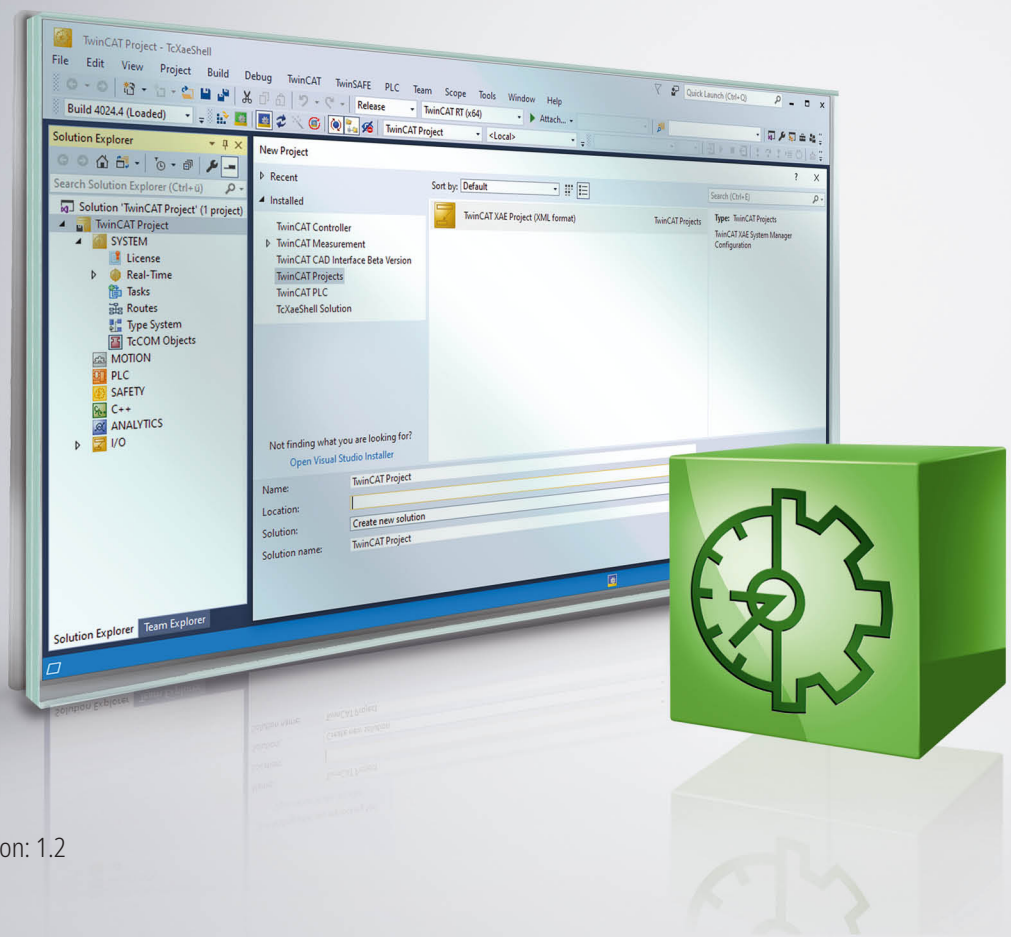
BECKHOFF New Automation Technology

Manual | EN

TE132x

TwinCAT 3 | Bode Plot



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1 Foreword

1.1 Notes on the documentation

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

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

Disclaimer

The documentation has been prepared with care. The products described are, however, constantly under development.
We reserve the right to revise and change the documentation at any time and without prior announcement.
No claims for the modification of products that have already been supplied may be made on the basis of the data, diagrams and descriptions in this documentation.

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Patent Pending

The EtherCAT Technology is covered, including but not limited to the following patent applications and patents:
EP1590927, EP1789857, EP1456722, EP2137893, DE102015105702
with corresponding applications or registrations in various other countries.

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1.2 Safety instructions

Safety regulations

Please note the following safety instructions and explanations!
Product-specific safety instructions can be found on following pages or in the areas mounting, wiring, commissioning etc.

Exclusion of liability

All the components are supplied in particular hardware and software configurations 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 engineering who are familiar with the applicable national standards.

Description of symbols

In this documentation the following symbols are used with an accompanying safety instruction or note. The safety instructions must be read carefully and followed without fail!

⚠ DANGER

Serious risk of injury!

Failure to follow the safety instructions associated with this symbol directly endangers the life and health of persons.

⚠ WARNING

Risk of injury!

Failure to follow the safety instructions associated with this symbol endangers the life and health of persons.

⚠ CAUTION

Personal injuries!

Failure to follow the safety instructions associated with this symbol can lead to injuries to persons.

NOTE

Damage to the environment or devices

Failure to follow the instructions associated with this symbol can lead to damage to the environment or equipment.

Tip or pointer

This symbol indicates information that contributes to better understanding.

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 Bode Plot can be used in connection with the AX5xxx drives 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 (“sinus 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 are easy to recognize in the Bode diagram. 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 physically loaded.

Key-Features:

- Illustration of mechanical resonances
- Determination of the bandwidth, as well as phase and amplitude reserves
- Direct simulation of the filter and its 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 then driven automatically for the selected axis. The current output values for amplitude gain and phase shift are continuously transmitted during the execution to the charting 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 make 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. releases, 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
Open Loop	✔
Close Loop	✔
Velocity Mode	✔
Current Mode	✔
Filter simulation	✔
Graph Overlapping	✔
Individual oversampling factor	✔ (Expert Mode)

3 Installation

3.1 System requirements

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

Supported operating systems

Windows XP, Windows XP Embedded, Windows Embedded Standard 2009, Windows 7

TwinCAT

Minimum is TwinCAT 3 ADS.

.NET Framework

The .NET Framework 4.0 is required.

The 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 free from licensing costs in the base version. Please refer to the product overview page for the functional scope of the base version.

3.2 Downloading the setup file

Like many other TwinCAT 3 engineering tools, the TwinCAT Bode Plot is available for download on the Beckhoff website. It is always the most current version of the product, which can be licensed for each product level. Perform the following steps to download the setup file:

1. Start a web browser of your choice and go to the Beckhoff website at www.beckhoff.com
2. Navigate in the tree to the nodes **Automation/TwinCAT3/TE1xxx | TC3 Engineering/TE132x | TC3 Bode Plot**
3. Here you can download the TwinCAT Measurement Setup file via the download button. If you select "Full", the setup also brings along the Microsoft Visual Studio Shell, in which the TwinCAT Bode Plot integrates itself. If the shell or another full version of Microsoft Visual Studio is already installed on the target system, the Update setup is sufficient.
4. Click on the Download link in order to place the software in the shopping cart. Then click on "Start download".

(Optional) Transfer the downloaded file to the TwinCAT runtime system you wish to install the product on.

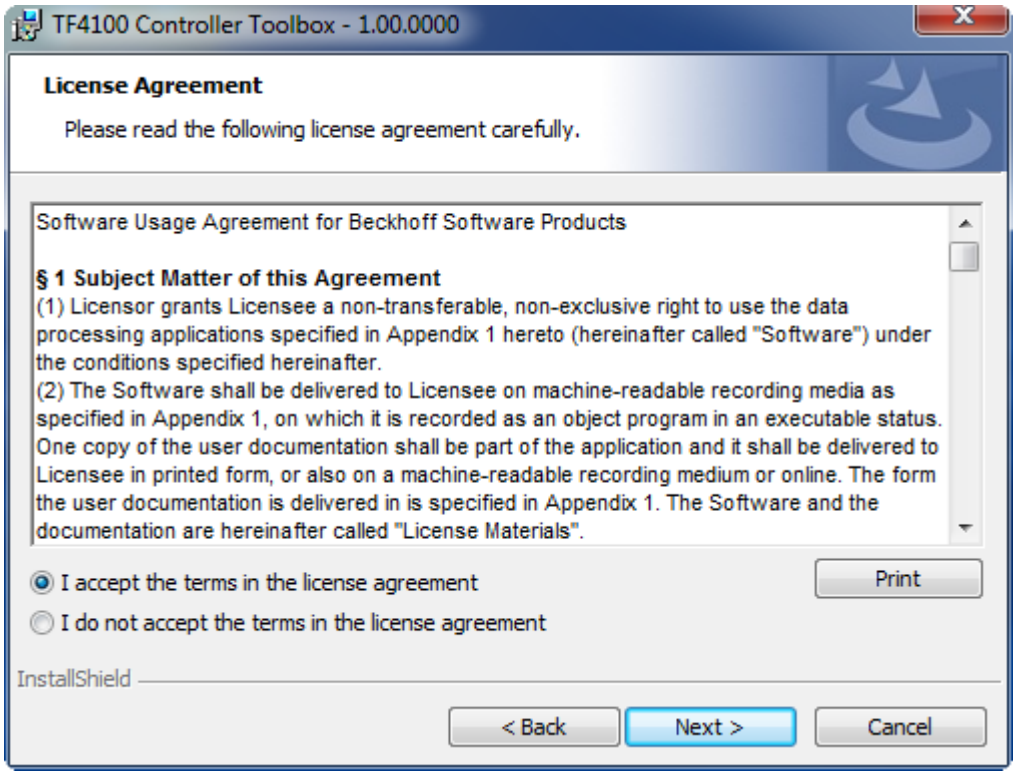
3.3 Installation

The following section describes how to install the TwinCAT 3 Function for Windows-based operating systems.

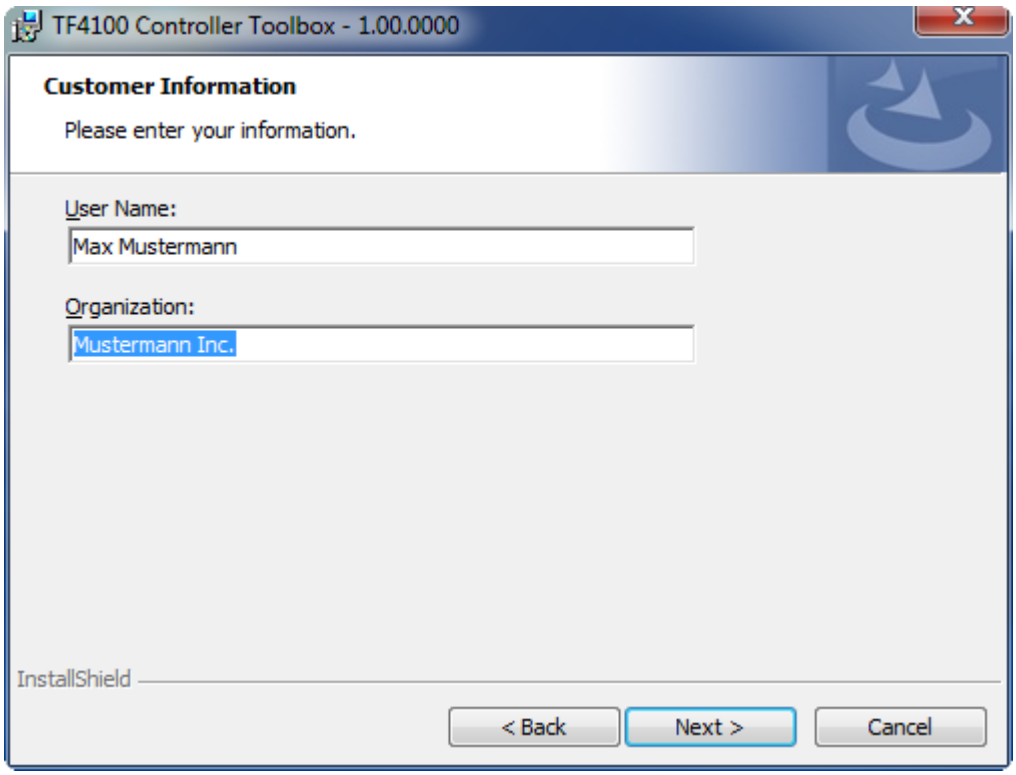
✓ The TwinCAT 3 Function setup file was downloaded from the Beckhoff website.

1. Run the setup file as administrator. To do this, select the command **Run as administrator** in the context menu of the file.
   ⇨ The installation dialog opens.

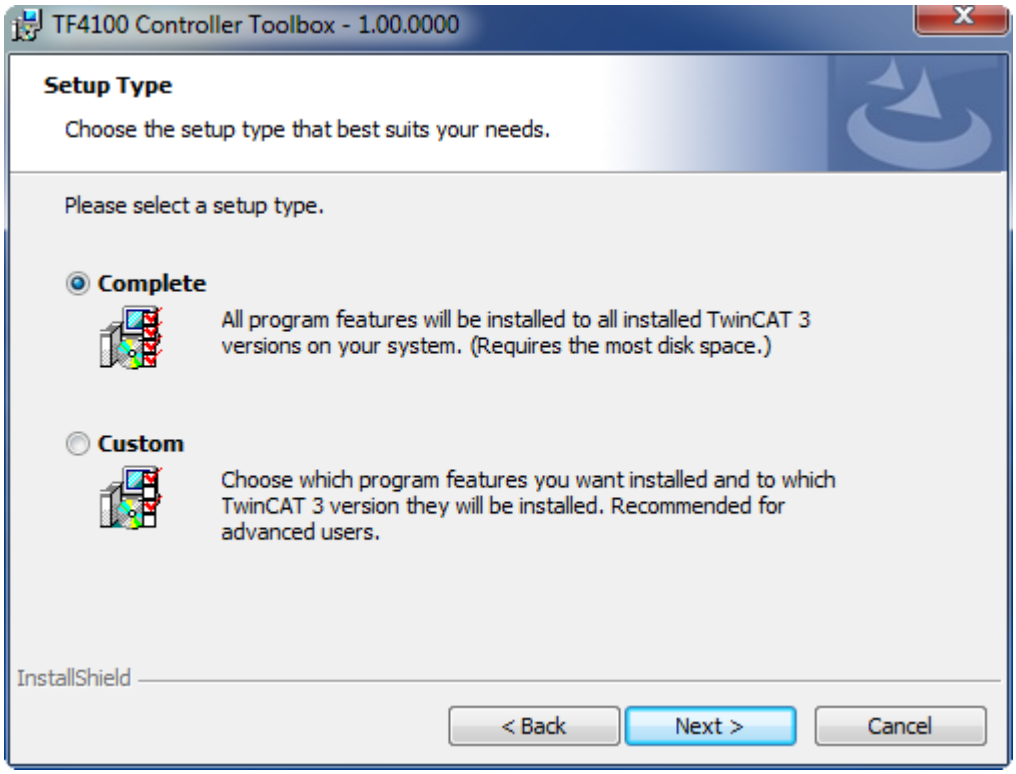
2. Accept the end user licensing agreement and click **Next**.



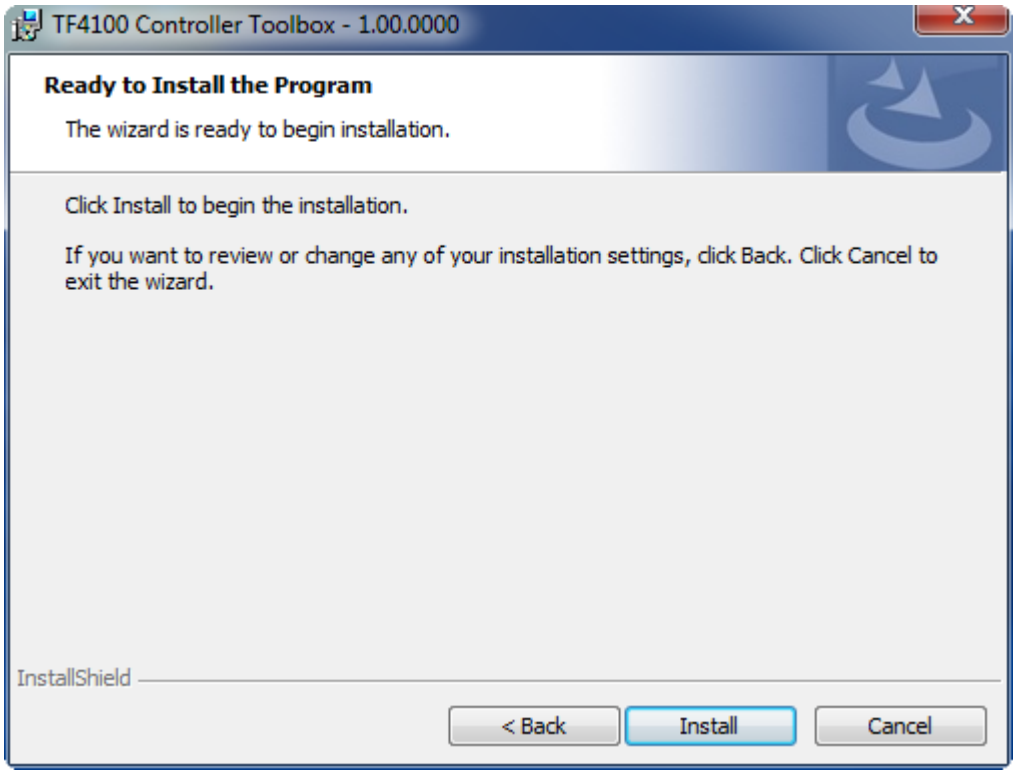
3. Enter your user data.



4. If you want to install the full version of the TwinCAT 3 Function, select **Complete** as installation type. If you want to install the TwinCAT 3 Function components separately, select **Custom**.

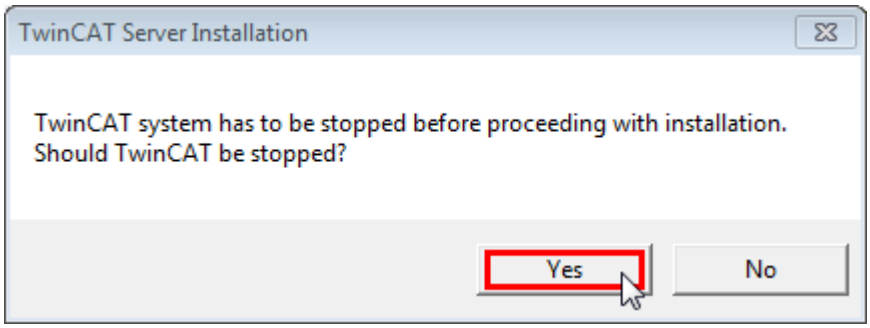


5. Select **Next**, then **Install** to start the installation.

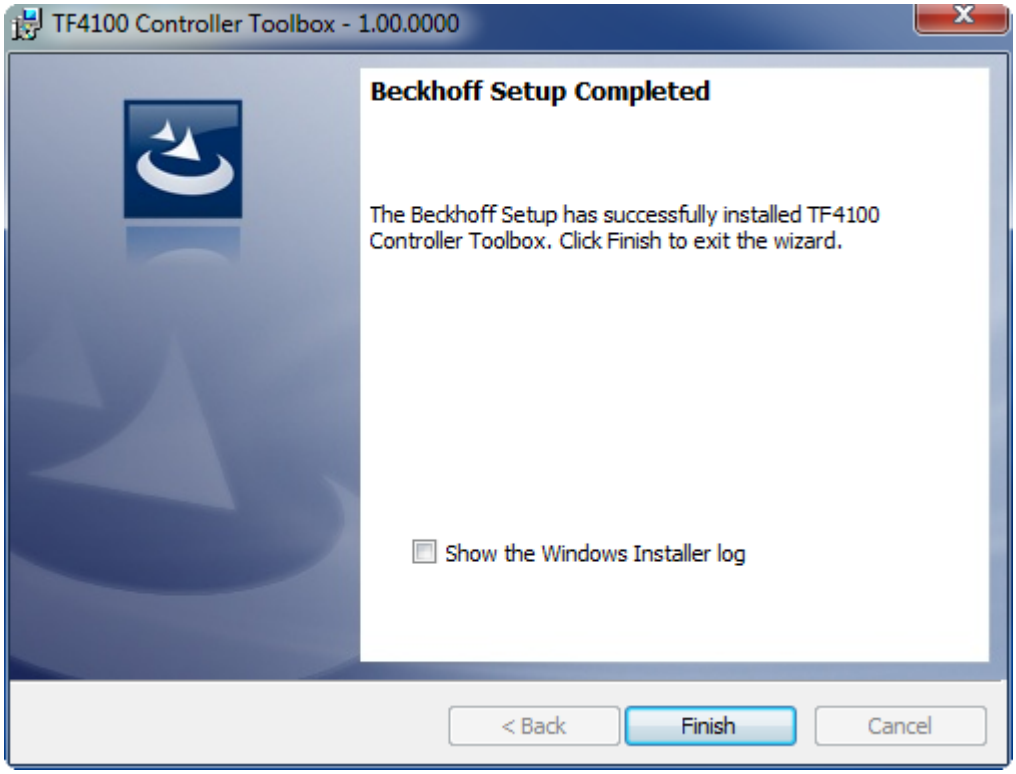


⇨ A dialog box informs you that the TwinCAT system must be stopped to proceed with the installation.

6. Confirm the dialog with **Yes**.



7. Select **Finish** to exit the setup.



⇨ The TwinCAT 3 Function has been successfully installed and can be licensed (see Licensing).

3.4 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 [▶ 16]

4 Technical introduction

4.1 Bode Plot principles

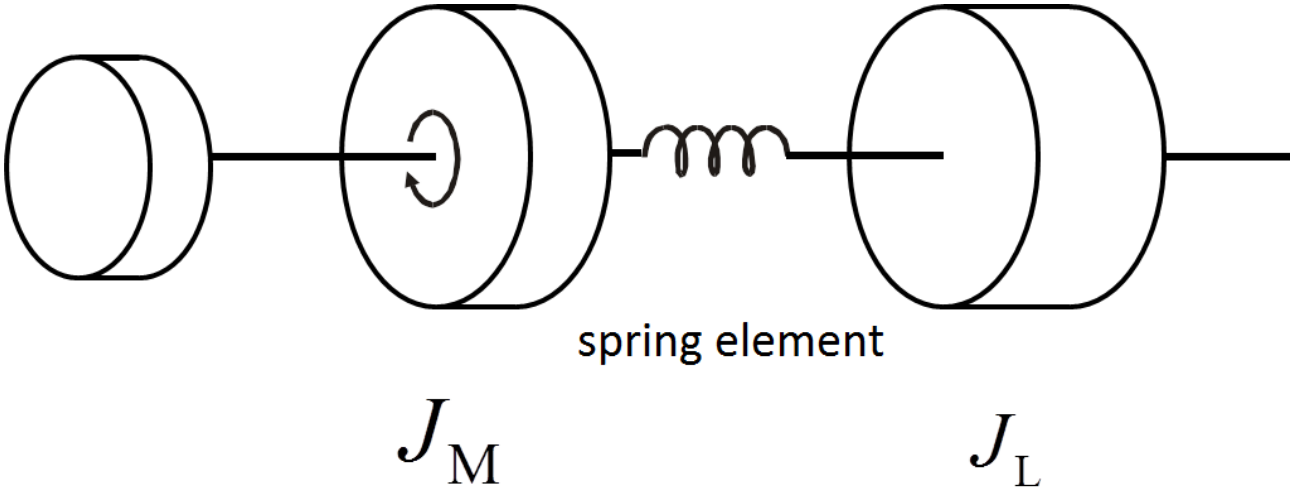
The Bode diagram is a special representation of a complex transfer function or of a system in the frequency range. The Bode diagram consists of a graph for the value (amplitude response) and a graph for the phase shift (phase response). It describes the stationary reaction of the system to a harmonic excitation (sinus 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 diagram analysis to analyze the behavior of the closed and open control 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 diagram 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
- Problem frequencies (mechanical resonance points) are simpler to analyze
- Filters can be determined and adapted accordingly

What generates resonances in a drive train?

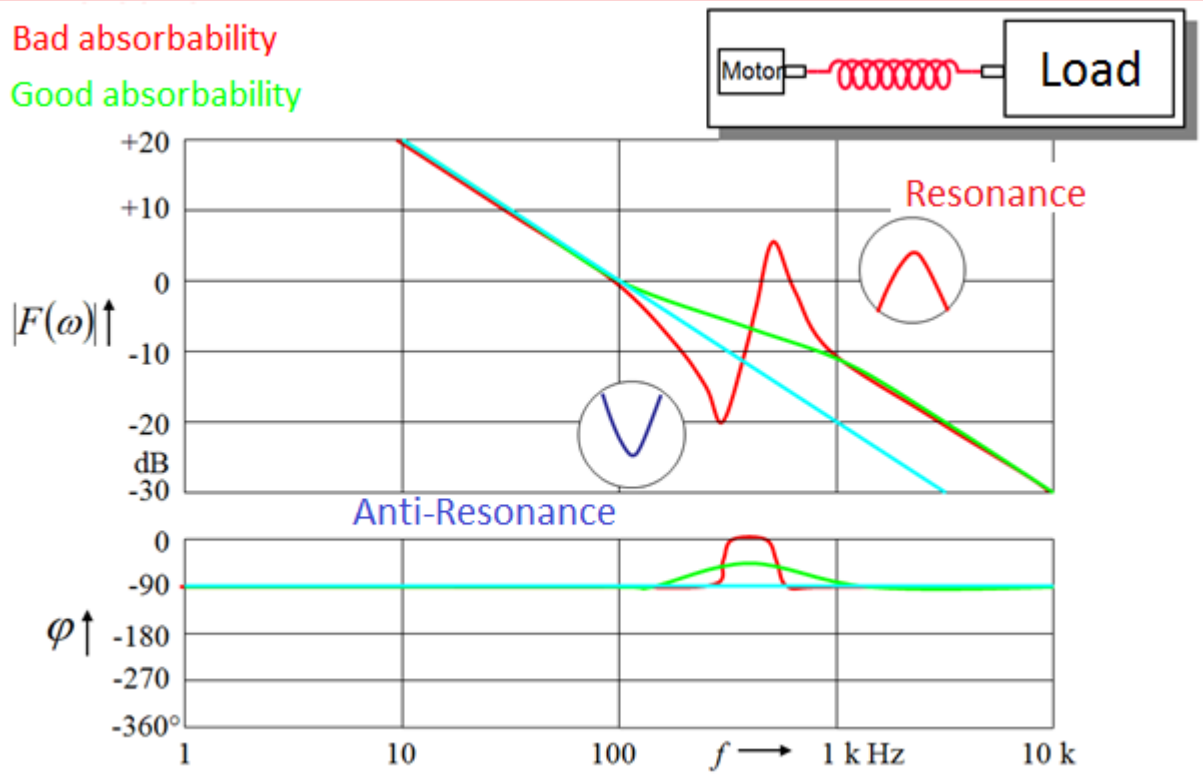


Each coupling between load and motor has a finite rigidity. This leads to different inertia ratios and different resonant frequencies of the complete system. These different frequencies are difficult to determine without a suitable tool. The frequency analysis can be performed with an almost infinitely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

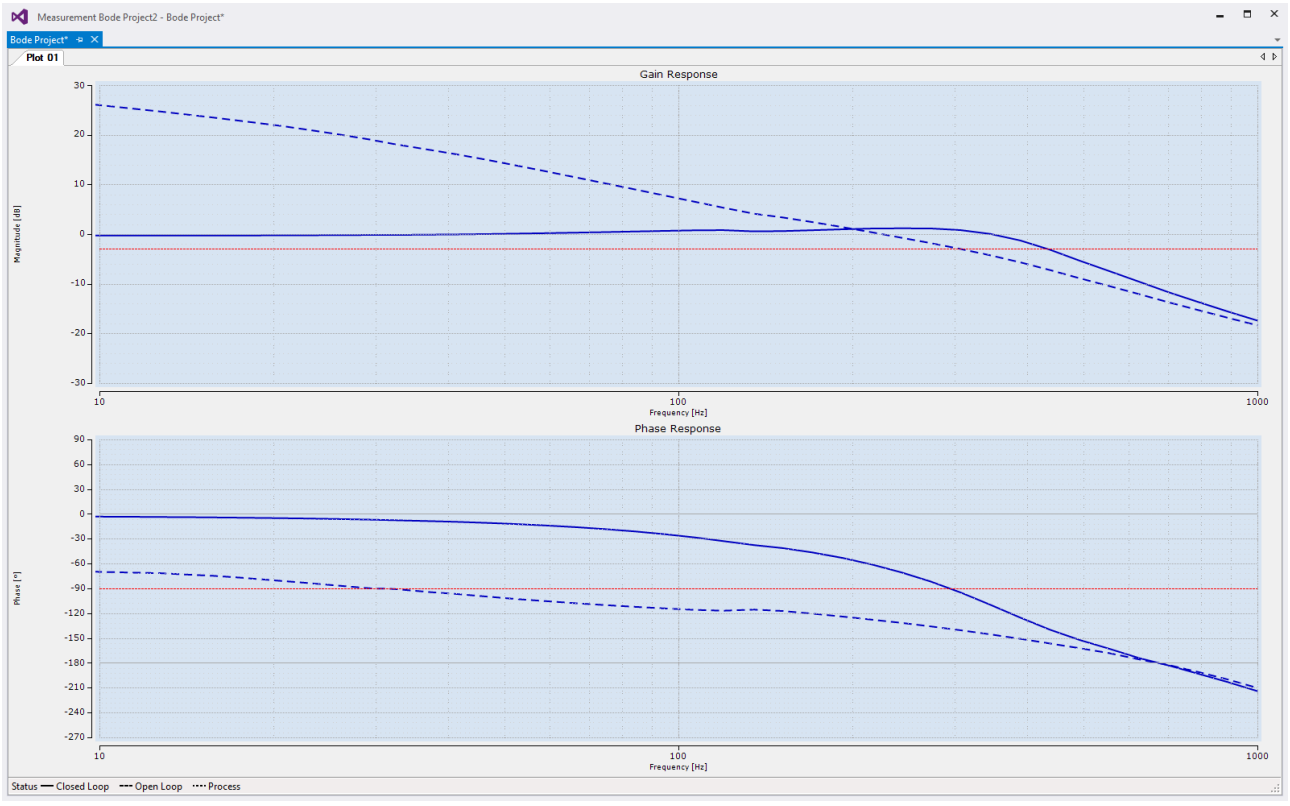
Mechanical friction must be eliminated during the measurement procedure, otherwise the measurement will be useless. Therefore, to overcome the static friction, a sine oscillation with a constant low frequency is additionally applied to the motor shaft. Sine frequencies, increased step by step, are modulated in this manner. 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.

Bode diagram

Resonance points are represented in a Bode diagram. 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 quite a wide bandwidth. The closed control loop is uses for the determination of the bandwidth, while the open control loop is regarded for calculating the amplitude response. The bandwidth is read where the amplitude response first crosses the -3 dB or 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 result in high dynamics.

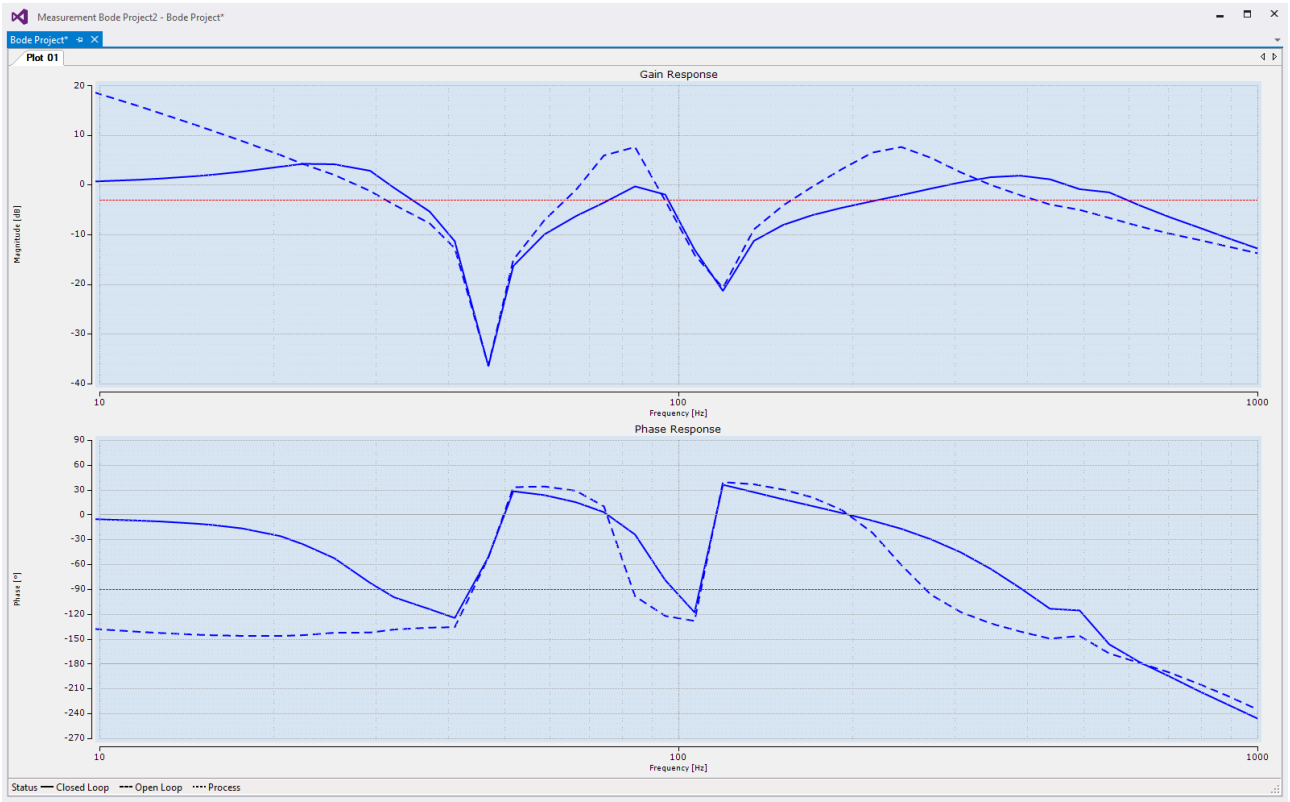


A typical curve with resonance points is shown in the next diagram: a curve with two resonance points and narrow bandwidth.

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

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

By increasing the P portion (proportional gain), the curve is shifted upwards in parallel to the abscissa; a reduction has the opposite effect.



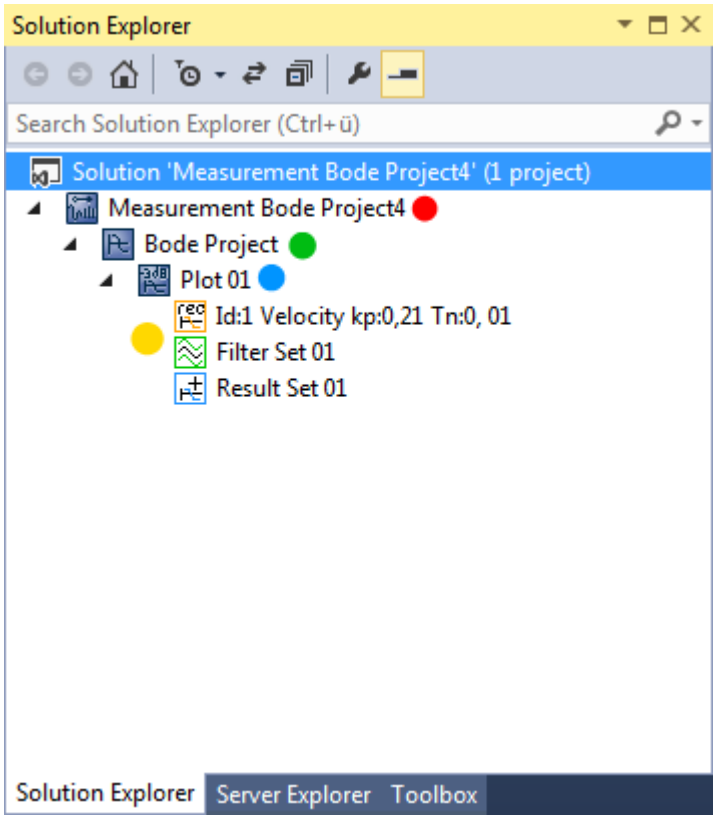
5 Configuration

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.

Bode Project:
All Bode Plots under a project are executed in parallel when a recording is started. If you click on a Bode project, the setting options are displayed in the Visual Studio Properties window.
See also: Bode Plot properties [▶ 23]

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 sets (characteristic curves) for the associated axis are displayed. While one recording is running, a third chart can also optionally be shown with the current actual and setpoint values.

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 Visual Studio Properties window.
See also: Bode Plot properties [▶ 23]

Set:
Each 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 control loops, as well as for the link.

Distinction is made between three set types:

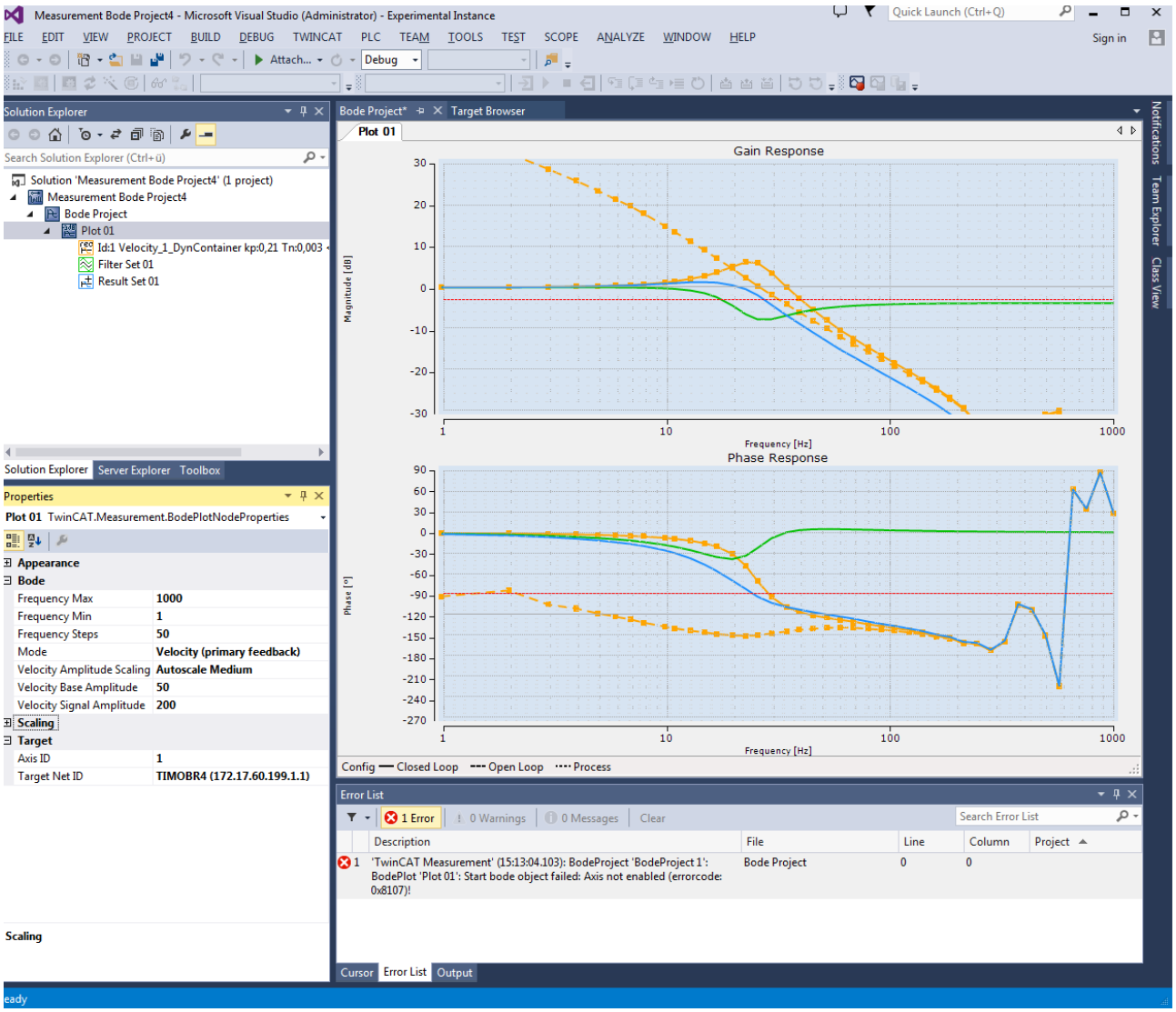
- Record sets represent real recorded values
- Filter sets represent the characteristic curve of a filter
- Result sets represent the combination of two sets in order, for example, to get an idea of how a filter affects a frequency response.

Among other things, the appearance, e.g. color and line width, can be adjusted in the Properties window.

See also: Set properties [▶ 27]

Window

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



Overview of the individual windows:

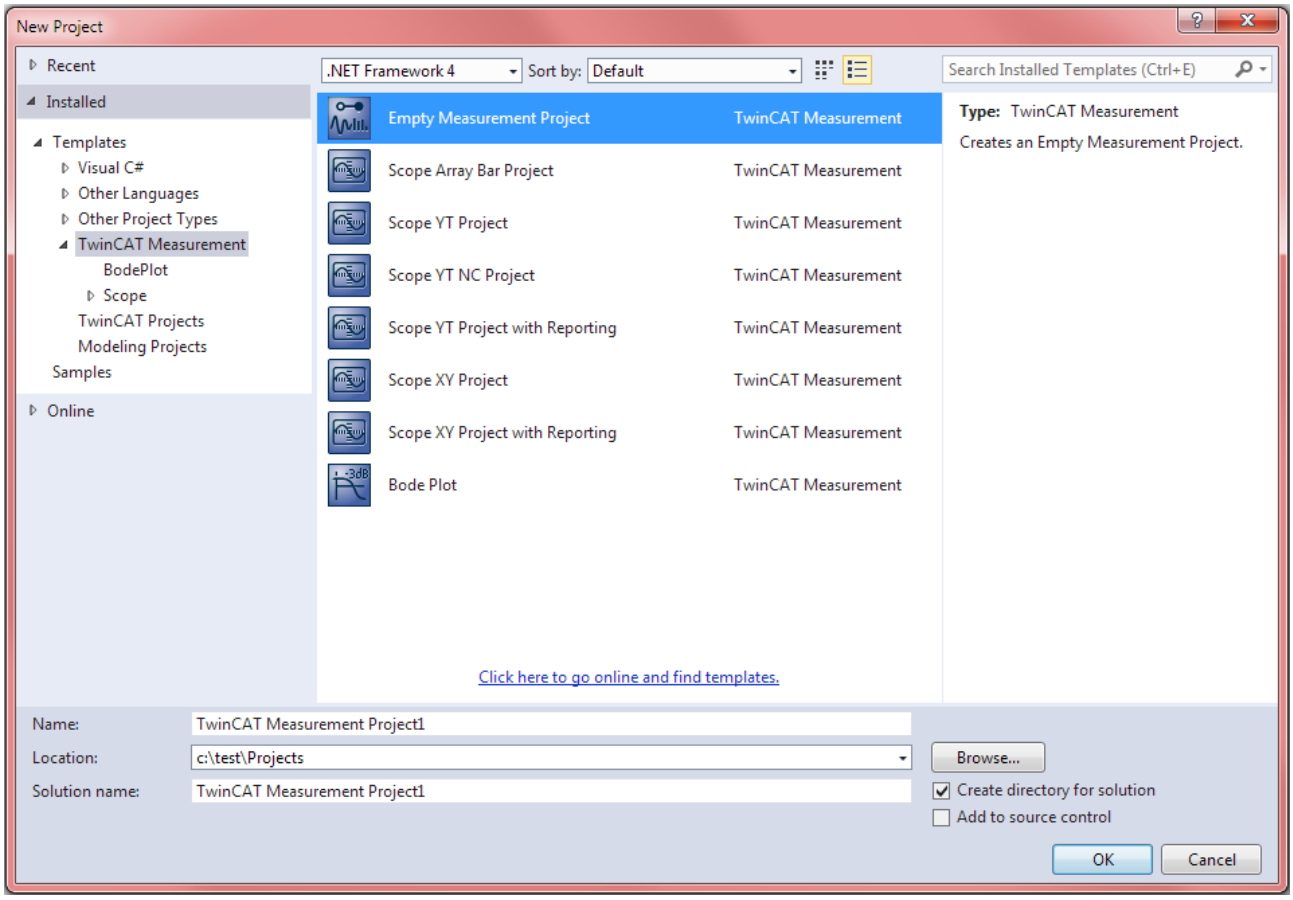
Solution Explorer	Display of the project structure within a solution.
Error list	List of errors, warnings and messages. Each scope project lists the generated messages independently here. The messages for the respectively selected Scope can be deleted via the context menu item "Clear Error List".
Properties	The settings of the respective element that is marked 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 → TwinCAT Measurement → Selection of the desired template.

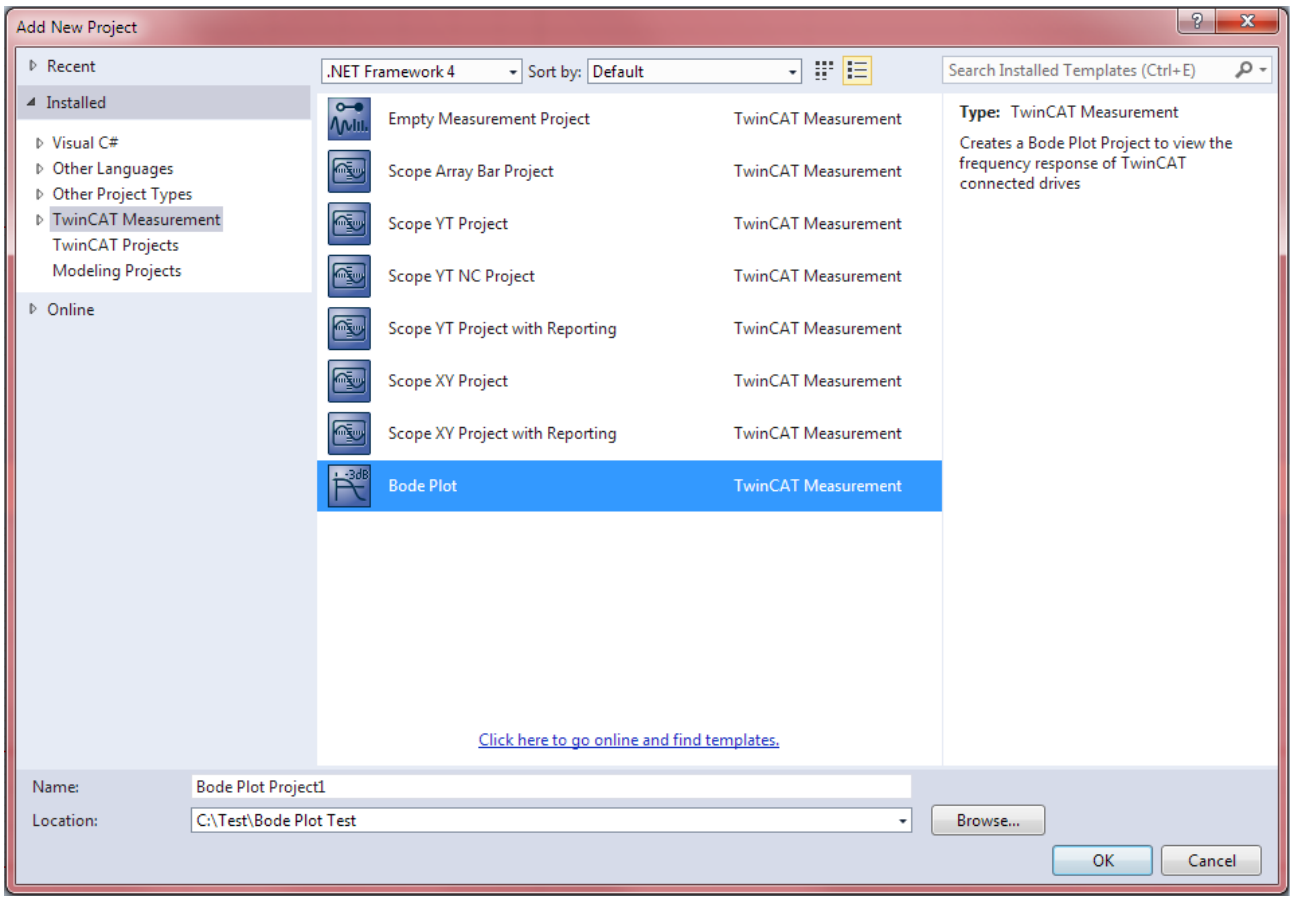


List of the available templates:

Measurement Bode project	Appends a Measurement project containing a Bode project with a plot.
Empty Measurement project	Empty Measurement project. Scope configurations (.sv2 | .tcscope) or scope data (.svd) can subsequently be inserted here.
Measurement Scope project	Contains a Scope instance as well as a pre-configured chart and an axis.
Measurement Scope project with reporting	See "Measurement Scope project" + a ready-made printing template for printing charts.
Measurement Scope NC project	Contains a Scope instance that has been specially pre-configured for working with axes.

Addition of a Bode project to a Measurement project

Context menu of 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 of the Measurement project → Add → Existing Item... → Selection of the desired file (.bodeproj)

Drag and drop the desired file (.bodeproj) 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

Deletion of elements

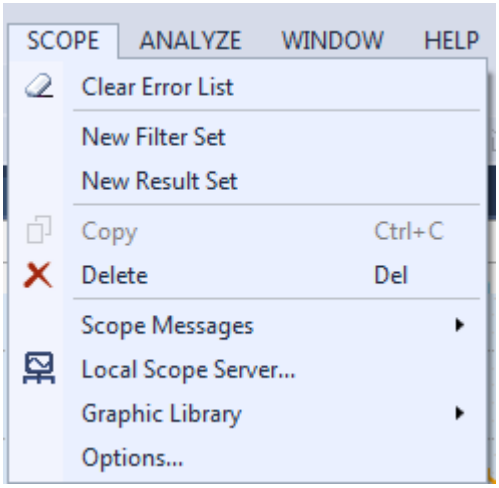
- Selection of the element in the Solution Explorer → [Del] key.
- Context menu of the element → Delete

Saving a Bode configuration

File → Save (shortcut assigned by default: [Ctrl] + [S])
A file (.bodeproj) is saved in the project directory.

5.1.2 Bode Plot - Scope menu

The Scope functions are accessible via the menu. The corresponding key assignments can also be viewed here.



Clear error list	Deletes all entries (Error | Warning | Message) of the currently active Scope from the error list.
New Filter set	Adds a new filter set, taking into consideration the default settings.
New Result set	Adds a new result set, taking into consideration the default settings.
Delete	Deletes the element currently selected in the Solution Explorer.
Local Scope Server...	Opens the configuration interface of the Scope Server.
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 traverse the sought frequency profile.

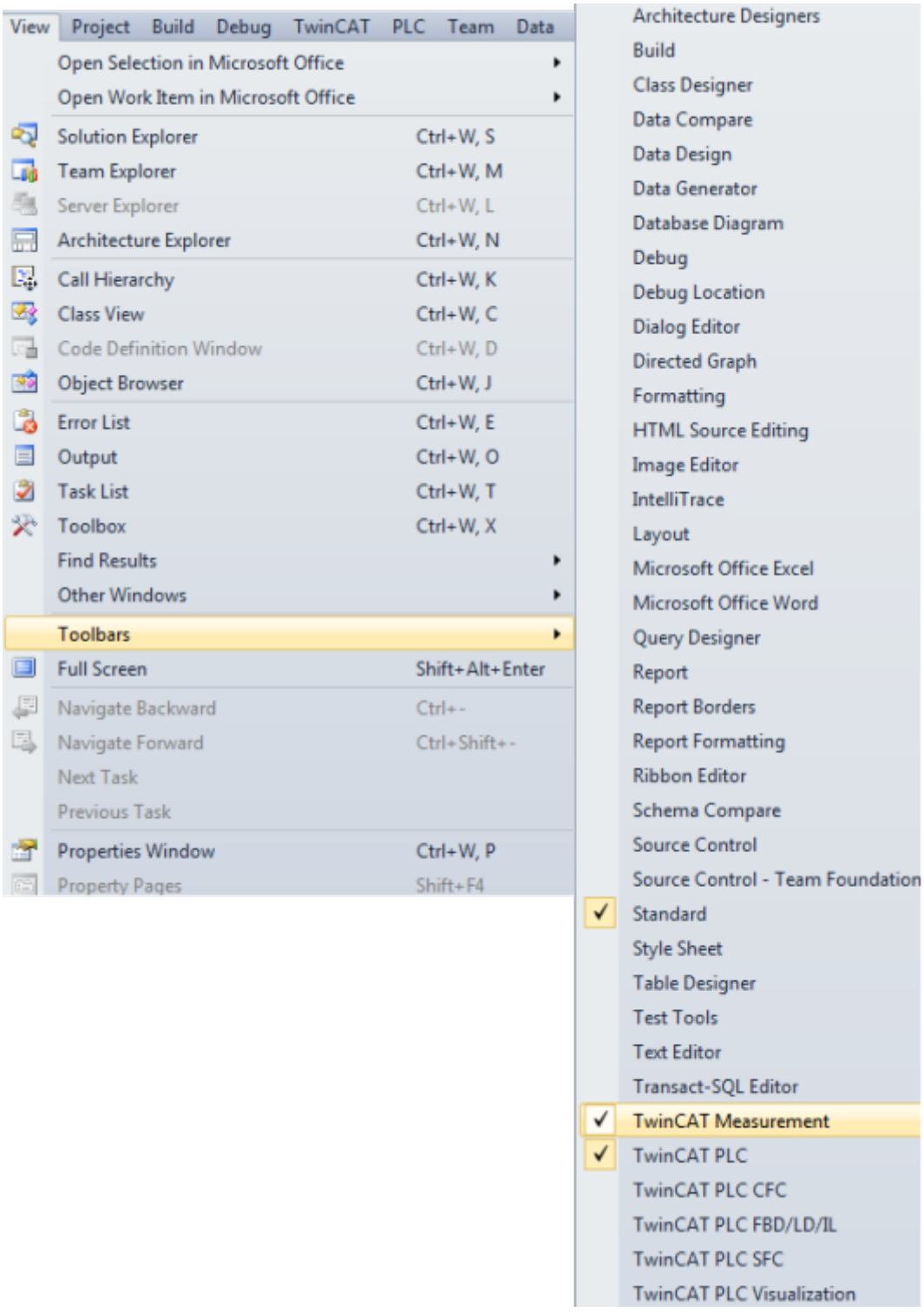
⚠ WARNING

Risk of injury due to the drive axis starting up automatically

In order to make 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. releases, monitoring, etc.).

- Ensure safety during the Bode Plot recording.

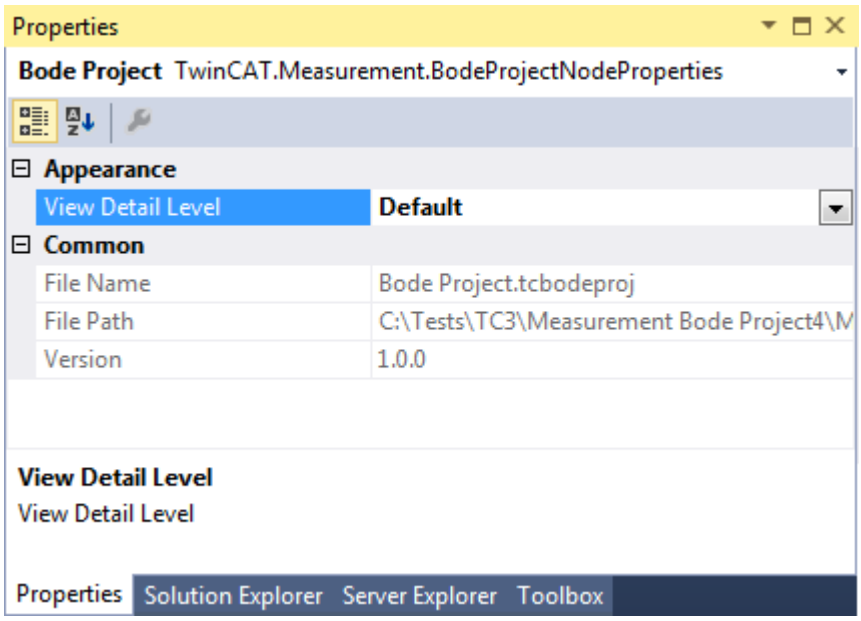
If the toolbar is not visible by default or has been closed, it can be reactivated under View > Toolbars > TwinCAT Measurement.



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

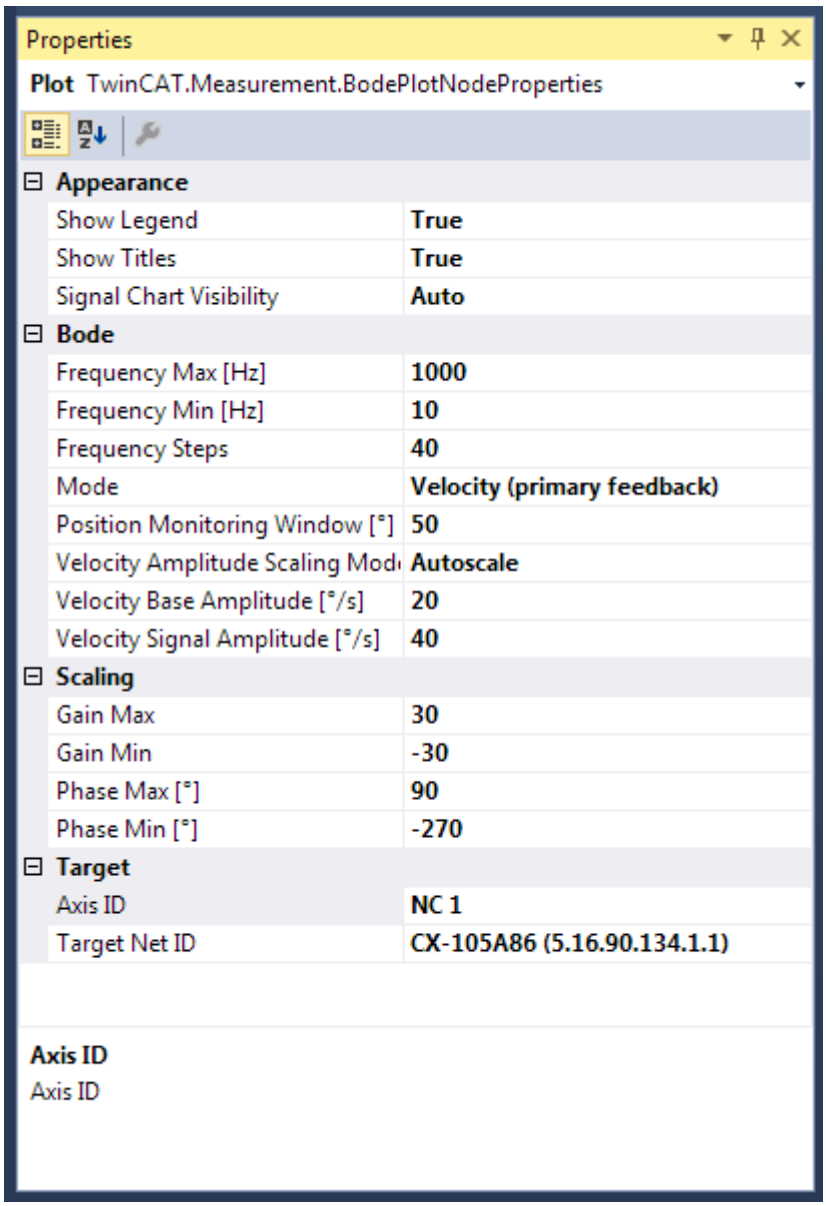
- **View Detail Level:** indicates whether the standard view or the extended view for special additional tasks is to be used in this project. In the default state all properties for the sub-elements (e.g. plots) necessary to create a Bode plot are visible. The extended mode makes additional properties visible that could be necessary in order, for example, to create a Scope View from the process data of the drive in parallel.

Common

- **File Name:** File name of the current Scope instance.
- **File Path:** Directory in which the Scope 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 assigned 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

Under this category all settings are summarized 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:** Number of interpolation 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 (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 for 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 [°]:** The amplitude of the excitation is set here.
- **Velocity Amplitude Scaling Mode:** Scales the signal amplitude during the recording so as to not have to make excessively large movements 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 at 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 larger 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:** Sets the amplitude of the signal (or measuring) oscillation at 1 Hz (cf. 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:** Sets the amplitude of the signal (or measuring) oscillation at 1 Hz (cf. 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

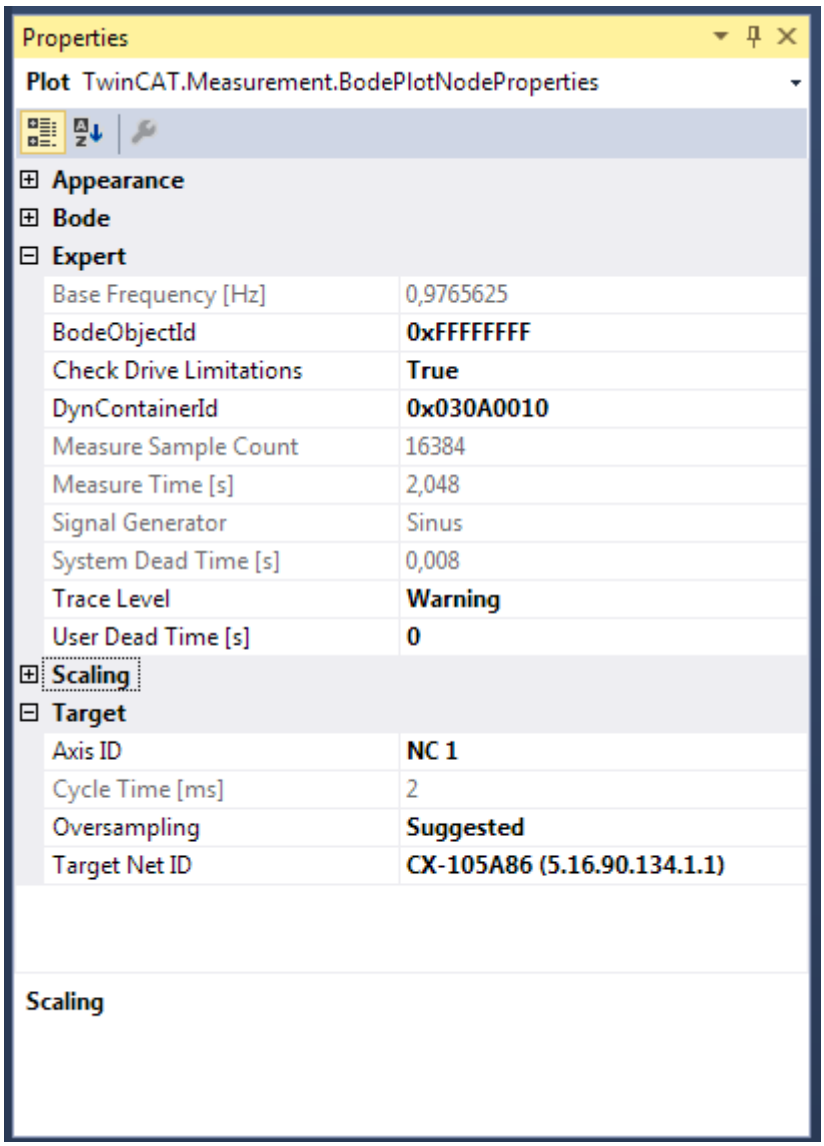
- **Gain Max:** Indicates the upper magnitude for the value axis in the chart of the amplitude response.
- **Gain Min:** Indicates the lower magnitude for the value axis in the chart of the amplitude response.
- **Phase Max:** Indicates the highest scale end in the chart of the phase response.
- **Phase Min:** Indicates the lowest scale end in the chart of the phase response.

Target

- **Axis ID:** indicates 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. master/slave coupling, CNC hard or soft gantry). Otherwise, starting the recording can lead to damage to man and the machine.**
- **Target Net ID:** indicates the ID of the target system on which the drive axis is located that is to be used for this Bode Plot.

Extended View

If "View Detail Level" in the Bode project settings is set to Extended, some additional properties are visible.



Expert

- **Base Frequency:** Shows the frequency [in Hz] of the basic oscillation for overcoming the static friction (in the velocity modes only).
- **Bode Object Id:** If the Bode Plot is to take place via a "Drive Diag TcCom Object" already set up in the System Manager (e.g. in order to scope additional process data from the drive), this can take place here via the Object ID.
- **Check Drive Limitations:** If a check of the drive is to take place, this can be specified here.
- **DynContainerId:** Sets the ID of the container for dynamic process data. The DynContainer is appended to the EtherCAT device in the TwinCAT project.
- **Measur Sample Count:** Indicates the number of setpoint values and actual values from which an interpolation value of the Bode characteristic curve (a frequency point) is calculated.
- **Measure Time:** Indicates the length of time [in s] for which the system is excited with one frequency.
- **Signal Generator:** Indicates the curve type of the signal generator used.
- **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 displayed 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.

Target

- **Cycle Time:** Indicates the last-used cycle time [in ms].

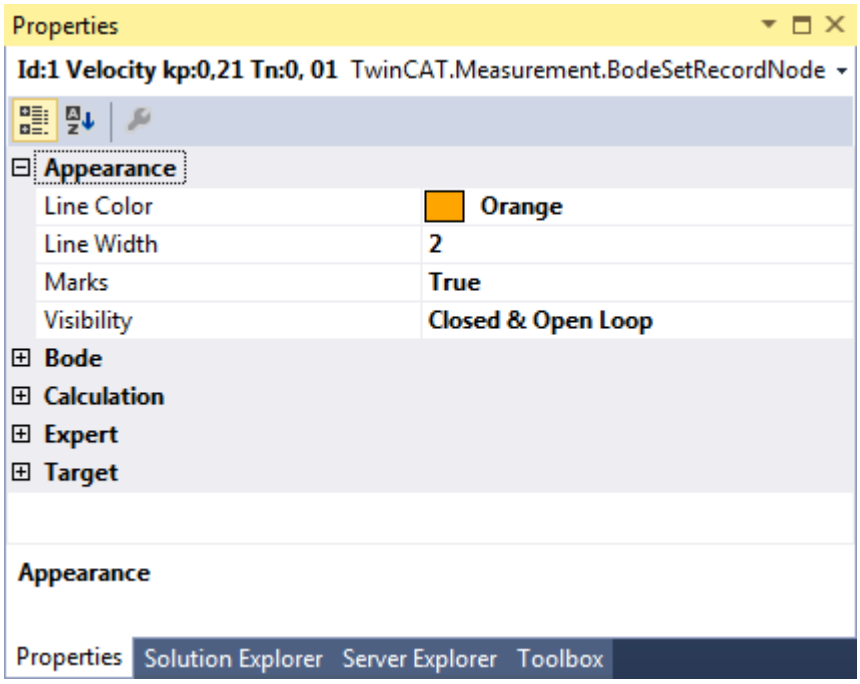
- **Oversampling:** Indicates the oversampling factor to be used. If set to "Suggested", the highest useful factor is automatically selected when starting the recording.

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

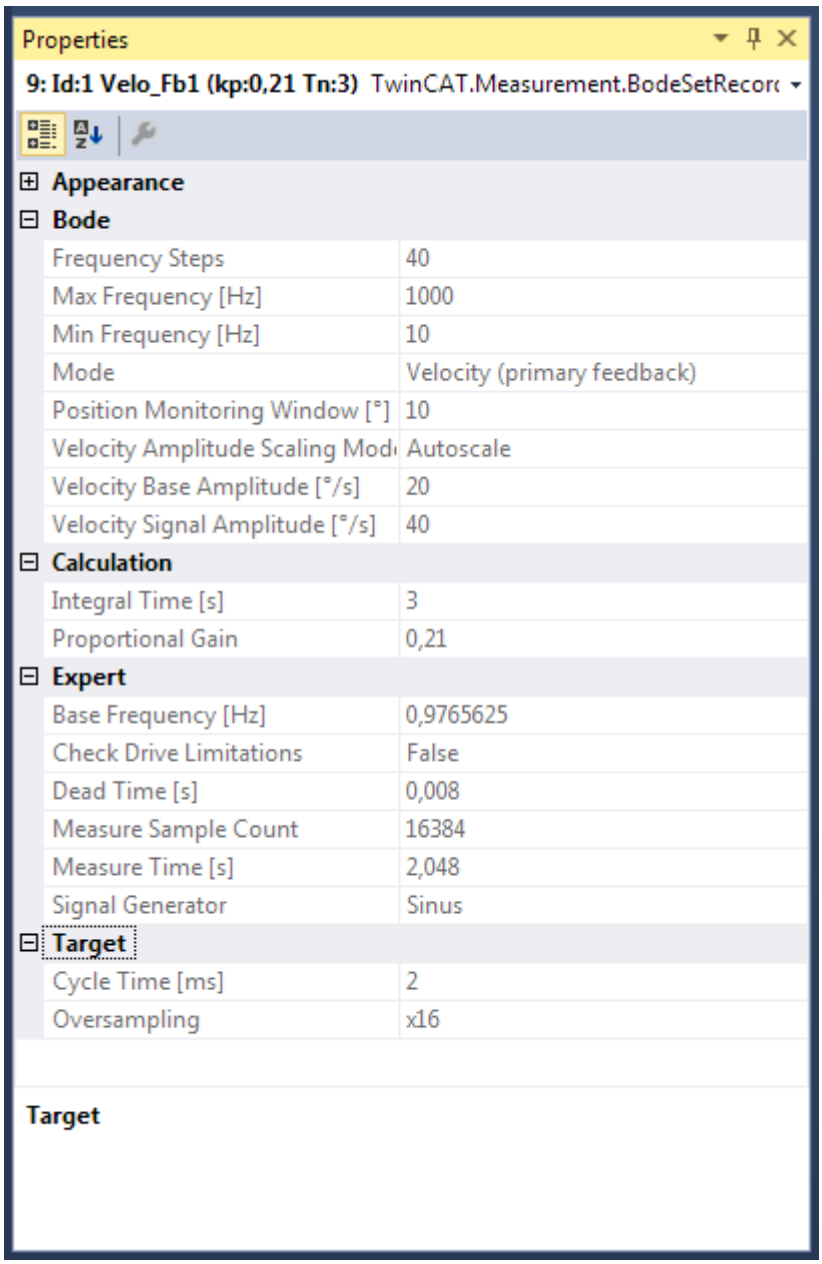


The settings in the Appearance category are available for all sets.

- **Line Colors:** Indicates the color of the set (characteristic curves and icon in 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 control loop.
- **Closed Loop:** Frequency response of the closed control loop.
- **Process:** Frequency response of the link.

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.



Bode

Under this category all settings are summarized in order to configure a new Bode Plot.

- **Frequency Steps:** Number of interpolation 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. (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 (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 for 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 [°]:** The amplitude of the excitation is set here.
- **Velocity Amplitude Scaling Mode:** Scales the signal amplitude during the recording so as not to require excessively large movements 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 at 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:** Sets the amplitude of the signal (or measuring) oscillation at 1 Hz (cf. 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:** Sets the amplitude of the signal (or measuring) oscillation at 1 Hz (cf. 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:** A desired performance can be achieved with the proportional gain.

Expert

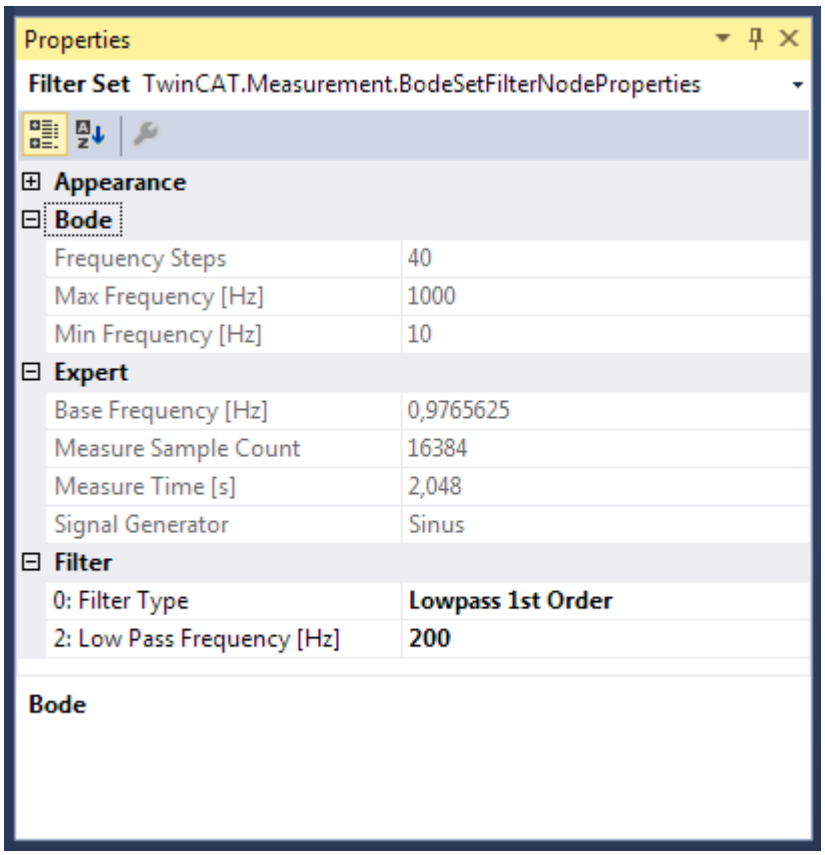
- **Base Frequency:** Shows the frequency [in Hz] of the basic oscillation for overcoming the static friction (in the velocity modes only).
- **Check Drive Limitations:** If a check of the drive is to take place, this can be specified here.
- **Dead Time [s]:** Indicates the complete dead time in seconds.
- **Measur Sample Count:** Indicates the number of setpoint values and actual values from which an interpolation value of the Bode characteristic curve (a frequency point) is calculated.
- **Measure Time:** Indicates the length of time [in s] for which the system is excited with one frequency.
- **Signal Generator:** Indicates the curve type of the signal generator used.

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 starting the recording.

Filter Set

The special settings for filter sets are represented as follows:



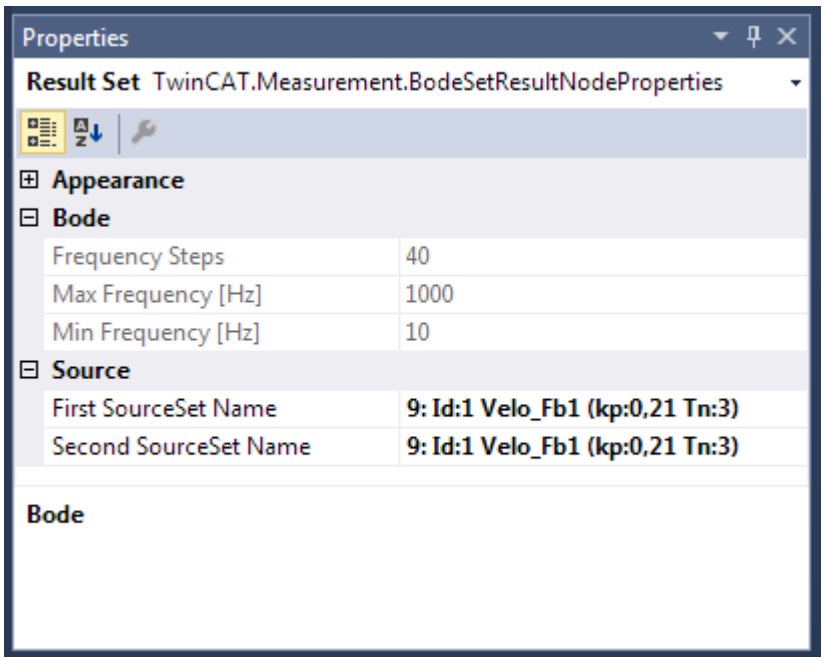
- **Filter Type:** The type of filter can be set here. The other properties can be edited, depending on the selection. The following are available:
- **Lowpass 1st Order:** First order low-pass.
- **Lowpass 2nd Order:** Second order low-pass
- **Phase Correction 1st Order:** First order phase correction link.
- **Phase Correction 2nd Order:** Second order phase correction link.
- **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 position of the interpolation points correlate. If one of the two source sets changes, then the result set is also re-calculated.

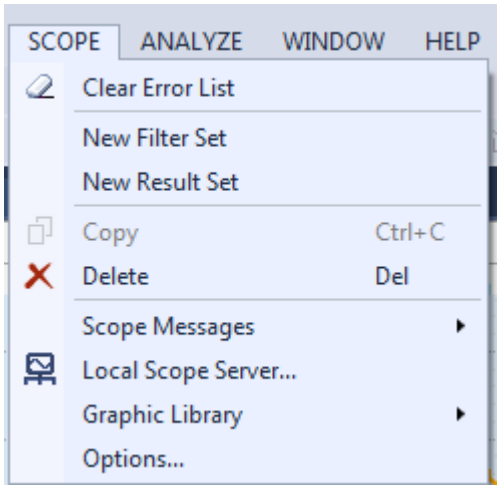


Source

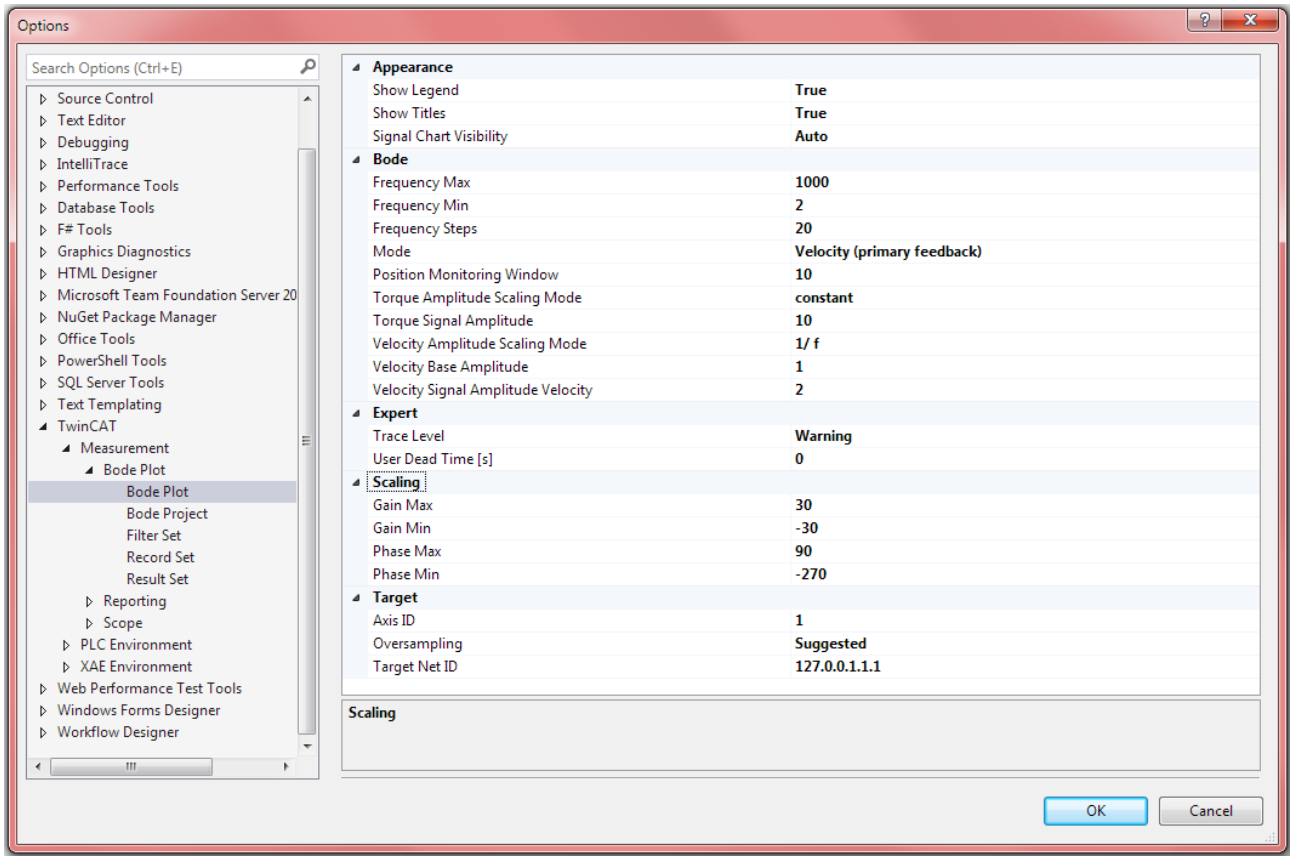
- **First SourceSet Name:** Name of the first source set.
- **Second SourceSet Name:** Name of the second source set.

5.1.7 Bode Plot - Options

You can go directly to the TwinCAT measurement options in the 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 project:** Basic settings for the project can be made here. To detailed description [▶ 23].
- **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 [▶ 23].
- **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 [▶ 27].
- **Record Set:** Definition of the standard record set settings that are used when a new recording is started. To detailed description [▶ 27].
- **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 [▶ 27].

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 make a Bode Plot recording of a TwinCAT CNC axis, note the instructions for configuring TwinCAT CNC axes [▶ 40] at the end of the section.

⚠ WARNING

Risk of injury due to the drive axis starting up automatically

In order to make 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. releases, monitoring, etc.).

- Ensure safety during the Bode Plot recording.

1. Installation

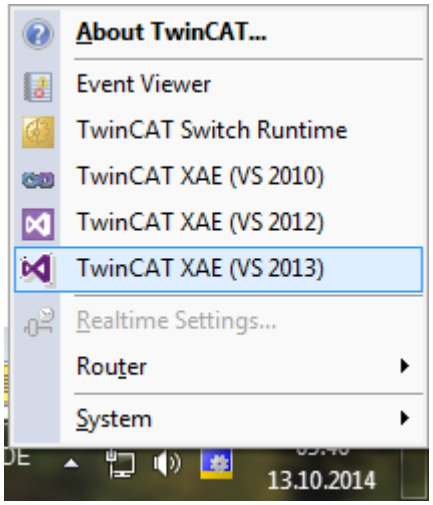
For a basic understanding it is important to know that the TwinCAT 3 Bode Plot is part of the Measurement installation, which also includes the Scope View and the Scope Server. Some functions are used across Measurement installations. For example, the toolbar controls both Scope and Bode projects. Since 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.

2. Licensing

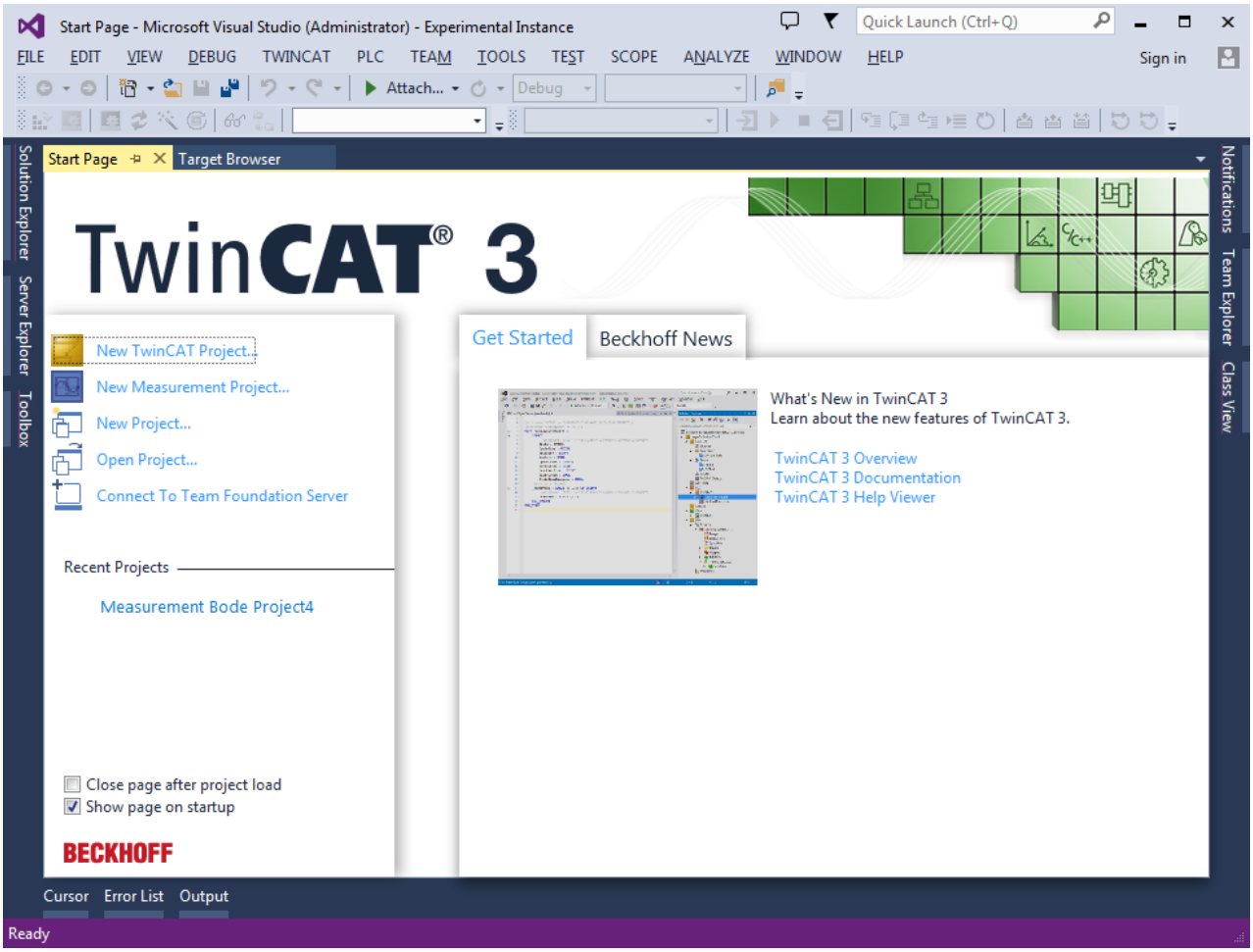
For the Bode Plot, the “Base” license is initially activated, irrespective of whether it has been installed via its own Measurement setup or via the TwinCAT 3 XAE setup.

3. New project

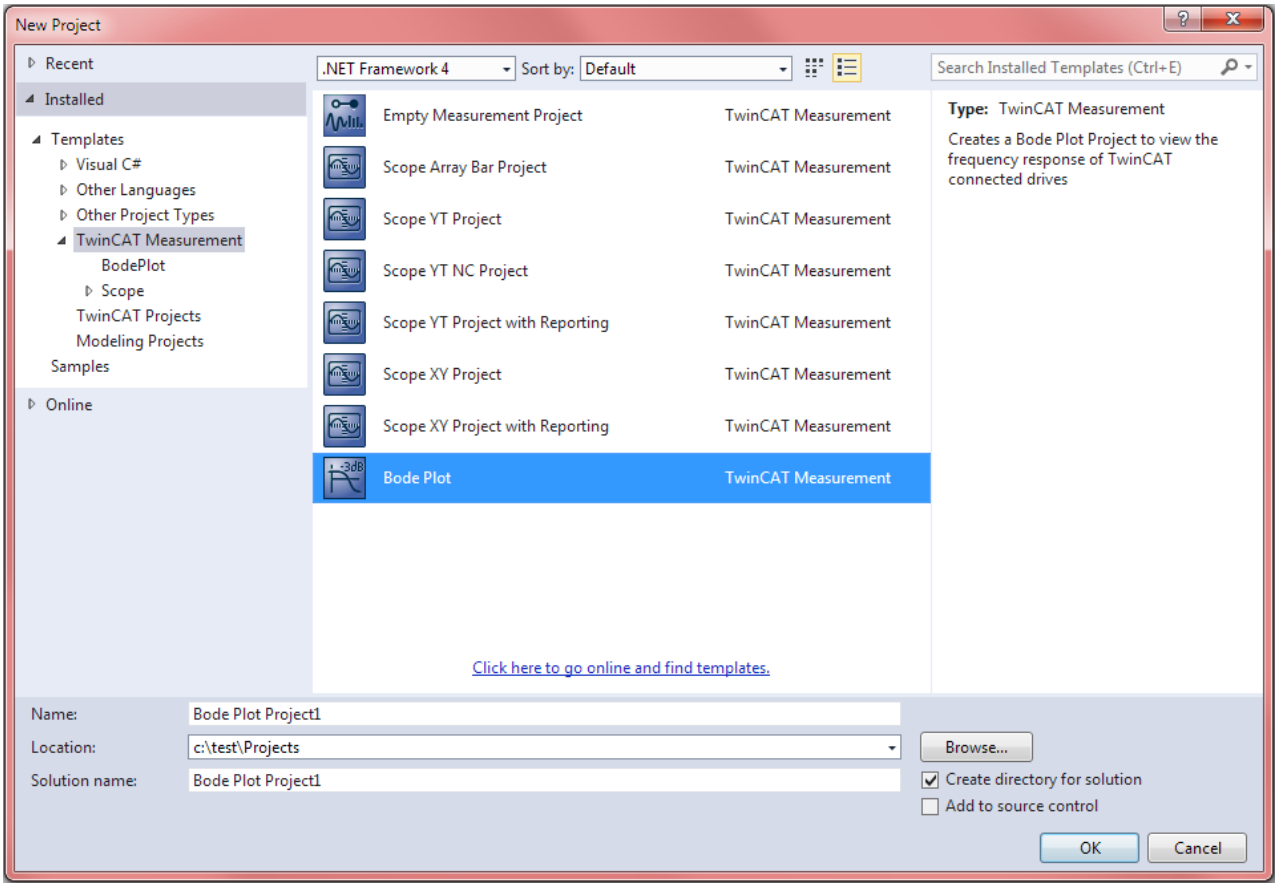
Open a new Visual Studio project in one of the installed versions via the context menu of the TwinCAT tray icon.



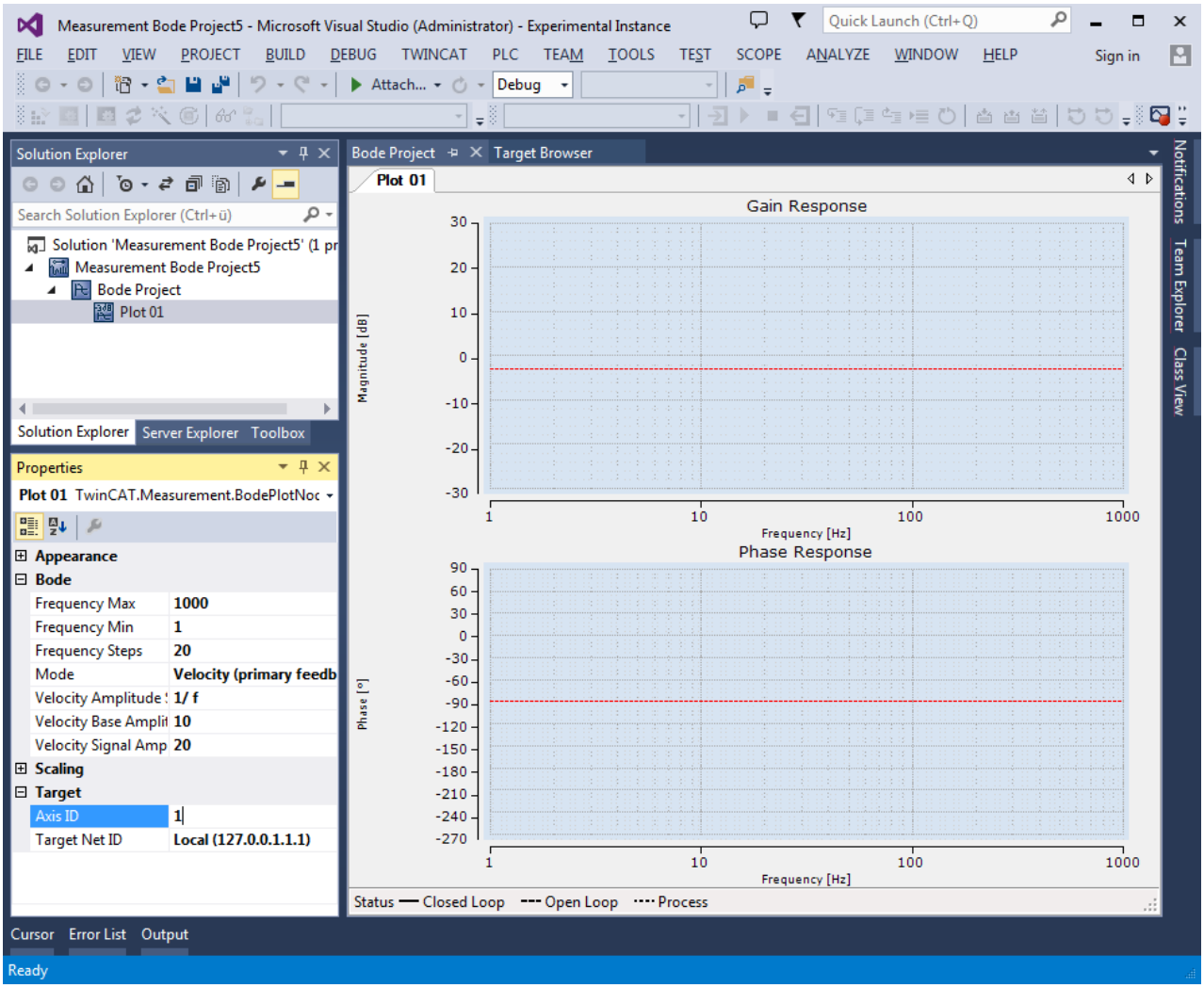
A new Visual Studio window opens. Create a new Measurement project via the TwinCAT 3 start page or via the File menu.



A window opens showing the existing Measurement templates. Select the already pre-configured Bode Plot here.



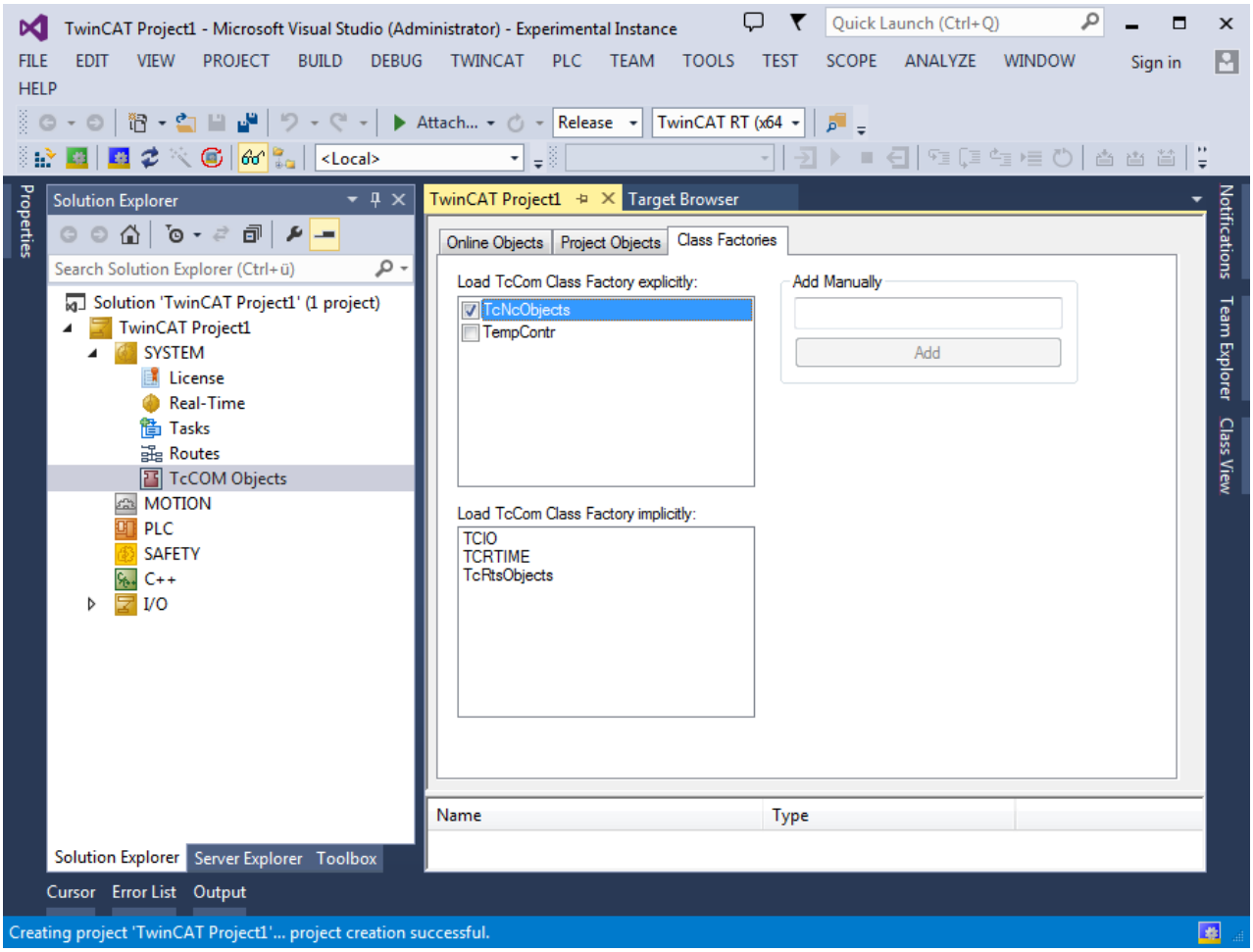
A solution with a project tree opens in the Solution Explorer. You can find the Bode Plot at the lowest level.



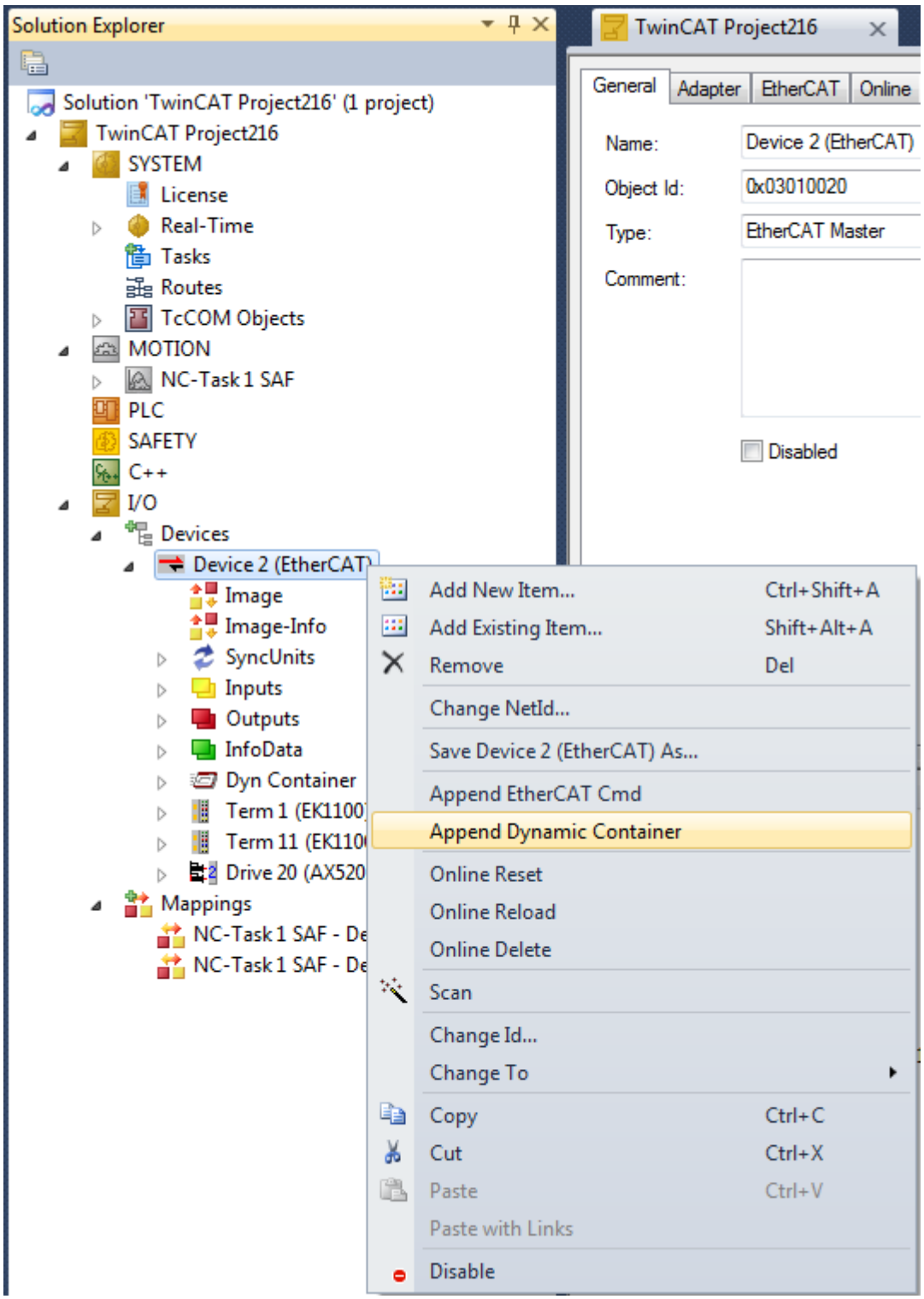
In the Properties window, set the "Axis ID" and "Target Net ID" for the drive axis with which the Bode Plot is to be created.

4. Preparing a TwinCAT project:

Before you can execute the actual Bode Plot, you must adjust the settings of the TwinCAT project once only. Announce the TcNcObjects Class Factory: the Bode Plot is executed by a TcCom object in the TwinCAT system. To ensure that this can be generated automatically from the Bode project, you must announce the Class Factory for TcNcObjects.

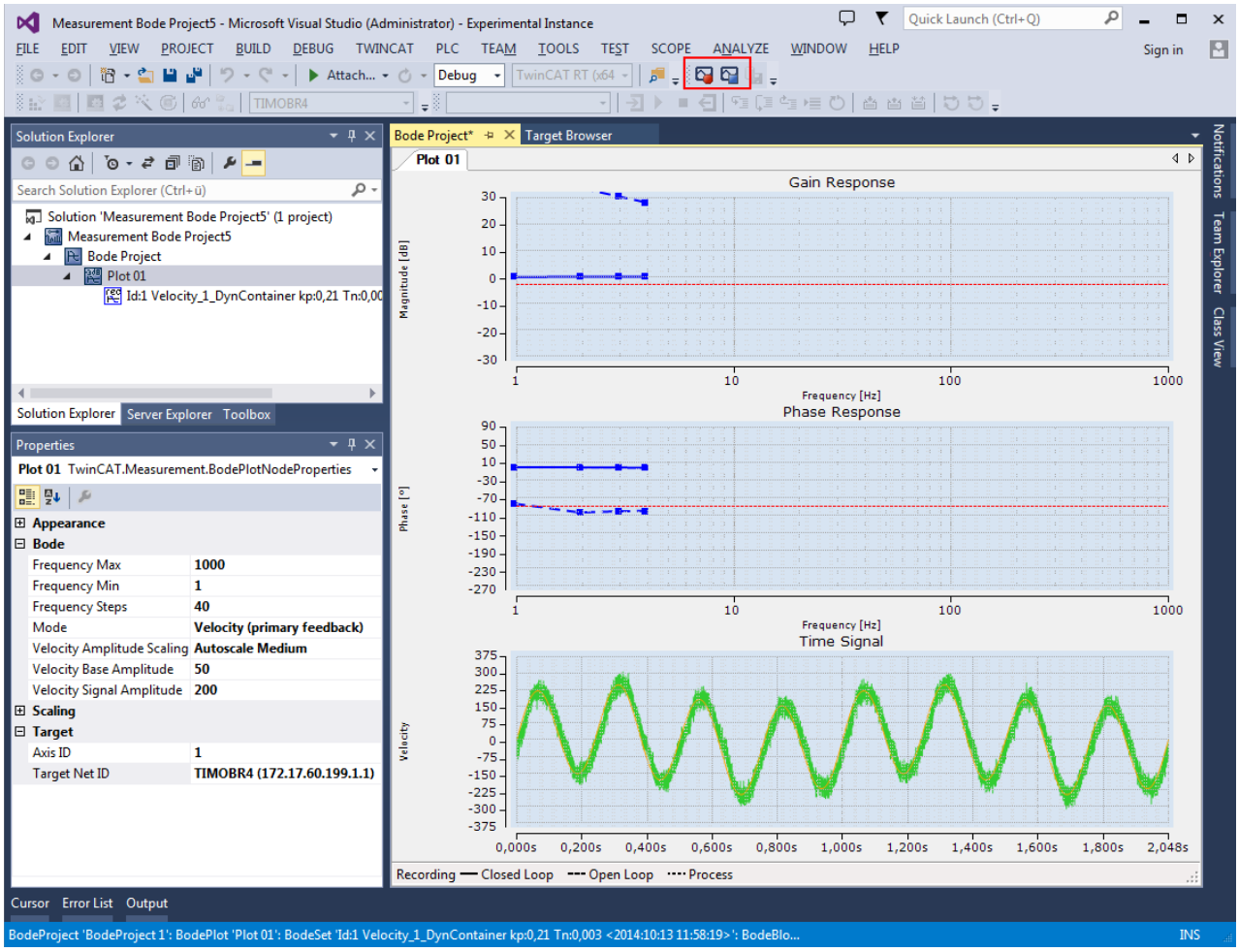


Append dynamic containers to the EtherCAT master: for dynamic communication with the drive, reserve a memory range once only per EtherCAT device. Confirm the subsequent dialog for querying the container size with OK.



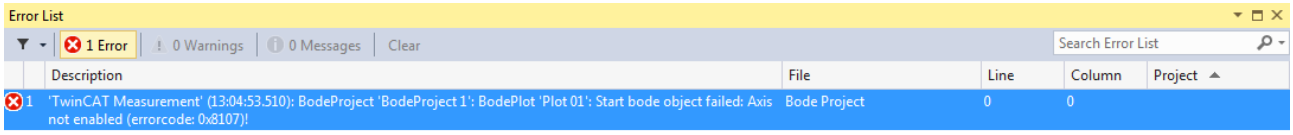
5. Making a Bode Plot recording

After having selected the target system and the drive axis, you can parameterize the recording in the Plot properties. The details for the plot settings can be found in the section "Bode Plot - Plot properties [▶ 23]". 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 button.



6. Error

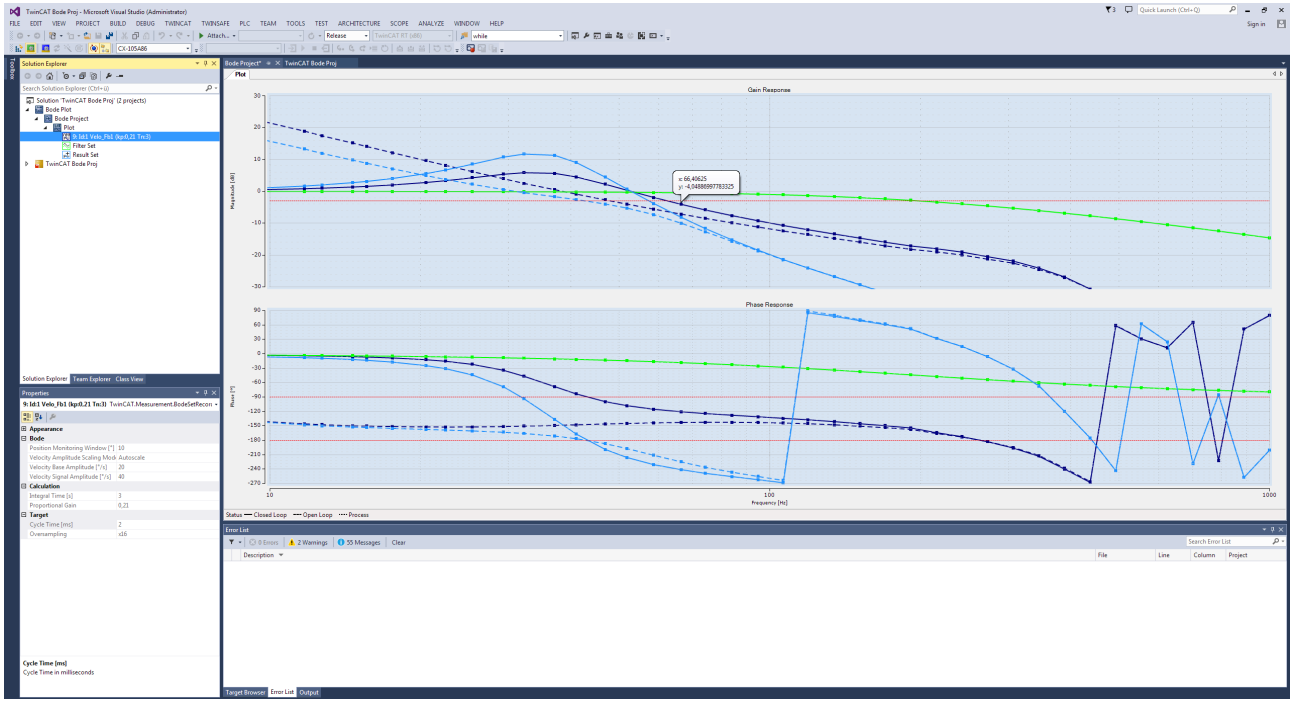
If errors should occur during the recording, they are displayed in the Visual Studio error list. For example, the Bode Plot signals a missing axis release when trying to start the recording.



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.

7. Analysis

Following the recording you can see all the characteristic curves created so far. You can change the display options in the properties. For example, it may be useful to view the "path" as well as the "open control loop" and "closed control loop", or to highlight or mask individual characteristic curves. Details for the settings can be found in the section "Bode Plot - Set properties [▶ 27]".
Beyond that you can also append filter sets for the simulation of filters or result sets for the determination of overlapping results.



Notes on the configuration of TwinCAT CNC axes

If a Bode Plot recording is to be made of a TwinCAT CNC axis, the matching speed standardization f must be set for this in the axis parameter set.
On the basis of the AX5000's internal speed scaling (1 increment corresponds to a speed of 5.588 x 10^{-5} rpm), the following equation is used for the calculation:

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

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)

Further information on the axis parameters can be found in the Beckhoff information system in the documentation "TwinCAT CNC". (TwinCAT 2 > TwinCAT NC > TwinCAT CNC > TwinCAT CNC axis parameters)

7 Appendix

7.1 Return values

7.1.1 ADS Return Codes

Grouping of error codes: 0x000 [▶ 41]..., 0x500 [▶ 41]..., 0x700 [▶ 42]..., 0x1000 [▶ 44]...

Global error codes

Hex	Dec	HRESULT	Name	Description
0x0	0	0x9811 0000	ERR_NOERROR	No error.
0x1	1	0x9811 0001	ERR_INTERNAL	Internal error.
0x2	2	0x9811 0002	ERR_NORTIME	No real-time.
0x3	3	0x9811 0003	ERR_ALLOCLOCKEDMEM	Allocation locked – memory error.
0x4	4	0x9811 0004	ERR_INSERTMAILBOX	Mailbox full – the ADS message could not be sent. Reducing the number of ADS messages per cycle will help.
0x5	5	0x9811 0005	ERR_WRONGRECEIVEHMSG	Wrong HMSG.
0x6	6	0x9811 0006	ERR_TARGETPORTNOTFOUND	Target port not found – ADS server is not started or is not reachable.
0x7	7	0x9811 0007	ERR_TARGETMACHINENOTFOUND	Target computer not found – AMS route was not found.
0x8	8	0x9811 0008	ERR_UNKNOWNCMDID	Unknown command ID.
0x9	9	0x9811 0009	ERR_BADTASKID	Invalid task ID.
0xA	10	0x9811 000A	ERR_NOIO	No IO.
0xB	11	0x9811 000B	ERR_UNKNOWNAMSCMD	Unknown AMS command.
0xC	12	0x9811 000C	ERR_WIN32ERROR	Win32 error.
0xD	13	0x9811 000D	ERR_PORTNOTCONNECTED	Port not connected.
0xE	14	0x9811 000E	ERR_INVALIDAMSLENGTH	Invalid AMS length.
0xF	15	0x9811 000F	ERR_INVALIDAMSNETID	Invalid AMS Net ID.
0x10	16	0x9811 0010	ERR_LOWINSTLEVEL	Installation level is too low –TwinCAT 2 license error.
0x11	17	0x9811 0011	ERR_NODEBUGINTAVAILABLE	No debugging available.
0x12	18	0x9811 0012	ERR_PORTDISABLED	Port disabled – TwinCAT system service not started.
0x13	19	0x9811 0013	ERR_PORTALREADYCONNECTED	Port already connected.
0x14	20	0x9811 0014	ERR_AMSSYNC_W32ERROR	AMS Sync Win32 error.
0x15	21	0x9811 0015	ERR_AMSSYNC_TIMEOUT	AMS Sync Timeout.
0x16	22	0x9811 0016	ERR_AMSSYNC_AMSERROR	AMS Sync error.
0x17	23	0x9811 0017	ERR_AMSSYNC_NOINDEXINMAP	No index map for AMS Sync available.
0x18	24	0x9811 0018	ERR_INVALIDAMSPORT	Invalid AMS port.
0x19	25	0x9811 0019	ERR_NOMEMORY	No memory.
0x1A	26	0x9811 001A	ERR_TCPSEND	TCP send error.
0x1B	27	0x9811 001B	ERR_HOSTUNREACHABLE	Host unreachable.
0x1C	28	0x9811 001C	ERR_INVALIDAMSFRAGMENT	Invalid AMS fragment.
0x1D	29	0x9811 001D	ERR_TLSSEND	TLS send error – secure ADS connection failed.
0x1E	30	0x9811 001E	ERR_ACCESSDENIED	Access denied – secure ADS access denied.

Router error codes

Hex	Dec	HRESULT	Name	Description
0x500	1280	0x9811 0500	ROUTERERR_NOLOCKEDMEMORY	Locked memory cannot be allocated.
0x501	1281	0x9811 0501	ROUTERERR_RESIZEMEMORY	The router memory size could not be changed.
0x502	1282	0x9811 0502	ROUTERERR_MAILBOXFULL	The mailbox has reached the maximum number of possible messages.
0x503	1283	0x9811 0503	ROUTERERR_DEBUGBOXFULL	The Debug mailbox has reached the maximum number of possible messages.
0x504	1284	0x9811 0504	ROUTERERR_UNKNOWNPORTTYPE	The port type is unknown.
0x505	1285	0x9811 0505	ROUTERERR_NOTINITIALIZED	The router is not initialized.
0x506	1286	0x9811 0506	ROUTERERR_PORTALREADYINUSE	The port number is already assigned.
0x507	1287	0x9811 0507	ROUTERERR_NOTREGISTERED	The port is not registered.
0x508	1288	0x9811 0508	ROUTERERR_NOMOREQUEUES	The maximum number of ports has been reached.
0x509	1289	0x9811 0509	ROUTERERR_INVALIDPORT	The port is invalid.
0x50A	1290	0x9811 050A	ROUTERERR_NOTACTIVATED	The router is not active.
0x50B	1291	0x9811 050B	ROUTERERR_FRAGMENTBOXFULL	The mailbox has reached the maximum number for fragmented messages.
0x50C	1292	0x9811 050C	ROUTERERR_FRAGMENTTIMEOUT	A fragment timeout has occurred.
0x50D	1293	0x9811 050D	ROUTERERR_TOBEREMOVED	The port is removed.

General ADS error codes

Hex	Dec	HRESULT	Name	Description
0x700	1792	0x9811 0700	ADSERR_DEVICE_ERROR	General device error.
0x701	1793	0x9811 0701	ADSERR_DEVICE_SRVNOTSUPP	Service is not supported by the server.
0x702	1794	0x9811 0702	ADSERR_DEVICE_INVALIDGRP	Invalid index group.
0x703	1795	0x9811 0703	ADSERR_DEVICE_INVALIDOFFSET	Invalid index offset.
0x704	1796	0x9811 0704	ADSERR_DEVICE_INVALIDACCESS	Reading or writing not permitted.
0x705	1797	0x9811 0705	ADSERR_DEVICE_INVALIDSIZE	Parameter size not correct.
0x706	1798	0x9811 0706	ADSERR_DEVICE_INVALIDDATA	Invalid data values.
0x707	1799	0x9811 0707	ADSERR_DEVICE_NOTREADY	Device is not ready to operate.
0x708	1800	0x9811 0708	ADSERR_DEVICE_BUSY	Device is busy.
0x709	1801	0x9811 0709	ADSERR_DEVICE_INVALIDCONTEXT	Invalid operating system context. This can result from use of ADS function blocks in different tasks. It may be possible to resolve this through Multi-task data access synchronization in the PLC.
0x70A	1802	0x9811 070A	ADSERR_DEVICE_NOMEMORY	Insufficient memory.
0x70B	1803	0x9811 070B	ADSERR_DEVICE_INVALIDPARM	Invalid parameter values.
0x70C	1804	0x9811 070C	ADSERR_DEVICE_NOTFOUND	Not found (files, ...).
0x70D	1805	0x9811 070D	ADSERR_DEVICE_SYNTAX	Syntax error in file or command.
0x70E	1806	0x9811 070E	ADSERR_DEVICE_INCOMPATIBLE	Objects do not match.
0x70F	1807	0x9811 070F	ADSERR_DEVICE_EXISTS	Object already exists.
0x710	1808	0x9811 0710	ADSERR_DEVICE_SYMBOLNOTFOUND	Symbol not found.
0x711	1809	0x9811 0711	ADSERR_DEVICE_SYMBOLVERSIONIN-VALID	Invalid symbol version. This can occur due to an on-line change. Create a new handle.
0x712	1810	0x9811 0712	ADSERR_DEVICE_INVALIDSTATE	Device (server) is in invalid state.
0x713	1811	0x9811 0713	ADSERR_DEVICE_TRANSMODENOTSUPP	AdsTransMode not supported.
0x714	1812	0x9811 0714	ADSERR_DEVICE_NOTIFYHNDINVALID	Notification handle is invalid.
0x715	1813	0x9811 0715	ADSERR_DEVICE_CLIENTUNKNOWN	Notification client not registered.
0x716	1814	0x9811 0716	ADSERR_DEVICE_NOMOREHDLS	No further handle available.
0x717	1815	0x9811 0717	ADSERR_DEVICE_INVALIDWATCHSIZE	Notification size too large.
0x718	1816	0x9811 0718	ADSERR_DEVICE_NOTINIT	Device not initialized.
0x719	1817	0x9811 0719	ADSERR_DEVICE_TIMEOUT	Device has a timeout.
0x71A	1818	0x9811 071A	ADSERR_DEVICE_NOINTERFACE	Interface query failed.
0x71B	1819	0x9811 071B	ADSERR_DEVICE_INVALIDINTERFACE	Wrong interface requested.
0x71C	1820	0x9811 071C	ADSERR_DEVICE_INVALIDCLSID	Class ID is invalid.
0x71D	1821	0x9811 071D	ADSERR_DEVICE_INVALIDOBJID	Object ID is invalid.
0x71E	1822	0x9811 071E	ADSERR_DEVICE_PENDING	Request pending.
0x71F	1823	0x9811 071F	ADSERR_DEVICE_ABORTED	Request is aborted.
0x720	1824	0x9811 0720	ADSERR_DEVICE_WARNING	Signal warning.
0x721	1825	0x9811 0721	ADSERR_DEVICE_INVALIDARRAYIDX	Invalid array index.
0x722	1826	0x9811 0722	ADSERR_DEVICE_SYMBOLNOTACTIVE	Symbol not active.
0x723	1827	0x9811 0723	ADSERR_DEVICE_ACCESSDENIED	Access denied.
0x724	1828	0x9811 0724	ADSERR_DEVICE_LICENSENOTFOUND	Missing license.
0x725	1829	0x9811 0725	ADSERR_DEVICE_LICENSEEXPIRED	License expired.
0x726	1830	0x9811 0726	ADSERR_DEVICE_LICENSEEXCEEDED	License exceeded.
0x727	1831	0x9811 0727	ADSERR_DEVICE_LICENSEINVALID	Invalid license.
0x728	1832	0x9811 0728	ADSERR_DEVICE_LICENSESYSTEMID	License problem: System ID is invalid.
0x729	1833	0x9811 0729	ADSERR_DEVICE_LICENSENOTIMELIMIT	License not limited in time.
0x72A	1834	0x9811 072A	ADSERR_DEVICE_LICENSEFUTUREISSUE	License problem: Time in the future.
0x72B	1835	0x9811 072B	ADSERR_DEVICE_LICENSETIMETOLONG	License period too long.
0x72C	1836	0x9811 072C	ADSERR_DEVICE_EXCEPTION	Exception at system startup.
0x72D	1837	0x9811 072D	ADSERR_DEVICE_LICENSEDUPLICATED	License file read twice.
0x72E	1838	0x9811 072E	ADSERR_DEVICE_SIGNATUREINVALID	Invalid signature.
0x72F	1839	0x9811 072F	ADSERR_DEVICE_CERTIFICATEINVALID	Invalid certificate.
0x730	1840	0x9811 0730	ADSERR_DEVICE_LICENSEOEMNOT-FOUND	Public key not known from OEM.
0x731	1841	0x9811 0731	ADSERR_DEVICE_LICENSERESTRICTED	License not valid for this system ID.
0x732	1842	0x9811 0732	ADSERR_DEVICE_LICENSEDEMODENIED	Demo license prohibited.
0x733	1843	0x9811 0733	ADSERR_DEVICE_INVALIDFNCID	Invalid function ID.
0x734	1844	0x9811 0734	ADSERR_DEVICE_OUTOFRANGE	Outside the valid range.
0x735	1845	0x9811 0735	ADSERR_DEVICE_INVALIDALIGNMENT	Invalid alignment.

Hex	Dec	HRESULT	Name	Description
0x736	1846	0x9811 0736	ADSERR_DEVICE_LICENSEPLATFORM	Invalid platform level.
0x737	1847	0x9811 0737	ADSERR_DEVICE_FORWARD_PL	Context – forward to passive level.
0x738	1848	0x9811 0738	ADSERR_DEVICE_FORWARD_DL	Context – forward to dispatch level.
0x739	1849	0x9811 0739	ADSERR_DEVICE_FORWARD_RT	Context – forward to real-time.
0x740	1856	0x9811 0740	ADSERR_CLIENT_ERROR	Client error.
0x741	1857	0x9811 0741	ADSERR_CLIENT_INVALIDPARM	Service contains an invalid parameter.
0x742	1858	0x9811 0742	ADSERR_CLIENT_LISTEMPTY	Polling list is empty.
0x743	1859	0x9811 0743	ADSERR_CLIENT_VARUSED	Var connection already in use.
0x744	1860	0x9811 0744	ADSERR_CLIENT_DUPLINVOKEID	The called ID is already in use.
0x745	1861	0x9811 0745	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	0x9811 0746	ADSERR_CLIENT_W32ERROR	Error in Win32 subsystem.
0x747	1863	0x9811 0747	ADSERR_CLIENT_TIMEOUTINVALID	Invalid client timeout value.
0x748	1864	0x9811 0748	ADSERR_CLIENT_PORTNOTOPEN	Port not open.
0x749	1865	0x9811 0749	ADSERR_CLIENT_NOAMSADDR	No AMS address.
0x750	1872	0x9811 0750	ADSERR_CLIENT_SYNCINTERNAL	Internal error in Ads sync.
0x751	1873	0x9811 0751	ADSERR_CLIENT_ADDHASH	Hash table overflow.
0x752	1874	0x9811 0752	ADSERR_CLIENT_REMOVEHASH	Key not found in the table.
0x753	1875	0x9811 0753	ADSERR_CLIENT_NOMORESYM	No symbols in the cache.
0x754	1876	0x9811 0754	ADSERR_CLIENT_SYNCRESINVALID	Invalid response received.
0x755	1877	0x9811 0755	ADSERR_CLIENT_SYNCPORTLOCKED	Sync Port is locked.

RTime error codes

Hex	Dec	HRESULT	Name	Description
0x1000	4096	0x9811 1000	RTERR_INTERNAL	Internal error in the real-time system.
0x1001	4097	0x9811 1001	RTERR_BADTIMERPERIODS	Timer value is not valid.
0x1002	4098	0x9811 1002	RTERR_INVALIDTASKPTR	Task pointer has the invalid value 0 (zero).
0x1003	4099	0x9811 1003	RTERR_INVALIDSTACKPTR	Stack pointer has the invalid value 0 (zero).
0x1004	4100	0x9811 1004	RTERR_PRIOEXISTS	The request task priority is already assigned.
0x1005	4101	0x9811 1005	RTERR_NOMORETCB	No free TCB (Task Control Block) available. The maximum number of TCBs is 64.
0x1006	4102	0x9811 1006	RTERR_NOMORESEMAS	No free semaphores available. The maximum number of semaphores is 64.
0x1007	4103	0x9811 1007	RTERR_NOMOREQUEUES	No free space available in the queue. The maximum number of positions in the queue is 64.
0x100D	4109	0x9811 100D	RTERR_EXTIRQALREADYDEF	An external synchronization interrupt is already applied.
0x100E	4110	0x9811 100E	RTERR_EXTIRQNOTDEF	No external sync interrupt applied.
0x100F	4111	0x9811 100F	RTERR_EXTIRQINSTALLFAILED	Application of the external synchronization interrupt has failed.
0x1010	4112	0x9811 1010	RTERR_IRQLNOTLESSOREQUAL	Call of a service function in the wrong context
0x1017	4119	0x9811 1017	RTERR_VMXNOTSUPPORTED	Intel VT-x extension is not supported.
0x1018	4120	0x9811 1018	RTERR_VMXDISABLED	Intel VT-x extension is not enabled in the BIOS.
0x1019	4121	0x9811 1019	RTERR_VMXCONTROLSMISSING	Missing function in Intel VT-x extension.
0x101A	4122	0x9811 101A	RTERR_VMXENABLEFAILS	Activation of Intel VT-x fails.

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. **Sample 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). **Sample 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. **Sample 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	POSITIONMONITORING (=> 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 initial 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 speed or current is limited in the drive unit, 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, speed 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 operating 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 area**

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.

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 [▶ 51].

7.3 Support and Service

Beckhoff and their partners around the world offer comprehensive support and service, making available fast and competent assistance with all questions related to Beckhoff products and system solutions.

Beckhoff's branch offices and representatives

Please contact your Beckhoff branch office or representative for local support and service on Beckhoff products!

The addresses of Beckhoff's branch offices and representatives round the world can be found on her internet pages: https://www.beckhoff.com

You will also find further documentation for Beckhoff components there.

Beckhoff Support

Support offers you comprehensive technical assistance, helping you not only with the application of individual Beckhoff products, but also with other, wide-ranging services:

- support
- design, programming and commissioning of complex automation systems
- and extensive training program for Beckhoff system components

Hotline:	+49 5246 963 157
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7.4 Third-party components

This software contains third-party components.
Please refer to the license file provided in the following folder for further information:
…\TwinCAT\Functions\TwinCAT Measurement\Legal

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.

More Information:
www.beckhoff.de/te1320

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