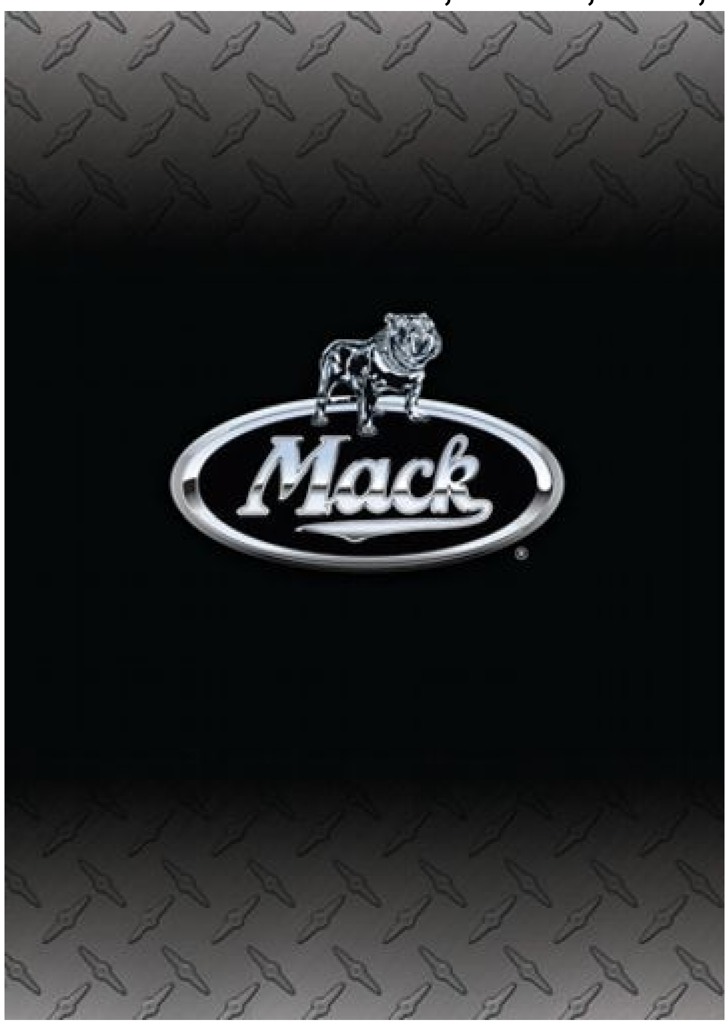
Service Manual
Trucks

Group **28**

Engine Control Module (ECM), On Board Diagnostic (OBD) Monitors
2010 Emissions
CHU, CXU, GU, TD, MRU, LEU



PV776-88983801

Foreword

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

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Greensboro, NC USA

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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;

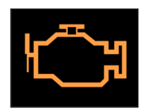
- Engine Control Module (ECM)
- Vehicle Electronic Control Unit (VECU)
- Aftertreatment Control Module (ACM)
- Aftertreatment Nitrogen Oxides (NOx) Sensors
- Engine Variable Geometry Turbocharger (VGT) Smart Remote Actuator (SRA)

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.



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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

Accelerator Pedal Position (APP) Sensor, Circuit Monitors

Both signals are continuously monitored (sampled) by the vehicle electronic control unit (VECU) at 50 ms intervals to detect any distortion or disruption of these signals. Signals detected as invalid for a period extending over 500 ms trigger active faults that are broadcast by the VECU. The APP sensor circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Accelerator Pedal Position (APP) Sensor, Rationality Monitors

The vehicle electronic control unit (VECU) simultaneously reads the APP sensor and the idle validation (IV) switch values and performing a plausibility to verify sensor performance.

Aftertreatment Control Module (ACM), Rationality Monitors

If electrical power to the ACM is lost or very low the ACM will stop functioning. Aftertreatment diesel exhaust fluid (DEF) dosing will stop. The engine control module (ECM) will log a diagnostic trouble code (DTC) indicating SAE J1939 data link (sub data link CAN2) communications from the ACM is missing.

Aftertreatment Control Module (ACM) 5 Volt Supply 1, Circuit Monitors

The ACM 5 volt supply “1” circuit is monitored to identify the following:

- Circuit low
- Circuit high

When either fault is detected the supply is disabled.

Aftertreatment Control Module (ACM) 5 Volt Supply 2, Circuit Monitors

The ACM 5 volt supply“2” circuit is monitored to identify the following:

- Circuit low
- Circuit high

When circuit high or circuit low faults are detected the supply is disabled.

Aftertreatment Control Module (ACM) Actuator Supply Voltage 1, Circuit Monitors

The ACM actuator supply voltage “1” circuit is monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

When circuit high or circuit low faults are detected the supply is disabled.

Aftertreatment Control Module (ACM) Actuator Supply Voltage 2, Circuit Monitors

The ACM actuator supply voltage “2” circuit is monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

When circuit high or circuit low faults are detected the supply is disabled.

Aftertreatment Diesel Exhaust Fluid (DEF) Dosing Valve, Circuit Monitors

The aftertreatment DEF dosing valve circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Aftertreatment Diesel Exhaust Fluid (DEF) Dosing Valve, Rationality Monitors

The aftertreatment DEF pump control value is monitored when the aftertreatment DEF dosing valve duty cycle has been above a predetermined threshold, for a short duration. If the control value is too low a diagnostic trouble code (DTC) is set. This indicates a clogged dosing valve or blocked aftertreatment DEF line.

Aftertreatment Diesel Exhaust Fluid (DEF) Pressure Sensor, Circuit Monitors

The aftertreatment DEF pressure sensor circuits are monitored to identify the following:

- Circuit open/circuit high
- Out of range low
- Out of range high
- Circuit low

Aftertreatment Diesel Exhaust Fluid (DEF) Pressure Sensor, Rationality Monitors

During pressure build up (aftertreatment DEF pump runs with maximum speed with no dosing) if selective catalytic reduction (SCR) system pressure stays low for a preset duration, a diagnostic trouble code (DTC) is set. Pressure is also evaluated during normal operation with aftertreatment DEF pump turned off. If the pressure is too high for a preset duration a DTC is set

Aftertreatment Diesel Exhaust Fluid (DEF) Pump, Circuit Monitors

The aftertreatment DEF pump circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high
- Battery voltage

Aftertreatment Diesel Exhaust Fluid (DEF) Pump, Rationality Monitors

The aftertreatment DEF pump gets a signal for the required pump speed from the aftertreatment control module (ACM). The pump has internal diagnosis which evaluates the pump speed quality. If the pump speed deviates from commanded speed for some time a diagnostic trouble code (DTC) is set.

The aftertreatment DEF return value is monitored during specific conditions to identify if a leak in the system is present. A DTC is set if a leak condition is identified. The leak can be invisible (internal to the pump or valve) or visible (aftertreatment DEF lines or connections).

Aftertreatment Diesel Exhaust Fluid (DEF) Return Value, Circuit Monitors

The aftertreatment DEF return valve circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Aftertreatment Diesel Exhaust Fluid (DEF) Return Valve, Rationality Monitors

During reverse DEF flow conditions on a pressurized selective catalytic reduction (SCR) system, pressure drop is evaluated. If DEF pressure drop is too low, the aftertreatment DEF return valve is considered to have a mechanical fault (blocked or stuck) and a diagnostic trouble code (DTC) is set.

Aftertreatment Diesel Exhaust Fluid (DEF) Tank Heater Valve, Circuit Monitors

The aftertreatment DEF tank heater valve circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Aftertreatment Diesel Exhaust Fluid (DEF) Tank Heater Valve, Rationality Monitors

Aftertreatment DEF tank heater valve diagnostics evaluates if tank heater is taking place, when demanded. A comparison of an initial aftertreatment DEF tank temperature without heating and then a tank temperature with aftertreatment DEF tank heater valve open for some duration is performed. If the increase in temperature is smaller than the threshold, a diagnostic trouble code (DTC) is set.

Aftertreatment Diesel Exhaust Fluid (DEF) Tank Temperature Sensor, Circuit Monitors

The aftertreatment DEF tank temperature sensor circuits are monitored to identify the following:

- Circuit open/circuit high
- Out of range low
- Out of range high
- Circuit low

Aftertreatment Diesel Exhaust Fluid (DEF) Tank Temperature Sensor, Rationality Monitors

Aftertreatement DEF tank temperature is checked for high frequency oscillations with high amplitude that is so large that is physically impossible for a temperature to achieve. A fault is set when this behavior is observed. Aftertreatement DEF tank temperature diagnostics is also evaluating if the aftertreatement DEF temperature is too high and will activate reverse flow (to protect aftertreatment selective catalytic reduction (SCR) system components) and a timer is started. If the temperature stays high for a short duration, a fault is set.

Aftertreatment Diesel Particulate Filter (DPF), Differential Pressure Sensor, Circuit Monitoring

The aftertreatment DPF differential pressure sensor circuits are monitored to identify the following:

- Circuit low
- Circuit high
- Circuit open

Aftertreatement Diesel Particulate Filter (DPF) Differential Pressure Sensor, Rationality Monitors

The evaluation of the pressure-drop sensor is carried out as follows. When the pressure model indicates a low pressure the sensor should also show a low pressure otherwise there is a (large) positive offset fault. Combining this with a check that the sensor shows high values when the model is high gives a sensor stuck check. The second step can also find (large) negative offset faults.

Aftertreatment Fuel Pressure Sensor, Circuit Monitors

The aftertreatment fuel pressure sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Aftertreatment Fuel Shutoff Valve, Circuit Monitors

The aftertreatment fuel shutoff valve circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Aftertreatment Hydrocarbon Doser, Circuit Monitors

The aftertreatment hydrocarbon doser circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Aftertreatment Nitrogen Oxides (NOx) Sensors, Circuit Monitors

The NOx sensors circuits are monitored to identify the following:

- open circuit
- high voltage
- circuit low or high

Aftertreatment Nitrogen Oxides (NOx) Sensors, Rationality Monitors

There are two different monitors which diagnose aftertreatment NOx sensor rationality. One compares the aftertreatment intake NOx sensor value to a calculated engine NOx output value. This is only perform within a given set of predetermined conditions. If the NOx sensor value is not deemed within range, a faulty is set.

The other compares theaftertreatment intake NOx sensor value to the aftertreatment outlet NOx sensor value to determine rationality. This is only perform within a given set of predetermined conditions. If either of the aftertreatment NOx sensor values are deemed not plausible, a diagnostic faulty code (DTC) is set.

Ambient Air Temperature (AAT) Sensor, Circuit Monitors

The AAT sensor circuits are monitored by the instrument cluster module to identify the following:

- Current below normal or open
- Current above normal or grounded

None of the AAT sensor circuits are monitored by the ECM or the VECU.

Ambient Air Temperature (AAT) Sensor, Rationality Monitors

Plausibility of the sensor value is determined by comparing the AAT with the intake air temperature (IAT).

Barometric Pressure (Baro) Sensor Circuit Monitoring

The BARO sensor circuits are monitored to identify the following:

- Circuit low
- Circuit high
- Circuit open

Barometric Pressure (BARO) Sensor Rationality Monitors

The BARO sensor, intake manifold pressure (IMP) sensor, and crankcase pressure (CCP) sensor should show the same pressure when engine speed (RPM) and torque is low. The diagnosis calculates the difference between:

- BARO and IMP
- BARO and CCP
- IMP and CCP

These comparisons are used to identify defects.

Camshaft Position (CMP) Sensor, Circuit Monitors

The CMP sensor circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Camshaft Position (CMP) Sensor, Rationality Monitors

The CMP sensor is monitored by comparing it’s output signal to the output signal of the crankshaft position (CMP) sensor. This comparison is used to identify abnormal CKP and CMP sensor frequency as well as camshaft to crankshaft phasing (calculated top dead center (TDC). Abnormal sensor frequency and shaft phasing angle will set faults.

Crankcase Pressure (CCP) Sensor, Circuit Monitors

The CCP circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Crankcase Pressure (CCP) Sensor, Rationality Monitors

The BARO sensor, intake manifold pressure (IMP) sensor, and crankcase pressure (CCP) sensor should show the same pressure when engine speed (RPM) and torque is low. The diagnosis calculates the difference between:

- BARO and IMP
- BARO and CCP
- IMP and CCP

Crankshaft Position (CKP) Sensor, Circuit Monitors

The CKP sensor circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Crankshaft Position (CKP) Sensor, Rationality Monitors

The CKP sensor is monitored by comparing it’s output signal to the output signal of the camshaft position (CMP) sensor. This comparison is used to identify abnormal CKP and CMP sensor frequency as well as camshaft to crankshaft phasing (calculated top dead center (TDC). Abnormal sensor frequency and shaft phasing angle will set faults.

Engine Control Module (ECM) 5 Volt Supply A, Circuit Monitors

The ECM 5 volt supply “A” circuit is monitored to identify the following:

- Circuit low
- Circuit high

When either fault is detected the supply is disabled.

Engine Control Module (ECM) 5 Volt Supply B, Circuit Monitors

The ECM 5 volt supply “B” circuit is monitored to identify the following:

- Circuit low
- Circuit high

When either fault is detected the supply is disabled.

Engine Coolant Temperature (ECT) Sensor, Circuit Monitors

The ECT sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Circuit low
- Circuit high

Engine Coolant Temperature (ECT) Sensor, Rationality Monitors

The ECT sensor is monitored for rationality at key **ON** by comparing the ECT with engine oil temperature (EOT) and engine turbocharger compressor outlet temperature. For more information refer to “Engine Coolant Temperature (ECT) Sensor Overview”, page 8 .

Engine Exhaust Gas Recirculation (EGR), Differential Pressure Sensor, Circuit Monitoring

The engine EGR differential pressure sensor circuits are monitored to identify the following:

- Circuit low
- Circuit high
- Circuit open

Engine Exhaust Gas Recirculation (EGR), Differential Pressure Sensor, Rationality Monitors

Engine EGR differential pressure is estimated based on engine speed (RPM) or torque and corrected for variable geometry turbocharger (VGT) position, EGR valve position, intake manifold pressure (IMP) and barometric pressure (BARO). This estimated engine EGR differential pressure is compared with actual measured pressure. This comparison is used to identify if the engine EGR differential pressure sensor is faulty. During certain conditions the engine EGR differential pressure should be zero. The engine EGR differential pressure sensor is also monitored during these conditions to verify that the engine EGR is closing as necessary as well as to verify proper engine EGR differential pressure sensor operation.

Engine Exhaust Gas Recirculation (EGR) Temperature Sensor, Circuit Monitors

The engine EGR temperature sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Engine Exhaust Gas Recirculation (EGR) Temperature Sensor, Rationality Monitors

For information about the engine EGR temperature sensor rationality refer to “Intake Air Temperature (IAT) Sensor, Rationality Monitors”, page 20.

Engine Exhaust Gas Temperature (EGT) Sensors, Circuit Monitors

The exhaust system is equipped with the following three engine EGT sensors:

1 Engine EGT sensor

2 Aftertreatment diesel particulate filter (DPF) intake temperature sensor

3 Aftertreatment DPF outlet temperature sensor

The engine EGT sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Engine Exhaust Gas Temperature (EGT) Sensors, Rationality Monitors

There are two independent tests that can evaluate temperature sensor plausibility in the exhaust system. One is performed while stationary and the other is performed at cold start. Each sensors output value is used to compare against the other sensor values. This in turn is used to determine the plausibility of the sensors. If the temperatures received by any of the sensors is deemed to be out of range, a plausibility fault is set.

Engine Turbocharger Compressor Bypass Valve Solenoid, Circuit Monitors

The engine turbocharger compressor bypass valve solenoid circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Engine Turbocharger Compressor Bypass Valve Solenoid, Rationality Monitors

The engine turbocharger compressor bypass valve solenoid fault detection is performed during the phase where the valve is opened, the intake manifold pressure (IMP) is monitored and compared to the maximum allowed.

Engine Turbocharger Compressor Outlet Temperature Sensor, Circuit Monitors

The engine turbocharger compressor outlet temperature sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Engine Turbocharger Compressor Outlet Temperature Sensor, Rationality Monitors

The engine turbocharger compressor outlet temperature sensor, is monitored for rationality by comparing the sensor output value against an estimated temperature based on ambient air temperature (AAT), intake manifold pressure (IMP), barometric pressure (BARO) and a calculated efficiency of the turbocharger.

Engine Turbocharger Speed Sensor, Circuit Monitors

The engine turbocharger speed sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Engine Turbocharger Speed Sensor, Rationality Monitors

An engine turbocharger speed sensor test is run within a set of conditions to evaluate the speed sensor output value. The engine turbocharger speed sensor value is compared to a calculated speed value that is based on intake manifold pressure (IMP). If the sensor output value is deemed out of range a fault is set.

Engine Variable Geometry Turbocharger (VGT) Actuator Position, Circuit Monitors

The engine VGT actuator position position actuator circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Engine Variable Geometry Turbocharger (VGT) Actuator Position, Rationality Monitors

The engine VGT has a smart actuator position that is checked within Smart Remote Actuator (SRA) unit. Engine VGT position is then communicated to engine control module (ECM) via the SAE J1939 (CAN) data link.

Exhaust Gas Recirculation (EGR) Valve Actuator, Circuit Monitors

The EGR valve actuator circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Exhaust Gas Recirculation (EGR) Valve Actuator, Rationality Monitors

When EGR valve is commanded to be closed, the EGR differential pressure sensor is monitored and expects no pressure difference between upstream and downstream of EGR venture. A fault occurs when differential pressure greater than a fault limit due to a stuck-open EGR valve or a leaking EGR valve is detected for a period of time. A stuck-closed EGR valve can be detected if the difference from the actual burned fraction to the demanded burned fraction is lower than a fault limit for a period of time. There is no EGR Valve position feedback.

Fan, Circuit Monitors

The fan circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Electrical power is supplied to the fan drive from the chassis. Circuit monitoring is performed on the low side drive. The fan circuitry is such, that when the low side drive is opened the fan will be on. Closing the path to ground causes the fan to turn off. Since the low side is monitored the checks are only performed under certain conditions:

- Open circuit monitoring is only performed when the fan is ON (open circuit low). The open circuit fault detects when power is not supplied to the high side of the fan drive
- Circuit low monitoring is only performed when the fan is ON (open circuit low). The circuit low fault detects when the low side control line is shorted to ground
- Circuit high monitoring is only performed when the fan is OFF (closed circuit low). The circuit high fault detects an over-current condition on the low side control line. If this over-current condition is detected the drive is disabled (fan ON) until the key is cycled

Some fans also have a fan speed sensor. If the fan is equipped with a speed sensor circuit high is also supported. This diagnostic is used for any electrical cause of a missing signal. If the fan does not support a speed sensor this circuit monitor is not supported.

Fan, Rationality Monitors

Fan speed is calculated from the commanded percent engagement, the engine speed and the fan drive ratio. If a fan speed sensor is present the sensor speed signal is sent.

Injector, Circuit Monitors

The injector circuits are monitored to identify the following:

- Circuit open
- Circuit low
- Circuit high

Intake Air Temperature (IAT) Sensor, Circuit Monitors

The IAT sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Circuit low
- Circuit high

Intake Air Temperature (IAT) Sensor, Rationality Monitors

The IAT sensor is used to calculate engine charge air cooler (CAC) ambient air temperature (AAT). The CAC AAT can be calculated in the two following ways,

- Using engine exhaust exhaust gas recirculation (EGR) temperature and IAT with their corresponding mass flow rates.
- Using AAT, engine turbocharger compressor outlet temperature and the mass air flow (MAF) rate.

If there is a mismatch in these two estimated temperatures it is concluded that the most probably cause is on of the temperature sensors. The system then rationalizes which sensor is faulty.

Intake Manifold Pressure (IMP) Sensor Circuit Monitoring

The IMP sensor circuits are monitored to identify the following:

- Circuit open
- Out of range low
- Out of range high
- Circuit low
- Circuit high

Intake Manifold Pressure (IMP) Sensor Rationality Monitors

The IMP sensor, BARO sensor, and crankcase pressure (CCP) sensor should show the same pressure when engine speed and torque is low. The diagnosis calculates the difference between:

- BARO and IMP
- BARO and CCP
- IMP and CCP

These comparisons are used to identify defects.

Injector, Rationality Monitors

For injector rationality monitor information refer to “Fuel System”, page 9 .

Parking Brake Switch, Circuit Monitors

The vehicle electronic control unit (VECU) does not support comprehensive circuit monitoring on parking brake switch.

Parking Brake Switch, Rationality Monitors

The vehicle electronic control unit (VECU) does not support rationality monitors on the parking brake switch.

Power Take-off (PTO) Enable Switch, Circuit Monitors

The vehicle electronic control unit (VECU) does not support comprehensive circuit monitoring for the PTO enable switch input. However, based on the type of failure modes to the circuit the PTO operation will be or become non-functional. The failure mode behaviors are defined as:

- **Short to Ground –** A short circuit to ground will result in a non-functional PTO operation.
- **Short to Battery –** A short circuit to battery voltage will not have an immediate affect to the PTO operation, but will result in a non-functional PTO operation after exiting the PTO function or during the next VECU power down/up sequence (I.e. Cycling of the ignition key switch).
- **Open Circuit –** An open will result in a non-functional PTO operation.

Power Take-off (PTO) Enable Switch, Rationality Monitors

The vehicle electronic control unit (VECU) does not support rationality monitors on the PTO enable switch.

SAE J1939 (CAN1) Data Link, Circuit Monitors

Error detection of the SAE J1939 (CAN1) data link is performed by multiple electronic control units (ECUs). An ECU detecting an error condition signals this by transmitting an error flag. There are 5 types of error detections:

- Bit error
- Stuff error
- Cyclic Redundancy Code (CRC) error
- Form error
- Acknowledgement error

SAE J1939 (CAN1) Data Link, Rationality Monitors

Rationality monitors do not exist for the SAE J1939 (CAN1) data link.

SAE J1939 (CAN2) Data Link, Overview

The SAE J1939 (CAN2) data link is a sub-data link that communicates information directly to the engine control module (ECM). There's no direct communication to other electronic control units (ECUs) residing on the on the SAE J1939 (CAN1) data link. Information that is sent across the CAN2 data link can be shared on the CAN1 data link via the ECM. Diagnostic trouble codes (DTCs) are set 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.

SAE J1939 (CAN2) Data Link, Circuit Monitors

Error detection of the SAE J1939 (CAN2) data link is performed by multiple electronic control units (ECUs). An ECU detecting an error condition signals this by transmitting an error flag. There are 5 types of error detections:

- Bit error
- Stuff error
- Cyclic Redundancy Code (CRC) error
- Form error
- Acknowledgement error

SAE J1939 (CAN2) Data Link, Rationality Monitors

Rationality monitors do not exist for the SAE J1939 (CAN2) data link.

Time/Date, Circuit Monitoring

The instrument cluster does not support comprehensive circuit monitoring for the Time/Date.

Time/Date, Rationality Monitoring

The engine control module (ECM) does support rational monitoring by comparing time and date from instrument cluster. Soak time is based on engine cooling down using temperatures before and after soak.

Vehicle Speed Sensor (VSS), Circuit Monitors

The comprehensive circuit monitors are supported by the vehicle electronic control unit (VECU) and are determined by the vehicle road speed source. When a dedicated speed sensor is used, electrical error detection is supported. When the transmission output shaft speed (OSS) sensor is used via the SAE J1939 data link, the diagnostics are based on a communication timeout and receiving "error indicator" flagged from the transmitting electronic control unit (ECU).

Vehicle Speed Sensor (VSS), Rationality Monitors

Error detection is performed by comparing another source of vehicle speed information to the calculated vehicle road speed. At zero vehicle road speed an error is generated when the comparison vehicle speed source (ABS/EBS) is higher than a specified limit. When the vehicle road speed is greater than zero the difference between the calculated vehicle road speed and the comparison vehicle speed source (ABS/EBS) is not allowed to be greater than a specified value or a fault is registered.

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