SRT / SRAE SOFTWARE DOCUMENTATION SUPER-USER

4. ENGINE SYNCHRONIZATION

chapter 4

Release : 1.0

REVISIONS DOCUMENT

Release	*Author*	*Date*	*Modifications*
1.0	**O.Nazorek**	**01/12/2006**	• **Creation**

4.1 Configuration

4.1.1 Crank sensor definition

Type and electrical edge detection of crank sensor should be defined according to the ECU pin out.
In group "***INPUT ASSIGNEMENT***" of the map file (.pta), set the parameter "*Crank sensor input selection*" using values described in the comment lines:

- If using an electromagnetic Pickup sensor (recommended for a flywheel with many teeth), set a value to detect falling edge of the electrical signal (zero crossing).
  For example: with a crank sensor connected to the **IN_PICKUP1** input of the ECU then set the value to **1**.

- If using a Hall Effect sensor delivering an electrical low level when metal is present in front of the sensor, set a value to detect falling edge of the electrical signal.
  For example: with a crank sensor connected to the **IN_HALL1** input of the ECU then set the value to **81**

- If using a Hall Effect sensor delivering an electrical high level when metal is present in front of the sensor, set a value to detect rising edge of the electrical signal.
  For example: with a crank sensor connected to the **IN_HALL1** input of the ECU then set the value to **1**

NOTE: If using Hall Effect sensors, prefer detection of the starting point of the electrical signal because of sensor latching effect - (Values are hexadecimal values).

4.1.2 Crankshaft flywheel definition

User should set parameters corresponding to the crankshaft type used on the engine.
These parameters can be found in the map file (.pta) in group "***ENGINE CONFIGURATION***".

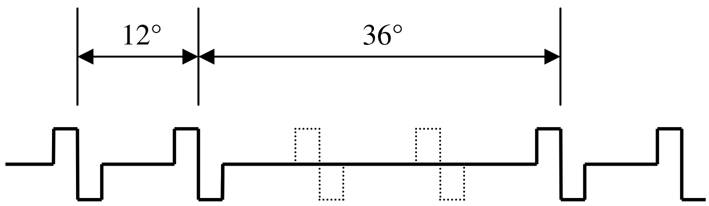
4.1.2.1 Crankshaft flywheel with missing teeth

1. Set the parameter "*Number of Crank Teeth*" with the number of equidistant teeth on flywheel including the missing teeth.
   For example: Using a flywheel with 30 teeth with 2 missing teeth then set **30** teeth.

2. Set the parameter "*Missing or added Crank Teeth*" with the number of missing teeth.
   This parameter defines the type of singularity the system should detect for engine synchronization.
   For example: Using a flywheel with 30 teeth with 2 missing teeth then set **-2** teeth.

Engine synchronization is done by crankshaft singularity detection. This singularity should then be set correctly to detect it:

1. Set the parameter "Singularity ratio" with the singularity's angular size divided by the regular teeth angular size.
   For example: 30 – 2 teeth crankshaft:
   - singularity angular size = 36° crankshaft
   - regular teeth angular size = 360°/30 = 12° crankshaft
   - singularity ratio = 36° / 12° = 3



2. Set the parameter "Singularity margin" to define a range around the "Singularity ratio". As it is not easy to have exactly the size due to metal machining and to prevent synchronization loss during acceleration or deceleration phases, this parameter is used to create a period measurement window when the engine is running. Typically, half of the "Singularity ratio" value can be used:
   For example: Using 30 – 2 teeth crankshaft, singularity margin = 3 / 2 = 1.5

4.1.2.2 Crankshaft flywheel with added teeth

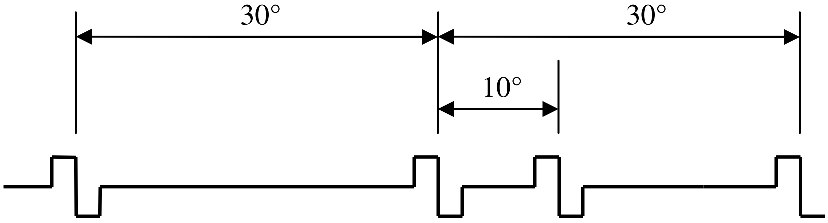
1. Set the parameter "*Number of Crank Teeth*" with the number of equidistant teeth on the flywheel excluding the additional teeth.
   For example: Using a flywheel with 12 teeth with 1 additional tooth then set **12** teeth.

2. Set the parameter "*Missing or added Crank Teeth*" with the number of additional teeth. This parameter defines the type of singularity the system should detect for engine synchronization.
   For example: Using a flywheel with 12 teeth with 1 additional tooth then set **1** tooth.

Engine synchronization is done by crankshaft singularity detection. This singularity should then be set correctly to be detected:

3. Set the parameter "Singularity ratio" with the singularity's angular size divided by the regular teeth angular size.
   For example: 12 + 1 teeth crankshaft flywheel:

- singularity angular size = 10° crankshaft (example)
- regular teeth angular size = 360°/12 = 30° crankshaft
- singularity ratio = 10°/30° = 0.33



4. Set the parameter "Singularity margin" to define a range around the "Singularity ratio". To prevent synchronization loss during acceleration or deceleration phase, this parameter is used to create a period measurement window around the '*Singularity ratio*" when the engine is running. Typically, half the value of the singularity ratio can be used:
   For example: Using 12 +1 teeth crankshaft, singularity margin = 0.33 / 2 = 0.16

4.1.2.3 Regular flywheel Crankshaft

A regular flywheel Crankshaft has no missing or added teeth, only equidistant teeth.

1. Set the parameter "*Number of Crank Teeth*" with the number of equidistant teeth on the flywheel.
   For example: Using a flywheel with 4 teeth then set **4** teeth.

2. Set the parameter "*Missing or added Crank Teeth*" to **0**.

As there is no singularity to detect, parameters "Singularity ratio" and "Singularity margin" don't have any sense here.
Engine synchronization will be given by the Cam state, so a Hall Effect sensor should be used as Cam1 sensor.

4.1.3 Cam sensor definition

Type and electrical edge detection for the engine synchronization cam sensor should be defined according to the ECU pin out with the *Cam1* parameters:

In the group "***INPUT ASSIGNEMENT***" of the map file (.pta), set the parameter "*Cam1 sensor input selection*" using the values described in the comment lines (Warning: Use only this parameter for the cam giving the engine synchronization) :

- If using an electromagnetic Pickup sensor, set the value to detect a falling edge of the electrical signals (zero crossing).
  For example: if the cam sensor is connected to the **IN_PICKUP2** input of the ECU then set the value to **2**.

- If using a Hall Effect sensor delivering an electrical low level when metal is in front of the sensor, set the value to detect falling edge of the electrical signal.
  For example: if the cam sensor is connected to the **IN_HALL2** input of the ECU then set value the value to **82**

- If using a Hall Effect sensor delivering an electrical high level when metal is in front of the sensor, set the value to detect a rising edge of the electrical signal.
  For example: if the cam sensor is connected to the **IN_HALL2** input of the ECU then set the value to **2**

NOTE: If using Hall Effect sensors, prefer detection of the starting point of the electrical signal because of sensors' latching effect - (Values are hexadecimal values).

NOTE: Parameter "*Cam2 sensor input selection*" is only used with variable cam timing function (See chapter "**VARIABLE CAM TIMING**" for more details).

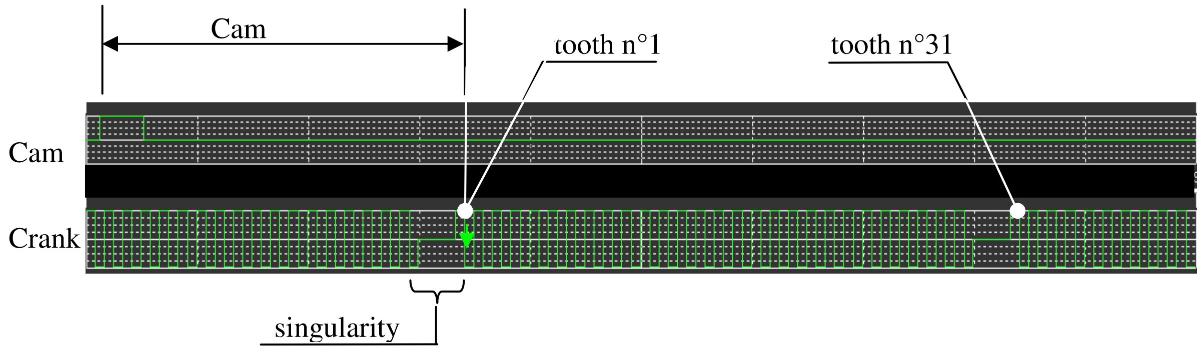
4.1.4 Camshaft definition

Engine synchronization is given by the Cam1 position regard with crankshaft.

4.1.4.1 Using a Crankshaft flywheel with singularity

If using a crankshaft flywheel with singularity (missing or added teeth), the Cam can be placed anywhere before the crankshaft singularity. The Cam position is very important because it defines the first tooth following the singularity as tooth n°1 and then the TDC positions.

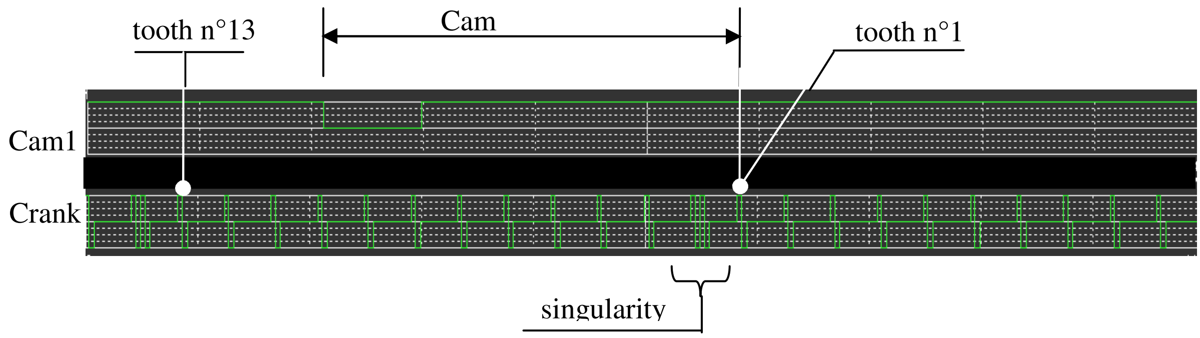
4.1.4.1.1 Example using a crankshaft 30 – 2 teeth



The Cam position is to be set in the group "***ENGINE CONFIGURATION***" of the map file by the parameter "*CAM Position / Teeth N°1*". In our case the value to be set is **-240**°.

NOTE: Position is to be measured between the chosen edges of the Cam and Crank electrical signals. In this example cam detection is done on rising edge.

4.1.4.1.2 Example with a crankshaft 12 + 1 teeth

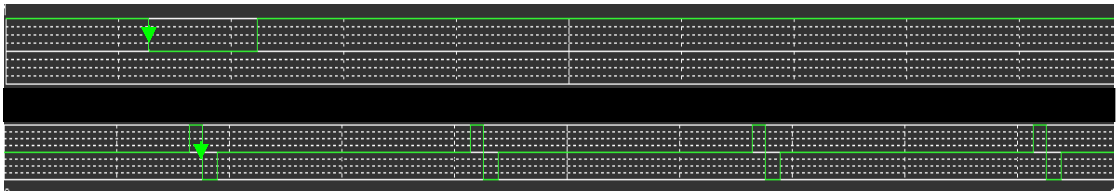


The Cam position is to be set in the group "***ENGINE CONFIGURATION***" of the map file by the parameter "*CAM Position / Teeth N°1*". In our case the value to be set is **-270**°.

NOTE: Position is to be measured between the chosen edges of the Cam and Crank electrical signals. In this example cam detection is done on falling edge.

4.1.4.2 Using a regular Crankshaft

If using a regular crankshaft (no singularity), the Cam position numbers directly the following crankshaft tooth as 1. As tooth number 1 is the reference for TDC positions, Cam position is very important is this case.



In this example, the crankshaft flywheel has 2 equidistant teeth for 360° using an electromagnetic pickup sensor to detect the falling edge of teeth.
Cam sensor is a Hall Effect sensor, set to detect falling edge of the electrical signal.

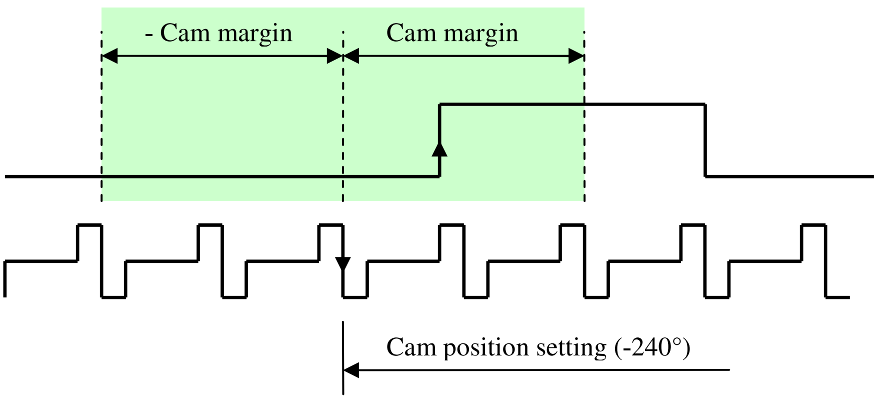
4.1.4.3 Cam position margin

User should define a window around the cam position setting:

- To cope with potentially noisy electrical cam signal.
- If using a camshaft with more than one tooth.
- If cam position setting is an approximate value.

This window allows to detect only one synchronization cam and only one.

In the group "***ENGINE CONFIGURATION***" of the map file, set the parameter "*Cam Position margin*" with an angular value.



In this example, "*CAM Position / Teeth N°1*" is not the real cam position (approximate value) and "*Cam Position margin*" is set to 24° using a 30 – 2 teeth crankshaft flywheel.

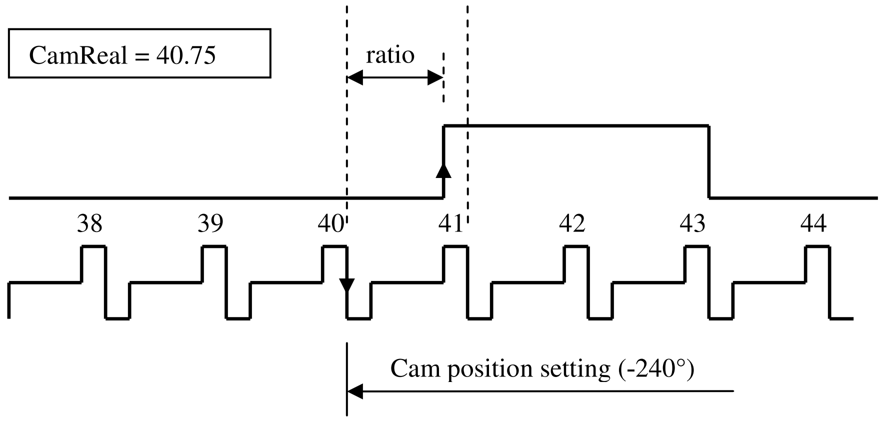
Whenever an electrical cam edge is detected:

- If it is in the defined window, the counter of phased cam is increase.
- If it is out of the defined window, then the counter of misplaced cam is increased.

4.1.4.4 Real Cam position

To help user to correctly set these parameters, the **CamReal** data can be read with VISION in a window named **VRS**. This value gives the number of the crankshaft tooth on which the edge of the cam is detected, plus the decimal ratio after the tooth (between 2 teeth).

For example, using a 30 – 2 teeth crankshaft flywheel:



4.2 TDC positions setting

Set the parameter "*TDC1 position / Tooth N°1*" with the real position of the cylinder 1 TDC with reference to the tooth number 1 of the crankshaft (don't forget that the reference is the electrical signal edge set for the crankshaft sensor).

Then, the space between TDCs must be set in the group "***ENGINE CONFIGURATION***" of the map file by the "*TDC Positions*" parameter following the number of cylinders. Values here are not real positions but only the gap between TDCs (in crankshaft degrees) in the engine cycle.

NOTE: First TDC is always set to 0° crankshaft

This is to simplify setting up TDCs for various engines (with different numbers of cylinders) or not balanced engines (with TDCs not equally spread throughout the engine cycle).
This method only requires to define the exact position of the first TDC and then the space between them.

As example using a balanced 4 cylinders engine, values to be set are **0**, **180**, **360** and **540**. Other values don't matter.

4.3 Synchronization sequence

Engine synchronization states can be read through **SyncState** data using VISION in a window named **VRS**. Engine synchronization timing follows the sequence below:

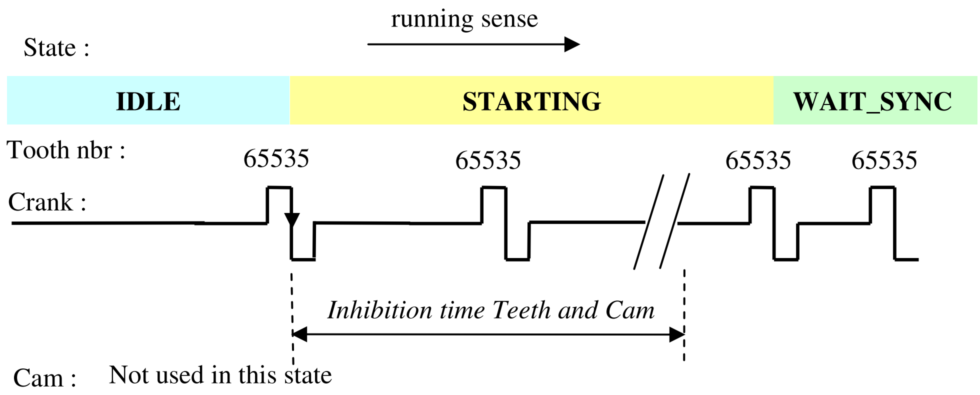
Values	Enum.	Definition
0	IDLE	Engine is stalled (Initial state)
1	STARTING	Crankshaft is moving
2	WAIT_SYNC	Synchronization waits for inhibition time
4	SY_ZING	Singularity + cam search (Synchronizing)
8	SY_ZED	Singularity confirmed (Synchronized)
16	PHASED	Engine phased

4.3.1 IDLE state

IDLE state is the initial state at power up.
In this state, current tooth number is 65535 (invalid)
State shifts to ***STARTING*** as soon as teeth are detected by the system.
Synchronization can return to ***IDLE*** state if the engine stalls (See section "Engine states").

4.3.2 STARTING state

STARTING state means that the engine begins to crank and it is issued from ***IDLE*** state.
During this state, current tooth number is 65535 (invalid).
An inhibition capture time is launched at startup of this state to prevent detection of a distorted signal.
In the group "***ENGINE CONFIGURATION***" of the map file, set the parameter "*Inhibition time Teeth and Cam*" with the duration of this state.
When inhibition time elapses, state shifts directly to the ***SY_ZING*** state if using a regular crankshaft flywheel, else to the ***WAIT_SYNC*** state if using crankshaft flywheel with singularity.



4.3.3 WAIT_SYNC state

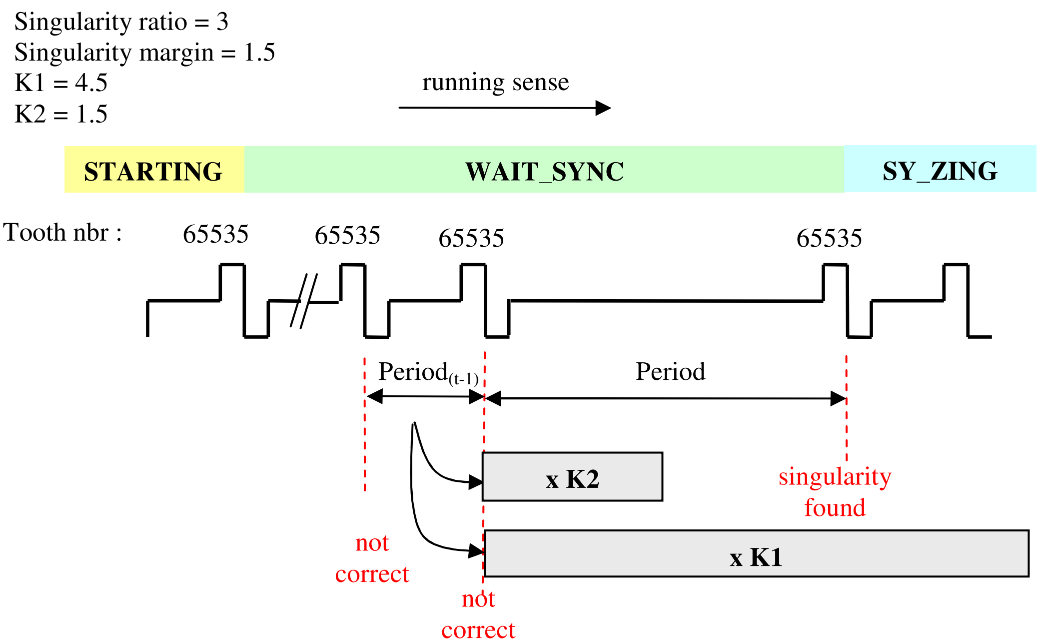
WAIT_SYNC state is issued from ***STARTING*** state if using crankshaft flywheel with singularity.
During this state, current tooth number is 65535 (invalid).
System can now measure the period existing between 2 teeth of crankshaft and then determine an engine speed. This period is used to detect the crankshaft singularity too.
Singularity is detected when:

$$\text{Period} < \text{K1 x Period}_{(t-1)} \text{ and Period} > \text{K2 x Period}_{(t-1)}$$

with:

- K1 = Singularity ratio + singularity margin
- K2 = Singularity ratio – singularity margin

When singularity is detected then state shifts to the ***SY_ZING*** state (synchronizing).



4.3.4 SY_ZING state

SY_ZING state is issued from the ***STARTING*** state if using regular crankshaft flywheel or from the ***WAIT_SYNC*** state if using a crankshaft flywheel with singularity.
During this state, current tooth number is 65535 (invalid) until synchronization with the cam is correctly seen in the defined angular window (See Cam position margin section for more details).

2 cases are available depending on the type of crankshaft flywheel used:

1. Using a crankshaft flywheel with singularity:
   The system tries first to confirm the singularity on the following tooth. It is confirmed if:

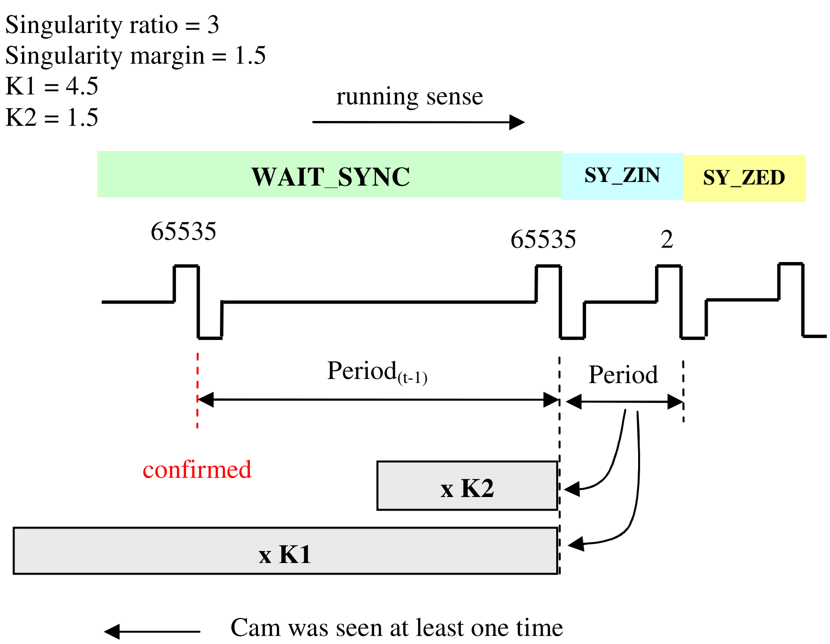
$$\text{Period}_{(t-1)} < \text{K1 x Period and Period}_{(t-1)} > \text{K2 x Period}$$

with:

- $\text{Period}_{(t-1)}$ = singularity period

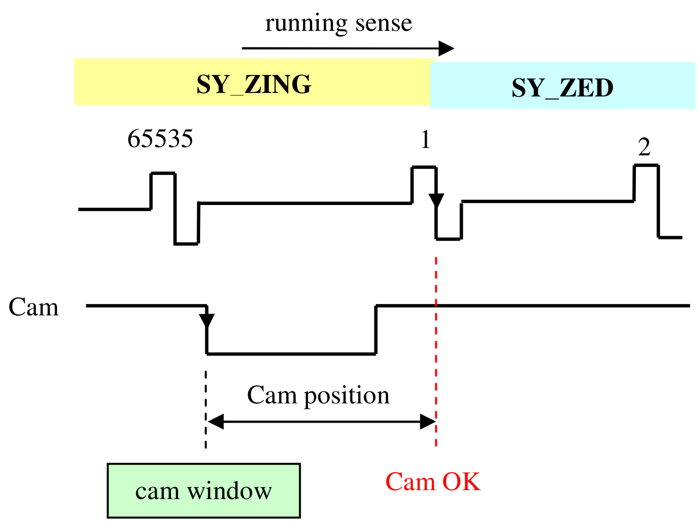
- K1 = Singularity ratio + singularity margin
- K2 = Singularity ratio – singularity margin

  - If it is confirmed and synchronization cam is seen at least one time, the tooth is numbered 2. Otherwise, it is numbered “*Number of Crank Teeth*” + 2. The state then shifts to ***SY_ZED***.
  - If not confirmed, the system is looking for a new singularity period to be confirmed. State returns to ***WAIT_SYNC***.



2. Using a regular crankshaft flywheel:

   In this case, the system verifies only the cam position with reference to the current tooth, and then numbers this tooth 1 if the Cam is in the window defined by the margins. Then synchronization state shifts to ***SY_ZED***.



4.3.5 SY_ZED state

SY_ZED (synchronized) state is issued from the ***SY_ZING*** (synchronizing) state.
During this state, tooth number is increased continuously on each tooth until:

- <u>If using a crankshaft flywheel with singularity:</u>
  A new singularity + Cam are detected. In this case tooth following singularity returns to 1.

- <u>If using a regular crankshaft flywheel:</u>
  A new cam is detected. In this case tooth following the cam returns to 1.

In all cases:

- A minimum number of cams should be seen during cycles before moving to the ***PHASED*** state.
  This number of cam is to be set in the group "***ENGINE CONFIGURATION***" of the map file by the parameter "*Min cam required*".
- For singularity with missing teeth, if the check of singularity on tooth number 1 or tooth number "*Number of Crank Teeth*" + 1 is not confirmed anymore, then state returns to ***WAIT_SYNC*** and the synchronization lost counter will be incremented.
- For singularity with added tooth or with regular crankshaft flywheel, system checks for crankshaft regularity.
  On each tooth and if engine speed is above the "*Synchro check threshold*" parameter

  If Period < $\text{Period}_{(t-1)}$ x 0.75 or Period > $\text{Period}_{(t-1)}$ x 1.25

  Then state returns to ***WAIT_SYNC*** and the synchronization lost counter will be incremented.

NOTE: Ignition and phased injection only begin with this synchronization state.

4.3.6 PHASED state

PHASED state is issued from the ***SY_ZED*** state.
At this point, Cam has no more effect to the synchronization state, only the constant check of the crankshaft regularity or singularity can make the state return to the ***WAIT_SYNC*** state:

- For singularity with missing teeth, if the check of singularity on tooth number 1 or tooth number "*Number of Crank Teeth*" + 1 is not confirmed anymore, then the state returns to ***WAIT_SYNC*** and the synchronization lost counter will be incremented.
- For singularity with added tooth or with regular crankshaft, system checks for crankshaft regularity.
  On each tooth and if engine speed is above the "*Synchro check threshold*" parameter

  $$\text{If Period} < \text{Period}_{(t-1)} \times 0.75 \text{ or Period} > \text{Period}_{(t-1)} \times 1.25$$

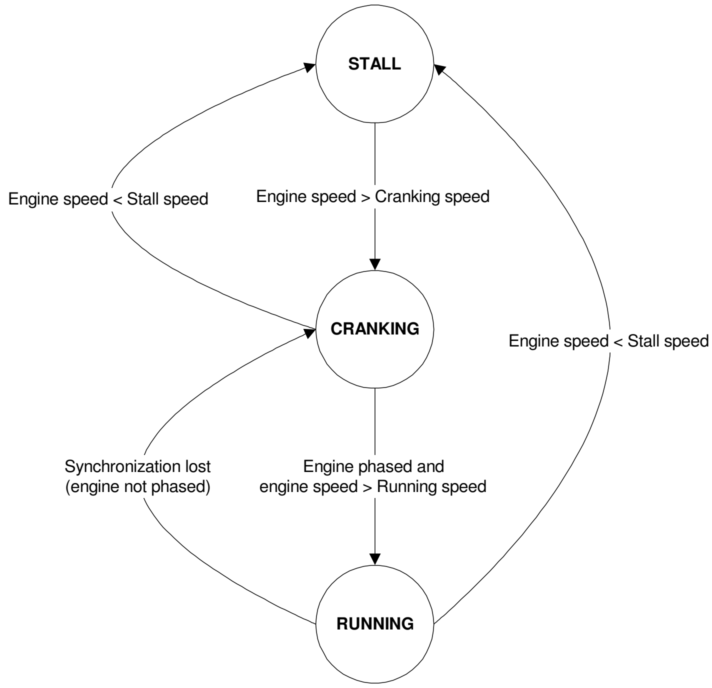
  Then state returns to ***WAIT_SYNC*** and synchronization lost counter will be incremented.

4.4 Engine states

Engine states depend on engine synchronization states and on engine speed.
States can be read in **Vrs_Status** using VISION, in the window named **VRS**. To be easier to read, values are enumerating expressions:

Values	Enum.	Definition
0	STALL	Engine is stalled (Initial state)
1	CRANKING	Engine is moving
2	RUNNING	Engine is running

The scheme below explains how engine states are set:



In the group "***ENGINE CONFIGURATION***" of the map file:

- Set the parameter "RPM threshold to declare Stall engine" as engine speed threshold under which engine is declared as stalled.
- Set the parameter "RPM threshold to declare Cranking engine" as minimum engine speed to declare the engine cranking.
- Set the parameter "RPM threshold to declare Running engine" as minimum engine speed to declare the engine running if the engine is phased.