Velocity Devices Inc.

The fire in your ATV

Copperhead EFI
Operating Instructions

Rev. 4.1.6
Release Date: 2016/04/28

Velocity Devices Inc.

The fire in your ATV

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1 INSTALLATION

Step 1:
BEFORE CONNECTING THE LIVE TUNER, navigate to:
http://www.velocitydevices.com

Select the Live Tuner product, and download the "Copperhead EFI Windows Application".

Download and install the CopperheadEFI application. This will install the application in a start menu time called "Velocity Devices Inc.", as well as install the necessary files for the Live Tuner driver.

If the error "This program is blocked because of compatibility issues":
- Right click on the CopperheadEFI install
- Select "Properties"
- Select "Unblock"

The application should now install properly.

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Step 2:

Connect the Live Tuner to the USB port. Windows should automatically detect and install the appropriate driver.

NOTE: The Live Tuner uses the standard Windows virtual serial port driver. Should the warning message, below, occur indicating the software cannot be verified; click "Install this driver software anyway". The driver is safe for installation.
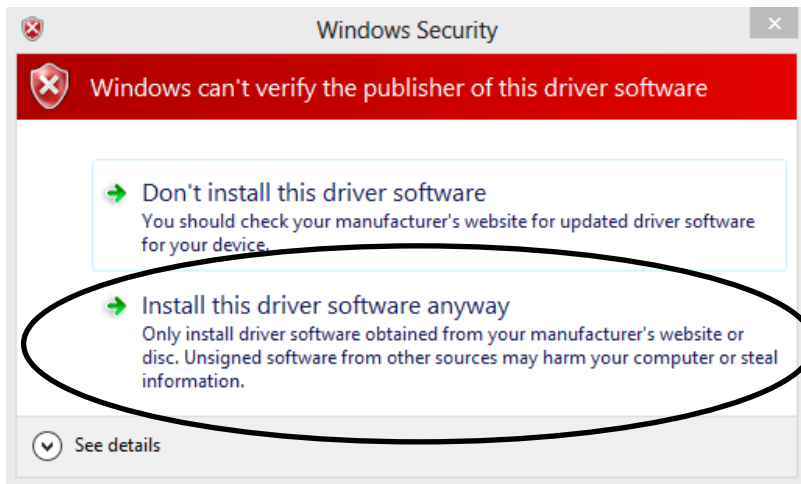
Windows 8:

If the driver fails to install due to increased driver security measures, you will need to "disable driver signature enforcement". Follow the directions below.

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To disable Windows 8 driver enforcement:

1) Unplug the Live Tuner from the USB port.
2) Press the **Windows button + I** to launch the charm bar.
3) Click **Change PC Settings** at the bottom.
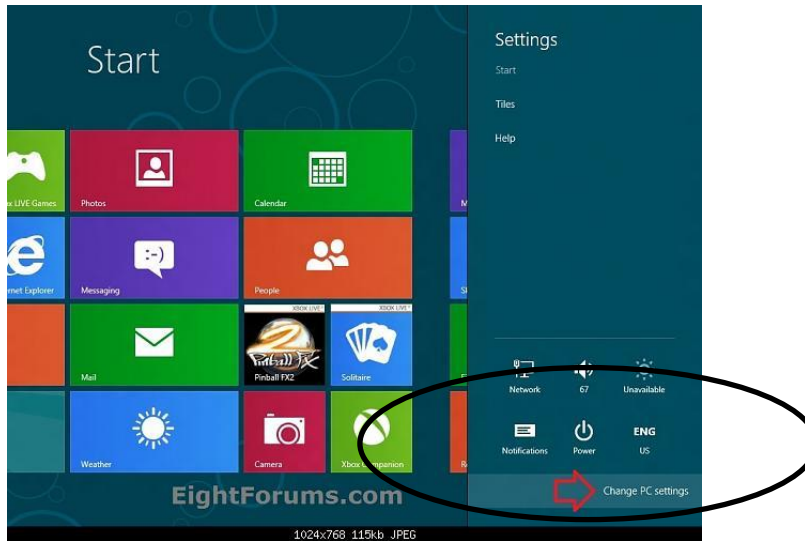
4) Select **General**, scroll to the bottom of the page, select **Restart Now** under the **Advanced Startup** section.

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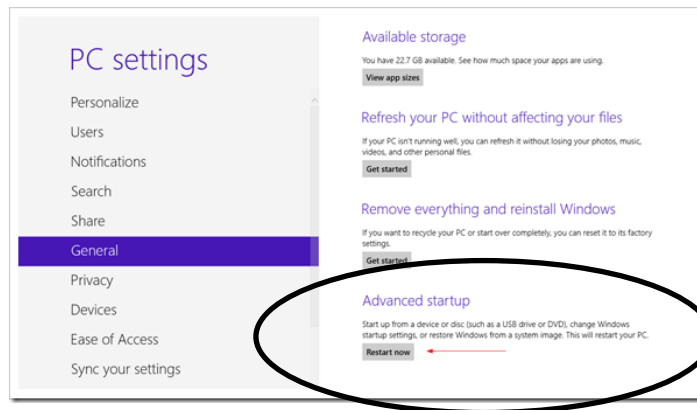
5) The computer will reboot to a startup menu. Select **Troubleshoot**.
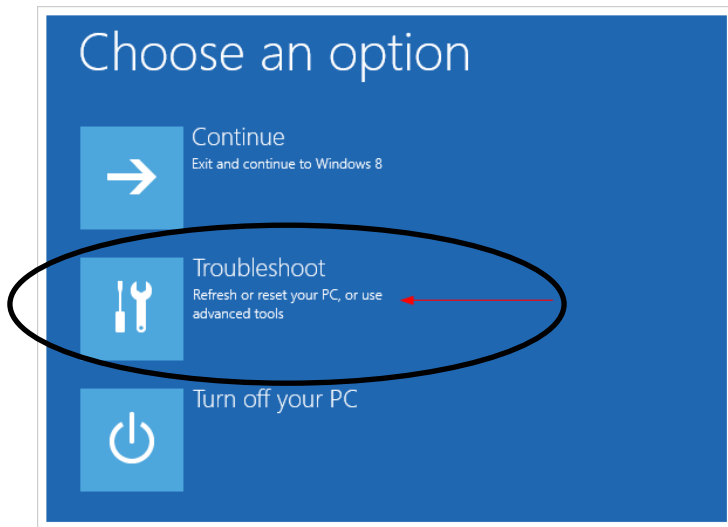
6) Select **Advanced Options**.

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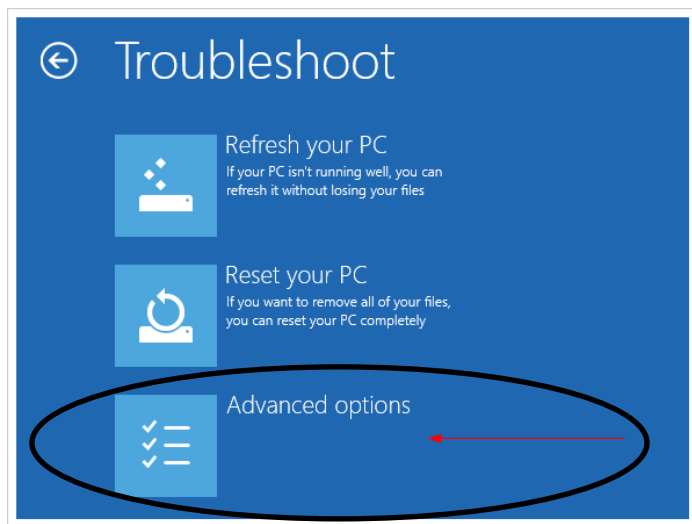
7) Select **Startup Settings**.

8) Select **Restart**.

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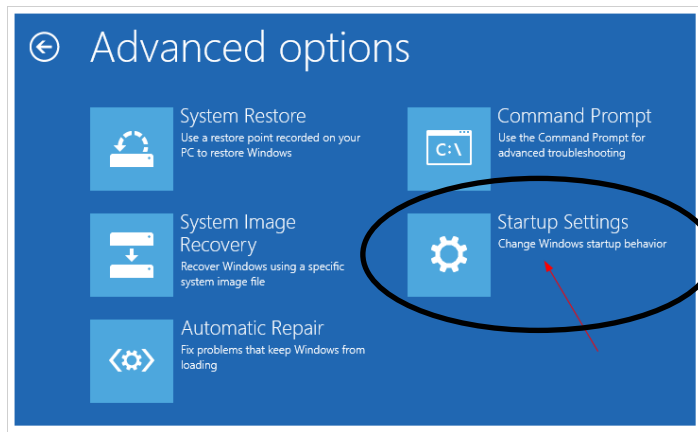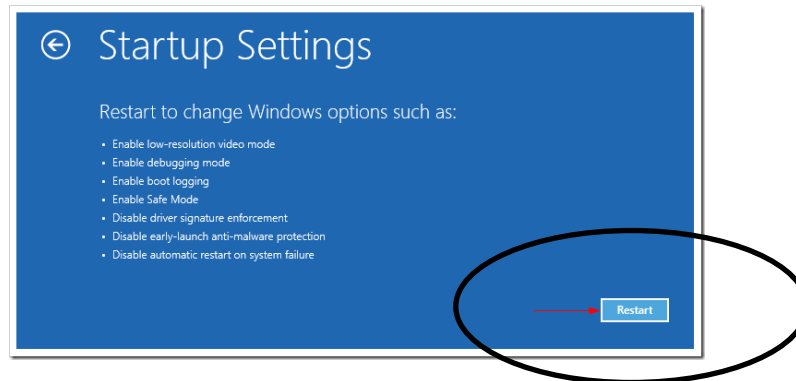
9) Press **7** or **F7** to boot with **Disable driver signature enforcement** disabled.

Startup Settings

Press a number to choose from the options below:

Use number keys or functions keys F1-F9.

1) Enable debugging
2) Enable boot logging
3) Enable low-resolution video
4) Enable Safe Mode
5) Enable Safe Mode with Networking
6) Enable Safe Mode with Command Prompt
7) Disable driver signature enforcement
8) Disable early launch anti-malware protection
9) Disable automatic restart after failure

Press F10 for more options
Press Enter to return to your operating system

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10) Connect the Live Tuner to the USB port. If the device does not automatically install, browse to the "**C:\Program Files (x86)\Velocity Devices Inc**" folder. Right click on the **VDI_VirtualSerial.inf**, and choose **Install**. The Live Tuner uses the standard windows serial port driver. When prompted, select "Install this driver software anyway" to install the driver. This driver is safe to install.
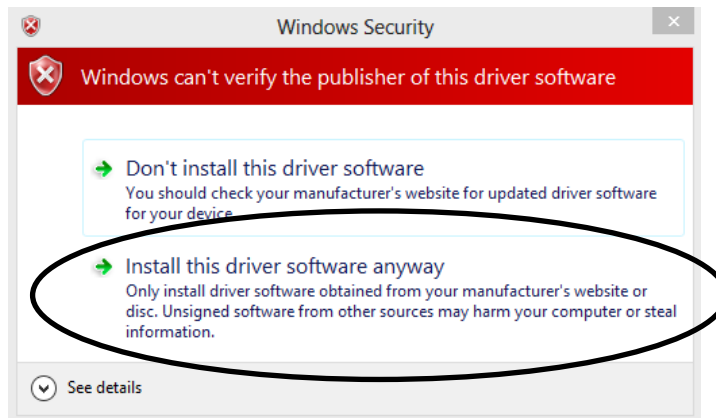
Step 3:
Navigate to your "Start Menu->All Programs->Velocity Devices Inc." folder.   Click on the "CopperheadEFI" program. The program should start, and display a spreadsheet type environment.
NOTE: Should the program fail to start with a "Side by Side Configuration Error", your computer is missing the necessary Windows library files. Click on the "Install vcredinst_x86" in the "Start Menu->All Programs->Velocity Devices Inc." to install the necessary files.

Step 4:
If the Live Tuner properly installed, selecting the "Live Tuner" button on the toolbar will pop down a list of operations that are all enabled. If the device is not connected, then most of the items will be disabled.

NOTE:
THE USB MEMORY INTERFACE MUST BE LOADED WITH A MAP BEFORE CONNECTING IT TO THE COPPERHEAD.   DO NOT CONNECT THE USB MEMORY INTERFACE TO THE ECU UNTIL THE USB MEMORY INTERFACE HAS BEEN PROGRAMMED. THE LIVE TUNER CAN BE CONNECTED WITH NO MAP LOADED.

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2 TIMING ADVANCE PRIMER:

The gasoline combustion engine requires three elements in order to produce horsepower:

1) Air
2) Fuel
3) Source of ignition (i.e. spark plug)

Key Terms and Acronyms:

Stoichiometric Ratio	14.7 parts air to 1 part fuel, where during combustion 100% of the fuel is burned (theoretical combustion)
A/F	Air / Fuel mixture
TDC	Top Dead Center
BTDC	Before Top Dead Center
ATDC	After Top Dead Center
WOT	Wide Open Throttle
Pre-ignition (pinging)	A/F mixture ignites slightly early, and combustion tries to push the piston backwards just as it reaches TDC.
Detonation	Advanced stage of pre-ignition where combustion finishes before the piston reaches TDC. The combination of the combustion and the compression stroke can cause piston damage in extreme cases.

For proper ignition the ratio of air to fuel must be controlled. Ideally, 14.7 parts of air are mixed with 1 part of fuel (14.7:1, or stoichiometric ratio). This gives a 100% burnt mixture. For maximum power, the ratio is typically dropped to 12.5:1. This gives a richer mixture that generates more power, and is less prone to detonation. The leaner the mixture, the better the fuel economy. If the mixture becomes too lean, then you get "lean surge", and it extreme cases, misfiring.

In the ideal world, the spark plug would be fired when the piston reached TDC on the compression stroke. The combustion would force the piston down, and power would be generated.

Unfortunately, in the real world, there is a finite amount of time required for the A/F mixture to light and for combustion to be complete. For maximum power, maximum cylinder pressure from the combustion occurs ATDC. If it happens too soon, detonation occurs. If it happens too late, the combustion doesn't fully translate into power, and is lost as heat.

The crucial point is that for each RPM, we must fire at a specified time BTDC to ensure that maximum cylinder pressure occurs at the optimum time ATDC. The time before TDC is the critical component, and gets translated to timing advance, as we can measure angular markings on the crankshaft.

Several factors affect the need for timing advance.

1) Compression Ratio: Ratio of cylinder volume at BDC to the cylinder volume at TDC. Compression ratio is measured at WOT. During part throttle driving, the cylinders are only partially full of A/F. The effective compression ratio is lower, and more timing advance is required, since lower A/F mixtures burn slower. (Increase advance for low compression)
2) Octane level: Higher octane fuel burns slower and is less prone to detonation. (Increase advance for higher octane)

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3) Air/Fuel Ratio: Leaner mixtures burn slower since the ratio is not optimum. (Increase advance for higher A/F ratio)
4) Temperature: Cooler engines are less prone to detonation. (Increase advance for lower temperature)

NOTE:
As the throttle is used, it is varying the amount of air entering the engine. When the throttle is fully depressed, the engine runs at its specified compression ratio, and requires less timing advance for optimum operation. When running at part throttle, less air enters the engine, and its burn speed decreases. In this case we need to add more timing advance to ensure maximum power can be achieved from the fuel.

Maximum power out of an engine occurs when the timing advance is set so that for every RPM, the timing advance is picked so that it is approximately 4 degrees before the detonation point of the engine.

Running less than optimum advance will make the engine run hotter, and will decrease the power output. Running more than required advance will lead to pre-ignition, which makes the engine run hotter, and decreases the power output of the engine at a larger rate than lower advance. For example, if a particular engine generates 100 HP at optimum advance. Running 2 degrees below optimum may give you only 95 HP. Running 2 degrees above optimum may give you 85 HP. Reason being is pre-ignition occurs, and it forces the engine backwards acting like a brake.

For optimum operation of an engine, the proper timing advance curve must be applied. Too much timing advance can be catastrophic to the pistons and bearings. Timing advance is typically set at less than optimum, because increases in outside temperature, engine load, etc. will cause the engine to heat up, and makes the engine more prone to detonation. Also, the cooling system is less optimum at lower speeds, which also causes a temperature increase of the engine.

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3 ELECTRONIC FUEL INJECTION PRIMER

3.1 Background

Electronic Fuel Injection (EFI) is used to meter fuel to an engine by using data from a multitude of sensors. An EFI system can give a more consistent Air to Fuel Ratio (AFR) over a wide range of changing environmental parameters (air temperature, altitude, air pressure changes due to weather, outside temperature, etc.) This stable AFR translates to stable power output from the engine since it requires no adjustments for changing environmental conditions.

EFI systems are based on one of two different styles:
1) Mass Air Flow (MAF)
2) Manifold Absolute Pressure (MAP)

The MAF system utilizes several small wires that are inserted into the incoming air stream. One wire is heated, one is not. It measures the rate of cooling between the two, and outputs the mass of air entering the engine. Due to the nature of the MAF sensor, it automatically compensates for air temperature and density changes. Also, since it is measuring actual flow into the engine, the ECU can compensate for engine modifications (camshaft changes, porting, exhaust changes, as well as engine wear). This is the style adopted by the auto industry as it gives consistent power and emissions, regardless of modifications made by the user. The downfall of the MAF sensor, is that it is slow to react, but most importantly for the ATV, is the MAF is fragile.

The second system is an older technology, the MAP sensor. The MAP sensor measures the air pressure in the manifold, and it, with the addition of the air temperature sensor, can estimate the air density going into the engine. This system requires that a Volumetric Efficiency (VE) table be specified for the flow through the engine at all air flows and RPMs. The downfall of the MAP system, is it cannot compensate for humidity changes, or changes to flows through the engine (camshafts, porting, exhaust work, or engine wear). But it is robust, and has no fragile components.

The MAP sensor can compensate for changes to the intake air path though. If you have a restrictive air intake, then the engine will not be able to reach maximum intake pressure. For example, at sea level, you should be able to reach 100 kPa. With a restrictive filter, you may have 5 kPa of restriction, so you'll only reach 95 kPa. The ECU will then only pick the values from the 95 kPa portions of the table. If you remove the filter, then it'll automatically start picking the 100 kPa values.

The MAP typical measures the air pressure between 45 kPa and 100 kPa. The air pressure at idle is between 45 kPa and 50 kPa. The air pressure at full throttle is based on the air pressure at your elevation and current weather. The pressure can be determined with one of

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those commonly available home weather stations. Take the value in milli-bars, and divide by 10 to get it in kPa. The values reported by most weather reports already have the barometric pressure normalized out, so you'll need the raw data from them if it is available.

It automobiles, they utilize an oxygen sensor to monitor the AFR leaving the engine. This sensor is only used for idle and steady state cruise to make the engine run as lean as possible for fuel economy reasons. Once you snap the throttle, the system leaves this closed loop feedback mode to run fuel maps that do not use the oxygen sensor. Oxygen sensors are not used on ATVs for a couple of reasons. One, you don't spent a lot of time cruising at constant throttle. And the most important reason, the oxygen sensor is expensive and does not like water.

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3.2 MAP System Overview

The MAP system the ECU is utilizes requires the following sensors for data:

1) MAP (Manifold Absolute Pressure) – For barometric pressure, as well as engine vacuum.
2) ECT (Engine Coolant Temperature) – For cold enrichment ("choke")
3) IAT (Intake Air Temperature) – For air density calculations
4) BAT (Battery Voltage) – The injector is a solenoid valve, and its opening time is based on voltage.
5) TPS (Throttle Position Sensor) – For acceleration enrichment (sharp throttle jabs), and light throttle fuel table leaning (to prevent over-rich conditions when maintaining constant speed or deceleration).

The EFI system goes through three (3) stages at startup:

1) Starting Fuel
2) After Start Enrichment
3) Run Fuel

The ECU calculates a pulse width for the injector by picking a pulse width from the starting fuel curve based on engine temperature. It uses this value to start the engine. Once the engine has started, it enrichens the mixture with the after start enrichment. This prevents the engine from stalling due to the poor atomization of a cold engine. After a few rotations after starting, the ECU then starts using the run fuel, which is END_PULSEWIDTH, below.

To determine the duration of the injector pulse at any given RPM, the ECU first starts with the maximum amount of time the injector can be fired (based on injector flow rate and engine size). This is the START_PULSEWIDTH.

It then requires the following data:
BARO (Barometric pressure - by measuring the MAP sensor on startup)
DENSITY (by using the IAT temperature)
VE (by looking up a value from the VE table corresponding to the measured RPM and MAP value).
IOT (Injector Opening Time – by using the BAT voltage)
ACCEL (Acceleration Enrichment – based on RPM and throttle position)
LEAN (% reduction in fuel based on throttle position – only used for light throttle (<35%))
COLD_ENRICH (based on ECT)

The END_PULSEWIDTH is:
END_PW = START_PW * BARO * MAP * DENSITY * VE + COLD_ENRICH + IOT + ACCEL - LEAN

One thing to note is the START_PW is calculated based on the injector flow rate in lbs/hr, which is specified for a given fuel rail pressure. If the fuel pressure is above or below the specification, then the ECU will be putting in more or less fuel, which will effect overall operation.

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4 SCREEN OVERVIEW

The application starts with no data configured.   Use the slider on the bottom of the screen to scroll left and right to display all the data if it doesn't fit on the screen. At the bottom of the screen are tabs that can be selected to view the other configurable data.
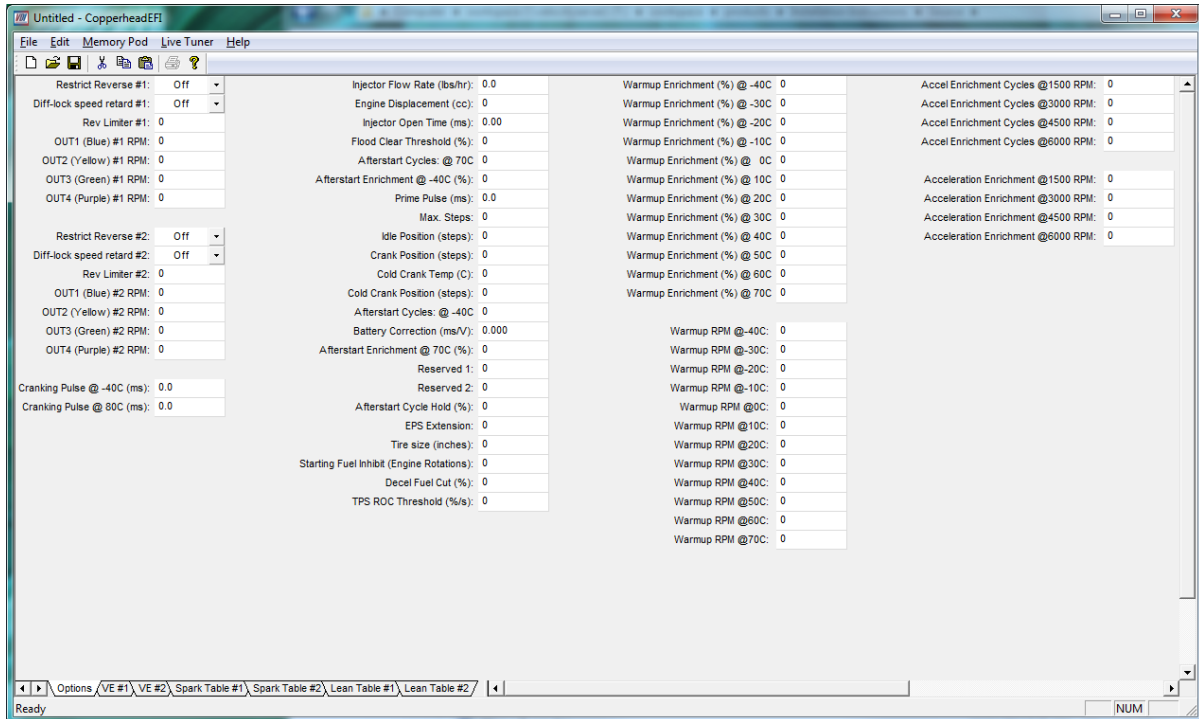
The header indicates the name of the maps you are editing. It will remain "Untitled" until you have saved the map under a different name, or until you load another file. The task menu gives access to all the functions, and the toolbar (if enabled) will give quick access to many of the task menu functions.

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4.1 <u>Task Bar</u>

4.1.1 File
The file menu allows you to open/save maps and configurations. The ***Export Log to CSV*** button can be selected to convert a Live Tuner log file into a Microsoft Excel compatible .CSV file.

4.1.2 Edit
The edit menu allows you to copy/cut/paste single cells, rows, columns, full tables or groups of cells. To select a row, click on the number in the green column. To select a column, click on the pink bar directly above the RPM number (in the bar with RPM). You can also left-click and drag to highlight a group of cells. To select the entire table, click on the top-left corner of the table (in the green box). Note: If you select a row, you can only paste it as a single row. You cannot copy one row, and then paste it into multiple rows.

In addition, you can copy/paste to/from any Windows application. This allows for data transfer to/from a spreadsheet application for data manipulation and graphing.

The "Labels..." feature allows for the VE/Spark Tables to have split scales. This will be automatically set when opening one of our maps based on the machine, and typically never needs to be modified.

4.1.3 Memory Pod
Contains the functions specific to the Memory Pod. The functions will be disabled if no valid Memory Pod is connected.

4.1.3.1 *Write Map*
The ECU will download new maps when the key is first turned on, and the USB Memory Interface is connected to the ECU.

Select ***Write Map*** to load the USB Memory Interface with your desired maps. Disconnect the interface from your computer.

Remove the cover from the DB9 interface port on the ECU. Ensure the key is turned off, and connect the USB memory interface directly to the ECU. This process does not require a computer to complete. Turn on the key (but do not start the engine).
NOTE: DAMAGE TO THE USB MEMORY INTERFACE AND/OR ECU MAY OCCUR IF THE ENGINE IS CRANKED DURING THIS DOWNLOAD PROCESS.

The ECU status will flash slowly while the maps are being downloaded. Once the download is complete, the status light will flash rapidly, and then come on solid to indicate

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completion. **Do not unplug or disturb the unit while it's programming.** This can take up to 30 seconds if the maps are vastly different from the onboard maps. If the changes are minor, the download will take less than a second.

Turn off the key, and unplug the interface. Replace the DB9 protective cover. The machine is now ready to use.

NOTE: Downloading new maps overwrites the maps that were currently in the ECU. There is no way to read out and save the ECU maps that were previously loaded. Multiple USB Memory Interface devices can be loaded with different maps, and easily downloaded with the above procedure.

4.1.3.2 Update ECU Firmware

The Copperhead ECU has the ability to upgrade its firmware to support new features and updates.

In order to upgrade the ECU firmware, the USB interface must be connected to the computer and the ECU at the same time. The ECU requires power to be programmed, and must remain in the ATV. Using a laptop is the easiest method.

Before upgrading the firmware, the USB Memory Interface MUST be pre-loaded with a set of maps. The ECU will download the maps after the firmware upgrade.

Plug the USB Memory Interface into the computer via the USB cable, and directly into the ECU. Turn on the ignition, but do not start the engine.

NOTE:
THE KEY MUST BE OFF WHEN THE MEMORY POD IS CONNECTED OR DISCONNECTED. FAILURE TO DO SO MAY DAMAGE THE POD AND/OR ECU.

Click on the **Update ECU Firmware** menu. Browse for the new firmware file (with the .VDI extension), and click "Open". Latest versions can be downloaded off of our website: http://www.velocitydevices.com. Click on the "Support" tab. Find the version that is applicable to your ECU, and "right-click" and "Save Target As" to save it to disk. A dialog box will display the programming status. **Do not unplug or disturb the unit while it's programming.** If the download was successful, the ECU will turn on the status light. Once the unit has been successfully programmed, click "OK", turn off the ignition, and unplug the USB Memory interface. It can take up to 5 minutes to download new firmware into the ECU.

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If the ECU failed to program correctly, ensure the USB interface is fully connected to the ECU and retry the process. If you still have problems, contact technical support.

NOTE:
THE ECU WILL NOT START THE ENGINE WITH THE MEMORY POD CONNECTED. DO NOT ATTEMPT TO START THE ENGINE WITH THE POD CONNECTED.

4.1.4 Live Tuner

Contains the functions specific to the Live Tuner. Most functions will be disabled if no valid Live Tuner is connected.

4.1.5 Write Map

Writes all the maps and configurations to the Live Tuner.

The ECU will download new maps when the key is first turned on, and the Live Tuner is connected to the ECU.

Select ***Write Map*** to load the Live Tuner with your desired maps. The ECU does not need to be connected at this time. If the Live Tuner is connected to the ECU, and it is powered on, the map will automatically get loaded into the ECU.

The ECU status will flash slowly while the maps are being downloaded. Once the download is complete, the status light will flash rapidly, and then come on solid to indicate completion. **Do not unplug or disturb the unit while it's programming.** This can take up to 30 seconds if the maps are vastly different from the onboard maps. If the changes are minor, the download will take less than a second.

Once complete, the ECU will reboot. If the Live Tuner is no longer required, turn off the key, and unplug the interface. Replace the DB9 protective cover. The machine is now ready to use.

NOTE: DO NOT ATTEMPT TO CRANK THE ENGINE DURING THIS DOWNLOAD PROCESS.

NOTE: Downloading new maps overwrites the maps that were currently in the ECU. There is no way to read out and save the ECU maps that were previously loaded.

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4.1.6 Update ECU Firmware

This button allows you to upgrade the ECU firmware when updates are available.

The ECU requires power to be programmed, and must remain in the ATV. To update the ECU without a computer present, load the firmware file into the Live Tuner and connect the Live Tuner to the ECU. Once the ECU is powered on, use the button on the Live Tuner to initiate the firmware update process (consult the Live Tuner instructions for more information).

Click on the **Update ECU Firmware,** browse for the new firmware file (with the .VDI extension), and click "Open" to save to the Live Tuner. Latest versions can be downloaded off of our website: http://www.velocitydevices.com. Click on the "Support" tab. Find the latest version, and "right-click" and "Save Target As" to save it to disk. If the ECU is connected, the firmware can then be upgraded when the prompt appears. Follow the onscreen directions, and wait for the process to complete.

Do not unplug or disturb the unit while it's programming. If the download was successful, the ECU will turn on the status light, and the ECU version will be displayed on the Remote Access screen. It will take approximately 30 seconds to download new firmware into the ECU.

NOTE:
DO NOT ATTEMPT TO START THE ENGINE DURING THE FIRMWARE UPDATE.

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4.1.7 Remote Access

Allows remote access to the Live Tuner.
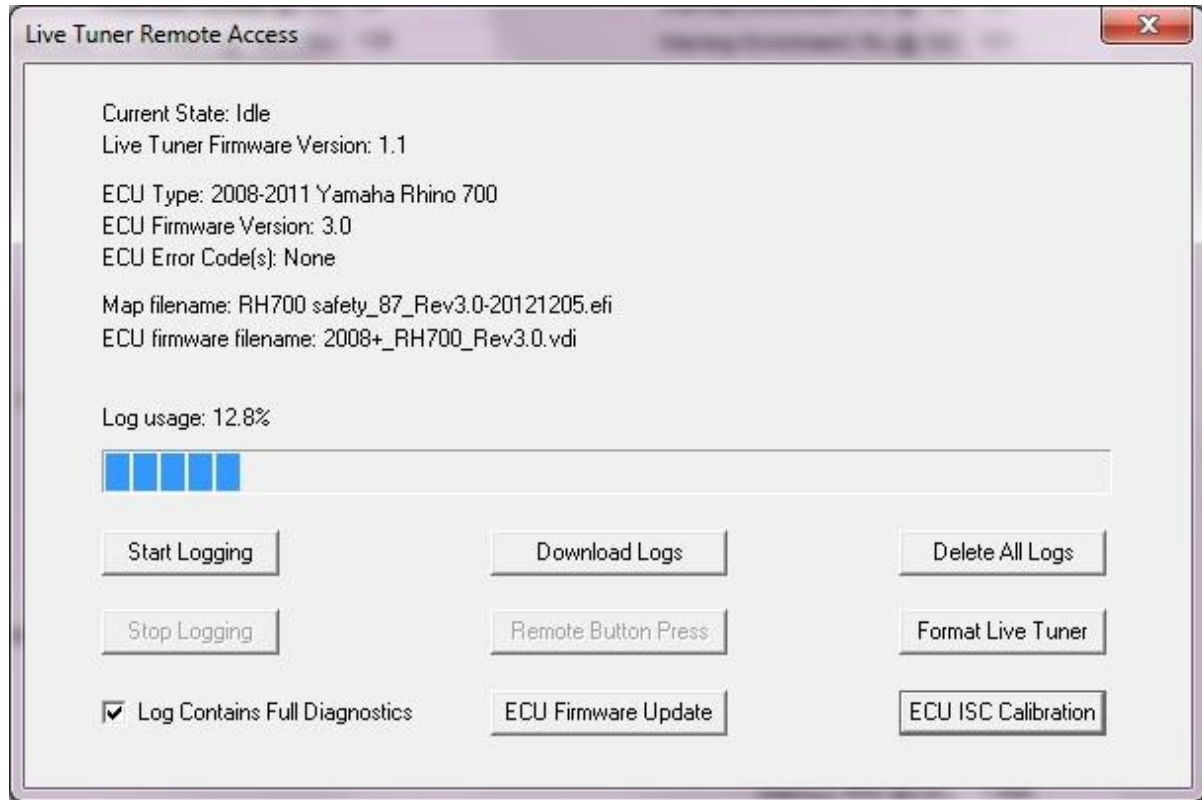
Through this screen you can see current state of the Live Tuner, its firmware version, the ECU information (if connected), currently stored firmware and map file names, as well as log usage. This screen also contains several buttons to access the following functions:

- **Start/Stop Logging:** Starts/stops logging of the EFI data to the Live Tuner's internal memory.
- **Download Logs:** Downloads the stored log files to the computer.
- **Remote Button Press:** Used to acknowledge a firmware upgrade failure. Same as pressing the physical button on the Live Tuner.
- **ECU Firmware Update:** Initiates an ECU firmware update. This button will be disabled if no valid firmware file is stored, or if no ECU is detected.
- **Delete All Logs:** Deletes the stored log files in the Live Tuner.
- **Format Live Tuner:** Deletes the logs, map and firmware file from the Live Tuner.
- **ECU ISC Calibration:** Initiates the ISC calibration on the ECU if a valid ECU is connected. See the ECU specific instructions for more detail.
- **Log Contains Full Diagnostics:** Toggles the normal/full diagnostic mode.

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4.1.8 Playback Live / Log Data

This is the Live Tuner main screen. For optimal operate, your screen resolution should be at least 1280x1024. Smaller resolutions can be used, but you will need to use the scroll bars to pan around the screen.
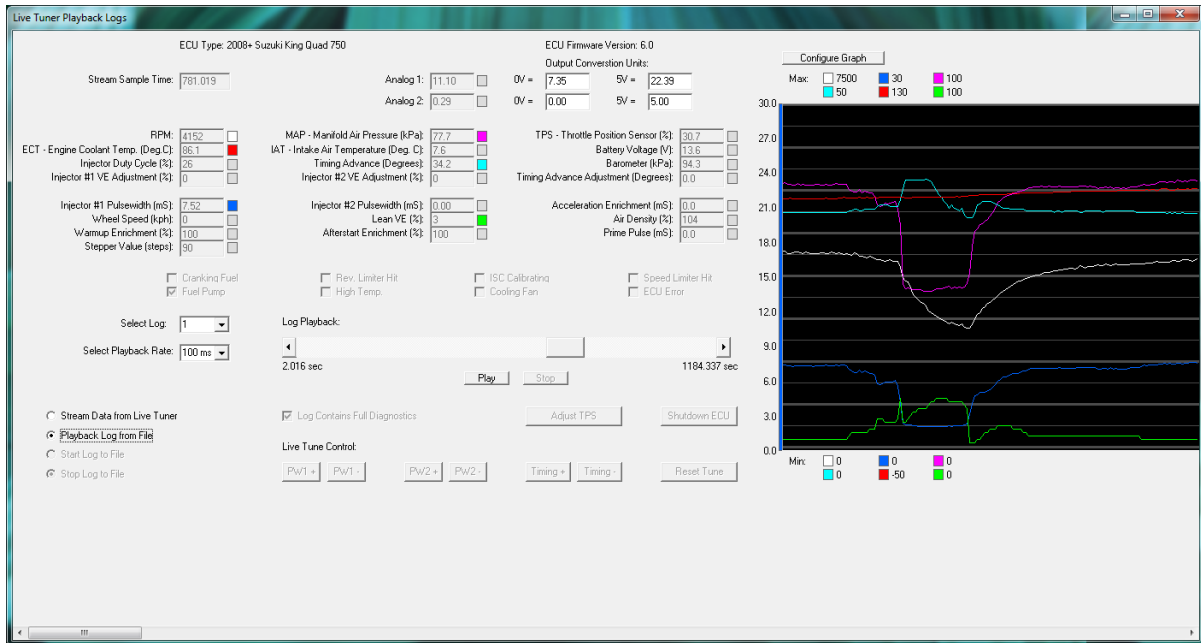
The screen layout is broken into several sections:

4.1.8.1 Section 1, ECU Information and Analog Signals:

The ECU type and firmware version are displayed on the top line for indication of which machine is being tuned, or the machine that the log was retrieved from. This section contains the following information:

- The sample time of the sample being displayed.
- The "analog" block displays the "converted" analog signals connected to the Live Tuner's 1/8" jack. Enter the desire conversion values for the 0V and 5V inputs in the white boxes. Analog 1 defaults to the Innovate Motorsports Wideband O2 Meter 0V=7.35AFR and 5V=22.39AFR conversion values.

4.1.8.2 Section 2, ECU Data:

The next twelve (12) diagnostic values (starting at "RPM" and ending at "Timing Advance Adjustment") are displayed regardless of the state of the diagnostic level.

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NOTE: The "Injector #1 VE Adjustment", "Injector #2 VE Adjustment", and "Timing Advance Adjustment" display the Live Tuning adjustment from the "PW1+/-", "PW2+/-" and "Timing +/-" buttons. Normally these will be zero.

If the "Log Contains Full Diagnostic" checkbox is selected, then the next block of eleven (11) values (starting at "Injector #1 Pulsewidth" and ending at "Stepper Value") are displayed.

NOTE: The "Full Diagnostics" will consume 2x more storage space when logging, so you can only store half has much log data. This checkbox can only be selected when streaming live data. It will configure the Live Tuner for future logs.

NOTE: Some machines do not support all the fields. For example, if the machine does send "Wheel Speed" to the ECU, then that field will always be zero.

4.1.8.3 Section 3, ECU Status:

The block of eight (8) disabled checkboxes give indication of specific ECU conditions, if applicable. They are either checked or unchecked.

4.1.8.4 Section 4, Stream/Playback Selection:

The bottom left corner contains four (4) radio buttons:

- *Stream Data from Live Tuner:* This button will enable the stream of data from the Live Tuner. When this button is selected, data being used by the ECU is simultaneously displayed on the screen. The screen gets updated each time the ECU generates a new EFI value, or on one second boundaries if the engine is off. The Start/Stop Log to File can be selected, as well as the Full Diagnostic checkbox, and live tuning buttons when this button is active. While streaming is connected, clicking the "Adjust TPS" button will remove the ECU's zero offset from the TPS reading. The TPS box will now report the ACTUAL TPS value. Adjust the TPS so the value is zero. Once complete, select "OK" to stop the adjustment and reboot the ECU.
- *Playback Log from File:* Select this button to open a saved log file. Use the "**Select Log**" pull down to pick the log to display (every time a new log is started, it receives a new number. Picking log "5" would be the fifth log recorded). Use the "**Select Playback Rate**" to change the time between each displayed sample. You can select rates between 1 millisecond/sample to 5 seconds/sample. The default is 100 milliseconds/sample. The Play/Stop buttons and progress bar is used to control the playback operation.
- *Start/Stop Log to File:* During *Stream Data from Live Tuner* mode, the data can simultaneously be logged to a file on the computer.

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4.1.8.5 Section 5, Live Tuner Control:

During the **Stream Data from Live Tuner**, the injector pulse widths (PW1 and PW2), as well as timing advance can be raised/lowered on 1% increments Their current adjustment level is shown in the "Injector #1 VE Adjustment", "Injector #2 VE Adjustment", and "Timing Advance Adjustment" boxes. Selecting **Reset Tune** will return the adjustments back to zero.

NOTE: These buttons are only enabled when supported by the ECU. For example, a single cylinder machine does not have a second injector, so PW2+ and PW2- will be disabled.

4.1.8.6 Section 6, Graphing:

The **Configure Graph** button is used to select the desired items to graph. Select the desired plot items (up to six). Once an item is selected, their default minimum and maximums will be displayed. If different display limits are desired, type them in the boxes, and click **OK** to apply the changes. The selected plot items on the main screen will then get a colored box that matches the plot color to the right of the item. Clicking on the "Vertical Scale" radio button will select one of the plots to be used for the vertical scale of the graph grid. A colored bar matching the pen that is being used for the vertical scale is displayed on the left of the graph. Selecting a blank source will disable that particular plot pen.

During graphing mode, all new data is displayed at the right of the graph. If the window is resized, the graph will also get resized, and past data will be loaded into the graph if the display source is a log file.

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4.1.9 Help

Lists the application version and copy write information.

4.2 Options Tab

4.2.1 Column 1

The first column contains the configurable outputs as well as the starting fuel values

Restrict Reverse #1	Limits the engine to 4000 RPM when in reverse, unless the override button is pressed - for switch position #1.
Diff-lock speed retard #1	Limits the engine to 4000 RPM when the differential is locked, unless the override button is pressed - for switch position #1.
Rev Limiter #1	Engine revolution limiter for switch position #1.
OUT1 (Blue) #1 RPM	RPM where the BLUE wire grounds for switch position #1.
OUT2 (Yellow) #1 RPM	RPM where the GREEN wire grounds for switch position #1.
OUT3 (Green) #1 RPM	RPM where the PURPLE wire grounds for switch position #1.
OUT4 (Blue) #1 RPM	RPM where the YELLOW wire grounds for switch position #1.
Restrict Reverse #2	Limits the engine to 4000 RPM when in reverse, unless the override button is pressed - for switch position #2.
Diff-lock speed retard #2	Limits the engine to 4000 RPM when the differential is locked, unless the override button is pressed - for switch position #2.
Rev Limiter #2	Engine revolution limiter for switch position #2.
OUT1 (Blue) #1 RPM	RPM where the BLUE wire grounds for switch position #2.
OUT2 (Yellow) #1 RPM	RPM where the GREEN wire grounds for switch position #2.
OUT3 (Green) #1 RPM	RPM where the PURPLE wire grounds for switch position #2.
OUT4 (Blue) #1 RPM	RPM where the YELLOW wire grounds for switch position #2.
Cranking Pulse @ -40C (ms)	Injector pulse width for an engine temperature of -40C and colder.
Cranking Pulse @ 80C (ms)	Injector pulse width for an engine temperature of +80C and hotter.

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4.2.2 Column 2

The second column contains all the critical configuration data for the ECU. Most of these values should never be modified.

Injector Flow Rate (lbs/hr)	Specified flow rate for the injector at specified fuel rail pressure. Running fuel rail pressures that are above/below the specified value will increase/decrease the injector's actual lbs/hour of fuel delivery.
Engine Displacement (cc)	Engine Displacement in Cubic Centimeters
Injector Open Time (ms)	Time for the injector valve to start to physically open at a 13.2V supply voltage.
Flood Clear Threshold (%)	When the throttle is pressed above this value, the fuel to the engine is turned off while cranking.
Afterstart Cycles @70C	If the engine temperature is above 70C, and the engine just started, this is the number of engine rotations that the engine is enrichened for.
Afterstart Enrichment @ -40C (%)	% addition of fuel to add at -40C and colder.
Prime Pulse (ms)	Amount of time to add to the first injection pulse after startup to purge out the air in the line. This value shouldn't be much larger than the injector open time, or flooding during startup will result.
Max. Steps	Number of steps the Idle Speed Control (ISC) valve takes from full open to full closed, plus a few extra to ensure it is fully closed.
Idle Position (steps)	Number of steps to set the ISC valve at to maintain idle.
Crank Position (steps)	Number of steps to set the ISC valve at for cranking when engine temperature is above the cold crank temp.
Cold Crank Temp. (C)	Temperature where the ECU will switch to the cold crank position.
Cold Crank Position (steps)	Number of steps to set the ISC valve at for cranking when engine temperature is below the cold crank temp.
Afterstart Cycles @-40C	If the engine temperature is below -40C, and the engine just started, this is the number of engine rotations that the engine is enrichened for.
Battery Correction (ms/V)	Amount the pulse width is compensated for based on the battery voltage.
Afterstart Enrichment @ 70C (%)	% addition of fuel to add at 70C and hotter.
Reserved 1	Reserved field.
Reserved 2	Reserved field.
Afterstart Cycle Hold (%)	Used to hold the afterstart enrichment value for a period before it begins to taper to zero. Useful to deal with lean chug issues during cold starts.
EPS Extension	If set to "1" it allows for power steering (if applicable) to have an extended RPM range (useful when running tracks).
Tire size (inches)	Setting the tire size causes the ECU to recalibrate the acceleration enrichment and speedometer (if applicable).
Starting Fuel Inhibit (Engine Rotations)	Used to disable the injector for the entered number of rotations during starting. This is used to clean out an engine that tends to be over rich during starting.
Decel Fuel Cut (%)	% reduction in fuel during deceleration (when RPM is above 2500 RPM)
TPS ROC Threshold (%/s)	Rate Of Change in %/s that the TPS must move for the ECU to apply acceleration enrichment or deceleration fuel cuts.

4.2.3 Column 3

This column contains the warmup enrichment (choke) in % for various engine temperatures. 100% indicates no extra enrichment. Also contains the warmup RPM for various engine temperatures. The value at 70C will be used as the idle speed once the engine is hot. Increasing the hot idle speed will improve the launch off the line. Make sure it's below the clutch engagement RPM, otherwise the bike will creep when in gear.

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4.2.4 Column 4

This column contains the acceleration enrichment. The ECU will do a linear interpolation to find values in between the set points. For example, if the enrichment @ 1500 RPM is 15, and the enrichment @ 3000 RPM is 5, then the value at the midpoint (2250 RPM) will be 10. More enrichment is needed for lower RPM.

Acceleration Enrichment @ 1500 RPM	% extra fuel to add to compensate for acceleration at 1500 RPM (and below)
Acceleration Enrichment @ 3000 RPM	% extra fuel to add to compensate for acceleration at 3000 RPM
Acceleration Enrichment @ 4500 RPM	% extra fuel to add to compensate for acceleration at 4500 RPM
Acceleration Enrichment @ 6000 RPM	% extra fuel to add to compensate for acceleration at 6000 RPM (and above)
Accel Enrichment Cycles @ 1500 RPM	Number of engine rotations to add the acceleration enrichment for at 1500 RPM (and below)
Accel Enrichment Cycles @ 3000 RPM	Number of engine rotations to add the acceleration enrichment for at 3000 RPM
Accel Enrichment Cycles @ 4500 RPM	Number of engine rotations to add the acceleration enrichment for at 4500 RPM
Accel Enrichment Cycles @ 6000 RPM	Number of engine rotations to add the acceleration enrichment for at 6000 RPM (and above)

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4.3 VE #1 / VE #2

Indicates the VE (Volumetric Efficiency) table correction for the listed RPMs and engine air pressures for the ECU when the switch is set to position #1 (VE #1) or position #2 (VE #2).

The air pressure at idle is between 45 kPa and 50 kPa. The air pressure at full throttle is based on the air pressure at your elevation and current weather.

The values in each bin indicates the +/- % that will be added to the VE table that the ECU has hard coded by default from the current firmware. As with the acceleration enrichment, the ECU will interpolate between bins to smooth out the data.

These values do not have to vary much when tuning. For example, if you measured the AFR to be 13.0:1, but you wanted it to be 12.5:1, you would need to change the particular bin by $100* (13.0/12.5) - 100 = 4\%$.

On twin cylinder engines like the BF750EFI, intake harmonics cause issues in MAP measurements after a certain engine load, so the vertical scale is split. The ECU will use the top four (4) rows when measuring the MAP sensor (low load), and then the bottom eight (8) rows when measuring the TPS sensor (high load). A row with TPS = 100, means 100% throttle. TPS=50, means 50% throttle.

4.4 Spark Table #1 / Spark Table #2

Indicates the timing advance table for listed RPMs and engine air pressures for the ECU when the switch is set to position #1 (spark table #1) or position #2 (spark table #2).

At WOT, the fuel mixture burns faster, so less advance is used. At part throttle, there is less mixture in the cylinder, so it burns slower, and requires more advance.

Thinking about it from the distributor days in automobiles, the values for a MAP value of 100 would be the centrifugal advance (set by turning the distributor and changing the weights). The values for 45-95 would be governed by the vacuum advance.

On twin cylinder engines like the BF750EFI, intake harmonics cause issues in MAP measurements after a certain engine load, so the vertical scale is split. The ECU will use the top four (4) rows when measuring the MAP sensor (low load), and then the bottom eight (8) rows when measuring the TPS sensor (high load). A row with TPS = 100, means 100% throttle. TPS=50, means 50% throttle.

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4.5 Lean Table #1 / Lean Table #2

Indicates the reduction of fuel for listed RPMs and throttle positions for the ECU when the switch is set to position #1 (Lean Table #1) or position #2 (Lean Table #2).

The engine requires more fuel to accelerate up the fuel table versus running at steady state or decelerating. The VE table is calibrated to provide optimum fuel for acceleration, but this can lead to over-rich conditions that can cause stall and bogs when cruising at a constant speed. The lean table is used to reduce the fuel at light throttle positions to eliminate this condition. Going too high on the lean table will cause lean bogs/stutters/misses at light throttle in the mid-band.

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5 TUNING GUIDE

NOTE:
This application allows you to modify any point of the Copperhead EFI system. To prevent detonation, there cannot be any large steps between data points. The curves must have smooth flows to ensure trouble free operation. IMPROPER CONFIGURATION, NON-UNIFORM MAPS, AND/OR EXCESSIVE TIMING ADVANCE CAN DESTROY YOUR ENGINE.   CONSULT AN AUTHORIZED ENGINE BUILDER FOR ADVICE IF NECESSARY. VELOCITY DEVICES INC. IS NOT LIABLE FOR ANY DAMAGES OCCURRED BY IMPROPER USE OF THIS APPLICATION.

5.1 Starting

The cranking pulse values govern the starting fuel. Too little or too much starting fuel can cause starting kickbacks, and/or starting issues. The ECU figures out the desired starting fuel by making a straight line between the cold cranking pulse and hot cranking pulse.

Start by warming the engine up (until the fan cycles), and then setting the cranking pulse at 80C to a value that doesn't have any starting issues. If the engine is hot, and then is shut off, the coolant temperature will continue to rise.   The 80C value is used for these hot temperatures as well.   Then adjust the cranking pulse at -40C to eliminate cold starting issues. Note: During the cold starts, you must be within 0.5ms of the optimum value for proper operation.

The Prime Pulse can be adjusted to eliminate any lean conditions when the engine is started after sitting for a period of time. The value should be marginally larger than the Injector Open Time, otherwise flooding can result. You only want the prime pulse to be large enough to crack the injector open to bleed off the air. You don't want to be adding extra fuel. It is only used when the coolant temperature and intake air temperature are almost the same (I.E. a cold start)

5.2 After Start

If the engine labors for a bit after the engine has started, then you'll need to adjust the afterstart enrichment and/or the afterstart cycles. If it stalls right after starting, then it needs more/longer enrichment. If it starts, but labors for a few seconds and then smooths out, then it needs less/shorter enrichment. The ECU figures out the afterstart enrichment and cycles by calculating a straight line between the two endpoints. Once the engine starts, it starts by applying the enrichment, and decreases it to no extra enrichment over the duration. The "Afterstart Cycle Hold (%)" allows the unit to maintain a constant afterstart enrichment for a % of the total cycles, before it starts to taper to zero. For example, if the afterstart cycles are set to 1000, and the afterstart cycle hold (%) = 2, then the unit will hold

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the afterstart value for 2% of 1000 cycles = 20 cycles, before it tapers it to zero. If it was set to 0%, then it would start tapering as soon as the engine starts.

5.3 Warmup Enrichment

The warmup enrichment will need to be changed if you are getting lean or rich stalls at any RPMs while the engine is warming up. The value at 70C should be 100% (no extra fuel).

5.4 Warmup RPM

The warmup RPM governs the idle RPM (the value for 70 C), as well as the RPM for other engine temperatures.

If you are having issues switching gears when the engine is cold, then the RPM's can be reduced to eliminate that. They only need to be high enough to sustain stable idle when the engine is cold.

Increasing the idle speed (value for 70C) will improve the off the line launch and performance. It must be below the clutch engagement, otherwise the machine will creep when in gear.

5.5 Acceleration Enrichment

If you are experiencing lean/rich bogs when the throttle is jabbed, then the acceleration enrichment will need to be adjusted.

The enrichment consists of two values, enrichment in percent, and duration in engine cycles. The ECU will taper between different values to ensure a smooth transition. The percent value will eliminate lean bogs when the throttle is first jabbed, the duration will prevent lean bogs while the engine accelerates. If you jab the throttle, and the engine starts to rev, and then bogs down, then the duration is typically too large. If it bogs when you first stab the throttle, then the percent is too lean/rich.

Typically, too lean will make the launch feel soft and the engine may stall. Too rich will make it bog, and give a large lag at the bottom end.

5.6 VE Tables

The VE tables can be modified to compensate for an aftermarket pipe, or different machine configurations. Values can be entered as a negative to remove fuel.

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5.7 Spark Tables

The spark tables can be modified if necessary. You'll have more spark advance at 45 kPa than you will at 100 kPa. There should be a smooth transition from the top to bottom of the table. The idle advance should be kept under 20 degrees to prevent issues when starting.

5.8 Lean Tables

The lean tables can be adjusted to prevent rich stalls at light throttle. If you put too much reduction in, then you will get lean stumbles and stutters when running light throttle in the mid band.

5.9 Idle Issues

If you find that the engine wants to almost stall after blipping the throttle, you may need to increase your idle position (steps) value. This value is basically the electronic "throttle stop". The ECU will close the ISC valve until this value (minimum idle), and open the ISC valve as far as necessary to maintain constant idle. The lower this number, the higher the minimum idle. You can make this as high as necessary to maintain normal idle. If it's too small, you will have gear shifting issues due to the high idle.

If you are experiencing an idle that is smooth, and then seems to go rich, and then recover, you may be having issues with a miss-calibrated TPS sensor or possibly a noisy TPS sensor. First verify the TPS is properly centered. If it is, you may need to increase the TPS ROC Threshold (%/s). This value governs how sensitive the ECU is to changes in throttle position. Making the number too small will cause noise to trigger the acceleration enrichment and cause rich stumbles when idling. Making the number too large will limit the response of the acceleration enrichment which will make light throttle jabs less responsive.

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