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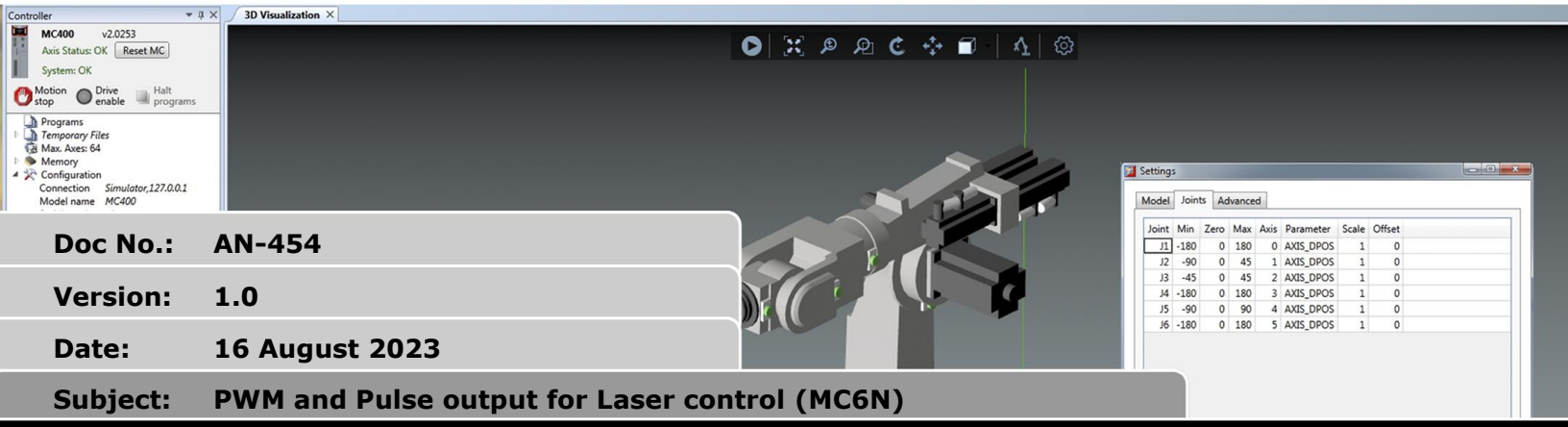

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Version: **1.0**

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Subject: **PWM and Pulse output for Laser control (MC6N)**

APPLICATION NOTE

Contents

1. Version

16th August 2023	V1.0	First release

2. Introduction

The MC6N-ECAT Motion Coordinator includes PWM and pulse outputs for control of lasers and similar devices with the output coordinated with the motion profile being run on one or more axes. There is a basic performance specification for the outputs which all versions of firmware will have, and in addition there are some enhanced modes that are available on specific firmware / FPGA versions.

This document is designed to provide the envelope of speeds and resolution which can be expected from the Trio range of Motion Coordinators.

3. Basic performance (Encoder port)

The built-in encoder port on the MC6N-ECAT runs as an incremental encoder port or stepper pulse port with internal step counting circuit. This port runs a position comparator which can be used to generate pulses on the Z channel or on digital output 8.

Control for the pulse output circuit is via a command called HW_PSWITCH assigned to the encoder axis. The circuit has a FIFO buffer which can be loaded with a list of positions at which the output must go ON or OFF. The size of the FIFO buffer is 512 positions.

3.1. Output rate

As the FIFO and comparator are all in hardware, the rate of ON/OFF transitions is limited by the capability of the FPGA and the output RS422 line driver. However, the time taken to load the FIFO from software must also be taken into account so it cannot be expected to have 512 transitions in 1 servo cycle running continuously.

If all 512 transitions were required to trigger in one msec, the setup time of approximately 30 points per msec needs to be allowed for. The setup time minimum for 512 points is 18 msecs.

4. Basic performance (EtherCAT axes)

EtherCAT axes are read cyclically by the MC6N-ECAT with the latest Position Actual Value returned by the servodrive once per EtherCAT cycle. When a Trio Motion Coordinator is the EtherCAT master, the EtherCAT cycle is the same as SERVO_PERIOD. For normal operation, HW_PSWITCH requires the SERVO_PERIOD to be 1000 µsecs.

As the MC6N is not directly counting the encoder pulses, the HW_PSWITCH uses time interpolation to determine the switching position of the output transition or pulse. The actual position is known for the previous and current millisecond cycles, therefore the time where the output must be triggered can be calculated and loaded into a high resolution timer.

The timer has a base clock frequency of 20MHz so time resolution is 50 nanoseconds.

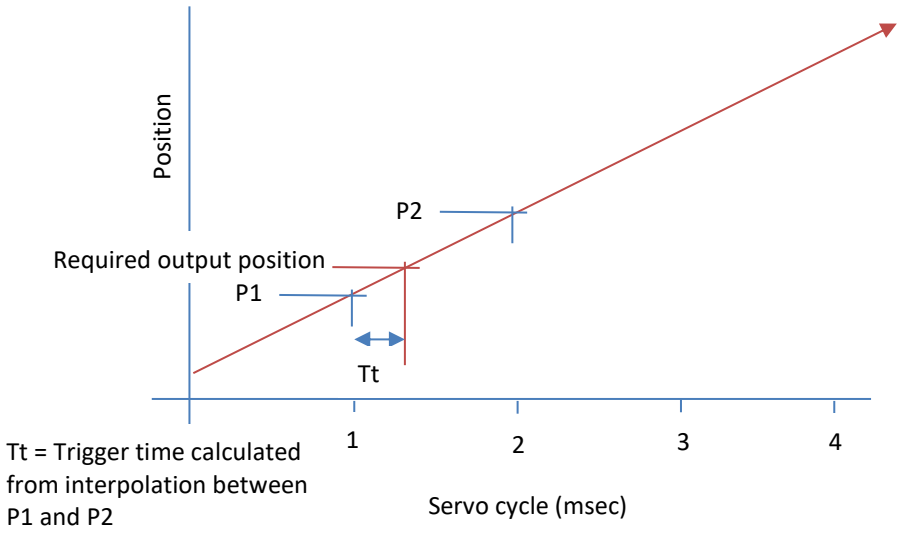

Figure1 - Generation of HW_PSWITCH output

4.1. Output rate (Basic mode)

In the default mode, one trigger position may be output every millisecond. Therefore the maximum rate of either edge transitions or pulses is 1000 per second, or 1kHz for pulses and 500 Hz for edge transitions.

4.2. Output resolution

The time resolution is 50 nsecs.

This corresponds to position resolutions which depend on the axis speed.

Axis speed (mm s^{-1})	Output position resolution	Comment
10 mm s^{-1}	0.5 nm	The position encoder on the axis must have the same resolution or better. Recommended encoder resolution is 0.1 x the figures quoted.
100 mm s^{-1}	5 nm	
1 m s^{-1}	50 nm	
2 m s^{-1}	100 nm	
5 m s^{-1}	250 nm	

Table 1 -HW_PSWITCH output resolution

5. Enhanced mode (EtherCAT axes)

When enhanced mode is enabled, the FPGA can store up to 30 transitions or up to 30 pulse positions per millisecond. Ie 30,000 pulses per second or 30 kHz.

The position resolution is the same as basic mode, see table 1 above. Pulse or transition rate can be used to calculate the minimum position interval between pulses or edges. See table 2.

Axis speed (mm s^{-1})	Minimum position interval	Comment
10 mm s^{-1}	0.333 µm	Assumes constant equally spaced output transitions. There can be up to 30 transitions per msec. Positions do not have to be equally spaced.
100 mm s^{-1}	3.333 µm	
1 m s^{-1}	33.33 µm	
2 m s^{-1}	66.67 µm	
5 m s^{-1}	166.67 µm	

Table 2 - HW_PSWITCH position interval

6. Pulse output

Output pulses are generated by the FPGA hardware and the range of pulse width is from 1 µsec to 65.535 msecs. Pulse width can be set in 1 µsec intervals between those values.

7. Physical outputs

The MC6N-ECAT HW_PSWITCH function can route outputs for up to 4 HW_PSWITCH functions to either 24V outputs 8 … 11, or to the 3 RS422 line drivers on the built-in encoder port.

Output selection is controlled by the HW_PSWITCH command “mode” parameter.

Any EtherCAT axis may be used as the position source for the output.

mode:	0	Disable switch
	1	Toggles Digital Output at specified positions which are loaded into the HW FIFO. When each position is reached the output is set to the

		requested ON/OFF state.
	2	Clears FIFO
	3	When the specified positions are reached, loads a timer (microseconds, 0 - 65535) and sets the digital output for the timer period.
	4	When the specified positions are reached loads a timer (microseconds, 0 - 65535) and sets the axis port RS422 output for the timer period.
	5	MC6N only: As per mode 1 but triggers an internal FPGA signal linked directly to the HW_TIMER without affecting the physical outputs.
	6	MC6N only. As per mode 3 but triggers an internal FPGA signal linked directly to the HW_TIMER without affecting the physical outputs.
	7	Not available on MC6N.
	+0	MC6N only. Adding this offset to one of the modes 0 to 6 selects the mode to use with HW_PSWITCH_0. HW_PSWITCH_0 is linked to output 8 when using modes 1 or 3 and channel A (step) on the built-in axis when using mode 4.
	+16	MC6N only. Adding this offset to one of the modes 0 to 6 selects the mode to use with HW_PSWITCH_1. HW_PSWITCH_1 is linked to output 9 when using modes 1or 3 and channel B (dir) on the built-in axis when using mode 4.
	+32	MC6N only. Adding this offset to one of the modes 0 to 6 selects the mode to use with HW_PSWITCH_2. HW_PSWITCH_2 is linked to output 10 when using modes 1or 3 and channel Z (enable) on the built-in axis when using mode 4.
	+48	MC6N only. Adding this offset to one of the modes 0 to 6 selects the mode to use with HW_PSWITCH_3. HW_PSWITCH_3 is linked to output 11 when using modes 1or 3. Mode 4 cannot be used with HW_PSWITCH_3.
	+64	MC6N only. Adding this offset to one of the modes 0 to 6 selects the mode to use with HW_PSWITCH_4. HW_PSWITCH_4 is linked to output 12 when using modes 1or 3. Mode 4 cannot be used with HW_PSWITCH_4.

Table 3 - HW_PSWITCH modes (MC6N-ECAT)

Example 1: Set up a HW_PSWITCH on axis 5 to output On/Off transitions to 24V output 10.

```
BASE(5)
HW_PSWITCH(33, …..) ' Using HW_PSWITCH_2
```

Example 2: Set up a HW_PSWITCH on axis 8 to output pulses to the axis port A channel.

```
BASE(8)
HW_PSWITCH(4, …..)  ' Using HW_PSWITCH_0
```

8. PWM Output

TBA

9. Appendix 1 – calculations

9.1. Table 1

Values are derived from the axis speed in m s^{-1} and the timer resolution of 50 nsecs.

Output position resolution = 50 x 10^{-9} / axis_speed

9.2. Table 2

Values are derived from the axis speed in m s^{-1} and the maximum number of transitions allowed in 1 second.

Minimum position interval = axis_speed / 30000

Note that the assumption is for the transitions to be evenly spaced at 30 per msec. In fact, shorter distances are allowed so long no more than 30 are programmed for each servo cycle.

For example, at 2 m s^{-1} there could be a transition at 100 µm followed by another at 101 µm provided that subsequent transitions are spaced such that only 30 occur in 1 msec. These 2 transitions will output a pulse just 500 nsec long so must be output from the RS422 built-in axis port.

10. References

1. AN-436 Extended HW_PSWITCH functionality, V2.5 14 January 2021
2. AN-361 HW_PSWITCH XY Mode, V1.0 18 November 2016
3. Motion Perfect V5.3 “Trio BASIC” Help, 26 June 2023