Achieving Fuel Enrichment in Closed Loop

One of the most vexing problems facing tuners of aftermarket turbo or supercharger kits is the achievement of enrichment in closed loop. A variety of proven schemes are available to add fuel in boost. Techniques including rising rate regulators, larger injectors and additional injectors are used to add fuel. These techniques work fine when the Electronic Control Unit (ECU) is in open loop. The issue generally arises when the engine is making boost at part throttle and the ECU is in closed loop. Under this condition, the additional fuel that is introduced for enrichment is trimmed away through adaptation in the ECU.

The Split Second Enricher provides a way to achieve enrichment even when the ECU is in closed loop. This resolves a number of drivability issues. These issues can include poor throttle response, hesitation during the transition into boost and a lack of power climbing hills. The number one problem that the Enricher corrects is the lean fuel mixture that occurs in closed loop. A lean mixture in boost makes the engine run hotter, can lead to pinging and result in damage.

What does Closed Loop Mean?

All engines that have an O2 sensor are able to operate in closed loop mode. In this mode the ECU fine-tunes the fuel mixture as you drive. Any vehicle that has a catalytic converter requires closed loop operation in order to maintain the stoichiometric air fuel ratio (AFR) of 14.7:1. This air fuel ratio is critical for proper operation of the catalytic converter and provides the best compromise between low emissions, good fuel economy and performance.

In closed loop mode, the ECU uses the reading from the O2 sensor to measure the fuel mixture. This information is used 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.

The O2 sensors used in vehicles until the late 1990s are narrowband meaning they are especially accurate over a narrow range of AFR centered around 14.7:1. ECUs are programmed to operate in closed loop mode except during cold start, deceleration and high load conditions. Under high load the ECU ignores the O2 sensor reading and operates in open loop. The open loop AFR in high load conditions is typically set at a richer AFR around 12.5:1. This is enrichment, a richer mixture than 14.7:1.

On early vehicles, open loop operation and enrichment is frequently activated according to throttle position. At high throttle positions, the engine is under high load and requires enrichment to operate safely. When the ECU goes open loop it is possible to alter the AFR through external means without intervention by the ECU.

On late model vehicles, AFR is often controlled by wideband O2 sensors. These sensors produce a very accurate reading over a wide range of AFR. With these sensors it is possible to operate in closed loop under virtually all load conditions. This makes the engine management more precise, but makes it even harder to achieve enrichment in boost.

Do You Need the Enricher?

One of the benefits of the universal OBDII standard is the availability of low cost diagnostic tools that will work on virtually all vehicles built after 1996. Armed with a scan tool that can read engine data, you can determine if the Enricher can help you tune your vehicle. 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.

Plug your scan tool into the diagnostic port and pull up the fuel status parameter. This will indicate whether the ECU is in closed loop or open loop. If you see that the ECU is in closed loop while you are in boost, you need the Enricher. A good test is to drive in a light load cruise condition and progressively squeeze on the throttle. This is a common condition encountered in daily driving. It will allow you to make boost at part throttle. You can also pull up the short term and long term fuel trim parameters on the scan tool. If you go into boost and see a large negative trim that indicates that your ECU is taking away fuel in boost through adaptation.

If you do not have access to a scan tool or if you are working on an older vehicle, you can look at the AFR in boost with a wideband AFR meter. These meters can be installed permanently on the vehicle or fitted temporarily to the exhaust for the purpose of measurement and removed when you are done. When the engine transitions into boost you should see a rapid onset of enrichment. The AFR should go from 14.7:1 in cruise to a mixture richer than 12.0:1 even at only a few pounds of boost. If it stays near 14.7:1 in boost, you need the Enricher.

How the Split Second Enricher Works

The Split Second Enricher modifies the O2 sensor readings to make them look leaner. This allows you to run a richer mixture while presenting a normal reading to the ECU. The Enricher can modify the reading for up to 4 O2 sensors and is compatible with both narrowband and wideband sensors. The Enricher is boost activated so that the O2 sensor readings are stock in the vacuum region and modified in boost.

Since the Enricher operates inside the feedback loop between the O2 sensors and the ECU, it alters the closed loop operation in a way that is consistent and predictable. The enrichment occurs quickly and is stable over time. The ECU will not "learn around" the enrichment and adapt back to stock. The Enricher is so effective at adding fuel that on some late model vehicles with wideband sensors, it is all you need to fuel the engine for up to 5 psi of boost.

The Enricher has a number of user-adjustable controls that make it very versatile. The amount of modification for each O2 sensor is individually adjustable. The boost activation threshold is adjustable over a wide range of vacuum or pressure. You can also make the activation based on a combination of boost and a second input. The second input can be used to fine tune the

enrichment. For example you can set it to provide enrichment when you go into boost at part throttle and turn off at wide open throttle.

Enricher Installation

The Enricher data sheet contains a lot of useful installation information. There are also detailed instructions available for certain specific vehicles. If such instructions are not available, it is not too hard to determine how to do the installation from an ECU wiring diagram. The first thing is to determine the number and type of sensors that are being used.

Most vehicles up to the 1996 model year use one or two narrowband sensors. The signal wires are cut and intercepted by a pair of wires on the Enricher. There is also a sensor reference voltage wire that needs to be connected. On one-wire or three-wire sensors it is tied to chassis ground. On four-wire sensors it is tied to the sensor ground wire on the O2 sensor. On many newer cars that use four-wire sensors, the sensor ground is at a voltage elevated above ground. On these applications it is especially important to connect the sensor reference wire to the sensor ground.

On most cars up to the 2000 model year you will only have to connect to the pre-cat sensors as the post-cat sensors are only used for measuring catalytic converter efficiency. On newer vehicles, the post-cat sensors have to be intercepted by the Enricher because they can also be used for adaptation.

There are certain late model vehicles that use four-wire sensors in current mode. These sensors are actually wideband sensors. Toyota refers to them as air/fuel sensors. The reading from these sensors can be modified by a simpler connection than the one used for traditional four-wire sensors. Instead of cutting the signal wire and intercepting the signal, the connection is a T-tap with a single wire.

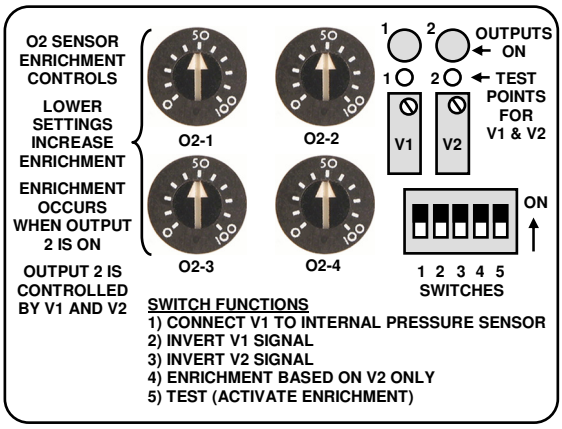
The typical connection on five-wire and 6-wire wideband sensors is a T-tap type of connection. Some applications use a combination of wideband and narrowband sensors. That is why there are separate signal reference wires for the pre-cat and post-cat sensor channels on the enricher.

Once the O2 sensor wiring is done, the only other connections that are required are for power, ground and V2 (voltage activation). If you are activating by pressure only, the V2 wire is tied to the internal +5 V reference on the Enricher. The V2 wire can be connected in a variety of ways to create a more complex activation scheme. It can be used to activate in a range of pressure with user adjustable lower and upper limits. It can also be tied to an external signal from the throttle position sensor, MAF sensor etc.

The Enricher has an internal 2.5 bar map sensor. Complete the installation by connecting the map sensor vacuum line to a source of manifold pressure. The map sensor signal is available on the Enricher connector. You can use it as an input to another control module or a data acquisition system. There are also two active low outputs that can be used to activate relays and turn external loads on and off.

Enricher Adjustment

The controls that are used to adjust the Enricher are found under the cover. Remove the four corner screws and you will see the controls arranged as shown on the diagram below.



Enrichment is activated according to thresholds that are adjusted by the V1 and V2 settings. When both thresholds are exceeded, the output 2 LED is turned on and the enrichment function is turned on. The adjustment labeled V1 sets a voltage that can be measured with a DVM at test point 1. It is factory pre-set to 2V. When switch 1 is on, the default setting of 2 V will activate the Enricher at 1 psi of boost. Vary the V1 voltage to set the activation pressure.

The V2 setting comes preset to 3V. In most cases the V2 input is tied to the +5V reference which makes the activation dependent on manifold pressure only. There are more details about the switch and wiring options in the Enricher data sheet. Turn on switch 5 to activate and test the enrichment function.

Use the adjustments O2-1 through O2-4 to modify the O2 sensor readings. Use a lower setting to increase enrichment. As you make changes to those settings you will see corresponding changes to fuel trim on a scan tool. Without the Enricher you should see negative fuel trims as the ECU removes the fuel added in boost. With the Enricher activated and correctly set, you should see no net change or positive fuel trims in boost. A positive fuel trim means you are using the ECU to help add fuel in boost.

The Enricher is an effective way to address the closed loop issue in boost. It is the missing piece of the puzzle that completes the job of tuning an aftermarket turbo or supercharger system. It addresses drivability issues at part throttle where you spend most of your time during daily driving. It is versatile and works on virtually all vehicles.