

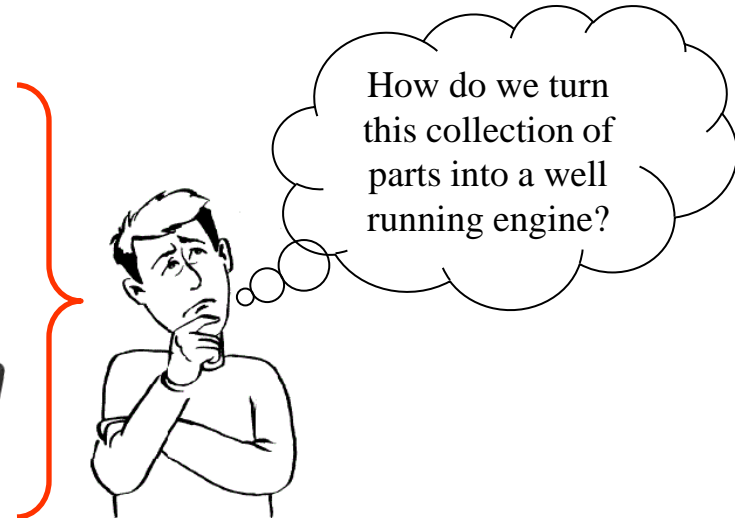


ECUs and Engine Calibration 201

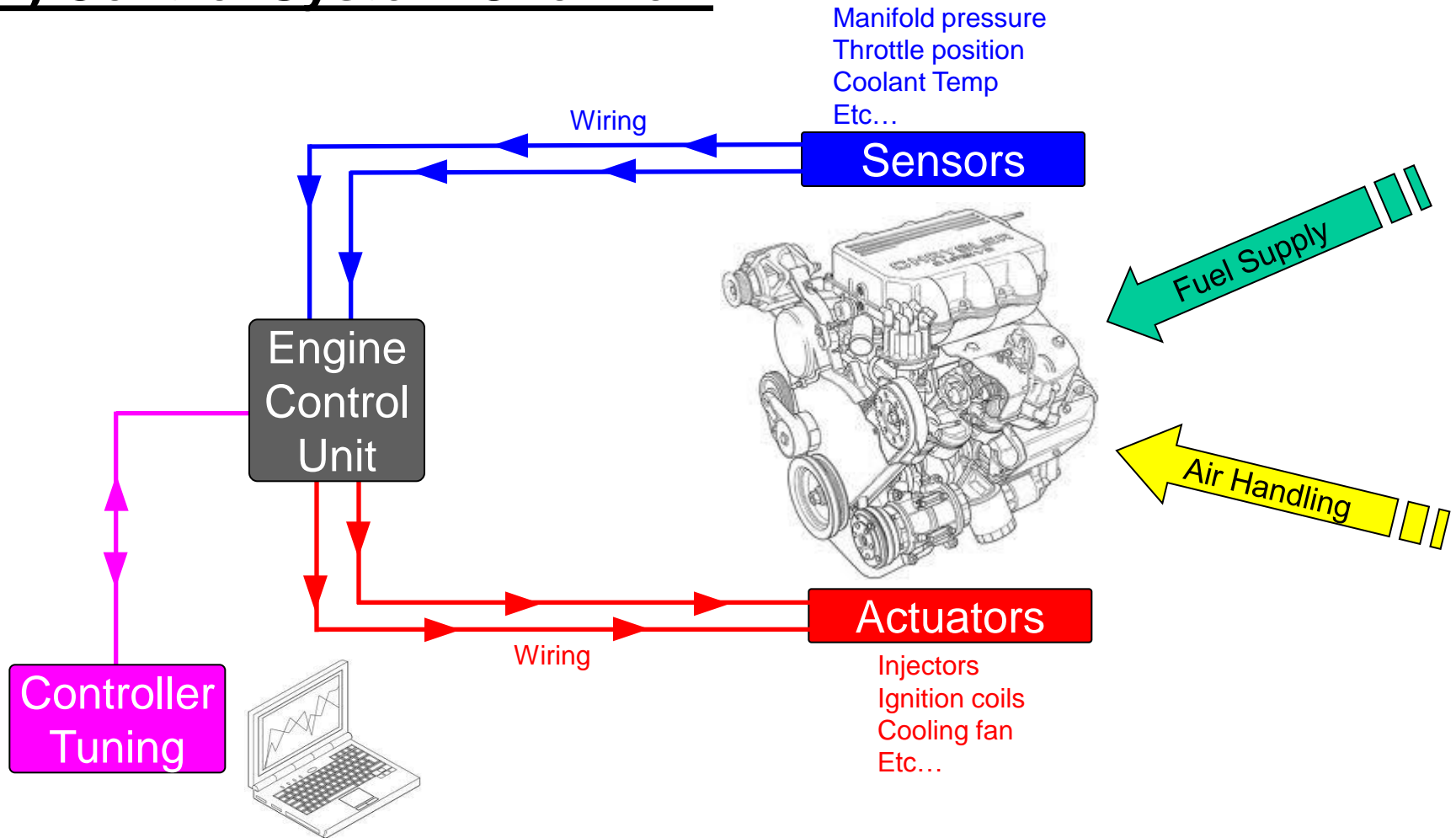
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Performance Electronics, Ltd.
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Before we get started.....

- The goal of this presentation is to explain the **PRACTICAL** application of engine control theory.
- Throughout the presentation, examples will be provided using the PE3 engine control system. However, the fundamental principles apply to almost any type of controller.



1) Control System Overview



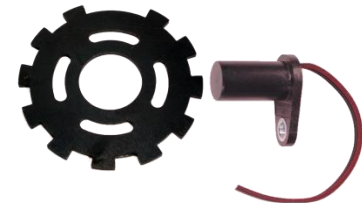
2) Sensors

In its most basic form, only 2 kinds of sensors are **ABSOLUTELY REQUIRED** to electronically control a fuel injected, spark-ignition engine....

- Load Indication (MAP, TPS, MAF)



- Engine Position/Speed (Crank or Cam)



However, limiting the inputs severely hinders the control system's ability to perform at a high level.

2) Sensors – Pressure

Manifold Absolute Pressure (MAP) Sensor

- Used to indicate engine load, provides indirect measurement for mass of air entering cylinder
- Sensors read in **Absolute** pressure not **Gauge** pressure
- High pressure = low vacuum = high load
- Available up to several bar for forced induction engines
- MAP measurement can be latched at startup for barometric pressure compensation or separate BARO/MAP sensor can be used



Example PE3 ECU Software Setup

MAP

1 Atm - GM Sensor 16137039

Low Out Of Range Limit (psi) 1.0

High Out Of Range Limit (psi) 16.0

Pressure (kPa) at 0.5 (V) 19.8

Pressure (kPa) at 4.5 (V) 95.3

Filter level 6

Barometer

Use Map Channel

1 Atm - GM Sensor 16137039

Low Out Of Range Limit (psi) 11.0

High Out Of Range Limit (psi) 104.0

Pressure (kPa) at 0.5 (V) 19.77

Pressure (kPa) at 4.5 (V) 95.31

☒ Latch at Startup

Filter Off

2) Sensors – Throttle Position

Throttle Position (TPS) Sensor

- Used to approximate engine load by measuring throttle angle
- Also very important for determining acceleration/deceleration compensation when the throttle is opened or closed
- Sensor creates a voltage divider as the wiper moves along a fixed resistance



Example PE3 ECU Software Setup

TPS	
<input type="button" value="voltage based TPS"/>	TPS Voltage 0.00
0% Throttle Voltage	<input type="text" value="1.24"/>
100% Throttle Voltage	<input type="text" value="4.67"/>
Low Out Of Range Limit (V)	<input type="text" value="0.50"/>
High Out Of Range Limit (V)	<input type="text" value="4.80"/>
Filter	<input type="button" value="Off"/>

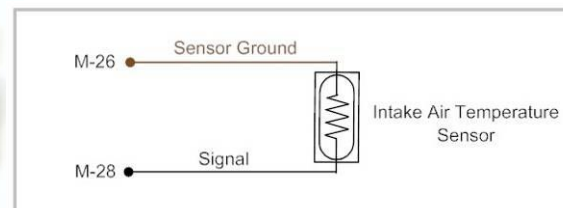
2) Sensors – Temperature

Intake Air Temperature (IAT) Sensor

- Thermistor element, non-linear resistance change with temperature
- Compensates for changes in air density due to temperature changes

Coolant Temperature (CLT) Sensor

- Thermistor element, non-linear resistance change with temperature
- Compensates for startup conditions where more fuel and timing may be required



Example PE3 ECU Software Setup

Air Temperature

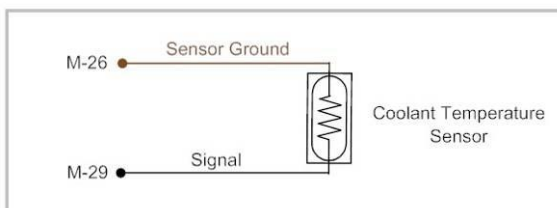
User Defined

Low Out Of Range Limit (°F)	-40
High Out Of Range Limit (°F)	250
Resistance at 0°C (32°F)	94952
Resistance at 20°C (68°F)	37306
Resistance at 80°C (176°F)	3844
Filter	Off

Coolant Temperature

User Defined

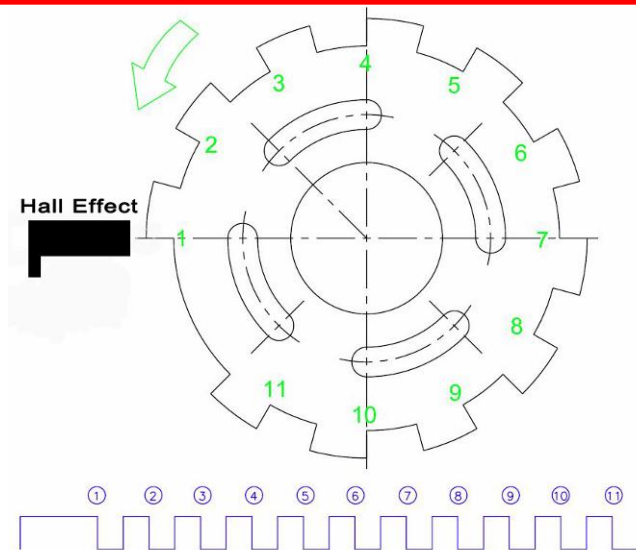
Low Out Of Range Limit (°F)	-40
High Out Of Range Limit (°F)	300
Resistance at 0°C (32°F)	94952
Resistance at 20°C (68°F)	37306
Resistance at 80°C (176°F)	3844
Filter	Off



2) Sensors – Crank/Cam Position

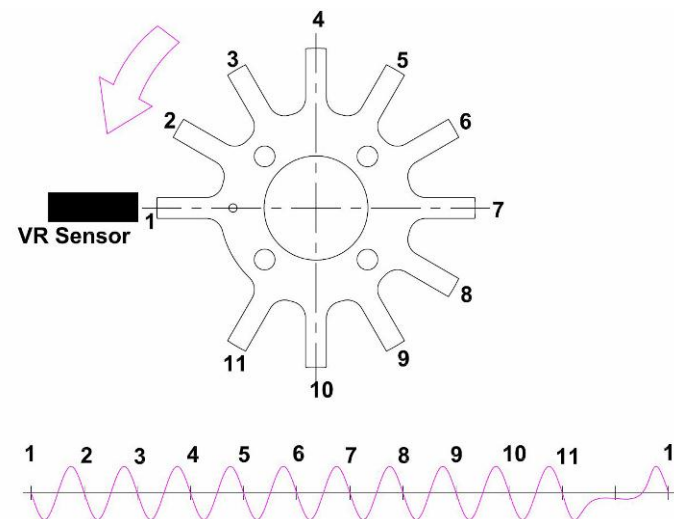
Hall Effect Sensor

- 3-wire sensor, creates square wave output
- Requires power to function
- Edge of the trigger tooth corresponds to a rising or falling signal voltage



Variable Reluctance Sensor

- 2-wire sensor, sine wave output, amplitude a function of speed, material and gap
- Center of the tooth corresponds to 'zero-crossing'. **The zero-crossing is what the ECU uses to indicate position.**



2) Sensors – Lambda

Narrow Band Sensor

- Efficient at measuring lambda at or around stoichiometric ratios
- Generally used as a 'switch' to indicate rich condition or lean condition
- Characterized as having 1-4 wires depending on presence of heating element

Wide Band Sensor

- Much wider range of measurement. Can be used to accurately measure rich and lean air-fuel ratios
- More than 4 wires to the sensor
- More costly and more complicated to control but worth the added expense



Example PE3 ECU Software Setup

Lambda Sensor	
Wide Band	
Use Analog Input #6	
Lambda at 0 (V)	0.50
Lambda at 5 (V)	1.52
Low Out Of Range Limit (V)	0.10
High Out Of Range Limit (V)	4.95
Filter	Off



2) Sensors – Generic Inputs

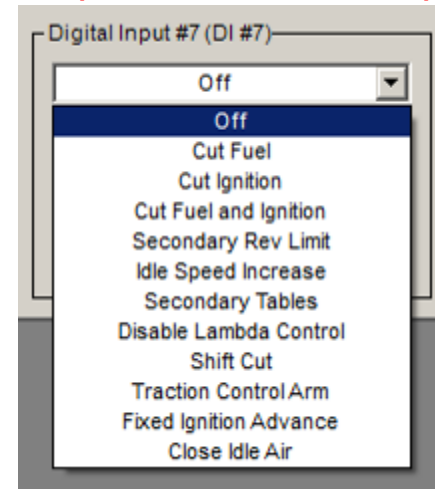
Analog Inputs

- 0-5v and 0-22v analog inputs
- Can be used to modify fuel, modify ignition timing or log for data acquisition
- Very useful for adding 'on-the-dash' fuel and ignition trims

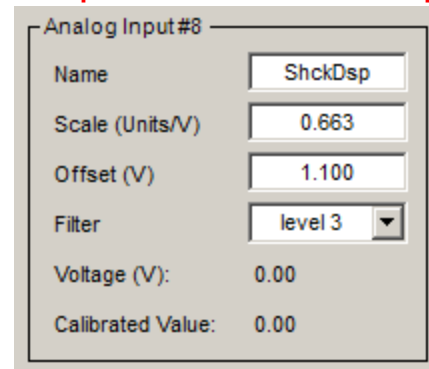
Digital Inputs

- Active pulled 'high' and active pulled to GND
- Many possible functions including:
 - Measuring speeds
 - Cutting fuel and/or ignition
 - Secondary rev limit
 - Traction control
 - Shift cut
 - etc

Example PE3 ECU Software Setup



Example PE3 ECU Software Setup

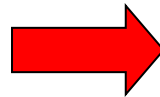


2) Actuators

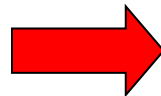
For this discussion, actuators are defined as any component or device that are controlled by the ECU for the purpose of running the engine.

There are many types of actuators but the two most important actuators for running an engine are....

- Fuel Injectors

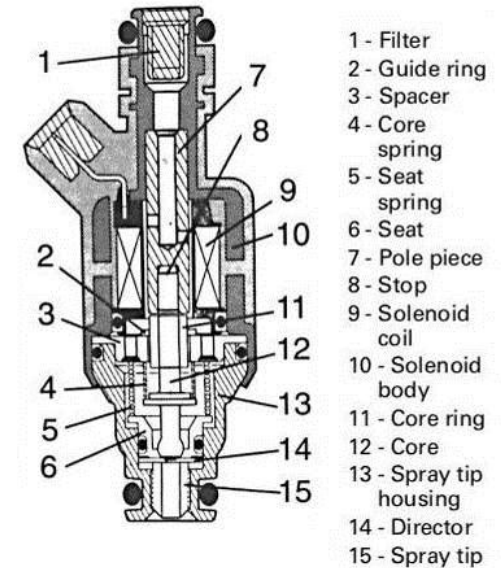


- Ignition Coils



2) Actuators – Fuel Injectors

- Gasoline injectors are just valves, capable of two states open and closed.
- Reliable operation depends on a clean flow of pressurized fuel at a predictable pressure.
- Two types of injectors:
 - **Saturated** – High impedance (>10 ohms), easy to drive by just flowing 12v through the injector
 - **Peak and Hold** – Low Impedance (<3 ohms), more difficult to drive because they require high 'peak' current to open (~ 4 amps) then lower 'hold' current to stay on without burning up (~ 1 amps)



2) Actuators – Fuel Injectors, Types Pros/Cons

Type	Pros	Cons
Saturated	<ul style="list-style-type: none">• Used for almost all production systems• Readily available in many sizes• Easy to drive and configure	<ul style="list-style-type: none">• Slower response• Lower flow rates
Peak and Hold (P&H)	<ul style="list-style-type: none">• Faster response• Very large flow rates available	<ul style="list-style-type: none">• Require more complicated drive electronics and setup• More expensive and less readily available

P&H and Saturated Injectors typically look the same. Easiest way to tell them apart is to measure the electrical resistance.



If the engine that you are using came from the factory with fuel injection, use the stock injectors. There are very few cases where doing otherwise provides any real benefit.

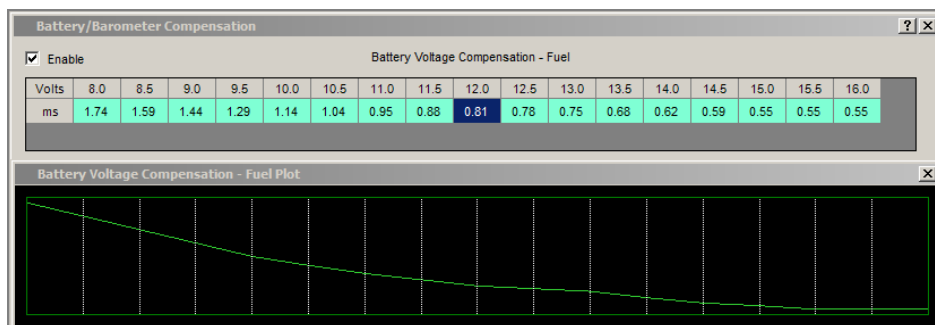


2) Actuators – Fuel Injectors, Setup

Whether using P&H or Saturated injectors, one **VERY** important setting is sometimes overlooked when configuring the control system...

Battery Voltage Compensation (A.K.A. Injector Dead-time)

1. Added term to the final calculated injector open time
2. Compensates for decreased battery voltage at the injector when supply drops (3.5ms @ 15v = 3.5ms @ 10v with correct Battery Comp)
3. By definition, the correct Battery Voltage Compensation creates a **LINEAR** relationship between the final open time and mass of fuel.



Example PE3 ECU Software
Setup For Battery Voltage
Compensation

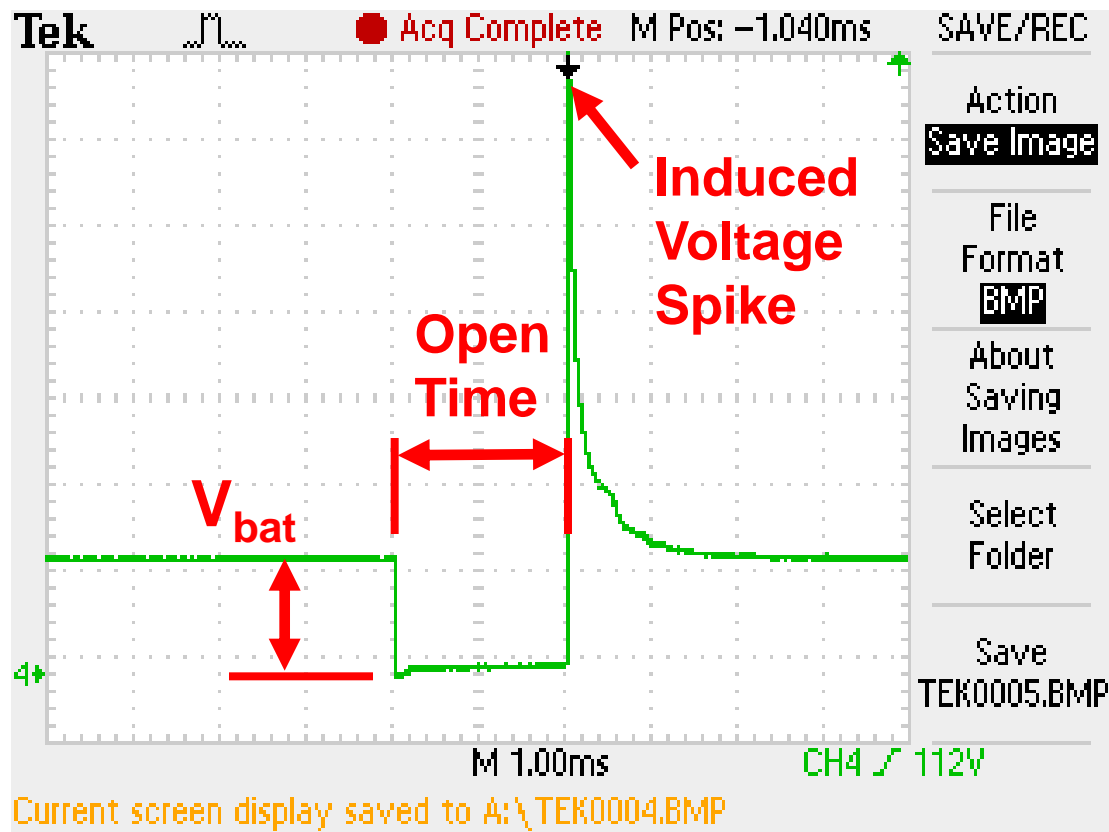
2) Actuators – Fuel Injectors, Battery Compensation (cont)

- Injectors open faster with more voltage (non-linear)
- For given base open time, with constant fuel pressure and temperature, more voltage = more fuel flow
- If no compensation is applied, at a fixed load and rpm, open time will provide different mixtures proportional to electrical load on system.

This is impossible to tune well!

- Battery voltage compensation accounts for latency of injector and can't be measured electrically. **It must be measured and calculated using mass flow!**
- With the correct compensation, a xx% change in pulse width corresponds to a xx% change in fuel flow. This makes it much easier to tune as well as keeping all of the compensation terms happy.

2) Actuators – Saturated Fuel Injector Trace



2) Actuators – Ignition Coils

Ignition coils are step up transformers that use primary side voltage and current to induce large secondary voltages. There are several types of coils.

- **Inductive (Dumb)**

- Used on most modern production applications
- Uses 12v to charge the primary side of the coil
- High turns ratio (high inductance)



- **Inductive (Smart)**

- Same basic construction as 'dumb' inductive coils except they have a built in ignition driver (igniter). GM LS series motors use 'smart coils'
- Have 3 or more wire connections

- **Capacitive Discharge Ignition (CDI)**

- Used on many pre-computer controlled, production, small engines
- Still used for some performance applications (MSD)
- Requires much higher primary voltage (>150v)
- Generally, lower primary resistance than inductive coils



2) Actuators – Ignition Coils

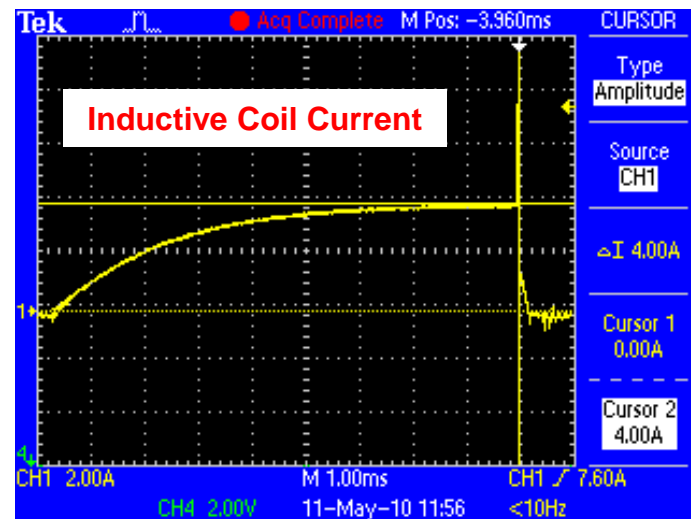
- Inductive and CDI coils require entirely different types of ignition drivers. They **ARE NOT** interchangeable.
- If you have an existing OEM coil and are unsure of the type, there are several ways for determining inductive or CDI.
 - Turn on ignition key. If the coil measures 12v, the coils are inductive.
 - Refer to the stock wiring diagram. If the one side of the primary goes to 12v it is inductive. If both sides of the primary go to an ignition box, it is likely CDI.
- The **PE3** engine controller has built in inductive ignition igniters. It can drive inductive ‘smart’ or ‘dumb’ coils directly from the ECU.



- If possible use the stock coils. There are very few cases where doing otherwise provides any real benefit.
- Most 600cc engines can benefit from running the ‘hottest’ available plugs. This helps to reduce fouling.

2) Actuators – Ignition Coils, Inductive Charge Time

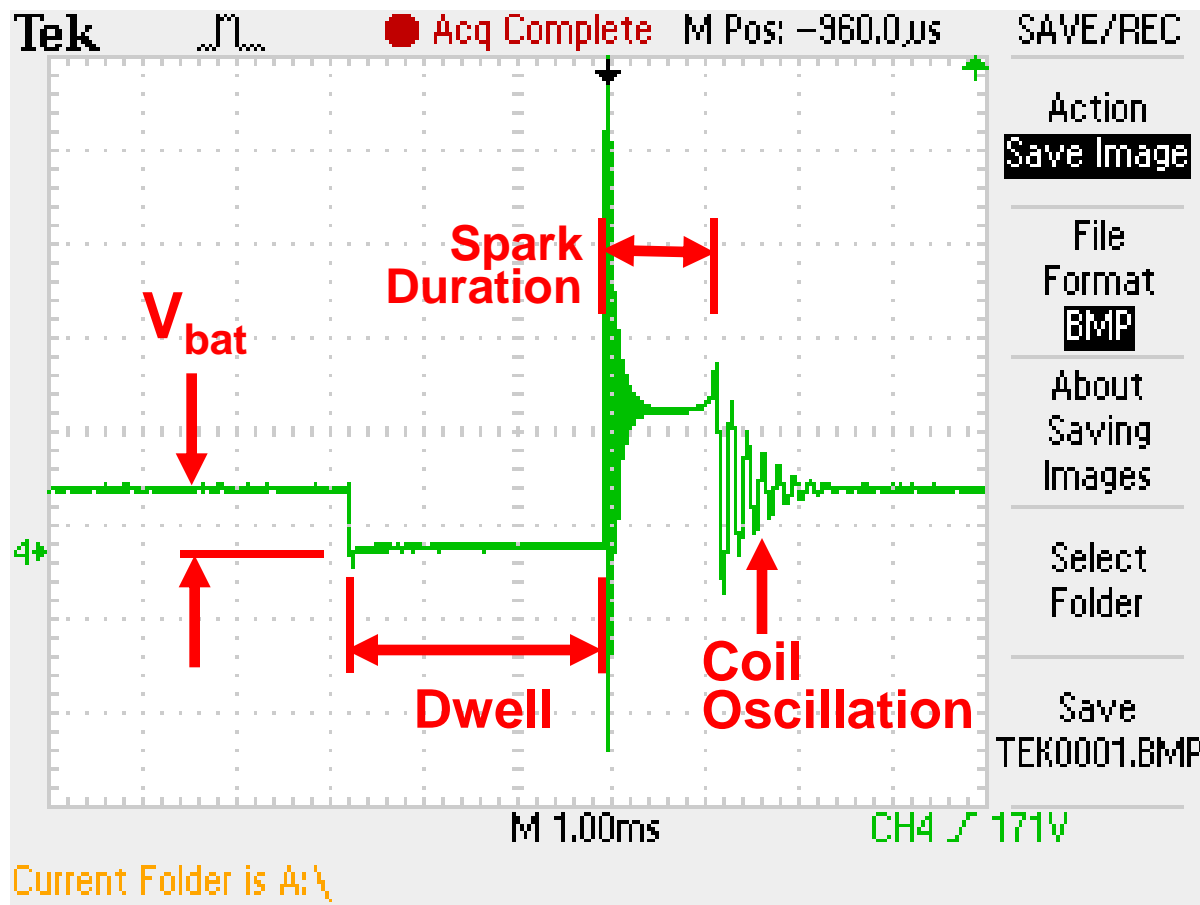
- Inductive coils require a specific amount of time to charge, *Charge Time*.
- To obtain the same output under all operating conditions, charge time must be a function of battery voltage.
- Charge time is best determined by measuring current through the coil using an oscilloscope at different voltages.
- Generally the charge time is set so max current is at least 3 time constants.
- As the coil current approaches saturation, extra charge time simply heats up the coil and the driver.



Example PE3 ECU Software Setup

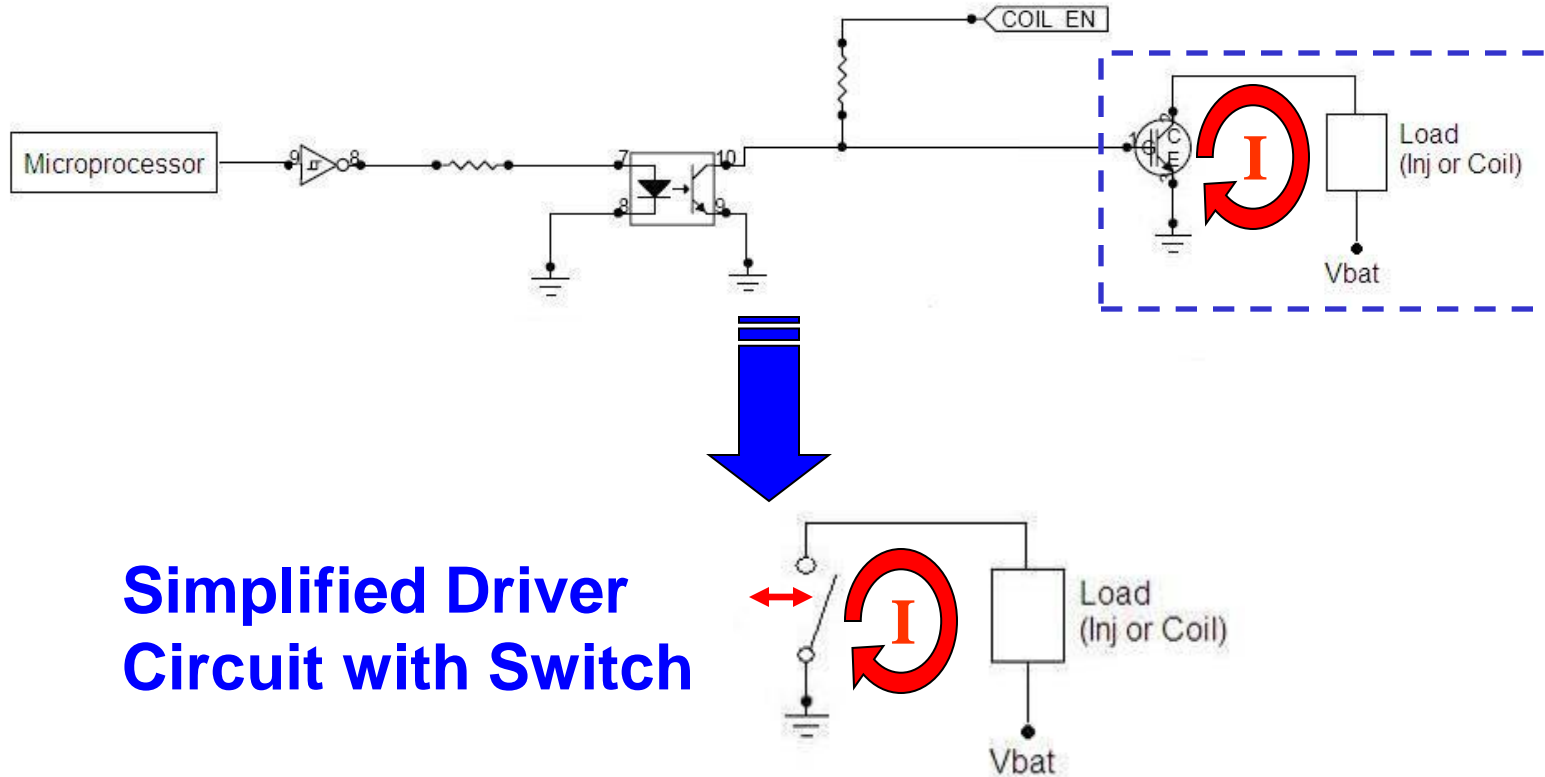
Engine	Fuel	Ignition	Enables	Define TDC	Rev Limit										
<div> <div> Ignition <input checked="" type="checkbox"/> Enable </div> <div> Ignition Type Sequential </div> <div> <input type="checkbox"/> Enable external coil drivers. (Fire on rising edge) </div> </div> <div> Ignition Range (DBTDC) Max: 100 Min: -20 </div> <div> Charge Time (ms) <table border="1"> <tr> <td>8.0 Volts</td> <td>5.50</td> </tr> <tr> <td>10.0 Volts</td> <td>4.25</td> </tr> <tr> <td>12.0 Volts</td> <td>3.00</td> </tr> <tr> <td>14.0 Volts</td> <td>2.25</td> </tr> <tr> <td>16.0 Volts</td> <td>1.00</td> </tr> </table> </div>						8.0 Volts	5.50	10.0 Volts	4.25	12.0 Volts	3.00	14.0 Volts	2.25	16.0 Volts	1.00
8.0 Volts	5.50														
10.0 Volts	4.25														
12.0 Volts	3.00														
14.0 Volts	2.25														
16.0 Volts	1.00														

2) Actuators – Inductive Ignition Coil Trace (Primary)



2) Actuators – Coil and Injector Driver Explanation

The following example applies only to saturated (high impedance) injectors and inductive (not CDI) ignition coils. More on the types of injectors and ignition coils later.



3) Control Strategies – Overview

- The two main jobs of an engine control system is to control the fuel flow and the ignition timing....**everything else is just fluff.**
- Optimized fueling and ignition timing are dependent on many different factors. All of these factors must be measured and accounted for in order to produce a well running engine under all conditions.



3) Control Strategies – Calculation of Inj Open Time

$$\text{Open Time (ms)} = (\text{BOT} \times \text{AT} \times \text{CT} \times \text{ST} \times \text{AC} \times \text{BP} \times \text{MP} \times \text{STF} \times \text{LTF} \times \text{CC} \times \text{UI}) + \text{BA}$$

Where:

BOT = Base open time from the main fuel table

AT = Air temperature compensation

CT = Coolant temperature compensation

ST = Starting compensation

AC = Acceleration compensation

BP = Barometric pressure compensation

MP = MAP compensation

STF = Short term factor for closed loop lambda compensation

LTF = Long term factor for closed loop lambda compensation

CC = Individual cylinder compensation

UI = User selectable input compensations (could be several if configured)

BA = Battery voltage compensation

3) Control Strategies – Calculation of Ignition Timing

$$\text{Total Ignition Timing (deg)} = \text{BIT} + \text{AT} + \text{CT} + \text{BP} + \text{MC} + \text{CC} + \text{UI}$$

Where:

BIT = Base ignition timing from the main ignition table

AT = Air temperature compensation

CT = Coolant temperature compensation

BP = Barometric pressure compensation

MC = MAP compensation

CC = Individual cylinder compensation

UI = User selectable input compensation (could be several if configured)

4) Engine Tuning – Overview

Successful Engine Tuning

- 1) General ECU setup (engine type, # cylinders, sensor setup, etc)
 - 2) **Tune main fuel table**
 - 3) **Tune main ignition table**
- } ***Must iterate to best “tune”***
- 4) Add in additional compensation (air, coolant, starting, etc.)
 - 5) Setup additional inputs and outputs (idle air, fuel cut, secondary rev limiter, etc)

4) Engine Tuning – General ECU Setup, Engine

The screenshot shows the 'Setup Engine' window with the following settings:

- Engine** tab selected.
- Cylinders:** 4
- Load Control:** TPS
- Tach Pulses per Rev:** 2
- Trigger Input:** VR (2-wire) Sensor, 12-0 Wheel
- Sync Input:** VR (2-wire) Sensor, 1 Pulse per rev
- Sync Tooth:** 1
- Engine Configuration:** Even Fire
- Model Configuration:** Not Specified
- Checkboxes:**
 - Positive Going Zero Crossing (unchecked)
 - Peak Track Low (unchecked)

- **Cylinders** – Number of cylinders in the engine
- **Trigger and Sync Types** – Variable Reluctance or Hall Effect
 - Pick the tooth arrangement on your trigger and sync from the drop down menu
 - Choose which edge to trigger on (Positive or negative going)
 - Enable peak track low for signals that vary by more than 30% from one peak to the next
- **Load Control** – Controls which input is used to indicate engine load
- **Tach Pulses per Rev** – Sets the number of tach pulses for every crank revolution

4) Engine Tuning – General ECU Setup, Fuel

The screenshot shows the 'Setup Engine' window with the 'Fuel' tab selected. The settings are as follows:

- Fuel:** ☒ Enable
- Injection Type:** Sequential (dropdown)
- Min Open Time (ms):** 1.40
- Peak & Hold:** ☐ Enable, Peak Current: 4.0, Hold Current: 1.0, ☐ Enable Adaptive Mode
- Open Time Range:** 0 to 8 ms (dropdown)
- Staged Injection:** ☐ Enable, Min Load: 98.0 (dropdown), Min RPM: 163 (dropdown)
- Flood Clear:** ☐ Enable
- Every Other Rev:** ☐ Enable, Max Open Time: 2.0

- **Injection Type** – Sequential, Semi-Sequential, Throttle Body, Random Sequential
- **Min Open Time** – Defines the minimum allowable pulse width for injection
- **Peak And Hold** – Enable peak and hold mode and set peak and hold currents
- **Open Time Range** – Sets the maximum base table open time. (The higher the range, the less resolution)
- **Staged Injection** – Enable secondary injectors and set the thresholds where they are activated.
- **Flood Clear** – With this enabled, when TPS is above 98% and RPM is less than cranking speed, no fuel is injected
- **Every other Rev** – Used to aid in idling and part throttle loads with large injectors

4) Engine Tuning – General ECU Setup, Ignition

The screenshot shows the 'Setup Engine' window with the 'Ignition' tab selected. The window has a blue title bar and a tabbed interface with tabs for Engine, Fuel, Ignition, Enables, Define TDC, and Rev Limit. The Ignition tab contains three main sections: Ignition, Ignition Range (DBTDC), and Charge Time (ms). The Ignition section has an 'Enable' checkbox checked and an 'Ignition Type' dropdown set to 'Sequential'. There is also an unchecked checkbox for 'Enable external coil drivers. (Fire on rising edge)'. The Ignition Range (DBTDC) section has 'Max' set to 100 and 'Min' set to -20. The Charge Time (ms) section is a table with voltage levels and corresponding charge times.

Charge Time (ms)	
8.0 Volts	4.00
10.0 Volts	3.00
12.0 Volts	2.00
14.0 Volts	1.50
16.0 Volts	1.20

- **Ignition Type** – Sequential, Wasted-Spark, Distributor (External drivers for “smart” coils)
- **Ignition Range** – Defines the adjustable range of timing BDTC
- **Charge Time** – Sets charge time of the ignition coil

4) Engine Tuning – General ECU Setup, Sensors

- Sensors can accept a user defined calibration or choose a predefined sensor calibration.
- Units are selectable (SI or English).
- Sensors can be turned on or off independently.
- High and low 'out-of-range limits' can be set as well. Errors will be latched each time a sensor goes out of range.

Setup Sensors

Display Units
Pressure - psi
Temperature - °F

Display Lambda
Common Stoichiometric Air-Fuel Ratios
14.7 - Gasoline
15.5 - LPG
6.4 - Methanol
9.0 - Ethanol
17.2 - CNG
14.6 - Diesel

Primary Table Stoichiometric Air-Fuel Ratio 14.70
Secondary Table Stoichiometric Air-Fuel Ratio 14.70

TPS
voltage based TPS
TPS Voltage 0.00
0% Throttle Voltage 0.50
100% Throttle Voltage 4.44
Low Out Of Range Limit (V) 0.00
High Out Of Range Limit (V) 5.00
Filter Off

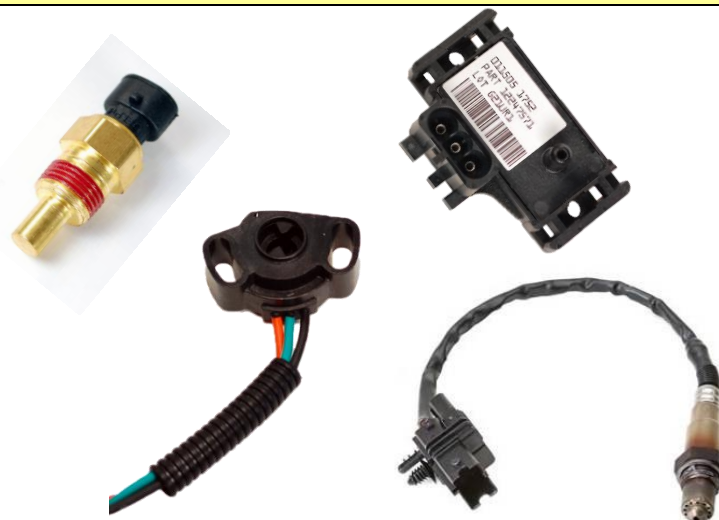
MAP
1 Atm - GM Sensor 16137039
Low Out Of Range Limit (psi) 1.0
High Out Of Range Limit (psi) 18.0
Pressure (kPa) at 0.5 (V) 0.0
Pressure (kPa) at 4.5 (V) 0.0
Filter Off

Air Temperature
GM #1
Low Out Of Range Limit (°F) -30
High Out Of Range Limit (°F) 250
Resistance at 0°C (32°F) 0
Resistance at 20°C (68°F) 0
Resistance at 80°C (176°F) 0
Filter Off

Lambda Sensor
Wide Band
Not Used

Barometer
Use Map Channel
1 Atm - GM Sensor 16137039
Low Out Of Range Limit (psi) 10.0
High Out Of Range Limit (psi) 16.0
Pressure (kPa) at 0.5 (V) 19.77
Pressure (kPa) at 4.5 (V) 95.31
Latch at Startup
Filter Off

Coolant Temperature
GM #1
Low Out Of Range Limit (°F) -30
High Out Of Range Limit (°F) 250
Resistance at 0°C (32°F) 0
Resistance at 20°C (68°F) 0
Resistance at 80°C (176°F) 0
Filter Off

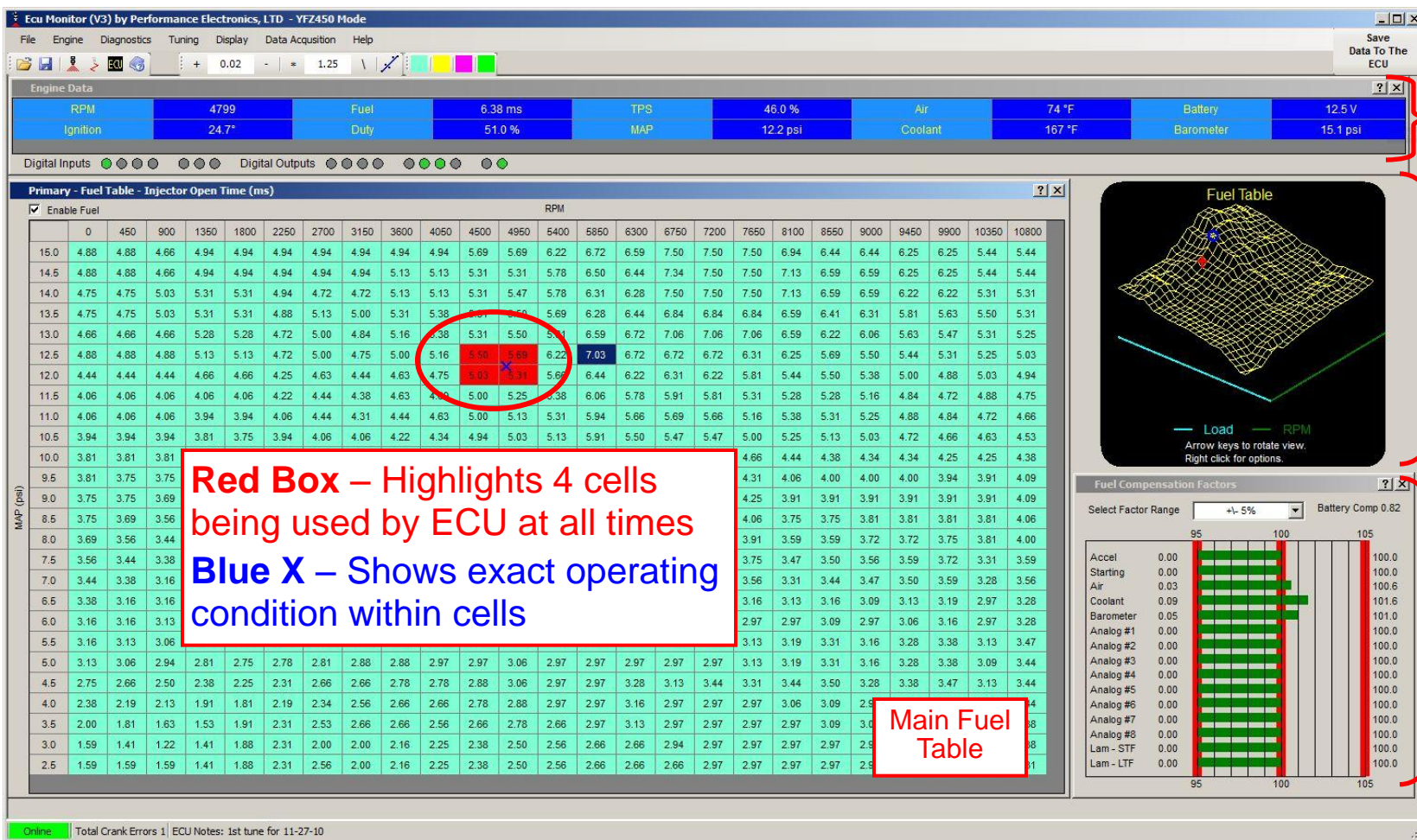


4) Engine Tuning – Overview

Successful Engine Tuning

- 1) General ECU setup (engine type, # cylinders, sensor setup, etc)
 - 2) Tune main fuel table
 - 3) Tune main ignition table
- } *Must iterate to best “tune”*
- 4) Add in additional compensation (air, coolant, starting, etc.)
 - 5) Setup additional inputs and outputs (idle air, fuel cut, secondary rev limiter, etc)

4) Engine Tuning – Main Fuel and Ignition Tables



Current Engine Conditions

3-D Table View

Bar Graph of Comp Terms

4) Engine Tuning – Overview

Successful Engine Tuning

- 1) General ECU setup (engine type, # cylinders, sensor setup, etc)
 - 2) **Tune main fuel table**
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- } *Must iterate to best “tune”***
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- 5) Setup additional inputs and outputs (idle air, fuel cut, secondary rev limiter, etc)

4) Engine Tuning – Temperature Compensation Terms

Air Temp Compensation - Fuel

Load - TPS (%)

80.0
60.0
40.0
20.0

☒ Enable

Compensation Factor - Percent

125.0	116.0	108.0	100.0	93.1	86.8	81.0	77.0
125.0	116.0	108.0	100.0	93.1	86.8	81.0	77.0
125.0	116.0	108.0	100.0	93.1	86.8	81.0	77.0
125.0	116.0	108.0	100.0	93.1	86.8	81.0	77.0

Temperature (°F)

-40.0	0.0	40.0	80.0	120.0	160.0	200.0	240.0
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Coolant Temp Compensation - Fuel

Load - TPS (%)

80.0
60.0
40.0
20.0

☒ Enable

Compensation Factor - Percent

200.0	200.0	175.0	150.0	125.0	100.0	100.0	100.0
200.0	200.0	175.0	150.0	125.0	100.0	100.0	100.0
200.0	200.0	175.0	150.0	125.0	100.0	100.0	100.0
200.0	200.0	175.0	150.0	125.0	100.0	100.0	100.0

Temperature (°F)

-40.0	0.0	40.0	80.0	120.0	160.0	200.0	240.0
-------	-----	------	------	-------	-------	-------	-------

- 3-D Tables
- 100% = No modification for fuel compensation terms
- Air temp fuel compensations can be approximated using Ideal Gas Law ($PV=nRT$)
- Coolant temp compensations are determined through testing

4) Engine Tuning – Starting Compensation Terms

Starting/Accel/Decel Compensation

Starting - Fuel

☒ Enable

0 °F (%) 300.0

* 80 °F (%) 250.0

160 °F (%) 150.0

240 °F (%) 105.0

Duration (revs) 100

Fuel Starting RPM 400

Initial Fuel Pulse (ms) 0.0

* value used if no sensor defined

Starting - Ignition

☐ Enable

Timing (deg) 10.0

Ignition Starting RPM 400

Accel

☐ Enable

Type TPS

min TPS rate (%/sec) 20.0

min TPS (%) 2.0

Max Factor (%) 170.0

Duration (sec) 0.5

Max RPM 7000

Decel

☐ Enable

min TPS (%) 1.0

max RPM 2450

RPM Delta 250

- **0°F, 80°F, 160°F, 240°F** – Compensation factors at coolant temperature values. Applied as long as the RPM is less than **Fuel Starting RPM**.
- **Duration** – The number of revolutions that the compensation decays over once the engine is above **Fuel Starting RPM**.
- **Initial Fuel Pulse** – Length of time the injectors are opened for a priming pulse on the first revolution.

4) Engine Tuning – Accel Compensation Terms

Starting/Accel/Decel Compensation

Starting - Fuel

- ☒ Enable
- 0 °F (%) 300.0
- * 80 °F (%) 250.0
- 160 °F (%) 150.0
- 240 °F (%) 105.0
- Duration (revs) 100
- Fuel Starting RPM 400
- Initial Fuel Pulse (ms) 0.0
- * value used if no sensor defined

Starting - Ignition

- ☐ Enable
- Timing (deg) 10.0
- Ignition Starting RPM 400

Accel

- ☐ Enable
- Type TPS
- min TPS rate (%/sec) 20.0
- min TPS (%) 2.0
- Max Factor (%) 170.0
- Duration (sec) 0.5
- Max RPM 7000

Decel

- ☐ Enable
- min TPS (%) 1.0
- max RPM 2450
- RPM Delta 250

Type – Choose Map or TPS

Min TPS Rate – Determines the Accel circuit's sensitivity to throttle changes. The larger the number is, the less sensitive the circuit is.

Min TPS – This is the minimum required throttle position before the Accel compensation is allowed to take effect.

Max Factor – Maximum compensation percent.

Duration – This is the amount of time that the Accel compensation degrades over.

Max RPM – This is the maximum RPM allowed for Accel compensation.

4) Engine Tuning – Decel Comp and Start Ignition

Starting/Accel/Decel Compensation

Starting - Fuel

- ☒ Enable
- 0 °F (%) 300.0
- * 80 °F (%) 250.0
- 160 °F (%) 150.0
- 240 °F (%) 105.0
- Duration (revs) 100
- Fuel Starting RPM 400
- Initial Fuel Pulse (ms) 0.0
- * value used if no sensor defined

Accel

- ☐ Enable
- Type TPS
- min TPS rate (%/sec) 20.0
- min TPS (%) 2.0
- Max Factor (%) 170.0
- Duration (sec) 0.5
- Max RPM 7000

Starting - Ignition

- ☐ Enable
- Timing (deg) 10.0
- Ignition Starting RPM 400

Decel

- ☐ Enable
- min TPS (%) 1.0
- max RPM 2450
- RPM Delta 250

- **Decel Fuel Cut-Off** – If the throttle position is less than **Min TPS** and the RPM is greater than **Max RPM** the ECU assumes that the engine is being motored and does not open the injectors until either the TPS increases or the RPM slows down to below **Max RPM – RPM Delta**.

- **Starting-Ignition** – When Enabled, this fixes the timing at specified degrees BTDC until RPM is > **Ignition Starting RPM**

4) Engine Tuning – User Inputs

User #1 - Modify Fuel/Ignition

☒ Enable

Input Parameter

0.00	0.31	0.63	0.94	1.25	1.56	1.88	2.19	2.50	2.81	3.13	3.44	3.75	4.06	4.38	4.69	5.00
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Analog Input #1 (volts)

Compensation - Fuel (%)

70.0	73.8	77.5	81.2	85.0	88.8	92.5	96.2	100.0	103.8	107.5	111.2	115.0	118.8	122.5	126.2	130.0
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Modify Fuel

- 2-D Array
- 8 User Input compensation terms that can be configured for analog inputs, frequency inputs, PWM duty cycle, IAC position, etc
- Can be used to modify fueling or ignition timing
- 100% = no modification for Fuel. 0 = no modification for ignition

4) Engine Tuning – Overview

Successful Engine Tuning

- 1) General ECU setup (engine type, # cylinders, sensor setup, etc)
- 2) **Tune main fuel table**
- 3) **Tune main ignition table**
- 4) Add in additional compensation (air, coolant, starting, etc.)
- 5) Setup additional inputs and outputs (idle air, fuel cut, secondary rev limiter, etc)

Must iterate to best “tune”

4) Engine Tuning – Digital Outputs

The screenshot displays the 'Digital Outputs for On/Off Control' window, which contains 10 digital output channels. Each channel is configured with a specific parameter and two points (Point 1 and Point 2). The channels are:

- Digital Output #1 (Fan): Coolant Temp, Point 1: 175, Point 2: 170
- Digital Output #2 (Info): Info Light, Configure In: - Engine, - Info Light Config
- Digital Output #3 (WOT_AC): TPS, Point 1: 96.0, Point 2: 98.0
- Digital Output #4 (Clt_Lg): Coolant Temp, Point 1: 210, Point 2: 205
- Digital Output #5 (Shft_Lg1): RPM, Point 1: 4500, Point 2: 4400
- Digital Output #6 (Shft_Lg2): RPM, Point 1: 5000, Point 2: 4400
- Digital Output #7 (IAC): PWM Idle Control
- Digital Output #8 (Bst_Sol): Table based PWM
- PWM Frequency A: 189.5 Hz, For Digital Outputs 1,2,5,6
- Digital Output #9 (Alw_On): Always On, This output is on when the ECU is on
- Digital Output #10 (Fuel): Fuel Pump
- PWM Frequency B: 189.5 Hz, For Digital Outputs 3,4,7,8

Overlaid on the top right is the 'Digital Output #8 (Bst_Sol) - PWM Table' window. It shows an 8x8 table of PWM duty cycle percentages. The table is indexed by TPS (Y-axis) and RPM (X-axis). The current value is 76.5. A red box highlights the value 75.5 at the intersection of 8.0 TPS and 4000 RPM.

PWM Table

TPS \ RPM	2000	3000	4000	5000	6000	7000	8000	9000
5.0	10.0	98.0	96.5	95.0	96.0	91.5	90.0	
4.5	9.5	87.0	89.0	89.5	92.5	90.5	80.5	
3.5	8.5	75.5	81.0	84.0	89.0	90.0	71.0	
3.0	8.0	64.5	73.5	78.5	85.5	89.0	61.5	
2.0	7.0	53.5	66.0	73.5	82.0	88.0	51.5	
1.5	6.5	42.5	58.5	68.0	78.5	87.0	42.0	
0.5	5.5	31.0	50.5	62.5	75.0	86.5	32.5	
0.0	5.0	20.0	43.0	57.0	71.5	85.5	23.0	

- 10 Digital Outputs, 8 can be Pulse Width Modulated (PWM) at 5 – 950 Hz
- On/Off as a function of any on-board parameter
- If PWM selected, each PWM channel has an 8x8 3D adjustable indices table

4) Engine Tuning – Digital Inputs

Digital Inputs

Digital Input #1 (Neut_Sw) —
Cut Fuel and Ignition
☐ Invert

Digital Input #2 (Baro) —
Frequency
☐ Invert

Digital Input #3 (AC_Sw) —
Idle Speed Increase
☐ Invert
RPM Increase 50

Digital Input #4 (IgAdv) —
Fixed Ignition Advance
☐ Invert
Angle (DBTDC) 0.0

Digital Input #5 (2ndTbl) —
Secondary Tables
☐ Invert
This input switches the primary fuel, ignition and target lambda tables to the secondary tables.

Digital Input #6 (2ndRev) —
Secondary Rev Limit
☐ Invert
Configure In:
- Engine
- Setup Engine
- Rev Limit

Digital Input #7 (SftCt) —
Shift Cut
☐ Invert
Cut Fuel and Ignition
75.0 ms

- 5 Digital Inputs active when pulled high (5-22 volts)
- 2 Digital Inputs active when pulled low (< 2 volts)
- Can be configured to Cut Fuel and/or Ignition or to bump idle speeds, enable launch or traction control, etc.
- 4 channels can also be used to measure frequencies (0-6000 Hz)

4) Engine Tuning – Rev Limits

The screenshot shows the 'Setup Engine' window with the 'Rev Limit' tab selected. The window is divided into three main sections: Primary Rev Limit, Secondary Rev Limit, and Boost Rev Limit. Each section has a table of settings.

Section	Parameter	Value
Primary Rev Limit	RPM	6500
	Deadband (RPM)	250
	None	<input type="radio"/>
	Cut Ignition	<input type="radio"/>
	Cut Fuel and Ignition	<input checked="" type="radio"/>
Secondary Rev Limit	RPM	4000
	Deadband (RPM)	250
	None	<input type="radio"/>
	Cut Ignition	<input checked="" type="radio"/>
	Cut Fuel and Ignition	<input type="radio"/>
Boost Rev Limit	MAP (psi)	35.0
	Deadband (psi)	2.0
	None	<input type="radio"/>
	Cut Ignition	<input type="radio"/>
	Cut Fuel and Ignition	<input checked="" type="radio"/>

- Can have multiple rev limits activated by MAP, RPM or Digital Input
- Each rev limit can be activated by controlling fuel or ignition or both
- Each rev limit is equipped with a **Deadband**. The rev limit is activated at the **RPM** specified, but is not de-activated until RPM drops below (**RPM – Deadband** In this case $6500 - 250 = 6250$ RPM)
- The Soft option retards the timing when **RPM** is reached. If RPM still increases, then ECU will cut ignition

Thank You and Happy Tuning!

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