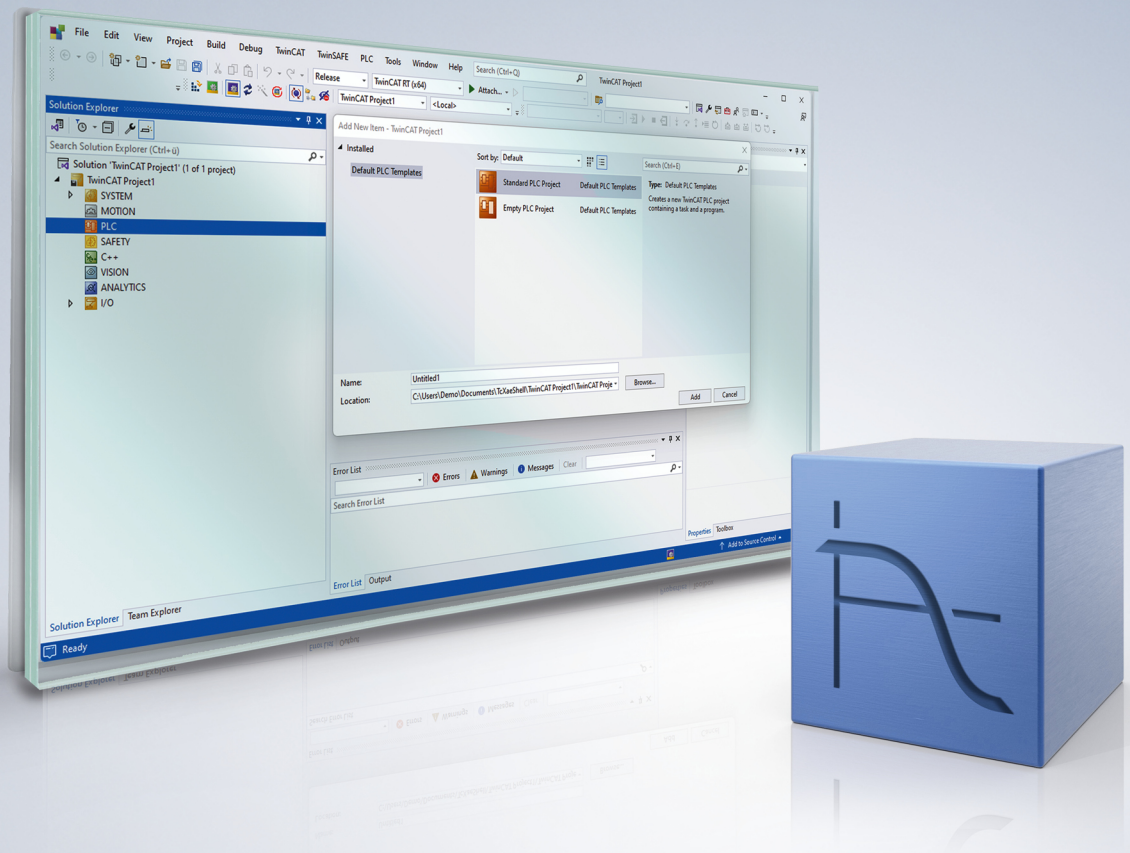
BECKHOFF New Automation Technology

Manual | EN

TE132x

TwinCAT 3 | Bode Plot



2026-07-22 | Version: 1.3.0

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1 Foreword

1.1 Notes on the documentation

This description is intended exclusively for trained specialists in control and automation technology who are familiar with the applicable national standards.
The documentation and the following notes and explanations must be complied with when installing and commissioning the components.
The trained specialists must always use the current valid documentation.

The trained specialists must ensure that the application and use of the products described is in line with all safety requirements, including all relevant laws, regulations, guidelines, and standards.

Disclaimer

The documentation has been compiled with care. The products described are, however, constantly under development.
We reserve the right to revise and change the documentation at any time and without notice.
Claims to modify products that have already been supplied may not be made on the basis of the data, diagrams, and descriptions in this documentation.

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1.2 For your safety

Safety regulations

Read the following explanations for your safety.
Always observe and follow product-specific safety instructions, which you may find at the appropriate places in this document.

Exclusion of liability

All the components are supplied in particular hardware and software configurations which are appropriate for the application. Modifications to hardware or software configurations other than those described in the documentation are not permitted, and nullify the liability of Beckhoff Automation GmbH & Co. KG.

Personnel qualification

This description is only intended for trained specialists in control, automation, and drive technology who are familiar with the applicable national standards.

Signal words

The signal words used in the documentation are classified below. In order to prevent injury and damage to persons and property, read and follow the safety and warning notices.

Personal injury warnings

⚠ DANGER
Hazard with high risk of death or serious injury.

⚠ WARNING
Hazard with medium risk of death or serious injury.

⚠ CAUTION
There is a low-risk hazard that could result in medium or minor injury.

Warning of damage to property or environment

NOTICE
The environment, equipment, or data may be damaged.

Information on handling the product



This information includes, for example:
recommendations for action, assistance or further information on the product.

1.3 Notes on information security

The products of Beckhoff Automation GmbH & Co. KG (Beckhoff), insofar as they can be accessed online, are equipped with security functions that support the secure operation of plants, systems, machines and networks. Despite the security functions, the creation, implementation and constant updating of a holistic security concept for the operation are necessary to protect the respective plant, system, machine and networks against cyber threats. The products sold by Beckhoff are only part of the overall security concept. The customer is responsible for preventing unauthorized access by third parties to its equipment, systems, machines and networks. The latter should be connected to the corporate network or the Internet only if appropriate protective measures have been set up.

In addition, the recommendations from Beckhoff regarding appropriate protective measures should be observed. Further information regarding information security and industrial security can be found in our https://www.beckhoff.com/secguide.

Beckhoff products and solutions undergo continuous further development. This also applies to security functions. In light of this continuous further development, Beckhoff expressly recommends that the products are kept up to date at all times and that updates are installed for the products once they have been made available. Using outdated or unsupported product versions can increase the risk of cyber threats.

To stay informed about information security for Beckhoff products, subscribe to the RSS feed at https://www.beckhoff.com/secinfo.

2 Overview

The TwinCAT 3 Bode Plot is the ideal tool for the analysis and optimization of mechanical resonances within a mechatronic system. The TwinCAT 3 Bode Plot can be used in conjunction with the AX5000 and AX8000 drive systems from Beckhoff. It shows the gain and the phase of a system for every frequency within a frequency range. A graphic display of the stationary reaction, at an output to a harmonic excitation (“sine oscillation”) at an input of a system, is thus possible with this tool within the scope of TwinCAT Measurement in Visual Studio. Problematic frequency ranges can easily be identified in the Bode Plot. With the help of Filter Sets, possible filter settings and their effects on the drive can be simulated in the TwinCAT Bode Plot before the settings for optimizing the drive axis are actually applied.

Key features:

- Representation of mechanical resonances
- Determination of the bandwidth, as well as phase and amplitude reserves
- Direct simulation of the filters and their effect on the system
- Adaptation of filters to optimize resonance points

Principle of operation:

For the harmonic excitation of a drive axis, the frequencies can be specified in the TwinCAT Bode Plot, integrated in Visual Studio as an independent Measurement project. The input data are transmitted in the real-time context and are then automatically followed for the selected axis. The current output values for amplitude gain and phase shift are continuously transmitted during the execution to the chart of the Bode Plot in order to graphically display the results.

⚠ WARNING

Risk of injury due to the drive axis starting up automatically

In order to create the Bode Plot recording, the drive axis executes a motion sequence that is dependent upon the settings. At the start of the Bode Plot recording the drive axis starts up automatically in accordance with the set motion profile and can endanger people and material. During the Bode recording the drive axis remains integrated in the application context (e.g. enables, monitoring, etc.).

- Ensure safety during the Bode Plot recording.

Product level / feature list:

This table shows which functions are available at which product level with the corresponding licensing:

Feature	TwinCAT Bode Plot Base
Support AX5xxx	From firmware version 2.10
Support AX8xxx	From firmware version 1.04
Support XPlanar	From TF5430 version 3.3.62
Open loop	✔
Closed loop	✔
Velocity mode	✔
Current mode	✔
Filter simulation	✔
Graph overlapping	✔
Individual oversampling factor	✔ (Expert mode)

3 Installation

The TwinCAT 3 Measurement installation package is available as a download from the Beckhoff website. It contains various measurement products, such as Scope View, Scope Server, Bode Plot, Filter Designer, etc. This range of functions can only be activated via licenses.

3.1 System requirements

The following system requirements must be fulfilled for proper functioning of the TwinCAT 3 Bode Plot.

Supported operating systems

Windows 10, Windows 11

TwinCAT

Minimum is TwinCAT 3 ADS.

.NET Framework

The .NET Framework 4.7.2 is required.

In TwinCAT 4024, TwinCAT 3 Bode Plot is installed together with TwinCAT 3 XAE. An update of the TwinCAT Bode Plot independent of TwinCAT XAE can be implemented via the TwinCAT Measurement Setup. The Bode Plot is license-free in the base version. Please refer to the product overview page for the feature set of the Base version.
In TwinCAT 4026, the Bode Plot is not included in TwinCAT.Standard.XAE; instead, it must be installed via a separate workload, TE1320.BodePlotBase.XAE.

3.2 Installation

Depending on the TwinCAT version and operating system used, this TwinCAT 3 Function can be installed in different ways, which are described in more detail below.

Update installation

An update installation always uninstalls the previous installation.

- Create a backup of your configuration files before the update.

TwinCAT 3 Package Manager: Installation (TwinCAT 3.1 Build 4026)

If you are using TwinCAT 3.1 Build 4026 (and higher) on the Microsoft Windows operating system, install this function via the TwinCAT Package Manager (TcPkg). Detailed instructions on installing products can be found in the chapter Managing TwinCAT Software in the TwinCAT 3.1 Build 4026 installation instructions.

NOTICE

Unprepared TwinCAT restart can cause data loss

The installation of this function may result in a TwinCAT restart.

- Make sure that no critical TwinCAT applications are running on the system or shut them down in an orderly manner first.

TwinCAT Package Manager UI

Install the following workload via the TcPkg **U**ser **I**nterface (UI) to use the product:

- **TE132x | TwinCAT 3 Bode Plot**

TwinCAT Package Manager CLI

You can use the TcPkg Command Line Interface (CLI) to display the available workloads on the system:

```
tcpkg list -t workload
```

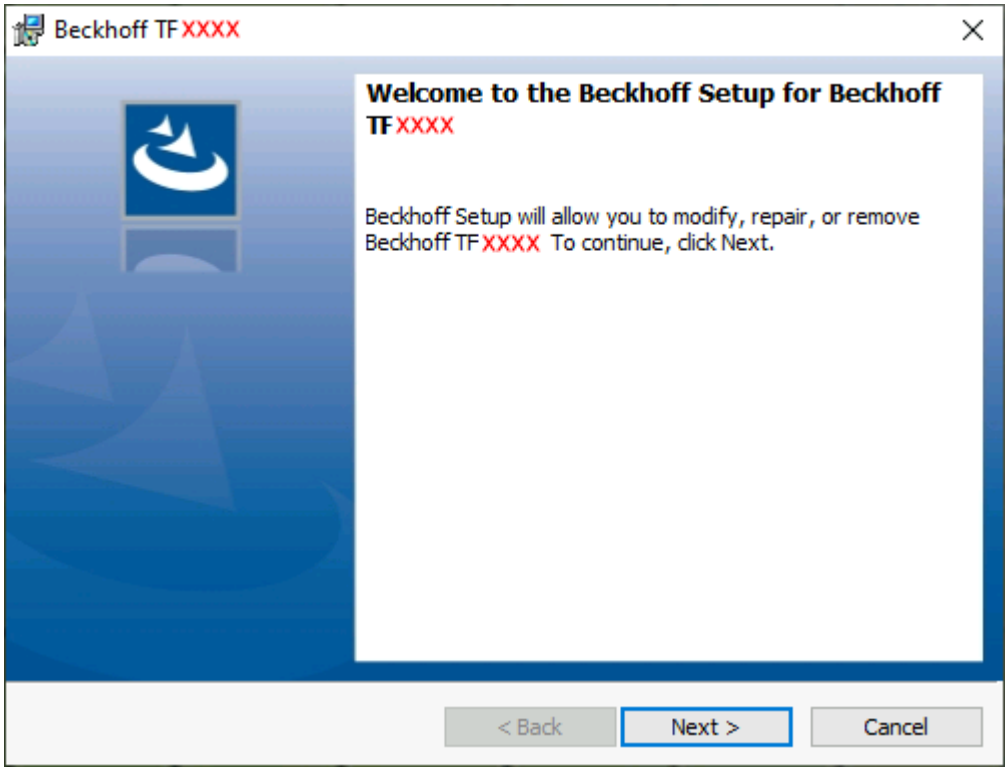
Use the following command to install the Workload:

```
tcpkg install tcpkg install TE1320.BodePlotBase.XAE
```

TwinCAT 3 setup: Installation (TwinCAT 3.1 Build 4024 and earlier)

If you are using TwinCAT 3.1 Build 4024 on the Microsoft Windows operating system, install this function via a setup package, which you can download from the Beckhoff website at https://www.beckhoff.com/download.

Depending on the system on which you need the function, the installation can be done on either the engineering or runtime side. The following screenshot is an example of the Setup interface.



To complete the installation process, follow the instructions in the Setup dialog.

NOTICE

Unprepared TwinCAT restart can cause data loss

The installation of this function may result in a TwinCAT restart.

- Make sure that no critical TwinCAT applications are running on the system or shut them down in an orderly manner first.

After the Installation

It is not necessary to license the base version. By default the Base product level is active and is available without a license.

Further steps:

TwinCAT 3 Bode Plot - first steps [▶ 33]

Bode Plot - Architecture [▶ 14]

4 Technical introduction

4.1 Bode Plot principles

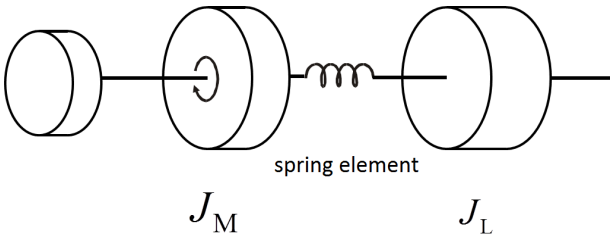
The Bode Plot is a special representation of a complex transfer function or of a system in the frequency range. The Bode Plot consists of a graph for the value (gain response) and a graph for the phase shift (phase response). It describes the stationary reaction of the system to a harmonic excitation (sine oscillation). The frequency is displayed logarithmically on the X-axes. As a result, the behavior over a wide frequency range is visible at a glance.

In a servo system, it is possible with the help of the Bode Plot analysis to analyze the behavior of the closed and open loops, as well as the transmission link (e.g. the connected mechanism) and to make or optimize controller and filter settings. In general, this can take place in the typical operating modes - current, speed and position control - and can also serve as the basis for automatic tuning algorithms. There are currently two variants in TwinCAT - current and speed control.

Conventional methods, such as optimization to a step response, are usable only to a limited extent. The Bode Plot contains much more information than the step response and is thus the ideal tool for the analysis and optimization of control loops:

- The system performance and stability over the entire frequency range are directly visible (accuracy in the rest position - in the lower frequency range; the dynamic reaction - in the mid frequency range; noise suppression - in the upper frequency range)
- A bandwidth can be specified more simply and more precisely without disruptions due to noise effects
- Problematic frequencies (mechanical resonance points) are easier to analyze
- Filters can be determined and adapted accordingly

What generates resonances in a drive train?



Each coupling between load and motor has a finite rigidity. This leads to different inertia ratios and different resonant frequencies of the complete system. These different frequencies are difficult to determine without a suitable tool. The frequency analysis can be performed with an almost infinitely fine graduation in order to reliably detect all resonance points.

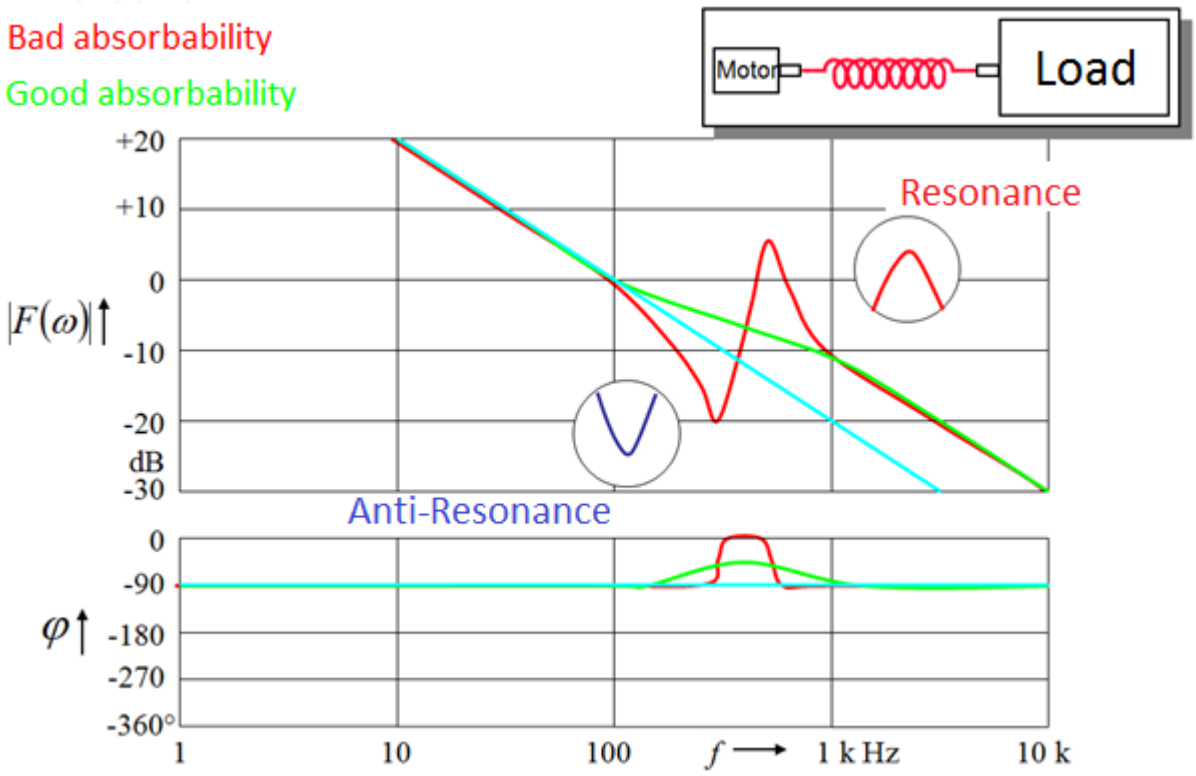
Mechanical friction must be eliminated during the measurement procedure, otherwise the measurement will be useless. Therefore, to overcome the static friction, a sine oscillation with a constant low frequency is additionally applied to the motor shaft. Gradually increasing sine wave frequencies are modulated onto this signal. To ensure that the motor current remains more or less constant in speed (and position) control, the amplitude of the sine oscillations decreases as the frequency increases. The actuating amplitudes are thus very small at high frequencies. The current in the Bode Plot is constant.

Open and closed loop

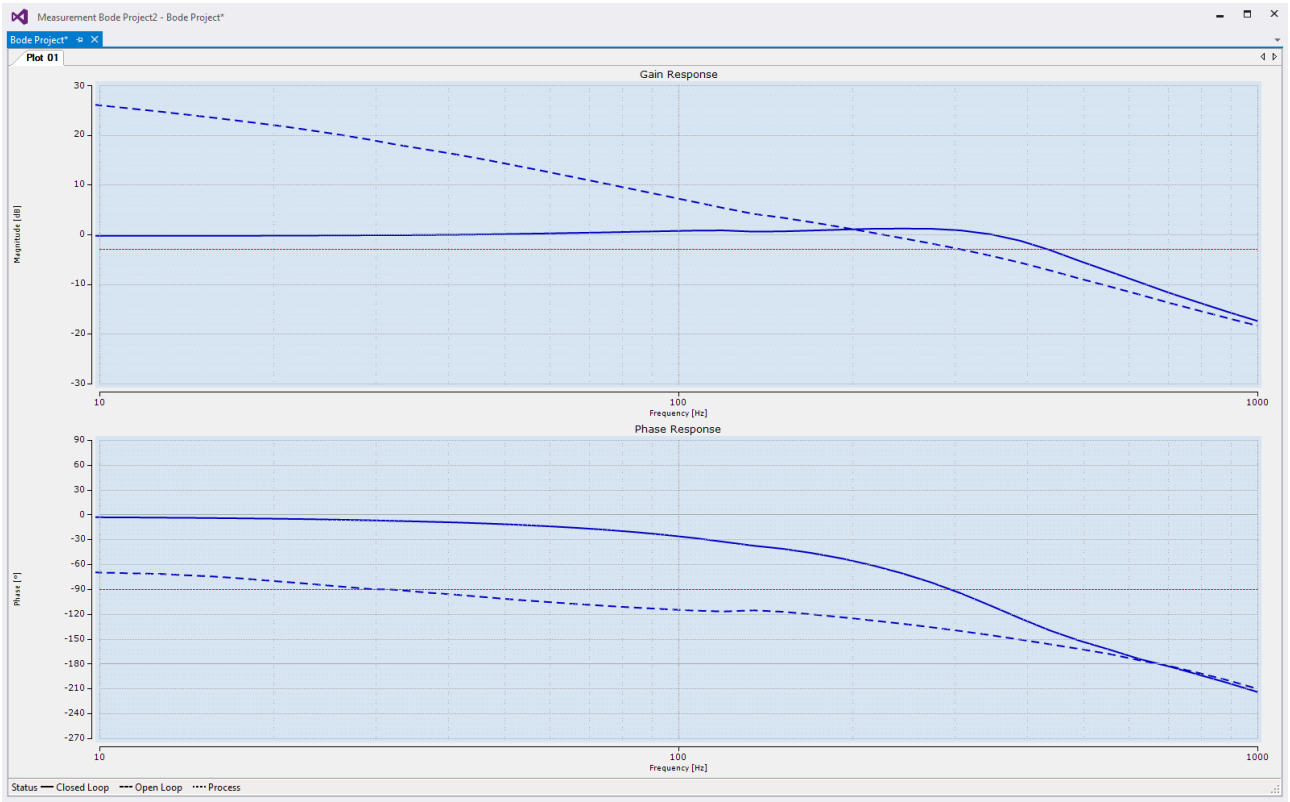
When analyzing control loops, the behavior of the controller and the process is generally considered separately with and without feedback. The so-called “open loop” ignores feedback effects in this context. By closing the control loop – that is, by incorporating feedback – one obtains a “closed-loop”. In some cases, the “process” is also considered separately.

Bode Plot

Resonance points are represented in a Bode Plot. In the representation, a resonance point consists of an anti-resonance (frequency response exhibits a pronounced minimum) and a resonance (frequency response exhibits a pronounced maximum).



The following illustration shows an example of the frequency response of a motor with no load, no resonance points and a rather high bandwidth. The closed loop is used for the determination of the bandwidth, while the open loop is regarded for calculating the gain response. The bandwidth is read where the gain response first crosses the -3 dB or the phase response first crosses the -90° line. The higher the bandwidth of a system, the more stable it is and the higher the control loop gain can be set. This results in higher dynamics.

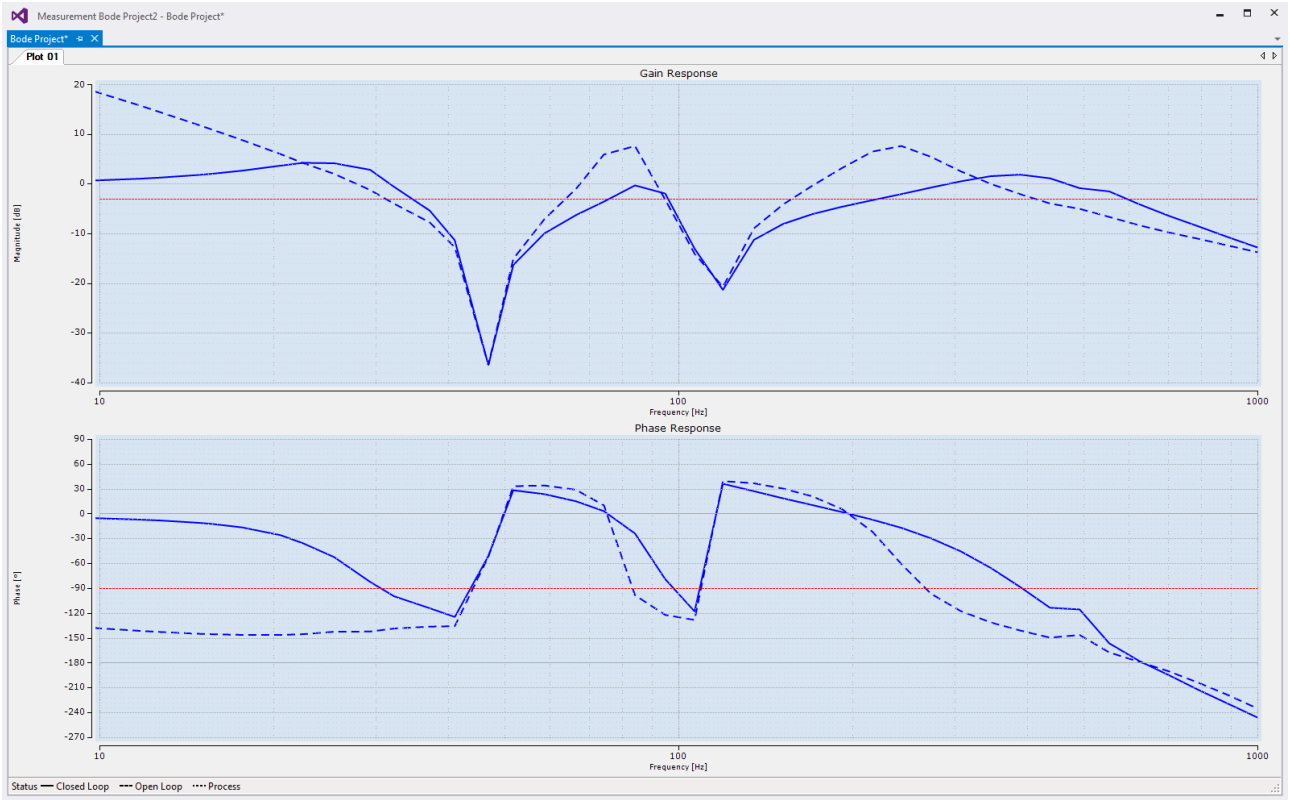


The following figure shows a typical response with resonance points: a response with two resonance points and a narrow bandwidth.

The second important limit is the +3 dB line. If the gain response of the closed loop exceeds this limit, this is referred to as positive feedback, analogous to the field of audio engineering (a speaker with a microphone close to the loudspeaker)

This positive feedback generates an undesired mechanical oscillation, which can lead to uncontrolled behavior.

By increasing the P part (proportional gain), the curve is shifted upwards in parallel to the x-axis; a reduction has the opposite effect.



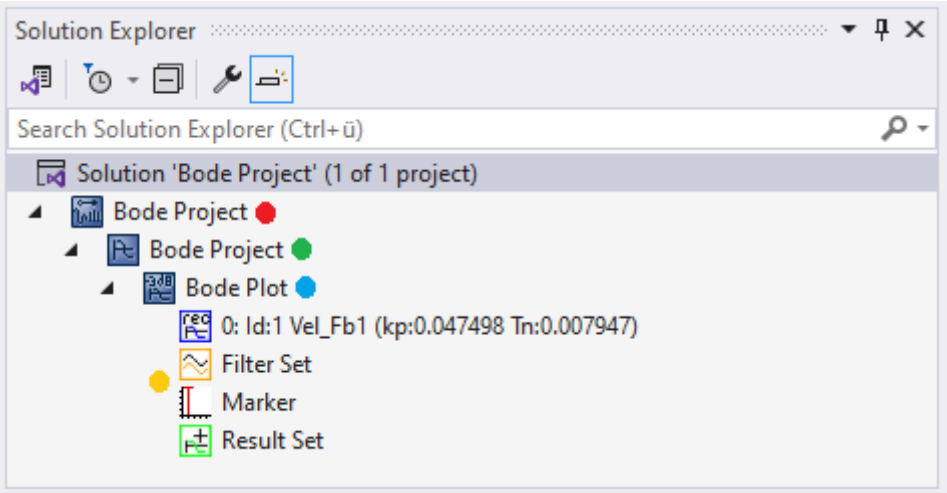
5 Configuration

5.1 Bode Plot

5.1.1 Bode Plot - Architecture

Not only are signal curves represented in the TwinCAT Bode Plot; recording configurations are also created. For the creation of these configurations, it is important to be familiar with the architecture of the Bode Plot. The architecture is reflected in the tree structure within the Measurement project in the Solution Explorer.

The architecture of a Bode project



(Measurement) Bode Project:
The main level, in which several Bode (or Scope) projects can be inserted. The Bode projects within a Measurement project can be controlled independently of one another. See also: Bode Plot - Project properties [▶ 20]

Bode project:
All Bode Plots within a project are processed in parallel when a recording is started. When you click on a Bode project, the available properties are displayed in the Properties window.
See also: Bode Plot properties [▶ 20]

Bode Plot:
Every Bode Plot represents the connection with a drive axis. Several plots can exist in one Bode project.

The display area for a plot contains one chart each for the amplitude and phase responses, in which the already recorded or generated characteristic curves (sets) for the associated axis are displayed. While a recording is in progress, a third chart showing the current actual and setpoint values may be displayed.

Apart from the connection data for the drive axis, the parameters for the next recording are also set via the Bode Plot.

If you click on a Bode project, the setting options are displayed in the Properties window. See also: Bode Plot properties [▶ 20]

Set:
Each Bode Set corresponds to a recorded or generated frequency response and represents the resulting characteristic curves for amplitude and phase over frequency. Graphs can be displayed for the open and closed loops, as well as for the process.

There are three types of sets:

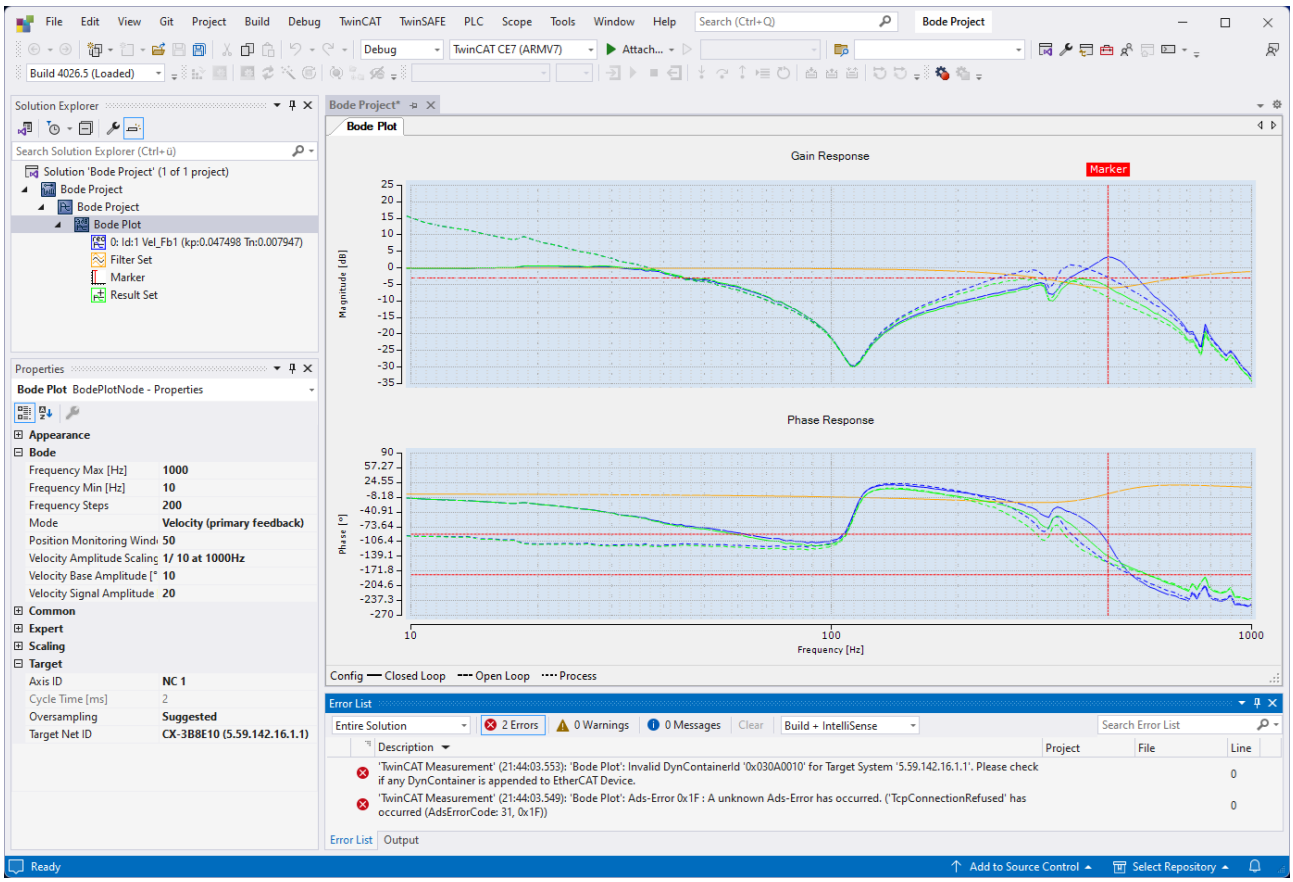
- Record sets represent real recorded values
- Filter Sets represent the characteristic curve of a filter
- Result Sets represent the combination of two sets in order, for example, to get an idea of how a filter affects a frequency response.

Among other things, the appearance, e.g. color and line width, can be adjusted in the Properties window.
See also: Set Properties [▶ 24]

Markers:
Bode markers can be used to assist in the analysis of the recorded characteristic curves. These make it easier to read and compare the frequency responses in the MarkerWindow. See also: Bode Plot - marker properties [▶ 29]

Window

The interfaces for the control of the Bode Plot are divided into several windows (Tool windows) and their position and size are freely configurable.



Overview of the individual windows:

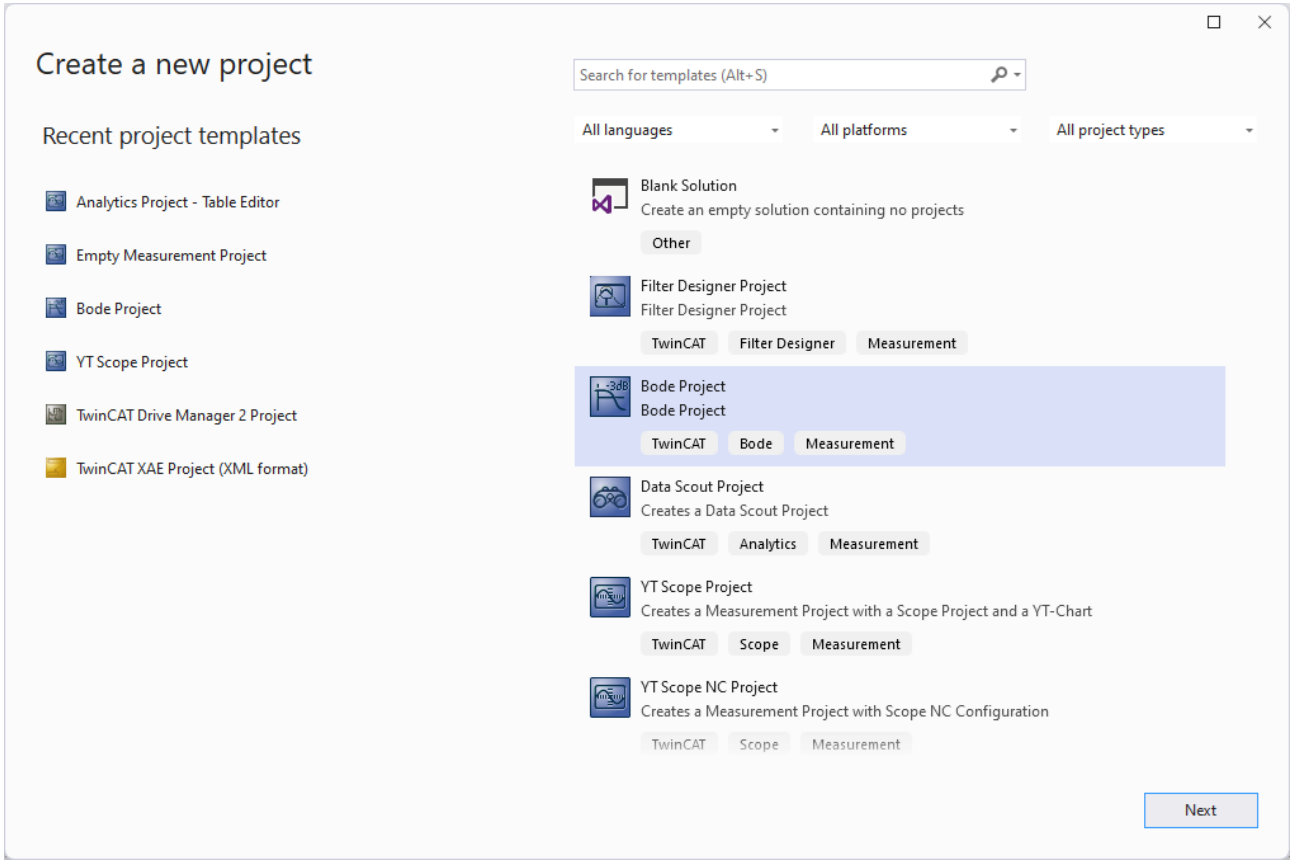
Solution Explorer	Representation of the project structure within a solution.
Error list	List of errors, warnings and messages. Each scope project lists the generated messages independently here. The messages for the respectively selected Scope can be deleted via the context menu item "Clear Error List".
Properties	The settings of the respective element that is selected in the Solution Explorer can be modified here.
Bode Plot editor	Representation of the individual plots of a Bode project. The plots can be displayed next to each other or in overlapping tabs within the project window, exactly like all other windows.

Configuration

The options for creating or editing a Bode configuration are explained below. The way in which the properties of the respective elements can be changed is described in the description of the associated window.

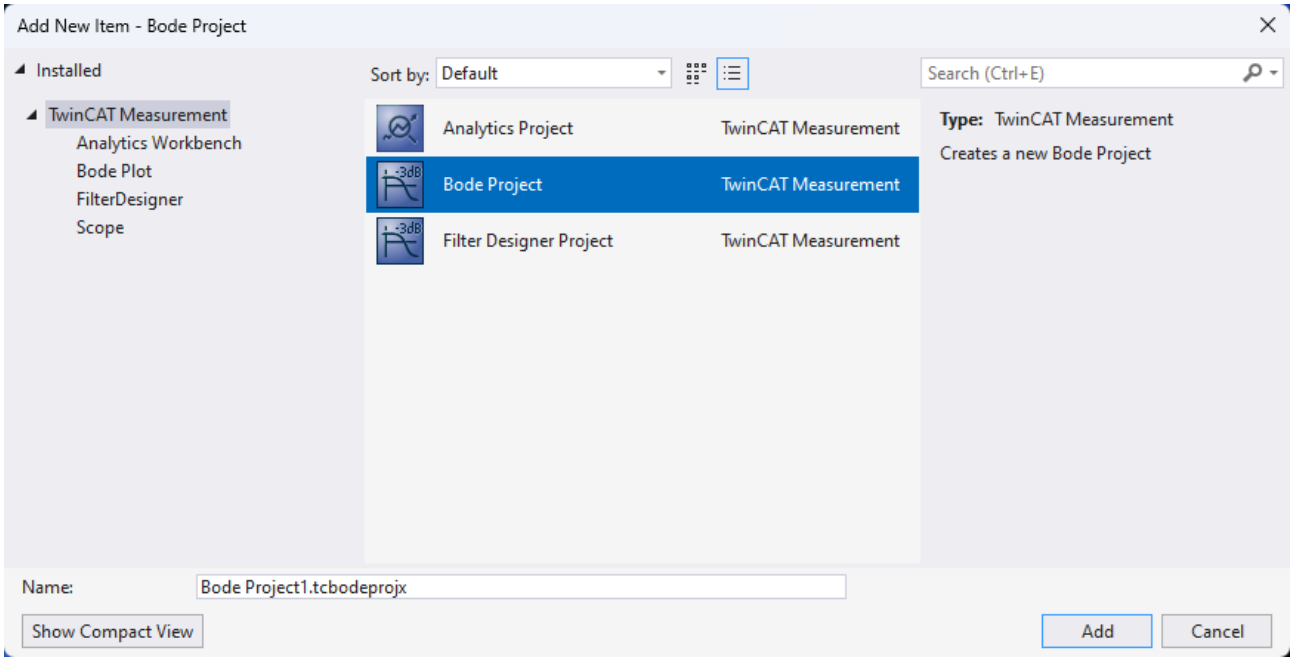
Creation of a Measurement project

File > New > Project… > Selection of the desired template.



Addition of a Bode project to a Measurement project

Context menu for the Measurement project > Add > New Item... > Selection of the desired template.



List of the available templates:

Bode project	Standard Bode project with a Bode Plot

Context menu for the Measurement project > Add > Existing Item... > Selection of the desired file (.bodeprojx)

Drag and drop the desired file (.bodeprojx) onto the Measurement project in the Solution Explorer.

Addition of individual elements:

New Plot	Context menu of the Bode project instance → New Plot
New Filter Set	Context menu of the plot instance → New Filter Set
New Result Set	Context menu of the plot instance → New Result Set
New Marker	Context menu of the plot instance → New Marker

Deletion of elements

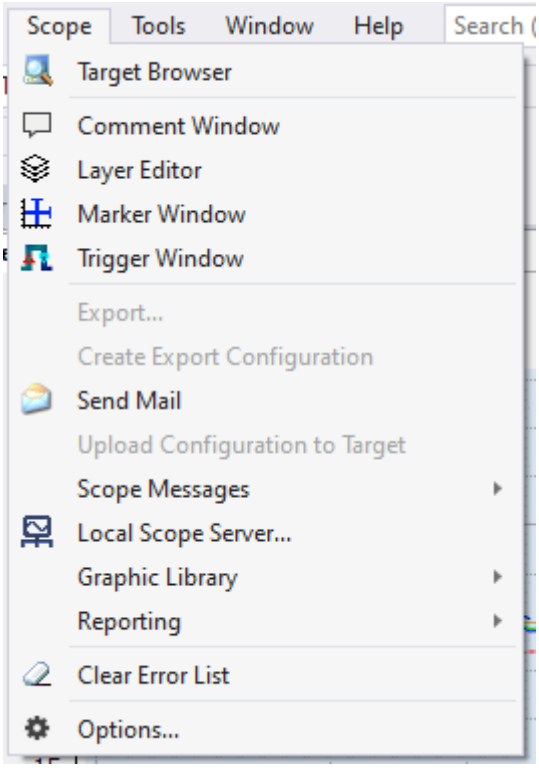
- Select the element in the Solution Explorer > [Del] key.
- Context menu of the element > Delete

Saving a Bode configuration

File > Save (Default keyboard shortcut: [Ctrl] + [S])
A file (.bodeprojx) is saved in the project directory.

5.1.2 Bode Plot - Scope menu

The Scope functions are accessible via the menu.



Marker Window	Opens the marker window for configuring markers.
Local Scope Server...	Opens the configuration interface of the Scope Server.
Clear Error List	Deletes all entries (Error | Warning | Message) of the currently active Scope from the Error List.
Options...	Opens the Visual Studio Options window and selects the Scope entry.

5.1.3 Bode Plot - Toolbar

The recording of a Bode Plot is started and stopped with the toolbar. The preset parameters for controlling the specified drive axis are used to follow the sought frequency profile.

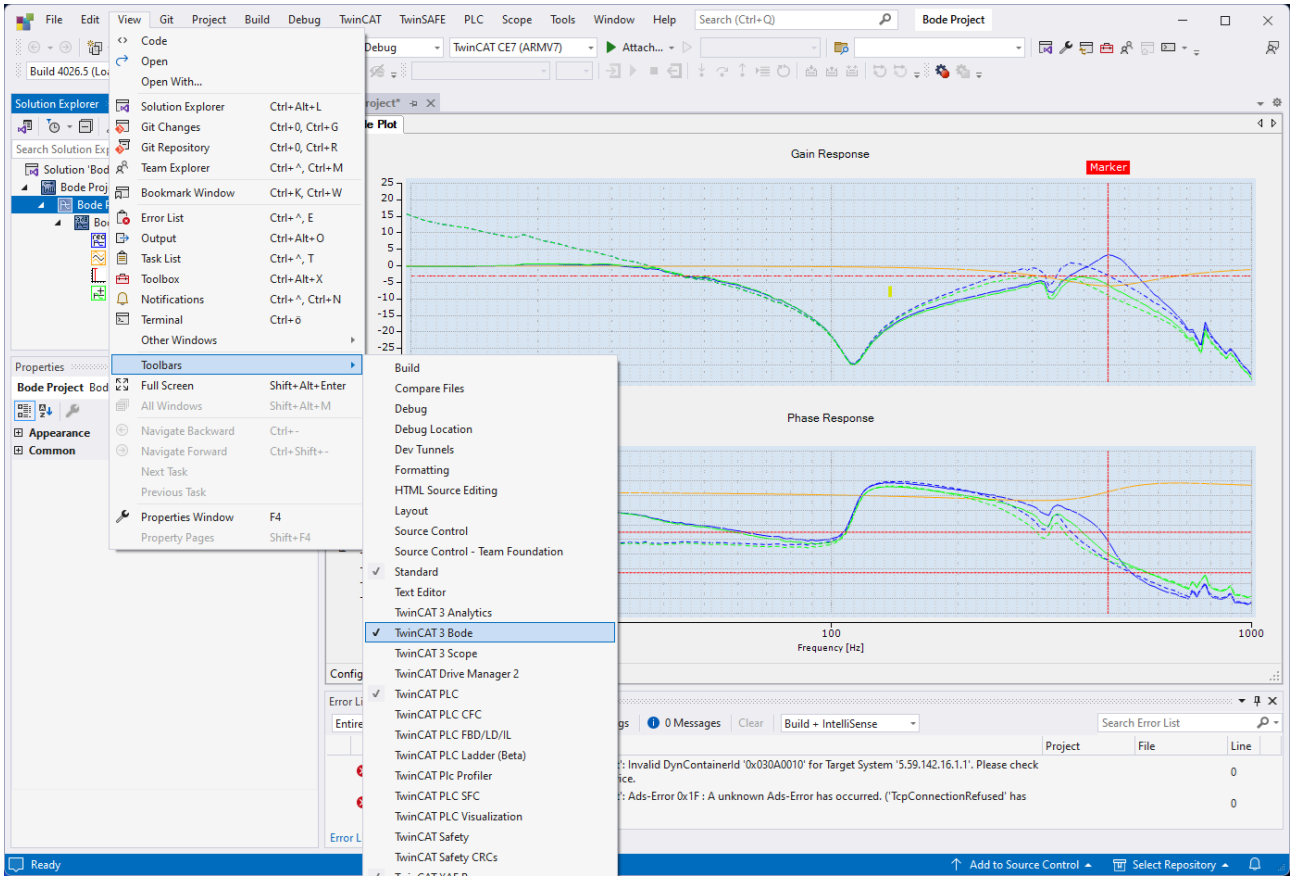
⚠ WARNING

Risk of injury due to the drive axis starting up automatically

In order to create the Bode Plot recording, the drive axis executes a motion sequence that is dependent upon the settings. At the start of the Bode Plot recording the drive axis starts up automatically in accordance with the set motion profile and can endanger people and material. During the Bode recording the drive axis remains integrated in the application context (e.g. enables, monitoring, etc.).

- Ensure safety during the Bode Plot recording.

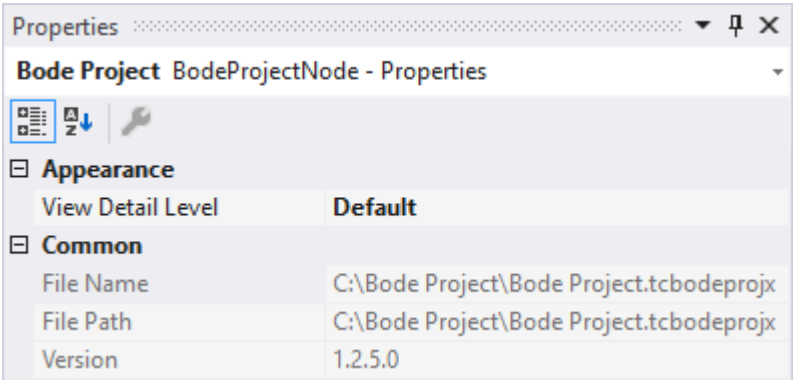
If the toolbar is not visible by default or has been closed, it can be reactivated under View > Toolbars > TwinCAT 3 Bode.



The following elements are available by default in the toolbar:

	**Start Record:** all plots connected to the selected Bode project start recording in parallel. The preset parameters are used to control the axes.
	**Stop Record:** all plots connected to the selected Bode project abort the recording. The connected drive axes are reset to the original operation mode.

5.1.4 Bode Plot - Project properties



Appearance

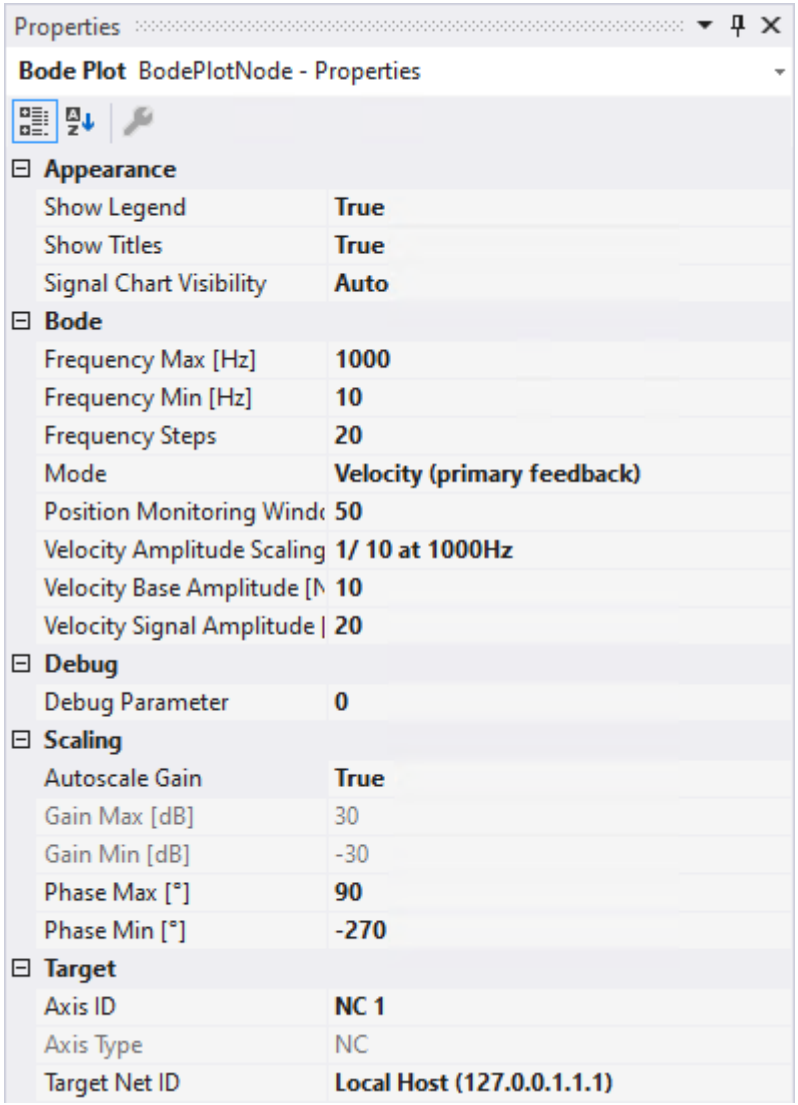
- **View Detail Level:** specifies whether the default view or an extended view should be used for the properties in this project. In the default state all properties for the sub-elements (e.g. plots, sets) necessary to create a Bode Plot are visible. Extended Mode displays additional properties that allow for detailed configuration of the recording. See Expert [▶ 23]

Common

- **File Name:** the filename of the current Bode instance.
- **File Path:** directory in which the Bode instance was saved.
- **Version:** indicates the current version of the configuration.

5.1.5 Bode Plot - Plot properties

All settings for a Bode Plot can be executed here. The following description refers to the representation in categories (switchable in the Properties toolbar).



Appearance

- **Show Legend:** Indicates whether the legend should be shown in the footer of the Bode Plot editor.
- **Show Titles:** Indicates whether the headings of the charts should be shown in the Bode Plot editor.
- **Signal Chart Visibility:** Indicates whether the chart with setpoint and actual values of the recording should be shown or hidden. If Auto is set, the chart is only shown during a running recording.

Bode

All settings are summarized under this category in order to configure a new Bode Plot.

- **Frequency Max:** indicates the upper frequency limit of the Bode Plot [in Hz].
- **Frequency Min:** indicates the lower frequency limit of the Bode Plot [in Hz].
- **Frequency Steps:** indicates the number of measuring points in the Bode Plot.
- **Mode:** sets the Bode Plot mode. The following are available:
  - **Torque:** executes a Bode Plot for the torque (or current) interface. (AX5000 only)
  - **Velocity (primary feedback):** executes a Bode Plot for the velocity interface. The actual values of the primary encoder are used for this. (AX5000 only)
  - **Velocity (dp/dt directly from primary feedback):** executes a Bode Plot for the velocity interface. (AX5000 only)
  - **Velocity (secondary feedback):** executes a Bode Plot for the velocity interface. The actual values of the secondary (external) encoder are used for this. (AX5000 only)
  - **Position (without oversampling):** executes a Bode Plot for the position.

- **Velocity NC (without oversampling):** executes a Bode Plot for the velocity.
- **Velocity DRIVE (without oversampling):** executes a Bode Plot for the velocity.
- **Torque (without oversampling):** executes a Bode Plot for the torque (or current).
- **Position (primary feedback): executes** a Bode Plot for the position. This mode is only available when an XPlanar mover is selected.

The following settings are shown or hidden, depending on the mode.

- **Position Monitoring Window [°]:** defines a window that is monitored during the Bode Plot. The object must not leave this window. The unit actually set is read out and the number is interpreted in accordance with the unit.
- **Position Signal Amplitude [°]:** this is where you set the amplitude of the excitation signal.
- **Velocity Amplitude Scaling Mode:** scales the signal amplitude during recording so that movements are not too large as the frequency increases. The following are available:
  - **Constant:** the amplitude corresponds to the parameterized signal amplitude and remains constant over the entire frequency range.
  - **1 / X at 1000Hz:** scales the amplitude so that at 1000 Hz it has fallen to 1 / X of the start amplitude of 1 Hz (~1/f). Useful ratios in practice are 1/5, 1/10 and 1/20.
- **Torque Amplitude Offset:** specifies an offset for the torque amplitude [in %].
- **Torque Amplitude Scaling Mode:** scales the signal amplitude during the recording, depending on the current frequency. The following are available:
  - **Autoscale:** scales the amplitude so that it is somewhat higher than the noise at a standstill.
  - **Constant:** the signal amplitude remains the same over the entire frequency range. The amplitude 100 means 100% of the maximum current.
- **Torque Signal Amplitude:** represents the amplitude of the signal (or measurement) oscillation at 1 Hz (see Torque Amplitude Scaling Mode). The unit of measurement is to be taken from the system settings (e.g. Drive, NC, etc.) and cannot be specified here.
- **Velocity Base Amplitude:** sets the amplitude of the basic oscillation (~1 Hz) for overcoming the static friction. The unit of measurement is to be taken from the system settings (e.g. Drive, NC, etc.) and cannot be specified here.
- **Velocity Signal Amplitude:** represents the amplitude of the signal (or measurement) oscillation at 1 Hz (see Velocity Amplitude Scaling Mode). The unit of measurement is to be taken from the system settings (e.g. Drive, NC, etc.) and cannot be specified here.

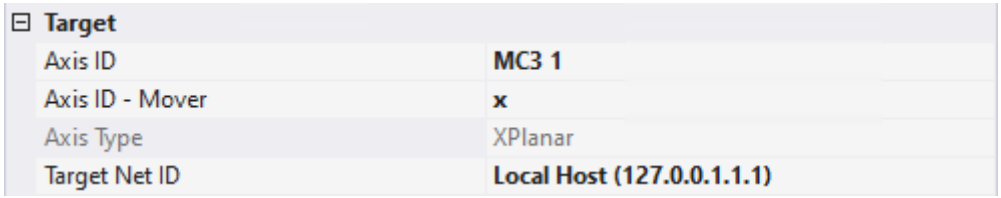
Scaling

- **Autoscale Gain:** disables/enables the automatic scaling in the gain response chart.
- **Gain Max:** indicates the upper magnitude for the value axis in the gain response chart.
- **Gain Min:** indicates the lower magnitude for the value axis in the gain response chart.
- **Phase Max:** indicates the upper end of the scale in the chart of the phase response.
- **Phase Min:** indicates the lower end of the scale in the chart of the phase response.

Target

- **Axis ID:** states the ID of the drive axis that is to be used for this Bode Plot. **WARNING The selected axis may not be part of an axis coupling (e.g. NC master/slave coupling, CNC hard or soft gantry). Otherwise, starting the recording can lead to injury to persons or damage to the machine.**
- **WARNING Axis Type:** specifies the type of the selected axis.
- **Target Net ID:** indicates the net ID of the target system that the drive axis is located on and which is to be used for this Bode Plot.

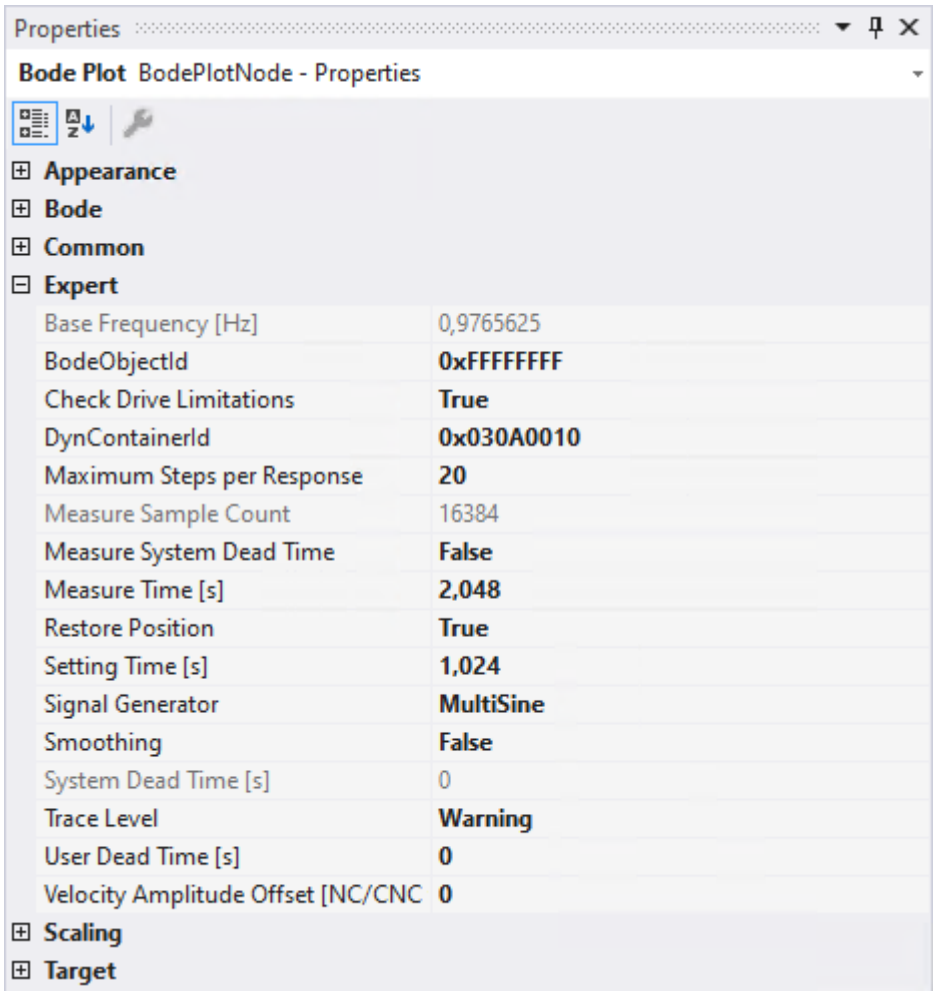
When selecting an XPlanar mover, you must select the axis dimension.



- **Axis ID – Mover:** Dimension of the XPlanar mover, i.e., an element consisting of “x,y,z,a,b,c”.

Extended View

If "View Detail Level" in the Bode project settings is set to Extended, some additional properties are visible. See Bode Plot - Project properties [▶ 20]



Expert

- **Base Frequency:** displays the frequency [in Hz] of the basic oscillation required to overcome static friction (only in velocity modes).
- **Bode Object Id:** If the Bode Plot is to be executed via a "TcCom Object" already set up in the System Manager (e.g. in order to visualize additional process data from the drive), this can take place here via the Object ID.
- **Check Drive Limitations:** If you want to check via the axes, you can specify this here.
- **DynContainerId:** sets the ID of the container for dynamic process data. The DynContainer is appended to the EtherCAT device in the TwinCAT project.
- **Maximum Steps per Response:** sets the number of measuring points per system response for broadband excitations (e.g. MultiSine, Chirp, PRBS).
- **Measure Sample Count:** indicates the number of setpoint values and actual values from which an interpolation point of the Bode characteristic curve (a frequency point) is calculated.

- **Measure System Dead Time:** If enabled, the setpoints are linked to the actual values in the controlled EtherCAT segment, e.g., AX8000. This option is only available for the Torque and Velocity modes (primary feedback).
- **Measure Time:** displays the duration [in s] during which the system is excited to produce a response.
- **Setting Time:** displays the duration [in s] during which the system settles to the current excitation.
- **Signal Generator:** displays the excitation type of the signal generator used. The following are available:
  - **Sine:** standard sine oscillation with regard to the set amplitude.
  - **MultiSine:** amplitude-modulated broadband sine.
  - **Chirp:** time-varying, sinusoidal excitation, chirp.
  - **PRBS:** the Pseudorandom Binary Sequence (PRBS) approximates a broadband white noise.
- **Smoothing: enables or disables smoothing of the recorded frequency response. The calculation is based on a moving average of the measurement points.**
- **Smoothing Diameter: sets the radius of the measurement points when smoothing is enabled.**
- **System Dead Time:** the complete dead time can be entered here in seconds.
- **Trace Level:** sets the detail level of the messages generated by the “Drive Diag –TcCom Object” and output in the Error List. The available options are Always, Error, Verbose and Warning.
- **User Dead Time:** the dead time in seconds can be specified here.
- **Velocity Amplitude Offset:** Defines the offset of the signal amplitude in the unit that belongs to the selected axis. If the value is not zero, the axis moves continuously in the desired direction. This is only recommended for freely moving axes.

Target

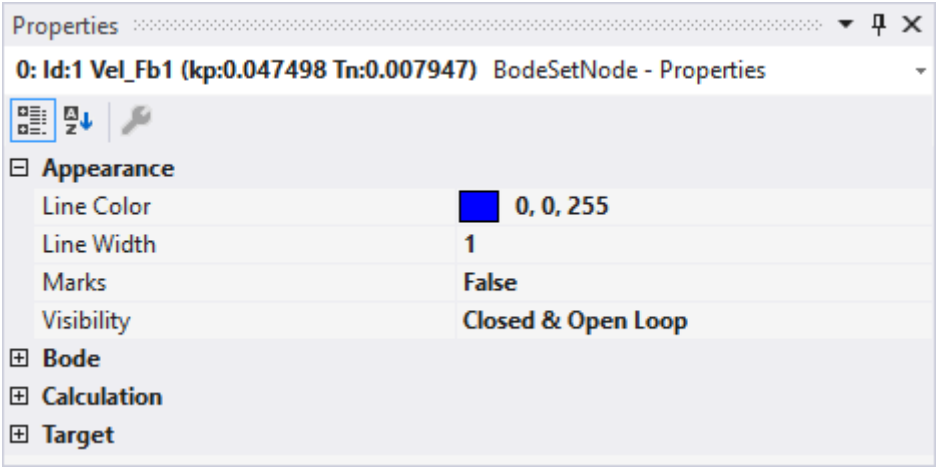
- **Cycle Time:** Indicates the last-used cycle time [in ms].
- **Oversampling:** indicates the oversampling factor to be used. If set to Suggested, the highest useful factor is automatically selected when the recording is started.

5.1.6 Bode Plot - Set properties

A Bode Plot can contain three different types of sets (characteristic curves). Record sets for displaying the result of a recording, Filter sets for assessing the characteristic curve of a filter and Result sets for combining two already existing sets.

Some settings concern all sets, some are specialized.

Appearance



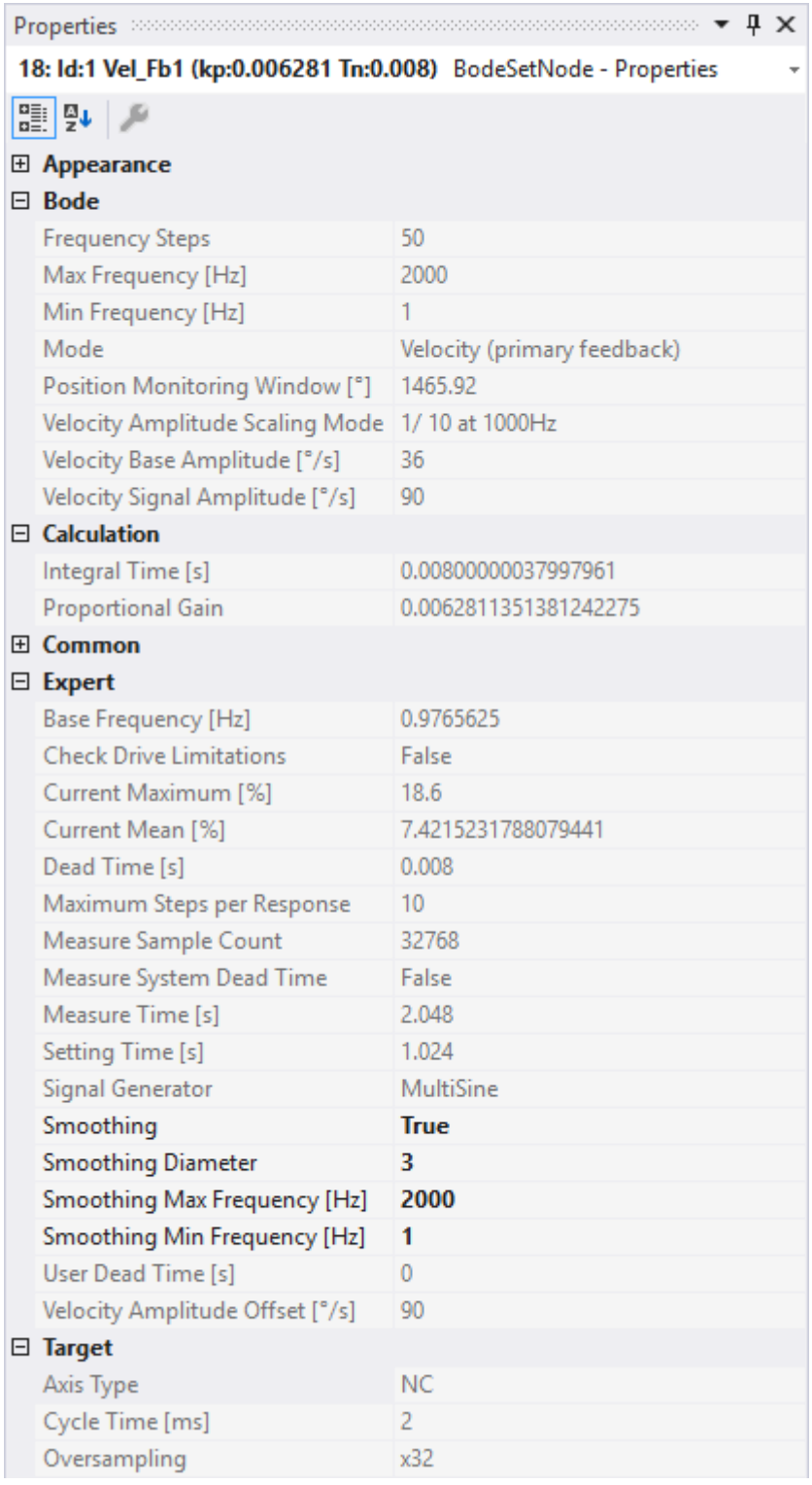
The settings in the Appearance category are available for all sets.

- **Line Color:** sets the color of the set (characteristic curves and icon in the Solution Explorer).
- **Line Width:** sets the line width of the set in the Bode Plot editor.

- **Marks:** indicates whether the interpolation points of the characteristic curve should be displayed.
- **Visibility:** indicates which variants of the characteristic curves should be displayed. The following values and their combinations are available:
  - **Open Loop:** frequency response of the open loop.
  - **Closed Loop:** frequency response of the closed loop.
  - **Process:** frequency response of the process.

Record Set

In the settings for the record set, you can see the configuration with which the recording took place. Therefore, the same values exist here that are already described in the plot. See Bode Plot - Plot properties [▶ 20]



Bode

All settings are summarized under this category in order to configure a new Bode Plot.

- **Frequency Steps:** indicates the number of measuring points in the Bode Plot.
- **Max Frequency [Hz]:** indicates the upper frequency limit of the Bode Plot [in Hz].
- **Min Frequency [Hz]:** indicates the lower frequency limit of the Bode Plot [in Hz].
- **Mode:** sets the Bode Plot mode. The following are available:
  - **Torque:** executes a Bode Plot for the torque (or current) interface (only for AX5000, AX8000).
  - **Velocity (primary feedback):** executes a Bode Plot for the velocity interface. The actual values of the primary encoder are used for this. (AX5000 only)

- **Velocity (dp/dt directly from primary feedback):** executes a Bode Plot for the velocity interface. (AX5000 only)
- **Velocity (secondary feedback):** executes a Bode Plot for the velocity interface. The actual values of the secondary (external) encoder are used for this. (AX5000 only)
- **Position (NC interface without oversampling):** executes a Bode Plot for the position.
- **Velocity (NC interface without oversampling):** executes a Bode Plot for the velocity.
- **Torque (NC interface without oversampling):** executes a Bode Plot on the torque (or current).

The following settings are shown or hidden, depending on the mode:

- **Position Monitoring Window [°]:** defines a window that is monitored during the Bode Plot. The object must not leave this window. The unit actually set is read out and the number is interpreted in accordance with the unit.
- **Position Signal Amplitude [°]:** this is where you set the amplitude of the excitation signal.
- **Velocity Amplitude Scaling Mode:** scales the signal amplitude during recording so that movements are not too large as the frequency increases. The following are available:
  - **Constant:** the amplitude corresponds to the parameterized signal amplitude and remains constant over the entire frequency range.
  - **1 / X at 1000Hz:** scales the amplitude so that at 1000 Hz it has fallen to 1 / X of the start amplitude of 1 Hz (~1/f). Useful ratios in practice are 1/5, 1/10 and 1/20.
- **Torque Amplitude Offset:** specifies an offset for the torque amplitude [in %].
- **Torque Amplitude Scaling Mode:** scales the signal amplitude during the recording, depending on the current frequency. The following are available:
  - **Autoscale:** scales the amplitude so that it is somewhat higher than the noise at a standstill.
  - **Constant:** the signal amplitude remains the same over the entire frequency range. The amplitude 100 means 100% of the maximum current.
- **Torque Signal Amplitude:** represents the amplitude of the signal (or measurement) oscillation at 1 Hz (see Torque Amplitude Scaling Mode). The unit of measurement is to be taken from the system settings (e.g. Drive, NC, etc.) and cannot be specified here.
- **Velocity Base Amplitude:** sets the amplitude of the basic oscillation (~1 Hz) for overcoming the static friction. The unit of measurement is to be taken from the system settings (e.g. Drive, NC, etc.) and cannot be specified here.
- **Velocity Signal Amplitude:** represents the amplitude of the signal (or measurement) oscillation at 1 Hz (see Velocity Amplitude Scaling Mode). The unit of measurement is to be taken from the system settings (e.g. Drive, NC, etc.) and cannot be specified here.

Calculation

- **Integral Time [s]:** this is read during the plot. It is the integral time of the controller that is set on the drive.
- **Proportional Gain:** the proportional gain can be used to achieve the desired performance.

Expert

- **Base Frequency:** shows the frequency [in Hz] of the basic oscillation for overcoming the static friction (in the velocity modes only).
- **Check Drive Limitations:** If you want to check via the axes, you can specify this here.
- **Current Maximum:** displays the maximum current utilization [in %] of the recording.
- **Current Mean:** displays the average current utilization [in %] of the recording.
- **Dead Time [s]:** Indicates the complete dead time in seconds.
- **Maximum Steps per Response:** sets the number of measuring points per system response for broadband excitations (e.g. MultiSine, Chirp, PRBS).
- **Measure Sample Count:** indicates the number of setpoint values and actual values from which an interpolation point of the Bode characteristic curve (a frequency point) is calculated.
- **Measure System Dead Time:** Indicates whether the system's dead time was measured with this recording, i.e., whether setpoints were copied to actual values.

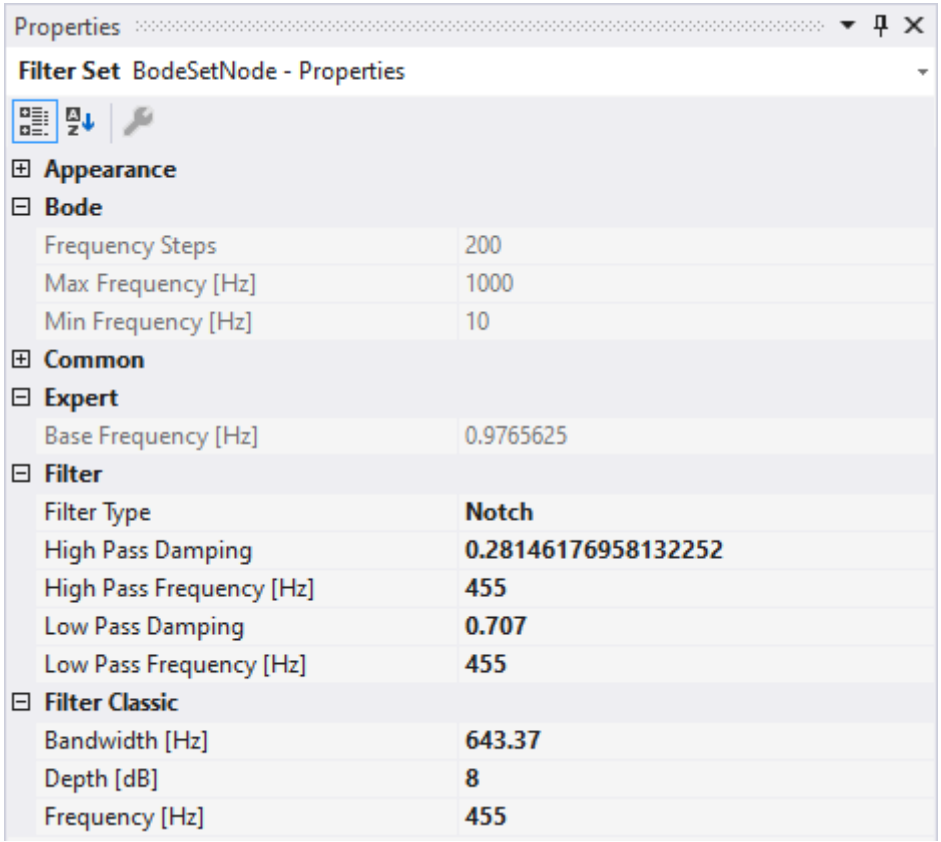
- **Measure Time:** indicates the length of time [in s] for which the system is excited with one frequency.
- **Setting Time:** displays the duration [in s] during which the system settles to the current excitation.
- **Signal Generator:** displays the excitation type of the signal generator used.
- **Smoothing:** smoothing of the image using a moving average. The original data are retained here.
  - **Smoothing Diameter:** diameter of the moving average in frequency points.
  - **Smoothing Max Frequency [Hz]:** upper limit for smoothing. Only frequency points below this value are converted.
  - **Smoothing Min Frequency [Hz]:** Lower limit for smoothing. Only frequency points above this value are converted.
- **User Dead Time [s]:** displays the system's configured dead time.
- **Velocity Amplitude Offset [°/s]:** displays the offset used for the excitation amplitude.

Target

- **Cycle Time:** Indicates the last-used cycle time [in ms].
- **Oversampling:** indicates the oversampling factor to be used. If set to Suggested, the highest useful factor is automatically selected when the recording is started.

Filter Set

The special settings for Filter Sets are represented as follows:



- **Filter Type:** the type of filter can be set here. The other properties can be edited, depending on the selection. The following are available:
- **Lowpass 1st Order:** first-order low-pass filter.
- **Lowpass 2nd Order:** second-order low-pass filter
- **Phase Correction 1st Order:** first-order phase correction element.
- **2nd-Order Phase Correction:** second-order phase correction element.
- **Notch:** notch filter.
- **High-Pass Damping:** high-pass damping factor.

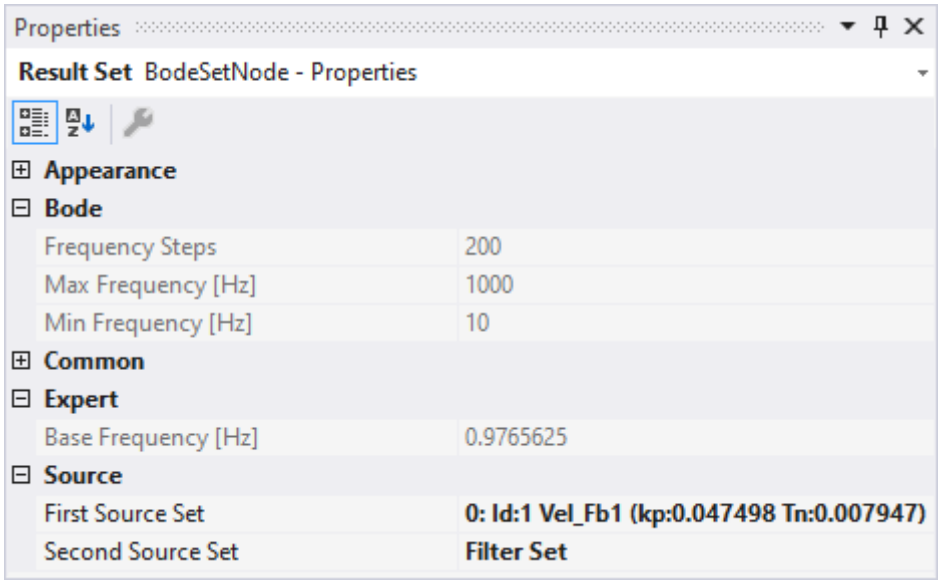
- **High-Pass Frequency:** high-pass frequency [in Hz].
- **Low-Pass Damping:** low-pass damping factor.
- **Low Pass Frequency:** low-pass frequency [in Hz].

Result Set

In order to obtain the overlapping of two already existing sets, they must be specified in the settings for the Result Set.

Upon selecting the field, a list of possible sets is displayed.

The resulting characteristic curve is automatically determined from the two sets if the number and positions of the interpolation points match. If one of the two source sets changes, then the Result Set is also re-calculated.

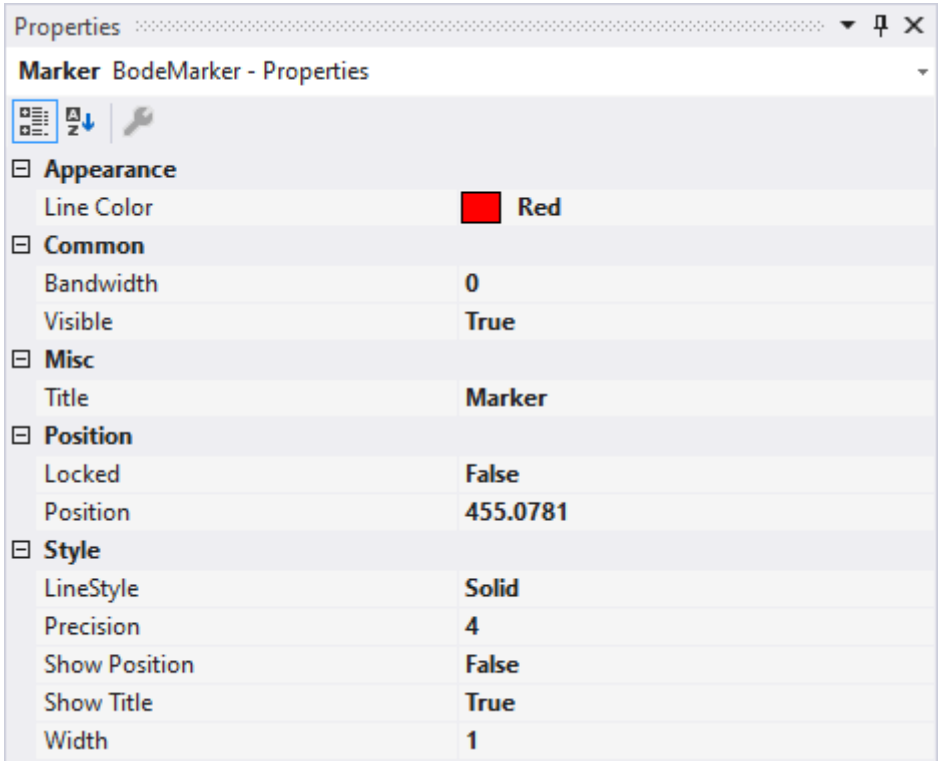


Source

- **First SourceSet Name:** name of the first source set.
- **Second SourceSet Name:** name of the second source set.

5.1.7 Bode Plot - marker properties

All settings for a Bode Marker can be assigned here. The following description refers to the representation in categories (switchable in the Properties toolbar).



Appearance

- **Line Color:** sets the color of the marker (vertical lines and icon in Solution Explorer).

Common

- **Bandwidth:** sets the width of the marker's band. The value is given as a proportion [in %] of the chart's width.
- **Visible:** sets the marker's general visibility.

Misc

- **Title:** sets the title displayed for the marker.

Position

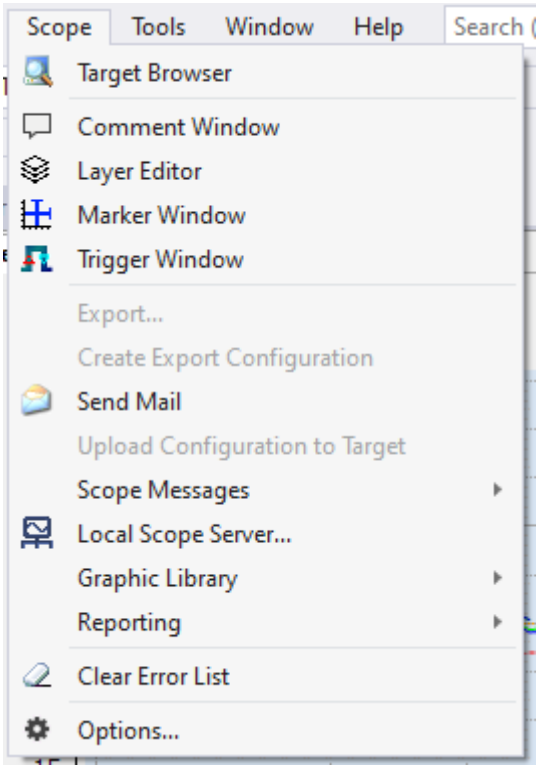
- **Locked:** toggles the marker's lock on or off.
- **Position:** displays/sets the marker's position [in Hz].

Misc

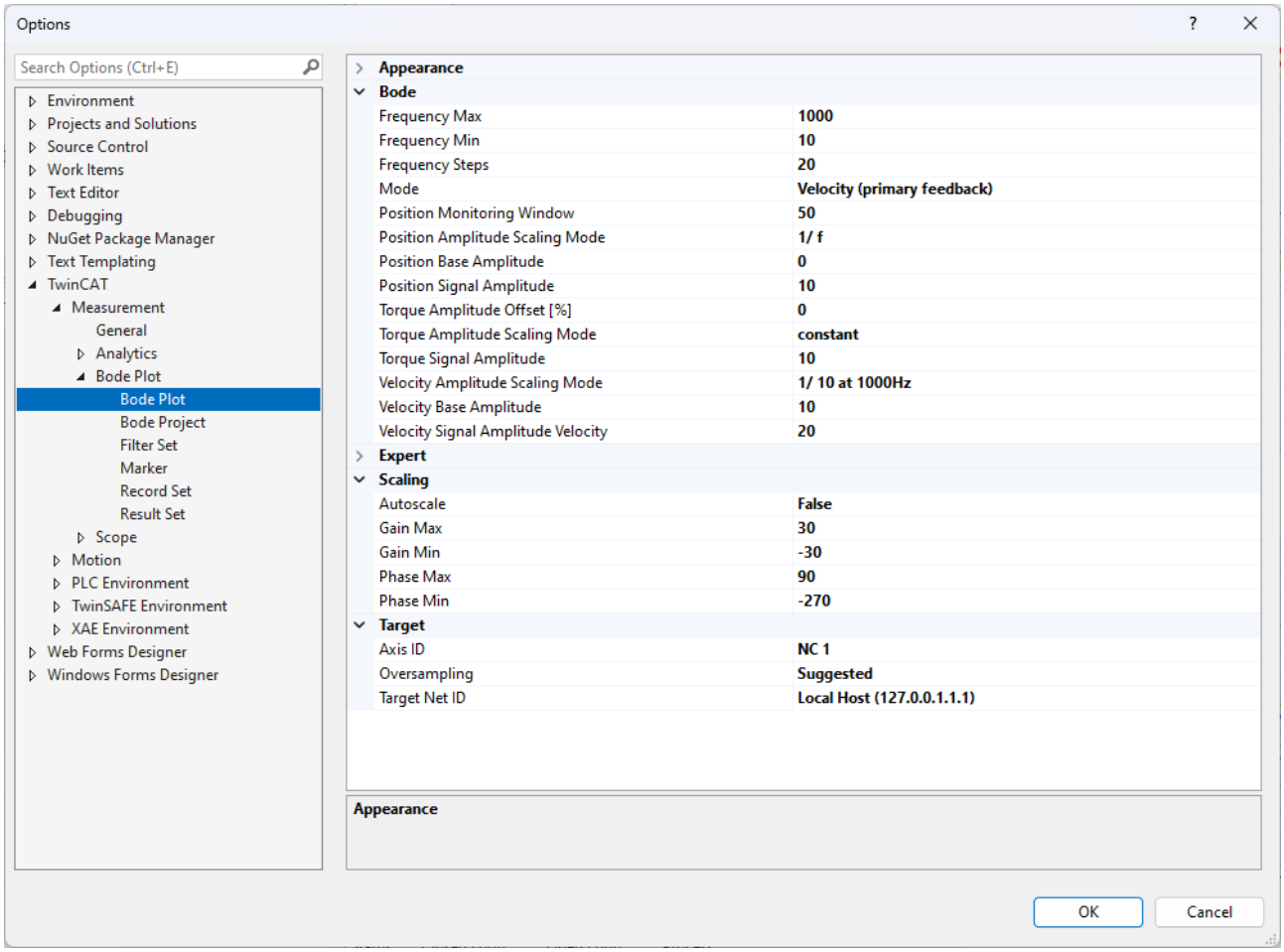
- **Style:** sets the marker's line type.
- **Precision:** sets the accuracy of the marker's position display.
- **Show Position:** enable or disable the marker's position display
- **Show Title:** enable or disable the marker's title display.
- **Width:** defines the line width of the marker.

5.1.8 Bode Plot - Options

You can go directly to the TwinCAT Measurement options in the TwinCAT XAE Shell / Visual Studio Options window via the Scope menu item **Options...**.



The standard or default settings that serve as the template for newly created elements can be made here.



Bode Default Settings

- **Bode Projekt:** basic settings for the project can be made here. To detailed description [▶ 20].

- **Bode Plot:** definition of the standard Bode Plot settings that are used when a new Bode Plot is appended to a project. To detailed description [▶ 20].
- **Filter Set:** definition of the standard Filter Set settings that are used when a new Filter Set is appended to a plot. To detailed description [▶ 24].
- **Record Set:** definition of the standard record set settings that are used when a new recording is started. To detailed description [▶ 24].
- **Result Set:** definition of the standard Result Set settings that are used when a new Result Set is appended to a plot. To detailed description [▶ 24].
- **Marker:** definition of the standard marker settings that are used when a new Bode marker is appended to a plot. To detailed Bode Plot - marker properties [▶ 29].

6 Samples

6.1 TwinCAT 3 Bode Plot - first steps

In order to enable you to get up and running quickly and to simplify work with the TwinCAT 3 Bode Plot, the first steps towards a Bode Plot recording are briefly summarized on this page.

If you wish to create a Bode Plot for a TwinCAT CNC axis, note the instructions for configuring TwinCAT CNC axes [▶ 38] at the end of the section.

⚠ WARNING

Risk of injury due to the drive axis starting up automatically

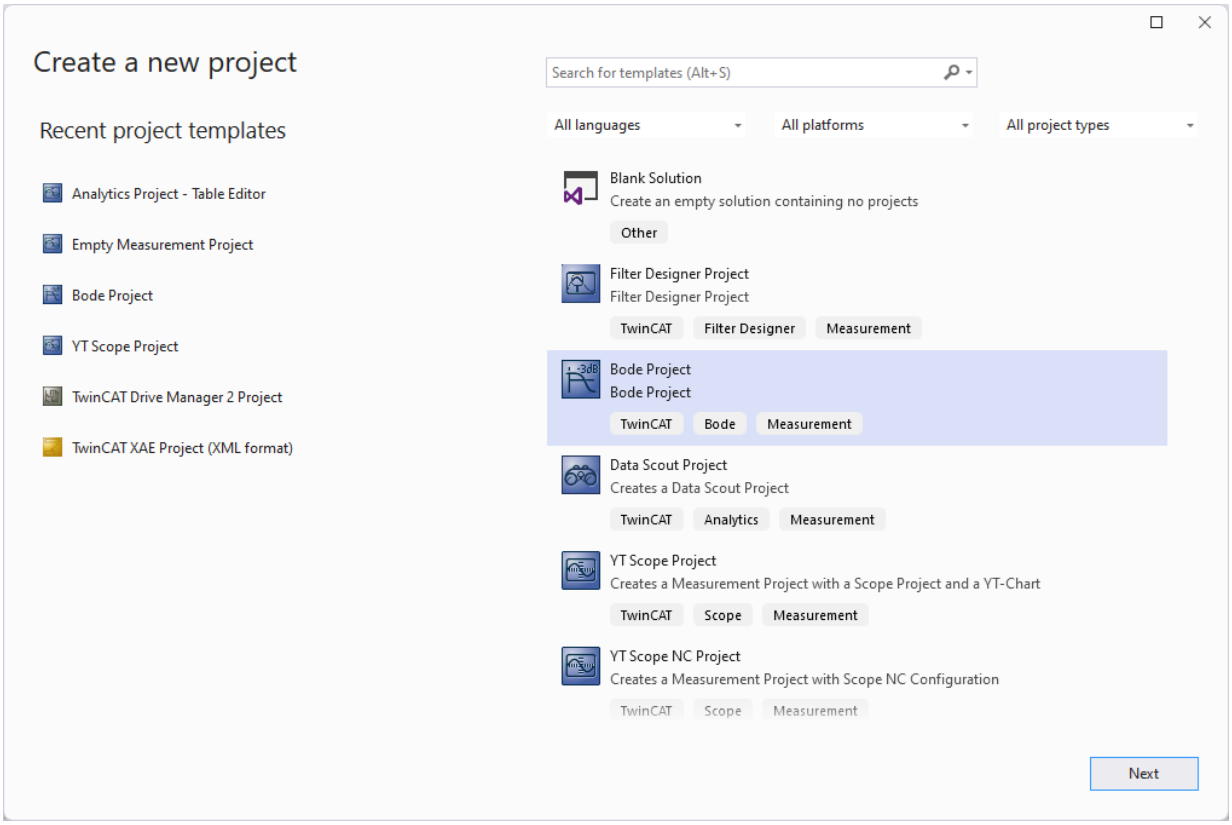
To create the Bode Plot, the drive axis performs a motion sequence that depends on the settings. At the start of the recording the drive axis starts up automatically in accordance with the set motion profile and can endanger people and material. During the recording the drive axis remains integrated in the application context (e.g. enables, monitoring, etc.).

- Ensure safety during the Bode Plot recording.

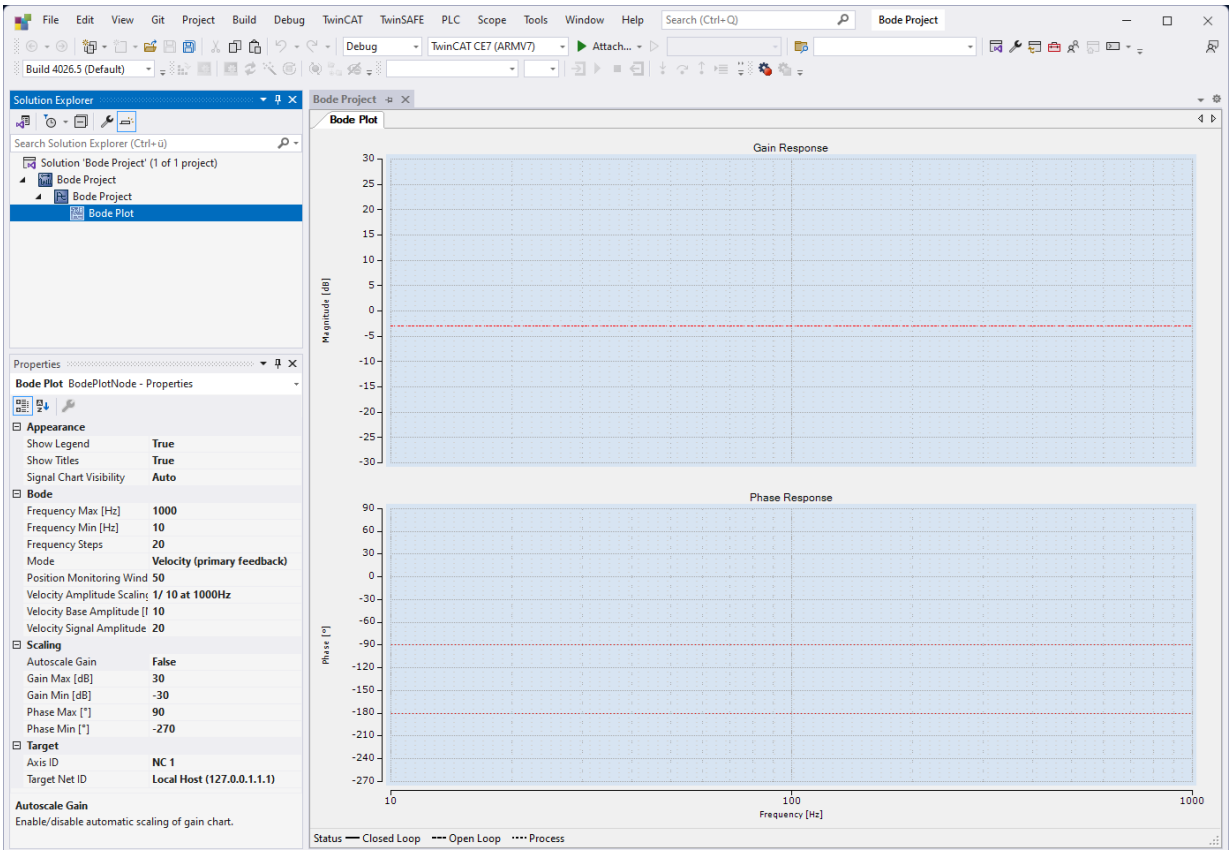
For a basic understanding it is important to know that the TwinCAT 3 Bode Plot is part of the Measurement installation, which also includes the Scope View and the Scope Server. Some functions are used across Measurement installations. For example, the toolbar controls both Scope and Bode projects. Since all Measurement projects use the Scope Server for the recording of the data, this is always installed as well. However, it can also be installed individually on a target device via the component installation.

✓ For the Bode Plot, the “Base” license is initially activated, irrespective of whether it has been installed via its own Measurement setup or via the TwinCAT 3 XAE setup.

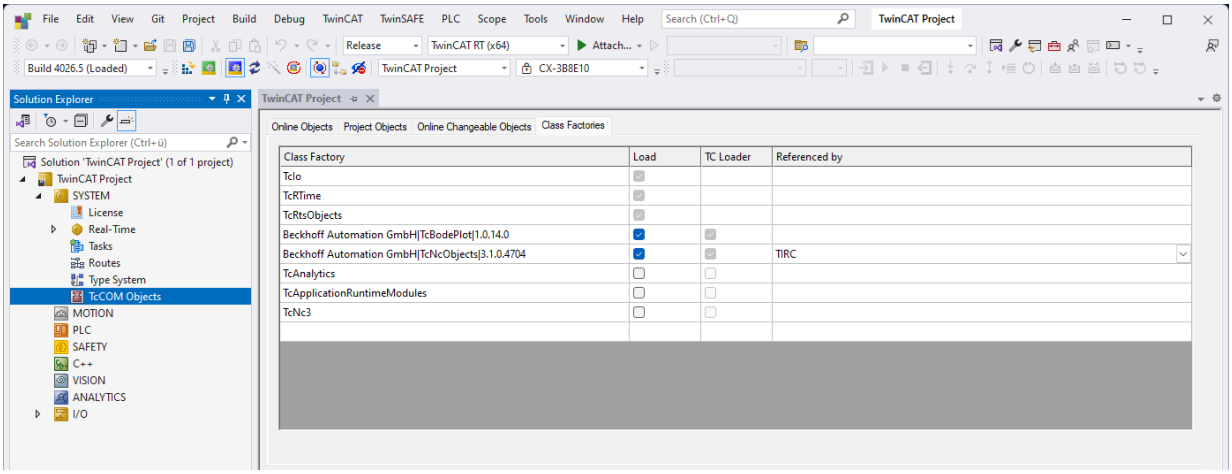
1. Create a new project and select the preconfigured **Bode Project** from the available Measurement templates.



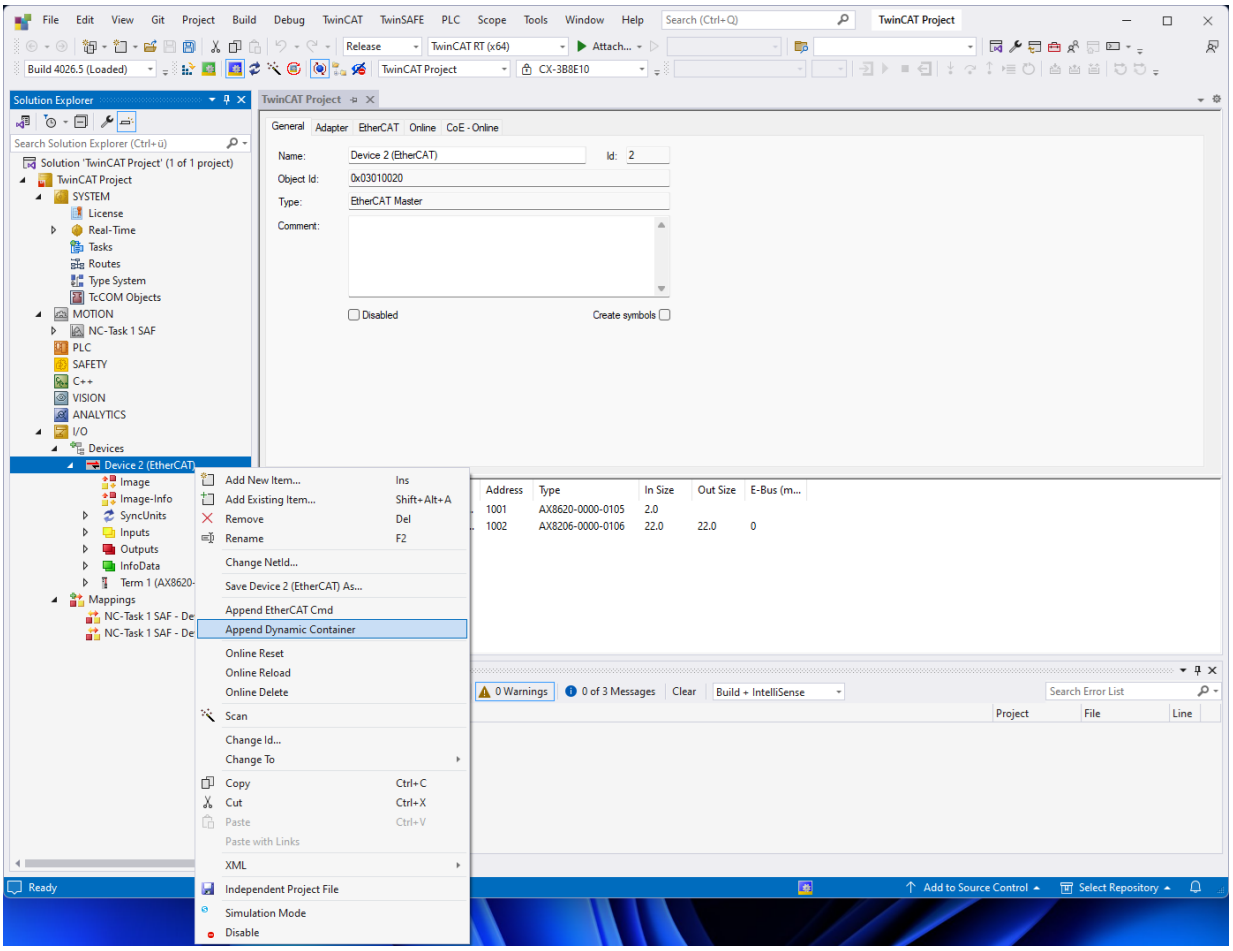
2. A solution with a project tree opens in the Solution Explorer. The Bode Plot can be found at the lowest level.
   In the Properties window, set the **Axis ID** and **Target Net ID** for the drive axis for which the Bode Plot is to be created.



3. Before you can perform the actual recording for the Bode Plot, you must adjust the settings in the TwinCAT project once.
   The Bode Plot is executed in the TwinCAT system by a TcCOM object. To ensure that this can be generated automatically from the Bode project, you must register the Class Factory for TcBodePlot and TcNcObjects.

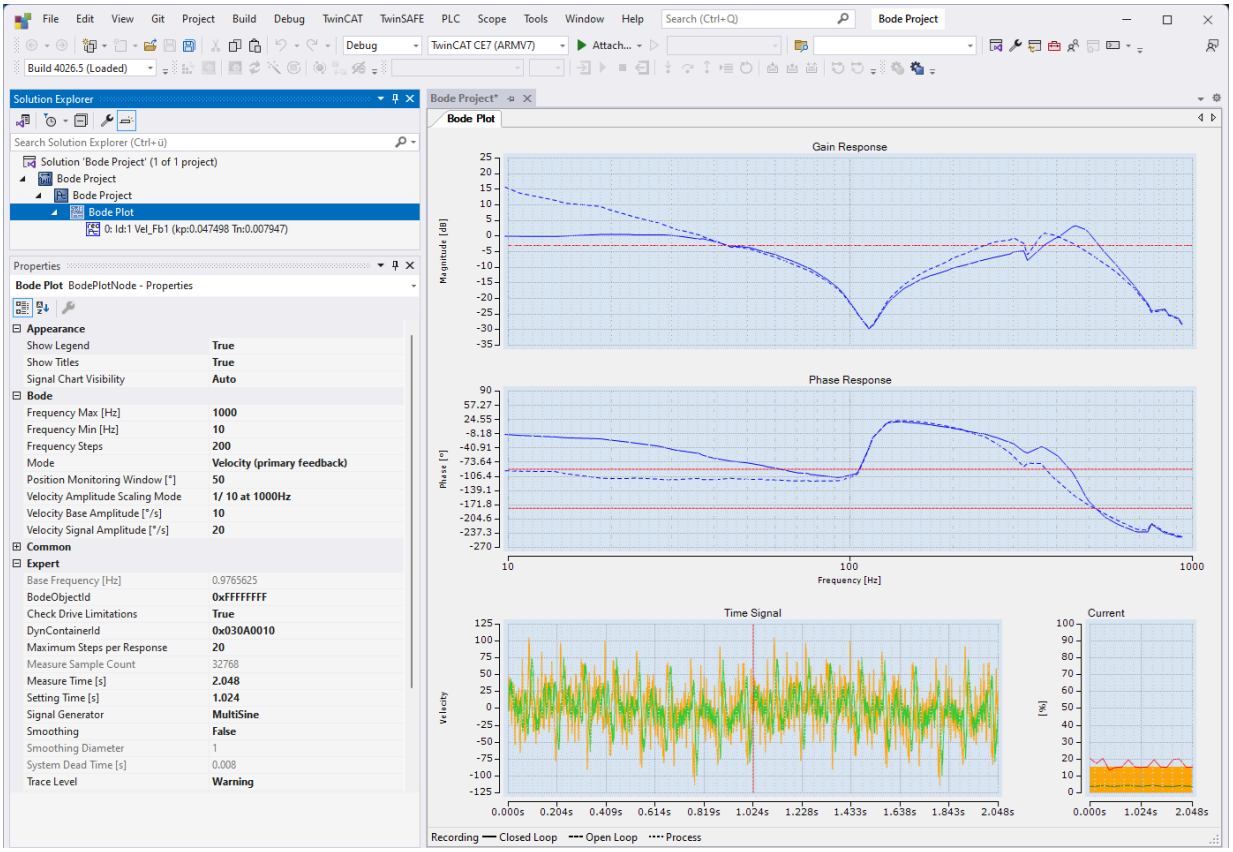


4. For dynamic communication with the drive, reserve a single memory area per EtherCAT device—known as a “Dynamic Container”—on the EtherCAT master.
   Confirm the subsequent dialog for querying the container size with **OK**. When using TcAutotuning, which is based on the Bode Plot, a container size of 512 is required.

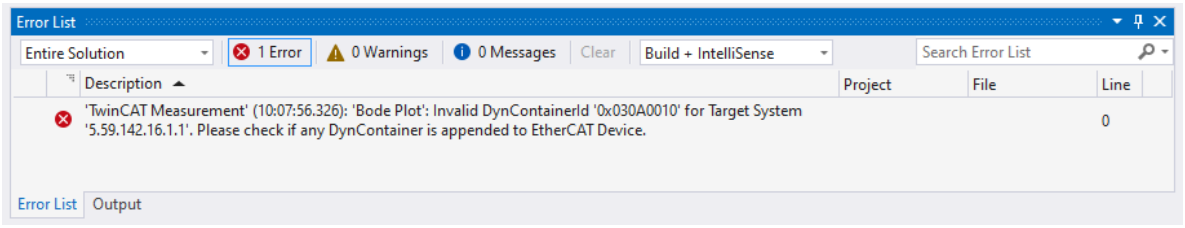


⇨ After having selected the target system and the drive axis, you can parameterize the recording in the Bode Plot properties. The details for the settings can be found in the section "Bode Plot – plot properties [▶ 20]".

5. The Bode Plot is started with the **Start Record** button in the Measurement toolbar. During the recording the current time signals are displayed below in the plot. You can abort the recording at any time with the **Stop Record** button.



⇨ If errors should occur during the recording, they are displayed in the Error List of the TwinCAT XAE Shell (or Visual Studio). For example, the Bode Plot reports a missing axis enable or the absence of a Dynamic Container when attempting to start the recording

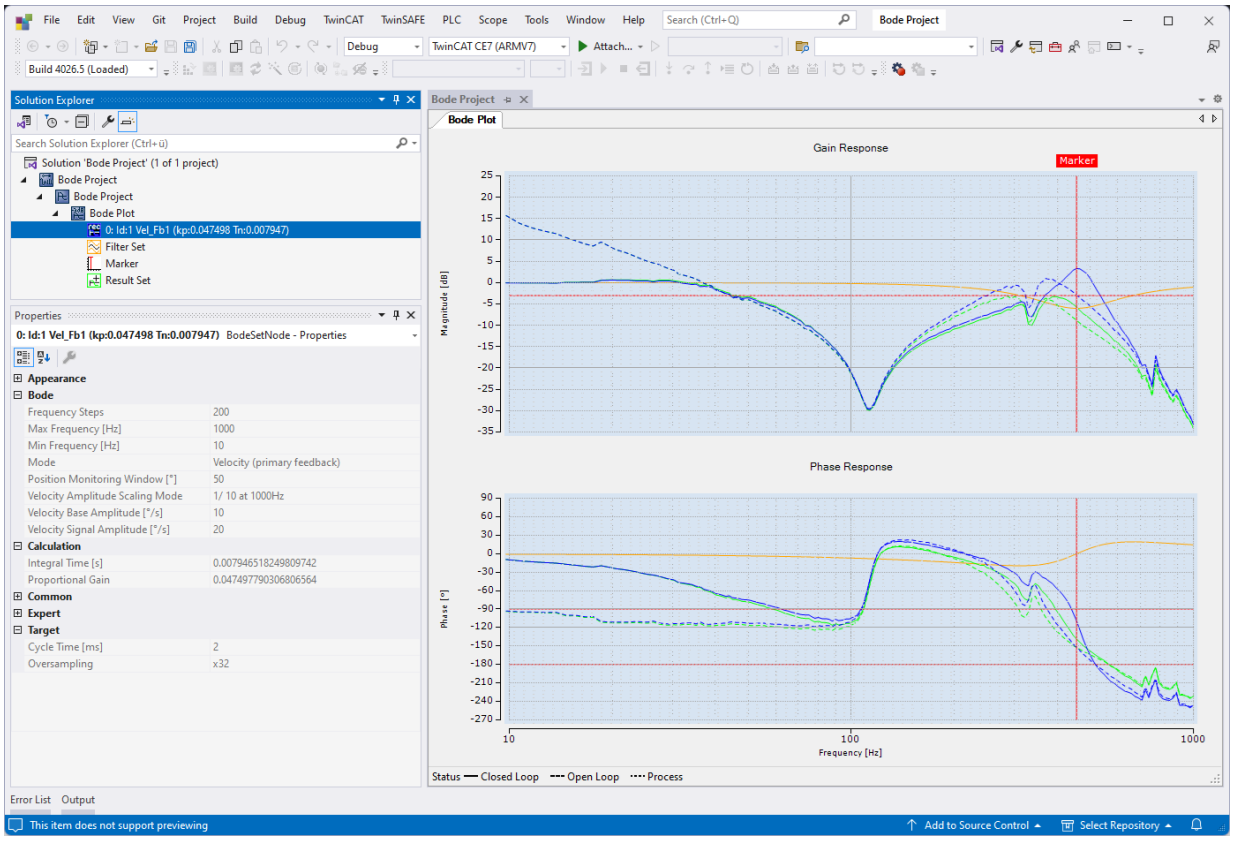


⇨ However, the Error List only displays the errors output by projects that are part of the active solution. Example: If a lag error is signaled for the drive axis and the project is not part of the active solution, a general Bode Plot error is output.
If the project is part of the active solution, then the lag error is also output in the Error List.

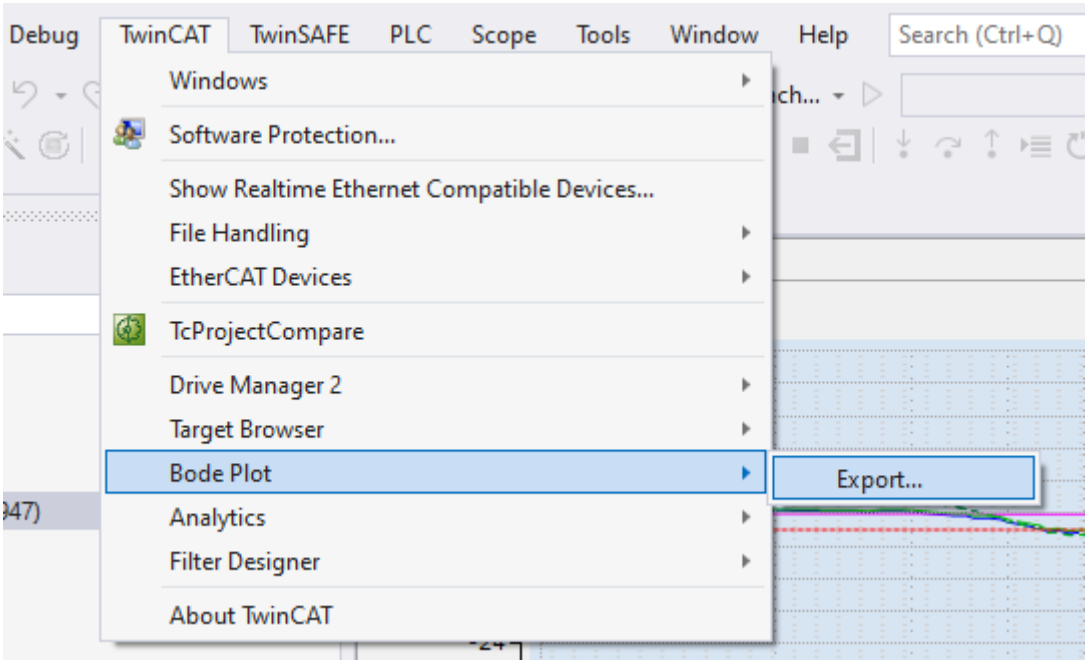
⇨ Following the recording you can see all the characteristic curves created so far.

6. You can change the display options in the Properties. For example, it may be useful to view the "process" as well as the "open loop" and "closed loop" (see Open and closed loops [▶ 11]), or to highlight or mask individual characteristic curves. For details on the settings, see the section"Bode Plot - set properties [▶ 24]."
In addition, you can also add Filter Sets to simulate filters or Result Sets to determine superposition

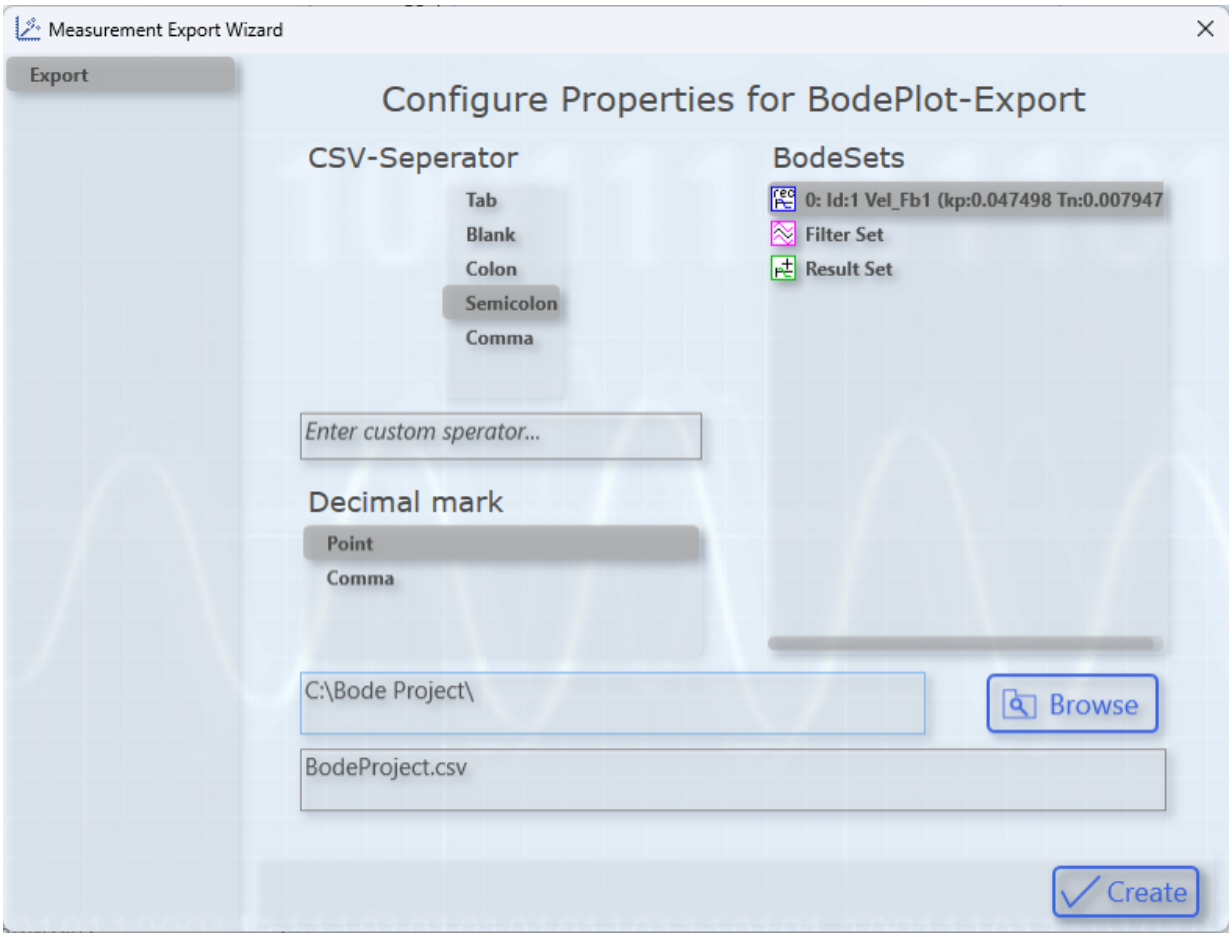
results.
Using markers makes it easier to read and compare the results.



7. After recording and analyzing the frequency responses, you can export the data. You can launch the Measurement Export Wizard from the TwinCAT menu.



8. In the following window, you have the choice of which Bode elements you want to export and can configure basic settings for the CSV format.



⇨ You have now created a Bode Plot.

Notes on the configuration of TwinCAT CNC axes

If a Bode Plot recording is to be generated for a TwinCAT CNC axis, the matching speed standardization f must be set for that axis in the axis parameter set.
Based on the AX5000's internal speed scaling (1 increment corresponds to a speed of 5.588×10^{-5} rpm), this is calculated using the following formula:

$$f = 5{,}588 \cdot 10^{-5} \cdot \frac{d}{i}$$

With

f: scaling factor [µm/min] or [10-3°/min]

d: feed per motor revolution [µm/rev] or [10-3°/rev]

i: gear ratio [-]

The resulting factor must then be entered in the axis parameter set for the respective axis. This is done by means of the parameters P-AXIS-00205 - P-AXIS-00207.

Example:

Linear axis with 5 mm feed per motor revolution and gear ratio 4.

$$f = 5{,}588 \cdot 10^{-5} \left[\frac{U}{min}\right] \cdot \frac{5000[\mu m]}{4[U]} = 0.06985 \left[\frac{\mu m}{min}\right]$$

This results in the following axis parameters:

antr.v_time_base	0	(P-AXIS-00207: time base = 1/min)
antr.v_reso_num	100000	(P-AXIS-00206: standardization factor counter)
antr.v_reso_denom	6985	(P-AXIS-00205: standardization factor denominator)

For more information on axis parameters, see the Beckhoff Information System:
TF5200 | TwinCAT 3 CNC Axis Parameters

7 Appendix

7.1 Return values

7.1.1 ADS Return Codes

Grouping of error codes:
Global error codes: 0x0000 [▶ 40]... (0x9811_0000 ...)
Router error codes: 0x500 [▶ 40]... (0x9811_0500 ...)
General ADS errors: 0x700 [▶ 41]... (0x9811_0700 ...)
RTime error codes: 0x1000 [▶ 43]... (0x9811_1000 ...)

Global error codes

Hex	Dec	HRESULT	Name	Description
0x0	0	0x98110000	ERR_NOERROR	No error.
0x1	1	0x98110001	ERR_INTERNAL	Internal error.
0x2	2	0x98110002	ERR_NORTIME	No real time.
0x3	3	0x98110003	ERR_ALLOCLOCKEDMEM	Allocation locked – memory error.
0x4	4	0x98110004	ERR_INSERTMAILBOX	Mailbox full – the ADS message could not be sent. Reducing the number of ADS messages per cycle will help.
0x5	5	0x98110005	ERR_WRONGRECEIVEHMSG	Wrong HMSG.
0x6	6	0x98110006	ERR_TARGETPORTNOTFOUND	Target port not found – ADS server is not started, not reachable or not installed.
0x7	7	0x98110007	ERR_TARGETMACHINENOTFOUND	Target computer not found – AMS route was not found.
0x8	8	0x98110008	ERR_UNKNOWNCMDID	Unknown command ID.
0x9	9	0x98110009	ERR_BADTASKID	Invalid task ID.
0xA	10	0x9811000A	ERR_NOIO	No IO.
0xB	11	0x9811000B	ERR_UNKNOWNAMSCMD	Unknown AMS command.
0xC	12	0x9811000C	ERR_WIN32ERROR	Win32 error.
0xD	13	0x9811000D	ERR_PORTNOTCONNECTED	Port not connected.
0xE	14	0x9811000E	ERR_INVALIDAMSLENGTH	Invalid AMS length.
0xF	15	0x9811000F	ERR_INVALIDAMSNETID	Invalid AMS Net ID.
0x10	16	0x98110010	ERR_LOWINSTLEVEL	Installation level is too low –TwinCAT 2 license error.
0x11	17	0x98110011	ERR_NODEBUGINTAVAILABLE	No debugging available.
0x12	18	0x98110012	ERR_PORTDISABLED	Port disabled – TwinCAT system service not started.
0x13	19	0x98110013	ERR_PORTALREADYCONNECTED	Port already connected.
0x14	20	0x98110014	ERR_AMSSYNC_W32ERROR	AMS Sync Win32 error.
0x15	21	0x98110015	ERR_AMSSYNC_TIMEOUT	AMS Sync Timeout.
0x16	22	0x98110016	ERR_AMSSYNC_AMSERROR	AMS Sync error.
0x17	23	0x98110017	ERR_AMSSYNC_NOINDEXINMAP	No index map for AMS Sync available.
0x18	24	0x98110018	ERR_INVALIDAMSPORT	Invalid AMS port.
0x19	25	0x98110019	ERR_NOMEMORY	No memory.
0x1A	26	0x9811001A	ERR_TCPSEND	TCP send error.
0x1B	27	0x9811001B	ERR_HOSTUNREACHABLE	Host unreachable.
0x1C	28	0x9811001C	ERR_INVALIDAMSFRAGMENT	Invalid AMS fragment.
0x1D	29	0x9811001D	ERR_TLSSEND	TLS send error – secure ADS connection failed.
0x1E	30	0x9811001E	ERR_ACCESSDENIED	Access denied – secure ADS access denied.

Router error codes

Hex	Dec	HRESULT	Name	Description
0x500	1280	0x98110500	ROUTERERR_NOLOCKEDMEMORY	Locked memory cannot be allocated.
0x501	1281	0x98110501	ROUTERERR_RESIZEMEMORY	The router memory size could not be changed.
0x502	1282	0x98110502	ROUTERERR_MAILBOXFULL	The mailbox has reached the maximum number of possible messages.
0x503	1283	0x98110503	ROUTERERR_DEBUGBOXFULL	The Debug mailbox has reached the maximum number of possible messages.
0x504	1284	0x98110504	ROUTERERR_UNKNOWNPORTTYPE	The port type is unknown.
0x505	1285	0x98110505	ROUTERERR_NOTINITIALIZED	The router is not initialized.
0x506	1286	0x98110506	ROUTERERR_PORTALREADYINUSE	The port number is already assigned.
0x507	1287	0x98110507	ROUTERERR_NOTREGISTERED	The port is not registered.
0x508	1288	0x98110508	ROUTERERR_NOMOREQUEUES	The maximum number of ports has been reached.
0x509	1289	0x98110509	ROUTERERR_INVALIDPORT	The port is invalid.
0x50A	1290	0x9811050A	ROUTERERR_NOTACTIVATED	The router is not active.
0x50B	1291	0x9811050B	ROUTERERR_FRAGMENTBOXFULL	The mailbox has reached the maximum number for fragmented messages.
0x50C	1292	0x9811050C	ROUTERERR_FRAGMENTTIMEOUT	A fragment timeout has occurred.
0x50D	1293	0x9811050D	ROUTERERR_TOBEREMOVED	The port is removed.

General ADS error codes

Hex	Dec	HRESULT	Name	Description
0x700	1792	0x98110700	ADSERR_DEVICE_ERROR	General device error.
0x701	1793	0x98110701	ADSERR_DEVICE_SRVNOTSUPP	Service is not supported by the server.
0x702	1794	0x98110702	ADSERR_DEVICE_INVALIDGRP	Invalid index group.
0x703	1795	0x98110703	ADSERR_DEVICE_INVALIDOFFSET	Invalid index offset.
0x704	1796	0x98110704	ADSERR_DEVICE_INVALIDACCESS	Reading or writing not permitted. Several causes are possible. For example, an incorrect password was entered when creating routes.
0x705	1797	0x98110705	ADSERR_DEVICE_INVALIDSIZE	Parameter size not correct.
0x706	1798	0x98110706	ADSERR_DEVICE_INVALIDDATA	Invalid data values.
0x707	1799	0x98110707	ADSERR_DEVICE_NOTREADY	Device is not ready to operate.
0x708	1800	0x98110708	ADSERR_DEVICE_BUSY	Device is busy.
0x709	1801	0x98110709	ADSERR_DEVICE_INVALIDCONTEXT	Invalid operating system context. This can result from use of ADS blocks in different tasks. It may be possible to resolve this through multitasking synchronization in the PLC.
0x70A	1802	0x9811070A	ADSERR_DEVICE_NOMEMORY	Insufficient memory.
0x70B	1803	0x9811070B	ADSERR_DEVICE_INVALIDPARM	Invalid parameter values.
0x70C	1804	0x9811070C	ADSERR_DEVICE_NOTFOUND	Not found (files, ...).
0x70D	1805	0x9811070D	ADSERR_DEVICE_SYNTAX	Syntax error in file or command.
0x70E	1806	0x9811070E	ADSERR_DEVICE_INCOMPATIBLE	Objects do not match.
0x70F	1807	0x9811070F	ADSERR_DEVICE_EXISTS	Object already exists.
0x710	1808	0x98110710	ADSERR_DEVICE_SYMBOLNOTFOUND	Symbol not found.
0x711	1809	0x98110711	ADSERR_DEVICE_SYMBOLVERSIONINVALID	Invalid symbol version. This can occur due to an online change. Create a new handle.
0x712	1810	0x98110712	ADSERR_DEVICE_INVALIDSTATE	Device (server) is in invalid state.
0x713	1811	0x98110713	ADSERR_DEVICE_TRANSMODENOTSUPP	AdsTransMode not supported.
0x714	1812	0x98110714	ADSERR_DEVICE_NOTIFYHNDINVALID	Notification handle is invalid.
0x715	1813	0x98110715	ADSERR_DEVICE_CLIENTUNKNOWN	Notification client not registered.
0x716	1814	0x98110716	ADSERR_DEVICE_NOMOREHDLS	No further handle available.
0x717	1815	0x98110717	ADSERR_DEVICE_INVALIDWATCHSIZE	Notification size too large.
0x718	1816	0x98110718	ADSERR_DEVICE_NOTINIT	Device not initialized.
0x719	1817	0x98110719	ADSERR_DEVICE_TIMEOUT	Device has a timeout.
0x71A	1818	0x9811071A	ADSERR_DEVICE_NOINTERFACE	Interface query failed.
0x71B	1819	0x9811071B	ADSERR_DEVICE_INVALIDINTERFACE	Wrong interface requested.
0x71C	1820	0x9811071C	ADSERR_DEVICE_INVALIDCLSID	Class ID is invalid.
0x71D	1821	0x9811071D	ADSERR_DEVICE_INVALIDOBJID	Object ID is invalid.
0x71E	1822	0x9811071E	ADSERR_DEVICE_PENDING	Request pending.
0x71F	1823	0x9811071F	ADSERR_DEVICE_ABORTED	Request is aborted.
0x720	1824	0x98110720	ADSERR_DEVICE_WARNING	Signal warning.
0x721	1825	0x98110721	ADSERR_DEVICE_INVALIDARRAYIDX	Invalid array index.
0x722	1826	0x98110722	ADSERR_DEVICE_SYMBOLNOTACTIVE	Symbol not active.
0x723	1827	0x98110723	ADSERR_DEVICE_ACCESSDENIED	Access denied. Several causes are possible. For example, a unidirectional ADS route is used in the opposite direction.
0x724	1828	0x98110724	ADSERR_DEVICE_LICENSENOTFOUND	Missing license.
0x725	1829	0x98110725	ADSERR_DEVICE_LICENSEEXPIRED	License expired.
0x726	1830	0x98110726	ADSERR_DEVICE_LICENSEEXCEEDED	License exceeded.
0x727	1831	0x98110727	ADSERR_DEVICE_LICENSEINVALID	Invalid license.
0x728	1832	0x98110728	ADSERR_DEVICE_LICENSESYSTEMID	License problem: System ID is invalid.
0x729	1833	0x98110729	ADSERR_DEVICE_LICENSENOTIMELIMIT	License not limited in time.
0x72A	1834	0x9811072A	ADSERR_DEVICE_LICENSEFUTUREISSUE	Licensing problem: time in the future.
0x72B	1835	0x9811072B	ADSERR_DEVICE_LICENSETIMETOLONG	License period too long.
0x72C	1836	0x9811072C	ADSERR_DEVICE_EXCEPTION	Exception at system startup.
0x72D	1837	0x9811072D	ADSERR_DEVICE_LICENSEDUPLICATED	License file read twice.
0x72E	1838	0x9811072E	ADSERR_DEVICE_SIGNATUREINVALID	Invalid signature.
0x72F	1839	0x9811072F	ADSERR_DEVICE_CERTIFICATEINVALID	Invalid certificate.
0x730	1840	0x98110730	ADSERR_DEVICE_LICENSEOEMNOTFOUND	Public key not known from OEM.
0x731	1841	0x98110731	ADSERR_DEVICE_LICENSERESTRICTED	License not valid for this system ID.

Hex	Dec	HRESULT	Name	Description
0x732	1842	0x98110732	ADSERR_DEVICE_LICENSEDEMODENIED	Demo license prohibited.
0x733	1843	0x98110733	ADSERR_DEVICE_INVALIDFNCID	Invalid function ID.
0x734	1844	0x98110734	ADSERR_DEVICE_OUTOFRANGE	Outside the valid range.
0x735	1845	0x98110735	ADSERR_DEVICE_INVALIDALIGNMENT	Invalid alignment.
0x736	1846	0x98110736	ADSERR_DEVICE_LICENSEPLATFORM	Invalid platform level.
0x737	1847	0x98110737	ADSERR_DEVICE_FORWARD_PL	Context – forward to passive level.
0x738	1848	0x98110738	ADSERR_DEVICE_FORWARD_DL	Context – forward to dispatch level.
0x739	1849	0x98110739	ADSERR_DEVICE_FORWARD_RT	Context – forward to real-time.
0x740	1856	0x98110740	ADSERR_CLIENT_ERROR	Client error.
0x741	1857	0x98110741	ADSERR_CLIENT_INVALIDPARM	Service contains an invalid parameter.
0x742	1858	0x98110742	ADSERR_CLIENT_LISTEMPTY	Polling list is empty.
0x743	1859	0x98110743	ADSERR_CLIENT_VARUSED	Var connection already in use.
0x744	1860	0x98110744	ADSERR_CLIENT_DUPLINVOKEID	The called ID is already in use.
0x745	1861	0x98110745	ADSERR_CLIENT_SYNCTIMEOUT	Timeout has occurred – the remote terminal is not responding in the specified ADS timeout. The route setting of the remote terminal may be configured incorrectly.
0x746	1862	0x98110746	ADSERR_CLIENT_W32ERROR	Error in Win32 subsystem.
0x747	1863	0x98110747	ADSERR_CLIENT_TIMEOUTINVALID	Invalid client timeout value.
0x748	1864	0x98110748	ADSERR_CLIENT_PORTNOTOPEN	Port not open.
0x749	1865	0x98110749	ADSERR_CLIENT_NOAMSADDR	No AMS address.
0x750	1872	0x98110750	ADSERR_CLIENT_SYNCINTERNAL	Internal error in Ads sync.
0x751	1873	0x98110751	ADSERR_CLIENT_ADDHASH	Hash table overflow.
0x752	1874	0x98110752	ADSERR_CLIENT_REMOVEHASH	Key not found in the table.
0x753	1875	0x98110753	ADSERR_CLIENT_NOMORESYM	No symbols in the cache.
0x754	1876	0x98110754	ADSERR_CLIENT_SYNCRESINVALID	Invalid response received.
0x755	1877	0x98110755	ADSERR_CLIENT_SYNCPORTLOCKED	Sync Port is locked.
0x756	1878	0x98110756	ADSERR_CLIENT_REQUESTCANCELLED	The request was canceled.

RTime error codes

Hex	Dec	HRESULT	Name	Description
0x1000	4096	0x98111000	RTERR_INTERNAL	Internal error in the real-time system.
0x1001	4097	0x98111001	RTERR_BADTIMERPERIODS	Timer value is not valid.
0x1002	4098	0x98111002	RTERR_INVALIDTASKPTR	Task pointer has the invalid value 0 (zero).
0x1003	4099	0x98111003	RTERR_INVALIDSTACKPTR	Stack pointer has the invalid value 0 (zero).
0x1004	4100	0x98111004	RTERR_PRIOEXISTS	The request task priority is already assigned.
0x1005	4101	0x98111005	RTERR_NOMORETCB	No free TCB (Task Control Block) available. The maximum number of TCBs is 64.
0x1006	4102	0x98111006	RTERR_NOMORESEMAS	No free semaphores available. The maximum number of semaphores is 64.
0x1007	4103	0x98111007	RTERR_NOMOREQUEUES	No free space available in the queue. The maximum number of positions in the queue is 64.
0x100D	4109	0x9811100D	RTERR_EXTIRQALREADYDEF	An external synchronization interrupt is already applied.
0x100E	4110	0x9811100E	RTERR_EXTIRQNOTDEF	No external sync interrupt applied.
0x100F	4111	0x9811100F	RTERR_EXTIRQINSTALLFAILED	Application of the external synchronization interrupt has failed.
0x1010	4112	0x98111010	RTERR_IRQLNOTLESSOREQUAL	Call of a service function in the wrong context
0x1017	4119	0x98111017	RTERR_VMXNOTSUPPORTED	Intel® VT-x extension is not supported.
0x1018	4120	0x98111018	RTERR_VMXDISABLED	Intel® VT-x extension is not enabled in the BIOS.
0x1019	4121	0x98111019	RTERR_VMXCONTROLSMISSING	Missing function in Intel® VT-x extension.
0x101A	4122	0x9811101A	RTERR_VMXENABLEFAILS	Activation of Intel® VT-x fails.

Specific positive HRESULT Return Codes:

HRESULT	Name	Description
0x0000_0000	S_OK	No error.
0x0000_0001	S_FALSE	No error. Example: successful processing, but with a negative or incomplete result.
0x0000_0203	S_PENDING	No error. Example: successful processing, but no result is available yet.
0x0000_0256	S_WATCHDOG_TIMEOUT	No error. Example: successful processing, but a timeout occurred.

TCP Winsock error codes

Hex	Dec	Name	Description
0x274C	10060	WSAETIMEDOUT	A connection timeout has occurred - error while establishing the connection, because the remote terminal did not respond properly after a certain period of time, or the established connection could not be maintained because the connected host did not respond.
0x274D	10061	WSAECONNREFUSED	Connection refused - no connection could be established because the target computer has explicitly rejected it. This error usually results from an attempt to connect to a service that is inactive on the external host, that is, a service for which no server application is running.
0x2751	10065	WSAEHOSTUNREACH	No route to host - a socket operation referred to an unavailable host.
More Winsock error codes: Win32 error codes			

7.1.2 Bode Return Codes

The following bode plot specific error codes are used in the bode plot server:

Code (Hex)	Code (Dec)	Symbol	Description
0x8100	33024	INTERNAL	Internal error
0x8101	33025	NOTINITIALIZED	Not initialized (e.g. no nc axis)
0x8102	33026	INVALIDPARAM	Invalid parameter
0x8103	33027	INVALIDOFFSET	Invalid index offset
0x8104	33028	INVALIDSIZE	Invalid parameter size
0x8105	33029	INVALIDSTARTPARAM	Invalid start parameter (set point generator)
0x8106	33030	NOTSUPPORTED	Not supported
0x8107	33031	AXISNOTENABLED	Nc axis not enabled
0x8108	33032	AXISINERRORSTATE	Nc axis in error state
0x8109	33033	DRIVEINERRORSTATE	IO drive in error state
0x810A	33034	AXISANDDRIVEINERROR-STATE	Nc axis AND IO drive in error state
0x810B	33035	INVALIDDRIVEOPMODE	Invalid drive operation mode active or requested (no bode plot mode)
0x810C	33036	INVALIDCONTEXT	Invalid context for this command (mandatory task or windows context needed)
0x810D	33037	NOAXISINTERFACE	**Missing TCom axis interface (axis null pointer).** There is no connection to the NC axis. Either no axis (or axis ID) has been parameterized, or the parameterized axis does not exist.
0x810E	33038	INPUTCYCLECOUNTER	**Invalid input cycle counter from IO drive (e.g. frozen).** The cyclic drive data are backed up by an ‘InputCycleCounter’ during the bode plot recording. This allows firstly the detection of an unexpected communication loss (keyword: LifeCounter) and secondly a check for temporal data consistency to be performed. **Example 1:** This error can occur if the cycle time of the calling task is larger than the assumed drive cycle time (in this case, however, the error occurs right at the start of the recording). **Example 2:** This error can occur if the calling task has real-time errors (e.g. the "Exceed Counter" of the task increments or the task has a lower priority, as is often the case, for example, with the PLC). In this case the error can also occur at any time during the recording. **Example 3:** This error can occur more frequently if the real-time load on the computer is quite high (>50 %). **Note:** Refer also to the corresponding AX5000 drive error code F440.

Code (Hex)	Code (Dec)	Symbol	Description
0x810F	33039	POSITION MONITORING (=> NC Runtime Error)	**Position monitoring: Axis position is outside of the maximum allowed moving range.** The axis has left the parameterized position range window, whereupon the recording was aborted and the NC axis was placed in the error state 0x810F (with standard NC error handling). The position range window acts symmetrically around the start position of the axis (see also parameter description *Position Monitoring Window*). Typical error message in the logger: *"BodePlot: 'Position Monitoring' error 0x%x because the actual position %f is above the maximum limit %f of the allowed position range (StartPos=%f, Window=%f)"*
0x8110	33040	DRIVELIMITATIONDETECTED	**Driver limitations detected (current or velocity limitations) which causes a nonlinear behavior and invalid results of the bode plot.** A bode plot recording requires an approximately linear transmission link. If the velocity or current is limited in the drive device, however, this non-linear behavior is detected and the bode plot recording is aborted. Reasons for these limitations can be: choosing too large an amplitude for the position, velocity or torque interface, or an unsuitable choice of amplitude scaling mode (see also parameter description *Amplitude Scaling Mode, Base Amplitude, Signal Amplitude*). Typical error message in the logger: *"BodePlot: Sequence aborted with error 0x%x because the current limit of the drive has been exceeded (%d times) which causes a nonlinear behavior and invalid results of the bode plot"*
0x8111	33041	LIFECOUNTERMONITORING (=> NC Runtime Error)	**Life counter monitoring (heartbeat): Lost of communication to GUI detected after watchdog timeout is elapsed.** The graphical user interface from which the bode plot recording was started is no longer communicating with the bode plot driver in the expected rhythm (keyword: ‘Life Counter’). Therefore the recording is terminated immediately and the NC axes are placed in the error state 0x8111 (with standard NC error handling). Possible reasons for this can be an user interface crash or a major malfunction of the Windows context. Typical error message in the logger: *"BodePlot: Sequence aborted with GUI Life Counter error 0x%x because the WatchDog timeout of %f s elapsed ('%s')"*

Code (Hex)	Code (Dec)	Symbol	Description
0x8112	33042	NCERR_BODEPLOT_WCSTATE	**WC state error (IO data working counter)** IO working counter error (WC state), for example due to real-time errors, EtherCAT CRC errors or telegram failures, EtherCAT device not communicating (OP state), etc.
0x8113-0x811F	33043-33055	RESERVED	**Reserved range**

7.2 FAQ - frequently asked questions and answers

Frequently asked questions are answered in this section in order to make it easier for you to work with TwinCAT 3 Bode Plot.
If you have any further questions, please contact our support (-157) and ask to speak to a drive expert.

1. Can a machine get into a critical situation due to the Bode function? [▶ 47]
2. The Bode recording is started and nothing happens. What could be the cause? [▶ 47]
3. Can the Bode function be executed in U/F mode with an asynchronous motor? [▶ 47]
4. Can the Bode function be started with vertical axes? [▶ 47]
5. How does the Bode function behave on axes with play? [▶ 47]
6. Can the Bode function be used with "non-Beckhoff motors"? [▶ 47]
7. How many measuring points should be selected for a meaningful representation? [▶ 48]
8. Which measuring ranges are useful? [▶ 48]
9. Does the NC cycle time have an effect on the Bode representation? [▶ 48]
10. What system requirements must my PC fulfill? [▶ 48]
11. Are open source software components used in TwinCAT Measurement products? [▶ 48]

Can a machine get into a critical situation due to the Bode function?

Yes, undesired movements may occur due to the occurrence of a mechanical resonance. A functioning emergency stop circuit is therefore essential.

The Bode recording is started and nothing happens. What could be the cause?

Possible causes could be:

- The axis is not released.
- There is a drive error. (This can be read in the TC_Drive_Manager).
- Safety has canceled the release.
- Lag error monitoring is active.

Can the Bode function be executed in U/F mode with an asynchronous motor?

No, the Bode function is possible only in controlled mode with feedback.

Can the Bode function be started with vertical axes?

Yes, but only in the "Velocity" mode. Note that "drifting " of the axis can occur here. If the axis is equipped with pneumatic assistance, this damping also affects the measurement result.

How does the Bode function behave on axes with play?

The mass may be metrologically decoupled. It is particularly important here to adapt the fundamental oscillation and measuring amplitude.

Can the Bode function be used with "non-Beckhoff motors"?

Yes, there is no manufacturer limitation.

How many measuring points should be selected for a meaningful representation?

10 to 20 per decade and of course more if necessary.

Which measuring ranges are useful?

5 - 500 Hz in Velocity mode, 50 - 3000 Hz in Current mode.

Does the NC cycle time have an effect on the Bode representation?

The measured values are transmitted in so-called dynamic containers. Furthermore, the oversampling method ensures precise reproduction of the measured values. The NC cycle time should be around </= 2 ms.

What system requirements must my PC fulfill?

At least TC3.1X4016.x XAE and the system requirements associated with it.

Are open source software components used in TwinCAT Measurement products?

Yes, various open source components are used.
Please see the information on the page Third-party components [▶ 48].

7.3 Third-party components

This software contains third-party components.
Please refer to the license file provided in the following folder for further information:
C:\Program Files(x86)\Beckhoff\Legal\TwinCAT-XAE-BodePlot

8 Support and Service

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Glossary

Bode Diagramm/Plot

Displays two functional graphs, one of which shows the amplitude gain and the other the phase shift.

Filter Set

Displays the characteristic curve of a filter in the TwinCAT Bode Plot project.

Record Set

Displays the result of a real measurement in the TwinCAT Bode Plot project in Visual Studio.

Result Set

Displays the combined result of two already existing sets.

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