MotionDesigner Help

USER MANUAL

PSMotion Ltd

MechDesigner & MotionDesigner 16.1

Reference Manual

by PSMotion Ltd

MechDesigner and MotionDesigner are a superb solution for the design of Cams, Mechanism, and Motion, for multi-axis machines.

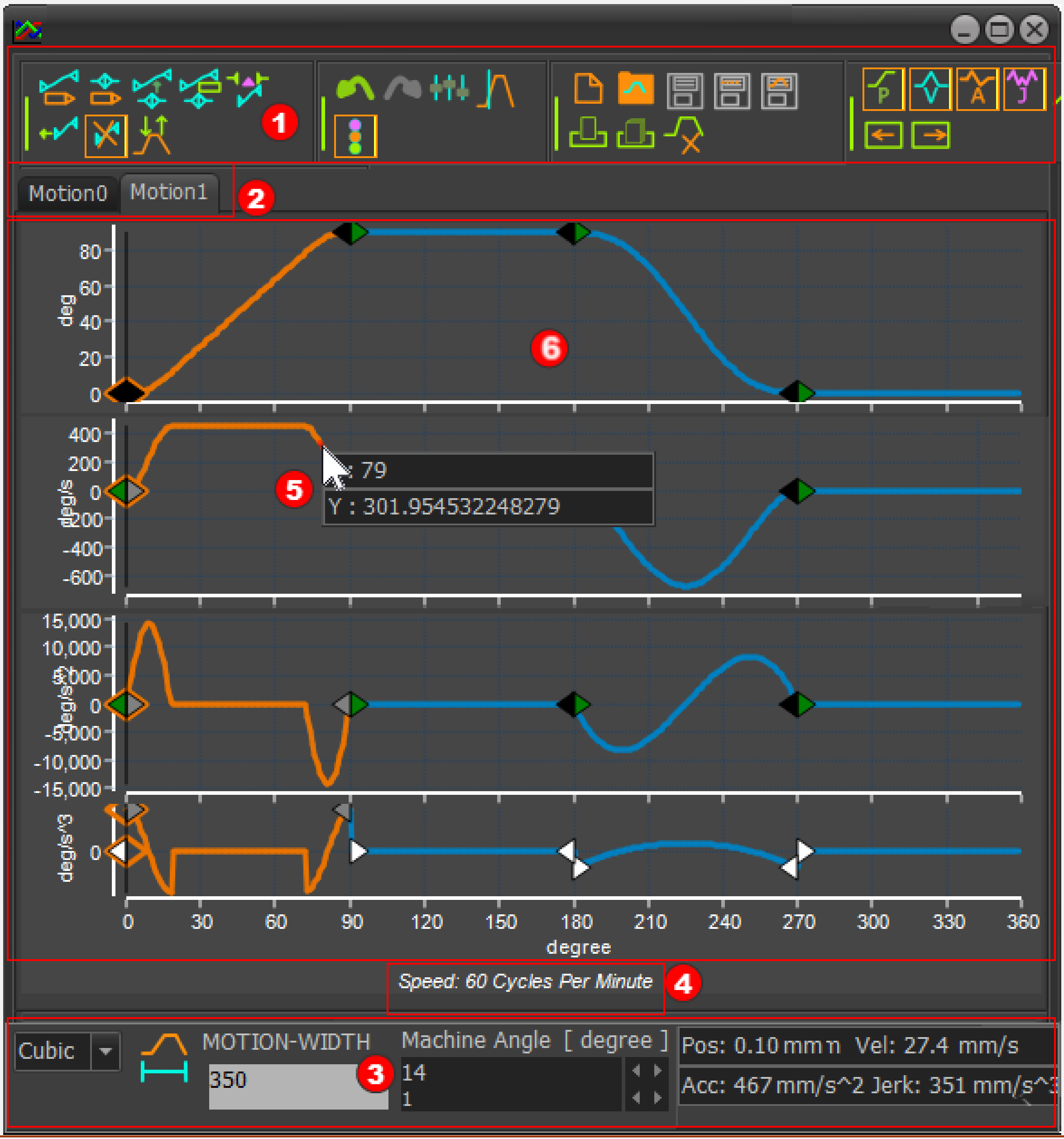
MotionDesigner Reference & User Interface

Use MotionDeisgner to design complex motion for multi-axis machines. The motions can have any number of segments. There are many different Motion-Laws you can select. Many of the Motion-Laws have different segment-parameters that can modify their functionality.

1 MotionDesigner Reference & User Interface

MotionDesigner: Main User Interface

We update the ***MechDesigner*** model immediately as you use the tools to edit a motion in ***MotionDesigner***.



MotionDesigner :

❶ Blend-Point and Segment, Edit, File, and View toolbars (11)

❷ Motion name-tabs (11) - see also Rename Motion (11)

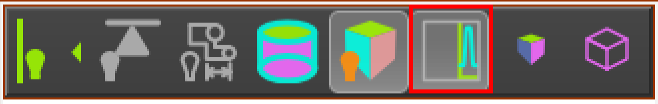
❸ Motion-toolbar (59)

❹ Machine Speed - edit in ***MechDesigner*** > **Edit menu** > **Machine-Settings**

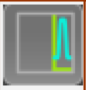
❺ Motion Values at Pointer (12)

❻ Position, Velocity, Acceleration, Jerk (P.V.A.J) Motion-Graphs.

MotionDesigner: Float or Dock.



MECH-Designer -Visibility toolbar > Float or Dock



When you start *MechDesigner*, the ***MotionDesigner*** application is docked to the right of the main application-window.

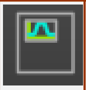
To Float MotionDesigner :

1. Click *MechDesigner* > Visibility toolbar > Dock / Float MotionDesigner.

MotionDesigner is now floating.

The first time only:

2. Re-size and re-position ***MotionDesigner***.

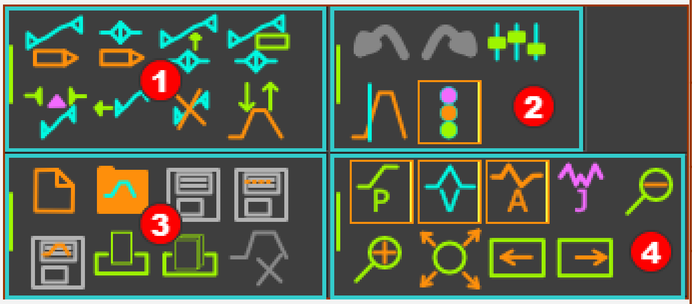


To Dock MotionDesigner :

1. Click *MechDesigner* > Visibility toolbar > Dock / Float MotionDesigner.

MotionDesigner is now docked again to the right of *MechDesigner*'s main application-window.

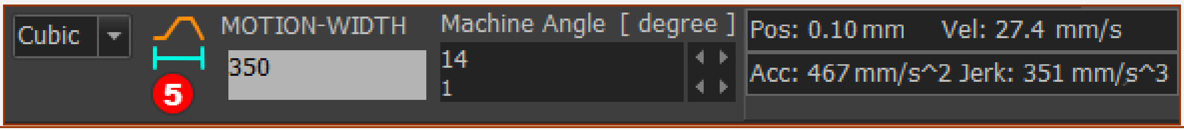
1 MotionDesigner: Toolbars



MotionDesigner toolbars

1. Blend-Point & Segment toolbar [37]
2. Edit toolbar [51]
3. File toolbar [44]
4. View toolbar [56]

5 Motion toolbar [59] (below the graphs)



2 MotionDesigner: Motion name-tabs

4 x Motion name-tabs

Motion name-tabs

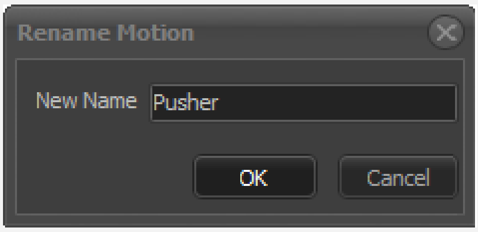
In the image, there are four motion name-tabs - **Y Axis, X Axis, Motion0**, and **Motion1**.

Motion0 and **Motion1** are the default names for a **Motion name-tab** when you do Add Motion [44].

The other two motions have been renamed to **Y Axis** and **X Axis**.

To rename a Motion

1. Right-click a **Motion graph** or its **Motion name tab**
2. Click **Rename** in the pop-up



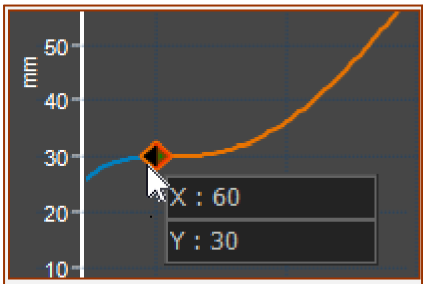
Motion: Rename dialog-box

3. Enter a new name
4. Click the ⊗ at the top and right to close the dialog-box.

OR

1. **Do Edit toolbar > Active Motion-Settings > Motion tab >** [52] MOTION NAME > Motion name [51]

MotionDesigner: Motion-Values at Pointer



1. Move your pointer to a graph, or to a BLEND-POINT.

The X and Y motion-values show under your pointer.

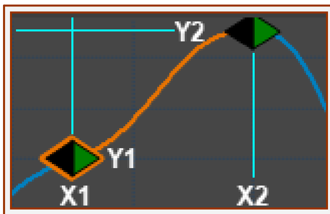
See also: Motion-Value Evaluator [60].

Note: It may help you to increase the LINE-THICKNESS [51] (of the graphs) and increase SYMBOL-SIZE [51] (of the BLEND-POINTS).

1.1 Terminology and Symbols

MotionDesigner Terminology:

SEGMENTS :



A Segment

A motion is split into SEGMENTS.

Each SEGMENT has a duration (also called its period).

The duration is specified by its SEGMENT-WIDTH parameter.

The SEGMENT-WIDTH is measured on the **X-axis**.

In the image above, the SEGMENT-WIDTH of the SEGMENT is the period from **X1** at its start to **X2** at its end.

Each SEGMENT has **Y-axis** values that we define at its start and its end

In the image above, the motion-values are **Y1** at its start (**X1**), and **Y2** at its end (**X2**).

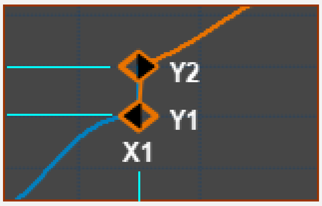
Note that the motion-values are defined for all motion-derivatives - **P.V.A.J.**

Each SEGMENT has a **Motion-Law**.

The **Motion-Law** specifies the motion-values **between X1,Y1** and **X2,Y2**.

Use the SEGMENT EDITOR to specify the motion-values at **X1,Y1** - at the **Start of the Selected-Segment**, and at **X2,Y2** - at the **End of the Select-Segment.**

BLEND-POINTS :



A Blend-Point

BLEND-POINTS do not have a SEGMENT-WIDTH. They have one value on the **X-axis**.

In the image, the BLEND-POINT is at **X1**.

Each BLEND-POINT has TWO **Y-axis** motion-values, for EACH motion-derivative **P,V,A, J**.

In the image, the motion-values are **Y1** at the **End of the** PREVIOUS-SEGMENT, and **Y2** at the **Start of the** SELECTED-SEGMENT (X1,Y2).

For each motion-derivative, the two motion-values can be forced to be different or equal to each other.

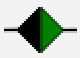
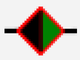
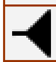
Use the BLEND-POINT EDITOR to specify the motion-values at **X1,Y1 -** the **End of Previous-Segment**, and **X1,Y2** - the **Start of Selected-Segment**.

Other Important Terminology

MOTION-LAW :	You must select a **Motion-Law** for each SEGMENT. The **Motion-Law** should be able to satisfy the motion requirements for your design. Each **Motion-Law** is a mathematical function. The **Motion-Law**, together with the motion-values at its BLEND-POINTS, specify the motion-values between each BLEND-POINT.
MOTION-DERIVATIVE :	**Velocity**, **Acceleration**, and **Jerk** are the first, second, and third motion-derivatives of **Position**.
SEGMENT EDITOR :	Use the SEGMENT EDITOR to edit the SEGMENT-WIDTH, to select the Motion-Law, to edit the SEGMENT-PARAMETERS, and to edit the motion-values at the **Start of the Selected-Segment**(Y1) and at the **End of the Selected-Segment**(Y2).
BLEND-POINT EDITOR :	Use the BLEND-POINT EDITOR to edit the **X-axis motion-value**(X1) for the BLEND-POINT that is at the start of the SELECTED-SEGMENT. Edit the **Y-axis motion-values** at the **End of the Previous-Segment**(Y1) and at the **Start of the Selected-Segment** (Y2)
SELECTED-SEGMENT :	The active segment. It is a different color to the other segments.
PREVIOUS-SEGMENT :	The SEGMENT that precedes (is to the left of / is earlier than / is before) the SELECTED-SEGMENT. If the SELECTED-SEGMENT is the first SEGMENT, then the **PREVIOUS-SEGMENT** is the last **SEGMENT**.
NEXT-SEGMENT :	The SEGMENT that follows (is to the right of / is later than / is after) the SELECTED-SEGMENT. If the SELECTED-SEGMENT is the last SEGMENT, then the **NEXT-SEGMENT** is the first SEGMENT.
END OF THE PREVIOUS-SEGMENT :	Refers to the last motion-value of the segment that is to the left of the SELECTED-SEGMENT. If the SELECTED-SEGMENT is the

	first segment in the motion, then the End of the **PREVIOUS-SEGMENT** refers to the motion-value at the end of the motion.

Blend-Point Symbols

<table>
<tr><td colspan="2">Each BLEND-POINT has a one(1) X-axis value. It is the instant on the X-axis when a segment ends and the next segment starts.
The symbol for a BLEND-POINT is the shape of a diamond. The diamond shape is actually two(2) triangles.</td></tr>
<tr><td></td><td>BLEND-POINT - the symbol is two triangles. Each triangle is a symbol for the end of a segment and the start of a segment.</td></tr>
<tr><td></td><td>ACTIVE BLEND-POINT - has an outline. The BLEND-POINT has Y-axis motion-values at the START OF THE SELECTED SEGMENT AND at the END OF THE PREVIOUS-SEGMENT.</td></tr>
<tr><td></td><td>The START OF A SEGMENT. The symbol may be GREEN, BLACK, CLEAR, or GREY.</td></tr>
<tr><td></td><td>The END OF A SEGMENT. The symbol may be BLACK, CLEAR or GREY.</td></tr>
<tr><td colspan="2">Note: To increase the size of the symbols, see: Active-Motion-Settings > Accessibility > Line and Symbol Sizes > Symbol Size. 53</td></tr>
</table>

1.2 BLEND-POINT (NODE) EDITOR

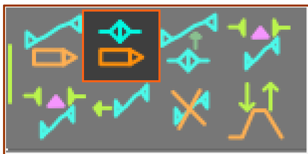
BLEND-POINT (NODE) EDITOR

See also: SEGMENT EDITOR [25].

How to open the BLEND-POINT EDITOR

There is one method to open the the **BLEND-POINT-EDITOR:**

METHOD 1: Use the toolbar



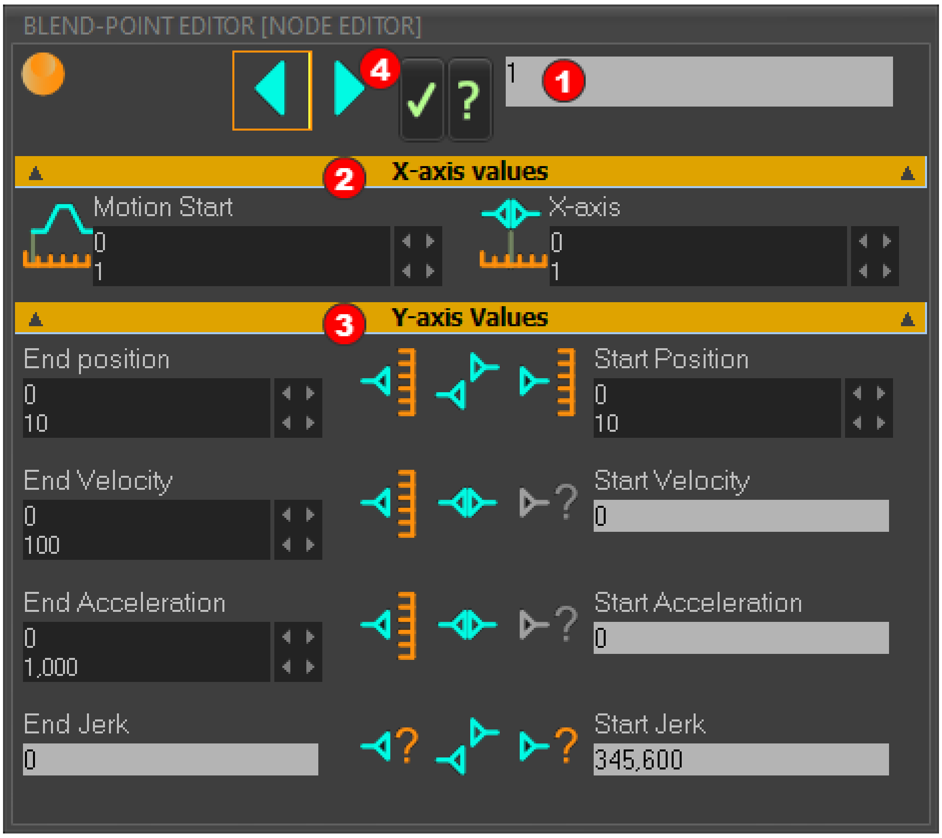
Blend-Point Editor icon

1. Click **Blend-Point & Segment toolbar > Open Blend-Point Editor**

The **BLEND-POINT EDITOR** is now open.

BLEND-POINT EDITOR

We update the model immediately as you edit motion-values with the **BLEND-POINT EDITOR**.



BLEND-POINT EDITOR

BLEND-POINT NUMBER ❶

The **BLEND-POINT NUMBER** is the number of the **active BLEND-POINT**, which is at the start of the **SELECTED-SEGMENT**.
The **BLEND-POINT NUMBER** indicates to which **BLEND-POINT** the motion-values in the **BLEND-POINT EDITOR** apply.

X-AXIS VALUES ❷ - See Blend-Point - X-axis Controls [17]

Summary

These parameters do NOT change the MOTION-WIDTH. However, **see** **Warning** [17].

MOTION START **(default = 0)**

Edit to advance (make earlier) or delay (make later) the motion relative to **0** on the **X-axis.**

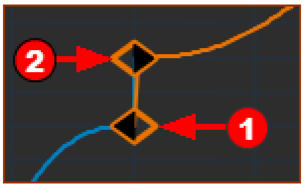
X-AXIS

Edit to move the **active** BLEND-POINT along the **X-axis** (at the start of the SELECTED-SEGMENT)

Units: **See** **Active-Motion-Settings > Motion tab > Motion Units** [51]

Y-AXIS VALUES ❸ - **See** **Blend-Point - Y-axis Controls** [19]

Summary



The BLEND-POINT EDITOR can edit the motion-values at the:

❶ **End of the** PREVIOUS-SEGMENT

AND / OR at the:

❷ **Start of the** SELECTED-SEGMENT

The motion-derivatives (P V A J) you can edit are a function of the:

- Motion-Law [36]
- Y-axis Control-Buttons settings [29].

To use the BLEND-POINT EDITOR efficiently, it is important to understand how to use the **Y-axis Control-Buttons** for each **motion-derivative.**

PREVIOUS / NEXT / OK / HELP **buttons** ❹

Make the PREVIOUS-SEGMENT be the SELECTED-SEGMENT

Make the NEXT-SEGMENT be the SELECTED-SEGMENT

Close the BLEND-POINT EDITOR and to apply the new motion-values to the active Blend-Point.

Open the MotionDesigner contextual help

1.2.1 Blend-Point Editor: X-axis Values

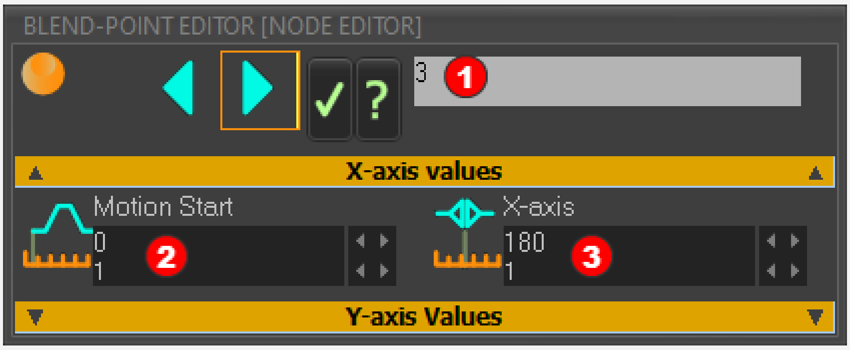
BLEND-POINT EDITOR : X-AXIS VALUES

When you edit the X-AXIS value of a BLEND-POINT, you change the SEGMENT-WIDTH of the PREVIOUS-SEGMENT and the SELECTED-SEGMENT.

You do NOT change the MOTION-WIDTH.

However, please read this Warning [17].

X-AXIS VALUES



X-axis values of Blend-Point #3

MOTION START ❷

Edit to move the motion relative to the MASTER MACHINE ANGLE

The MOTION-WIDTH does not change.

X-AXIS ❸

Edit to move the X-AXIS value of BLEND-POINT NUMBER❶ (3 in this image) along the X-AXIS - however, see SPECIAL CASE and WARNING

The X-AXIS values of the other BLEND-POINTS do not move - however, see WARNING

SPECIAL CASE: X-AXIS value if BLEND-POINT NUMBER = 1

If BLEND-POINT NUMBER = #1

- You CANNOT edit its X-AXIS value
- Its X-AXIS value is always equal to the MOTION-START value.

However:

If you **attempt** to increase its X-AXIS value (move it to the right) ...

... you will increase the SEGMENT-WIDTH [28] of the PREVIOUS-SEGMENT* and decrease the SEGMENT-WIDTH of the SELECTED-SEGMENT (see WARNING).

If you **attempt** to decrease its X-AXIS value (move it to the left) ...

... you will decrease the SEGMENT-WIDTH of PREVIOUS-SEGMENT* and increase the SEGMENT-WIDTH of the SELECTED-SEGMENT (see WARNING).

* : in this special-case, the PREVIOUS-SEGMENT is the last segment in the motion.

WARNING: Bumping Blend-Points !

You can **bump** a BLEND-POINT into an adjacent BLEND-POINT as you edit its X-AXIS value.

If you do this:

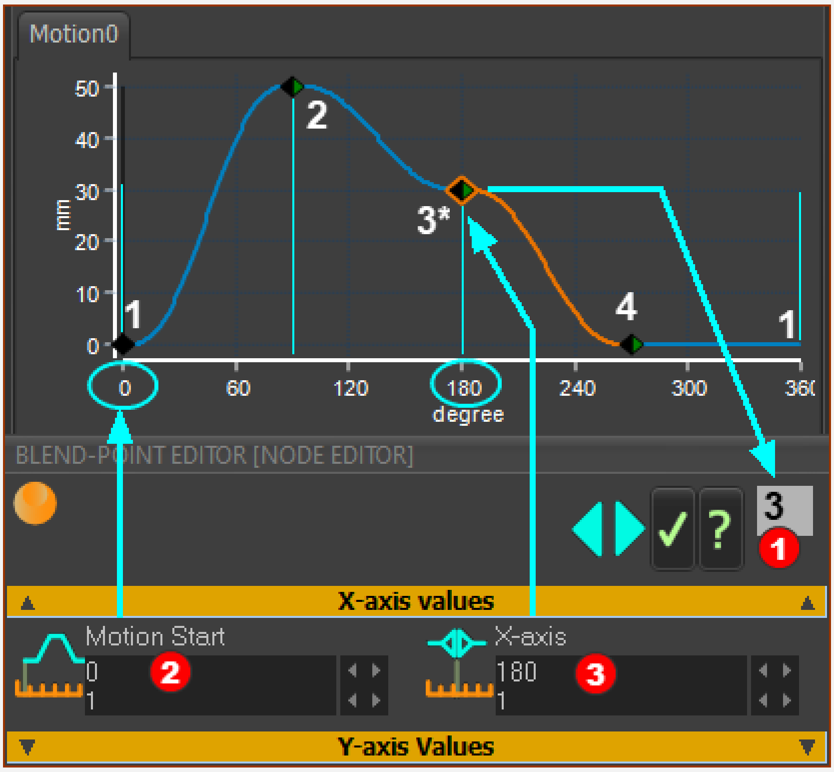
- the active BLEND-POINT AND the adjacent BLEND-POINT move together along the X-axis
- the SEGMENT-WIDTH of the PREVIOUS-SEGMENT (or NEXT-SEGMENT) will be very short (e.g. 0.0000036 degrees) and invisible to you.
- AND the MOTION-WIDTH will increase by a small amount (e.g. it increase to 360.0000036 degrees).

If you edit the X-AXIS value to separate the BLEND-POINTS:

- the MOTION-WIDTH does not revert to 360 degrees.

You MUST use the SEGMENT EDITOR [25] to edit the SEGMENT-WIDTH [28] of each segment to edit the MOTION-WIDTH. E.g., to make the MOTION-WIDTH equal to 360 again.

EXAMPLE:



Motion-Start and X-axis Value of Blend-Point #3

BLEND-POINT NUMBER ❶

The BLEND-POINT NUMBER is #3

X-AXIS VALUE

❷ MOTION START value is 0°.

❸ X-AXIS value of BLEND-POINT #3 is 180°

You should edit the X-AXIS value of BLEND-POINT NUMBER 3 within these limits:

- Minimum > 90° - at BLEND-POINT NUMBER 2
- Maximum < 270° - at BLEND-POINT NUMBER 4

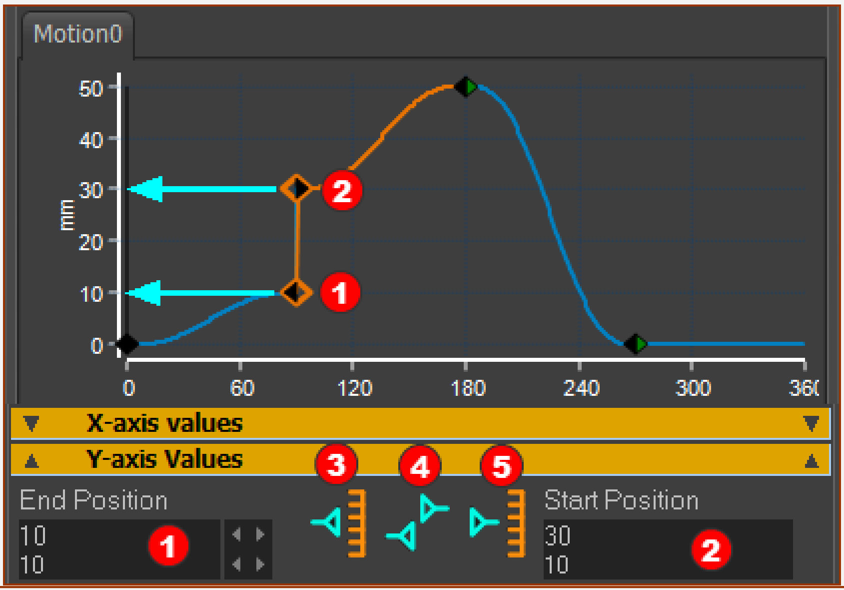
As you edit the X-AXIS value, the BLEND-POINT moves to the left(<) or to the right(>)

See also: WARNING [17], above.

See also: How to edit a value in a data-box [153].

1.2.2 Blend-Point Editor: Y-axis Values

Blend-Point Editor: Y-AXIS VALUES



Y-AXIS VALUES

There are **FOUR Motion-Derivatives.**

Note: Only the Flexible Polynomial can directly edit all of the motion-derivatives. There are limits with the other motion-laws.

Position(P), Velocity(V), Acceleration(A), and Jerk(J).

❶❷TWO MOTION-VALUES (for each Motion-Derivative) :

❶ END (*MOTION-VALUE*) OF PREVIOUS SEGMENT **(Read-Only OR Read-Write)**

E.g. In the image above, the motion-value at the:

END POSITION OF THE PREVIOUS-SEGMENT = 10mm

❷ START (*MOTION-VALUE*) OF THE SELECTED-SEGMENT **(Read-Only OR Read-Write)**

E.g. In the image above, the motion-value at the:

START POSITION OF THE SELECTED-SEGMENT = 30mm

These data-boxes have two possible states: **Read-Only OR Read-Write**

The **Motion-Law, Motion-Derivative** and the **CONTROL-BUTTONS** determine the state of the two data-boxes.

❸❹❺ THREE CONTROL BUTTONS (for each Motion-Derivative) :

See more at **Control Buttons: States and Patterns** 21

❸ END CONTROL BUTTON - to control if you can specify the motion-value at the END OF THE PREVIOUS-SEGMENT.

This button has three(3) possible states - **Do Edit, Do Not Edit**, and **Can Not Edit**

❹ MATCH CONTROL BUTTON - to control flow of motion-values from the PREVIOUS-SEGMENT to the SELECTED-SEGMENT .

This button has two(2) possible states -

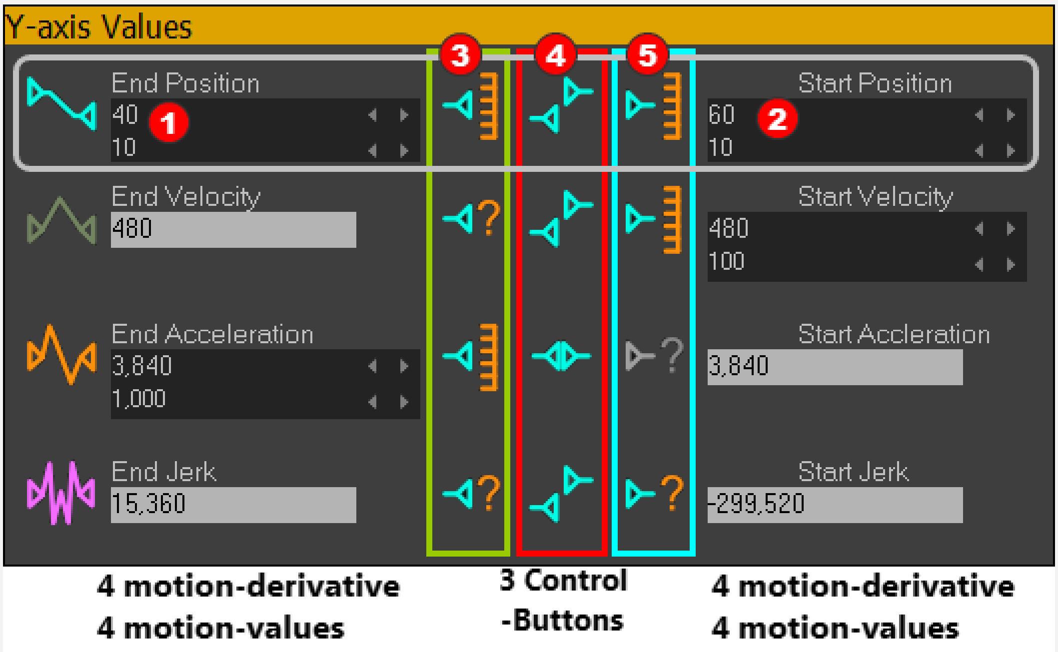
Do Force START OF THE SELECTED-SEGMENT = END OF THE PREVIOUS-SEGMENT

Do NOT Force START OF THE SELECTED-SEGMENT = END OF THE PREVIOUS-SEGMENT

❺ START CONTROL BUTTON - to control if you can specify the motion-value at the START-OF THE SELECTED-SEGMENT.

It has three(3) possible states - **Do Edit**, **Do Not Edit**, and **Can Not Edit**

Example: Blend-Point Editor: Three(3) Control-Buttons with EACH Motion-Derivative



In this example, the states of the 3 CONTROL-BUTTONS for **POSITION** are:

❸	EDIT the motion-value ...at END POSITION of Previous-Segment
❹	DO NOT force the START POSITION to equal the END POSITION
❺	EDIT the motion-value ...at START POSITION of the Selected-Segment

1.2.3 Blend-Point Editor: Control-Button: States and Patterns

Blend-Point Editor Control-buttons

It is ***extremely*** important to understand how to use the three(3) **Control-Buttons** in the **BLEND-POINT EDITOR** (and the SEGMENT EDITOR[29]) for each motion-derivative.

They control the Y-axis values of the motion.

Whether it is possible to specify a motion-value of a Blend-Point is a function of the:

A. Motion-Law

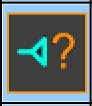
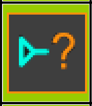
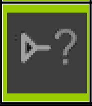
B. Motion-Derivative

C. **Control-Buttons States**

CONTROL-BUTTONS DEFINITIONS

EACH motion-derivative (**P V A J**) has **THREE** CONTROL-BUTTONS.

We must understand the possible states of each Control-Button. Please read carefully the definitions in this table.

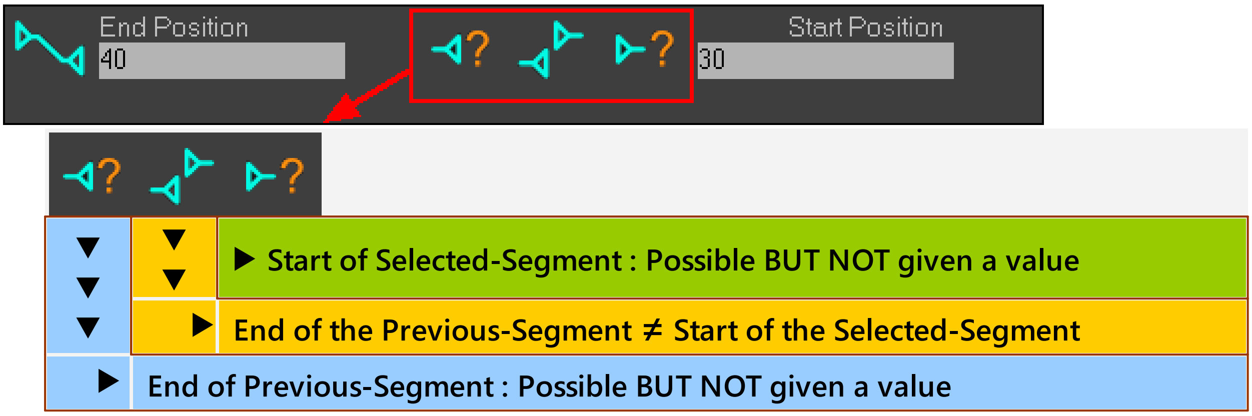
	Definition:
	DO **edit End (motion-value) of Previous-Segment** : It **IS** possible **AND** a motion value **IS** specified
	DO NOT **edit End (motion-value) of Previous-Segment** : It **IS** possible, **BUT** a motion-value **IS NOT** specified
	CAN NOT **edit End (motion-value) of Previous-Segment** : It **IS NOT** possible to specify a motion-value.
	DO NOT **Match : DO NOT FORCE** the **Start (motion-value) of the Selected-Segment TO EQUAL** the **End (motion-value) of the Previous-Segment**
	DO MATCH : **DO FORCE** the **Start (motion-value) of the Selected-Segment TO EQUAL** the **End (motion-value) of the Previous-Segment**
	DO **edit Start (motion-value) of Selected-Segment** : It **IS** possible **AND** a motion-value **IS** specified
	DO NOT **edit Start (motion-value) of Selected-Segment** : It **IS** possible, but a motion-value **IS NOT** specified
	CAN NOT **edit Start (motion-value) of Selected-Segment** : It **IS NOT** possible to specify a motion-value.

Control-Button: Patterns: 1- 9

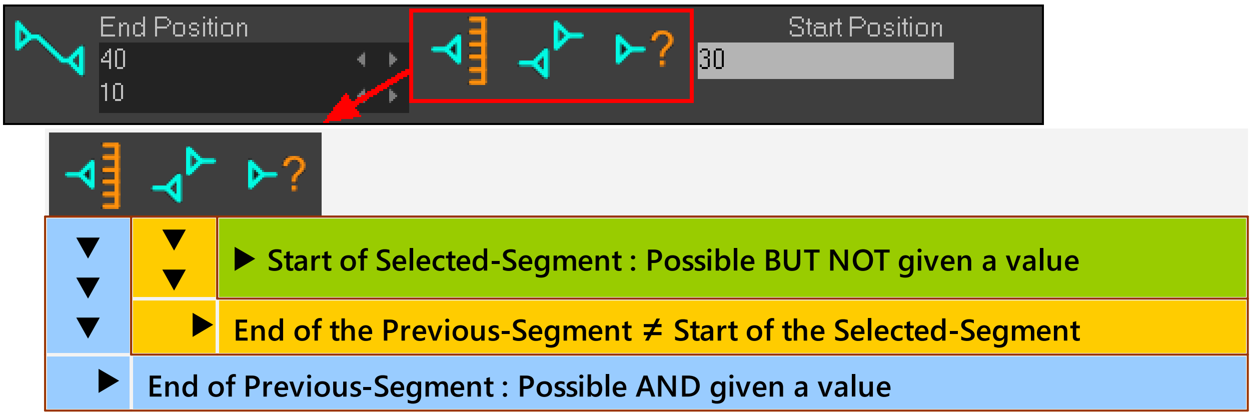
The state of each **Control-Button** can combine to give nine possible patterns.

These patterns are:

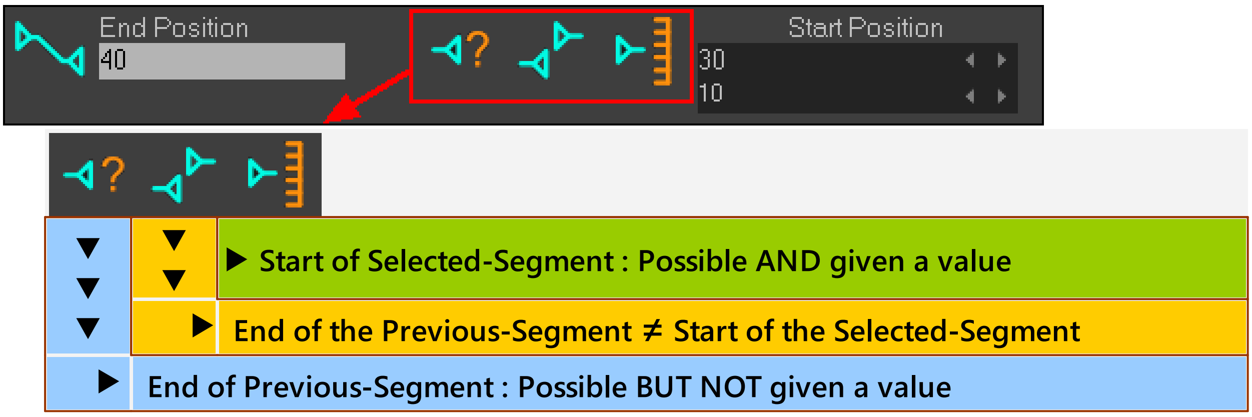
Pattern 1



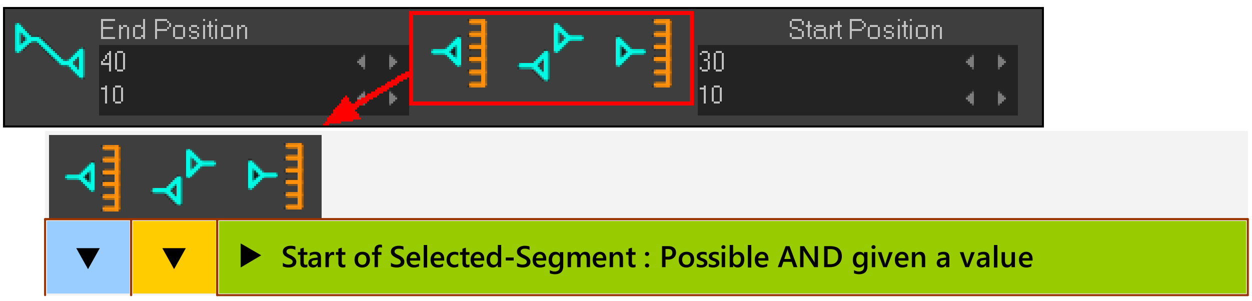
Pattern 2



Pattern 3



Pattern 4

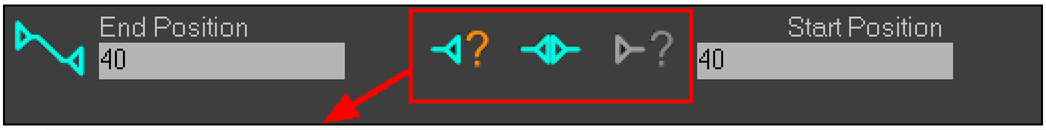


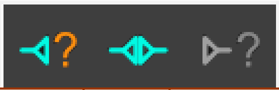
▼ ▼ ▼

▼ ▶ End of the Previous-Segment ≠ Start of the Selected-Segment

▶ End of Previous-Segment : Possible AND given a value

Pattern 5



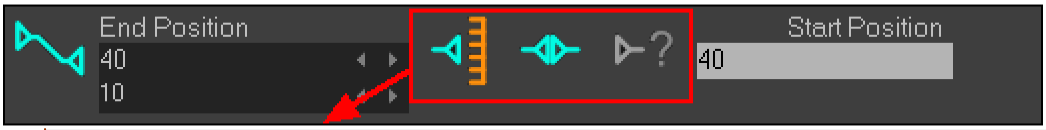


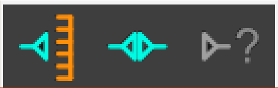
▼ ▼ ▶ Start of Selected-Segment : NOT possible to give a value (Motion-Law)

▼ ▼ ▶ End of the Previous-Segment = Start of the Selected-Segment

▼ ▶ End of Previous-Segment : Possible BUT NOT given a value

Pattern 6



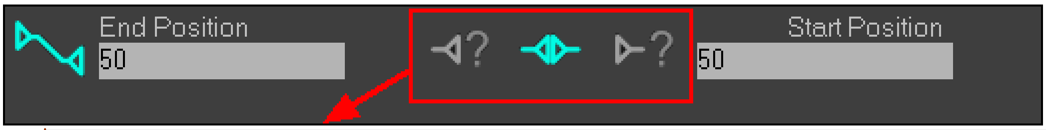


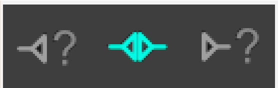
▼ ▼ ▶ Start of Selected-Segment : NOT possible to specify a value

▼ ▼ ▶ End of the Previous-Segment = Start of the Selected-Segment

▼ ▶ End of Previous-Segment : Possible AND given a value

Pattern 7



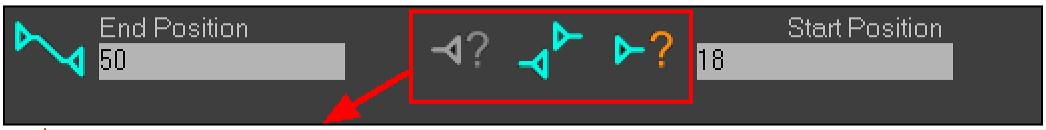


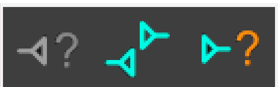
▼ ▼ ▶ Start of Selected-Segment : NOT possible to specify a value

▼ ▼ ▶ End of the Previous-Segment = Start of the Selected-Segment

▼ ▶ End of Previous-Segment : NOT possible to specify a value

Pattern 8



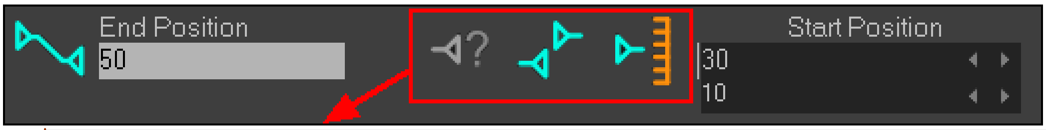


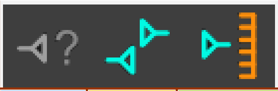
▼ ▼ ▶ Start of Selected-Segment : Possible BUT NOT given a value

▶ End of the Previous-Segment ≠ Start of the Selected-Segment

▶ End of Previous-Segment : NOT possible to specify a value

Pattern 9





▶ Start of Selected-Segment : Possible AND given a value

▶ End of the Previous-Segment ≠ Start of the Selected-Segment

▶ End of Previous-Segment : NOT possible to specify a value

1.3 SEGMENT EDITOR

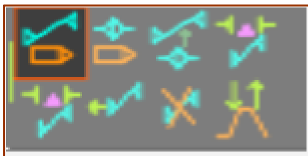
SEGMENT EDITOR

See also : BLEND-POINT (NODE) EDITOR [15] .

How to open the Segment Editor

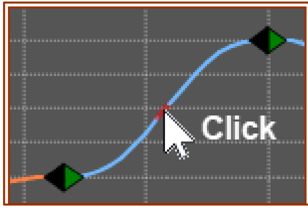
There are two methods to open the the **SEGMENT EDITOR**:

METHOD 1: Use the toolbar


Segment-Editor icon


1. Click **Blend-Point & Segment toolbar > Open Segment Editor**

METHOD 2: Click the Segment in the motion-graph



1. Move your mouse-pointer above a **SEGMENT** graph line.

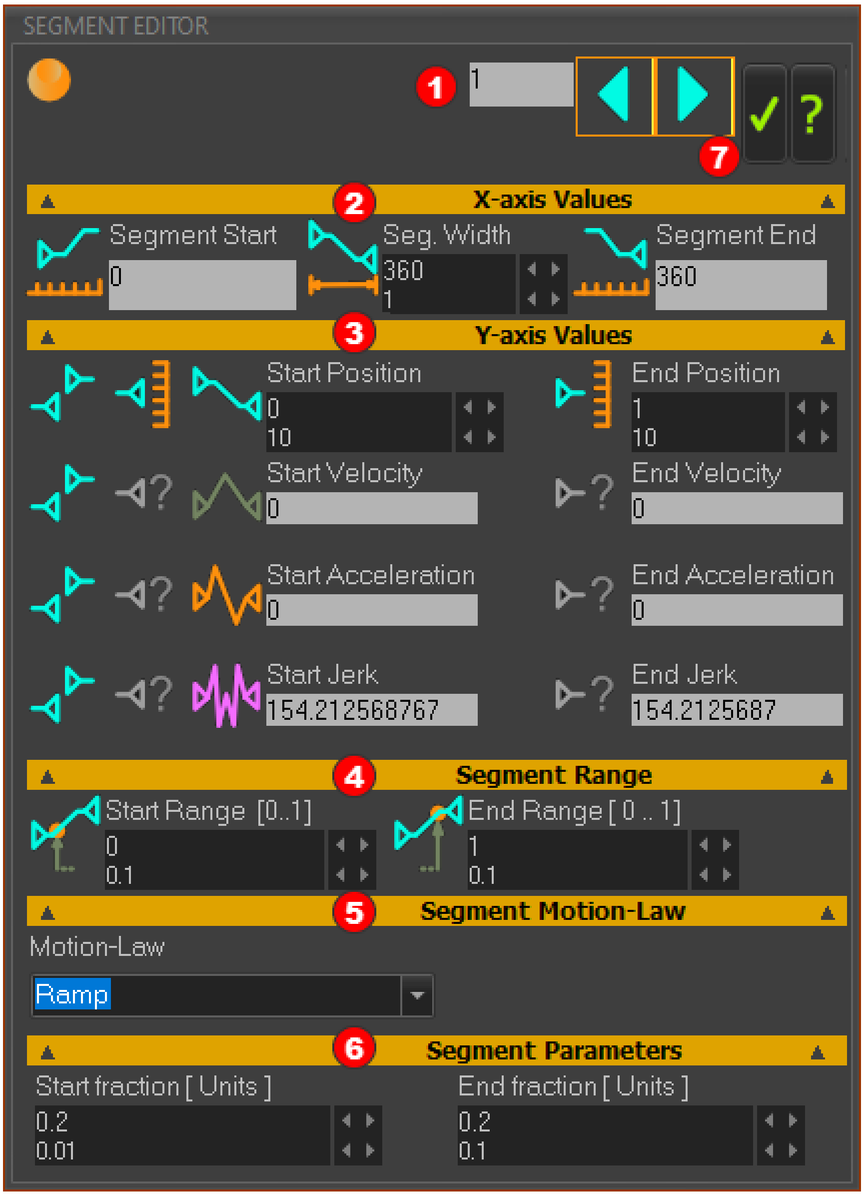
A short section of the segment becomes **red**

2. Click your mouse-button

The **SEGMENT EDITOR** is now open.

SEGMENT EDITOR DIALOG-BOX

We update the model immediately as you edit motion-values with the **SEGMENT EDITOR**.



SEGMENT-EDITOR

SEGMENT NUMBER ❶

The active SEGMENT NUMBER is the number of the SELECTED-SEGMENT.
The SEGMENT NUMBER indicates to which SEGMENT the motion-values and parameter values in the SEGMENT EDITOR apply.

X-AXIS VALUES ❷

Summary

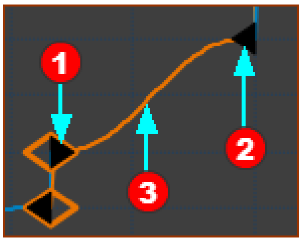
SEGMENT START (Read-Only) - the X-axis value at the start of the SELECTED-SEGMENT

SEGMENT-WIDTH - **See more here** [28]

SEGMENT END (Read-Only) - the X-axis value at the end of the SELECTED-SEGMENT

Y-AXIS VALUES ❸

Summary



A Segment(3)

The **SEGMENT EDITOR** edits motion-values at the:

❶ Start of the SELECTED-SEGMENT ❸

❷ End of the SELECTED-SEGMENT ❸

The motion-derivatives (P V A J) you can edit are a function of the:

- Motion-Law [36]
- Y-axis Control-Buttons settings [29].

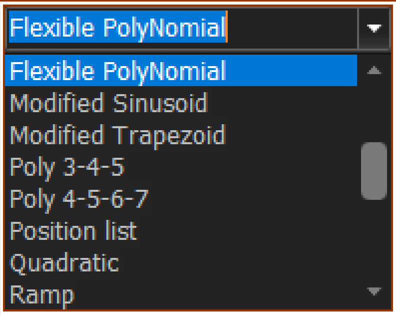
SEGMENT RANGE ❹

Available only with Traditional Motion-Laws [71]

- **See more Segment-Range** [32]

SEGMENT MOTION-LAW ❺

Summary



Motion-Law Selector

Use the drop-down box to select the **Motion-Law** for the **Selected-Segment**.

WARNING

After you select a **Motion-Law** for a Segment, click somewhere in the motion graph area to remove the focus from the **MOTION-LAW SELECTOR** list-box.

- **See more: Segment Motion-Laws** [71]

SEGMENT PARAMETERS ❻ - See more: Segment-Parameters [36]

Available only with Traditional Motion-Laws [71]

PREVIOUS / NEXT / OK / HELP buttons ❼

Make the PREVIOUS-SEGMENT be the SELECTED-SEGMENT

Make the NEXT-SEGMENT be the SELECTED-SEGMENT

Close the SEGMENT EDITOR and apply the new motion-values and parameter settings to the SELECTED-SEGMENT.

Open the contextual help

1.3.1 Segment Editor: X-axis Values / Segment-Width

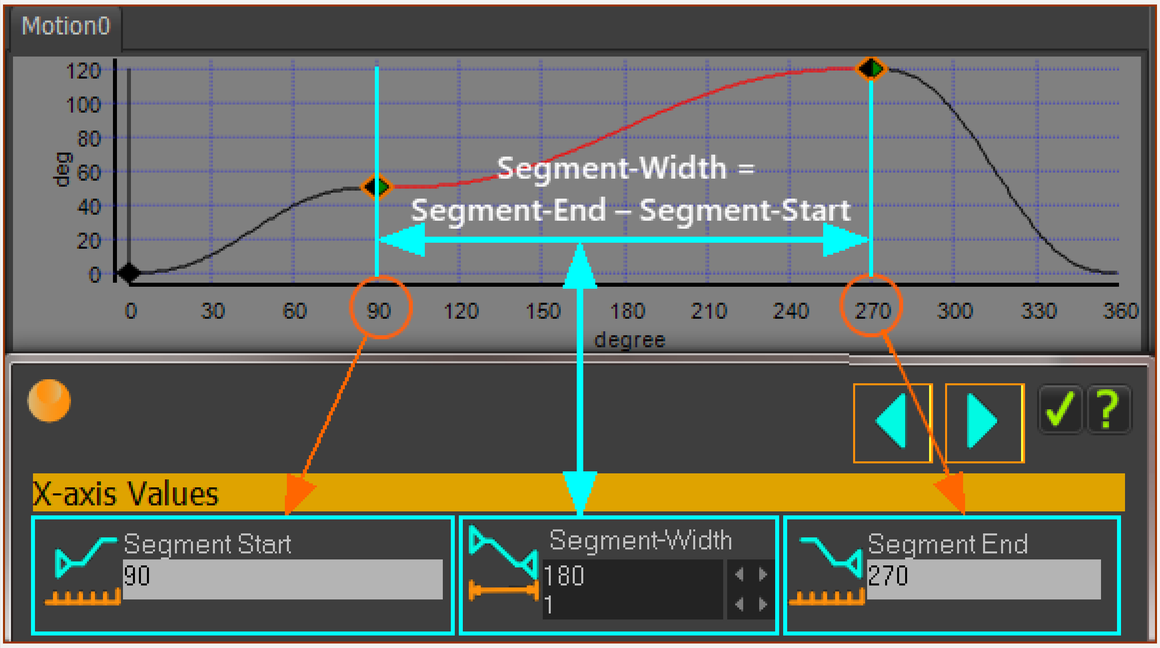
Segment Editor : X-AXIS VALUES

X-AXIS UNITS:

All values are specified with **X-axis units.**

The **X-axis units** are defined with Active-Motion-Settings > Motion tab > Motion Units > X-axis [52]

The default units are **degrees.**



SEGMENT-EDITOR - X-axis Values - Segment-Width Parameter

X-AXIS VALUES

SEGMENT-START (Read-Only) **:** The **X-axis** value at the **START** of the SELECTED-SEGMENT

SEGMENT-WIDTH (**Read-Write**) : Enter the width of the SELECTED-SEGMENT in **X-axis units**

SEGMENT-END (Read-Only) **:** The **X-axis** value at the **END** of the SELECTED-SEGMENT

WARNING:

When you edit the SEGMENT-WIDTH you also edit the MOTION-WIDTH.

If you do not want the MOTION-WIDTH to change, you must edit the SEGMENT-WIDTH of a minimum of two segments.

See also: Segment-Range [32], Segment-Parameters [36], Y-AXIS VALUES

1.3.2 Segment Editor: Y-axis Values / Control-Buttons

Segment Editor: Y-axis values

SEGMENT-EDITOR - Example Y-axis Value of Position only

Y-AXIS VALUES

There are **FOUR Motion-Derivatives.**

Note: Only the Flexible Polynomial can directly edit all of the motion-derivatives. There are limits with the other motion-laws.

Position(P), Velocity(V), Acceleration(A), and Jerk(J).

❶❷TWO MOTION-VALUES (for each Motion-Derivative) :

❶ START (*MOTION-VALUE*) OF SELECTED SEGMENT **(Read-Only OR Read-Write)**

E.g. In the image above, the motion-value at the:

START POSITION OF THE PREVIOUS-SEGMENT = **50mm**

❷ END (*MOTION-VALUE*) OF SELECTED-SEGMENT **(Read-Only OR Read-Write)**

E.g. In the image above, the motion-value at the:

END POSITION OF THE SELECTED-SEGMENT = **150mm**

These data-boxes have two possible states: **Read-Only OR Read-Write**

The **Motion-Law, Motion-Derivative** and the **CONTROL-BUTTONS** determine the state of the two data-boxes.

❸❹❺ THREE CONTROL BUTTONS (for each Motion-Derivative) :

See more at Control Buttons: States and Patterns 21

❹ MATCH CONTROL BUTTON - to control the flow and continuity of motion-values from the PREVIOUS-SEGMENT to the SELECTED-SEGMENT.

This button has two(2) possible states -

Do Force (motion-values at) START OF THE SELECTED-SEGMENT = END OF THE PREVIOUS-SEGMENT

Do NOT Force (motion-values at) START OF THE SELECTED-SEGMENT = END OF THE PREVIOUS-SEGMENT

❸ START CONTROL BUTTON - to control if you can specify the motion-value at the START OF THE SELECTED-SEGMENT.

This button has three(3) possible states -

Do Specify (motion-value at) START OF THE SELECTED-SEGMENT

Do NOT Specify (motion-value at) START OF THE SELECTED-SEGMENT

Not possible to Specify (motion-value at) START OF THE SELECTED-SEGMENT

❺ END CONTROL BUTTON - to control if you can specify the motion-value at the END OF THE SELECTED-SEGMENT.

It has three(3) possible states -

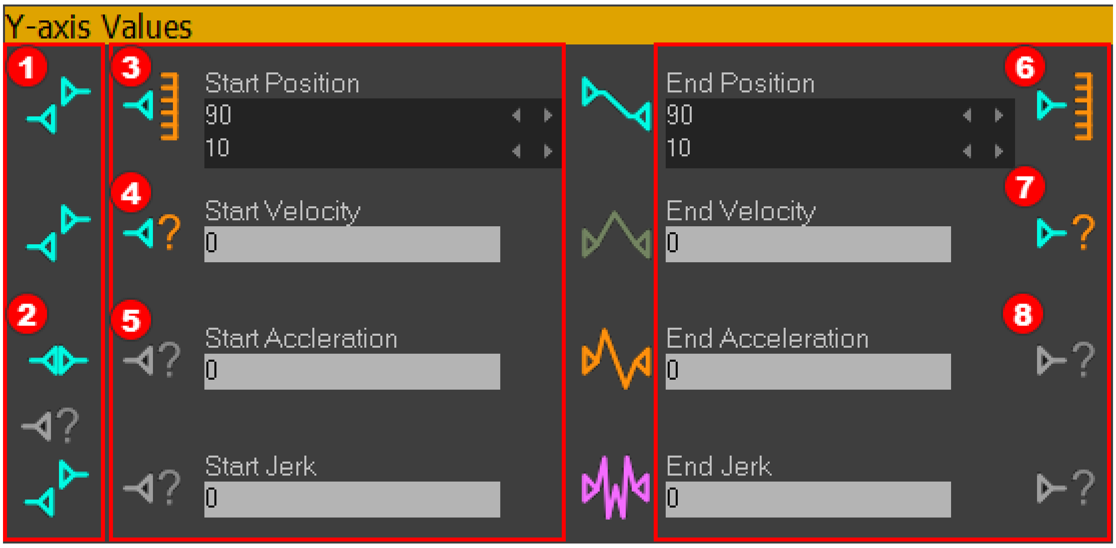
Do Specify (motion-value at) END OF THE SELECTED-SEGMENT

Do NOT Specify (motion-value at) END OF THE SELECTED-SEGMENT

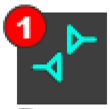
Not possible to Specify (motion-value at) END OF THE SELECTED-SEGMENT

See also BLEND-POINT EDITOR CONTROL BUTTONS 21

Segment Editor: Possible Control-Button Settings

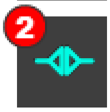


MATCH from Previous-Segment



DO NOT FORCE

Start of Selected-Segment TO EQUAL End of Previous-Segment

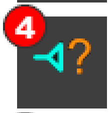


FORCE ...

Start of Selected-Segment TO EQUAL End of Previous-Segment

Motion-value at START of Selected-Segment

DO SPECIFY

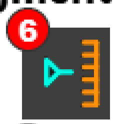


DO NOT SPECIFY

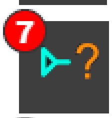
NOT POSSIBLE TO SPECIFY

Motion-value at END of Selected-Segment

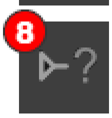
DO SPECIFY



DO NOT SPECIFY



NOT POSSIBLE TO SPECIFY



1.3.3 Segment Editor: Segment-Range

Segment Editor : SEGMENT-RANGE

Many Traditional Motion-Laws [71] have SEGMENT-RANGE parameters.

The SEGMENT-RANGE parameters specify the phases at which to start and end the mathematical-function of the motion-law.

Default Segment Ranges

START-RANGE ≥ 0 END-RANGE ≤ 1

0 ≤ START RANGE < END RANGE ≤ 1

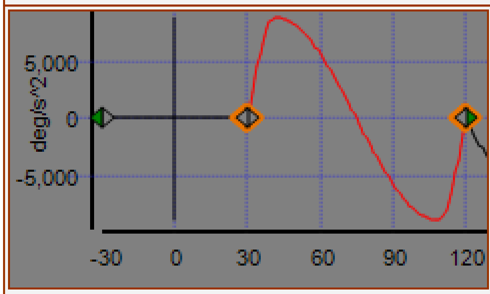
SEGMENT-RANGE parameters do NOT change the SEGMENT-WIDTH.

One application of SEGMENT-RANGE is to design **Asymmetrical Motions - see** below [33].

Example:

The images below show the acceleration graph of a **MODIFIED SINUSOID** motion-law with different SEGMENT-RANGE parameter values.

Note: the SEGMENT-WIDTH does not change.

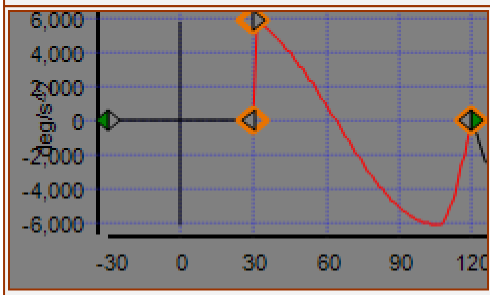


1) Standard Mod Sine

1) Modified Sinusoid Motion-Law.

SEGMENT-WIDTH = 120º-30º = 90º

- START-RANGE = 0.0
- END-RANGE = 1.0



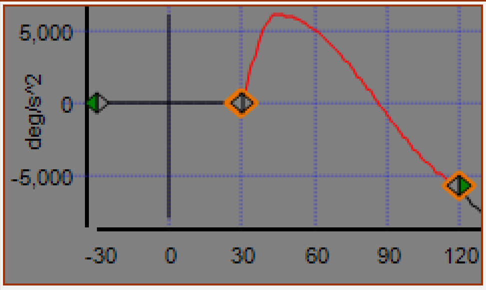
2) Start Range = 0.2 ; End-Range = 1

2) Modified-Sinusoid - 20% clipped from its Start.

SEGMENT-WIDTH = 120º-30º = 90º

- START-RANGE = 0.2 - to remove **0 - 20%** from the start of the **MODIFIED-SINUSOID** mathematical function

- END-RANGE = 1.0



Start Range = 0.0 ; End-Range = 0.8

Modified-Sinusoid - 20% clipped from the End.

SEGMENT-WIDTH = 120°-30° = 90°

- START-RANGE = 0.0
- END-RANGE = 0.8 - to remove the **20%** from the end of the **MODIFIED-SINUSOID** mathematical function

See also: Segment Editor: Segment-Width [28], Segment Editor: Parameters [36]

Asymmetric Motion

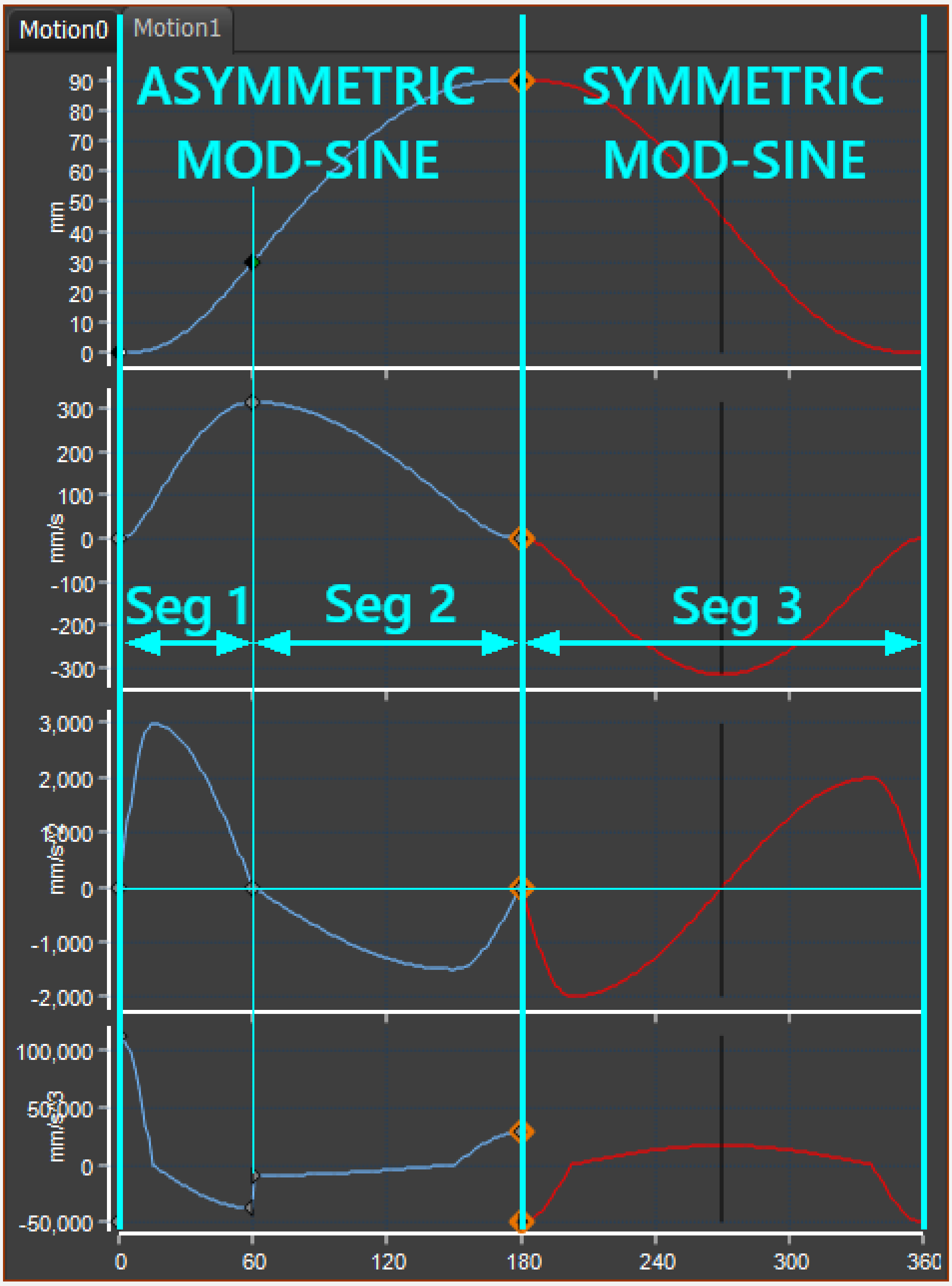
You can use an **Asymmetric Motion** to accelerate rapidly and decelerate more gradually, or **vice versa**.

In MotionDesigner, Asymmetric motion-laws combine two segments.

In the image below, there is a Rise and Return motion. Usually, you would need two segments.
However, there are three segments.

Segments 1 (0-60°) and **Segment 2** (60°-180°) combine to give an **asymmetric Mod-Sine**. The crossover is at 60°.

Segment 3 (180°-360°) is a **symmetric Mod-Sine**. The crossover is at 270° the mid-point.



Aysymmetric Mod-Sine | Symmetric Mod-Sine

Asymmetrical Mod-Sine Segments :

$X - axis\ : 0 - 180°$

$Crossover\ at\ 60°$

$\therefore \lambda = 60/180 = 1/3$

SEGMENT 1

Machine angle : $X - axis\ : 0 - 60°$ ($1/3$ of total Asymmetric motion-law)

Displacement : $Y - axis\ : 0 - 30mm$ ($1/3$ of total Asymmetric Displacement)

START-RANGE = 0 ; END RANGE = 0.5

SEGMENT 2

Machine angle : $X - axis\ : 60 - 180°$ ($2/3$ of total Asymmetric motion-law)

Displacement : $Y - axis\ : 30 - 90mm$ ($2/3$ of total Asymmetric Displacement)

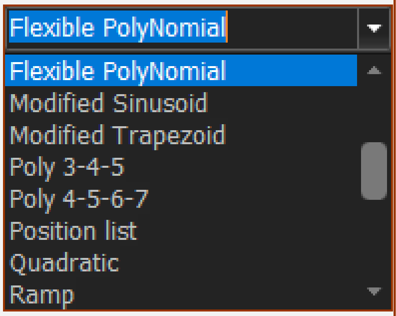
START-RANGE = 0.5 ; END RANGE = 1.0

Characteristics Values: Asymmetric and Symmetric Compared.

Velocity Coefficient :	$Cv_{asym} = Cv_{sym}$
Acceleration Coefficient :	$Ca_{asym} = Ca_{sym}/2\lambda$
Deceleration Coefficient :	$Ca_{asym} = Ca_{sym}/2(1-\lambda)$
Jerk at Crossover :	$C_{Jc} =- 39.48$

1.3.4 Segment-Editor: Motion-Law Selector

Segment Editor: Motion-Law Selector ❹



Motion-Law Selector

Use the drop-down list-box to select the **Motion-Law** for the SELECTED-SEGMENT.

WARNING

After you select a **Motion-Law**, click somewhere in the motion graph area to remove the focus from the **Motion-Law Selector** list-box.

See: Motion-Laws [71]

1.3.5 Segment Editor: Segment-Parameters

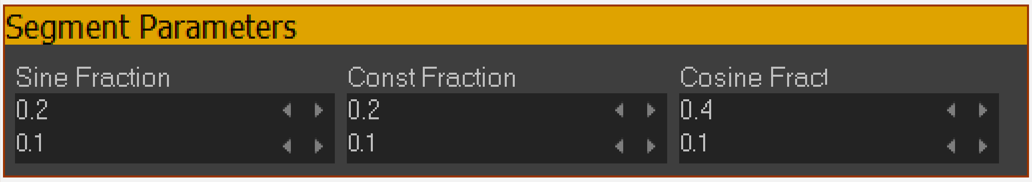
Segment Editor : SEGMENT PARAMETERS

The SEGMENT PARAMETERS separator is used with many (not ALL) Traditional Motion-Laws [71].

The Segment-Parameters are unique to the **Motion-Law**.

Their details are described with the Motion-Law.

The best way to learn about the different parameters is to experiment with their values.



Segment-Parameters with the Sine-Constant Acceleration-Cosine motion-law

The image above shows the three SEGMENT-PARAMETERS for the SINE-CONSTANT-ACCELERATION-COSINE [126] motion-law.

The CONSTANT-FRACTION parameter, refers to the **Non-Zero Constant Acceleration**, and not the **Zero Constant-Acceleration**.

Note: Commercial Indexers

Commercial Indexers frequently use a **Modified-Sine with** motion-law with **20%, 33%, 50%, or 66% Constant-Velocity** of the index-period.

A period of Constant-Velocity will:

- reduce the maximum velocity and a
- reduce a Cam's Pressure-Angle.
- increase the minimum width between the cam -tracks of a Globoidal-Cam, to increase the width of the rib.

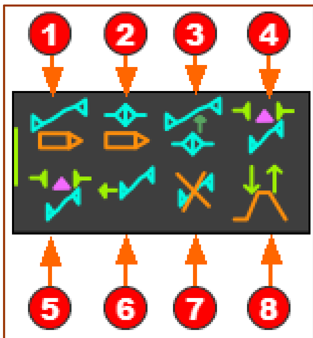
In *MotionDesigner*, you can specify any percentage of **Constant Velocity**.

NOTE:

See also: Segment-Range [32], Segment-Width [28]

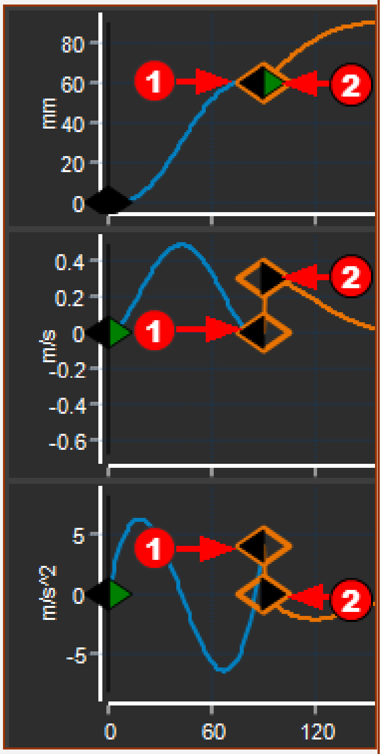
1.4 Blend-Point & Segment toolbar

Blend-Point & Segment toolbar



1	SEGMENT EDITOR[25]
2	BLEND-POINT EDITOR[15]
3	Insert Blend-Point[41]
4	Insert Blend-Point At[42]
5	Insert Segment[37]
6	Append Segment[39]
7	Delete Segment[40]
8	Data Transfer Table[61]

About Blend-Points (Nodes) and Motion-Values



Each BLEND-POINT is defined by :

1 × **X-AXIS MOTION-VALUE**

There is *one* **X-axis value**, for all motion-derivatives

2 × **Y-AXIS MOTION-VALUES**

There are *two* **Y-axis values**, for each motion-derivative

There is a:

1 a **Y-axis value** at the END of the PREVIOUS-SEGMENT

AND

2 a **Y-axis value** at the START of the SELECTED-SEGMENT

The **Y-axis values** can be forced to be equal, or they can be different, or not specified, or one value is specified and the other is not specified.

To specify the **X-axis value** and **Y-axis-values** of **each** BLEND-POINT, use the:

- BLEND-POINT EDITOR[15]

and / or the

- SEGMENT EDITOR[25]

1.4.1 Segment: Insert

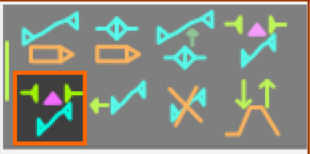
Insert Segment

Use **Insert-Segment** to add a new segment immediately to the left of the SELECTED-SEGMENT.

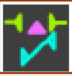
Note:

The **MOTION-WIDTH** will increase by **90º** (or an equivalent value for other X-axis units[52]).

If you want to add a new segment, but you do NOT want to increase the MOTION-WIDTH, it is better to use Insert Blend-Point at[42] or Insert-Blend-Point[41].



Insert Segment



1. Click **Blend-Point & Segment toolbar > Insert Segment**

A new segment is now in the motion, and it becomes the **SELECTED-SEGMENT.**

The new segment has a **SEGMENT-WIDTH** = **90º** (or an equivalent value for other X–axis units [52]).

Use the **SEGMENT EDITOR** [25] to reduce the SEGMENT-WIDTH of segments, and so reduce the MOTION-WIDTH again.

1.4.2 Segment: Append

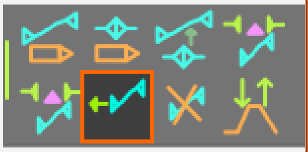
Append Segment

Use **Append-Segment** to add a new segment to the end of the last segment and motion.

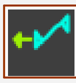
Note:

The **MOTION-WIDTH** will increase by **90º** (or an equivalent value for other X-axis units[52]).

If you want to add a new segment, but you do NOT want to increase the MOTION-WIDTH, it is better to use Insert Blend-Point at[42] or Insert-Blend-Point[41].



Append Segment



1. Click Blend-Point & Segment toolbar > Append Segment

A new segment is now at the end of the motion, after the last segment. It is the SELECTED-SEGMENT.

The new segment has a **SEGMENT-WIDTH** = **90º** (or an equivalent value for other X–axis units[52]).

Note:

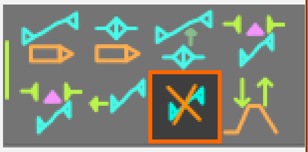
The MOTION-WIDTH will also increase by **90º** (or an equivalent value for other X-axis units[52]).

If required, use the SEGMENT EDITOR[25] to reduce the SEGMENT-WIDTH of the segments, and so reduce the MOTION-WIDTH to **360º**, again.

1.4.3 Segment: Delete

Delete Segment

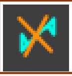
Use **Delete-Segment** to remove the SELECTED-SEGMENT.



Delete Segment

Use your mouse to select a segment. It is now the SELECTED-SEGMENT.

To delete the SELECTED-SEGMENT:



1. Click **Blend-Point & Segment toolbar > Delete Segment**

The SELECTED-SEGMENT has been removed from the motion.

Notes:

The SEGMENT WIDTH of the **PREVIOUS-SEGMENT** increases by the SEGMENT-WIDTH of the segment that you delete.

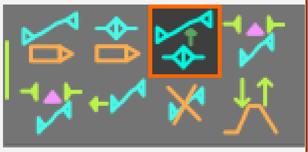
You do not get a warning that you will delete the segment.

Do **CTRL+Z** to undo, but the MOTION-WIDTH may increase.

1.4.4 Blend-Point: Insert approximately

Add Blend-Point (approximately)

Split one segment into two segments.



Insert Blend-Point 'Approximately'

1. Click **Blend-Point & Segment toolbar > Insert Blend-Point**
2. Move your mouse-pointer to the position (in the motion graph) at which you want the new BLEND-POINT.
3. Click the motion-graph

A new BLEND-POINT is now at your mouse-pointer. The SEGMENT you click becomes two SEGMENTS.

The two SEGMENTS have the same MOTION-LAW.

See also: TOP-Tip: Motion Planning

See also:

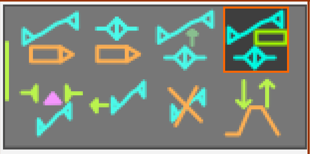
Add Blend-Point At 42

1.4.5 Blend-Point: Insert exactly at

Insert Blend-Point at...

Split one segment into two segments, at an exact value on the **X-axis.**

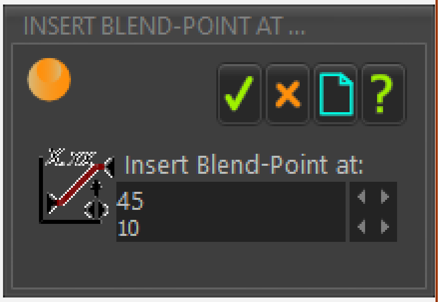
To add a BLEND-POINT at an exact value on the **X-axis.**



STEP 1. Do Insert Blend-Point at...

1. Click **Blend-Point & Segment toolbar** > **Insert Blend-Point at ...**

The INSERT BLEND-POINT AT... DIALOG-BOX opens.



STEP 2. Edit the X-axis value of the Blend-Point

You must edit the X-axis value

1. Edit the INSERT BLEND-POINT AT.,.

A new BLEND-POINT is at the X-axis value as specified in the dialog-box

2. Click ✓ to close the dialog-box

Note:

You cannot enter an X-axis value that is

- Less than the MOTION-START
- More than MOTION-WIDTH + MOTION-START

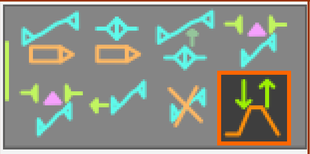
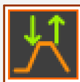
See-also: TOP-Tip: Motion Planning

1.4.6 Open Data-Transfer Table

Open Data-Transfer Table

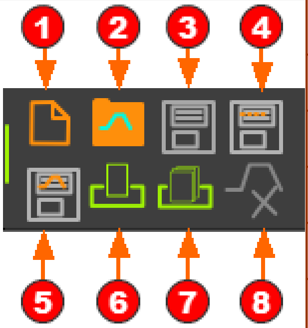
Use this command to open the **Data-Transfer Table**

Use the **Data-Transfer Table** to export and to import motion-files.

	To open the **Data-Transfer Table**:  **1.** Click **Blend-Point & Segment toolbar > Data Transfer Table** The **Data-Transfer Table** is now open- **see Data Transfer Table** 61

1.5 File toolbar

File Toolbar



File toolbar

1. Add Motion [44]
2. Open and Append Motion [45]
3. Save all [45] - See Note
4. Save all as... [46] - See Note
5. Save Active Motion as... [48] - See Note
6. Print Active Motion [50]
7. Print all Motions [50]
8. Delete Active Motion [50]

NOTE:

When you save a ***MechDesigner*** model to a CXL file (default), at the same time, we save all of the Motions to an MTD file with the same file-name as the CXL file. Thus, when working in the normal way, you do not need to save ***MotionDesigner*** motion files.

However, you can also use the ***MOTIONDesigner*** > **File toolbar** > **Save all as**, or **Save Active Motion, ...** to save all of the motions or the active motion to a different MTD file-name.

Why save a motion to a different file-name when it is also automatically saved when you save the MechDesigner model file?

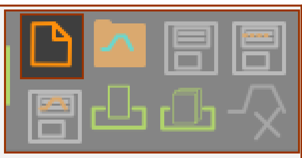
If one motion-design is complex you may want to save it and then re-import it. You can then use it as the basis of a new motion for a different product, size, format, or machine.

You can also re-import a motion to experiment with it to try different motion options.

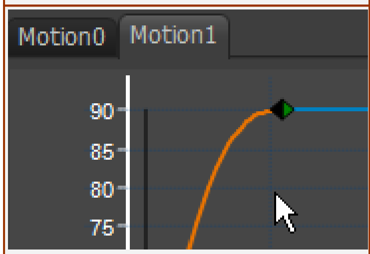
1.5.1 File: Add Motion

Add Motion

To add a new **Motion name-tab.**


Add New Motion


1. Click **File toolbar** > **Add New Motion**



Motion name-tabs

The new **Motion name-tab**:

- is to the right of the other **Motion name-tabs**
- becomes the active **Motion name-tab**

The new motion:

- is the default motion, with four segments arranged as a Rise-Dwell-Return-Dwell motion.

- is four Flexible-Polynomial [91]

See also:

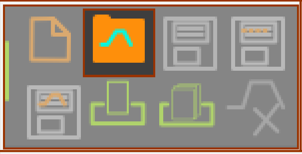
Motion name-tabs [11]

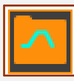
Open and Append [45]

1.5.2 File: Open and Append

Open and Append Motion

You can open motion files you have saved to append to those existing **Motion name-tab(s)**.





1. Click **File toolbar > Open and Append**

See also: Add Motion [44]

File-Types you can open and append:

MTD: the default ***MotionDesigner*** file-type.

A **MTD** file may include more than one motion. Each motion in the MTD file will add one more **Motion name-tab.**

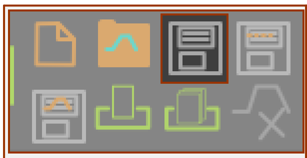
DA: Jetter file-type.

TXT: Logix 5000 Cam file-types

SHP: Camlinks Motion file-type

1.5.3 File: Save All Motions

Save All



To save all motions to one file:

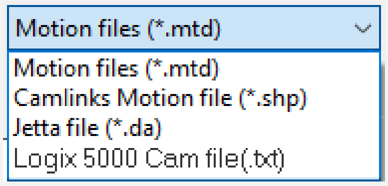
1. Click **File toolbar > Save All**

MotionDesigner files-types are **MTD** file-type.

Note: All of the motions are also saved when you save the ***MechDesigner*** model.

See also: Open And Append [45], Save All As [46], Add Motion [44], Save [48], Close [50]

Other File-Types



SHP: ***Camlinks and Motion*** file-type

The Camlinks file-type is a different kinematics and motion-design program.

It is one motion.

DA: Jetter File-Type

This is the Jetter Automation file-type.

It is one motion.

TXT: Logix 5000 Cam file (Beta-testing)

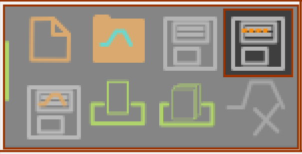
This is the **Allen-Bradley** (Rockwell) Logix 5000 Cam file-type.

Enter the units for the X-axis and the Y-axis.

It is one motion.

1.5.4 File: Save All Motions As...

Save All as



To save all motions to one file , with a new file-name:

1. Click **File toolbar > Save All as ...**

Note: When you save the ***MechDesigner*** model, **ALL** motions are automatically saved to the **MTD** file-type.

See also: Save All [45], Save Active Motion [48], Delete/Remove [50], Add Motion [44], Open and Append [45]

Motion Save as file-types

MTD: MotionDesigner file-type

Save all of the Motions to one MTD file.

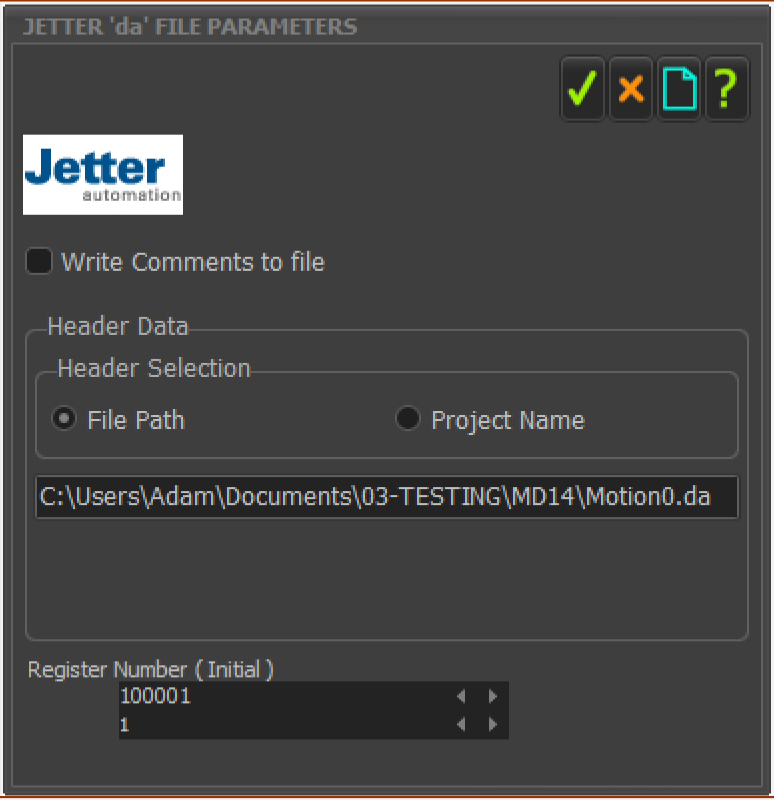
DA: Jetter file-type

Save as the Jetter Automation file-type - see below.

TXT: Logix 5000 Cam file (beta-testing) file-type

Save as the Allen-Bradley (Rockwell) Logix 5000 Cam file-type.

Jetter File-Type Dialog-box



WRITE COMMENTS TO FILE

Click the check-box if you want the DA file to explain the function and parameter of each line

HEADER DATA BOX

Use the check-box to write, as text, at the top of the DA file:

- **File Path** - the path is in the box- it is **Read Only**.

- or -

- **Project Name** - you must write the Project Name in the box

REGISTER NUMBER AT START BOX

Enter a ***Register Offset*** in the box

OK, CLOSE, CANCEL OR HELP BUTTONS

MotionDesigner saves each motion to a different file. The file-name is the Motion name-tab.

Notes on the DA file

All motion-type are saved as the Polynomial file-type, with their coefficients.

If the segment is a **Traditional Motion-Law** of the **Harmonic Type**, for example **Modified-Sinusoid**, then:

1. The actual **Mod-Sine** segment is divided into sub-segments.

   The Blend-Points for the sub-segments are at the 'natural' positions within the Segment.

2. The sub-segments are saved as **Polynomials.**

   The Polynomial coefficients minimize the error between the actual Segment and the **Polynomial** Segment.

For example:

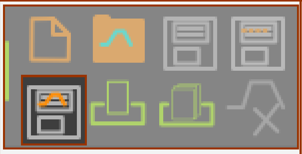
- **Modified-Sinusoid Motion-Law** has three sub-segments

- **Modified-Trapezoidal Motion-Law** has five sub-segments

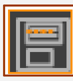
To review the Blend-Points and the sub-segments, you can do: Open and Append [45] and select the **DA** file-type after you save it.

1.5.5 File: Save Active Motion

Save Active Motion



To save the active Motion only:



1. Click **File toolbar > Save Active Motion**

See also: MOTION FILE-TYPES, below

See also: **Save All** [45] , **Save** [48]

Motion File-Types:

MTD: MotionDesigner File-Type.

The active motion is saved to the MTD file-type

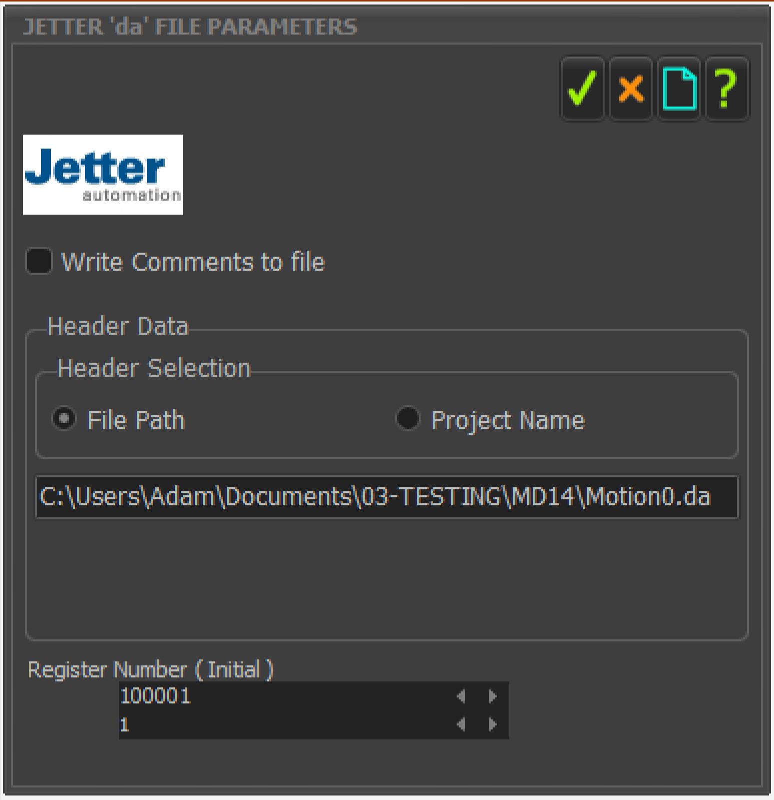
DA: Jetter File-Type

This is the Jetter Automation file-type - see below.

TXT: Logix 5000 Cam file (beta-testing)

This is the Allen-Bradley (Rockwell) Logix 5000 Cam file-type.

Jetter File-Type Dialog-box



Jetter .DA Save as interface

When you select DA as the file-type, this interface opens.

You have the option to enter these parameters:

WRITE COMMENTS TO FILE

Click the check-box if you want the DA file to explain the function and parameter of each line

HEADER DATA BOX

Use the check-box to write, as text, at the top of the DA file:

- **File Path** - the path is in the box- it is **Read Only**.

- or -

- **Project Name** - you must write the Project Name in the box

REGISTER NUMBER AT START BOX

Enter a ***Register Offset*** in the box

OK, Close, Cancel or Help buttons

MotionDesigner saves the motion as a .DA file-type. The file-name is the same as the Motion name-tab.

Notes on the DA file

All motion-types are saved as a polynomial file-type, with their coefficients.

If the segment is a **Traditional Motion-Law** of the **Harmonic Type**, for example **Modified-Sinusoid**, then:

1. The actual **Mod-Sine** segment is divided into sub-segments.

   The Blend-Points for the sub-segments are at the 'natural' positions within the Segment.
2. The sub-segments are saved as **Polynomials**.

The Polynomial coefficients minimize the error between the actual Segment and the **Polynomial** Segment.

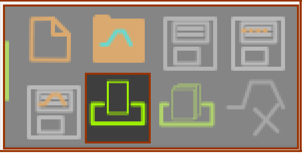
For example:

- **Modified-Sinusoid Motion-Law** has three sub-segments
- **Modified-Trapezoidal Motion-Law** has five sub-segments

To review the Blend-Points and the sub-segments, you can do: Open and Append [45] and select the **DA** file-type after you save it.

1.5.6 File: Print

Print Active Motion

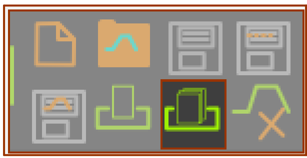


File toolbar > Print Motion

Prints the active Motion

1.5.7 File: Print All

Print All Motions

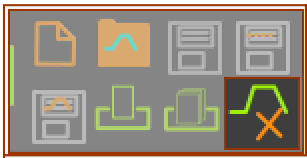


File toolbar > Print ALL Motions

Print **ALL** of the motions.

1.5.8 File: Delete Active Motion

Delete Active Motion



THERE IS NO WARNING AND YOU CANNOT UNDO

File toolbar > Delete Active Motion IMMEDIATELY

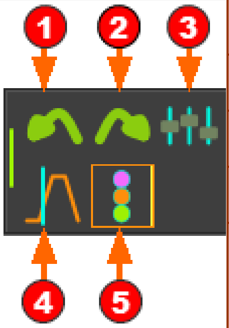
1. Click the name-tab of the motion that you want to delete
2. Click File toolbar > Delete Active Motion

Notes:

- You cannot delete all Motions - one Motion must be available.
- You cannot delete a motion that is linked to a MOTION FB (in *MechDesigner*).

1.6 Edit toolbar

Edit Toolbar

 Edit toolbar	1	Undo [51]
	2	Redo [51]
	3	Active Motion Settings [51] / Rename Motion [51]
	4	Sweep Display [54]
	5	Auto-Update [55]

1.6.1 Edit: Undo

Undo

	**Edit toolbar > Undo** ... to ***undo*** the previous motion edit. You can continue to ***undo*** more edits. **Note:** Click in the **MotionDesigner Application Window** - to make it active - before you use Undo.
See also: Redo [51]	

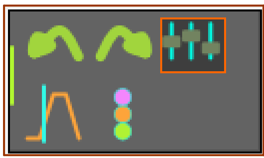
1.6.2 Edit: Redo

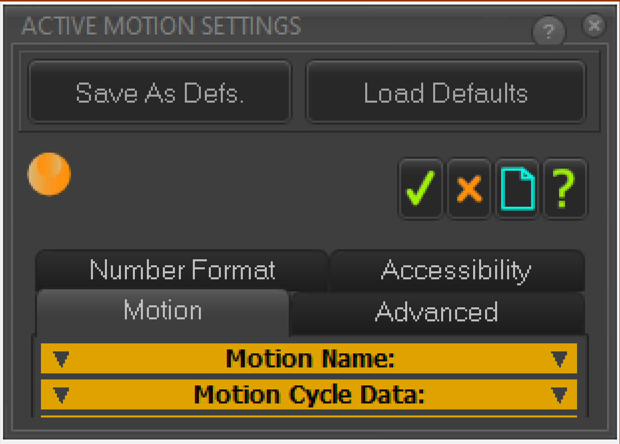
Redo

	**Edit toolbar > Redo** 1. Click **Edit toolbar > Redo** to ***redo*** the last undone command. You can continue to ***redo*** all undone commands. **Each Motion name-tab has its own Redo *stack*.**
See also: Undo [51]**, Command History** [51]	

1.6.3 Edit: Active Motion Settings

Active Motion Settings

	**Edit toolbar > Active Motion Settings** Each motion has its own settings.



Active Motion Settings

The buttons:

SAVE AS DEFS (defaults).

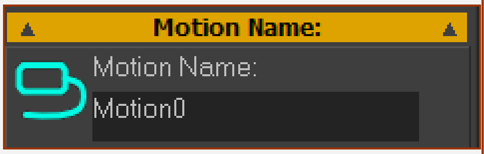
- Save the **Active Motion Settings** as the default motion-settings.

LOAD DEFAULTS

- Load **Motion Settings** to the **Active-Motion.**

Note: The Active Motion Settings become the **default motion settings** when you restart ***MechDesigner***.

Motion tab



Motion name-tab (Read-Write)

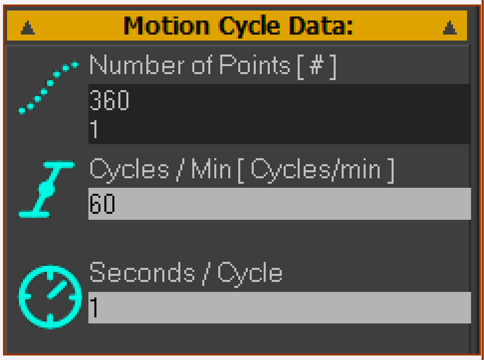
MOTION NAME

MOTION NAME **(read-write) (default = Motion0, Motion1, ...)**

Enter a new MOTION NAME with your keyboard.

Press the ENTER key on your keyboard.

The new motion name will show as the MOTION NAME-TAB.



MOTION CYCLE DATA

NUMBER-OF-POINTS **(read-write): *(default = 360)***

The NUMBER-OF-POINTS along the active motion graph.

Note: Enter NUMBER-OF-POINTS = 361 to put a Motion-Point exactly on each machine-degree as defined by the **MMA**.

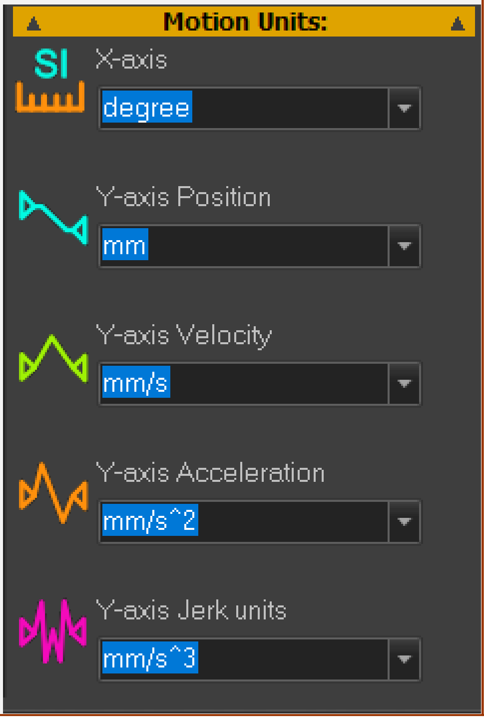
CYCLES / MIN **(read-only)**

RPM : machine-cycles in one minute.

See: Edit in MechDesigner ONLY - Edit menu>Machine Settings>Cycling Parameters>Cycles/Min

SECONDS / CYCLE **(read-only)**

SECONDS / CYCLE = 60 / CYCLES/MIN



MOTION UNITS

X–AXIS UNITS: (default = degrees)

Units available: **counts: sec, msec, cycle, degree, radian.**

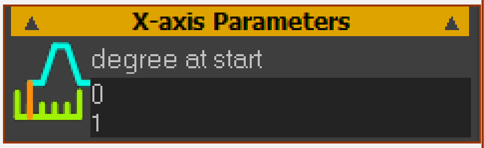
Y–AXIS UNITS: (default = degrees or mm)

Units available: **mm, cm, m, inch, degree, radian, cycle, count**

POSITION :	Units
VELOCITY :	Units/sec
ACCELERATION :	Units/sec/sec
JERK :	Units/sec/sec/sec

Note: The motion does not change its physical value when you select different X-AXIS UNITS and/or Y-AXIS UNITS. E.g. 90mm becomes 0.090m or 3.543inches.

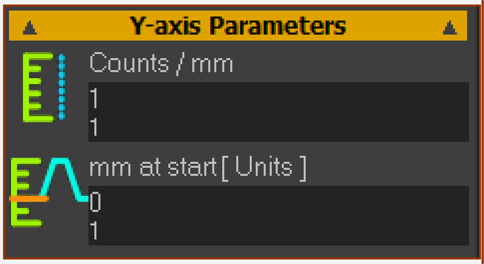
Advanced tab



X-AXIS PARAMETERS

[UNITS] AT START (default = 0)

Edit **Unit** data-type in Motion tab > 52 Motion Units



Y-AXIS PARAMETERS

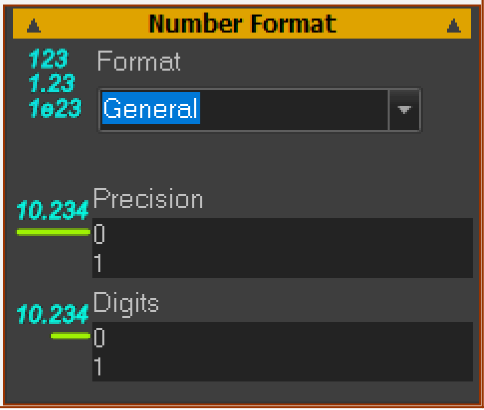
COUNTS / DEGREE (default =1)

Edit **Unit** data-type in Motion tab > 52 Motion Units

COUNTS AT START (default = 0)

Edit **Unit** data-type in Motion tab > 52 Motion Units

Number Format tab



NUMBER FORMAT

FORMAT (default : General)

See Number Format

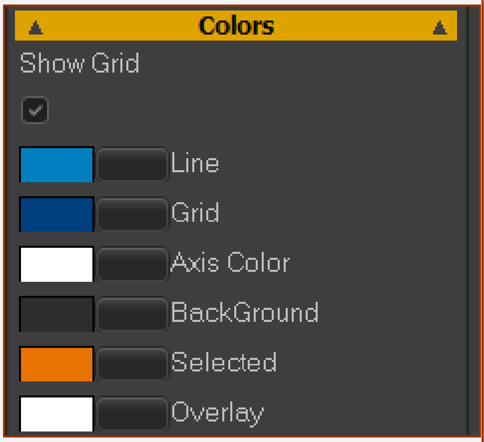
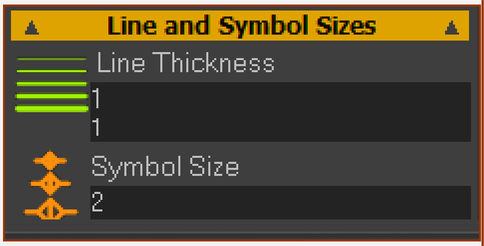
PRECISION (default = 6)

See Precision

DIGITS (default = 3)

See Digits

Accessibility tab

	**MOTION COLORS** ☑ Show Grid : Click to show horizontal and vertical lines in the graph-plot area. **Colors** : edit with **Windows Color Picker®** : • **Line:** of all segments, but not the **Selected-Segment** • **Grid:** the vertical and horizontal Grid-Lines • **Axis Color** : X and Y-axis text • **Background:** the graph area • **Selected:** the **Selected-Segment (typically** Red**)** • **Overlay:** the Overlay-Trace [68]
	**LINE AND SYMBOL SIZES** LINE THICKNESS **(default = 1 ; Maximum = 8)** The thickness, in pixels, of the motion-graphs. SYMBOL SIZE **(default = 2 ; Maximum = 8)** The scale/size of the BLEND-POINT symbols

1.6.4 Edit: Sweep-Display

Sweep-Display

A **Cursor** shows in the graphs of the active Motion at the **X-axis** as defined by the CURSOR-POSITION parameter.

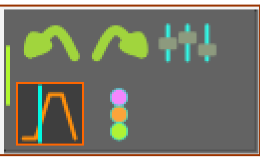
Use the **Sweep-Display** dialog to read the exact motion-values of all motion-derivatives (P V A J) at the position of the Cursor on the X-axis, as defined by the CURSOR-POSITION parameter.

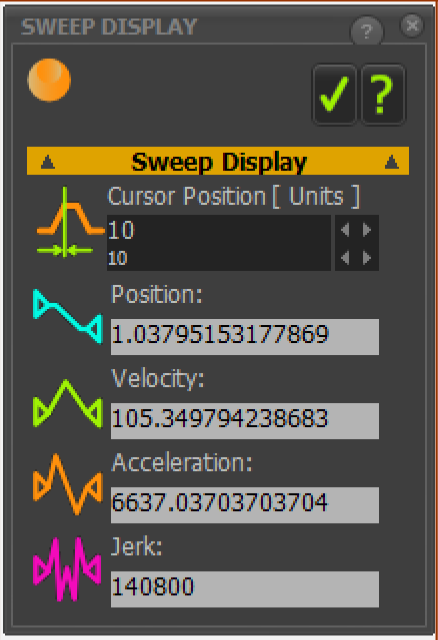
BUG: The Sweep Display does not sweep past the Motion-Start value - see Blend-Point Editor > X-axis Values > Motion-Start [17].

Sweep-Display: is almost the same as the Motion-Value Evaluator [60]

The Advantage of the Sweep Display is that you can see a Cursor.

The Advantage of the Motion-Value Evaluator is that you can enter an X-axis value greater than the last X-axis point - see **Notes** below.

	To open the **Sweep-Display dialog:** 1. Click **Edit toolbar > Sweep-Display icon**



SWEEP-DISPLAY

CURSOR POSITION: (Read-Write)

The X-axis value at which we want to read the POSITION, VELOCITY, ACCELERATION, and JERK motion-values.

Notes:

Edit DIGITS and PRECISION of the motion-values with:

Edit toolbar > Active Motion Settings > Number Format tab | Number-Format separator [53].

Maximum CURSOR POSITION = MOTION-WIDTH – (NUMBER OF STEPS / MOTION-WIDTH).

For example: If:

NUMBER-OF-STEPS = 360; Maximum CURSOR POSITION = 359

NUMBER-OF-STEPS = 3600; Maximum CURSOR POSITION = 359.9

See also: Motion-Width [60], Number of Steps [52], Motion-Value Evaluator [12]

1.6.5 Edit: Rebuild Motions

Auto-Update Motion

Edit toolbar > Rebuild icon

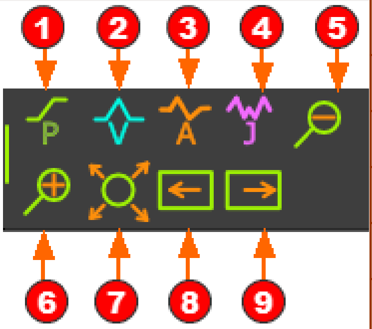
Enable - to rebuild and apply the motion to the model in *MechDesigner* after each edit of a motion-value.

or

Disabled - to edit motion-values quickly. The model will mostly, but not always, update to the new motion-value after each edit.

1.7 View toolbar

View Toolbar



View Toolbar

1	Show Position Graph [56]
2	Show Velocity Graph [56]
3	Show Acceleration Graph [57]
4	Show Jerk Graph [57]
5	Zoom Out [57]
6	Zoom In [57]
7	Zoom Extents [57]
8	Pan Left [57]
9	Pan Right [58]

Notes on Graphs

You must show at least one graph.

If you show more than one graph:

- the Position graph is above all other graphs
- the Velocity graph is below the Position graph, and above the Acceleration and/or Jerk graph
- the Acceleration graph is below the Velocity graph, and above the Jerk graph
- the Jerk graph is below all other graphs

1.7.1 View: Show Position Graph

Show Position

View toolbar > Show POSITION Graph

Enable or Disable the **POSITION** graph.

Note:

- **POSITION** is the absolute place, similar to an X, Y, Z coordinate.
- **DISPLACEMENT** is a movement from one position to a different position.

See also: Show Velocity [56], Show Acceleration [57], Show Jerk [57]

1.7.2 View: Show Velocity Graph

Show Velocity

View toolbar > Show VELOCITY Graph

Enable or Disable the **VELOCITY** graph.

Note:

Velocity is the rate-of-change of Position with respect to time

See also: Show Position [56], Show Acceleration [57], Show Jerk [57]

1.7.3 View: Show Acceleration Graph

Show Acceleration

View toolbar > Show ACCELERATION Graph

Enable or Disable the **ACCELERATION** graph.

Note:

Acceleration is the rate-of-change of Velocity with respect to time.

See also: Show Position [56], Show Velocity [56], Show Jerk [57]

1.7.4 View: Show Jerk Graph

Show Jerk

View toolbar > Show JERK Graph

Enable or Disable the Jerk graph.

Note:

Jerk is the rate-of-change of Acceleration with respect to time.

See also: Show Position [56], Show Velocity [56], Show Acceleration [57]

1.7.5 View: Zoom-In

Zoom-In

View toolbar > Zoom-In

Expand the X–axis (NOT the Y-axis) to see less of the motion.

See also: Zoom-Out [58], Zoom Extents [57], Pan Left [57], Pan Right [58]

1.7.6 View: Zoom-Extents

Zoom-Extents

View toolbar > Zoom Extents

Scale the X-axis to equal the Motion-Width.

See also: Zoom-In [57], Zoom-Out [58], Pan Left [57], Pan Right [58]

1.7.7 View: Pan Left

Pan-Left

View toolbar > Pan Left

Move the X-axis of the motion graph to the right.

This tool does not change the timing of the motion.

To change the timing of the motion, see:

Blend-Point Editor > X-axis values > Motion-Start.

See also: Zoom-In [57], Zoom-Out [58], Zoom Extents [57], Pan Right [58]

1.7.8 View: Pan Right

Par Right

View toolbar > Pan Right

Move the X-axis of the motion graph to the left.

This tool does **not** change the timing of the motion.

To change the timing of the motion, see:

Blend-Point Editor > X-axis values > Motion-Start.

See also: Zoom-In [57], Zoom-Out [58], Zoom Extents [57], Pan Right [58]

1.7.9 View: Zoom-Out

Zoom-Out

View toolbar > Zoom-Out

Contract the X–axis (NOT the Y-axis) to see more of the motion.

See also: Zoom-In [57], Zoom Extents [57], Pan Left [57], Pan Right [58]

1.8 Motion toolbar

Motion toolbar

The **Motion toolbar** is below the graphs.

Note: To see all of the **Motion toolbar**, you may need drag to the left the vertical divider that is between ***MotionDesigner*** and ***MechDesigner***.

❶ Motion-Law Selector [59]

❷ Motion-Width [60] (Read-Only)

❸ Motion Value Evaluator [60]

1.8.1 Motion Law Selector

Motion-Law Selector

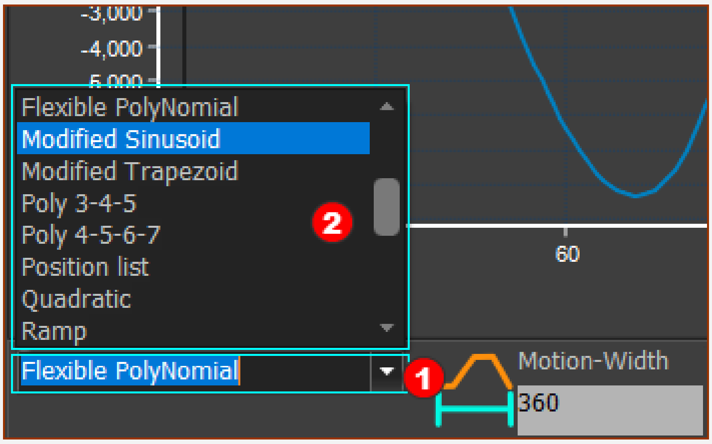
This is below the **Motion graphs**.

Use the **MOTION-LAW SELECTOR** to

- Identify the **MOTION-LAW** for the **SELECTED-SEGMENT**
- Select a **MOTION-LAW** for the **SELECTED-SEGMENT**.

See also Motion-Laws [71]

Use the Motion-Law Selector



Motion-Law Selector list box

To IDENTIFY the Motion-Law of the Selected-Segment

1. Click above or below a **SEGMENT**
2. Click again if the focus was not in ***MotionDesigner***.

The segment is now the **SELECTED-SEGMENT**

The **MOTION-LAW** of the **SELECTED-SEGMENT** shows in the **MOTION-LAW SELECTOR**❶

To SELECT a different Motion-Law for the Selected-Segment

1. Click above or below a **SEGMENT**
2. Click again if the focus was not in ***MotionDesigner***.

The segment is now the **SELECTED-SEGMENT**.

The MOTION-LAW of the SELECTED-SEGMENT shows in the MOTION-LAW SELECTOR❶

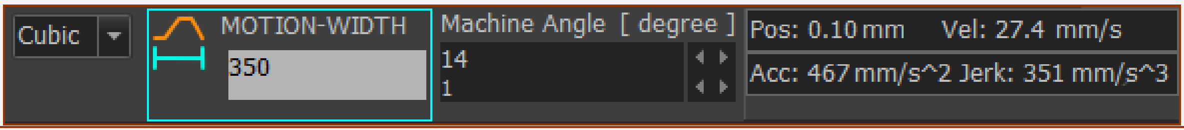
3. Click the drop-down arrow of the MOTION-LAW SELECTOR list-box❶ to see the different motion-laws.
4. Click a different MOTION-LAW❷ in the drop-down list.

The SELECTED-SEGMENT now uses the MOTION-LAW that you select.

5. Click somewhere in the motion graph area to remove the focus from the MOTION-LAW SELECTOR list-box.

1.8.2 Motion-Width

Motion-Width (Read-Only)



MOTION-WIDTH = ∑ SEGMENT-WIDTHS [28]

You can edit the SEGMENT-WIDTH of each SEGMENT with the SEGMENT EDITOR [25]

When the X-AXIS UNIT [52] is set to **degrees**, then, usually, the MOTION-WIDTH = 360

If the X-AXIS UNITS are:

Radians, then usually MOTION-WIDTH =2×Π.

Seconds, then MOTION-WIDTH = 60 / (CYCLES / MINUTE)

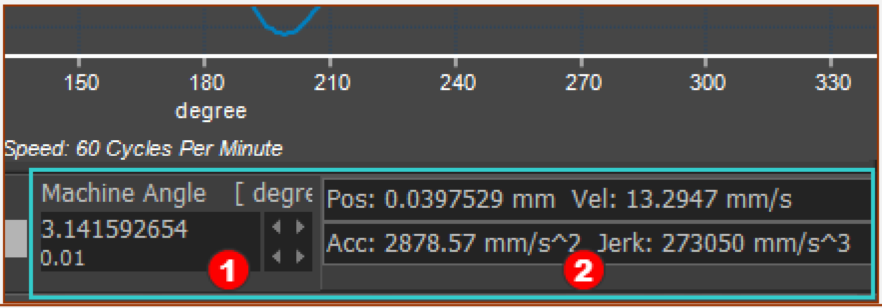
Milliseconds, then MOTION-WIDTH = 60 000 / (CYCLES / MINUTE)

To edit the X-axis Units:

Active Motion-Settings > Motion tab > Motion Units > X-axis [52]

1.8.3 Motion-Value Evaluator

Motion-Values Evaluator



To evaluate Motion-Values at a Machine-Angle

1. Edit the MACHINE-ANGLE❶ to any real value
2. The POSITION, VELOCITY, ACCELERATION, and JERK motion-values are evaluated❷

Note:

The evaluated motion-values (❷) are the exact motion-values at MACHINE-ANGLE (❶) .

The MACHINE-ANGLE can be set to any angle.

See also: Motion-Values at Pointer [12], Sweep-Display [54]

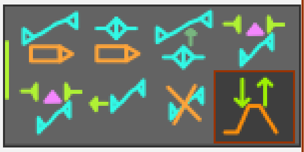
1.9 Data-Transfer Table

Data-Transfer Table

Use the **Data-Transfer Table** to:

- **Import data** from an application (e.g. NotePad, Excel) to the table and then to a **List segment-type**
- **Export data** from one segment or the complete motion to the table and then to an application
- **Display data** in the table as a dumb-graph - **see Overlay Trace** [68]

Open the Data Transfer Table

	To open the **Data-Transfer Table**: 1. Click **Blend-Point & Segment toolbar > Data Transfer Table icon.** The **Data-Transfer Table** is now open.

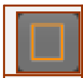
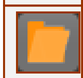
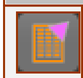
Data-Transfer Table

	X	Pos	Vel	Acc	Jer
0	0	2.271919E-27	-9.087678E-27	7.270142E-26	-2.617251[illegible]
1	0.9749304	4.225703E-5	0.06200593	67.93618	49066.87
2	1.949861	0.0006585551	0.4799283	259.9388	91684.99
3	2.924791	0.003246669	1.566548	559.0289	128211.4
4	3.899721	0.00999034	3.589962	949.1837	158995.1
5	4.874652	0.02374175	6.77615	1415.315	184377.1

Data Transfer Table

Note: X-axis of First Row is equal to Motion-Start [17]. First Row is designated Row 0

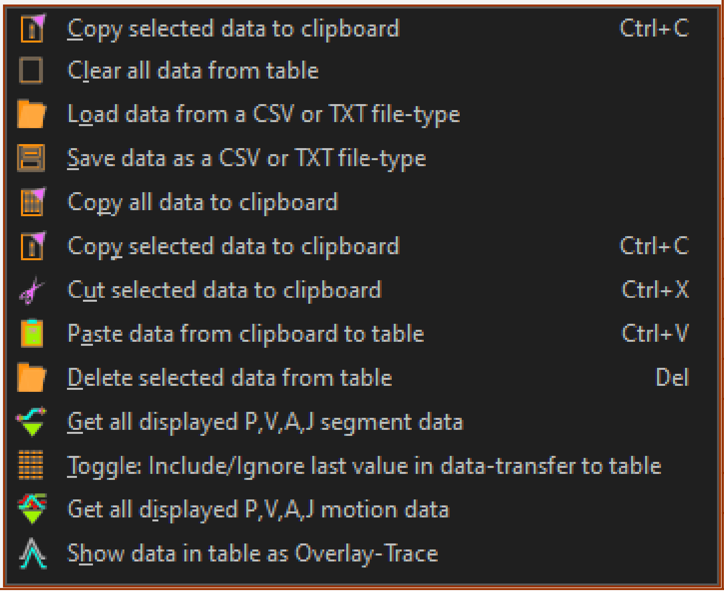
Data-Transfer Table toolbar

	Clear all data from the table [64]: Remove all the data from the **Data-Transfer Table.**
	Save data to a CSV, TXT, or DAT file-type [64]: Save all of the data in the motion-graphs to a **CSV**, **TXT**, or a **DAT** file-type. The **DAT** file-type is exported by the **Camlinks & Motion** application, which is now not available (Limaçon).
	Open and load data from a CSV, TXT, DAT file-type [64]: Load data in a **CSV, TXT**, or **DAT** file-type, and paste into the table.
	Copy all data to clipboard [65]: Copy **all** data in the **Data-Transfer Table** to the Windows© clipboard.

	Copy selected data to clipboard [65]: Copy the selected data to the Windows© clipboard.
	Cut selected data to clipboard [65]: Remove selected data from the **Data-Transfer Table** and copy to the Windows© clipboard
	Paste clipboard to table [65]: Paste data in the Windows© clipboard to the **Data-Transfer Table**, starting at the active cell.
	Delete selected data from table [66]: Delete the selected data from the **Data-Transfer Table**.
	Get data from List segment-type [66]: The **Selected-Segment** must be a **List Segment-Type**.
	Put data to a List segment-type [66]: The **Selected-Segment** must be a **List Segment-Type**.
	Get all displayed P,V,A,J data [67]: Transfer to the Data-Transfer Table the motion data of each motion-derivative graph
	Get all displayed P,V,A,J segment data [67]: Transfer to the Data-Transfer Table, for the Selected-Segment only, the data of each motion-derivative graph
	Show data as an Overlay-Trace [68] : Display the motion-data in the **Data-Transfer Table** as an OVERLAY-TRACE. You can toggle this icon to show or hide the OVERLAY-TRACE. An OVERLAY-TRACE is a ***dumb graph*** that shows together with the active motion graph.
	Toggle: Include/Ignore last value in data transfer to table [69] Often you want to transfer the motion-data that is in the **Data Transfer Table** to another application. Your application may need: • the last row in the table to equal the first row in the table • the last row in the table to equal the last data-value in the motion Note: you may need to increase or decrease the Number of Points [52] in the motion by 1 to get a motion-value at each degree or millisecond.

Data Transfer Table: Contextual menu

Right-click in the **Data-Transfer Table** to show the contextual menu.



Copy Selected Data to the Clipboard 65
Clear all data from table 64
Load data from a CSV or TXT file-type 64
Save to Text File 64
Copy all data to clipboard 65
Copy selected data to clipboard 65
Cut selected data from table 65
Paste data from clipboard to table 65
Delete selected data from table 66
Get all displayed P,V,A,J segment data 67
Toggle: include/ignore last value in data transfer to table 69
Get all displayed P,V,A,J motion data 67
Show Data as an Overlay Trace 68

What happens when we PUT data to a List segment-type

When you **PUT data** to a **List segment-type**:

- ***MotionDesigner*** re-calculates the data in your list to put the correct NUMBER-OF-STEPS and proportional to the SEGMENT-WIDTH of the **List segment-type**.
- ***MotionDesigner*** numerically calculates all motion-derivatives from the data.

The minimum number-of-points (rows) you can transfer to a **List segment-type** is 6. However, we recommend many more!

Get data from Motion / Segment

When you **GET data** from the motion or a segment:

NUMBER OF COLUMNS: X-axis + each displayed motion-derivative

NUMBER OF ROWS (Motion) = NUMBER-OF-STEPS in ACTIVE-MOTION-SETTINGS [51]

NUMBER OF ROWS (Segment) = NUMBER-OF-STEPS * SEGMENT-WIDTH / MOTION-WIDTH

1.9.1 Clear all data from the table

Clear All data from the Data-Transfer Table

Click to clear, or remove, all data from the **Data-Transfer Table**.

1.9.2 Save data to a CSV or TXT file-type

Save All or Selected Data to a Text File

Click to Save all data **in the graphs** to a file.

You can save the file with these file-types: CSV, TXT, or DAT.

The data does not need to be in the **Data-Transfer Table**.

File-type	Description	Data
CSV	Comma Separated Values Numbers separated with the List separator	Index Number, X-axis value, Motion-Value at X-axis value for each graph.
TXT	Numbers separated with List Separator	Index Number, X-axis value, Motion-Value at X-axis value for each graph.
DAT	Compatible with Camlinks DAT file-type.	Index Number, X-axis value, Motion-Value at X-axis value for each graph.

1.9.3 Load a CSV or TXT file-type

Open a Text File

Open a file that is a CSV, TXT or DAT file-type.

The data in the file will fill the table from the active cell in the **Data-Transfer Table**

The data is usually intended for a segment that is a **List Segment-Type** or an Overlay Trace [68].

List Segments-Types are:

- Position List [115] : ***MotionDesigner*** differentiates the data to create Velocity, Acceleration, and Jerk
- Acceleration List [74] : ***MotionDesigner*** integrates the data to create Velocity and Displacement
- Z Raw-Data [143] : ***MotionDesigner*** differentiate the data to create Velocity, Acceleration, and Jerk

1.9.4 Copy all data to clipboard

Copy all Data

Copy all data in the **Data Transfer Table** to the Windows® Clipboard.

1.9.5 Copy selected data to clipboard

Copy Selected Data

Save data to the Windows® Clipboard.

Select the Data:

1. Click a cell in the table
2. SHIFT+Click a different cell

The data is now **selected.**

3. Click this tool.

The **selected data** is now on your Clipboard.

1.9.6 Cut selected data from table

Cut Selected Data from Table to Clipboard

Use to cut the **Selected Data*** from the table and place on your Windows Clipboard.

You can:

- Paste the data to a computer application, such as Notepad, WordPad, Word, Excel, etc.
- Paste the data back into the Data-Transfer table.

*** Selected Data:**

1. Click a cell in the table
2. SHIFT+Click a different cell

The highlighted data is now the **Selected Data.**

see also:

Data-Transfer: Copy [65],

Data-Transfer: Paste [65]

1.9.7 Paste data from clipboard to table

Paste Data to Table

Paste data from your clipboard to the **Data-Transfer Table.**

1. Click a cell in the table
2. Click the icon to paste the data

The data is now in the Data Transfer Table.

See also:

Data-Transfer: Cut [65],

Data-Transfer: Copy [65]

1.9.8 Delete selected data from table

Delete Selected Data from Table

	Delete **selected data*** from table.
	*** To select data:** 1. Click a cell in the table 2. SHIFT+Click a different cell The Selected Data is now the **Selected Data**.

See also:

Data-Transfer: Copy (65),

Data-Transfer: Paste (65)

1.9.9 Get data from List Segment-Type

Get Data from a List Segment-Type

Note: This icon is in the toolbar **only** when the Selected-Segment is a **List Segment-Type**.	
	Get List Data : get the data-points that were originally put to the **List Segment-Type** with **Put List Data** button. The data will be transferred to the **Data-Transfer Table.**
	List Segment-Types are: • Position-List (115) • Acceleration-List (74) • Z-Raw-Data (143)

see also: Put List Data (66), Get Segment Data (67)

1.9.10 Put data to List Segment-Type

Put Data to a List Segment-Type

This icon is in the **Data-Transfer Table** toolbar **only** when the SELECTED-SEGMENT is a **List Segment-Type.** **List Segment-Type** are • Position-List (115) • Acceleration-List (74) • Z-Raw-Data (143)	
	Put List Data : to put the **selected data*** from the **Data-Transfer Table** to a **List Segment-Type.**
	The ***number of data values*** you **PUT** to the **List Segment-Type** does not need to be equal to the ***Number-of-Points*** that are allocated to the segment with the SEGMENT-WIDTH After you put the data-points to the **List Segment-Type**, ***MotionDesigner*** : • allocates motion-points appropriate to the SEGMENT-WIDTH • calculates all motion-derivatives

* **To Select Data:**

1. Click a Header to select all of the data under that header that column

OR

2. Click a cell in the table
3. SHIFT+Click a different cell in the table

The highlighted data is now the **Selected-Data.**

The minimum number-of-points you can select to **Put** to the **List Segment-Type** is **6.**

You should usually put many more points to the **List Segment-Type**.

See also:

Get List Data [66]

Get Motion Data [67]

Get Selected-Segment Data [67]

Overlay-Trace [68]

1.9.11 Get motion data from displayed graphs

Get Motion Data from displayed Graphs

Get Motion Data

Transfer to the **Data-Transfer Table** the **motion-values** of the **complete motion** and of the **displayed** graphs.

- **# Columns:** X-axis + each motion-derivative that is displayed as a graph.
- # Rows : NUMBER-OF-STEPS

See Active Motion Settings > Motion tab > Motion Cycle Data [52] > NUMBER-OF-STEPS

Number Format : **see** Active Motion Settings > Number-Format tab > NUMBER-FORMAT [52] > PRECISION / DIGITS

Units : **see** Active Motion Settings > Motion tab > MOTION-UNITS [52] > X-AXIS / Y-AXIS UNITS

1.9.12 Get segment data from displayed graphs

Get Segment Data from displayed Graphs

Get Selected Segment Data

Transfer to the **Data-Transfer Table** the motion-values of the **SELECTED-SEGMENT** of the displayed graphs.

- **# Columns** : X-axis + each motion-derivative that is displayed as a graph.
- # Rows : NUMBER-OF-STEPS [52] × SEGMENT-WIDTH(DEGREES) / 360

Number Format : **see** Active Motion Settings > Number-Format tab > NUMBER-FORMAT [52] > PRECISION / DIGITS

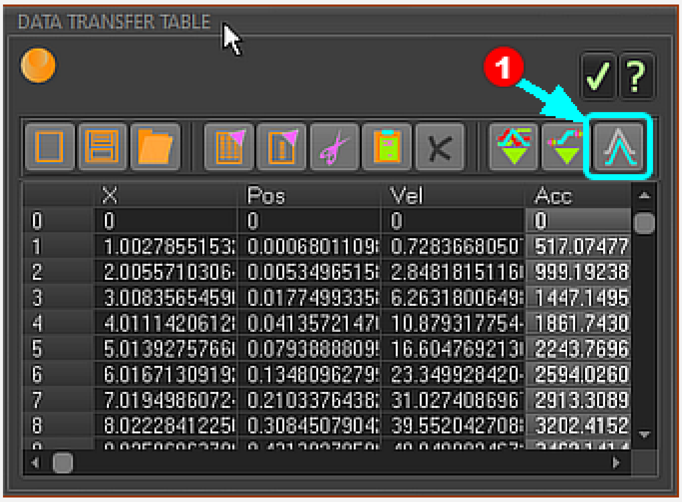
Units : **see** Active Motion Settings > Motion tab > MOTION-UNITS [52] > X-AXIS / Y-AXIS UNITS

1.9.13 Show data as Overlay-Trace

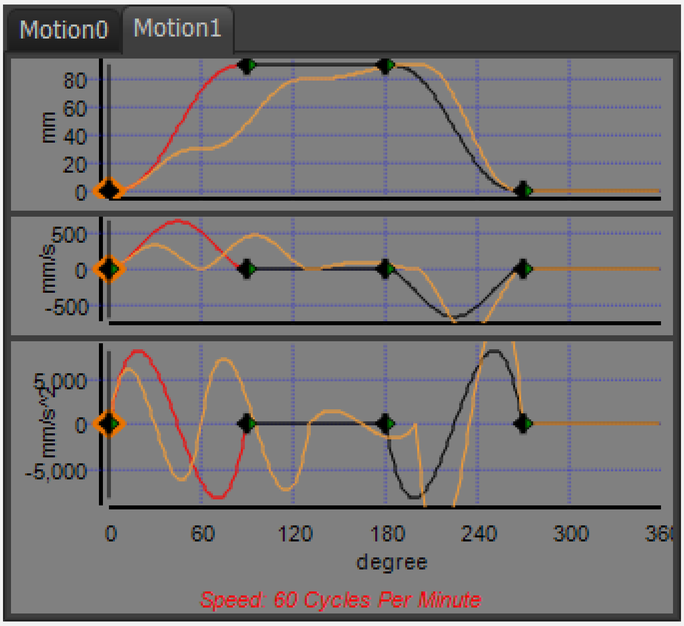
Overlay-Trace

Show the data in the **Data-Transfer Table** as a dumb graph over the active **Motion**.

We call this dumb graph an **Overlay-Trace**.

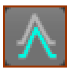


Position, Velocity, Acceleration motion-values for Overlay-Trace.



Overlay-Trace (in Orange) and the active Motion

To show an Overlay-Trace

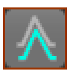


1. Make sure there is data in the **Data-Transfer Table** (see Prepare the Data for an Overlay Trace [69], below)
2. Click the **Overlay-Trace** icon in the toolbar.

   The data will show as the **Overlay-Trace** together with the active motion.
3. Click in the graph to scale the graphs correctly.

   The active-motion and the **Overlay-Trace** will rescale to their maximum and minimum values.

To hide the Overlay-Trace:



1. Click the **Overlay-Trace** icon again

	The plot is removed.

To edit the color of the Overlay-Trace

MotionDesigner > Edit toolbar > Active Motion Settings [53] > Accessibility tab > Overlay Trace color button.

Prepare the Data for an Overlay Trace

The data in the **Data-Transfer Table should be arranged as follows:**

- Data in Column 2, from Row 0, will display in the **Position** graph.
- Data in Column 3, from Row 0, will display in the **Velocity** graph.
- Data in Column 4, from Row 0, will display in the **Acceleration** graph.
- Data in Column 5, from Row 0, will display in the **Jerk** graph.

Note:

- The **Overlay-Trace** will show even if the data in each column are not motion-derivatives of each other.
- The **Overlay Trace** will show for each column of data in the **Data-Transfer Table.**

Overlay-Trace example:

To show the motion-values of **Motion0** as an **Overlay Trace** in **Motion1.**

If necessary:

1. Click File toolbar > Add Motion [44] to add a **Motion1** as a new motion name-tab
2. Click View toolbar [56] > P, V, A, J buttons to show all motion-derivatives in **Motion1**
3. Click **Motion0 name-tab** to make it the active motion
4. Click View toolbar > P, V, A, J buttons to show all motion-derivatives in **Motion0**

Open the Data-Transfer Table.

5. Click Blend-Point and Segment Editor toolbar > Data-Transfer Table [61].

We want to get the motion-values from Motion0 into the Data-Transfer Table.

6. Click Data-Transfer Table > Get Motion Data [67].

   The **Data-Transfer Table** will fill with the motion-values for each motion-derivative in **Motion0.**

Make Motion1 the active motion.

7. Click **Motion1 name-tab** to make it the active motion

Show the data that is in the Data-Transfer Table as the Overlay-Trace in Motion1.

8. Click Data-Transfer Table > Overlay Trace button

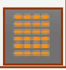
   You will see the motion-values of **Motion0** as an **Overlay Trace** in **Motion1.**

9. Click in the Graph of Motion1 to re-scale **Motion1** and the **Overlay Trace.**

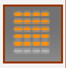
   The graphs should rescale to show the maximum and minimum of the **Motion1** and the **Overlay-Trace.**

1.9.14 Get Last Point

Toggle: Do Transfer or Do Not Transfer Last Motion Point



A Toggle for when you **GET Motion-Data** [67]:

OR 	• Do transfer the last motion data point from the motion graphs to the **Data-Transfer Table**. OR • Do not transfer the last motion data point from the motion graphs to the **Data-Transfer Table.**

Example:

1. Edit the NUMBER OF POINTS = 361.

The NUMBER-OF-POINTS parameter is set in the **Active Motion Settings > Motion tab**.

2. Toggle IN the **Get Last Point**
3. Click **Get Motion Data**

The number of Rows in the Data-Transfer Table = 0 to 360, a total of 361 Rows

4. Click Clear Data from the Table [64]
5. Toggle OUT the **Get Last Point**
6. Click **Get Motion Data**

The number of Rows in the Data-Transfer Table = 0 to 359, a total of 360 Rows

---

Often you want to transfer the motion-data in the **Data Transfer Table** to another application.

Your application may need:

- the last row in the table to be equal to the first row in the table
- the last row in the table to be equal to the last point in the motion

---

See also:

See Active Motion Settings > Motion tab > Motion Cycle Data [52] > NUMBER-OF-POINTS

1.10 Motion Laws / Cam-Laws

Motion-Laws - also called Cam-Laws.

Select the **Motion-Law** for each segment with the Motion-Law Selector [59].

Each **Motion-Law** specifies with a mathematical expression how an **output variable** changes as a function of an **input variable.**

The mathematical expressions evaluate exactly the **displacement, velocity, acceleration,** and **jerk** motion-values The user does not need to know any mathematics.

We can separate the motion-laws into three groups.

Note: We list the motions in the **Motion-Law Selector** alphabetically (English spelling).

Traditional Motion-Laws

The **Traditional Motion-Laws** (also named **Standard Motion-Laws**) have been used for many years in cam mechanisms for motions that have **Rise** and **Return** segments that are separated with **Dwell** segments.

The **Traditional Motion-Laws** are based on:

- Trigonometric Functions, or
- Polynomials Functions

Traditional Motion-Laws:

1. Constant-Acceleration & Deceleration [75] - Polynomial Function
2. Constant-Velocity [78] - Polynomial Function
3. Cubic [83] - Polynomial Function
4. Cycloidal [85] - Trigonometric Function
5. Cycloidal Constant-Velocity 50% [87] -Trigonometric Function
6. Dwell [89] - Polynomial Function
7. Modified-Sinusoid [105] - Trigonometric Functions
8. Modified-Trapezoidal [108] - Trigonometric Functions
9. Polynomial 2-3 [104] - Polynomial Function
10. Polynomial 3-4-5 [111] - Polynomial Function
11. Polynomial 4-5-6-7 [113] - Polynomial Function
12. Polynomial Low Impact Crossover [102] - construct with two Flexible-Polynomial segments
13. Quadratic [118] - Polynomial Function
14. Ramp [120] - Trigonometric Function
15. Simple-Harmonic [123] - Trigonometric Functions
16. Sine-Constant-Cosine [126] + SCCA with Constant-Velocity 20%, 33%, 50%, 66%.... - Trigonometric Functions
17. Sine-Squared [129] - Trigonometric Functions
18. Sinusoidal [131] - Trigonometric Functions
19. Triple-Harmonic [133] - Trigonometric Functions

You can edit the SEGMENT PARAMETERS in the SEGMENT EDITOR to get a motion-law similar to:

a. Triple Harmonic - Modified Trapezoidal [137]
b. Triple Harmonic - Modified Sine [136]
c. Triple Harmonic - Zero Jerk at Crossover [138]

Throw Motion-Laws (Symmetrical & Asymmetrical)

A **Throw** motion-law is a **rise** segment followed **immediately** by a **return** segment.

We design different **Throw** motion-laws with two Flexible Polynomial [91] segments. They have different continuity, and the shape of the motion graph as they rise and return from the maximum displacement

20. Throw: Quick-Return 1 - Finite Jerk @ Start / End [94]
21. Throw: Quick-Return 2 - Zero Jerk @ Start / End [96]
22. Throw: Rapid-Return 1: Finite-Jerk @ Start/End/Mid-Point [98]
23. Throw: Rapid-Return 1: Zero Jerk @ Start/End, Finite Jerk @ Mid-Point [100]
24. Low Impact at Crossover [102]

Special Motion-Laws

These meet the needs of specific applications.

25. Y–Inverse-Sinusoid [140] **:** when applied to the motion of a **crank**, it gives a constant linear velocity at the tip of a crank. Maximum of one Y-Inverse-Sinusoid segment per crank rotation.
26. CV Inverse Crank [145] : similar to the **Y-Inverse-Sinusoid**, Not limited to one Crank-Constant-Velocity segment per motion.
27. Flexible-Polynomial [91] - a VERY important and useful motion-law - see also **Motion-Laws 20 - 24**
28. Ramp [120] - also a useful motion-law - see also **Motion-Law 5, Cycloidal CV50**

List Segment-Types

You can import your own motion-values to a **List Segment-Type**:

29. Position-List [115]
30. Acceleration-List [74]
31. Z-Raw-Data [143]

When to use the Flexible Polynomial OR a Traditional, or the both Motion-Laws?

The **Flexible Polynomial** is the default motion-law. It is very powerful. We recommend that you learn how to use it effectively and efficiently.

Traditional Motion-Laws have advantages in some circumstances.

We recommend that you use:

- **All Flexible-Polynomials** - to give powerful and flexible motion-design possibilities

OR

- **All Traditional Motion-Laws** - usually the easiest to design a Rise and Return type motion.

OR

- **A mixture of Flexible-Polynomial and Traditional Motion-Laws** - most difficult motion-design but may have advantages

The **Motion-Laws** available in ***MotionDesigner*** exceed the German Technical VDI-guidelines 2143 Papers (Part) 1 and 2. Also bear in mind, that a motion at a cam-follower or servomotor is usually found by MechDesigner with Inverse-Kinematics. When this is the case, the motion at the cam-follower or servomotor is not the same as the motion-design that is given to the tooling, or **MOTION-PART**.

1.10.1 Acceleration-List [Import Data]

Acceleration List

See also: Position-List[115], Z-Raw Data[143]

MOTION-DESCRIPTION

The **ACCELERATION LIST** is a List Segment-Type[72].

Import **Acceleration data.**

See Position-List[115] to learn how to Import data to a **List Segment-Type**.

MOTION-VALUES

MotionDesigner integrates (numerically) your data calculate and show the **Velocity** and **Position** graphs.

MotionDesigner re-samples the data to give the correct number-of-points in the segment, such that:

Number of points in a Segment = SEGMENT-WIDTH × NUMBER-OF-STEPS in Motion / 360

SEGMENT PARAMETERS

None

SEGMENT-RANGE

None

SAMPLING ACCELERATION-DATA - RECOMMENDATIONS.

Acquire **acceleration-data** of a machine component with an **Accelerometer Sensor**.

- We recommend a **DC-Accelerometer Sensor** that gives an output from **0** to **1000Hz**.
- From **0Hz** is important. At **0Hz**, you can use ±g to calibrate the accelerometer by turning it over (g = ~9811mm/s/s).
- Import the data for one machine cycle. You can use an Encoder on a machine shaft to trigger the start and end the Acceleration Data acquisition.
- You will get better results if you sample the data from a Dwell to a Dwell.
- Although there are mathematical techniques to compensate for any bias in the Acceleration Data, we do not use them when we integrate the your Acceleration data to get Velocity and Position.

1.10.2 Constant Acc and Dec Motion-Law [Parabolic]

Constant-Acceleration and Constant-Deceleration Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law [71]. Its name is often give **Constant-Acceleration**, or **Triangular Velocity.**

It has lowest **nominal** maximum **Constant Acceleration** of the **Dwell-Rise-Dwell** type motion-laws. For this reason, historically, it was recommended for cam motion-design. It is still commonly used for Servo and Stepper motions.

However, it has three **Acceleration Discontinuities (infinite Jerk)**. The middle acceleration discontinuity (Step change in value), when its acceleration reverses sign, is twice those at the start and end of the motion-law. These tend to induce vibrations in the mechanism it is driving.

Also, its peak **Drive Torque** is relatively high to others, and its **Drive Torque** reverses direction instantly at the crossover. The high peak torque can lead to drive shaft wind-up, and the instant reversal can lead to drive speed over-run in which the drive shaft increases its speed as it begins to decelerate the mechanism and payload.

It is **not** recommend for high-speed machinery, even if the motion is applied by Servo-motor or a Stepper-motor.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY & END VELOCITY

START ACCELERATION & END ACCELERATION

START JERK & END JERK

SEGMENT PARAMETERS

None

SEGMENT-RANGE

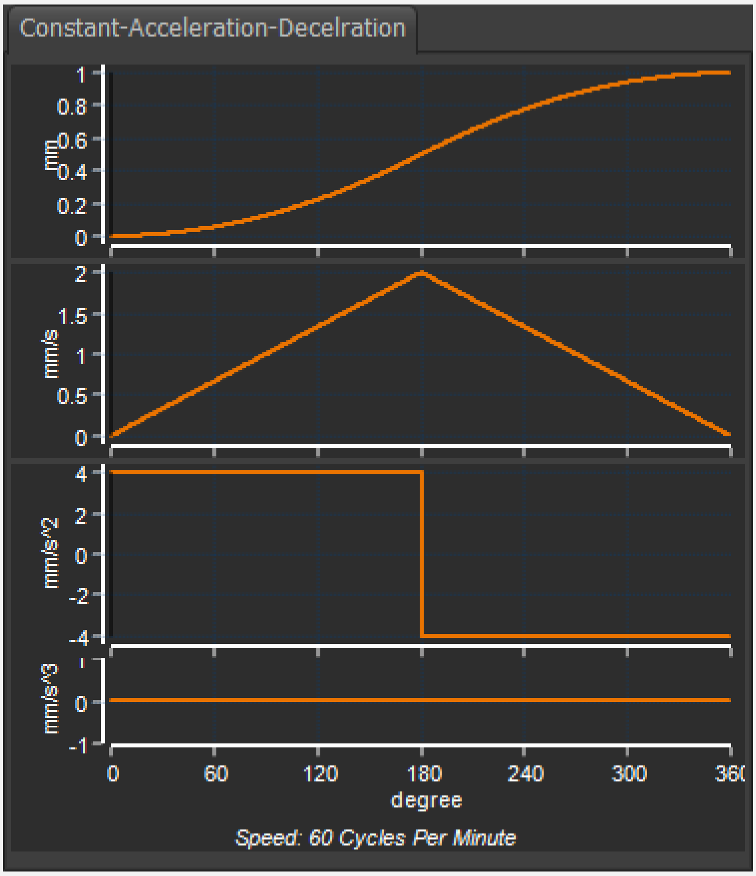
START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Constant-Acceleration - Constant-Deceleration Motion-Law - Parabolic Motion (Cam-Law)

Motion-Law Coefficients

Velocity Coefficient :	$C_v = 2.000$
Acceleration Coefficient :	$C_a = 4.000$
Jerk Coefficient :	$C_j = \infty$
Jerk at Crossover :	$C_{Jc} = 2\infty$

APPLICATION NOTES

This Motion-Law was used in the past because it has the lowest **nominal acceleration** of the **Traditional Motion-Laws.** However, it has infinite-jerk at three points: at its start, end, and at its crossover. This makes it a very poor choice form a dynamic viewpoint. Infinite-Jerk incites vibrations in any mechanical system. We do **not** recommend this motion-law if the **PERIOD-RATIO** is less than 10, or even 20.

Dynamic Performance

The actual acceleration of the load being driven by Constant-Acceleration motion will be significantly higher than the nominal value because of induced vibrations.

For this reason, this segment should only be used in applications where inertia effects are small or even insignificant.

Pressure-Angle Considerations

This segment produces a relatively large pressure-angle - and so might need a large cam for a given lift. The pressure-angle for this segment varies quite severely throughout this Motion-Law indicating that it is unsuitable for roller follower applications because of the severe accelerations imposed on the roller that will tend to induce roller slip.

Drive-Torques

This law performs badly in terms of drive torque considerations. All of the torque factor curves for this law exhibit a discontinuity, indicating shock loading and noise in operation. Particularly notable is the sudden reversal of the inertia torque factor, and hence of the torsional strain energy, at the crossover of the motion segment. These reversals will contribute further to noise, shock loading and vibration during operation.

1.10.3 Constant-Velocity : Specify Velocity

Constant-Velocity Cam-Law, Motion-Law

This is a Polynomial motion type

See also : Constant-Velocity: Specify Two Positions [81].

MOTION-DESCRIPTION

The Velocity is Constant for the period of the SEGMENT-WIDTH.

MOTION-VALUES

You CAN specify the:

START-POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

START-VELOCITY

The START-VELOCITY usually **flows** from the END-VELOCITY of the PREVIOUS-SEGMENT

You CANNOT specify the:

END-POSITION

The END-POSITION is a calculated from the START-POSITION, START-VELOCITY, and SEGMENT-WIDTH [28]

END-VELOCITY

The END-VELOCITY is equal to its START-VELOCITY

END-ACCELERATION

END-JERK

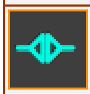
Example

VELOCITY CONTINUITY

1. Use the Motion-Law Selector [59] to change a motion-law of a segment to a CONSTANT-VELOCITY.
2. Click above or below the segment in the motion-graphs.

The CONSTANT-VELOCITY segment is now the SELECTED-SEGMENT.

3. Open the BLEND-POINT EDITOR



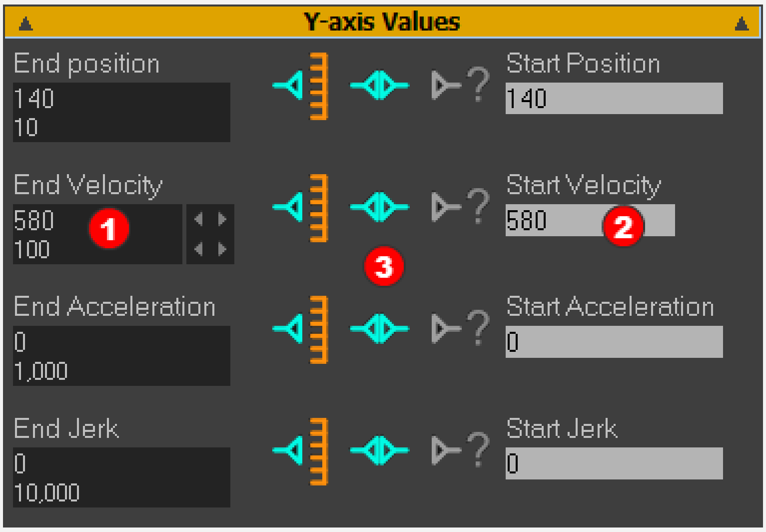
1. Set the **Match Control Button** to **Flow / Match** - see image ❸

The Velocity at the **Start of the Selected-Segment** is now forced to be equal to the Velocity at the **End of the Previous-Segment**.

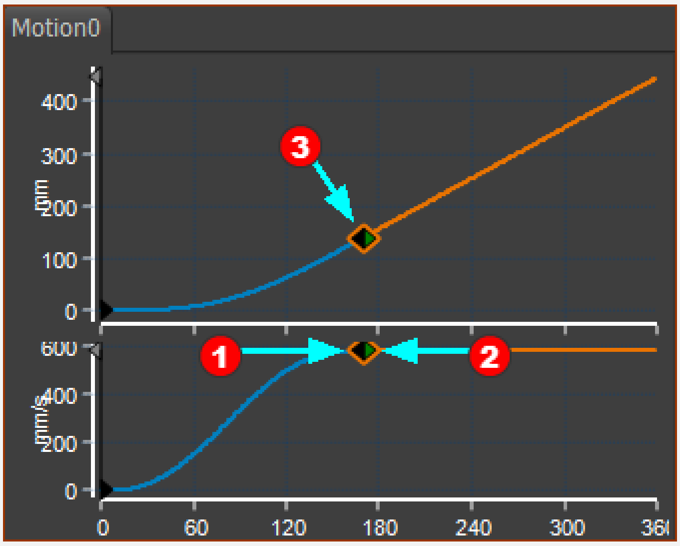
The Start Velocity becomes Read-Only.

2. Edit the **End Velocity**❶

See that the **Start-Velocity**❷ is always equal to the **End-Velocity**.



Blend-Point Editor: Velocity Equal at Blend-Point.



Smooth Flow of Velocity at Blend-Point
Equal Gradients of Position Graph at Blend-Point

Example continued...

VELOCITY DIS-CONTINUITY

Definition of dis-continuity: the motion-value of the motion-derivative changes instantly, with a step. A Dis-continuity is also called a **Step-Change**.

A **discontinuity** in **Velocity** is NOT recommended, of course.

A **discontinuity in Velocity** is also **INFINITE ACCELERATION** - mechanically impossible.

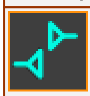
A **discontinuity** puts a **kink** in the **Position** graph.

An example of a Velocity Dis-Continuity.

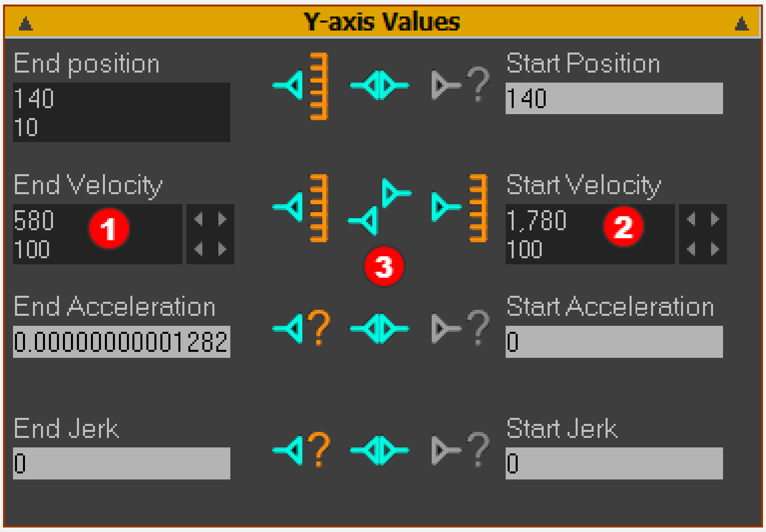
1. Use the Motion-Law Selector 59 to change a motion-law of a segment to a **CONSTANT-VELOCITY**.
2. Click above or below the segment in the motion-graphs.

The **CONSTANT-VELOCITY** segment is now the SELECTED-SEGMENT.

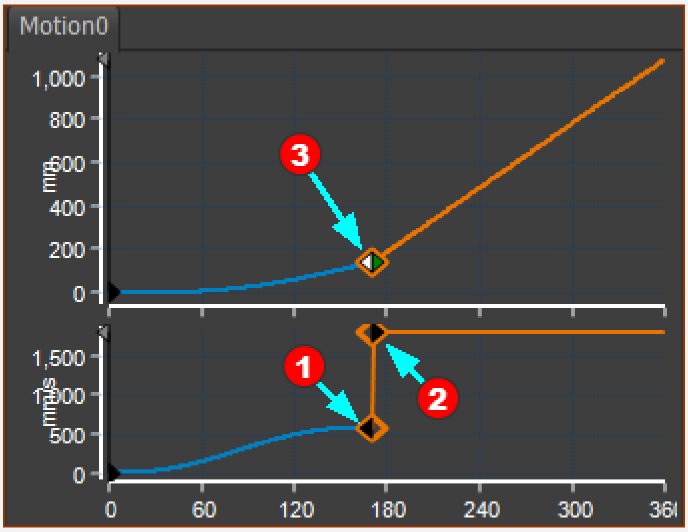
3. Open the BLEND-POINT EDITOR



4. Set the **MATCH CONTROL-BUTTON** to **DO NOT MATCH**3
5. Enter a **START-VELOCITY**1 value that is not equal to the **END-VELOCITY**2 value.



Blend-Point Editor: Velocities at Blend-Point are not Equal



Step in Velocity Graph, & Kink(corner) in Position Graph.
Step in gradient at Blend-Point in Position-Graph.

1.10.4 Constant-Velocity : Specify Two Positions

Constant-Velocity | Two Position

See also : Constant-Velocity: Specify Velocity (78).

MOTION-DESCRIPTION

Use the **Flexible-Polynomial** to define a Two-Position Constant-Velocity

The Velocity is calculated from the SEGMENT-WIDTH and the difference between the END-POSITION and START-POSITIONS.

You must make sure the Velocity at the End of the PREVIOUS-SEGMENT is equal to the velocity of this segment.

The Acceleration and Jerk Values at the start and end of the segment are zero.

MOTION-VALUES

You CAN specify the:

START-POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END-POSITION

You CANNOT specify the:

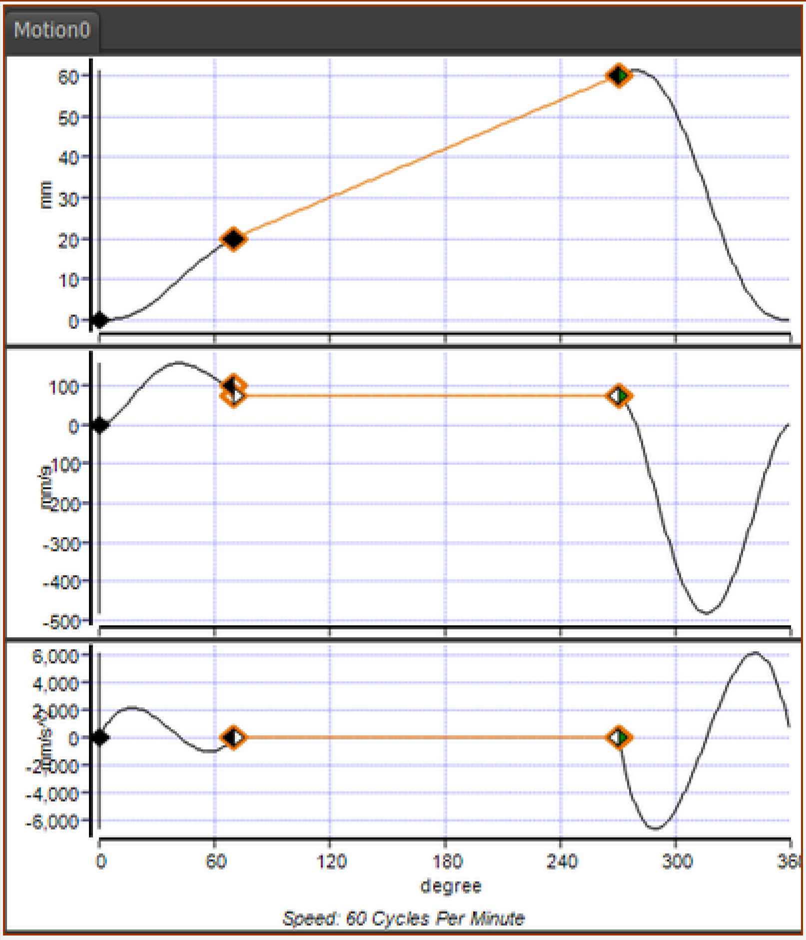
START-VELOCITY & END-VELOCITY

START-ACCELERATION & END-ACCELERATION

START-JERK & END-JERK

SEGMENT EDITOR: Control-Buttons for a 'Two Position | Constant-Velocity motion-law.

1. Use the Motion-Law Selector (59) to select a **Flexible-Polynomial** motion-law
2. Select the Segment and open the **SEGMENT EDITOR**
3. De-select ALL MATCH (FLOW) **Control-Buttons**
4. De-select START-VELOCITY, START-ACCELERATION, START-JERK **Control-Buttons**
5. De-select END-VELOCITY, END-ACCELERATION, END-JERK **Control-Buttons**
6. Select the START-POSITION and END POSITION **Control-Buttons**
7. Enter the START-POSITION and END-POSITION
8. Enter the correct X-axis values.



Note:

When the **Constant-Velocity** segment is one segment of a complete machine-cycle use a GEARING FB, to replace a MOTION FB - assuming a LINEAR-MOTION FB is connected to the input of the GEARING FB.

When the GEARING-RATIO = 1 (in the GEARING DIALOG-BOX), the output will equal its input, it will increase steadily from 0 to 360.

If you enter the equation 270/360 as the GEARING RATIO the output will be from 0 to 270, when its input is from 0 to 360.

Thus, you can see it is easy to use a GEARING FB to output a **Constant-Velocity** for a complete a machine-cycle.

1.10.5 Cubic Motion-Law

Cubic Cam-Law, Motion-Law

MOTION-DESCRIPTION

A Traditional Motion-Law [71]. **The Jerk motion-values of this motion-law are constant.**

Apply it when you want the Jerk to be a constant value, or the Acceleration to increase linearly.

MOTION-VALUES

You CAN specify the:

START POSITION

The START POSITION usually **flows** from the END POSITION of the PREVIOUS-SEGMENT.

END POSITION

START VELOCITY

The START VELOCITY usually **flows** from the END VELOCITY of the PREVIOUS-SEGMENT)

END VELOCITY

You CANNOT specify the:

START ACCELERATION & END ACCELERATION

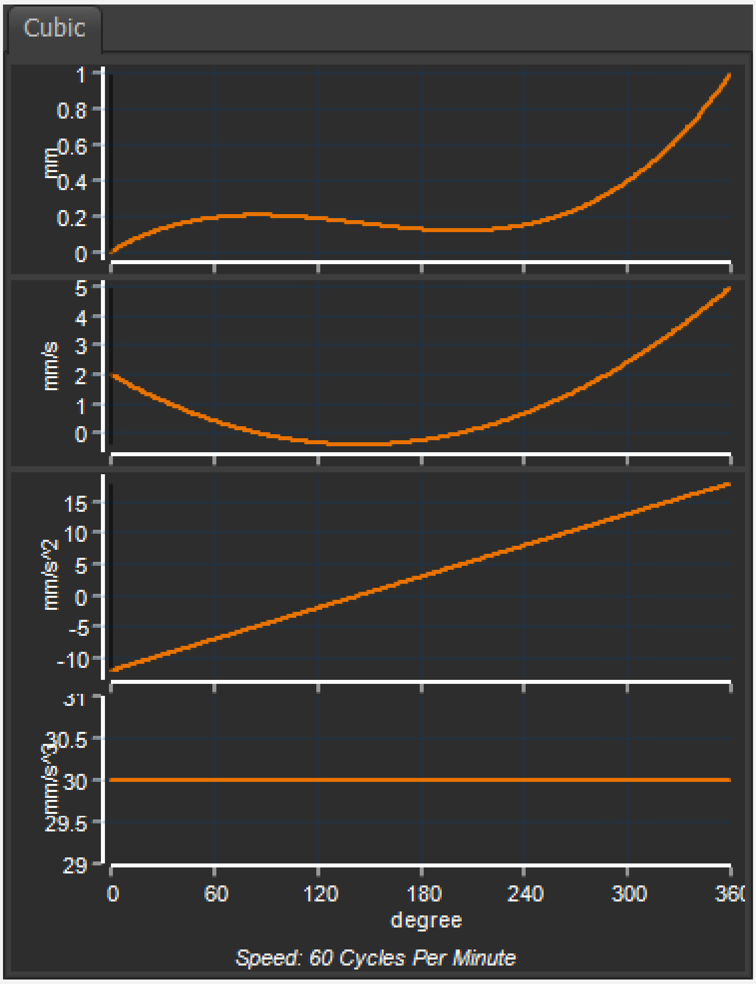
START JERK & END JERK

SEGMENT PARAMETERS

None

SEGMENT-RANGE

None



Cubic Motion-Law

1.10.6 Cycloidal Motion-Law

Cycloidal Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law [71].

A motion with continuous Velocity and Acceleration from start to end. There is Jerk discontinuity at its start and end.

The Cycloidal motion-law is recommended in applications where the period ratio is near to 5 and when the input drive is stiff and the shaft speed does not fluctuate significantly under load. It has good acceleration characteristics at the load and should be used in systems where low residual vibration (vibration after the end of the motion segment) is desired.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY & END VELOCITY

START ACCELERATION & END ACCELERATION

START JERK & END JERK

SEGMENT PARAMETERS

None

SEGMENT-RANGE

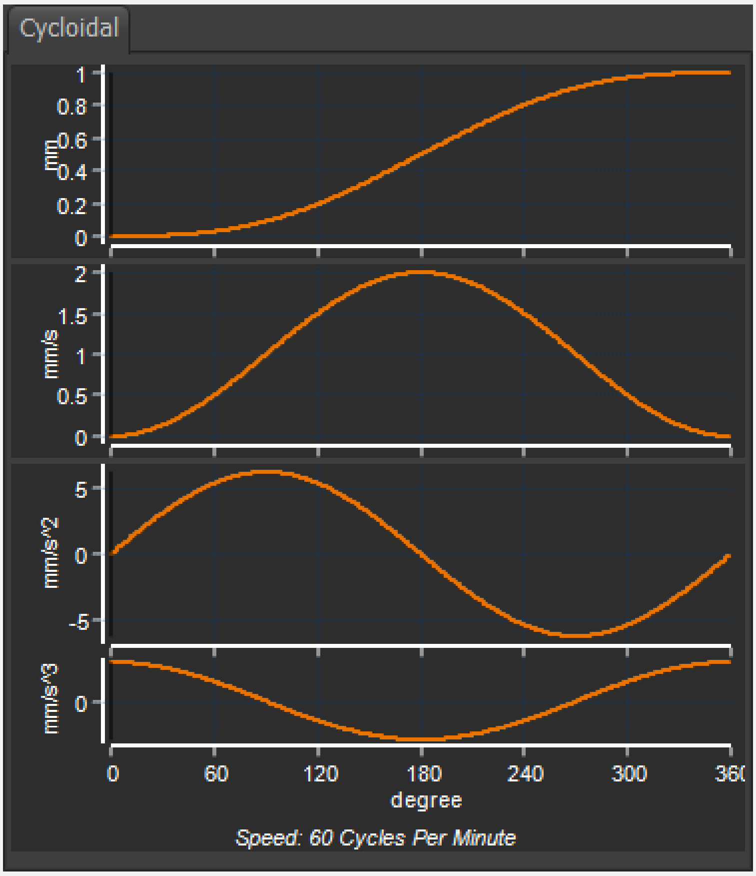
START-RANGE - DEFAULT = 0

END-RANGE - DEFAULT = 0

0 ≤ START-RANGE < END-RANGE ≤ 1

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Cycloidal Motion-Law (Cam-Law)

MOTION-LAW COEFFICIENTS

Velocity Coefficient :	$C_v = 2.000$
Acceleration Coefficient :	$C_a = 6.28$
Jerk Coefficient :	$C_j = 39.48$
Jerk at Crossover :	$C_{Jc} =- 39.48$

APPLICATION NOTES

Dynamic Performance

This Motion-Law is recommended in applications where the period ratio is near to 5 when the input drive is stiff and the shaft speed does not fluctuate significantly under load. It has a good acceleration characteristics at the load and should be used in systems where low residual vibration (vibration after the end of the motion segment) is desired.

Pressure Angle Considerations

It gives a relatively large pressure angle - and so might need a large cam for a given lift and predetermined pressure angle limits, to reduce it.

Drive Torques

This Motion-Law is recommended in applications where no sudden change of input torque is a requirement. Its torque characteristics are particularly good in relation to the other Traditional Motion-Laws when the period ratio is less than approximately 10.

1.10.7 Cycloidal-CV50 Motion-Law

Cycloidal-CV50 Cam-Law, Motion-Law

MOTION-DESCRIPTION

A Traditional Motion-Law[71]. We use the **Ramp**[120] **Motion-Law** to design a **CYCLOIDAL-CV50.**

The **Cycloidal-CV50** has three phases:

- **Phase 1:** Acceleration : first ½ wave of a Sine function : 25% of the SEGMENT-WIDTH.
- **Phase 2:** Zero Acceleration, Constant Velocity : 50% of the SEGMENT-WIDTH.
- **Phase 3:** Deceleration : last ½ wave of a Sine function : 25% of the SEGMENT WIDTH

A motion with continuous Velocity and Acceleration, from start to end, The Jerk is finite at its start and end.

Its peak Acceleration is quite high, but its peak Velocity is quite low.

MOTION-VALUES

You CAN specify the:

Select the RAMP Motion-Law[120] :

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY & END VELOCITY - by definition, they are zero(0)

START ACCELERATION & END ACCELERATION - by definition, they are zero(0)

START JERK & END JERK - by definition, they are finite

SEGMENT PARAMETERS

We are using the **Ramp**[120] motion-law to give the **Cycloidal CV50** motion-law.

START-FRACTION × 100 = % of SEGMENT-WIDTH

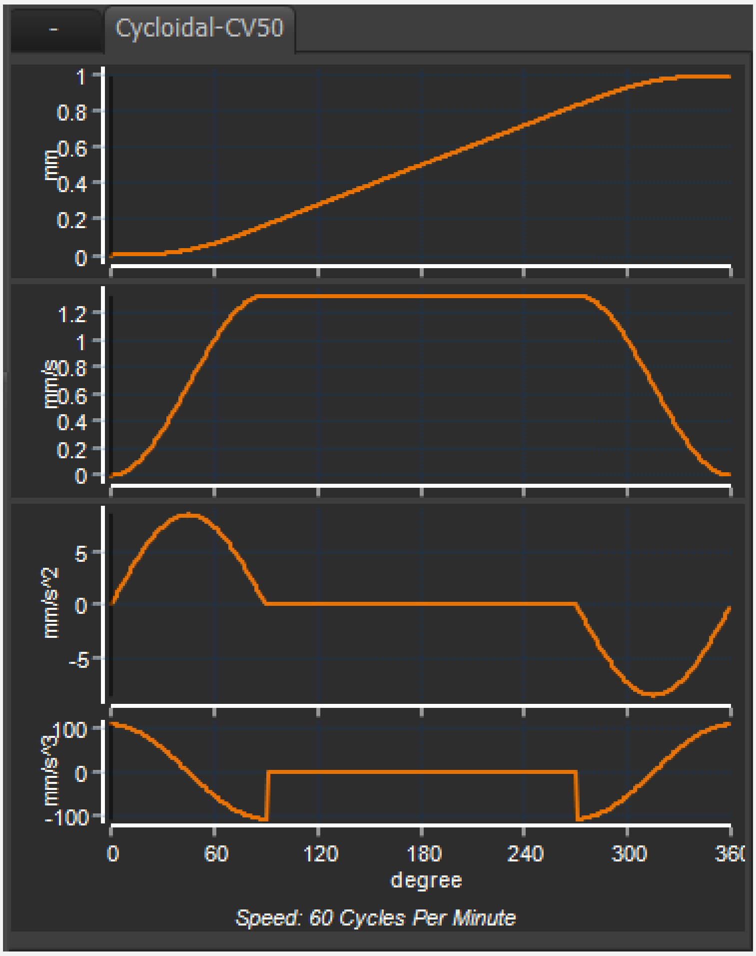
END-FRACTION × 100 = % of SEGMENT-WIDTH

SEGMENT-RANGE

START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1



Cycloidal-CV50 (50% is Constant-Velocity (with Ramp Motion-Law / Cam-Law

MOTION-LAW COEFFICIENTS

Velocity Coefficient :	$C_v = 1.333$
Acceleration Coefficient :	$C_a = 8.378$
Jerk Coefficient :	$C_j = 105.276$
Jerk at Crossover :	$C_{Jc} = 105.276$

APPLICATION NOTES:

Dynamic Performance

The **Cycloidal CV50 Motion-Law** is recommended in applications where you need the peak velocity to be low when compared to others. It has a large Peak Acceleration, with a short duration, thus more likely to induce vibrations.

Pressure Angle Considerations

It gives a relatively low pressure angle - because of its low peak velocity.

Drive Torques

This Motion-Law is not recommended in many applications as it will give a sudden change in torque. The input transmission rigidity would need to be high.

1.10.8 Dwell Motion-Law

Dwell Cam-Law, Motion-Law

MOTION DESCRIPTION

Dwell is a Traditional Motion-Law [71]. It is a **Polynomial Motion-Law.**

The **DWELL** motion-law has a constant **POSITION**, or zero displacement.

By definition, its motion-values for VELOCITY, ACCELERATION, and JERK are zero throughout the SEGMENT-WIDTH.

MOTION-VALUES

You CAN specify the:

POSITION at the START - which usually **flows** from the POSITION at the end of the PREVIOUS-SEGMENT

You CANNOT specify the:

POSITION at the END - by definition, it is equal to the POSITION at its START

VELOCITY at the START or END

ACCELERATION at the START or END

JERK at the START or END

SEGMENT PARAMETERS

None

SEGMENT-RANGE

None

APPLICATION NOTES:

Use a **Dwell** when you want a tool to be stationary.

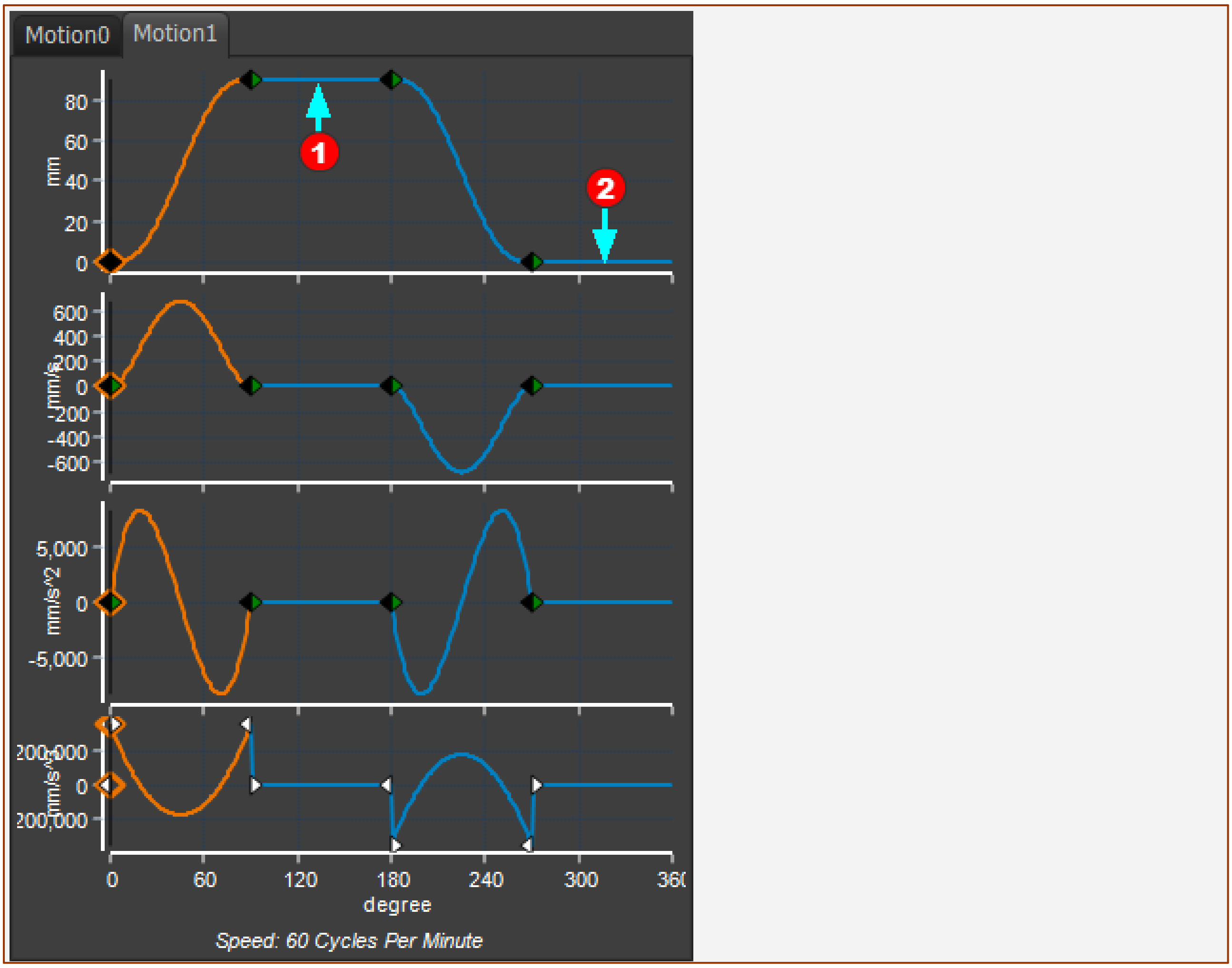
However, **Dwell** segments are used too frequently. Why?

The other segments become shorter in duration, and their peak accelerations also increase. Shorter segment are more likely to induce vibration in the mechanism. The Peak Torque of the drive-shaft also increases, and reverses from a positive to a negative torque more rapidly. This can lead to wind-up and over-run of the drive-shaft.

TOP-TIP

Try **not** to use a **Dwell** segment unless you need a tool to be absolutely stationary for at least 20° range of the X-axis.

If the dwell is less than 20°, then. as an alternative, try to delete the **Dwell** segment. Then, use segments that are before and after the 'dwell' that have zero jerk-values at the Blend-Point that replaces the Dwell segment.


Motion0
Motion1
mm
80
60
40
20
0
1
2
600
400
200
0
-200
-400
-600
5,000
0
-5,000
mm/s^2
0
60
120
180
240
300
degree
Speed: 60 Cycles Per Minute

1.10.9 Flexible-Polynomial Motion-Law

Flexible-Polynomial Cam-Law, Motion-Law

MOTION DESCRIPTION

You can use the **FLEXIBLE-POLYNOMIAL** motion-law for many, or most, design applications.

You can, for each motion-derivative (P, V, A, J) :

- **edit** the motion-values at its start and end,
- **not edit** the motion-values at its start and end
- **force** the motion-value at its start to match the motion-value at the end of the PREVIOUS-SEGMENT

You can use the **Flexible-Polynomial** to replicate a **motion-law** that is based on any of the other Polynomial Functions:

- Dwell 89, Constant-Velocity 78, Cubic 83, Quadratic 118, Throw 94, Poly 345 111 and Poly 4567 113 motion-laws.

Finally, you can edit the **Flexible-Polynomial** to design a motion-law you don't even know you need!

See Tutorial: Introduction to the Flexible-Polynomial Motion-Law.

MOTION-VALUES

You CAN choose to edit the:

START POSITION and END POSITION

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

You CANNOT edit the:

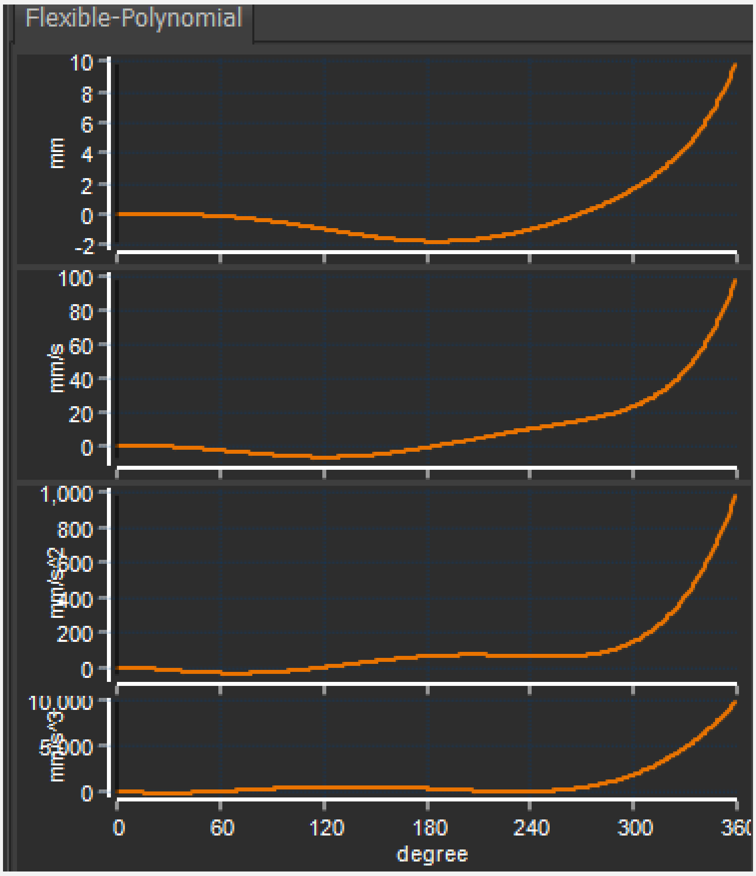
None

SEGMENT PARAMETERS

None

SEGMENT-RANGE

None



Flexible-Polynomial

1.10.10 Throw Motion-Law

The Throw Motion-Law

Unlike other motion-laws, the **Throw motion-law** is a Rise followed immediately with a Return motion. There is not a Dwell segment between the Rise and Return.

Throw type motion-laws have zero velocity and acceleration at their start and end. Acceleration is continuous at its mid-point.

To give different motion characteristics, we can specify the Jerk values at the start and end of the Rise and Return, and also Jerk continuity at its mid-point.

For maximum flexibility, we use two **Flexible Polynomial** segments.

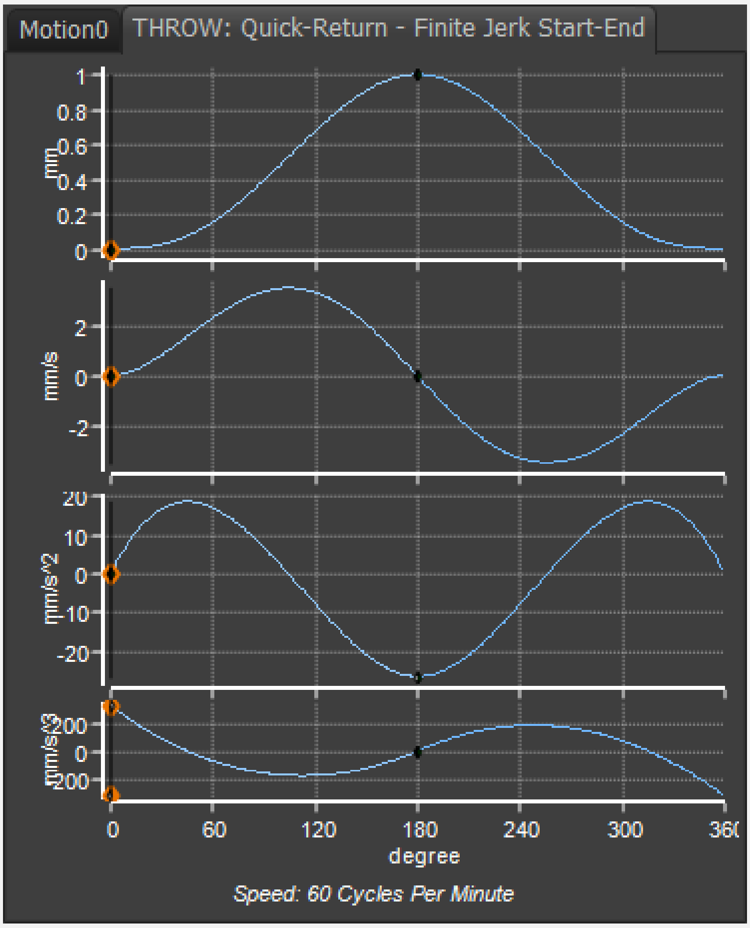
- Throw Quick-Return 1 94
- Throw Quick-Return 2 96
- Throw Rapid-Return 1 98
- Throw Rapid-Return 2 100
- Low Impact at Crossover 102

1.10.10.1 Throw Quick-Return: 1: Finite Jerk @ Start/End Motion-Law

Throw Quick-Return 1 - Finite Jerk at Start and End

Throw Quick-Return 1 - Finite Jerk at Start and End.

This **Throw Quick-Return 1** is the classic Rise-Return motion-law. It has a **Quick-Return** when compared to two Polynomial 345 segments because it has a negative acceleration at its maximum displacement - at the transition from Rise to Return.



Throw Quick Return 1 - Finite-Jerk at Start and End nts

MOTION-VALUES OF EACH MOTION-DERIVATIVE

Start of rise segment 1 :

- Position = 0
- Velocity = 0
- Acceleration = 0
- Jerk = Unspecified (Actual value = 320 mm/s/s/s)

Mid-Point :

- Position = 1
- Velocity = 0
- Acceleration = Unspecified (Actual value = –26.666 mm/s/s)

  OR Acceleration = –20 mm/s/s
- Jerk = 0

End of return Segment 2 :

- Position = 0
- Velocity =0

- Acceleration = 0
- Jerk = Unspecified (Actual value = –320 mm/s/s/s)

See also:

- Throw: Quick Return: Zero Jerk @ Start/End/Mid-Point [96]
- Throw: Rapid Return: Finite Jerk @ Start/End/Mid-Point [98]
- Throw: Rapid Return: Smooth-Start/End [100]

1.10.10.2 Throw Quick-Return: 2: Zero Jerk @ Start/End/Mid-Point

Throw: Quick-Return with Zero Jerk at its Start and End

The Throw Motion-Law

Unlike the other motion-laws, the **Throw motion-law** rises from its **Start-Position** to its maximum displacement, and then returns to its **Start-Position**.

We use two **Flexible Polynomial** segments to design the **Throw motion-law**. Usually, the two segments have equal durations, but it is not necessary.

Throw: Quick-Return 1 - Zero Jerk at Start and End.

Because we use two **Flexible-Polynomial** segments to design the **Throw motion-law**, we can specify different motion-values and motion-constraints at its start, its maximum displacement, and at its end.

All **Throw motion-laws** have zero velocity and acceleration at their start and end.

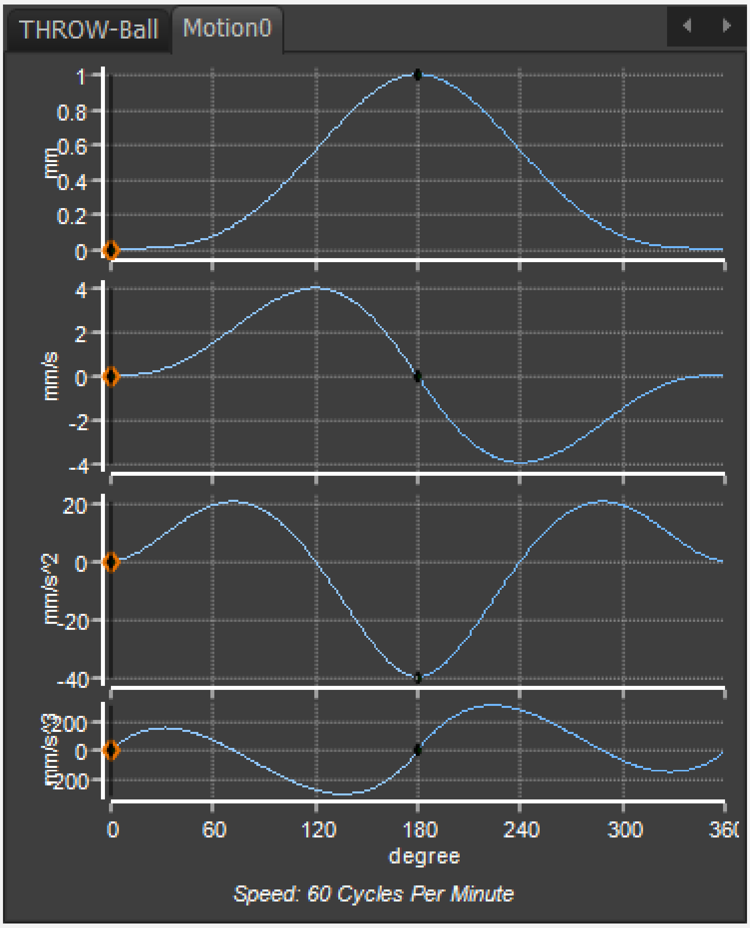
This **Throw motion-law** also has zero Jerk at its start and end.

This **Throw** has a **Quick-Return** because it has a negative acceleration at its maximum displacement - the transition from Rise to Return.

See also:

- Throw: Quick Return 1 Finite Jerk @ Start/End/Mid-Point [94]
- Throw: Rapid Return: Finite Jerk @ Start/End/Mid-Point [98]
- Throw: Rapid Return: Smooth-Start/End [100]

Throw: Quick-Return - Zero Jerk at its Start-and End.



THROW: Quick-Return Zerk Jerk Start, Middle, End

MOTION-VALUES OF EACH MOTION-DERIVATIVE

Start of rise segment 1 :

X =0

- Position = 0
- Velocity = 0
- Acceleration = 0
- Jerk = 0

Mid-Point :

X=180* (you can move the mid-point)

- Position = 1
- Velocity = 0
- Acceleration = Unspecified (Actual value = -40.0mm/s/s)
- Jerk = 0

End of return Segment 2 :

X=360

- Position 2 = 0
- Velocity = 0
- Acceleration = 0
- Jerk = 0

1.10.10.3 Throw Rapid-Return 1: Finite-Jerk @ Start/End/Mid-Point Motion-Law

Throw: Rapid-Return Finite Jerk

The Throw Motion-Law

Unlike other motion-laws, the **Throw motion-law** rises from its **Start-Position** to its maximum displacement, and then returns to its **Start-Position**.

To give you maximum flexibility, we use two **Flexible Polynomial** segments to design the **Throw motion-law**. Usually, the two segments have equal durations, but it is not necessary.

Throw: Rapid-Return 1 - Zero Jerk at Start and End.

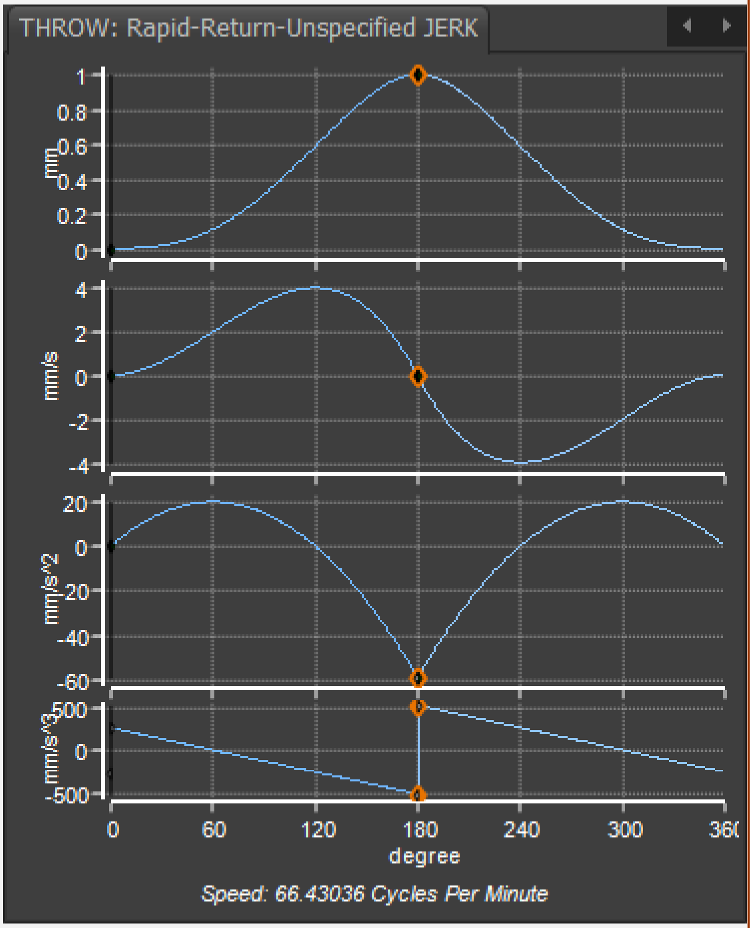
Because we use two **Flexible-Polynomial** segments to design the **Throw motion-law**, we can specify different motion-values and motion-constraints at its start, its maximum displacement, and at its end.

This **Throw** has a **Quick-Return** because it has a LARGE negative acceleration, and unspecified Jerk, at its maximum displacement - the transition from Rise to Return.

See also:

- Quick Return 1: Finite Jerk @ Start/End/Mid-Point 94
- Quick Return 2: Zero Jerk @ Start/End/Mid-Point 96
- Rapid Return 2: Smooth-Start/End 100

Two Segment 'Rapid-Return Motion 1



MOTION-VALUES OF EACH MOTION-DERIVATIVE

Start of Rise segment 1 :

- Position = 0
- Velocity = 0
- Acceleration = 0
- Jerk = Unspecified (Actual value = 260.6m/s/s/s)

Middle Blend-Point* :

- Position = 1
- Velocity = 0
- Acceleration = Unspecified (Actual value = -58.84mm/s/s)
- Jerk = Unspecified (Actual value = ±521.167mm/s/s/s)

End of Return segment 2 :

- Position 2 = 0
- Velocity = 0
- Acceleration = 0
- Jerk = Unspecified (Actual value = -260.6mm/s/s/s)

	* Edit the X-axis value of the middle Blend-Point to give an asymmetrical motion.

1.10.10.4 Throw Rapid-Return 2: Zero-Jerk @ Start/End Motion-Law, Finite at Mid-Point

Throw: Rapid-Return with Zero Jerk

The Throw Motion-Law

Unlike other motion-laws, the **Throw motion-law** rises from its **Start-Position** to its maximum displacement, and then returns to its **Start-Position**.

To give you maximum flexibility, we use two **Flexible Polynomial** segments to design the **Throw motion-law**. Usually, the two segments have equal durations, but it is not necessary.

Throw: Rapid-Return 2 - Zero Jerk at Start and End, unspecified at its mid-point.

Because we use two **Flexible-Polynomial** segments to design the **Throw motion-law**, we can specify different motion-values and motion-constraints at its start, its maximum displacement, and at its end.

All **Throw motion-laws** have zero velocity and acceleration at their start and end.

This **Throw motion-law** also has zero Jerk at its start and end.

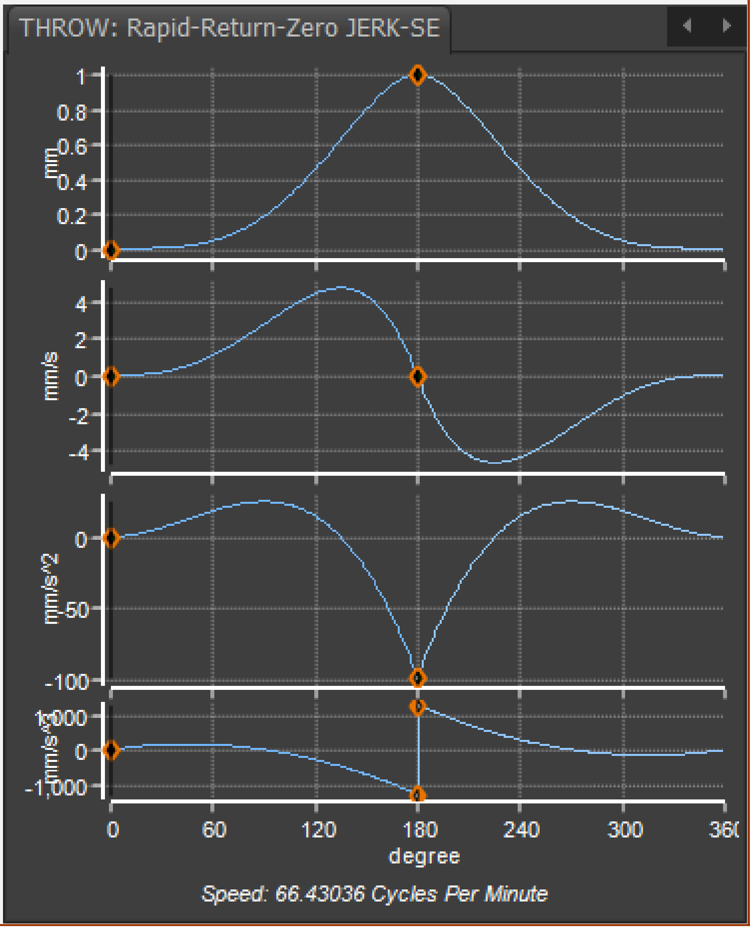
This **Throw** has a **Quick-Return** because it has a LARGE negative acceleration, and unspecified Jerk, at its maximum displacement - the transition from Rise to Return.

The **Throw type motion-law** it typically symmetrical. You can make it asymmetrical, if you move the X-axis value at its mid-point.

See also:

- Quick Return 1: Finite Jerk @ Start/End/Mid-Point [94]
- Quick Return 2: Zero Jerk @ Start/End/Mid-Point [96]
- Rapid Return 1: Finite-Jerk @ Start/End/Mid-Point [98]

Two Segment 'Rapid-Return with Zero Jerk at Start/End, 2'



MOTION-VALUES OF EACH MOTION-DERIVATIVE

Start of rise segment 1 :

- Position = 0
- Velocity = 0
- Acceleration = 0
- Jerk = 0

Mid-Point :

- Position = 1
- Velocity = 0
- Acceleration = Unspecified (Actual value = -98.mm/s/s)
- Jerk = Unspecified (Actual value = ±1303mm/s/s/s)

End of return Segment 2 :

- Position 2 = 0
- Velocity = 0
- Acceleration = 0
- Jerk = 0

1.10.11 Low Impact Crossover Motion-Law

Low Impact at Crossover.

Impact, Overrun, and Crossover.

Crossover is the timing in a motion at which the acceleration becomes a deceleration, and vice versa.

At crossover, machine components in the cam-system will traverse any **backlash** in the transmission. There will be an **impact** between the components.

As the Torque reverses, the motor becomes driven by the payload. The drive motor may accelerate so that the motor is rotating faster than intended for a short period. This is called **overrun**. As a result, the velocity and acceleration of the cam-follower may also be greater than intended.

A motion-law with **Low Jerk at Crossover** will mean the acceleration is changing less rapidly at crossover. Impacts, and Overrun are reduced.

Low Impact at Crossover.

Low or Zero Impact at Crossover motion-law is not available in the Motion-Law Selector [59]. We use two **Flexible Polynomial motion-laws.**

Velocity and Acceleration are zero at the start and end.

Acceleration and Jerk are zero at the mid-point.

The **Low Impact at Crossover** is typically symmetrical. You can make it asymmetrical if you move the X-axis and the Position at the mid-point. The maximum Velocity should not change, but the maximum Acceleration and Jerk values will increase.

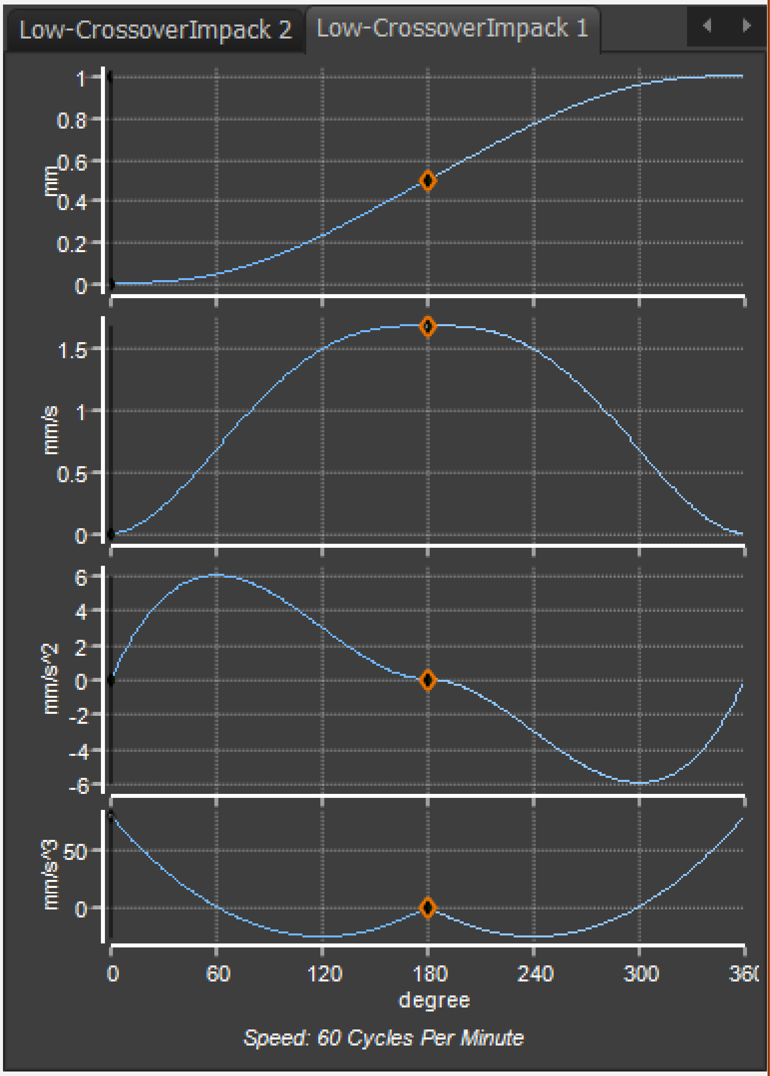
MOTION-LAW COEFFICIENTS

Velocity Coefficient :	$C_v = 1.667$
Acceleration Coefficient :	$C_a = 5.926$
Jerk Coefficient :	$C_j = 80, -26.667$
Jerk at Crossover :	$C_{Jc} = 0.0$

See also:

- Quick Return 1: Finite Jerk @ Start/End/Mid-Point [94]
- Quick Return 2: Zero Jerk @ Start/End/Mid-Point [96]
- Rapid Return 1: Finite-Jerk @ Start/End/Mid-Point [98]

Two Segment 'Rapid-Return 2'



MOTION-VALUES OF EACH MOTION-DERIVATIVE - Normalized values

Start of rise segment 1 :

X = 0 (0°)

- Position = 0
- Velocity = 0
- Acceleration = 0
- Jerk = Unspecified (Actual value = 80 mm//s/s/s)

Mid-Point :

X = 0.5 (180°)

- Position = 0.5
- Velocity = Unspecified (Actual value = 1.6667 mm/s)
- Acceleration = 0
- Jerk = 0

End of return Segment 2 :

X = 1 (360°)

- Position = 1
- Velocity = 0
- Acceleration = 0
- Jerk = Unspecified (Actual value = 80 mm//s/s/s)

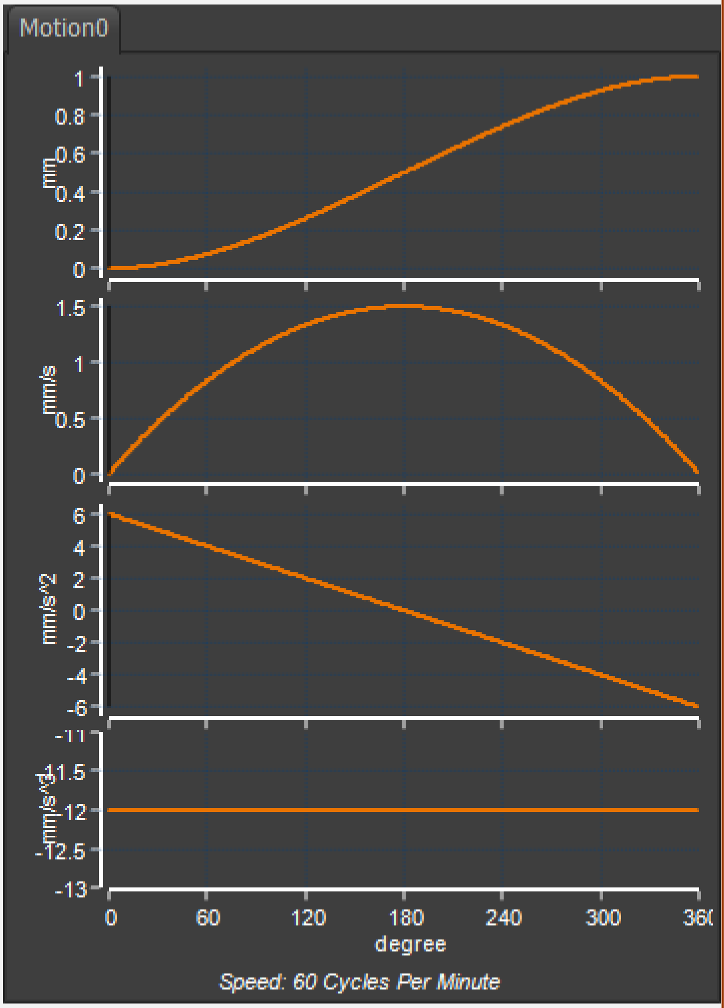
1.10.12 Polynomial 2-3 Motion-Law

Polynomial 2-3 Cam-Law, Motion-Law

The **Polynomial 2-3 Motion-Law** is not available directly with the Motion-Law Selector.

You can use the Control Button [21] (also Segment Editor Control-Buttons [29]) with the Flexible-Polynomial [91] to be a Polynomial 2-3.

You can use the Control Button with the Cubic Motion-Law [83], but you must specify 0 units/s for its START-VELOCITY and END-VELOCITY.



Polynomial 2-3

This segment is included for reference.

A different name for this motion-law is a **Parabolic Velocity.** This motion-law is not usually recommended.

The maximum velocity is the lowest of the *Traditional Motion-Laws* .

I have read somewhere that it requires the least possible kWh of all the possible motions.

Dynamic Performance

Polynomial 2-3:

- there is a **Motion Discontinuity** in acceleration at the start and end of the segment.
- there is an **infinite jerk** at the start and end of the segment.
- should only be used in applications where the period-ratio is greater than 10, ideally at least 20.
- uses the minimum energy from a servomotor or stepper motor.

Polynomial 2-3 with Flexible Polynomial Motion-Laws

If you can put a Flexible Polynomial motion-law before and after this segment, then it is possible to make sure the motion is continuous in position, velocity and acceleration.

Some

1.10.13 Modified-Sinusoid Motion-Law

Modified-Sinusoid Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law 71. Its name is often reduced to **Mod-Sine.**

A motion with continuous **Velocity** and **Acceleration**, from start to end. The Jerk is finite at its start and end.

It is commonly used in high-speed mechanisms. It is the most common motion-law used with Cam Indexing mechanisms.

Its **Drive Torque** is relatively low and it reverses its sign most gradually of all the **Traditional Motion-Laws.**

MOTION-VALUES

You CAN specify the:

START POSITION - which usually **flows** from the End-Position of the PREVIOUS-SEGMENT

END POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

None

SEGMENT-RANGE

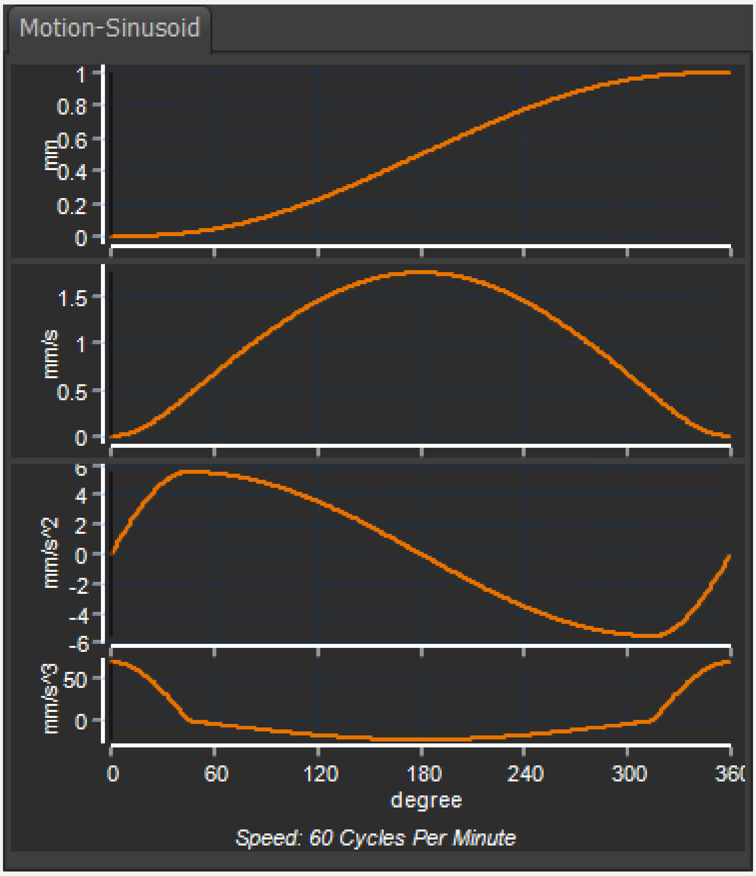
START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Modified-Sinusoid Cam-Law / Motion-Law

MOTION-LAW COEFFICIENTS

Velocity Coefficient :	$C_v = 1.760$
Acceleration Coefficient :	$C_a = 5.530$
Jerk Coefficient :	$C_j = 69.47$
Jerk at Crossover :	$C_{J(co)} =- 25.13$

APPLICATION NOTES

The **Modified Trapezoidal** motion-law has finite jerk throughout the segment. It has an average peak nominal acceleration compared to the other Traditional Motion-Laws.

Dynamic Performance

This Motion-Law is a good general purpose type particularly in applications where the period ratio is above about 5. It is not good in applications where the input drive has backlash or is relatively flexible. As long as the drive satisfies these conditions, then this segment exhibits low residual vibrations.

Pressure Angle Considerations

This one of the **Traditional Motion-Laws** that produce a relatively large pressure angle - and so might need a large cam for a given lift and pre-prescribed maximum pressure angle.

Drive Torques

This Motion-Law exhibits a rapid reversal of acceleration at the crossover (mid) point. Only the Constant-Acceleration Motion-Law is more rapid, of the Traditional Segments. It is unsuitable to drive heavy masses at high speeds. The rapid reversal of torque may give rise to severe vibrations and shock loading especially if the period ratio is less than 10.

More information:

The Acceleration function is a series of Sinusoid functions.

- a ¼ Sine wave function, starting from zero acceleration, for 12.5% of the SEGMENT-WIDTH.
- a ½ Cosine function, for 75% the SEGMENT-WIDTH
- a ¼ Sine wave function, returning to zero acceleration, for 12.5% of the SEGMENT-WIDTH.

1.10.14 Modified-Trapezoidal Motion-Law

Modified-Trapezoid Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law [71]. Its name is often reduced to **Mod-Trap**.

A motion with continuous Velocity and Acceleration, from start to end. The Jerk is finite at its start and end. Its peak acceleration is moderate.

It is commonly used in high-speed mechanisms. It was often used in Dwell-Rise-Dwell-Return cam-mechanisms. It has a low peak acceleration and velocity.

The **Drive Torque** is high and reverses rapidly, when compared to the Modified-Sinusoid [105] motion-law.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

None

SEGMENT-RANGE

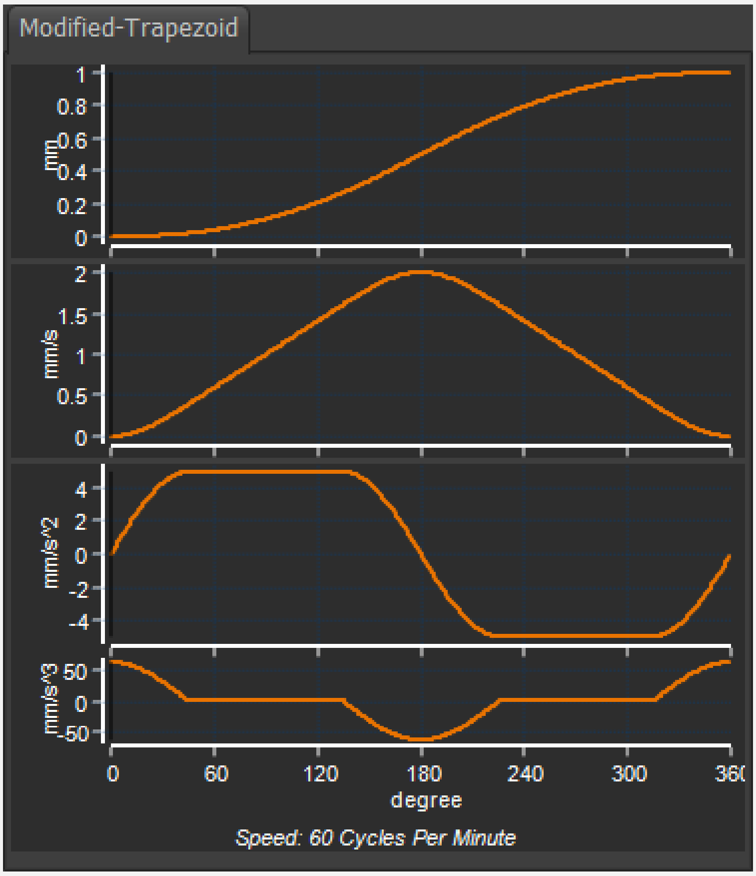
START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Modified Trapezoid Cam-Law / Motion-Law

MOTION-LAW COEFFICIENTS

Velocity Coefficient :	$C_v = 2.00$
Acceleration Coefficient :	$C_a = 4.890$
Jerk Coefficient :	$C_j = \pm 61.43$
Jerk at Crossover :	$C_{J(co)} = -61.43$

APPLICATION NOTES

Dynamic Performance

This Motion-Law is a good general purpose type particularly in applications where the period ratio is above about 5. It is not good in applications where the input drive has backlash or is relatively flexible. As long as the drive satisfies these conditions, then this segment exhibits low residual vibrations.

Pressure Angle Considerations

This one of the Traditional Motion-Laws that produce a relatively large pressure angle - and so might need a large cam for a given lift and pre-prescribed maximum pressure angle.

Drive Torques

This Motion-Law exhibits a rapid reversal of acceleration at the crossover (mid) point. Only the Constant-Acceleration Motion-Law is more rapid, of the Traditional Segments. It is unsuitable to drive heavy masses at high speeds. The rapid reversal of torque may give rise to severe vibrations and shock loading especially if the period ratio is less than 10.

More information:

The acceleration function of the **Modified-Trapezoidal** is:

- 0.125 of SEGMENT-WIDTH - 1/4 Sine function
- 0.250 of SEGMENT-WIDTH - Constant-Acceleration
- 0.250 of SEGMENT-WIDTH - 1/2 Cosine function
- 0.250 of SEGMENT-WIDTH - Constant-Acceleration
- 0.125 of SEGMENT-WIDTH - 1/4 Sine function

1.10.15 Polynomial 3-4-5 Motion-Law

Polynomial 3-4-5 Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law 71. Its name is often reduced to **Poly-345.**

A motion with continuous **Velocity** and **Acceleration**, from start to end. The **Jerk** is finite at its start and end. It has finite **Jerk** throughout.

It gives a relatively low nominal peak velocity, but a relatively high peak nominal Acceleration. It has a relatively low Jerk value at the crossover point (the mid-point). It is commonly used in high-speed mechanisms.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

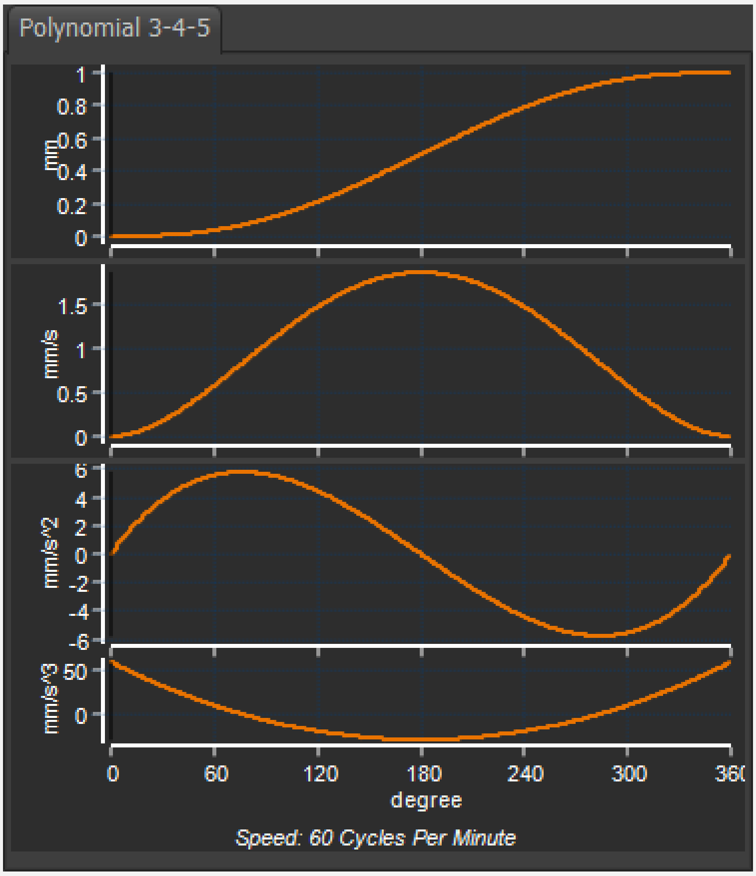
None

SEGMENT-RANGE

NONE

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law

See also : Tutorial 9: Asymmetrical Motions



Polynomial 3-4-5 Motion-Law / Cam-Law

MOTION-LAW COEFFICIENTS

Velocity Coefficient :	$C_v = 1.875$
Acceleration Coefficient :	$C_a = 5.773$
Jerk Coefficient :	$C_j = \pm 60.000$
Jerk at Crossover :	$C_{Jc} = -30.00$

APPLICATION NOTES

Dynamic Performance:

This Motion-Law is recommended for applications where the period ratio is between 5 and 10, particularly where the input drive is flexible and has backlash. It also performs relatively well from a residual vibration viewpoint.

Pressure Angle Considerations

This is a Traditional Motion-Law that produces a relatively small pressure angle - and so might allow a smaller cam for a given lift and pre-prescribed maximum pressure angle.

Drive Torques

Both the nominal drive torque characteristics and the actual drive torques for low period ratio values are reasonable for this law. The peak values and smooth variation of the drive torque during the motion segment makes it suitable in applications where the input drive is relatively flexible or exhibits backlash.

1.10.16 Polynomial 4-5-6-7 Motion-Law

Polynomial 4-5-6-7 Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law [71]. Its name is often reduced to **Poly-4567**.

A motion with continuous **Velocity** and **Acceleration**, from start to end. The **Jerk** is finite at its start and end. It has finite **Jerk** throughout.

It has a high maximum-velocity, high maximum-acceleration, high crossover jerk. Only the **MODIFIED-TRAPEZOIDAL** (of those with finite Jerk) has a greater crossover jerk.

At the start and end of this Motion-Law, the **Y-axis** does not change very much with a significant **X–axis** change - e.g. 0.02% Y-axis with 5% X-axis change.

Therefore, to accurately reproduce this segment, it needs precise machining, a large cam, or an encoder with a high resolution.

If possible, increase the SEGMENT-WIDTH [28] to reduce its maximum Velocity, Acceleration and Jerk values.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

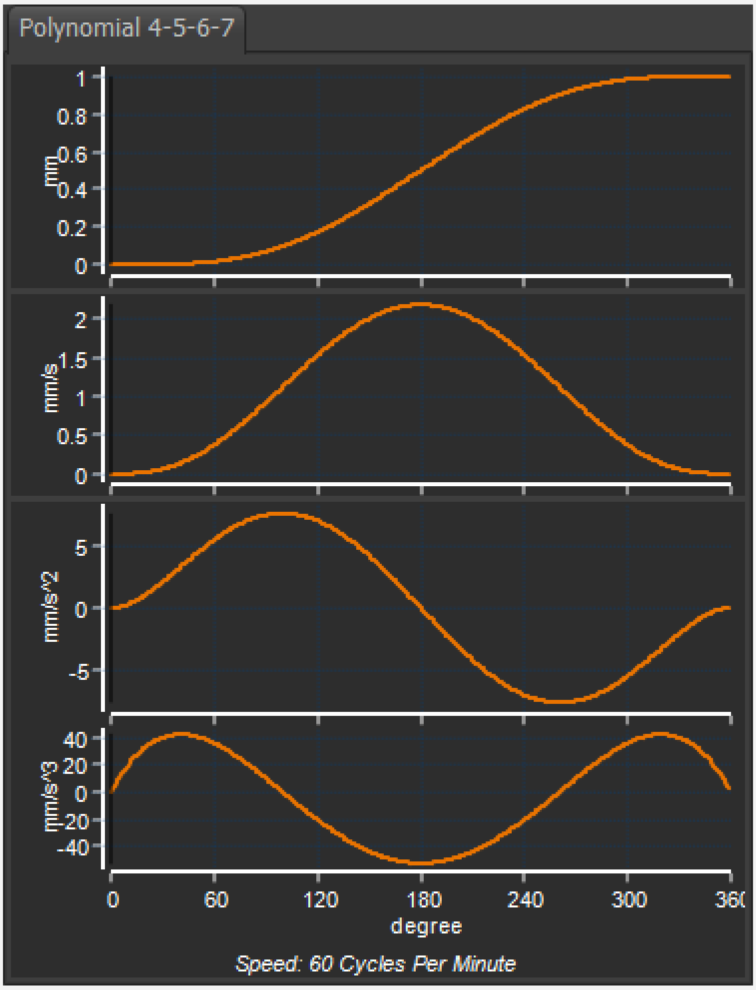
None

SEGMENT-RANGE

None

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Polynomial 4-5-6-7 Motion-Law / Cam-Law

Motion-Law Coefficients

Velocity Coefficient :	$C_v = 2.188$
Acceleration Coefficient :	$C_a = 7.513$
Jerk Coefficient :	$C_j = 52.5$
Jerk at Crossover :	$C_{Jc} = -52.50$

APPLICATION NOTES

Dynamic Performance:

This Motion-Law is recommended in applications where the period ratio is between about 5 and 10.

Pressure Angle Considerations

This has a relatively large maximum-acceleration and maximum velocity, which will increase the maximum pressure-angle.

Drive Torques

It has a high peak torque.

1.10.17 Position List [Import Data]

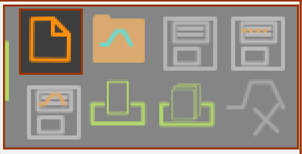
Import Data: Position List

The **Position List** is a **List Segment-Type.**

Other **List Segment-Types** are **Z-Raw-Data** [143] and the **Acceleration-List** [74]

You must use the Data-Transfer Table [61] to import data into a **Position-List segment.**

STEP 1. Add a new Motion



Add New Motion

See also Add Motion [44]

STEP 2. Delete Segments

Usually, the data you want to import is for one motion cycle.

In that case, you will need one segment in the motion.

You must delete three of the four segments from the default motion-law.

See Delete Segment [40]

STEP 3. Change the Motion-Law of the segment to Position-List

See Motion-Law Selector [59] > Position List

STEP 4. Import your motion-values (data) into the Data-Transfer Table

We must import the motion-values that you want to use as your motion into the **Data-Transfer Table.**

1. Open the Data-Transfer Table [61]
2. Click a cell in the first row of the **Data-Transfer Table** to make it the active cell.

To transfer data from a data file:

3a : Copy & Paste data from your clipboard into the **Data-Transfer Table**

OR

3a : Use the toolbar icon Load Data from a CSV or TXT file-type [64]

OR

3a : Get all displayed P, V- A J Segment-Data [67] or Get all displayed P, V , A, J Motion Data [67] from a **different Motion name-tab.**

Motion-values (data) are now in the **Data-Transfer Table.**

STEP 5. Transfer the data from the Data-Transfer Table to a Position List segment-type.

To transfer all of the data:

1. Select the Position motion-values in the **Data-Transfer Table**

   To select the data, you can click the header in the **Data-Transfer Table** with the Position motion-values.
2. Click Put List Data [66]  in the **Data-Transfer Table** toolbar.

Note : These two icon show only when the segment is a **List Segment-Type**.

OR

To transfer a sub-section of the data:

1. **CLICK** the **first data-point** you want to paste
2. **SHIFT+CLICK** the **last data-point** you want to paste

When the cells are **active**:

3. Click Put List Data [66] in the **Data-Transfer Table** toolbar.

Note : GET DATA and PUT DATA icons show **only** when the segment is a **List Segment-Type.**

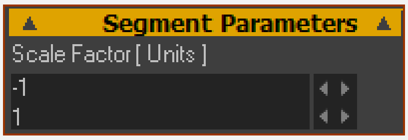
STEP 6. SCALE the data.

The minimum and maximum values will be equal to the actual values in the data.

However, you can also scale the data.

There are two cases:

CASE 1: First and Last data points are EQUAL



Scale-Factor and Position-List
Use when First = Last data point.

1. Open the SEGMENT EDITOR
2. Expand SEGMENT PARAMETERS
3. Edit the SCALE FACTOR parameter.

Notes:

If required, to see the SEGMENT PARAMETERS, expand and collapse the SEGMENT MOTION-LAW .

A SCALE FACTOR = 1 will scale the data to the actual minimum and maximum values.

You can edit the START POSITION to offset the data on the **Y-axis**

You can edit the MOTION-START value to move the data along the **X-axis.**

The Velocity, Acceleration and Jerk values scale automatically.

CASE 2: First and Last data points are NOT EQUAL

SEGMENT EDITOR : Start and End Positions of a Position-List segment

1. Start the SEGMENT EDITOR or BLEND-POINT-EDITOR
2. Edit the START-POSITION and END-POSITION

Note:

When the range from the START-POSITION to the END-POSITION do not equal the actual values the Velocity, Acceleration and Jerk values scale automatically.

You can edit the MOTION-START value to move the data along the **X-axis**.

1.10.18 Quadratic Motion-Law

Quadratic Cam-Law, Motion-Law

MOTION DESCRIPTION

A Traditional Motion-Law [71]. This is a Polynomial motion-law.

The Velocity increases or decreases linearly.

Acceleration is constant, but it is discontinuous at its start and end.

Jerk is generally zero, but has infinite Jerk at its start and end.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

START VELOCITY

You CANNOT specify the:

END VELOCITY

START ACCELERATION and END ACCELERATION

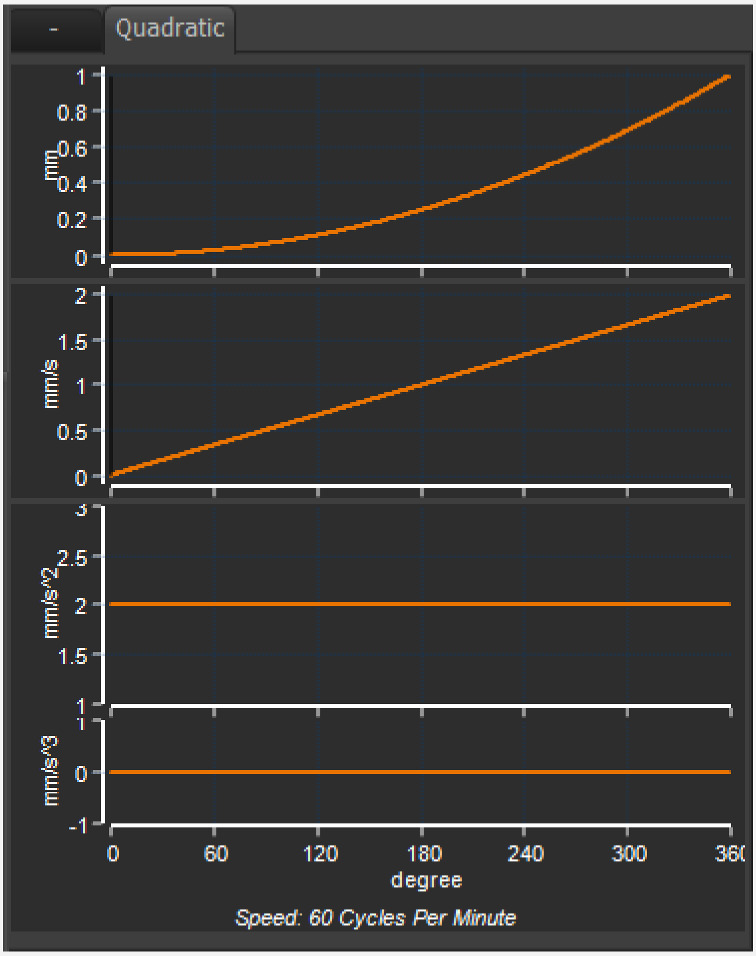
START JERK and END JERK

SEGMENT PARAMETERS

None

SEGMENT-RANGE

None



Quadratic Motion-Law

In the image above of the Quadratic segment and motion, the motion-values are:

- START POSITION = 0mm
- END POSITION = 1mm
- START VELOCITY = 0mm/s

APPLICATIONS

Segments with Constant Acceleration, Linearly Increasing-Velocity, or Linearly Decreasing Velocity.

You can use this to model a Part under the influence of a Constant-Acceleration, or a constant force or torque.

1.10.19 Ramp Motion-Law

Ramp Cam-Law, Motion-Law

A Traditional Motion-Law [71]

MOTION DESCRIPTION

The **Ramp.** has three phases:

Phase 1: Acceleration : first ½ wave of a Sine function (see SEGMENT-PARAMETERS)

Phase 2: Zero Acceleration : Constant Velocity

Phase 3: Deceleration : last ½ wave of a Sine function : (see SEGMENT-PARAMETERS)

You can design an **Asymmetric Segment**, in which the Acceleration phase is longer or shorter than the Deceleration phase.

Velocity and Acceleration are continuous from start to end.

The Jerk is finite and discontinuous at its start and end

The Jerk is finite and discontinuous at the end of the Acceleration and start of the Deceleration phases.

MOTION-VALUES

You CAN specify the:

START-POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END-POSITION

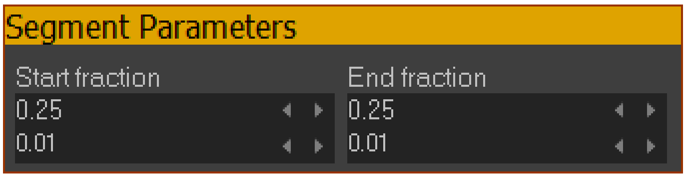
You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS



START-FRACTION × 100 = % of SEGMENT-WIDTH to accelerate from zero-velocity* to maximum-velocity

END-FRACTION × 100 = % of SEGMENT-WIDTH to decelerate from maximum-velocity to zero-velocity**

START-FRACTION + END FRACTION $\leq$ 1

∴ Constant-Velocity % = 1- START-FRACTION – END-FRACTION

---

* assuming START-RANGE is zero

** assuming END-RANGE is zero

SEGMENT-RANGE

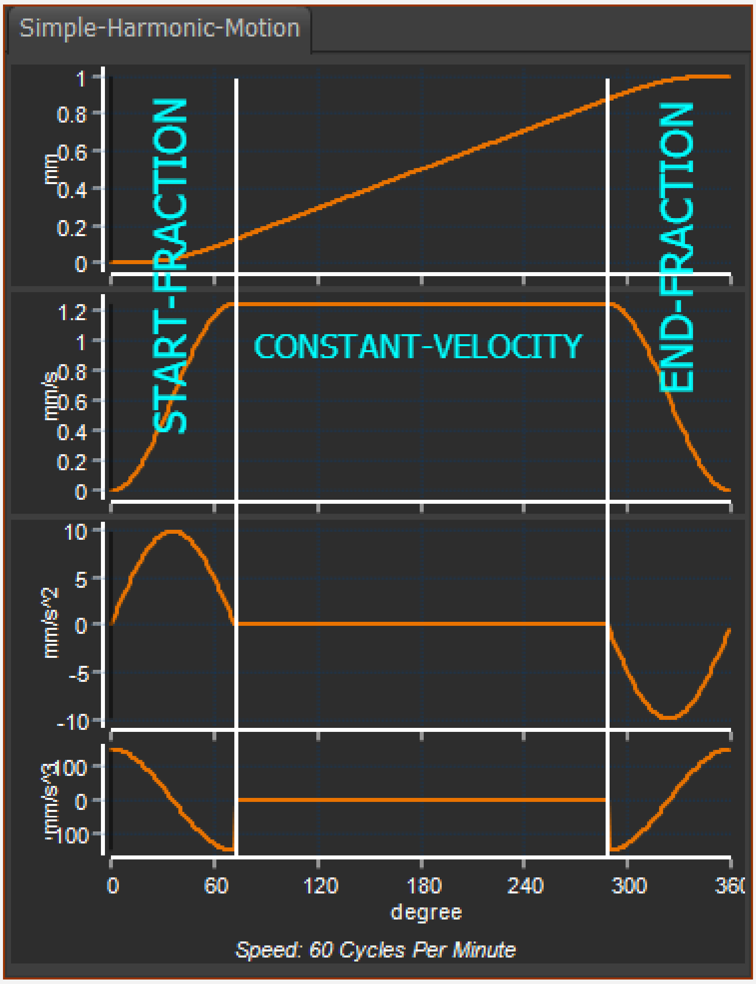
START-RANGE - remove the start of the segment.

END- RANGE- remove the end of the segment.

0 ≤ START-RANGE < END-RANGE ≤ 1

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law

See also : Tutorial 9: Asymmetrical Motions



1 x Ramp Segment, Symmetrical

Applications

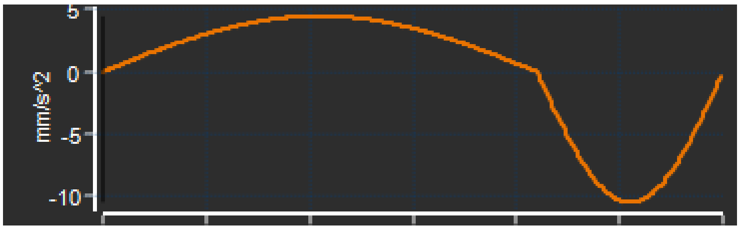
Asymmetric Segments, in which the Acceleration phase is longer or shorter than the Deceleration phase.

Motion with a long displacement, in which the maximum-velocity is less than other motion-laws.

Asymmetrical Example (see image below)

- START-FRACTION ≠ END-FRACTION
- START-FRACTION = 0.7
- END-FRACTION = 0.3
- START-FRACTION + END-FRACTION = 1

∴ CONSTANT-VELOCITY % = 0%



E.g.: RAMP Segment: Start-Fraction = 0.7, End-Fraction = 0.3
(Constant-Velocity Fraction = 0)

1.10.20 Simple-Harmonic Motion-Law

Simple Harmonic Motion Cam-Law, Motion-Law

A Traditional Motion-Law [71].

MOTION DESCRIPTION

This Motion-Law has the lowest maximum nominal velocity of all the Traditional Motion-Laws. However, it also produces infinite jerk at its start and end.

This makes it a poor choice form a dynamic viewpoint if you use it between Dwell Segments. However, you can usefully apply it between Flexible-Polynomial segments, with which it is possible to remove the acceleration discontinuities at its start and end.

MOTION-VALUES

You CAN specify the:

START-POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END-POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

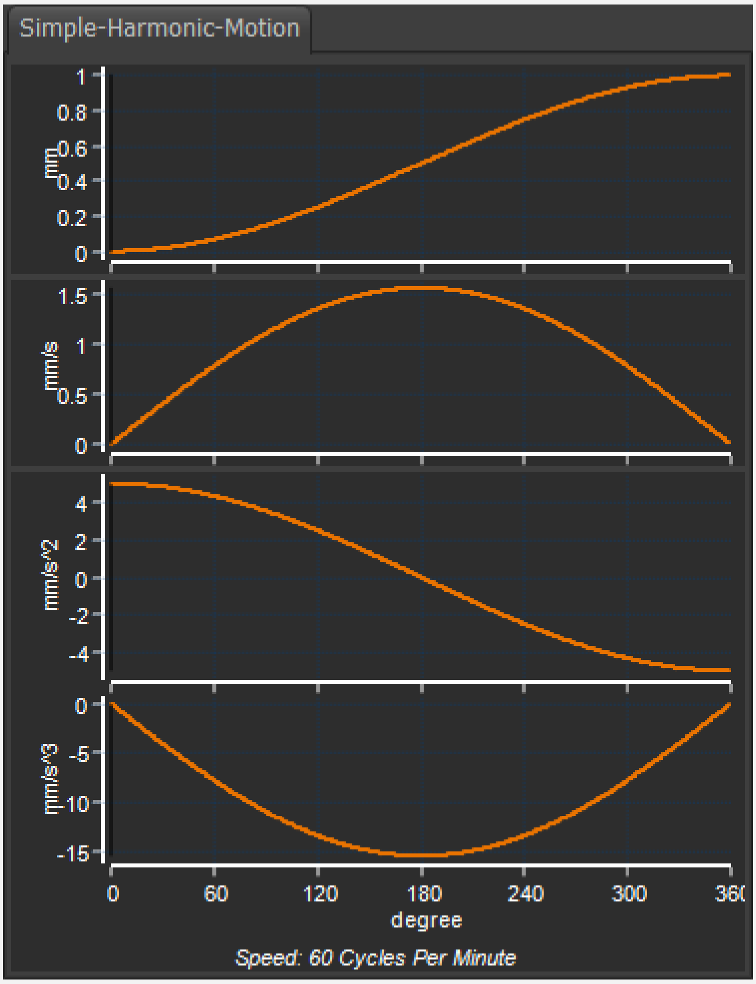
None

SEGMENT-RANGE [32]

None

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Simple-Harmonic-Motion Motion-Law

Motion-Law Coefficients

Velocity Coefficient :	$C_v = 1.517$
Acceleration Coefficient :	$C_a = 4.935$
Jerk Coefficient :	$C_j = 15.503$
Jerk at Crossover :	$C_{Jc} =- 15.503$

APPLICATION NOTES

Dynamic Performance:

This law should only be used in applications where inertia loading is not very significant. For values of Period-Ratio less than 10, the use of this law will give rise to shock loading, noise and vibration during operation.

The actual acceleration at the load being driven by this Motion-Law will always be significantly higher than the nominal value, and for this reason, this segment should only be used in mechanical applications where inertia effects are insignificant.

Pressure Angle Considerations:

This is one of the Traditional Motion-Laws that produce a relatively small pressure angle - and so might allow a smaller cam for a given lift.

Drive Torques:

When considering drive torques in isolation, the nominal torque for this Motion-Law is the best of Traditional Motion-Laws - it has both the lowest value and the smoothest variation throughout the segment. For compliant systems of high speed systems (period ratio between 2 and 10) the Modified Sine 105 and the Cycloidal 85 are preferred.

1.10.21 Sine-Constant-Cosine (SCCA) Motion-Law

Sine-Constant-Cosine Acceleration (SCCA) Cam-Law, Motion-Law - a Traditional Motion-Law [71]

MOTION DESCRIPTION

The SEGMENT-PARAMETERS make this motion-law very flexible. It is possible to get **many** of the Traditional Motion-Laws that are based on Sine and Cosine harmonics.

See below: Segment-Parameters for Traditional Motion-Laws [127].

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

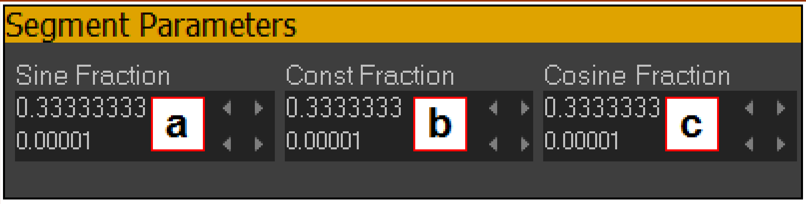
You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS



The **SCCA motion-law** is a defined by a sequence of trigonometric segments in acceleration motion-derivative. The motion-law is symmetrical, thus the sequence is:

$0.0 \le X \le 0.5$

a. Sine Fraction
b. Constant Fraction
c. Cosine Fraction:
d. Zero Acceleration

$0.5 \le X \le 1$

d. Zero Acceleration
c. Cosine Fraction
b. Constant Fraction
a. Sine Fraction

Example Motion-Law - see image below

a = 0.25 ; 25% : TOTAL SINE ACCELERATION FRACTION

b = 0.25 ; 25% : TOTAL CONSTANT ACCELERATION FRACTION

c = 0.25 ; 25% : TOTAL COSINE ACCELERATION FRACTION

∴ d = 1 – a – b – c = 0.25 ; 25% TOTAL ZERO ACCELERATION FRACTION.

Rules for the segment parameters:

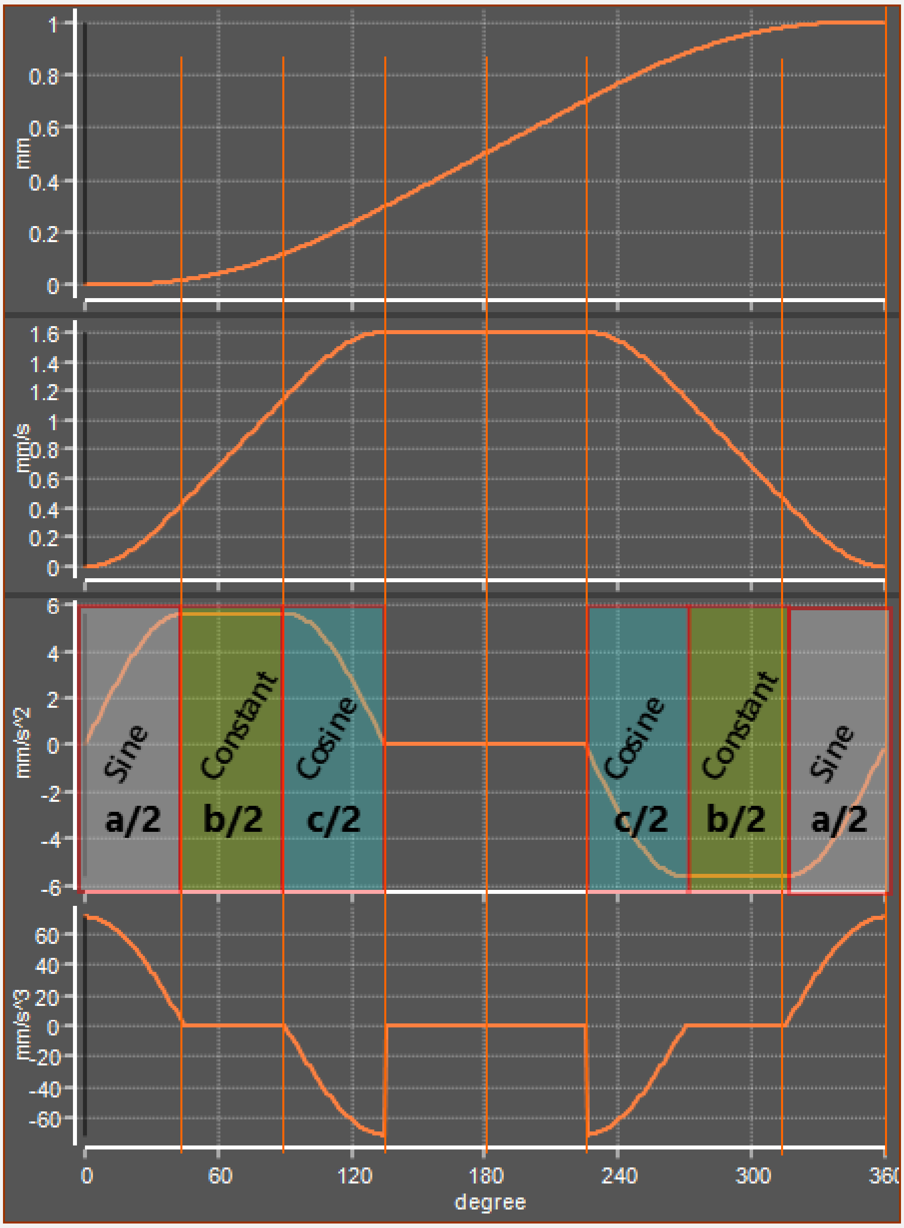
SEGMENT-PARAMETERS may be zero, but not all.

SEGMENT-PARAMETERS cannot be negative.

SEGMENT-RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1

An Example Sine Constant-Cosine Acceleration Law.



Example motion with Sine-Constant-Cosine Motion Law with Segment Parameters: Sine Fraction a=0.25, Constant b=0.25, Cosine Fraction c=0.25

Segment Parameters to give other Traditional Motion-Laws.

MOTION-LAW:	Coefficients		Parameters		
	Cv	Ca	a	b	c
Modified Trapezoidal:	2	4.89	0.25	0.5	0.25
'Lazy' Modified Trapezoidal:	2	4.88	0.333	0.333	0.333
Modified-Sine:	1.760	5.5	0.25	0	0.75
Modified-Sine CV 20%:	1.528	5.999	0.2	0	0.6
Modified-Sine CV 33%:	1.404	6.616	0.1667	0	0.5

Modified-Sine CV 50%:	1.275	8.0127	0.125	0	0.375
Modified-Sine CV 66%:	1.168	11.009	0.0833	0	0.25
Cycloidal:	2	6.2832	0.5	0	0.5
Cycloidal CV 50%:	1.333	8.378	0.25	0	0.25
Constant Acceleration-Deceleration:	2	4	0	1	0
Trapezoidal Velocity CV33%:	1.5	4.5	0	0.6667	0

1.10.22 Sine-Squared Motion-Law

Sine-Squared Cam-Law, Motion-Law

A Traditional Motion-Law [71].

MOTION DESCRIPTION

This maximum velocity and maximum-acceleration are large when compared with other motion-laws. However, it has zero crossover jerk.

At the start and end of this Motion-Law, the **Y-axis** does not change very much with a significant **X–axis** change. E.g. 0.02% Y-axis after 5% X-axis change.

Therefore, to accurately reproduce the Motion-Law, it needs precise machining, a large cam, or an encoder with a high resolution. If possible, increase the SEGMENT-WIDTH [28] by ~20% to reduce the maximum Velocity, Acceleration, and Jerk values.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

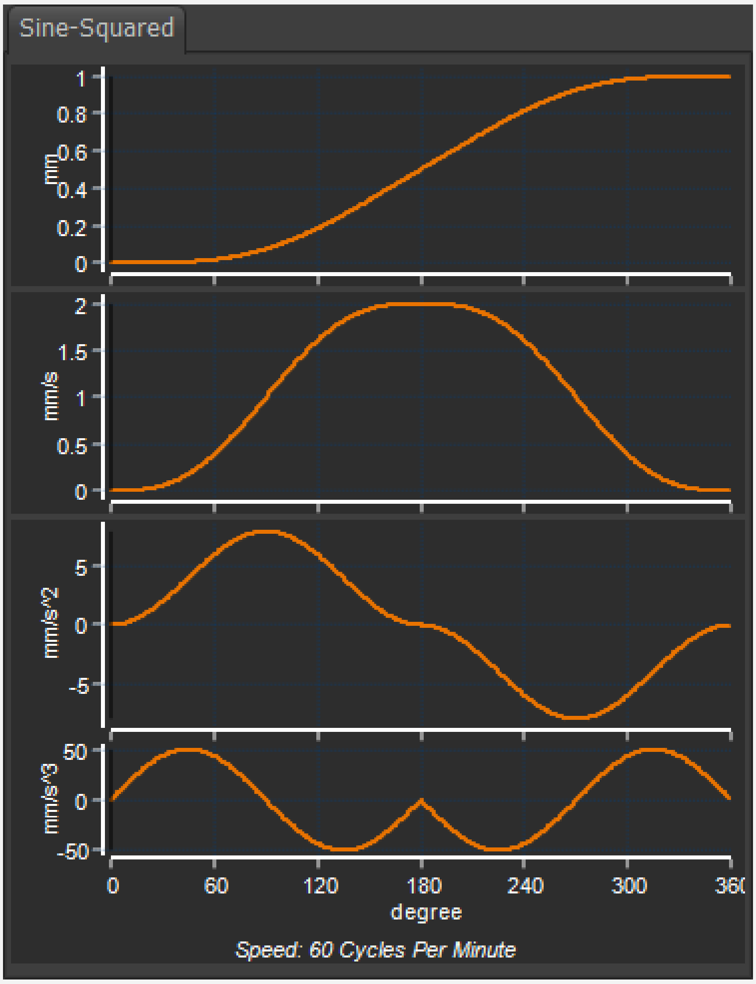
None

SEGMENT-RANGE [32]

None

See also : Tutorial 5: Edit the Start of a Traditional Motion-Law.

See also : Tutorial 9: Asymmetrical Motions.



Sine-Squared Motion-Law / Cam-Law

Motion-Law Coefficients

Velocity Coefficient :	$C_v = 2.000$
Acceleration Coefficient :	$C_a = 8.000$
Jerk Coefficient :	$C_j = 52.265$
Jerk at Crossover :	$C_{Jc} = 0.000$

APPLICATION NOTES

Dynamic Performance:

This Motion-Law is recommended in applications where the period ratio is greater than 10.

Pressure Angle Considerations

This has a relatively large maximum-acceleration and maximum velocity, which will increase the maximum pressure-angle.

Drive Torques

It has a high peak torque.

1.10.23 Sinusoidal Motion-Law

Sinusoid Cam-Law, Motion-Law

This is a Traditional Motion-Law [71]

MOTION DESCRIPTION

This motion-law is a Sinusoid or **Sine-Wave**. The SEGMENT-PARAMETERS can define the number-of-cycles, the phase at which the first cycle starts, and the amplitude of the Sinusoid.

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

You CANNOT specify the:

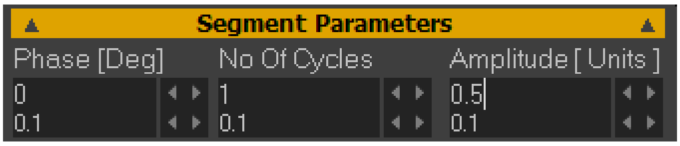
END POSITION

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS



PHASE - (DEGREES)

Enter the circular degrees at the start of the segment

NUMBER-OF-CYCLES - (360 DEGREES / CYCLE)

Enter NUMBER-OF-CYCLES

One machine-cycle = 360 of the circular sinusoidal function.

AMPLITUDE

This is the Maximum amplitude of the Sine wave

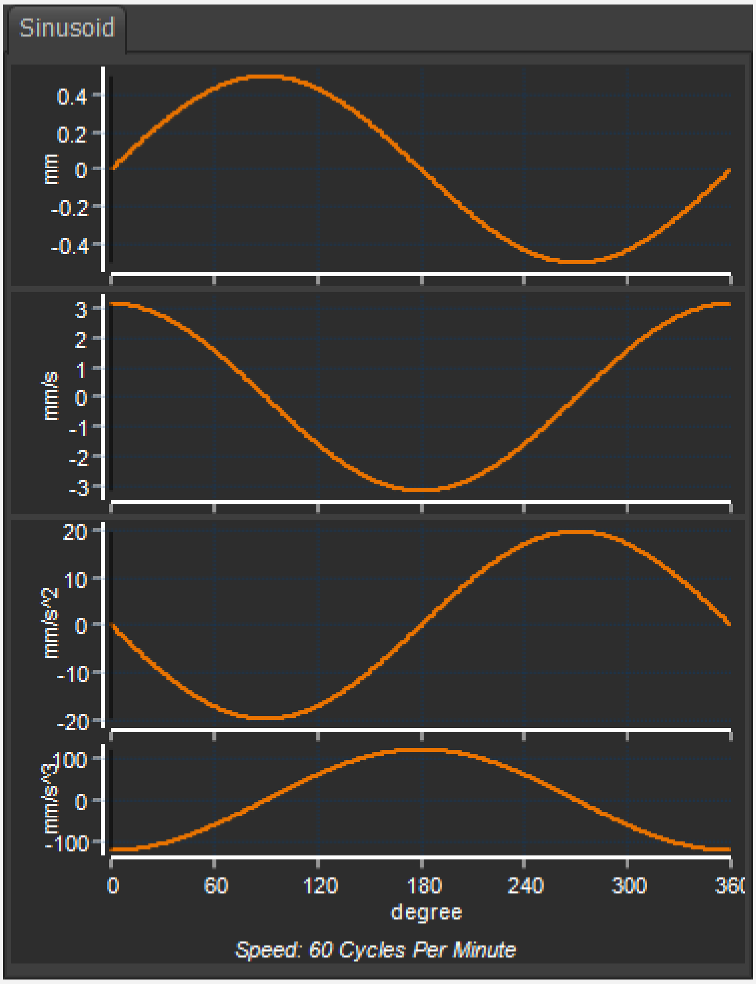
Amplitude = Peak-to-Peak / 2

SEGMENT-RANGE

START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1



SINUSOID segment
Amplitude =0.5 ; Number of Cycles = 1, Phase = 0

1.10.24 Triple-Harmonic Motion-Law

Triple-Harmonic Motion-Law

A Traditional Motion-Law

MOTION DESCRIPTION

The **Triple-Harmonic Motion-Law** can approximate the Cycloidal [85], Modified-Trapezoidal [108], Modified Sine [105], Polynomial 3-4-5 [111] Motion-Laws by using the SEGMENT-PARAMETERS

MOTION-VALUES

You CAN specify the:

START POSITION

The START-POSITION usually **flows** from the END-POSITION of the PREVIOUS-SEGMENT.

END POSITION

You CANNOT specify the:

START VELOCITY and END VELOCITY

START ACCELERATION and END ACCELERATION

START JERK and END JERK

SEGMENT PARAMETERS

THREE SEGMENT-PARAMETERS:

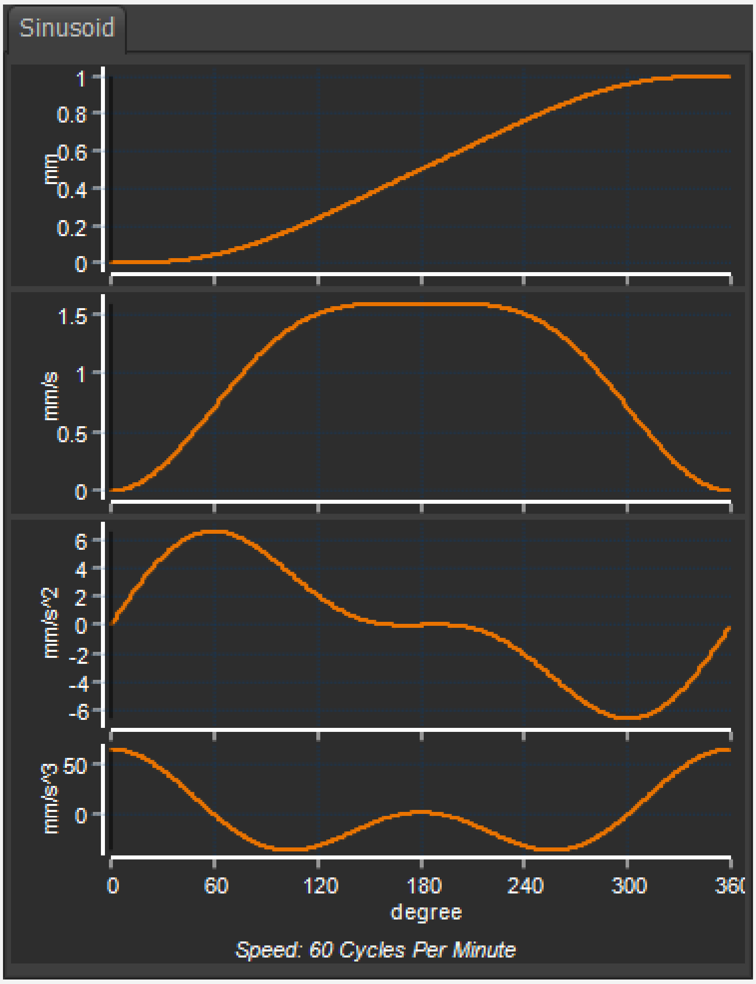
1. FIRST HARMONIC
2. SECOND HARMONIC
3. THIRD HARMONIC (calculated automatically from FIRST HARMONIC and SECOND HARMONIC)

SEGMENT-RANGE

START-RANGE - remove the start of the **RAMP** Motion-Law

END- RANGE- remove the end of the **RAMP** Motion-Law

0 ≤ START-RANGE < END-RANGE ≤ 1



TRIPLE HARMONIC
1st Harmonic = 4.983 ; 2nd Harmonic = 2.6 ; 3rd Harmonic = 0

Triple Harmonic as Approximate Motion-Laws

- **Cycloidal**

Parameter 1 (First Harmonic): 2*pi

Parameter 2 (Second Harmonic): 0.0

Parameter 3 (Third Harmonic): 0.0

- **Modified Trapezoidal**

Parameter 1 (First Harmonic): 6.04

Parameter 2 (Second Harmonic): 0.0

Parameter 3 (Third Harmonic): 0.73

- **Modified Sine**

Parameter 1 (First Harmonic): 5.1968

Parameter 2 (Second Harmonic): 1.769

Parameter 3 (Third Harmonic): 0.6057

- **Polynomial 3-4-5**

Parameter 1 (First Harmonic): 5.9

Parameter 2 (Second Harmonic): 0.704

Parameter 3 (Third Harmonic): 0.9

Triple Harmonic and other Motion-Laws

Zero-Jerk at Start, End and Cross-over

Parameter 1 (First Harmonic): 9*pi/4

Parameter 2 (Second Harmonic): 0.0

Parameter 3 (Third Harmonic): -3*pi/4

Zero-Jerk at Cross-over

Parameter 1 (First Harmonic): 4.9832

Parameter 2 (Second Harmonic): 2.6

Parameter 3 (Third Harmonic): 0.0

Zero-Jounce * at Start

Parameter 1 (First Harmonic): 7.79

Parameter 2 (Second Harmonic): -2.29

Parameter 3 (Third Harmonic): -1.08

*Jounce is a term used for rate-of-change of Jerk.

1.10.24.1 Triple-Harmonic: Modified Sine Motion-Law

Triple-Harmonic: Approximate Modified Sine

To use this Motion-Law:

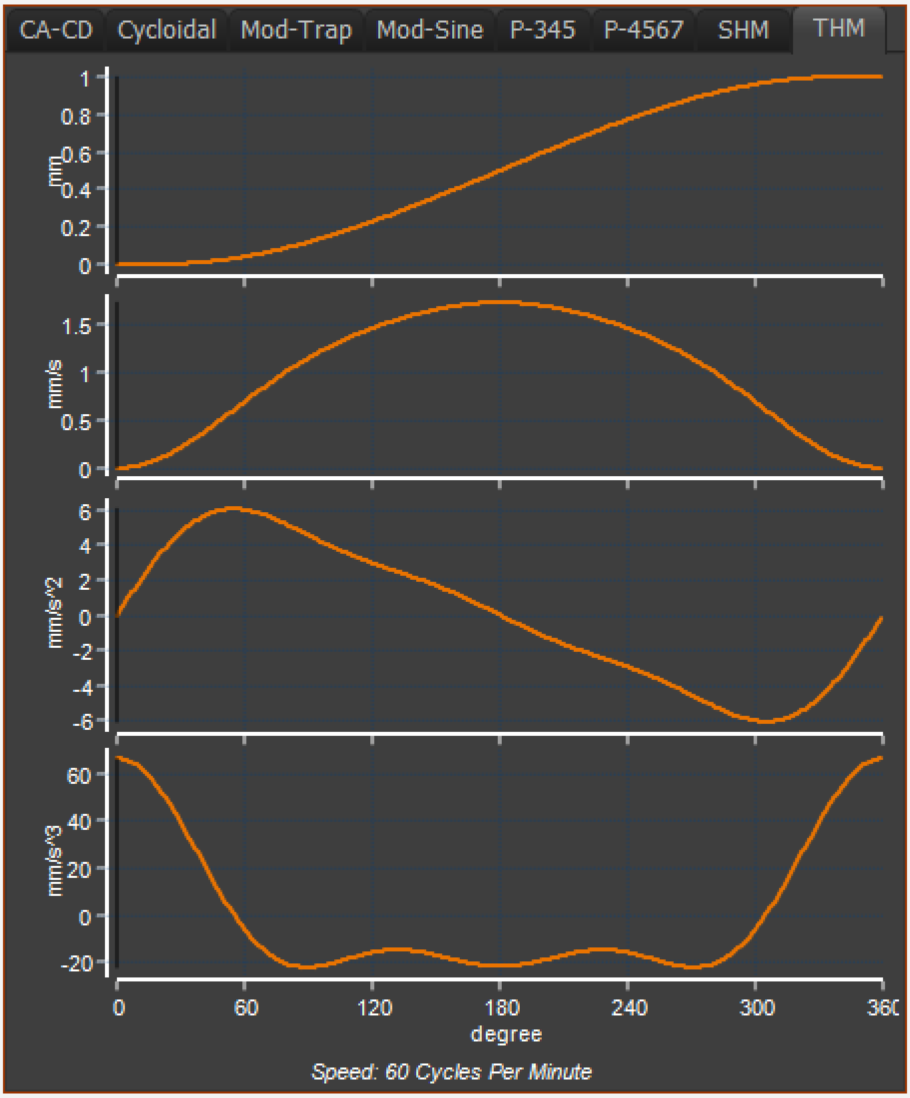
1. Select the **TRIPLE HARMONIC** in the Motion-Law Selector [59]
2. Open the **SEGMENT EDITOR** [25].
3. Edit the **SEGMENT PARAMETERS** [36]:

- FIRST HARMONIC = 5.1968
- SECOND HARMONIC = 1.7690
- THIRD HARMONIC = 0.6057

MotionDesigner calculates the THIRD HARMONIC, based on the fact that the segment always creates a Dwell-Rise-Dwell type segment.

SEGMENT-PARAMETERS - for pseudo MODIFIED-SINUSOID

Segment-Parameters (Harmonics 1,2,3) for a pseudo Modified Sinusoid motion-law.



Pseudo Modified-Sinusoid motion-law from 3 Harmonics.

Summary

This motion-law is continuous and symmetrical.

It is near to the traditional Modified Sinusoid Acceleration Cam-Law[105].

However, because it has only three harmonics, it is smoother at the higher derivatives.

The maximum velocity is slightly lower and the nominal acceleration is slightly higher than the Modified-Sinusoid mot. law.

1.10.24.2 Triple-Harmonic: Modified Trapezoidal Motion-Law

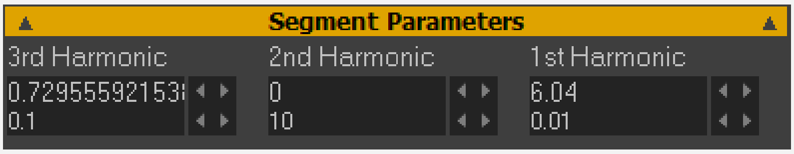
Triple-Harmonic: Approximate Modified Trapezoidal

To use this Motion-Law:

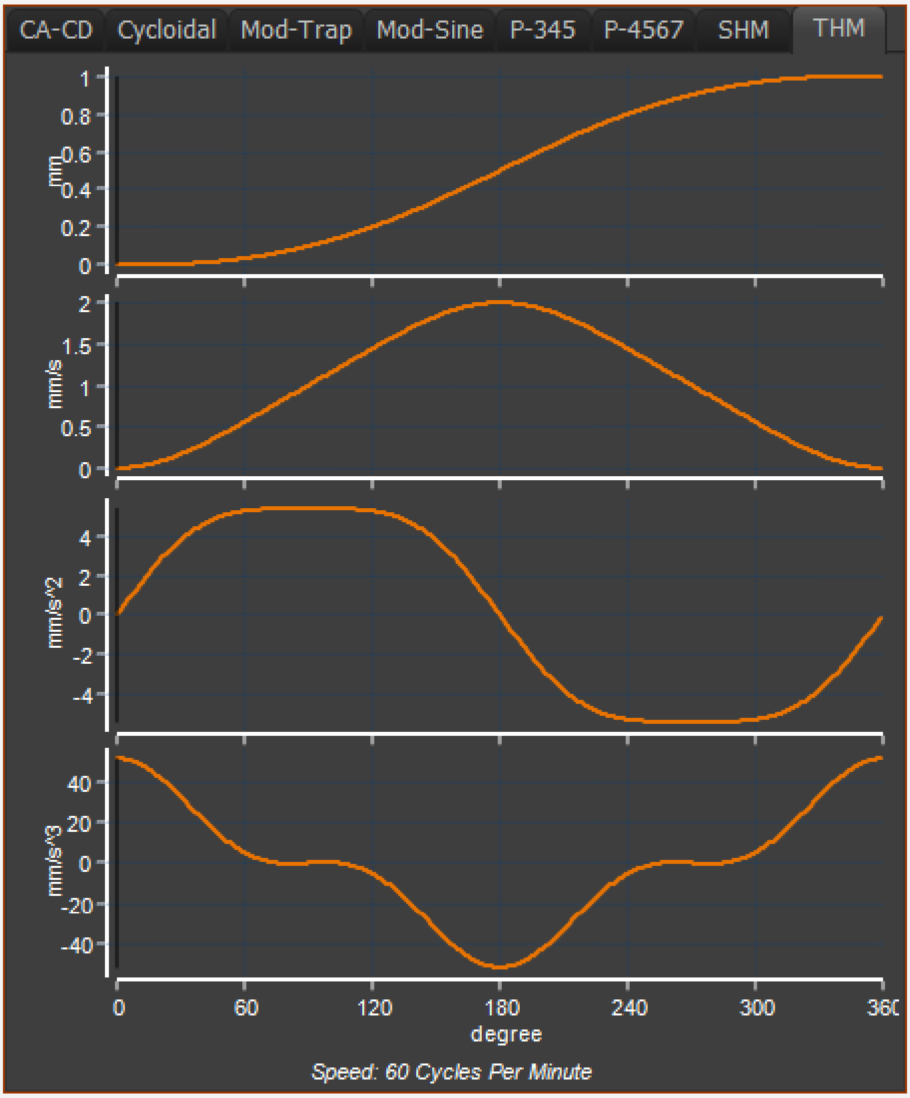
1. Select the **TRIPLE HARMONIC** in the Motion-Law Selector[59]
2. Open the SEGMENT EDITOR.
3. Edit the SEGMENT PARAMETERS[36]:

- FIRST HARMONIC = 6.04 (optionally 5.96)
- SECOND HARMONIC = 0.0
- THIRD HARMONIC = 0.7296 (optionally 0.9696)

MotionDesigner calculates the third harmonic, based on the fact that the segment always creates a D-R-D segment.



Example Harmonic Settings that give an Acceleration similar to a Modified Trapezoid.



Pseudo Modified-Trapezoid motion-law from 3 Harmonics.

Summary

This law is continuous to Acceleration.

The output motion is near to the traditional Modified Trapezoidal Acceleration Cam-Law [108]. However, it can be described by one mathematical function.

The maximum velocity is the same as the traditional law, but the nominal acceleration is slighter greater.

1.10.24.3 Triple-Harmonic: Zero-Jerk-at-Crossover Motion-Law

Triple-Harmonic: 'Approximate Zero-Jerk at Crossover'

Crossover : the point at which the Acceleration changes to Deceleration.

When Jerk is zero, and the also the acceleration changes from a positive value to a negative value, we say the Motion-Law has **Zero Jerk at Crossover**. Jerk changes slowly.

When acceleration changes slowly, and it is also near to zero, the velocity changes slowly.

If there is backlash in the mechanical transmission between the follower and the tool, then backlash is traversed as the force changes from a positive action to a negative action. Since the velocity happens to be changing slowly, the impact velocity should also be small, with this motion-law.

(Note: the Force will change when the total force on the mechanical element changes sign. The force in the system is not only a function of the Motion-Law. The Force may also include: constant, spring, damping and other forces).

To use this Motion-Law:

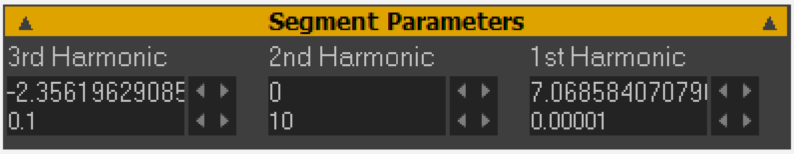
1. Select **Triple Harmonic**
2. Open the SEGMENT EDITOR.
3. Edit the SEGMENT PARAMETERS 36:

FIRST HARMONIC = 9*Π/4

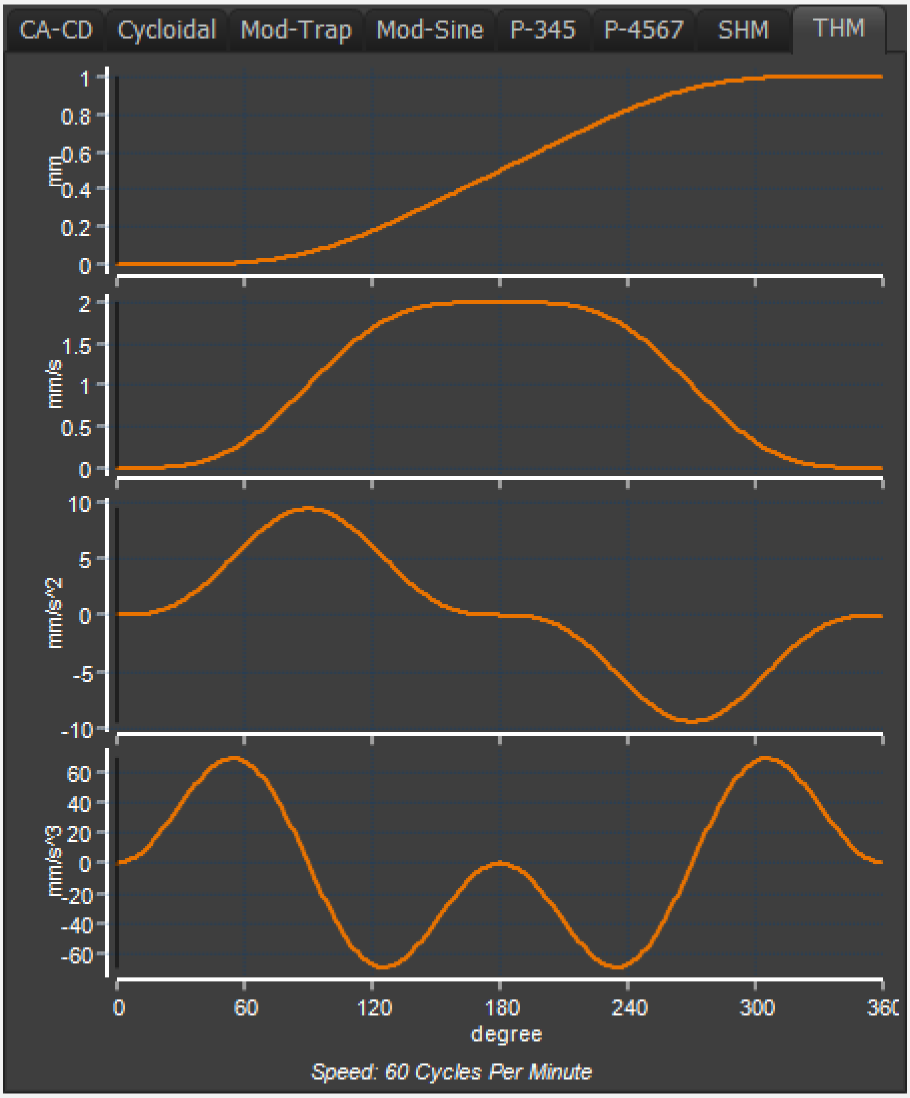
SECOND HARMONIC = 0.0

THIRD HARMONIC = -3*pi/4

MotionDesigner calculates the third harmonic, based on the fact that the segment **always** creates a D-R-D segment.



Harmonic Settings that give an Acceleration with Zero Jerk at Crossover



Pseudo Zero Jerk at Start, End and at Crossover from 3 Harmonics.

1.10.25 Y-Inverse-Sinusoid [Special]

Y–Inverse-Sinusoid

Note: The **Y-Inverse-Sinusoid** motion-law is usually applied to a rotating part, e.g. a Crank. There can be only one **Y-Inverse-Sinusoid** segment in each motion.

The Constant-Velocity Inverse Crank 145 is a similar motion-law. There can be more than Constant-Velocity Inverse Crank 145 one segment in each motion.

MOTION-DESCRIPTION

This segment is best explained by considering the motion of a POINT at the end of a CRANK that is projected onto a LINE.

When a **Crank** rotates with **CONSTANT** ANGULAR **VELOCITY**, the projected motion of the POINT on the LINE is **SIMPLE-HARMONIC-MOTION**.

When you use **Y-INVERSE-SINUSOID**, the projected motion of the POINT on the LINE is **CONSTANT** LINEAR **VELOCITY**.

MOTION-VALUES

You CAN specify the

START-POSITION - defined by the three SEGMENT-PARAMETERS - see below.

END-POSITION - defined by the three SEGMENT-PARAMETERS - see below.

You CANNOT specify the:

VELOCITY at the START or END

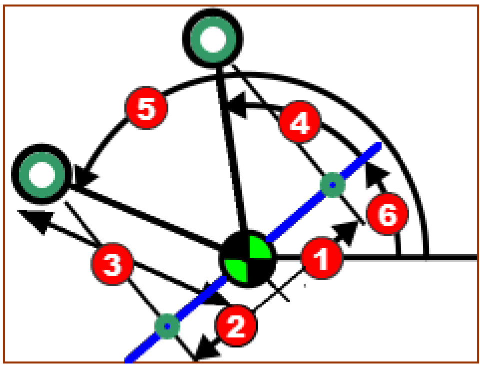
ACCELERATION at the START or END

JERK at the START or END

See Note below, and example.

SEGMENT PARAMETERS

Example Segment Parameters



Schematic of Crank made to give a constant linear velocity ...

Angle❻ is to Blue line relative to any other line, as defined by the BASE-VALUE of the MOTION-DIMENSION FB.

RADIUS OF ROCKER* **(Example is 100mm)**

The Radius of the Rocker (rotating-Part) specifies the minimum and maximum distance from the rotating-axis of the Green point, at the end of the Rocker, projected onto the Blue line.

START-POSITION❶ **(Example SP=-50mm)**

Directional Distance from the rotating-axis of the Green point projected onto the Blue line when the Green point starts to move with Constant-Velocity along the Blue line.

END-POSITION❷ **(Example EP = -50mm)**

Directional Distance from the rotating-axis of the Green point projected onto the Blue line when the Green point ends moving with Constant-Velocity along the Blue line.

MechDesigner calculates angles ❹ and ❺ for the Rocker relative to the Blue Line, from the START-POSITION and END-POSITION.

Note:

The Crank rotates Counter-Clockwise when START-POSITION is a **Negative** and END-POSITION is a **Positive.**

The Crank rotates Clockwise when END-POSITION is a **Negative** and START-POSITION is a **Positive.**

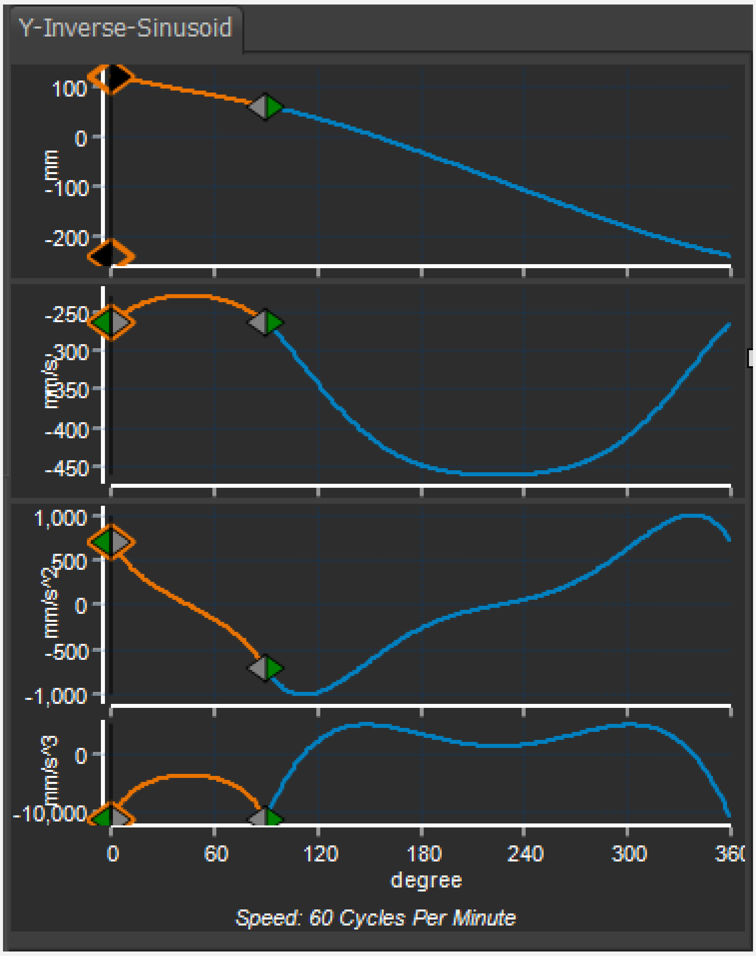
SEGMENT-RANGE

START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1

Play Video of Y-Inverse-Sinusoid Example



Y-Inverse Sinusoid

Example: with two segments.

Crank rotates in a Counter-Clockwise direction

Constant-Velocity Starts at 50mm to Left of Crank-Center (angle 120°)

Constant-Velocity Ends at 50 to Right of Crank-Center (angle 60º)

SEGMENT 1:

- X-axis Start = 0 ; End = 90º

The **Y–INVERSE SINUSOID** SEGMENT-PARAMETERS are:

- RADIUS OF ROCKER = 100mm, START POSITION = -50, END POSITION = 50mm.

With these SEGMENT-PARAMETERS:

- The Y–axis is 120º†, when the MASTER MACHINE ANGLE (MMA) is 0º .
- The Y–axis is 60º, when the MASTER MACHINE ANGLE is 90º .

SEGMENT 2:

- X-axis Start = 90º, End = 360º (0º)

A **FLEXIBLE-POLYNOMIAL**

- The Y–axis is 60º, when the MASTER MACHINE ANGLE is 90º (= end of **SEGMENT 1**)
- The Y–axis –240º when the MASTER MACHINE ANGLE is 360º .

Thus the Crank makes a full rotation from +120 to -240 in a counter-clockwise direction.

1.10.26 Z-Raw-Data [Import Data]

Import Data: Z-Raw-Data

Z-RAW-DATA is a **List Segment-Type.**

The **Z-RAW-DATA** is a segment that uses the **Data Transfer Table** to import your data as the motion-values.

See also: Acceleration-List [74], Position-List [115], Tools: Data-Transfer [61],

STEP 1. Import your data to the Data-Transfer Table

1. Use the Motion-Law Selector [59] to select Z-RAW-DATA for a segment.
2. Open the **Data-Transfer Table**
3. Click cell left and top row (cell equivalent to A1) of the **Data-Transfer Table** to make it the active cell.

   To import your data to into the **Data-Transfer Table.**
4. Do:

   a. Copy and Paste your data into the **Data-Transfer Table**

or do:

   a. Open a CSV, TXT or DAT (Camlinks based) [64] file

or do:

   a. Get Motion-Values [67] from a different motion or segment

Note: In your original data, include as many decimal points as possible.

The data is now in the **Data-Transfer Table**

STEP 2. Move your data to the Z-RAW-DATA segment from the Data-Transfer Table

1. Click the **Pos HEADER** in the **Data-Transfer Table** to select the column of data
2. Click PUT LIST DATA [66] in the **Data-Transfer Table** toolbar.

To move a sub-section of the data:

1. **Click** the **first** data point you want in move to the Z-RAW-DATA
2. **SHIFT + Click** the **last** data point you want to move to the Z-RAW-DATA
3. Click PUT LIST DATA in the **Data-Transfer Table** toolbar

Note : Put List Data icons show only when the segment is a List Segment-Type [72]

Data-Transfer Table toolbar

The data is a plot in the **Z-Raw Data segment** in the motion graph.

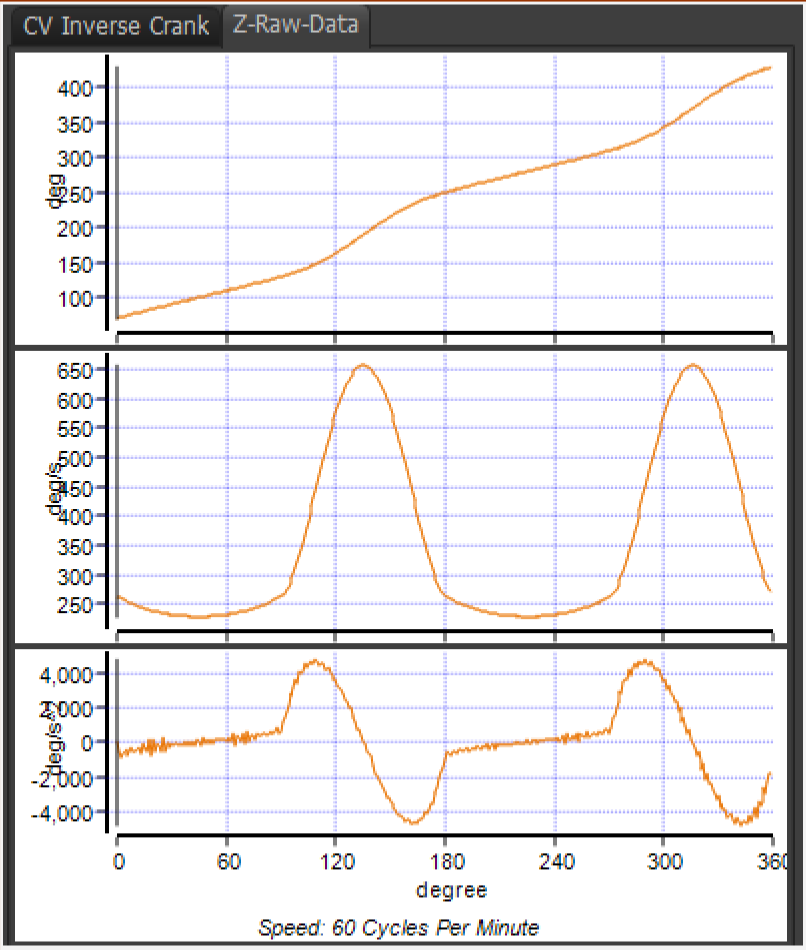
RESULT: ***MotionDesigner*** :

- Does nothing if you try to put less than 5 data-points. ***MotionDesigner*** will tell you to select more data-points.
- Transforms the data to calculate points that coincide with the points in the segment.

- Numerically differentiates the data to create **Position, Velocity, Acceleration, and the Jerk** motion-values.

In the Data-Transfer Table,

- You can use the Get Motion Data [67] button or the Get Segment Data [67] button to get the new **Position**, **Velocity**, **Acceleration**, and **Jerk** motion-values that ***MotionDesigner*** has calculated from your data.
- When the segment is a **List Segment-Type**, you can use the Get List Data [66] button to move the original data back to the table.



Example of Z-Raw Data Segment

1.10.27 CV Inverse Crank [Special]

CV (Constant-Velocity) Inverse Crank

MOTION-DESCRIPTION

This segment is best explained by considering the motion of a POINT at the end of a CRANK that is projected onto a LINE.

When the **Crank** rotates with **CONSTANT** ANGULAR **VELOCITY**, the projected-motion of the POINT along the LINE is **SIMPLE-HARMONIC-MOTION.**

When the **Crank** rotates with the **CV-INVERSE-CRANK** motion-law, the projected-motion of the POINT along the LINE is **CONSTANT** LINEAR **VELOCITY.**

MOTION-VALUES

START POSITION - defined by three SEGMENT-PARAMETERS - see below.

END POSITION - defined by three **SEGMENT-PARAMETERS** - see below.

You CANNOT specify the:

VELOCITY at the START or END

ACCELERATION at the START or END

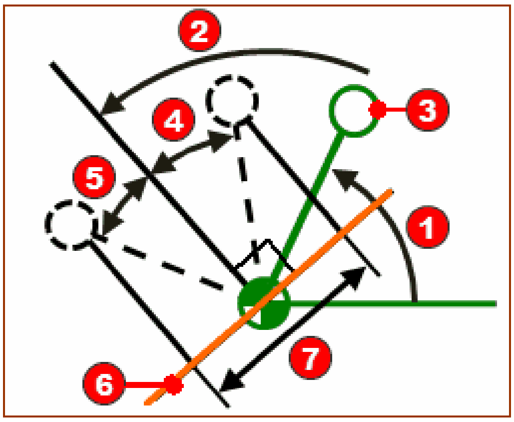
JERK at the START or END

The actual velocity, acceleration, jerk values, and the distance the POINT moves along the LINE is a function of the:

- SEGMENT-WIDTH
- LENGTH OF THE ROCKER/CRANK
- SEGMENT-PARAMETERS

SEGMENT PARAMETERS

Typical Segment-Parameters



Svhematic to help you understand how to use the CV-Crank motion-law.

The three SEGMENT-PARAMETERS are **ANGLES:**

MIN VEL❷ (MINIMUM VELOCITY)

The **ANGLE** relative to the BASE-VALUE❶ angle defined by the MOTION-DIMENSION FB at which the Crank rotates with Minimum-Velocity.

REL START❹ (RELATIVE START)

Directional angle relative to the angle defined by MIN VEL❷ at which **Point**❸ starts moving along the Orange **Line** with Constant-Velocity.

REL END❺ (RELATIVE END)

Directional angle relative to the angle defined by MIN VEL ❷ at which **Point**❸ ends moving along the Orange Line with Constant-Velocity.

Note:

The Crank rotates Counter-Clockwise when REL. START is a **Negative** and REL. END is a **Positive.**

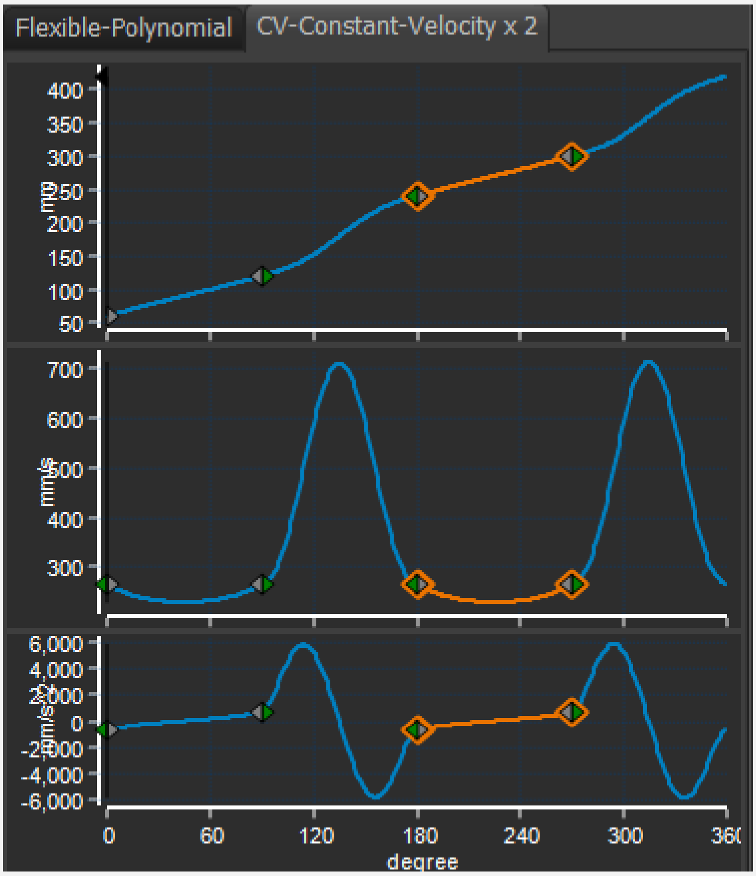
The Crank rotates Clockwise when REL. START is a **Positive** and REL. END is a **Negative.**

SEGMENT-RANGE

START-RANGE

END- RANGE

0 ≤ START-RANGE < END-RANGE ≤ 1



2 x CV Inverse-Crank

EXAMPLE Motion with two CV Inverse Crank segments.

SEGMENT 1: Constant-Velocity Inverse-Crank

- X-AXIS : 0 TO 90º

SEGMENT PARAMETERS are:

- ANGLE OF MINIMUM VELOCITY = 90º
- RELATIVE START ANGLE = -30º
- RELATIVE END = 30º

With these Parameters:

- WHEN X-AXIS = 0º ; Y–AXIS = 60º.
- WHEN X-AXIS =90 ; Y–AXIS = 120º

SEGMENT 2: Flexible-Polynomial

- X-AXIS : 90 TO 180º
- Y-AXIS AT START P=120. **V**, **A**, **J** flow from the end of the **Constant-Crank-Velocity Segment.**
- Y-AXIS AT END 240º

SEGMENT 3: Constant-Velocity Inverse-Crank

- X-axis : 180 to 270º

SEGMENT PARAMETERS are:

- ANGLE OF MINIMUM VELOCITY = 270º
- RELATIVE START ANGLE = -30º
- RELATIVE END = 30º

With these Parameters:

- WHEN X-AXIS = 180º ; Y–AXIS = 240º
- WHEN X-AXIS =270 ; Y–AXIS = 300º

SEGMENT 4: Flexible-Polynomial

- X-AXIS : 90 TO 180º
- Y-AXIS P AT START = 300º. **V**, **A**, **J** flow from the end of the **Constant-Crank-Velocity Segment.**
- Y=AXIS AT END = 420º.

1.11 Motion-Law Coefficients

MOTION-LAWS COEFFICIENTS

We can use **Motion-Law Coefficients** DE: Kennwert to compare motions that we design with **Traditional Motion-Laws.**

Motion-Law Coefficients

C_v	Velocity Motion Coefficient
C_a	Acceleration Motion Coefficient
C_j	Jerk Motion Coefficient

The **Motion-Law Coefficients** are equal to the maximum motion-values of each motion-derivative when the motion has a:

- Motion Period (T) = 1 second

AND

- Output Displacement (Y) = 1 Linear or Angular Unit

Actual Velocity and Actual Acceleration

You can calculate the **actual motion-values** for each motion-derivative if you know the **Actual Displacement** (Y) and the **Actual Period** (T) of the Motion:

Actual Maximum Velocity =	$C_v \times Y/T$
Actual Maximum Acceleration =	$C_a \times Y/T^2$
Actual Maximum Jerk =	$C_j \times Y/T^3$

Torque Coefficients

C_t	Output Torque Coefficient
C_c	Input Torque Coefficient (Driving Torque)
$C_c = max(v_i \times a_i)/C_a$	

Note on Input Torque Coefficient

The maximum torque of a motion-law is important. Just as important is the rate-of-change of torque at crossover from Acceleration to Deceleration.

A positive input torque on the cam-shaft will wind-up (twist) the cam-shaft. Similarly, a negative torque on the cam-shaft will wind-down (untwist) the cam-shaft. When the rate-of-change of torque is rapid, the winding and unwinding of the cam-shaft is also rapid.

When the Torque changes from a positive to a negative value - at the crossover - backlash is traversed. The speed of the drive-motor may increase rapidly as the load is released from it and actually becomes driven by the load. If the speed of the motor does increase, then the motion-law is also distorted. The maximum deceleration increases when the driving-shaft momentarily increases its speed.

Power

Constant Power

$P = \mathrm{T} \times \omega$	**Power - constant Torque and Angular Velocity**
$P = F \times v$	**Power - constant Linear-Force and Linear-Velocity**

Variable Power

Of course, the Torque and the Angular Velocity of the output shaft continuously change throughout the motion. Thus, the Power of the output shaft also changes continuously.

If we use the suffix i to indicate an instant in the motion, then the Instantaneous Power, when calculated at the output is:

$P_i = \mathrm{T}_i \times \omega_i$	**Instantaneous Power - varying Torque and Angular Velocity**
$P_i = F_i \times v_i$	**Instantaneous Power - varying Force and Linear-Velocity**

Total Load Torque or Load Force are found from values of inertia, mass, and acceleration.

However, the:

- Acceleration continually changes throughout the motion - of course.
- Load Inertia and Mass, referred to the driven-shaft, can be constant (e.g. Dial-Plate) or can continually change (e.g. Toggle mechanism).

In the general case, the Load Inertia or Load Mass reflected to the Cam-Follower shaft varies throughout the motion.

If we use the suffix 'i' to indicate any instant in the motion, the instantaneous **Load Torque** and **Load Force** are:

$T_i = I_i \times \alpha_i$	Load Torque with changing Load Inertia and Angular Acceleration.
$F_i = m_i \times a_i$	Load Force with changing Load Mass and Linear Acceleration

Also, the instantaneous Load Power is:

$P_i = I_i \times \alpha_i \times \omega_i$	Load Power with changing Load Inertia, Angular Acceleration, and Angular Velocity.
$P_i = m_i \times a_i \times v_i$	Load Power with changing Load Mass, Linear Acceleration, and Linear Velocity.

When reflected Load Inertia is not a function of the motion, the **Power-Coefficient** is less complex.

The instantaneous Load Power, with constant reflected Load Inertia or Load Mass is:

$P_i = I \times \alpha_i \times \omega_i$	Load Power with constant Load Inertia, Angular Acceleration, and Angular Velocity.
$P_i = M \times a_i \times v_i$	Load Power with constant Load Mass, Linear Acceleration, and Linear Velocity.

Power Coefficient

Power Coefficient	$P_c = max\left(v_i \times a_i\right)\Big\vert$ (i = equal increments; from 1 to n)

$$P_{c(rms)} = \sqrt{\frac{\sum_{i=1}^{n} (v_i \times a_i)^2}{n}}$$

MOTION COEFFICIENTS OF THE TRADITIONAL MOTION-LAWS

Motion-Law Name	Velocity Coefficient C_v	Acceleration Coefficient C_a	Torque Coefficient C_c	Power Coefficient P_c
Constant Acceleration, Parabolic	2	4	2	8
Simple Harmonic	1.570796 (p/2)	4.934803 ($p^2/2$)	0.785	3.8758
Cycloidal	2	6.283185	1.298	8.1621
Modified Trapezoid	2	4.888124	1.655	8.0894
Polynomial 3-4-5	1.875	5.773503	1.159	6.6925
Polynomial 4-5-6-7	2.1875	7.5132	1.431	10.750
Modified Sine	1.759603	5.527957	0.987	5.4575

SINE-CONSTANT-COSINE ACCELERATION (SCCA) with CONSTANT VELOCITY

Edit the SEGMENT PARAMETERS [36] (in the SEGMENT EDITOR [25]) of the SINE-CONSTANT-COSINE ACCELERATION [126] *(SCCA) Motion-Law* to give many of the popular motion cam-laws for industrial cams.

Motion-Law Name	Coefficients		SCCA Parameters (Factors)		
	Velocity Coefficient C_v	Acceleration Coefficient C_a	a	b	c
Modified-Sine CV 0%	1.760	5.528	0.25	0	0.75
Modified-Sine CV 20%	1.528	5.999	0.2	0	0.6
Modified-Sine CV 33%	1.404	6.616	0.1667	0	0.5
Modified-Sine CV 50%	1.275	8.0127	0.125	0	0.375

Motion-Law Name	Coefficients		SCCA Parameters (Factors)		
	Velocity Coefficient C_v	Acceleration Coefficient C_a	a	b	c
Modified-Sine CV 66%	1.168	11.009	0.0833	0	0.25
Cycloidal CV 50%	1.333	8.378	0.25	0	0.25
Trapezoidal Velocity CV 33%	1.5	4.5	0	0.6667	0

3-HARMONIC MOTION-LAWS

Edit the SEGMENT PARAMETERS [36] (in the SEGMENT EDITOR [25]) of the ***Triple Harmonic Motion-Law*** to give alternatives to some of the popular motion-laws.

Motion-Law Name	Coefficients		Harmonic		
	Velocity Coefficient C_v	Acceleration Coefficient C_a	1st	2nd	3rd
3-Harmonic Modified Trapezoidal	2.0	5.16	5.96	0	0.9696
3-Harmonic Modified Sine	1.72	6.07	5.1968	1.7690	0.6057
3-Harmonic Zero-Jerk at Crossover	2.0	9.42	$9*\Pi/4$	0	$-3*\Pi/4$

1.12 How to? and other FAQs...

How to and other FAQs

How to .... ?

1. How to design a Motion- First Steps 153
2. How to edit a value in a data-box 153
3. How do I edit the start of the motion so it does not start at 0. 156 What is 'Motion-Design' 157

FAQs

1. What is 'Motion-Design'? 157
2. Where is the Spin-Box in the Segment / Blend-Point Editor? 158

1.12.1 How to?

How to .... ?

1.12.1.1 How to Design a Motion - First Steps.

Motion Design

It is always important to try to improve the design of your motion when you need to improve the performance of a machine.

First Steps

There are a number of steps to design a motion. You must:

1. Write a Motion-Specification that satisfies the positional, velocity, acceleration and even jerk requirements for each **machine-axis** or tool in the machine as a function of the **Master Machine Angle**.
2. As necessary, split the motion into a number of segments - this is called Segmentation.

Each segment can define a particular action - such as 'Push', or 'Lift', followed by 'Return', etc.

The segments are joined together, end-to-end, so that they describe the motion of a tool over one complete machine cycle.

3. Begin to define the duration of each segment making some shorter and others longer. The total duration remains as 360°.
4. Select a Motion-Law for each segment. The **Motion-Law** must be able to meet the motion-values as defined in the motion-specification at the start and end of the segment.
5. Edit the motion-values at the start and or end of each segment - using the Blend-Point Editor and Segment Editor - to fully satisfy the motion requirements.
6. Complete the motion design for all of the axes on a machine.

See also: What is a motion? 157

1.12.1.2 How to edit a value in data-box

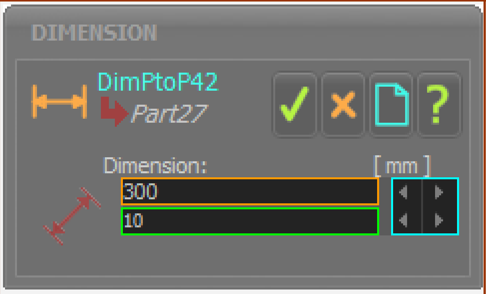
Edit a value in a data-box.

A typical dialog-box and Parameter.

You edit motion-values or parameter-values in exactly the same way in all dialog-boxes.

This image is the DIMENSION DIALOG-BOX that you use in *MechDesigner*.

It has one parameter (DIMENSION) and data-box (currently set to 300).



In this image of the DIMENSION DIALOG-BOX, I have added a 'window' to highlight the PARAMETER BOX.

The three areas of the PARAMETER BOX are:

300	PARAMETER VALUE - the data value that you edit and apply to the element.
10	SPIN-INCREMENT VALUE - edit with the arrows at the bottom of the Spin-Box control [154]

SPIN-BOX CONTROL: arrowheads - see below [154]

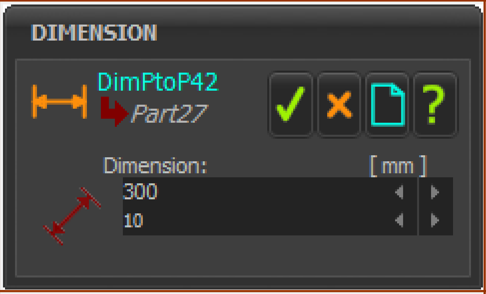
If you cannot see the **Spin-Box**:

- Double-click in the PARAMETER VALUE box.

How to edit parameters in a dialog-box.

There are three different procedures you can use to edit a parameter in a dialog-box.

1: Enter the Parameter Value with your Keyboard



Enter a value directly:

1. Use your keyboard to enter the data-value
2. Press the Enter key on your keyboard to update to the new value

You must press the Enter key.

Enter a value as a symbolic equation:

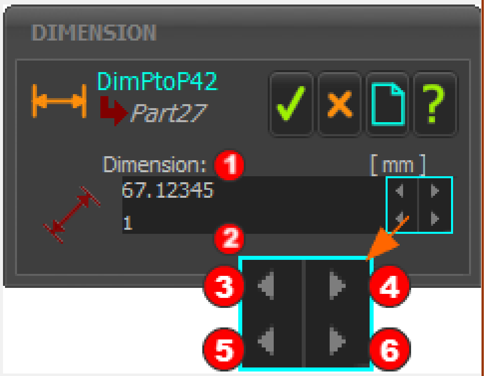
1. Use your keyboard to enter an equation
2. Press the Enter on your keyboard to update to the new value

You must press the Enter key

Symbolic parameters for an Equation:

- **Simple Arithmetic**: +, –, *, /
- **Indices**: ^, Sqrt()
- **Trigonometric** (Angles are Radians), Sin(), Cos(), Tan(), Sinh, Cosh, Tansh, ArcSin(), ArcCos(), ArcTan2(;)

2: Use the 'Spin-Box' tool



Spin-Box arrowhead buttons (in the CYAN-BOX)

❸ **TOP : LEFT** arrowhead to subtract (–) the PARAMETER-VALUE❶ by the **SPIN-INCREMENT**❷

❹ **TOP : RIGHT** arrowhead to add (+) the PARAMETER-VALUE❹ by the **SPIN-INCREMENT**❷

❺ **BOTTOM : LEFT** arrowhead to divide (÷) the **SPIN-INCREMENT**❷ by 10

❻ **BOTTOM : RIGHT** arrowhead to multiply(×) the **SPIN-INCREMENT**❷ by 10

EXAMPLE:

Edit the PARAMETER-VALUE

- **Click the Top & Left**❸ **arrowhead**: Subtract the Spin-Increment(1)❷ from the PARAMETER-VALUE❶
  PARAMETER-VALUE after one click: **67.12345 – Spin-Increment = 66.12345**
- **Click the Top & Right**❹ **arrowhead** two **times**: Add the Spin-Increment(1)❷ to the PARAMETER-VALUE❶ 2 x
  Parameter-value after one click: **66.12345 + 2 × Spin-Increment = 68.12345**

Edit the Spin-Increment

- **Click the Bottom & Left**❺ **arrowhead**: Divide the Spin-Increment by 10❷
  Spin-Increment value after one click: **1 ÷ 10 = 0.1**
- **Click the Bottom & Right**❻ **arrowhead** two **times**: Multiply the Spin-Increment by 10 ❷ 2 x
  Spin-Increment value after one click: **0.1 × 10 x 10 = 10**

WARNING: The model re-builds each time you click the top arrowhead buttons in the **Spin-Box tool**. If the model is complex, there is a long time to update the model.

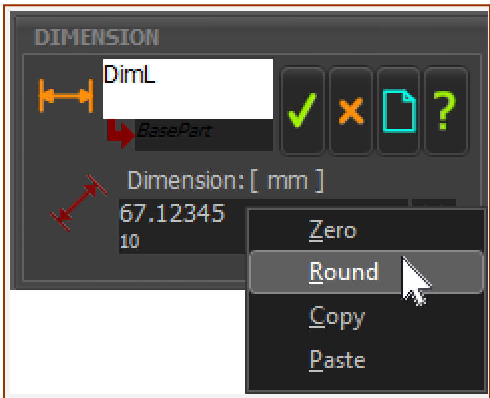
Show / Hide the Spin-Box

< >
'Double-Click'

Double-click **inside** the data-box to hide the **SPIN-BOX**.

Double-click the data-box ***again*** to show the **SPIN-BOX**.

3: Use the Zero/Round contextual menu



To see the Zero / Round / Paste / Copy menu:

1. Right-click inside the data-box

The **Zero / Round / Copy / Paste** contextual-menu shows.

- **Zero -** the parameter-value becomes zero(0), or the smallest possible value for the parameter-value
- **Round -** the parameter-value becomes the nearest value that is exactly divisible by the **Spin-Increment.** The **Spin-Increment** is below the data-box - ten(10) in the image

	• **Copy** - to copy the parameter-value to your clipboard. • **Paste** to paste the parameter-value from your clipboard.

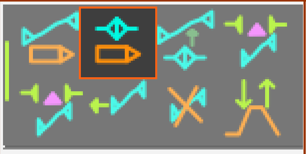
1.12.1.3 How to start my motion at 30º not at 0º

Frequently, the timing of a motion means the first segment cannot easily start at **0** of the **Master-Machine-Angle**. In this case you will want to move **BLEND-POINT #1** from 0.

To move **BLEND-POINT #1** to an angle that this not 0, edit the **MOTION-START** parameter in the **BLEND-POINT EDITOR**.

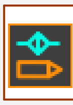
The whole motion moves along the **X-axis** by the **MOTION-START** parameter.

STEP 1. Open the Blend-Point Editor



Blend-Point Editor icon

Use the toolbar.

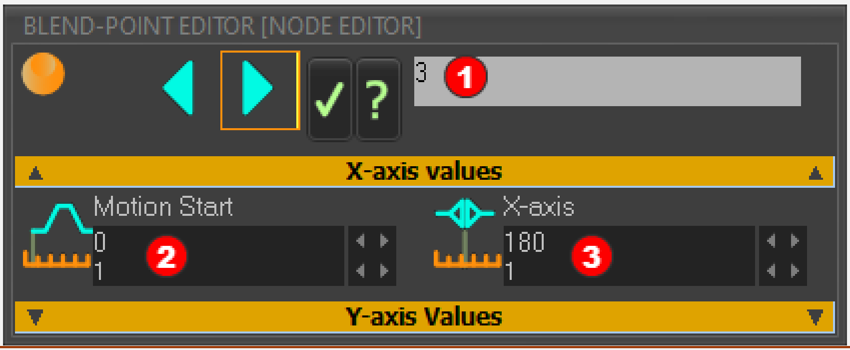


1. Click **Blend-Point & Segment toolbar > Start Blend-Point Editor**

The **BLEND-POINT EDITOR** is now open.

STEP 2. Expand the X-AXIS VALUES separator

STEP 3. Edit the Motion-Start-parameter



MOTION START

Edit **MOTION- START** to move **BLEND-POINT #1** relative to the **MASTER MACHINE ANGLE**.

Note:

All of the motion moves by the **MOTION-START** parameter.

1.12.2 FAQs

FAQs

1.12.2.1 What is 'Motion Design'?

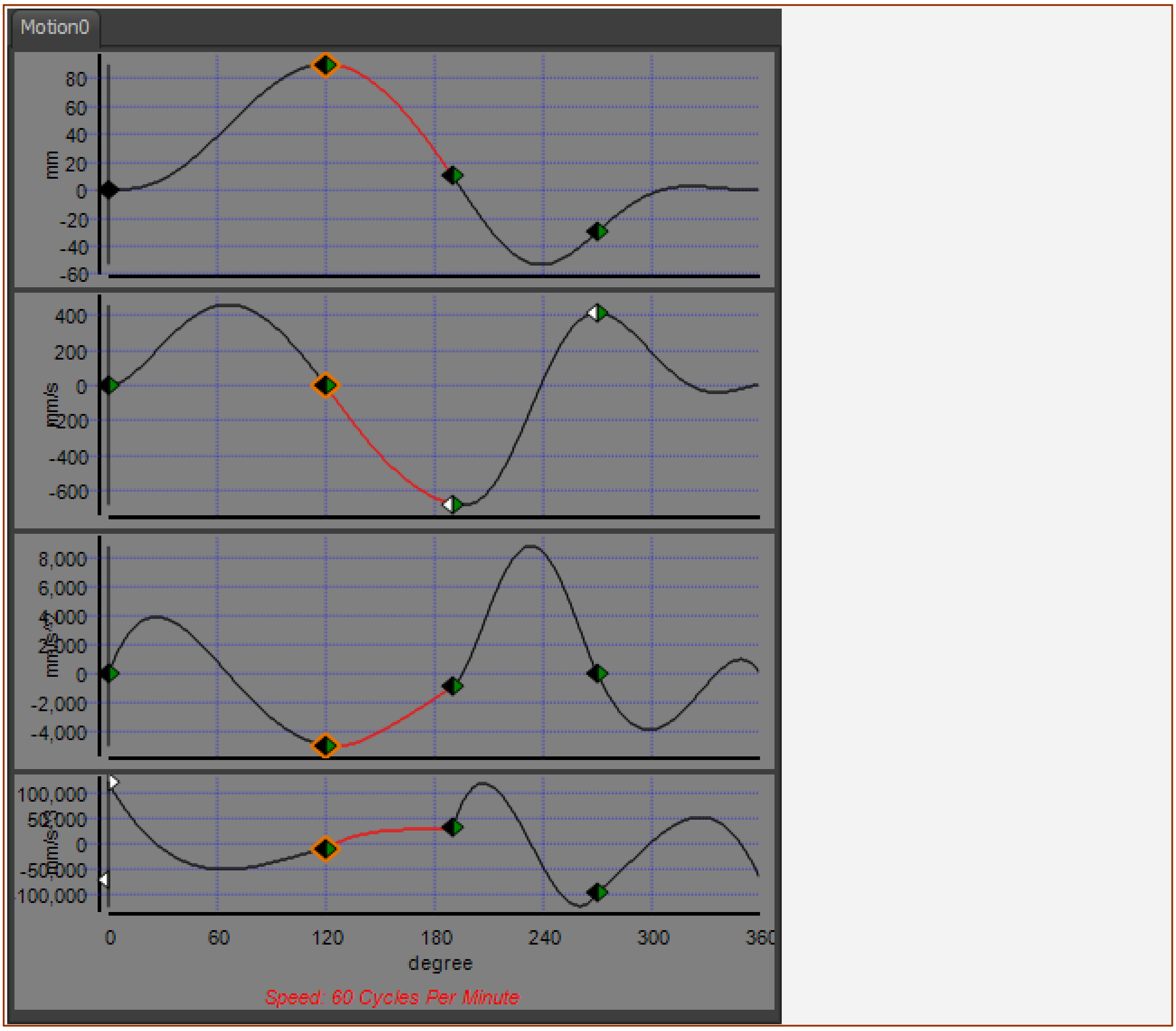
Motion Design

There are many disciplines that use the term **Motion Design**: E.g.: Graphic Design, Dance Choreography.

However, in ***MotionDesigner***, we usually design motions for machine elements for a machine cycle. In machinery, all the machine parts have mass and inertia. As such, the forces that develop between machine elements that are a result of their motions are also important. Parts with inertia must be moved carefully, especially as speeds are increased. If motions are not designed carefully, machine elements will vibrate needlessly.

MotionDesigner

MotionDesigner, provides all the tools to design motions for high-speed, multi-axis machines, such as those found in the packaging, assembly, textile industries.



What is Motion Design?

1. A motion is a sequence of positions for a machine element - or a Rocker or Slider in ***MechDesigner***.
2. A motion-design satisfies a number of position, velocity, acceleration, and/or jerk specifications for the angle or distance between two parts throughout a machine cycle.
3. When the number of motion specification become extensive or complex, it is difficult to find one mathematical function that can satisfy the motion specification throughout a machine cycle.
4. Therefore, it is convenient to split a motion into **segments**. Segments are joined end-to-end (concatenated, to give the technical term). The number of segments in the machine-cycle is dependent on the number of different motion requirements in the machine-cycle.
5. The process of splitting into segments is called **segmentation** The image above shows a motion split into 4 segments.
6. Each segment may have a different math function, which we call its **motion-law**. We select the **motion-law** that can satisfy the motion specification during its segment period.
7. A **Motion-Law** will have different parameters that you can use to satisfy the motion specification.
8. A **Blend-Point** is at the instant when one segment ends and another starts.
9. We have two editors in ***MotionDesigner*** to edit the **Blend-Points**, and **Motion-Law**. and any other parameters.

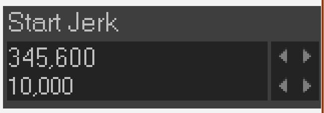
- Segment Editor [25]
- Blend-Point-Editor [15]

1.12.2.2 Where is the Spin-Box in the Segment-Editor/Blend-Point Editor?

In the SEGMENT EDITOR and the BLEND-POINT, it is convenient to edit motion-parameters with the **Spin-Box tool**.

However, very often, the **Spin-Box tool** does not show at the right-side of the motion-parameter.

To show or hide the Spin-Box tool

	If the **Spin-Box tool** is not to the right-side of a motion-parameter: 1. Double-Click
	The first time you double-click, the the Spin-Box does NOT show.
	1. Double-Click again Now the Spin-Box shows.

1.13 Motion Design Considerations

Motion Design Considerations

1.13.1 Refresher: Blend-Point and Segments

A Refresher on Segments and Blend-Points in MotionDesigner

Motion is:

1. A motion evaluates the displacement of a machine element at each instant of a machine-cycle.
2. In addition to the Position, the important motion-derivatives are also evaluated exactly at all machine angles.

The process of motion-design specifies at particular instances of the machine cycle the exact values for position, velocity, acceleration, and/or jerk. Mathematical-functions evaluate the motion-values at all instances of the machine cycle.

When the motion requirements becomes complex, it is difficult to find a single mathematical-function that satisfies all of the motion's requirements for a complete machine cycle.

Therefore, you will usually split, or divide, the machine-cycle into two or more motion-periods that we join end-to-end to give a complete machine cycle. We can then use a different mathematical-function for each motion-period.

We use the term **SEGMENT** for each motion-period.

We use the term **BLEND-POINT** for each instance in the machine-cycle that we split the motion.

Each **Segment** has a **Blend-Point** at its start and at its end.

Not only do motion-designers need to specify when and where to split the motion into different Segments, they must also select the mathematical function that can best satisfy the motion requirements at all points in the Segment.

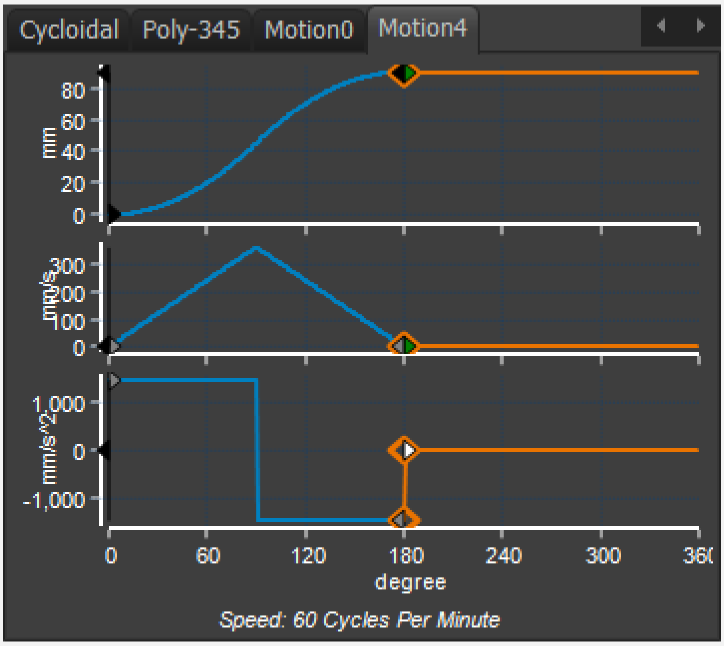
The mathematical-functions, from which the user can select, have been chosen by PSMotion to meet the different requirements of most machine designs, each with different applications or advantages.

Each mathematical-function is called a **MOTION-LAW** or **CAM-LAW**.

1.13.2 Segment Blending and Motion-Continuity

see also: Impact, Acceleration Shock, How to Blend Two Segments 160

Motion Discontinuity



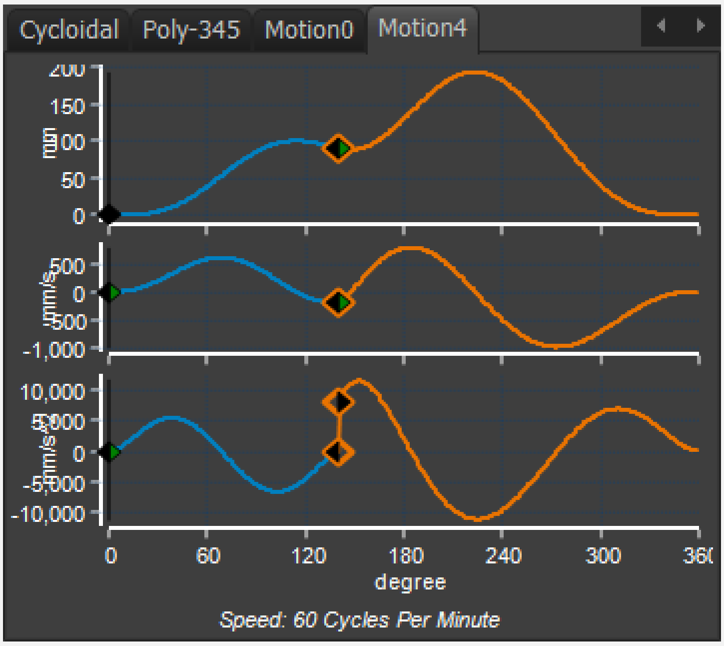
Motion-Law Discontinuity

Motion Discontinuity Definition.

A **motion discontinuity** is one in which the **Y-axis** of a motion-derivative has two values at one instant on its **X–axis.** The name we give to the motion-discontinuity refers to the lowest motion-derivative in which the motion-discontinuity occurs. For example, we say the motion has an **acceleration-discontinuity**

There are two example motions above and below.

In the image above, the motion-law is the **Constant Acceleration & Deceleration Motion-Law.** It has **three(3) motion-discontinuities.** The motion-discontinuity that is in the middle is the most aggressive, as it changes from the maximum acceleration to the maximum deceleration.



Segment Discontinuity

The motion above also has an **Acceleration-Discontinuity.**

This discontinuity can be eliminated when the motion-laws are **Flexible-Polynomial**.

Segment Blending

Segment Blending considers the motion-values at the **Blend-Points**.

It is recommended that you design your motions with at least **Position**, **Velocity**, and **Acceleration** continuity.

Jerk motion continuity may also be appropriate, but not in all circumstances.

⚠ In ***MotionDesigner*** it is possible to design motions with motion-discontinuities at any motion-derivative, even Position. A Position motion-discontinuity is only needed with progressive, indexing motion, in which the position at the end of the index motion is different to the position at the start of the index motion. Clearly, the mechanical system does not move from one position to the next in zero time. It does not have a positional motion-discontinuity.

Position Continuity

A Step-change in Position?

Mechanical systems cannot respond to a **Position-Discontinuity** - to move from one position to a different position in zero time! It would be a magic trick! Cartoon characters can do this motion, but not mechanical systems. A Cam would need a step in it.

You must use at least the **Match Control** button in the **Segment and Blend-Point Editors** to give **Position-Continuity**

Velocity Continuity

A Step-change in Velocity?

Mechanical system cannot respond to a **Velocity-Discontinuity**. You are trying to make the system respond as if it has been hit.

A Servo motor would need to change its speed instantly, with infinite acceleration. This is unattainable.

A Cam would have a corner, or kink.

Acceleration Continuity

A Step-change in Acceleration?

Mechanical systems do not like **Acceleration-Discontinuities.** The mechanical system will tend to vibrate.

We can show an **Acceleration-Discontinuity** with this experiment:

1. Clamp (or hold down) a 300mm ruler at one end, so it hangs over the edge of a table.
2. Release a coin from zero height onto the ruler, near to its end.

   The velocity-impact is zero because we release the coin from zero-height.

   The ruler experiences a step change in force (gravitational force) as you release the coin on to it.

   The ruler vibrates with a displacement amplitude of about two times the final resting position of the ruler with the coin on it

Jerk Blending and Continuity

A Step-change in Jerk?

Finally, it is sometimes required that adjacent segments have **Jerk-Continuity**.

Jerk-Continuity gives the least mechanical vibration in the mechanical system, at the expense of higher peak nominal accelerations.

When Jerk is Zero at the start of a segment, there is only a tiny change of the Position graph for the first 10º of input. It is almost a dwell for the first 10º.

If it frequently possible to increase the duration of a segment, and thereby reduce the accelerations.

1.13.3 Motion-Laws Compared

Motion-Laws.

A motion is made from usually more than one segment. You select the motion-law for each segment with the Motion-Law Selector 59.

A common question is **'Which motion-law is best?'**

When the motion is complex, possibly with many segments, that must satisfy many different position, velocity, and acceleration requirements, it is almost impossible to answer the question: **'Which motion-law is best?'**.

However, when the motion is simple, when the segments are arranged for a **Dwell-Rise-Return-Dwell** motion, then it is easier to select a motion-law that is best for the mechanical system.

Which Motion-Law?

You will see that, with many of the motion-laws, especially the 'Traditional Motion-Laws 71', you can only specify the position at the start and end of the segment. When you give the same position at the start and the same position at the end of the segment , then the displacement plot of each *Traditional Motion-Law* is almost the same!

Surely, if you want to move the part, then why worry as to which motion-law you select for the segment?

The question is **'Why are there so many different motion-laws when each provides nearly the same result?'**.

Actually, it is the shape of the acceleration plot, and not the displacement plot, that become more important as machine-speed is increased.

Although there is little difference between the **Displacement** of each Motion-Laws, there is more difference between their **Velocity** plots, and a large difference between their **Acceleration** plots. The **SHAPE** of the **ACCELERATION** plot has a significant influence on the dynamic response of the part.

For this reason, it is the shape of the acceleration plot that gives the name to a **TRADITIONAL MOTION-LAW**, and not the shape of the displacement plot.

When the motion is simple, it is easier to explore the advantages and disadvantages of each motion-law.

See also: General Design Information Manual(coming 2019): Design of Cam Mechanical Systems.

Initial Selection

We can give relative ratings to the most common **Traditional Motion-Laws**. You can use the ratings to help you select a law at the initial stage of a machine design. The ratings range from1 (bad) to 5 (excellent). The ratings apply to Dwell-Rise Dwell type motions.

Of the laws listed, that the Modified Sine(MS) is the best for general purposes. Its particular merit is that it is very tolerant of a bad input drive and transmission (elasticity, backlash, wear, low inertia). It is frequently the first choice of cam designers and is almost always used by commercial manufacturers of cam-operated indexing and oscillating mechanisms.

Additionally, you can look at the Motion-Law Coefficients 148 of the common cam motion-laws. These indicate the relative values of their **Velocity Coefficient** and **Acceleration Coefficient**.

Cam-Law Designation	Peak Acceleration	Output Vibration	Peak Velocity	Impact	Input Torque	Input Vibration	Residual Vibration
Constant Acc & Dec 75	5	1	2	1	1	1	1
Simple Harmonic 123	3	1	4	4	5	2	1
Modified Trapezoid 108	3	3	2	2	2	3	3
Modified Sinusoid 105	2	4	3	4	4	4	4
Cycloidal 85	1	5	2	3	3	4	5

Explanatory Notes

Peak Acceleration

This merit rating applies to the nominal maximum output acceleration during the motion period, calculated by the motion-law equation.

Output Vibration

Output vibration is superimposed on the nominal output acceleration, thereby increasing the nominal peak value. The vibration severity depends on the elasticity and operating speed of the mechanism. The merit rating applies to mechanisms of average rigidity running at fairly high speed.

Peak Velocity

Peak Velocity is the nominal maximum output velocity during the motion period, calculated by the motion-law equation. Its value is also increased by superimposed vibration.

Impact / Backlash

Impact forces occur at the locations of backlash in the mechanism when the changeover from acceleration to deceleration occurs. The severity of the impact depends on how gradually the changeover takes place. That is, how low the jerk is at point of impact. Strictly speaking, it is the changeover from positive to negative force or torque that matters, but in most high speed systems, that almost coincides with the acceleration changeover.

Input Torque

The nominal input torque of a mechanism varies throughout the motion period and is a function of the output load profile, and the velocity pattern. The peak acceleration and the peak velocity do not coincide and neither coincides with the peak input torque. Motion-Laws with good, that is low, acceleration do not necessarily have good input torque.

Input Vibration

The elasticity and backlash of the input transmission can cause serious 'over-run'. This is when the sudden reversal of the input torque at the changeover from acceleration

to deceleration - or load - causes the cam to jump forwards before it can transmit a decelerating force to the output. The more gradual that the nominal input torque changes over, the less severe is the overrun and its consequences.
Residual Vibration Residual Vibration takes place in the dwell period immediately following the motion period in high speed or elastic systems. Its amplitude depends on the vibration generated during the motion period, and the degree of damping present in the output transmission. It is very difficult to add sufficient damping to high speed mechanisms to eliminate residual vibration, so the choice of a motion-law is vital in some cases.

1.13.4 To Improve a Motion

Improve the Motion

This is a very subjective problem. A good motion for one application may not be a good motion for another.

An attempt to answer...

Assumptions:

- The motion is for a machine, and not a cartoon character.
- The motion is intended for a machine where the machine elements reciprocate, oscillate, index, or the speed modulates in some way.

General Advice:

- If possible, use the Flexible Polynomial Motion-Law for all of the segments in your motion. This motion-law has the most motion-design flexibility.
- Remove Velocity Discontinuities.
- Remove Acceleration Discontinuities, in nearly every machine design circumstance
- Always ask yourself 'Can I reduce the number of segments?' Use a minimum number of segments.
- Always ask yourself 'Can I delete a Dwell Segment?' Try to remove Dwell Segments - especially short dwells. Usually it is better to remove a Dwell segment, and give the adjacent segments zero-jerk.
- Reduce the number of motion specifications.

  E.G. You can make a motion continuous in position, but it may be possible not to specify the actual position at a Blend-Point.
- Try to make the peak acceleration values of each segment similar to each other, or try to give similar motion durations.

  This is not always possible or desirable. But consider balancing the motion to give similar motion durations or peak accelerations, or both.
- Can you reduce (or even increase) the distance a part is moved?

Why select different Motion-Laws?

A motion-law might:

- give more flexibility for you to specify the motion-derivatives at the Blend-Points
- suit the mechanical system. For example, the motion-law might have a 'low peak maximum velocity'.
- give a good dynamic response to the mechanical system. For example, the motion-law might have a good response to system backlash, low drive stiffness.
- agree with a company preference(!) - for example Modified Sinusoid is often a company preference.

However, I nearly always design my motions with the Flexible-Polynomial segments as they give me almost all of the flexibility I need.

1.13.5 Motion: Dynamic Considerations

Dynamic Response and Considerations

We use vibration terminology to describe the dynamic performance and response (or output) of a mechanical system to a regular, repeating motion design (or input).

Nominal Motion: The intended (input) motion that you want the mechanical part or system to follow. It is given by your motion design in MotionDesigner and MechDesigner.

Transient Motion: The actual (output) motion that the mechanical part or system has during the motion period.

Residual Vibration: The actual (output) motion that the mechanical part or system has after the motion period. This term usually applies to the dwell period after an indexing motion period.

Dynamic Performance

All mechanical systems have a degree of elasticity. In applications, the elasticity means that the resulting actual accelerations at the driven tooling (the output and the point where the motions is actually applied to the product) will be greater than the nominal acceleration as applied by the cam-follower (the input and the point where the motion is intended) and predicted by the Motion-Law and the motion design (as designed in ***MotionDesigner***) . This issue is a reality of all mechanical systems.

Transient oscillations, or vibrations, occur in all mechanical systems when the input motion-law has a discontinuity in the function at any motion derivative, particularly lower derivatives such as velocity and acceleration.

The **Dynamic Performance**, or **Dynamic Response**, is a result of many factors.

The speed of the drive shaft (cycle speed) is one of the factors which determine the Period Ratio (**speed category**) of the mechanism. Others being:

- the natural frequency,
- the segment duration angle and
- the range of movement (lift) - this being the LEAST significant.

Besides the effect of these factors on jerk and the resultant distortion of the actual motion produced, the maximum allowable operating speed is also influenced by the accuracy of profile manufacture. The adverse effect of local profile inaccuracies is aggravated as the speed of operation increases but, in some cases, may be compensated by the flexibility of the system. Very stiff mechanisms are to be preferred in all cases, provided the cam profile is smooth.

Account must be taken of the compliance of the following system.

Residual Vibration

Vibration levels don't stop when the segment is finished! Residual vibration levels should be considered. If high vibration levels are experienced by the system in a dwell immediately after a segment, then frequently the machine tooling may well be out of position as another mechanism tries to interact with it. Some designers then redesign the motion with an even longer dwell (= shorter motion segment) creating even more vibrations and longer to wait. This is not good motion-design.

Period Ratio

In order to provide an accurate definition of the operating characteristics of a mechanism, including induced vibration of the following system, use the non-dimensional parameter called **Period-Ratio**.

The **Period-Ratio** is the ratio of the:

> Period (duration) of the motion segment to the Period (duration) of the fundamental vibration of the following system.

Period-Ratio >10 indicate stiff, low mass systems, operating at moderate or low shaft speeds.

Period-Ratio <5 occur in systems with compliant followers, a large driven mass or high shaft speed which produces a short motion segment duration.

Period Ratio < 5 represents very compliant or 'high speed mechanisms'

Mechanisms operating at moderate speeds with fairly stiff follower systems would be indicated by **Period-Ratio** values of approximately 10.

For **Period-Ratio** values of more than 20, the acceleration at the driven mass approaches the nominal acceleration defined by the Motion-Law and the dynamic response of the follower system may be neglected when determining actual accelerations.

However, it is very important to note:

In the case of the Simple-Harmonic-Motion 123 and the Constant-Acceleration motion-laws 75, the actual acceleration will always be significantly more than the nominal value, no matter what the **Period-Ratio** or machine speed.

Motion-Laws or motions that exhibit discontinuities in acceleration (infinite jerk), at any point in their cam profile, produce particularly severe vibrations at the driven mass.

The actual acceleration/deceleration at the driven mass will be up to 2 times the nominal acceleration when driven by a (cam) motion with infinite jerk. The nominal acceleration ignores the flexibility or compliance in the following mechanical system.

Pressure Angle Considerations.

Clearly, this relates to Cam designs, and the influence of Motion-Law on the Pressure Angle of Cams.

The pressure angle and the way in which it varies throughout a DRD motion segment depends upon the basic dimension of the cam, the type of the follower (roller, or flat faced) and, to a lesser extent on the particular cam-law employed.

Drive Torque

The operating torques for a cam system depends on the Motion-Law and may influence the choice of the most suitable one.

In general, you want the cam-shaft to rotate as near as possible to constant-velocity. You should design the input drive system to reduce the effect of the varying Drive Torque on the speed of the cam-shaft.

Typically, make drive shaft short, and large a diameter as possible. Add a flywheel to the input near to the Cam.

Maximise the rotating speed of the drive motor with a gear-box. The armature of the motor will also act as a flywheel. The Load Torque (and its variation), referred to the motor are minimized.

There are three Torque factors to consider:

Constant Load Factor

This is the component of torque required to overcome the constant component of the external load on the cam follower! The constant load is usually due to the weight of the following system (or the referred weight), the load at the start of the motion due to any spring constraint, and also friction. This is usually the least significant of the three, for a 'normal' cam driven system - but it depends on the other two!

Inertia Torque Factor

This is the component of torque required to accelerate the mass of the follower assembly. It is usually the most significant in normal systems - but that depends on the others!

Spring Stiffness Torque Factor

This component is due to the linear change of spring constraint with the follower movement. This factor is based on the minimum spring force required at the point of maximum deceleration to maintain contact between the follower and the cam. The spring, might be an 'air-cylinder' which might be either a 'constant force' or as a 'fixed air mass'.

The magnitude of the total drive torque gives some indication of the amount of torsional deflection in the drive shaft and therefore the amount of segment motion distortion that may occur. The distortion will tend to attenuate (reduce) the accelerations and amplify (increase) the decelerations of the follower. An abrupt reversal of torque (e.g. due to backlash in the drive train) will result in torsional vibration in the driving shaft which will then be transmitted through the cam to the driven system. Such distortions can be reduced by increasing the torsional stiffness of the shaft and by increasing the mass moment of inertia, especially near the cam.

Motion distortion can result from shaft bending/flexing (due to cam contact forces)The shaft size and the position of its support bearings should be chosen to minimize any distortion of the cam-shaft.

Motion distortion can also result from the deflection of the cam-follower support shaft due to the pressure angle and cam contact-force.

Jerk

The Jerk function is related to the rate-of-change of the strain-energy of the system throughout the motion design.

Jerk should not be considered in isolation; it must be considered with the systems rigidity/stiffness and its operating speed.

The machine designer is usually most interested in jerk:

- Start and End Jerk: At the start and end of a motion or segment
- Maximum Jerk: Motions with zero jerk at the start, may have a large maximum acceleration. The mechanical system will nominally (without vibrational considerations) strain more when the acceleration is increased.
- Crossover Jerk: The value of jerk as the acceleration changes sign from positive to negative, or *vice versa* . This is called the ***crossover jerk***. Low values ***crossover jerk*** are beneficial for systems with backlash. Backlash will typically traverse once the velocity has reached its peak and begins to reduce. Standard 'Rise' Motions, between dwells, with low '***crossover jerk***' will typically have low peak velocity. A low peak velocity will mean a reduced impact as the backlash traversal is completed.
- Continuity of Jerk: For many of the Traditional Motion-Laws 71, jerk changes instantaneously from zero to some finite value immediately after the motion segment starts. This will tend to induce vibrations in the mechanical system being driven. Other motions will start and end with infinite jerk - this is an even worse condition. These motion are not usually preferred.

- A -

- B -

- C -

- D -

- E -

- F -

- H -

- I -

- L -

- M -

- N -

- O -

- P -

- R -

- S -

- U -

- W -