rusEFI Manual

Contents

Quick Start

Minimal Setup

All official units are shipped with firmware installed. Modern Windows comes with the necessary drivers.

1. Download and Install TunerStudio (See Download and Install on page 6).

   EFI Analytics logo (See Download and Install on page 6)

2. Click the 'Detect' button and let TunerStudio automatically find and download the correct definition file from the internet.

You are ready to go control boost!

Continue reading for more detailed setup steps.

Waiting for your ECU to arrive?

1. Download the rusEFI bundle (https://wiki.rusefi.com/Download) for your ECU.

2. Extract the bundle and launch the rusEFI console. Hit the "Install Drivers" button to install the Virtual COM Port and DFU drivers. If necessary, the bundle will also help you install the Java runtime.

Figure 1: console

3. Get friendly on the rusEFI forums (https://rusefi.com/forum). Introduce yourself, start a build thread, and ask questions.

4. Download and Install TunerStudio (See Download and Install on page 6)

5. Create a project in TunerStudio (See Creating a Project on page 6)

Once your ECU has arrived

Your board comes with rusEFI firmware installed on it, but it should be updated.

How to update your firmware (https://wiki.rusefi.com/HOWTO-Update-Firmware)

Getting Your Car Running

With a Universal ECU

Follow the Get Running With a Universal ECU guide (See Get Running With a Universal ECU on page 11).

With a Plug-and-Play ECU

Follow the Get Running With a Plug-and-Play ECU guide (See Get Running With a Plug-and-Play ECU on page 9).

Tuning

Get Tuning (See Get Tuning with TunerStudio and your rusEFI ECU on page 22)

Logging

Any troubleshooting begins with logs. One of rusEFI's powers is the amount of data points available for logging!

Shaky videos will not do. Even high-resolution screenshots wil not do—*it has to be a proper log file.*

TunerStudio's built-in logging utility is the preferred method for producing logs. For more information and instructions, see the Logging Guide (https://wiki.rusefi.com/Logging-Guide).

Analyzing Logs

EFI Analytics MegaLogViewer (https://www.efianalytics.com/MegaLogViewer/) is an industry leading log charting application.

Share Your Tunes and Logs

You will definitely need your tune and log online for any community discussion.

rusEFI Online (https://wiki.rusefi.com/Online) is the platform to share and compare your tune with other tunes!

Get Support

See Support & Community (https://wiki.rusefi.com/Support)

Want to learn more about rusEFI features?

See https://rusefi.com/docs/guide/

FAQ

Q: How do I change settings?
A: You can change settings and your engine tune using TunerStudio (See How to Create a TunerStudio Project on page 6).

Q: *Do I need to compile source code myself?*
A: Nope, not at all. Prebuilt bundles are available on the Download Page (https://wiki.rusefi.com/Download).

Q: *I've made some changes in TunerStudio & hit Burn. 'Need Burn' has appeared but the values are not there after rusEFI reset?*
A: rusEFI does not write to internal flash memory while your engine is running. In order to really write the values into the permanent memory you would need to stop the engine (or disconnect your stimulator). Online tuning is not affected by this issue; you can tune and the new values will be applied right away, but they will not be saved until you stop the engine.

Q: *I've remapped some analog inputs and outputs but nothing has changed, looks like the old pins are still used for output?*
A: For most of the pinout changes to be applied you need to reset rusEFI. Do not forget to stop the engine so that the new config is saved into internal memory!

Q: *What does this error code mean?*
A: See Error Codes (https://wiki.rusefi.com/Error-Codes)

How to Create a TunerStudio Project

EFI Analytics TunerStudio (https://www.efianalytics.com/TunerStudio/) is a third party commercial tuning application used to configure and tune your rusEFI ECU. TunerStudio is available on Windows, Mac and Linux.

Most rusEFI ECUs can be powered through the USB port, so you can set it up in the comfort of your living room and have it communicate with TunerStudio before it is installed in the car. This approach is highly recommended.

Download and Install

TunerStudio (https://www.tunerstudio.com/index.php/tuner-studio)

MegaLog Viewer (https://www.efianalytics.com/MegaLogViewer/download/)

The paid versions of both programs are recommended.

Creating a Project

Connect TunerStudio to your ECU. You will need a USB cable to establish communication between your computer and the rusEFI unit. Most rusEFI units feature a USB port. microRusEFI requires an externally-wired USB port.

Your laptop should give you an audible notification when you plug in the ECU. This indicates that it sees a new device connected to a USB port.

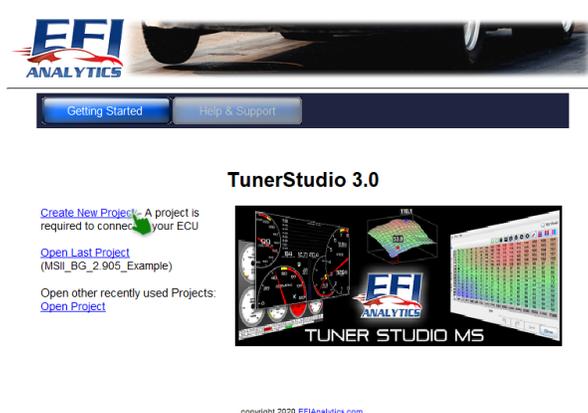Open TunerStudio and click *"Create New Project""*.

Figure 2: First Project

TunerStudio needs an ECU definition file (usually with a .ini extension) in order to start communicating with rusEFI.

Auto-detect Mode

All official rusEFI boards support automatic ECU definition file download if connected via USB, serial port, or Bluetooth. Just hit 'Detect' and wait for the name of your ECU to appear.
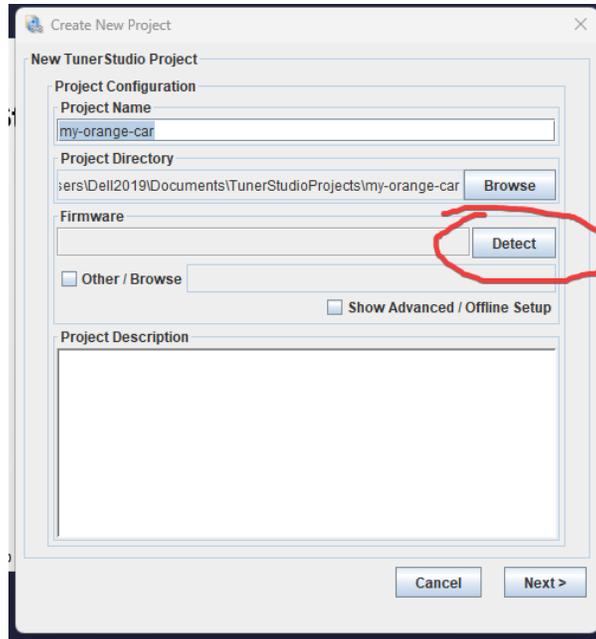
Figure 3: TunerStudio Detect Button

Manual Definition Selection

If the definition for your unit wasn't detected automatically, select the file from your rusEFI bundle (https://wiki.rusefi.com/Download).

Your rusEFI board should also present itself as a USB storage device to your computer, containing the .ini file you need. This is the most foolproof method of making sure you have the correct .ini file.
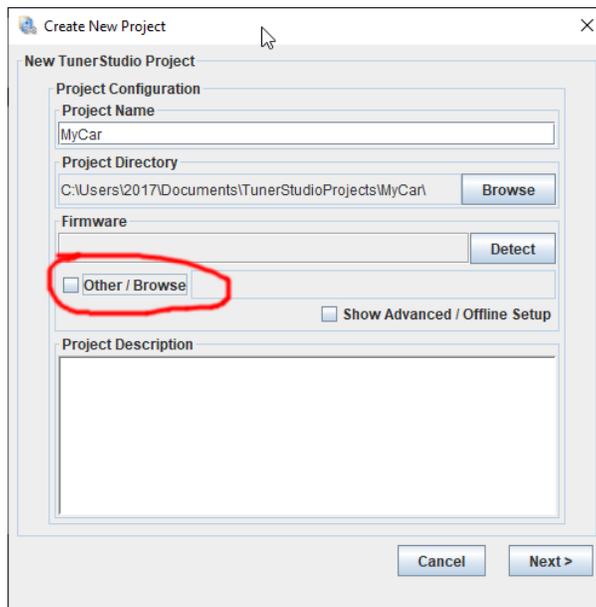
Figure 4: Browse for Definition

After clicking Next, selecting your preferred lambda display mode, and clicking Next again, you'll see this:
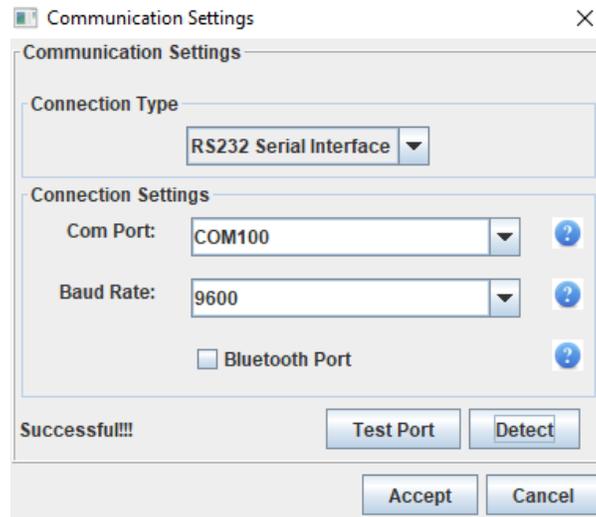
Figure 5: TunerStudio Communication Settings

See Tunerstudio Connectivity (https://wiki.rusefi.com/Tunerstudio-Connectivity) if you need detailed instructions on these settings.

Once you have compled the communications settings and clickd Next once more, TunerStudio will let you pick a Dashboard theme. If you have the free version of TunerStudio, only one option is available.

When you are done, click Finish.

With this your TunerStudio screen should come to life! You should see sensor inputs and some output values like ignition timing and dwell. If your ECU isn't connected to a car, the values displayed might not make any sense, but at least you can see that TunerStudio and your computer are communicating.

Get Running With a Plug-and-Play ECU

Warm it Up

If possible, run your car using your stock ECU to warm it up. This may make it easier to start, especially when it's cold outside.

Plug it In

Unplug your stock ECU and plug in your rusEFI ECU. It's best to leave the ECU's case open for now, so you can observe blinking lights, etc.

Power On

Turn on the ignition, but **do *NOT* start the engine!**

Connect

Connect TunerStudio to your ECU. See the TunerStudio guide (See Creating a Project on page 6) if you haven't yet created a project in TunerStudio.

Assuming the prerequisites for sensors (See Sensor Requirements on page 16) are met, your TunerStudio screen should come to life!

You should see sensor inputs and some output values like ignition timing and dwell.

If things are set up properly, you should see reasonable values for:

- Coolant Temperature (CLT)
- Intake Air Temperature (IAT)
- Battery Voltage (VBATT)
- Manifold Air Pressure (MAP/MAF) (should be near 100 kPa if you're using a MAP sensor)
- Throttle Position Sensor (TPS)

The values may show some jitters. RPMs should be 0. Push your throttle pedal and see if you get a response. Congratulations—your rusEFI ECU can "see" your car.

Calibrate the Throttle

Calibrate your throttle pedal.

1. In TunerStudio, go to "Tools" -> "Calibrate TPS".
2. Without touching the throttle, click on "Get Current" next to "Closed Throttle ADC count".
3. With the throttle wide open, click on "Get Current" next to "Full Throttle ADC count".

Save your Changes

Save (Burn) calibration to ECU.

Test Outputs

Test your outputs. Under "Controller" -> "Bench Test & Commands" you can see a lot of options for outputs you can test. Let's focus on the basic ones for now.

Spark and Fuel

First, if your car's fuel pump is controlled by the ECU, test "Fuel Pump". You should hear the fuel pump running.

Then move on to spark. Here it depends on how your car is set up. If you have a 4-cylinder with wasted spark (which is likely the majority of users), you will likely be using "Spark #1" and "Spark #3". When you click the test button, you should hear the corresponding ignition coil firing. If you can't hear the spark, you may want to pull a spark plug (or use a spare) and hook it up to the spark plug connector and ground it. Test again and you should see a spark arcing. Don't shock yourself.

Now it's time to test your injectors. Again, this depends on your vehicle. Most cars will at least have two banks of injectors. So you should definitely hear injectors firing when you're testing "Injector #1" and "Injector #2". If you have full-sequential fuel, you should try as many injectors as your engine has cylinders. **Fuel is flammable. Have a fire extinguisher nearby just in case.**

That's the basic outputs tested. With this, you should be able to get the engine to run. You can go ahead and test the other outputs as well. For example: Check Engine Light, Engine Fan, AC, Cooling Fan, etc.

Close the test window. We're getting close to starting the car.

Start it Up

If you have trouble, see Performing A First Start On A New rusEFI Install (See Performing the First Start On a New rusEFI Install on page 16) for a more complete guide.

Turn the ignition off and unplug the USB cable to remove all power sources from the unit, just to make sure we're in a defined state. Then reconnect the USB cable, turn on the ignition, wait for TunerStudio to come to life, and then crank the engine. You should see the RPMs jump to a positive value (typically anywhere between 200 and 600 RPM) and your engine should start. It may take a few cranks for RPMs to register. If you see RPMs in Tunerstudio, but the engine isn't starting, keep at it. It may take quite a bit longer than the stock ECU. rusEFI takes about two seconds of cranking before it can identify the position of the crankshaft, then it will fire the injectors and ignition coils. It may take more than ten seconds for the engine to catch, which seems like an eternity when cranking, but don't give up. There may be coughs and sputters. Play with the throttle a little, and it will start eventually. Post your findings to the forum (https://rusefi.com/forum/) and we can help!

We're done with the initial startup. Congratulations—you have your car running on your standalone aftermarket ECU! Now the fun really begins! ☺

Get Running With a Universal ECU

Summary

So you either have hardware underway, or are considering getting rusEFI hardware. This manual is intended for those that are using purchased hardware. If you are not, don't worry, we also encourage DIY and like hearing back from those that have. We also encourage people to use their purchased board as a starting point for a DIY effort; feel free to modify your board and we'll likely make suggestions on how to make your effort better.

Plan the Engine Wiring

The engine will need wires that connect to various sensors and devices. You will need crimp tools, soldering tools, and certain electrical and mechanical skills.

We suggest that you create a plan with a schematic before purchasing hardware. Even if the schematic is on a napkin, I suggest you take a picture of it with your phone or scan it in and get feedback from members in the forum. We can help steer you to a successful build.

You are going to need to know technical details about the items referenced below.

See our partial list of sensors and actuators (https://wiki.rusefi.com/Pages-Sensors-and-Actuators).

Crankshaft and Camshaft Position Sensors

 • Are they Hall-effect or Variable Reluctance (VR) sensors?

See Triggers (https://wiki.rusefi.com/Trigger)

See VVT Overview (https://wiki.rusefi.com/VVT)

Injectors

 • Is it a high or a low impedance injector?
 • What is the flow rate?

See Fuel Injectors (https://wiki.rusefi.com/FAQ-Basic-Wiring-and-Connections#fuel-injectors)

Temperature Sensors

 • Oil temperature

 • Coolant temperature

 • Air intake temperature

 • NTC sensor curves

See Temperature Sensing (https://wiki.rusefi.com/Temperature-Sensing)

Air Mass or Pressure Sensor

Does your engine have a Mass Air Flow (MAF) sensor, a Manifold Absolute Pressure (MAP) sensor, or both?

See Mass Air Flow Sensor (https://wiki.rusefi.com/MAF)

Lambda Sensor

A wide band oxygen sensor is required

See Wide Band Sensors (https://wiki.rusefi.com/Wide-Band-Sensors).

Throttle Control

See Electronic Throttle Body (https://wiki.rusefi.com/Electronic-Throttle-Body).

Idle Air Control Valve (IACV)

If you're not using an Electronic Throttle Body (ETB), you will need an Idle Air Control Valve (IACV).

See Idle Control (https://wiki.rusefi.com/Idle-Control)

Ignition Coils

See the Vault of Ignition Parts (https://wiki.rusefi.com/Vault-Of-Ignition-Parts) for a few of the ignition coils that have been used with rusEFI.

Engine Characteristics

- Total number of sensors
- Number of cylinders
- Turbocharged or natural aspiration
- Single or dual spark

ECU Connector(s)

- Number of pins
- Shape of connector

OEM connectors (https://wiki.rusefi.com/OEM-connectors)

Start Ordering Components

Once you have a plan, you can start making a bill of materials. You'll likely be purchasing harnesses, wires, connectors, and all sorts of things. You may have to do junkyard runs to get certain hard-to-obtain items, etc. If you have your rough schematic at arm's length, it will really help you know what you need and when you'll need it.

Preparing your engine

Physically Locating the Controller

Find some place that is away from hot items like the exhaust, preferably in a dry, well ventilated location, were the wires can be easily routed to and from it. Mount it on a piece of steel that can function as a heat sink.

Route the Wires and Harnesses

- Start by drawing out your engine layout. This can be as simple as a sketch on a napkin or pizza box. This is handy as it tracks how many injectors you need, what kind of IAC, TPS, IAT, etc. options you need.

- It is recommended you route your wires in two different groups, analog and digital/high power. This helps ensure good signals make it to and from the ECU.

- Wire size and fusing go together. The fuse is used to protect the wire against electrical fire. So the wire you can use depends largely on the upstream fuse you select. High-Z injectors are going to draw about 1A, so you can technically get by with tiny stuff like 24AWG or 22AWG. However that is generally not very strong and is prone to breaking and failure. So you would be well advised to follow the NFPA79's suggestion to use a min of 18AWG, as smaller is easily mechanically damaged. In terms of electrical sizing this is very much oversized, which is only suggested to get more rugged mechanical properties.

- You should always reference the MFG's specifications for the wire you are using, as different insulations have different properties. Some wire is rated for 30A in 18AWG wire, but that is some really special wire which is rated for such conditions. See this general suggestion for general fusing.

    – 18AWG, no larger than a 15A fuse
    – 20AWG, no larger than a 10A fuse
    – 22AWG, no larger than a 7A fuse
    – 24AWG, no larger than a 3A fuse Those fuse sizes are based on this table (http://www.powerstream.com/Wire_Size.htm) for chassis wiring.

- When selecting a fuse, you can use the below guide to help. Generally you choose the fuse and wire based on what the load needs. If your load is 1A capable, you need wire and fusing that can provide at least 1A. However you don't want too large of a wire as it adds costs, or the wire size might be too large for certain connectors, etc.

  Littelfuse Fuseology (http://www.littelfuse.com/~/media/automotive/catalogs/littelfuse_fuseology.pdf)

- Take note there is a fatigue issue known as I2t (That's amps squared time) which is a common reason for failures after several cycles.

- If you want to properly select a fuse, you really need a scope with a current measurement probe, then choose the I2t with the suggested method in the PDF. If you do not have such a scope, make sure to have extra fuses on hand just in case it blows a fuse some time down the road.

  Littelfuse Mini Data sheet (http://www.littelfuse.com/~/media/automotive/datasheets/fuses/passenger-car-and-commercial-vehicle/blade-fuses/littelfuse_mini_datasheet.pdf)

- Check in the forums for additional information. Often members can identify bumps in the road before you hit them. Forum members can also make suggestions that could make things go smoothly.

- If you do something cool, or new, feel free to share in the forums, Discord, Github, e-mail or wherever. It's common that someone doing something new and cool will get more help than someone doing the same old thing.

Connecting ECU if it's Not Plug-and-Play

- Start by getting junkyard ECU
- Delicately break apart the junkyard ECU, salvaging the ECU connector and perhaps the enclosure.

Figure 6: Harness on car

- If you have a connector that has a breakout PCB board for it, you probably want to obtain the breakout PCB for that harness connector. If not, you can simply solder wires directly to the connector, similarly to this forum post (http://rusefi.com/forum/viewtopic.php?f=4&t=507).
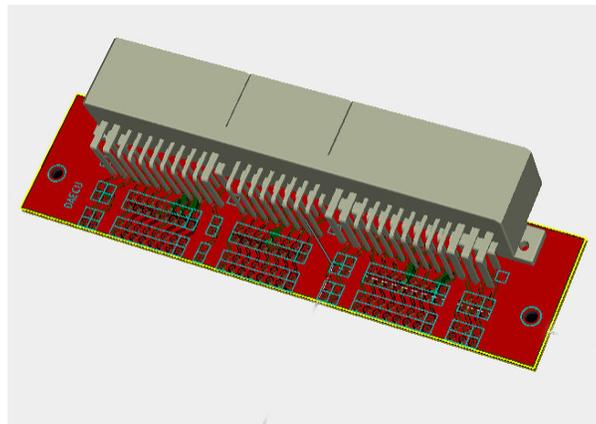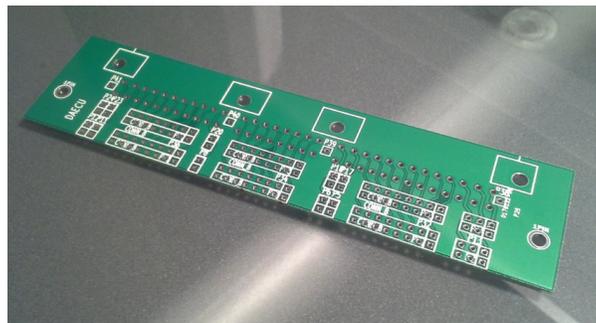

Figure 7: Breakout Render

Figure 8: Breakout PCB

- It will likely be helpful to get a partial harness from a junkyard, and switch to rusEFI circuit-by-circuit.
- Use junkyard harness to make extension harness. Use the junkyard ECU connector to break out the wire harness to the breakout board. Then from the far side of the breakout board, install the junkyard harness connector. Then connect the original ECU. This should allow you to start and run the engine as normal.

Prepare Engine Wiring

- Connect TPS, MAP, IAT, and other such analog signals to the IO board.
- Connect the 12V system / battery to the IO board connector.
- Calibrate the sensors using TS and Java console as required.
- Crank engine and see whether the RPMs are registering correctly on the Java Console.
- Connect injectors and ignition as required and see if it will start.

Test Engine Wiring

Once connected, you should test the wires. Especially the power wires like coil wires and injector wires. A poor connection with a slight resistance like .1 ohms can cause an electrical fire, which I'm sure you do not want. Once everything is connected, measure both the voltage drop and current from the ECU connector, or wherever is appropriate. Using your voltage and current readings, calculate the resistance, if it's above about .1 ohms, there is an issue. Take note that .1 ohms at 1A is about .1 watt that the connection will have to dissipate. If you have a 12 cylinder, and 12 .1 ohm connections, the connector will have to dissipate 1.2 watts.

Test Outputs

Both rusEFI Console and TS allow you to test whether rusEFI properly controls things like injectors (you would hear the clicks), cooling fan (you would hear it - if needed), fuel pump (you would usually hear it - if needed), ignition coil (that's challenging if you have a distributor).

Start Your Engine

See Performing A First Start On A New rusEFI Install (See Performing the First Start On a New rusEFI Install on page 16)

Performing the First Start On a New rusEFI Install

One of the toughest aspects of any new ECU install is the first start of a new engine. It is an issue that a lot of users find, so hopefully this comprehensive first-start guide will help by clarifying the purpose of the settings and providing some best-practice procedures.

Before you can even try to start the engine, you have to get some of the basics right:

Sensor Requirements

You must have known, good sensors with a correct calibration.

Without this you have no hope of getting things to work in the long run, so be sure you have a correct working MAP/MAF, CLT, IAT, TPS, and fuel pressure sensor if you have it.

See How to Get Running With a Universal ECU (See Get Running With a Universal ECU on page 11) for more detailed sensor requirements.

Ignition and Fuel & Injection System Requirements

Fuel Supply

You must be sure you have fuel pressure; without a working fuel pump and functional fuel pressure regulator, you are not going to get a good start up. If the engine has a returnless fuel system or a fuel pressure sensor, the same applies.

Finally, make sure there is fuel in the tank; the number one non-start issue is a dry fuel tank right up to pro-level.

Injectors and Ignition Coils

Again, you need to be sure you have the correct information on your injectors and coils; without this you won't be able to set the dead times, flow rate or dwell correctly.

Injectors and ignition coils need to be bench tested to check that each one is wired and set to the correct ECU channel. This is critical: incorrect wiring or channel setting is like having the HT leads in the wrong order. You will fuel and spark the wrong cylinders.

Cranking Requirements

The engine must be cranking well with the starter. If the engine cranks lazily, fix that first. You need a good, strong, consistent cranking speed.

Check that your throttle is correctly adjusted with its idle stop, your idle air control valve works, and your ETB config is correct for idling the engine.

See Cranking (https://wiki.rusefi.com/Cranking) for more details.

Verify Your Crank Sensor Reads the Trigger Wheel

Information on your crank trigger wheel is really really important, knowing the number of teeth on the trigger wheel and where the TDC offset is positioned is half the battle; if these are unknown then you will have to get that information before you can start your engine.

This can be done before setting anything in the ECU and should be the first test done.

To do this go into TunerStudio and disable the fuel injection and the ignition under each of the settings tabs.

Next go into the high-speed logger and simply crank the engine. The rusEFI Console is the best tool for this job as it has a really good logger in the "engine sniffer" tab.

What you should see is the top row giving grey bars that match your expected trigger pattern. If you see no grey bars, you have no trigger events, which means you need to ensure your crank sensor works and your trigger channel is correct.

Hopefully you have grey bars showing your crank pattern. If you're unsure of the pattern it makes a lot of sense at this point to take a screenshot and compare it to the list of rusEFI-compatible crank trigger patterns found in All Supported Triggers (https://wiki.rusefi.com/All-Supported-Triggers).

TunerStudio and rusEFI Console should show correct cranking RPM, usually between 150 and 300 with a fully charged battery.

See Triggers (https://wiki.rusefi.com/Trigger) for more details.

Confirm Top Dead Center (TDC) Position

Assuming you have the hardware ready to spark we now need to find the TDC position - we know trigger shape but we do not know the trigger wheel position in relation to TDC#1 (Top Dead Center, cylinder #1).

See Setting Trigger Offset (See Setting Trigger Offset on page 19)

Cranking Parameters

rusEFI has a separate cranking control strategy for your first couple of engine revolutions - usually you want more fuel, different timing, and simultaneous injection to start an engine.
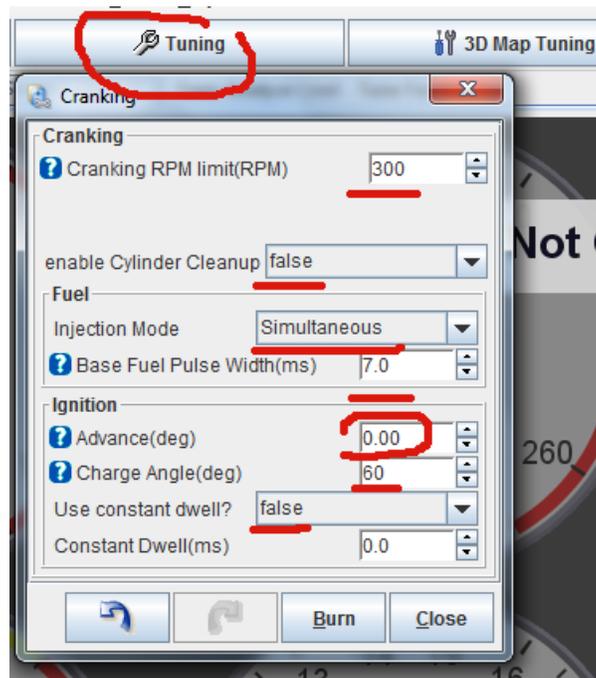

Figure 9: Initial Cranking Parameters

An engine can start rich, as long as it's not too rich and you have the cranking timing angle set close enough to the optimum. By default, cranking mode is active if RPM is below 500.

Please note that the trigger synchronization point often does not match TDC, so just try different values between 0 and 720. For example, try 0, then 20, then 40. etc.

Next Steps & Troubleshooting

Get Tuning (See Get Tuning with TunerStudio and your rusEFI ECU on page 22)

There are three ways to produce logs - the intention is for these three to have same exact data.

1. TunerStudio logging
2. SD card logging
3. rusEFI console logging

See also output_channels.txt (https://github.com/rusefi/rusefi/blob/master/firmware/console/binary/output_channels.txt)

See also Error Codes (https://wiki.rusefi.com/Error-Codes)

External Links

Fuel injectors at first start - Forum (https://www.youtube.com/watch?v=lgvt0mh_UB8)

Diagnostics and Troubleshooting of Your Engine

Basic Tests

Is the ECU properly powered and communicating with your computer?

Are the on-board LEDs lit as expected (https://wiki.rusefi.com/LED-states)?

Tests using Test Equipment

If your ECU is not reading a sensor correctly, you may need electrical test equipment to make sure that the sensor is behaving as you have told the ECU to expect. For simple sensors such as temperature sensors, a digital multimeter is all you need. For other sensors such as crankshaft and camshaft position sensors, you may need an oscilloscope.

Get Help From a Local

We provide much more info than most OEM options. If you are stuck, you may be able to get help from a local mechanic or someone local. Try asking for help in the forums; there may be a member or a club meeting that's nearby. It's common you can find local people who are willing to help.

Onboard Hardware Diagnostics

If you don't have an oscilloscope, you can connect the circuit in question to a digital or analog input of your ECU, using it as a basic oscilloscope. Record a log and you will see exactly what your ECU is seeing.

Setting Trigger Offset

DISABLE FUEL WHEN ADJUSTING TRIGGER OFFSET

FIRE DANGER

The following guide will provide a general overview of finding and setting the trigger offset value to use in TunerStudio. This is an engine-specific value, but you may be able to use another's settings as a starting point if they have a similar trigger setup on their engine. You should always make sure your trigger setting is accurate to your engine, as this value influences every other value in your tune.

This guide assumes that you have already configured your trigger (https://wiki.rusefi.com/Trigger-Configuration-Guide).

Why Do I Care About Trigger Offset?

In order for your engine to run properly, the ECU must know *exactly* where the engine is in its rotation. This is determined by your trigger solution, but there's a catch. In many cases, the trigger pattern does not properly align with the position of the engine, and this is what trigger offset is for. Trigger offset is a fixed value that tells the ECU how much the position of the trigger differs from top dead center on cylinder #1.

How do I Set My Trigger Offset?

To set your trigger offset setting, you must determine how far your ECU is from your engine position. The easiest way to do this is to use a timing light on cylinder #1 and check its position on your engine's timing marks.

1. Have a fire extinguisher ready.

2. In TunerStudio, open "Injection" -> "Injection Settings". Set "Enabled" to "false", and save the setting. In your fuse box, find and remove the fuse(s) that power your injectors. Drain the carburetors if applicable.

3. Open "Ignition" -> "Ignition Settings" and set "Timing Mode" to "fixed". Set "Fixed Timing(deg)" to a value that corresponds to a mark on your crank pulley. Zero will correspond to the TDC mark, or your manufacturer may specify different values.
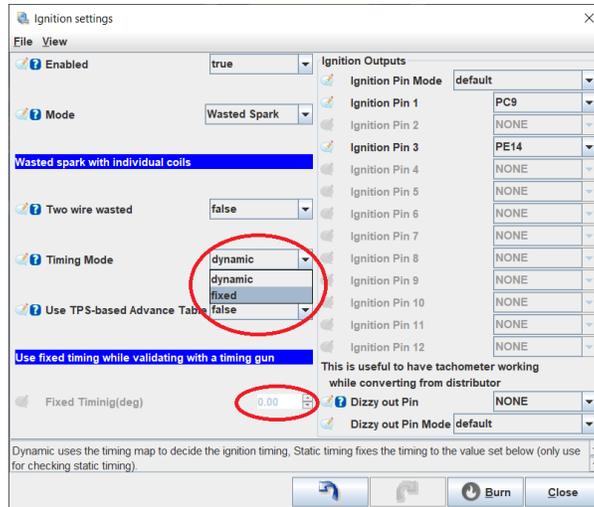
Figure 10: Fixed Timing

4. Remove the spark plugs. This will eliminate compression in the cylinders, allowing the engine to turn freely and give better results when checking timing.

5. Connect a timing light and spark plug to the #1 spark plug wire. In engines with individual coils, you may need to get creative here, such as extending the coil with a spare plug wire to give you a place to attach the timing light. Ground the threads on this spark plug somewhere on the engine.

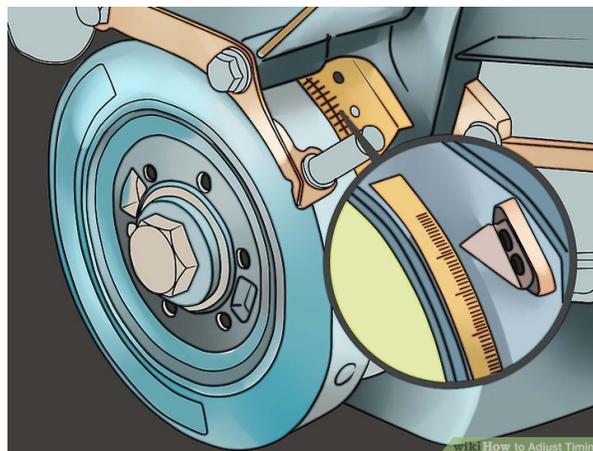6. Crank the engine, watching the position of your engine's timing marks.

Figure 11: Timing Mark

7. Adjust "Setup" -> "Trigger" -> "Trigger Angle Advance" up or down (negative values are allowed) until you get spark at TDC. This is now your trigger offset.

8. Reinstall your spark plugs, re-enable fuel, set your timing to something sensible, (manufacturer recommendations) and try to start your engine. Verify the timing again with a timing light once the engine runs, and adjust the offset if needed.

9. Change your timing mode back to "dynamic" or you will continue to run on fixed timing

and give up a ton of power and fuel economy and have some *really* high exhaust temper-
atures.

Get Tuning with TunerStudio and your rusEFI ECU

Tuning is a subject too complex to be dealt with exhaustively in a short wiki page; the purpose of this page is to give you some pointers.

This tutorial assumes that you will be using the Speed Density fuel strategy, which is good for peak power applications.

Prerequisites

- You have followed the Performing the First Start On a New rusEFI Install (See Performing the First Start On a New rusEFI Install on page 16) guide and have set your timing.
- You have gotten your engine to run, or at least sputter, using your rusEFI ECU.
- You have a PC which is running TunerStudio, and can connect it to the ECU.
- Your engine is attached to a dyno or is in a vehicle which is capable of driving on the road, track, or a dyno.
- All the main inputs and outputs needed to make an engine run are functioning correctly.

Inputs:

- Trigger Inputs (https://wiki.rusefi.com/Trigger-Configuration-Guide) (crank and cam(s))
- Manifold Air Pressure sensor*
- Coolant Temperature (https://wiki.rusefi.com/FAQ-Basic-Wiring-and-Connections#thermistors)
- Intake Air Temperature (https://wiki.rusefi.com/FAQ-Basic-Wiring-and-Connections#thermistors)
- Wideband O2 Sensor (https://wiki.rusefi.com/Wide-Band-Sensors)

*If you are using a Mass Air Flow sensor, the fuel-related sections of this guide are not for you, but other sections may be helpful.

Outputs:

- Fuel pump (if controlled by the ECU)
- Ignition coil(s) (https://wiki.rusefi.com/FAQ-Basic-Wiring-and-Connections#coils)
- Fuel Injectors (https://wiki.rusefi.com/FAQ-Basic-Wiring-and-Connections#fuel-injectors)
- Idle Air Control Valve (https://wiki.rusefi.com/FAQ-Basic-Wiring-and-Connections#idle-air-control-valve) or Electronic Throttle Body (https://wiki.rusefi.com/Electronic-Throttle-Body)

Getting the Engine to Idle

This section assumes that you have a wideband O2 sensor installed and getting reasonable readings. If your idle is rough and low, way too high, or oscillating wildly, the most likely issue is that your idle control is not set properly. Open the main idle control dialog under "Idle" -> "Idle Settings" and change the first setting to "Manual" (circled in yellow). This will allow you to manually control your idle setting. Then use the slider (circled in purple) to change your idle RPM.
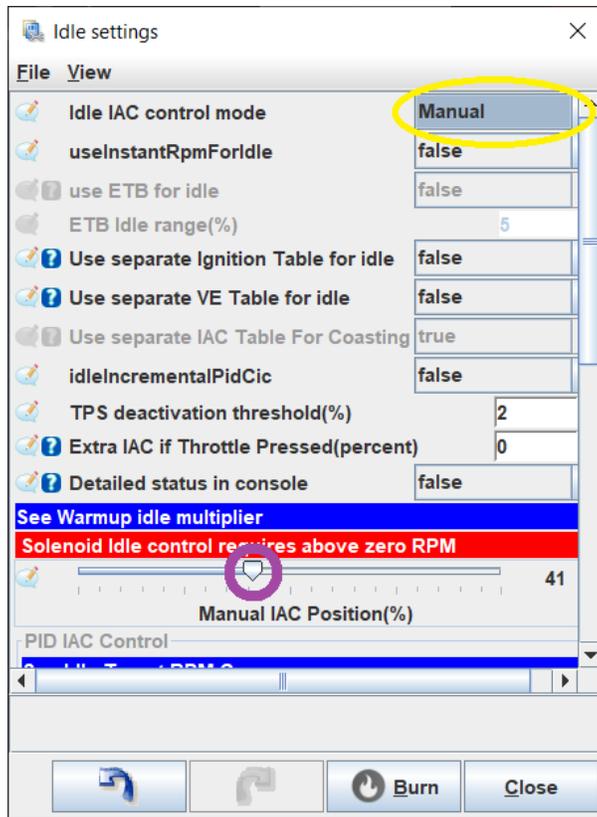
Figure 12: Idle Settings

If this doesn't do anything, chances are that your idle control has an issue and you need to do some troubleshooting of the hardware and basic settings.

Try to get your idle between 800 and 1200 RPM. Make sure it's not fluctuating much. If you can change your idle to some degree with the idle control, but can't really get it right, chances are either your engine is running with a terrible air-fuel ratio or your ignition timing is way off.

Adjusting the Idle Air-fuel Ratio

If your AFR is too high (probably > 15 for gasoline), you need to increase the amount of fuel delivered to the engine. If it's too low (typically < 10 for gasoline), you need to reduce the amount of fuel.

The quick and dirty trick is to tell your ECU that your injectors are smaller or larger than they really are. You can do this under "Fuel" -> "injection Settings" -> "Injector Settings". If you do this, remember to undo it when you are ready to properly tune your fuel table.

The proper way to achieve the correct AFR is by adjusting the Volumetric Efficiency table. Open the "Fuel" -> "VE" table. The region of this table relevant to idling is near the lower left-hand corner.
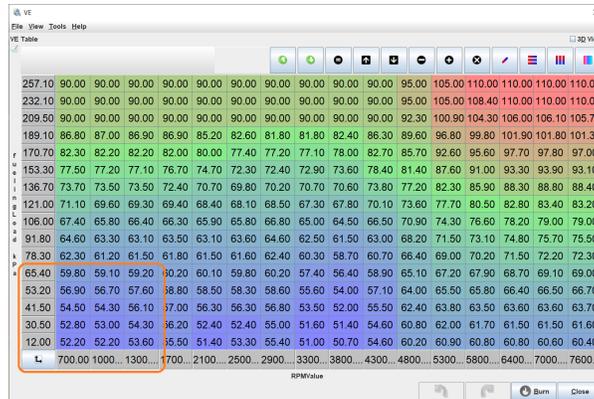
Figure 13: Idle Cells

The x-axis is RPM, and the y-axis is the engine load (typically Manifold Air Pressure or Air Mass). With the engine running, TunerStudio will display a little dot indicating which VE cell your engine is currently running in. Please note that your engine will almost never be using a value precisely in the center of a cell. It will usually interpolate between four neighboring cells. It's usually a good idea for rough-tuning to change a whole set of 3x3 cells or so at once. Maybe even 4x4 cells. We can worry about fine-tuning later. It is also recommended to use fairly significant changes for rough tuning. If the engine is running lean, add maybe 20%. If it's too rich, lean it out by 20%. Don't be shy. So, if your AFR is too high, let's say 16, mark the 9 cells around where the engine is running right now and multiply their values by 1.2. You can do this by selecting all 9 cells with your mouse and then hitting the asterisk key on your keyboard. Or, if your AFR is too low, multiply by 0.8 to reduce the amount of fuel injected by 20%. Don't worry about getting this "just right" for now. All we want is a fairly smooth idle. We don't really care if it's rich or lean. 1200 RPM and an AFR of 10.5 works.

Note that if you end up running the engine super-rich for extended periods of time, you should change the oil. You will likely have a substantial amount of fuel that has been washed into the oil. Fuel is not a great lubricant.

Fuel tuning

Some quick theory

Most people who use an aftermarket ECU are looking to get around the track faster. This section assumes you are looking for fast track times. This commonly means you are looking for minimal fuel consumption when you are maintaining or decreasing speed, then max power when you are at higher engine loads. Each person will prefer a different power vs. fuel efficiency balance at a given RPM and load. The below graphic shows how you vary horsepower as you change AFR.
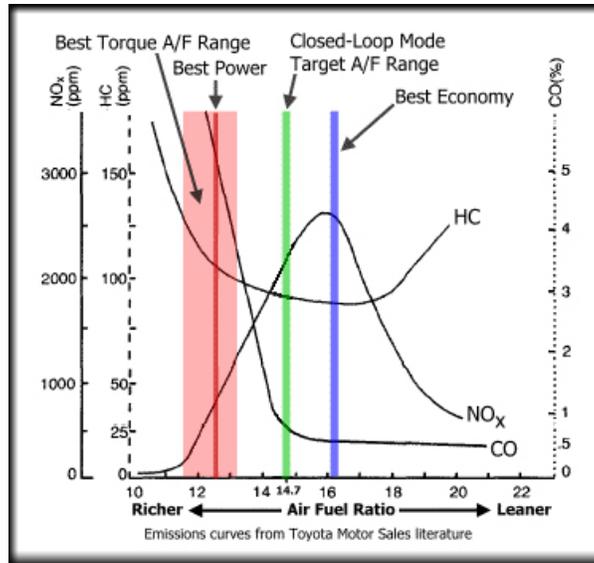
Figure 14: Airfuel emissions chart

For an example of a light load, let's say you have a V8 in a Miata and you are approaching a turn. In this scenario, you might have a load of around 20%. You don't need much power and you want to minimize fuel consumption, in order to get the most out of the fuel in the tank, so in this region your tuning table should have a target AFR of about 16. On the other hand, when you are at 80% to 100% load you likely want all the power you can squeeze from your engine. You'll want this part of the map to be something closer to 11.5 to 12.5. Between light load and wide-open throttle, you'll want a variety of AFRs based on your driving habits, race events, personal preferences, etc. You will take your best stab to guess what is the optimal way to get to the finish line fastest.

However, if you have a four-cylinder Miata, then your load under the light load scenario described above might be about 40% instead of 20%. If your four-cylinder Miata has a turbo, it could be around 30%. Different engine and vehicle combinations will require a tuning table that is adjusted differently at different points.

The tuning tables are mostly for tuning steady state conditions. There is also a bunch of tuning to deal with short-term dynamic conditions, cold engine conditions, etc. Everyone has a different tuning preference for a variety of reasons, some good, some not so good. This tutorial is going to make some suggestions; keep in mind there are going to be many different opinions and different reasons for doing things differently. This tutorial is just a suggestion, and will suggest you first start with a warm engine and tune the load table such that you get the AFRs that you are looking for, then tune the wall wetting, then tune the cold start conditions.

Manual Tuning

Open TunerStudio and guess at your VE table; it will probably look similar to the one below:
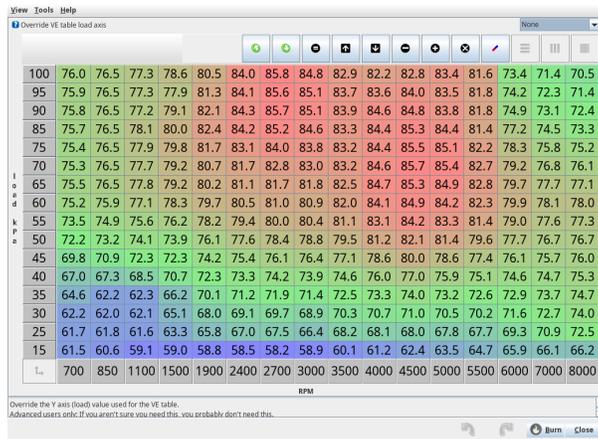
Figure 15: VE Table

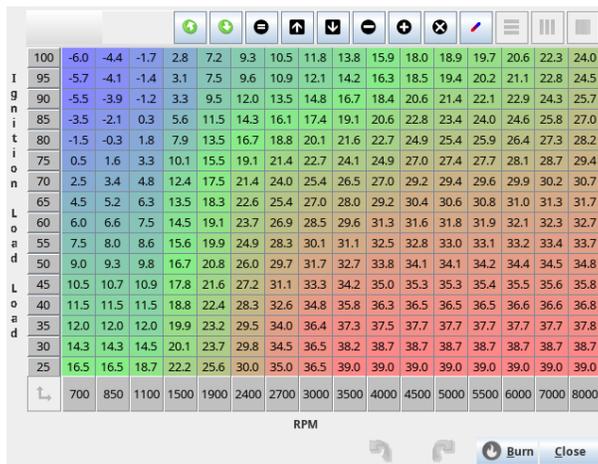Guess at your spark table; it will look something like this:

Figure 16: Ignition Advance Map

Once you have a guess that seems to keep things running, tune the fuel table by running TunerStudio and looking at your WBO2 AFR. Find a long hill, put it in high gear and put your foot to the floor. Keep adjusting the cell to keep your AFR at about 11.5 to 12.5. Doing this on a dyno is better as you don't really care about this range of AFR, you care about max power which is at an unknown AFR. Somehow adjust this for full load and keep an eye on your AFR. If you can't get the AFR in the 11.5 to 12.5 range, it likely means your fuel pump is not providing enough fuel. Once you achieve your desired AFR at full load, repeat for medium load, low load, etc, until you have a fuel table that you are happy with.

Once fuel is good, do the same with spark; adjust for max power and if possible tune with a knock sensor. If you detect knock, stop advancing, and back away by perhaps 2 to 4 degrees. Don't get too close to the absolute limit, as variations in temperature, pressure, carbon buildup, etc, could change this limit. Once spark is adjusted, go back and redo fuel, then again back to spark; keep doing this until they are both perfect.

Auto-tuning via TunerStudio

Requires a registered version of TunerStudio.

But before we get to the exciting subject of tuning, there is the slightly more boring subject of target AFRs. These are defined in the table found at "Fuel" -> "Target AFR". To start with, having a value of 14 in all cells is probably good enough.

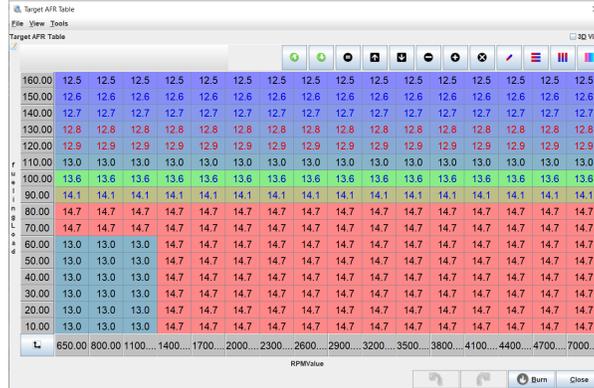You can get a bit more creative and use something like this:

Figure 17: Fancy Target AFR

Eventually, you'll want something more like this:

Figure 18: Target AFR Table

Let's talk about stoichiometry: A stoichiometric mixture of fuel and gas is where every oxygen molecule gets fully burned by the fuel and all the fuel is burned by the oxygen. So there's no excess oxygen and no excess fuel. If you have excess oxygen, the mixture is lean. If you have excess fuel, the mixture is rich. With regular gasoline, the stoichiometric mixture is about 14.7. This means you need 14.7 pounds of air to burn 1 pound of fuel. This is what a wideband O2

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sensor displays. Rich is safer than lean. Rich mixtures tend to burn more slowly and cooler. Lean mixtures burn hotter and faster, so there's more potential damage to your engine from running lean than from running rich. Also lean mixtures are more difficult to ignite than rich mixtures. While you may have trouble getting your engine to run nicely at an AFR of 15.7 (one point more than stoichiometric), your engine will run fine all day at an AFR of 13.7. All this is to say that it's better to start out too rich than to start out too lean.

The auto-tuning procedure is similar to the manual tuning method, but instead of adjusting the VE cells manually, you set the desired AFR in a table, drive the vehicle, and TunerStudio will adjust the cells to achieve the AFR that you have targeted. While it is effective, peak power can be obtained using a dyno, not by AFR measurements. Auto-tuning is great for those who don't have a dyno, but if you are looking for peak power, you really need one.

Wall Wetting Tuning

Once it's operational, you will now want to tune the dynamics in order to achieve faster throttle response.

Cold Temperature

Once it's working well and reacts well to quick changes in throttle, you'll want to tune cold temperature enrichments so that it starts nice and easy.

See Also

- Fuel Overview (https://wiki.rusefi.com/Fuel-Overview)
- Ignition (https://wiki.rusefi.com/Ignition)
- Idle Control (https://wiki.rusefi.com/Idle-Control)
- Some tips on the rusEFI Forum (http://rusefi.com/forum/viewtopic.php?f=2&t=1124&p=21278)

Share your tune

Take Notes and Collect Information

We all benefit from sharing the tune, so we would like to suggest that you share it. Sharing your tune allows others to find issues with it or use it as a starting point for their own tunes. By sharing your tune, we can better help you when you are doing your initial configurations. Your tune isn't something you need to protect by keeping it secret, so share it with the world and we all can benefit!

rusEFI Online (https://wiki.rusefi.com/Online) is our preferred tune upload location.

Take notes about your setup, preferably including whatever parameters you can provide, for example:

- Intake components
- Exhaust
- Cam
- Pistons
- Geographical location