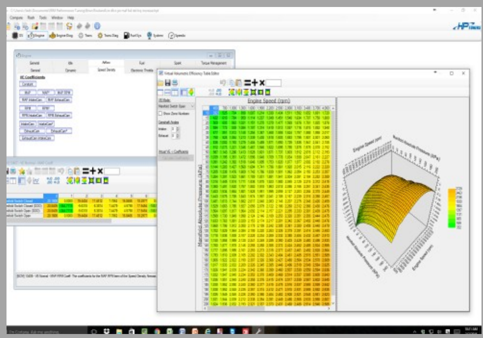
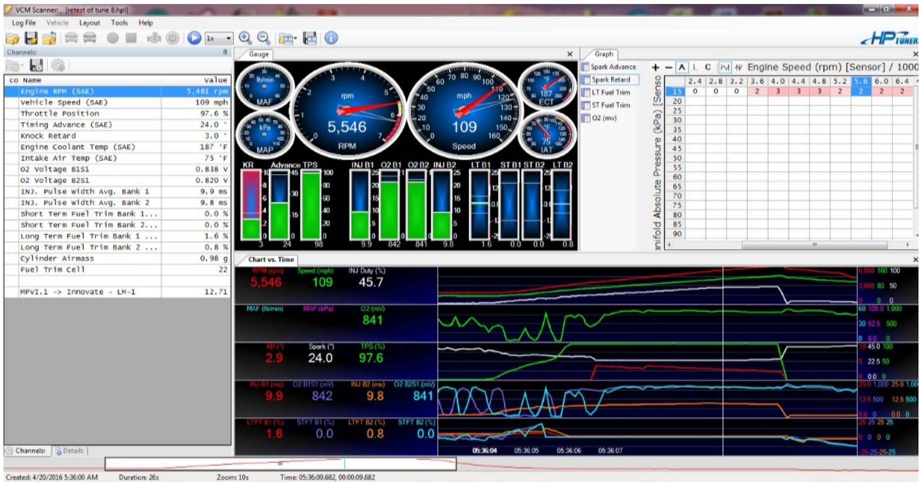


Course Module 1

GM EFI Engine Management Overview

(Rev H – 07/05/17)



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Course Module 1 – EFI Engine Management Overview Table of Contents

Introduction

Congratulations, you are about to embark on the most effective , multi- hour, one on one training course available today, which at the end of the day, will provide you all the information you will need to understand the fine art of Electronic Fuel Injection (EFI) Tuning as well as seamless operation of the HP Tuners VCM Tuning Suite. **While we will be presenting this Course through the eyes of an HP Tuners VCM Suite, a very large majority of this information applies to any tuning software package you may be utilizing....** or vehicle you may want to tune. So get comfortable, grab a drink, a pad/pen to take lots of notes and let's begin. More importantly, if you haven't already, sign up for one of our one on one, interactive training packages so you can receive your own, customized curriculum right in the comfort of your own house. For more information on this unique and **exciting approach to EFI training visit our website www.ermperformancetuning.com or our Face book page ERM Performance Tuning**.

The advent of the EFI is not a new one; it dates back to early 1900's and began primarily as the way a Diesel engine was to operate. Many aircraft versions were developed over the years as well as automobiles. Over the years, the technology improved and car manufacturers began using EFI more and more to preclude the need for very complex carburetors to try and stay ahead of the increasing emissions standards. Our story really starts in 1997, where GM replaced their PROM based computers with a PCM that was EPROM (Erasable Programmable Read Only Memory) based and re-programmable from an external plug.....this evolution opened new doors for the software engineers and off they went reverse engineering and developing the Tuning tools we have today.... In no time they had cracked the code and even invented a means for the average backyard mechanic to modify these computers and increase timing and control fueling....rudimentary but what a step forward. From LS1 Edit to today's HP Tuners and EFI Live OEM Programming Suites to stand alone EFI systems for converting carbureted setups to EFI. Even EFI Connections sells a 24x reluctor adapter kit (sensors, harness and PCM included) where you can now run a vintage LT-1/LT-4 from an LS1 PCM.....But enough about that, back to our course :-)

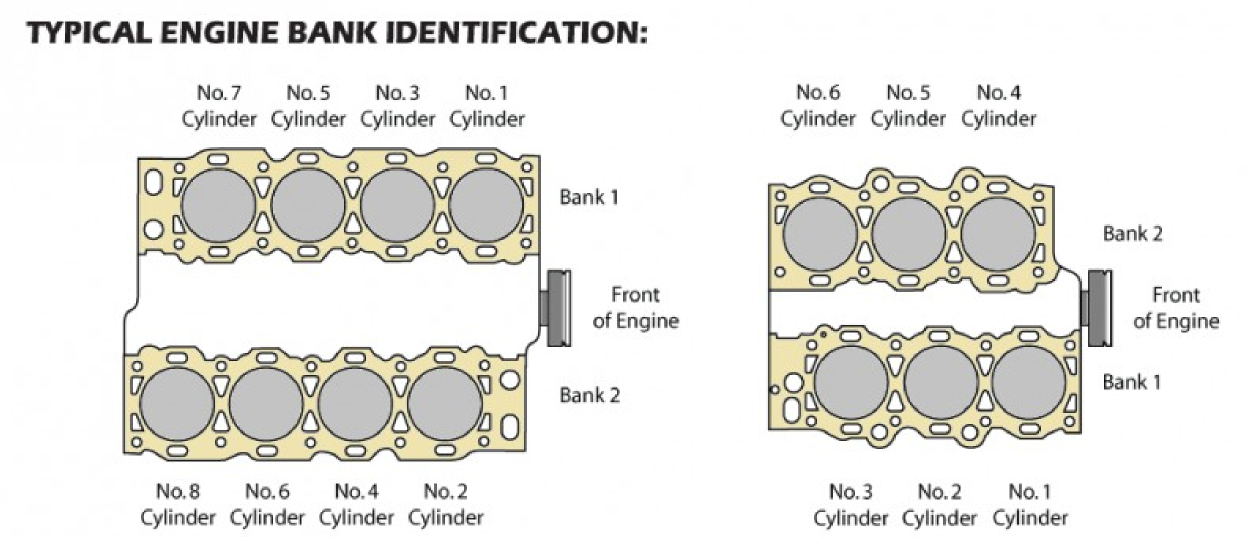
We are going to jump right into this subject with what is an EFI System and how does it do what it does. Basically, an **EFI system is going to take over fueling and spark control through reading of on-board engine/transmission/vehicle sensors, performing many calculations, developing engine air models, developing how much air is making it into the cylinders, vehicle/engine load, driver expectations and demands etc**. Additionally, the OEM control systems manages many vehicle/platform functions like traction control, torque management and braking. The **sensors include**, but are not limited to, **Mass Air Flow (MAF), Manifold Absolute Pressure (MAP), Engine Coolant temp (ECT),Intake Air Temp (IAT), Vehicle Speed Sensors (VSS) and CAM/Crank Position sensors (CPS/KPS). Details for these sensors is found in section 3.** These capabilities of today's EFI systems allow real time management of fuel and spark to compensate for weather conditions, mechanical wear/tolerance changes, vehicle stability safety, accessory load changes and most important....our "NEED FOR SPEED" to steal a quote from one of my most favorite movies...Top Gun,

Think of the **engine as a big air pump** that **needs fuel supplied at an exact amount** and an **ignition source** to support sufficient combustion. This section will deal with the fuel and air combination mixture and how to understand its requirements and limits. The PCM performs thousands of calculations a minute in its effort to keep our engines and transmissions happy and safe. Proper amounts of fuel and air are a must which will provide the necessary mixture for the power we are seeking and more importantly prevent the engine from melting down...

Cylinder/Bank assignments **-- there are two sides to every motor…..most times!**

As you go through this Tutorial as well as the VCM Editor and Scanner, you will see references to Bank 1 and Bank 2 as well as cylinder numbers. Here is a quick graphic to become a sticky for future reference….

Figure 1 -- V8 and V6 Engine Bank and Cylinder Identification



Initial Engine Design Goals and Requirements

To develop (or verify acceptability) an EFI System we first need to determine what our ultimate goal is for our project. What will be our operating environment...street, strip, road course or maybe all three! What platform will we be powering....what is the weight, auto or manual etc. Based on our target goals, how much power are we designing for and will we be Naturally Aspirated, Supercharged or Turbocharged? No matter what you choice, you will have to start with a fueling system that is up to the challenge. The following will guide you through the design criteria for your fueling system.

Fuel Consumption, Delivery and Injector sizing

- **Fuel Consumption, delivery and injector selection** -- Design or validate your Fuel System capabilities in accordance with your power needs. Fuel Delivery/consumption based on Brake Specific Fuel Consumption (BSFC) which is engineering developed factor relating to the amount of fuel needed to make the desired power under a specified application. **Figure 2 shows the math and results for fuel delivery requirements as well as injector sizing to support a sample horsepower criteria.** The working excel file is included in Section 1's support package. Additionally, it depicts the difference between E10 fuel and E85 where as almost **30% more fuel is required when using E85.**

Figure 2 – Sample Fuel System calculator based on desired Horsepower and number of cylinders (E10 vs. E85)

HP (Crank)	Setup	BSFC (gasoline)	Fuel (lb/hr)	# of Cylinders	inj size @ 100% DC (lb/hr)	Inj Margin	Req'd Inj size (lb/hr)	Req'd Fuel Supply (lb/hr)	Desired FP flow rate @ 6lb/gal	Desired FP flow rate @ L/hr
HP	X	BSFC	= Fuel	÷ NOC	= IFR	÷ %	= IFR	X NOC	÷ 6	Gal to Ltr
500	NA	.45/.50	237.5	8	29.69	80%	37.11	296.88	49.48	184.98
	SC	.55/.60	287.5	8	35.94	80%	44.92	359.38	59.90	223.93
	TC	.60/.65	312.5	8	39.06	80%	48.83	390.63	65.10	243.40
HP (Crank)	Setup	BSFC (E85)	Fuel (lb/hr)	# of Cylinders	inj size @ 100% DC (lb/hr)	Inj Margin	Req'd Inj size (lb/hr)	Req'd Fuel Supply (lb/hr)	Desired FP flow rate @ 6lb/gal	Desired FP flow rate @ L/hr
500	NA	.63/.70	315	8	39.38	80%	49.22	393.75	65.63	245.35
	SC	.77/.84	385	8	48.13	80%	60.16	481.25	80.21	299.87
	TC	.84/.91	420	8	52.50	80%	65.63	525.00	87.50	327.13

- Injectors are selected in accordance with the above table based on fuel demand. **We also like to use a 20% margin factor to leave enough "play" to reduce the injectors duty cycle to a reasonable level as not to overwork them and minimize the injection time to keep up with the higher demand from Cam/FI upgrades. Remember, in an 8 cylinder engine, at 6000 rpm, you only have a maximum of 19 milliseconds to complete the injection process. The greater the headroom of the injector, the less time will be needed to squirt the proper mass of fuel. In the E85 scenario above, the criticality for having sufficient fuel delivery and injector sizing is even more crucial. Also, an injector operating at a 100% duty cycle (on all the time) for extended periods of time will adversely affect the life of your injectors and leave no margin, should additional fuel be needed for some reason**. Remember in a typical EFI System, it's the PCM's job to deliver a pulsed, on-off signal to the injector based on its flow ratings and air model requirements to satisfy the Air to Fuel Ratio requirements. There are a dozen or so parameters that define how the **injector** ultimately operates and they will be covered in detail later in the course.

- **Fuel lines and rails shall be selected to support the fuel pump capabilities.** Would be a shame to get the right pump and choke it off with undersized hoses or rails. Aeromotive and BBK are two of the many manufacturers who offer **high flow fuel rails. With higher horsepower and E85 they are a must to relief the fuel pressure/volume restrictions presented by the stock setup**. Figure 2 shows a rough estimate for fuel line sizing based on horsepower goals. Also includes AN to inch conversions for you.

Figure 3 -- Example of hose sizing to Horsepower (AN to inch conversion included)

RWHP	Supply Fuel Line	Equivalent	Return Fuel Line	Equivalent
<650	Stock	N/A	Stock	N/A
<800	8AN	1/2"	6AN	3/8"
<1200	10AN	5/8"	8AN	1/2"
>1200	12AN+	3/4"	10AN+	5/8"

- **One important characteristic of fuel pumps is their fuel flow is proportional to pressure.... but in a negative way. What this means is fuel flow reduces as pressure increases.** Consider that a **carbureted system only requires 6-8 psi** while and **EFI system typically runs at 40-60 psi.** Pump flow/volume will be much higher on the carbureted system as you can see due to the lower fuel pressure required. You need to be careful that your **fuel delivery specs (operating pressure, volume and pump voltage) are based on your operating fuel pressure/voltage settings**. Some cheaper units will advertise a higher volume but won't tell you that its been rated at 0 psi pressure. **Supercharged systems present even a higher burden** to the fuel system as boost levels subjected to the injector nozzle will require even greater pressure thus further reducing volume. En lieu of increasing the pump size, you can implement a **Boost A Pump or BAP (at app 2-3 psi of boost increases pump voltage thus increasing flow) or a 1:1 regulator which will increase the fuel pressure proportional to the MAP pressure**. Utilizing the later, will also change the way you input your Injector Flow Rate (IFR) and Offset data. **As the fuel pressure is being increased proportionally to the MAP pressure, you use the rated IFR and Offset values (0 kPa) across the entire table.** But again remember the fundamental rule that says as you increase pressure you decrease flow....so stay ahead of the curve.

Airflow monitoring and calculations – MAF, VE and VVE fundamentals

So we now have a fuel system that will deliver the required amount of fuel through its pump, hoses, fuel rails and injectors to support our power goals. The **EFI system has to calculate how much air is actually making it into the cylinders** to determine the **required Injector pulse width** which equates to a specific mass of fuel. **Figure 6 lists a few of the basic equations that are utilized for both the Mass Air Flow (MAF) and Volumetric Efficiency (VE) as well as the most**

important calculation....cylinder air mass (charge) or g/cyl. As stated here and below in the equations, you can see the need to determine an accurate cylinder air mass prediction as **fuel mass (grams per cyl/AFR)** and timing (**axis for Timing table)** are very dependent on it.

Before we go on, let's make sure we understand MAF and VE. MAF, the simpler of the two, is a mass versus time value (i.e **g/sec, lb/hr etc)** which is developed into a specific **frequency (Hz)** being sent from the MAF sensor **based on air mass (density) into the engine**. The MAF is not a velocity measuring device, rather a mass detector which the PCM uses to develop its fueling requirements. The higher the pressure, the denser the air, the more airmass there is and the more fuel is needed to satisfy the Stoichiometric or WOT AFR requirements. As the MAF sensor is a factory calibrated sensor, based on the stock air intake system, you should find the stock settings will remain pretty close until you adversely alter the input pipe diameter, geometry, MAF placement etc. Your Fuel trims/WB will provide the feedback necessary to see if and to what degree re-tuning is necessary. If so then you will recalibrate it by performing MAF tuning (See Module 9 -- Tuning strategies).

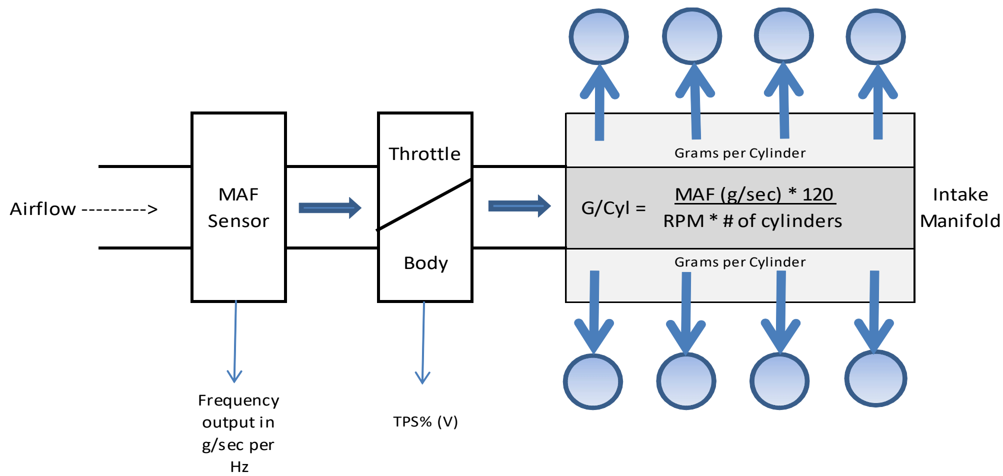
Volumetric Efficiency is the ability for the cylinder to fill itself to its maximum (or more if Force Injection is employed). This efficiency is based on many parameters including intake/Engine temperature, MAP, RPM, airflow etc. The VE data is developed through 100’s (if not 1000's) of hours of bench testing by the OEM engineers and is unique to each engine setup, modification etc. The VE values are normally mapped against RPM and MAP (engine load). As in the MAF sensor above, altering the engine flow/pumping ability with heads, cams, super/turbochargers etc. will require these tables to be re-tuned (see Module 10 – Tuning Strategies and Procedures).

To this, we must re-establish these values through MAF/VE tuning. This simply put is to **develop a new g/sec and or VE value derived from the Lambda/AFR error value (commanded AFR /actual AFR) at a specific cell in the applicable table**.

- **From MAF Sensor data, calculated to Cylinder air mass used to calculate cylinder fuel mass to calculate the Injector pulse width and required ignition timing**

MAF Sensor to PCM -- MAF Airflow to Cylinder Airmass to Fuel Mass calculations

Figure 4 -- MAF airflow to Cylinder mass flow chart and PCM calculation



MAF Airflow (g/sec)	13	MAF Airflow (g/sec) x 120 / RPM x NOC (# of cylinders)	0.2438	g/cyl
RPM	800			
# of cylinders	8			
Constant	120			

-------------------End Of Sample -----------------