JAGUAR

ON-BOARD DIAGNOSTICS

ZF 6HP26 TRANSMISSION

Vehicle Coverage:

XK8 from 2003 model year
XJ Range from 2003 model year
S-Type from 2003 model year

1 Contents

2 Introduction

This document describes the On Board Diagnostic (OBD) monitoring strategy and malfunction criteria for the ZF 6HP26 transmission systems.

2.1 OBDII Systems

California OBDII applies to all gasoline engine vehicles up to 14,000 lbs. Gross Vehicle Weight Rating (GVWR) starting in the 1996 model year and all diesel engine vehicles up to 14,000 lbs. GVWR starting in the 1997 model year.

"Green States" are states in the Northeast that chose to adopt California emission regulations, starting in the 1998 model year. At this time, Massachusetts, New York, Vermont and Maine are Green States. Green States receive California certified vehicles for passenger cars and light trucks up to 6,000 lbs. GVWR.

The National Low Emissions Vehicle program (NLEV) requires compliance with California OBDII, including 0.020" evaporative system monitoring requirements. The NLEV program applies to passenger cars and light trucks up to 6,000 lbs. GVWR nationwide from 2001 model year through 2003 model year.

Federal OBD applies to all gasoline engine vehicles up to 8,500 lbs. GVWR starting in the 1996 model year and all diesel engine vehicles up to 8,500 lbs. GVWR starting in the 1997 model year.

OBDII system implementation and operation is described in the remainder of this document.

3 ZF 6HP26 Transmission System

3.1 Transmission System Overview

The ZF 6HP26 automatic transmission has been developed for vehicles with an engine torque of up to 600 Newton-meters (Nm). This transmission uses planetary gears with hydraulic-electronic control. The Transmission Control Module (TCM) and the main control valve body unit forms a composite element that is installed as a single unit inside the automatic transmission.

The 6HP26 has the following features:

- Six forward speeds.
- A torque converter with an integral Torque Converter Clutch (TCC).
- Electronic shift and pressure controls.
- A single planetary gear set.
- A double planetary gear set.
- Two fixed multi-disc brakes.
- Three multi-plate clutches.

All hydraulic functions are directed by electronic solenoids to control:

- Engagement feel.
- Shift feel.
- Shift scheduling.
- Modulated TCC applications.
- Engine braking utilizing the coast clutch.

Engine power reaches the transmission by a torque converter with integral TCC. The 6 forward gears and 1 reverse gear are obtained from a single planetary set followed by a double planetary set also known as lepelletier-type gear sets, these gear sets make it possible to obtain 6 forward gears.

The 6HP26 automatic transmission is a six speed electronically controlled transmission comprising the basic elements of a TCM and main control valve body unit, a torque converter, one solenoid valve and six pressure regulators. Gearshift selection is achieved by the control of automatic transmission fluid flow to operate various internal clutches. The TCM operates the electrical components and provides for the control of gearshift selection shift pressure that increases refinement and torque converter slip control.

In the event of a system fault the TCM also provides for Failure Mode Effect Management (FMEM) to maintain maximum functional operation of the transmission with a minimum reduction in driver, passenger or vehicle safety. In the event of a total loss of control or electrical power the basic transmission functions park (P),

reverse (R), neutral (N) and drive (D) are retained. Also third or fifth gear is retained by the hydraulic system, the gear retained is dependant upon the gear selected at time of the failure.

The transmission also contains Input Shaft Speed (ISS) and Output Shaft Speed (OSS) sensors, an internal transmission range (P, R, N, D) selector shaft position sensor, and a transmission fluid temperature sensor. The TCM also requires information from the gearshift selector to determine when the driver has initiated manual gear selection. The TCM communicates with other electronic control modules by the Controller Area Network (CAN).

The TCM also provides for legislated transmission diagnostics, which meet the requirements of CARB OBDII legislation, monitoring all components, which may effect vehicle emissions. Additional diagnostic functions are also supported to ensure fast repairs of all failures in the service environment.

3.1.1 Upshifts

Transmission upshifting is controlled by the TCM. The TCM receives inputs from various engine or vehicle sensors and driver demands to control shift scheduling, shift feel and TCC operation.

The TCM has an adaptive learn strategy to electronically control the transmission, which will automatically adjust the shift feel.

3.1.2 Downshifts

Under certain conditions the transmission will downshift automatically to a lower gear range (without moving the gearshift lever). There are three categories of automatic downshifts, coastdown, torque demand and forced or kickdown shifts.

3.1.3 Coastdown

The coastdown downshift occurs when the vehicle is coasting down to a stop.

3.1.4 Torque Demand

The torque demand downshift occurs (automatically) during part throttle acceleration when the demand for torque is greater than the engine can provide at that gear ratio. If applied, the transmission will disengage the TCC to provide added acceleration.

3.1.5 Kickdown

For maximum acceleration, the driver can force a downshift by pressing the accelerator pedal to the floor. A forced downshift into a lower gear is possible below calibrated speeds. Specifications for downshift speeds are subject to variations due to tire size, engine, and transmission calibration requirements.

3.1.6 Range Selection

Depending on the vehicle options selected the transmission range selector may have different range positions. The standard range selector has eight positions: P, R, N, D, 5, 4, 3 and 2.

3.2 Transmission Electronic System

The TCM and its input/output network control the following transmission operations:

- Shift timing.
- Line pressure (shift feel).
- TCC.

In addition, the TCM receives input signals from certain transmission related sensors and switches. The TCM also uses these signals when determining transmission operating strategy.

Using all of these input signals, the TCM can determine when the time and conditions are right for a shift, or when to apply or release the TCC. It will also determine the pressure needed to optimize shift feel. To accomplish this the TCM uses six pressure control solenoids and one shift solenoid to control transmission operation.

The following provides a brief description of each of the sensors and actuators used to control transmission operation.

3.2.1 TCM

The TCM for the transmission is mounted on top of the main control valve body. The control module for the transmission has been designed to operate correctly in the environment in which the TCM is located. The TCM is activated and deactivated by the ignition supply and is connected to the transmission link harness by a 16-way connector.

The TCM controls the operation of the transmission. The TCM processes information received in both analogue and digital form such as:

- Transmission Input Shaft Speed (ISS).
- Output Shaft Speed (OSS).
- Throttle pedal position.
- Gearshift selector position.
- Engine torque.
- Engine speed.

- Transmission Fluid Temperature (TFT).
- Brake pedal status.
- Engine oil temperature.
- Engine Coolant Temperature (ECT).
- Anti-lock Braking System (ABS) wheel speed.

This information is then used by the TCM to decide which shift pattern to select and for shift energy management. Electro-hydraulic solenoid valves and pressure regulators control the transmission gear changes.

Five pressure regulators and one solenoid valve are used to control direct transmission fluid flow to select internal clutches and control the fluid pressure at the clutch. A separate pressure regulator is used exclusively for the TCC control.

The TCM monitors all TCM inputs and outputs to confirm correct system operation. If a fault occurs the TCM is able to perform a default action and inform the driver of the problem, this is by the instrument pack message center.

3.2.2 Solenoids

The hydraulic module contains one solenoid valve. The solenoid valve is actuated by the TCM and has two positions of open or closed, it is used to switch the position valve.

There are six electronic pressure control valves, these convert an electric current into a proportional hydraulic pressure. The solenoids are energized by the TCM and actuate the valves belonging to the relevant switching elements.

3.2.3 Controller Area Network Interface

For the TCM to be able to perform shift point and shift quality management a number of external signals are required. For shift point management alone the TCM requires an OSS sensor, throttle pedal position, brake pedal status and gear selector position. The Controller Area Network (CAN) bus is used to share information between control modules. The TCM obtains most of its required data over the CAN bus from the electronic engine controls, J-Gate and ABS, Instruments pack and diagnostic tools.

3.2.4 Brake Pedal Position Switch

The Brake Pedal Position (BPP) switch tells the TCM when the brakes are applied, and disengages the TCC. The BPP switch closes when the brakes are applied and opens when they are released. The BPP is also used to disengage the brake shift interlock and stops gradient calculations.

3.2.5 Engine Coolant Temperature Sensor

The ECT sensor detects engine coolant temperature and supplies the information to the TCM. The ECT sensor is used to control the TCC operation.

3.2.6 Accelerator Pedal Position Sensor

The Accelerator Pedal Position (APP) sensor is a potentiometer mounted on the accelerator pedal. The APP sensor detects the position of the accelerator pedal and sends this information to the Engine Control Module (ECM). The APP sensor is used for shift scheduling and TCC lock-up.

3.2.7 Input Shaft Speed Sensor

The Input Shaft Speed (ISS) sensor is a Hall effect type sensor.

The ISS sensor is mounted internally on the transmission and is located on the TCM and main control valve body unit.

3.2.8 Output Shaft Speed Sensor

The Output Shaft Speed (OSS) sensor is a Hall effect type sensor.

The OSS sensor is mounted internally on the transmission is used for shift scheduling.

3.2.9 Transmission Fluid Temperature Sensor

The TCM utilizes one TFT sensor located on the main control valve body. The TCM uses the sensor input to activate various shift strategies. The sensor is in the form of a temperature dependent resistor.

The temperature sensor performs plausibility checks on each sensor reading. Obviously, the transmission oil temperature should not jump in value excessively between sensor readings. If the inputs from the temperature sensor are outside the working range it possible that the sensor is short or open circuit.

3.2.10 Position sensor

The TCM uses the position of this switch housed on the TCM and main control valve body, to determine the selected gear range on the automatic side of the gearshift selector lever.

The gearshift selector lever is connected to the transmission by a cable, which operates the transmission selector shaft between positions park (P), reverse (R), neutral (N) and drive (D). The TCM detects the driver's choice of manual range selection (5,4,3,2) by means of a 3-bit code generated by the J-gate. This 3-bit code is then transformed in to a CAN message by the J-Gate module and transmitted on to the CAN bus where it is detected by the TCM.

The TCM uses this information to generate the CAN message 'Gear Position Selected', which must not be confused with the similar message 'Gear Position Actual' indicating the current mechanical gear ratio activated by the TCM.

Movement of the lever between park, reverse, neutral and drive manually controls the flow of transmission fluid, the TCM having control of the forward gear selected in drive. Additional movement of the lever to 5,4,3 and 2 positions does not manually modify the fluid flow, the TCM detects these positions, and controls the gear selected electronically.

3.2.11 Sport Mode Switch

The Sport mode switch:

- Allows the driver to select or de-select the automatic transmission Sport mode.
- Allows the automatic transmission to operate normally when the Sport mode is selected, but under acceleration, the gearshift points are extended to make full use of the engine's power reserves.
- Allows the driver to drive the vehicle in the 'D' position with the full automatic transmission shift or manually shift gears in the 'second, third, fourth and fifth' positions.
- Is illuminated when Sport mode is selected.
- Communicates with the TCM through the CAN to show the Sport mode switch status.

3.3 Transmission Shift Selection

3.3.1 Shift Map Selection

The transmission control system utilizes a number of driver selectable operating modes and a number of adaptive/automatically selectable modes. Sport, Normal and speed control mode are all driver selectable. Hot mode, traction control mode and trailer towing mode are all adaptive modes i.e. the transmission will automatically select this mode dependent upon the current driving conditions.

3.3.2 Normal Mode

Normal mode can be selected by activation of the transmission mode switch located on the J-Gate. Once activated this mode will remain engaged until the driver deselects the mode or engages the speed control system. If the driver engages speed control when Normal mode is active upon deactivation of the cruise system the transmission will automatically re-engage Normal mode. This mode can be over-ridden by a number of adaptive modes.

The mode switch is of the momentary type.

3.3.3 Cruise Mode

When the driver engages the cruise control system the TCM receives a CAN message transmitted by the adaptive speed control or engine electronic controls which informs the TCM that speed control is currently active. Upon receipt of this message the TCM selects a new transmission shift map. This map has been developed to reduce busy gearshift during cruise mode. It has also been developed to increase fuel economy.

3.3.4 Hot Mode

This is one of the adaptive modes the transmission can enter when conditions are correct. When the TFT, chip temperature, engine oil temperature or ECT becomes hot enough to reach threshold values, the TCM will cause the transmission to enter hot mode. This mode will automatically engage new shift and lock-up maps to reduce heat generated within the transmission. The shift map will enable the transmission to change to higher gears at lower vehicle speeds and the lock-up map will engage the TCC at lower vehicle speeds and in lower gears. The effect of this is that less heat will be generated within the transmission due to the effects of TCC slip and churning effects. There is a forced upshift strategy used in hot mode. To exit hot mode the gearshift selector lever must be moved or the brake pedal applied or the accelerator pedal applied 100%. During all of these methods of exiting from hot mode the fluid temperature must be lower than the threshold values.

3.3.5 Traction Control Mode

Traction control mode is an adaptive mode, which is automatically engaged when a traction event occurs. When driving on slippery surfaces (i.e. sand, ice) it is possible for the driven wheels to begin to spin. The TCM believes the vehicle speed is increasing and therefore it may begin to upshift. These upshifts reduce the torque at the wheel and so tend to reduce wheel slip. The downshift lines are forced downwards to prevent unwanted shifts. To reduce the effects of this, if a traction event occurs a signal is transmitted by the ABS module to the TCM over the CAN, the TCM uses this signal to change the currently selected shift map. The new shift map will have gearshift lines further apart, thus inhibiting the transmission shifting to a lower gear.

3.3.6 Hill/Trailer Towing Mode

This is an adaptive mode. When the TCM detects reduced vehicle acceleration for a certain percentage of throttle opening then this mode is automatically engaged by the TCM. When this mode is engaged a new shift map and TCC map is selected. This new shift map is designed to reduce the number of gearshifts when towing a trailer or with the car climbing a steep hill. The shift map will cause the transmission to hold on to gears for longer this increases acceleration and reduces the number of gearshifts. This mode can also give an advantage when driving at high altitudes, where the torque produced by an engine is greatly reduced by the effects of reduced ambient pressure and airflow.

3.3.7 Driving Mode Priority

Each of the above modes has an associated priority i.e. Normal mode cannot over-ride cruise mode etc.

3.4 Adaptive Shift Strategies

The six speed ZF automatic TCM incorporates adaptive strategies which improve the accessibility of the vehicles performance in driving conditions while maintaining a relaxed driving experience when cruising.

In 'Sport' mode, accelerator pedal usage and cornering behavior are monitored to assess driving style and road conditions. When an enthusiastic driving style or a demanding road is detected, sixth gear is inhibited and the lower gears are made slightly more accessible in order to prevent unwanted 'hunting' between gears. Conversely, when cruising conditions are detected, sixth gear is again made available to maximize driving refinement and economy.

Under conditions of heavy braking, the transmission will perform one or more downshifts to improve response to a subsequent accelerator pedal application. Similarly, if the accelerator pedal is released rapidly following hard acceleration, one or more upshifts are inhibited to increase engine braking and improve subsequent response.

To complement these features, when a corner is detected transmission upshifts are inhibited. This inhibition is also maintained for a short distance after the corner allowing the driver to achieve a smooth balance through the bend without unwanted shifting mid-corner.

3.4.1 Torque Converter Clutch Control

The TCM controls how the TCC is engaged as a function of the accelerator pedal position, OSS, TFT, gear selected and shift program. Lock-up is possible in all forward gears, but usually it is restricted to fourth, fifth and sixth gears. To make use of the comfort enhancing effect of the torque converter, the TCC can be disengaged prior to a downshift or upshift. The TCC is always modulated to allow controlled slip, to further improve the shift quality.

3.4.2 Shift Energy Management

This function involves reducing or increasing the engine output torque during shifting. The aim when up-shifting is to reduce the energy that is dissipated in the friction elements of the transmission. This is done by reducing the engine torque during synchronization without interrupting the tractive drive. This function may be used for:

- Increasing the transmission service life by shortening the slipping time.
- Improving the shift comfort by reducing the step change in torque caused by the gearshift.
- Transferring a higher engine power, this is allowed by the mechanical in-gear strength of the transmission.

Real-time control of engine torque is required to maintain maximum shift quality and transmission durability. The TCM has the ability to control the engine output torque during the gearshift to synchronize with the operation of the transmission clutches.

3.4.3 Pressure Modulation

To provide a high level of shift comfort and durability, the hydraulic pressure in the shift related friction elements of the transmission must be matched very accurately to the transmission input torque. This hydraulic pressure is composed of a hydraulically pre-set basic pressure and a controlling pressure that is set by one of the electro-hydraulic pressure regulators.

The transmission input torque can be directly calculated from the following operating parameters: engine torque signals, engine speed or any signals transmitted from the ECM by CAN, and converter slip. Separate pressure characteristics for each gear change make it possible to adapt precisely to the particular shift operation. A further improvement in shift comfort is achieved by individual treatment of special cases, such as manual shifts.

3.4.4 Shift Quality Adapts

The shift quality adapts are used to obtain a high quality and consistent shift feel. This is achieved through monitoring shift quality and then adapting the shift pressures and shift energy management to overcome hardware variability and 'in service wear'.

It will typically take a new transmission approximately 161 kilometers (100 miles) of use to fully adapt.

3.4.5 Shift Point Selection

The gearshift points are selected by the TCM, as a function of the output speed, accelerator pedal position, selector position and shift program selected. The driver has control over the shift points by the selector lever, accelerator pedal movement and mode switch.

3.5 Safety Features

The safety functions are designed to safeguard against mis-operation by the driver as well as against system malfunctions. The mis-operation system prevents reverse gear from being engaged at high forward speeds (above 3 mph) and prevents manual downshifting at excessive engine speeds.

Great attention has been paid to safeguarding against, and detecting, malfunctions in the electronic control system. The design of the electrical and diagnostic system is such that system integrity is protected at all times.

The hydraulic system has 'fail-safe' characteristics regarding its electrical energisation, i.e. as a result of the power supply being lost to the electro-hydraulic actuators the transmission engages a reliable emergency gear ratio to facilitate a basic limp-home mode.

Recognition of critical shift operation by monitoring the last element in the signal path, i.e. the solenoid valve, and checking by means of redundant measured variables, i.e. engine speed, ISS and OSS.

Measures are in place, which guarantee a high degree of availability of safeguard functions, i.e. monitoring of safety circuits. For this purpose each time the vehicle is started there is a check on the entire safety hardware, this is during TCM initialization and the associated program parts and signal paths used during the TCM operation status. A malfunction in this part of the system, or triggering of the safety circuit, will be communicated to the driver by the instrument pack message center.

4 On Board Monitoring

The TCM monitors all input and outputs to identify possible failures. If a fault is detected the TCM takes the appropriate action to ensure the transmission enters a safe mode of operation, without sacrificing transmission durability or driver safety.

This section only contains those monitors that will cause the Malfunction Indicator Lamp (MIL) to illuminate.

4.1 System Power Supply

4.1.1 Battery voltage

Battery voltage is continuously monitored whilst the engine speed is greater than the threshold speed. The diagnostic monitors the TCM supply voltage for voltages greater than, or less than fixed thresholds. If the engine speed is low, but battery voltage is high, a jump-start condition (batteries in series) has been detected, and the diagnostic will not flag.

The monitor starts by checking for the jump-start condition. The battery voltage is checked against its high threshold of 16v whilst the ISS sensor is checked to see if it is below it's low threshold of 1000 RPM (indicating engine speed). If both conditions are true then a jump-start condition is identified, the transmission is temporarily put into limp home and the battery voltage monitor is deactivated. When either the jump-start timer times out or the monitored conditions change to within the required thresholds, the limp home is deactivated and the monitor restarted.

If a jump-start condition is not identified, the engine speed is above its minimum threshold and the transmission is not in limp home because of another code then the battery voltage check continues. The voltage is checked against both upper and lower limits. If either is exceeded a Diagnostic Trouble Code (DTC) is logged.

4.1.2 Pressure Regulator and Solenoid Power Supply

The pressure regulator and solenoid supply is the power supply from the TCM that supplies the shift solenoid, pressure regulators and the TCC solenoid. The supply is monitored when any of the solenoids are activated. The TCM will detect a fault condition if the supply voltage either exceed its upper threshold or falls below the lower threshold. If either condition exists, DTC P0651 will be logged.

4.1.3 Sensor Supply

The sensor supply is the power supply from the TCM that supplies the two speed sensors and the gear selector hall effect switches. The sensor supply is continuously monitored whilst the ignition is on. The TCM will detect a fault condition if the supply voltage either exceed its upper threshold or falls below the lower threshold. If either condition exist, DTC P0641 will be logged.

Note: Unless specifically included in the tables below, Intake Air Temperature (IAT), ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – System Power Supply								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
System voltage	P1794	Power supply out of range	Battery voltage or	< 7 volts	Engine speed No jump start	>1400 RPM	Continuous	2 DTC
			Battery voltage	> 16 volts	Engine speed No Jump start	> 1000 RPM		
	P0651	Pressure regulator and solenoid power supply	Supply voltage	> 8.0 volts < 5.5 volts	Battery voltage	> 8.5 volts	Continuous	2 DTC
	P0641	Sensor supply voltage out of range	Supply voltage	> 8.0 volts < 5.5 volts	Battery voltage	> 8.5 volts	Continuous	2 DTC

4.2 Transmission Control Module Malfunctions

4.2.1 Checksum Failures – P0605/P1603

To diagnose errors with the Electrically Erasable Programmable Read Only Memory (EEPROM) the TCM calculates 4 checksums continuously: If the processor identifies discrepancies in any of the four checksums the TCM will engage mechanical limp-home mode.

Diagnosis is only performed during TCM initialization. There is no fail-safe mechanism associated with this function as the EEPROM is mainly used for the storage of fault codes and transmission calibration adaptions. If a fault occurs the TCM is able to perform a default action and inform the driver of the problem, via the instrument pack message center.

4.2.2 Watchdog Mechanism – P0606

The watchdog monitoring function serves two tasks. Firstly, it checks that it is possible to inhibit output control by the activation of the solenoid supply transistor. Secondly, the watchdog checks that the safety circuit is functioning correctly.

During initialization, the watchdog checks that it is possible to inhibit control of the pressure regulator and solenoid valves by switching the solenoid supply transistor. A fault is present if activation of the solenoids cannot be inhibited by the watchdog (NB. the supply to the solenoids can still be inhibited by the high side switch responsible for control of each solenoid i.e. one safety path is lost).

4.2.3 Combination of Substitute

The transmission has two ways of monitoring vehicle speed for shift scheduling and torque converter control. One way is for it to use it's own OSS sensor and the other way to use the individual rear wheel speeds that are transmitted by the ABS module on CAN. If the TCM detects a problem with either of the above signal inputs the transmission will perform all related control functions using the alternative/substitute value. If both systems fail then a double fault DTC will be logged by the TCM.

This DTC logs because two diagnostics with priority 2 have logged simultaneously. The only diagnostics with priority 2 within the TCM software are the OSS (P0720) and ABS wheel speed diagnostics (P1799).

4.2.4 Substrate Temperature Sensor

The TCM is situated within the transmission on the valve body. As the TCM controls a number of high power solenoids and is surrounded by transmission fluid it can get very hot. If the temperature of the hardware rises above a pre-determined level the TCM will be shut down and the transmission will enter mechanical limp-home mode. Prior to the TCM shutting down the TCM will log a fault code. A temperature dependent resistor mounted on the processor performs monitoring of the substrate temperature.

4.2.5 Plausibility Checking

The TCM detects a fault if an excessive voltage jump is identified between any two consecutive measurements. Also, with the engine started from cold the TFT will start to rise. Therefore the substrate or fluid temperature will also start to rise because the TCM is surrounded by transmission fluid. If the engine and OSS is higher than a set threshold for a predetermined length of time without the substrate temperature rising above a set threshold a fault will be detected.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Control Module Malfunctions								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
TCM Internal	P1603	EEPROM communications	Calculated Checksum does not match stored checksum				Continuous	1 DTC
	P0605	Flash memory checksum	Calculated Checksum does not match stored checksum				Continuous	2 DTC
	P0606	Watchdog mechanism	Asynchronous functionality failure, software in infinite loop		Transistor switched off TCM in initialization phase		Continuous Continuous	2 DTC 2 DTC
Combination of substitute	P0701	Impossible substitute functions	OSS sensor fault and CAN wheel speed sensor fault. or Transmission fluid sensor fault and internal chip fault.				Continuous	2 DTC

4.3 Transmission Range Switch

The TCM can identify errors with the position switch located within the transmission. If an unrecognized position code is read by the TCM, a plausibility fault will be logged. (A code is checked between positions).

The position switch outputs a 4-bit code to the TCM, the bits being labeled L1-L4.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Transmission Range/Position Switch								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Position detection	P0705	Position switch	Implausible position detected on lines L1–L4		No sensor supply fault Sensor supply voltage No crank in progress No CAN bus fault	> 7.0 volts	Continuous	2 DTC

4.4 Shaft Speed Sensors

4.4.1 Output Shaft Speed Monitor

It is possible for the TCM to diagnose electrical errors associated with the OSS sensor while the vehicle is stationary as well as moving. Plausibility monitoring is performed on the sensor output when the vehicle is moving.

The plausibility monitor runs continuously by checking the difference between the transmission output shaft speed and the calculated OSS gained from the road speed transmitted on the CAN. If the difference exceeds 510 RPM then the DTC is logged. Additionally if the maximum OSS exceeds its upper threshold then the DTC is also logged.

4.4.2 Input Shaft Speed Monitor

It is possible for the TCM to diagnose electrical errors associated with the ISS sensor while the vehicle is stationary as well as moving. Plausibility monitoring is performed on the sensor output when the vehicle is moving.

The plausibility monitor runs continuously by checking the difference between the transmission ISS and the engine speed gained from the road speed transmitted on the CAN. If the difference exceeds the defined threshold then the DTC is logged. Additionally if the maximum turbine speed exceeds its upper threshold then the DTC is also logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation –Speed Sensors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Speed sensors	P0720	Transmission OSS	OSS Or	> 7100 RPM	OSS sensor not faulty		Continuous	2 DTC
			Maximum difference between OSS and driven road wheel speed Or	> 512 RPM				
			OSS sensor	Open circuit or short circuit				
	P0715	Transmission ISS	ISS sensor Or	Short circuit or Open circuit	No ISS sensor fault		Continuous	2 DTC
			ISS Or	< 20 RPM	Engine speed OSS No shift in progress No position switch sensor fault	> 608 RPM > 150 RPM		
			ISS	> 6800 RPM	No sensor supply fault OSS	 >150 RPM		

4.5 Torque Converter Clutch

The torque converter connects the engine flywheel to the transmission input shaft. To increase fuel economy and to reduce emissions the TCM can lock the torque converter to give direct drive from the flywheel to the transmission input shaft.

The function of the torque converter diagnostic is to identify when the torque converter has not locked when requested to do so, by the TCM. The monitor runs continuously when TCC is requested.

The monitor starts by checking the TCC pressure, if this is above a predefined threshold and the level of clutch slip is also above its predefined threshold then status of the ISS sensor is checked. If the status is OK and the engine torque is below its predefined threshold, then a fault timer will start. If the conditions still exist after the fault timer has reached a defined period then the fault is logged and the monitor ends.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Torque Converter Clutch								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
TCC	P0741	TCC stuck open					Continuous	2 DTC

4.6 Shift Solenoid - P0787, P0788

The shift solenoid valves are used to control the oil flow used in gearshift selection, and TCC control. The solenoids are driven by the TCM at Pulse Width Modulating (PWM) rates from 0 to 100%.

The diagnostic monitors the feed back voltage from the solenoids, the methods of fault detection dependant on the PWM duty cycle. Short circuits to battery voltage, ground, or open circuit can be detected. Fault detection results in mechanical or electrical limp home mode being selected depending on which DTC is flagged. The monitors are very similar in operation, however, the diagnostics performed at each stage are different so they have been described individually below.

4.6.1 P0787

DTC P0787 will cause the TCM to invoke mechanical limp home if it is logged.

The monitor starts by checking that the solenoid supply voltage is above its minimum threshold, the solenoid supply transistor is switched on and the low side solenoid drivers are unlocked. If any of these conditions are not met then the monitor will stop and restart.

Once the above entry conditions have been met then the monitor will take two successive captures of the duty cycle of the PWM driver signal to the solenoid.

If the two duty cycle ratios do not match then the monitor will stop and restart. Providing the two duty cycle ratios match, a check is performed to confirm the value is above 0%. If not a short circuit to ground test is performed. If this fails (i.e. the solenoid is short circuit to ground) DTC P0787 is logged. If the solenoid is not short circuited to ground the monitor is stopped and restarted.

If the value of the duty cycle ratio is not 0% it is checked against a low threshold of 7.6%. If the ratio is below this threshold, a software diagnostic is run on the solenoid to check that the solenoid off voltage is below its threshold. If this is the case then DTC P0787 is logged, if not the monitor is restarted.

If the ratio of the duty cycle is above the low threshold, it is checked against the high threshold of 92.4%. If the ratio is above the threshold, it is checked whether it is stuck at 100%. A short circuit to battery voltage test is performed, if this fails (i.e. the solenoid is shorted to battery voltage) again the DTC is logged.

The final check is performed if the duty cycle ratio is within the upper and lower limits. In this case the solenoid on voltage is checked to ensure it is below its low voltage threshold, if this is the case the monitor is stopped and restarted. If not the DTC is logged.

4.6.2 P0788

DTC P0788 will cause the TCM to invoke electrical limp home if it is logged.

The monitor for P0788 starts by performing the same initial checks as performed for P0787. The solenoid supply voltage is above its minimum threshold, the solenoid supply transistor is switched on and the low side solenoid drivers are unlocked. If any of these conditions are not met then the monitor will stop and restart. Once the entry conditions have been met then the monitor will take two successive captures of the duty cycle of the PWM driver signal to the solenoid.

If the two duty cycle ratios do not match the monitor will stop and restart. Providing the two duty cycle ratios match a check is performed to confirm the value is above 0%. If not an open circuit test is performed on the solenoid. If this fails (i.e. the solenoid is open circuit) DTC P0788 is logged. If the solenoid is not open circuit to ground the monitor is stopped and restarted.

If the value of the duty cycle ratio is not 0% it is checked against a low threshold of 7.6%. If the ratio is below this threshold, a software diagnostic is run on the solenoid to check that the solenoid off voltage is between its lower and upper threshold. If this is the case then DTC P0788 is logged, if not the monitor is restarted. If the ratio of the duty cycle is above the low threshold, it is checked against the high threshold of 92.4%. If the ratio is above the threshold, it checked whether it is stuck at 100%. If this is the case then an open circuit test is performed. If this fails, (i.e. the solenoid is open circuit) then again, the DTC is logged.

If the ratio of the duty cycle is above 92.4 % but below 100% then the solenoid on voltage is checked against its high threshold. If the voltage is above the high threshold then a short circuit to battery voltage has been detected and the DTC is logged.

The final check is performed if the duty cycle ratio is within the upper and lower limits. In this case the solenoid on voltage is checked to ensure it is between its upper and lower voltage thresholds, If this is the case then the monitor is stopped and restarted. If not the DTC is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Shift Solenoid								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Solenoid monitoring	P0787	Solenoid valve 1 open circuit or short circuit to battery voltage	PWM (low drive) duty cycle	< 7.6%	Solenoid supply Transistor	On	Continuous	2 DTC
	P0788	Solenoid valve 1 short circuit to ground	PWM (high drive) duty cycle	> 92.4%	Supply tension of output stages	< 1.5 volts		

4.7 Gear Monitoring

4.7.1 Gear Ratio – P0731, P0732, P0733, P0734, P0735, P0729

The objective behind gear monitoring is to detect non-electrical errors that are caused by slipping clutches or by the mechanical failure of actuators. When outside shift functions, verification checks are conducted for the OSS in relation to the ISS. Failure results in a default gear being selected by the TCM.

When the TCM detects that both the OSS and engine speed are above the thresholds required for the transmission to shift, it checks to confirm that the shift is in progress. If no shift is happening then the TFT is checked to ensure it is above its minimum threshold. If the fluid temperature is correct the level of slip is also checked. If the level of slip exceeds its threshold then a fault timer is started and the checks repeated.

When the fault timer exceeds its predefined threshold, a fault counter is incremented. When the counter exceeds a defined limit, the relevant DTC is logged.

4.7.2 Gear Load – P0781, P0782, P0783, P0784, P0829

These monitors identify excessive or reduced slip during gear changes. The excessive slip part of the monitors is caused by the engaging clutch not coming on quickly enough. The reduced slip monitoring identifies that the off going clutch is not coming off quickly enough. These monitors run continuously as long as the entry conditions continue to be satisfied.

When a gearshift is detected the monitor initially checks that the transmission fluid pressure and output shaft speeds are both above their required thresholds for the monitor to run. If either is not above its threshold, then the monitor is stopped.

The level of slip is first checked against the slip high threshold. If the actual slip exceeds the high threshold then a fault present timer is incremented and the check repeated. When the fault present timer exceeds it predefined threshold then the shift is aborted and a fault counter is incremented.

If the level of slip is below the slip high threshold, it is then checked against the slip low threshold. If the actual slip is less than the low threshold then a fault present timer is incremented and the check repeated. When the fault present timer exceeds it predefined threshold the shift is aborted and a fault counter is incremented.

When the fault counter exceeds its predefined threshold, the relevant DTC is logged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Gear Monitoring								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Gear monitoring	P0731	1st gear error	Calculated slip on 2nd engagement	> 400 RPM (internal map)	Forward range Gear engaged Shift in progress OSS ISS sensor	Selected = 1 = No > 250 RPM Not faulty	Continuous	2 DTC
Gear monitoring	P0732	2nd gear error	Calculated slip on 2nd engagement	> 400 RPM (internal map)	Forward range Gear engaged Shift in progress OSS ISS sensor	Selected = 2 = No > 250 RPM Not faulty	Continuous	2 DTC
Gear monitoring	P0733	3rd gear error	Calculated slip on 2nd engagement	> 400 RPM (internal map)	Forward range Gear engaged Shift in progress OSS ISS sensor	Selected = 3 = No > 250 RPM Not faulty	Continuous	2 DTC
Gear monitoring	P0734	4th gear error	Calculated slip on 2nd engagement	> 4 00 RPM (internal map)	Forward range Gear engaged Shift in progress OSS ISS sensor	Selected = 4 = No > 250 RPM Not faulty	Continuous	2 DTC
Gear monitoring	P0735	5th gear error	Calculated slip on 2nd engagement	> 400 RPM (internal map)	Forward range Gear engaged Shift in progress OSS ISS sensor	Selected = 5 = No > 250 RPM Not faulty	Continuous	2 DTC
Gear monitoring	P0729	6th gear error	Calculated slip on 2nd engagement	> 400 RPM (internal map)	Forward range Gear engaged Shift in progress OSS ISS sensor	Selected = 6 = No > 250 RPM Not faulty	Continuous	2 DTC

Electronic Transmission Operation – Gear Monitoring – Continued								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0781	Gear load 1-2/2-1	Calculated slip during shift is excessive		ISS sensor OSS sensor No gear ratio error	Not faulty Not faulty	Continuous	2 DTC
	P0782	Gear load 2-3/3-2	Calculated slip during shift is excessive		ISS sensor OSS sensor No gear ratio error	Not faulty Not faulty	Continuous	2 DTC
	P0783	Gear load 3-4/4-3	Calculated slip during shift is excessive		ISS sensor OSS sensor No gear ratio error	Not faulty Not faulty	Continuous	2 DTC
	P0784	Gear load 4-5/5-4	Calculated slip during shift is excessive		ISS sensor OSS sensor No gear ratio error	Not faulty Not faulty	Continuous	2 DTC
	P0829	Gear load 5-6/6-5	Calculated slip during shift is excessive		ISS sensor OSS sensor No gear ratio error	Not faulty Not faulty	Continuous	2 DTC

4.8 Pressure Regulator Monitors

Each pressure regulator and solenoid is monitored for open circuits and short circuits. The TCM also checks that the current being delivered to each solenoid valve or pressure regulator is within valid limits.

When each solenoid is being driven with minimum current the TCM checks that the current is not above a threshold value. If a solenoid is being driven with maximum current, it checks that the current is not below a valid threshold. If either of these two errors occurs a plausibility error is logged and the appropriate fail-safe action is performed.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Pressure Regulator Monitors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary Parameter	Enable Conditions	Time Required	MIL
Pressure regulator monitoring	P0750	Pressure regulator 1 open circuit or short circuit to battery voltage	Maximum current deviation for low current	< 100 mA	Pressure regulator supply	> 7 volts	Continuous	2 DTC
	P0753	Pressure regulator 1 short circuit to ground	Minimum current deviation for high current	> 150 mA				
	P0755	Pressure regulator 2 open circuit or short circuit to battery voltage	Maximum current deviation for low current	< 100 mA	Pressure regulator supply	> 7 volts	Continuous	2 DTC
	P0758	Pressure regulator 2 short circuit to ground	Minimum current deviation for high current	> 150 mA				

Electronic Transmission Operation – Pressure Regulator Monitors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0760	Pressure regulator 3 open circuit or short circuit to battery voltage	Maximum current deviation for low current	< 100 mA	Pressure regulator supply	> 7 volts	Continuous	2 DTC
	P0763	Pressure regulator 3 short circuit to ground	Minimum current deviation for high current	> 150 mA				
	P0765	Pressure regulator 4 open circuit or short circuit to battery voltage	Maximum current deviation for low current	< 100 mA	Pressure regulator supply	> 7 volts	Continuous	2 DTC
	P0768	Pressure regulator 4 short circuit to ground	Minimum current deviation for high current	> 150 mA				
	P0770	Pressure regulator 5 open circuit or short circuit to battery voltage	Maximum current deviation for low current	< 100 mA	Pressure regulator supply	> 7 volts	Continuous	2 DTC
	P0773	Pressure regulator 5 short circuit to ground	Minimum current deviation for high current	> 150 mA				
	P0740	Pressure regulator 6 open circuit or short circuit to battery voltage	Maximum current deviation for low current	< 100 mA	Pressure regulator supply	> 7 volts	Continuous	2 DTC
	P0743	Pressure regulator 6 short circuit to ground	Minimum current deviation for high current	> 150 mA				

4.9 Communications Network Monitors

If the TCM does not receive the required messages from the ECM for a set time, or the message is received as Hex FFFF then a fault is flagged.

Note: Unless specifically included in the tables below, IAT, ECT, vehicle speed and time after start up are not critical to enable these monitors.

Electronic Transmission Operation – Communications Network Monitors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
CAN link	P1796	CAN bus off	Bit, stuff, cyclic redundancy check or form error.	> 0.500s	Battery voltage	> 9 volts	Continuous	2 DTC
	P0725	Engine speed signal	Engine speed	= FFFF or > 7000 RPM	No CAN bus error Engine not cranking No CAN EMS error		Continuous	2 DTC
	P1719	Engine torque signal	Any engine torque message	= FFFF	No CAN bus error Engine not cranking		Continuous	2 DTC
	P1797	CAN timeout EMS	EMS CAN identifier missing	> 0.500s	No CAN bus error Engine not cranking		Continuous	2 DTC