Exhaust Gas Recirculation (EGR) System Monitor

Exhaust Gas Recirculation (EGR) Rate System Monitor — Transit

The percentage of EGR is calculated using two different methods and the difference between these two calculations is used to determine if the system is operating correctly. The expected amount of exhaust gas in the cylinder is calculated using a model that is based on the commanded EGR rate and the intake throttle position. The actual amount of exhaust gas in the cylinder is measured by subtracting the mass airflow (MAF) sensor reading from a calibrated value of the intake air charge in the cylinder. The expected EGR model accounts for both fresh air and the exhaust gas, and is based on the volumetric efficiency of the engine. An excessive EGR flow is detected when the measured amount of EGR is greater than the expected amount of EGR. An insufficient EGR flow is detected when the measured amount of EGR is less than the expected amount of EGR.

The monitor compares the two calculations, when a set of entry conditions are met, and determines if the system is operating correctly. The concern must be detected for a minimum amount of time before being reported. A timer counts up when the entry conditions are met and the concern is present. The timer counts down when the entry conditions are met, the concern is not present, and the current count is greater than 0. When this timer exceeds the time required to detect a concern, a DTC is set.

Exhaust Gas Recirculation (EGR) Low Flow System Monitor — Transit

The low or insufficient EGR flow is detected by the EGR systems inability to meet calibrated thresholds. The intake throttle will close partially to lower manifold air pressure to create more favorable conditions for EGR flow. The average intake throttle position can be monitored to detect a low or insufficient EGR flow concern.

When the entry conditions are met and remain met, the monitor averages the intake throttle position over a calibrated period of time. The time and averaging will pause if the entry conditions are no longer met, and resume when they are met again. When the monitoring time is achieved the monitor completes one event. The monitor will continue to run until a calibrated number of events has completed. The event counter increments up when an event is completed and the average throttle position during the event exceeds a threshold. The event counter increments down if the event completes and the average throttle position during the event is within the threshold, and the current count is greater than zero. A concern is detected when the event counter increments greater than a threshold and a DTC is set.

Exhaust Gas Recirculation (EGR) System Slow Response Monitor — Transit

The EGR system slow response is detected using the EGR rate system monitor. For additional information, refer to the Exhaust Gas Recirculation (EGR) Rate System Monitor in this section.

Exhaust Gas Recirculation (EGR) Cooler System Monitor — Transit

The functionality of the EGR cooler system, including the EGR cooler bypass valve and the exhaust gas temperature bank 1 sensor 2 (EGRT12), is monitored by comparing the measured EGR gas temperature downstream of the EGR cooler assembly, with the measured engine coolant temperature when certain engine operating conditions exist. The operating conditions in which this detection can occur are the monitor entry conditions. Changes in engine operating conditions cause a delay before the changes are reflected in the EGR cooling system temperatures. The entry conditions timers must complete before the monitor is complete. When a condition feeding a timer is no longer met, the timer resets. Excessive EGR cooling and insufficient EGR cooling can be detected using the EGR cooler bypass monitor.

The insufficient EGR cooling monitor detects when the EGR is being cooled less than desired, such as when the EGR cooler bypass is stuck in the bypass position. The entry conditions for the insufficient EGR cooling monitor must be met for the monitor to be enabled. Once the entry conditions are met and while they continue to be met, the measured exhaust gas temperature downstream of the EGR cooler assembly is compared to a threshold based on measured engine coolant temperature. A typical value for this threshold is 150° C (270° F) above engine coolant temperature. If the measured exhaust gas temperature downstream of the EGR cooler assembly is greater than the threshold, for a predetermined amount of time, a DTC is set.

The excessive EGR cooling monitor can detect when EGR is being cooled greater than desired, such as when the EGR cooler bypass is stuck in the cooling position. The entry conditions for the excessive EGR cooling monitor must be met for the monitor to be enabled. Once the entry conditions are met and while they continue to be met, the measured exhaust gas temperature downstream of the EGR cooler assembly is compared to a threshold based on measured engine coolant temperature. A typical value for this threshold is 30° C (54° F) above engine coolant temperature. If the measured exhaust

gas temperature downstream of the EGR cooler assembly is less than the threshold, for a predetermined amount of time, a DTC is set.

Exhaust Gas Recirculation (EGR) Closed Loop Control Limits System Monitor — All Others

The control system is closed loop around EGR rate during normal operation and the limits of the control system are monitored by observing the control deviation calculated as the difference between the desired EGR rate setpoint (after dynamic correction) and the actual EGR rate determined from an air system model. The air system model EGR estimates the percent of EGR in the cylinder by modeling the induction system based on the mass airflow (MAF) sensor reading and an estimate of the airflow over the throttle restriction. The EGR mass flow is then calculated as the difference between the cylinder charge from the speed density equation and this model of the mass airflow into the intake manifold. This model value of the actual EGR flow based on measured values is compared with the desired EGR rate setpoint. If the deviation between the controller setpoint EGR rate and the modeled EGR rate exceed the calibrated thresholds, a system control limit concern is indicated.

If no air system concerns are present, the control limit monitor functions continuously during closed loop operation once the engine coolant temperature is greater than 70°C (158°F). Separate threshold maps indicate the EGR system operation is at its control limits for both the high flow and low flow extremes. Control limit threshold maps are a function of engine torque and engine speed and are based upon the expected distribution of deviations from a statistical sampling. An up/down counter is used that counts upward when the control deviation exceeds the calibrated threshold and counts downward when the control deviation falls below the threshold for the case where the system operation is limited to EGR rates higher than the controller setpoint. Similarly, the up/down counter counts upward when the rate deviation falls below a calibrated threshold and counts downward when it rises above the threshold for the case where the system operation is limited to EGR rates lower than the controller setpoint. Once the counter exceeds a calibrated threshold for either case a concern is detected.

Exhaust Gas Recirculation (EGR) Cooler System Monitor — All Others

The EGR cooler system, including the EGR cooler bypass valve, is monitored by comparing a modeled EGR gas temperature downstream of the EGR cooler to an actual temperature sensor value. Both under cooling and over cooling conditions are monitored.

The over cooling monitor occurs when the engine is in normal closed loop operation, the engine coolant temperature is between 60-90°C (140-194°F), and no air system DTCs are present.

The under cooling monitor occurs when the engine is in normal closed loop operation, the engine coolant temperature is above 70°C (158°F), and no air system DTCs are present. If the difference between the modeled EGR gas temperature downstream of the EGR cooler and the actual EGR gas temperature sensor value is greater than a calibrated amount a concern is detected.

The monitor detects an under cooling condition if the EGR cooler is inoperative or EGR cooler bypass valve is stuck open. The monitor detects an over cooling condition if the EGR cooler bypass valve is stuck closed.

Exhaust Gas Recirculation (EGR) System Monitor — All Others

The EGR system is a closed loop EGR control system that uses an air system model EGR to estimate the percent of EGR in the cylinder. Airflow into the engine is modeled using a mass airflow sensor (MAF) and a model of airflow over the throttle restriction. The EGR mass flow is then calculated as the difference between the cylinder charge from the speed density equation and this model of the mass airflow after the throttle. This model value of the actual EGR flow based on measured values is compared with the estimated EGR rate computed by the EGR rate controller. The EGR rate controller calculates the mass flow based on an open area estimate at the EGR valve and a modeled value of mass flow per open area. The EGR open area estimate uses a combination of the area calculated from the modeled EGR rate and a calibrated curve of the expected open area based on EGR valve position.

Once the engine is warm and the system is in closed loop EGR control, the monitor awaits calibrated engine speed/load conditions selected for robust detection of high flow and low flow concerns. When the engine enters the operational regime for robust detection, the calculated rate deviation (modeled controller estimate) is compared to thresholds that are calibrated as a function of speed and load. An up/down counter is used that counts upward when the rate deviation exceeds the calibrated threshold and counts downward when the deviation falls below the threshold for the case of high flow. Similarly, the up/down counter counts upward when the rate deviation falls below a calibrated threshold and counts downward when it rises above the threshold for the case of low flow. Once the debounce counter exceeds a calibrated threshold for either high or low flow a concern is detected and DTC P0401 sets for a low flow concern while DTC P0402 sets for a high flow concern.

The typical EGR low flow monitor entry conditions include:

- Engine torque is 100 - 600 Nm (74 - 443lb-ft)
- Engine RPM is between 600 RPM and 2500 RPM
- Engine coolant temperature is 70 - 100°C (158 - 212°F)
- EGR valve position between 40% and 60%
- EGR rate desired value between 0% and 100%

DTC P0401 sets when the delivered EGR is 28% less than expected for the operating conditions. EGR rates are specified as a function of engine RPM and indicated torque setpoint.

The typical EGR high flow monitor entry conditions include:

- Engine torque between 100 Nm (74 lb-ft) and 600 Nm (443 lb-ft)
- Engine RPM is between 600 RPM and 2500 RPM
- Engine coolant temperature between 70°C (158°F) and 100°C (212°F)
- EGR valve position between 0% and 6%
- EGR rate desired value between 0% and 15%

DTC P0402 sets when the delivered EGR is 15% greater than expected for the operating conditions. EGR rates are specified as a function of engine RPM and indicated torque setpoint.
