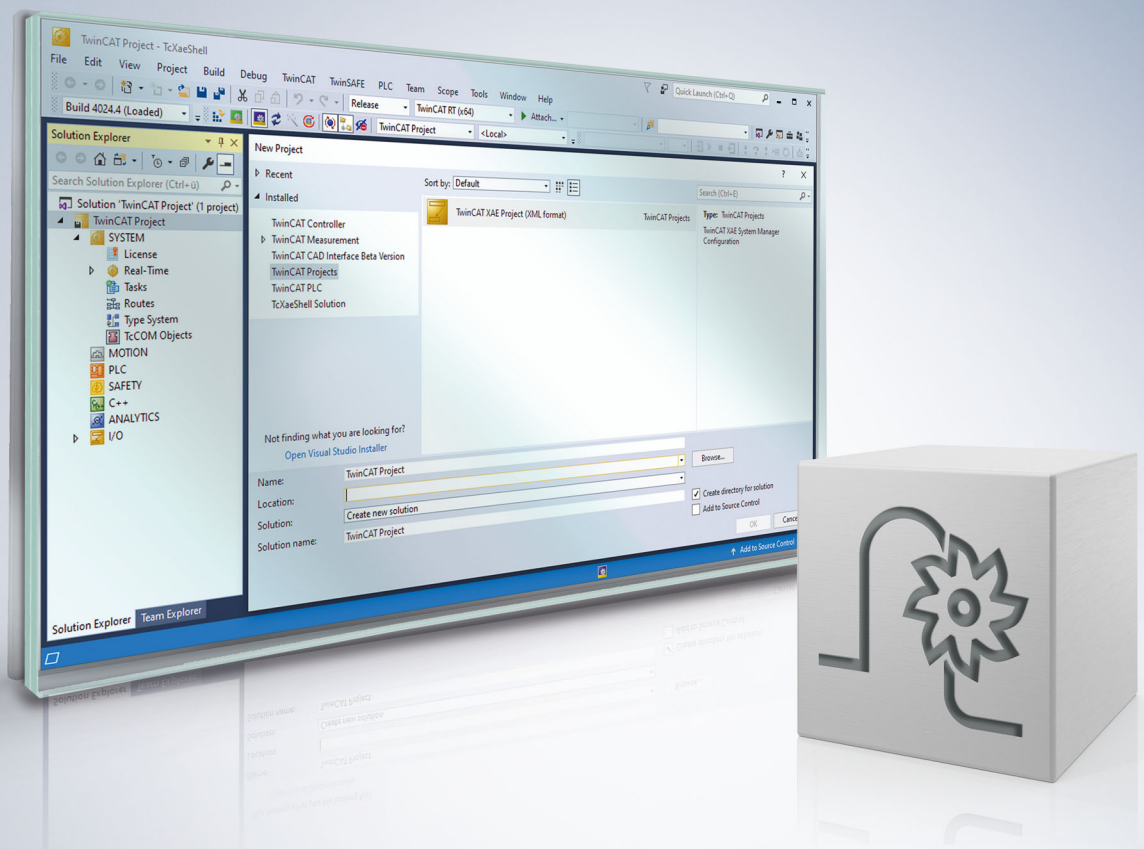
BECKHOFF New Automation Technology

Functional description | EN

TF5200 | TwinCAT 3 CNC

Contour look-ahead



1/18/2024 | Version: 1.04

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It is essential that the documentation and the following notes and explanations are followed when installing and commissioning the components.
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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.

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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

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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.

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.

Specific version information

Optional or restricted function. The availability of this function depends on the configuration and the scope of the version.

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List of figures

1 Overview

Task

The “contour look-ahead” function of the CNC provides the PLC with programmed contour elements on the HLI in advance.

Effectiveness / possible applications

Process parameters, such as velocity, can be optimised based on the information about the future contour.

Parameterisation

The “contour look-ahead” function must be configured with the following parameters:

- P-CHAN-00650 (alternatively P-STUP-00070) and
- P-CHAN-00658 (alternatively P-STUP-00076).

Programming

In order to command the CNC to provide future contour elements on the HLI,

- program sequences can be marked using the commands #CONTOUR LOOKAHEAD LOG ON/OFF or
- the PLC can send a request via the control unit [▶ 15].

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

When optimising processes, it can be and advantage to know future contour elements in advance. The CNC can supply them using the contour look-ahead function.

The PLC can use these elements to optimise the process parameters. Data provision is either programmed by NC commands or by request from the PLC.

The data provided for future contour elements are:

- Type of contour element: Linear block, circular block, polynomial block
- Block number
- Start position of the contour element
- Length of the contour element
- Swept angle, programmed and compensated radius
- Program line number
- Length of the scales geometry for die sinking EDM

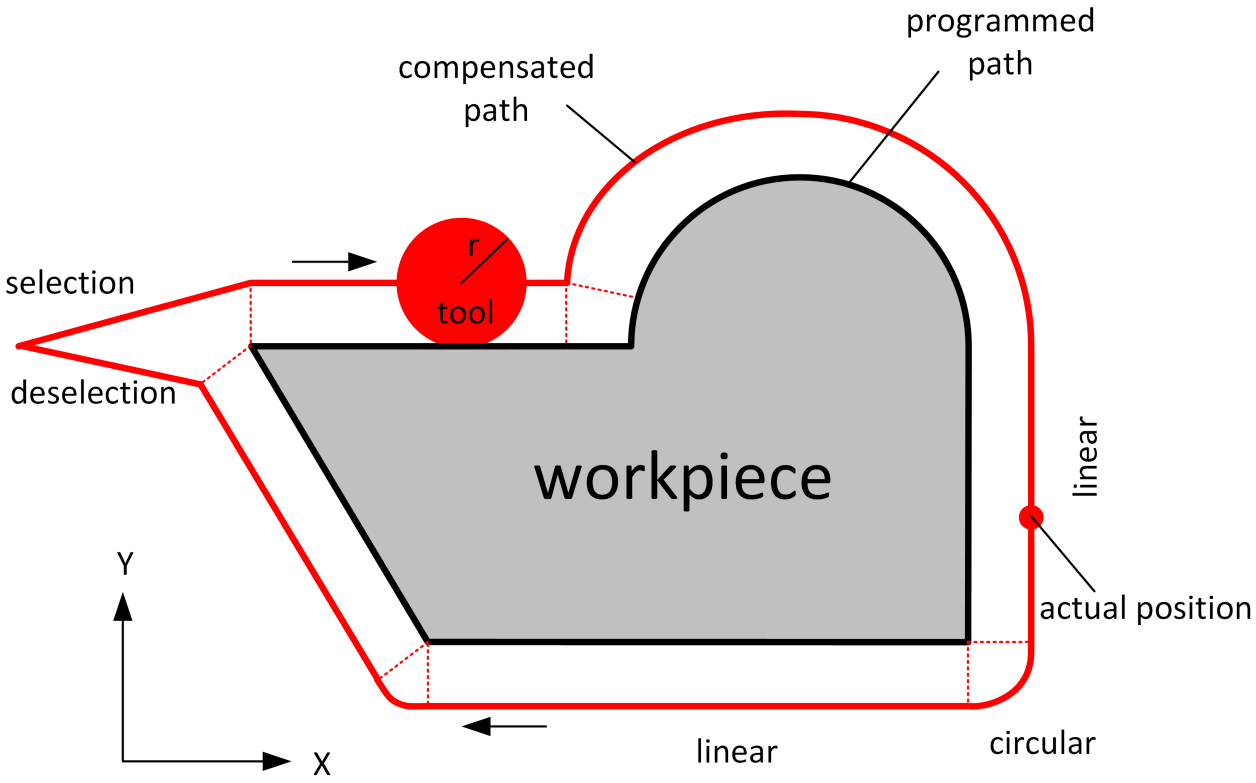

Fig. 1: Example of a programmed contour with tool radius compensation

Sequence of a PLC request

The PLC sends a request to the CNC. The request contains either an index that belongs to a motion block ore a distance based on the program start.

There are 2 modes for these two different requests:

- Mode 1: Request via the index [▶ 11].
- Mode 2: Request via distance from program start [▶ 13].

The CNC then sends the reply information to this request for each motion block. The process looks like this:

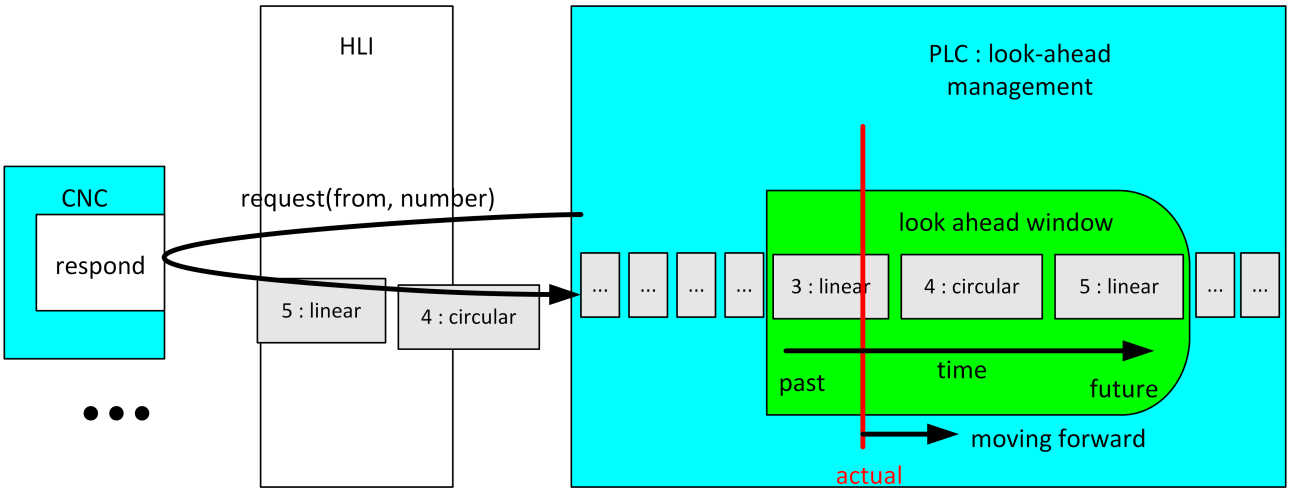

Fig. 2: Schematic diagram of a PLC request

2.1 Mode 1 – Request via index

This mode is available as of CNC Build V3.1.3105.01.

To use Mode 1, a suitable value must be set for the parameter P-STUP-00033 [▶ 22].

In this mode, the PLC reads the look-ahead buffer of NC blocks of the CNC previously marked with the command #CONTOUR LOOKAHEAD LOG ON/OFF [▶ 19].

The information is provided before these blocks are actually executed. The PLC can set synchronisation with any stop conditions (e.g. M functions) to ensure that the PLC has all the necessary data.

The command #CONTOUR LOOKAHEAD LOG [**PARAM=<val>**] is used to provide the PLC with an additional parameter value within a flagged area.

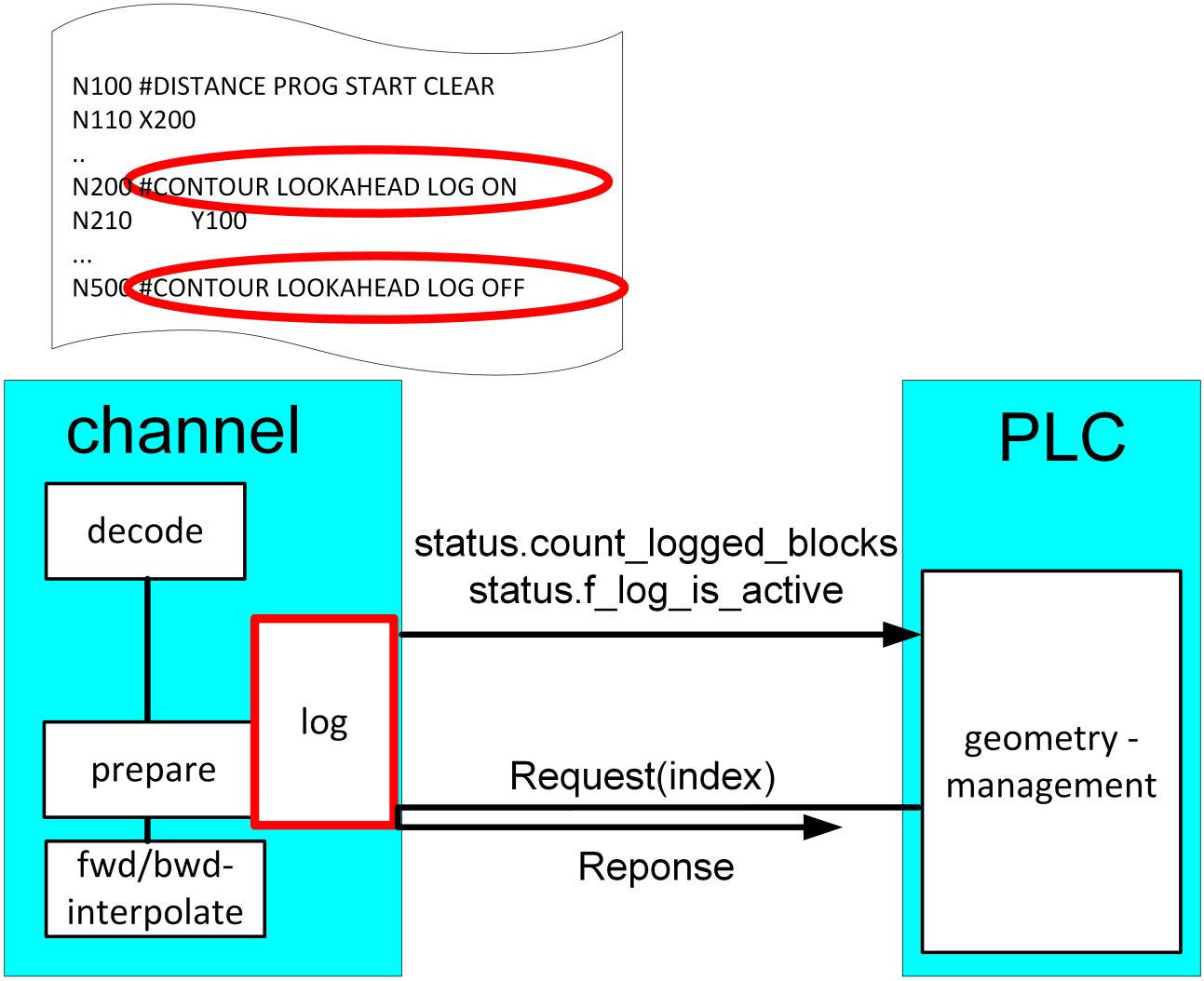

Fig. 3: PLC request via index

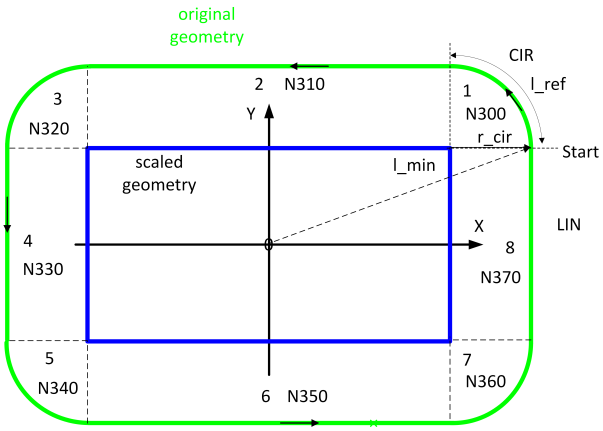

Fig. 4: Example of a logged programmed contour

In index mode, the individual elements can be requested multiple times, including backward motion on the path. The elements starting from the specified index are always output to the end.

2.2 Mode 2 - Request via distance from program start

This mode can only be used if P-CHAN-00658 [▶ 23] is parameterised.

Every contour element is identifiable by the path distance covered.

By default the distance starts at program start and is re-initialised with zero at every program start.

The distance can also be reset in the NC program with the NC command #DISTANCE PROGRAM START CLEAR.

While an NC program is in process, the distance covered is aggregated and displayed as the current distance.

The start position of a contour element ($CLAH_{start\_position}$) is defined as:

$$CLAH_{start\_position,n} = \sum_{k=0}^{n-1} block_{length_k}$$

If the PLC requests contour elements via distance, the correct distance must be specified for the blocks.

The figure below is a schematic diagram of a programmed contour using tool radius compensation (TRC) and the relationship between distance and $CLAH_{start\_position}$.

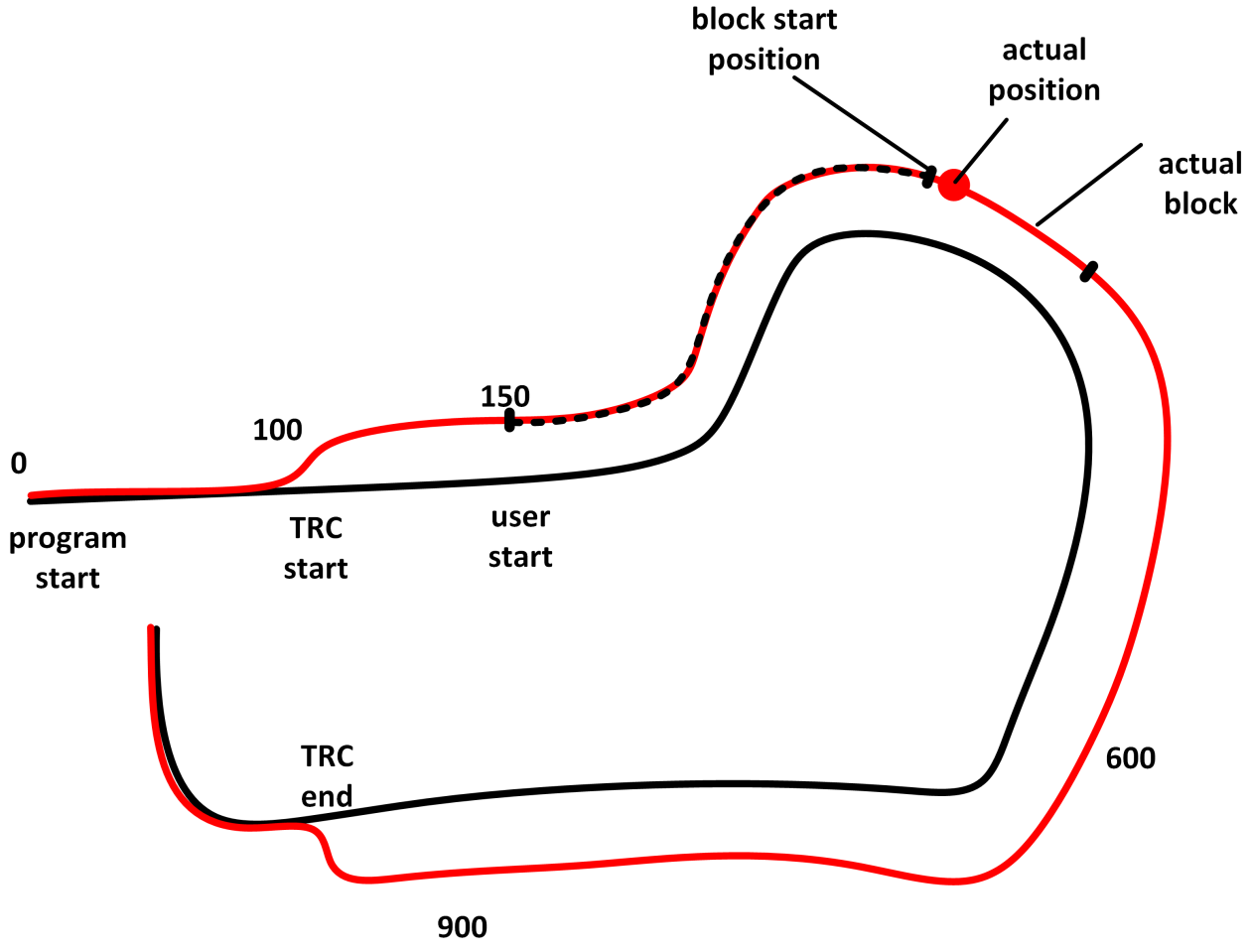

Fig. 5: Schematic diagram - distance and CLAH start_position

Properties of the look-ahead function:

- The maximum look-ahead distance available in the CNC is supplied by the HLI in each cycle and can be requested by a PLC. This information can be used to detect and request new available contour elements (start distance of the last element + length of the last element < maximum look-ahead distance).
- The maximum look-ahead distance depends on the internal buffer size of the interpolator and the block supply of the path preparation.
- The maximum look-ahead distance is independent of feedhold, override, synchronised M functions or G04.

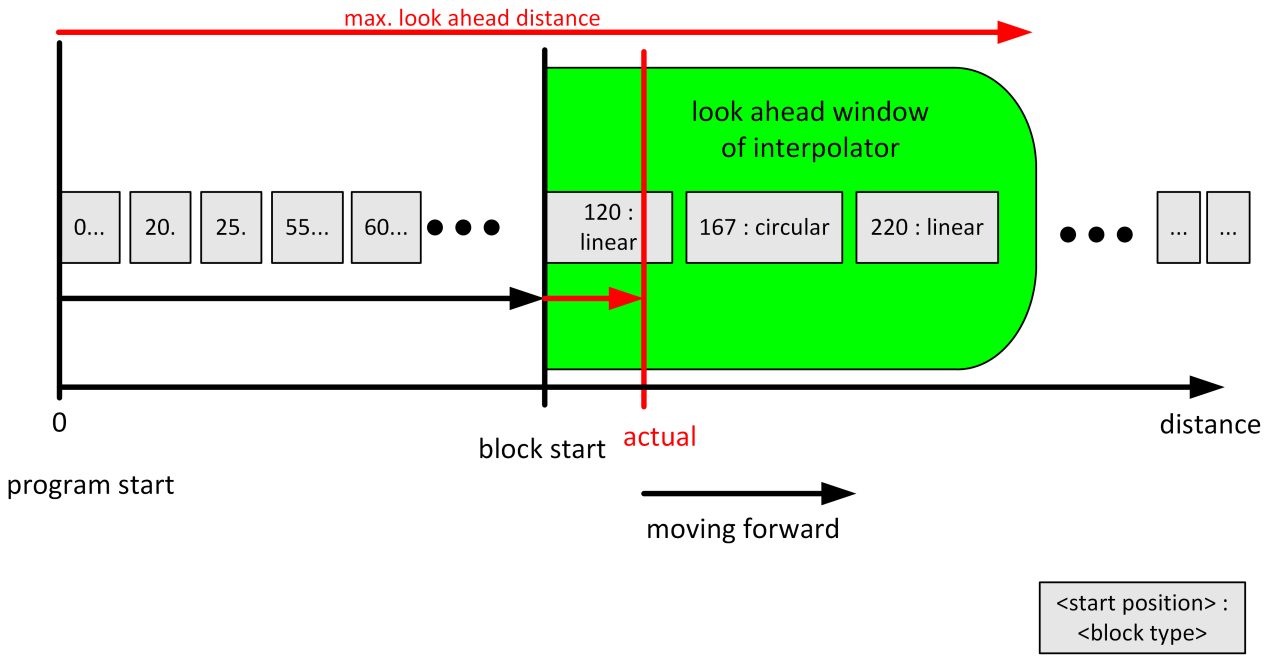

Fig. 6: Representation of the reply in PLC to distance request

2.3 PLC interface

The following data is available on the HLI to use the function:

1. The current distance from program start on the path corrected for tool radius compensation is displayed on the channel-specific HLI area (see bahn_state.dist_prog_start_high [▶ 24]). This distance can be used to request future contours in Mode 2.
2. The contour look-ahead control unit is provided to request and read out contour elements. The PLC requests information with increasing semaphore. The CNC supplies the information and deletes the semaphore afterwards.

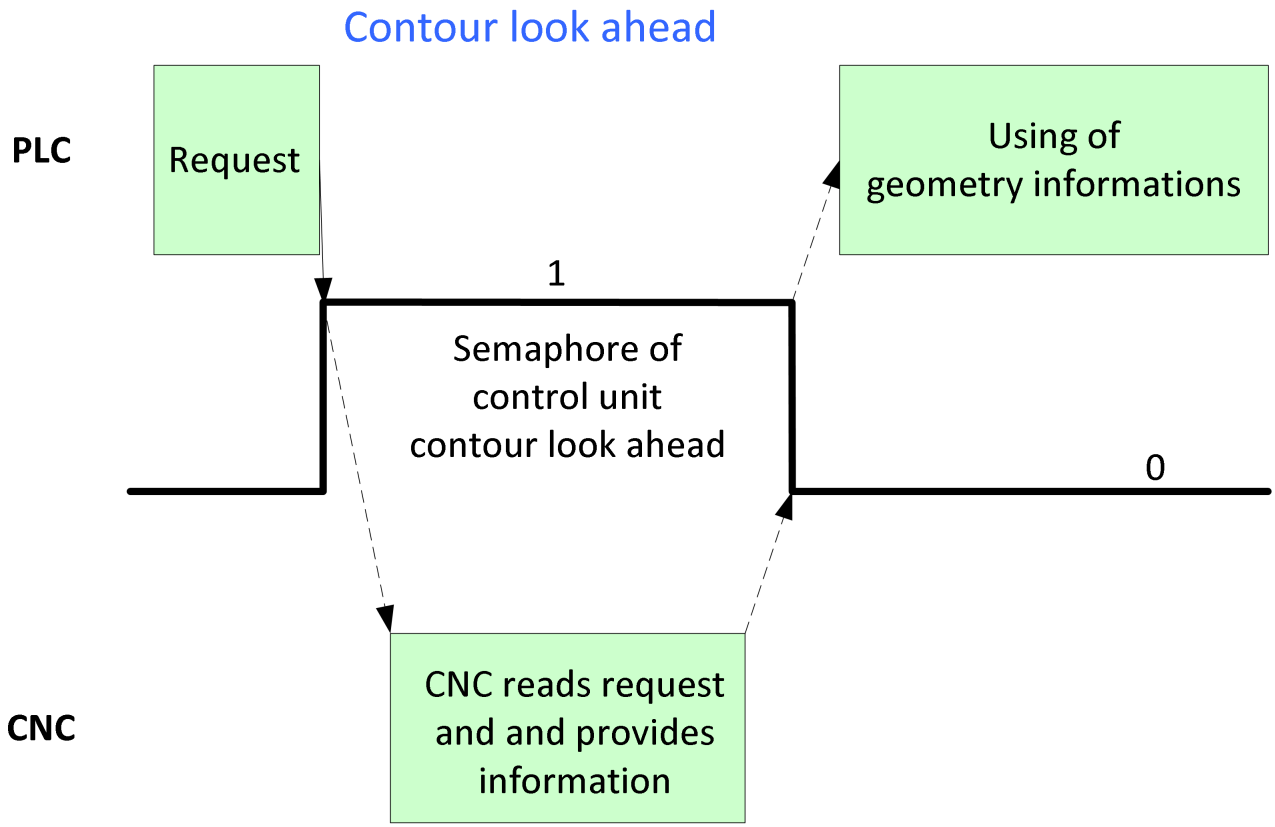

Fig. 7: Handshake - contour look-ahead control unit

Contour look-ahead	
Description	The PLC can use this control unit to request and read out information on contour elements from the CNC. The PLC can use this information to plan the look-ahead process.
Data type	HLI_CONTOUR_LOOKAHEAD
ST path	gpCh[*channel_idx*]^.**contour_lookahead**
Command data	
ST Element	**.request**
Data type	HLI_CONTOUR_LOOKAHEAD_REQUEST [▶ 16]
Access	PLC writes request
Return data	
ST element	**.response**
Data type	HLI_CONTOUR_LOOKAHEAD_RESPONSE [▶ 16]
Access	PLC reads
Flow control of commanded value	
ST element	**.semaphor_rw**

Data type	BOOL
Value range	[TRUE, FALSE]
Special features	**Consumption data item**
Access	TRUE : PLC triggers on new request FALSE : CNC has read new request
Status value	
ST Element	**.state**
Data type	HLI_CONTOUR_LOOKAHEAD_STATE [▶ 16]

2.3.1 User data

Contour look-ahead request data	
Description	Data to request the contour elements from the CNC
ST path	gpCh[*channel_idx*]^.*contour_lookahead.request*
ST name	HLI_CONTOUR_LOOKAHEAD_REQUEST
ST element	**.start_position**
Data type	LREAL
Description/ special features	The meaning of the element is dependent on the mode of the contour look-ahead function used. Mode 1: Index of the contour element in the marked area Mode 2: Start distance from which the distance of the “length” parameter applies
ST element	**.length**
Data type	LREAL
Description/ special features	A distinction is made whether mode 1 or 2 should be used depending on the entry of this element. Value = 0 : Request contour element by index, mode 1 Value != 0: Request contour element by distance, mode 2 This mode indicates the distance up to which contour element is to be requested

Contour look-ahead status data	
Description	Status data of the contour look-ahead control unit
ST Path	gpCh[*channel_idx*]^.contour_lookahead**.state**
ST name	HLI_INSERT_CMD_STATE
ST element	**.max_dist_prog_start**
Data type	LREAL
Description	Maximum look-ahead distance from program start in [0.1 µm].
ST element	**.count_logged_blocks**
Data type	UDINT
Description	Number of available contour elements that can be read out.
ST element	**.f_log_is_active**
Data type	BOOL
Description	This flag signals whether logging is still active for the marked area and all contour elements were read in. TRUE : not all contour elements were read in

Contour look-ahead return data	
Description	Contour information supplied by the CNC
ST Path	gpCh[*channel_idx*]^.contour_lookahead**. response**

ST name	HLI_CONTOUR_LOOKAHEAD_RESPONSE
ST Element	**.block[i]**
Data type	HLI_CONTOUR_LOOKAHEAD_BLOCK [▶ 17]
Description	

Structure HLI_CONTOUR_LOOKAHEAD_BLOCK	
Description	Information on a contour element that was supplied to the PLC by the CNC
ST Element	**.block_type**
Description	Block type 0 – no element exists 1 - linear contour element 2 - circular contour element 3 - #CONTOUR LOOKAHEAD LOG ON 4 - #CONTOUR LOOKAHEAD LOG [PARAM] 5 - #CONTOUR LOOKAHEAD LOG OFF 6 – Polynomial contour element
ST Element	**.block_number**
Description	Programmed NC block number
ST Element	**.block_count_r**
Description	Unique NC block ID number Corresponds to the displayed number of block_count_r in the Status information of a channel.
ST Element	**.start_position**
Description	Start distance of the contour element from program start
ST Element	**.length**
Description	Length of the contour element of the programmed value of the PARAM.
ST Element	**.programmed_radius**
Description	Programmed radius of the circular element
ST Element	**.compensated_radius**
Description	Compensated radius of the circular element
ST Element	**.circle_angle**
Description	Swept angle of the circular element. • Clockwise [-2*pi,0) • Counter-clockwise (0,2*pi].
ST Element	**.length_min**
Description	With die sinking, the length of the contour element is displayed on the scaled contour (radius = R_MAX_SCALE).
ST Element	**.tangent_variation**
Description	End angle to the previous motion block. (0,pi)

2.4 Examples (graphic)

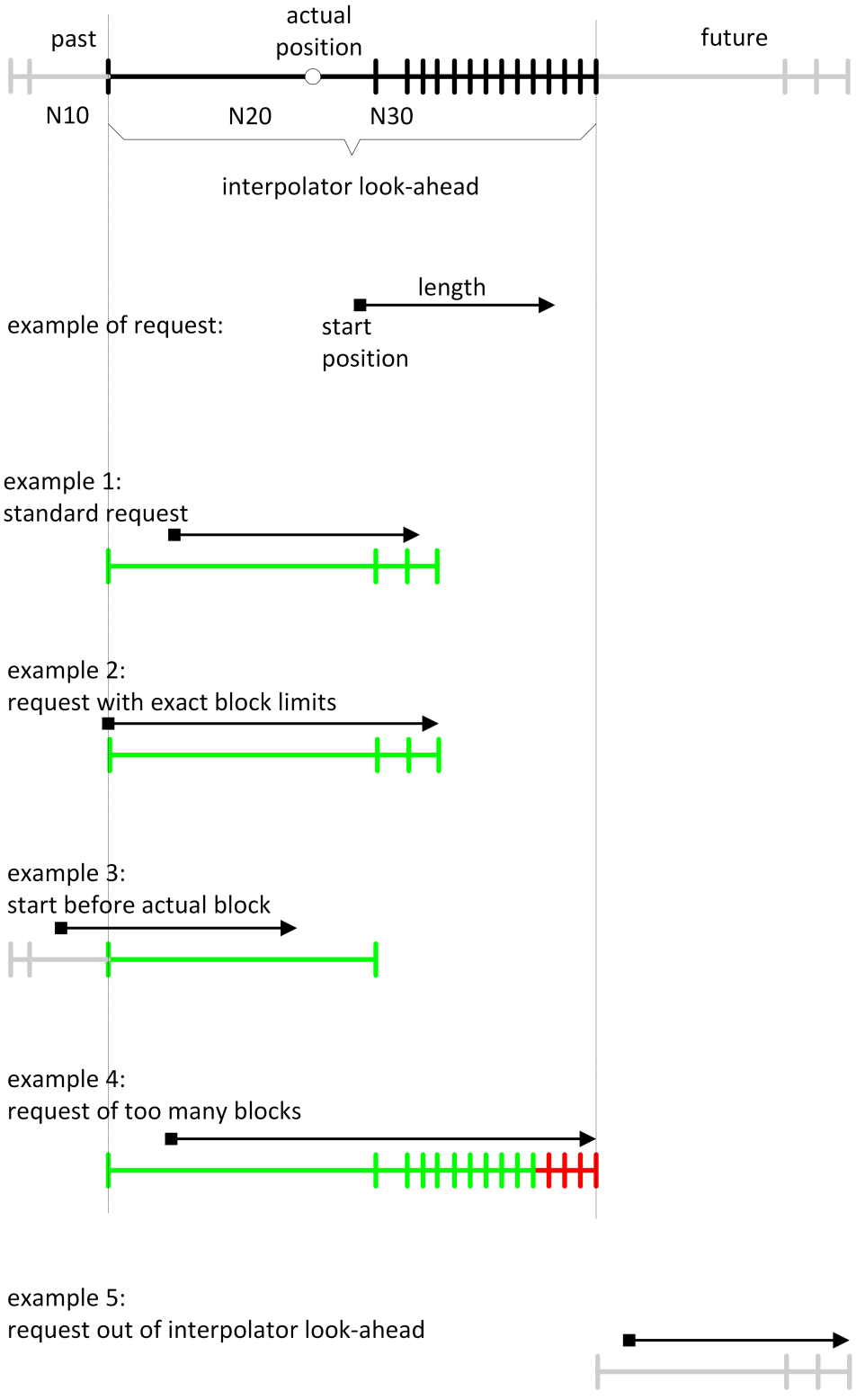

Fig. 8: Examples (graphic) of PLC requests

3 Programming

- Mode 1: Modifications required to the NC program.
- Mode 2: Only controlled by the PLC.

```
Syntax:
```

#CONTOUR LOOKAHEAD LOG [**ON | OFF | CLEAR**] [**[PARAM**=.. **]**]

ON	Activate logging of contour elements by the NC command.
OFF	Deactivate logging of contour elements by the NC command.
CLEAR	The logging buffer is cleared at every program start. Use this NC command if the buffer needs to be cleared while the program is running to log a new area. Every time the buffer is cleared, decoding and execution are synchronised by an implicit #FLUSH&WAIT. Clearing can be executed while logging is active or inactive.
PARAM=..	This parameter allows the user to add an user-defined additional parameter (8 byte floating value) in the log entry.

If #CONTOUR LOOKAHEAD LOG ON is detected several times while a program is running, only the first marked area is provided. The command #CONTOUR LOOKAHEAD LOG CLEAR can be used to delete the last marked area. The next area is then supplied again with #CONTOUR LOOKAHEAD LOG ON.

3.1 Contour look-ahead and real-time loops

There are two programming options to obtain contour elements in a real-time loop (#RT WHILE/ ENDWHILE) in Mode 1:

1. Only one geometry is provided when programming #CONTOUR LOOKAHEAD LOG ON/OFF within a real-time loop. It has the properties of the entry loop, which means the parameter "tangent variation [▶ 17]" has the angle to the motion block before the loop.
2. If #CONTOUR LOOKAHEAD LOG ON/OFF is programmed outside the real-time loop, the elements are supplied three times to obtain all the properties of the possible transitions. The transitions are:
   - start of loop
   - loop-loop
   - end of loop

NOTICE

Do not program the NC command #CONTOUR LOOKAHEAD CLEAR within a real-time loop.

If the command is programmed within the real-time loop, error ID 22073 is output.

Behaviour of contour look-ahead within a real-time loop

In this programming example, the contour look-ahead function is programmed within a real-time loop. The contour of the motion blocks 80 - 120 is logged once.

```
N060 #RT WHILE
N070 #CONTOUR LOOKAHEAD LOG ON [PARAM=1]
N080 G1 X4 Y4
…
N120 G1 X0 Y0
N130 #CONTOUR LOOKAHEAD LOG ON [PARAM=8]
N140 #RT ENDWHILE
```

Behaviour of contour look-ahead outside a real-time loop

In this programming example, the contour look-ahead is programmed outside a real-time loop. The contour of the motion blocks 80 to 120 is logged three times.

```
N060 #CONTOUR LOOKAHEAD LOG ON [PARAM=1]
N070 #RT WHILE
N080 G1 X4 Y4
…
N120 G1 X0 Y0
N130 #RT ENDWHILE
N140 #CONTOUR LOOKAHEAD LOG ON [PARAM=8]
```

4 Parameter

4.1 Overview

ID	start-up parameters	Description
P-STUP-00033	fb_storage_size[i]	Memory size for backward motion

ID	Channel parameters	Description
P-CHAN-00650	function	Activating functions (alternative to P-STUP-00070)
P-CHAN-00658	contour_lookahead_log_max	Maximum number of logged contour elements in the look-ahead area. (alternative P-STUP-00076)

4.2 Description

Start-up parameters

P-STUP-00033	Memory size for backward motion
Description	This parameter defines the memory size in bytes used for backward motion on the path. During start-up, the NC checks whether the required minimum size is available. If this is not the case, a warning is output and the memory size is set to the required minimum value. If the size is set to 0, the “forward/ backward motion on the path” function is not available. The maximum size is only limited by the resources available on the PC.
Parameter	fb_storage_size[i] where i = 0 to 11 (maximum number of channels: 12, application-specific)
Data type	UNS32
Data range	0 ... MAX(UNS32)
Dimension	----
Default value	0
Remarks	

Channel parameters

P-CHAN-00650	Definition of interpolator functionalities
Description	This parameter defines individual functionalities and the size of the look-ahead buffer in the interpolator, i.e. it defines the number of blocks required to calculate deceleration distance and dynamic planning.
Parameter	configuration.interpolator.function
Data type	STRING
Data range	See Description [▶ 23]
Dimension	----
Default value	FCT_IPO_DEFAULT
Remarks	

Interpolation function table

Identifier	Description
FCT_IPO_DEFAULT	FCT_LOOK_AHEAD_STANDARD
FCT_LOOK_AHEAD_LOW	30 blocks
FCT_LOOK_AHEAD_STANDARD	120 blocks
FCT_LOOK_AHEAD_HIGH	190 blocks
FCT_LOOK_AHEAD_CUSTOM	Any number of look-ahead blocks in the interval [0; 200]. Specification by parameter P-CHAN-00653.
FCT_SYNC	Synchronisation of an axis on a path group. Example: FCT_IPO_DEFAULT | FCT_SYNC
FCT_LOOK_AHEAD_OPT	The path velocity curve can be further improved for HSC machining by additional calculations. This generally reduces machining time. The additional calculations place greater demands on the controller hardware.
FCT_LIFT_UP_TIME	Automatic lifting/lowering of an axis (time-based coupling). Example: FCT_IPO_DEFAULT | FCT_LIFT_UP_TIME
FCT_SHIFT_NCBL	Path-controlled offset of M functions (dwell time). Example: FCT_IPO_DEFAULT | FCT_SHIFT_NCBL
FCT_CALC_STATE_AT_T	Calculation of path velocity at a time in the future. Function only available in combination with HSC slope and only as of V3.1.3057.0 Example: FCT_IPO_DEFAULT | FCT_CALC_STATE_AT_T
FCT_CALC_TIME	Calculation of interpolation time to next feed block (G01,G02,G03). Example: FCT_IPO_DEFAULT | FCT_CALC_TIME
FCT_CONTOUR_LAH	Contour look-ahead: advance output of motion blocks to the PLC as of V3.1.3104.07
FCT_DYN_POS_LIMIT	Dynamic limitation of axis positions

The look-ahead buffer size specified above applies as of CNC Build V2.11.2800 and higher. The following values apply as of CNC Build V2.11.20xx:

FCT_LOOK_AHEAD_LOW	30 blocks
FCT_LOOK_AHEAD_STANDARD	70 blocks
FCT_LOOK_AHEAD_HIGH	120 blocks

P-CHAN-00658	Maximum number of logged contour elements in the contour look-ahead.

Description	This parameter can be used to set the maximum number of stored motion blocks that can be supplied to the PLC in advance.
	The CNC command #CONTOUR LOOKAHEAD LOG [] can be used to activate the save function.
	FCT_CONTOUR_LAH must be enabled in P-CHAN-00650 [▶ 22] for this functionality.
	`configuration.interpolator.fct_enable[0]`
	`FCT_IPO_DEFAULT|FCT_CONTOUR_LAH`

Parameter	configuration.interpolator.contour_lookahead_log_max
Data type	UNS32
Data range	0 <= contour_lookahead_log_max < MAX_UNS32
Dimension	----
Default value	128
Remarks	Parameter available as of V3.1.3107.10

4.3 PLC parameters

Currently covered path in the NC program (PCS)	
Description	Reads the current distance covered in the NC program since program start or since the last # DISTANCE PROG START CLEAR NC command. The calculation is based on the current position in the current NC block.
Signal flow	CNC → PLC
ST path	gpCh[*channel_idx*]^.bahn_state.**dist_prog_start**
Data type	UDINT (* LREAL)
Unit	0.1 µm
Access	PLC is reading
Special features	* As of CNC Build V3.1.3104.01 the data element is provided in LREAL forma.

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