Computers and Control Systems: Description and Operation
Powertrain Control Software
POWERTRAIN CONTROL SOFTWARE

Multiplexing
The increased number of modules on the vehicle necessitates a more efficient method of communication. Multiplexing is a method of sending two or more signals simultaneously over a single circuit. In an automotive application, multiplexing is used to allow two or more electronic modules to communicate simultaneously over a single media. Typically this media is a twisted pair of wires. The information or messages that can be communicated on these wires consists of commands, status or data. The advantage of using multiplexing is to reduce the weight of the vehicle by reducing the number of redundant components and electrical wiring.

Multiplexing Implementation
Currently Ford Motor Company uses two different types of communication language protocols to communicate with the powertrain control module (PCM). These protocols are Standard Corporate Protocol (SCP) and Controller Area Network (CAN). For the 2004 model year the following vehicles will utilize the High Speed -CAN (HS-CAN) protocol for PCM communication:
- 2.3L Focus PZEV (partial zero emission vehicle)
- LS6
- LS8
- Taurus/Sable
- Thunderbird
- Explorer/Mountaineer
- 4.6L 2V and 5.4L 3V F150 (Non-Heritage)

The LS and Thunderbird will use HS-CAN between the DCL (Data Communication Link) connector and the PCM for scan tool to PCM diagnostics only. Inter communication (PCM to other network modules) for the LS and Thunderbird will continue to use SCP. The other CAN vehicles will use HS-CAN for PCM to network module communication and for scan tool diagnostics.

All other vehicles for model year 2004 will continue to use SCP as its communication media for the PCM.

Standard Corporate Protocol (SCP)
SCP is a communication language protocol based on SAE J1850 and is used by Ford Motor Company for exchanging bi-directional message (signals) between electronic modules. Two or more signals can be sent over one SCP network circuit. Fords SCP network operates at **41.6 kB/sec (kilobytes per second)**.

Included in these messages is diagnostic data that is outputted over the BUS (+) and BUS (-) lines to the data link connector (DLC). PCM connection to the DLC is typically done with a two wire, twisted pair cable used for network interconnection. The diagnostic data such as Self-test or PIDs can be accessed with a scan tool. Information on scan tool equipment is described in Diagnostic Methods.

High Speed - Controller Area Network (HS-CAN)
HS-CAN is based on SAE J2284, ISO-11898 and is a serial communication language protocol used to transfer messages (signals) between electronic modules or nodes. Two or more signals can be sent over one CAN network circuit allowing two or more electronic modules or nodes to communicate with each other. This communication or multiplexing network operates at **500 kB/sec (kilobytes per second)** and allows the electronic modules to share their information messages.

Included in these messages is diagnostic data that is outputted over the CAN High (+) and CAN Low (-) lines to the data link connector (DLC). PCM connection to the DLC is typically done with a two wire, twisted pair cable used for the network interconnection. The diagnostic data such as Self-test or PIDs can be accessed with a scan tool. Information on scan tool equipment is described in Diagnostic Methods.

Flash Electrically Erasable Programmable Read Only Memory
The Flash Electrically Erasable Programmable Head Only Memory (EEPROM) is an Integrated Circuit (IC) within the PCM. This IC contains the software code required by the PCM to control the powertrain. One feature of the EEPROM is that it can be electrically erased and then reprogrammed without removing the PCM from the vehicle. If a software change is required to the PCM, the module no longer needs to be replaced, but can be reprogrammed at the dealership through the DLC.

Idle Air Trim

IDLE AIR TRIM LEARNING MODES

Transmission Range	Air Conditioning Mode
NEUTRAL	A/C ON
NEUTRAL	A/C OFF
DRIVE	A/C ON
DRIVE	A/C OFF

Idle Air Trim Learning Modes

Idle Air Trim is designed to adjust the Idle Air Control (IAC) calibration to correct for wear and aging of components. When engine conditions meet the learning requirement, the strategy monitors the engine and determines the values required for ideal idle calibration. The Idle Air Trim values are stored in a table for reference. This table is used by the PCM as a correction factor when controlling idle speed. The table is stored in Keep Alive Random Access Memory (RAM) and retains the learned values even after the engine is shut off. A Diagnostic Trouble Code (DTC) is output if the Idle Air Trim has reached its learning limits.

Whenever an IAC component is replaced or cleaned or a service affecting idle is performed, it is recommended that Keep Alive RAM be cleared. This is necessary so the idle strategy does not use the previously learned Idle Air Trim values.

To clear Keep Alive RAM, refer to PCM Reset in Diagnostic Methods. It is important to note that erasing DTCs with a scan tool does not reset the Idle Air Trim table. See: Testing and Inspection/Reading and Clearing Diagnostic Trouble Codes/Clearing Diagnostic Trouble Codes/With Scan Tool

Once Keep Alive KAM has been reset, the engine must idle for **15 minutes** (actual time varies between strategies) to learn new idle air trim values. Idle quality will improve as the strategy adapts. Adaptation occurs in four separate modes. The modes are shown in the table.

Fuel Trim

Short Term Fuel Trim

If the oxygen sensors are warmed up and the PCM determines that the engine can operate near stoichiometric air/fuel ratio (14.7 to 1 for gasoline), the PCM goes into closed loop fuel control mode. Since an oxygen sensor can only indicate rich or lean, the fuel control strategy must constantly adjust the desired air/fuel ratio rich and lean to get the oxygen sensor to "switch" around the stoichiometric point. If the time between switches are the same, then the system is actually operating at stoichiometry. The desired air/fuel control parameter is called short term fuel trim (SHRTFT1 and 2) where stoichiometry is represented by 0%. Richer (more fuel) is represented by a positive number and leaner (less fuel) is represented by a negative number. Normal operating range for short term fuel trim is +/- 25%. Some calibrations will have time between switches and short term fuel trim excursions that are not equal. These unequal excursions are used to run the system slightly lean or rich of stoichiometry. This practice is referred to as using "bias". For example, the fuel system can be biased slightly rich during closed loop fuel to help reduce NOx.

Values for SHRTFT1 and 2 may change a great deal on a scan tool when the engine is operated at different rpm and load points. This is because SHRTFT1 and 2 will react to fuel delivery variability that can change as a function of engine rpm and load. Short term fuel trim values are not retained after the engine is turned off.

Long Term Fuel Trim

While the engine is operating in closed loop fuel, the short term fuel trim corrections can be "learned" by the PCM as long term fuel trim (LONGFT1 and 2) corrections. These corrections are stored in Keep Alive Memory (KAM) in tables that are referenced by engine speed and load (and by bank for engines with two HO2S sensors forward of the catalyst). Learning the corrections in KAM improves both open loop and closed loop air/fuel ratio control. Advantages include:

- Short term fuel trim does not have to generate new corrections each time the engine goes into closed loop.
- Long term fuel trim corrections can be used both while in open loop and closed loop modes.

Long term fuel trim is represented as a percentage, just like short term fuel trim, however it is not a single parameter. There is a separate long term fuel trim value that is used for each rpm/load point of engine operation. Long term fuel trim corrections may change depending on the operating conditions of the engine (rpm and load), ambient air temperature and fuel quality (% alcohol, oxygenates, etc.). When viewing the LONGFT1/2 PID(s), the values may change a great deal as the engine is operated at different rpm and load points. The LONGFT1/2 PID(s) will display the long term fuel trim correction that is currently being used at that rpm/load point.

Idle Speed Control Closed Throttle Determination (applications without Electronic Throttle Control)

One of the fundamental criteria for entering rpm control is an indication of closed throttle. Throttle mode is always calculated to the lowest learned throttle position (TP) voltage seen since engine start. This lowest learned value is called "ratch", since the software acts like a one-way ratch. The ratch value (voltage) is displayed as the TPREL PID. The ratch value is relearned after every engine start. Ratch will learn the lowest, steady TP voltage seen after the engine starts. In some cases, ratch can learn higher values of TP. The time to learn the higher values is significantly longer than the time to learn the lower values. The brakes must also be applied to learn the higher values.

All PCM functions are done using this ratch voltage, including idle speed control. The PCM goes into closed throttle mode when the TP voltage is at the ratch (TPREL PID) value. Increase in TP voltage, normally less than **0.05 volts**, will put the PCM in part throttle mode. Throttle mode can be viewed by looking at the TP MODE PID. With the throttle closed, the PID must read C/T (closed throttle). Slightly corrupt values of ratch can prevent the PCM from entering closed throttle mode. An incorrect part throttle indication at idle will prevent entry into closed throttle rpm control, and could result in a high idle. Ratch can be corrupted by a throttle position sensor or circuit that "drops out" or is noisy, or by loose/worn throttle plates that close tight during a decel and spring back at a normal engine vacuum.

Fail-Safe Cooling Strategy

The fail-safe cooling strategy is activated by the PCM only in the event that an overheating condition has been identified. This strategy provides engine temperature control when the cylinder head temperature exceeds certain limits. The cylinder head temperature is measured by the Cylinder

Head Temperature (CHT) sensor. For additional information about the CHT sensor, refer to PCM Inputs for a description of the CHT sensor.

NOTE: Not all vehicles equipped with a CHT sensor will have the fail-safe cooling strategy.

A cooling system failure such as low coolant or coolant loss could cause an overheating condition. As a result, damage to major engine components could occur. Along with a CHT sensor, the fail-safe cooling strategy is used to prevent damage by allowing air cooling of the engine. This strategy allows the vehicle to be driven safely for a short time with some loss of performance when a overheat condition exist.

Engine temperature is controlled by varying and alternating the number of disabled fuel injectors. This allows all cylinders to cool. When the fuel injectors are disabled, their respective cylinders work as air pumps, and this air is used to cool the cylinders. The more fuel injectors that are disabled, the cooler the engine runs, but the engine has less power.

NOTE: A wide open throttle (WOT) delay is incorporated if the CHT temperature is exceeded during WOT operation. At WOT, the injectors will function for a limited amount of time allowing the customer to complete a passing maneuver.

Before injectors are disabled, the fail-safe cooling strategy alerts the customer to a cooling system problem by moving the instrument cluster temperature gauge to the hot zone and a PCM DTC P1285 is set. Depending on the vehicle, other indicators, such as an audible chime or warning lamp, can be used to alert the customer of fail-safe cooling. If overheating continues, the strategy begins to disable the fuel injectors, a DTC P1299 is stored in the PCM memory, and a malfunction indicator light (MIL) (either CHECK ENGINE or SERVICE ENGINE SOON), comes on. If the overheating condition continues and a critical temperature is reached, all fuel injectors are turned off and the engine is disabled.

Failure Mode Effects Management

Failure Mode Effects Management (FMEM) is an alternate system strategy in the PCM designed to maintain engine operation if one or more sensor inputs fail.

When a sensor input is perceived to be out-of-limits by the PCM, an alternative strategy is initiated. The PCM substitutes a fixed value and continues to monitor the incorrect sensor input. If the suspect sensor operates within limits, the PCM returns to the normal engine operational strategy.

All FMEM sensors display a sequence error message on the scan tool. The message may or may not be followed by Key On Engine Off or Continuous Memory DTCs when attempting Key On Engine Running Self-Test Mode.

Engine RPM/Vehicle Speed Limiter

The powertrain control module (PCM) will disable some or all of the fuel injectors whenever an engine rpm or vehicle overspeed condition is detected. The purpose of the engine rpm or vehicle speed limiter is to prevent damage to the powertrain. The vehicle will exhibit a rough running engine condition, and the PCM will store one of the following Continuous Memory DTCs: P0219, P0297 or P1270. Once the driver reduces the excessive speed, the engine will return to the normal operating mode. No repair is required. However, the technician should clear the PCM and inform the customer of the reason for the DTC.

Excessive wheel slippage may be caused by sand, gravel, rain, mud, snow, ice, etc. or excessive and sudden increase in rpm while in NEUTRAL or while driving.