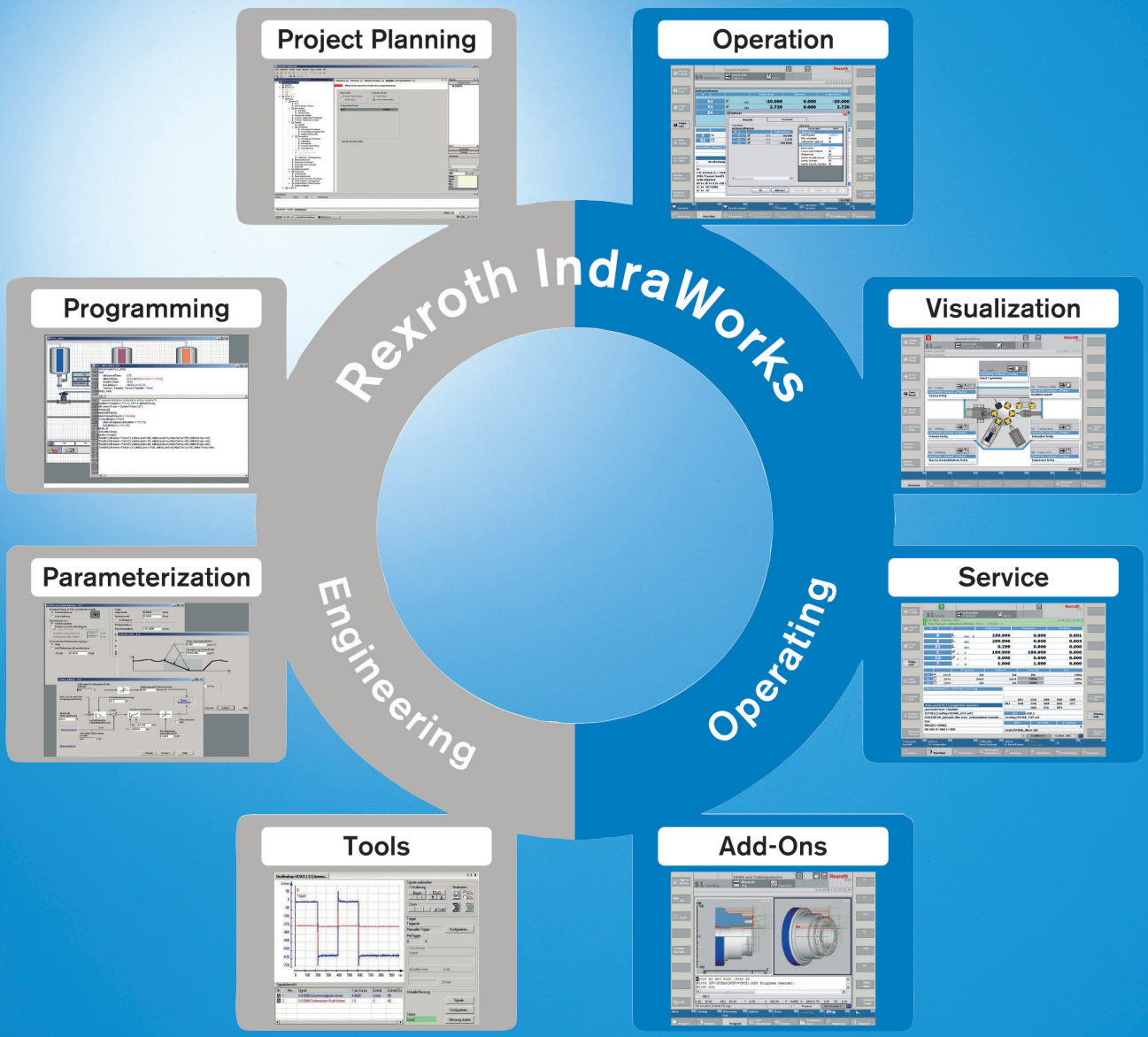
Electric Drives and Controls | Hydraulics | Linear Motion and Assembly Technologies | Pneumatics | Service

Rexroth Bosch Group

Rexroth IndraWorks CamBuilder 13VRS

R911336291
Edition 01

Application Manual



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Purpose of Documentation This documentation describes the basic principles and operation of the CamBuilder, the cam editing tool.

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1 About this Documentation

1.1 Validity of the Documentation

This documentation describes the basics and the operation of the CamBuilder for the version 13VRS.

Target group This documentation helps to create electronic cams using the CamBuilder.

Application phases This documentation supports the user during the phases:

- Engineering
- Commissioning

1.2 Documentation Structure

The first part of the documentation includes instructions for use and safety (chapter 2 "Important Instructions on Use" on page 15 and chapter 3 "Safety Instructions for Electric Drives and Controls" on page 17).

The chapter 4 "Introduction" on page 27 provides general notes on synchronization modes, CamBuilder features as well as term definitions.

The chapter 5 "First Steps – CamBuilder" on page 29 provides information on licensing, creating, downloading and analyzing cams.

The chapter 6 "Creating Cams and Preview Objects" on page 43 describes the creation of cams and preview objects.

The chapter 7 " Editing and Analyzing Cams" on page 47 provides information on editing and analyzing cams.

The chapter 8 "Managing Cams and Preview Objects in the IndraWorks Project" on page 77 describes the cam management (e.g. to create "Cam Pool" folder, open/save cam) and preview objects in the IndraWorks project.

The chapter 9 "Interacting with Bosch Rexroth Devices" on page 79 describes the download/upload from/to devices as well as the generation of a PLC function block.

The chapter 10 "Importing and Exporting Cams" on page 83 contains information on the import and export of cams.

The chapter 11 "CamBuilder Options and Cam Properties" on page 85 describes the CamBuilder options and the cam properties.

The chapter 12 " Printing Cams" on page 87 describes the possible print presettings to print a cam.

The chapter 13 "Motion Laws" on page 89 provides an overview on the available motion laws as well as a description of the analytic functions and the definition of a slave axis motion of a motion step using a cam table.

The chapter 14 "Service and Support" on page 121 provides information on the customer service helpdesk.

1.3 Required and Supplementing Documentations

Documentation titles with type codes and parts numbers

IndraWorks		MLC	XLC
/36/	**Rexroth IndraWorks 13VRS Software Installation** DOK-IWORKS-SOFTINS*V13-COxx-EN-P, R911336880 This documentation describes the IndraWorks installation.	X	X
/5/	**Rexroth IndraWorks 13VRS Engineering** DOK-IWORKS-ENGINEE*V13-APxx-EN-P, R911336870 This documentation describes the application of IndraWorks in which the Rexroth Engineering tools are integrated. It includes instructions on how to work with IndraWorks and how to operate the oscilloscope function.	X	X
/20/	**Rexroth IndraMotion MLC 13VRS Functional Description** DOK-MLC***-FUNC****V13-APxx-EN-P, R911336295 This documentation describes wizards, context menus, dialogs, control commissioning, device configuration and functionalities of the IndraMotion MLC.	X	
/20/	**Rexroth IndraLogic XLC 13VRS Functional Description** DOK-XLC***-FUNC****V13-APxx-EN-P, R911336352 This documentation describes wizards, context menus, dialogs, control commissioning, device configuration and functionalities of the IndraLogic XLC.		X
/7/	**Rexroth IndraWorks 13VRS CamBuilder** DOK-IWORKS-CAMBUIL*V13-APxx-EN-P, R911336291 This documentation describes the basic principles and operation of the CamBuilder, the cam editing tool.	X	X
/37/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS Automation Interface** DOK-XLCMLC-AUT*INT*V13-APxx-EN-P, R911336356 This documentation describes the script-based access to IndraWorks project data via the interface of the Automation Interface.	X	X
/38/	**Rexroth IndraWorks 12VRS FDT Container** DOK-IWORKS-FDT*CON*V12-APxx-EN-P, R911334398 This documentation describes the IndraWorks FDT Container functionality. It includes the activation of the functionality in the project and working with DTMs.	X	X
/29/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS Project Conversion** DOK-XLCMLC-PROCONV*V13-APxx-EN-P, R911336366 This documentation describes the project conversion of IndraLogic 04VRS and IndraMotion MLC04VRS on IndraWorks version 12 with IndraLogic 2G. Changes with regard to Motion and PLC are described in detail.	X	X
/28/	**Rexroth IndraMotion MLC 13VRS Commissioning** DOK-MLC***-STARTUP*V13-COxx-EN-P, R911336308 This documentation describes the steps required to commission and perform service on the IndraMotion MLC system. It includes checklists for tasks to be frequently performed and a detailed description of the steps.	X	

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Fig.1-1: XCL/MLC documentation overview

Motion		MLC	XLC
/23/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS PLCopen Libraries** DOK-XLCMLC-FUNLIB**V13-LIxx-EN-P, R911336360 This documentation describes the function blocks, functions and data types of the RIL_Common-Types, ML_Base and ML_PLCopen libraries for the IndraLogic XLC/IndraMotion MLC. It also includes the error reactions of function blocks.	X	X
/27/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS Generic Application Template** DOK-XLCMLC-TF*GAT**V13-APxx-EN-P, R911336370 This documentation provides a structured template to the IndraLogic PLC programmer. This template can be used to add and edit the PLC programming code. It includes the template, the template wizard and example applications.	X	X
/31/	**Rexroth IndraMotion MLC 13VRS RCL Programming Instruction** DOK-MLC***-RCL*PRO*V13-APxx-EN-P, R911336297 This documentation provides information on the RobotControl. The programming language RCL (RobotControl Language) is focused. The program structure, variables, functions, motion statements and the required system parameters are described.	X	
/21/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS Parameters** DOK-XLCMLC-PARAM***V13-RExx-EN-P, R911336364 This documentation describes the parameters of the XLC/MLC systems as well as the interaction between parameterization and programming. It includes the axis parameters, control parameters, kinematic parameters, touch probe parameters and programmable limit switch parameters.	X	X
/10/	**Rexroth IndraDrive Firmware for Drive Controllers MPH-, MPB-, MPD-, MPC-07** DOK-INDRV*-MP*-07VRS**-FKxx-EN-P, R911328670 This documentation describes all functional properties of the IndraDrive firmware in the variants MPH-07, MPB-07, MPD-07 and MPC-07.		
/11/	**Rexroth IndraDrive MPx-17 Functions** DOK-INDRV*-MP*-17VRS**-APxx-EN-P, R911331236 This documentation describes all functional properties of the IndraDrive firmware in the variants MPB-17, MPM-17, MPC-17 and MPE-17.		

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Fig.1-2: XCL/MLC documentation overview

About this Documentation

Field buses		MLC	XLC
/39/	**Rexroth IndraMotion MLC 11VRS PLCopen Field Bus** DOK-IM*ML*-PLCFBUS*V11-APxx-EN-P, R911333896 This documentation describes the creation of field bus drives in an IndraWorks project, function blocks, functions and data types of the RIL_CommonTypes.library (excerpt for field bus drives), the RMB_PLCopenFieldBus.library and the RIL_Utilities.library (excerpt for field bus drives). It also includes the error reactions of function blocks.	X	X
/4/	**Rexroth IndraWorks 13VRS Field Buses** DOK-IWORKS-FB******V13-APxx-EN-P, R911336872 This documentation describes the supported field buses and their diagnostic function blocks.	X	X
/63/	**SERCOS System Manual for I/O Devices** DOK-CONTRL-ILS3*******-APxx-EN-P, R911333512 This documentation describes the configuration, parameterization, commissioning and diagnostics of I/O devices with a SERCOS interface.	X	X

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Fig.1-3: XCL/MLC documentation overview

HMI		MLC	XLC
/8/	**Rexroth IndraWorks 13VRS HMI** DOK-IWORKS-HMI*****V13-APxx-EN-P, R911336874 This documentation describes the functions, configuration and operation of the user interfaces IndraWorks HMI Engineering and IndraWorks HMI Operation.	X	X
/6/	**Rexroth IndraWorks 13VRS WinStudio** DOK-IWORKS-WINSTUD*V13-APxx-EN-P, R911336882 This documentation describes the installation of the software, working with WinStudio and the creation and operation of applications.	X	X
/50/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS HMI Connection** DOK-XLCMLC-HMI*****V13-APxx-EN-P, R911336362 This documentation describes the visualization systems supported by the IndraLogic XLC and IndraMotion MLC and their connection.	X	X

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Fig.1-4: XCL/MLC documentation overview

PLC		MLC	XLC
/3/	**Rexroth IndraWorks 13VRS IndraLogic 2G Programming Instruction** DOK-IWORKS-IL2GPRO*V13-APxx-EN-P, R911336876 This documentation describes the PLC programming tool IndraLogic 2G and its use. It includes the basic use, first steps, visualization, menu items and editors.	X	X
/33/	**Rexroth IndraWorks 13VRS, Basic Libraries, IndraLogic 2G** DOK-IL*2G*-BASLIB**V13-LIxx-EN-P, R911336285 This documentation describes the system-comprehensive PLC libraries.	X	X

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Fig.1-5: XCL/MLC documentation overview

Technology		MLC	XLC
/30/	**Rexroth IndraMotion MLC 13VRS Technology Libraries** DOK-MLC***-TF*LIB**V13-LIxx-EN-P, R911336324 This documentation describes the function blocks, functions and data types of the "ML_TechInterface.library", "ML_TechMotion.library", "RMB_TechCam.library" and "ML_TechBase.library". It also includes libraries for the winder functionality, register controller functionality and CrossCutter functionality.	X	
/60/	**Rexroth IndraMotion MLC 13VRS RegisterControl (Library)** DOK-MLC***-REGI*CO*V13-LIxx-EN-P, R911336306 This documentation describes the inputs and outputs of the individual function blocks and provides notes on their use.	X	
/62/	**Rexroth IndraMotion MLC 13VRS RegisterControl (Application Manual)** DOK-MLC***-REGI*CO*V13-APxx-EN-P, R911336304 This documentation describes the application of the integrated register control for a rotogravure printing machine. The components of the mark stream sensor, the HMI application and the error recovery options are described. This instruction provides information on how to operate the register control, react to errors and query diagnostics. This documentation is written for machine setters and machine operators.	X	
/49/	**Rexroth IndraMotion MLC 13VRS Winder Function Application** DOK-MLC***-TF*WIND*V13-APxx-EN-P, R911336326 This application-related system documentation describes the application of the winder technology functions.	X	

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Fig.1-6: XCL/MLC documentation overview

Hardware		MLC	XLC
/1/	**Rexroth IndraControl L45/L65** DOK-CONTRL-IC*L45*L65*-PRxx-EN-P, R911324661 This documentation describes the IndraControl L45/L65 controls.	X	X
/2/	**Rexroth IndraControl L25** DOK-CONTRL-IC*L25*****-PRxx-EN-P, R911328474 This documentation describes the IndraControl L25 controls.	X	X
/24/	**Rexroth IndraControl Lxx 13VRS Function Modules** DOK-CONTRL-FM*LXX**V13-APxx-EN-P, R911336283 This documentation describes all function modules of the Lxx controls including engineering and diagnostics.	X	X
/12/	**Rexroth IndraDrive Drive Controllers MPx-02 to MPx-07** DOK-INDRV*-GEN-**VRS**-PAxx-EN-P, R911297317 This documentation describes all parameters implemented in the firmware for drive controllers of the IndraDrive family. It supports the parameterization of the drive controllers.		

About this Documentation

Hardware		MLC	XLC
/13/	**Rexroth IndraDrive MPx-02 to MPx-07 and HMV** DOK-INDRV*-GEN-**VRS**-WAxx-EN-P, R911297319 This documentation describes all diagnostics implemented in the following firmwares: • Drive controller firmwares from MPx-02 to MPx-08 and • firmwares of the supply devices of the type "HMV". It supports the operating crew as well as the programmer at troubleshooting.		
/35/	**Rexroth IndraDrive Drive Controller Control Sections CSB01, CSH01, CDB01** DOK-INDRV*-CSH********-PRxx-EN-P, R911295012 This documentation is a project planning manual to select and use the control sections CSB01, CDB01 and CSH01 for drive controllers of the product families Rexroth IndraDrive M and Rexroth IndraDrive C.		

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Fig.1-7: XCL/MLC documentation overview

Diagnostics and service		MLC	XLC
/26/	**Rexroth IndraMotion MLC/MLP/XLC 11VRS IndraMotion Service Tool** DOK-IM*ML*-IMST****V11-RExx-EN-P, R911331940 This documentation describes the IndraMotion Service Tool (IMST). It is a web-based diagnostic tool to access the control systems IndraMotion MLC L25, L45 or 65 as well as the MLP via an Ethernet high-speed connection. The IMST allows OEMs, end users and service engineers to access and remotely diagnose a system. A PC with Internet Explorer version 6 or 7 is required.	X	X
/22/	**Rexroth IndraLogic XLC IndraMotion MLC 13VRS Diagnostics** DOK-XLCMLC-DIAG****V13-RExx-EN-P, R911336358 This documentation includes all control parameters implemented in the control systems IndraLogic XLC and IndraMotion MLC.	X	X

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Fig.1-8: XCL/MLC documentation overview

System Overview		MLC	XLC
/48/	**Rexroth IndraMotion for Printing 13VRS System Overview** DOK-IM*PR*-SYSTEM**V13-PRxx-EN-P, R911336289 This documentation describes the product IndraMotion for Packaging. It introduces the control systems, drive systems and I/O systems as well as the commissioning and programming.	X	
/48/	**Rexroth IndraMotion for Packaging 13VRS System Overview** DOK-IM*PA*-SYSTEM**V13-PRxx-EN-P, R911336287 This documentation describes the product IndraMotion for Packaging. It introduces the control systems, drive systems and I/O systems as well as the commissioning and programming.	X	

System Overview		MLC	XLC
/9/	**Rexroth IndraMotion MLC 13VRS System Overview** DOK-MLC***-SYSTEM**V13-PRxx-EN-P, R911336310 This documentation provides an overview on the hardware/software components of the automation system IndraMotion MLC in the mentioned version. It helps assembling a system.	X	
/9/	**Rexroth IndraLogic XLC 13VRS System Overview** DOK-XLC***-SYSTEM**V13-PRxx-EN-P, R911336354 This documentation provides an overview on hardware/software components of the automation system IndraLogic XLC in the respective version. It helps assembling a system.		X

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Fig. 1-9: XCL/MLC documentation overview

First steps		MLC	XLC
/25/	**Rexroth IndraMotion MLC 13VRS, First Steps** DOK-MLC***-F*STEP**V13-COxx-EN-P, R911336293 This documentation describes the first steps of the IndraMotion MLC and the RobotControl. It includes the hardware and software prerequisites as well as the creation of a project.	X	
/25/	**Rexroth IndraLogic XLC 13VRS, First Steps** DOK-XLC***-F*STEP**V13-COxx-EN-P, R911336350 This documentation describes the first steps of the IndraLogic XLC. It includes the hardware and software prerequisites as well as the creation of a project.		X

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Fig. 1-10: XCL/MLC documentation overview

1.4 Information Representation

1.4.1 Safety Instructions

If there are the safety instructions in the documentation, they contain certain signal words ("Danger", "Warning", "Caution", "Notice") and sometimes a safety alert symbol (according to ANSI Z535.6-2006).

The signal word draws the attention to the safety notice and indicates the risk potential.

The safety alert symbol (triangular safety reflector with three exclamation marks), preceding the signal words "Danger", "Warning", "Caution" indicates hazards for persons.

The safety instructions are represented as follows in this documentation:

⚠ DANGER

In case of non-compliance with these safety instructions, death or serious injury **will** occur.

⚠ WARNING

In case of non-compliance with these safety instructions, death or serious injury **can** occur.

⚠ CAUTION

In case of non-compliance with these safety instructions, minor or moderately severe injury can occur.

NOTICE

In case of non-compliance with these safety instructions, material or property damage can occur.

1.4.2 Symbols Used

Note Notes are represented as follows:

 This is a note for the user.

Tip Tips are represented as follows:

 This is a tip for the user.

1.4.3 Names and Abbreviations

Term	Explanation
Cam Pool	Folder in IndraWorks (to store the created cams)
Function block	Provides application-specific functionalities
Graph	Graphic representation of a function
VisualMotion	Programmable multi-axis motion control system
IndraMotion MLC	Compact MotionLogic system with MotionControl, RobotControl and LogicControl functionality
IndraLogic XLC	Compact PLC system with integrated motion functionality
IndraWorks	Configuration and commissioning tool by Bosch Rexroth
IndraDrive	Drive-control device
IndraSize	Software tool to determine the drive design
Wizard	Wizard guiding through several dialogs for an ergonomic data input
IEC	International Electrotechnical Commission (standards committee for electrical engineering)
XML	The Extensible Markup Language, XML, represents hierarchically structured data as text data.
CSV	This file format describes the structure of a text file to save or exchange simply structured data. The file extension .csv is an abbreviation for Comma-"Separated Values"
PAR	Parameter file in ASCII format to save data
ST	Structured Text
CFC	Continuous Function Chart

TPD	Turning Point Displacement
ms	Millisecond
mm	Millimeter
%	Percent
Rad/s	Angular velocity
rpm	Speed
Degrees	Angular size

Fig.1-11: Terms and abbreviations used

2 Important Instructions on Use

2.1 Intended Use

2.1.1 Introduction

Bosch Rexroth products are developed and manufactured according to the state-of-the-art. The products are tested prior to delivery to ensure operating safety and reliability.

⚠ WARNING **Personal injury and damage to property due to incorrect use of products!**

The products have been developed for the use in an industrial environment and may only be used as intended. If they are not used as intended, situations occur that can result in damage to property and injury to persons.

☞ Bosch Rexroth as manufacturer shall not assume any warranty, liability or payment of damages in case of damage resulting from a non-intended use of the products; the user shall solely bear all risks arising from unintended use of the products.

Before using Bosch Rexroth products, the following requirements have to be met to guarantee the intended use of the products:

- Anybody dealing with Bosch Rexroth Products in any way is obliged to read and consent to the relevant safety instructions and the intended use.
- Hardware products may not be altered and have to remain in their original state; i.e., no structural changes are permitted.
- The decompilation of software products or the alteration of source codes is not permitted
- Do not install or operate damaged or faulty products
- It has to be ensured that the products have been installed as described in the relevant documentation.

2.1.2 Scope of Use and Application

The products IndraMotion MLC/IndraLogic XLC of Bosch Rexroth are intended for Motion/Logic applications.

☞ The IndraMotion MLC/IndraLogic XLC must only be used together with the accessories and attachment parts given in this documentation. Components that are not expressly mentioned must neither be attached nor connected. The same is valid for cables and lines.

The operation must only be carried out with the component configurations and combinations that were expressly mentioned and with the software and firmware indicated and specified in the respective functional description.

The IndraMotion MLC/IndraLogic XLC has been developed for Logic applications as well as for the usage in single and multi-axes drive and control tasks.

To allow for application-specific requirements of the IndraMotion MLC/ IndraLogic XLC, various device types with different performance and interfaces are provided.

Typical areas of application of the IndraMotion MLC/IndraLogic XLC are:

- Handling and mounting systems
- Packaging and food machines
- Printing and paper-processing machines
- Machine tools
- Presses
- Foundry and rolling technology
- Conveying engineering
- Building automation and control
- Special-purpose machines
- Wood working machinery

The IndraMotion MLC/IndraLogic XLC may only be operated under the mounting and installation conditions, position and ambient conditions (temperature, degree of protection, moisture, EMC, etc.) specified in this documentation.

2.2 Unintended Use

Usage of the IndraMotion MLC/IndraLogic XLC in applications areas other than those specified or described in the documentation and technical data is considered as "unintended".

The IndraMotion MLC/IndraLogic XLC must not be used if

- they are subjected to operating conditions not corresponding to the specified ambient conditions. Operation under water, under extreme temperature fluctuations or under extreme maximum temperatures or in explosion-prone areas is prohibited.
- the intended applications have not expressly been released by Bosch Rexroth. Therefore, please read the information given in the general safety instructions!

Furthermore, the use as safety-relevant part of controls according to DIN EN ISO 13849 is considered as unintended use. The functional safety has to be ensured by additional safety-relevant certified components.

3 Safety Instructions for Electric Drives and Controls

3.1 Definitions of Terms

Application Documentation Application documentation comprises the entire documentation used to inform the user of the product about the use and safety-relevant features for configuring, integrating, installing, mounting, commissioning, operating, maintaining, repairing and decommissioning the product. The following terms are also used for this kind of documentation: User Guide, Operation Manual, Commissioning Manual, Instruction Manual, Project Planning Manual, Application Manual, etc.

Component A component is a combination of elements with a specified function, which are part of a piece of equipment, device or system. Components of the electric drive and control system are, for example, supply units, drive controllers, mains choke, mains filter, motors, cables, etc.

Control System A control system comprises several interconnected control components placed on the market as a single functional unit.

Device A device is a finished product with a defined function, intended for users and placed on the market as an individual piece of merchandise.

Electrical Equipment Electrical equipment encompasses all devices used to generate, convert, transmit, distribute or apply electrical energy, such as electric motors, transformers, switching devices, cables, lines, power-consuming devices, circuit board assemblies, plug-in units, control cabinets, etc.

Electric Drive System An electric drive system comprises all components from mains supply to motor shaft; this includes, for example, electric motor(s), motor encoder(s), supply units and drive controllers, as well as auxiliary and additional components, such as mains filter, mains choke and the corresponding lines and cables.

Installation An installation consists of several devices or systems interconnected for a defined purpose and on a defined site which, however, are not intended to be placed on the market as a single functional unit.

Machine A machine is the entirety of interconnected parts or units at least one of which is movable. Thus, a machine consists of the appropriate machine drive elements, as well as control and power circuits, which have been assembled for a specific application. A machine is, for example, intended for processing, treatment, movement or packaging of a material. The term "machine" also covers a combination of machines which are arranged and controlled in such a way that they function as a unified whole.

Manufacturer The manufacturer is an individual or legal entity bearing responsibility for the design and manufacture of a product which is placed on the market in the individual's or legal entity's name. The manufacturer can use finished products, finished parts or finished elements, or contract out work to subcontractors. However, the manufacturer must always have overall control and possess the required authority to take responsibility for the product.

Product Examples of a product: Device, component, part, system, software, firmware, among other things.

Project Planning Manual A project planning manual is part of the application documentation used to support the sizing and planning of systems, machines or installations.

Qualified Persons In terms of this application documentation, qualified persons are those persons who are familiar with the installation, mounting, commissioning and operation of the components of the electric drive and control system, as well as with the hazards this implies, and who possess the qualifications their work

requires. To comply with these qualifications, it is necessary, among other things,

1) to be trained, instructed or authorized to switch electric circuits and devices safely on and off, to ground them and to mark them

2) to be trained or instructed to maintain and use adequate safety equipment

3) to attend a course of instruction in first aid

User A user is a person installing, commissioning or using a product which has been placed on the market.

3.2 General Information

3.2.1 Using the Safety Instructions and Passing Them on to Others

Do not attempt to install and operate the components of the electric drive and control system without first reading all documentation provided with the product. Read and understand these safety instructions and all user documentation prior to working with these components. If you do not have the user documentation for the components, contact your responsible Bosch Rexroth sales partner. Ask for these documents to be sent immediately to the person or persons responsible for the safe operation of the components.

If the component is resold, rented and/or passed on to others in any other form, these safety instructions must be delivered with the component in the official language of the user's country.

Improper use of these components, failure to follow the safety instructions in this document or tampering with the product, including disabling of safety devices, could result in property damage, injury, electric shock or even death.

3.2.2 Requirements for Safe Use

Read the following instructions before initial commissioning of the components of the electric drive and control system in order to eliminate the risk of injury and/or property damage. You must follow these safety instructions.

- Bosch Rexroth is not liable for damages resulting from failure to observe the safety instructions.
- Read the operating, maintenance and safety instructions in your language before commissioning. If you find that you cannot completely understand the application documentation in the available language, please ask your supplier to clarify.
- Proper and correct transport, storage, mounting and installation, as well as care in operation and maintenance, are prerequisites for optimal and safe operation of the component.
- Only qualified persons may work with components of the electric drive and control system or within its proximity.
- Only use accessories and spare parts approved by Bosch Rexroth.
- Follow the safety regulations and requirements of the country in which the components of the electric drive and control system are operated.
- Only use the components of the electric drive and control system in the manner that is defined as appropriate. See chapter "Appropriate Use".
- The ambient and operating conditions given in the available application documentation must be observed.
- Applications for functional safety are only allowed if clearly and explicitly specified in the application documentation "Integrated Safety Technolo-

gy". If this is not the case, they are excluded. Functional safety is a safety concept in which measures of risk reduction for personal safety depend on electrical, electronic or programmable control systems.

- The information given in the application documentation with regard to the use of the delivered components contains only examples of applications and suggestions.

  The machine and installation manufacturers must

  – make sure that the delivered components are suited for their individual application and check the information given in this application documentation with regard to the use of the components,

  – make sure that their individual application complies with the applicable safety regulations and standards and carry out the required measures, modifications and complements.

- Commissioning of the delivered components is only allowed once it is sure that the machine or installation in which the components are installed complies with the national regulations, safety specifications and standards of the application.
- Operation is only allowed if the national EMC regulations for the application are met.
- The instructions for installation in accordance with EMC requirements can be found in the section on EMC in the respective application documentation.

  The machine or installation manufacturer is responsible for compliance with the limit values as prescribed in the national regulations.
- The technical data, connection and installation conditions of the components are specified in the respective application documentations and must be followed at all times.

National regulations which the user must take into account

- European countries: In accordance with European EN standards
- United States of America (USA):
  – National Electrical Code (NEC)
  – National Electrical Manufacturers Association (NEMA), as well as local engineering regulations
  – Regulations of the National Fire Protection Association (NFPA)
- Canada: Canadian Standards Association (CSA)
- Other countries:
  – International Organization for Standardization (ISO)
  – International Electrotechnical Commission (IEC)

3.2.3 Hazards by Improper Use

- High electrical voltage and high working current! Danger to life or serious injury by electric shock!
- High electrical voltage by incorrect connection! Danger to life or injury by electric shock!
- Dangerous movements! Danger to life, serious injury or property damage by unintended motor movements!
- Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric drive systems!

- Risk of burns by hot housing surfaces!
- Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!
- Risk of injury by improper handling of batteries!
- Risk of injury by improper handling of pressurized lines!

3.3 Instructions with Regard to Specific Dangers

3.3.1 Protection Against Contact With Electrical Parts and Housings

☞ This section concerns components of the electric drive and control system with voltages of **more than 50 volts**.

Contact with parts conducting voltages above 50 volts can cause personal danger and electric shock. When operating components of the electric drive and control system, it is unavoidable that some parts of these components conduct dangerous voltage.

High electrical voltage! Danger to life, risk of injury by electric shock or serious injury!

- Only qualified persons are allowed to operate, maintain and/or repair the components of the electric drive and control system.
- Follow the general installation and safety regulations when working on power installations.
- Before switching on, the equipment grounding conductor must have been permanently connected to all electric components in accordance with the connection diagram.
- Even for brief measurements or tests, operation is only allowed if the equipment grounding conductor has been permanently connected to the points of the components provided for this purpose.
- Before accessing electrical parts with voltage potentials higher than 50 V, you must disconnect electric components from the mains or from the power supply unit. Secure the electric component from reconnection.
- With electric components, observe the following aspects:

  Always wait **30 minutes** after switching off power to allow live capacitors to discharge before accessing an electric component. Measure the electrical voltage of live parts before beginning to work to make sure that the equipment is safe to touch.
- Install the covers and guards provided for this purpose before switching on.
- Never touch electrical connection points of the components while power is turned on.
- Do not remove or plug in connectors when the component has been powered.
- Under specific conditions, electric drive systems can be operated at mains protected by residual-current-operated circuit-breakers sensitive to universal current (RCDs/RCMs).

- Secure built-in devices from penetrating foreign objects and water, as well as from direct contact, by providing an external housing, for example a control cabinet.

High housing voltage and high leakage current! Danger to life, risk of injury by electric shock!

- Before switching on and before commissioning, ground or connect the components of the electric drive and control system to the equipment grounding conductor at the grounding points.
- Connect the equipment grounding conductor of the components of the electric drive and control system permanently to the main power supply at all times. The leakage current is greater than 3.5 mA.
- Establish an equipment grounding connection with a minimum cross section according to the table below. With an outer conductor cross section smaller than 10 mm^2 (8 AWG), the alternative connection of two equipment grounding conductors is allowed, each having the same cross section as the outer conductors.

Cross section outer conductor	Minimum cross section equipment grounding conductor Leakage current ≥ 3.5 mA	
	1 equipment grounding conductor	2 equipment grounding conductors
1,5 mm^2 (AWG 16)	10 mm^2 (AWG 8)	2 × 1,5 mm^2 (AWG 16)
2,5 mm^2 (AWG 14)		2 × 2,5 mm^2 (AWG 14)
4 mm^2 (AWG 12)		2 × 4 mm^2 (AWG 12)
6 mm^2 (AWG 10)		2 × 6 mm^2 (AWG 10)
10 mm^2 (AWG 8)		-
16 mm^2 (AWG 6)	16 mm^2 (AWG 6)	-
25 mm^2 (AWG 4)		-
35 mm^2 (AWG 2)		-
50 mm^2 (AWG 1/0)	25 mm^2 (AWG 4)	-
70 mm^2 (AWG 2/0)	35 mm^2 (AWG 2)	-
...	...	...

Fig.3-1: Minimum Cross Section of the Equipment Grounding Connection

3.3.2 Protective Extra-Low Voltage as Protection Against Electric Shock

Protective extra-low voltage is used to allow connecting devices with basic insulation to extra-low voltage circuits.

On components of an electric drive and control system provided by Bosch Rexroth, all connections and terminals with voltages between 5 and 50 volts are PELV ("Protective Extra-Low Voltage") systems. It is allowed to connect devices equipped with basic insulation (such as programming devices, PCs, notebooks, display units) to these connections.

Danger to life, risk of injury by electric shock! High electrical voltage by incorrect connection!

If extra-low voltage circuits of devices containing voltages and circuits of more than 50 volts (e.g., the mains connection) are connected to Bosch Rexroth products, the connected extra-low voltage circuits must comply with the requirements for PELV ("Protective Extra-Low Voltage").

3.3.3 Protection Against Dangerous Movements

Dangerous movements can be caused by faulty control of connected motors. Some common examples are:

- Improper or wrong wiring or cable connection
- Operator errors
- Wrong input of parameters before commissioning
- Malfunction of sensors and encoders
- Defective components
- Software or firmware errors

These errors can occur immediately after equipment is switched on or even after an unspecified time of trouble-free operation.

The monitoring functions in the components of the electric drive and control system will normally be sufficient to avoid malfunction in the connected drives. Regarding personal safety, especially the danger of injury and/or property damage, this alone cannot be relied upon to ensure complete safety. Until the integrated monitoring functions become effective, it must be assumed in any case that faulty drive movements will occur. The extent of faulty drive movements depends upon the type of control and the state of operation.

Dangerous movements! Danger to life, risk of injury, serious injury or property damage!

A **risk assessment** must be prepared for the installation or machine, with its specific conditions, in which the components of the electric drive and control system are installed.

As a result of the risk assessment, the user must provide for monitoring functions and higher-level measures on the installation side for personal safety. The safety regulations applicable to the installation or machine must be taken into consideration. Unintended machine movements or other malfunctions are possible if safety devices are disabled, bypassed or not activated.

To avoid accidents, injury and/or property damage:

- Keep free and clear of the machine’s range of motion and moving machine parts. Prevent personnel from accidentally entering the machine’s range of motion by using, for example:
  - Safety fences
  - Safety guards
  - Protective coverings
  - Light barriers
- Make sure the safety fences and protective coverings are strong enough to resist maximum possible kinetic energy.
- Mount emergency stopping switches in the immediate reach of the operator. Before commissioning, verify that the emergency stopping equip-

ment works. Do not operate the machine if the emergency stopping switch is not working.

- Prevent unintended start-up. Isolate the drive power connection by means of OFF switches/OFF buttons or use a safe starting lockout.
- Make sure that the drives are brought to safe standstill before accessing or entering the danger zone.
- Additionally secure vertical axes against falling or dropping after switching off the motor power by, for example,
  - mechanically securing the vertical axes,
  - adding an external braking/arrester/clamping mechanism or
  - ensuring sufficient counterbalancing of the vertical axes.
- The standard equipment **motor holding brake** or an external holding brake controlled by the drive controller is **not sufficient to guarantee personal safety**!
- Disconnect electrical power to the components of the electric drive and control system using the master switch and secure them from reconnection ("lock out") for:
  - Maintenance and repair work
  - Cleaning of equipment
  - Long periods of discontinued equipment use
- Prevent the operation of high-frequency, remote control and radio equipment near components of the electric drive and control system and their supply leads. If the use of these devices cannot be avoided, check the machine or installation, at initial commissioning of the electric drive and control system, for possible malfunctions when operating such high-frequency, remote control and radio equipment in its possible positions of normal use. It might possibly be necessary to perform a special electromagnetic compatibility (EMC) test.

3.3.4 Protection Against Magnetic and Electromagnetic Fields During Operation and Mounting

Magnetic and electromagnetic fields generated by current-carrying conductors or permanent magnets of electric motors represent a serious danger to persons with heart pacemakers, metal implants and hearing aids.

Health hazard for persons with heart pacemakers, metal implants and hearing aids in proximity to electric components!

- Persons with heart pacemakers and metal implants are not allowed to enter the following areas:
  - Areas in which components of the electric drive and control systems are mounted, commissioned and operated.
  - Areas in which parts of motors with permanent magnets are stored, repaired or mounted.
- If it is necessary for somebody with a heart pacemaker to enter such an area, a doctor must be consulted prior to doing so. The noise immunity of implanted heart pacemakers differs so greatly that no general rules can be given.
- Those with metal implants or metal pieces, as well as with hearing aids, must consult a doctor before they enter the areas described above.

Safety Instructions for Electric Drives and Controls

3.3.5 Protection Against Contact With Hot Parts

Hot surfaces of components of the electric drive and control system. Risk of burns!

- Do not touch hot surfaces of, for example, braking resistors, heat sinks, supply units and drive controllers, motors, windings and laminated cores!
- According to the operating conditions, temperatures of the surfaces can be **higher than 60 °C** (140 °F) during or after operation.
- Before touching motors after having switched them off, let them cool down for a sufficient period of time. Cooling down can require **up to 140 minutes**! The time required for cooling down is approximately five times the thermal time constant specified in the technical data.
- After switching chokes, supply units and drive controllers off, wait **15 minutes** to allow them to cool down before touching them.
- Wear safety gloves or do not work at hot surfaces.
- For certain applications, and in accordance with the respective safety regulations, the manufacturer of the machine or installation must take measures to avoid injuries caused by burns in the final application. These measures can be, for example: Warnings at the machine or installation, guards (shieldings or barriers) or safety instructions in the application documentation.

3.3.6 Protection During Handling and Mounting

Risk of injury by improper handling! Injury by crushing, shearing, cutting, hitting!

- Observe the relevant statutory regulations of accident prevention.
- Use suitable equipment for mounting and transport.
- Avoid jamming and crushing by appropriate measures.
- Always use suitable tools. Use special tools if specified.
- Use lifting equipment and tools in the correct manner.
- Use suitable protective equipment (hard hat, safety goggles, safety shoes, safety gloves, for example).
- Do not stand under hanging loads.
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

3.3.7 Battery Safety

Batteries consist of active chemicals in a solid housing. Therefore, improper handling can cause injury or property damage.

Risk of injury by improper handling!

- Do not attempt to reactivate low batteries by heating or other methods (risk of explosion and cauterization).
- Do not attempt to recharge the batteries as this may cause leakage or explosion.
- Do not throw batteries into open flames.
- Do not dismantle batteries.

- When replacing the battery/batteries, do not damage the electrical parts installed in the devices.
- Only use the battery types specified for the product.

☞ Environmental protection and disposal! The batteries contained in the product are considered dangerous goods during land, air, and sea transport (risk of explosion) in the sense of the legal regulations. Dispose of used batteries separately from other waste. Observe the national regulations of your country.

3.3.8 Protection Against Pressurized Systems

According to the information given in the Project Planning Manuals, motors and components cooled with liquids and compressed air can be partially supplied with externally fed, pressurized media, such as compressed air, hydraulics oil, cooling liquids and cooling lubricants. Improper handling of the connected supply systems, supply lines or connections can cause injuries or property damage.

Risk of injury by improper handling of pressurized lines!

- Do not attempt to disconnect, open or cut pressurized lines (risk of explosion).
- Observe the respective manufacturer's operating instructions.
- Before dismounting lines, relieve pressure and empty medium.
- Use suitable protective equipment (safety goggles, safety shoes, safety gloves, for example).
- Immediately clean up any spilled liquids from the floor due to the risk of falling!

☞ Environmental protection and disposal! The agents (e.g., fluids) used to operate the product might not be environmentally friendly. Dispose of agents harmful to the environment separately from other waste. Observe the national regulations of your country.

3.4 Explanation of Signal Words and the Safety Alert Symbol

The Safety Instructions in the available application documentation contain specific signal words (DANGER, WARNING, CAUTION or NOTICE) and, where required, a safety alert symbol (in accordance with ANSI Z535.6-2011).

The signal word is meant to draw the reader's attention to the safety instruction and identifies the hazard severity.

The safety alert symbol (a triangle with an exclamation point), which precedes the signal words DANGER, WARNING and CAUTION, is used to alert the reader to personal injury hazards.

⚠ DANGER

In case of non-compliance with this safety instruction, death or serious injury **will** occur.

Safety Instructions for Electric Drives and Controls

⚠ WARNING

In case of non-compliance with this safety instruction, death or serious injury **could** occur.

⚠ CAUTION

In case of non-compliance with this safety instruction, minor or moderate injury could occur.

NOTICE

In case of non-compliance with this safety instruction, property damage could occur.

4 Introduction

4.1 General Information

The CamBuilder is a tool integrated into IndraWorks Engineering to simply and conveniently create electronic cams. The CamBuilder supports the direct download of cams to Bosch Rexroth drive controllers as well as the creation of cam PLC function blocks to parameterize FlexProfiles. Thanks to these features, this tool meets the requirements and characteristics of the Bosch Rexroth drive controllers.

4.2 Cams and Synchronization Modes

Electronic cams control the motion sequences of slave axes with regard to master axes.

The Bosch Rexroth drive controllers have different synchronization modes to execute cams.

Cam table The position of the slave axis is calculated from the distance and the percentage values of the table at runtime.

MotionProfile The position of the slave axis is calculated using analytical functions or cam tables at runtime.

FlexProfile The FlexProfile corresponds to an extension of the MotionProfile (the time can be used as reference variable for the slave axis and has a greater selection of motion laws and an event control).

The CamBuilder is a superordinate tool and does not differentiate between the various operation modes while creating and editing. Only if a cam is downloaded to a device, the corresponding operation mode has to be specified.

4.3 CamBuilder - Features

The essential features of the CamBuilder are:

- Easy creation of cams using graphic objects
- Comfortable cam editing
- Opening of several cams parallelly in a preview and analyzing them at different master axis velocities
- Usage of VDI 2143-compliant motion laws
- Upload and download of cams to Bosch Rexroth drives and controls
- Generating a PLC code to change the cam in the PLC program at runtime
- Entering variables, formulas and references into the cam editor to generate flexible cam definitions.
- Automatic display of position, acceleration, velocity and jerk
- Support for common requirements (application-specific cams such as CrossCutter) using wizards
- Import of cam tables as motion laws
- Automatic identification and calculation of the boundary conditions of the individual cam motion steps
- Zoom functionality
- Import/export functionality in different formats (*.XML, *.PAR, *.CSV)

4.4 Definition of Terms

Cam

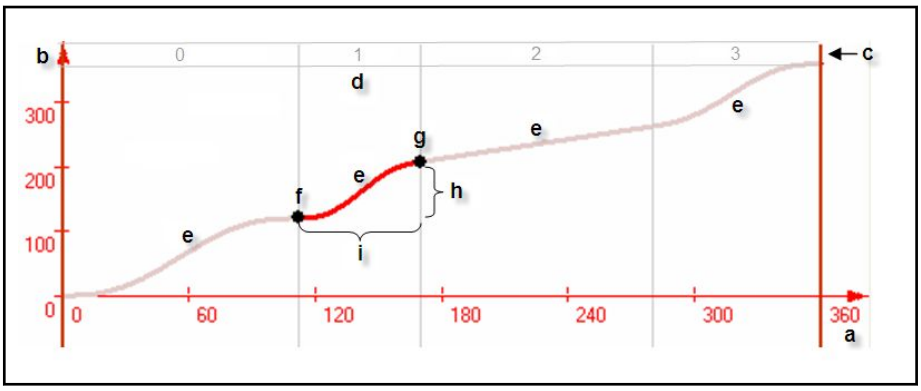


Fig.4-1: Chart of a cam graph for the term definition

a **Master axis** (x-axis)

b **Slave axis** (y-axis)

c **Motion steps** (0 – n)

d **Focused motion step**

e **Motion law** (analytical function or cam table)

f **Starting point** of the focused motion step (X_n,Y_n)

g **End point** of the focused motion step (X_{n+1},Y_{n+1})

h **Distance** of the focused motion step (ΔY)

i **Range** of the focused motion step, which can either be the time duration (ΔT) or the master axis range (ΔX).

A cam defines the position of a slave axis with regard to a master axis or the time. It consists of one or more motion steps. Each motion step has a motion law that specifies the connection between master axis or time and slave axis. The individual motions of the steps combined create a cam.

In the CamBuilder, it is the focused motion step of a cam that is always edited. Editing takes place either via a graphic representation or numeric inputs. Depending on the editing mode and the change, the preceding or subsequent motion steps can also change.

☞ From the second motion step onwards, all motion steps start with the end point of the preceding step.

5 First Steps – CamBuilder

5.1 Preparation

Installation and Start

The CamBuilder is integrated into the IndraWorks Suite installation package and is installed automatically.

If the CamBuilder is licensed, it starts automatically with the IndraWorks Engineering program.

Licensing

1. Purchase a full license to use the CamBuilder without limitations.
2. Open the license overview via the menu items **Tools** ▸ **Options** ▸ **General** ▸ **Software Licenses**.

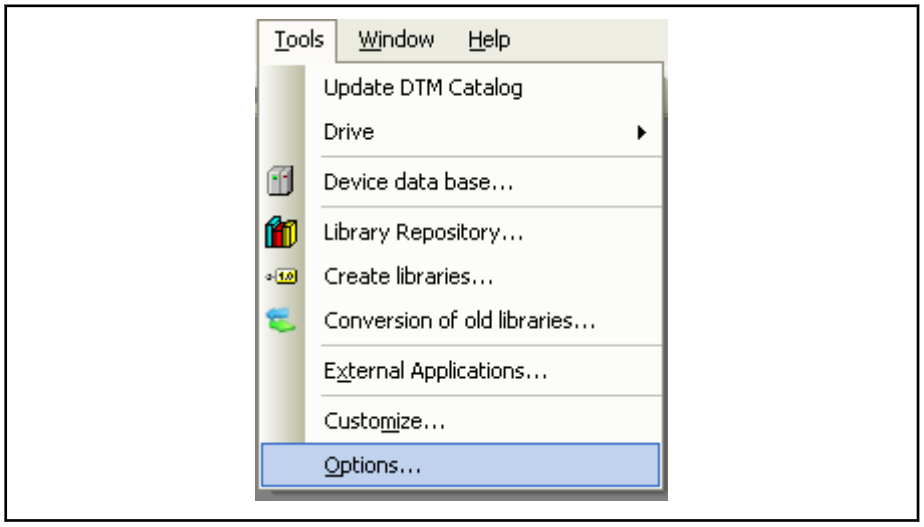


Fig.5-1: Menu: Tools

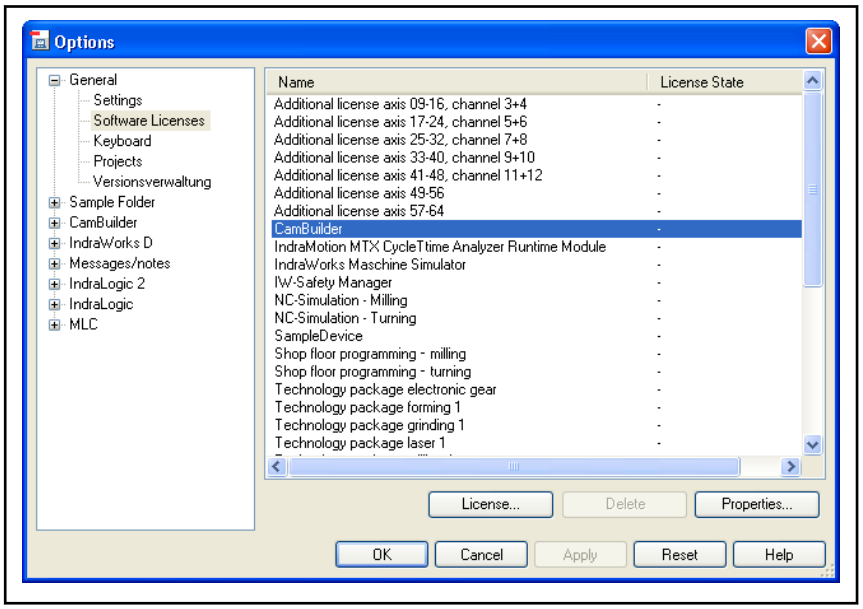


Fig.5-2: Dialog: Options (Software Licenses)

3. Enable the CamBuilder license via the **License...** button.

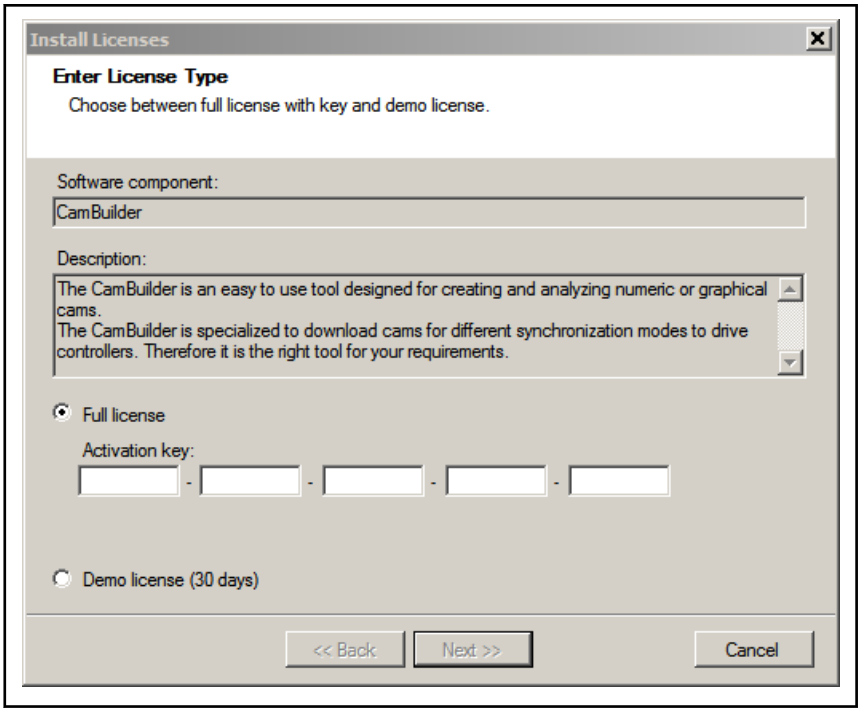


Fig.5-3: Dialog: Install Licenses

A demo license valid for 30 days is available without activation key.
After 30 days, the objects managed by the CamBuilder are disabled in IndraWorks projects. The CamBuilder can be licensed to continue using the cams created. If the disabled objects are no longer required, delete them.

Library All CamBuilder objects can be found in the IndraWorks library under "CamBuilder". These objects can be inserted via drag&drop (it is focused on individual elements in the following examples).

The following objects are available:

Cam Pool A "Cam Pool" folder manages all cams created in the current project with the CamBuilder.

Also create a new cam via the context menu of a "Cam Pool" node.

Cam A cam in the CamBuilder is defined by one or several motion steps.

Double-click to open the cam for editing purposes.

Preview A preview in the CamBuilder shows one or several cams with regard to a master axis.

Double-click to open the preview. Add more cams to the preview via drag&drop.

5.2 Creating and Downloading Cams

This chapter describes how to create and download a cam consisting of three motion steps.

Task

The master and slave axis are rotary axes. The master axis rotates at a velocity of 100 rpm.

The slave axis starts at 0 degrees and should be moved on a fixed axis range of 180 degrees from the standstill to 120 degrees. It should pause there for 100 milliseconds (irrespective of the master axis velocity) and then travel up to the master axis end position of 360 degrees and return to standstill at 0 degrees.

The cam is then downloaded to an IndraMotion MLC or IndraLogic XLC control.

Operating sequence

1. Creating a cam

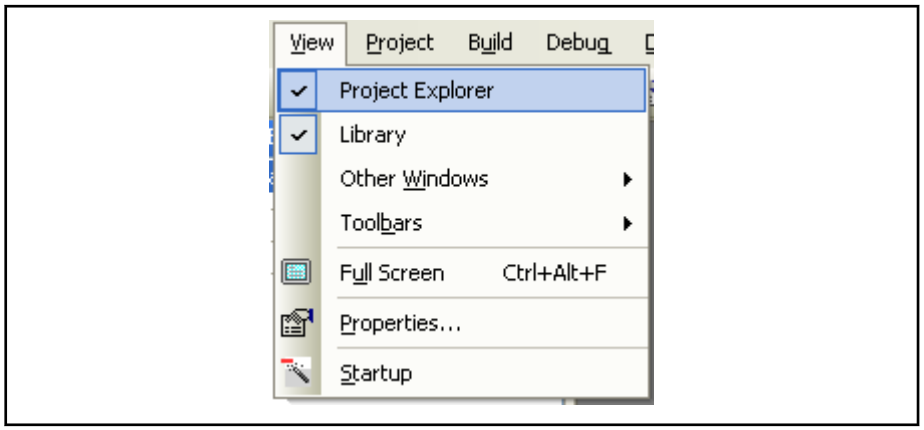


Fig.5-4: Menu: View

The "Project Explorer" and the "Library" are made visible via the "View" menu.

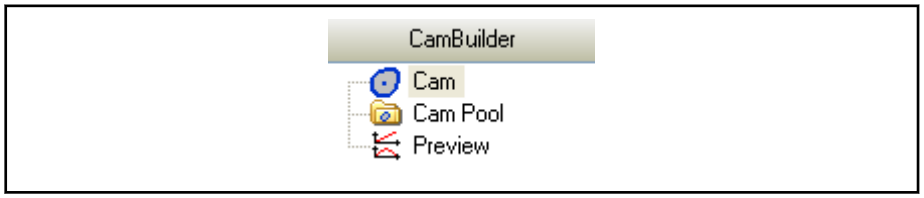


Fig.5-5: Library: CamBuilder section

Add a "Cam Pool" from the IndraWorks library to the "CamBuilder" section via drag&drop.

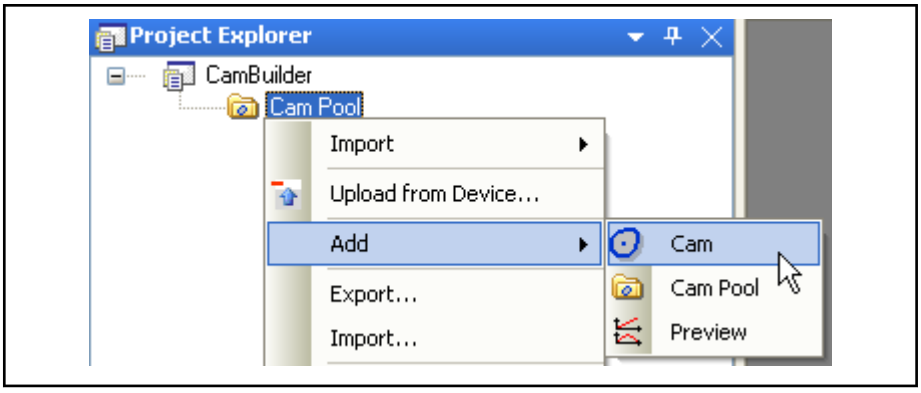


Fig.5-6: Context menu: Cam Pool

In the Project Explorer, right click on the "Cam Pool" node and select **Add ▸ Cam** in the context menu.

2. Wizard

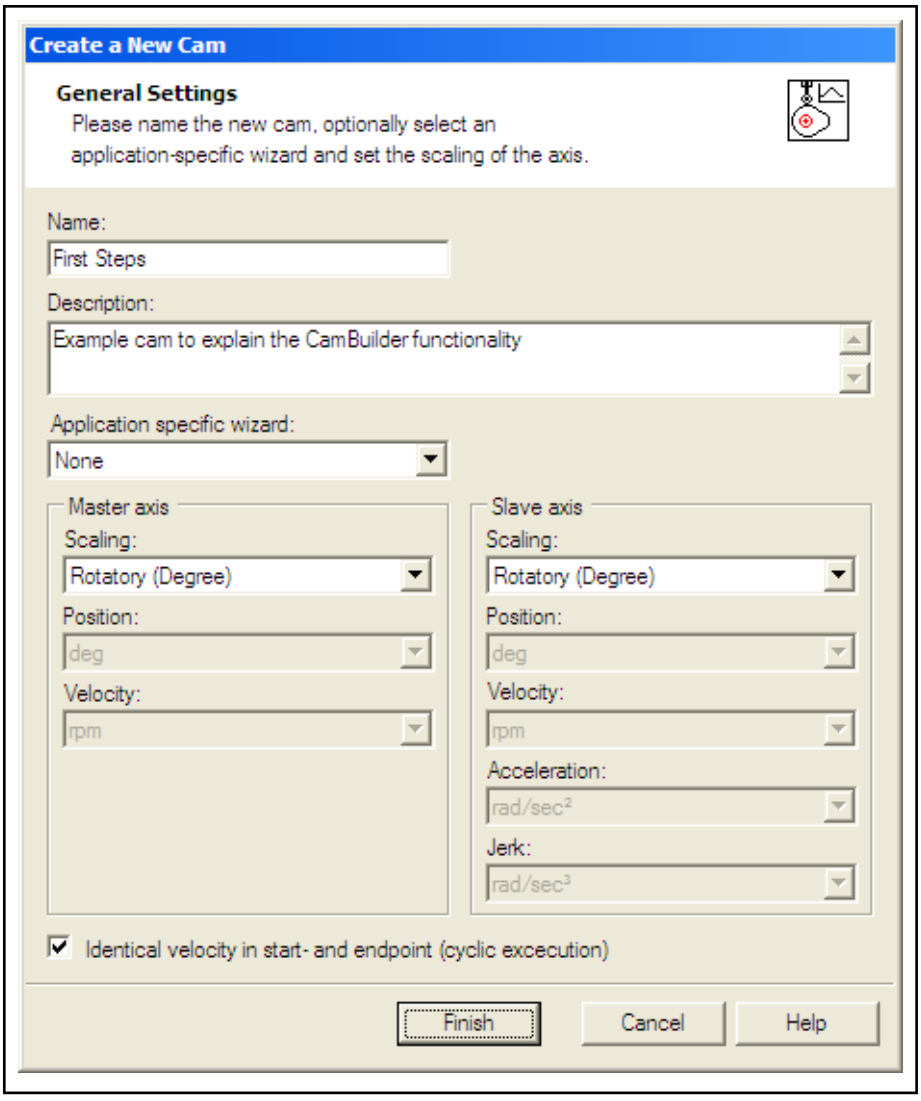


Fig.5-7: Dialog: Create a New Cam (wizard)

Enter a specific name into the wizard and optionally a description for the new cam. To create a freely definable cam, select "none" under "Application-specific wizard".

The scalings of master and slave axis are set to "Rotary (Degree)."

To execute the cam cyclically, the option "Identical velocity in starting and end point (cyclic execution)" is selected.

Press **Finish** and a default cam is created, saved in IndraWorks and a graph window opens automatically.

3. Editing motion step 0

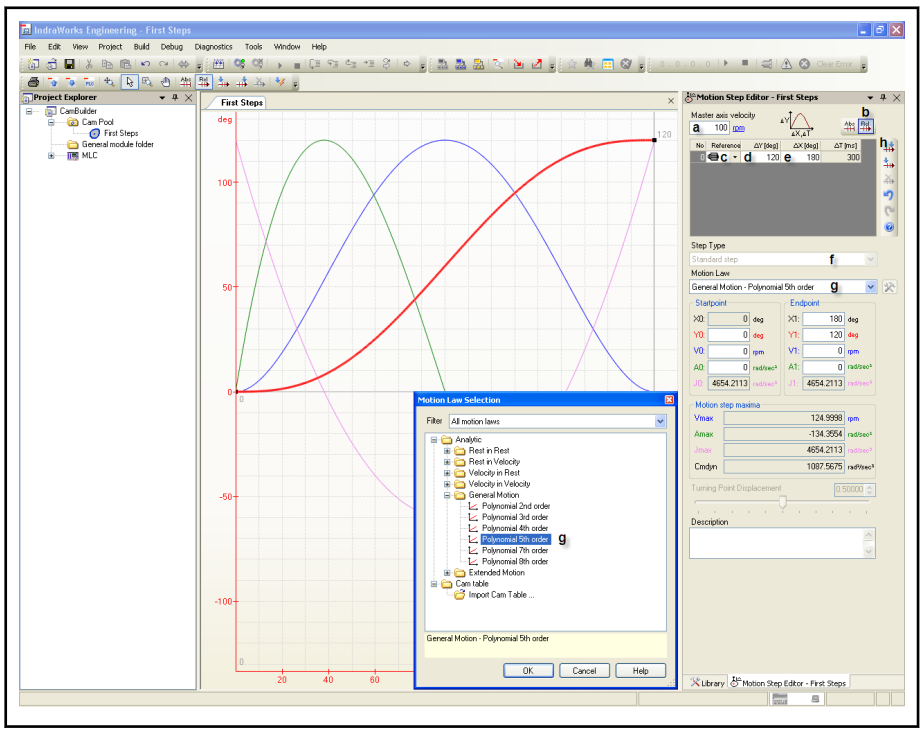


Fig.5-8: Dialog: IndraWorks Engineering – First steps (cam)

The motion step editor opens at the same time as the graph window. The first motion step was automatically generated and is filled with default values. Depending on the motion law and mathematical degrees of freedom, not all fields of a step can be edited. To facilitate the input of values, all editable fields have a white background.

a The master axis rotates at 100 rpm.

b As all steps have to be input consecutively, the editing mode shows "Relative".

c The slave axis should follow the master axis. Thus, the reference is to be set to the motor symbol.

d The relative distance of the slave axis is defined at 120 degrees (ΔY).

e The distance refers to a master axis range of 180 degrees (ΔX).

f If the cam consists of only one step, the step type is automatically defined as "Default step".

g The "Rest-in-rest - Polynomial 5th order" is selected as motion law. All other fields are automatically filled in.

h Add another step to the end of the focused step using the "Add motion step after focused step" button.

If focused, modify the graph with the following keys:

- <Pos1> - Show all
- <Arrow keys> - Move view
- <+ / -> - Zoom in/out view

Change the zoom factor via mouse wheel. Press the <space> key/mouse key in the middle to move the view.

Find special tools to change the graph view in the CamBuilder toolbar.

Fig.5-9: CamBuilder toolbar, graph

4. Editing motion step 1

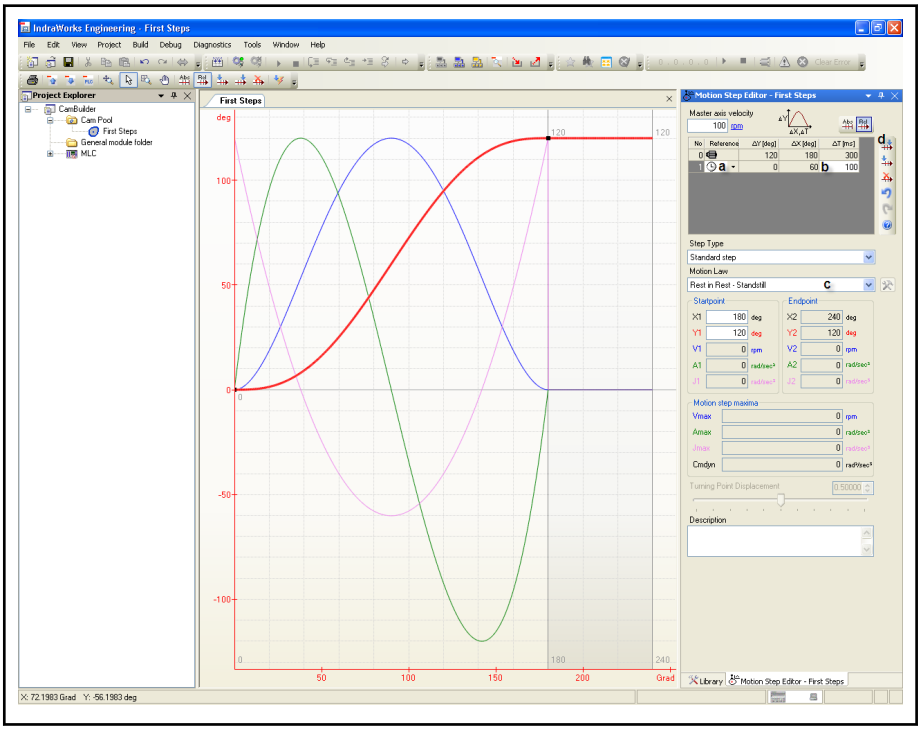


Fig.5-10: Dialog: IndraWorks Engineering – First steps (cam)

The fields of the second motion step are pre-assigned with default values from the CamBuilder options.

a The reference of the slave axis is changed from the master axis to the time, thus disabling the input fields ΔX and X_2.

b Now, the duration of the step in milliseconds has to be entered into the column ΔT (100 ms).

c After switching the motion law to "Rest-in-Rest - Standstill", all automatically calculated fields are disabled.

After every input, the cam is automatically recalculated and it is checked whether all values are valid. In case of invalid values, the relevant input field is highlighted and a message is output.

Click on the first line of the table to change to the first motion step. If the active step includes input errors, it is not possible to change to another step. Click on "Undo" to discard the last changes at the cam.

d Add another step to the end of the focused step using the "Add motion step after focused step" button.

5. Editing motion step 2

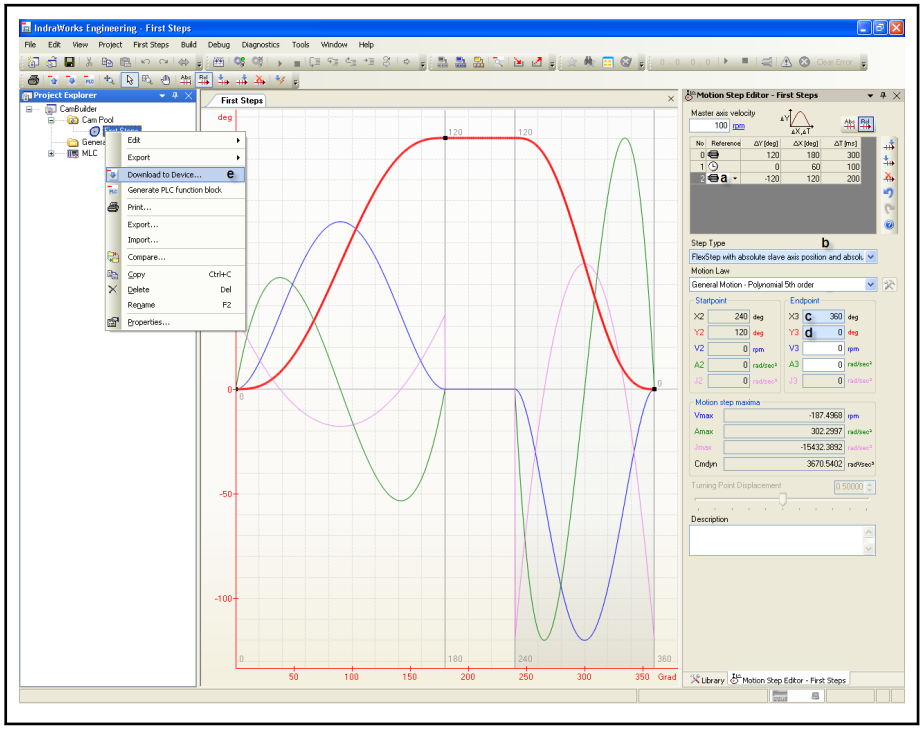


Fig.5-11: Dialog: IndraWorks Engineering – First steps (cam)

a The last step should refer to the master axis again. Thus, the slave axis reference is set to the motor symbol.

b To refer the slave axis absolutely to the master axis again, the step type is set to "FlexStep with absolute slave axis position and absolute master axis position".

c The master axis end position X_3 is set to 360 degrees.

d The slave axis end position Y_3 is set to 0 degrees.

e The new cam is now located in the Project Explorer as node below the "Cam Pool" node.

If the IndraMotion MLC/IndraLogic XLC in the project is in online or offline parameterization mode, the cam can be downloaded to the control via its context menu in the Project Explorer.

6. Downloading the cam

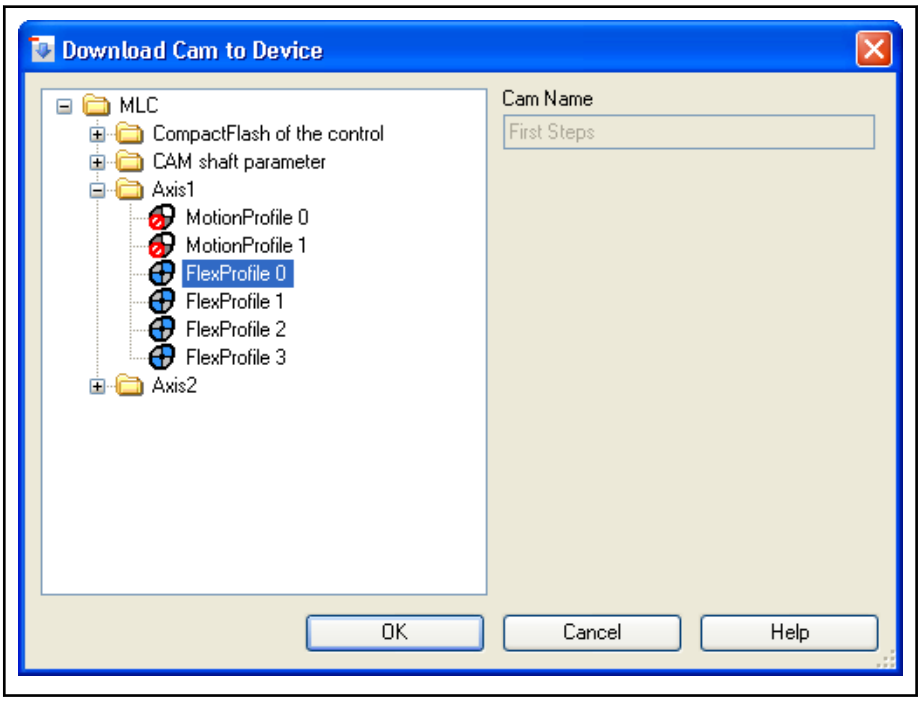


Fig.5-12: Dialog: Download Cam to Device

The target "FlexProfile 0" of "Axis 1" is selected. Confirm with **OK** and the parameters of the cam "First steps" are loaded to the parameters of the control. A message confirms that the process has been completed successfully.

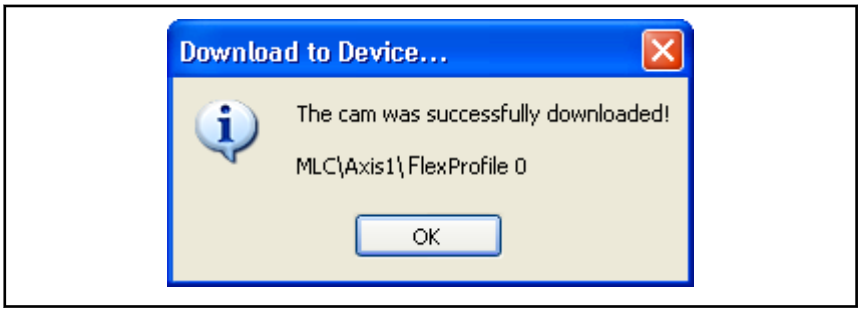


Fig.5-13: Dialog: Download to Device...

☞ If a FlexProfile is already on the axis and currently in use (axis in motion), the FlexProfile is write-protected and cannot be replaced. Close the operation mode and write the FlexProfile to another empty profile set.

5.3 Analyzing the Cam

This chapter describes the analysis of the cam from the previous chapter 5.2 "Creating and Downloading Cams" on page 31.

Task

The cam reaction at different master axis velocities is to be analyzed.

Operating sequence

1. Creating a preview

   In the Project Explorer, right-click on the "Cam Pool" node and select the context menu items **New ▸ Preview...**.

2. Adding cams to the preview

   In the Project Explorer, move the cam "First steps" to the preview window by keeping the left mouse button pressed and dropping the cam there.

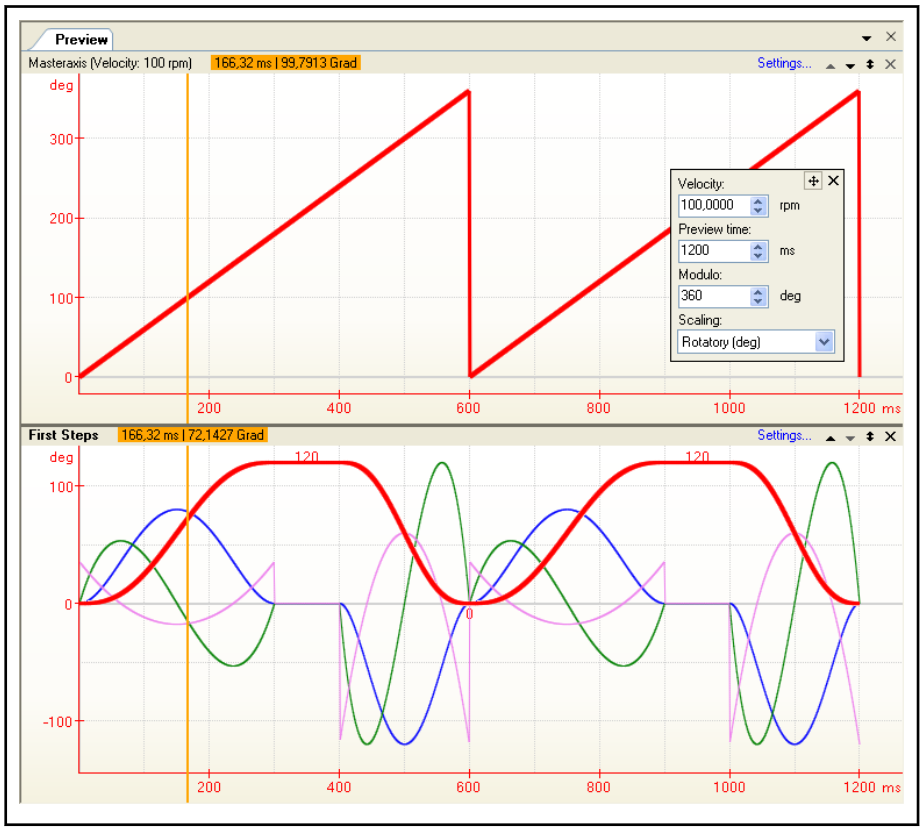


Fig.5-14: Position preview of the cam at a master axis velocity of 100 rpm

3. Changing the master axis velocity

   Click on the "Settings..." link to change the master axis velocity to 200 rpm for example.

   As the 2nd cam motion step does not have a master axis range but it refers to the time, there is less time for the 3rd motion step (FlexStep) to return to the home position.

First Steps – CamBuilder

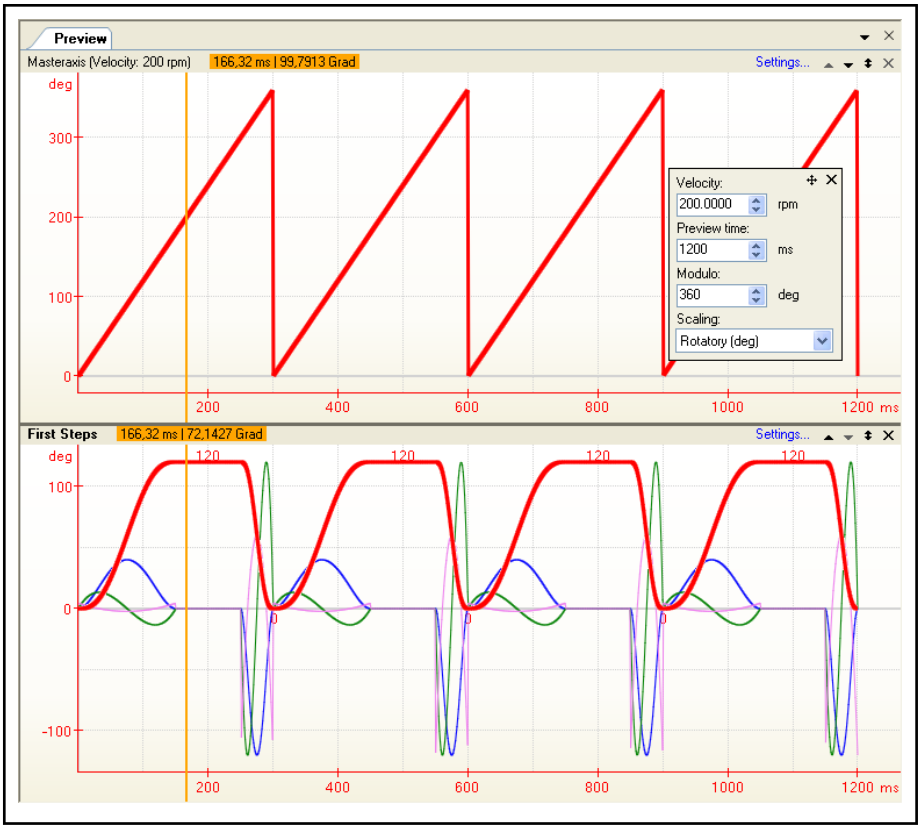


Fig.5-15: Position preview of the cam at a master axis velocity of 200 rpm

Use the mouse to move the measuring line.

Change the view of a preview window in the CamBuilder toolbar using the graph tools.

4. Analyzing the slave axis velocity

   Click on the blue position profile of the cam and the position preview of the cam changes to a velocity preview. Analyze the velocity using the measuring tool.

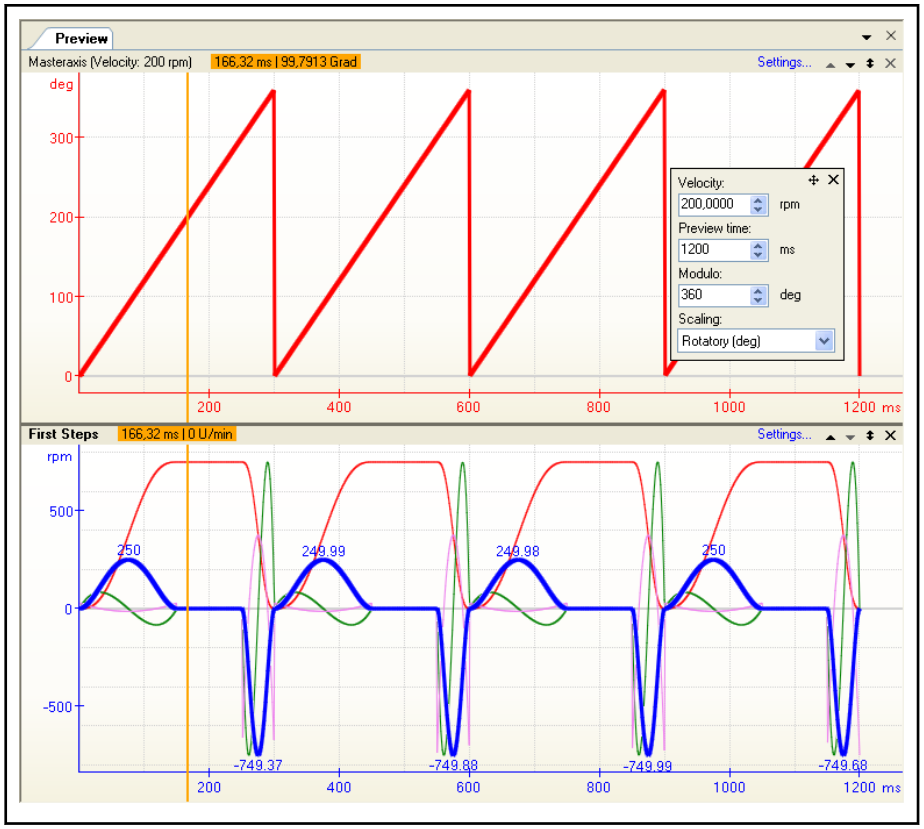


Fig.5-16: Velocity preview of the cam at a master axis velocity of 200 rpm

Several cams can be added to a preview via drag&drop. The cams can be analyzed simultaneously relating to the same master axis.

5.4 Creating a Variable Cam and a PLC Function Block

This chapter explains how to create and download a variable cam consisting of two motion steps.

Task

The master and slave axis are rotary axes. The master axis rotates at a velocity of 100 rpm.

The slave axis starts at 0 degrees and is to be moved to a variable position (Variable "Distance") from standstill to a variable master axis range (sum of 10 and a variable "Range"). From this position, the slave axis has to be traveled up to a defined master axis end position of 360 degrees and then back to 0 degrees at standstill.

A PLC function block should be created from the cam. With this function block, the FlexProfile of an axis can be variably parameterized in an IndraMotion MLC/IndraLogic XLC PLC application.

Operating sequence

1. Creating a cam

   A new cam with default settings is created under the name "Cam1" as described in chapter chapter 5 "First Steps – CamBuilder" on page 29.

2. Editing motion step 0

   The cam is defined without a formula input in the first draft. Make the following entries:

The master axis velocity is 100 rpm.

The editing mode is set to "Relative".

At first, the relative distance of the slave axis distance should be set to 120 degrees (ΔY).

At first, the master axis range should be set to 180 degrees (ΔX).

Add another step to the end of the focused step using the "Add motion step after focused step" button.

3. Editing motion step 1

   The master axis end position X_2 is set to 360 degrees.

   The slave axis end position Y_2 is set to 0 degrees.

4. Creating a variable distance of first step

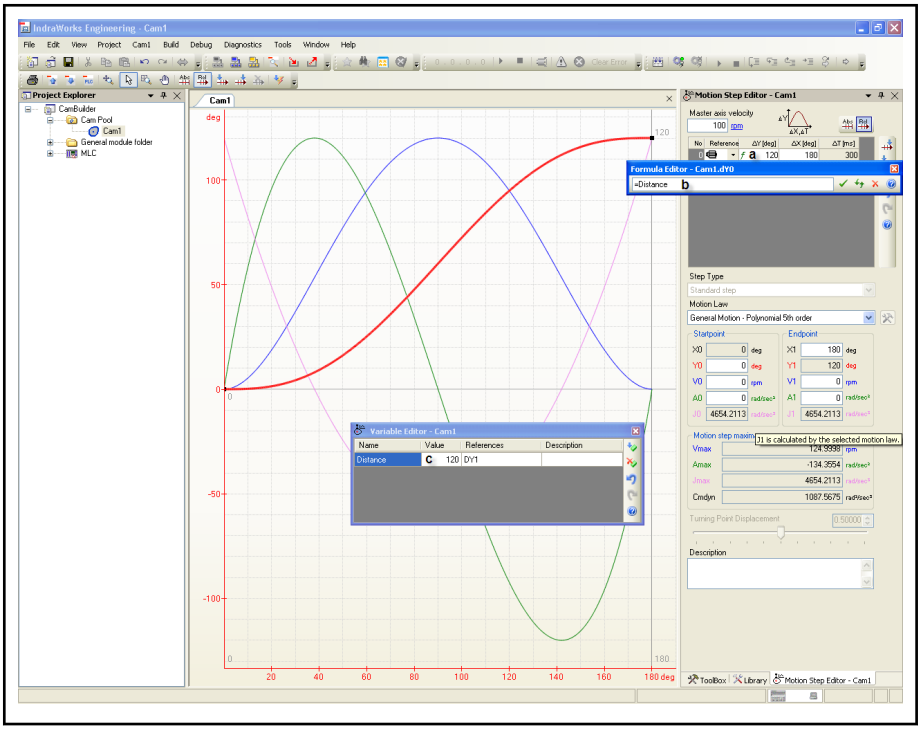


Fig.5-17: Dialog: IndraWorks Engineering – Cam1 (variable cam)

a The distance of the first motion step is to be defined via a "Distance" variable. No digit is entered into the [ΔY] input field of the motion step editor, but a "=" character as in a table calculation.

b A formula editor window opens in which the "=Distance" formula can be entered for the current field.

The formula is applied when confirming the dialog and a prompt is displayed, asking if the unknown "Distance" variable should be automatically created with a default value. Confirm with **Yes**.

c A value of 120 degrees for example can now be entered for the "Distance" variable into the newly opened variable window .

5. Creating a variable master axis range of the first step

   The master axis range of the first motion step is defined by the sum of 10 and a "Range" variable. No digit is entered in the [ΔY] input field of the motion step editor, but a "=" character as in a table calculation.

   The formula "=10 + Range" is entered in the formula editor for the current field.

   This variable is created automatically with a default value.

   A value of e.g. 170 degrees can now be entered in the new variable window for the "Range" variable.

6. Creating a variable distance of the second step

   The slave axis end position of the second motion law has to be 0 degrees. The distance of the second step has to be equal to the negative distance of the first step. Therefore, enter the formula "= - DY0" in the formula editor for the [ΔY] input field. DY0 stands for the distance of the first motion step.

7. Creating a variable master axis range of the second step

   The master axis end position of the second motion law has to be 360 degrees. Consequently, the master axis range of the second step has to be 360 degrees minus the master axis range of the first step. This is achieved by entering the formula "=360 - DX0" in the formula editor for the [ΔY] input field. "DX0" stands for the master axis range of the first motion step.

8. Creating a PLC function block

   Start the creation of the PLC function block via the context menu of the cam in the Project Explorer or via the CamBuilder toolbar.

   If there is an IndraMotion MLC/IndraLogic XLC in the project, the function block is created in the "General Module Folder".

9. Using a PLC function block

   Instantiate and execute the function block in the PLC application of the IndraMotion MLC/IndraLogic XLC. Change the parameterization of the FlexProfile via the "Range" and "Distance" inputs.

   Example ST code:

Program:

```
PROGRAM PlcProg
VAR
    fbCam1       : ChangeFlexSet_Cam1;
    bExecute     : BOOL    := TRUE;
    uiSetNumber : UINT    := 0;
    lrDistance   : LREAL   := 180;
    lrRange      : LREAL   := 170;
END_VAR
-------------------------------------------------
fbCam1(
    Execute      := bExecute,
    SetNumber    := uiSetNumber,
    Distance     := lrDistance,
    Range        := lrRange,
    Axis         := SlaveAxis,
    Done=> ,
    Active=> ,
    Error=> ,
    ErrorID=> ,
    ErrorIdent=> );
```

Example CFC code:

First Steps – CamBuilder

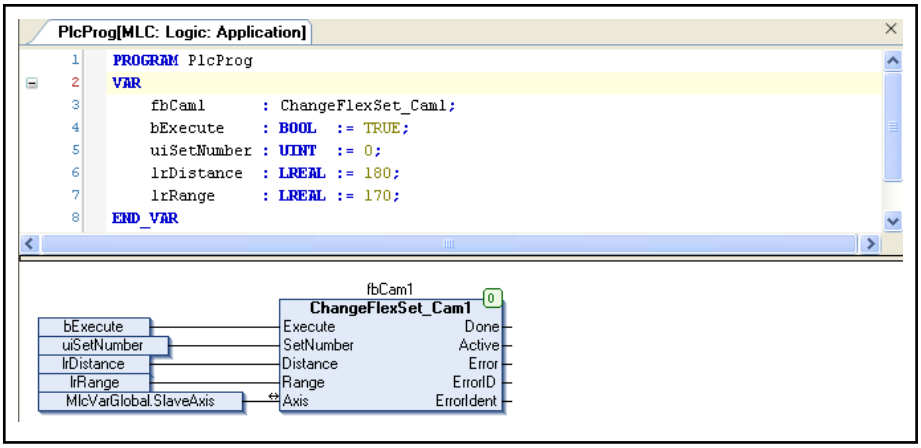


Fig.5-18: Example CFC code

Result:

The FlexProfile of the "SlaveAxis" of the IndraMotion MLC/IndraLogic XLC is parameterized according to the function block inputs and can be executed by executing the cam function block in the PLC program on the IndraMotion MLC/IndraLogic XLC.

6 Creating Cams and Preview Objects

6.1 Creating New Cams

Starting the wizard

A new cam is created in in one step using the wizard.

Start the wizard via the context menu items **Add** ▸ **Cam** of the "Cam Pool" node in the Project Explorer. Alternatively, copy a "cam" from the IndraWorks library from the "CamBuilder" section to the project.

General settings

Multiple attributes of the cam are preset in the wizard.

The wizard suggests a default **name** ("Cam#") for the cam that can be changed.

The user can also enter a short **description** of the cam.

The **application-specific wizard** determines whether a wizard is to be used for a specific application.

The CamBuilder provides wizards for common technologies (CrossCutter, feed, print length correction, FlyingShear) which assist when creating a cam. All requirements and unique features of the application are dialog-controlled.

No application-specific wizard is set by default. The user can freely define the individual motion steps in the following motion step editor.

This property is set once when creating a cam and cannot be modified later on.

Additionally, the **scalings of master and slave axis** can be set. These settings are automatically entered and disabled when an application-specific wizard is selected.

Three standards can be selected for the scaling of an axis:

1. Rotary (degree)
   - Position = degree
   - Velocity = rpm
   - Acceleration = rad/s^2
   - Jerk = rad/s^3
2. Translatory (mm)
   - Position = mm
   - Velocity = mm/min
   - Acceleration = mm/s^2
   - Jerk = mm/s^3
3. Translatory (inch)
   - Position = inch
   - Velocity = inch/min
   - Acceleration = inch/s^2
   - Jerk = inch/s^3

The selection of the units "position", "velocity", "acceleration" and "jerk" can be modified individually. The unit of the position specifies whether the axis is a rotary or a translatory axis. For the other variables, only the respective units can be selected.

1. Rotary
   - Position = degree; radiant

- Velocity = rpm; rps; degrees/min; degrees/s; rad/min; rad/s
- Acceleration = rpm^2; rps^2; $degree/min^2$; $degree/s^2$; rad/min^2; rad/s^2
- Jerk = rpm^3; rps^3; $degree/min^3$; $degree/s^3$; rad/min^3; rad/s^3

2. Translatory
   - Position = mm; inch
   - Velocity = mm/min; mm/s; inch/min; inch/s
   - Acceleration = mm/min^2; mm/s^2; $inch/min^2$; $inch/s^2$
   - Jerk = mm/min^3; mm/s^3; $inch/min^3$; $inch/s^3$

Completing or canceling

Once the entries are complete, the wizard creates a cam after clicking on **Finish**.

Each cam can either be edited after "Completion" via the motion step editor or via the graph.

Click on **Cancel** at any time and the wizard closes. All already detected entries to define a new cam are discarded.

Application-specific cams can additionally be edited using a wizard. If an application parameter is changed and applied to the wizard window, the cam is recalculated and any possible changes of the motion step editor or graph are discarded.

To edit cams, see chapter 7 " Editing and Analyzing Cams" on page 47.

6.2 Creating Preview Objects

Creating a preview

Create an empty new preview via the context menu items **Add ▸ Preview** of the "Cam Pool" node in the Project Explorer. Alternatively, copy a "preview" from the IndraWorks library from the "CamBuilder" section to the project.

The wizard suggests a unique name ("preview#") for the preview which can be changed.

Adding cams to the preview

Add one or several cams from the current project to a preview via drag&drop or copy&paste. Therefore, select the desired cams in the Project Explorer and drag them to the preview with the left mouse button pressed and drop them there. Alternatively, select the cams in the Project Explorer and copy them via "Edit/Paste" in the menu and add them to the preview window with "Edit/Paste".

Removing cams from the preview

A cam opened in the preview can be removed from the preview via the **X** interface of its title bar.

To analyze the cams in a preview, refer to chapter 7.9 "Cam Preview" on page 74.

6.3 Creating Preview Objects of Superimposed Cam Motions

Creating a preview

Create an empty new preview via the context menu items **Add ▸ Preview superimposed cams (XY)** of the "Cam Pool" node in the Project Explorer. Alternatively, copy a "preview of superimposed cams" from the IndraWorks library from the "CamBuilder" section to the project.

The wizard suggests a unique name ("preview#") for the preview which can be changed.

Adding cams of the x- and y-axis to the preview

Add two translatory cams from the current project to a preview via drag&drop or copy&paste. Therefore, select the desired cams in the Project Explorer and drag them to the preview with the left mouse button pressed and drop

them there. Alternatively, select the cams in the Project Explorer and copy them via "Edit/Paste" in the menu and add them to the preview window with "Edit/Paste".

Editing cams from the x- and y-axis

Edit the cam selection of the x- or y-axis via the **X-axis...** button of the preview title bar.

To analyze the superimposition of the two translatory cam motions in x- and y-direction in a preview, see chapter 7.10 "Preview of Superimposed Cams (XY)" on page 75.

7 Editing and Analyzing Cams

7.1 Graph Editor

7.1.1 General Information

The graph window is the core element of the CamBuilder. Open a graph (double-click on a cam of a "Cam Pool" node) and the graph is displayed in the IndraWorks main screen. Only one cam is always "focused" in the CamBuilder and can be edited via the graph or the motion step editor. If another cam is opened, this cam is "focused." Focus (click on a cam window with the mouse) and the cam is automatically registered as focused by the CamBuilder. All CamBuilder inputs and displays refer to the focused cam.

7.1.2 Structure

A CamBuilder graph consists of a cam in a **coordinate system**.

In the coordinate system, up to four different slave axis profiles are displayed at the same time (**position profile**, **velocity profile**, **acceleration profile** and **jerk profile**).

Show or hide the different profile diagrams using the Graph Manager (refer to chapter 7.1.5 "Graph Manager Settings" on page 49). Set the color in which the profiles are drawn in the "Options" dialog (see chapter 11.1 "CamBuilder Options" on page 85).

The **x-axis unit** is the unit of the master axis.

The **y-axis unit** corresponds to the respectively focused profile diagram. Focus a profile diagram by clicking on the respective profile.

The **axes of the coordinate system** always have the color of the focused diagram. The grid is used to provide a better overview.

The **motion step limits** are vertical lines marking the limits of the motion steps.

The **focused motion step** is highlighted with a different background color.

Focus another step by clicking into the area of that motion step.

The **limit points** of a **focused motion step** are highlighted by a black square.

Zoom in/out or move the section of the cam displayed in the coordinate system.

7.1.3 Editing a Cam Graphically

Moving the starting or end point

The starting and end points of the focused profile (position, velocity, acceleration or jerk) of the focused motion step are displayed as black squares.

How to move a point is shown as symbol with arrows when the cursor is on the point.

 Data point can be moved horizontally and vertically

 Data point can only be moved horizontally

 Data point can only be moved vertically

The data points of the **position diagram** can be moved vertically and horizontally depending on the editability of the values defined by the selected motion law.

The cam changes in different ways depending on the editing mode set (relative or absolute). The reaction of the cam due to changes of the boundary values is described in detail in chapter 7.2.9 "Absolute Editing of the Master Axis Range (X-Values)" on page 58 and chapter 7.2.10 "Relative Editing of the Master Axis Range (X-Values)" on page 59.

The data points of the **velocity, acceleration** and **jerk diagrams** can only be moved vertically according to the editability of the values defined by the selected motion law.

Deleting a focused motion step
Delete

Delete a motion step via the context menu of the graph as described in chapter 7.2.14 "Deleting a Focused Motion Step" on page 64.

7.1.4 Changing the View

Set a graph to different modes via the toolbar. By default, a selection tool (arrow) is enabled.

Fig.7-1: Icons: Tools for the CamBuilder graph window

Show All

The entire cam is drawn via the context menu item **Show all**.

Alternatively, enable this function via the "toolbar", the "Graph Manager" and the <Pos1> key.

Selection

The context menu item **Selection** enables an arrow as mouse cursor. Points can be moved and profiles can be enabled in this mode.

Alternatively, enable this mode via the "toolbar", the "Graph Manager" and the <Esc> key.

Zoom In

The context menu item **Zoom In** enable a magnifying symbol as mouse cursor. Click into the coordinate system and mark a rectangle to specify the area to be zoomed in.

Alternatively, enable this mode via the "toolbar" and the "Graph Manager".

The mouse wheel also controls the zoom level.

The keys <+>/<-> zoom the view in/out by 25%.

Pan View

The context menu item **Pan** enable a hand symbol as mouse cursor. Click into the coordinate system and drag. This pans the section.

Alternatively, enable this mode via the "toolbar" and the "Graph Manager".

Alternatively, pan the graph via the mouse button the middle or via the <space> key.

Copying the view to clipboard

Copy the section of the cam currently displayed to the clipboard via the context menu and use it in other applications such as word processing.

Showing tool window

The context menu of the main graph window includes a menu to enable all other CamBuilder tools windows.

Furthermore, there is an option to show and hide all other tool windows created by the CamBuilder in the IndraWorks **View ▸ Other Windows** menu.

Restoring default layout

The **Restore Default Layout** menu hides all CamBuilder tools except the motion step editor and the Graph Manager and enables the toolbar.

Arrange, show and hide all windows freely. Each layout change is permanently saved. The last layout used is preset at a CamBuilder restart.

7.1.5 Graph Manager Settings

Open the Graph Manager via the context menu of a graph or a preview: **Tool window ▸ Graph Manager**. It can also be shown and hidden via the main menu **View ▸ Other windows ▸ Graph Manager**.

The Graph Manager is used to focus, show and hide the different profile diagrams.

- **Slave axis position** (shown/hidden and focused/not focused)
- **Velocity** (shown/hidden and focused/not focused)
- **Acceleration** (shown/hidden and focused/not focused)
- **Jerk** (shown/hidden and focused/not focused)

Start the different actions on the graph window via the "Graph tool selection" buttons

- **Show All**
- **Selection**
- **Zoom in**
- **Pan**

The cursor coordinate area displays the mouse coordinates related to the focused profile diagram with all units.

Set the visibility of different data in the graph window via the advanced options.

- **Coordinate axes** (shown/hidden)
- **Coordinate net** (shown/hidden)
- **Motion step limits** (shown/hidden)
- **Border Coordinates** (shown/hidden)

The settings in the Graph Manager directly affect the graphic output.

Cross-project settings, such as colors and line thickness of the graph and preview window can be set in the menu **Tools ▸ Options ▸ CamBuilder ▸ Graph** (see chapter 11.1 "CamBuilder Options" on page 85).

7.2 Motion Step Editor

7.2.1 Overview

A cam can consists of any number of motion steps. The motion step editor configures the individual motion steps.

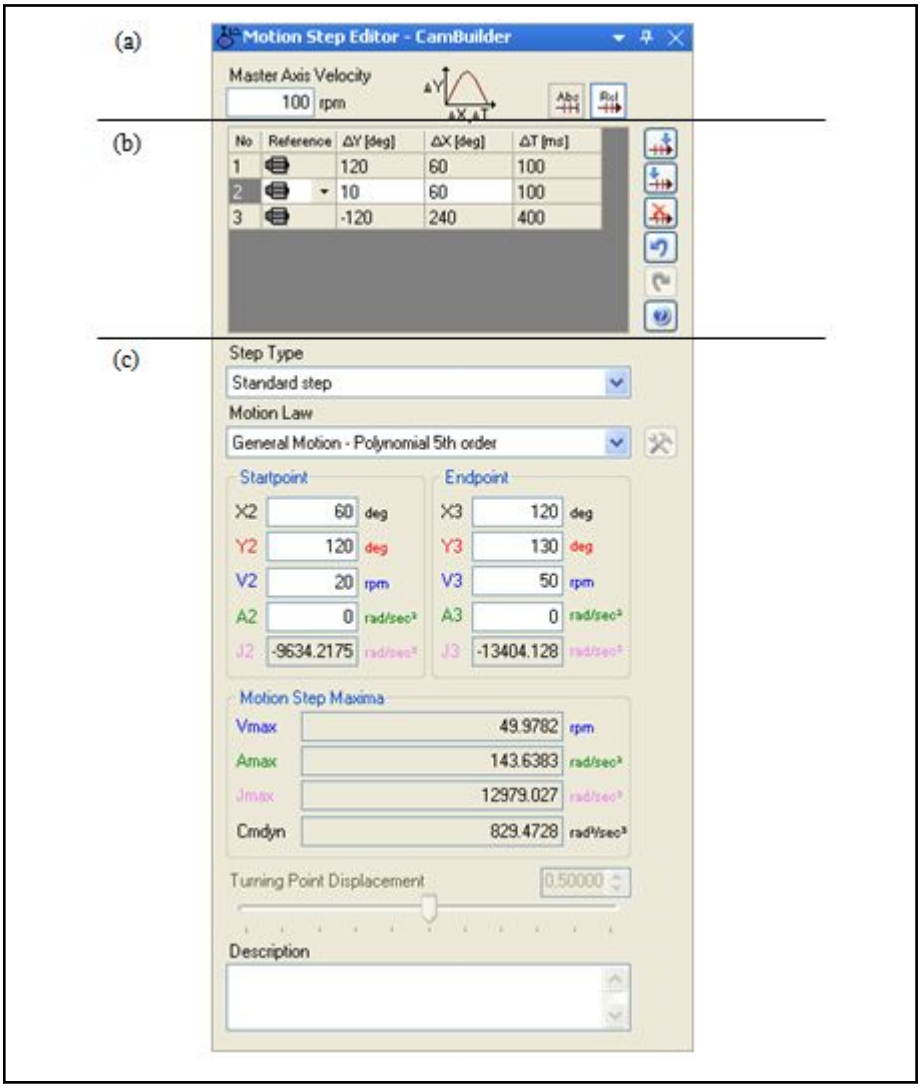


Fig.7-2: Dialog: Motion Step Editor

The editor is divided into three sections.

a The **superordinate** section relates to all cam motion steps.

b The **tabular** section provides an overview and navigation between the individual motion steps and allows to change single attributes.

c The **form-based** section provides the option of editing other attributes of the motion step focused in the tabular part.

One motion step is set as default.

Not all attributes can always be edited. Some attributes are automatically calculated depending on the selection of other attributes. All disabled attributes are always calculated after a property change (after clicking on <Enter> or by moving the cursor to another attribute). If a non-numerical value is entered into a numerical entry field, the value is automatically reset. Other incorrect entry fields are marked by an error symbol and a note.

The latest 50 changes made to a cam can be undone providing the cam has not yet been saved.

Instead of constant values, formulas can also be entered into almost all fields to calculate the values (see chapter 7.5 "Formula Editor" on page 67).

7.2.2 Attributes of the Superordinate Section

The attributes of the superordinate section refer to the entire cam.

Master axis velocity

A cam is defined with reference to a master axis velocity. All limit values of the motion steps refer to the master axis velocity in the editor.

Create a "preview" (see chapter 6.2 "Creating Preview Objects" on page 44) to analyze the cam response at different master axis velocities.

The master axis velocity is set depending on the preset master axis scaling.

This attribute can always be edited.

Minimum

- Master axis velocity > 0
- The master axis velocity has to be high enough that no ΔX of a time-related motion step is lower than the minimum step size (see chapter 11.1 "CamBuilder Options" on page 85)

Maximum

- The master axis velocity has an upper limit if there are time-related motion steps in front of a FlexStep with an absolute master axis end position and these would extend beyond the absolute master axis end position

Editing mode

The "relative" or "absolute" editing mode determines the reaction of the subsequent motion steps when editing ΔY, ΔX, ΔT, Y1 or X2 (see also chapter 7.2.9 "Absolute Editing of the Master Axis Range (X-Values)" on page 58 and chapter 7.2.10 "Relative Editing of the Master Axis Range (X-Values)" on page 59).

7.2.3 Attributes of the Tabular Section

The attributes of the tabular section show the values of all cam motion steps. Only the values of the focused motion step can be edited.

Reference

The reference defines the reference of the slave axis. There are two options:

- The motion of the slave axis should follow the master axis. This option is displayed by a motor symbol (default)
- The motion of the slave axis should follow the time. This option is displayed by a clock symbol

This attribute can always be edited.

ΔY

ΔY represents the relative distance of the slave axis within the focused motion step and is specified in the unit of the slave axis.

Changing ΔY results in the immediate calculation of Y_2.

This attribute cannot be edited if the step type is a "FlexStep with absolute slave axis position" or if the current motion law defines the distance.

ΔX ΔX represents the relative master axis range of the focused motion step with regard to the master axis and is given in the unit of the master axis.

Changing ΔX results in the immediate calculation of X_2 and ΔT.

This attribute cannot be edited if the reference of the slave axis is the time (the value is then calculated by specifying the master axis velocity and ΔT.)

This attribute cannot be edited if the step type is a "FlexStep with an absolute master axis position" or if the current motion law defines the master axis range.

Minimum

- ΔX >= minimum step size

Maximum

- ΔX has an upper limit if a FlexStep with an absolute master axis end position follows and if ΔX would extend the focused step beyond the absolute master axis end position

ΔT ΔT represents the relative duration of the focused motion step measured in milliseconds.

Changing ΔT results in the immediate calculation of ΔX and X_2.

This attribute cannot be edited if the reference of the slave axis is the master axis position (the value is then calculated by specifying the master axis velocity and ΔX).

This attribute cannot be edited if the step type is a "FlexStep with an absolute master axis position" or if the current motion law defines the master axis range.

Minimum

- ΔT >= 1 millisecond

Maximum

- ΔT has an upper limit if a FlexStep with an absolute master axis end position follows and if ΔT would extend the focused step beyond the absolute master axis end position

7.2.4 Attributes of the Form-Based Section

The attributes of the form-based section refer to the focused motion step.

Step type There are two categories of step types.

- **Default step**

  At the time of creation, a default step has defined boundary values (X_1, Y_1, V_1, A_1, J_1, X_2, Y_2, V_2, A_2, J_2). The motion path is calculated based on these values. The motion path of a default step is thus fix and does not change at runtime.

  Use any motion law for this step type.

- **FlexStep**

  A FlexStep is an active step, i.e it applies the boundary values of the starting point at runtime from the real values (X_1, Y_1, V_1, A_1, J_1) and the boundary values of the end point from the predefined values (ΔX or X_2, ΔY or Y_2, V_2, A_2, J_2). The motion path is calculated at runtime in such as way that no velocity jumps result.

  There are four different FlexStep types

  – **FlexStep with relative distance and relative master axis range**

ΔX and ΔY are user-defined.

X_2 is calculated from X_1 + ΔX

Y_2 is calculated from Y_1 + ΔY

– **FlexStep with absolute slave axis end position and relative master axis range**

Y_2 and ΔX are user-defined

ΔY is calculated from Y_2 - Y_1

X_2 is calculated from X_1 + ΔX

– **FlexStep with relative distance and absolute master axis end position**

This step type cannot be selected for time-dependent motion steps.

X_2 and ΔX are user-defined

ΔX is calculated from X_2 – X_1

Y_2 is calculated from Y_1 + ΔY

– **FlexStep with absolute slave axis end position and absolute master axis end position**

This step type cannot be selected for time-dependent motion steps.

Y_2 and X_2 are user-defined

ΔX is calculated from X_2 – X_1

ΔY is calculated from Y_2 - Y_1

Use only motion laws of the "General motion type" (polynomial 5th order or polynomial 7th order) for a FlexStep.

If a FlexStep is selected, and the current motion law does not match, there is an automatic changeover to a polynomial 5th order.

The step type attribute can be edited if the subsequent step is a default step. If the last step is focused and the starting velocity and the starting acceleration are identical to the end velocity and the end acceleration of the cam (cyclical design of cam), the first step of the cam is used as subsequent step.

Motion law

The motion law defines the **motion of the slave axis**, to be performed between the starting and end points of the focused motion step.

The different motion laws are described in detail in chapter 13 "Motion Laws" on page 89.

The motion law is selected using the following dialog:

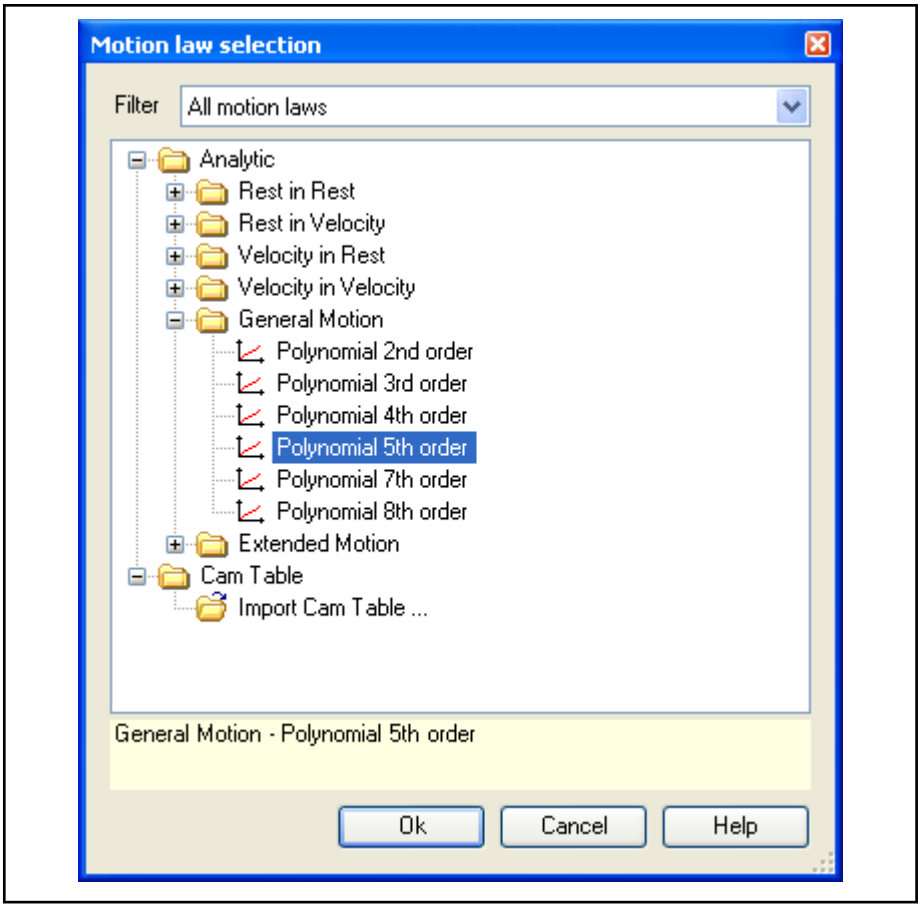


Fig.7-3: Dialog: Motion law selection

The dialog is sub-divided into two sections:

At the top, there is a filter option which is used to display only specific motion laws, e.g. only for MotionProfile.

The lower sections displays the motion laws.

Existing cam tables for the focused cam can be uploaded as a motion law under the category "Cam Table". Only the cam tables used as motion law are saved together with the cam. Imported cam tables which are not used are no longer accessible once the cam has been closed and reopened.

Not all motion laws can always be selected. If the preceding step ends in rest, the focused motion step has to be continued with rest or a general motion law. If the step type is not a default step, only two motion laws of the general motion type (polynomial 5th order and 7th order) are available.

Starting point X1 X_1 is the master axis position at the starting point of the focused motion step in the master axis unit.

Minimum

- X_1 >= 0

Maximum

- X_1 has an upper limit if a FlexStep with an absolute master axis end position follows and if X_1 would extend the focused step beyond the absolute master axis end position.

Y1 X_1 is the **slave axis position at the starting point** of the focused motion step in the slave axis unit.

This attribute cannot be edited if Y_2 of the preceding step cannot be edited.

Y_1, the offset of the first motion step, serves only for the purpose of illustration in the CamBuilder and is deducted during transmission into the devices.

V1 V_1 is the **velocity at the starting point** of the focused motion step. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if V_2 of the preceding step cannot be edited.

A1 A_1 is the **acceleration at the starting point** of the focused motion step. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if A_2 of the preceding step cannot be edited.

J1 A_1 is the **jerk at the starting point** of the focused motion step. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if J_2 of the preceding step cannot be edited.

End point X2 X_2 is the master axis position at the end point of the focused motion step in the master axis unit.

In case of a motion step in the cam including an absolute master axis end position as its step type, the X_2 change of the other motion steps is limited by this point.

The following applies if the focused motion step lies before the step with an absolute master axis end position:

($X_{1\ focus}$ + minimum step size <= $X_{2\ focus}$ <= $X_{2\ fix}$ + minimum step size)

This attribute X_2 cannot be edited if the reference of the slave axis is the time (the value is then calculated by the master axis velocity and ΔT.)

The attribute X_2 cannot be edited if the step type is a FlexStep with a relative master axis range or if the motion law is an extended motion law with acceleration-limited motion trapezoid profile, with an acceleration-limited motion sinusoid profile or with a jerk-limited motion.

Minimum

- X_2 >= X_1 + minimum step size

Maximum

- X_2 has an upper limit if a FlexStep with an absolute master axis end position follows and if X_2 would extend the focused step beyond the absolute master axis end position.

Y2 Y_2 is the **slave axis position at the end point** of the focused motion step in the slave axis unit.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if Y_1 of the preceding step cannot be edited.

V2 V_2 is the **velocity at the end point** of the focused motion step. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if Y_1 of the preceding step cannot be edited.

A2 A_2 is the **acceleration at the end point** of the focused motion step. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if Y_1 of the preceding step cannot be edited.

J2

J_2 is the **jerk at the end point** of the focused motion step. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the selected motion law or if Y_1 of the preceding step cannot be edited.

Maximum values Vmax

V_{max} is the **maximum velocity of the focused motion step**. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the motion law selected in the focused motion step.

Amax

A_{max} is the **maximum acceleration of the focused motion step**. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the motion law selected in the focused motion step.

Jmax

J_{max} is the **maximum jerk of the focused motion step**. The unit depends on the selected slave axis scaling.

This attribute cannot be edited if it is automatically calculated by the motion law selected in the focused motion step.

Cmdyn

The dynamic torque characteristic value C_{mdyn} is calculated on the basis of the following equation:

C_{mdyn}= Maximum value (V * A)

The unit depends on the selected slave axis scaling.

This attribute can never be edited and is always calculated automatically.

Turning point displacement

The turning point displacement specifies at which point the curving behavior changes for a symmetrical motion law.

The turning point displacement can either be changed with the slider or by entering a percentage value between 0 and 1.

This attribute can be edited for all symmetric "Rest-in-rest" motion laws.

Description

The description includes brief user-defined information on the focused motion step.

This attribute can always be edited.

7.2.5 Calculating the Motion Step

The cam is recalculated after each entry (changing to another input field or confirming by means of the <Enter> key). If the calculation is not possible, the incorrect input fields are highlighted and detailed information is provided. The motion step is only applied if all entries are correct.

By means of the "Undo motion step" function, all changes that have been made since the motion step was successfully calculated the last time can be undone.

If an action is to be performed, which requires the focused motion step in a calculated format, e.g. another motion step is highlighted in the table as an active motion step or a new motion step is to be inserted, the active motion step has to be error-free.

In case of incorrect entries, the last focused motion step remains active until all the inputs are correct or have been undone.

7.2.6 Undo / Redo Editing

The **Edit** ▸ **Undo** menu allows the last 50 processes, which have been performed on the focused cam since the last save, to be undone.

Once editing has been undone, it can still be redone providing no further changes have been made to the cam.

7.2.7 Absolute Editing of the Slave Axis Position (Y-Values)

If the Y-value or ΔY in a motion step is changed in the **"Absolute edit mode"**, only this individual value is changed and the rest of the position profile remains at the original position.

If the change to a motion step results in the limit values of the subsequent step no longer matching its motion law, the distance of the subsequent step is regarded as a fixed value and the motion law is sporadically set to a Polynomial 5th order.

In the following example, the distance of the 3rd motion step cannot be edited that. That is why the distance of the 4th motion step is adjusted.

Example:

Absolute editing of ΔY

Fig.7-4: Absolute edit mode

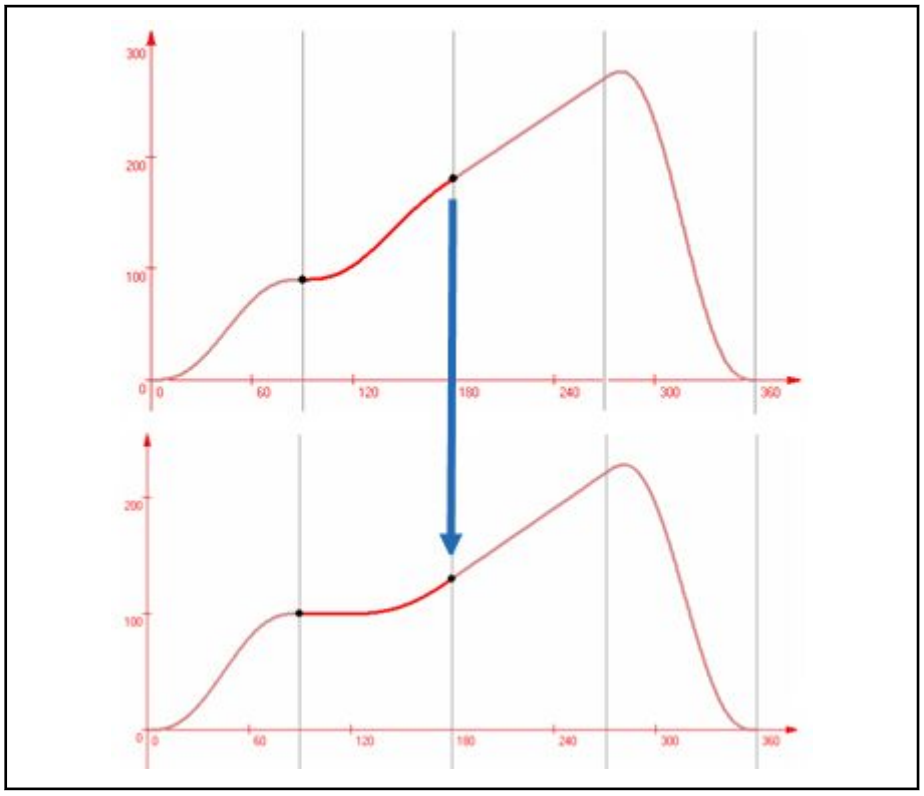


Fig.7-5: Changing ΔY in the second motion step by -50 degrees

7.2.8 Relative Editing of the Slave Axis Position (Y-Values)

If the Y-value or ΔY in a motion step is changed in the **"Relative edit mode"**, the remainder of the position profile is displaced in the Y-direction by the value of the change.

☞ If the change to a motion step results in the limit values of the subsequent step no longer matching its motion law, the distance of the subsequent step is regarded as a fixed value and the motion law is sporadically set to a Polynomial 5th order.

Example:

Relative editing of ΔY

Fig.7-6: Relative edit mode

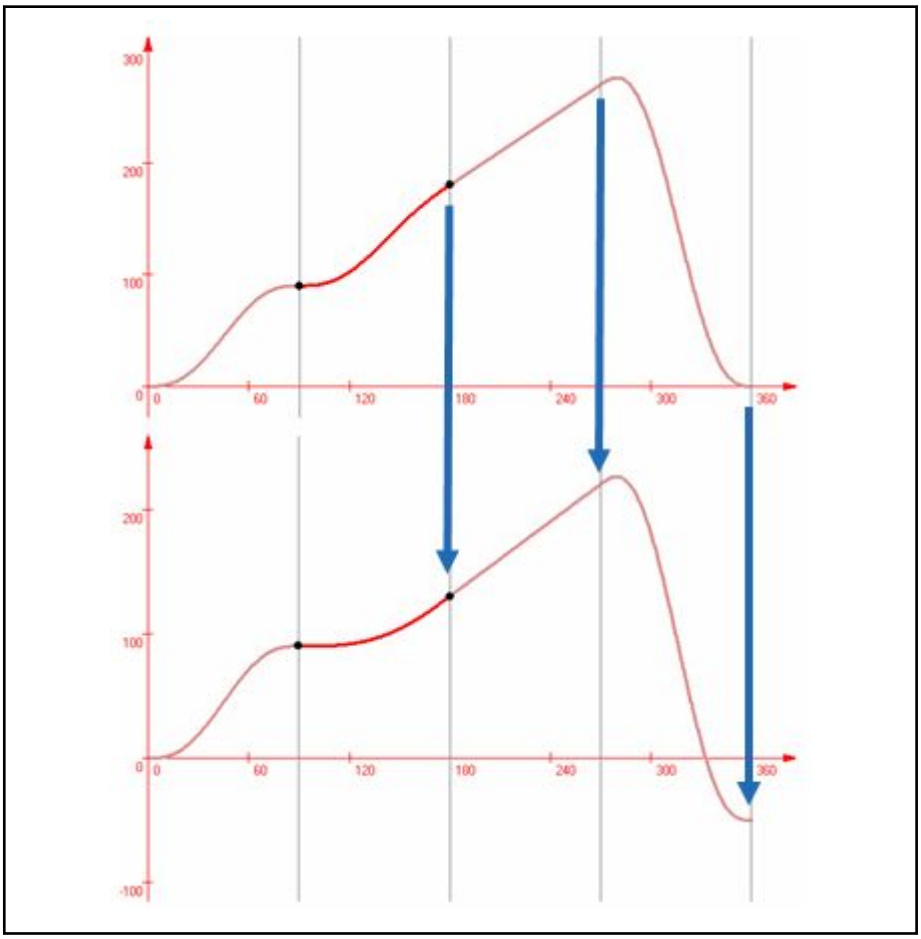


Fig.7-7: Changing ΔY in the second motion step by -50 degrees

7.2.9 Absolute Editing of the Master Axis Range (X-Values)

In case of changes to the master axis range (ΔX, ΔT, X1 or X2) of individual motion steps in the **"Absolute edit mode"**, the total length of the cam is retained. This means that the change to the length of an individual motion step changes the length of the preceding or subsequent motion step.

This mode is recommended if, for example, a cam with a fixed length of 360 degrees is to be edited and a motion step in the cam has to be shortened or extended, but the total length of the cam has to be retained.

If, in the "Absolute edit mode", a (new) motion step extends in the X-direction beyond one or more subsequent steps, these steps are overwritten.

Example:

Absolute editing of ΔX or Xn

Fig.7-8: Absolute edit mode

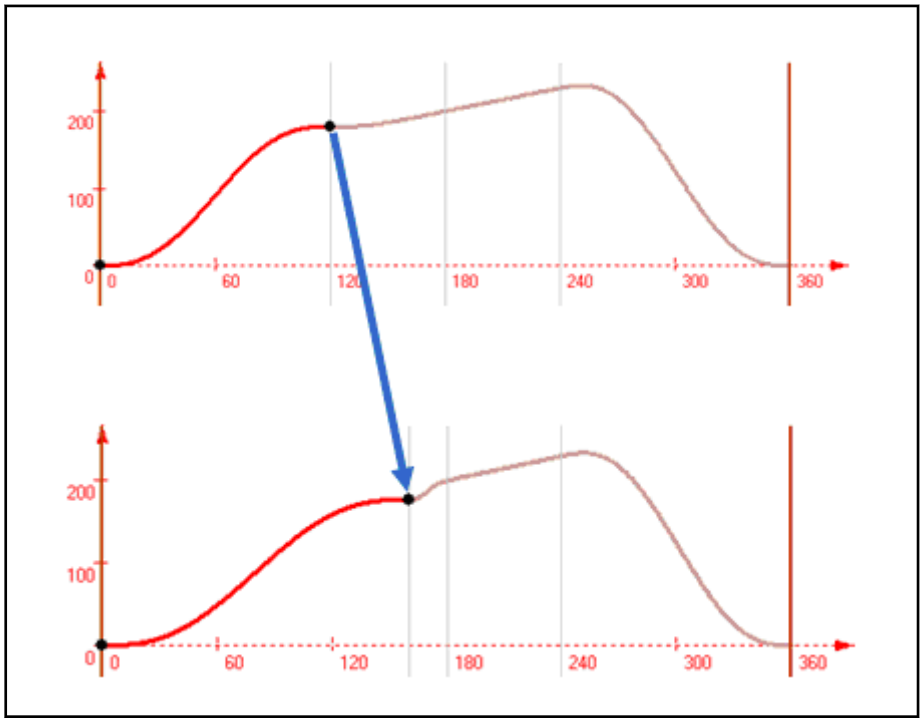


Fig.7-9: Changing ΔX in the second motion step by +40 degrees

7.2.10 Relative Editing of the Master Axis Range (X-Values)

The total length of the cam changes with a change to the master axis range (ΔX, ΔT, X1 or X2) of individual motion steps in the **"Relative edit mode"**. The ΔX or ΔT values of the preceding and subsequent motion steps are not changed.

This mode is recommended if, for example, a cam is being created for the first time or if time-dependent motion steps have to be identified. If, for example, the duration of a motion step is shortened, the duration of the total cam is also shortened.

Example:

Relative editing of ΔX or Xn

Fig.7-10: Relative edit mode

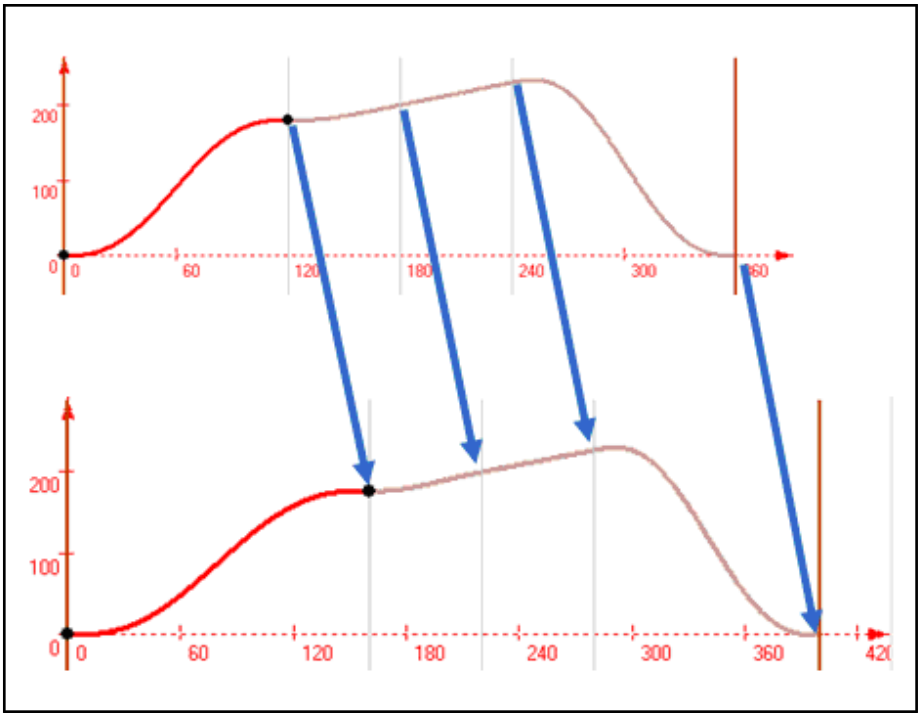


Fig.7-11: Changing ΔX in the second motion step by +40 degrees

7.2.11 Editing the Motion Step Cam Table

If the focused motion step includes a cam table as motion law, in addition to selecting the motion law, a modal window can be opened via an interface for editing the cam table.

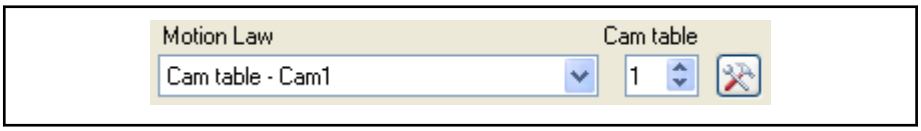


Fig.7-12: Icon: Edit cam table

All **% values** of the cam table can be **edited** in this window.

Points can be **deleted**. In this case, the X-values are recalculated and the existing Y-values retain their values. At least 3 points have to remain.

New points will be **added** after the focused line, the X-values are recalculated and the existing Y-values retain their value. At least 3 and max. 1.024 points can be entered.

The X-values are always specified as a unit of the master axis and the Y-values are recorded as a percentage value. In the cam table, the first X-value always corresponds to the first master axis position of the motion step and the last X-value corresponds to the last master axis position of the motion step.

7.2.12 Adding a New Step after the Focused Step

This function adds a new motion step at the end of the focused motion step and gives ΔX the default step size from the options and the motion law "General motion - Polynomial 5th order".

The limit values of the starting point of the new motion step are applied from the focused end point.

If the **"Relative edit mode"** is active, the total length of the cam increases.

The limit values of the end point are, if available, applied by the starting point of the subsequent motion step. If there is no subsequent motion step, the limit values are assigned "0" values.

If the **"Absolute edit mode"** is active, the total length of the cam is retained.

The boundary values of the end point are assigned the values of the previous subsequent step at its point (X_1 + default step size) and the subsequent step is shortened by the default step size. If this is not possible, a clear and understandable message appears explaining why a step cannot be inserted at this position. If there is no subsequent motion step, the limit values are assigned "0" values.

The inserted motion step is activated following the insertion.

Example:

Fig.7-13: Absolute edit mode

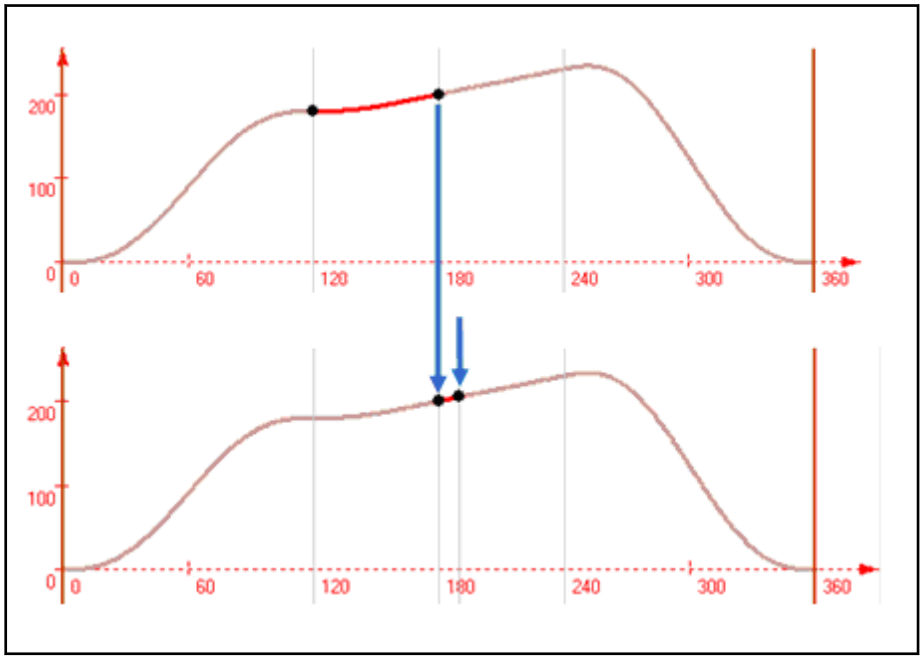


Fig.7-14: A new step is added at the end of the 2nd motion step.

Example:

Fig.7-15: Relative edit mode

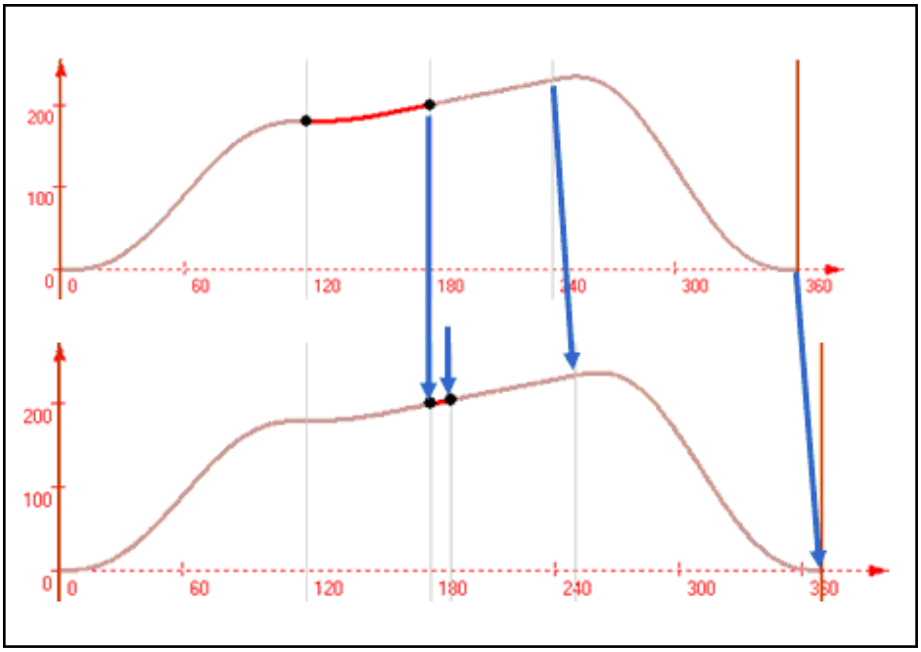


Fig.7-16: A new step is added at the end of the 2nd motion step.

7.2.13 Adding a New Step before the Focused Step

The "Add before" function adds a new motion step before the focused motion step and gives ΔX the default step size and gives the motion law the Polynomial 5th order.

The limit values of the starting point of the new motion step are applied from the end point of the preceding step.

If the **"Relative edit mode"** is active, the total length of the cam increases.

All subsequent steps are displaced backwards by ΔX.

If the **"Absolute edit mode"** is active, the total length of the cam is retained. The limit values of the end point are assigned the values of the previous step focused at its point (X_1 + default step size) and the previous step is shortened by the default step size. If this is not possible, a clear and understandable message appears explaining why a step cannot be inserted at this position.

The new inserted step is activated after the insertion.

Example:

Fig.7-17: Absolute edit mode

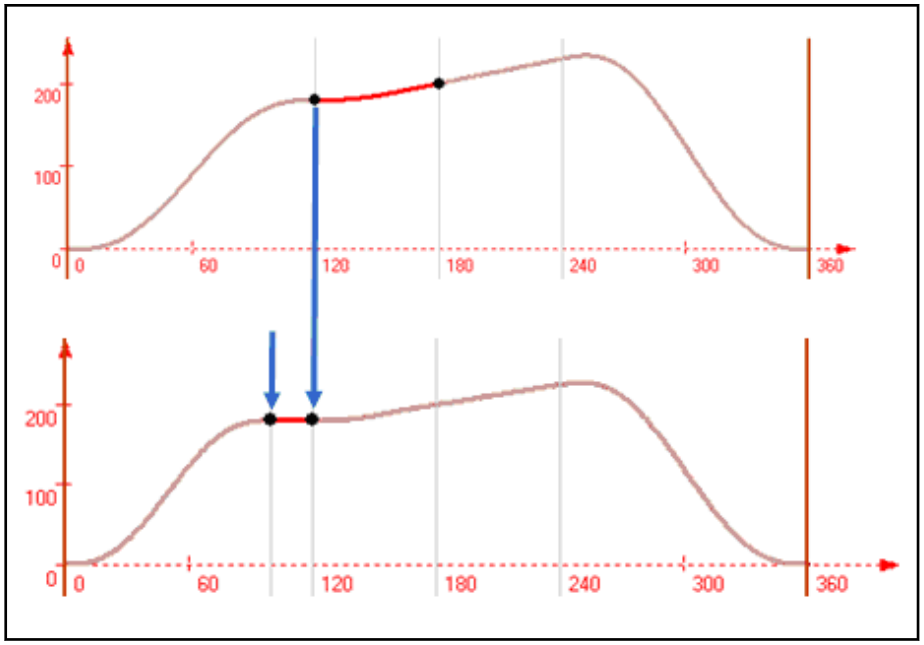


Fig.7-18: A new step is added at the end of the 2nd motion step

Example:

Fig.7-19: Relative edit mode

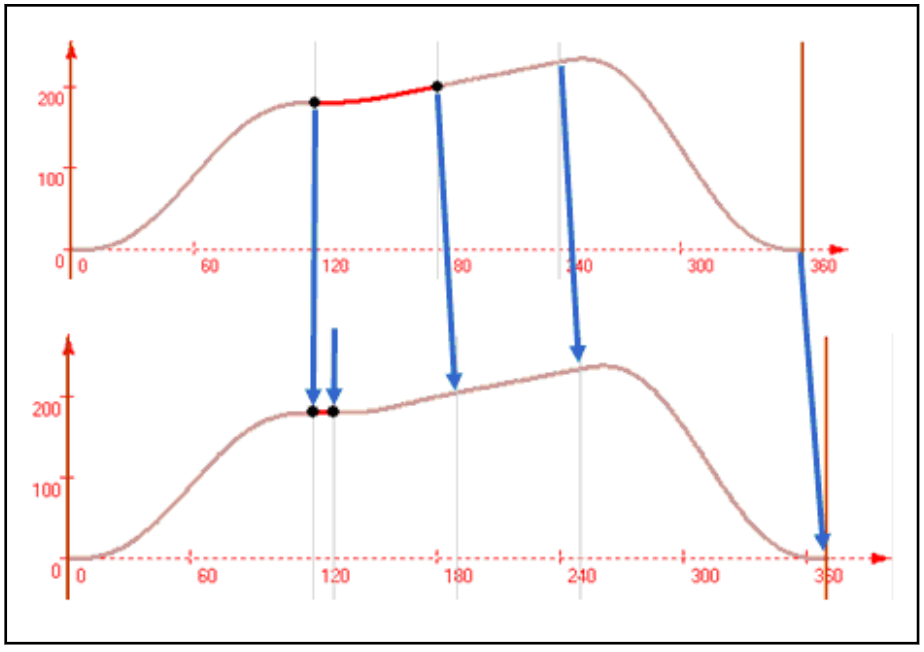


Fig.7-20: A new step is added at the start of the 2nd motion step

7.2.14 Deleting a Focused Motion Step

A cam requires at least one motion step. If a cam consists of more than one motion step, the focused motion step can be deleted.

If the **"Relative edit mode"** is active, the total length of the cam decreases.

If the **"Absolute edit mode"** is active, the total length of the cam is retained.

The total length is retained by the subsequent motion step (if not available, by the preceding step), extended by ΔX of the step to be deleted. If this is not possible, the motion step cannot be deleted.

Example:

Fig.7-21: Absolute edit mode

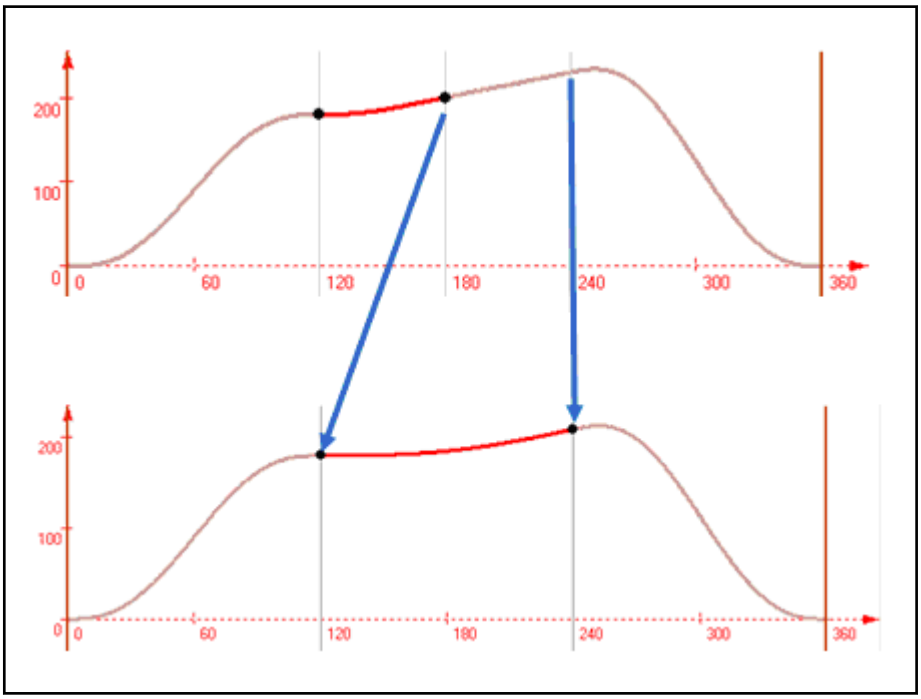


Fig.7-22: Deleting motion step 2

Example:

Fig.7-23: Relative edit mode

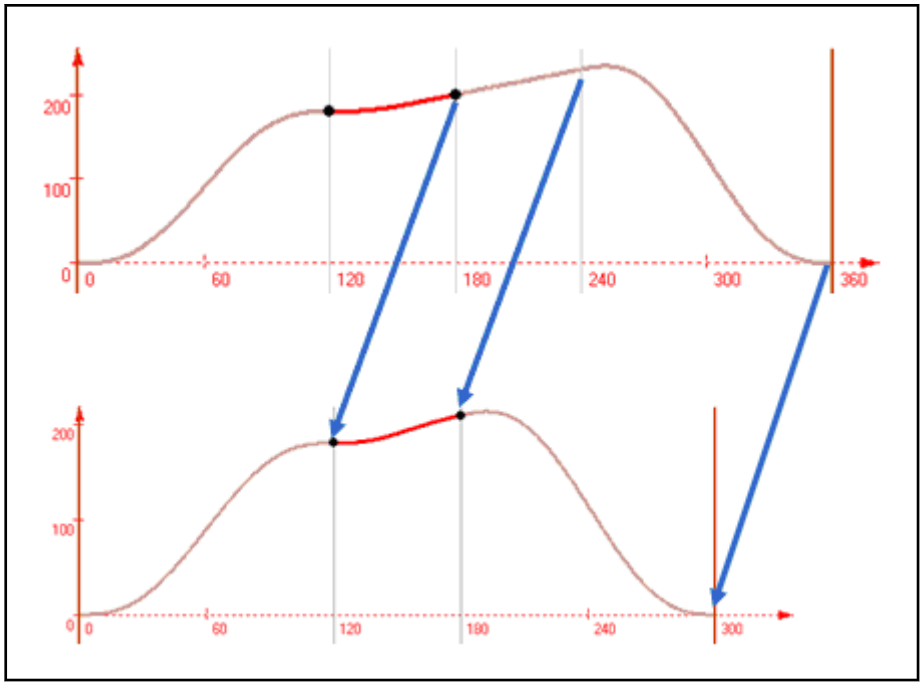


Fig.7-24: Deleting motion step 2

7.3 Event Editor

7.3.1 Overview

The event editor is used to define events.

The **FlexProfile** supports the event control. **Events** can be assigned to motion steps. Events consist of a **trigger** and an **action**. Bits of the AxisData structure can be set during the execution time of the FlexProfile via the action of an event. The PLC offers solutions to react to these events.

Add an event to a focused motion step via the toolbar in the CamBuilder.

Fig.7-25: Icon: Add event

7.3.2 Attributes

Events can be added to each motion step of a cam. An event consists of a trigger and an action.

No. The number is assigned automatically and serves to identify the event.

Motion step Each event is assigned to a certain motion step (Selection option: All motion steps of the focused cam).

Trigger The trigger is the criteria when the event is triggered:

- Absolute master axis position reached

  The event is triggered when the master axis position entered in the assigned motion step is reached.

  Similarly to a programmable limit switch, the current position of an axis can be monitored. If it crosses a specified position in the current motion step, the event occurs.

- Relative master axis path traveled

  The event is triggered when the master axis position entered in the assigned motion step is reached.
- Absolute slave axis position reached

  The event is triggered when the master axis position entered in the assigned motion step is reached.
- Relative slave axis path traveled

  The event is triggered when the slave axis position entered in the assigned motion step is reached.
- PLC signal

  The event is triggered if the PLC signal is set during execution of the assigned motion step.
- Time lapsed

  The event is triggered when the time specified as value has lapsed during the execution of the assigned motion step.

Value The value depends on the trigger (position, travel distance or time).

Unit The unit is displayed depending on the selected trigger (position and travel distance, specified in the unit of the master or slave axis, time in s).

Bit If the trigger criteria is fulfilled during the execution of the assigned motion step, the selected bit of the AxisData structure is set. (Selection options: Bit0 to Bit15).

Action The action defines when the bit should be set:

- At the end of the profile

  The selected bit is set after executing the last motion step at the end of the profile.
- At the end of the motion step

  The selected bit is set after executing the selected motion step.
- Set immediately

  The selected bit is set immediately.
- Set immediately and connect next motion step immediately

  The selected bit is set immediately and the next motion step is executed. If the next motion is a FlexStep, the limit values can be applied dynamically during runtime and the transition can be started without jerks.

☞ If one or more events are assigned to a motion step, they are displayed in the Graph editor in the lower right area as active lighting symbol. The event editor opens by clicking on the symbol.

If a cam with events is displayed in a preview, it is displayed at which time which bit is activated.

7.3.3 Functionality

Creating a new event A standard event is inserted at the end of the event list. (Motion Step: focused step; trigger: PLC signal; bit: Bit0; action: set immediately).

Editing Events can be edited in this list.

Remove event The event focused in the list is removed.

Undo Undoes the most recent change.

Restore If a change has been undone, this function restores it again.

Help Opens the Event Editor chapter of the CamBuilder online help.

By downloading a cam, the events are written in the corresponding parameter.

If a cam contains events, they are generated using the PLC function block for the FlexProfile generation.

If a motion step number changes, as e.g. an additional step is inserted, events remain assigned to the originally assigned motion step. If a motion step is removed, the events belonging to the motion step are also removed.

7.4 Variable Editor

7.4.1 Overview

The variable editor defines variables of a cam definition.

Variables can be used in formulas (see chapter 7.5 "Formula Editor" on page 67) of the cam input fields. When generating a PLC function block to parameterize a FlexProfile, these variables are displayed as inputs at the block.

7.4.2 Attributes

Name The variable name has to be IEC-compliant and unique.

If a variable value is changed, all references to this variable are renamed.

Variables can also be defined as variable fields. For example: "Range[1]" and "Range[2]". When generating a PLC function block, only the variable field is displayed at the input of the block.

Value The variable value can be defined user-specifically and is displayed as default value when generating a PLC function block.

References This field "References" cannot be edited. All abbreviations of formula fields referencing the variable are listed.

Description Variable descriptions are displayed as comment in the PLC function block when declaring the variable.

7.4.3 Functionality

Creating a new variable A new variable is added to the variable list.

Editing Variables can be edited in this list.

Remove variable The variable focused in the list is removed unless it is not used anymore in the cam definition.

Undo Undoes the most recent change.

Restore If a change has been undone, this function restores it again.

Help Opens the Variable Editor chapter of the CamBuilder online help.

If values are calculated using formulas or variables in a cam definitions, the relative editing mode is used for the recalculation.

7.5 Formula Editor

7.5.1 Overview

The formula editor is used to enter formulas to calculate cam properties.

The use of formulas instead of constant input values when defining cams allows to variably define certain values of a cam definition. If a PLC function

block is generated using the CamBuilder definition using a "variable" cam definition, different cam variants can be parameterized as FlexProfile via variable inputs using this block.

The formula editor opens automatically if an "=" character was entered in an input field.

The following input fields support the input of a formula if they are not automatically calculated:

Motion Step Editor

- Distance of the slave axis (ΔY)
- Master axis range (ΔX)
- Duration of the motion step (ΔT)
- Velocity in the starting point of the motion step (V1)
- Velocity in the end point of the motion step (V2)
- Velocity limit value of motion step (V_{max})
- Acceleration in the starting point of the motion step (A1)
- Acceleration in the end point of the motion step (A2)
- Acceleration in the motion step (A_{max})
- Jerk in the starting point of the motion step (J1)
- Jerk in the end point of the motion step (J2)
- Jerk limit value of motion step (J_{max})

Event Editor

- Motion step number
- Trigger value

☞ If the motion step number of an event is calculated with a formula, the result is rounded as integer.

7.5.2 Functionality

Editing formula Edit formulas via the formula text field.

Apply formula and close (OK) The formula is checked and if valid, the calculated formula result is applied to the cam definition. The formula editor is closed.

Applying the formula (refresh) The functionality is as described. Only the formula editor remains open.

Removing formula The formula of the current CamBuilder input field is removed and the last value is used as constant value of the input field instead.

Help Opens the Formula Editor chapter of the CamBuilder online help.

☞ Changes are not applied when clicking on <Esc> or closing the editor.

Click on <Enter> or exit the editor by selecting a different input field, the changes are applied.

If values are calculated with formulas in a cam definition, the relative editing mode is used for recalculation.

7.5.3 Keyword Formula

Mathematical Operators

+	Addition
-	Subtraction
*	Multiplication
/	Division
()	Brackets

Fig.7-26: Formula editor, mathematical operators

Constants

E	Euler number e
PI	Pi

Fig.7-27: Formula editor, constants

Mathematical Functions

ABS(n)	Returns the absolute value of the transferred number
ACOS(n)	Returns an angle whose cosine is the specified number (radian)
ASIN(n)	Returns an angle whose sine is the specified number (radian)
ATAN(n)	Returns an angle whose tangent is the specified number (radian)
CEILING(n)	Returns the smallest integer number that is greater or equal to the specified number
	The return value for n = 7.03 is 8
	The return value for n = 7.64 is 8
	The return value for n = 0.12 is 1
	The return value for n = -0.12 is 0
	The return value for n = -7.1 is -7
	The return value for n = -7.6 is -7
COS(n)	Returns the cosine of the specified angle (radian)
DEG_TO_RAD(n)	Converts an angle from degrees to radian
EXP(n)	Returns the specified power of e
EXPT(n1,n2)	Exponentiates a specified number with the specified exponent
FLOOR(n)	Returns the largest integer number that is smaller or equal to the specified number
	The return value for n = 7.03 is 7
	The return value for n = 7.64 is 7
	The return value for n = 0.12 is 0
	The return value for n = -0.12 is -1
	The return value for n = -7.1 is -8
	The return value for n = -7.6 is -8
LN(n)	Returns the natural logarithm of a specified number
LOG(n)	Returns the logarithm for basis 10 of the specified number

MAX(n1,n2)	Returns the greater number of two specified numbers
MIN(n1,n2)	Returns the smaller number of two specified numbers
RAD_TO_DEG(n)	Converts an angle from radian to degrees
SIGN(n)	Returns a value that specifies the sign of a number
	The return value is -1, if n is smaller than 0
	The return value is 0, if n is equal to 0
	The return value is 1, if n is greater than 0
SIN(n)	Returns the sine of the specified angle (radian)
SQRT(n)	Returns the square root of a specified number
TAN(n)	Returns the tangent of the specified angle (radian)
TRUNC(n)	Calculates the integer part of a number

Fig.7-28: Formula editor, mathematical functions

Cam Attributes

MASTERVELOCITY	Master axis velocity
DYn	Slave axis range of motion step n
DXn	Master axis range of motion step n
DTn	Duration of motion step n
Vn	Initial velocity of the motion step n or end velocity of the motion step n+1
An	Initial acceleration of the motion step n or end acceleration of the motion step n+1
Jn	Initial jerk of the motion step n or end jerk of the motion step n +1
VMAXn	Velocity limit value of motion step n
AMAXn	Acceleration limit value of motion step n
JMAXn	Jerk limit value of motion step n
EVENT_STEPn	Assigned motion step of the event n
EVENT_VALUEn	Trigger value of event n

Fig.7-29: Formula editor, references to fields

References to cam properties that are defined by motion laws are not supported! Only references to editable cam properties can be used in formulas.

User-defined variables

Variable1	Sample variable (see chapter 7.4 "Variable Editor" on page 67)
Variable2	Sample variable
ArrayVariable[1]	Sample variable array
ArrayVariable[2]	Sample variable array

Fig.7-30: Formula editor, references to variables

7.6 Application-Specific Wizard

7.6.1 General Information

Depending on its type of application, an application-specific cam has a special wizard used to edit the entire cam.

Re-edit single motion steps later at any time using the Motion Step Editor (see chapter 7.2 "Motion Step Editor" on page 50). However, as soon as a change has been made using the wizard, all Motion Step Editor changes are overwritten.

7.6.2 CrossCutter Wizard

The CamBuilder provides a wizard for common requirements, such as the CrossCutter functionality, which supports the user in creating the cam. All requirements and unique features of the application are dialog-controlled.

The specific inputs for the CrossCutter functionality are:

- Format length
- Roller diameter
- Cutting angle
- Velocity of the master axis

7.6.3 Feed Wizard

The CamBuilder provides a wizard for common requirements, such as the feed function, which supports the user in creating the cam. All requirements and special features of the application are set using dialog-controlled inputs.

The specific inputs for the feed function are as follows:

- Format length
- Roller diameter
- Maximum delay
- Acceleration path
- Roller position
- Distance between two products
- Velocity of the master axis

To attain the feed configured in the CamBuilder, the distance factor during the download as points table has to be set equal to the distance factor for executing the application.

7.6.4 Print Length Correction Wizard

The CamBuilder provides a Wizard for common requirements, such as the print length correction that supports the user in creating the cam. All requirements and unique features of the application are dialog-controlled.

The specific inputs for the print length correction are as follows:

- Diameter of the pressurized cylinder
- Length of the printing plate
- Correction value
- Velocity of the master axis

Another parameter is calculated by the wizard:

- Gradient in the synchronous range

7.6.5 FlyingShear Wizard

The CamBuilder provides a Wizard for common requirements, such as the print length correction that supports the user in creating the cam. All the requirements and unique features of the application are dialog-controlled.

Specific entries for the FlyingShear:

- Synchronous range - range within which the step is executed
- The motion law in the transition area - the modified sine curve, polynomial 3rd order, polynomial 5th order and polynomial 7th order motion laws are available.

Another parameter is calculated by the wizard:

- Gradient in the synchronous range

7.7 Cam Table

The cam table is an overview of the complete behavior of the cam.

The user can specify the **number of data points** for the entire position profile. It is also possible to define with which **distance** the percentage values are to be calculated.

Specify the distribution of the points across the master axis range using the following option:

The last data point in the table belongs to X: 100% (Yes/No) (table format).

Assuming the number of data points is to be 1,024:

Yes:	The 100% are split to exactly 1,024 points for example		
	0,0000%	=	Point 1
	99,9023%	=	Point 1023
	100,0000%	=	Point 1024
No:	100% is divided between 1024 + 1 points		
	0,0000%	=	Point 1
	99,9024%	=	Point 1024
	100,0000%	=	Point 1

Fig.7-31: The units in the columns depend on the master and slave axis units

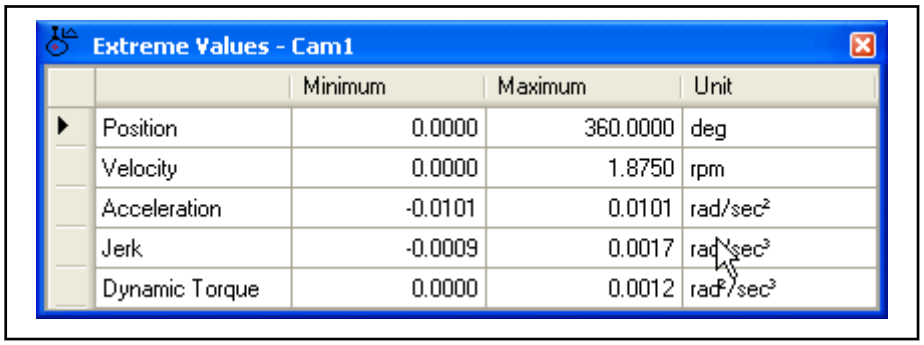
The table is write-protected and has the following columns:

Number, Y [%], Master axis position, Slave axis position, Velocity, Acceleration, Jerk. The values refer to the master axis velocity defined in the motion step editor.

Copy the values of the table to the clipboard and apply them with "Insert".

7.8 Extreme Values

The minimum and maximum values referred to the master axis velocity defined in the motion step editor for the entire cam are displayed in the extreme values list.



	Minimum	Maximum	Unit
Position	0.0000	360.0000	deg
Velocity	0.0000	1.8750	rpm
Acceleration	-0.0101	0.0101	rad/sec²
Jerk	-0.0009	0.0017	rad/sec³
Dynamic Torque	0.0000	0.0012	rad²/sec³

Fig.7-32: Example: Extreme Values List

The dynamic torque characteristic value is calculated on the basis of the following equation:

C_{mdyn} = maximum value (V_{max} * A_{max})

where V_{max} = maximum velocity and A_{max} = maximum acceleration.

☞ Display or hide this window via the menu items **View** ▸ **More Windows** ▸ **Extreme Values**.

7.9 Cam Preview

Cams are graphically edited in the "GraphEditor" (see chapter 7.1 "Graph Editor" on page 47).

To compare several cams with regard to a master axis, open the cams in a preview and analyze them.

A new preview is added to the project via a "Cam Pool" or the IndraWorks library (see chapter 6.2 "Creating Preview Objects" on page 44).

☞ Depending on the selected operation mode in the application, differences to the preview can occur. Cam tables and MotionProfiles do not support any time-dependent steps or events.

Slave axis and master axis offset have to be explicitly specified when enabling the respective synchronous operation mode in the user program via function blocks. (e.g. MB_PhasingSlave, MB_Phasing for all operation modes or via the corresponding inputs at the ML_FlexProfile block)

Preview window design

A preview window consists of time-dependent position representation of a master axis and the optional time-dependent profile representations (position/velocity/acceleration/jerk) of the slave axes.

Move the individual positions in the preview window upwards or downwards via a system menu in the upper right corner of the respective preview. The previews can be distributed in the preview window and individual previews can also be closed.

☞ Change the height of the individual previews with the mouse. The line between two previews is "held" using the mouse and the size is adjusted by moving the mouse.

If the <Ctrl> key is pressed when changing the size, the entire size of the preview can be adjusted.

Measuring function

Move the measuring line in the selection mode (arrow) using the mouse. The measuring results are shown in the title bar of each preview. To measure another profile (position/velocity/acceleration/jerk), select it with the mouse. The measuring results refer to this profile.

Changing the view

Change the view using the same tools as the Graph Editor (see chapter 7.1.4 "Changing the View" on page 48).

The individual views of the previews are synchronized on the X axis. The same time range is always displayed.

Master axis properties

Change the following attributes of the master axis representation using the link "Settings...":

- **Master axis velocity**

  The unit of the master axis velocity depends on the scaling
- **Preview of time**

  The unit of the preview time is milliseconds
- **Modulo**

  Defines the overflow for the graphic representation

- **Scaling**

  (rotary or translatory and unit)

Properties of the slave axis

Change the following attributes of the slave axis representation using the link "Settings..." of the slave axis:

- **Modulo**

  Defines the overflow for the graphic representation
- **Master axis offset**

  Defines the offset in the master axis range
- **Slave axis offset**

  Defines the offset in the slave axis range
- **Execution mode**

  Cyclical

  Cyclical with defined pause

  One-time

The cyclic representation with a defined pause is used to preview cams started with the processing type "One-time execution" by cyclic events (e.g. of other cams) .

The master axis offset can either be entered in the master axis unit or in ms.

7.10 Preview of Superimposed Cams (XY)

Cams are graphically edited in the "GraphEditor" (see chapter 7.1 "Graph Editor" on page 47).

To compare the superimposition of two translatory cams in x- and y-direction with regard to a master axis, open the cams in a preview and analyze them.

A new preview of the superimposed cams is added to the project via a "Cam Pool" or the IndraWorks library (see chapter 6.3 "Creating Preview Objects of Superimposed Cam Motions" on page 44).

The preview of the superimposed cams generally works like the simple cam preview (see chapter 7.9 "Cam Preview" on page 74).

Structure of the window

The preview window consists of the representation of the master axis, the superimposed motion of the cams in x- and y-direction and a representation of the resulting variables of the superimposed motion (velocity, acceleration and jerk).

Measuring function

Move the measuring line in the master axis representation or the representation of the resulting values Using the mouse in the selection mode (arrow). The measuring results are shown in the title bar of each preview.

Properties of the x- and y-axis

Change the following attributes of the axes using the links "X-axis..." and "Y-axis..." of the representation of the cam superimposition:

- **Cam**

  Selection of the translatory cam
- **Master axis offset**

  Defines the offset in the master axis range of the selected cam
- **Slave axis offset**

  Defines the offset in the slave axis range of the selected cam
- **Execution mode**

  Cyclical

Cyclical with defined pause

One-time

The cyclic representation with a defined pause is used to preview cams started with the processing type "One-time execution" by cyclic events (e.g. of other cams) .

The master axis offset can either be entered in the master axis unit or in ms.

8 Managing Cams and Preview Objects in the IndraWorks Project

General Information

The CamBuilder manages cams and preview objects within the project and archives and restores them. They are managed in the Project Explorer below the **"Cam Pool"** node.

Export a cam to use it outside the project as well.

It is also possible to import existing cams into a project (refer to chapter 10 "Importing and Exporting Cams" on page 83).

If one or more devices are in online or offline parameterization mode, cams within the project can also be downloaded to these devices or uploaded from these devices to the project (refer to chapter 9 "Interacting with Bosch Rexroth Devices" on page 79).

"Cam Pool" Create folder

Copy a "Cam Pool" folder from the IndraWorks library from the "CamBuilder" section to the project via drag&drop.

Use the context menu of a "Cam Pool" node to create a new folder below this one. Cams and preview objects can also be created and edited in this folder. Rename or delete this folder via the context menu.

A "Cam Pool" folder can be moved in the project. Several "Cam Pool" folders can exist in one project.

Opening a cam / Preview

Open a cam or a preview by double-clicking on the relevant symbol in the "Cam Pool" node in the Project Explorer. The relevant graphical view opens.

Saving a cam / Preview

Once a cam was edited in the project and is focused, changes can be permanently applied to the project via the menu item **File ▸ Save (Ctrl+S)**.

The menu item **File ▸ Save All** also saves changes to cams and preview objects currently not focused.

If a preview is saved, all the cams in the preview are saved as well!

When closing a project, all open documents are automatically saved (without confirmation)!

Copying a cam / Preview

Copy a cam or a preview to the Project Explorer by highlighting and selecting **File ▸ Edit ▸ Copy**.

Inserting a cam

A cam or a preview can also be re-inserted into the project after it has been copied. Therefore, highlight a "Cam Pool" node and insert the copy of the cam via the menu item **File ▸ Edit ▸ Paste**.

Renaming

Rename a Cam Pool, cam or preview clicking slowly twice on its name in the Project Explorer. Alternatively, highlight the object and rename it via the context menu. Another option is to access the "Properties" dialog via the cam context menu when the cam is open and to change the name.

Deleting

Delete a Cam Pool, cam or preview via the context menu by highlighting it in the Project Explorer. Alternatively, highlight the object and delete it with the <Del> key.

9 Interacting with Bosch Rexroth Devices

9.1 Downloading Cams to Devices

9.1.1 General Information

The CamBuilder supports communication to different devices in the IndraWorks project.

The devices either have to be in online or offline parameterization mode and require an interface to the CamBuilder in order to use the following functions.

The "Download cam" dialog is started via the context menu of a cam in the Project Explorer. The devices in the IndraWorks project, which are either in online or offline parameterization mode and support the download of cams, provide their cam parameters in an overview.

The parameters have different symbols for different operation modes:

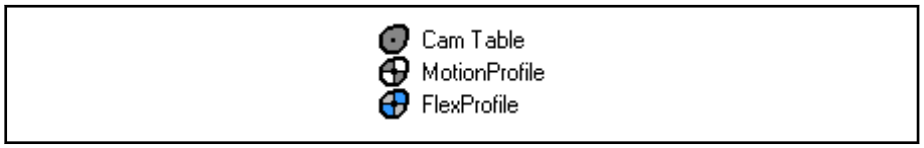


Fig.9-1: Device symbols for different operation modes

9.1.2 Downloading Cams to Cam Table Parameters

If the focused cam is to be downloaded to cam table parameters, a data point table - with percentage values of at least three and at maximum of the number of points supported by the device - is created for the complete course of the position profile.

The following information is required when downloading as cam table:

- **Number of data points**
- **Distance** - Factor to calculate the percentage values
- **Removing linear portions of the cam** - Applies only to drives from a specific version onwards
- **The last data point in the table corresponds to X = 100%** - (Yes / No) (table format)

  This setting only applies to drives. For control, the last data point always corresponds to X = 100%

  To specify the calculation of the x-values, there are two different formats on the drive.

Assuming the number of data points is to be 1,024:

Historically:	The 100% are split to 1,024 + 1 point		
	0,0000%	=	Point 1
	99,9024%	=	Point 1024
	100,0000%	=	Point 1
Current:	The 100% are split to exactly 1,024 points for example		
	0,0000%	=	Point 1
	99,9023%	=	Point 1023
	100,0000%	=	Point 1024

☞ If the cam contains motion steps with time reference, the slave axis motion is calculated using the entered master axis velocity. The dynamic functionality is lost. The dynamics of the FlexSteps is also lost.

9.1.3 Downloading Cams to MotionProfile Parameters

To download a cam to MotionProfile parameters, it may only contain motion laws supported by the MotionProfile operation mode. The master axis range has to be rotatorily fixed at 360 degrees.

No further settings are required.

☞ If the cam contains motion steps with time reference, the slave axis motion is calculated using the entered master axis velocity. The dynamic limit values are lost. The dynamics of the FlexSteps is also lost.

9.1.4 Downloading Cams to FlexProfile Parameters

To download a cam to FlexProfile parameters, it may only contain motion laws supported by the FlexProfile operation mode.

No further settings are required.

9.1.5 Downloading Cams to a CF Memory Card

If an IndraMotion MLC/IndraLogic XLC is online in the project, cams can also be stored on its Compact Flash card.

Unlike as for parameters for cam tables, MotionProfiles and FlexProfiles, there is no predefined format for cams on the CF card. The user has to specify the desired format. The cam is then saved as file under its name specified in the CamBuilder. If the file already exists, a query is displayed prompting whether it should be overwritten.

9.2 Uploading Cams from Devices

The CamBuilder supports communication to different devices in the IndraWorks project.

The devices either have to be in online or offline parameterization mode and require an interface to the CamBuilder in order to use this function.

The "Upload Cam" dialog is started via the context menu of a "Cam Pool" node in the Project Explorer via "Upload Cam from Device". The devices in the IndraWorks project that are either in online or offline parameterization mode and that support the cam upload, provide its cams ready for upload in an overview.

The parameters have different symbols for different operation modes:

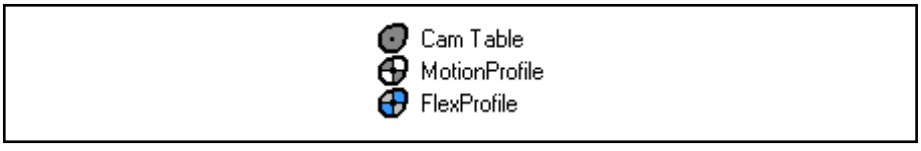


Fig.9-2: Device symbols for different operation modes

The process of uploading cams is identical for all cam types.

Only a specific name has to be entered when saving the cam in the IndraWorks project. The cam is then converted to the neutral CamBuilder for-

mat. Editing a cam is thus always identical in the CamBuilder, the format of the cam is only of significance when downloading it to a device.

9.3 Creating a PLC Function Block

A PLC code (in structured text) can be created for a function blocks using the CamBuilder. This function block writes the cam defined in the CamBuilder to the FlexProfile parameters of an IndraMotion MLC/IndraLogic XLC axis.

Create a PLC code for a cam via its context menu in the Project Explorer via the menu item "Create PLC function block". Alternatively, the code generation with open cam is started via the "PLC" button.

Fig.9-3: Creating PLC function blocks

If a folder named "General module folder" (IndraLogic) is available in the current project, a new function block is automatically created for the selected "Cam1" under the name "ChangeFlexSet_Cam1" for example. The function block name consists of a prefix specified in the "Options" dialog (see chapter 11.1 "CamBuilder Options" on page 85) and the cam name (non-IEC-compliant characters are replaced by the character "_").

If the folder "General module folder" does not exist in the current project, the generated PLC code is only displayed in an output window. From this window, the code text can be copied to the clipboard and can be used in other applications.

To create a variable function block, formulas with references to variables can be used in the CamBuilder instead of constant values for cam properties (see chapter 7.5 "Formula Editor" on page 67).

Brief description of the function block

The created "ChangeFlexSet_Cam1" function block loads the motion steps and events of the cam defined in the CamBuilder to a FlexProfile of an IndraMotion MLC/IndraLogic XLC axis.

Interface Description

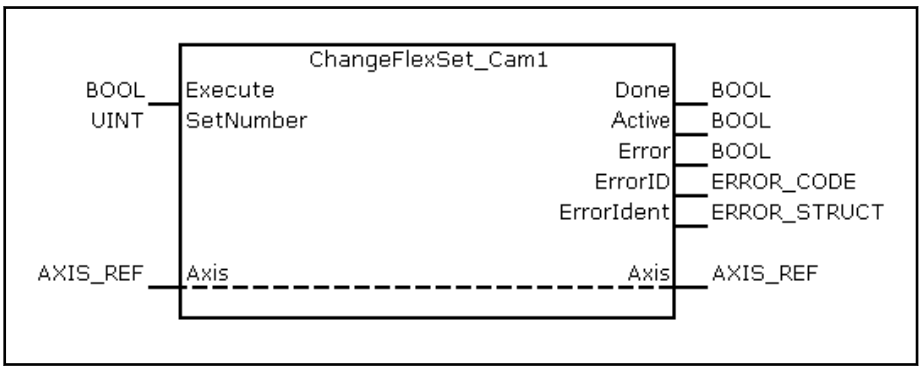


Fig.9-4: "ChangeFlexSet_Cam1" function block

	Name	Type	Comment
VAR_IN_OUT	Axis	AXIS_REF	Contains information on the axis whose FlexProfile set is to be exchanged
VAR_INPUT	Execute	BOOL	Starts the action at a rising edge

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	Name	Type	Comment
	SetNum-ber	UINT	Selecting the FlexProfile (0 ... 3)
VAR_OUTPUT	Done	BOOL	Data was applied
	Active	BOOL	Data processing runs after preprocessing
	Error	BOOL	Indicates that an error occurred in the function block instance
	ErrorID	ERROR_CODE	Brief note on the error cause
	ErrorIdent	ERROR_STRUCT	Detailed error information

Fig.9-5: Interface of the "ChangeFlexSet_Cam1" function block

If formulas with variables are used in cam definitions (see chapter 7.4 "Variable Editor" on page 67), the function block contains these as additional inputs of type "LREAL".

Signal-time diagram

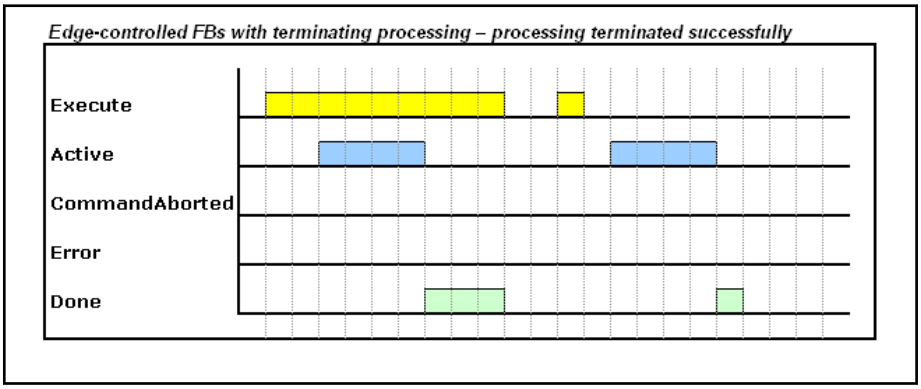

Fig.9-6: Signal-time diagram: ChangeFlexSet_Cam1

10 Importing and Exporting Cams

10.1 General Information

Import or export cams from/to an IndraWorks project using the CamBuilder. The following formats are supported for these import/export functionalities:

- **CamBuilder file (*.XML)**

  Internal CamBuilder format.

  Enables an unrestricted further editing of the cam in other CamBuilder projects.

- **Parameter file (*.PAR)**

  Parameter file for drives and controls (e.g. IndraDrive and IndraMotion MLC or IndraLogic XLC).

  Enables parameter files to be uploaded to the target device using IndraWorks or DriveTop for example. The cam is converted into a cam table.

- **Cam table (*.CSV)**

  The position values, velocity values, acceleration values and jerk values of the cam are saved in a file that can be read with Excel. The cam is converted into a cam table. This ensures that it can also be read via DriveTop.

10.2 Exporting Cams

The export of a cam is started via the cam context menu in the "Cam Pool" node of the Project Explorer.

To further edit the cam in another project, export it as XML format and import it to the other project.

To analyze the cam with the **IndraSize** tool, export it to XML format and import it to IndraSize.

To transmit the cam to a drive using DriveTop for example, the PAR or CSV format can be used. The cam is exported and the exported file is read with DriveTop and the cam table is transmitted to the drive.

The CSV format is available to further analyze position values, velocity values, acceleration values and jerk values of a cam.

As CamBuilder file (*.xml) Only the target location of the file has to be specified.

As parameter file (*.par) Specify the following for an export as parameter file:

- **Device type** - The drive or control type on which the cam is to be stored
- **Cam table** - The parameter, to which the cam is to be saved, e.g.drives of the ECODRIVE family support two cams (P-0-0072 and P-0-0092)
- **Remove linear components of the cam** - If this function is set, the data sent is modified. This functionality is only available for drives and also only for specific firmware versions. For more information refer to the functional description of the device used
- **Address** - Address of the drive or control on which the cam is to be saved (limited between 0 - 100)
- **The last data point in the table belongs to X: 100%** - (Yes/No) (table format)
- **Number of data points** (limited from 3 to 1,024)

- **Distance** - Factor to calculate the % values of the data point table.

As cam table (*.csv)

Specify the following when exporting the cam to **CSV format**:

- **Adding information** - If this setting is not set, only the cam table is exported. Otherwise, the following information is added:
  - Date created
  - CamBuilder version
  - User-defined name
  - Column headings
- **Remove linear components of the cam** - If this function is set, the data sent is modified. This functionality is only available for drives and also only for specific firmware versions. For more information refer to the functional description of the device used
- **Backup in VisualMotion-8 format** - Automatically exports in VisualMotion-8-csv-file format. This setting automatically resets all other settings.
- **The last data point in the table belongs to X: 100%** - (Yes/No)
- **Number of data points** (limited from 3 to 1,024)
- **Distance** - Factor to calculate the % values of the data point table.
- **Additional data** - This setting enables the velocity profile, acceleration profile and the jerk profile to be exported as well
- **Field separator** - Specifies the separator the values are exported with. Comma and semicolon are possible

10.3 Importing Cams

The import of a cam is started via the context menu in the "Cam Pool" node of the Project Explorer. The file to be imported has to be selected in the **Open File** dialog.

No further entries are required when importing the cam in XML format.

sercos ASCII format files can include more than one parameter which contains a cam table. If a *.par file is selected for import and this file includes more than one cam table, the user gets all cam table parameters found for selection. The user can then select the cam table from this list.

The CamBuilder internally requires cam tables whose last y-data point corresponds to X = 100%. To import a CSV file or a PAR file, specify the table format. If the last y-value equals 0.xxx % or +-99.xxx %, a last data point is automatically suggested in the input field.

11 CamBuilder Options and Cam Properties

11.1 CamBuilder Options

Open the "Options" dialog via the menu items **Tools ▸ Options ▸ CamBuilder**.

Enter all general settings affecting the entire CamBuilder (all opened cams) here.

The options are divided into two parts:

General options

- **Minimum rotary motion step length**
- **Minimum translatory motion step length**
- **Default rotary motion step length**
- **Default translatory motion step length**

  Minimum motion step lengths can be defined for the slave axis. When a change is applied to a motion step, it is checked whether the length of the focused step is greater than this setting.

  The defined default values are used when inserting new motion steps.
- **FlexProfile function block name prefix**

  The name prefix is used to generate a PLC function block from a cam. The name of the function block consists of the prefix and the cam name.

Chart options

- **General Information**
  - **Snap radius**

    Radius in pixels around the mouse pointer to select objects
  - **Using grid positions during editing**

    Click on the <Ctrl> key to disable this option while editing
  - **Line width of the focused profile**
  - **Line width of the inactive profiles**
  - **Brightness of the focused motion steps**
  - **Brightness of the inactive motion steps**
  - **Line type of the coordinate grid**
- **Colors**

  Predefined color schemes can be selected or changed.

  The following colors can be adapted:
  - **Color of the position profile**
  - **Color of the velocity profile**
  - **Color of the acceleration profile**
  - **Color of the jerk profile**
  - **Color of the selected step (top)**
  - **Color of the selected step (bottom)**
  - **Color of the motion step limits**
  - **Color of the coordinate grid**
  - **Color of the chart background (top)**
  - **Color of the chart background (bottom)**

Each change is permanently saved and thus preset at the CamBuilder restart.

11.2 Cam Properties

Open the "Properties" dialog of a cam via the context menu of the focused cam in the Project Explorer or via the CamBuilder toolbar. Make settings for the focused cam here.

Opening "Properties" automatically loads the corresponding cam.

The properties to be edited correspond to those in the first step of the wizard for a new cam (refer to chapter 6 "Creating Cams and Preview Objects" on page 43).

12 Printing Cams

The CamBuilder prints the different cams individually.

Select the following print settings via the "Print" context menu item in the Project Explorer.

- Print the **graphic output** of the cam (Yes/No) - The current graphic output is printed. To enable this option, open a cam in the workspace
- Print the **description** of the cam (Yes/No) - The cam description is printed. To enable this option, the cam has to include a description
- Print the **application data** of the cam (Yes/No) - The application data is printed from the application wizard. To enable this option, the cam has to include an application wizard
- Print the **motion steps** of the cam (Yes/No) - Data of the individual motion steps (position, velocity, motion law, description, ...) is printed
- Print the **extreme values** of the cam (Yes/No) - The content of the extreme values list is printed
- Print the **cam table** of the cam (Yes/No) - e.g. 1.024 percentage values of the slave axis position are printed

To print or to view a preview, select at least one of the options.

13 Motion Laws

13.1 General Information

The CamBuilder supports 36 different motion laws to define the motion between the starting and end point of a motion step. Moreover, free cam tables can also be imported to define the motion.

Further information on motion laws is given in the FlexProfile documentation.

The different motion laws provide different degrees of freedom in terms of limit values and are subdivided into categories:

	Definition of the motion law at the input "MotionLaw" (ProfileStepAdr)		Travel range		Boundary values left			Boundary value right			Max (not considered everywhere)			TPS possible	FlexStep possible	Operation modes
			Distance	Range	StVel	StAcc	StJerk	EndVel	EndAcc	EndJerk	MaxVel	MaxAcc	MaxJerk			
Rest-in-rest																
Standstill	REST_IN_REST_LINEAR	2048	0	*	0	0	0	0	0	0	=	=	=	x		CT, FP
Sine curve	REST_IN_REST_SINE	2560	*	*	0	=	=	0	=	=	=	=	=	x		CT, FP
Inclined sine curve	REST_IN_REST_INCLINEDSINE	0	*	*	0	0	=	0	0	=	=	=	=	x		CT, MP, FP
Acc.-opt. inclined sine curve	REST_IN_REST_SINEACC	3072	*	*	0	0	=	0	0	=	=	=	=	x		CT, FP
Torque-opt. inclined sine curve	REST_IN_REST_SINETORQUE	3328	*	*	0	0	=	0	0	=	=	=	=	x		CT, FP
Gutman sinoide	REST_IN_REST_GUTMANSINE	2816	*	*	0	0	=	0	0	=	=	=	=	x		CT, FP
Modified sine curve	REST_IN_REST_MOD_SINE	3840	*	*	0	0	=	0	0	=	=	=	=	x		CT, FP
Modified acceleration trapezoid	REST_IN_REST_MOD_TRAPEZE	3584	*	*	0	0	=	0	0	=	=	=	=	x		CT, FP
Polynomial 5th order	REST_IN_REST_POLY5	256	*	*	0	=	=	0	=	=	=	=	=	x		CT, FP
Polynomial 7th order	REST_IN_REST_POLY7	2304	*	*	0	0	=	0	0	=	=	=	=	x		CT, FP
Polynomial 8th order	REST_IN_REST_POLY8	5120	*	*	0	0	0	0	0	0	=	=	=	x		CT, MP, FP
Quadratic parabola	REST_IN_REST_PARABOLA	4864	*	*	0	0	0	0	0	0	=	=	=	x		CT
Rest-in-velocity																

Motion Laws

	Definition of the motion law at the input "MotionLaw" (ProfileStepAdr)		Travel range		Boundary values left			Boundary value right			Max (not considered everywhere)			TPS possible	FlexStep possible	Operation modes
			Distance	Range	StVel	StAcc	StJerk	EndVel	EndAcc	EndJerk	MaxVel	MaxAcc	MaxJerk			
Polynomial 5th order	REST_IN_VELOCITY_POLY5	512	*	*	0	0	=	*	0	=	=	=	=			CT, MP, FP
Polynomial 7th order	REST_IN_VELOCITY_POLY7	768	*	*	0	0	0	*	0	0	=	=	=			CT, FP
Velocity-in-velocity																
Constant velocity	CONSTANT_VELOCITY	1536	*	*	=	0	0	=	0	0	=	=	=			CT, MP, FP
Polynomial 5th order	VELOCITY_IN_VELOCITY_POLY5	1792	*	*	*	0	=	*	0	=	=	=	=			CT, MP, FP
Polynomial 7th order	VELOCITY_IN_VELOCITY_POLY7	4096	*	*	*	0	0	*	0	0	=	=	=			CT, FP
Modified sine curve	VELOCITY_IN_VELOCITY_MOD_SINE	4352	*	*	*	0	=	*	0	=	=	=	=			CT, FP
Velocity-in-rest																
Polynomial 5th order	VELOCITY_IN_REST_POLY5	1024	*	*	*	0	=	0	0	=	=	=	=			CT, MP, FP
Polynomial 7th order	VELOCITY_IN_REST_POLY7	1280	*	*	*	0	0	0	0	0	=	=	=			CT, FP
General motion																
Polynomial 2nd order	COMMON_POLY2	16896	*	*	*	=	=	=	=	=	=	=	=			CT
Polynomial 3rd order	COMMON_POLY3	17152	*	*	*	=	=	*	=	=	=	=	=			CT
Polynomial 4th order	COMMON_POLY4	17408	*	*	*	=	=	*	=	=	=	=	=	x		CT
Polynomial 5th order	COMMON_POLY5	16384	*	*	*	*	=	*	*	=	=	=	=		x	CT, FP
Polynomial 7th order	COMMON_POLY7	16640	*	*	*	*	*	*	*	*	=	=	=		x	CT, FP
Polynomial 8th order	COMMON_POLY8	17664	*	*	*	*	*	*	*	*	=	=	=			CT
Extended motion																
- Resulting distance																
Velocity 2nd Order (StartAcc zero)	X_VEL_STARTACC	33280	=	*	*	0	=	*	=	=	=	=	=			CT

	Definition of the motion law at the input "MotionLaw" (ProfileStepAdr)		Travel range		Boundary values left			Boundary value right			Max (not considered everywhere)			TPS possible	FlexStep possible	Operation modes
			Distance	Range	StVel	StAcc	StJerk	EndVel	EndAcc	EndJerk	MaxVel	MaxAcc	MaxJerk			
Velocity 2nd Order (EndAcc zero)	X_VEL_ENDACC	33280	=	*	*	=	=	*	0	=	=	=	=			CT
Linear velocity	X_LINEAR_VEL	33024	=	*	*	=	=	*	=	=	=	=	=			CT
Linear acceleration	X_LINEAR_ACC	32768	=	*	*	*	=	=	*	=	=	=	=			CT
- Resulting master axis range																
Acceleration-lim. motion (trapezoid profile)	X_FIT_VEL_TRAPEZE_ALIM	7000	*	=	*	=	=	*	=	=	*	*	=			CT, FP
Acceleration-lim. Sine curve	X_FIT_SINE_TRAPEZE_ALIM	28928	*	=	*	=	=	*	=	=	*	*	=			CT, FP
Jerk-lim. motion (trapezoid profile)	X_FIT_ACC_TRAPEZE_JLIM	29184	*	=	*	=	=	*	=	=	*	*	*			CT, FP
- Other																
Velocity-lim. Polynomial 5th order	X_MOTION_IN_MOTION_POLY5_VLIM	24576	*	*	*	*	=	*	*	=	*	=	=			CT, FP
Overshooting-free polynomial 5th order	X_MOTION_IN_MOTION_POLY5_SLIM	24832	*	*	*	0	=	*	0	=	=	=	=			CT, FP
Acceleration-lim. (trapezoid profile)	X_VELOCITY_IN_VELOCITY_TRAPEZE_ALIM	20480	*	*	*	0	=	*	0	=	*	*	=			CT, FP
Point table																
Cam	CAMTABLE_1	1...99	*	*	=	=	=	=	=	=	=	=	=			CT, MP, FP

0 Explicitly 0
* User-defined
= Calculated automatically
CT Cam table
MP MotionProfile
FP FlexProfile

Fig. 13-1: Boundary conditions of the FlexProfile motion laws

13.2 Analytic Functions

13.2.1 General Information

The following motion laws enable a selection based on different criteria.

A high quality is achieved by reducing damaging oscillations and abrasion and noise are also minimized.

13.2.2 Rest-in-Rest

There are twelve rest-in-rest motion laws available. These motion laws are only defined by the distance and the master axis range. Starting and end velocity are 0.

Rest-in-rest, standstill

(up to CamBuilder 08VRS: linear rest)

$$f(z) = 0$$

Fig. 13-2: Function: Rest-in-rest, standstill

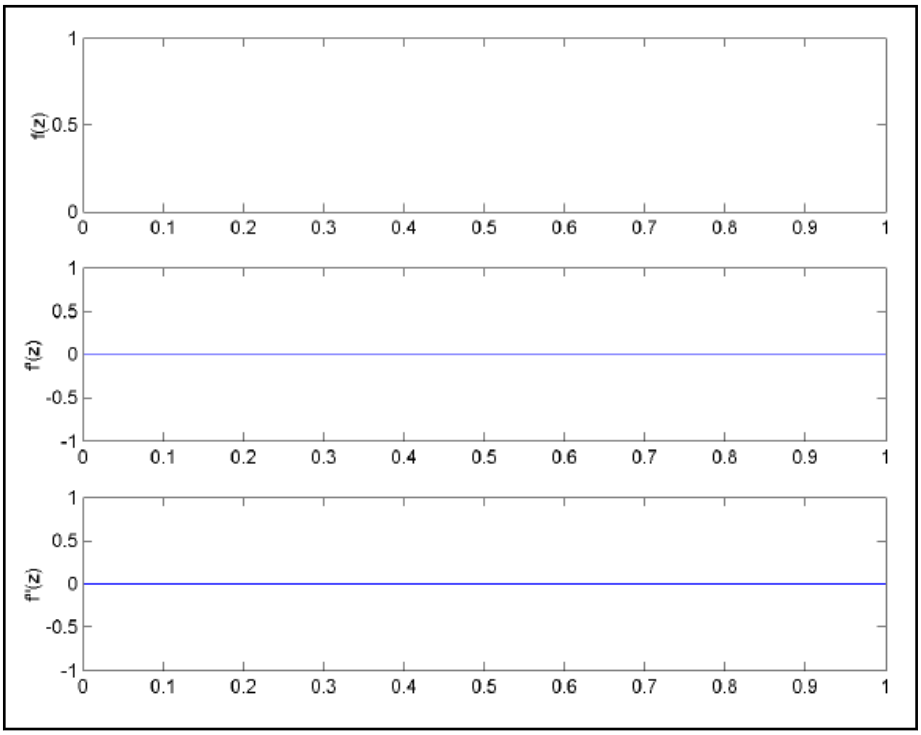

Fig. 13-3: Graph: Rest-in-rest, standstill

Rest-in-rest, simple sine curve

Advantages

- Low velocity characteristic value
- Low acceleration characteristic value
- Low dynamic torque characteristic value

Disadvantages

- Acceleration jump
- Oscillations, noise, wear

$$f(z) = \frac{1}{2}\left[1 - \cos(\pi z)\right]$$

Fig. 13-4: Function: Rest-in-rest, simple sine curve

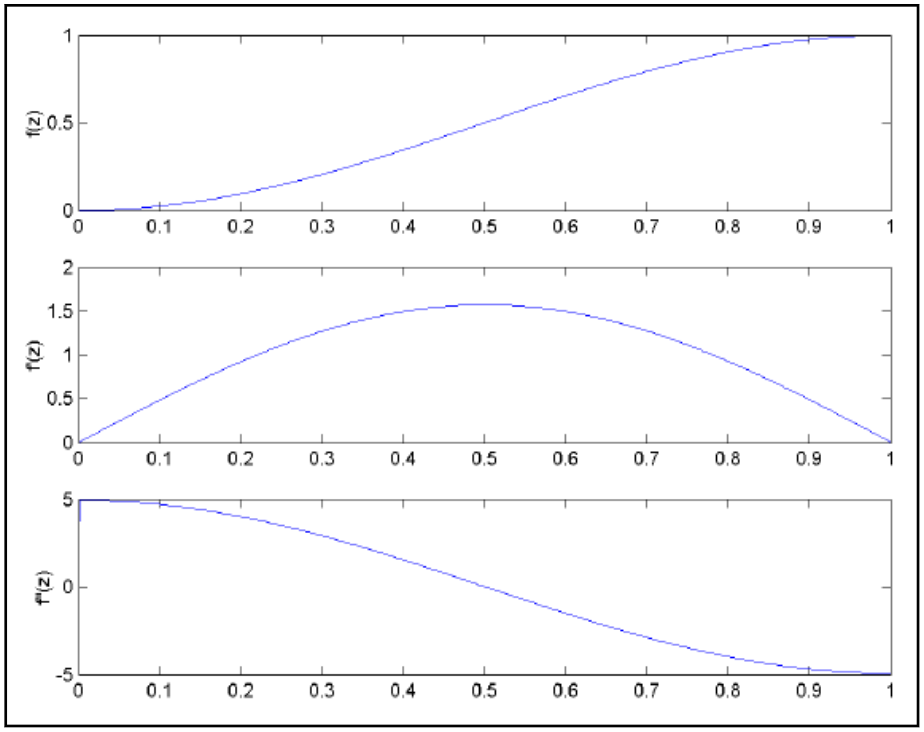

Fig. 13-5: Graph: Rest-in-rest, Sine curve (simple sinoide)

Rest-in-rest, inclined sine curve (Bestehorn sinoide)

Advantages

- Especially low jerk characteristic value
- Low oscillation, ideal for high speeds

Disadvantages

- Velocity characteristic value, acceleration characteristic value and
- dynamic torque characteristic value are higher than for the polynomial 5th order

$$f(z) = z - \frac{1}{2\pi}\sin(2\pi z)$$

Fig. 13-6: Function: Rest-in-rest, inclined sine curve (Bestehorn sinoide)

Motion Laws

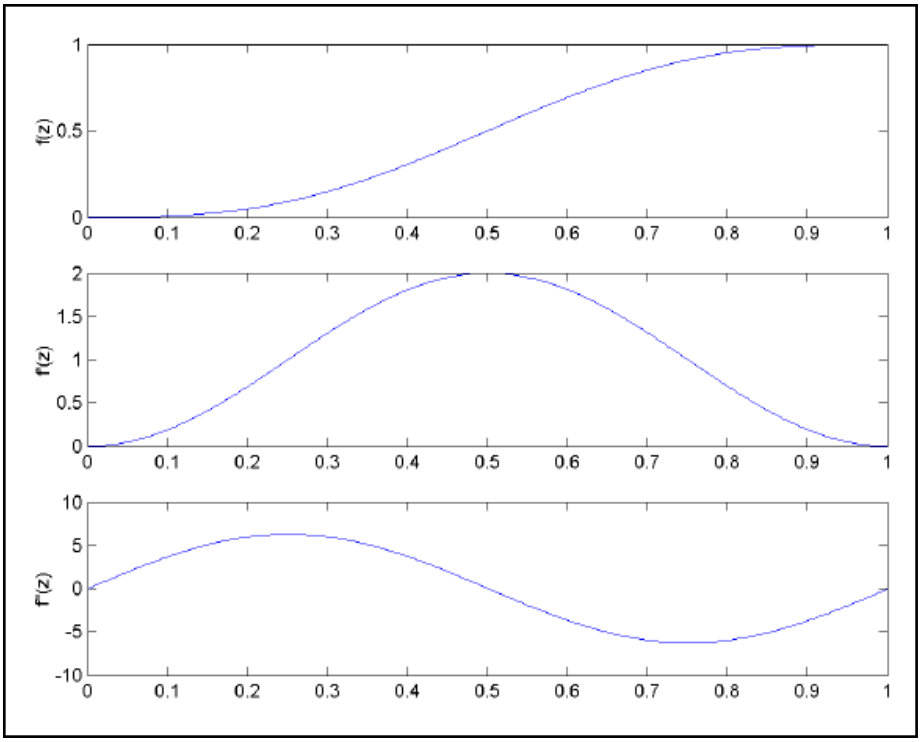

Fig.13-7: Graph: Rest-in-rest, inclined sine curve (Bestehorn sinoide)

Rest-in-rest, acceleration-optimum inclined sine curve

$$f(z) = z - \frac{1}{2\pi}\sin(2\pi z)$$

$$g(z) = z - \frac{0.41}{2\pi}\sin(2\pi z)$$

Fig.13-8: Function: Rest-in-rest, acceleration-optimum inclined sine curve

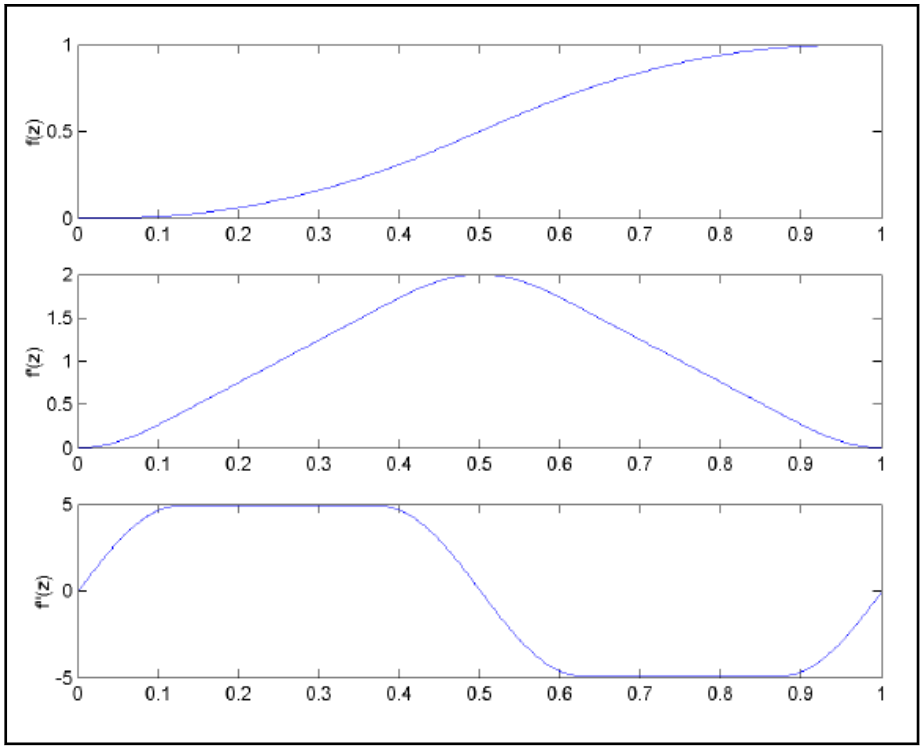

Fig. 13-9: Graph: Rest-in-rest, acceleration-optimum inclined sine curve

Rest-in-rest, moment-optimum inclined sine curve

$$f(z) = z - \frac{1}{2\pi}\sin(2\pi z)$$

$$g(z) = z - \frac{0.134}{2\pi}\sin(2\pi z)$$

Fig. 13-10: Function: Rest-in-rest, torque-optimum inclined sine curve

Motion Laws

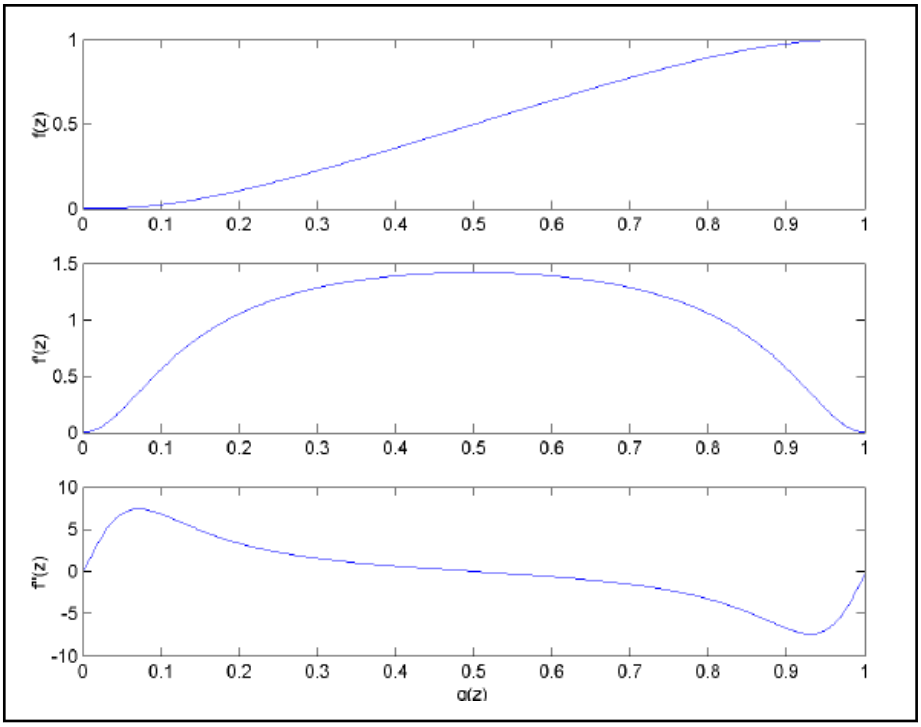

Fig.13-11: Graph: Rest-in-rest, torque-optimum inclined sine curve

Rest-in-rest, sinoide of Gutman

$$f(z) = z - \frac{15}{32\pi}\sin(2\pi z) - \frac{1}{96\pi}\sin(6\pi z)$$

Fig.13-12: Function: Rest-in-rest, Gutman sinoide

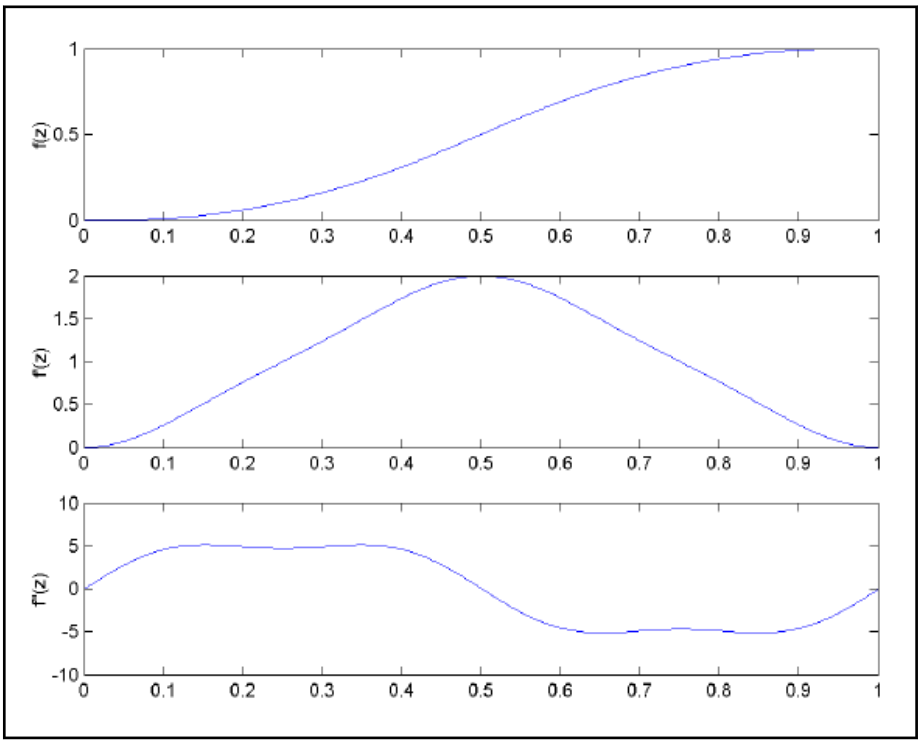

Fig.13-13: Graph: Rest-in-rest, Gutman sinoide

Rest-in-rest, modified sine curve

Advantages

- Ideal for high speeds
- Low velocity characteristic value
- Low acceleration characteristic value
- Low dynamic torque characteristic value

Disadvantages

- Jerk characteristic value higher than for the inclined sine curve

$$0 \le z \le \frac{1}{8}: f(z) = \frac{1}{4+\pi}\left[\pi z - \frac{1}{4}\sin(4\pi z)\right]$$

$$\frac{1}{8} \le z \le \frac{7}{8}: f(z) = \frac{1}{4+\pi}\left[2 + \pi z - \frac{4}{9}\sin\left(\frac{4\pi}{3}z + \frac{\pi}{3}\right)\right]$$

$$\frac{7}{8} \le z \le 1: f(z) = \frac{1}{4+\pi}\left[4 + \pi z - \frac{1}{4}\sin(4\pi z)\right]$$

Fig. 13-14: Function: Rest-in-rest, modified sinoide

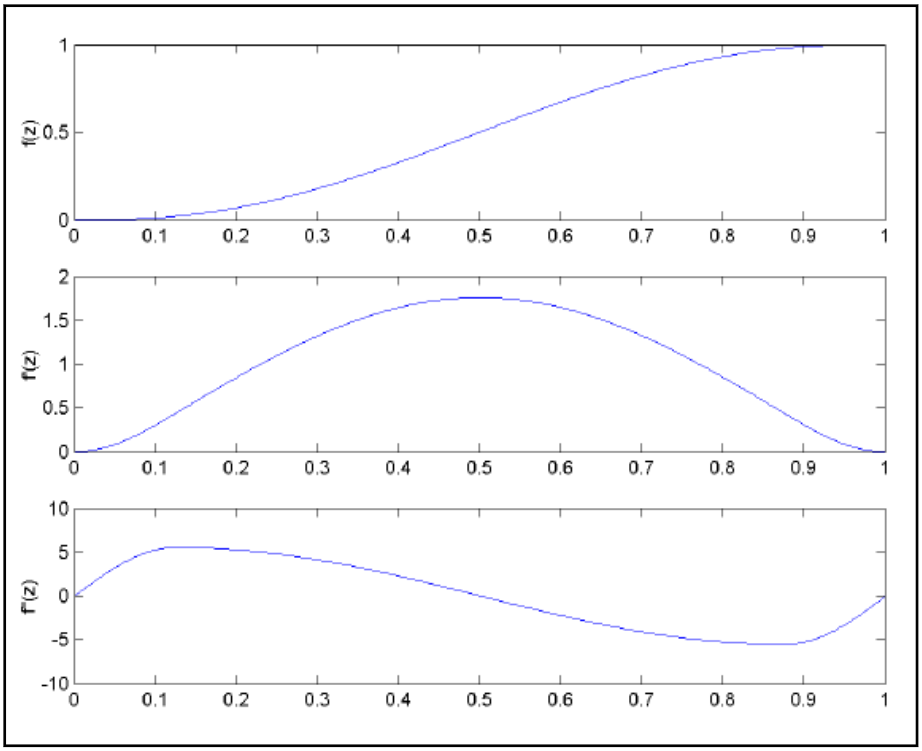

Fig. 13-15: Graph: Rest-in-rest, modified sinoide

Rest-in-rest, modified acceleration trapezoid

Advantages

- Especially low acceleration characteristic value
- Low inertia forces

Disadvantages

- Jerk characteristic value higher than for the inclined sine curve

Motion Laws

$$0 \le z \le \frac{1}{8}: f(z) = \frac{1}{2+\pi}\left[2z - \frac{1}{2\pi}\sin(4\pi z)\right]$$
$$\frac{1}{8} \le z \le \frac{3}{8}: f(z) = \frac{1}{2+\pi}\left[-\frac{1}{2\pi} + 2z + 4\pi\left(z + \frac{1}{8}\right)^2\right]$$
$$\frac{3}{8} \le z \le \frac{1}{2}: f(z) = \frac{1}{2+\pi}\left[-\frac{\pi}{2} + 2(1+\pi)z - \frac{1}{2\pi}\sin(4\pi z - \pi)\right]$$
$$\frac{1}{2} \le z \le 1: f(z) = 1 - f(1-z)$$

Fig.13-16: Function: Rest-in-rest, modified acceleration trapezoid

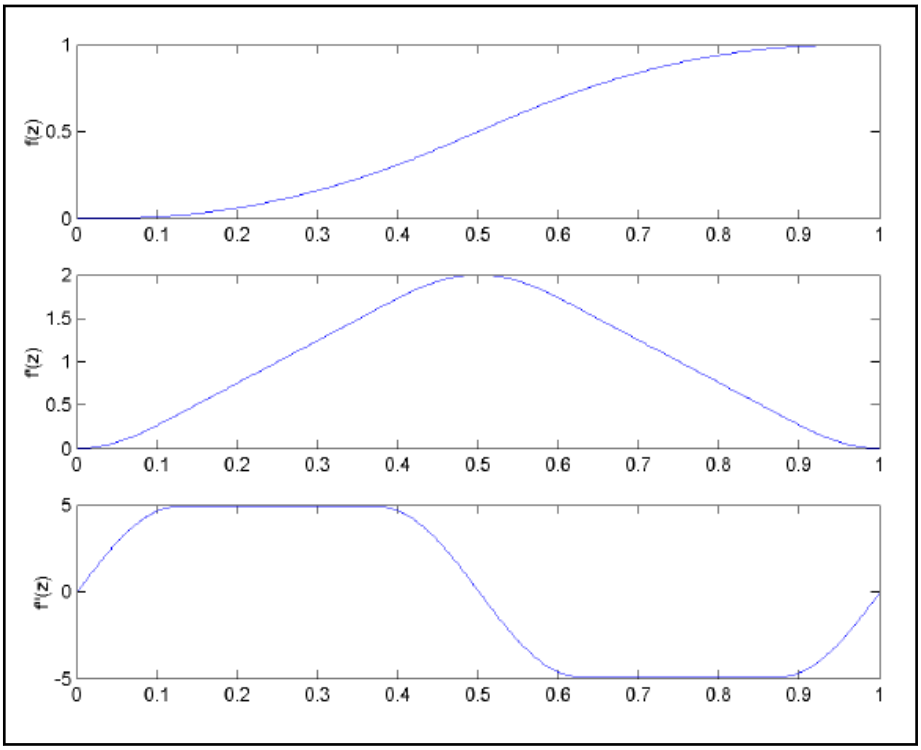

Fig.13-17: Graph: Rest-in-rest, modified acceleration trapezoid

Rest-in-rest, quadratic parabola

$$0 \le z \le 0.5: f(z) = 2z^2$$
$$0 \le z \le 0.5: f(z) = 1 - 2(z-1)^2$$

Fig.13-18: Function: Rest-in-rest, quadratic parabola

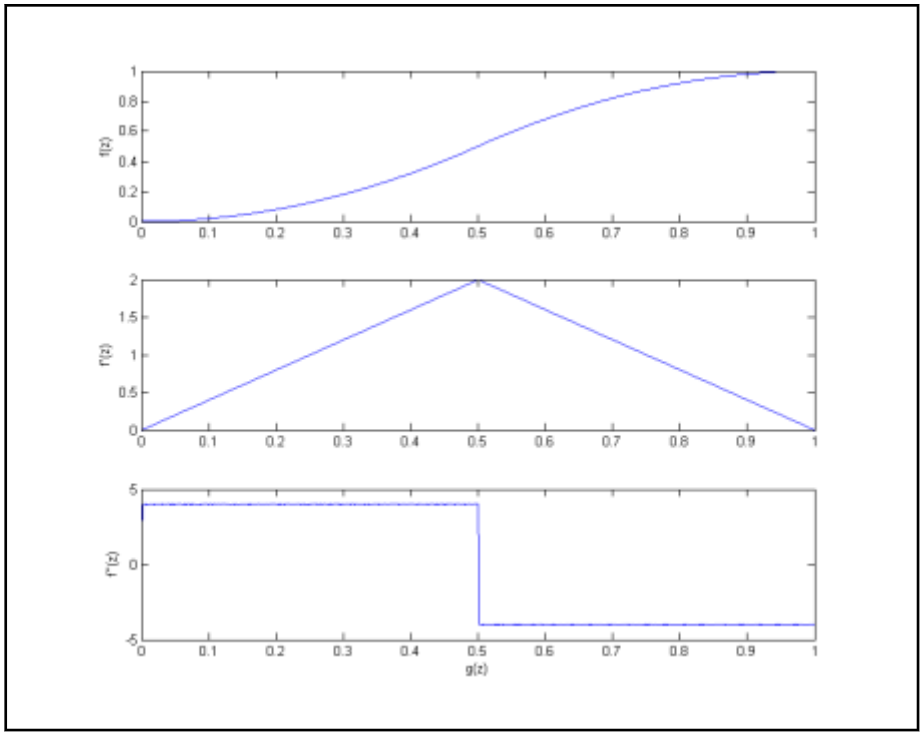

Fig. 13-19: Graph: Rest-in-rest, quadratic parabola

Rest-in-rest, polynomial 5th order

Advantages

- Low velocity characteristic value
- Low acceleration characteristic value
- Low dynamic torque characteristic value
- Low forces and torques

Disadvantages

- Jerk characteristic value higher than for the inclined sine curve

$$f(z) = 6z^5 - 15z^4 + 10z^3$$

Fig. 13-20: Function: Rest-in-rest, polynomial 5th order

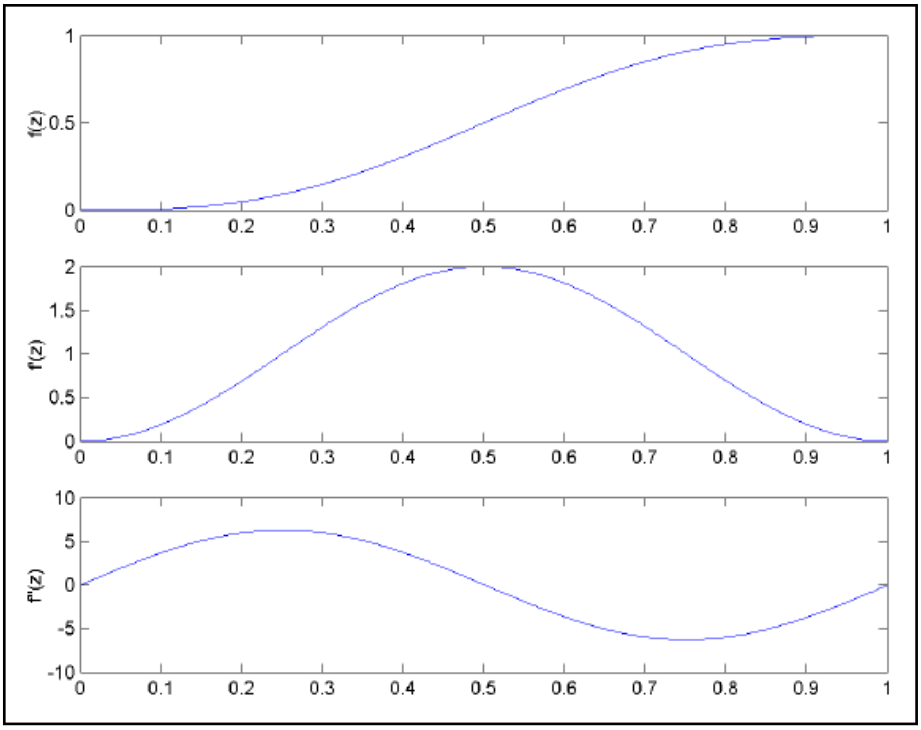

Fig.13-21: Graph: Rest-in-rest, polynomial 5th order

Rest-in-rest, polynomial 7th order

$$f(z) = -20z^7 + 70z^6 - 84z^5 - 35z^4$$

Fig.13-22: Function: Rest-in-rest, polynomial 7th order

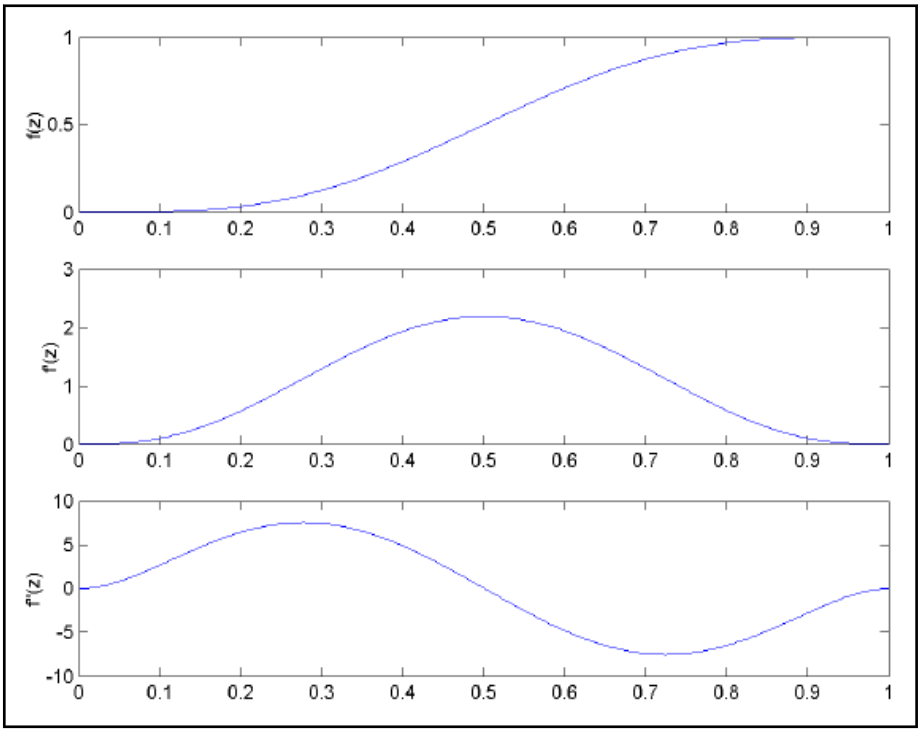

Fig.13-23: Graph: Rest-in-rest, polynomial 7th order

Rest-in-rest, polynomial 8th order

$$f(z) = A_8 z^8 + A_7 z^7 + A_6 z^6 + A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig. 13-24: Function: Rest-in-rest, polynomial 8th order

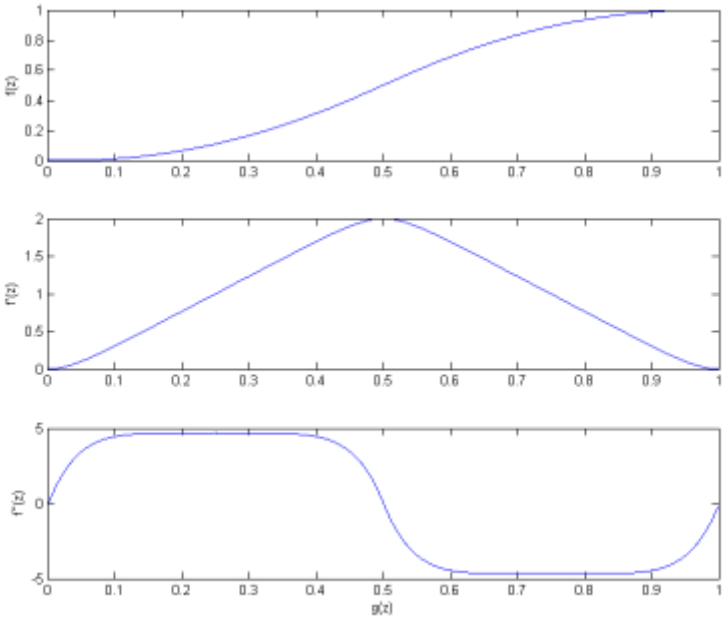

Fig. 13-25: Graph: Rest-in-rest, polynomial 8th order

13.2.3 Rest-in-Velocity

Rest-in-velocity motion laws are used for impact-free and jerk-free transition from standstill to defined velocities.

Rest-in-velocity, polynomial 5th order

$$f(z) = A_5 z^5 + A_4 z^4 + A_3 z^3$$

Fig. 13-26: Function: Rest-in-velocity, polynomial 5th order

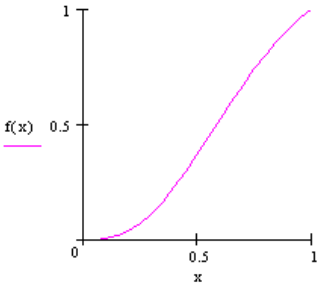

Fig. 13-27: Graph: Rest-in-velocity, polynomial 5th order

Rest-in-velocity, polynomial 7th order

$$f(z) = A_7 z^7 + A_6 z^6 + A_5 z^5 + A_4 z^4 + A_3 z^3$$

Fig.13-28: Function: Rest-in-velocity, polynomial 7th order

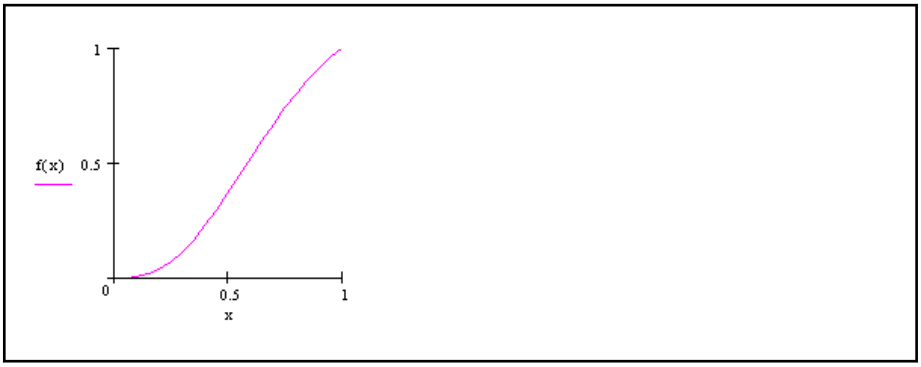

Fig.13-29: Graph: Rest-in-velocity, polynomial 7th order

13.2.4 Velocity-in-Rest

Velocity-in-rest motion laws are used for impact-free and jerk-free transition from defined velocities to standstill.

Velocity-in-rest, polynomial 5th order

$$f(z) = A_5 z^5 + A_4 z^4 + A_3 z^3 + A_1 z$$

Fig.13-30: Function: Velocity-in-rest, polynomial 5th order

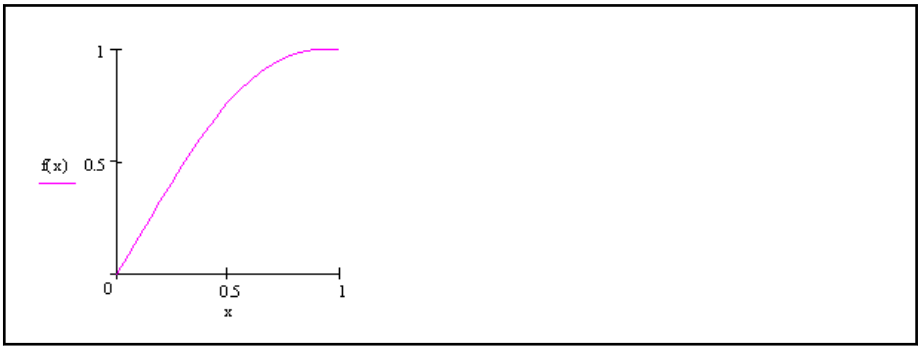

Fig.13-31: Graph: Velocity-in-rest, polynomial 5th order

Velocity-in-rest, polynomial 7th order

$$f(z) = A_7 z^7 + A_6 z^6 + A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-32: Function: Velocity-in-rest, polynomial 7th order

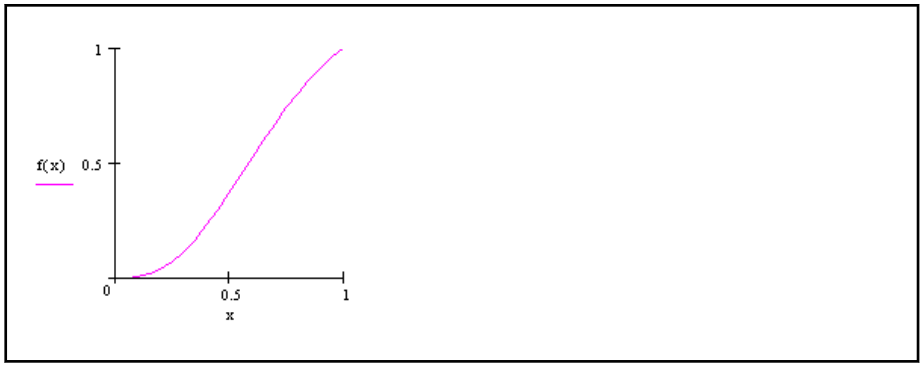

Fig. 13-33: Graph: Velocity-in-rest, polynomial 7th order

13.2.5 Velocity-in-Velocity

Velocity-in-velocity motion laws are used for impact and jerk-free transition from defined velocities to other defined velocities.

Velocity-in-velocity, constant velocity

(up to CamBuilder 08VRS: Analytic G-G / linear interpolation)

The velocity is calculated using the specified distance and the given master axis range. Specify a constant velocity in the motion law "Extended, linear velocity" (see chapter "Resulting Distance" on page 110).

$$f(z) = z$$

Fig. 13-34: Function: Velocity-in-velocity, Constant velocity

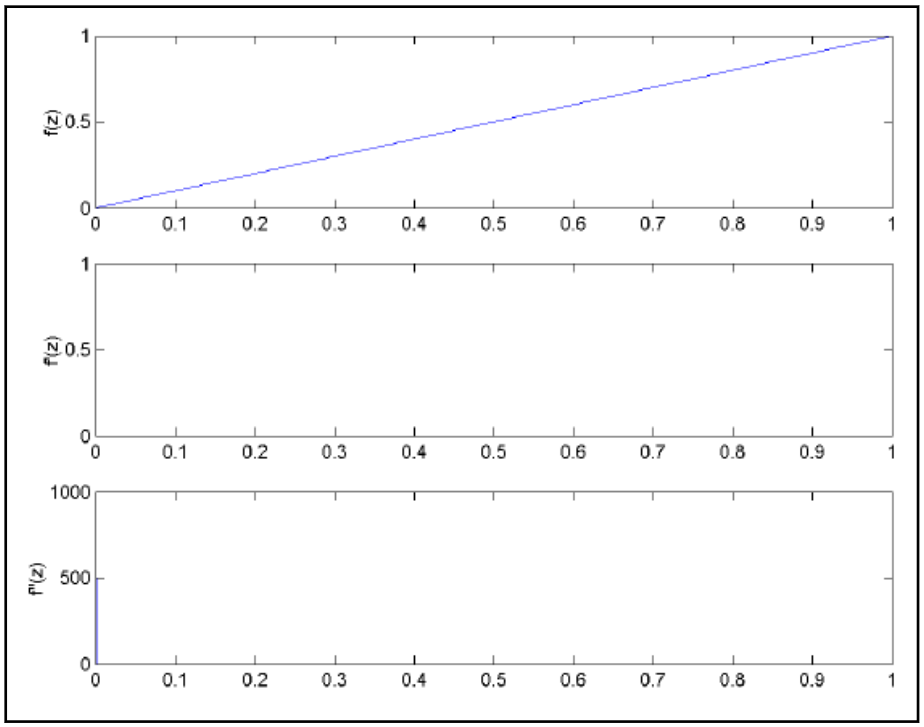

Fig. 13-35: Graph: Velocity-in-velocity, Constant velocity

Velocity-in-velocity, polynomial 5th order

Motion Laws

$$f(z) = A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-36: Function: Velocity-in-velocity, polynomial 5th order

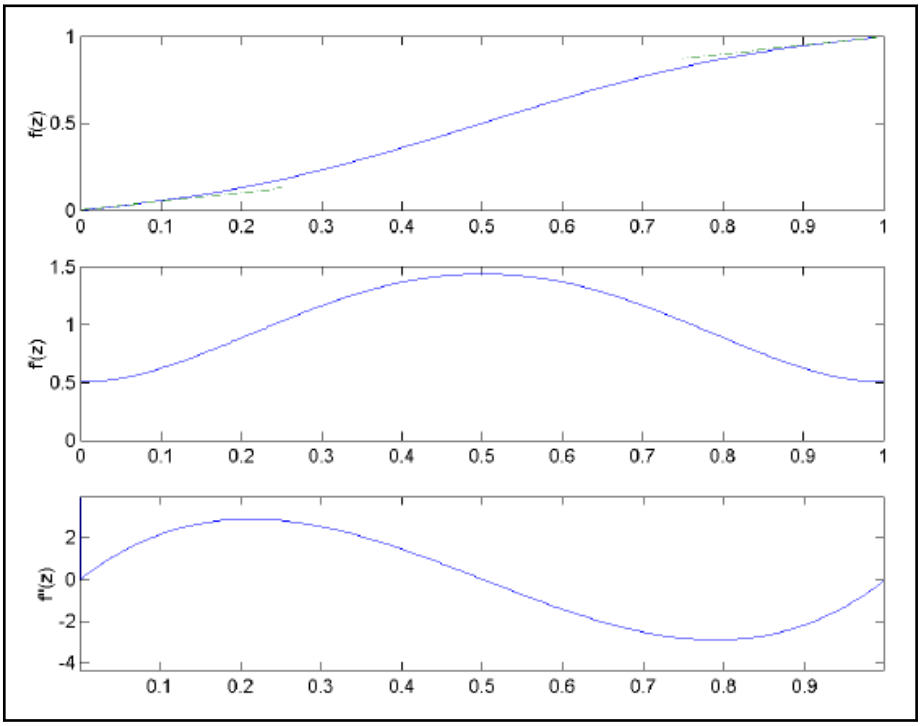

Fig.13-37: Graph: Velocity-in-velocity, polynomial 5th order

Velocity-in-velocity, polynomial 7th order

$$f(z) = A_7 z^7 + A_6 z^6 + A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-38: Function: Velocity-in-velocity, polynomial 7th order

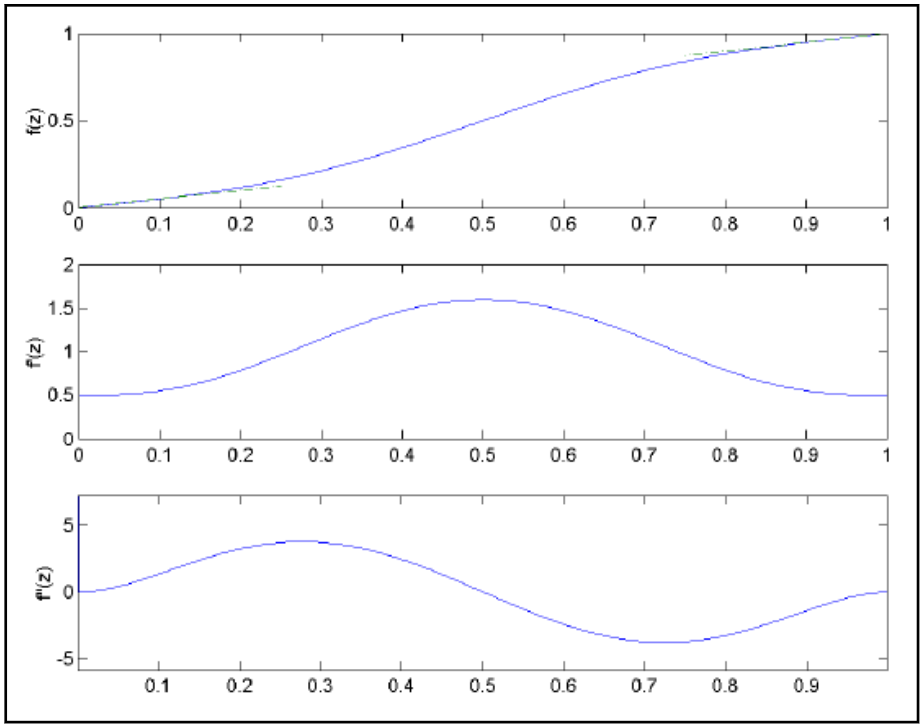

Fig.13-39: Graph: Velocity-in-velocity, polynomial 7th order

Velocity-in-velocity, modified sine curve

$$0 \le z \le \frac{\lambda}{8} : f'(z) = C_a \frac{\lambda}{2\pi}\left(z - \frac{\lambda}{2\pi}\sin\left(2\pi\frac{z}{\lambda}\right)\right) + f'(0)z$$

$$\frac{\lambda}{8} \le z \le \lambda : f'(z) = C_a \frac{\lambda}{2\pi}\left(z - \frac{9\lambda}{2\pi}\sin\left(2\pi\frac{z+\frac{\lambda}{2}}{3\lambda}\right) + \frac{4\lambda}{\pi}\right) + f'(0)z$$

$$\lambda \le z \le 1 - \frac{1-\lambda}{4} : f'(z) = C_b \frac{1-\lambda}{2\pi}\left(z - \frac{9(1-\lambda)}{2\pi}\sin\left(2\pi\frac{z+\frac{3-5\lambda}{3(1-\lambda)}}{3\lambda}\right) + \frac{4\lambda}{\pi}\right)$$

$$+ f'(1) + \left(f'(0) - + f'(1)\right)\left(\frac{3}{4} - \frac{1}{\pi}\right) + \lambda$$

$$1 - \frac{1-\lambda}{4} \le z \le 1 : f'(z) = -C_b \frac{1-\lambda}{2\pi}\left(z - \frac{1-\lambda}{2\pi}\sin\left(2\pi\frac{z+\lambda}{1-\lambda}\right) - 1\right)$$

$$+1 + f'(1) + (z-1)$$

Fig.13-40: Function: Velocity-in-velocity, modified sine curve

13.2.6 General Motion

Motion laws for general motion can always be used.

General motion, polynomial 2nd order

$$f(z) = A_2 z^2 + A_1 z$$

Fig.13-41: Function: General motion, polynomial 2nd order

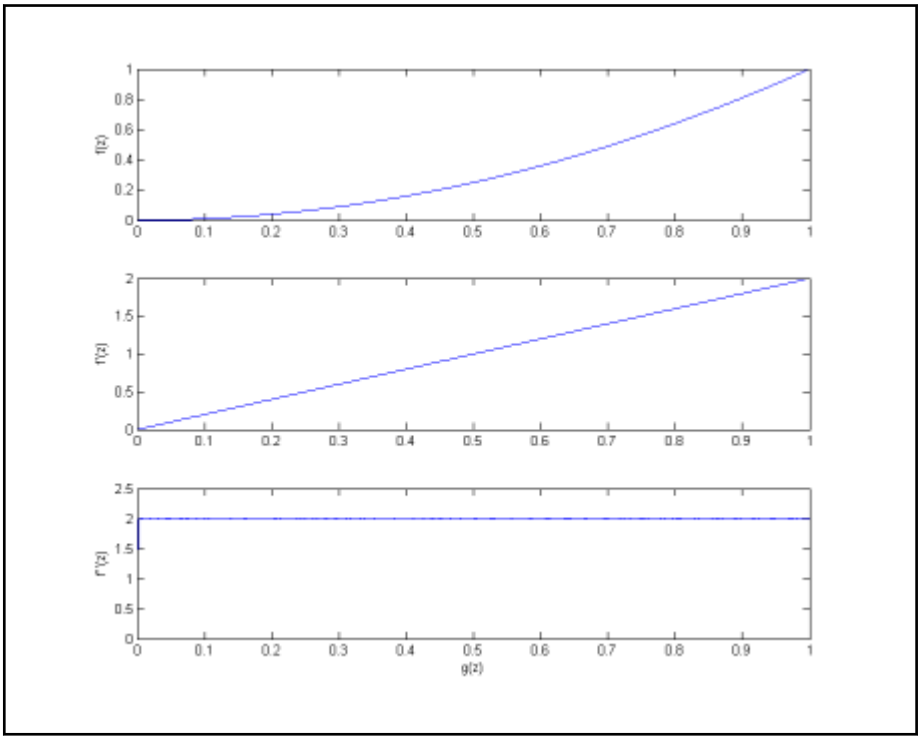

Fig.13-42: Graph: General motion, polynomial 2nd order

General motion, polynomial 3rd order

$$f(z) = A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-43: Function: General motion, polynomial 3rd order

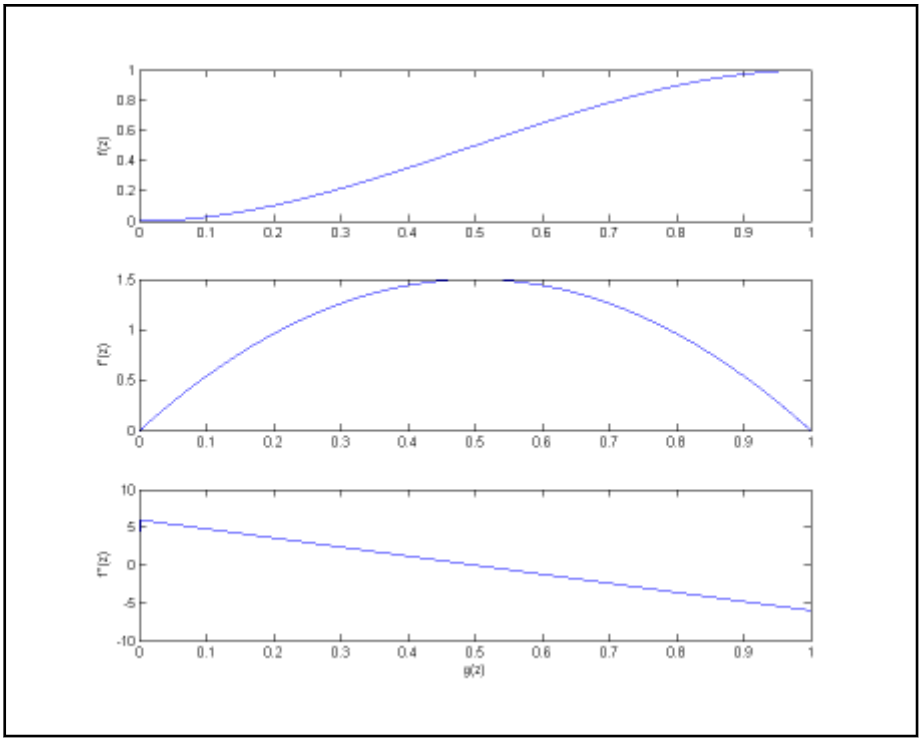

Fig.13-44: Graph: General motion, polynomial 3rd order

General motion, polynomial 4th order

(Special case with turning point displacement 0.57735 up to CamBuilder 08VRS: Polynomial 4th order (S))

$$f(z) = A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-45: Function: General motion, polynomial 4th order

Motion Laws

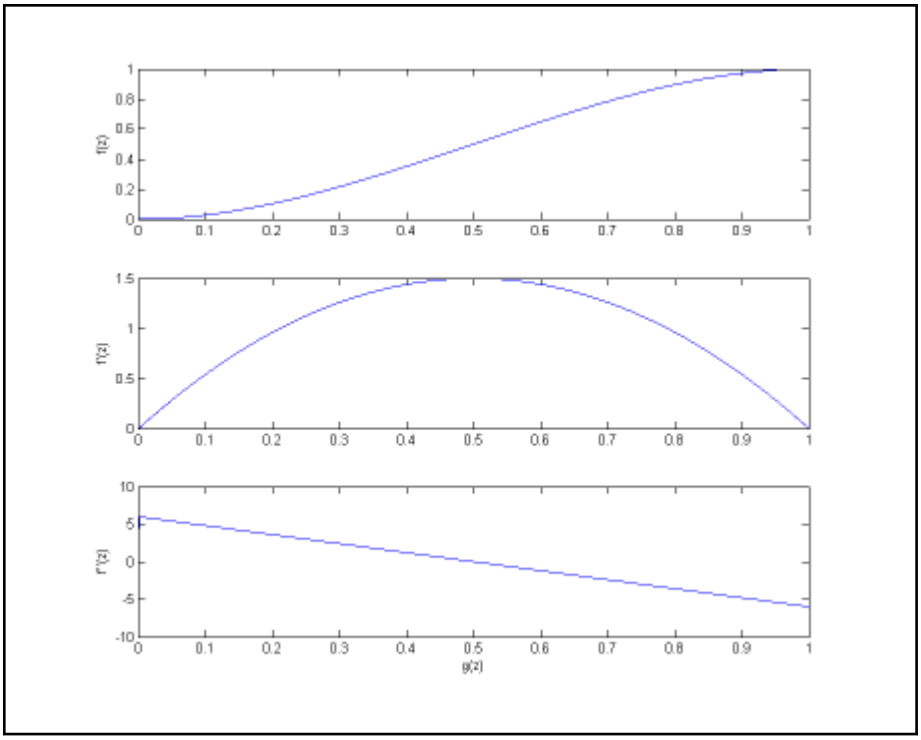

Fig.13-46: Graph: General motion, polynomial 4th order

General motion, polynomial 5th order

$$f(z) = A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-47: Function: General motion, polynomial 5th order

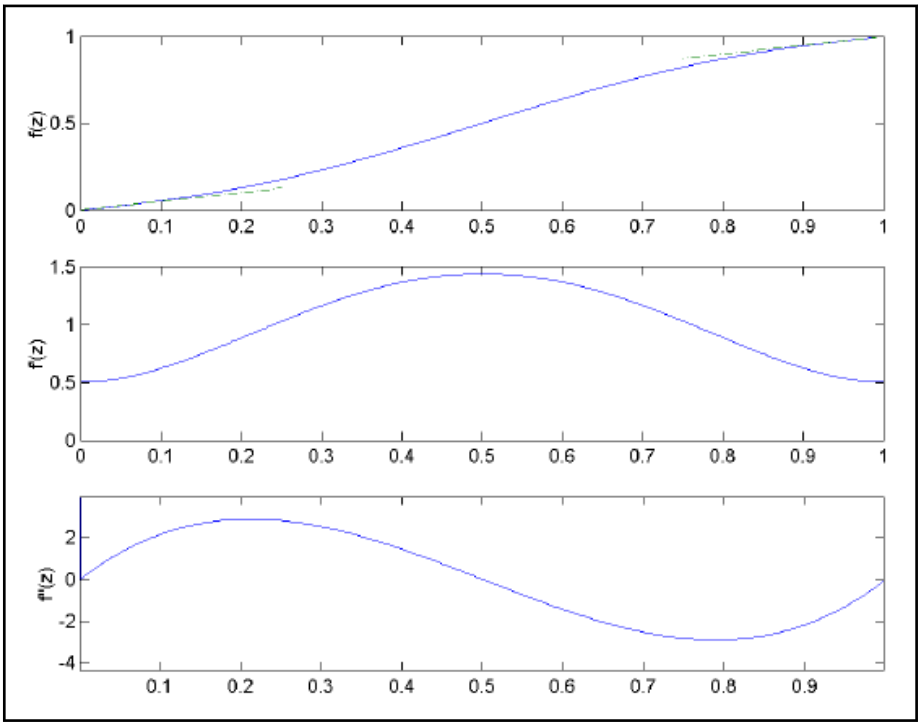

Fig.13-48: Graph: General motion, polynomial 5th order

General motion, polynomial 7th order

$$f(z) = A_7 z^7 + A_6 z^6 + A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig. 13-49: Function: General motion, polynomial 7th order

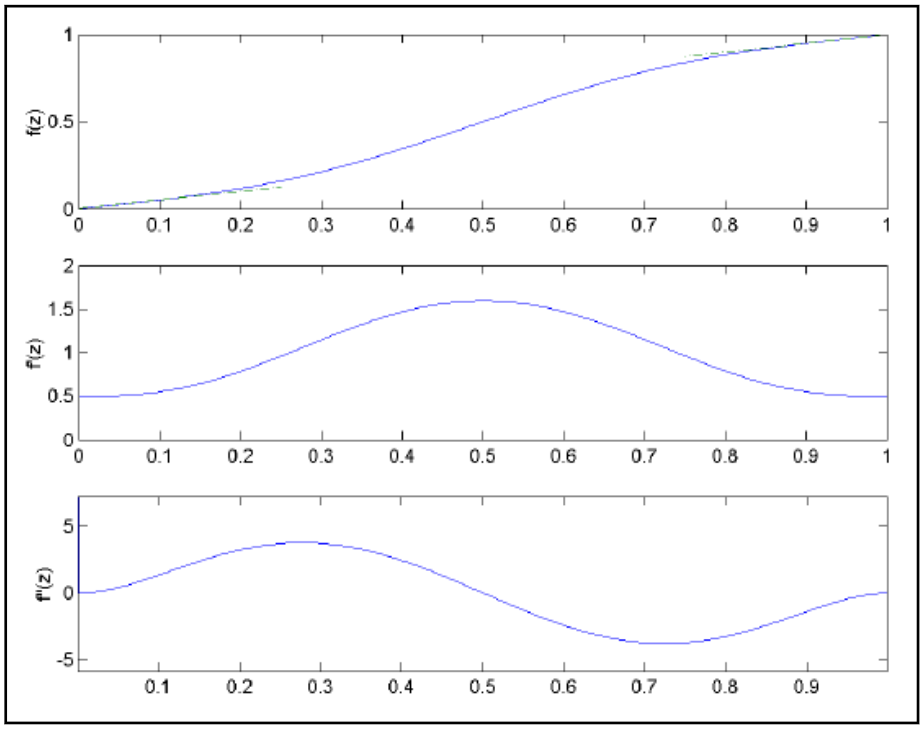

Fig. 13-50: Graph: General motion, polynomial 7th order

General motion, polynomial 8th order

$$f(z) = A_8 z^8 + A_7 z^7 + A_6 z^6 + A_5 z^5 + A_4 z^4 + A_3 z^3 + A_2 z^2 + A_1 z$$

Fig. 13-51: Function: General motion, polynomial 8th order

Motion Laws

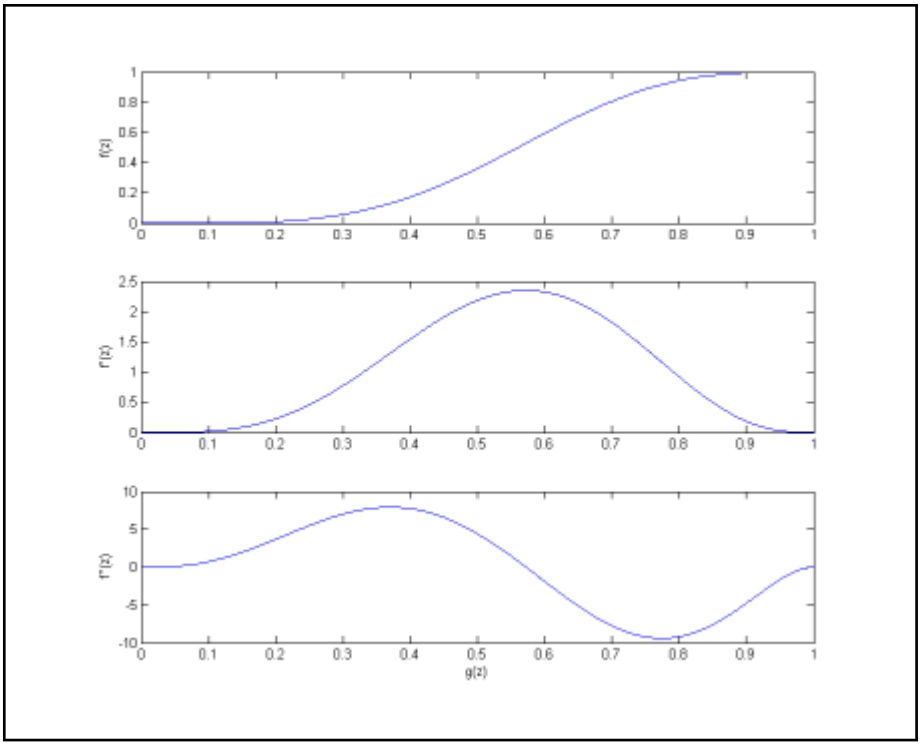

Fig.13-52: Graph: General motion, polynomial 8th order

13.2.7 Extended Motion Laws

Resulting Distance

Extended, linear velocity

(up to CamBuilder 08VRS: V-CAM linear)

$$f(z) = A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-53: Function: Extended, linear velocity

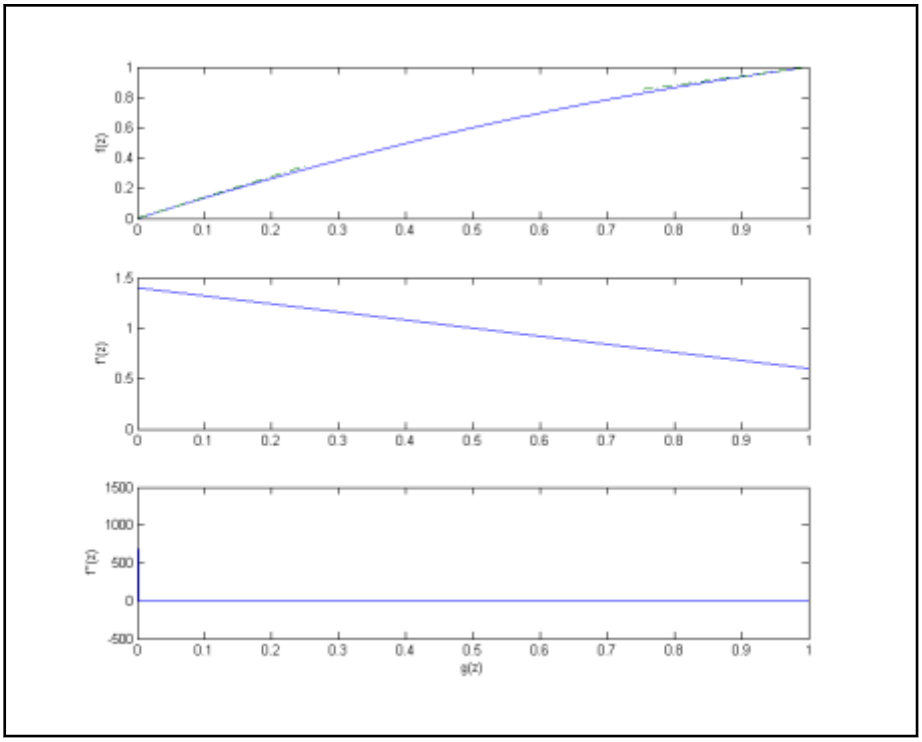

Fig.13-54: Graph: Extended, linear velocity

Extended, linear acceleration

(up to CamBuilder 08VRS: A-CAM linear)

$$f(z) = A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-55: Function: Extended, linear acceleration

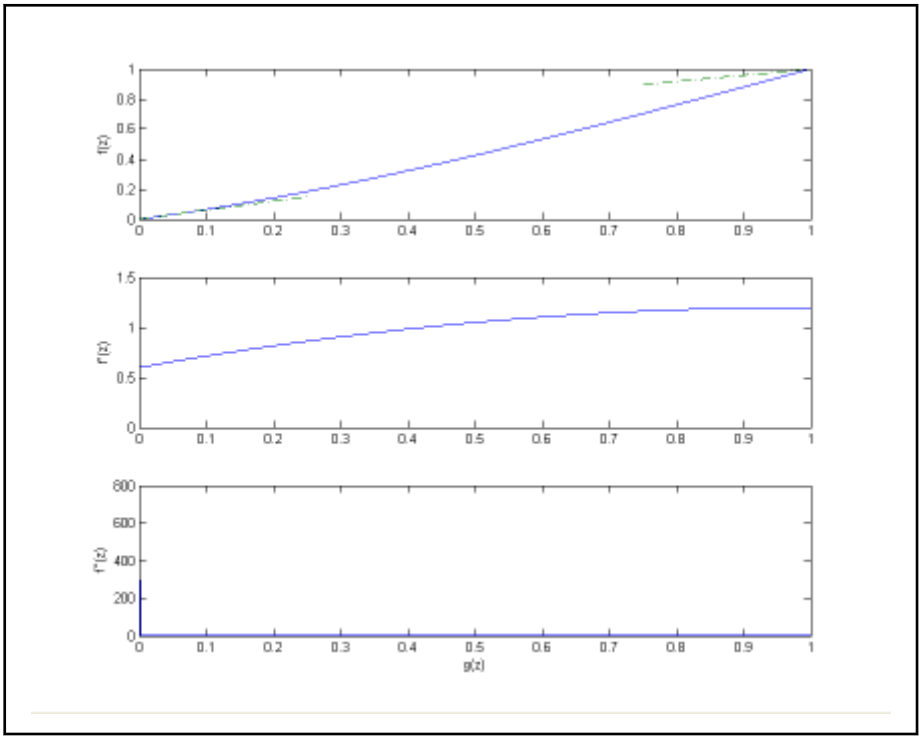

Fig.13-56: Graph: Extended, linear acceleration

Motion Laws

Extended, velocity 2nd order (starting acc. zero)

(up to CamBuilder 08VRS: V-CAM 2nd order (1)

$$f(z) = A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-57: Function: Extended, velocity 2nd order (starting acc. zero)

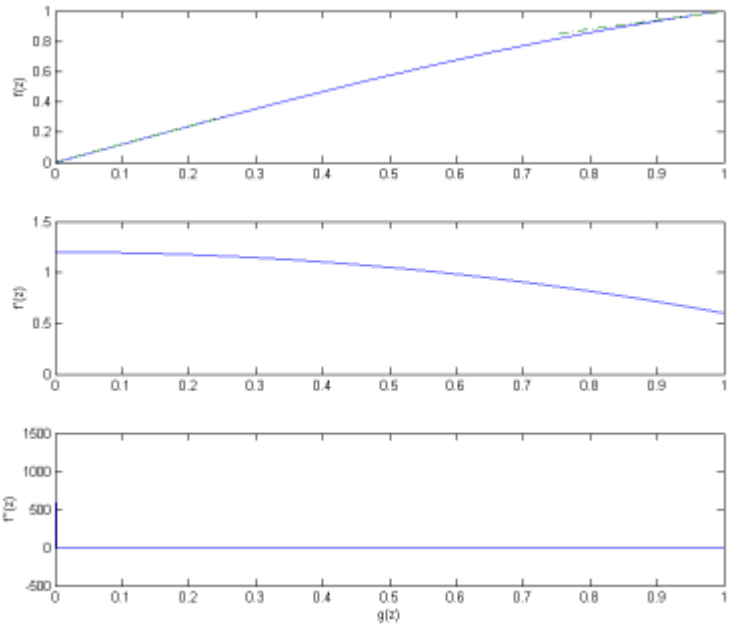

Fig.13-58: Graph: Extended, velocity 2nd order (starting acc. zero)

Extended, velocity 2nd order (end acc. zero)

(up to CamBuilder 08VRS: V-CAM 2nd order (2)

$$f(z) = A_3 z^3 + A_2 z^2 + A_1 z$$

Fig.13-59: Function: Extended, velocity 2nd order (end acc. zero)

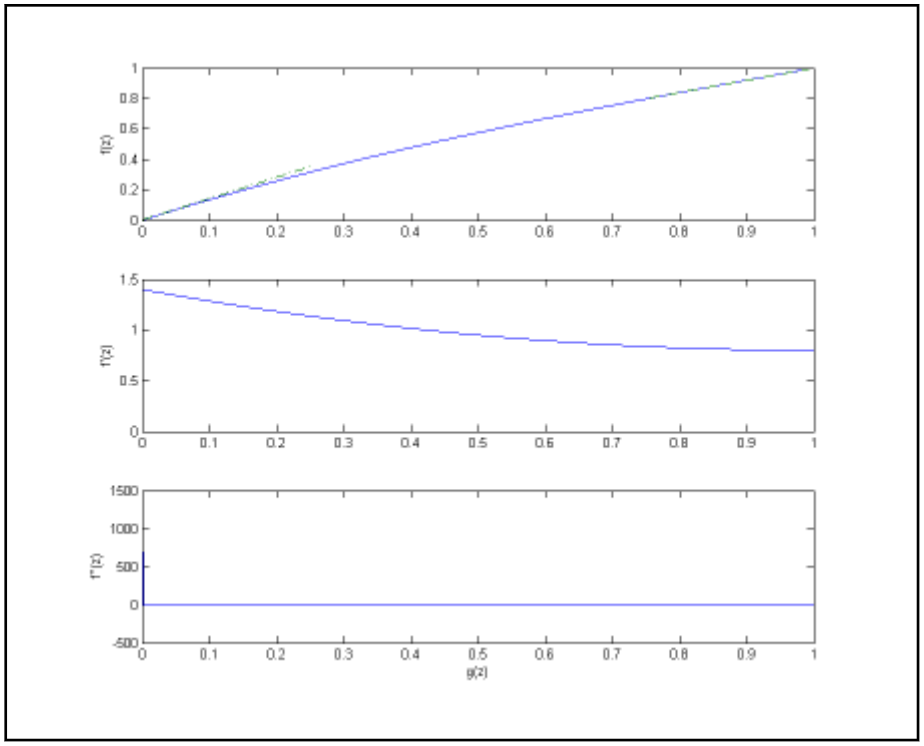

Fig. 13-60: Graph: Extended, velocity 2nd order (end acc. zero)

Extended, Resulting Master Axis Range

These extended motion laws are special motion laws. They differ from the known motion laws from the VDI guidelines due to their new degrees of freedom. While a standard motion law is clearly defined by the details of its left-hand and right-hand limit values, the motion laws shown here enable even further different setting options such as a required maximum velocity. In this case, the master axis range of the motion step is not to be specified. Instead, this results from the parameterization of the motion law and the specification of characteristic values. Thus, for example, acceleration-limited motion allows the distance, starting and end velocity to be specified, but not the setting of a master axis range. The latter, and thus also the duration of the motion step, results from the maximum acceleration and maximum velocity values, which can also be specified.

Extended, acceleration-limited motion (trapezoid profile)

The trapezoid profile, often also known as a ramp profile, can be seen as the simplest form of path interpolation. If a path "s" should be traveled, it is accelerated up to a specified travel velocity in the first phase (acceleration phase) using a given acceleration value. In the second phase (constant phase), it is traveled with a constant velocity and finally, in the third phase (deceleration phase), it is decelerated with a predetermined delay. The role of path interpolation is to calculate the starting and end time points t1, t2 and t3 and the individual runtimes T1, T2 and T3 from the preset acceleration values a1 and a3 and the required velocity vm and the distance to be traveled "s". In the variant shown, the required starting velocity v0 and end velocity v3 is also taken into consideration.

Extended, acceleration-limited motion (sine curve)

With the sinoide profile, the starting and end velocity can be unequal to "0" and have the different acceleration factors a1 and a3 for the acceleration and deceleration phase. Moreover, the special cases are also taken into consideration, in which the starting velocity v0 is already greater than the required travel velocity vm. The same also applies to the end velocity v3.

Motion Laws

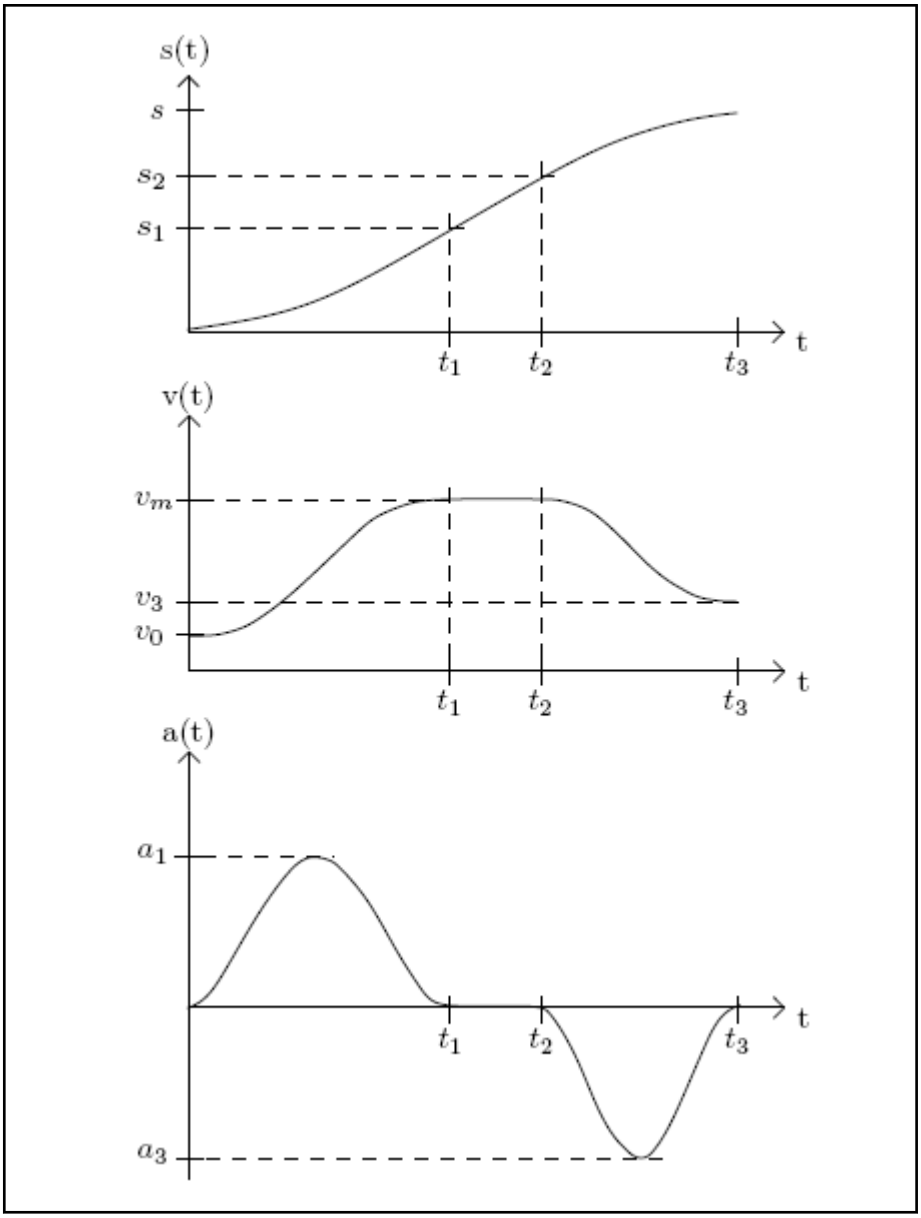

Fig.13-61: Graph: Acceleration-limited motion (sine curve)

Extended, jerk-limited motion (trapezoid profile)

The acceleration with jerk limitation applies to many motion tasks, for example, to the transportation of fluids and to machines easily susceptible to vibration.

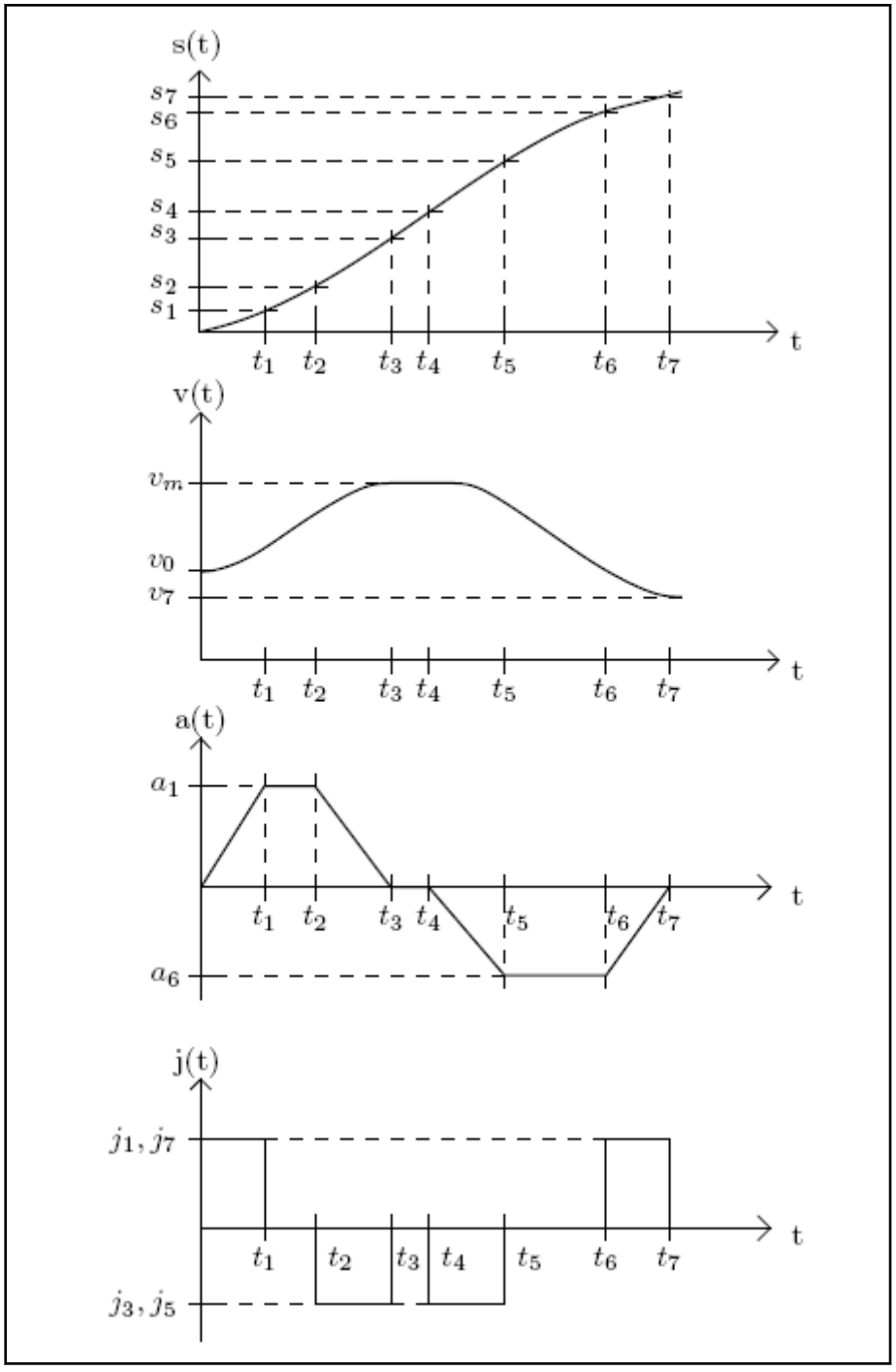

Fig. 13-62: Graph: Jerk-limited motion

Miscellaneous

Extended, velocity-limited polynomial 5th order

The polynomial 5th order, known from the VDI, allows no control of the maximum travel velocity. The motion law is subdivided into three sections to solve this problem. The middle section corresponds to a straight line with the required velocity. This is surrounded by two polynomials 5th order. This ensures a smooth transition from the starting to the travel velocity and from the travel to the end velocity. The intersecting points between the first and second and the second and third sections have to be determined. The points are selected in such a way that no turning point is set for the two polynomials.

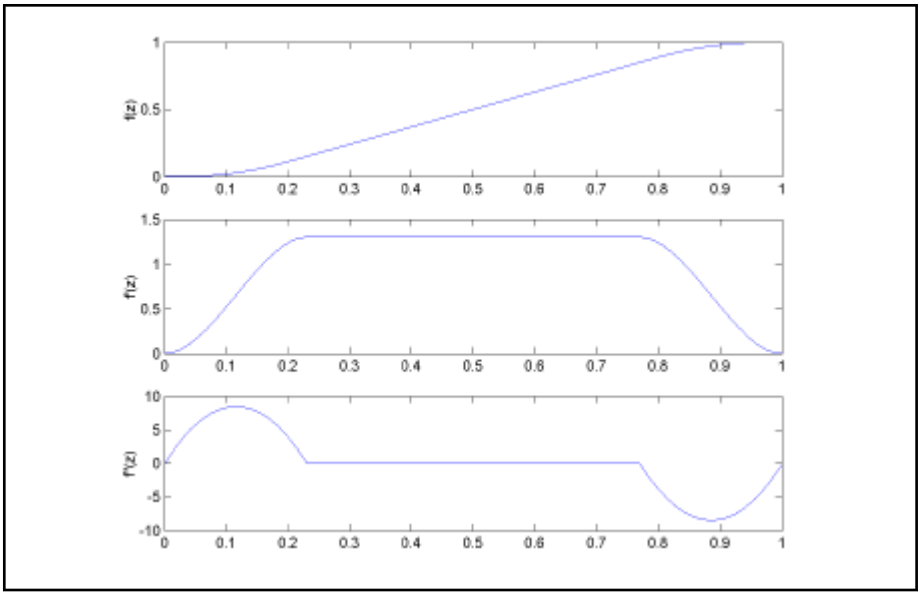

Fig.13-63: Graph: Velocity-limited polynomial 5th order

Extended, overshooting-free polynomial 5th order

The overshooting-free polynomial 5th order detects and prevents a possible polynomial overshoot. The kind of modification depends on the combination of the standardized boundary velocity values. Four cases result. This motion law cannot be used for combinations in which the normalized starting velocity V_1 and the normalized end velocity V_2 have different signs. This means that the motion path would have a bend at a limit point if it was not able to leave the standardized range of 0 <= z <=1 and 0 <=f(z) <= 1.

- Case 1:

  V_0<=1 and V_1<=1

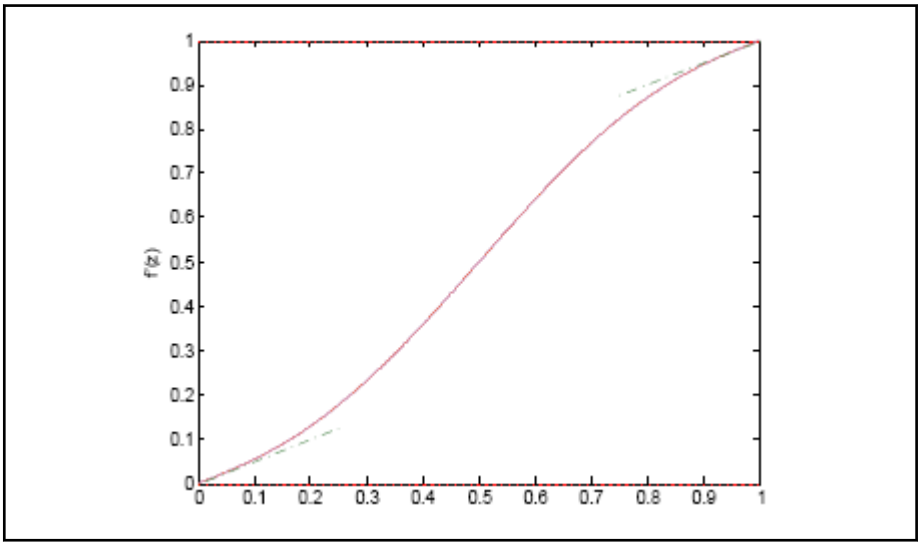

Fig.13-64: Case 1

- Case 2:

  V_0<=1 and V_1>1

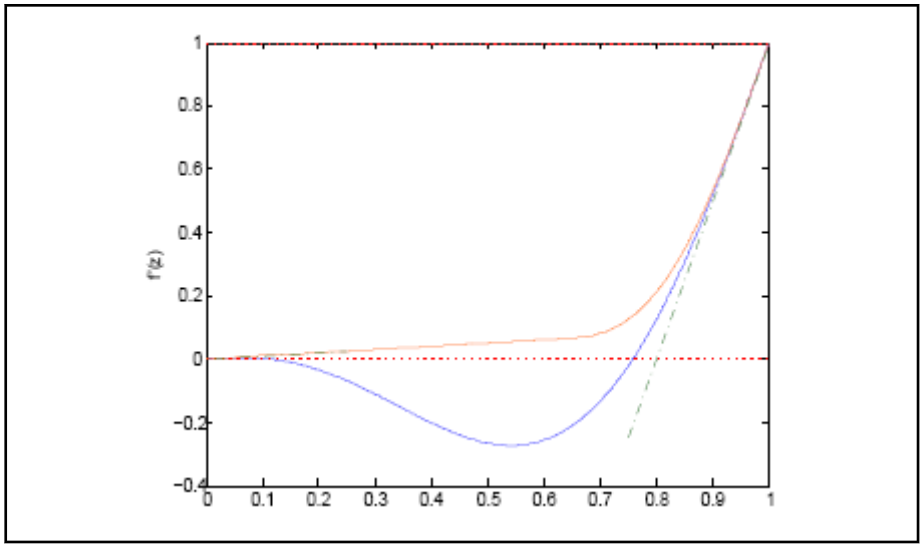

Fig. 13-65: Case 2

- Case 3:
  V_0>1 and V_1<=1

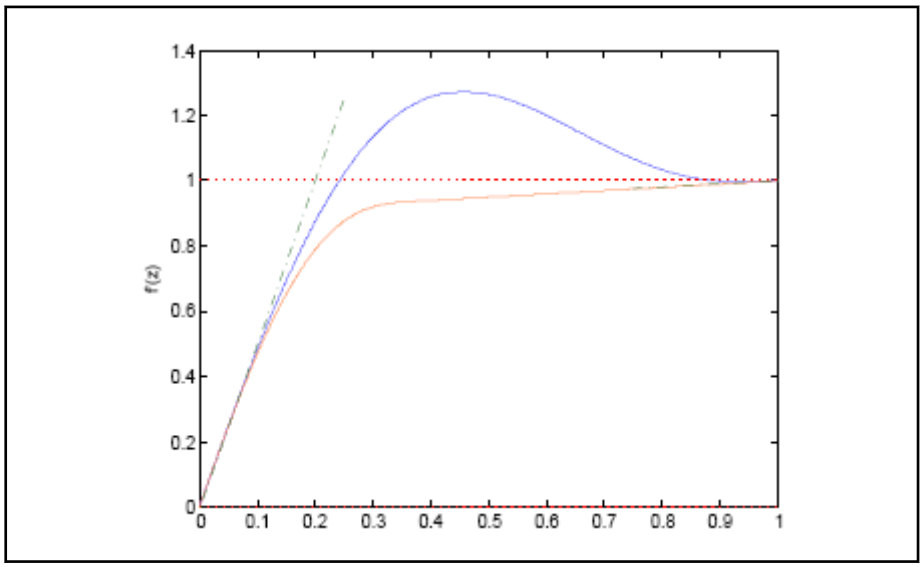

Fig. 13-66: Case 3

- Case 4:
  V_0>1 and V_1>1

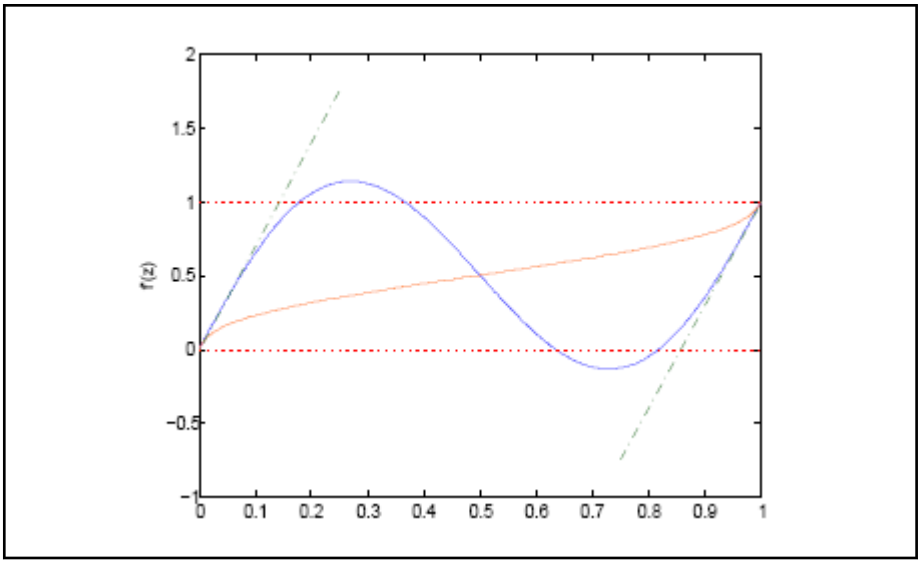

Fig. 13-67: Case 4

13.3 Cam Tables

The slave axis motion of a motion step can be defined by a cam table.

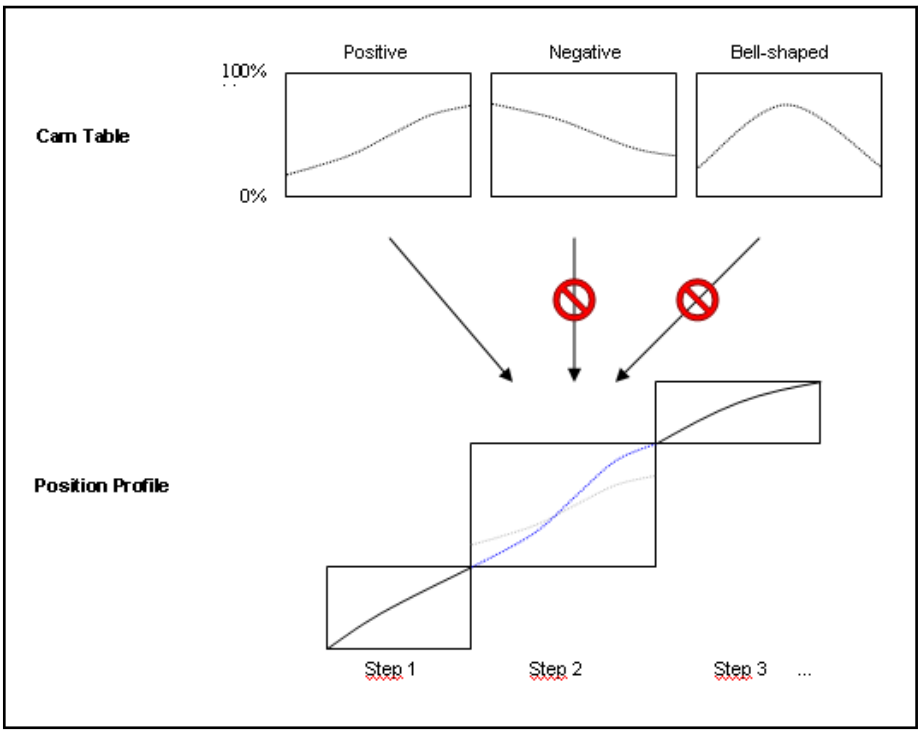

Fig. 13-68: Cam tables supported by the CamBuilder

To allocate a cam table to a motion step as a motion law using CamBuilder, the menu item **Cam Table ▸ Import Cam Table...** has to be selected as a motion law in the motion step editor or an existing imported table is selected. A new import dialog opens if a new table is to be imported.

There are three different options to select a cam table:

1. Importing a cam table from a cam of the current project

   All the cams of the current project can be listed and selected in a selection dialog

2. Importing a cam table from a parameter file
3. Importing a cam table from a CSV file

With cams from the project, it is possible to state how many data points have to be created (at least 3, at most 1,024.) Moreover, the distance to calculate the data points can be specified (if 0 is specified as distance factor, the CamBuilder automatically calculates a distance factor creating a point table with value 0% to 100%.) Following the import, a memory space number has to be defined for the subsequent memory location on a device for this selected cam table.

It is distinguished between cams consists of one and cams consisting of multiple motion steps when handling cam tables in the CamBuilder.

Cams consisting of one motion step:

All cam table forms are supported here, that is cam tables whose end value is greater or less than the starting value. Starting values not equal to 0 are also allowed, as are cam tables with the same starting and end point (e.g. bell). The response is as for the MotionProfile, that is that points from the cam table are simply multiplied by the distance (no offset, no scaling).

Cams consisting of multiple motion steps:

Cam tables whose end point s greater than the starting point are scaled in such a way that they end at 100%. A starting point, which is not equal to 0%, is offset to 0%. Thus, the entire cam table is automatically adapted to the distance preset for the respective motion step. Cam tables with the same or smaller end point than the starting point are not supported.

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- Detailed description of malfunction and circumstances resulting in the malfunction
- Type plate name of the affected products, in particular type codes and serial numbers
- Your contact data (phone and fax number as well as your email address)

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Notes

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