Fuel Trim Diagnostics

Using Fuel Trims during a diagnostic plays an important function in plotting a trend, be it either a RICH or LEAN trend. Being able to interpret your scanner Fuel Trim Data requires a basic knowledge of the interaction of Short Term Fuel Trim and Long Term Fuel Trim data.

For the purpose of this discussion paper, we will use references to the GMH VT Commodore V8 and the VT Series II Gen III V8.

OBD 1

Pre OBDII GMH injection systems provided a means of fuel monitoring by the Electronic Control Unit (ECU).

The fuel monitoring system allowed for corrections to the base fuel injection "On Time" of the injectors over time i.e. as the engine run parameters altered over the life of the engine, the systems fuelling would adapt to suit those running conditions.

Scanners used two data streams which represented the ECU recorded fuel monitor:

- **Integrator**
- **Block Learn**

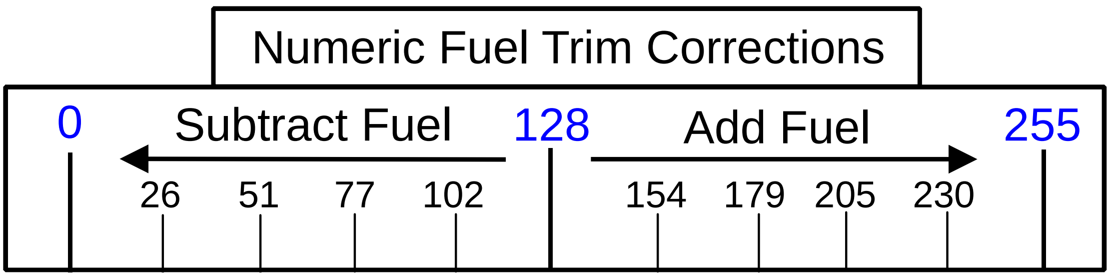
The **Integrator** value is the referenced Short Term Fuel Correction and the **Block Learn** is the referenced Long Term Fuel Correction.
Hence, we could now reference the two data streams as:

- **Integrator** = **Short Term Fuel Trim**
- **Block Learn** = **Long Term Fuel Trim**

The data stream represented by the scan tool is expressed as a numeric value of 0 to 255.
If there was no fuel correction occurring in either Block Learn or Integrator, the numeric value would centre at 128.

If the ECU had to **ADD** fuel to either the Integrator or the Block Learn to maintain a stoichiometric balance (Air/Fuel Ratio), the numeric value would be between 129 and 255.

If the ECU had to **SUBTRACT** fuel from either the Integrator or Block Learn, the numeric value would be between 0 and 127.



OBD II

The implementation of increased of vehicle tailpipe emission control led to a change in industry standards.

A vehicles computer power increased, the number of Oxygen Sensors fitted to vehicles increased, vehicle globalisation was growing etc. so a new recognised set of rules was required. Thus, the OBD II standards were introduced.

With the OBD II standards in place, new nomenclature was also introduced. Terms such as Block Learn and Integrator and the way these were viewed and measured on your scanner also changed.

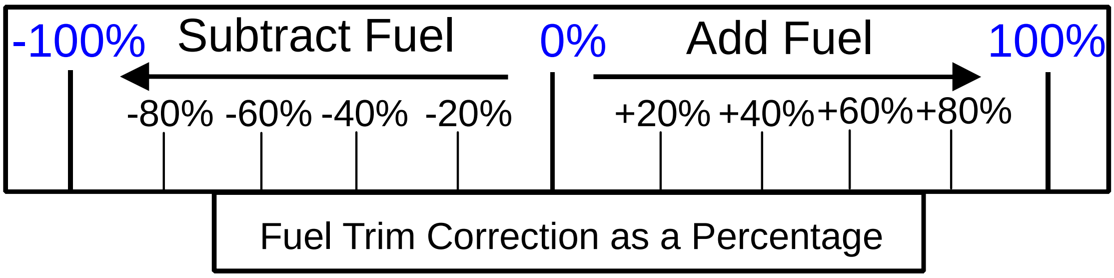
However, the transition to new naming and viewed measurements uses an application of the same set of general rules as used by OBD 1.

Block Learn is now known as Long Term Fuel Trim (LTFT) and Integrator as Short Term Fuel Trim (STFT).

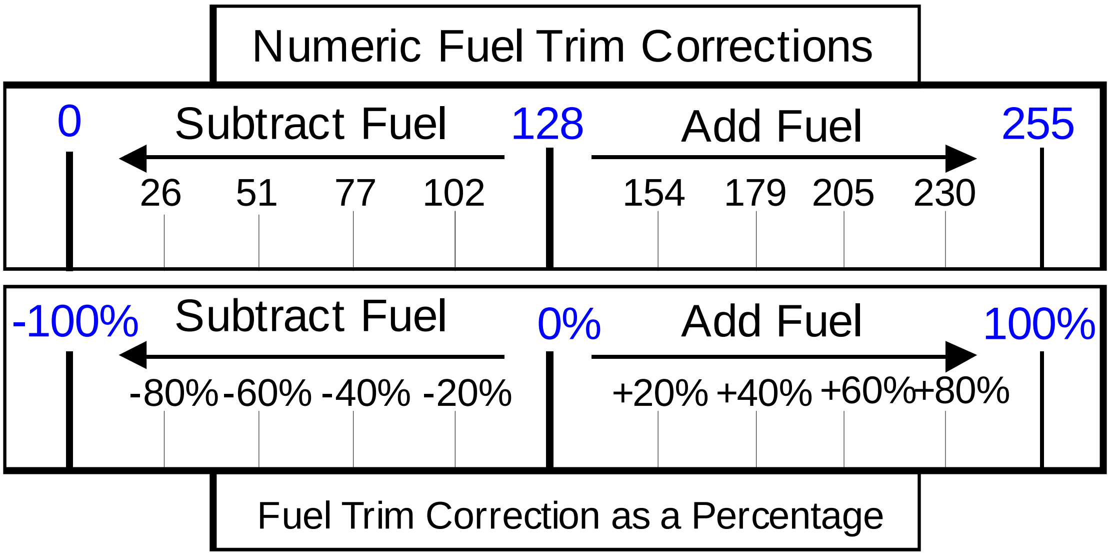
- Block Learn = **LTFT**
- Integrator = **STFT**

The measurement values are now expressed as a percentage when viewed on your scanner. Instead of using a range of 0 to 255, the range is now 0 to -100% and 0 to +100%

Percentage Chart



Numeric and Percentage Comparison Chart



OBD II has specific monitoring of the fuel trim corrections. If the system detects problems with the air/fuel ratio, the system will log a Data Trouble Code (DTC) and turn on the vehicle dashboard Malfunction Indicator Lamp (MIL).

Note: OBD II fuel trim data is also stored in your scanner Freeze Frame Data mode if the system is true OBD II. Many Australian vehicles may incorporate the OBD II 16 pin connector but that does not necessarily mean the system is OBD II compliant. Always check the scanner Freeze Frame mode to see if the system supports the Fuel Trim data. If it is not supported, then the system is unlikely to be OBD II compliant.

Comparison of Fuel Trim data for V type engines when the system utilises fuel system monitoring is a good way to see if a problem exists on one bank or is affecting both banks.

STFT and LTFT values will be displayed by number e.g. STFT B1, STFT B2.

Remember, Fuel Trim data contained in either scanner Freeze Frame mode, or, that contained in Enhanced Data mode is of vital importance, so always check both scanner modes during diagnostics.

Fuel Trim Data Storage

To enable the correct air/fuel ratio, (stoichiometry = 14.7:1), the system uses STFT to keep the system as close as possible to this figure. STFT is known as a volatile value. STFT values are usually erased when the ignition is switched off. Upon engine start and run, the STFT values are restarted.

LTFT is a learned value and stored in the Power Train Control Module (PCM) Keep Alive Memory (KAM). The LTFT values stay stored unless there is an interruption to the PCM power supply or you use your scanner to reset the LTFT values.

- STFT = Values are volatile (erasable)
- LTFT = Values stay in PCM KAM

STFT and LTFT Operation

STFT relies on the PCM receiving input data from the Oxygen Sensors. To keep the fuel system as near as possible to the air/fuel ratio (stoichiometric), PCM STFT operation makes constant adjustments to the injection system i.e. injector or injectors ms 'ON' time. STFT corrections are made when the system enters **CLOSED LOOP** operation.

If the Oxygen Sensor (O^2) data input to the PCM indicates a decrease in the O^2 voltage, an **increase** in STFT will occur.

If the O^2 Sensor data input to the PCM indicates an increase in the O^2 voltage, a **decrease** in STFT will occur.

- Decrease in O^2 voltage = Increase in STFT

- Increase in O^2 voltage = Decrease in STFT

To examine this in its context, let us consider this example:

The vehicles fuel pump begins to fail, delivering less and less fuel. The PCM is monitoring the general trend and to compensate, shifts the STFT to add more fuel by keeping the injector or injectors' ms 'ON' time longer and longer.

If the PCM detects that the trend is adding fuel all the time, the PCM compensates by moving the STFT corrections to an earlier start point in the enrichment correction. By doing so, the STFT corrections call for the PCM to calculate and enable LTFT, which in this example, allows the LTFT to shift richer.

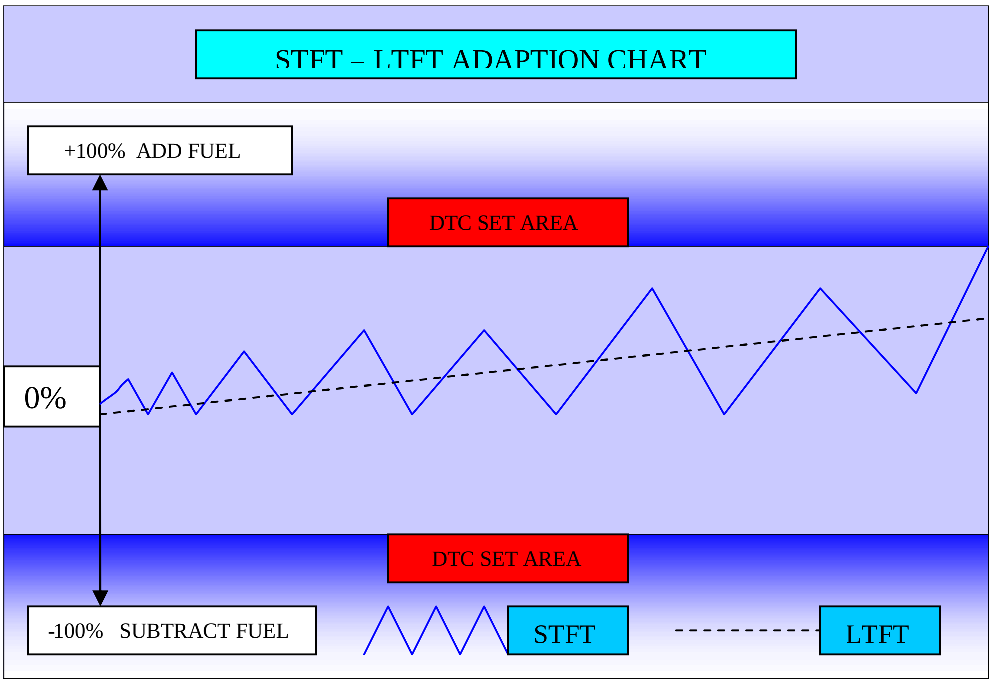
Now we can see that LTFT follows STFT and if we monitor the trims trends carefully, the trends provide powerful data to help in the diagnostic.

If the combined trim corrections exceed the pre programmed allowable limits the dashboard MIL will illuminate and a DTC will store in the PCM.

This is known as **Adaptive Limits**.

Combined STFT and LTFT correction can compensate for rich and lean trends, but, only to a certain point. PCM pre determined control is programmed, and, when that limit is reached and a severe imbalance with the air/fuel ratio still persists, the PCM will store the appropriate DTC.

- **LTFT follows STFT**
- **Monitor fuel trim data with these options; use your Hanatech scanner to record/playback the trim data, use the Hanatech scanner graphing mode or use the Hanatech Host-Pro PC programme to record/playback trim data.**



General Information – GMH

Now that you are aware of the basics of STFT and LTFT, let us look at the way the trims are handled with a GMH vehicle. For the purpose of this general discussion we will use references to the VT V8 and VT Series II Gen III.

STFT

To recap: STFT represents injector ms 'ON' time being corrected based on data input to the PCM from the O^2 sensors.

During an engine cold start the system is in 'Open Loop' mode. Base fuel calculations by the PCM from various sensors, (TPS, RPM, ECT, MAF etc.), allows for injector ms 'ON' time until the O^2 sensors reach an operating temperature of approximately 315°C.

At this time STFT and LTFT are disabled. Your Hanatech scanner will show the trims as reading '0%', 'Disabled' etc.

At approximately 600°C, the O^2 sensors normal operating temperature, the O^2 sensor being positioned to sample oxygen after combustion in the exhaust gas stream, produces a varying voltage which is sent to the PCM. The PCM uses the voltage data as an indication as to what has happening during combustion in the engine cylinders combustion chambers.

At this point the PCM will change from 'Open Loop' mode to 'Closed Loop' mode. Watch your scanner data to see the data stream change modes. PCM STFT mode will now constantly monitor the O^2 data signal so that the PCM can control injector ms with greater accuracy than when the PCM has control during 'Open Loop'.

- **To maintain the air/fuel ratio, (stoichiometric = 14.7:1), and aid in keeping correct catalytic converter efficiency, STFT corrections are based on O^2 sensor data input to the PCM.**

- **A STFT value of '0%' is the same as an Air/Fuel Ratio of 14.7:1 and an <u>average</u> O^2 Sensor reading of 450 mV.**

Any change in the STFT position of '0%, (+ or -), is an indication the base fuel injector ms is being corrected. The theoretical normal operating range of STFT is between -22% and +25% and any %value outside of this range normally indicates a malfunction.

note: the above statement contains the word **<u>theoretical</u>**. Real world application of the range of -22% to +25% of STFT is not absolute. We have found a range of -10% to +25% to be a worthwhile range to monitor.

Within this range we have found that there is further range within in the -10% to +25% to aid in diagnostics.

We know that a STFT reading a (minus -) value is telling us the system is reducing fuel and a (plus +) % value is adding fuel. But the question is why? Is it because of a particular fault with fuelling or could it be caused by a mechanical or ignition failure?

Here is the range of STFT that will help to decide your path in the diagnostic. Use this as a sort of 'Rule of Thumb' if you will.

For ignition/mechanical miss-fire: - 10% to +15% and fuelling: -10% to +15% / +25%.

Lets us examine this a little further; a miss-fire condition results in an excess in O^2 in the exhaust gas stream. During miss-fire, blasts of O^2 are detected by the O^2 sensor. The O^2

voltage will drop to a low voltage. The PCM will interpret this low voltage as a low air/fuel ratio and drive the injector ms 'ON' time wider to add fuel to maintain the correct air/fuel ratio. So in effect a +% of the STFT is occurring. The result? Addition of fuel! And if this condition were constant enough, a high STFT % value would occur.

What would occur if the miss-fire were intermittent? STFT corrections would include (plus +) corrections and (minus -) corrections. This would result in a lesser STFT % correction and the STFT % value would be of a lower value.

Another question; if in a V type engine and the engine banks have O^2 sensors for each bank, could the influence of one bank O^2 affect the other the injection ms 'ON' time of the other bank?

The answer is yes, if the systems control programming strategy is so designed. So, be aware of this and monitor multi STFT and LTFT modes and the relevant injector ms 'ON' times.

Another example of fuel trim correction; the fuel filter has become restrictive. Fuel pressure and flow gradually becomes less and less. The lack of Hydrocarbons, (HC), during combustion will result in excess O^2 in the exhaust stream causing the O^2 sensor voltage data to the PCM to recognise a 'LEAN' air/fuel ratio that is not correct for the particular drive mode.

The PCM will shift the STFT to a +% value thus allowing injector ms 'ON' time to allow more fuel to be injected. If the enrichment trend continues, the PCM will try to maintain fuel control, resetting of STFT % value to 0% until the O^2 sensor data reaches above 450mV. This is a PCM strategy that continues until the pre-programmed **Adaptive Limit** is reached i.e. the PCM no longer is able to control the air/fuel Ratio.

Interaction of STFT and LTFT – GMH

As we know from the basic introduction to STFT and LTFT, they are PCM monitored trends. LTFT trend follows the STFT trend.

To recap: LTFT is used for adjustment to engine aging, engine variation and fuel control over time. LTFT correction only occurs during 'Closed Loop' mode.

Using the previous example of a restricted fuel filter; As STFT correction attempts made by the PCM climb above 0%, (let's say +2%) and stays there for period a time, the STFT will scale back to 0% as the PCM attempts to maintain the correct air/fuel ratio.

If the fuel flow is restrictive enough and the STFT +% trend exceeds the adaptive threshold, (let's say +8%), and the pre programmed criteria is met for the time held for this value, the PCM will shift the LTFT % value, (let's say to +10%), and wait to see if the STFT % value will go back to 0%. If after set period time this does not occur, STFT and LTFT limits will reach their respective limits and a DTC will set.

In the case of the VT V8, DTC's set could be DTC 44, (RH Lean Exhaust Indicated), 45 (RH Rich Exhaust Indicated), DTC 64 (RH Lean Exhaust Indicated), DTC 65 (LH Rich Exhaust Indicated). If these DTC's are set, the PCM will revert to 'Open Loop' mode. In our restricted fuel filter example, if the reduced flow was great enough, the 'Lean' DTC's would be set.

note: The PCM will set and hold the STFT to 0% during power enrichment, (Wide Open Throttle – WOT), this is done to prevent PCM LTFT correction while WOT is occurring.

The PCM retains learned LTFT values in its LTFT memory cells. The VT V8 uses data from the Mass Air Flow sensor, (MAF), and engine rpm to determine which LTFT cell in which to operate. An interruption to PCM power supply, scanner reset of LTFT or DTC erasure will reset PCM learned LFTF to 0%.

The VT Series II Gen III PCM system operation follows the basic strategy of the VT V8 but uses variations in system control.

Being a **Speed Density** System, let us review a few basics with a description of a Speed Density System.

The Gen III PCM requires specific sensors data inputs for basic fuel management: engine speed, manifold absolute pressure and inlet air temperature.

Engine speed is derived from the ignition system, (rpm), air density is derived from the temperature of the air entering the engine (Inlet Air Temperature Sensor - (IAT) and Manifold Absolute Pressure (MAP) sensor.
The IAT sensor works in conjunction with the MAP to establish the air density.
As inlet air temperature changes and inlet manifold changes occur, the sensors data is used by the PCM to control injector pulse width.

The speed density system is also used to monitor Mass Air Flow (MAF) operation i.e.

- To check for MAF malfunctions.
- To allow the PCM to take control of fuel management when there is a malfunction of the MAF.

STFT fuel corrections of -99% to +99% are the theoretical % values to which can be observed with scanner data. A deviation from 0% +99% equals ‘lean’ and a deviation from 0% to -99% equals ‘rich’.
STFT values changes the injector pulse width by varying the ‘Closed Loop’ injector base pulse width equation.
As STFT corrections take place and if the corrections exceed a pre determined % value and time held, the following DTC’s will set:

- DTC P0171 (Bank 1 too lean)
- DTC P0172 (Bank 2 too rich)
- DTC P0174 (Bank 2 too lean)
- DTC P0175 (bank 2 too rich)

If LTFT correction exceeds the pre determined % value and time held, the following DTC’s will set:

- DTC P0171 (Bank 1 too lean)
- DTC P0172 (Bank 1 too rich)
- DTC P0174 (Bank 1 too lean)
- DTC P0175 (Bank 2 too rich)

Under WOT conditions, the PCM resets STFT to 0% and is held there so as to not allow the ‘Closed Loop’ factor and LTFT to influence and correct for the power enrichment mode.

When a PCM DTC is set there will be DTC data stored in Freeze Frame mode. Remember to check both History DTC mode, Enhanced data mode and Freeze Frame mode. Do not erase DTC’s without first taking a notation the stored DTC data.

note: The Gen III PCM utilises programmed software to enable ‘Field Service Mode’. If the diagnostic test terminal, (16 pin), is grounded while the engine is running, Field Service mode will be activated and you can run diagnostics without setting new DTC’s.

GMH Long Term Fuel Trim Cell Descriptive

The PCM LTFT % as we know allows for (plus +), and (minus -) corrections. The PCM software programmed LTFT is divided into a matrix of cells and these cells are arranged by MAF and Engine Speed.

Each cell is arranged so that each parameter (MAF and RPM) corresponds to a region on a MAF versus RPM table. The nominated value of 0% is given to LTFT for each region.

As the engine is accelerated or decelerated the LTFT calibration will shift into a different cell. STFT will follow into the shifted cell. However, STFT corrections will only be of a lesser time value for what ever cell the LTFT has moved to.

Typically for the VT V8 when the engine is in idle mode you will see one of two cell values on your Hanatech scanner while viewing the data stream.

Vehicles with automatic transmission and if canister purge mode is in effect, you will see cell 0 and if canister purge mode is not operational, you will see cell 17.

Respectively, for manual transmission vehicles, you will see cell 16 or cell 33 during engine idle mode.

Whatever cell the engine is operating in, the PCM will monitor the LTFT value of that cell and attempt to correct the injector ms ‘ON’ time. Typically if STFT stays above/below 0%, LTFT % values will be higher in all cells.

Remember, use STFT % values for real time correction and LTFT % values (for each cell) to see if a trend is developing with the fuel control over time.

LTFT is the learned value, so look at the LTFT % value throughout the engines entire modes of operation. If the LTFT % value shows rich/lean only at part throttle, concentrate on those components that would affect the part throttle operating range.

Know the STFT and LTFT DTC Setting Criteria

DTC’s are set according to predetermined software programming for the PCM. We need the correct information on the DTC setting criteria and also a diagnostic path to analyse why the DTC set and the ‘fix’ to effect the correct repair for the particular DTC or range of stored DTC’s.

Technical reference information (manuals, CD’s etc.) provides that means. Not only will you learn the system control, you will also learn the correct diagnostic approach and repair techniques.

Mount AutoEquip supports a full range of technical references. Use the Technical Support page form or phone **Mount AutoEquip** to reference pricing and availability of technical resources.

Let’s examine a typical diagnostic for DTC P0171, DTC P0174 on a VT Series II Gen III engine.

DTC P0171 (Fuel System Lean Bank 1)

We know **DTC P0171** sets because a fuel trim +% value has been adding fuel due to lean condition i.e. longer injector ms ‘ON’ time enrichment correction due to ‘lean’ run problems.

note: **DTC P0174** (Fuel System Lean Bank 2) may also set with a **DTC P0171**.

We must be aware of any PCM DTC run conditions (predetermined PCM programmed conditions) before attempting a repair for DTC P0171 - DTC P0174.

DTC P0171/4 requires a range of DTC's not to be present before attempting a diagnostic. If any of the DTC's below are set, note them down and carry out the appropriate repairs.

P0101, P0102, P0103, P0107 P0108, P0112, P0112, P0113, P0117, P0118, P0121, P0122, P0123, P0335, P0336, P0351, P0352, P0353, P0354, P0355, P0356, P0357, P0358, P1111, P1112, P1258 - (refer to a fault code chart for DTC's definitions).

Other PCM DTC run conditions:

- Engine coolant temperature between 50°C and 115°C
- Barometric pressure is more than 74kPa
- Mass air flow is between 5 g/s and 90 g/s
- Manifold pressure is between 26 kPa and 90 kPa
- Intake air temperature is between -20°C and 90°C
- Engine rpm is between 400 rpm and 3000 rpm
- Throttle Position Switch (TPS) angle is less than 90%
- Vehicle speed is less than 137 km/h

The technical resource information on DTC P0171/4 as provided by GMH is quite comprehensive and any quality technical resource should include the same DTC run criteria. Contact **Mount AutoEquip** for pricing and availability of technical resources.

The above run criteria (less the noted DTC's) will set the DTC P0171/4 if all the above required run conditions are present for 6 seconds AND if the average LTFT cells % values are above a predetermined threshold.

The action the PCM will carry out on a failure during the diagnostic run is: Dashboard MIL is illuminated and the PCM will record data parameters in Freeze Frame mode during the failure condition.

Now we know the importance of scanner Freeze Frame data referred to earlier in this discussion paper. Recorded data in Freeze Frame mode should be noted down. If the problem is of an intermittent type, you can operate the vehicle according to the saved Freeze Frame data in an attempt to replicate the conditions that is causing the DTC's to set.

note: If after 3 consecutive vehicle trips and the PCM diagnostic check does not see a failure with the system within the same conditions for running the DTC as it last saw, the PCM will turn the dashboard MIL off. So again, if the DTC was tripped by the PCM and later the 3 trip detection was proved to have corrected itself by the PCM, please look at the both DTC History mode and Freeze Frame mode during a diagnostic.

However, be aware that the dashboard MIL may remain 'ON' longer than the 3 trips if the last PCM diagnostic records a failure during a non typical driving condition. Check the Freeze Frame data for the last failure conditions.

The DTC History mode/Freeze Frame mode can provide valuable diagnostic information, especially, when you are trying to trace an intermittent problem.

Also of note; the PCM programming allows for History DTC's to be automatically erased after 40 consecutive warm up cycles, if no emission related PCM diagnostic failures are detected during this time.

Diagnostic Direction

If DTC P0171 and P0174 are set together:

The DTC's descriptions are that both engine banks are operating 'LEAN'. This would indicate that the PCM has been using Fuel Trims to add fuel in an attempt to correct the air/fuel ratio but has reached adaptive limits thus logging the DTC's.

Any time these DTC's are set together could indicate: Incorrect delivery of fuel, the fuel supply is very low, engine vacuum leaks.

Before you attempt repairs, we advise that you confirm that the fault is indeed present.

Power up your Hanatech scanner and with the correct vehicle system selected. Start the engine. Allow the engine to reach operating temperature. Monitor relevant sensor data until 'Closed Loop' mode is attained.

Use the many options available with your Hanatech scanner to monitor the scanner data stream (record/playback, Graph Mode, Host-pro etc.).

As a further option you should also monitor the vehicles exhaust tailpipe emissions. The Hanatech 4/5 Gas Analyser is the ideal tool to compliment your Hanatech scanner. Contact **Mount AutoEquip** for further details.

Once the system has reached 'Closed Loop', check LTFT to see if PCM has reached adaptive limit (+25% LTFT). If the LTFT is at the limit, turn the engine 'OFF'.

With the ignition turned 'ON' and the engine not running, select Freeze Frame data to check the parameters recorded. You could also check live data during the LTFT adaptive check phase, but, if the problem is intermittent and adaptive limit is not reached, the DTC's will not set. However, you will still be able to plot the STFT and LTFT trend.

At this point, your Freeze Frame data record shows DTC's P0171 and P0174 and the conditions that they set at. We know both engine banks are lean so we would check anything that will affect both banks.

Vacuum leaks, fuel supply would require investigation for these two DTC's.

Smoke Detector, Gas Analyser, Fuel Pressure gauge, Low Current Clamp and Oscilloscope are the recommended tooling for the systems analysis/repair.

Let's suppose the system has a vacuum leak at the Throttle Body. Both engine banks would be affected. A visual inspection does not readily find the leak. Your Hanatech Smoke Detector is the ideal tool to use in this instance.
Power up the Hanatech Smoke Detector, see the applied smoke leaking from the perforated hose. How simple is that!

Contact **Mount AutoEquip** for details on the Hanatech Smoke Tester.

Let's suppose the system has a fuel supply problem. You could monitor fuel supply with the Fuel Pressure Gauge, (some times this will be the only way), but a far easier and cleaner way to approach this is to use 'Current Ramping'. The Low Current Probe and Oscilloscope can find fuel pump problems in minutes. Incorrect current waveforms depicting pump brush, bearing, commutator wear, incorrect amperage (high/low) and fuel pump speed are just a few things you can do with the Low Current Probe and Oscilloscope.

Contact **Mount AutoEquip** for details on available current probes and oscilloscopes.

If your testing finds incorrect fuel pump operation or fuel supply restrictions and/or vacuum leaks, effect the appropriate repairs.

Power up your scanner and clear any DTC information.

Re run the vehicle simulating your previous test parameters.

If the DTC's do not re set, consider this an effective repair.

Obviously this discussion paper hasn't the scope to cover every aspect of these two DTC's but is intended to give the viewer a basic overall look at GMH STFT and LTFT interaction, Tooling, Diagnostic Direction etc.

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