Pulsing Unit

Application Note 152

This document describes the setup and usage of a *Pulsing Unit (PU)*. *PU* is a *Software Option* (see [2]). It enables the encoder *Option Modules EN* or *EH* to fire pulses with up to 10 MHz or output a position signal in reference to the connected encoder or path planner position. The *Pulsing Unit works only with analog encoders.*

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Version 005, 2025-07-25
Source Q:\doc\ApplicationNotes\
Destination T:\doc\ApplicationNotes
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1 Purpose and Usage

A *Triamec Pulsing Unit* has two main use cases. For one, it can control an external device by triggering a process with a digital electrical signal. The triggers are fired with reference to a position information of the motion system at a firing rate of up to 10MHz. The second use is to output a TTL- or RS422-encoder signal to communicate a position information to an external measurement system.

The *Pulsing Unit* is controlled via *Tama* program, *TAM API* or by main controllers via fieldbus. As it is fully controllable with drive registers, simple use cases can also be set up manually via *TAM System Explorer*.

For the explanations on the usage of the *Pulsing Unit*, *Triamec* uses the following terms (1).

Term	Description
Pattern	Contains all pulses to form the target image or structure.
Row	A pulse pattern is configured by a set of rows. This is because the Pulsing Unit only has position information from one dimension.
Sequence	A row can have one or more sequences of equidistant pulses.
Pulse (pulsing)	The Pulsing Unit output
Pulse (position output)	A Pulsing Unit event, corresponding to a change of one of the phase signals
Pitch	The distance between two pulses, corresponding to a quarter of the position-output signal period.

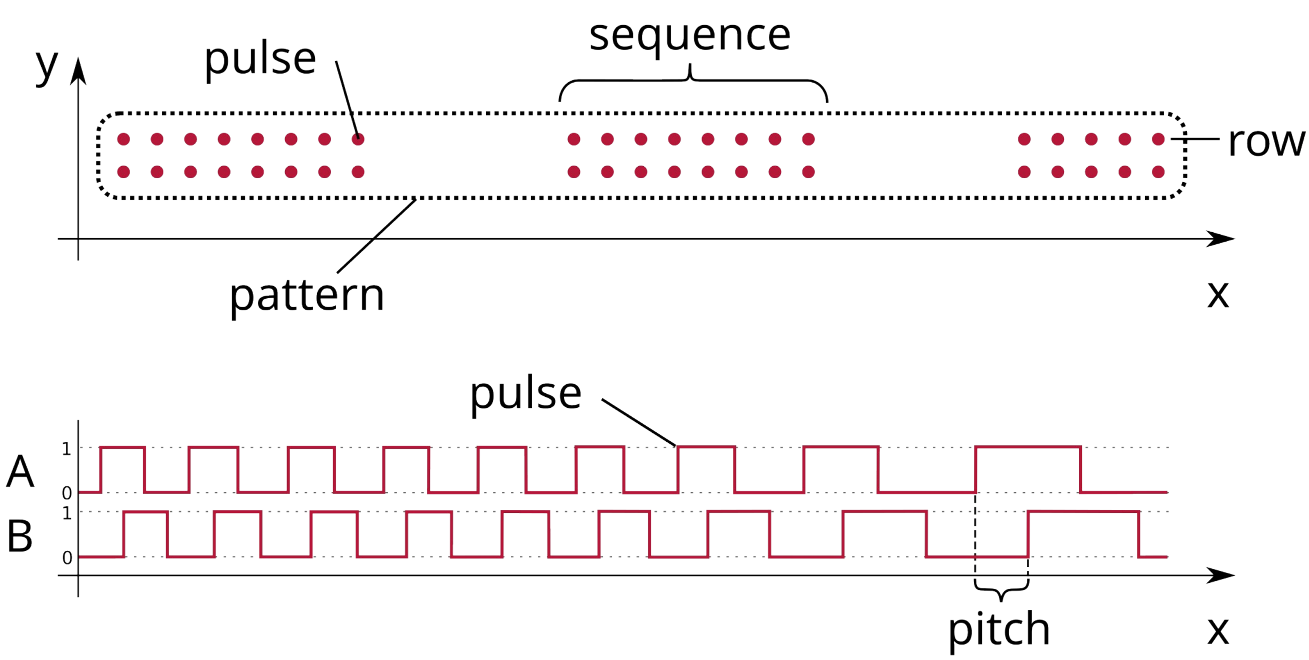


Figure 1: Visualization of Pulsing Unit specific terms for the pulsing use (top) and the position output mode (bottom). A pulsing pattern consists of pulse sequences that temselves consist of equidistant pulses, fired with respect to one position signal (here, x). The position-output signal is made up of two signals A and B that imitate an incremental encoder signal. The pitch of the position output is defined as the distance between two pulse events and is therefore a quarter of the pitch of an equivalent encoder signal.

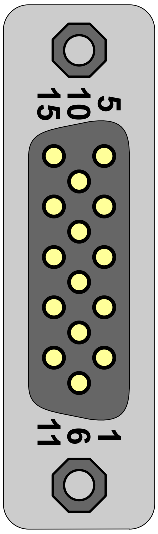
2 Preconditions

The following are mandatory for proper functionality.

- Only available on *Option Module Encoders EN* and *EH* (see [1])
- Only available in combination with analog sin/cos encoders. Exception: PU_Source = PathPlanner.
- Correct encoder settings must be configured, also in case of PU_Source = PathPlanner.
- Incompatible with EncoderTopology = Standard.
- The command SetPosition should not be used while the Pulsing Unit is active.

3 Pinout

The encoder pinout with enabled *Software Option PU* is based on the analog encoder interface. Pins, names and signals in bold signify the different outputs that can be used by the Pulsing Unit. **Pulse** (**PhX**) in the name of a TTL or RS422 channel identify outputs for the pulsing (position output) modes with the corresponding output types.

Pin Layout X10/X11	Pin	Name	Signals
15-pin female D-Sub socket 	1	+5VDC	Encoder Supply
	2	ChA+	Channel A positive, Cosine 1Vpp
	3	ChB+	Channel B positive, Sine 1Vpp
	4	ChZ+/ **PhA+**	Index channel positive, RS-422 input / **[PosOut] Phase A, RS-422 output**
	5	**Pulse+/** **PhB+**	**[Pulse] Pulse positive, RS-422 output /** **[PosOut] Phase B, RS-422 output**
	6	Gnd	Supply Ground
	7	ChA−	Channel A negative, Cosine 1Vpp
	8	ChB−	Channel B negative, Sine 1Vpp
	9	ChZ−/ **PhA−**	Index channel negative, RS-422 input / **[PosOut] Phase A-, RS-422 output**
	10	**Pulse−/** **PhB−**	**[Pulse] Pulse negative, RS-422 output /** **[PosOut] Phase B-, RS-422 output**
	11	EncIn0 **PhA−**	TTL Level Input No. 0 (max 5VDC Input) / **[PosOut] Phase A-, TTL single-ended 3.3V**
	12	EncIn1/ **PhB−**	TTL Level Input No. 1 (max 5VDC Input) / **[PosOut] Phase B-, TTL single-ended 3.3V**
	13	EncIn2/ **PhA+**	TTL Level Input No. 2 (max 5VDC Input) / **[PosOut] Phase A, TTL single-ended 3.3V**
	14	EncIn3/ **PulseOut/** **PhB+**	TTL Level Input No. 3 (max 5VDC Input) / **[Pulse] PulseOut, TTL single-ended 3.3V /** **[PosOut] Phase B, TTL single-ended 3.3V**
	15	Gnd	Signal Ground

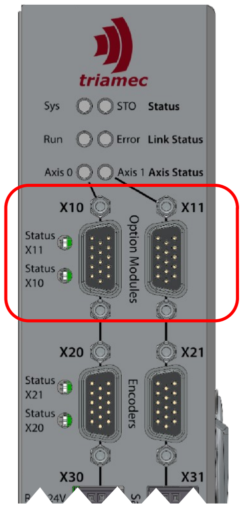


Figure 2: Option Modules jack (X10,X11)

4 TAM Registers

The *Software Option PU* introduces new *TAM Registers* to control the *Pulsing Unit* functionality.

These registers appear on the Axes[], where the corresponding *Option Module EN* or *EH* is installed. If *Option Module* encoders are installed on both axes, the *Pulsing Unit* registers will be available on both Axes[].

The registers should ideally be set in the order they are listed in the next subsections. First the PU_Source and PU_Output, then the pulse configuration and the PU_Mode.

4.1 Source

The position used for the pulse generator can be configured with the following register.

Axes[].Commands.OptionModule.PU_Source

The sources have different delay times, introduced by different signal paths with filters (see figure 3):

Value	Description	Delay EN*	Delay EH*
EncoderFast	Encoder signals with the fast filter.	5.2 µs	7.6 µs
EncoderSlow	Encoder signals as used by the position controller.	49.3 µs	51.7 µs
PathplannerAx0	Path planner position of axis 0.	49.3 µs	51.7 µs
PathplannerAx1	Path planner position of axis 1.	49.3 µs	51.7 µs
EncoderFastCompensated	Encoder signals with the fast filter and corrected by AxisCompensation	5.2 µs	7.6 µs
EncoderSlowCompensated	Encoder signals as used by the position controller and corrected by AxisCompensation	49.3 µs	51.7 µs

* Delays are perfectly repeatable. More precise values will be given here as more precise measurements of the actual delays become available.

It is recommended to start with EncoderFast and try other modes if the results are unsatisfactory. EncoderSlow and Pathplanner might provide an advantage at closely spaced pulses (e.g. 1nm) at very low speeds (e.g. 1 mm/s).

The delay may be compensated by adding it to the value in PU_DelayTime, see chapter 4.4 Pulse Configuration. PU_DelayTime is used to calculate the correct firing time depending on current speed and acceleration, so that the actual position of the pulse is the desired one. If the speed changes during pulsing it is important to correctly configure PU_DelayTime, even if only the relative distance of the pulses matters.

If PathplannerAx0 or PathplannerAx1 is used as the source for the pulse generator, the parameter Encoder[].Pitch of the option module encoder must be configured, even if Encoder[].Type is set to None.

We recommend $Encoder[\,].\,Pitch > \frac{\sqrt{move\,range}}{5'000'000}$ as the value for Pitch in this use case.

Note The quality of the pulsing unit is strongly related to the quality of the encoder signals. Noisy and nonlinear encoder signals will directly affect the pulse firing position. Therefore the encoder input provides a slight signal filtering in order to reduce the effects of noise. Further the encoder auto calibration removes offset and gain errors from the sin/cos signals, but only if they are smoothly changing.

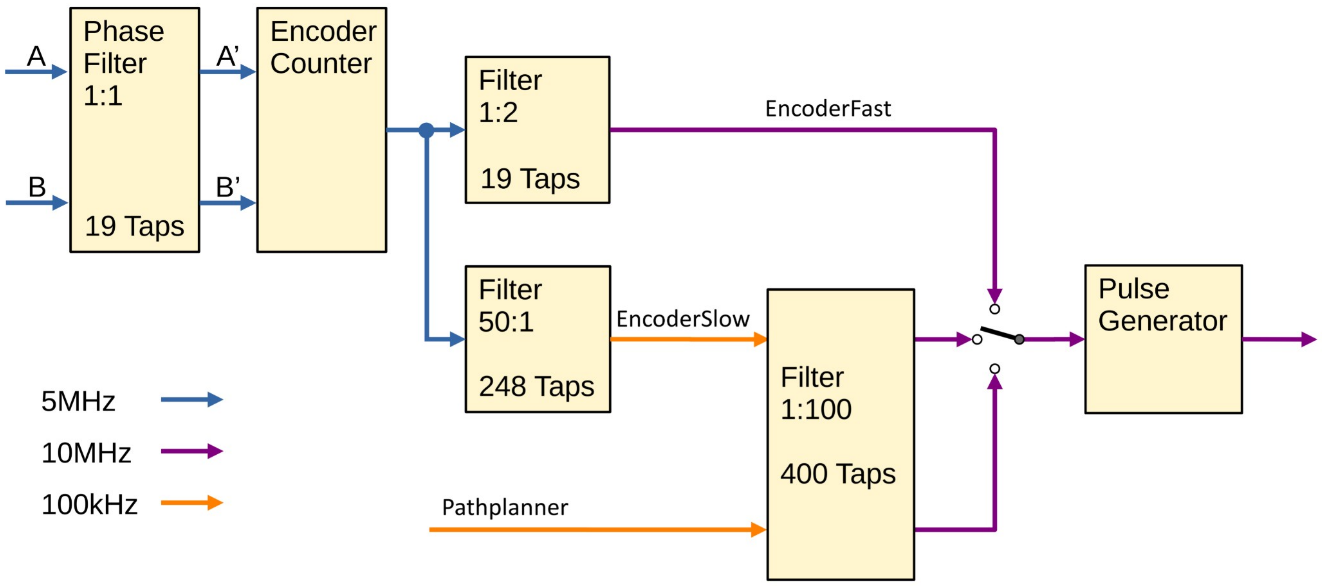


Figure 3: Signal path of the pulse position source

4.2 Output

Generated pulses can be routed to either a differential output, or a single ended output (see chapter 3). The corresponding output is configured with the following register. This register can also be used to change the polarity of the desired output and thus also control the static state.

Axes[].Commands.OptionModule.PU_Output

Value	Description
Disabled	The outputs are high impedance
RS422	Output as RS-422
RS422inverted	Output as inverted RS-422 (or inverted counting direction for Position Output)
TTL	Output as TTL 3V3
TTLinverted	Output as inverted TTL 3V3 (or inverted counting direction for Position Output)
TTL4 (Position Output)	Output with four TTL 3V3 (phases A/B and inverted phases A/B)
TTL4inverted (Position Output)	Output with four TTL 3V3 (phases A/B and inverted phases A/B) with inverted counting direction.

4.3 Mode

The Pulsing Unit can run in different modes. The discretely triggered pulses can be realised either with the Direct or Fifo mode, as shown in figure 4. The main difference between the two modes is how the pulse configuration is applied. With the mode PositionOutput, the digital channels are controlled in such a way that they output an encoder-like position signal. The configuration for Direct and Fifo is shown in more detail in chapter 4.4, the configuration for PositionOutput in chapter 4.5.

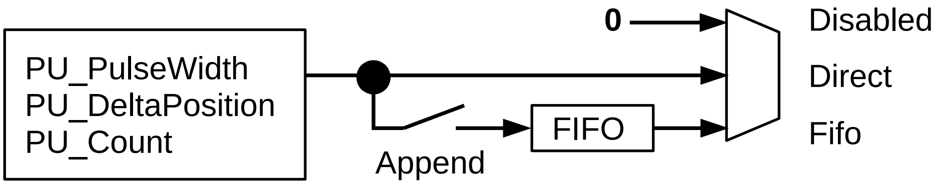


Figure 4: Visualization of Pulsing Unit modes

Axes[].Commands.OptionModule.PU_Mode

Value	Description
Disabled	Disable the pulse generator.
Direct	Allows instant change of the pulse settings.
Fifo	Run sequences as stored in the FIFO.
PositionOutput	Generates incremental encoder signals with phases A/B or A+/B+/A−/B−

The two following register value is written once, when a mode is activated. While the mode is active, all other configuration changes refer to these values and changes in these two registers have no effect.

- PU_ReferencePosition is the absolute position of the first pulse and thus the start of a pattern in modes Direct and Fifo. Each subsequent pulse position is calculated internally by adding the PU_DeltaPosition to the last fired pulse position. See also chapter 4.4. For PositionOutput, this parameter is ignored since the reference position for this point is the position at mode activation.

The following signal is reset and set to zero when a mode is activated.

- PU_ActualPulseCount is reset when a mode is disabled. Accordingly, this value is 0 when activating a mode. From this point in time the value in PU_Count must be set larger than PU_ActualPulseCount to generate new pulses. See also chapter 4.6.

Direct

Use this mode to change the pulse configuration at any time (see figure 4). Changing a register described in chapter 4.4 takes effect with each 10kHz cycle of the drive. There are two ways of usage:

- PU_Count = 0
  When activating the PU_Mode = Direct with PU_Count = 0, pulses will fire as long as the mode is active. The pulses start with crossing the PU_ReferencePosition once, and fire each time the PU_DeltaPosition is traveled. This is convenient if the pulse count is unknown or not calculated in advance.

A typical use case is pulsing a spiral, where the pulse distance is recalculated for each 10kHz cycle.

- PU_Count > 0
  When activating the PU_Mode = Direct with PU_Count > 0, the configured amount of pulses fire while traveling across the positions. Further pulses only fire if the PU_Count is increased.
  Typical use cases are simple pulse rows, without gaps and equidistant pulse positions.

The mode Direct is not compatible with outputs TTL4 and TTL4inverted.

Fifo

The *Fifo* mode allows to buffer pulse sequences, where one entry represents an equidistant set of pulses as configured per chapter 4.4. Only one FIFO entry can be appended per 10kHz cycle. The register PU_FIFO is used for FIFO commands.

This mode is configured as follows:

- Configure a pulse sequence with the registers described in chapter 4.4. Add up PU_Count for each sequence.
- Push the sequence to the FIFO, by setting PU_FIFO = Append.
- Repeat the above steps to join different sequences, i.e. to create a heterogeneous pulse pattern.

The next sequence will move into the active state as soon as the previous sequence has been fired. The previous sequence is deleted.
The mode Fifo is not compatible with outputs TTL4 and TTL4inverted.

Note The FIFO has a size of 512 entries for sequences. The currently active sequence doesn't occupy a place in the FIFO. The amount of pulses within one sequence is not limited.

PositionOutput

The PositionOutput mode works fundamentally differently from the regular pulsing modes. Instead of discrete pulsing events, this mode outputs a continuous encoder-like signal which can be fed to external measurement devices that rely on position information. The supported encoder-signal types are defined by the PU_Output. These are single-ended TTL (phase A/B), differential TTL4 (phase A+/B+/A-/B-) and RS422 (phase A+/B+/A-/B-). The corresponding outputs with suffix *inverted invert the encoder counting direction and not the individual signals. The configuration of this mode is explained in chapter 4.5.

4.4 Pulse Configuration for Pulsing

The following registers in Axes[].Commands.OptionModule, define the pulses, as visualized in figure 5. Also refer to chapter 5, for application examples.

Register	Units	Resolution	Update Rate	Description
PU_PulseWidth	seconds	10ns	10kHz	Desired ON-time of the pulse.
PU_DeltaPosition	axis units	64bit float	10kHz	Distance between pulses. The sign indicates the crossing direction.
PU_Count	-	32bit int	10kHz	The accumulated number of pulses to fire.
PU_ReferencePosition	axis units	64bit float	at mode activation	Position of the first pulse when a mode is activated.
PU_DelayTime	seconds	10ns	10kHz	Shift the pulse to compensate propagation delays. Fire early with negative values, or late with positive values. The delay is used to calculate the correct firing time depending on speed, acceleration and the desired position at the time of the pulse, see also Chapter 4.1 Source.

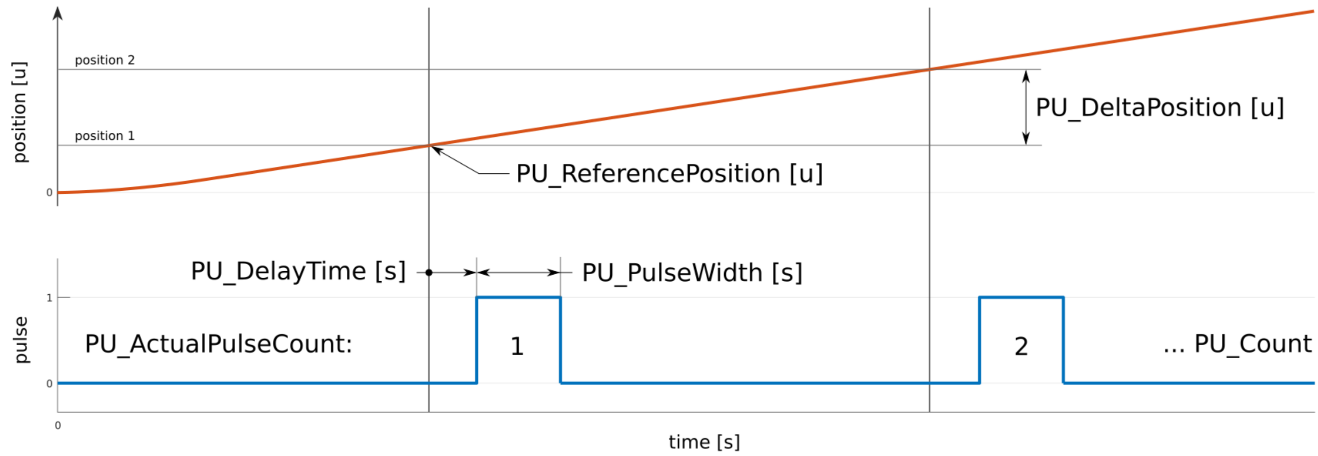


Figure 5: Visualization of Pulsing Unit parameters

Note	The PU_ReferencePosition is only updated when the *Mode* is activated. To configure a sequence with a new reference position, set PU_Mode = Disabled, then configure the new sequence and lastly activate the *Mode*.

4.5 Pulse Configuration for Position Output

The following registers in Axes[].Commands.OptionModule, define the position-output signal, as visualized in figure 6.

Register	Units	Resolution	Update Rate	Description
PU_PulseWidth	seconds	10ns	10kHz	Minimal time between two pulsing events (switching of a signal channel) and therefore minimal time within a signal quadrant. The actual resolution is the next higher multiple of 100ns. This parameter is important if the position is at standstill near a pulsing position to reduce uncontrolled jitter of the position output. It can be set to zero if the following electronics can handle signal changes faster than 10 MHz.
PU_DeltaPosition	axis units	64bit float	10kHz	Distance between pulses. Only positive values are allowed. Corresponds to a quarter of the resulting encoder-signal pitch.
PU_Count	-	-	-	Ignored in this mode
PU_ReferencePosition	-	-	-	Ignored in this mode
PU_DelayTime	seconds	10ns	10kHz	Shift the pulse to compensate propagation delays. Fire early with negative values, or late with positive values. The delay is used to calculate the correct firing time depending on speed, acceleration and the desired position at the time of the pulse, see also Chapter 4.1.

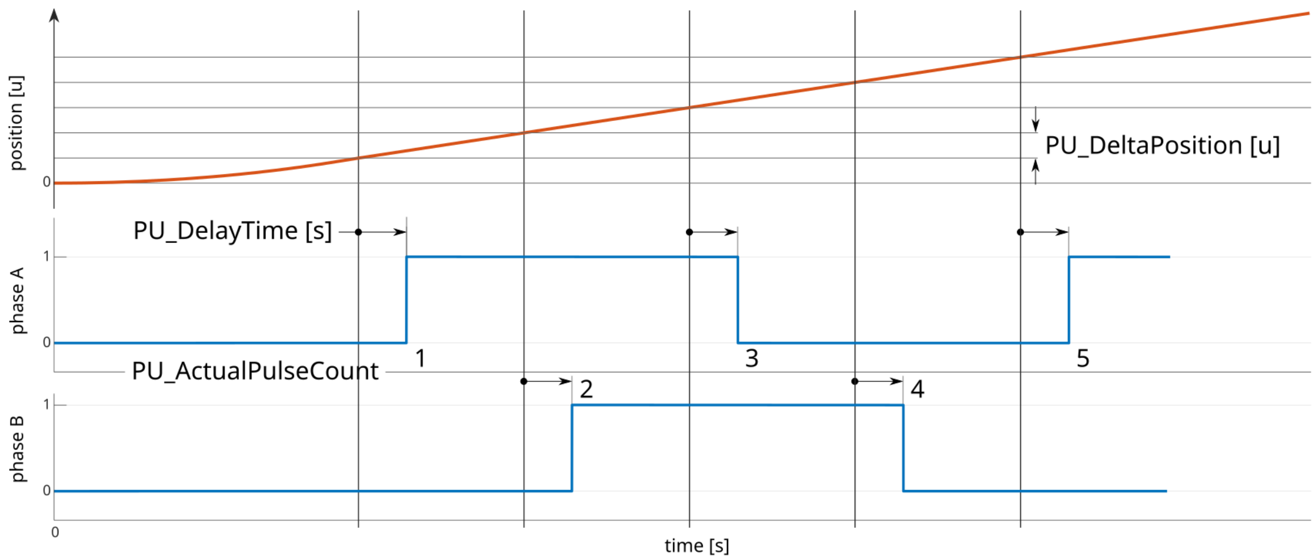


Figure 6: Visualization of Position Output parameters

4.6 Signals

The following signals are available in Axes[].Signals.OptionModule and useful for debugging and programming.

- PU_ActualPulseCount indicates the last fired pulse index. If this value does not show the correct amount of pulses, it is usually an indicator for faulty configurations. This value also counts pulsing events for the mode PositionOutput but can increase uncontrollably fast if the position jitters around a pulsing event.

- PU_FreeFifoEntries indicates the currently available configuration slots. The first sequence pushed into the FIFO is not reflected by this signal, as it is moved instantly into the active slot. While the value is 0, the FIFO is full and configurations are discarded. The following scenarios can lead to a full FIFO.
  - A pulse configuration with PU_Count ≤ PU_ActualPulseCount has been pushed to the FIFO.
  - A pulse configuration has been pushed to the FIFO with a PU_Count ≤ a previously pushed configuration. See also chapters 4.3 and 4.4.
  - Continuously pushing to the FIFO, without actually consuming the pulse sequences.
    - The axis is not moving.
    - The axis is moving in the wrong direction, or
    - The pulses are configured for the wrong direction (negative PU_DeltaPosition).

Note The signals are delayed by 0.2ms (two cycles at 10kHz). In case of pushing sequences with *Tama*, consider to stop with a safety margin on PU_FreeFifoEntries, or count the entries with an own counter variable. Same applies to checks against PU_ActualPulseCount.

Using the *TAM System Explorer* Scope, the pulse output for all TTL-output modes can be recorded with the register Axes[].Signals.General.DigitalInputBits.OptionEncIn0-3.

- When using PU_Mode = Direct or Fifo with PU_Output = TTL or TTLinverted, the register OptionEncIn3 shows the output, provided the pulse duration PU_PulseWidth is larger than 20 µs.
- When using the PU_Mode = PositionOutput with PU_Output = TTL or TTLinverted, the registers OptionEncIn2,3 show the current output.
- When using the PU_Mode = PositionOutput with PU_Output = TTL4 or TTL4inverted, the registers OptionEncIn0-3 show the current output.

Check the pin-out in chapter 3 to see which pins correspond to which signal.

4.7 Remarks

When activating or deactivating a pulsing unit mode, the following behavior applies:

- When activating PU_Mode = Direct or Fifo with any PU_Output = *inverted, the corresponding outputs switch to high.
- When deactivating PU_Mode = Direct or Fifo with any PU_Output = *inverted, the corresponding outputs remain high.
- When activating PU_Mode = PositionOutput, the phases are initialized as phA+ = 0 and phB+ = 0 (and consequently phA− = 1 and phB− = 1 if applicable).

5 Examples

Applications involving a *Pulsing Unit* are very flexible and therefore it is most probably commanded from *Tama* programs. To get started, *Triamec* provides examples on GitHub.

Glossary

FIFO A FIFO is a data structure where the first item added is the first item to be removed.

References

[1] “Option Modules Manual “, HWTO_OptionModulesManual_EP019.pdf, Triamec Motion AG, 2023.

[2] “Software Options Overview”, SWTO_SoftwareOptions_EP002.pdf, Triamec Motion AG, 2023.

Revision History

Version	Date	Editor	Comment
001	2023-04-27	sm	initial version
002	2023-05-12	Bl, lk	Clarification on pulse frequency and compensation of delays with PU_DelayTime
003	2023-09-27	sm	Add signals delay info, move example to GitHub
004	2024-02-21	ab	Added hints for the use case PathPlanner, Additional debug functionality added
005	2025-07-25	yz, yb	Added information for mode PositionOutput and output TTL4(inverted)

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