Rexroth Bosch Group

Rexroth IndraWorks 09VRS CamBuilder

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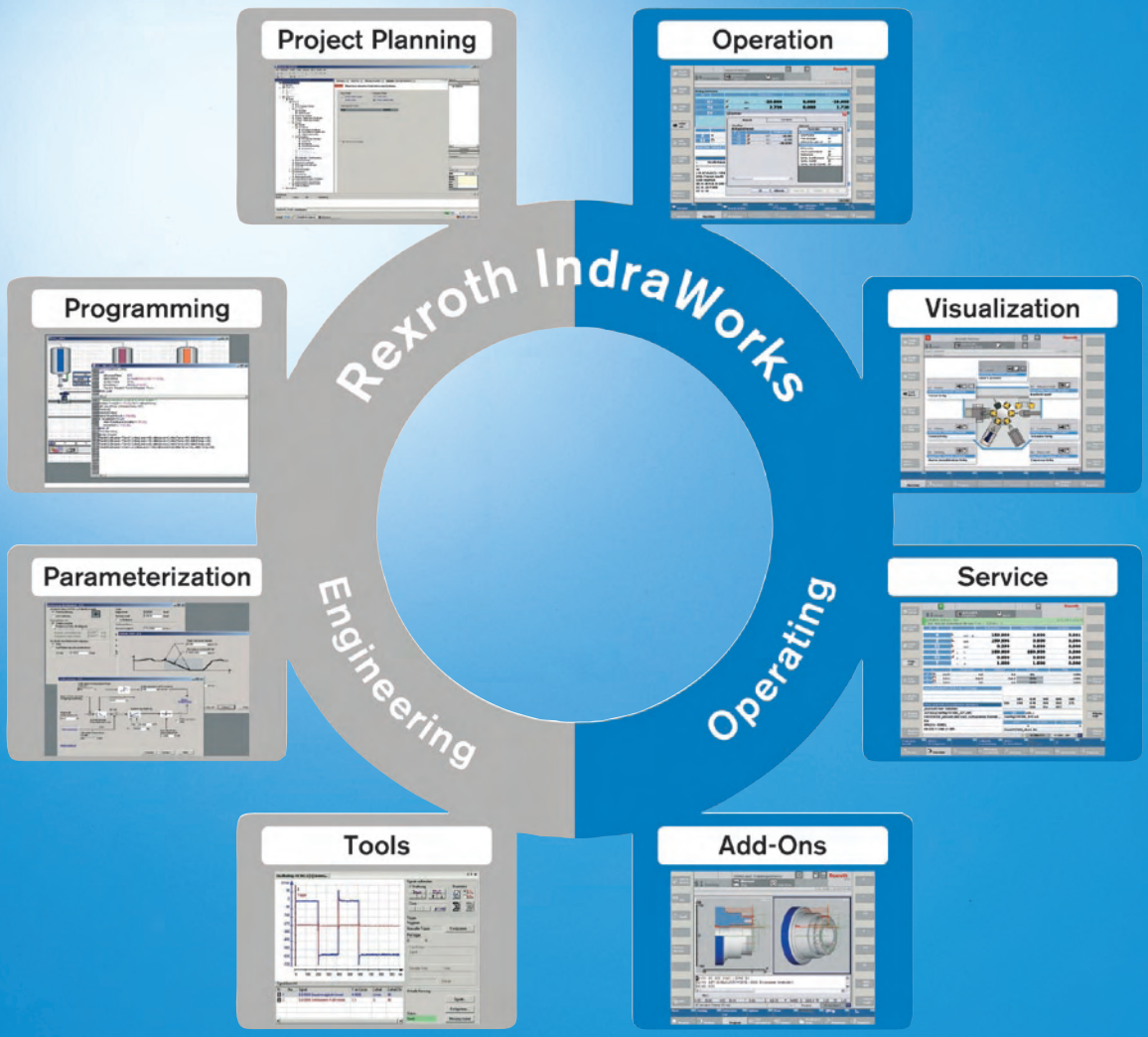
Edition 02

Functional Description



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

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1 Introduction

1.1 General

The CamBuilder is a tool integrated into the IndraWorks Engineering Desktop for the simple and convenient creation of electronic cams. The CamBuilder supports the direct downloading of cams into the Rexroth drive controller, with the result that this tool is specific and predestined for its requirements and special features.

1.2 Cams and Synchronization Modes

Electronic cams control the motion sequences of slave axes in relation to master axes.

The Rexroth driver controllers have different synchronization modes for performing cams.

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

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

FlexProfile The FlexProfile corresponds to an extension of the MotionProfile (the time can optionally be used as a reference variable for the slave axis; it has a larger choice of motion laws and an event controller).

The CamBuilder is a higher-level tool and, during creation and editing, does not differentiate between the various operating modes. Only if the user decides to download a cam onto a device does he have to specify the corresponding operating mode.

1.3 CamBuilder - Features

The essential features of the CamBuilder are as follows:

- Simple creation of cams using graphic tools
- Convenient editing of existing cams
- Open and edit multiple cams simultaneously
- Use of VDI 2143-compliant motion laws
- Upload and download cams into BRC drives and controllers
- Automatic display of position, acceleration, velocity and jerk
- Support for common requirements (application-specific cams, such as cross cutter) with wizards
- Import of cam tables as motion laws
- Automatic recognition and calculation of the limit conditions of the individual motion steps of the cam
- Zoom functions
- Import / Export functions in different formats (*.XML, *.PAR, *.CSV)

1.4 Definition of Terms

Cam

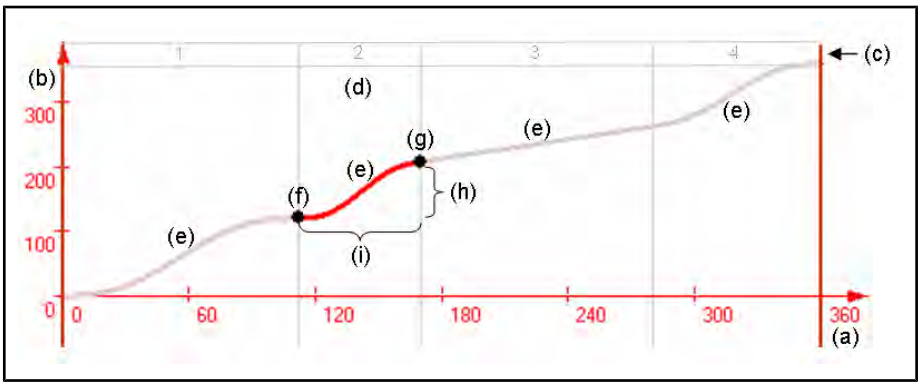

Fig.1-1: Diagram of a cam graph to provide a definition of terms

(a) **Master axis** (X-axis)

(b) **Slave axis** (Y-axis)

(c) **Motion steps** (1 – 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, either the time duration (ΔT) or the master axis range (ΔX).

A cam defines the position of a slave axis in relation to a master axis or in relation to the the time. A cam comprises one or more motion steps. Each motion step has a motion law that specifies the connection between the master axis or time and the slave axis. The individual motions of the steps together create a cam.

In the CamBuilder, the focused motion step of a cam is always edited. This can either take place via a graphic diagram or via numerical inputs. Depending on the editing mode and the type of change, the preceding or subsequent motion steps can also change.

From the second motion step on, all motion steps begin with the end point of the preceding step.

2 First Steps - CamBuilder

2.1 Preparation

Installation and starting

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

The CamBuilder starts automatically with the IndraWorks Engineering program if it is licensed.

Licensing

1. A full license key has to be purchased in order to work unrestrictedly with the CamBuilder.
2. The license overview opens via the **Tools** ▸ **Options** ▸ **General** ▸ **Software Licenses** menu.

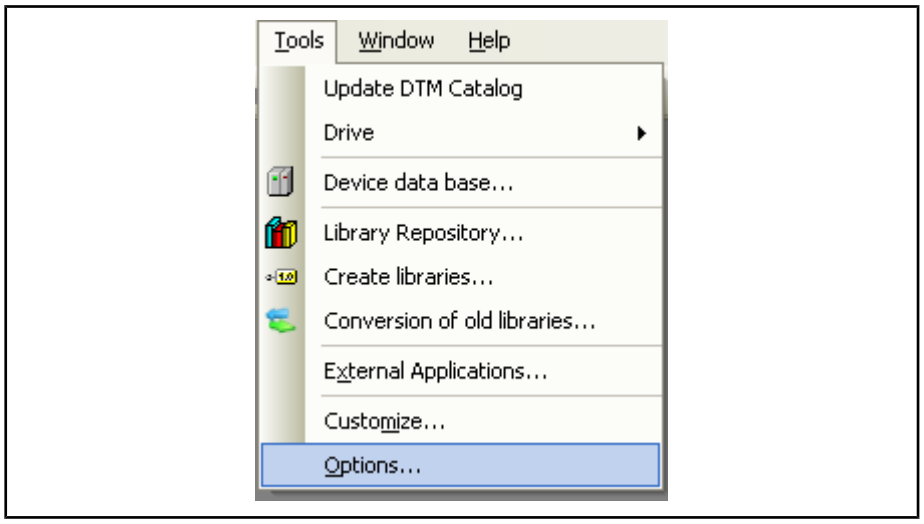

Fig.2-1: Tools menu

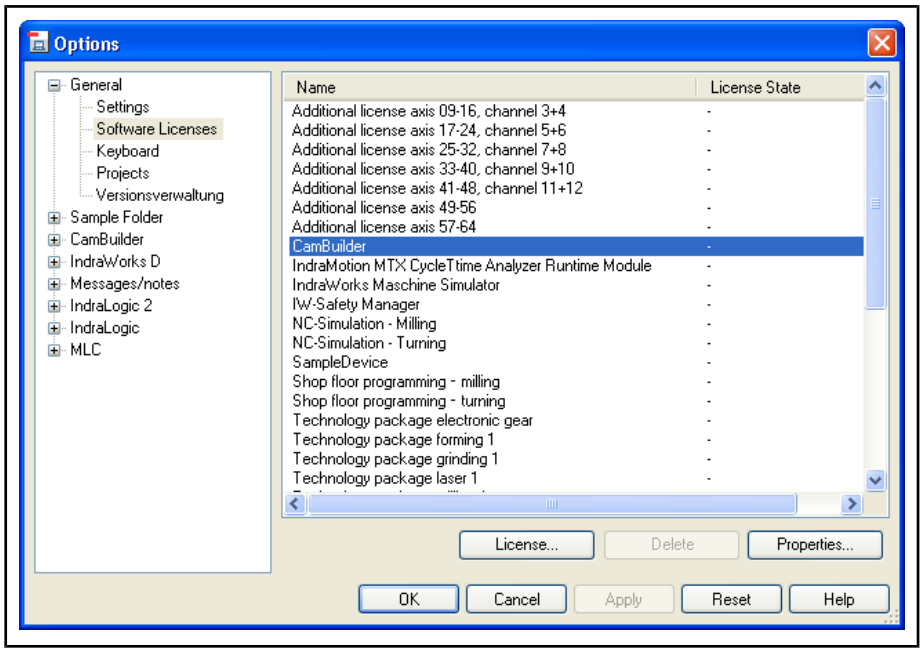

Fig.2-2: Options dialog

3. The CamBuilder license can be activated via the "License…" button.

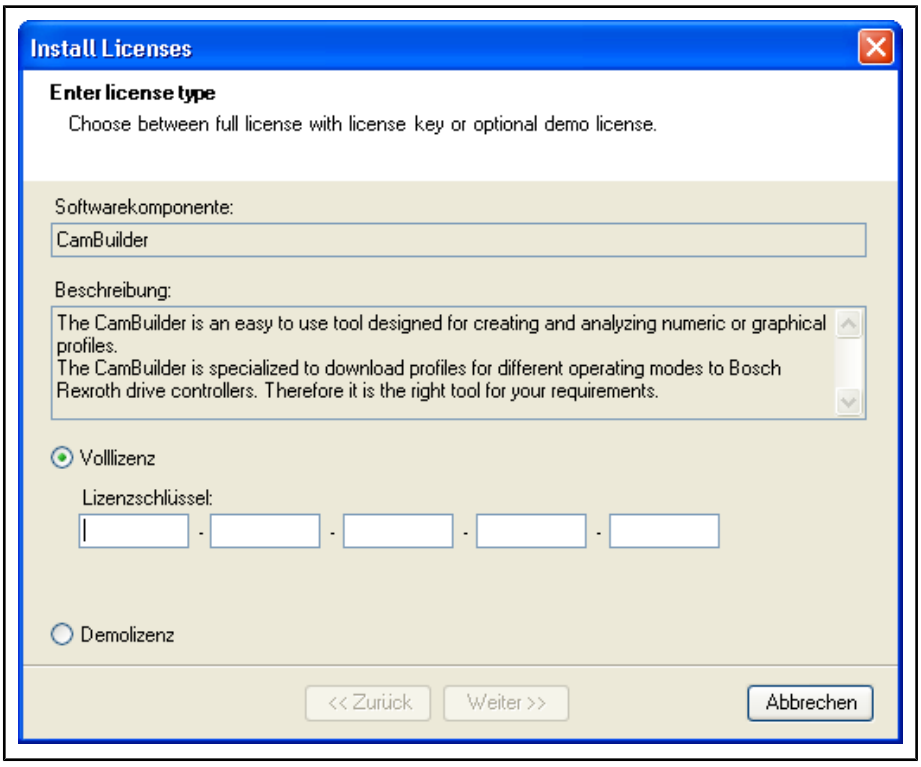

Fig.2-3: License dialog

A demo license valid for 30 days is available without an activation key. Once the 30 days have expired, the Cam Pool is deactivated in IndraWorks. The CamBuilder can be licensed to continue to use the cams created. Otherwise the Cam Pool can be deleted from existing projects.

Cam Pool

Once the CamBuilder is licensed, a "Cam Pool" node will be displayed in the Project Explorer. All the cams generated with the CamBuilder in the current project are managed in this.

A new cam can also be created via the Cam Pool node context menu.

2.2 Creating and Downloading Cams

This Chapter explains, by means of an example, how to create and download a cam consisting of 3 motion steps.

Task

The master and slave axis are rotational. The master axis rotates at a velocity of 100 rotations per minute.

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

The cam created is then downloaded onto an MLC controller.

Procedure

1. Creating the cam

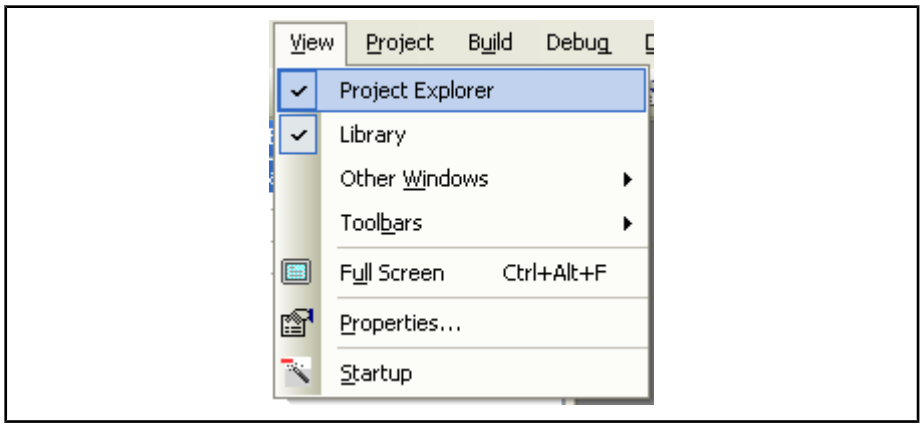

Fig.2-4: View menu

The Project Explorer is opened up first of all.

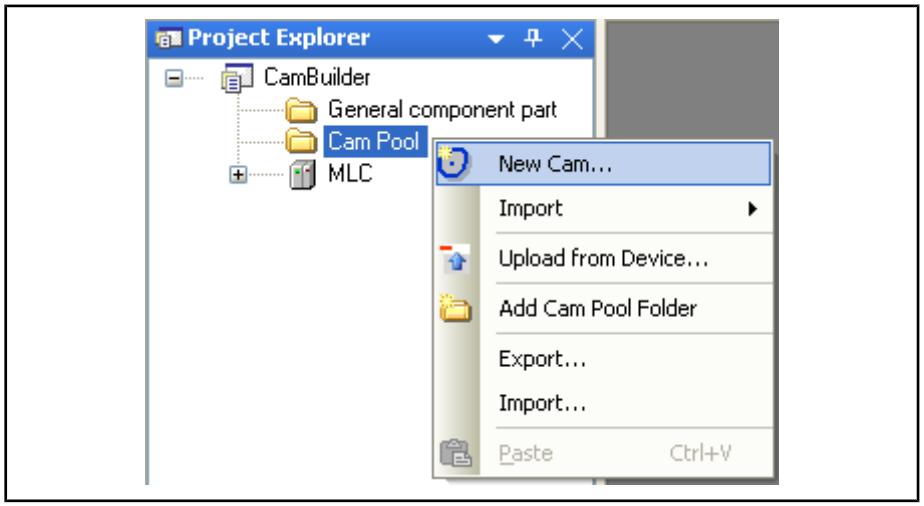

Fig.2-5: Cam Pool context menu

In the Project Explorer, right click on the "Cam Pool" node and select the "New Cam" context menu.

First Steps - CamBuilder

2. Wizard

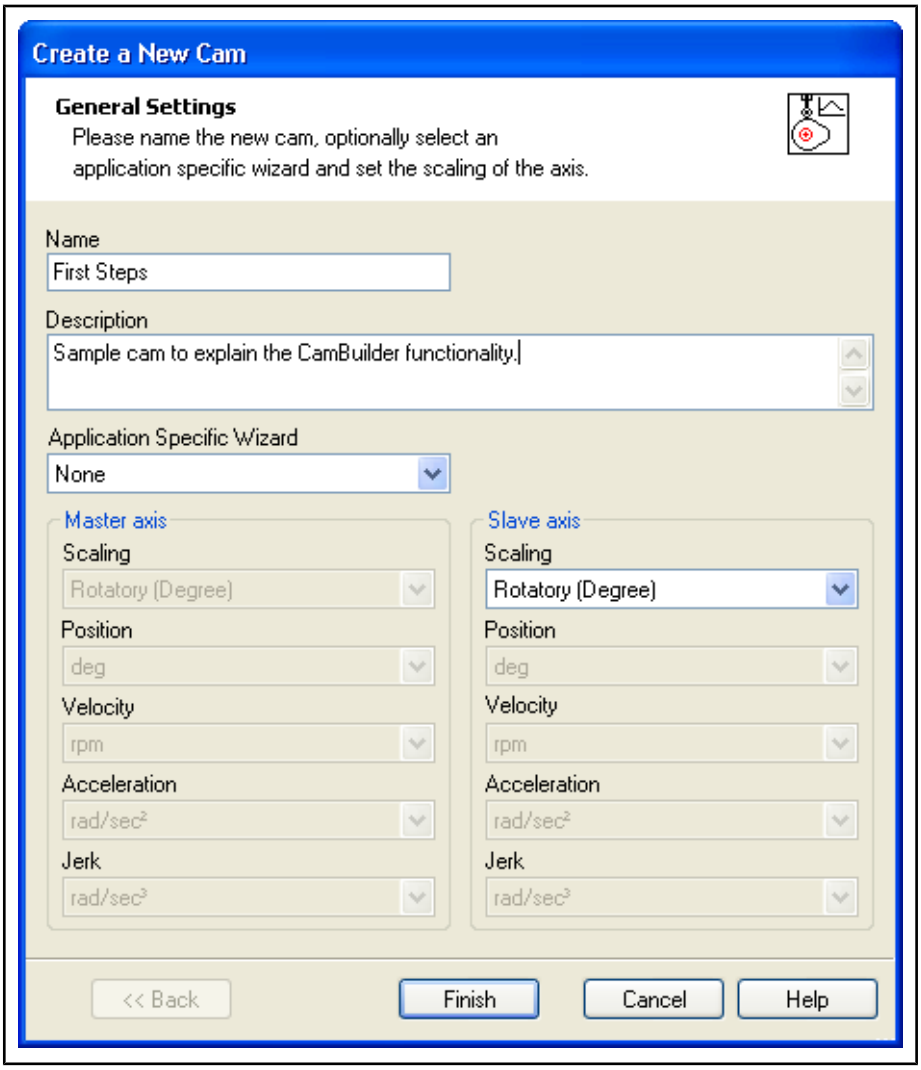

Fig.2-6: Creating a new cam (Wizard)

Enter a specific name and optionally a description for the new cam in the wizard. No Application-Specific Wizard is selected to create a freely-defined cam.

The scaling of the slave axis is set to "Rotatory (degree)."

The "Finish" button creates a default cam, saves it in the IndraWorks project and automatically opens a graph window.

3. Edit motion step 1

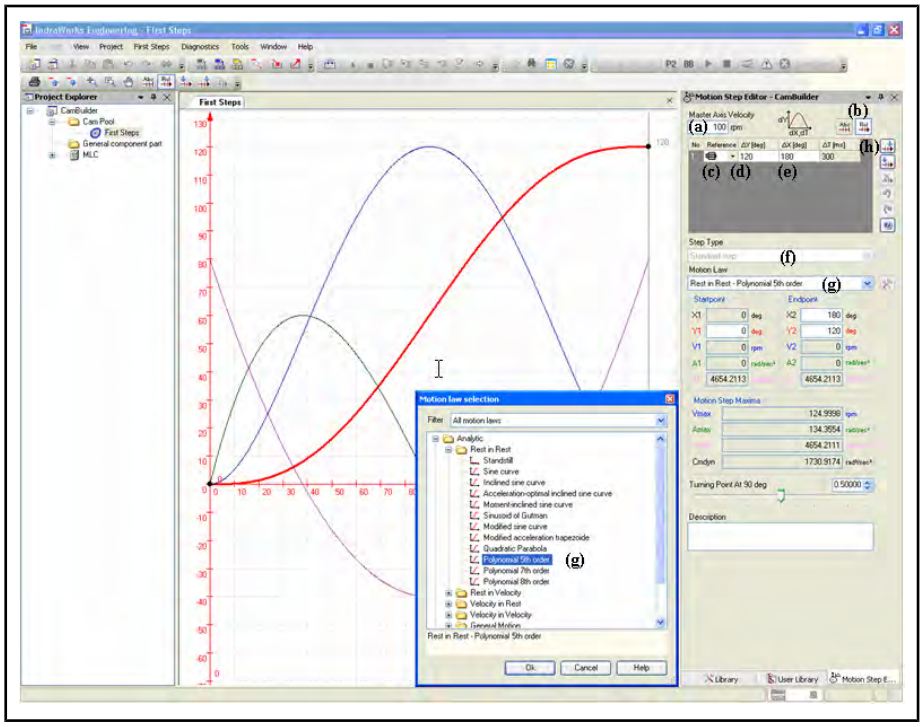

Fig.2-7: IndraWorks cam first steps

The Motion Step Editor opens at the same time as the graph window. The first motion step has been automatically generated and is entered with default values. In order to make inputting simpler for the user, all the fields to be completed have a white background.

(a) The master axis rotates at 100 rpm.

(b) As all the steps have to be inputted in sequence, the editing mode shows "Relative."

(c) The slave axis should follow the master axis, therefore the Reference should be set to the motor symbol.

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

(e) The distance is based on a master axis range of 180 degrees (ΔX).

(f) If the cam only consists of one step, the step type automatically has to be defined as a "Default step".

(g) The "Rest in rest - Polynomial 5th order" is selected as the motion law. All other fields are automatically completed by this.

(h) A further step is added to the end of the focused step with the "Add motion step after focused step" button.

First Steps - CamBuilder

4. Edit motion step 2

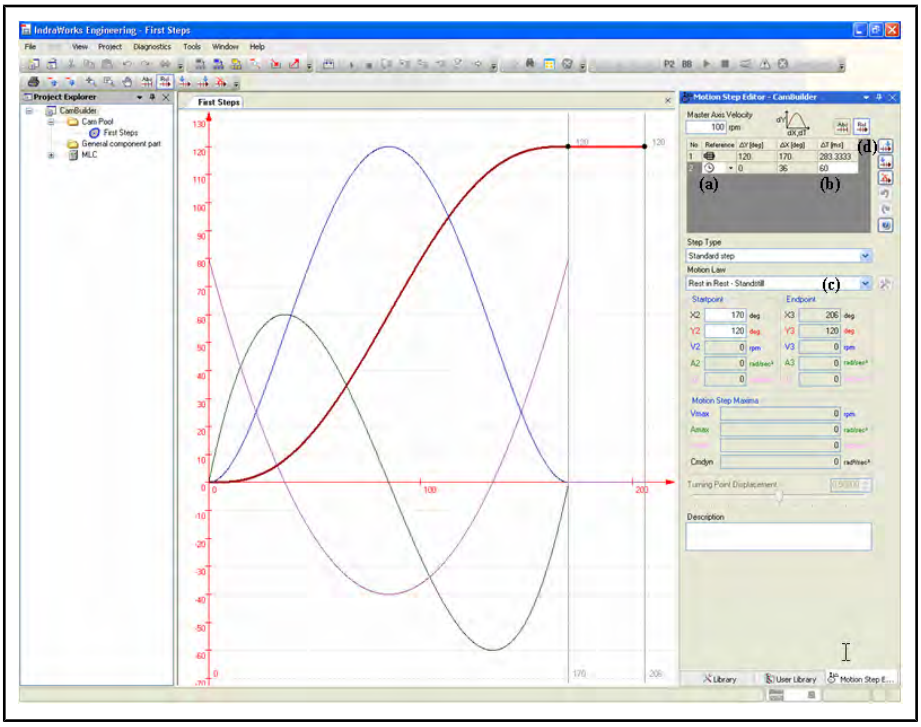

Fig.2-8: IndraWorks cam first steps

The fields of the 2nd motion step have standard values from the CamBuilder options pre-entered.

(a) The reference of the slave axis is changed from the master axis to the time deactivating the input fields ΔX and X_3.

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

(c) Following the changeover of the motion law to "Rest in rest - Standstill", all automatically calculated fields are deactivated.

After every input, the cam is automatically recalculated, and in doing so rechecks whether all the values are feasible. Should values not be correct, the relevant input field is marked and a message appears.

Clicking on the first row of the table changes back to the first motion step. If the active step includes input errors, then it is not possible to change to another step. There is an option to undo the last changes to the cam using the "Undo" button..

(d) A further step is added to the end of the focused step with the "Add motion step after focused step" button.

5. Edit motion step 3

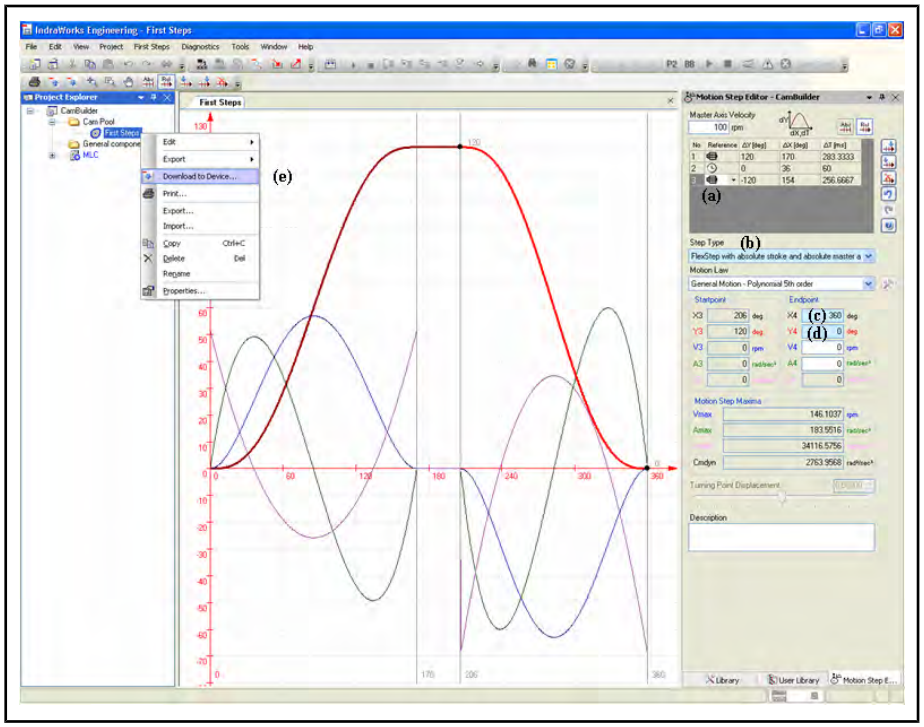

Fig.2-9: IndraWorks cam first steps

(a) The last step should relate again to the master axis and, to this end, the slave axis reference is set to the motor symbol.

(b) In order to relate the slave axis absolutely to the master axis, the step type is set to "FlexStep with absolute distance and absolute master axis range".

(c) The master axis end position X_4 is set to 360 degrees.

(d) The slave axis end position Y_4 is set to 0 degrees.

(e) The new cam can be seen in the Project Explorer as a node below the "Cam Pool" node.

(f) If the MLC in the project is online or is in offline-parameterizable mode, the cam can be downloaded to the controller via its context menu in the Project Explorer.

First Steps - CamBuilder

6. Downloading the cam

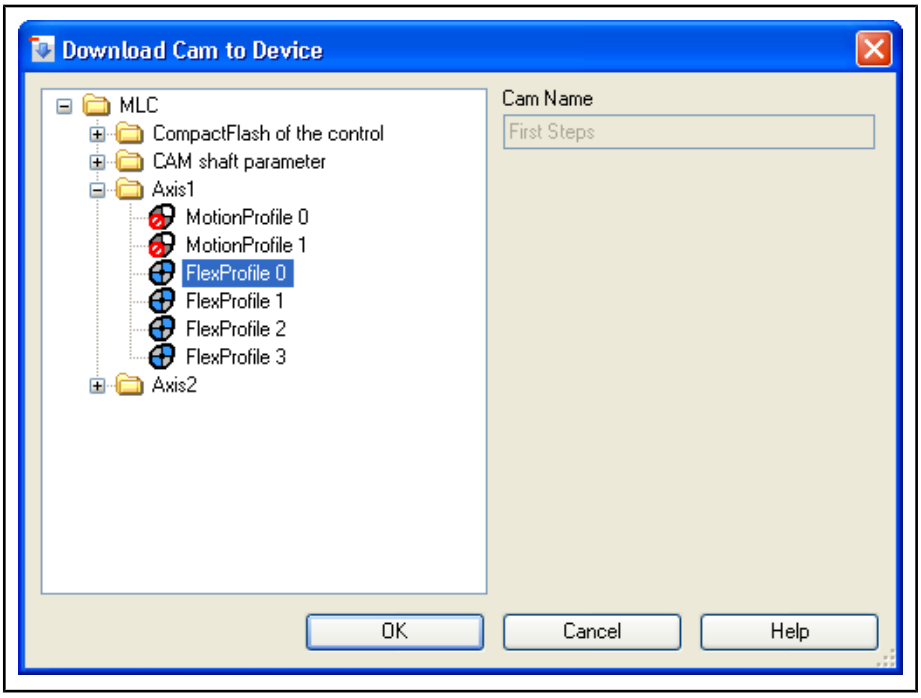

Fig.2-10: Downloading the dialog

The destination "FlexProfile 1" of "Axis 1" is selected. Confirming the dialog with "OK" downloads the cam "first steps" into the controller 's parameters. A message confirms that the process has been successful.

Fig.2-11: Message window

3 Creating New Cams

Starting the wizard

A new cam can be created in one step using the wizard.

Start the wizard via the **New Cam** menu via the "Cam Pool" node in the Project Explorer.

General settings

Multiple attributes of the cam are preset in the wizard.

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

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

The **Application-Specific Wizard** determines whether a wizard should be used for a specific application.

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

No Application-Specific Wizard is preset by default. The user can freely specify the individual motion steps in the Motion Step Editor.

This property is set once when creating a cam and can no longer be changed thereafter.

The **scaling of the slave axis** can also be set. This setting is automatically entered and deactivated when an Application-Specific Wizard is selected.

Complete or Cancel

After the entries have been completed, a cam is created by confirming the wizard clicking on the "Finish" button.

Every cam can either be edited after "Completion" using the Motion Step Editor or it can be edited via the graph.

The wizard can be ended at any time by using the "Cancel" function. All inputted entries for the new cam are thereby cancelled.

Application-specific cams can still be edited by the same wizard. If an application parameter is changed and applied in the wizard window, the complete cam is recalculated and any Motion Step Editor or graph changes are overwritten.

4 Editing and Analyzing Cams

4.1 CamBuilder Graph

4.1.1 General

The graph window is the core element in the CamBuilder. By opening a graph (by double clicking on a cam via a "Cam Pool" node), the graph is displayed in the IndraWorks main screen. Only one cam is always "focused" in the CamBuilder and this can be edited via the graph or the Motion Step Editor. If another cam is opened, then this cam is then "focused." By focusing (clicking the cursor on a cam window), the cam is automatically registered as focused by the CamBuilder. All CamBuilder inputs and displays relate to the focused cam.

4.1.2 Setup

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

In the coordinate system, up to 4 different profiles of the slave axis are displayed at the same time (**Position profile**, **Velocity profile**, **Acceleration profile** and **Jerk profile**).

The different profile diagrams can be shown and hidden using the Graph Manager (refer to chapter 4.1.5 "Graph Manager Settings" on page 14). The color in which the profiles are displayed can be set using the Options dialog (see chapter 8.1 "CamBuilder Options" on page 43).

The **X-axis unit** is the unit of the master axis (degree)

The **Y-axis unit** corresponds to the respective focused profile diagram. A profile diagram can be focused by clicking on the respective profile.

The **axes of the coordinate system** always have the color of the focused diagram; the grid helps to make the graph clearer.

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

The **focused motion step** is highlighted by a different thickness of line.

Another step can be focused by clicking on the line of this motion step.

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

The section of the cam displayed in the coordinate system can be zoomed in and out or offset.

4.1.3 Editing a Cam

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 shown as black dots.

If a point can be moved, this is shown as a symbol with arrows when the cursor hovers over the point.

 Base point can be moved horizontally and vertically

 Base point can only be moved horizontally

 Base point can only be moved vertically

 Base point cannot be moved

The base 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 (relative or absolute) which has been set. The behavior of the cam, when the limit values are changed, is described in more detail in chapter 4.2.9 "Absolute Editing of the Master Axis Range (X-values)" on page 25 and chapter 4.2.10 "Relative Editing of the Master Axis Range (X-values)" on page 26.

The base points of the **Velocity, Acceleration** and **Jerk diagrams** can only be offset vertically, in line with the editability of the values defined by the selected motion law.

Deleting a focused motion step

A motion step is deleted using the graph context menu in the same way as is described in chapter 4.2.14 "Deleting a Focused Motion Step" on page 30.

4.1.4 Functions

Zoom In

The **Context Menu ▸ Zoom In** function activates a magnifying glass as a cursor. Clicking on the coordinate system and drawing a rectangle specifies the area to be enlarged.

Pan

The context menu function **Pan** activates a hand symbol as a cursor. It is possible to move a section by clicking on the coordinate system and pulling it.

General View

The total cam is shown with the **General View** function in the context menu.

Copy Graph to Clipboard

The section of the cam currently being displayed can be copied to the clipboard via the context menu and used in other applications, such as word processing.

Show Tool Window

The main graph window context menu has a menu to activate all other CamBuilder Tools windows.

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

Restore Default Layout

The **Restore Default Layout** menu hides all CamBuilder tools, with the exception of the Motion Step Editor and the Graph Manager and activates the Toolbar.

All windows can be arranged at will and shown or hidden by the user. Every change to the layout is permanently saved and the last layout used is restored when the CamBuilder is restarted.

4.1.5 Graph Manager Settings

The Graph Manager can be opened via **Tool window ▸ Graph Manager** in the graph context menu. Similarly it can also be shown and hidden via **View ▸ Other windows ▸ Graph Manager** on the main menu.

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)

Different actions on the graph window can be started via the "Change view" buttons

- **General View**
- **Zoom In**
- **Pan**

The cursor coordinates in relation to the focused profile diagram of all units are shown in the cursor coordinates area.

In the extended Options, the visibility of different data can be set in the Graph window.

- **Motion step limits** (Shown/Hidden)
- **Border Coordinates** (Shown/Hidden)
- **Cursor position** (Shown/Hidden)

The settings in the Graph Manager have a direct effect on the graphic output.

☞ Cross-project settings, such as colors and line thickness of the graph window, can be set via **Tools** ▸ **Options** ▸ **CamBuilder** ▸ **Graph** in the main menu (see chapter 8.1 "CamBuilder Options" on page 43).

4.2 Motion Step Editor

4.2.1 Overview

The Motion Step Editor serves to configure the individual motion steps. A cam can consists of any number of motion steps.

☞ The MotionProfile and FlexProfile operating modes of the devices are limited to a maximum number of motion steps! If too many steps are defined, then the cam can no longer be downloaded for the corresponding operating mode.

Editing and Analyzing Cams

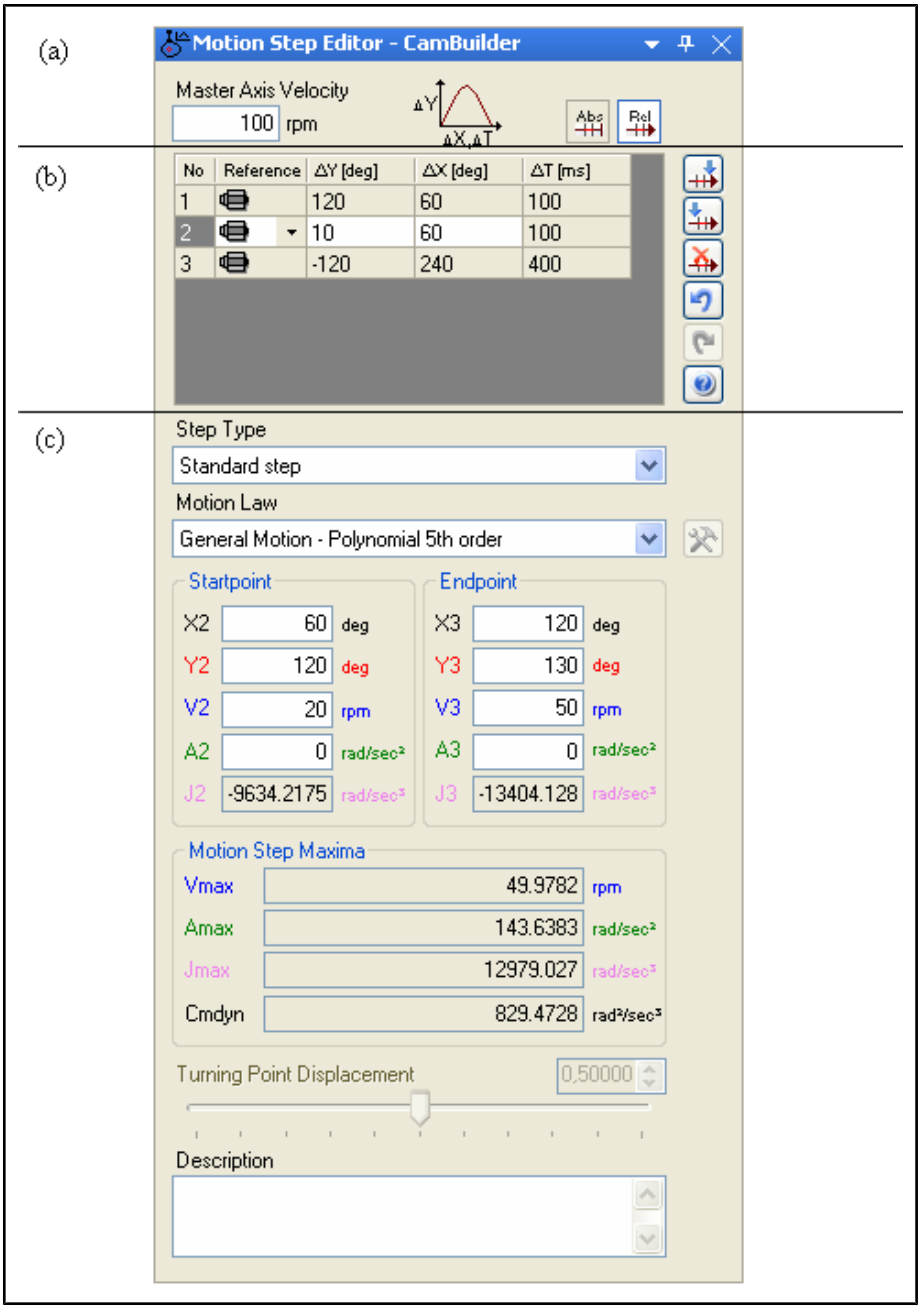

Fig.4-1: Motion Step Editor

The Editor is sub-divided into three areas.

1. The **higher-level** part (a) relates to all of the cam motion steps.
2. The **tabular** part (b) provides, on the one hand, an overview and navigation between the individual motion steps and, on the other hand, allows changes to be made to the single attributes.
3. The **form-based** section (c) provides the option of editing other attributes of the motion step focused in the tabular part.

A motion step is set as default.

Not all attributes can always be edited. Some attributes are automatically calculated depending on the choice of other attributes. All deactivated attributes are always calculated after a property has been changed (after clicking on the "Enter" key or by changing the cursor to another attribute.) If a non-numerical

value is entered into a numerical entry field, then the value is automatically rejected. Other incorrect entry fields are marked by an error symbol and a message appears.

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

4.2.2 High-Level Attributes

The high-level attributes relate to the entire cam.

Master axis velocity

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

Unit

- Rotatory (degree) - rotations per minute
- Rotatory (degree) - rotations per minute
- Translational (millimeter) - millimeters per minute
- Translational (inch) - inches per minute

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 less than the minimal step size (see chapter 8.1 "CamBuilder Options" on page 43).

Maximum

- The master axis velocity has an upper limit, in case 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 behavior of the subsequent motion steps when ΔY, ΔX, ΔT, Y1 or X2 are edited (see also chapter 4.2.9 "Absolute Editing of the Master Axis Range (X-values)" on page 25 and chapter 4.2.10 "Relative Editing of the Master Axis Range (X-values)" on page 26).

4.2.3 Attributes of the Tabular Section

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

Reference

Reference defines to what the slave axis should orient itself. 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

Delta Y represents the relative distance of the slave axis within the focused motion step and is given as a unit of the slave axis.

Changing delta Y immediately results in a calculation of Y_2.

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

ΔX

Delta X represents the relative master axis range of the focused motion step in relation to the master axis and is given as a unit of the master axis.

Changing delta X immediately results in the calculation of X_2 and ΔT.

This attribute cannot be edited if the reference of the slave axis is time (the value is then calculated by 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 ΔX would extend the focused step beyond the absolute master axis end position.

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

Changing delta T immediately results in the calculation 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 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 ΔT would extend the focused step beyond the absolute master axis end position.

4.2.4 Attributes of the Form-Based Section

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

Step type There are 2 categories of step type.

- **Default step**

  A default step has limit values defined when it is created (X_1, Y_1, V_1, A_1, J_1, X_2, Y_2, V_2, A_2, J_2) and the motion path is calculated on the basis of these values. The motion path of a default step is thus rigid and does not change in operation.

  Any motion law can be used for this step type.

- **FlexStep**

  A FlexStep is an active step, that it to say it carries over the starting point limit values in operation from the real values (X_1, Y_1, V_1, A_1, J_1) and the limit values of the end point from the pre-defined values (ΔX or X_2, ΔY or Y_2, V_2, A_2, J_2). The motion path is calculated in operation so that there are no steps in velocity.

  There are four different types of FlexStep

  – **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 $X_1 + \Delta X$

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

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

X_2 and ΔX are user-defined

ΔX is calculated from $X_2 – X_1$

Y_2 is calculated from $Y_1 + \Delta Y$

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

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

Y_2 and X_2 are user-defined

ΔX is calculated from $X_2 – X_1$

ΔY is calculated from $Y_2 - Y_1$

Only motion laws of the General motion type (Polynomial 5th order or Polynomial 7th order) can be used for a FlexStep.

If a FlexStep is selected, and the current motion law does not fit, then 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), then the first step of the cam is adopted as the subsequent step.

Motion Law

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

A detailed description of the different motion laws can be found in chapter 10 "Motion Laws" on page 47.

The motion law is selected using the following dialog:

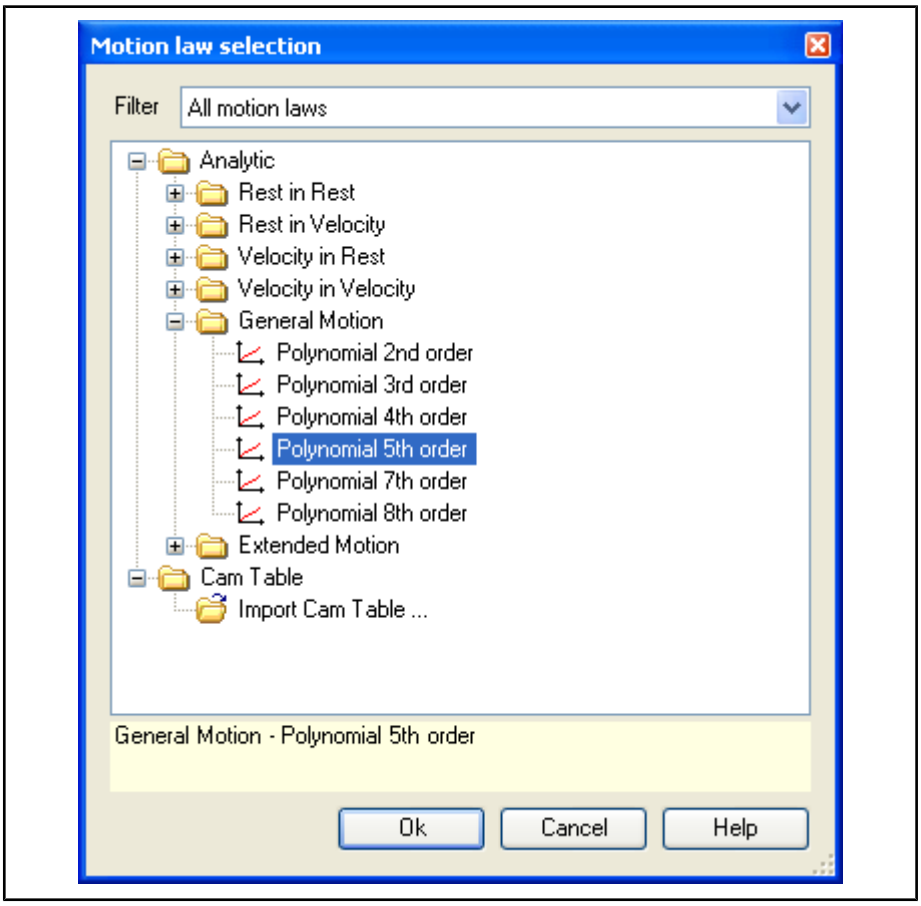

Fig.4-2: Motion law selection dialog

The dialog is sub-divided into two sections:

At the top 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 the motion law with the cam are stored. 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, then 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 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.

Important note: Y_1, the offset of the first motion step, serves only for the purpose of illustration in the CamBuilder and is deducted when carried over into the devices.

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

Unit

- Rotatory (degree) - rotations per minute
- Translational (millimeter) - millimeters per minute
- Translational (inch) - inches per minute

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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotation per second^2
- Translational (millimeter) - millimeters per minute^2
- Translational (inch) - inches per second^2

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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotation per second^3
- Translational (millimeter) - millimeters per minute^3
- Translational (inch) - inches per second^3

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.

Should there be a motion step in the cam which includes an absolute master axis end position as its step type, then 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 (trapezium profile) or with Acceleration-limited motion (sinusoid profile) or with 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 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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotations per minute
- Translational (millimeter) - millimeters per minute
- Translational (inch) - inches per minute

This attribute cannot be edited if it is automatically calculated by the motion law selected in the focused motion step or if V_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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotation per second^2
- Translational (millimeter) - millimeters per minute^2
- Translational (inch) - inches per second^2

This attribute cannot be edited if it is automatically calculated by the motion law selected in the focused motion step or if A_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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotations per minute
- Translational (millimeter) - millimeters per minute
- Translational (inch) - inches per minute

This attribute cannot be edited if it is automatically calculated by the motion law selected in the focused motion step or if J_1 of the preceding step cannot be edited.

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

Unit

- Rotatory (degree) - rotations per minute
- Translational (millimeter) - millimeters per minute
- Translational (inch) - inches per minute

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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotation per second^2
- Translational (millimeter) - millimeters per minute^2
- Translational (inch) - inches per second^2

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 is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotations per minute
- Translational (millimeter) - millimeters per minute
- Translational (inch) - inches per minute

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

Cmdyn C_{mdyn}: The dynamic torque characteristic value is calculated on the basis of the following equation: Cmdyn= Maximum value (V * A)

The unit is dependent on the slave axis scaling selected.

Unit

- Rotatory (degree) - rotation^2 per second^3
- Translational (millimeter) - millimeters^2 per second^3
- Translational (inch) - inches^2 per second^3

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

Turning point displacement The turning point displacement stipulates 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 inputting a percentage value between 0 and 1.

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

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

This attribute can always be edited.

4.2.5 Calculating Motion Steps

The cam is recalculated following every input (changing to another input field or confirming by means of the <Enter> key). Should the calculation not be possible, the incorrect input fields are highlighted and clear explanatory information is provided. The motion step is only applied if all inputs are correct.

The Undo motion step function allows all changes that have been made since the motion step was successfully calculated the last time to 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, then the active motion step has to be error-free.

If there are still incorrect entries, then the last focused motion step remains active until all the inputs are correct or have been undone.

4.2.6 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 change has been made to the cam.

4.2.7 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"**, then only this individual value is changed and the rest of the position profile remains at the original position.

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

Example:

Absolute editing of ΔY

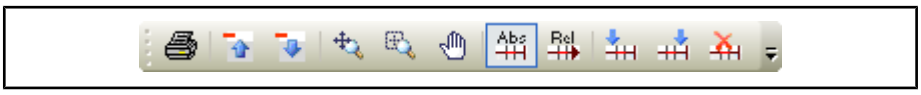

Fig.4-3: Absolute edit mode

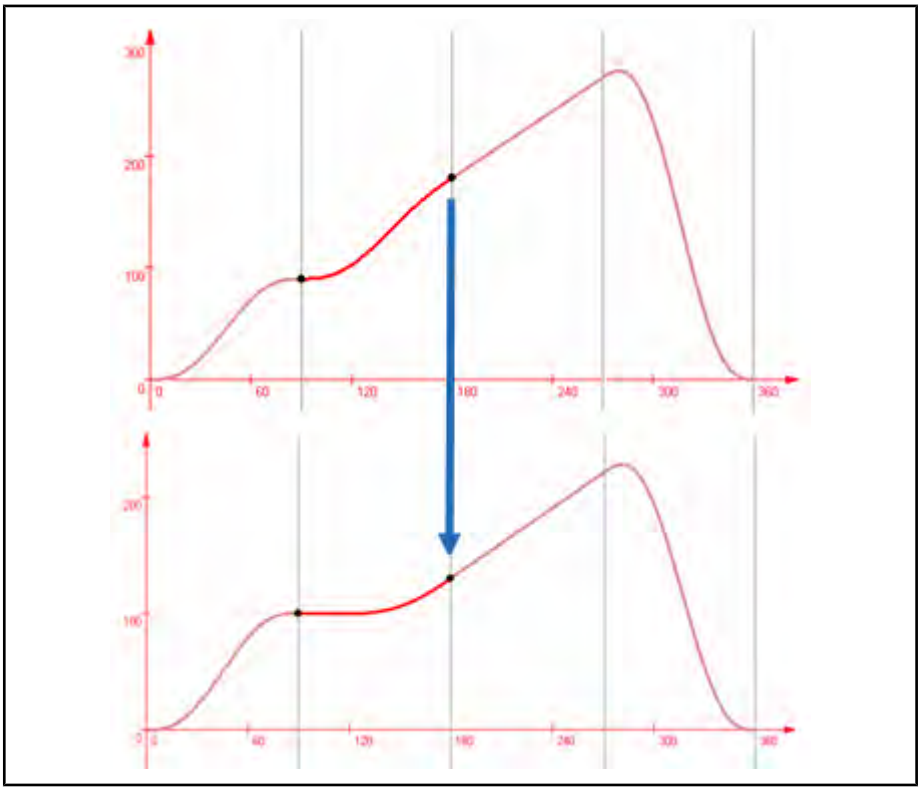

Fig.4-4: Changing ΔY in the second motion step by -50 degrees

4.2.8 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"**, then the remainder of the position profile is displaced in the Y-direction by the value of the change.

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

Example:

Relative editing of ΔY

Fig.4-5: Relative edit mode

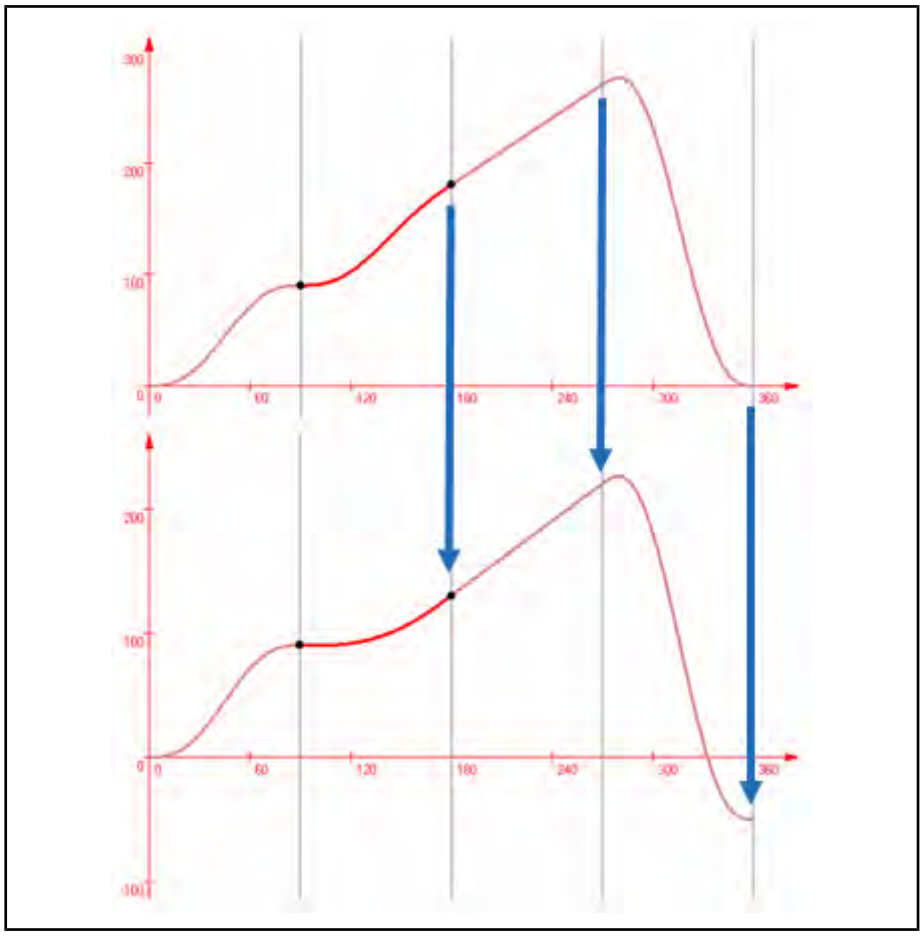

Fig.4-6: Changing ΔY in the second motion step by -50 degrees

4.2.9 Absolute Editing of the Master Axis Range (X-values)

With 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 remains. 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, then the user is asked whether he actually wishes to overwrite this.

Example:

Absolute editing of ΔX or Xn

Fig.4-7: Absolute edit mode

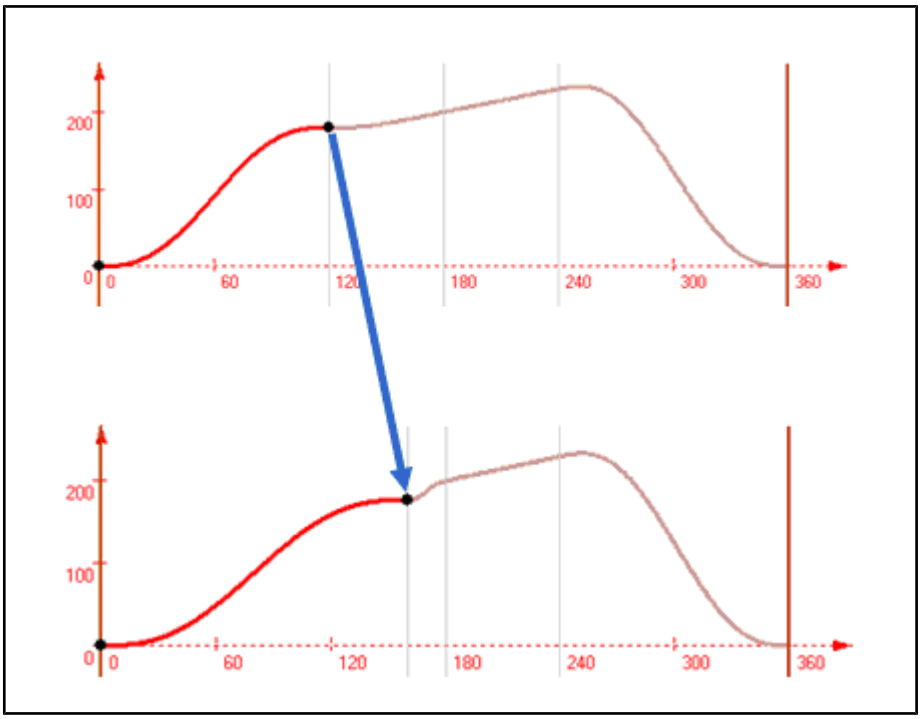

Fig.4-8: Changing ΔX in the second motion step by +40 degrees

4.2.10 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 delta X or delta T 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, then the duration of the total cam has to be shortened.

Example:

Relative editing of ΔX or Xn

Fig.4-9: Relative edit mode

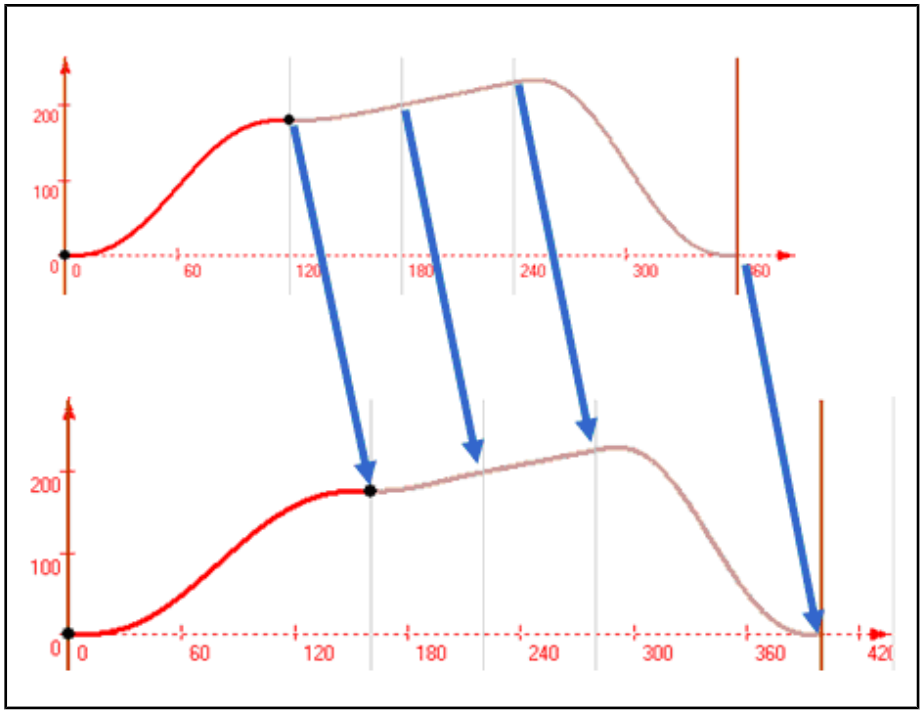

Fig.4-10: Changing ΔX in the second motion step by +40 degrees

4.2.11 Editing the Motion Step Cam Table

If the focused motion step includes a cam table as a motion law, then, in addition to selecting the motion law, a modal window can be opened via an interface for editing the 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 row, then the X-values are recalculated and the existing Y-values retain their value. At least 3 and at most 1024 points can be inputted.

The X-values are always given 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.

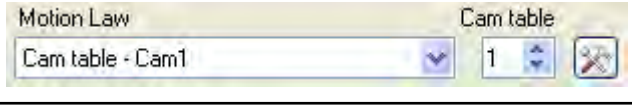

Fig.4-11: "Edit cam table" button

4.2.12 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 carried over from the focused end point.

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

The limit values of the end point are carried over from the starting point of the subsequent motion step, if there is one and, should there not be a subsequent motion step, then the limit values are given the value 0.

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

The limit values of the end point are given 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. Should this not be possible, then a clear and understandable message appears explaining why a step cannot be inserted at this position. If there is no subsequent motion step, then the limit values are given the value 0.

The new inserted motion step is activated following the insertion.

Example:

Fig.4-12: Absolute edit mode

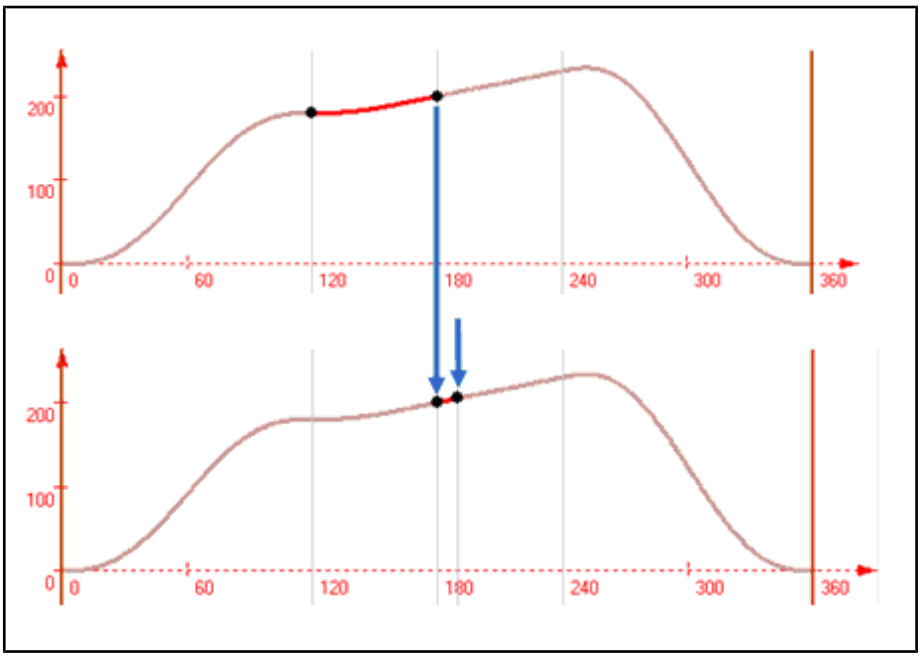

Fig.4-13: A new step is added at the end of the 2nd motion step.

Example:

Fig.4-14: Relative edit mode

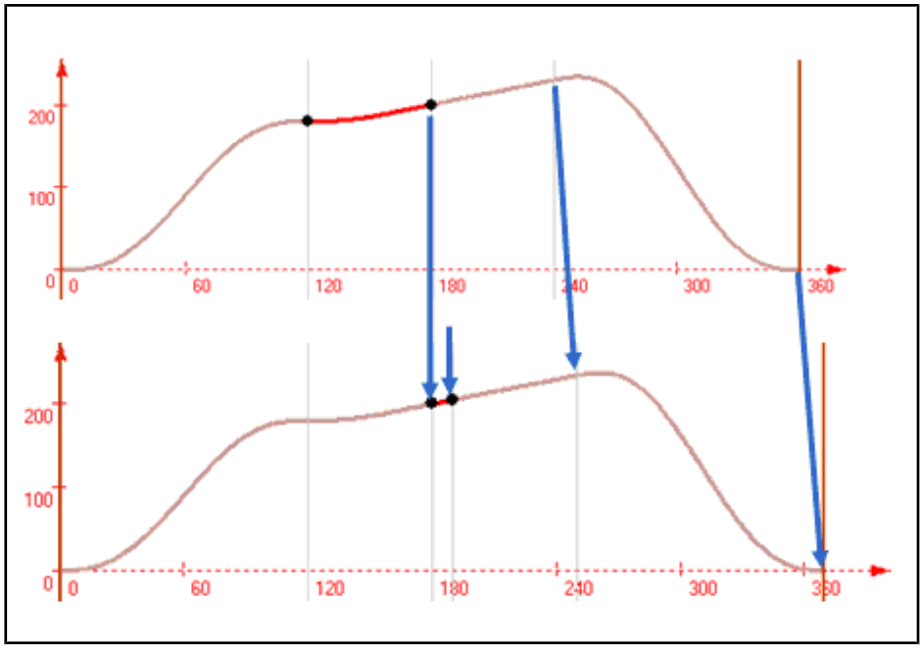

Fig.4-15: A new step is added at the end of the 2nd motion step.

4.2.13 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 carried over from the end point of the preceding step.

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

All subsequent steps are displaced backwards by ΔX.

If the **"Absolute edit mode"** is active, then the total length of the cam is retained. The limit values of the end point are given 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. Should this not be possible, then a clear and understandable message appears explaining why a step cannot be inserted at this position.

The new inserted step is activated following the insertion.

Example:

Fig.4-16: Absolute edit mode

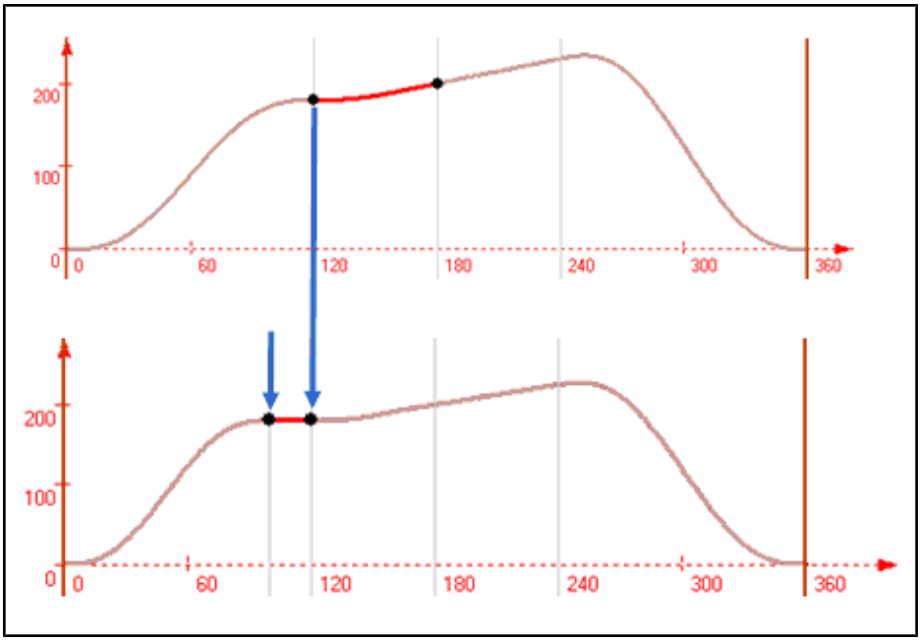

Fig.4-17: A new step is added at the start of the 2nd motion step.

Example:

Fig.4-18: Relative edit mode

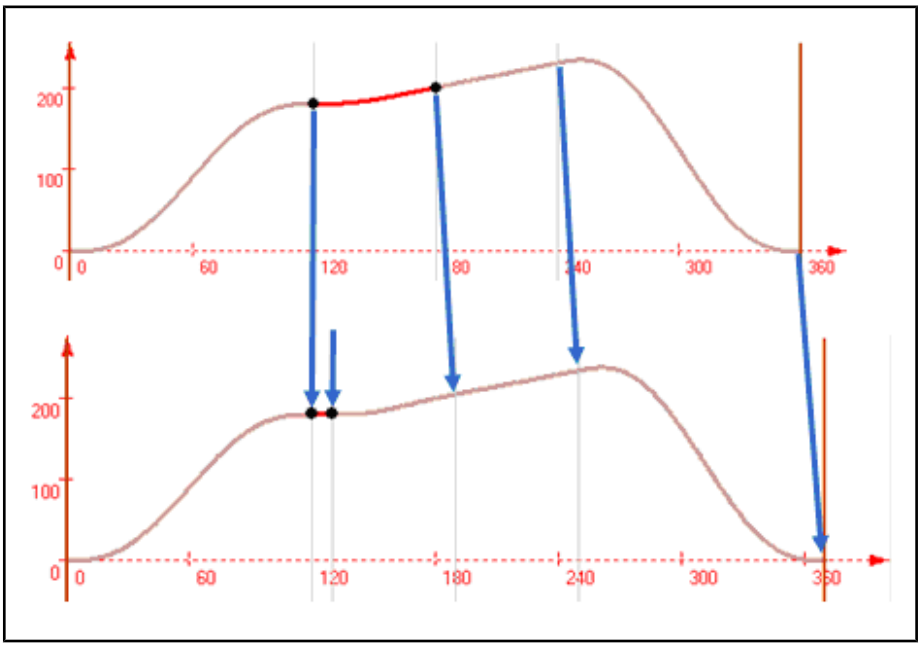

Fig.4-19: A new step is added at the start of the 2nd motion step.

4.2.14 Deleting a Focused Motion Step

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

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

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

The total length is retained by the subsequent motion step (if there is not one, then the preceding) being extended by delta X of the step to be deleted. Should this not be possible, then the motion step cannot be deleted.

Example:

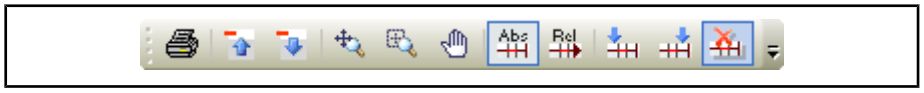

Fig.4-20: Absolute edit mode

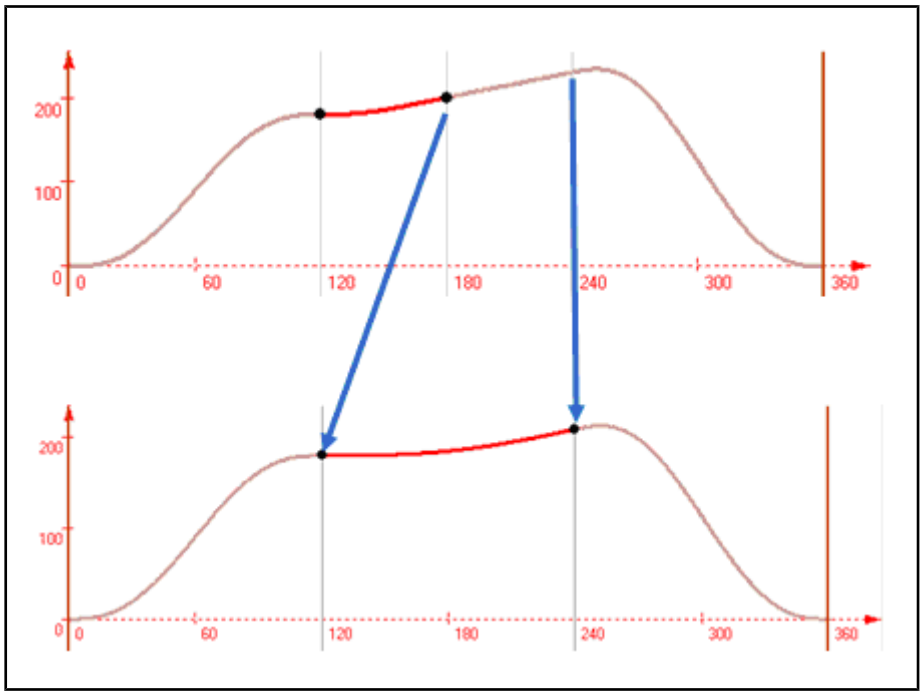

Fig.4-21: Deleting motion step 2

Example:

Fig.4-22: Relative edit mode

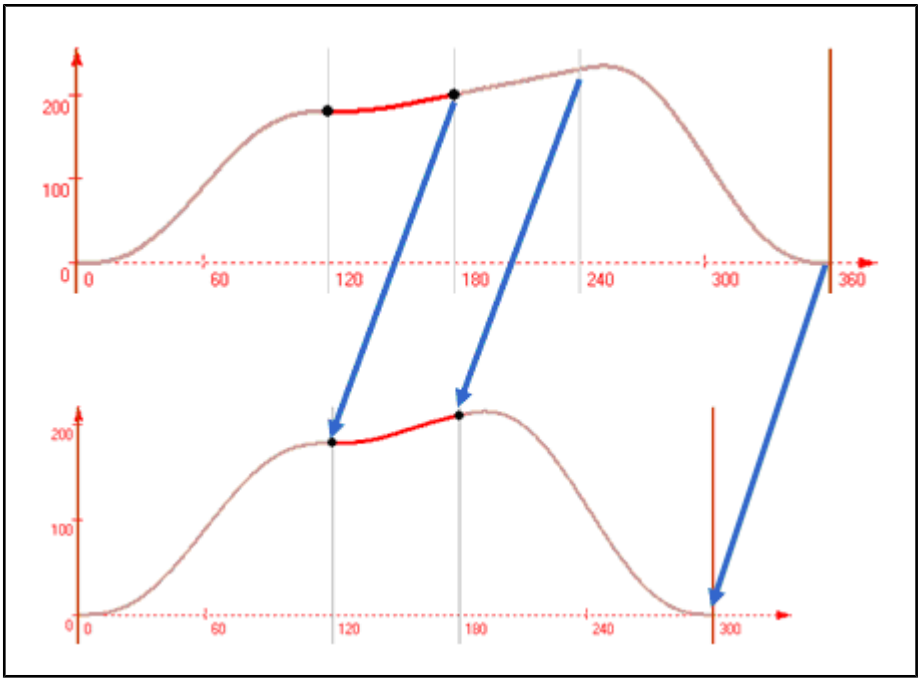

Fig.4-23: Deleting motion step 2

4.3 Application-Specific Wizard

4.3.1 General

An application-specific cam has, depending on its type of application, a special wizard with which the entire cam can be edited.

Single motion steps can be reedited later at any time using the Motion Step Editor (see chapter 4.2 "Motion Step Editor" on page 15). However, as soon as a change has been performed using the wizard, all Motion Step Editor changes are overwritten.

4.3.2 Cross Cutter Wizard

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

The specific inputs for the cross cutter function are as follows:

- Length format
- Roller diameter
- Cutting angle
- Velocity of the master axis

4.3.3 Feeder Wizard

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

The specific inputs for the feed function are as follows:

- Length format
- Roller diameter
- Maximum delay

- Acceleration path
- Roller position
- Distance between two products
- Velocity of the master axis

4.3.4 Print Length Correction Wizard

The CamBuilder provides a wizard for common requirements, such as the print length correction, which supports the user in creating the cam. All the 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

A further parameter is calculated by the wizard:

- Gradient in the synchronous range

4.3.5 Cross Seal Wizard

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

The specific inputs for the cross seal function are as follows:

- Synchronous range - range within which the sealing is performed
- 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.

A further parameter is calculated by the wizard:

- Gradient in the synchronous range

4.4 Cam Table

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

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

The distribution of the points across the master axis range can be specified using the following option:

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

Assuming the number of base points is 1024:

Yes:	The 100% is divided exactly between 1024 points		
	0,0000%	=	Point 1
	99,9023%	=	Point 1023
	100,0000%	=	Point 1024
No:	The 100% is divided between 1024 + 1 points		
	0,0000%	=	Point 1

99,9024%	=	Point 1024
100,0000%	=	Point 1

Fig.4-24: The units in the gaps are dependent 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 of the table can be copied to the clipboard and the values can be taken from there and, via "Insert", can be used in other programmes.

4.5 Extreme Values

The minimum and maximum values for the total cam are displayed in the Extreme values list.

Extreme values list

Profile diagram	Minimum	Maximum	Unit
Slave axis position			
Velocity			
Acceleration			
Jerk			
Dyn. torque char. value			

Fig.4-25: Creating the extreme values list

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

Cmdyn= Maximum value (V_{max} * A_{max})

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

This window can be displayed or hidden via the **View ▸ CamBuilder ▸ Extreme Values** menu.

5 Managing Cams in the IndraWorks Project

General

Cams are managed by the CamBuilder within the IndraWorks project and are also archived and restored using this project. They are located in the Project Explorer under the **"Cam Pool"** node.

A cam can also be exported if it is to be used outside the project.

It is also possible to import existing cams into a project (refer to chapter 7.3 "Importing Cams" on page 42).

Cams can also be used within the project if one or more devices are online or are in offline parameterization mode, can be downloaded to these or can be uploaded from these to the project (refer to chapter 6 "Interaction with Rexroth Devices" on page 37).

Opening a cam

A cam is opened by double clicking on the relevant symbol in the "Cam Pool" node in the Project Explorer. The relevant graphical view opens.

Saving a cam

Once a cam has been edited within the project and is focused, changes can be continuously carried over into the project via the **File ▸ Save (Ctrl+S)** menu.

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

Copying a cam

A cam can be copied by highlighting it in the Project Explorer and copying it via the **File ▸ Edit ▸ Copy** menu.

Inserting a cam

A cam can also be reinserted into the project once it has been copied. To do so, a "Cam Pool" node is highlighted and the copy of the cam is inserted via the **File ▸ Edit ▸ Insert** menu.

Renaming a cam

A cam can also be renamed by clicking twice slowly on its name in the Project Explorer. Alternatively, the cam can also be highlighted in the Project Explorer and renamed via its context menu. A further option is to call up the "Properties" dialog via the cam context menu, when the cam is open, and change the name there.

Deleting a cam

A cam can be deleted by highlighting it in the Project Explorer via its context menu. Alternatively, the cam can also be highlighted and deleted using the <Del> key.

Creating other folders within the "Cam Pool"

A new folder can be created below the "Cam Pool" via the **"Cam Pool"** node context menu in the Project Explorer. Cams can also be created and edited within this folder. This folder can be renamed or deleted via the context menu.

Comparing two cams

Two cams can be compared visually with each other. To do so, one of the two cams is focused in IndraWorks and executed via the **Window ▸ New Horizontal Registration Card** menu. Then the focused cam is opened in its own window underneath the existing window. The two cams can the be compared visually with each other.

6 Interaction with Rexroth Devices

6.1 Downloading Cams to Devices

6.1.1 General

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

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

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

The parameters have different symbols for the different operating modes:

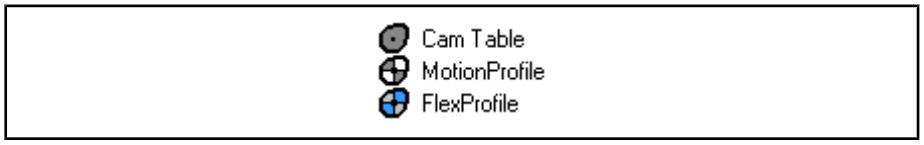

Fig.6-1: Device symbols for different operating modes

6.1.2 Downloading Cams to Cam Table Parameters

If the focused cam is to be downloaded to cam table parameters, then a base point table, with percentage values with at least 3 and at most the number of points supported by the device, is created for the complete travel of the position profile.

The following information is required for downloading into a cam table:

- **Number of base points**
- **Distance** factor for calculating the percentage values.
- **Removing linear sections of the cam** only applies to drives above a specific version.
- **The last base point in the table corresponds to X = 100%**. (Yes/No) (Table format)

  This setting only applies to drives; with controllers, the last base point always corresponds to X = 100%.

  There are only two different formats on the drive for specifying the calculation of the X-values.

Assuming the number of base points is 1024:

Historically:	The 100% is divided between 1024 + 1 points		
	0,0000%	=	Point 1
	99,9024%	=	Point 1024
	100,0000%	=	Point 1
Currently:	The 100% is divided exactly between 1024 points		
	0,0000%	=	Point 1
	99,9023%	=	Point 1023
	100,0000%	=	Point 1024

☞ If the cam has motion steps with time reference, then the slave axis motion is calculated using the inputted master axis velocity. The dynamic function is then lost here. The dynamic of the FlexSteps is also lost.

6.1.3 Downloading a Cams to MotionProfile Parameters

If a cam is to be downloaded to EMP parameters, then it can only include motion laws supported by the EMP operating mode. The master axis range has to be rotatorically fixed at 360 degrees.

No further settings are possible.

☞ If the cam has motion steps with time reference, then the slave axis motion is calculated using the inputted master axis velocity. The dynamic limit values are lost here. The dynamic of the FlexSteps is also lost.

6.1.4 Downloading Cams to FlexProfile Parameters

If a cam is to be downloaded to FlexProfile parameters, then it can only include motion laws supported by the FlexProfile operating mode.

No further settings are possible.

6.1.5 Downloading a Cams to CF Memory Cards

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

Unlike with the 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 saved as file with the name given in the CamBuilder. If the file already exists, a query appears asking whether it should be overwritten.

6.2 Uploading Cams from Device

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

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

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, which are either online or in an offline parameterizable mode, and support the uploading of cams, provide an overview here of the cams ready for uploading.

The parameters have different symbols for the different operating modes:

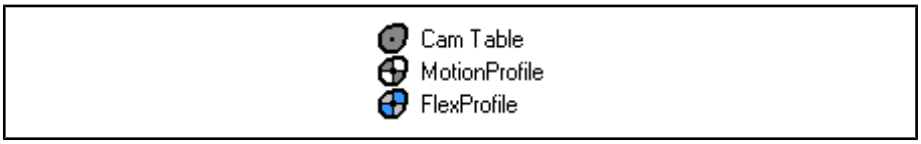

Fig.6-2: Device symbols for different operating modes

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

A specific name simply has to be entered when saving the cam in the IndraWorks project. The cam is then converted into the neutral CamBuilder format.

The editing of the cam is thus always identical in the CamBuilder, the format of the cam is only of significance when downloading it onto a device.

7 Importing and Exporting Cams

7.1 General

Cams can be imported into an IndraWorks project or exported from an IndraWorks project using the CamBuilder. The following formats are supported for these Import / Export functions:

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

  Internal CamBuilder format

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

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

  Parameter file for drives and controllers (e.g. IndraDrive and MLC).

  Enables parameter files to be uploaded into the destination device using IndraWorks and 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 by Excel. The cam is converted into a cam table. This ensures that it can also be read via DriveTop.

7.2 Exporting Cams

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

If the cam is to be further edited in another project, then it has to be exported in XML format and imported into the other project.

If the cam is to be analyzed with the **IndaSize** tool, then it has to be exported in XML format and imported into IndraSize.

If the cam is to be sent to a drive using DriveTop, for example, then the PAR format or the CSV format can be used for this. The cam is exported and the exported file is read with DriveTop and the cam table is sent to the drive.

The CSV format is available for examining the position values, velocity values, acceleration values and jerk values of a cam more closely.

As a CamBuilder file (*.xml)

The destination location of the file simply has to be specified.

As a parameter file (*.par)

The following information has to be provided for export as a parameter file:

- **Device type** - the drive or controller 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 function is only available with drives and also only with specific firmware versions. You can find further information in the Description of Functions of the device used.
- **Address** - address of the drive or controller on which the cam is to be saved. (limited from 0-100)
- **The last base point in the table belongs to X: 100%.** (Yes/No) (Table format)
- **Number of base points** (limited from 3 to 1024)

- **Distance** factor for calculating the percentage values of the base point table.

As a cam table (*.csv)

The following information has to be provided when exporting the cam in **CSV format**:

- **Adding information** - if this setting is not set, only the cam table will be exported. Otherwise the following information will be 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 function is only available with drives and also only with specific firmware versions. You can find further information in the Description of Functions 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 base point in the table belongs to X: 100%** (Yes/No)
- **Number of base points** (limited from 3 to 1024)
- **Distance** - factor for calculating the % values of the base point table.
- **Additional data** - this setting enables the velocity profile, acceleration profile and the jerk profile to be exported as well.
- **Field separator** - specifies with which separator the values will be exported. It is possible to choose between a comma and a semi-colon.

7.3 Importing Cams

The import of a cam is started via the context menu in the Project Explorer "Cam Pool" node. The data to be imported has to be selected in an **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 includes a cam table. If a *.par file is selected for import, which includes more than one cam table, then the user will be offered a selection of all the cam table parameters found. The user can then select the cam table required from this list.

The CamBuilder internally requires cam tables, the last Y base point of which corresponds to X = 100%. If a CSV file or a PAR file is to be imported, then the table format still has to be given. If the last Y value equals 0.xxx % or +-99.xxx %, then a suggested last base point is automatically entered in the input field.

8 CamBuilder Options and Cam Properties

8.1 CamBuilder Options

The Options dialog is opened via the **Tools** ▸ **Options** ▸ **CamBuilder** menu.

All the general settings can be entered here, which affect the entire CamBuilder (all opened cams).

The options are sub-divided into two areas:

General options

- **Minimum rotatory motion step length**
- **Minimal translational motion step length**
- **Default rotatory motion step length**
- **Default translational motion step length**

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

  The defined default values are used when inserting new motion steps.

Graph options

- **General**
  - **Mouse sensitivity** - Resolution when double clicking with the mouse. This gives the value for the master axis and the slave axis which is rounded up or down to by double clicking.
  - **Line thickness of the focused profile**
  - **Line thickness of the inactive profiles**
  - **Brightness of the focused motion steps**
  - **Brightness of the inactive motion steps**
  - **Line type of the coordinate grid**
- **Colors**
  - **Color of the graph background**
  - **Color of the coordinate grid**
  - **Color of the position profile**
  - **Color of the velocity profile**
  - **Color of the acceleration profile**
  - **Color of the jerk profile**

Every change is permanently saved and thus reproduced when the CamBuilder is restarted.

8.2 Cam Properties

The "Properties" dialog of a cam is called up via the context menu of the focused cam in the Project Explorer or via the CamBuilder toolbar. Settings for the focused cam can be inputted here.

Opening Properties automatically loads the corresponding cam.

The properties to be edited here correspond to the first step of the wizard for a new cam (refer to chapter 3 "Creating New Cams" on page 11).

9 Printing Cams

The CamBuilder allows the user to print the different cams individually.

The following print settings can be selected via the "Print" option in the cam context menu in the Project Explorer.

- Print the **graphic output** of the cam (Yes/No) - the current graphic output will be printed. A cam has to be open in the workspace to allow this option to be selected.
- Print the **description** of the cam (Yes/No) - the cam description will be printed. The cam has to have a description for this option to be chosen.
- Print the **application data** of the cam (Yes/No) - the application data from the application wizard will be printed. The cam has to have an application wizard for this option to be chosen.
- Print the **motion steps** of the cam (Yes/No) - the data of the individual motion steps (position, velocity, motion law, description, ...) will be printed.
- Print the **extreme values** of the cam (Yes/No) - the content of the extreme values list will be printed.
- Print the **cam table** of the cam (Yes/No) - e.g. 1024 percentage values of the slave axis position will be printed.

A selection has to be made to print or start the preview.

10 Motion Laws

10.1 General

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 about motion laws is given in the MLC FlexProfile documentation.

The different motion laws provide different degrees of freedom in terms of limit values and can be sub-divided into categories:

	Driverange		Bordervalues Left			Bordervalues Right			Max (not always considered)			TPD	FlexStep	Operating
	Stroke	Range	StartVel	StartAcc	StartJrk	EndVel	EndAcc	EndJrk	LimitVel	LimitAcc	LimitJrk	possible	possible	Modes
Rest in Rest														
Standstill	0	*	0	0	0	0	0	0	=	=	=	x		CT,FP
Sine curve	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Inclined sine curve	*	*	0	0	=	0	0	=	=	=	=	x		CT,MP,FP
Acceleration-optimal inclined sine curve	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Moment-inclined sine curve	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Sinusoid of Gutman	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Modified sine curve	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Modified acceleration trapezoide	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Quadratic Parabola	*	*	0	=	=	0	=	=	=	=	=	x		CT,FP
Polynomial 5th order	*	*	0	0	=	0	0	=	=	=	=	x		CT,FP
Polynomial 7th order	*	*	0	0	0	0	0	0	=	=	=	x		CT,MP,FP
Polynomial 8th order	*	*	0	0	0	0	0	0	=	=	=	x		CT,FP
Rest in Velocity														
Polynomial 5th order	*	*	0	0	=	*	0	=	=	=	=			CT,MP,FP
Polynomial 7th order	*	*	0	0	0	*	0	0	=	=	=			CT,FP
Velocity in Velocity														
Constant velocity	*	*	=	0	0	=	0	0	=	=	=			CT,MP,FP
Polynomial 5th order	*	*	*	0	=	*	0	=	=	=	=			CT,MP,FP
Polynomial 7th order	*	*	*	0	0	*	0	0	=	=	=			CT,FP
Modified sine curve	*	*	*	0	=	*	0	=	=	=	=			CT,FP
Velocity in Rest														
Polynomial 5th order	*	*	*	0	=	0	0	=	=	=	=			CT,MP,FP
Polynomial 7th order	*	*	*	0	0	0	0	0	=	=	=			CT,FP
General Motion														
Polynomial 2nd order	*	*	*	=	=	=	=	=	=	=	=			CT,FP
Polynomial 3rd order	*	*	*	=	=	*	=	=	=	=	=			CT,FP
Polynomial 4th order	*	*	*	=	=	*	=	=	=	=	=	x		CT,FP
Polynomial 5th order	*	*	*	*	=	*	*	=	=	=	=		x	CT,MP,FP
Polynomial 7th order	*	*	*	*	*	*	*	*	=	=	=		x	CT,FP
Polynomial 8th order	*	*	*	*	*	*	*	*	=	=	=			CT,FP
Extended Motion														
Resulting Hub														
Velocity 2nd Order (Startacc. zero)	=	*	*	0	=	*	=	=	=	=	=			CT,FP
Velocity 2nd Order (Endacc. zero)	=	*	*	=	=	*	0	=	=	=	=			CT,FP
Linear Velocity	=	*	*	=	=	*	=	=	=	=	=			CT,FP
Linear Acceleration	=	*	*	*	=	=	*	=	=	=	=			CT,FP
Resulting Master Axis Range														
Acceleration-limited motion (trapezoid profile)	*	=	*	=	=	*	=	=	*	*	=			CT,FP
Acceleration-limited motion (sinusoid profile)	*	=	*	=	=	*	=	=	*	*	=			CT,FP
Jerk-limited motion (trapezoid profile)	*	=	*	=	=	*	=	=	*	*	*			CT,FP
Miscellaneous														
Velocity-limited polynomial 5th order	*	*	*	*	=	*	*	=	*	=	=			CT,FP
Free of harmonics polynomial 5th order	*	*	*	0	=	*	0	=	=	=	=			CT,FP
Acceleration-limited (trapezoid profile)	*	*	*	0	=	*	0	=	*	*	=			CT,FP
Cam Table														
Cam Table	*	*	=	=	=	=	=	=	=	=	=			CT,MP,FP

Legend
0 Explicit 0
* User defined
= Calculated automatically

CT Points Table
MP MotionProfile
FP FlexProfile

Fig. 10-1: CamBuilder motion laws

10.2 Analytic Functions

10.2.1 General

The following motion laws enable a selection to be made on the basis of different criteria.

A high throughflow of goods is achieved by reducing damaging vibrations and abrasion and noise is also minimized by this.

10.2.2 Rest in Rest

There are 12 Rest in rest motion laws available. These motion laws are defined only 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.10-2: Function: Rest in rest, standstill

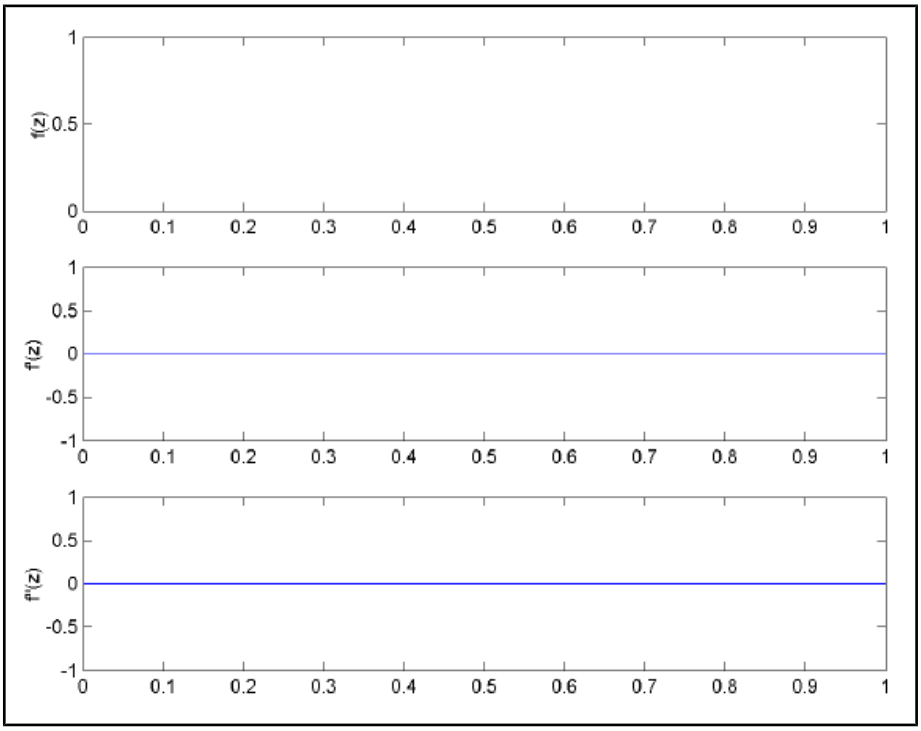

Fig.10-3: Graph: Rest in rest, standstill

Rest in rest, Simple sine curve

Advantages

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

Disadvantages

- Acceleration step
- Vibrations, noise, abrasion

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

Fig.10-4: Function: Rest in rest, Simple sine curve

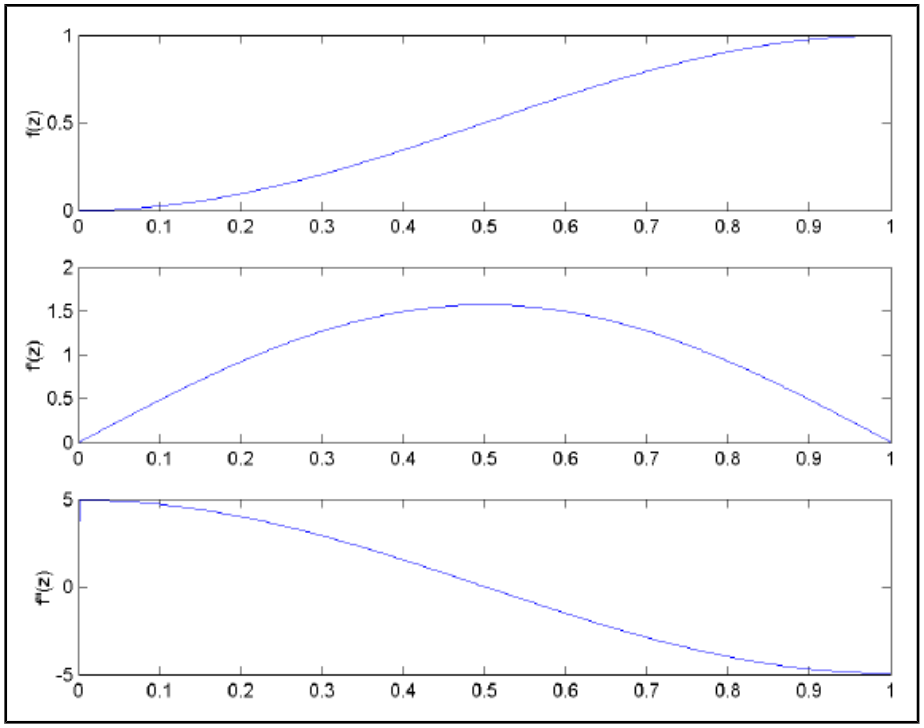

Fig.10-5: Graph: Rest in rest, Sine curve (simple sinoide)

Rest in rest, Inclined sine curve (Bestehorn sinoide)

Advantages

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

Disadvantages

- Velocity characteristic value, acceleration characteristic value and
- dynamic torque characteristic value are higher than with Polynomial 5th order

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

Fig.10-6: Function: Rest in rest, Inclined sine curve (Bestehorn sinoide)

Motion Laws

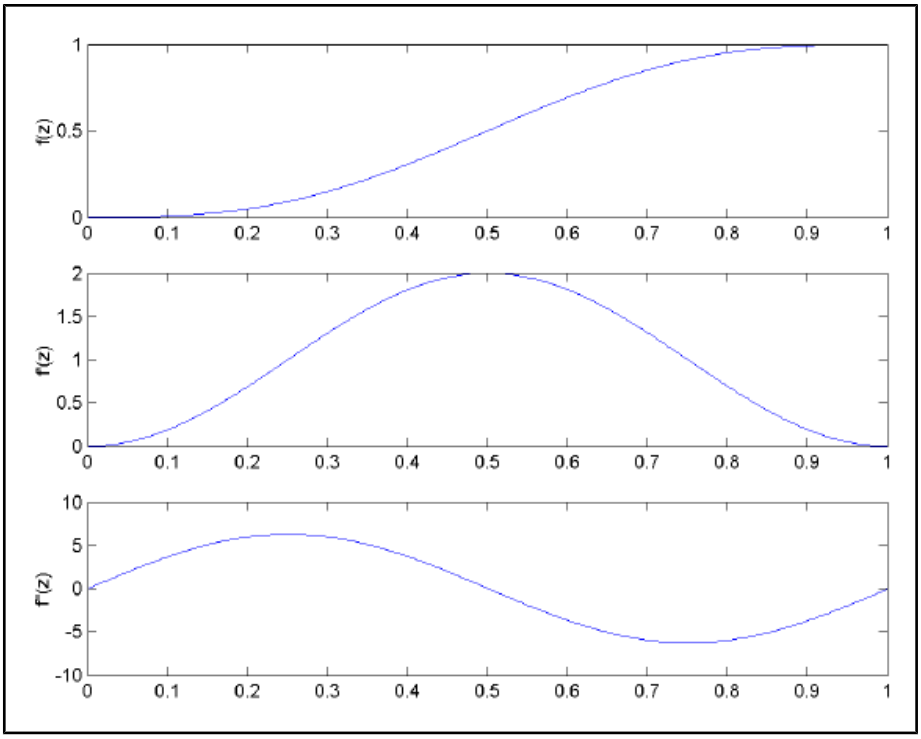

Fig.10-7: Graph: Rest in rest, Inclined sine curve (Bestehorn sinoide)

Rest in rest, Acceleration-optimal 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.10-8: Function: Rest in rest, Acceleration-optimal inclined sine curve

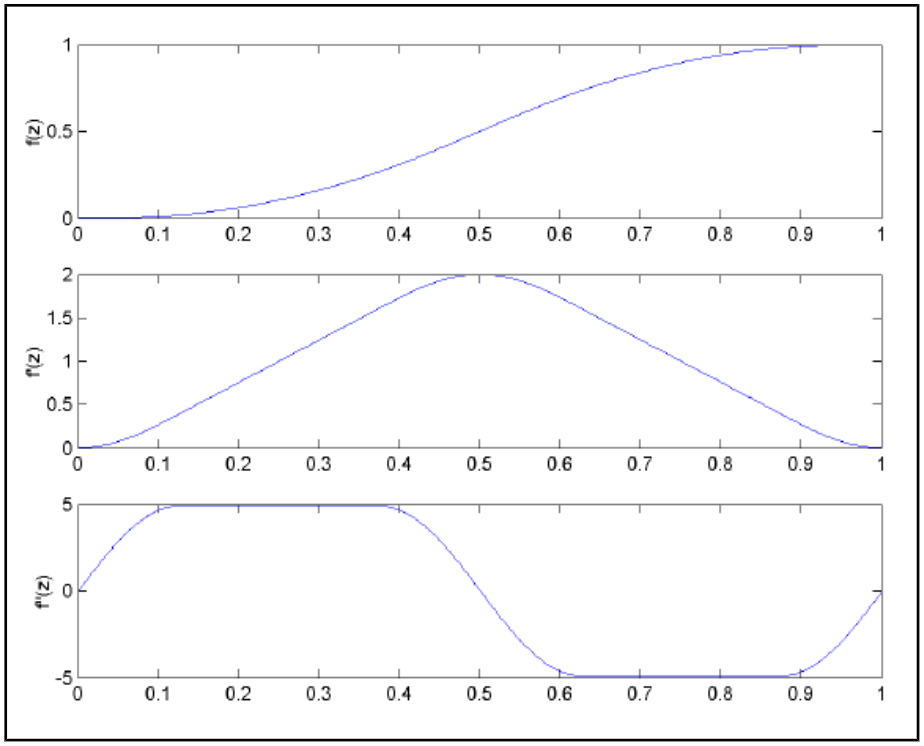

Fig.10-9: Graph: Rest in rest, Acceleration-optimal inclined sine curve

Rest in rest, Moment-optimal 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.10-10: Function: Rest in rest, Moment-optimal inclined sine curve

Motion Laws

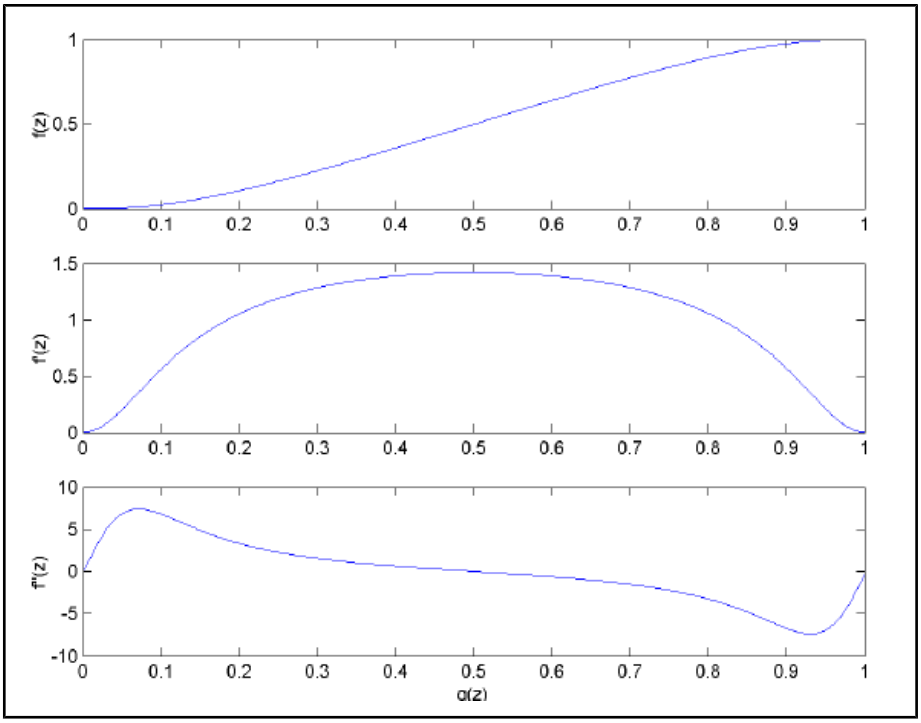

Fig.10-11: Graph: Rest in rest, Moment-optimal inclined sine curve

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.10-12: Function: Rest in rest, Sinoide of Gutman

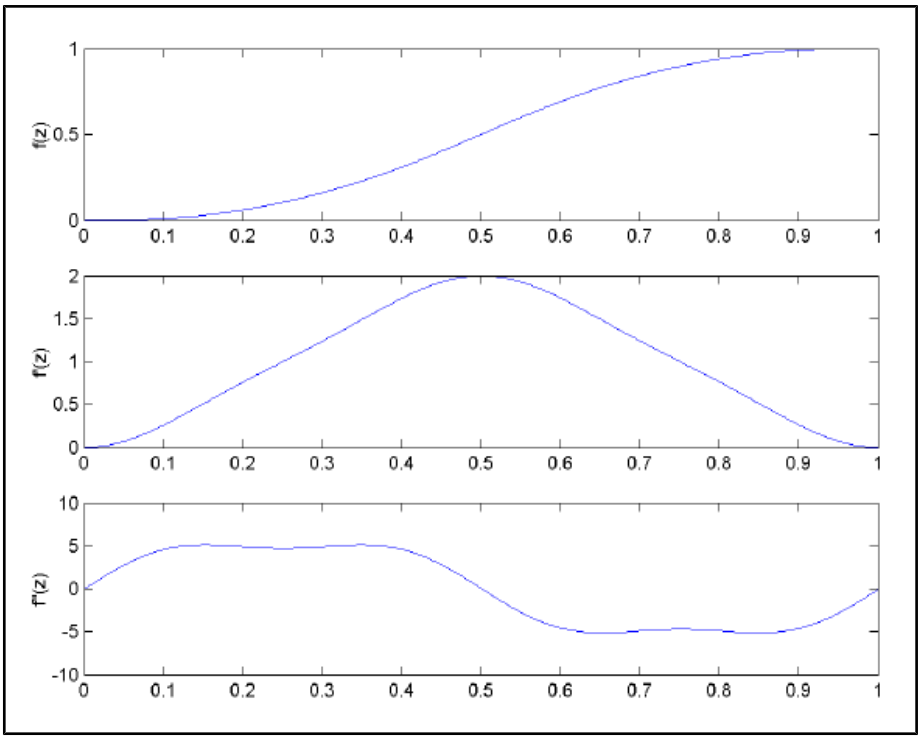

Fig.10-13: Graph: Rest in rest, Sinoide of Gutman

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 is higher than with 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.10-14: Function: Rest in rest, Modified sine curve

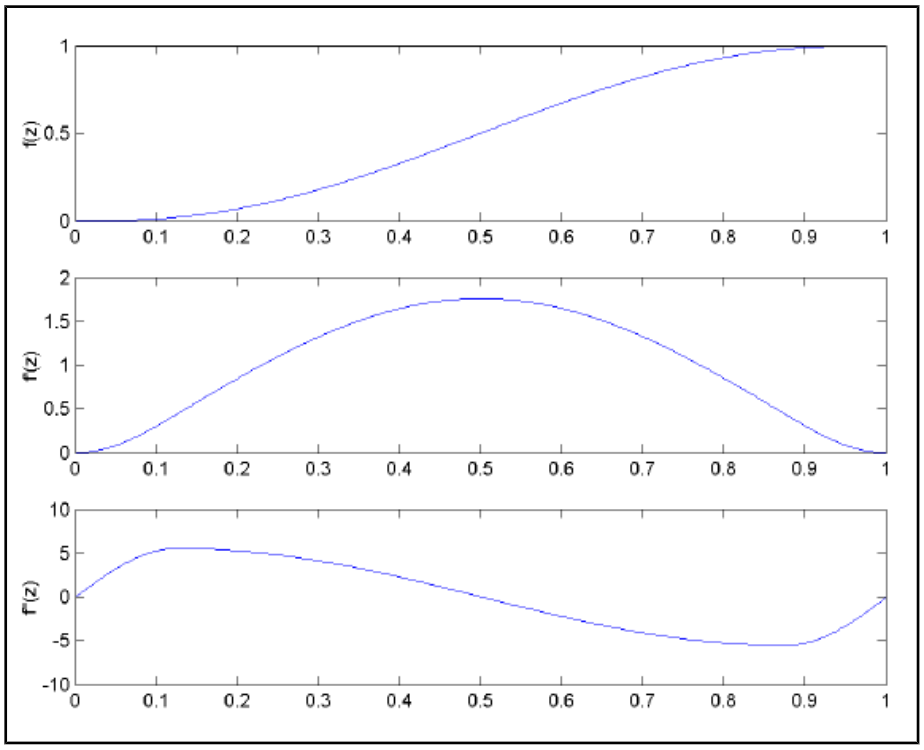

Fig.10-15: Graph: Rest in rest, Modified sine curve

Rest in rest, Modified acceleration trapezoid

Advantages

- Especially low acceleration characteristic value,
- Low inert forces

Disadvantages

- Jerk characteristic value is higher than with 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.10-16: Function: Rest in rest, Modified acceleration trapezoid

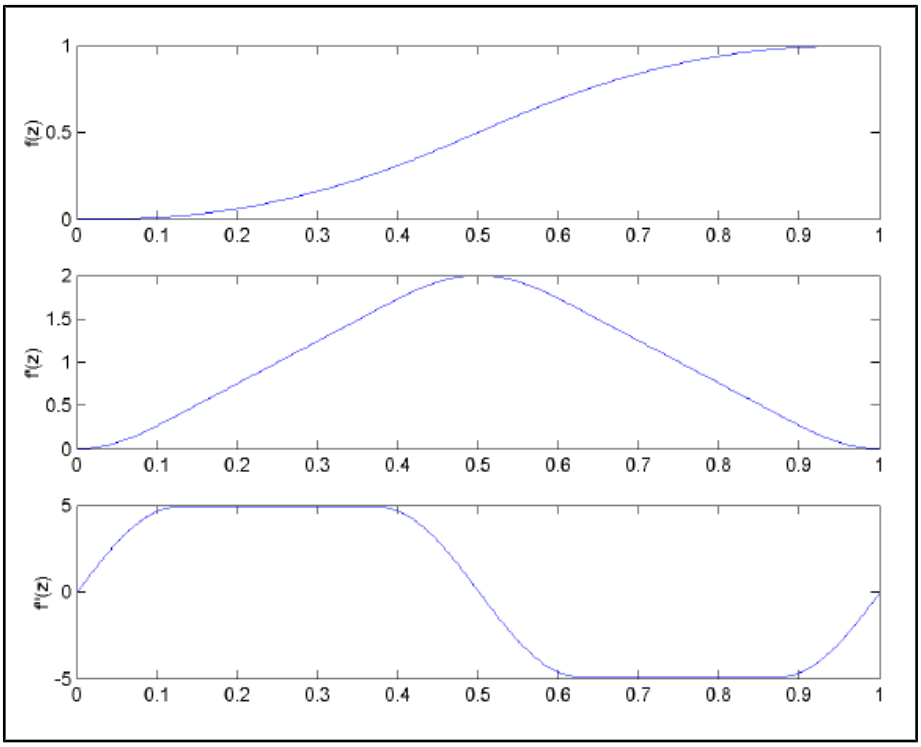

Fig.10-17: Graph: Rest in rest, Modified acceleration trapezoid

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.10-18: Function: Rest in rest, Quadratic parabola

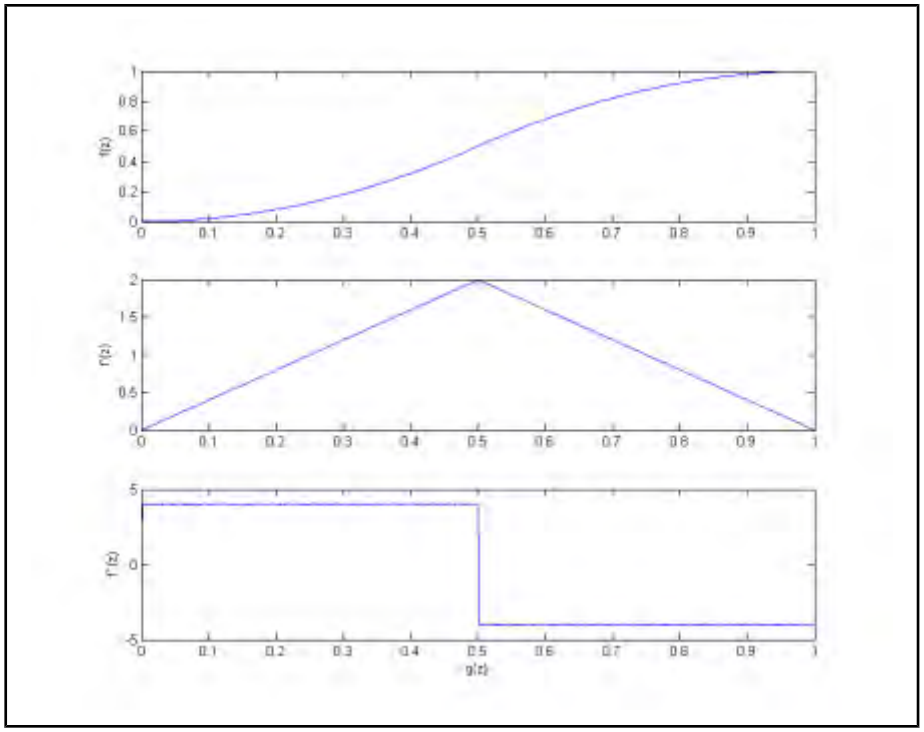

Fig.10-19: Graph: Rest in rest, Quadratic parabola

Rest in rest, Polynomial 5th order

Advantages

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

Disadvantages

- Jerk characteristic value is higher than with the inclined sine curve

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

Fig.10-20: Function: Rest in rest, Polynomial 5th order

Motion Laws

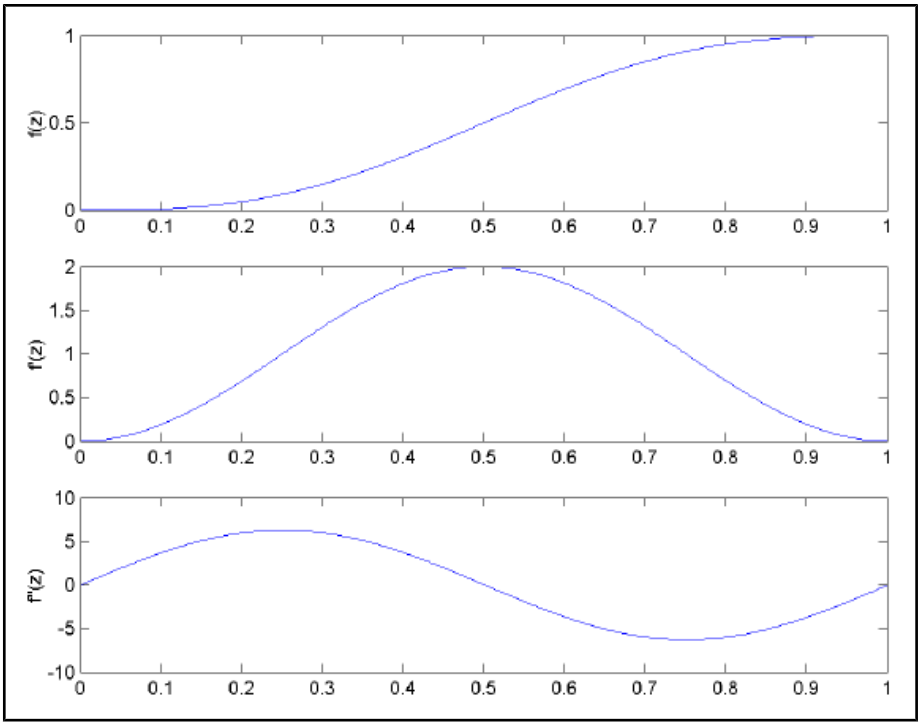

Fig.10-21: Graph: Rest in rest, Polynomial 5th order

Rest in rest, Polynomial 7th order

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

Fig.10-22: Function: Rest in rest, Polynomial 7th order

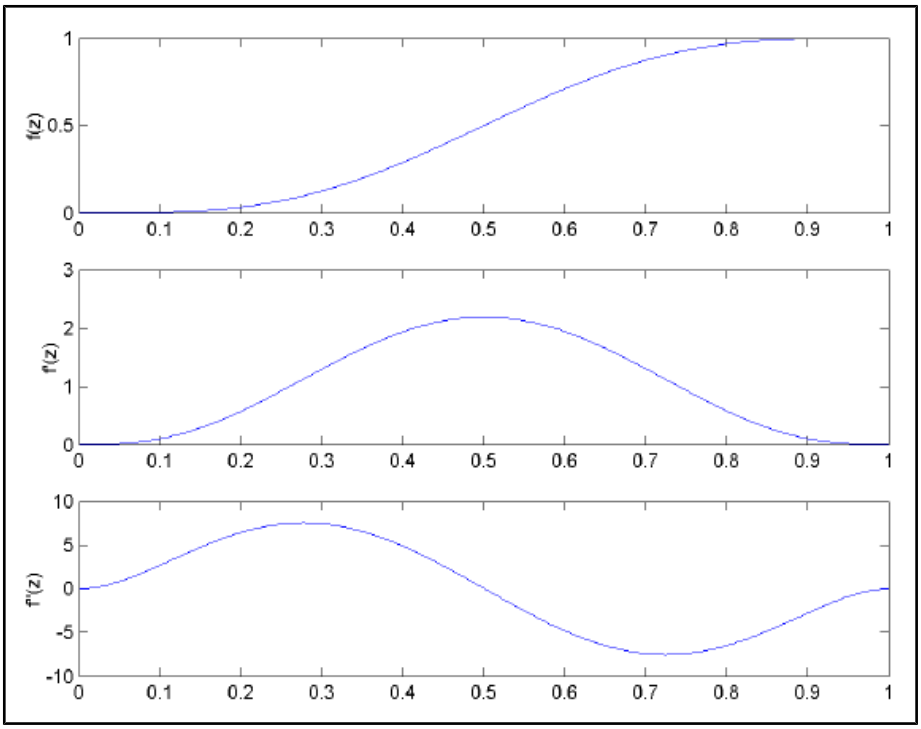

Fig.10-23: Graph: Rest in rest, Polynomial 7th order

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. 10-24: Function: Rest in rest, Polynomial 8th order

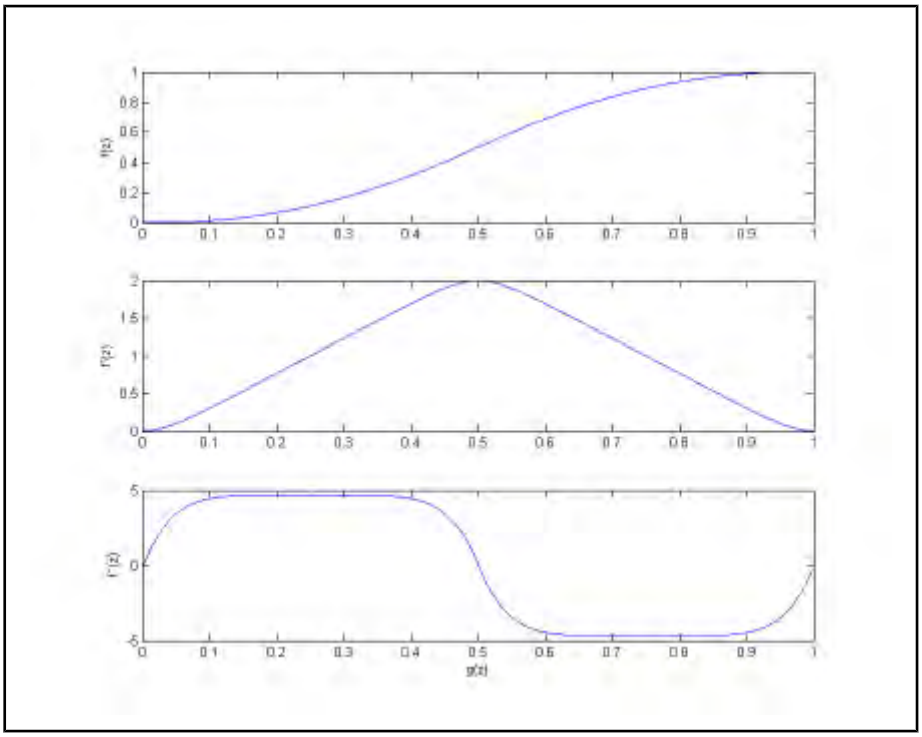

Fig. 10-25: Graph: Rest in rest, Polynomial 8th order

10.2.3 Rest in Velocity

Rest in velocity motion laws are used for impact- 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. 10-26: Function: Rest in velocity, Polynomial 5th order

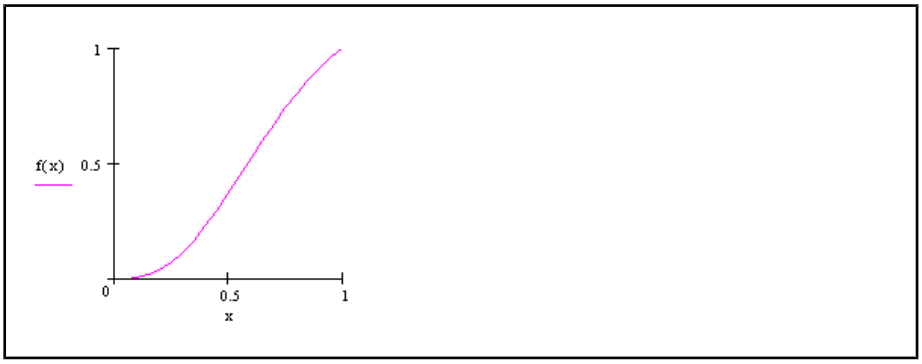

Fig. 10-27: Graph: Rest in velocity, Polynomial 5th order

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. 10-28: Function: Rest in velocity, Polynomial 7th order

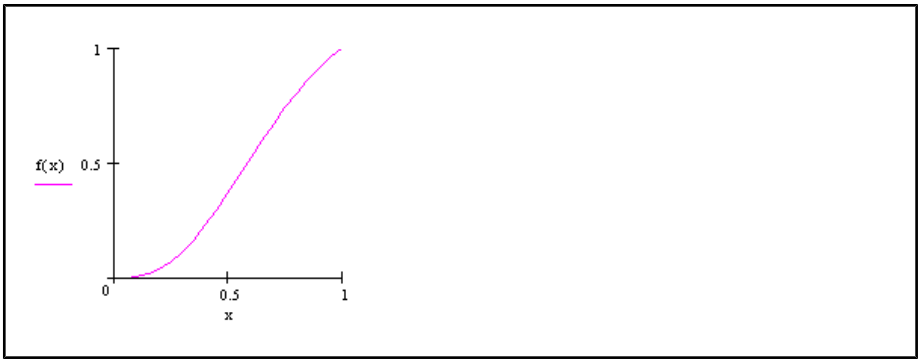

Fig.10-29: Graph: Rest in velocity, Polynomial 7th order

10.2.4 Velocity in Rest

Velocity in velocity motion laws are used for impact- 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.10-30: Function: Velocity in rest, Polynomial 5th order

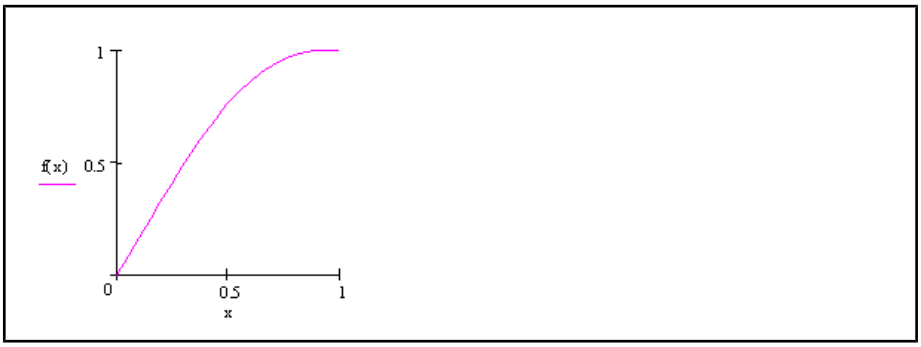

Fig.10-31: Graph: Velocity in rest, Polynomial 5th order

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.10-32: Function: Velocity in rest, Polynomial 7th order

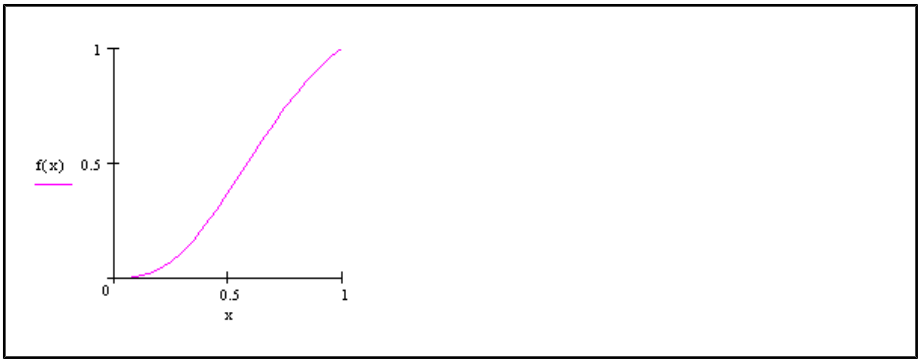

Fig.10-33: Graph: Rest in velocity, Polynomial 7th order

10.2.5 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)

$$f(z) = z$$

Fig. 10-34: Function: Velocity in velocity, Constant velocity

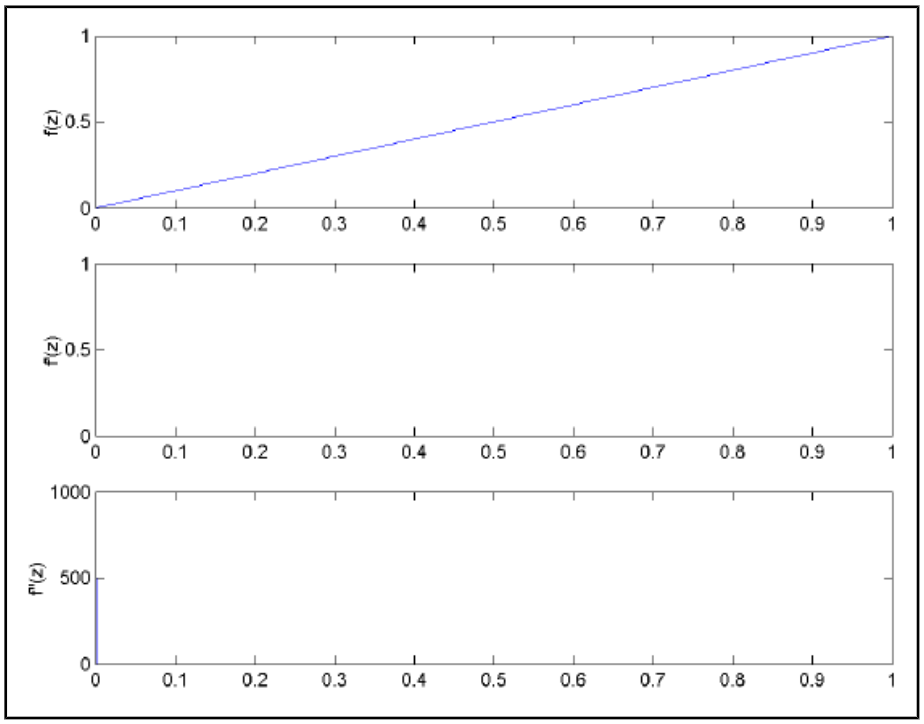

Fig. 10-35: Graph: Constant velocity

Velocity in velocity, 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. 10-36: Function: Velocity in velocity, Polynomial 5th order

Motion Laws

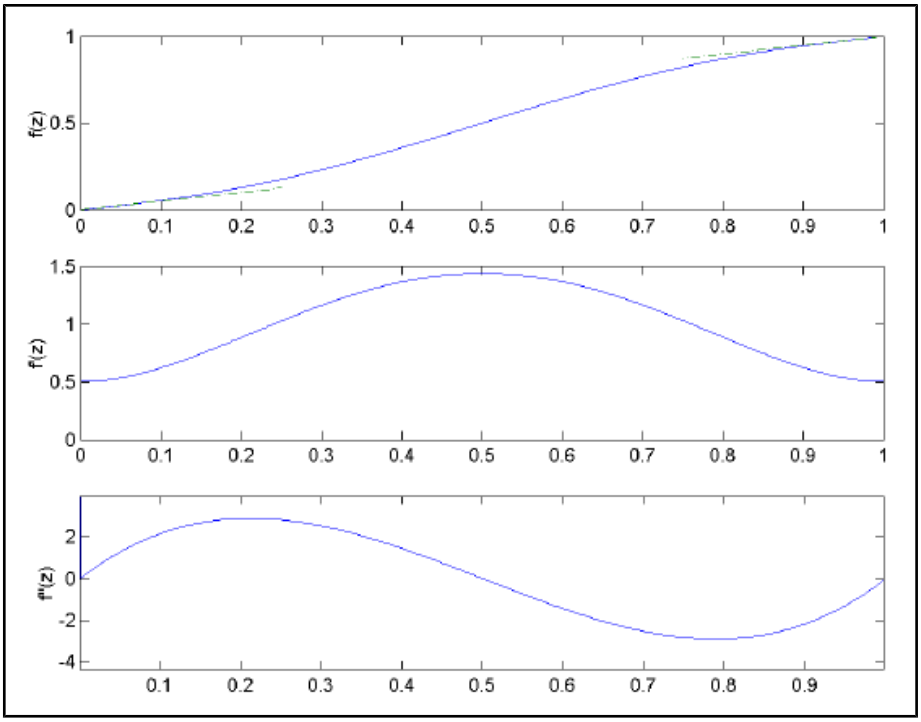

Fig.10-37: Graph: Velocity in velocity, Polynomial 5th order

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.10-38: Function: Velocity in velocity, Polynomial 7th order

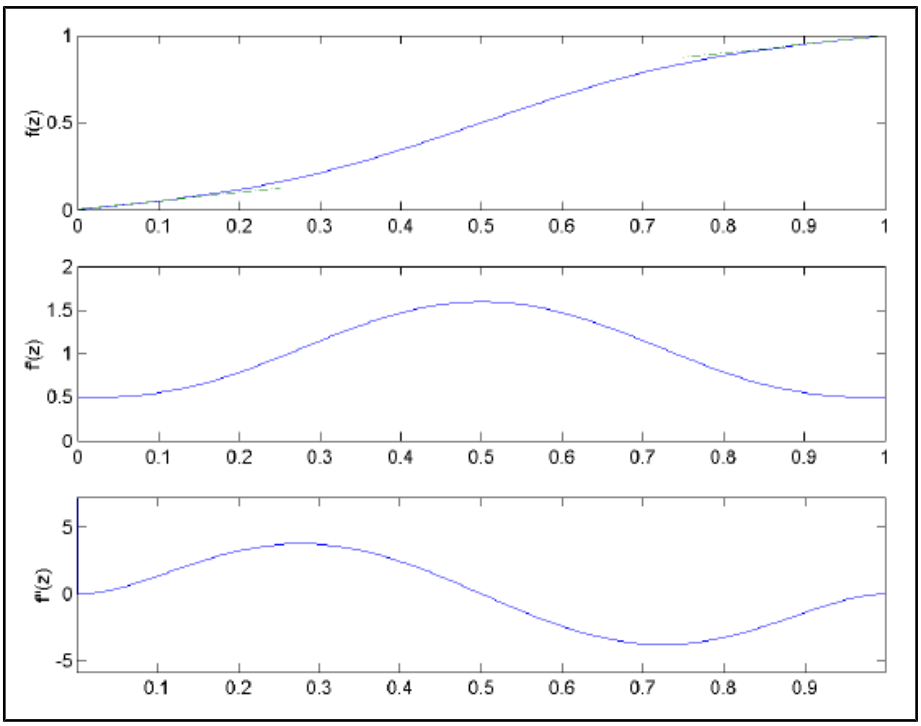

Fig.10-39: Graph: Velocity in velocity, Polynomial 7th order

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. 10-40: Function: Velocity in velocity, Modified sine curve

10.2.6 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. 10-41: Function: General motion, Polynomial 2nd order

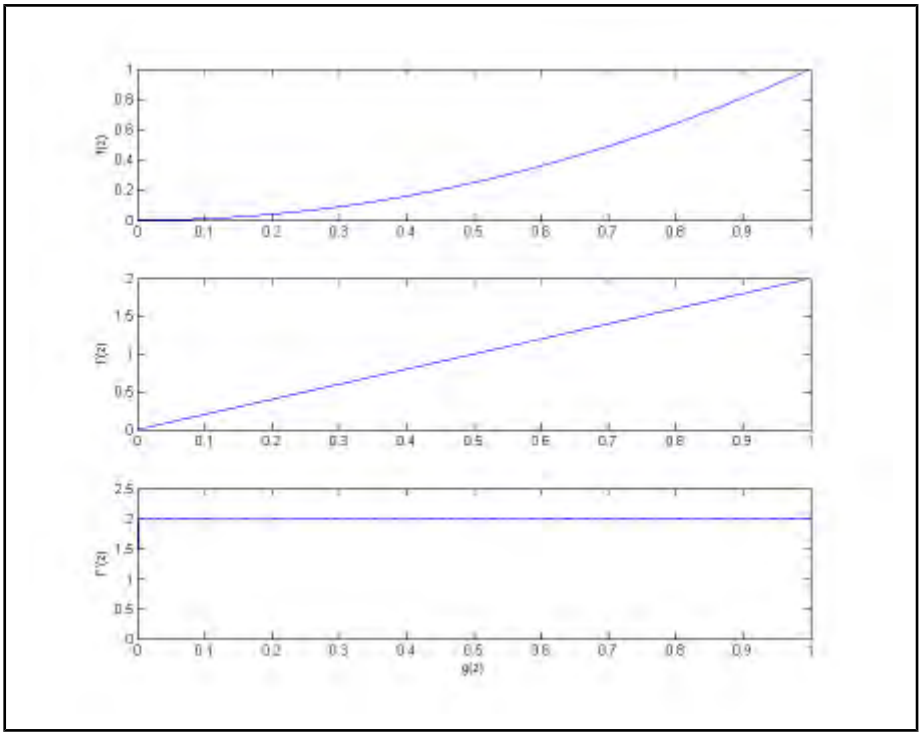

Fig. 10-42: Graph: General motion, Polynomial 2nd order

General motion, Polynomial 3rd order

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

Fig.10-43: Function: General motion, Polynomial 3rd order

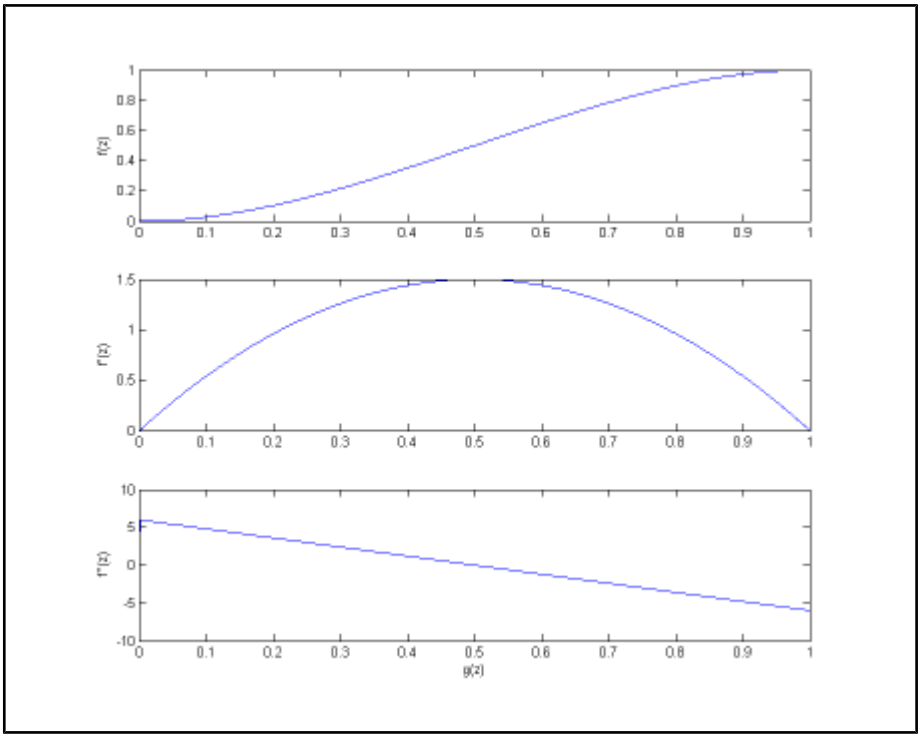

Fig.10-44: Graph: General motion, Polynomial 3rd order

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.10-45: Function: General motion, Polynomial 4th order

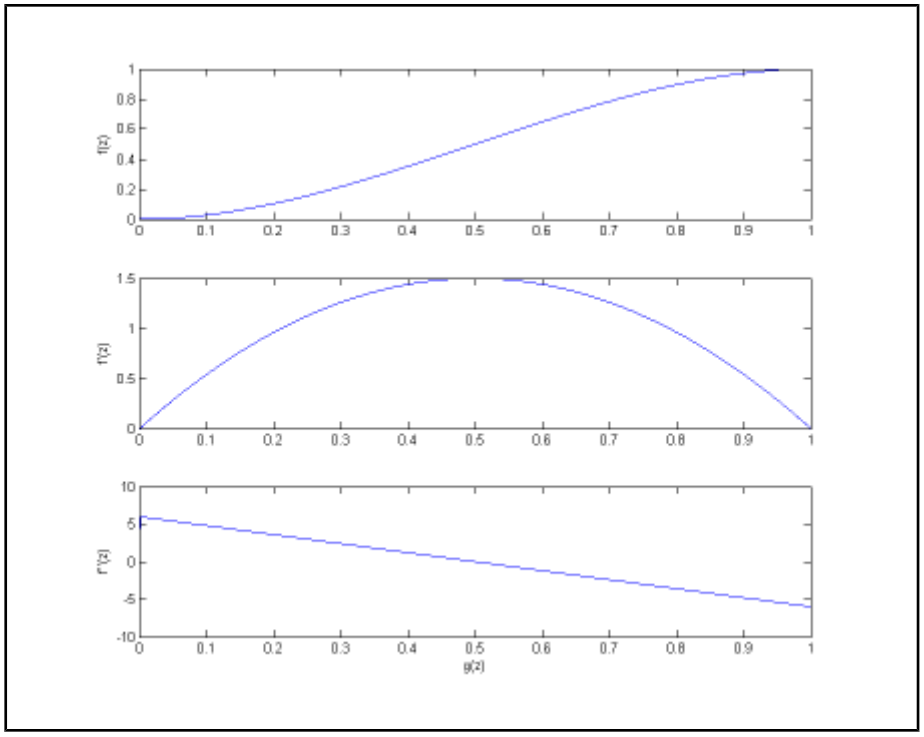

Fig.10-46: Graph: General motion, Polynomial 4th order

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.10-47: Function: General motion, Polynomial 5th order

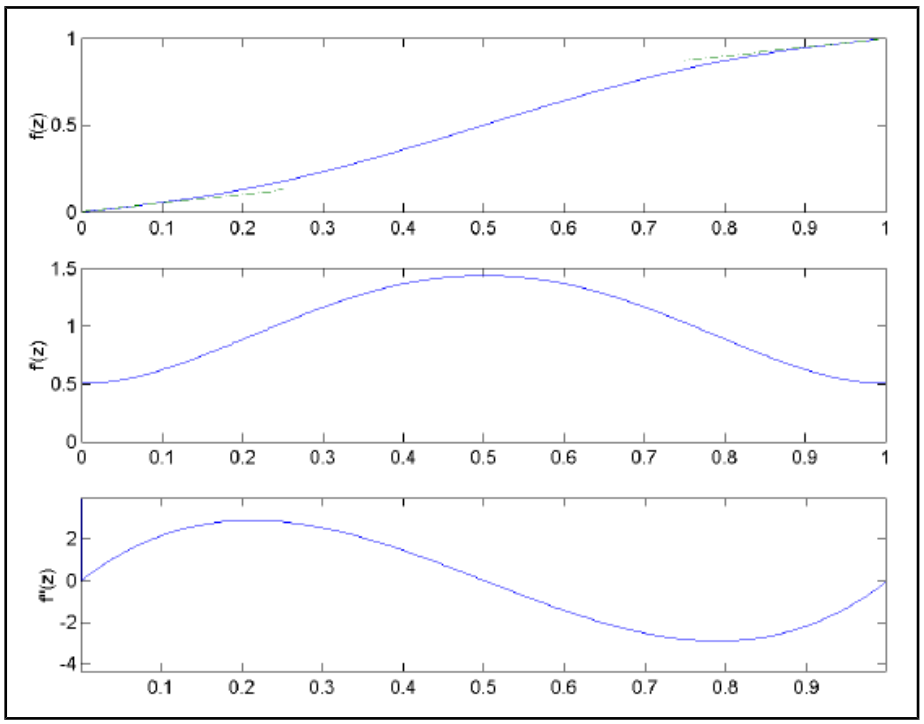

Fig.10-48: Graph: Velocity in velocity, Polynomial 5th order

General motion, Polynomial 7th order

Motion Laws

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

Fig.10-49: Function: General motion, Polynomial 2nd order

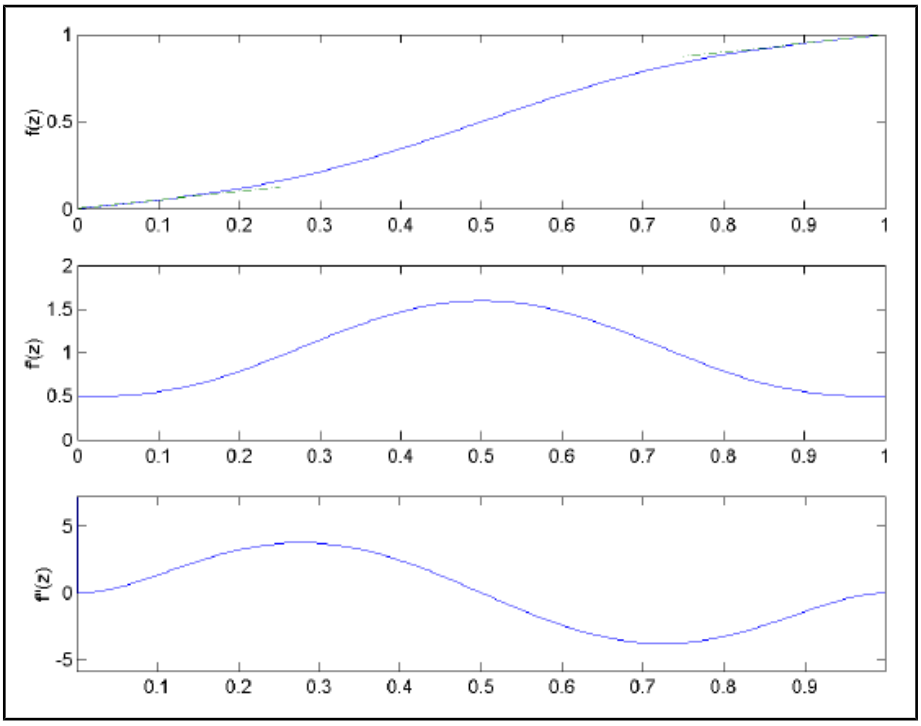

Fig.10-50: Graph: Velocity in velocity, Polynomial 7th order

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.10-51: Function: General motion, Polynomial 8th order

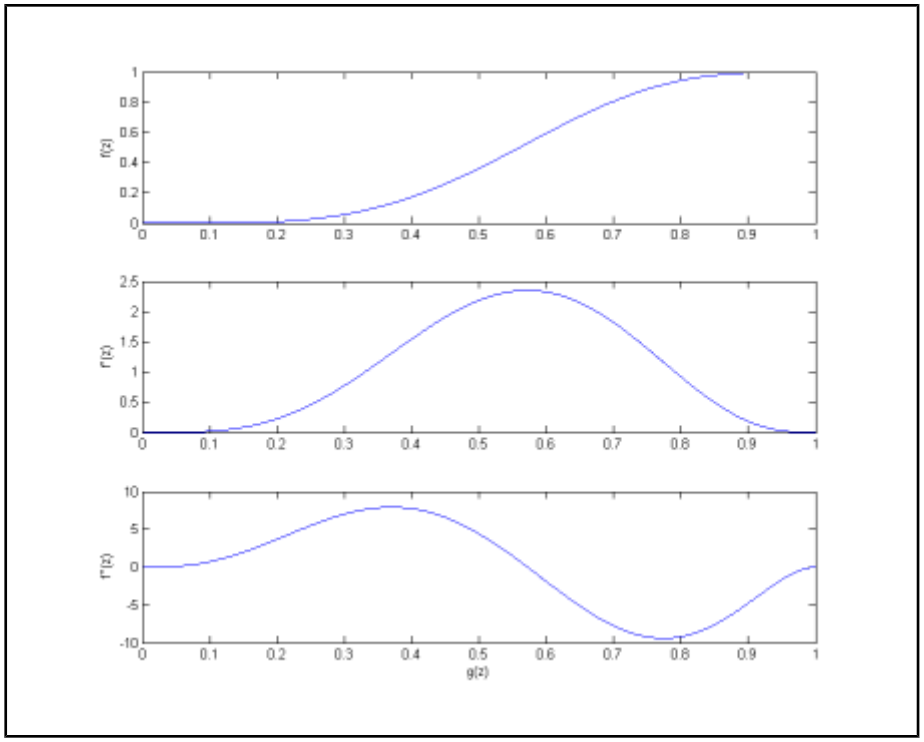

Fig. 10-52: Graph: General motion, Polynomial 8th order

10.2.7 Extended Motion Laws

Resulting stroke

Extended, Linear velocity

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

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

Fig. 10-53: Function: Extended, Linear velocity

Motion Laws

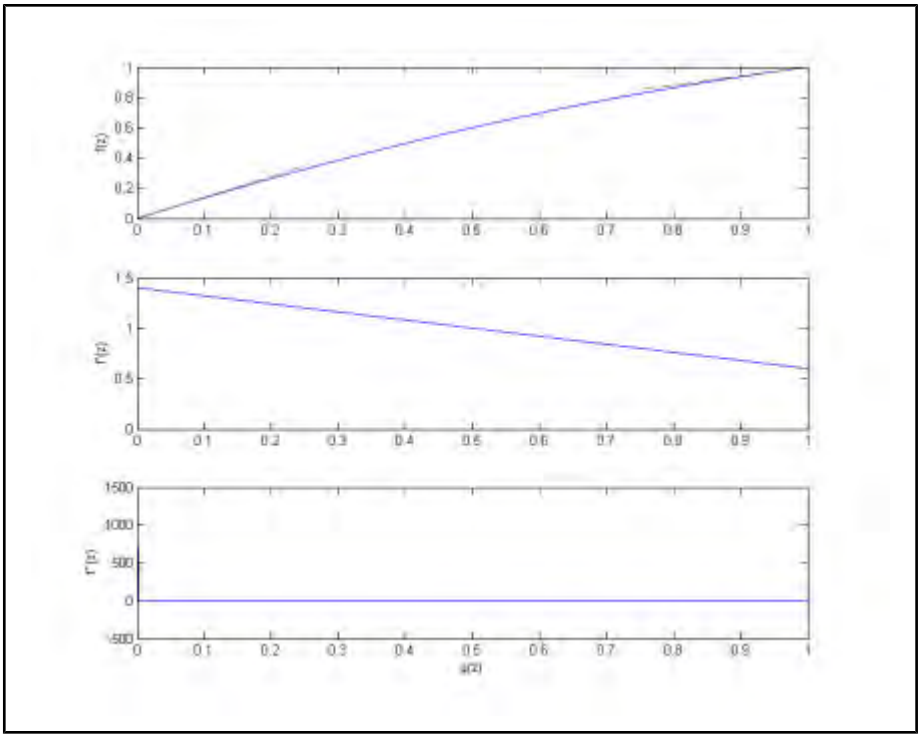

Fig.10-54: Graph: Extended, Linear velocity

Extended, Linear acceleration

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

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

Fig.10-55: Function: Extended, Linear acceleration

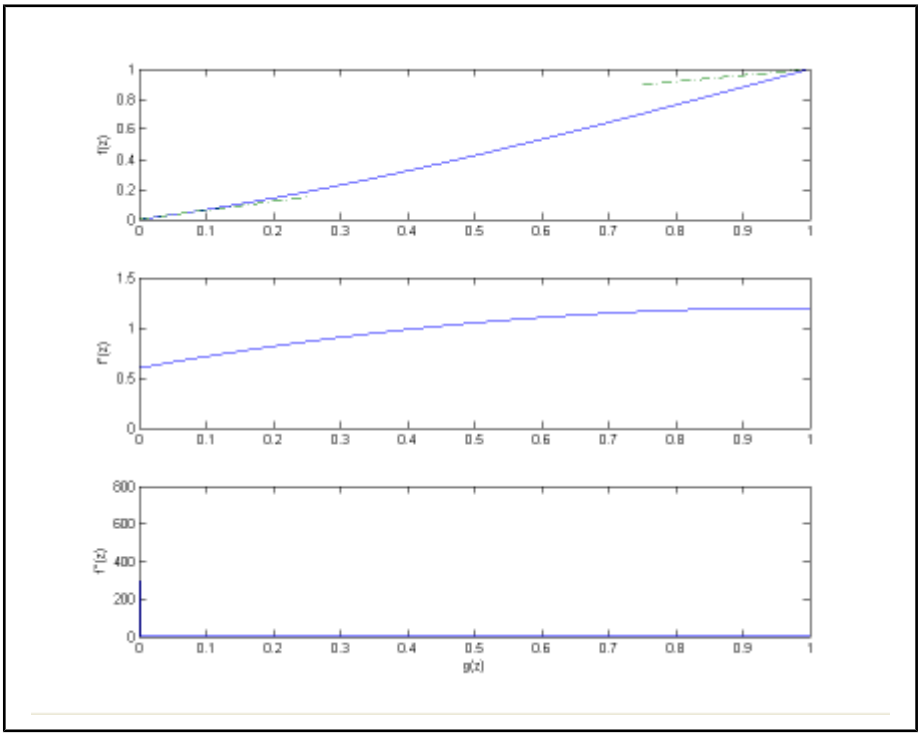

Fig.10-56: Graph: Extended, Linear acceleration

Extended, Velocity 2nd Order (Starting acc. zero)

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

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

Fig.10-57: Function: Extended, Velocity 2nd Order (Starting acc. zero)

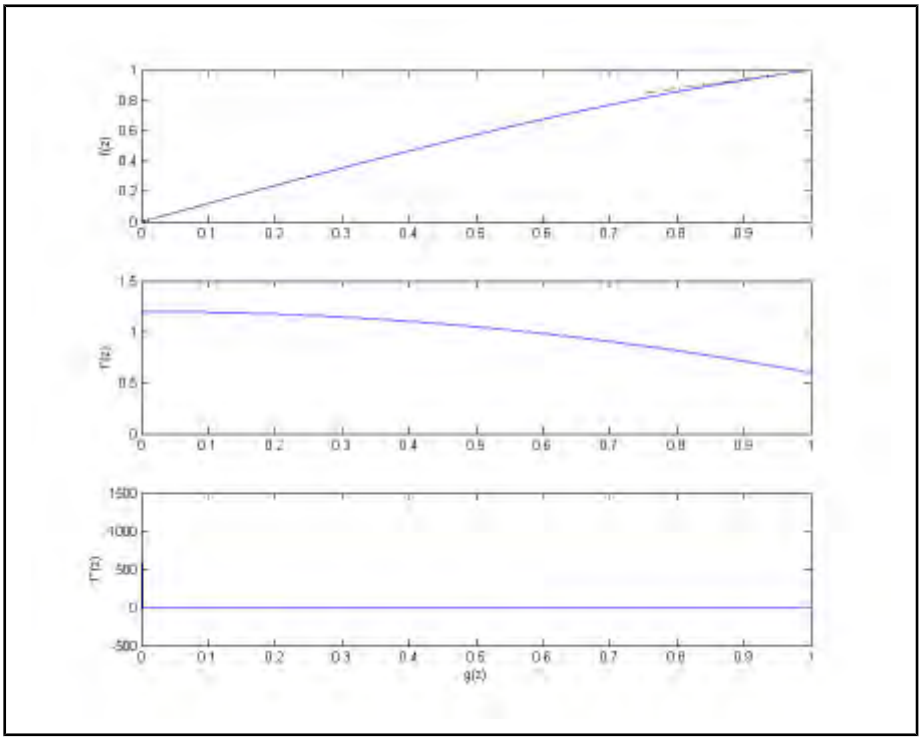

Fig.10-58: Graph: Extended, Velocity 2nd Order (Starting acc. zero)

Extended, Velocity 2nd Order (End acc. zero)

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

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

Fig.10-59: Function: Extended, Velocity 2nd Order (End acc. zero)

Motion Laws

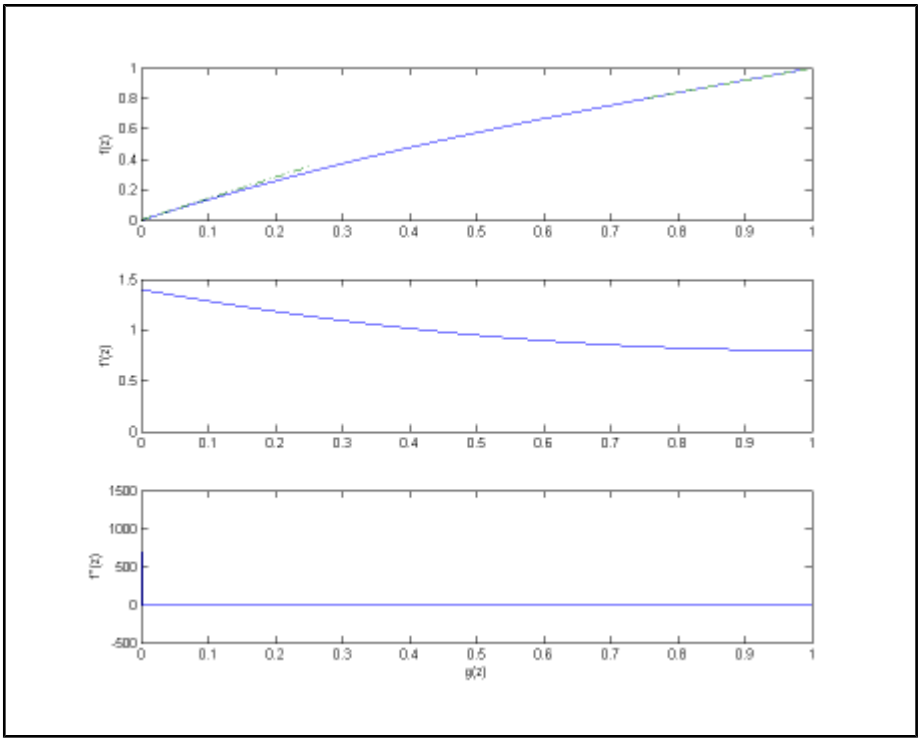

Fig.10-60: Graph: Extended, Velocity 2nd Order (End acc. zero)

Extended, Resulting master axis range

These extended motion laws are special motion laws. They differ from the known motion laws from the VDI guidelines by 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 required. Instead, this is produced 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 velocities to be specified, but not the setting of a master axis range. The latter, and thus also the duration of the motion step, is produced from the values of maximum acceleration and maximum velocity, which can also be specified.

Extended, Acceleration-limited motion (trapezoid profile)

The trapezium profile, often also known as a ramp profile, can be regarded as the simplest form of path interpolation. If a path "s" is to be traveled, the phase in which there is acceleration from a preset acceleration value to a preset travel velocity, into a second phase of constant velocity and then into a braking phase, in which braking is performed at a given 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 variation shown here, 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 velocities can be different to 0, and have different acceleration factors a1 and a3 for the acceleration and braking 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.

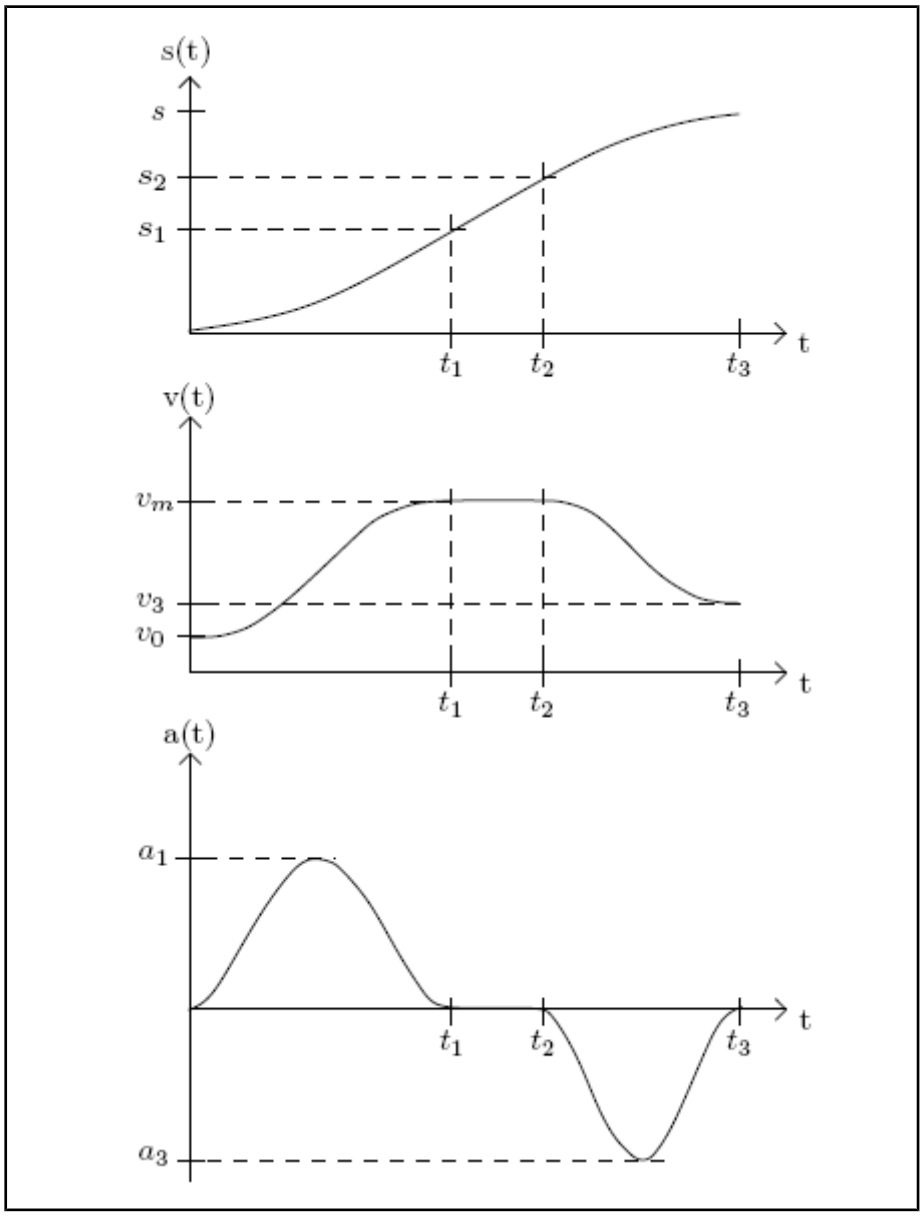

Fig.10-61: Graph: Acceleration-limited motion (sine curve)

Extended, Jerk-limited motion (trapezoid profile)

Maintaining acceleration with jerk-limitation is applicable to many demanding motion tasks. This applies, for example, to the transportation of fluids and to machines easily susceptible to vibration.

Motion Laws

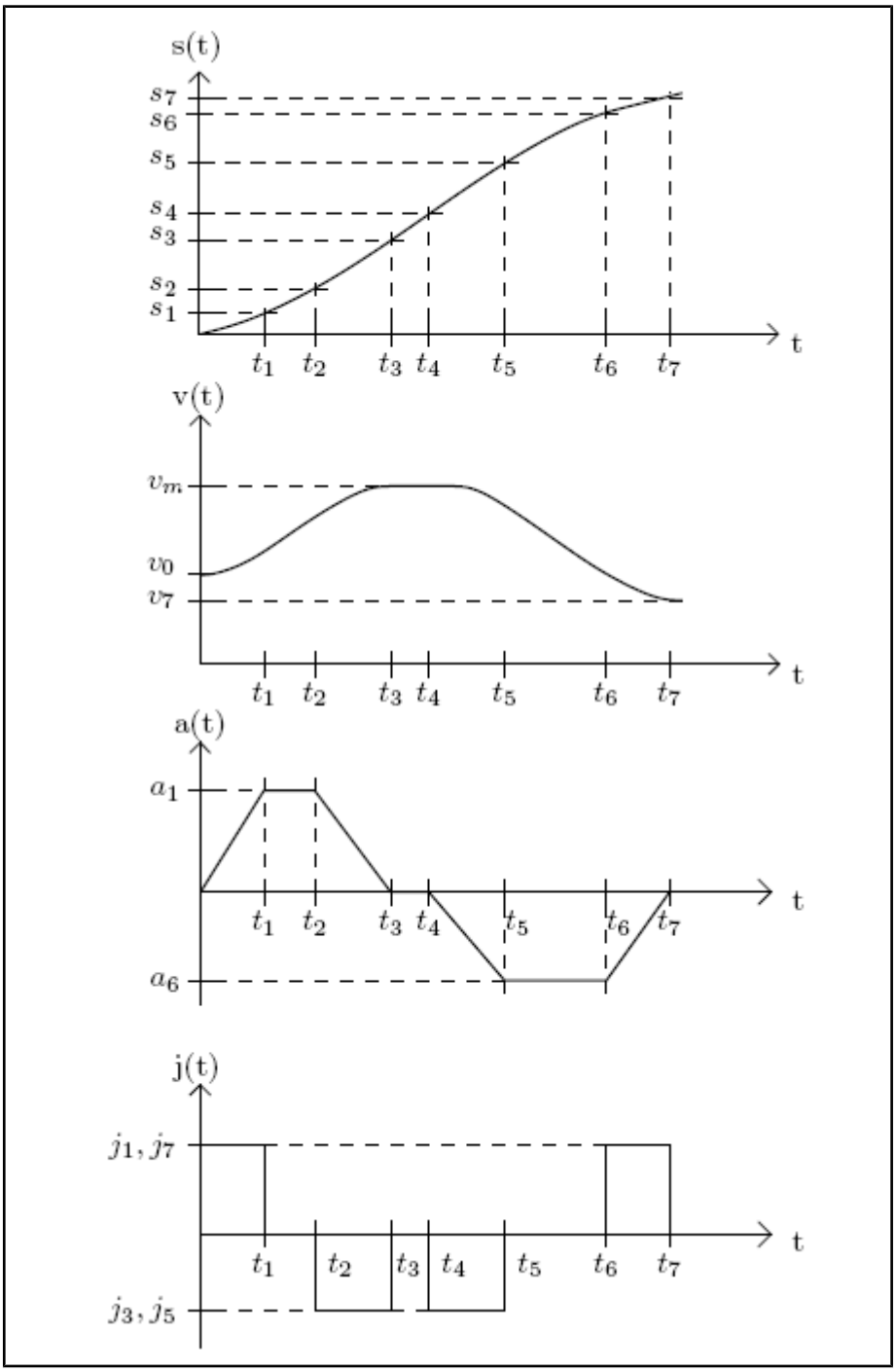

Fig.10-62: Graph: Jerk-limited motion

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 sub-divided 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 of the 5th order. These ensure that there is a smooth transition from the starting and end velocity to the travel 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

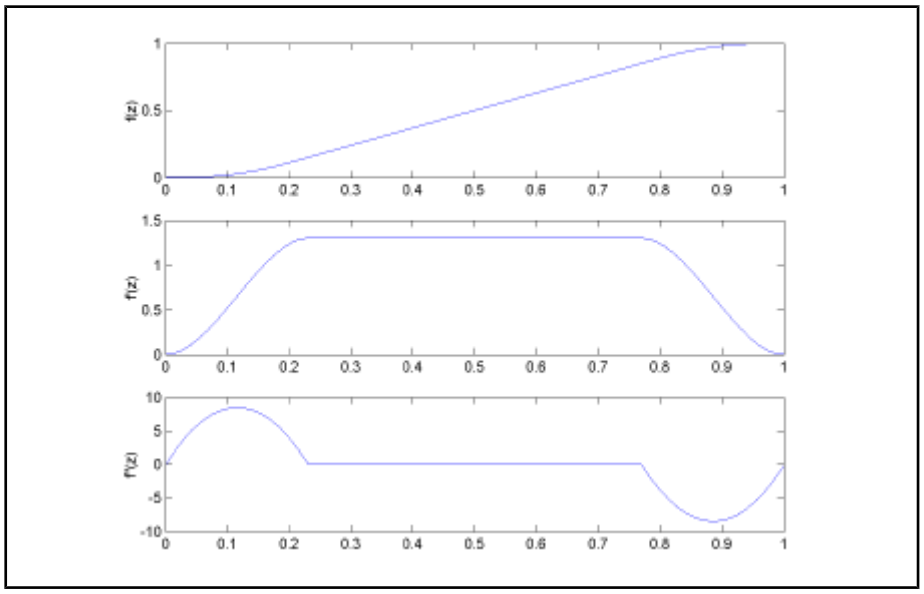

Fig.10-63: Graph: Velocity-limited Polynomial 5th order

Extended, Free of harmonics polynomial 5th order

The Free of harmonics polynomial 5th order recognizes and prevents possible polynomial overvibration. How this is modified, depends on the combination of the normalized velocity limit values. Four cases are produced. 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 prefixes. This would mean that the motion path would have a bend at a limit point, if it was not able to leave the normalized range of 0 <= z <=1 and 0 <=f(z) <= 1.

- Case 1:

  V_0<=1 and V_1<=1

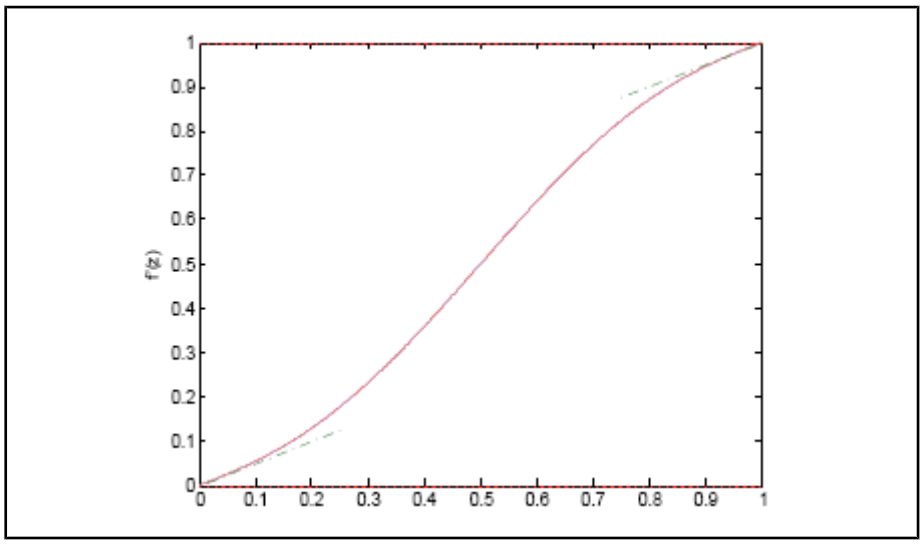

Fig.10-64: Case 1

- Case 2:

  V_0<=1 and V_1>1

Motion Laws

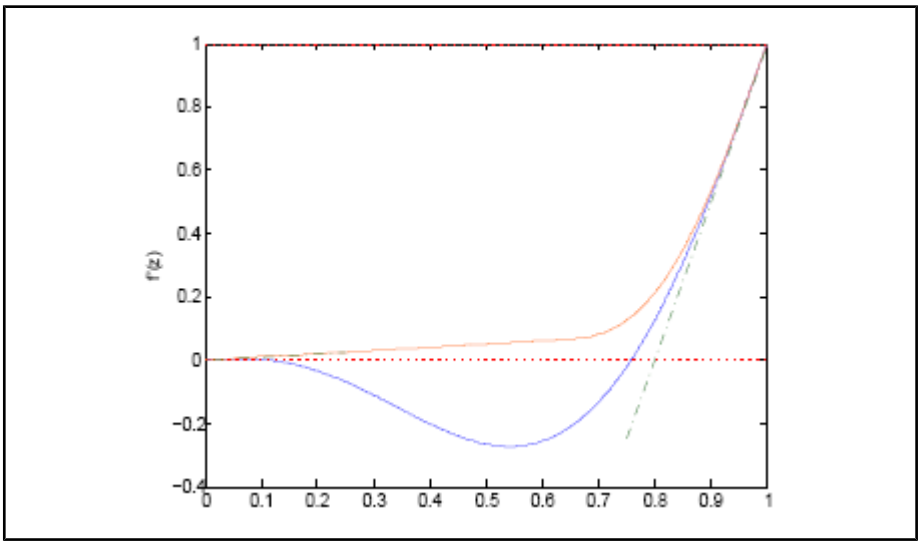

Fig. 10-65: Case 2

- Case 3:

  V_0>1 and V_1<=1

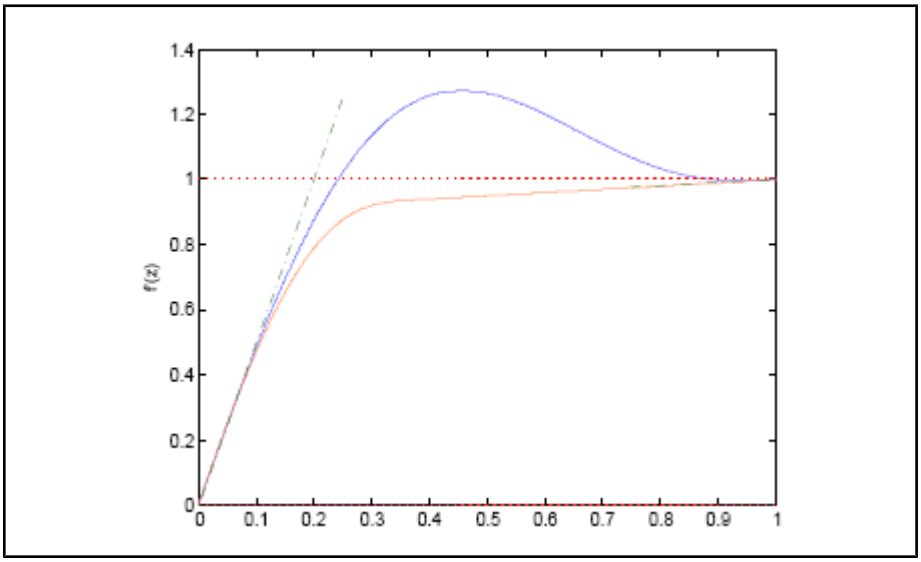

Fig. 10-66: Case 3

- Case 4:

  V_0>1 and V_1>1

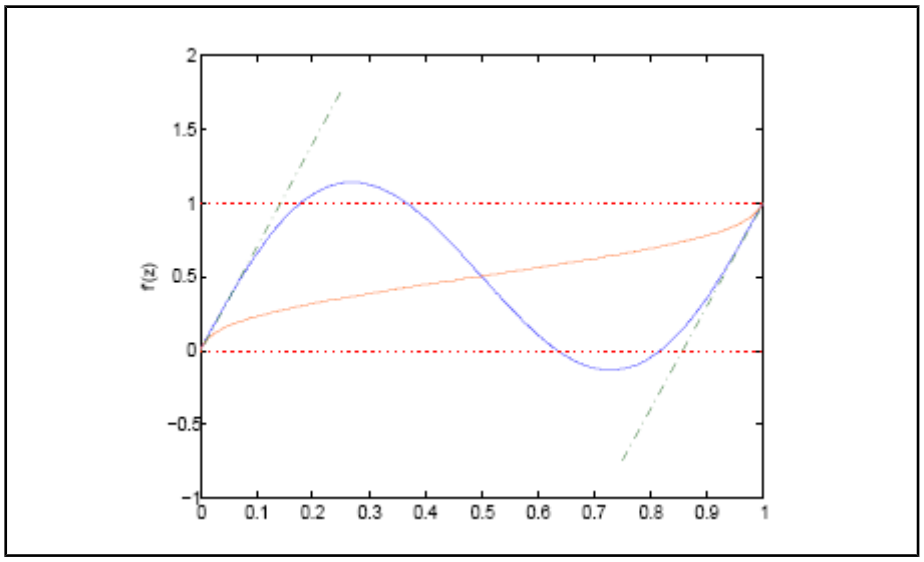

Fig. 10-67: Case 4

10.3 Cam Tables

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

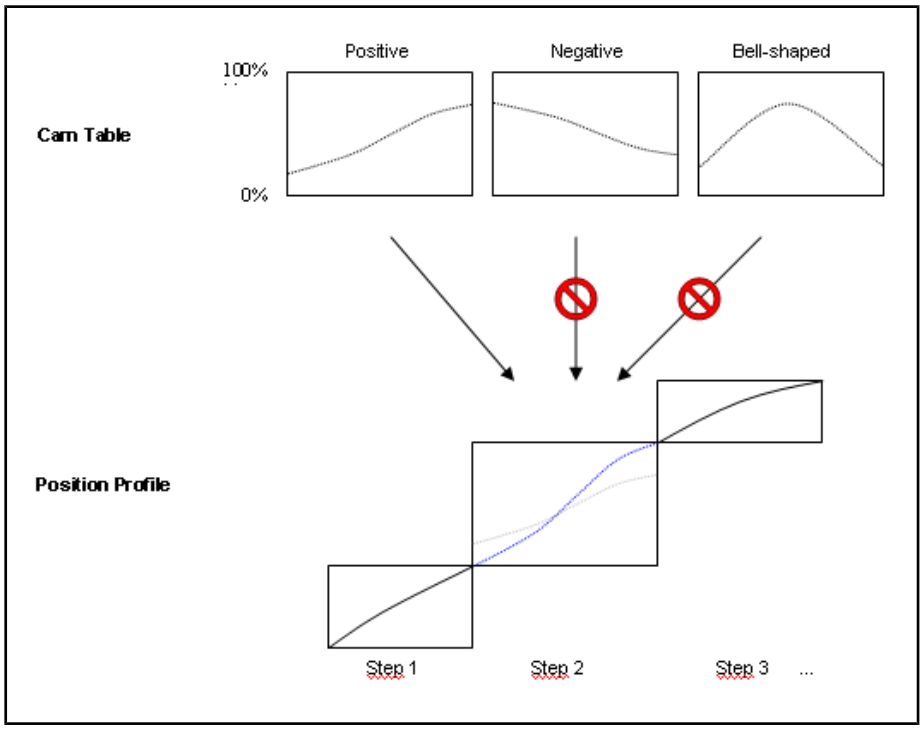

Fig. 10-68: Cam tables supported by the CamBuilder

In order to allocate a cam table to a motion step as a motion law using CamBuilder, the point **Cam Table ▸ Import Cam Table...** has to be selected as a motion law in the Motion Step Editor or an existing imported table will be 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 in the current project

   All the cams of the current project are listed and can be 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 base points have to be created (at least 3, at most 1024.) Moreover, the distance can be specified for calculating the base points (0 corresponds to an automatic distance factor - base points from 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.

A differentiation is made between cams, which consists of one or multiple motion steps, when processing cam tables in the CamBuilder.

Cams consisting of one motion step:

All cam table forms are supported here, that is to say 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 points (e.g. bell). The behavior here is identical to EMP, that is to say that points from the cam table are simply multiplied by the distance (no offset, no scaling).

Cams consisting of multiple motion steps:

Cam tables, the end point of which is 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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Notes

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