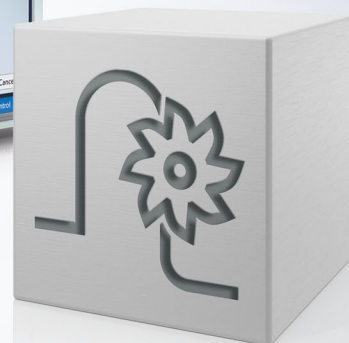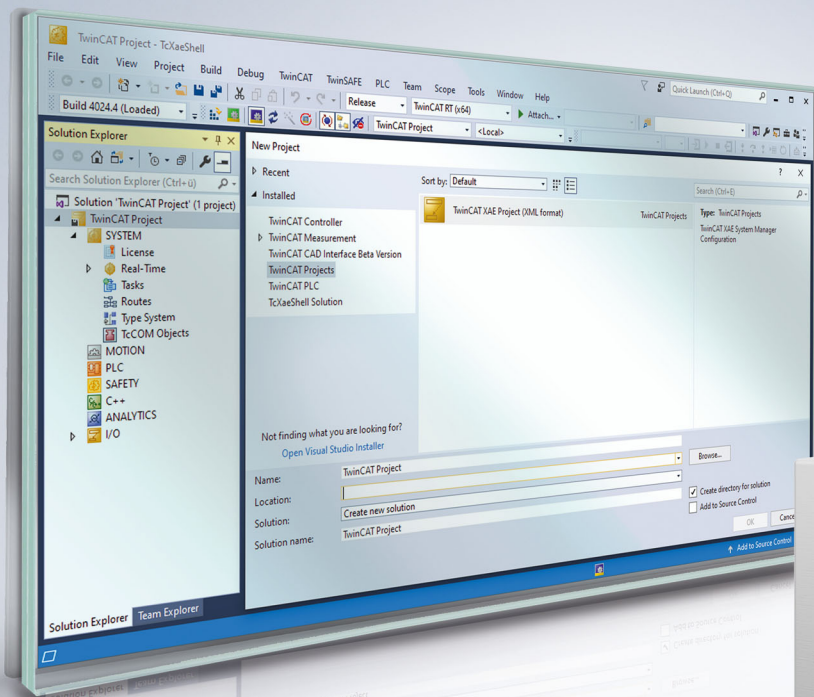**BECKHOFF** New Automation Technology

Functional description | EN

TF5200 | TwinCAT 3 CNC

Oscillating axis

Notes on the documentation

This description is only intended for the use of trained specialists in control and automation engineering who are familiar with the applicable national standards.
It is essential that the documentation and the following notes and explanations are followed when installing and commissioning the components.
It is the duty of the technical personnel to use the documentation published at the respective time of each installation and commissioning.

The responsible staff must ensure that the application or use of the products described satisfy all the requirements for safety, including all the relevant laws, regulations, guidelines and standards.

Disclaimer

The documentation has been prepared with care. The products described are, however, constantly under development.
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General and safety instructions

Icons used and their meanings

This documentation uses the following icons next to the safety instruction and the associated text. Please read the (safety) instructions carefully and comply with them at all times.

Icons in explanatory text

1. Indicates an action.
⇨ Indicates an action statement.

⚠ DANGER
Acute danger to life!
If you fail to comply with the safety instruction next to this icon, there is immediate danger to human life and health.

⚠ CAUTION
Personal injury and damage to machines!
If you fail to comply with the safety instruction next to this icon, it may result in personal injury or damage to machines.

NOTICE
Restriction or error
This icon describes restrictions or warns of errors.

> **ℹ Tips and other notes**
>
> This icon indicates information to assist in general understanding or to provide additional information.

General example

Example that clarifies the text.

NC programming example

Programming example (complete NC program or program sequence) of the described function or NC command.

> **ℹ Specific version information**
>
> Optional or restricted function. The availability of this function depends on the configuration and the scope of the version.

Table of contents

List of figures

1   Overview

Task

Oscillating axis motions (oscillation) are used for the grinding machining process, for example. As a result of the oscillating motion, a tool (grinding disc) moves in the reverse direction across the workpiece in order to reach the final dimension with high precision and surface quality.

Characteristics

The essential characteristics of the oscillating motion result from the oscillating motion between two absolute positions as well as the feed rate.

Parametrisation

Settings are required in the channel and axis parameter lists to parameterise an oscillating motion. The section Parameter [▶ 16] contains a detailed description of the commands.

Programming

An oscillating motion is defined in the NC program by the axis-specific command X[OSC…] (see Chapter Programming [▶ 12]).

Mandatory note on references to other documents

For the sake of clarity, links to other documents and parameters are abbreviated, e.g. [PROG] for the Programming Manual or P-AXIS-00001 for an axis parameter.

For technical reasons, these links only function in the Online Help (HTML5, CHM) but not in pdf files since pdfs do not support cross-linking.

2   Description

An oscillating axis motion is required in certain machining technologies, e.g. grinding, and this is executed mainly independently of a path motion.

This motion referred to below as an "oscillating motion" is executed by the tool with periodic reversal across the workpiece.

In the strict physical sense of the word, a typical oscillating motion is sinusoidal. It must be borne in mind that, when the term "oscillating motion" is used for the periodic reversal motion described in this section, the timing of the motion is not generally sinusoidal.

This is also not intended since in typical grinding work, the relative velocity between the disc and the workpiece should be constant, at least during tool engagement.

An oscillating axis during grinding is presented in the figure below as an example. The workpiece is machined by superimposing the oscillating X motion on positioning motions in the Y and Z axes.
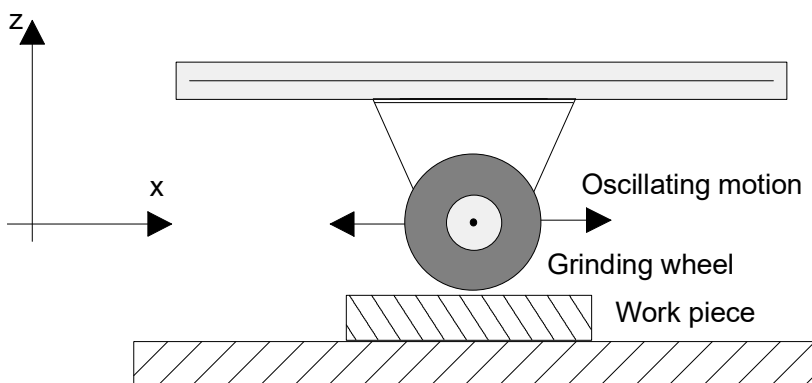
Fig. 1: Grinding with an oscillating axis

Description of parameters

An oscillating motion can be described by the following parameters in addition to the profile type which defines the velocity curve in the dynamic phase.

v_{osc}:   Oscillation feed
T_{osc}:   Oscillating period
f_{osc}:   Oscillating frequency (1/ T_{osc})
p1:   Oscillation reversal position 1
p2:   Oscillation reversal position 2
t_{d1}:   Waiting/delay time at oscillation reversal position 1
t_{d2}:   Waiting/delay time at oscillation reversal position 2
s_{exc}:   Oscillation excursion

The time and path diagrams below explain the parameters:

Fig. 2: Oscillating motion in the time range with linear slope profile
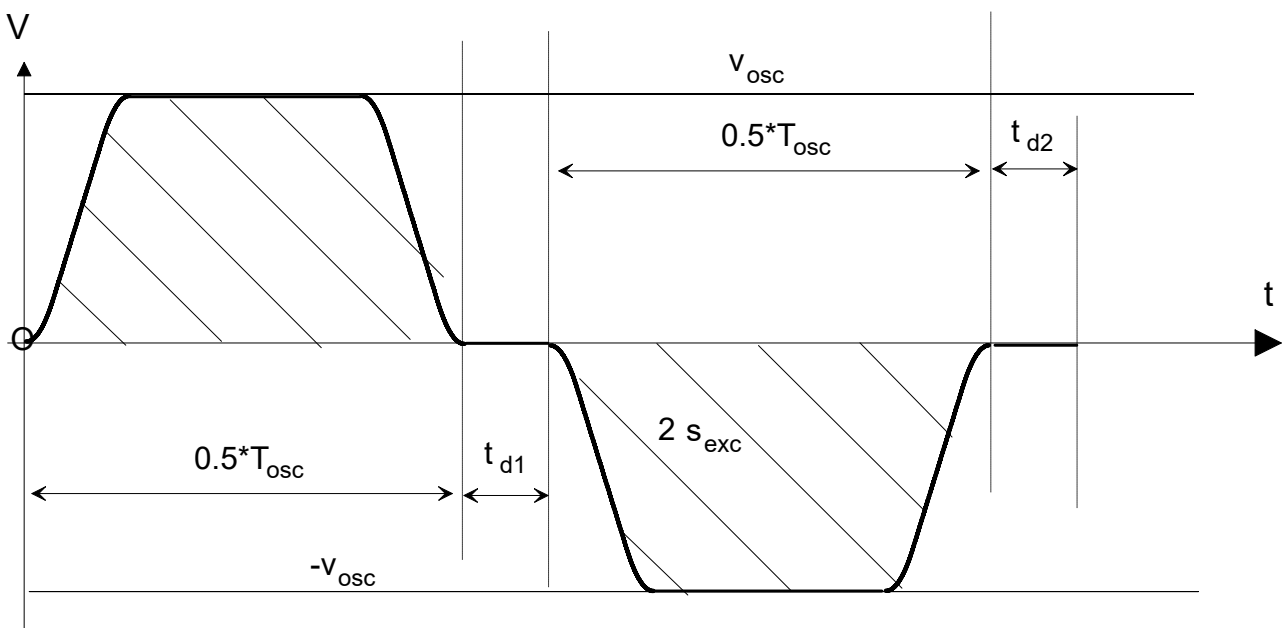
Fig. 3: Oscillating motion in the time range with non-linear slope profile
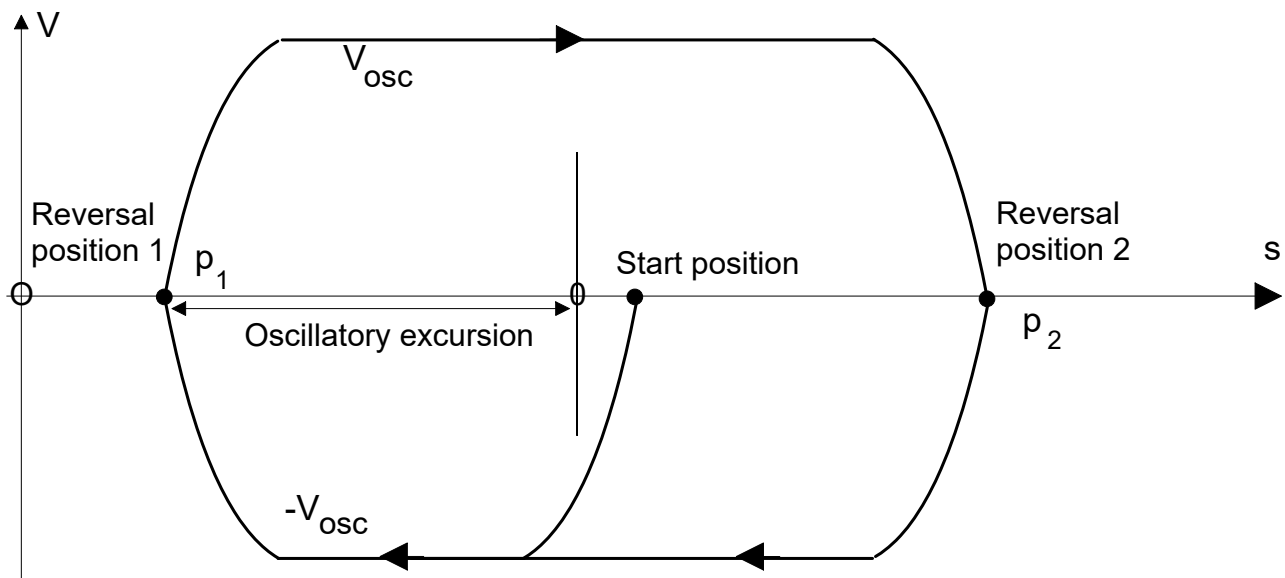
Fig. 4: Positioning procedure with pendulum movement

Properties

- The essential characteristics of the oscillating motion result from the oscillating motion between two absolute positions as well as the feed rate.
- Any definition of the oscillating axis within the configured axes
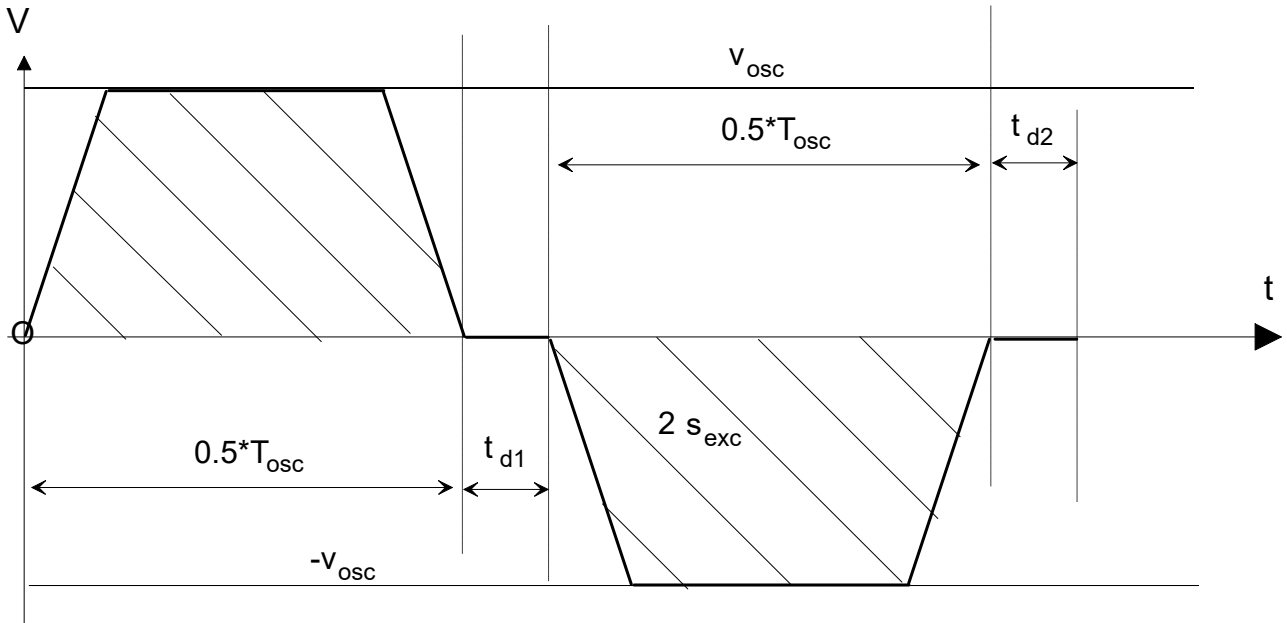- Asynchronous oscillating motion
- Alternative programming of the oscillating axis in the path compound
- The oscillating motion is started, stopped and parameterised via the NC program
- Slope type depending on the channel parameter settings
- Programmable waiting times at the reversal points of the oscillating motion
- Using G01 acceleration in the dynamic phases of the motion
- Interrupting the path motion if oscillating motion is commanded
- Implicit deactivation of oscillating motion when:
  - transiting from programmed oscillating axis to path motion
  - Issuing new command without previous deselection
  - requesting axis positions to synchronise decoding and interpolation
  - Program end

> **i** After an oscillating motion is deactivated, the motion is always stopped at oscillating position 2 .

3 Programming

The programming syntax is based on the axis-specific programming of independent axes [PROG].

After the axis identifier, the parameters of the oscillating motion are defined by keywords and, if applicable, an associated value:

X[<keyword> <(value1)>, [<keyword2> <(value2) >,...]

The characteristic of the oscillating motion is determined by the locations of the reversal positions and the axis feedrate. The reversal positions can be either specified directly or alternatively they are determined automatically via the zero position and the excursion.

The oscillation velocity must be specified. It can be defined by:

- feed
- frequency
- period

If it is not defined, Error ID 50593 is output.

If no restriction occurs due to the dynamic axis characteristics, the frequency and the period are maintained exactly when the linear slope is used and maintained approximately when the non-linear slope is used.

```
Syntax for programming an oscillation motion:
```
<axis:name> **[OSC ON** | [**OFF | OFF FEED**=.. **| OFF INSTANT**]
        FEED=.. | **FREQ**=.. | **TIME**=.. [**1ST_POS**=.. **2ND_POS**=..]
        | [**ZERO_POS**=.. **EXCUR**=..] [**1ST_DELT**=.. **2ND_DELT**=..] [**NBR_OSC**=..] { \ } **]**

<axis_name>	Name of the oscillating axis
OSC	Identifier for "Oscillating" function. Must always be programmed as the <u>first</u> keyword.
ON	Oscillation on. The motion is stopped at block end when a path motion is active and the oscillating motion is then commanded.
OFF	Oscillation off. Current oscillation cycle is finished. The oscillating axis can then move again in the coordinated motion. If the oscillating motion is stopped implicitly if it is not previously deselected when a new axis motion is programmed.
OFF FEED=..	Fast oscillation stop. The current oscillation cycle is aborted and the axis moves at the specified feedrate to target position (2ND POS). The oscillating axis can then move again in the coordinated motion.
OFF INSTANT	Immediate oscillation stop. Axis stops immediately and can be moved again within the path compound immediately. Available as of V3.1.3107.38
FEED=..	Feedrate of the oscillating motion in [mm/min, m/min, inch/min]
FREQ=..	Frequency of the oscillating motion in [Hz]
TIME=..	Period of the oscillating motion in [s]
1ST_POS=..	First reversal position in [mm, inch]
2ND_POS=..	Second reversal position in [mm, inch]
ZERO_POS=..	Zero point or zero crossing of the oscillating motion in [mm, inch]
EXCUR=..	Excursion in [mm, inch]
1ST_DELT=..	Wait time at first reversal position in [s]
2ND_DELT**=..**	Wait time at second reversal position in [s]
NBR_OSC=..	Number of oscillations
\	Separator ("backslash") for clear programming of the command over multiple lines.

Programming the oscillating axis

The equals signs between the keyword and the value are optional.

Specifying the oscillating motion path via reversal positions:

```
N10 X[OSC ON 1ST_POS=-100 2ND_POS=100 FEED=1000]
```

Specifying the oscillating motion path via the zero position and the excursion:

```
N20 X[OSC ON ZERO_POS=0 EXCUR=100 FEED=1000]
```

Specifying oscillation frequency 1 Hertz, 10 oscillations:

```
N30 X[OSC ON ZERO_POS=0 EXCUR=100 FREQ=1 NBR_OSC=10]
```

Specifying a 4s oscillating period:

```
N40 X[OSC ON ZERO_POS=0 EXCUR=100 TIME=4]
```

Oscillating motion with feed motion of a path axis:

```
N50 X[OSC ON 1ST_POS=111 2ND_POS=222 FREQ=1]
N60 G01 G90 Y500 F200
```

Oscillate with wait times of 0.5 s each at reversal positions

```
N70 X[OSC ON 1ST_POS=-100 1ST_DELT=0.5 2ND_POS=200
     2ND_DELT=0.5 FEED=1000]
```

Deselecting oscillation:

Oscillation is stopped when reversal position 2 is reached:

```
N80 X[OSC OFF]
```

Fast oscillation stop:

If a feedrate is programmed with FEED in combination with OFF, the oscillating motion is stopped immediately (feedhold of oscillating axis) and the reversal position 2 is directly approached at the new feed rate.

```
N90 X[OSC OFF FEED=5000]
```

> **ℹ** **Restrictions of kinematic transformations**
>
> When kinematic transformation (#TRAFO ON) is active, an oscillating motion is only permitted if the kinematics have a basic Cartesian structure and the oscillation direction vector lies in the z axis direction of the machine.

If an oscillating motion is defined by the number of oscillations, it can be aborted before the specified number of oscillations is reached by programming an oscillation stop.

4 Oscillating motion dynamics

Depending on the profile type, limiting effects occur at relatively high frequency or short period or short oscillation path. This is caused by the limited axis velocities and accelerations.

In this case, the real oscillation frequency or period deviates from the required programmed frequency or period.

The examples listed below show the limits of motion dynamics. In general these motion profiles should be avoided since the motion velocity and therefore the machining velocity during the oscillating motion are not constant or tend to deviate lower.

4.1 Example of limitation by acceleration

Limitation by acceleration

Dynamic characteristics used:a_max: 1000 mm/s2v_max: 5000000µm/s

```
%L sub_mv
N1000 G01 G90 Y100 F500
N2000 Y-100
M29

%osc_7
N10 X[OSC ON 1ST_POS=-120 2ND_POS=120 FREQ=0.6]
N20 LL sub_mv
N30 X[OSC OFF]
N180 M30
```


Fig. 5: Limited oscillating frequency due to axis acceleration

A full oscillation requires 1.964 s. The required 1.666 s (approx. 833 cycles) are therefore not possible with the dynamic characteristics listed above due to the oscillating frequency of 0.6 Hz.

4.2 Example of limitation by velocity

Limitation by velocity

Dynamic characteristics used:a_max: 1000 mm/s2v_max: 500000µm/s

```
%L sub_mv
N1000 G01 G90 Y100 F500
N2000 Y-100
M29

%osc_7
N10 X[OSC ON 1ST_POS=-520 2ND_POS=520 FREQ=0.2]
N20 LL sub_mv
N30 X[OSC OFF]
N180 M30
```
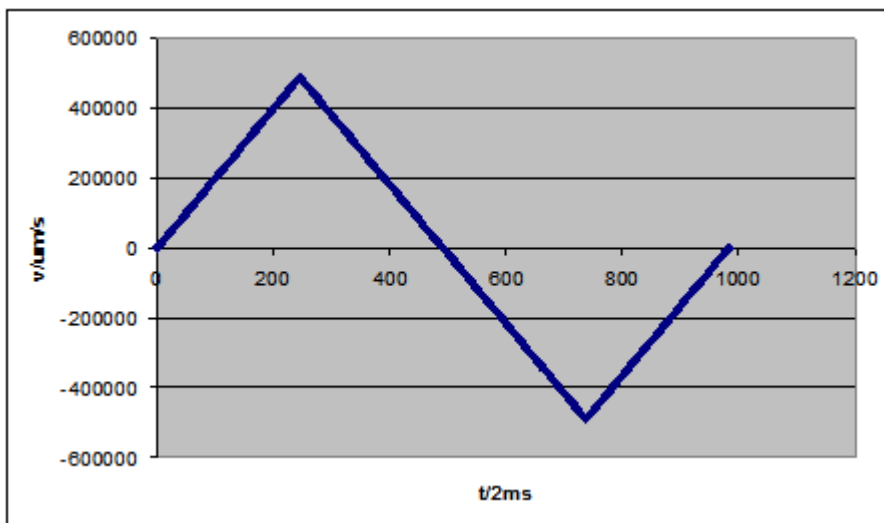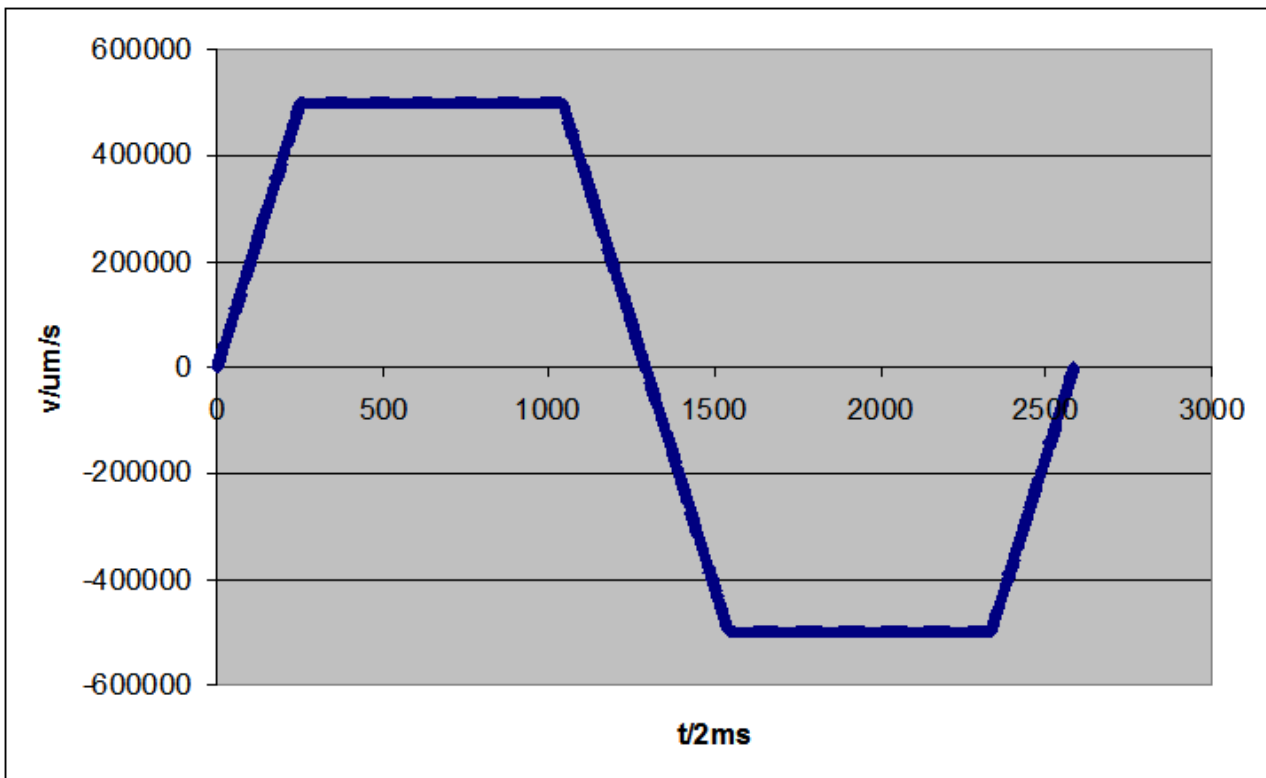

Fig. 6: Limited oscillating frequency due to axis acceleration

A full oscillation requires 5.164 s. The required 5 s (approx. 2500 cycles) are therefore not possible with the dynamic characteristics listed above due to the oscillating frequency of 0.2 Hz.

NOTICE
When the dynamic limits are reached, an error message is output.

5 Parameter

The actual oscillating motion is completely parameterised via the NC program except for the profile type.

5.1 Overview

5.1.1 Channel parameters

The parameter below defines the profile type for the oscillating motion:

ID	Parameter	Description
P-CHAN-00071	profile	Default acceleration profile

5.1.2 Axis parameters

The parameters below are the limiting characteristics for oscillating dynamics.

Linear slope parameters

ID	Parameter	Description
P-AXIS-00011	a_stufe_1	Acceleration in Step 1
P-AXIS-00012	a_stufe_2	Acceleration in Step 2
P-AXIS-00221	vb_stufe_1_2	Changeover velocity between acceleration steps

Non-linear slope parameters

ID	Parameter	Description
P-AXIS-00001	a_beschl	Acceleration at machining feed rate
P-AXIS-00002	a_brems	Deceleration at machining feed rate
P-AXIS-00195	tr_beschl_ab	Ramp time for acceleration down-gradation
P-AXIS-00196	tr_beschl_zu	Ramp time for acceleration up-gradation
P-AXIS-00197	tr_brems_ab	Ramp time for deceleration down-gradation
P-AXIS-00198	tr_brems_zu	Ramp time for deceleration up-gradation

5.2 Description

5.2.1 Channel parameters

P-CHAN-00071	Default acceleration profile at program start
Description	Default value for the selected acceleration profile type with path movements and oscillating axis movements.
Parameter	prog_start.slope.profile
Data type	SGN16
Data range	0: Step-shaped acceleration profile (default) 1: Trapezoidal acceleration profile 2: Sine-square acceleration profile 3: Trapezoidal HSC acceleration profile (across blocks)
Dimension	----
Default value	0
Remarks	The acceleration profile and the associated acceleration and ramp time weighting can be programmed in the NC program with the #SLOPE [TYPE..] command [PROG]. The maximum of the weighted ramp times P-AXIS-00195 is always effective with the trapezoidal HSC acceleration profile. P-AXIS-00198. For every independent axis, the acceleration profile can also be programmed specifically in the NC command with the key word SLOPE_TYPE [PROG].

5.2.2 Axis parameters

5.2.2.1 Linear slope

P-AXIS-00011	Acceleration of step 1 (linear slope)	
Description	The parameter only becomes active during the deceleration phases. It defines the acceleration in step 1.	
Parameter	getriebe[i].lslope_profil.a_stufe_1	
Data type	UNS32	
Data range	1 ≤ a_stufe_1 ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in detail in [PROG//G130, G131] in greater detail.	

P-AXIS-00012	Acceleration of step 2 (linear slope)	
Description	The parameter only becomes active during the deceleration phases. It defines the acceleration in step 2.	
Parameter	getriebe[i].lslope_profil.a_stufe_2	
Data type	UNS32	
Data range	1 ≤ a_stufe_2 ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	

Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in detail in [PROG//G130, G131] in greater detail.

P-AXIS-00221	**Changeover speed (linear slope)**	
Description	The parameter becomes active during the acceleration and deceleration phases.	
	It defines the changeover speed between step 1 and step 2 (P-AXIS-00011 and P-AXIS-00012 or P-AXIS-00283 and P-AXIS-00282).	
Parameter	getriebe[i].lslope_profil.vb_stufe_1_2	
Data type	UNS32	
Data range	1 ≤ vb_stufe_1_2 ≤ P-AXIS-00212	
Axis types	T, R, S	
Dimension	T: µm/s	R,S: 0.001°/s
Default value	100000	
Drive types	----	
Remarks		

5.2.2.2   Non-linear slope

P-AXIS-00001	Acceleration at machining feed (non-linear slope)	
Description	The parameter represents the axis acceleration with increasing velocity.	
Parameter	getriebe[i].slope_profil.a_beschl	
Data type	UNS32	
Data range	1 ≤ a_beschl ≤ P-AXIS-00008	
Axis types	T, R	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G130/G131] in greater detail.	

P-AXIS-00002	Deceleration at machining feed (non-linear slope)	
Description	The parameter represents the axis deceleration with decreasing velocity.	
Parameter	getriebe[i].slope_profil.a_brems	
Data type	UNS32	
Data range	1 ≤ a_brems ≤ P-AXIS-00008	
Axis types	T, R, S	
Dimension	T: mm/s²	R,S: °/s²
Default value	1000	
Drive types	----	
Remarks	The acceleration ramps can be changed in the NC program. The appropriate NC commands are described in [PROG//G130/G131] in greater detail.	

P-AXIS-00195	Ramp time for acceleration down-gradation (non-linear slope)	
Description	The parameter defines the acceleration ramp time for the down-gradation of acceleration P-AXIS-00001.	
Parameter	getriebe[i].slope_profil.tr_beschl_ab	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_beschl_ab ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G233/G338/G339)] in greater detail.	

P-AXIS-00196	Ramp time for acceleration up-gradation (non-linear slope)	
Description	The parameter defines the acceleration ramp time for the up-gradation of the acceleration P-AXIS-00001.	
Parameter	getriebe[i].slope_profil.tr_beschl_zu	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_beschl_zu ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	

Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G233/G338/G339)] in greater detail. The default value for ramp time weighting can be defined in P-CHAN-00073.

P-AXIS-00197	**Ramp time for deceleration down-gradation (non-linear slope)**	
Description	The parameter defines the acceleration ramp time for the down-gradation of deceleration P-AXIS-00002.	
Parameter	getriebe[i].slope_profil.tr_brems_ab	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_brems_ab ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G233/G338/G339)] in greater detail.	

P-AXIS-00198	**Ramp time for deceleration up-gradation (non-linear slope)**	
Description	The parameter defines the acceleration ramp time for the up-gradation of deceleration P-AXIS-00002.	
Parameter	getriebe[i].slope_profil.tr_brems_zu	
Data type	UNS32	
Data range	P-AXIS-00201 ≤ tr_brems_zu ≤ MAX(UNS32)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	50000	
drive types.	----	
Remarks	The ramp time can be changed in the NC program. The appropriate NC commands are described in [PROG//Ramp time weighting (G132/G133/G134/G233/G338/G339)] in greater detail.	

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