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PREFACE
This manual assists the reader in the applications of the 4LHD/4LHDX transmission to vehicle systems. It gives an overview of the transmission characteristics, as well as focusing on the interface systems between the transmission and vehicle. The performance of the transmission is dependent on the vehicle design and integration of the interface systems.

This manual is divided into three sections:

Section 1 Transmission Specifications and Attributes: Includes guidelines that describe the transmission’s internal features, external features, performance limitations, and functionality options.

Section 2 Transmission to Vehicle Interfaces: Defines the transmission integration subsystem characteristics, options, limitations, and integration requirements.

Section 3 Production Line Procedures: Describes transmission installation and transmission handling methods. Adhering to the requirements set forth in this document is imperative to proper transmission system operation.

All dimensions and values in this manual are for reference only. Refer to the appropriate transmission installation detail drawing(s) for definitive information.

For more detailed information on the Transmission Control Module (TCM), calibration process, and diagnostic procedures refer to your TCM manual, as an example the PCS TCM2600 Manual.

For more detailed information on transmission maintenance, diagnostic, and troubleshooting procedures please refer to the latest version of the PCS 4LHD/4LHDX Technician’s Guide.

Additional information for PCS provided kits and their part numbers are available in the latest version of the PCS OEM Parts Catalog.

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SECTION 1
TRANSMISSION SPECIFICATION
AND ATTRIBUTES
Section 1. Transmission Specifications and Attributes

1.1 General Description

The 4LHD/4LHDX is a fully automatic, electronically controlled, RWD/4WD transmission. It consists primarily of a three element hydraulic torque converter with a converter clutch, two planetary gear sets, various clutches, an oil pump, and a control valve body. There are four forward driving gear ranges in addition to neutral, reverse, and park. The torque converter clutch is available in 2nd, 3rd, and 4th (overdrive) gear. Park range is available in applications that do not exceed the GVW ratings provided in Section 1.2.5. The mass of a complete system package is estimated to be between 87-113 kg (192-250 lb). This does not include cooler lines, radiator, fluid within the external cooling system, shifter cable, shifter bracket assembly, rear transmission mount isolator, external sensors (such as TPS), and otherwise anything else vehicle specific not included in Section 1.2.1.

Figure 1.1-1
1.1.1 Identification
The transmission nameplate is used to identify the transmission model as well as build date and manufacturing site. A typical nameplate is shown and defined in Figure 1.1.1-2.

![Figure 1.1.1-1 Transmission I.D. Nameplate Locations](image)

![Figure 1.1.1-2 Transmission I.D. Nameplate Features](image)
1.1.2 Feature Location Illustrations

The following figures show all external components and their locations on the transmission case. Manual shaft, fluid level screw, vent cap, output vehicle speed sensor, bottom pan, electrical pass-through connector, cooler line attachment interface and powertrain mount boss provisions are shown in these diagrams.

Figure 1.1.2-1: PCS 4LHD/4LHDX with GM GEN III Bellhousing and 2WD Extension Housing (Right Side View)

Figure 1.1.2-2: PCS 4LHD/4LHDX with GM GEN III Bellhousing and 2WD Extension Housing (Left Side View)
1.1.3 Gear Ratios

<table>
<thead>
<tr>
<th>Gear</th>
<th>Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>3.059:1</td>
</tr>
<tr>
<td>2nd</td>
<td>1.625:1</td>
</tr>
<tr>
<td>3rd</td>
<td>1.000:1</td>
</tr>
<tr>
<td>4th</td>
<td>0.696:1</td>
</tr>
<tr>
<td>Reverse</td>
<td>2.294:1</td>
</tr>
</tbody>
</table>

1.2 Physical Specifications

1.2.1 Mass Properties

**Transmission Mass**

<table>
<thead>
<tr>
<th>Transmission Mass</th>
<th>As Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>4LHD/4LHDX</td>
<td>75 kg (165 lbs)*</td>
</tr>
</tbody>
</table>

* This can vary +/- 3kg (6.6lbs) based on torque converter and output shaft

**Bellhousing Mass**

<table>
<thead>
<tr>
<th>Bellhousing Mass</th>
<th>As Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM Gen III</td>
<td>4.9 kg (10.8 lbs)</td>
</tr>
<tr>
<td>C6 Replacement</td>
<td>5.2 kg (11.5 lbs)</td>
</tr>
<tr>
<td>SAE3</td>
<td>5.2 kg (11.5 lbs)</td>
</tr>
<tr>
<td>SAE4</td>
<td>4.5 kg (9.9 lbs)</td>
</tr>
<tr>
<td>SAE5</td>
<td>7.3 kg (16.1 lbs)</td>
</tr>
</tbody>
</table>

**Extension Housing Mass**

<table>
<thead>
<tr>
<th>Extension Housing Mass</th>
<th>As Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM 2WD</td>
<td>1.8 kg (4.0 lbs)</td>
</tr>
<tr>
<td>GM 4WD</td>
<td>2.4 kg (5.3 lbs)</td>
</tr>
<tr>
<td>PCS Fixed Flange Output</td>
<td>10.2 kg (22.5 lbs)*</td>
</tr>
<tr>
<td>Ford C6 Drum Brake</td>
<td>4.3 kg (10.1 lbs)**</td>
</tr>
</tbody>
</table>

* Mass measured without drive shaft flange  
** Mass measured without C6 brake housing and drum brakes

**Accessory Mass**

<table>
<thead>
<tr>
<th>Accessory Mass</th>
<th>As Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission Harness</td>
<td>0.7 kg (1.6 lbs)*</td>
</tr>
<tr>
<td>Dipstick Kit</td>
<td>0.4 kg (0.9 lbs)</td>
</tr>
<tr>
<td>Heat Shield Kit</td>
<td>0.4 kg (0.9 lbs)</td>
</tr>
<tr>
<td>Controller (TCM)</td>
<td>0.3 kg (0.7 lbs)</td>
</tr>
<tr>
<td>TCU Bracket Kit</td>
<td>0.5 kg (1.1 lbs)</td>
</tr>
<tr>
<td>Overflow Vent Kit</td>
<td>0.2 kg (0.5 lbs)</td>
</tr>
<tr>
<td>Flexplate Kit</td>
<td>1.8 kg (4.0 lbs)</td>
</tr>
<tr>
<td>Flywheel Adapter</td>
<td>8.8 kg (19.4 lbs)**</td>
</tr>
</tbody>
</table>

* This can vary +/- 0.3kg (0.7lbs) based on vehicle application  
** This can vary +/- 4.0kg (8.8lbs) based on flywheel application
1.2.2 Driveline Lengths

For an example, the following dimensions are based on the GM 2WD extension housing. For other extension housing lengths, reference Section 2.2.3.

![Diagram of Driveline Lengths](image)

<table>
<thead>
<tr>
<th>Type</th>
<th>DIM (mm)</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>GM GEN III Bell</td>
<td></td>
<td>176.3</td>
<td>259.2</td>
<td>618.0</td>
<td>794.3</td>
<td>568.0</td>
<td>226.3</td>
</tr>
<tr>
<td>C-6 Bell</td>
<td></td>
<td>142.3</td>
<td>225.2</td>
<td>584.0</td>
<td>760.3</td>
<td>534.0</td>
<td>266.3</td>
</tr>
<tr>
<td>SAE 3 Bell</td>
<td></td>
<td>189.0</td>
<td>271.9</td>
<td>630.7</td>
<td>807.0</td>
<td>580.7</td>
<td>266.3</td>
</tr>
<tr>
<td>SAE 4 Bell</td>
<td></td>
<td>189.0</td>
<td>271.9</td>
<td>630.7</td>
<td>807.0</td>
<td>580.7</td>
<td>266.3</td>
</tr>
<tr>
<td>SAE 5 Bell</td>
<td></td>
<td>189.0</td>
<td>271.9</td>
<td>630.7</td>
<td>807.0</td>
<td>580.7</td>
<td>266.3</td>
</tr>
</tbody>
</table>

- A = Bellhousing Length
- B = Engine Face to Manual Shaft Distance (C = Engine Face to Vehicle Mount Distance)
- C = Engine Face to Vehicle Mount Distance
- D = Overall Length (Engine Face to Rear Face of Extension)
- E = Length of Case Dimension
- F = Length of Extension Housing
1.2.3 Center of Gravity

<table>
<thead>
<tr>
<th>Object Weight</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>83.9 kg (185.00 lb)</td>
<td>-253 mm (-9.96 in)</td>
<td>3 mm (.12 in)</td>
<td>17 mm (.67 in)</td>
</tr>
</tbody>
</table>

Figure 1.2.3-1 4LHD/4LHDX with 2WD Extension Housing

<table>
<thead>
<tr>
<th>Object Weight</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>85.28 kg (188.00 lb)</td>
<td>-251 mm (-9.90 in)</td>
<td>10 mm (.40 in)</td>
<td>18 mm (.70 in)</td>
</tr>
</tbody>
</table>

Figure 1.2.3-2 4LHD/4LHDX with 4WD Extension Housing
Approximate location of CG; actual location will depend on transmission model. Contact PCS if actual is desired.

### 258 mm Torque Converter

<table>
<thead>
<tr>
<th></th>
<th>2WD</th>
<th>4WD</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>-253 mm</td>
<td>-251 mm</td>
</tr>
<tr>
<td>Y</td>
<td>3 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>Z</td>
<td>17 mm</td>
<td>18 mm</td>
</tr>
</tbody>
</table>

**1.2.4 Inertia Properties**

Approximate location of CG; actual location will depend on transmission model. Contact PCS if actual is desired.

### Rotational Inertia

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>lxx</td>
<td>0.94 kg-m²</td>
</tr>
<tr>
<td>lyy</td>
<td>2.93 kg-m²</td>
</tr>
<tr>
<td>lzz</td>
<td>2.99 kg-m²</td>
</tr>
</tbody>
</table>

Approximate values, dependent on transmission model.
Reference: *SAE Engine Coordinate System* or figures found in Section 1.2.3-1

### Rotational Inertia

<table>
<thead>
<tr>
<th>Gear</th>
<th>Rotational Inertia</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>0.0547 kg-m²</td>
</tr>
<tr>
<td>2nd</td>
<td>0.039616 kg-m²</td>
</tr>
<tr>
<td>3rd</td>
<td>0.02553 kg-m²</td>
</tr>
<tr>
<td>4th</td>
<td>0.06692 kg-m²</td>
</tr>
</tbody>
</table>

Referred to the input shaft of the transmission without torque converter, transfer case, or parking brake.

### 1.2.5 Gross Vehicle Weight

<table>
<thead>
<tr>
<th>GVW</th>
</tr>
</thead>
<tbody>
<tr>
<td>3,900 kg (8,600 lb) maximum*</td>
</tr>
</tbody>
</table>

*This figure is limited by the strength of the parking pawl. If other parking mechanisms are utilized, and the transmission is not shifted into park, higher GVWs are possible. Contact PCS for vehicle calculations in this case.
1.3 Maximum Performance Limitations

1.3.1 Torque Limitations

**Engine Input Torque**
4LHD with 258 MM Converter - 340 Nm (250 lb-ft) Maximum
4LHDX with 300 MM Converter - 542 Nm (400 lb-ft) Maximum

**Gearbox Input Torque**
4LHD with 258 MM Converter - 660 Nm (487 lb-ft) Maximum
4LHDX with 300 MM Converter - 1057 Nm (780 lb-ft) Maximum

**Torque Converter Capacity - Speed**
258 mm: 7,000 RPM @ 690 kPa (100 psi), 6500 RPM @ 1020 kPa (150 psi)
300 mm: 7,000 RPM @ 900 kPa (130 psi)

**Torque Converter Capacity - Input Torque**
258 mm: 340 Nm (250 lb-ft)
300 mm: 542 Nm (400 lb-ft)

**Torque Converter Capacity - Stall Power**
258 mm: 79.1 kW (106 hp)
300 mm: 124.6 kW (167 hp)

*NOTE:* Values @ 690 kPa (100 psi), increase limit by 0.75 kW/14 kPa (1 hp/psi), not to exceed 1020 kPa (150 psi).

To calculate stall power: \[
\text{To calculate stall power: } \frac{(\text{engine stall speed}) \times (\text{engine torque at stall})}{9546}
\]

**Torque Converter Capacity - Turbine Torque**
258 mm: 632 Nm (392 lb-ft)
300 mm: 943 Nm (696 lb-ft)

*NOTE:* Must verify adequate spline engagement. Reference Section 2.1.1.

**Calculated:** (engine torque) x (converter ratio)

**Torque Converter Capacity - Stator Torque**
258 mm: 340 Nm (250 lb-ft)
300 mm: 542 Nm (400 lb-ft)

**Calculated:** (engine torque) x \[ (\text{converter ratio}) - 1 \]

**Torque Converter Capacity - Max TCC Apply Pressure**
258 mm: 930 kPa (135 psi)
300 mm: 862 kPa (125 psi)

Minimum pressure, all operating conditions 415 kPa (60 psi).
1.3.2 RPM Limitations

**Maximum Speed in Park and Neutral**
Maximum engine speed cannot exceed 4,000 RPM when the transmission is in park or neutral.

**Maximum Shift Speed**
The maximum shift speed allowed is application dependent. Note: These maximum shift speeds are dependent on final drive ratio, torque converter stall torque ratio, and the engine torque curve profile. Consult with Powertrain Control Solutions for application specific maximum shift speeds.

**Minimum Engine Idle Speed**
- 600 RPM when ATF is above 115°C (240°F)
- 550 RPM when ATF is 0°C to 115°C (32°F to 240°F)
- 700 RPM when ATF is below 0°C (32°F)

**Minimum TCC Apply**
Minimum TCC apply speeds are dictated by powertrain and chassis response in the following ranges at normal operating temperatures.

<table>
<thead>
<tr>
<th>Engine</th>
<th>Engine RPM (Light Throttle)</th>
<th>Engine RPM (Heavy Throttle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>1000</td>
<td>1800</td>
</tr>
</tbody>
</table>

**Maximum Output Speed**
Maximum output speed is 7,200 RPM with the GM 2WD Slip Yoke and 4WD transfer cases. The PCS Fixed Flange Output and C6 extension housings are limited to 6,500 RPM.

**Maximum Vehicle Speed**
Maximum vehicle speed is dependent on final drive ratio, torque converter ratio and engine torque curve profile. Powertrain Control Solutions must be consulted for application specific maximum speeds.

1.3.3 Acceleration Limitations

The 4LHD/4LHDX automatic transmission has been tested for longitudinal and lateral acceleration capability in vehicles under the following maneuvers at the entire temperature range:

- **Longitudinal**
  - W.O.T. acceleration on level road. Panic stop from 30 mph followed by W.O.T. acceleration.
  - Gradual stop from 30 mph followed by W.O.T. acceleration.

- **Lateral**
  - Right turn at 20 mph with W.O.T. acceleration. Left turn at 20 mph with W.O.T. acceleration. Right turn panic stop from 20 mph. Left turn panic stop from 20 mph. Continuous right turn at 60 ft turning radius. Continuous left turn at 60 ft turning radius.

*W.O.T. = Wide Open Throttle*
1.3.4 Temperature Limitations

Functional Range: -40°C to 55°C (-40°F to 131°F)

Defined as the ambient range where the vehicle will function without causing transmission operational concerns or thermal distress in adequately cooled installations.

Underbody Temperature

Life of the transmission gaskets, seals and connectors is affected by elevated temperatures. Airflow around the transmission and the proximity to heat sources such as catalytic converter or exhaust system influence the temperature build up at the transmission surface. It should be noted that shift cable systems are also sensitive to heat, and should be routed to avoid extreme temperatures.

Temperatures shall be monitored during testing to ensure appropriate temperature levels. A thermal packaging study is recommended to verify all underbody temperatures.

Component Skin Temperature Limits

The following maximum temperatures are based on released component materials. These temperatures must not be exceeded during test.

<table>
<thead>
<tr>
<th>Exposed Area</th>
<th>Maximum Continuous</th>
<th>Maximum Excursion</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Seals</td>
<td>138°C (280°F)</td>
<td>150°C (302°F)</td>
</tr>
<tr>
<td>Oil Pan Gasket</td>
<td>138°C (280°F)</td>
<td>150°C (302°F)</td>
</tr>
<tr>
<td>Trans. Based on Non Metallic Connectors</td>
<td>138°C (280°F)</td>
<td>138°C (280°F)</td>
</tr>
<tr>
<td>Trans. Electrical Terminals</td>
<td>135°C (275°F)</td>
<td>135°C (275°F)</td>
</tr>
<tr>
<td>Trans. Wiring Harness</td>
<td>125°C (257°F)</td>
<td>125°C (257°F)</td>
</tr>
<tr>
<td>Controller (TCM)</td>
<td>105°C (221°F)</td>
<td>125°C (257°F)</td>
</tr>
</tbody>
</table>

* Reference Section 2.3 for cooler requirements and transmission sump operating temperatures.

Heat Shield

Shown in Figure 1.3.4-1 is an available heat shield that protects the gasket, connector, and accumulator from common exhaust positions. Consult with PCS if this is necessary or adequate for your application.

Figure 1.3.4-1: Heat Shield Exploded View
1.3.5 Grade Limitations

**Maximum Grade for Hydraulic Operation**
This transmission is validated to operate on longitudinal and lateral slopes of up to 30% (16.7 degree grade) without detrimental effect on the operation of the hydraulic system at normal working temperature. Consult with Powertrain Control Solutions if the proposed application exceeds these values.

**Maximum Grade for Park System**
There is a maximum grade capability of 30% (16.7 degree grade) for park pawl engagement with both the park mechanism engaged and the parking brake on.
1.4 Valve body Features and Specifications
The following are valve body options. When ordering from PCS, you must specify your desired valve body configuration.

1.4.1 Abuse Protection
Often times the operator causes the most damage to the transmission, reducing the service life and causing costly repairs and downtime. The PCS 4LHD/4LHD-X abuse protection valve body protects the transmission by locking out reverse engagement until the vehicle is stopped and the engine is at idle. It also prevents “neutral drops” by only engaging the forward gears when the engine is at idle.

1.4.2 Neutral Idle
As an option, the PCS valve body can disengage the forward gears when the vehicle is stopped and the brake pedal is pressed. By reducing the number of rotating components during idle, fuel consumption can be reduced especially for vehicles that spend a lot of time idling in gear. With the forward gears disengaged, the reduced brake force required to hold the vehicle, especially in high gear reduction drivelines, can significantly improve the drivability of the vehicle from the operator’s perspective.

1.4.3 Electronic Range (Optional)
This allows you to eliminate the shift cable and shift the transmission electronically with a push button or a movement of a lever. Driver inputs can be validated based on vehicle modes and conditions so the vehicle is operated within standard operating protocols. This also eliminates transmission failures due to the shift cable not being adjusted properly. Reference Section 2.5.8 for external setup.

1.4.4 Inching Mode (Optional)
This allows the operator to move the vehicle forward or backward in small increments from an operator’s panel remotely mounted on the vehicle. This greatly reduces time when connecting to trailers or other equipment and makes the operation more efficient for one person.

Figure 1.4-1: PCS Valve Body Explosion View
1.5 Electrical Specifications

1.5.1 Solenoids and Sensors

<table>
<thead>
<tr>
<th>Range</th>
<th>Gear</th>
<th>Shift Solenoid</th>
<th>Abuse Solenoid</th>
<th>2-4 Band</th>
<th>Reverse Input Clutch</th>
<th>Overrun Clutch</th>
<th>Forward Clutch</th>
<th>Forward Sprag CL. Assembly</th>
<th>3-4 Clutch</th>
<th>LO/ Roller Clutch</th>
<th>LO/REV Clutch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park</td>
<td>ON^1</td>
<td>ON^1</td>
<td>OFF</td>
<td>OFF</td>
<td>Applied</td>
<td></td>
<td></td>
<td></td>
<td>Applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse</td>
<td>ON^1</td>
<td>ON^1</td>
<td>ON</td>
<td>ON^3</td>
<td>Applied</td>
<td></td>
<td></td>
<td></td>
<td>Applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutral</td>
<td>ON^1</td>
<td>ON^1</td>
<td>ON</td>
<td>ON^3</td>
<td></td>
<td></td>
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<td>OD</td>
<td>1st</td>
<td>ON</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Holding</td>
<td>Holding</td>
<td>Holding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd</td>
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<td>ON</td>
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<td>Applied</td>
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<td></td>
<td>Holding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3rd</td>
<td>OFF</td>
<td>OFF</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Holding</td>
<td>Applied</td>
<td>Applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4th</td>
<td>ON</td>
<td>OFF</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Holding</td>
<td>Applied</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>1st</td>
<td>ON</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Holding</td>
<td>Holding</td>
<td>Holding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>OFF</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Holding</td>
<td></td>
<td>Holding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3rd</td>
<td>OFF</td>
<td>OFF</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Holding</td>
<td>Applied</td>
<td>Applied</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1st</td>
<td>2</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Applied</td>
<td>Holding</td>
<td>Holding</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>OFF</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Applied</td>
<td>Holding</td>
<td>Holding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1st</td>
<td>ON</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Applied</td>
<td>Holding</td>
<td>Holding</td>
<td></td>
<td>Applied</td>
</tr>
<tr>
<td></td>
<td>2nd</td>
<td>OFF</td>
<td>ON</td>
<td>ON^3</td>
<td>OFF</td>
<td>Applied</td>
<td>Applied</td>
<td>Holding</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Shift solenoid state is a function of vehicle speed and may change if vehicle speed increases.
2. Manual Second - First gear is electronically prevented under normal operating conditions.
3. Solenoid state will be opposite shown during abuse protection.

Shift Solenoids
The two identical shift solenoids are two port, on/off solenoids (normally on) that are used to control the shift change events.

- The shift solenoid coil resistance should be 20-40 ohms at 20.0 +/- 5.0°C.
- The shift solenoid current flow should not exceed 0.75 Amps.
- The shift solenoid energizes at 7.5 volts or more.
- The shift solenoid de-energizes at 1.0 volts or less.

TCC Enable Solenoid
The TCC Enable Solenoid is a two port, on/off solenoid (normally on) that is used to apply and release pressure to the Torque Converter Clutch.

- The TCC Enable Solenoid coil resistance should be 20-40 ohms at 20.0 +/- 5.0°C.
- The TCC Enable Solenoid current should not exceed 1.5 Amps.

TCC Control Solenoid
The TCC Control Solenoid is a three port (normally closed) device used to control the apply and release pressure of the Torque Converter Clutch. Adjusting this in the TCU Calibration changes the shift firmness of the Torque Converter Clutch.

- The TCC Control Solenoid operates at a fixed frequency (negative duty cycle) of 32 Hz.
- The TCC Control Solenoid coil resistance should be 10.0 - 11.5 Ohms when measured at 20.0 +/- 5.0°C.
Abuse Protection Solenoid (Non-Electronic Range)
The identical Forward/Reverse Abuse Protection Solenoids (Non-ER) three port linear pressure control solenoids (normally open).

- The Non-ER Forward/Reverse solenoids coil resistance is 5.0-5.6 ohms at 25.0 +/- 1.0°C.
- The Non-ER Forward/Reverse solenoids operate at a fixed frequency of 300Hz.

![Abuse Protection Solenoid Valve Current Flow](image1)

Abuse Protection Solenoid (Electronic Range)
The two identical ER Forward/Reverse Abuse Protection solenoids are three port PWM (Pulse Width Modulation) solenoids (normally closed).

- The ER Forward/Reverse solenoids operate at a fixed frequency (negative duty cycle) of 32 Hz.
- The ER Forward/Reverse solenoids coil resistance should be 10.4-10.8 Ohms when measured at 20.0 +/- 5.0°C
- The ER Forward/Reverse solenoids coil resistance should be approximately 16 Ohms when measured at 150 +/- 5.0°C.

Pressure Control Solenoid
The Pressure Control Solenoid is a three port electronic pressure regulator used to control line pressure. When the solenoid is off, line pressure is unrestricted from the line pressure pump. When the solenoid is on, line pressure is restricted to the values shown in the chart. A line pressure tap is available. The torque rating for this fitting is 8 lb*ft / 11 N*m. Reference Figure 2.4.6.1-3.

- The Pressure Control Solenoid operates at a fixed frequency of 292.5 Hz.
- The Pressure Control Solenoid coil resistance is 3.5-4.6 Ohms at 20.0 +/- 5.0°C.

![Pressure Control Solenoid Valve Current Flow](image2)
Transmission Fluid Temperature Sensor
- The Transmission Fluid Temperature Sensor is a negative temperature coefficient temperature sensitive resistor that drops an input 5V signal to the values shown below.
- The Transmission Fluid Temperature Sensor voltage range is 5.0-0.0V DC.

Internal Mode Switch (IMS)
The internal mode switch (IMS) is a sliding contact switch attached to the manual shift shaft inside the transmission. The five inputs to the TCM from the transmission manual shift shaft switch assembly indicate the transmission gear selector lever position. Refer to this pinout in Figure 1.5.2-2.

Transmission Input Speed Sensor (TISS)
Mounted within the pump, the Transmission Input Speed Sensor (TISS) contains an AC-coupled Hall-effect chip that switches in response to changing differential magnetic fields created by rotating ferrous targets and requires a constant supply voltage between 4.0 and 26.5 volts to operate. The signal is induced by a 15 tooth spline on the turbine shaft (a.k.a. input shaft).

Engine RPM Sensor (Optional)
The Engine RPM Sensor is a two wire “zero-crossing” variable reluctance signal generator. The sensor (our part number is SNS1025) picks up on the outer ring of 31 tabs on the 258mm and 300mm torque converters. To install, insert the copper sleeve into the bellhousing bore and then bottom the sensor against one of the tabs. Do not install the sensor before the transmission and torque converter are installed on the engine. Do not pull the sensor out for air gap, it will self adjust when the engine is started for the first time. Ensure the sensor is not bottomed-out on the plastic connector, for 258mm converters the bellhousing boss may have to be machined or ground down.
Output Speed Sensor (VSS)
The Output Speed Sensor (also known as Vehicle Speed Sensor) is a variable reluctance magnetic pickup which receives a sin wave from a speed gear on the output shaft and generates a square wave output. The sensor requires a two wire connector from the Extension Housing to the TCM.

- The output speed sensor coil resistance is 1850-2250 ohms at 25.0 +/- 1.0°C.
- The maximum output speed sensor inductance is 2000 mH at 1000 Hz with 50 mA applied.
- The speed sensor will produce a minimum voltage (loaded) of 0.25 V peak positive and 0.25 negative at minimum speed of 100 RPM.
- The speed sensor will produce a maximum voltage (loaded) of 100 V peak positive and 100 negative at a maximum speed of 7200 RPM.
- All available GM and PCS extension housings use a symmetrical 40 tooth speed gear on the output shaft, resulting in 40 pulses per revolution to the TCM.

Pass-Thru Connector
The transmission to vehicle electrical interface is a 20 pin connector used to mate the internal and external harnesses of the transmission. Use the alignment key to ensure proper installation. Reference Figure 1.5.1-5.

- The pass-thru connector envinromental temperature shall not exceed -40 to 135°C at any time. Proper shielding is required. Reference Section 1.3.4 for temperature details.

**NOTE:** The Pass-Thru Connector’s arrow should face out. Reference Figure 1.5.1-5.
1.5.2 Internal Wiring
Unless otherwise specified, electrical components operating range shall be 8.0 to 18.0 VDC. It is recommended that the transmission controls solenoids are not engaged without the engine running. Transmission electrical components should be fused separately from other vehicle components.

Electrical Connections
Two connections must be made to the transmission to interface with the TCM. The connections are for the transmission control connector and the output speed sensor. Figures 1.5.2-1 and 1.5.2-2 shows the internal system schematic.

<table>
<thead>
<tr>
<th>CAV</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Shift SOL 'A'</td>
</tr>
<tr>
<td>B</td>
<td>Shift SOL 'B'</td>
</tr>
<tr>
<td>C</td>
<td>Line Pressure +</td>
</tr>
<tr>
<td>D</td>
<td>Line Pressure -</td>
</tr>
<tr>
<td>E</td>
<td>Switched +12V</td>
</tr>
<tr>
<td>F</td>
<td>IMS A</td>
</tr>
<tr>
<td>G</td>
<td>IMS C</td>
</tr>
<tr>
<td>H</td>
<td>IMS B</td>
</tr>
<tr>
<td>J</td>
<td>IMS P</td>
</tr>
<tr>
<td>K</td>
<td>Turbine Speed +</td>
</tr>
<tr>
<td>L</td>
<td>Trans Temp Sensor</td>
</tr>
<tr>
<td>M</td>
<td>Trans Temp Sensor Ground</td>
</tr>
<tr>
<td>N</td>
<td>IMS Ground</td>
</tr>
<tr>
<td>R</td>
<td>Forward Clutch SOL</td>
</tr>
<tr>
<td>S</td>
<td>Reverse Clutch SOL</td>
</tr>
<tr>
<td>T</td>
<td>TCC SOL</td>
</tr>
<tr>
<td>U</td>
<td>TCC PWM</td>
</tr>
<tr>
<td>V</td>
<td>Turbine Speed</td>
</tr>
<tr>
<td>W</td>
<td>Neutral Safety</td>
</tr>
</tbody>
</table>

Figure 1.5.2-1: Transmission Connector and Terminal Locations
Figure 1.5.2-2: Transmission Electrical Schematic
SECTION 2
TRANSMISSION TO VEHICLE INTERFACES
Section 2 Transmission to Vehicle Interfaces

2.1 Transmission Input

2.1.1 Torque Converters

Power input and torque multiplication are accomplished by the transmission torque converter. Converters are available with a variety of internal components that offer torque ratios up to 1.95 to 2.1 (Refer to Section 2.2.4). A spring damper smooths out torsional variation when the converter clutch is locked. The correct choice of components will result in a package that provides an optimum level of fuel economy, performance, and driveability.

We offer two torque converters, 258mm and 300mm. The 258mm torque converter is used in SAE4/SAE5 applications while the 300mm torque converter is used in SAE3 and GM 3.0L/4.3L applications.

<table>
<thead>
<tr>
<th>Common Name</th>
<th>K Factor</th>
<th>ST/Ratio</th>
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</thead>
<tbody>
<tr>
<td>258</td>
<td>146</td>
<td>1.95</td>
</tr>
<tr>
<td>300</td>
<td>114</td>
<td>2.1</td>
</tr>
</tbody>
</table>

258mm is used with SAE4/SAE5 applications

300mm is used with SAE3, GM 3.0L & 4.3L applications

Figure 2.1-1: Torque Converters
Converter piloting is provided by a counter bore in the end of the engine crankshaft or flywheel adapter, shown in Figure 2.1.1-2. Axial movement of the converter is contained within this “floating pilot” to ensure that thrust loads are not transferred to the crankshaft thrust bearing. Grease should be applied to the pilot or bore to act as a lubricant and corrosion inhibitor. Care must be taken to ensure that the converter pilot is seated properly in the engine crankshaft or flywheel adapter bore.

During assembly to the engine, the transmission must be supported so that it is horizontal, or with the bell housing slightly elevated. This will prevent the torque converter from slipping out of engagement with the oil pump shaft when the shipping bracket is removed. The bellhousing face must be squarely seated against the engine face, with locating features fully engaged, before its attaching bolts are tightened.

After the bellhousing attachment is made, check the converter pullout (Reference 2.1.3) and then move its lug surface into contact with the flexplate (and to bring the pilot diameter into the crankshaft bore). All bolts must be hand started to prevent cross threading. Moving the converter into place before tightening its attaching bolts ensures that both the transmission to engine and the converter to flexplate have been properly aligned and that the converter is free to move in the crankshaft bore without loading the crankshaft bearings. The transmission to engine attachment, and the converter to flexplate must NOT be drawn into position with only one bolt tightened with a power gun.

The flexplate must be indexed for alignment to the converter attachment lugs. Access for indexing the flexplate ring gear is available on some of the transmission bell housings adjacent to the starter pocket. In other cases, there is no access provision and the flexplate is indexed via the engine crankshaft pulley.

A paint spot is applied to the front edge of the torque converter to indicate the lowest mass location as measured during the converter balancing operation at the manufacturing plant. The spot may be used to line up with any identified heavy spot on the flexplate during assembly to the engine.

The following figures illustrates the converter bolt patterns and thread sizes. The choice of bolt must consider factors such as thread engagement and clearances at the bolt head and thread end. The threaded end must not bottom out against the converter cover. A thread adhesive should be used to ensure durability.
Dimension A: Rear face of engine to torque converter mounting lug.
Dimension B: Rear face of engine to flexplate.

The flexplate shown above is PCS part number TRN7007, reference Section 2.1.2 in this document or the PCS OEM Parts Catalog for more information.

The dimensions provided indicate the installed depth of the torque converter. The tolerance is +/- 0.062".

Every installation must have the converter pull-out measured and verified before the vehicle is operated. Improper torque converter pull-out will result in transmission malfunction and/or damage.

To measure the Torque Converter Pull-Out:

1. Align and install the bellhousing/transmission assembly to the engine. Before tightening the bellhousing fasteners completely, check to be sure converter rotates freely.

2. Once the bellhousing fasteners are torqued to specification, push the torque converter back into the transmission as far as possible.

3. Using feeler gauges or calipers measure the gap between the flexplate mounting surface and the torque converter mounting pads. If the gap distance is between .060" (1.5mm) and .187" (4.7mm) it is OK to bolt up the torque converter.

Reference Section 2.1.3 for a more detailed description of this verification process.
Figure 2.1.1-4 300 mm Torque Converter Attachment Features

Figure 2.1.1-5: 300 mm Torque Converter Attachment Features

Figure 2.1.1-5 300 mm Torque Converter Attachment Features

Figure 2.1.1-5: 258 mm Torque Converter Attachment Features

Figure 4.2.4-3 258 mm Torque Converter Attachment Features
NOTE: A standard “bent” flexplate must be implemented. Flat plate adapters will interfere with the converter body during assembly.
2.1.2 Flexplate

PCS uses a universal flexplate for our GM and SAE applications, while the C6 converter is designed for the stock C6 flexplate.

Figure 2.1.2-1 GM Flexplate

Figure 2.1.2-2 C6 Flexplate
2.1.3 Flywheel Interface

Having the torque converter correctly spaced with the transmission pump is critical for optimal functionality and to prevent permanent damage during installation/operation. To adapt to a wide variety of flywheels and bellhousing combinations, PCS uses Flywheel Kits (a combination of Engine Spacers and Flywheel Adapters as shown in Figure 2.1.1-3) to mate the 4LHD/4LHDX flexplate/torque converter with the engine’s flywheel. These parts must not be swapped between different Flywheel Kits. After installation of the Flywheel Kit/flexplate to the engine and then installation of the transmission/bellhousing to the engine, it is necessary to verify the "Torque Converter Pull Out" which can be measured by the distance between the torque converter pad and the flexplate, referenced in Figure 2.1.1-3. This measurement only works if the torque converter has been gently pushed into the transmission pump as far as possible, which should already be the case for proper installation referenced in section 3.1.3. If the torque converter is removed from the transmission/pump for any reason, reinsertion of the torque convert must be done gently and precisely. There are two tabs in the transmission pump assembly, which must be correctly aligned and integrated with the corresponding slots on the torque converter pilot. If this is not done properly, permanent damage to the transmission will result when the engine/transmission are assembled. Reference the PCS OEM Parts Catalog for a current list of engine and flywheel applications, and PCS engineering for new ones.

![Figure 2.1.3-1 Example Flywheel Kit](image-url)

**NOTE:** The flexplate kit is not included in the flywheel kit.
2.1.4 Bellhousing to Flywheel Housing Interface

The configuration of the engine mounting face varies according to engine usage. The 4LHD/4LHDX currently supports five types of mounting faces. Contact PCS for an updated list. Figures 2.1.4-1 to 2.1.4-5 show these bellhousing configurations. Dimensions are for reference only.

Reference section 3.1 for a discussion of assembly considerations that are critical to the alignment of the transmission to the engine. These bellhousings have been factory installed to 51 lb*ft / 70 N*m, removing them without the instruction/permission of PCS will damage the transmission and void your warranty.
NOTE: PCS has GM LS to SAE3 adapter plates available. Consult PCS Engineering for bellhousing options.
NOTE: Revisions are identical in dimension. Rev 5 incorporates dipstick mounting.
Figure 2.1.4-4 PCS SAE5 Adapter Plate Front View

NOTE: PCS has GM LS to SAE5 adapter plates available. Consult PCS Engineering for bellhousing options
Figure 2.1.4-5: PCS C6 Bellhousing Front View
2.2 Transmission Output

2.2.1 Lubrication and Sealing
Referenced in Figure 2.2.1-1 is the lubrication system for all 4LHD/4LHDX extension housings. This system ensures the spline engagement, rear bearings, and seals retain optimal functionality for the life of the transmission. It is critical that the extension housing is properly sealed from the environment and transfer case oil. Fluid enters the cavity from both the oil jet and output shaft bearing, and drains to the oil pan through the return vent. PCS uses a universal extension housing to transmission seal. The seal between the transmission case and the extension housing is referenced in Figure 2.2.3-4. During transmission operation the return vent must not be plugged, as this will cause the extension housing to fill with fluid which can cause permanent damage. Contact PCS in the case of applications requiring dry extension housings.

![Extension Housing Fluid Control](image)

2.2.2 Output Shaft Requirements

Propshaft Alignment and Torsional Vibrations
The presence of universal joints in the propshaft will induce torsional vibrations in the driveline, due to the angles at which the driveshafts operate. This can have a detrimental effect on component durability.

The chassis shall be designed to minimize the torsional vibration resulting from excessive driveshaft angle. Refer to *SAE Design Guideline AE-7: Universal Joint and Driveshaft Design*. Excitations in the driveline, during any continuously operating condition, shall not exceed:

- **Torsional excitation:** 400 rad/s²
- **Inertia excitation:** 1000 rad/s²

If a design approaches or exceeds these criteria, or if a design is considered at risk, a test shall be conducted to ensure that the transmission is not compromised. This information can be found in the *SAE Design Guide Line AE-7: Universal Driveshaft Design*. 
Noise and Vibration
Special attention should be given to the following areas when developing a vehicle mounting system. Attachments to these areas where the noise is generated will result in a direct noise path and could ultimately result in noise quality concerns. In addition, mounts should not have the same excitation frequency at or near the natural vibrations of the following components:

- Gears
- Bearings
- Converter
- Oil pump

2.2.3 Extension Housings

Typical vehicle mounting applications are shown in Figures 2.2.3-1 to 2.2.3-10. All four standard extension housings available through PCS have integrated vehicle mounts. Any proposed boss locations and threaded fastener designs must have PCS Engineering approval for load analysis. Mount loads should be supplied by the customer. For an updated list of vehicle mount options reference the PCS OEM Parts Catalog. The factory torque rating for the six transmission to extension housing bolts is 37 ft*lbs / 45 N*m. In addition, the speed sensor bolt in 2WD applications has a torque rating of 8 lb*ft / 11 N*m.

A proper installation supports the transmission weight but must also:

- Avoid loading the internal components
- Allow for frame twist
- Absorb driveline torque
- To damp driveline shock forces
- Not exceed 200 lbs on transmission mount

GM 2WD Extension Housing

Used in rear wheel drive applications, this extension housing does not have a parking brake incorporated. When installed properly the journal of the slip yoke provides a seal for the rear of the transmission. This is critical due to the lubrication jet and return vent on the rear face of the 4LDH/4LHDX. The slip yoke features referenced in the table below are required to ensure proper functionality and durability of the driveline system with respect to the transmission interface subcomponents i.e., bushing and seal. There are many options available through Spicer and other manufacturers, as each vehicle has different driveline lengths and power ratings. A common example is the Spicer 2-3-12411X from their Slip Yoke Assemblies Catalog. Reference Figure 2.2.3-1 for transmission output interface.

<table>
<thead>
<tr>
<th>Slip Yoke Details</th>
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</thead>
<tbody>
<tr>
<td>Spline Type</td>
</tr>
<tr>
<td>Journal Diameter</td>
</tr>
<tr>
<td>Journal Surface Finish</td>
</tr>
</tbody>
</table>

NOTE: For the finishing procedure, Residual burrs produced by the turning, grinding and polishing operations to the slip yoke journal must be of a favorable i.e., non-aggressive direction of lay to the journal rotational direction when the vehicle is in forward drive.
### 2WD Spline Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Teeth</td>
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</tr>
<tr>
<td>Form Diameter</td>
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</tr>
<tr>
<td>Module</td>
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</tr>
<tr>
<td>Min Effective Tooth Thickness</td>
<td>1.732 mm</td>
</tr>
<tr>
<td>Diameter Pitch</td>
<td>24000 mm</td>
</tr>
<tr>
<td>Max Effective Tooth Thickness</td>
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</tr>
<tr>
<td>Pressure Angle</td>
<td>30.0’</td>
</tr>
<tr>
<td>Min Actual Tooth Thickness</td>
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</tr>
<tr>
<td>Pitch Diameter (Reference)</td>
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<tr>
<td>Max Actual Tooth Thickness</td>
<td>1.795 mm</td>
</tr>
<tr>
<td>Base Diameter (Reference)</td>
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<tr>
<td>Measure Over Pins</td>
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</tr>
<tr>
<td>Min: 31.173 mm</td>
<td></td>
</tr>
<tr>
<td>Max: 31.051 mm</td>
<td></td>
</tr>
<tr>
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<tr>
<td>Pin Diameter</td>
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<tr>
<td>Minor Diameter</td>
<td>27.00-27.20 mm</td>
</tr>
<tr>
<td>Spline Length</td>
<td>115.5 mm</td>
</tr>
</tbody>
</table>

---

**Figure 2.2.3-1: GM 2WD Extension Housing**
GM 4WD Extension Housing
Shown in Figures 2.2.3-2 and 2.2.3-3 is the PCS approved two speed electronic shifting transfer case. 2Hi, 4Hi, Neutral, and 4Lo are controlled via an external PCS Transfer Case Module. The rear output shaft takes a GM 32 tooth female yoke, while the front output shaft takes a GM 32 tooth make yoke. Reference the PCS OEM Parts Catalog for part numbers.

Figure 2.2.3-2: GM 4WD Extension Housing
Figure 2.2.3-3: GM 4WD Transfer Case
PCS Fixed Flange Output
The PCS Fixed Flange Output is an extension housing developed primarily for industrial applications. The result is a package shorter than both the GM 2WD Slip Yoke and the Ford C6 Drum Brake. The unit retains the same transmission mounting pattern as the GM 2WD Slip Yoke, and has adapters available for the C6 pattern. Our Fixed Flange Output may be installed as a non-brake unit, with disc and caliper options currently available for “mechanical”, “mechanical/hydraulic”, and “electric” applies. See the PCS Fixed Flange Output Application Guide for more information.

The caliper can be mounted in several different clocking orientations and is available with a left hand cable exit or a right hand cable exit.

Figure 2.2.3-4: PCS Fixed Flange Output Explosion View

Figure 2.2.3-5: PCS Fixed Flange Output Dimensions
The PCS Fixed Flange Output is designed and manufactured to take a standard driveshaft flange yoke, dimensions shown in Figure 2.2.3-8. A common example, shown in figure 2.2.3-7 is the Spicer 3-2-159. For units incorporating a disc brake, this is a parking brake only and not an emergency brake. Max vehicle holding weight is dependant on final gear ratio and tire size. Contact PCS for application engineering.
PCS C6 Extension Housing
This replacement package holds all the same specifications as the old Ford C6 w/ drum parking brake option. Shown in Figures 2.2.3-9 to 2.2.3-10. This utilizes the original brake housing, drum, driveshaft yoke, and other hardware to correctly seal and operate. Same as the original, our output shaft is an SAE10B spline. Reference SAE Standard J499 for full spline detail.

![PCS C6 Extension Housing Diagram](image-url)
Figure 2.2.3-10: PCS C6 Extension Housing
2.3 Transmission Cooling
Transmission fluid is heated primarily by the pumping action that occurs within the torque converter. Heat load varies, depending on speed, grade, duty cycle, ambient temperature, etc. A method of heat dissipation must be provided in order to maintain proper transmission temperature.

Cooling is accomplished by circulating the fluid through a cooler that is external to the transmission. Incorporation of the cooler within the radiator is recommended since this provides the added advantage of quick warm-up of the transmission in cold climates. If the cooler is located in a radiator end tank, the inlet pipe should be at the lowest point of the cooler.

If an auxiliary cooler is used, it should be located in the return line to the transmission, and the system should incorporate a bypass to allow lubrication flow under very low ambient temperature conditions. Adequate flow shall be verified by test.

**NOTE:** It is recommended for the transmission cooler to flow IN at the cooler bottom port and OUT at the cooler top port. This is recommended not only so that heavy particles and sediment fall to the bottom of the cooler instead of returning to the transmission sump, but also allows any trapped air in the system to rise and leave the heat exchanger via the upper outlet fitting.

2.3.1 Cooling System Overview

**Automatic Transmission Fluid**
Automatic transmission fluid (ATF) is a complex lubricant that consists of a base oil and an additive package. The additive package is designed to impart several desirable performance characteristics, above and beyond those that the base oil could do alone. The performance of ATF’s are driven by the needs of the product and must provide excellent fluidity values for both low and high temperature transmission performance. Fill tubes, fill caps and bottom pans should be accessible for repair without removing the transmission from the vehicle. In addition, external seals should be accessible for serviceability.

**Fluid Specification**
The ATF to be used in any PCS 4LHD/4LHDX shall be Dexron® VI or equivalent. Transmission damage caused by the use of improper fluid will not be covered under warranty.
2.3.2 Cooler Requirements
To provide proper operation and longevity, the cooling system must maintain the transmission sump temperature below 132°C (270°F) and stator temperature below 177°C (350°F) at all times. This is defined as a “never exceed” limit under all operating conditions. Average sump temperature must not exceed 110°C (230°F). The cooler must be capable of 4-5 kW of heat rejection for light duty applications, and 8-10 kW for heavy use such as industrial vehicles, off road equipment, military and ground support equipment.

2.3.3 Cooler Lines
Cooler Line Connection: Cooler lines connect the transmission to the radiator (cooler). Cooler lines should be as short, and with as few bends as possible. The largest feasible pipe bore should be used. Routing should avoid external heat sources (such as exhaust pipes, catalytic converters etc.), protect the pipe from road hazards and provide for ease of installation and removal. The cooler lines should be adequately supported along their length to prevent vibrations from generating noise or fatigue distress, and to prevent noise transmission into the vehicle structure.

Flow Requirements: The transmission cooler lines and the oil cooler must flow a minimum of 6 LPM at 345 kPa (50 psi) and 11 LPM at 690 kPa (100 psi). The flow test shall be run with 93˚C (200˚F) ATF.

Pressure Requirements: Cooler line pressure under normal operation will be between 200 kPa (30 psi) and 1,000 kPa (150 psi). The transmission may produce pressure of up to 2,086 kPa (300 psi) at the cooler line entrance. This pressure may be observed on start up or if there is blockage in the transmission cooling system (cooler lines, oil cooler, return fitting at transmission). The lines and fittings must all be rated for a minimum of 300 psi.

Temperature Requirements: The cooler lines, cooler, and fittings shall be capable of withstanding fluid temperatures of 177°C (350°F).
The cooler line interface exiting the case of the 4LHD/4LHDX is a #6 SAE Dash Size ORB (O-Ring Boss) for the hydraulic fitting on new units. Some reman units may have 1/4-18” NPS threads. Reference figure 2.3.3-2 for dimensions and SAE J514 for more detailed specifications.

NOTE: As of 02/20/2018, all PCS transmissions will be shipped with male JIC-6 flared cooler interface fittings.

Cooler Line Installation
The following two sections provide the general guidelines for cooler line installation.

I. Flare Type Fittings
1. Remove shipping plugs from cooler lines and fittings. Plugs should be removed as late as possible to avoid damage or contamination of the cooler lines and fittings.

2. Loose assemble the lines to the transmission and hand start nuts. Torque as specified, 28 lb*ft / 38 N*m. Over torquing could distress the established thread lock of the connector in the transmission case.

3. Assure hoses/pipes are not kinked, crossed, twisted or grounded to any unspecified vehicle components. Due care must be taken to prevent intentional movement of the cooler lines in the assembly process. Unnecessary vibration, leakage or transmission malfunction may occur. (JIC-6 Fittings are available upon request.)

II. Quick Connect Type Fittings
1. Remove shipping plugs from cooler lines and fittings. Plugs should be removed as late as possible to avoid damage or contamination of the cooler lines and fittings.

2. While gripping pipe body below plastic cap, insert pipe into connector until a click is felt - DO NOT use cap to insert pipe.

3. Ensure yellow identification band is entirely within quick connector assembly. If not, insert pipe until yellow is completely hidden.
4. Pull sharply on pipe to assure a correct connection.

5. Snap plastic cap onto quick connector assembly. Do not depress the retainer clip. There should be no gap between the cap and the quick connector hex.

6. Ensure no pipe damage occurred during the process.

7. Assure hoses/pipes are not kinked, crossed, twisted or grounded to any unspecified vehicle components. Due care must be taken to prevent intentional movement of the cooler lines in the assembly process. Unnecessary vibration, leakage or transmission malfunction may occur.

### 2.3.4 Dipstick

Level setting must be done by means of a dipstick type indicator. The indication hardware is attached at the time of assembly to the engine or vehicle. The configuration of the upper end of the fill tube is specific to each vehicle, according to vehicle packing requirements.

Based on the OEM customer preference, if an indicator stopper type is used, it is recommended that the words “Trans Fluid” are plainly labeled for customer identification.

The top of the fill tube must be arranged so that any fluid expelled from the fill under extreme adverse conditions can not fall on surfaces hot enough (e.g. exhaust system, turbo charger, etc.) to cause ignition of the fluid.

Powertrain Control Solutions Engineering will specify nominal indicator marking positions. These will have been derived from the transmission’s functional fluid level limits, which are different from the indicator markings. The procedure to develop the indicator markings from the functional level limits must take into account the tolerance added by the indicator stick. The 4LHD/4LHDX system depends on the tip of the indicator contacting the indicator stop.

The system depends on the indicator being longer than the nominal path thru the center of the fill tube. The extra length is taken up as wind-up within the fill tube. The amount of extra length is determined by tube and indicator tolerances and length, and must be such that it covers dimensional stack, but does not load the indicator beyond the room available within the fill tube path.

It is the customer’s responsibility to package and source the proper indicator tube and indicator. PCS has common dipsticks available. Reference the **PCS OEM Parts Catalog** for more information.

![Figure 2.3.4-1 Fluid Level Indication](image-url)
2.3.5 Overflow Vent
During operation the transmission is subjected to heating and cooling. A breather tube is provided to prevent the inside of the transmission from becoming pressurized. Refer to Section 1.1.2 or Figure 2.3.5-1 for location of the breather tube.

In the event that transmission fluid is overfilled, some fluid may be expelled from the breather passage; therefore the breather opening must not be directed at any hot components. The breather opening can be located remotely by attaching a hose to the existing breather tube. The hose length and diameter shall be such that the pressure of the inside of the transmission is always ±4.0 psi of atmospheric. A hose must not have any low spots that would allow any fluid or condensation to collect and prevent the free movement of air. The end of the hose shall be located at a position that does not inhale environmental or vehicle contaminants.

Remotely attached breathers are required, new designs must be provided by the vehicle manufacturer to be reviewed with Powertrain Control Solutions Engineering. PCS overflow vent kits serve this purpose and are available for purchase. Reference the PCS OEM Parts Catalog for part numbers.

Overflow Vent Kit Installation
The following procedure should be applied when installing an overflow vent kit. Improper installation could result in transmission fluid expelled from the hose and onto potential heat sources.

1. Apply lubricant to inner circumference of transmission vent hose. Secure hose 19 mm onto transmission vent tube.

2. Secure overflow vent kit to local features on transmission or body. The fluid release vent should be routed toward rear of transmission to avoid leakage onto transmission and vehicle components. The pressure release vent should be moved towards the top of the bellhousing to prevent fluid from accumulating in the hose.

3. The release vents referenced in Figure 2.3.5-1 must be directed away from potential heat sources, such as exhaust or catalytic converter.
2.3.6 Fluid Capacity
A universal bottom pan is provided with the PCS 4LHD/4LHDX. Approximate total fluid capacity values are listed below. Cooler size and cooler line lengths will alter these values.

- 8.4 L (8.8 qt) with 258 mm torque converter
- 10.8 L (11.4 qt) with 300 mm torque converter

2.3.7 Check Fluid Level
Proper fluid level is vital to the operation of the transmission. An overfill condition can be as detrimental as an under-fill. With improper fluid-level, fluid may contact the rotating parts or the pump intake may become exposed, causing aeration, possible overheating and erratic operation.

The transmission fluid serves several functions, therefore it is imperative the fluid supply be maintained appropriately. A fill tube and dipstick must maintain the fluid level above the pump suction port to prevent aeration of the oil. Aeration could result in pump cavitation and erratic operation of the transmission. Aeration could also occur if the oil level is too high. The fluid could contact the rotating components within the transmission and result in erratic operation. In addition, overheating or horsepower loss may occur. Fluid levels must be maintained within the recommended operating bands.

This procedure checks the transmission fluid level, as well as the condition of the fluid itself. Caution: Always use the proper automatic transmission fluid listed. Using incorrect automatic transmission fluid may damage the vehicle.

Before checking the fluid level, perform the following:

1. Start the engine and park the vehicle on a level surface. Keep the engine running.
2. Apply the parking brake and place the shift lever in PARK (P) or NEUTRAL (N).
3. Depress the brake pedal and move the shift lever through each gear range if available, pausing for about 3 seconds in each range. Then, move the shift lever back to PARK (P) or NEUTRAL (N).
4. Allow the engine to idle 500–800 RPM for at least 1 minute. Slowly release the brake pedal.
5. Keep the engine running and observe the transmission fluid temperature (TFT) using a scan tool or PCS software.
6. Using the TFT reading, determine and perform the appropriate check procedure. If the TFT reading is not within the required temperature ranges, allow the vehicle to cool, or operate the vehicle until the appropriate TFT is reached.

Cold Check Procedure
Use the cold check procedure only as a reference to determine if the transmission has enough fluid to be operated safely until a hot check procedure can be made. The hot check procedure is the most accurate method to check the fluid level. Perform the hot check procedure at the first opportunity. Use this cold check procedure to check fluid level when the TFT is between 27–32°C (80–90°F).

1. Start the engine and locate the transmission dipstick at the rear of the engine compartment, on the passenger’s side of the vehicle.
2. Flip the handle up, and then pull out the dipstick and wipe the dipstick end with a clean rag or paper towel.
3. Install the dipstick by pushing it back in the dipstick tube all the way, wait three seconds and then pull it back out again.
NOTE: Always check the fluid level at least twice. Consistent readings are important to maintaining proper fluid level. If inconsistent readings are noted, inspect the transmission vent assembly to ensure it is clean and unclogged.

4. Keep the dipstick pointing down and check both sides of the dipstick, and read the lower level. Repeat the check procedure to verify the reading. Reference Figure 2.3.7-1.

5. Inspect the color of the fluid on the dipstick.

6. If the fluid level is below the COLD check line, add only enough fluid as necessary to bring the level into the COLD line. It does not take much fluid, generally less than one pint (0.5L). **Do not overfill.**

7. If the fluid level is in the acceptable range, push the dipstick back in all the way, then flip the handle down to lock the dipstick in place.

8. Perform a hot check at the first opportunity after the transmission reaches a normal operating temperature between 82–93°C (180–200°F).

**Hot Check Procedure**

Use this procedure to check the transmission fluid level when the TFT is between 82–93°C (180–200°F). The hot check procedure is the most accurate method to check the fluid level. The hot check should be performed at the first opportunity in order to verify the cold check. The fluid level rises as fluid temperature increases, so it is important to ensure the transmission temperature is within range.

1. Start the engine and locate the transmission dipstick at the rear of the engine compartment, on the passenger side of the vehicle.

2. Flip the handle up, and then pull out the dipstick and wipe the dipstick end with a clean rag or paper towel.

3. Install the dipstick by pushing it back in the dipstick tube all the way, wait three seconds and then pull it back out.

**NOTE:** Always check the fluid level at least twice. Consistent readings are important to maintaining proper fluid level. If inconsistent readings are noted, inspect the transmission vent assembly to ensure it is clean and unclogged.

4. Keep the dipstick tip pointing down and check both sides of the dipstick. Read the lower level. Repeat the check procedure to verify the reading. Reference Figure 2.3.7-2.
5. Inspect the color of the fluid on the dipstick.

6. A safe operating fluid level is within the HOT crosshatch band on the dipstick. If the fluid level is not within the HOT band, and the transmission temperature is between 82–93°C (180–200°F), add or drain fluid as necessary to bring the level into the HOT band. If the fluid level is low, add only enough fluid to bring the level into the HOT band.

**NOTE:** To assist in reaching the correct temperature range of 82–93°C (180–200°F), drive the vehicle in second gear until the desired temperature is reached.

7. If the fluid level is low, add only enough fluid to bring the level into the HOT band. It does not take much fluid, generally less than one pint (0.5L). Do not overfill. Also, if the fluid level is low, inspect the transmission for leaks.

8. If the fluid level is in the acceptable range, push the dipstick back into the dipstick tube all the way, and then flip the handle down to lock the dipstick in place.

9. If applicable and if the vehicle is equipped, reset the transmission oil life monitor only if the fluid was changed.

**How to Add Fluid**

Add fluid only after checking the transmission fluid while it is hot. (A cold check is used only as a reference.) If the fluid level is low, add only enough of the proper fluid to bring the level up to the HOT area for a hot check. It doesn’t take much fluid, generally less than one pint (0.5 L). Don’t overfill.

**NOTICE:** Use only fluid labeled DEXRON® VI, because fluid with that label is made especially for your automatic transmission. Damage caused by fluid other than DEXRON® VI is not covered by your transmission warranty.

- After adding fluid, recheck the fluid level as described under “How to Check”.
- When the correct fluid level is obtained, push the dipstick back in all the way; then flip the handle down to lock the dipstick in place.
2.3.8 Fluid Change
The useful life of the transmission depends on the time at temperature of the ATF, which is a function of the transmission duty cycle, cooling system efficiency and local ambient temperatures. Transmission Fluid must be changed as listed below.

<table>
<thead>
<tr>
<th>Vehicle Class</th>
<th>Normal Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial</td>
<td>1000 Hours or 12 Months (whichever comes first)</td>
</tr>
</tbody>
</table>

NOTE: The transmission filter must be replaced at every fluid change.

Removal Procedure
Disconnect the battery from the vehicle prior to performing this procedure.

**WARNING:** When the transmission is at operating temperatures, take necessary precautions when removing the pan, to avoid being burned by draining fluid.

![Image of transmission fluid change](image)

Figure 2.3.8-1

1. Raise and support the vehicle.

**NOTE:** The fluid can be reused after this procedure unless it smells burnt or is discolored. If a recovery system is available, remove and store the fluid. Remove the pan bolts and skip to step 6.

2. On some vehicles an exhaust heat shield may need to be removed to access the pan bolts. Remove this if necessary.

3. Place a drain pan under the transmission oil pan.

4. Remove the oil pan bolts from the front and sides of the pan only.
5. Loosen the rear oil pan bolts approximately 4 turns.

6. Lightly tap the oil pan with a rubber mallet in order to loosen the pan to allow the fluid to drain. Reference Figure 2.3.8-1.

7. Remove the remaining oil pan bolts. Reference Figure 2.3.8-2.

8. Remove the oil pan and gasket. Reference Figure 2.3.8-3.
9. Grasp filter firmly while pulling down with a twisting motion in order to remove the filter. Reference Figure 2.3.8-4.

10. If the filter is going to be replaced, remove the filter seal. The filter seal may be stuck in the pump; if necessary, carefully use pliers or another suitable tool to remove the seal. Reference Figure 2.3.8-5.

11. Discard the seal.
1. Coat the new filter seal with automatic transmission fluid.

2. Install the new filter seal into the transmission case. Tap the seal into place using a suitable size socket. Reference Figure 2.3.8-6.

3. Install the new filter into the case.

4. Install the oil pan and a new gasket. Reference Figure 2.3.8-7.
5. Install the oil pan bolts and tighten alternately and evenly to 11 Nm (97 lb in). Reference Figure 2.3.8-8.

6. If previously removed, reinstall the exhaust heat shield.

7. Lower the vehicle.

8. Fill the transmission to the proper level with DEXRON® VI transmission fluid. Refer to Section 2.3.6 for fluid capacity.

9. Check the COLD fluid level reading for initial fill only.

10. Inspect the oil pan gasket for leaks.

11. Test drive vehicle and verify proper transmission operation.

12. Check fluid level when transmission is at operating temperature.
2.4 Transmission Shift Lever
Driver selection of the transmission range is normally accomplished through a cable linkage connecting a floor or column mounted selection lever to a transmission shift lever on the manual shaft. The vehicle manufacturer must make provisions to provide all the linkage and controls up to the transmission manual shaft. Sections 2.4.1-2.4.2 describe how to design this linkage. For an electronic shift reference Section 2.4.3.

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![Diagram of Transmission Shift Lever](image)

**Figure 2.4-1 Typical Shift System**

- Shifter Bracket
- Shifter Cable
- Mount Bracket

---

![Diagram of Transmission Shift Lever with NSBU Switch](image)

**Figure 2.4-2 Shift System with NSBU Switch**

- Shifter Bracket
- Shifter Cable
- NSBU (Neutral-Start Backup Switch) (Some Applications)
- Transmission Shift Lever
- Shift Cable Mounted to Column or Floor Range Selection Lever
- Shift Cable Reaction Bracket
2.4.1 Shaft Specs
The shift lever (which is to be supplied by the vehicle manufacturer) must conform to the following specification:

**Stock Thickness:** 4.3 to 4.7 mm (0.169 to 0.185 in)

**Hardness:**
Surface file hard Rc 59 min.
Case depth 0.12 to 0.25 mm (0.005 to 0.010 in)
Parts should not be brittle.

**Manual shaft connection:**

The interface between the manual shaft flats and the lever flats must have a press fit of 0.00 to 0.13 mm (0.000 to 0.005 in).

Punch direction must be from the lead-in side.

Slot dimensions to be maintained for a minimum of 50% stock thickness from lead-in side. No burrs permissible around slot on lead-in side.

Corrosion protection of external nut and lever required to be compatible with coating on manual shaft.

![Figure 2.4.1-1 Manual Shaft Dimension](image-url)
2.4.2 Lever Specs
Angular positions of the nominal transmission range detents are shown in the following figure.

Shift System Assembly Process
The shift lever must be retained on the manual shaft by a hand started nut tightened to 20 +/- 4 Nm (14.8 +/- 3 ft lb). The tightening of the manual shaft nut to the transmission manual shaft must be performed with the shift lever and manual shaft fixtured to prevent rotation.

The adjustment of the shift cable or linkage must be performed with the selector system in its final routed position, the vehicle resting on its wheels, and the transmission in Neutral. This “adjusts out” positional tolerances between the transmission and the shifter mechanism. After the cable or linkage is properly adjusted, the indicator may be installed and adjusted. Adjustment of the indicator must also be completed in Neutral. The indicator adjustment must not precede the shift cable or linkage adjustment.
Transmission Range Selection System Requirements

System Drag: The maximum amount of drag associated with the shifter system as seen by the transmission must be a minimum of 0.45 Nm (4.0 in lb) lower than the detent centering torque provided by the transmission. (See following figure.) This will enable the transmission to control the position of the range selection system within each gear range.

Transmission Range Selection System Analysis
Driver selection lever effort is found by measuring the load at the end of the selection lever. The lever is moved from Park to Low and Low to Park with the corresponding maximum load readings recorded.

System drag is evaluated by taking torque measurements at the manual shaft nut when rotating it through the ranges. Measurements are recorded first to determine total system torque with the shifter gate defeated and with the shift cable/linkage system attached to the transmission shift lever. The transmission detent centering torque is then determined by detaching the shift cable/linkage, removing the neutral start switch and again rotating the manual shaft nut. The system drag, as seen by the transmission, is equal to the total system torque minus the detent centering torque. The detent centering torque must be greater than the system drag. For shifter systems which contain a detent spring in the shifter, total system torque is measured with the cable disconnected from the shifter. The shifter detent spring must provide greater centering torque than the drag associated with the shifter and the indicator/close-out.

Typical sources of system drag include
• Cable friction
• Neutral start switch rotating torque
• Shifter pawl to gate plate
• Indicator slide effort
• Column to dashboard closeout
• Shifter closeout

![System Drag vs. Transmission Centering Torque](image_url)

Figure 2.4.2-2 System Drag vs. Transmission Centering Torque
Transmission Range Selection System Kinematic Relationship

Requirements
The transmission Park system is designed for park engagement with the transmission detent roller located in the Park valley of the detent lever. The range selection system must be designed to ensure that the roller is in the Park valley when the range selection lever is in the minimum Park gate position.

Definitions

Minimum Park Gate: The operator lever position closest to Reverse that will allow the shifter pawl to enter the park gate. Reference Figure 2.4.2-3.

Lost System Motion: The difference between range selection lever movement and transmission detent lever movement. Lost system motion consists of system lash and component deflection.
Kinematic Requirements
Under minimum stack conditions and neglecting lost system motion, the kinematic relationship between the detent lever and the range selection lever is to ensure that the detent roller is in the Park valley when the range selection lever is in the minimum Park gate as seen in the following figure.

The addition of lost system motion to the analysis will result in the detent roller being initially positioned short of the Park valley at this point as seen in the following figure. Spring forces from component deflection and the detent spring are to absorb the lost system motion and position the detent roller in the Park valley.
2.5 Electrical Interface
The PCS 4LHD/4LHDX uses an electro-hydraulic control system to control shift pattern, line pressure, torque converter clutch operation and transmission diagnostic actions. The electronic control system consists of inputs and outputs to the control module. Inputs are defined as sensors and signals that monitor engine and transmission performance. Outputs are signals to request the engine controller to modify engine torque during specific transmission shift and stall conditions. It may also request increased idle speeds at elevated temperatures.

2.5.1 Electrical Overview
The purpose of the Transmission Control Module (TCM) and Transmission Harness is to receive the necessary power requirements and vehicle system information to properly and safely shift the transmission into the requested gear range. This definition has become blurred with the introduction of improved vehicle operation and safety protocols. These protocols, becoming possible through the highly configurable nature of the electronic transmission controller, have allowed features resembling a Body Control Module to be carried out by the TCM. The example layout in Figure 2.5.1-1 and the explanations of the related systems in this section are common for most industrial vehicles (such as GSE Tractors). All wiring system integrations are to be validated both by the vehicle manufacturer and PCS Engineering.

At PCS, we design and produce our harnesses using decades of automotive experience and customer feedback. We have many standard 4LHD/4LHDX harnesses available, and we are eager to assist vehicle manufacturers in developing vehicle specific units. When routing the wiring harness on the vehicle and transmission, avoid all high temperature heat sources in the engine compartment. Assure the connection of all harnesses by using the "PUSH-CLICK-VERIFY" method. Avoid twisting of the harness when securing the harness in clips. Secure the clips to transmission studs where appropriate. Insure that the proper amperage fuses are used in the correct locations. Failure to do so will void the warranty and cause permanent damage to the transmission system. Refer to the PCS 4LHD/4LHDX Technician’s Guide for further instructions.
2.5.2 Transmission Electrical Interface
See Section 1.5 for information regarding the transmission’s internal electrical properties.

2.5.3 Output Speed Sensor Interface
See Section 1.5 for information regarding the Output Speed Sensor’s (OSS) properties.

2.5.4 Engine RPM Sensor Interface
Acquisition of engine RPM is an important variable in an efficient and effective calibration. Engines that are electronically controlled (via an Engine Control Module, ECM) may have RPM and/or torque available via a CANBUS or another form of I/O. Engines that are mechanically controlled and without an existing engine RPM sensor must install one remotely. This data can be picked up by some alternators, or by an optional tone generator on the torque converter. This Engine RPM Sensor is available on PCS 4LHD transmissions with SAE4 and C6 bellhousings. See Section 1.5 for more information regarding the Engine RPM Sensor.

2.5.5 Transmission Control Module

2.5.5.1 TCM Overview
The PCS 4LHD/4LHDX uses an electro-hydraulic control system to control shift pattern, line pressure, torque converter clutch operation, and transmission diagnostic actions. The electronic control system consists of inputs and outputs to the control module. Inputs are defined as sensors and signals that monitor engine and transmission performance. Outputs are signals to request the engine controller to modify engine torque during specific transmission shift and stall conditions. It may also request increased idle speeds at elevated temperatures.

2.5.5.2 TCM Handling
The following considerations must be adhered to when handling a PCS Transmission Control Module (TCM):

- Any TCM displaying visible damage shall not be installed in a vehicle.
- TCM enclosures shall not be opened by vehicle assembly personnel, and only on a case to case basis.
- Electrostatic discharge prevention techniques shall be employed by vehicle assembly personnel when handling the TCM.
- PCS and the customer shall work together to define the TCM programming.
- To properly install and uninstall the TCM2600 or TCM2800 connector, reference the MX123 Connection System User Manual which can be found online. This is critical to prevent pin damage. For other TCMs, reference their respective PCS TCM manuals.

2.5.5.3 TCM Installation
TCM mounting location definition, mounting bracket design, sourcing, validation, and vehicle assembly process are all the responsibility of the customer. If the vehicle will be subjected to electrical welding procedures (e.g. during body building assembly process) the harness and TCM must be electrically isolated (removed) from the vehicle. Wire gage between the transmission, TCM, and other vehicle systems shall comprehend the distances between components to minimize voltage drop and signal degradation. The electrical supply for other electrical devices such as remote starters, alarm systems, communication systems, etc. shall not interfere with the TCM voltage requirements. Reference the PCS 4LHD/4LHDX Technician’s Guide for more information.
2.5.5.4 Operating and Storage Temperature
Operating and storage temperature capabilities depend on control module design. PCS and the customer must agree upon applicable TCM storage and operating temperature specifications. Generally, control modules may be stored between -40°C and 125°C. Typical operating temperatures range from -40°C to 85°C for passenger compartment mounted TCMs and from -40°C to 105°C for under the hood mounting locations. The customer is responsible for meeting the agreed temperature limitations. PCS offers a bracket kit to mount the TCM on the transmission case. Reference Figure 2.5.2-1 and the PCS OEM Parts Catalog for more information.

2.5.5.5 Water/Dust Intrusion
PCS and the customer must agree upon applicable water and dust intrusion specifications, test levels, and report formats. More stringent requirements will increase TCM costs due to enclosure and connector sealing requirements.

2.5.5.6 Electromagnetic Compatibility (EMC)
PCS and the customer must agree upon applicable EMC specifications, PCS shall be responsible for TCM testing to applicable EMC specifications. The customer shall be responsible for vehicle-level testing and certification.

2.5.5.7 Control Algorithms
The TCM uses an electronic transmission control algorithm to monitor and control the transmission. This algorithm is actually a combination of many algorithms.

2.5.5.8 Shift Point Control
PCS transmissions select proper operating gear based upon driver input, vehicle dynamics, engine operation, and vehicle self-diagnostic operation. The TCM will operate the shift control solenoids to command the selected gear.

2.5.5.9 Shift Quality Control
PCS automatic transmissions provide smooth and precise ratio transitions between gears. During steady-state operation, control algorithms optimize operation to increase vehicle fuel economy while protecting transmission durability. The TCM will operate the line pressure control solenoid to ensure smooth ratio transitions and to maximize fuel economy.

2.5.5.10 Torque Converter Clutch Control
The Torque Converter Clutch is used to eliminate slip across the transmission torque converter. In some applications, a continuously-slipping converter clutch may be available to improve vehicle performance. The TCM will operate the Torque Converter Clutch solenoid(s) to maximize fuel economy and vehicle performance.

2.5.5.11 Abuse Protection
The automatic transmission control system will work to minimize torque disturbances shifts and to manage sudden torque when abusive or excessive torque is being transmitted through the transmission. This interface is usually achieved by software interfaces in TCM that will disable certain functions if they are determined abusive maneuvers.

2.5.5.12 Diagnostic System
PCS TCMs provide self-diagnostic testing to detect failures and degradation within the TCM and transmission hardware. All PCS automatic transmissions will support the latest On-Board Diagnostic (OBD) legislation and J1939.
### 2.5.5.13 Electronic Control System Summary
Selecting an appropriate TCM solution requires several defining characteristics to be agreed between PCS and the customer. Here is an example summary chart of plausible defining characteristic combinations:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Example TCM(2600)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.37 kg (0.82 lbs)</td>
</tr>
<tr>
<td>Case Material</td>
<td>Die Case Aluminum</td>
</tr>
<tr>
<td>Case Finish</td>
<td>Black Electrocoating</td>
</tr>
<tr>
<td>Voltage Range</td>
<td>8 - 36 VDC</td>
</tr>
<tr>
<td>Current</td>
<td>ON: 100mA Quiescent: 9mA</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-50 to 125 °C (-58 to 257 °F)</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>-55 to 150 °C (-67 to 302 °F)</td>
</tr>
<tr>
<td>Ingress Protection</td>
<td>IP69K</td>
</tr>
<tr>
<td>Electromagnetic Compatibility</td>
<td>GM 9100</td>
</tr>
<tr>
<td>Harness Interface</td>
<td>Molex MX123, Option 9, 56 Pin Sealed Connector</td>
</tr>
<tr>
<td>Communication Interface</td>
<td>2X CAN 2.0B (J1939, GMLAN/PCSCAN), 1X Serial RS-232, 1X J1850 CAN</td>
</tr>
<tr>
<td>Digital Inputs</td>
<td>16X, Programmable Active High/Low and Toggle/Momentary</td>
</tr>
<tr>
<td>Digital Outputs</td>
<td>2X, Low Side Drive Only</td>
</tr>
<tr>
<td>Analog Inputs</td>
<td>2X, 0-5VDC (See Pinout Notes)</td>
</tr>
<tr>
<td>Frequency Inputs (Range 0-10kHz)</td>
<td>4X (See Pinout Notes)</td>
</tr>
<tr>
<td>PWM Outputs</td>
<td>7X, Low Side Drive Only (4 w/Current Monitoring)</td>
</tr>
<tr>
<td>Max Output Currents</td>
<td>3.5 AMP Per</td>
</tr>
<tr>
<td>Reverse/Transient Protection</td>
<td>Yes</td>
</tr>
<tr>
<td>Real Time Tuning</td>
<td>Yes (w/Laptop)</td>
</tr>
<tr>
<td>Data Logging</td>
<td>Yes (w/Laptop)</td>
</tr>
<tr>
<td>In Field Flash Upgradable</td>
<td>Yes</td>
</tr>
<tr>
<td>Analog Input Failure Diagnostic</td>
<td>Yes</td>
</tr>
<tr>
<td>Input Over-Voltage Protections</td>
<td>Yes</td>
</tr>
<tr>
<td>Short Circuit Protection</td>
<td>Yes</td>
</tr>
<tr>
<td>Over Current Protection</td>
<td>Yes</td>
</tr>
<tr>
<td>Thermal Protection</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Figure 2.5.6.13-1: TCM Block Diagram
2.5.6 Calibration and Diagnostic Interface (Laptop)
The TCM can be accessed electronically through the Laptop Calibration Connector. This requires a PCS Communication Cable (TCM4180 “Standard” or TCM4182 “Rugged”) which are available separately. This system connects with the Serial RS232 Data Interface within the controller and the a USB port on a Windows based PC. All PCS TCMs are based on the PCS proprietary real-time operating system which contains the functionality to control and diagnose nearly any automatic transmission. The customer shall be responsible for service tool system testing and certification. See the PCS Technician’s Guide or the TCM Manual (controller specific) for more information.

2.5.7 Vehicle Electrical Interface (Bulkhead Connector)
For ease of explanation Section 2.5 has been summarized with the assumption that the following pins and features are all wired to one vehicle-to-transmission bulkhead connector. This is one of many examples of how the transmission harness may be set up. This layout is dependent on customer/vehicle feature requirements. For existing vehicles see your vehicle manual for more information regarding the harness layout and functionality, or contact PCS Engineering with the harness number. The PCS Harness I.D. Sticker is always located near the TCM connector, do not remove this label. For new vehicles and vehicle upgrades consult with PCS Engineering, the PCS OEM Parts Catalog, and this document to determine the most effective layout strategy for your system. Standardized transmission harnesses and vehicle adaption pigtails (TCM4659) are available, in addition to custom harness requests.

<table>
<thead>
<tr>
<th>Pin#</th>
<th>Wire Color</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>White/Black</td>
<td>CAN 1 Low</td>
</tr>
<tr>
<td>2</td>
<td>Brown/Red</td>
<td>Neutral Safety</td>
</tr>
<tr>
<td>3</td>
<td>Brown/Black</td>
<td>Ground When Reverse</td>
</tr>
<tr>
<td>4</td>
<td>Black/White</td>
<td>Signal Ground (Throttle Position Sensor)</td>
</tr>
<tr>
<td>5</td>
<td>Grey/White</td>
<td>Digital Input 5 (Shift Inhibit)</td>
</tr>
<tr>
<td>6</td>
<td>Red/White</td>
<td>+5V Sensor (Throttle Position Sensor)</td>
</tr>
<tr>
<td>7</td>
<td>White/Red</td>
<td>CAN 1 Hight</td>
</tr>
<tr>
<td>8</td>
<td>Pink/Light Green</td>
<td>Check Transmission Light</td>
</tr>
<tr>
<td>9</td>
<td>Yellow/Black</td>
<td>Analog Input 1 (Throttle Position Sensor)</td>
</tr>
<tr>
<td>10</td>
<td>Red</td>
<td>+12V Battery</td>
</tr>
<tr>
<td>11</td>
<td>Yellow</td>
<td>+12V Ignition</td>
</tr>
<tr>
<td>12</td>
<td>Black</td>
<td>Ground</td>
</tr>
</tbody>
</table>

Figure 2.5.8-1 Example Bulkhead Connector
(Female connector body, male pins, transmission bulkhead connector views from transmission side)
2.5.7.1 Required Vehicle Interfaces
The following wires / systems must be integrated into the vehicle as described, failure to do so may lead to permanent damage to the electrical systems, permanent damage to the transmission internals, and/or serious injury to anyone in or around the vehicle.

+12V Battery (PIN 10): Provides continuous power to the transmission system. This shall be an exclusive connection to the +12V battery, receive protection from a 5A fuse, and not share fusing with any other vehicle system.

+12V Ignition (PIN 11) (also called “Switched +12V”): Provides power to the transmission system while the vehicle is in operation. This shall be connected to a source capable of providing and rated for 10A. This circuit is to receive protection from a 10A fuse, and not share fusing with any other vehicle system.

Ground (PIN 12): Provides a completed circuit to all transmission systems receiving power from pins 10 and 11. This wire shall be fastened firmly to the vehicle chassis in a location that does not risk isolation from the negative battery terminal.

Throttle Position Sensor (PINS 4, 6, AND 9): Acquisition of throttle position is an important variable in an efficient and effective calibration, and may be carried out through CAN or other inputs if available. If utilized pins 4, 6, and 9 must be wired to a sensor capable of providing 0-5V in a linear relationship to the throttle pedal position. See Section 2.6 for more information on our available throttle position sensor “TPS”. See the PCS 4LHD Parts Guide or PCS Engineering for available sensor models. IMPORTANT: The TCM disables shifts out of Neutral while more than 15% throttle is present, do not attempt to “Rev-the-engine” before or during a shift. Excessive engine throttling while the transmission is in Neutral will cause permanent damage to the transmission and void the warranty.

2.5.7.2 Optional Vehicle Feature Interfaces
The body control and safety features listed below are optional per the vehicle manufacturer’s or owner’s requirements. The features available are not limited to the ones shown below, contact PCS Engineering for further options and feature inquiries.

CAN (PINS 1 AND 7): Vehicles with Engine Control Modules or Body Control Modules may have provisions for CANBUS communication. This communication protocol enables constant status updates between any linked vehicle systems. CANBUS is an efficient way to share data and reduce the number of wires between systems. Functions such as Engine RPM, Engine Torque, Throttle Position, battery voltage, light status, and accessory status can be communicated via CANBUS instead of having their own dedicated remote sensors, systems, and wires. Most PCS controllers are capable of J1939, GMLAN, PCSCAN, and other custom protocols upon request. Check with your TCM Manual or PCS Engineering for specific applications.

Neutral Safety (PIN 2): Grounded while the shifter is in neutral, this option enables the starter circuit to activate. A relay must be implemented in this circuit, wiring the starter to the transmission controller directly will cause permanent damage to the module.

Ground When Reverse (PIN 3): Grounded while the shifter is in reverse, therefore providing the option to activate the reverse lights. A relay must be implemented in this circuit, wiring the starter to the transmission controller directly will cause permanent damage to the module.

Shift Inhibit (PIN 5): Also called “Neutral Input” in our software, if a 5V brake pressure switch is installed in the brake line system, this option will notify the TCM when the operator is applying the brakes. The TCM will then enable a shift operation from neutral to either forward or reverse gear.

Check Transmission Light (PIN 8):Grounds a PWM output in the event of an error code to enable a “Trans Light” on the operator’s dash panel. LED indicators require a resistor to operate.
2.5.8 Electronic Range Interface

Use of a PCS GENIII (3) valvebody and PCS transmission controller can eliminate the mechanical shift cable system. This allows for electronic shifting of the transmission with the push of a button or movement of an electronic lever. In this application the transmission manual shaft must be engaged in neutral at all times. Figure 2.5.8-1 represents one of many position switch options available. Reference the PCS OEM Parts Catalog for other available options.

**Shifter Specifications**

<table>
<thead>
<tr>
<th>Column Size</th>
<th>38mm, 45mm, 55mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral Lock</td>
<td>none, drop-down</td>
</tr>
<tr>
<td>Available Speeds</td>
<td>F-N-R, F-N-R-3-2-1; Others available upon request.</td>
</tr>
<tr>
<td>Lights</td>
<td>-</td>
</tr>
<tr>
<td>Wiper Speeds</td>
<td>-</td>
</tr>
<tr>
<td>Connectors</td>
<td>integral Packard, integral Deutsch, wire harness</td>
</tr>
<tr>
<td>Expected Life Cycle</td>
<td>1,000,000 (rotary); 500,000 (shifter handle)</td>
</tr>
<tr>
<td>Operating Temp Range</td>
<td>-40°C - 85°C (-40°F - 185°F) 0% - 95% relative humidity</td>
</tr>
<tr>
<td>Operating Volt Range</td>
<td>3V - 32V</td>
</tr>
<tr>
<td>Solenoid Load</td>
<td>2A @ 12.8V with arc suppression</td>
</tr>
<tr>
<td>Measurements</td>
<td>Ø 65.02 mm x 220.47mm L (Ø 2.56 in x 8.68 in L)</td>
</tr>
<tr>
<td>Features</td>
<td>IP67; turn signals are built to complement the shifter, or can be mounted as stand alone</td>
</tr>
</tbody>
</table>

**Example Shifter Pinout**

<table>
<thead>
<tr>
<th>Shifter Pin</th>
<th>TCU Pin</th>
<th>TCU Channel</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>Digital 6</td>
<td>Reverse</td>
</tr>
<tr>
<td>3</td>
<td>29</td>
<td>Digital 9</td>
<td>Gear Selection</td>
</tr>
<tr>
<td>4</td>
<td>**</td>
<td>**</td>
<td>**</td>
</tr>
<tr>
<td>5</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>Digital 8</td>
<td>Gear Selection</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>Digital 7</td>
<td>Forward</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>Digital 10</td>
<td>Optional Button</td>
</tr>
</tbody>
</table>

* N/A; Items are unterminated
** Signal Ground
2.6 Throttle Position Sensor

The throttle position sensor is a critical input to the TCM. Failure to properly install the throttle position sensor will result in improper transmission operation and damage. PCS can provide a throttle position kit as shown in Figure 2.6-1.

**Position 1:** LOW FAILURE POSITION. The sensor arm should return to this position when it is disconnected from the pedal or throttle linkage. When the sensor is connected to the TCM the signal should measure less than 0.2V.

**Position 2:** IDLE POSITION. The sensor arm should be off of the minimum stop such that the reported voltage is between 0.5V and 1.5V.

**Position 3:** FULL THROTTLE POSITION. The sensor arm should not contact the maximum stop. The reported voltage in this position should be 3.5V to 4.5V.

**Position 4:** HIGH FAILURE POSITION. The maximum stop position is designed to protect the sensor if a failure in the linkage allows the sensor arm to extend past the normal operating range.

**Electrical Pinout**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>+5V</td>
</tr>
<tr>
<td>B</td>
<td>Ground</td>
</tr>
<tr>
<td>C</td>
<td>Output Signal</td>
</tr>
</tbody>
</table>

**Figure 2.6-2: TPS Positions**
TPS Verification Checklist

You must be able to answer YES to all of these statements to verify proper sensor installation.

1. The sensor is mounted in a location that is free from excessive vibration, protected from heat sources, debris, and fluids.

2. The sensor is mounted with proper fasteners (lock washers, lock nuts, etc) and uses appropriate materials (no uncoated steel, etc) for the sensor to last the anticipated life of the vehicle.

3. When the accelerator pedal is at idle (not depressed), the sensor arm is off of the minimum stop and the voltage as shown on the TCM software monitor screen is between 0.5V and 1.5V.

4. When the sensor arm is disconnected from the linkage that connects it to the engine or pedal, the sensor arm returns to the minimum stop and the voltage on the TCM software monitor screen is below 0.2V. Code 22 becomes active after three seconds.

5. When the pedal is pressed, the sensor arm moves accordingly. There is no movement or “slop” such that the pedal or engine throttle blade can move without seeing a voltage change on the TCM software monitor screen.

6. The sensor moves freely without binding. The sensor does not provide any resistance or change to the operation of the throttle linkage.

7. When the accelerator pedal is at full throttle, the sensor arm does not contact the maximum stop and the voltage as shown on the TCM software monitor screen is between 3.5V and 4.5V.

It is strongly recommended to use the arm provided by PCS. In situations where the vehicle manufacturer must design a custom arm, refer to figure 2.6.8.12-3 provided for the design of the arm to the sensor.
SECTION 3
PRODUCTION LINE PROCEDURES
Section 3 Production Line Procedures

3.1 Assembly Procedures

3.1.1 Storage Requirements
The transmission shipping containers are designed to protect the transmission from some environmental conditions. They are only effective if they are properly closed. Verify the top cover on the cocoons is properly aligned to insure no foreign materials such as water can get inside. Transmissions should remain in shipping cocoons until engine marriage. Transmissions should be stored in a dry, dust free environment at room temperature. Do not store outside. Even if they are in the cocoons, there is still a risk for water and other foreign mater to get inside. If water accumulates inside the cocoon, there are no drain holes for it to escape. The resulting condensation cycles will insert water and debris into the transmission fluid and cause permanent damage. Water damage will void all warranties.

3.1.2 Handling Requirements
Transmissions should be assembled to vehicles in a timely manner to avoid contamination risks or damage during the storage period.

Transmissions should be lifted from appropriate shipping racks by approved lifting hooks. The lifting hooks should be designed to allow the following:

1. Lift the transmission by at least two lift points.

2. Employ one counter balance arm to ensure that the transmission is lifted straight up from the rack and it does not swing or tilt.

3. Lift hook must include a safety latch to prevent the transmission from sliding off the hook during lifting.

4. The hooks utilized to lift and place the transmission parallel to the engine should position the transmission so that the torque converter will line up with the flywheel and fit squarely on the engine block alignment features.

The transmission should not be allowed to tip forward. The torque converter may be disengaged from the transmission causing injury or damage, or it may move away from the transmission bell housing far enough to disengage from the oil pump (pump could be damaged).

Once the transmission is removed from the cocoon, the transmission shall not be set down on the bottom pan or be allowed to contact any sharp or hard objects. Damage to the oil pan, gaskets, or internal components may result from resting transmissions on their bottom pans. If transmissions must be staged, they should be placed on approved racks that allow them to sit on oil pan bolt heads.

Transmission storage time should be held to a minimum by using a first-in/first-out process.
3.1.3 Assembly Requirements

1. Remove the converter shipping bracket and its fasteners from the converter and transmission case while ensuring that debris does not fall behind the converter.

2. All pieces should be placed in the appropriate containers for return to the source plant.

3. The transmission should be held parallel to the engine axis by the lift hooks and should not be tipped forward once the shipping bracket has been removed. Adhering to this prevents the torque converter from slipping out of the bell housing.

4. It is recommended to apply grease to the torque converter pilot. Position the transmission flush against the engine block dowel pins.

5. Install bolt to the bell housing at the 3 and 9 o’clock positions. Then install remaining bolts in a crossing pattern to ensure proper fit. Install the appropriate transmission to engine fasteners per the vehicle assembly instructions. Assure any fastening sequence and torque values are followed.

Transmission to Engine Fasteners and Installation Torque

It is preferred that a single part number fastener be used at all of the transmission to engine fastener locations. The preferred fastener is an M10x1.5 flanged hex bolt with a minimum strength grade of 10.9. Double-ended stud usage for electrical grounding and clip attachment can be evaluated. The installation torque or dynamic torque should be 50 Nm ±10 Nm. The checking torque, or static torque, should be 55 Nm ±15 Nm. An access area 85 mm long by 25 mm in diameter is recommended for accessibility to the transmission to engine fasteners. When using the PCS provided adapters all necessary hardware including the bolts are provided. If you need further assistance contact PCS.
3.2 End-of-Line Inspection Procedures
Several items must be inspected prior to operating the vehicle and a test drive must be performed prior to delivering the vehicle to the end-user. Data from the inspections outlined below must be retained during the transmission warranty period and available for PCS review if a warranty claim is made on a transmission. PCS encourages vehicle manufacturers to implement a rigorous quality inspection prior to customer delivery, but requires the minimum items specified in this section to be inspected and documented. Improper installation will result in transmission damage that is not covered under warranty. The critical items required include:

- Fastener selection, installation, and torque
- Position Lever
- TCM firmware and calibration
- Transmission fluid type and level
- Throttle position
- Engine RPM
- Vehicle speed
- Diagnostic codes

3.2.1 Pre-Start Checks

Fastener Torque
Prior to starting the vehicle for the first time, inspect all mounting bolts, torque converter bolts, flywheel bolts, and all other driveline hardware to ensure it is present and torqued to the proper value.

Position Lever Check
Move the shift lever through all the ranges and verify that the transmission shift arm is centered in the detent for each position. This may require disconnecting the cable at the transmission for each position to ensure the arm is in the detent. Improper shift cable adjustment will result in premature transmission failure.

3.2.2 Stationary Engine-Off Checks

Firmware
Turn the ignition on (do not start the engine) and connect to the TCM with the PCS TCM Diagnostic Software. Verify the firmware version is the current, recommended version on the PCS website referenced below. Perform a firmware upgrade if necessary. Record the firmware version.

https://www.powertraincontrolsolutions.com/latest/firmware/

Calibration
PCS Transmission Control Modules are shipped with a base calibration that limits the transmission to first gear. Every vehicle model must have a PCS validated calibration to install at this point during vehicle assembly. Verify the proper calibration is installed or program now if necessary.

Position Lever Verification
Move the shift lever through the ranges and verify the actual shift lever position matches the position shown in the software. This is also a good time to verify any applicable lights illuminate in the proper gear positions.

Throttle Position Sensor
Verify the throttle position reading is zero at when the pedal is not pressed, and 100% when fully depressed. For a detailed description of TPS installation/assembly requirements reference Section 2.6.
3.2.3 Stationary Engine-Running Checks

**Fluid Level Check**
Start the engine and check the fluid level as specified in Section 2.3.7. Adjust fluid level as necessary.

**Engine RPM**
Verify the engine RPM on the software matches the actual engine RPM.

**Diagnostic Code Check**
Verify there are no diagnostic trouble codes set. If any are present refer to the *PCS 4LHD/4LHDX Technicians Guide* for a full list of these codes and troubleshooting instructions.

3.2.4 Test Drive

**Vehicle Speed**
Move the vehicle and verify that the vehicle speed operates properly.

**Shifting**
A test drive should be performed to check proper transmission operation in all gears. This includes but is not limited to shift quality, gear range, and abuse protection (if equipped). Operate the vehicle until the transmission is at operating temperature.

3.2.5 Post Drive Check

**Diagnostic Code Verification**
Upon completion of the test drive, check to see if any diagnostic codes have been set. If any are present refer to the *PCS 4LHD/4LHDX Technicians Guide* for a full list of these codes and troubleshooting instructions.

**Fluid Level Verification**
Verify the fluid level is correct and no fluids are leaking from the vehicle. Adjust fluid level as necessary.