HOW-TO

How-to Configure VVT in EMU PRO

Document version: 1.1
Client: 102.0
Published on: 01 February 2024

ECU MASTER

1. Introduction

VVT systems are used to modify valve timing and lift in order to improve engine performance, fuel economy and emissions. In most cases intake camshafts can be advanced and exhaust camshafts can be retarded according to their base position. However every engine producer designs different VVT systems and the operation may vary.

In simple terms, VVT timing systems can be divided into groups:

- Discrete adjustment – camshafts can be phased only to fixed positions, typically depending on engine RPM (e.g. VTEC with third camshaft profile). See: *VVT / **Switched*** in Smart Grid
- Continuous adjustment – camshafts can be phased to every position within working range. See: *VVT / **Timing*** in Smart Grid

Camshafts are phased by hydraulic systems controlled by actuators. To reach specified camshaft position, PID controllers are used to run the solenoids.

> ✎ **Note:**
>
> This document covers continuous camshaft phasing only.

2. Getting started

This chapter explains key concepts of VVT handling in EMU PRO. In this document, the following convention is used for Smart Grid navigation: *[In\Ex]* means it can be either an intake or exhaust camshaft, and # indicates it can be either 1 or 2.

Position read-out
*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / **Position***
Position of each camshaft is calculated from camshaft trigger wheel position in relation to primary trigger. Position is determined at each camshaft tooth.

Position unit [°ADV]
*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / **Position***
The unit of camshaft position in EMU PRO is advance degrees for both intake and exhaust. Negative values mean retard. VVT Tuner assumes that intake camshaft moves in advance direction and exhaust one in retard.

Signal edge

*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / **Signal edge***

Unlike secondary trigger edge, for VVT purpose choose the one, which provides evenly spaced edges (if possible). For example for the following trigger rising edge is for synchronization and falling edge is for VVT position read-out.
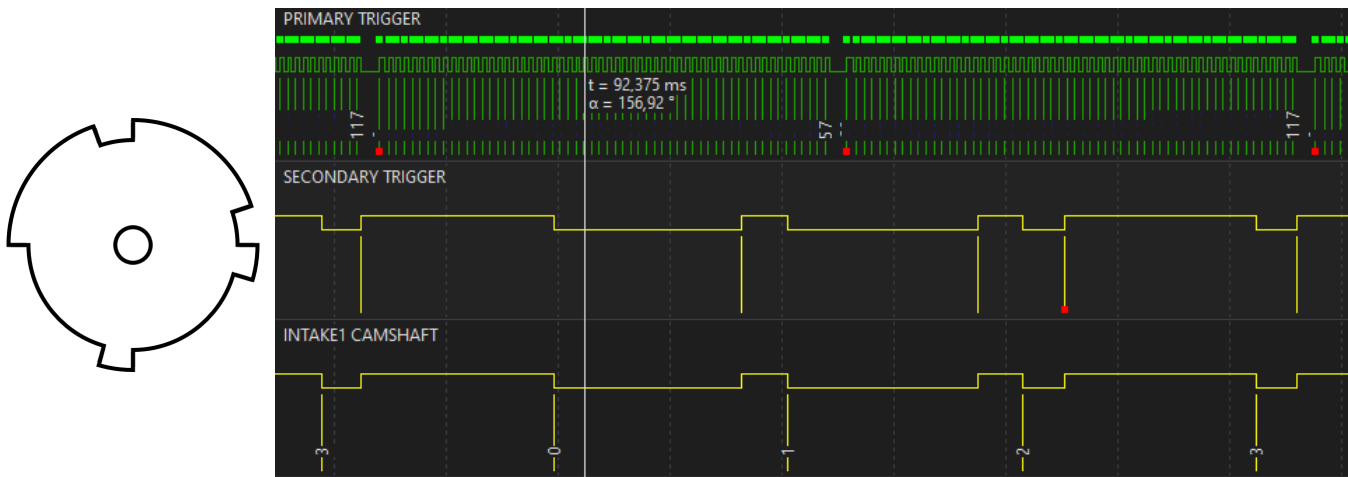
Primary trigger start tooth

*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / **Primary trigger start tooth***

This parameter defines the primary trigger tooth number from which camshaft teeth are numbered and counted for one cycle. If a camshaft tooth crosses the sync primary trigger tooth, it is crucial to set offset in reference to the sync primary trigger tooth, which would assure that camshaft teeth numbering would not change.

This value can be automatically calculated by VVT Tuner.

Duty cycle range

*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Duty cycle [min\max]***

Range of duty cycle must be large enough to assure quick camshaft move in both directions. In some cases (e.g. Ford Coyote engine) there is a minimal duty cycle which enables VVT.

Moving average

*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / **Moving average***

Do not use *Moving average* feature when configuring VVT. It averages position from all teeth and thus it could conceal problems with position read-out when *… / Position / **Initial teeth angles*** or *… / Position / **Primary trigger start tooth*** are not configured correctly. If needed, turn it on after proper configuration.

VANOS with dual solenoid

VVT configuration in this case assumes using *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Output*** to move camshaft away from base position and *… / Actuator / Solenoid / **Output 2*** to move towards base position – it should be configured in that way.

Similarly in case of using H-bridge output *… / Actuator / **Active state*** set to High side (12V)) positive PWM duty cycle should move camshaft away from base position and negative towards base position.

VVT Tuner can detect reverse direction of control and work properly, however tuning procedure would take more time.

3. Configuration

1. Specify VVT activation rules

In *VVT / Timing / **Activation***

- *Engine RPM min*
- *Engine RPM hysteresis*
- *Engine coolant temperature min*
- *Engine coolant temperature hysteresis*
- *Engine oil temperature min*
- *Engine oil temperature hysteresis*
- *Engine runtime min*

2. Set camshafts count for each intake and exhaust

In *VVT / Timing / [In\Ex] / **[In\Ex] camshafts count***

- None – VVT control disabled
- Single – one camshaft with VVT
- Dual – two camshafts with VVT (for two cylinder banks)

Steps 3-7 needs to be performed for each camshaft separately.

3. Configure Position settings

In *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / **Position***

- *Sensor input* – digital input pin to which camshaft trigger wheel sensor is connected
- *Sensor type* – VR or Hall
- *Pullup / pulldown* – None or 1K
- *Signal edge* – rising or falling.

4. Configure Actuator settings

In *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / **Actuator***

- *Type* – single solenoid (most cases) or dual solenoid (one of VANOS variants)
- *Active state* – the state of active solenoid output, low side (GND) or high side (12V) – applies to dual solenoid type setting only
- *Solenoid / Output* – output pin connected to VVT solenoid. For high side dual solenoid only H-bridge can be used
- *Solenoid / Output 2* – output pin connected to the second solenoid – used for low side dual solenoid only
- *Solenoid / Frequency* – output PWM frequency
- *Solenoid / Duty cycle [min\max]* – range of PWM duty cycle used to control the solenoid

5. Run the VVT Tuner

To simplify the configuration of other necessary settings, you can use the VVT Tuner. For more details about its operation, see chapter 4.

> ⚠️ **Warning:**
> VVT Tuner uses full range of VVT position.
> If your engine does not have VVT position limiters thus some positions could damage the engine, DO NOT USE this tuner!

VVT should be tuned at operating conditions. It is recommended to warm up the engine and keep at least 2000 RPM during VVT Tuner procedure running to build oil pressure.

Select the camshaft to configure and press the START button.

After successful calibration output log will show:

- number of teeth in camshaft trigger wheel (*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / **Teeth count***)
- calculated *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / **Primary trigger start tooth*** (if non-zero)
- minimum duty cycle (if detected) *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Duty cycle min***
- camshaft position at LOW duty cycle
- camshaft position at HIGH duty cycle
- steady state duty cycle

- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid /* **Control direction**
- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid /* **PID** settings

6. Verify the results

The chart in VVT Tuner window shows whether the configured camshaft moves as intended. Additional look at output log would give more information about the calibration.

Usually in VVT systems:

- working range is up to 70°
- P and I gains are between 1 and 6
- D gain is lower than 0.5
- P gain is greater than I gain

7. Check the operation

In *Graph Log* add camshaft position *VVT Timing [In\Ex] camshaft # Position* and target *VVT Timing [In\Ex] position target* channels on the same graph and set for them at least 100 Hz of logging frequency.
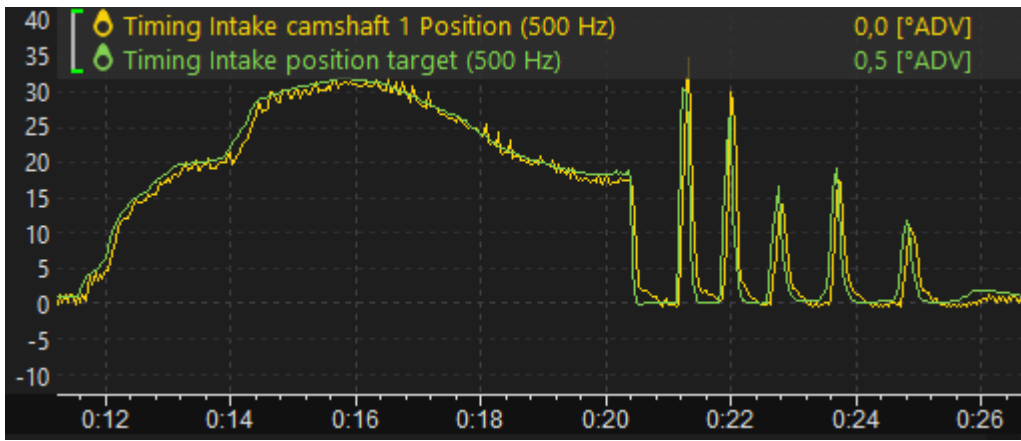
To check whether VVT is working properly, change target values in base map *VVT / Timing / [In\Ex] / [In\Ex] position target /* **Base** and observe the position changes. Since values from maps are interpolated, select the whole map and set the value for all the cells. For example change between 5 and 25 for advancing camshaft (or -5 and -25 for retarding case).

Position should reach the target quickly (approx. 200-300 ms) and without significant overshoot.
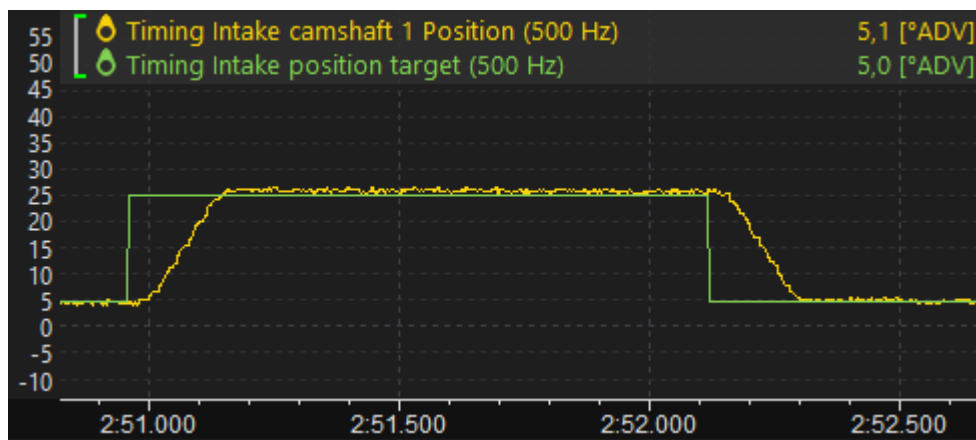
8. Configure target position maps

Set the map *VVT / Timing / [In\Ex] / [In\Ex] position target /* **Base** values to reach the best performance. It is a good idea to check VVT work during normal usage too. Position value should follow the target.

4. VVT Tuner

VVT Tuner configures:

*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / **Position***:
- *Primary trigger start tooth*
- *Teeth count*
- *Initial teeth angles*

*VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / **Solenoid***:
- *Control direction*
- *Steady state duty cycle*

- *PID* gains
- *Duty cycle min* (only when necessary)

There are two algorithms for *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / PID* gains calculations. The first one, Relay algorithm, should work for most cases. If not, AMIGO algorithm may be used instead.

If the position signal is very noisy, enabling *Moving average* option sometimes may improve the VVT Tuner work.

While the VVT Tuner is active, you can view the current position and duty cycle values on sliders. The chart will also display how the position changes when the duty cycle varies from 0 to the specified duty cycle. Light blue background shows the duty cycle range specified by *... / Actuator / Solenoid / Duty cycle min* and *Duty cycle max* parameters.

Some of the VVT systems (e.g. in Ford Coyote engine) needs to be controlled by duty cycle above some threshold to enable VVT work and move to the border position. If the minimal duty cycle was detected, it would appear on the chart as a red line. *... / Actuator / Solenoid / Duty cycle min* parameter would be set 3% above the detected threshold.
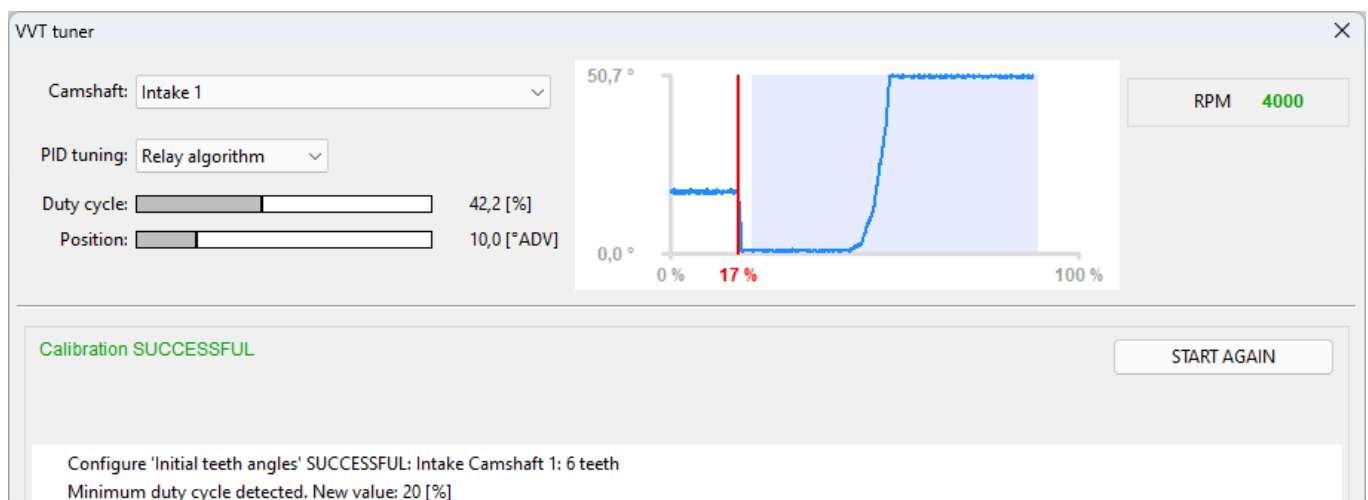
5. VVT Tuner errors

'*VVT / Timing / [In\Ex] / [In\Ex] camshafts count*' - wrong setting for this camshaft.
➢ Set *Single* for one cylinder head or *Dual* for two cylinder heads.

'*VVT / Timing / [In\Ex] / [In\Ex] camshaft / Position / Sensor input*' - not defined.
➢ Set proper input pin with connected camshaft trigger wheel sensor.

*'VVT / Timing / [In\Ex] / [In\Ex] camshaft / Actuator / Solenoid / **Output**'* - not defined.

➢ Set proper output pin with connected actuator (solenoid).

*'VVT / Timing / [In\Ex] / [In\Ex] camshaft / Actuator / Solenoid / **Output 2**'* - not defined.

➢ Set proper output pin with connected actuator (solenoid) - only for low side dual solenoid system.

➢ Set *Single* camshafts count if the engine has one cylinder head.

'Duty cycle max' must be greater than *'Duty cycle min'*. Correct the values and try again.

➢ Please look at *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Duty cycle min*** and *… / **Duty cycle max*** parameters, and correct the values.

'*Duty cycle min*' seems to be too high. Consider decreasing the value.

'*Duty cycle max*' seems to be too low. Consider increasing the value.

➢ Specified range should allow to control the camshaft. If there is no reason to narrow down the operating duty cycle range, keep *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Duty cycle min*** close to 0 and *… / **Duty cycle max*** close to 100. PWM output duty cycle value is in the range of:

- 0% to 100% for single solenoid VVT
- -100% to 100% for dual solenoid VVT

Can't get scope from device!

➢ There could be a problem with primary trigger wheel signal or camshaft trigger wheel signal. Check the trigger wheel sensors and specified input pins in configuration.

Too low position range. Check the setup and restart calibration.

➢ Position range of camshaft movement usually is greater than 20°. When camshaft does not move or it moves too close, the problem could be caused by:

- too low duty cycle range
- steady state duty cycle is too close to *Duty cycle min* or *Duty cycle max*
- output testing is enabled
- camshaft position sensor not connected or problem with wiring
- actuator not connected or problem with wiring
- wrong setting of *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / Sensor input **Pullup / pulldown*** for specified ***Sensor type***

Too high position range. Check the setup and restart calibration.

➢ Since camshaft movement is usually mechanically limited, the problem is caused by wrong position read-out because of wrong calculations of *VVT / Timing / Intake / Intake camshaft / Position /* **Initial teeth angles** or **Primary trigger start tooth**. If restarting VVT Tuner calibration does not succeed, changing the *Signal edge* could solve the problem.

PID calibration failed. Check the setup and restart calibration.

➢ This could happen when VVT Tuner wrongly determine the *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid /* **Control direction**. Too low duty cycle range could be one of the possible reasons. If this problem occurs repeatedly, contact us on tech@ecumaster.com

PID parameters were clamped to maximal values. Please check the numbers and consider recalibration.

➢ That indicates some problem with calculating the PID gains. Too low duty cycle range could be one of the possible reasons. If this problem occur repeatedly, contact us on tech@ecumaster.com

6. Troubleshooting

The position channel is very noisy:

- Some of the *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid /* **PID** gains are too large
- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid /* **Frequency** of PWM output is too low or too high
- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position /* **Initial teeth angles** are not properly configured – check the angles values in a scope
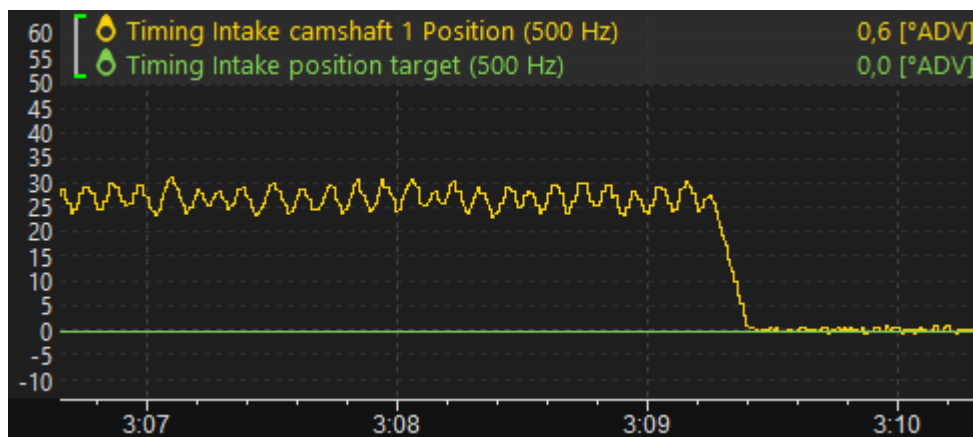

Camshaft position does not follow the target at all:

- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Output** testing mode is enabled*
- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **PID** gains are set to zero*
- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **Control direction** is set incorrectly*
- Target values in the map *VVT / Timing / [In\Ex] / [In\Ex] position target / **Base*** are outside the camshaft working range
- Camshaft position sensor not connected or problem with wiring
- Actuator not connected or problem with wiring
- Wrong setting of *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / Sensor input* **Pullup / pulldown** for specified ***Sensor type***
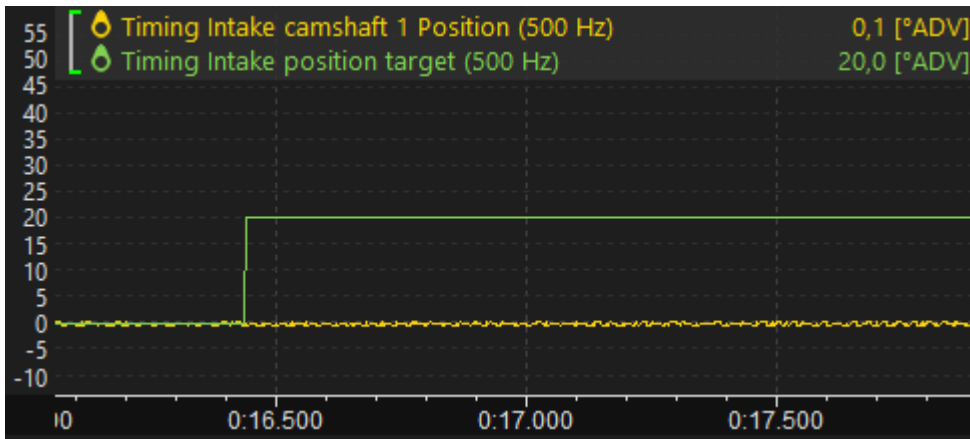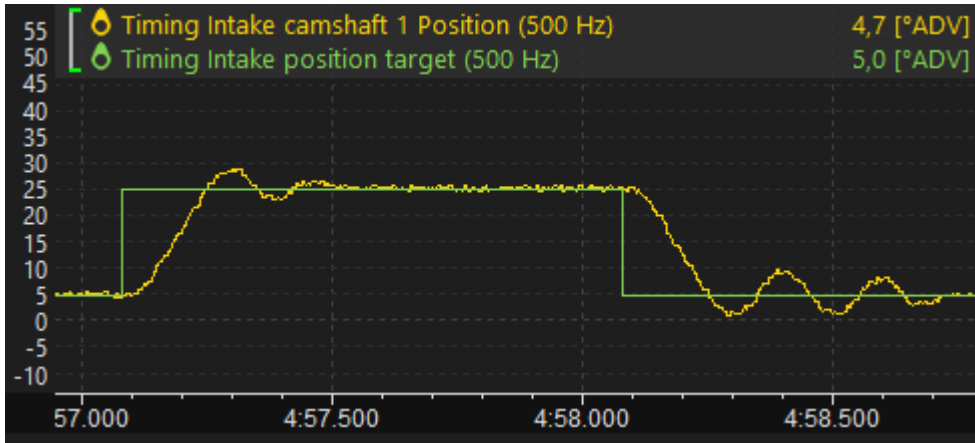

Camshaft position follows the target too slow:

- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **PID** proportional and/or integral gain are too small*
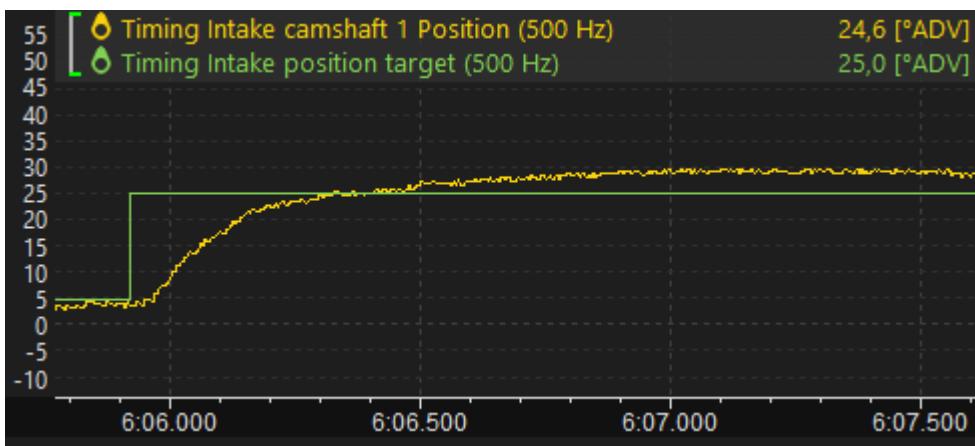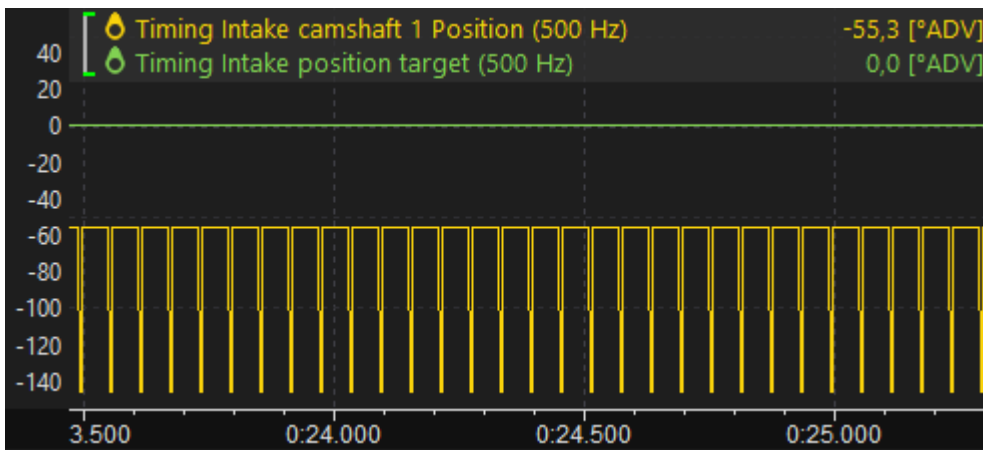

Camshaft position follows the target with high overshoot:

- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Actuator / Solenoid / **PID** proportional and/or integral gain are too large*

Camshaft position has spikes:

- *VVT / Timing / [In\Ex] / [In\Ex] camshaft # / Position / **Initial teeth angles** or **Primary trigger start tooth** are not configured properly*

7. Document history

Version	Date	Changes
1.0	2024.02.01	Initial release