Service Manual
Trucks

Group **28**

Engine Control Module (ECM), Diagnostic Trouble Code (DTC), Guide

2010 Emissions

CHU, CXU, GU, TD

PV776-88961816

Foreword

The descriptions and service procedures contained in this manual are based on designs and methods studies carried out up to March 2010.

The products are under continuous development. Vehicles and components produced after the above date may therefore have different specifications and repair methods. When this is believed to have a significant bearing on this manual, supplementary service bulletins will be issued to cover the changes.

The new edition of this manual will update the changes.

In service procedures where the title incorporates an operation number, this is a reference to a Labor Code (Standard Time).

Service procedures which do not include an operation number in the title are for general information and no reference is made to a Labor Code (Standard Time).

Each section of this manual contains specific safety information and warnings which must be reviewed before performing any procedure. If a printed copy of a procedure is made, be sure to also make a printed copy of the safety information and warnings that relate to that procedure. The following levels of observations, cautions and warnings are used in this Service Documentation:

Note: Indicates a procedure, practice, or condition that must be followed in order to have the vehicle or component function in the manner intended.

Caution: Indicates an unsafe practice where damage to the product could occur.

Warning: Indicates an unsafe practice where personal injury or severe damage to the product could occur.

Danger: Indicates an unsafe practice where serious personal injury or death could occur.

Mack Trucks, Inc.
Greensboro, NC USA

Order number: PV776-88961816
Repl:

USA40713

Contents

Design and Function

Engine Control Module (ECM)

The manufacturer scan tool is the preferred tool for performing diagnostic work. Contact your local dealer for more information or visit “www.premiumtechtool.com”.

Note: The use of a scan tool is necessary to perform diagnostic work as well as clearing of any diagnostic trouble codes (DTCs). DTC(s) can no longer be cleared using the vehicles instrument cluster digital display and stalk switch control.

System Overview

Six electronic control units (ECUs) are used; the engine control module (ECM), instrument control module (ICM), Vehicle Electronic Control Unit (VECU), transmission control module (TCM), the gear selector control module (GSCM) and the aftertreatment control module (ACM). Together, these modules operate and communicate through the SAE J1939 (CAN 1) data link to control a variety of engine and vehicle cab functions. The ECM controls such things as fuel timing and delivery, fan operation, engine protection functions, engine brake operation, the exhaust gas recirculation (EGR) valve and the turbocharger nozzle. The VECU controls cruise control functions, accessory relay controls and idle shutdown functions. The ICM primarily displays operational parameters and communicates these to the other ECUs. All have the capability to communicate over the SAE J1587 data link primarily for programming, diagnostics and data reporting.

In addition to their control functions, the modules have on board diagnostic (OBD) capabilities. The OBD is designed to detect faults or abnormal conditions that are not within normal operating parameters. When the system detects a fault or abnormal condition, the fault will be logged in one or both of the modules’ memory, the vehicle operator will be advised that a fault has occurred by illumination a malfunction indicator lamp (MIL) and a message in the driver information display, if equipped. The module may initiate the engine shutdown procedure if the system determines that the fault could damage the engine.

In some situations when a fault is detected, the system will enter a "derate" mode. The derate mode allows continued vehicle operation but the system may substitute a sensor or signal value that may result in reduced performance. In some instances, the system will continue to function but engine power may be limited to protect the engine and vehicle. Diagnostic trouble codes (DTCs) logged in the system memory can later be read, to aid in diagnosing the problem using a diagnostic computer or through the instrument cluster display, if equipped. When diagnosing an intermittent DTC or condition, it may be necessary to use a scan tool connected to the Serial Communication Port.

The use of a scan tool is necessary to perform diagnostic work as well as clearing of any diagnostic trouble codes (DTCs). DTC(s) can no longer be cleared using the vehicles instrument cluster digital display and stalk switch control. Additional data and diagnostic tests are available when a scan tool is connected to the Serial Communication Port.

For diagnostic software, contact your local dealer.

The ECM is a microprocessor based controller programmed to perform fuel injection quantity and timing control, diagnostic fault logging, and to broadcast data to other ECUs. The fuel quantity and injection timing to each cylinder is precisely controlled to obtain optimal fuel economy and reduced exhaust emissions in all driving situations.

The ECM controls the operation of the injectors, engine brake solenoid, EGR valve, turbocharger nozzle position, and cooling fan clutch based on inputs from many sensors and information received over the data links from other ECUs.

The VECU and ECM are dependent on each other to perform their specific control functions. In addition to switch and sensor data, the broadcast of data between modules also includes various calculations and conclusions that each module has developed, based on the input information it has received.

On Board Diagnostic (OBD) Monitors

System Electronic Control Unit (ECU) Overview

The engine control module (ECM) monitors and models (using physical principles) engine parameters to monitor the engine system's performance in real time. This is performed to aid the ECM with its self diagnostic capabilities. Many sensors are used for input to the emission control system.

The system contains the following "emission critical" ECUs that are monitored;

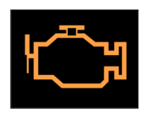
- Engine Control Module (ECM)
- Vehicle Electronic Control Unit (VECU)
- Aftertreatment Control Module (ACM)
- Aftertreatment Nitrogen Oxides (NOx) Sensors
- Engine Variable Geometry Turbocharger (VGT) Smart Remote Actuator (SRA)

These ECUs all communicate with the ECM via data links. The VECU communicates across the SAE J1939 (CAN1) data link while the others use the SAE J1939-7 (CAN2) data link.
The OBD systems use SAE J1939 data link protocol for communication with scan tools but, MACK trucks still are capable of communicating via the SAE J1587 data link for diagnostics. The use of a scan tool is necessary to perform diagnostic work as well as clearing of any diagnostic trouble codes (DTCs). DTC(s) can no longer be cleared using the vehicles instrument cluster digital display and stalk switch control.

There are other ECUs such as the Instrument Control Module (ICM), Transmission Control Module (TCM) and Anti-lock Brake System (ABS) Module that provide data to the emission control system or the diagnostic system but are not "emission critical".

Malfunction Indicator Lamp (MIL), Description and Location

A MIL located in the instrument cluster. This amber colored lamp is used to inform the driver that a "emission critical" malfunction signal has occurred.



W2036007

Systems Monitoring Information

Section Content

Accelerator Pedal Position (APP) Sensor, Overview

The APP sensor input is an analog voltage signal proportional to the pedal position that is read by the vehicle electronic control unit (VECU). The angular position of the pedal is divided in three different areas used for fault detection and/or recovery. The value that is transmitted under normal conditions (value of 0 - 100%), is directly proportional to the pedal's angular position. The physical accelerator assembly also supports a digital DC voltage (On/Off) generated by an idle validation (IV) switch that is also powered by the same regulated reference voltage source.

Active/intrusive Injection (Aftertreatment Hydrocarbon Doser Clogging)

This diagnostic is based on the checking the aftertreatment diesel particulate filter (DPF) intake temperature during aftertreatment DPF active parked regeneration cycles. If the aftertreatment DPF intake temperature does not reach a minimum regeneration temperature within a specified time then the aftertreatment hydrocarbon doser is considered to be clogged.

Aftertreatment Diesel Exhaust Fluid (DEF) Feedback Control

The aftertreatment DEF control consists of a feedforward control together with a feedback control. The feedforward control value is how much urea that must be injected in order to obtain the demanded nitrogen oxides (NOx) conversion efficiency. The feedback controls the ammonia (NH3) buffer in the aftertreatment selective catalytic reduction (SCR).

Aftertreatment Diesel Exhaust Fluid (DEF) Quality

Aftertreatment DEF quality is evaluated and determined through conversion efficiency. If the aftertreatment SCR system efficiency is below the specified limit, a fault is reported.

Aftertreatment Diesel Particulate Filter (DPF)

The aftertreatment DPF collects particulate and soot in a ceramic wall-flow substrate. The strategy to manage the accumulation of soot is to take advantage of natural aftertreatment DPF passive regeneration whenever possible, and to invoke an operating mode that enhances aftertreatment DPF passive regeneration when necessary. Aftertreatment DPF active regeneration is performed using an aftertreatment hydrocarbon doser.

Aftertreatment Diesel Particulate Filter (DPF) Regeneration Frequency

This function detects if the aftertreatment DPF regeneration frequency increases to a level that it would cause the non-methane hydro carbon (NMHC) emissions to exceed the legal limitation or if the frequency exceeds the design requirements. If the number of aftertreatment DPF regenerations are above the threshold at the end of the time period a fault is reported.

Aftertreatment Diesel Particulate Filter (DPF) Incomplete Regeneration

The aftertreatment DPF regeneration strategy is to reduce the soot level in the DPF using passive regeneration. However, if the driving conditions do not enable enough exhaust heat for passive regeneration to keep up with the soot loading an active parked aftertreatment DPF regeneration will be required. An interrupted parked aftertreatement DPF regeneration is detected by this function. This is not a fault mode but handled by the aftertreatment system. If the ratio between the uncompleted and completed regenerations is above the specified limit, a fault is reported.

Aftertreatment Diesel Particulate Filter (DPF) Regeneration Feedback Control

This function monitors the particulate matter regeneration feedback control and detects:

- If the system fails to begin feedback control
- If a failure or deterioration causes open loop
- If the feedback control has used up all of the allowed adjustment

When the aftertreatment hydrocarbon doser is used, the feedback control is monitored for a saturated controller or a saturated actuator. A saturated controller or actuator means that all allowed adjustment has been used up. The monitors detect a malfunction if the controller is saturated more than a given percentage of the time and the target temperature can not be reached or if the actuator is saturated more than a given percentage of the time.

Aftertreatment Fuel System, Rationality Monitors

The aftertreatment fuel system consists of a aftertreatment fuel shutoff valve, a separate aftertreatment hydrocarbon doser (injector), and an aftertreatment fuel pressure sensor. The aftertreatment fuel shutoff valve diagnostic function look at the aftertreatment fuel pressure when the valve is opened and closed. When conditions are proper for the diagnostic, the function requests an opening of the aftertreatment fuel shutoff valve in order to pressurize the aftertreatment fuel system. This action should increase system pressure. When the aftertreatment fuel shutoff valve is closed the system pressure should decrease since the valve has an internal drain pipe that constantly depressurizes the system. For more information about these components refer to “Aftertreatment Fuel Pressure Sensor, Circuit Monitors”, page 16, “Aftertreatment Fuel Shutoff Valve, Circuit Monitors”, page 16 or “Aftertreatment Hydrocarbon Doser, Circuit Monitors”, page 16.

Aftertreatment Non-Methane Hydro Carbons (NMHC) Catalyst

To detect when the hydrocarbon conversion fails in the aftertreatment diesel oxidation catalyst (DOC), the temperature reaction at the aftertreatment DOC outlet is monitored when fuel is injected in the exhaust. The amount of hydrocarbon supplied by the aftertreatment hydrocarbon doser will determine the expected increase in temperature after the aftertreatment DOC. The aftertreatment hydrocarbon doser injection rate (duty cycle) is monitored and used to calculate whether there should be a corresponding heat reaction. Once it has reached an acceptable accumulated duty cycle the expected temperature difference can be calculated. This difference should then be above a certain limit if the hydrocarbon conversion was achieved.

Aftertreatment Nitrogen Oxides (NOx) Sensor(s) Overview

The NOx sensors consist of:

- Housing holding the sensing element.
- An electronic control unit (ECU), interfacing the sensor and the engine control module (ECM).
- A wire, electrically connecting the sensing element with the ECU.

There are two aftertreatment NOx sensors, one before and one after the aftertreatment selective catalytic reduction (SCR) catalyst. The aftertreatment NOx sensor before and after SCR catalyst have unique CAN identification numbers hence can not be swapped. The sensor before the SCR catalyst monitors the engine out NOx level. The sensor after SCR monitors system out NOx level.

Aftertreatment NOx sensor diagnostics monitor the sensors signal quality and performance. The purpose of this function is to detect the following,

- Bad signal quality
- Removed sensor
- Missing signal

Circuit integrity of the aftertreatment NOx sensor is checked by the sensor itself and the status is transmitted to the engine control module (ECM) over the CAN data link. The following can be transmitted,

- open circuit
- high voltage
- circuit low or high

Aftertreatment Selective Catalytic Reduction (SCR)

The aftertreatment SCR system is a catalyst system that is used to reduce exhaust Nitrogen Oxides (NOx) emissions. This reduction is performed by injecting diesel exhaust fluid (DEF) (a urea solution) into the exhaust fumes prior to the aftertreatment SCR catalyst. A chemical process performed by aftertreatment SCR catalyst and DEF, converts NOx to nitrogen oxide (NO) and water (H2O). The aftertreatment control module (ACM) is used to control the aftertreatment SCR components and relays system information to the Engine Control Module (ECM). The ECM controls the overall system function.

Aftertreatment Selective Catalytic Reduction (SCR) Conversion Efficiency

The aftertreatment SCR catalyst diagnosis calculates the low temperature performance of the aftertreatment SCR system and compares it to the performance when the catalyst is warm enough to reach high nitrogen oxides (NOx) conversion. This is based on the premise that a deteriorated catalyst can be considered as a catalyst with less volume. The volume is critical to reach the low temperature performance of the aftertreatment SCR system.

Ambient Air Temperature (AAT) Sensor, Overview

The AAT sensor is an analog input that is read by the instrument cluster electronic control unit. The instrument cluster processes the raw signal and transmits the AAT value on the SAE J1939 data link. The vehicle electronic control unit (VECU) receives the AAT value and based on certain vehicle conditions the value is adjusted. The VECU then transmits the AAT value back on the SAE J1939 data link where it is received by the engine control module (ECM).

Charge Air Cooler (CAC)

The nominal CAC efficiency is a map based on mass air flow (MAF) and ambient air temperature (AAT). The method to evaluate the CAC efficiency is to compare a nominal CAC efficiency with one calculated based on the exhaust gas recirculation (EGR) and the intake air temperature (IAT) sensor along with their corresponding mass flows.

Combined Monitoring

Cylinder balancing function is used to detect fuel system pressure, quantity and timing fault. By processing the tooth times cylinder balancing detects if the combustion power contribution from one or several cylinders is too week or too strong and need to be compensated to get even combustion power from all cylinders. The compensation is calculated at the lower engine speed (RPM) and torque regions during warm engine where the impact from each combustion becomes most visible. If the compensation becomes too high or too low fault is detected.

Crankcase Ventilation

The crankcase pressure (CCP) depends on the blow-by flow and the under pressure generated by the separator. Blow-by gases come mainly from the combustion when exhaust gas passes the piston rings. A malfunctioning of the valve guides, or the turbocharger can also contribute. The blow-by gases consist of exhaust gases mixed with oil. A high speed rotating separator is used to expel engine oil from these gases.

Crankcase Ventilation Diagnostic Function

When the high speed separator enabling conditions exist, the minimum value of the difference between crankcase and barometric pressure (BARO) during a time period is stored. The system performs high speed and low speed evaluations of the separator to conclude if the system is tight.

Engine Control Module (ECM), Rationality Monitors

If electrical power to the ECM is lost or very low, the ECM will stop to functioning and the engine will stop. Other electronic control units (ECUs) on the SAE J1939 (CAN1) data link will indicate that data from the ECU is missing.

Engine Coolant Temperature (ECT) Sensor Overview

The ECT sensor is monitored for rationality at key **ON** by comparing the ECT with the other engine temperature sensors (engine oil temperature (EOT) and engine turbocharger compressor outlet temperature). Using this comparison the following conclusions may be made when a problem occurs:

- Unable to reach Closed loop/Feedback enable Temperature (covered by thermostat warmed up temperature)
- Time to reach Closed loop/Feedback enable Temperature (covered by thermostat warmed up temperature)
- Stuck in a range below the highest minimum Enable temperature
- Stuck in a Range Above the Lowest maximum Enable temperature - Rationality Check

When the engine is used, the three temperatures are not the same and depending on how fast the engine is restarted normal differences will be found. When these differences and the ambient air temperature (AAT) exceeds a limit, the fault limits are adjusted in order to allow these differences.

Exhaust Gas Recirculation (EGR)

US2010 emission level MACK engines use EGR to enhance engine out Nitrogen Oxides (NOx) control. EGR flow is managed using an EGR valve and a Variable Geometry Turbocharger (VGT) nozzle position. These actuator settings are based on open loop settings established to achieve desired burned fraction rates. These settings can be modified in a closed loop burned fraction mode by feedback from a combustion property model. The EGR system is diagnosed by monitoring the burned fraction whenever the engine enters burned fraction closed loop mode.

Exhaust Gas Recirculation (EGR) Low Flow

This function monitors the reduction of EGR flow in the EGR system, i.e. too low EGR mass flow compared with demand. It is activated when the engine enters the burned fraction mode with minimum demand for BF and the engine speed/torque is in a range where EGR flow measurements and BF calculations have sufficient accuracy.

Exhaust Gas Recirculation (EGR) High Flow

This function diagnoses too much EGR in the system, i.e. too high EGR mass flow compared with the demand. This function handles positive deviations when EGR closed loop control is active. When closed loop EGR control is entered, an initial difference between measured burned fraction and burned fraction demand might exist. Due to the fact that some time is needed for adaptation, not all the difference is taken into account.

Exhaust Gas Recirculation (EGR) Slow Response

As described in “Exhaust Gas Recirculation (EGR) Low Flow”, page 8 and “Exhaust Gas Recirculation (EGR) High Flow”, page 8 , the deviation between the demanded and measured burned fraction are monitored when EGR closed loop control is active. Slow response is detected when the deviation (high/low) above the threshold is detected.

Exhaust Gas Recirculation (EGR) Feedback Control

This function detects:

- If any of the feedback control loops are not achieved.
- If feedback control mode is inhibited.

Exhaust Gas Recirculation (EGR) Cooler Performance

This function uses an equation based off of engine turbocharger turbine intake temperature, EGR temperature and the engine coolant temperature (ECT), to calculate cooler efficiency. The calculated efficiency is deemed too low if it is below a certain constant limit.

Exotherm

Exotherm, exothermic or exothermal all refer to a chemical change that is accompanied by a great release of heat.
The aftertreatment heating function uses the aftertreatment hydrocarbon doser, to heat up the exhaust system for parked aftertreatment diesel particulate filter (DPF) regeneration. When the aftertreatment hydrocarbon doser is used the hydrocarbons (HC) create an exotherm in the aftertreatment diesel oxidation catalyst (DOC). The aftertreatment hydrocarbon doser injection rate (duty cycle) is monitored and used to calculate whether there should be a corresponding exotherm. A starting temperature value is set when the aftertreatment hydrocarbon doser starts to inject fuel. As soon as the model says that exotherm should occur, the difference is calculated to identify whether it has occurred.

Filtering Performance

A malfunction of the aftertreatment diesel particulate filter (DPF) can be detected by analysing the pressure drop over the aftertreatment DPF. During the aftertreatment DPF evaluation, the lower and upper limiting values of the measured pressure drop are calculated. If the pressure drop is lower or higher than expected a fault indication occurs.

Fuel System

The D13L engine uses a unit injector system (as opposed to a rail injector system) to inject fuel in the cylinders. The unit injectors are not equipped with any pressure sensors and therefore it is not possible to measure fuel pressure. Diagnostics of the fuel injection system is done using the crankshaft position (CKP) sensor. The flywheel of the engine has slots machined at 6 degree intervals around its circumference. Three gaps where two slots are missing, are equally spaced around its circumference also. The three gaps are used to identify the next cylinder in firing order.

Idle Speed, Rationality Monitors

The target idle engine speed (RPM) and fuel injection quantity are monitored in the idle control system. The diagnosis monitors compare the measured engine speed (RPM) (averaged over each engine cycle) and target idle engine speed (RPM). The accumulated difference is averaged over a number of revolutions. If the averaged difference is above or below the defined fault limits, diagnostic trouble codes (DTCs) will be set for high fault and for low fault, respectively.
The same holds true for the fuel quantity. The accumulated fuel value is averaged over a number of revolutions. If the averaged difference is above, DTCs will be set for high fault.

Intake Manifold Pressure (IMP) Control System

A IMP sensor located in the intake manifold is used to measure IMP. The IMP system is monitored by comparing target/estimated IMP with actual measured pressure during certain engine speed (RPM) or load.
The target/estimated IMP is continuously calculated based on engine speed and fuel angle and adjusted for the influence of variable geometry turbocharger (VGT) nozzle position, exhaust gas recirculation (EGR) position and barometric pressure (BARO).

Misfire

The misfire monitor is disabled during Power Take Off (PTO) operation. It is active during positive brake torque, idle, and high idle. Engine misfire events are monitored by measuring tooth times on the crank wheel that indicates combustion acceleration in each cylinder. It is also possible to compare the previous acceleration contribution on each cylinder in order to examine if there has been a misfire or not.

After monitoring misfire events during idle conditions for the accumulation of less than 15 seconds, the percentage of misfire is evaluated. If the percentage of misfire exceeds the threshold limit, the misfire diagnostic trouble code (DTC) will be set for the fault.

Missing Substrate

The aftertreatment diesel particulate filter (DPF) is backpressure monitored. This monitoring is used to determine whether the aftertreatment DPF is either clogged, missing or significantly cracked.

Over-boost

If the measured intake manifold pressure (IMP) is over the deviation upper limit then the high boost average calculation is positive. If the measured IMP is below the deviation upper limit then the high boost integration is negative. If the integrated value exceeds the maximum limit a fault for high IMP is set.

Parking Brake Switch, Overview

The parking brake switch is a pressure switch that is physically connected to the vehicle’s parking brake pneumatic circuit and is used to determine if the parking brake is applied or released. The parking brake switch signal is received by the vehicle electronic control unit (VECU). When the vehicle’s parking brake is applied a ground signal is applied to the input and the VECU acknowledges the parking brake as being applied. The parking brake switch signal is provided to the engine control module (ECM) via the SAE J1939 data link.

Power Take-off (PTO) Enable Switch, Overview

The PTO enable switch is an input that is read by the vehicle electronic control unit (VECU). When 12V is applied to the input the VECU acknowledges the PTO function is being commanded on. The PTO Enable switch signal is provided to the engine control module (ECM) from the VECU by via the SAE J1939 data link.

SAE J1939 (CAN1) Data Link, Overview

Communication between the electronic control units (ECUs) is performed via the vehicle’s SAE J1939 (CAN1) data link and is accessible for diagnostics through the vehicle’s SAE J1939-13 data link connector (DLC). This data link is the main powertrain communication bus.

Diagnostic trouble codes (DTCs) are set for this data link when an ECU is found to not be communicating or recognized on the data link (off bus mode) or when there is an abnormal rate of occurrence of errors on the data link.

Thermostat Monitor

This feature monitors and compares the engine coolant temperature (ECT), engine speed (RPM), engine torque, fan speed and ambient air temperature (AAT) to conclude when the thermostat may be stuck open or closed.

Time/Date Overview

The time and date is calculated from an internal clock within the instrument cluster. The internal clock is backed up by an internal battery therefore the time and date is retained even when vehicle battery supply to the instrument cluster is removed. The time and date signal is provided to the engine control module (ECM) from the instrument cluster via the SAE J1939 data link.

Variable Geometry Turbocharger (VGT) Feedback Control

This function detects:

If any of the feedback control loops are not achieved.

If feedback control mode is inhibited.

If the actuators have used up all the adjustment allowed when in feedback mode.

Vehicle Speed Sensor (VSS), Overview

The vehicle road speed is calculated by the vehicle electronic control unit (VECU). The source for calculating vehicle road speed can be derived from multiple sources depending on vehicle equipment. Some trucks may use a dedicated speed sensor (which may be inductive or hall effect type) and some may use the transmission output shaft speed (OSS) sensor signal which is communicated across the SAE J1939 data link.

Under-boost

If the measured intake manifold pressure (IMP) is less than the deviation lower limit then the low boost average calculation is negative. If the measured IMP is above the deviation lower limit then the low boost integration is positive. If the integrated value becomes less than the minimum limit a fault for low IMP is set.

Variable Geometry Turbocharger (VGT) Slow Response

The VGT actuator reports a fault to the engine control module (ECM) when it has detected that the VGT nozzle is not moving, or if it has not been able to close the set-point error to acceptable limits.

Sensor and Component Information

Section Content