LT1 SCANNER READINGS - WHAT DO THEY MEAN?

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WARNING – THIS DOCUMENT WAS PREPARED SPECIFIALLY FOR THE LT1 ENGINE USED IN THE 1993-1997 CAMAROS AND FIREBIRDS. IT IS NOT INTENDED TO COVER ANY OTHER VEHICLE/ENGINES/COMPUTERS

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This description was prepared to cover the ScanMaster LT1, when being used to monitor the functions of an LT1 engine, specifically one operating with an MAF sensor. In this version of the document I have deleted some ScanMaster specific info, like the install and operating directions. This is now intended as a more generic document with regard to scanning the LT1 PCM.

It is not completely applicable to the '93's because they operate in speed-density mode, not with an MAF. But a lot is actually the same. It is also not applicable to the LS1 family of engines, or the V6 engines.

A lot of the data will be similar if you are looking at something other than a 1994-1997 LT1 using something other than a ScanMaster. You will see a lot of the same data and values in many similar vehicles, and you will get similar readings from most other scanners and data recording devices.

Be careful, because the units of measurement may be different. With some scanners MAF is expressed in "grams per second". Yet other systems report in "pounds per minute". Same with MAP…. some scanners report in "inches of Mercury" ("Hg), while others use "kiloPascals" (kPa). I have tried to point out the differences where appropriate, but I probably haven't covered all the possibilities.

The descriptions of how the engine control system works are somewhat simplified. Not all the possible variations of operation are covered. Most of this just comes from my reading and study of a lot of reference material, and 20+ years of helping people on bulletin boards covering the LT1 engine. I do not have a manual that specifically tells me how GM engineers decided to make this system work. There is a third-party written manual on Corvette EFI through the years, and the author of this manual appears to have had access to GM engineers. See “References” at end of document. Some of what it presented here is the result of inductive reasoning, based on what I have seen in my own 1994 Formula M6. I am weak on A4's for example, because I have never really studied one. But, I do receive a lot of data records from people using AutoTap (discontinued), Auto X-ray, TTS DataMaster (still available from private sources but not supported by TTS), Scan9495, and some other systems.

And, because I have converted my engine to operate on a MoTeC M48Pro engine management computer, and a fully manual TH400 transmission, I can no longer even check some of these numbers to make sure they are correct. I have to rely on the reader to feed back to me any differences they have seen in their cars.

DEFINITIONS:

- **ECM** = Engine Control Module…. This is what the engine management computer was called in 1993, because it only controlled the engine.

- **PCM** = Powertrain Control Module….. This is what the engine/transmission management computer was called for 1994, and up. This is basically the same device as the "ECM" without a removable chip, but when they added the 4L60E electronically controlled automatic transmission, they changed the terminology. The PCM does NOT control the ABS, nor can ABS codes be retrieved from the PCM.

- **Bank 1** = The left, cylinders 1/3/5/7, or driver's side of the engine. You will see references to the "Bank 1 O_2 sensor"… this means the one associated with the driver's side of the engine.

- **Bank 2** = The right, cylinders 2/4/6/8, or passenger side of the engine.

- **Position 1** = the "pre-cat" O2 sensor (nomenclature used in OBD-2, for 96/97 only)

- **Position 2** = the "after-cat" O2 sensor (in OBD-2, for 96/97 only)

- **ALDL** = The Assembly Line Diagnostic Link connector located under the dashboard, near your right knee, that allows you to connect your scanner to the PCM. Sometimes called the Data Link Connector (DLC).

- **OBD-I** = The Onboard Diagnostic system used in the computers of 1993-95 F-Bodys. It utilizes a 12-pin ALDL connector. The 1995 models have a 16-pin connector, similar to the OBD-II computers, but ALL the 1995's are still OBD-I, including the dual-cat California emissions A4's.

- **OBD-1.5** = The Onboard Diagnostic system used on the computers of the 94/95 Corvette LT1 PCM's. This is not an "official" designation, just something convenient to describe a system that incorporates OBD-1 diagnostics and codes, plus a few OBD-2 diagnostics and codes. OBD-1.5 was **NOT** used for the 95 F-Body (Camaro/Firebird) PCM. GM apparently planned to switch, installed a 16-pin ALDL connector, but then dropped the rest of the conversion plan.

- **OBD-II** = The Onboard Diagnostic system used in the computers of the 1996-97 F-Bodys. It uses a 16-pin ALDL connector. The engine control logic is not very different than the OBD-I system, but there are many more diagnostic routines used to identify malfunctions, particularly those related to emissions, and they are much more intrusive.

- **WOT** = Wide Open Throttle - pedal to the metal!!

READING SENSORS THROUGH THE PCM:

The following are just computer readouts similar to (but not necessarily the same as) the gauges on your dash, or things that are connected to the outside world and can be measured in other ways. The PCM readouts are more accurate than the gauges on your dash. Hence, it is worth comparing the dash readouts to the scanner readouts for each parameter, to make sure that you know if your dash gauge is any good, or how far "off" it is.

The following dashboard mounted items are driven from the PCM:

-speedometer/odometer
-tachometer
-SES light
-skip shift light

The following dashboard mounted items are NOT driven from the PCM:

-coolant temperature gauge
-charging system voltmeter
-oil pressure gauge
-fuel level gauge
-other idiot lights
-ABS, BRAKE and AIRBAG lamps

The PCM cannot measure, control or indicate the following:

-fuel pressure
-oil temperature (some scanners will report a value, but there is no sensor on the F-Body, only on the Corvette.)
-oil level
-coolant level
-misfires not detected in OBD-I

MPH (Mile Per Hour):

By reading the pulses from your Vehicle Speed Sensor (VSS) on the tailshaft of the transmission, the PCM **thinks** it knows how fast your car is moving. The PCM has been pre-programmed with the information it needs to convert the speed of the driveshaft to the speed of the car. This includes the **rear axle ratio** and the **tire rolling diameter**. If you change either of these, the speedometer will no longer be accurate, and the data in the PCM must be reprogrammed.

You can't tell if your speedo is reading correctly just by looking at the dashboard speedometer, or the scanner MPH readout. You need to drive your car on an Interstate (or other) highway equipped with mile markers. Check vs. a GPS MPH readout. Or - drive at a constant speed of 60mph for 5 miles. Measure the number of seconds it takes to go from the first mile marker to the one five miles down the road. Divide the number of seconds it took to reach the 5-mile point, into 18,000. This will give you your true speed

Example:

290 seconds to cover 5 miles

18,000 / 290 = 62.07 mph

It's easier to use the digital readout of the scanner to try and hold a steady speed. If your indicated speed fluctuates a little, try and make sure it shows readings above 60 mph about as much as it shows readings below 60 mph. Do this several times to get the best results.

RPM (Revolutions Per Minute):

The PCM reads the low resolution pulses from the Opti-Spark, to measure the RPM. Because of the way it converts the pulses, and the 8-bit binary format, the readout is in 25 RPM increments. If you have an M6, for example, it should indicate 800 RPM at idle (warm engine). However, as the speed fluctuates, you might see it drop to 775 RPM or rise to 825 RPM. Automatic trans cars will vary +/- 25 RPM from the programmed values shown below. You should not see much more variation than this at idle. Compare this to your stock dash tachometer. The scanner is dead nuts correct…. If there is a difference in the readings, your TACH is WRONG.

Check it at several points, particularly near your max RPM. You might find you are shifting at the wrong point. I found my tach was indicating it was time to shift, but it was actually turning several hundred less RPM than the tach showed. At idle, it is not unusual for your dash tach to read 100-200 RPM higher than the scanner.

As noted above, for a stock PCM that hasn't been reprogrammed, the idle speeds are:

- M6 = 800 RPM
- A4 = 650 RPM - neutral
- A4 = 550 RPM - in gear

It should be noted that these are the idle specs for a full warmed up engine. The idle specs for a cold engine are higher:

COOLANT	A4	A4	M6
TEMP	IN	IN	IN
deg F	GEAR	NEUTRAL	NEUTRAL
-40	800	1200	1200
-19	800	1200	1050
3	800	1200	1050
24	800	1000	1000
46	800	950	900
68	800	900	900
89	800	900	900
111	800	900	800
132	750	850	800
154	650	750	800
176	550	650	800
>176	550	650	800

CLT (Engine Coolant Temperature):

This is the temperature of the coolant, (usually) in degrees Fahrenheit. It is measured by a sensor in the water pump housing. This is NOT the same sensor that supplies the temperature to your dash mounted temperature gauge. The gauge sensor is located in the driver's side head, between #1 and #3 cylinders (under the exhaust manifold). You may find a 10-15 degree difference between the dash gauge and the scanner. Remember, the PCM only sees the same reading as the scanner, so that is the temperature it is going to look at to turn your fans on and off, modify timing, etc.

At COLD startup, your CLT should be close to the temperature of the outside air. It will start to rise immediately. At 180 degrees F (or 160 deg F, if you have changed your thermostat) you might see the temperature stop increasing for a while. Then if you let it sit and idle, in hot weather, the CLT can reach the fan switch temperature, in excess of 210 degrees F. GM designed the engine to run at 210-degF. That is intended to maximize fuel economy while minimizing emissions.

Watch the temperature drop as the fans run, and note the temperature at which the fans turn off. The CLT will cycle between these two temperatures in stop-and-go traffic, but on the open road, at 50 MPH or so, your CLT should start to approach your 180 deg thermostat temp, or in the case of a 160 deg. 'stat, maybe run at 172-175 degrees F.

A **CAUTION**: The 1993 dash coolant temperature gauge is mis-calibrated. The lowest hash mark reading is shown as 100-degF. It should be 160-degF like the 94-97 models. This mis-calibration leads some people to believe their 1993 runs unusually cool. No, it’s just a screwed up marking on the first hash mark. The second hash mark is ~185-190-degF.

Typical computer settings, with a stock 180-degF thermostat are:

1st fan on (93/early 94); or both fans at low speed (late 94-97) - 226degF

2nd fan on (93/early 94); or both fans on high speed (late 94-97) - 235degF

The output of the CLT sensor is a resistance. Since the device is a "thermistor", high ohms = low temperature; low ohms = high temperature. If you want to check your sensor, some typical values are:

deg C	deg F	OHMS
-40	-40	100,700
-20	-4	28,680
0	32	9,420
10	50	5,670
20	68	3,520
30	86	2,238
40	104	1,459
50	122	973
60	140	667
70	158	467
80	176	332
90	194	241
100	212	177

IAT - Intake Air Temperature, also called ATS - Air Temperature Sensor:

This is the inlet air temperature, picked up by the sensor in the inlet bellows (elbow). It is subject to heat soak in that location. When you start your car cold, the IAT should read the same as an outdoor thermometer…if it's 50 deg-F outside, the IAT should read 50 deg-F.

As you car warms up, the difference between the outside air temp, and the IAT will start to increase, with the IAT being higher. This is because 1) the air entering the system is starting to be heated by cast off engine heat, either before it enters the air cleaner, or in the duct that flows it to the MAF/TB; and 2) the sensor starts to absorb heat directly from the engine compartment.

If you are sitting in traffic, the IAT can jump up to 130-140 deg-F. This is no longer the true inlet air temperature, but includes the heat that is flowing into the sensor from under the hood. Move your IAT sensor to the air cleaner cap on your cold air intake package, and note the difference while sitting in traffic. The temperature will rise only because of the engine heat that is starting to build up under the car. You now have a handy outside temperature indicator.

The IAT sensor is a thermistor, just like the CLT sensor, and has the same values of resistance shown in the table above.

BAR (Barometric Pressure):

This is the barometric pressure in the area where you are driving. At sea level, the barometric pressure is about 30 "Hg (inches of Mercury). As your elevation increases, the barometric pressure decreases, since this is effectively the weight of the air pressing down on you from the very top of the air layer that surrounds the earth. In Denver, for example, at 5,800 ft. elevation, the barometric pressure might only read 24.0 "Hg. As atmospheric conditions change at any location, the barometric pressure will change slightly. When a storm approaches, the barometric pressure will drop.

ELEV	STD BAR
Feet	"Hg
0	29.92
1,000	28.86
2,000	27.82
3,000	26.81
4,000	25.84
5,000	24.89

6,000	23.98

Different scanners can report the readings in different units. Some scanners read in "kiloPascals" (kPa). 101 kPa is roughly "one atmosphere" or 30" Hg. There is a table below, under MAP, showing the equivalent readings in "Hg, kPa and sensor Volts.

In effect, in a naturally aspirated engine, this is the maximum pressure you can see in your cylinders as they pull the air/fuel mixture into the cylinder. The higher the barometric pressure, the more mass of air can potentially be fed into your engine. Just remember, there is nothing you can do to change BAR…. It is a reading of the atmosphere, not your engine, and should be very close to the barometric pressure reported by the local weather service, or printed on your drag strip time slip.

If you want to check your stock "1 Bar" sensor, the output voltage should be about 4.8 Volts with the key on, but the engine not running. If you have a supercharged engine, and are running a speed-density or N-Alpha system, you might have a "2 Bar" or "3 Bar" sensor.

The MAP sensor measures the barometric pressure when the key is turned on, but before the engine starts. The sensor is about the size of a domino, black plastic, and mounts at the front/passenger side of the intake manifold.

MAP (Manifold Absolute Pressure):

Here is where you can do something about the pressure that forces the air/fuel mixture into your engine. The air cleaner is exposed to atmospheric pressure (BAR). As the air passes through the filter, it loses some pressure. It loses more pressure in the ductwork that feeds it into the engine, the MAF sensor, the throttle body, the intake runners and the restriction of the open valve. Each of these items reduces the air pressure slightly. And gives you a pressure LOWER than atmospheric pressure in your intake manifold. This pressure is called manifold absolute pressure, to avoid using the negative numbers required to measure vacuum.

When a stock LT1 is idling, the "MAP" reading should be about one-third of the "BAR" reading. Check the "BAR", and remember it - it won't change for a while, unless you're in the middle of a hurricane… Then display "MAP". If the BAR = 30.0 “Hg (101 kPA), MAP should be at 10.0 “Hg (34 kPa), or below. On my relatively stock LT1, with a BAR = 30 “Hg, I would see MAP readings at idle of 9.3 “Hg (31.5 kPa) to 9.5 “Hg (32.2 kPa). The readings would fluctuate slightly with the idle. Maybe as low as 8.9 “Hg, and maybe as high as 9.8 “Hg.

If you have a cam that is more aggressive than the stocker, you will see a higher MAP reading at idle. With a fairly radical cam, you might see reading of 18 “Hg or so**.**

The difference between MAP and BAR is your manifold vacuum. If BAR = 30.0 and MAP = 9.5, then your vacuum is 30.0 - 9.5 = 20.5 inches of Hg. If you connect a vacuum gauge to the correct port on the manifold, that is what it should read.

When you start driving, the MAP will fluctuate with the throttle position and the engine load. Close the throttle completely at 2,000 RPM, and the MAP will drop well below 9.0 “Hg. Floor it at low RPM, and the MAP should shoot up to a number equal to, or very close to "BAR". The output of the MAP sensor is very important, because it tells the PCM where to look in the fuel and ignition timing tables. High MAP = high engine load. Low MAP = low engine load.

Conversion Table - MAP pressure units:

VOLTS	0.0	0.3	0.6	1.1	1.7	2.2	2.7	3.3	3.8	4.4	4.9
INCHES Hg	0	2.9	5.9	8.9	11.8	14.8	17.7	20.7	23.6	26.6	29.5
kPa	0	10	20	30	40	50	60	70	80	90	100

TPS (Throttle Position Sensor):

The Throttle Position Sensor (TPS) is the reading out of the rotary motion sensor on the throttle blade shaft. The sensor is located on the throttle body, on the end of the pivot shaft, on the passenger side. When you turn your car "on", the PCM sees the closed throttle voltage reading, and sets this as "0%", or closed throttle. The factory spec for this seems to be as low as 0.40V, and as high as 0.70V. But, I have seen reports of systems that work fine with TPS closed voltages in the range of 0.20 to 0.90V (acceptable voltages to avoid a code vary from year-to-year). Some people drill out the holes in the TPS sensor and try and get the closed position voltage as close as possible to some value like 0.50V, but this doesn’t appear to be necessary. Mine always read 0.64V closed. The key number is “Throttle Position Percent”. That’s what the PCM uses.

As you rotate the throttle shaft, the voltage climbs, typically to a value about 4V higher than the closed throttle reading, or in the range of 4.30 to 4.60V. In between, the voltage should change smoothly, without voltage spikes or dropouts, with throttle position.

TPP (Throttle Position Percent):

Read the description above. With no pressure on the throttle, you should see "0%". With your foot all the way on the floor, "100%". Some scanners seem to max out at "99%". Not sure why. If you aren't getting 99% or 100% at WOT, look for linkage problems, or the carpet under the throttle.

At 2000 rpm cruise, you might only see 10-15 % throttle.

IAC (Idle Air Control):

The Idle Air Control is a little stepper motor (each “step” is a “count”) that moves a pintle in and out of a hole in the plate at the bottom of the throttle body, and allows air to bypass the throttle blades, and enter the intake manifold. This is required to allow the car to idle when the throttle blades are completely closed (as they should be). The PCM plays with the IAC motor to keep the idle at spec, 800rpm for M6's and 650rpm for A4's in neutral. The scanner reads the position the PCM has told the valve motor to move to, which can range from "1" to "160". At idle, you should see **roughly** "20" to "40" counts. And, it should be steady. Any lower and you probably have a vacuum leak, or the throttle return stop screw on the throttle body is preventing the blades from fully closing. If you see numbers higher than this at idle, it is possible you have a dirty IAC motor pintle which is not moving correctly, or plugged air passages leading to the IAC motor. If you have installed a throttle boy airfoil, it is possible it is blocking air flow through the opening that supplies air to the IAC system.

CAUTION – The scanner only shows what the PCM is telling the stepper motor to do. There is NO feedback to the PCM as to the actual position the IAC has moved to. If the scanner indicates the PCM is increasing or decreasing the IAC counts at idle, but the idle speed is not responding, IAC motor may be faulty. There are no codes related to the IAC motor in OBD-1. There is a code in OBD-2 for the actual engine RPM differing significantly from the programmed RPM.

When you start to drive, the IAC value will start to rise. This is done in order to keep enough air flowing into the manifold that if you suddenly let off on the throttle, and let the blades fully closed, there will be enough air to keep the motor from stalling, and provides air to minimize pollutants. The counts I have seen under cruising and WOT conditions are in the range of 60 - 100.

The IAC motor is located at the base of the throttle body, on the passenger side. The PCM stores the "learned" idle position, so that it can return to this value quickly, in order to control idle. This stored value can be "lost" if the power to the PCM is lost, and idle may hunt a bit on startup until the value is relearned.

MAF (Mass Air Flow):

In a "mass air" engine control system, as used in the 94 and later F-bodies, the PCM only needs a few pieces of information to manage the air and fuel mixture.

The most important is the amount of air entering the engine, to be used for combustion with the correct amount of gasoline. More specifically, it needs to know the "mass" (weight) of air, or the number of pounds or grams of air that entered the engine to be used to burn the gasoline.

The Mass Air Flow (MAF) sensor measures the mass of air entering the engine, expressed in "grams per second" or "pounds per minute". Many scanners displays only the metric units - grams per second (gps). But some use pounds/minute.

Note - to convert grams per second to pounds per minute:

grams/second = pounds/minute x 7.56

Example: 30.0 pounds/minute x 7.56 = 226.8 grams/second

At idle, the air mass flow will range from as low as 6gps to as high as 10gps. If you reading is suspiciously low, you may have a vacuum leak. If it is suspiciously high, and the idle speed is correct, it's most likely a "faulty" or "mis-calibrated" MAF. This problem is typical of "home ported" units.

At WOT, the peak air flow in a stock, normally aspirated engine, with a 5,800rpm rev limit will be about 240gps. If the MAF sensor fails to open circuit, it will read ~470 gps.

The MAF sensor works by internally measuring the temperature of the air coming into the system. It then uses the wires to heat the small amount of air that is actually touching the wires, a fixed number of degrees above the incoming air. By measuring the electrical power required to heat the air, and knowing the specific heat of air, the MAF sensor can calculated the "mass" (or roughly "pounds" or “grams”) of air entering the engine. It then converts this signal to a variable frequency output. Inside the PCM, there is a calibration table that converts the frequency to a "mass air flow" rate.

The calibration chart is based on the specific configuration of the stock MAF sensor and air inlet ducting. If you change any component of the system, you upset the calibration of the sensor. The "screen" - actually a honeycomb, made out of thin paper - is there to provide a uniform flow of air across the full face area of the sensor. In this way, since the amount of air flowing past the sensors is the same as the amount of air flowing in other parts of the sensor, it can calculate the total air mass flow through the sensor by measuring only the small sample of air that touches the wire. Removing the "screen", or removing the dividing wing in the housing inlet and outlet halves can destroy the calibration of the sensor.

INTRODUCTION - AIR/FUEL MANAGEMENT MEASUREMENTS:

Now we are getting to the tough stuff. In order to understand what you are looking at, you need to know how the PCM manages the fuel and ignition. Here it is in a nutshell:

- The MAF sensor tells the PCM how much air is flowing into the engine
- The PCM needs to calculate the injector pulse width (time it is turned on and spraying) that will add the correct amount of fuel to give the correct air/fuel (A/F) ratio.
- The PCM divides the mass air flow by the target Air/Fuel (A/F) ratio to determine the mass of fuel required.
- The PCM calculates the injector pulse width required to supply that mass of fuel, and opens the injector to spray the required fuel into the incoming air.

When the computer is operating as described above, it is often referred to as being in "open loop". This means it makes a calculation based on the operating conditions, adds the required fuel, but has no way to tell if it achieved the correct air fuel ratio. "Open loop" is used at startup, until the engine warms up. During "normal" driving, at idle, in-town or on the highway, the PCM tries to maintain a 14.7:1 air/fuel (A/F) ratio. This means by weight, there is 14.7 pounds of air being mixed with every 1 pound of fuel. This applies to hot engine, part throttle, closed loop operation only.

14.7:1 A/F ratio was chosen for several reasons. 1) This is the A/F ratio that produces the least amount of harmful emissions; 2) the catalytic converter is designed to operate best at this ratio; and 3) this A/F ratio gives a reasonable level of fuel economy.

But, what if the engine doesn't behave the way the programmer thought it would? What if someone improved the inlet air system, or the exhaust system and increased the volumetric efficiency of the engine? What if the calculated amount of fuel is wrong, and the A/F ratio is NOT 14.7:1? This is where the oxygen sensors, the short term fuel corrections and the long term fuel corrections come into play. This is called "closed loop" operation:

- To check the results, once in closed loop, an O_2 sensor reports the A/F ratio.
- If the mixture is too lean (above 14.7:1) the PCM adds a little bit extra fuel to the next calculation to richen the mixture up. This is a "short term fuel trim” (STFT), also called the "integrator" (INT)..
- If the mixture is too rich (below) 14.7:1, the PCM subtracts a little bit of fuel from the next calculation. Whether it is adding or subtracting from the calculation, it is still called a STFT.
- Then the cycle is repeated, and as a result the mixture is constantly cycling from very slightly lean to very slightly rich. This is done to help the catalytic converters function efficiently. The average, however should be 14.7:1.
- If the computer sees that it is always making the same correction with the short term values – say always adding fuel - after a while it will make a "long term fuel trim" (LTFT) or "block learn multiplier" (BLM). This means that a new correction factor is actually stored in the PCM so that it can be used over and over again in future calculations.
- If the LTFT value is right, the short term or integrator corrections will become smaller, and again start to vary slightly rich and slightly lean, with the average equal to 14.7:1.

- There is a different LTFT for each of at least 18 operating conditions. This is arranged as a 4x4 (16 "cells") matrix, with MAP on one axis, and RPM on the other. This means that if you move the throttle or increase the rpm's, you will probably jump to a different cell in the grtid, and see a slightly different value for the LTFT.

In order to operate in "closed loop", three conditions must be met after startup, and these are explained below in the "CEL" section.

All of the info immediately above explains how the engine works when it is in closed loop. This condition only applies to "normal" driving and NOT to wide open throttle (WOT) driving - the kind we like best! Once the throttle exceeds about 70-75% open (varies, depending on engine RPM), the PCM no longer responds to the O_2 sensors. The O_2 sensors are dropped out of the "loop", and the PCM enters "power enrichment" (PE) mode.

It targets a new, richer A/F ratio (typically around 11.7:1 with stock tuning), that is better suited to high power/torque, rather than good gas mileage. The system then operates as described in the first section, simply measuring the air flows, dividing by the target A/F ratio, and putting in what it thinks is the correct amount of fuel. In PE mode, there is no "feedback" from the O_2 sensors to tell the PCM it is making the correct calculation, and the STFT's, are usually locked at their neutral value of 128. The LTFT's **may** or **may not** be used in "enrichment" mode. It appears that if the PCM was using the LTFT's to **add** fuel (LTFT greater than 128), the PCM will use the Cell 15 LTFT's for enrichment mode. If the PCM was using the LTFT's to **subtract** fuel (LTFT under 128), the PCM will use Cell 18, and lock the LTFT's at 128 also.

In the LT1's, AS NOTED, the PE mode target A/F ratio is ~11.7:1. In general terms, this is too rich for peak power or peak torque. Classical engine design generally assumes that peak power/torque is made with a 12.8 to 13.2:1 A/F ratio. Now you know where the line "our cars run too rich" comes from. In WOT driving the target A/F ratio is on the rich side, and the engine will generally make more power with a slightly leaner mixture. Quick way to pick up 10 – 15 HP…. Lean out the PE mode target A/F ratio in the program.

If you truly understand all of the above, you will understand that in a properly functioning engine, with all the sensors reporting accurately, there is no way for your car to "run rich" during "normal" driving. If it is, and you smell raw fuel during normal driving, or if you are seeing significant carbon build-up from the exhaust, there is probably something wrong with the control system. For the LTFT's and the STFT's, the "neutral" value is 128. If the PCM believes the engine is running lean, this value will be increased above 128, to prevent the engine from continuing to run lean. The maximum value for the LTFT is 160. Since the "trim" number is a multiplier, in the equation it is divided by 128. So 128/128 = 1.000 and there is no correction to fuel flow. If the "trim" number increases to 160, the multiplier is 160/128 = 1.250, which means the "trim" is adding 25% extra fuel to keep the engine from running lean. In OBD-1, the "trims" are reported as a "number"…. like 128 or 160. In OBD-2, the "trims" are reported as a percent. 128 = 0%, 140 = +9.4%, 160 = +25%, etc.

If the “trims” are subtracting fuel, the minimum value for the LTFT is 108. 108/128 = 0.8438. In that case the PCM is subtracting 15.5% of the “normal” fuel. In OBD-2 this would show up as -15.6%.

STFT’s have a much wider range, but they are not saved, and are recalculated many times per second.

And just to clarify, to make the whole system more accurate, in our LT1 engines, the control system has been divided into two separate systems….Bank 1 (driver's side) and Bank 2 (passenger side) of the engine.

If you have a scanner that reports “air/fuel ratio”, keep in mind that this is the “target” A/F ratio the PCM is commanding. There is no accurate feedback as to the actual A/F ratio. If the PCM is commanding 14.7:1, and the O2 sensors are producing an average output of 450 millivolts (mV), is can be inferred that the system is operating as intended, but there is no direct feedback as to the actual A/F ratio the engine is running at.

CEL or CELL # (Fuel Map Cell):

Remember that "long term fuel correction matrix" from above. It is a grid of 16 cells, with MAP on one side and RPM on the other. In addition to the 16 cells shown above, there are 3 more that you will see:

- Cell 16 is the "idle" cell
- Cell 17 is used on start-up, at low load, or when the throttle is closed and the car is moving
- Cell 18 is used on start-up, at higher loads.

Cells 16, 17 and 18 are the only cells used on cold start-up (Cell 16 is used at idle for all conditions). They will remain in use until the engine meets all the requirements for closed loop operation. These requirements include:

-The O_2 sensors have reached operating temperature and are beginning to cycle above and below 450mV

-The coolant temperature has reached the minimum set in the PCM. This seems to be in the range of 120 -140 degrees F.

-The "timer" has timed out - this seems to vary from 3 to 5 minutes (206 seconds is most common), and seems to be longer in colder weather.

So, all the "CEL" reading tells you is what cell you are operating in. If you display "CEL" and start driving, you can watch the PCM move through the fuel map. Drive in 4th gear at 1,500RPM, with very light throttle pressure. CEL should display "02". Press your foot down gradually on the accelerator, pedal, trying not to go above 2,000RPM. The CEL display will progress from "02" to "06" to "10" and finally to "14".

Try it again, this time starting above 2,000RPM. At low load you will see CEL = 03, and as you press the accelerator, it will progress "03", "07", "11" and finally "15".

RPM................900.....1200.....2000

..................12...|...13...|...14...|...15

MAP=80---------|--------|--------|--------

..................08...|...09...|...10...|...11

MAP=50---------|--------|--------|--------

..................04...|...05...|...06...|...07

MAP=30---------|--------|--------|--------

..................00...|...01...|...02...|...03

As noted in the section above, if you go to WOT, and go "open loop" (actually "enrichment" mode), the OBD-I PCB's will usually move to CEL = 15. This appears to be where the PCM gets the LTFT’s from at WOT. This is a key, and would explain how the PCM uses what it learned in closed loop, to set the fuel rates in open loop. And this would explain why you can't change your WOT A/F ratio with an AFPR. Note that sometimes the system will shift to CEL = 18 at WOT. In this instance, if you could watch the LTFT’s and STFT’s, you would find that all have been set to "128". This was explained in the section above.

Other than watching the numbers, there's not a lot you can learn, unless you construct a table of LTFT’s corresponding to Cells 01 through 16. This would allow you to diagnose a vacuum leak or a leaking injector. This is where a data logging system like Scan9495, TTS DataMaster (no longer supported by TTS, but you can find copies of the files online) or AutoTap (discontinued) really shines.

Finally, it would be interesting to see if you have ever actually seen the system operate on Cell "00".

LO2/RO2 (Left O_2 Sensor/Right O_2 Sensor):

In the single-cat 93 to 95's, there is an oxygen sensor located at the base of the driver's side exhaust manifold, and another just below the passenger side exhaust manifold, in the y-pipe branch. These sensors generate a small voltage, proportional to the difference between the amount of oxygen in the exhaust gasses, and the amount of oxygen normally occurring in the atmospheric air. If the combustion of the air/fuel mixture is chemically "perfect", it is called "stoichiometric". It has an input composition of 14.7 pounds of air per pound of fuel, or a 14.7:1 air/fuel ratio, and the O_2 sensor will generate a signal level of 0.450 volts (or 450 mV = millivolts). The PCM actually feeds the 450 mV voltage to the sensor, and the sensor adds or subtracts voltage based on the difference between the oxygen levels in the exhaust on the outside of the sensor thimble, and the oxygen in the ambient air on the inside of the sensor thimble.

When you first hook up a scanner displaying real time values, and start your car, you will be convinced either the scanner is broken, or your car is "possessed". Don't worry…… the scanner is SUPPOSED to be showing constantly changing O_2 sensor values. The sensor is extremely sensitive at an A/F ratio of 14.7:1. Go very slightly richer than that (14.6:1) and the voltage can soar to 700mV. Go very slightly leaner than 14.7:1 (say 14.8:1) and the sensor output voltage plummets to 200mV. Since the PCM is constantly juggling the fuel up and down to keep it right at 14.7:1, the voltage is going to jump up and down too. So, you will see that, since the PCM updates it's calculations nearly 9 times per second, **the O_2 sensor voltages are going to be cycling rapidly back and forth** between ~100 and ~900mV, and you might even see values as low as 050 mV, and as high as 950 mV. **THIS IS NORMAL.**

As described above, when you go WOT, the O_2 sensors are no longer part of the control "loop", but they still report the A/F ratio by way of the voltage they generate. Note however, that this is NOT the primary function of the sensors, and they were never intended to be used this way. Because of this, they are NOT necessarily accurate at the kind of A/F ratios you see, or want at WOT. But, they can tell you ROUGHLY whether you are running rich (12:5 or richer) or lean (13.5:1 or leaner). And, by watching the voltages before and after a modification, you can measure whether the mod made the car run richer or leaner. But you can't really tune in WOT with them.

The output voltage of the O_2 sensors is very "flat" under rich conditions… a very large change in A/F ratio only results in a very small change in mV's. And, under these rich operating conditions, the sensors become extremely sensitive to operating temperature. A change in operating temperature can alter the mV's as much as an actual change in A/F ratio - so be careful with the O_2 sensor readings. They are only a "guide" at best.

A caution - if you have "reset" the computer by pulling the PCM-BAT fuse, or a cable off the battery, you should only look at the O_2 sensor readings after you have driven for a few hours, in order for the long term correction values to stabilize.

My ROUGH guidelines for evaluating the WOT O_2 readings, as recorded on a scanner:

> The left and right bank readings should be no more than 30mV apart. It is normal for the right and left volts to differ.. If you use a scanner with data log recording software, the best readings will differ left to right by 5 or 10mV, and 20 to 30mV is not unusual. Anything over that is suspect. Either one sensor (or even both) is screwed up, or the engine has a problem that only shows up on one side of the motor.
>
> My car ran best with O_s readings in the high 800's… say 870-890mV. Keith at ws6.com seems to prefer readings as low as 820mV. Others like low 900's. All of this is for a normally aspirated (no supercharger or nitrous) motor. When you get into a major power adder, you want a richer mixture, and readings in the range of 925-950mV may be desirable for these motors.
>
> If you ever run your car on a chassis dyno, and they hook up a wide-band O_2 sensor for tuning, try to find out how your OEM sensor mV's compare to the wide-band A/F ratio. This will give you a baseline to tell you how "accurate" your OEM sensors are, and help you interpret future changes.

Remember, the O_2 sensor can only measure OXYGEN. It can't measure fuel, or other components of the exhaust, so if you have a cylinder that misfires, there will be all the oxygen that was in that cylinder, and all the fuel that was in that cylinder, in the exhaust. The sensor will see that oxygen, and the voltage will drop, indicating "lean", but it is not really lean.

Same with an exhaust leak. If you have an exhaust leak before the sensor, the fast moving exhaust gasses can actually "suck" ("educt" is the technical term) air in through the leak, and the sensor will report the mixture as too lean, the PCM will add more fuel, and most of the fuel will be wasted…. maybe just a little burned in the hot exhaust gas, reducing the oxygen. An exhaust gas leak can really mess up your computer's calculations, and cause the gas mileage to plummet.

At cold start, the O_2 sensors are cold, and will not work. They have to heat up to 600^oF before they work accurately. When you start your car, a scanner will show about 450 mV. As the car heats up, over a 2 or 3 minute period, **IF YOU HAVE A FUNCTIONING AIR PUMP** the readings will gradually drop, going below 100mV. Then they will suddenly start to fluctuate, in the 100 to 800mV range, indicating the car is operating in closed loop. If the AIR pump shuts off before the PCM enters closed loop, you will see richer O2 sensor readings of 800 mV and above, due to the cold start enrichment target A/F ratios.

A word of caution here - I hear a lot of people asking if they can just measure their O_2 sensor voltages with a voltmeter. Everything I have read says the answer to this is probably "NO". First, the O_2 sensor generates a small current. Many VOM's also apply a tiny current to the circuit. This current can damage the O_2 sensors. The caution in the Howell Engine Development Manual states:

> "If measuring sensor voltage with a voltmeter, make sure the impedance of the meter is at least 50megohms. And, the resulting voltage measurements can still be off by 200 - 300 mV's. "

I have never tried to use a voltmeter on an O_2 sensor, so I don’t know how well it would work, but based on the above, it sounds risky.

LP/RP (Left Injector Pulse Width/Right Injector Pulse Width):

After the PCM has received the air flow mass, it calculates the amount of fuel required. It then turns on the injectors for just long enough to spray this amount of fuel. The amount of time the injectors are "turned on" is a small fraction of a second, and hence the "on time" or "pulse width" needs to be measured in "milliseconds", which are 1/1000ths of a second. The scanner tells you what pulse width the PCM has calculated. Note that it is NOT measuring how long the injector actually stayed open, or if it opened at all. It is only showing what the PCM thinks is the amount of time required to spray the required amount of fuel. If your injectors have locked closed due to excessive pressure, or they are stuck open because they are dirty, the computer will still show the calculated pulse width.

The injectors are rated at how may pounds an hour of fuel they would flow, if the fuel pressure is 43.5 psi (3 bar) and they are wide open all the time. This is why you can't change the injectors without telling the PCM, and correcting the values used for pulse width calculation. And, if you change the pressure in the fuel system, there is no way for the PCM to directly correct the calculation. It has to wait until the extra flow (in the case of a higher fuel pressure) shows up in the exhaust as "rich", and then change the long term fuel corrections to reduce the amount of pulse width.

At idle, you will see pulse widths around 2 to 3 mS. At WOT, in a stock engine, you will see pulse widths of about 15.0 mS. And, the left and right values should be approximately the same. If they are significantly different, you have a malfunction that is only affecting one side of your engine.

LIN/RIN (Left Integrator/Right Integrator):

As noted above, the engine calculates how much fuel is required, and sprays it. The O_2 sensor tells the PCM how good its calculation was. If the calculation is "off" slightly, the PCM will briefly store a correction factor. Think of the fuel calculation as an equation, where the correction factor is a "multiplier". The "normal" multiplier, or neutral or uncorrected value in the equation is "128". This was chosen because it is the midpoint of an 8-bit binary number system… the kind used in digital computers. If the PCM feels it needs a little extra fuel for the next try, is increases this number, lets say to 130 or 135. It makes the calculation, and the cycle starts again.

The key points here:

- This is the "short term" fuel correction. It is used once and basically (and to simplify) thrown away.
- When the integrators are above 128, the PCM is adding more fuel than it "normally" would. This means the oxygen sensors have told it the engine is running "lean" with the uncorrected calculation.
- When the integrators are below 128, the PCM is subtracting some fuel from what it "normally" would calculate. This means the oxygen sensors have told it the engine is running "rich" with the uncorrected calculation.

These numbers, when displayed on the ScanMaster, will be constantly moving, just like the O_2 sensor readings. In fact, they are responding to the O_2 sensors' readings, via the PCM. You won't learn much from watching them, but, as a guideline, the Integrators should seldom stray too far from 128…. Say they stay most of the time in the range of 123-133. And they should be above 128 as often as they are below 128. You will probably see them stabilize as close as 126-130 during extended periods of idling, or steady throttle cruising.

Another use for the Integrators is to tell you if the PCM has gone into "closed loop" operation. Remember that when you start your car, the O_2 sensors are not able to operate. They have to heat up to 600 degrees F. So the PCM can not operate in closed loop. In this case, it locks the Integrators at 128. On a cold start, switch the ScanMaster to LIN or RIN, and watch it. It will stay at 128. When it starts to move, your engine has just met the three required conditions for closed loop operation. Not much to learn from this, except it will give you an idea of the period the "timer" requirement takes, and the coolant temperature that it needs. And if the Integrators never start moving, you have a big problem that is preventing you from operating in closed loop.

When you go to WOT, the Integrators will also lock at 128. Again, the PCM has dropped the O_2 sensors out of the loop. Technically, this is still "closed loop" and if you have a scanner that shows the "loop status", it will still show "closed loop" because 1) the conditions required for closed loop have been met, 2) technically, at WOT you enter the "enrichment" mode, not "open loop".

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LBL/RBL (Left Block Learn/Right Block Learn):

Here's where your ScanMaster is going to tell you a lot more…. You just have to know how to find it.

When the PCM misses on the fuel calculation, it attempts to correct the condition by using the "Integrators". But, often this isn't enough. If the PCM sees that the Integrators are always on the high side, or always on the low side of 128, it figures something has affected the engine that will keep it operating at this point for a longer term. So, rather than correcting with a "short term correction" (integrator) and then throwing the value away, it better make a "long term correction" and save it. These long term corrections are call "Block Learns", one for the left side of the engine and one for the right.

The Block Learns look just like the Integrators. They theoretically can range from 1 to 255, with a mid-point, or neutral or "normal" value of 128. They are used just like the Integrators. They are multipliers in the fuel calculation equation. The main difference between a Block Learn and an Integrator is that the Block Learn is stored in the PCM, in volatile memory. And there is a Block Learn, or long term fuel correction factor, for each Cell in the BLM matrix. The Integrators are used once and thrown away (this is a little bit of a simplification, but it is essentially how it works).

When you pull the power to the PCM, you lose the volatile memory. The only thing in the volatile memory seems to be the Block Learns, the stored DTC's and the "learned idle" value for the IAC motor. So, when you "reset" your computer, you "reset" the Block Learns to the default value, which is 128. And when people say the PCM learns about changes to the engine, this it the primary learning area… the Block Learns. Pull the PCM power and clear the Block Learns. Start the car and let it idle, watching the LBL or RBL. It will start at 128. Switch to the corresponding Integrator, and it will NOT be 128. It will be mostly on one side of 128. Gradually, the PCM will move the BL in the same direction as the INT. This pushes the BL to one side of 128, and pulls the INT back down closer to 128, but still moving slightly above or below 128.

It appears that the BLM's can not go below 108. When they reach 108, the PCM will set a "rich" code. This doesn't necessarily mean the O_2 sensor is faulty. It may just be that something is causing the PCM to add way more fuel than the motor needs, and the long term corrections can not subtract enough fuel to overcome that seemingly "rich" condition. Similarly, it appears that the maximum value for a BLM is 160, and when that value is reached, a "lean" code will be set.

Now remember, there are 16 fuel BLM "Cells". If you did what was described above, your "idle" Cell (16) will have rebuilt the BL for that Cell, but all of the other Cells will still be at 128, because you have not operated the car under the conditions that define those Cells. You need to drive it, and you need to make sure it operates over a broad range of RPM and engine load. This will assure you that you have reached a stable value for the BL's in each of the fuel map Cells. Now you can start trying to extract these values from the PCM. This is where a data collection type software beats the ScanMaster… it will record the data for you.

Try and get the LBL and RBL values for a range of Cells. This requires that you display the "CEL" and when you get the one you want, switch quickly to RBL or LBL and have someone write down what you see. This is easy for Cell 16 = idle, but harder for the high load cells. But, try to get idle (16), max rpm/max load (15) and one or two of the lower ones (02, or 03) and some mid ones (7, 8, 9 or 10).

If you have made a significant change to your engine, example an AFPR set at 38psi (no vacuum), rather than the factory 43.5psi, you will see the effects of the change in the BL's for ALL Cells. In this example, you might find that all the BL's have gone into the low or mid 130's to add the extra fuel that the lower pressure is not providing. If all the BL's are close to each other, and LBL and RBL are not too far apart in each Cell, try to think of what you did that would be requiring more or less fuel. You should be able to explain it away.

But, let's say you see differences:

- If LBL for a Cell is a lot different than RBL for that Cell, there is something affecting one side of the engine. Example would be a leaky or clogged injector, an exhaust leak or a misfire. This is somewhat subjective, but I would suggest you look for reasons when the difference from right to left is 5 or greater.

- If the low load/low RPM cells (16, 02, 03) are well above 128, but the high load/high RPM Cells are close to 128, you might have a small or medium vacuum leak.

And let's clarify a couple of misconceptions:

- If your BL's are above 128, it is telling you that IF your PCM was not making these corrections, the engine would be running lean in closed loop operation. But, it is making the corrections, so the engine is neither lean, nor rich. It is using the corrections to stay exactly it 14.7:1.
- If your BL's are below 128, it is telling you that IF your PCM was not making the corrections, the engine would be running rich in closed loop operation. But, it is making the corrections, so the engine is neither lean, nor rich. It is using the corrections to stay exactly it 14.7:1.

- You engine can not run lean or rich in closed loop, unless the control system is not working, or the oxygen sensors are providing incorrect information. They will provide incorrect information if the are defective, there is an exhaust leak, there is a leaky injector, or there is a miss.

SP (Spark Timing):

This is one of the spark timing tables. On the scanner, it is tyupically shown as a positive number (actually there is no "+" sign). On some other scanners, this is shown as a negative number. Don’t panic. Just call it "advance" and ignore the negative sign. The main spark map has supposedly been extracted from the LT1 factory tuning, and is presented below. It is only part of the "map"… in actuality it extends to 7,000rpm. And there is another table for idle. And there appears to be “offsets” that add or subtract timing based on other sensor inputs. The scanner shows spark timing in whole degrees. In other words, there is no decimal point. Spark retard includes the decimal.

	400	600	800	1000	1200	1400	1600	1800	2000	2200	2400	2800	3200	3600	4000
25	16	24	27	32	34	35	35	35	35	35	35	35	35	35	35
30	16	24	31	38	40	40	41	40	40	40	40	40	40	40	41
35	27	27	32	39	39	41	41	43	43	43	43	43	43	43	43
40	28	30	33	36	38	40	41	43	43	43	43	43	43	44	44
KPA	28	30	33	34	37	38	40	41	41	42	43	42	42	43	43
50	26	29	32	33	35	36	38	39	40	40	41	41	41	42	42
55	24	27	29	31	34	35	37	38	39	40	40	40	41	41	41
60	24	25	26	29	33	34	35	37	38	39	39	39	40	41	41
65	20	24	25	26	29	32	34	36	37	38	39	38	38	39	39
70	20	21	22	23	25	28	31	34	35	37	37	37	37	38	39
75	18	18	19	20	22	25	27	30	31	34	35	36	36	37	38
80	14	16	16	16	18	22	23	26	28	31	34	35	36	37	38
85	12	13	14	14	16	20	20	23	25	28	32	35	35	37	37
90	11	11	11	11	14	17	18	21	24	28	31	35	35	35	35
95	9	9	9	9	12	14	16	19	23	27	30	34	34	35	35
100	8	8	9	9	12	14	16	19	23	27	30	33	33	33	33

The top of the columns is labeled in "RPM", the rows, across, are labeled with manifold absolute pressure (MAP) expressed in kiloPascals. Remember, from the write-up above, MAP is an indicator of "load" on the engine. At WOT, your MAP will approach 100kPa, or 29 to 30"Hg depending on the scanner (at sea level).

This means your engine is under high load… the throttle is wide open. As RPM increases, the spark timing changes.

At idle, you will typically see 18-22 degrees advance. That would be shown on the idle map, not the table above.

At 2,000rpm cruise (low load), you will start to see spark timing at up to 45 degrees advance. At WOT. I saw numbers in the 38-39 degree advance range.

The scanner reading is what the PCM is telling the ignition system to do. There is no feedback telling the PCM, or the scanner exactly when the spark is occurring. The scanner indicates the value from the above table +/- any offsets, MINUS the spark retard. A scanner will NOT show any retard that is invoked by an external timing retard box, like the ones built in the MSD or Accel units.

Let's say, using the table above, you are at WOT, with 95kPa MAP, and 3,600 rpm. The map says to use 35 degrees, and if there is no knock detected, this is what the PCM sets the timing at. BUT, if there is knock detected under the above conditions, and lets say the PCM (as indicated on the scann) is pulling out (retarding) the spark by 4 degrees, the net timing called for by the PCM (and shown on your scanner) is 35 degrees, minus the 4 degrees retard = 31 degrees advance.

Another caution - It appears that there may be additional tables in the PCM that affect ignition timing. The value shown on a scanner seemingly can exceed the value show in the spark map by up to 3 degrees. Perhaps this is a function of an offset table that uses inlet air temperature or coolant temperature. I honestly do not know. I do use corrections like that in my MoTeC programming, so it doesn't seem to be unreasonable that the factory PCM makes similar offsets. I would like to hear from anyone who has more specific data.

RETARD:

This is easy. Retard should be "0.0". Finished.

Well, not quite. The knock sensor is screwed into the lower block on the passenger side. It also functions as a coolant block drain plug. When the knock sensor (a little microphone) is activated by the correct noise (there is actually "some" tuning built into the sensor, in the form of a frequency sensitive piezo crystal pickup) it sends a signal to the knock module (only on 94-97). The knock module (hopefully) filters out the "non-knock" related noise, and passes the remaining signal to the PCM. The PCM immediately, and rapidly pulls out timing at a relatively high rate, until all "knock" type noise disappears (or at least reaches the acceptable threshold value). Then, the PCM starts to more slowly put the timing back in.

This is why ANY knock hurts performance. The PCM pulls out timing very fast, and probably overcorrects. Then, even if the cause of the knock is gone, the PCM puts the timing back in very slowly. Hence, some people have even suggested that the HPP+ strategy may even be LESS timing, because that way there is less chance for harmful retard… confusing. But I don't think anyone uses the Hypertech Power Programmer any more, so it's a moot point.

But, as far as your scanner is concerned, you want ZERO-point-ZERO retard. If you are using cheap gas, or get a tank of poor quality premium, you might see retard beginning to appear it idle or under very light throttle changes. If you suspect this is bad gas, dump in a can of 104+, or similar octane boost. It will help.

Under certain other conditions, you might see an occasional small amount of retard as you drive. Most likely, you will also be experiencing high coolant temperatures, or high inlet air temperatures. But for most of your driving, retard should be "0".

Another caution - when the knock sensor is active, the engine is operating on the edge of detonation, but the PCM is retarding the spark to prevent any real damage. In this case, you will probably NOT hear any knock. If you hear knock, there is a probably a problem with the knock control circuit, or the amount of knock is too great for your PCM to correct. You may have a serious problem and need to get it fixed!

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EGR (Exhaust Gas Recirculation):

This readout tells you when the Exhaust Gas Recirculation (EGR) system is working. The EGR valve is opened to allow exhaust gasses to enter the combustion chamber with the air and fuel. This reduces the combustion temperatures, and reduces the formation of oxides of nitrogen, a pollutant - not to be confused with nitrous oxide (N_2O) which is an aphrodisiac to the bottle-fed types among us….

The EGR system typically does not work at idle, and does not work at WOT. So it has little impact on performance. If the system is leaking, it will hurt performance though, and it tends to heat up the back corner of the intake manifold, but that is not of interest to the ScanMaster.

The EGR valve is turned on by applying vacuum. The vacuum is controlled (turned on and off) by the vacuum solenoid. The solenoid is "pulse modulated". The vacuum solenoid is switched on and off rapidly, and the more "on" time is has, the more EGR is flowing. The ScanMaster reads the pulse modulation "percentage" or the percent of the time (out of 100%) that the EGR valve is (supposed to be) operating. This is not a measure of how much EGR is actually flowing, only of how much it is supposed to be flowing. If there is a problem elsewhere in the EGR system, the ScanMaster doesn't know about it.

Watch the readout. Most likely, if you are cruising along, and push the throttle a little firmly and a little rapidly, the EGR value will jump from "0" to "100". You don’t see values in between too much, but it is possible.

The EGR valve is the big black donut shaped device on the back of the intake manifold. Exhaust gas flows from a tube on the #8 exhaust manifold runner, to the back of the intake manifold. The EGR valve controls how much, if any, exhaust gas it admitted to the intake manifold. The solenoid that activates the vacuum is located on the drivers side of the intake manifold, on a clip near the back. The source of vacuum is a port on the drivers side of the intake manifold, near the middle by the PCV valve.

CCP (Carbon Canister Purge):

The carbon canister is a "can" of "carbon" (surprise) located in the driver's side rear fender, near the fuel fill pipe (93-98); and on top of the plastic fuel tank on the 99-02 models. The fuel tank is sealed, and if any vapors are generated they will vent through the canister. The carbon absorbs the hydrocarbon vapors and keeps them from polluting the atmosphere. The collected vapors are then sucked out of the canister by a vacuum line from the intake manifold. This is called the Carbon Canister Purge (CCP) - also called EEC by the factory - and like the EGR system above, it is a pulse modulated system, and the scanner tells you the % open (% modulated on) the system is. You can see this occur almost any time, even at WOT. This data is not really very useful, but looking at some lean or rich conditions, they can be correlated to the EVAP system, by looking at the rich or lean events side by side with the EVAP %..

The solenoid that activates the purge is located on a clip that mounts in the middle of the passenger side of the intake manifold. The vapor is brought from the rear of the car in what appears to be a "third" fuel line - it is just a vapor line. The line connects to a metal tube and then a hose that curves around the front of the engine under the throttle body, and connects to the solenoid. The line from the solenoid connects to the passenger side of the throttle body.

ACP (Air Conditioning Pressure):

This is the Air Conditioning system Pressure (ACP). This is important to the PCM, because when the air conditioning is on, it needs to alter the amount of fuel the engine needs, maybe turn on the fans at lower temperatures, and cut off the A/C at WOT.

MAL/DTC (Malfunctions/Diagnostic Trouble Code):

The scanner will retrieve trouble codes.

These are the OBD-I Diagnostic Trouble Codes (DTC). You can look these up in a chart and find out what the problem is. Just make sure it’s a chart for an LT1 V8, of the correct year. Many charts are out of date, confuse the old TPI codes with the newer codes, confuse 6-cylinder codes with the V8's. Just be sure you have the right table. The ones on the f-body.org FAQ's, for example have several errors. The list shown below is believed to be reliable for 94/95's.

Shoebox has the correct OBD-1 codes, plus the OBD-2 codes.

11 - SES lamp circuit

13 - Bank 1 (left) O2 sensor, open circuit

14 - Coolant temp sensor, signal voltage low, high temperature

15 - Coolant temp sensor, signal voltage high, low temperature

16 - OptiSpark low resolution pulse not found

18 - Injector circuits

21 - TPS voltage high

22 - TPS voltage low

23 - IAT sensor, signal voltage high, low temperature

24 - VSS circuit

25 - IAT sensor, signal voltage low, high temperature

26 - Evaporative emissions canister purge solenoid circuit

27 - EGR solenoid circuit

28 - Transmission range pressure switch fault

29 - AIR pump circuit

32 - EGR recirculation

33 - MAP sensor, signal voltage high, low vacuum

34 - MAP sensor, signal voltage low, high vacuum

36 - OptiSpark high resolution signal faulty

37 - Brake switch stuck "on"

38 - Brake switch stuck "off"

41 - Ignition control circuit, open

42 - Ignition control circuit, short or grounded

43 - Knock sensor circuit

44 - Bank 1 (left) O2 sensor, lean

45 - Bank 1 (left) O2 sensor, rich

46 - PASS-Key II circuit

47 - Knock sensor module circuit, or module missing

48 - MAF sensor circuit

51 - EEPROM program error

53 - System voltage high

55 - Fuel lean monitor

58 - Transmission fluid temp circuit, voltage low, high temperature

59 - Transmission fluid temp circuit, voltage high, low temperature

61 - A/C system performance

63 - Bank 2 (right) O2 sensor, open circuit

64 - Bank 2 (right) O2 sensor, lean

65 - Bank 2 (right) O2 sensor, rich

66 - A/C refrigerant pressure sensor circuit, open or shorted

67 - A/C refrigerant pressure sensor circuit, pressure sensor or clutch problem

68 - A/C relay circuit, shorted

69 - A/C clutch circuit

70 - A/C clutch relay driver

71 - A/C evaporator temp sensor circuit

72 - VSS loss

73 - Pressure control solenoid circuit, current error

74 - TCS circuit low

75 - Transmission system voltage low

77 - Cooling fan relay control circuit

79 - Transmission fluid overtemp

80 - Transmission component slipping

81 - Transmission 2-3 shift solenoid circuit

82 - Transmission 1-2 shift solenoid circuit

83 - (M6) Reverse inhibit system

84 - (A4) Transmission 3-2 control solenoid circuit

84 - (M6) Skip shift solenoid circuit

85 - Transmission TCC stuck "on"

90 -Transmission TCC solenoid circuit

91 - Skip shift lamp circuit

97 - VSS output circuit

REFERENCES:

Here are a few books and manuals that I use, and which might help you learn more:

- "How to Tune & Modify Chevrolet Fuel Injection", Ben Watson, Motorsports International, ISBN 0-7603-0422-X

- "Understanding Automotive Electronics", William B. Ribbens, Newnes, ISBN 0-7506-2100-1
- "Camaro/Firebird 1993-98 Repair Manual", Chilton's, ISBN 0-8019-8814-4
- "Service Manual for Corvette/Firebird/Camaro LT1 & TPI", Howell Engine Developments, Inc.
- "Corvette Fuel Injection", Charles O. Probst, Bentley Publishers, ISBN 0-8376-0861-9