

Haptic Functions Documentation

XeelTech GmbH

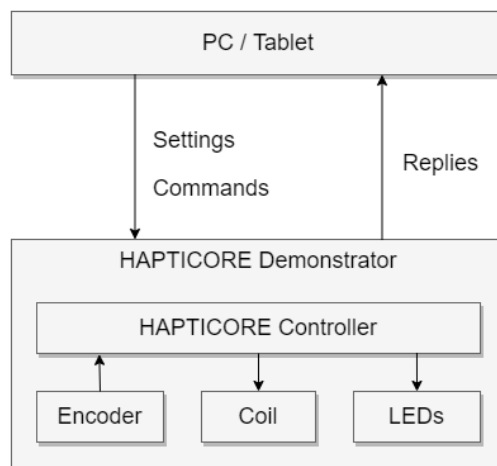
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1 General

This document contains the description of possible setting parameters to generate different haptic feedback. Generally, a distinction has to be made between the chapters *General Commands*, *General Settings*, *Reports*, *Information* and *Haptic Mode Generation*. The chapters *General Commands* and *General Settings* describe commands and settings that are not directly related to the haptic feedback of the knob for example, the device's idle detection. In *Reports* the communication between the rotary knob and the host device will be outlined. In *Haptic Mode Generation* the settings for haptic feedback of the knob will be explained.



1.1 List of Abbreviations

Abbreviation	Definition
CW	Clockwise
CCW	Counterclockwise

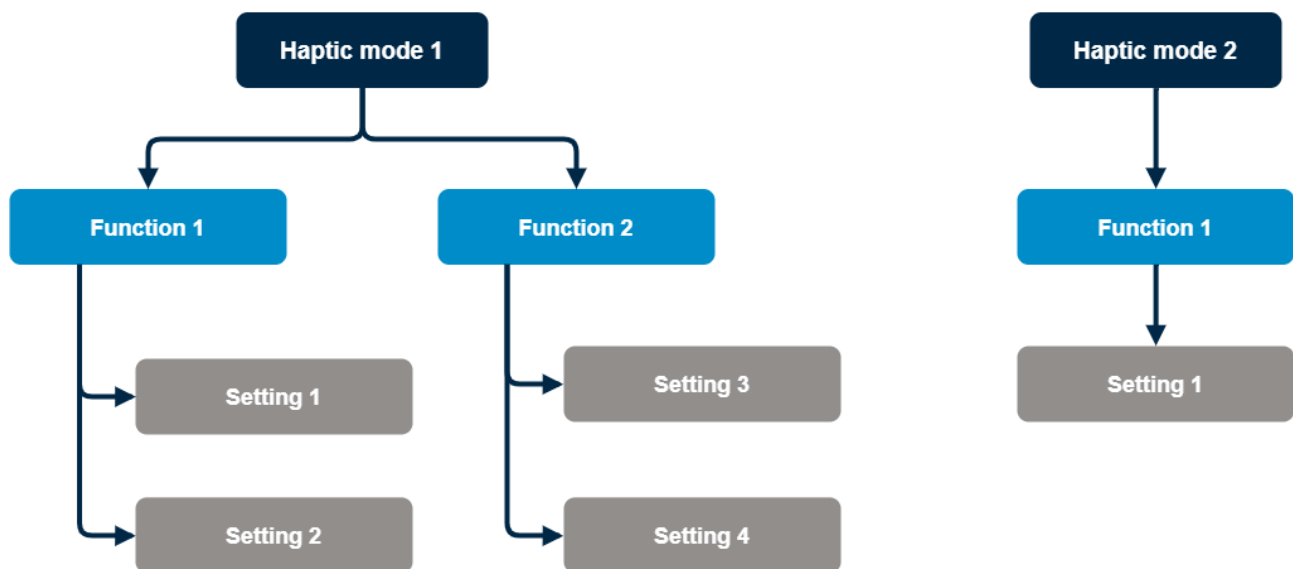
1.2 Glossary

HAPTICORE: Rotary knob with haptic feedback function based on magnetorheological materials (MRM).

Host device: A PC, PLC, mobile device, microcontroller etc.

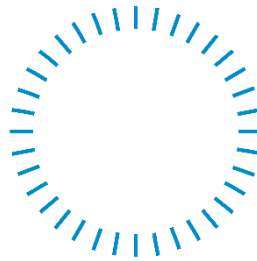
2 Haptic Modes and Functions

For the generation of haptic feedback, a distinction is made between haptic modes, functions and settings, whereby a haptic mode is understood to be the currently active haptic feedback as a whole. As shown in the figure below, a haptic mode can consist of several haptic functions, which can be configured by their respective settings. The functions can be enabled, disabled and adjusted individually. For example, if you want to switch from Haptic mode 1 to Haptic mode 2 (figure below), the configuration of function 1 must be adjusted and function 2 must be disabled. All available functions can be found in chapter 2.1 and their adjustable settings in the respective subchapters.



2.1 Haptic Functions

2.1.1 Tick



Ticks are defined as resistance in the rotation that create a haptic feedback for the user of the rotary knob. The haptic feedback generated through the application of ticks is comparable to the haptic feedback a traditional mechanical rotary knob produces in applications like changing the volume of a car stereo or turning a mouse scroll wheel.

Enable Tick

Enable Tick activates or deactivates the function ticks

Tick Angle CW / Tick Angle CCW

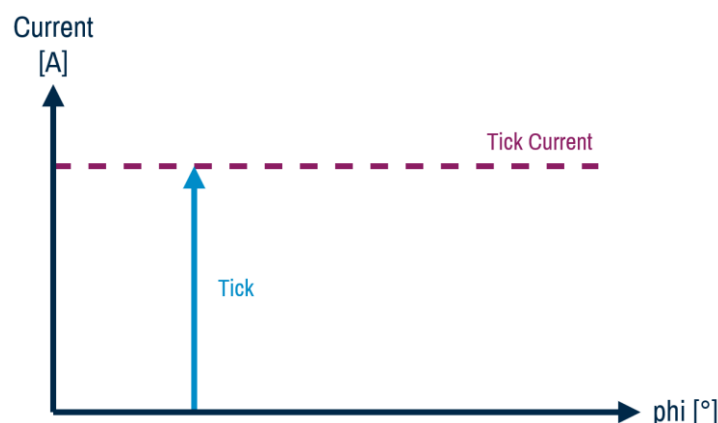
Tick Angle CW and *Tick Angle CCW* set the distance between two ticks and are specified in degrees (°).

By setting different values for *Tick Angle CW* and *Tick Angle CCW*, the tick angle can be adjusted directionally. For example, if the *Tick Angle CW* is 2 degrees and the *Tick Angle CCW* is 4 degrees, there are 180 ticks per rotation in clockwise direction and 90 ticks per rotation in counterclockwise direction.

If the *Tick Angle CCW* is 0, the angle of *Tick Angle CW* is automatically used as *Tick Angle CCW* as well.

Tick Current

The *Tick Current* sets the strength of the ticks. The higher the value, the more noticeable is the haptic feedback.

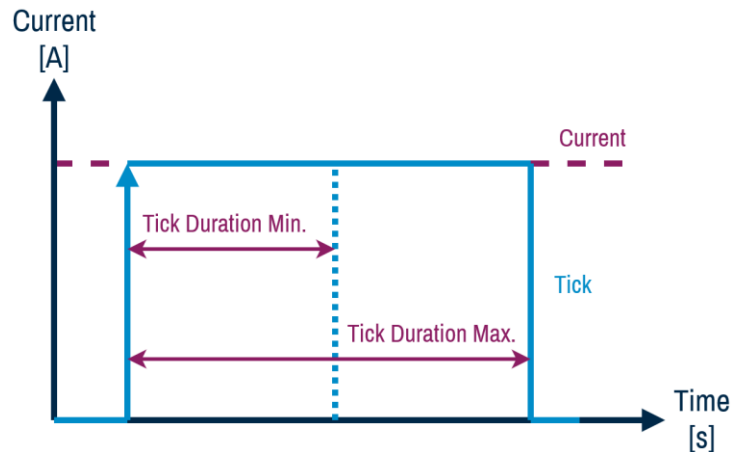


Tick Duration Min / Max

The *Tick Duration* sets the duration of the individual ticks. With a high duration value, a single tick becomes more noticeable as it takes longer to overturn the resistance in the rotation. Duration is defined by *Tick Duration Min* and *Tick Duration Max* as depicted below. The velocity of the rotation determines the effective duration between the values *Tick Duration Min* and *Tick Duration Max* applied to the haptic pattern. If both values are equal, the duration of each tick will always be the same, regardless of the velocity applied to the rotary knob. If the min and max duration values are

different, the tick duration will vary depending on the velocity with which the rotary knob is turned. If the knob is turned slowly, the *Tick Duration Max* is applied to each tick. If the knob is turned faster, the *Tick Duration Min* is applied. The feature of adaptive duration is key to allow users to quickly go through a large number of ticks but regain adjustment accuracy once the user slows down the rotation velocity. An example for the use of such a setting could be scrolling through a contact list. A user might want to scroll quickly from A to Z without much resistance at each tick but once the contacts starting with a certain letter are reached, a highly accurate haptic feedback pattern is needed to select an individual contact.

Note: This setting is only available on Tick Mode 1.



Tick Velocity Factor

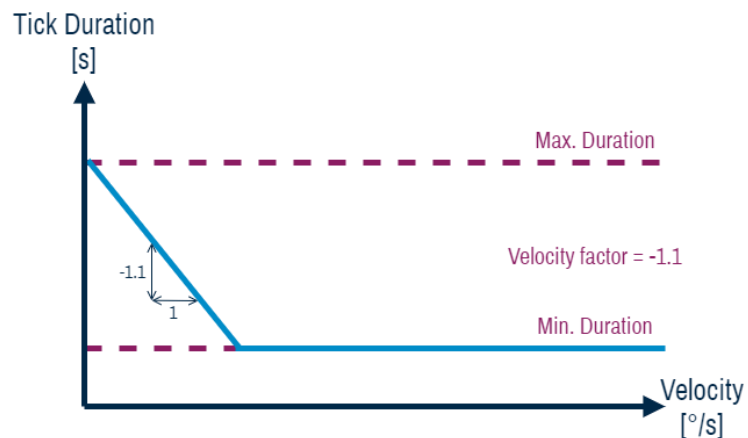
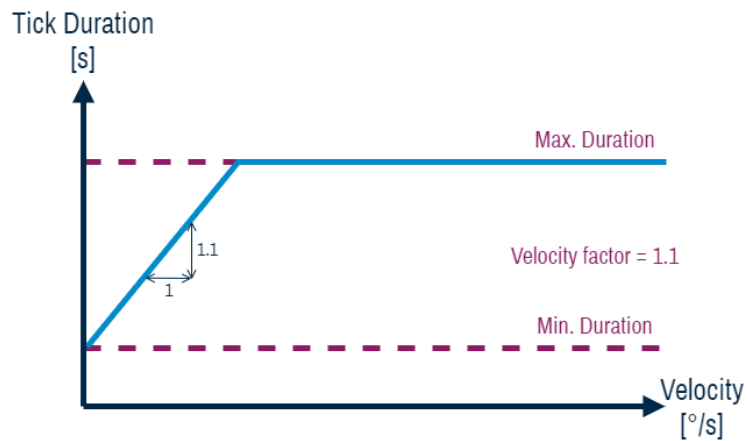
- For Tick Mode 1

The *Tick Velocity Factor* for Tick Mode 1 defines the actual *Tick Duration* as a function of the velocity within the minimum and maximum tick duration limits. As shown in the diagrams below, the *Tick Duration* increases or decreases linearly as a function of the velocity. The velocity factor determines the linear gradient. If the calculated *Tick Duration* is below the specified *Tick Duration Minimum*, the *Tick Duration Minimum* will be set and vice versa.

If the velocity factor is positive, the tick is started from the tick duration Min and the tick duration Max limit is approached as the rotational velocity increases. If the velocity factor is negative, the tick starts from the tick duration Max and approaches the tick duration Min limit as the rotation velocity increases.

Shown in a formula, the following applies:

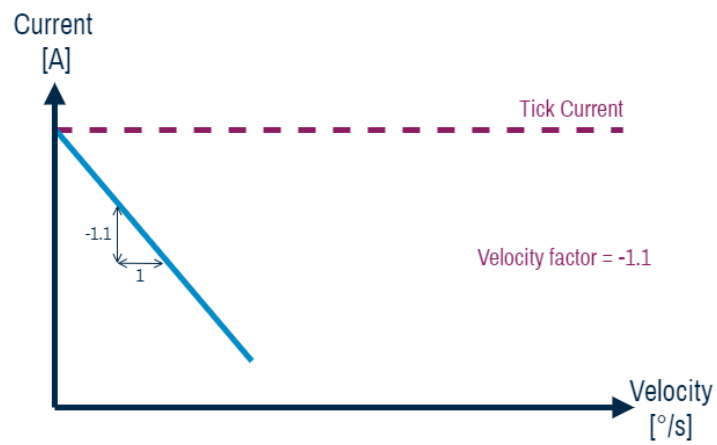
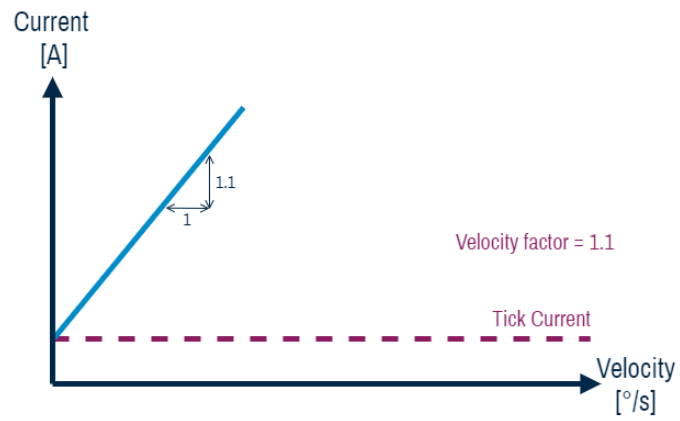
$$\text{Tick Duration} = \text{Tick Duration Minimum} + \text{Velocity} * \text{Tick Velocity Factor (positive or negative Tick Velocity Factor)}$$



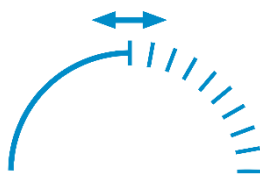
- For Tick Mode 2, 3, 4

The *Tick Velocity Factor* for *Tick Mode 2, 3 and 4* influences the actual tick current depending on the rotation velocity. The larger the factor set, the more sensitive the knob is to variations in rotational velocity. In contrast to the *Tick Velocity Factor* on *Tick Mode 1*, there is no adjustable minimum or maximum current on *Tick Modes 2, 3 and 4*. Shown in a formula, the following applies:

Tick Current = *Tick Current* + *Velocity* * *Tick Velocity Factor* (positive or negative *Tick Velocity Factor*)



Tick Active Direction

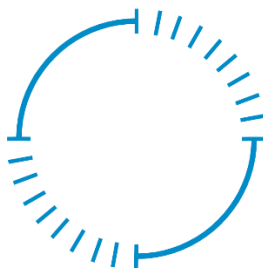


The setting *Tick Active Direction* activates the tick function for a defined direction of rotation.

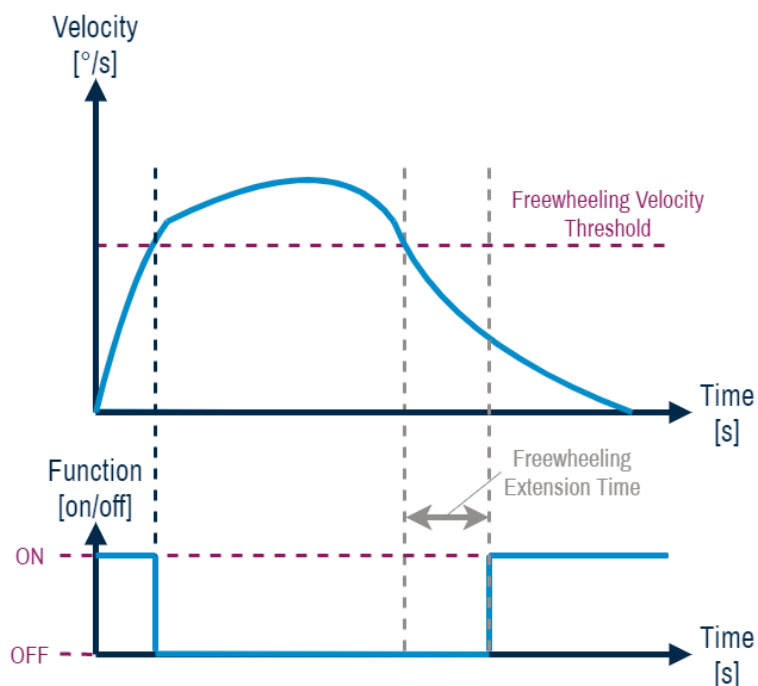
The following *Tick Active Direction* settings are possible:

- *Both* The tick is active in both directions of rotation (default)
- *CW* The tick is only active in clockwise direction
- *CCW* The tick is only active in counterclockwise direction

Tick Freewheeling Velocity Threshold



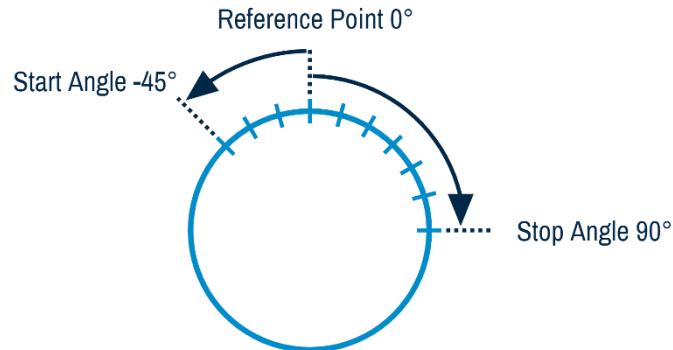
With the *Tick Freewheeling Velocity Threshold* setting, a velocity threshold can be defined. If this value is exceeded, the tick function is deactivated. As soon as the rotation velocity falls below the set value, the tick function remains deactivated for the set *Tick Freewheeling Extension Time* and is then reactivated. See figure below.



Tick Freewheeling Extension Time

The *Tick Freewheeling Extension Time* is the time the tick function remains disabled after the actual velocity falls below the set *Tick Freewheeling Velocity Threshold* value. See figure of *Tick Freewheeling Velocity Threshold*.

Tick Start / Stop Angle

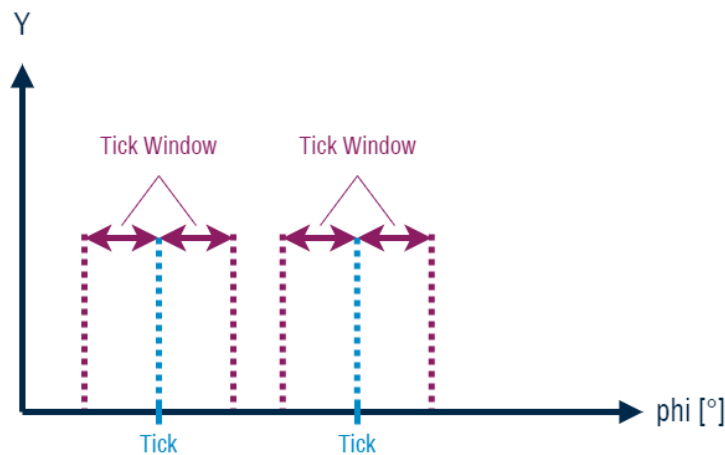


The *Tick Start* and *Tick Stop Angle* define the range where the Tick function is enabled. The *Tick Start Angle* setting defines the start of the range from the reference point in counterclockwise direction. The *Tick Stop Angle* setting defines the end of the range from the reference point clockwise direction.

Note: This means that, for example, with a *Start Angle* of -45 degrees and a *Stop Angle* of 90 degrees, ticks are only active in this range and only at *Multi Turn Counter 0*.

Tick Window

The *Tick Window* defines the area around the individual tick where a haptic feedback is to take place. Depending on the selected *Tick Mode*, the resistance is changed within the tick window. The *Tick Window* is symmetrically structured.



Tick Mode

The Tick Mode allows to select from a variety of ticks with a different haptic feedback by applying different coil current patterns. The following tick modes can be included in the library:

Tick Mode 1

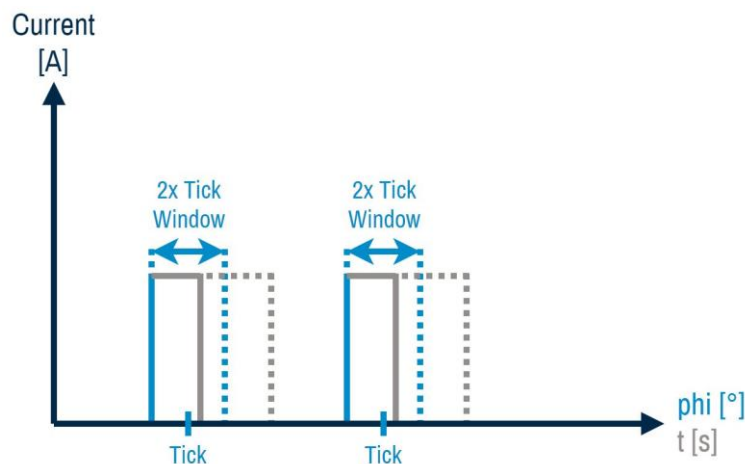
Tick Mode 1 generates ticks as a function of time and angle. The tick resistance starts by reaching the respective *Tick Window* which extends to the left and right of the *Tick Angle* (angle dependent, in the figure drawn in blue). After that the resistance is held as long as the *Tick Duration* is set (time dependent, in the figure drawn in grey). The *Tick Duration* can be variable.

In this *Tick Mode* the maximum resistance is not at the set *Tick Angle*, but is advanced by the set *Tick Window* angle.

Example:

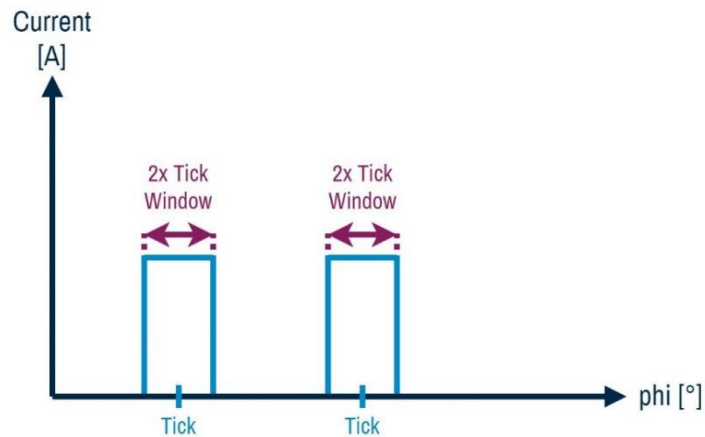
Tick Angle is 10° and *Tick Window* is 4° .

The noticeable resistance is not at 10, 20, 30, ... degrees but clockwise at 8, 18, 28, ... degrees and counterclockwise at 12, 22, 32, ... degrees.



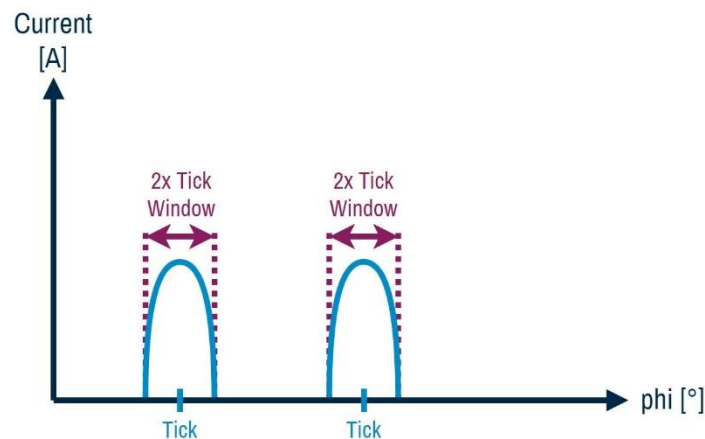
Tick Mode 2

Tick Mode 2 generates ticks only by the angular position of the knob. A so-called tick window is spanned over each tick (see figure below). If the knob is turned to an area within the window, the coil generates resistance. This resistance is upheld as long as the knob is within the area. In *Tick Mode 2*, the tick current is decisive; if it is too high, the knob can no longer be turned out of the *Tick Window*.



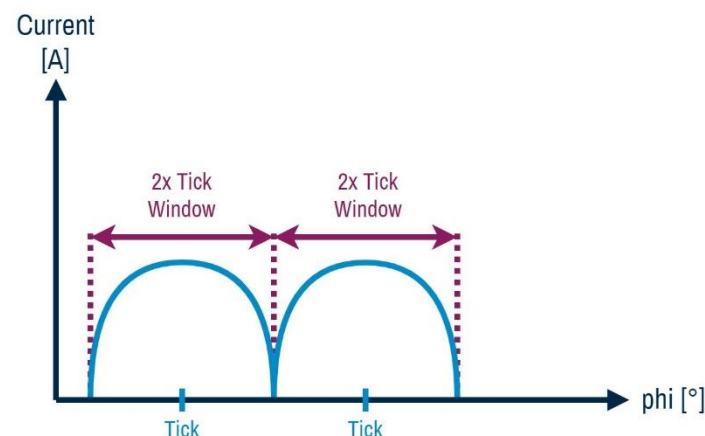
Tick Mode 3

In *Tick Mode 3* the current applied to the coil is also angle-dependent and is controlled within the *Tick Window*. In contrast to *Tick Mode 2*, where the current rises abruptly to the set *Tick Current*, *Tick Mode 3* slowly increases the resistance as the *Tick Angle* is approached and slowly decreases once the *Tick Angle* has been overturned.



Tick Mode 4

In *Tick mode 4* is the coil current is also angle dependent and is controlled within the *Tick Window*. In contrast to *Tick Mode 3*, the *Tick Window* of *Tick Mode 4* extends to the maximum possible space without overlapping with an adjacent *Tick Window*. In this mode the *Tick Window* is calculated by itself and does not need to be set.

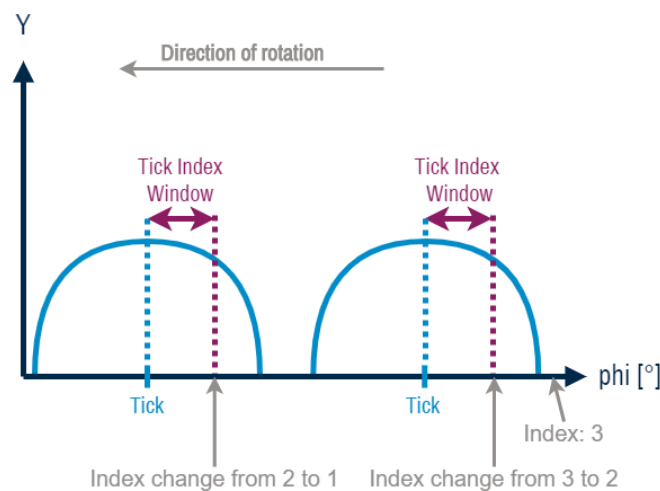
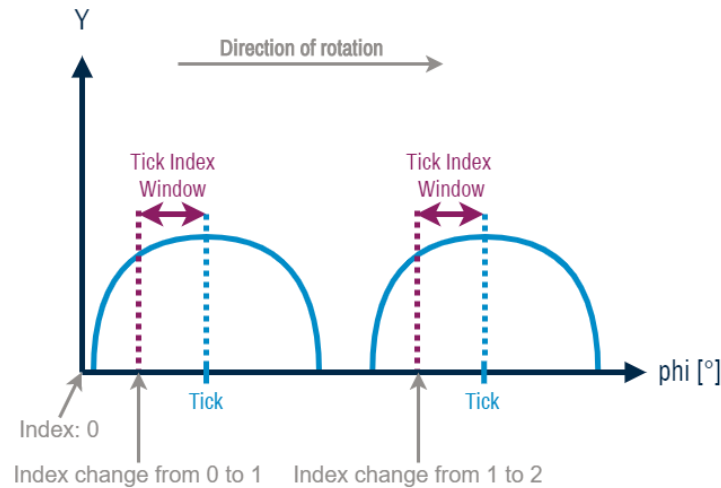


Tick Index Window

The *Tick Index Window* determines the distance at which the system recognizes a change in value even before the defined tick angle is reached.

If, for example, a *Tick Angle* of 10 degrees, a *Tick Index Window* of 2 degrees and an angle position is 0 degrees are defined, the Tick Index is 0. If you now turn in clockwise direction, the index is increased from 0 to 1 when it reaches 8 degrees and from 1 to 2 when it reaches 18 degrees.

Conversely, if the current angular position is at 29 degrees, the tick index is 3. If you now turn in counterclockwise direction, the tick index changes at 22° from 3 to 2, at 12° from 2 to 1 and at 2° from 1 to 0.

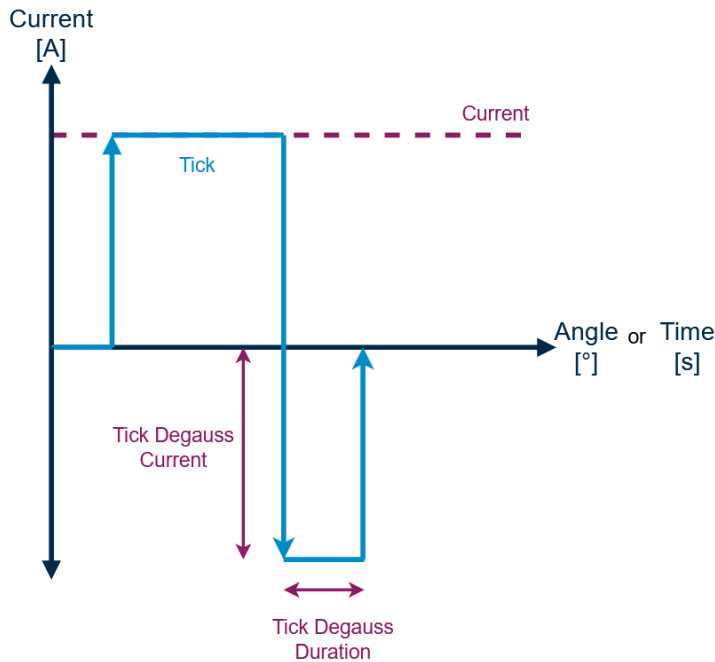


Tick Degauss Current

The *Tick Degaussing Current* sets the level of a current pulse that is generated with opposite polarity after the actual tick. This reduces the remanence of the Hapticore and thus can lower the basic torque. The *Tick Degaussing Current* is only available for the tick modes 1 and 2.

Tick Degauss Duration

The *Tick Degaussing Duration* sets the duration of a current pulse that is generated with opposite polarity after the actual tick. This reduces the remanence of the Hapticore and thus can lower the basic torque. The *Tick Degaussing Duration* is only available for the tick modes 1 and 2.



Tick Exponential Ramp Down Velocity Threshold

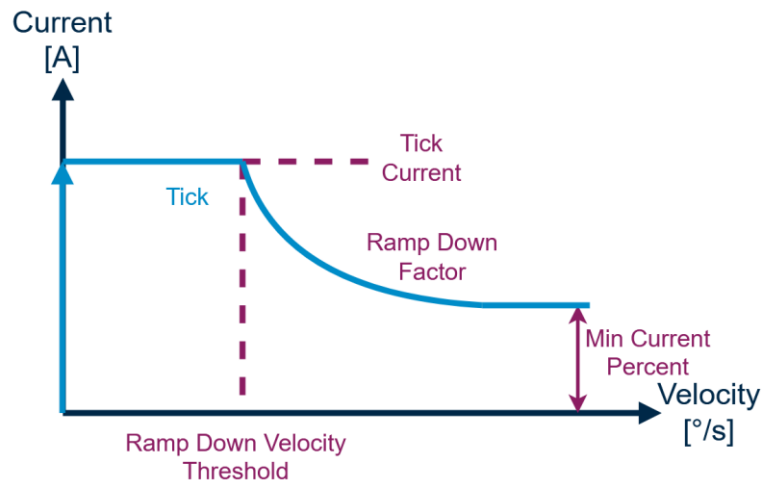
The *Tick Exponential Ramp Down Velocity Threshold* set the velocity threshold at which the current of a tick haptic function is being ramped down exponentially.

Tick Exponential Ramp Down Factor

The *Tick Exponential Ramp Down Factor* set the rate at which the current of a tick haptic function is being ramped down exponentially.

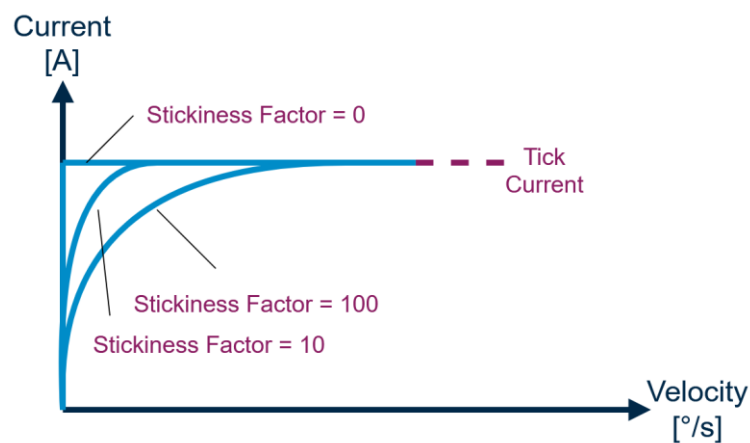
Tick Exponential Ramp Down Current Min Percent

The *Tick Exponential Ramp Down Current Min Percent* sets the minimum current level in percent of the set *Tick Current* to which the exponential ramp down will converge.



Tick Stickiness Prevention Factor

The Tick Stickiness Factor can be used to shape the velocity compensation curve at low velocities as exponential function in order to avoid a “sticky” haptic feeling of haptic functions. The higher the Stickiness Factor the more distinctive the velocity compensation is.



2.1.2 Barrier



The *Barrier* mode limits the rotation angle from the reference point in either direction. Each rotation angle can be individually set (e.g. *Barrier Start Angle*: -90° ; *Barrier Stop Angle*: 90°). Reaching the limit of the defined rotation angle will result in a full rotation blockage in turning direction.

Enable Barrier

Enable Barrier activates or deactivates the haptic function “Barrier”.

Barrier Mode

Depending on the HAPTICORE used, different barrier modes can result in improved haptic feedback.

All *Barrier Modes* have in common that they differ depending on the angle whether the actual HAPTICORE angle position is inside or outside the allowed rotation range (*Barrier Start / Stop Angle*).

They differ, however, in how a change of direction outside the allowed rotation range is detected and how occurring encoder noise is filtered. To illustrate the functionality of the barrier modes, they are split into regions that are set active at specific conditions.

The basic principle of the barrier is as follows. The current angular position is compared with the permitted barrier angle range (*Barrier Start / Stop Angle*). If the current position is within the range, the rotary knob is not blocked. If the current position is outside this permitted range, the current direction of rotation determines whether the rotary knob is blocked or not. If you try to turn further away from the permitted barrier angle range, it is blocked and if you try to turn back into the permitted angle range, the rotary knob is not blocked. This basic principle is the same for all barrier modes.

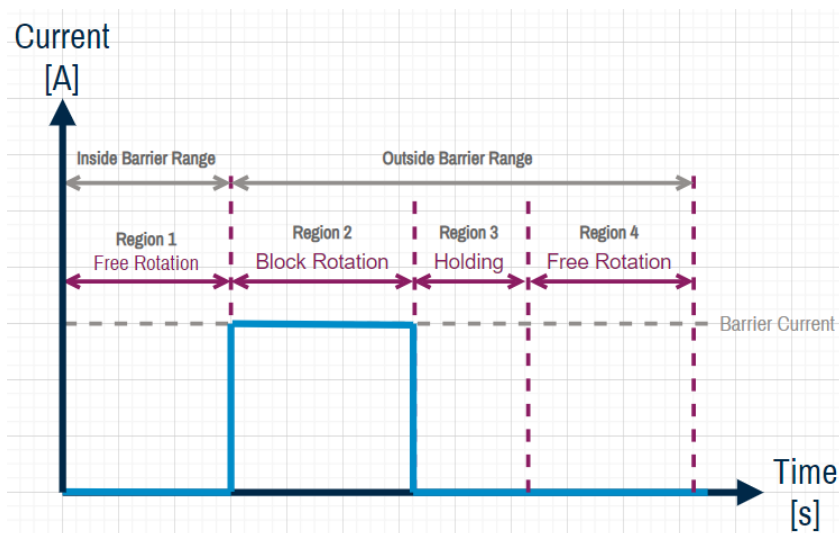
However, a problem arises when the HAPTICORE is not in the permitted range. Because if the HAPTICORE blocks in order to prevent an impermissible turning movement, the turning velocity drops to 0 due to the blockage. Now there are two options for action that contradict each other. On the one hand, an attempt can be made to turn the Hapticore further against the permitted direction. In this case the HAPTICORE would have to continue to block. On the other hand, an attempt can also be made to turn the Hapticore back in the direction of the permitted area. In this case, the HAPTICORE must not block, as otherwise the rotary movement cannot be detected. The HAPTICORE would have to block and not block at the same time, which is not physically possible. In addition, the encoder noise has a negative effect on direction detection. This problem is solved differently in the individual barrier modes.

Barrier Mode 1

Barrier Mode 1 detects the direction of rotation based on the velocity (positive negative). The *Encoder Velocity Noise Threshold* is used to suppress the encoder noise. If the velocity is below this threshold, the current drops to the set *Current Controller Idle Current*. In the table below, *Barrier Mode 1* is divided into four different regions.

Barrier regions and conditions:

Barrier Region	Knob position	Rotary direction	Velocity
Free Rotation	Inside the Barrier Start / Stop Angle range	Irrelevant	Irrelevant
Block Rotation	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Above the Encoder Velocity Noise Threshold
Holding	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Below the Encoder Velocity Noise Threshold
Free Rotation	Outside the Barrier Start / Stop Angle range	To Barrier Start / Angle range	Irrelevant



If the current angular position of the rotary knob is between the *Barrier Start* and *Stop Angle*, region 1 of *Barrier Mode 1* is active and the rotary knob can be turned. If the rotary knob is turned outside of the *Barrier Start* and *Stop* area, it changes to region 2 and the rotary knob is blocked. By blocking the rotary knob, the current rotation velocity falls below the set *Encoder Velocity Noise Threshold* and region 3 is activated. The blockage is released. This allows the rotary knob to be turned back to the permitted *Barrier Start* and *Stop Angle* (region 4). Once within the permitted angular range, region 1 is active again.

If the knob does a transition from region 2 to region 3 and the knob is still turned against the permitted direction of rotation, it will switch back and forth between these two regions. Since the blockage activates region 3 and region 3 enables a rotary movement again until the set *Encoder Velocity Noise Threshold* value is exceeded and region 2 is activated again. This can lead to the haptic trembling of the barrier being felt. If this is the case, by adapting the *Encoder Velocity Noise Threshold* or by changing to another barrier mode, this behavior can be reduced.

Barrier Mode 2

Barrier Mode 2 detects the direction of rotation through the change in angle (comparing the previous angular position with the current angular position). A *Hysteresis* is used to suppress the encoder noise. A rotary movement is only

detected when the previous angle has changed by at least the set hysteresis value. If the rotary knob position is outside the permitted barrier range and no change in angle is greater than the hysteresis value, the knob does not block. Barrier Mode 2 is therefore identical to Barrier Mode 1 except for the noise suppression on an angle basis with a hysteresis value.

Barrier regions and conditions:

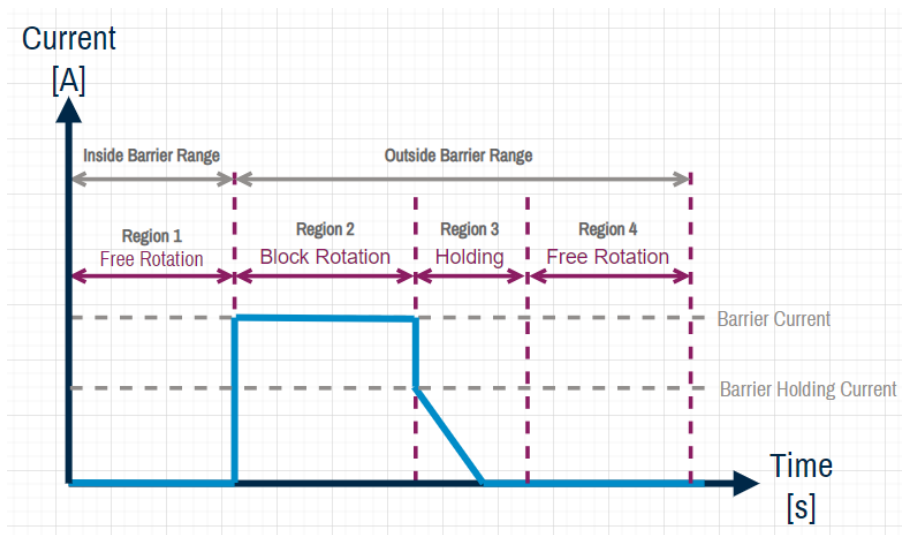
Barrier Region	Knob position	Rotary direction	Angle Hysteresis
Free Rotation	Inside the Barrier Start / Stop Angle range	Irrelevant	Irrelevant
Block Rotation	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Outside the Angle Hysteresis
Holding	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Inside the Angle Hysteresis
Free Rotation	Outside the Barrier Start / Stop Angle range	To Barrier Start / Angle range	Irrelevant

Barrier Mode 3

Like *Barrier Mode 1*, *Barrier Mode 3* detects the direction of rotation based on the rotation velocity (positive or negative). The distinction between the two barrier modes 1 and 3 lies in region 3 (holding). If the rotation velocity falls below the set *Encoder Noise Velocity Threshold*, region 3 is activated and the set *Barrier Holding Current* is set. Then the set current decreases depending on the set *Barrier Ramp Slope* down to the set *Current Controller Idle Current*. The aim of the ramp down should not be to release the blockage of the button abruptly, but rather to loosen slightly. This is intended to detect faster whether the attempt is made to continue turning against the permitted direction of rotation. If this is the case, you can switch to region 2 earlier and constant switching back and forth between region 2 and 3 is no longer as noticeable. The *Barrier Holding Current* reduces the initial blockage in region 3. This has a positive haptic effect on turning back into the permitted turning range.

Barrier regions and conditions:

Barrier Region	Knob position	Rotary direction	Velocity
Free Rotation	Inside the Barrier Start / Stop Angle range	Irrelevant	Irrelevant
Block Rotation	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Above the Encoder Velocity Noise Threshold
Holding	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Below the Encoder Velocity Noise Threshold
Free Rotation	Outside the Barrier Start / Stop Angle range	To Barrier Start / Angle range	Irrelevant

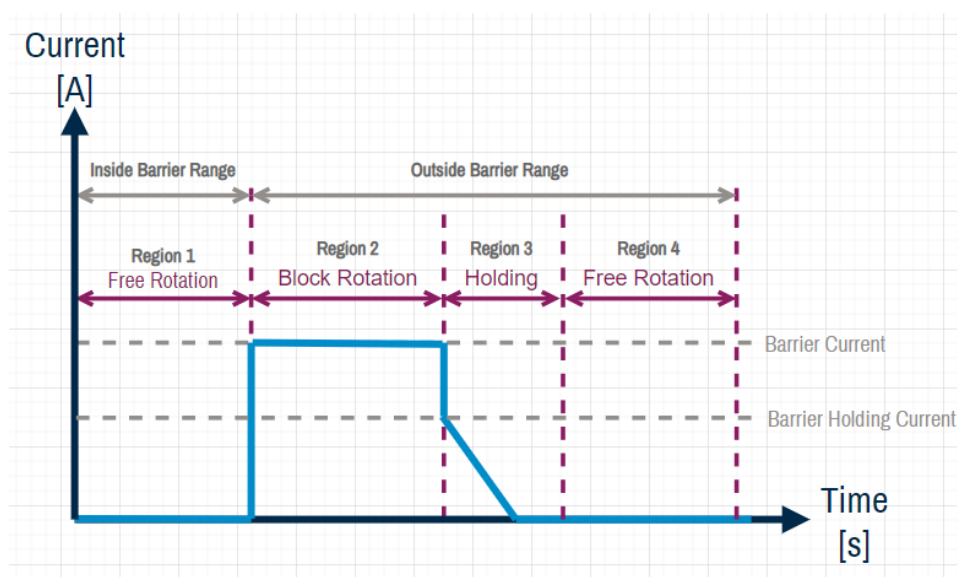


Barrier Mode 4

Barrier Mode 4 is a combination of Barrier Mode 2 and 3. As with Barrier Mode 2, the change in rotational movement is detected based on the angle. However, it also has the ramp down used in Barrier Mode 3 to improve the haptic feeling when changing from region 3 and region 2.

Barrier regions and conditions:

Barrier Region	Knob position	Rotary direction	Angle Hysteresis
Free Rotation	Inside the Barrier Start / Stop Angle range	Irrelevant	Irrelevant
Block Rotation	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Outside the Angle Hysteresis
Holding	Outside the Barrier Start / Stop Angle range	Away from Barrier Start / Stop Angle range	Inside the Angle Hysteresis
Free Rotation	Outside the Barrier Start / Stop Angle range	To Barrier Start / Angle range	Irrelevant



Barrier Current

The *Barrier Current* defines the maximum current used for the barrier to prevent an unauthorized rotation. If the *Barrier Current* is too low, the knob can be turned outside the permitted angle.

Barrier Holding Current

The *Barrier Holding Current* defines in Barrier Mode 3 and 4 the current that is set when no or a turn below the *Encoder Velocity Noise Threshold* or the *Hysteresis* value occurs. If a *Barrier Ramp Slope* lower than 0 is set, the *Barrier Holding Current* is used as starting point of the ramp.

Barrier Hysteresis

The *Barrier Hysteresis* value defines the angular change required to detect a rotational movement for the barrier function. The value should be set slightly above the encoder angle noise.

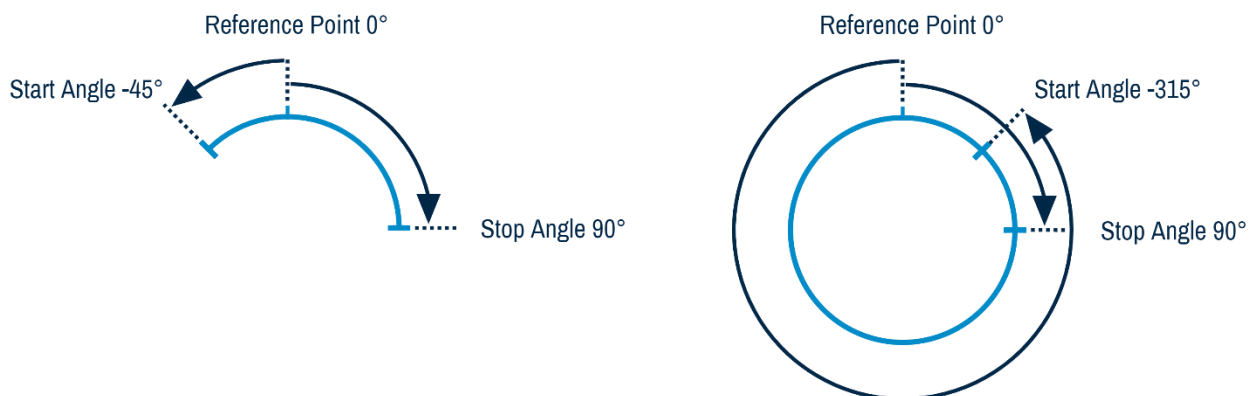
Barrier Ramp Down Slope

The *Barrier Ramp Down Slope* defines the slope of Barrier Region 3 (Holding) in *Barrier Mode* 3 and 4. The lower the slope, the faster the set *Current Controller Idle Current* is reached and held. The *Barrier Holding Current* is used as the starting point of the ramp.

Barrier Start / Stop Angle

The *Barrier Start Angle* parameter defines the allowed angle range from the reference point in counterclockwise direction. The *Barrier Stop Angle* parameter defines the allowed angle range from the center in clockwise direction. It is also possible to overlap the two angle parameters as shown in the illustration below. The unit is measured in degrees (°).

Note: The given start and stop angles are absolute to the reference point. Input values above 360 or below -360 degrees are possible.



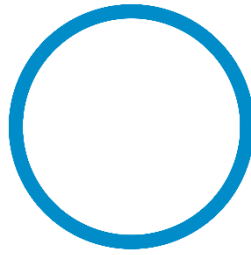
Barrier Polarity

This setting allows to specify the barrier polarity for both barrier stops. It is used as an optimization targeting remanence if the barrier is used in combination with ticks. To counteract a positive current tick right before the barrier stop, the barrier polarity can be swapped to a negative polarity. This prevents a certain stickiness when the knob is rotated out of the barrier stop.

Barrier Limit Angle

If active, this setting limits the encoder angle internally to the defined start / stop angle. Therefore, the angle is “held” right at the edge of the barrier the ensure turning out of it can happen in the most optimal way, which means with the least possible stickiness.

2.1.3 Current

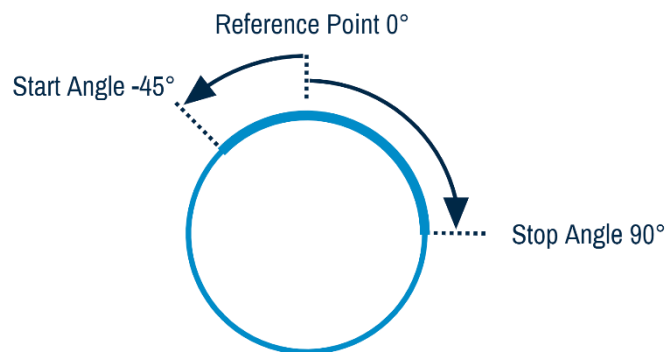


The *Current* mode applies continuous current to the coil. This results in a rotational resistance that varies depending on the rotational velocity.

Enable Current

Enable Current activates or deactivates the function current

Current Start / Stop Angle



The *Current Start Angle* and *Current Stop Angle* define the range in which the current function is enabled. The *Current Start Angle* setting defines the start of the range from the reference point in counterclockwise direction. The *Current Stop Angle* setting defines the end of the range from the reference point in clockwise direction. If the *Current Start Angle* and *Current Stop Angle* are zero, the function is active in every angle position.

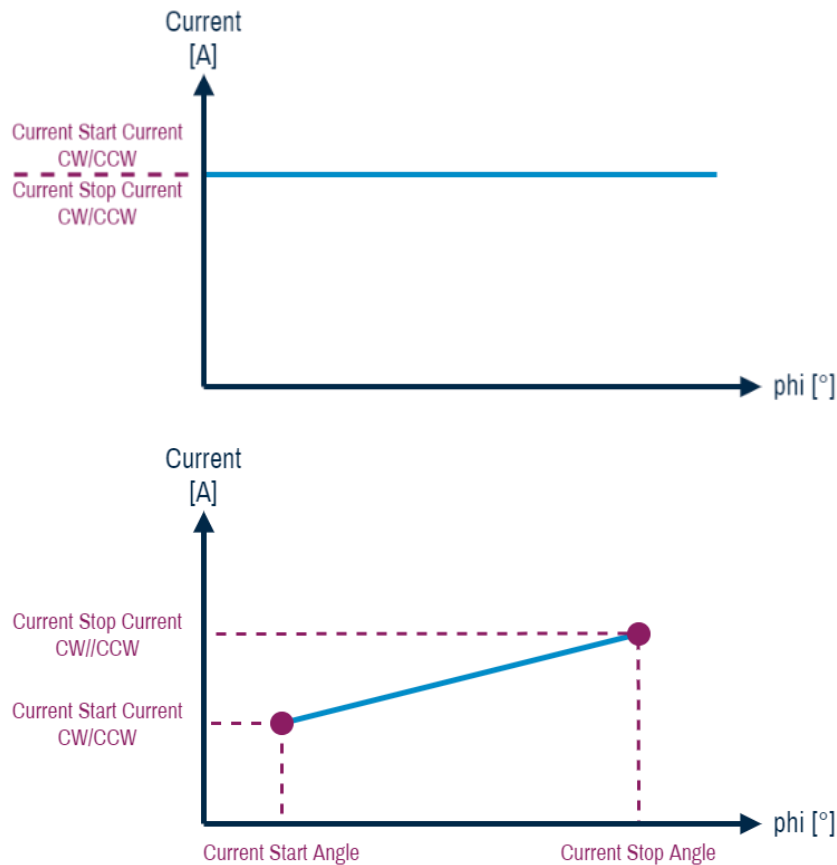
Note: This means that, for example, with a *Start Angle* of -45 degrees and a *Stop Angle* of 90 degrees, the function current is only active in this range and only at *Multi Turn Counter 0*.

Current Start / Stop Current CW

The *Current Start/Stop Current* indicates the current that is applied to the coil in clockwise direction.

If the values of *Current Start Current CW* and *Current Stop Current CW* are identical, the applied current is equal and does not differ with the angular position.

If the two values differ, a linear interpolation happens between the two values. Hence, this function allows for both a constant or an increasing / decreasing current function to be applied to the HAPTICORE.

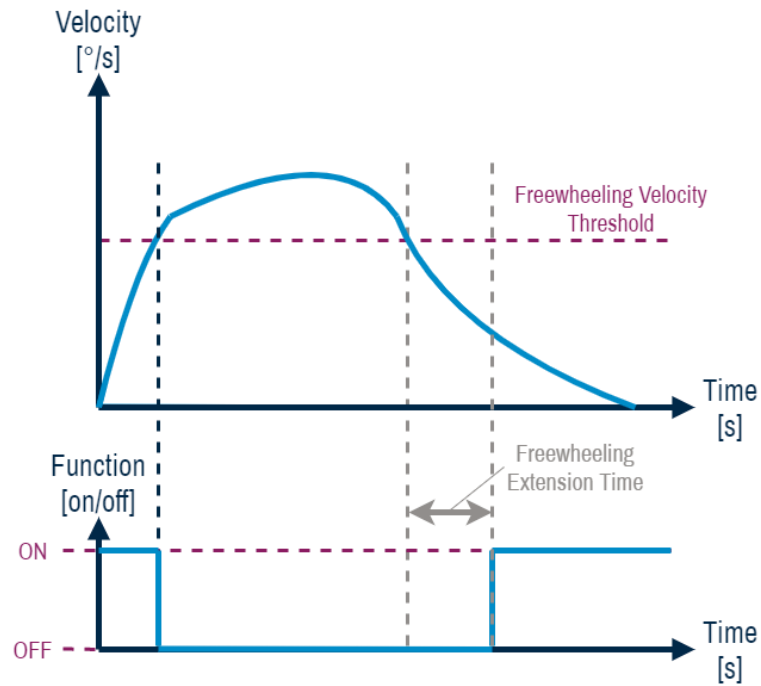


Current Start / Stop Current CCW

The setting *Current Start / Stop Current CCW* is the same as *Current Start / Stop Current CW*. Except that the set values are active when turning the knob counterclockwise. If the two values *Current Start Current CCW* and *Current Stop Current CCW* are zero, the values of *Current Start Current CW* and *Current Stop Current CW* are used.

Current Freewheeling Velocity Threshold

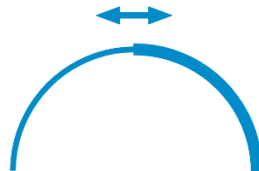
With the *Current Freewheeling Velocity Threshold* setting, a velocity threshold can be defined. If this value is exceeded, the current function is deactivated. As soon as the rotation velocity falls below the set value, the current function remains deactivated for the set *Current Freewheeling Extension Time* and is then reactivated. See figure below.



Current Freewheeling Extension Time

The *Current Freewheeling Extension Time* is the time the current function remains disabled after the actual velocity falls below the set *Current Freewheeling Velocity Threshold* value. See figure of *Current Freewheeling Velocity Threshold*.

Current Active Direction

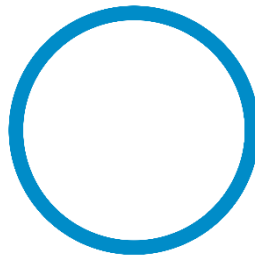


The setting *Current Active Direction* activates the current function for a defined direction of rotation.

The following *Current Active Direction* are possible:

- *Both* The current function is active in both directions of rotation (default)
- *CW* The current function is only active in clockwise
- *CCW* The current function is only active in counterclockwise

2.1.4 Torque

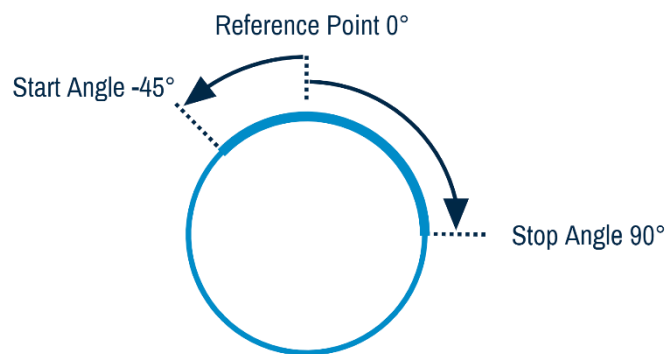


The *Torque* mode generates a rotational resistance that is not depending on the rotational velocity but is applied constantly to the knob.

Enable Torque

Enable Torque activates or deactivates the function *Torque*.

Torque Start / Stop Angle



The *Torque Start Angle* and *Torque Stop Angle* define the range where the torque function is enabled. The *Torque Start Angle* setting defines the start of the range from the reference point in counterclockwise direction. The *Torque Stop Angle* setting defines the end of the range from the reference point in clockwise direction. If the *Torque Start Angle* and *Torque Stop Angle* are zero, the function is active in every angle position.

Note: This means that, for example, with a *Start Angle* of -45 degrees and a *Stop Angle* of 90 degrees, the function torque is only active in this range and only at *Multi Turn Counter 0*.

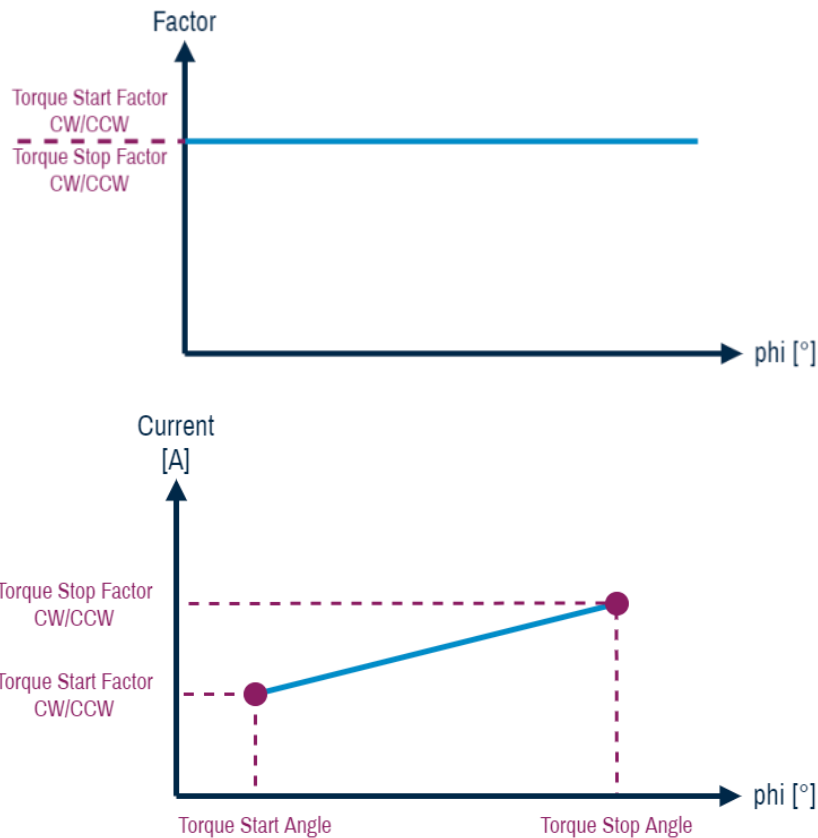
Torque Start / Stop Factor CW

The *Torque Start / Stop Factor* indicates the resistance that is activated in clockwise direction.

The factor determines the actual current applied depending on the rotational velocity. This causes the knob to brake with a defined torque which is independent of the velocity.

If the values of *Torque Start Factor CW* and *Torque Stop Factor CW* are identical, the factor is equal and does not differ with the angular position.

If the two values are different, linear interpolation is used between the two values. Hence, this function allows for both a constant or an increasing / decreasing current function to be applied to the HAPTICORE.

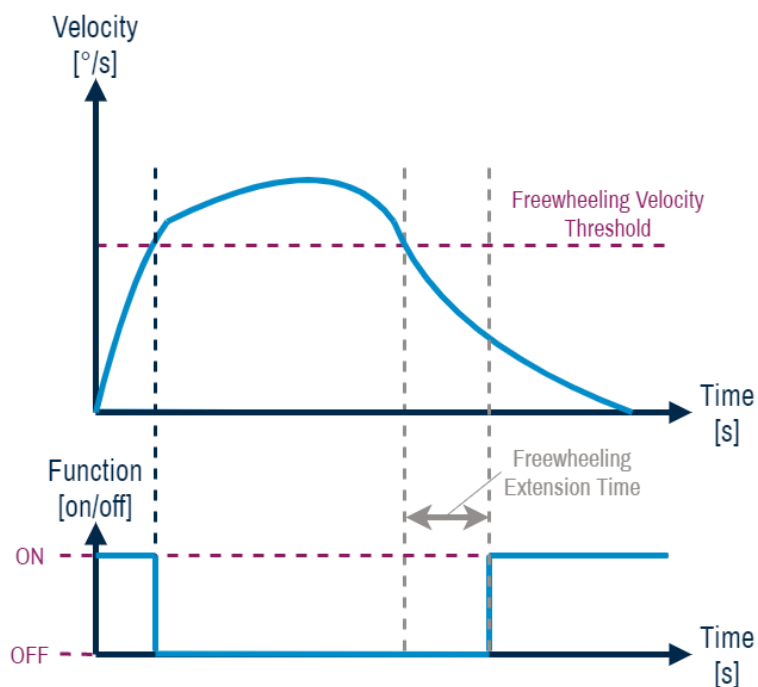


Torque Start / Stop Factor CCW

The setting *Torque Start / Stop Factor CCW* is the same as *Torque Start / Stop Factor CW*. Except that the set values are active when the knob is turned counterclockwise. If the two values *Torque Start Factor CCW* and *Torque Stop Factor CCW* are zero, the values of *Torque Start Factor CW* and *Torque Stop Factor CW* are used.

Torque Freewheeling Velocity Threshold

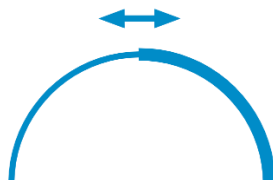
With the *Torque Freewheeling Velocity Threshold* setting, a velocity threshold can be defined. If this value is exceeded, the torque function is deactivated. As soon as the rotation velocity falls below the set value, the torque function remains deactivated for the set *Torque Freewheeling Extension Time* and is then reactivated. See figure below.



Torque Freewheeling Extension Time

The *Torque Freewheeling Extension Time* is the time the current function remains disabled after the actual velocity falls below the set *Torque Freewheeling Velocity Threshold* value. See figure of *Torque Freewheeling Velocity Threshold*.

Torque Active Direction



The setting *Torque Active Direction* activates the torque function for a defined direction of rotation.

The following *Torque Active Direction* are possible:

- *Both* The torque is active in both directions of rotation (default)
- *CW* The torque is only active in clockwise
- *CCW* The torque is only active in counterclockwise

2.1.5 Lock



The *Lock* function allows to lock one or both directions of rotation.

Enable Lock

Enable Lock activates or deactivates the function *Lock*.

Lock Direction

The setting *Lock Direction* defines the direction of rotation that is locked.

The following *Lock Direction* are possible:

- *Both* The knob can no longer be turned in any direction.
- *CW* The knob can only be turned counterclockwise.
- *CCW* The knob can only be turned clockwise.

Lock Current

The *Lock Current* defines the maximum current used for the *Lock* function to prevent an unauthorized rotation. If the *Lock Current* is too low, the knob can be turned in a not allowed direction.

Lock Holding Current

The *Lock Hold Current* defines in *Lock Mode 2* the current that is set when there is no rotation or a rotation below the set lock hysteresis value. If a *Lock Ramp Down Slope* lower than 0 is set, the *Lock Holding Current* is used as starting point of the ramp.

Lock Mode

As with the barrier function, there are different lock modes with the lock function, which, depending on the HAPTICORE, achieve a better haptic locking of the rotary knob.

The basic function of the lock function is to recognize the direction of rotation and, if necessary, block or not block the rotary knob. However, since the rotary movement is stopped at 0 when the rotary knob is blocked, it is no longer possible to detect in which direction it is turned. The rotary knob should therefore be blocked at the same time in order to be able to turn in a direction that is not permitted, but also not be blocked in order to enable rotation in the permitted direction. Encoder noise makes it difficult to detect the smallest changes in direction. The different lock modes try to handle this problem in different ways.

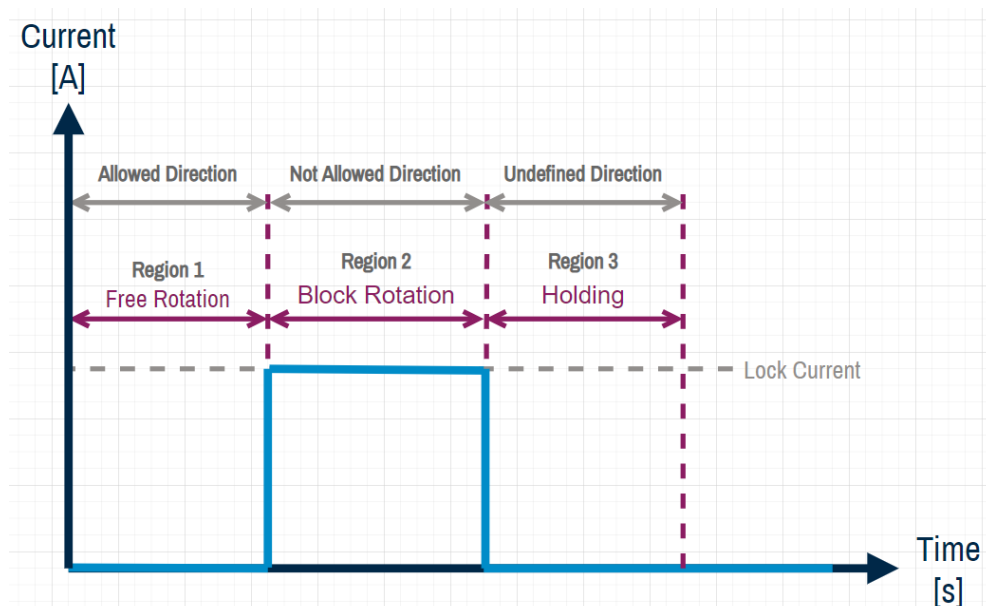
Lock Mode 1

Lock Mode 1 detects the direction of rotation based on the velocity (positive or negative). The *Encoder Velocity Noise Threshold* is used to suppress the encoder noise. If the velocity is below this threshold, the current drops to the set *Current Controller Idle Current*. In the table below, Lock Mode 1 is divided into three different regions.

Lock regions and conditions:

Barrier Region	Rotary direction	Velocity
Free Rotation	Allowed direction	Above the <i>Encoder Velocity Noise Threshold</i>
Block Rotation	Not allowed direction	Above the <i>Encoder Velocity Noise Threshold</i>
Holding	Undefined	Below the <i>Encoder Velocity Noise Threshold</i>

If the knob is turned in the permitted direction with a velocity above the set *Encoder Velocity Noise Threshold*, region 1 of the lock function becomes active. When the rotary movement is released or stopped, it changes to region 3. The rotary knob is still not locked. The knob only blocks when it is turned against the permitted direction of rotation that is faster than the set *Encoder Velocity Noise Threshold*. As a result of the blocking of the rotational movement, the rotational velocity drops below the set *Encoder Velocity Noise Threshold* and Region 2 becomes active. This in turn releases the blockage, which enables a rotary movement against the permitted direction of rotation. If you try to turn against the permitted direction of rotation, you will constantly switch back and forth between region 2 and 3. If the *Encoder Velocity Noise Threshold* is set too high, it can lead to noticeable tremors. If the *Encoder Velocity Noise Threshold* cannot be lowered any further, another lock mode must be used.



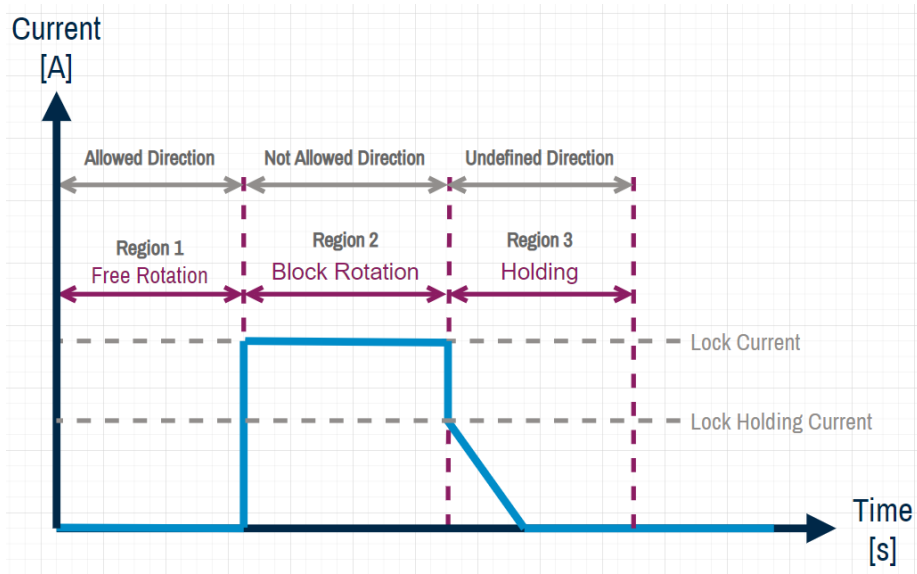
- Lock Mode 2

Lock Mode 2 detects the direction of rotation through the change in angle (comparing the previous angular position with the current angular position). A *Hysteresis* is used to suppress the encoder noise. A direction of rotation is only detected when the previous angle has changed by at least the set hysteresis value. If the angle changes less than the

set hysteresis, the rotary knob is slightly blocked. The strength of this blockage is defined by the *Lock Holding Current*. However, the blockage becomes weaker and weaker over time until the set *Current Controller Idle Current* is reached. The time of the falling blockage can be defined with the *Lock Ramp Slope* parameter. The aim of this ramp is to recognize a maintained, prohibited rotational movement more quickly and to switch from region 3 to region 2 without noticing a slight rotational movement.

Lock regions and conditions:

Barrier Region	Rotary direction	Angle Hysteresis
Free Rotation	Allowed direction	Outside the angle hysteresis
Block Rotation	Not allowed direction	Outside the angle hysteresis
Holding	Undefined	Inside the Angle Hysteresis



Lock Hysteresis

The *Lock Hysteresis* value defines the angular change required to detect a rotational movement for the barrier function. The value should be set slightly above the encoder angle noise.

Lock Ramp Down Slope

The *Lock Ramp Slope* defines the slope of Lock Region 3 (Holding) in *Lock Mode 2*. The lower the slope, the faster the set *Current Controller Idle Current* is reached and maintained. The *Lock Holding Current* is used as the starting point of the ramp.

2.1.6 Single Tick

The function *Single Tick Current* works on the same principle as the function *Ticks* in chapter 2.1.1. However, the function addresses only a single tick rather than a series of identical ticks.

Enable Single Tick

Enable Single Tick activates or deactivates the function *Single Tick*.

Single Tick Mode

The *Single Tick Mode* setting defines the Tick Mode to be used and is the same as in chapter 2.1.1, except that the tick modes for the Single Tick function are limited to tick modes 1 - 3.

Single Tick Active Direction

The setting *Single Tick Active Direction* is the same as *Tick Active Direction* in chapter 2.1.1. However, this setting refers only to a single tick and not to several.

Single Tick Angle

The *Single Tick Angle* sets the position of a single tick and is specified in degrees (°). For example, if the *Single Tick Angle* is 20 degree the single tick is only active at 20 degree and only at *Multi Turn Counter 0*.

Single Tick Current

The setting *Single Tick Current* works on the same principle as the function *Tick Current* in chapter 2.1.1. However, the function addresses only a single tick rather than a series of identical ticks.

Single Tick Duration Min

The setting *Single Tick Duration Min* works on the same principle as the function *Tick Duration Min* in chapter 2.1.1. However, the function addresses only a single tick rather than a series of identical ticks.

Single Tick Duration Max

The setting *Single Tick Duration Max* works on the same principle as the function *Tick Duration Max* in chapter 2.1.1. However, the function addresses only a single tick rather than a series of identical ticks.

Single Tick Window

The setting *Single Tick Window* works on the same principle as the function *Tick Window* in chapter 2.1.1. However, the function addresses only a single tick rather than a series of identical ticks.

Single Tick Velocity Factor

The setting *Single Tick Velocity Factor* works on the same principle as the function *Tick Velocity Factor* in chapter 2.1.1. However, the function addresses only a single tick rather than a series of identical ticks.