is a 7.3L DIT diesel engine option kit, available on ambulances, tow trucks, and other vehicles requiring manual throttle control.

This kit provides adaptive vehicle charging system protection (CHARGE PROTECT), and driver selectable elevated idle operation and/or manual rpm control. A user programming option allows for deselecting of any of these functions. This kit is compatible with in-cab only mounting of the operator interface (APC) module.

REVIEW QUESTIONS

1. The ___________________ and ___________________ sensor signals are used by the PCM to determine engine operating temperature for adjustment of fuel delivery.
2. The _________________signal is used by the PCM to generate the signals that will be sent to the Injector Driver Module (IDM).
3. The Injector Driver Module (IDM) receives two digital control signals from the PCM, they are the ____________________________ and ______________________________.
4. The IDM contains a step up transformer that raises supply voltage to the injectors to_____________ ____ .
5. It is recommended that injector circuit voltage checks under the valve covers be done with the engine running.
   A. True
   B. False
6. Gold-plated connector terminals should be replaced with ____________ terminals.
   A. gold-plated
   B. copper
   C. brass
   D. aluminum
7. The _______________ and _______________ are the only outputs used by the glow plug control system.
8. If a disagreement between the idle validation switch (IVS) and the accelerator pedal (AP) sensor is detected by the PCM:
   A. the engine will not start.
   B. the engine will run at high idle only.
   C. the engine will run at low idle only.
   D. the engine will operate normally and a DTC will be generated.
9. The engine oil temperature (EOT) sensor is mounted in the:
   A. oil pan.
   B. engine block.
   C. high-pressure pump housing.
   D. high-pressure reservoir.

REVIEW QUESTIONS (Continued)

10. The injection control pressure (ICP) sensor is located in the:
    A. right-hand cylinder head.
    B. left-hand cylinder head.
    C. injection control pressure regulator (IPR).
    D. high-pressure oil reservoir.
11. Turbocharger wastegate control is based on the __________ sensor reading.
    A. manifold absolute pressure (MAP)
    B. manifold air temperature (MAT)
    C. barometric pressure (BARO)
    D. exhaust backpressure (EBP)
12. Maximum glow plug on time is ___________ seconds.
13. The sensor most responsible for glow plug on time is the:
    A. manifold air temperature (MAT) sensor.
    B. engine oil temperature (EOT) sensor.
    C. intake air temperature (IAT) sensor.
    D. engine coolant temperature (ECT) sensor.
14. The exhaust backpressure regulator (EPR) controls vacuum flow to the EBP regulator piston.
    A. True
    B. False
15. _______________is a snapshot taken by the PCM in the determination of exhaust backpressure valve use.
16. The PCM disengages the electric fuel pump while the engine is cranking if a signal is not detected from the:
    A. idle air temperature (IAT) sensor.
    B. manifold absolute pressure (MAP) sensor.
    C. engine oil temperature (EOT) sensor.
    D. camshaft position (CMP) sensor .
17. The ___________ signal is the only output to control speed control on a 7.3L DIT engine.

REVIEW QUESTIONS (Continued)

18. A flashing transmission control indicator lamp (TCIL) is an indication of:

    A. overdrive cancelled.

    B. PCM detection of a sensor or actuator failure in the transmission control system.

    C. both A and B

    D. neither A nor B

19. On a two-generator charging system, the primary generator is turned off by the PCM during glow plug operation.

    A. True

    B. False

20. The intake air heater is found on vehicles:

    A. with a catalytic converter.

    B. without a catalytic converter.

    C. either A or B

    D. both A and B

NOTES

TECHNICIAN OBJECTIVES

- Define PCM strategy.
- Describe the key ON engine OFF strategy.
- Describe the crank/start strategy.
- Describe the engine idle strategy.
- Describe the part throttle strategy.
- Describe the peak power strategy.
- Describe PCM strategies for cold weather operation.
- Describe PCM strategies for warm weather operation.
- Describe PCM strategies for altitude.
- Describe PCM diagnostic strategies.
- Describe the strategies for the OBD I and II control systems.
- Describe PCM strategies for failure and default.
- Describe IDM strategies for failure and default.

CONTENTS

PCM STRATEGIES

Various strategies within the PCM are used to optimize powertrain operation. The strategies are pre-programmed into the PCM, which uses input information to help determine which strategy is required to operate specific outputs under certain driving conditions. These strategies allow for different modes of operation such as: key ON engine OFF, crank and start, idle, steady cruise, and peak power. These strategies also allow for failure mode operation in the event of a component or system failure.

In the charts that follow are examples of how PCM operating strategies use various inputs and control outputs within the 7.3L DIT diesel engine electronic control system.

NOTE: Keep in mind that during the explanations and examples that follow, input communication and output actuation are laid out in a sequence for better understanding. The actual events during engine operation are primarily simultaneous.

NOTES

Key ON Engine OFF Strategy

When the ignition switch is rotated to the ON position, the PCM will detect signals from all of the sensors. The PCM reads the CMP sensor to determine if the engine is cranking. The PCM takes a snapshot of IAT to determine if the EBP strategy should be enabled. The PCM reads the EOT and BARO sensors to determine glow plug on time, WAIT TO START lamp on time and initiates them if needed. The PCM will activate the electric fuel pump during the initial key-on. If a CMP signal is not detected within 20 seconds, the pump will be deactivated. The PCM grounds the IDM enable circuit to activate the IDM. The PCM reads the AP sensor to determine accelerator pedal position, however, this signal is not used to adjust fuel delivery until the PCM recognizes the IVS transition from idle to off idle. The PCM reads the MAP sensor to determine base measurements for boost pressure. The IPR will be at 14% duty cycle, anticipating that the engine will be cranked. This allows the high-pressure oil system to build starting pressures as soon as cranking begins.

All of these factors allow the PCM to ready itself for engine start-up and carry out system checks.

KEY ON ENGINE OFF – NORMAL OPERATING STRATEGY		
PID Name	**Expected PID Value**	**PCM Signal Usage**
IAT Intake Air Temperature	Voltage reading (proportional to ambient air temperature) Example: 20°C (68°F) = 3.09 volts	PCM uses this signal to enable EBP if ambient temperature is below 5ºC (40°F)
EOT Engine Oil Temperature	Voltage reading (proportional to engine oil temperature) Example: 60°C (140°F) = 2.11 volts	PCM uses this signal to determine glow plug need and WAIT TO START lamp initiation
MAT Manifold Air Temperature	Voltage reading (relative to engine oil and ambient air temperatures) Example: 60°C (140°F) = 2.11 volts	Not used in this strategy
CMP Camshaft Position Sensor	0 rpm	PCM uses this signal to monitor continuous rpm feedback
ICP Injection Control Pressure Sensor	0.17 – 0.30 volts	Feedback for IPR %
IPR% Injection Control Pressure Regulator	Preset at 14%	Output from the PCM
FUEL PW Fuel Pulse Width	0.42-0.52 ms (Non-fueling pulse width)	Output from the PCM
BARO Barometric Pressure Sensor	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	PCM uses this signal to regulate glow plug on time relevant to altitude

KEY ON ENGINE OFF – NORMAL OPERATING STRATEGY (*Continued*)		
EBP Exhaust Back Pressure	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	Not used in this strategy
EPR% Exhaust Pressure Regulator	0%	No command during this strategy
MAP Manifold Absolute Pressure Sensor	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	Not used in this strategy
WGC% Wastegate Control	99%	Not used in this strategy. Wastegate is closed
AP Accelerator Pedal Position Sensor	0.5-1.25 volts (with foot off pedal)	PCM uses this signal to determine accelerator position
IVS Idle Validation Switch	OFF (with foot off pedal)	PCM uses this signal to check the AP sensor

Crank/Start Strategy

When the ignition switch is turned to the START position, the engine will begin cranking. The PCM reads the CMP sensor signal to determine if the engine is actually cranking, and the position of the camshaft. The PCM uses this information to enable the fuel pump relay. It also produces an FDCS signal and sends it to the IDM. The IDM uses the signal to synchronize and control injector timing and fuel quantity. The PCM also produces a CID signal for the IDM. Injector synchronization can only occur after both of these signals are received by the IDM. The PCM reads the ICP signal to determine when enough injection control pressure has been developed in the high-pressure oil system to start the engine and allow it to run. The PCM requires a minimum of 3,447.3 kPa (500 psi) from the ICP to command a fueling pulse width to the IDM. The PCM will command higher injection control pressure by increasing IPR percentage until the engine starts.

All of these factors allow the PCM start the engine and carry out system checks.

NOTE: The highlighted items in the chart below are the inputs and outputs most critical to the Crank/Start Strategy.

CRANK/START: PCM – NORMAL OPERATING STRATEGY		
PID NAME	**EXPECTED PID VALUE**	**PCM SIGNAL USAGE**
IAT	Voltage reading (proportional to ambient air temperature) Example: 20°C (68°F) = 3.09 volts	**Not used in this strategy**
EOT	Voltage reading (proportional to engine oil temperature) Example: 60°C (140°F) = 2.11 volts	**Not used in this strategy**
MAT	Voltage reading (relative to engine oil and ambient air temperatures) Example: 60°C (140°F) = 2.11 volts	**Not used in this strategy**
CMP	Cranking rpm example: 100 rpm minimum	PCM uses this signal to monitor continuous rpm feedback. CID generated at 100-or greater rpm
ICP	Minimum 3,447.3 kPa (500 psi) is necessary to deliver fuel	PCM uses this signal to determine if injector oil pressure is high enough to start the engine
IPR%	Preset to 14% increases during cranking if the engine does not start to maximum of 65%	The PCM will keep increasing % during cranking to a maximum of 65% or until the engine starts.
FUEL PW	0.42 ms Non-fueling until 3,447.3 kPa (500 psi) of ICP then will increase to greater than 1.0 ms	Output from the PCM
BARO	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	**Not used in this strategy**
EBP	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	**Not used in this strategy**
EPR%	0%	**No command during this strategy**
MAP	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	**Not used in this strategy**
WGC%	99%	Not used in this strategy. Wastegate is closed
AP	0.5-1.25 volts (with foot off pedal)	**Not used in this strategy**
IVS	OFF (with foot off pedal)	**Not used in this strategy**

Idle Strategy

When the engine is started the PCM reads the AP sensor and the IVS to make sure that the accelerator pedal is in the idle position. The PCM adjusts injection control pressure by varying IPR percentage in attempt to reach and then maintain idle rpm. The PCM reads the EOT and CMP sensors to determine required fuel quantity and injector timing. Input from the MAP and BARO sensors is also used for minor fuel delivery compensations.

All of these factors allow the PCM keep the engine running at idle and perform system checks.

IDLE: PCM – NORMAL OPERATING STRATEGY		
PID Name	**Expected PID Value**	**PCM Signal Usage**
IAT	Voltage reading (proportional to ambient air temperature) Example: 20°C (68°F) = 3.09 volts	**Not used in this strategy**
EOT	Voltage reading (proportional to engine oil temperature) Example: 60°C (140°F) = 2.11 volts	PCM uses this signal to adjust fuel quantity, injection timing and glow plug afterglow (glow plug operation after the engine has started)
MAT	Voltage reading (proportional to ambient air temperature) Example: 20°C (68°F) = 3.09 volts	PCM uses this signal to adjust fuel quantity and injection timing
CMP	Engine rpm approx. 650	PCM uses this signal to monitor continuous rpm feedback
ICP	3,447.3-4826.3 kPa (420-700 psi)	PCM uses this signal for feedback for IPR%/ command
IPR%	8 – 16	Adjusted to maintain target rpm
FUEL PW	Greater than 1.0 ms	Output from the PCM
BARO	Atmospheric pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	Used to determine atmospheric pressure
EBP	Variable depending on pressure in the exhaust system Example: 14.7 psia (sea level)	PCM uses this signal for feedback relative to EPR%/command
EPR%	0	Refer to exhaust backpressure system summary for operating conditions
MAP	Manifold absolute pressure reading (Variable depending on altitude) Example: 1.5 volts = 14.7 psia (sea level)	PCM uses this signal for fuel calculations
WGC%	99 venting to atmosphere	Wastegate closed, no pressure applied
AP	0.5-1.25 volts with foot off pedal	PCM uses this signal to determine accelerator position
IVS	OFF (0 volts with foot off pedal)	PCM uses this signal to check the AP sensor is in off idle position.

Part Throttle Strategy

The AP sensor and the IVS are continuously read by the PCM to determine driver demand. The PCM adjusts injection control pressure by varying IPR percentage in an attempt to reach and then maintain driver demand. The ICP sensor is monitored to verify commanded injection control pressure has been established. The PCM also reads the EOT, CMP, MAP, MAT and BARO sensors to determine required fuel quantity and injector timing.

All of these factors allow the PCM to operate the engine at part throttle speeds and carry out system checks.

PART THROTTLE: PCM – NORMAL OPERATING STRATEGY		
PID Name	**Expected PID Value**	**PCM Signal Usage**
IAT	Voltage reading (proportional to ambient air temperature) Example: 20°C (68°F) = 3.09 volts	**Not used is this strategy**
EOT	Voltage reading (proportional to engine oil temperature) Example: 60°C (140°F) = 2.11 volts	PCM uses this signal to adjust fuel quantity, injection timing
MAT	Voltage reading (proportional to ambient air temperature) Example: 20°C (68°F) = 3.09 volts	PCM uses this signal to help adjust fuel quantity and injection timing
CMP	Engine rpm	PCM uses this signal to monitor continuous rpm feedback and adjust CID and FDCS signals
ICP	Above 3,447.3 kPa (500 psi)	PCM uses this signal for feedback for IPR%/command. Pressure relative to IPR command
IPR%	Greater than 16	IPR adjusted to achieve injection pressure desired to meet driver demand for power
FUEL PW	1.0 to 6.0 ms	Output from the PCM
BARO	Atmospheric pressure reading (Variable depending on altitude)	PCM samples to monitor altitude
EBP	Variable depending on EBP in the exhaust system	PCM uses this signal for feedback relative to EPR%/command
EPR%	0	Refer to exhaust backpressure system summary for operating conditions
MAP	Relative to turbo boost and greater than atmospheric	PCM uses this signal for fuel calculations. Dependent on boost pressure
WGC%	99 when boost is less than 124.1 kPa (18 psi)	PCM will adjust % to achieve and maintain desired boost pressure
AP	Greater than 0.5 volts	PCM uses this signal to determine accelerator position
IVS	ON (12 volts)	PCM uses this signal to check the AP sensor is off idle

Peak Power Strategy

Peak power occurs between 2,400 and 2,800 rpm, when both driver demand and vehicle load are very high. Peak power is achieved when the maximum amount of fuel and boost pressure are being delivered. During peak power AP voltage will be near maximum. The PCM will adjust injection control pressure by increasing IPR percentage in accordance with driver demand. The ICP sensor is monitored to verify commanded injection control pressure has been established. The PCM also reads the EOT, CMP, MAP, MAT and BARO sensors to determine required fuel quantity and injector timing. Another important factor during peak power situations is boost pressure control. On vehicles equipped with electronic wastegate control, the PCM varies WGC percentage to maintain maximum boost levels.

All of these factors allow the PCM to operate the engine at peak power output and carry out system checks.

PEAK POWER: PCM – NORMAL OPERATING STRATEGY (Heavy acceleration 2,400-2,800 rpm [max load with min rpm gain])		
PID Name	**Expected PID Value**	**PCM Signal Usage**
IAT	**Not used in this strategy**	**Not used in this strategy.**
EOT	Between 82ºC and 110ºC (180°F and 230°F) (engine should be completely warmed up before expecting peak power)	PCM uses this signal to adjust fuel quantity, injection timing
MAT	Between IAT and EOT temperatures	PCM uses this signal to help adjust fuel quantity and injection timing
CMP	Engine rpm (2,400 to 2,800 rpm)	PCM uses this signal to monitor continuous rpm feedback and CID
ICP	Greater than 12,410.56 kPa (1,800 psi)	PCM uses this signal for feedback for IPR%/ command. Pressure relative to IPR
IPR%	Greater than 35	IPR adjusted to achieve injection pressure desired to meet driver demand for power
FUEL PW	3.0 to 6.0 ms	Fueling PW supplied to IDM to achieve peak power under operating conditions
BARO	Atmospheric pressure reading (Variable depending on altitude)	PCM samples to monitor altitude
EBP	Variable depending on EBP in the exhaust system Example: 206.8-275.7 kPa (30-40 psi)	PCM uses this signal for feedback relative to EPR%/command
EPR%	(0) Disabled	Output from the PCM
MAP	Atmospheric pressure + boost pressure Example: 28-32 psia (manifold gauge pressure = 103.4-124.1 kPa [15-18 psi])	PCM uses this signal for fuel calculations. Dependent on boost pressure
WCG%	(99 when boost is less than 124.1 kPa [18 psi])	PCM will adjust % to achieve and maintain desired boost pressure
AP	Maximum voltage (3.8 – 4.2 volts)	PCM uses this signal to determine accelerator position
IVS	ON (12 volts)	PCM uses this signal to check the AP sensor is in off idle position

Cold Weather Operating Strategies

Other operating strategies also exist within the PCM. Listed below are some of them:

- Cold weather operation
  - The PCM has cold weather strategies that use various inputs and control various outputs to allow the engine to run at a higher rpm and the torque converter clutch not to engage until operating temperature is reached.
  - The strategy that controls cold weather engine operation is called Cold Ambient Protection (CAP). CAP is also referred to as "idle kicker." The PCM uses certain parameters and readings from the IAT, EOT, and battery voltage. The PCM will raise engine idle to 1,000 rpm if these sensors provide readings within the following ranges:
    - IAT – Below 10°C (50°F) snapshot during KOEO
    - EOT – Below 70°C (158°F)
    - Batt Voltage – 11.7 volts or greater

    CAP will be deactivated if any of these parameters are over specification or the PCM senses movement of the brake pedal, clutch pedal, or accelerator pedal.

IDM Operating Strategies

The injector driver module (IDM) is equipped with strategies on control fuel pulse width and control electrical current to the injectors. The FDCS signal from the PCM is used by the IDM to control fuel injection timing and duration. The CID signal from the PCM to the IDM allows it to control synchronization to the engine's first and fifth injector (cylinders number one and four in the firing order). The IDM strategy verifies that the FDCS and CID signals occur at valid timing intervals. Also included are strategies that allow the IDM to detect faults in the electrical part of an injector, or within itself, and to send a DTC to the PCM through the EF signal. If the EF circuit fails, the IDM strategy allows it to function normally, but the PCM will detect this communication error and set a fault code.

OBD I AND OBD II CONTROL SYSTEMS

The California Air Resources Board (CARB) began regulation of On Board Diagnostic (OBD) systems for vehicles sold in California beginning with the 1988 model year. OBD consists of two phases: OBD I and OBD II. They are similar in that they both use strategies to monitor and calculate changes within the vehicle operation and conditions. OBD I and OBD II act upon the conditions by changing electrical output voltages and monitoring various input voltages.

The main difference between the strategies for OBD I and OBD II is expanded fault monitoring capabilities.

California vehicles utilize a Glow Plug Monitor (GPM) system designed to locate failed glow plugs or failed wiring in the glow plug system. DTCs indicate which bank has failed glow plugs or failed glow plug wiring.

⚠ **CAUTION: Modifications or additions such as burglar alarms, cellular telephones, citizen band radios (CBs) and stereos/amplifiers, etc. may cause incorrect operation of the OBD systems.**

These add-ons must be carefully installed.

NOTE: Do not install add-on devices by tapping into, or running wires close to the PCM, wires or components.

PCM FAILURE AND DEFAULT STRATEGIES

Failure Mode Effects Management (FMEM)

Failure Mode Effects Management (FMEM) is an alternate system strategy, programmed into the PCM, and designed to maintain vehicle operation if one or more inputs fail. When an input is perceived to be out of limits by the PCM, an alternate strategy is initiated. The PCM substitutes a value and continues to monitor the incorrect input. In some cases, FMEM may direct the PCM to look at signals from secondary or backup components in substitution of a failed component. For example, the main signal used by the PCM for barometric pressure information is the BARO sensor. If the PCM cannot read the BARO information, the MAP sensor signal at low idle may be substituted by the PCM. If a suspected out of range input begins operating within limits, the PCM returns to a normal engine running strategy.

REVIEW QUESTIONS

1. The PCM disengages the electric fuel pump, while the engine is cranking, if a signal is not detected from the:

   A. Idle Air Temperature (IAT) sensor.

   B. Manifold Absolute Pressure (MAP) sensor.

   C. Engine Oil Temperature (EOT) sensor.

   D. Camshaft Position (CMP) sensor.

2. The IDM needs to receive a __________ and ___________ signal before injector synchronization can occur.

   A. Cylinder Identification (CID), Fuel Delivery Control (FDCS)

   B. Manifold Air Temperature (MAT), Engine Oil Temperature (EOT)

   C. Barometric Pressure (BARO), Cylinder Identification (CID)

   D. Camshaft Position (CMP), Fuel Delivery Control (FDCS)

3. Cold Ambient Protection (CAP) allows the PCM to _________ engine idle on the 7.3L DIT engine when certain perameters are met.

4. The PCM takes a snapshot of what sensor to determine if the EBP strategy should be enabled?

   A. IAT

   B. EOT

   C. BARO

   D. MAP

NOTES

TECHNICIAN OBJECTIVES

- Describe the purpose for carrying out the KOEO on-demand self-test.
- Describe the purpose for retrieving and clearing continuous codes.
- Describe the purpose for carrying out the KOEO injector electrical self-test.
- Describe the purpose for carrying out the KOER switch test.
- Describe the purpose for carrying out KOEO output state check.
- Describe the purpose for carrying out the KOER on-demand self-test.
- Describe the purpose for carrying out the KOER cylinder contribution test.
- Describe the purpose for carrying out the glow plug monitor test.
- Describe the purpose for monitoring PIDs.
- Describe how to choose PIDs to monitor during diagnosis.
- Describe how to determine if a given PID is normal or abnormal.
- Describe calculated PID values.
- Describe the importance of understanding the relationships between PIDs.
- Describe the flash Electronically Erasable Programmable Read Only Memory (FEEPROM).
- Describe when to reprogram the PCM.

CONTENTS

PCM SELF-TESTS

PCM self-tests are divided into eight specialized tests. These tests provide a quick check of the integrity of the PCM and the subsystems, including the sensors, switches and actuators. These self-tests are usually carried out at the start of each diagnostic procedure. They should also be carried out at the end of most pinpoint tests to verify repairs and make sure no other faults were generated as a result of carrying out a repair. All of the PCM self-tests are on-demand tests except retrieve/clear continuous codes, which is a continuous test.

DIAGNOSTIC TROUBLE CODES

Diagnostic Trouble Codes (DTC) are provided to guide the technician to the correct pinpoint test as directed by the Diagnostic Trouble Code Description chart in the PC/ED manual. This is necessary to isolate the system or component that may be causing a customer concern. DTCs can be retrieved with a scan tool by carrying out one or more of the eight self-tests.

There are two types of DTCs that can be generated:

- Continuous DTCs, which are stored in the PCM memory. Any time that the ignition key is in the RUN or START position, the PCM continuously monitors sensor input data and actuator output operation. If sensor data is not valid or an actuator fails to work correctly, the PCM stores a DTC. This allows the PCM to store information about historic faults that may occur. If a fault is detected that will affect power and emissions, a DTC is stored in the PCM memory and on OBD II vehicles the Malfunction Indicator Lamp (MIL) will be illuminated after two drive cycles to notify the driver that a problem exists. Because continuous codes may be related to historic faults, they do not necessarily indicate that a problem exists at the time they are retrieved.
- On-demand codes, are codes that are displayed at the end of an on-demand self-test and indicate conditions as they exist in the system at the time of testing.

Key ON Engine OFF (KOEO) On-Demand Self-Test

The Key ON Engine OFF on-demand self-test can be used to determine if a continuous code is a hard fault. During the on-demand self-test, the PCM tests the circuits of all input sensors and output devices to make sure that they are operating normally. If a DTC is retrieved during the test, it indicates that a fault exists at the time of the test.

Any IDM related codes retrieved during this test might be continuous codes. In order to make sure that IDM related codes are hard faults, record all IDM fault codes, clear the continuous codes, drive the vehicle and rerun the on-demand self-test. If continuous codes are cleared, and the DTC is again received during the on-demand self-test, the code is a hard fault.

Retrieve/Clear Continuous Codes

Retrieving continuous codes provides a history of recent DTCs that can guide the diagnostic procedure to the most likely cause of a symptom. Be sure to run the KOEO on-demand test first before clearing codes to prevent clearing IDM codes.

During retrieve/clear continuous codes, the scan tool will not display any IDM continuous codes. Carry out the KOEO on-demand self-test or the KOEO injector electrical self-test to retrieve IDM codes.

NOTE: It is important to note that even though the retrieve/clear continuous codes function of the scan tool does not display the IDM codes, if continuous codes are cleared, all IDM codes are also cleared.

If the system did not pass, make a note of the DTC(s) before clearing codes. Keep in mind that because continuous codes are memory codes, they do not necessarily indicate a concern that is present at the time of the test.

KOEO Injector Electrical Self-Test

The KOEO injector electrical self-test is a functional test by the IDM of the injector electrical circuits that determines if they are operating correctly. Because the IDM will report both continuous and hard DTCs during this test, you should clear all continuous DTCs prior to beginning this test. Be sure to record all IDM fault codes before clearing them.

When the test begins, the IDM turns on all of the injectors for approximately two seconds. Then, the IDM will turn on each injector individually for approximately one second. If a fault occurs in an injector circuit, a DTC will be recorded.

KOER Switch Self-Test

The KOER switch self-test is designed to check the operation of certain input devices to determine if they are operating correctly. A DTC is set if the PCM does not detect a transition of one or more of the switches during the test. This is an interactive test that requires technician input.

The PCM monitors the following input switches when they are operated during the test:

- Idle Validation Switch (IVS)
- Parking Brake Applied (PBA) switch
- Speed Control Command Switches (SCCS):
  - speed control ON
  - speed control OFF
  - speed control RESUME
  - speed control COAST
  - speed control SET/ ACCEL
- Transmission Control Switch (TCS)
- Clutch Pedal Position (CPP) switch
- Brake Pressure Applied (BPA) switch
- Brake ON/OFF (BOO) switch

This test must start with the idle validation switch and end with the brake ON/OFF switch. If any of the switches are inoperative, or if the test is not completed in the correct order, a DTC will be recorded and displayed on the scan tool.

NOTE: Vehicles not equipped with speed control will generate codes for speed control command switches and brake pressure applied switch during this test.

KOEO Output State Self-Test

The KOEO output state self-test is designed to cycle outputs on and off. During this test, the accelerator pedal is depressed and released twice – once to cycle the outputs high (on) and a second time to cycle them low (off). This self-test does not set any codes. It allows the circuit to be tested in its active state.

Output devices that are actuated during this test include:

- solenoids
- glow plug relay
- WAIT to START lamp
- injector driver module relay
- Transmission Control Indicator Lamp (TCIL)
- Fuel Delivery Command Signal (FDCS) and the Cylinder Identification (CID) from the PCM to the IDM

During the output test, suspect components are checked for correct operation by using a voltmeter to determine if the component is receiving the correct command signals from the PCM.

You should also wiggle the wiring harness of any suspected components during this test. This can sometimes help in diagnosing intermittent wiring concerns.

Key ON Engine Running (KOER) On-Demand Self-Test

To check the function of the ICP and EBP systems, it is necessary to carry out an engine running on-demand self-test. During the testing, engine rpm will increase as the PCM tests the performance of the ICP and EBP systems. The PCM will first command ICP high and low, then command EBP high and low. If a fault is present at the time of the test it will be displayed on the scan tool at the end of the test.

KOER Cylinder Contribution Test

The KOER cylinder contribution test is carried out by the PCM to determine if all of the cylinders are contributing equally to engine performance. If a weak cylinder is detected, a DTC is recorded and displayed on the scan tool. Based on the model year, engines may respond differently during the test. On some years, the engine idle will rise and injector operation may vary (a knocking noise may be heard). On other years, the engine will not exhibit any noticeable change during the test. Because cam timing is used to measure cylinder attributes.

If a weak cylinder is detected, it will be necessary to eliminate base engine concerns as the cause. Additional diagnostic tests will need to be performed to isolate the root cause of the weak cylinder.

KOER Glow Plug Monitor Test

The KOER glow plug monitor test is an on-demand test. It activates the glow plug relay and monitors the glow plugs for a difference in current between the two banks. This test is only available on certain E-series and California E- and F-series vehicles.

During the test, the PCM will activate the glow plugs and monitor the amount of current used by each bank. If the amount of current used by one bank of glow plugs is 8.5 amps lower than the current used by the other bank, or either bank is using less than 32 amps, a DTC will be recorded and displayed on the scan tool.

PID DATA MONITOR

One of the most effective ways to find the cause of vehicle concerns is the parameter identification (PID) data monitor. The PID data monitor allows you to monitor and record certain sensor data and actuator outputs while the vehicle is in operation. PID values are snapshots and do not reflect real time values. Output values are what the PCM is commanding, and not what the output is actually doing.

PIDs must be monitored in order to determine if they accurately represent the operating conditions of the vehicle. By monitoring PIDs, you can observe the signal as interpreted by the module. This allows you to determine if the signal or PID reflects actual operating conditions.

To choose the appropriate PIDs, use S-S-C-C logical diagnostic thinking. Choose PIDs that are related to the symptom that is being diagnosed. For example, if the symptom is a lack of power, you might observe PIDs like manifold gauge pressure, rpm, and AP. A PID such as glow plug control time would not help in the diagnosis of this concern. For further assistance in choosing appropriate PIDs, refer to the Diagnostic Methods sections of the PC/ED.

When analyzing sensor data, look for abrupt changes in sensor data that occur without a corresponding change in driver input. For example, while monitoring the AP sensor when depressing the accelerator pedal, the displayed voltage should correspond to accelerator pedal movement. If an abrupt change in voltage occurs without a corresponding change in accelerator pedal position, this may indicate a fault in the sensor or circuit.

NOTE: When monitoring PID data you are actually looking at PCM provided information not actual sensor values.

Output PID data represents the PCM command to actuate an output. It does not necessarily indicate that the output is actually functioning.

Determine if a Given PID is Normal or Abnormal

There are situations where a sensor or component has deteriorated, yet its signal is not outside the programmed calibrations of the module. In these cases, operation of the vehicle may be affected, yet no DTC will be stored in memory. For this reason, the scan tool has the capability to monitor PIDs. You need to compare PIDs to:

- operating conditions
- relationships to other PIDs
- experience and understanding
- other means of measuring the same data

If the PID reading is abnormal, it may be necessary to run additional diagnostics to determine why the PID reading is out of range.

Calculated PID Values

Some PIDs may not correspond directly to an actual sensor or output device. Input from several sensors may be used to calculate these values. For example, the PCM measures the MAP and BARO signals and converts them into manifold gauge pressure (MGP) by subtracting the BARO value from the MAP value (20 psia MAP – 13.5 psia BARO = 6.5 psi MGP).

Relationship Between PIDs

It is important to understand the relationship between PID values. For example, we already know that during normal operation sensors should provide the same value when they are measuring the same information. For example, temperature readings for IAT, and EOT should be the same if the engine has not been running or if the vehicle has been parked overnight. As a result, it is very important to know how a system operates so that you can understand the relationships that exist between its sensors and actuators.

REPROGRAMMING THE PCM

Flash Electrically Erasable Programmable Read Only Memory (FEEPROM)

The Flash Electrically Erasable Programmable Read Only Memory (FEEPROM), or E_PROM, is an integrated circuit within the PCM. This integrated circuit contains the software code required by the PCM to control the powertrain. One feature of the FEEPROM is that it can be electrically erased and then reprogrammed without removing the PCM from the vehicle. If a software change is required to the PCM, the module no longer needs to be replaced, but can be reprogrammed at the dealership. The reprogramming is done through the DLC.

When to Reprogram the PCM

The PCM should only be reprogrammed when directed to do so by Technical Service Bulletins (TSBs) or Special Service Messages (SSM) or recall.

⚠ **CAUTION: Transmission damage may occur if reprogramming is done incorrectly or for the wrong application.**

NOTES

REVIEW QUESTIONS

1. Historic faults that may have occurred during engine operation are called ________________

   ____ .

2. ___________________ codes indicate conditions that exist in the vehicle at the time a self-test is run.

3. Which self-test needs to be run first before clearing continuous codes to prevent clearing of the injector driver module (IDM) codes?

   A. Key ON Engine OFF (KOEO) injector electrical test

   B. Key ON Engine OFF (KOEO) on-demand self-test

   C. either A or B

   D. neither A nor B

4. To determine if an IDM related code is a hard fault, the codes should be recorded and cleared. Then, the key ON engine OFF (KOEO) on-demand self-test should be rerun after a road has been completed.

   A. True

   B. False

5. During which self-test should a “wiggle” test be carried out?

   A. Key ON Engine Running (KOER) on-demand self-test

   B. Key ON Engine OFF (KOEO) on-demand self-test

   C. Key ON Engine Running (KOER) switch self-test

   D. Key ON Engine OFF (KOEO) output state self-test

6. A sensor with an abnormal Parameter Identification (PID) should be replaced without first reading all other PIDs that may be related to the concern.

   A. True

   B. False

7. Reprogramming of the PCM is done through the ___________.

NOTES

LESSON 1: DIESEL ENGINE CONCEPTS AND CHARACTERISTICS

1. The 7.3L DIT electronic engine control system is divided into how many subsystems?
   A. three
   B. seven
   C. five
   D. ten
2. Which of the following is not an electronic engine control output?
   A. Turbocharger boost pressure control
   B. Transmission shift scheduling
   C. Starting aid operation
   D. Engine load
3. The _________________ and _________________ systems are responsible for controlling fuel timing and delivery.
   Fuel injector control & high-pressure oil control
4. The high-pressure oil system is used to:
   A. supply lube oil the crankshaft.
   B. lubricate the turbocharger.
   C. actuate the HEUI fuel injectors.
   D. operate the exhaust backpressure valve.
5. The system that has the greatest affect on assisting with cold start is the:
   A. Engine control subsystem.
   B. Electronic fuel supply subsystem.
   C. Glow plug control subsystem.
   D. None of the above.

NOTES

LESSON 2: DIESEL ENGINE POWERTRAIN CONTROL SYSTEM

1. The __________________ and __________________ sensor signals are used by the PCM to determine engine operating temperature for adjustment of fuel delivery.

   Engine Oil Temperature (EOT) and Manifold Air Temperature (MAT)

2. The ________________signal is used by the PCM to generate the signals that will be sent to the Injector Driver Module (IDM).

   Camshaft Position (CMP) sensor

3. The Injector Driver Module (IDM) receives two digital control signals from the PCM, they are the ___________________________ and ____________________________.

   Fuel Delivery Control Signal (FDCS) and Cylinder Identification (CID) signal

4. The IDM contains a step up transformer that raises supply voltage to the injectors to____________.

   115 volts DC

5. It is recommended that injector circuit voltage checks under the valve covers be done with the engine running.

   A. True

   B. False

6. Gold-plated connector terminals should be replaced with ___________ terminals.

   A. gold-plated

   B. copper

   C. brass

   D. aluminum

7. The ______________ and ______________ are the only outputs used by the glow plug control system.

   Glow Plug Relay (GPR) / Glow Plug Lamp (GPL)

NOTES

LESSON 2: DIESEL ENGINE POWERTRAIN CONTROL SYSTEM (Continued)

8. If a disagreement between the Idle Validation Switch (IVS) and the Accelerator Pedal (AP) sensor is detected by the PCM.

   A. the engine will not start.

   B. the engine will run at high idle only.

   C. the engine will run at low idle only.

   D. the engine will operate normally and a DTC will be generated.

9. The Engine Oil Temperature (EOT) sensor is mounted in the:

   A. oil pan.

   B. engine block.

   C. high-pressure pump housing.

   D. high-pressure reservoir.

10. The Injection Control Pressure (ICP) sensor is located in the:

    A. right hand cylinder head.

    B. left hand cylinder head.

    C. injection Control Pressure Regulator (IPR).

    D. high-pressure oil reservoir.

11. Turbocharger wastegate control is based on the __________ sensor reading.

    A. Manifold Absolute Pressure (MAP)

    B. Manifold Air Temperature (MAT)

    C. Barometric Pressure (BARO)

    D. Exhaust Backpressure (EBP)

12. Maximum glow plug on time is ___________ seconds.

    120

13. The sensor most responsible for glow plug on time is the:

    A. Manifold Air Temperature (MAT) sensor

    B. Engine Oil Temperature (EOT) sensor

    C. Intake Air Temperature (IAT) sensor

    D. Engine Coolant Temperature (ECT) sensor

NOTES

LESSON 2: DIESEL ENGINE POWERTRAIN CONTROL SYSTEM (Continued)

14. The Exhaust Backpressure Regulator (EPR) controls vacuum flow to the EBP regulator piston.
    A. True
    B. False
15. ________________is a snapshot taken by the PCM in the determination of exhaust backpressure valve use.
    Intake Air Temperature (IAT)
16. The PCM disengages the electric fuel pump while the engine is cranking if a signal is not detected from the:
    A. Idle Air Temperature (IAT) sensor
    B. Manifold Absolute Pressure (MAP) sensor
    C. Engine Oil Temperature (EOT) sensor
    D. Camshaft Position (CMP) sensor
17. The ____________ signal is the only output to control speed control on a 7.3L DIT engine.
    Fuel Delivery Control Signal (FDCS)
18. A flashing Transmission Control Indicator Lamp (TCIL) is an indication of:
    A. Overdrive cancelled.
    B. PCM detection of a sensor or actuator failure in the transmission control system.
    C. Both A and B.
    D. Neither A nor B.
19. On a two generator charging system, the primary generator is turned off by the PCM during glow plug operation.
    A. True
    B. False
20. The intake air heater is found on vehicles:
    A. with a catalytic converter.
    B. without a catalytic converter.
    C. either A or B.
    D. both A and B.

NOTES

LESSON 3: MODULE CONTROL AND FAILURE STRATEGIES

1. The PCM disengages the electric fuel pump, while the engine is cranking if a signal is not detected from the:

   A. Idle Air Temperature (IAT) sensor

   B. Manifold Absolute Pressure (MAP) sensor

   C. Engine Oil Temperature (EOT) sensor

   D. Camshaft Position (CMP) sensor

2. The IDM needs to receive a __________ and ___________ signal before injector synchronization can occur.

   A. Cylinder Identification (CID), Fuel Delivery Control (FDCS)

   B. Manifold Air Temperature (MAT), Engine Oil Temperature (EOT)

   C. Barometric Pressure (BARO), Cylinder Identification (CID)

   D. Camshaft Position (CMP), Fuel Delivery Control (FDCS)

3. Cold Ambient Protection (CAP) allows the PCM to _________ engine idle on the 7.3L DIT engine when certain perameters are met.

   Raise

4. The PCM takes a snapshot of what sensor to determine if the EBP strategy should be enabled?

   A. IAT

   B. EOT

   C. BARO

   D. MAP

NOTES

LESSON 4: DIESEL ENGINE DIAGNOSTIC TESTS

1. Historic faults that may have occurred during engine operation are called ________________.

   Continuous Diagnostic Trouble Codes (DTC)

2. ___________________ codes indicate conditions that exist in the vehicle at the time a self-test is run.

   On-demand

3. _ Which self-test needs to be run first before clearing continuous codes to prevent clearing of the injector driver module (IDM) codes?

   A. Key ON Engine OFF (KOEO) injector electrical test

   B. Key ON Engine OFF (KOEO) on-demand self-test

   C. either A or B

   D. neither A nor B

4. To determine if an IDM related code is a hard fault, the codes should be recorded and cleared. Then, the key ON engine OFF (KOEO) on-demand self-test should be rerun after a road has been completed.

   A. True

   B. False

5. During which self-test should a “wiggle” test be carried out?

   A. Key ON Engine Running (KOER) on-demand self-test

   B. Key ON Engine OFF (KOEO) on-demand self-test

   C. Key ON Engine Running (KOER) switch self-test

   D. Key ON engine OFF (KOEO) output state self-test

6. A sensor with an abnormal Parameter Identification (PID) should be replaced without first reading all other PIDs that may be related to the concern.

   A. True

   B. False

7. Reprogramming of the PCM is done through the ___________.

   Data Link Connector (DLC)

NOTES

DIESEL ENGINE ELECTRONICS TERMINOLOGY

The diesel engine electronic terminology used throughout this course is as follows:

ABSOLUTE PRESSURE – Pressure relative to a complete vacuum. Absolute pressure is usually measured in inches of mercury. At sea level this is 29.9 in. hg. Converted to pounds it is 14.7 psi. Absolute pressure is used when atmospheric conditions are important in the reading of a particular pressure, such as MGP for boost control of the 7.3L DIT engine. Absolute pressure = gauge pressure + atmospheric pressure.

ACTUATOR – A device that delivers motion in response to vacuum, pressure or an electrical signal.

AFTERGLOW – The continued heating of glow plugs after a diesel engine has started.

AMBIENT – The temperature of the air surrounding an object. For an example, ambient temperature is the temperature in the garage where the vehicle is being repaired or the temperature outdoors where the vehicle is being operated.

ANALOG – A continuously variable voltage signal.

ATMOSPHERIC PRESSURE – The pressure due to the weight of the earth's atmosphere. At sea level, the atmosphere pressure is about 14.69 pounds per square inch and is affected by weather. Atmospheric pressure is lower at altitudes above sea level.

BANK – A term used to indicate one side of an engine. Example: left bank of the engine.

BOOST – The term used for pressure produced by a turbocharger when it increases airflow into the combustion chamber. Boost is usually measured in pounds per square inch (psi).

CALIBRATION – The data values used by the strategy in a processor to solve equations and make decisions. Calibrations are stored in the ROM as scalars, functions and tables. Calibration values are input into the processor during programming to allow the engine to operate within certain parameters.

CHARGE AIR COOLING – A process of cooling the air coming out of the turbocharger before it enters the engine.

CLOSED LOOP – An operating mode of the PCM in which the PCM samples input sensors to determine how much the command output actually changed. Then, the PCM makes another change (if required) to produce the desired result.

DRIVER – A transistorized switch inside the PCM or module, which turns outputs on and off.

DIESEL THERMAL RECIRCULATION MODULE (DTRM) – Located on the fuel Pick-Up unit, the purpose is two fold. First, it screens fuel before it is drawn into the fuel pump. Second, it helps to warm the fuel in the fuel system and maintain a controlled fuel temperature.

DUTY CYCLE – The ratio of the signal ("on") time to the total length of the cycle (on time plus off time). Duty cycle is measured during one full cycle of a signal. Duty cycle is expressed as a percentage.

GAUGE PRESSURE – The reading of pressure that starts at zero. Used when atmospheric pressure is not important.

HALL EFFECT SENSOR – A sensor that opens and closes a circuit electronically based on changes in magnetic flux. Typically used for rpm or position measurement, such as the camshaft.

HIGH SIDE – Term used to describe voltage or power side of an electronic circuit.

IDLE KICKER – A strategy within the PCM that raises engine idle under certain conditions.

IN-RANGE FAILURE – When a sensor value is not out of its operating limits, but its information in inaccurate.

IMPEDANCE – A form of opposition to current flow measured in ohms.

KEEP ALIVE RANDOM ACCESS MEMORY – Information stored by the PCM in Keep Alive RAM (a memory integrated circuit chip) about vehicle operating conditions, and then uses this information to compensate for component variability. Keep Alive RAM remains powered when the vehicle key is off so that this information is not lost.

LOW SIDE – Commonly used to describe the ground side (0V) of an electronic circuit.

MODULATE – The controlling of a solenoid by varying the amplitude or frequency of the voltage supplied to that solenoid. An example of this would be the exhaust backpressure regulator.

NORMALLY CLOSED – A normally closed switch allows the flow of electrical current.

NORMALLY OPEN – The position the switch is designed to be in until it is actuated. An open switch prevents the flow of electrical current.

POWER TAKE OFF (PTO) – An addition to the transmission which allows the transmission to operate optional accessories, such as a tow truck boom winch.

POTENTIOMETER – A device that converts a mechanical movement to a voltage value. It is most often used to sense the position of a component. This sensor works as a variable voltage divider. The wiper arm is mechanically connected to the moving part of the component to be sensed. Potentiometers have three connections: VREF, signal out, and ground.

PULSE-WIDTH – The length of time an actuator, such as an fuel injector, remains energized.

RATIONALITY CHECK – The strategy used in diagnosis to determine if a sensor is supplying the correct value. For example, when the key is turned to the ON position, the PID values are for the MAP and BARO sensors are used to determine if they are both reading atmospheric pressure.

READ ONLY MEMORY (ROM) – A type of memory used to store information permanently. Information cannot be written to ROM; as the name implies, information can only be read from ROM.

SELF-LIMITING – An electrical component that changes the current it uses to operate in relation to temperature.

SNAPSHOT – A sample of a particular sensor value taken by the PCM at a particular time. For example, the PCM takes a snapshot of the IAT sensor when the key is turned ON to determine whether to enable EBP.

SPLIT SHOT INJECTOR (PRIME) – An injector that provides improved exhaust emissions and quiet engine operation by tailoring the injection of fuel, without a decrease in performance.

STRATEGY – The operating programs within the PCM that allow it to provide outputs commands based on input values.

THERMISTOR – A resistor that changes its resistance with temperature. Increasing temperature results in a decrease in resistance; decreasing temperature results in an increase in resistance.

VARIABLE CAPACITANCE – A sensor that stores an electrical charge corresponding to pressure and produces analog voltage signal being returned. Usually used in pressure measurement.

VARIABLE FORCE SOLENOID – A solenoid that is controlled by a variable current from a module or processor. By varying the current to the solenoid, force or pressure can be controlled.

DIESEL ENGINE ELECTRONICS ACRONYM LIST

The diesel engine electronics acronyms are as follows:

ACCS – Air Conditioning Clutch

AP – Accelerator Pedal

APC – Auxiliary Powertrain Control Module

BARO – Barometric Pressure

BOO – Brake ON/OFF

BPA – Brake Pressure Applied

CAC – Charge Air Cooler

CCS – Coast Clutch Solenoid

CID – Cylinder Identification

CMP – Camshaft Position

CPP – Clutch Pedal Position

DIT – Direct Injection Turbocharged

DLC – Data Link Connector

DTC – Diagnostic Trouble Code

DTR – Digital Transmission Range

DTRM – Diesel Thermal Recirculation Module

DVOM – Digital Volt Ohmmeter

EBP – Exhaust Backpressure

ECT – Engine Coolant Temperature

EEC – Electronic Engine Control

EF – Electronic Feedback

EOT – Engine Oil Temperature

EPC – Electronic Pressure Control

FDCS – Fuel Delivery Command Signal

FEEPROM – Flash Electrically Erasable Programmable Read Only Memory

FMEM – Failure Mode Effects Management

FP – Fuel Pump

FPM – Fuel Pump Monitor

FPR – Fuel Pump Relay

GPC – Glow Plug Control

GPL – Glow Plug Lamp

GPR – Glow Plug Relay

G.C.V.W. – Gross Combined Vehicle Weight

HEUI – Hydraulically Actuated, Electronic Controlled Unit Injector

IAT – Intake Air Temperature

ICP – Injection Control Pressure

IDM – Injector Driver Module

IDM_EN – Injector Driver Module Enable

INJ – Injector

IPR – Injector Pressure Regulator

KAM – Keep Alive Memory

IVS – Idle Validation Switch

KOEO – Key ON Engine OFF

KOER – Key ON Engine Running

MAP – Manifold Absolute Pressure

MAT – Manifold Air Temperature

MCCC – Modulated Converter Clutch Control

MIL – Malfunction Indicator Lamp

MGP – Manifold Gauge Pressure

OBD – On-Board Diagnostics

OSM – Output State Monitor

OSS – Output Shaft Speed

PBA – Parking Brake Applied

PC/ED – Powertrain Control/Emissions Diagnosis Manual

PCM – Powertrain Control Module

PID – Parameter Identification

PSI – Pounds Per Square Inch

PSIA – Absolute Pressure

PSIG – Gauge Pressure

PTO – Power Take Off

PWR GND – Power Ground

RAM – Random Access Memory

ROM – Read Only Memory

RPM – Revolutions Per Minute

SCCS –Speed Control Command Switches

SCP – Standard Corporate Protocol

SIG RTN – Signal Return

SS – Shift Solenoid

TACH – Tachometer

TCIL – Transmission Control Indicator Lamp

TCC – Torque Converter Clutch

TCS – Transmission Control Switch

TFT – Transmission Fluid Temperature

TR – Transmission Range

TSS – Turbine Shaft Speed

UVC Harness – Under Valve Cover Harness

VPWR – Vehicle Power/Battery Power

VREF – Voltage Reference

VSS –Vehicle Speed Signal

WGC – Wastegate Control

WG – Wastegate

WIF – Water In Fuel

WIFIL – Water In Fuel Indicator Lamp

WOT – Wide Open Throttle