



ON-BOARD DIAGNOSTICS

ZF 5HP24 TRANSMISSION

Vehicle Coverage:

XJ Series 3.2L and 4.0L N/A 1998 to 2002 model year

XK8 4.0 L N/A 1997 to 2002 model year



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2 Introduction

This document describes the on-board diagnostic monitoring strategy and malfunction criteria for the ZF 5HP24 Transmission Systems.

2.1 OBD-II Systems

California OBD-II applies to all gasoline engine vehicles up to 14,000 lbs. Gross Vehicle Weight Rating (GVWR) starting in the 1996 MY and all diesel engine vehicles up to 14,000 lbs. GVWR starting in the 1997 MY.

"Green States" are states in the Northeast that chose to adopt California emission regulations, starting in the 1998 MY. 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 LEV program (NLEV) requires compliance with California OBD-II, including 0.020" evaporative system monitoring requirements. The NLEV program apply to passenger cars and light trucks up to 6,000 lbs. GVWR nation-wide from 2001 MY through 2003 MY

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

OBD-II system implementation and operation is described in the remainder of this document.

2.2 ZF 5HP24 Transmission System

The transmission management system uses both analogue and digital signals, to control the operation of the transmission. Digital signals are processed by the TCM to and from the vehicle multiplex network. Other input/output analogue signals are hardwired to the TCM. This information is used primarily by the TCM to decide which shift program to implement, which gear to select and for shift energy management. If a fault occurs, the TCM will take default action and inform the driver via the Message Center and amber warning light.

2.2.1 Harness Connector

The vehicle harness connector for the TCM is an 88-way latching connector. The TCM is wired to the electrical pressure regulators/solenoids, oil temperature sensor and shaft speed sensors in the transmission casing.

2.2.2 Sport Mode

When the driver using the mode switch selects sport mode, the sport pattern is only activated when a set cornering force is achieved, or the kickdown switch is pressed. The vehicle speed and the difference in speeds between the two front wheels is used to calculate the amount of cornering force.



2.2.3 Torque Converter Lock-up

The torque converter lock-up clutch is engaged as a function of throttle position, output speed, oil temperature, gearshift and shift program. Lockup is possible in 2nd, 3rd, 4th and 5th gears but is usually restricted to 4th and 5th gears. During a gear shift the TCM controls the amount of slip of the lock-up clutch to enhance shift quality.

2.2.4 Oil Temperature

When the engine coolant or transmission oil temperature exceeds set thresholds a hot mode program is selected which locks the torque converter clutch, minimizing the amount of heat entering the engine cooling system from the transmission oil.

2.2.5 Gear Shift Interlock

Gearshift interlock is controlled by the BPM, part of the SCP network. The gearshift release will only be activated when the ignition is in position II, transmission is in Park and the brake pedal is depressed. Once transmission is out of Park, the brake pedal has no effect on gear shifting and the interlock is disabled.

2.2.6 Reverse Inhibit

Selection of reverse with the vehicle moving forwards above walking pace is electrically inhibited, unless the vehicle is in the default "limp-home" mode.

2.2.7 Kickdown

A floor mounted switch/pedal position sensor signals the TCM to select the lowest gear to give maximum torque for acceleration.

2.2.8 Torque Control

The TCM synchronizes the operation of the transmission clutches and invokes shift energy management to control engine output torque during a gear shift.

2.2.9 Traction Mode

The traction program compliments the traction control system and is implemented whenever traction control intervenes to maximize wheel stability.

2.2.10 Cruise Mode

Cruise mode reduces unwanted hunting of the transmission gear shifting and is activated when cruise control is resumed and when the vehicle is cruising near the set speed.



2.2.11 Gradient Mode

The gradient program enhances vehicle performance, driveability and cooling when the vehicle is climbing a gradient.

2.2.12 Start Inhibit

The rotary switch also provides the start inhibit function to the ECM, which will not allow an engine start until the gear selector is in either Park or Neutral.

2.2.13 Fault Monitoring/Diagnostics

The TCM constantly monitors the transmission system for faults. In the event of a fault occurring, the transmission is protected by a limp home mode. This mode allows use of P, R, N, and 4. It also signals the ECM to switch on the CHECK ENG (MIL) lamp. The TCM is able to diagnose faults in components which affect exhaust emissions. Communication with the PDU is through the J1962 connector which allows accurate diagnosis of transmission problems. Additional diagnostic functions facilitate fast repair of faults. All transmission OBDII information is stored for future data analysis in the ECM.

2.3 Inputs and Outputs

Inputs and outputs are directed to and from the TCM through hard-wired connections and the CAN and ISO 9141/2 (Serial Communication) data buses contained in the harness.

ECM Pin Connections

EM007

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	Pressure Regulator 2	023	Shield (Input Speed Sensor)	045	Mode Switch Pin A
002	Mode Switch Illumination	024	Not used	046)
003	Not used	025	Not used	047	Not used
004	Pressure Regulator 4	026	Battery Feed	048)
005	Pressure Regulator 1	027	Not used	049)
006	Power Ground	028	Digital Ground	050)
007	Not used	029	Pressure Regulator 3	051	Pressure Regulator 5
008	Position Switch L2	030	Shift Solenoid 1	052	Solenoid Valve +ve
009	Position Switch L4	031	Not used	053	Pressure Regulator +ve
010	Not used	032	Shift Solenoid 3	054	Fused Ignition +ve



EM007- Cont'd

Pin	Circuit	Pin	Circuit	Pin	Circuit
011	Not used	033	Shift Solenoid 2	055	Fused Ignition +ve
012	Mode Switch Pin B	034	Power Ground	056	
013	Drive to Fourth Switch	035	Not used	To	
014	Turbine Speed (-)	036	Position Switch L1	061	Not used
015	Shield (Output Speed Sensor)	037	Position Switch L3	062	CAN Link In -ve
016	Output Speed (+)	038)	063	CAN Link In +ve
017	Not used	039	Not used	064	CAN Link Screen
018	Kickdown Switch	040)	065	CAN Link Out -ve
019	Not used	041)	066	CAN Link Out +ve
020	Not used	042	Turbine Speed (+)	067	Not used
021	Analogue Ground	043	Not used	068	Not used
022	Oil Temperature Sensor	044	Output Speed (-)		



3 On-Board Monitoring

When the ignition switch is set to position II (ignition ON) the TML comes on briefly and then goes off again.

When the TCM detects a fault, it stores the fault code and activates the transmission fault warning lamp (TWL). For faults detected in less critical inputs/outputs, the TCM substitutes the faulty input/output with a default value and continues the normal mode of operation. This allows the vehicle to be driven normally, although gear change quality will be affected.

For certain faults the TCM also disables the sport mode.

For more serious faults, the TCM may adopt a 'limp home' mode by disabling the shift and torque converter clutch solenoids. This allows the vehicle to be driven, but no gear changes will occur in the forward range. If the 'limp home' mode is adopted while the vehicle is in motion the transmission is kept in fourth gear. If the vehicle is then brought to a halt, neutral selected and drive re-selected, or if the 'limp home' mode is adopted while the vehicle is stationary, the transmission is kept in third gear.

3.1 Control Module Malfunctions

The diagnostic detects malfunctions in the TCM ignition switched supply by measuring the system voltage. A fault is logged if the voltage is either too high or too low. The voltage is measured at the TCM.

Electronic Transmission Operation – Control Module Malfunctions								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Transmission (electrical)	P0702	TCM internal supply switch to solenoids/pressure regulators not correct.	Switch "ON", voltage too high or Switch "OFF", voltage too high.	<2.5v >0.8* U_ battV	None	None	300ms	2 Drive Cycles
CAN Link	P1795	Incorrect network token received from other nodes.	Network token values are incorrect.	N/ A	None	None	30ms	2 Drive Cycles
	P1796	CAN IC internal diagnostics	No CAN bus activity.	300ms	None	None	250ms	2 Drive Cycles
	P1797	No network token received from ECM node.	No token received from ECM	850ms	None	None	850ms	2 Drive Cycles
System Voltage	P1793	Ignition supply out of allowable range.	Ignition supply checked.	7<::> 16v	Engine speed	>1600RPM	300ms	2 Drive Cycles
	P1789	Ignition supply too low to operate solenoids, but able to maintain the present solenoid state.	Ignition supply checked.	7<::< 9.0v	Engine speed	>1600RPM	2.55s	2 Drive Cycles



Electronic Transmission Operation – Control Module Malfunctions								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
TCM Internal	P1605	PROM fault, incorrect checksum.	Calculated checksum does not match stored checksum.	94.2s	None	None	2.56s	2 Drive Cycles
	P1603	EEPROM fault.	Write to EEPROM and read back value.		None	None	Immediate	Immediate
	P1608	Watchdog fault.	Internal TCM watchdog detects fault.		None	None	200ms	2 Drive Cycles

The following data changed from the 2000 model year introduction

Electronic Transmission Operation – Control Module Malfunctions –2000 MY Changes								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P1608	Watchdog fault.	Internal TCM watchdog detects fault.		None	None	10ms	2 Drive Cycles

3.2 Transmission Oil Temperature

Electronic Transmission Operation – Transmission Oil temperature								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Oil Temperature Sensor	P0711	Oil temperature sensor value suddenly changes	Oil temperature change between samples. (100 ms)	>5° C			1.5s	No Mil
		or			Disable:	engine idle speed diag		
		Oil temperature does not rise correctly from cold.	Oil temperature	<20° C	Engine running	>600rpm	180ms	No Mil
			d oil temperature	>10° C	Time	180ms		
					Disable:	engine idle speed diag		



Electronic Transmission Operation – Transmission Oil Temperature – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0712	Oil temperature input too low.	Input voltage to TCM	<0.294v			1.5s	No Mil
	P0713	Oil temperature input too high.	Input voltage to TCM	<0.294v	Disable:	engine idle speed diag		
					Disable:	engine idle speed diag		No Mil

3.3 Transmission Range/Position Sensor

The diagnostic detects malfunctions of the transmission range/position switch assembly circuit. It detects illegal switch combinations and legal, but invalid transmission ranges. A legal, but invalid, signal is indicated if the range switch indicates a transmission range which, given the secondary conditions, cannot be correct.

Electronic Transmission Operation – Transmission Range/Position Switch

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Range Sensor	P0706	Illegal code detection or position switch does not indicate !P" nor "N" during cranking.	Illegal 5- bit position code	Not valid	None	None	200ms	2 Drive Cycles
			or position switch code	R, D, 4, 3 or 2	Engine start detected		200ms	2 Drive Cycles
					Engine speed less than 100RPM Then engine speed between 100<RPM<448 Then engine speed >448RPM for 200ms			

3.4 Output Speed Sensor Circuit

Electronic Transmission Operation – Output Speed Sensor Circuit								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Output Speed Sensor	P1720	Loss of output speed and wheel speed	P0721 logged and then ABS module logs wheel speed fault or ABS off-CAN		None		200ms	2 Drive Cycles

The following data changed from the 2000 model year introduction

Electronic Transmission Operation – Output Speed Sensor Circuit – 2000 MY Changes								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Output Speed Sensor	P1720	Loss of output speed and wheel speed	P0721 logged and then ABS module logs wheel speed fault or ABS off-CAN		None		70ms	2 Drive Cycles

3.5 Input Speed Sensor Circuit

Electronic Transmission Operation – Engine Speed Input Circuit								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Input Speed Sensor	P0715	Input/ turbine speed sensor fault	Turbine speed > max. value	>7500RPM	None	None	200ms	2 Drive Cycles
			or turbine speed <min value	160 RPM	Engine speed	>608RPM	200ms	2 Drive Cycles
					Output speed	>224RPM		



The following data changed from the 2000 model year introduction

Electronic Transmission Operation – Engine Speed Input Circuit – 2000 MY Changes									
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL	
Input Speed Sensor	P0715	Input/ turbine speed sensor fault	Turbine speed > max. value	>7500RPM	None	None	200ms	2 Drive Cycles	
			or						
			turbine speed <min value	0 RPM	Engine speed	>608RPM	200ms	2 Drive Cycles	
					Output speed	>180RPM			

3.6 Shift Solenoid "1"

The solenoids are connected directly to the +12 Ignition supply and also to the TCM. The TCM switches this circuit to ground to operate the solenoid. The diagnostic monitors the voltage at the solenoid connection to the TCM. A fault is logged if this voltage is HIGH when the solenoid is commanded ON or LOW when the solenoid is commanded OFF.

Electronic Transmission Operation – Shift Solenoid "1"								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Shift solenoid 1	P0753	Condition active	Solenoid "ON", voltage too high or	=U_ batt	None	None	50ms	2 Drive Cycles
		Condition inactive	Solenoid "OFF", voltage too low	<0.2* Ubatt				

3.7 Shift Solenoid "2"

Electronic Transmission Operation – Shift Solenoid "2"								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Shift solenoid 2	P0758	Condition active	Solenoid "ON", voltage too high or	=U_ batt	None	None	70ms	2 Drive Cycles
		Condition inactive	Solenoid "OFF", voltage too low	<0.2* Ubatt				



3.8 Shift Solenoid "3"

Electronic Transmission Operation – Shift Solenoid "3"								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Shift solenoid 3	P0763	Condition active	Solenoid "ON", voltage too high or	=U_ batt	None	None	70ms	2 Drive Cycles
		Condition inactive	Solenoid "OFF", voltage too low	<0.2* Ubatt				

3.9 Torque Converter Clutch System

Electronic Transmission Operation – Torque Converter Clutch System								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Torque Converter System	P0743	TCC system (pressure regulator 4) validation conditions: voltage > 9v or current <500 mA and Voltage > 7v	PWM signal should toggle	100%	Ignition voltage	>9v	70ms	2 Drive Cycles
			or PWM signal should toggle	0%				
Stuck "ON"	P0742	Detected by measuring slip (calculated using engine and input speeds)	Slip < threshold	< 10RPM	Commanded clutch pressure	>0.5 bar	2.55s	2 Drive Cycles
Stuck "OFF"	P0741		Slip > threshold	> 250RPM	Engine torque Commanded clutch pressure Engine torque	>100Nm >5.24bar <500Nm	2.55s	2 Drive Cycles



The following data changed from the 2000 model year introduction.

Electronic Transmission Operation – Torque Converter Clutch System – 2000MY Changes								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Stuck “ON”	P0742	Detected by measuring slip (calculated using engine and input speeds)	Slip < threshold	< 10RPM	Commanded clutch pressure	>0.4 bar	2.55s	2 Drive Cycles
					Engine torque	>150Nm		

3.10 Transmission System Mechanical

Electronic Transmission Operation – Transmission System Mechanical									
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL	
Transmission (mechanical)	P1722	Detects failure of transmission or output speed sensor	Turbine speed > threshold	>1696RPM	Output speed Time in “D, 4, 3, or 2”	<160RPM >500ms	200ms	2 Drive Cycles	
	P1726		Engine over speed	Engine speed	>7392RPM	In “D, 4, 3, or 2”	None	200ms	2 Drive Cycles
	P1779		Fault detection during gear changes 2- 3 or 3- 4	Synchronization not being achieved during shift.		Shifting 2- 3 or 3- 4 Transmission oil temperature	>20° C	Event controlled	2 Drive Cycles
Gear ratio (2, 3, and 4)	P1730	Ratio calculated using input and output speed. Also acts as rationality check of the input and output speed sensors.	2nd gear turbine/ output 3rd gear turbine/ output 4th gear turbine/ output	Ratio= 2.2 Ratio= 1.508 Ratio= 1.0	In 2, 3 or 4 (not shifting) two symptoms (P1731) logged. In “D, 4, 3” position: DKI (throttle position) nab (output speed)	<5% >200RPM	Event controlled	2 Drive Cycles	
Gear ratio (5)	P1734		5th gear	Ratio= 0.803	In 5 (not shifting) two symptoms (P1731) logged. DKI (throttle position) nab (output speed)	<5% >200RPM	Event controlled	2 Drive Cycles	



Electronic Transmission Operation – Transmission System Mechanical – Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Gear	P1700	Double gear fault to react on gear ratio problems in two different gears and under criteria: Two substitute functions for gear ratio fault active in same time			None		200ms	2 D/ C

The following data changed from the 1999 model year introduction.

DTC P1730 re-numbered to DTC P1739.

The following data changed from the 2000 model year introduction.

Electronic Transmission Operation – Transmission System Mechanical – 2000 MY Changes								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P1726	Engine over speed	Engine speed	>7200RPM	In "D, 4, 3, or 2"	None	200ms	2 Drive Cycles

The following DTCs were deleted from the 2000 model year introduction.

DTC P1739; DTC P1734

The following data was added from the 2000 model year introduction.

Electronic Transmission Operation – Transmission System Mechanical – 2000 MY Additions								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0731	Gear monitoring 1 st Ratio calculated using input & output speed. Also acts as a rationality check of these two sensors	Calculated ratio outside allowable range. nab i - nt> threshold	f (nab)	In gear 1 (not shifting) Two symptoms		Event controlled	2 Drive Cycles



Electronic Transmission Operation – Transmission System Mechanical – 2000 MY Additions – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0732	Gear monitoring 2 nd Ratio calculated using input & output speed. Also acts as a rationality check of these two sensors	Calculated ratio outside allowable range nab i - nt> threshold	f (nab)	In gear 2 (not shifting) Two symptoms		Event controlled	2 Drive Cycles
	P0733	Gear monitoring 3 rd Ratio calculated using input & output speed. Also acts as a rationality check of these two sensors	Calculated ratio outside allowable range. nab i - nt> threshold	f (nab)	In gear 3 (not shifting) Two symptoms		Event controlled	2 Drive Cycles
	P0734	Gear monitoring 4 th Ratio calculated using input & output speed. Also acts as a rationality check of these two sensors	Calculated ratio outside allowable range. nab i - nt> threshold	f (nab)	In gear 4 (not shifting) Two symptoms		Event controlled	2 Drive Cycles
	P0735	Gear monitoring 5 th Ratio calculated using input & output speed. Also acts as a rationality check of these two sensors	Calculated ratio outside allowable range. nab i - nt> threshold	f (nab)	In gear 5 (not shifting) Two symptoms		Event controlled	2 Drive Cycles
	P1732	Fault detection during gear changes 2 - 3	Synchronisation not achieved		Shifting 2 - 3		Event controlled	2 Drive Cycles
	P1733	Fault detection during gear changes 3 - 4	Synchronisation not achieved		Shifting 3 - 4		Event controlled	2 Drive Cycles



3.11 Pressure Regulator Solenoid

Electronic Transmission Operation – Pressure Regulator solenoid								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Pressure regulator 1	P1745	Validation conditions: voltage > 9v or current < 500mA and voltage > 7v	PWM signal should toggle or PWM signal should toggle	100% 0%	Ignition voltage	>9.0v	70ms	2 Drive Cycles
Pressure regulator 2	P1746	Validation conditions: voltage > 9v or current < 500mA and voltage > 7v	PWM signal should toggle or PWM signal should toggle	100% 0%	Ignition voltage	>9.0v	70ms	2 Drive Cycles
Pressure regulator 3	P1747	Validation conditions: voltage > 9v or current < 500mA and voltage > 7v	PWM signal should toggle or PWM signal should toggle	100% 0%	Ignition voltage	>9.0v	70ms	2 Drive Cycles
Pressure regulator 5	P1748	Validation conditions: voltage > 9v or current < 500mA and voltage > 7v	PWM signal should toggle or PWM signal should toggle	100% 0%	Ignition voltage	>9.0v	70ms	2 Drive Cycles

The following data was added from the 2000 model year introduction.

Electronic Transmission Operation – Pressure Regulator solenoid – 2000 MY Additions								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P1758	Electrical check of pressure regulator 2, 3 & 5 current	Calculated sum of pressure regulator 2, 3 and 5 current Measured sum of pressure regulator 2, 3 and 5 current Threshold	< 0.15 A	None		200ms	2 Drive Cycles



3.12 Throttle Position Sensor

The following data was added from the 2000 model year introduction.

Electronic Transmission Operation – Throttle Position Sensor – 2000 MY Additions								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Throttle Position	1632	Receive error value for throttle position via can CAN message	Error value for throttle position = 255 via CAN message	sec	None	None	200ms	2 D/ C