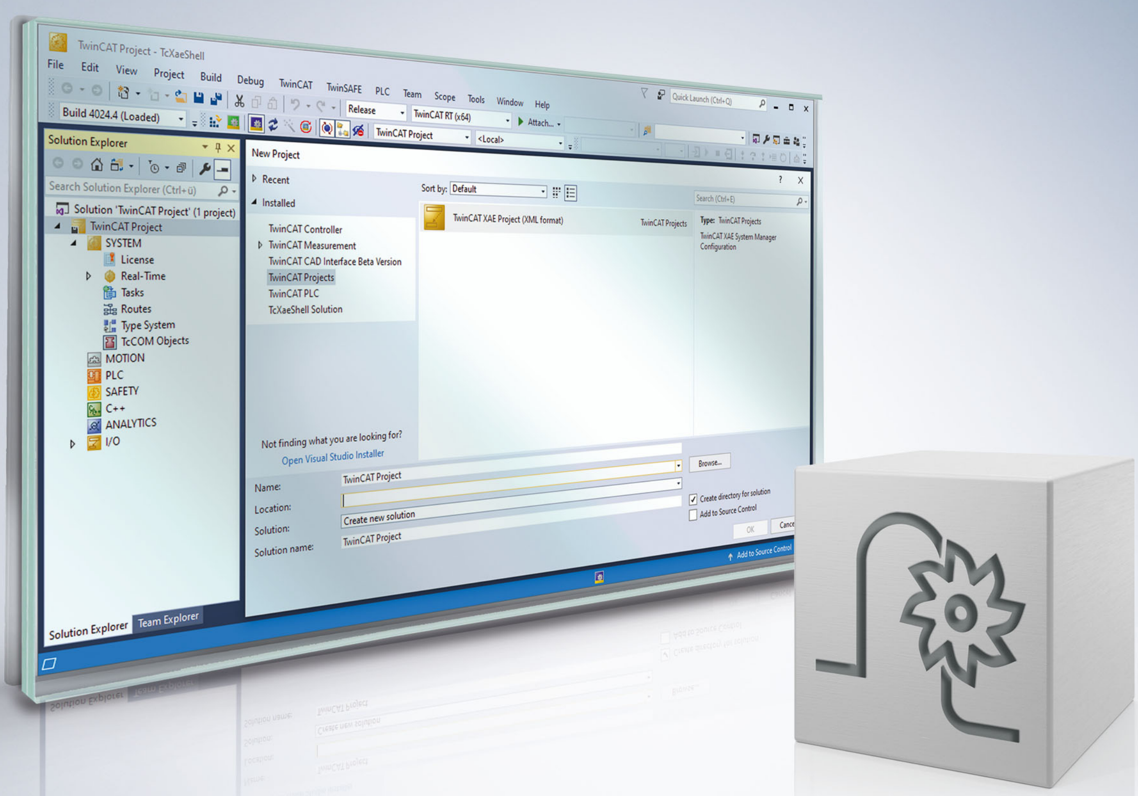
BECKHOFF New Automation Technology

Functional description | EN

TF5200 | TwinCAT 3 CNC

Axis filters



6/6/2025 | Version: 1.05

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.

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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.

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.

Table of contents

List of figures

1 Overview

Task

Filters are used to influence the signal profile.

Depending on the required effect, the filters can be defined as low-pass, high-pass, band-pass or band-stop and all-pass filters. Depending on the filter type, the following is possible:

- Smooth signal curve
- Limit bandwidth
- Suppress noise
- Select frequency bands
- Attenuate frequency bands
- Compensate dead times

The filters are also used to reduce resonance phenomena.

The filters act on the values for the absolute position setpoint that were calculated by path interpolation.

Characteristics

Filters can be classified according to their characteristic transmission behaviour and their purpose. Filter types with different characteristics can be used for control. A distinction is made between standard and HSC filters. Filter prototypes 1-4 are standard filter types and filter prototype 5 describes HSC filters.

The parameter-definable filters are effective with:

- Linear axes
- Rotary axes without modulo calculation, i.e. those that have a limited motion range (see P-AXIS-00015)
- Rotary axes with modulo handling, i.e. rotating endlessly
- Spindles (as of CNC Version V3.00). Only standard filters are available for spindles;HSC filters cannot be used.

Parametrisation and programming

Filter settings are configured and adapted in the axis lists. Standard filters are also activated in the axis lists. HSC filters are only preconfigured in the axis lists; they are activated by an NC command.

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

General

The filter algorithms that are implemented in the controller are characterised by high selectivity with a low order of the filter. For each specific axis, the properties of the filters used can be defined via the axis parameter record.

Filter response is basically determined by:

- Filter prototypes
- Filter type
- Order
- Characteristic frequency.

For certain filter types, the quality P-AXIS-00080 is also a defining attribute.

With a standard filter (exception: HSC filters), up to 3 filters can be defined for each axis and they are then connected in series. In addition, 1 filter for each filter can be parameterised for the additional interface.

2.1 Standard filters

Up to 3 axis filters can be connected in series and parameterised for each axis. A filter is active when the filter[i].enable parameter is set to 1 and the value of the filter[i].order parameter is > 0. In addition, 1 filter for each filter can be parameterised for the additional interface.

The operating principle of standard filters can be controlled by using the following CNC objects in the GEO task:

Name	Index-Group	Index-Offset	Data type	Description
Active position	0x121300 +<ch_id> Example Channel 1: 0x121301	0x61 +0x10000*<ax_idx> Example 1 Axis: 0x10061	SGN32	ACS command position unfiltered [unit 0.1µm or 10^-4°]
Ft_sollwert_gestern	0x121300 +<ch_id> Example Channel 1 0x121301	0x1C +0x10000*<ax_idx> Example 1 Axis 0x1001C	SGN64	ACS command position after filter cascade [unit 0.1µm or 10^-4°]

<ch_id> channel ID, <ax_idx> Axis index in the NC channel

The following standard filters are available:

- **Low-pass filter**
  All frequencies below a certain cut-off frequency are passed through the filter. Higher frequencies above this cut-off frequency are attenuated or are not passed through at all. High frequencies are filtered out.
- **High-pass filters**
  Lower signal frequencies are attenuated or are not passed through at all. Only frequencies above a cut-off frequency are transmitted unchanged.
- **Band-stop filters**
  One frequency range out of the transmit frequency range is filtered out. All other frequencies are transmitted almost without attenuation. The characteristic frequency is called the centre frequency.
- **Band-pass filters**
  All frequencies except for the chosen frequency band are filtered out. All other frequencies are attenuated.
- **All-pass filters**
  These filters have constant gain but generate a frequency-dependent phase shift. They are used for phase correction and to delay signals.
- **PT1 filters**
  A PT1 filter is a first-order delay element that has a transmission response similar to that of a first-order low-pass filter. The filter transmits frequencies under the cut-off frequency fg = 1 / (2 * Pi * filter[i].time_constant). Frequencies > the cut-off frequency are attenuated at –20 dB/decade.
- **PT2 filters**
  A PT2 filter is a 2nd order delay element whose transmit function $G(s)=1/(1+Ts)^2$ corresponds to two first order delay elements switched in series. The transmission response is similar to a second-order low-pass filter. Frequencies up to a cut-off frequency of fg = 1 / (2 * Pi * filter[i].time_constant) are transmitted by the filter but higher frequencies are attenuated at –40dB/decade.
- **Time delay filters** (as of CNC Build 2013, 2803 or 3013)
  A time delay filter can delay the signal time signature. This does not change the signal profile.

2.1.1 Low-pass filters

Frequency response

The diagram below shows the frequency transmission response of low-pass filters that are each based on one of the filter prototypes. To elucidate the characteristic transmission response, filters of the 4th order were chosen because the characteristics are more distinct due to the higher order.

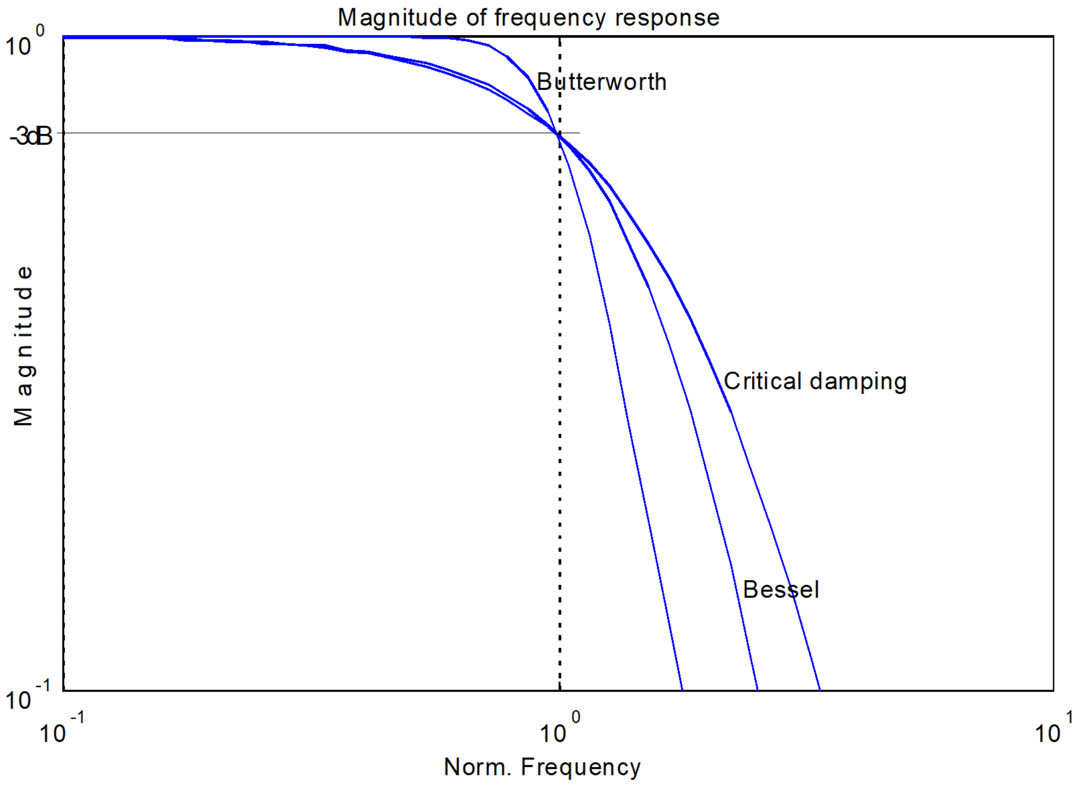


Fig. 1: Amplitude frequency response of filter prototypes (4th order)

In the range below the cut-off frequency, low-pass filters of the "critical attenuation" and "Bessel" prototypes have very similar responses. In this range, Butterworth filters transmit almost without attenuation over a wide range. Attenuation of the transmitted frequencies only sets in just before the cut-off frequency. Of the filters presented here, the Butterworth filter has the highest attenuation in the range above the cut-off frequency.

Step response

The step response of a low-pass filter with "critical attenuation" does not display any overshoot. This is why this filter is highly suitable for control applications despite its lower frequency selection response compared to other filters.

A slight overshoot with filter orders > 1 can be observed in the case of Bessel low-pass filters. This is why this filter should not be applied to position values.

In the case of Butterworth low-pass filters considerable overshoot is exhibited in response to an abrupt change at the input. The overshoot increases with the filter's order. Due to this keen reaction, the Butterworth low-pass filter is unsuitable for control applications.

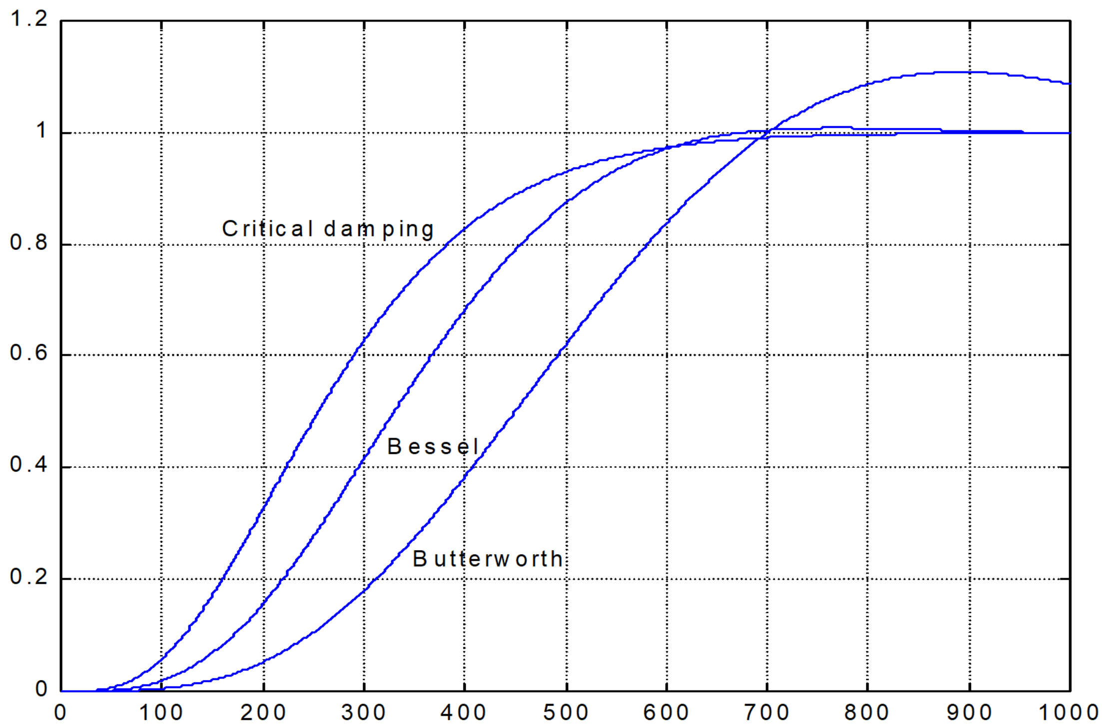


Fig. 2: Step response of filter prototypes (4th order)

Axis filters 4th order low-pass filters with a cut-off frequency of 15 Hz:

filter[0].enable	1
filter[0].order	4
filter[0].prototype	CRIT_DAMPING
filter[0].type	LOWPASS
filter[0].fg_f0	15
filter[0].share_percent	100

Additional interface: 3rd order low-pass filters with a cut-off frequency of 8 Hz:

lr_param.add_interface.enable	1
lr_param.add_interface.filter[0].enable	1
lr_param.add_interface.filter[0].order	3
lr_param.add_interface.filter[0].prototype	BUTTERWORTH
lr_param.add_interface.filter[0].type	LOWPASS
lr_param.add_interface.filter[0].fg_f0	8
lr_param.add_interface.filter[0].share_percent	100

2.1.2 High-pass filters

Frequency response

The frequency response of high-pass filters results from mirroring the frequency response of the corresponding low-pass filter at the cut-off frequency line.

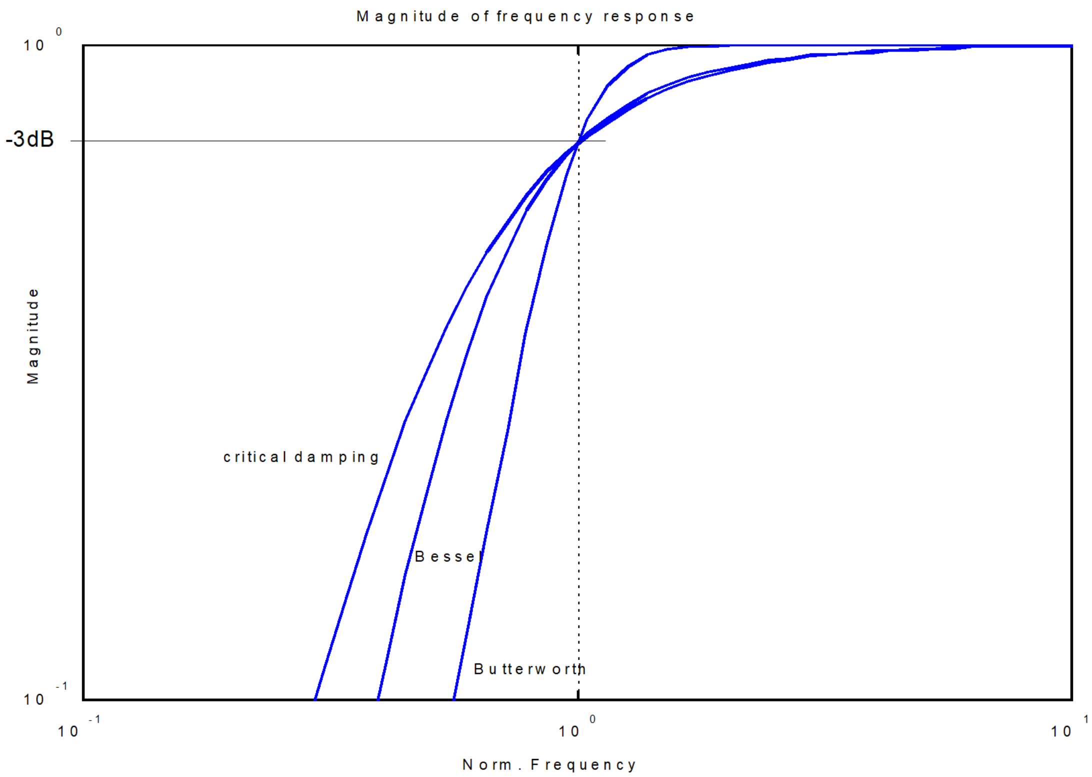


Fig. 3: Amplitude frequency response of high-pass filters (4th order)

Step response

Contrary to low-pass filters, the filter output values of the step response in the case of high-pass filters fluctuate about the stationary value.

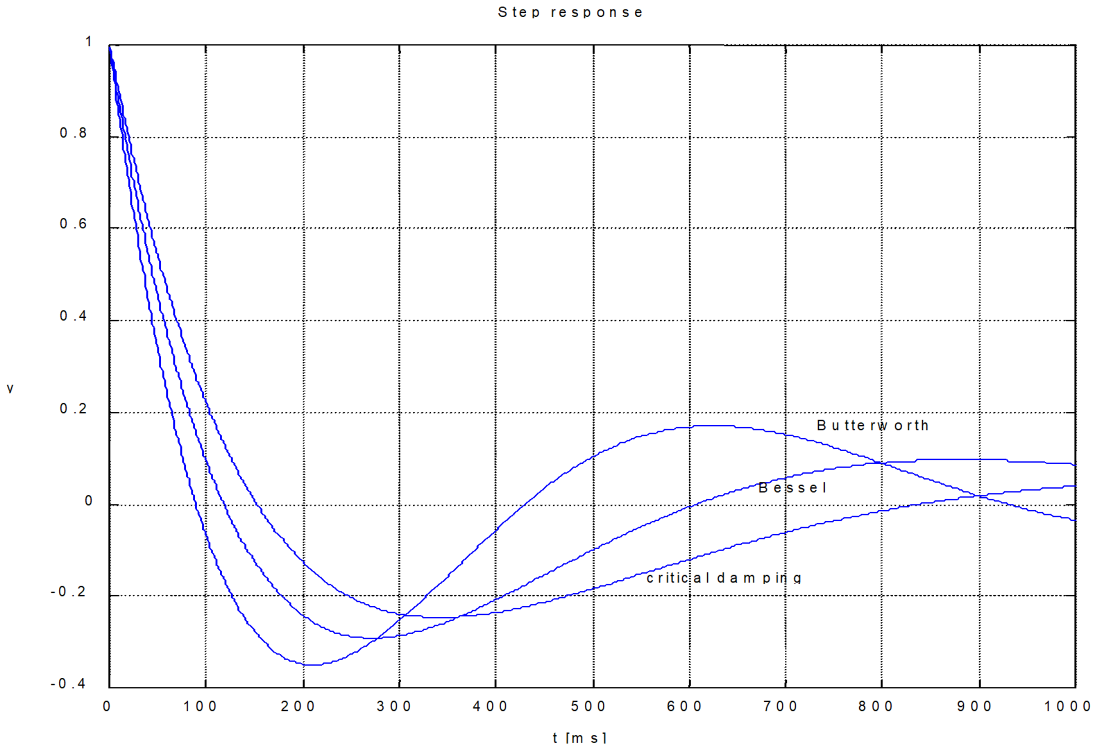


Fig. 4: Step response of high-pass filters (4th order)

2.1.3 Band-pass filters

Frequency response

Bandwidth $\Delta\Omega = f_0 - f_u$ within the pass-band of the band-pass filter is defined by the cut-off frequencies f_0 and f_u. They are defined as frequencies where the amplitude has exceeded –3dB (~0.707). When a band-pass filter is configured, the bandwidth is defined by specifying the quality factor (filter[i].guete [▶ 33]). The quality factor is the ratio of the characteristic filter frequency to bandwidth ΔΩ:

$$P - AXIS - 00080 = \frac{P - AXIS - 00064}{f_0 - f_u}$$

For this reason, the frequency range f_0-f_u reduces as the quality rises. The following relationship exists between the characteristic frequency of the band-pass filter and the cut-off frequencies f_0 and f_u (geometric mean):

$$P - AXIS - 00064 = \sqrt{f_0 * f_u}$$

With band-pass filters, the filter prototype has only a minor influence on filter response.

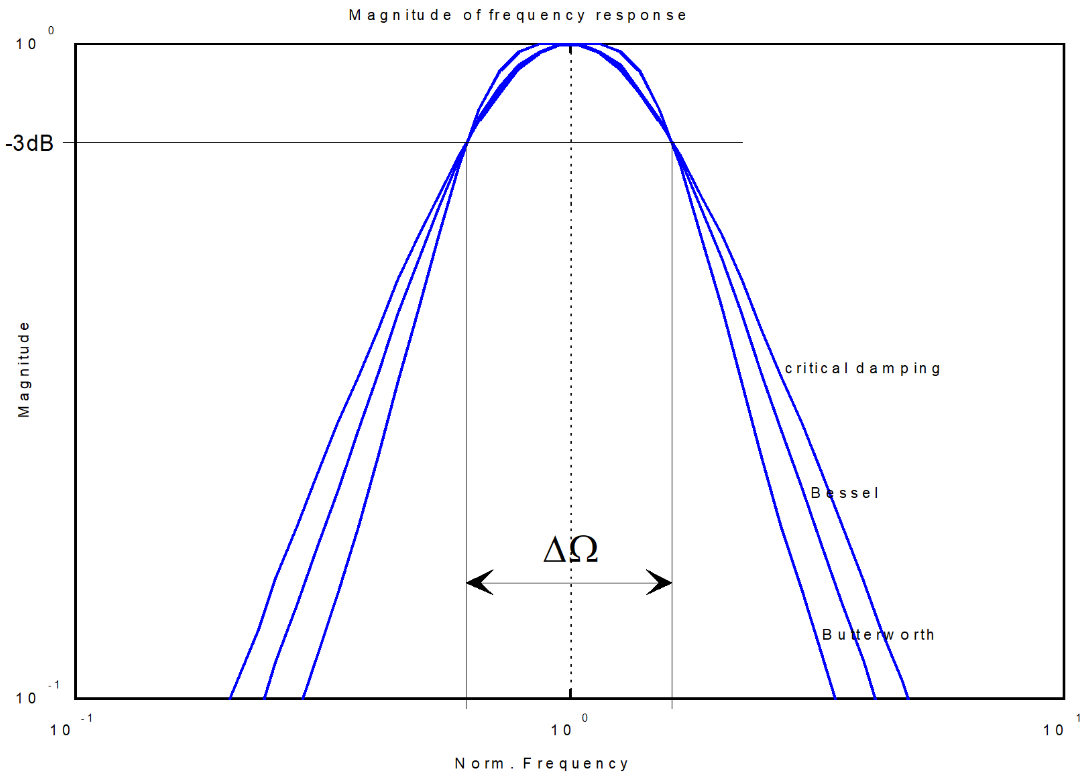


Fig. 5: Amplitude frequency response of band-pass filters (4th order, quality = 1)

2.1.4 Band-stop filters

Frequency response

Bandwidth $\Delta\Omega = f_0 - f_u$ within the stop band of the band-stop filter is defined by the cut-off frequencies f_0 and f_u. They are defined as frequencies where the amplitude drops by -3dB (~0.707). When a band-stop filter is configured, the bandwidth is determined by specifying the quality factor (filter[i].guete [▶ 33]) . The quality factor is the ratio of the characteristic filter frequency to bandwidth ΔΩ:

$$P - AXIS - 00080 = \frac{P - AXIS - 00064}{f_0 - f_u}$$

For this reason, the frequency range f_0-f_u reduces as the quality rises. The following relationship exists between the characteristic frequency of the band-stop filter and the cut-off frequencies f_0 and f_u (geometric mean):

$$P - AXIS - 00064 = \sqrt{f_0 * f_u}$$

With band-stop filters, the filter prototype has only a slight influence on filter response.

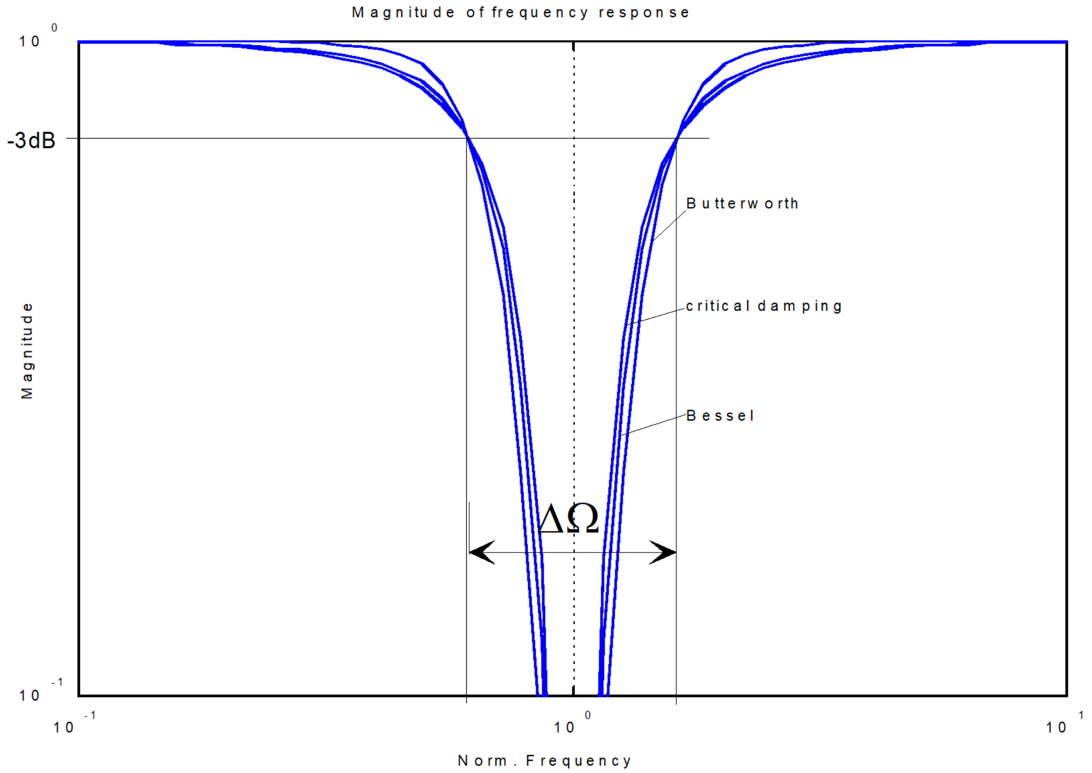


Fig. 6: Amplitude frequency response of band-stop filters (4th order, quality = 1)

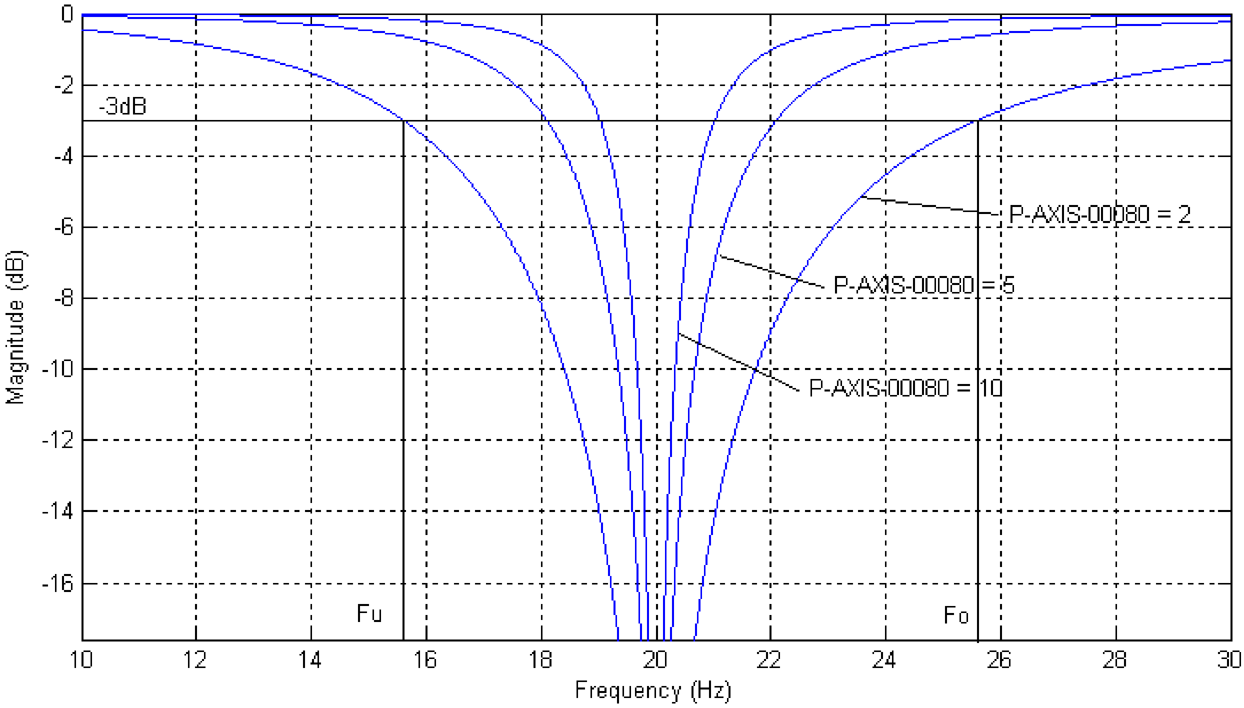


Fig. 7: Amplitude response of band-stop filters

The figure shows the amplitude response of band-stop filters depending on the specified quality factor (2nd order, characteristic frequency fg_f0 = 20 Hz)

Response

In general notch filters tend to oscillate due to the strong weakening of the characteristic frequency. This also leads to axis overshoots at block transitions.

The higher the filter order or the smaller the cut-off frequency fg_f0, the greater the overshoot may be. However, in general this error is much smaller than the contour error that may occur by exciting a resonance frequency. This must be verified for a particular application. Otherwise the use of a band-stop filter makes no sense.

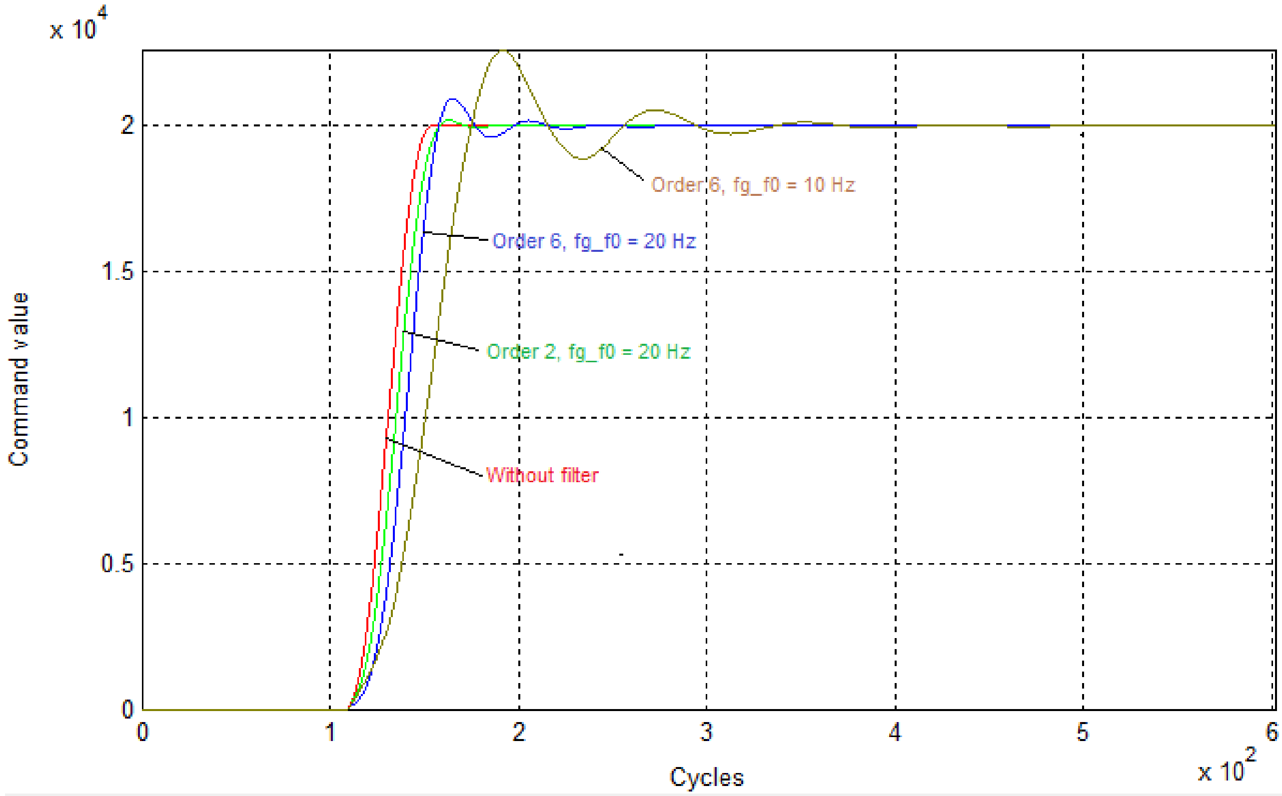


Fig. 8: Oscillation response of band-stop filters

The figure shows the oscillation response of band-stop filters depending on the order and characteristic frequency.

Dynamic monitors may react in the CNC due to an overshoot of the band-stop filters. In this case either the axis dynamics must be reduced or a (slightly!) higher excess in command velocity must be permitted (see P-AXIS-00440).

Axis filters: 2nd order band-stop, with characteristic frequency 20 Hz and quality 4:

filter[0].enable	1
filter[0].order	2
filter[0].prototype	BUTTERWORTH
filter[0].type	BANDSTOP
filter[0].fg_f0	20
filter[0].guete	4
filter[0].share_percent	100

Additional interface: 3rd order band-stop, with characteristic frequency 17Hz and quality 1.8

Lr_param.add_interface.enable	1
lr_param.add_interface.filter[0].enable	1
lr_param.add_interface.filter[0].order	3
lr_param.add_interface.filter[0].prototype	BUTTERWORTH
lr_param.add_interface.filter[0].type	BANDSTOP
lr_param.add_interface.filter[0].fg_f0	17
lr_param.add_interface.filter[0].guete	1.8
lr_param.add_interface.filter[0].share_percent	100

2.1.5 All-pass filters

All-pass filters transmit all frequencies at a gain factor of 1. All-pass filters only change the phase of the sinusoidal input signals. They are used for phase correction and to delay signals.

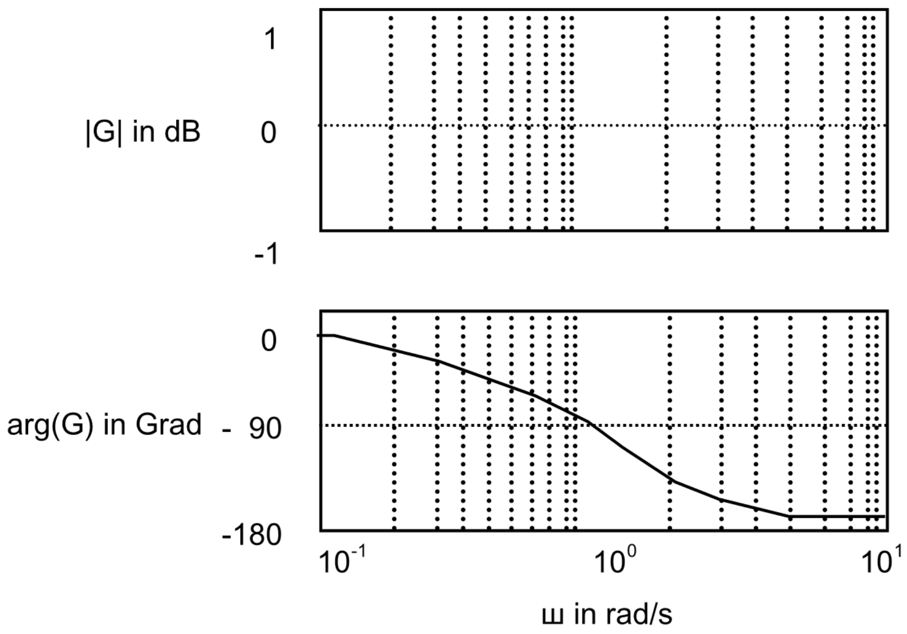


Fig. 9: Bode diagram of an all-pass filter

When the parameters of an all-pass filter are defined, the Bessel filter prototype should be parameterised because it approximates a constant group run time for all frequencies.

The group run time is the time that a "group" of cos-shaped oscillations takes when passing through a transmission system.

2.1.6 PT1-filter

Frequency response

The PT1 filter has the transmission response of a first order delay element. Contrary to the other axis filters, it is parameterised by specifying a time constant (filter[i].time_constant). No filter prototype needs to be specified for this filter type. To activate the filter, an order > 1 (filter[i].order) must be set.

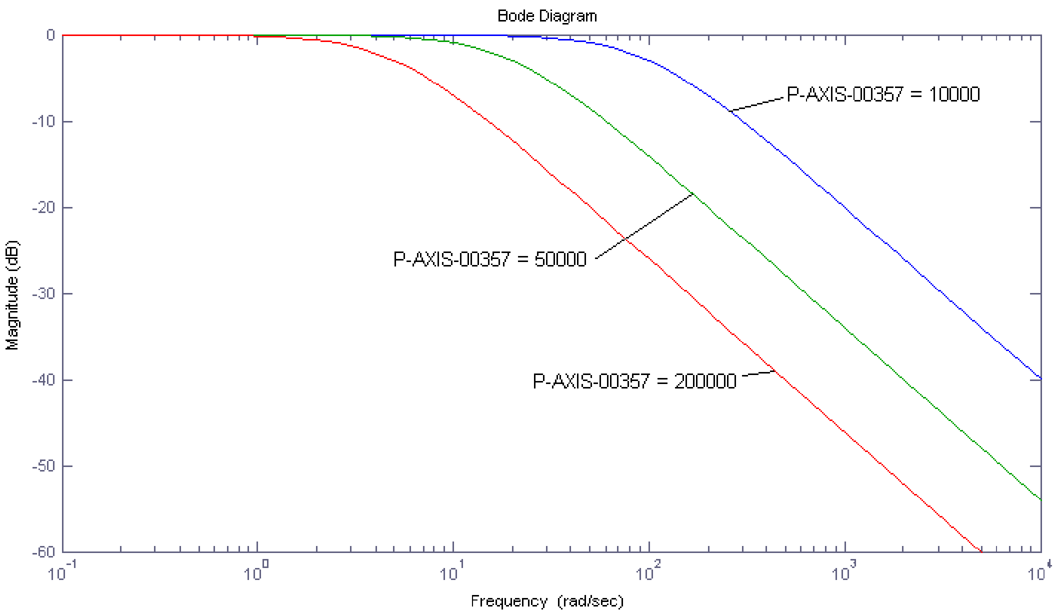


Fig. 10: Time constant of the PT1 filter

The figure shows the amplitude response of the PT2 filter depending on the filter[i].time_constant.

Axis filters: PT1 filter with time constant of 0.01 seconds:

filter[0].enable	1
filter[0].order	1
filter[0].type	PT1
filter[0].time_constant	10000
filter[0].share_percent	100

Additional interface: PT1 filter with time constant of 0.01 seconds

Lr_param.add_interface.enable	1
lr_param.add_interface.filter[0].enable	1
lr_param.add_interface.filter[0].order	1
lr_param.add_interface.filter[0].type	PT1
lr_param.add_interface.filter[0].time_constant	10000
lr_param.add_interface.filter[0].share_percent	100

2.1.7 PT2-filter

Frequency response

The PT2 filter has the transmission response of a second order delay element. Contrary to the other axis filters, it is parameterised by specifying a time constant (filter[i].time_constant). No filter prototype needs to be specified for this filter type. To activate the filter, an order > 1 (filter[i].order) must be set.

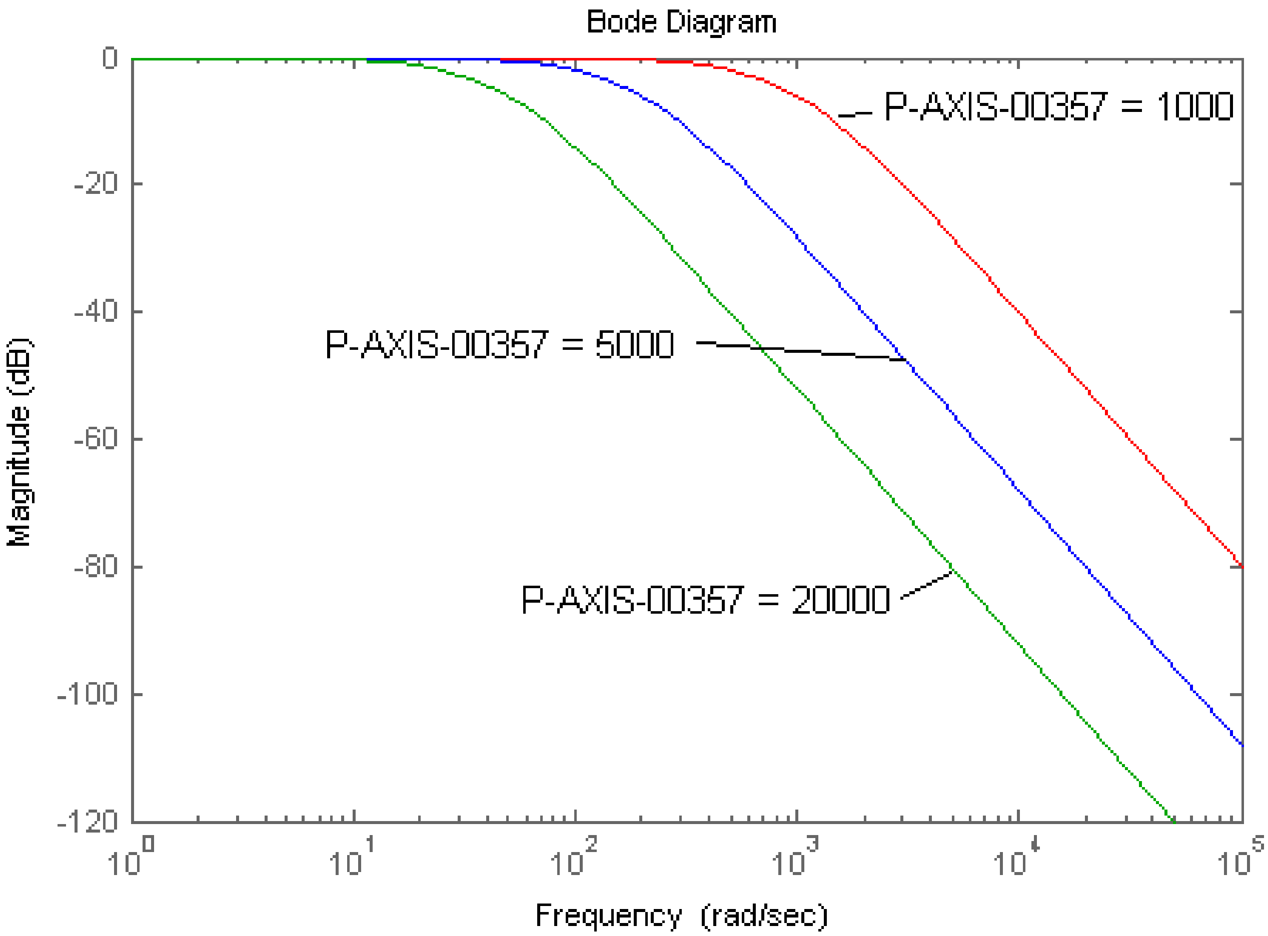


Fig. 11: Time constant of the PT2 filter

The figure shows the amplitude response of the PT2 filter depending on the filter[i].time_constant.

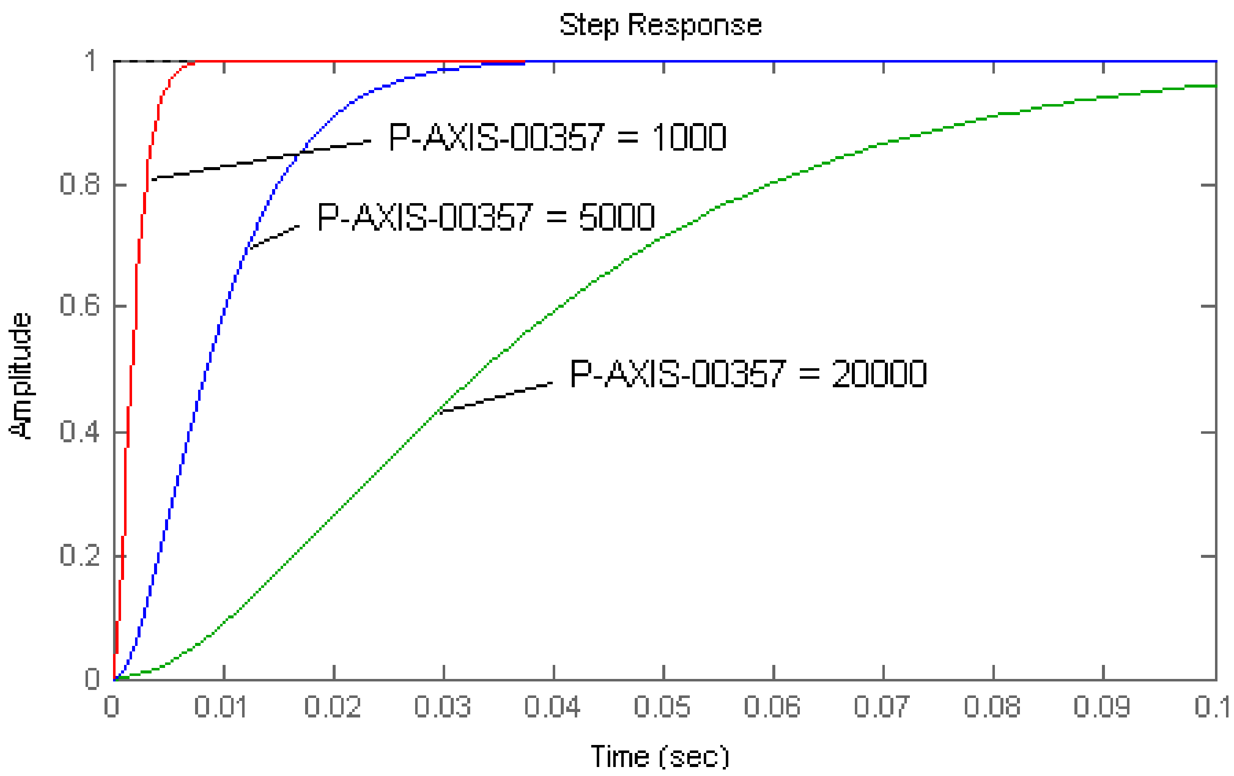


Fig. 12: Step response of the PT2 filter

The figure shows the step response of the PT2 filter depending on the filter[i].time_constant.

Axis filters: PT2 filter with time constant of 0.005 seconds:

filter[0].enable	1
filter[0].order	2
filter[0].type	PT2
filter[0].time_constant	5000
filter[0].share_percent	100

Additional interface: PT2 filter with time constant of 0.005 seconds

lr_param.add_interface.enable	1
lr_param.add_interface.filter[0].enable	1
lr_param.add_interface.filter[0].order	2
lr_param.add_interface.filter[0].type	PT2
lr_param.add_interface.filter[0].time_constant	5000
lr_param.add_interface.filter[0].share_percent	100

2.1.8 Time delay filter

The time delay filter is available in each of the CNC Builds as of V2.11.2013, V2.11.2803 and V3.00.3013.

Response

A signal can be delayed by the time delay filter. The amplitude response of this filter is constant 1, i.e. the signal profile does not change One application, for example, is to compensate for dead times in the drive train, if this is not identical in all axes. The filter delay time must be within the interval 0 ≤ delay time (filter[i].time_constant) < 6 * cycle time of the NC controller.

The filter is parameterised by defined the required filter time constant (filter[i].time_constant). It is not necessary to specify a filter prototype of a cut-off frequency for the time delay filter. To activate the filter, a filter order must also be specified > 0 (filter[i].order). However, the order is recalculated in the CNC when the filter coefficients are generated depending on the delay time settings.

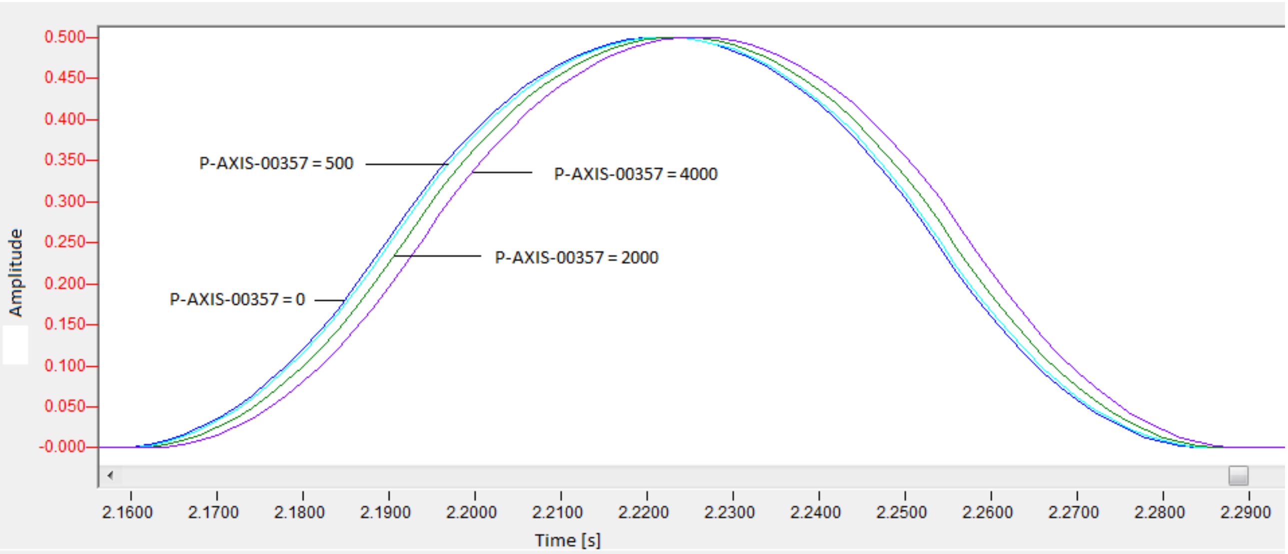


Fig. 13: Signal profiles of the time delay filter

The figure shows the signal profiles of the time delay filter with different time constants (filter[i].time_constant).

Axis filters: Time delay filter with time constant of 0.002 seconds:

filter[0].enable	1
filter[0].order	1
filter[0].type	TIME_DELAY
filter[0].time_constant	2000
filter[0].share_percent	100

Additional interface: Time delay filter with time constant of 0.002 seconds

lr_param.add_interface.enable	1
lr_param.add_interface.filter[0].enable	1
lr_param.add_interface.filter[0].order	1
lr_param.add_interface.filter[0].type	TIME_DELAY
lr_param.add_interface.filter[0].time_constant	2000
lr_param.add_interface.filter[0].share_percent	100

2.2 HSC filters

As of CNC Build V3.1.3075.02 it is advisable to use FIR filters in FCT-C37. They replace the HSC filters described here and have a larger scope of functions.

With these filters, only one HSC filter per axis is allowed and it must imperatively be the first filter (filter[0]). In the axis lists, HSC filters are only preconfigured but do not take effect until activated by the NC command #FILTER ON[HSC] in the NC program. In the pre-configuration, make sure that all axes in an axis group are configured identically. Otherwise axis behaviour may become asynchronous. In addition, it is possible to deactivate HSC filters during machining or to redefine their parameters.

The following filter types may only be used in conjunction with the prototype HSC.

- **HSC-average**
  The HSC average filter is an acausal time range average filter. It acts within the frequency band as a low-pass filter.
- **HSC-NoVib**
  The HSC NoVib is an acausal FIR filter. The internal filter core, which depends on its natural frequency among other things, suppresses oscillations.

Step response

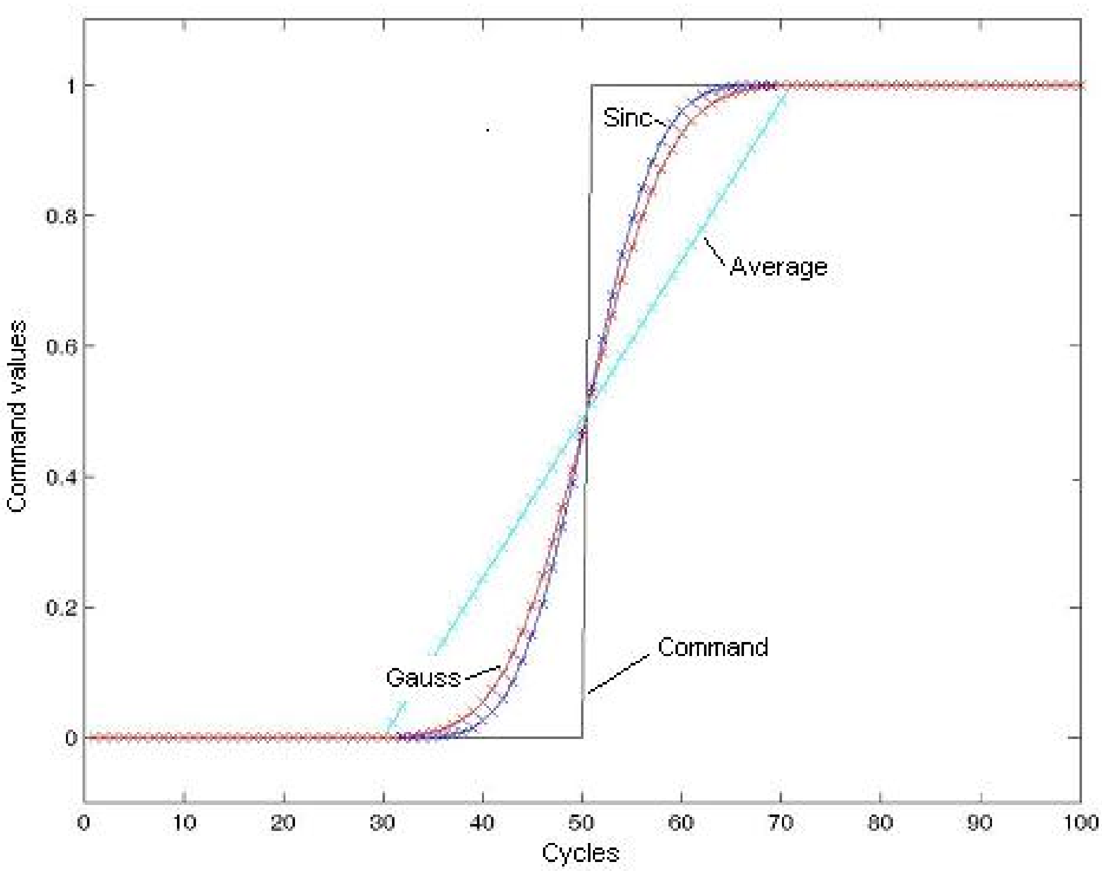


Fig. 14: Step response of the HSC filter

Contour deviation adjustment aid

The contour deviation when using HSC axis filters is composed of three components.

1. Cycle time
2. Filter order
3. Feed rate run

The following simple relationships apply:

- Double cycle time = double error
- Double feed rate = double error
- Double filter order = double errorThe graphic below represents a cycle time of 1 ms and a feed rate of F1000 at a 90° corner. With different marginal data, the filter orders must be uprated according to the ratios above.

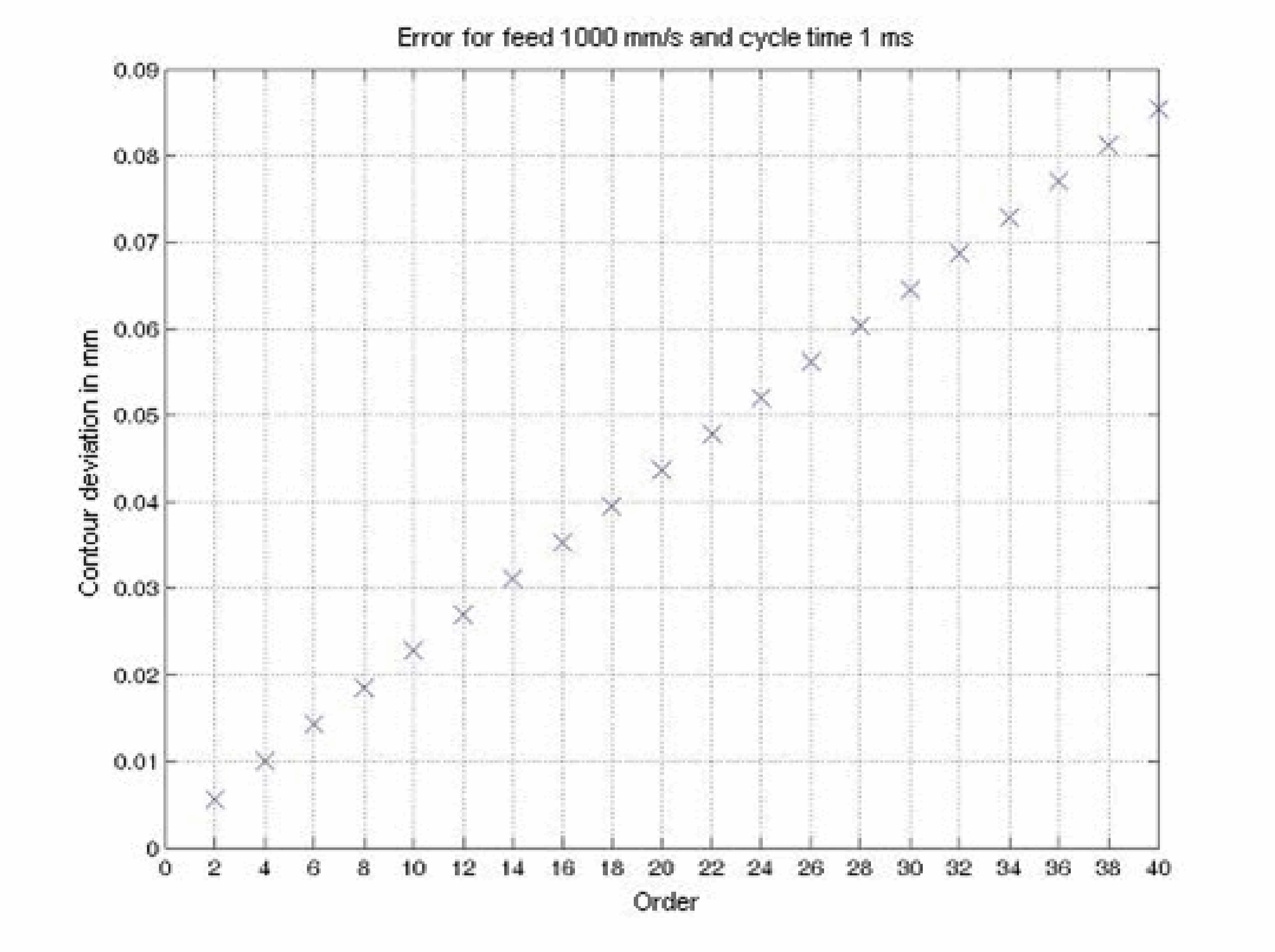


Fig. 15: Contour error per filter order at a 90° corner

The figure above assumes a corner velocity of 1000mm/s and a cycle time of 1ms.

2.3 Filter prototypes

Four different filter prototypes can be set. They are essentially distinguished by their response for transmitting frequencies and their response to step excitation (filter step response).

These are:

- Filter with critical attenuation
- Bessel filter
- Butterworth filter
- HSC

3 Parameter

3.1 Overview

The following parameters are available to adjust filters in the axis parameter record:

ID	Parameter	Description
P-AXIS-00319	enable	Activates standard filter
P-AXIS-00067	fg_f0	Characteristic frequency of a filter
P-AXIS-00080 **P-AXIS-00740***	guete	Quality of the filter
P-AXIS-00140	order	Order of the filter
P-AXIS-00153	prototype	Filter characteristic
P-AXIS-00164 **P-AXIS-00741***	share_percent	Signal component that is routed through the filter
P-AXIS-00204	type	Type of the filter
P-AXIS-00357	time_constant	- Use with standard filters: Time constant of the PT1, PT2 and time delay filters. - Use with HSC filters: Filter order in µs [alternative to P-AXIS-00140 [▶ 34])
P-AXIS-00735	enable	Enables standard filter of the additional interface
P-AXIS-00739	fg_f0	Characteristic frequency of an additional interface filter
P-AXIS-00740	guete	Quality of the additional interface filter
P-AXIS-00736	order	Order of the additional interface filter
P-AXIS-00737	prototype	Filter characteristic of the additional interface
P-AXIS-00741	share_percent	Signal component that is routed through the filter
P-AXIS-00738	type	Type of the additional interface filter
P-AXIS-00742	time_constant	- Use with standard filters of the additional interface Time constant of the PT1, PT2 and time delay filters. - Use with HSC filters: Filter order in µs [alternative to P-AXIS-00140)

Parameter	Standard filters	HSC filters
enable	X	- (**)
fg_f0	X (*)	X (*)
guete	X (*)	-
order	X	X
prototype	X	X
share_percent	X	X
type	X	X
time_constant	X (*)	X

(*) Depending on the filter type

(**) Activated via NC command

The relevant filter parameters for each filter type are:

Filter type	Order	Character Frequency	Prototype	Time constant	Quality	Signal com-ponent
Low-pass	X	X	X			X
High-pass	X	X	X			X
Band-stop	X	X	X		X	X
Band-pass	X	X	X		X	X
All-pass	X	X	X			X
PT1	(X)			X		X
PT2	(X)			X		X
Delay	(X)			X		X
HSC mean*	X		X	X		X
HSC NoVib*	(X)	X	X	(X)		X

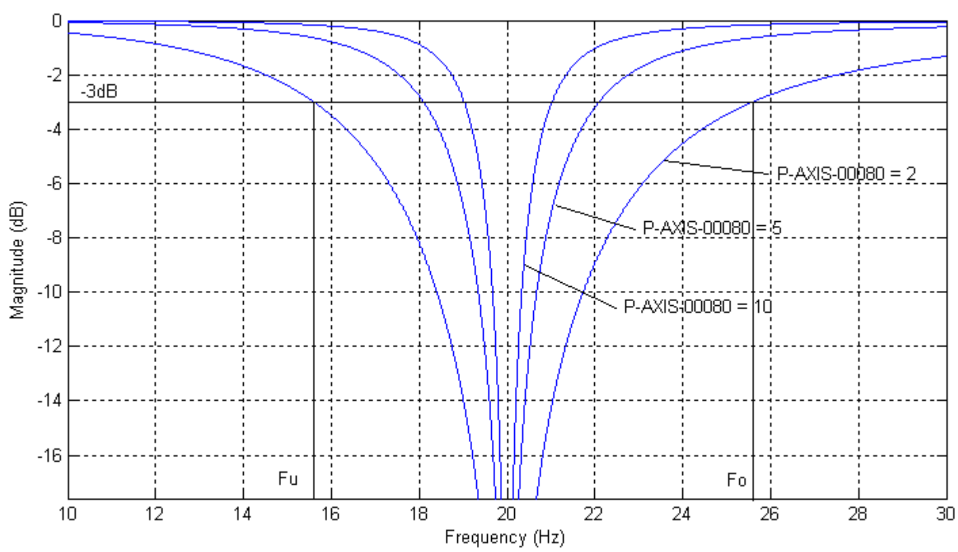
(X) only to active the filter; order is calculated internally

* Can only be used as axis filter

3.2 Axis filter parameter

P-AXIS-00319	Activate the axis-specific command value filter (for standard filters)	
Description	This parameter controls the general enabling/disabling of the filter function.	
Parameter	filter[i].enable	
Data type	BOOLEAN	
Data range	0: Filter is disabled 1: Filter is enabled	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Drive types	----	
Remarks	The filter function is only activated for filter order > 0 (P-AXIS-00140).	

P-AXIS-00067	Characteristic frequency of the axis-specific command value filter	
Description	- The frequency range parameter defines the following standard filters: • Low-pass: Beginning of cut-off frequency range (ideal filter) • High-pass : Beginning of pass-band frequency range (ideal filter) • Band-pass and band-stop filters : Middle frequency - This parameter defines the first natural frequency to be suppressed for the HSC NoVib	
Parameter	filter[i].fg_f0	
Data type	REAL64	
Data range	0 ≤ fg_f0 < 0.5/T_{fall} (where T_{fall} is the NC cycle time)	
Axis types	T, R, S	
Dimension	T: Hz	R,S: Hz
Default value	3.000000e+001	
Drive types	----	
Remarks		

P-AXIS-00080	Bandwidth of axis specific command value filter
Description	Definition of reciprocal of bandwidth for band-pass and band-stop filter types. The figure below illustrates the parameter behaviour. 
Parameter	filter[i].guete

Data type	REAL64	
Data range	1 ≤ guete ≤ 10	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1.0	
Drive types	----	
Remarks		

P-AXIS-00140	**Order of axis specific command value filter**	
Description	This parameter defines the filter order. In addition, this parameter is a value which expresses the fall of frequency response (fall = - order x 20 dB/ decade). The value **order = 0** means: no filter is active. With HSC NoVib or time delay filters, the order is calculated internally but an order > 0 is required, otherwise the filter is not active.	
Parameter	filter[i].order	
Data type	UNS32	
Data range	0 ≤ order ≤ 6 for low-pass, high-pass and all-pass filters 0 ≤ order ≤ 3 for band-pass and band-stop filters order = 0 or 1 for PT1 filters order = 0 or 2 for PT2 filters order = 0 or > 0 for time delay filters 0 ≤ order ≤ 200 for HSC filters	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	0	
Drive types	----	
Remarks		

P-AXIS-00153	**Characteristic of axis-specific command value filter**	
Description	The parameter defines the filter characteristic.	
Parameter	filter[i].prototype	
Data type	STRING	
Data range	CRIT_DAMPING 1: 'Critical damping' filter characteristic: BUTTERWORTH 2: Butterworth filter characteristic BESSEL 3: Bessel filter characteristic HSC - 5: Filter characteristic 'HSC'	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	CRIT_DAMPING	
Drive types	----	
Remarks		

P-AXIS-00164	**Signal share of axis specific command value filter**	
Description	The parameter defines the signal share in percent which is processed by the filter.	
Parameter	filter[i].share_percent	
Data type	REAL64	
Data range	0 ≤ share_percent ≤ 100	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----

Default value	1.000000e+002
Drive types	----
Remarks	

P-AXIS-00204	Type of axis-specific command value filter	
Description	The parameter defines the filter type.	
Parameter	filter[i].type	
Data type	UNS32	
Data range	1 ≤ type ≤ 12 where:	
	1	Low-pass filter
	2	High-pass filter
	3	Band-pass filter
	4	Band-stop filter
	5	All-pass filter
	6	PT1 filter
	7	reserved
	8	HSC average
	9	reserved
	10	PT2 filter
	11	Time delay filter (as of CNC Build 3013 and higher)
	12	HSC NoVib
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1 for standard filters (filter[i].prototype 1-4) 8 for HSC filters (filter[i].prototype 5)	
Drive types	----	
Remarks		

P-AXIS-00357	Time constant of axis specific command value filter	
Description	- Application for standard filters: The parameter defines the time constants of the PT1, PT2 and time delay filters. - Application with HSC filters: Filter order in µs [alternative to parameter P-AXIS-00140 [▶ 34] The value time_constant is only used if P-AXIS-00140 [▶ 34] is not configured or has the value 0. If time_constant < NC cycle time, the filter is not active unless the parameter order P-AXIS-00140 [▶ 34] has a valid value which is then used in this case. With HSC NoVib, the order is calculated internally but an order > 0 is required, otherwise the filter is not active.	
Parameter	filter[i].time_constant	
Data type	UNS32	
Data range	- Standard filters: For PT1 / PT2 filters: TAb ≤ P-AXIS-00357 ≤ MAX(UNS32) For time delay filters: 0 ≤ P-AXIS-00357 < 6 * TAb (where TAb is NC cycle time in s) - HSC filters: TAb < P-AXIS-00357 < 200 * TAb (where TAb is NC cycle time in µs)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs

Default value	10000
Drive types	----
Remarks	

3.3 Additional interface parameters

P-AXIS-00735	**Enable the additional interface filter**	
Description	This parameter controls the general enabling/disabling of the filter function.	
Parameter	lr_param.add_interface.filter[i].enable	
Data type	BOOLEAN	
Data range	0: Filter is disabled 1: Filter is enabled	
Axis types	T, R, S	
Dimension	T:----	R,S: ----
Default value	0	
Drive types	----	
Remarks	The filter function is only enabled for filter order > 0 (filter[i].order).	

P-AXIS-00739	**Frequency range of the additional interface filter**	
Description	The parameter defines the frequency range for: • Low-pass: Beginning of cut-off frequency range (ideal filter) • High-pass: Beginning of cut-off frequency range (ideal filter) • Band-pass and band-stop filters: middle frequency	
Parameter	lr_param.add_interface.filter[i].fg_f0	
Data type	REAL64	
Data range	0 < FG_F= > 0.5/T_{fall} (where T_{fall} is the NC cycle time)	
Axis types	T, R, S	
Dimension	T: Hz	R,S: Hz
Default value	30	
Drive types	----	
Remarks		

P-AXIS-00740	**Bandwidth of the additional interface filter**	
Description	Definition of reciprocal of bandwidth for band-pass and band-stop filter types. The behaviour is similar to parameter P-AXIS-00080.	
Parameter	lr_param.add_interface.filter[i].guete	
Data type	REAL64	
Data range	1 < guete < 10	
Axis types	T, R, S	
Dimension	T: ----	R,S: ----
Default value	1.0	
Drive types	----	
Remarks		

P-AXIS-00736	**Order of the additional interface filter**
Description	This parameter defines the filter order. In addition, this parameter is a value which expresses the fall of frequency response (fall = -order x 20 dB/decade). The value order = 0 means: no filter connected.
Parameter	lr_param.add_interface.filter[i].order
Data type	UNS32

Data range	0 < order < 6 for low-pass, high-pass and all-pass filters 0 < order < 3 for band-pass and band-stop filters order = 0 or <= 1 for PT1 filters order = 0 or <= 1 for PT2 filters	
Axis types	T, R, S	
Dimension	T:----	R,S: ----
Default value	2	
Drive types	----	
Remarks	An order of < 1 need only be specified for filters types PT1, PT2 and TIME_DELAY to activate the filter. The corresponding order is calculated internally.	

P-AXIS-00737	**Characteristic of the additional interface filter**	
Description	This parameter defines the filter characteristic.	
Parameter	lr_param.add_interface.filter[i].prototype	
Data type	STRING	
Data range	CRIT_DAMPING: ‘Critical damping’ filter characteristic BUTTERWORTH: ‘Butterworth’ filter characteristic BESSEL: ‘Bessel’ filter characteristic	
Axis types	T	
Dimension	T:----	
Default value	CRIT_DAMPING	
Drive types	----	
Remarks		

P-AXIS-00741	**Signal share of the additional interface filter**	
Description	The parameter defines the signal share in percent which is processed by the filter.	
Parameter	lr_param.add_interface.filter[i].share_percent	
Data type	REAL64	
Data range	0 < share_percent < 100	
Axis types	T	
Dimension	T:----	R, S: ----
Default value	1.000000e+002	
Drive types	----	
Remarks		

P-AXIS-00738	**Type of the additional interface filter**
Description	This parameter defines the filter type.
Parameter	lr_param.add_interface.filter[i].type
Data type	STRING

Data range	LOWPASS	Low-pass filter	
	HIGHPASS	High-pass filter	
	BANDPASS	Band-pass filter	
	BANDSTOP	Band-stop filter	
	ALLPASS	All-pass filter	
	PT1	PT1 filter	
	HSC_SINE	HSC Sine	
	HSC_MEAN	HSC mean	
	HSC_GAUSS	HSC Gauss	
	PT2	PT2 filter	
	TIME_DELAY	Time delay filter (as of CNC Build 3013 and higher)	
Axis types	T, R, S		
Dimension	T:----		R,S: ----
Default value	PT2		
Drive types	----		
Remarks			

P-AXIS-00742	**Time constant of the additional interface filter**	
Description	The parameter defines the time constants of the PT1, PT2 and time delay filters.	
Parameter	lr_param.add_interface.filter[i].time_constant	
Data type	UNS32	
Data range	For PT1 / PT2 filters: TAb ≤ filter[i].time_constant ≤ MAX(UNS32) (with TAb ->NC cycle time) For time-delay filter: 0 ≤ filter[i].time_constant < 6 * TAb (Where TAb ->NC cycle time)	
Axis types	T, R, S	
Dimension	T: µs	R,S: µs
Default value	0	
Drive types	----	
Remarks		

4 Application

Smoothing signals with low-pass filters

The ability of low-pass filters to attenuate high frequencies is used to smooth signal profiles. The diagram below shows the step response of low-pass filters of different orders but with the same cut-off frequency of 1 Hz.

It is found that the maximum slope of the step response is almost independent of the filter order. As a result, it can be estimated from the slope at the start of the step response of a first-order filter. This requires only a simple calculation.

For a step Δ x at the input of a low-pass filter at cut-off frequency f_g the following equation is obtained for the maximum slope of the output signal:

$$\left.\frac{dy}{dt}\right|_{max} \cong \Delta x 2\pi f_g$$

This equation is important because it reflects the relationship between the bandwidth of the signal and the maximum slope of the filtered signal.

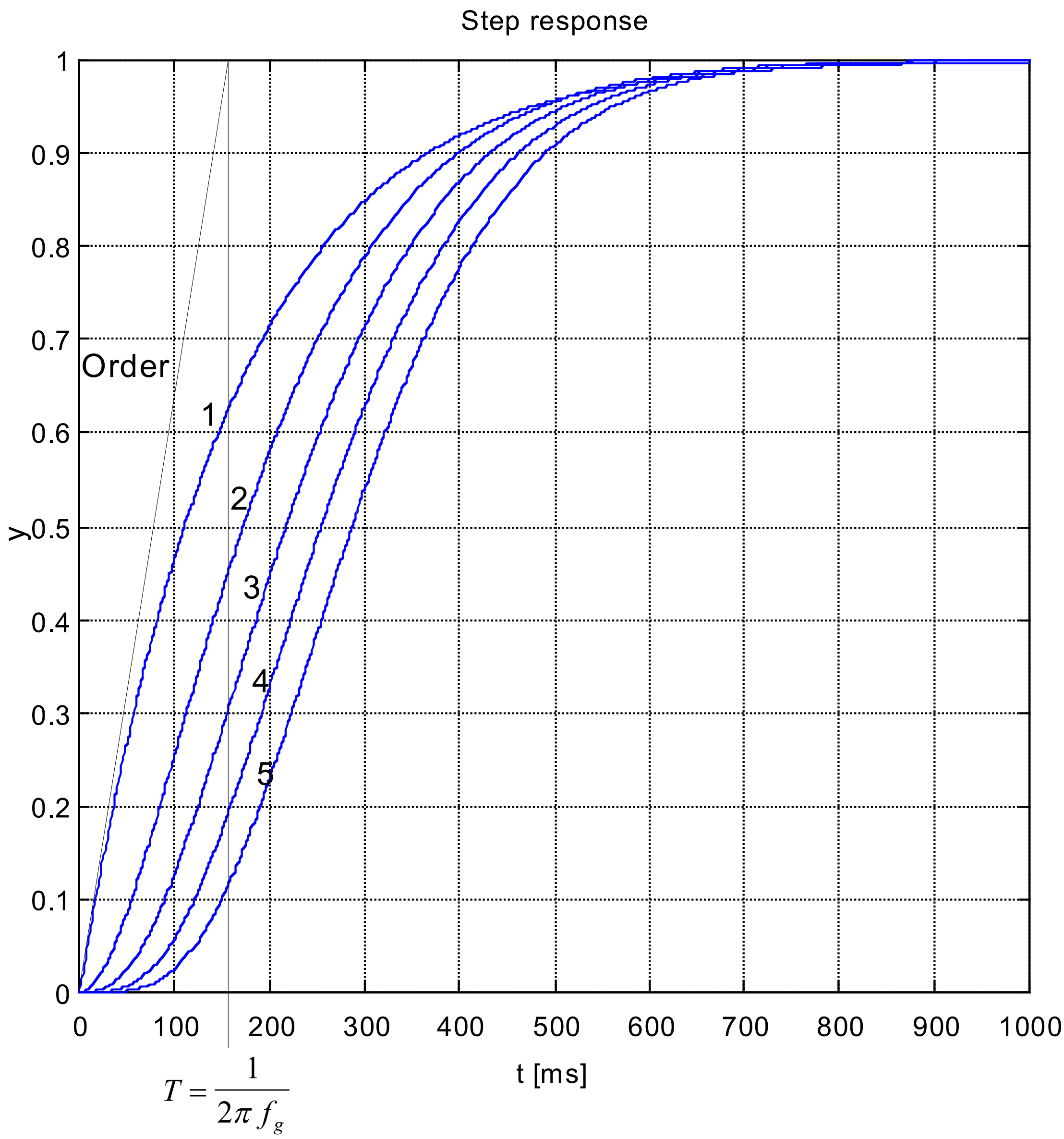


Fig. 16: Step response of low-pass filters of different orders

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