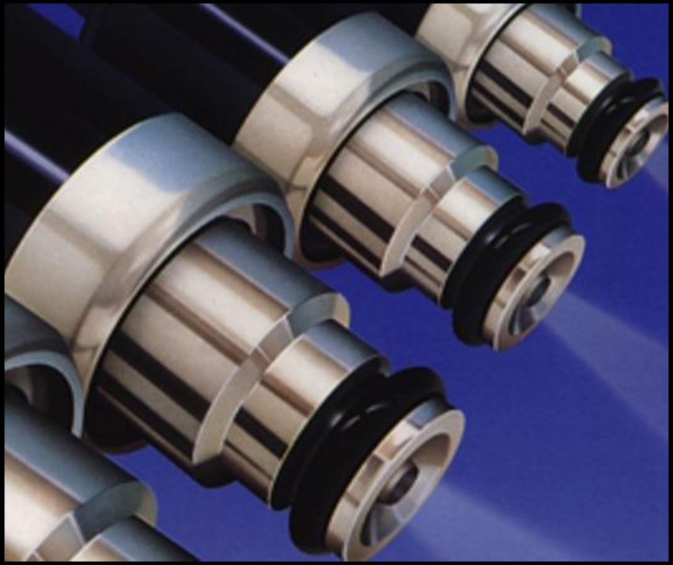
EFI Basics

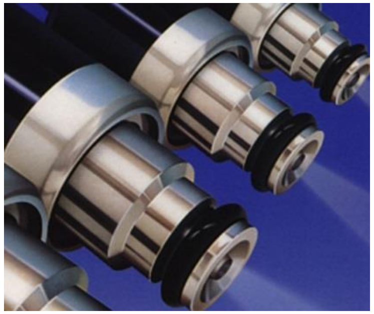


Electronic Fuel Injection

HD -Motorcycles

EFI Basics

Topics



1. Introduction to EFI
2. Injectors & air/fuel ratios
3. Pulse width
4. Fuel delivery system
5. Closed-loop operation
6. Open-loop operation
7. How ECM works
8. Look-up tables
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17. Tuning devices and software

Introduction to EFI

Harley-Davidson ® motorcycles first introduced EFI systems back in the 1990's on their touring motorcycles.

These systems were produced by Magneti-Marelli and use the Alpha-N (throttle position based) technology for controlling fuel and timing along with pre-programmed data tables stored in the ECM to calculate the amount of fuel needed.

EFI System

Electronic Fuel Injection

A computer controlled **engine management system**

Uses fuel injectors controlled by the computer …no carburetor

The computer uses sensors to gather information from the engine, then calculates the required fuel needed.

The amount of fuel injected into the engine is determined by how long the injector is cycled open. Known as “Pulse width”

Delphi EFI system

First introduced in the softails in 2001
Touring and V-rod motorcycles in 2002

Dyna motorcycles in 2004
Standard in all models in 2007

Injectors

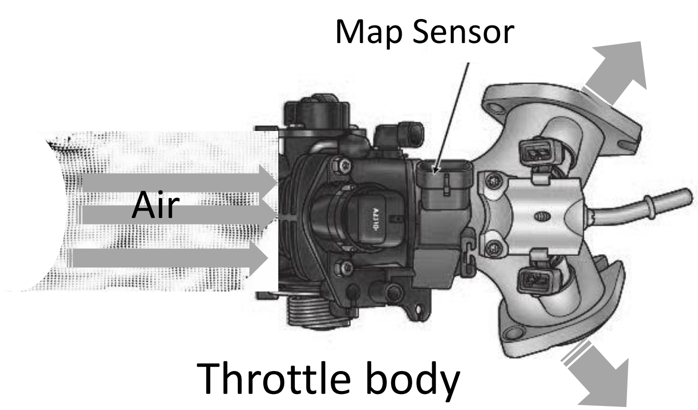
Throttle body

The Delphi EFI system

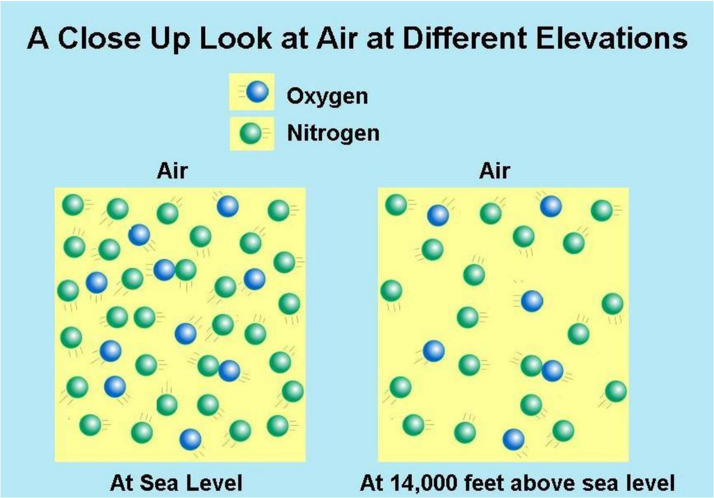
The Delphi system is able to use **manifold air pressure** from the intake, allowing it to more accurately determine the load on the engine. Utilizes the mass air flow sensor.

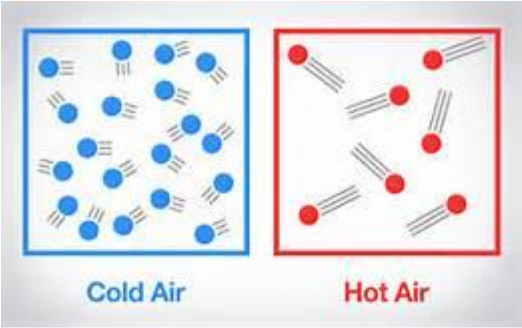
MAP = Manifold Absolute Pressure

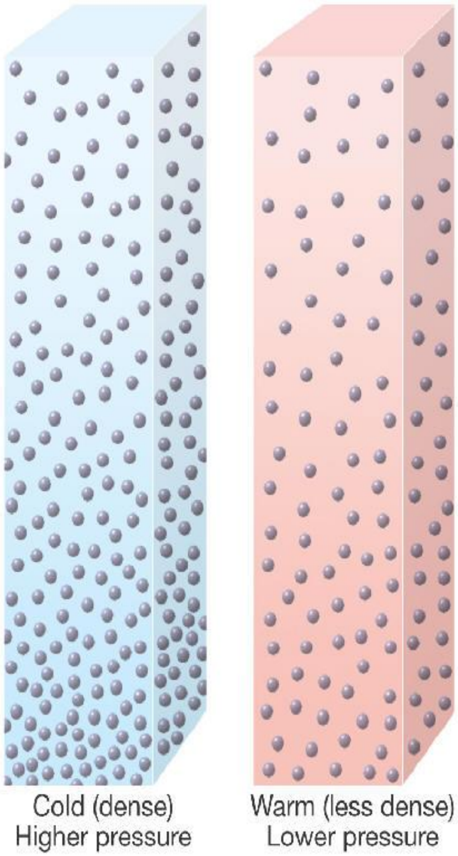
The MAP sensor provides instantaneous air pressure data to the ECM.
The data is used to calculate air density and air mass flow rate.



Air Density


A Close Up Look at Air at Different Elevations
Oxygen
Nitrogen
Air
Air
At Sea Level
At 14,000 feet above sea level


Cold Air
Hot Air


Cold (dense)
Higher pressure
Warm (less dense)
Lower pressure

EFI Systems

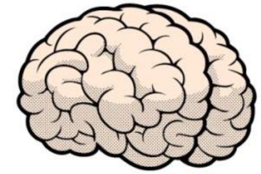
One of the **major differences** between fuel injection systems is how it senses the amount of load that is placed on the engine. The load can be determined by two methods:

1. Throttle position sensor & rpm
2. MAP sensor & rpm

EFI systems that sense engine load by the use of the (throttle position) are referred to as an ***Alpha-N system*.**

EFI systems that sense engine load by the use of a (MAP sensor) are referred to as a ***Speed-Density system* … Latest version**

ECM



Electronic Control Module

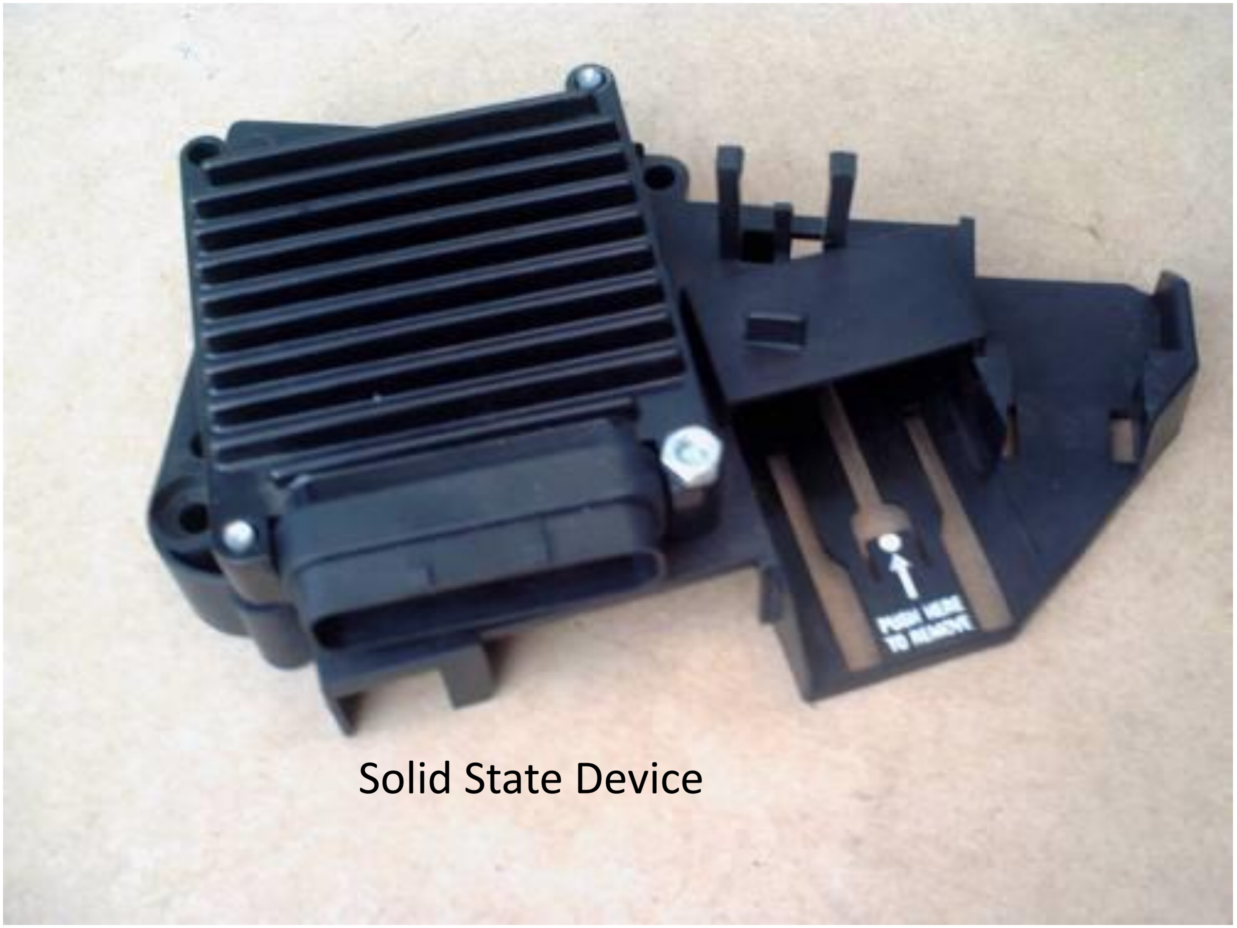
The computer is the brains of the EFI system.

The ECM regulates the proper air/fuel ratio and spark timing needed for the engine to run efficiently by using a complex set of calculations based on sensor input and pre-programmed data.

The demands of the engine are always changing, so the ECM must make fuel and timing adjustments accordingly.

DURING: Start - Warm-up - Idle - Cruise - Power

ECM Computer
Module



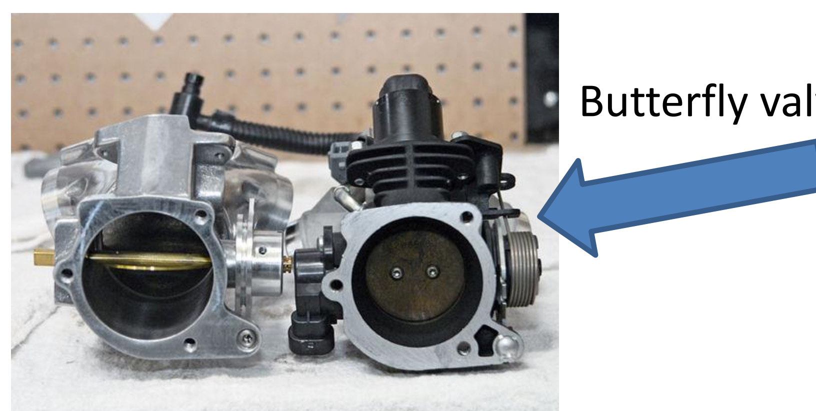
Solid State Device

Throttle Position

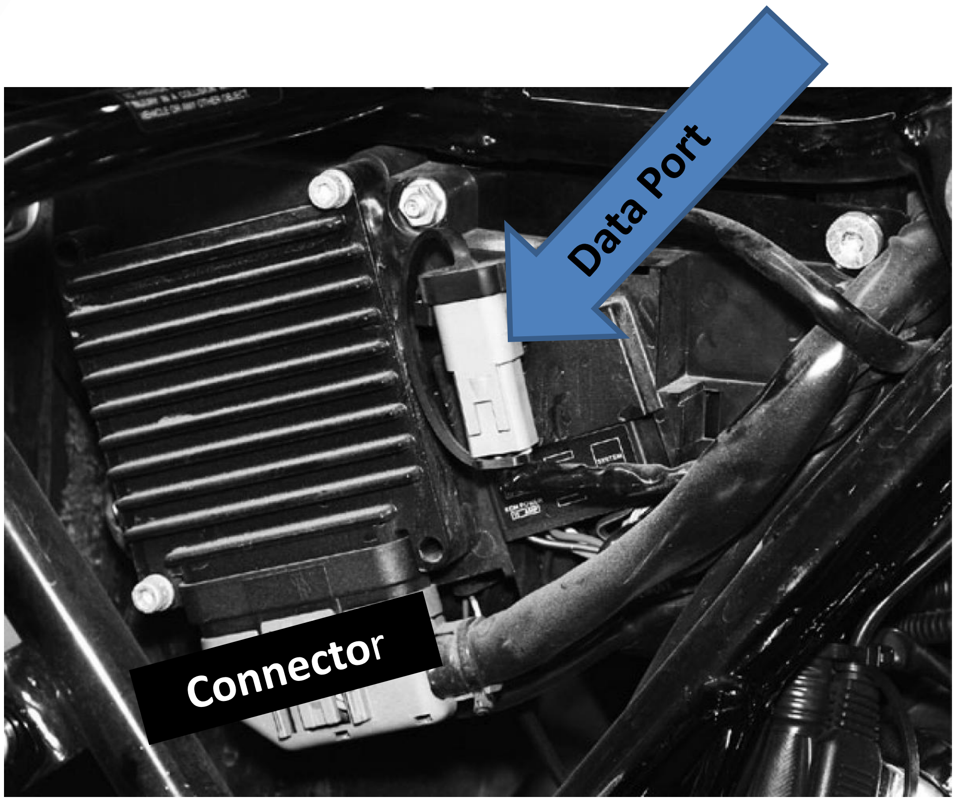
A butterfly is still present in the intake to control airflow.

Throttle by cable: Sensor located on the throttle body
Mechanical cable opens the butterfly

Throttle by wire: Sensor located on handgrip
Electric motor opens the butterfly



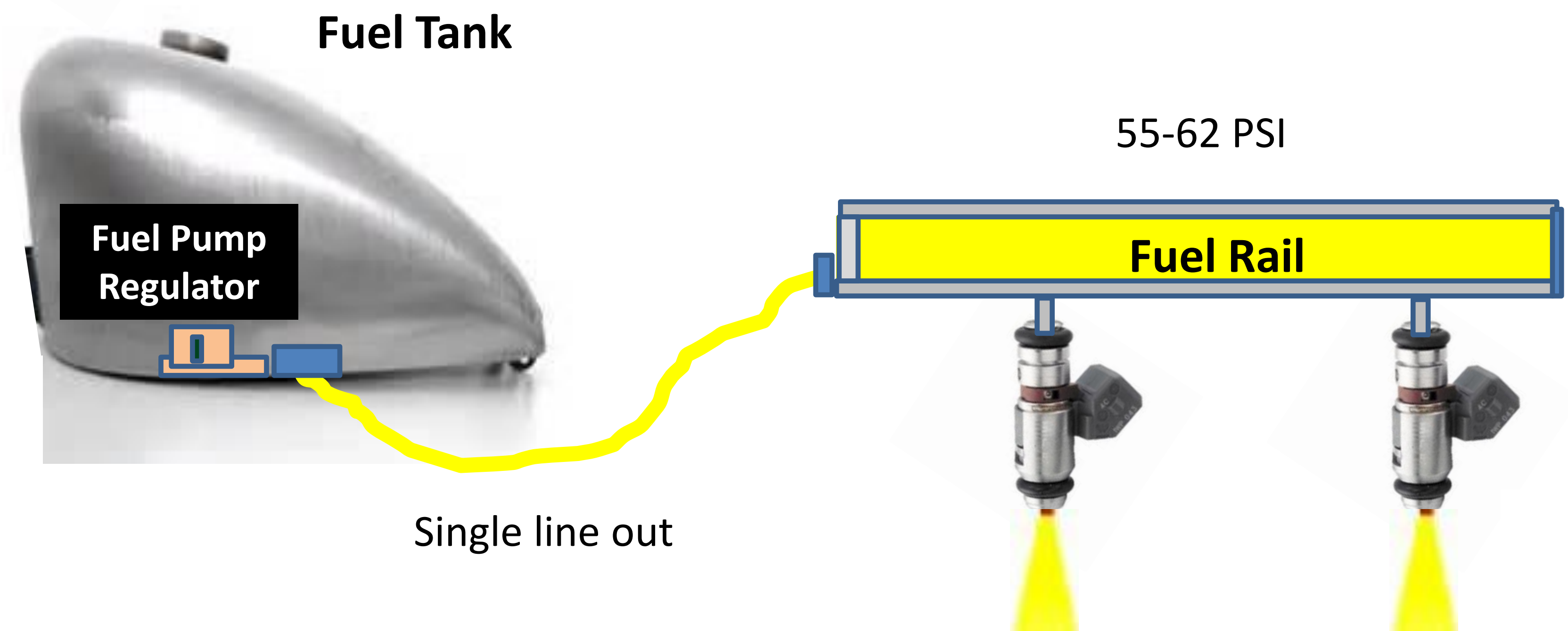
ECM Data Port



6 pin can

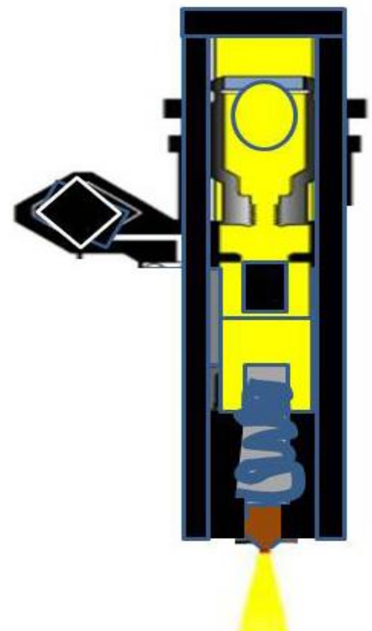
The data link port is used to attach electronic accessory items to your bike.
It is also used to connect tuning devices for diagnostic analysis.

Fuel Delivery System



The electric fuel pump and pressure regulator are located in the tank and are used to provide fuel to the fuel rail. Fuel is routed back into the fuel tank through the pressure regulator.

Injector



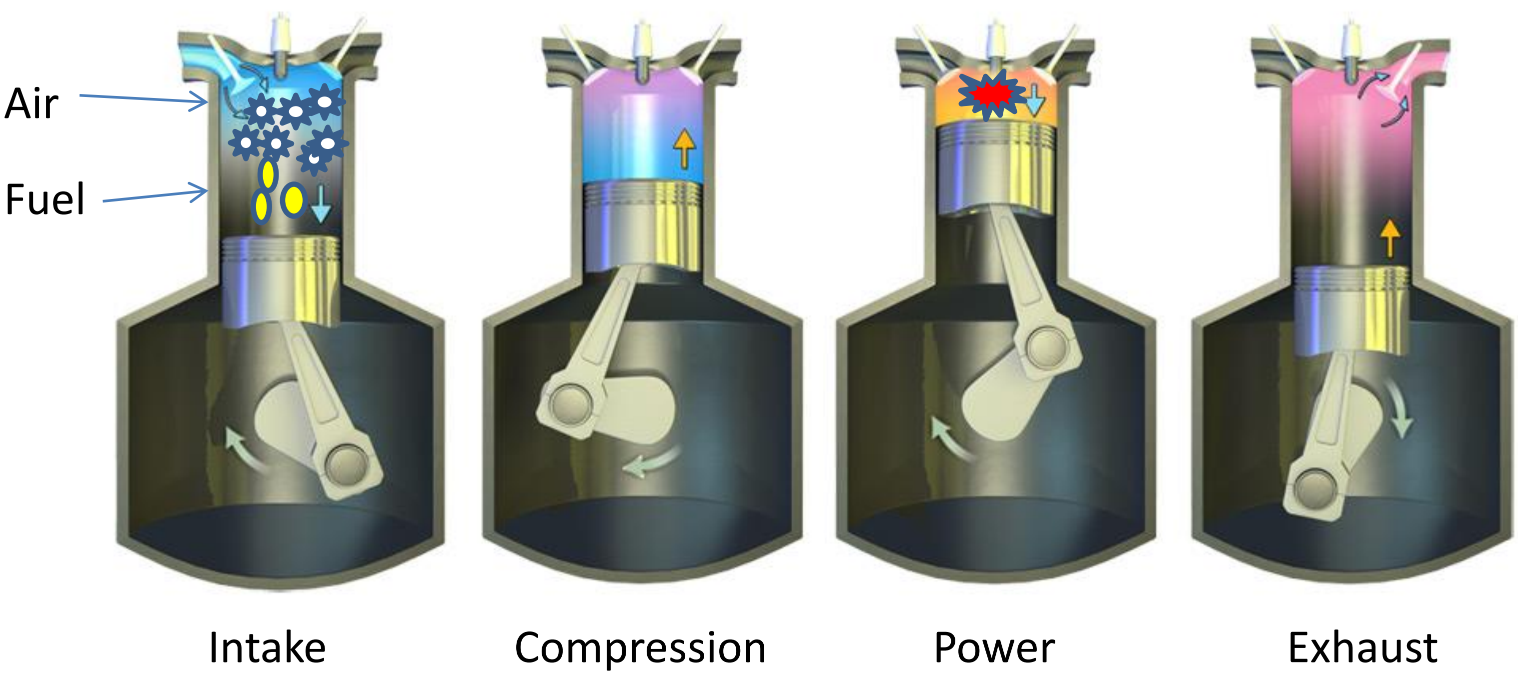
Pulse width is the amount of time the injector is open in milliseconds

The injector sprays fuel into the cylinder under pressure. Electrical signals from the ECM controls the amount of fuel sprayed into the engine by adjusting the injector pulse width.

Air / Fuel ratio   AFR

The AFR describes the amount of air vs. fuel that is being filled into the engine cylinder on each intake stroke.

Ex. A ratio of 14.7 = 14.7 parts air to 1 part fuel



Air/ Fuel mixtures

Here the chart also shows another scale known as Lambda

Lambda 1 = Stoich

Stoichiometric
"STOICH "

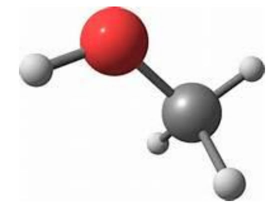
14.7

Operating Range	Lambda	Gasoline
Very Rich	0.78	11.5
	0.81	11.8
	0.83	12.2
Rich	0.86	12.6
	0.89	13.2
	0.91	13.4
	0.93	13.6
	0.94	13.8
Lean	0.98	14.4
	0.99	14.6
Stoich	1	14.7
Very Lean	1.01	14.8
	1.02	15

Operating Range

Stoichiometric
When there is enough air in the cylinder to burn all the fuel.

Lambda (λ)



Lambda is a scale that relates the air to fuel ratio of ANY fuel.

1.0 is the stoich value of that fuel.

*The chemically perfect ratio of air to fuel for a complete burn

However, stoich is different for all fuels. Some fuels may need 14.7 lbs of air some may need 6 lbs of air for a complete burn. Lambda 1.0 is always the perfect ratio for the fuel in use

Gasoline

Propane

Methanol

Ethanol

Diesel

Lambda values per fuel

Stoich

Lambda	Gasoline	Propane	Methanol	Ethanol	Diesel
0.70	10.3	11.0	4.5	6.3	10.2
0.75	11.0	11.8	4.9	6.8	10.9
0.80	11.8	12.5	5.2	7.2	11.6
0.85	12.5	13.3	5.5	7.7	12.3
0.90	13.2	14.1	5.8	8.1	13.1
0.95	14.0	14.9	6.1	8.6	13.8
1.00	14.7	15.7	6.5	9.0	14.5
1.05	15.4	16.5	6.8	9.5	15.2
1.10	16.2	17.2	7.1	9.9	16.0
1.15	16.9	18.0	7.4	10.4	16.7
1.20	17.6	18.8	7.8	10.8	17.4
1.25	18.4	19.6	8.1	11.3	18.1
1.30	19.1	20.4	8.4	11.7	18.9

Lambda conversion chart

Oxygen sensor readings

Lambda	AFR	O2 mV	Lambda	AFR	O2 mV	Lambda	AFR	O2 mV
0.800	11.74	909	0.991	14.55	758	1.020	14.97	102
0.810	11.89	907	0.992	14.56	756	1.030	15.12	95
0.820	12.04	904	0.993	14.58	750	1.040	15.27	90
0.830	12.18	901	0.994	14.59	746	1.050	15.41	87
0.840	12.33	896	0.995	14.61	741	1.060	15.56	84
0.850	12.48	893	0.996	14.62	730	1.070	15.71	80
0.860	12.62	887	0.997	14.64	645	1.080	15.85	78
0.870	12.77	882	0.998	14.65	580	1.090	16.00	73
0.880	12.92	875	0.999	14.67	515	1.100	16.15	71
0.890	13.07	868	1.000	14.68	450	1.110	16.29	69
0.900	13.21	862	1.001	14.69	385	1.120	16.44	66
0.910	13.36	853	1.002	14.71	320	1.130	16.59	64
0.920	13.51	844	1.003	14.72	255	1.140	16.74	62
0.930	13.65	836	1.004	14.74	190	1.150	16.88	60
0.940	13.80	828	1.005	14.75	150	1.160	17.03	58
0.950	13.95	819	1.006	14.77	142	1.170	17.18	58
0.960	14.09	809	1.007	14.78	135	1.180	17.32	56
0.970	14.24	799	1.008	14.80	129	1.190	17.47	55
0.980	14.39	786	1.009	14.81	124	1.200	17.62	55
0.990	14.53	761	1.010	14.83	120			

AFR   Rich / Lean

AFR numbers lower than stoichiometric are considered

Rich

14.7 ↓

Rich mixtures are less efficient, but produce more power and burn cooler, which is easier on the engine.

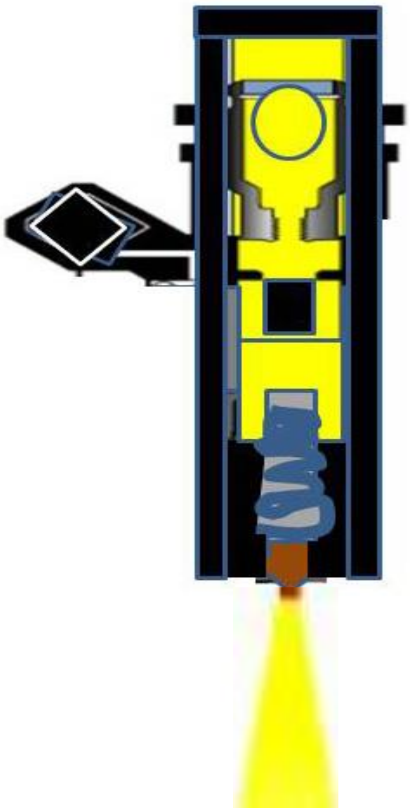
AFR numbers higher than stoichiometric are considered

Lean

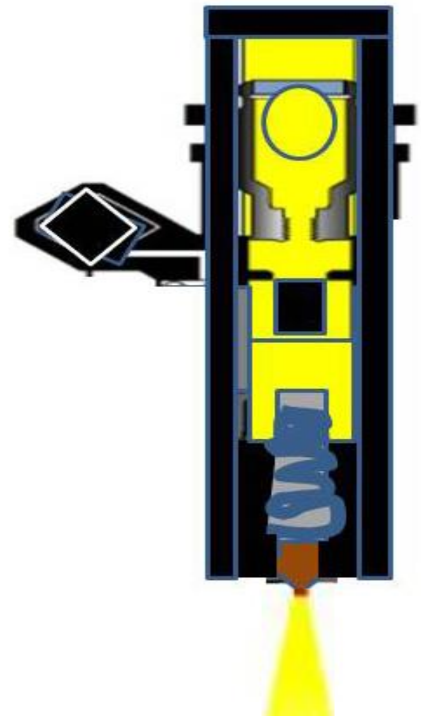
14.7 ↑

Lean mixtures are more efficient in controlling pollution but may cause engine damage or premature wear

Injector Pulse Width



Longer pulse width = More fuel
Richer mixture
13.2



Shorter pulse width = Less fuel
Leaner mixture
14 : 6

Government Regulations

EPA

The Environmental Protection Agency works to protect the environment and in so doing makes motorcycle manufacturers follow a strict set of guidelines when setting up a tune for your bike from the factory. Most bikes are manufactured with afr values set more to the lean side to reduce emissions.

Lean mixtures provide less unburned hydrocarbons emitted into the atmosphere . However, the engines tend to run hotter.

Rich mixtures **run cooler**. “ But produce more emissions “

Factory Settings

Manufacturers program the tune into the ECM at the factory and must conform to government standards and regulations.

OEM regulations for AFR settings = 14:6

* Leaner fuel mixtures will run **hotter.**

* Richer fuel mixtures will run **cooler.**

AFR Fuel Mixtures

Signs an engine is running too lean

Bike hesitates when throttle is increase
Bike runs jerky or surges at steady throttle openings
Engine spits back or coughs through intake system
Spark plug color is white

Signs an engine is running too rich

Engine chokes when throttle is increased
Engine fouls spark plugs…. Dark deposits in the exhaust
Black smoke from exhaust

Reading Spark Plugs

Removing the spark plugs and taking a reading can often times help in determining if an engine is running too rich or too lean.

Catalytic converters

A component made of specialized materials that helps reduce exhaust emissions established by the government.

They are placed in the exhaust pipe , either in the upper or lower header pipe. As far as the catalytic converters in the exhaust goes, a certain amount of heat is created by the catalytic reaction.

Converts toxic pollutants in the exhaust gas to less toxic pollutants by a catalytic reaction .

Catalytic converters are designed to operate at 14.7 afr to be efficient and work properly.

Effects of a lean mixture

The tune set by the manufacturer with the AFR set very lean and the use of catalytic converters can make the exhaust run hotter.

Converter Damage

Emission control regulations forced the removal of anti-knock **tetraethyll lead** from gasoline because the lead caused catalytic damage.

Computer sensors

Electronic sensors are located around the engine that send information as voltage signals back to the ECM .

The ECM uses these signal values in calculating
the proper fuel and spark needed for the bike to run properly.

List of Delphi Sensors

The number of sensors used depends
on the particular bike model

MAP sensor – measures manifold pressure

TPS sensor – measures throttle position

CKP sensor – measures the crankshaft position and RPM

IAT sensor – measures intake air temperature

ECT sensor – measures engine coolant temperature

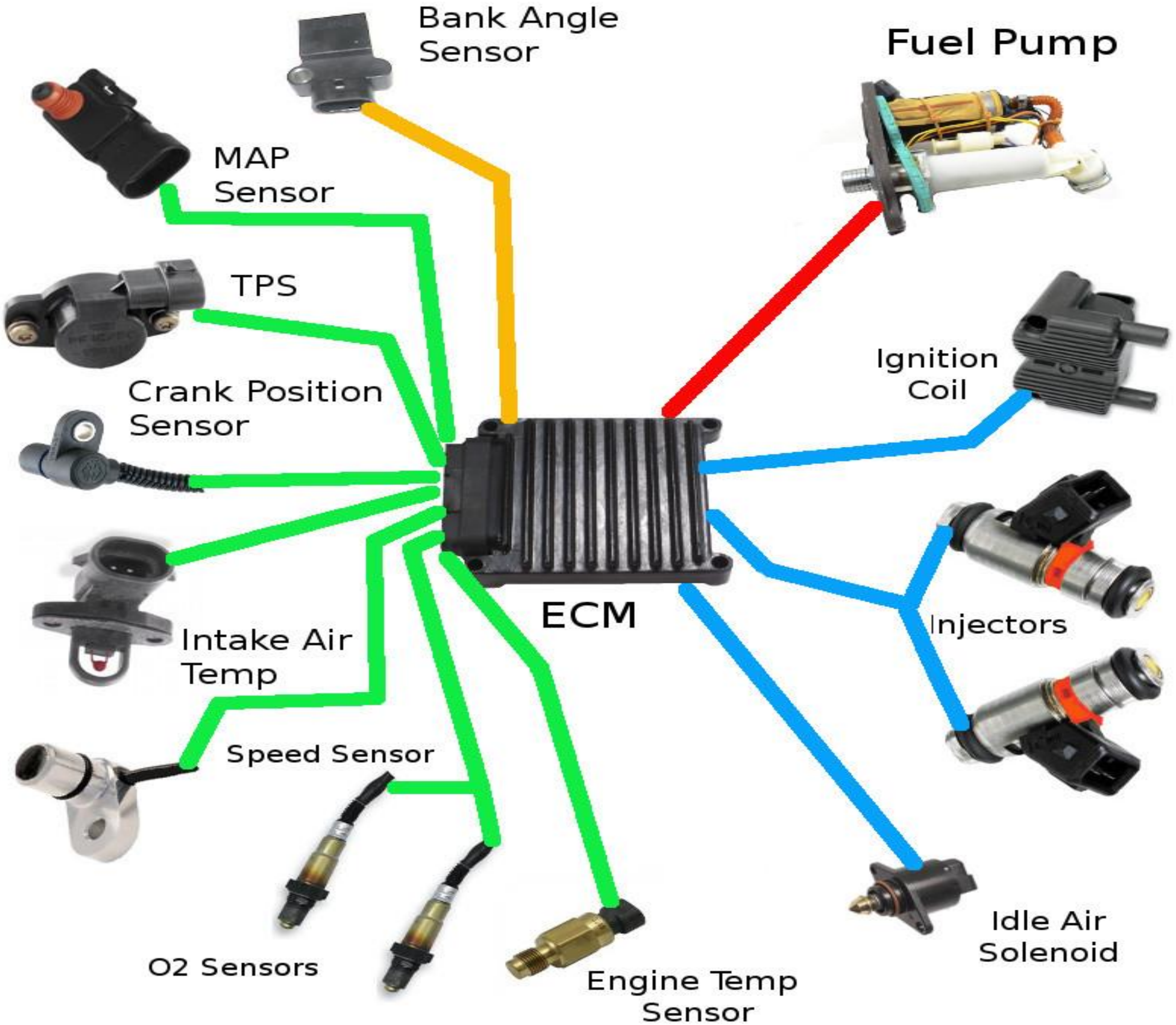
VSS sensor – measures vehicle speed

O2 sensor – measures oxygen in the exhaust

BAS – Bank Angle Sensor – detects if bike is tipped more than 45 degrees

Knock Sensor - Detects detonation in the combustion chamber

Sensors



Bank Angle Sensor
Fuel Pump
MAP Sensor
TPS
Crank Position Sensor
Ignition Coil
Injectors
Intake Air Temp
ECM
Speed Sensor
O2 Sensors
Engine Temp Sensor
Idle Air Solenoid

Engine Temperature Sensor

Many new EFI motorcycles are very hot running engines. One of the most common complaints about the new bikes is the heat produced by the engine and exhaust system.

During (warm-up) engines run in open –loop mode with a rich AFR of 12 : 1 .
After that they change over to closed –loop mode and start running more lean at 14.6

Temperatures can range anywhere from 200 – 350 degrees.
"After a 16 min. Idle"

Air Temperature Sensor

The temperature of the air going into the engine is important to the ECM for making *fine tune* adjustments to the AFR.

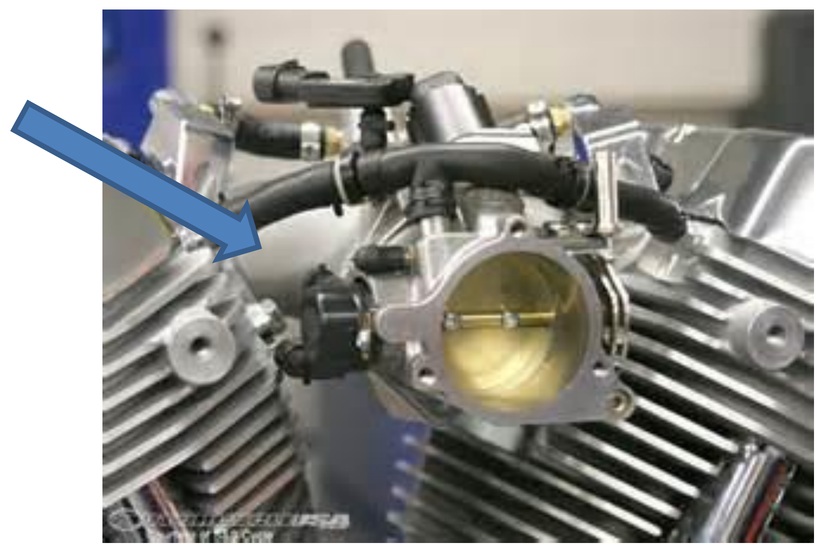
Cold air has more oxygen present , causing the ECM to richen the fuel mixture.

Throttle Position Sensor

The throttle position sensor provides the ECM with an indication of how much the throttle has been opened. Higher voltage signals sent to the ECM means more throttle.

The TPS sensor uses an electronic component that provides a 0-5 volt signals to the ECM.

Throttle Body

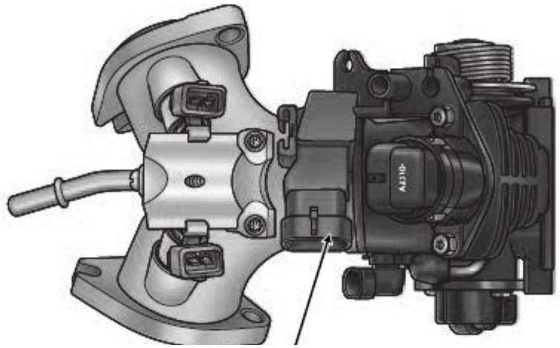


Crank Sensor

Provides sensor data for engine rpm and ignition timing.

Map Sensor

Manifold Absolute Pressure sensor provides instant air pressure information back to the ECM. Air density and air mass flow are measured and are a part of the fuel equation.



Map Sensor

kPa : kilopascal is a unit of measure that describes air pressure

MAP : Typical kPa readings

Idle: 30 kPa to 40 kPa

Full throttle: 80 kPa to 100 kPa

Bank Angle Sensor

This sensor determines the lean angle of the motorcycle.

If the banking on the bike exceeds designated levels, the engine will **turn off**. Usually, beyond 45 degrees. Location and application depends on the model of the bike.

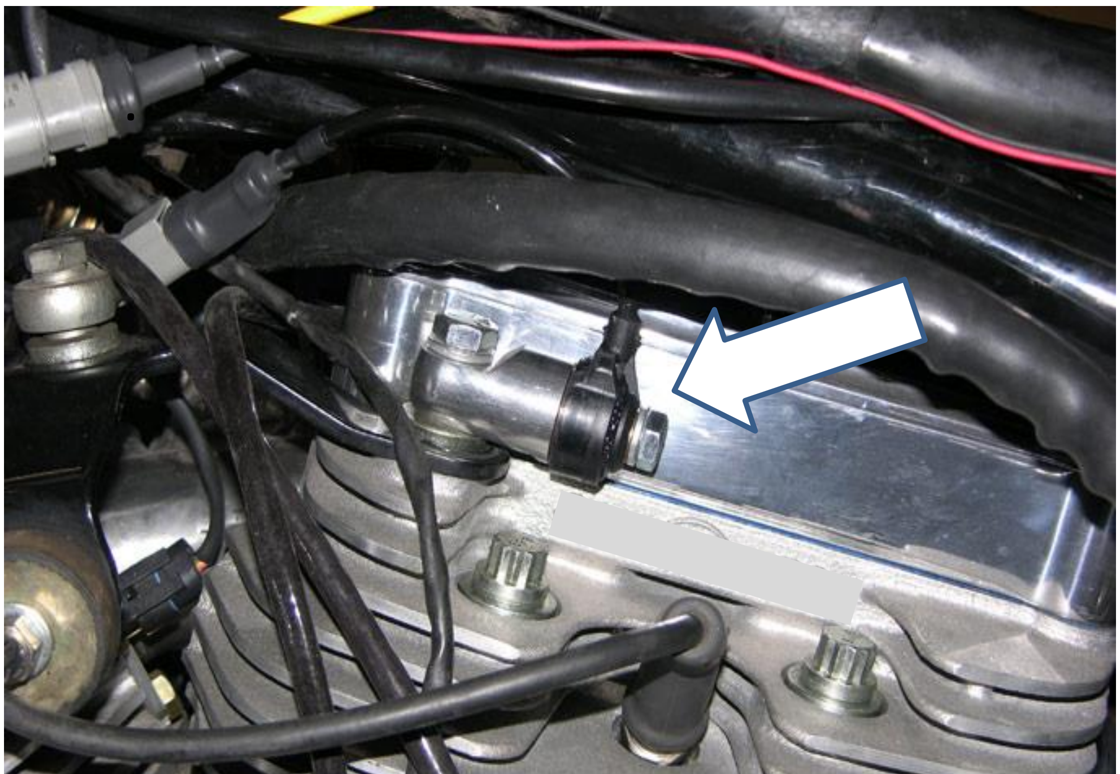
This sensor is a safety feature on EFI systems.

Re-setting the bike to re-start varies by models.
First try recycling the ignition switch. On/off

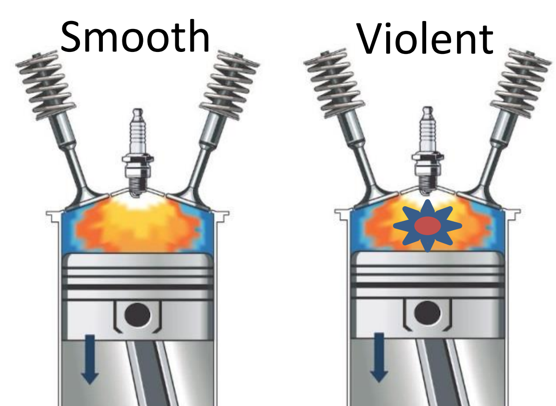
Knock Sensor

Detects engine detonation . The ECM will retard the timing & richen the fuel mixture to reduce the knock.

Note: Not all engines have knock sensors.



Detonation - When the combustion in the engine explodes violently rather than with a smooth burn.



Idle Air Control

Idle Air Control controls and maintains a consistent engine idle RPM under a wide variety of conditions by making minor adjustments to the airflow into the engine.

The IAC is a stepper motor, similar to a valve that can allow varying amounts of air into the engine to keep the idle stable.

Idle speed is also managed by a memory table in the ECM that responds to engine temperature.

When the engine is keyed-off, the Idle Air Control is reset to a "parked" position

Oxygen Sensors

O2

The oxygen sensor is located inside in the exhaust pipe, and it is used to detect rich or lean mixtures.

The sensor is an essential component in the emissions control system as it transmits data to the engine's ECM.

The primary function of the oxygen sensor is to help the engine operate as smoothly as possible by detecting and using fuel efficiently while reducing those harmful exhaust emissions.

Oxygen Sensor

O2

Measures the amount of oxygen in the exhaust which is a reflection of the Air/Fuel ratio. (AFR)

Signal to ECM : 0 to 1 volt output

Narrowband sensor

Measures AFR in the range of 14.3 – 15 :2

O2 Sensor Locations

Ahead of catalytic converter

O2

O2

Narrowband O2 Sensor

A **narrowband** O2 sensor only works for adjusting low load & cruise areas and does not work well in performance applications because it can only monitor a small area within the 14.6 range.

This range is considered too lean a fuel mixture for performance.

If you are wanting to monitor the AFR outside the range of a narrowband sensor, you must install a **wideband sensor.**

Narrowband vs.

Wideband O2 Sensors

Narrowband sensors are used as a stock sensor from the manufacturer and has a small range of operation ..

14.3 – 15: 2 AFR

The Wideband sensor uses a wider operating range for performance applications that utilize richer mixtures.

10 – 14 AFR

Narrowband 12 mm

Wideband 18 mm

Fuel-maps

Fuel maps are a part of the tables stored in the ECM memory. They are used by the ECM to provide proper AFR to the engine.

Tuners can make changes to the fuel maps and change the AFR.

Fuel maps can be downloaded from the manufacturers websites and flashed into the ECM.

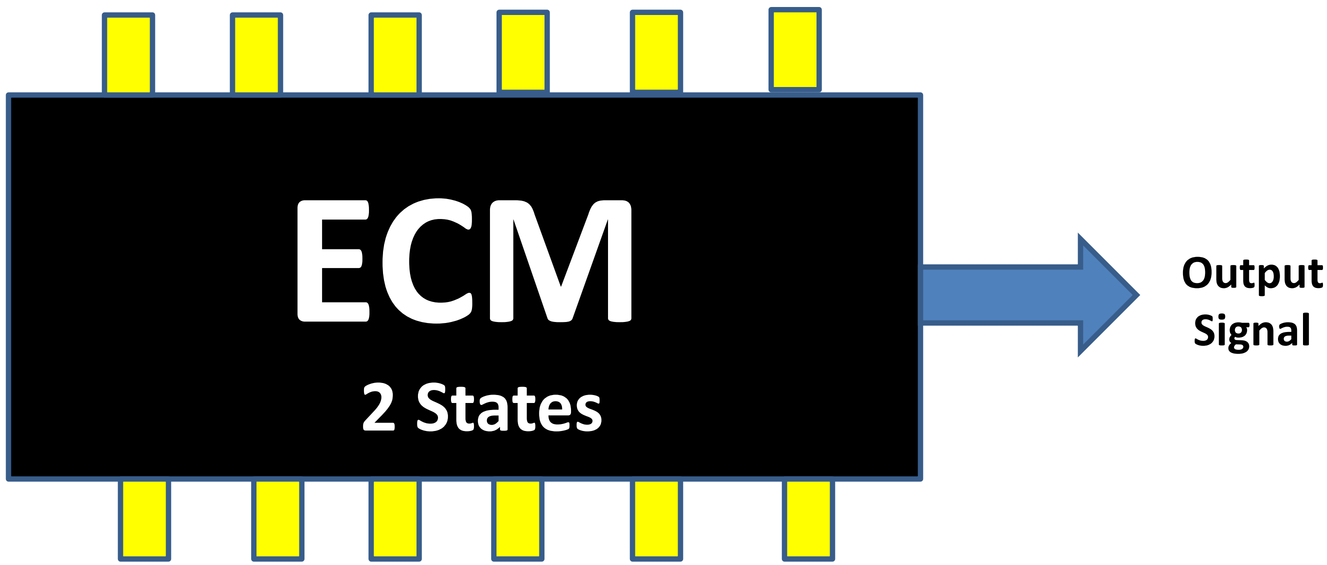
Fuel maps are used in Open – loop operation

Fuel Map

Air-Fuel Ratio (Stoich)
PV-2H.pvt

RPM	MAP (KPa)										
	20	27	30	40	50	60	70	80	85	90	100
750	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1000	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1125	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1250	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1500	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.5	13.9	13.0
1750	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2000	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2250	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2750	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
3000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
3500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
5000	14.0	13.0	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.0
5500	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
6000	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0

How the ECM works



Closed–loop mode
The ECM receives voltage signals from the O2 sensors and other sensors located on the engine to provide the proper fuel and spark.

Open –loop mode
The ECM uses pre-programmed data stored in its memory to provide an output signal for fuel and spark.

"Open Loop" and "Closed Loop"

When the engine is first started, and begins to idle and warm up, the system will go into 'Open Loop' operation. Here, the ECM will use pre-programmed tables in the ECM memory to provide the proper air/fuel ratio needed by the engine.

In 'Open Loop', the ECM will ignore the signals from the oxygen sensors and rely only on its fuel maps and tables in its memory.

When ready, the system will go into closed –loop operation and the ECM will use data from its 02 sensors to set the proper air/fuel ratio for the best fuel efficiency and pollution control.

Closed vs. Open- Loop

Closed- loop:

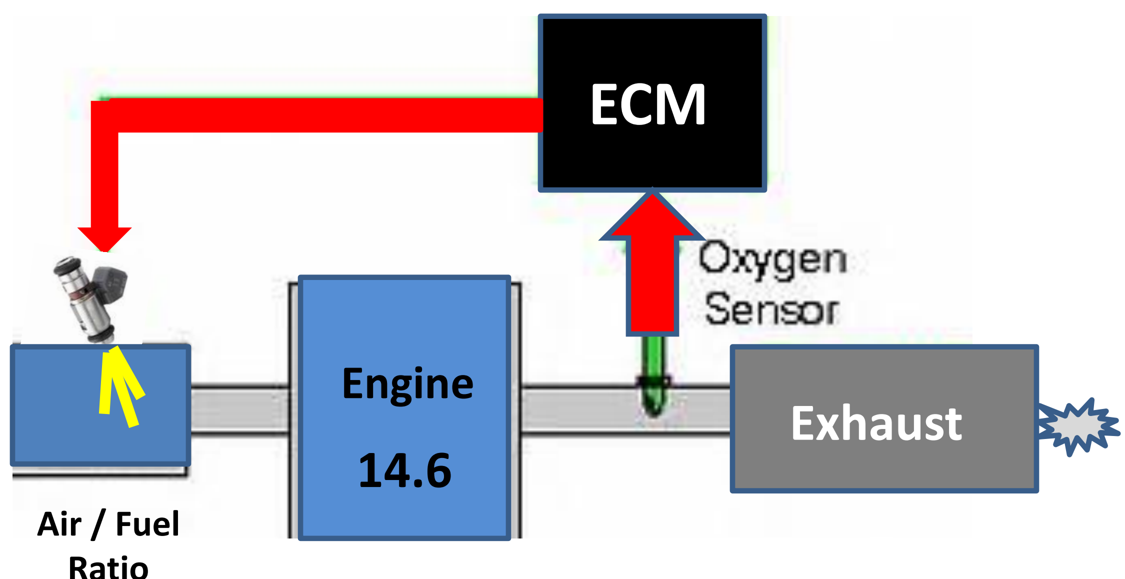
O2 sensors are used to monitor the AFR .... Providing feedback to the ECM that will make adjustments on the fly to maintain a 14:6 AFR **Self Monitoring System**

Open – loop:

The O2 sensors are not used.
The ECM uses "look up tables" and maps stored in memory to provide the proper AFR. **Programmed Maps**

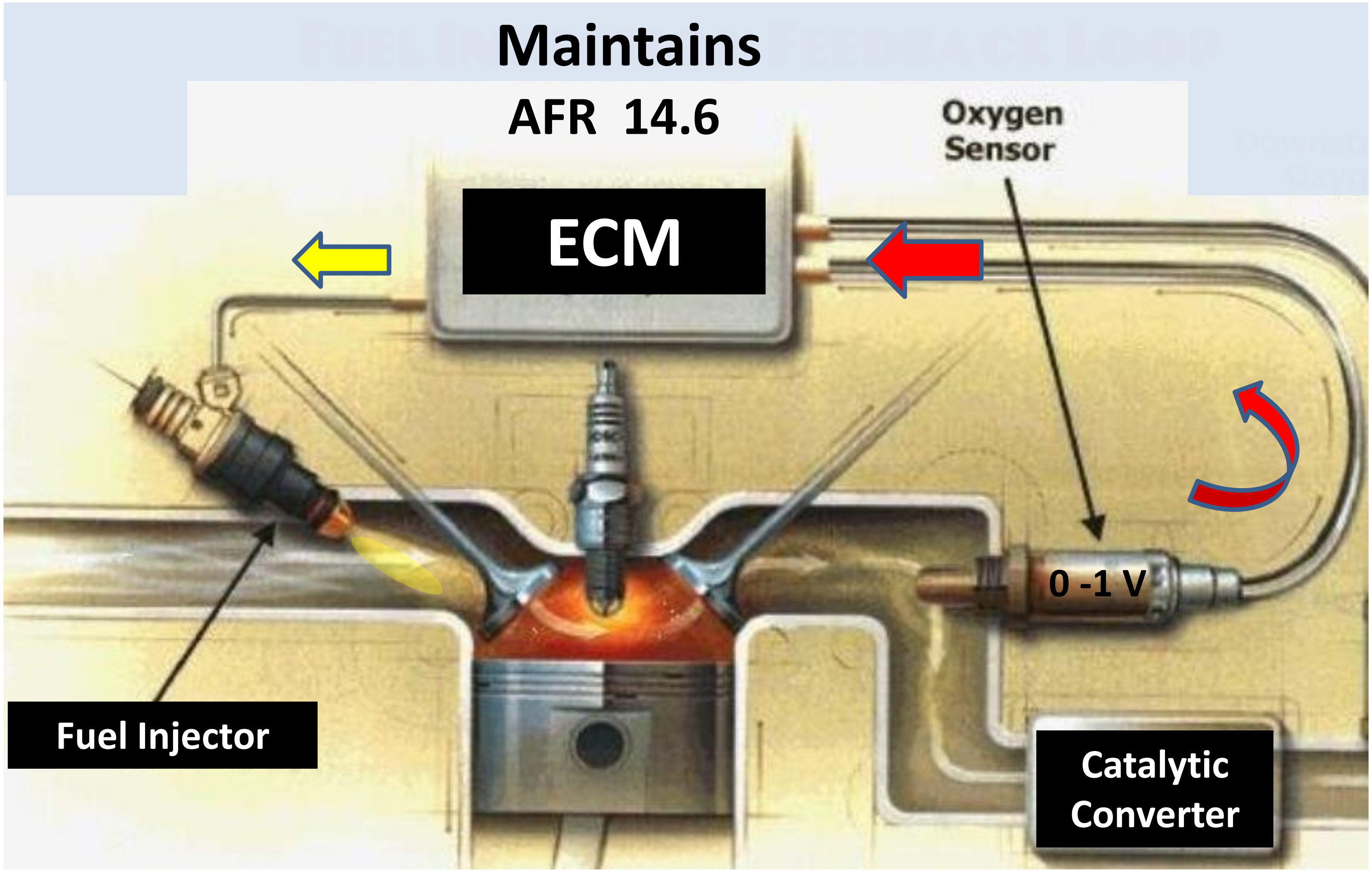
Closed Loop Operation

As the engine runs at different operating conditions , it will constantly be running in and out of open and closed loop.



Closed-Loop self monitoring

Closed – Loop Operation



In closed-loop , the ECM manages the AFR and maintains a 14.6 ratio

02 Override

O2 sensor voltage is transmitted to the ECM. After determining if the mixture is rich or lean, the ECM adjusts the amount of fuel that enters the engine. The fuel map is ignored during closed-loop.

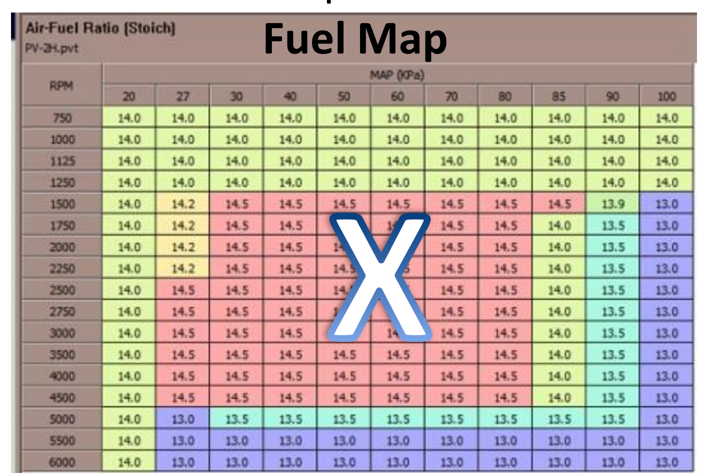
1 Volt
750 mV
500 mV
250 mV
0 V

→ Rich signal output (1 Volt)

→ Lean signal output (0 V)

O2

Fuel map not used



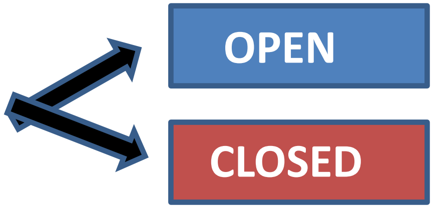
Air-Fuel Ratio (Stoich)
PV-2H.pvt

Fuel Map

RPM	MAP (KPa) 20	27	30	40	50	60	70	80	85	90	100
750	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1000	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1125	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1250	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1500	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.5	13.9	13.0
1750	14.0	14.2	14.5	14.5	[illegible]	[illegible]	14.5	14.5	14.0	13.5	13.0
2000	14.0	14.2	14.5	14.5	[illegible]	[illegible]	14.5	14.5	14.0	13.5	13.0
2250	14.0	14.2	14.5	14.5	14.5	[illegible]	14.5	14.5	14.0	13.5	13.0
2500	14.0	14.5	14.5	14.5	[illegible]	[illegible]	14.5	14.5	14.0	13.5	13.0
2750	14.0	14.5	14.5	14.5	[illegible]	[illegible]	14.5	14.5	14.0	13.5	13.0
3000	14.0	14.5	14.5	14.5	[illegible]	[illegible]	14.5	14.5	14.0	13.5	13.0
3500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
5000	14.0	13.0	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.0
5500	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
6000	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0

Idle and Cruise

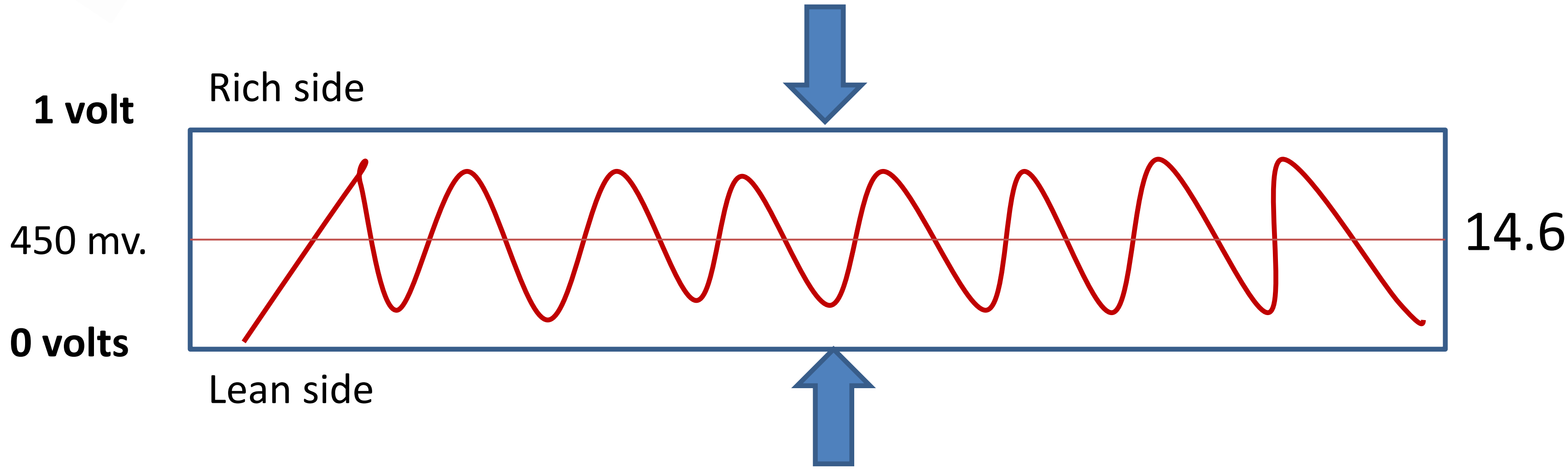
Constantly switching 95% of the time in closed loop



The ECM uses the closed position the majority of the time because the bike is most often idling or cruising.

It's open and running on the fuel tables for a short but important time during acceleration and power , which is above three-quarter throttle .

O2 Output Voltage



The ECM constantly adjusts the AFR to stay within this window

Narrowband Oxygen Sensors send signals from 0 to 1 volt back to ECM

Targeted AFR

The target AFR is found on the fuel map and is pre-programmed into the ECM at the factory.

The target AFR can be changed using a tuner program connected to the ECM data port.
AFR is changed using computer software.

The actual AFR is what is actually produced and can be measured in the exhaust with a special afr gauge.

It is one goal of the tuner to make sure the targeted AFR on the map equals the measured AFR in the exhaust.

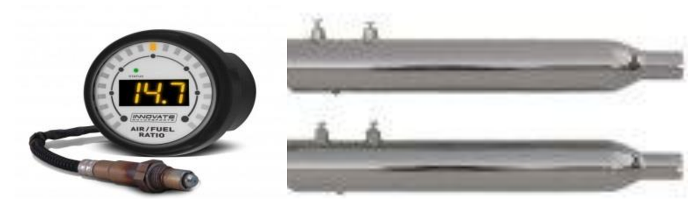
Target vs. Actual AFR

Fuel Map

RPM	MAP (kPa) 20	30	40	50	60	70	75	80	90	100
750	14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.9	12.7	12.5
1000	14.6	14.6	14.6	14.6	[illegible]	14.6	14.6	13.9	12.7	12.5
1250	14.6	14.6	14.6	14.6	[illegible]	14.6	14.6	13.9	12.7	12.5
1500	14.6	14.6	14.6	14.6	[illegible]	14.6	14.6	14.6	12.7	12.5
1750	14.6	14.6	14.6	14.6	[illegible]	[illegible]	14.6	14.6	12.7	12.5
2000	14.6	14.6	14.6	14.6	[illegible]	[illegible]	14.6	14.6	12.7	12.5
2250	14.6	14.6	14.6	14.6	14.6	[illegible]	14.6	14.6	12.7	12.5
2500	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.7	12.5
3000	14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.9	12.7	12.5
3500	14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.9	12.7	12.5
3750	14.6	14.6	14.6	14.6	14.6	14.6	14.6	13.9	12.7	12.5
4000	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.7	12.7	12.5
4500	13.2	13.2	13.2	13.2	13.2	13.1	13.0	12.8	12.6	12.5
5000	12.8	12.8	12.8	12.8	12.8	12.8	12.7	12.6	12.5	12.5
5500	12.8	12.8	12.8	12.8	12.8	12.7	12.6	12.5	12.5	12.5
6000	12.8	12.8	12.8	12.8	12.8	12.7	12.6	12.5	12.5	12.5
7000	12.8	12.8	12.8	12.8	12.8	12.7	12.6	12.5	12.5	12.5

Targeted AFR is also known as Commanded AFR

Actual AFR is measured in the exhaust



Target vs. Actual AFR

One goal in tuning is to calibrate the VE tables so that they accurately represent that the **Targeted AFR = Actual AFR**

If they are far apart, then the tuner needs to make adjustments to VE table to correct the problem. The AFR at the exhaust should match the targeted AFR on the fuel map.

The only time the VE tables would need to be re-calibrated is if mechanical changes have been made to the engine.

* New high flow air filter
* New exhaust system
* Cam replacement

ECM Calibrating

Example: If the ECM has a fuel map target value of 14.2 in a cell but the measured exhaust value of the AFR is 13.5. Then , the ECM VE table needs to be re-calibrated.

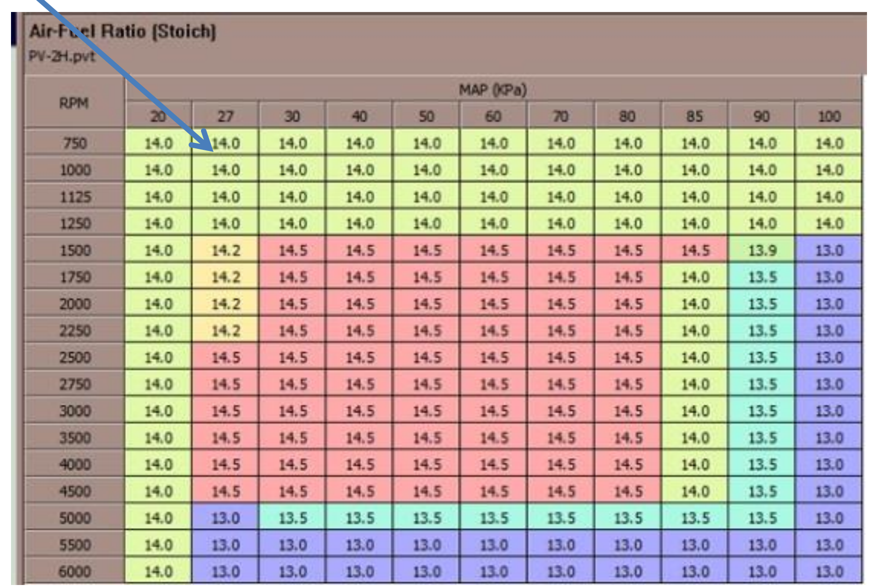
When tuning, the VE tables are calibrated to match the target AFR.

Cell

VE Table

kPa \ RPM	600	1100	1800	2400	3100	3800	4500	5200	5900	6600	7300	8000
100.0	84	85	85	90	95	102	108	112	115		112	111
99.0	83	78	83	88	81	87	105	108	115	113	112	111
97.0	82	65	66	74	69	73	96	99	111	112	112	110
95.0	81	61	63	63	55	60	81	99	107	110	114	110
93.0	66	52	50	49	44	49	60	104	100	108	111	110
89.0	53	36	35	38	36	35	47	73	105	103	105	109
81.0	44	33	31	34	35	34	40	50	90	102	105	107
68.0	37	31	32	33	34	34	35	46	53	80	90	90
62.0	31	28	27	30	31	33	31	42	55	70	72	80
54.0	28	28	25	27	28	30	30	37	56	63	67	65
46.0	27	26	22	24	24	24	27	37	52	54	61	63
35.0	27	24	17	16	15	15	14	17	23	31	60	59

Fuel Map



Air-Fuel Ratio (Stoich)

PV-2H.pvt

RPM	MAP (KPa)										
	20	27	30	40	50	60	70	80	85	90	100
750	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1000	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1125	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1250	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1500	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.5	13.9	13.0
1750	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2000	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2250	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2750	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
3000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
3500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
5000	14.0	13.0	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.0
5500	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
6000	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0

Fuel-Map

Changing this value to 13.2 will richen the AFR

RPM	Mass Airflow Pressure Kpa										
	20	27	30	40	50	60	70	80	85	90	100
750	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
[illegible]	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1125	[illegible]	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1250	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
1500	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.5	13.9	13.0
1750	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2000	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2250	14.0	14.2	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
2750	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
3000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
3500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4000	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
4500	14.0	14.5	14.5	14.5	14.5	14.5	14.5	14.5	14.0	13.5	13.0
5000	14.0	13.0	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.0
5500	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
6000	14.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0

Note: If the VE tables are properly calibrated, then changes you want to make to AFR during engine operation can be made on this Fuel Map .

AFR Switch

Setting the fuel map cells to 14. 6 acts like a switch and tells the ECM to run in the closed –loop mode to modify the AFR.

	MAP (kPa)											
RPM	20	27	30	40	50	60	70	80	85	90	95	100
750	14.0	14.0	14.0	14.0	14.2	14.2	14.2	13.4	13.0	13.0	13.0	13.0
1000	14.[illegible]	14.0	14.2	14.2	14.2	14.2	14.2	13.4	13.0	13.0	13.0	12.5
1125	14.4	[illegible]6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	13.0	12.5
1250	14.4	14.6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	13.0	12.5
1500	14.4	14.6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	12.5	12.5
1750	14.4	14.6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	12.5	12.5
2000	14.4	14.6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	12.5	12.5
2250	14.4	14.6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	12.5	12.5
2500	14.4	14.6	14.6	14.6	14.6	14.6	13.3	13.3	13.3	13.0	12.5	12.5
2750	14.4	14.5	14.6	14.6	14.6	14.5	13.3	13.3	13.0	12.5	12.0	12.0
3000	14.2	14.2	14.2	14.2	14.2	13.9	13.3	13.3	12.5	12.2	11.5	11.5
3500	14.0	14.0	14.2	14.2	14.2	13.9	13.3	13.3	12.5	12.2	11.5	11.5
4000	13.9	13.9	14.2	14.2	14.2	13.9	13.3	13.2	12.5	12.2	12.0	12.0
4500	13.0	13.5	14.2	14.2	13.5	13.5	13.2	12.8	12.5	12.2	12.0	12.0
5000	12.8	13.5	13.5	13.5	13.5	13.5	13.2	12.8	12.5	12.2	12.2	12.2
5500	12.8	13.0	13.0	13.0	13.0	13.0	13.0	12.2	12.2	12.2	12.2	12.2
6000	12.6	12.6	12.6	12.6	12.6	12.6	12.5	12.1	12.0	12.0	12.0	12.0

Fuel Map Regions

RPM	MAP (KPa)									
	20	30	40	50	60	70	75	80	90	100
750	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1000	13.7	13.7	13.7	13.7	13.7	13.8	13[illegible]	13.2	13.1	13.1
1125	13.7	13.7	13.7	13.7	13.7	13.8	1[illegible]8	13.2	13.1	13.1
1250	13.7	13.7	13.7	13.7	13.7	13.8	[illegible]3.8	13.2	13.1	13.1
1500	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1750	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2000	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2250	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2500	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2750	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.2	13.1	13.1
3000	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.2	13.1	13.1
3500	13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.2	13.1	13.1
4000	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	13.1	13.1
4500	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	13.1	13.1
5000	12.8	12.8	12.8	12.8	12.8	12.8	12.8	13.1	13.1	13.1
5500	12.8	12.8	12.8	12.8	12.8	12.8	12.8	13.1	13.1	13.1
6000	12.8	12.8	12.8	12.8	12.8	12.8	12.8	13.1	13.1	13.1

Fuel Map

14. 6 indicates the ECM will operate in closed - loop

RPM	MAP (KPa)											
	20	25	30	40	50	60	70	75	80	85	90	100
750	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
1000	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
1250	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
1500	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
1750	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
2000	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
2250	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
2500	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
2750	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
3000	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
3500	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
4000	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
4500	13.0	14.3	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	12.5	12.5
5000	13.0	14.3	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.5	12.5
5500	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.5	12.5
6000	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.5	12.5
6500	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	12.5	12.5

Fuel-Map

Air-Fuel Ratio (Stoich)

0809-96-JPHB-O16.pvt

RPM	MAP (KPa)									
	20	30	40	50	60	70	75	80	90	100
750	13.8	13.8	13.8	13.8	13.8	13.3	13.3	12.1	12.1	12.1
1000	13.8	13.8	13.8	13.8	13.8	13.3	13.3	12.1	12.1	12.1
1250	13.8	13.9	14.1	14.2	14.2	13.8	13.8	12.1	12.1	12.1
1500	12.7	13.9	14.1	14.2	14.2	13.8	13.8	12.4	12.4	12.4
1750	12.7	13.9	14.1	14.2	14.2	13.8	13.8	12.5	12.5	12.5
2000	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
2250	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
2500	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
3000	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
3500	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.5	12.5	12.5
3750	13.8	14.1	14.1	14.1	14.1	13.8	13.8	12.5	12.5	12.5
4000	13.8	12.9	12.9	12.9	12.9	12.8	12.8	12.5	12.5	12.5
4500	13.2	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
5000	12.5	12.5	12.5	12.5	12.4	12.4	12.4	12.4	12.4	12.4
5500	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
6000	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
6500	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4

Fuel Map

Lambda values

RPM	MAP (KPa)									
	20	30	40	50	60	70	75	80	90	100
750	0,938	0,938	0,932	0,932	0,932	0,932	0,925	0,911	0,870	0,856
1000	0,938	0,938	0,938	0,938	0,938	0,938	0,938	0,911	0,870	0,856
1250	0,938	0,938	0,938	0,938	0,938	0,938	0,938	0,911	0,870	0,856
1500	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
1750	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
2000	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
2250	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
2500	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
3000	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
3500	0,966	0,966	0,966	0,966	0,966	0,938	0,911	0,904	0,870	0,856
3750	0,952	0,952	0,952	0,952	0,952	0,938	0,911	0,904	0,870	0,856
4000	0,938	0,938	0,938	0,938	0,938	0,925	0,897	0,904	0,870	0,856
4500	0,904	0,904	0,904	0,904	0,904	0,897	0,890	0,884	0,863	0,856
5000	0,877	0,877	0,877	0,877	0,877	0,877	0,870	0,863	0,856	0,856
5500	0,877	0,877	0,877	0,877	0,877	0,870	0,863	0,856	0,856	0,856
6000	0,877	0,877	0,877	0,877	0,877	0,870	0,863	0,856	0,856	0,856
6500	0,877	0,877	0,877	0,877	0,877	0,870	0,863	0,856	0,856	0,856

Adaptive fuel trim

Fuel trim: The ability of the ECM to make fuel corrections to the programmed afr when in closed loop mode by adapting itself to engine environmental mechanical changes. Keeps afr values in-line. Base value = 14.6

These are learned values stored in memory after hours of riding. These long term fuel corrections are stored in the ECM memory and become a part of the tune for the bike.

Note: Fuel trims can be erased using a tuning program. When the battery is dis-connected , it also erases the adaptive fuel trim values stored in the ECM memory.

Adaptive Fuel Trim

How it works

Adaptive fuel control works by the ECM calculating how much fuel to deliver to hit the **Targeted** AFR Value.

O2 sensors determine what the **Actual** AFR Value really is.

If there is a difference in the two values, the ECM makes an adjustment (correction) and stores the difference in an Adaptive Fuel Value cell in the ECM memory.

It is known as a correction profile and is applied to the fuel equation each time the bike is started.

Fuel Trim

If the o2 sensor sends a signal to the computer that the exhaust mixture is lean, the computer adds fuel by lengthening injector pulse . If the o2 sensors send a voltage signal to the ECM that the engine is running rich, then the computer takes fuel away.

This is known as : **Fuel Trim**

Since the ECM is monitoring the
AFR at the exhaust using the o2 sensors
in closed-loop , the ECM compensates when
the afr is not within a tolerance close to target value

Taking fuel away

Adding fuel

Fuel Trim

For the engine to operate within the factory specs , the AFR needs to stay close to targeted values while in closed- loop operation.

The ECM is trying to maintain this proper air/fuel ratio by fine-tuning the afr going into the engine by making corrections.

The fuel trim values are used by the ECM as part of its overall fuel equation calculations that determine pulse width.

These values even with diagnostic tools and tuners can not be seen for evaluation.

Fuel Trim

Fuel trim values were created to comply with EPA emission standards along with catalytic converters to reduce exhaust emissions. Catalytic converters need a stoichiometric AFR of 14.7 to operate the best at reducing toxic emissions.

Fuel trims are developed during closed-loop operation.

Positive fuel trim means the ECM is richening the fuel mixture to compensate for a lean condition.

Negative fuel trim means the ECM is trying to lean out the fuel mixture to compensate for a rich condition.

ECM Learning

Your bike has the ability to learn while running in closed-loop mode. As you ride the fuel trims (corrective adjustments made by the ECM to maintain targeted values) will be stored in memory and will be used in the fuel equation until erased.

Note: Dis-connecting the battery will erase the trim values … they will then have to be re-learned. (takes about 1 hour of riding time)

Closed- loop Fuel trims are created and used

Open –loop When recorded , fuel trims are used

Fuel Trim

Values

Adaptive fuel trim values as a result of corrections to the afr in closed-loop operation are recorded in memory of the ECM.

Problem: Intake manifold leak / Lean exhaust / Creates Positive Fuel Trim
Problem: Fuel injector stuck open / Rich exhaust / Creates Negative Fuel Trim

ECM corrective fuel control

Problem

Rich Exhaust

ECM stores a lean value in memory

Problem

Lean Exhaust

ECM stores a rich value in memory

- 10 % ← 0% → + 10%

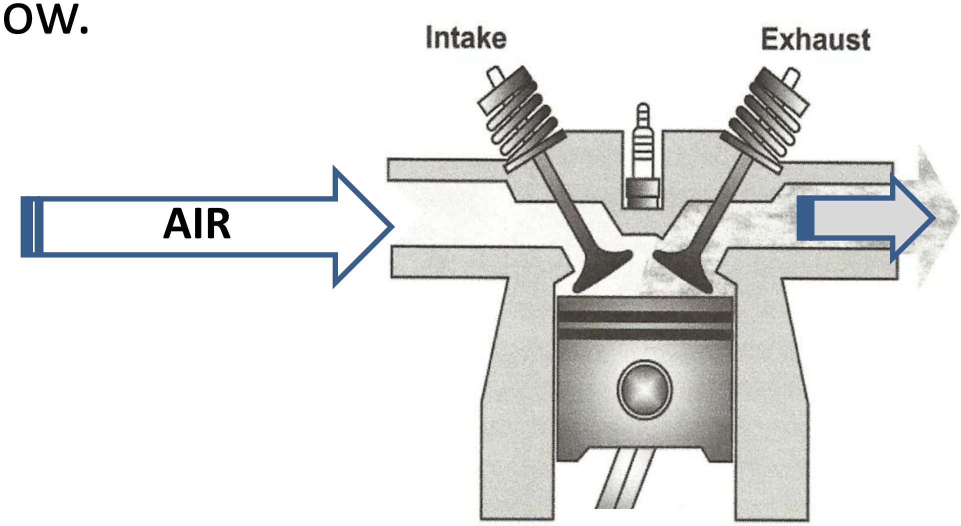
Base

Volumetric Efficiency

The amount of air that enters the engine compared to what the the engine could theoretically could manage is the volumetric efficiency . It is the air moving in and out of the engine.

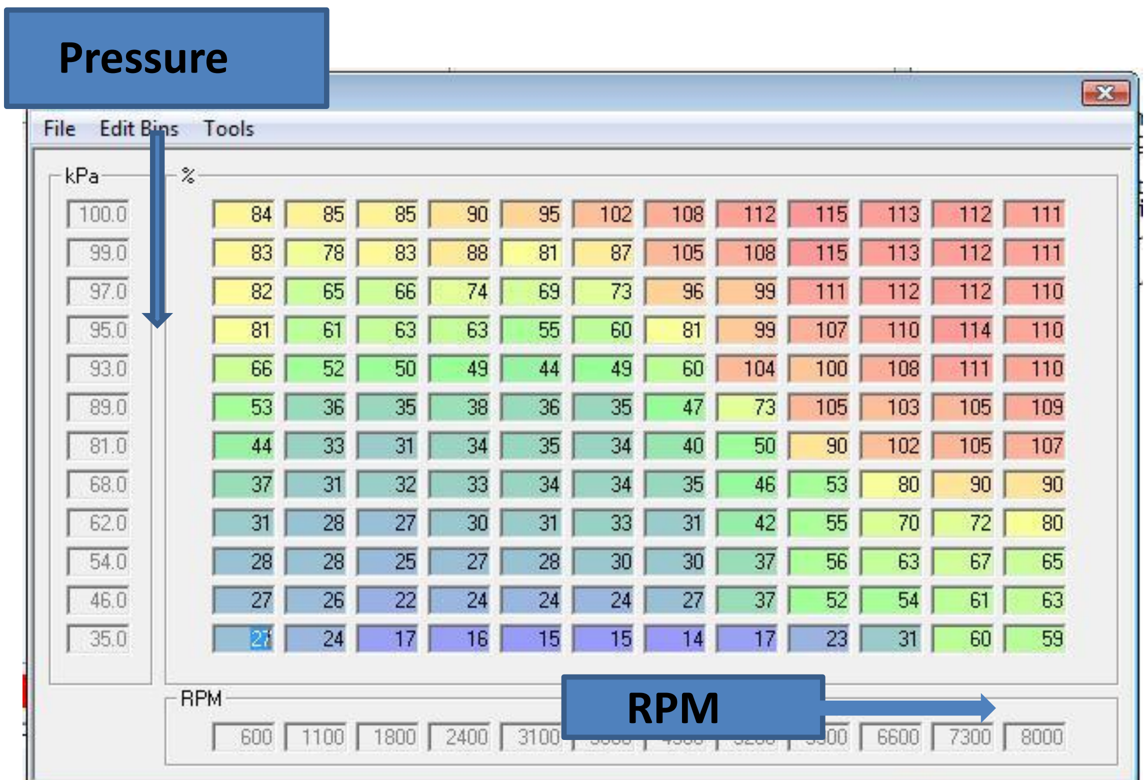
Air management can be changed by adding different exhaust systems, adding a performance cam, or changing the air cleaner to provide more unrestricted air flow.

VE



VE Table

The ECM looks at data stored in the VE table.
Tuners can change this data , which in effect will change the AFR.
Increasing these values , enriches the AFR.



kPa \ RPM	600	1100	1800	2400	3100	[illegible]	[illegible]	[illegible]	[illegible]	6600	7300	8000
100.0	84	85	85	90	95	102	108	112	115	113	112	111
99.0	83	78	83	88	81	87	105	108	115	113	112	111
97.0	82	65	66	74	69	73	96	99	111	112	112	110
95.0	81	61	63	63	55	60	81	99	107	110	114	110
93.0	66	52	50	49	44	49	60	104	100	108	111	110
89.0	53	36	35	38	36	35	47	73	105	103	105	109
81.0	44	33	31	34	35	34	40	50	90	102	105	107
68.0	37	31	32	33	34	34	35	46	53	80	90	90
62.0	31	28	27	30	31	33	31	42	55	70	72	80
54.0	28	28	25	27	28	30	30	37	56	63	67	65
46.0	27	26	22	24	24	24	27	37	52	54	61	63
35.0	27	24	17	16	15	15	14	17	23	31	60	59

VE Table

Increasing these values ..tells the ECM that more air is entering the engine, and through its calculations for determining AFR , will richen the mixture.

RPM	Throttle Position (Percent)										
	0	2	5	10	15	20	30	40	60	80	100
500	79.0	81.0	82.0	84.5	87.0	94.5	91.0	88.0	91.0	94.0	97.0
750	79.0	81.0	82.0	84.5	87.0	94.5	91.0	88.0	91.0	94.0	97.0
1000	80.5	81.5	82.5	85.0	87.5	97.5	91.0	88.0	91.0	94.0	97.0
1250	80.5	91.5	94.0	95.0	98.5	107.5	93.5	88.0	91.0	94.0	97.0
1500	80.5	91.5	94.0	95.0	98.5	107.5	93.5	88.0	91.0	94.0	97.0
1750	70.5	87.0	87.0	90.0	91.5	99.5	93.5	82.0	85.0	88.0	91.0
2000	74.0	88.5	90.5	93.5	95.0	102.0	97.0	67.0	70.0	73.0	76.0
2250	74.0	83.5	86.5	88.5	90.5	97.0	97.0	71.0	74.0	77.0	80.0
2500	77.0	85.5	88.5	90.5	94.0	97.0	97.0	70.0	73.0	76.0	79.0
2750	78.0	91.5	94.5	94.5	100.0	103.0	108.0	71.0	74.0	77.0	80.0
3000	78.0	91.5	94.5	94.5	100.0	103.0	108.0	76.0	79.0	82.0	85.0
3500	78.0	104.5	107.5	107.5	111.0	115.0	119.0	86.0	89.0	92.0	95.0
4000	78.0	108.0	110.5	110.5	115.5	118.0	123.5	90.0	93.0	96.0	99.0
4500	73.0	107.0	109.5	109.5	114.5	117.0	122.5	89.0	92.0	95.0	98.0
5000	73.0	101.0	103.5	103.5	108.5	111.0	116.5	89.0	92.0	95.0	98.0
5500	73.0	101.0	103.5	103.5	108.5	111.0	116.5	90.0	93.0	96.0	99.0
6000	73.0	101.0	103.5	103.5	108.5	111.0	116.5	91.0	94.0	97.0	100.0
7000	73.0	101.0	103.5	103.5	108.5	111.0	116.5	91.0	94.0	97.0	100.0

VE Map

Differences

The VEs will never be identical in both cylinders because of differing intake length, exhaust pipe length, reversion, timing, cooling and other factors. Front cylinders cool more than rear.

Reversion
Back pressures in the exhaust that is present due to the design of the cam, engine timing and valve overlap.

VE Table 1 (MAP)

File Edit Bins Tools

kPa \ RPM (%)	600	1100	1800	2400	3100	3800	4500	5200	5900	6600	7300	8000
100.0	84	85	85	90	95	102	108	112	115	113	112	111
99.0	83	78	83	88	81	87	105	108	115	113	112	111
97.0	82	65	66	74	69	73	96	99	111	112	112	110
95.0	81	61	63	63	55	60	81	99	107	110	114	110
93.0	66	52	50	49	44	49	60	104	100	108	111	110
89.0	53	36	35	38	36	35	47	73	105	103	105	109
81.0	44	33	31	34	35	34	40	50	90	102	105	107
68.0	37	31	32	33	34	34	35	46	53	80	90	90
62.0	31	28	27	30	31	33	31	42	55	70	72	80
54.0	28	28	25	27	28	30	30	37	56	63	67	65
46.0	27	26	22	24	24	24	27	37	52	54	61	63
35.0	27	24	17	16	15	15	14	17	23	31	60	59

Engine Timing

The ignition spark plug firing must occur at the proper time for the engine to run its best.

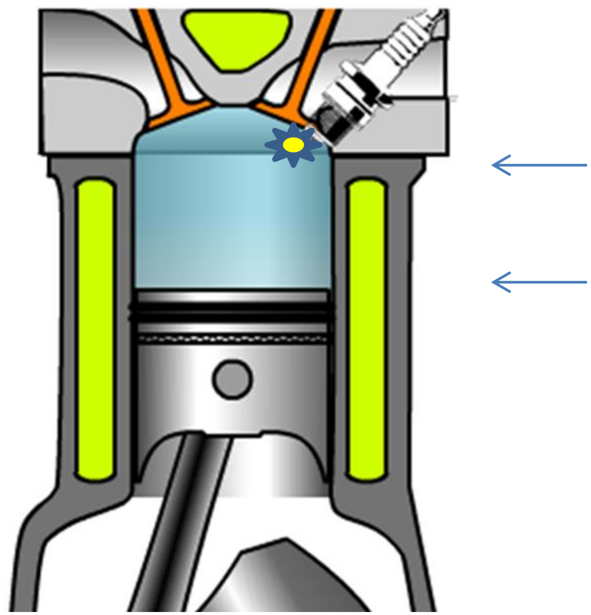
Spark timing can be advanced or retarded .
BTDC Before top dead center.

Timing of the spark is controlled by the ECM for start, idle, cruise and power ranges.

Setting the correct ignition timing is crucial in the performance of an engine. Sparks occurring too soon or too late in the engine cycle are often responsible for excessive vibrations and even engine damage.

Ignition Timing

The computer has a timing map (lookup table) with spark advance values for all combinations of engine speed and load. These tables are used by the ECM to calculate engine timing.



Spark Map

Spark Advance (Front Cyl) (Read Only)

original_tune_Harley.pvt

RPM	MAP (KPa)									
	20	30	40	50	60	70	80	90	95	100
750	16.00	16.00	16.00	16.00	14.00	9.00	2.00	2.00	2.00	2.00
1000	16.00	16.00	16.00	16.00	14.00	10.00	2.00	2.00	2.00	2.00
1125	17.00	17.00	17.00	17.00	15.00	11.00	2.00	2.00	2.00	2.00
1250	20.00	20.00	20.00	19.00	18.00	13.00	2.00	2.00	2.00	2.00
1500	25.00	25.00	23.00	23.00	21.00	18.00	7.00	3.00	2.50	2.00
1750	27.00	27.00	26.00	25.00	23.00	21.00	13.00	7.50	6.50	5.00
2000	29.00	29.00	29.00	28.00	27.00	24.00	18.00	11.00	9.00	8.00
2250	33.00	33.00	33.00	31.00	30.00	27.00	22.00	14.00	12.00	12.00
2500	39.00	39.00	37.00	34.00	31.00	29.00	24.00	18.00	15.00	15.00
2750	42.00	42.00	39.00	36.50	33.50	31.00	26.00	21.00	17.00	17.00
3000	45.00	45.00	42.00	39.00	36.00	32.00	28.00	23.00	19.00	19.00
3500	45.00	45.00	45.00	42.00	37.50	34.00	30.00	25.00	22.00	22.00
4000	45.00	45.00	45.00	43.00	37.50	35.00	31.00	27.00	24.00	23.00
4500	45.00	45.00	45.00	44.00	38.00	36.00	32.00	29.00	26.50	25.00
5000	45.00	45.00	45.00	45.00	39.00	37.00	33.00	31.00	28.00	27.00
5500	45.00	45.00	45.00	45.00	41.00	38.00	35.00	32.00	30.00	29.00
6000	45.00	45.00	45.00	45.00	42.00	38.00	35.00	32.00	30.00	30.00
6500	35.00	40.00	45.00	45.00	45.00	42.00	39.00	36.00	33.00	30.00
7000	35.00	40.00	45.00	45.00	45.00	42.00	39.00	37.00	33.00	30.00
7500	35.00	40.00	45.00	45.00	45.00	42.00	39.00	37.00	33.00	30.00
8000	35.00	40.00	45.00	45.00	45.00	42.00	39.00	37.00	33.00	30.00

Understanding
“look-up” Tables”

Most tuning involves making changes to tables (also called **“look-up”** tables) that the ECM uses to control various functions during engine operation over various loads & rpm. These tables are pre-programmed into the ECM.

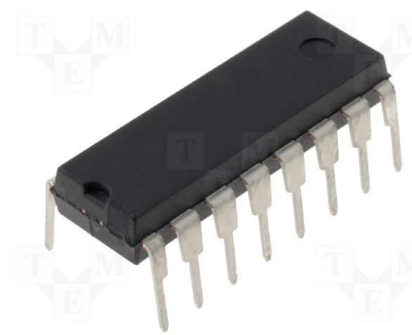
The ECM takes input data from the bike’s sensors , then looks up pre-programmed values in the tables to make fuel and spark timing calculations.

ECM must calculate
How much fuel does the engine need
and when do I fire the plug ?

Basic ECM

Look-up Tables

- Cranking table
- Engine crank to run
- Warm up enrichment table
- Idle air control table
- Idle RPM table
- Fuel map AFR table
- Volumetric Efficiency table
- Accelerator enrichment table
- Power enrichment table
- Deceleration en-leanment table



Stored in the ECM flash memory

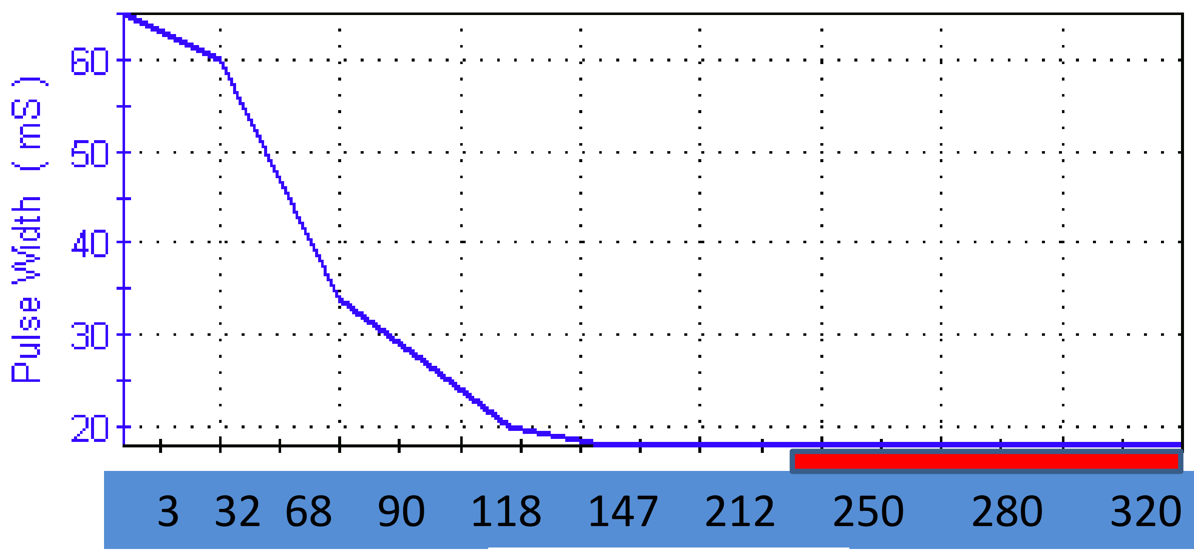
Crank Table

* The following (Modifier) tables are for reference only as each bike tune is different

During crank mode, timing is always fixed at 0 degrees Top Dead Center (TDC) and the AFR is controlled by the **Cranking Fuel** table. Auto-choke

Deg F	m Sec
3	65
32	59.9
68	33.8
90	27.8
118	20
147	17.9
176	17.9
205	17.9
234	17.9
290	17.9
320	17.9

Fuel Pulse width vs. Engine Temperature



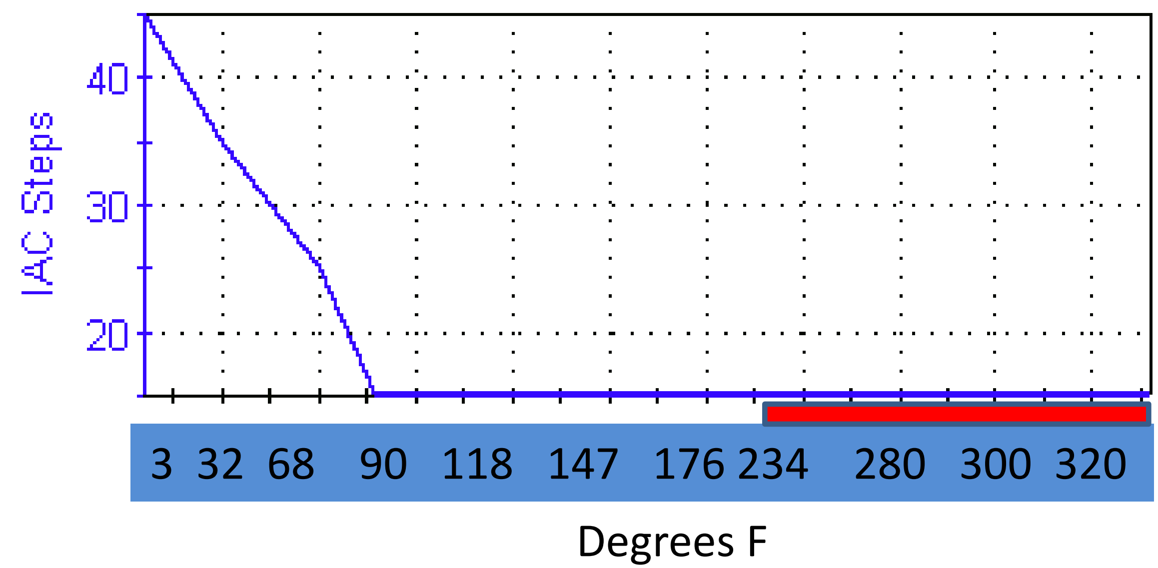
Degrees F

Engine Crank to Run

As soon as the engine fires, it begins a transition to the “Run” mode. During this transition, additional fuel and air is needed to prevent the engine from stalling or hesitating. This transition is controlled by the IAC Crank to run table.

Deg F	Steps
3	45
32	35
68	25
90	15
118	15
147	15
176	15
234	15
320	15

Idle air steps vs Engine Temperature

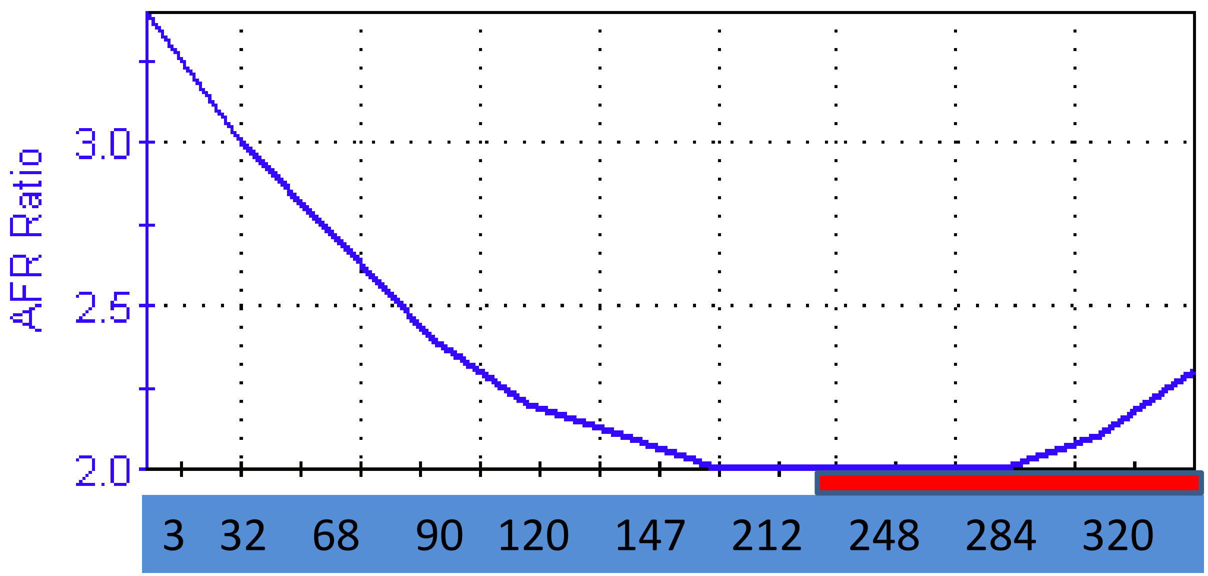


Warm-up Table

During engine warm up, the engine will run in open loop mode and use a 12.5:1 Rich AFR. Enrichment Table.

Deg F	AFR
3	3.4
32	3.0
68	2.7
90	2.4
120	2.2
147	2.1
176	2.0
205	2.0
234	2.0
262	2.0
291	2.1
320	2.3

AFR vs. Engine Temperature



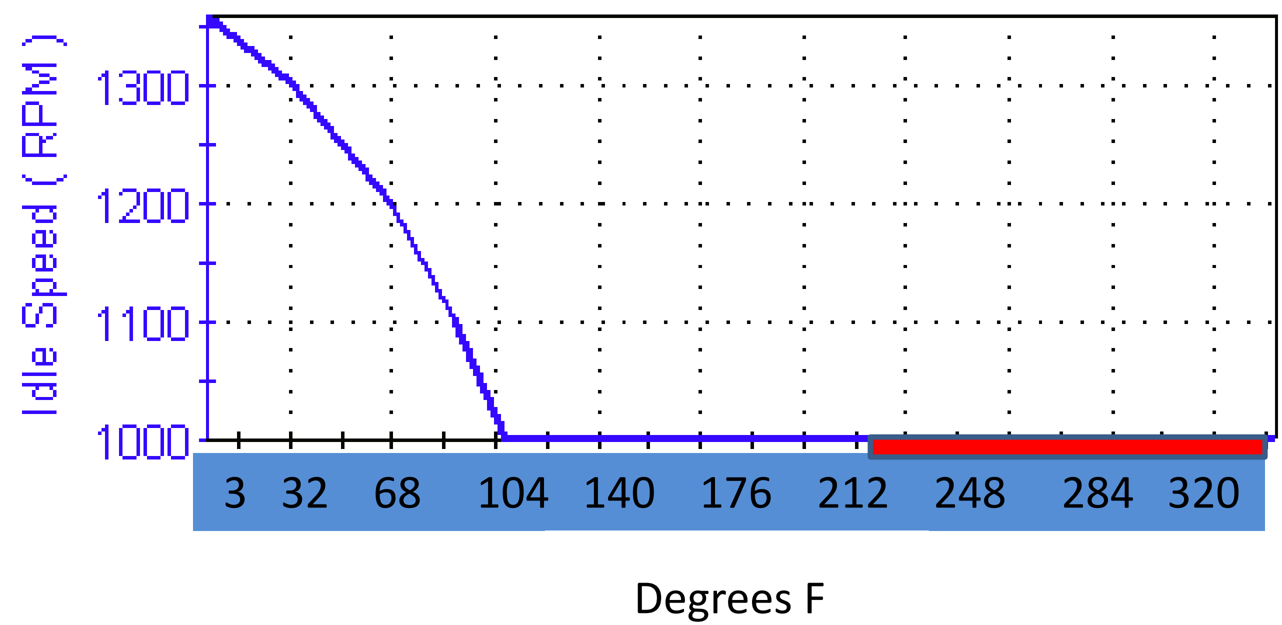
Degrees F

Idle Rpm Table

As the engine warms up, the idle speed is controlled by the **Idle RPM** table.

Deg F	RPM
3	1360
32	1304
68	1200
90	1104
108	1000
147	1000
176	1000
205	1000
234	1000
320	1000

Idle RPM vs. Engine Temperature



Idle Air Control

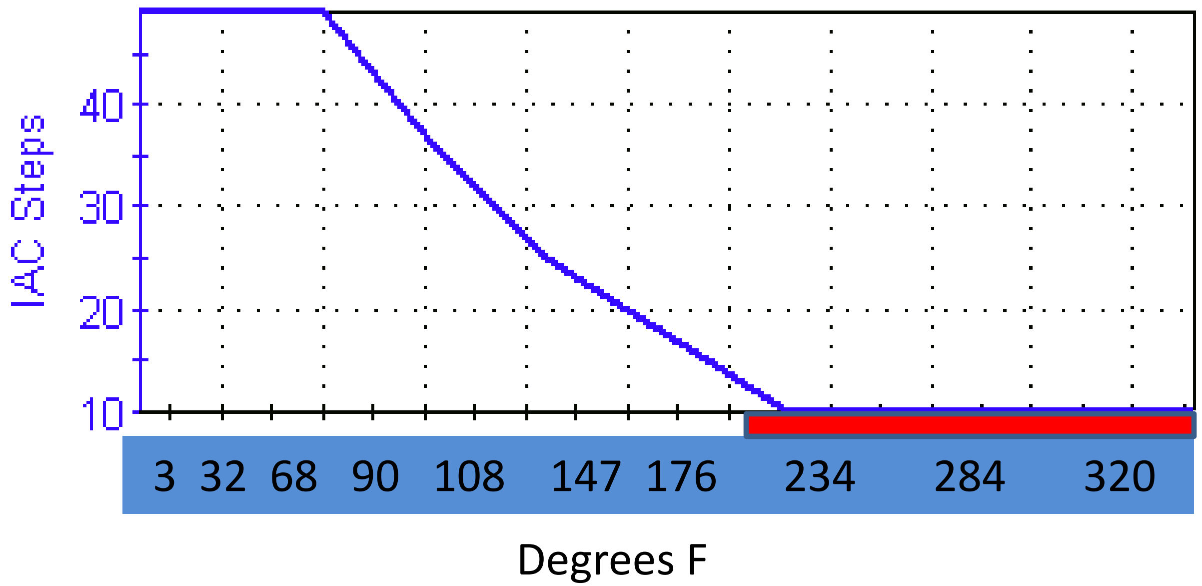
Warm-up Steps

Is used to maintain stable idle speed during warm-up.

If the bikes warm-up idle speed is unstable, try adjusting this table

Deg F	Steps
3	49
32	49
68	49
90	42
108	36
147	25
176	20
205	15
234	10
320	10

IAC steps vs. Engine Temperature

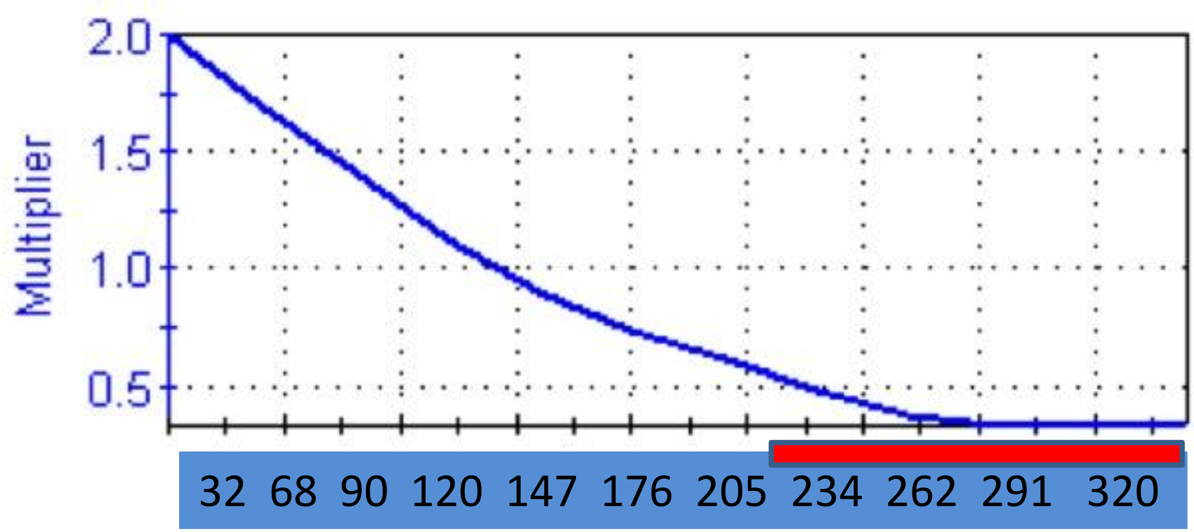


Accelerator Enrichment Table

Multiplier table that injects fuel on acceleration to prevent hesitation when the throttle is opened quickly . To increase the fuel delivered, increase the multiplier value.

Deg F	Mult X
32	2.0
68	1.7
90	1.4
120	1.13
147	0.91
176	0.73
205	0.61
234	0.48
262	0.38
291	0.33
320	0.33

Fuel multiplier vs. Engine Temperature

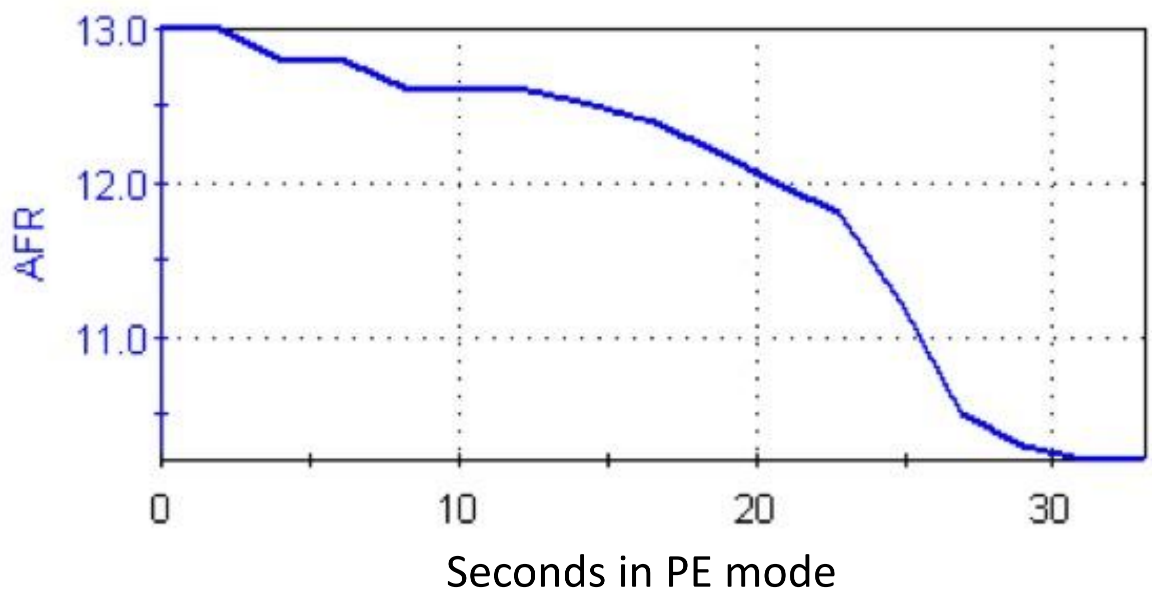


Degrees F

Power Enrichment Table

Operates when the throttle is **Wide –Open** …for a period of time.
The AFR gradually richens over time to prevent engine overheating.

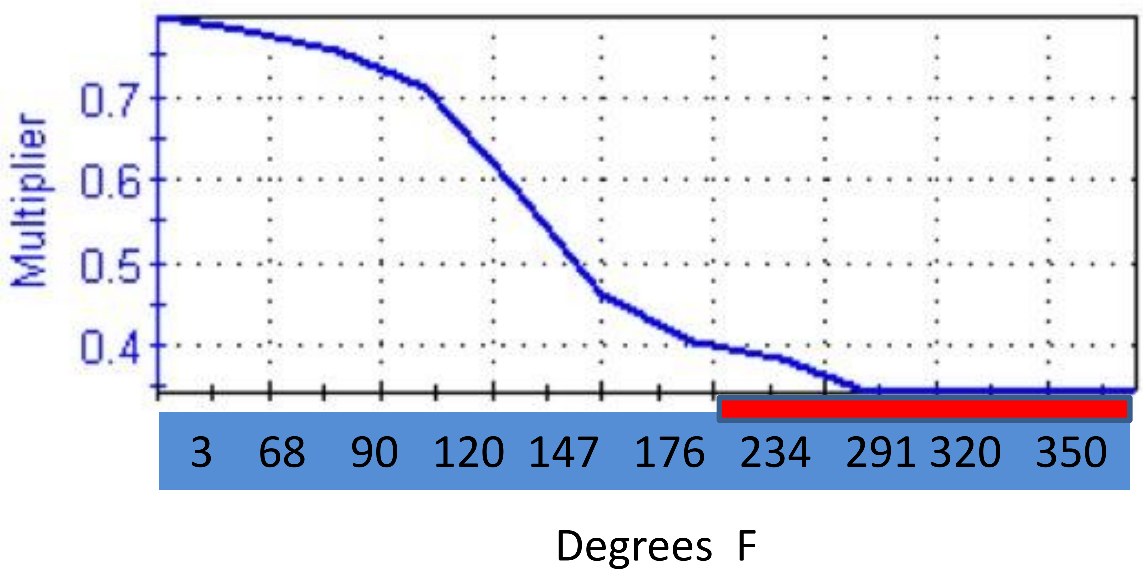
Seconds	AFR
0	13
2	13
4	12.8
6	12.8
8	12.6
10	12.6
12	12.6
14	12.5
17	12.2
21	12
27	10.5
30	10.2



De-Leanment Table

The table affects exhaust popping when the throttle is closed.
Control is by the multiplier table. Most often the popping occurs because the mixture is too lean. Setting the multiplier value lower will richen the AFR.

Deg F	Mult X
3	0.8
68	0.78
90	0.76
120	0.71
147	0.59
176	0.46
205	0.41
234	0.38
262	0.34
291	0.34
320	0.34
350	0.34

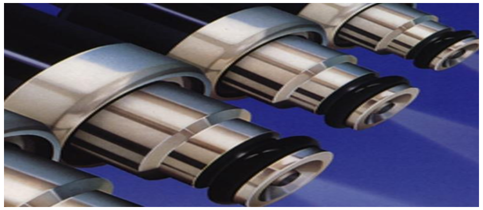


Fuel Equation

The fuel equation that includes spark timing involves a complex set of instructions necessary to provide the engine with the commanded afr.

Open-loop: Fuel map + VE Map + Tables = Injector pulse width

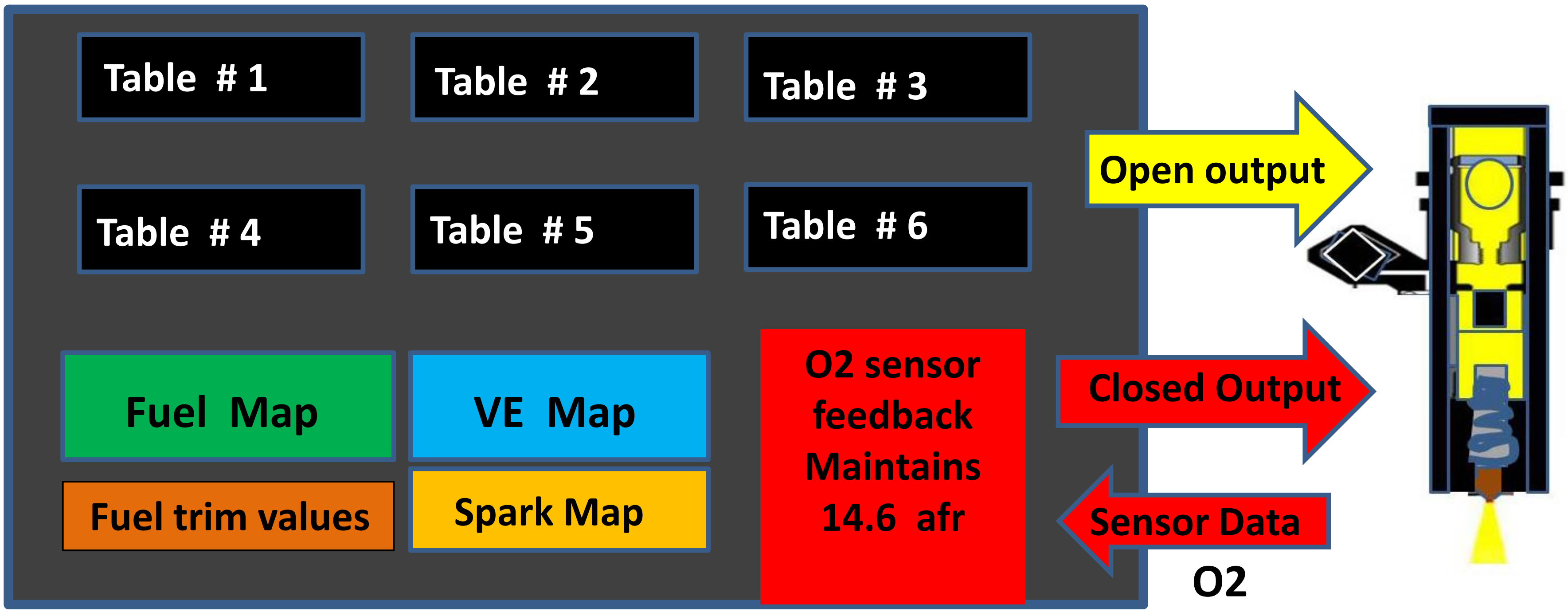
Closed –loop: Engine sensors + ECM = Injector pulse width



Along with a timed spark

ECM Output

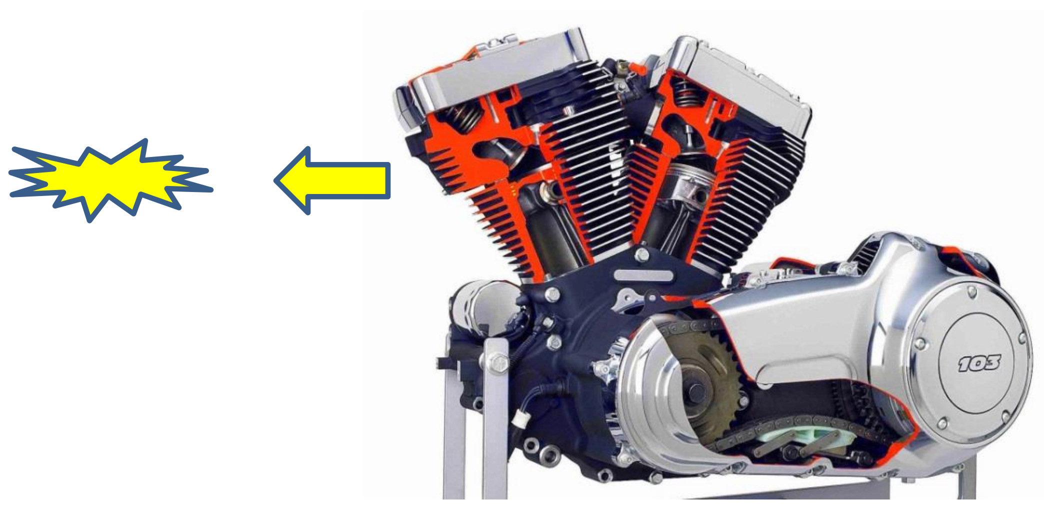
In open-loop, the ECM will use maps and tables to control fuel.
In closed-loop the ECM will modify fuel based on O2 sensor data.



Clear Flood Mode

A mode that overrides the Cranking Fuel table.

If the throttle is held at **70%** or more open during cranking, no fuel will be delivered to the engine to help flush out any excess fuel that has accumulated in the cylinders.



EITMS

The EITMS system (Engine Idle Temperature Management System) was developed to reduce heat buildup in the engine during prolonged idling.

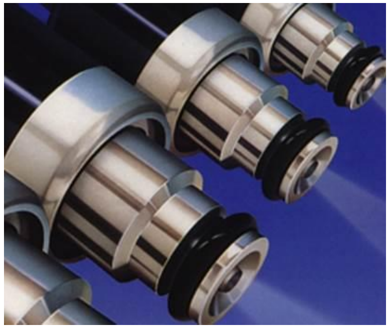
Mode 1   AFR fuel enrichment
Mode 2   Skip fire / rear cylinder shuts off to keep it cool

Mode 1 Activated under the following conditions

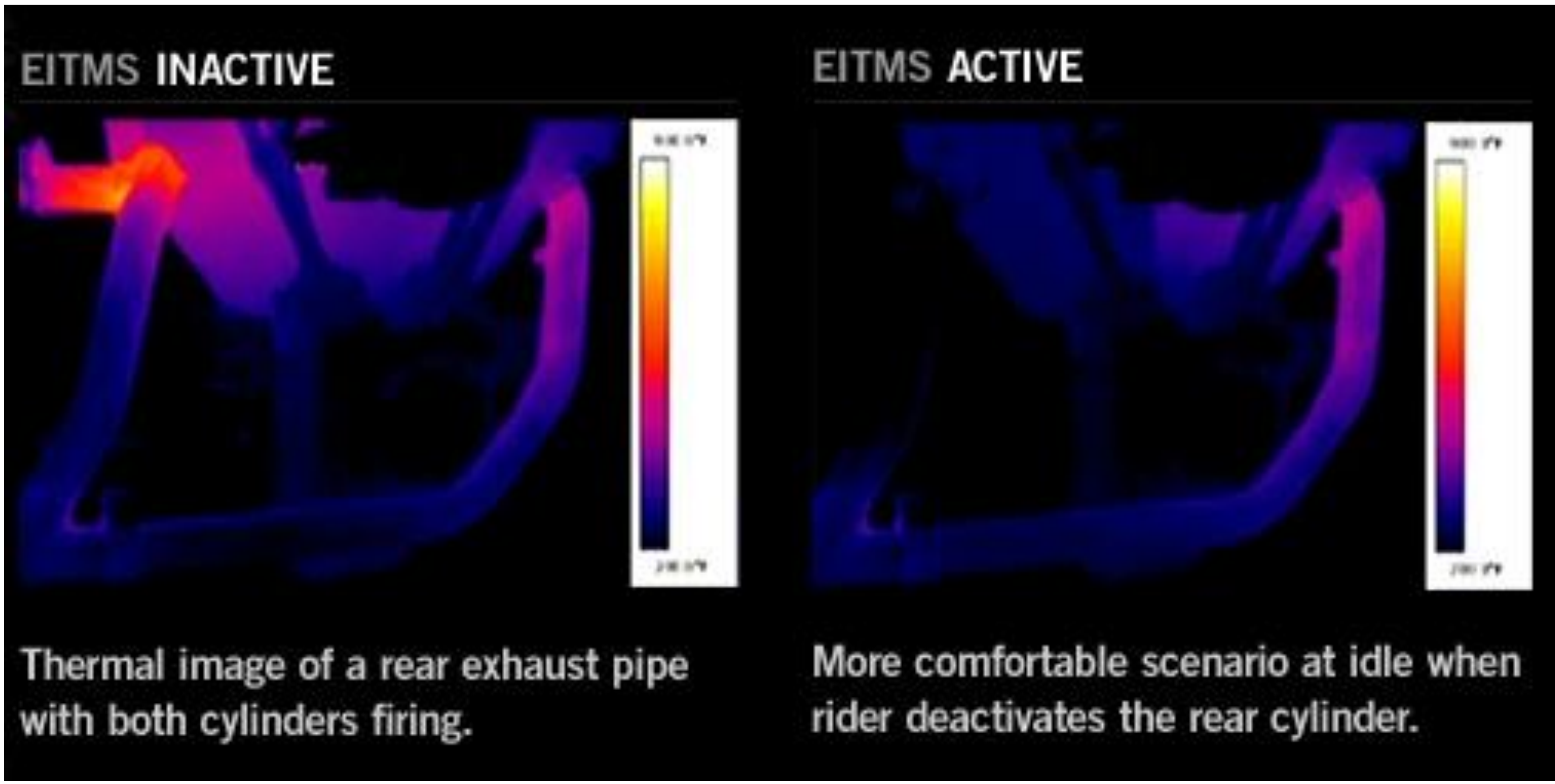
1. Engine temperature exceeds 290 F
2. RPM is under 1200

Mode 2 For Big Twins only

1. Engine temperature exceeds 300
2. Bike speed is less than 10 mph



EITMS
Parade Mode



EITMS

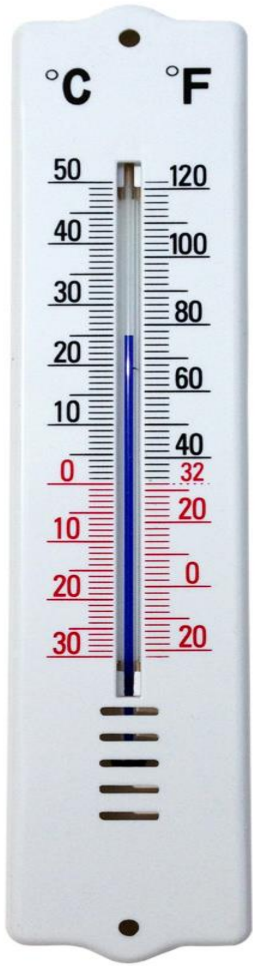
Turning on /off

The ETIMS (Engine Temperature Idle Management System) can be turned on or off by the rider on all touring models 08 and later, the 07 models have the ETIMS but the dealer has to hook in a external computer to turn it on/off.

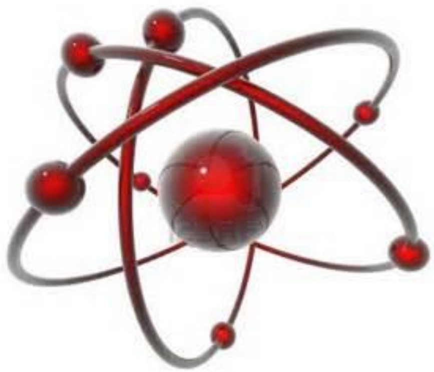
The ETIMS will then turn off the rear cylinder to help slow down the over heating process. As soon as you give the bike some throttle the rear cylinder will turn back on and the engine will run on both cylinders.

Consult your manual for learning how your particular model works.

Convert Degrees C to F



C	F
0	32
20	68
40	104
60	140
80	176
100	212
120	248
140	284
160	320

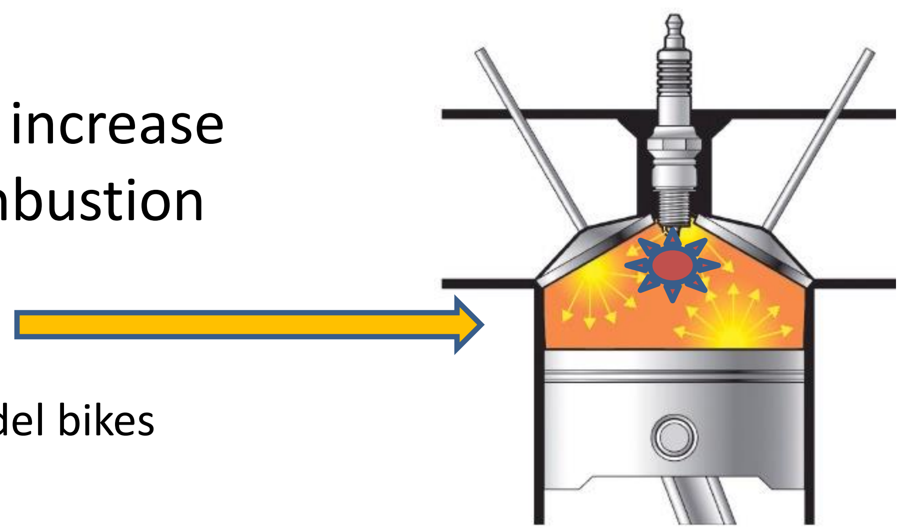


Ion- Sensing

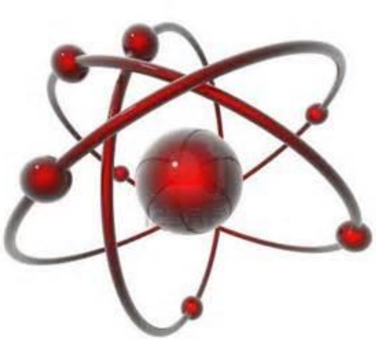
Used on V-rods and
2005 later touring bikes

Ion- sensing is a method of determining engine knock by using a special circuit designed into the coil of the ignition circuit and utilizing the air gap between the electrodes of the spark plug.

When knocking occurs, pressures increase and atoms change within the combustion chamber .....***creating ions***....

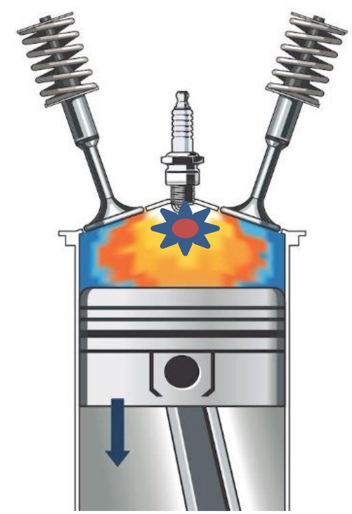


VS. using a knock sensor in other model bikes

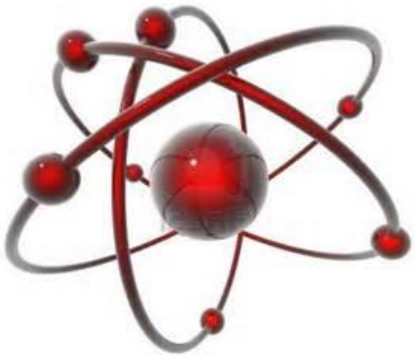


Ion- Sensing

When detonation occurs, the resistance of the ions in the cylinder containing the fuel atoms changes . This resistance can be measured by Ion-sensing circuitry through the gap in the spark plug. Once detonation is detected…
the ECM retards the timing and richens the fuel .



Engine knock is caused from detonation when the fuel explodes violently rather than burning smoothly.

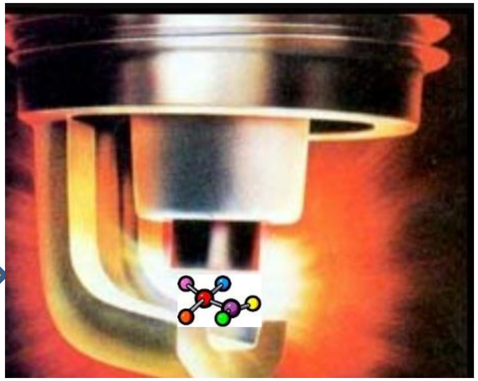


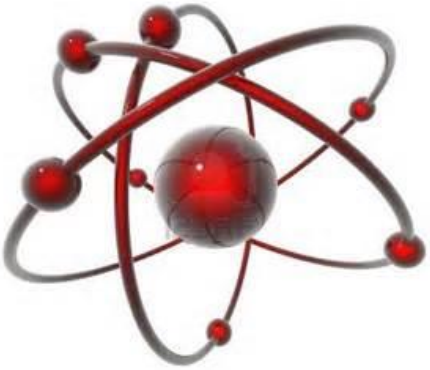
Ion- Sensing

Ion- sensing systems are based on the principle that electric current flowing in an ionized gas is proportional to the conductivity of the flame. It is this conductivity that the Ion-sensing circuit measures and reports back to the ECM.

In this manner, the spark plug can be seen as a sensor.

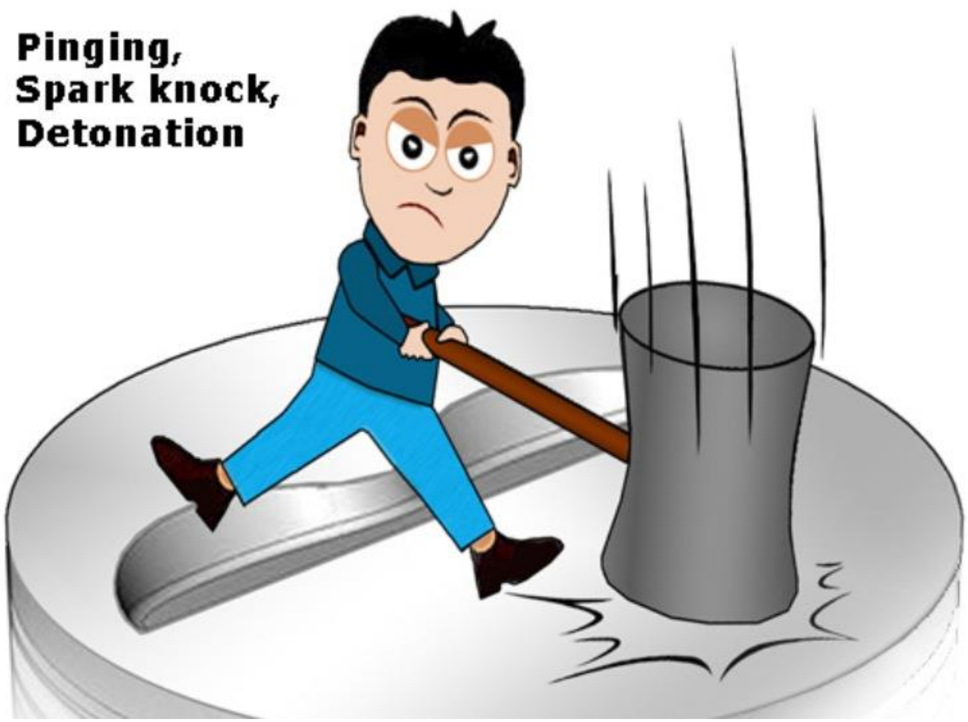
Ions are detected here
Higher pressures = more ions





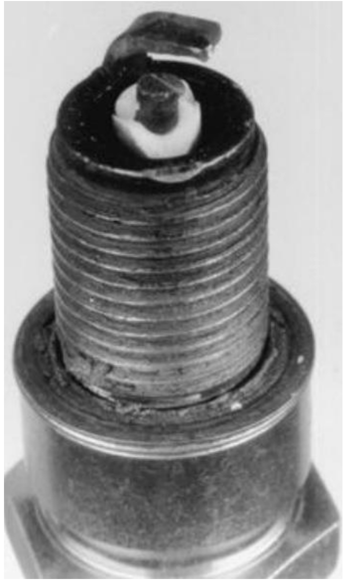
Ion- Sensing

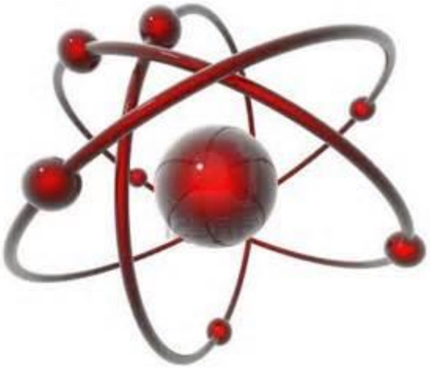
Prevents these events from happening



Ion- Sensing

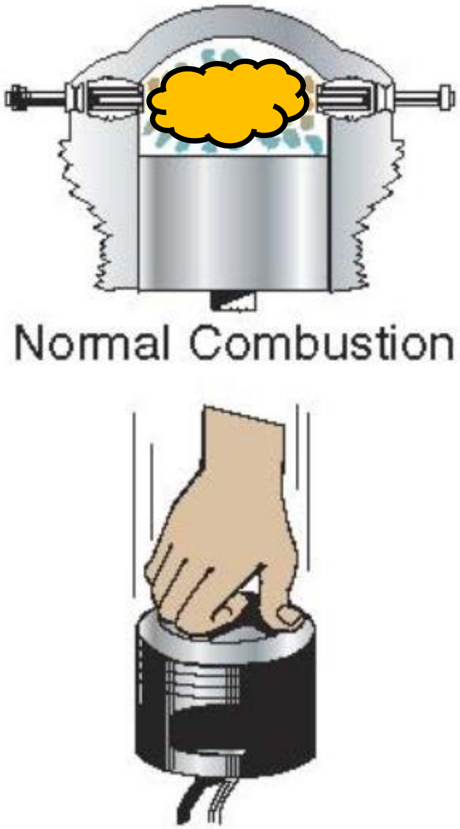
Engine knock is caused from detonation
(fuel exploding rather than burning)

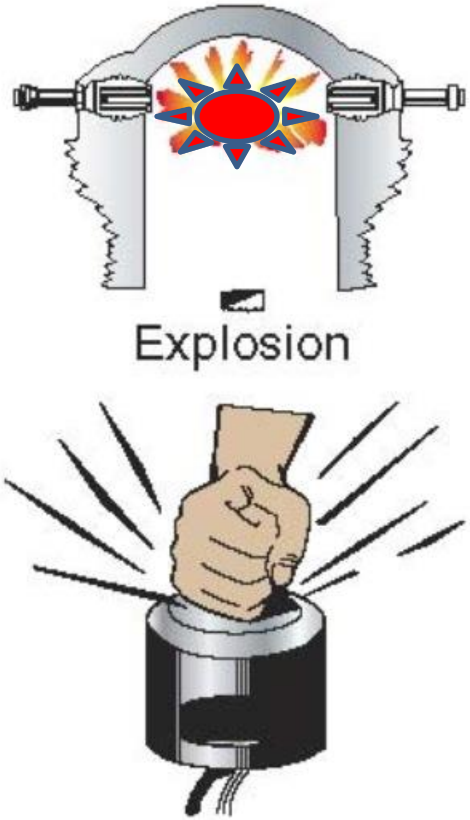


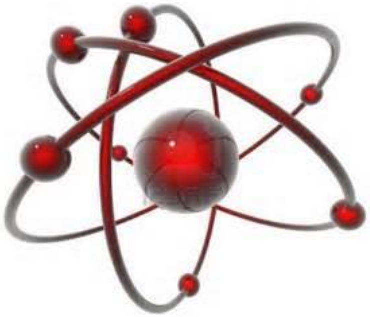


Ion- Sensing

Detonation

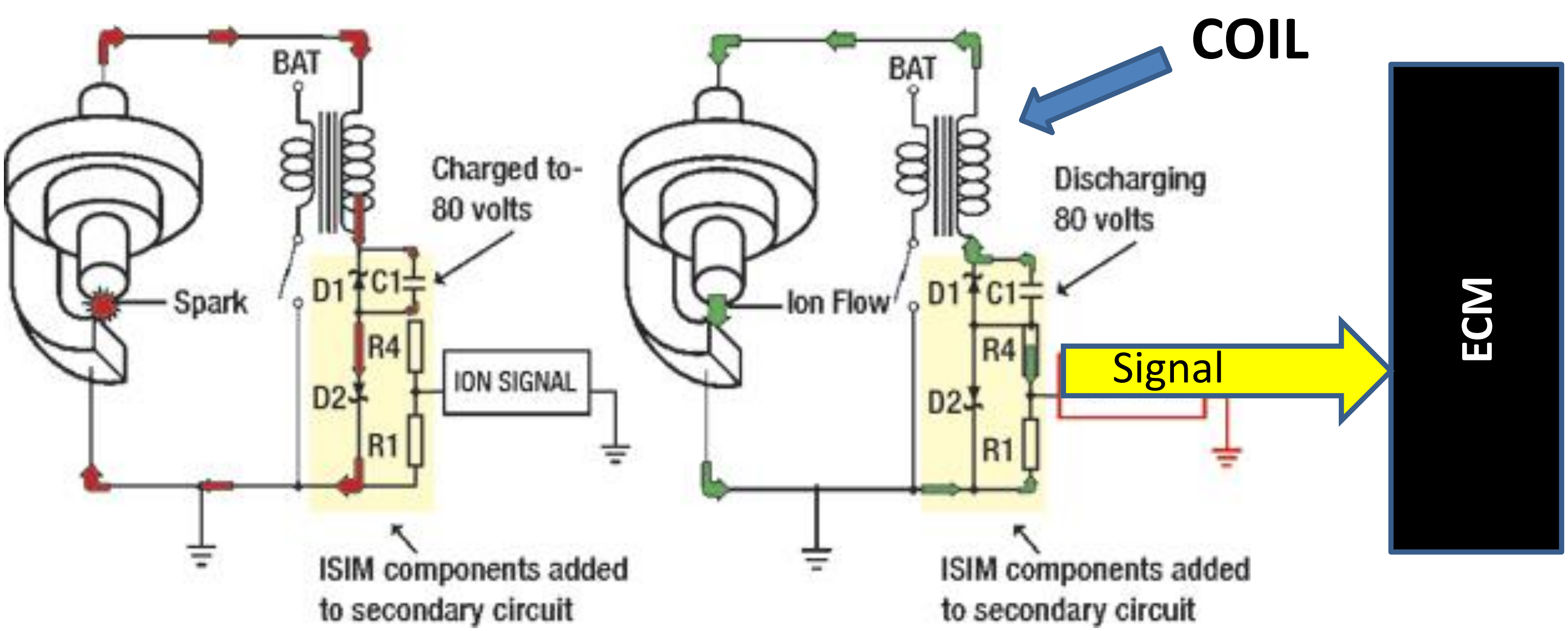




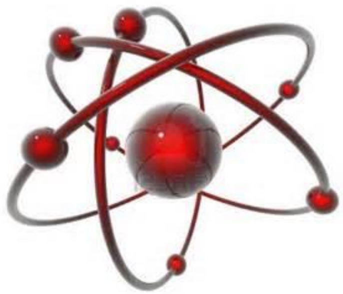


Ion- Sensing

The **coil** sends a signal to the **ECM** based on the amount of **voltage** needed to fire the plug within the ionized gas in the combustion chamber.



When knock (ping) is detected…. The ECM retards the timing.

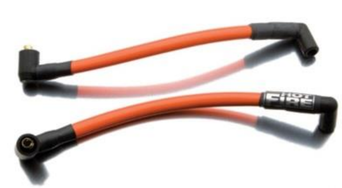


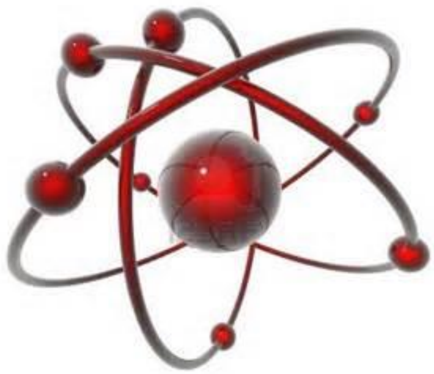
Ion- Sensing

Ion detection depends on the values that have been pre-programmed into the ECM . Also, using proper octane fuel is important. Low octane fuels knock , higher octane fuels burn smoother.

Wrong spark plugs, wires, compression ratios, cams and AFR have an effect on the ion –sensing system and may turn it off.

Stay with factory specs. HD suggests that Knock Control be turned off for compression ratios above 10.5



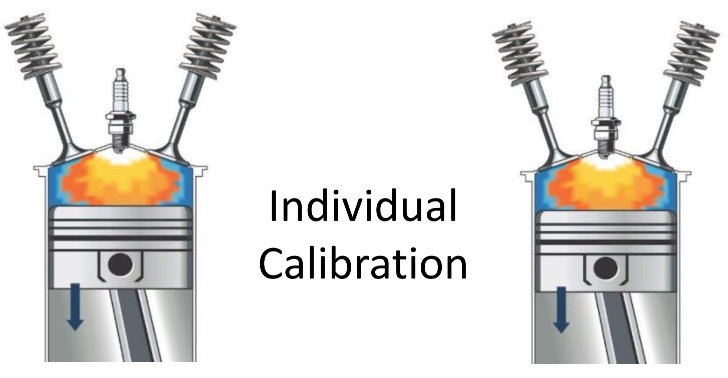


Ion- Sensing

Advantages

The externally mounted sensor (Pezio) devices only detect basic noise from detonation and are not capable of making individual changes to each cylinder. Their changes to timing and fuel effect all cylinders at the same time. (globally)

The advantage of ion-sensing is that it can be calibrated to modify each cylinder individually at all engine speeds and loads.



Why Tune ?

Tuning provides the opportunity for your bike to run its very best under all riding conditions. Tuning calibrates the ECM and balances out the look up tables and maps so they are accurate.

Just a small difference in AFR and spark timing can dramatically change the reaction in the combustion chamber , effecting how the bike performs. Tune for performance .

Basic Tune

The Delphi EFI system is used on current Twin Cam engines produced by Harley Davidson uses the Speed Density system..

A TUNE is a process of *calibrating* the ECM to factory specs. and working toward improving overall performance for :

1. Power output
2. Economy
3. Durability

Tuning Advantage

1. Provide improved torque and horsepower
2. Improve throttle response
3. Improve fuel mileage
4. Adjust for little or no decel pop
5. Provide cooler running engine at idle speeds

Tuning

Q: I installed a Hi-flow air cleaner. Do I need to update the tune?

A: Closed-loop bikes will compensate for minor changes if you give the system time to learn. (100 miles of riding)

It can be made to run better with tuning, but it is *not necessary to re-tune or update the fuel maps when adding a high –flow* air cleaner or a new exhaust system.

If you make tuning adjustments , it will be to the VE table , letting the engine know it is getting more air.

Tuning

For reasonable performance and drivability the manufactured spec of 14.7:1 afr is very lean and this is the reason why many bikes run very hot with poor drivability.

This condition gets even worse when you change your exhaust or air cleaner allowing more air to enter the cylinder.

Optimum AFR for cruise area is   **13.4 - 13.6:1**

Wide open throttle :   **12.8 - 13.2:1**

Dyno Tuning

The process of tuning a bike using a machine that allows for the motorcycle to operate while simulating an on the road riding experience is called dyno-tuning.

Tuning sets the bike back to factory specs. or allows the user to adjust the ECM programming for even better performance or horsepower by matching the tune to the bike.

Tuning

When you make a change to add or subtract ignition timing, you will normally see a corresponding change in power output.

One thing you will want to make sure you do is use a tuning software program and TURN OFF CLOSED LOOP when you are starting out tuning your bike.

This is because as you don't want the ECM modifying the AFR the same time you are trying to develop your base maps.

Modifications

When a bike is modified with an improved airflow filter and a performance exhaust system , the VE map should be re-calibrated to compensate for the increased air getting into the engine.

Slip-on mufflers, conventional 2-2 and 2-1 exhaust systems all allow more air flow through the engine .

Note: The ECM will learn and compensate for more air flow through the engine in closed loop mode.

It is the open loop **VE map** calibrations that needs to be modified.

Add-on Fuel Modules

Fuel modules are connected in series between the ECM and the fuel injectors and are used to override the bike's ECM factory settings by providing more fuel and performance to the engine.

Common names:

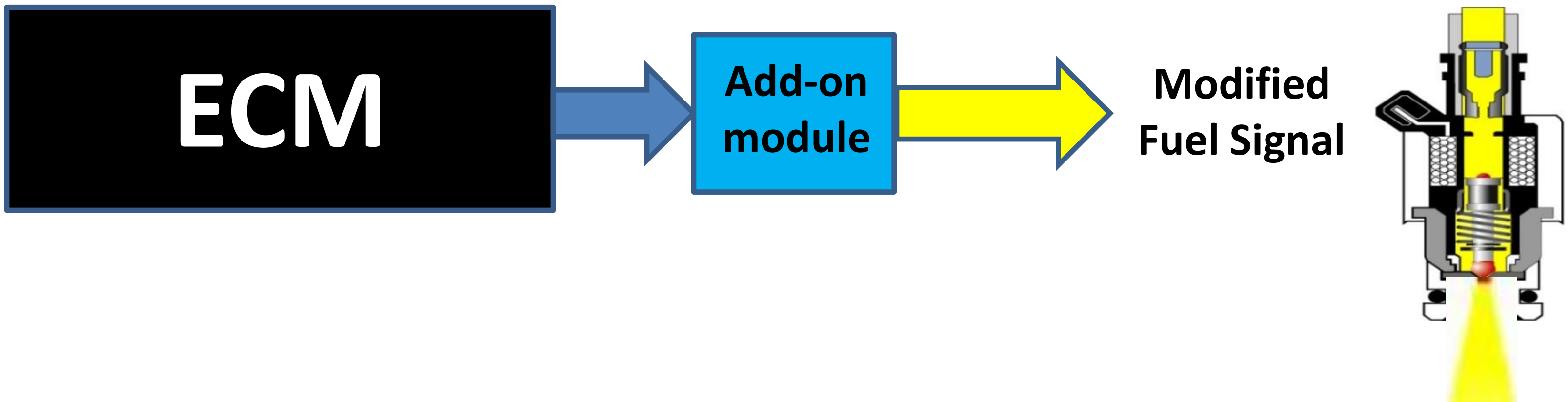
* Post fuel devices
* Signal modifiers
* Piggy backs

Aftermarket Manufacturers

• Dynojet	Power Commander
• Vance and Hines	Fuelpak
• Dynatek	Cobra
• Harley Davidson	SE Pro Race Fueler
• Kuryakyn	Wild Thing
• Daytona Twin Tec	Twin Tuner

Note: Some devices are generally low-cost but have certain limitations as to the range of performance and engine modifications they can make.

Add-on Module



The add-on fuel modules main purpose is to add more fuel to the engine. Each module operates a little bit different from each other. Some have downloaded maps that can be used , others operate by turning or adjusting screws mounted on the module.

Power Commander

The Power Commander is a small, square-shaped device that plugs inline into the engine's electronic control module.

The Power Commander comes with several factory-installed "maps," which is a PC term for a program that tunes the engine to run at a level that matches or exceeds the bike's fuel delivery.

In fact, all the owner has to do is remove the Power Commander from the bike to restore the original ECM settings.

Power Commander

Manufactured by Dynojet… utilizes wideband sensors and a special feature called: AutoTune

Vance & Hines
Fuelpak 3

The Fuelpak is designed to download a program map made especially for your bike from their website.

It does not alter the current ECM program… it overrides the ECM with its own programming that you can modify using your smart phone.

The device is married to your bike and can't be transferred to another.

Vance & Hines

Fuel/Pak 3 Wireless

Connecting wirelessly by Bluetooth to any iPhone or Android Smartphone, Fuelpak uses Flash technology to re-calibrate engine parameters and mapping for exhaust systems and other performance upgrade.
Download a library of tunes from the internet.

Also standard for the **Fuelpak** FP3 is an Autotune feature, making use of all factory sensors to add another layer of precision tuning for specific requirements .

Vance & Hines
Fuelpak 3

With the Fuelpak FP3 module plugged-in, Live Sensor Data can be viewed through the smartphone to display speed, RPM, cylinder head temperature, voltage, gear selection and other vital information using the Bluetooth connection.

- Smartphone App User Interface (iOS & Android)
- Re-calibrates ECM by Flash Tuning
- Capable Displaying Live Sensor Data
- Autotune for added tuning features

Daytona Twin Tec

Twin Tuner Fuel Injection Controller add –on module installation that has the ability to use and export data maps.

Push button switches are used to make fuel trim adjustments in the RPM and throttle position ranges that alter the AFR using their wideband O2 sensors.

Module ECM
Replacement

The **ThunderMax**® replaces the existing ECM.

It can improve overall engine performance with a smoother & cooler running engine using a richer AFR.

ThunderMax utilizes 18mm Bosch wide-band oxygen sensors and requires compatible oxygen sensors bungs located in your exhaust systems' header pipes for assembly.

ThunderMax offers hundreds of different basemaps which have been pre-dyno tuned and can be selected & loaded using the TMax software. Designed for "race engines " .

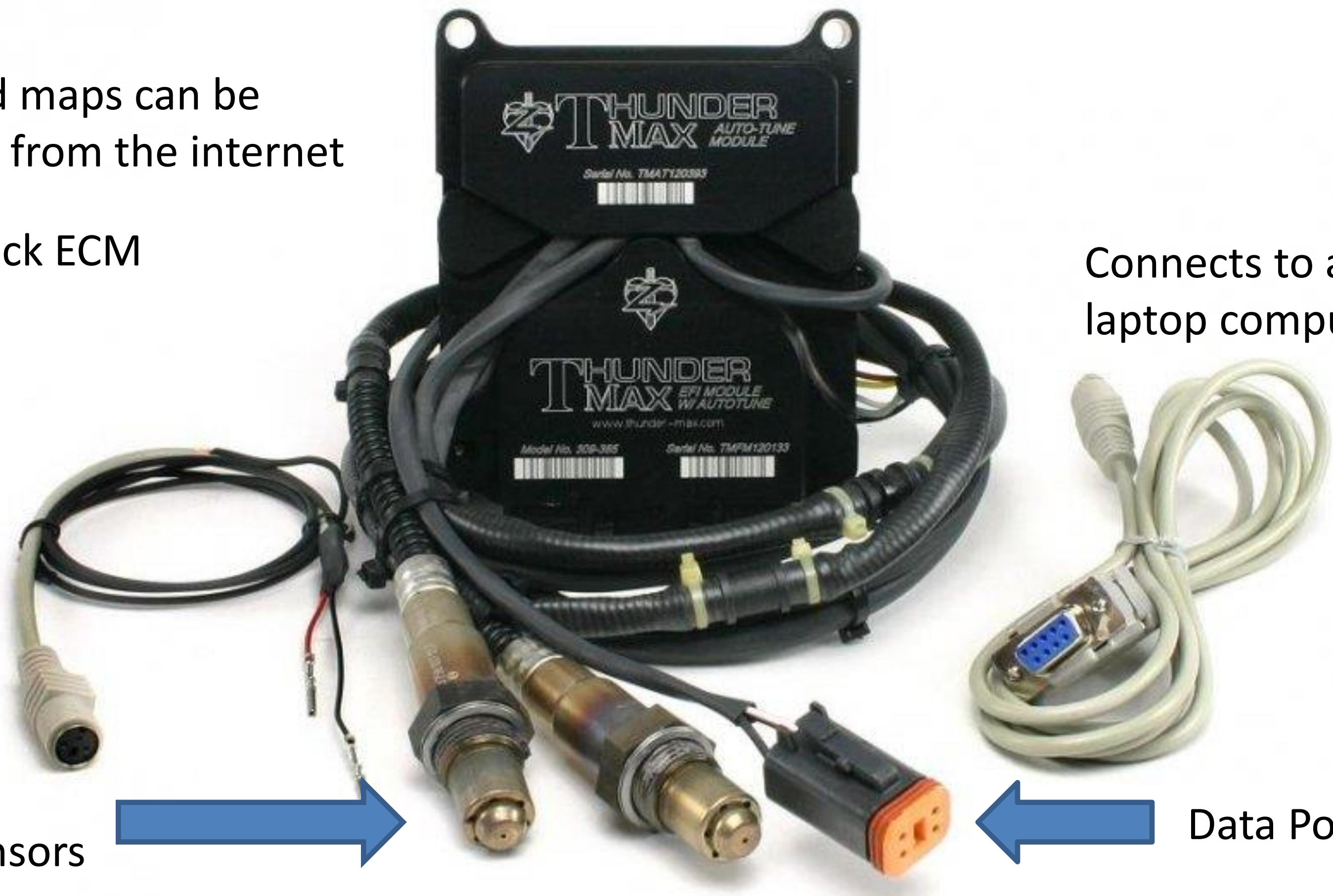
Thundermax.com

ECM Module

Programmed maps can be downloaded from the internet

Replaces stock ECM

Connects to a laptop computer



Wide band Oxygen sensors

Data Port

Tuning Devices

A **windows-based** ECM re-programming tool specifically for use with 2001 and later Delphi-equipped motorcycles that utilize the diagnostic interface. (Data Port)

Tuners attach to the bike through the data port interface on the bike and allow the user to *view* the ECM maps and tables using a laptop computer. Software changes to the ECM programming are made using these tuners.

Tuners are (*married to the bike*) .. Meaning that each bike has to have its own unique tuner and can't be shared on another bike. Vin # specific One tuner per bike

Flashing a Tune

Flash tuning is a process of making ECM software adjustments to your bike. The process *re-programs* the ECM.

Several resources on the internet provide downloadable maps that will match you bike model and provide a very close tune.

Dyno- tuning is a professional way of getting a complete tune designed *specifically for your bike* using high priced equipment.

Flash tuning using existing tunes from manufacturers that match your bikes' setup is the easiest and most cost effective way to go.

EPA
Making an impact

Companies have agreed to obtain certification from the California Air Resources Board…CARB for any tuners they sell in the future to demonstrate they do not cause motorcycles to exceed certified emission limits.

This is a major impact as motorcycles will be tuned to EPA specs.
In the past, modified settings increased power and performance, but also increased emissions of hydrocarbons and nitrogen oxides.

EPA compliant calibrations only

Screaming Eagle Race Tuner

Due to EPA regulations, the Super Tuner is **no longer** available to consumers. After 2016

Connects to the bike via data port connection then to a laptop computer

Screaming Eagle “Pro” Street Tuner

Part Number 41000008C

Once installed it will allow you to modify or upload calibrations (H-D factory) to the ECM based on your bike’s specific modifications. New maps will provide better performance. These maps are designed to match your bike and no dyno tuning is necessary. However, this tuner will not let you program the ECM outside of EPA regulations!

* Pro Street Tuner … Basic tuner .. Uses stock 02 sensors

H-D.. Smart Tune Pro

This is an ADD-On to the Pro Street Tuner.
The Smart Tune Pro uses wide-band sensors for "**Autotuning**." ..... Automatic tuning while you ride.

Wideband sensors can **calibrate the VE maps** throughout the part throttle cruising and *full-throttle acceleration* operating range that is limited by stock narrow-band sensors.

New 18 mm holes must be drilled in the exhaust pipes to allow for the installation of the new wide-band sensors.

Fully factory supported & EPA compliant ..all 50 states

TTS MasterTune

Tuning Device

A **Windows-based** ECM re-programming tool specifically for use with 2001 and later Delphi-equipped Harley-Davidson motorcycles that utilize the diagnostic interface using a 4 or 6 pin port. The tuner is (married to the bike).

AutoTune program : V-Tune

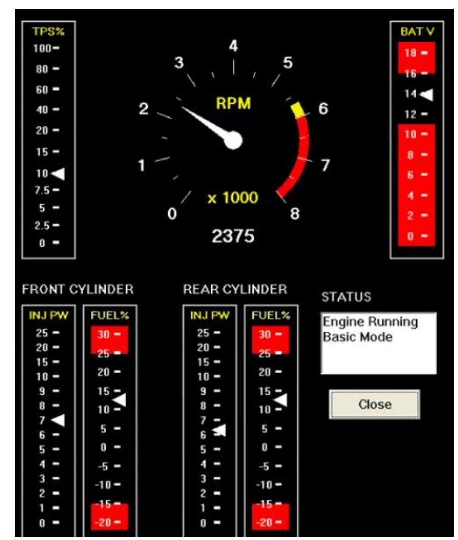
www.mastertune.com

Daytona Twin Scan Kit

The Scan Kit Tuner log software allows the user to display real time engine data on an instrument panel computer screen.

The software runs in conjunction with the Twin Tuner module and provides engine diagnostics and tuning . The tuning aid can also be used with Screaming Eagle Pro tuner and Dynojet's Power Commander .

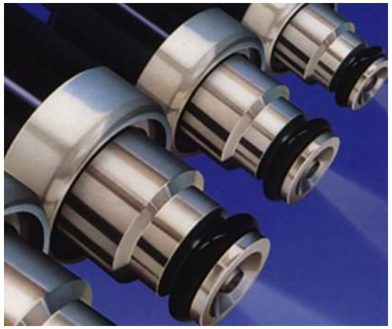
Daytona Twin Tec



Power Vision Tuner

The **Power Vision**® can tune any fuel injected motorcycle with the Delphi ECM , including all of the latest models.

The Power Vision Product Suite includes a full color ***touch screen*** flash device, built in Autotune feature , vehicle interface cable, and WinPV (Windows PC based tuning software).



Touch Screen Display !

6 Pin Data Port

Married to the bike

Power Vision® is the most powerful and quickest flash tuning device for motorcycles on the market.

It is a performance tuner and data monitor that offers the latest flash tuning technology, data logging and other tuning features.

The power vision can also be mounted to the bike for on the road viewing of the gauges and other functions as you ride and functions can be performed *without* a laptop computer.

Power Vision Tuner

POWERFULL ..Simply select the tune, follow the on-screen prompts to download the tune, and if you'd like, edit your tune without ever touching a computer. You can flash and make changes to your tune without ever getting off your bike.

Tuning maps can be downloaded from various sources on the internet. Ex. Fuelmoto.com

- View gauges
- Adjust idle speed
- Autotune
- Flash new maps
- Adjust AFR

Dynojet.com

Power Vision Tuner

Mounted on the handlebar

Dynojet.com

AutoTune

AutoTune is a program that allows the user to automatically calibrate (tune) the bike while riding. Narrowband and wideband oxygen sensors can be used to monitor AFR. It's basic application provides for some simple tuning without using a dynamometer. Narrowband sensors have limited ability. This is why it would be best to use wideband sensors in tuning for performance.

Sometimes referred to as **reverse-engineering,** the AutoTune program makes changes to the VE table.

VE table is one of the main memory tables used by the ECM in making calculations for determining the required AFR .

AutoTune

A computer program

AutoTune calibrates the VE table using the O2 sensors on the bike by monitoring the Actual AFR with the Targeted AFR of the engine *while you ride.* The program actually learns the values needed to make corrections to the VE table.

Narrow band 02 sensors will autotune a small area on the VE table..

Wide band 02 sensor will autotune larger areas on the VE table.

Autotune Mode

Using an autotune program the ECM will be in closed loop mode and will constantly receive feedback from the narrowband oxygen sensors installed on the bike. It is using this feedback to correct the volumetric efficiency (VE) of the bike as you ride it.

However, the ECM has a limited amount of range that it can correct. The closer the VE values stored in the ECM are to the actual values that the engine needs, the more accurate and better your bike will run .

If you are able to use wideband sensors, they will give you better performance by covering a wider range of cells in the VE table.

AutoTune

During the AutoTune process, the program will make changes to the VE table, making any corrections to re-calibrate the map and match the target AFR with the actual AFR… An example of *Reverse-Engineering* .

VE Calibration

The values pre-programmed at the factory for the VE table only need to be adjusted when the air flow through the engine changes.

If for example , you have changed : air filter, pipes, cams etc.

Calibration means to adjust the values in the VE table whereby

The actual AFR = the targeted AFR

Measured at the exhaust

AutoTune

Reverse Engineering

The AutoTune program will use the data from the O2 sensors , then look at the fuel map before correcting the corresponding VE table. The bike needs to be running either on a dyno or on the rode to create real-time feedback needed for the program to make corrections to the VE table.

VE table corrections

VE Table 1 (MAP)

File Edit Bins Tools

New Values

kPa \ RPM	600	1100	1800	2400	3100	3800	4500	5200	5900	6600	7300	8000
100.0	84	85	85	90	95	102	108	112	115	113	112	111
99.0	[illegible]	[illegible]	[illegible]	[illegible]	81	87	105	108	115	113	112	111
97.0	[illegible]	[illegible]	[illegible]	[illegible]	69	73	96	99	111	112	112	110
95.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	60	81	99	107	110	114	110
93.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	49	60	104	100	108	111	110
89.0	53	36	35	[illegible]	36	35	47	73	105	103	105	109
81.0	44	[illegible]	31	[illegible]	35	34	40	50	90	102	105	107
68.0	37	31	32	33	34	34	35	46	53	80	90	90
62.0	31	28	27	30	31	33	31	42	55	70	72	80
54.0	28	28	25	27	28	30	30	37	56	63	67	65
46.0	27	26	22	24	24	24	27	37	52	54	61	63
35.0	27	24	17	16	15	15	14	17	23	31	60	59

=

Target fuel map

Air-Fuel Ratio (Stoich)

0809-96-JPHB-O16.pvt

RPM	MAP (KPa)									
	20	30	40	50	60	70	75	80	90	100
750	13.8	13.8	13.8	13.8	13.8	13.3	13.3	12.1	12.1	12.1
1000	13.8	13.8	13.8	13.8	13.8	13.3	13.3	12.1	12.1	12.1
1250	13.8	13.9	14.1	14.2	14.2	13.8	13.8	12.1	12.1	12.1
1500	12.7	13.9	14.1	14.2	14.2	13.8	13.8	12.4	12.4	12.4
1750	12.7	13.9	14.1	14.2	14.2	13.8	13.8	12.5	12.5	12.5
2000	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
2250	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
2500	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
3000	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.6	12.6	12.6
3500	12.7	14.1	14.1	14.2	14.2	13.8	13.8	12.5	12.5	12.5
3750	13.8	14.1	14.1	14.1	14.1	13.8	13.8	12.5	12.5	12.5
4000	13.8	12.9	12.9	12.9	12.9	12.8	12.8	12.5	12.5	12.5
4500	13.2	12.6	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
5000	12.5	12.5	12.5	12.5	12.4	12.4	12.4	12.4	12.4	12.4
5500	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
6000	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
6500	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4

O2 Sensor Readings

Calibrating the VE table

AutoTune

For best results using AutoTune, a wide variety of riding conditions are needed to populate the cells in the VE table. This might take several riding times of 30 min. or more for the program to learn what values need to be corrected.

Populate : When cells in the VE table have recorded new learned values

Throttle Position (Percent)

RPM	0	2	5	10	15	20	25	30	40	60	80	100
750	0	0	0	0	0	0	0	0	0	0	0	0
[illegible]	7888	32	0	0	0	0	0	0	0	0	0	0
1500	169	43	78	36	0	0	0	0	0	0	0	0
2000	187	124	144	194	45	0	0	0	0	0	0	0
2500	185	36	1666	1765	1325	785	9	0	0	0	0	0
3000	86	58	505	6189	4081	868	295	0	0	0	0	0
3500	18	0	529	4227	4925	1373	814	247	0	0	0	0
4000	0	18	180	1269	3425	1114	650	679	36	0	0	0
4500	0	9	63	875	1212	1294	889	308	195	0	0	0
5000	0	0	9	252	792	1464	672	382	434	0	0	0
5500	0	9	9	72	198	288	477	360	54	0	0	0
6000	0	0	0	0	0	0	0	0	0	0	0	0
6500	0	0	0	0	0	0	0	0	0	0	0	0

AutoTune

Here is a screen shot from the Power Vision AutoTune program.

Notice each of the cells that have been populated

Narrowband sensors can be used to run the AutoTune program in basic mode, however, to get the best results over a wider range of riding experiences, wideband sensors should be use. Wideband sensors can measure in a greater range of AFR.

VE Table

Dyno Calibration

Set the entire AFR table to a constant value (13.6) and adjust the VE table so that you get a measured AFR value of 13.6 out the tailpipe. Once this calibration is complete, the Fuel Map can be changed as desired and the ECM will calculate the correct targeted AFR using these calculations.

Re- Set all values to 13. 6

Fuel Map

RPM	MAP (KPa)									
	20	[illegible]	40	50	60	70	75	80	90	100
750	13.7	[illegible]	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1000	13.7	[illegible]	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1125	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1250	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1500	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
1750	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2000	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2250	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2500	13.7	13.7	13.7	13.7	13.7	13.8	13.8	13.2	13.1	13.1
2750	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.2	13.1	13.1
3000	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.2	13.1	13.1
3500	13.8	13.8	13.8	13.8	13.8	13.8	13.5	13.2	13.1	13.1
4000	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	13.1	13.1
4500	13.2	13.2	13.2	13.2	13.2	13.2	13.2	13.1	13.1	13.1
5000	12.8	12.8	12.8	12.8	12.8	12.8	12.8	13.1	13.1	13.1
5500	12.8	12.8	12.8	12.8	12.8	12.8	12.8	13.1	13.1	13.1
6000	12.8	12.8	12.8	12.8	12.8	12.8	12.8	13.1	13.1	13.1

=

Adjust VE Table

VE Table 1 (MAP)

File Edit Bins Tools

kPa \ RPM (%)	600	1100	1800	2400	3100	3800	4500	5200	5900	6600	7300	8000
100.0	84	85	85	90	95	102	108	112	115	113	112	111
99.0	83	78	83	88	81	87	105	108	115	113	112	111
97.0	82	65	66	74	69	73	96	99	111	112	112	110
95.0	81	61	63	63	55	60	81	99	107	110	114	110
93.0	66	52	50	49	44	49	60	104	100	108	111	110
89.0	53	36	35	38	36	35	47	73	105	103	105	109
81.0	44	33	31	34	35	34	40	50	90	102	105	107
68.0	37	31	32	33	34	34	35	46	53	80	90	90
62.0	31	28	27	30	31	33	31	42	55	70	72	80
54.0	28	28	25	27	28	30	30	37	56	63	67	65
46.0	27	26	22	24	24	24	27	37	52	54	61	63
35.0	27	24	17	16	15	15	14	17	23	31	60	59

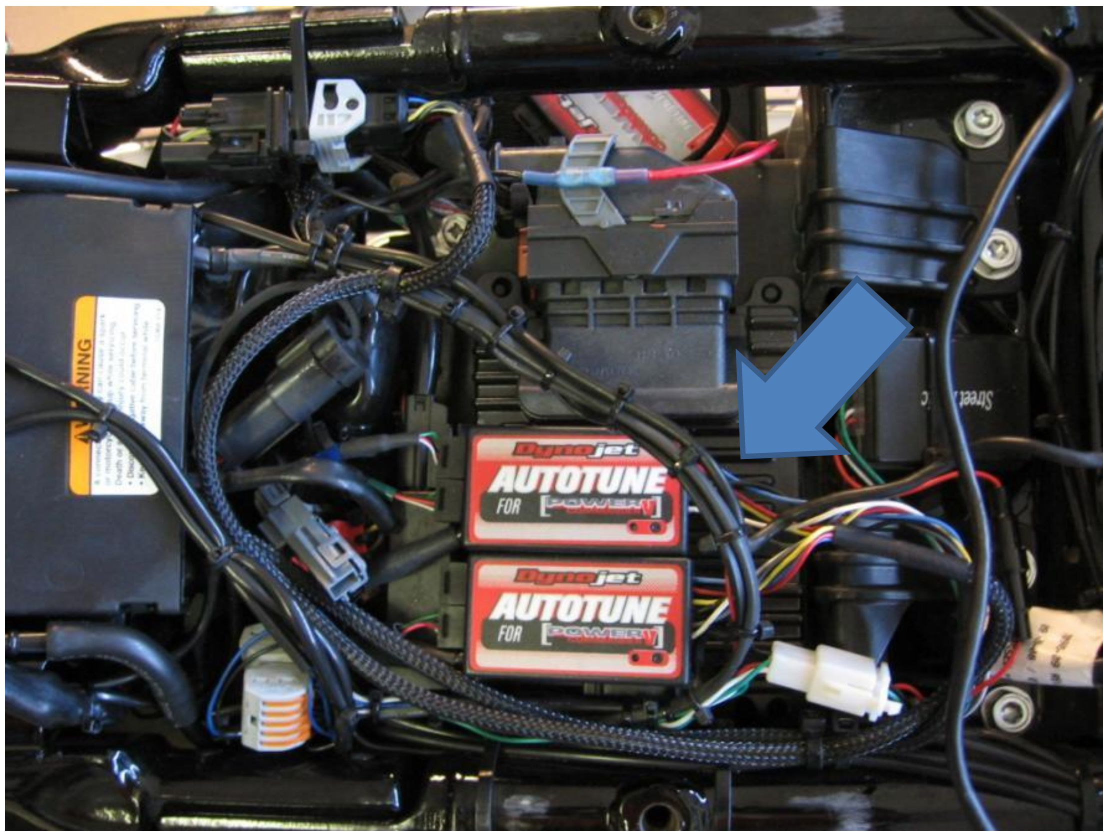
AutoTune

Here is an example of the AutoTune device developed by Dynojet that utilizes wideband oxygen sensors.

Harley –Davidson uses a program called: **Smart -Tune**

AutoTune Modules

Power Vision can automatically fix the deviation between the target AFR and actual AFR by adjusting the **VE tables**.



Basic VE check

1. Set the whole AFR fuel table to 13.6   **TARGET VALUE**

2. Setup a dyno run

3. Measure the AFR in the exhaust with a wide-band sensor

4. Check to see if the exhaust AFR “ *matches* “ the **TARGET**

Adjust the values in the VE cells

* If leaner than 13.6 Make VE number larger
* If richer than 13.6 Make VE number smaller

Tuning Q and A

Q: When do you need to clear trim values ?

A: When a TUNE is flashed into a bike, trim tables need to be cleared from the ECM so they do not influence the new calibration.

The goal is to get the TUNE very close to the optimum values (target vs. actual a/f ratio) so very little trim is needed.

Tuning programs usually clear the trim tables every time a calibration is flashed into the bike.

Tuning Q and A

Q: How do I decide which downloaded TUNE is best for my bike?
Can I swap tunes from other bikes ?

A: As a starting point, select the tune that best matches the *components* on your bike. Many tune programs can be downloaded from the dealer or manufacturer on the internet.

Most of the TwinCam tune programs can be swapped around without too much trouble if most of the changes to the engine have been modest.

Tuning Q and A

Q: I flashed a new tune program but still have exhaust "popping" during de-acceleration . What can I do?

A: Exhaust popping is most often caused by a rich mixture whereby unburned fuel is being ignited by oxygen entering the exhaust.

If the popping happens immediately after the throttle is closed, adjust the "Decel Enleanment" table to increase or decrease the afr.

Tuning Q and A

Q: When knock retard occurs, how long is it active?

A: When knock is first detected, the timing is immediately retarded up to 5 degrees and the fuel is also made richer.

The ECM decays the retard back to zero over a 10 to 20 second period (assuming there is no additional knock detected).

Tuning Q and A

Q: Does the fuel I'm running make any difference to my tune?

A: Yes, changes in the fuel quality will change the tune.
For best results, always tune with fresh fuel .

Most bikes will run on E 10…   10 % alcohol 90 % gas

Best to run: Unleaded 92 % or better octane

Octane : A value that describes the burn rate of the fuel.
Higher octane fuels burn with a slower flame front in the cylinder.
Helps to eliminate pinging.

Oxygen Sensor

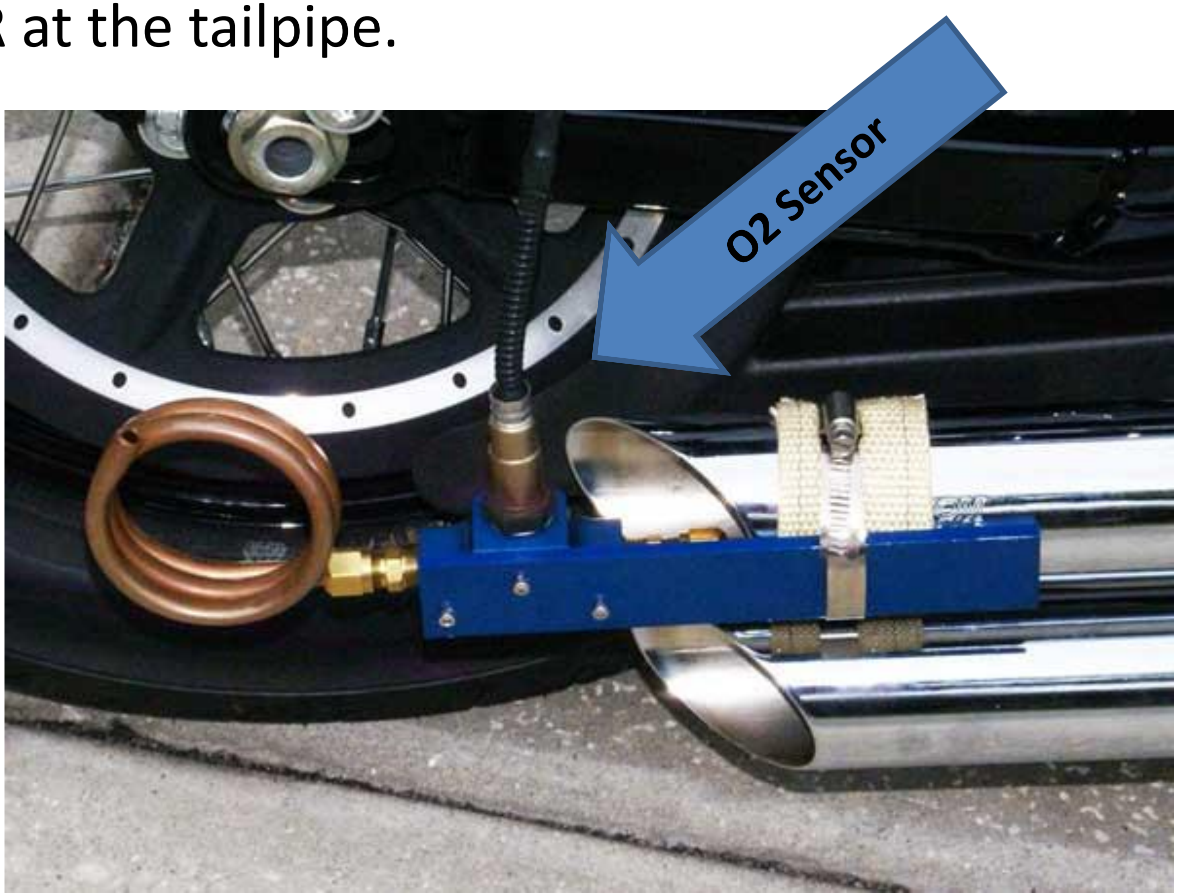
Eliminator Plugs

The oxygen sensor eliminator plugs are used to mimic the output signal that will replace the original O2 sensor's signal to the ECM when rich afr are being used outside the sensor's range.

They are used in off road and racing vehicles to prevent the check engine light from coming on.

Sniffers

Sniffers are devices placed into the exhaust system during a tuning session. *Exhaust gas analyzers* are able to measure the actual AFR at the tailpipe.



O2 Sensor Bungs

12 mm

18 mm

12 to 18 mm O2 sensor adapter
Can be used to insert a wideband sensor into a 12 mm slot designed for a narrowband.

O2 Sensor Bungs need to be welded in place

O2 Sensor Plugs

Used to plug an 18 mm hole in the exhaust pipe.

Special O2 Sensor

Socket Wrench

Used to remove and install an O2 sensor

Wideband AFR gauge

Reads 10 – 18 :1 AFR

O2 Wideband

Sensor Bung

This is an 18 mm bung that is welded into the exhaust pipe , allowing a wideband sensor to be installed. A normal narrowband sensor is installed into an opening of only 12mm.

18 mm bung

18 mm bung

12 mm to 18 mm adapter

Sniffer

Homemade sniffer

Sniffer

Innovate product

IED Devices

By slightly richening the mixture, the engine and exhaust temperatures are lowered. The IED's will work on Twin Cam, Sportster and V-Rod engines.

Simple plug-n-play upgrades are inexpensive and can be installed in under 15 minutes. They are the quickest and easiest way to reduce engine heat by adding additional fuel compared to other tuning choices.

In-line enrichment devices

IED Devices

IED devices are a reasonable option if you plan on keeping the bike stock, or a muffler change only, but if anything else is done (air cleaner , etc.)

It is suggested that you buy a real tuner that will provide optimal performance throughout the RPM range.

IED Devices

Inline Enrichment Devices

Devices only work in closed –loop mode.

O2 sensor Inline Enrichment Device (IED) for 2007 and later Harley-Davidson motorcycles with OEM narrow band O2 sensors richens the fuel mixture from 14.6 to 13.8

IED Devices

IED devices will alter the signal from the O2 sensors that fools the ECM into thinking it is running leaner than it really is, so it provides more fuel , enriching the AFR.

Purchased through Nightrider.com

O2 IED at 14.2:1 AFR
X14IED at 14.0:1 AFR
XIED at 13.8:1 AFR

Dyno Tuning Equipment

Dyno tuning provides a professional tune designed for each individual bike.

This tuning process may take several hours to complete.

Horsepower, torque and engine parameters are closely monitored using a tuning program and a computer.

Mikedanielsperformance.com

Dyno Tuning

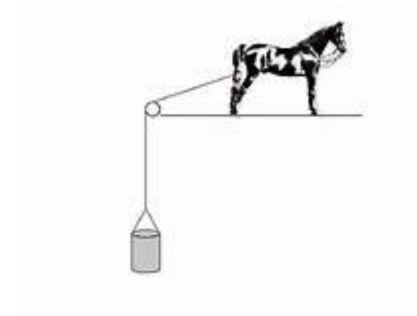
A Chassis dyno is used to test a motorcycle's level of performance in **Torque & Horsepower.**

After hardware modifications of new air filter, pipes, cams etc. are made to a bike, a new dyno run can record the results in improvement.

ECM tuning: Modifying computer maps for performance

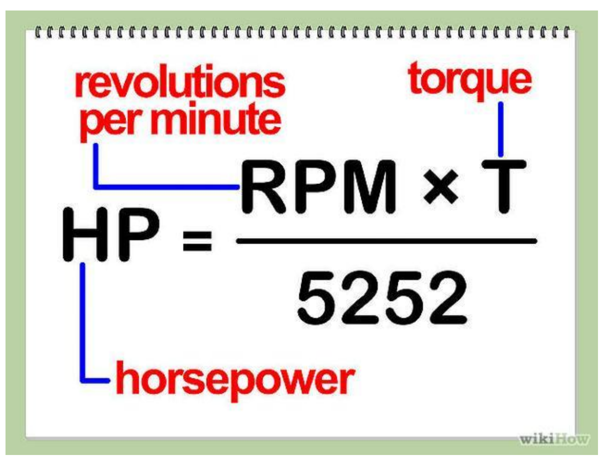
Dyno Run: Test performance on hardware modifications
Dyno Run: Test performance made to ECM Custom Maps

Dyno Tuning



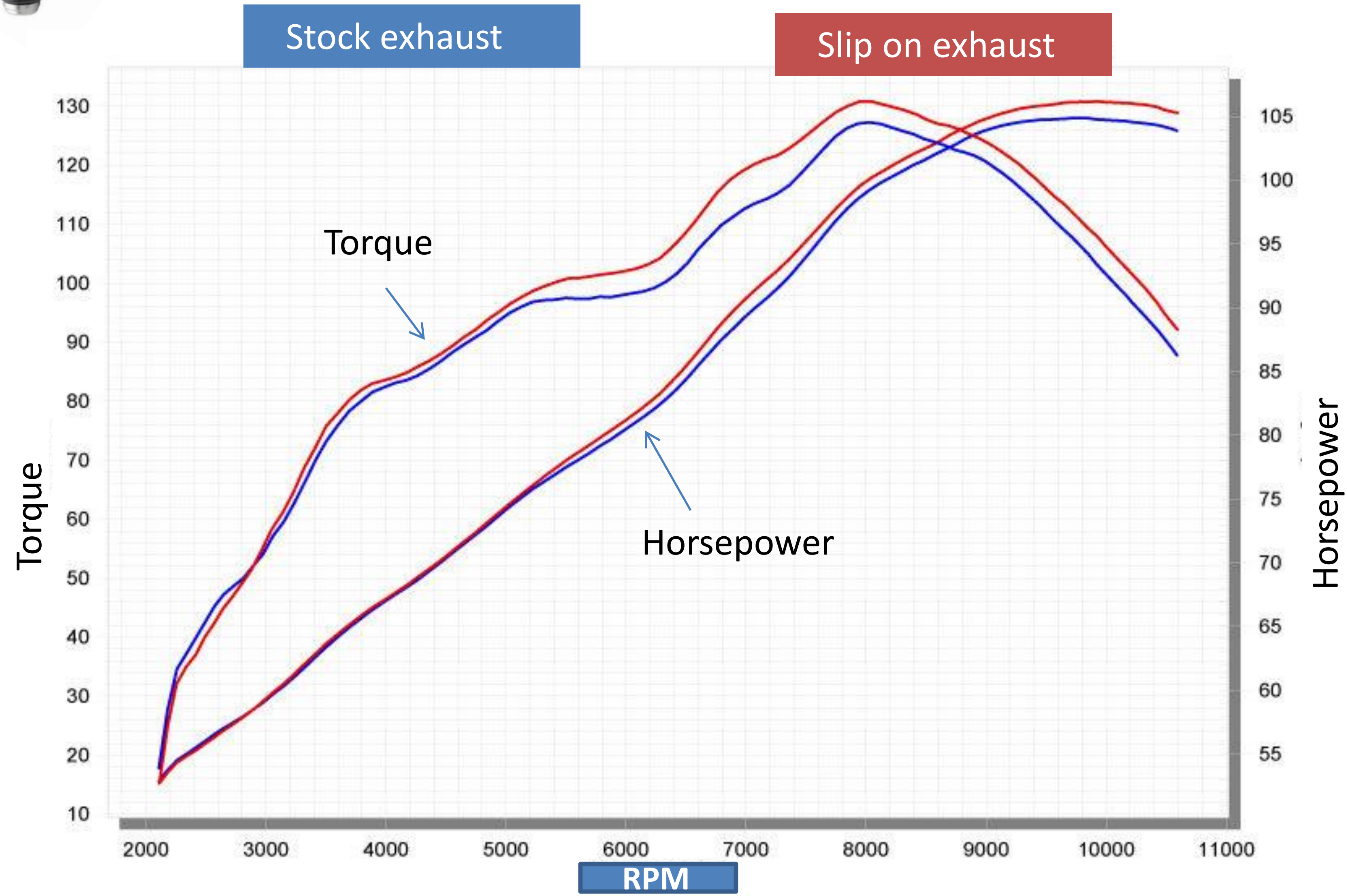
Horsepower: A common unit that describes power
Work that is done over a period of time

Torque: A rotational force generated by the engine
Brute force



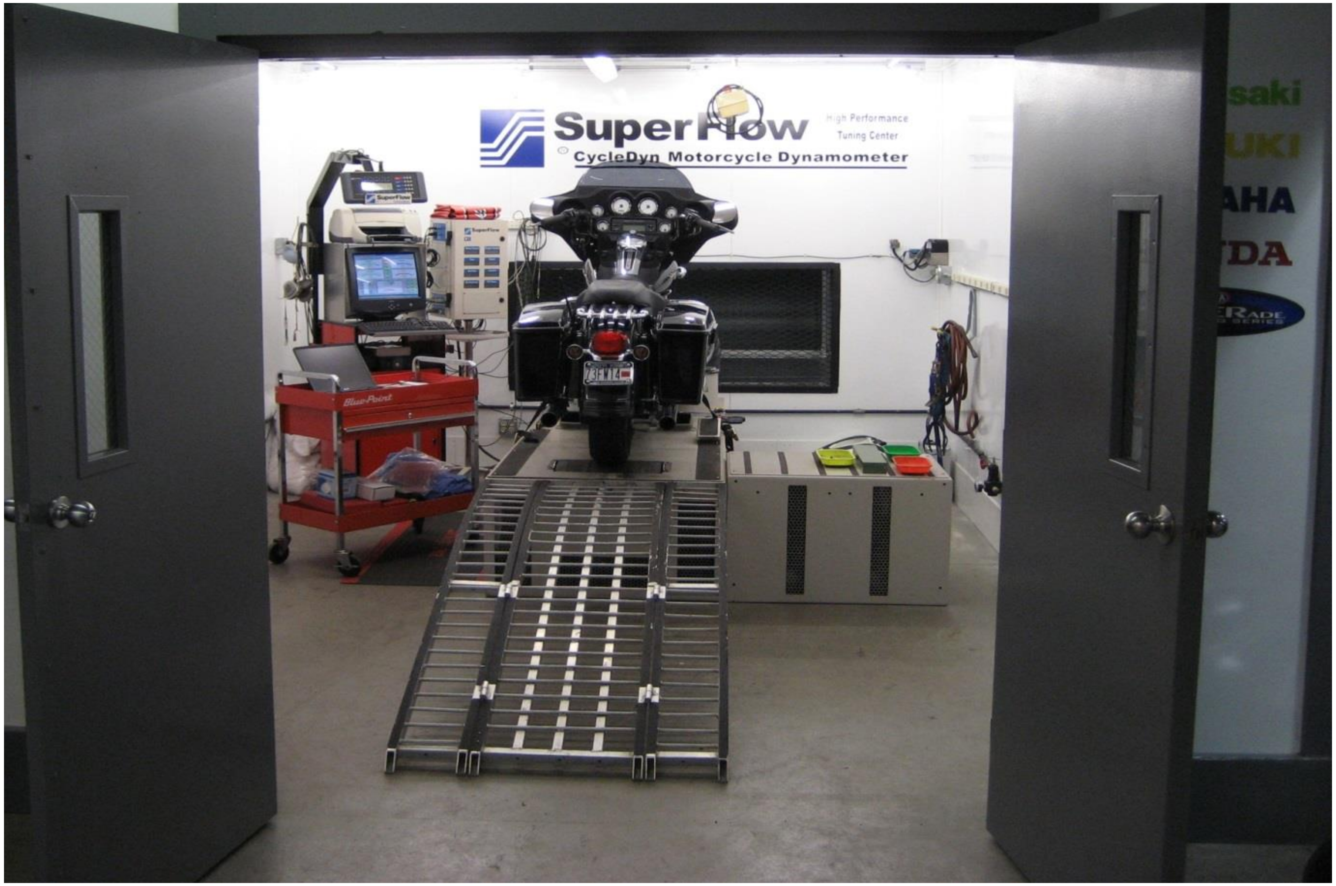
5252 is a constant value that is used in the *formula* for calculating horsepower

Dyno Tuning


Stock exhaust
Slip on exhaust
Torque
Horsepower
Torque
Horsepower
130
120
110
100
90
80
70
60
50
40
30
20
10
105
100
95
90
85
80
75
70
65
60
55
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
RPM

Dyno Tuning

Testing for performance



Dyno Tuning

Diagnostic Codes

Diagnostic codes provide insight to specific problems when troubleshooting an engine.

Refer to your manual on how to retrieve diagnostic codes from your bike using the odometer display.

Or you can use diagnostic code readers that plug into the data port on the bike. The code readers are able to list the trouble codes and also have the ability to clear the codes.

Diagnostic Codes

TTS MasterTune® and H.D devices used to tune your bike can also be used as code readers.

Street Tuner

These tuning devices are married to the bike when tuning and flashing updated maps. However, they can be used freely from one bike to another when reading diagnostic codes.

Resources and Credits

Harley-Davidson ®
Phone: 1-800-258-2464
Website: harley-davidson.com

Kuryakyn parts & accessories
Phone: 1-866-277-9598
Website: kuryakyn.com

Fuel Moto
Phone 1 317-877-729-4754
Website: fuelmotousa.com

Nightrider performance parts
Phone: 1-313-444-9433
Website: nightrider.com

Daniels Performance
Phone: 702-283-3781
mikedanielsperformance.com

Dennis Kirk parts & accessories
Phone: 1-800-969-7501
Website: denniskirk.com

Daytona Twin Tec
Phone:86-304-0700
Website: daytona-twintec.com

J&P Cycle parts
Phone: 1-800-318-4823
Website: jpcycles.com

Vance and Hines
Phone: 1-562- 921-7461
Website: vanceandhines.com

Dynojet Research, Inc.
Phone: 800-992-4993
Website: dynojet.com

KbrWebworks Educational Resources