Tuning Injector Timing 1.1.3 (7/14/03)
By David Crow, with input of many

Injector timing is the delay before each injector output is fired. The delay is taken from TDC of the reference PIP signal for each injector output [for each cylinder]. The units for injector timing are absolute engine crank degrees. The range is 0 degrees TDC to 720 degrees ATDC with 4 degree resolution. Either edge (on or off) of the injector pulse can be timed. The calibration switch INJREF defines the reference edge for injector timing.
INJREF = 0, Use start of fuel pulse.
INJREF = 1, Use end of fuel pulse.

Most strategies use End pulse Timing. If the stock injector-timing table has values around 300-400, the strategy uses End pulse timing. If the stock injector-timing table has values around 100-200, the strategy is using Start pulse timing

Regardless of which edge is used; the injector delay is used only to start a fuel pulse. Once started, pulsewidth accuracy has top priority.

When the system is not in sync (SYNFLG = 0), the injector timing is coincident with the relevant PIP signal. The injector outputs are fired in sequence after receiving the rising edge of the reference PIP signals.
Actual timing will be the result of the random link between signature PIP (cylinder #1) and #1 injector output.

The delay to output is related to your camshaft profile, particularly the intake lobe profile. A cam spec card list degrees as xATC or xBTC, xABC or xBBC, these are After/Before TopCenter/BottomCenter. Some cam spec cards list "-" negative degrees, this really just flips your value from After to Before or Before to After. (-9ATC = 9BTC). Also most cards list open/close events @ .050, but some also list @.002. If your spec card lists degrees @.002 lift, you can forgo the corrections in the examples to get the start of valve opening. Some cam manufacturers list degrees as (A,B)BDC and (A,B)TDC, this can cause confusion as "Dead" centers typically refer to the crank, but these do not seem to refer to crank degrees.

The 4-stroke cycle can be mapped to abs crank degrees as follows:
0-90 (+/- 30) Power stroke
90-360 (+/-30) Exhaust
360-630(+/-30) Intake
630-720(+/-30) Compression
The intake stroke 0TC=360abs engine crank degrees. Intake stroke 0BC=540abs.
1 degree cam move = 2 degrees abs crank move (ie: advancing your cam 4* = -8*abs)

Lets take the stock 302HO cam from a 90's GT (A9L, End pulse timing):
302HO: Int Open: 11ATC Int Close: 41ABC Int Duration: 210@.050/266Adv

This puts our valve timing at: IO (@.050):382 IC (@.050):622
But this must be corrected for raw lobe start. To get our raw start position we must use both the Advertised duration and duration @.050 lift.
(382-((266-210) /2))= 354 raw start position

Note: Ford ended the injection pulse 2 crank degrees early.

Now to the HIGH LOAD/HIGH RPM (HIGH oil pressure). At high pressure the hydraulic lifter is nearly a solid lifter.
((622-382)/2)=120 382+120=502 Halfway through the lobe.
Now you say… 502 does NOT equal 464 from the stock table. Well there is still the matter of just how much lobe you can use.

At 502 the valve is as high as it is going to get. Ford decided to set the max to 464. This could have been for a number of reasons. Perhaps the 19LB injectors required this much extra time to inject enough volume at these high loads. It seems that you could move this either direction. Keep in mind that the Exhaust valve on this cam will begin opening at 72, and the intake is closed at 650.

Larger injector should not be a major consideration in low-mid load/rpm End pulse timing, unless you would like more fuel on valve time. But on the same note, larger injectors could reduce the required high-load/rpm time, as they require less lead-time per given volume.

It has been recommended to fire earlier rather then later. Firing the injectors too late can cause the fuel to wash down the cylinder wall causing excessive wear and oil contamination. While firing the injector early will puddle fuel on the top of the valve, this does allow the fuel to absorb heat from the intake track and valve. This heat will help keep the fuel close to vaporization. The longer it sits on top of the valve the more heat it can absorb. But this could also be very hazardous under boost, were you want the coolest charge possible.

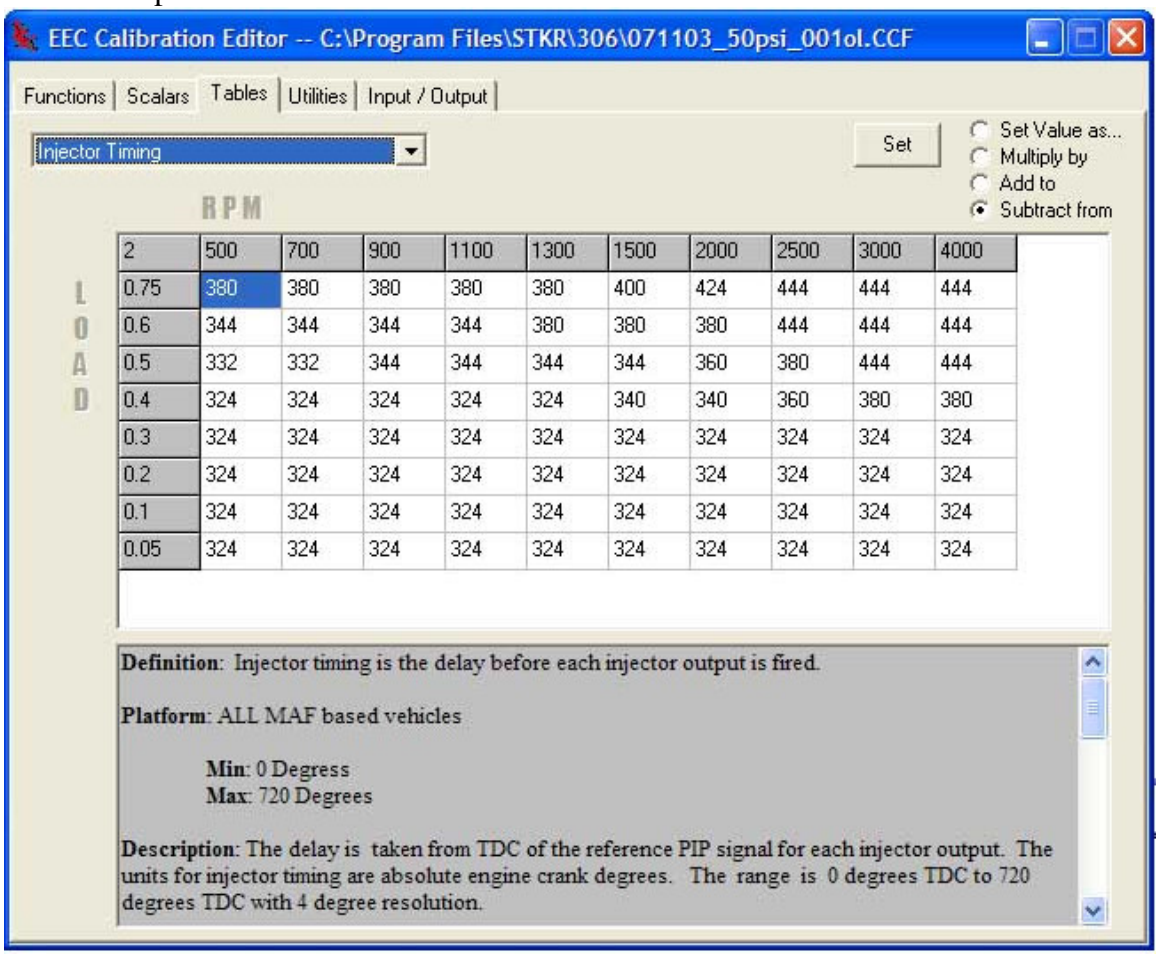
It has been stated that fuel on the valve could cause carbon buildup. I don't believe this to be the case. Carbon buildup is most likely caused at the point where the exhaust valve is closing, the intake is opening and there is residual pressure in the chamber is higher then intake pressure (nearing TDC, just as the intake stroke starts). This pressure zone occurs for approximately 31* with an E303 between the exhaust to intake overlap.

With these methods in-place, lets look at the E303 (A9L, End pulse timing):
E303:: IO:0BTC IC:40ABC EO:40BBC EC:0BTC INT 220/282 EXH 220/282 LC INT 110
LobeLift:.311/.311

IO:360 IC:620
360-((282-220)/2)=329 (IO start)
329-2(fords example)=327 setting for low-med load/rpm
((620-360)/2)=130 360+130=490 (top of intake lobe)
490-32(fords example)=458 (high-load/rpm setting, obviously a very flexible)
Exhaust valve begins opening (under high pressure) at (100-((282-220)/2)=69
The intake valve closes completely at 651, 620 @ .050
So at high load/rpm we are finishing our injection roughly 331abs deg before the exhaust valve opens. This allows about 200abs for the compression and power strokes from int@.050 to exh@.050.

This leaves the between values. They should be "feathered", using t he difference between stock values applied to your new values. (this has worked well for me)

E303 Example w/ 3-14extra advance for more heat soak:



Injector timing is about the accurate, delivery of fuel volume at the correct time, and there are many functions that could affect this. Injector Offset VS. Battery Voltage changes pulse width accuracy. This in turn affects your injector timing.

Getting the injector timing right does affect you're A/F Ratio's. You will need to re -tune your MAF_Transfer function.

Comments/Input requested:
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Cam Timing Links:
http://mail.symuli.com/vw/camp1.html
http://mail.symuli.com/vw/camp2.html