# Injection Duration

Injection Duration is the pulse width applied to the injector(s) solenoid(s) for the main injection event. It commands how long (how much time) the injector is held open and flows fuel. The unit of measure for the Duration is in Microseconds (μs). One μs is one millionth of a second (or 1 / 1,000,000).
In a common rail injection system the injectors are opened by voltage applied to a solenoid rather than by the fuel pressure, like in older injection systems. This allows for very precise fuel metering.

As a rule of thumb, with a "matched engine build", anytime the engine produces heavy black smoke the Duration is too long. Heavy black smoke means, wasted fuel and power.
Definition of "matched engine build": the injectors at their maximum flow keep the turbo(s) within their efficiency map and of course all other components involved are matched for this purpose.

It is very common that engines are built with either not enough or too much turbo(s) for the injectors used for that build.

"Not enough turbo" means that the injectors flow more fuel than what the turbo(s) can provide adequate air, to properly burn said fuel.
Normally this translates into very high EGT's, heavy black smoke and very high back pressure. This is the only situation where over fueling (thus heavy smoke) makes more power than reducing the fuel flow. Yet, this comes with a price tag, VERY HIGH EGT's and very high backpressure! At least with injectors flowing too much fuel it is possible to reduce the duration table and adapt it to the injectors. Although, it can be very difficult to control very big injectors, it is a viable option.

"Too much turbo" means that the injectors can't flow enough fuel to light the turbo(s). This can also result in high EGT's and normally makes for sluggish engine responsiveness.

The right combination consists of injector fuel flow, matching the efficient air flow of the turbo (s).

A few hints about tuning the Duration tables.

It is probably easier to think about the "Load" as if it was the "throttle position". While they're not really the same, the results are rather close.

IMPORTANT!
The values of all the first points in the different load maps are zero. NEVER change those cells!
If these values are increased you will get an un-predictable engine run away when the throttle is released! Leave these cells alone!!!

Increasing the duration in the load tables before 50 - 56% load may or will result in heavy smoke under light throttle. Smoke hinders the performance and the turbo spool up. It is easier to light a large turbo with little fuel, rather than with too much of it.

Increasing the last 2-3 load ranges too much (81,4 to 100%), can result in a "hanging

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throttle". Yet at the same time, not enough duration at the highest load and RPM will feel like the engine is defueling and a huge power loss in the high RPM range will result.
Also with not enough duration on the top end, the engine will be limited in the RPM's it can rev up to. Please, look at the comparison files that come with this tuning software. They work very well with an average injector size.

There is no way to predict exactly how much the duration needs to be changed for the best performance possible. Everything depends upon the injector size or in other words how much fuel they can flow during the time the duration commands the injector to be open. With very large injectors it is possible that you will need to decrease the Duration, rather than increasing it. The comparison files we've provided make for a very good starting point.

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# Injection Timing

The Injection Timing defines the moment in which voltage is applied to the injector(s) solenoid(s) in regards to the piston position related to Top Dead Center (TDC). The unit of measure for the injection timing is in degrees. Positive numbers mean: the injection event starts Before TDC. Zero degrees means: the injection event starts at the TDC. Negative numbers mean: injection starts After TDC.
In a common rail injection system the injectors are opened by a voltage applied to a solenoid rather than by the fuel pressure like in older injection systems. This allows for very precise injection timing.

**There is no good tuning without good timing!**
If you were to spend a hundred hours tuning an engine, spend at least ninety of them on the timing!
One very important concept that needs to be taken into account while tuning the timing is the Ignition Delay (ID) of the diesel fuel. The ID is the time it takes for the fuel to start to burn from the moment it is injected. Diesel fuel does not burn immediately when it is injected, but it takes quite some time for it to ignite. Diesel burns significantly slower than gas. ID depends upon parameters like, fuel atomization, compression, boost and fuel quality. The fuel quality is most important. The higher the cetane rating, the faster the fuel burns.

What this means in the real world:
At 3000 RPM an engine turns 1.080.000 degrees in a minute (360° X 3000). Or 18.000 degrees in a second (108.000 / 60). Or 0,018 degrees in a µs (18.000 / 1.000.000). If the ID is, let's say 500 µs then the crank has turned nine degrees from the moment the fuel was injected to the moment the fuel ignites! At 4000 RPM the ID will then be twelve degrees! At 5000 RPM... 15 degrees!
This clearly tells that the timing needs to be increased (injecting earlier before TDC) as the RPM's raise. Yet, there is a limit for the timing. If the fuel is injected too soon, the fuel will ignite before the piston has reached the TDC. NOT GOOD! Be CAREFUL here, severe engine damage will result in a short time.

In a completely stock engine, very good timing alone (means, everything else remains the same) can gain up to 70 HP over the stock timing! In a highly modified engine, the difference can be several hundred HP!!! Also, the higher timing can lower the EGT's of a stock engine by several hundred degrees F.

What effect does the timing have on performance?
(All other parameters remain unchanged. The only change is a higher or a lower timing.)

A higher timing does: More power, lower EGT's, more smoke, better MPG and *less* boost.
A lower timing does: Less power, higher EGT's, less smoke, worse MPG and *more* boost.

Why does less timing make higher boost, but less power?
Everybody always says that more boost = more power!
Think about the timing as if you were to decide where the thermal energy of the engine will be directed to. Into the combustion chamber with the higher timing or part into the exhaust / turbo with a lower timing. More energy into the combustion chamber of course increases the power, but at the same time reduces the available energy to spool the turbo.

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This means in the real world, that you want a lower timing in the low load part of the timing tables to help the turbo spool up. Once the turbo is spooled up, you then (may) want to rapidly increase the timing for max power.

Unfortunately in regards to timing, there is no way to predict how much is too much.
The only way to set the timing correctly for max power, is by test and trial. On the dyno, increase the timing, verify your results. Continuously increase the timing run after run. The timing becomes too high, when the power becomes less than the previous run. When the power becomes less than in the previous run, then the fuel is injected too soon, thus it ignites before TDC, thus the power loss.

Attention!
Always look at the whole dyno graph! Anytime less power is achieved ANYWHERE in the dyno graph,then too much timing has been added. It is easier to set the timing too high in the lower RPM's, than the high ones.
If you have increased the timing as a whole and you loose power around the start of the run, but gain power at the top end, then the timing at low RPM's is set too high. Likely the high RPM's still have some room left for a further timing increase.

The comparison files provided with the UDC are from real world tuning and can give a rather good idea about what works.

The only real indication we can provide, is that we have never seen any further gain above +32. Use this as a safe maximum limit, but like said before, everything depends upon the individual engine build.
De-compressed engines come to mind. Those may (or may not) need an even higher timing value.

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# Rail Pressure

Rail Pressure defines at what pressure the fuel in the common rail is stored. The unit of measure for the Rail Pressure is PSI. In a common rail injection system the Rail Pressure does not depend upon engine speed (within limits) like in older injection systems. This combined with the average higher fuel pressure (compared to older injection systems) provides very fine fuel atomization.

Attention!
The 5.9L Cummins injectors are rated by Bosch to 1.600 Bar which is equal to 23.207 PSI.
The 6.7L Cummins injectors are rated by Bosch to 1.800 Bar which is equal to 26.107 PSI.
Exceeding these pressures can lead to injector damage!

A distinction between daily drivers and race trucks needs to be made.

A daily driver should not exceed the stock rail pressure. Period. In fact, the highest rail pressure in the stock tables is already set to the maximum Bosch rating. Giving the rail pressure tables a closer look, you will notice that the stock rail pressure is always reduced in the highest RPM points. Of course, this should be addressed if the goal is performance. Raise those points to the highest value you find in the stock tables. Now the rail pressure does not exceed the maximum rating, but the performance will increase.

The goal for a race truck, is of course a whole different story.
Our advice, use as much rail pressure for the race as you need (or can get) but reduce it when driving home...

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# Waste Gate

The Waste Gate table defines at what boost pressure the waste gate will be opened and route part of the exhaust gases around the turbine to prevent turbo over speed or excessive boost pressure.
The unit of measure for the boost pressure / waste gate opening point, is in PSI.
Only the 2004.5 to 2007 trucks actually have the electronically actuated waste gate.

Higher boost means more power and lower EGT's. It is essential to increase the boost pressure in order to be able to effectively burn any added fuel. The stock boost pressure sensor can only read 36 to 38 PSI (Depending upon the individual sensor tolerance). If the boost pressure is set higher than what the boost pressure sensor can actually read, the result will be that the waste gate does not open.

The best thing for mileage is to set the boost pressure as low as possible at cruising speed. You want the engine to work against the least possible back pressure (waste gate open) which yields very good fuel mileage gains. The nice thing about tuning the electronics, is that it is possible to keep the waste gate open at low loads and RPM's. As soon as more throttle is applied (more load) close the waste gate, and keep it closed for best power and performance.

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# Torque Management

The torque management defines how much torque the engine is allowed to produce for a given throttle position. In other words, how much fuel is allowed for a given throttle position.

Never change the first value of the table. The throttle will become too sensitive almost like an on / off switch. Also don't increase the second and third values too much because the engine response to the throttle will become violent, almost out of control. Please, look up the different comparison file, to get an idea how this table is modified.

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