



Welcome to Zeus

How we do things in this manual.

To start with, we would like to introduce some conventions used throughout this manual. The icons below depict various activities and warnings.



Critical. This is the most important icon that you will see. It is a warning that something bad will happen if you do not do as it says! If you disregard this icon, your Zeus may explode, your engine may blow up, your truck may cease working, and you may go back in time and be reborn as a toad.

Ignore this warning icon at your own risk! (In other words ***DON'T IGNORE IT!!***)



This **Warning** icon indicates actions that are slightly less risky than the first icon, but still dangerous none the less. Disregarding this icon's warning could still result in damage to your Zeus, your engine, and/or your vehicle, but it is unlikely that you will be reborn as a toad.



Information. This icon lets you know that there is information here that you would be well advised to learn. Things like the finer points of common-rail operation, or the whys and wherefores of multiple injection events. Studying this information will give you a greater insight into your engine's operation and help you make better tuning choices.

After reading the above, hopefully one thing stands out, that nearly anything that you do with your Zeus unit has the ability to seriously damage your engine. We have tried to provide you with a baseline configuration that is safe and usable and a good starting point for further performance tuning. It is your responsibility to understand what you are doing and the consequences of your actions.

This is complicated stuff. Not rocket-science tough, but very different from anything that most of you will have encountered. The only sure way to stand a reasonable chance of success is to thoroughly understand your engine's operation, including what parameters have what effects. One rule of thumb that we developed here over the years is – if you don't know what something is, either don't change it, or if you must, make very small changes- and for the love of all things Holy- only change ONE thing at a time. The single biggest problem that we see with customers is changing a bunch of stuff at the same time. Many of these engine parameters interact in ways that are not obvious.

With experience comes confidence. Fortunately, the modify-evaluate-modify cycle is quick with Zeus.

This manual will perform the following functions:

1. Provide an overview of common-rail diesel engine operational characteristics and parameters.
2. Provide an overview of how the Zeus controller works.
3. Explain the workings of the Zeus interface software -ZeusControl and ZeusTune (HowTo)

Theory of Operation

or alternately

Read This First if You Don't Want to Blow Up Your Engine!

As stated earlier, the operation of the common rail diesel engine is different from older mechanical diesels, and significantly different from spark ignition (gasoline) engines. The following chapter is intended to give an overview of the theory and actual events that comprise compression-ignition engine operation. If you understand how things work, you will be much more likely to be successful in your modification efforts and far less likely to do damage to your engine. If you understand the basics, everything else from there on out will seem simple!

Abbreviations and Terms used in this manual;



CR: Common rail

PW: Injector pulse width

TDC-BTDC-ATDC:Top dead center, before top dead center, after top dead center

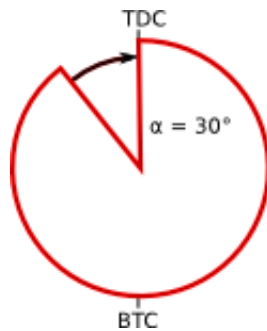
RPM: yeah, you know what this one means

Compression ignition: Technically, this is what a diesel engine is called, we use this term occasionally to emphasize just what exactly is happening inside your engine.

Perspective:

Seems like a strange way to start, but perspective is one of the most important elements of understanding a common-rail (CR) engine. Being able to visualize the internal workings of your engine is the single most important aspect of successful tuning.

So to start with, let's look at what is going on inside of a diesel engine.



The figure above shows a stylized representation of a crankshaft's revolution. The particular area that we are concerned with is the quadrant from 90 degrees before top dead center (BTDC) to top dead center (TDC). This is the part of the engine's revolution where all of the fun stuff happens. During this angular range the fuel is injected and ignites.

One thing that is not shown in the graphic is time. It's the hardest tuning element to visualize, yet time is the controlling variable and will set limits on all of the other variables that you will be changing.

Old vs New

There are significant differences between mechanical injection and CR. With mechanical injection, one could set the start of injection (in angular degrees BTDC) but could not determine precisely when (again in angular

terms) the injection would end. Or, one could specify the end time of injection but not the start. With injection pressure fixed, (think VE pump here) the time to inject a given amount of fuel varied and therefore one could know the start or the end of injection but not both. When the commanded fuel quantity is changed (more throttle/less throttle) the length of injection must change. This is terrible for performance, but makes it relatively easy to tune - you don't have many choices.

With CR we can precisely set the start and end of when fuel enters the combustion chamber and therefore the duration of the injection event. And because we can arbitrarily (within certain limits) set fuel pressure, we can change the amount of fuel delivered almost without limit. The opposite side of the coin is that while this is great for performance and horsepower (HP), it can make tuning very difficult (think Rubik's Cube). This is where the ZeusTune software comes in. We have tried to provide you with the tools to make tuning as easy as possible.

Let's deal now with one of the concepts that causes the most confusion when dealing with CR; Timing vs Injection Duration. Specifically, the generally accepted definition of timing is when the start of injection occurs in terms of crankshaft degrees. Injection duration, or just duration, is the length of the injection, again in terms of crankshaft degrees. Most of the confusion seems to come from the fact that both are expressed in degrees of crankshaft rotation. The two are obviously related. You cannot have a length without a start, and a start with no length is not really a start.

For the purposes of this manual we will make a simplifying assumption: Fuel injection will end at TDC. If we make this assumption, we can refer to timing and duration as the same thing. For example, if we have an injection duration of 31 degrees of crankshaft travel, and we have the timing set at 31 degrees BTDC we could say that the timing and duration are both 31 degrees. Generally, stopping injection close to TDC is best for efficiency. For maximum power there may be conditions where extending the injection beyond TDC will increase power at the expense of efficiency. Injection that extends too far past TDC will be harmful to your engine. Making sure the injection event is not too long is the customers responsibility.



Saying that duration and timing are the same is just a simplifying convention! Injection can, and will, end before TDC when under low-load conditions and it CAN AND WILL end far after TDC if you do not set your PWs correctly. See the sidebar example.

REMEMBER: When injection ends is a function of timing and PW and RPM. If you don't know the rpm, you can't tell when the injection will end.

Let's take a look at the relationship between timing and duration. The crankshaft of an engine running at 700 RPM is turning over at 11.66 times per second. ($700 \text{ rpm}/60\text{sec} = 11.66 \text{ rev/sec}$) and therefore takes .08576 seconds to make 1 revolution (.08576 sec/rev). .08576 seconds = 85.76 milliseconds (ms). Since 1 revolution is 360 degrees, 360 degrees @ 700rpm is 85.76 ms.

So let's see how long it takes to go 30 degrees of crankshaft travel (no, we wouldn't give our engine 30 degrees of timing at 700 rpm, but this is just an example). $30/360 = .083333$ or approximately 8.33%. 8.33% of 85.76 ($85.76 * .083333$) is 7.1469 ms or for those more comfortable with microseconds, 7146 μsec .



Don't worry, ZeusControl has a built in calculator to figure this out for you!

In summary; 30 degrees of crankshaft travel @ 700 RPM is 7.1469 ms or 7146 μ sec. Now let's look at the same example but with the engine running at 2,000 RPM. In this case the numbers are very different. 30 degrees @ 2,000 RPM is 2,500 μ sec. What does all of this mean? Remember these numbers, we'll see how it all ties together in the next section.

An example: A customer had engine difficulties after an exceptionally strong dyno run. Exhaust temps were very (very) high, and the engine experienced internal damage. Working with the customer we found that the injection pulse width (PW) was too long and that fuel was still burning going out the exhaust valve. The customer had set the timing at a conservative 15 degrees BTDC. What was the problem? The PW was set at 2300 μ sec. Seemed reasonable, but it wasn't. 2300 μ sec at 2200 rpm is 30 degrees of duration but that same 2300 μ sec at 5400 rpm is 75 degrees of duration! With the start of injection at 15 degrees BTDC, fuel was still spraying into the cylinder at 60 degrees After Top Dead Center. So much for your exhaust valves. The customer in question is not an idiot, in fact he is one of the best diesel tuners in the business and is rapidly becoming one of the best Zeus tuners. He just hadn't thought about all of the ramifications of his changes. To be fair, he didn't have this manual either.

Flow vs Pressure

At the beginning of this chapter we said that one's perspective is important in understanding your engine's operation. Here is an example that almost everyone knows, but don't usually think about; the relationship between flow and pressure.

Simply put, a diesel pump does *not* produce pressure, it only produces flow. Pressure is a result of restricting that flow. In the case of a CR engine, pressure is a result of how fast fuel flows into a storage volume (rail and lines) vs how fast it is allowed to escape (injector PW). Therefore the fuel flow into an engine is determined by how much flow we create, which is controlled by the fuel control actuator (FCA) located on the high pressure diesel pump, using duty cycle, and injector PW. These relationships are critically important to keep in mind, not only when running the engine in manual mode, but also when editing tables. Here is an exercise that can be performed on any engine. To start, let's say that the engine is running in manual mode. The settings are (for illustrative purposes only, your settings may be different):

900 RPM, timing -4.5 degrees BTDC, engine coolant temperature (ECT) 185 degrees F, pump duty cycle 38.75, PW .45 and fuel pressure 4,200 psi.

Change the PW a small amount (approx .05 to .1) and you

may be surprised at what happens.

Basically, the engine RPM will not change. If you increase the injector PW you would imagine that the engine RPM would increase. But that's not what happens. What happens is that the fuel pressure drops so that the overall fuel flow remains the same, and therefore engine speed does not change. The reason is that we did not change flow rate out of the pump, so increasing PW just reduced the restriction (pressure) but the flow stayed the same.

Now if we had maintained the *pressure* while increasing the PW, the engine most certainly would have sped up.

In most circumstances, especially at idle, Zeus will automatically maintain a desired pressure so that the customer does not need to worry about it. However, there are tables that can affect Zeus's ability to control pressure; it is the user's responsibility to understand what effect their table edits will have. Don't worry too much though, the tables in question are clearly marked and how to modify them, if needed, is explained in detail later.

ZeusControl and ZeusTune

How you interact with and control the Zeus ECU

The Zeus ECU is controlled and monitored through two pieces of user software, ZeusControl and ZeusTune. ZeusControl is the main control software, and the user's only method of dealing directly with the Zeus ECU. ZeusTune is an application for editing and saving tables. ZeusTune can be accessed from ZeusControl or opened separately, and used as a stand alone.

ZeusControl:

There are two modes of operational control; manual mode and normal (automatic) mode. For manual operation the Zeus ECU must be connected to a computer with the ZeusControl software installed, usually a laptop.

In manual mode the user controls all aspects of the engine's operation in real time. The user sets the injector PW, timing, and sets the fuel pressure indirectly through pump duty cycle. All changes commanded by the user are executed immediately in real time. In manual mode the throttle is inoperative, all engine parameter changes take place through the use of the keyboard and mouse of the computer running the ZeusControl software.



Black --> Red:

The convention used in the ZeusControl software is that, with one exception, all values that you may set and send to the ECU are in black. All values that the Zeus ECU sends to the ZeusControl software are in red. It is very helpful to be able to see at a glance what you told the ECU and what the ECU understands. It is a further confirmation that your commands have been received and executed. Many of the red indicators also display real time data when in normal mode.

Using the ZeusControl Software

We will walk through the ZeusControl software tab by tab with an explanation of all of the controls and indicators.

When you first double click the ZeusControl icon the program will start in the running state. A dialog box will appear asking if you wish to data log that session. After making your choice, the dialog box will disappear and ZeusControl will be running. If you are connected to your Zeus ECU and it is powered up you will see the uptime counter begin to increment and many of the gauges will show values. If the uptime counter does not begin to run you should check your serial connection. This is discussed in the chapter 'Getting Started'.

On the left side of the ZeusControl window is a tab labeled Analog (Figure 1.) This pane is always visible.

1. Start Program Arrow - Clicking this arrow will restart the ZeusControl software if it has been stopped.

Note: this arrow does not start the Zeus ECU. The Zeus ECU starts automatically on power-up. While running this arrow will be black. When stopped this arrow will be white.

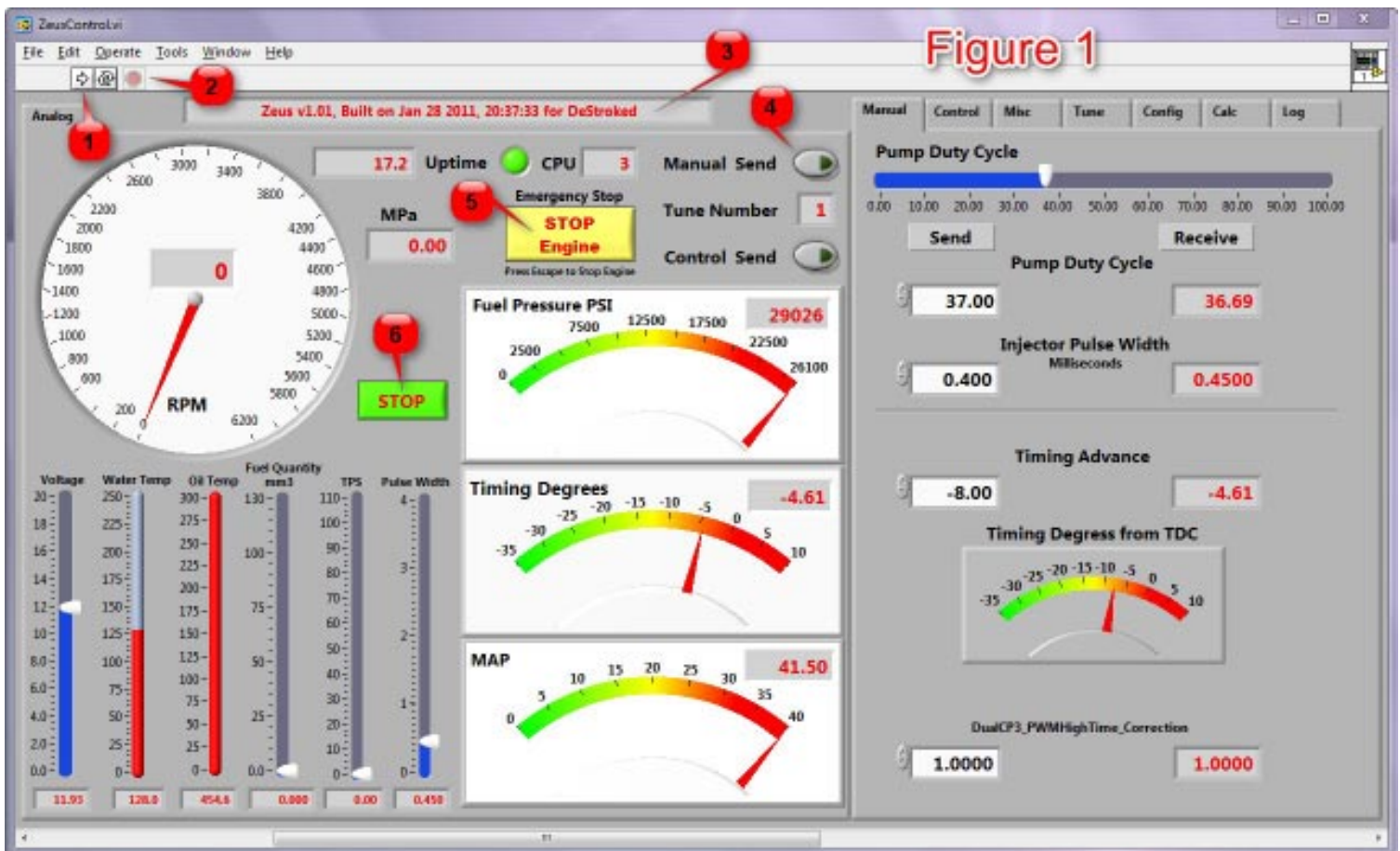
2. Stop Program (Force End) Button - Clicking this arrow will force the ZeusControl software to stop if it is running. Note: this arrow does not stop the Zeus ECU. While running this arrow will be red. When stopped this arrow will be grayed out red.

3. Build Info Box - Indicates which version of Zeus software is running in the ECU. On power up, the Zeus ECU sends this data to ZeusControl for display. This information is important during tuning and will be explained further in the ZeusControl->Tune->BurnFlash section and in the ZeusTune section.
4. Manual Send and Control Send - These buttons when clicked send commands to the Zeus ECU. What each controls is explained in the text below.
5. Stop Engine - This button will stop a running engine at any time. Sets the PW to zero and the fuel pressure to zero. It cannot be reset until engine RPM goes to zero (engine stopped) or the power is cycled off and on. This button may be pressed by mouse or by the 'Escape' key on your keyboard.
6. Stop Button - This button stops the ZeusControl software - it does *not* stop the Zeus ECU. This is the normal preferred method of stopping the program

On the right side of the ZeusControl window are a series of tabs. Any tab may be selected at any time.

Manual:

The controls on this tab are everything needed to control an engine running in manual mode. In manual mode the red indicators on the right should be the same as the black controls on the left. In automatic mode the red indicators show what values the ECU is actually using, they will not match the black controls on the right.



In manual mode most of the rapid changes that you will make will be to duty cycle. Pressing the PageUp key on your keyboard will highlight the Pump Duty Cycle input box. The value there can be scrolled up or down using the arrow keys on the keyboard. Then just hit enter to send.

Control:

Rev Limit RPM - This control does just what it says. Note: This is a hard rev limit and will stop the engine by setting the PW to zero and the fuel pressure to zero. It cannot be reset until engine RPM goes to zero (engine stopped) or the power is cycled off and on.

Control Frame Set and Status - This is the only control/indicator set that does not follow the red/black convention. Clicking a button on the left toggles it from black to green and back. A green button on the left indicates that the feature will be sent to the Zeus ECU and turned on at the next Control Send. A corresponding green button on the right indicates that the feature has been accepted by the ECU and is active.

This control is used to change the engine's operation between manual and automatic. The reset default is automatic operation. To disable automatic operation (and place the engine in manual mode) deselect Fuel Press Gov (fuel pressure governor), RPM Gov (RPM governor), Throttle Fuel (table lookup control), and Feed Forward. Alt Gov Enable (alternator operation) may be used in manual or automatic mode. These features may be removed in future software releases.



Critical - FuelPressGov, RPM Gov, Throttle Fuel, and Feed Forward **must** be selected or deselected as a group! Turning these features on or off individually **will** cause erratic engine behaviour and **may result in an uncontrollable engine!**

Misc

Stall RPM - The RPM below which the ECU checks to see if the engine is stalled. If the engine stalls all fuel injection and timing parameters go back to their initial state.

Ratio RPM, Tight Ratio, Loose Ratio- Because internal combustion engines have a great deal of torsional resonance during starting, especially inline six-cylinder diesel engines, the Zeus ECU software 'loosens' its internal timing requirements to allow for more easily synchronizing with the 60-2 tooth wheel on the crankshaft. This parameter is called Ratio and is a number between 1 and 3.98. Ratio RPM is RPM at which the ECU changes from Loose Ratio to Tight Ratio. Tight Ratio should not normally be set less than 1.5. At a Ratio of 1.5 the Zeus ECU has injection timing accuracy of (+/-).001 degree at 8,000 RPM. For the Cummins engines these numbers should not be changed unless there is a problem.

Valve Resistance- The theoretical resistance, in ohms, of the FCA (inlet metering valve on the diesel pump). In fact, this is an approximation, and not the exact value. Changing this value will have the effect of changing fuel pressure over the entire operating range. This value should not ordinarily be changed. Take great care if you change this value, it is very sensitive and you can easily create an overpressure situation and uncontrollable engine.

Desired Idle RPM- Show the current desired idle RPM as taken from the table of the same name.

Boost Pulse (ticks)- Displays the duration of the high voltage boost pulse to the injectors.



Tune.

Edit Tunes- Starts the ZeusTune application.

Burn Flash- Initiates the process of programming the Zeus ECU internal flash memory with the user selected tune.

1. Starts by opening a file selector dialog box that allows the user to select a tune to write to memory. All Zeus tunes are files that end in .ztun. When a file is selected, ZeusControl checks with Zeus ECU to see if the tune file and the embedded program version match. If they do not, the flash burning operation will abort and not allow the burning of the incorrect file. Zeus .ztun files can have any name, but it is **HIGHLY** recommended that the .ztun file maintain the same date in the name that shows in the Build Info Box (labeled 3 in Figure 1). This will allow the user to keep embedded versions properly matched with their tunes. The information that ZeusControl uses to compare is embedded in the .ztun file itself and does not depend on the file name. None the less, keeping the .ztun name the same as the embedded version number will save much confusion and potential damage.

2. Next, if the embedded code and .ztun file match, a warning dialog box will appear asking if you are sure that you wish to burn the flash memory. At this point, no changes have been made to Zeus ECU. Once you select 'Yes, Burn It!' the flash programming begins. Any interruption after you click the 'Yes, Burn It!' button will result in a non functioning (bricked!) Zeus ECU that must be returned to the factory for reprogramming.



Config

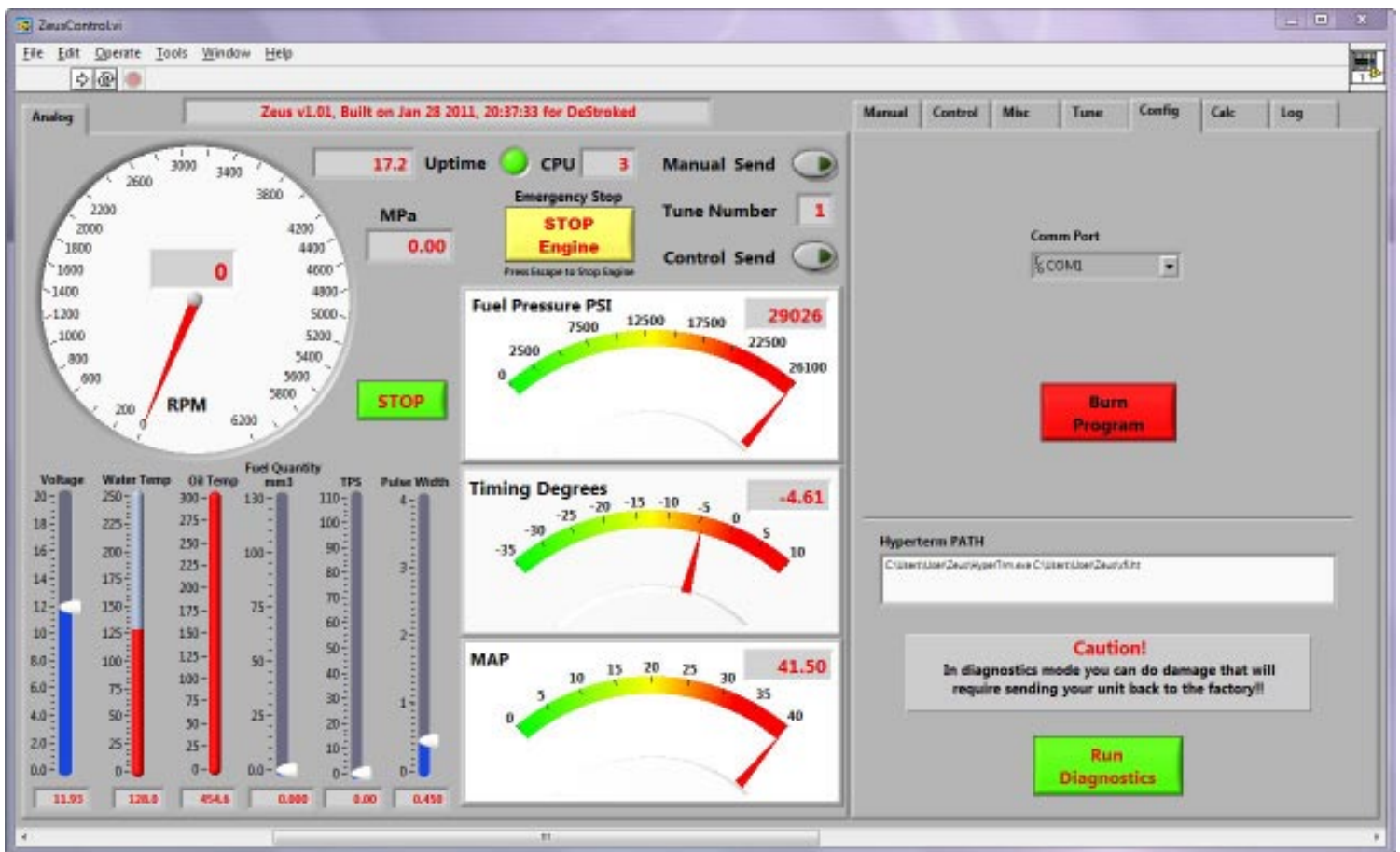
Comm Port - This drop down box allows the user to choose which comm port will communicate with the Zeus ECU. Setting up communications is covered in detail in the 'Getting Started' section.

Burn Flash- Initiates the process of programming the Zeus ECU internal flash memory with the user selected program. This function used mainly for installing updates to the embedded Zeus software. It is not a part of the regular tuning process.

1. Starts by opening a file selector dialog box that allows the user to select a program to write to memory. All Zeus embedded programs are files that end in .bin.

2. Next, a warning dialog box will appear asking if you are sure that you wish to burn the flash memory. At this point no changes have been made to Zeus ECU. Once you select 'Yes, Burn It!' the flash programming begins. Any interruption after you click the 'Yes, Burn It!' button will result in a non functioning (bricked!) Zeus ECU that must be returned to the factory for reprogramming.

Run Diagnostics - Allows a user to access certain diagnostic screens. Generally, normal users should not attempt to use this function. Do so at your own risk. Currently the user must have HyperTerminal® installed, on the path shown in the box labeled 'Hyperterm PATH', for this to work. Clicking this button will shut down a running engine, stop ZeusControl, and cause the Zeus ECU to run a diagnostics program.



Use extreme caution if attempting to use this feature. It is presently only useful for checking the raw A/D numbers (and if you don't know what that means then you *really* shouldn't be messing with this)

CAUTION: In this mode, it is easy to do damage to your Zeus ECU that **will** require sending it back to the factory!!

Calc

This calculator allows a user to quickly and easily determine relevant fuel injection parameters. Enter any two parameters, select the desired output, and click calculate. Example; enter 30 degrees of injection duration, 2,500 rpm, select the μsec button and click 'Calculate'. The calculator will output 2,000 μsec (divide by 1,000 to obtain ms).



Log

When ZeusControl is started, the user is presented with a dialog box asking whether or not to datalog that session. If yes is selected, data logging begins as soon as the Zeus ECU is powered up. On this tab the path to the datalog is shown in the “Recorded Datalog path and filename” text box. The filename is created automatically and includes the date and timestamp in the name. The datalog path is set to a default. Neither the filename created automatically or the default path are user changeable. The datalog can be renamed after it is created.

Playback follows a specific procedure.

1. Make sure that the Zeus ECU is powered down (off).
2. Make sure that ZeusControl is **not** running (turned off).
3. Flip the ‘Play File’ Switch from the ‘off’ to the ‘on’ position.
4. Turn ZeusControl on - arrow labeled 1 in Figure 1.
5. A file selector dialog will open to the default directory. You may navigate to any directory that you wish. Select a datalog file.
6. As soon as the “Play” button is clicked the datalog playback begins.



The user can then pause/restart the datalog, change the playback speed, or, by dragging the pointer in the ‘Starting Position in File’ indicator, cause the file to begin playing at the selected point. Every time “Play” is clicked the datalog will restart at the selected point giving the ability to have unlimited replays (very cool).

Scrolling Display

At the bottom of the main ZeusControl window is a horizontal scroll bar. Scrolling to the right will reveal an entire window of chart type displays. While ZeusControl is running and the Zeus ECU is powered up these displays update in real time.

These charts save data of the last 5 to 10 minutes (approximately) of operation (actual time varies with the host computer). These charts will not be erased if ZeusControl is turned off. This data will not be erased until it is over written or ZeusControl is turned off and then on again.



At the bottom of the chart display is another horizontal scroll bar, located above the window scroll bar. This scroll bar can be used to view any of the data saved in the chart window. This provides a convenient way to monitor engine operation without having to datalog a session. The data shown in the charts is also saved when data logging is enabled and will play back with the datalog.

ZeusTune:

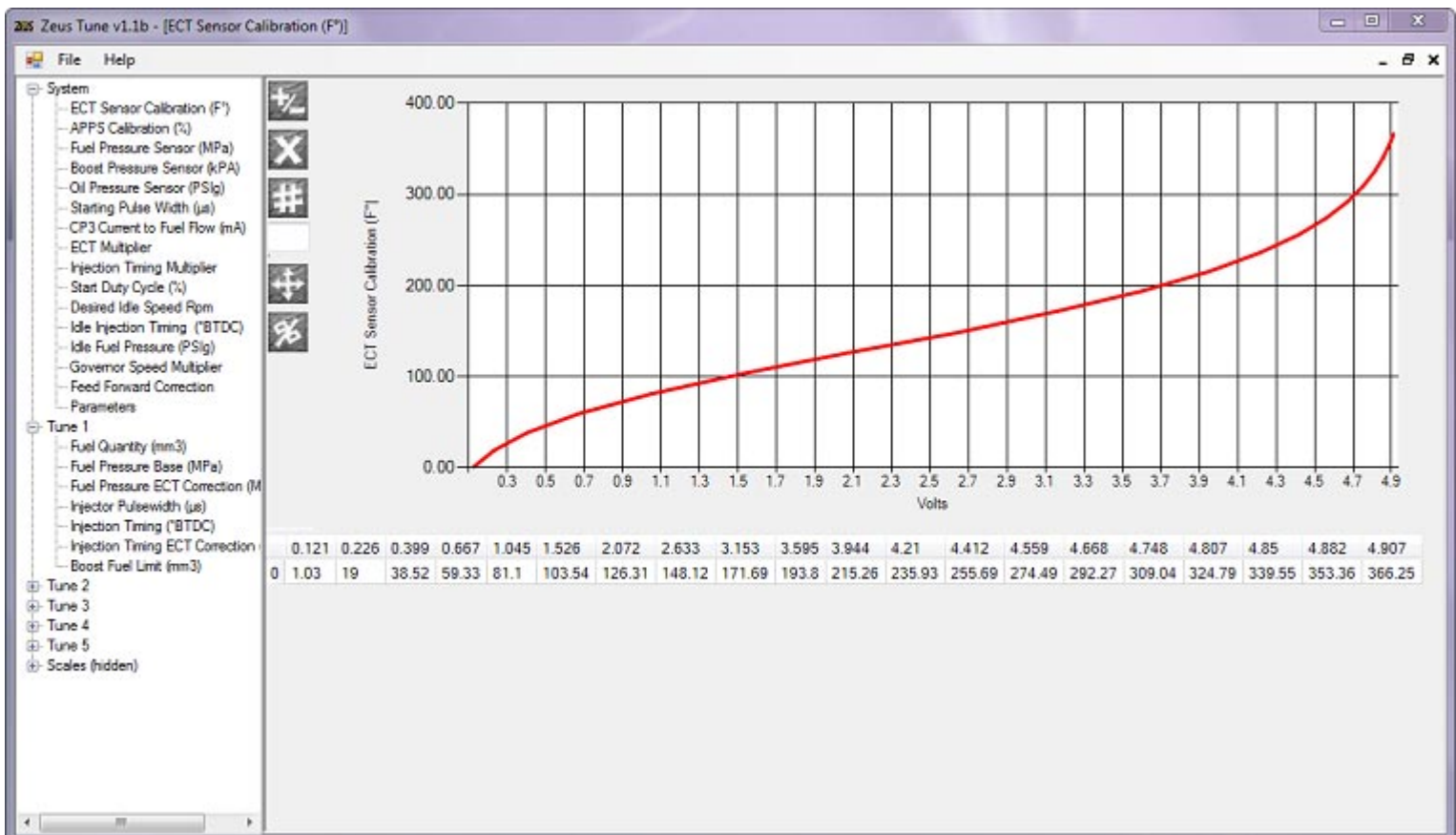
ZeusTune is a program for editing the tables that go into a .ztun. It may be run stand alone or called up from ZeusControl. In the default installation there will be an icon placed on the user's desktop.

The figure below shows the System and Tune 1 headings expanded. System consists of tables of values that will be in effect for all tunes. Tunes 1 through 5 contain the same entries, only Tune 1 is expanded for clarity's sake.

The tables themselves are one of three types: one dimensional tables, such as 'Parameters' that have single entry values that may or may not be related e.g. Rev limit, Fan turn off RPM, etc.; two dimensional tables such as the ECT Sensor Calibration table shown; or three dimensional tables that have their data arranged in rows and columns similar to a spreadsheet.

To the right of the tree view in the graph area are 5 buttons and a text entry box. The first three buttons will perform mathematical operations on any rectangular region of selected cells based on the value placed in the text box. For example, with a value of 3.0 placed in the text box, the topmost button will add the value 3.0 to all selected cells (-3.0 would subtract). The second button would multiply those same cells by 3.0. The third button would set all of the selected cells to the value 3.0.

The forth button linearizes the values between the first and last selected cells in any single row or column. Only cells in one row, or the whole row, or one column, or whole column, may be selected at one time. We recommend opening a test copy of a .ztun and experimenting.



System Tables

ECT Sensor Calibration (F°)

This table correlates voltage from the ECT sensor into actual temperature. This table is calibrated by default for the stock Cummins ECT sensor. Unless changing to a different style sensor there should be no need to edit this table.

Most OEM and aftermarket sensors have a 5 volt input, therefore the output is between 0 and 5 volts. Simple resistive sensors such as the ECT sensor have a reading range of 0-5v. Most sensitive strain type sensors, such as the accelerator pedal position sensor (APPS) or rail pressure sensor have a reading range of .5-4.5v. Using the fuel rail pressure sensor as an example, a voltage reading of .5v would indicate 0 PSIG pressure and a reading of 4.5v would indicate the maximum pressure that the sensor is calibrated for. For most common rail Cummins the max calibrated pressure is 180 MPa (26107 PSIG).

APPS Calibration (%)

See above. Unless you are using a different accelerator pedal position sensor (APPS) pedal/sensor there should be no need to edit this table.

Fuel Pressure Sensor (MPa)

See above. Unless you are using a different fuel rail pressure sensor there should be no need to edit this table.

Boost Pressure Sensor (kPa)

See above. This table is for use by an aftermarket boost pressure sensor, this is *not* the stock MAP sensor. This table has by default a generic table. If an additional aftermarket boost pressure sensor is used, this table should be calibrated accordingly.

Oil Pressure Sensor (PSIG)

See above. This table is for use by an aftermarket oil pressure sensor, the stock Cummins engine does not have an oil pressure sensor. This table is generic table by default . If an aftermarket oil pressure sensor is used, this table should be calibrated accordingly.

Starting Pulse Width (µs)

This table provides the initial lookup value for starting injector PW. This value is used only during cranking. Once the engine starts the idle governor takes this value for its starting point and then continuously adjusts it for idle speed. This value in conjunction with the starting duty cycle value will determine the cranking fuel pressure.

CP3 Current to Fuel Flow (mA)



This table shows the correlation between current to the FCA (fuel control actuator) and fuel flow from the pump. In theory this is an observed/measured relationship and should not be changed. In practice it is possible to make small changes to this table. **DO NOT** modify this table without an extremely good reason, Serious damage *will* result from incorrect modifications to this table.

ECT Multiplier

This table determines how the values from the Fuel Pressure ECT Correction table will be applied. The value from this table is multiplied by the value from the Fuel Pressure ECT Correction table and the commanded fuel pressure is corrected by the resulting amount.

Injection Timing Multiplier

This table determines how the values from the Injection Timing ECT Correction table will be applied. The value from this table is multiplied by the value from the Injection Timing ECT Correction table and the commanded fuel pressure is corrected by the resulting amount.

Start Duty Cycle (%)

This table provides the initial lookup value for starting pump duty cycle. This value is used only during cranking. Once the engine starts the idle governor takes this value for its starting point and then continuously adjusts it for idle speed. This value in conjunction with the starting pulse width value will determine the cranking fuel pressure.

Desired Idle Speed Rpm

This table is self explanatory.

Idle Injection Timing (°BTDC)

The values from this table determine the idle injection timing when the throttle is in the off/unpressed position.

Idle Fuel Pressure (PSIg)

This table sets the desired idle fuel pressure. *Caution* - setting the idle fuel pressure too high may result in an un-governable engine.

Governor Speed Multiplier

This value has the effect of speeding up or slowing down how fast the idle governor acts. The numbers are multipliers. A value of 1.5 would speed the governor up by 50% and a value of .75 would slow it down by 25%.

Feed Forward Correction

The X axis scale is in RPM above or below the set point RPM, which is in most cases the value from Desired Idle Speed Rpm table. The Y axis scale is in rate of rpm change per unit time (rpm/.01sec). The primary purpose of this table is to correct for unexpected (to the ECU) loads at idle. Putting the transmission into gear would be one example. This table is active only when the throttle is in the off/unpressed position.

Parameters

The Parameter table contains a number of single value entries. These values are usually used for setting user defaults. All of the values in this table can be set by ZeusControl real time and will over ride the table values as long as the engine is running or the Zeus ECU stays powered up. Commands set by ZeusControl are

lost when the Zeus ECU powers down. The values set in the Parameter table are burned to flash and will not be lost when the Zeus ECU is powered down. This way a user can set defaults that will be used whenever the Zeus ECU is turned on, regardless of whether or not ZeusControl is being used.

1. Dual CP3 Correction Factor - As the name states, this parameter is for engines with two (or more!) high pressure injection pumps. This value primarily affects the fuel flow rate from the pump(s) by increasing the duty cycle. The duty cycle calculated by the Zeus ECU is multiplied by this number. Higher duty cycle means lower flow and hence pressure. Because the flow rate from multiple pumps is greater than from a single pump, everything else being equal, the flow from the multiple pump system must be reduced to maintain the same pressure. This parameter is not the place to command higher fuel pressures, if desired. Those type tuning changes should be made in the tuning tables as described below.

2. Rev limit - This is a hard rev limit. When this value is exceeded, duty cycle is set to 100% (no fuel pressure) and injector PW is set to zero. The rev limiter will not reset until engine RPM goes to zero or the Zeus ECU is powered down and then up.

3. Fan turn off RPM - RPM above which the fan is disengaged. Below this RPM the fan will operate if the water temperature is above the Fan turn on temp. Turning the fan off at high engine speed has benefits for performance and also for safety reasons.

4. Fan turn on temp (F°) - The temperature above which the fan will turn on if the engine is not above the Fan turn off RPM. Below this temperature the fan will be off.

5. Tight Ratio and Loose Ratio - Ratio is a value used by the Zeus ECU to synchronize its operation to the toothed timing wheel on the engine crankshaft. Tight ratio is used during normal engine operation and should not be set lower than 96. A value of 96 decimal translates into a ratio of 1.5 as shown by ZeusControl (base 64). Loose ratio is used only for cranking and is normally set to 128 decimal for a ratio of 2.0 (base 64).

During start up, the cranking engine experiences great torsional resonance and crankshaft twisting. Loose ratio makes the injection timing less precise but allows the Zeus ECU to sync to the crankshaft much faster. Above a certain rpm ratio changes to Tight ratio for extremely precise timing. Users should not normally change these values.

6. Ratio RPM - The RPM at which the Zeus ECU switches from Loose ratio to Tight ratio.

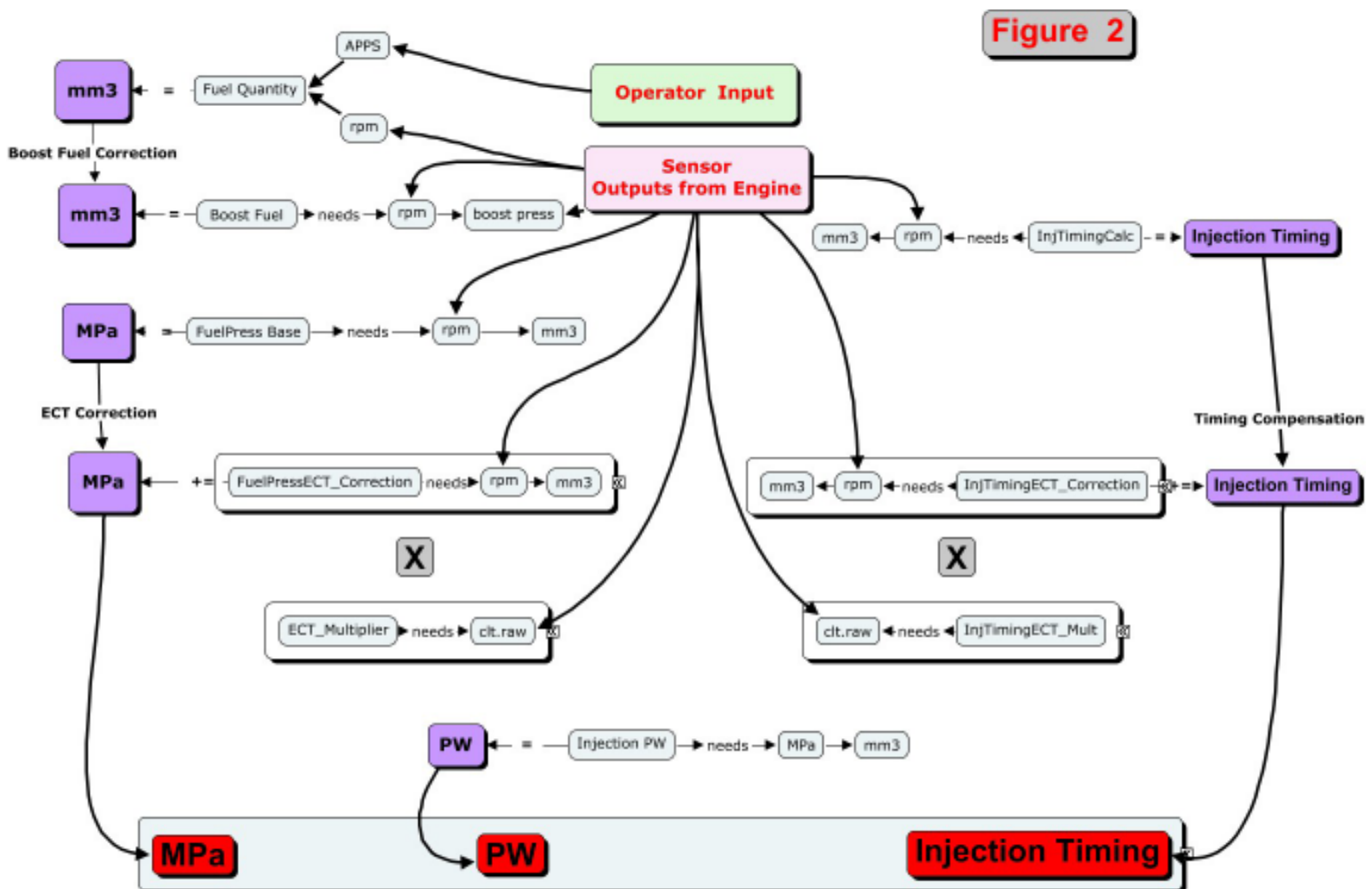
7. Stall RPM - The RPM below which the Zeus ECU looks for a stalled condition. Upon determining that the engine is stalled the ECU returns all operating variables to the starting condition.

Tuning Tables

This section describes the generalized workings of the Zeus ECU, the tuning tables the Zeus ECU uses, the relationship between those tables, and what kind of data each table contains.

Figure 2 depicts a stylized and simplified flow diagram of the way the fuel injection variables are computed and their relationship to the various tables. All computer software of this type consists of repeating loops.

Looking at the diagram, imagine the process starts at the top with the Zeus ECU reading the operator input, that is the pressing of the throttle pedal, and reading various engine sensors. From there it works its way down until at the bottom all of the parameters necessary to run the engine have been calculated (fuel pressure, injector PW, and injection timing). Then the whole process starts over again from the top. This process repeats itself indefinitely until the Zeus ECU is powered down. A description of the process is given in more detail in the next section.



Description of Operation

While the above diagram may seem confusing at first glance a written description will help to clarify things.

Overall the basic operation of the fuel injection calculations are simple. They happen in a precise order. Once you understand that sequence not only will the diagram make more sense but it will help you to gain a clear understanding of the relationships of the tables to each other. Assume that the engine is already running and the throttle pedal is pressed some amount (it is not in the unpressed/off position).

1. The Zeus ECU embedded software reads the throttle position (APPS sensor).
2. It (the Zeus ECU embedded software) reads all of the engine sensors.
3. Now knowing the engine RPM and throttle position it looks up the desired fuel quantity in the table 'Fuel Quantity'.
4. Knowing the RPM and boost pressure it looks up the boost pressure fuel correction in the table 'Boost Fuel'.
5. It adds (or subtracts) the boost fuel correction to the desired fuel quantity taken from the table 'Fuel Quantity'. This is the final value of mm3 (fuel quantity desired).
6. Now knowing the RPM and mm3 it looks up the desired fuel pressure from the table 'Fuel Pressure Base'.
7. Knowing the RPM and mm3 it looks up the fuel pressure engine temperature correction from the table 'Fuel Pressure ECT Correction'.
8. Knowing the engine coolant temperature it looks up the fuel pressure engine temperature correction multiplier from the table (in System) 'ECT Multiplier'.
9. It multiplies the value obtained from the 'Fuel Pressure ECT Correction' table by the value just obtained from the 'ECT Multiplier' table.
10. It adds (or subtracts) this value from the value found in step 6 and computes the final desired fuel pressure MPa.
11. Now knowing the MPa and mm3 it looks up the value for the injection pulsewidth from the table 'Injector Pulsewidth'. This is the final value for PW.
12. Knowing RPM and mm3 it looks up the value for timing advance from the table 'Injection Timing'.
13. Knowing RPM and mm3 it looks up the value for timing advance engine temperature correction from the table 'Injection Timing ECT Correction'.
14. Knowing the engine coolant temperature it looks up the timing advance engine temperature correction multiplier from the table (in System) 'Injection Timing Multiplier'.
15. It multiplies the value obtained from the 'Injection Timing ECT Correction' table by the value just obtained from the 'Injection Timing Multiplier' table.
16. It adds (or subtracts) this value from the value found in step 12 and computes the final Injection Timing ($^{\circ}$ BTDC)
17. The process is complete. It goes to the top and starts all over again!

Fuel Quantity (mm³) - Inputs are throttle position in percent (APPS) and RPM. Output is desired fuel quantity in cubic millimeters per injection (mm³). Basically, the Zeus ECU looks at RPM and throttle and decides how much fuel you are calling for. This is the best place it increase fuel if desired.

Boost Fuel (mm³) - Inputs are rpm and boost pressure in kPa. Output is the desired addition (or subtraction) in mm³ to the desired fuel quantity just calculated.

Fuel Pressure Base (MPa) - Inputs are RPM and mm³. Output is the desired fuel pressure (before correction for ECT).

Fuel Pressure ECT Correction (MPa) - Inputs are RPM and mm³. Output is in an addition (or subtraction) to the desired fuel pressure. This table is not operative without the multiplier from the table 'ECT Multiplier' found in System.

Injector Pulsewidth (μs) - Inputs are MPa and mm³. Output is the injector pulsewidth (PW) in μsec.

Injection Timing (°BTDC) - Inputs are RPM and mm³. Output is the desired injection timing (before correction for ECT).

Injection Timing ECT Correction (°BTDC) - Inputs are RPM and mm³. Output is in an addition (or subtraction) to the desired injection timing. This table is not operative without the multiplier from the table 'Injection Timing Multiplier' found in System.