Piggyback Tuning

Piggyback tuning is the process of adjusting the operation of a stock engine management system to make a modified engine run properly. Piggyback tuning involves some type of hardware that is used in addition (piggyback) to the stock Electronic Control Unit (ECU). The other widely used methods for tuning modified engines are ECU reprogramming and stand-alone engine tuning where the stock ECU is replaced with an aftermarket unit.

ECU reprogramming is a very effective way to tune an engine. It involves changing map tables and control registers to directly adjust ECU operation and the tune of the engine. Reprogramming has the advantage that it does not require any additional hardware and does not alter any wiring. Reprogramming is well suited for stock engines or engines with well defined modifications. It is not always an option. In many cases a reprogramming solution is not available, or undesirable due to warranty concerns. Most manufacturers will void the powertrain warranty if the ECU has been reprogrammed. A common problem with late model vehicles is that dealerships frequently reprogram vehicles when they come in for service as new versions of ECU software are released. When this happens, the aftermarket tune is lost.

Stand-alone systems offer the highest level of flexibility and versatility. This comes at a relatively high cost. Stand-alone ECUs are expensive. There is also considerable additional cost in sensors, wire harness and tuning. Stand-alone tuning is generally used in off-road and racing applications. Modern street cars have too many interconnected modules to make a stand-alone ECU practical. Stand-alone ECUs lack support for the OBDII diagnostic port and do not meet emission requirements for operation on public roads.

What Piggyback Tuning Can Do

There are many cases where piggyback tuning is the best solution. Piggyback tuning can be used to change ECU inputs and outputs to achieve the desired results. Mass air flow (MAF) sensor signals can be changed to adjust fuel mixture and compensate for larger injectors. Crank and cam sensor signals can be delayed to retard timing in boost as needed to avoid detonation. Manifold Absolute Pressure (MAP) sensor signals can be clamped to avoid fuel cut on supercharged and turbocharged engines. The injector pulse-width can be changed to add or take away fuel. This short list gives just a taste of what can be done.

Piggyback tuning can be used on stock engines to optimize performance. In many cases, manufacturers run a very rich fuel mixture at wide open throttle and higher RPM. One of the reasons for doing this is to cool the cylinder temperature and prolong engine and catalytic converter life. Often the mixture is so rich that a gain of ten horsepower can be realized by just leaning out the mixture to a normal optimum 12.5:1 Air Fuel Ratio (AFR).

Piggyback tuning has application on engines with mild modifications like a cold air intake, free-flowing exhaust and lightweight flywheel. In many cases these modifications are unique to an individual vehicle. Unique modifications don’t lend themselves to a one-size-fits-all chip tune or re-flash. A programmable piggyback calibrator can be a very effective way to get the most out of mild engine modifications.

Piggyback tuning can be very effective in tuning aftermarket turbo and supercharger applications. Piggyback methods are widely used to compensate for larger injectors, keep signals within their normal range, retard timing as needed and adjust for the correct AFR in boost. Applications with boost up to 14 psi and even higher can be served effectively using piggyback techniques.

Load sensor calibration can be used to make larger injectors work that are as big as double the size of stock injectors. For even higher fuel requirements, piggyback controllers can be used to control additional injectors. High boost, high horsepower engines can be fueled with an additional injector per cylinder.

What Piggyback Tuning Can't Do

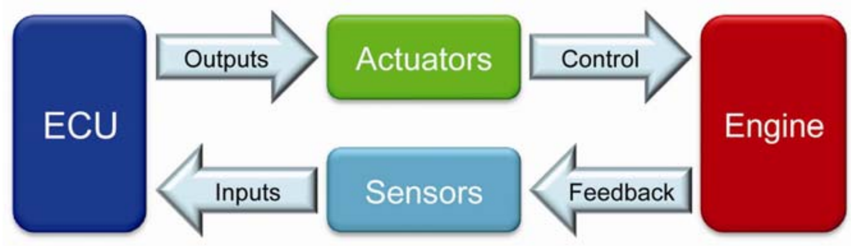
There are things that piggyback tuning can do and things that it can't. The essential limitation is that you are constrained by working within the limitations of the stock engine management system. For example, if the ECU is in closed loop and you try to change the fuel mixture, the ECU will do everything it can to restore its target mixture. This in turn can be overcome by altering the O2 sensor feedback to the ECU. Changes to the O2 sensor readings must be done in a way that readings stay within their normal range and continue to respond to fuel mixture changes.

The main limitation when adjusting sensor signals is to keep them within their normal range. For example it is common for a MAP sensor to have a maximum reading of 4.6 V. ECU programming is often set to generate a fault if the reading is greater than 4.7 V. That means that when you reach 4.6 V on a MAP sensor signal, it's game over. You can't add fuel at that point by simply increasing the reading. In fact you are more likely to induce fuel cut.

Beyond keeping signals within their normal operating range, you must keep signals within their range of plausibility. ECUs are programmed to expect a range of readings from an MAF sensor given a certain TPS reading. If the MAF sensor deviates outside the expected value range, the ECU will set a fault. This means you can't just do whatever you want when doing piggyback tuning. You have to operate within the limits that the ECU gives you.

The Engine Management System

Figure 1 shows a basic block diagram of the engine management system. The ECU operates as an integral part of the entire system. It takes in inputs from sensors that provide critical information about the engine such as coolant temperature, air temperature, barometric pressure, throttle position, air flow and crank position. These inputs determine the current operating conditions. Based on these conditions and the programmed response, the ECU generates the appropriate outputs to various actuators. The ignition coils, fuel injectors, idle air valve and other assorted solenoids and switches control the physical processes in the engine.



The ECU is part of a closed loop control system. Outputs and inputs can be modified to tune the engine.

Figure 1 Engine Management System

Piggyback calibration can be used on either the inputs or outputs of the ECU. For example, the MAF sensor signal input can be adjusted to change injector pulse-width. Fuel can also be adjusted by intercepting the injector drive signals and changing the pulse-width directly. There are pros and cons to each approach. Adjusting the MAF can be accomplished by intercepting a single signal versus multiple signals for each injector. On the other hand, intercepting the injector drive signals provides direct control while changing the MAF reading is a more indirect method that is limited by ECU programming.

Piggyback Signal Calibration

The reading from the primary load sensor can be modified in order to achieve the desired change in fuel mixture. In most cases this will be a mass air flow (MAF) or manifold absolute pressure (MAP) sensor. In some cases, some other sensor such as the throttle position sensor (TPS) may be used. As load on the engine increases, the signal from the primary load sensor increases.

It is possible to tune the engine by altering the load signal in a precise way for all the different possibilities of load and RPM. Figure 2 shows a theoretical fuel map for an engine. The axes for the map table are load and RPM. The map contains numbers that represent the on-time in milliseconds. These numbers are not actual numbers that would be used to run an engine. They are calculated based on the total amount of time for one cam revolution.

These numbers are based on the time for a complete engine cycle at different RPMs. The actual pulse-width will be less than these numbers. Actual injector duty cycle rarely exceeds 80%.

LOAD (%) →

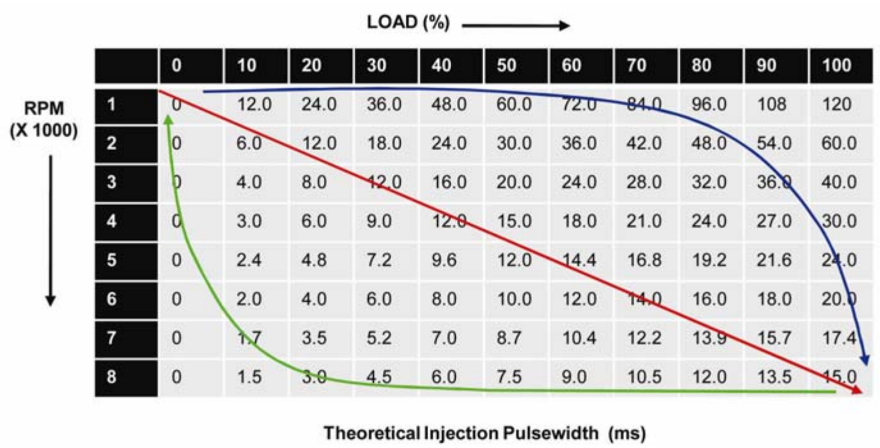
RPM (X 1000) ↓	0	10	20	30	40	50	60	70	80	90	100
1	0	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108	120
2	0	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
3	0	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
4	0	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
5	0	2.4	4.8	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0
6	0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
7	0	1.7	3.5	5.2	7.0	8.7	10.4	12.2	13.9	15.7	17.4
8	0	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0

Theoretical Injection Pulsewidth (ms)

The numbers in the 100% column are based on 100% injector duty cycle at indicated engine RPM. At 8,000 RPM, the cam rotates 360° in 15 ms. Actual injector duty cycle will generally not exceed 80%.

Figure 2 Theoretical Injection Map

In figure 3, a load trace is shown in red diagonally across the table. This trace roughly describes the path that would be followed if you were to gradually squeeze on the throttle and reached wide open throttle (WOT) at 8,000 RPM. As you travel along the diagonal trace, the pulse width increases from zero to 15.0 ms. For comparison, the blue trace shows the path you would trace by applying WOT from a low RPM. The green trace shows the path if you lift the throttle abruptly from 8,000 RPM.

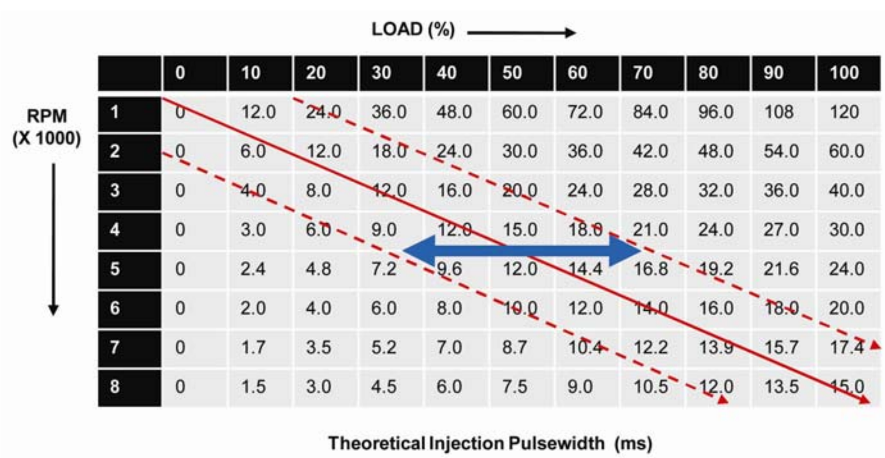


RPM (X 1000) \ LOAD (%)	0	10	20	30	40	50	60	70	80	90	100
1	0	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108	120
2	0	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
3	0	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
4	0	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
5	0	2.4	4.8	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0
6	0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
7	0	1.7	3.5	5.2	7.0	8.7	10.4	12.2	13.9	15.7	17.4
8	0	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0

The blue trace shows WOT from low RPM. The green trace shows a throttle lift from high RPM. The red trace shows progressive application of throttle with WOT at 8,000 RPM.

Figure 3 Map Traces for Various Throttle Inputs

Piggyback calibration can be achieved by varying the load reading to the ECU. Figure 4 shows an example range of adjustment. At any given RPM the fuel can be varied by changing the load reading to the ECU. The horizontal blue arrow shows the range of pulse width that can be achieved.



RPM (X 1000) \ LOAD (%)	0	10	20	30	40	50	60	70	80	90	100
1	0	12.0	24.0	36.0	48.0	60.0	72.0	84.0	96.0	108	120
2	0	6.0	12.0	18.0	24.0	30.0	36.0	42.0	48.0	54.0	60.0
3	0	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0
4	0	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0
5	0	2.4	4.8	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0
6	0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0
7	0	1.7	3.5	5.2	7.0	8.7	10.4	12.2	13.9	15.7	17.4
8	0	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0

The fuel mixture can be precisely controlled by varying the load signal input to the ECU for every combination of load and RPM. Fuel is adjusted by moving around on the stock map table.

Figure 4 Piggyback Fuel Calibration Range

In this example the pulse-width is 12 ms at 5,000 RPM and can be adjusted from roughly 7.2 ms to 16.8 ms by varying the load signal by ±20%. While this example is based on theoretical numbers, it illustrates how varying a load signal can be used to change the amount of fuel delivered to the engine and the resulting AFR. When piggyback tuning by varying a load signal, what you are really doing is moving around on the stock map table. When doing this, you are fundamentally limited by the range of injector pulse width that is programmed into the stock

ECU. For example, if the programmed injector pulse-width at a given RPM is only capable of reaching a 65% duty cycle, that is the maximum duty cycle you can get. This means you have to work within the range that the stock ECU gives you.

Load sensor adjustment is frequently used to compensate for larger injectors. At light load when the new injectors deliver too much fuel per stock programming, the load signal can be shifted to read a lower load which results in a shorter injector pulse-width.

There can be unintended consequences when doing piggyback tuning. The most important area of concern is ignition timing. In the process of adjusting the fuel mixture it is possible to change the load signal in a way that advances timing. In the extreme case, this can lead to engine damage. Figure 4 shows a theoretical timing map. Consider the same variation in load that was used in Figure 3 to adjust AFR and you see a substantial variance in ignition timing from roughly 25 to 35 degrees of advance. This is why calibrators for use in forced induction applications with larger injectors have the ability to retard timing as well as adjust fuel.

LOAD (%) →

RPM (X 1000) ↓	0	10	20	30	40	50	60	70	80	90	100
1	20.8	20.0	19.2	18.4	17.7	16.9	16.1	15.3	14.6	13.8	13.0
2	26.2	25.0	23.8	22.6	21.3	20.1	18.9	17.7	16.4	15.2	14.0
3	37.2	35.0	32.8	30.6	28.3	26.1	23.9	21.7	19.4	17.2	15.0
4	42.7	40.0	37.3	34.7	32.0	29.3	26.7	24.0	21.3	18.7	16.0
5	42.6	40.0	37.4	34.9	32.2	29.8	27.2	24.7	22.1	19.6	17.0
6	42.3	40.0	37.7	35.3	33.0	30.7	28.3	26.0	23.7	21.3	19.0
7	42.2	40.0	37.8	35.6	33.3	31.1	28.9	26.7	24.4	22.2	20.0
8	42.1	40.0	37.9	35.8	33.7	31.6	29.4	27.3	25.2	23.1	21.0

Example Ignition Timing (degrees)

As the load signal is varied to tune fuel, it can also change ignition timing. When compensating for larger injectors, a lower load reading can result in dangerous timing advance.

Figure 5 Altering the Load Signal Can Change Ignition Timing

A typical example would be a naturally aspirated engine that has been converted to forced induction with either a turbocharger or supercharger. In order to fuel the motor in boost, it is fitted with larger injectors. The big injectors do a fine job of fueling the engine at the top end, but result in a mixture that is too rich in the light load region. To compensate for the large injectors, the load reading is modified according to an overlay map in the piggyback calibrator. Cell values are chosen in the overlay map that subtract a precise amount from the load signal. As a result the ECU provides less fuel to the engine by shortening the injector pulse width.

Closed Loop vs. Open Loop Operation

All engines with an O2 sensor are able to operate in closed loop mode. In this mode the ECU fine-tunes the fuel mixture as you drive. The actual fuel mixture is determined by one or more O2 sensors. These sensors may be narrowband, wideband or a combination of both. The narrowband O2 sensor is highly accurate at 14.7:1 which is known as the stoichiometric air fuel ratio (AFR). This AFR is targeted for the best compromise between fuel economy, performance and emissions. Stoichiometric AFR is essential to the proper operation of catalytic converters.

In closed loop mode, the ECU uses the readings from the O2 sensors to adjust the injector pulse-width to maintain stoichiometric AFR. This AFR is targeted during idle, cruise and moderate acceleration. The base fuel or nominal injector pulse-width is set according to air flow, RPM and environmental factors. The base fuel is modified according to O2 sensor feedback through a process called adaptation. Adaptation occurs both in real time and based on history. Historical adaptation data is stored in volatile memory that can be cleared by disconnecting the battery on the vehicle for 10 minutes.

A large part of the tuning process involves achieving stoichiometric operation over the light-load range. This is the range where we spend most of the time during daily driving. Tuning this region is essential to achieving good drivability. Tuning in the light-load region involves adjusting fuel for minimum adaptation as viewed on an OBDII scan tool.

ECUs that use narrowband O2 sensors need to be able to switch off the closed loop process to achieve enrichment. When the closed loop mode is switched off, the engine is operating in open loop. In open loop, the ECU no longer uses the O2 sensor to fine-tune the fuel mixture. Under high load conditions, the engine computer targets a richer mixture than 14.7:1 to safely support the combustion process. An AFR of 12.5:1 is typical for high load conditions.

Wideband O2 sensors produce precise readings over a wide range of AFR. ECUs that use wideband sensors are able to stay in closed loop over most of the load range of the engine. Rather than going open loop, the wideband based ECU can get enrichment by targeting a rich fuel mixture and trimming precisely to that mixture.

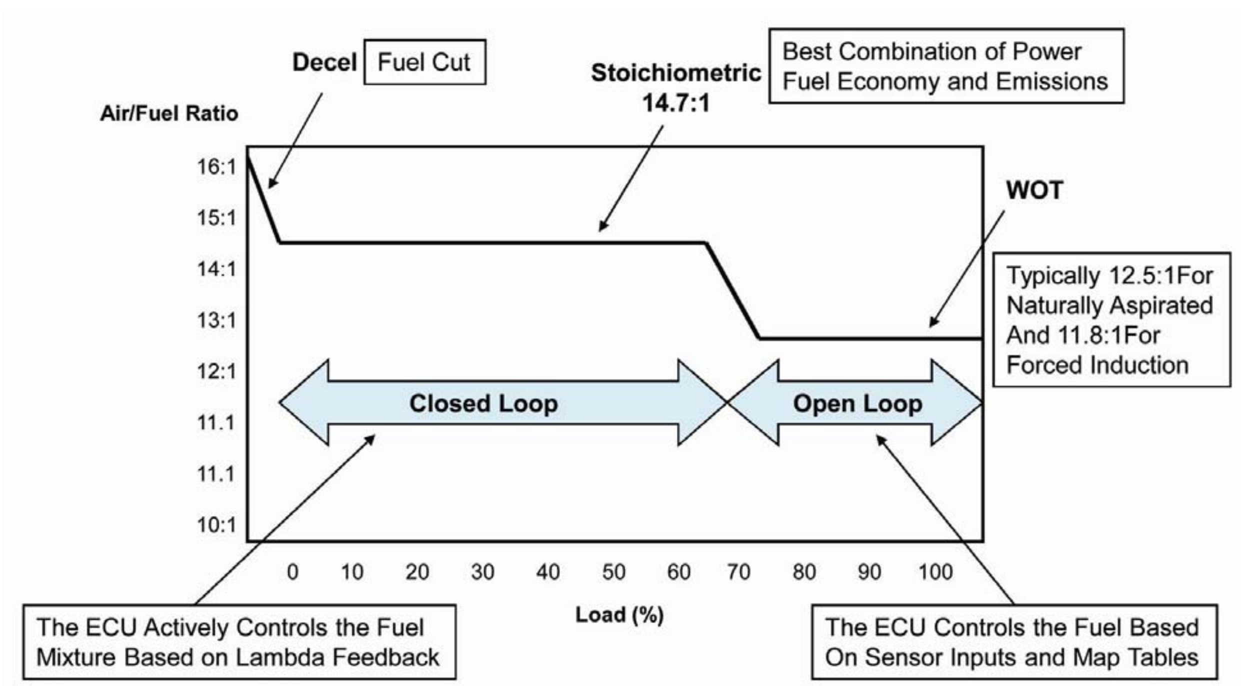


Figure 6 Closed Loop and Open Loop operation vs. Load

The OBDII Scan Tool

One of the benefits of the universal OBDII standard is the availability of low cost diagnostic scan tools that will work on virtually all vehicles built after 1996. These tools are widely available from auto parts stores for $150 or less. Before you purchase one of these tools, make sure that it displays parametric data and is compatible with your vehicle. A scan tool is an indispensible tuning aid. Figure 1 shows the Autoxray EZ-SCAN 400 diagnostic scan tool which sells for around $350. It can read and clear diagnostic trouble codes, display real-time parametric data and can be updated as needed via the internet to assure compatibility with new vehicles.

The OBDII scan tool is an invaluable tuning aid. It can read trouble codes which can help diagnose problems. It can monitor parametric data like fuel status and sensor readings. Most importantly for tuning, it can show fuel trim information which is critical for tuning the closed loop region of operation.

Figure 5 The Autoxray EZ-SCAN 4000 Diagnostic Scan Tool

Armed with a scan tool that can read engine data, you can tune the entire closed-loop region of operation. The process of tuning in the closed-loop region is one of minimizing adaptation. Adaptation is expressed as short term (ST) and long term (LT) fuel trim. ST fuel trim is an indication of the immediate compensation required to maintain the target AFR. LT trim is based on the history of adaptation acquired over up to 100 miles of driving. To determine the net trim add the two numbers together. Net trim can be used as a guide to adjust the fuel calibration in a piggyback engine management system.

The net trim is an indication of how much the ECU has to change the fuel to reach the target AFR. On a stock vehicle the net trim is normally in the +/- 5% range. If the net trim is a large positive number, it means that the ECU has to add a lot of fuel to reach its target. Large positive trims above 20% or so will result in a fault and diagnostic trouble code (DTC) for system too lean. A piggyback fuel calibrator can be used to add enough fuel in the region of interest to bring the net trim close to zero. Proper adjustment for minimum net trim throughout the closed loop region will give you optimum smoothness and drivability.

The Wideband Lambda Meter

The single most important tuning tool is the wideband lambda meter. Particularly when mounted in a bung located in the pre-cat location, the wideband lambda meter will provide a highly accurate measurement of air fuel ratio. If is it not possible to locate the sensor in the pre-cat location, you can use a tailpipe clamp. The tailpipe method will usually match the pre-cat location reading within a variance of 0.3 AFR.

Lambda meters are available as handheld instruments or gauges that can be installed in the instrument panel. The Innovate Motorsports DB series gauges shown in figure 2 are available with either blue or red color displays for $209.

The Innovate Motorsports DB series AFR gauges are available in either blue or red color. They provide a continuous, real-time AFR reading at low cost.

Figure 6 Innovate Motorsports DB series air/fuel ratio gauges

A lambda meter may display either in the units of lambda or AFR. As such the meter may be referred to as a lambda meter or a wideband air/fuel ratio meter. The stoichiometric air/fuel ratio of 14.7:1 for gasoline is also known as a lambda of 1. Lambda is defined as L=AFR/14.7. Many meters are programmable so they can display with the units of either AFR or lambda. Table 1 shows some typical AFR values and the equivalent lambda values.

Air/Fuel Ratio	Lambda
11.8	0.80
12.5	0.85
13.2	0.90
13.2	0.90
14.0	0.95
14.7	1.00
15.4	1.05

Table 1 Lambda Readings for Various Air/Fuel Ratios

Throughout the closed-loop region of operation the AFR should be 14.7:1. As an engine is tuned in the closed-loop region there is usually no change in the AFR reading. This because the ECU adapts to changes to the base fuel and trims the fuel to its target AFR of 14.7:1 as needed. This is why the OBDII scan tool is used to tune the closed-loop region. The AFR meter is used to tune the open-loop region of operation. This normally occurs at high loads where the ECU is programmed to go into enrichment. A common target for enrichment at high load is 12.5:1 AFR.

The Tuning Process

With the use of an OBDII scan tool and a wideband AFR meter, it is easier than ever to street-tune an engine for proper operation. Even if you have a dyno at your disposal, we recommend that you do a certain amount of street tuning. This is especially important to achieve good drivability under real-world conditions.

There is a logical progression to the tuning process. Generally you want to start with the light load region and work your way up to higher loads and RPMs. If you are working with a highly modified engine, you will first have to get the engine to start. You can then work on a good tune for the idle region. With a good idle tune you can get the engine to free-rev and crisply respond to throttle inputs.

Once the idle and free-rev regions are set, you can work on tuning the light load region by driving the car at a constant speed around 30 mph. Very little throttle input is required to sustain a constant 30 mph. Adjust the fuel mixture for minimum net fuel trim in the active region of the map table. The street-tuning process is vastly simplified by using two people. That way one person can watch the road, drive the car and hold the engine at various load points. The other person can concentrate on the scan tool, AFR gauge and tuning software. Use data logging that you can analyze later if you are tuning by yourself.

After the light-load region is set you can work your way up to higher loads. This is done by holding slightly higher and higher throttle positions. For each of these higher loads, adjust the fuel for minimum net fuel trim. Complete tuning the entire closed-loop region according to fuel trim. A well tuned closed-loop region will form a solid foundation for tuning the high-load region where the ECU goes into enrichment.

You can tell when the ECU goes into open loop by monitoring the fuel status parameter on the scan tool. Once the ECU goes into open loop, you can tune the fuel according to the AFR meter. Naturally aspirated engines are usually tuned for approximately 12.5:1 AFR at high load. Forced induction engines are usually tuned for a value between 11.0:1 and 12.0:1 depending on whether the engine is intercooled, has methanol injection and other factors.

Classic Pitfalls with Piggyback Tuning

There are all sorts of ways to get into trouble when doing piggyback tuning. Some of the more common issues are described below.

The engine runs but is hard to start

> Piggyback calibrators must be connected to a reliable source of power during cranking. Many circuits are turned off by the unloader relay during cranking in order to provide maximum power to the starter motor. If you use one of those circuits to power the calibrator, the engine can be impossible to start. It is best to power the calibrator from the same switched ignition circuit that powers the ECU.

The tune is unstable and changes when the headlights or accessories are turned on

Piggyback calibrators work by modifying signals. In the process of doing that, signals are measured, modified according to a mathematical operation and regenerated. The measurement and regeneration are done with respect to the ground wire. It is best to connect the ground wire to the sensor ground coming from the ECU. If you use chassis ground, your signal readings can easily be corrupted.

The engine stumbles after it warms up

It is mandatory that you locate piggyback electronics in a location away from heat. The components are usually rated for the industrial temperature range which goes to 185 degrees F. It is not hard to reach that temperature in an engine compartment. It is best to locate piggyback electronics under the dash or elsewhere in the passenger compartment.

The tach reading is jumpy

Tach inputs are frequently designed to work with square wave signals. These inputs can produce erratic readings when connected to an ignition coil. Due to the inductance of the ignition coil, the signal on the primary winding has a lot of ringing that can cause false triggering. In most cases the trigger pulse used in a coil-on-plug application can be used. Fuel injector signals can also be used to pick up a tach reading at the one-cylinder rate.

Throttle response is sluggish

If your piggyback calibrator has a vacuum line, it is imperative that you provide a solid connection to manifold vacuum. Lines can be pinched or cracked especially going through the firewall. Use semi-rigid nylon line where possible and make vacuum lines as short as possible.

The engine cuts out in boost

Many stock ECUs will go into fuel cut if either the MAF or MAP sensor reading exceed a maximum value. This results in an abrupt drop in power when you transition into boost. By carefully selecting the cell values in a programmable calibrator this problem can be avoided. The Split Second VC2 and VC2-5 voltage clamps are popular for limiting signals to within their normal operating range.

The tune changes over the first few minutes of operation

This is a classic sign of an incorrect barometric pressure reading. Speed density ECUs that use a MAP sensor as the primary load sensor rely on the barometric pressure reading with key-on, engine-off to account for elevation change. If the calibration of the MAP sensor is not correct during the barometric pressure reading, the ECU will have to do a lot of fuel trimming when it goes into closed loop.

The tune changes over the first hundred miles of operation

This is an indication that the ECU is adapting to your fuel curve. Even on a completely stock engine, the tune will change over the first one hundred miles of driving after the battery is disconnected. This adaptation is part of the self-tuning process that modern ECUs go through. The key when tuning is to look at the net trim which is the sum of the ST and LT fuel trim numbers. If you have a ST of -20% and an LT of +20%, you have a net trim of zero which is what you want. If you check the fuel trim at that load point after 100 miles of driving, both trim numbers should be close to zero.

The real-time data does not match the map table

This can happen when the current file in your calibration software does not match the file in the calibrator. To synchronize the files you have to either read the file from the calibrator or write the file form the calibration software.

The car dies when it comes back to idle

This can usually be fixed by adding fuel in the light load region at RPMs above idle and loads below idle.

Conclusion

By now it should be clear that there are a lot of issues to consider when doing piggyback tuning. The reality is that there is even more to worry about. Not all piggyback systems are plug-and-play. Some require finding and splicing wires on the vehicle. This opens up the possibility of poor electrical connections that cause problems down the road.

A host of issues are caused by how you get power and ground. Some ECUs stay active for as long as a half hour after the ignition is turned off. During this time, sensor readings are checked. If the piggyback circuit does not have power, the ECU will set a fault for a bad sensor reading. Sensor ground is generally used when modifying sensor readings, while power ground is used when directly controlling injectors and high current loads. The use of the incorrect ground can easily cause faults or can even make the engine shut down abruptly.

Even with all the issues involved in piggyback tuning there is still a place for it in the realm of aftermarket engine tuning. Successful use of piggyback tuning can frequently offer the least expensive, or the only solution. Piggyback modules are often included as part of an aftermarket kit. Make sure you have installation instructions for your specific vehicle and follow them exactly. If you are doing your own thing, make sure you have the ECU wiring diagram for your vehicle so you can find the correct places for your connections.

Start your tuning project by determining your fuel strategy and selecting the components you want to use. Study the proper documentation for your vehicle and piggyback components. Make sure that you have tuning tools that work with your vehicle and learn how to use them. Install your hardware carefully with high quality connections and double check everything. Take your time tuning starting with the light load region. Gradually work up to higher loads and RPMs. Watch out for detonation and avoid running lean. With a basic understanding of how an ECU works and what piggyback calibrators do, you can tune your engine for peak performance.