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).

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.
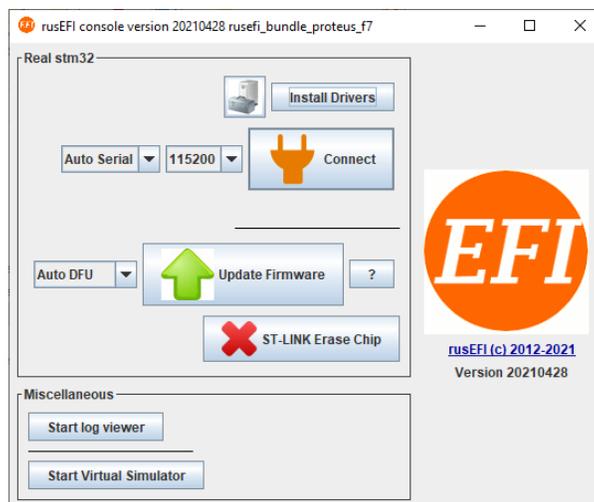
Figure 1: console

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 & Play ECU

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

Tuning

Get Tuning (See Get Tuning with TunerStudio and your rusEFI on page 20)

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 screen shots 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 instrucions, 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)

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"*.
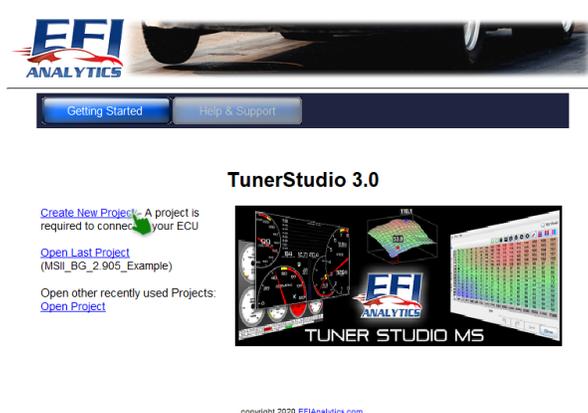
Figure 2: First Project

TunerStudio needs an ECU Definition file (usually with .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.
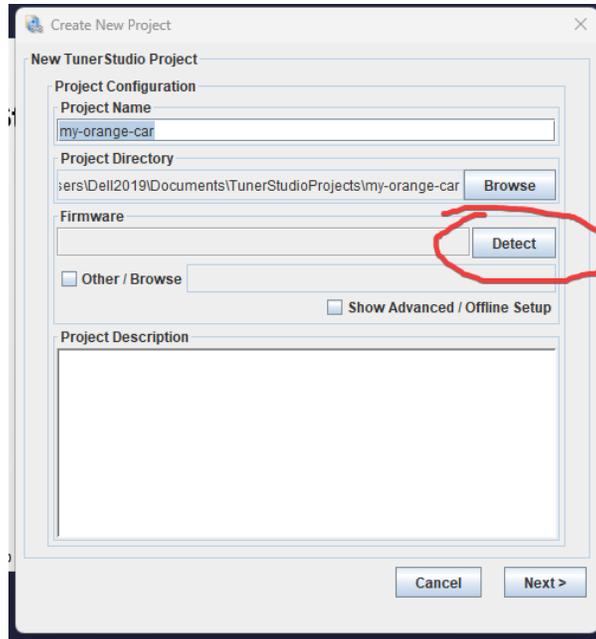
Figure 3: TunerStudio Detect Button

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.
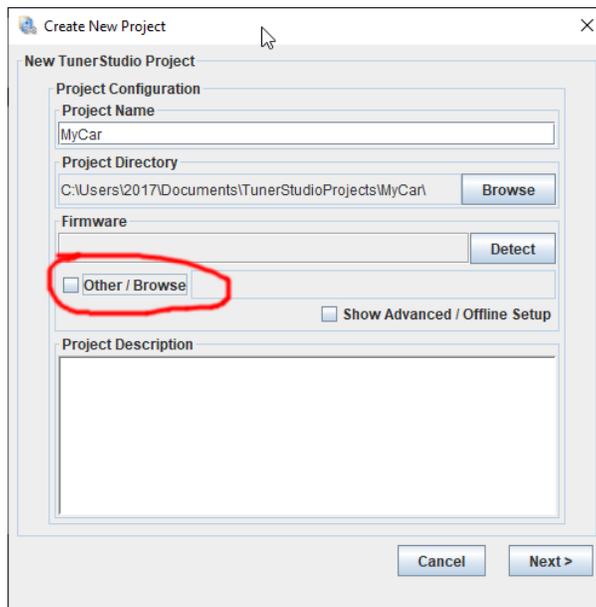
Figure 4: Browse for Definition

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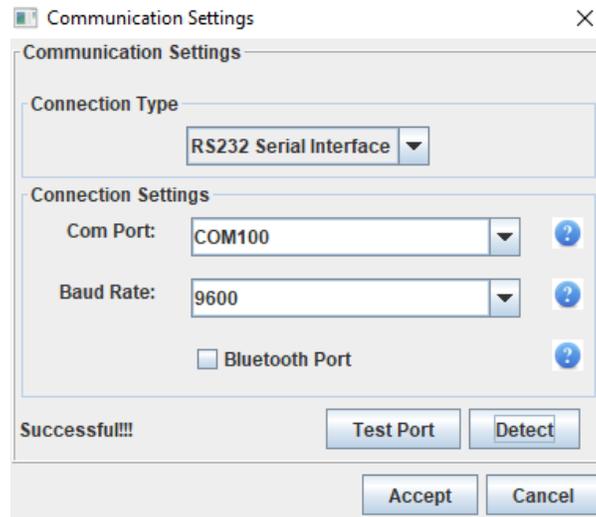
Figure 5: TunerStudio Communication Settings

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 & Play ECU

Warm it Up

If possible, run your car on 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 (BV)
- Manifold Air Pressure (MAP/MAF) (should be near 100kpa 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 near by 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. Like Check Engine Light. Engine-Fan, AC, AC-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 A 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 under way, 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 the purchased boards as a starting point for a DIY effort, feel free to modify the board 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 before you purchase hardware, that you create a plan with a schematic. Even if the schematic is on a napkin, I suggest you take 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 below referenced items.

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

Crankshaft and Camshaft Position Sensors

   • Are they Hall 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/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 junk yard runs to get certain hard to obtain items, ect. If you have your rough schematic at arms length, it will really help you know what you need and when you'll need it.

Preparing your engine

Physically Locating the Controller

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

Route the Wires and Harnesses

- Start by drawing our your engine layout. This an 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, ect 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 over sized, 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 insulation's 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 to 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 where ever. 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 junk yard ECU
- Delicately break apart the junk yard ECU salvaging the ECU connector and perhaps the enclosure.

Figure 6: Harness on car

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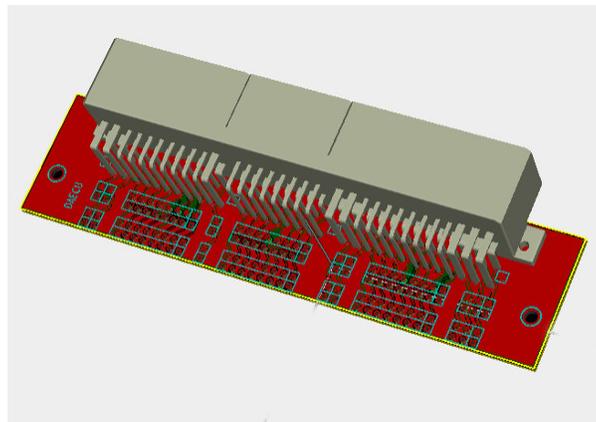

Figure 7: Breakout Render
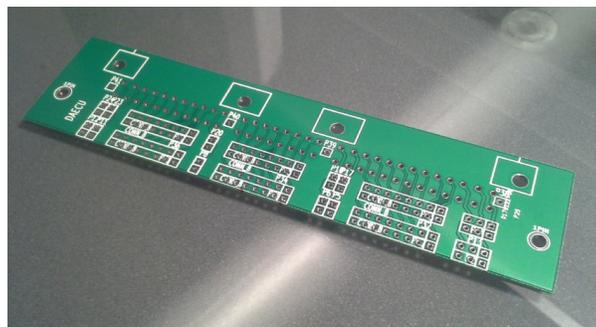
Figure 8: Breakout PCB

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

Prepare Engine Wiring

- Connect TPS, MAP, IAT, and other such analog signals to the IO board.
- Connect 12V system / battery to the IO board connector.
- Calibrate the sensors using TS and Java console as required.
- Crank engine and see RPM's are registering correctly on the Java Console.
- Connect LED to pins TODO, which will blink at TDC. Verify that TDC is correct by shining on a crank wheel like a timing light. PS: actually right now we do not have this - see this issue (https://github.com/rusefi/rusefi/issues/297) and this issue (https://github.com/rusefi/rusefi/issues/2732) and this issue (https://github.com/rusefi/rusefi/issues/3120)
- 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 where ever is applicably appropriate. Using your voltage and current readings, calculate the ohms, if it's above about .1 ohms fix the issue. Take note that .1 ohms at 1A is about .1watt that that connection will have to dissipate. If you have a 12 cyl, 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 if 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 A First Start On A New rusEFI Install on page 16)

Performing A 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 a lot of users find, so hopefully this comprehensive first start guide will help but 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 is a dead head fuel line or has a fuel pressure sensor then the same applies and I will address that in the correct section as they are special cases.

Finally, make sure there is fuel in it, 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 wont 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, or 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 up.

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 then you have no trigger events, this means you need to check your crank sensor works or your trigger channel is correct.

Hopefully you have grey bars showing your crank pattern. If your unsure of the pattern it makes a lot of sense at this point to grab a snapshot of the screen 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 your 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).

Set cranking advance angle to zero for now. Use a timing gun while cranking. We now need to try different values of Engine->Trigger->global trigger angle offset until we get spark at zero advance - that's because we might know the relation between TDC#1 and trigger signal.

On Engine Sniffer tab of rusEFI console TDC#1 is shown with the green vertical line.

Cranking Parameters

rusEFI has 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.
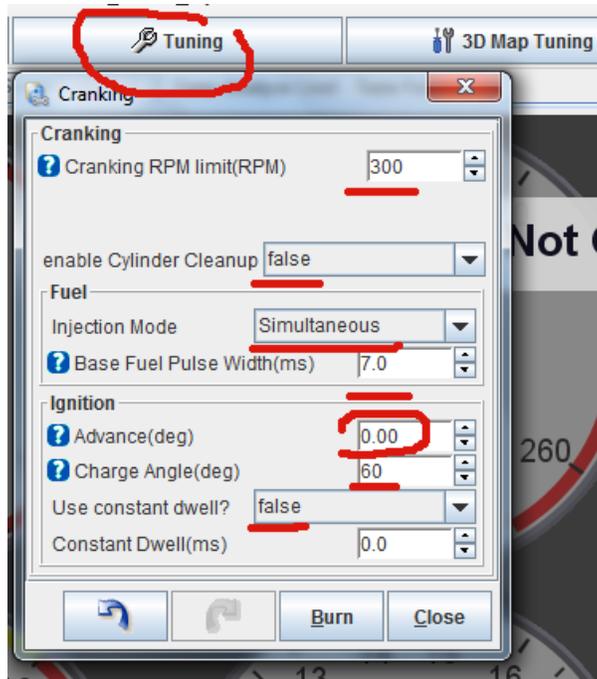
Figure 9: Initial Cranking Parameters

Engine would start rich, as long as it's not too rich, as long as you have close-enough cranking timing angle. By default, cranking mode is active if RPM is below 500 RPM.

Please note that 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. Use `showconfig` to see current setting.

Running Parameters

For first run I suggest running based on MAF sensor - even if you do not have MAF sensor, and flat maps.

Once plain MAF works next step is running with proper MAP sensor calibration & flow rate setting.

Next Steps & Troubleshooting

Get Tuning (See Get Tuning with TunerStudio and your rusEFI on page 20)

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?

See Troubleshooting (https://wiki.rusefi.com/Troubleshooting).

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 it to. For simple sensors such as temperature sensors, a digital multi-meter 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 near by. 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.

Get Tuning with TunerStudio and your rusEFI

Prerequisites

This section assumes

- You have hardware connected to an engine.
- You can connect to the rusEFI board with a USB cable, or some communications stream.
- You have a PC which is running Tuner Studio, and can connect it to the board
- You have calibrated the sensors like TPS, MAP, crank decoder, etc
- WO2 or tail pipe probe to measure your AFR or HP.
- This tutorial assumes that you want speed density, which is good for peak power applications and it's assumed you are tuning the load tables.

Fuel tuning

Some quick theory

Most people who do the after market 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 speed or decreasing speed, then max power when you are at higher engine loads. Every person will be differ in what RPM and loads they want power vs fuel efficiency. The below graphic shows how you vary horse power as you change AFR.
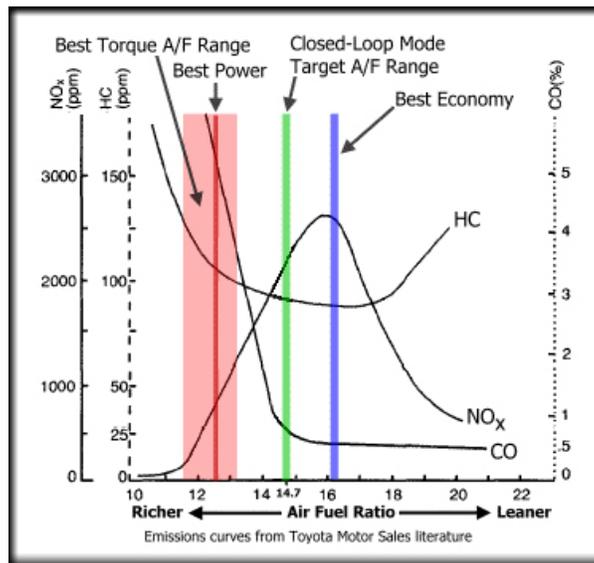
Figure 10: Airflow chart

If you have a V8 in a Miata, and you need a lite load perhaps like when approaching a turn, you might have a load around 20%. At this point you have enough power and you want to minimize fuel consumption. Such that you get the most out of the fuel in the tank. Then when you are say 80% or 100% load you want maximum power, as you do not have enough power and you want every Hp you can get. So your tuning table around the 20% would be tuned to have an AFR around 16, while when at 100% load your tune will be tuned for something closer to 11.5 to 12.5, and a variety of AFRs based on your driving habits, race event, personal preferences

etc. You will take your best stab to guess what is the most optimal way to get to the finish line fastest.

However if you have a 4 cyl Miata, then your load under the same conditions as noted above would be about 40% instead of 20%, which means your tuning table will be adjusted differently at different points. As well if you have a 4 cyl Miata with a turbo, you might be at around 30% under these same conditions.

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

Quick version

Manual tuning via TS

Open TS, and guess at your fuel table, it will probably look similar to the below.
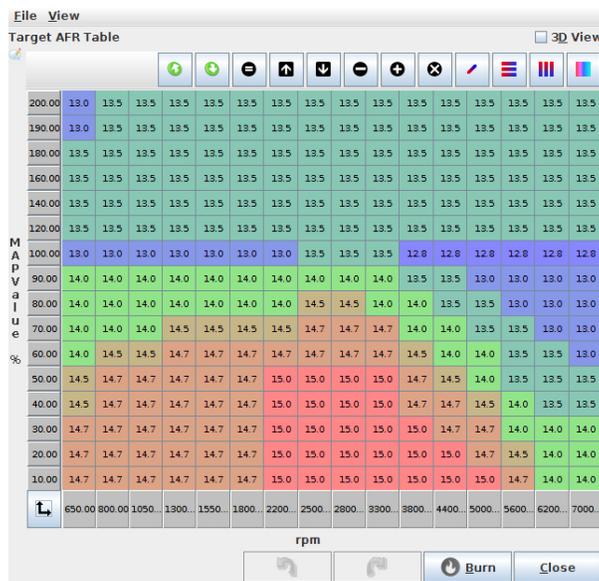
Figure 11: Target AFR chart

Guess at your spark table it will look something similar to this

[insert picture]

Once you have a guess that seems to keep things running, tune 100% by running TS and looking at your WO2 AFR, find a long hill put it in high gear and put your foot the the floor. Keep adjusting the cell to keep your AFT 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 HP which is at an unknown AFR. Some how adjust this for full load and keep an eye on your AFT. If you can't get the AFT in the 11.5 to 12.5 range, it likely means your fuel pump is not providing enough fuel. Once you

know full load, do this for medium load, low load, etc, until you have a fuel table that you are happy with.

Once fuel is good, then do the same with spark, again 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 to close to the absolute limit, as variations in temperature, pressure, carbon build up, etc could change this limit. Once spark is adjusted, go back and re-do fuel, then again back to spark, keep doing this until they are both perfect.

Auto tuning via TS

This requires a resisted version of TS. The general procedure here is similar to the manual tune method, but you set the desired AFR in a table drive it around and TS will adjust the cells to get the AFR that it's commanded to get to. While is is effective, peak power can be obtained via dyno, not by AFR measurements, so this is great for those that don't have a dyno, but if you are looking for peak power, you really need a dyno.

Wall wetting tuning

Once it's operational, you now want to tune the dynamic such that you get faster throttle response. TBD

Cold temperature

Once it's working well and reacts well to quick changes in the long pedal, you'll want cold temperature enrichments such that it starts nice and easy. TBD

See Also

- Fuel Overview (https://wiki.rusefi.com/Fuel-Overview)
- Ignition (https://wiki.rusefi.com/Ignition)
- Idle Control (https://wiki.rusefi.com/Idle-Control)
- this forum thread (http://rusefi.com/forum/viewtopic.php?f=2&t=1124&p=21278)

Share your tune

Take notes and collect information

We all benefit from from sharing the tune, so we would like to suggest you share it. By sharing it others may notice issues with your tune, as well it can function as a starting point for other which you have likely used when you did your tune. By sharing your tune, we can better help people when they are doing their initial configurations. After all it's not like your tune is something you need to protect and can't share, so we would find it nice if you were to share your tune.

Take notes about your setup, preferably including what ever parameters you can provide, like what you have for intake components, exhaust, CAM, pistons, geographical location, ect. We hope to have a web page form that can be used to simplify the process. For now, we hare hoping you can post it in the forum, or e-mail it to a developer.

Post on forum or e-mail the tune

Find the forum sub section where people are sharing tunes, then fill out your posting the with the suggested XYZ format. At the time of writing this most of this tuning sharing stuff new and pre-alpha.

Obviously tuning is a subject too complex to be dealt with exhaustively in a short wiki page. So all we can do here is give you some pointers. At this point we assume that you got the engine to run, or at least sputter using your rusEFI. All your main inputs and outputs needed to make an engine run OK are working.

This should be at least: Inputs:

- Trigger Inputs (crank and cam or cams)
- Mass Airflow Meter* or Manifold Air Pressure sensor
- Coolant Temperature
- Intake Air Temperature
- Wideband O2 sensor would be really great to have too

*Using a Mass Airflow Meter assumes that you have a known MAF transfer function for your specific Mass Airflow Meter

Outputs:

- Fuel pump (if controlled by ECU)
- Ignition coil(s)
- Fuel Injectors
- Idle Air Valve or other Idle Air Controller

Now we need the engine to idle acceptably, so we can check base timing. If your engine idles fine and your Air-fuel-ratio is within the acceptable range (let's say between 11 and 15 or so), continue to the base timing section.

Getting the engine to idle

This section assumes that you have a wideband O2 sensor installed and you get readings that make some sort of sense. If your idle is just rough and low, or way too high, or maybe oscillating wildly, the most likely issue is that your idle control is not set right. Open the idle control main 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.
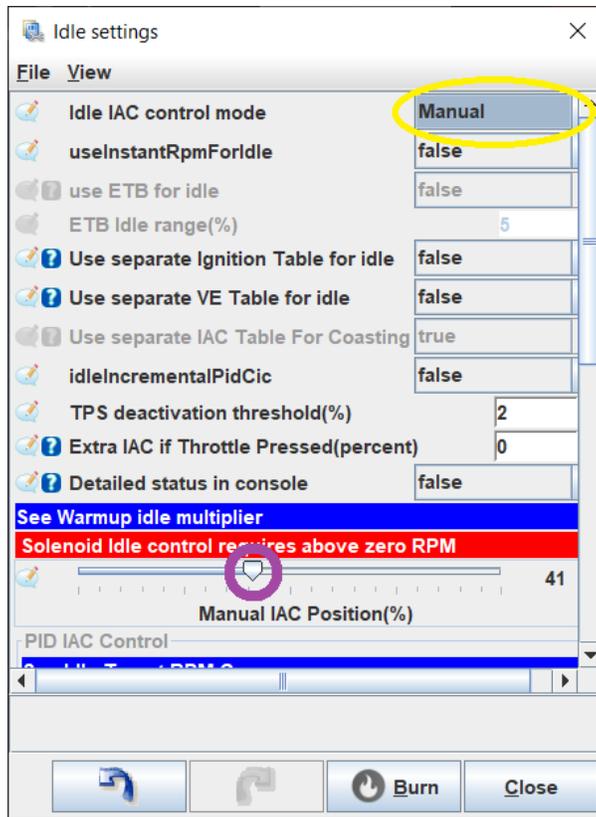
Figure 12: Idle Settings

(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 of basic settings). Try and get your idle to between 800 and 1200 rpm or so. 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 possibly your ignition timing is way off.

Adjusting 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. The quick and dirty trick is to tell your ECU that your injectors are smaller than they really are. You can do that under "Fuel" -> "injection Settings" -> "Injector Settings". Alternatively, if your AFR is too low (typically < 10 for gasoline), you need to reduce the amount of fuel delivered. So the quick and dirty trick is to cheat and tell the ECU that the injectors are bigger than they actually are. If you use this, make sure to remember to undo it when you are ready to properly tune your fuel table.

You can also adjust the AFR the proper way by adjusting the Volumetric Efficiency. Open the "Fuel" -> "VE" table. The area on the left side, towards the bottom contains the cells that are used in the calculation for how much fuel is to be injected with each cycle when idling.
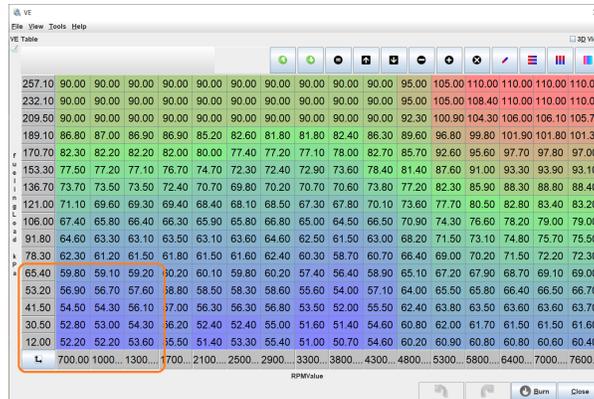
Figure 13: Idle Cells

The x-axis is your rpm, the y-axis is your 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 4 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 abotu 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 too rich, or too high. 1200rpm and an AFR of 10.5 works. Just don't run it like that for 5 hours*.

(* if you've been running the engine super-rich for extended periods of time, change your oil. You will likely have a substantial amount of fuel that has been washed into your oil now. Fuel is not a great lubricant)

Adjust base timing

Now that you have a somewhat smooth idle, it's time to adjust your base timing. In order to do this, you must have some sort of timing mark on your crank pulley and some pointer on the engine block. You need to know what the ignition timing is, when the two are lined up.

Figure 14: Timing Mark

We are working on the assumption that your ECU has a "safe" spark advance tune already uploaded. This would be a tune that allows the engine to run reasonably well with 93 Octane (US super) fuel without excessive detonation (ping) or pre-ignition, but is not yet optimized for hp or economy.

Borrow your neighbor's timing light and hook it up, following the original instructions for the timing light that your neighbor kept carefully locked away and absolutely grease-free for the last 25 years. Chances are, if the engine is running smoothly, you are within +/- 25 degrees of where you are supposed to be.

In order to get this just right, you need to change your timing from "dynamic" to "fixed". Open "Ignition" -> "Ignition Settings" and set "Timing Mode" to "fixed". Set the "Fixed Tinming(deg)" to whatever the value is when the mark on your crank-pulley lines up.
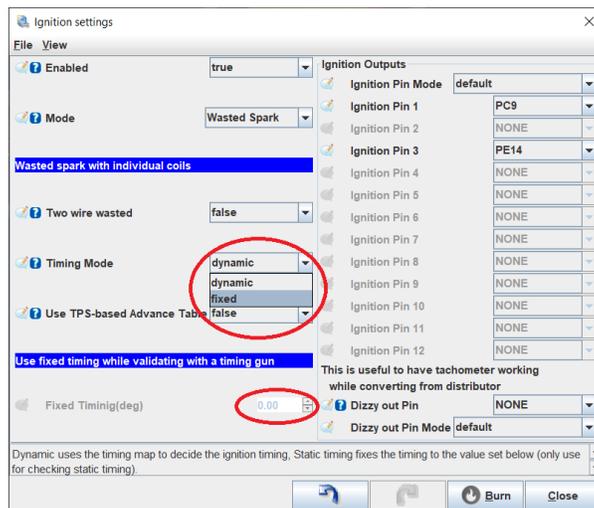
Figure 15: Fixed Timing

This is very often 10 degrees or something thereabouts. Now check with your timing light if the marks line up. If they do- great. Your base timing is set. Go ahead and change your timing mode back to "dynamic". If the marks don't line up, you need to adjust your trigger settings. Go to "Base Engine" -> "Trigger" and adjust "Trigger Angle Offset(deg)" until your timing mark

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lines up. Once this is done, don't forget to change your timing mode back to "dynamic" or you will continue to run on fixed timing and give up a ton of horsepower/fuel economy and have some REALLY high exhaust temperatures.

Time to Tune your VE table with TS AutoTune

This is assuming that you are using the purchase version of TunerStudio with Autotune enabled. If you are planning on tuning your fuel table manually, you probably know what you're doing and don't need to read this wiki.

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 aptly named target AFR table. Go to "Fuel" -> "Target AFR" and to start with having a value of 14 in all cells is probably good enough. Or you can go a bit more creative and use something like this.

| Load	650.00	800.00	1100...	1400...	1700...	2000...	2300...	2600...	2900...	3200...	3500...	3800...	4100...	4400...	4700...	7000...
160.00	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
150.00	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
140.00	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7	12.7
130.00	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8	12.8
120.00	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9	12.9
110.00	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
100.00	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6	13.6
90.00	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1	14.1
80.00	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
70.00	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
60.00	13.0	13.0	13.0	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
50.00	13.0	13.0	13.0	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
40.00	13.0	13.0	13.0	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
30.00	13.0	13.0	13.0	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
20.00	13.0	13.0	13.0	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7
10.00	13.0	13.0	13.0	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7	14.7

Figure 16: Fancy Target AFR

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 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 mixture. 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.

Now we are assuming at this point that your engine is at least idling and you can hopefully keep it alive if you give it some throttle. Maybe it even runs alright through most of the normal operating range. This would be the case if you received a fuel base map from some engine that is at least similar to your engine.