

**Revised 2020**



***ELECTRONIC DIESEL ENGINE  
DIAGNOSIS SPECIALIST TEST (L2)***

***MEDIUM/HEAVY  
COMPOSITE VEHICLE TYPE 4  
REFERENCE BOOKLET***

*This booklet is intended only for reference when preparing for and taking the ASE Electronic Diesel Engine Diagnosis Specialist (L2) Test. The medium/heavy composite vehicle control system is based on designs common to many engine and vehicle manufacturers, but is not identical to any actual production engine or vehicle.*

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## Introduction

This ASE Composite Vehicle Type 4 was conceived and built by technical committees of industry experts to accommodate high level diagnostic questions on the L2 test. While some aspects of this Composite Vehicle may appear similar to vehicles from a number of manufacturers, it is important to understand this vehicle is a unique design and is NOT intended to represent any specific make or model. This reference document should be used when answering questions identified as Composite Vehicle questions.

Note: All testing is performed at sea level unless otherwise indicated. The reference materials and questions for this test use terms and acronyms that are consistent with SAE standards J1930 and J2012.

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## **POWERTRAIN**

- Generic, in-line six cylinder diesel engine.
- Equipped with variable geometry turbocharger (VGT), charge air cooler (CAC), electronic fuel injectors, closed crankcase ventilation (CCV), exhaust gas recirculation (EGR), and exhaust aftertreatment (AFT) system.
- Engine produces 425 hp at 1800 rpm and peak torque of 1650 lb. ft. at 1100 rpm.
- 10-speed automated manual transmission (AMT) with transmission control module (TCM).
- Equipped with electronic transmission shift select module.

## **MODULES**

### ***ENGINE CONTROL MODULE (ECM)***

- Receives inputs from and provides outputs to other control modules, sensors, switches, and actuators.
- Calculates fuel metering, injection timing and duration, diagnostics, emissions controls, and engine protection.
- Stores calibration values that define rated horsepower, torque curves, rpm specifications.
- The control system software is stored in the ECM and can be updated using factory-supplied calibration files and computer-based interface software, along with a scan tool or reprogramming device that connects to the vehicle's or engine's data link connector.
- Communicates with other vehicle system control modules through the J1939 data link controller area network (CAN).
- 9.0 to 16.0 VDC supply voltage.
- Provides a regulated 5-volt supply.
- The ECM is mounted on the engine.

### ***TRANSMISSION CONTROL MODULE (TCM)***

- Receives inputs from and provides outputs to other control modules, sensors, switches, and actuators.
- Provides the correct transmission outputs for desired driveability, fuel economy, and emissions control.
- Provides a regulated 5-volt supply.
- Control system software in the TCM can be updated in the same way as the ECM.
- Failures that result in a DTC will cause the TCM to default to fail-safe mode.
- Communicates with other vehicle system control modules through the J1939 data link controller area network (CAN).
- The TCM will also default to fail-safe mode if it is unable to communicate with the ECM.
- The TCM is mounted on the transmission.
- Communicates over the J1939 data link with an electronic clutch actuator module and an electronic transmission shift select module.

### ***BODY CONTROL MODULE (BCM)***

- Receives inputs from and provides outputs to other control modules, sensors, switches, and actuators.
- Provides a regulated 5-volt supply.
- Communicates with other vehicle system control modules through the J1939 data link controller area network (CAN).
- If the BCM fails to communicate with the ECM and/or TCM, the MIL is continuously illuminated.

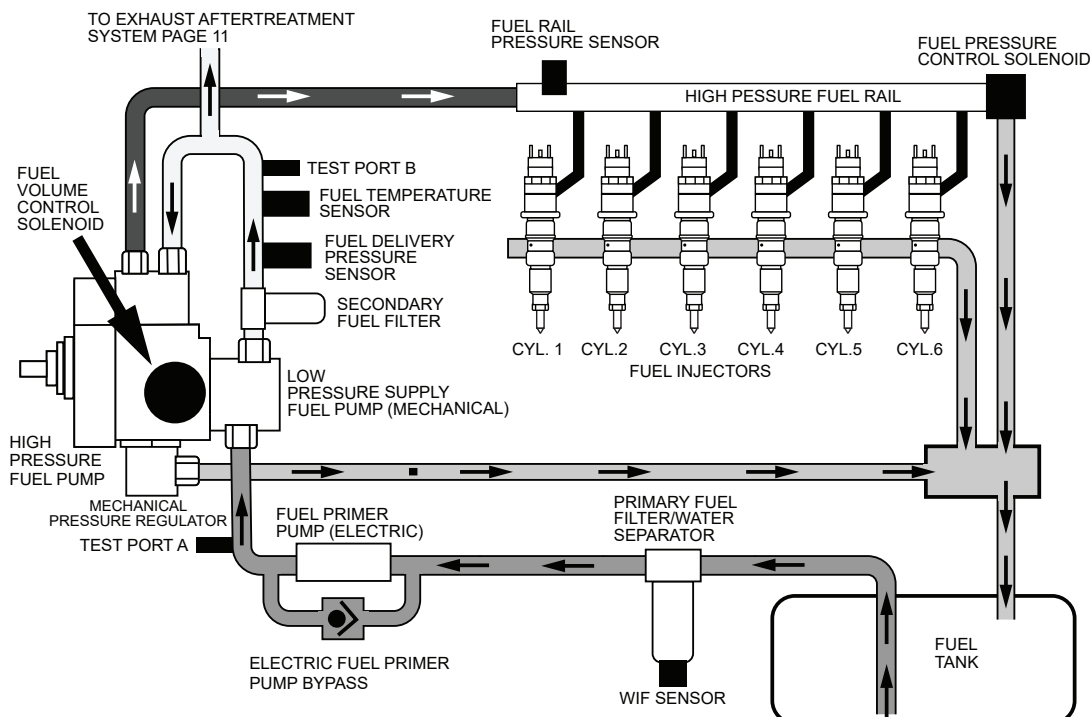
## INSTRUMENT CLUSTER MODULE (ICM)

- Receives inputs from and provides outputs to other control modules, sensors, switches, and actuators.
- Includes the following lamps: Check Engine (amber), Malfunction Indicator (amber), Stop Engine (red), Wait-to-Start, Water-in-Fuel, Maintenance Required, DEF Low, DPF Malfunction, High Exhaust Temperature, and Aftertreatment Regeneration.
- Communicates with other vehicle system control modules through the J1939 data link controller area network (CAN).
- If the ICM fails to communicate with the ECM and/or TCM, the malfunction indicator lamp (MIL) is continuously illuminated.

## SYSTEMS

### FUEL SYSTEM

- Common rail fuel injection system consists of an ECM, primary fuel filter/water separator, water-in-fuel (WIF) sensor, electric fuel primer pump, low-pressure fuel supply pump, secondary fuel filter, fuel delivery pressure sensor, fuel temperature sensor, high-pressure fuel pump, fuel volume control solenoid, fuel rail pressure sensor, fuel pressure control solenoid, high pressure fuel rail, fuel injectors, and fuel tank.
- ECM-controlled electric fuel primer pump runs for 60 seconds at ignition ON or engine cranking.
- A low pressure fuel supply pump (mechanical) driven by the high pressure fuel pump delivers fuel to the high pressure fuel pump and to the exhaust aftertreatment system.
- High-pressure fuel is provided by a positive displacement, mechanically driven pump.
- A preset spring-operated regulated valve mounted in the high-pressure fuel pump is used to maintain internal fuel supply pressure.
- Key ON/engine OFF fuel primer pump (electric) fuel pressure = 15 psi (103 kPa) at test port A.
- Key ON/engine CRANKING low pressure supply fuel pump (mechanical) pressure = 40 psi (276 kPa) at test port B.
- Fuel supply pressure at rated engine rpm of 1800 = 125 to 160 psi (862 to 1103 kPa) at test port B.
- Minimum fuel rail pressure to start: 5000 psi (34,474 kPa).
- Fuel rail pressure relief: 35,000 psi (241,317 kPa).
- Fuel injection is provided by electronically controlled solenoid fuel injectors controlled by the ECM.
- Fuel injector quantity adjustment (IQA) is accomplished through injector calibration coding in the ECM.



## ENGINE PROTECTION SYSTEM

- Monitors coolant temperature, coolant level, oil temperature, intake manifold temperature, oil pressure, fuel temperature, EGR exhaust gas temperature, and diesel particulate filter (DPF) restriction.
- Three levels of protection: warning, derate, and shutdown.
- Warning mode illuminates amber check engine lamp (CEL) and/or amber malfunction indicator lamp (MIL) to alert operator to potential problems.
- Derate (limp) mode illuminates the amber check engine lamp (CEL) and/or amber malfunction indicator lamp (MIL) and the ECM will gradually reduce engine power beginning 30 seconds after initial warning.
- Shutdown mode is indicated by flashing red stop engine lamp (SEL) and a warning buzzer which activates for engine coolant temperature, coolant level, engine oil pressure, engine oil temperature or aftertreatment system faults.
- Shutdown occurs when condition reaches a preset value, after warning and derate modes have activated.
- Engine protection override switch can be used to temporarily delay shutdown mode.

### High Engine Coolant Temperature

The ECM will turn the engine cooling fan ON at 210° F (99° C).

<u>Engine Coolant Temperature</u>	<u>Power Derate/Shutdown</u>
225° F (107° C)	20% Derate
230° F (110° C)	40% Derate
235° F (113° C)	60% Derate
240° F (116° C)	Shutdown

### High Fuel Temperature

A 20% power derate begins when the fuel temperature reaches 180° F (82° C). The derate increases to 40% if the temperature remains high.

### High Intake Manifold Temperature

ECM will turn the engine cooling fan ON at 190° F (88° C). A 20% derate begins when the manifold temperature reaches 210° F (99° C). The derate increases to 40% if the temperature remains high.

### High EGR Exhaust Gas Temperature

A 20% power derate begins when the EGR exhaust gas temperature reaches 425° F (218° C). The MIL is illuminated and the power derate increases to 40% when the temperature reaches 475° F (260° C).

### Low Engine Coolant Level

After the initial warning, shutdown will occur if the coolant level remains Low/Severe for 2 minutes.

Normal	=	No Action
Low	=	Warning
Low/Moderate	=	Derate
Low/Severe	=	Shutdown

### Low Engine Oil Pressure

If the oil pressure falls below these specifications, power derate will begin, and shutdown will occur if oil pressure remains low.

- Less than 10 psi = Red stop engine lamp (SEL) illuminated
- Less than 10 psi for 30 seconds = Derate
- Less than 10 psi for 60 seconds = Shutdown

### High Engine Oil Temperature

The ECM will turn the engine cooling fan on at 245° F (118° C). A 40% derate begins when the oil temperature reaches 260° F (127° C). Shutdown occurs after 2 minutes if the temperature remains high.

### High Diesel Particulate Filter Restriction

With moderate DPF soot load (Level 2), the DPF lamp flashes and a 25% derate begins. When DPF restriction reaches full soot load (Level 3), the DPF lamp flashes, the MIL is illuminated and a 40% derate begins. When the restriction reaches over-full soot load (Level 4), the SEL is illuminated and power derate increases to 80%. A severely restricted DPF may limit vehicle speed to 5 mph.

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## ***IDLE SHUTDOWN TIMER (IST)***

- Reduces amount of fuel consumed, lowers engine emissions, and increases engine life.
- Shuts down engine after period of engine idling with no driver activities.
- 30 seconds before shutdown occurs, the red stop engine lamp (SEL) flashes and a warning buzzer activates to alert the driver to impending shutdown.
- Driver can reset shutdown timer by applying service brake, accelerator pedal, or by releasing the parking brake.
- Any change to one or more of the enable conditions will reset or disable the IST.
- Enable conditions for IST:
  - Engine speed below 750 rpm.
  - Vehicle speed is 0 mph.
  - No active vehicle speed diagnostic faults.
  - Ambient air temperature is between 40° F and 85° F (4° C and 29° C).
  - No active inlet air temperature sensor diagnostic faults.
  - Engine coolant temperature is above 140° F (60° C).
  - No active engine coolant temperature sensor diagnostic faults.
  - Stationary diesel particulate filter (DPF) regeneration is inactive.
  - Accelerator pedal position is released (at idle).
  - Service brake pedal is released (pedal up).
  - Parking brake applied.

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## **DATA COMMUNICATIONS SYSTEMS**

### **Public Network**

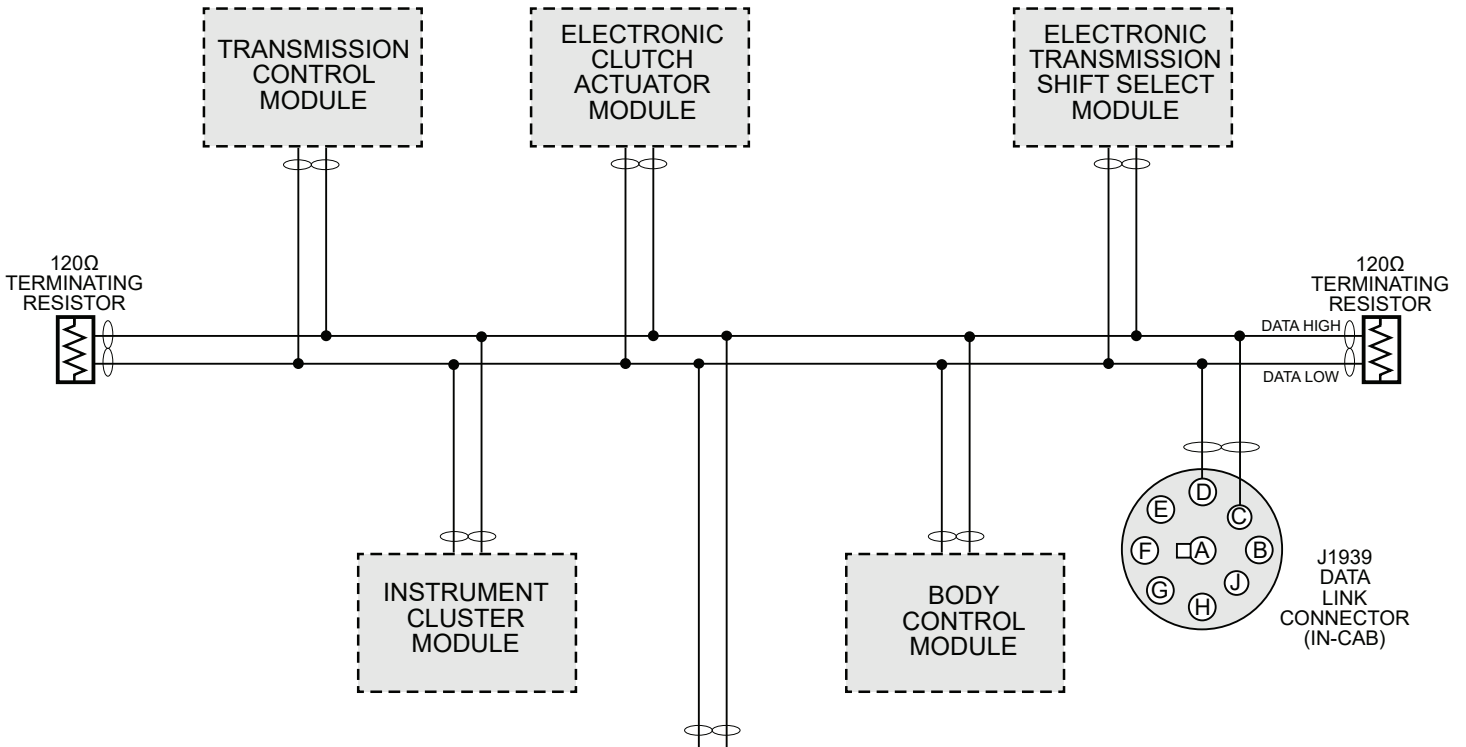
- SAE J1939 data link bus controller area network (CAN).
- Allows communication between electronic control modules: engine, transmission, automatic traction control, antilock brake, instrument cluster and body systems.
- J1939 data link is an unshielded twisted pair.
- All modules on the public data link broadcast messages when key switch is in ON position.
- Data bus can remain active up to 120 seconds after ignition OFF.
- Two 120-ohm terminating resistors, one located at each end of the backbone harness.
- Any of these conditions will cause data communications bus faults and result in the storage of network DTCs:
  - either data line shorted to ground.
  - an open in either data line.
  - a missing or open terminating resistor.
- Any of these conditions will result in no communication on the data bus:
  - either data line shorted to power.
  - one data line shorted to the other data line.
  - a failure of both terminating resistors.
- Diagnostic tool communicates with network modules through 9-pin connector allowing diagnostic information retrieval, software updates, coding, and programming.
- 9-pin data link connector is located in cab.

### **Private Network**

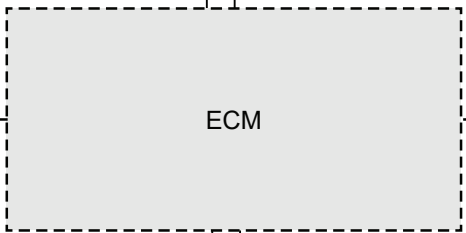
- SAE J1939 data link bus controller area network (CAN).
- Allows engine ECM to communicate with other vehicle control systems such as exhaust aftertreatment, EGR, and VGT.
- J1939 data link is an unshielded twisted pair.
- All modules on the private data link broadcast messages when key switch is in ON position.
- Data bus can remain active up to 120 seconds after ignition OFF.
- Two 120-ohm terminating resistors. One located in the end of the backbone harness and the other located in the variable geometry turbocharger (VGT) actuator.
- Any of these conditions will cause data communications bus faults and result in the storage of network DTCs:
  - either data line shorted to ground.
  - an open in either data line.
  - a missing or open terminating resistor.
- Any of these conditions will result in no communication on the data bus:
  - either data line shorted to power.
  - one data line shorted to the other data line.
  - a failure of both terminating resistors.
- Diagnostic tool communicates with network modules through 3-pin connector allowing diagnostic information retrieval, software updates, coding, and programming.
- 3-pin data link connector is located in engine compartment.



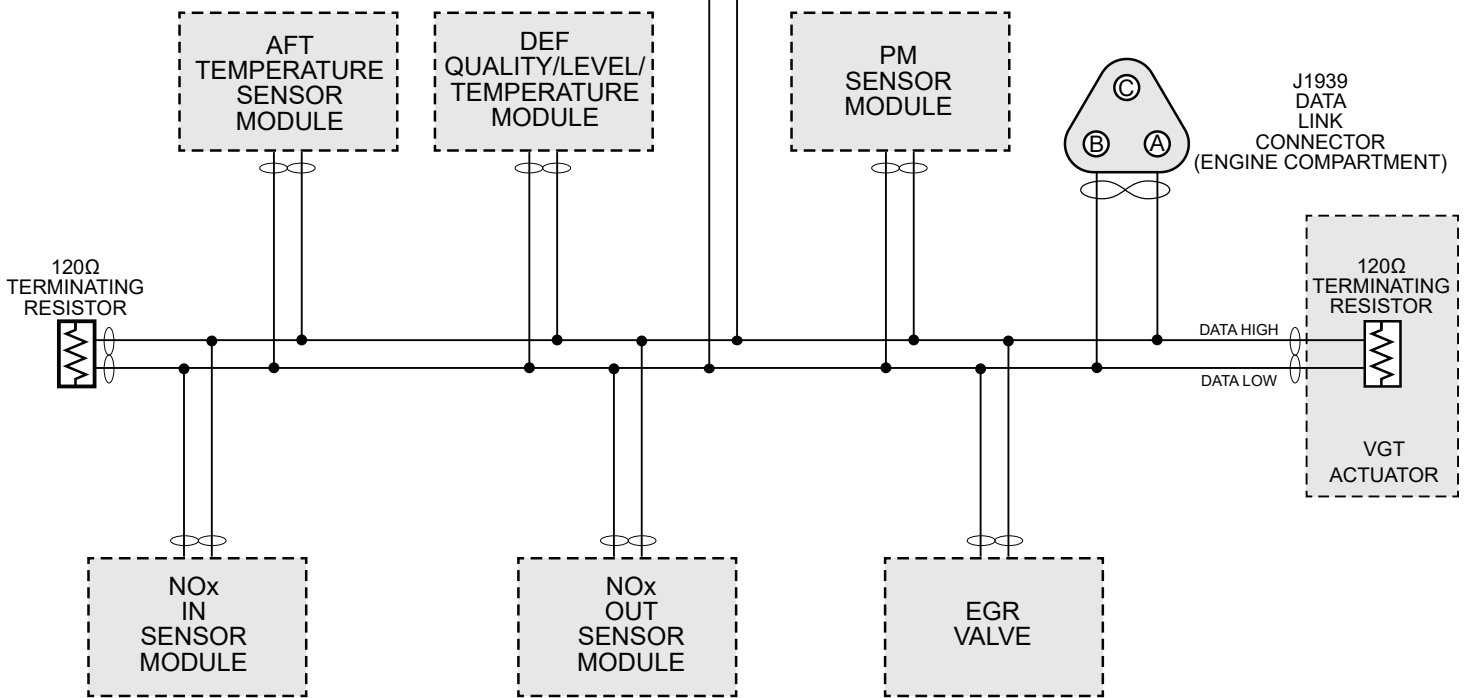
# BUS NETWORK - PUBLIC BUS



## BUS NETWORK - PUBLIC BUS



## BUS NETWORK - PRIVATE BUS

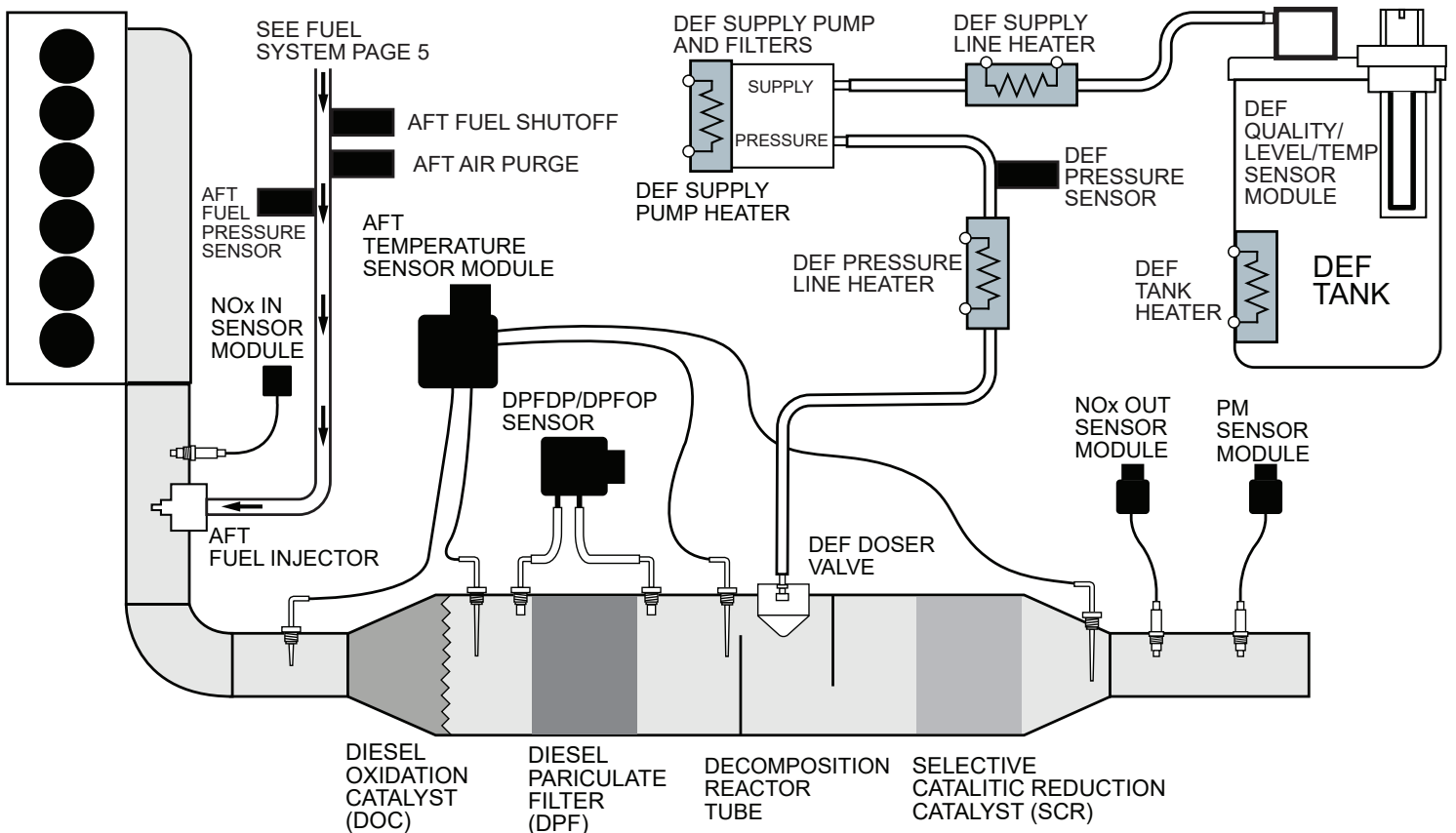


## BUS NETWORK - PRIVATE BUS

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## EXHAUST AFTERTREATMENT

- Consists of diesel oxidation catalyst (DOC), diesel particulate filter (DPF), decomposition reactor tube, selective catalytic reduction (SCR) unit, NOx IN sensor module, NOx OUT sensor module, aftertreatment (AFT) fuel injector, aftertreatment (AFT) fuel shutoff, aftertreatment (AFT) air purge, aftertreatment (AFT) fuel pressure sensor, DOC/DPF temperature sensor module, diesel particulate filter differential pressure/diesel particulate filter outlet pressure (DPFDP/DPFOP) sensor, diesel exhaust fluid (DEF) doser valve, PM sensor module, diesel exhaust fluid (DEF) supply pump, diesel exhaust fluid (DEF) quality/level/temperature sensor module, diesel exhaust fluid (DEF) tank heater, diesel exhaust fluid (DEF) line heaters, and diesel exhaust fluid (DEF) tank.
- Fuel may be injected into the exhaust stream to react with oxygen in the DOC to raise exhaust temperatures.
- Fuel for aftertreatment is monitored by the AFT fuel pressure sensor.
- Fuel is removed from the line to the AFT fuel injector by the AFT air purge and fuel flow is blocked by the AFT fuel shutoff.
- Aftertreatment diesel particulate filter accumulates soot during engine operation.
- Soot is oxidized during regeneration creating ash.
- Ash accumulates in the DPF over service life of unit.
- When the ash load reaches FULL value, the DPF needs to be disassembled and ash is removed by a special cleaning process.
- Regeneration is based on engine operating conditions, DPF restriction level, and the driver's response requirement.
- Exhaust temperature during regeneration should not exceed 1100° F (593° C).
- High exhaust system temperature (HEST) lamp illuminates any time exhaust outlet exceeds 850° F (454° C) or when an active regeneration is occurring. The lamp will flash when a parked regeneration is occurring.
- DPF soot load is monitored by the DPFDP/DPFOP sensor and the ECM will assign a level to the amount of restriction and provide driver indicators.
  - Level 0 - Minimal soot load. No lamps or alarms. Normal operation.
  - Level 1 - Low soot load. The DPF status lamp is illuminated. Regeneration is needed.
  - Level 2 - Moderate soot load. DPF status lamp is flashing. 25% engine derate. Regeneration is needed.
  - Level 3 - Full Soot Load. DPF status lamp is flashing and MIL is illuminated. Warning buzzer alerts. 40% engine derate. Parked regeneration is needed.
  - Level 4 - Overfull soot load. DPF status lamp is flashing and stop engine lamp (SEL) is illuminated. Warning buzzer alerts. 80% engine derate. Vehicle speed is limited to 5 mph. A scan tool is required to perform regeneration.
- The ECM has four modes of regeneration to reduce soot to ash in the DPF:
  - **Passive** regeneration occurs when exhaust temperatures become high enough during normal engine operation to oxidize soot. This typically happens at highway speeds or under heavy loads.
  - **Active** regeneration occurs when exhaust temperatures do not get high enough to oxidize soot collected in DPF under normal driving conditions. This occurs more frequently in vehicles with low speed and/or low duty cycles. The ECM will enable and disable active regeneration as needed. The vehicle speed must remain greater than 25 mph for active regeneration to occur. During active regeneration, the ECM injects diesel fuel into exhaust gas stream ahead of the DOC via the AFT fuel injector to react with the catalyst and raise exhaust temperature. The DOC must be at least 550° F (288° C) to react with the fuel and heat the DPF. Activating the regeneration inhibit switch will temporarily halt any attempts by the ECM to perform an active regeneration.



- **Parked** regeneration is required when vehicle operation cycles do not meet passive or active regeneration requirements and soot load is at level 1, 2, or 3. This type of regeneration is activated by a driver-operated switch. The vehicle must be parked with the transmission in NEUTRAL and parking brake applied. The accelerator pedal and service brake must be released. Vehicle speed must be at 0 mph and engine coolant temperature must be at least 170° F (78° C). During parked regeneration, the ECM commands the VGT closed to increase exhaust backpressure and the DOC temperature to a minimum of 550° F (228° C). The ECM then injects diesel fuel into the exhaust gas stream ahead of the DOC via the AFT fuel injector to react with the catalyst and raise exhaust temperatures. The ECM may raise or lower the engine speed to achieve target temperatures. The parked regeneration process may last up to 1 1/2 hours depending on the level of DPF restriction. Any change in accelerator pedal, parking brake, service brake, or vehicle speed inputs will abort the regeneration.
- **Forced** regeneration is enabled by a scan tool. This is the only type of regeneration available at Level 4. Forced regeneration operates under the same conditions as parked regeneration but may last longer and can be more aggressive. Forced regeneration will stop when soot load reaches Level 0, exhaust temperatures reach catalyst thresholds, or a scan tool or sensor input aborts the regeneration.
- Engine performance or transmission DTCs may inhibit regeneration from starting, or may abort regeneration if they are set while the regeneration is in progress.
- If the particulate matter (PM) sensor detects soot bypassing the DPF, a DTC for the DPF will be set, and the engine will derate.
- Selective catalytic reduction (SCR) reduces NOx levels in the exhaust. NOx is measured by the NOx IN sensor and NOx OUT sensor module. Exhaust NOx levels are dependent on the operational load of the engine.
- The DEF doser valve injects DEF into the decomposition reactor tube. The reactor tube blends the fluid with the hot exhaust gases.

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- The mixture then travels through the SCR catalyst unit where it reacts with the NOx. The NOx is converted into nitrogen (N<sub>2</sub>) and water (H<sub>2</sub>O).
  - The ECM monitors SCR efficiency using the NOx IN and OUT sensor modules. The ECM adjusts the DEF doser valve injection rate based on the NOx output of the engine and SCR efficiency.
  - The DEF is stored in the DEF tank, which contains a tank heater.
  - DEF is kept in a liquid state by 12 V heaters in the lines, the tank, and the pump.
  - DEF quality/concentration, tank level, and the temperature of the fluid is monitored by the DEF quality/level/temp sensor module.
  - DEF is delivered from the tank to the doser valve by the DEF supply pump.
  - The DEF is kept clean by an inlet screen and an outlet filter located in the DEF supply pump.
  - DEF LOW lamp is illuminated when the tank level reaches 10%.
  - DEF LOW lamp will flash, and the warning buzzer will alert at a tank level of 5%. The engine will derate to 80%.
  - At 0% DEF level, the DEF lamp will flash, the warning buzzer will alert, and the vehicle speed will be limited to 5 mph.
  - If the DEF quality sensor detects a deviation of  $\pm 3\%$  from the 32.5% urea concentration in the tank, the DEF LOW lamp will flash, the MIL will illuminate, and the engine will derate to 80%.

## ***TRANSMISSION***

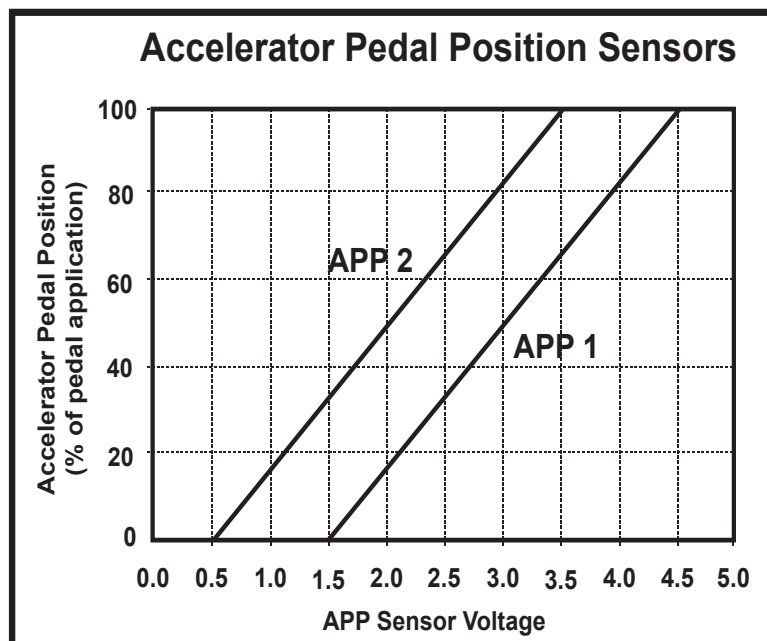
- Computer controlled, J1939 networked, two-pedal automated manual transmission.
- Ten forward speeds, two reverse speeds.
- Push button electronic transmission shift select module with LCD display.
- Performs self-diagnostic check with key ON.
- Returns to NEUTRAL with clutch applied at key OFF.
- TCM engages gears in the front main gear housing with the transmission electric gear and transmission electric rail select motors.
- Range section is operated with an electric-over-pneumatic solenoid assembly supplied with clean filtered air from transmission mounted regulator.
- Transmission air supplied from secondary air tank.
- Power interruption to TCM will leave transmission in its current gear.
- Loss of communication of the TCM with the J1939 network will result in the transmission defaulting to the current gear until the next key cycle.
- Electronic clutch actuator module located on the transmission bell housing and communicates over the J1939 network.

## INPUTS - SENSORS

### Accelerator Pedal Position (APP 1 and APP 2) Sensors

- A pair of redundant non-adjustable potentiometers that sense accelerator pedal position.
- Located on the accelerator pedal assembly.
- APP 1 sensor output varies from 1.5 volts (pedal released) to 4.5 volts (pedal fully applied); increasing voltage with increasing pedal position, offset from the APP 2 sensor signal by 1.0 volt.
- APP 2 sensor output varies from 0.5 volts (pedal released) to 3.5 volts (pedal fully applied); increasing voltage with increasing pedal position.
- A circuit failure of one APP sensor will set a DTC.
- A circuit failure of both APP sensors, or a correlation error, will set a DTC and only allow the engine to idle.

Accelerator Pedal Position (% applied)	APP 1 Sensor Voltage	APP 2 Sensor Voltage
0	1.50	0.50
5	1.65	0.65
10	1.80	0.80
15	1.95	0.95
20	2.10	1.10
25	2.25	1.25
40	2.70	1.70
50	3.00	2.00
60	3.30	2.30
75	3.75	2.75
80	3.90	2.90
100	4.50	3.50



**Aftertreatment Fuel Pressure Sensor** - Monitors the pressure in the AFT fuel system. The ECM uses this signal in determining operation of the aftertreatment fuel injector during regeneration. If an active AFT fuel pressure fault is detected, active and parked regeneration will be disabled. See table below.

Pressure		Voltage
kPa	psi	VDC
0	0	0.50
345	50	1.50
689	100	2.50
1034	150	3.50
1379	200	4.50

**Note: This table pertains to the following sensors:**

- AFT Fuel Pressure Sensor
- DEF Pressure Sensor
- Engine Oil Pressure Sensor
- Exhaust Back Pressure Sensor
- Fuel Delivery Pressure Sensor

**Barometric Pressure Sensor (BARO)** - The BARO sensor monitors ambient air pressure. Mounted in the engine compartment. The ECM uses this signal to adjust injection timing and fuel metering based on altitude.

Pressure	Altitude	Voltage
in. Hg	feet	VDC
29.9	0 (sea level)	4.25
26.8	3000	3.90
24.0	6000	3.50
21.4	9000	3.30
19.1	12000	2.90

**Camshaft Position Sensor (CMP)** - A magnetic-type sensor that detects rotation and position of the engine camshaft. The CMP is located in the engine rocker box cover facing the trigger/tone wheel that is mounted on the camshaft gear. Generates a signal that increases with the speed of the engine camshaft. The ECM uses this signal to determine camshaft position for fuel control and injection timing. The ECM will use this signal for calculated engine speed if CKP signal is lost. A DTC will be set and ECM will default to CKP signal if CMP signal is lost.

**Crankshaft Position Sensor (CKP)** - A magnetic-type sensor that detects rotation and position of the engine crankshaft. The CKP is located in the engine rear flywheel housing facing the trigger/tone wheel mounted on the crankshaft. Generates a signal that increases with the speed of the engine crankshaft. The ECM uses this signal to determine crankshaft position for fuel control and injection timing. A DTC will be set and ECM will default to CMP signal if CKP signal is lost.

**Crankcase Pressure Sensor** - A sensor that monitors pressure in the engine crankcase. The ECM uses this signal to verify the condition of the closed crankcase ventilation system and filter.

**DEF Pressure Sensor** - A sensor that monitors DEF pressure and is installed in the DEF pressure line. The ECM uses this signal to monitor pressure supplied to the DEF doser valve. See table p.13.

**DEF Quality/DEF Tank Level/DEF Tank Temperature Sensor Module** - This is a three-part sensor. ECM uses sensor to monitor urea concentration of diesel exhaust fluid (DEF), fluid level in tank, and fluid temperature in tank. Low DEF quality, low tank fluid level, or faults with fluid temperature in the tank may cause the ECM to initiate a progressive derate strategy. This sensor communicates on the J1939 data bus.

**Diesel Particulate Filter Differential Pressure / Diesel Particulate Filter Outlet Pressure Sensor (DPFDP/DPFOP)** - A sensor that has two ports that monitor the exhaust gas pressure across the diesel particulate filter. A port is located on each side of the DPF. The ECM uses pressure differential to calculate the amount of DPF restriction.

**EGR Differential Pressure Sensor** - A sensor that has 2 ports that monitor the exhaust gas pressure across the EGR differential pressure venturi. One port is located on each side of the EGR venturi. The ECM uses this pressure differential signal and the EGR temperature signal to calculate the amount of EGR flow into the intake manifold. The ECM commands the EGR valve and the VGT actuator positions to control the amount of cooled exhaust gases entering the engine.

**Engine Coolant Level Sensor (CL)** - A sensor that monitors the level of the coolant in the radiator surge tank. The ECM uses this signal for engine protection when coolant is low or not detected.

- 4.5 V = Normal - No Action
- 3.5 V = Low - Warning
- 2.5 V = Low/Moderate - Derate
- 1.5 V = Low/Severe - Shutdown

**Engine Oil Pressure Sensor (EOP)** - A sensor that monitors engine oil pressure and is installed in the main engine oil gallery. The ECM uses this signal for engine protection and the instrument cluster pressure gauge. Normal Idle: 15 psi. min. Rated rpm: 35-70 psi. See table p.13.

**Exhaust Back Pressure Sensor (EBP)** - A sensor that monitors exhaust gas pressure from a tube connected to the exhaust manifold. The ECM uses this signal for EGR valve and variable geometry turbocharger (VGT) operation. See table p.13.

**Fuel Delivery Pressure Sensor** - A sensor that monitors fuel supply pressure after the secondary fuel filter before it enters the high pressure fuel pump. The ECM uses this signal to control fuel metering and injection timing. See table p.13.

**Fuel Rail Pressure Sensor** - A strain gauge sensor that monitors high pressure fuel in the fuel rail. ECM uses the signal to maintain fuel rail pressure control.

Pressure		Voltage
kPa	psi	VDC
34,473	5000	0.50
103,421	15000	1.50
173,369	25000	2.50
241,316	35000	3.50
310,264	45000	4.50

**Intake Manifold Pressure Sensor (IMP)** - A 4-wire sensor used to monitor intake manifold pressure. Located in the intake manifold. (Also see: temperature sensors, manifold temperature sensor). ECM uses this signal to control fuel metering, injection timing, and turbocharger control. Full load at rated rpm: 40 to 45 psi (276 to 310 kPa).

Pressure		Voltage
psig	in. Hg	VDC
0.0 (atmospheric)	0.0 (atmospheric)	0.50
12.5	25.45	1.50
25.0	50.90	2.50
37.5	76.35	3.50
50.0	101.80	4.50



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**Oxides of Nitrogen (NOx) IN Sensor Module** - The inlet sensor module consists of a sensor permanently attached to a control unit that communicates on the J1939 private CAN to the ECM. Located before the DOC, it monitors oxides of nitrogen in the exhaust stream within a range of 0-3000 ppm. The ECM uses this input to measure engine efficiency and as an input for DEF doser actuation.

**Oxides of Nitrogen (NOx) OUT Sensor Module** - The outlet sensor module consists of a sensor permanently attached to a control unit that communicates on the J1939 private CAN to the ECM. Located after the SCR catalyst, it monitors oxides of nitrogen in the exhaust stream within a range of 0-3000 ppm. The ECM uses this input to measure SCR efficiency and as an input for DEF doser actuation.

**Particulate Matter (PM) Sensor Module** - A sensor module that consists of a sensor permanently attached to a control unit that communicates over the J1939 private CAN to the ECM. This sensor is used to measure the soot emissions at the outlet of the exhaust aftertreatment system.

**Transmission Gear Position Sensor** - A non-adjustable potentiometer located on the transmission top plate to monitor the position of the transmission gear select motor. Delivers a signal of 0.5V to 4.5V to the TCM.

**Transmission Rail Position Sensor** - A non-adjustable potentiometer located on the transmission top plate to monitor the position of the transmission rail select motor. Delivers a signal of 0.5V to 4.5 V to TCM.



## Temperature Sensors

**Ambient Air Temperature Sensor (AAT)** - A sensor that monitors the outside (ambient) air temperature and is mounted on the cab. The signal is sent from the body control module (BCM) to the ECM on the J1939 data link (CAN).

**Charge Air Cooler Outlet Temperature Sensor** - A sensor that monitors the charge air temperature. The ECM uses signal for emissions management and to monitor charge air cooler efficiency.

**Compressor Side Turbocharger Outlet Temperature Sensor** - A sensor that monitors the turbocharger outlet air temperature. The ECM uses signal for emissions management and to monitor charge air cooler efficiency. Located on the inlet side of the charge air cooler.

**Engine Coolant Temperature Sensor (ECT)** - A sensor that monitors engine coolant temperature and is mounted in the cylinder head near the coolant thermostats. The ECM uses this signal to control fuel management, engine protection, cooling fan operation, the instrument cluster temperature gauge, and DPF regeneration.

**Engine Oil Temperature Sensor (EOT)** - A sensor that monitors engine oil temperature and is installed in the main engine oil gallery. The ECM uses this signal for engine protection, cooling fan operation, and controlling fuel management.

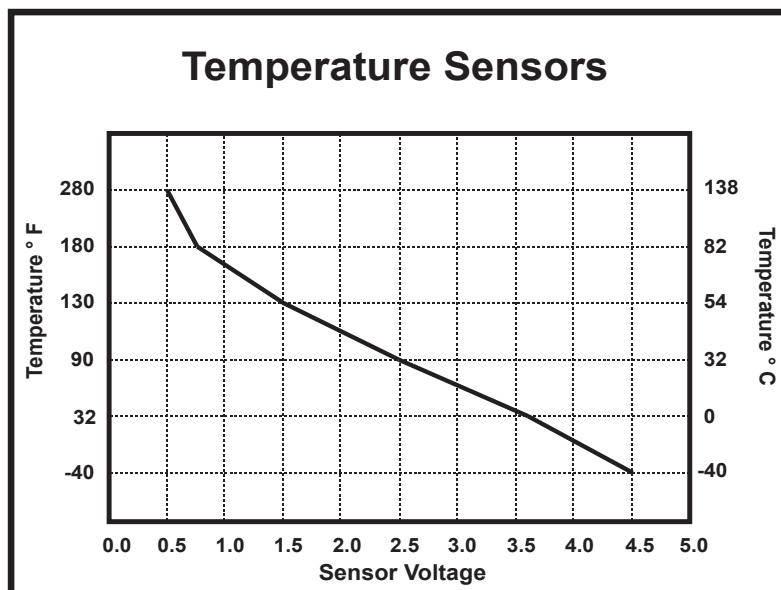
**Fuel Temperature Sensor (FT)** - A sensor that monitors fuel temperature and is mounted on the secondary fuel filter housing. The ECM uses this signal to control fuel management to compensate for changes in fuel temperature and for engine protection.

**Inlet Air Temperature Sensor (IAT)** - A sensor that monitors air temperature in the inlet pipe before the turbocharger. ECM uses this signal for fuel management.

**Intake Manifold Temperature Sensor (IMT)** - A 4-wire, combined, solid-state sensor used to measure intake manifold air temperature. (Also see: intake manifold pressure sensor). Located on the intake manifold after EGR mixing chamber.

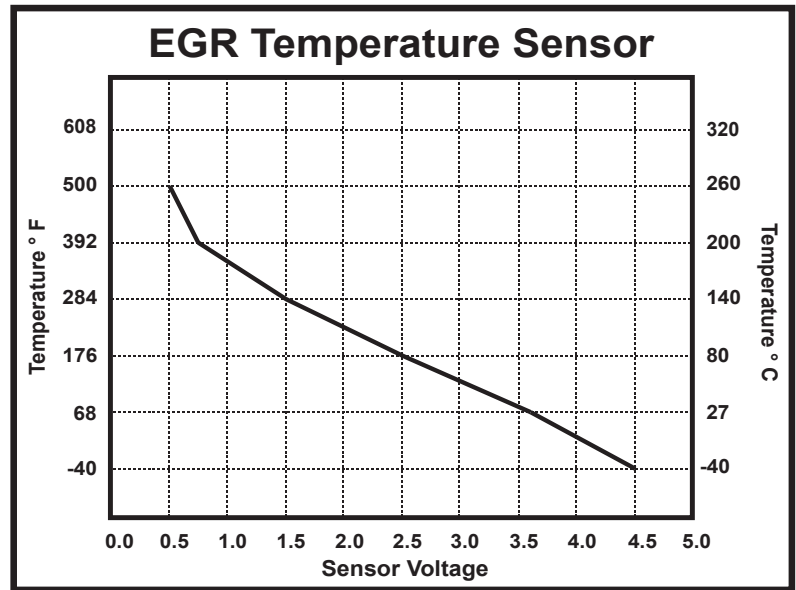
Temperature ° F	Temperature ° C	Sensor Voltage
280	138	0.50
180	82	0.75
130	54	1.50
90	32	2.50
32	0	3.60
-40	-40	4.50

**Note: This table and chart refer to the sensors listed above.**



**EGR Temperature Sensor (EGRT)** - A sensor that monitors the temperature of the exhaust gases, located in the outlet of the EGR cooler. The ECM uses this signal for emissions management and EGR cooler efficiency.

Temperature ° F	Temperature ° C	Sensor Voltage
500	260	0.50
392	200	0.75
284	140	1.50
176	80	2.50
68	27	3.60
-40	-40	4.50



**Aftertreatment Temperature Sensor Module** - Consists of four individual temperature sensor probes located in the exhaust stream: DOC Inlet Temperature Sensor (before the diesel oxidation catalyst), DPF Inlet Temperature Sensor (after the diesel oxidation catalyst), DPF Outlet Temperature Sensor (after the diesel particulate filter) and SCR Outlet Temperature Sensor (after the selective catalytic reduction unit). The aftertreatment temperature sensor module monitors all four temperature sensor probes and communicates on the J1939 private CAN to the ECM. The ECM uses this data to monitor exhaust aftertreatment performance and efficiency.

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**Transmission Input Shaft Speed (ISS) Sensor** - A magnetic-type sensor that senses rotation of the transmission input shaft and generates a signal that increases with the speed of the input shaft. Located in the front of the transmission shift bar housing. TCM uses this signal to determine input shaft speed for gear ratio and clutch slippage. This is calculated in conjunction with the Crankshaft Position sensor and the Transmission Main Shaft Speed sensor. Sensor resistance is  $1000 \pm 50 \Omega$ .

**Transmission Main Shaft Speed (MSS) Sensor** - A magnetic-type sensor that senses rotation of the transmission main shaft and generates a signal that increases in frequency with the speed of the main shaft. Located in the rear of the transmission shift bar housing. TCM uses this signal to determine main shaft speed for gear ratio and range selection. This is calculated in conjunction with the Transmission Input Shaft Speed sensor and the Transmission Output Shaft Speed sensor. Sensor resistance is  $1000 \pm 50 \Omega$ .

**Transmission Output Shaft Speed (OSS) Sensor** - A magnetic-type sensor that senses rotation of the transmission output shaft and generates a signal that increases with the speed of the output shaft. Located between the rear cover and the yoke. TCM uses this signal to determine output shaft speed for vehicle speed and range selection. This is calculated in conjunction with the Transmission Input Shaft Speed. Sensor resistance is  $1000 \pm 50 \Omega$ .

**Water-in-Fuel (WIF) Sensor** - A 2-wire sensor, mounted in the bottom of the primary fuel filter/water separator, that allows the ECM to measure resistance across a pair of terminals on the end of the sensor. When the ECM detects  $130 \text{ k}\Omega$  across the contacts, it sends a command to the instrument cluster to illuminate the Water-in-Fuel Lamp.

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## INPUTS - SWITCHES

**A/C High Pressure Switch** - A 2-wire, normally closed pressure switch, wired to the BCM, that opens when the air conditioner high-side pressure reaches a preset value. This signals the ECM to operate the engine cooling fan.

**Cruise Control On/Off Switch** - A 2-wire, normally open switch, wired to the BCM, that enables cruise control operation when it is closed by the operator.

**Cruise Set/Resume Switch** - A 3-wire switch, wired to the BCM, that has two momentary positions: SET/COAST and RESUME/ACCELERATE. The two set/resume switch positions are also used for engine speed settings during PTO operation.

**Diesel Particulate Filter Regeneration Switch** - A 2-wire, normally open momentary switch, wired to the BCM, that when pressed (closed) and released, requests the ECM to enable a parked DPF regeneration.

**Diesel Particulate Filter Regeneration Inhibit Switch** - A 2-wire, normally open momentary switch, wired to the BCM, that when pressed (closed) and released, requests the ECM to inhibit DPF regeneration. The switch resets on each key cycle.

**Electronic Transmission Shift Select Module** - A keypad that communicates operator selected gear position to the TCM and the J1939 network. Also receives inputs from the TCM and other modules to display gear position on the LCD display or flash gear position if a condition is present which will not allow a gear shift. Loss of communication with the TCM will illuminate an error message on the electronic transmission shift select module display, default to current gear, and return to NEUTRAL after key OFF. Power interruption to the electronic transmission shift select module will default transmission to last operator selected position until the next key cycle.

**Engine Brake On/Off Switch** - A 2-wire, normally open switch, wired to the BCM, that signals the ECM that the operator is requesting engine brake system activation when closed. The ECM will energize the engine brake solenoids based on inputs from the accelerator pedal and the cruise control on/off and service brake switches.

**Engine Brake Selector Switch** - A 3-wire, two-position switch, wired in series with the BCM and engine brake ON/OFF switch, that sets the level of engine braking (LOW or HIGH). The engine brake solenoid for engine cylinders 1, 2 & 3 is energized for the LOW level. The engine brake solenoids for all cylinders, 1–6, are energized for the HIGH level.

**Engine Cooling Fan Control Switch** - A 2-wire, normally open switch that is wired to the BCM. When closed by the operator, the switch requests that the ECM de-energize the engine cooling fan solenoid. This will cause the engine cooling fan to operate continuously. If the switch is turned off, the fan may continue to operate for up to 180 seconds.

**Engine Protection Override Switch** - A 2-wire, normally open momentary switch, wired to the ECM, that, when pressed (closed) and released during the shutdown warning period, requests the ECM to override (delay) an engine protection shutdown for 30 seconds.

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**Ignition Switch** - The ignition switch is a 3-position switch: OFF, ON, CRANK. The switch supplies 12 V to the ECM through the ECM power relay in the ON position to command the ECM and other modules to begin communication. When in the START position the switch provides 12 V to the ECM to request starter operation.

**Parking Brake Switch** - A 2-wire, normally closed air pressure switch, wired to the BCM, that opens when the parking brake is released.

**PTO On/Off Switch** - A 2-wire, normally open switch that is wired to the BCM to enable PTO mode operation when closed.

**Service Brake Pedal Switch** - A 2-wire, normally open air pressure switch that closes when the service brake pedal is applied. This signals the ECM to enable engine braking, cancel cruise control and power take-off mode, and to override the idle shutdown timer.

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## OUTPUTS - ACTUATORS/INDICATORS

**Aftertreatment Air Purge Valve** - A 2-wire valve that is commanded by the ECM to purge fuel from the aftertreatment fuel injector and line. Air is supplied to the valve from the secondary air tank.

**Aftertreatment Fuel Injector** - A 2-wire pulse width modulated (PWM) injector controlled and monitored by the ECM. Commanded by the ECM to inject diesel fuel into the exhaust system upstream of the DOC to raise exhaust temperature. The injector is activated once DOC inlet temperature is over 550° F (287° C). The injector is supplied fuel from a cut-off valve located on the secondary fuel filter outlet.

**Aftertreatment Fuel Shutoff Valve** - A 2-wire valve that is commanded by the ECM to control fuel flow (ON/OFF) to the AFT fuel injector. If a fault is detected during a self-test, the ECM disables active and stationary regeneration until the next key cycle.

**Alternator/Generator** - A 200-amp, internally regulated alternator equipped with remote sense. Target voltage is 14.1 VDC ( $\pm 0.5$  VDC).

**Check Engine Lamp (CEL)** - An amber lamp illuminated in the instrument cluster module (ICM) when commanded by the ECM as part of the engine protection system strategy.

**DEF Doser Valve** - A 2-wire injector commanded and monitored by the ECM to inject DEF into the exhaust aftertreatment system to reduce NOx.

**DEF Heater Relay** - When energized by the ECM, the relay provides battery voltage (B+) to the DEF system heaters. ECM requests heater activation when ambient temperature is less than 50°F (10°C). Coil resistance is  $90 \pm 4 \Omega$ .

**DEF Low Lamp** - The ICM illuminates the DEF low lamp when it receives a signal indicating less than 10% of DEF is remaining in the tank.

**DEF Supply Pump** - The DEF supply pump is supplied with battery voltage (B+) by the DEF supply pump relay. The pump is used to supply DEF to the DEF doser valve at a pressure of 130 psi. The pump contains an inlet screen and an outlet filter. Upon key OFF, the ECM commands the DEF supply pump to reverse rotation to clear the lines of DEF by grounding its directional control circuit.

**DEF Supply Pump Relay** - When energized by the ECM, the relay provides battery voltage (B+) to the DEF supply pump. Coil resistance is  $90 \pm 4 \Omega$ .

**DEF System Heaters** - The DEF heaters are supplied with battery voltage (B+) by the DEF heater relay. The heaters are located in the lines, pump, and tank, and are designed to keep the DEF in a liquid state.

**DPF Malfunction Lamp** - The ICM illuminates the DPF malfunction lamp when it receives a signal from the ECM indicating a fault with the DPF.

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**DPF Status Lamp** - The ICM illuminates the DPF status lamp when it receives a signal from the ECM indicating a need for regeneration. Depending on the status of the exhaust aftertreatment system, the SEL may also illuminate.

**ECM Power Relay** - When energized by the ignition switch, the relay provides battery voltage (B+) to the ECM. Coil resistance is  $90 \pm 4 \Omega$ .

**EGR Valve** - A 12 V stepper motor, monitored by a position sensor, that actuates a butterfly valve located between the EGR cooler and the intake manifold venturi. The ECM varies the valve position to regulate the flow of cooled exhaust gases into the intake manifold. Supplied with power and ground, it is commanded over the J1939 private CAN. If the EGR valve loses communication with the ECM, the valve will default to the closed position. If power is interrupted to the valve, it will default to its current position.

**Electric Fuel Primer Pump** - A 2-wire pump located in line with the fuel suction line that is energized by the electric fuel primer pump relay. At key ON or engine cranking, the pump operates for 60 seconds or until a valid engine rpm signal is detected. The mechanical lift pump then takes over, drawing fuel through the bypass check valve. Charge pressure is 15 psi (103kPa).

**Electric Fuel Primer Pump Relay** - When energized by the ECM, the relay provides battery voltage (B+) to the electric fuel primer pump. Coil resistance is  $90 \pm 4 \Omega$ .

**Electronic Clutch Actuator Module** - A 12 V stepper motor that is commanded by the TCM over the J1939 network to actuate the clutch. The actuator module is monitored by a position sensor and is supplied with a battery voltage (B+) and a switched power input.

**Engine Brake Solenoids** - Two solenoids commanded by the ECM to provide engine braking on 3 (low) or all 6 (high) cylinders. Coil resistance is  $10 \Omega \pm 1 \Omega$ .

**Engine Cooling Fan Solenoid** - A 12 V electric-over-air solenoid commanded by the ECM. When energized, the solenoid supplies air to the engine cooling fan clutch to disengage it, turning the fan OFF. The ECM will operate the fan for engine protection when coolant temperature reaches 210° F (94° C), the engine oil temperature reaches 245° F (118° C), the intake manifold temperature reaches 190° F (88° C), or when the A/C high-pressure switch opens.

**Fuel Injectors** - Six solenoid-actuated high-pressure common rail (HPCR) fuel injectors installed in the cylinder head. The ECM supplies voltage to the injectors and controls the ground side to actuate the solenoid. Fuel injector quantity adjustment (IQA) is accomplished through injector calibration coding in the ECM. Coil resistance is  $2 \Omega \pm 0.5 \Omega$ .

**Fuel Pressure Control Solenoid** - An ECM controlled solenoid mounted to the fuel rail that returns fuel from the fuel rail to the tank. The solenoid works in conjunction with the fuel volume control solenoid to regulate fuel pressure. The solenoid defaults to the closed position and upon key OFF, will hold 5,000 psi (34,474 kPa) for 30 seconds. Includes a spring-loaded mechanical system relief fail-safe set at 35,000 psi (241,317 kPa).

**Fuel Volume Control Solenoid** - An ECM controlled solenoid mounted to the pump that works to control the volume of fuel into the high-pressure pumping chambers. At key OFF, the solenoid defaults to the open position.



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**High Exhaust System Temperature Lamp (HEST)** - The ICM illuminates the HEST lamp when it receives a signal from the ECM indicating that the exhaust outlet temperature is 850° F (454° C) or greater with a vehicle speed of under 5 mph.

**High-Pressure Fuel Pump** - A gear-driven, 3-piston radial pump that is supplied with fuel at 125-160 psi (862-1034 kPa) from a mechanical supply pump driven by the high-pressure pump. The pump is lubricated internally with fuel, and excess fuel is returned to the fuel tank through the mechanical pressure regulator.

**Intake Grid Heater** - The intake grid heater is supplied with battery voltage (B+) by the intake heater relay. It is designed to warm the manifold air to assist engine starting. Current draw is 170A ± 10A.

**Intake Grid Heater Relay** - When energized by the ECM, the relay provides battery voltage (B+) to the intake grid heater. The ECM requests the heater to be active when ambient temperature is less than 50° F (10° C). Coil resistance is 90 ± 4 Ω.

**Malfunction Indicator Lamp (MIL)** - The ICM illuminates the amber MIL when it receives a signal from the ECM indicating DTCs are set, during stages of engine protection or engine/emission system faults.

**Starter** - A 12 V gear reduction starter mounted to the flywheel housing. The minimum engine cranking speed needed to start is 200 rpm.

**Starter Relay** - When energized by the ECM, the relay provides battery voltage (B+) to the starter “S” terminal. Coil resistance is 90 ± 4 Ω.

**Stop Engine Lamp (SEL)** - The red Stop Engine Lamp (SEL) illuminates when the engine protection system is in warning mode or when electronic control system failures are occurring and an active fault is present. The CEL and the SEL are used in combination with the DPF Malfunction lamp for DPF restriction status and regeneration requirements.

**Transmission Electric Gear/Rail Select Motors** - A pair of 12 V stepper motors mounted on the transmission top plate and monitored by the rail and gear select sensors. The motors are commanded by the TCM to actuate a screw to move a foot in the transmission top plate to select gears. The motors are commanded to return to NEUTRAL at key OFF.

**Transmission Range Valve** - One assembly, consisting of two TCM-controlled ON/OFF air solenoids. Used to apply air to either side of a servo to shift the range gear in the transmission.

**Variable Geometry Turbocharger (VGT) Actuator** - Mounted on the turbocharger and commanded by the ECM over the J1939 Private CAN, the VGT actuator operates an internal sliding nozzle that allows for control of the turbine shaft speed. The actuator has self-diagnostic capabilities and contains a 120 Ω terminating resistor. Communication failure results in the VGT defaulting to the fully open position.

**Wait-to-Start Lamp** - The ICM illuminates the Wait-to-Start lamp when it receives a signal from the ECM indicating that ambient and engine temperatures warrant use of the intake heater.



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**Warning Buzzer** - A 2-wire, 12 V buzzer commanded ON by the ICM when it receives requests from other modules to activate the buzzer as part of operational warning strategies.

**Water-in-Fuel Lamp (WIF)** - The ICM commands ON the WIF lamp when it receives a signal indicating the presence of water in the fuel/water separator.

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## ***DIAGNOSTIC TROUBLE CODES (DTC)***

- Active codes indicates a fault currently exists.
- Inactive codes indicate faults are stored.
- An emissions-related DTC will illuminate the MIL.
- An engine protection-related DTC will illuminate the amber check engine lamp (CEL) and/or red stop engine lamp (SEL).
- When using diagnostic tool, DTCs are formatted using SAE J1939 standards and descriptions.

## ***DIAGNOSTIC EQUIPMENT***

- A PC-based diagnostic tool and an interface cable can be connected to the 9-pin or 3-pin ATA-type data link connector to access vehicle data, diagnostic codes, and to set programmable parameters.
- A PC-based diagnostic tool can be used to install initial operating software and/or update software calibrations in the electronic control modules.
- A breakout tool (box/cable) can be connected into a circuit to perform circuit measurements.

The Displayed Data chart on page 27 shows how diagnostic tool data will be presented in some Composite Vehicle test questions. The chart shows how the status of components (switches and lamps) or operational modes will be indicated. The minimum/maximum measurement range and values for engine data (voltages, temperatures, pressures, and speeds) is also shown.



## Displayed Data

Displayed Data	Value Range
A/C High Pressure Switch	Closed / Open
Accelerator Pedal Position Sensor 1 (APP 1)	0 – 100% / 0.0-5.0 VDC
Accelerator Pedal Position Sensor 2 (APP 2)	0 – 100% / 0.0-5.0 VDC
Aftertreatment Air Purge Valve	ON / OFF
Aftertreatment Fuel Injector	0 – 100%
Aftertreatment Fuel Pressure Sensor	0 – 200 psi / (0 – 1400 kPa) / 0.0 – 5.0 VDC
Aftertreatment Fuel Shutoff Valve	ON / OFF
Aftertreatment Regeneration Status Lamp	ON / OFF / Flashing
Ambient Air Temperature Sensor (AAT)	-40 – 248° F (-40 – 120° C) / 0 – 5 VDC
Ash Load	0 – 100%
Barometric Pressure Sensor (BARO)	0 – 30 in. Hg (0 – 5 VDC)
Body Control Module (BCM) Supply Voltage	0 – 16 VDC
Cam / Crank Sync	Yes / No
Camshaft Position Sensor Signal (CMP)	Yes / No
Charge Air Cooler Outlet Temperature Sensor	-40 – 248° F (-40 – 120° C) / 0 – 5 VDC
Clutch Actuator Module	Applied / Released
Compressor Side Turbocharger Outlet Temperature Sensor	-40 – 248° F (-40 – 120° C) / 0 – 5 VDC
Cooling Fan Solenoid	ON / OFF
Crankcase Pressure Sensor	0 – 40 in. H2O / 0.0 – 5.0 VDC
Crankshaft Position Sensor Signal (CKP)	Yes / No
Cruise ON / OFF Switch	ON / OFF
Cruise Resume / Accelerate Input	Resume / Accelerate
Cruise Set / Coast Input	Set / Coast
DEF Doser Valve Injection Rate	0 – 100%
DEF Heater Relay	ON / OFF
DEF Lamp	ON / OFF / Flashing
DEF Level	0 – 100%
DEF Pressure Sensor	0 – 200 psi
DEF Pump Relay	ON / OFF
DEF Quality	0 – 100%
DEF Temperature Sensor	-40 – 248° F (-40 – 120° C)
DOC Inlet Temperature	0-2300° F (0-1260° C)
DPF Differential Pressure (DPFDP)	0 – 5 psi / 0 – 35 kPa
DPF Inlet Temperature	0 – 2300° F (0 – 1260° C)
DPF Malfunction Lamp	ON / OFF
DPF Outlet Pressure	0 – 5 psi / 0 – 35 kPa
DPF Outlet Temperature	0 – 2300° F (0 – 1260° C)
DPF Regen Inhibit Switch	ON / OFF
DPF Regen Switch	ON / OFF
ECM Power Relay	ON / OFF
ECM Supply Voltage	0 – 16.0 VDC
EGR Differential Pressure	0 – 5 psi / 0 – 35 kPa
EGR Temperature Sensor (EGRT)	-40 – 500° F (-40 – 260° C) / 0-5 VDC
EGR Valve (Actual)	0 – 100%
EGR Valve (Desired)	0 – 100%
Electric Cooling Fan Solenoid	ON / OFF
Electric Fuel Primer Pump Relay	ON / OFF

Displayed Data	Value Range
Engine Brake On/Off Switch	ON / OFF
Engine Brake Selector Switch	LOW / HIGH
Engine Brake Solenoid A	ON / OFF
Engine Brake Solenoid B	ON / OFF
Engine Coolant Level	0 – 5 VDC
Engine Coolant Temperature Sensor (ECT)	-40 – 248° F (-40 – 120° C) / 0-5 VDC
Engine Cooling Fan Solenoid	ON / OFF
Engine Cooling Fan Control Switch	ON / OFF
Engine Load	0 – 100%
Engine Oil Pressure (EOP)	0 – 200 psi (0 – 1400 kPa) 0.0 – 5.0 VDC
Engine Oil Temperature Sensor (EOT)	-40 – 280° F (-40 – 138° C) / 0.0 – 5.0 VDC
Engine Protection Override Switch	ON / OFF
Engine Protection Shutdown	Active / Inactive
Engine Speed	0 – 4000 rpm
Exhaust Back Pressure (EBP)	0 – 200 psi (0 – 1400 kPa) 0.0 – 5.0 VDC
Fuel Delivery Pressure Sensor	0 – 200 psi (0 – 1400 kPa) 0.0 – 5.0 VDC
Fuel Injector 1	0 – 100%
Fuel Injector 2	0 – 100%
Fuel Injector 3	0 – 100%
Fuel Injector 4	0 – 100%
Fuel Injector 5	0 – 100%
Fuel Injector 6	0 – 100%
Fuel Pressure Control Solenoid	0 – 100%
Fuel Pump Relay	ON / OFF
Fuel Rail Pressure Sensor	0 – 40,000 psi (0 – 275,800 kPa)
Fuel Temperature Sensor (FT)	-40 – 248° F (-40 – 120° C) / 0 – 5 VDC
Fuel Volume Control Solenoid	0 – 100%
High Exhaust System Temperature Lamp (HEST)	ON / OFF / Flashing
Ignition Switch	OFF / ON / CRANK
Inlet Air Temperature Sensor (IAT)	-40 – 248° F (-40 – 120° C) / 0 – 5 VDC
Intake Manifold Pressure Sensor (IMP)	0 – 120 in. Hg Gauge / 0 – 60 psi / 0 – 414 kPa / 0.0 – 5.0 VDC
Intake Manifold Temperature Sensor (IMT)	-40 – 248° F (-40 – 120° C) / 0 – 5 VDC
Maintenance Required Lamp	ON / OFF
Malfunction Indicator Lamp (MIL)	ON / OFF / Flashing
NOx Sensor IN Module	0 – 3000 ppm
NOx Sensor OUT Module	0 – 3000 ppm
Parking Brake Switch	Applied / Released
Particulate Matter Sensor (PM)	0 – 100% (calculated value)
PTO On/Off Switch	ON / OFF
PTO Remote Switch	ON / OFF
PTO Status	Active / Inactive
SCR Outlet Temperature	0 – 2300° F ( 0 – 1260° C)
Sensor Supply Voltage	0 – 5.5 VDC
Service Brake Pedal Switch	Applied / Released
Soot Load	0 / 1 / 2 / 3 / 4

Displayed Data	Value Range
Starter Relay	ON / OFF
Stop Engine Lamp (SEL)	ON / OFF / Flashing
TCM Supply Voltage	0 – 16 VDC
Transmission Gear Actual	R1 /R2 /N /1 /2 /3 /4 /5 /6 /7 /8 /9 /10
Transmission Gear Desired	R1 /R2 /N /1 /2 /3 /4 /5 /6 /7 /8 /9 /10
Transmission Gear Position Sensor	0.0 – 5.0 V
Transmission Gear Select Motor	0 – 255 Steps
Transmission Gear Selected	R /N /D / + or –
Transmission Input Shaft Speed	0 – 6000 rpm
Transmission Mainshaft Speed	0 – 6000 rpm
Transmission Output Shaft Speed	0 – 6000 rpm
Transmission Rail Position Sensor	0.0 – 5.0 V
Transmission Rail Select Motor	0 – 255 Steps
Transmission Range Valve A	ON / OFF
Transmission Range Valve B	ON / OFF
Vehicle Speed	0 – 130 mph (0 – 210 kph)
VGT Actuator (Actual)	0 – 100%
VGT Actuator (Desired)	0 – 100%
Wait-to-Start Lamp	ON / OFF
Warning Buzzer	ON / OFF
Water-in-Fuel Lamp	ON / OFF
Water-in-Fuel Sensor (WIF)	ON / OFF

## PROGRAMMABLE PARAMETERS

Programmable parameters are the specifications that can be set within the ECM to control operating functions. The parameters are stored in non-volatile memory. A customer password is available for programming protection. A list of parameter ranges and their settings are shown below.

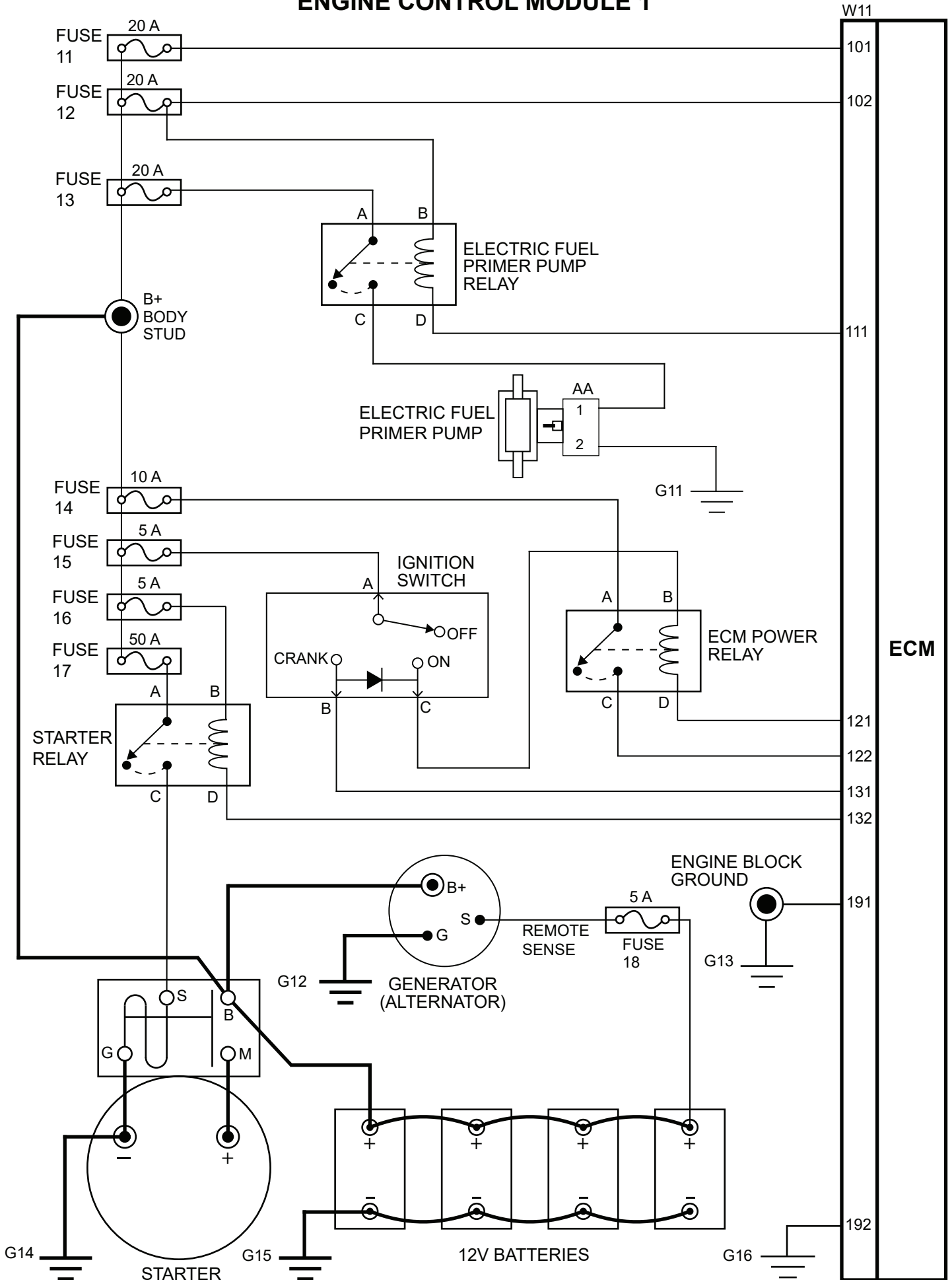
Feature	Range	Setting
<b>Road Speed Governor</b>		
Accelerator Max. Road Speed	30 – 120 mph / 48 – 193 kph	65 mph / 105 kph
Global Max. Road Speed	0 – 120 mph / 0 – 193 kph	120 mph / 193 kph
<b>Idle Speed Control</b>		
Idle Engine Speed	600 – 850 rpm	700 rpm
<b>Idle Shutdown</b>		
Idle Shutdown Timer	1 – 100 min.	3.0 min.
Idle Shutdown Lower Ambient Air Temperature	0 – 100° F / -18 – 38° C	40° F / 4° C
Idle Shutdown Upper Ambient Air Temperature Override	0 – 100° F / -18 – 38° C	85° F / 29° C
Idle Shutdown	Enabled / Disabled	Enabled
Idle Shutdown Manual Override	Enabled / Disabled	Disabled
<b>Fan Control</b>		
Minimum Fan On Time	0 – 1000 sec.	180 sec.
Fan Control A/C Press Switch	Enabled / Disabled	Enabled
Fan Control Solenoid Logic	12 V = OFF / 0 V = ON	0 Volts
Fan Control Switch	Enabled / Disabled	Enabled
Fan On During Engine Braking	Enabled / Disabled	Enabled
Fan Cut-In Temperature	180 – 215° F / 82 – 102° C	210° F / 99° C
Fan Cut-Out Temperature	160 – 195° F / 71 – 90° C	195° F / 90° C
<b>Cruise Control</b>		
Cruise Control Feature	Enabled / Disabled	Enabled
Cruise Control Upper Droop	0 – 3 mph / 0 – 5 kph	0 mph / 0 kph
Cruise Control Lower Droop	0 – 3 mph / 0 – 5 kph	2 mph / 3 kph
Cruise Control Speed Delta for Max. Engine Brake	0 – 6 mph / 0 – 10 kph	5 mph / 8 kph
Cruise Control Speed Delta for Min. Engine Brake	0 – 6 mph / 0 – 10 kph	3 mph / 5 kph
Max. Cruise Control Speed	30 – 120 mph / 48 – 193 kph	65 mph / 105 kph
<b>Engine Brakes</b>		
Engine Brake Cruise Control Activation	Enabled / Disabled	Enabled
Engine Brake Min. Vehicle Speed	0 – 35 mph / 0 – 56 kph	25 mph / 40 kph
Engine Brake Delay	0 – 10 sec	0 sec
Engine Brake Service Brake Activation	Enabled / Disabled	Enabled
Engline Brake Control	Enabled / Disabled	Enabled

Feature	Range	Setting
<b>PTO (Auxiliary Engine Speed Control)</b>		
Max PTO Speed	600 – 2500 rpm	1200 rpm
Min PTO Speed	600 – 2500 rpm	700 rpm
Set PTO Speed	600 – 2500 rpm	900 rpm
Resume PTO Speed	600 – 2500 rpm	1000 rpm
Remote PTO Speed	600 – 2500 rpm	1000 rpm
Max. Engine Load	0 – 1850 ft.lb.	800 ft.lb.
Max. Vehicle Speed	0 – 30 mph / 0 – 48 kph	0 mph / 0 kph
Ramp Rate	100 – 250 rpm / sec	250 rpm / sec
<b>Aftertreatment</b>		
Stationary Regeneration in PTO	Enabled / Disabled	Enabled
Automatic Stationary Regeneration	Enabled / Disabled	Enabled
Diesel Particulate Filter Regeneration Disable Switch	Enabled / Disabled	Enabled
<b>Vehicle Setup Parameters</b>		
Rear Axle Ratio	2.28 – 15.98:1	2.73:1
Tire Size	301 – 700 rev / min	501
Vehicle Speed Sensor Type		J1939
Max. Engine Speed without VSS	1200 – 1800 rpm	1400 rpm
Max. Engine Speed with VSS	1200 – 2500 rpm	2100 rpm
Transmission Type		Automated
Multiplexing Ambient Air Temperature Sensor		J1939
<b>Engine Protection</b>		
Engine Protection Shutdown Feature	Warning / Derate / Shutdown	Shutdown
Engine Protect Restart Inhibit	Enabled / Disabled	Enabled
Manual Override	Enabled / Disabled	Enabled



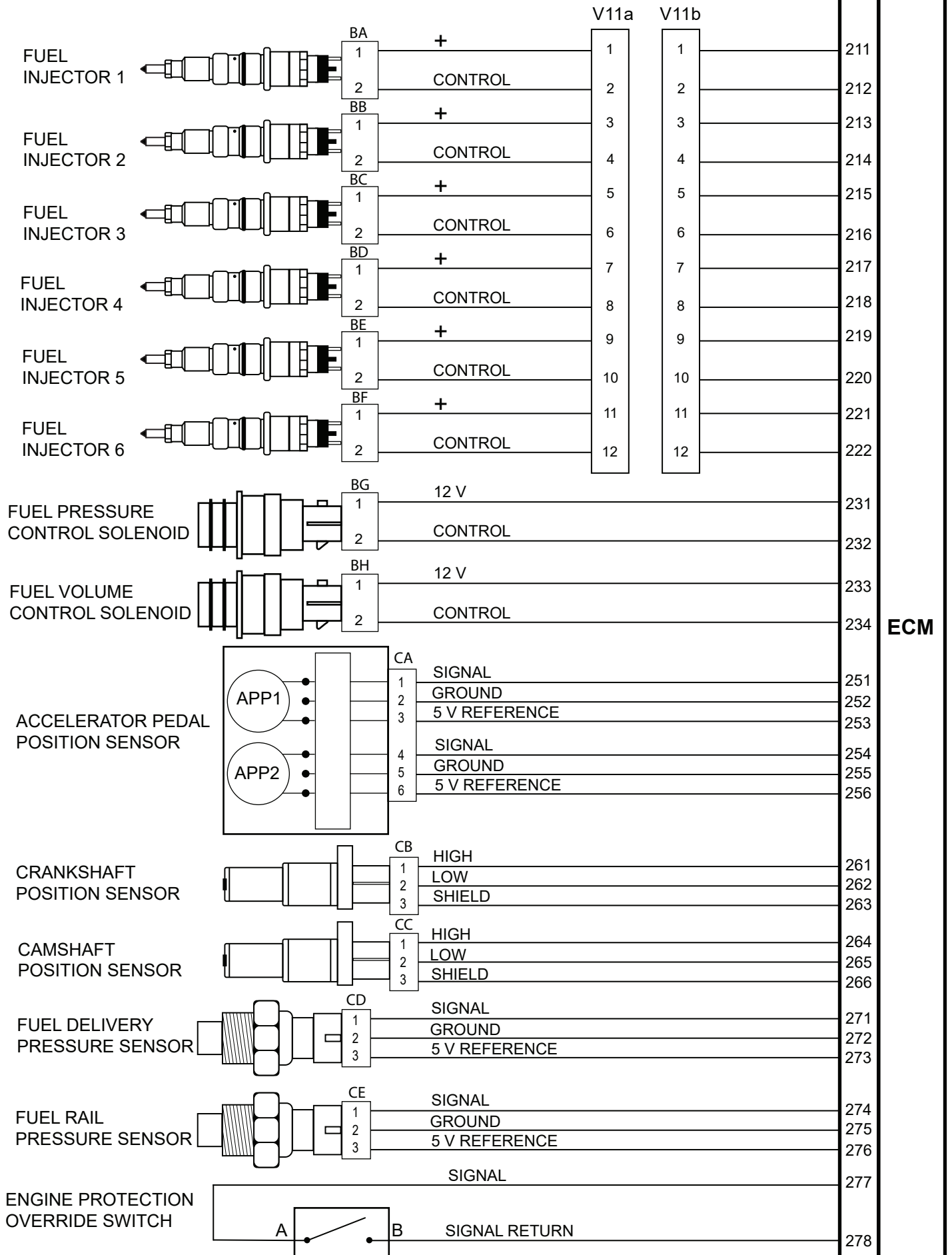


# ENGINE CONTROL MODULE 1



# ENGINE CONTROL MODULE 2

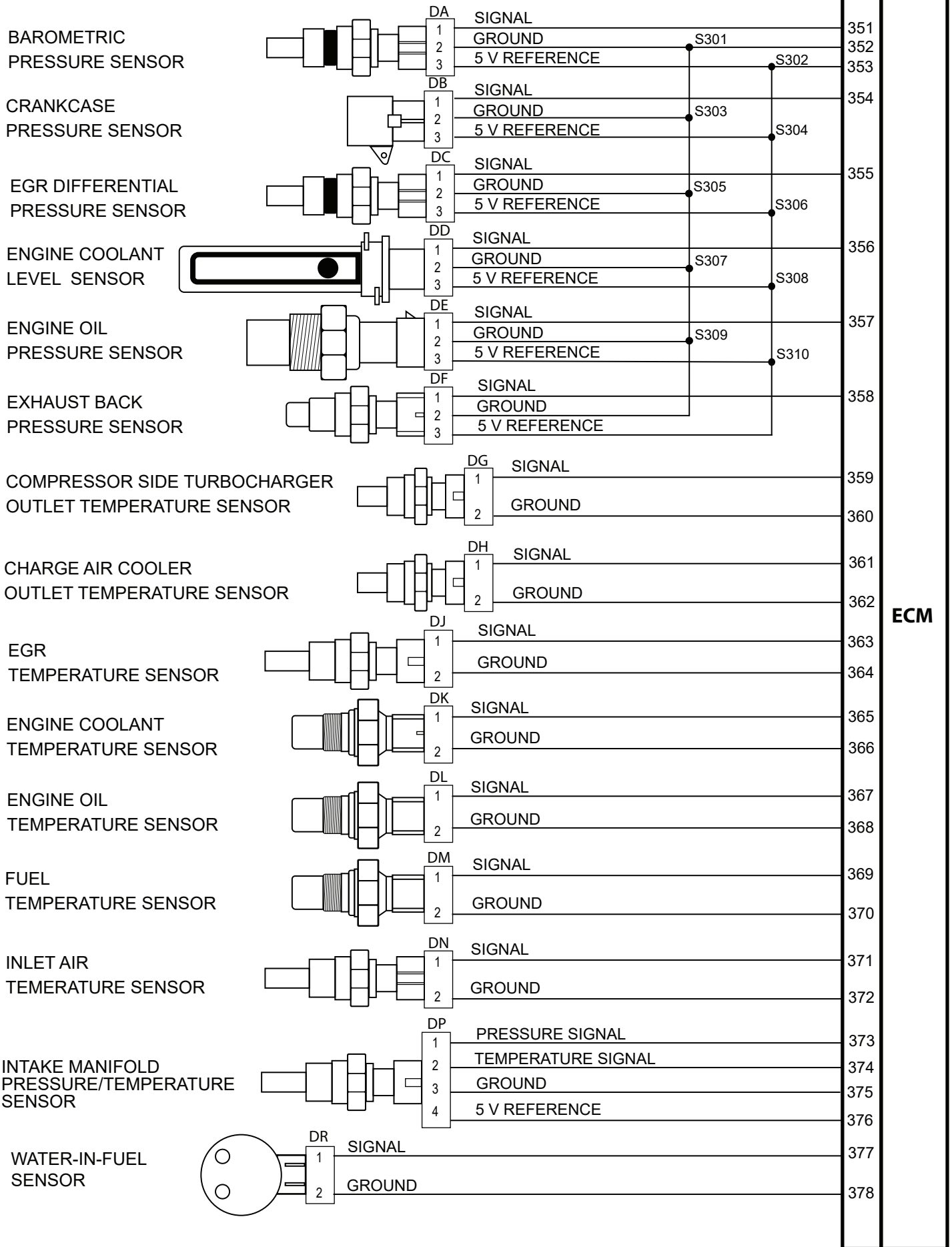
W12



**ECM**

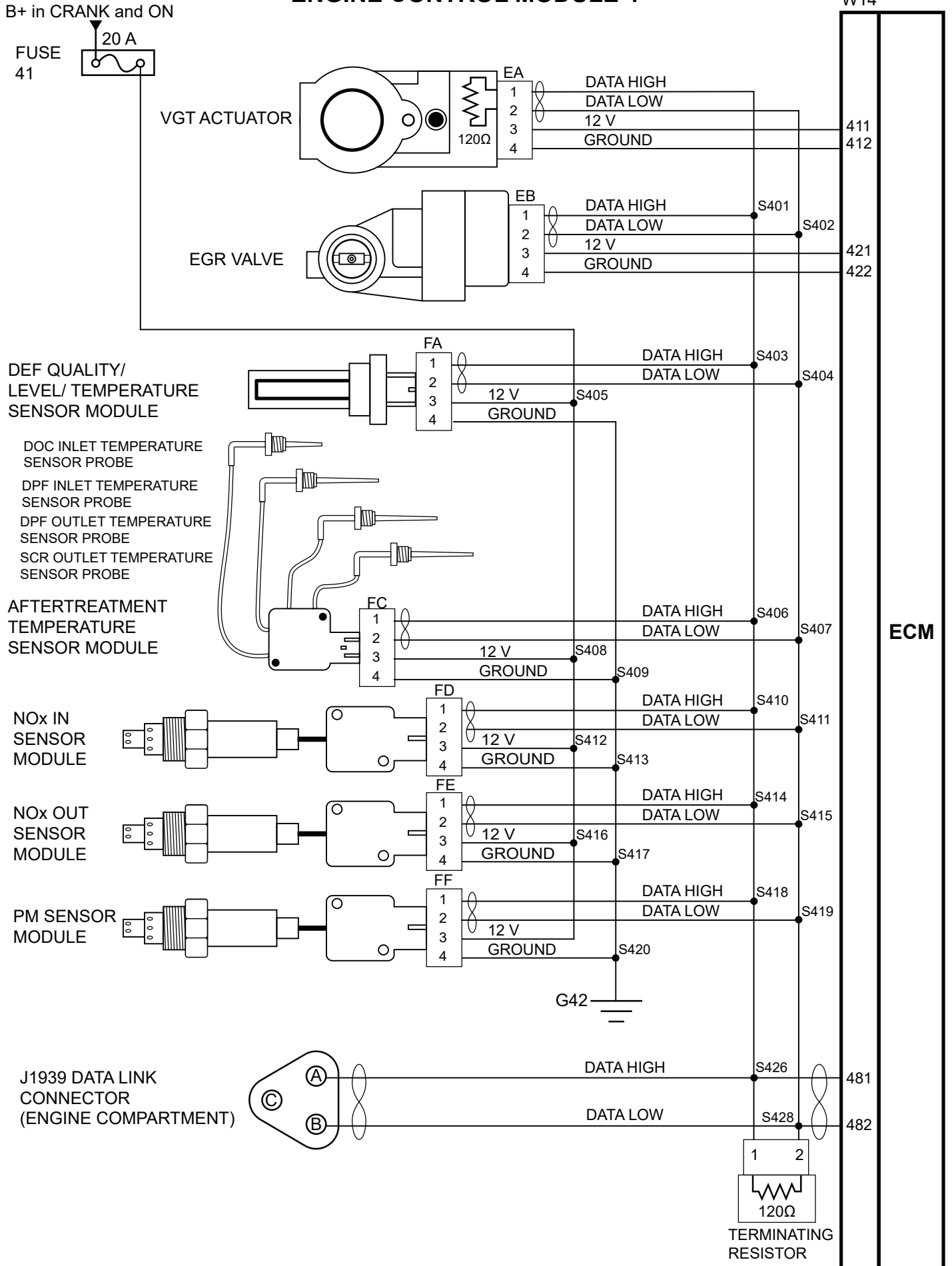
# ENGINE CONTROL MODULE 3

W13



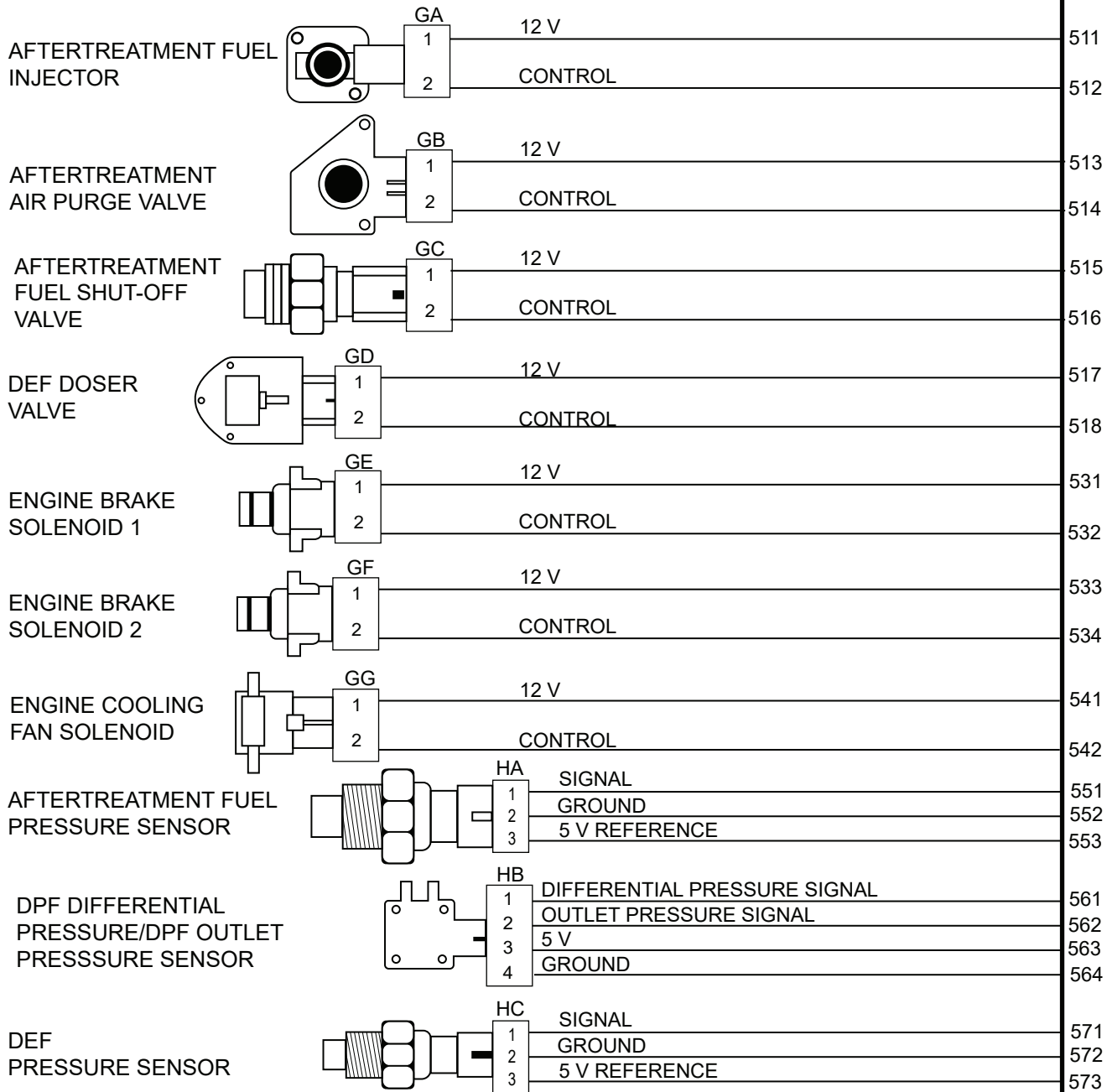
**ECM**

# ENGINE CONTROL MODULE 4

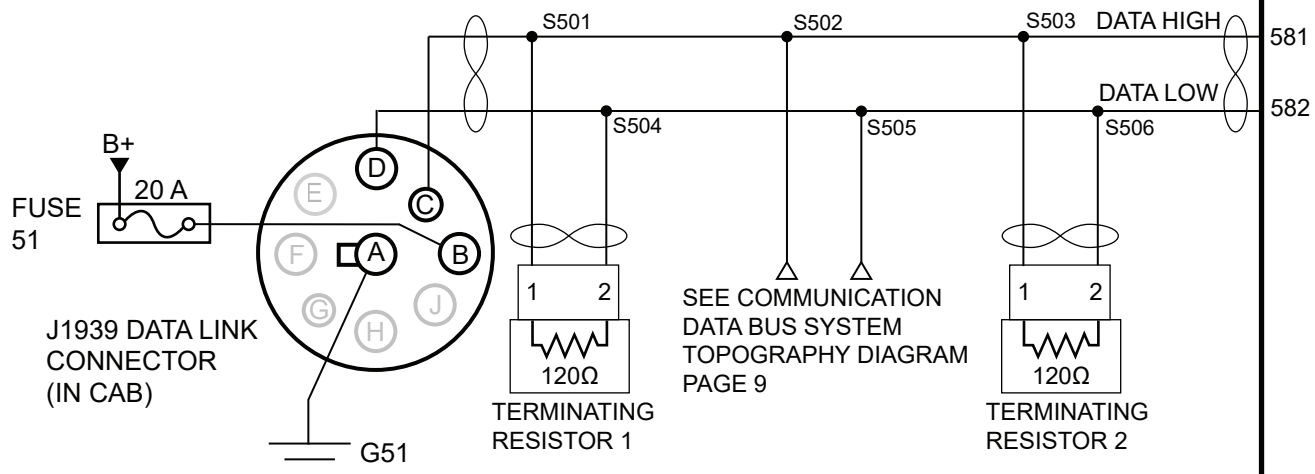


# ENGINE CONTROL MODULE 5

W15

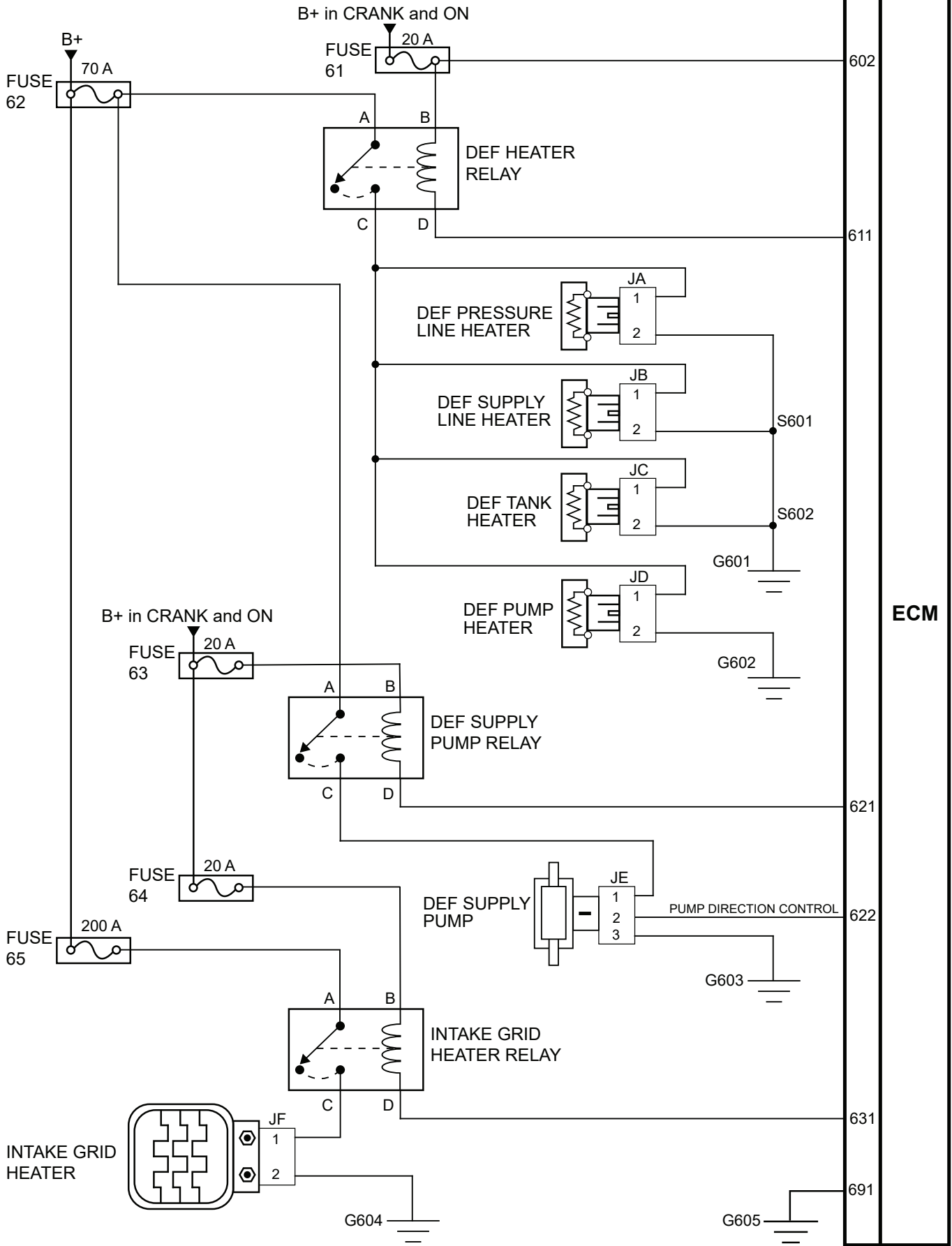


ECM

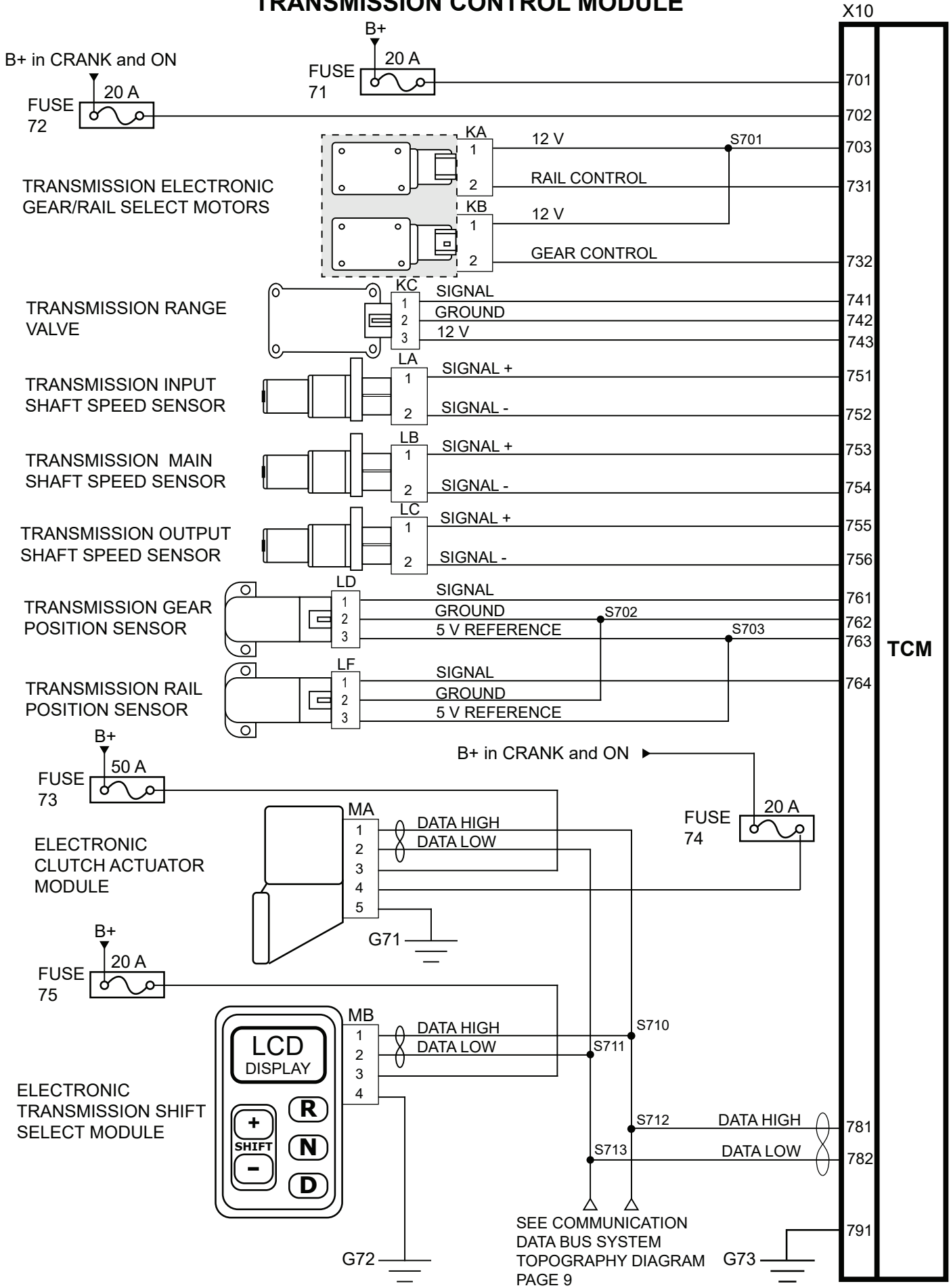


# ENGINE CONTROL MODULE 6

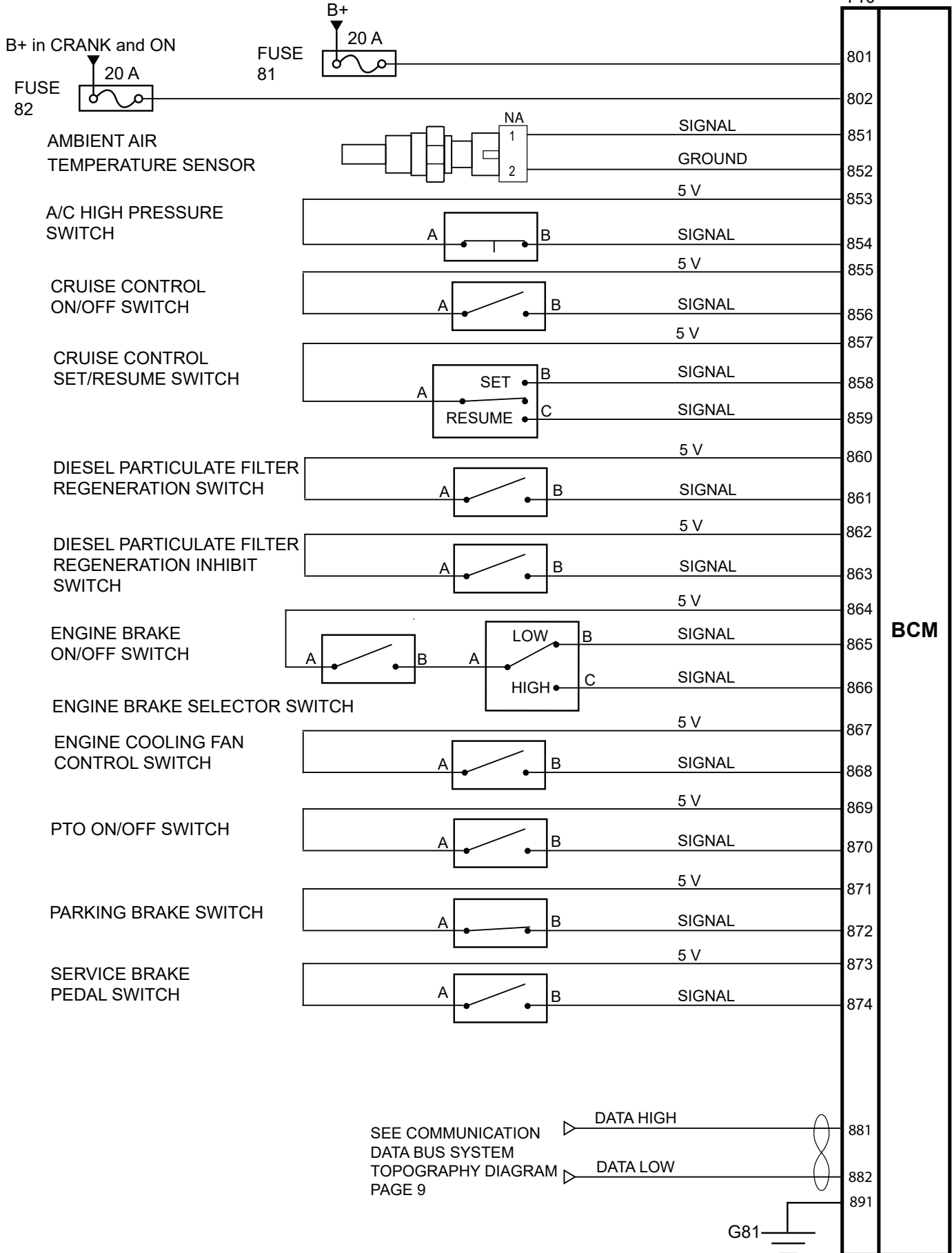
W16



# TRANSMISSION CONTROL MODULE



# BODY CONTROL MODULE



**BCM**

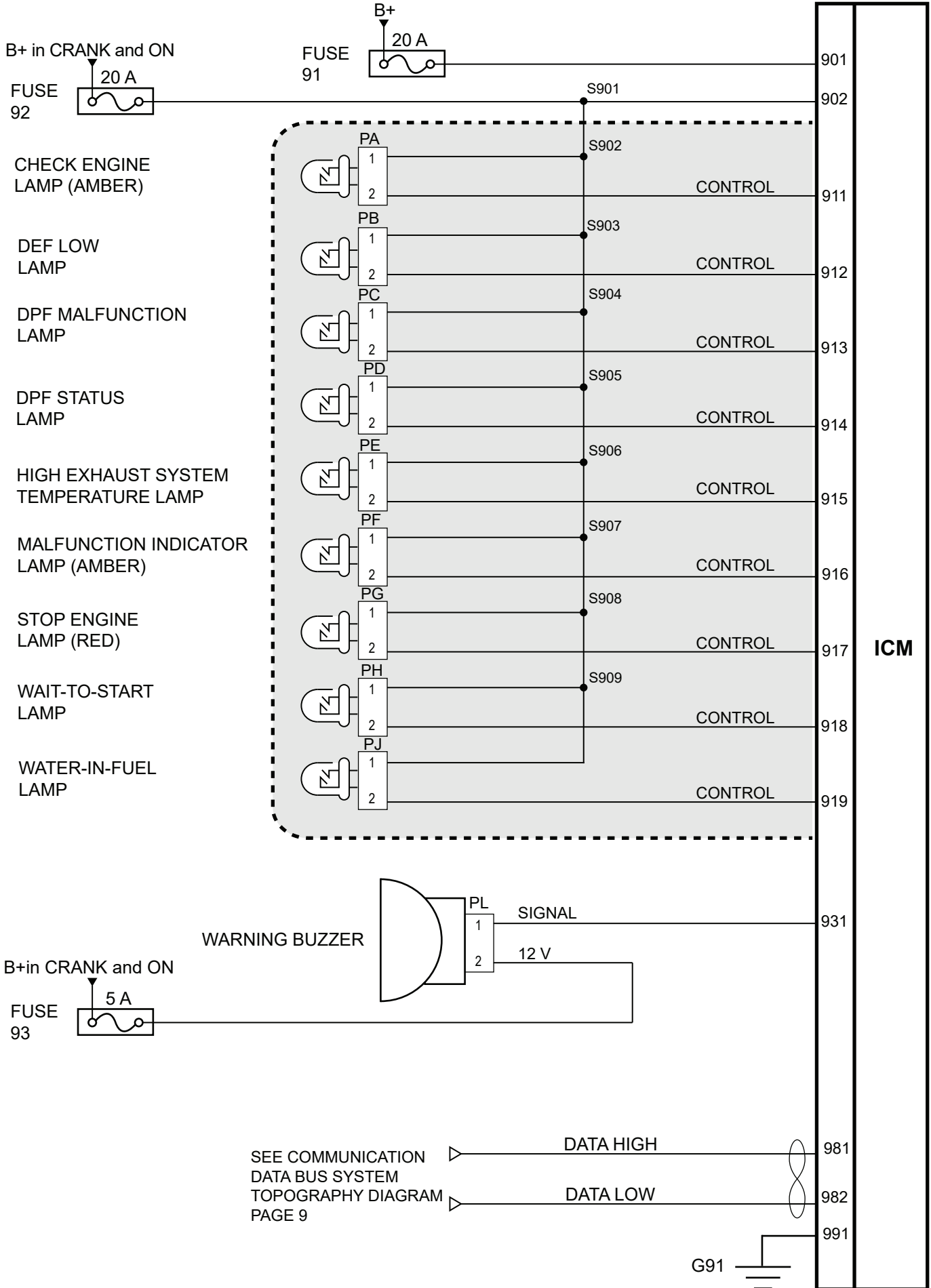
SEE COMMUNICATION  
 DATA BUS SYSTEM  
 TOPOGRAPHY DIAGRAM  
 PAGE 9

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# INSTRUMENT CLUSTER MODULE

Z10









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