Technical Paper
PLCopen Technical Committee 2 – Task Force

Function Blocks for motion control: Part 4 –Coordinated Motion

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Function blocks for motion control

The following paper is a document under construction within the PLCopen Task Force Motion Control. As such it is an addition to the PLCopen Task Force Motion Control, Technical Document Version 1.0.
It summarizes the results of the PLCopen Task Force Motion Control, containing contributions of all its members.

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V 0.2	May 3, 2005	As result of meeting with Klas Hellmann, Joachim Mayer and EvdWal
V 0.3	May 20, 2005	As send to group. Includes feedback KH, JM and EvdWal
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V 0.99B	November 20, 2008	Version with editorial feedback from group on Version 0.99A
V 1.0	December 3, 2008	Official release

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1 General

1.1 Objectives

The objective of this document is to define a set of extensions to "Part 1 - PLCopen Function Blocks for Motion Control", as well as "Part 2 - Extensions" focused to the coordinated multi-axes motion in 3D space, to serve the majority of user's application needs in this area.
Part 1 and Part 2 deal with Master / slave motion control, a type of coordinated motion control where the master axis position is used to generate one or more slave axis position commands.
For multi dimensional movements, one goes beyond this point via a grouping of a set of axes, without a master axis. This is done via the definition of a set of Function Blocks with related coordinated motion functionality as well as a higher level state diagram, linking the single axis state diagrams in the group. In this way a better trajectory planning is possible. Also, the current Master/Slave axes can have the problem that if an error occurs, the other axes have no knowledge about this, and continue their movement. By combining axes in a group one knows upfront which axes are involved and has the basis for a better error behavior.

1.2 Introduction

The level of the PLCopen Motion Control Function Blocks are specified at such a level that the user quickly recognizes the functionality of the function block and what happens if it is activated or connected to other blocks in a sequence of motion commands. Path oriented movements are programmed either with specific robot oriented programming languages, or "G-code" (for instance cf. DIN 66025) as used in the CNC world. Both consist of a relative small number of users. But without a doubt, the movements which can be described in these languages are applicable to a broader area of use. This PLCopen initiative transforms the functionalities as known in the CNC and Robotic world to the PLC world. With this, an additional part is added to the range of PLCopen Motion Control specifications. The relationship with the other PLCopen parts is shown below.

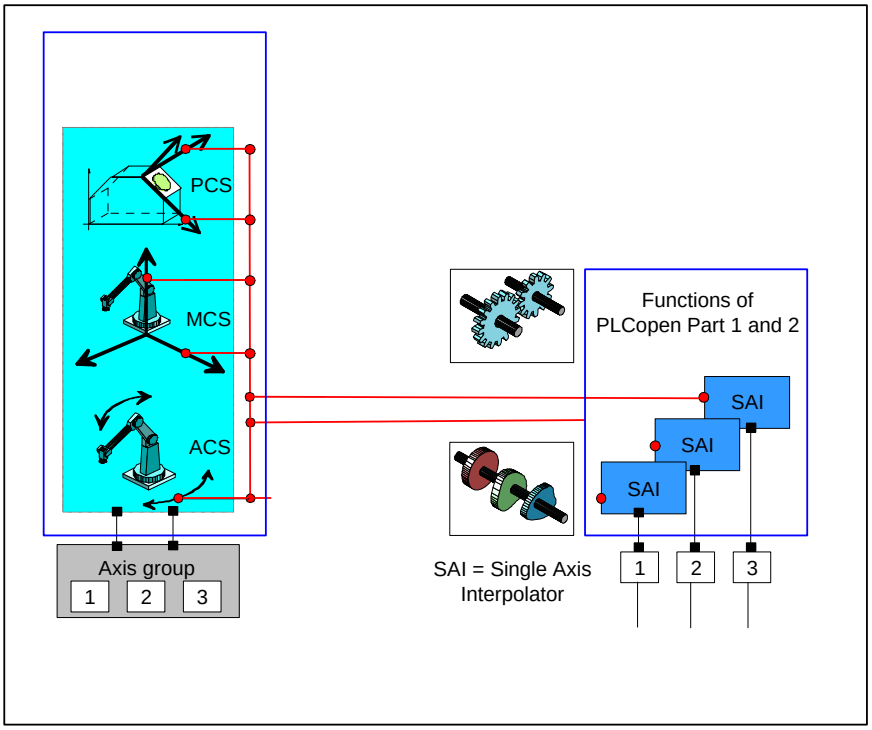


Figure 1: Relationships between the different parts of the PLCopen Motion Control

1.3 Overview of the defined Function Blocks

The following table gives an overview of the defined Function Blocks, divided into administrative (not driving motion) and motion related sets.

Administrative	***Motion***	
Coordinated	***Coordinated***	***Synchronized***
MC_AddAxisToGroup	MC_GroupHome	MC_SyncAxisToGroup
MC_RemoveAxisFromGroup	MC_GroupStop	MC_SyncGroupToAxis
MC_UngroupAllAxes	MC_GroupHalt	MC_TrackConveyorBelt
MC_GroupReadConfiguration	MC_GroupInterrupt	MC_TrackRotaryTable
MC_GroupEnable	MC_GroupContinue	
MC_GroupDisable	MC_MoveLinearAbsolute	
MC_SetKinTransform	MC_MoveLinearRelative	
MC_SetCartesianTransform	MC_MoveCircularAbsolute	
MC_SetCoordinateTransform	MC_MoveCircularRelative	
MC_ReadKinTransform	MC_MoveDirectAbsolute	
MC_ReadCartesianTransform	MC_MoveDirectRelative	
MC_ReadCoordinateTransform	MC_MovePath	
MC_GroupSetPosition		
MC_GroupReadActualPosition		
MC_GroupReadActualVelocity		
MC_GroupReadActualAcceleration		
MC_GroupReadStatus		
MC_GroupReadError		
MC_GroupReset		
MC_PathSelect		
MC_GroupSetOverride		
MC_SetDynCoordTransform		

Table 1: Overview of the defined Function Blocks

This specification currently does not support issues like:

- Spline interpolation functionality
- Digital CAM switch on axes group
- Work space monitoring, taking care that the mechanics are not moving outside a certain area (like a standing pole)

These issues may be covered by future releases.

1.3.1 Length of FB names and ways to shorten them

There are systems that only support a limited number of significant characters in the name. For these rules for shorter names are provided here. These names are still seen as compliant, although have to be mentioned in the certification document.

List of rules to shorten names:

Group	Grp
Remove	Rem
Cartesian	Cart
Coordinate	Coord
Transformation	Trans
Kinematic	Kin
Dynamic	Dyn
Synchronized	Sync
Configuration	Cfg
Position	Pos
Velocity	Vel
Acceleration	Acc

Linear	Lin
Circular	Circ
Absolute	Abs
Direct	Dir
Relative	Rel
Actual	Act
Conveyor	Conv

Resulting compliant names:

MC_AddAxisToGrp	MC_GrpContinue
MC_RemAxisFromGrp	MC_GrpReadStatus
MC_UngroupAllAxes	MC_GrpReadError
MC_GrpReadCfg	MC_GrpReset
MC_GrpEnable	MC_MoveLinAbs
MC_GrpDisable	MC_MoveLinRel
MC_GrpHome	MC_MoveCircAbs
MC_SetKinTrans	MC_MoveCircRel
MC_SetCartTrans	MC_MoveDirAbs
MC_SetCoordTrans	MC_MoveDirRel
MC_ReadKinTrans	MC_PathSelect
MC_ReadCartTrans	MC_MovePath
MC_ReadCoordTrans	MC_GrpSetOverride
MC_GrpReadActPos	MC_SyncAxisToGrp
MC_GrpReadActVel	MC_SyncGrpToAxis
MC_GrpReadActAcc	MC_SetDynCoordTrans
MC_GrpStop	MC_TrackConvBelt
MC_GrpHalt	MC_TrackRotaryTable
MC_GrpInterrupt	

1.4 Glossary

Name/ Acronym	Explanation
ACS	Axes Coordinate System: The system of coordinates related to the physical motors and the single movements caused by the single drives.
Blending	A way that consecutive function blocks cooperate in the transition from the first to the next.
Contour curve	Inserted curve that modifies the original path. It is the resulting curve after blending.
Coordinate system	The reference system in which a coordinate or path is described.
Corner deviation	The shortest distance between the programmed corner point and the contour curve.
Corner distance	Distance of the start point of the contour curve to the programmed target point.
Direction	The orientational components of a vector in space. (Note: this is different from the MC_Direction input as used in part 1).
Drive	A unit controlling a motor via the current and timing in its coils.
Group-FB	The set of function blocks that can work on a group of axes.
MCS	Machine Coordinate System - the system of coordinates that is related to the machine. A Cartesian coordinate system with the origin in a fixed position relative to the machine (the origin is defined during the machine setup). Sometimes called "World Coordinate System" or "Base Coordinate System". (Note: with Cartesian build machines, MCS is a Cartesian Coordinate system and may be identical to ACS, or mapped via a trivial transformation). The coordinate system from the physical multiple axes ACS is linked to the MCS via a kinematic transformation (forward and backward conversion). The MCS represents an imaginable space with up to 6 dimensions.
Motor	An actuator focused to a movement, converting electrical energy in a force or torque.
Orientation	The rotational components of a vector in space.
Path	Set of continuous positions and orientation information in multi-dimensional space Geometrical description of a space curve that the TCP of an axesgroup moves along.
PathData	Description of a path which can include additional information like velocity and acceleration.
PCS	The coordinate system of the product can be called PCS – Product Coordinate System (or "Program Coordinate System" in CNC world, or Programmers Coordinate System). The PCS is based on the MCS typically by shifting and maybe rotating the MCS. The Zero point of the PCS is related to the product and can be changed during runtime by the program. The real work piece can have a rotation or shift to the MCS coordinate system or even might be moving relative to the MCS coordinate system. By specifying a trajectory in PCS one is able to describe the trajectory independent from the machine situation. To map these two worlds (MCS to PCS and vice versa), a cartesian or cylindrical transformation is normally done.
Position	Position means a point in space which is described by different coordinates. Depending on the used system and transformation it can consist of up to 6 dimensions (coordinates) meaning 3 Cartesian coordinates in space and 3 coordinates for the orientation. In ACS there can be even more than 6 coordinates. If the same position is described in different coordinate systems the values of the coordinates are different.
Pose *(not used)*	Position and orientation (DIN EN ISO 8373). Position is used instead in this document.
Scara	A special kinematic for robot or handling applications.
Speed	Speed is the absolute value of the velocity without direction.
Synchronization	Combines an axis or axes group (as slave) with an axis as master in order that the slave executes its path with synchronization to the progress of the master, meaning linked to a one-dimension source for synchronization.
TCP	Tool Centre point, the point in the machine that is commanded to move, typically the center or the head of the tool. It can be described in different coordinate systems.
Tracking	Is characterized by an axis group that follows with its movement the movement of another axis group.
Trajectory	Time dependent description of the path the TCP of an axes group moves along. Additionally to the geometrical description of the space curve, time dependent state variables like velocity, acceleration, jerk, forces etc. are specified.
Velocity	For a group of axes this means: - in ACS the velocities of the different axes;

	- in MCS and PCS it provides the velocity of the TCP.

2 Principles of Coordinated Motion

2.1 Coordinate System and kinematic transformation

The essence of a trajectory is the coordinated motion of two or more axes from a starting point to a target point via a defined path with a specified path velocity. As path one can think of a straight line, a circular movement, or via a spline function. The definition of a path– or any position information - in space requires a coordinate system. Within this specification three coordinate systems are defined:

ACS	Axis related
MCS	Machine related
PCS	Product or Workpiece related

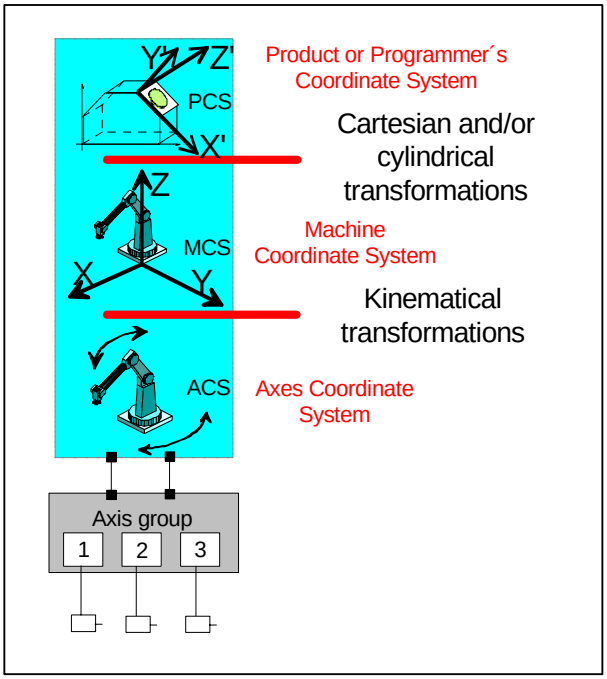


Figure 2: Overview of the coordinate systems and transformations

ACS: Axes Coordinate System – actual position of the physical axis (after homing).

MCS: Machine Coordinate System – Cartesian coordinate system with the origin is a fixed position relative to the machine. (Sometimes called “World Coordinate System” or “Base Coordinate System”). (Note: with Cartesian build machines, MCS may be identical to ACS, or mapped via a trivial transformation). The coordinate system from the physical multiple axes ACS is linked to the MCS via a kinematic transformation (forward and backward conversion).

PCS: The real work piece can have a rotation or shift to the MCS coordinate system or even might be moving relative to the MCS coordinate system, and often one wants to describe the trajectory independent from the machine situation. To map these two worlds (MCS to PCS and vice versa), a cartesian or cylindrical transformation is normally done. The coordinate system of the product can be called PCS – Product Coordinate System (or “Program Coordinate System” in CNC world). There can be more than one PCS transformation applicable at the same time. In this case the ENUM to specify the coordinate system (CS) has to be extended. A PCS can be a static or a dynamic transformation.

In order to specify a point or orientation in space a position always has to be related to a coordinate system. By means of transformations this position can be transformed to other coordinate systems. Within this specification, function blocks are defined for these transformations, hiding the complexity of these transformations to the programmer in its day to day use. All multi axes motion commands are related to only one of the coordinate systems at the same time.

The example below demonstrates how a point P, which is situated on a 2D workpiece (red trapezoid), can be described

equivalent in PCS (blue), MCS (black) and ACS (green). Point P could be specified by referring to PCS resulting in the position $P_{PCS} = (x_{PCS}, y_{PCS})$. Given the shift and orientation of PCS relative to MCS, point P equivalently could be specified by $P_{MCS} = (x_{MCS}, y_{MCS})$. Assuming a SCARA robot with two rotary axes point P also could be described by the angles of the axes $P_{ACS} = (\phi_1, \phi_2)$.

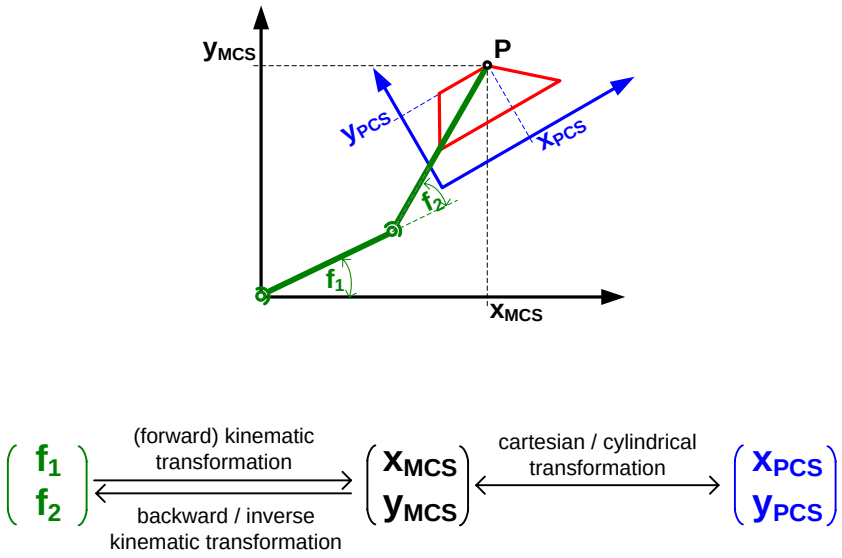


Figure 3: Example for specifying point P in PCS, MCS or ACS

assuming a SCARA robot with two rotary axes

2.1.1 Kinematic Transformation

Axes are connected via mechanical links providing movements of the 'Tool Center Point', TCP in space. TCP is a distinguished point of the machine, sometimes also called 'Point of Interest', POI, or 'effector'. The physical assembly of the axes and therefore the position of the TCP in MCS is described by a so called kinematic transformation. The kinematic transformation connects ACS to MCS (forward conversion). By applying the kinematic transformation on a position related to ACS, this position can be transformed into a position in MCS. The other way round, applying the inverse kinematic transformation, a position related to MCS can be transformed into a position in ACS (backward conversion).

With simple cartesian machine constructions, in which axes are directly oriented in X-, Y-, and Z-directions of MCS, the kinematic transformation can easily be specified. One just has to define which axis is in the X-direction, which in Y, and which in the Z-direction. In the simplest case ACS is identically to MCS and one needn't distinguish between both. But in praxis there are many non-cartesian structures, like SCARA robots or Tripods, where the kinematic transformation is more complex.

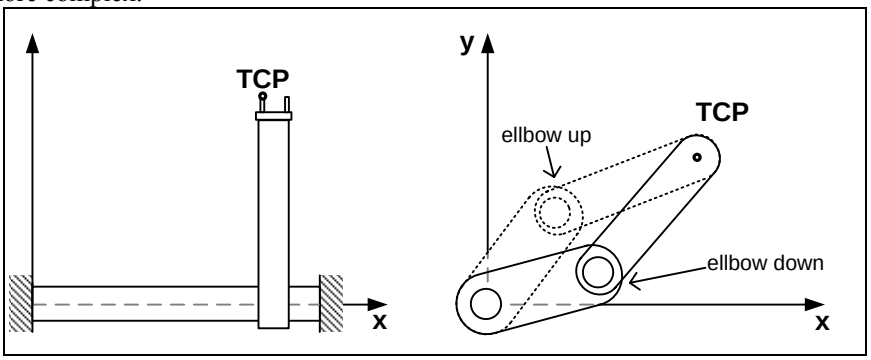


Figure 4: Example for reaching the same position in space

with a) a cartesian handling (2 linear axes) and b) a SCARA (2 rotary axes) with two possible configurations (elbow down and elbow up). (Note: the orientation is fixed in both examples)

Above example demonstrates how a position in space could be reached by a cartesian handling or a SCARA. Whereas the positions of the linear axes are more or less identical to the coordinates of the position in MCS, the positions of the axes of the SCARA are not that easy to calculate. Additionally there are two possible solutions of the backward kinematic transformation, different configurations of the machine: elbow down and elbow up.

2.2 How do commands behave in dynamic coordinate systems

If the TCP should follow a moving target, this can be achieved by a dynamic coordinate transformation, leading to a PCS which is moving in relation to the MCS.
The activation of a dynamic transformation is done by activating MC_SetDynCoordTransform.
If there is a dynamic transformation active, the axis may follow the dynamic transformation or stay in the static ACS or MCS. The following example is showing the behavior. The example describes a robot fetching a screw from a fixed position and mounting it on a product that is moving on a belt.

Step	**Move command**	**Axes (group) behavior**	**Application example**
1	Activating Transformation ACS to MCS	Group is staying still (not moving)	Initialization MCS is static
2	MC_MoveAbsolute in MCS	Group moves to the commanded position in MCS and stays in static MCS (not moving)	Moving to standby position and waiting for products
3	Motion command in static MCS	Group moves to the commanded position in MCS and stays in static MCS (not moving)	Moving to a fixed box of screws
4	Motion command in static MCS	Picking command	Picking up a screw
5	Activating a dynamic PCS	PCS is active and moves synchronized with the belt	PCS is ready for use
6	Motion command in dynamic PCS	Group moves to commanded position in PCS and is moving together with the dynamic PCS	Placing the screw and following the product on the belt
7	Screwing command	Group is still following the product on the belt	Screw is being screwed into the product
8	Motion command in static MCS	Group moves to commanded position in MCS at the fixed screw box	Moving to the fixed box of screws and waiting for the next product on the belt
9	Motion command in dynamic PCS	Group moves to commanded position in PCS and is moving together with the dynamic PCS	Placing the screw to the new product and following the product on the belt

Rule: An axis group stays in the coordinate system which is specified with the last motion command. If this is a PCS with dynamic transformation, it will follow the PCS (keeping the same position in this PCS).

2.3 Movements

Applying a movement on a machine via a function block causes the TCP to move towards the new commanded position. The kind of function block applied specifies the path via which the new target position is reached. (Note: the coordinate system in which the new commanded position is specified does not have an influence on the path.)

Basically there are two types of movements which have to be distinguished:

Point - to - Point movements, PTP (also referred to as Joint Interpolated Movements):
With this type the essence is to reach the commanded position as fast as possible. This can be achieved by moving each axis on the shortest way from its starting position to its target position. Usually this kind of movement is the fastest way to reach a new commanded position, because at any time at least one axis moving at it's dynamic limit. The path and the path velocity of the TCP are not important. They are determined by the process of the positions of the axes and the kinematic transformation of the machine. Therefore this kind of movement is applicable for handlings and whenever the path of the TCP is not crucial. It is recommended that all axes will arrive at the commanded position at the same point in time (synchronized).
The applicable Function Blocks as specified herein are:

- MC_MoveDirectAbsolute
- MC_MoveDirectRelative

Cartesian Path movements, CP (also referred to as Continuous Path movements):
CP movements cause the TCP to move along a defined path in Cartesian space. A path can be (a set of) a straight line, a circular movement, or a spline function. The path via which the new commanded position is reached is important. For example, this is essential if a workpiece is being processed. Further, the path velocity of the TCP can be controlled directly. Contrary to joint interpolated movements the process of the position of each axis is determined by the desired path and the inverse kinematic transformation.
The applicable Function Blocks as specified herein are:

- MC_MoveLinearAbsolute
- MC_MoveLinearRelative
- MC_MoveCircularAbsolute
- MC_MoveCircularRelative
- MC_MovePath

The figure below illustrates the differences between different types of movement by means of a theoretical machine.

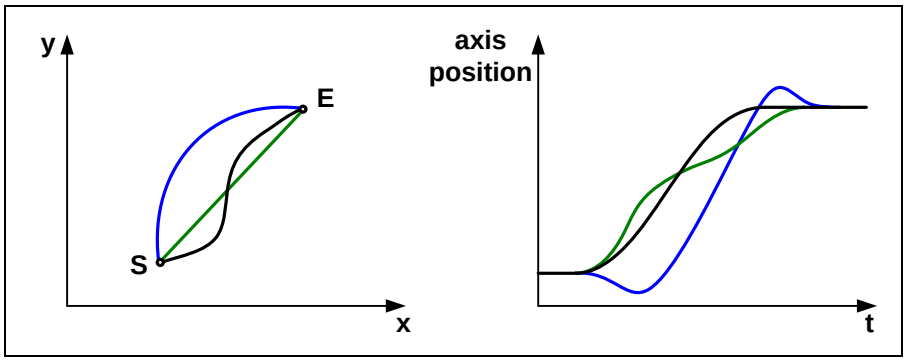


Figure 5: Different types of movements

MC_MoveDirect (black), MC_MoveLinear (green) and MC_MoveCircular (blue) and typical positions of one of the axis of the machine participating in the movement

2.4 Blending and Buffering of Movements

2.4.1 General Information

A fundamental part of interpolated motion control is blending of (buffered) consecutive motion commands on an axes group. Without blending the TCP of an axes group moves towards the commanded position, decelerates and comes to standstill exactly at the commanded position. The following buffered motion command doesn't become active until now. Obviously the axes group has to accelerate again. In many applications a different behaviour of the TCP is desired and one wants to concatenate movements without stopping.
Reasons for this are:

- Reduction of the process cycle time (e.g. pick and place)
- Generate a smoother movement in order to reduce the mechanical stress
- Some applications demand a constant Velocity of the TCP (e.g. applying glue, painting, welding, etc.)

All this can be achieved by different types of blending. Common to all types of blending is a modification of the original path, resulting in a smooth trajectory without corners.
Blending of motion commands in interpolated motion control differs from blending of motion commands on single axes. With single axes the commanded position is always reached. Just the velocity at the time when the commanded position is reached (or passed) can be changed according to the input parameter BufferMode.
With interpolated motion control several types of blending can be thought of, depending on the application and process. Therefore new types of blending have to be introduced for interpolated motion control.
The input parameter for blending might vary due to the kind of interpolation method applied. So this input is supplier specific.
The type of inserted curve that modifies the original path (the 'contour curve') is not part of this specification and can be defined by the supplier specific input parameter for blending.

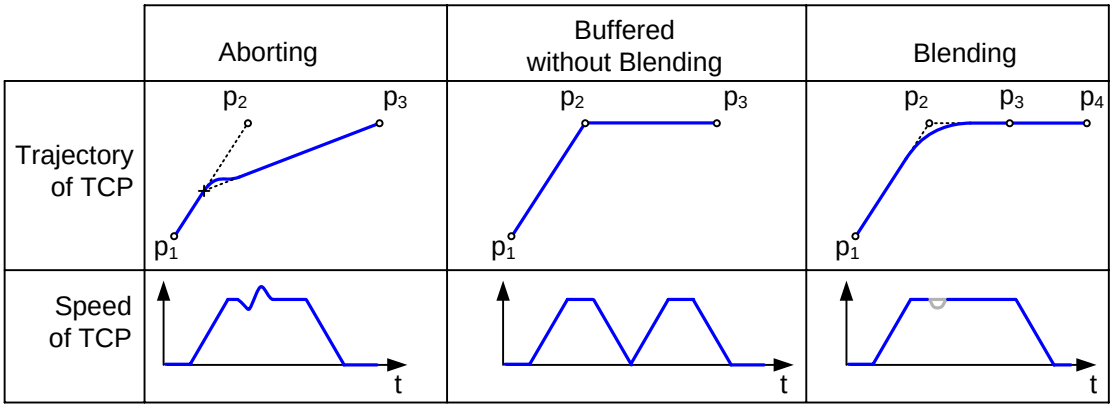


Figure 6: Trajectories and process of Velocity in principle of two consecutive motion commands in three modes

2.4.2 Overview of Buffer Modes

For axes group motions the same buffer modes are used as for single axis motions (ENUM of type MC_BUFFER_MODE).

No.	MC_BUFFER_MODE	Description
0	Aborting	Start FB immediately (default mode)
1	Buffered	Start FB after current motion has finished
2	BlendingLow	The velocity is blended with the lowest velocity of both FBs
3	BlendingPrevious	The velocity is blended with the velocity of the first FB
4	BlendingNext	The velocity is blended with velocity of the second FB
5	BlendingHigh	The velocity is blended with highest velocity of both FBs

Table 2: Overview of Buffer Modes

For details refer to Chapter 77 - Details of Blending and Buffering of Movements.

2.4.3 Overview of Transition Modes

Depending on the transition mode different supplier specific transition parameters can be given, which characterize the contour curve.
The basic transition modes are defined. Other modes as well as supplier specific modes can be added.

No.	MC_TRANSITION_MODE	Description
0	TMNone	Insert no transition curve (default mode)
1	TMStartVelocity	Transition with given start velocity
2	TMConstantVelocity	Transition with given constant velocity
3	TMCornerDistance	Transition with given corner distance
4	TMMaxCornerDeviation	Transition with given maximum corner deviation
5 - 9	Reserved by PLCopen	
10 -…	Supplier specific modes	

Table 3: Overview of Transition Modes

For details refer to Chapter 7 Details of Blending and Buffering of Movements.

2.4.4 Matrix of available transition modes

This matrix shows the available transition modes for the different buffer modes.
This matrix can be used by the supplier to document its supported transition modes.

BufferMode / **TransitionMode**	Aborting	Buffered	Blending Low	Blending Previous	Blending Next	Blending High
TMNone	A	A	N	N	N	N
TMMaxVelocity	D	D	D	D	D	D
TMDefinedVelocity	A	N	A	A	A	A
TMCornerDistance	N	N	A	A	A	A
TMMaxCornerDeviation	N	N	A	A	A	A

Table 4: Matrix of available transition modes

Legend:
A = Available
N = Not possible
D = BlendingMode is dispensable

3 Model

3.1 State diagram

The state-diagram of the group describes the commanded state of the group of axes. It is on top of the state diagram per axis (like defined in Parts 1 and 2). While axes are in a group state, the single axis state diagram is also active per axis. Therefore interdependencies between the 2 types of state-diagrams exist.

GroupDisabled is the initial state at power up where a group can be created. Issuing MC_GroupEnable leaves this state. The next state is GroupStandby. In this state the group is enabled and no function block has control on one of the axes in the group. In this state the group can additionally be altered and homed if needed (State GroupHoming).
In the state GroupHoming a homing sequence can be defined for a group of axis. This can be applicable due to the mechanical constraints of multiple motors (for example in an mechanical construct looking like the letter "I" with 2 motor mechanically coupled via one band or belt moving over the form of the letter I, need to be homed differently.).
If a function block has control on (one of the axis of) the group, the state changes to GroupMoving.
GroupStopping is a special state that deals with the MC_GroupStop command, which automatically tranfers to the state GroupStandby as soon as "Done" is SET and "Execute" is FALSE in MC_GroupStop.
In case an error arises (in one of the axis) the state changes to GroupErrorStop, which can only be left via issuing MC_ResetGroup.

Explanations:

- Group motion commands will always lead to a SynchronizedMotion state in the single axis state diagram. In case of a GroupStandby all axes of the group are also in single axis state StandStill.
- A GroupErrorStop will not lead to ErrorStops of the grouped axes as the error may only affect the group. In case of a single axis ErrorStop the Group will also change to GroupErrorStop as the single error effects the group.

The state diagram reflects the state of the group and the issued FBs..

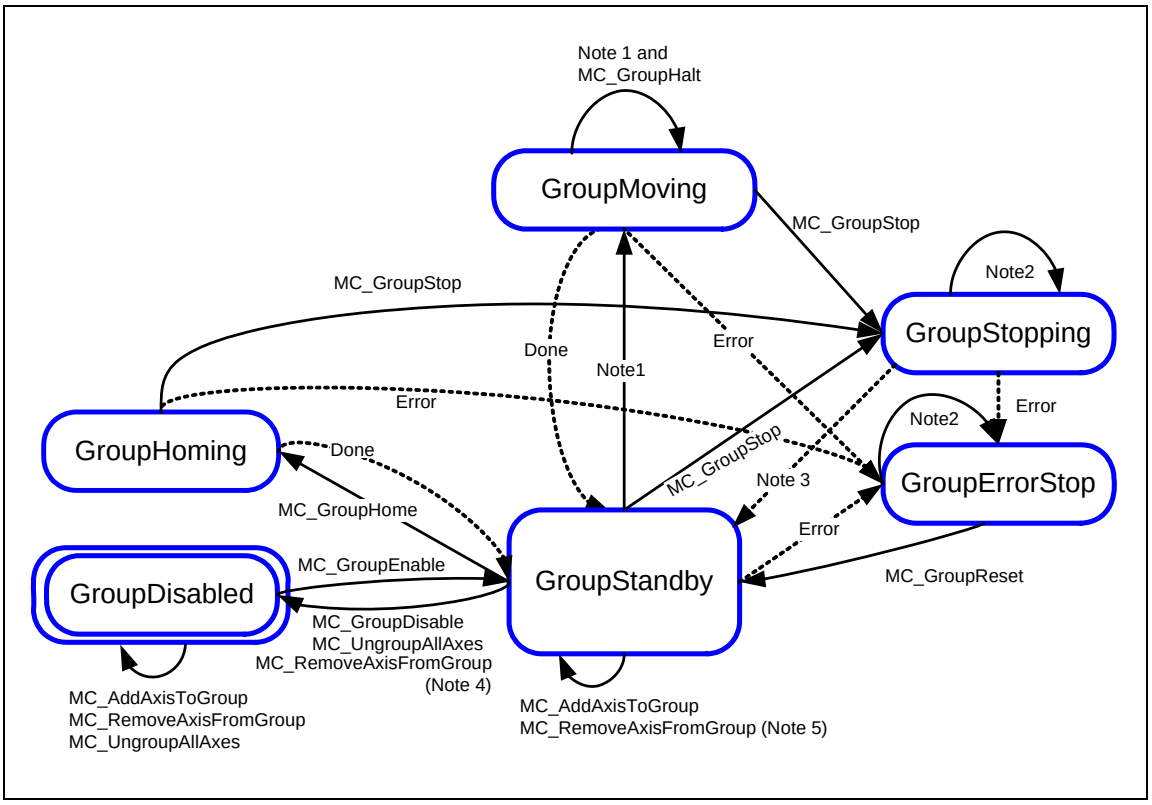


Figure 7: The State Diagram

Note to transitions: Continuous lines are commanded transitions; dotted lines are automatic transitions.

Note 1: Applicable for all non-administrative (moving) function blocks.
Note 2: In the states GroupErrorStop or GroupStopping, all Function Blocks can be called, although they will not be executed, except MC_GroupReset for GroupErrorStop and any occurring Error– they will generate the transition to GroupStandby or GroupErrorStop respectively
Note 3: MC_GroupStop.DONE AND NOT MC_GroupStop.EXECUTE
Note 4: Transition is applicable if last axis is removed from the group
Note 5: Transition is applicable while group is not empty.
Note 6: MC_GroupDisable and MC_UngroupAllAxes can be issued in all states and will change the state to GroupDisabled.

3.2 Relationship Single Axis and Grouped Axes State Diagrams

Example of the relationship between 3 single axes combined in an axes group.

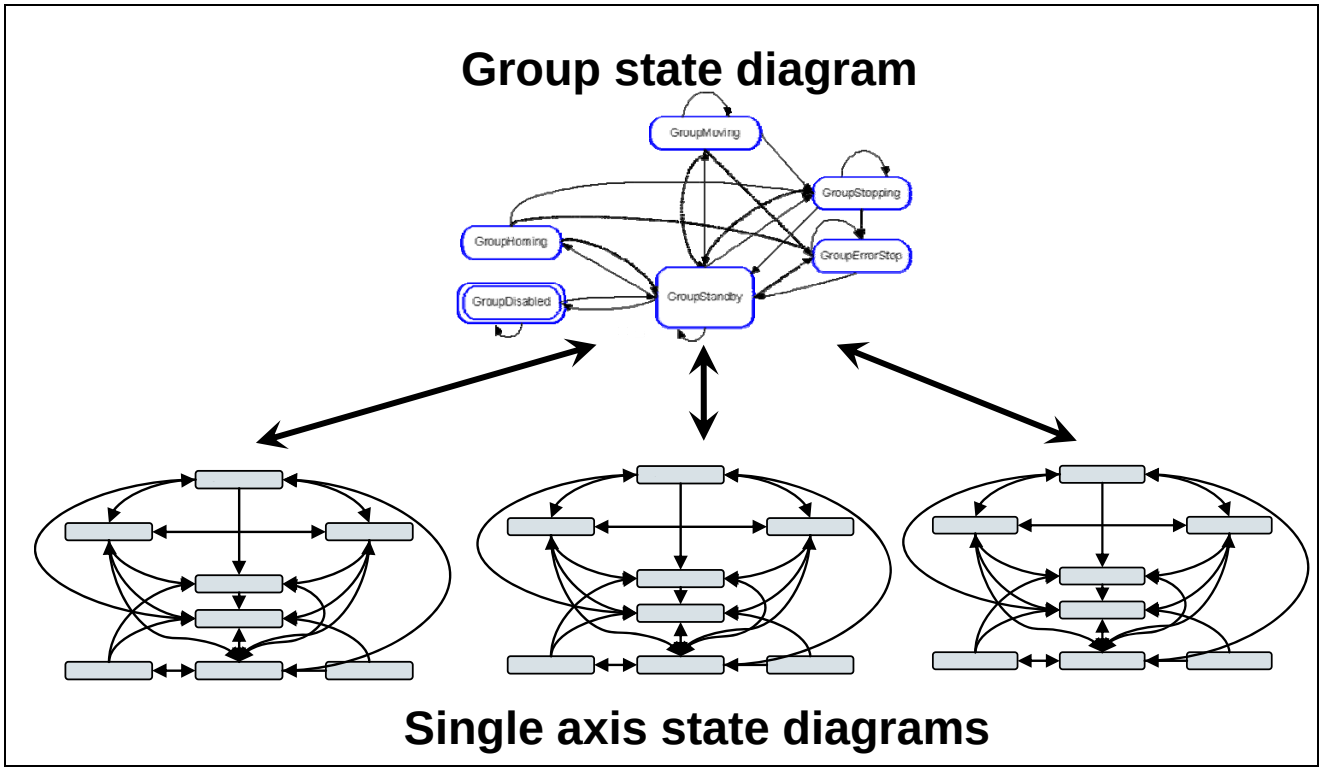


Figure 8: Relationship Single Axis and Grouped Axes State Diagrams

When a number of axes are grouped, and a single axis command, like MC_MoveAbsolute, is issued to an axis in this group, there are basically 3 options:

1. Not allowed. Issuing a single axis command is not accepted and not performed: it signals this by setting the error output of the applicable (issued) single axis function block. There is no change to the group, and as such continues their movements.
2. Aborting the current group command(s), as well as following group commands, and continue with the single axis command only. The remaining axes of the group move to the state StandStill (via an implicit MC_Halt per axis). The original trajectory will not be finalized.
3. Superimpose the single axis commands to the group commands.

This specification does not restrict to any of these options. This means that different implementations of this behavior will exists, and the supplier of the system has to specify what their system does support.

General rules for the interaction between a single axis towards its groups (for all 3 options above):

- If at least one axis in the group is moved by a command then the group is in the state GroupMoving.
- If all axes are in StandStill, the group can be in the state GroupStandby, GroupDisabled or GroupErrorStop.
- If one axis in a group is in ErrorStop, the whole group is in GroupErrorStop.

- If a single axis MC_Home is issued the group is in state GroupMoving.
- If a single axis MC_Stop is issued the group is in state GroupMoving.
- If supported by the system, it is allowed to disable a single axis of the axis group without influencing the axes group state. This can be useful to save energy or to apply a mechanical brake for a single axis not involved in the on-going motion.

General rules for the interaction between a group and the single axis in it (for all 3 options above):
- If the group is commanded by a group moving command, all the single axes in the group are in the state SynchronizedMotion
- If the group is in the state GroupStandby, the states of the single axes do not have to be all in StandStill
- If the group is in the state GroupErrorStop the state of the single axis is not affected

Overview of the influence of group motion commands on a single axis state:

Command	**Group State**	**Axis state**
MC_MoveLinearXxx MC_MoveCircularXxx MC_MoveDirectXxx MC_MovePath MC_GroupHalt MC_TrackConveyorBelt MC_TrackRotaryTable	GroupMoving	SynchronizedMotion
MC_GroupStop	GroupStopping / GroupStandby	SynchronizedMotion / StandStill
MC_GroupReset	GroupErrorStop / GroupStandby	Not relevant for Axis
MC_GroupHome	GroupHoming	SynchronizedMotion

Table 5: Overview of the influence of group motion commands on a single axis state

Explanation: A stopping group leaves the single axis in synchronized motion as none of the single axis performs a single axis stop.

3.3 Input Execution Mode

The input MC_EXECUTION_MODE is an ENUM providing information on the behavior of administrative function blocks.
The modes are:
- Immediately - the functionality is immediately valid and may influence the on-going motion but not the state
- Delayed - The functionality is valid when the ongoing motion command sets one of the following output parameters: Done, Aborted or Error. This also implies that the output parameter Busy is set to FALSE.
- Queued - The new functionality becomes valid when all previous motion commands sets one of the following output parameters: Done, Aborted or Error. This also implies that the output parameter Busy is set to FALSE.

4 Axes Grouping

Within this specification for interpolation, the related axes are grouped in an "AxesGroup", and can be accessed via the type AXES_GROUP_REF. The relationship between the different axis levels and groups is shown hereunder.

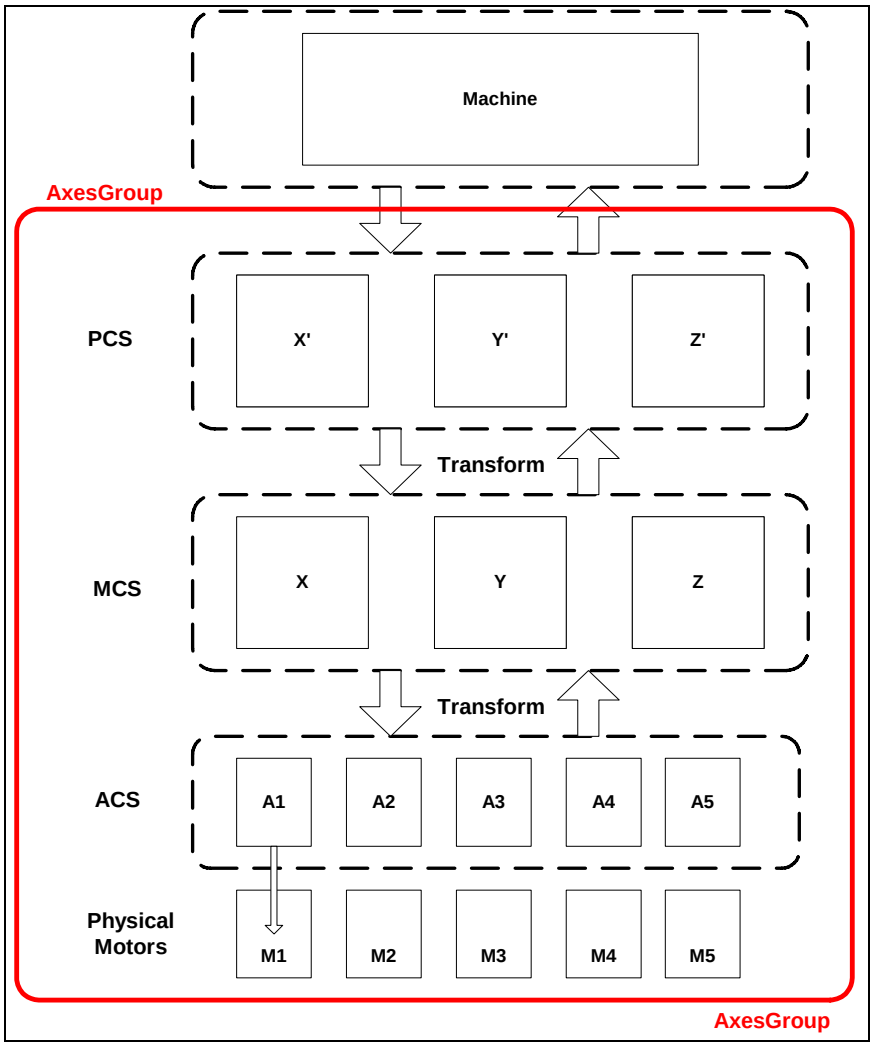


Figure 9: Overview AxesGroup

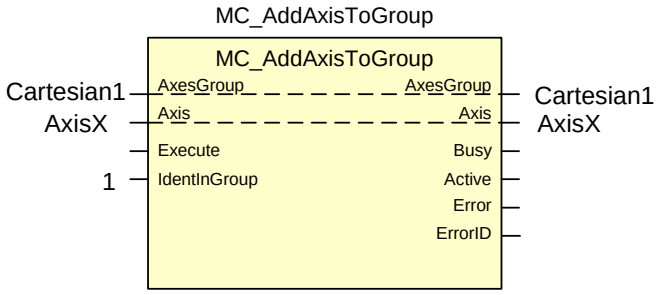
The AxesGroup shown in red above provides the interface to the user of the group of axes. To access the relevant coordinate system, the relevant function blocks have an input CoordSystem which supports the three levels ACS, MCS and PCS.
Parameters in the AxesGroupRef can include remaining time and remaining distance before target position (or velocity or equal) is reached.

4.1 Creating and using an AxesGroup

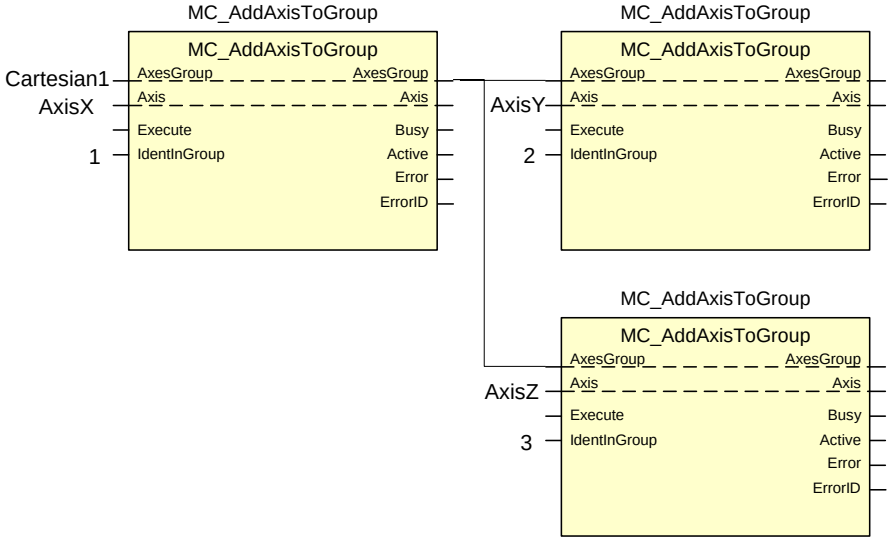
In order to create a group, one can go through the following steps:

1. If necessary, move the first axis (or all axes) to the relevant position(s) via single axis commands
2. Give the group a name (create a variable of type AXES_GROUP_REF). Group now in state GroupDisabled.
3. Add the first axis to this group via MC_AddAxisToGroup
4. Repeat this till all axes are defined in the group in the right order
5. Link the kinematic model to the group via MC_SetKinTransform even if it is per default a Cartesian system
6. Link the next level(s) of transformation(s) to the group via MC_SetCartesianTransform and /or MC_SetCoordinateTransform
7. Enable the group (via MC_GroupEnable) in order to use it.

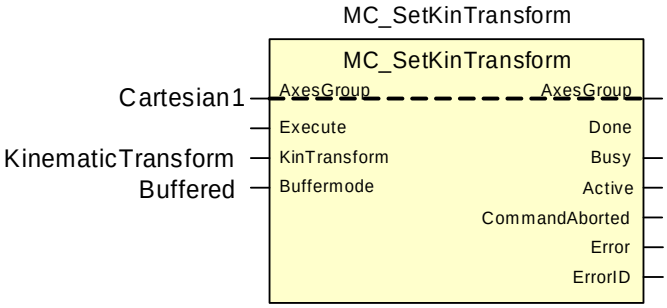
Example
If not done per axis yet, one switches on the power, and does a homing sequence per relevant axis with the single axis function blocks. These relevant axes are now in the single axis state StandStill. (Note: It can be that the homing must (additionally) be done in the group itself, due to special constructional constraints).
One creates a group by adding the first axis to it, and giving it a name. For instance:



MC_AddAxisToGroup with a group name Cartesian1 for AxesGroupRef. The used Axis is referenced via AxisRef, like AxisX. The input IdentInGroup gives the reference in the group, like 1.
Now a group has been created, called Cartesian1, with one Axis, AxisX, coupled in position 1. The state is still GroupDisabled.
Now we add a second axis, called AxisY, in position 2, and a third axis, AxisZ, in position 3.

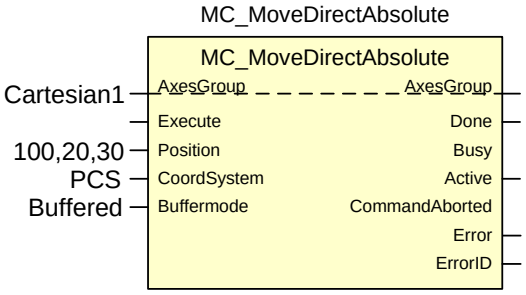


The group now consists of 3 axes, with all axes in the state GroupDisabled.
The next step is linking the transformations to this group. For instance, for the kinematic transformation we use MC_SetKinTransform.



The other relevant function blocks for the transformations are MC_SetCartesianTransform and MC_SetCoordinate-Transform.

With issuing MC_GroupEnable we transfer the state of the group to GroupStandby, enabling it to accept movements. A movement changes the state to GroupMoving. To tell the relevant movement command in which coordinate system the coordinates are applicable, the input CoordSystem is used, supporting the three levels ACS, MCS and PCS.



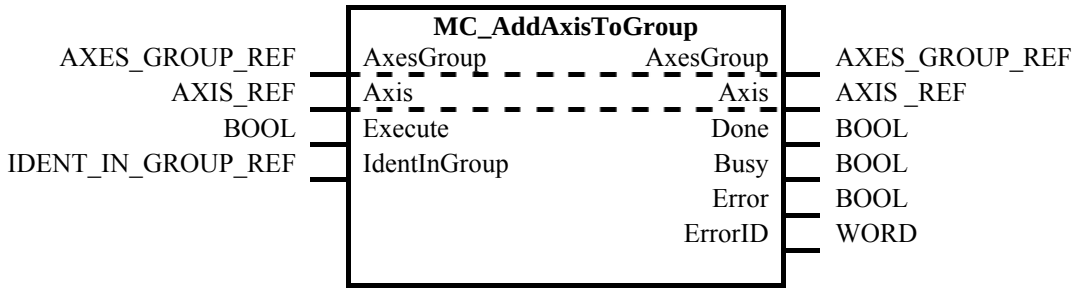
After "Done" is set, the state changes back to GroupStandby.
With MC_UngroupAllAxes we ungroup all axes at once, getting them all to the state StandStill for each axis.
An existing AxesGroup can be changed. This can be applicable with a tool change which includes an additional motor. This changes both the number of axes as well as the kinematic model. The change can be done in the states GroupDisabled and GroupStandby, and adds the axis to the group and changes the link to the applicable kinematic model. The same procedure is valid for changing the tool back, although the MC_RemoveAxisFromGroup is used.
Having an axis in the group that is not linked to the kinematics model (yet) is allowed - however the use case is not defined.

Of course it is possible to use a graphical software tool to generate the steps above, even in a different sense like starting from the kinematics model and generate the software steps to create the axes group with the connections to the transformations like described above.

5 Function Blocks for Coordinated Motion

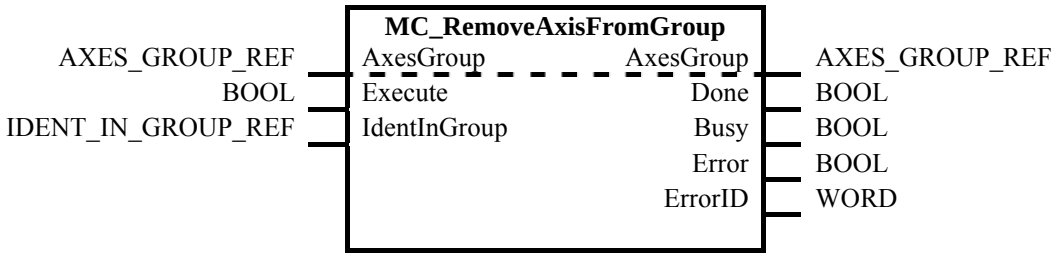
5.1 MC_AddAxisToGroup

FB-Name		**MC_AddAxisToGroup**		
This Function Block adds one axis to a group in a structure AxesGroup. This is an administrative FB, since no movement is generated. The command cannot be buffered.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
	B	Axis	AXIS_REF	Reference to the axis to be added
VAR_INPUT				
	B	Execute	BOOL	Start the grouping process at the rising edge
	E	IdentInGroup	IDENT_IN_GROUP_REF	Identifies the order in the group of the added axis. Done via a REF in order to give the different axes a name in the order, which can be coupled to the names in the kinematic model (like “foot”, “shoulder”)
VAR_OUTPUT				
	B	Done	BOOL	AXES_GROUP_REF is valid and the axis added
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: Each IdentInGroup can be used only once, otherwise it leads to an error				



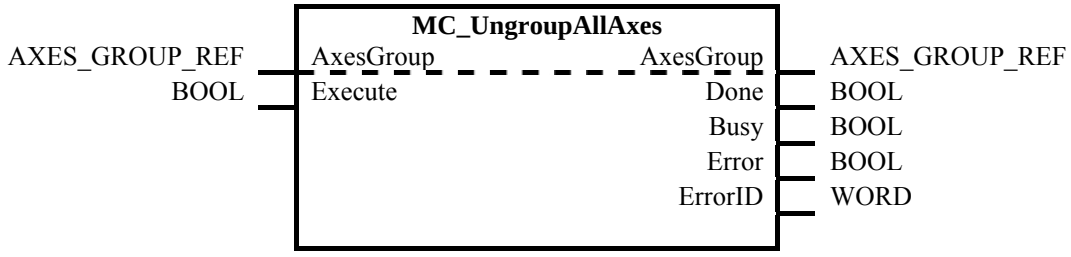
5.2 MC_RemoveAxisFromGroup

FB-Name		**MC_RemoveAxisFromGroup**		
This Function Block removes one axis from the group AxesGroup. This is an administrative FB, since no movement is generated. The command cannot be buffered. If there is no axis left in the group, the state changes to GroupDisabled.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the axis removal process at the rising edge
	E	IdentInGroup	IDENT_IN_GROUP_REF	Identifies the axis in the group
VAR_OUTPUT				
	B	Done	BOOL	AXES_GROUP_REF is valid and the axis removed
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: If issued on a group that is not in GroupDisabled, GroupStandby or GroupErrorStop, it generates an error and the FB is not executed.				



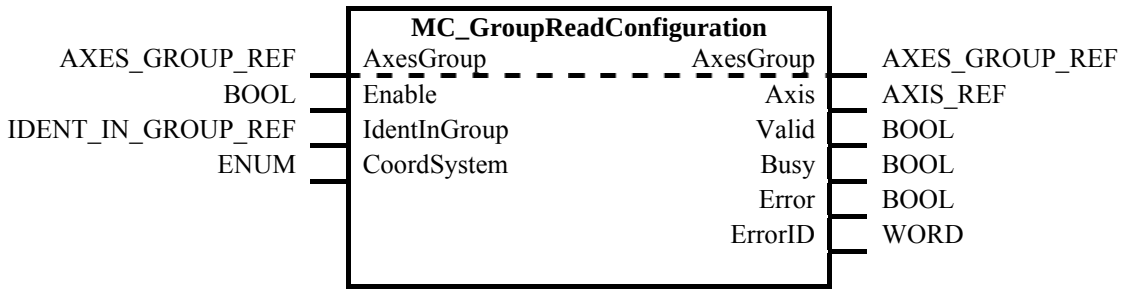
5.3 MC_UngroupAllAxes

FB-Name		**MC_UngroupAllAxes**	
This Function Block removes all axes from the group AxesGroup. This is an administrative FB, since no movement is generated. The command cannot be buffered. After finalization the state is changed to GroupDisabled			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT			
B	Execute	BOOL	Start the process at the rising edge
VAR_OUTPUT			
B	Done	BOOL	All axes are removed
E	Busy	BOOL	The FB is not finished
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification
Notes: If issued on a group that is not in GroupDisabled, GroupStandby or GroupErrorStop, it generates an error and the FB is not executed.			



5.4 MC_GroupReadConfiguration

FB-Name		**MC_GroupReadConfiguration**		
This Function Block gets the axis reference according to the given group identifier in order to read the current configuration of an axes group. For CoordSystem-Input "ACS" you get a conventional axis reference, but for CoordSystem-Input "MCS" or "PCS" you get the axis reference of a virtual axis according to the transformation that is active. This is an administrative FB, since no movement is generated.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to the group of axes
VAR_INPUT				
	B	Enable	BOOL	Gets the axis reference according to the given group identifier while enabled
	B	IdentInGroup	IDENT_IN_GROUP_REF	Identifies the axis in the group
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
VAR_OUTPUT				
	B	Axis	AXIS_REF	Reference to the selected axis
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: -				

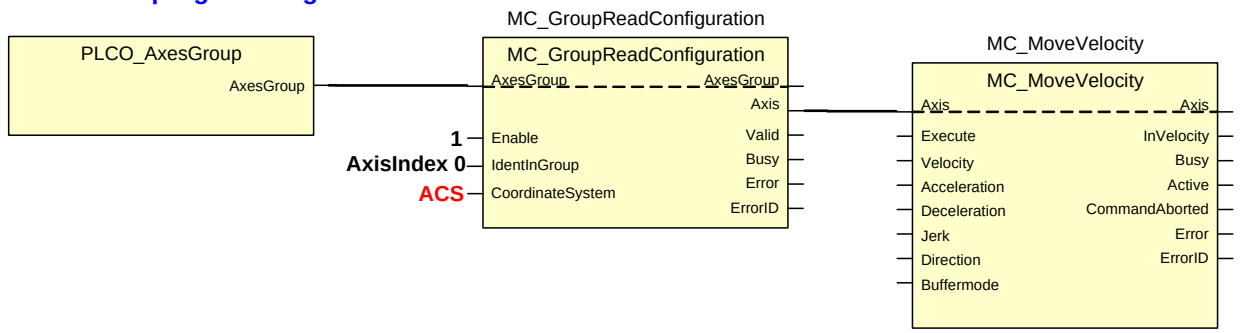


Examples on how to use this function block:

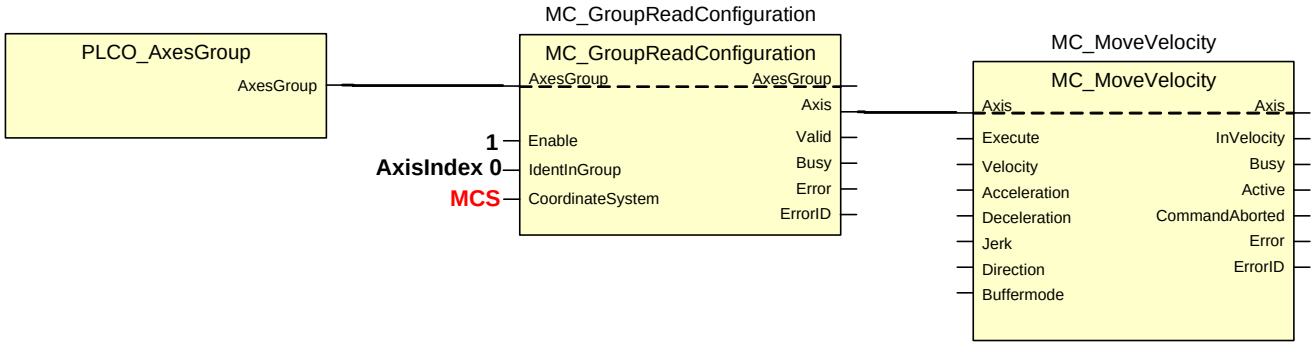
1. Conventional single axis motion → a single axis is moved

Conventional programming

Alternative programming

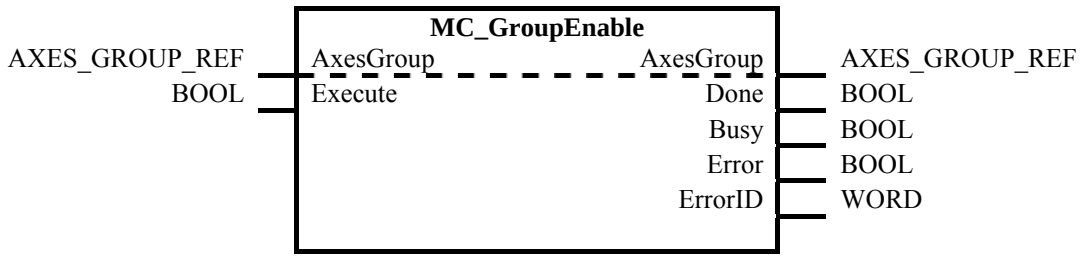


2. Virtual single axis motion → a path axis is moved



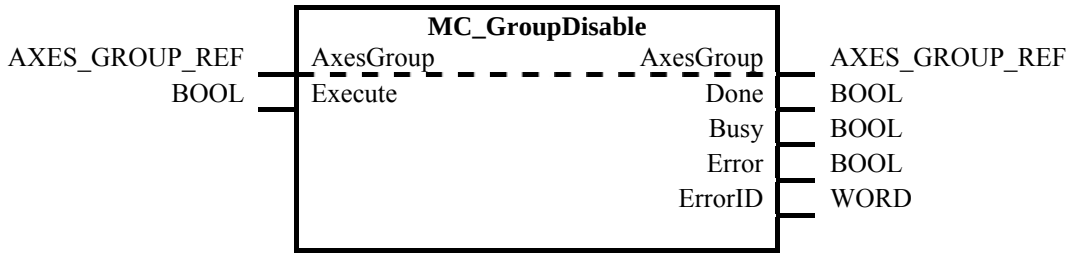
5.5 MC_GroupEnable

FB-Name		**MC_GroupEnable**		
This Function Block changes the state for a group from GroupDisabled to GroupStandby. This is an administrative FB, since no movement is generated.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the change of state at the rising edge
VAR_OUTPUT				
	B	Done	BOOL	AxesGroup in state GroupStandby
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: The command does not influence the power state of any of the single axes in the group				



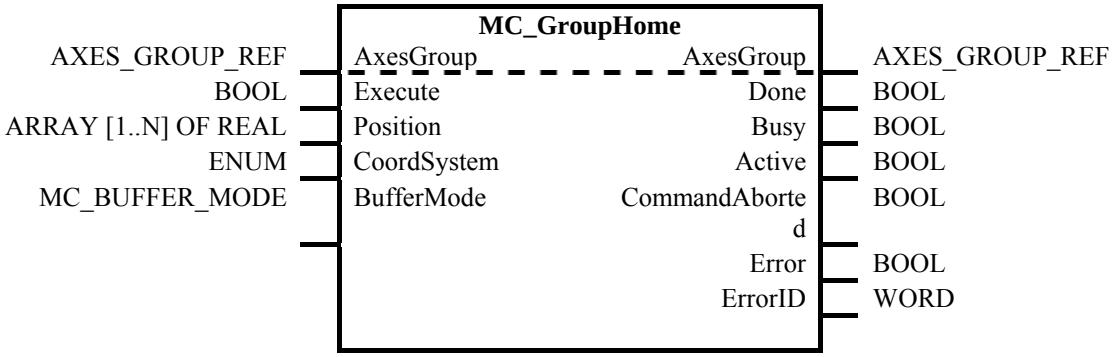
5.6 MC_GroupDisable

FB-Name		**MC_GroupDisable**		
This Function Block changes the state for a group to GroupDisabled, although it is an administrative FB, since no movement is generated. If the axes are not standing still while issuing this command, it is up to the application to take the necessary precautions.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the change of state at the rising edge
VAR_OUTPUT				
	B	Done	BOOL	AxesGroup in state GroupDisabled
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: The command does not influence the power state of any of the single axes in the group				



5.7 MC_GroupHome

FB-Name		**MC_GroupHome**		
This Function Block commands the AxesGroup to perform the «search home» sequence. The details of this sequence are manufacturer dependent and can be set by the axis' parameters. The "Position" input is used to set the absolute position when reference signal is detected. This Function Bock completes at "GroupStandby".				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the homing sequence at the rising edge
	B	Position	ARRAY [1..N] OF REAL	Array of coordinates incl. Positions and orientations
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
	E	BufferMode	MC_BUFFER_MODE	Buffer mode. Modes "Aborting" and "Buffered" are useful. All other modes should act like "Buffered".
VAR_OUTPUT				
	B	Done	BOOL	Homing sequence ended successfully
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB is processed
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: If you issue this FB with BufferMode "Aborting" outside the state GroupStandby, an error is generated.				



5.8 Transformation FBs

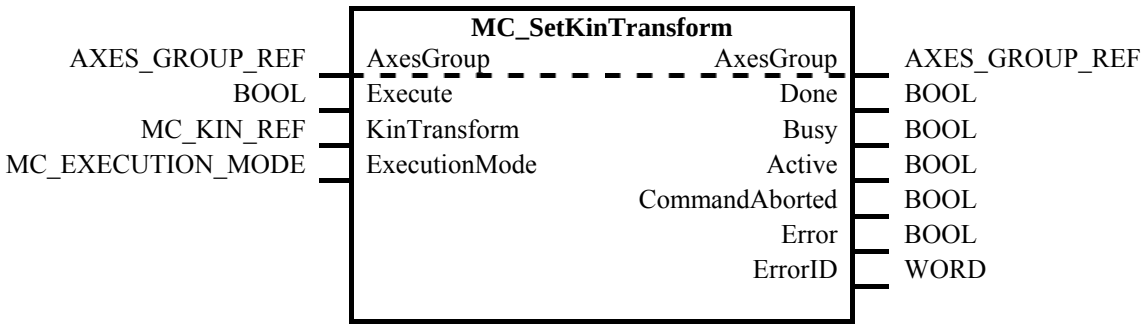
This chapter provides an overview of the transformation function blocks. Although they are administrative FBs, the transformation FBs can be buffered.

5.8.1 MC_SetKinTransform (ACS to MCS)

FB-Name		**MC_SetKinTransform**		
This Function Block sets a kinematic transformation between the ACS and MCS based on the predefined kinematic model.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Sets the kinematic model transformation on rising edge
	E	KinTransform	MC_KIN_REF	Reference to a Kinematic Model. Vendor specific datatype.
	E	ExecutionMode	MC_EXECUTION_MODE	Describes when the command is executed and the new transformation becomes valid. (See 3.3 Input Execution Mode)
VAR_OUTPUT				
	B	Done	BOOL	Transformation is set successfully
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB is processed
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

Notes:

- A kinematic transformation is a representation of the machine construction. For kinematically simple machine constructions, like a three axes Cartesian robot, a kinematic transformation may not be necessary.
- The input KinTransform refers to a kinematic model including the parameters. The details of the kinematic model and of the parameters are outside the scope of PLCopen.
- The system may support a neutral KinTransform. With activating the neutral transformation the axes are referenced in the ACS system again.
- The FB always acts on a pre-defined AxesGroup. Since a kinematic transformation always has to fit to an appropriate AxesGroup, a call to this FB will lead to an error unless an appropriate AxesGroup is defined.



Timing Diagram:

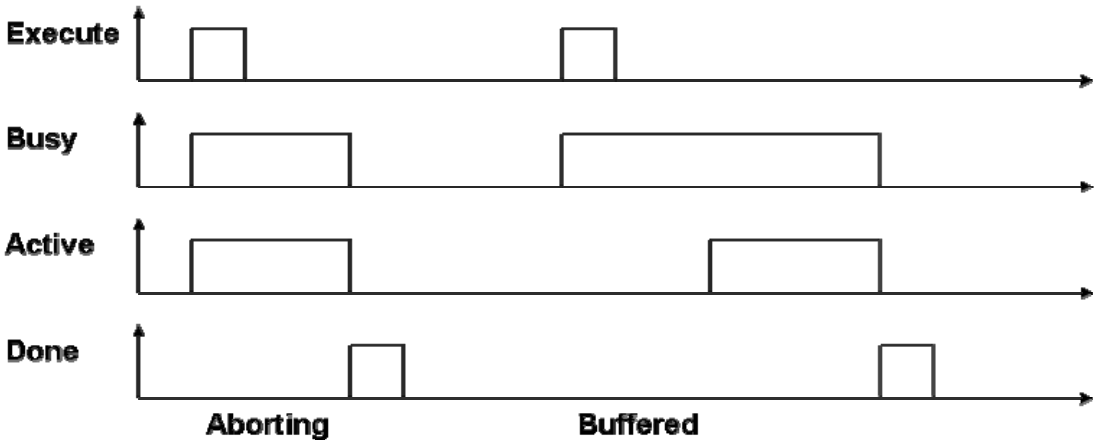
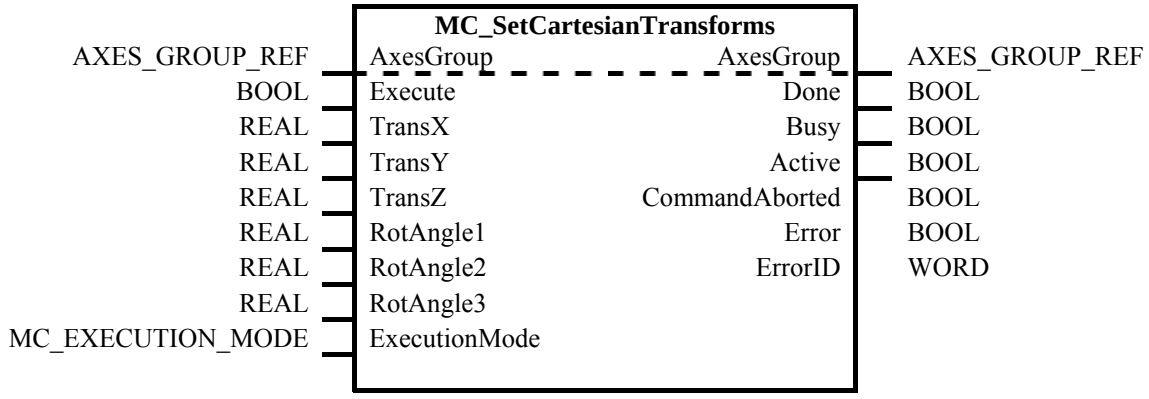


Figure 10: Typical timing diagram for setting the transformation

5.8.2 MC_SetCartesianTransform (MCS to PCS)

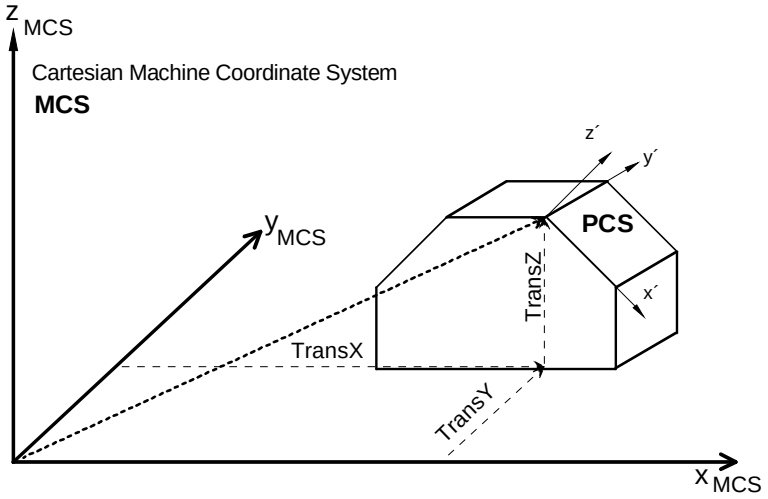
FB-Name		**MC_SetCartesianTransform**	
This Function Block sets a Cartesian transformation between the MCS and PCS.			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT			
B	Execute	BOOL	Sets the cartesian transformation on rising edge
B	TransX	REAL	X-component of Translation Vector
B	TransY	REAL	Y-component of Translation Vector
B	TransZ	REAL	Z-component of Translation Vector
B	RotAngle1	REAL	Rotation angle component
B	RotAngle2	REAL	Rotation angle component
B	RotAngle3	REAL	Rotation angle component
E	ExecutionMode	MC_EXECUTION_MODE	Describes when the command is executed and the new transformation becomes valid. (See 3.3 Input Execution Mode).
VAR_OUTPUT			
B	Done	BOOL	Transformation is set successfully
E	Busy	BOOL	The FB is not finished
E	Active	BOOL	Indicates that the FB is processed
E	CommandAborted	BOOL	Command is aborted by another command
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification

Notes:
- The interpretation and order of the vector components (specifically the rotation components) are vendor specific
- De-selection of PCS can be done by a execution of this FB with {TransX, TransY, TransZ, RotAngle1, RotAngle2, RotAngle3 }={0, 0, 0, 0, 0, 0} as translation and rotation input values.
- The system may support a neutral transformation. With activating the neutral transformation the axes are referenced in the MCS system again.
- More then one cartesian transformation can be applicable at the same time on the same group of axes.

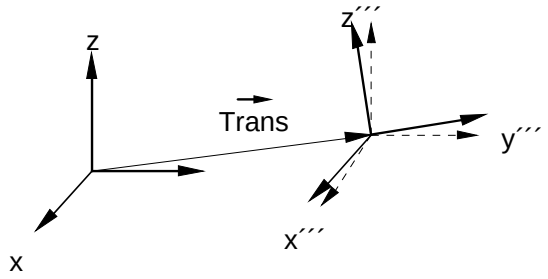


The timing diagram is equal to that of MC_SetKinTransform

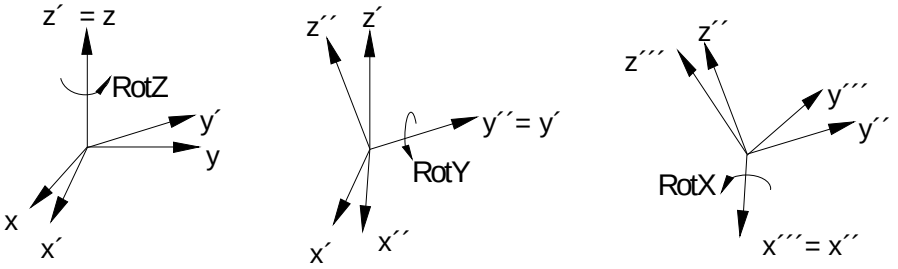
Explanation:
Definition of the translation:



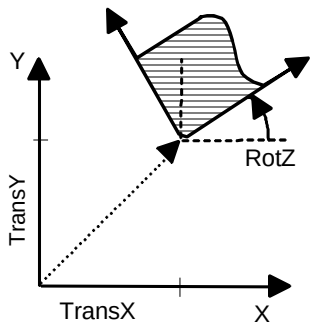
Example of the definition of the rotation:
The rotation is defined by a subsequent rotation around every coordinate direction beginning with the Z-direction.



Definition of the rotation:



Example: Use of the FB for a rotation in the plane (2-dimensions):
Execution of MC_SetCartesianTransform with: {**50**,**50**,0,0,0,**30**}

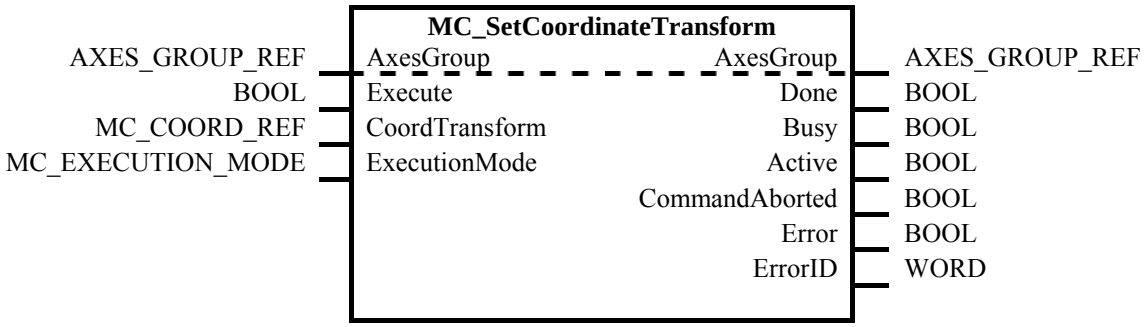


5.8.3 MC_SetCoordinateTransform (MCS to PCS)

FB-Name		**MC_SetCoordinateTransform**		
This Function Block sets a coordinate transformation between the MCS and PCS.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Sets the coordinate transformation on rising edge
	E	CoordTransform	MC_COORD_REF	Reference to a Coordinate Transformation. Vendor specific datatype.
	E	ExecutionMode	MC_EXECUTION_MODE	Describes when the command is executed and the new transformation becomes valid. (See 3.3 Input Execution Mode).
VAR_OUTPUT				
	B	Done	BOOL	Transformation is set successfully
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB is processed
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

Notes:

- CoordTransform refers to a coordinate transformation including the parameters. The details of the transformation and of the parameters are outside the scope of PLCopen.
- The system may support a neutral transformation. With activating the neutral transformation the axes are referenced in the MCS system again..
- When PCS is dynamic (in the sense that the PCS is moving relative to MCS), one should use MC_SetDynCoordTransform.
- This FB does not start a movement (administrative FB). The movement is initiated by a command in PCS.

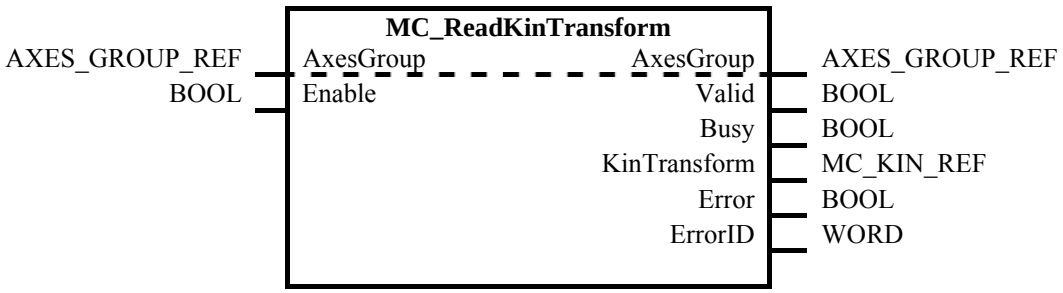


Example of MC_COORD_REF
As an example of MC_COORD_REF, one can use a structure of the 6 inputs X, Y, Z, and rotations as defined in MC_SetCartesianTransforms.

The timing diagram is equal to that of MC_SetKinTransform

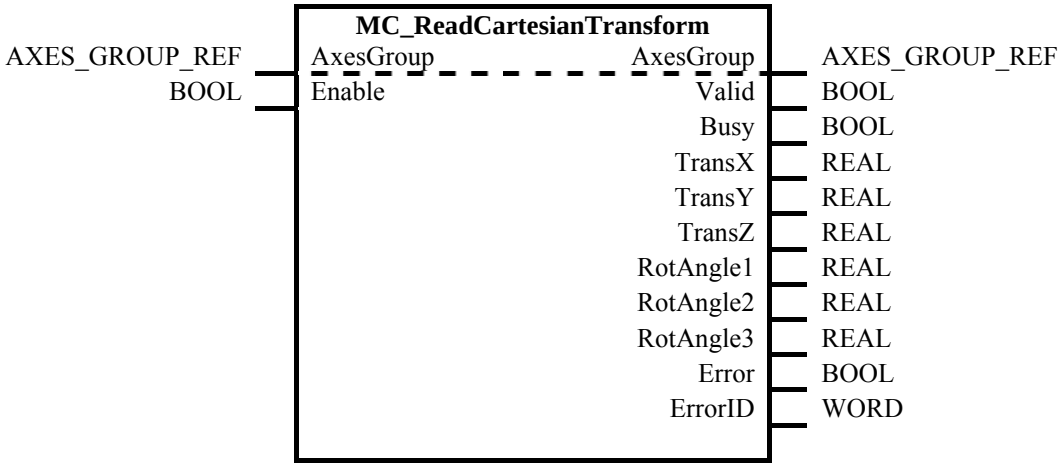
5.8.4 MC_ReadKinTransform (ACS to MCS)

FB-Name		**MC_ReadKinTransform**		
This Function Block reads the kinematic transformation that is active between the ACS and MCS.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Enable	BOOL	Get the actual kinematic transformation reference of the axes group continuously while enabled
VAR_OUTPUT				
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	KinTransform	MC_KIN_REF	Reference to a Kinematic Model. Vendor specific datatype.
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes:				



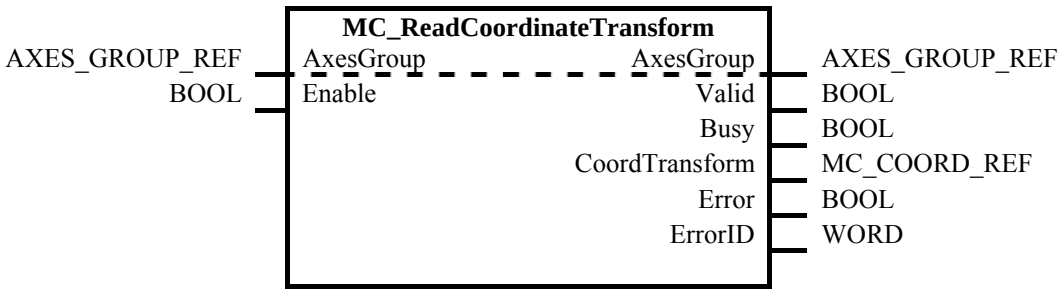
5.8.5 MC_ReadCartesianTransform (MCS to PCS)

FB-Name			**MC_ReadCartesianTransform**	
This Function Block reads the parameter of the cartesian transformation that is active between the MCS and PCS. If more than one transformation is active, the resulting cartesian transformation is given.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Enable	BOOL	Get the cartesian transformation parameter of the axes group continuously while enabled
VAR_OUTPUT				
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	TransX	REAL	X-component of Translation Vector
	B	TransY	REAL	Y-component of Translation Vector
	B	TransZ	REAL	Z-component of Translation Vector
	B	RotAngle1	REAL	Rotation angle 1
	B	RotAngle2	REAL	Rotation angle 2
	B	RotAngle3	REAL	Rotation angle 3
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: -				



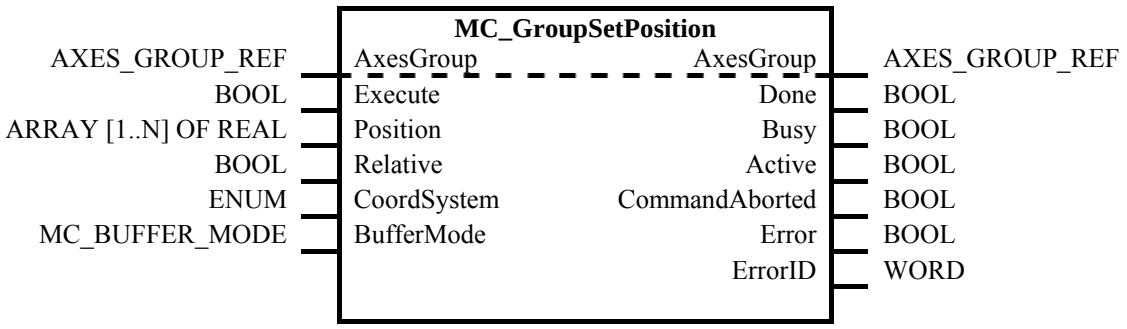
5.8.6 MC_ReadCoordinateTransform (MCS to PCS)

FB-Name			**MC_ReadCoordinateTransform**	
This Function Block reads the coordinate transformation that is active between the MCS and PCS.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Enable	BOOL	Get the actual coordinate transformation reference of the axes group continuously while enabled
VAR_OUTPUT				
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	CoordTransform	MC_COORD_REF	Reference to a Coordinate Transformation. Vendor specific datatype.
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: -				



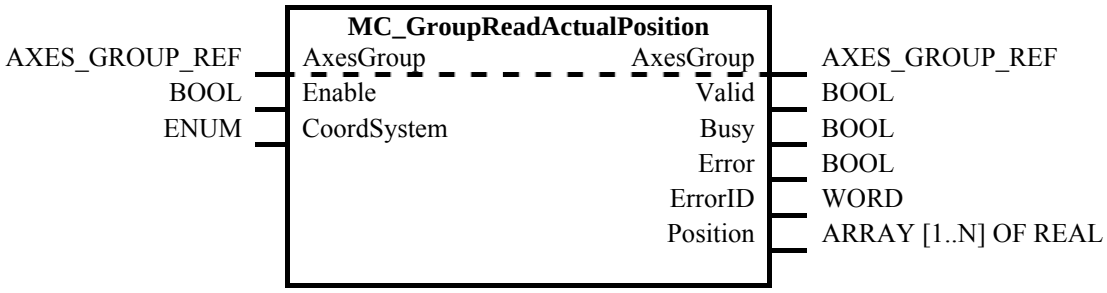
5.9 MC_GroupSetPosition

FB-Name		**MC_GroupSetPosition**	
This function block sets the Position of all axes in a group without moving the axes. The new coordinates are described in an array. With the coordinate system input the according coordinate system is selected. It can be seen as a way of referencing or a transformation. MC_GroupSetPosition shifts the position of the addressed coordinate system and affects the higher level coordinate systems (so if ACS is selected, MCS and PCS are affected).			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axis
VAR_INPUT			
B	Execute	BOOL	Start the action at rising edge
B	Position	ARRAY [1..N] OF REAL	Array of coordinates, incl. positions and orientations (Means 'Distance' if Mode = RELATIVE)
E	Relative	BOOL	Mode of position inputs - RELATIVE =True, ABSOLUTE = False (Default)
E	CoordSystem	ENUM	Reference to the coordinate system used: ACS, MCS, or PCS
E	BufferMode	MC_BUFFER_MODE	Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT			
B	Done	BOOL	Commanded end positions reached for all axes
E	Busy	BOOL	The FB is not finished
E	Active	BOOL	Indicates that the FB has control on the axes group
E	CommandAborted	BOOL	Command is aborted by another command
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification
Note: This FB is similar to MC_SetPosition.			



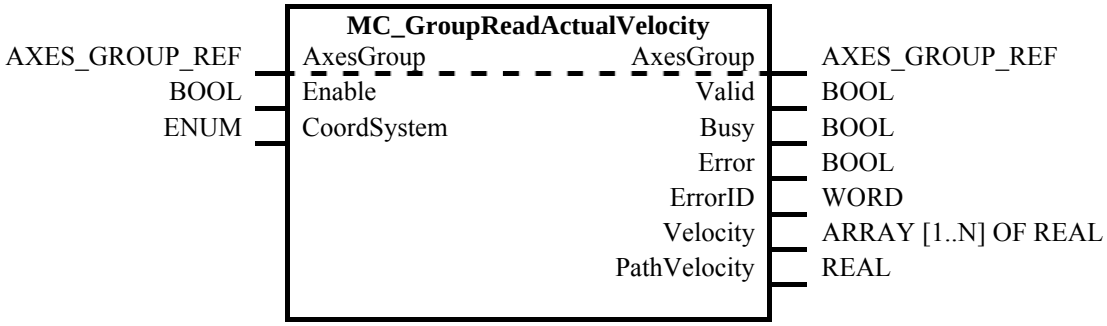
5.10 MC_GroupReadActualPosition

FB-Name		**MC_GroupReadActualPosition**	
This Function Block returns the actual position in the selected coordinate system of an axes group. This is an administrative FB, since no movement is generated.			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT			
B	Enable	BOOL	Get the actual position in the selected coordinate system of the axes group continuously while enabled
E	CoordSystem	ENUM	Reference to the coordinate system (ACS, MCS, PCS)
VAR_OUTPUT			
B	Valid	BOOL	True if valid outputs are available
E	Busy	BOOL	The FB is not finished
B	Error	BOOL	Signals that an error has occurred within the Function Block
E	ErrorID	WORD	Error identification
B	Position	ARRAY [1..N] OF REAL	Current position of the group. See 1.4 Glossary
Notes: -			



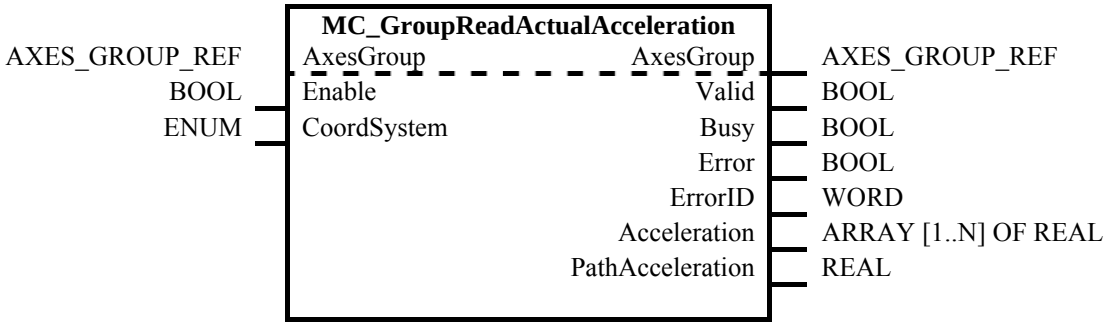
5.11 MC_GroupReadActualVelocity

FB-Name		**MC_GroupReadActualVelocity**		
This Function Block returns the actual velocity in the selected coordinate system of an axes group. This is an administrative FB, since no movement is generated.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Enable	BOOL	Get the actual velocity in the selected coordinate system of the axes group continuously while enabled
	E	CoordSystem	ENUM	Reference to the coordinate system (ACS, MCS, PCS)
VAR_OUTPUT				
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the Function Block
	E	ErrorID	WORD	Error identification
	B	Velocity	ARRAY [1..N] OF REAL	Current velocity of the group: - in ACS the velocities of the different axes - in MCS and PCS it provides the velocity of the TCP
	E	PathVelocity	REAL	Current path velocity (speed, combined result) of the TCP.
Notes: -				



5.12 MC_GroupReadActualAcceleration

FB-Name		**MC_GroupReadActualAcceleration**		
This Function Block returns the actual acceleration in the selected coordinate system of an axes group. This is an administrative FB, since no movement is generated.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Enable	BOOL	Get the actual acceleration in the selected coordinate system of the axes group continuously while enabled
	E	CoordSystem	ENUM	Reference to the coordinate system (ACS, MCS, PCS)
VAR_OUTPUT				
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the Function Block
	E	ErrorID	WORD	Error identification
	B	Acceleration	ARRAY [1..N] OF REAL	Current acceleration of the group: - in ACS the acceleration of the different axes - in MCS and PCS it provides the acceleration of the TCP
	E	Path Acceleration	REAL	Current combined path acceleration of the TCP.
Notes: -				

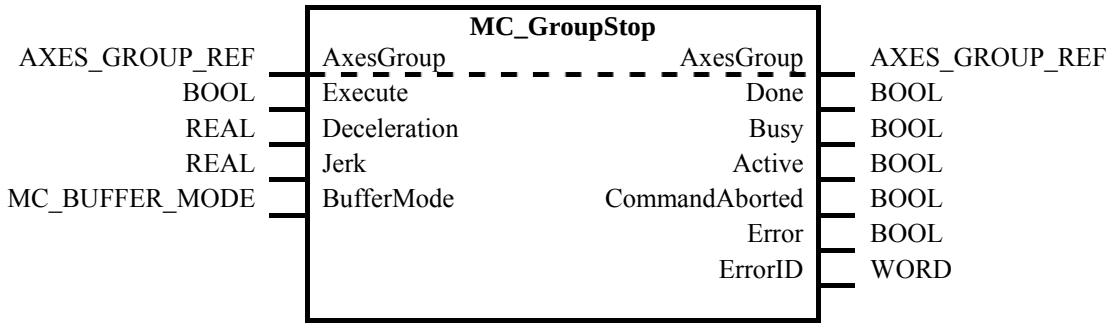


5.13 MC_GroupStop

FB-Name		**MC_GroupStop**	
This Function Block commands a controlled motion stop and transfers the axes group to the state “GroupStopping”. It aborts any ongoing Function Block execution. While the axes group is in state GroupStopping, no other FB can perform any motion on the same axes group. After the axes group has reached velocity zero, the Done output is set to TRUE immediately. The axes group remains in the state ”GroupStopping” as long as Execute is still TRUE or velocity zero is not yet reached. As soon as “Done” is SET and “Execute” is FALSE the axes group goes to state “GroupStandBy”. The command can only be aborted by MC_GroupDisable.			
VAR_IN_OUT			
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axis
VAR_INPUT			
	B	Execute	BOOL	Start the action at rising edge
	E	Deceleration	REAL	Value of the deceleration [u/s2]
	E	Jerk	REAL	Value of the Jerk [u/s3]
	E	BufferMode	MC_BUFFER_MODE	Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT			
	B	Done	BOOL	Stop for all axes done.
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axes group
	E	CommandAborted	BOOL	Command is aborted by disabling MC-Power of one or more of the axes in the group. The state changes to GroupDisabled.
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

Notes:

- The relevant axes stay on the path.
- If Deceleration is set to zero the resulting action is vendor specific.
- If issued during a MoveDirectXxx command, the velocity/acc-/deceleration/jerk values as properties of the AxisRef of each axis are used, and not specified within this function block, and not to be exceeded during the movement.
- Any synchronization of the group to a master is cancelled by issuing MC_GroupStop



A typical timing diagram for MC_GroupStop is shown below, including the relevant states and state-transitions.

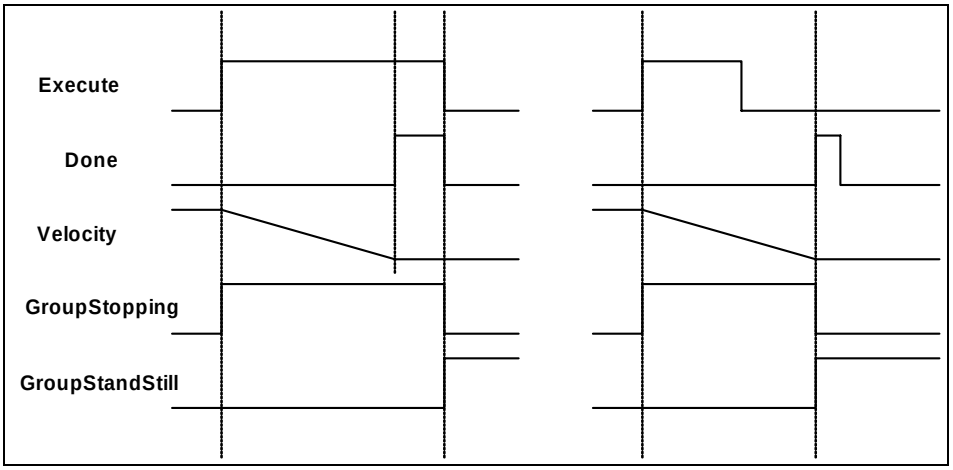


Figure 11: MC_GroupStop timing diagram

The example below shows the behavior in combination with a MC_MoveLinearRelative.
a) An axes group in linear movement is ramped down with FB MC_GroupStop. The group stops on the original path.
b) The axes group rejects motion commands as long as MC_GroupStop parameter "Execute" = TRUE. FB MC_MoveLinearRelative reports an error indicating the busy MC_GroupStop command. This error is an FB error, so the group is not moving to the state GroupErrorStop.
At the 3rd "Exe1" rising edge, the group starts the next movement.

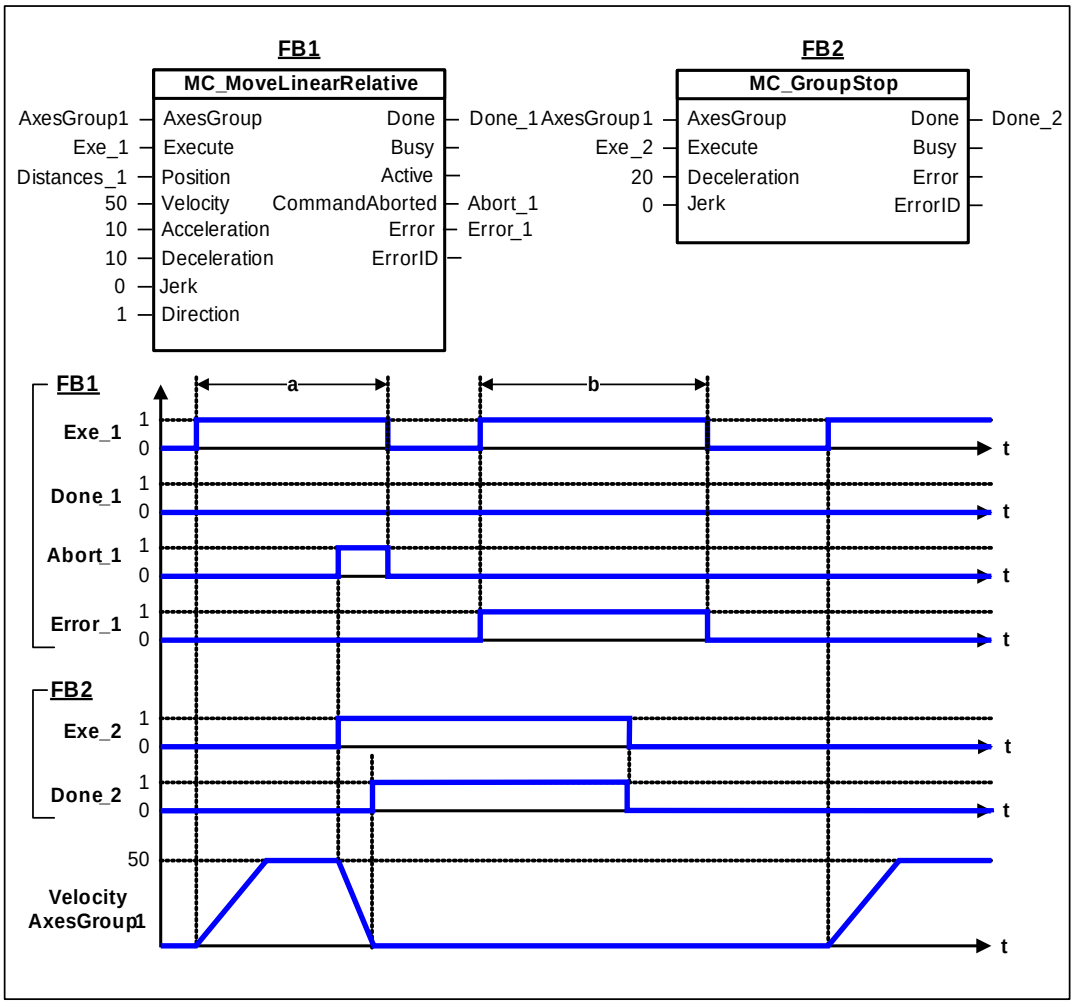


Figure12: Behavior of MC_GroupStop in combination with MC_MoveLinearRelative

The following example demonstrates the behaviour of MC_GroupStop in combination with two MC_MoveLinear-Absolute which are blended with defined constant path velocity:

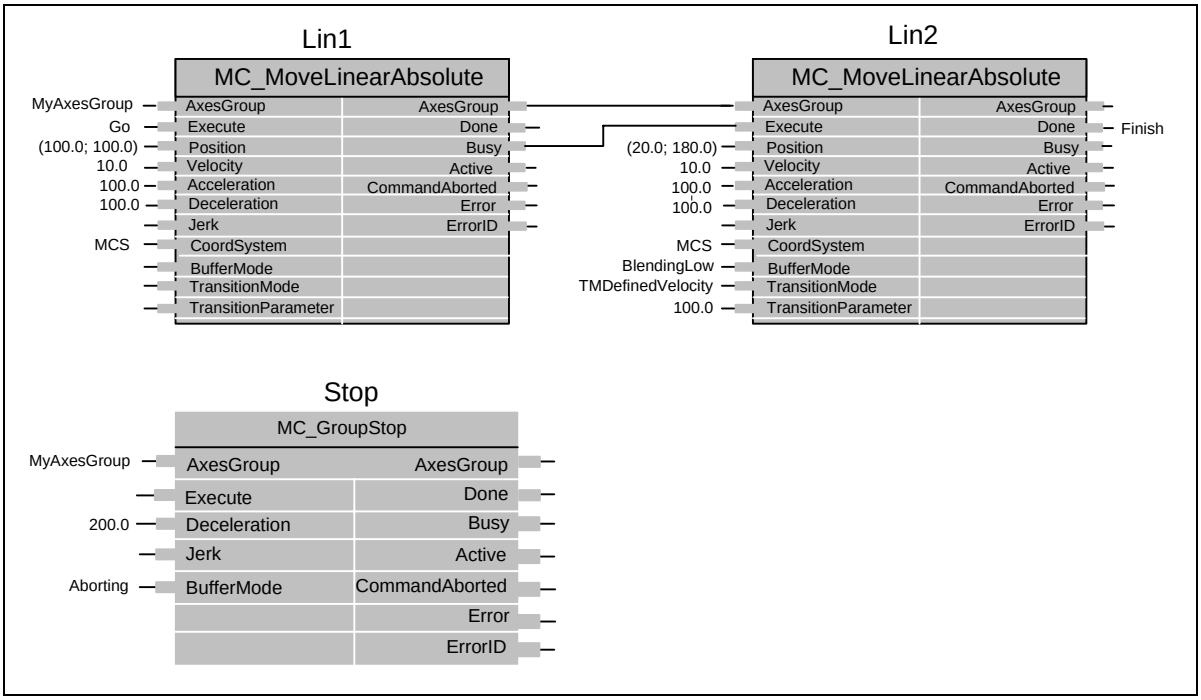
t_0) Two FBs MC_MoveLinearAbsolute are commanded on axes group MyAxesGroup. The first FB becomes active immediately and MyAxesGroup starts to move from its actual position (20.0; 20.0) towards the first target position.

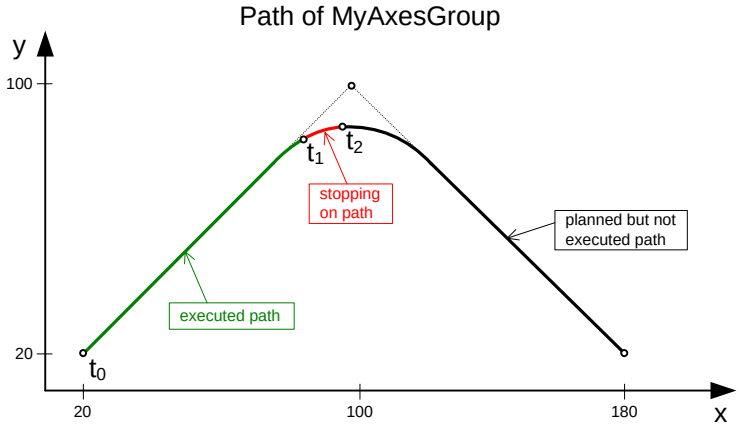
t_1) Shortly after the TCP has started to move on the blending contour blending Lin1 into Lin2, a FB MC_GroupStop is issued in buffermode Aborting. The state of the axes group changes from GroupMoving to GroupStopping. MyAxesGroup decelerates, following the path which would have been executed without having issued MC_GroupStop.

Note: Though the path velocity of MyAxesGroup decreases strictly monotonic while stopping, single axes of the group might accelerate in between due to the given path and kinematic transformation of MyAxesGroup.

t_2) MyAxesGroup comes to standstill. The Done output of the FB MC_GroupStop is set. Since the input Execute of the FB Stop is still set the group stays in state GroupStopping.

t_3) The input Execute of the FB Stop is reset. All outputs of the FB Stop are reset. The group state changes to GroupStandby.





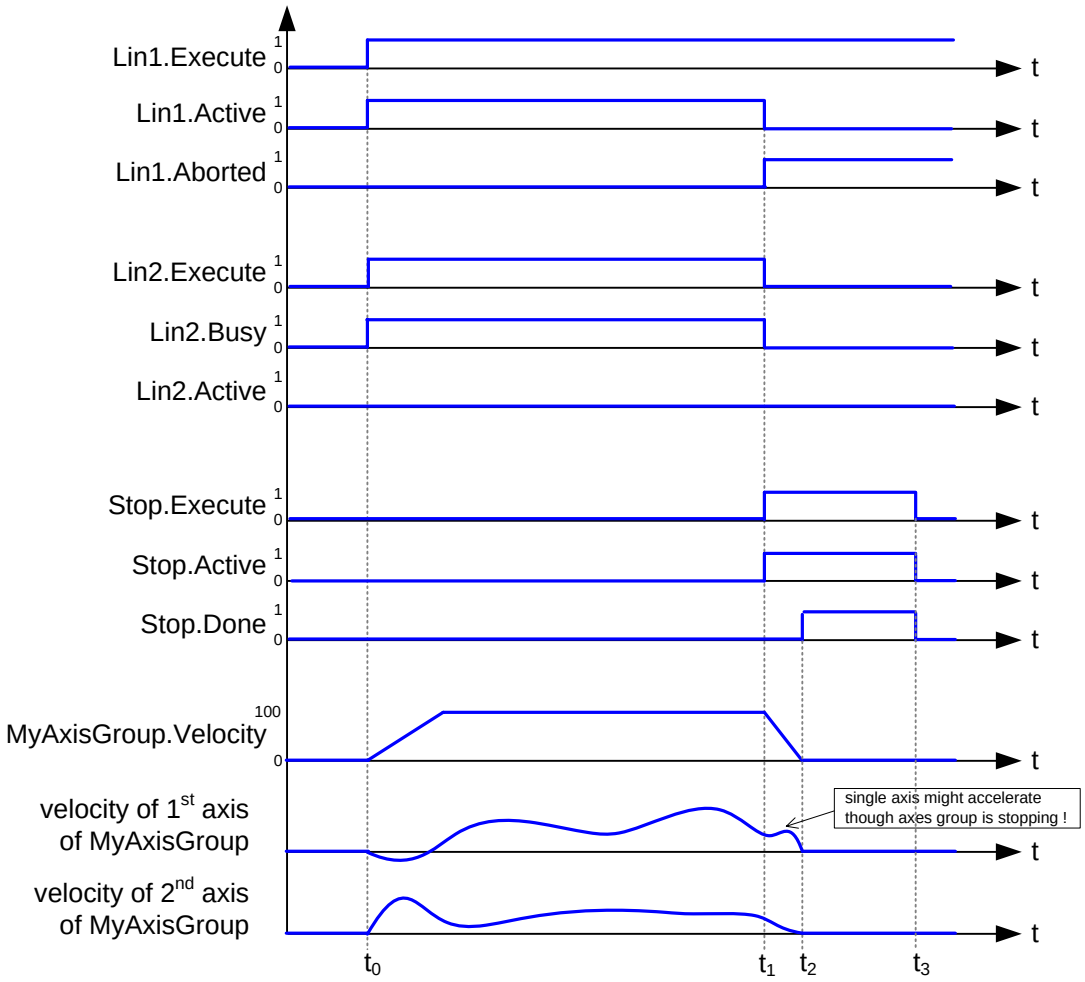


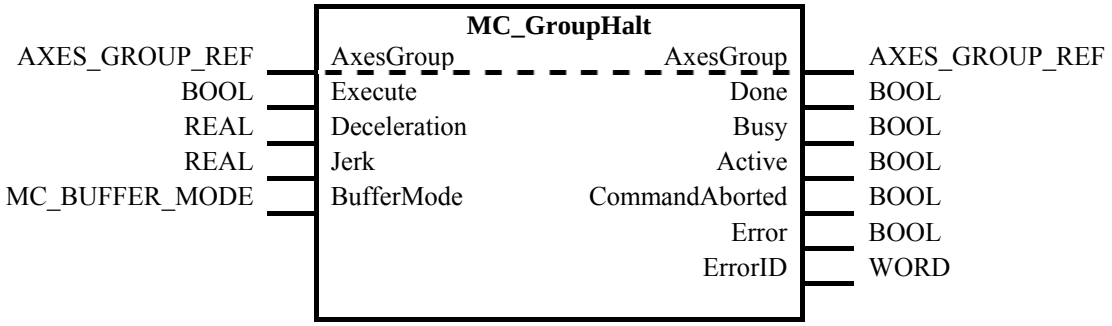
Figure 13: Example of MC_GroupStop in combination with two MC_MoveLinearAbsolute

5.14 MC_GroupHalt

FB-Name		**MC_GroupHalt**		
This function block commands a controlled motion stop. It aborts any ongoing function block execution. AxesGroup is moved to the state "GroupMoving", until the velocity is zero. With the DONE output set, the state is transferred to GroupStandby.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the action at rising edge
	E	Deceleration	REAL	Value of the deceleration [u/s^2]
	E	Jerk	REAL	Value of the jerk [u/s^3]
	E	BufferMode	MC_BUFFER_MODE	Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT				
	B	Done	BOOL	Zero velocity reached
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axes group
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

Notes:

- MC_GroupHalt is used to stop the axes group under normal operation conditions. In non-buffered mode: during deceleration of the axes group it is possible to set another motion command, which will abort the MC_GroupHalt and will be executed immediately.
- If this command is active the next command can be issued. E.g. a driverless vehicle detects an obstacle and needs to stop. MC_GroupHalt is issued. Before the standstill is reached the obstacle is removed and the motion can be continued by setting another motion command, so the vehicle does not stop.
- The relevant axes stay on the same path which would have been executed without having issued MC_GroupHalt.



The following example shows the behaviour of MC_GroupHalt in combination with a MC_MoveCircularAbsolute:

S) MyAxesGroup starts at Position (10.0; 10.0; 0.0). A FB MC_MoveCircularAbsolute is commanded with auxiliary position (30.0; 30.0; 0.0) and end position (50.0; 10.0; 0.0). This results in a 180° circular motion within the xy-plane of any coordinate system.

H) The circular motion is aborted by FB MC_GroupHalt. MyAxesGroup stays on the path during halt.

R) MC_MoveCircularAbsolute is executed again and aborts MC_GroupHalt. MC_GroupHalt allows this, in contrast to MC_GroupStop. AxesGroup can accelerate again without reaching standstill. (MC_MoveCircularAbsolute can be retriggered in order to continue the original circular motion as long as MyAxesGroup didn't pass the auxiliary position.)

E) MyAxesGroup reaches end position (50.0; 10.0; 0.0)

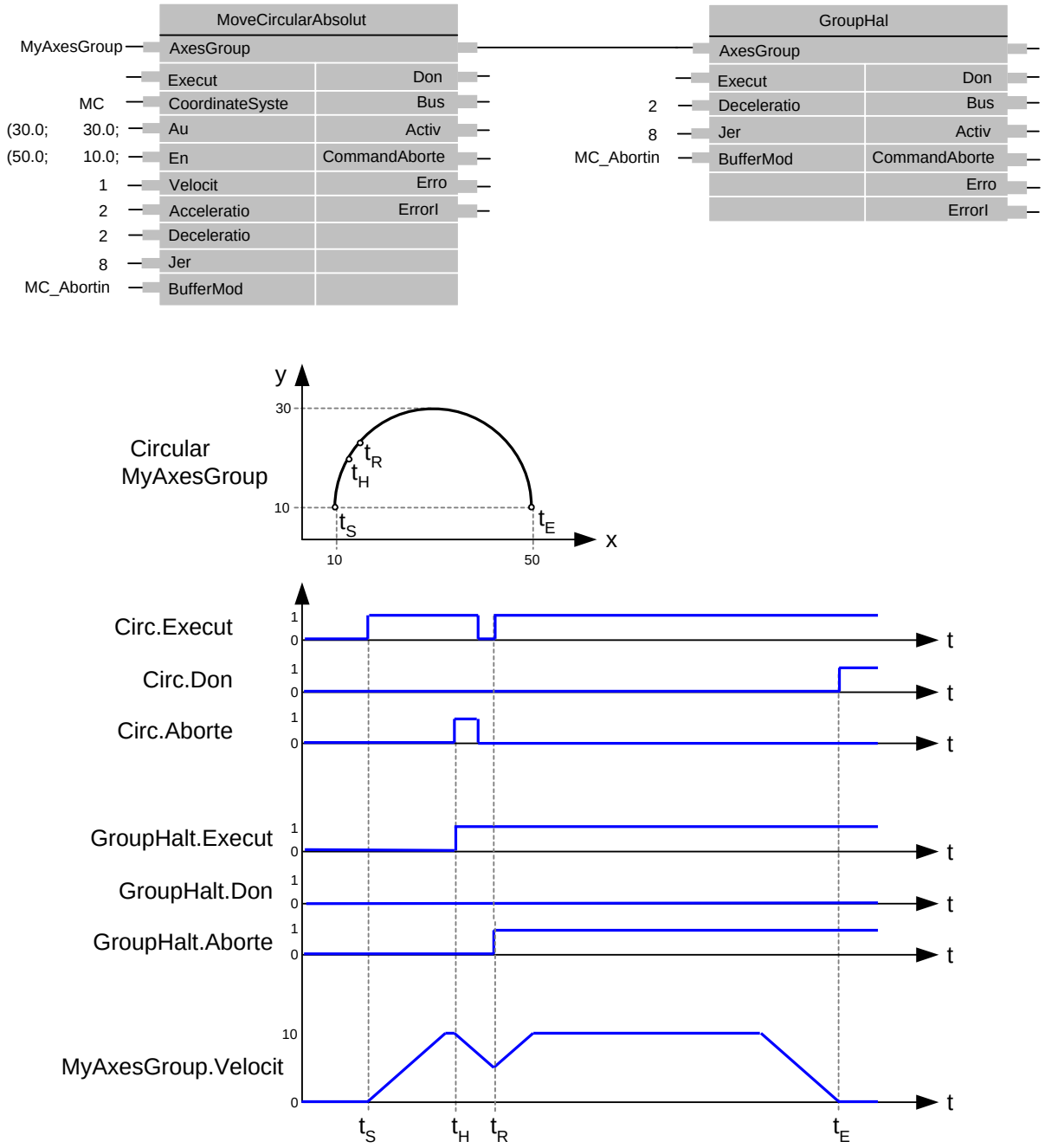


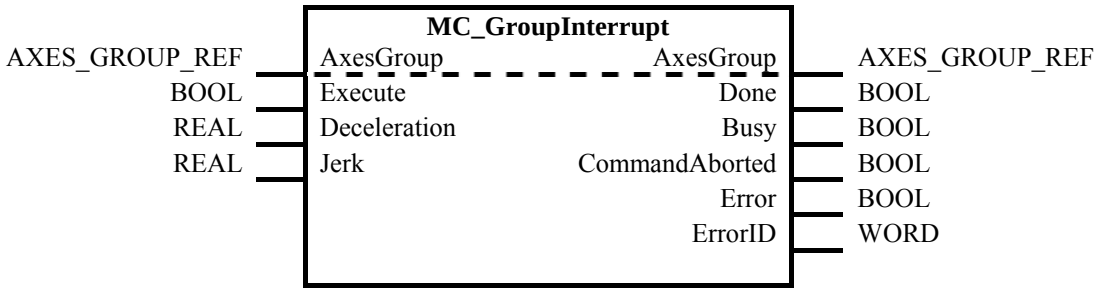
Figure14: Behavior of MC_GroupHalt in combination with MC_MoveCircularAbsolute

5.15 MC_GroupInterrupt

FB-Name		**MC_GroupInterrupt**		
This function block interrupts the on-going motion and stops the group from moving, however does not abort the interrupted motion (meaning that at the interrupted FB the output CommandAborted will not be Set, Busy is still high and Active is reset). It stores all relevant track or path information internally at the moment it becomes active. The AxesGroup stays in the original state even if the velocity zero is reached and the DONE output set.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the action at rising edge
	E	Deceleration	REAL	Value of the deceleration [u/s^2]
	E	Jerk	REAL	Value of the jerk [u/s^3]
VAR_OUTPUT				
	B	Done	BOOL	Zero velocity reached
	E	Busy	BOOL	The FB is not finished
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

Notes:

- This FB is coupled to MC_GroupContinue. Issuing MC_GroupContinue transfers the program back to the situation at issuing MC_GroupInterrupt.
- Further motion commands may be accepted by the group.

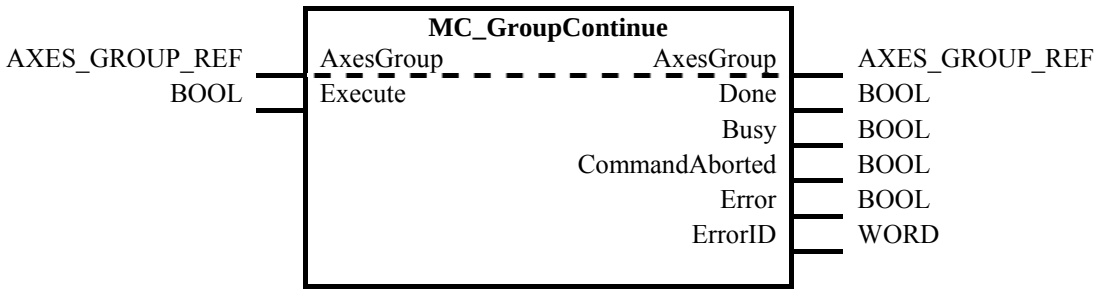


5.16 MC_GroupContinue

FB-Name		**MC_GroupContinue**		
This function block transfers the program back to the situation at issuing MC_GroupInterrupt. It uses internally the data set as stored at issuing MC_GroupInterrupt, and at the end (output DONE set) transfer the control on the group back to the original FB doing the movement on the axes group, meaning also that at the originally interrupted FB the output Busy is still high and Active is set again.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the action at rising edge
VAR_OUTPUT				
	B	Done	BOOL	Control transferred back to original FB
	E	Busy	BOOL	The FB is not finished
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

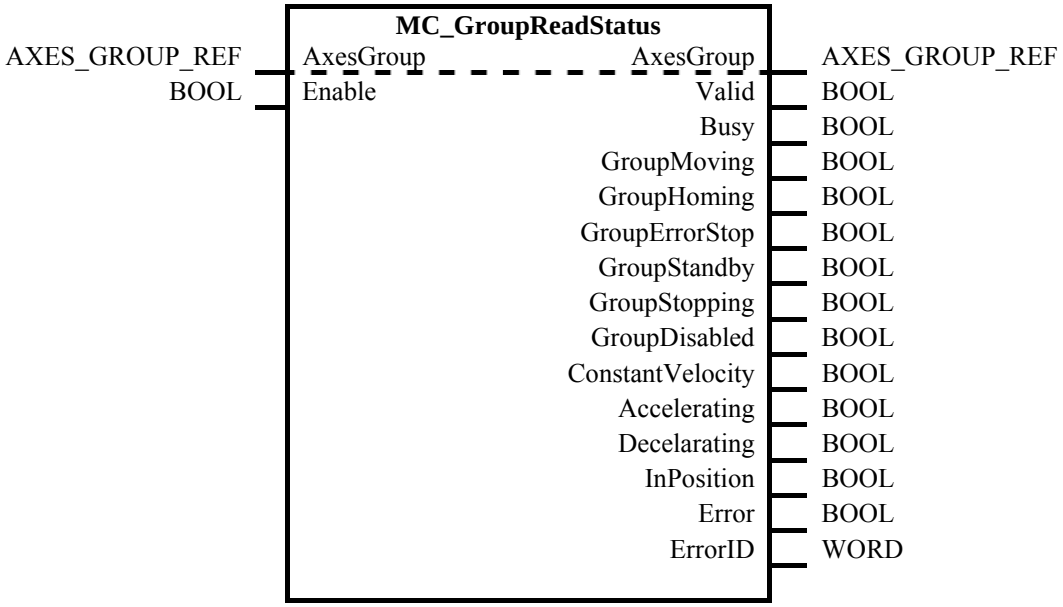
Notes:

- The dynamics of the FB that is continued can be used for the velocity, acceleration, deceleration and jerk.
- This FB can also be used to continue after an error in case the necessary set of data is stored at the occurrence of the error.



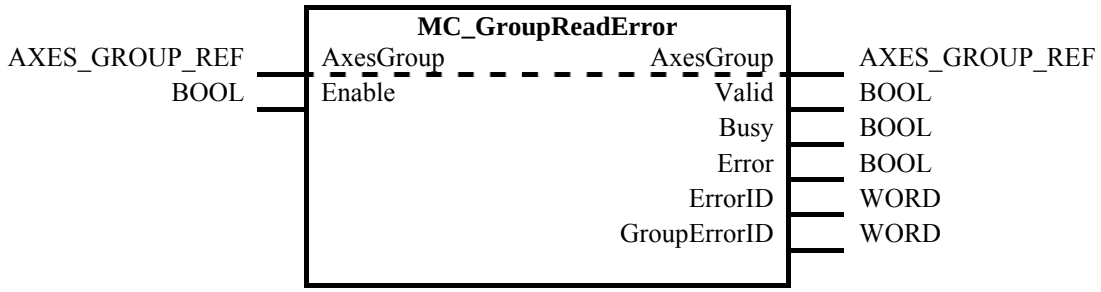
5.17 MC_GroupReadStatus

FB-Name		**MC_GroupReadStatus**	
This Function Block returns the status of an axes group according to the active Group-FB. This is an administrative FB, since no movement is generated.			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT			
B	Enable	BOOL	Get the status of the axes group continuously while enabled
VAR_OUTPUT			
B	Valid	BOOL	True if valid outputs are available
E	Busy	BOOL	The FB is not finished
B	GroupMoving	BOOL	See group state diagram
B	GroupHoming	BOOL	See group state diagram
B	GroupErrorStop	BOOL	See group state diagram
B	GroupStandby	BOOL	See group state diagram
B	GroupStopping	BOOL	See group state diagram
B	GroupDisabled	BOOL	See group state diagram
E	ConstantVelocity	BOOL	Moving with constant velocity on commanded path
E	Accelerating	BOOL	Increasing Velocity on commanded path
E	Decelerating	BOOL	Decreasing Velocity on commanded path
E	InPosition	BOOL	Movement has reached target position
B	Error	BOOL	Signals that an error has occurred within the Function Block
E	ErrorID	WORD	Error identification
Notes: The outputs reflect the commanded state of the group			



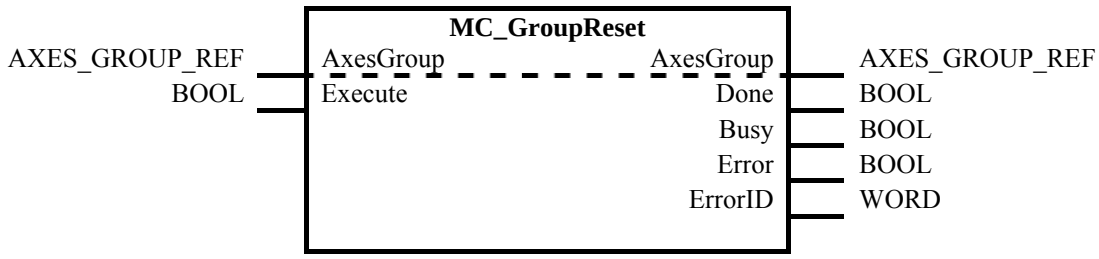
5.18 MC_GroupReadError

FB-Name		**MC_GroupReadError**		
This Function Block describes general axes group errors not relating to the Function Blocks. This is an administrative FB, since no movement is generated.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axis
VAR_INPUT				
	B	Enable	BOOL	Get the value of the GroupErrorID continuously while enabled
VAR_OUTPUT				
	B	Valid	BOOL	True if valid outputs are available
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the Function Block
	B	ErrorID	WORD	Error identification on an FB error
	E	GroupErrorID	WORD	The value of the axes group error. These values are vendor specific.
Notes: Examples are (software) limit switch exceeded or single axis error in GroupStandby state.				



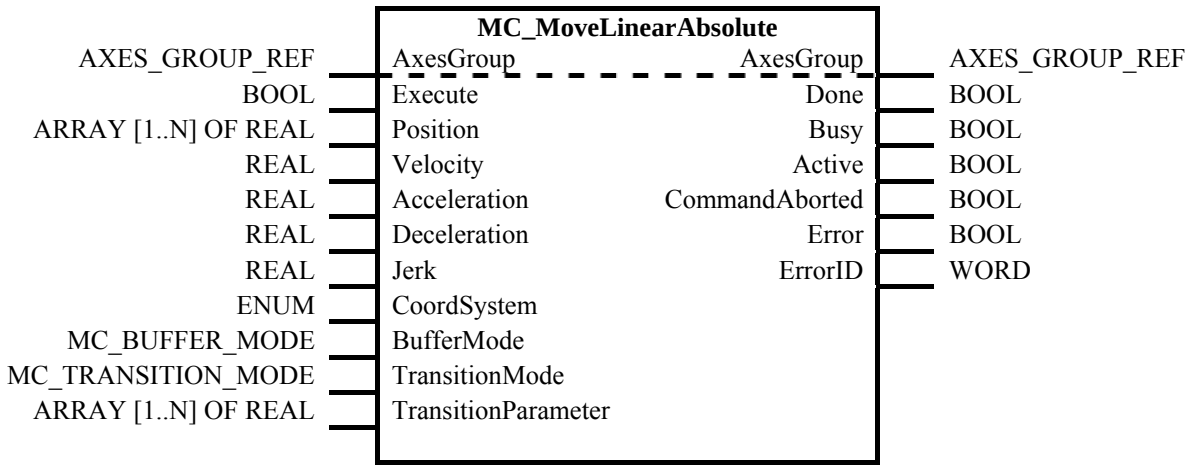
5.19 MC_GroupReset

FB-Name		**MC_GroupReset**		
This function block makes the transition from the state GroupErrorStop to GroupStandby by resetting all internal group-related errors – it does not affect the output of the FB instances. This function block also resets all axes in this group like MC_Reset.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axis
VAR_INPUT				
	B	Execute	BOOL	Start the action at rising edge
VAR_OUTPUT				
	B	Done	BOOL	Reset for axes group and all axes in this group done.
	E	Busy	BOOL	The FB is not finished
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: -				



5.20 MC_MoveLinearAbsolute

FB-Name		**MC_MoveLinearAbsolute**		
	This function block commands an interpolated linear movement on an axes group from the actual position of the TCP to an absolute position in the specified coordinate system			
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the motion at rising edge
	B	Position	ARRAY [1..N] OF REAL	Array [1..N] of absolute end positions for each dimension in the specified coordinate system. The value of n is supplier specific. See 1.4 Glossary
	E	Velocity	REAL	Maximum Velocity [u/s] for the path for the coordinate system in which the path is defined. Always positive. Not necessarily reached
	E	Acceleration	REAL	Maximum acceleration. Always positive. Not necessarily reached
	E	Deceleration	REAL	Maximum deceleration. Always positive. Not necessarily reached
	E	Jerk	REAL	Maximum jerk. Always positive. Not necessarily reached
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
	E	BufferMode	MC_Group BufferMode	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
	E	TransitionMode	MC_TRANSITION_MODE	See 2.4.3 Overview of Transition Mode
	E	TransitionParameter	ARRAY [1..N] OF REAL	Additional parameter for the transition mode (N = supplier specific)
VAR_OUTPUT				
	B	Done	BOOL	Commanded end positions reached for all axes
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axis
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: -				



First example (continued..)

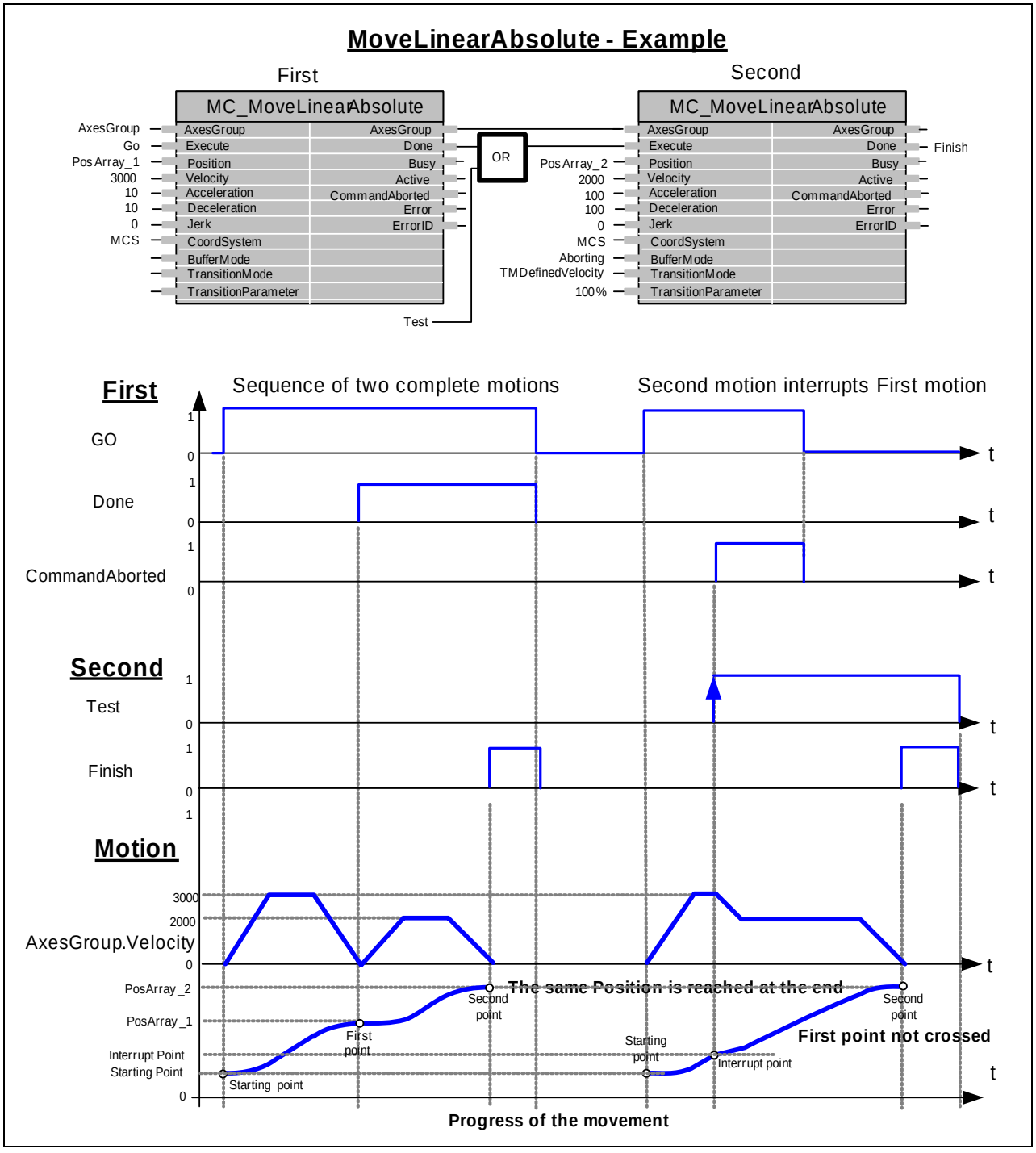
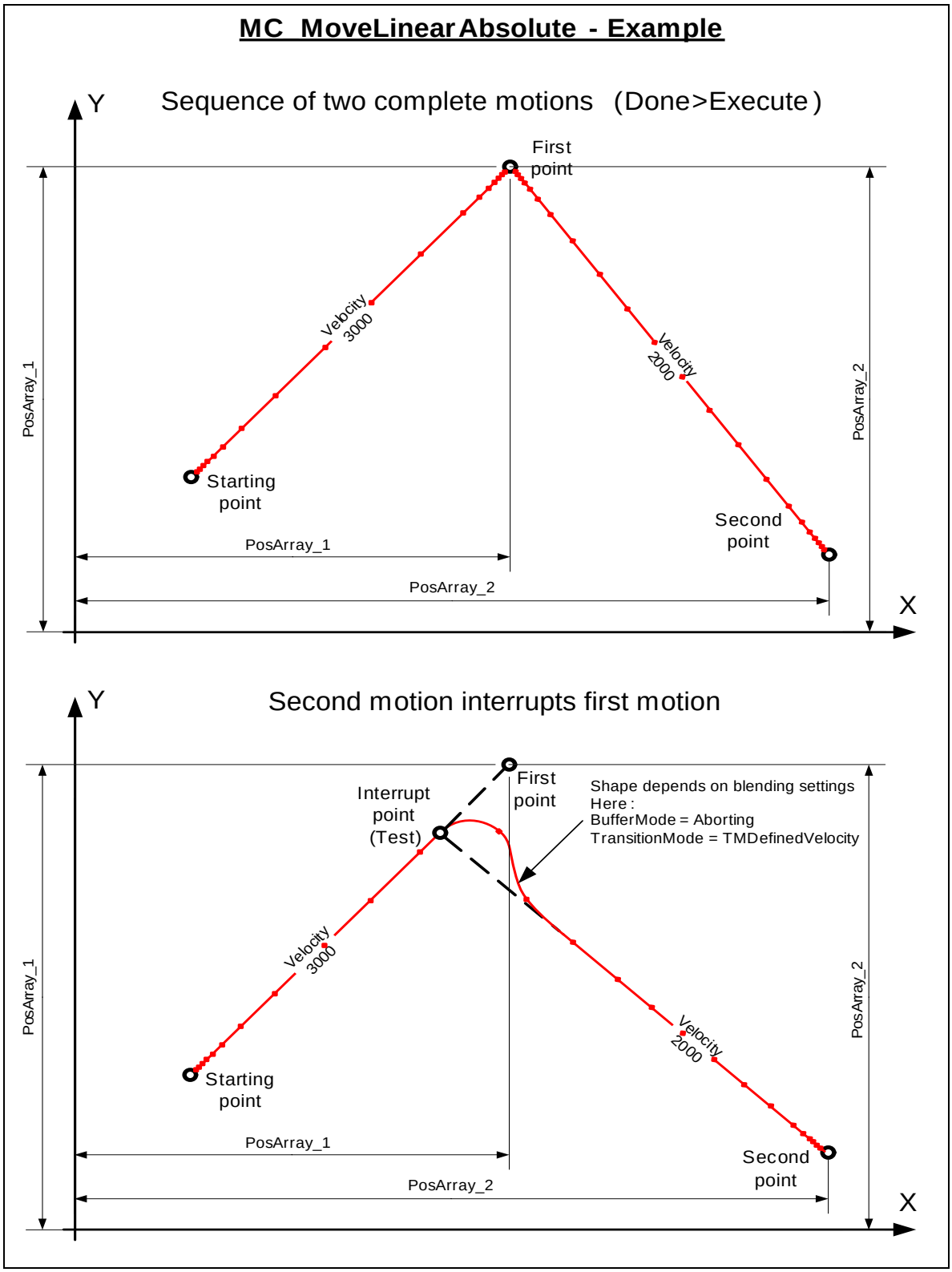


Figure15: Example MC_MoveLinearAbsolute

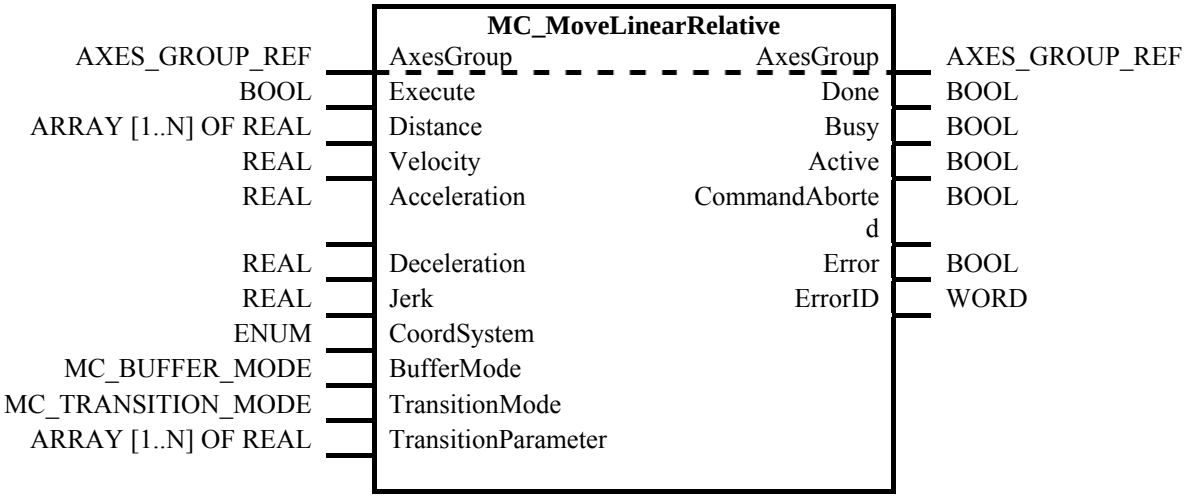
Timing diagram (continued..)

Timing diagram for example above (the dots on the red line are based on the same timing difference and representing the velocity)



5.21 MC_MoveLinearRelative

FB-Name		**MC_MoveLinearRelative**		
This function block commands an interpolated linear movement on an axes group from the actual position of the TCP to a relative position in the specified coordinate system.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the motion at rising edge
	B	Distance	ARRAY [1..N] OF REAL	Array [1..N] of relative distances for each dimension in the specified coordinate system. The value of n is supplier specific. See 1.4 Glossary
	E	Velocity	REAL	Maximum Velocity [u/s] for the path for the coordinate system in which the path is defined. Always positive. Not necessarily reached
	E	Acceleration	REAL	Maximum acceleration. Always positive. Not necessarily reached
	E	Deceleration	REAL	Maximum deceleration. Always positive. Not necessarily reached
	E	Jerk	REAL	Maximum jerk. Always positive. Not necessarily reached
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
	E	BufferMode	MC_BUFFER_MODE	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
	E	TransitionMode	MC_TRANSITION_MODE	See 2.4.3 Overview of Transition Mode.
	E	TransitionParameter	ARRAY [1..N] OF REAL	Additional parameter for the transition mode (n = supplier specific
VAR_OUTPUT				
	B	Done	BOOL	Commanded end positions reached for all axes
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axis
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: -				



Example of MC_MoveLinearRelative

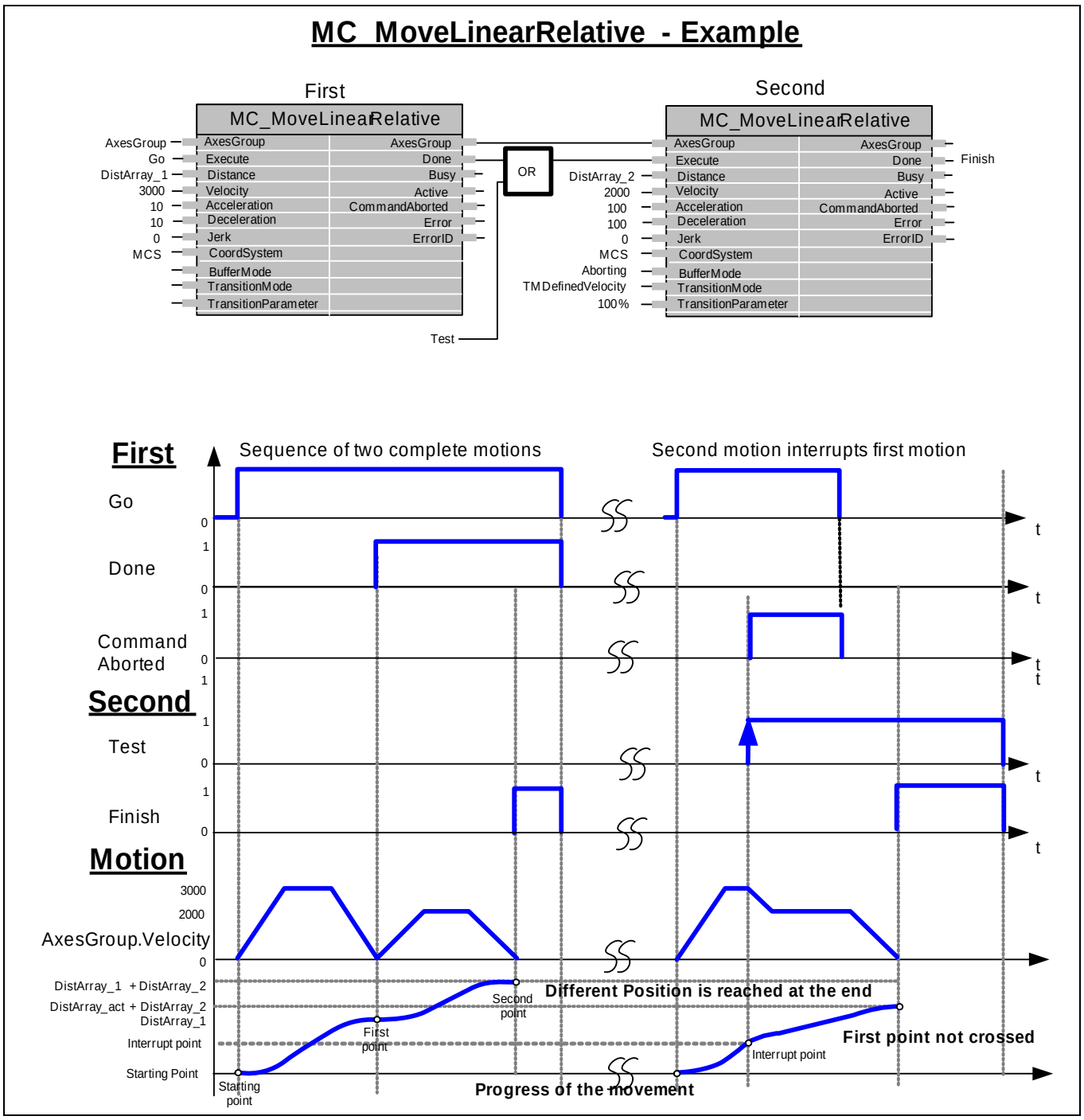
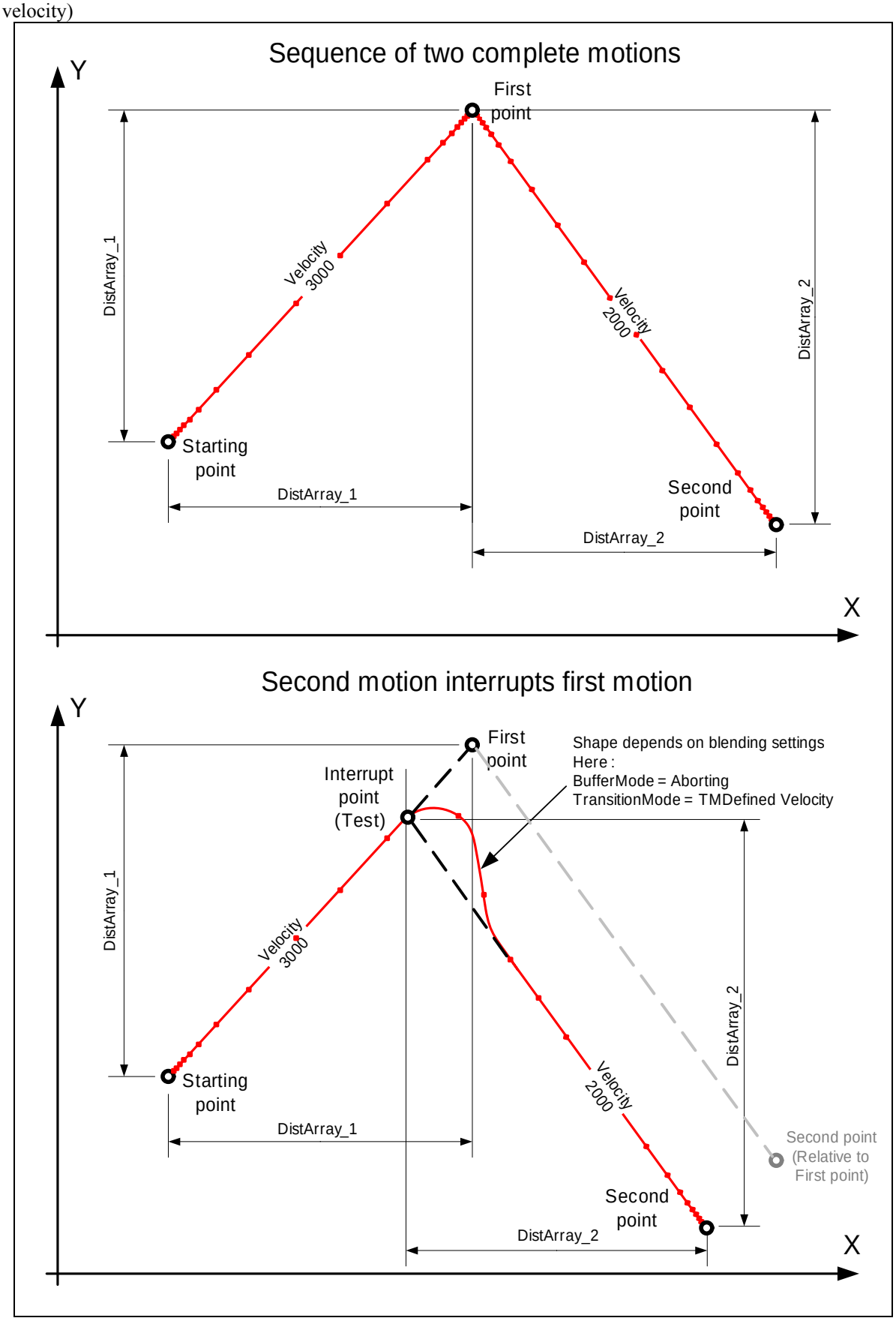


Figure16: Example MC_MoveLinearRelative

(continued..)

Timing diagram for example above (the dots on the red line are based on the same timing difference and representing the velocity)



Example 2 (continued…)

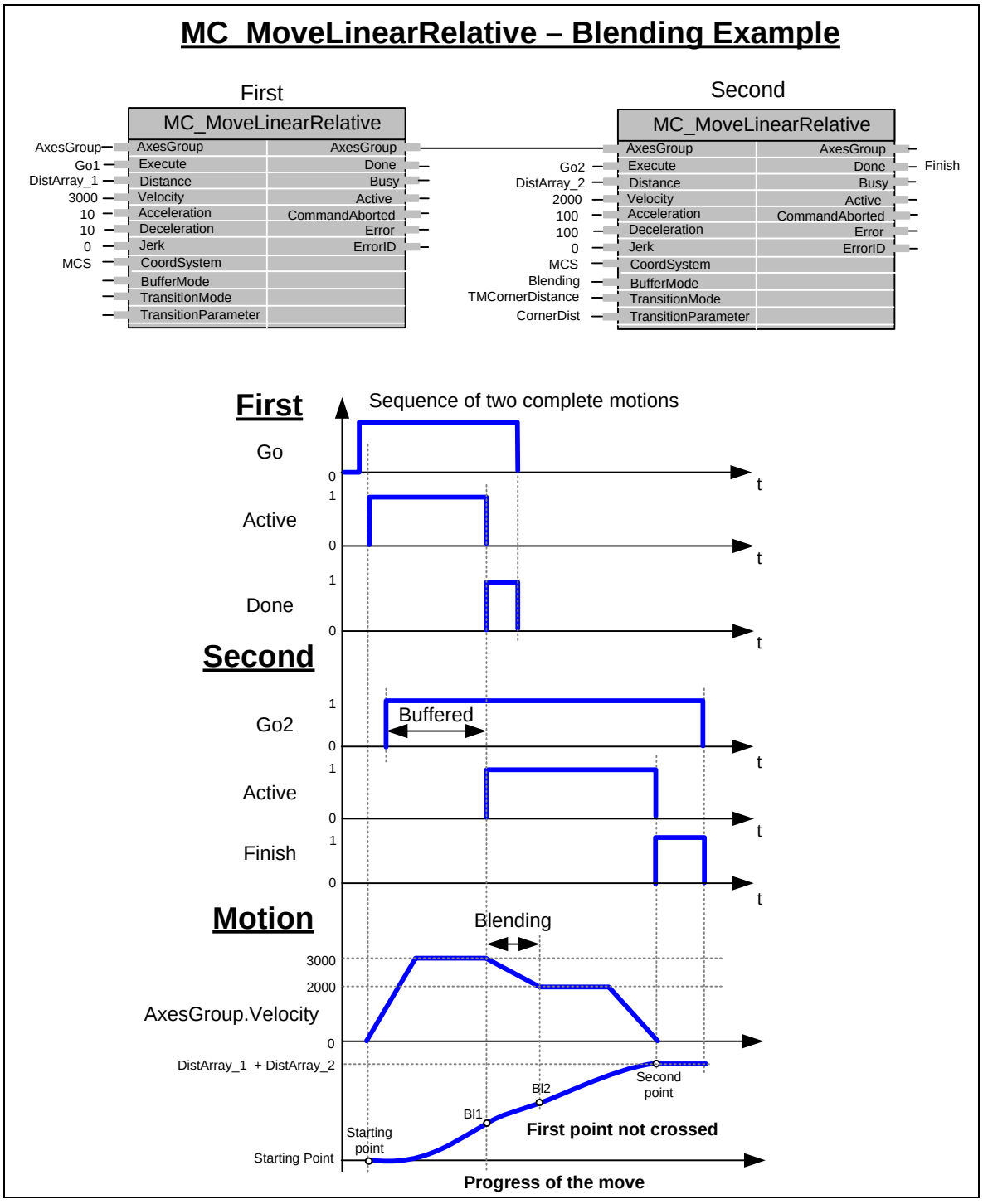
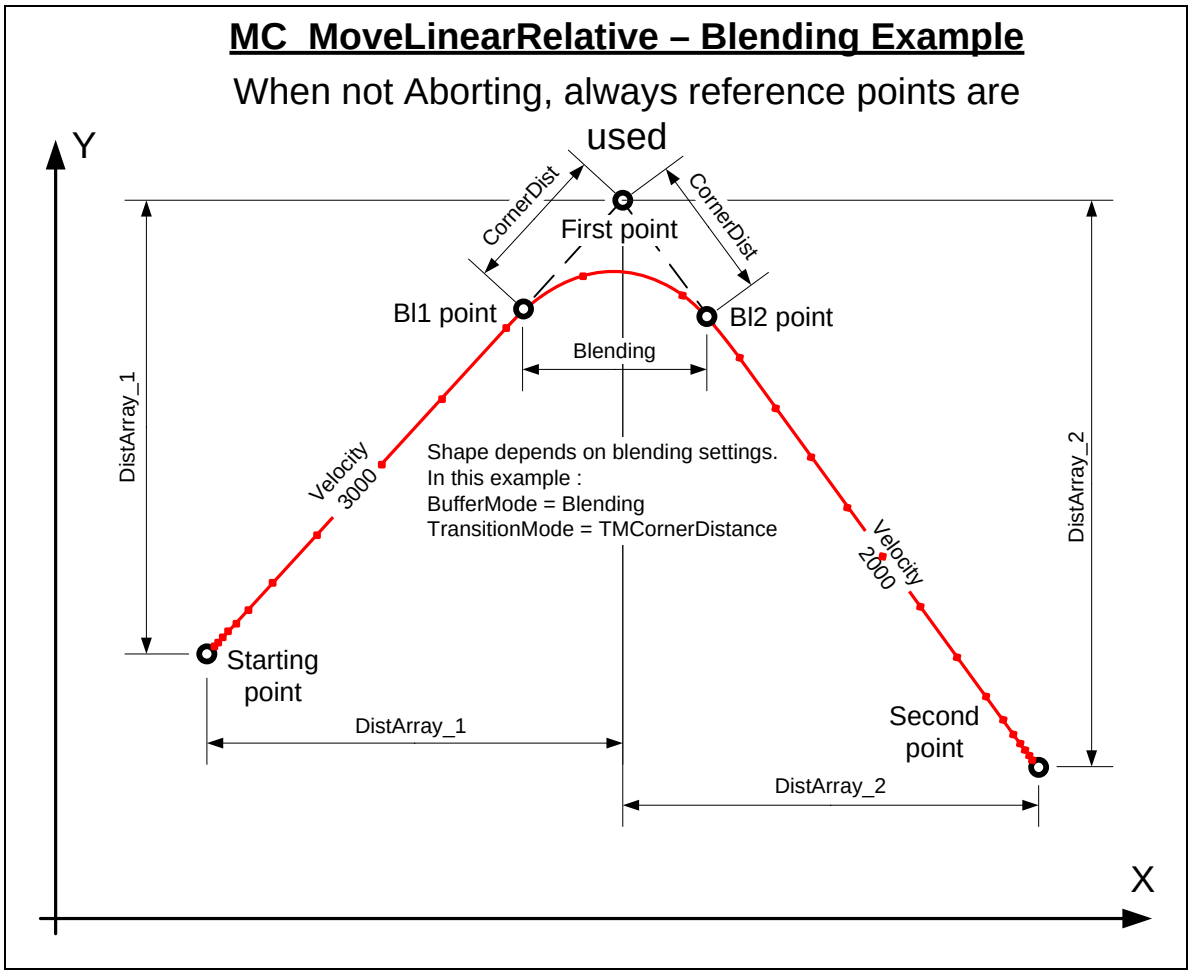


Figure17: Second example with MC_MoveLinearRelative and Blending

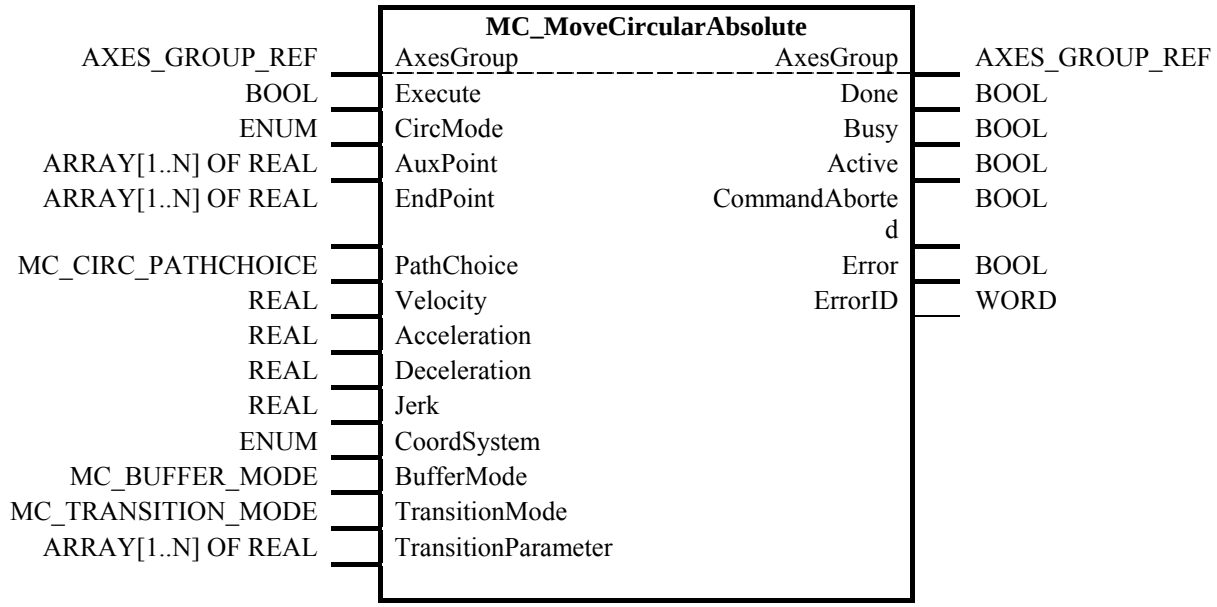
(Continued..)

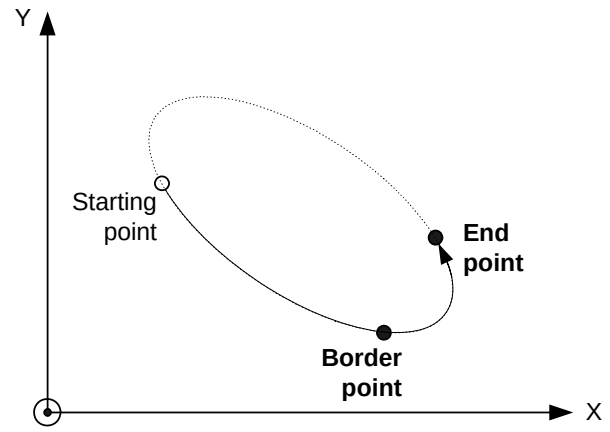
Timing diagram for example above (the dots on the red line are based on the same timing difference and representing the velocity)



5.22 MC_MoveCircularAbsolute

FB-Name		**MC_MoveCircularAbsolute**		
This function block commands an interpolated circular movement on an axes group from the actual position of the TCP. The end point as well as the auxiliary point (meaning depending on applied mode, see below) are defined absolutely in the specified coordinate system.				
VAR_IN_OUT				
B	AxesGroup	AXES_GROUP_REF		Reference to a group of axes
VAR_INPUT				
B	Execute	BOOL		Start the motion at rising edge
B	CircMode	ENUM	Specifies the meaning of the input signals 'AuxPoint' and 'CircDirection': BORDER → 'AuxPoint' defines a point on the circle which is crossed on the path from the starting to the end point. CENTER → 'AuxPoint' defines the center point of the circle. RADIUS → 'AuxPoint' defines the spearhead point of the perpendicular of the circle plane according to the rule of right thumb. The radius of the circle is the length of the vector. In the FB MC_MoveCircularAbsolute, the points are specified absolutely, i.e. the perpendicular vector begins in the origine and ends in the spearhead point specified at the input signal 'AuxPoint'.	
B	AuxPoint	ARRAY [1..N] OF REAL		Array [1..N] of absolute positions for each dimension in the coordinate system specified by the input signal 'CoordSystem', n vendor specific. See 1.4 Glossary
B	EndPoint	ARRAY [1..N] OF REAL		Array [1..N] of absolute positions for each dimension in the coordinate system specified by the input signal 'CoordSystem', n vendor specific. See 1.4 Glossary
E	PathChoice	MC_CIRC_PATHCHOICE		Choice of path: CLOCKWISE or COUNTERCLOCKWISE (ENUM)
E	Velocity	REAL		Maximum Velocity [u/s] for the path for the coordinate system in which the path is defined. Always positive. Not necessarily reached
E	Acceleration	REAL		Maximum acceleration [u/s^2]. Always positive. Not necessarily reached
E	Deceleration	REAL		Maximum deceleration [u/s^2]. Always positive. Not necessarily reached
E	Jerk	REAL		Maximum Jerk [u/s^3]. Always positive. Not necessarily reached
E	CoordSystem	ENUM		Reference to the applicable coordinate system: ACS, MCS, PCS
E	BufferMode	MC_GROUP_BUFFER_MODE		Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
E	TransitionMode	MC_TRANSITION_MODE		See 2.4.3 Overview of Transition Mode.
E	TransitionParameter	ARRAY [1..N] OF REAL		See 2.4.3 Overview of Transition Mode.
VAR_OUTPUT				
B	Done	BOOL	Commanded end positions reached for all axes	
E	Busy	BOOL	The FB is not finished	
E	Active	BOOL	Indicates that the FB has control on the axes group	
E	CommandAborted	BOOL	Command is aborted by another command	
B	Error	BOOL	Signals that an error has occurred within the function block	
E	ErrorID	WORD	Error identification	
Note: see below				



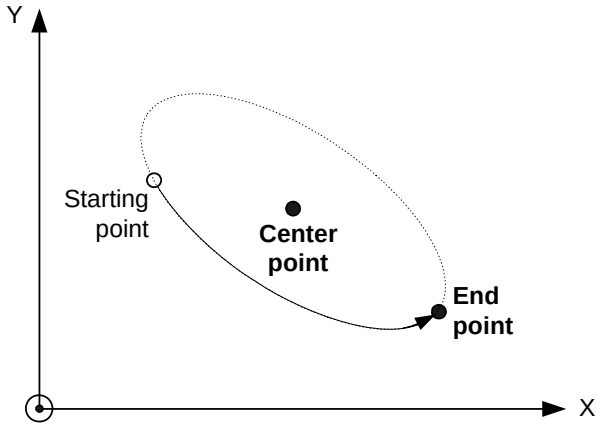


CircMode = **BORDER**

The user defines the end point and a border point (= input 'AuxPoint') on the sector of the circle, which shall be cruised by the machine.

Advantages of this mode:
+ The border point usually can be reached by the machine, i.e. it can be teached.

Inconvenience of this mode:
– Restriction to angles < 2π in one single command

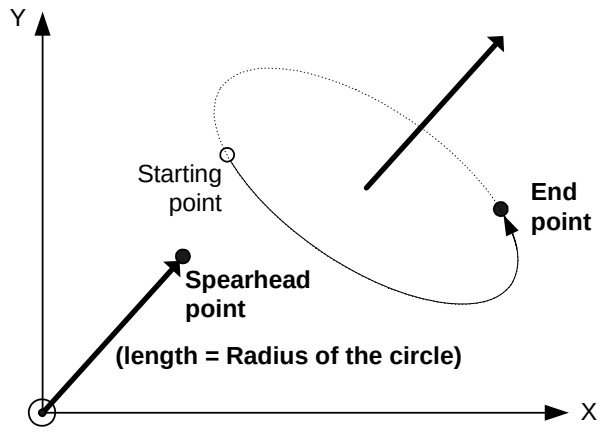


CircMode = **CENTER**

The user defines the end point and the center point (= input 'AuxPoint') of the circle.

When using this mode, the input 'PathChoice' defines, if the short or the long sector has to be cruised by the machine.

Inconveniencies of this mode:
– Restriction to angles < 2π and ≠ π in one single command
– Overdetermination of circle equation
– The center point usually cannot be teached in due to collisions with obstacles.



CircMode = **RADIUS**

The user defines the end point and the perpendicular vector of the circle plane according to the rule of right thumb (see figure below). The length of the vector corresponds to the radius of the circle. The spearhead point of the vector is the input signal 'AuxPoint' in absolute coordinates, i.e. referring to the origine of the coordinate system specified in 'CoordSystem'.

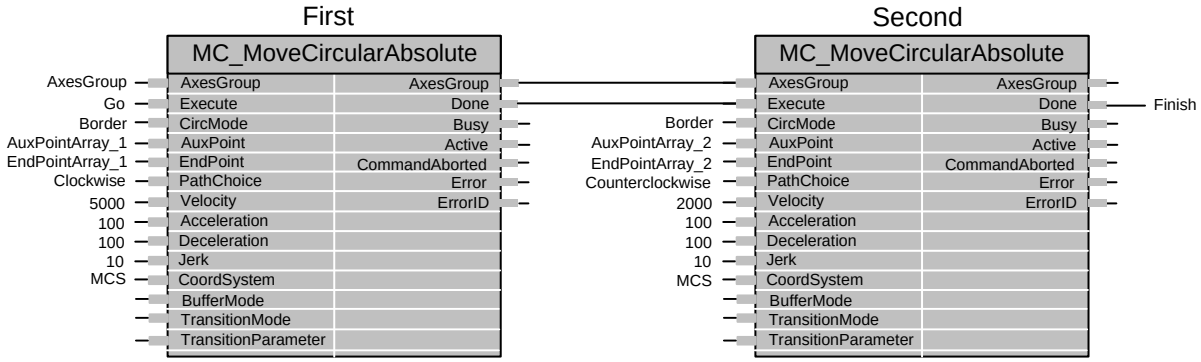
If the diameter is larger than the distance between starting and end point, two different circles have to be considered. When using this mode, the input 'PathChoice' defines, if the circle with the short sector or the circle with the long sector to reach the end point has to be cruised by the machine.
With positive radius value the shortest possible circle is determined, and with negative radius value the largest possible circle.

Inconvenience of this mode:
– Restriction to angles < 2π in one single command
– The perpendicular vector has to be computed.
– Overdetermination of circle equation

Example:
AuxPoint = (50,0,0) → Circle in plane parallel to y-z plane with radius 50 and rotation around axis parallel to x-axis according to the rule of right thumb (CoordSystem = MCS)

Sequenced example of 2 MC_MoveCircularAbsolute FBs

MC_MoveCircularAbsolute – Sequenced Example



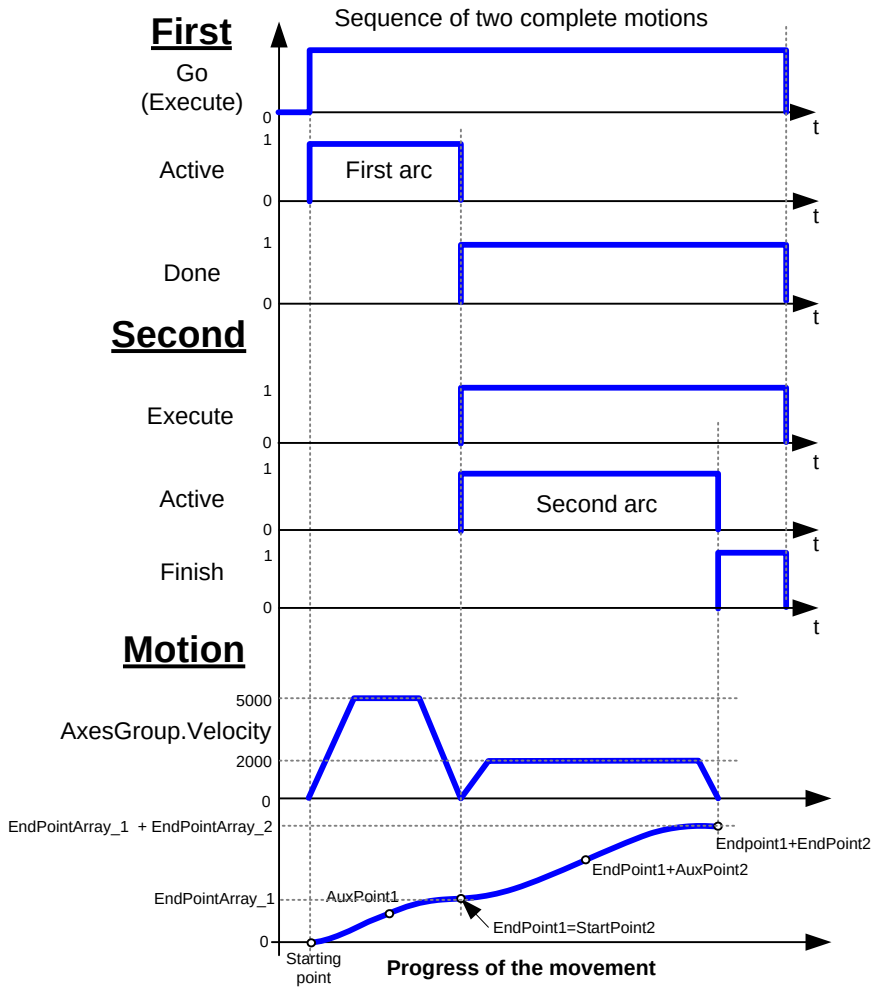
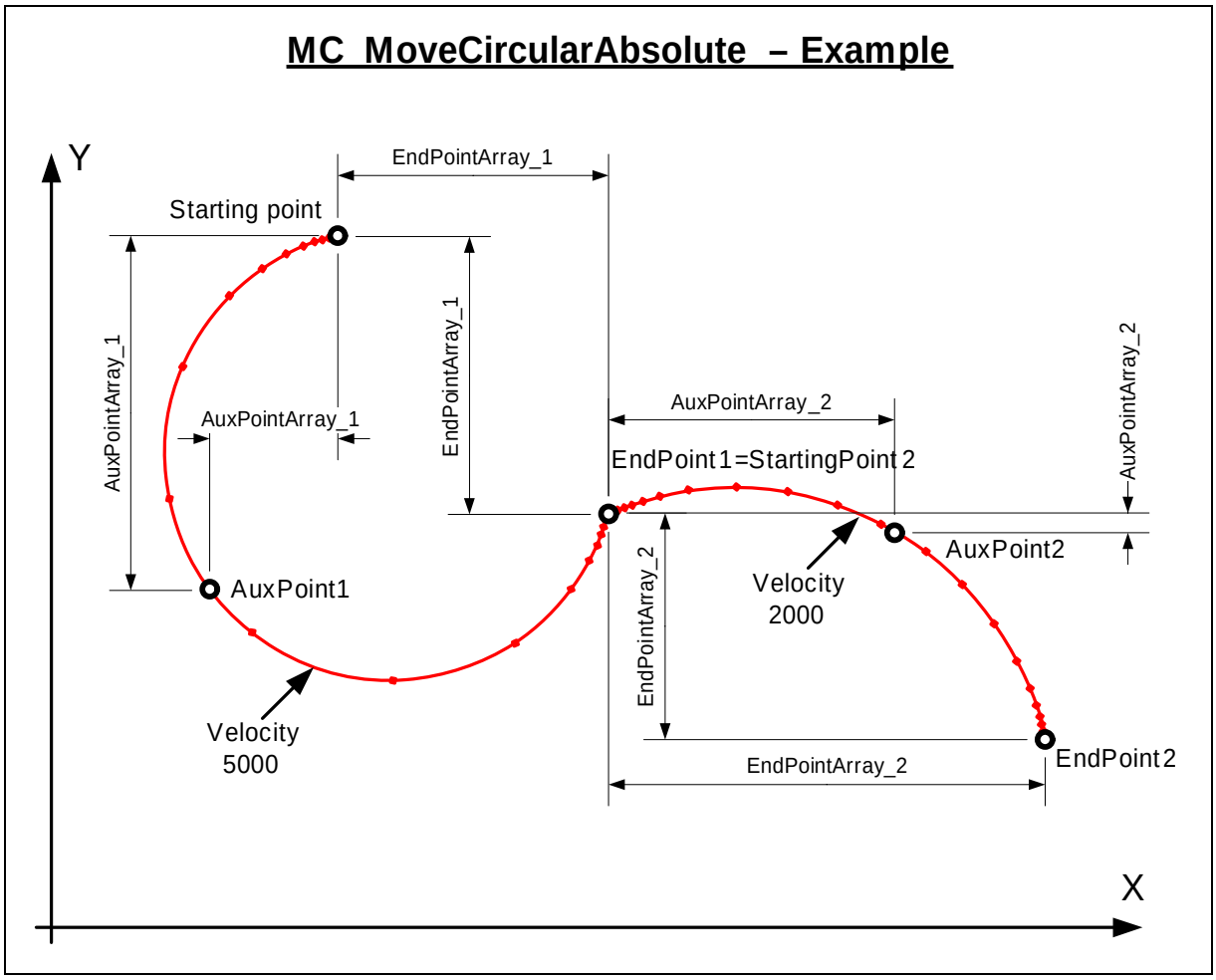


Figure18: Example MC_MoveCircularAbsolute

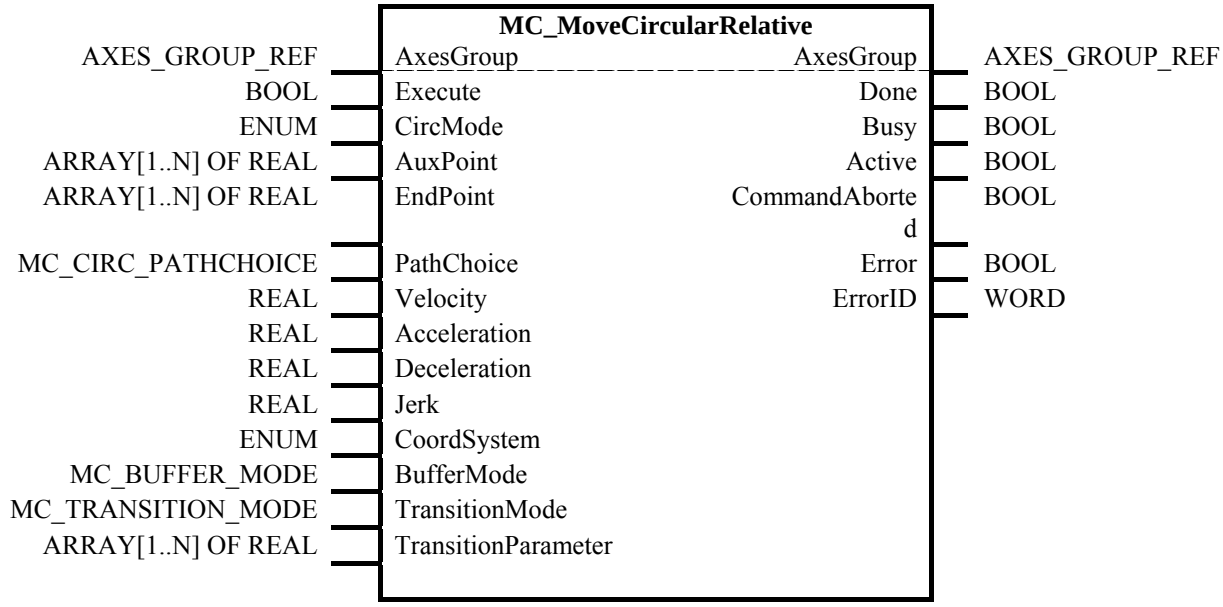
(continued..)

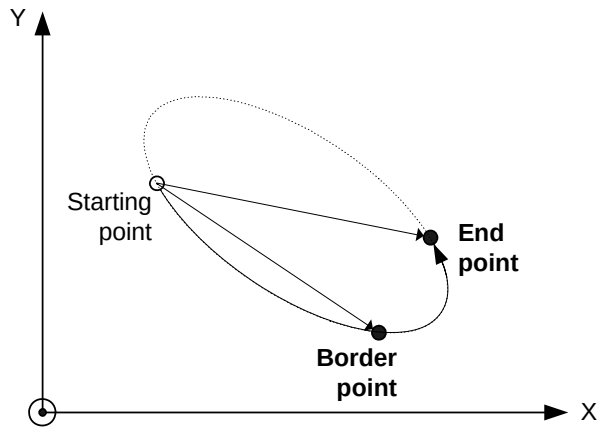
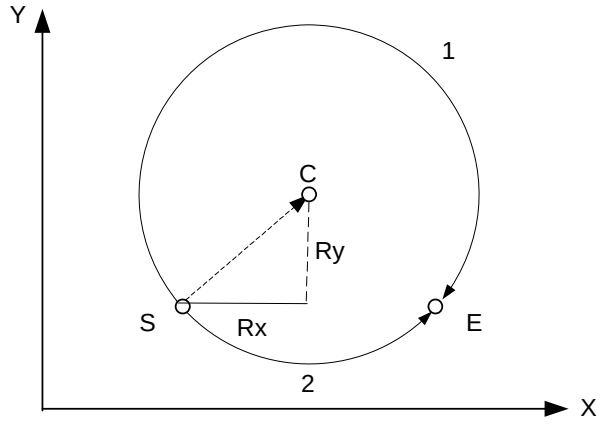
Timing diagram of example above. (the dots on the red line are based on the same timing difference and representing thevelocity)



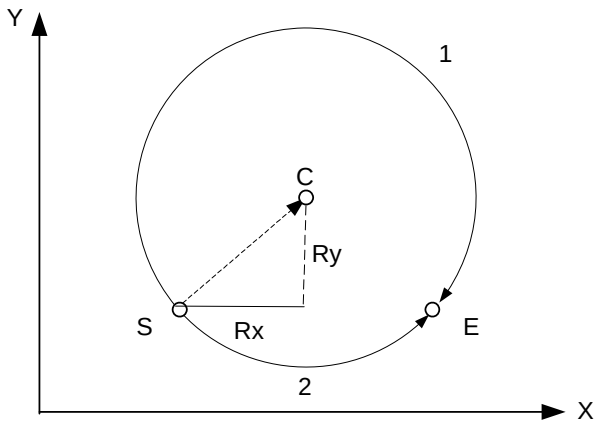
5.23 MC_MoveCircularRelative

FB-Name		**MC_MoveCircularRelative**		
This function block commands an interpolated circular movement on an axes group from the actual position of the TCP. The end point as well as the auxiliary point (meaning depending on applied mode, see below) are defined in the specified coordinate system relatively to the starting point.				
VAR_IN_OUT				
B	AxesGroup	AXES_GROUP_REF		Reference to a group of axes
VAR_INPUT				
B	Execute	BOOL		Start the motion at rising edge
B	CircMode	ENUM	Specifies the meaning of the input signals 'AuxPoint' and 'CircDirection': BORDER → 'AuxPoint' defines a point on the circle which is crossed on the path from the starting to the end point. It is specified relatively to the starting point. CENTER → 'AuxPoint' defines the center point of the circle. It is specified relatively to the starting point. RADIUS → 'AuxPoint' defines the spearhead point of the perpendicular of the circle plane according to the rule of right thumb. The radius of the circle is the length of the vector. In the FB MC_MoveCircularRelative, the points are specified relatively, i.e. the perpendicular vector begins in the starting point and ends in the spearhead point specified at the input signal 'AuxPoint'.	
B	AuxPoint	ARRAY [1..N] OF REAL		Array [1..N] of positions for each dimension in the coordinate system specified by the input signal 'CoordSystem', N vendor specific. These positions are defined relatively to the according positions of the starting point. See 1.4 Glossary
B	EndPoint	ARRAY [1..N] OF REAL		Array [1..N] of absolute positions for each dimension in the coordinate system specified by the input signal 'CoordSystem', n vendor specific. These positions are defined relatively to the according positions of the starting point. See 1.4 Glossary
E	PathChoice	MC_CIRC_PATHCHOICE		Choice of path: CLOCKWISE or COUNTERCLOCKWISE (ENUM)
E	Velocity	REAL		Maximum Velocity [u/s] for the path for the coordinate system in which the path is defined. Always positive. Not necessarily reached
E	Acceleration	REAL		Maximum acceleration [u/s^2]. Always positive. Not necessarily reached
E	Deceleration	REAL		Maximum deceleration [u/s^2]. Always positive. Not necessarily reached
E	Jerk	REAL		Maximum Jerk [u/s^3]. Always positive. Not necessarily reached
E	CoordSystem	ENUM		Reference to the applicable coordinate system: ACS, MCS, PCS
E	BufferMode	MC_BUFFER_MODE		Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
E	TransitionMode	MC_TRANSITION_MODE		See 2.4.3 Overview of Transition Mode.
E	TransitionParameter	ARRAY[1..N] OF REAL		See 2.4.3 Overview of Transition Mode.
VAR_OUTPUT				
B	Done	BOOL	Commanded end positions reached for all axes	
E	Busy	BOOL	The FB is not finished	
E	Active	BOOL	Indicates that the FB has control on the axes group	
E	CommandAborted	BOOL	Command is aborted by another command	
B	Error	BOOL	Signals that an error has occurred within the function block	
E	ErrorID	WORD	Error identification	
Note: see below				



	CircMode = **BORDER** The user defines the end point and a border point (= input 'AuxPoint') on the sector of the circle, which shall be cruised by the machine. Both points are defined relatively to the starting point. Advantages of this mode: + The border point usually can be reached by the machine, i.e. it can be teached. Inconvenience of this mode: – Restriction to angles < 2π in one single command
	CircMode = **CENTER** The user defines the end point and the center point (= input 'AuxPoint') of the circle. Both points are defined relatively to the starting point When using this mode, the input 'PathChoice' defines, if the short or the long sector has to be cruised by the machine. Inconveniencies of this mode: – Restriction to angles < 2π and ≠ π in one single command – Overdetermination of circle equation – The center point usually cannot be teached-in due to collisions with obstacles.

	CircMode = **RADIUS** The user defines the end point and the perpendicular vector of the circle plane according



to the rule of right thumb (see figure below). The length of the vector corresponds to the radius of the circle. The spearhead point of the vector is defined relatively to the starting point at the input signal 'AuxPoint'.

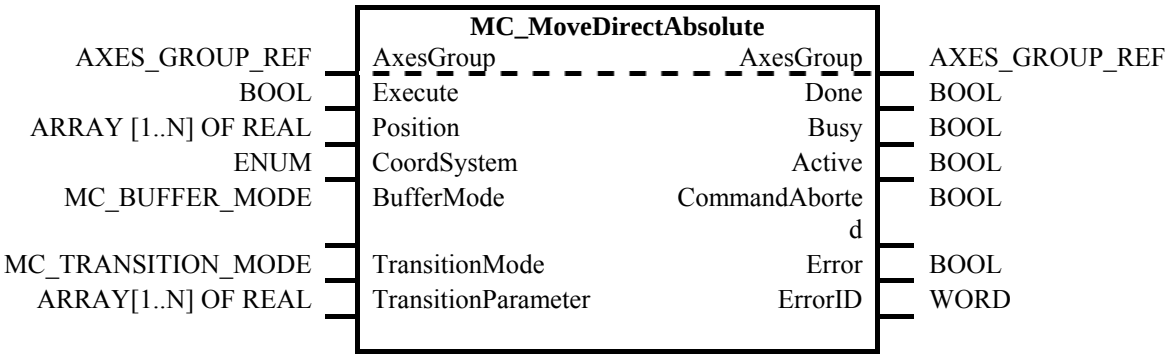
If the diameter is larger than the distance between starting and end point, two different circles have to be considered. When using this mode, the input 'PathChoice' defines, if the circle with the short sector or the circle with the long sector to reach the end point has to be cruised by the machine.
With positive radius value the shortest possible circle is determined, and with negative radius value the largest possible circle.

Inconvenience of this mode:
– Restriction to angles < 2π in one single command
– The perpendicular vector has to be computed.
– Overdetermination of circle equation

Example:
AuxPoint = (starting_point[0], starting_point[1] - 30, starting_point[2]) → Circle in plane parallel to x-z plane with radius 30 and rotation around axis parallel to y-axis contrariwise the rule of right thumb (CoordSystem = MCS)

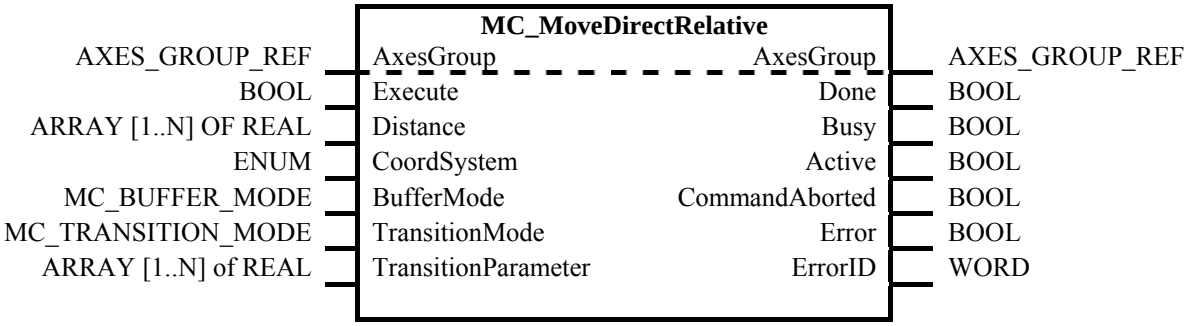
5.24 MC_MoveDirectAbsolute

FB-Name		**MC_MoveDirectAbsolute**	
This function block commands a movement of an axes group to the specified absolute position in the specified coordinate system without taking care of how (on which path) the target position is reached.			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT			
B	Execute	BOOL	Start the motion at rising edge
B	Position	ARRAY [1..N] OF REAL	Array [1..N] of end position for each dimension in the specified coordinate system. The value of n is supplier specific. See 1.4 Glossary.
E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
E	BufferMode	MC_BUFFER_MODE	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
E	TransitionMode	MC_TRANSITION_MODE	See 2.4.3 Overview of Transition Mode.
E	TransitionParameter	ARRAY[1..N] OF REAL	See 2.4.3 Overview of Transition Mode.
VAR_OUTPUT			
B	Done	BOOL	Commanded end positions reached for all axes
E	Busy	BOOL	The FB is not finished
E	Active	BOOL	Indicates that the FB has control on the axis
E	CommandAborted	BOOL	Command is aborted by another command
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification
Note: The velocity/acc-/deceleration/jerk of every axis are properties of each axis and not specified within this function block, but not to be exceeded during the move.			



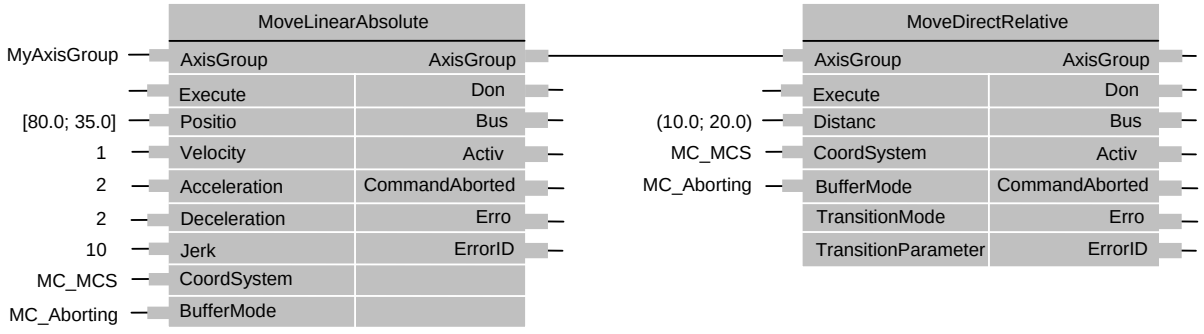
5.25 MC_MoveDirectRelative

FB-Name		**MC_MoveDirectRelative**		
This function block commands a movement of an axes group to a relative position without taking care of how (on which path) the target position is reached. Start position is the actual position of the TCP.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT				
	B	Execute	BOOL	Start the motion at rising edge
	B	Distance	ARRAY [1..N] OF REAL	Array [1..N] of distances for each dimension in the specified coordinate system. The value of n is supplier specific.
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
	E	BufferMode	MC_BUFFER_MODE	Refer to Chapter 7.3 Buffer Modes
	E	TransitionMode	MC_TRANSITION_MODE	See 2.4.3 Overview of Transition Mode.
	E	TransitionParameter	ARRAY[1..N] OF REAL	See 2.4.3 Overview of Transition Mode.
VAR_OUTPUT				
	B	Done	BOOL	Commanded end positions reached for all axes
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axis
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: The velocity/acc-/deceleration/jerk of every axis are properties of each axis and not specified within this function block, but not to be exceeded during the move.				



Following example shows the behaviour of MC_MovePositionDirectRelative. All positions are related to MCS:

- Starting at position p_0 (10; 10) a MC_MoveLinearAbsolute to position p_1 (80; 35) is commanded.
- While the TCP is moving towards p_1, the MC_MoveLinearAbsolute command is aborted by a MC_MovePositionDirectRelative command. The actual position of the TCP, when MC_MovePositionDirectRelative becomes active, is (44.5; 21.63).
- The TCP leaves the line p_0p_1 and moves to the new target position p_2 (54.5; 41.63). The resulting trajectory depends on the kinematic transformation of the axes group.



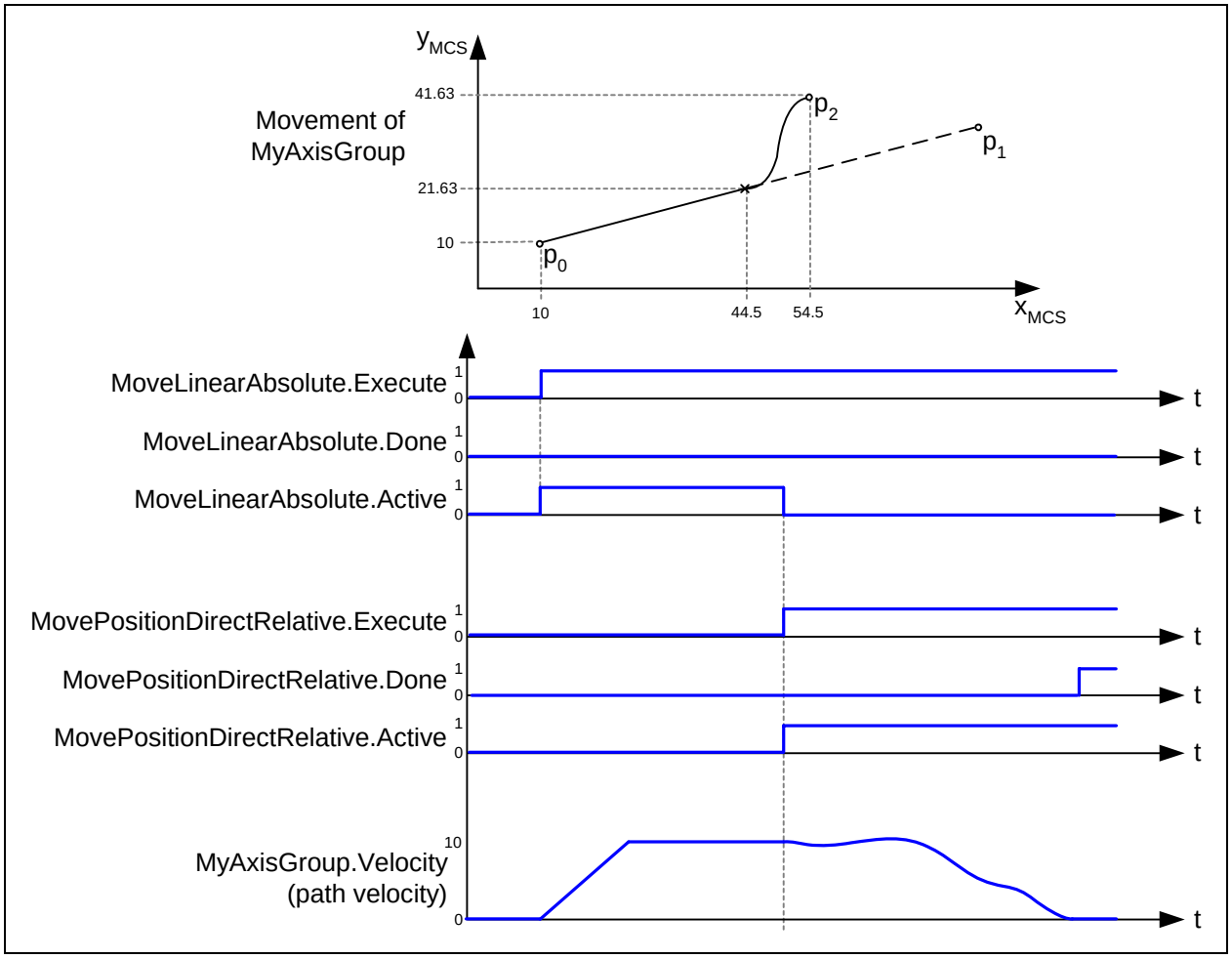
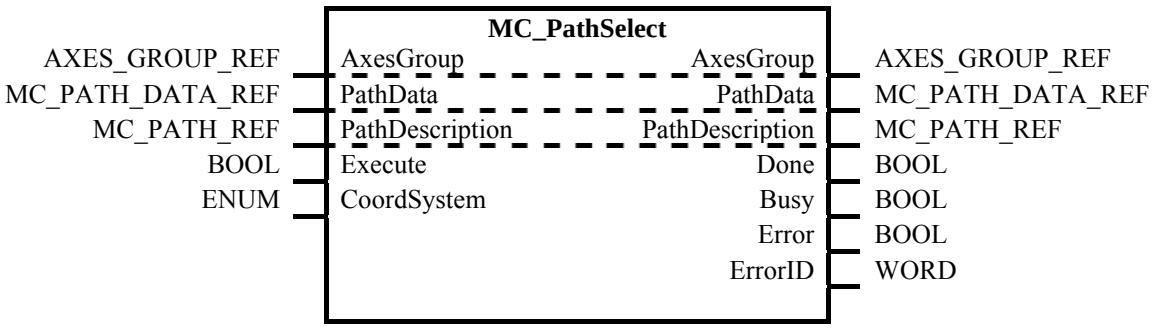


Figure19: Example MC_MoveDirectRelative

5.26 MC_PathSelect

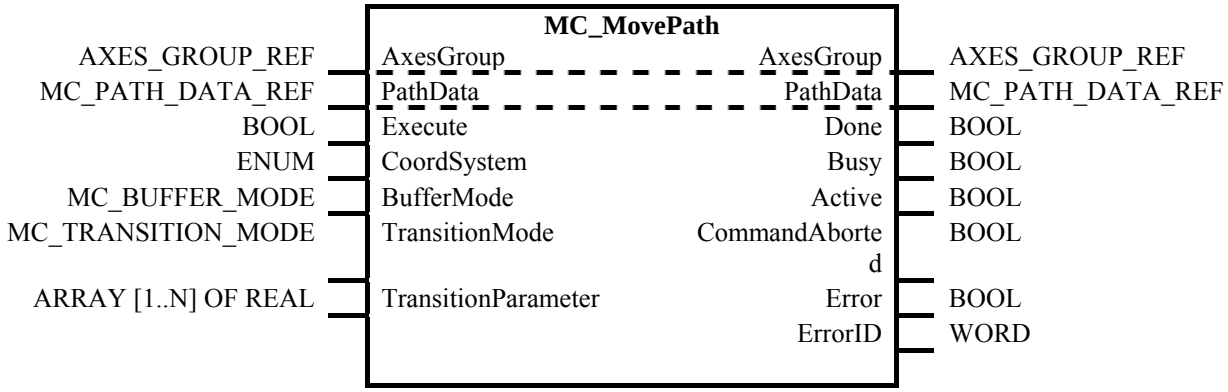
FB-Name		**MC_PathSelect**	
This function block prepares the relevant path data and makes these available to the system as an output (PathData). Administrative function block.			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to the group of axes
B	PathData	MC_PATH_DATA_REF	Reference to the resulting path data to be used in FBs requiring a path description.
B	PathDescription	MC_PATH_REF	Reference to the path description
VAR_INPUT			
B	Execute	BOOL	Start the preparation at the rising edge
E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
VAR_OUTPUT			
B	Done	BOOL	The PathData is valid
E	Busy	BOOL	The FB is not finished
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification

Note:
- MC_PATH_DATA_REF is a supplier specific data type
- MC_PATH_REF is a supplier specific data type
- PathSelect makes data available. This can include:
  1. Starting point of a download of a path profile, as represented in PathData and referenced by PathDescription
  2. Start to generate a path profile



5.27 MC_MovePath

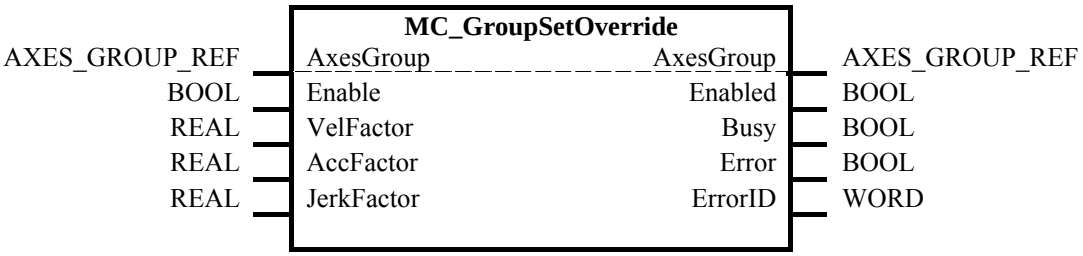
FB-Name		**MC_MovePath**		
This function block commands an AxesGroup to move according to the path specified in the PathData.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to the AxesGroup
	B	PathData	MC_PATH_DATA_REF	Reference to the path data, which can be prepared by MC_PathSelect
VAR_INPUT				
	B	Execute	BOOL	Start the motion at rising edge
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
	E	BufferMode	MC_BUFFER_MODE	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
	E	TransitionMode	MC_TRANSITION_MODE	See 2.4.3 Overview of Transition Mode.
	E	TransitionParameter	ARRAY [1..N] OF REAL	See 2.4.3 Overview of Transition Mode.
VAR_OUTPUT				
	B	Done	BOOL	Commanded end positions reached for all axes
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axes group
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: -				



5.28 MC_GroupSetOverride

FB-Name		**MC_GroupSetOverride**		
This function block sets the values of override for the coordinated motion of several axes, and all functions that are working on that axes group. The override parameters act as a factor that is multiplied to the commanded vector velocity, acceleration, deceleration and jerk of all axes group function blocks. Not applicable to master-slave group synchronized motion commands.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to the group of axes
VAR_INPUT				
	B	Enable	BOOL	If SET, it writes the value of the override factor continuously. If RESET it should keep the last value.
	B	VelFactor	REAL	New override factor for the vector velocity
	E	AccFactor	REAL	New override factor for the vector acceleration/deceleration
	E	JerkFactor	REAL	New override factor for the vector jerk
VAR_OUTPUT				
	B	Enabled	BOOL	Signals that the override factor(s) is (are) set successfully
	E	Busy	BOOL	Is SET when the FB is active (not in idle mode).
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification

Notes:
1. The Input AccFactor acts on positive and negative acceleration (deceleration).
2. This FB sets the factor. The override factor is valid until a new override is set.
3. The default values of the override factors are 1.0.
4. The value of the overrides can be between 0.0 and 1.0. The behavior of values > 1.0 is supplier specific. Values < 0.0 are not allowed. The value 0.0 is not allowed for AccFactor and JerkFactor. and generates an error
5. The value 0.0 set to the VelFactor stops the axis without bringing it to the state GroupStandby.
6. Override does not act on slave axes groups. (Axes groups in the state Group Synchronized motion).
7. The FB does not influence the state diagram of the axes group.
8. VelFactor can be changed at any time and acts directly on the ongoing motion.
9. Reducing the AccFactor and/or JerkFactor can lead to a position overshoot – a possible cause of damage.



Graphical Explanation

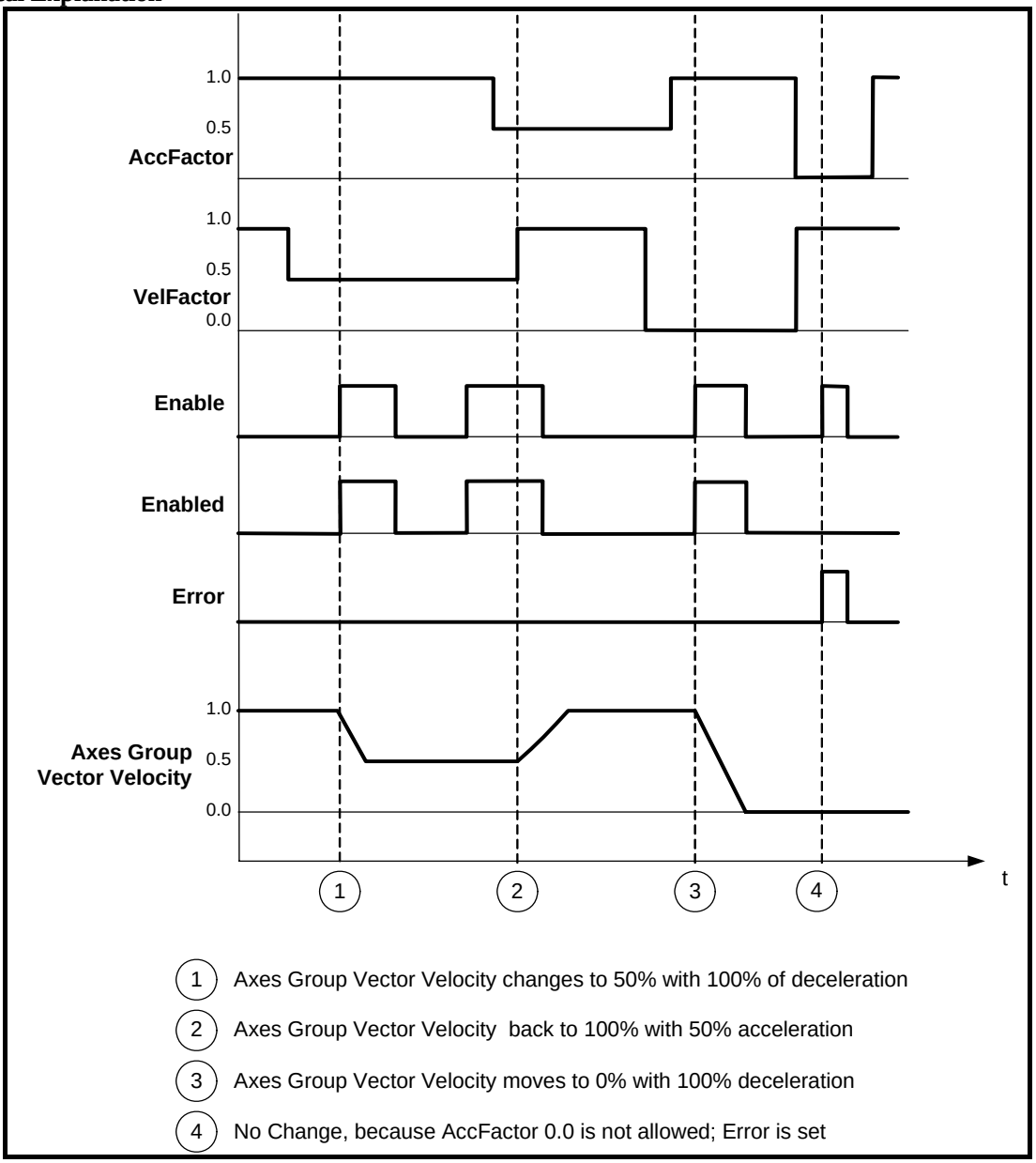


Figure 20: Graphical explanation of MC_GroupSetOverride

6 Axes Group Synchronized Motion

The function blocks as defined in this chapter deal with a master/ slave relationship between a single or group of axes and a single or group of axes for coordination purposes.

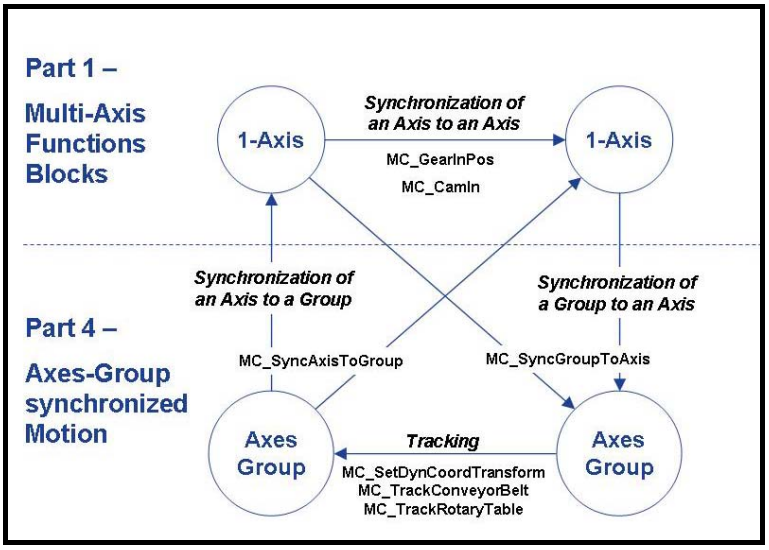


Figure 21: Graphical explanation of coordination

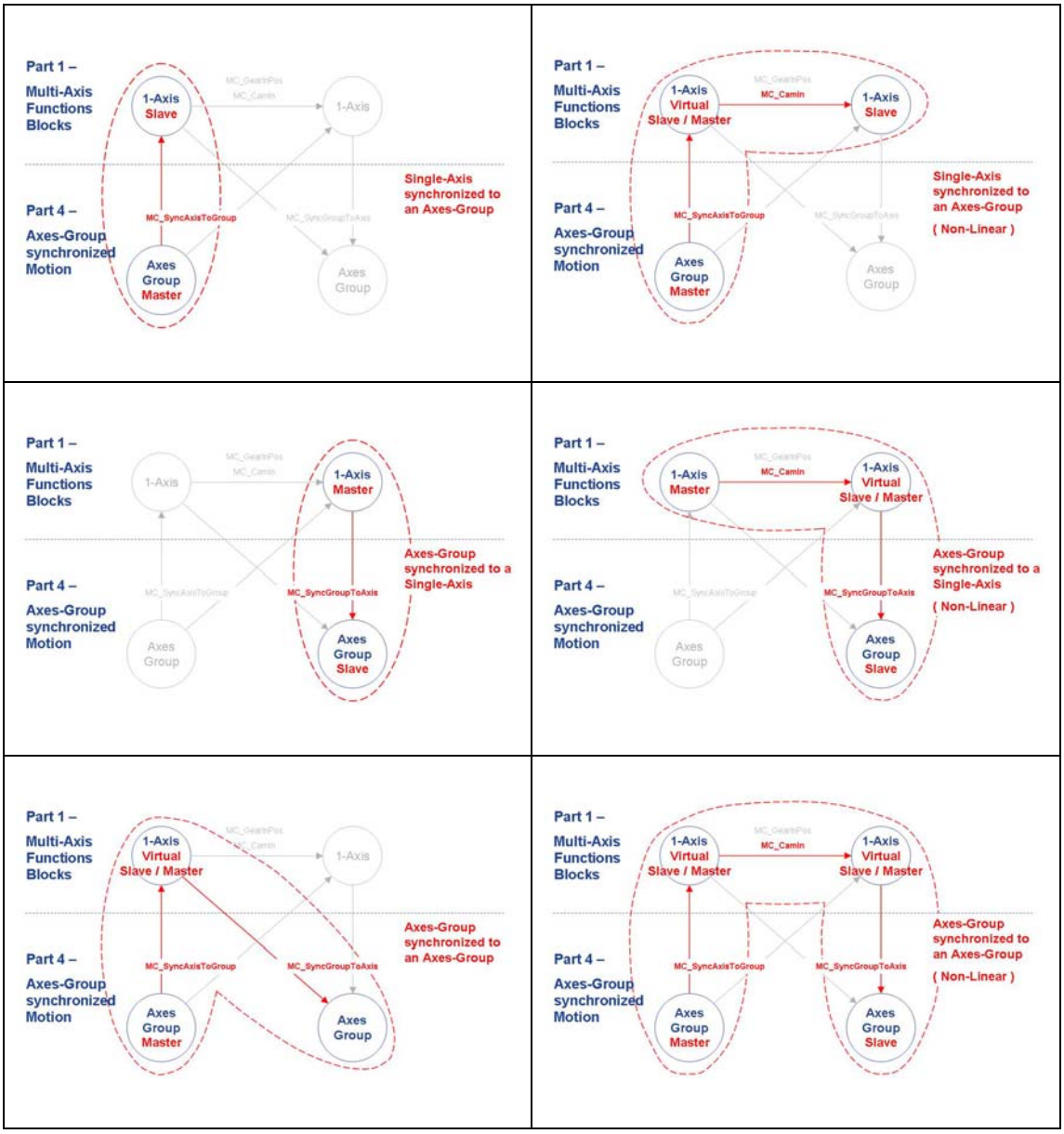
There are two kinds of coordinated motion that have to be distinguished from a programming point of view and in the realization of the motion control itself. These two modes are identified here through their names:

- Synchronization
- Tracking

6.1 Synchronization

The relationship between single axis commands and synchronized motion is shown here.
There are 6 possibilities of associations:

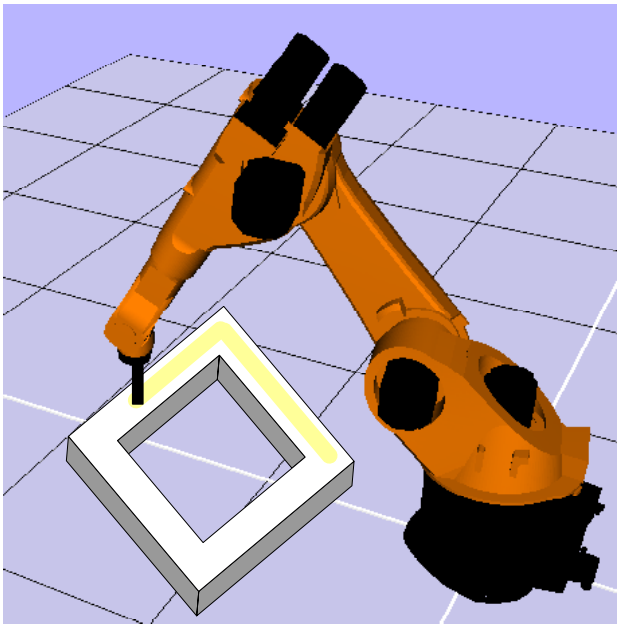
1. Single-axis synchronized to an Axes-Group, Linear Synchronization
2. Single-axis synchronized to an Axes-Group, Non-Linear Synchronization (using MC_CamIn)
3. Axes-Group axis synchronized to a Single-axis, Linear Synchronization
4. Axes-Group axis synchronized to a Single-axis, Non-Linear Synchronization (using MC_CamIn)
5. Axes-Group axis synchronized to an Axes-Group, Linear Synchronization
6. Axes-Group axis synchronized to an Axes-Group, Non-Linear Synchronization (using MC_CamIn)



6.1.1 Synchronization of single axis to an axes group

This is an example of a single axis (as slave) synchronized to an axes group (master). The master follows its path and the slave is linked to the position, velocity, acceleration, or any other magnitude of the master. An example is glue dispensing, where the amount of glue to be dispensed is coupled to the velocity of the TCP of the robot. The single axis slave motor movement of the glue dispenser is coupled to the trajectory of the TCP of the group over the surface of the object via MC_AxisFollowGroup. Alternatively, if the position information is not critical, one can use

MC_GroupReadActualVelocity, perhaps combined with a gearing factor, and thus providing the input to the motor of the glue dispenser,



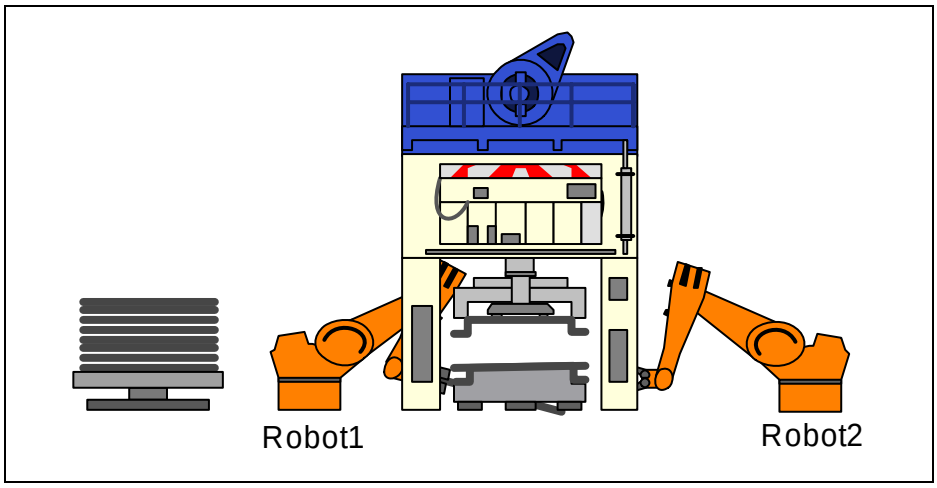
6.1.2 Synchronization of an axes group to a single axis

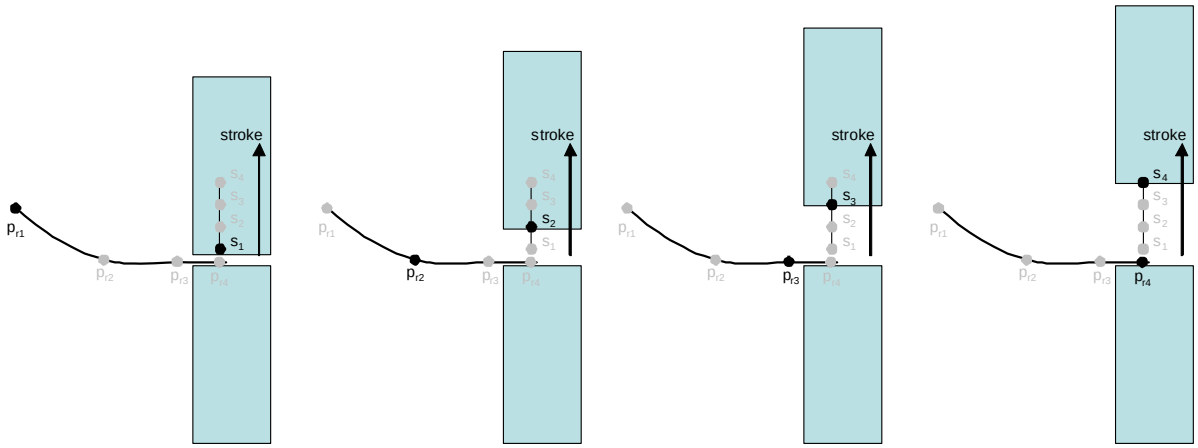
This mode combines an axes group (as slave) with an axis as master in order that the slave executes its path with synchronization to the progress of the master, meaning linked to a 1-dimensional source for synchronization. Examples here include press synchronization. (Note: in case the slave is an axes group, a transformation to a virtual axis can be applicable to generate the 1-dimensional synchronization data. In case both the master and the slave are axes groups, a virtual master axis on the slave side is applicable (linked via cam profiles to the different axes) to use the 1-dimensional synchronization data of the master side).

As an example of synchronization between a master single axis and a group can be the robot which places material in a press machine: the robot has to synchronize to the opening phase of the press. A second robot also synchronizes to take the material out.

The master is the (single or virtual) axis controlling the press. The axes group for both robot 1 and robot 2 has to follow the press in a certain area of the master movement: opening for robot 2 to take the product out and closing for robot 1 to add the new product.

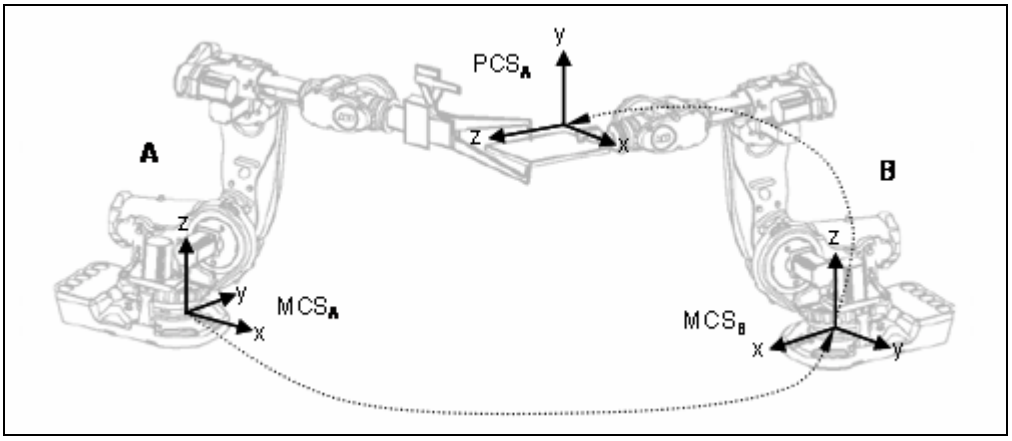
For this synchronization the FB MC_SyncGroupToAxis is defined.





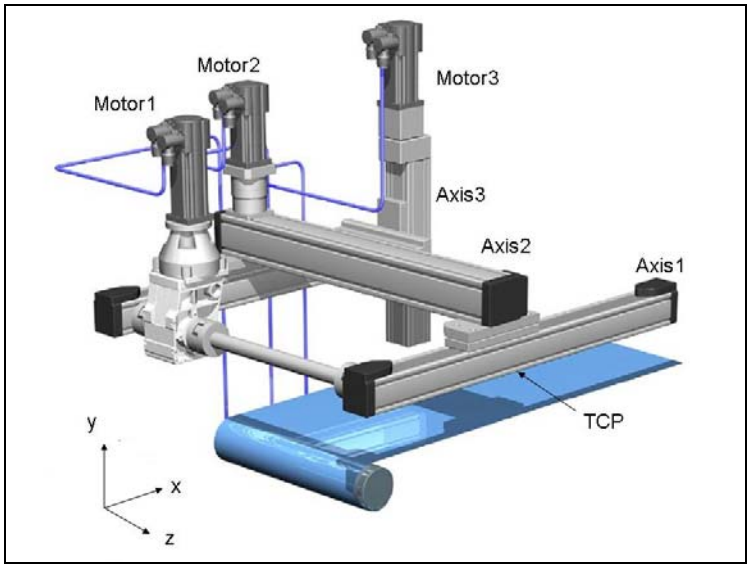
6.2 Tracking

Tracking is characterized by an axis group (A) that follows with its movement the movement of a single axis or another axis group (B). During the coordinated following A is performing a movement/task relative to the movement of B. The tracking data is a multidimensional source incl. position and orientation. Solutions can include a moving coordinate system or a multi-dimensional gear functionality.
Tracking can be seen as a superposition of two movements, although these movements are independent. One, which is the movement of the product (moving PCS) and the second one, which describes the path of the TCP that would be executed if the product is standing still (Positions have to be defined in PCS). The Position of the PCS and therefore also the movement of the PCS relative to MCS is described by the coordinate transformation MCS to PCS. For tracking the following function blocks are defined here: MC_SetDynCoordTransform as a general one, and MC_TrackConveyorBelt plus MC_TrackRotaryTable for specific applications. (Note: The considerations on the limitations of the dynamics or mechanics are implementation specific.)
The basic example for the tracking of an axis group and a single axis is conveyor tracking, where the robot picks or places parts on the moving conveyor or is putting some crème on a cake moving on the belt. An example for the tracking of another axes group is having two robots, where robot B is holding a work piece, and robot A is performing some welding on the part at the same time B is moving the work piece (see picture).



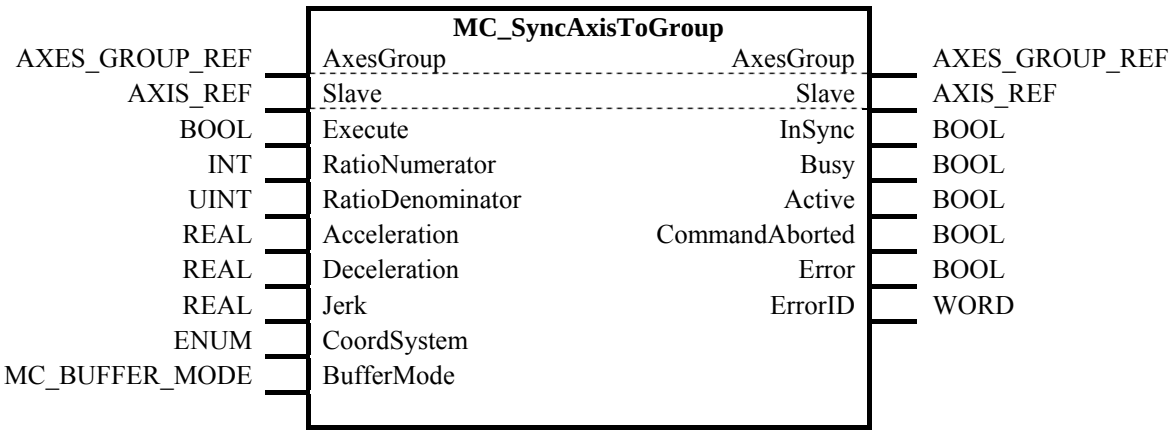
Generally there is no difference if A is tracking a single axis or an axis group, when thinking of a single axis as an axis group having only one axis but also a kinematic (even if it is very simple). Then concepts of the motion planning as well as of programming are the same.

A second tracking example deals with synchronization of a group and a transportation belt. The group synchronizes to the belt, which is the master.
We have a (simple) Cartesian robot, consisting of 3 motors moving 3 axes. Application examples are to pick something from the belt (with a correction in the Z-position), or to put some cream on a cookie that is lying on the belt.



6.3 MC_SyncAxisToGroup

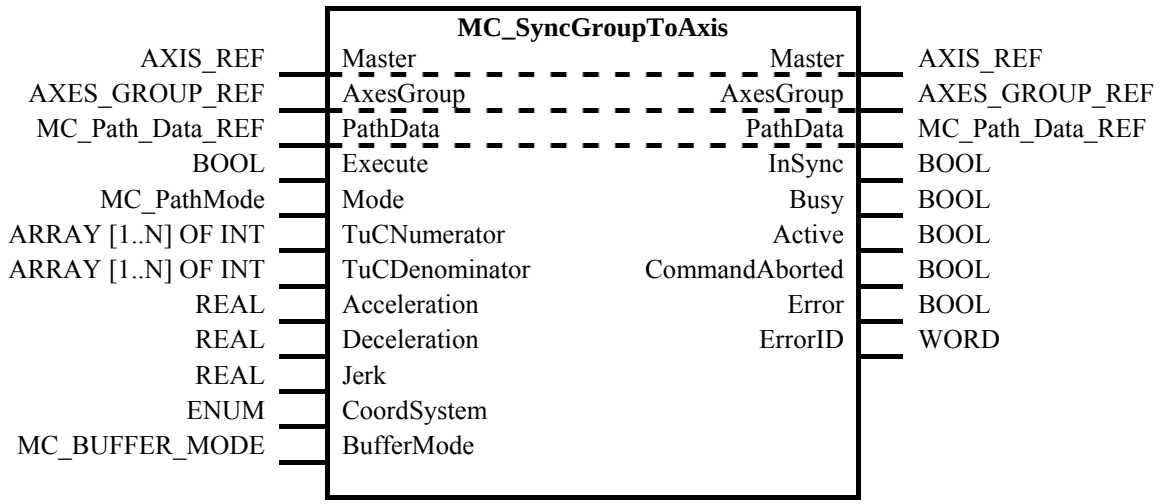
FB-Name		**MC_SyncAxisToGroup**		
This FB maps a single axis to a group. The single axis output represents the path length progression of the axes group. There is the ability to set a ratio between group and single axis.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to the group of axes
	B	SlaveAxis	AXIS_REF	Reference to the axis (real or virtual)
VAR_INPUT				
	B	Execute	BOOL	Starts the synchronization process on the rising edge
	E	RatioNumerator	INT	Gear Ratio Numerator.
	E	RatioDenominator	UINT	Gear Ratio Denominator
	E	Acceleration	REAL	Value of maximum acceleration
	E	Deceleration	REAL	Value of maximum deceleration
	E	Jerk	REAL	Value of maximum jerk
	E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
	E	BufferMode	MC_BUFFER_MODE	Defines the behavior of the axis: modes are Aborting, Buffered, Blending. Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT				
	B	InSync	BOOL	The (virtual) slave generates valid values
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axis
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: • This FB equals the mileage counter (odometer) in a car of the group and shows this via the Slave axis. • The slave ramps up to the ratio of the path speed and locks in position when this is reached. • The gearing ratio can be changed while FB is running, using a consecutive call of the FB • InSync is set the first time the ratio is reached. • After being InSync, a position locking or just a speed locking is system specific. The FB is stopped by issuing a single axis FB.				

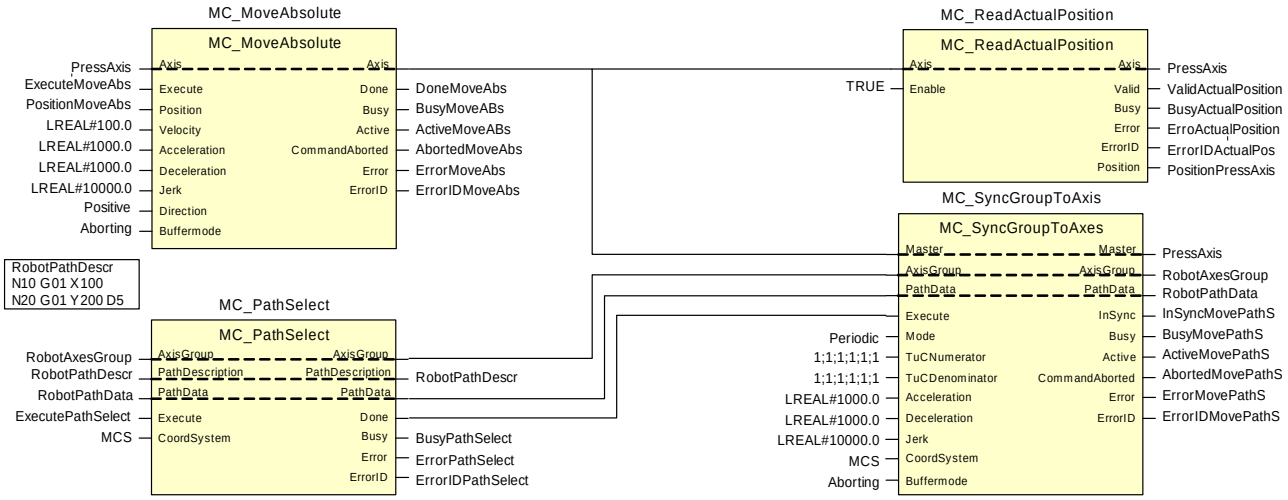


Example: glue dispenser motor coupled to the movement of the TCP of the robot.

6.4 MC_SyncGroupToAxis

FB-Name		**MC_SyncGroupToAxis**	
This function block commands an interpolated path movement on an axes group in the applicable coordinate system. The multi axes motion is synchronized with the Master motion like in a cam function.			
VAR_IN_OUT			
B	Master	AXIS_REF	Reference to the master axis
B	AxesGroup	AXES_GROUP_REF	Reference to the group of axes
B	PathData	MC_Path_Data_REF	Reference to the path data, which can be prepared by the function block MC_PathSelect
VAR_INPUT			
B	Execute	BOOL	Start the motion at rising edge
E	Mode	MC_PathMode	ENUM. Selects the mode of the FB like non_periodic, periodic.
E	TuCNumerator	ARRAY [1..N] OF INT	Numerator of the conversion factors of the technical units of each axis in the axes group to generate the applicable technical unit for the slave.
E	TuCDenominator	ARRAY [1..N] OF INT	Denominator of TuConversion
E	Acceleration	REAL	Maximum acceleration. Always positive. Not necessarily reached
E	Deceleration	REAL	Maximum deceleration. Always positive. Not necessarily reached
E	Jerk	REAL	Maximum jerk for the axes group during coupling. Not necessarily reached
E	CoordSystem	ENUM	Reference to the coordinate system used: ACS, MCS, or PCS
E	BufferMode	MC_BUFFER_MODE	Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT			
B	InSync	BOOL	The axes group follows the master axis
E	Busy	BOOL	The FB is not finished
E	Active	BOOL	Indicates that the FB has control on the axis
E	CommandAborted	BOOL	Command is aborted by another command
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification
Note: This synchronization of the axes group can be stopped via MC_GroupStop or any other motion command.			





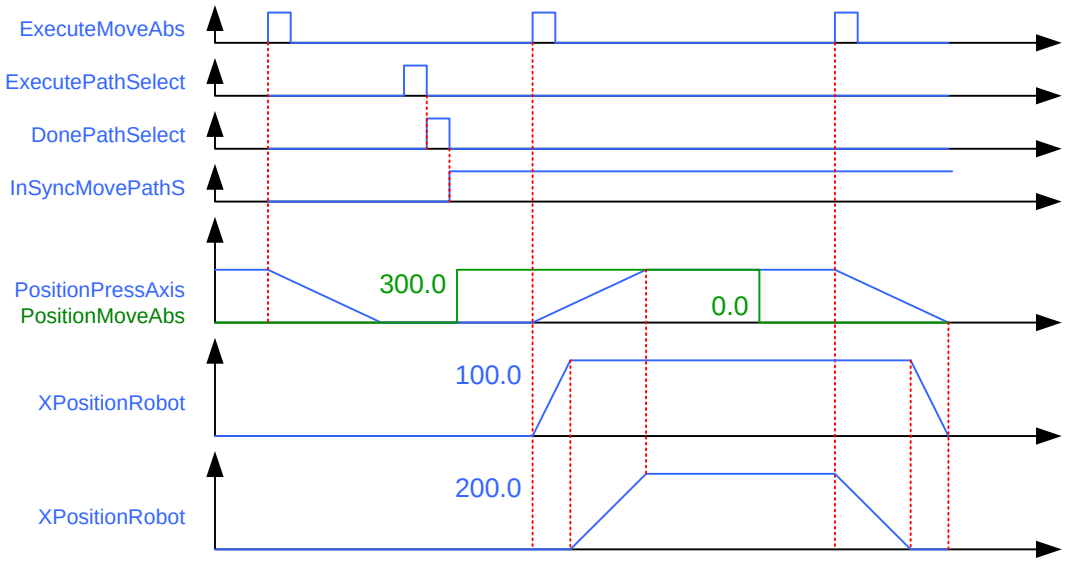
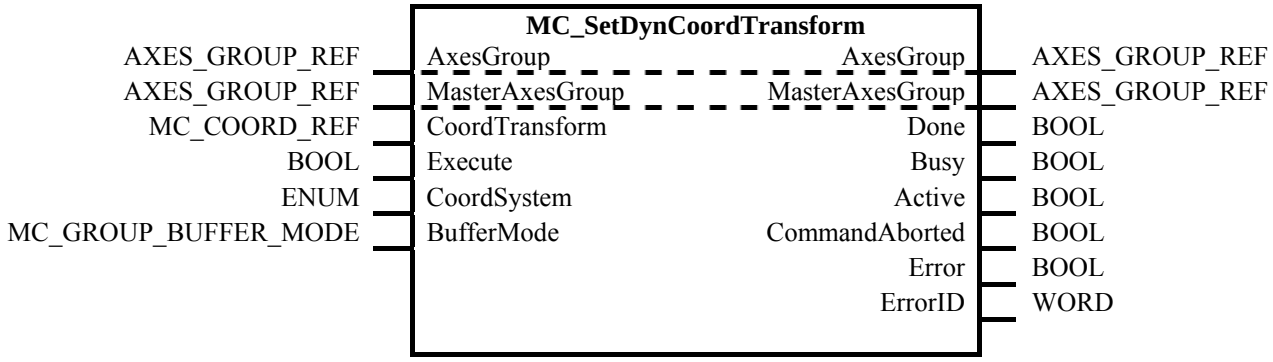


Figure 22: Example MC_SyncGroupToAxis

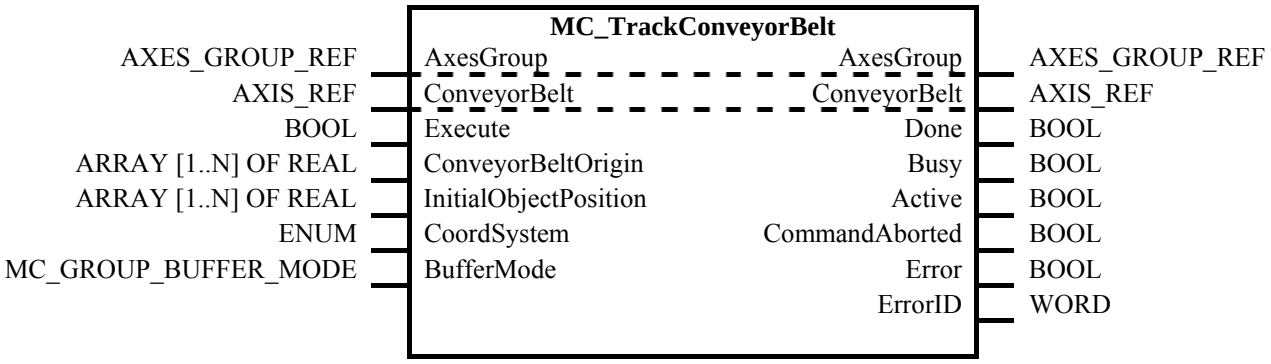
6.5 MC_SetDynCoordTransform

FB-Name		**MC_SetDynCoordTransform**		
This FB couples two Axes Groups via a dynamic coordinate transformation. The input for the coordinate transformation is the MasterAxesGroup. The result of the transformation is mapped to the AxesGroup, meaning that the coordinate system of AxisGroup will follow the MasterAxesGroup with the transformation as link				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to the group of axes
	B	MasterAxesGroup	AXES_GROUP_REF	Reference to the master axes group
	B	CoordTransform	MC_COORD_REF	See 5.8.3 MC_SetCoordinateTransform (MCS to PCS)
VAR_INPUT				
	B	Execute	BOOL	Start the motion at rising edge
	E	Mode	MC_PathMode	ENUM. Selects the mode of the FB like non_periodic, periodic.
	E	CoordSystem	ENUM	Reference to the coordinate system used: ACS, MCS, or PCS
	E	BufferMode	MC_BUFFER_MODE	Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT				
	B	Done	BOOL	The dynamic transformation is set successfully
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the FB has control on the axis
	E	CommandAborted	BOOL	Command is aborted by another command
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: The PCS specified by the ENUM belongs to AxesGroup. It follows the movement of the MasterAxesGroup. The relation between both AxisGroups is specified in CoordTransform. The AxesGroup contains the Coordinate System specified by the ENUM CoordSystem				

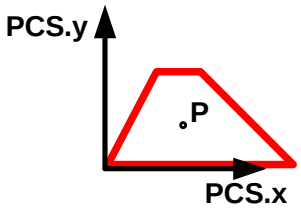


6.6 MC_TrackConveyorBelt

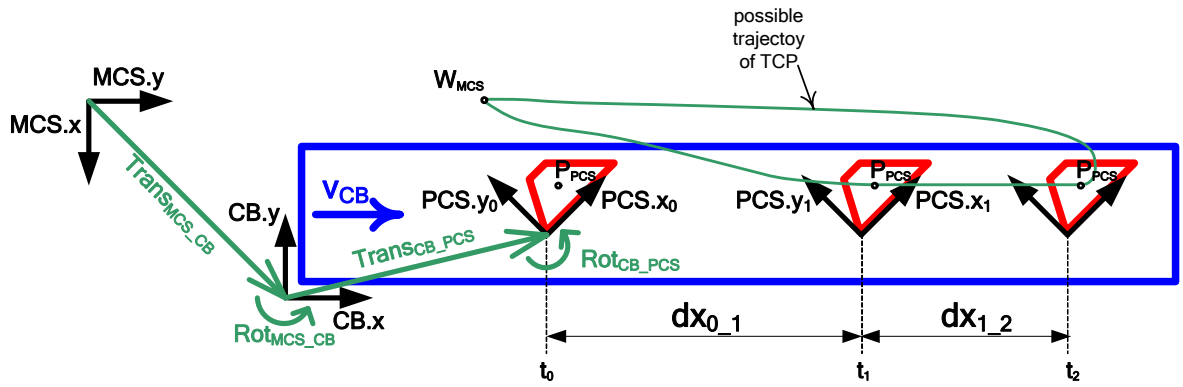
FB-Name		**MC_TrackConveyorBelt**		
This function block offers an abstraction layer for a conveyor belt, assisting the user with tracking objects moving on a straight line in space. The function block activates a dynamic calculation of the coordinate system transformation from MCS to the selected coordinate system of the axes group. The pose of the conveyor belt relative to MCS is given by a dedicated input of the FB. A further input specifies the initial pose of an object lying on the conveyor belt. The actual position, velocity, etc. of the conveyor belt is given by a single axis.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
	E	ConveyorBelt	AXIS_REF	Supplies the actual position, velocity, and etc. of the conveyor belt and thus the actual position of the object moved by the conveyor belt. The actual position is evaluated relative to the position of the conveyor belt when the FB had been started.
VAR_INPUT				
	B	Execute	BOOL	Start the action at rising edge
	B	ConveyorBeltOrigin	ARRAY [1..N] OF REAL	Specifies the pose of the conveyor belt relative to MCS. The conveyor belt might be shifted and/or rotated relative to MCS. This introduces a coordinate system of the conveyor belt in which the position of an object lying on the conveyor belt can be specified. The x-axis of the coordinate system of the conveyor belt has to point into the direction of movement of the conveyor belt.
	E	InitialObjectPosition	ARRAY [1..N] OF REAL	Specifies the pose of an object lying on the conveyor belt relative to the conveyor belt. The object might be shifted and/or rotated relative to the coordinate system of the conveyor belt.
	E	CoordSystem	ENUM	Selects the coordinate system which should be used for the implicit automatic calculation. This input is only necessary if the axes group supports more coordinate systems beside MCS than PCS. By default it could be PCS.
	E	BufferMode	MC_GROUP_BUFFER_MODE	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT				
	B	Done	BOOL	The transformation is set successfully
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the implicit calculation of the transformation is going on.
	E	CommandAborted	BOOL	Command is aborted by another command which changes the transformation for the selected coordinate system. This might be another ConveyorBelt, a RotaryTable or MC_SetCartesianTransform or MC_Set-CoordinateTransform.
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Note: This FB does not start any motion on itself. Motion is started by a motion command in PCS, and then the TCP is tracking the moving PCS, i.e. conveyor belt. This provides a coordinate system for the slave, following the master				



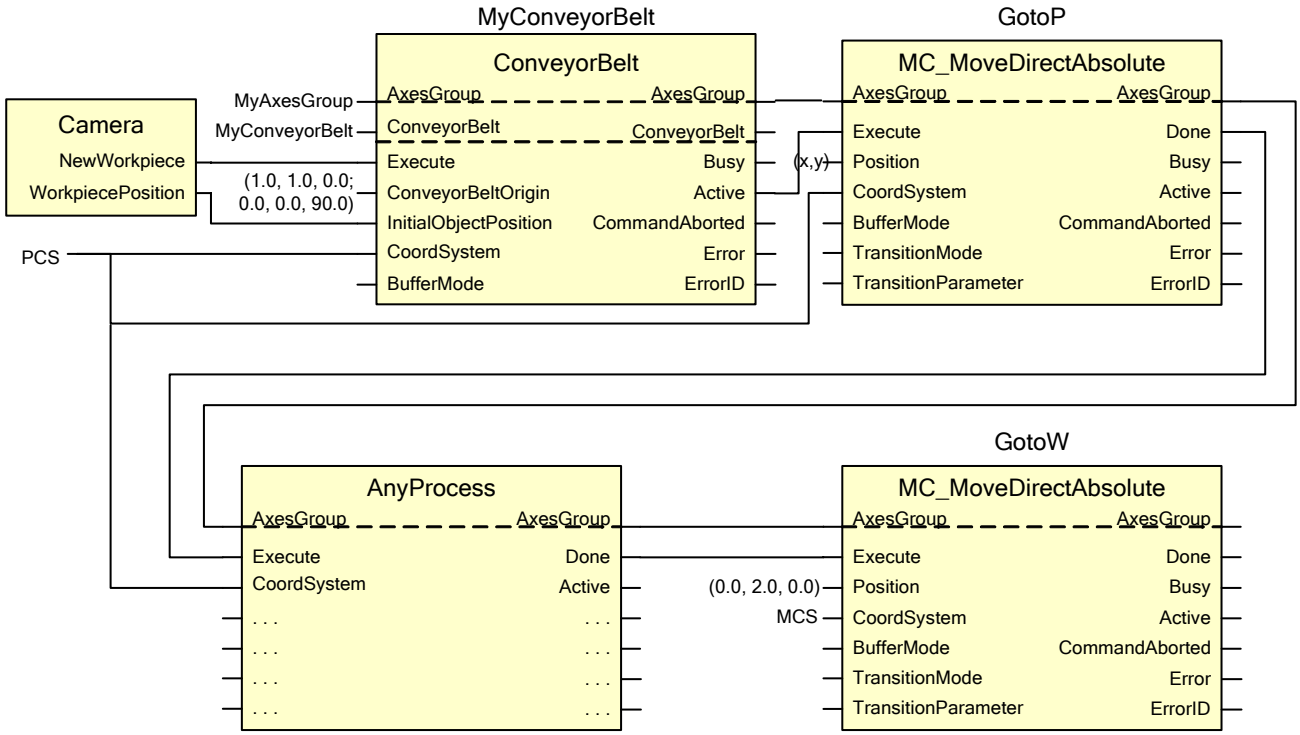
Following example should demonstrate the usage of the FB MC_TrackConveyorBelt.
The task is to manipulate a workpiece, starting from a certain position P_{PCS} (x_{PCS}; y_{PCS}; 0) on the workpiece.



The workpiece is lying on a conveyor belt (CB) which is moving with speed v_{CB}.
The workpiece is detected by a digital camera, which also provides the position (and orientation) of the workpiece relative to the conveyor belt when the workpiece is detected.
At point in time t_0, when the workpiece is detected by the camera, the FB MyConveyorBelt is executed. This activates the automatic calculation of the coordinate transformation MCS ↔ PCS. Activating MyConveyorBelt simultaneously executes the FB GotoP. The axes group starts to move from its waiting position W_{MCS} towards P_{PCS}.
At point in time t_1 the axes group has reached P_{PCS}. In meantime the conveyor belt has moved the distance dx_{0_1}. After having reached P_{PCS} the process can be started. All positions within the process have to be related to PCS. At point in time t_2 the process is finished and the axes group moves back to its waiting position W_{MCS}. A possible resulting trajectory of the TCP is drawn in the picture below.



The following examples demonstrate the usage:



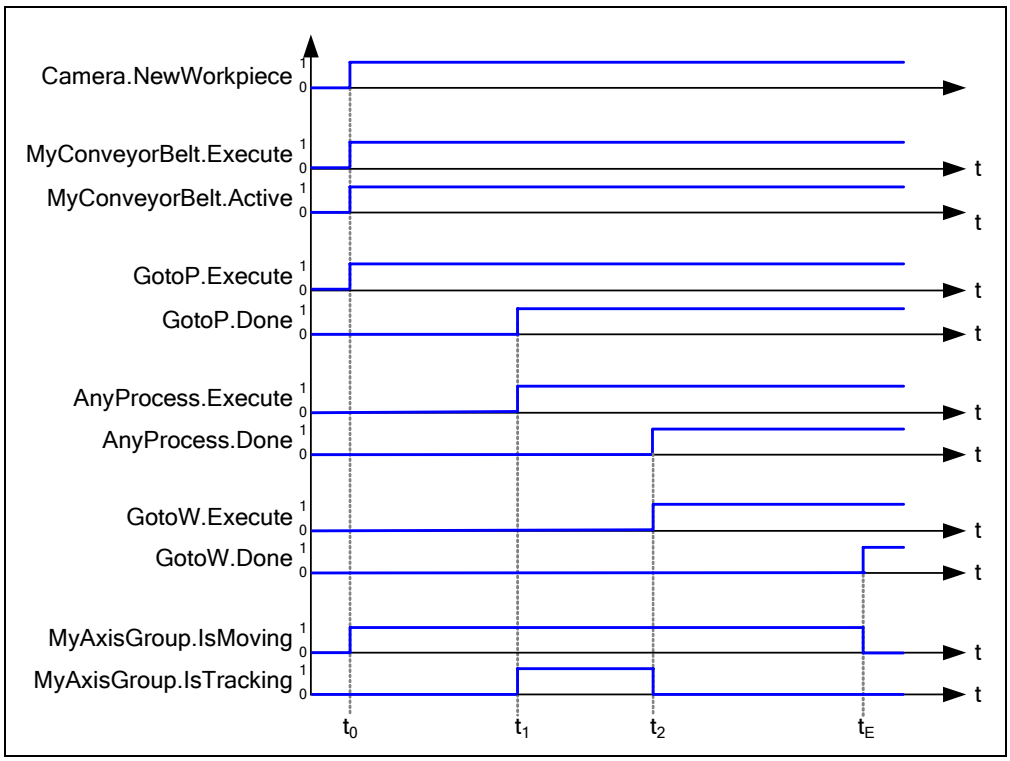
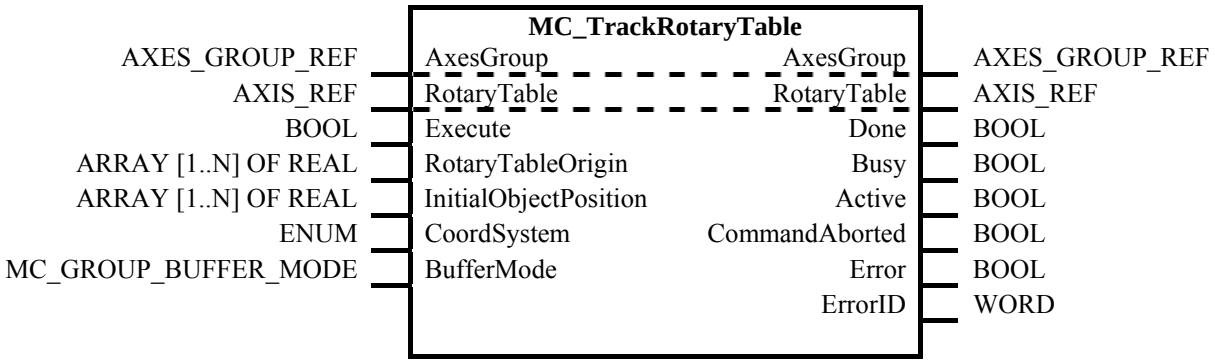


Figure 23: Example MC_TrackConveyorBelt

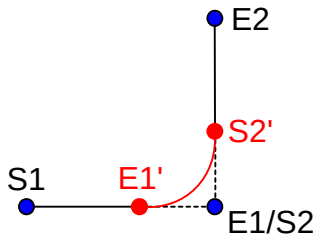
6.7 MC_TrackRotaryTable

FB-Name		**MC_TrackRotaryTable**		
This function block offers an abstraction layer for a rotary table, assisting the user with tracking objects moving on a circle in space. The pose of the rotary table relative to MCS is given by a dedicated input of the FB. A further input specifies the initial pose of an object lying on the rotary table. The actual position, velocity, etc. of the rotary table is given by the position of a single axis. The function block activates a dynamic calculation of the coordinate system transformation from MCS to the selected coordinate system of the axes group.				
VAR_IN_OUT				
	B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
	E	RotaryTable	AXIS_REF	Supplies the actual position, velocity, etc. of the rotary table and thus the actual position of the object moved by the rotary table. The actual position is evaluated relative to the position of the rotary table when the FB had been started.
VAR_INPUT				
	B	Execute	BOOL	Start the action at rising edge
	B	RotaryTableOrigin	ARRAY [1..N] OF REAL	Specifies the pose of the rotary table relative to MCS. The rotary table might be shifted and/or rotated relative to MCS. This results in a coordinate system of the rotary table in which the position of the object can be specified. The z-axis of the coordinate system of the rotary table has to be perpendicular to the rotary table.
	E	InitialObjectPosition	ARRAY [1..N] OF REAL	Specifies the pose of an object lying on the rotary table relative to the rotary table. The object might be shifted and/or rotated relative to the coordinate system of the rotary table.
	E	CoordSystem	ENUM	Selects the coordinate system that should be used for the implicit automatic calculation. This input is only necessary if the axes group supports more coordinate systems beside MCS than PCS. By default it could be PCS.
	E	BufferMode	MC_GROUP_BUFFER_MODE	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
VAR_OUTPUT				
	E	Done	BOOL	The transformation is set successfully
	E	Busy	BOOL	The FB is not finished
	E	Active	BOOL	Indicates that the implicit calculation of the transformation is going on.
	E	CommandAborted	BOOL	Command is aborted by another command which changes the transformation for the selected coordinate system. This might be another RotaryTable, a ConveyorBelt or MC_SetCartesianTransform or MC_Set-CoordinateTransform.
	B	Error	BOOL	Signals that an error has occurred within the function block
	E	ErrorID	WORD	Error identification
Notes: -				

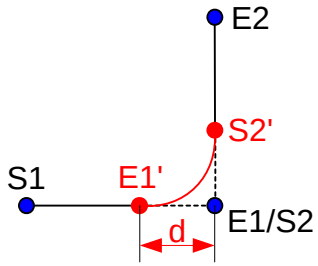

MC_TrackRotaryTable
AXES_GROUP_REF
AXIS_REF
BOOL
ARRAY [1..N] OF REAL
ARRAY [1..N] OF REAL
ENUM
MC_GROUP_BUFFER_MODE
AxesGroup
RotaryTable
Execute
RotaryTableOrigin
InitialObjectPosition
CoordSystem
BufferMode
AxesGroup
RotaryTable
Done
Busy
Active
CommandAborted
Error
ErrorID
AXES_GROUP_REF
AXIS_REF
BOOL
BOOL
BOOL
BOOL
BOOL
WORD

7 Details of Blending and Buffering of Movements

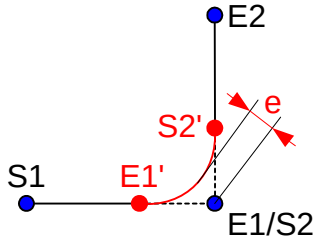
7.1 Terminological definitions



Contour curve: Inserted curve, which modifies the original path (E1' - S2').
Pre-block: Motion block before the contour curve (S1 – E1)
Post-block: Motion block after the contour curve (S2 – E2)
Corner distance: Distance (d) of the start point of the contour curve (E1') to the programmed target point (E1), see following figure.



Corner deviation: The shortest distance between the programmed corner point (E1/S2) and the contour curve (see following figure).



7.2 Input parameter for blending

The input parameter "TransitionMode", combined with the input "TransitionParameter", define the shape and dynamics of the inserted contour to connect the current motion block with the following motion block. For this purpose, the programmed motion blocks are modified. This parameter does not define the chronological execution time; this is given by the group specific input "BufferMode".
For each BufferMode a specific TransitionMode must be entered. The supported transition modes are supplier specific (see matrix of available transition modes).

Example: Input parameter BufferMode and TransitionMode in FB MC_MoveLinearAbsolute.

FB-Name		**MC_MoveLinearAbsolute**	
This function block commands an interpolated linear movement on an axes group from the actual position of the TCP to an absolute position in the specified coordinate system			
VAR_IN_OUT			
B	AxesGroup	AXES_GROUP_REF	Reference to a group of axes
VAR_INPUT			
B	Execute	BOOL	Start the motion at rising edge
B	Position	ARRAY [1..N] OF REAL	Array [1..N] of absolute end positions for each dimension in the specified coordinate system. The value of n is supplier specific. See 1.4 Glossary
E	Velocity	REAL	Maximum Velocity [u/s] for the path for the coordinate system in which the path is defined. Always positive. Not necessarily reached
E	Acceleration	REAL	Maximum acceleration. Always positive. Not necessarily reached
E	Deceleration	REAL	Maximum deceleration. Always positive. Not necessarily reached
E	Jerk	REAL	Maximum jerk. Always positive. Not necessarily reached
E	CoordSystem	ENUM	Reference to the applicable coordinate system: ACS, MCS, PCS
E	BufferMode	MC_Group BufferMode	Defines the chronological sequence of the FB relative to the previous block. Refer to Chapter 7.3 Buffer Modes
E	TransitionMode	MC_TRANSITION_MODE	See 2.4.3 Overview of Transition Mode.
E	Transition Parameter	ARRAY [1..N] OF REAL	Additional parameter for the transition mode (n = supplier specific)
VAR_OUTPUT			
B	Done	BOOL	Commanded end positions reached for all axes
E	Busy	BOOL	The FB is not finished
E	Active	BOOL	Indicates that the FB has control on the axis
E	CommandAborted	BOOL	Command is aborted by another command
B	Error	BOOL	Signals that an error has occurred within the function block
E	ErrorID	WORD	Error identification
Note: -			

7.3 Buffer Modes

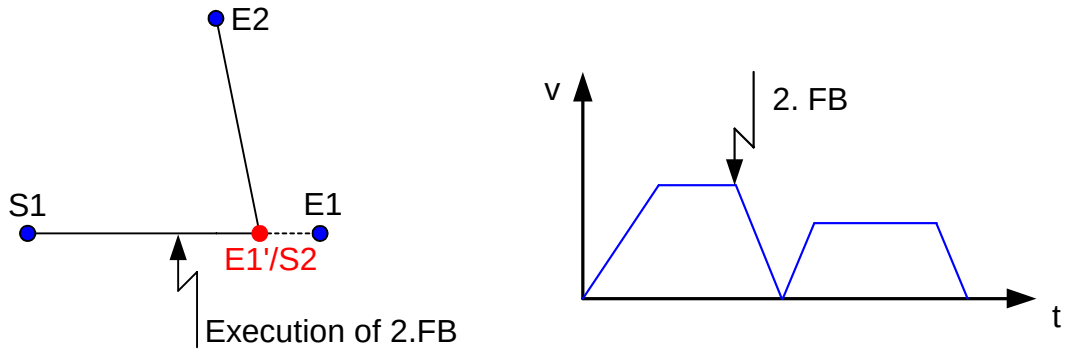
For axes group motions the same buffer modes are used as for single axis motions (ENUM of type MC_BUFFER_MODE).

No.	MC_BUFFER_MODE	Description
0	Aborting	Start FB immediately (default mode)
1	Buffered	Start FB after current motion has finished
2	BlendingLow	The velocity is blended with the lowest velocity of both FBs
3	BlendingPrevious	The velocity is blended with the velocity of the first FB
4	BlendingNext	The velocity is blended with velocity of the second FB
5	BlendingHigh	The velocity is blended with highest velocity of both FBs

Table 6: Overview of buffer modes

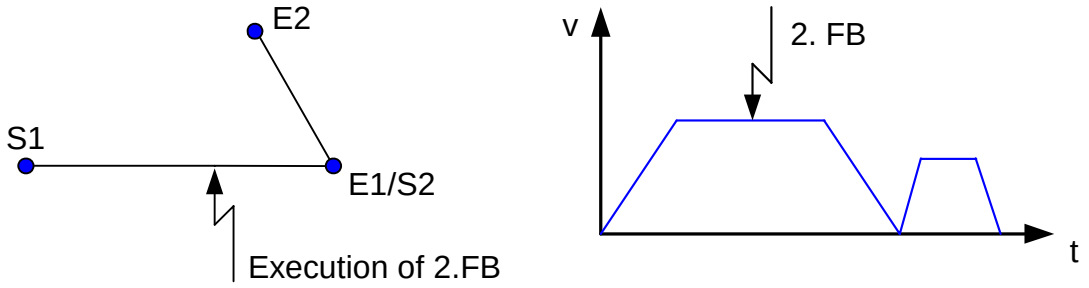
7.3.1 BufferMode "Aborting"

A FB with buffer mode "Aborting" aborts an ongoing motion and starts the new motion immediately.
The following figure shows just an example for buffer mode "Aborting". In this example the first motion is stopped and then the next motion is started.
The available transition modes are described later.



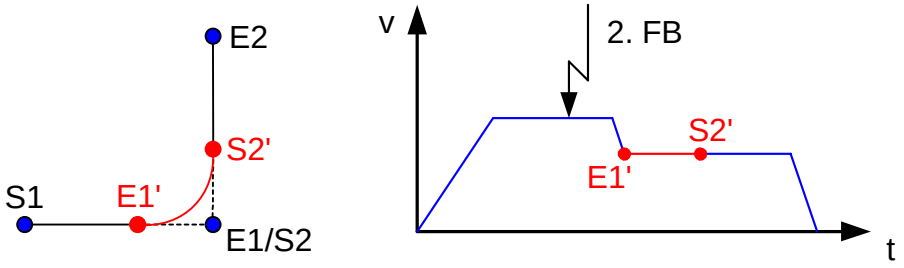
7.3.2 BufferMode "Buffered"

The next FB affects the axes group as soon as the previous motion is "Done". There is no blending, so the input TransitionMode is not evaluated.



7.3.3 BufferMode "Blending"

The current and the next motion FBs are blended, so the axes group will not stop between the motions. The velocity is blended according to the specified blending modes (BlendingLow, BendingPrevious, BlendingNext, BlendingHigh). The transition contour is defined by the input parameter TransitionMode.
The following figure shows just an example for buffer mode „BlendingNext". The available transition modes are described later.



7.4 TransitionMode

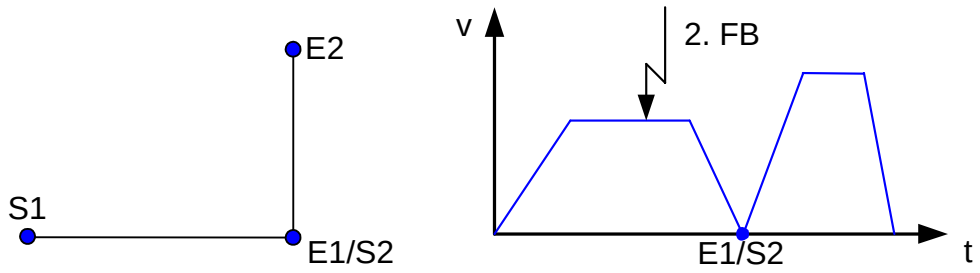
Depending on the transition mode different supplier specific transition parameters can be given, which characterize the contour curve.
The basic transition modes are defined. Other modes as well as supplier specific modes can be added.

No.	MC_TRANSITION_MODE	Description
0	TMNone	Insert no transition curve (default mode)
1	TMStartVelocity	Transition with given start velocity
2	TMConstantVelocity	Transition with given constant velocity
3	TMCornerDistance	Transition with given corner distance
4	TMMaxCornerDeviation	Transition with given maximum corner deviation
5 - 9	Reserved by PLCopen	
10 -…	Supplier specific modes	

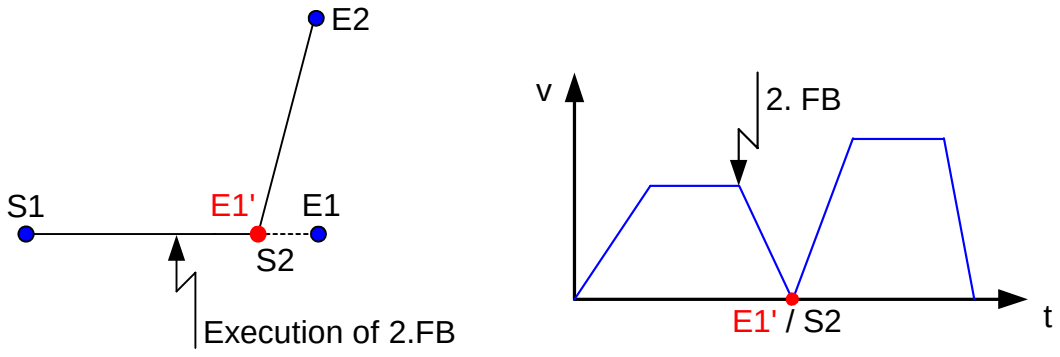
Table 7: Overview of available transition modes

7.4.1 TransitionMode “TMNone” (insert no transition curve)

The motion blocks are not modified and no transition curve is inserted. This is the only possible transition mode for buffer mode „Buffered”.
Any „Blending” buffer mode with this transition mode results to the same block transition like buffer mode „Buffered” (see following figure).

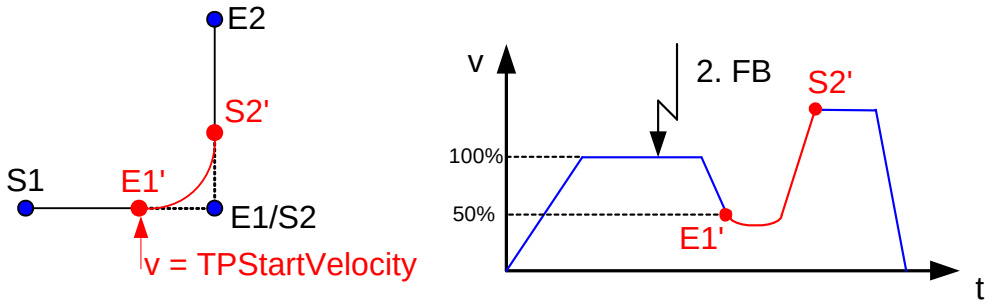


The following figure shows the contour for BufferMode “Aborting”.



7.4.2 TransitionMode “TMStartVelocity” (Transition with given maximum velocity)

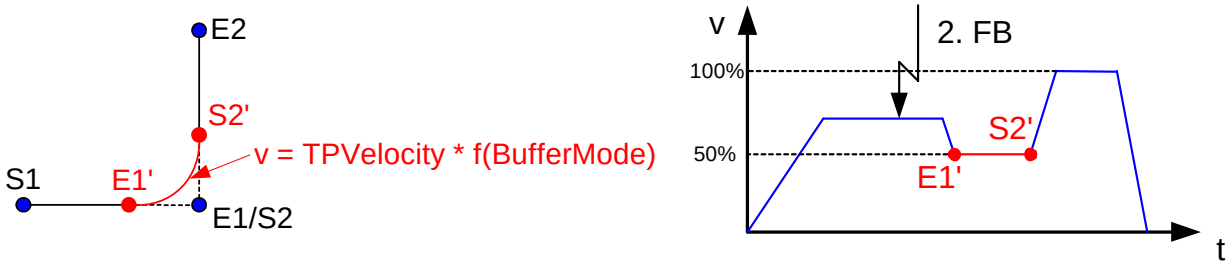
In this type of contouring, the corner distance of the contour curve is defined by a specified maximum percentage value “TPStartVelocity” of the programmed velocity of the pre-block in order to start the curve.
The blending modes in the BufferMode are not evaluated for this TransitionMode.
The velocity on the contour curve does not have to be constant.
If e.g., TPStartVelocity = 50%, the contour curve is started after the velocity has reached 50% of the velocity programmed in the pre-block during deceleration.



TransitionParameter	Description
TPStartVelocity <expr>	Maximum velocity in percent of pre-block

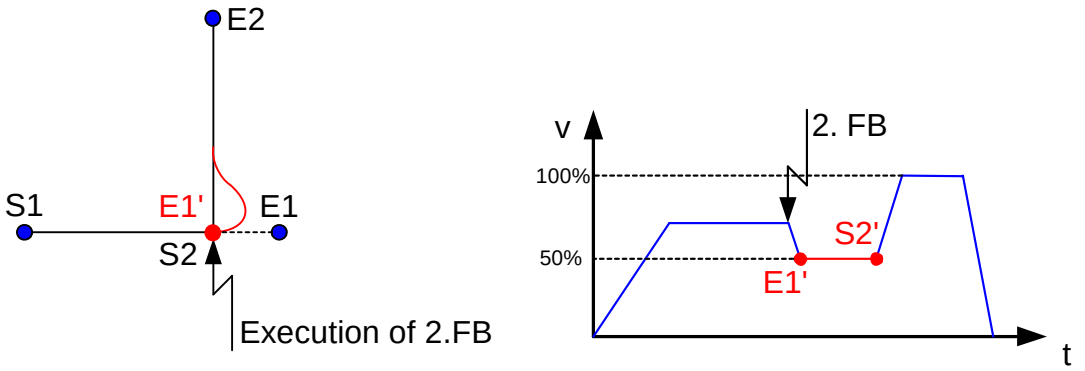
7.4.3 TransitionMode “TMConstantVelocity”(Transition with given constant velocity)

In this type of contouring, the contour curve is dimensioned in a manner, that the curve can be traversed with a constant specified percentage value “TPVelocity” of the transition velocity that results out of MC_BUFFER_MODE of the next motion block. If e.g. TPVelocity = 50%, the contour curve is traversed with half the velocity that results out of the buffer mode of the next motion block.
Because of the curvature of the contour and the given maximum acceleration of the axis nevertheless it is possible, that the desired velocity is not reached.
The following figure shows the contour for a „blending” BufferMode.



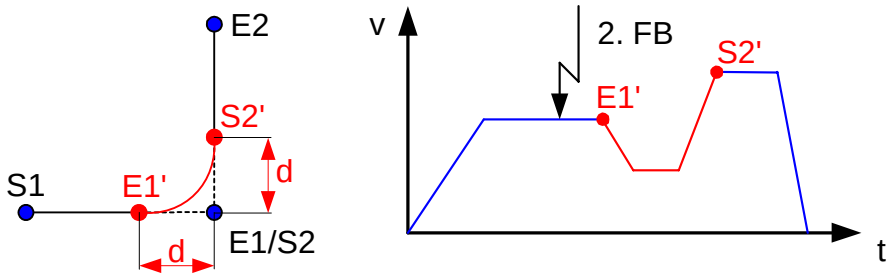
TransitionParameter	Description
TPVelocity <expr>	Velocity value in percent

For BufferMode “Aborting” the following contour curve is generated. The motion of the first FB is aborted and it is tried in a user specific way to get back to the commanded path.



7.4.4 TransitionMode “TMCornerDistance” (Transition with given corner distance)

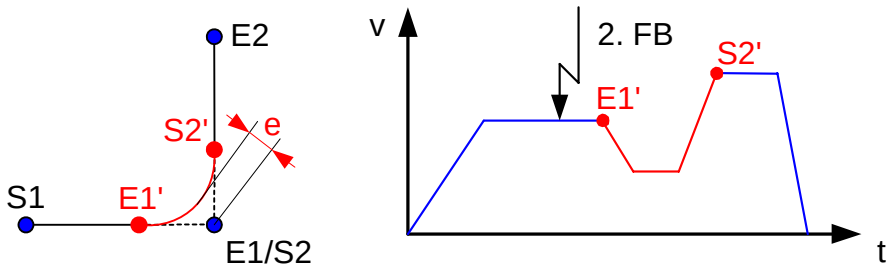
If the position, where the original contour can be left is known, the user can specify the corner distance of the pre- and post-block, by which the bordering motion blocks are to be shortened, explicitly.
The transition velocity is defined by the BufferMode. Because of the curvature of the contour and the given maximum acceleration of the axis nevertheless it is possible, that the desired velocity is not reached.



TransitionParameter	Description
TPCornerDistance <expr>	Distance (d) to the corner of the deviation and the return point from the original contour.

7.4.5 TransitionMode “TMMaxCornerDeviation” (Transition with given maximum corner deviation)

The corner distances, by which the bordering motion blocks are shortened, are automatically determined upon geometrical considerations in such a manner that the given corner deviation is not exceeded.
The transition velocity is defined by the BufferMode. Because of the curvature of the contour and the given maximum acceleration of the axis nevertheless it is possible, that the desired velocity is not reached.



TransitionParameter	Description
TPCornerDeviation <expr>	Corner deviation (e), the shortest distance between the programmed corner point and the contour curve.

Appendix 1. Compliance Procedure and Compliance List

Listed in this Appendix are the requirements for the compliance statement from the supplier of the Motion Control Function Blocks. The compliance statement consists of two main groups: supported data types (see Appendix 1.2 Supported Data types) and supported Function Blocks, in combination with the applicable inputs and outputs (see Appendix 1.2 Supported Data types and its paragraphs). The supplier is required fill out the tables for the used data types and Function Blocks, according to their product, committing their support to the specification.

By submitting these tables to PLCopen, and after approval by PLCopen, the list will be published on the PLCopen website, www.plcopen.org , as well as a shortform overview, as specified in Appendix 1.5 Short overview of the Function Blocks.

In addition to this approval, the supplier is granted access and usage rights of the PLCopen Motion Control logo, as described in chapter Appendix 1.6 The PLCopen Motion Control Logo and Its Usage.

Data types
The data type REAL listed in the Function Blocks and parameters (e.g. for velocity, acceleration, distance, etc.) may be exchanged to SINT, INT, DINT or LREAL without to be seen as incompliant to this standard, as long as they are consistent for the whole set of Function Blocks and parameters.
Implementation allows the extension of data types as long as the basic data type is kept. For example: WORD may be changed to DWORD, but not to REAL.

Function Blocks and Inputs and Outputs
An implementation which claims compliance with this PLCopen specification shall offer a set of Function Blocks for motion control, meaning one or more Function Blocks, with at least the **basic** input and output variables, marked as "**B**" in the tables. These inputs and outputs have to be supported to be compliant.
For higher-level systems and future extensions any subset of the **extended** input and output variables, marked as "**E**" in the tables can be implemented.
Vendor specific additions are marked with "**V**", and can be listed as such in the supplier documentation.

- **Basic** input/output variables are mandatory Marked in the tables with the letter "**B**"
- **Extended** input /output variables are optional Marked in the tables with the letter "**E**"
- **Vendor Specific** additions Marked in the vendor's compliance documentation with "**V**"

All the vendor specific items will not be listed in the comparison table on the PLCopen website, but in the detailed vendor specific list, which also is published.
All vendor specific in- and outputs of all FBs must be listed in the certification list of the supplier. With this, the certification listing from a supplier describes all the I/Os of the relevant FBs, including vendor-specific extensions, and thus showing the complete FBs as used by the supplier.

Appendix 1.1. Statement of Supplier

Supplier name	
Supplier address	
City	
Country	
Telephone	
Fax	
Email address	
Product Name	
Product version	
Release date	

I hereby state that the following tables as filled out and submitted do match our product as well as the accompanying user manual, as stated above.

Name of representation (person):

Date of signature (dd/mm/yyyy):

Signature:

Appendix 1.2. Supported Data types

Defined datatypes with MC library:	Supported	If not supported, which datatype used
BOOL		
INT		
WORD		
REAL		
ENUM		

Table 8: Supported datatypes

Within the specification the following derived datatypes are defined. Which structure is used in this system:

Derived datatypes:	Where used	Supported	Which structure
AXES_GROUP_REF	Nearly all FBs		
IDENT_IN_GROUP_REF	MC_AddAxisToGroup MC_RemoveAxisFromGroup		
MC_BUFFER_MODE	In all buffered FBs		
MC_KIN_REF	MC_SetKinTransform MC_ReadKinTransform		
MC_EXECUTION_MODE	MC_SetKinTransform		
MC_COORD_REF	MC_SetCoordinateTransformation		
MC_GROUP_BUFFER_MODE	MC_MoveLinearAbsolute MC_MoveCircularAbsolute		
MC_TRANSITION_MODE	MC_MoveLinearAbsolute MC_MoveLinearRelative MC_MoveCircularAbsolute MC_MoveCircularRelative		
MC_CIRC_PATHCHOICE	MC_MoveCircularAbsolute MC_MoveCircularRelative		
MC_PATH_DATA_REF MC_PATH_REF	MC_PathSelect MC_MovePath		

Table 9: Supported derived datatypes

Appendix 1.3. Supported Buffer Modes

No.	MC_BUFFER_MODE	Supported
0	Aborting	
1	Buffered	
2	BlendingLow	
3	BlendingPrevious	
4	BlendingNext	
5	BlendingHigh	

Table 10: Overview of buffer modes

Appendix 1.4. Supported Transition Modes

No.	MC_TRANSITION_MODE	Supported
0	TMNone	
1	TMMaxVelocity	
2	TMDefinedVelocity	
3	TMCornerDistance	
4	TMMaxCornerDeviation	
5 - 9	Reserved by PLCopen	
10 -…	Supplier specific modes	

Table 11: Overview of available transition modes

Appendix 1.5. Short overview of the Function Blocks

Coordinated Function Blocks	Supported Yes / No	Comments (<= 48 char.)
MC_AddAxisToGroup		
MC_RemoveAxisFromGroup		
MC_UngroupAllAxes		
MC_GroupReadConfiguration		
MC_GroupEnable		
MC_GroupDisable		
MC_GroupHome		
MC_SetKinTransform		
MC_SetCartesianTransform		
MC_SetCoordinateTransform		
MC_ReadKinTransform		
MC_ReadCartesianTransform		
MC_ReadCoordinateTransform		
MC_GroupSetPosition		
MC_GroupReadActualPosition		
MC_GroupReadActualVelocity		
MC_GroupReadActualAcceleration		
MC_GroupStop		
MC_GroupHalt		
MC_GroupInterrupt		
MC_GroupContinue		
MC_GroupReadStatus		
MC_GroupReadError		
MC_GroupReset		
MC_MoveLinearAbsolute		
MC_MoveLinearRelative		
MC_MoveCircularAbsolute		
MC_MoveCircularRelative		
MC_MoveDirectAbsolute		
MC_MoveDirectRelative		
MC_PathSelect		
MC_MovePath		
MC_GroupSetOverride		
Coordinated	**Supported Yes / No**	**Comments (<= 48 char.)**
MC_SyncAxisToGroup		
MC_SyncGroupToAxis		
MC_SetDynCoordTransform		
MC_TrackConveyorbelt		
MC_TrackRotaryTable		

Table 12: Short overview of the Function Blocks

Appendix A 5.1. MC_AddAxisToGroup

If Supported	**MC_AddAxisToGroup**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
B	Axis		
VAR_INPUT			
B	Execute		
E	IdentInGroup		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.2. MC_RemoveAxixFromGroup

If Supported	**MC_RemoveAxisFromGroup**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
E	IdentInGroup		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.3. MC_UngroupAllAxes

If Supported	**MC_UngroupAllAxes**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.4. MC_GroupReadConfiguration

If Supported	**MC_GroupReadConfiguration**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
B	IdentInGroup		
E	CoordSystem		
VAR_OUTPUT			
B	Axis		
B	Valid		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.5. MC_GroupEnable

If Supported	**MC_GroupEnable**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.6. MC_GroupDisable

If Supported	**MC_GroupDisable**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.7. MC_GroupHome

If Supported	**MC_GroupHome**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	Position		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.8. MC_SetKinTransform

If Supported	**MC_SetKinTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
E	KinTransform		
E	ExecutionMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.9. MC_SetCartesianTransform

If Supported	**MC_ SetCartesianTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	TransX		
B	TransY		
B	TransZ		
B	RotAngle1		
B	RotAngle2		
B	RotAngle3		
E	ExecutionMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.10. MC_SetCoordinateTransform

If Supported	**MC_ SetCoordinateTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
E	CoordTransform		
E	ExecutionMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.11. MC_ReadKinTransform

If Supported	**MC_ ReadKinTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	KinTransform		
B	Error		
E	ErrorID		

Appendix A 5.12. MC_ReadCartesianTransform

If Supported	**MC_ ReadCartesianTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	TransX		
B	TransY		
B	TransZ		
B	RotAngle1		
B	RotAngle2		
B	RotAngle3		
B	Error		
E	ErrorID		

Appendix A 5.13. MC_ReadCoordinateTransform

If Supported	**MC_ ReadCoordinateTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	CoordTransform		
B	Error		
E	ErrorID		

Appendix A 5.14. MC_GroupSetPosition

If Supported	**MC_ GroupSetPosition**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	Position		
E	Relative		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.15. MC_GroupReadActualPosition

If Supported	**MC_ GroupReadActualPosition**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
E	CoordSystem		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	Error		
E	ErrorID		
B	Position		

Appendix A 5.16. MC_GroupReadActualVelocity

If Supported	**MC_ GroupReadActualVelocity**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
E	CoordSystem		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	Error		
E	ErrorID		
B	Velocity		
E	PathVelocity		

Appendix A 5.17. MC_GroupReadActualAcceleration

If Supported	**MC_ GroupReadActualAcceleration**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
E	CoordSystem		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	Error		
E	ErrorID		
B	Acceleration		
E	Path Acceleration		

Appendix A 5.18. MC_GroupStop

If Supported	**MC_ GroupStop**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
E	Deceleration		
E	Jerk		
E	BufferMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.19. MC_GroupHalt

If Supported	**MC_ GroupHalt**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
E	Deceleration		
E	Jerk		
E	BufferMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.20. MC_GroupInterrupt

If Supported	**MC_ GroupInterrupt**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
E	Deceleration		
E	Jerk		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Comman Aborted		
B	Error		
E	ErrorID		

Appendix A 5.21. MC_GroupContinue

If Supported	**MC_ GroupContinue**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Comman Aborted		
B	Error		
E	ErrorID		

Appendix A 5.22. MC_GroupReadStatus

If Supported	**MC_ GroupReadStatus**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	GroupMoving		
B	GroupHoming		
B	GroupErrorStop		
B	GroupStandby		
B	GroupStopping		
B	GroupDisabled		
E	ConstantVelocity		
E	Accelerating		
E	Decelerating		
E	InPosition		
B	Error		
E	ErrorID		

Appendix A 5.23. MC_GroupReadError

If Supported	**MC_ GroupReadError**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
VAR_OUTPUT			
B	Valid		
E	Busy		
B	Error		
E	ErrorID		
B	GroupErrorID		

Appendix A 5.24. MC_GroupReset

If Supported	**MC_ GroupReset**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.25. MC_MoveLinearAbsolute

If Supported	**MC_ MoveLinearAbsolute**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	Position		
E	Velocity		
E	Acceleration		
E	Deceleration		
E	Jerk		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.26. MC_MoveLinearRelative

If Supported	**MC_ MoveLinearRelative**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	Distance		
E	Velocity		
E	Acceleration		
E	Deceleration		
E	Jerk		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.27. MC_MoveCircularAbsolute

If Supported	**MC_ MoveCircularAbsolute**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	CircMode		
B	AuxPoint		
B	EndPoint		
E	PathChoice		
E	Velocity		
E	Acceleration		
E	Deceleration		
E	Jerk		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.28. MC_MoveCircularRelative

If Supported	**MC_ MoveCircularRelative**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	CircMode		
B	AuxPoint		
B	EndPoint		
E	PathChoice		
E	Velocity		
E	Acceleration		
E	Deceleration		
E	Jerk		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.29. MC_MoveDirectAbsolute

If Supported	**MC_ MoveDirectAbsolute**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	Position		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.30. MC_MoveDirectRelative

If Supported	**MC_ MoveDirectRelative**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Execute		
B	Distance		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.31. MC_PathSelect

If Supported	**MC_ PathSelect**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
B	PathData		
B	PathDescription		
VAR_INPUT			
B	Execute		
E	CoordSystem		
VAR_OUTPUT			
B	Done		
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.32. MC_MovePath

If Supported	**MC_ MovePath**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
B	PathData		
VAR_INPUT			
B	Execute		
E	CoordSystem		
E	BufferMode		
E	TransitionMode		
E	TransitionParameter		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.33. MC_GroupSetOverride

If Supported	**MC_ GroupSetOverride**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
VAR_INPUT			
B	Enable		
B	VelFactor		
E	AccFactor		
E	JerkFactor		
VAR_OUTPUT			
B	Enabled	BOOL	
E	Busy		
B	Error		
E	ErrorID		

Appendix A 5.34. MC_SyncAxisToGroup

If Supported	**MC_ SyncAxisToGroup**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
B	SlaveAxis		
VAR_INPUT			
B	Execute		
E	RatioNumerator		
E	RatioDenominator		
E	Acceleration		
E	Deceleration		
E	Jerk		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
B	InSync		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.35 MC_SyncGroupToAxis

If Supported	**MC_ SyncGroupToAxis**	Sup.Y/N	Comments
VAR_IN_OUT			
B	Master		
B	AxesGroup		
B	PathData		
VAR_INPUT			
B	Execute		
E	Mode		
E	TuCNumerator		
E	TuCDenominator		
E	Acceleration		
E	Deceleration		
E	Jerk		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
B	InSync		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.36. MC_SetDynCoordTransform

If Supported	**MC_ SetDynCoordTransform**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
B	MasterAxesGroup		
B	CoordTransform		
VAR_INPUT			
B	Execute		
E	Mode		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.37. MC_TrackConveyorBelt

If Supported	**MC_ TrackConveyorBelt**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
E	ConveyorBelt		
VAR_INPUT			
B	Execute		
B	ConveyorBeltOrigin		
E	InitialObjectPosition		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
B	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix A 5.38. MC_TrackRotaryTable

If Supported	**MC_ TrackRotaryTable**	Sup.Y/N	Comments
VAR_IN_OUT			
B	AxesGroup		
E	RotaryTable		
VAR_INPUT			
B	Execute		
B	RotaryTableOrigin		
E	InitialObjectPosition		
E	CoordSystem		
E	BufferMode		
VAR_OUTPUT			
E	Done		
E	Busy		
E	Active		
E	CommandAborted		
B	Error		
E	ErrorID		

Appendix 1.6. The PLCopen Motion Control Logo and Its Usage

For quick identification of compliant products, PLCopen has developed a logo for the motion control Function Blocks:

Figure 24: The PLCopen Motion Control Logo

This motion control logo is owned and trademarked by PLCopen.

In order to use this logo free-of-charge, the relevant company has to fulfill all the following requirements:

1. the company has to be a voting member of PLCopen;
2. the company has to comply with the existing specification, as specified by the PLCopen Task Force Motion Control, and as published by PLCopen, and of which this statement is a part;
3. this compliance application is provided in written form by the company to PLCopen, clearly stating the applicable software package and the supporting elements of all the specified tables, as specified in the document itself;
4. in case of non-fulfillment, which has to be decided by PLCopen, the company will receive a written statement concerning this from PLCopen. The company will have a one month period to either adopt their software package in such a way that it complies, represented by the issuing of a new compliance statement, or remove all reference to the specification, including the use of the logo, from all their specification, be it technical or promotional material;
5. the logo has to be used as is - meaning the full logo. It may be altered in size providing the original scale and color setting is kept.
6. the logo has to be used in the context of Motion Control.