SRT / SRAE SOFTWARE DOCUMENTATION

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SUPER-USER

13. USER STRATEGIES

chapter 13

Release : 2.0

SUPER-USER

11. VARIABLE CAM TIMING

chapter 11

Release : 1.0

REVISIONS DOCUMENT

Release	*Author*	*Date*	*Modifications*
1.0	**O.Nazorek**	**22/11/2006**	• **Creation**

11.1 Configuration

Variable cam timing configuration depends on the type and number of camshafts the system is using. This document describes how to configure the map files using a crankshaft wheel with 30 - 2 teeth and a VCT camshaft described below.

11.1.1 Crankshaft

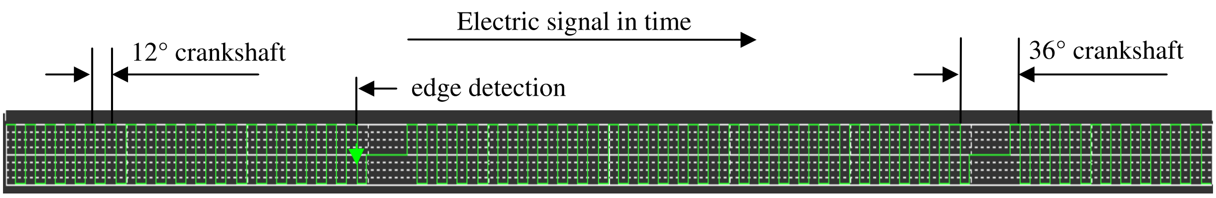
We use a 30 – 2 equidistant teeth crankshaft wheel as example with an electromagnetic pickup sensor for teeth detection.

We consider that the pickup sensor is correctly connected to the IN_PICKUP1 input (for example) of the ECU.
Then, some parameters should be set in the map file:

1. In section ***"FLYWHEEL DEFINITION"*** of group ***"ENGINE CONFIGURATION"*** of the map file:
   - Set the parameter "Number of Crank teeth" to **30**.
   - Set the parameter "Missing or added Crank teeth" to **-2**. (that defines the singularity)
   - Set the parameters "Singularity ratio" to **3** and "Singularity margin" to **1.5**

   See chapter "**ENGINE SYNCHRONIZATION**" for more details.

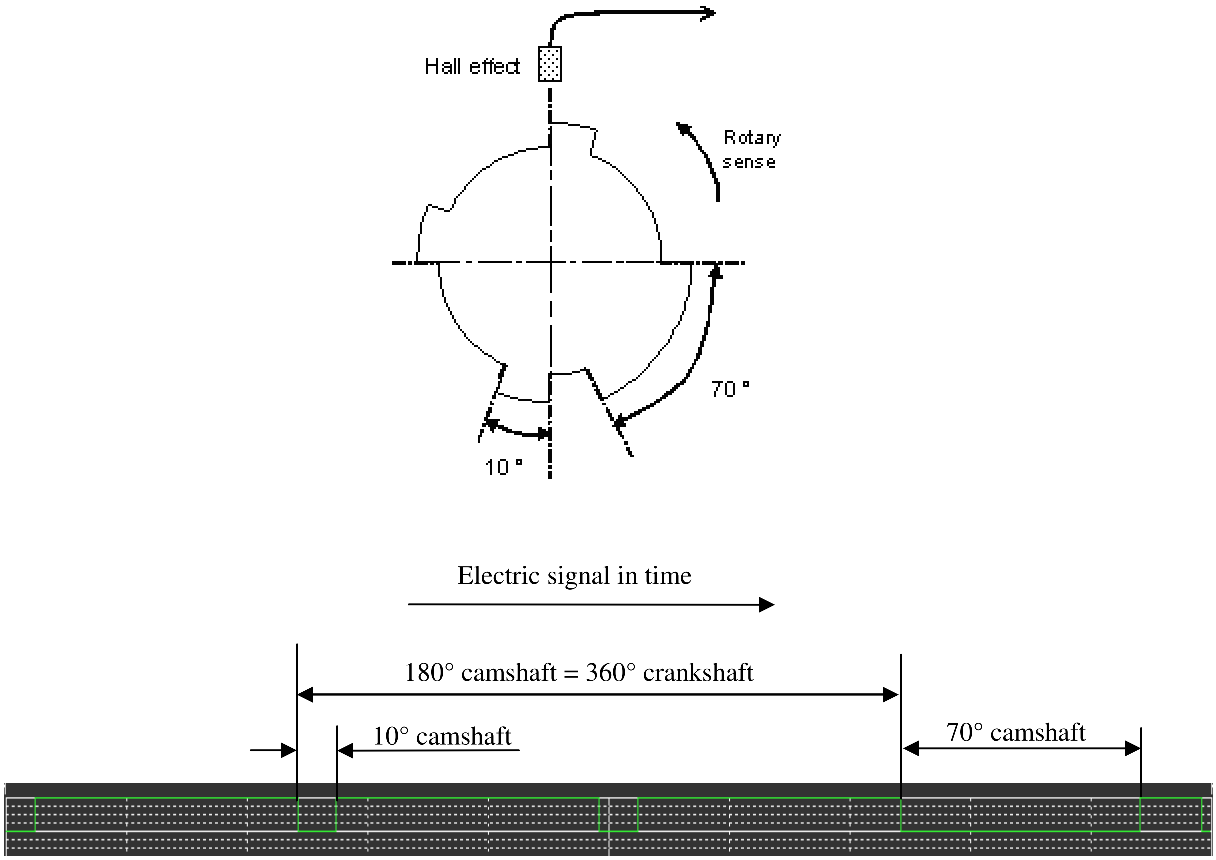
2. In section ***"FREQUENCY INPUTS"*** of group ***"INPUT ASSIGNEMENT"*** of the map file:
   - Set the parameter "Crank sensor input selection" to **1**.
     As specified in the comment lines, we connect the sensor to pickup 1 input to detect the falling edge of electrical signal delivered by the sensor (zero crossing).



Electrical signal generated by the pickup sensor when the engine is running

11.1.2 Camshaft

We suggest using the following camshaft wheel as variable cam timing wheel, with a Hall Effect sensor delivering a low level signal when metal is in front of the sensor. This type of camshaft allows the control function to read 4 cam references that is a good way to rapidly react with more precision.



Electrical signal generated by the hall effect sensor when engine is running

This document describes how to configure the map file using this type of camshaft.

11.1.2.1 System with only one camshaft

In this case, the camshaft electrical signal generates 4 cam positions (if using the recommended camshaft wheel), to control and drive the variable cam timing valve but it also gives the engine synchronization.
Synchronisation is achieved by checking the cam signal level when finding the crankshaft singularity on the crankchaft (on tooth number 1), thanks to the long cam tooth.

User should first set parameters corresponding to the synchronization cam. We consider the Hall Effect cam sensor is correctly connected to the IN_HALL2 input of the ECU (for example).

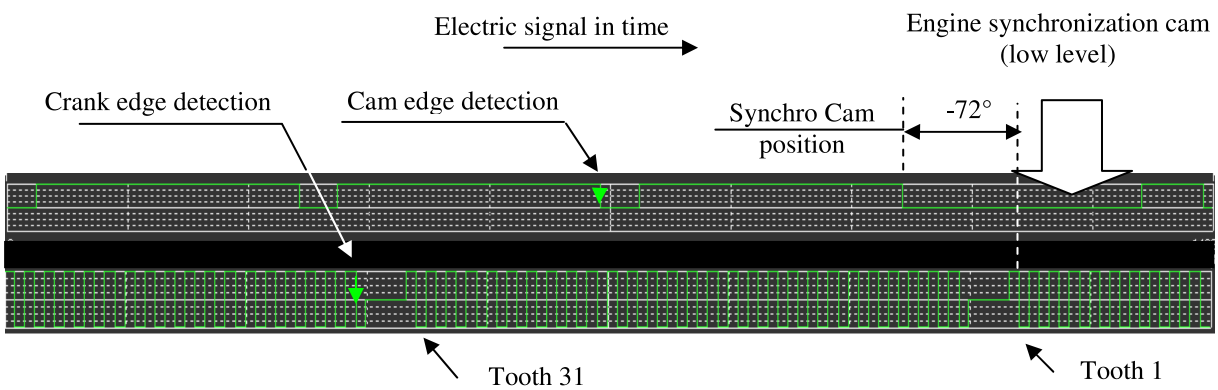
1. In section ***"FREQUENCY INPUTS"*** of group "***INPUT ASSIGNEMENT***" of map file:
   - Set parameter "*Cam 1 sensor input selection*" to **82** (hexadecimal) according to the comment lines of the map (depends on the ECU used) to detect a falling edge of the Hall Effect input.
   - Set parameter "*Cam 2 sensor input selection*" to **0** (No second camshaft).

- Set parameter "*Cam1 hall sensor synchro state*" to **0**. This refers to the electrical cam signal level obtained when the crankshaft singularity is encountered

NOTE: Cam 1 sensor input refers always to the synchronization cam.

2. In group "***ENGINE CONFIGURATION***" of map file:
   - Set parameter "*CAM Position / Tooth N°1*" with the angular ratio existing between the falling edge of synchronization cam signal and that of tooth number 1 (tooth following the singularity) with the valve command in neutral position (not activated). In our example the cam position is **-72**° crankshaft.
   - Set parameter "*Cam Position margin*" too (see chapter **ENGINE SYNCHRONIZATION** for more details).

3. To be considered as variable cam by the system, an output should be assigned to drive the valve driving cam1. In group "***OUTPUT ASSIGNEMENT***" of map file, set parameter "*VCT 1 output selection*" with an output number in accordance with the map's comment lines. As example, set 1 if ELV1 output drives the valve.



IMPORTANT: Synchronization cam must always cover the reference tooth number 1 whatever the variable cam displacement is.

11.1.2.2 System with two camshafts

When using two camshafts, there are two possibilities of set up, depending on the camshaft used for synchronization, and if it is variable or not.

11.1.2.2.1 One variable camshaft

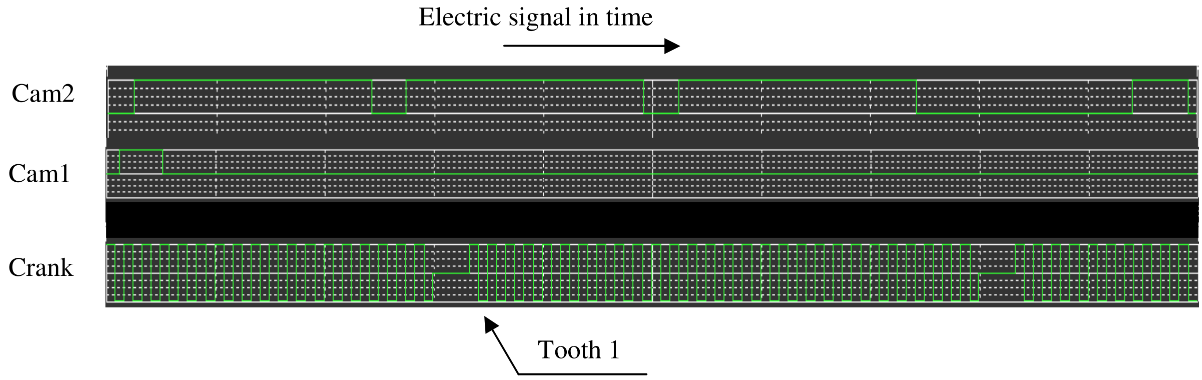
The possibility of one synchronization camshaft and one variable camshaft is available in the system.

- Synchronization camshaft can be a single cam for example. Synchronization cam always uses Cam1 parameters (Refer to chapter "**ENGINE SYNCHRONIZATION**" for setting).

As it is not a variable camshaft, parameter "*VCT 1 output selection*" of group "***OUTPUT ASSIGNEMENT***" must be set to **0**.

- Variable camshaft then uses Cam2 parameters.
  - In group "***INPUT ASSIGNEMENT***" of the map file, set the parameter "*Cam 2 sensor input selection*" with falling edge of Hall Effect sensor value in accordance with the comment lines.
  - In group "***OUTPUT ASSIGNEMENT***", set the parameter "*VCT 2 output selection*".

In the example below, we suppose that we use the recommended variable camshaft:



NOTE: Variable camshaft position can be fixed regardless of crankshaft

11.1.2.2.2 Two variable camshafts

Cam 1 parameters are assigned to the variable camshaft chosen for the engine synchronization. Cam 2 parameters are assigned to the second variable camshaft.

We consider that the variable camshaft 1 (for synchronization) Hall Effect sensor is correctly connected to the IN_HALL2 input of the ECU (for example), and the second variable camshaft to IN_HALL3 input:

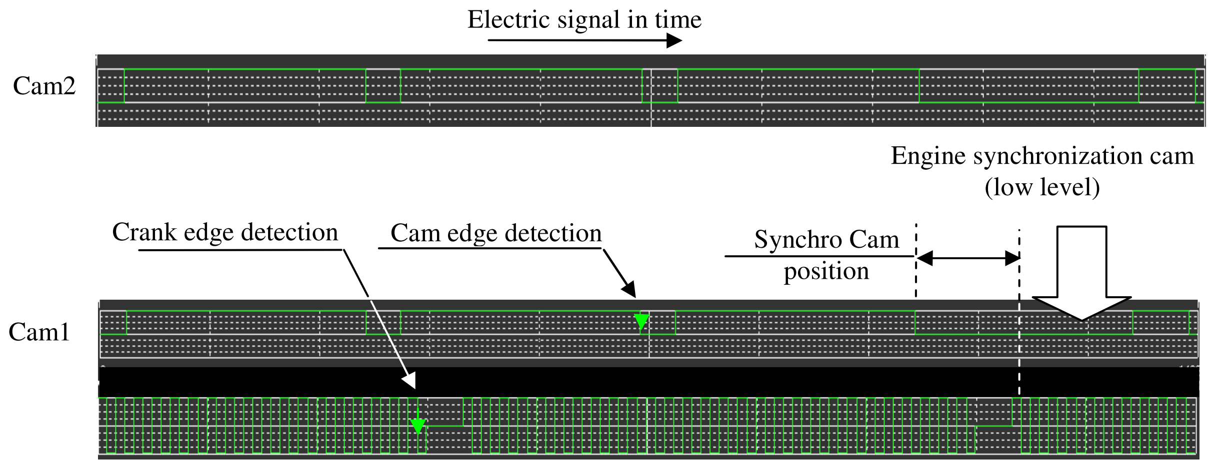
1. In section ***"FREQUENCY INPUTS"*** of group "***INPUT ASSIGNEMENT***" of the map file:
   - Set the parameter "*Cam 1 sensor input selection*" to **82** (hexadecimal) in accordance with the comment lines of the map (depending on the ECU used) to detect falling edge of Hall Effect input.
   - Set the parameter "*Cam 2 sensor input selection*" to **83**.
   - Set the parameter "*Cam1 hall sensor synchro state*" to **0**. This refers to the electrical cam signal level obtained when the crankshaft singularity is encountered.

NOTE: Cam 1 sensor input refers always to the synchronization cam.

2. In group "***ENGINE CONFIGURATION***" of map file:

- Set the parameter "*CAM Position / Tooth N°1*" with the angular ratio existing between the falling edge of synchronization cam signal and that of tooth number 1 (tooth following singularity) with the valve command in neutral position (not activated). In our example the cam position is **-72**° crankshaft.
- Set the parameter "*Cam Position margin*" too (see chapter **ENGINE SYNCHRONIZATION** for more details).

3. In group "***OUTPUT ASSIGNEMENT***" of map file:
   - Set the parameter "*VCT 1 output selection*" with an output number in accordance with the map's comment lines. As example, set 1 if ELV1 output drives the valve.
   - Set also parameter "*VCT 2 output selection*".

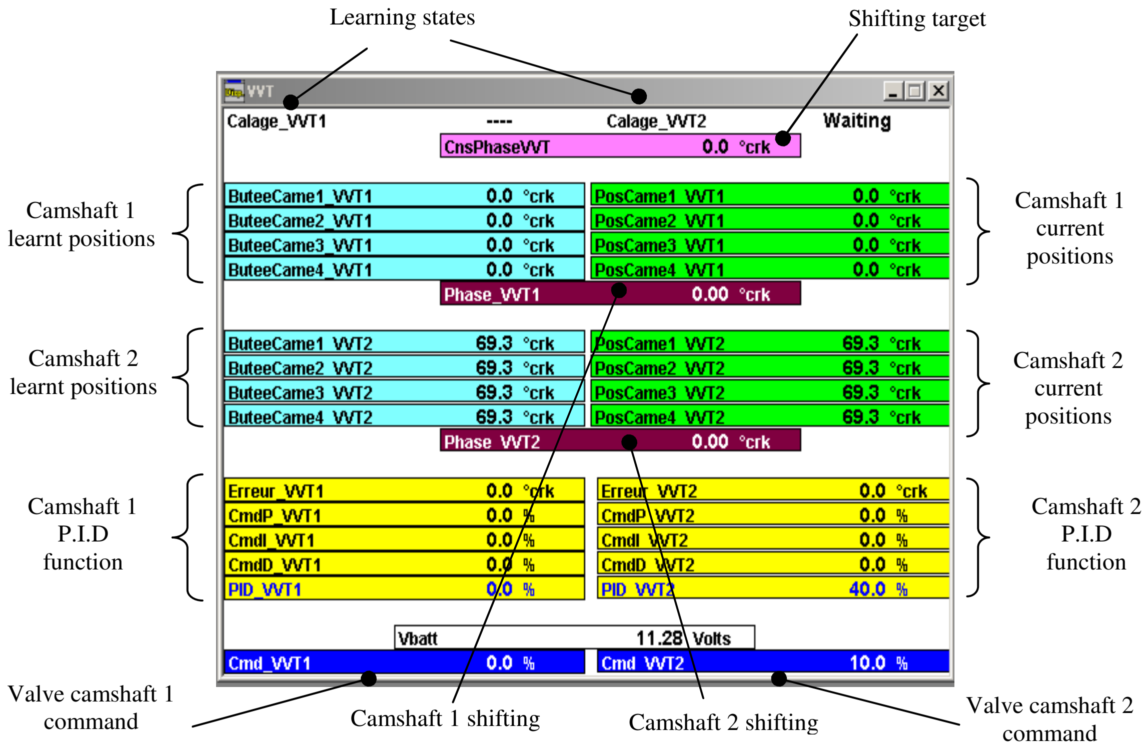


NOTE: Variable camshaft 2 position can be fixed regardless of crankshaft but not camshaft 1 because it is giving the engine's synchronization.

11.2 Variable camshaft control

Variable camshaft control works at a 10ms rate.
All parameters used by this function are located in the group "*VARIABLE CAM TIMING*" of the map file and are in common for both variable camshafts.

VISION view of variable camshaft timing is given by a window named "VVT":

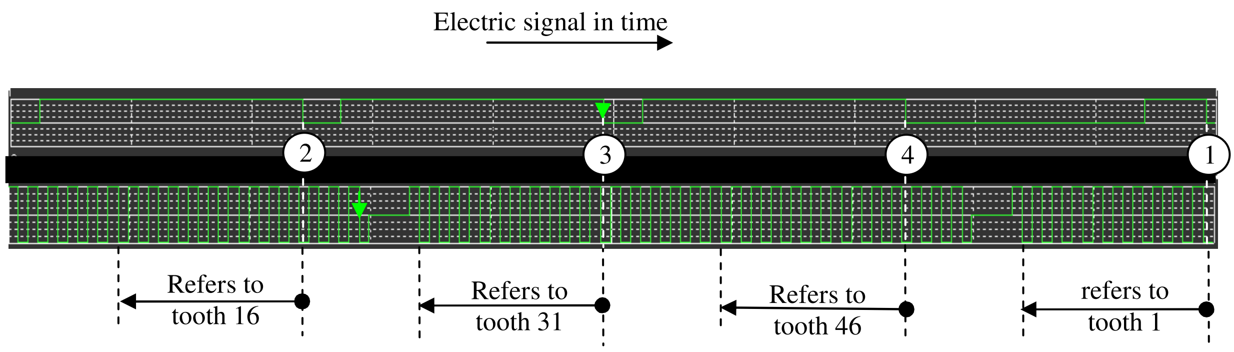


11.2.1 Learning reference positions

Learning sequence intends to measure the different cam positions of the variable camshafts in neutral position of the command valves (not driven), and finds the four reference crankshaft teeth. These reference teeth depend of the type of crankshaft used and are defined by:

- Cam numbered 1 refers to tooth number 1.
- Cam numbered 2 refers to tooth number = tooth reference cam 1 + (number of crankshaft teeth/2)
- Cam numbered 3 refers to tooth number = tooth reference cam 2 + (number of crankshaft teeth/2)
- Cam numbered 4 refers to tooth number = tooth reference cam 3 + (number of crankshaft teeth/2)

The following example gives the reference teeth found for a 30 – 2 teeth crankshaft.



Positions learnt are given in crankshaft degree unit.

NOTE: If cams are equidistant, positions learnt will be normally equal.
Due to the latching effect of some Hall Effect sensors, it is possible that the system cannot detect the cam following the long low state, but valves regulation will work correctly anyway.

Learning is effective in the range of engine speed defined by the "*Min Rpm to learn cam positions*" and "*Max Rpm to learn cam positions*" parameters and follows the sequence states reported by **Calage_VVTx** data in VISION window:

Learning state	Definition
---	No variable camshaft setting
Waiting	Waiting for engine speed conditions
Running	Learning camshaft positions
Done	Learning is done, position are stored.

- "***Waiting***" state is active from power ON (if a camshaft has been set as variable camshaft), until engine speed is stabilized for a minimum of 1second in the defined speed learning range, then the system shifts to "***Running***" state. During this state, no valve command is applied (**Cmd_VVTx** = 0% in VISION window).

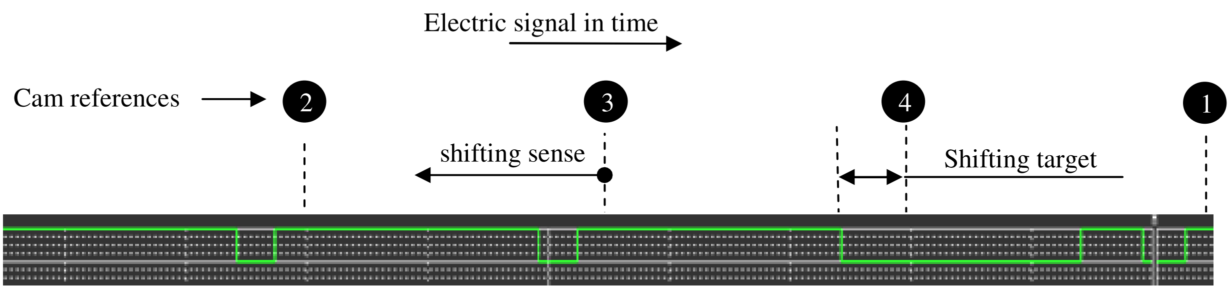
- "***Running***" state is active for a minimum of 1second while engine speed is in the defined speed learning range. During this state, specific valve command is applied to measure and store cam positions as reference values (in crankshaft degrees). When time elapses, the system's state shifts to "***Done***". Valve command in this state is to be set by the "*VCT PWM command to learn*" parameter.

Learnt Cam positions are stored in EEPROM to be restored at power ON. They can be read and written into map file using the F6 key.

11.2.2 Shifting target

Shifting target of camshaft is issued from "*Cam phasing target f(rpm, throttle)*" table as function of engine speed and throttle position. Shifting always refers to the learnt positions of camshaft and is in crankshaft degrees.
This value is filtered before being applied. Filter factor is to be set by the "*Target phasing filter*" parameter in range from **0.01** to **1**:

- Value **0.01** ⇒ strong filter
- Value **1** ⇒ no filter



Shifting is limited to the range defined by the "*Minimum target phasing*" and the "*Maximum target phasing*" parameters.

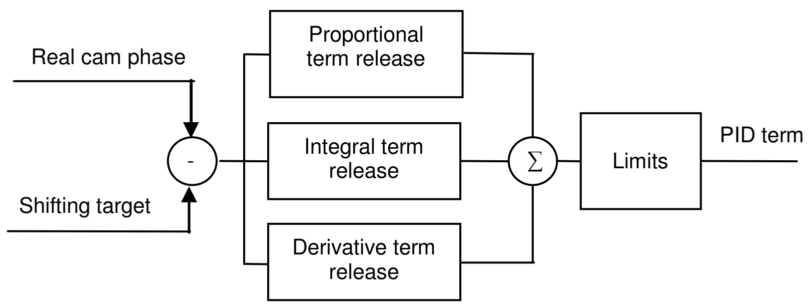
11.2.3 Regulation loop

Regulation loop of camshaft phasing starts when the learning position sequence is "***Done***".
The system measures the real camshaft phasing compared to the cam positions learnt, every time a cam is detected (**Phase_VVTx** in VISION window) if, and only if, engine speed is higher than the "RPM min to control VCT" threshold parameter.
For engine speed lower than this value, real cam phasing will not be measured but fixed by the "*VCT cam phasing by default*" parameter.

The error existing between this real phasing and the filtered shifting target will be used as input of a P.I.D function to correct the ratio:

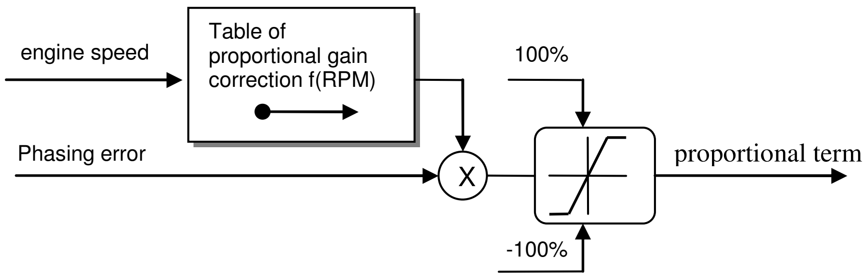
Error = Shifting target – Real cam phasing

This error is showing throughout **Erreur_VVTx** in VISION window.



Output of the P.I.D function will return a PWM target command to be applied to the electro valves.

11.2.3.1 Proportional term



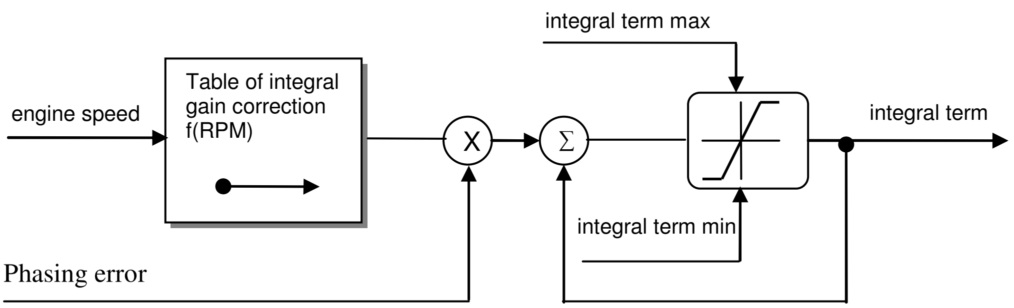
Proportional term is signed and is defined by:

Proportional term = phasing error x gain

Where the gain is issued from the "*VCT proportional gain*" map parameter as function of engine speed.
Table size is 8 engine speed breakpoints defined by the "*Rpm breakpoints used with VCT*" table.

This term is limited from -100% to +100% of PWM command and is showed by **CmdP_VVTx** in VISION window.

11.2.3.2 Integral term



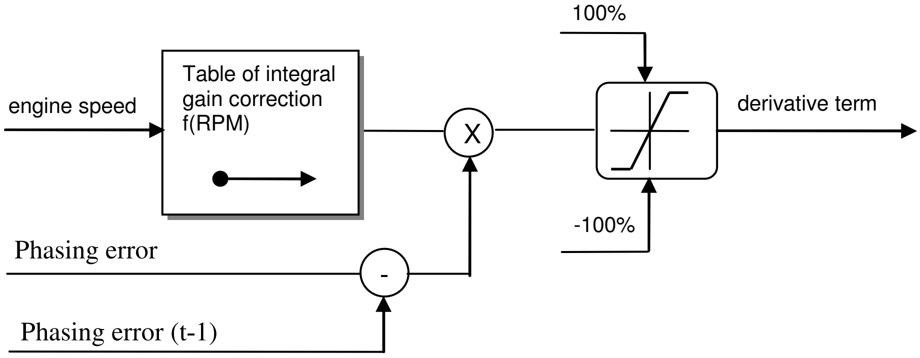
Integral term is signed and is defined by:

$$\text{Integral term} = \text{Integral term}_{(t-1)} + (\text{phasing error x gain})$$

Where the gain is issued from the "*VCT integral gains*" map parameter as function of engine speed.
Table size is 8 engine speed breakpoints defined by the "*Rpm breakpoints used with VCT*" table.

This term is limited from "*VCT integral term min*" to "*VCT integral term max*" of PWM command and is showed by **CmdI_VVTx** in VISION window.

11.2.3.3 Derivative term



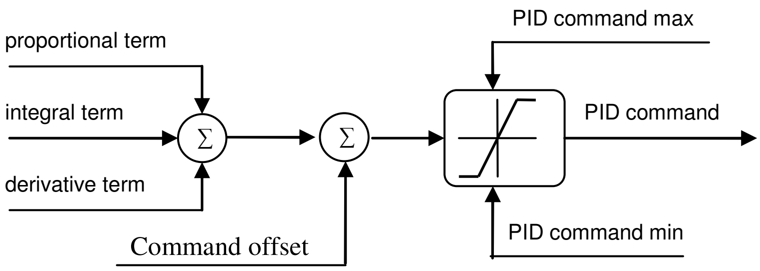
Derivative term is signed and is defined by:

$$\text{Derivative term} = (\text{phasing error} - \text{phasing error}_{(t-1)} \text{ x gain}$$

Where the gain is issued from the "*VCT derivative gains*" map parameter as function of engine speed. Table size is 8 engine speed breakpoints defined by the "*Rpm breakpoints used with VCT*" table.

This term is limited from -100% to +100% of PWM command and is showed by **CmdD_VVTx** in VISION window.

11.2.3.4 Resulting PID command



Result of P.I.D function is signed and is the sum of the 3 terms and an offset of command.
This offset (to be set by the "*VCT command offset*" parameter) is to be used to calibrate the zero of valve command (command value at which the valve begins to be really active).
Resulting PWM command is limited from "VCT command min" to "VCT command max" and is showed by **PID_VVTx** in VISION window.

11.3 Valve command

Valve driving frequency is to be set by the "*VCT command frequency*" parameter
Duty cycle of command results of different functional states:

- Whithout engine speed, PWM command is 0%.
- When learning cam positions, PWM command is this set by the "*VCT PWM command to learn*" parameter.
- If no cam is detected, PWM command is this set by the "*VCT command if no cam*" parameter.
- In all other cases, PWM command corresponds to the resulting PID command, corrected as function of the battery voltage (see below).

Battery voltage correction applied to the resulting PID command results of the voltage reference set by the "*Battery voltage reference*" parameter measured when maps was created.
Correction will then be applied as a gain:

Battery voltage correction = Battery voltage reference / current voltage measured

This corrected PWM command can be inverted too by setting "*To invert VCT command*" parameter to **1**.

11.4 Control diagnostic

Variable camshaft control diagnostic works for engine speed higher than the "*RPM min to control VCT*" threshold.
In this case and if absolute value of cam phasing error is higher than the "*VCT control error threshold*" threshold for more than "*VCT control error duration*", then the system will report a control error by setting the associated camshaft diagnostic to 1.