ACRONYMS AND ABBREVIATIONS

The following is a list of acronyms used throughout this course:

ADR	Constant RPM Option (Arbeitsdrehzahlregler)
CAN	Controller Area Network
CARB	Californian Air Resources Board
DLC	Data Link Connector
DTC	Diagnostic Trouble Code
EEPROM	Electrical Erasable Programmable Read Only Memory
EGR	Exhaust Gas Recirculation
EPA	Environmental Protection Agency
H2O	Water
K-Line	Serial Communications Line for Diagnostics
LCD	Liquid Crystal Display
MAPPS	Magnetic Passive Position Sensor
MgO	Magnesium Oxide
MIL	Malfunction Indicator Lamp
MOSFET	Metal-Oxide-Semiconductor Field Effect Transistor
NTC	Negative Temperature Coefficient (Thermistor)
O2	Oxygen
OBDII	On Board Diagnostics Second Generation
PTC	Positive Temperature Coefficient
RAM	Random Access Memory
SCI	Serial Communications Interface (K-Line may also be used)
SmCo	Samarium Cobalt
SRS	Supplemental Restraint System
TERMINAL 15	Ignition Powered Circuit
TERMINAL 30	Battery Powered Circuit
TERMINAL 31	Ground Circuit
TERMINAL 58	Circuit That is Powered When Parking Lights are ON
TERMINAL D+	Circuit That is Powered When The Engine is Running
WIF	Water-in-Fuel Sensor
ZRO2	Zirconium Dioxide

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COMPONENT CROSS-REFERENCE CHART

Description	Dodge	Freightliner
Airbag Control Module	ACM	AB
Automatic Temperature Control	ATC	HZR
Antilock Brakes	CAB	ABS
Central Timer Module	CTM	ZV
Diagnostic Scan Tool	DRB III	DAS
Engine Control Module	ECM	CR3
Keyless Entry Module & Immobilizer	SKREEM	WSP
Shift Lever Module	SLA	EWM
Transmission Control Module	TCM	EGS
Vehicle Theft Alarm	VTA	EDW

2001-2006 VA Sprinter Body Electrical

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COMPONENT CROSS-REFERENCE CHART

Description	Dodge	Freightliner
Accelerator Pedal Position Sensor	APPS	B147
Airbag Control Module	ACM	AB
Automatic Temperature Control	ATC	HZR
Antilock Brakes	CAB	ABS
Boost Pressure Sensor	BPS	B141
Boost Air Temperature Sensor	BTS	G14
Crank Position Sensor	CKP	B73
Cam Position Sensor	CMP	B108
Diagnostic Scan Tool	DRB III	DAS
EGR Actuator	EGR	Y85
Engine Control Module	ECM	CR3
Engine Coolant Temperature Sensor	ECT	B16
Engine Oil Sensor	EOS	B110
Fuel Pressure Solenoid	FPS	Y92
Fuel Quantity Valve	FQV	Y93
Fuel Rail Pressure Sensor	FRPS	B113
Fuel Temperature Sensor	FTS	B30
Intake Air Pressure Sensor	IAP	B142
Keyless Entry Module & Immobilizer	SKREEM	WSP
Kickdown Switch	KS	B97
Mass Air Flow Sensor	MAF	B101
Oxygen Sensor	O2	R25
Shift Lever Module	SLA	EWM
Transmission Control Module	TCM	EGS
Water-in-Fuel Sensor	WIF	B129

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Transmission Control Module	TCM	EGS
Water-in-Fuel Sensor	WIF	B129

MODULE 2 POWER DISTRIBUTION

CIRCUIT CONTROL AND PROTECTION

The power distribution system for the Sprinter van incorporates various types of circuit control and protection features, including:

- Micro ISO relays
- Mini ISO relays
- Power Mini ISO relay
- Mini ISO relay with reverse polarity protection
- Blade-type ATO fuses
- Blade-type MAXI fuses
- Bolt-on MIDI fuses (high current protection)

Micro ISO Relays

The Micro ISO Relays are located in Fuse Block No.1 (under the steering column) and the Relay Block under the driver's seat. The normally-closed contacts of the relay are rated at 10 A. The normally-open contacts are rated at 20 A.

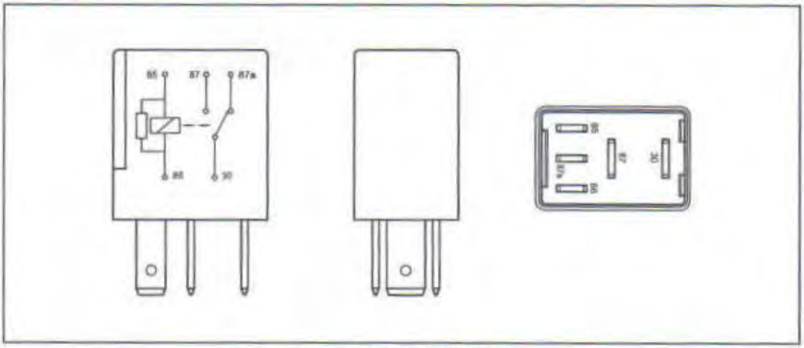
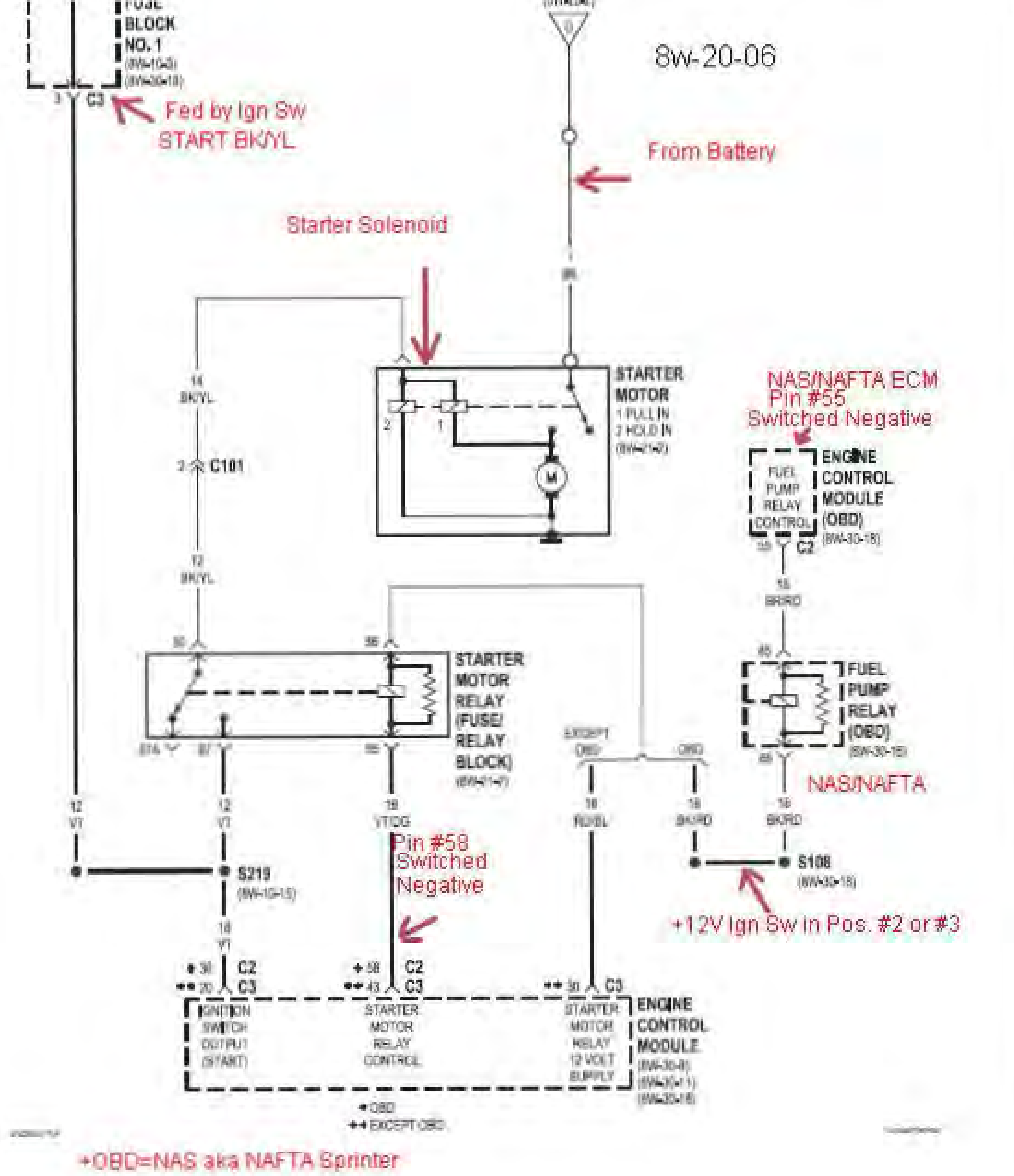


Figure 1 Micro ISO Relay



8w-20-06
FUSE BLOCK NO. 1
C3
Fed by Ign Sw START BK/YL
From Battery
Starter Solenoid
14 BK/YL
C101
12 BK/YL
STARTER MOTOR
1 PULL IN
2 HOLD IN
NAS/NAFTA ECM Pin #55 Switched Negative
ENGINE CONTROL MODULE (OBD)
FUEL PUMP RELAY CONTROL
C2
18 BK/RD
STARTER MOTOR RELAY (FUSE/ RELAY BLOCK)
EXCEPT OBD
OBD
FUEL PUMP RELAY (OBD)
NAS/NAFTA
12 VT
18 VT/DG
18 RD/BL
18 BK/RD
S219
S108
Pin #58 Switched Negative
+12V Ign Sw in Pos. #2 or #3
18 VT
C2
C3
IGNITION SWITCH OUTPUT (START)
STARTER MOTOR RELAY CONTROL
STARTER MOTOR RELAY 12 VOLT SUPPLY
ENGINE CONTROL MODULE
* OBD
** EXCEPT OBD
+OBD=NAS aka NAFTA Sprinter

Mini ISO Relay with Reverse Polarity Protection

The Mini ISO relay with reverse polarity protection is located in the Relay Block (under the driver's seat) and supplies power to the TCM and SLA control modules. A diode on the ground side of the relay coil prevents relay activation if the polarity of the vehicle is accidentally reversed. The normally-open contacts of the relay are rated at 40 A. The relay does not contain normally-closed contacts.

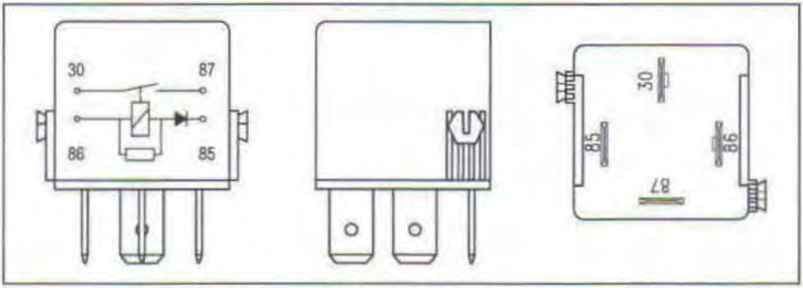
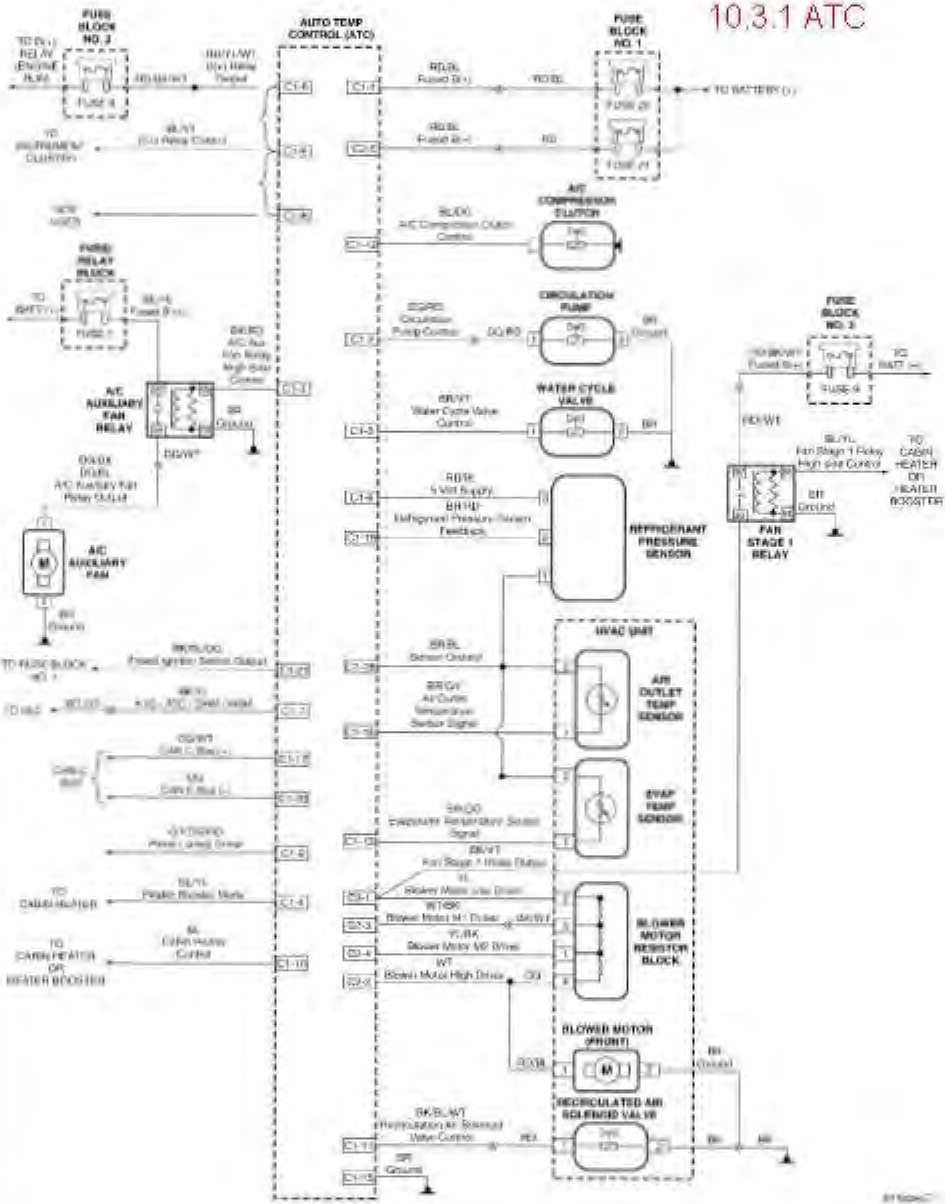
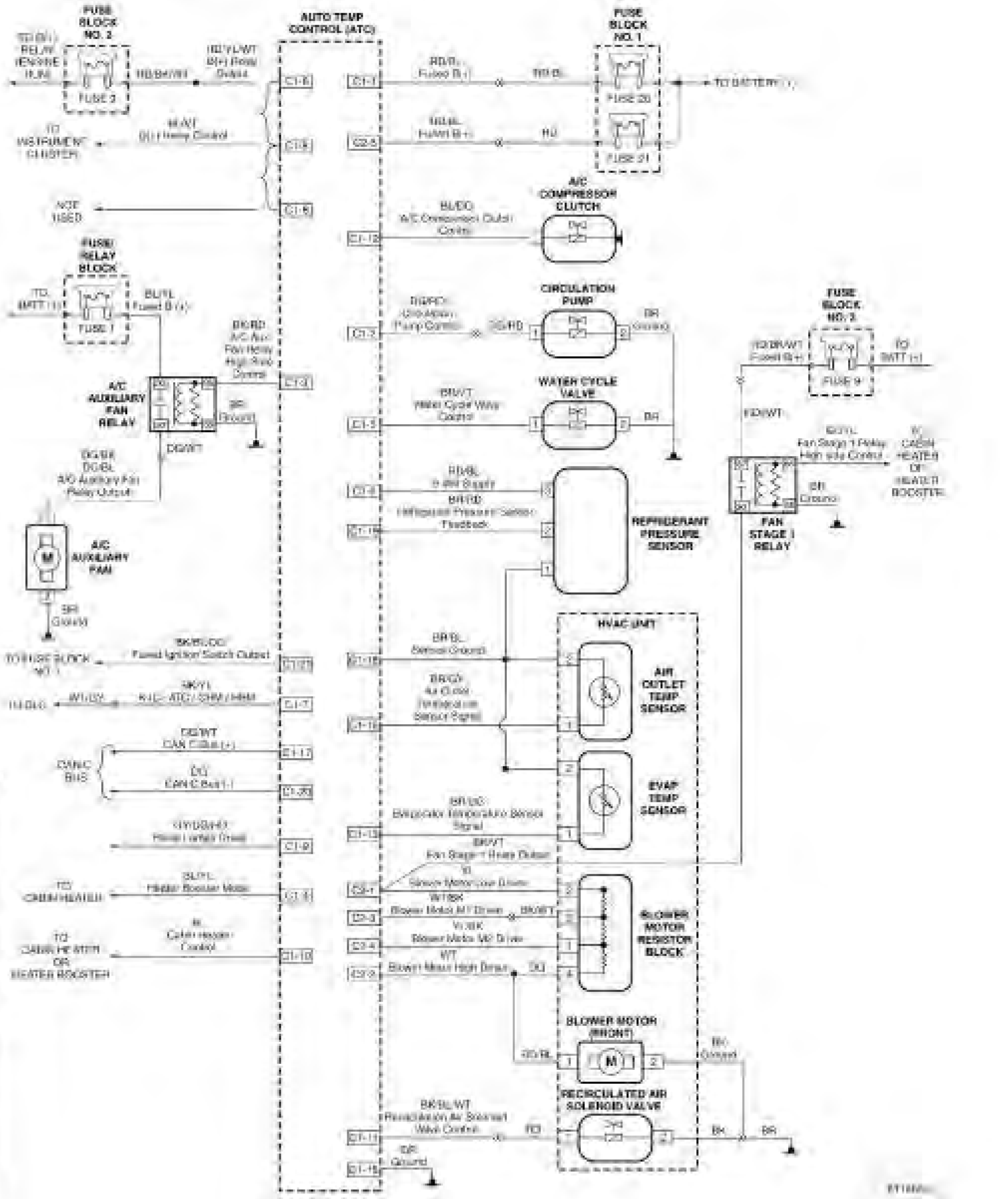


Figure 4 Mini ISO Relay with Reverse Polarity Protection

1 = 86, 2 = 85, 3 = 30, 4 = 87a, 5 = 87
Note: Starter 87 relay is a high amp special
(Right side, gray relay on my 2004)


FUSE BLOCK NO. 2
AUTO TEMP CONTROL (ATC)
FUSE BLOCK NO. 1
TO BATTERY (+)
A/C COMPRESSOR CLUTCH
CIRCULATION PUMP
WATER CYCLE VALVE
FUSE/RELAY BLOCK
A/C AUXILIARY FAN RELAY
FUSE BLOCK NO. 3
A/C AUXILIARY FAN
REFRIGERANT PRESSURE SENSOR
FAN STAGE I RELAY
HVAC UNIT
AIR OUTLET TEMP SENSOR
EVAP TEMP SENSOR
BLOWER MOTOR RESISTOR BLOCK
BLOWER MOTOR (FRONT)
RECIRCULATED AIR SOLENOID VALVE

10.3.1 AUTOMATIC TEMPERATURE CONTROL (ATC)



SCHEMATIC DIAGRAM

POWER DISTRIBUTION CENTER (PDC)

The PDC is located on the battery positive cable and houses six bolt-on midi fuse locations (Figure 6). It supplies power to all of the vehicle circuits, except the starter motor and auxiliary battery (if equipped). The fuses are numbered 1 through 6 starting from the left.

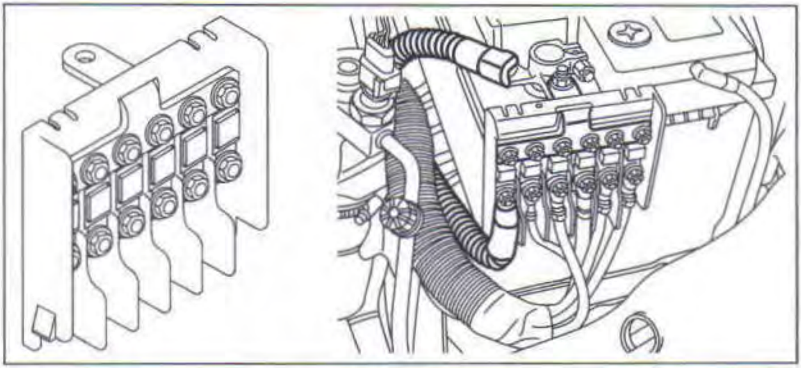


Figure 6 Power Distribution Center (PDC)

Table 1 Fuse Arrangement, Power Distribution Center (PDC)

Fuse Position	Circuit Description	Current Rating	Fuse Color
1	Alternator	200 A	Violet
2	Optional equipment relay	70 A	Brown
3	K26 relay, fuse block under driver's seat	125 A	Pink
4	Independent rear A/C unit (MY2004)	80 A	White
5	Glow plug module	125 A	Pink
6	Fuse block under steering column	100 A	Blue

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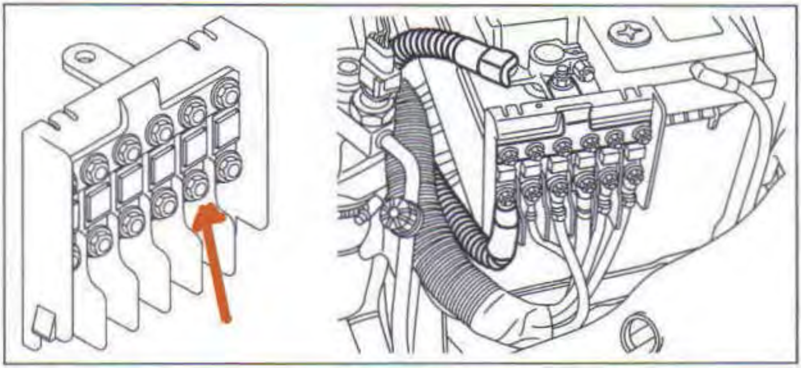

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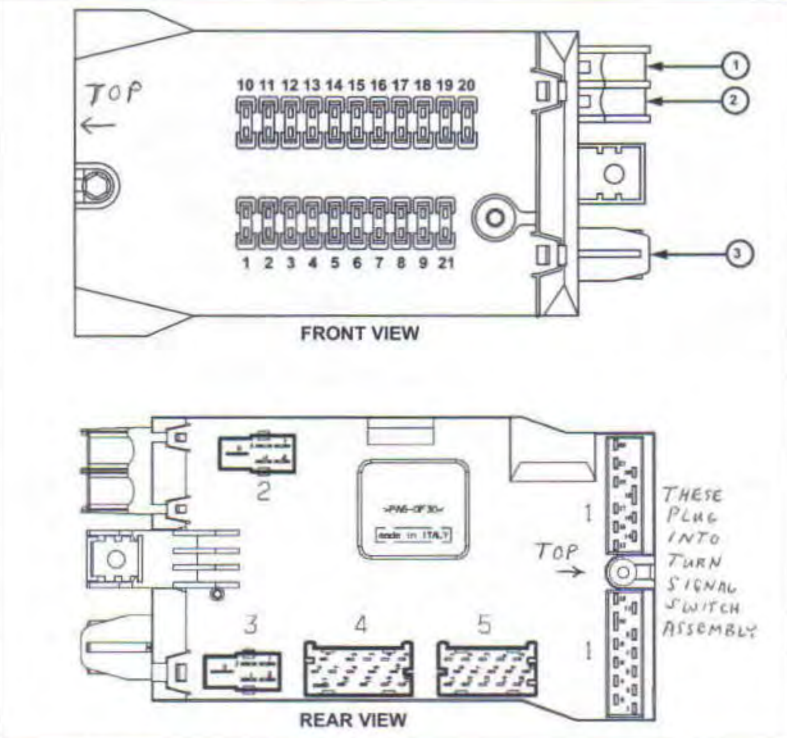
6	Fuse block under steering column	100 A	Blue

FUSE BLOCK #1

This molded plastic fuse block is located under the steering column and houses twenty-one blade-type mini fuses arranged in two rows. It also contains three micro ISO relays and an electronic timer circuit for the flashers, turn-signals and wipers. Five electrical connectors (1-5) are located on the back of the fuse block (Figure 7).



1	Turn Signal Relay (B)
2	Engine Control Relay (M)
3	Wiper ON/OFF Relay (W)

Figure 7 Fuse Block No. 1

Table 2 Fuse Arrangement, Fuse Block No.1

No.	Rat.	Consumer	No.	Rat.	Consumer
1	10A	Parking lamp, taillamp right	12	10A	Low beam headlamp, right
2	10A	High beam headlamp, right	13	10A	Low beam headlamp, left
3	10A	High beam, headlamp, left, high beam indicator lamp	14	15A	Fog lamp
4	10A	Backup lamp	15	10A	Radio (terminal 15)
5	10A	Brake lamp	16	25A	Engine control unit
6	20A	Windshield wiper motor	17	15A	Engine control unit
7	15A	Horn, heated rear window, air recirculation switch	18	15A	Ignition (terminal 15)
8	20A	Interior lighting, cigarette lighter, radio (terminal 30)	19	15A	Fuel pump relay
9	15A	Clock, hazard warning lamps	20	15A	Heater controls (terminal 30)
10	10A	Instrument lights, license plate, daytime running lts.	21	30A	Heater blower (terminal 30)
11	10A	Side lamp, left; tail lamp left			

TURN SIGNAL (B) RELAY

The turn signal (B) relay powers the turn signal and flasher circuits. The activation of the turn signal relay, and the flashing of the lights is controlled electronically by the Timer Module in Fuse Block No.1. The Timer Module (not to be confused with CTM) is also known as the Wiper/Turn Signal/Engine Start Control Module (Figure 8).

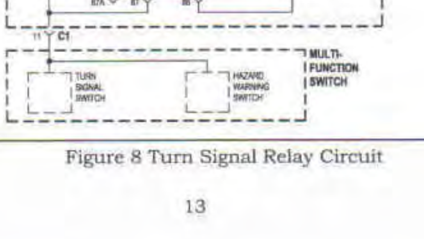


Figure 8 Turn Signal Relay Circuit

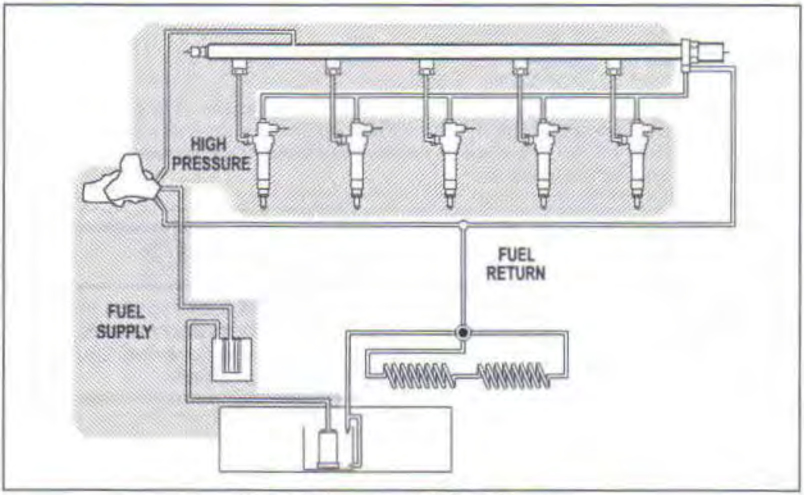


Figure 9 Common Rail Fuel Circuits

FUEL FLOW

Fuel Supply

The electric fuel pump delivers fuel from the fuel tank, through the fuel filter to the inlet side of the high pressure pump flange.

High Pressure Circuit

Fuel flows from the outlet side of the high pressure pump to the fuel rail to the injectors

Fuel Return

Return fuel from the injectors (control fuel), the fuel pressure solenoid and high pressure pump flange flows into the fuel return system and is returned to the fuel filter or the fuel tank (depending on the temperature of the returned fuel).

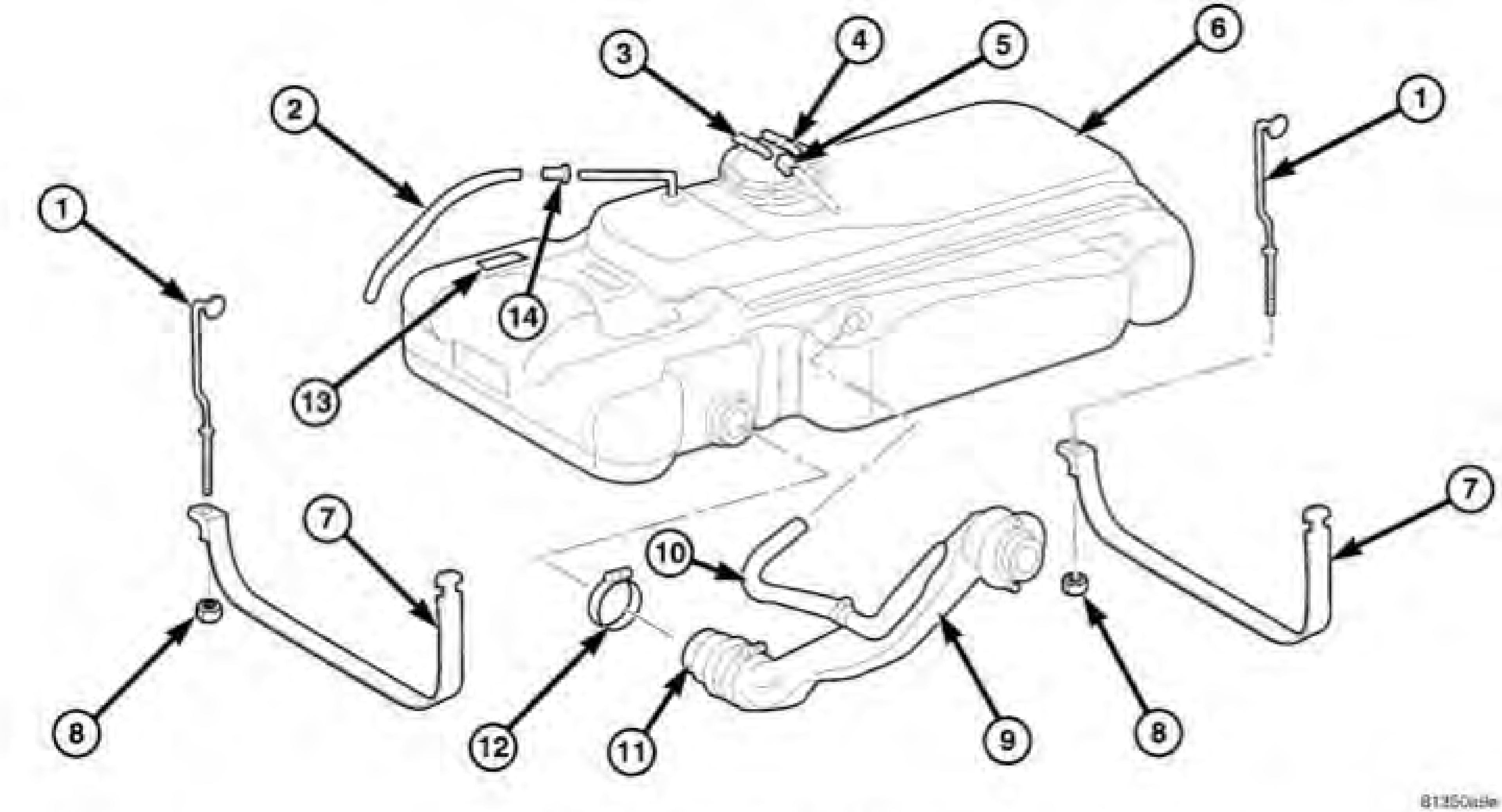


Fig. 20 FUEL TANK ASSEMBLY

1 - Strap Bolts (2)
2 - Hose (not with all engines)
3 - Fuel Outlet Line
4 - Fuel Return Line
5 - Plug
6 - Fuel Tank
7 - Tank Straps (2)
8 - Nuts (2)
9 - Filler Tube
10 - Vent Hose
11 - Hose
12 - Clamps
13 - Cushioning Material
14 - Two-Way Valve

ACTIVITY 2.1 : TURN SIGNAL (B) RELAY ACTIVATION

Answer questions 1 through 4 using the turn signal diagram in Figure 8.

1. Which pin provides the sense signal to the Turn Signal Control module when the turn signal switch, or the hazard switch has been actuated?
   Pin 7

2. What kind of signal does the module sense?
   It senses a ground through the turn signal bulbs

When the Timer Module senses that the turn signal switch or the hazard switch has been actuated, it responds by grounding terminal 85 of the Turn Signal Relay. Terminal 30 of the turn signal relay has already been supplied with voltage through pin 11 of the module. When the relay is grounded, the contact closes powering the turn signal lights (Figure 9).

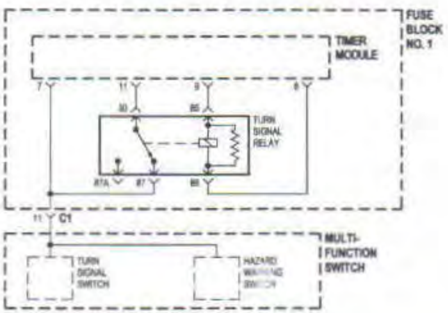


Figure 9 Turn Signal Relay Circuit, Relay Energized

3. What kind of signal is the module sensing now?
   Battery voltage

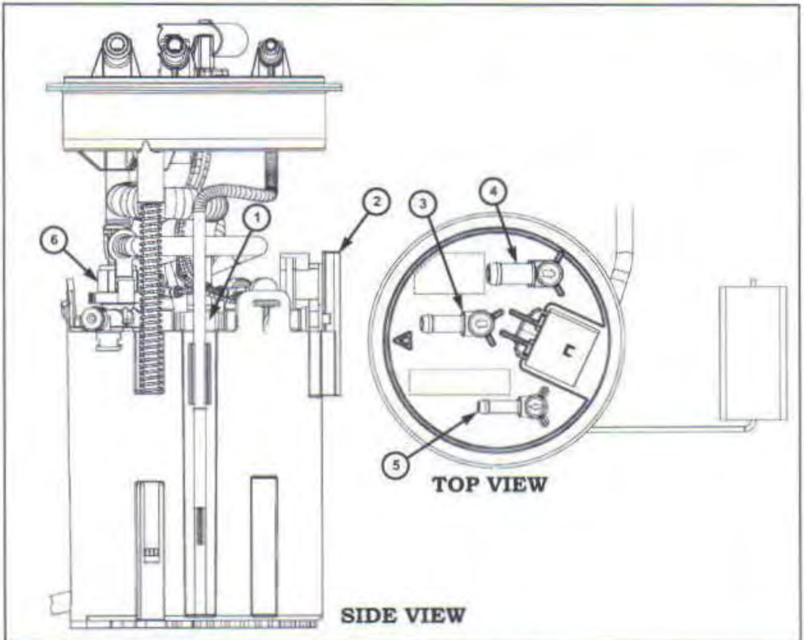
With the signal that the module is now sensing, it removes the ground at terminal 85. The contact opens and power is interrupted.

4. How does the flashing of the lights take place?
   The module senses a ground and the sequence is repeated until the turn signal or hazard switch is released.

FUEL PUMP MODULE

The fuel level sensor module is installed in the top of the fuel tank. It contains the following components:

- Electric fuel pump
- MAPPS fuel gauge sending unit
- Fuel supply/return pick-up tubes
- Suction jet pumps/throttle bypass
- Fuel pump module reservoir/baffle



1	Electric Fuel Pump	4	Fuel Return
2	MAPPS Fuel Gauge Sending Unit	5	Heater Booster Pick-Up (Option)
3	Fuel Outlet (Inlet to Fuel System)	6	Upper Suction Jet Pump

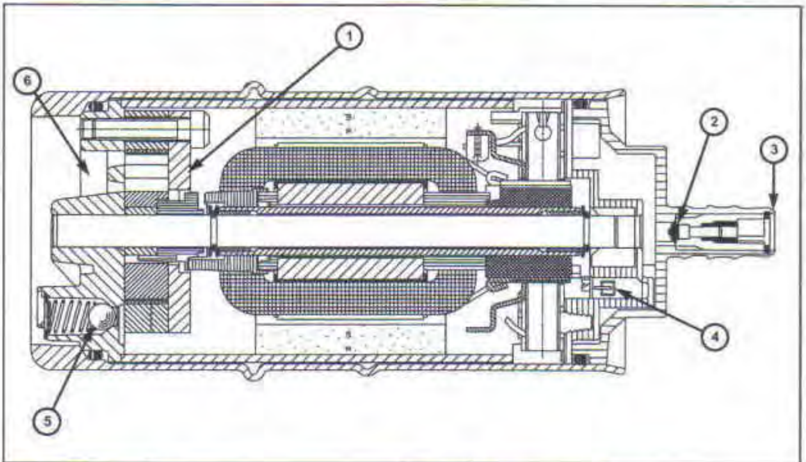
Figure 16 Fuel Tank Module

Electric Fuel Pump

The electric fuel pump delivers fuel from the fuel tank, through the filter to the high pressure pump. Excess fuel flows back to the tank through the fuel return circuit. When activated, the fuel pump runs continuously independent of engine speed.

A safety circuit prevents the delivery of fuel when the ignition is on and the engine not running. When the ignition is switched on, the electric lift pump runs for 20-30 seconds. If the engine starts, the pump will remain activated.

The electric fuel pump operates at a pressure between 4-4.5 bar (58-65 psi).



1	Roller Cell Pump	4	Suppression Capacitor
2	Check Valve	5	Presssure Relief Valve
3	Fuel Outlet Port	6	Fuel Inlet Port

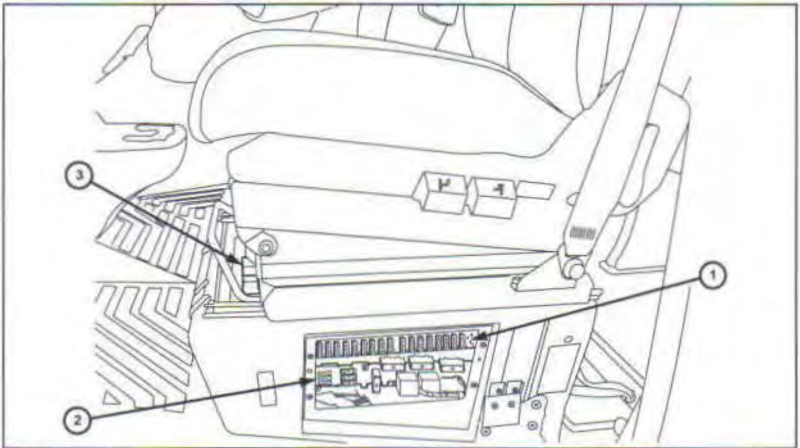
Figure 17 Fuel Pump Cutaway

The fuel pump is comprised of a positive-displacement pump and an electric motor within an aluminum housing. An end cover is crimp-sealed on the upper part of the pump housing. The fuel pump end cover contains the electrical connections and the fuel outlet port. A check valve in the fuel outlet port prevents the fuel in the supply line from draining back to the pump, maintaining system pressure. A 1uF/50V capacitor is integrated in the end cover for interference suppression. The end cover also includes the carbon brushes for the drive motor commutator.

FUSE BLOCKS/RELAY BLOCKS UNDER DRIVER SEAT

The following components are located under the driver's seat:

- Fuse Block #2
- Fuse/Relay Block
- Relay Block



1	Fuse Block No. 2
2	Fuse/Relay Block
3	Relay Block

Figure 14 Fuse Blocks/Relay Blocks Under Driver Seat

FUSE BLOCK NO. 2

The Fuse Block No.2 is a single or double-row molded plastic fuse block containing 18 fuse locations per row. The total number and arrangement of the fuses varies from one vehicle to another, depending on the optional equipment.

FUSE/RELAY BLOCK

The Fuse/Relay Block is mounted below Fuse Block No.2. It holds blade-type mini and maxi fuses, as well as mini ISO relays. The top side of the block has five slots where additional maxi fuse holders can be installed. The arrangement of these fuses vary depending on optional equipment.

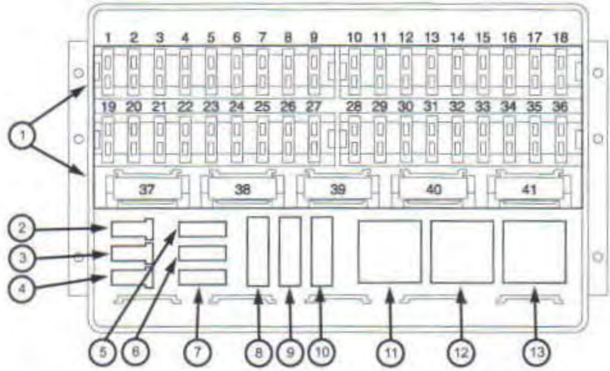


Figure 15 Fuse Block No. 2 and Fuse/Relay Block

Table 3 Fuse Arrangement, Fuse/Relay Block

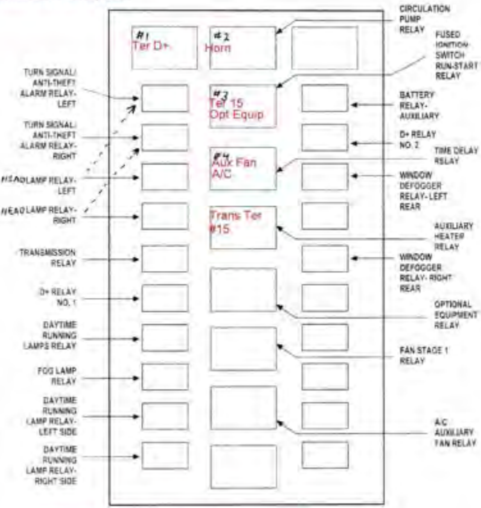
No.	Rat.	Component	No.	Rat.	Component
1		Fuse locations 1 - 41 depend on optional equipment installed on vehicle	8		Maxi Fuse (not in use)
2		Diode (idle-up option)	9	40 A	Maxi Fuse, Anti-lock brakes (CAB)
3		Diode (idle-up option)	10		Maxi Fuse (not in use)
4		Diode (idle-up option)	11	20/ 40 A	Mini ISO Relay, Electric Fuel Pump
5	10 A	Mini Fuse, Immobilizer (SKREEM)	12	70 A	Power Mini ISO Relay, Starter Motor
6	7.5A	Mini Fuse, Anti-lock brakes (CAB)	13		Power Mini ISO Relay (not in use)
7	25 A	Mini Fuse, Anti-lock brakes (CAB)			

NO ANTI-THEFT? THEN HEADLAMP RELAYS MAY SHIFT TO TOP?

FROM 2003 MANUAL?

Red Notes are from my 2004

RELAY BLOCK

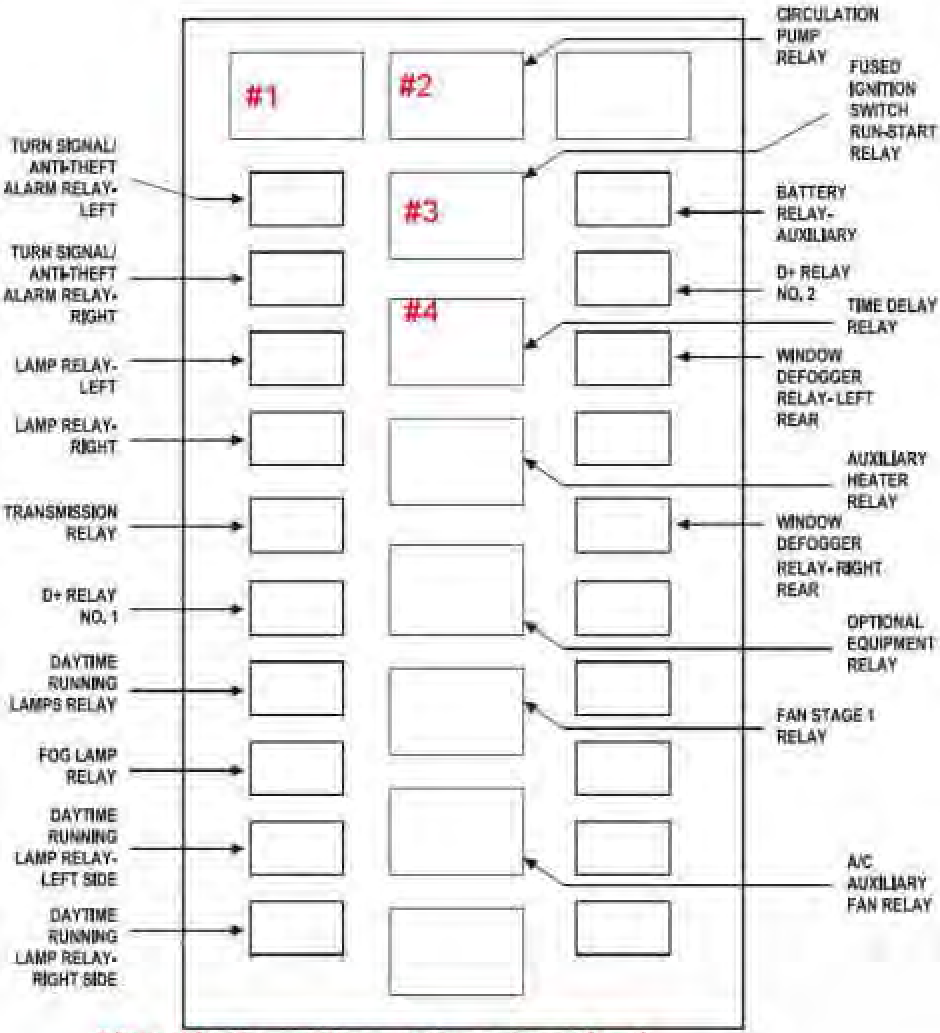


Note!!! Verify positions with wire colors before work

NOTE: THE RELAY LOCATIONS SHOWN HERE MAY VARY FROM VEHICLE TO VEHICLE.

THIS FUSE MAP IS MORE TYPICAL OF A FULL OPTIONED VAN.

RELAY BLOCK



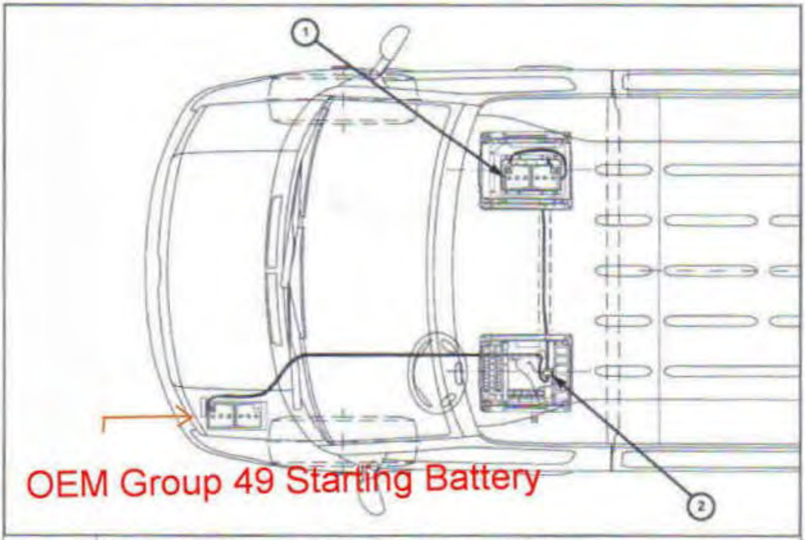
Note: Verify positions using wire colors!

NOTE: THE RELAY LOCATIONS SHOWN HERE MAY VARY FROM VEHICLE TO VEHICLE

AUXILIARY BATTERY

DESCRIPTION

An optional auxiliary 12V/100Ah deep cycle battery is installed for running additional electrical equipment. There is an isolation relay to separate it from the starter battery circuit. This battery may only be used to power defined auxiliary consumers such as auxiliary heating or air conditioning, a loading tailgate, etc.



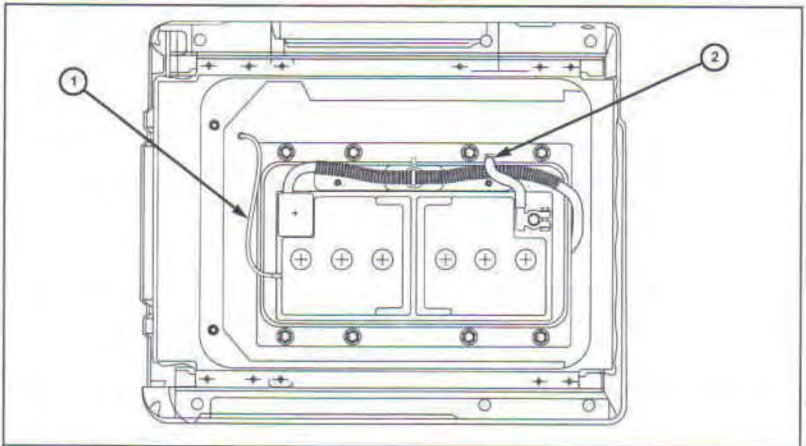
1	Auxiliary Battery - Battery Under Front Seat (BUFS)
2	Isolation Relay

Figure 18 Auxiliary Battery Layout

LOCATION OF COMPONENTS

The additional battery is located under the passenger seat. It mounts on a tray which is welded on to the floor of the vehicle. A breather venting tube is fed into the open air through an orifice in the floor.

NOTE: it is essential that the breather venting is fed into the open air through a central vent hose. Failure to provide for adequate ventilation of any additional battery may lead to contamination of the passenger compartment and may cause serious injury or death, and/or explosion.



1	Central Vent Hose
2	Ground Stud

Figure 19 Top View, Auxiliary Battery Location

The battery cable is grounded through a ground stud on the battery tray. The positive cable is routed under the battery tray, through a channel under the floor covering, to the isolation relay on the driver's seat base.

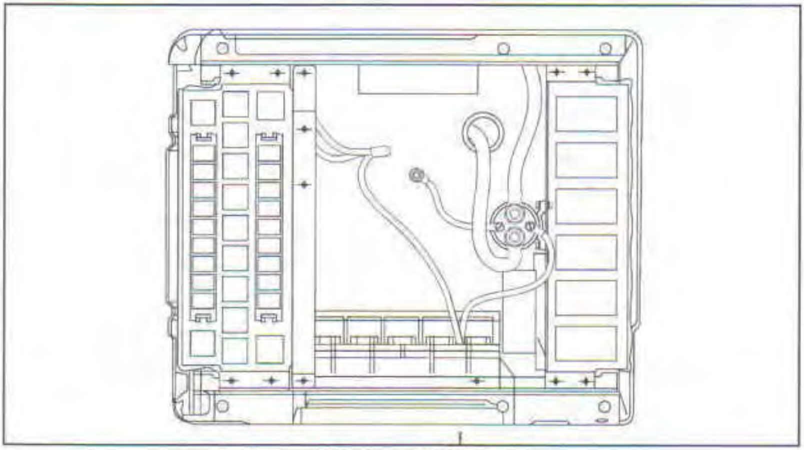


Figure 20 Isolation Relay Location

The isolation relay prevents electrical equipment connected to the auxiliary battery from discharging the starter battery. When the engine is running, the relay allows the battery to be charged. The isolation relay has a reversed-biased clamping diode connected in parallel to the coil circuit (Figure 21). This diode supresses the voltage peaks generated during the collapse of the coil's magnetic field. Proper polarity must be observed to avoid damage to the diode.

A new style isolation relay features a built-in resistor for voltage spike suppression and a diode for reverse polarity protection (Figure 21).

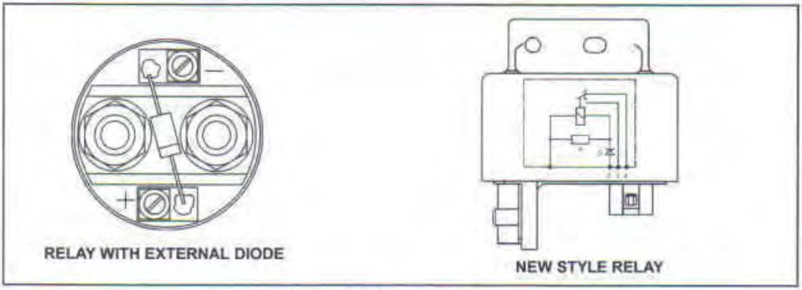


Figure 21 Isolation Relay

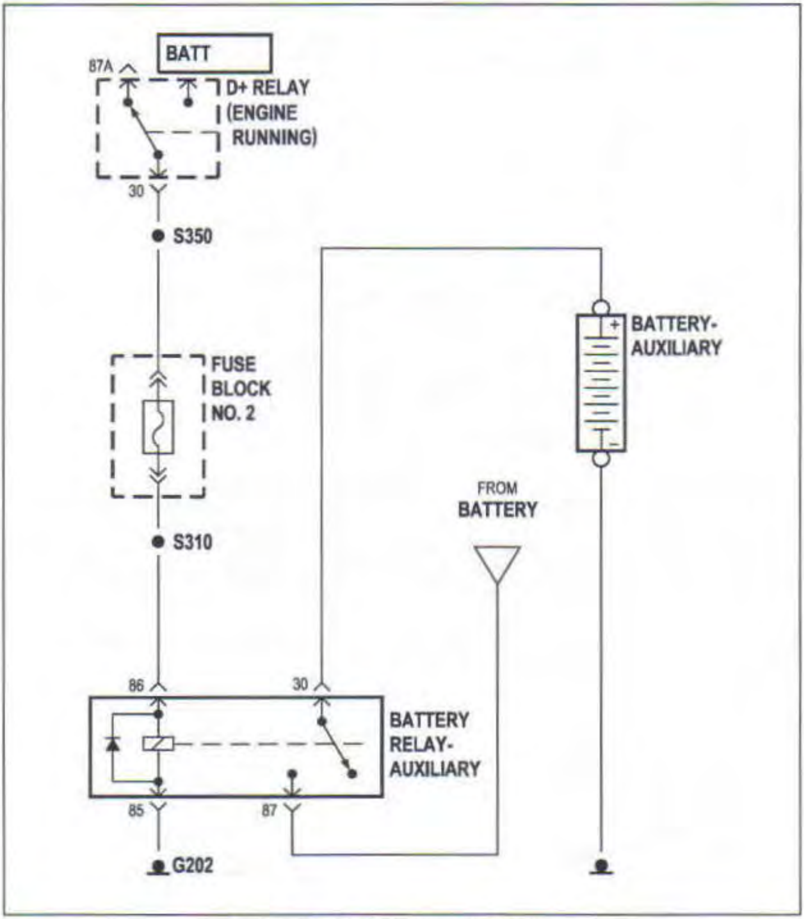
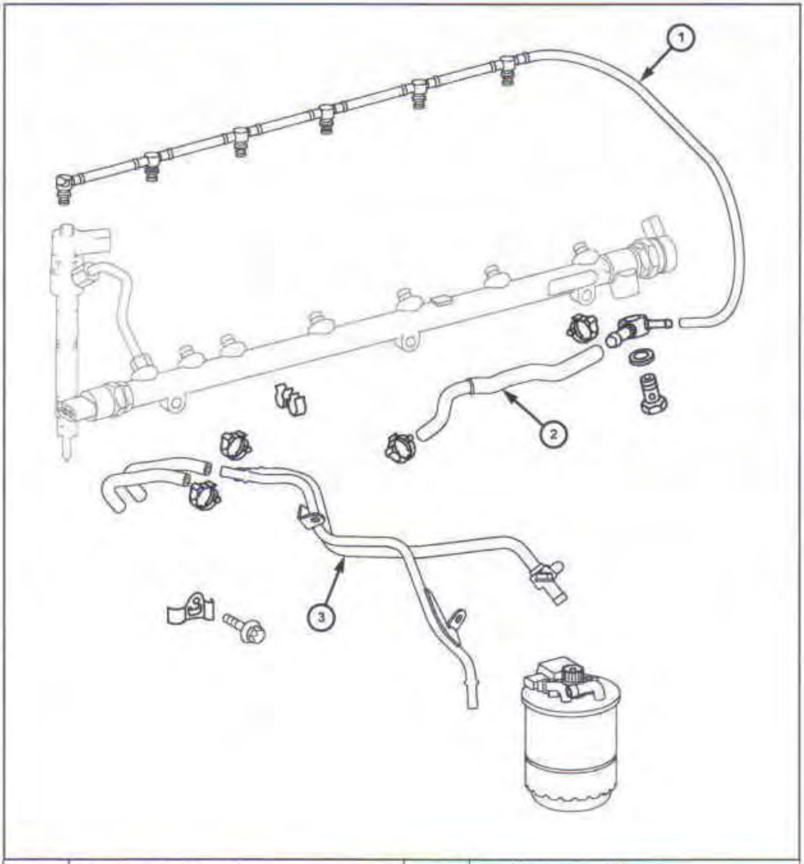
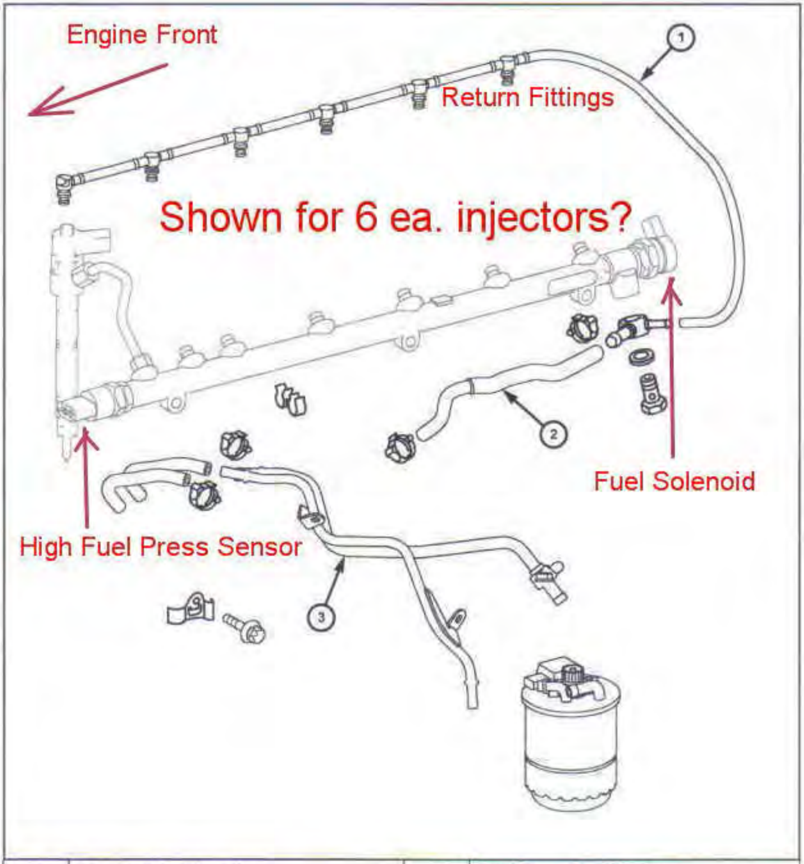


Figure 22 Auxiliary Battery Diagram



1	Braided Rubber Hose	3	Stainless Steel Tubing
2	HNBR Rubber Hose		

Figure 32 Low Pressure Fuel Lines



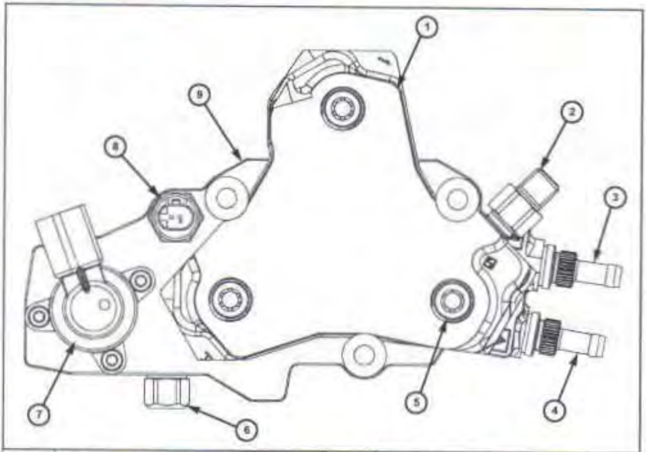
1	Braided Rubber Hose	3	Stainless Steel Tubing
2	HNBR Rubber Hose		

Figure 32 Low Pressure Fuel Lines

HIGH-PRESSURE FUEL CIRCUIT COMPONENTS

HIGH PRESSURE PUMP

The high pressure pump is mounted to the front of the cylinder head. The pump is driven at about 1.3 times the speed of the camshaft and requires no timing. Fuel that enters the high-pressure pump is pressurized between 200-1600 bar (2900 - 23,205 psi). The pressurized fuel is then supplied to the fuel rail.



1	High Pressure Pump Housing	6	Fuel Pressure Relief Valve
2	High Pressure Port	7	Fuel Quantity Valve
3	Fuel Inlet Port (From Filter)	8	Fuel Temperature Sensor
4	Fuel Return Port	9	Pump Flange
5	Pump Element Check Ball Plug (3)		

Figure 35 High Pressure Pump

The high pressure pump is a radial piston pump with three pistons arranged at an angle of 120°. The flange located behind the pump contains fuel passages and control elements, which regulate the flow of fuel to the pump.

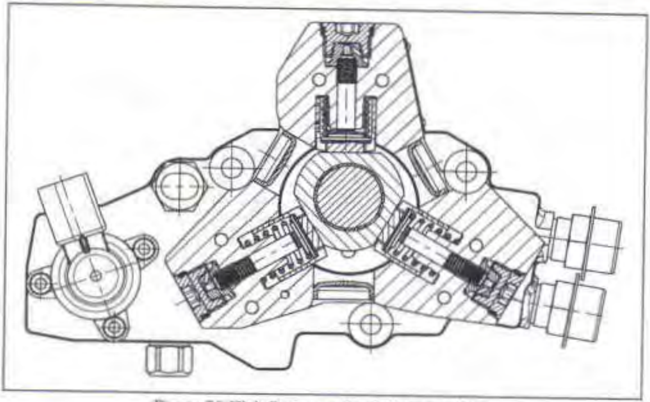


Figure 36 High Pressure Pump Cutaway View

Specific moving parts inside the high pressure pump feature a carbon based (C2) coating to assist with the lubrication process during operation. The high pressure pump is non-serviceable and must be replaced as an assembly.

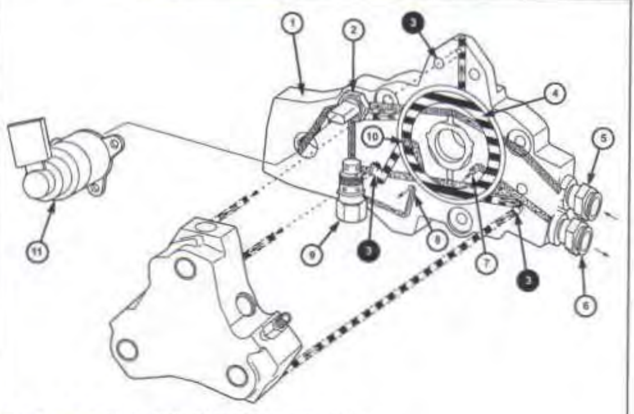
Operation

Low Pressure Side

Refer to Figure 37. The fuel supplied by the electric fuel pump flows through the fuel feed (5) at the high pressure pump flange (1) and is passed from there to the fuel quantity valve (11) and to the fuel pressure relief valve (9).

The fuel quantity control valve (11) controls the volume of fuel which flows along the annular passage (4) through the feed ports (3) to the three pump elements of the high pressure pump. To lubricate the plunger-and-barrel assemblies when the quantity control valve is closed (overrun mode), fuel is led directly into the annular port (4) via the zero delivery restrictor (10).
The fuel pressure relief valve (9) limits the fuel pressure which exists at the fuel quantity control valve (11) to approximately 5 bar (72.5 psi) maximum. If this pressure is exceeded, the pressure relief valve opens and again passes the excess fuel into the return flow (6) to the fuel tank.

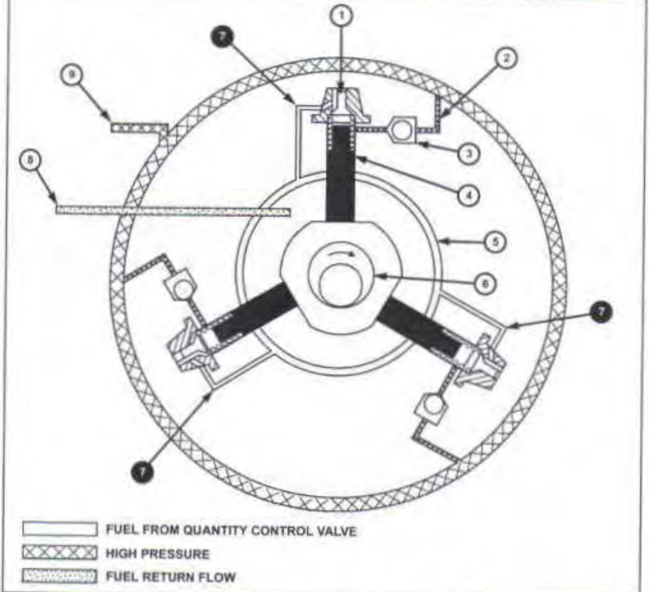
In addition, the fuel pressure relief valve (9) directs a part of the fuel as a lubrication quantity to the eccentric shaft (lubrication port 8).
Any air entrained by the fuel is passed through the fuel pressure relief valve to the return flow of the high pressure pump (bleed port 7).



1	High Pressure Pump Flange	7	Bleed Port
2	Fuel Temperature Sensor	8	Eccentric Shaft Lubrication Port
3	Fuel Feed to Pump Elements	9	Fuel Pressure Relief Valve
4	Fuel Annular Port	10	Zero Delivery Restrictor
5	Fuel Inlet Port (From Fuel Filter)	11	Fuel Quantity Valve
6	Fuel Return Port (To Fuel Tank)		

Figure 37 Low Pressure Side, Pump Flange

Refer to Figure 38 to follow the fuel flow into the high pressure pump. Fuel from the quantity control valve flows along the annular passage (5) through the feed ports (7) to the three pump elements of the high pressure pump.

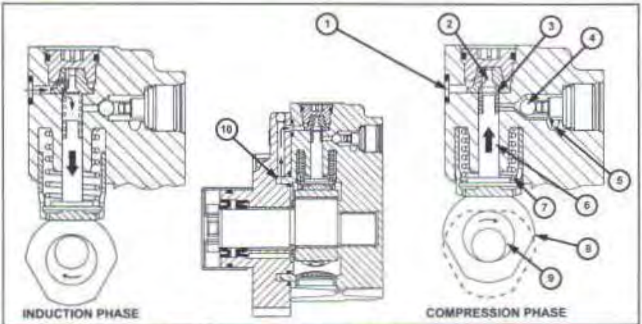


1	Valve	6	Eccentric Shaft
2	High Pressure Passage	7	Feed to High Pressure Elements
3	Check Ball	8	Return Port
4	Piston	9	High Pressure Line to Fuel Rail
5	Annular Passage		

Figure 38 Low Pressure Side, Pump Elements

High pressure side

Refer to Figure 39. The cam (8) of the eccentric shaft (9) moves the pistons (6) up and down against the piston spring (7).



1	Fuel Feed to Pump Elements	6	Piston
2	Valve	7	Piston Spring
3	Valve Spring	8	Cam
4	Check Ball	9	Eccentric Shaft
5	High Pressure Passage	10	Annular Passage

Figure 39 Fuel Pump, High Pressure Side

Filling the piston (Induction Phase)

The piston (6) is moved down as a result of the piston spring (7). The fuel supplied by the electric fuel delivery pump flows along the annular passage (10), the fuel feed (1) and, by overcoming the force of the valve spring (3) through the valve (2) into the cylinder. The check ball (4) prevents the fuel being able to flow back from the high pressure passage (5).

Producing high pressure (Compression Phase)

The piston (6) is moved up by the ascending eccentric shaft (9) and the fuel is pressurized. The valve (2) shuts off the delivery volume to the fuel feed (1). Once the fuel pressure in the cylinder rises beyond the pressure which exists in the high pressure circuit (5), the check ball (4) opens and the fuel is pumped into the high pressure circuit (5).

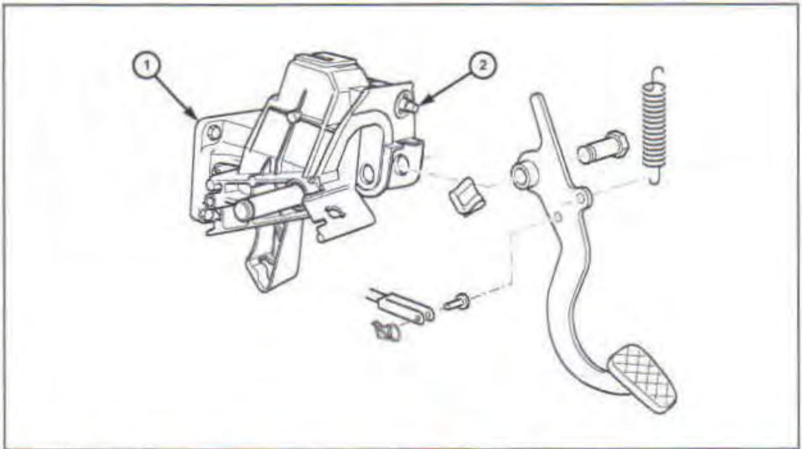
BRAKE LAMPS

The brake lamps operate only when the brake pedal is depressed. The purpose of the brake lamps is to alert following drivers of vehicle slowing or stopping.

Brake Lamp Switch

The brake lamp switch is located in the pedal mounting bracket above the brake pedal (Figure 39). When the brake pedal is released, the switch plunger is depressed. When the brakes are applied, an internal spring pushes the plunger out and the internal electrical contacts switch positions (open to closed and vice-versa).

The brake lamp switch also supplies a redundant signal to the ABS controller (See Figures 41 and 42). Depending on vehicle options, the switch may supply a signal to the shifter assembly (SLA).



1	Pedal Mounting Bracket	2	Brake Lamp Switch

Figure 39 Brake Lamp Switch Location

FUEL RAIL

The rail is located above the intake manifold. The fuel pressure solenoid, fuel pressure sensor, high pressure lines and return lines are attached to the rail. The rail acts as a high pressure fuel storage device (accumulator) for the injectors.

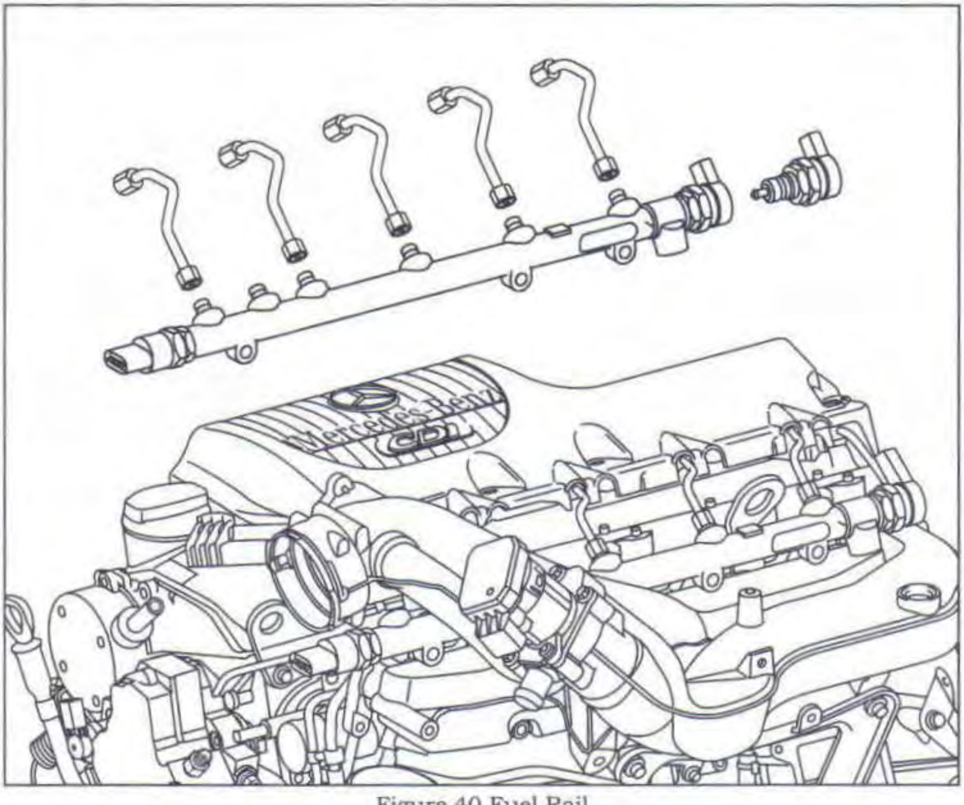


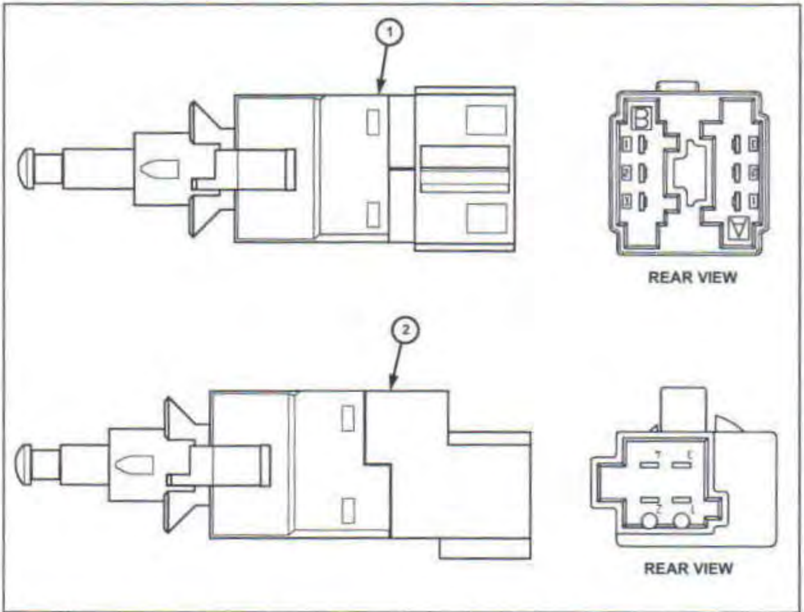
Figure 40 Fuel Rail

The stored volume also acts as a damper for pressure fluctuations resulting from the pulsating of the high pressure pump and the brief, large extraction of fuel by the injectors during injection. The constant pressure in the rail enables the ECM to accurately control the injected quantity.

Two types of brake lamp switches are installed depending on vehicle equipment. Vehicles without the Electronic Stability Program System (ESP) require an additional brake switch input for releasing the shift lever parking lock. Vehicles equipped with ESP provide this input to the shift lever control module (SLA) via the CAN bus.

Vehicles equipped with ESP have a 4-pin brake switch. The switch contains two sets of electrical contacts. One set of contacts is normally-open while the other set is normally-closed. The position of both sets of contacts is inverted when the plunger is depressed.

Vehicles without ESP have a 6-pin brake switch. The plunger is also 4 mm (0.157 in.) longer than the ESP brake switch. The switch contains three sets of contacts. Two sets of contacts are normally-open and the third set is normally-closed. The position of the contacts is inverted when the plunger is depressed.



1	Switch for Vehicles Without ESP	2	Switch for Vehicles With ESP

Figure 40 Brake Lamp Switches

Two types of brake lamp switches are installed depending on vehicle equipment. Vehicles without the Electronic Stability Program System (ESP) require an additional brake switch input for releasing the shift lever parking lock. Vehicles equipped with ESP provide this input to the shift lever control module (SLA) via the CAN bus.

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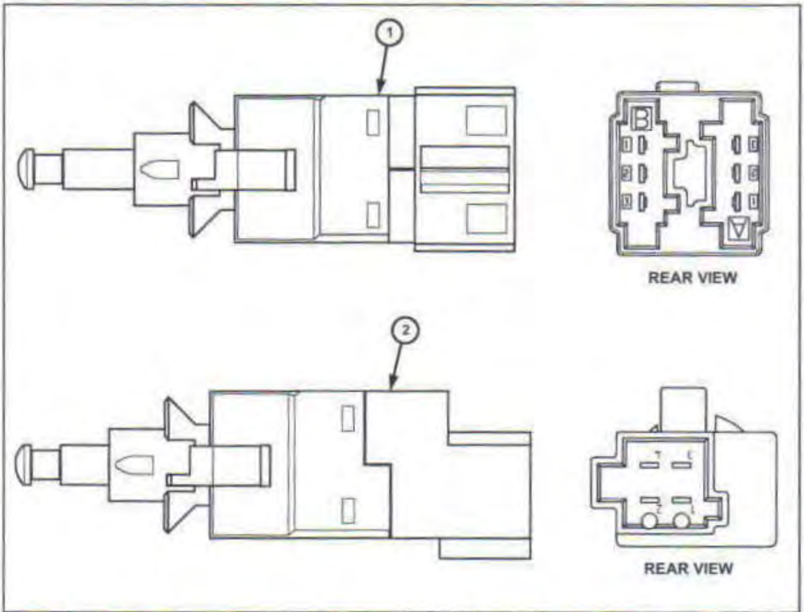

1	Switch for Vehicles Without ESP	2	Switch for Vehicles With ESP

Figure 40 Brake Lamp Switches

ESP was optional prior to NAFTA 2004. Std equip 2004 and on.

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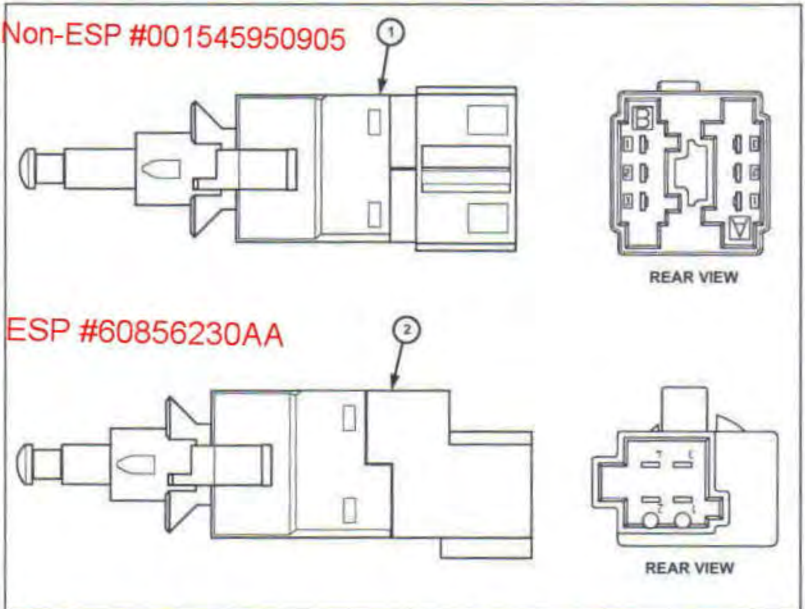
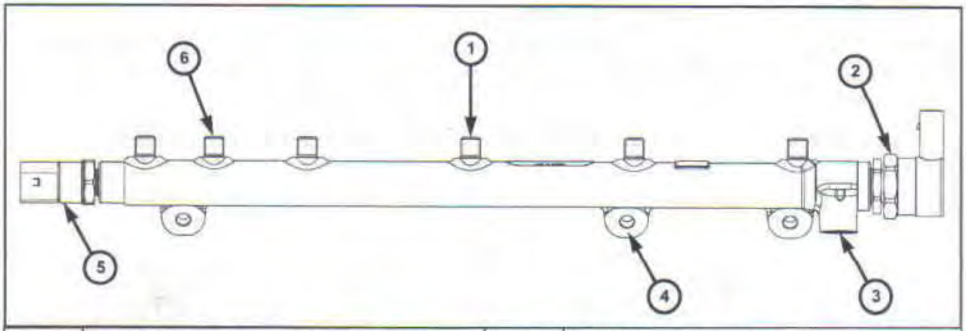


1	Switch for Vehicles Without ESP	2	Switch for Vehicles With ESP

Figure 40 Brake Lamp Switches

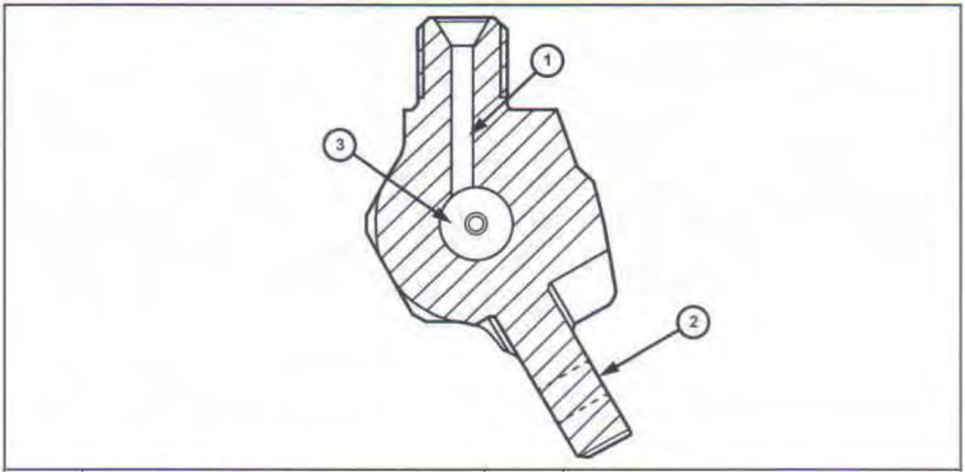
ESP was optional prior to NAFTA 2004. Std equip from 2004 and up.



1	Fuel Outlet Port to Injector (5)	4	Rail Mounting Hole (3)
2	Fuel Rail Pressure Solenoid	5	Fuel Rail Pressure Sensor
3	Fuel Return Port	6	Fuel Inlet Port From Pump

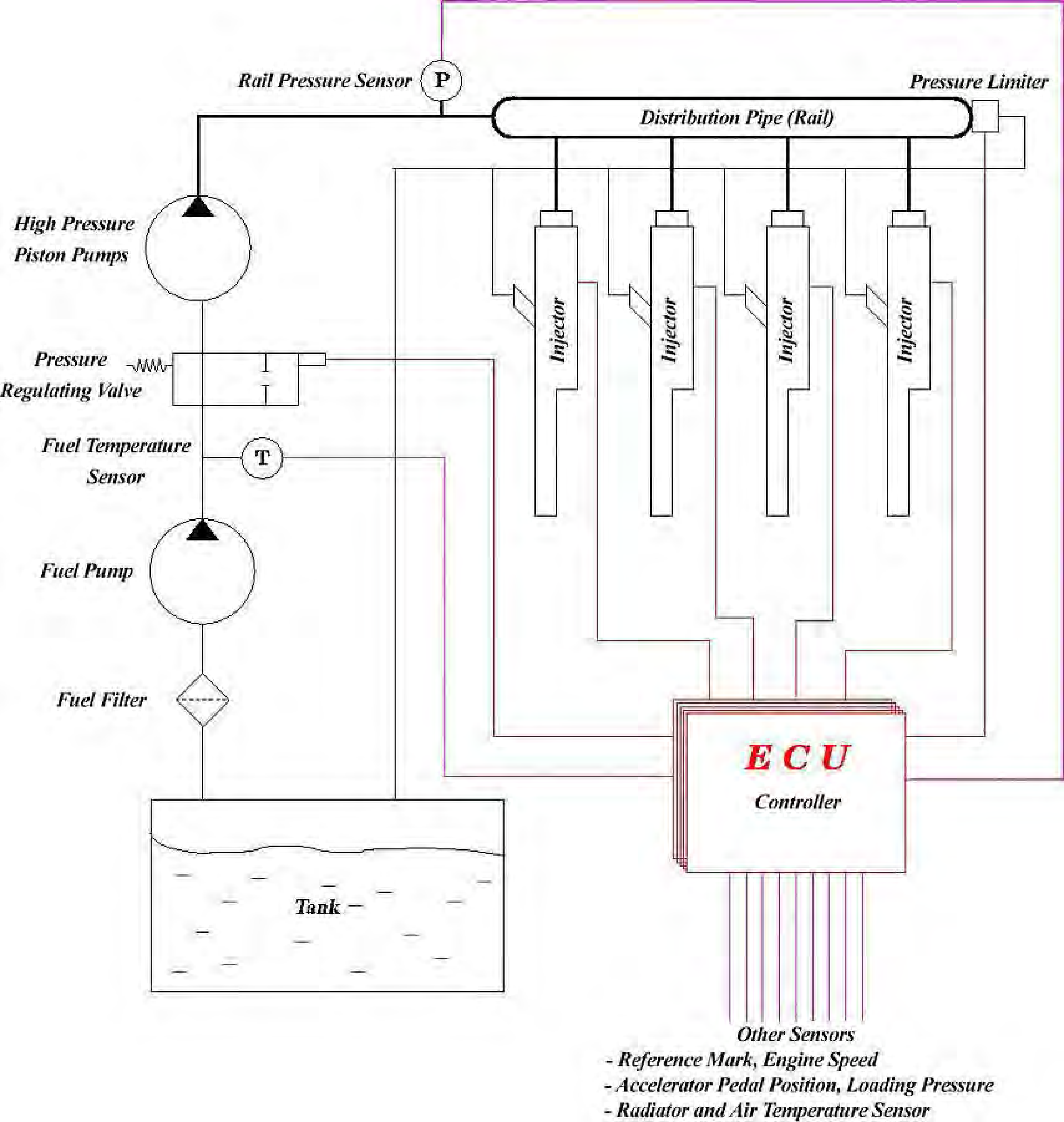
Figure 41 Fuel Rail Components

The drop forged steel fuel rail has a yellow chromate finish for surface protection. Due to the high fuel pressures it contains, the fuel gallery inside the rail has a small diameter relative to its outside diameter. The fuel rail has an ID of 10 mm (0.394 in.) and an OD of approximately 27 mm (1.063 in).



1	Fuel Outlet Port to Injector	3	Fuel Gallery
2	Rail Mounting Hole		

Figure 42 Fuel Rail Cross Section View



Rail Pressure Sensor
P
Pressure Limiter
Distribution Pipe (Rail)
High Pressure
Piston Pumps
Injector
Injector
Injector
Injector
Pressure
Regulating Valve
Fuel Temperature
Sensor
T
Fuel Pump
Fuel Filter
E C U
Controller
Tank
Other Sensors
- Reference Mark, Engine Speed
- Accelerator Pedal Position, Loading Pressure
- Radiator and Air Temperature Sensor

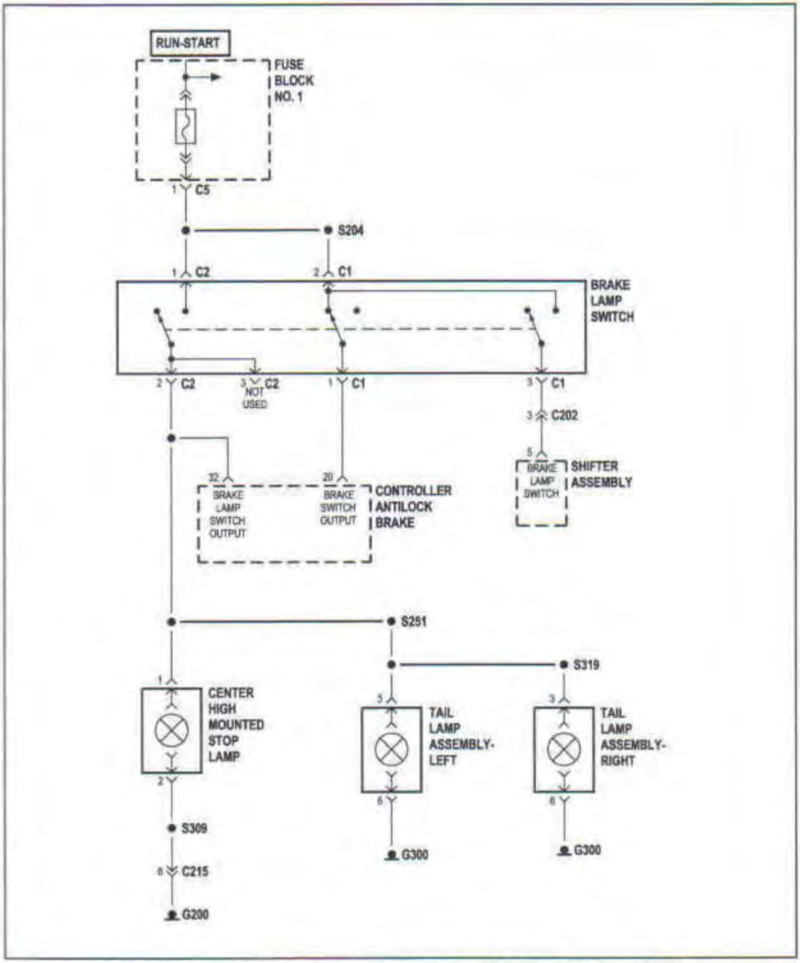


Figure 41 Stop Lamp Wiring Diagram, Vehicles Without ESP

FUEL INJECTORS

Five electronically-controlled fuel injectors are positioned on top of the cylinder head, under the engine cover (Figure 44). The injectors must be able to generate a fine fuel atomization at injection pressures up to 1,600 bar (23,205 psi) and small injection rates (approx 1.5 mm3/stroke).

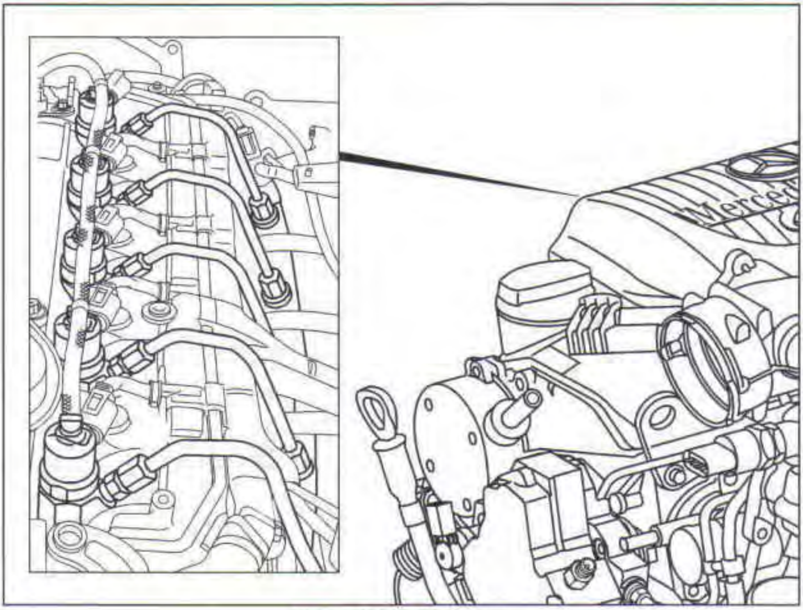


Figure 44 Fuel Injectors

The fuel injectors feature seat-hole type nozzles with seven spray holes. The spray holes have a diameter of approximately 0.135 mm (0.005 in.) and are formed by electrical discharge machining (EDM). EDM is a non-conventional machining technique in which the material is removed by the erosive action of electrical discharges (sparks) provided by a generator. The nozzle needle and injector plunger have a carbon based (C2) coating to reduce wear.

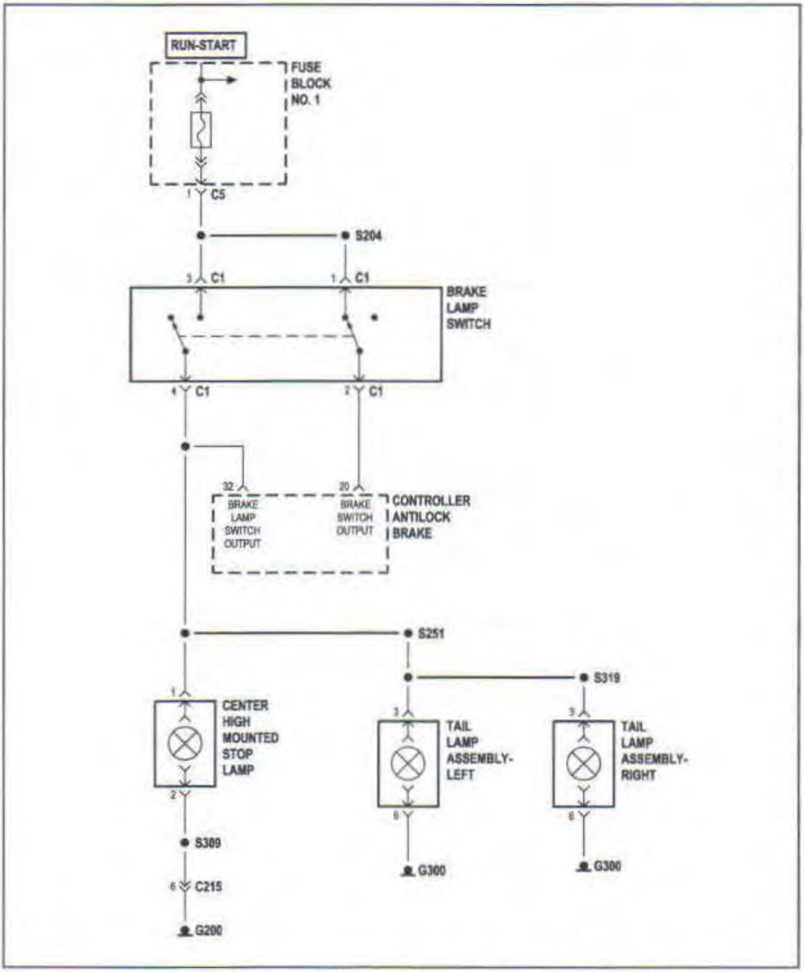
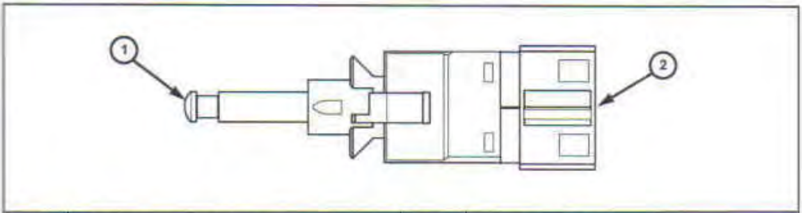


Figure 42 Stop Lamp Wiring Diagram, Vehicles With ESP

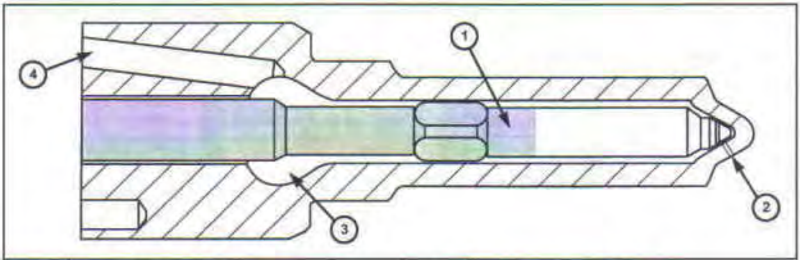
Brake Lamp Switch Adjustment

The brake lamp switch may affect engine performance if misadjusted. To adjust the switch, push the pedal to the applied position and pull the plunger until it stops.



1	Brake Switch Plunger	2	Electrical Connector

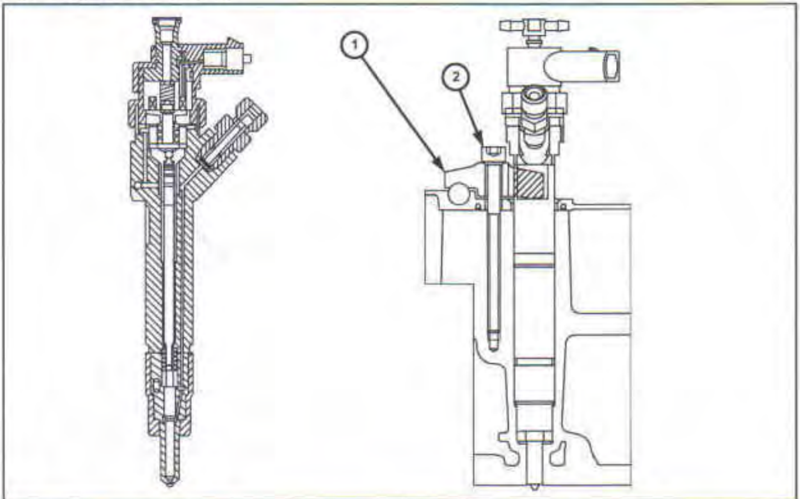
Figure 43 Brake Lamp Switch



1	Coated Nozzle Needle	3	Pressure Chamber
2	Injector Spray Hole (7)	4	Fuel Inlet Passage

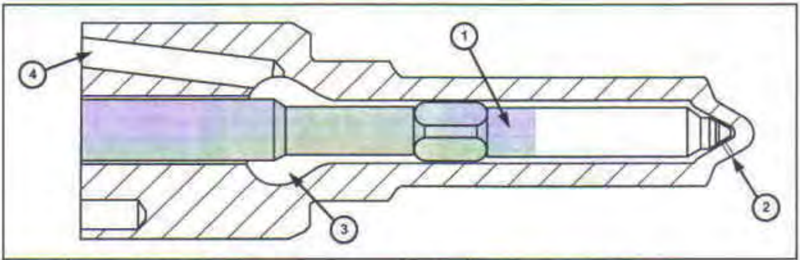
Figure 45 Injector Nozzle

Each injector is held in its recess by a tensioning claw and a retaining stretch bolt (Figure 46). A seal ring is located on the injector tip to seal off the injector to the combustion chamber. When removing the injectors, the seals and torque to yield bolts must always be replaced.



1	Tensioning Claw	2	Retaining Stretch Bolt

Figure 46 Fuel Injector Position



1	Coated Nozzle Needle	3	Pressure Chamber
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Figure 45 Injector Nozzle

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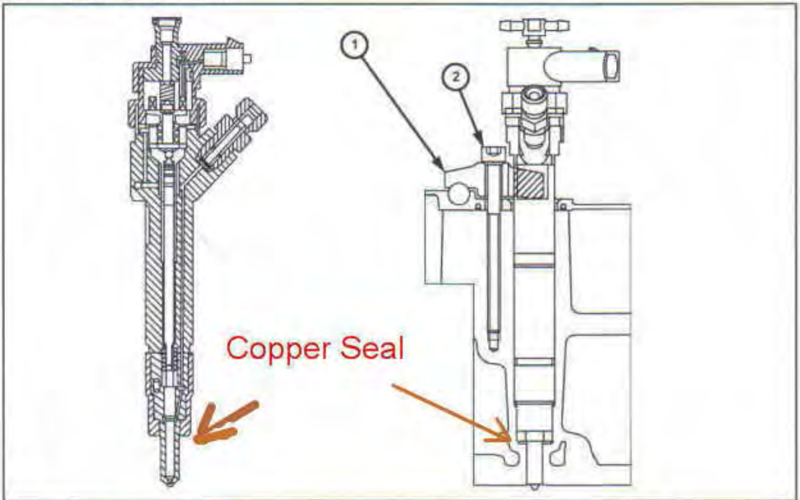


1	Tensioning Claw	2	Retaining Stretch Bolt

Figure 46 Fuel Injector Position

BACK-UP LAMPS

The SLA microcontroller recognizes the position of the shift lever via the shift lever potentiometer. With the selector lever in the "R" position, the microcontroller switches on a power field-effect transistor (FET) to activate the back-up lamps.

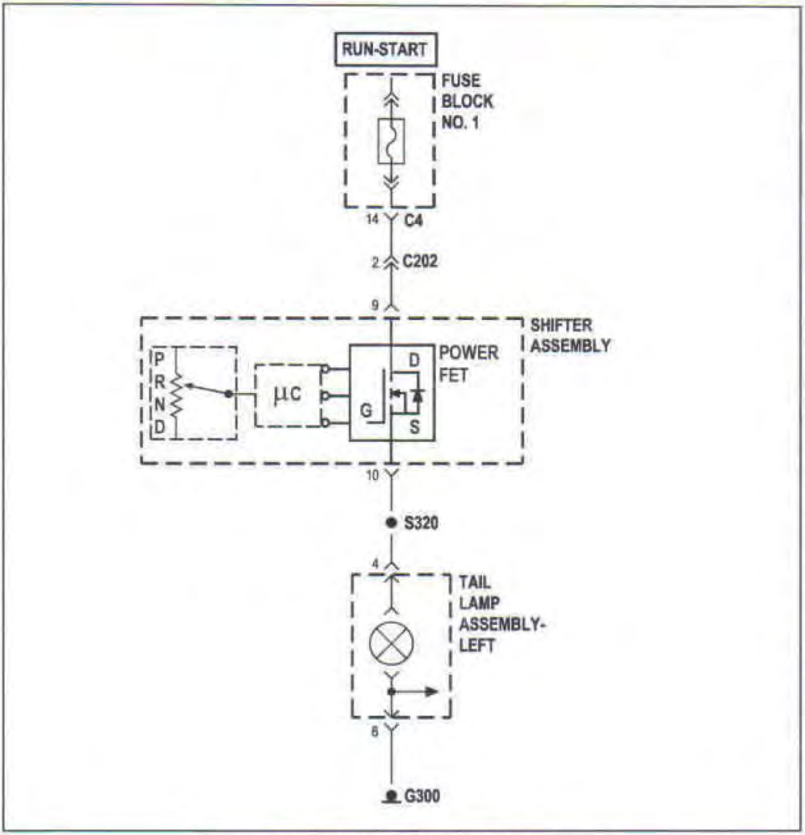
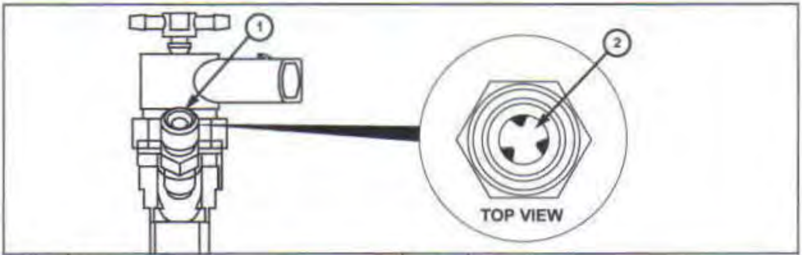


Figure 44 Wiring Diagram, Back-Up Lamps

An edge filter is mounted in the injector high pressure connector to filter impurities and dirt upstream of the injector nozzle (Figure 47). Edge filters are effective to filter particles in the fuel or particles created by machining of components and/or from the high pressure fuel flow. The edge filter has a flat front face with three V-shaped openings leading to V-shaped channels.



1	High Pressure Connector	2	Edge Filter

Figure 47 High Pressure Connector With Edge Filter

The injector operation can be subdivided into four operating states with the engine running and the high-pressure pump generating pressure:

Injector Closed (At-Rest State)

Refer to Figure 48. The fuel coming from the rail is present at the fuel inlet (2) in the valve control chamber (8) and in the chamber volume (4). The rail pressure builds up in both areas (8) and (4).
The surface difference of the valve control chamber (8) compared to the chamber volume (4) and the additionally acting force of the nozzle spring (6), prevent the nozzle needle (5) from opening. This condition exists when the start phase begins or if the vehicle is in the deceleration mode (engine running and high pressure pump delivering).

Injector Opens (Start of Injection)

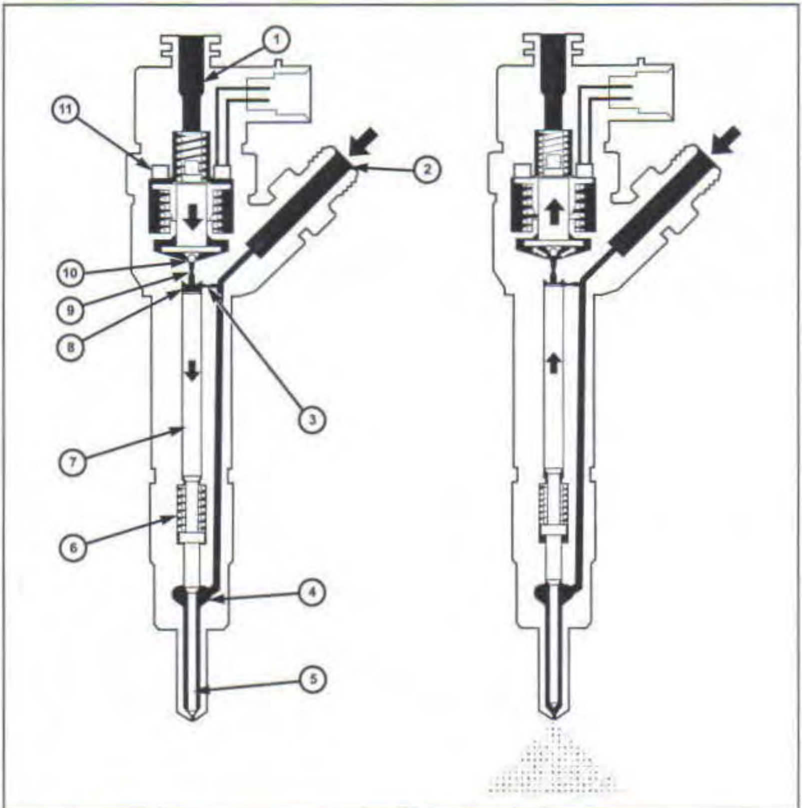
When the solenoid valve (11) is energized, the check ball (10) is attracted and overcomes the force of the valve spring. The check ball now opens the valve control chamber (8) and the controlled quantity of fuel is able to flow along the fuel return (1) back to the fuel tank. As a result of the pressure drop in the valve control chamber (8) the nozzle needle (5) is raised by virtue of the difference in pressure. The rate of opening of the nozzle needle depends on the cross-section of the bleed orifice (9) above the valve control chamber (8) and the feed orifice (3) positioned between high pressure feed (2) and valve control chamber.

Injector Opened Fully

The control plunger (7) reaches its upper stop where it remains supported by a cushion of fuel, which is generated by the flow of fuel between the bleed and feed orifices. The injector nozzle has now opened fully, and the fuel is injected into the combustion chamber at a pressure almost equal to that in the fuel rail.

Injector Closes (End of injection)

After the solenoid valve current is switched off, the valve spring pushes the check ball (10) back onto the valve seat. The bleed orifice is closed as a consequence of this and the pressure in the valve control chamber (8) rises to the level of the system pressure. The closing force which is active in the valve control chamber (8), is greater than that in the chamber volume (4), as a result of which the nozzle needle (5) closes.

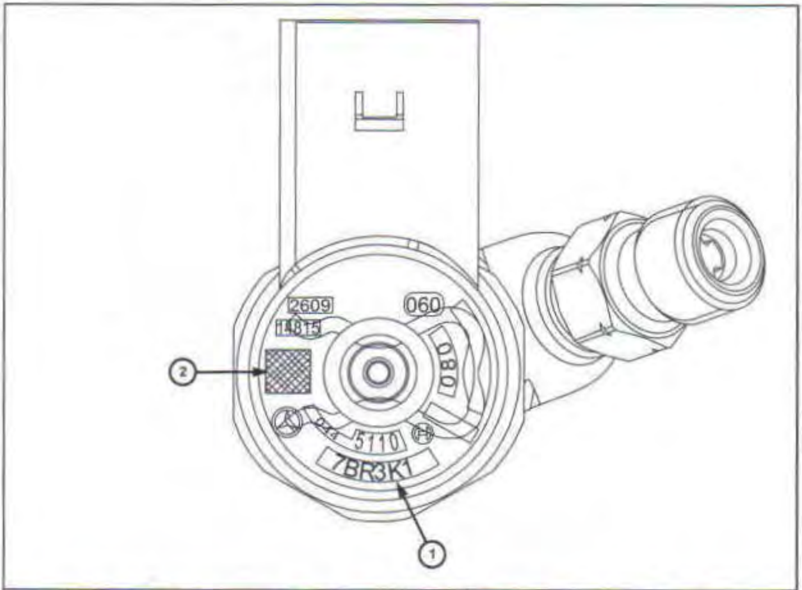


1	Fuel Return	7	Control Plunger
2	Fuel Inlet	8	Valve Control Chamber
3	Feed Orifice	9	Bleed Orifice
4	Chamber Volume	10	Check Ball
5	Nozzle Needle	11	Solenoid Valve
6	Nozzle Spring		

Figure 48 Fuel Injector Cutaway

Fuel Injector Classification

The ECM compensates for both injector variations due to production tolerances as well as due to injector wear over the life of the injector. The injectors are identified with a six-digit alphanumeric code etched on the injector top. To allow the ECM to compensate for tolerances, the code is programmed into the ECM memory using the diagnostic scan tool. At the end of the coding procedure, the diagnostic tool performs a proof check to ensure the code has been entered correctly.



1	Six-Digit Alphanumeric Code	2	Data Matrix Bar Code (Plant Use)

Figure 49 Injector Top View

SERVICE NOTE: WHEN REMOVING THE INJECTORS, THE SEAL RINGS AND TORQUE TO YIELD BOLTS MUST ALWAYS BE REPLACED. COAT THE INJECTOR BODY WITH THE APPROVED LUBRICANT BEFORE INSTALLING ON THE ENGINE.

MODULE 3 ECM INPUTS

The ECM output decisions are based on input values. As the input values change, the ECM will change the fuel curve for optimum performance.

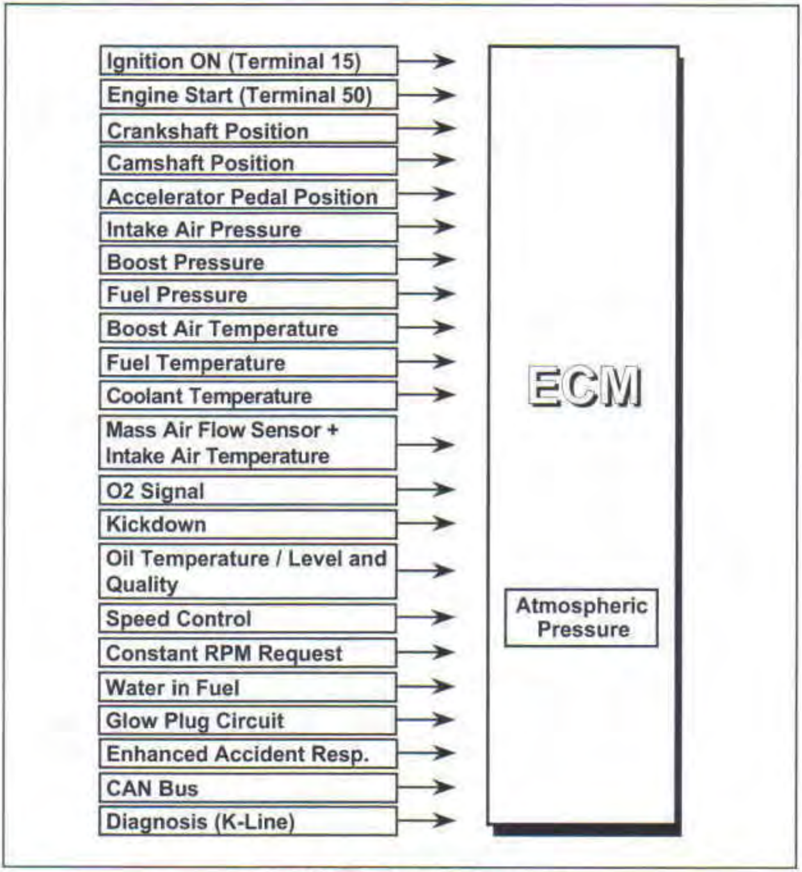


Figure 50 Block Diagram ECM Inputs

POSITION SENSORS

CRANKSHAFT POSITION SENSOR (CKP)

The crankshaft position sensor (CKP) is located opposite the teeth on the flywheel and uses a non contact method to record the position of the crankshaft. When the crankshaft is rotating, an alternating current signal is produced. The leading edges of each tooth on the flywheel generate a positive current signal in the CKP, while the trailing edges generate a negative current signal. The period or frequency of the signal is the time required by the crankshaft to turn through the gap between two flywheel teeth.

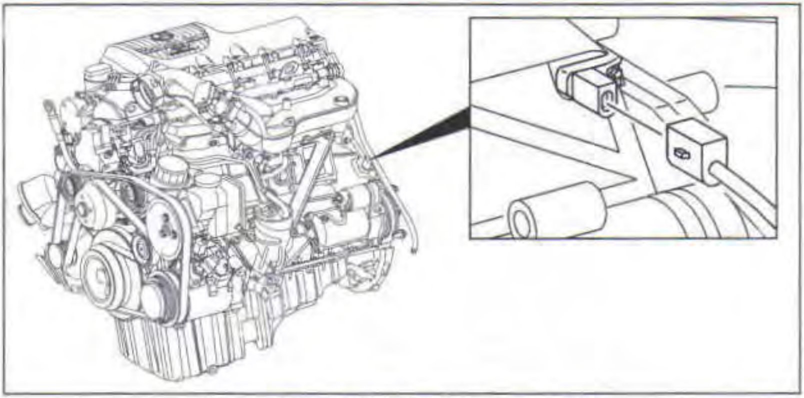


Figure 53 Crankshaft Position Sensor (CKP)

OPERATION

The clearance between the CKP and the flywheel are fixed by the installation position. The flywheel toothed ring has 58 teeth, which are evenly spaced every 6°. Two teeth on the flywheel are missing (the 59th and 60th). The resulting gap is used by the ECM to detect TDC of cylinder number one. The angle between the gap and TDC of cylinder number one is 108°, or 18 teeth. The crankshaft position is calculated so that the start and end of injection can occur at the right moment. The engine speed signal is also processed by the ECM from the crankshaft position sensor. This signal is then broadcast to other control modules over the CAN bus.
The loss of crank signal will cause the ECM to stop triggering the injectors. The engine shuts down and will not restart.

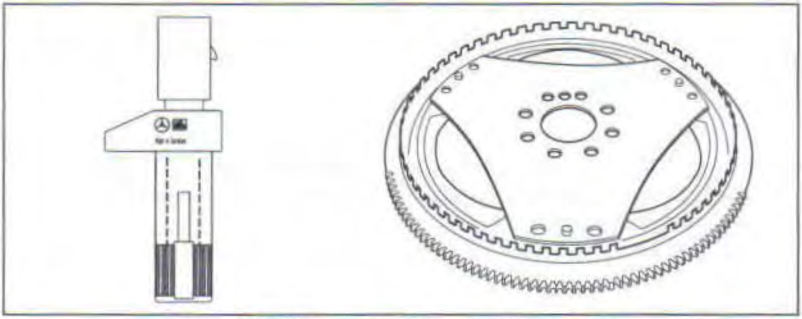


Figure 54 CKP Sensor and Flywheel Toothed Ring

When the crankshaft rotates, an alternating voltage is generated (Figure 55) in the CKP by the flywheel teeth. The front edge of a tooth generates a positive voltage pulse and the rear edge a negative voltage pulse. The distance from the positive to the negative voltage peak corresponds to the length of a tooth.
The gap produced by 2 missing teeth results in no voltage being generated in the CKP. This is used to detect the position of cylinder number one.

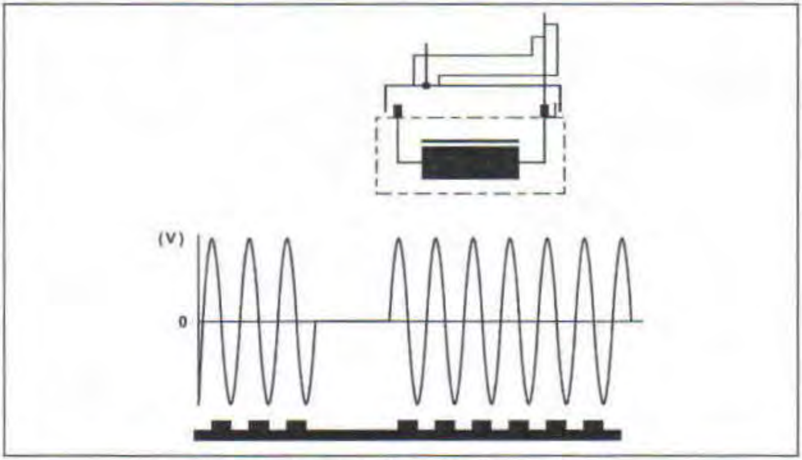


Figure 55 Crankshaft Position Sensor Signal

Failure Modes

The ECM monitors the operation of the CKP and stores fault codes related to the following conditions:

- Crankshaft sensor plausibility 1
- Crankshaft sensor plausibility 2
- Crankshaft sensor over speed detection
- Synchronization between crankshaft and camshaft - flow limiter activated
- Synchronization between crankshaft and camshaft - no crankshaft signal
- Synchronization between crankshaft and camshaft - plausibility
- Synchronization between crankshaft and camshaft - main injection correction is faulty

CAMSHAFT POSITION SENSOR (CMP)

The camshaft position sensor (CMP) is located on top of the exhaust camshaft, at the rear of the engine near injector number 5. The CMP utilizes a non contact method on one segment of the camshaft to record the camshaft position. When the ECM receives the signal from the CMP, it can then detect TDC of cylinder number one. The signal from the CMP is only required during engine starting for synchronizing injection timing.

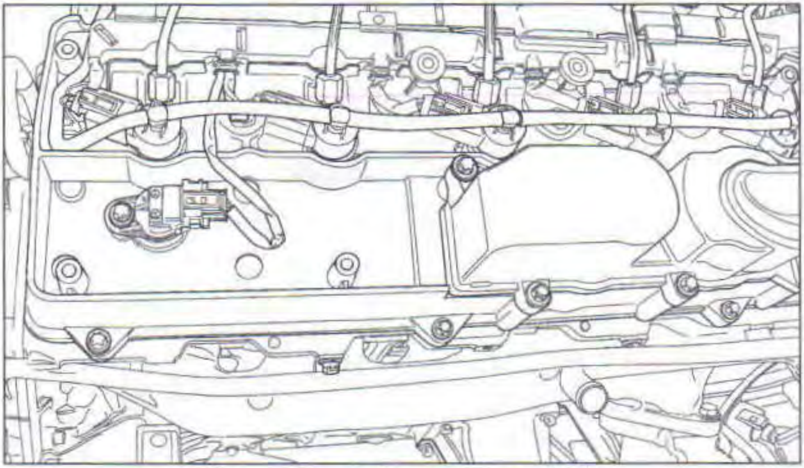


Figure 56 Camshaft Position Sensor (CMP)

OPERATION

The CMP consists of a Hall-effect integrated circuit, flexible printed circuit board, capacitors and a magnet (Figure 57).

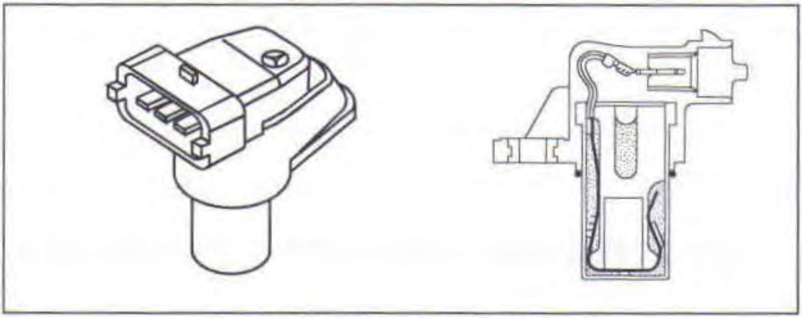


Figure 57 Camshaft Position Sensor (CMP)

The CMP is a 5 volt Hall-effect type sensor, with a return signal that switches from 0 to 5 volts depending on the position of the segment machined into the exhaust camshaft.

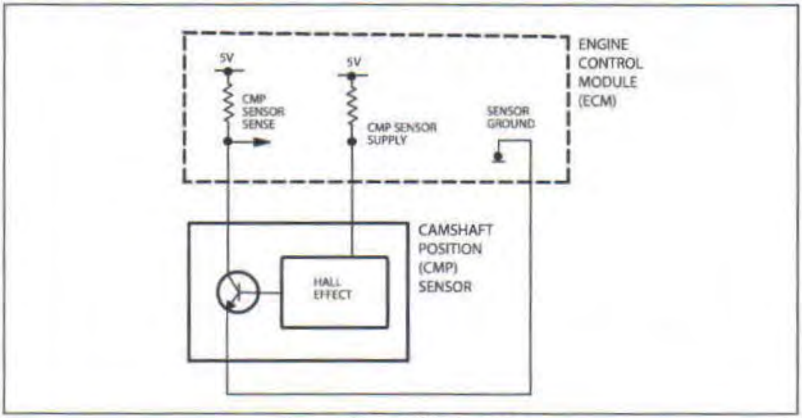


Figure 58 CMP Schematic

TRAILER TOW PROVISIONS

DESCRIPTION

Trailer towing electrical provisions are either factory installed or dealer/aftermarket installed. This chapter deals with the factory installed system, for dealer/aftermarket installed systems, refer to their installation instructions and wiring diagrams.

Figure 54 Trailer Tow Seven-Way Connector

MODULE FUNCTION

The Trailer Towing Module converts the separate brake and turn signal inputs from the vehicle into a combined turn/stop light signal for standard trailer wiring as well as providing a 12 volt signal for an electrical trailer brake.

Module Location

The Trailer Towing Module is located under driver seat.

Module Input

A five wire connector provides B+ over a 25 Amp fuse located in the Fuse Block No.2, a chassis ground, a brake switch input, a left turn signal input and a right turn signal input.

Module Output

A three wire connector provides left turn and stop light output, right turn and stop light output and electrical trailer brake output.

The signal wire of the CMP is normally switched high (approximately 5 volts). When the segment machined into the exhaust camshaft is positioned opposite the CMP, the camshaft signal switches to low (approximately 0V). A low signal is used for detecting ignition TDC of cylinder 1 by the ECM. If no signal is supplied by the CMP, the vehicle will not start because cylinder order can not be detected (Figure 59).

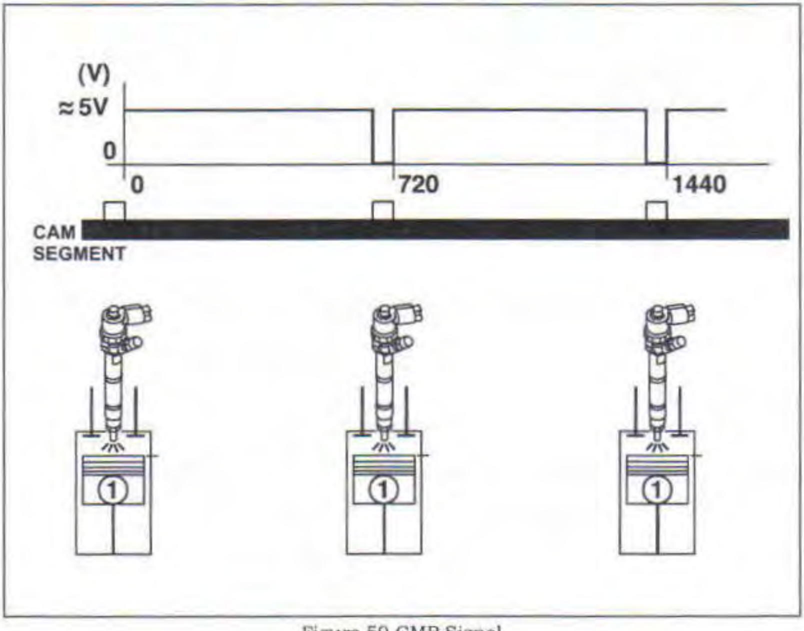


Figure 59 CMP Signal

Failure Modes

The ECM monitors the operation of the CMP and stores fault codes related to the following conditions:

- Synchronization between crankshaft and camshaft - no camshaft signal
- Synchronization between crankshaft and camshaft - flow limiter activated
- Synchronization between crankshaft and camshaft - camshaft frequency signal too high

The signal wire of the CMP is normally switched high (approximately 5 volts). When the segment machined into the exhaust camshaft is positioned opposite the CMP, the camshaft signal switches to low (approximately 0V). A low signal is used for detecting ignition TDC of cylinder 1 by the ECM. If no signal is supplied by the CMP, the vehicle will not start because cylinder order can not be detected (Figure 59).

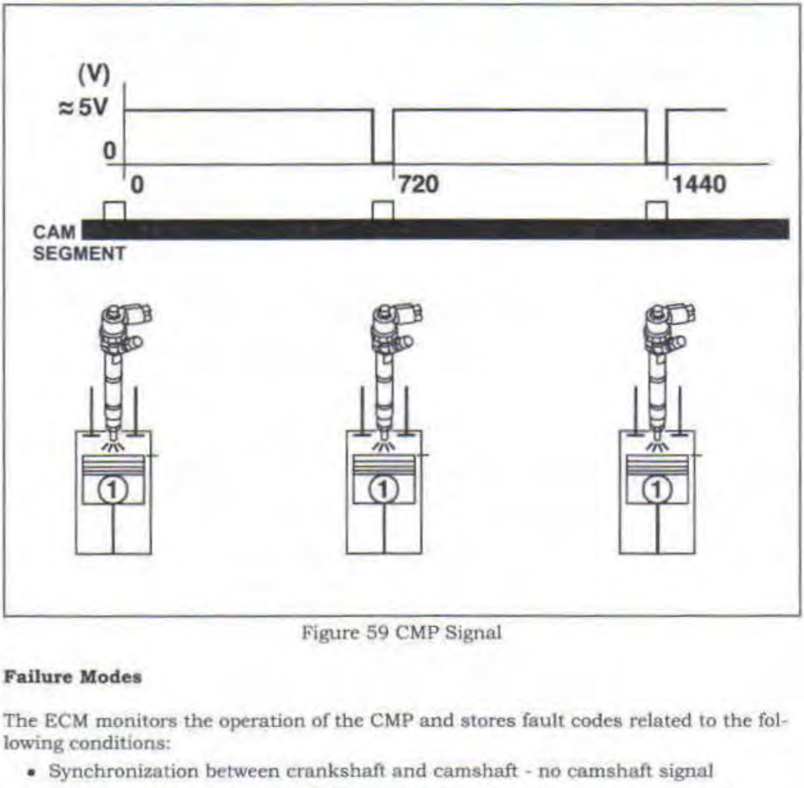


Figure 59 CMP Signal

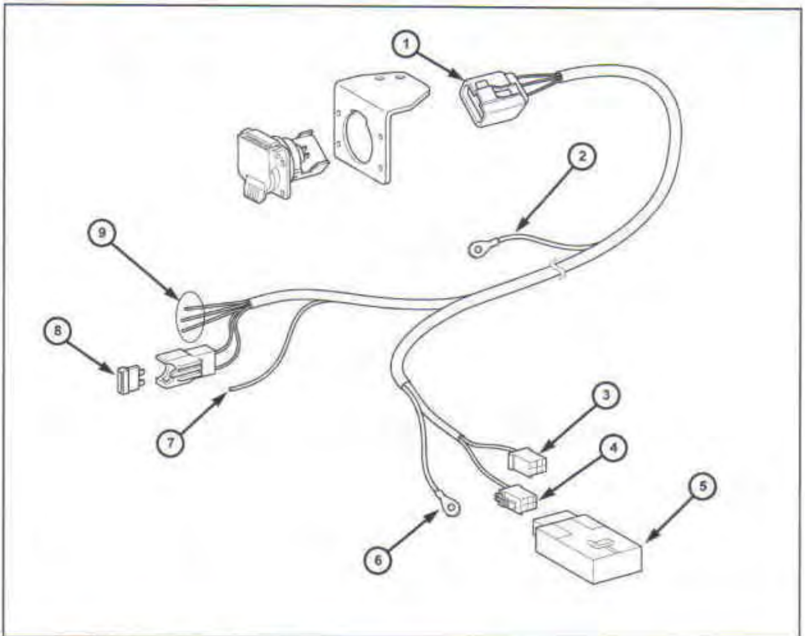
Failure Modes

The ECM monitors the operation of the CMP and stores fault codes related to the following conditions:

- Synchronization between crankshaft and camshaft - no camshaft signal
- Synchronization between crankshaft and camshaft - flow limiter activated
- Synchronization between crankshaft and camshaft - camshaft frequency signal too high

See page 140 for possible LHM 3200 RPM type limit

Note: The B+, ground, reverse light and tail light inputs at the trailer towing connector at the rear bumper come directly from the appropriate vehicle harness and are not provided by the trailer towing module.

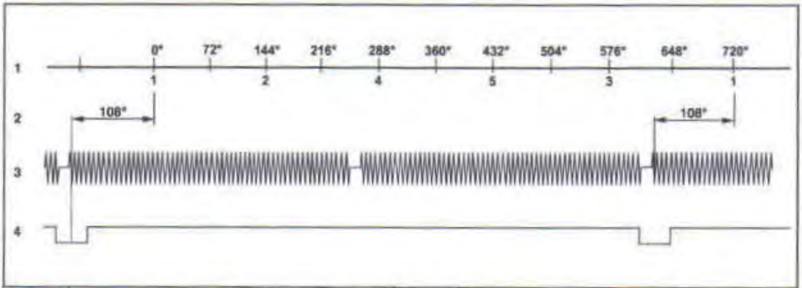


1	Trailer Tow Connector
2	Ground Wire To Ground G300 (Right Rear Body)
3	Six-Pin Connector C2 (Black)
4	Six-Pin Connector C1 (Green)
5	Trailer Tow Control Module
6	Ground Wire To Ground G202 (Under Driver Seat)
7	Wire To Brake Lamp Switch
8	25 A Fuse in Fuse Block No. 2
9	Wires To Fuse Block No. 1 (Left Turn/Right Turn Signal and Tail Lamps)

Figure 55 Trailer Tow Wiring Harness Layout

INJECTION TIMING SYNCHRONIZATION

The injection timing is synchronized by means of the signals supplied by the CKP and the CMP. The ECM analyzes both signals to detect the TDC position of cylinder number one. When the ECM detects the voltage gap resulting from the two missing teeth on the flywheel, it must also detect the low signal from the segment on the exhaust camshaft. The simultaneous voltage gaps are an indication to the ECM that the engine is 108° BTDC of cylinder number one.



1	Crankshaft Angle / Firing Order	3	CKP Signal
2	Offset Angle Cylinder No. 1	4	CMP Signal

Figure 60 Injection Timing Synchronization

SEVEN-WAY CONNECTOR LAYOUT

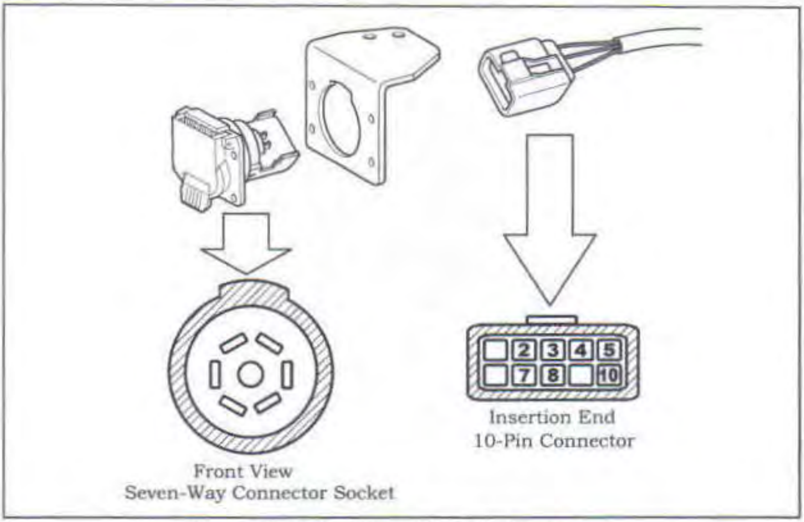


Figure 56 Seven-Way and 10-Pin Connectors

DESCRIPTION

A 10-pin rectangular connector is plugged to the back of the 7-way trailer tow connector socket. Cavities 1, 6 and 9 are not used and have seal plugs to keep moisture out.

The wiring diagrams show the pin layout of the 10-pin wiring harness connector. The seven-way connector socket is not shown. See Figure No. 57 for cavity numbers and corresponding trailer circuits.

Caution: The electric brake circuit does not provide brake modulation. If connected to the trailer, it will apply the trailer brakes at full power. An aftermarket unit will have to be installed in order to modulate the trailer brakes (See Figures 60 and 61).

Circuit Description	Cavity Number (10 Pin Connector)
Electric Brakes	7
RH Stop Turn	2
Backup Lamps	3
LH Stop Turn	10
Running Lamps	5
Power (+)	4
Ground (-)	8

Figure 57 Pin Layout, 10-Pin Connector

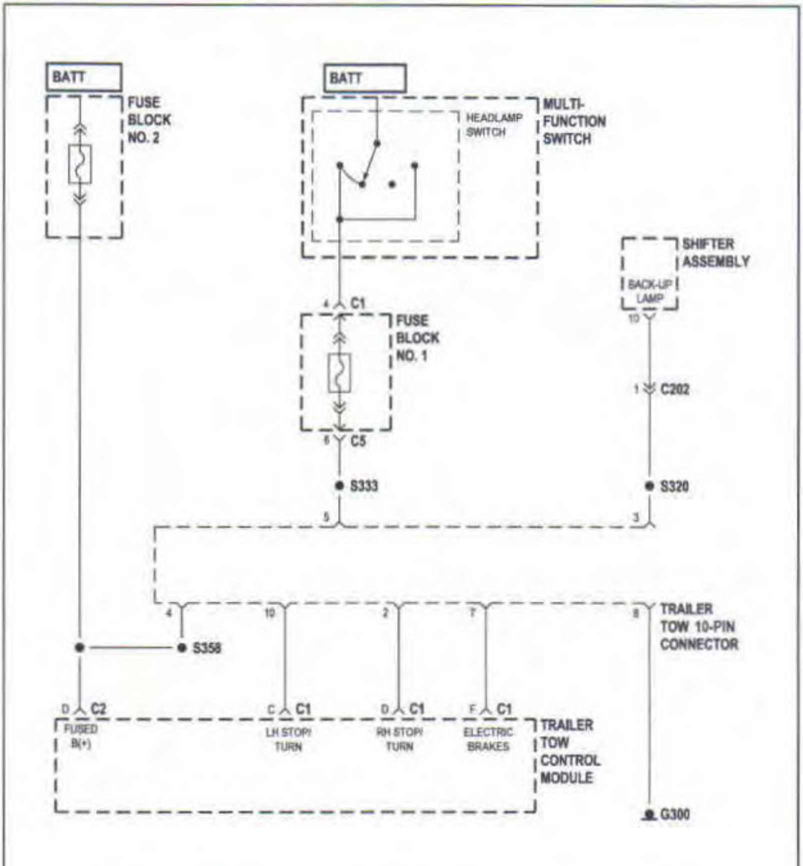


Figure 58 Trailer Tow Wiring Diagram (continued on next page)

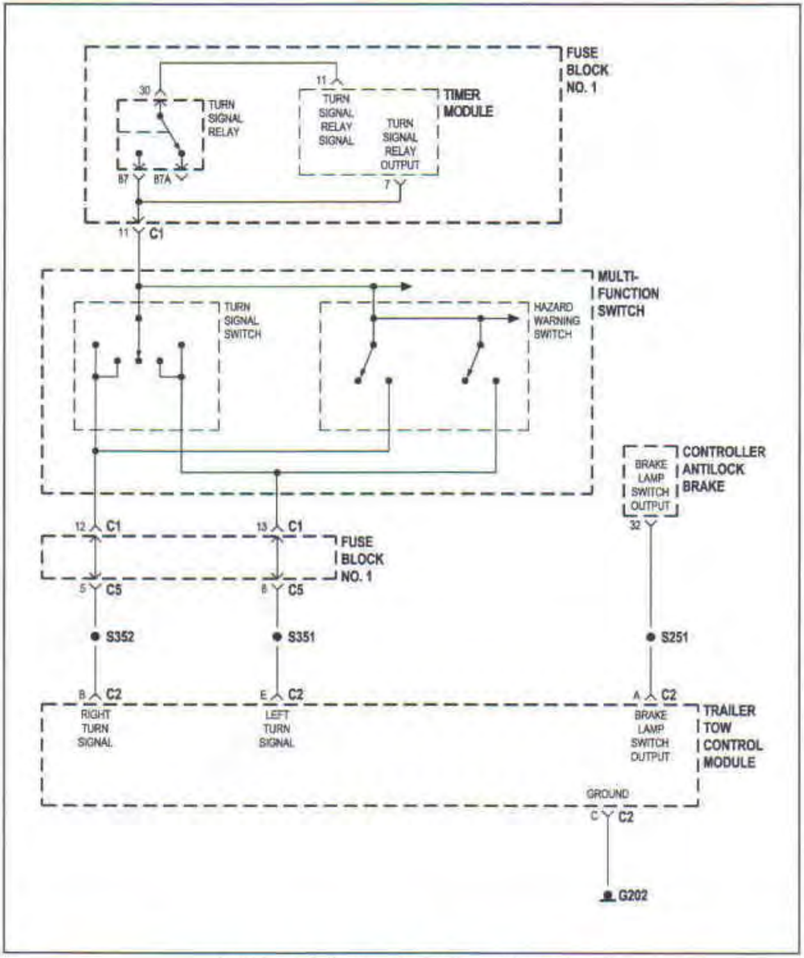


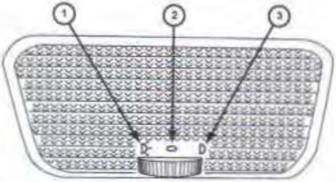
Figure 59 Trailer Tow Wiring Diagram

MODULE 4 INTERIOR LIGHTING

DESCRIPTION

The Sprinter van can be outfitted with a variation of interior lighting configurations depending upon model and options. The following is a list of components that are considered part of the interior lighting system:

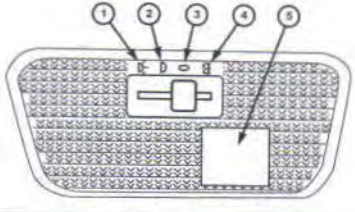
- Cargo/Dome Lamp - As standard equipment the Sprinter will be equipped with forward and rear cargo/dome lamps. The standard cargo/dome lamps contain a single incandescent bulb. A three position slide-type switch protrudes through the lamp lens.



1	Permanently ON Position
2	OFF Position
3	Interior Lamps are switched ON/OFF by the Door Jamb Switches

Figure 62 Cargo/Dome Lamp

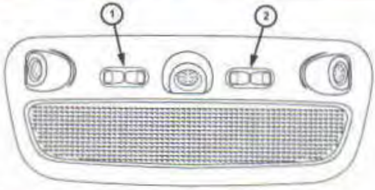
- Dome/Reading Lamp-The optional dome/reading lamp assembly will be located between the driver and passenger sun visors in the cab/roof area. This assembly contains two incandescent bulbs and a four position slide-type switch that protrudes through the lamp lens.



1	Permanently ON Position
2	Interior Lamps are switched ON/OFF by the Door Jamb Switches
3	OFF Position
4	Reading Lamp Position
5	Reading Lamp Lens

Figure 63 Dome/Reading Lamp

- Dome Lamp/Intrusion Sensor-An optional dome lamp/intrusion sensor is located overhead in the vehicle interior. This lamp features four incandescent bulbs, two for dome lamps and two dedicated reading lamps. There are two integral three-position switches. One switch to control interior lamp operation and one to control reading lamp operation. Three intrusion sensors, that are part of an optional vehicle theft security system, are housed in this unit.



1	Three-Position Interior Lamp Switch (ON, Jamb Switch Operation, OFF)
2	Three-Position Reading Lamp Switch (Left Lamp ON, OFF, Right Lamp ON)

Figure 64 Dome Lamp/Intrusion Sensor

- Cargo Lamp Switch - The Sprinter can be outfitted with momentary contact rocker-type Cargo Lamp Switches in the instrument panel center stack, behind the cargo area bulkhead and on the rear cargo door pillar. The switches all contain two LEDs, one for the purpose of illumination and the second for on/off indication. Only the front mounted switch will use the illumination LED.

Figure 65 Cargo Lamp Switch

- Time Delay Relay-Vehicles equipped with the optional remote cargo lamp switches also have a time delay relay located in the electrical center below the drivers seat in the rear row of relays and small ECUs.

Figure 66 Time Delay Relay

- Entry/Exit Lamp - An entry/exit lamp to illuminate each front and sliding side door step well is optional equipment on wagon models.

Figure 67 Entry/Exit Lamp

PRESSURE SENSORS

AIR INTAKE PRESSURE SENSOR

The air intake pressure sensor, also known as inlet air pressure sensor, is mounted to the air filter housing.

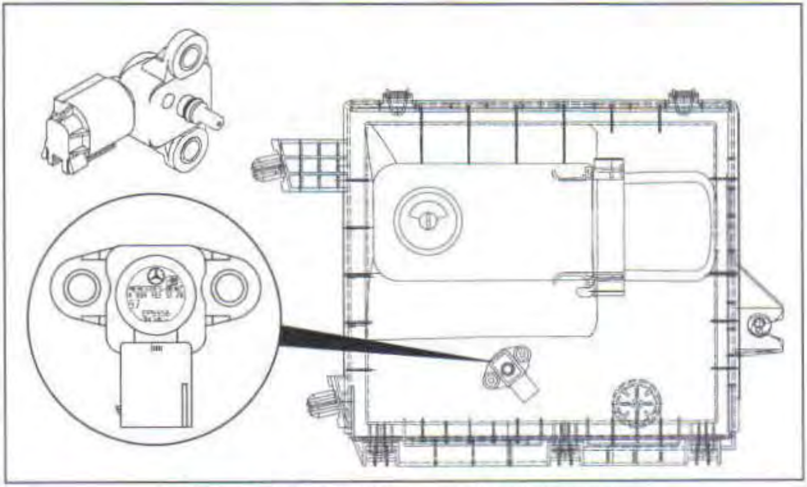


Figure 64 Air Intake Pressure Sensor Location

The ability to monitor intake pressure allows better control of variable geometry turbocharger to suit driving environment and preserve turbocharger durability. The sensor is used by the ECM to adjust for changes in altitude and for air intake obstructions due to clogging of the air filter.

OPERATION

The air intake pressure sensor consists of piezoresistive elements attached to a measuring diaphragm. The resistance value changes when stress is applied to the diaphragm. The resistors form a measuring bridge, so that when the diaphragm moves the bridge balance is changed. The bridge voltage is a measure for the boost presssure.

The sensor receives a 5-volt reference from the ECM. Sensor ground is also provided by the ECM. The bridge voltage varies from 0.5 to 4.5 volts depending on air intake pressure.

- Door jamb switch - Jamb switches for each front door are standard equipment on all models. A door jamb switch for each sliding side door and the right rear door is standard equipment on wagon models.

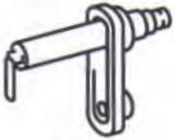
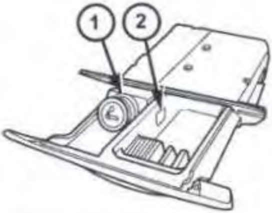


Figure 68 Door Jamb Switch

- Ash Receiver/Cigar Lighter Lamp-Located in the lower middle portion of the center stack is the Ash Receiver/Cigar Lighter assembly. The illumination comes from a single lamp that serves to light the translucent halo ring and ash receiver.



1	Halo Ring
2	Lamp Unit Lens

Figure 69 Cigar Lighter Illumination

When making repairs to any of the components in the interior lighting system always refer to the applicable Service or Diagnostic manual.

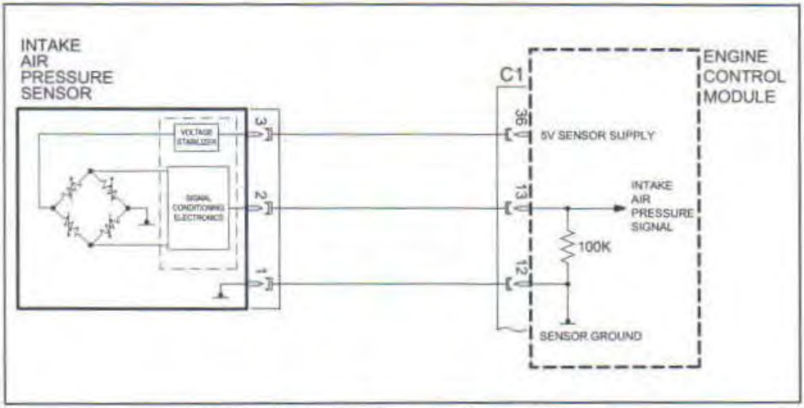


Figure 65 Air Intake Pressure Sensor Schematic

As air intake pressure increases, the signal voltage also increases. If the engine is not running, the value sent to the ECM is equal to the atmospheric pressure. The air intake pressure operating range is from 0.1 to 1.2 bar (1.45 to 17.4 psi).

OPERATION

Depending on the vehicle model and options the interior lighting may include cargo area lamps, entry/exit lamps, and overhead lighting. Interior lighting circuits are provided with battery current at all times by a fuse in Fuse Block #1.

Cargo/Dome Lamp and Dome/Reading Lamp

The front, side, and rear door jamb switches provide a ground path for each of the interior lamps except for the optional reading lamp. If equipped with the optional cargo/dome lamp the lamp assembly will have a three position slide-type switch protruding through the lamp lens. If equipped with the optional dome/reading lamp the switch will have four positions. Position one will provide a ground path independent of the door jam switches. Position two will allow the jam switches to turn the lamp on. The third position opens the circuit to turn off the lamp. The fourth position will illuminate the reading lamp bulb that will emit light on the passenger side of the cab.

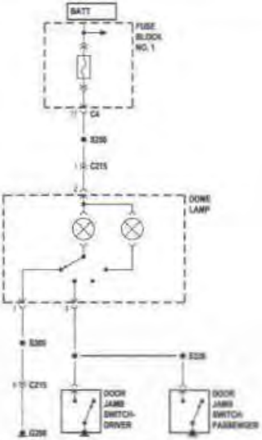


Figure 70 Dome Lamp/Reading Lamp Wiring Diagram

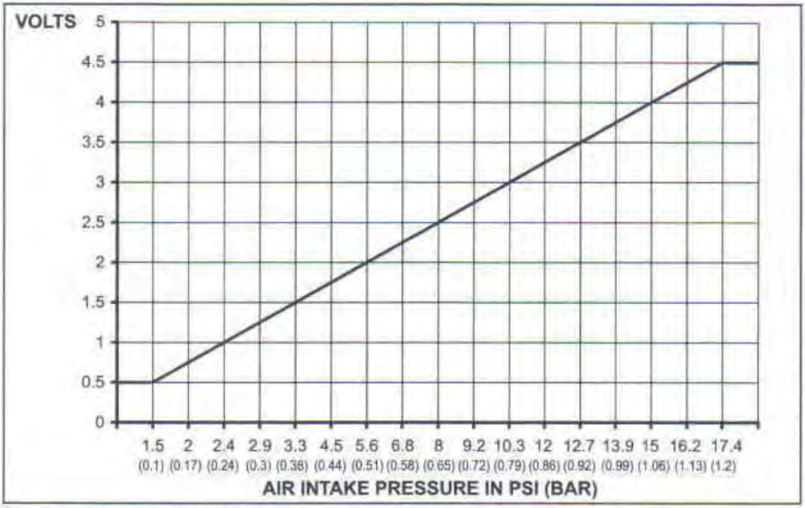


Figure 66 Air Intake Pressure Sensor Signal (Approximate Values)

Failure Modes

If the air intake pressure sensor fails, the ECM records a DTC into memory and continues to operate the engine in limp-in mode. When the engine is operating in this mode, a loss of power will be present, as if the turbocharger was not operating.

The ECM monitors the operation of the air intake pressure sensor and stores fault codes related to the following conditions:

- Signal voltage too low
- Signal voltage too high
- Supply voltage too high or too low

Substitute Values

- If the sensor ground wire has an open circuit, the actual value displayed is 38.29 psi
- If the signal wire has a short circuit to ground or open circuit, the substitute value is 11.2 psi
- If the 5-volt power supply has a short circuit to ground or open circuit, the substitute value is 11.2 psi

Cargo Lamp Switches and Time Delay Relay

If the vehicle is equipped with the optional remote cargo lamp switches the rear cargo area lamps are provided battery voltage by the time delay relay. The time delay relay is a "smart" relay that is comprised of internal electronics that control the relay operation based on input from the cargo lamp switches. When a cargo lamp switch is pressed the electronics will energize the control side of the relay and close the contacts in the high current path. The high current path through the relay will provide voltage to the cargo area lamps and the indicator portion of the cargo lamp switches. The electronics in the time delay relay will automatically shut off the rear cargo area lamps after a 15 minute period has elapsed. The user can press any of the cargo lamp switches and the cargo lamps will illuminate again for 15 minutes.

BOOST PRESSURE SENSOR

The boost pressure sensor is mounted to the charge air pipe (Figure 67). The sensor allows the ECM to monitor intake air downstream of the turbocharger.

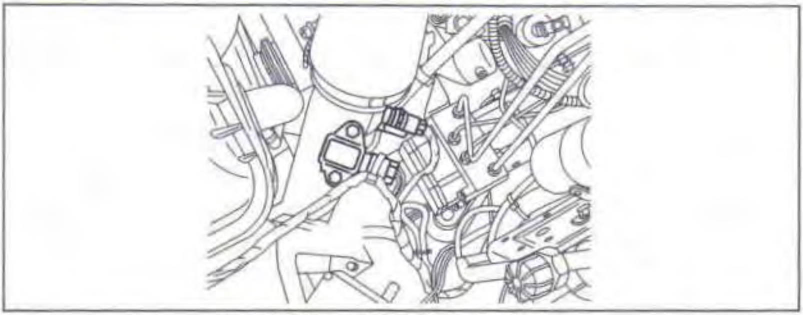


Figure 67 Boost Pressure Sensor Location

The boost pressure sensor is a three-wire sensor with a sensing pressure port on the bottom. The pressure port is inserted into the charge air pipe through an access hole. An O-ring provides the sealing once the sensor is mounted to the charge air pipe (Figure 68). The ECM uses boost pressure combined with intake air temperature to determine the volume of air entering the engine.

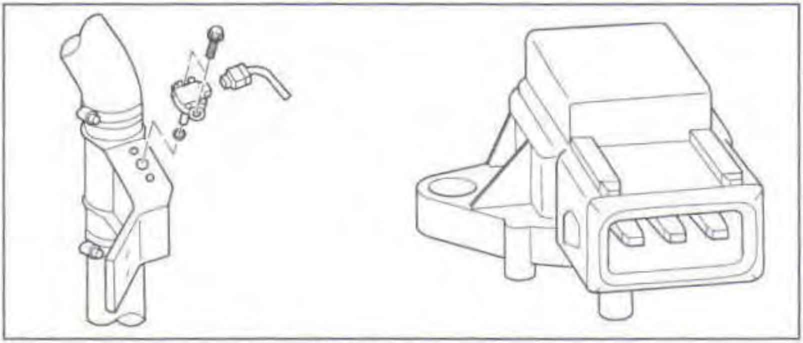


Figure 68 Boost Pressure Sensor

BOOST PRESSURE SENSOR

The boost pressure sensor is mounted to the charge air pipe (Figure 67). The sensor allows the ECM to monitor intake air downstream of the turbocharger.

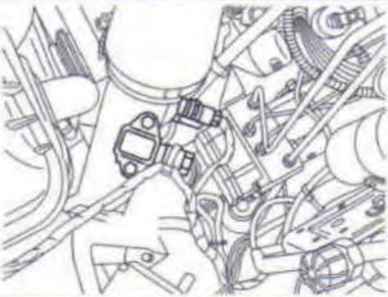


Figure 67 Boost Pressure Sensor Location

The boost pressure sensor is a three-wire sensor with a sensing pressure port on the bottom. The pressure port is inserted into the charge air pipe through an access hole. An O-ring provides the sealing once the sensor is mounted to the charge air pipe (Figure 68). The ECM uses boost pressure combined with intake air temperature to determine the volume of air entering the engine.

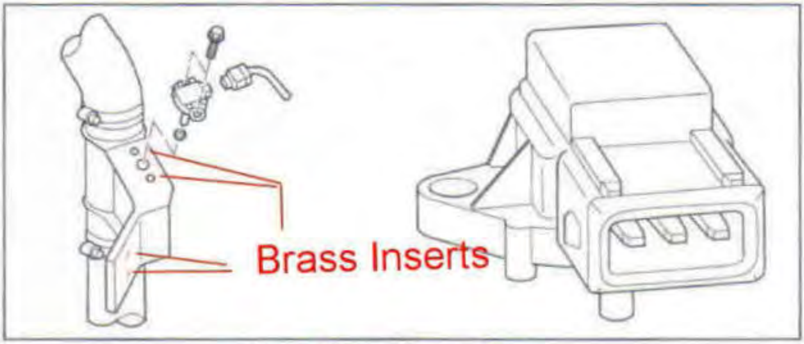


Figure 68 Boost Pressure Sensor

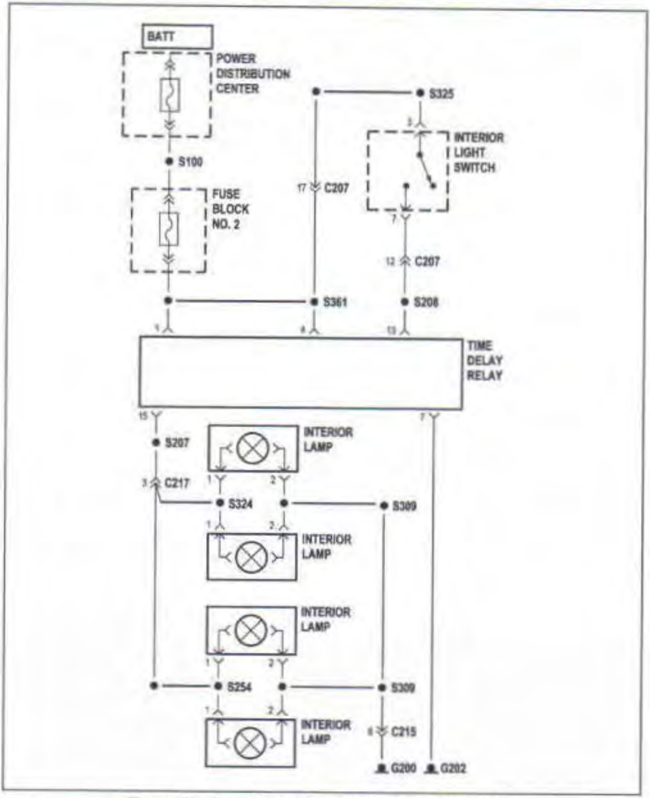


Figure 71 Cargo Area Lamps With Time Delay Relay

OPERATION

The boost pressure sensor consists of piezoresistive elements attached to a measuring diaphragm. The resistance value changes when stress is applied to the diaphragm. The resistors form a measuring bridge, so that when the diaphragm moves the bridge balance is changed. The bridge voltage is a measure for the boost presssure.

The sensor receives a 5-volt reference from the ECM. Sensor ground is also provided by the ECM. The bridge voltage varies from 0.5 to 4.5 volts depending on boost pressure.

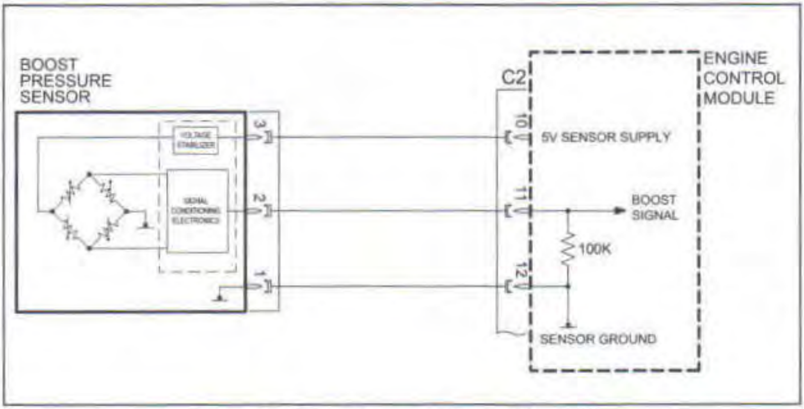


Figure 69 Boost Pressure Sensor Schematic

As boost pressure increases, the boost signal voltage also increases. If the engine is not running, the value sent to the ECM is equal to the atmospheric pressure. The boost pressure operating range is from 0 to 3 bar (0 to 43.5 psi).

Ash Receiver/Cigar Lighter Lamp

The ash receiver/cigar lighter lamp is illuminated any time the multifunction switch is in the "park", or "headlamp on" position. A small lens in the ash receiver bin allows light from the lamp on the halo ring to also illuminate the ash receiver.

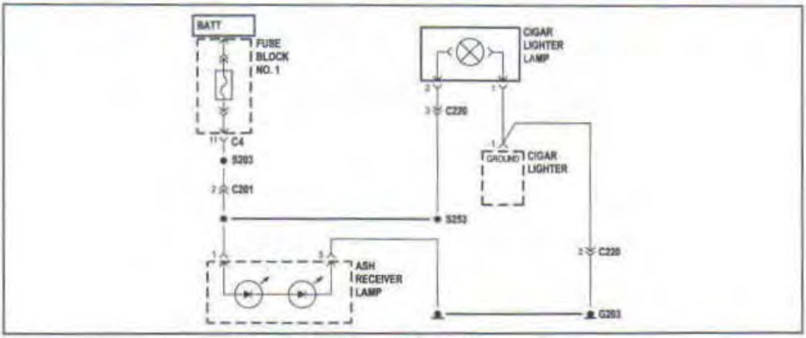


Figure 72 Cigar Lighter Illumination

Dash Illumination

The EMIC is illuminated when the multifunction switch is in the "park" or "headlight on" position. The EMIC illumination level can be adjusted with the "+" and "-" buttons. The other components: SLA, ATC, Ash Tray, and all center stack switches receive voltage from a fuse in fuse block #1 that is energized by a switched input from the multifunction switch.

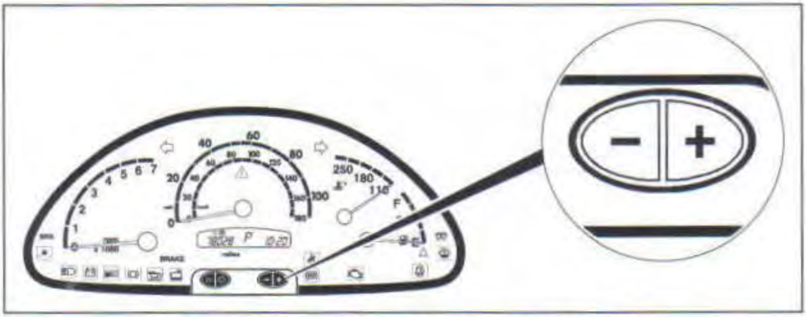


Figure 73 EMIC Illumination Adjustment Buttons

Figure 70 Boost Pressure Sensor Signal (Approximate Values)

Failure Modes

If the boost pressure sensor fails, the ECM records a DTC into memory and continues to operate the engine in limp-in mode. When the engine is operating in this mode, a loss of power will be present, as if the turbocharger was not operating.

The ECM monitors the operation of the boost pressure sensor and stores fault codes related to the following conditions:

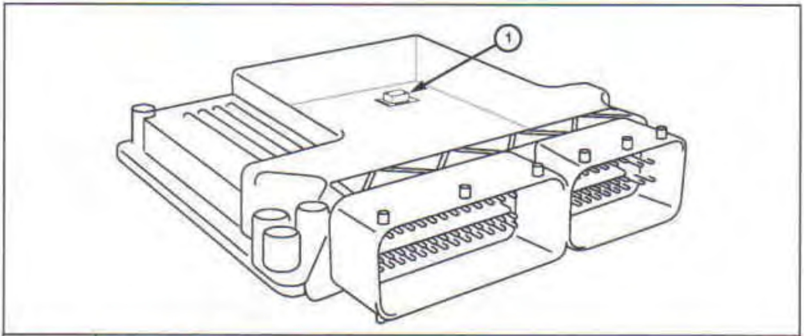
- Signal voltage too low
- Signal voltage too high
- Supply voltage too high or too low

Substitute Values

- If the sensor ground wire has an open circuit, the actual value displayed is 38.29 psi
- If the signal wire has a short circuit to ground or open circuit, the substitute value is 2.90 psi
- If the 5-volt power supply has a short circuit to ground or open circuit, the substitute value is 2.90 psi

BAROMETRIC SENSOR

The barometric sensor, also known as ATM pressure sensor, is integrated into the ECM. The pressure range of the sensor is from 950 to 1100 mbar (13.78 to 15.95 psi). This pressure value can be verified with the diagnostic scan tool.



1	Barometric Sensor

Figure 71 Internal View of ECM, Barometric Sensor Location

Failure Modes

The ECM monitors the operation of the barometric sensor and stores fault codes under any of the following conditions:

- Signal voltage too high
- Signal voltage too low

FUEL RAIL PRESSURE SENSOR

The fuel rail pressure sensor is mounted on the front of the fuel rail. The sensor provides an output voltage to the engine control module that corresponds to the applied pressure.

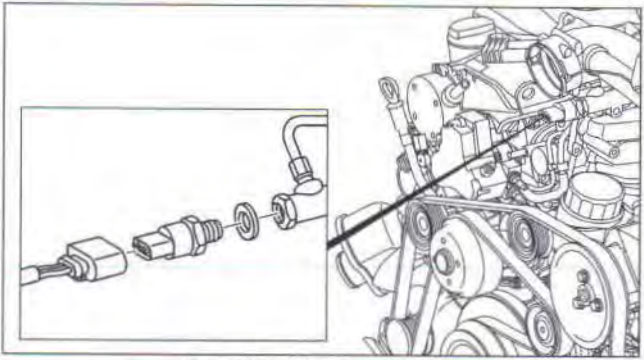
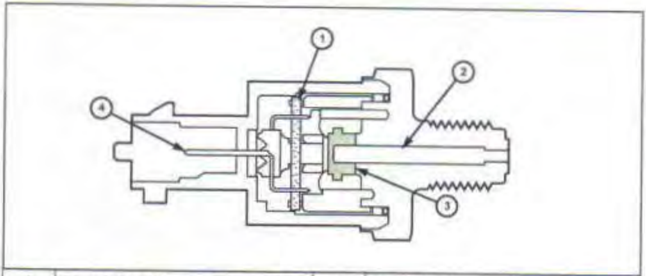


Figure 72 Fuel Rail Pressure Sensor

OPERATION

The fuel rail pressure sensor consists of a high-grade spring steel diaphragm with an attached strain gage. The deflection of the diaphragm changes the resistance of the strain gage. The sensor measures the current fuel rail pressure and sends a voltage signal to the ECM. The ECM then actuates the fuel rail pressure solenoid and fuel quantity valve until the desired rail pressure is achieved. If the rail pressure sensor fails, the engine will run in limp-in mode. The pressure actual value ranges from 200 to 1600 bar (2,900 to 23,205 psi).



1	Signal Conditioning Electronics	3	Metal Diaphragm & Sensor Circuit
2	Fuel Pressure Port	4	Electrical Connector

Figure 73 Fuel Rail Pressure Sensor Construction

The ECM uses the fuel rail pressure input to control the output of the fuel pressure solenoid. The ECM sends a 5 volt supply to the fuel rail pressure sensor. Depending on the fuel rail pressure, the sensor output signal varies from 0.5 to 4.5 volts (Figure 75).

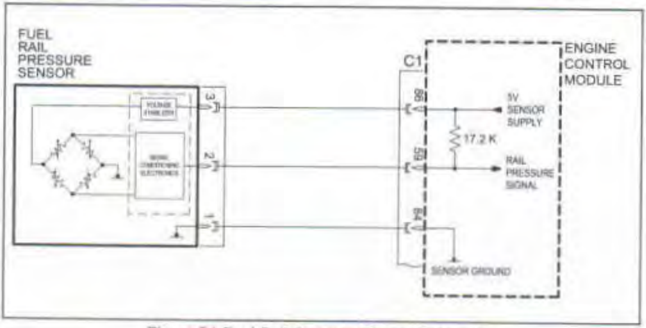


Figure 74 Fuel Rail Pressure Sensor Schematic

Failure Modes

The ECM stores fault codes under any of the following conditions:

- Voltage too high
- Voltage too low
- Voltage too high or too low
- Plausibility between fuel rail pressure sensor and fuel pressure solenoid
- Maximum pressure has been exceeded (inspect the fuel filter if DTC is present)
- Rail pressure too low
- No pressure build up. Fuel pressure solenoid open
- Fuel pressure solenoid stuck in closed position
- Fuel pressure leakage detected
- Control deviation engine speed too high

Substitute Values

The diagnostic scan tool may display a specified rail pressure value of 5801 PSI.

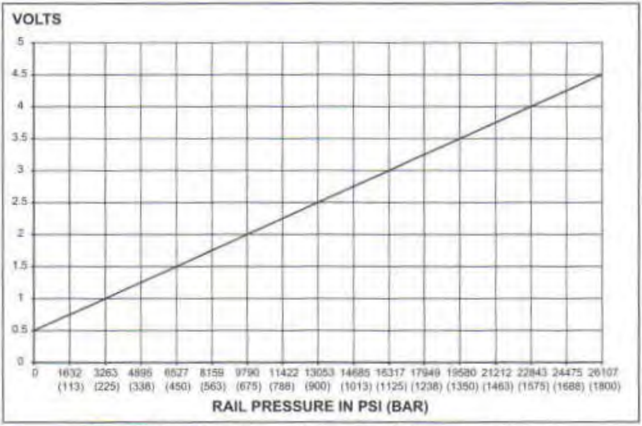


Figure 75 Fuel Rail Pressure Sensor Signal (Approximate Values)

TEMPERATURE SENSORS

INTAKE AIR TEMPERATURE SENSOR (IAT)

The inlet air temperature (IAT) sensor is mounted to the charge air pipe. The IAT is a two-pin sensor, which consists of an NTC resistor in a plastic housing. The IAT is locked in place by two retaining clips and sealed with an O-Ring (Figure 76).

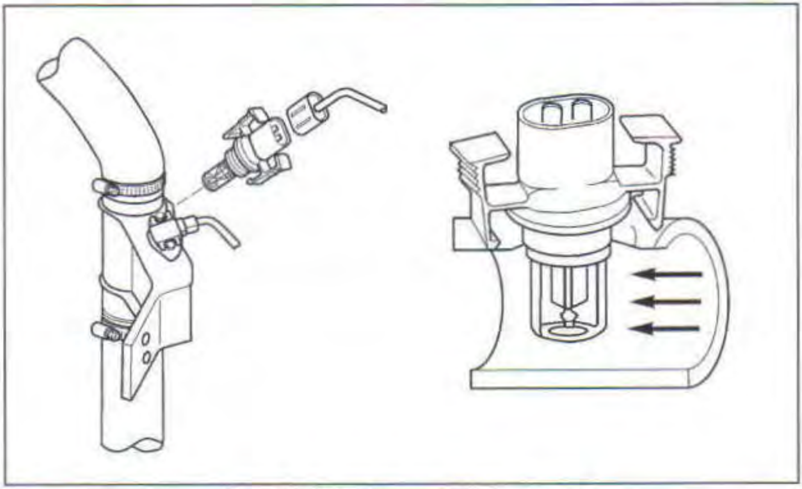


Figure 76 Inlet Air Temperature Sensor

Operation

The NTC resistor located within the IAT changes its resistance in line with the charge air temperature. The ECM sends 5 volts to the NTC resistor and grounds it through the sensor return line. The ECM interprets the voltage as air temperature.

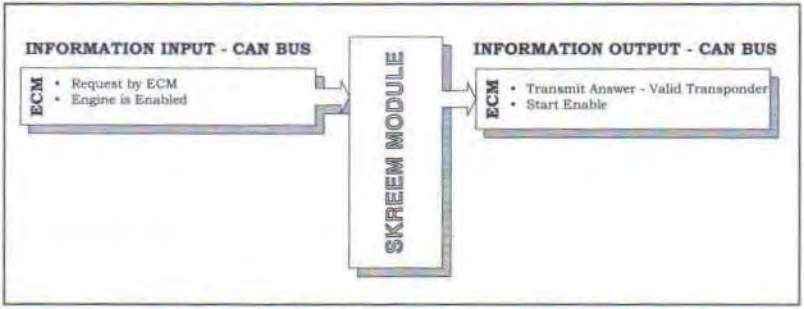


Figure 82 CAN Bus Data Exchange, SKREEM

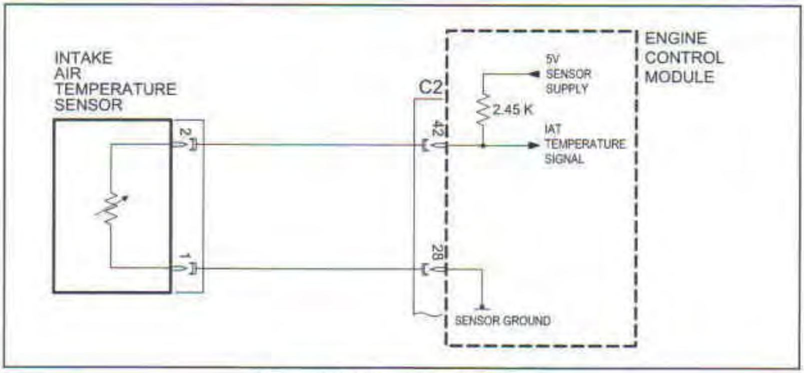


Figure 77 IAT Sensor Schematic

The IAT temperature value ranges from -40°C to 150°C (-40°F to 302°F). If the engine is cold, the IAT actual value equals the ambient temperature.

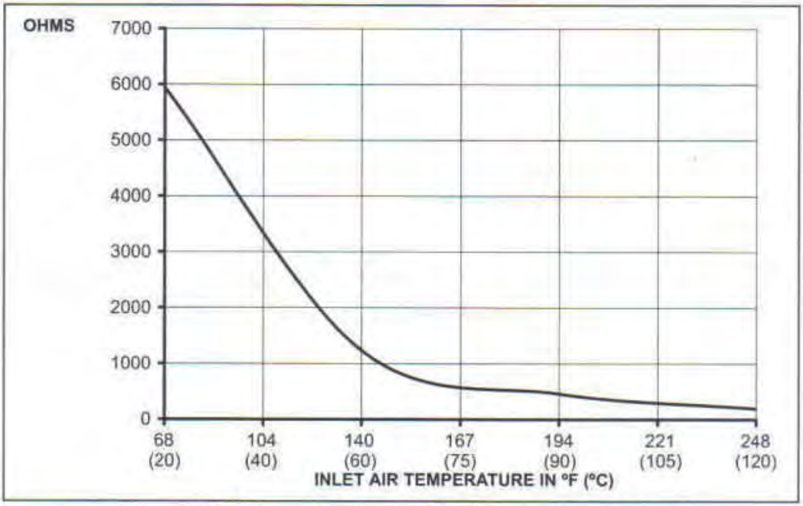


Figure 78 IAT Sensor Resistance Chart (Approximate Values)

Failure Modes

The ECM monitors the operation of the inlet air temperature sensor and stores fault codes under any of the following conditions:

- Signal voltage too high
- Signal voltage too low

Substitute Values

- If the signal wire is shorted to ground, the actual value displayed is 150°C (302°F)
- If the signal wire is shorted to positive, the actual value displayed is -40°
- If the signal wire has an open circuit, the actual value displayed is -40°

COOLANT TEMPERATURE SENSOR

The engine coolant temperature sensor (ECT) is a two-pin sensor located in the thermostat housing. The sensor consists of a plastic housing, which contains an NTC resistor. The ECT is locked in place by a locking spring and sealed with an O-Ring.

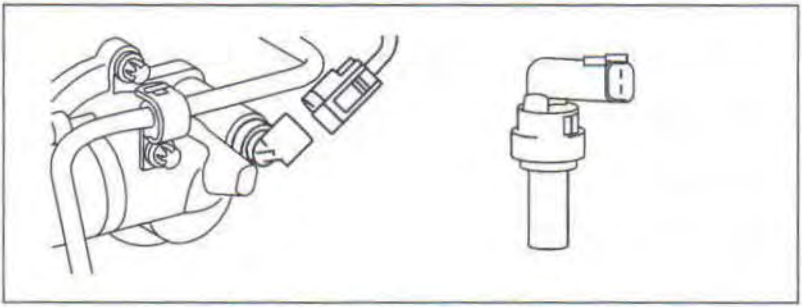


Figure 79 Coolant Temperature Sensor

Operation

The ECM sends 5 volts to the NTC resistor and grounds it through the sensor return line. The ECM determines the coolant temperature based on the voltage drop within the sensor circuit and changes the fuel supply accordingly.

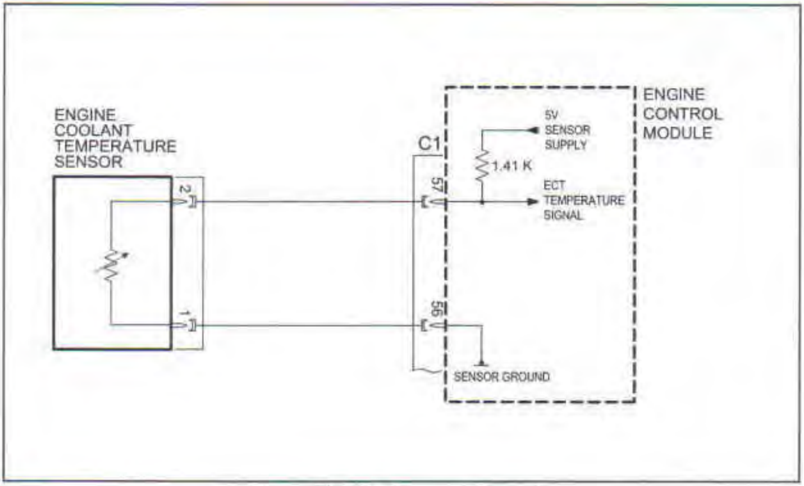


Figure 80 ECT Sensor Schematic

The ECT temperature value ranges from -40°C to 140°C (-40°F to 284°F). If the engine is cold, the ECT actual value is equal to the ambient temperature.

Failure Modes

The ECM monitors the operation of the coolant temperature sensor and stores fault codes under any of the following conditions:

- Signal voltage too high
- Signal voltage too low
- Operating temperature not reached

Substitute Values

- If the signal wire is shorted to ground the actual value displayed is 140°C (284°F)
- If the signal wire is shorted to positive, the actual value displayed is -40°
- If a wire has an open circuit, the actual value displayed is -40°

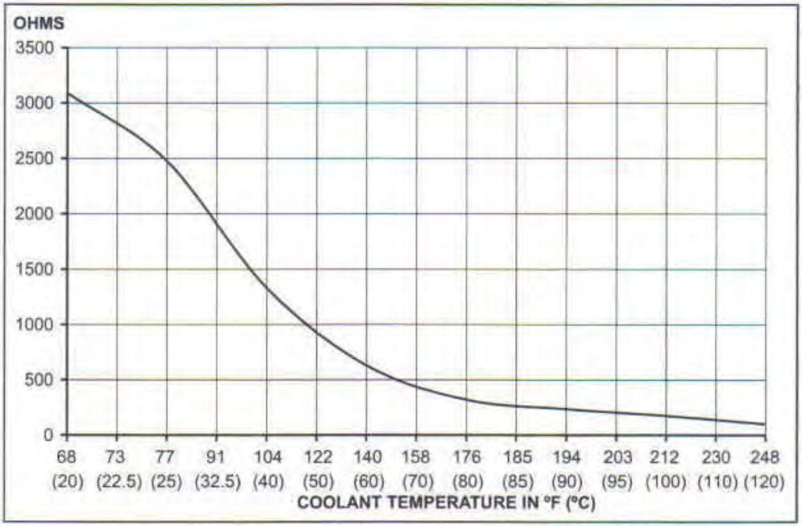


Figure 81 ECT Sensor Resistance Chart (Approximate Values)

MODULE 6 MODULES ON CAN BUS

SENTRY KEY REMOTE ENTRY MODULE

DESCRIPTION

The Sentry Key Remote Electronic Entry Module (SKREEM) contains the functions for the Sentry Key Immobilizer Module (SKIM) and the Remote Keyless Entry (RKE) Module.

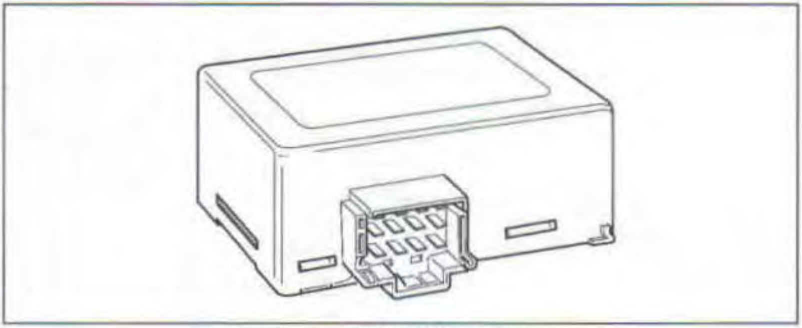


Figure 83 SKREEM Module

Sentry Key Immobilizer System (SKIS)

The Sentry Key Immobilizer receives a code from the transponder which is located in the ignition key. Comparing the received code with the stored codes, the SKREEM module decides if there is a drive authorization for this key or not. An "Authorized To Start" or "Not Authorized To Start" message is then sent via CAN-Bus to the ECM.

If there is no drive authorization, the engine will not start and a "Start Error" message will appear in the display on the instrument cluster.

The transponder works independently from the radio remote control. The transponder is energized without wires. The transponder code is sent via the transponder ring to the SKREEM module.

FUEL TEMPERATURE SENSOR

The temperature sensor is located at the front of the engine, on the high-pressure pump flange. The sensor detects the fuel temperature and supplies information to the engine control module (ECM). If the fuel is too warm, the rail pressure in the system is lowered. The controlled quantity of the pressure regulating valve is reduced and the fuel temperature lowered. The NTC resistor integrated in the fuel temperature sensor alters its electrical resistance in line with the fuel temperature. The electrical resistance becomes less as the temperature rises.

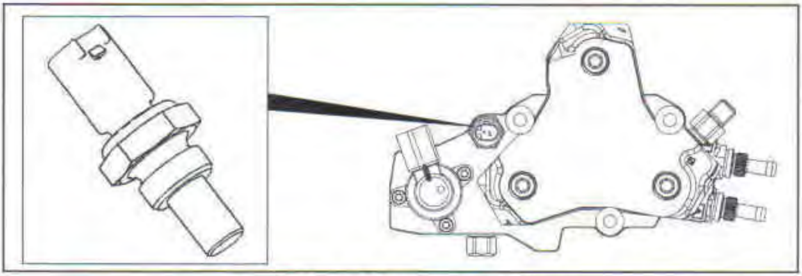


Figure 82 Fuel Temperature Sensor

The sensor ranges from - 40°C (-40°F) to 120°C (248°F). If the engine is cold, the actual value sent will read ambient temperature. The value rises after the engine has been started.

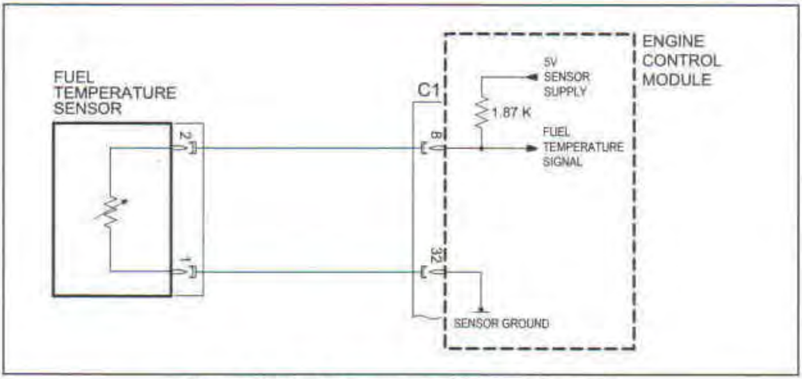


Figure 83 Fuel Temperature Sensor Schematic

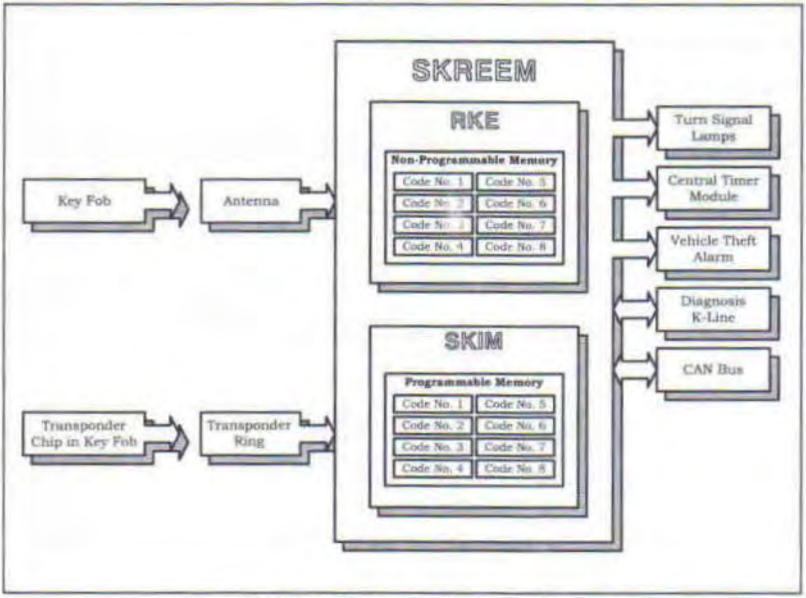


Figure 84 Block Diagram, Inputs and Outputs

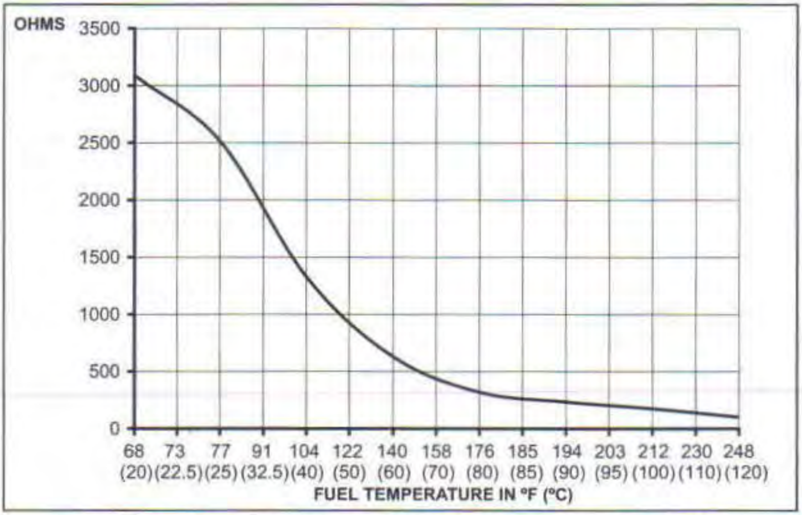


Figure 84 Fuel Temperature Sensor Resistance Chart (Approximate Values)

Failure Modes

The ECM monitors the operation of the fuel temperature sensor and stores fault codes under any of the following conditions:

- Signal voltage too high
- Signal voltage too low

Substitute Values

- If the signal wire is shorted to ground, or if the sensor wires short circuit to each other, the actual value displayed is 120°C (248°F)
- If the signal wire is shorted to positive, the actual value displayed is -40°. The intake temperature value displayed is also -40°
- If a wire has an open circuit, the actual value displayed is -40°

Key Fob / Transmitter Keys

The purpose of the key fob is to lock and unlock the vehicle via the central locking system and to release the drive authorization system. The key fob contains an RF transmitter, a transponder chip for the drive authorization system, two 3-volt internal batteries, and a mechanical key.

Figure 85 Key Fob

When the key fob button is pressed a radio frequency signal is transmitted to the SKREEM. The SKREEM receives the signal via an antenna.

With the key fob, all doors can be locked and unlocked via the central locking system. If equipped the anti-theft alarm is also activated or deactivated.

The SKREEM contains in its memory a list of fixed codes for transmitter keys. The module receives the radio frequency signal from the key fob and compares the fixed code contained in the signal. If the code matches one of the active codes in the SKREEM memory, it communicates with the CTM to lock or unlock the doors.

If the code received does not match any of the active codes in the SKREEM memory, the communication with the CTM is inhibited.

The key fobs use batteries to energize the RF transmitter. If the batteries are discharged, it is still possible to lock or unlock the vehicle using the mechanical key or the central locking switch in the dashboard. An LED in the key fob shows the status of the batteries.

ENGINE OIL SENSOR

The engine oil sensor is a three-wire sensor located on the left side of the oil pan, near the oil drain plug (Figure 85). The oil sensor detects oil temperature, oil level and oil quality. The sensor operates on the capacitance principle and an integrated electronic circuit analyzes the three signals.

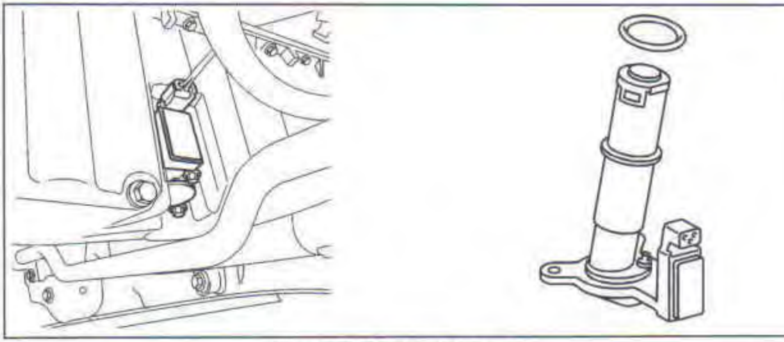


Figure 85 Engine Oil Sensor

Operation

The engine oil sensor consists of a platinum temperature element (Pt 1000), two cylindrical measuring capacitors and integrated electronics (Figure 86). The platinum element measures the oil temperature. One of the capacitors measures the oil quality, and is totally immersed in oil. The second capacitor measures the oil level and is positioned between the expected minimum and maximum oil levels. The measured values are transmitted as pulse-width-modulated (PWM) signals to the ECM.

The oil level sensor has a measuring range of 80 mm (3.15 in.). The minimum measuring limit for the oil level is approximately 40 mm (1.57 in.) The maximum measuring limit is approximately 120 mm (4.72 in.). The accuracy of the oil level measurement is approximately ±3 mm (0.118 in.).

The oil quality is used to determine oil change intervals. The engine oil condition measurement is based on the dielectric properties of the oil (dielectrics: does not conduct electricity). As engine oil breaks down and additives are depleted, the dielectric properties gradually increase. The oil quality sensor determines the dielectric constant number of the oil in a scale from 1 to 6. An oil quality number between 1 and 4 is good. A number between 5 and 6 indicates poor oil quality.

Confirmation of the locked or unlocked state is accomplished via the turn signals. (The process is confirmed by 3 flashes for locked status and 1 flash for unlocked status).

Note: The batteries operate with the remote keyless entry system. They are independent of the drive authorization system.

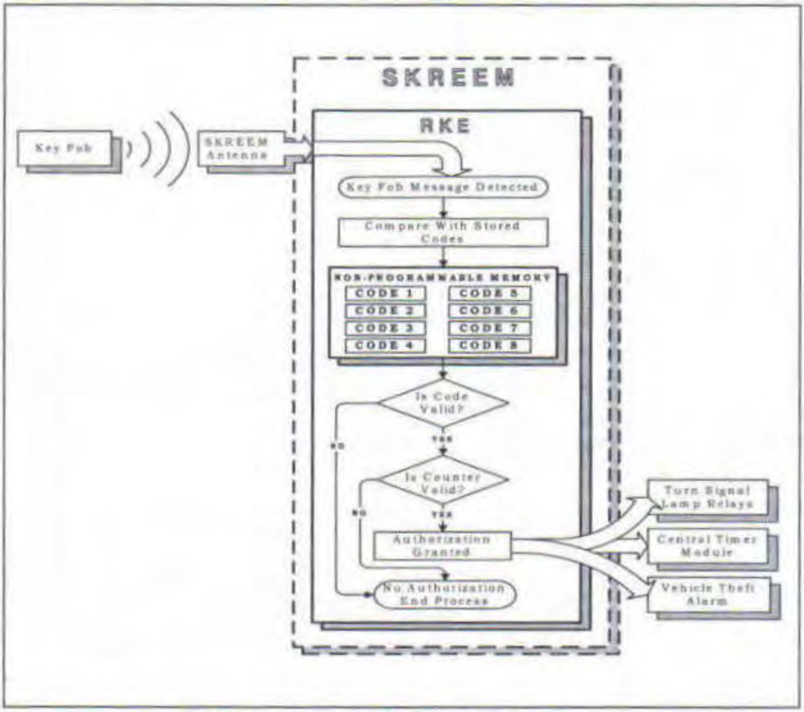
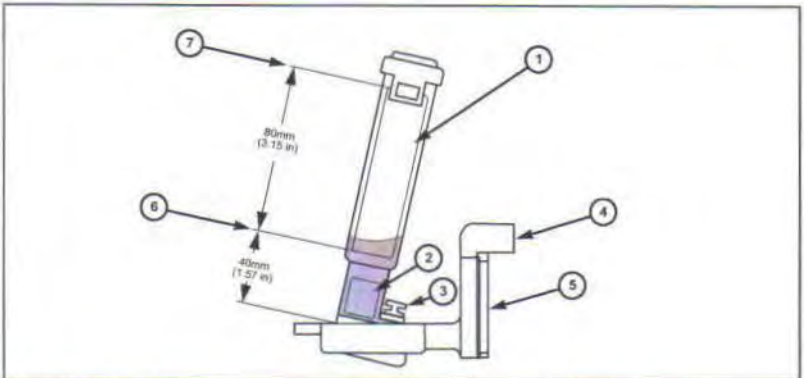


Figure 86 Block Diagram, RKE Function



1	Oil Level Sensor	5	Electronic Circuit
2	Oil Quality Sensor	6	Start of Measuring Range
3	Oil Temperature Sensor	7	End of Measuring Range
4	Electrical Connector		

Figure 86 Engine Oil Sensor

The engine oil sensor constantly supplies data to the ECM in the form of information blocks (Figure 87). Each information block consists of three successive square wave signals of 100 ms each, followed by a synchronization pause of 1 second + 200 ms. A measured variable is assigned to each square-wave signal (A, B, C). The values are determined by the ON/OFF ratio, which ranges from 19 to 81%.

Refer to the examples shown in Figure 87. The first information block (1) contains square wave signals which fall between the 20-80% window. The values for oil temperature (60%), oil level (50%) and oil quality (30%) are in order.

The second information block (2) contains square wave signals with ON/OFF ratios above 80%. The oil temperature signal (81%) indicates a temperature higher than 160°C (320°F), the oil level signal (80%) indicates an oil level higher than 80 mm (3.15 in.), and the oil quality (81%) indicates good oil quality.

The third information block (3) contains square wave signals with ON/OFF ratios below 20%. The oil temperature signal (19%) indicates a temperature lower than -40°C, the oil level signal (19%) indicates an oil level lower than 0 mm, and the oil quality (15%) indicates poor oil quality.

DRIVE AUTHORIZATION

The drive authorization system is intended to prevent unauthorized persons from removing the vehicle. When the ignition is switched on, the drive authorization is checked and the ECM is enabled if the authorization is OK.

Operational sequence

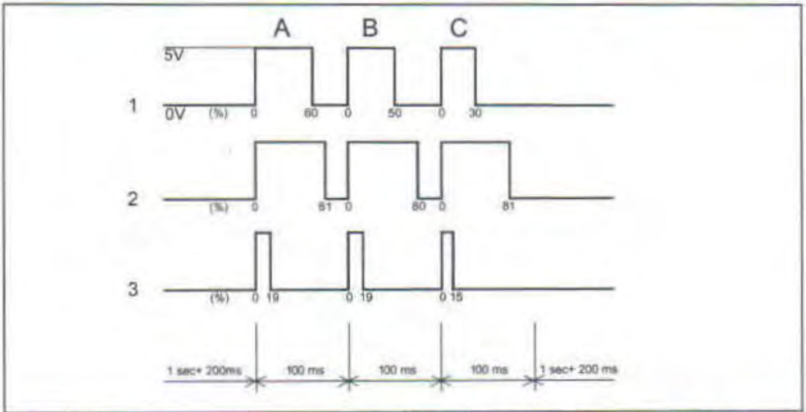
1. The ignition (terminal 15) is switched on
2. The transponder ring is energized, building a magnetic field. The field supplies the transponder in the key with inductive energy.
3. The SKREEM control module transmits a password and the number of the data block to be retrieved in the transponder, via the transponder ring to the transponder in the key (the password is specific to the vehicle and the key).
4. On receipt of a valid password, the transponder code validity is verified by the SKREEM control module.
5. When its validity has been verified, the Engine Control Module is enabled over the CAN bus.

Note: The drive authorization system is independent of the locking status of the central locking.

Engine startup is not enabled if:

- No request from the ECM is detected after ignition "on".
- No acknowledgment signal from the ECM is detected within 1.5 seconds after the request.
- The transponder code is invalid

If the startup is not enabled, the instrument cluster receives a signal and displays "Start Error".



A	Oil Temperature Signal	1	On/Off Ratio Between 20-80%
B	Oil Level Signal	2	On/Off Ratio > 80%
C	Oil Quality Signal	3	On/Off Ratio < 20%
T	Time Period		

Figure 87 Engine Oil Sensor Information Block

If the engine is cold, the oil temperature actual value is equal to the ambient temperature actual value. The actual value rises after the engine has been started.

Failure Modes

The ECM monitors the operation of the oil sensor and stores fault codes under any of the following conditions:

- Synchronization pause error
- Wire open or shorted to ground
- Supply voltage too high or too low
- Timing error
- Oil level plausibility
- Oil quality plausibility
- Water contamination

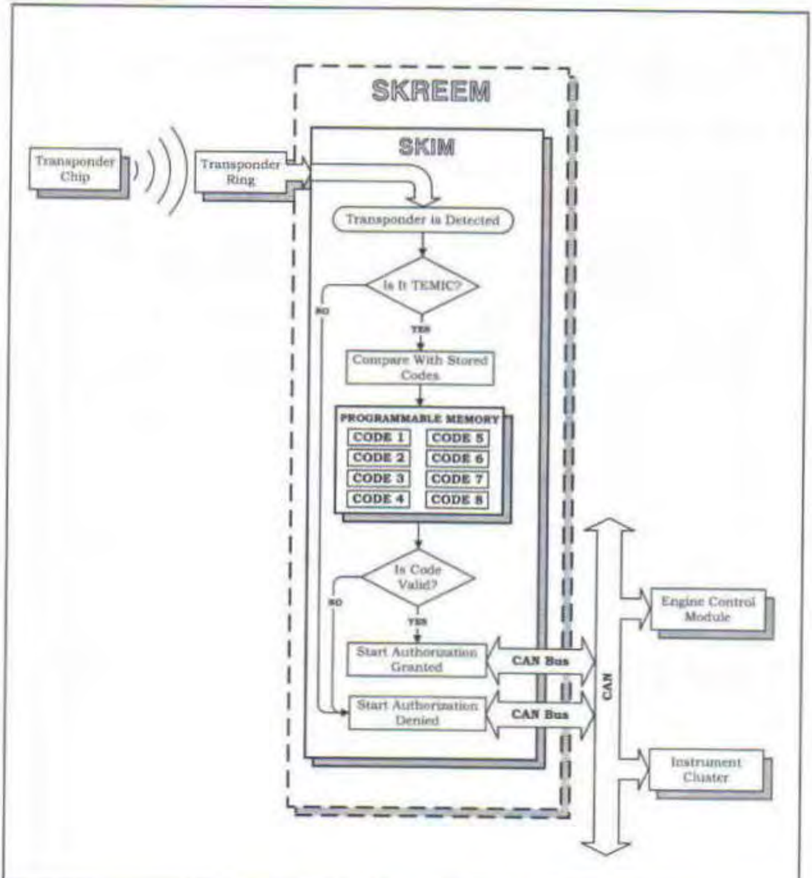


Figure 87 Block Diagram, SKIM Function

Substitute Values

The engine coolant temperature is used as a substitute value under the following circumstances:

- Signal wire is shorted to ground
- 5-volt supply wire is shorted to ground
- Open circuit in any wire

An oil quality value of 2 is displayed under the following circumstances:

- Signal wire is shorted to ground
- 5-volt supply wire is shorted to ground
- Open circuit in any wire

An oil level value of 40 mm (1.57 in.) is displayed under the following circumstances:

- Signal wire is shorted to ground
- 5-volt supply wire is shorted to ground
- Open circuit in any wire

Transponder Ring

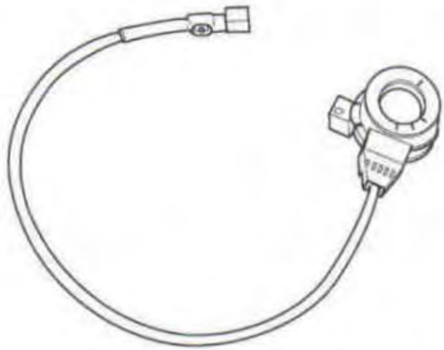


Figure 88 Transponder Ring

The transponder ring snaps onto the starter switch housing. It serves as the data link between the transponder and the SKREEM. Actuation of the transponder ring builds up a magnetic field which supplies energy to the transponder in the transmitter key and allows data to be transferred inductively.

DISABLING THE TRANSPONDER (SKIM FUNCTION)

When a key fob or a mechanical key with transponder is lost or stolen, it is necessary to erase the affected transponder code using the diagnostic scan tool. However, the process does not allow to erase only one key. All the active keys will be erased and the remaining keys (not stolen or lost) should be reprogrammed. It is necessary to relearn the keys still present to the SKREEM.

When a key (lost or stolen) is found or after receiving an additional key, it is necessary to relearn the key to the SKREEM.

Use the specific form when it is necessary to order an additional key fob, mechanical blade for key fob, mechanical key with transponder, cylinder locks or ignition tumbler.

MASS AIR FLOW SENSOR (MAF)

The Mass Air Flow (MAF) Sensor is located in the air intake duct between the air filter and the turbocharger (Figure 88). The MAF sensor uses semiconductor technology throughout, and is used to calculate the air mass flowing past it per time unit.
The ECM uses the mass air flow (MAF) sensor value for EGR control, particularly at high engine load. The MAF sensor also supplies an air temperature input to the ECM.

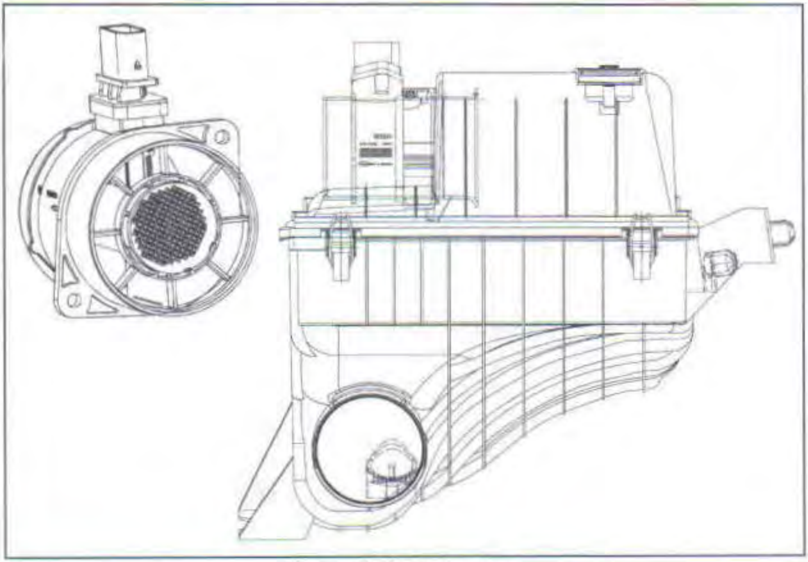


Figure 88 MAF Location

DISABLING THE RADIO FREQUENCY CODE (RKE FUNCTION)

A lost or stolen key fob must also be disabled to avoid unauthorized vehicle entry. The procedure involves turning the ignition key OFF/ON in the proper sequence, and pressing either the lock or unlock button of the remaining key fobs. Only the key fobs that are present while the procedure is carried out will remain active.

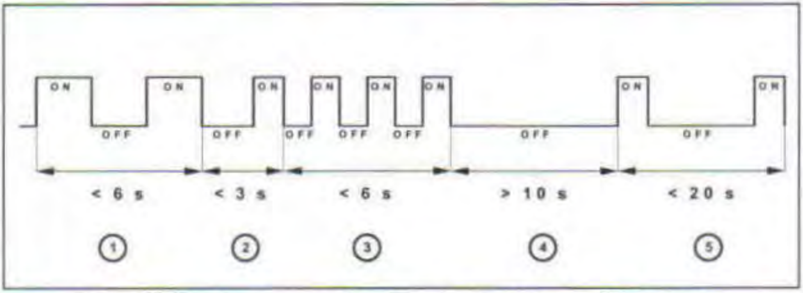


Figure 89 Five-Step Ignition Sequence for Disabling the RKE Function

PROCEDURE (SEE FIGURE 89)

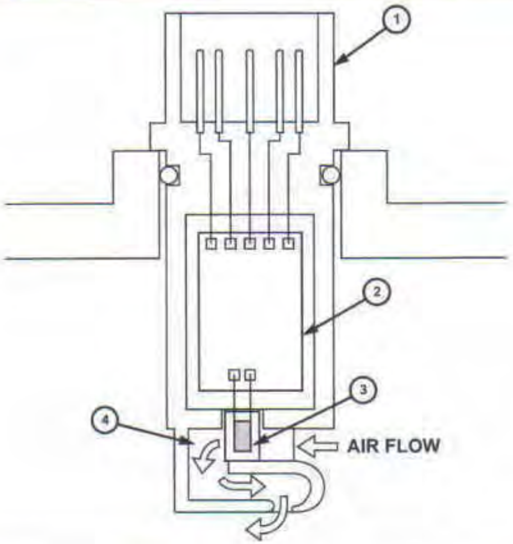
1. Switch the ignition ON and OFF twice within 6 seconds.
2. Press any key fob button (lock or unlock) within 3 seconds after turning the ignition OFF.
3. Press any key fob button (lock or unlock) 3 more times within 6 seconds.
4. Wait for 10 seconds.
5. Press any button of ALL key fobs belonging to the vehicle at least once within the next 20 seconds.

Note: If no key fob buttons are pressed in step 5, none of the key fobs will be enabled or disabled.

CONSTRUCTION

The MAF sensor contains an internal measuring tube with deflector screen. The shape of the measuring tube removes whirl effects from the incoming air. The deflector screen protects the sensor element against dirt and contamination. The screen separates water from the intake air and prevents clogging by dust particles.

The sensor uses a micromachined sensing element, which is etched from a silicon chip which is only a few thousandths of a millimeter thick. An integrated temperature sensor measures the incoming air temperature. A hybrid electronic circuit within the MAF sensor evaluates and conditions the sensor signals.



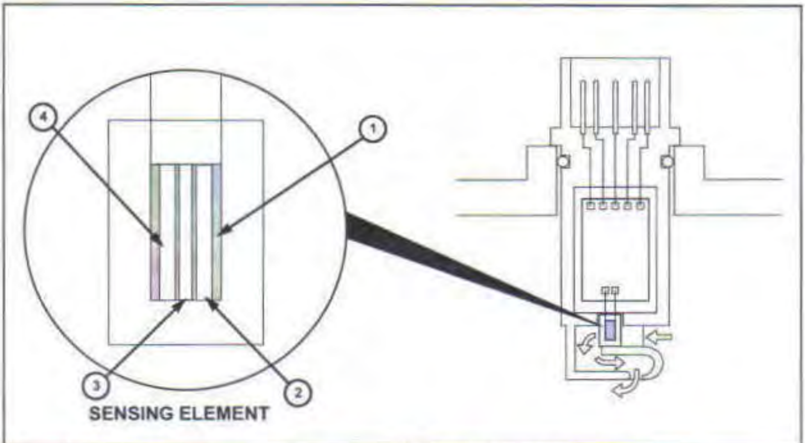
1	Electrical Connector	3	Sensing Element
2	Hybrid Circuit	4	Measuring Tube

Figure 89 Mass Air Flow Sensor

Note: Plug may have only 4 pins. See page #97

OPERATION

A micromechanical sensor diaphragm on the sensor element is heated by a central heating resistor and held at a constant temperature of 160°C (320°F) above the intake air temperature. The temperature on the diaphragm is measured by two resistors. Without air flow, the temperature is the same on both resistors. When air flows over the sensor element, a temperature differential is created between both resistors. The temperature differential is a measure of the air mass flow.



1	Sensor Diaphragm	3	Central Heating Resistor
2	Upstream Measuring Resistor	4	Downstream Measuring Resistor

Figure 90 MAF Sensing Element

The ECM provides a 12-volt signal and ground to the electronic evaluation circuit within the MAF sensor. The difference between both resistor values is converted by the electronic evaluation circuit within the MAF sensor into an air mass value. The measured air mass value is sent to the ECM as a digital signal with a 50% duty cycle and a variable frequency, which depends on air mass flow. The signal from the integrated intake air temperature sensor is also evaluated and converted into a PWM signal.

Note: Plug may have only 4 pins. See page #97

DRIVING SAFETY SYSTEMS

The Sprinter van can be equipped with the following driving safety systems:

- Antilock brakes (ABS)
- Acceleration skid control (ASR)
- Electronic stability program (ESP)
- Brake assist system (BAS)
- Electronic brake force distribution (EBD)

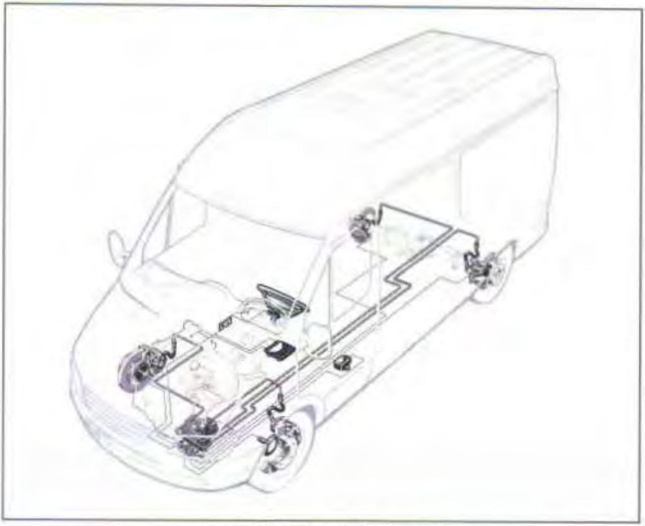


Figure 90 Driving Safety Systems

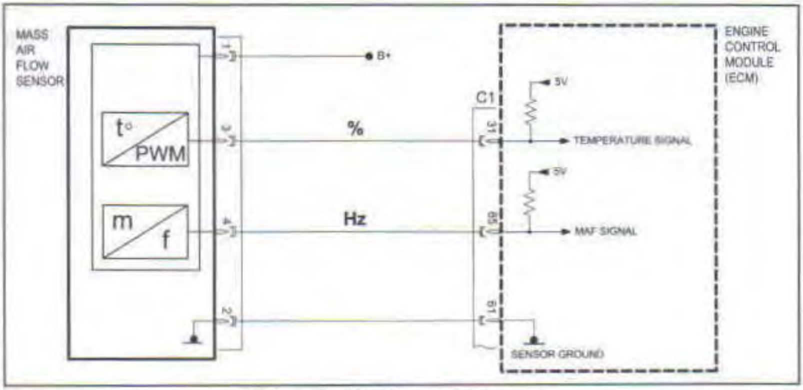


Figure 91 MAF Sensor Schematic

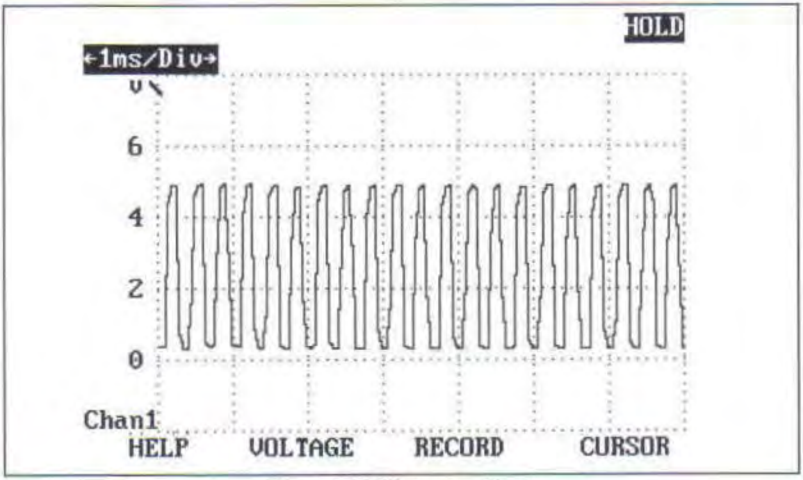


Figure 92 MAF Sensor Signal

Note: Only 4 wires connecting MAF to ECM

ANTILOCK BRAKES (ABS)

The antilock brake system is designed to prevent the wheels from locking. The vehicle can be steered around an obstacle even during a full brake application. The antilock brakes are operational after the ignition is switched on and the vehicle reaches a speed of 4 mph. All braking actions in the lock-up range are performed at control speeds at and above 6 mph.

The controller antilock brake (CAB) uses the input signals to decide which functions are to be performed by the hydraulic system:

- Normal Operation
- Pressure Hold
- Pressure Reduction
- Pressure Build-Up

When there is no speed differential detected between the individual wheels, all solenoid valves in the hydraulic control unit (HCU) are in the "at rest" position.

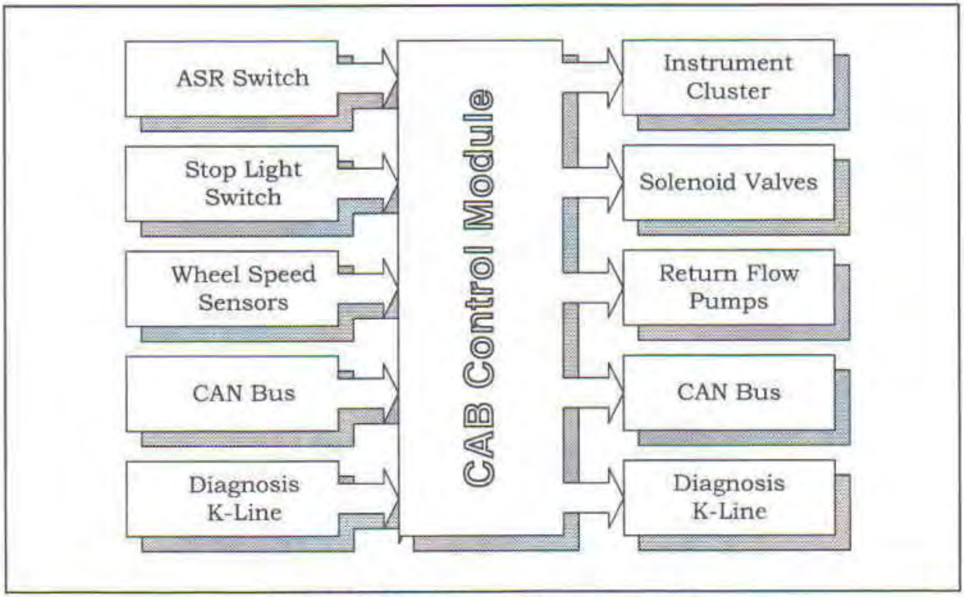


Figure 91 CAB Module Input/Output Block Diagram

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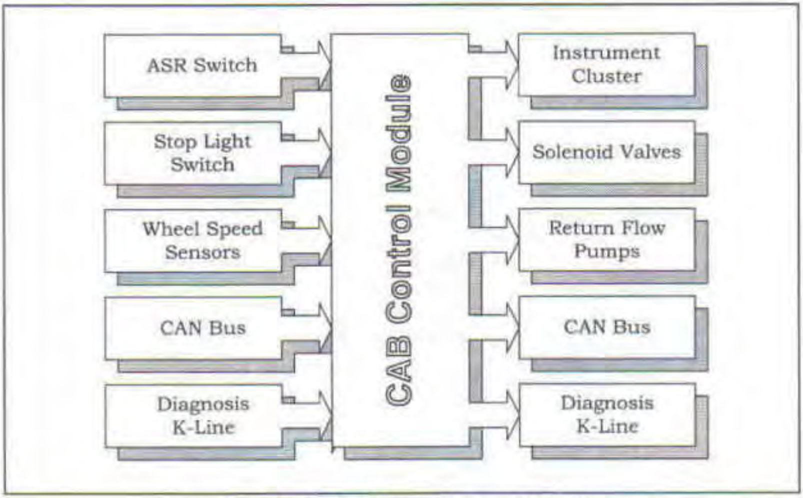


Figure 91 CAB Module Input/Output Block Diagram

Failure Modes

The ECM monitors the operation of the MAF sensor and stores fault codes under any of the following conditions:

- Signal voltage too low
- Signal voltage too high
- Supply voltage too high or too low
- Plausibility

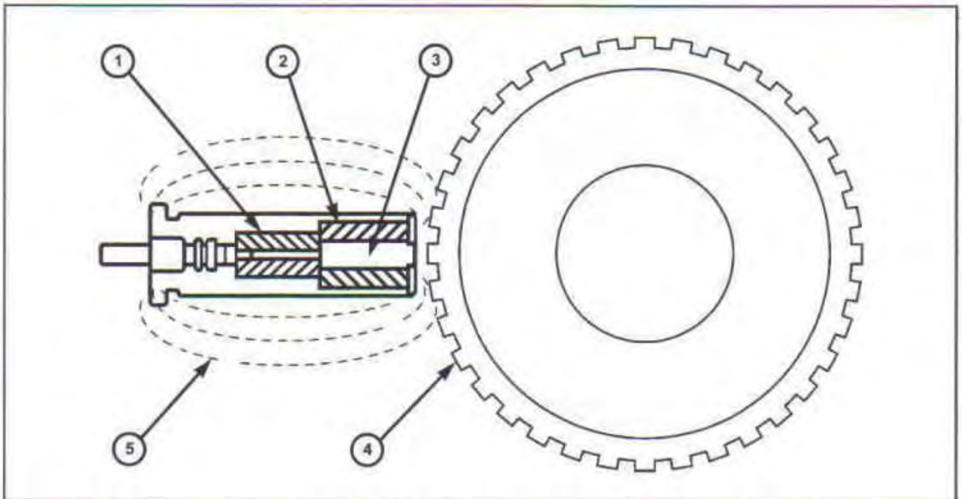
The antilock brake system consists of the following main components:

- Wheel speed sensors
- Hydraulic control unit (HCU)
- Controller antilock brake (CAB)

WHEEL SPEED SENSORS

The inductive wheel speed sensors provide the CAB module with information on wheel speed. The sensor consists of a magnet core and a coil.

The leading edge of each tooth on the tone wheel generates a positive signal in the position sensor, while the trailing edge creates a negative signal. When the tone wheel is rotating, an alternating current is produced as a result. The period of the signal is the time required by the tone wheel to turn through the gap between two teeth.



1	Permanent Magnet
2	Coil
3	Pole Pin
4	Tone Wheel
5	Magnetic Field

Figure 92 Wheel Speed Sensor and Tone Wheel

The clearance between the wheel speed sensor and the teeth of the tone wheel is fixed by the installation position and is not adjustable. The sensor is held in its mounting

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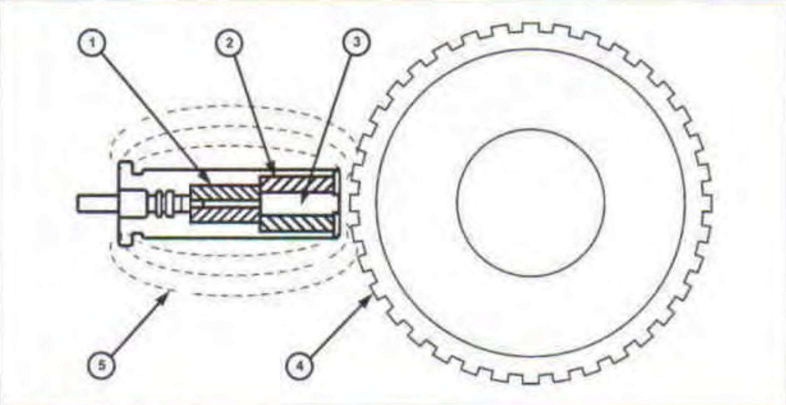

1	Permanent Magnet
2	Coil
3	Pole Pin
4	Tone Wheel
5	Magnetic Field

Figure 92 Wheel Speed Sensor and Tone Wheel

The clearance between the wheel speed sensor and the teeth of the tone wheel is fixed by the installation position and is not adjustable. The sensor is held in its mounting hole by a spring bushing. When installed in the vehicle the sensor is positioned against the tone wheel, and the gap is set automatically when driving. The wheel bearing play and elastic deformation of the axle result in the speed sensor positioning itself the correct distance from the sensor.

CONTROLLER ANTILOCK BRAKE (CAB)

The controller antilock brake (CAB) is mounted to the hydraulic control unit (HCU). The CAB/HCU assembly is located under the hood. The CAB controls the various functions of the hydraulic unit (HCU). The CAB module is supplied with power via fuse #5 in Fuse Block No.1.

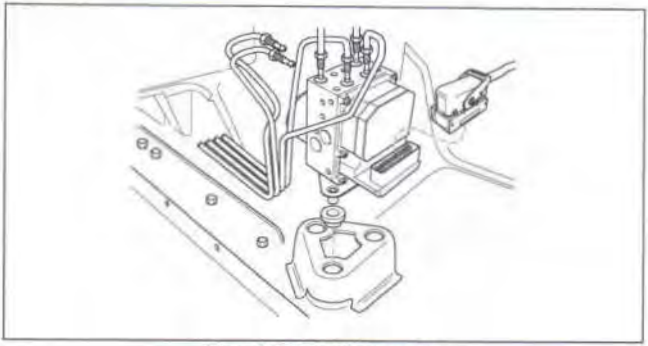

Figure 93 CAB/HCU Assembly

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CONTROLLER ANTILOCK BRAKE (CAB) See Below

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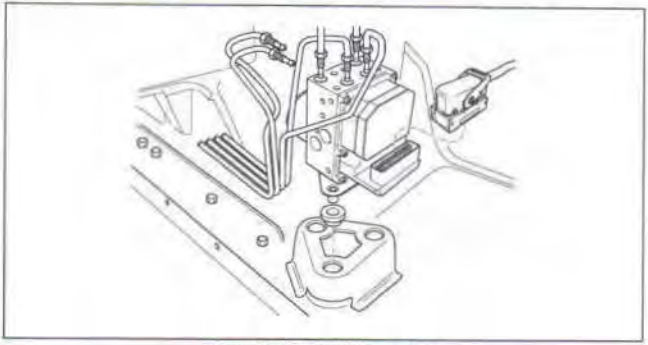


Figure 93 CAB/HCU Assembly

Adjustment per Doktor A.

Unless the bore is clean annd shiny you need to remove parts to see the gap. Then you can gently tap the sensor to adjust the gap closer if needed.

http://sprinter-source.com/forum/showthread.php?p=163321#post163321

The controller antilock brake (CAB) performs approximately 4 to 10 control cycles per second, depending on the road surface conditions. The control cycle for one wheel is the following:

From the alternating voltage generated from the wheel speed sensor, the electronic control module calculates the wheel rotation, deceleration and acceleration signals. By combining the individual wheel speeds, a "reference speed" is calculated, which approximates to the actual vehicle speed. Slip signals are derived from comparing the wheel speed and the reference speed.

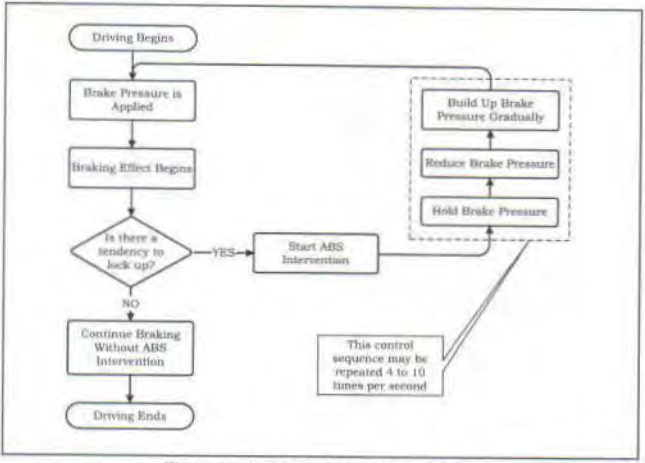


Figure 94 Anti-Lock Brakes Control Cycle

HYDRAULIC CONTROL UNIT (HCU)

The hydraulic control unit (HCU) consists of twelve solenoid valves and a return flow pump. There are two valves for each wheel brake cylinder and another two valves per brake diagonal circuit. When the ABS is inactive, the brake pressure produced by the driver travels direct to the brake cylinders (pressure build-up function). By actuating certain valves the pressure can either be held (pressure holding function) or reduced with the aid of the return flow pump (pressure reduction function). It is not possible to increase the brake pressure beyond the pressure produced by the driver with the brake pedal.

Table 4 Component Description, Hydraulic Unit

ASV	Inlet Valve (ASR)
AVHL	Outlet Valve Rear Left (ABS)
AVHR	Outlet Valve Rear Right (ABS)
AVVL	Outlet Valve Front Left (ABS)
AVVR	Outlet Valve Front Right (ABS)
D	Dampening Chamber
EVHL	Inlet Valve Rear Left (ABS)
EVHR	Inlet Valve Rear Right (ABS)
EVVL	Inlet Valve Front Left (ABS)
EVVR	Inlet Valve Front Right (ABS)
VL	Left Front Wheel
VR	Right Front Wheel
HL	Left Rear Wheel
HR	Right Rear Wheel
RVR	Non-Return Valve
SPK	Accumulator
USV	Change Over Valve (ASR)

ANTI-LOCK BRAKES CONTROL PHASES

- **Pressure Hold** - If a wheel is about to lock up due to excessive pressure in the brake caliper (a situation which is detected from the wheel speed sensor input) then the pressure is kept constant by closing both the pressure holding solenoid valve (EVXX), and pressure reducing solenoid valve (AVXX).

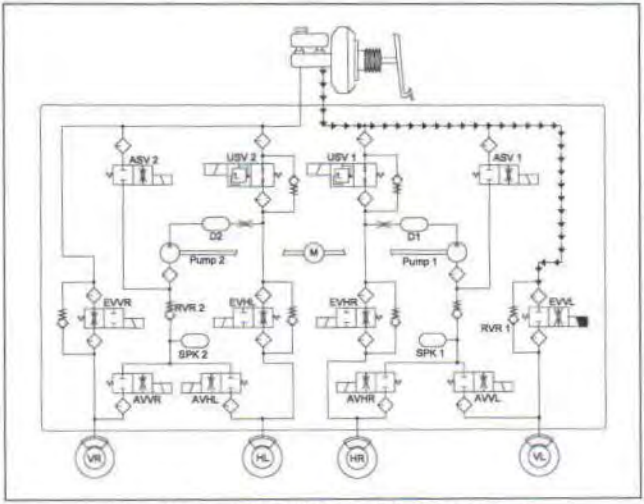


Figure 95 Pressure Hold Phase, Left Front Wheel Circuit

- **Pressure Reduction** - If the tendency to lock up continues to exist because the constant pressure is still too high, the pressure is reduced by opening the pressure reducing solenoid valve (AVXX). The brake fluid is pumped back to the master cylinder through the open pressure reducing solenoid valve (AVXX), a reservoir and check valve (RVR) by the return pump (RFP). The brake fluid is pumped upstream of the brake master cylinder in order to not exhaust its capacity.

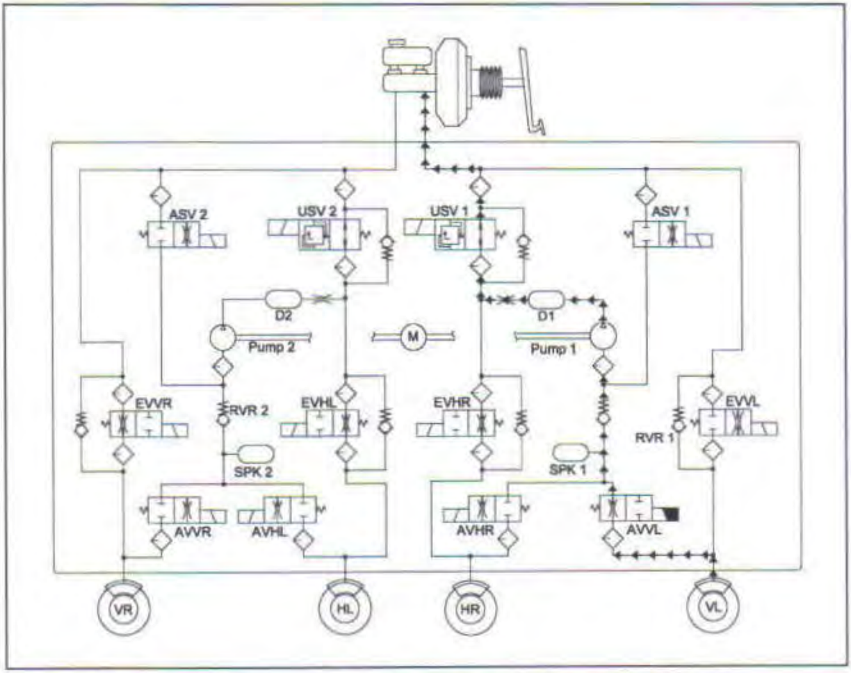


Figure 96 Pressure Reduction Phase, Left Front Wheel Circuit

- **Pressure Build-Up Phase** - If re-acceleration of the wheel exceeds a threshold value, the pressure is temporarily increased by opening the pressure holding solenoid valve (EVXX). Brake system pressure during this phase does not exceed the pedal force pressure within the master cylinder.

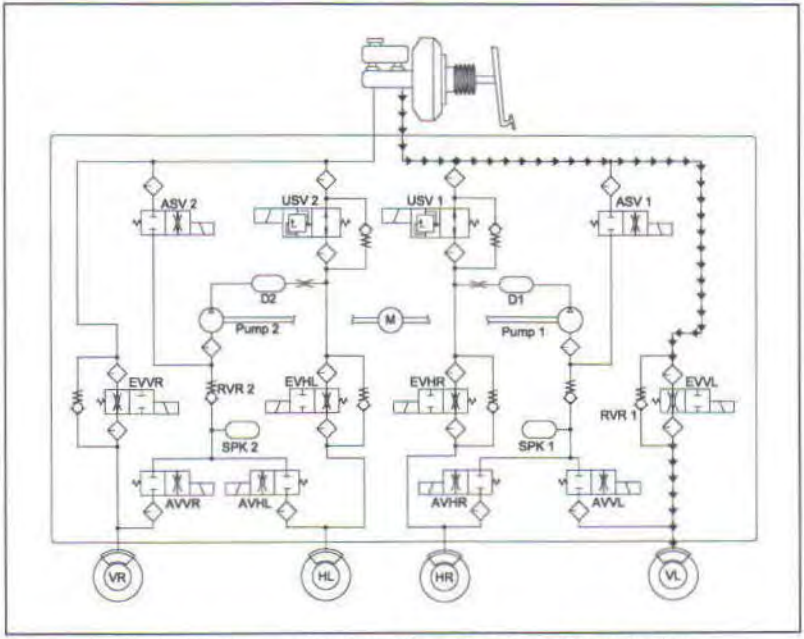
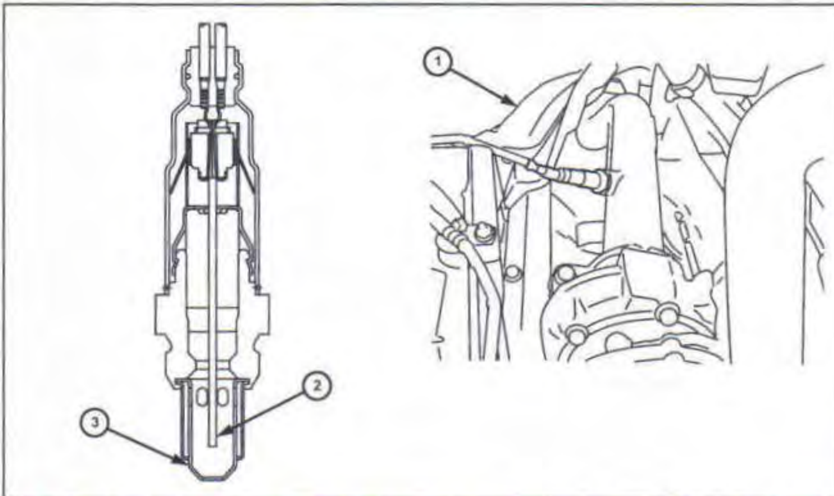


Figure 97 Pressure Build-Up Phase, Left Front Wheel Circuit

OTHER INPUTS

OXYGEN (O2) SENSOR

A heated wide-band oxygen sensor measures the oxygen content in the exhaust gas to control EGR. The sensor is mounted in the exhaust pipe at a 30 degree angle to prevent the collection of liquids between the sensor housing and sensor element during the cold start phase. The sensor is located close to the turbocharger for a quicker response.



1	O2 Sensor Location	3	Protective Tube
2	Planar Sensor Element (Pump Cell & Sensor Cell)		

Figure 101 Oxygen (O2) Sensor

The O2 sensor is a planar zirconium-dioxide (ZrO_2) dual cell limiting current probe with an integrated heater. The term wide-band refers to the ability of the sensor to generate a clear signal within a wide air-fuel ratio measuring range (from 0.7 to ∞). As a dual cell sensor, it incorporates a second chamber (oxygen pump cell), which requires a separate voltage supply. The O2 sensor has 5 wires (Heater power and ground, reference voltage, and 2 wires for pump cell current) and connects to a six-wire harness leading to the ECM.

System Diagnostics

If an error is detected either in the CAB/HCU or in the electrical system outside the control module, the system is shut down and the driver warned by the illumination of the ABS/ASR lamps. A safety circuit also constantly monitors the battery voltage. If the voltage drops below 9.5, the system is again shut down until the voltage returns to the specified range of at least 10 volts.

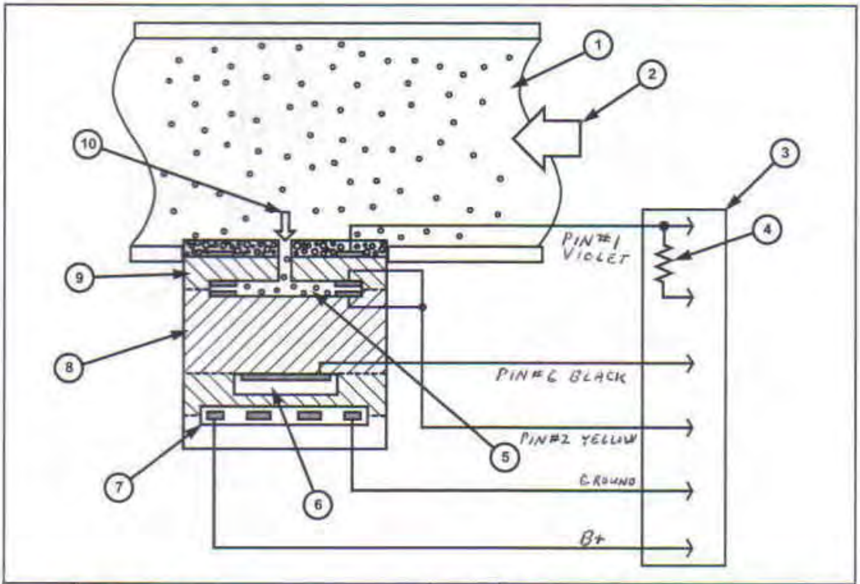
In addition to its monitoring function, the safety circuit also performs a test cycle when the ignition is switched on. The ABS/ASR lamps are illuminated while the following initialization test is performed:

- The solenoid valve circuits are checked for open circuits and short circuits to ground or positive
- The wheel speed sensor circuits are constantly checked for open circuits and short circuits to ground or positive
- The solenoid valves are briefly energized (this action can be felt if the brake pedal is depressed at the time of the test)

Construction

Refer to Figure 102. The sensor element combines a sensor cell (8) and an oxygen pump cell (9). Both cells are made of zirconium-dioxide (ZrO_2) and are coated with porous platinum electrodes. The sensor cell operates just like a typical O_2 sensor. The oxygen pump cell transports oxygen ions when voltage is applied to it.

A gas sample chamber (5) is sandwiched between the oxygen pump cell and the sensor cell. A pump cell electrode and a sensor cell electrode are located in the sample chamber. A sample passage (10) connects the sample chamber to the surrounding exhaust gas. A sensor cell electrode is located in the reference air channel (6), which connects to the outside air.



1	Exhaust Pipe	6	Reference Air Channel
2	Exhaust Gas Flow	7	Heater Element
3	O2 Sensor Connector	8	Sensor Cell
4	Trimming Resistor	9	Oxygen Pump Cell
5	Gas Sample Chamber	10	Sample Passage

Figure 102 Oxygen Sensor Construction

ASR

DESCRIPTION

Acceleration skid control (ASR) is a traction control system that is intended primarily to control wheel spin in low traction conditions. A spinning wheel is braked and its tractive power is transferred to the wheel with full grip. The engine torque is limited to improve driving stability.

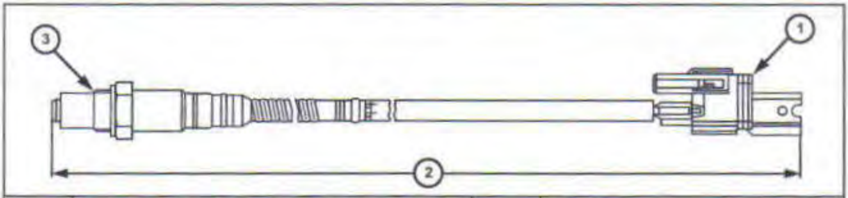
ASR is integrated with the Anti-Lock Brake system and is standard equipment on all Sprinter vans. The ASR system consists of the CAB/HCU integrated control unit located under the hood, the ABS/ASR wheel speed sensors, an ASR switch located in the center stack of the instrument panel, an ASR indicator lamp and ASR Malfunction indicator lamp both located in the electro-mechanical instrument cluster (EMIC).

OPERATION

When the CAB module determines that one of the rear wheels is slipping due to heavy acceleration, it commands the Change Over Valve (USV) to close and the Inlet Valve (ASV) to open for the affected wheel and energizes the pump motor to drive the pump. The pump then draws fluid from the master cylinder through the Inlet Valve (ASV). The pump output pressure is blocked by the Change Over Valve (USV). The fluid pressure flows through the ABS Inlet Valve (EVXX), increasing the pressure in that wheel cylinder. The pump runs to supply fluid pressure.

The CAB module also sends messages through the CAN Bus to the ECM and IC modules. The ECM reduces the specified engine torque and the instrument cluster flashes the traction control indicator.

A trimming resistor is built into the O2 sensor connector. The resistance value is dependent on the overall length and the type of sensor.



1	Connector With Trimming Resistor	3	O2 Sensor
2	Overall Sensor Length		

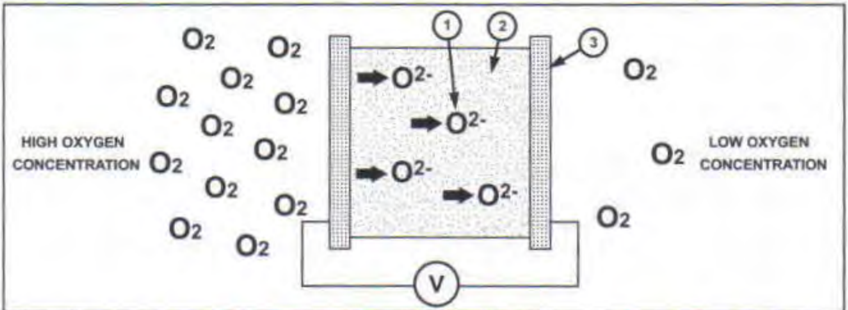
Figure 103 O2 Sensor and Cable

When replacing the O2 sensor, the trimming resistor is already installed in the new sensor and must not be changed (resistor is dependent on sensor).

O2 Sensor Fundamentals

At high temperatures, certain ceramic materials, such as zirconium-dioxide (ZrO2) become oxygen ion conductors.

In a typical O2 sensor, the ZrO2 is used as a solid electrolyte, which conducts oxygen ions. The solid electrolyte is sandwiched between two platinum electrodes. The sensor generates a small voltage when oxygen ions moves from the high concentration side to the low concentration side.



1	Oxygen Ion	3	Platinum Electrode (2)
2	Solid Electrolyte (ZrO2)		

Figure 104 Typical O2 Sensor Construction

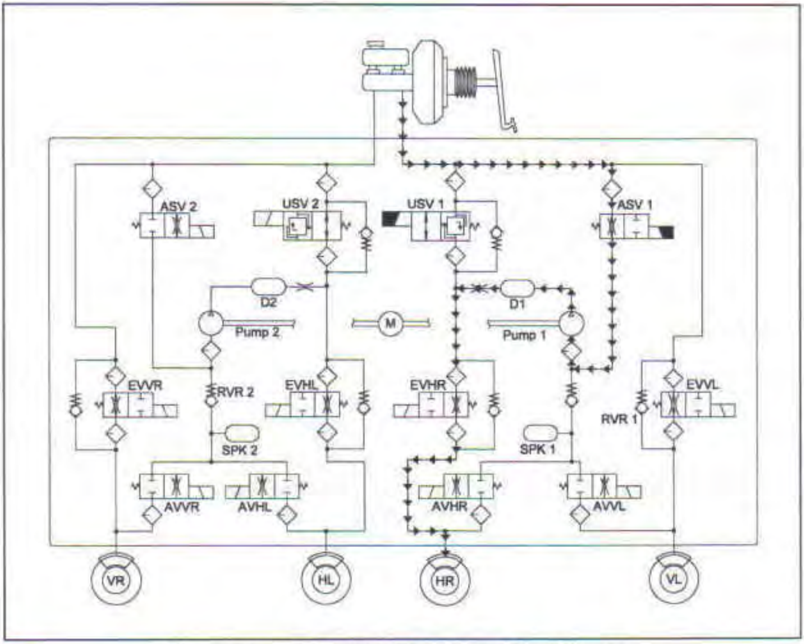
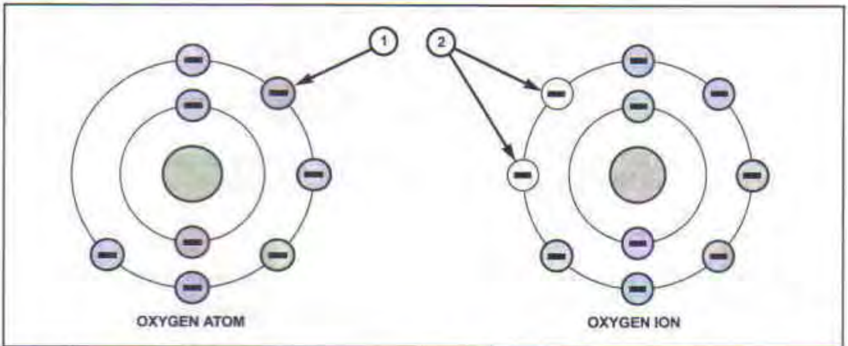


Figure 98 ASR Control, Right Rear Wheel Slipping

The same holds true if the process is reversed. If a voltage is applied to the platinum electrodes, oxygen can be pumped from one side of the solid electrolyte to the other (from cathode to anode), becoming an oxygen pump. The amount of current flow is directly proportional to the amount of oxygen pumped by the sensor. When the oxygen level on the supply side reaches zero, the current stops.

Oxygen atoms have six valence electrons in its outer shell and would like to gain two more (octet rule). Once they pick two free electrons they become oxygen ions, which have a negative charge.



1	Valence Electrons	2	Gained Electrons

Figure 105 Oxygen Atom and Oxygen Ion

Oxygen atoms pick up two electrons from the negative electrode (cathode) to become oxygen ions. These ions are then transported through the solid electrolyte (ZrO_2) to the positive electrode (anode). The ions transfer the negative charge (two electrons) to the anode and combine with other oxygen atoms to form O_2.

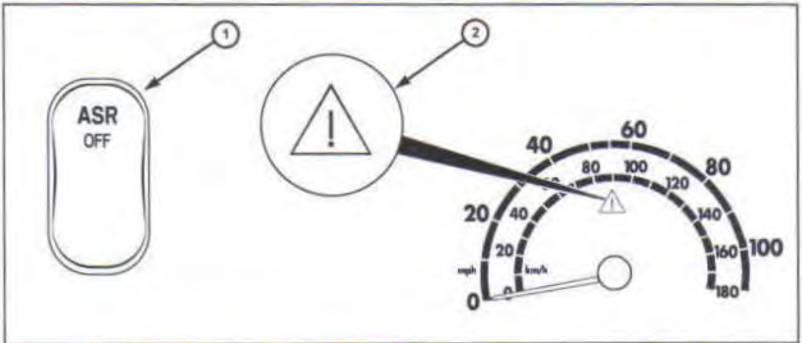
Stoichiometry

Stoichiometry is the ideal air-fuel ratio for perfect combustion. In theory, this ratio is 14.7:1 (14.7 pounds of dry air for 1 pound of fuel). A value of 1 is used as a reference point to denote stoichiometry. When stoichiometry equals 1, the ideal air-fuel ratio is achieved. A value higher than 1 means that more air is present than is needed for perfect combustion (lean mixture). A value lower than 1 indicates the amount of air is insufficient to produce a perfect combustion (rich mixture).

Gasoline engines run on air-fuel mixtures that are very close to stoichiometric (stoichiometry = 1). Diesel engines however, always run with excess air (stoichiometry > 1). If the excess air is low (stoichiometry < 1), the diesel engine will produce higher amounts of CO, HC and soot.

ASR OFF SWITCH

A switch mounted in the instrument panel allows the driver to manually deactivate the engine derate function of the ASR system when driving with snow chains, in deep snow, or on sand or gravel. The traction control is still operational, but the engine torque is no longer limited and the drive wheels are free to spin.



1	ASR OFF Switch
2	Traction Control Indicator

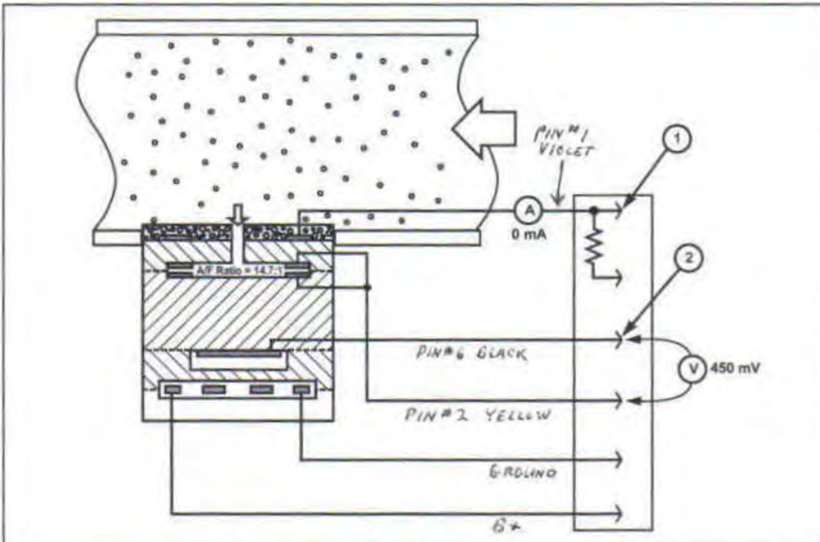
Figure 99 ASR OFF Switch

When the ASR OFF switch is pressed, the CAB module sends a message to the instrument cluster via the CAN Bus to turn on the traction control indicator.

The ASR can only be deactivated with the engine running. The system will return to normal operation once the ignition key is cycled.

Wide-Band O2 Sensor Operation

The ECM activates the integral heater element to raise the temperature of the sensor to 700°C (1292° F) for the ZrO_2 to become conductive. Once the sensor is heated, the exhaust-gas components diffuse through the gas sample chamber. Upon reaching the electrodes on the oxygen pump and concentration cells they achieve a state of thermo-dynamic balance.

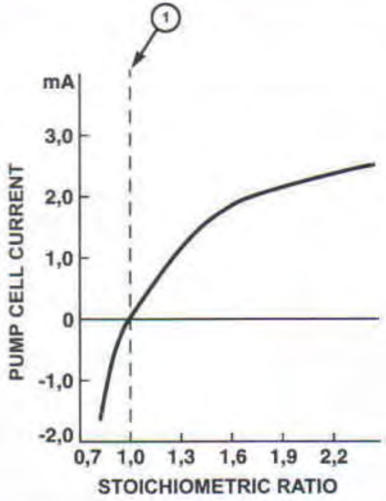


1	Oxygen Pump Cell Circuit	2	Sensor Cell Circuit

Figure 106 Wide-Band O2 Sensor Construction

The sensor cell measures the difference between the oxygen concentration in the gas sample chamber and the oxygen concentration in the outside air from the reference air channel. A small voltage is generated across the sensor, which is proportional to the air-fuel ratio in the sample chamber. At stoichiometry, the corresponding open-circuit voltage at the sensor cell is 450 mV. If the stoichiometric ratio in the sample chamber is higher than 1 (excess air) a lower voltage is produced. If the stoichiometric ratio is lower than 1 (insufficient air) a higher voltage is produced.

The ECM uses this voltage signal to determine how and when to run the oxygen pump cell. The goal of the ECM is to modulate the pumping current through the pump cell to always maintain a stoichiometric air-fuel ratio of 1 (14.7 to 1) in the gas sample chamber. When stoichiometry is reached, there is no current flowing to the oxygen pump cell.



1	Stoichiometric Point (14.7:1)

Figure 107 Oxygen Pump Cell Current Curve

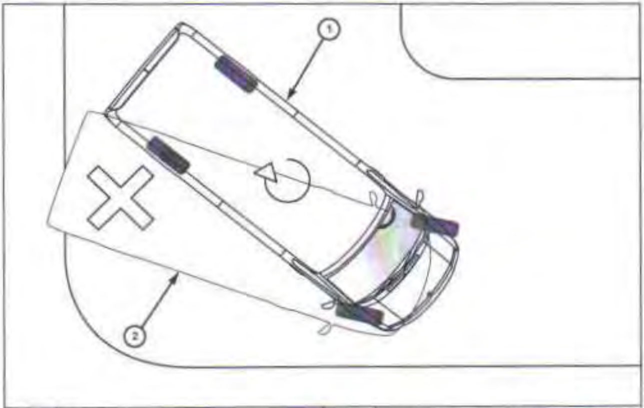
ELECTRONIC STABILITY PROGRAM (ESP)

The Bosch ESP version 5.7 is installed as standard specification on all Sprinter cargo vans with a GVWR of 8550 lbs. The Sprinter's electronic stability program (ESP) includes the following systems:

- Brake Assist System (BAS)
- Anti-Lock Brake System (ABS)
- Acceleration Skid Control (ASR)
- Electronic Force Distribution (EBD)

The dynamic handling control system ESP improves the driving stability and the traction of a vehicle in critical situations as it counteracts a vehicle's tendency of oversteering or understeering by applying braking force to appropriate wheels and, if required, by limiting engine torque.

ESP is designed to avoid many critical driving conditions already when they are about to arise and has become an important contribution to increased driving safety.

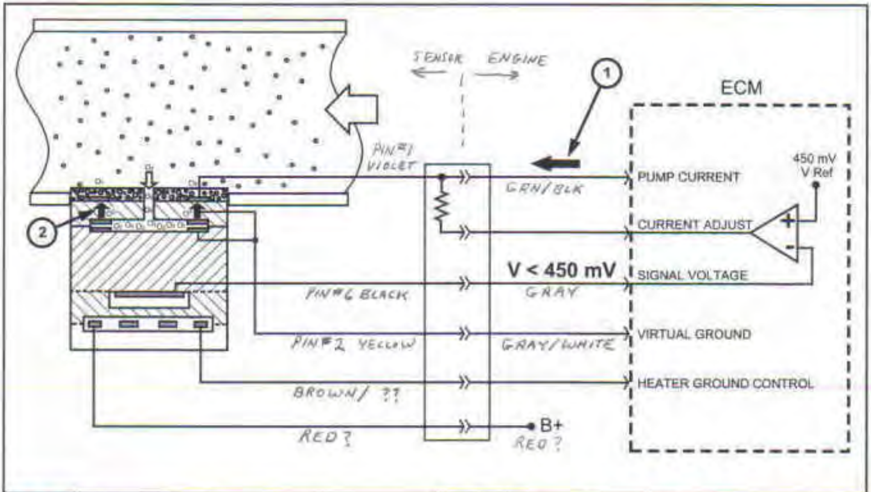


1	Driving Response With ESP	2	Driving Response Without ESP

Figure 100 Driving Stability With ESP

High Excess-Air Mode

When the exhaust gas is too lean, the oxygen concentration in the gas sample chamber is high. The sensor cell measures the difference between oxygen concentrations in the gas sample chamber and the reference air channel. A voltage lower than 450 mV is generated across the sensor cell, which is proportional to the air-fuel ratio in the sample chamber. The ECM compares the sensor cell voltage to a reference voltage (V Ref), which corresponds to the stoichiometric point voltage. Since sensor cell voltage is lower than V Ref, The ECM determines a lean condition exists. An amplifier applies an appropriate voltage to the pump cell to transfer oxygen from the gas sample chamber.



1	Flow of Pump Current	2	Flow of Oxygen Ions

Figure 108 O2 Sensor, High Excess Air

The oxygen atoms in the pump cell pick up two electrons from the negative electrode (cathode) to become oxygen ions. The ions are transported through the solid electrolyte (ZrO2) to the positive electrode (anode). Each ion transfers its negative charge (two electrons) to the anode and combines with other oxygen atoms to form O2. The amount of current flow is directly proportional to the amount of oxygen pumped by the pump cell. While the sensor cell voltage only provides a rough indication of the air-fuel ratio, the ECM can determine with precision the stoichiometric ratio based entirely on the amount of current flowing through the oxygen pump cell.

ESP acts both on the brake system and the engine management. It permanently evaluates the measurements made by the steering angle sensor, wheel speed sensors and the yaw rate/lateral acceleration sensor and detects unstable driving situations at a very early stage. Within fractions of a second, ESP intervenes via the engine control module (ECM) and the brake system and assists the driver in mastering the critical situation. It applies braking force to one or more of the wheels to produce a twisting movement which counteracts the danger of skidding and stabilizes the vehicle.

The ESP system does not take the vehicle load into account. Instead, the coefficient of friction is calculated in a 20 millisecond period, where the controller measures the rate at which the wheel speed is decelerated, as brake pressure is applied to the wheel.

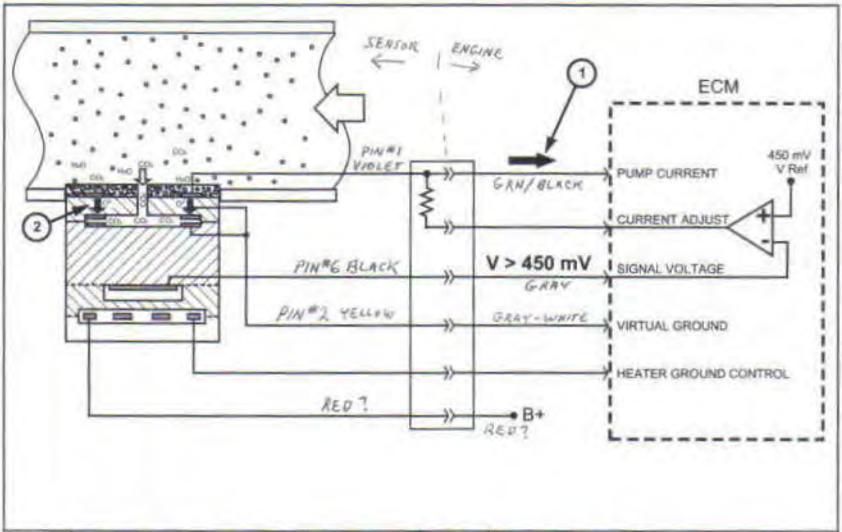
ESP operates:

- When cornering (vehicle under- or oversteered)
- When driving straight ahead (vehicle deviates off course due to uneven road conditions)

Essentially, all outside forces acting on a vehicle attempt to rotate it about its center of gravity, regardless of whether these are one-sided braking, drive forces, or lateral forces. ESP analyzes the vehicle behavior and applies specific braking forces to individual wheels to correct any instability.

Low Excess-Air Mode

With low excess air, the oxygen concentration in the gas sample chamber is low. The sensor cell measures the difference between oxygen concentrations in the gas sample chamber and the reference air channel. A voltage higher than 450 mV is generated across the sensor cell, which is proportional to the air-fuel ratio in the sample chamber. The ECM compares the sensor cell voltage to V Ref. Since sensor cell voltage is higher than V Ref, The ECM determines a low excess-air condition exists. The polarity of the pump cell is reversed and so is the direction of the current flow.

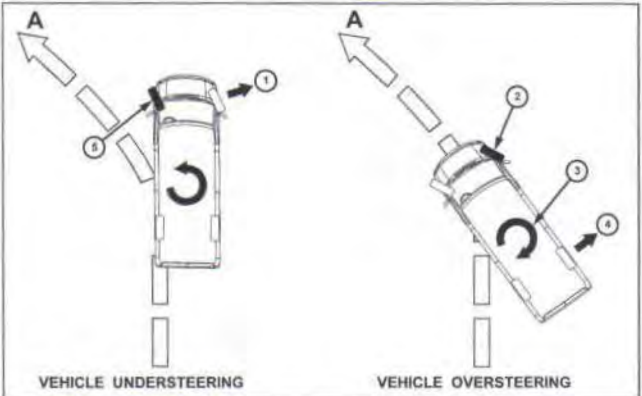


1	Flow of Pump Current	2	Flow of Oxygen Ions

Figure 109 O2 Sensor, Low Excess-Air

Decomposition of water (H2O) and carbon-dioxide (CO2) molecules occurs in the exhaust pipe, next to the pump cell. Oxygen atoms separate from the molecules and pick up two electrons from the cathode to become oxygen ions. The ions are transported through the solid electrolyte to the anode in the gas sample chamber (the direction of flow has been reversed). The ECM determines the stoichiometric ratio based on the amount of current flowing through the oxygen pump cell.

Refer to Figure 101 for examples of ESP activation. When the vehicle understeers on a left turn it pushes outwards over the front wheels (1). ESP applies a precisely calculated force to the left front wheel (5). When the vehicle oversteers on a left turn, the rear of the vehicle breaks away (4). ESP applies the braking force to the right front wheel (2).



1	Understeering Vehicle Motion	4	Oversteering Vehicle Motion
2	Braked Wheel	5	Braked Wheel
3	Vehicle Compensating Moment	A	Desired Direction of Travel

Figure 101 ESP Activation Examples

GLOW PLUG MODULE

The glow plug module is located in the engine compartment under the battery tray. The module integrates diagnostics and an electronic system that processes the input signals from the ECM for glow plug activation.

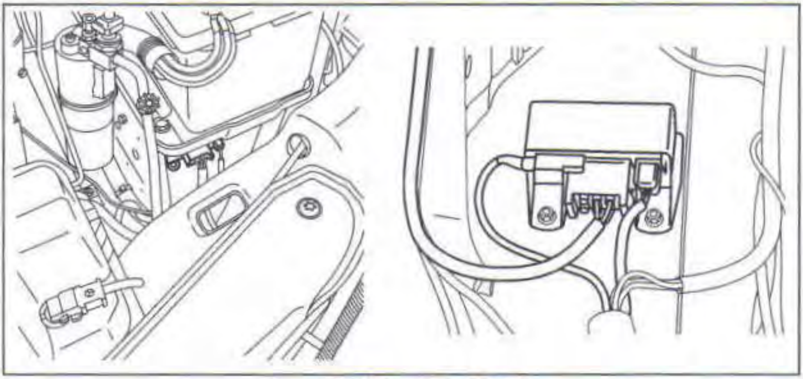
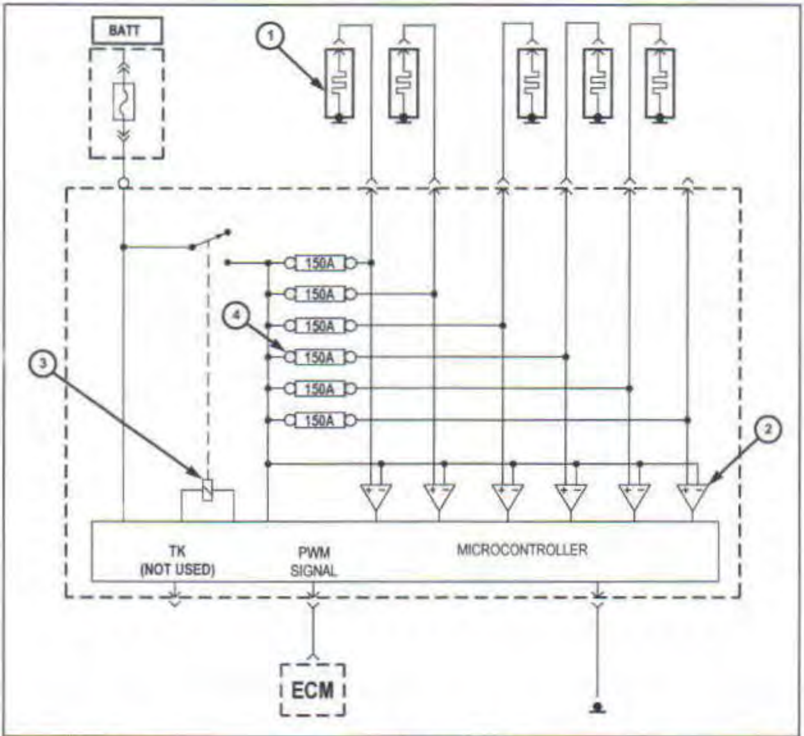


Figure 113 Glow Plug Module

The glow plug module is equipped with a single-wire serial communication interface for bi-directional data communication with the ECM. The glow plug module monitors the operation of the glow plugs and continuously informs the ECM by sending a PWM signal through the single-wire interface about the operating state (glow plugs ON/ OFF), and the presence of any system faults.

Detected faults in the glow plug system are stored in the diagnostic memory (RAM) of the glow plug module. The contents of the diagnostic memory are sent sequentially to the ECM through the single-wire communication interface.

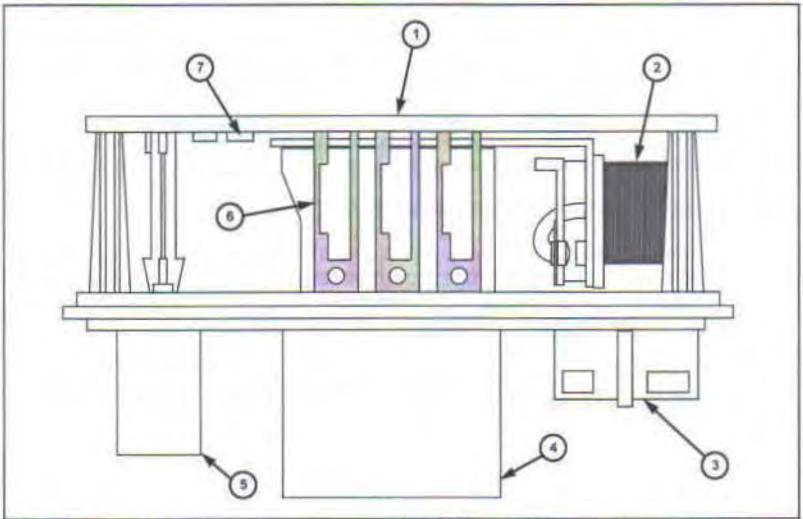


1	Glow Plug	3	Relay
2	Voltage Comparator	4	Fusible Link

Figure 114 Glow Plug Module Schematic

150 AMP SEEMS HIGH?

The glow plug module monitors the PTC properties of the glow plugs for diagnostics. Each glow plug circuit contains a fusible link rated at 150 A. When activated, current flows through the fusible links to the glow plugs and a small voltage drop is produced across the fusible links. A voltage comparator circuit within the glow plug module detects the voltage drop across each fusible link and triggers a signal if a threshold voltage is exceeded. Since the comparator circuit measures voltage drop, the monitoring is only possible while the glow plugs are energized.



1	Printed Circuit Board	5	Datalink to ECM Connector
2	Relay	6	Fusible Link
3	B+ Terminal	7	Voltage Comparator Circuit
4	Glow Plug Connector		

Figure 115 Glow Plug Module

Fault Recognition

The following faults are recognized by the glow plug module and transmitted to the ECM:

- Open circuit/short circuit to battery positive—The comparator circuit detects open circuit voltage instead of the desired voltage drop. The glow plug module stores a DTC (open circuit) in its memory.
- Short circuit to ground (same DTC as above)—The increase in current flow will cause the 150A fusible link within the glow plug module to blow out, leading to an open circuit. The comparator circuit detects no voltage and the glow plug module stores same DTC as above (open circuit), plus a general overcurrent fault. Once a fuse is blown, the glow plug module has to be replaced.
- Internal relay fault

The ECM stores a fault code when it receives an open glow plug circuit message from the glow plug module. The ECM will also activate the preglow indicator lamp in the instrument cluster for about one minute once the engine is running. If the message received by the ECM is related to a short circuit, or a communication fault, it will store a fault code and immediately activate the preglow indicator lamp. The lamp will remain activated until the fault is no longer current or the ignition is switched off.

SERVICE NOTE: TO AVOID INTERNAL DAMAGE, ALWAYS ENSURE THE GLOW PLUGS ARE NOT SHORTED BEFORE REPLACING A GLOW PLUG MODULE.

ACM ENHANCED ACCIDENT RESPONSE INPUT

The airbag control module (ACM) enhanced accident response input is received by the ECM in the event of an accident where the airbags have deployed. A hardwire signal from the ACM is sent to the ECM and central timer module (CTM) simultaneously (Figure 116).

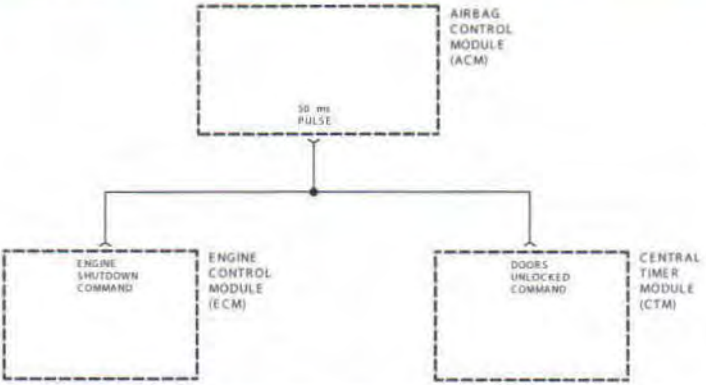


Figure 116 ACM Enhanced Accident Response Input

The enhanced accident response input signal consists of a 12 volt, 50 millisecond pulse generated by the ACM during airbag deployment. Upon receipt of this input, the ECM shuts the engine down. The engine can be restarted again if necessary.

The ECM stores a fault code when it receives an open glow plug circuit message from the glow plug module. The ECM will also activate the preglow indicator lamp in the instrument cluster for about one minute once the engine is running. If the message received by the ECM is related to a short circuit, or a communication fault, it will store a fault code and immediately activate the preglow indicator lamp. The lamp will remain activated until the fault is no longer current or the ignition is switched off.

— During my GP fuse failures the pre-glow coil didn't do as described above. (2004)

SERVICE NOTE: TO AVOID INTERNAL DAMAGE, ALWAYS ENSURE THE GLOW PLUGS ARE NOT SHORTED BEFORE REPLACING A GLOW PLUG MODULE.

ACM ENHANCED ACCIDENT RESPONSE INPUT

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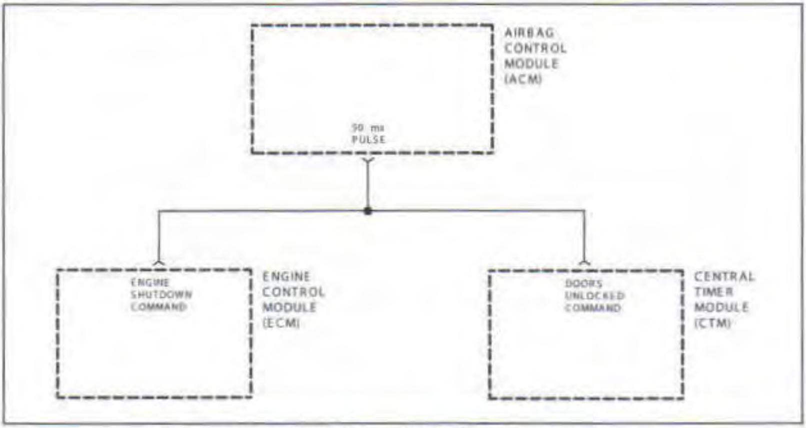
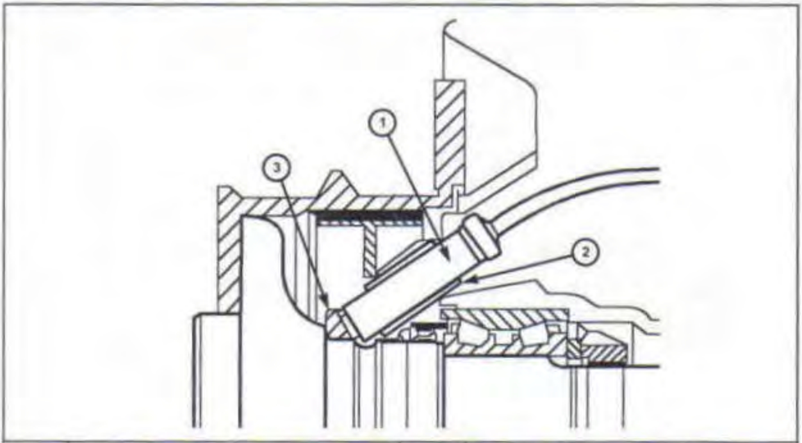


Figure 116 ACM Enhanced Accident Response Input

The enhanced accident response input signal consists of a 12 volt, 50 millisecond pulse generated by the ACM during airbag deployment. Upon receipt of this input, the ECM shuts the engine down. The engine can be restarted again if necessary.

WHEEL SPEED SENSORS

The wheel speed sensors are the same as those used on Sprinter vans with ABS/ASR. The sensors supply speed signals of the respective wheels.



1	Wheel Speed Sensor	3	Tone Wheel
2	Spring Bushing		

Figure 110 Wheel Speed Sensor

The four conditioned wheel speed signals are constantly compared with each other and with specified slip thresholds on the front and rear wheels in relation to the speed of the vehicle.
This comparison is used to determine the following values and control variables:

- Vehicle speed
- Acceleration/deceleration
- Brake slip (ABS)
- Acceleration slip (ASR)
- Deceleration slip (EBR)
- Signal from steering angle sensor

The wheel speed sensors detect the different rotational speeds when the vehicle changes direction or is being driven on a curve. With this information and the signal from the steering angle sensor, the ESP control module recognizes the vehicle handling characteristics desired by the driver.

INDIRECT INPUTS

CAN BUS INPUTS

In addition to the hardwired inputs, the ECM receives data from other control modules through the CAN bus.

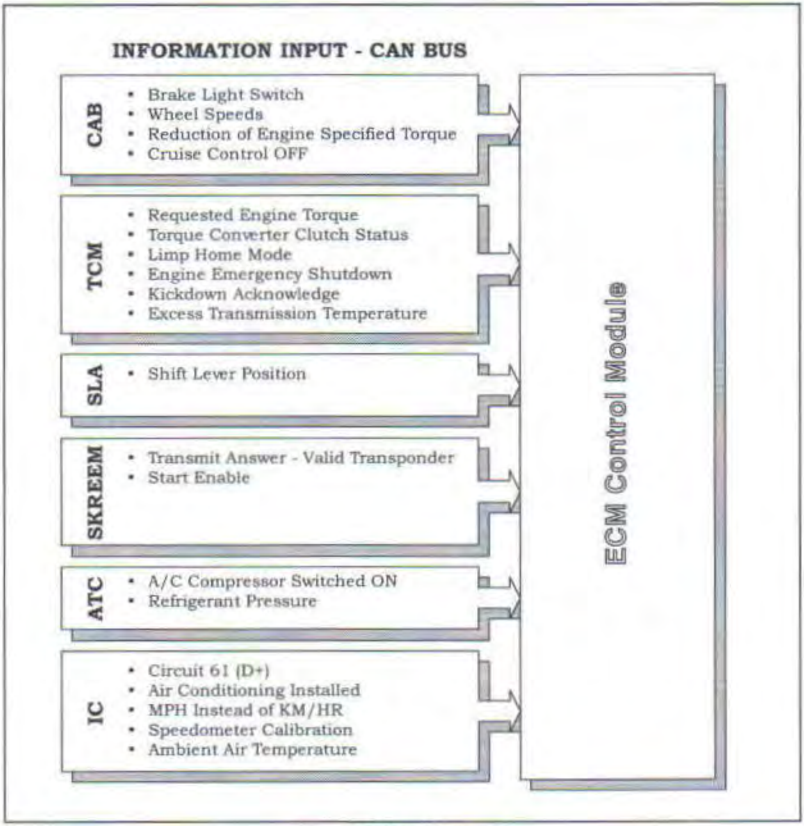


Figure 118 CAN Inputs

ACTIVITY 3.5 ENGINE SENSORS

The purpose of this activity is to familiarize the students with the engine's behavior resulting from various sensor failures. Task 2 of the activity familiarizes the students with the operation of the cruise control switch.

TASK 1

1. Disconnect the following sensors and observe the details as indicated. Use the diagnostic scan tool to read the sensor substitute values.

   Fuel Temp Sensor:

   Does the engine run? ☑ YES ☐ NO

   Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

   Engine maximum RPM: *4200 RPM*

   DTCs: *P0180-001 Fuel temp sensor voltage too high (clear code to turn out MIL)*

   Sensor value displayed: *-40.1°F*

   Coolant Temp Sensor:

   Does the engine run? ☑ YES ☐ NO

   Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

   Engine maximum RPM: *4200 RPM*

   DTCs: *P0115-001 ECT Voltage too high (clear the code to turn out the MIL)*

   Sensor value displayed: *-40.1°F*

   Connect a DMM to the coolant temperature sensor and measure its resistance.

   Sensor resistance value: ______________________

   Compare the resistance reading to the values of the ECT resistance chart in the student book. Does the sensor value agree with the chart ? ☐ YES ☐ NO

   Fuel Rail Pressure Sensor:

   Does the engine run? ☑ YES ☐ NO

   Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

   Engine maximum RPM: *2800 RPM*

   DTCs: *P0190-001 Fuel Pressure Sensor Voltage too high*

   Sensor value displayed: *KOEO=5801. Goes up with throttle (could be spec value)*

Oil Temp Sensor:

Does the engine run? ☑ YES ☐ NO

Is the MIL lamp ON ? ☐ YES ☑ NO *(oil level indicator - 10 seconds)*

Engine maximum RPM: *4200 RPM*

DTCs: *P2061-001, P2014-004, 2040-004, 2041-004*

Sensor value displayed: *Uses coolant temp, Oil Quality 2, Oil Level 1.57 in.*

Intake Air Temp Sensor:

Does the engine run? ☑ YES ☐ NO

Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

Engine maximum RPM: *4200*

DTCs: *P0110-001 IAT voltage too high (clear fault to turn out MIL)*

Sensor value displayed: *-40.1°F*

Boost Sensor:

Does the engine run? ☑ YES ☐ NO *(engine runs rough)*

Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

Engine maximum RPM: *4200 RPM with stumble*

DTCs: *P0105-002 boost pressure voltage too low (clear stored fault to turn out MIL)*

Sensor value displayed: *Uses ATM pressure value (fixed)*

MAF Sensor:

Does the engine run? ☑ YES ☐ NO *(engine runs rough)*

Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

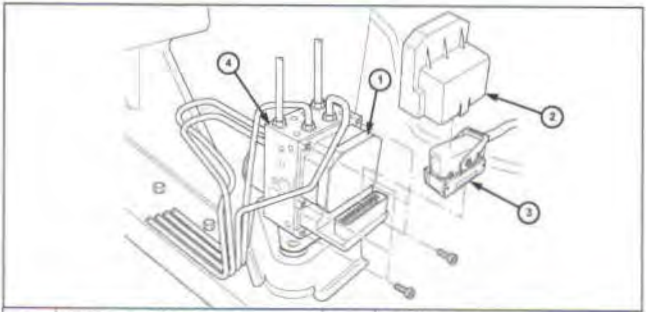
Engine maximum RPM: *4200 RPM with stumble*

DTCs: *P2067-002, 2067-004, 2068-004 (2 faults on 1st, add. fault on 2nd start)*

Sensor value displayed: *Low 500s (518-543 mg/stroke) very little movement*

HYDRAULIC CONTROL UNIT (HCU)

The Hydraulic Control Unit (HCU) is located in the engine compartment. The HCU has a brake pressure sensor mounted on the back of the unit. The port where the sensor is mounted to connects with the pressure circuit line from the master cylinder. The diameter of the brake fluid lines between master cylinder and the HCU has been increased for a faster response. DOT 4 Plus is the approved brake fluid.



1	ESP Control Module	3	ESP Harness Connector
2	Cover	4	Hydraulic Control Unit

Figure 113 Hydraulic Control Unit (HCU)

HCU COMPONENTS AND OPERATION

The hydraulic control unit (HCU) combines the control components of ABS, ASR, and ESP. Refer to Figures 114 through 116.

Isolation Valves (IVLF, IVRF, IVLR, IVRR)

The isolation valves are normally open 2/2 (two-port, two-position) valves. The valves close during ABS operation to prevent an increase in brake pressure. There is one valve for each brake channel.

Dump Valves (DVLF, DVRF, DVLR, DVRR)

The dump valves are normally closed 2/2 valves. There is one dump valve for each isolation valve. Opening a dump valve allows pressure to be released from its brake channel to the low pressure accumulator.

Intake Pressure Sensor:

Does the engine run? ☑ YES ☐ NO

Is the MIL lamp ON ? ☑ YES ☐ NO *(after 2nd start on 50 state van)*

Engine maximum RPM: *4200 RPM*

DTCs: *P2025-002 Intake pressure voltage too low*

Sensor value displayed: *11.4 and 0.000 volts on DRBIII - 11.269 on DAS*

TASK 2 CRUISE CONTROL SWITCH

1. Connect the diagnostic scan tool to the vehicle and access the engine.
2. Actuate/Press the cruise control stalk. Record your findings below.

Position: *UP*	ACC: *YES*	Safety Contact: *ON*
Position: *DN*	DEC: *YES*	Safety Contact: *ON*
Position: *BK*	RES: *YES*	Safety Contact: *ON*
Position: *FWD*	OFF: *YES*	Safety Contact: *ON*

3. How does the ECM determine a fault, or an unintentional actuation?
   By receiving a combination of switch inputs rather than single input.

Prime Valves (PRV1, PRV2)

The prime valves are closed during the pressure-holding phase of ASR and ESP control. The prime valves are also used to control the circuit pressure. The valves open to allow the pump to pull fluid into the unit during ASR and ESP control. A pressure between 3-5 bar (44-73 psi) is produced without driver intervention.

Pilot Valves (PIV1, PIV2)

The pilot valves close to keep fluid from returning to the master cylinder during the pressure build-up and pressure-holding phase of ASR and ESP control. The valves open during the pressure-reduction phase. The pilot valves are also designed as pressure relief valves and open at pressures of approximately 170 bar (2465 psi). The brake fluid flowing through the pilot valves is directed back to the master cylinder.

Pumps (P1, P2)/Motor Assembly (M1)

The pump/motor assembly supplies pressure during ASR and ESP control. The pump/motor assembly also returns brake fluid during ABS, ASR and ESP control.

Low Pressure Accumulators (LPA1, LPA2)

The low-pressure accumulators fill with returned brake fluid during the ABS/ASR/ESP pressure-reduction phase and sends it to the pump/motor assembly.

Damping Chambers (DC1, DC2)

Each brake circuit has a damper chamber to muffle the pumping sound.

Table 3 Component Description, Hydraulic Control Unit (HCU)

D1	Diagonal 1 Circuit (Left Front and Right Rear Wheels)
D2	Diagonal 2 Circuit (Right Front and Left Rear Wheels)
DC1	Damping Chamber, Diagonal 1 Circuit
DC2	Damping Chamber, Diagonal 2 Circuit
DVLF	Dump Valve, Left Front Wheel
DVLR	Dump Valve, Left Rear Wheel
DVRF	Dump Valve, Right Front Wheel
DVRR	Dump Valve, Right Rear Wheel
HL	Left Rear Brake Channel
HR	Right Rear Brake Channel
IVLF	Isolation Valve, Left Front Wheel
IVLR	Isolation Valve, Left Rear Wheel
IVRF	Isolation Valve, Right Front Wheel
IVRR	Isolation Valve, Right Rear Wheel
LF	Left Front Wheel
LR	Left Rear Wheel
LPA1	Low Pressure Accumulator, Diagonal 1 Circuit
LPA2	Low Pressure Accumulator, Diagonal 2 Circuit
M1	Electric Motor
P1	Hydraulic Pump, Diagonal 1 Circuit
P2	Hydraulic Pump, Diagonal 2 Circuit
PIV1	Pilot Valve, Diagonal 1 Circuit
PIV2	Pilot Valve, Diagonal 2 Circuit
PRV1	Prime Valve, Diagonal 1 Circuit
PRV2	Prime Valve, Diagonal 2 Circuit
RF	Right Front Wheel
RR	Right Rear Wheel
VL	Left Front Brake Channel
VR	Right Front Brake Channel

MODULE 4 ECM CONTROL

ENGINE CONTROL MODULE (ECM) HARDWARE

The engine control module (ECM) is located on the left hand side, under the instrument panel (Figure 119).

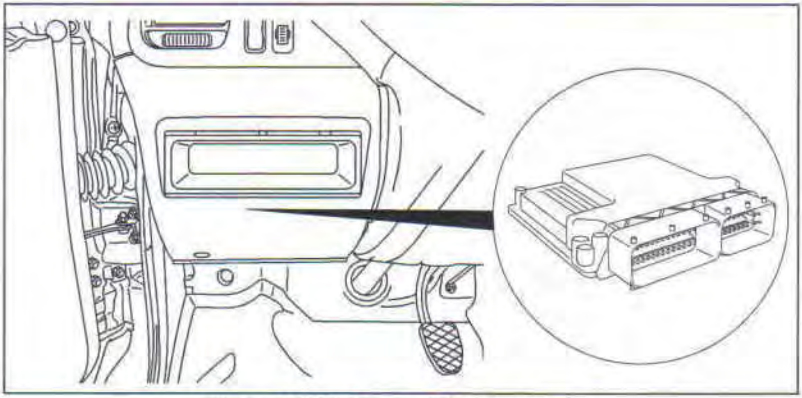
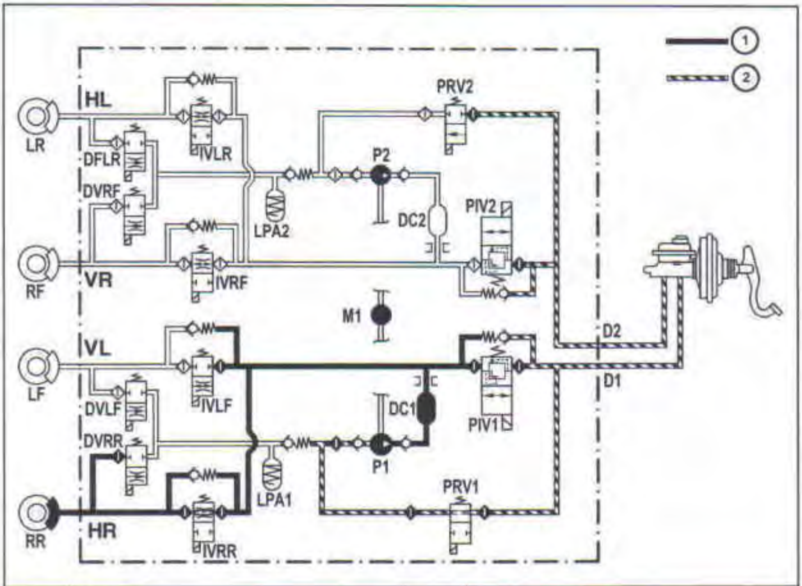


Figure 119 ECM Control Module Location

The ECM is made by Bosch and has a metal housing with finned surfaces for heat dissipation. The inputs, outputs, power supply and grounds are connected to the ECM through two plug-in connectors with a total of 154 pins. Six of the pins have a heavier gauge for carrying the higher current load from the main power supply and ground circuits.

ESP CONTROL MODE, PRESSURE BUILD-UP

The control procedure and valve positions shown in this example relate to the rear right brake circuit.

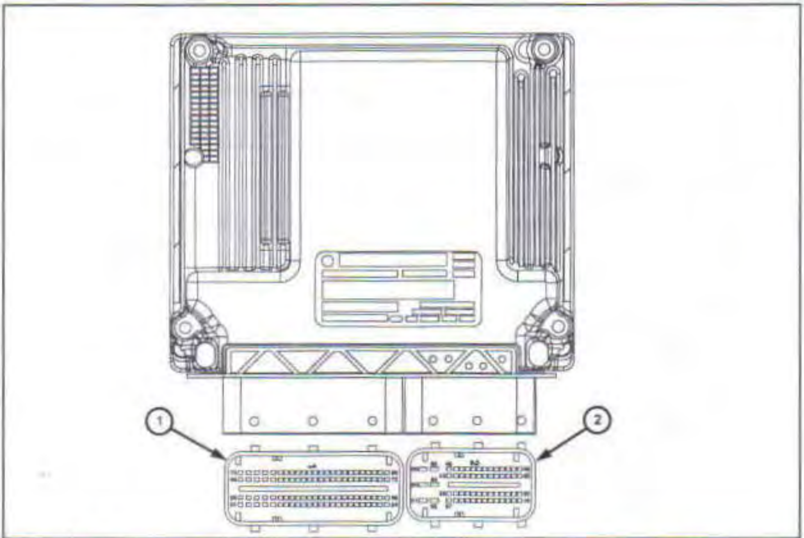


1	High Pressure	2	Primary Pressure

Figure 114 ESP Pressure Build-Up Phase

The ESP control module initiates brake intervention to stabilize the vehicle. At the start of the ESP control phase, the pilot valves of diagonal circuits 1 and 2 (PIV1, PIV2) are switched to the closed position and the pump/motor assembly is triggered. The prime valve of diagonal circuit 1 (PRV1) is only opened during the pressure build-up phases. The hydraulic pump (P1) draws brake fluid out of the reservoir via the prime valve (PRV1) and master brake cylinder.

The high pressure is limited by the pressure relief valve integrated into the pilot valve (PIV1) to approximately 170 bar (2465 psi).



1	96-Pin Engine Connector	2	58-Pin Vehicle Connector

Figure 120 ECM Connectors

The electrical circuits at the ECM are split into two separate wiring harnesses (vehicle and engine wiring harness). The 58-pin connector (marked F) is used for the vehicle wiring harness. The 96-pin connector marked M is for the engine wiring harness.

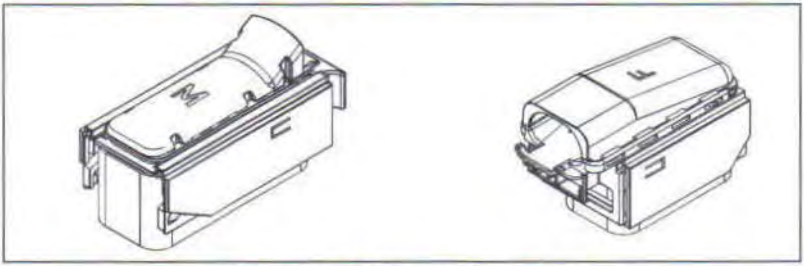
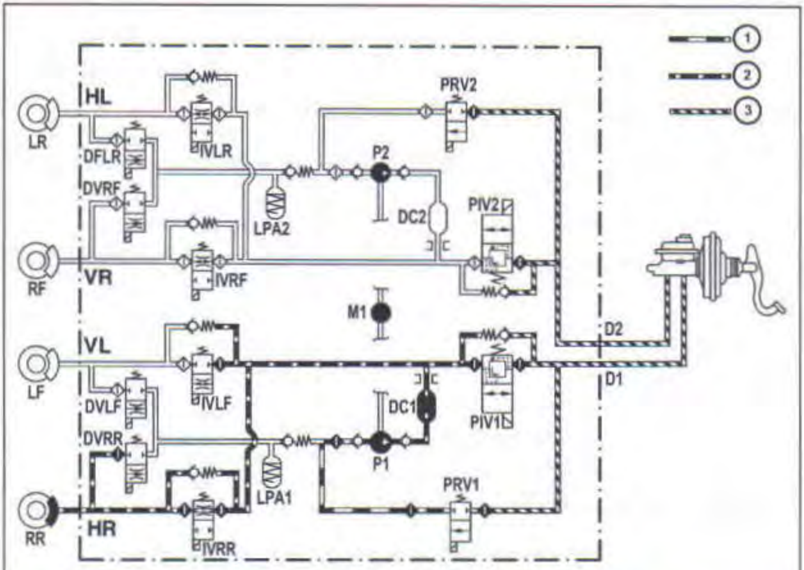


Figure 121 ECM Harness Connectors

ESP CONTROL MODE, PRESSURE HOLD

The control procedure and valve positions shown in this example relate to the rear right brake circuit.

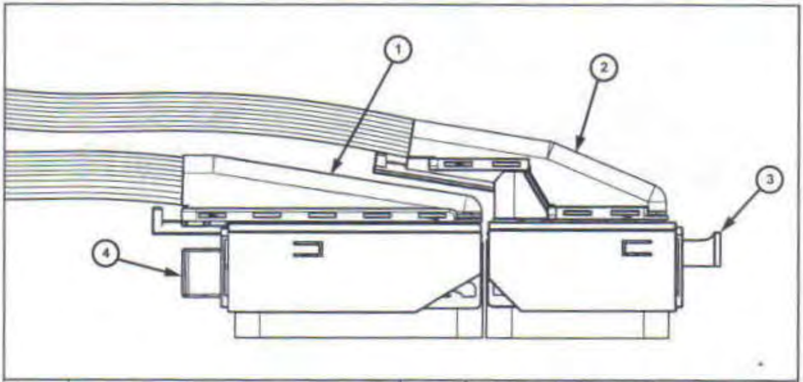


1	High Pressure	3	Primary Pressure
2	Wheel Brake Pressure		

Figure 115 ESP Pressure Holding Phase

When no more brake intervention is required to stabilize the vehicle, the ESP pressure hold control mode is initiated. The prime valve of diagonal circuit 1 (PRV1) is closed and the pressure in the brake caliper cannot be increased by the hydraulic pump (P1).

Both plug-in connectors are secured in place by means of slide locks. The slide locks are located on opposite ends. The 58-pin connector is mounted on top of the 96-pin connector. For this reason, it must be removed first and installed last during disassembly and assembly procedures. To remove the plug-in connectors, pull the slide locks sideways to the end of their travel and lift the plug-in connectors.

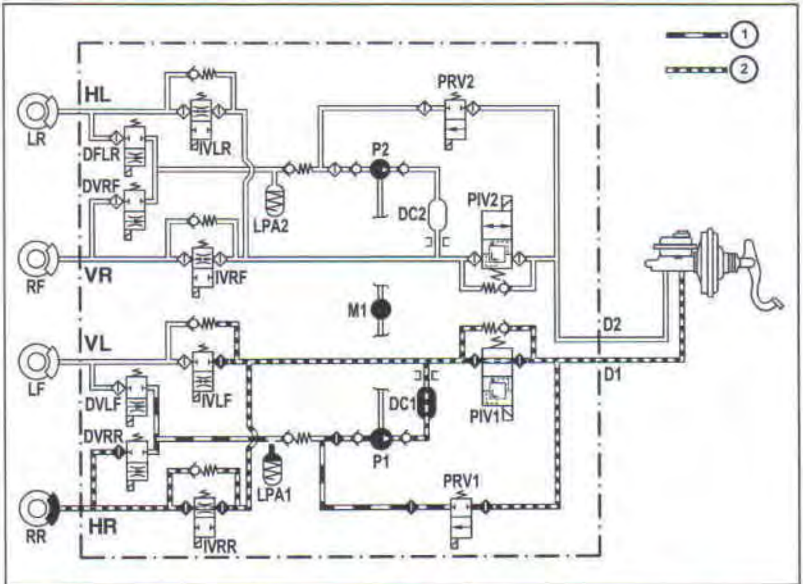


1	Engine Plug-In Connector	3	Vehicle Connector Slide Lock
2	Vehicle Plug-In Connector	4	Engine Connector Slide Lock

Figure 122 ECM Connector Mounting Position

ESP CONTROL MODE, PRESSURE REDUCTION

The control procedure and valve positions shown in this example relate to the rear right brake circuit.



1	Return Fluid	2	Reduced Pressure

Figure 116 ESP Pressure Reduction Phase

If the brake pressure required for stabilization is too high, the pressure-reduction phase of the ESP control is initiated.

The pressure reduction phase begins by opening the pilot valve of diagonal circuit 1 (PIV1). The right rear wheel isolation valve (IVRR) remains open and the right rear wheel dump valve (DVRR) remains closed. The hydraulic pump (P1) pumps the back-flowing brake fluid through the pilot valve of diagonal circuit 1 (PIV1), and then through the master brake cylinder back to the brake fluid reservoir.

The ECM has guide pegs to ensure the correct mounting position of the plug-in connectors. When re-installing the plug-in connectors, align the connector tracks with the guide pegs. Push the connector down while pressing the slide lock in to the end of its travel.

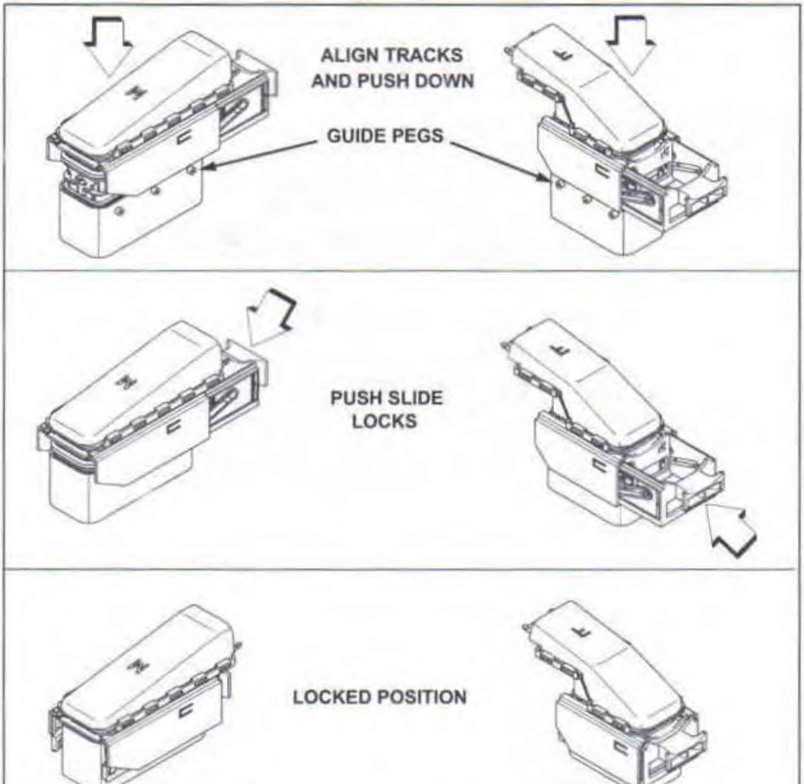


Figure 123 ECM Connector Installation

When retrofitting optional features to the vehicle, the 58-pin vehicle harness plug-in connector must be disassembled for inserting additional wires. Extreme care must be observed to avoid damage to the electrical pins or the connector housing.

ESP SYSTEM OPERATION

The Electronic Stability Program (ESP) module calculates the following values:

- Acceleration
- Deceleration
- Wheel slip
- Drive slip
- Decel slip

Depending on the traction condition the Electronic Stability Program (ESP) control module intervenes with any of the following control modes:

- ABS control
- ASR control
- BAS control
- ESP control

The purpose of the ESP control is to ensure, within physical limits, that the vehicle does not deviate from the course specified by the driver. Course deviations are caused by outside forces, such as braking and accelerating forces acting on one side, or side forces which want to rotate the vehicle about its center of gravity. The course deviations can occur both when cornering and driving straight ahead.

Example of Cornering

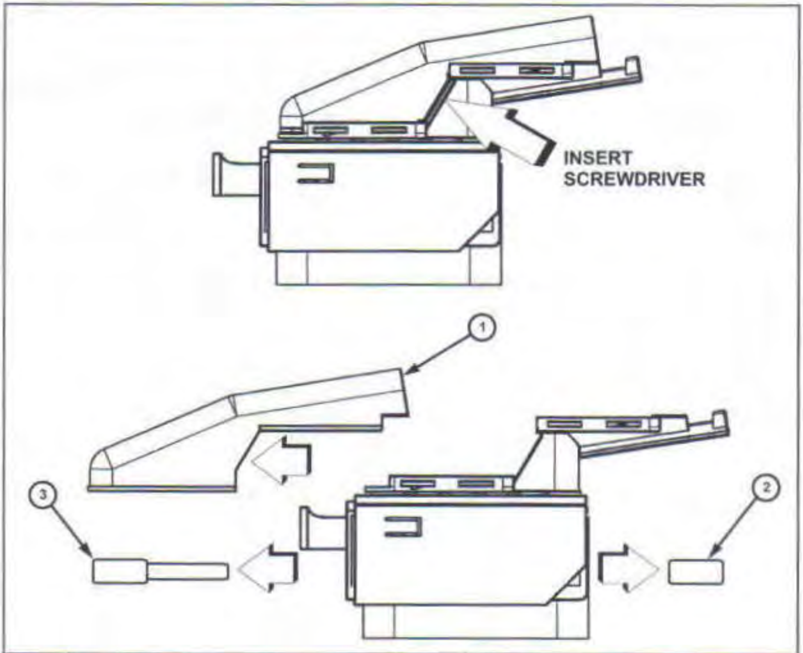
The frictional contact between the front and rear wheels and the road can be changed in such a manner that the vehicle no longer follows the direction of travel specified by the steering angle and yaw motions. The vehicle then deviates from the specified course. In this case the vehicle pushes outwards, either over the front wheels (understeer) or over the rear wheels (oversteer).

Example of Straight Ahead Driving

Uneven road conditions apply different forces of friction to the wheels and the slip of the individual wheels is different. Without regulating slip the vehicle would deviate from its course without steering correction.

The ESP control module processes the wheel speeds, the steering angle, the yaw rate of the vehicle, the lateral acceleration and the brake pressure. The ESP control module is linked to the engine and transmission control modules over the CAN data bus and is continuously supplied with current data on engine torque, accelerator pedal position and the actual transmission gear.
If the driving forces acting on the vehicle exceed certain control thresholds, the appropriate solenoids as well as the high-pressure/return-flow pump in the hydraulic unit are actuated via the ESP control module in order to apply precisely defined brake pres-

Refer to Figure 124 for disassembly of the vehicle plug-in connector. Insert a wide blade screwdriver in the wedged area between the connector housing and protective cap (arrow). Alternating between both sides of the connector, gently twist on the screwdriver handle to separate the protective cap from the connector housing. Slide the protective cap away from the housing.
Remove the electrical terminal holders only if you require more clearance when inserting additional wires. The electrical terminal holders are held in place with two locking pins. Carefully remove both locking pins with a small screwdriver and pull them out.



1	Protective Cap	3	Front Locking Pin
2	Rear Locking Pin		

Figure 124 Vehicle Harness Connector Disassembly

sure to one or more wheels. The ESP brake intervention counteracts the undesired driving behavior.

Commands are simultaneously passed over the CAN data bus to the engine control module (ECM), and the transmission control module (TCM). Calculated values for engine torque are predefined and downshifting is suppressed in order to reduce driving torque. ESP intervention is completed within a few fractions of a second to ensure optimum vehicle stability.

If oversteering or understeering is detected, a calculated braking force is applied to the front or rear axle via the ESP control module and the hydraulic unit. A signal sent to the ECM via the CAN data bus triggers the demand-based reduction in engine torque.

Safety Circuit

The safety circuit detects faulty signals from sensors and faults in the control module. The activation of the high-pressure/return-flow pump is monitored during the control process. The solenoid valves and stop lamp switch are monitored permanently. If a fault is detected, the system is shut down and the driver is alerted by the lighting of the ESP malfunction indicator lamp. In addition, a fault code is stored in the control module.

The safety circuit also constantly monitors the battery voltage. If the voltage falls below 10.5 V or exceeds 17.5 V, the system is switched off until the voltage returns to the specified range.

ESP SUB-SYSTEMS

In addition to dynamic handling control, the Sprinter's ESP includes the functionality of the following systems:

ANTI-LOCK BRAKE SYSTEM (ABS)

Same function as before - ABS prevents wheel lock-up during braking to enhance vehicle steerability.

ACCELERATION SKID CONTROL (ASR)

The traction control system improves the driving stability of a vehicle and regulates wheel spin during acceleration and speeding from a standing stop, particularly on slippery road surfaces. To prevent the driving wheels from spinning freely, traction control applies braking force to individual wheels or even cuts engine power.
If snow chains are fitted or if a vehicle is operated in deep snow, sand or gravel, it may be useful to switch off ASR to prevent the system from cutting the engine power. As a result, driven wheels may spin freely to generate a "milling" effect needed to work the vehicle out of loose sand or gravel. For this purpose, ASR can be switched off ("ASR OFF"). With ASR switched off, traction control is still active via the brake system, i. e. if only one driven wheel slips, it is braked to increase traction.

ASR also provides engine deceleration regulation. If the vehicle is on a patch of ice, the simple action of removing the foot off the throttle is enough to cause the rear wheels to slip. To avoid this, the throttle input is regulated so power drops slowly instead of abruptly. The engine power will be reduced (decelerated) as needed.

ELECTRONIC BRAKE FORCE DISTRIBUTION (EBD)

EBD is to ensure that the brake forces applied to the rear axle never cause the rear wheels to overbrake. The EBD system integrated in ESP is an improved version of the EBD from ABS/ASR. For this reason, vehicles equipped with ESP no longer come with an additional automatic twin controller for load-sensitive brake pressure control.

The EBD system self-adapts to operating conditions. It detects the vehicle's payload when the vehicle starts and pulls away. Based on the acceleration rate when the vehicle first pulls away from a standstill, the system is able to calculate the actual payload. This is a rough estimate which is used initially. Later on, the system gathers more precise information by monitoring the brake pressure and wheel speed and negative slip when the driver applies the brakes. The system will then produce a more accurate calculation of payload depending on brake retardation. The adaptation is erased when the ignition is switched off. A new adaptation will occur on the next driving cycle. By default, the system acts upon the vehicle as if in an unloaded condition (safe mode). Once a new driving cycle begins with the vehicle in a fully loaded condition (without having gathered more precise information) the system will detect ABS actuation in the front wheels and will allow enough pressure to be applied to the rear axle, to an extent where the wheels are just about to lock up (maximum braking possible).

The system calculates the braking force at the front and rear axles. If the driver brakes gently and then realizes the brakes need to be applied further, the EBD allows the proper pressure to be applied to the front and rear brakes.

When braking occurs, all the wheels slow down at the same rate initially. The rear axle brakes tend to overbrake, however, as the braking force increases, which increases slip at the rear wheels. If the slip thresholds established in the ESP control module are exceeded, the brake pressure of the rear wheel brake is controlled by the "pressure holding" function in the hydraulic control unit (HCU). The corresponding solenoid valves are activated. The high pressure/return flow pump is not activated for this.

The EBD also contains a feature called Corner Brake System (CBS), which operates when the vehicle is braked while cornering to avoid a possible oversteering condition. The EBD monitors the wheel speed of both rear wheels to detect when the vehicle is cornering and allows precise brake pressure application to the front and rear brakes. When the brakes are applied during cornering, the outer wheels get more of the vehicle's weight while the inner wheels get less weight. Wheel lock-up of the inner wheels may occur due to this condition. The EBD system splits the pressure between left and right sides in addition to front and rear brakes.

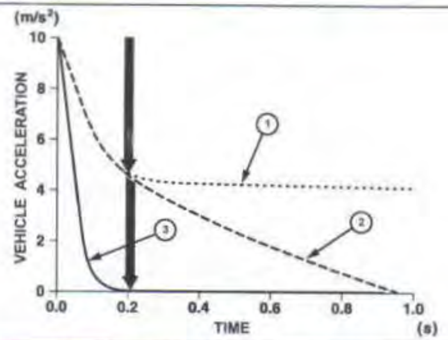
BRAKE ASSIST SYSTEM (BAS)

The Brake Assist System (BAS) analyzes how hard and fast the driver wants to brake. It monitors the brake pressure via the pressure sensor in the hydraulic control unit (HCU). The BAS then uses the HCU to develop the brake pressure.

The Brake Assist System (BAS) was developed due to the finding that most drivers, under normal braking conditions as well as under emergency conditions, start out with little brake pressure and whenever necessary will increase their pedal effort. In an emergency this behavior often leads to a crash since the vehicle cannot be stopped in time.

A distinction is made between the following conditions:

- Hesitant brake application—the driver applies too little pedal force in the initial phase and increases it too slowly.
- Insufficient brake application—the driver applies too little pedal force during the entire brake application.



1	Insufficient Brake Application	3	BAS Brake Application
2	Hesitant Brake Application		

Figure 117 Different Brake Responses Under Panic Braking Conditions

The BAS system interprets the braking behavior of the driver and initiates the full braking power when it identifies an emergency situation. This reduces the braking distance substantially as the full braking power is built up immediately by a pump integrated in the ESP actuator and modulator assembly. However, the wheels do not lock up as the braking power is limited by ABS to maintain the steerability of the vehicle. The well-known brake pedal pulsations during ABS control do not switch off the BAS function. The BAS function is deactivated as soon as the driver reduces the force applied to the brake pedal.

BAS OPERATION

BAS becomes active when the driver brakes very quickly in an emergency situation. The system detects whether an emergency braking situation exists based on the speed at which the brake pedal is depressed. If an emergency braking situation does exist, the ESP control module activates the pump/motor assembly in the hydraulic control unit (HCU) to achieve full braking power. The ESP module detects when the driver releases the brake and turns off the hydraulic pump again.

The BAS is fully integrated into the ESP program. The electronics are located in the ESP control module. A modified high pressure and return flow pump in the hydraulic unit is used to provide the pressure. To optimize the return brake fluid performance brake fluid lines with increased cross-section and a flow-optimized master brake cylinder are used. After the engine is started, a vehicle identification and self-check of the system takes place.

The BAS is ready to function if no fault is present and the vehicle has exceeded a speed of 10 kph (6.2 mph) after driving off. Following this, BAS can be activated down to a speed of 3 kph (2 mph).

The control module calculates the actuation speed of the brake pedal from the speed of pressure rise in the brake pressure sensor.

The speed of actuation of the brake pedal and the vehicle speed are measured in the ESP control module. If the pedal speed is greater than the threshold value specified for the particular vehicle speed, the high pressure and return flow pump in the hydraulic unit is activated and full braking power is achieved.

In the case of a defect, the BAS is disabled (indicated by a malfunction indicator lamp in the instrument cluster). The normal operation of the brakes is not affected by this.

BAS Pressure Reduction Function

The ESP control module receives the information from the brake pressure sensor that the emergency brake application has ended. The pump/motor assembly is no longer activated, the pilot valves (PIV1 and PIV2) are closed and the prime valves (PRV1 and PRV2) are opened. Maximum braking power support is now switched off. The normal braking assistance force remains unchanged.

BAS is switched off when one of the following conditions exists:

- The brake pedal pressure is reduced by the driver to a level at which emergency braking is no longer necessary
- Brake lamp switch is not actuated
- Speed lower than 3 kph (2 mph)
- A fault is detected that causes the BAS malfunction indicator lamp to be activated

BAS Pressure Increase Function

The ESP control module recognizes that the preconditions exist for BAS activation from the speed of the brake pressure rise and the vehicle speed.
At the start of the BAS control phase, the pilot valves (PIV1 and PIV2) are switched to the closed position and the pump/motor assembly is triggered.
The prime valves (PRV1 and PRV2) are opened. The hydraulic pump then draws brake fluid from the reservoir via the prime valves and the master brake cylinder.
A high-pressure limitation of approximately 170 bar (2466 psi) is provided by the integral pressure relief valves in the pilot valves (PIV1 and PIV2).

BAS is activated when the following conditions exist simultaneously:

- Vehicle speed is higher than 10 kph (6 mph)
- Brake lamp switch is operated
- No fault is currently detected
- The system is enabled (after self-test)
- The activation threshold of the pedal speed has been exceeded

ESP DIAGNOSTICS

As an additional check of the ESP system, a road test procedure is available in the diagnostic scan tool. This test should be carried out when any ESP component is replaced in order to ensure proper function. Since the wheel speed sensors are required inputs to the ESP, this test should also be performed if the wheel speed sensors are replaced. First, the brakes are applied with the vehicle stationary and as a second step the vehicle is driven at approximately 10 kph (6 mph). The driver has to make left and right turns, with a minimum 90 degree steering turning angle. If the indicator lamp goes out, everything is in order. If the lamp remains illuminated, the diagnostic scan tool will display the fault codes that are causing the test to fail. The road test function is set in the ESP control module, and can only be deactivated once there are no more fault codes detected.

If the vehicle is going to the shop for a wheel alignment, the steering angle sensor will have to be recalibrated with the diagnostic scan tool. The sensor must also be recalibrated if, after removing and reinstalling the steering column, the alignment has changed by more than 5 degrees.

Indicator Lamp Status

When the ignition is switched on (ignition switch in position 2), the ESP and ABS indicator lamps light up during the bulb check. Once the engine has started, the ESP and ABS indicator lamps should go out. This indicates that ESP is operational.

The ESP or ABS indicator lamp may light up when the vehicle is being driven, and then go out again after a while. This is caused by battery undervoltage or overvoltage.

If the ESP indicator lamp lights up while the engine is running, there is a fault in the ESP system. BAS and ESP are no longer functional.

If the ABS and ESP indicator lamps light up while the engine is running, a fault has occurred affecting the ABS, BAS, ASR and ESP control functions. All of the systems are deactivated.

ANTI-JERK CONTROL

The ECM detects irregularities in engine speed (resulting, for example, from load changes or gearshifts) from the signals supplied by the crankshaft position sensor and reduces them by adjusting the quantity injected into each of the cylinders.

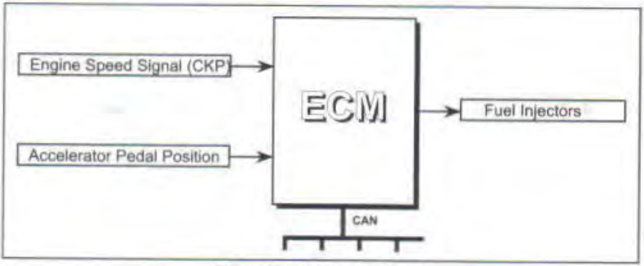


Figure 134 Anti-Jerk Control

FULL LOAD LIMITING

The ECM limits the injection quantity at full load to minimize smoke. If the engine is operating at full load, the ECM limits the amount of fuel injected and modulates the fuel quantity valve to limit the rail pressure. If there are faults in the boost pressure control system, the full load injected quantity is also reduced.

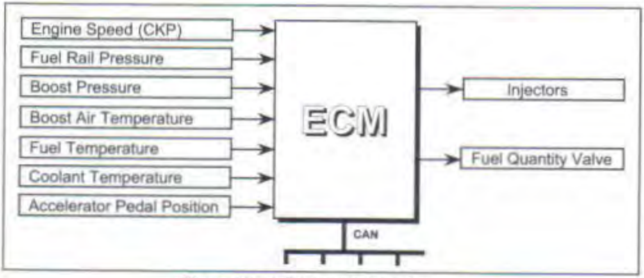


Figure 135 Full Load Limiting Control

MAXIMUM ENGINE SPEED CONTROL

Based on the signal from the crankshaft position sensor (CKP), the ECM limits the maximum engine speed by reducing the injected quantity. The engine speed is normally limited to a no load speed of 4200 rpm. In emergency running mode, the engine speed is limited to 3200 rpm by the ECM. A fuel rail pressure sensor failure limits the engine speed to 2800 rpm.

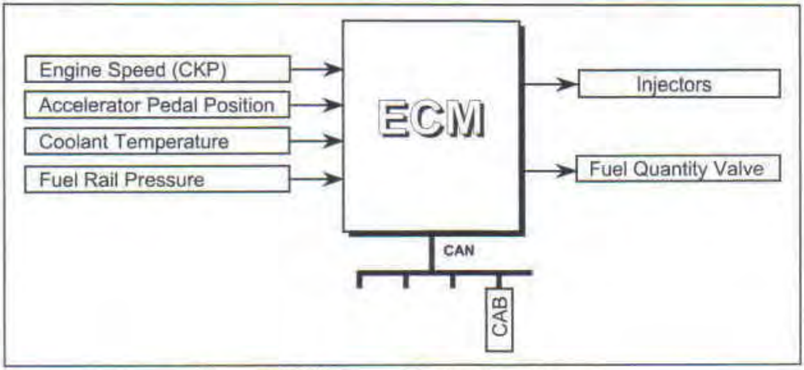


Figure 136 Maximum Engine Speed Control

MAXIMUM VEHICLE SPEED

The maximum vehicle speed is programmable from 22 - 82 mph

Ignition Lock Switch

The ignition lock switch (key-in-igniton switch signal) internally contains a push-on switch which detects when the ignition key is inserted. The 12 V circuit to the IC is closed when the ignition key is inserted in the ignition. This action signals the instrument cluster to activate the LCD display. The instrument cluster also activates a chime warning when the key is in the ignition OFF position (position 0) and the driver's door is opened.

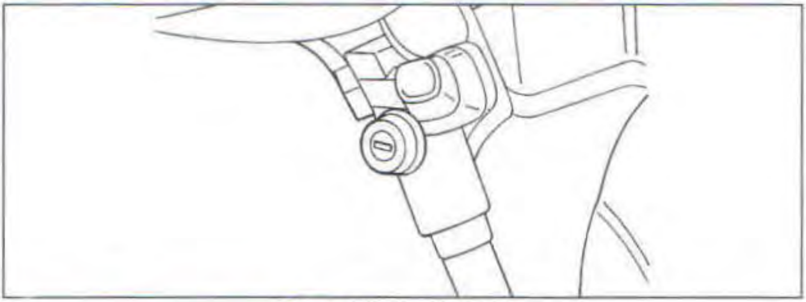


Figure 128 Ignition Lock

DISPLAYING VEHICLE SPEED

The vehicle speed is displayed on a gauge with a stepper motor. To determine the vehicle speed, a microprocessor in the instrument cluster uses the four wheel speed signals which it receives over the CAN bus from the CAB control module. The individual wheel speeds are compared and checked for plausibility at the same time. If there are no significant variations between the wheel speed signals, the vehicle speed is calculated from the rotational speed of one of the front wheels.

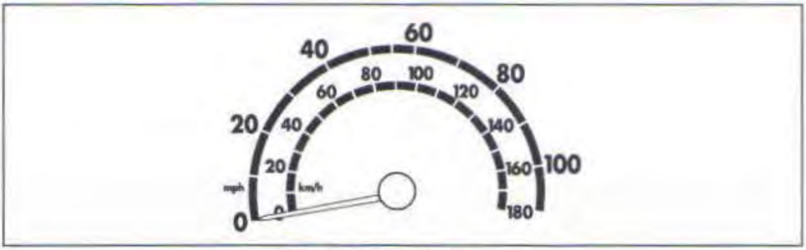


Figure 129 Speedometer

If the individual wheel speed signals vary substantially, the speed signals may be faulty or the vehicle may be cornering. The instrument cluster determines if the vehicle is cornering by comparing the difference in speed between the two sides. While cornering, vehicle speed is calculated from the mean value, (average speed), of the front wheels.

If the comparisons tend to suggest one or more faulty wheel speed signals, the vehicle speed is calculated from the highest wheel speed.

If error messages are received for all four wheel speeds, the vehicle speed is displayed as "0" (with the speedometer needle at the left-hand end of the scale).

AUDIBLE WARNINGS

An audible turn signal indicator (ticking) is integrated within the instrument cluster. This is a contactless relay.

The turn signal flasher is always accompanied by an acoustic clicking sound generated in the same frequency (rhythm). If one of the turn signals fails, the audible turn signal indicator operates at twice the usual frequency.

The instrument cluster has a warning buzzer that, in the event of certain errors or operating conditions sounds in different ways. A buzzer warning is given:

- With malfunction and warning messages with top priority (in addition to the optical warning).
- When the seat belt warning lamp comes on.
- When the brake fluid and parking brake warning lamp lights up if the vehicle starts to move before the parking brake is released.
- When the ignition key remains in the ignition switch with terminal 15 off and the driver's door is opened.
- When the parking lights are on, the ignition key is removed and the driver's door is opened

ON-BOARD DIAGNOSTICS (OBD)

On-Board Diagnosis (OBD) involves:

- Monitoring emission-relevant components and systems during driving
- Detecting and storing malfunctions
- Displaying malfunctions by activating the MIL lamp
- Transferring detected faults to a scan tool in the workshop via a standardized interface

The following systems are monitored electronically:

- Exhaust gas recirculation (EGR)
- Smooth running control (cylinders 1 to 5)
- Fuel system
- ECM and TCM control units
- Glow plug system
- Intake air path

Readiness Code

The readiness code makes it possible to recognize that test procedures (function chains) relating to fault recognition have been completed. The readiness code does not include all the electronic systems. The code is set when the following tests are completed:

- Exhaust gas recirculation (after 15 seconds)
- Fuel system (after 35 seconds)
- Smooth running control (after 70 seconds)

Warm-Up Cycle

Systems that are not constantly monitored are checked only when a warm-up cycle is executed. One warm-up cycle consists of:

- Engine start
- Temperature increase higher than 4.5 °C (40.1 °F)
- Final temperature higher than 60 °C (140 °F)
- Engine switched off

Driving Cycle

One driving cycle consists of:

- Engine start
- 35 seconds at idle
- Engine switched off

Fault Detection

The following faults and error states are detected:

Signals above or below the limit value (open circuits, short circuits, faulty sensor)

- Plausibility of signals
- Function chains with faults
- Fault messages over the CAN data bus (ECM and TCM control modules)

Fault Storage

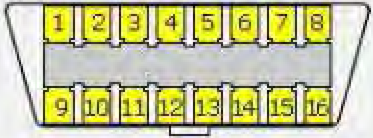
Faults detected are stored in the fault memory as a fault together with freeze frame data. If the fault is not confirmed in the subsequent driving cycle, it is erased. Emission-relevant faults are always entered, they have a high priority.
An emission-relevant fault is erased from the fault memory after 40 fault-free driving cycles.

Fault Freeze Frame Data/Operating Conditions

Certain engine parameters are stored in memory when a fault is detected. Although the data stored depends on the particular fault, the following parameters are usually stored by the ECM:

- Fault code
- Vehicle speed
- Engine speed
- Coolant temperature
- Charge air temperature
- Boost pressure
- Engine load

Pin Number	Pin Name	Description
1	K-Line	Ignition control (EZS), air-conditioner (KLA), PTS, safety systems (Airbag, SRS, AB) and some other
3	TNA	TD engine rotation speed
4,5	GND	Ground
6	CAN-high	CAN-High (including AirBag system in W203, W209, W220, W240, R230, ?215 after 2004y)
7	K-Line	Engine control diagnostic (ME/MSM/CDI)
8		Ignition....
9	K-Line	ABS, ASR, ESP, ETS, BAS diagnostic
11	K-Line	Gearbox and other transmission components (EGS, ETC, FTC)
12	K-Line	All activity module (AAM), Radio (RD), ICS, ...
13	K-Line	AB diagnostic - safety systems
14	CAN-Low	CAN
15	K-Line	IC, KI), TAU, LWR diagnostic
16	+12V	Power

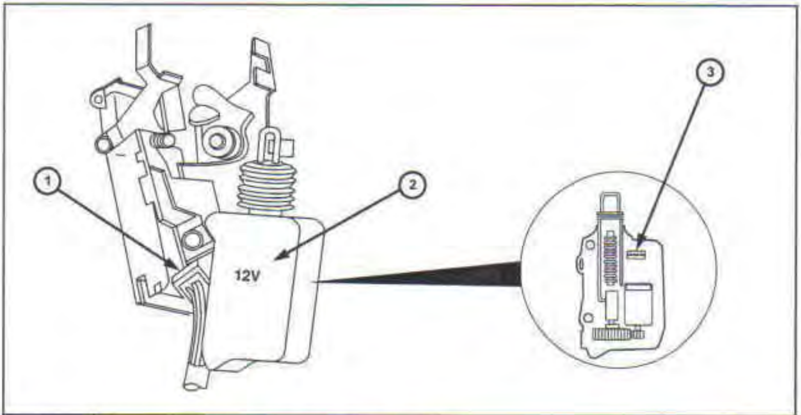


MODULE 7 CONTROL MODULES NOT ON CAN BUS

CENTRAL TIMER MODULE (CTM)

DESCRIPTION

The central locking system CTM consists of the control module and up to five active door actuators. It is possible to lock and unlock the vehicle completely from any door. The actuator is powered by an electric 12 V motor. An actuator motor operates a shaft drive which moves a plunger up or down, depending on the direction of rotation of the motor.



1	Door Ajar Switch (locked/unlocked)
2	Door Lock Motor/Command Switch
3	Command Switch (door open/closed)

Figure 131 Door Lock Motor/Ajar Switch Assembly

The result of this operation is that the door can be locked or unlocked. A command switch is integrated in the actuators and a rotary tumbler switch at the door. The rotary key tumbler switch signals the "Door open" or "Door closed" status and interrupts the motor current in the driver and passenger door in case of a door open status. The command switch is operated directly by the plunger and signals any change in the lock status, locked or unlocked.

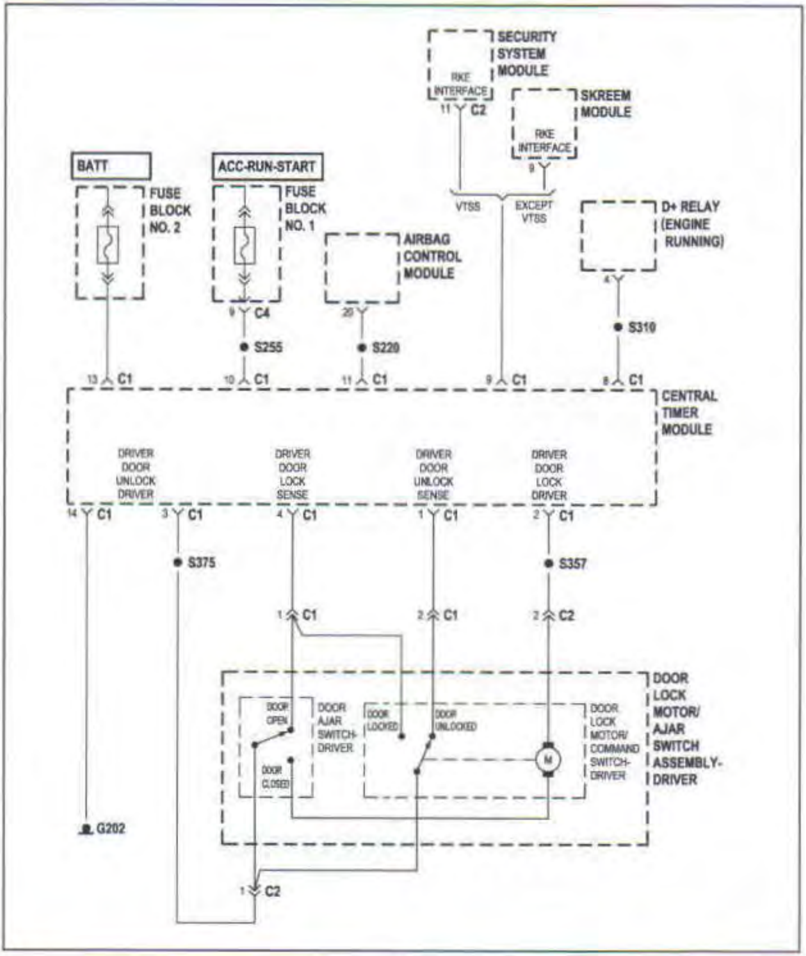


Figure 132 CTM Wiring Diagram

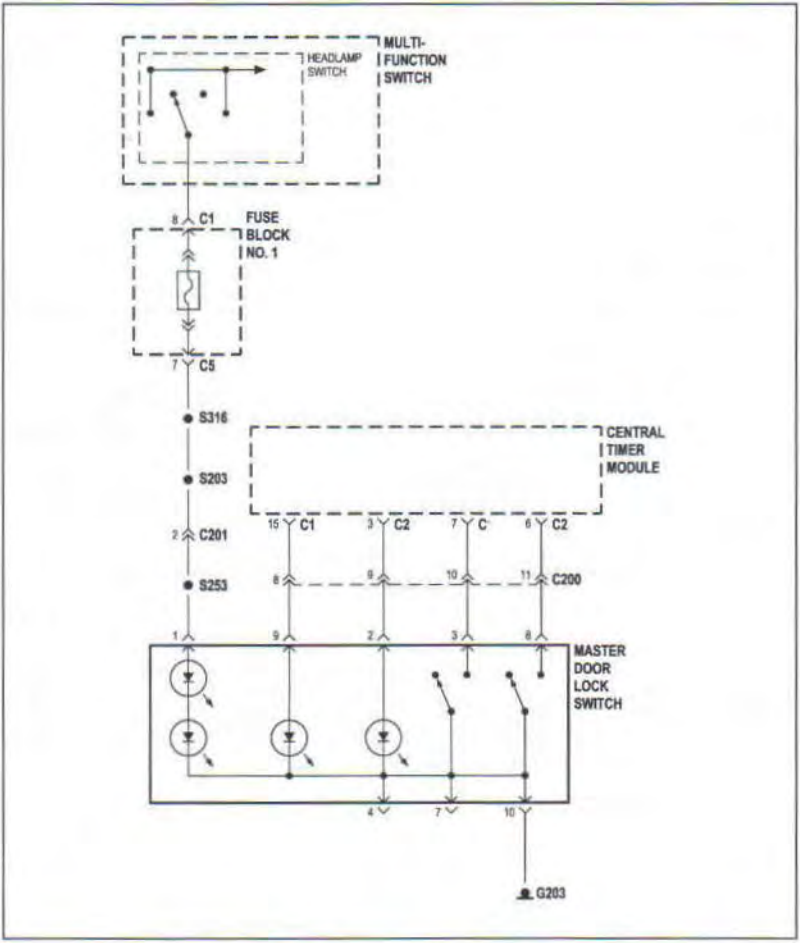


Figure 133 CTM Dash Switch Wiring Diagram

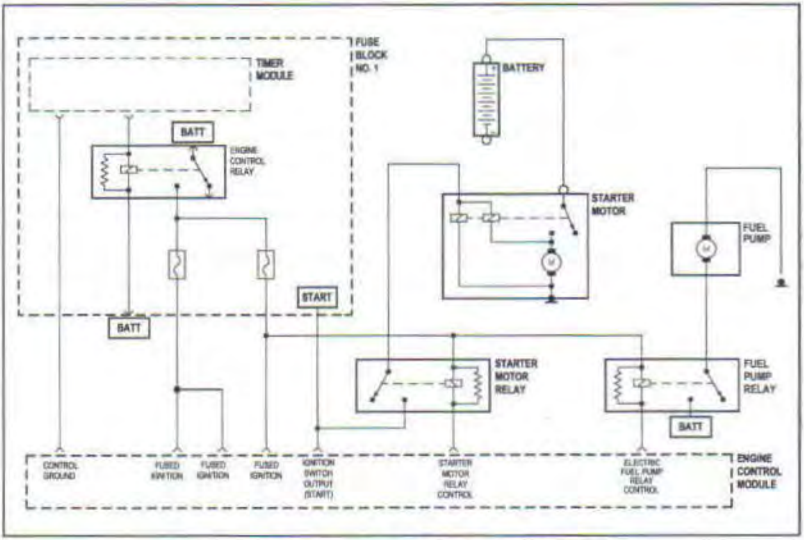


Figure 146 Schematic of ECM Controlled Relays

GLOW PLUG MODULE

The glow plug module activates the glow plugs to preheat the combustion chambers. Two relays within the module provide power to the glow plugs. With the ignition ON, a control signal is transmitted by the ECM to the glow plug module. If no data transfer takes place with the ECM, preglowing is switched off after two seconds.

The operation of the glow plugs is divided into three phases (Figure 147):

- Preglow phase
- Glow phase
- Afterglow phase

CTM OPERATION

The control module monitors the signals from the command switches and rotary key tumbler switches and operates the actuator motors accordingly. It detects the following states:

- Door unlocked
- Door locked
- Door open
- Door closed
- Door not electrically connected
- Actuator does not reach end position (asynchronous detection)

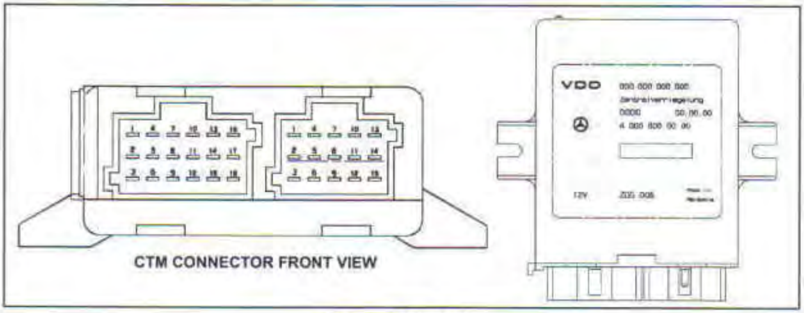


Figure 134 CTM

When a command is given, the actuator motors, which are connected in parallel, are energized through a locking relay (in the CTM) and the door lock is unlocked or locked in this way (pole reversal circuit). The control module is connected via an interface to the SKREEM. This bidirectional link to the SKREEM is used for initiating and unlocking or locking using the radio remote control.

SYSTEM COMPONENTS

- CTM
- An electric motor at every door that drives the lock to locked/ unlocked position
- 2 switches in every door (rotary key tumbler switch and command switch) to report to the CTM the open/close and unlocked/ locked status
- A rocker switch in the dashboard
- A connection to the SKREEM control unit

Figure 147 Glow Phases

Preglow Phase

The combustion chambers are preheated in order to achieve the ignition temperature required for burning of the air/fuel mixture. With the ignition on, the glow plug module and the preglow indicator lamp in the instrument cluster are activated by the ECM depending on coolant temperature. The glow plug module supplies the current required to activate the glow plugs.

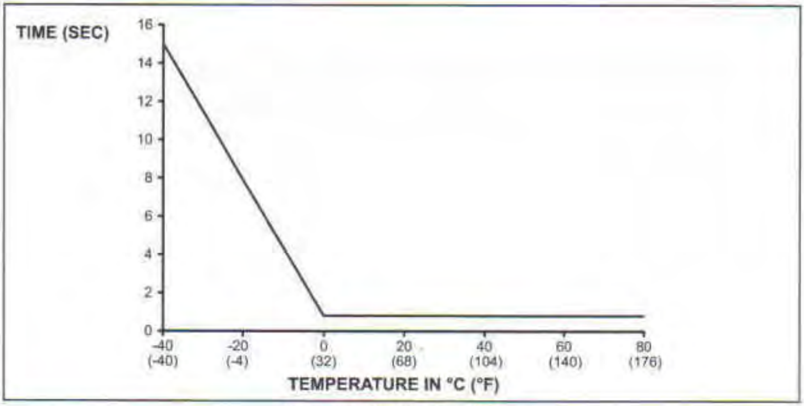


Figure 148 Preglow Phase

The CTM can be actuated with the key, the remote control, the switch in the dashboard, or programmed to automatically lock the doors with the starting of the engine. The system is shared in 2 circuits.

- Circuit 1: Drivers door
- Circuit 2: Passengers door, rear door, sliding door right, sliding door left (option)

Figure 135 Central Locking Switch (Dashboard)

FUNCTION NOTES

If a command switch is set from unlocked to locked, the locking relay in the central locking control unit is actuated, energizing the actuator motors in parallel and moving the door locks to the locked position. After this, the control module verifies the status of command switches. If all the command switches are in the "locked" position, the operation is completed and a dialog for "vehicle locked" is initiated with the SKREEM.

The procedure for unlocking is the same as for locking with the polarity of the locking relay reversed (pole reversal circuit), although the dialog is established before the unlocking command is executed.

If an open door is detected by the control unit after a locking command has started, the vehicle is locked and then automatically unlocked again. If the vehicle is once again locked within 5 seconds, a locking- unlocking-locking operation is performed. This serves as a "Door open" message. If following this, the opened door is closed, it is then automatically locked.

Note : A lockout protection exists only in the case of the driver's door. It is possible to lock all but the driver's door by operating the interior handle.

If one of the actuator motors does not reach the end position after a locking command, this is detected by the control module and the vehicle is then unlocked. If the central locking control unit fails, it is possible to lock or unlock the individual doors with the vehicle mechanical key or using the interior handle. If the vehicle is unlocked via the key FOB and no doors are opened within 40 seconds all doors will lock.

Glow Phase

The glow phase starts once the glow indicator lamp goes out and the ignition switch is turned to the engine start position. An engine start signal is supplied to the glow plug module by the ECM, and the glow plugs continue to be supplied with current.

Afterglow Phase

The ECM determines the afterglow period after engine start depending on coolant temperature. Afterglow is activated for 30 seconds in the event that no signal is received from the coolant temperature sensor.

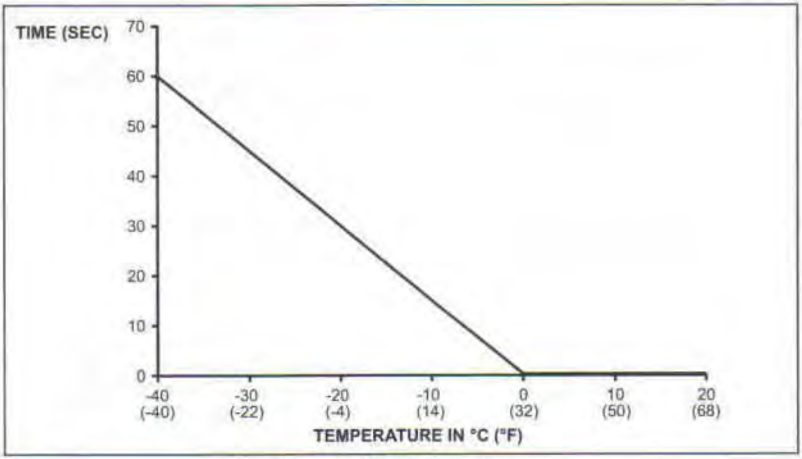


Figure 149 Afterglow Phase

Afterglow provides the following benefits:

- Improves engine warm-up
- Prevents exhaust smoke after a cold start
- Stabilizes the cold start speed

Inputs and Outputs

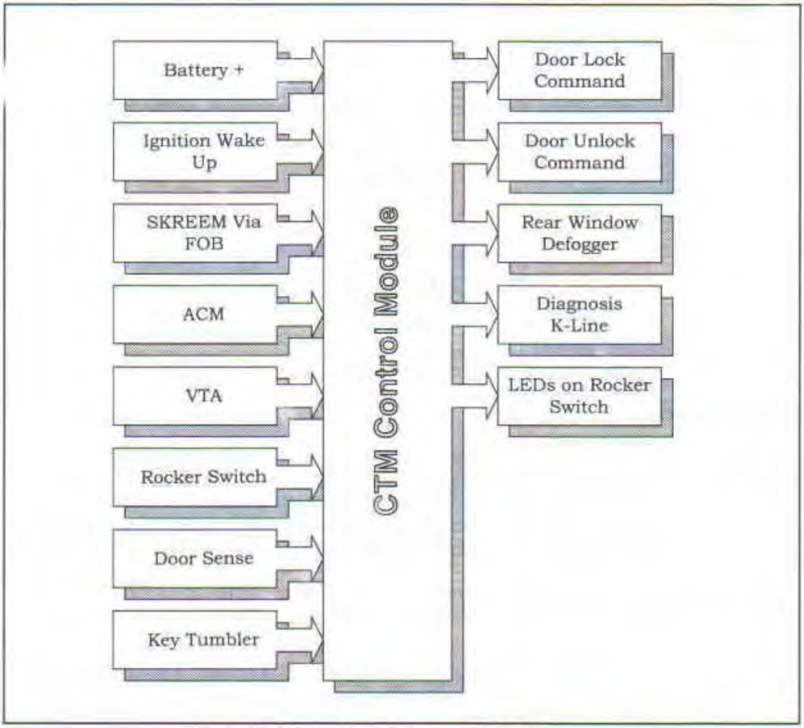
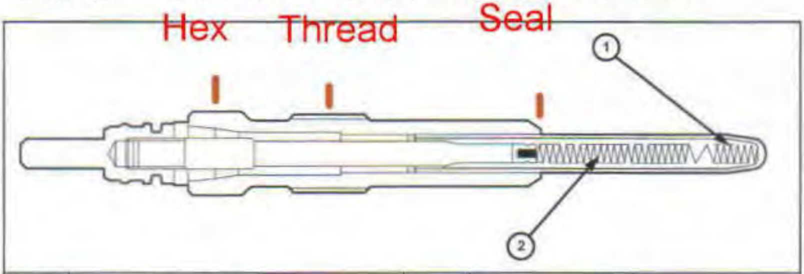


Figure 136 Inputs and Outputs Block Diagram

Glow Plugs

The glow plugs are located in the combustion chamber. The glow plug consists of a housing with a threaded fitting and an interference-fit glow tube. The glow tube contains the heating element. The heating elements is comprised of the heating winding and control winding, which are connected in series (Figure 150). The windings are surrounded by compressed magnesium oxide (MgO) powder. MgO powder is widely used as a filling for electrical heating elements for applications in contact with air or liquids. The MgO powder forms a layer between the windings and the outer sheath.



1	Heating Winding	2	Control Winding

Figure 150 Glow Plug Heating Element

Operation

The resistance of the heating winding is virtually unaffected by temperature. The control winding however, has positive temperature coefficient (PTC) properties. When the preglow system is activated, a current between 8-25A flows through each glow plug. The amount of current depends on the actual temperature of the glow plug. The heating winding (1) heats up the glow plug. The control winding (2) increases its resistance as the temperature rises, and limits the current. The glow plugs are protected this way from overloads.

The glow plugs reach the temperature needed for ignition of 850°C (1562°F) in 4 seconds. The glow plug temperature is also limited to a non-critical level to allow activation for up to 3 minutes following engine start.

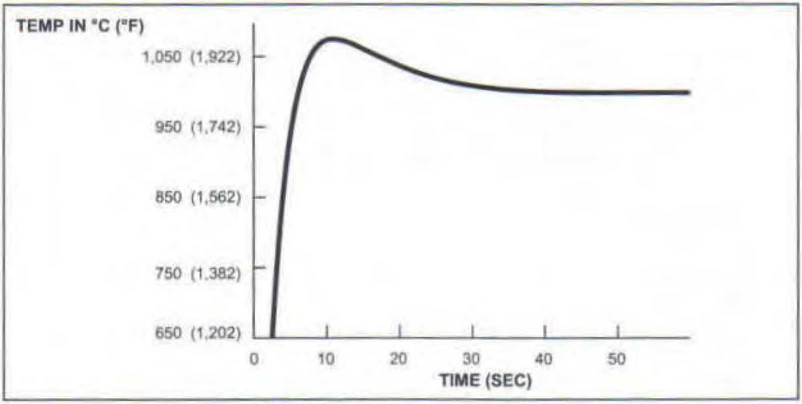
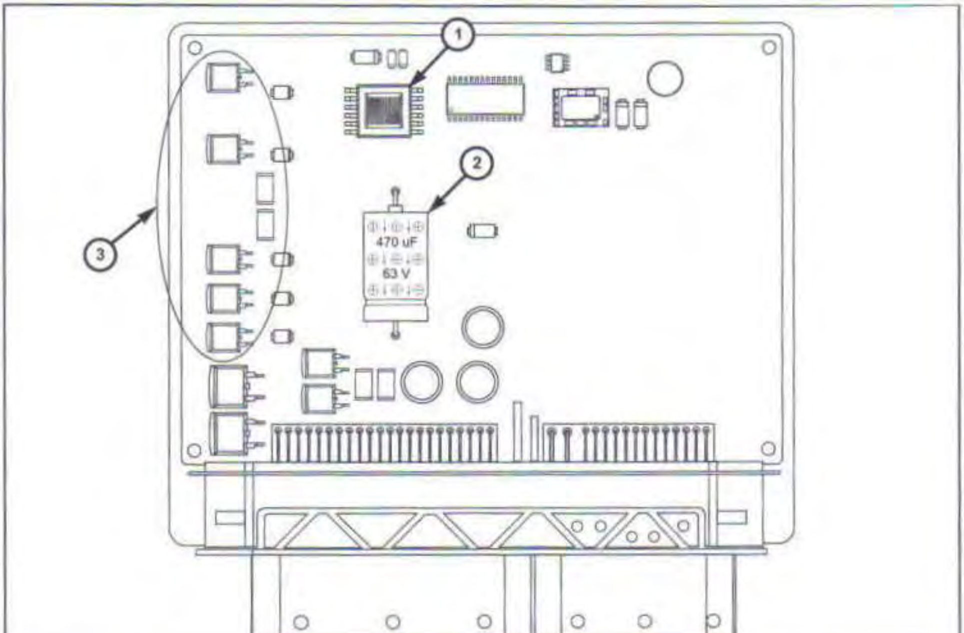


Figure 151 Glow Plug Temperature vs. Time

High Voltage Drive Circuit

In order to inject small pilot quantities of approximately 0.0015 cm^3/stroke under high pressure conditions, the injector solenoid valves must switch quickly and reliably within 200 microseconds. To achieve this, the injector coil must be triggered with steep current flanks. This requires high voltages being made available in the ECM.

With pilot injection, main injection and post injection, the number of injector activations have increased significantly. At idle speed for example, the ECM activates the injectors 85 times every second. Enough energy needs to be quickly stored by the ECM to properly activate the injectors within these time constraints. The ECM contains a special aluminum electrolytic capacitor (boost capacitor) and a ferrite core inductor (booster coil) to ensure the fast switching of the fuel injector solenoid valves. The capacitor has a rated capacitance of 470 µF and a nominal voltage of 63V. Once charged, the capacitor supplies the necessary current to energize the solenoids. Current peaks of up to 30 A at high frequencies (kilohertz range) are produced during the unloading and charging phases of the capacitor.



1	Booster Coil	3	Injector Ground Control MOSFETs
2	Boost Capacitor		

Figure 153 ECM Printed Circuit Board Layout

ACTIVITY 5.2 CYLINDER TESTING

The purpose of this activity is to use the diagnostic scan tool and compression gauge to check cylinder condition and injector operation.

TASK 1 INJECTOR SHUTOFF (KILL) TEST

The injector shutoff is a quick way to isolate the operation of the injectors.

1. Connect the diagnostic scan tool to the vehicle and access the ECM.
2. Start the engine and let it run at idle.
3. Perform the injector shutoff (kill) test on each cylinder. Notice any changes in engine idling characteristics.
4. Is there a noticeable change in all cylinders? YES __X__ NO ____
5. Although this test in itself is not conclusive, is there a cylinder you should pay closer attention to? YES _____ NO __X__

TASK 2 ELECTRICAL COMPRESSION TEST

The electrical compression test is performed with the engine at cranking speed. The test determines the power output from each of the engine's cylinders by measuring the engine rpm drop. During this test, all cylinders should have the same amount of speed drop, within a 7 rpm range of each other.

1. Connect the diagnostic scan tool to the vehicle and access the ECM.
2. Perform the engine compression test.
3. Record the compression readings on the table below.

Cylinder	RPM Reading
1	231
2	231
4	230
5	232
3	231

4. Is the engine rpm drop in all cylinders within specifications? YES __X__ NO ____
5. Although this test in itself is not conclusive, is there a cylinder you should pay closer attention to? YES _____ NO __X__

TASK 3 MECHANICAL COMPRESSION TEST

The mechanical compression test verifies the mechanical condition of the engine.

1. Disable the engine to avoid starting.
2. Remove the glow plugs.
3. Use the compression gauge to measure the compression of all cylinders.
4. Record the compression readings on the table below.

Cylinder	Compression Reading
1	
2	
3	
4	
5	

5. Are the compression readings within specifications? YES ____ NO ____

TASK 4 SMOOTH RUNNING CONTROL TEST

The smooth running control test displays variations in engine speed between cylinders with the engine running.

1. Connect the diagnostic scan tool to the vehicle and access the ECM.
2. Start the engine and let it run at idle.
3. Perform the smooth running control test.
4. Record the engine speed value of each cylinder on the table below. Notice that the table is arranged by engine firing order.

Cylinder	Engine Speed
1	
2	
4	
5	
3	
1	

Speed Variation Between Cylinders		↓↑
►Between 1-2		
►Between 2-4		
►Between 4-5		
►Between 5-3		
►Between 3-1		

5. Is there a noticeable engine drop between any of the cylinders? YES ___ NO ___
6. Although this test in itself is not conclusive, which cylinder do you need to pay closer attention to?

____

TASK 5 INJECTOR CORRECTION QUANTITY TEST

The injector correction quantity test displays the amount of fuel being added or removed at each injector by the smooth engine running control function of the ECM.

1. Connect the diagnostic scan tool to the vehicle and access the ECM.
2. Start the engine and let it run at idle.
3. Perform the injector correction quantity test (snap throttle once test has begun).
4. Record the injection quantities on the table below. Include whether the value is positive or negative.

Cylinder	(+/-)	With Good Injector	(+/-)	With Bad Injector
1	-	*00000*	+	*00511*
2	+	*00045*	-	*00162*
3	-	*00003*	+	*00153*
4	-	*00041*	-	*00257*
5	+	*00015*	-	*00241*

5. Install a bad injector and repeat the test. Fill out the last column of the table.
6. Are the correction quantities within specifications? YES _____ NO _____
7. Which injector(s) appear to be out of specifications?

____

TASK 6 INJECTOR LEAKAGE TEST

The injector leakage procedure tests the internal leak-tightness of each injector.

1. Using the service manual, find the procedure for removing the injector return lines and installing the test vials.
2. Connect the diagnostic tool to the vehicle and access the ECM.
3. Perform the injector leakage test.
4. Are all injectors within specifications? YES _X_ NO _____

FUEL PRESSURE SOLENOID

The fuel rail pressure solenoid is attached to the rear of the fuel rail (Figure 164). The fuel solenoid has a hex nut design with a threaded fitting for mounting the valve to the fuel rail. A lipped-edge metal disk is used to seal the solenoid to the fuel rail instead of O-rings. The metal disk is not serviceable and its sealing properties will be lost upon removal of the fuel pressure solenoid. Therefore, the fuel rail pressure solenoid must always be replaced with the fuel rail as an assembly.

Note: The fuel pressure solenoid and fuel rail are serviced as an assembly.

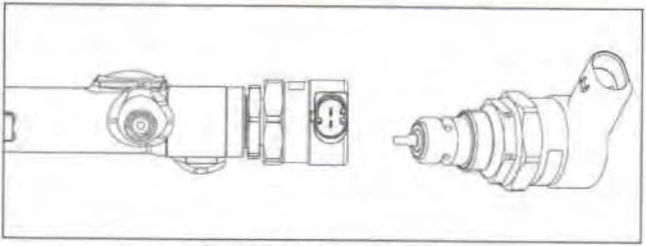


Figure 164 Fuel Pressure Solenoid

Two wires connect the fuel pressure solenoid to the Engine Control Module (ECM). The ECM supplies battery power to one end of the solenoid and sends a pulse width modulated (PWM) ground through the other end. The PWM signal has a fixed frequency of 1 kHz and a duty cycle between 5-95% depending on engine operating conditions (Figure 168). The 1 kHz frequency is high enough to avoid undesired armature oscillations, which could produce pressure fluctuations in the rail.

The solenoid has a current draw of approximately 400-600 mA with the engine at idle speed. After engine start up, the current draw remains in the lower end of the specified value for 30 seconds. After 30 seconds the current draw increases to the higher end of the specified value.

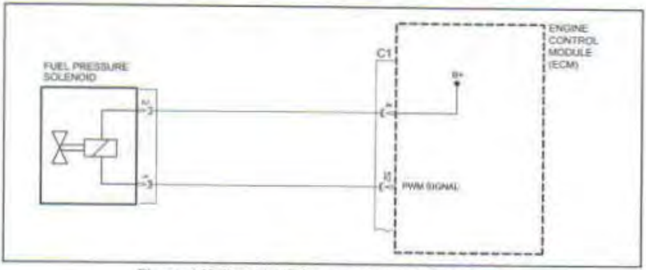
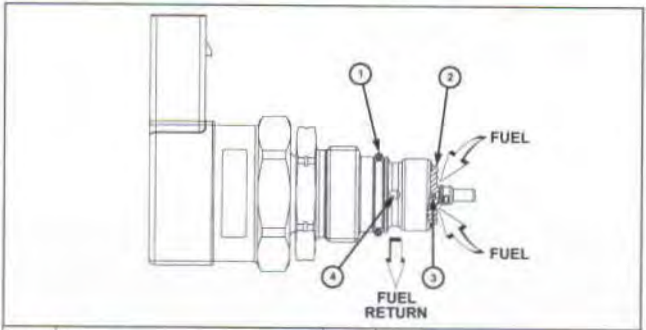


Figure 165 Fuel Rail Pressure Solenoid Schematic

Together with the quantity valve, the fuel pressure solenoid controls the fuel rail pressure and keeps it constant. The fuel pressure sensor measures the current rail pressure and supplies an appropriate voltage signal to the engine control module (ECM). Via a control circuit, the fuel pressure solenoid or fuel quantity control valve is activated accordingly by the ECM until the required rail pressure is reached.

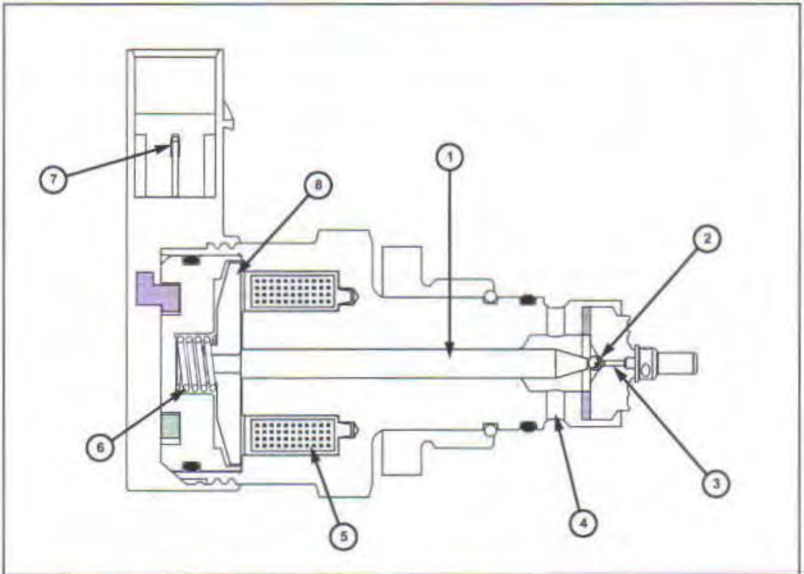


1	O-Ring	3	Fuel Passage
2	Metal Sealing Disc	4	Fuel Return Hole

Figure 166 Fuel Pressure Solenoid

Operation

When deactivated, the fuel pressure solenoid is closed, due to the spring force pressing the ball into the seat (Figure 167). The spring pressure maintains a minimum pressure of about 60 bar (870 PSI).



1	Armature Plunger	5	Magnetic Coil
2	Ball and Seat	6	Spring
3	Fuel Inlet Passage	7	Electrical Terminal
4	Fuel Return Passage	8	Armature

Figure 167 Fuel Pressure Solenoid Cutaway View

When operating, the ECM regulates the PWM signal (Figure 168) and the fuel pressure solenoid opens to a greater or lesser degree. At idle the control value is approximately 18% for the first 30 seconds after engine start up. The control value rises to approximately 24% after 30 seconds. The pressure of the fluid counteracts the force of the magnet coil and the spring force. A minimum fuel pressure of 200 bar (2900 PSI) must be achieved in order to start the engine.

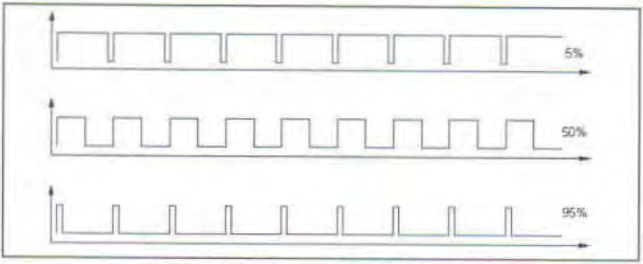


Figure 168 Fuel Pressure Solenoid PWM Signal

Failure Modes

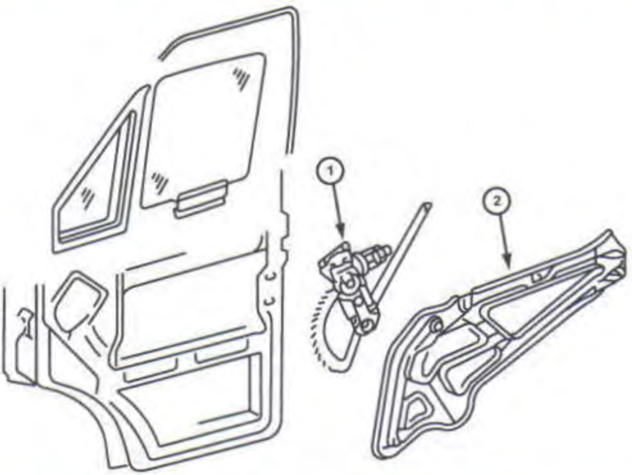
The ECM monitors the operation of the fuel pressure solenoid and stores fault codes related to the following conditions:

- Wire shorted to positive or shorted to ground
- Open circuit
- Plausibility

MODULE 8 POWER WINDOWS

DESCRIPTION

The power window system is a factory installed option. It allows each of the door windows to be raised and lowered electrically by actuating a switch on the front door panels.

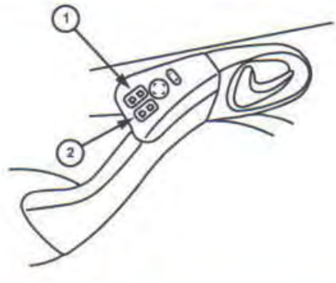


1	Window Motor/Regulator Assembly
2	Carrier Plate

Figure 155 Power Windows

OPERATION

When the ignition key is in the number 2 position B+ is supplied to two fuses in fuse block number 2. One fuse is for the driver's door window motor and the other fuse is for the passenger door window.



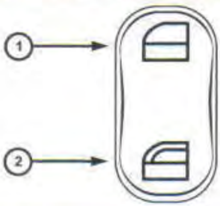
1	Driver's Door Window Switch
2	Passenger Door Window Switch

Figure 156 Driver's Door Window Switches

DRIVER DOOR WINDOW OPERATION:

The driver's door window switch directly operates the bi-directional power window motor located on the driver's door window regulator.

PASSENGER DOOR WINDOW OPERATION



1	To close the window
2	To open the window

Figure 157 Power Window Switch

The passenger door window can be operated by the master switch located on the driver's door, or the power window switch located on the passenger door. Both switches operate the bi-directional power window motor located on the passenger's door window regulator.

Note: The driver's power window switch and the master power window switch are the same. It is possible to mix up the connectors.

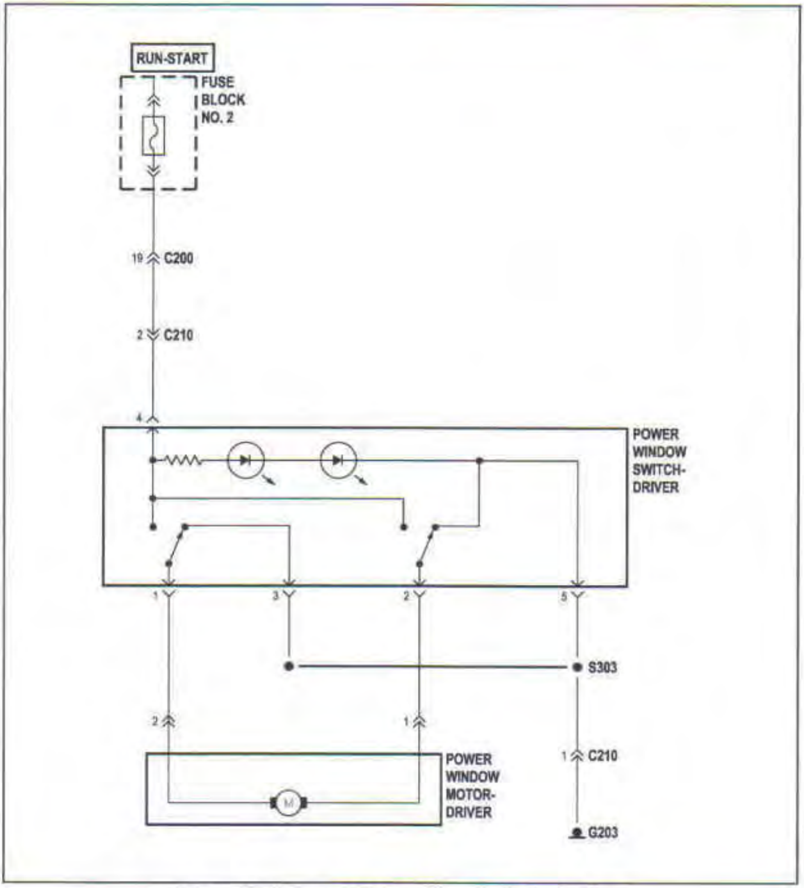


Figure 158 Power Window Circuit, Driver's Door

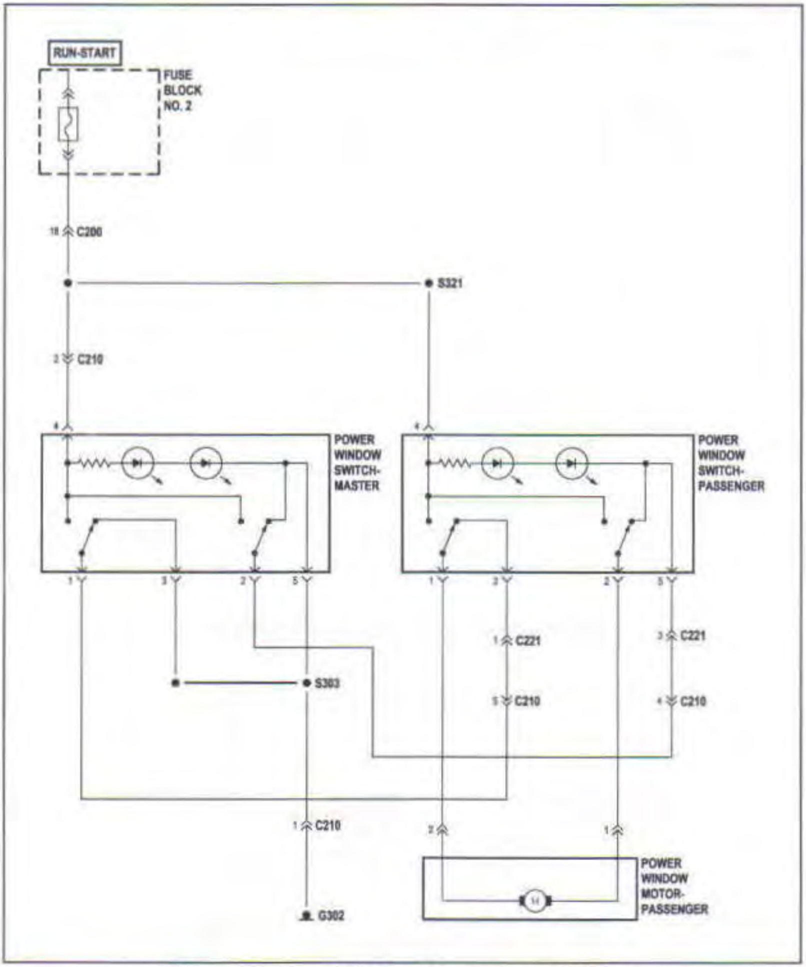


Figure 159 Power Window Circuit, Passenger Door

EGR VALVE ACTUATOR

The EGR valve actuator is mounted to the intake manifold (Figure 176).

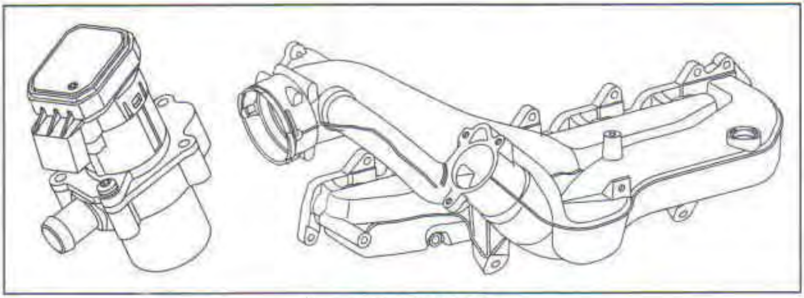


Figure 176 EGR Valve

Exhaust-gas recirculation (EGR) is a method for reducing the emissions of NOx. With EGR, a portion of the exhaust gases are diverted into the intake during part-load operation. Not only is the oxygen content reduced, but also the rate of combustion and the peak temperature at the flame front, which results in lower NOx emissions.
If too much exhaust gas is recirculated (exceeding 40% of the intake air volume), the particulates, CO, and HC emissions, as well as the fuel consumption rise due to the lack of oxygen.

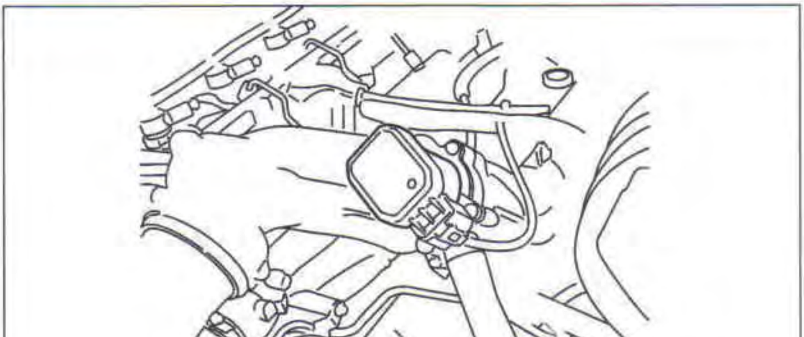
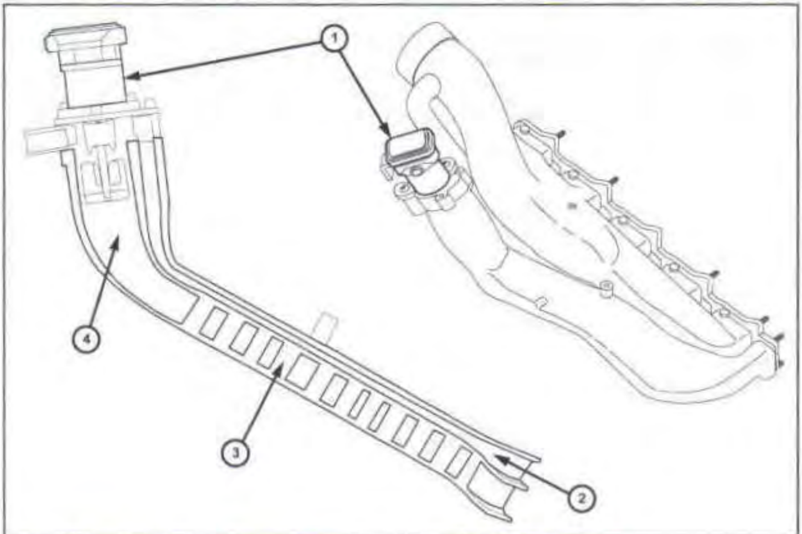


Figure 177 EGR Valve Location

The EGR system can provide up to 35% exhaust gas recirculation. The EGR operates during all engine speed and load conditions. At wide open throttle, it provides a 5% recirculation rate. The EGR shuts down during high engine idle to avoid carbon buildup on the valve (vehicles with the optional constant rpm feature). The EGR also deactivates if the EGR temperature is too high.

The intake manifold contains a finned EGR cooler. Coolant flows through the EGR cooler and around the EGR valve to lower the recirculated exhaust gas temperature. The reduced temperature achieved by the EGR cooler improves EGR operation at high engine load.

The recirculated exhaust gas temperature must be reduced significantly for emissions. The exhaust gases reach temperatures of approximately 700°C (1292°F). The temperature is reduced 200°C (392°F) by flowing through the cylinder head internal passage. The exhaust gases are led through the water cooled manifold, which reduces the exhaust gas temperature by another 200°C (392°F). As a result, the temperature of the exhaust gas being recirculated is approximately 300°C (572°F).



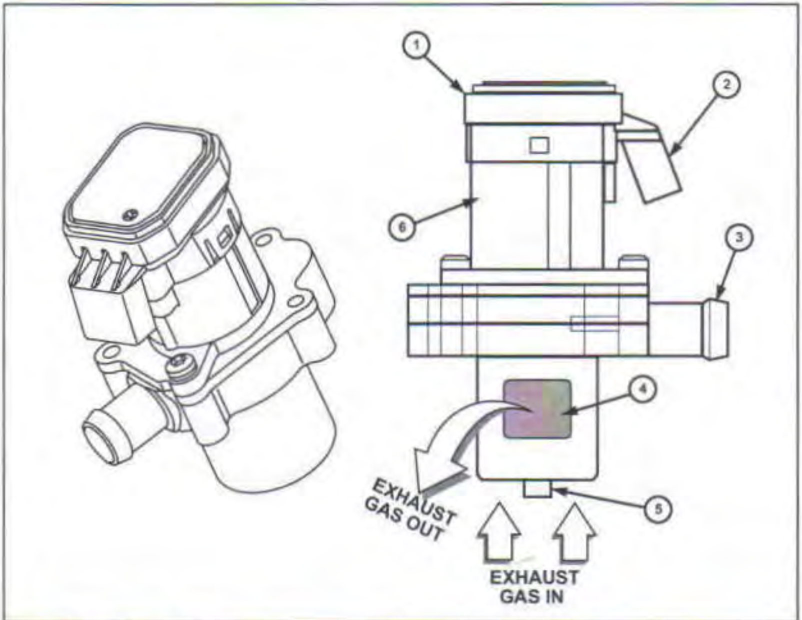
1	EGR Valve	3	Cooling Fins
2	Coolant Passage	4	Exhaust Gas Passage

Figure 178 EGR Water-Cooled Duct

Construction

The EGR valve is an electrically operated, rotary-type valve. Similar to the boost pressure actuator, the EGR valve is considered to be a smart actuator. Smart actuators have integrated electronics that allow them to measure and process data in order to perform tasks. The EGR valve housing contains the following subassemblies (Figure 179):

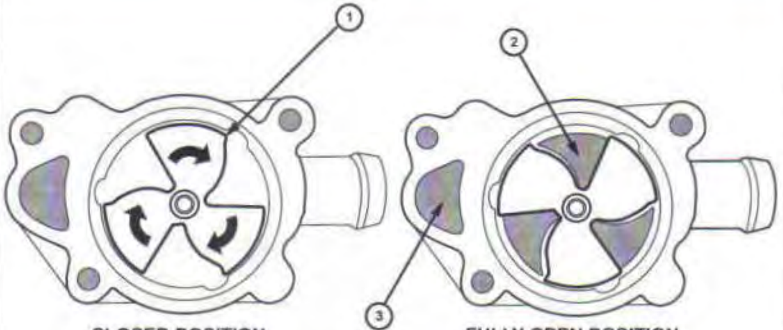
- **End cover**—Contains the electronic circuit using thick film hybrid technology. A thick film hybrid is a combination of film circuits and other elements, such as capacitors and integrated circuits on a ceramic substrate. The electronic circuit is mounted to a heat sink and covered with thermal gel. The end cover is a sealed unit and is not serviceable.
- **Motor subassembly**—Contains the torque motor, which turns the rotary valve. The torque motor turns the rotary valve up to a maximum of 70° from its fully closed position. The motor consists of a single stator, an armature with a permanent magnet and an SmCo magnetic ring for position feedback.
- **Coolant jacket**—Provides the path between the engine's coolant circuit and the EGR cooling duct.
- **Rotary valve subassembly**—Contains the rotary valve, valve shaft, return spring and EGR inlet and outlet ports. With a rotary valve arrangement, the position of the valve does not change due to boost pressure pulsations and the effects of varnish and soot build-up are reduced.



1	End Cover With Electronic Circuit	4	EGR Outlet Port
2	Electrical Connector	5	EGR Inlet Port (Rotary Valve)
3	Coolant Port	6	Torque Motor

Figure 179 EGR Valve

The EGR actuator turns the rotary valve to increase or reduce the opening at the inlet port. The position of the rotary valve determines the amount of exhaust gases flowing back into the combustion chambers.



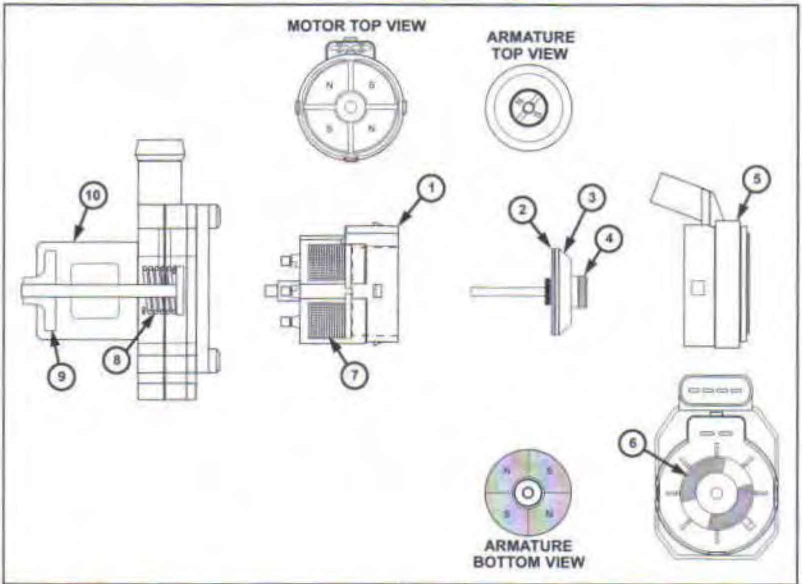
1	Rotary Valve	3	Coolant Jacket
2	EGR Inlet Port		

Figure 180 EGR Valve Bottom View

Operation

The ECM calculates the EGR rate based on a combination of various sensor signals instead of relying only on the MAF value as the control parameter. Such signals include boost pressure, air temperature, and engine speed. The calculation allows for a precise EGR rate, as well as better correction of the target value in case of changes in air density or ambient temperature.
The ECM evaluates these values and outputs a PWM signal in accordance with one of the maps stored in it. The signal is sent to the exhaust gas recirculation valve actuator. The map is formulated to keep the NOx as low as possible.

The electronic circuit within the EGR valve evaluates the PWM signal, and based on this input, generates a current signal to drive the torque motor. The angle of rotation of the valve is determined by the amount of current flowing through the torque motor stator. As current increases, a stronger magnetic field is produced. The armature increases its angle of rotation, which opens the valve further. Increasing the angle of rotation increases the amount of exhaust gases flowing back into the combustion chambers. When the current is reduced, the tension of the return spring overcomes the magnetic field strength, which closes the rotary valve.



1	Torque Motor	6	Position Sensing Elements
2	Permanent Magnet	7	Stator Windings
3	Armature	8	Return Spring
4	Position Feedback Magnet Ring	9	Rotary Valve
5	End Cover	10	Valve & Coolant Jacket Housing

Figure 181 EGR Valve Exploded View

The angle of rotation is monitored by an integrated position feedback control circuit. A samarium cobalt (SmCo) magnet ring is fixed to the top of the torque motor armature. The magnet ring has diametrically opposed poles, and when the armature turns, the direction of the magnetic field changes. The change is detected by a hall-effect sensing element within the end cover.

The EGR actuator is externally grounded and is supplied with battery power when the ignition is switched on. The ECM supplies a pulse width modulated (PWM) signal to the actuator.

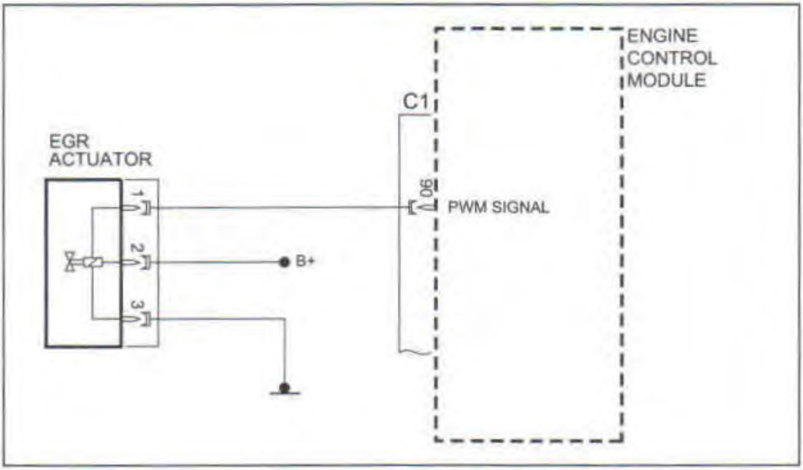


Figure 182 EGR Actuator Schematic

Self-Cleaning Function

The ECM provides the EGR valve with a self-cleaning function, which opens and closes the valve twice after the engine has been switched off to eliminate soot deposits. During the cleaning cycle, the valve turns a few degrees past the fully-open position to wipe off any carbon deposits.

Failure Modes

The ECM monitors the operation of the EGR valve and stores fault codes related to the following conditions:

- Open circuit
- Wire shorted to positive or shorted to ground
- Exhaust gas recirculation rate too high
- Exhaust gas recirculation rate too low
- Exhaust gas recirculation flow check

CAN BUS OUTPUTS

The ECM transmits information via the CAN bus to various control modules.

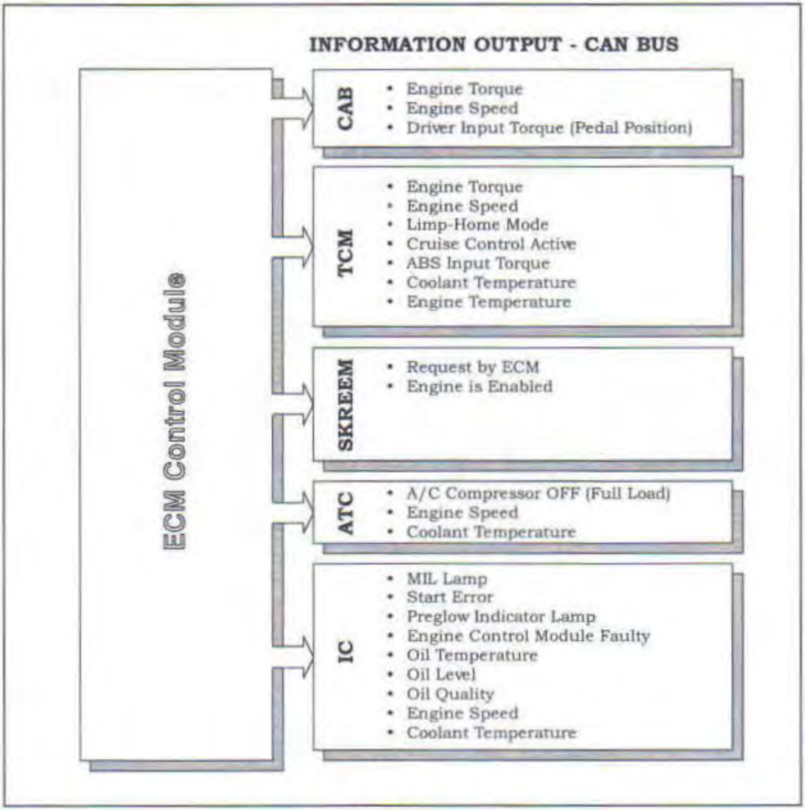


Figure 191 CAN Bus Outputs

MODULE 12 HORN AND CIGAR LIGHTER

DESCRIPTION

The horn is used as an audible attention device. United States motor vehicle standards require all automobiles sold in The United States to be equipped with a horn. The single-tone horn is located in the engine compartment, behind the right side head lamp.

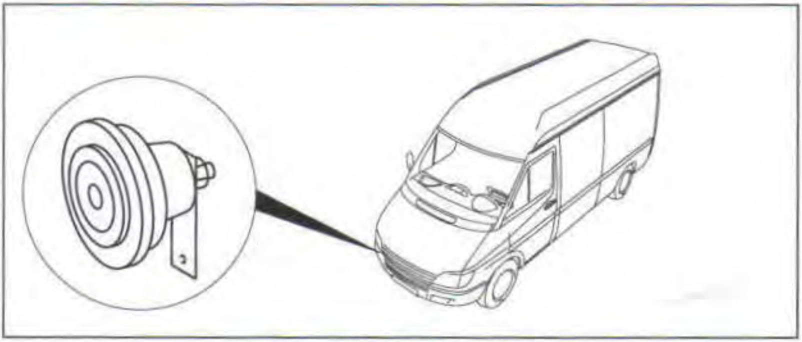


Figure 181 Horn Location

The horn is powered through a fuse in Fuse Block #1. The fuse powers both the control and controlled side of the horn relay. The horn relay is located near Fuse Block No.2, underneath the driver's seat. The ground for the horn relay is via the horn switch on the airbag cover to G200.

The horn switch consists of a U-shaped spring plate located in the steering wheel. Four set of contacts are evenly spaced along the spring plate. The driver airbag is mounted on top of the spring plate in such a way that when pushed downward it closes at least one set of contacts, providing a ground path to the horn relay coil circuit. The horn will operate as long as the ignition is ON.

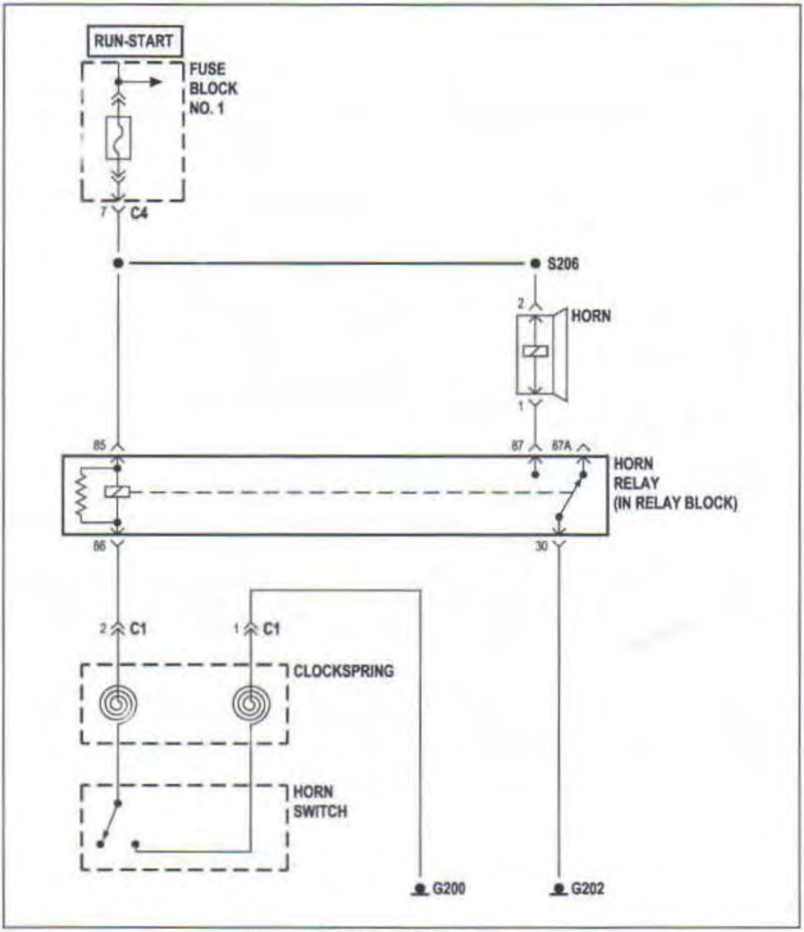


Figure 182 Horn Circuit Diagram

tening to a suspect component with a mechanic's stethoscope, or running the vehicle with the suspect component removed.
Use the Diagnosis Charts in the Service Manual to develop an action plan to determine which checks to make. Document any additional problems with the customer's vehicle. Pay particular attention to other concerns and problems that can cause an unsafe condition.

Step 5: Repair the Concern

The fifth step in the Six-Step Diagnostic Process is to make the necessary adjustments and repairs to correct the problem. The Service Manual may help when performing these operations.
Always look for the cause of component damage. If you replace the component that is causing the symptom but do not try to determine what caused that component to fail, the failure is likely to recur.

Step 6: Verify Proper Operation

The last step in the Six-Step Diagnostic Process is to verify that the vehicle operates properly. Eliminating or isolating the problem is the optimal goal. If the customer must tolerate the concern, thoroughly explain to the customer why the condition exists. It is possible that fixing one concern may reveal another. Take the time to road test and verify that no further problems exist. Studies show that almost one out of three service visits requires a return visit to fully correct the problem.

TYPES OF EXHAUST SMOKE

The High-Pressure Common Rail (HPCR) diesel engine should emit very little smoke. White smoke is not considered normal. The different types of exhaust smoke indicate different problems. Following is a brief discussion of black, blue, and white exhaust smoke.

Black Smoke

Black smoke is created by incomplete combustion. The reason for the fuel being only partially burned often relates to one of the following problems:

- Excess fuel in the combustion chamber
- Insufficient air supply (clogged air filter, kinked hoses, faulty turbo)
- Advanced injection timing due to poor diesel fuel quality not recommended being used in the vehicle

Black smoke is caused by too much fuel or poor fuel quality and not enough air or time to burn the fuel. Black smoke is not considered normal and is often related to low power or poor fuel economy problems.

Blue Smoke

Blue smoke is an indication of engine oil burning in the combustion chamber. Blue smoke is usually accompanied by excessive oil consumption. Any of the following conditions can cause excessive oil consumption:

- Overfilled crankcase
- Worn piston rings
- Failed valve stem seals
- Failed turbocharger seals

White Smoke

White smoke is caused by particles of fuel passing through the combustion chamber without burning and exiting with the exhaust gas. Fuel not burning is often related to low combustion chamber temperature. At light loads, the temperature in the combustion chamber may drop to 260°C (500°F). The lower temperature delays combustion, causing some fuel to be partially burned and blown out with the exhaust gas.

NO DTC DIAGNOSIS

When diagnosing diesel driveability concerns in the absence of codes, use the symptom-based diagnostic tables in the Service Information. Always follow the Six-Step Diagnostic Process when diagnosing a customer concern.

HIGH-PRESSURE DIAGNOSIS

The high-pressure fuel system can be diagnosed using a DRBIII. The DRBIII will show the fuel pressure setpoint and the actual pressure. If the actual pressure and the fuel pressure setpoint values are about the same, a concern with the high-pressure fuel system may not be present. If a small leak is suspected in the high-pressure lines, check them by using the cardboard test.

WARNING: THE HIGH-PRESSURE FUEL PUMP SUPPLIES FUEL WITH PRESSURES AS HIGH AS 1600 BAR (23,205 PSI) TO EACH INJECTOR THROUGH THE HIGH-PRESSURE LINES. FUEL UNDER THIS AMOUNT OF PRESSURE CAN PENETRATE THE SKIN AND CAUSE PERSONAL INJURY. WEAR SAFETY GOGGLES AND ADEQUATE PROTECTIVE CLOTHING AND AVOID CONTACT WITH FUEL SPRAY WHEN CHECKING HIGH-PRESSURE LINES FOR LEAKS

DIAGNOSIS WITH RELATED FAULT CODES

The ECM stores diagnostic information in the EEPROM. When fault codes are present, follow the proper diagnostic steps in the service information.

COMMON POINT ANALYSIS

Certain failures can affect several circuits, causing multiple fault codes, which can lead to excessive diagnosis time. These types of faults should be treated as a whole, instead of individually. First, find if the faults displayed share a common circuit. For example, a customer complains his engine doesn't start (Start Error) and the horn doesn't work. If properly diagnosed, these complaints can be quickly narrowed down to a burnt fuse which supplies power to these components.

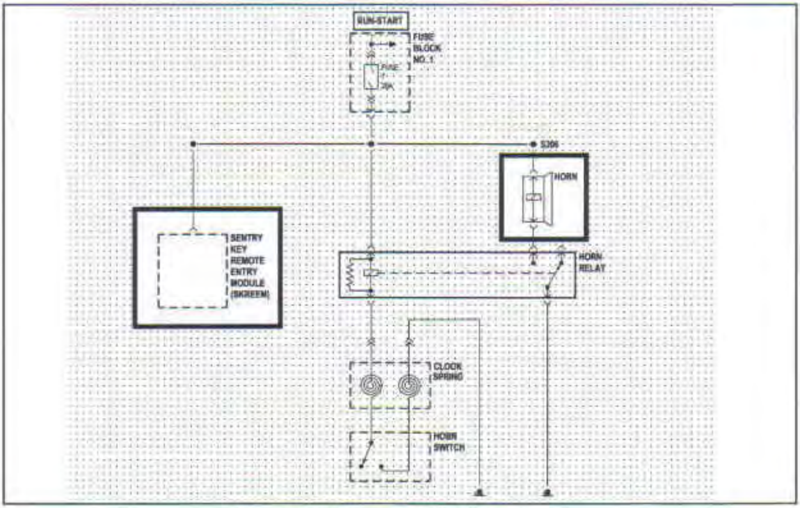


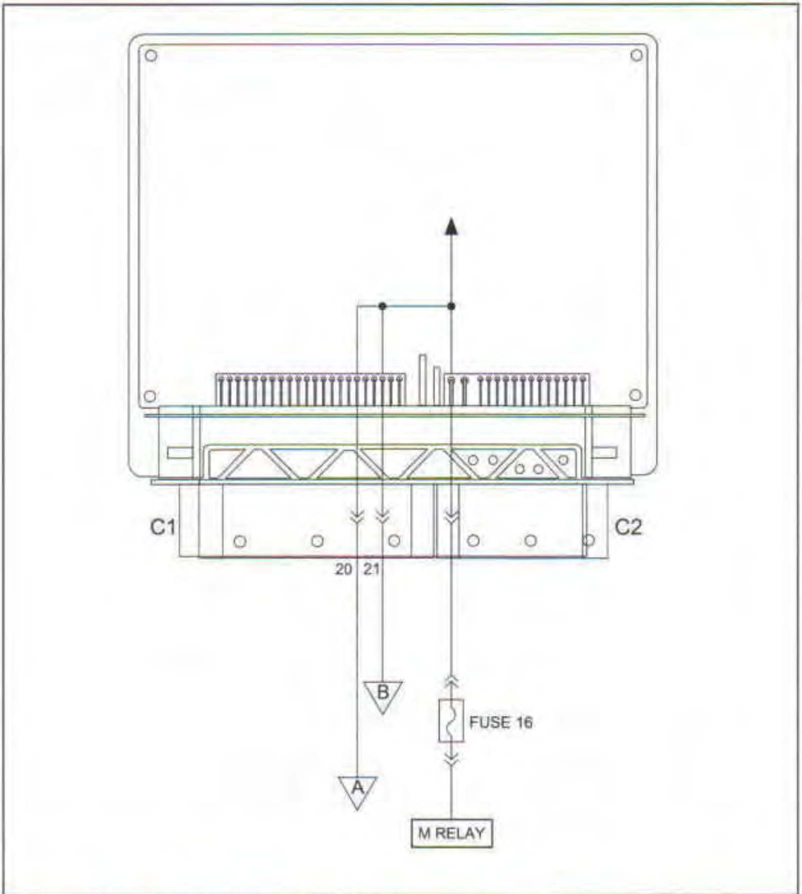
Figure 193 Common Point Analysis

ECM Internal Power and Ground Distribution

When diagnosing the common rail fuel system, the internal power supply and ground structure of the ECM must be taken into account. The ECM uses the power supply and distributes it among various inputs and outputs, both 12 volts and 5 volts. The ECM incorporates the following circuits:

- Two 12-volt power supplies
- Three regulated 5-volt power supplies (Reference 1, 2 and 3)
- Ground distribution

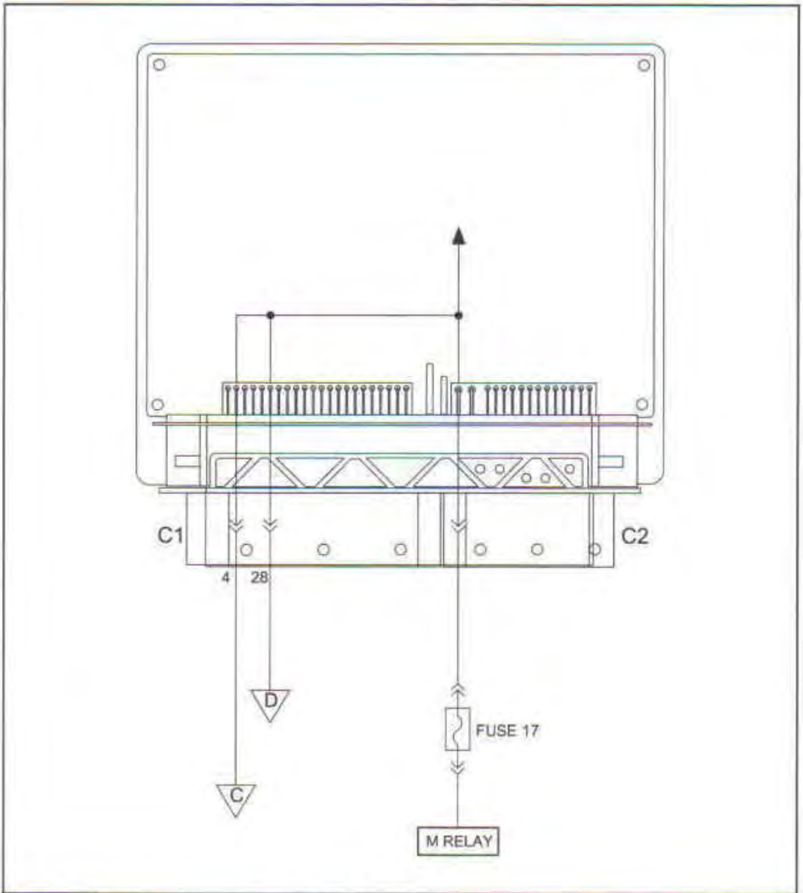
Internal Common Point Analysis, 12-Volt Power Supply Distribution



A	Water in Fuel Sensor 12 V Supply
B	Crankcase Ventilation Heater 12 V Supply

Figure 194 ECM, 12 Volt Supply 1

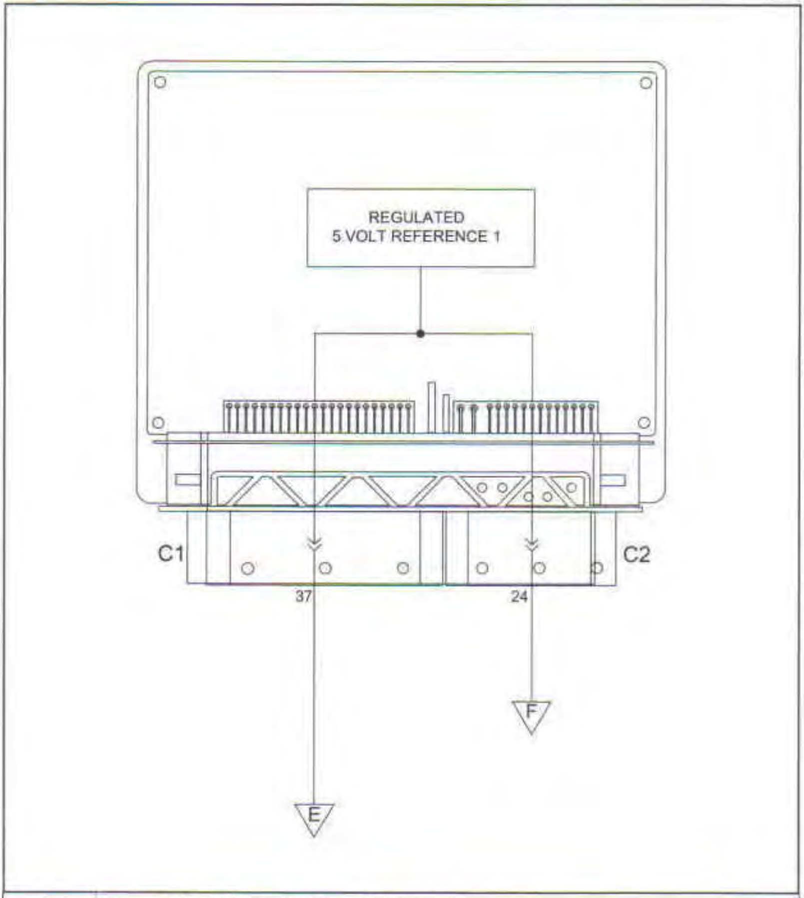
Internal Common Point Analysis, 12-Volt Power Supply Distribution



C	Fuel Pressure Solenoid 12 V Supply
D	Fuel Quantity Valve (Engine Management Valve) 12 V Supply

Figure 195 ECM, 12 Volt Supply 2

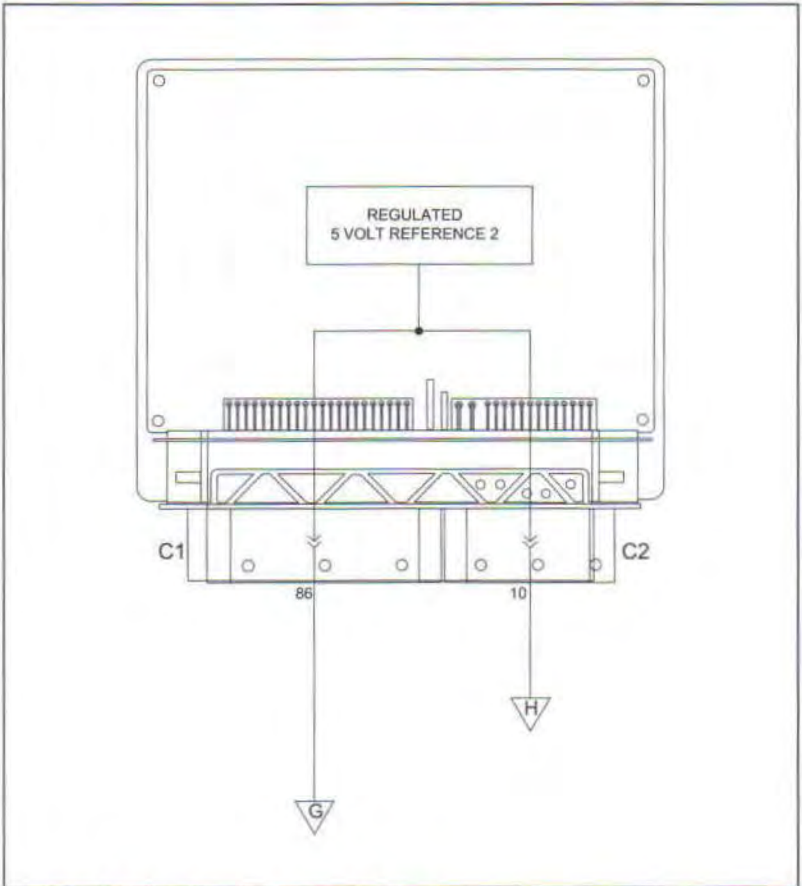
Internal Common Point Analysis, 5 Volt Reference 1



E	Camshaft Position Sensor 5V Supply
F	Accelerator Pedal Position Sensor (APP) 5 V Supply

Figure 196 ECM, 5 Volt Reference 1

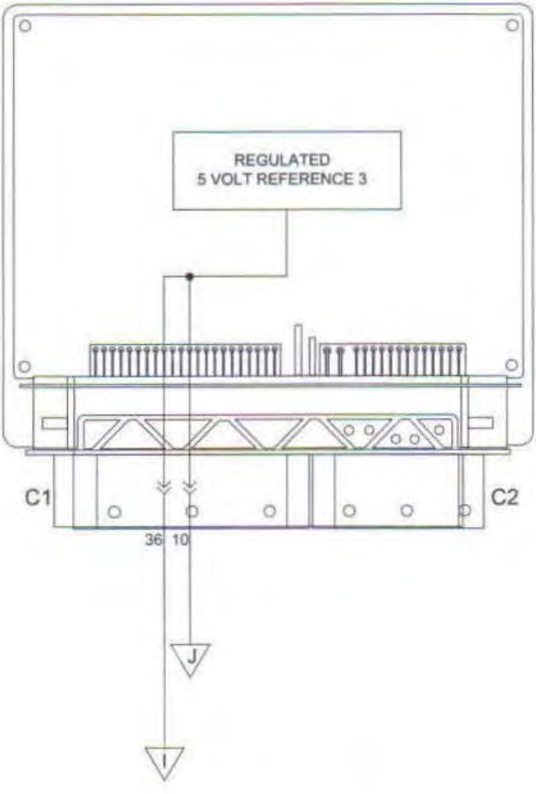
Internal Common Point Analysis, 5 Volt Reference 2



G	Fuel Rail Pressure Sensor 5V Supply
H	Boost Pressure Sensor 5 V Supply

Figure 197 ECM, 5 Volt Reference 2

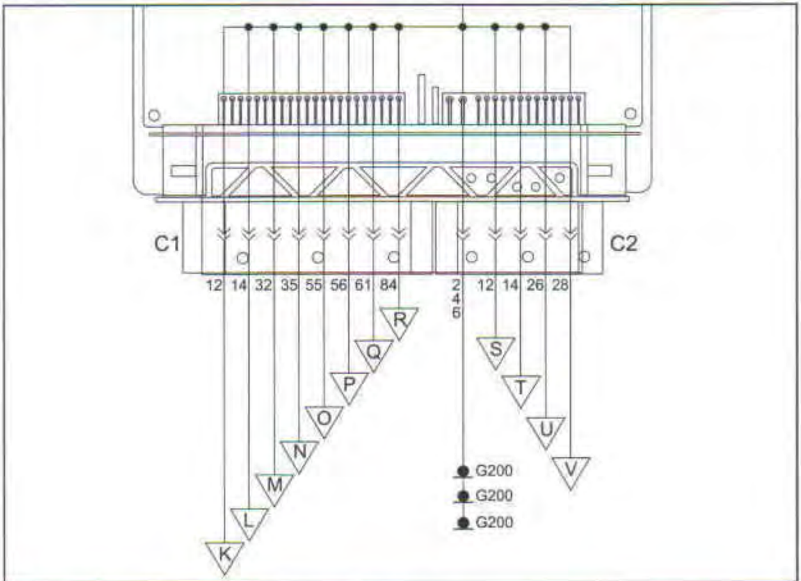
Internal Common Point Analysis, 5 Volt Reference 3



I	Intake Air Pressure Sensor 5V Supply
J	Engine Oil Sensor 5V Supply

Figure 198 ECM, 5 Volt Supply (3)

Internal Common Point Analysis, Grounds



K	Intake Air Pressure Sensor Ground
L	Camshaft Position Sensor Ground
M	Fuel Temperature Sensor Ground
N	Engine Oil Sensor Ground
O	Water In Fuel Sensor Ground
P	Coolant Temperature Sensor Ground
Q	MAF Sensor Ground
R	Fuel Rail Pressure Sensor Ground
S	Boost Pressure Sensor Ground
T	Accelerator Pedal Position Sensor 2 Ground
U	Accelerator Pedal Position Sensor 1 Ground
V	Boost Air Temperature Sensor Ground

Figure 199 ECM, Ground

COMPLAINT: ENGINE CRANKS, BUT DOESN'T START

Possible causes:

- Insufficient fuel pressure – low or high pressure circuits
- Insufficient Low pressure pump output
- Fuel pressure sensor malfunction
- Fuel pressure solenoid malfunction
- Leaking injector
- High pressure pump failure
- CPS pulse ring or flex plate damage

Troubleshooting Steps

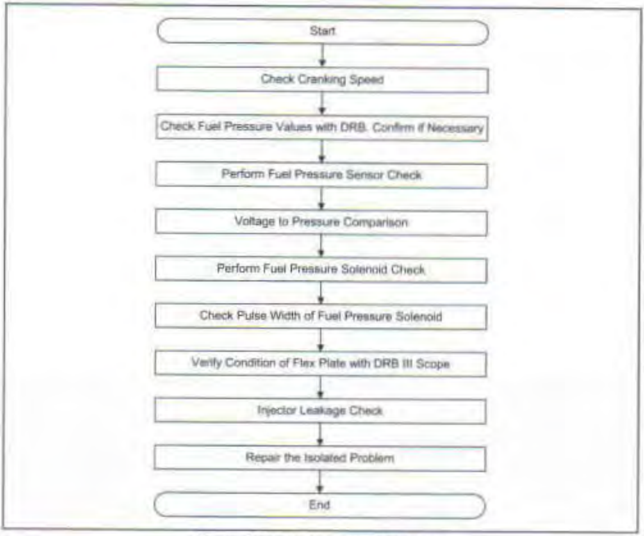


Figure 201 Engine Does Not Start

APPENDIX

OM647 ENGINE WIRING SCHEMATIC

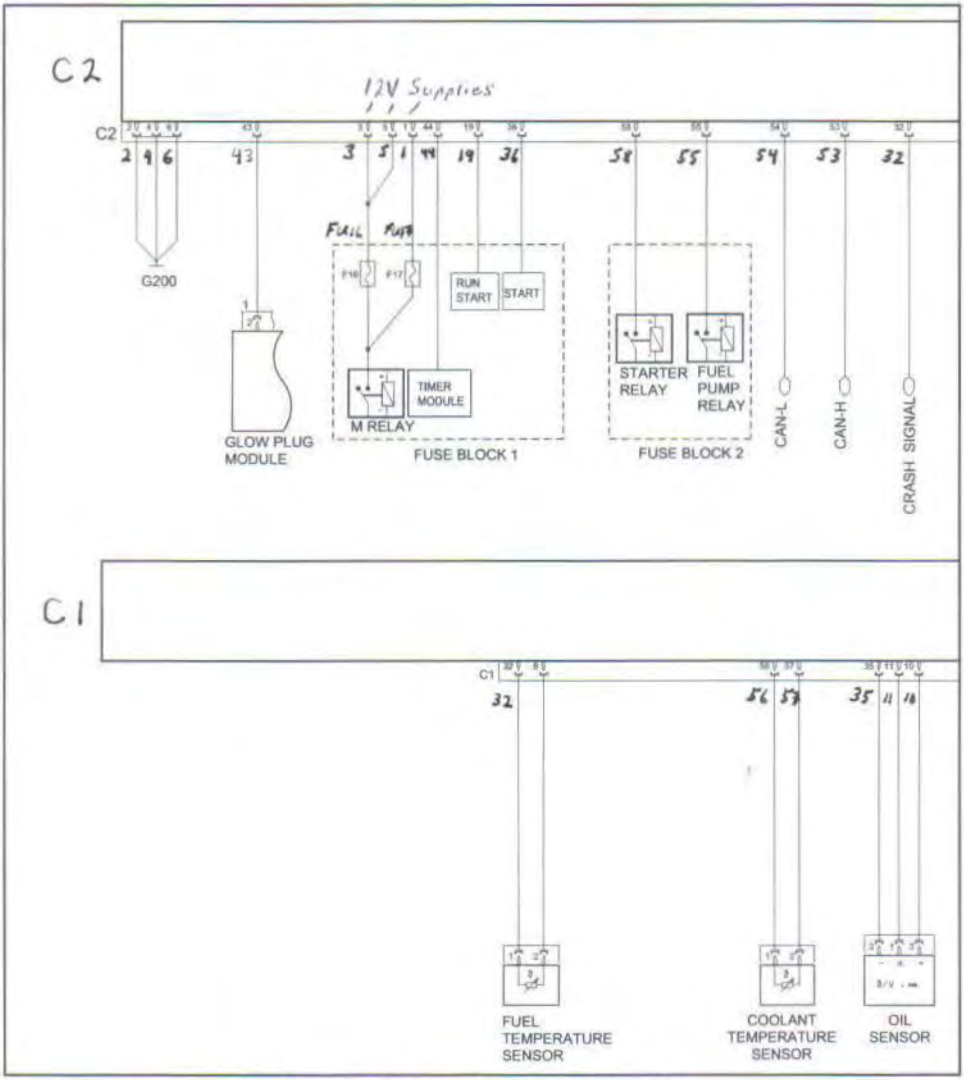


Figure 205 Engine Wiring Schematic

APPENDIX

OM647 ENGINE WIRING SCHEMATIC

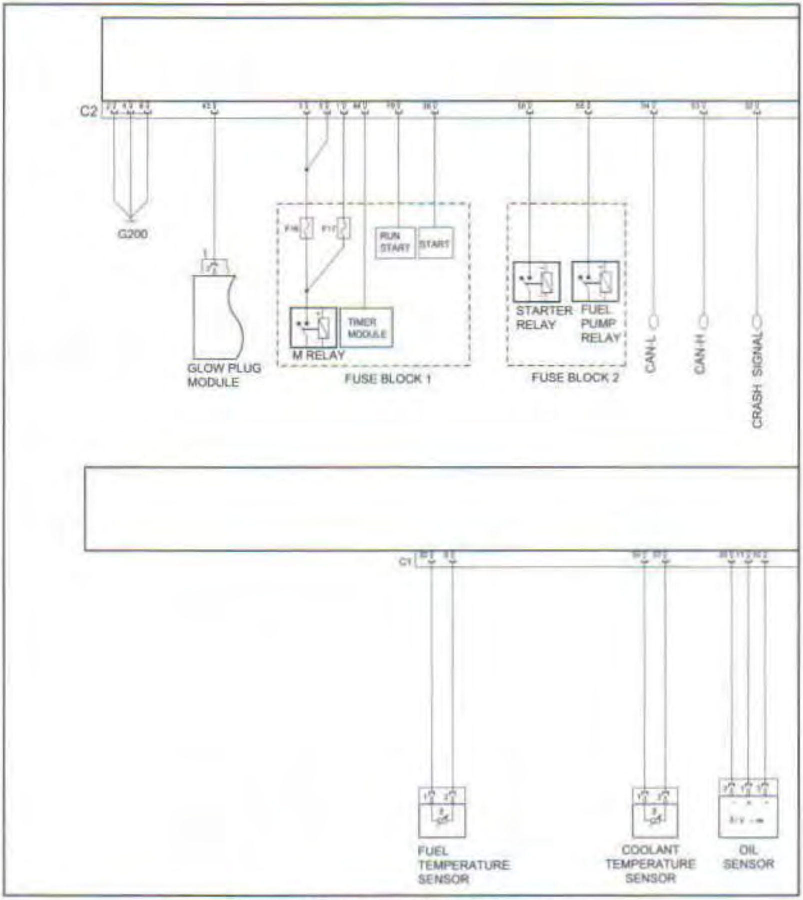


Figure 205 Engine Wiring Schematic

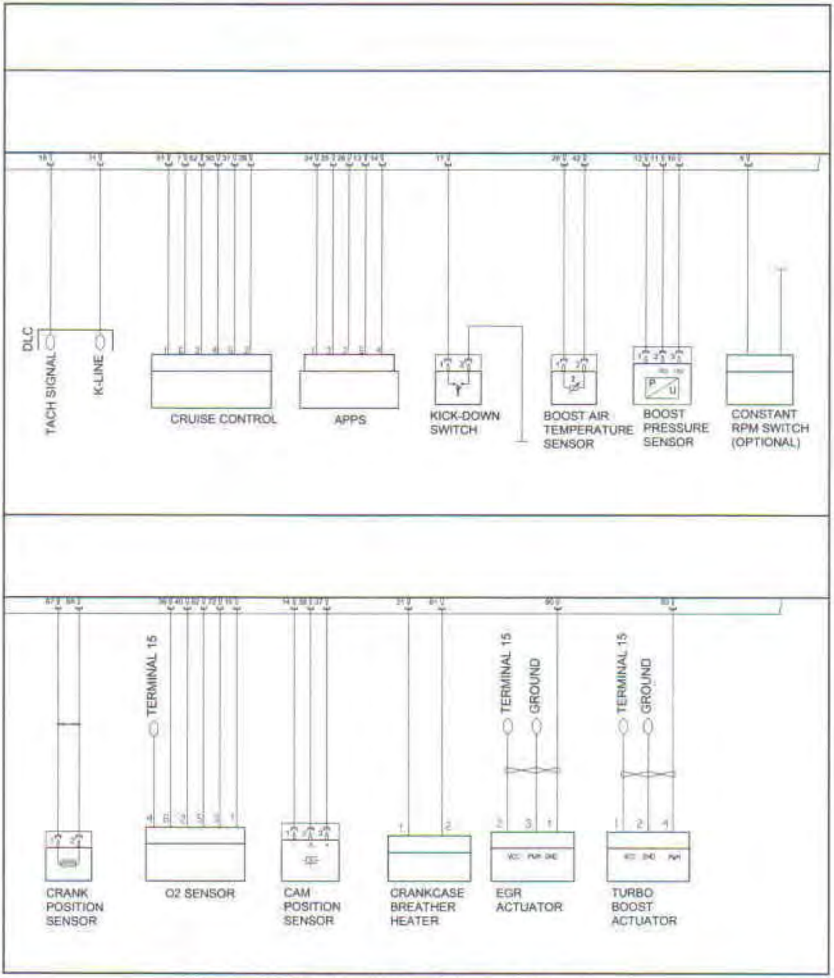


Figure 206 Engine Wiring Schematic (continued)

Figure 211 shows the relationship between the CKP and CMP sensor signals

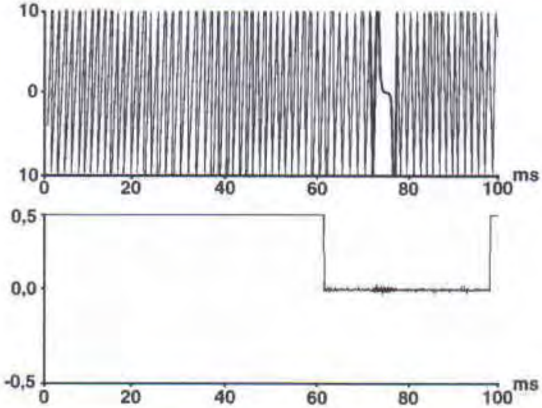


Figure 211 Crank (CKP) and Cam (CMP) Signals

Figure 212 shows the normal pattern of the CMP (Channel 1) and CKP (Channel 2) signals at idle.

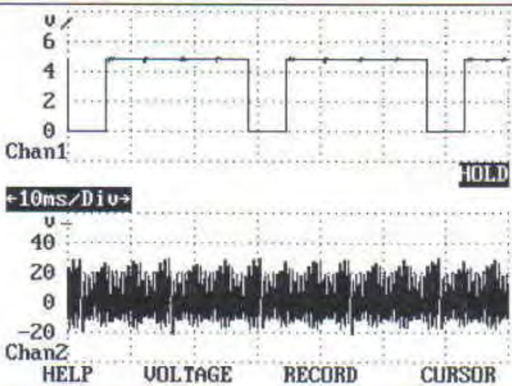


Figure 212 Fuel Injector Signal

Figure 213 shows the normal pattern of the CKP sensor (wires 1 and 2).

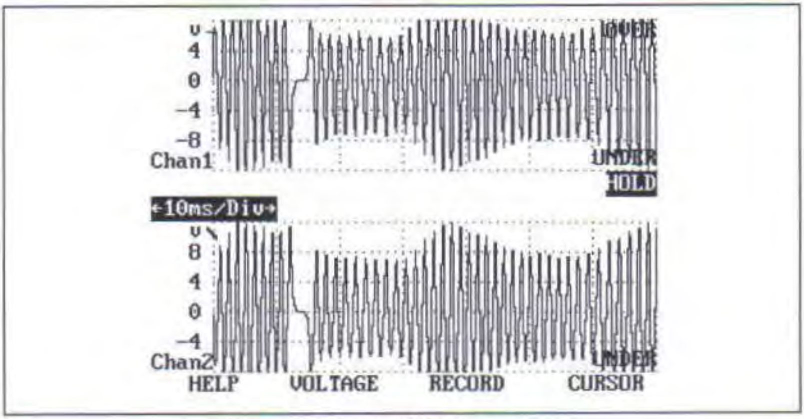


Figure 213 Crank (CKP) Sensor Signal

Figure 214 shows the Crank (CKP) Sensor pattern. Channel 2 shows the sensor wire No. 1 is shorted to ground.

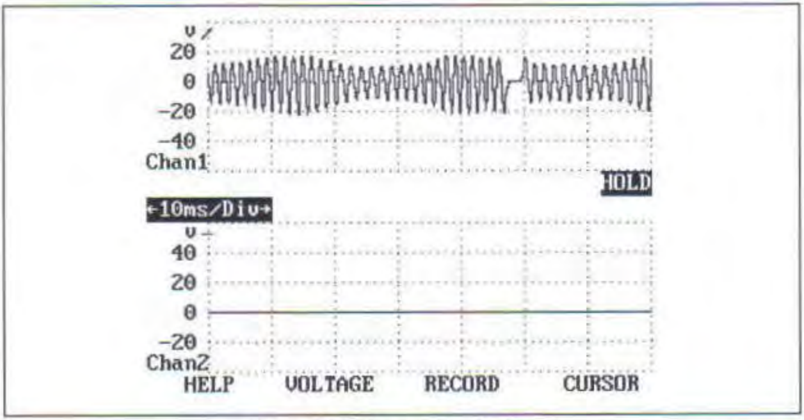


Figure 214 Shorted Crank Signal

MASS AIR FLOW (MAF) SENSOR SIGNAL

Figure 215 shows the pattern of the signal of the mass air flow sensor (MAF) at idle speed.

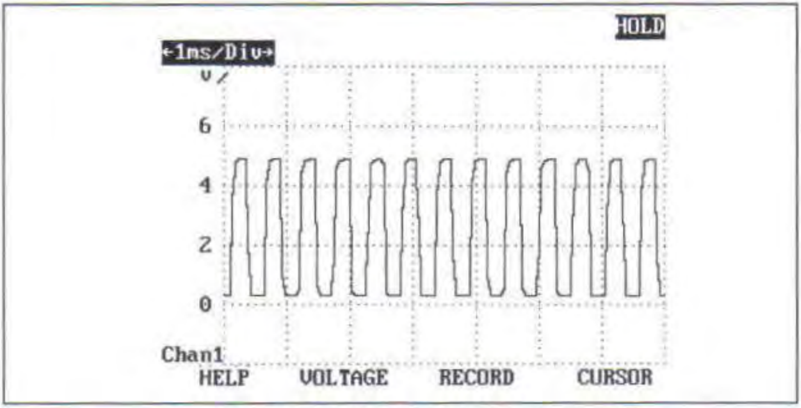


Figure 215 Mass Air Flow (MAF) Sensor Signal at Idle

Figure 216 shows the pattern of the mass air flow sensor (MAF) signal at 2000 rpm.

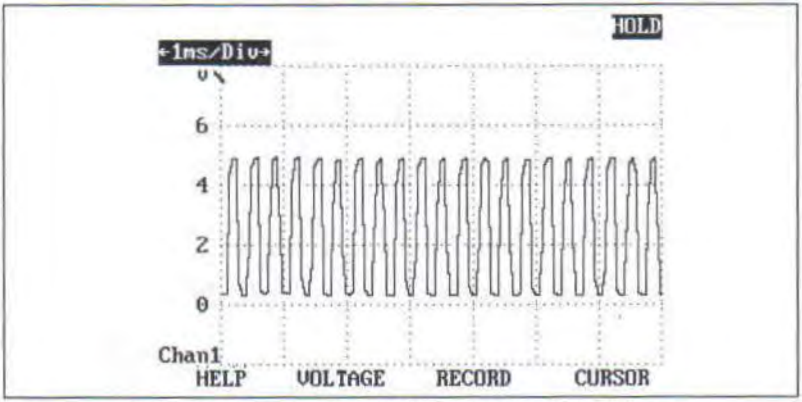


Figure 216 Mass Air Flow (MAF) Sensor Signal at 2000 rpm

FUEL RAIL PRESSURE SENSOR SIGNAL

Figure 217 shows the pattern of the rail pressure sensor signal at different stages: ignition off, ignition on, idle speed and snapping the throttle.

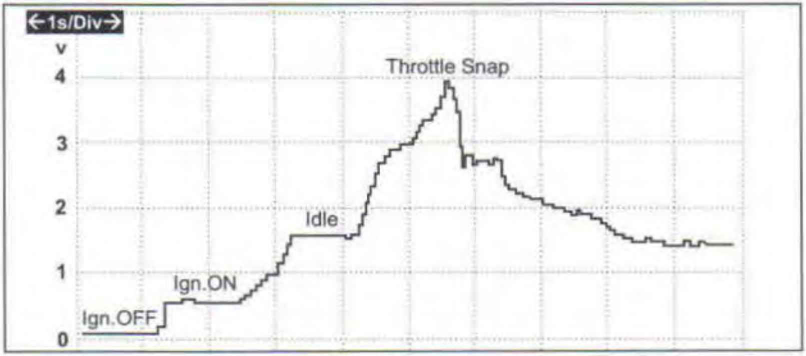


Figure 217 Rail Pressure Sensor Signal

FUEL INJECTOR PATTERN

Figure 218 shows the pattern of an injector at idle speed. The first voltage spike indicates the pilot injection phase, the second voltage spike indicates the main injection phase and the third spike indicates the post injection phase. Notice the longer injection time during the main injection phase.

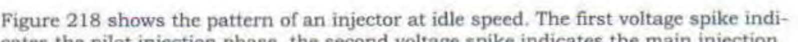


Figure 218 Fuel Injector Signal

FUEL PRESSURE SOLENOID

Figure 219 shows the pattern of the fuel pressure solenoid at idle speed.

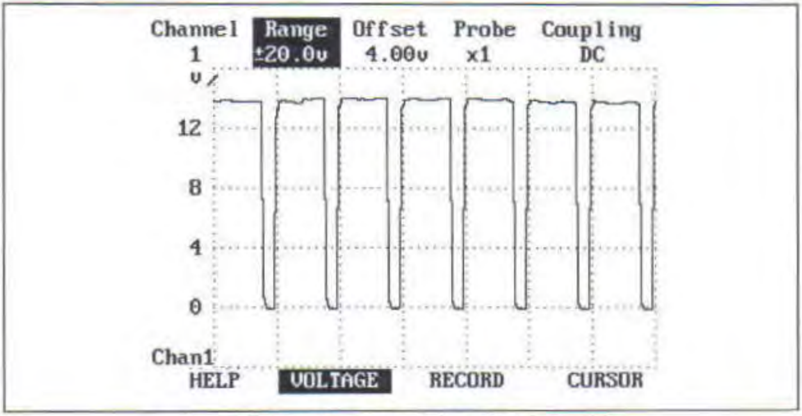


Figure 219 Fuel Pressure Solenoid Signal at Idle

Figure 220 shows the pattern of the fuel pressure solenoid at 2000 rpm.

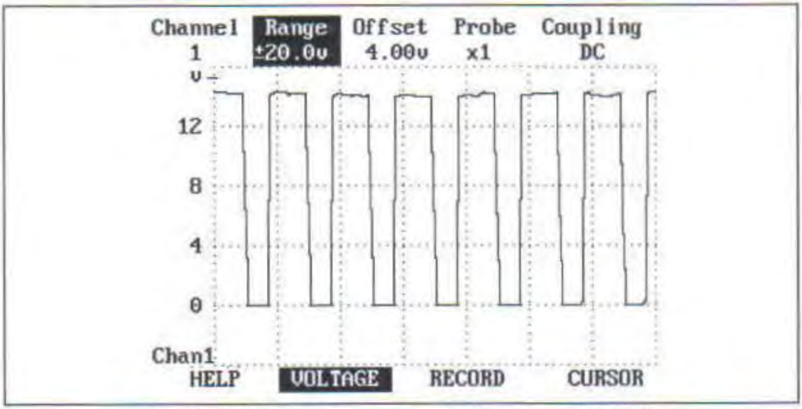


Figure 220 Fuel Pressure Solenoid Signal at 2000 RPM

Figure 221 shows the pattern of the fuel pressure solenoid during the ECM power-off phase.

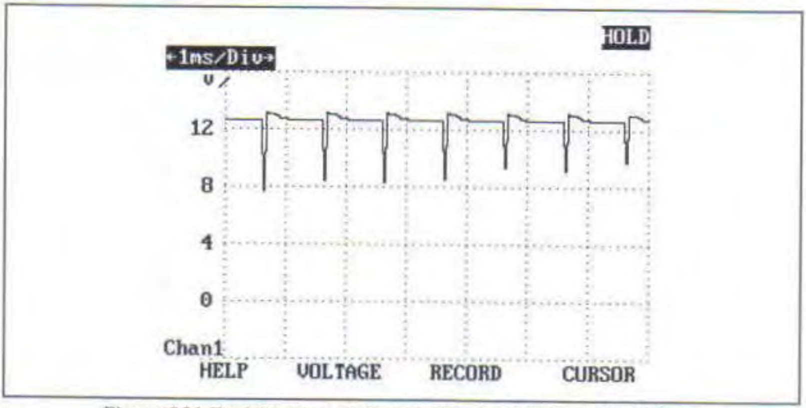


Figure 221 Fuel Pressure Solenoid Signal, ECM Power-Off Phase

FUEL QUANTITY VALVE

Figure 222 shows the pattern of the fuel quantity valve at idle speed.

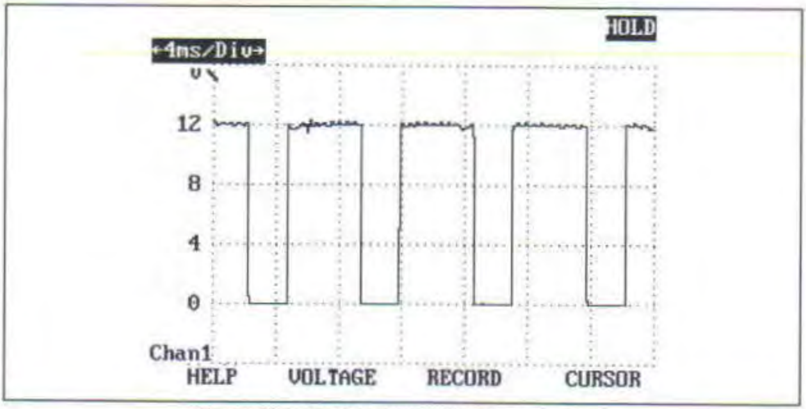


Figure 222 Fuel Quantity Valve Signal at Idle

EGR VALVE

Figure 223 shows the PWM signal to the EGR valve with the engine off/key on.

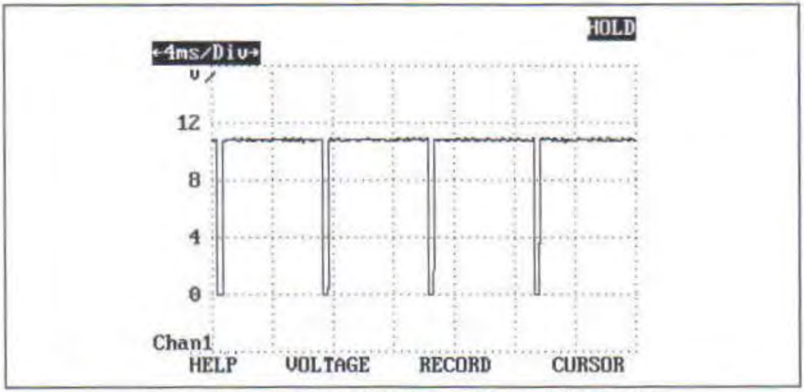


Figure 223 EGR Valve PWM Signal, Engine OFF/Key ON

Figure 224 shows the EGR valve signal with the engine at idle.

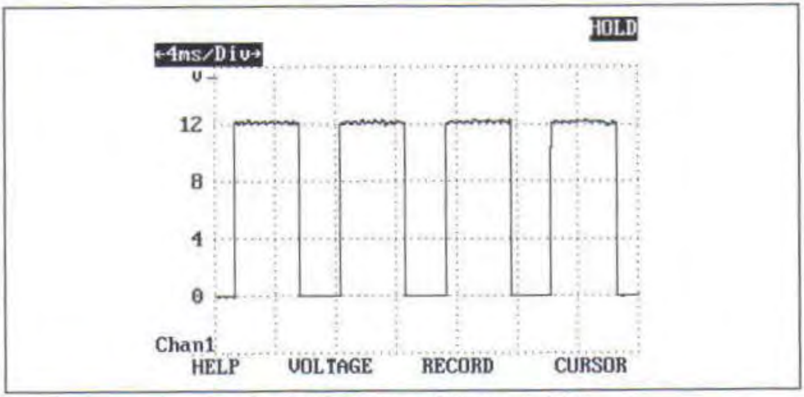


Figure 224 EGR Valve PWM Signal at Idle

Figure 225 shows the EGR valve signal with the engine under acceleration.

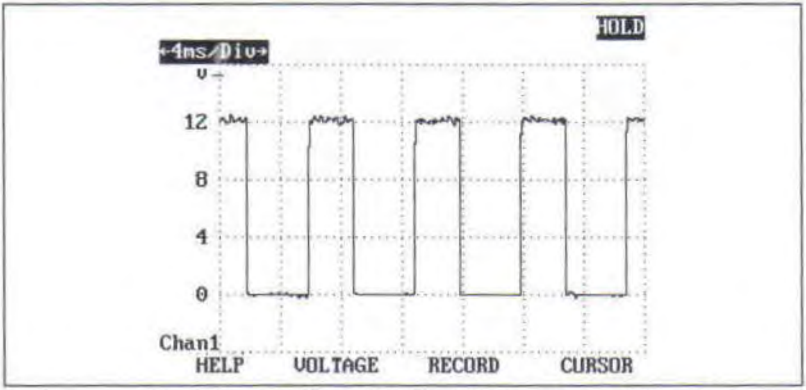


Figure 225 EGR Valve PWM Signal Under Acceleration

BOOST PRESSURE ACTUATOR

Figure 226 shows the PWM signal to the Boost Pressure Actuator with the engine off/ key on.

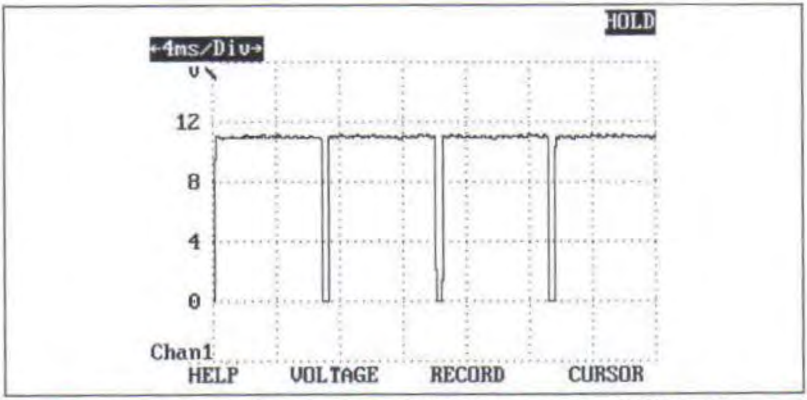


Figure 226 Boost Pressure Actuator PWM Signal, Engine OFF/Key ON

Figure 227 shows the Boost Pressure Actuator signal with the engine at idle.

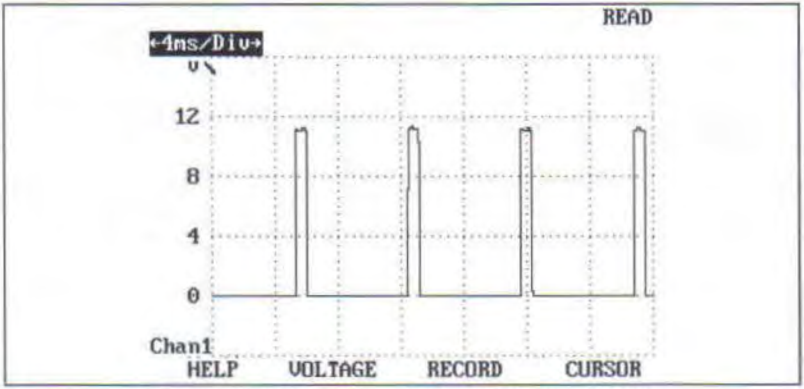


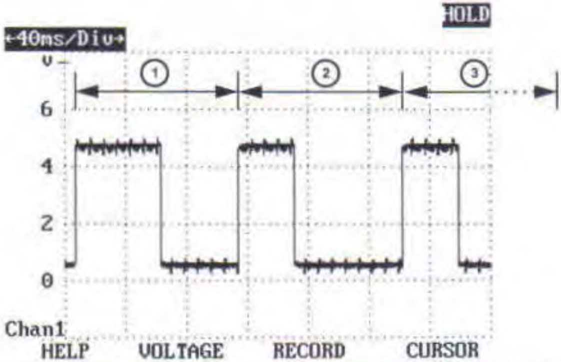
Figure 227 Boost Pressure Actuator PWM Signal at Idle

ENGINE OIL SENSOR

Figure 228 shows the pattern of the oil sensor. The first waveform (1) represents the oil temperature. The duty-cycle lower limit is 20%, which indicates an oil temperature of -40°. The upper limit is 80%, which indicates an oil temperature above 160°C.

The second waveform (2) represents the oil level value. The duty-cycle lower limit is 20%, which indicates an oil level of 0. The upper limit is 80%, which indicates an oil level of 80mm.

The third waveform (3) represents the dielectric number of the oil. The duty-cycle lower limit is 20%, which indicates a dielectric number of 1. The upper limit is 80%, which indicates a dielectric number of 6. The typical value is around 40%, indicating an oil quality of 2.7.



1	Oil Temperature Waveform
2	Oil Level Waveform
3	Dielectric Number of Oil Waveform (Oil Quality)

Figure 228 Oil Sensor Signal

GLOW PLUG MODULE

Figure 229 shows the digital pattern (PWM) in the signal wire between the glow plug module and the engine control module (ECM).

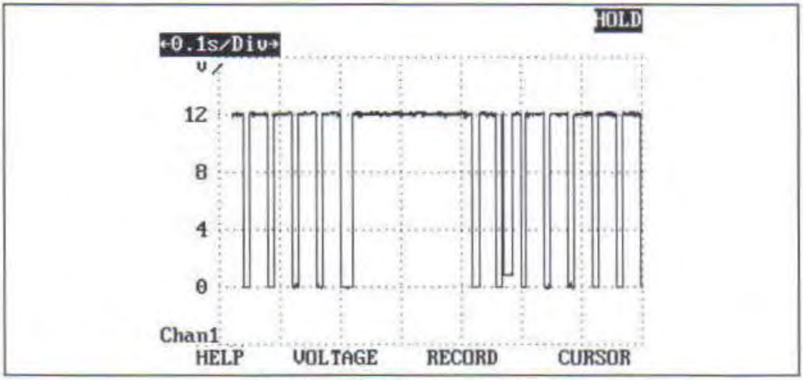


Figure 229 Glow Plug Module Signal

RETROFITTING SPEED CONTROL

This retrofit consists of installing a speed control switch in the steering column and changing the version coding of the engine control module (ECM) to enable the speed control feature.

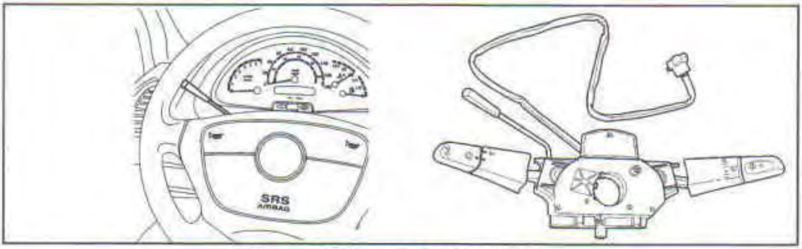


Figure 230 Speed Control Switch

PARTS REQUIRED

Following is the list of parts. The electrical wires listed must be purchased locally. It is strongly recommended to adhere to the color coding of the wires. It simplifies service procedures, troubleshooting of the electrical system, and is consistent with shop documentation and electrical wiring schematics.

NOTE: The parts list below may be issued in kit form in the near future.

Mopar Part Number	Description	Qty.
05103744AA	Speed control switch	1
05126175AA	Screw	1
05120786AA	Six-pin connector	1
05103882AA	Electrical terminal	6
05161275AA	Electrical terminal, ECM connector	6
- purchase locally -	Red electrical wire, 18 AWG	1 ft.
- purchase locally -	Black electrical wire, 18 AWG	1 ft.
- purchase locally -	Blue electrical wire, 18 AWG	1 ft.
- purchase locally -	Yellow electrical wire, 18 AWG	1 ft.
- purchase locally -	Dark green electrical wire, 18 AWG	1 ft.
- purchase locally -	Gray electrical wire, 18 AWG	1 ft.

Table 1 Parts List

PROCEDURE

1. Disconnect the cable from the negative battery post.
2. Remove fuse panel cover (1) by turning slotted screw 90° from position A to B (Figure 231).

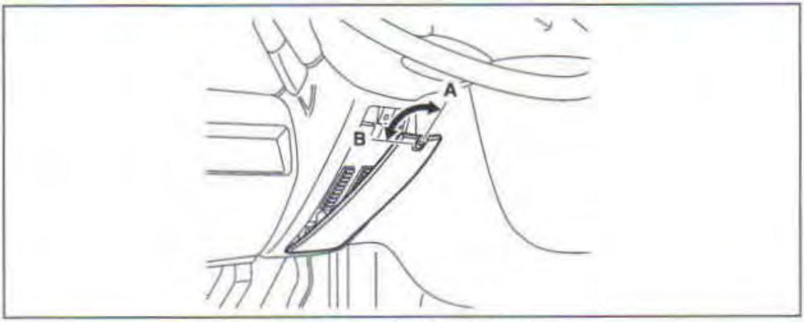


Figure 231 Removal of Fuse Panel Cover

3. Unscrew Phillips screws and nut (Figure 232). Remove steering column cover. Remove M relay for better access to steering column bracket.

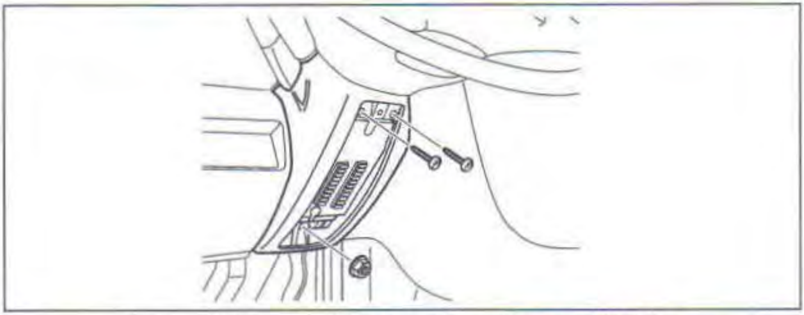


Figure 232 Removal of Steering Column Cover and M Relay

4. Unscrew both Phillips screws and remove upper cover (Figure 233).

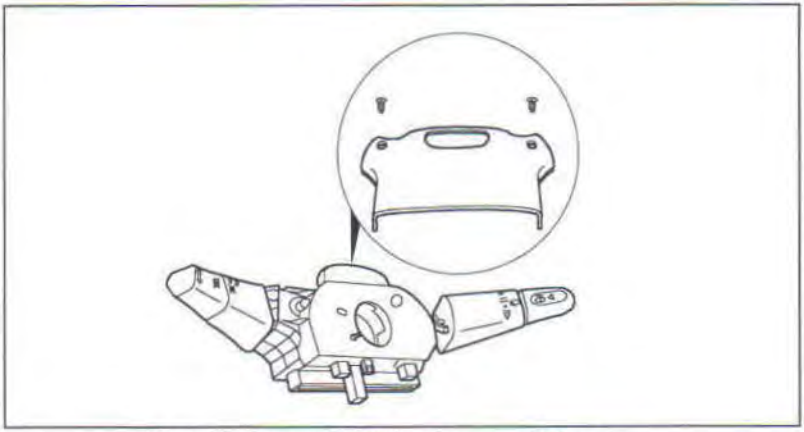


Figure 233 Removal of Phillips Screws and Upper Cover

5. Detach brake pedal spring from steering column (Figure 234).

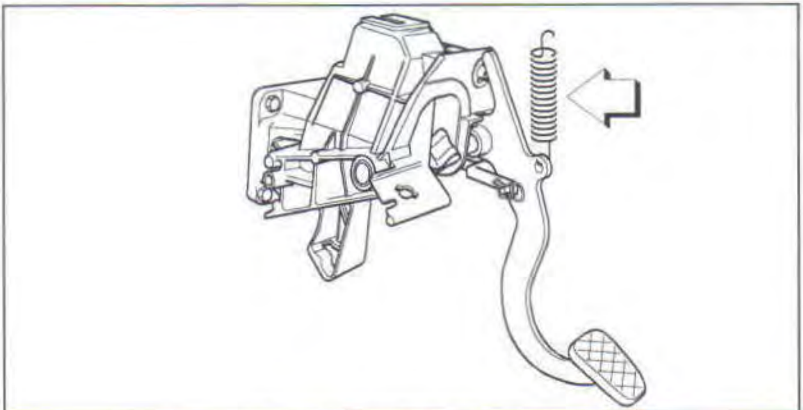


Figure 234 Brake Pedal Spring

6. Remove steering column bracket bolts (Figure 235).

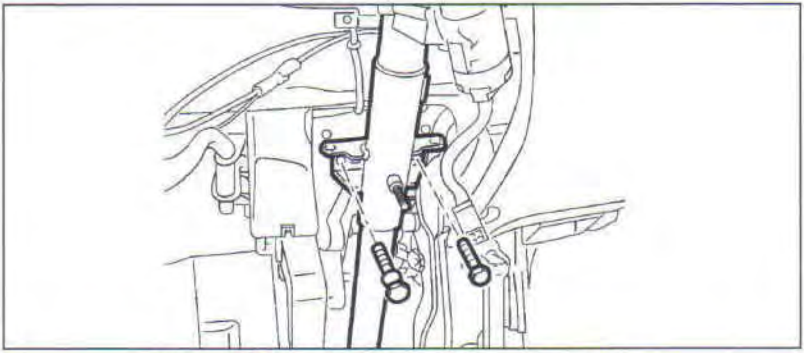
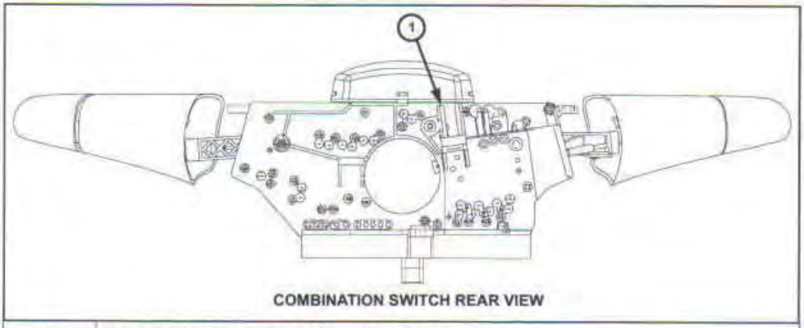


Figure 235 Removing Steering Column Bracket Bolts

7. Gently lower steering column about 6 inches (Figure 236).

Figure 236 Lowering The Steering Column

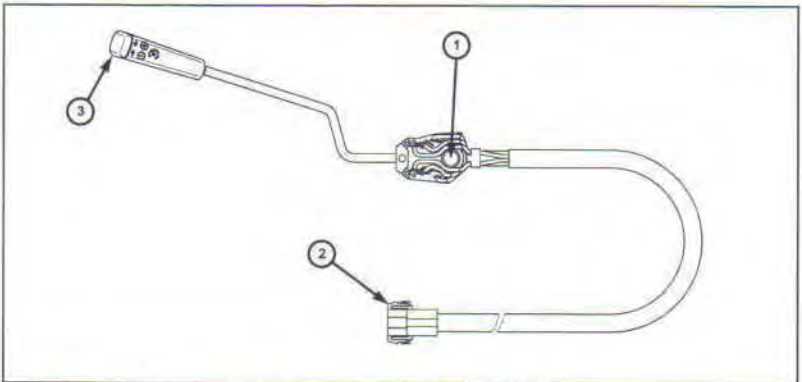
8. Locate the speed control switch mounting base (arrow) on the back of the combination switch (Figure 237).



1	Speed Control Switch Mounting Base

Figure 237 Location of Speed Control Switch Mounting Base

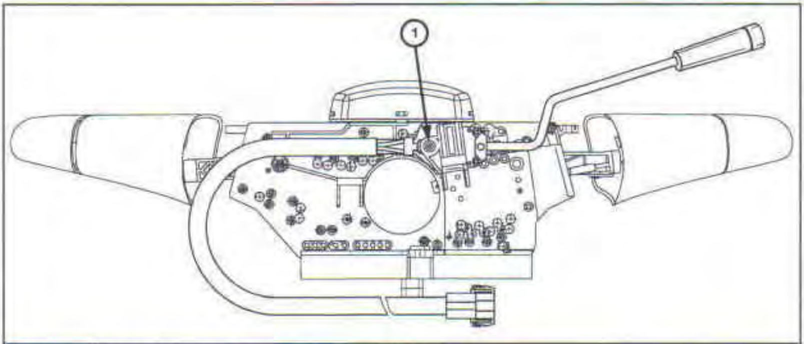
The speed control switch slides into the combination switch mounting base. A hole in the speed control switch lines up with a hole in the mounting base. A screw is inserted through the mounting hole to fasten the speed control switch.



1	Switch Mounting Hole	3	Switch Lever
2	Switch Harness 6-Pin Connector		

Figure 238 Speed Control Switch

9. Insert the speed control switch, part 05103744AA into its mounting base. Secure the switch with holding screw, part 05126175AA. See Figure 239.



1	Speed Control Switch Holding Screw

Figure 239 Speed Control Switch Installation

10. Ensure all connectors on the back of Fuse Block No.1 are tight. Gently raise the steering column and reinstall the column bracket bolts (Figure 240). Tighten the bolts to 25 Nm (18 lb.ft).

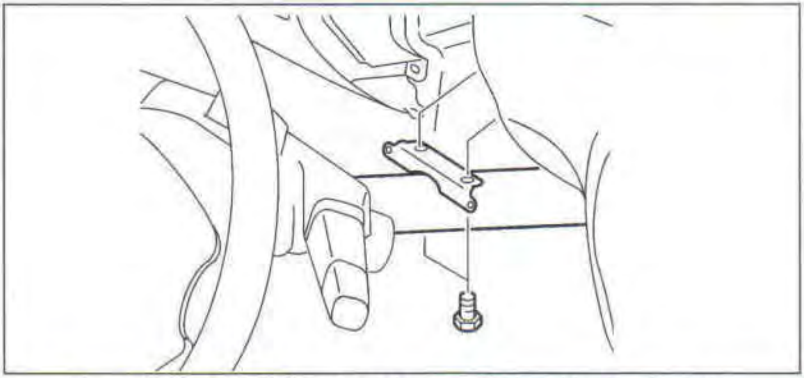


Figure 240 Raising the Steering Column and Reinstalling Bracket Bolts

11. Reinstall the brake pedal spring (Figure 234).

12. Route the speed control switch cable down the steering column towards the engine control module (ECM). See Figure 241.

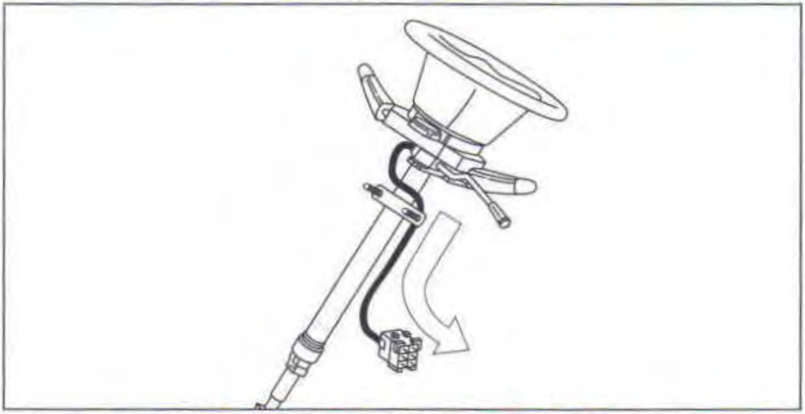


Figure 241 Routing of the Speed Control Switch Wiring Harness

13. Locate the engine control module (ECM) below the left knee protection next to the steering column (Figure 242). Pull the ECM down at the connection side until it releases. Pull it forward and out of the mounting bracket.

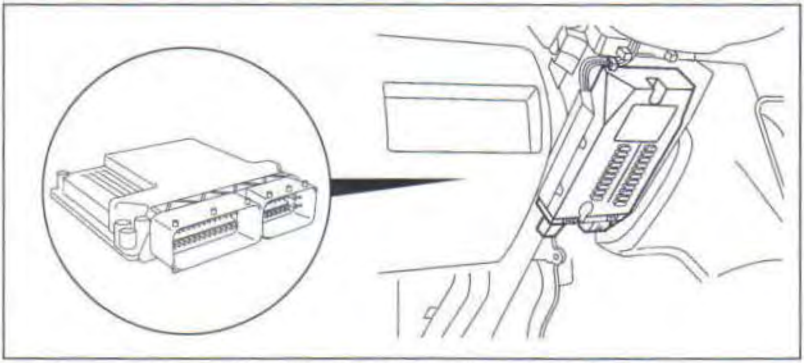
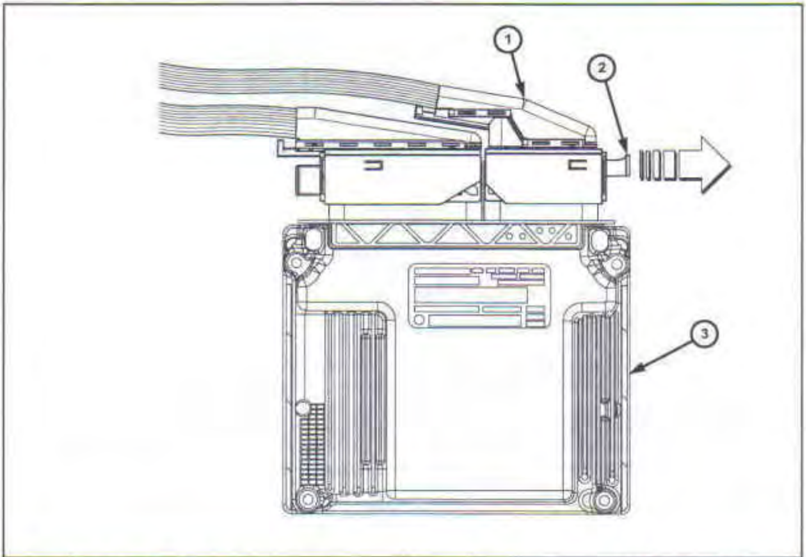


Figure 242 Location of the Engine Control Module (ECM)

14. Remove the 58-pin plug-in connector (marked F) from the ECM. To remove the plug-in connector, pull the slide lock sideways to the end of its travel and lift the plug-in connector.

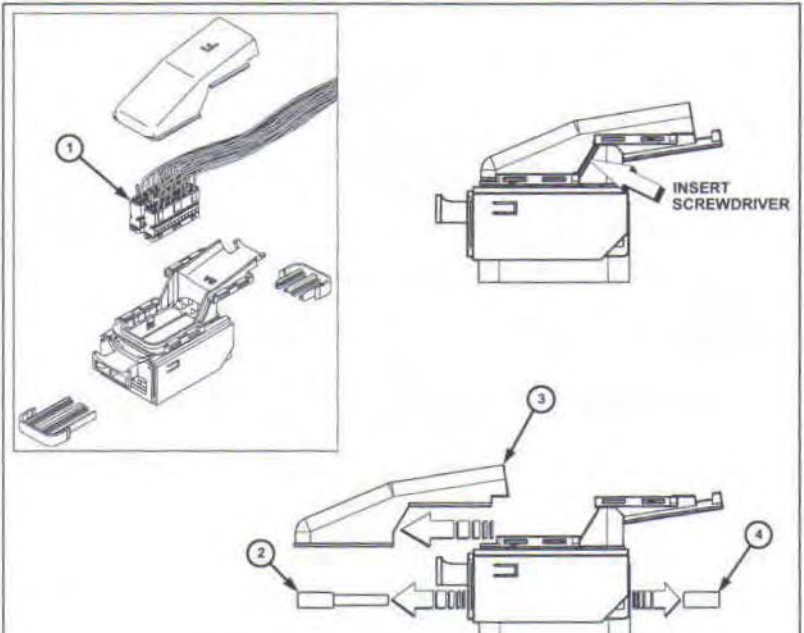


1	58-Pin Plug-In Connector	3	Engine Control Module (ECM)
2	Slide Lock		

Figure 243 Vehicle Harness 58-Pin Plug-In Connector

15. Carefully disassemble the plug-in connector to expose the wire insertion end of the connector. Remove the protective cap by inserting a wide blade screwdriver in the wedged area between the connector housing and protective cap (arrow). Alternating between both sides of the connector, gently twist on the screwdriver handle to separate the protective cap from the connector housing. Slide the protective cap away from the housing (Figure 244).

NOTE: If you require additional clearance for inserting the wires you may remove the electrical terminal holders. The electrical terminal holders are held in place with two locking pins. Carefully remove both locking pins with a small screwdriver and pull them out.



1	Electrical Terminal Holders	3	Protective Cap
2	Front Locking Pin	4	Rear Locking Pin

Figure 244 Vehicle Harness Connector Disassembly

16. Assemble an extension harness with the color-coded wires described in the parts list (Figure 245). Cut one piece out of each wire color, 12 inches long, and strip both ends of wire. Install six terminals, part 05103882AA, to one end of the wires, and six terminals, part 05161275AA, to the other end.

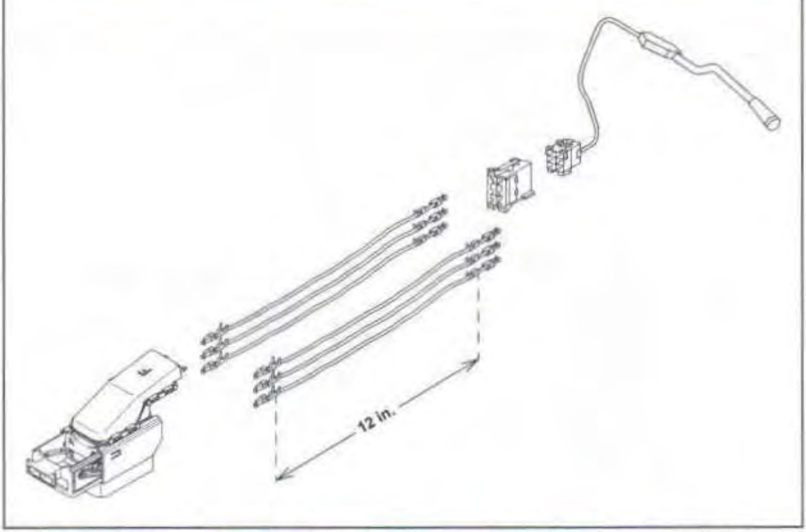
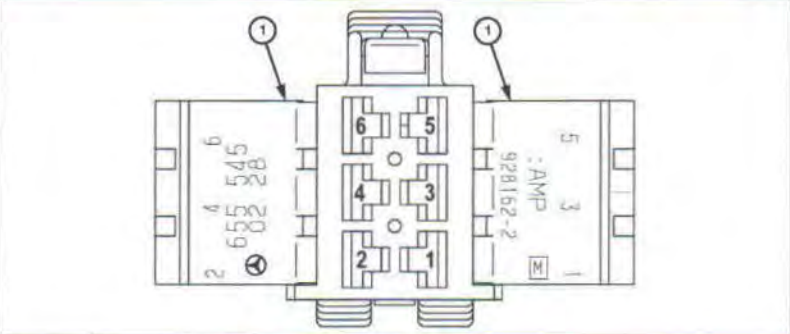


Figure 245 Assembling the Extension Harness to the Engine Control Module

17. Release the six-pin connector (05120786AA) secondary locks. Insert the terminals, part 05103882AA, into the cavities of the connector as follows: gray wire into cavity #1; black wire into cavity #2; blue wire into cavity #3; yellow wire into cavity #4; green wire into cavity #5, and red wire into cavity #6. Insert the wires until they click into place. Gently tug on the wires to make sure they are secure and fasten both secondary locks (Figure 246).



1	Secondary Lock

Figure 246 Six-Pin Connector Front View

18. Insert the other end of the wires with terminals, part 05161275AA, into the cavities of the 58-pin connector of the engine control module (ECM) as follows: gray wire into cavity #51; black wire into cavity #38; blue wire into cavity #52; yellow wire into cavity #50; green wire into cavity #37, and red wire into cavity #7. Insert the wires until they click into place. Gently tug on the wires to make sure they are secure.

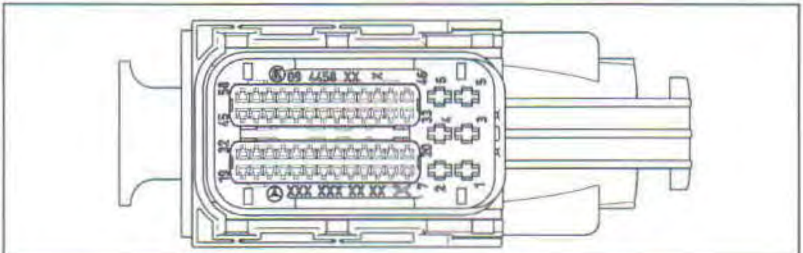


Figure 247 Vehicle Harness 58-Pin Connector Front View

19. Check the wires and cavities for proper position with the wiring diagram below (Figure 248). Plug the six-pin connector to the speed control switch connector. Reassemble the 58-pin connector. Install the connector back to the engine control module (ECM) and push the module back into its mounting bracket. Ensure the ECM is properly held in place by means of the tensioning spring clips.

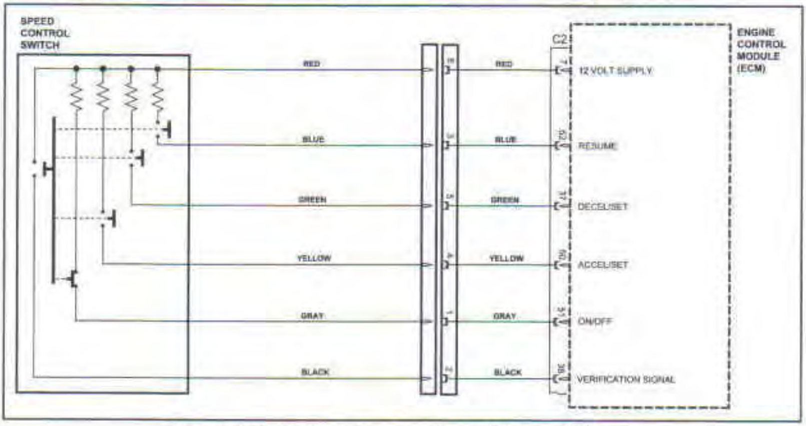


Figure 248 Wiring Diagram, Speed Control Circuit

20. Reinstall Fuse Block No. 1 and upper and lower steering column covers (Figure 249). The upper cover has a slot on the back (arrow) for the speed control switch lever. Reinstall the M relay and the fuse block locking cover.

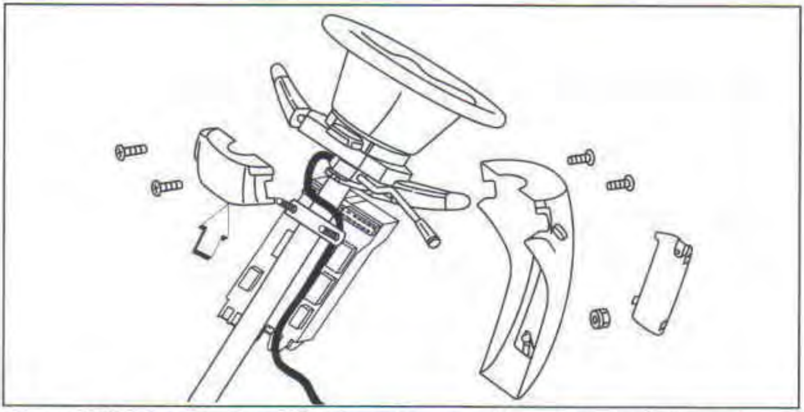


Figure 249 Reinstalling Fuse Block 1 and Upper and Lower Steering Column Covers

21. Reconnect the battery and code the radio if necessary. Connect the diagnostic scan tool to the vehicle.

NOTE: The following steps are for changing the ECM version coding. Follow the proper procedure with DRB III or DAS. Test drive the vehicle after completing the coding to ensure proper operation of the speed control switch (Figure 250).

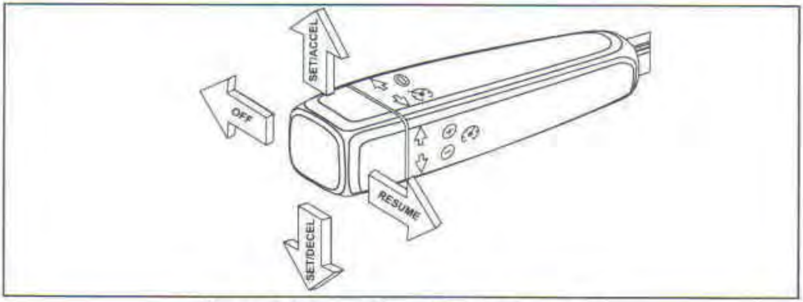


Figure 250 Speed Control Switch Operation

CHANGING THE ECM VERSION CODING WITH DRB III

1. Choose Engine in the System Select screen and Miscellaneous Functions in the Select Function screen (Figure 251).

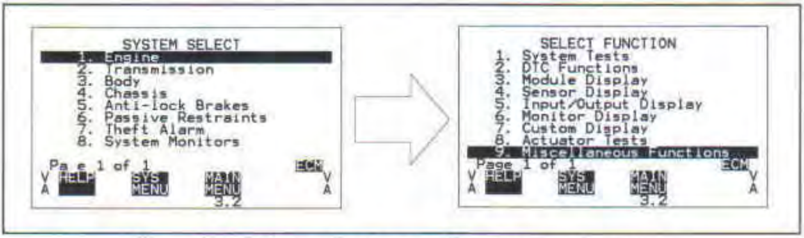


Figure 251 Selecting Engine and Miscellaneous Functions

2. Select Configuration in the Miscellaneous Functions screen. When asked, select Cruise Control Installed (Figure 252).

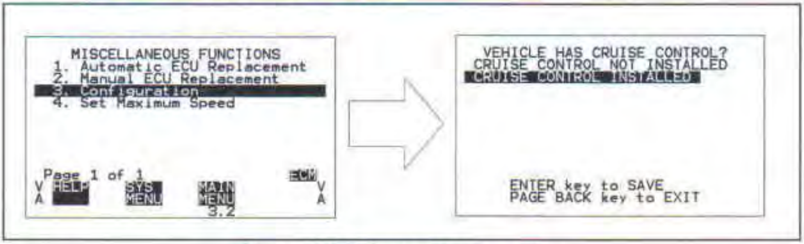


Figure 252 Selecting Configuration

3. Switch the ignition OFF and wait for the progress bar to indicate the completion of the configuration process (Figure 253).

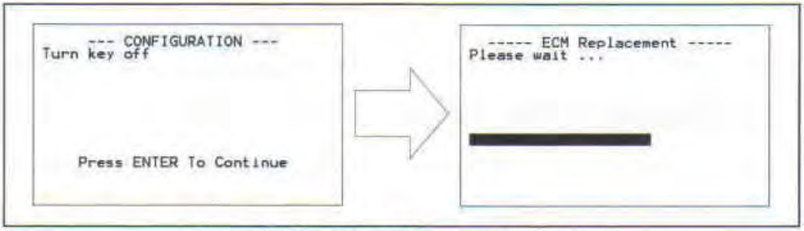


Figure 253 Key Off and Progress Bar Screens

4. Switch the ignition ON (Figure 254). The speed control installation is now complete.

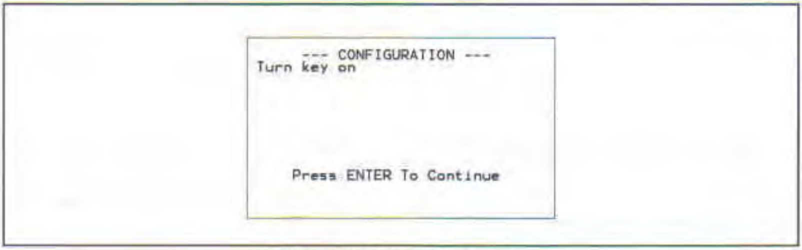


Figure 254 Key ON Screen

CHANGING THE ECM VERSION CODING WITH DAS

1. Select the CR Common Rail option in the Current Short Test screen. In the Common Rail screen select Control Unit Adaptations (Figure (255).

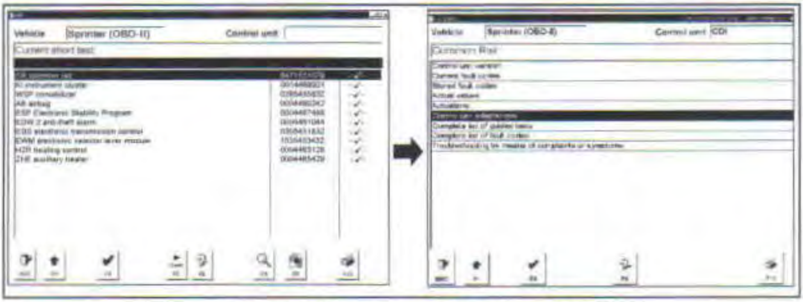


Figure 255 Current Short Test and Common Rail Screens

2. In the Control Unit Adaptations screen select SCN Coding. In the SCN Coding screen select Determine Vehicle Data for SCN Coding (Figure 256).

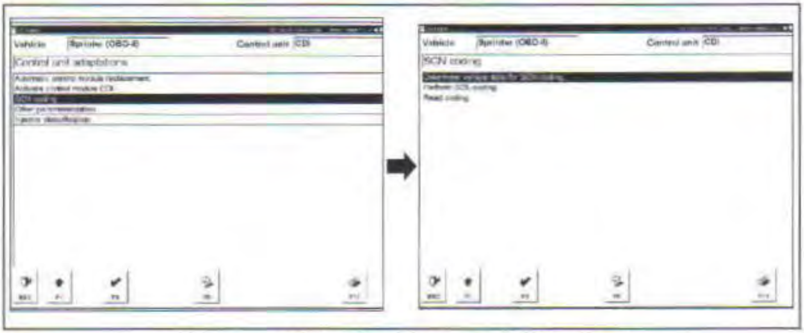


Figure 256 Control Unit Adaptations and SCN Coding Screens

3. Print or record the vehicle data (VIN, MB Code Number and Check Digit). You need to contact the Sprinter Technical Support Line (1-866-769-8092) to get a new SCN code. Provide the Support Line Representative with the vehicle data. The Technical Support Line Representative will issue a new Coding String, SCN and Check Digit. Return to the SCN Coding Screen and select the option Perform SCN Coding.

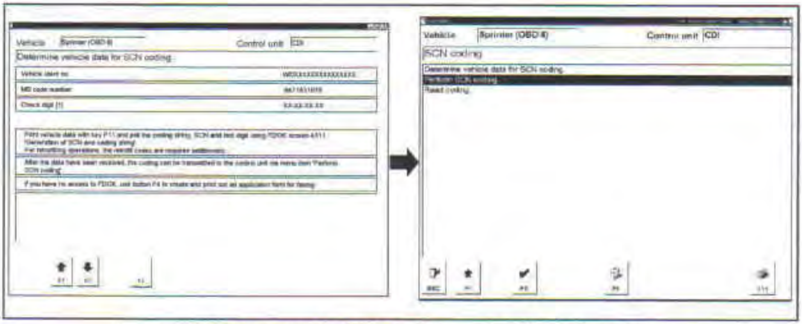


Figure 257 Determine Vehicle Coding and SCN Coding Screens

4. Enter the VIN and the new Coding String, SCN and Check Digit in the appropriate input fields (Figure 258). Press the YES button to complete the SCN coding.

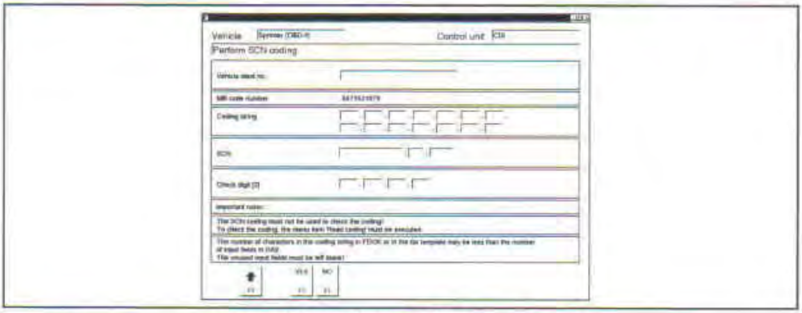


Figure 258 Perform SCN Coding Screen