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SIMOTION Web Accumulator

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Siemens AG
Division Digital Factory
Postfach 48 48
90026 NÜRNBERG
Germany

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1 Basic information and data

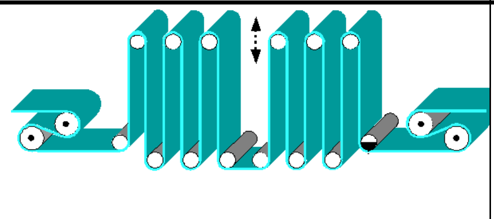
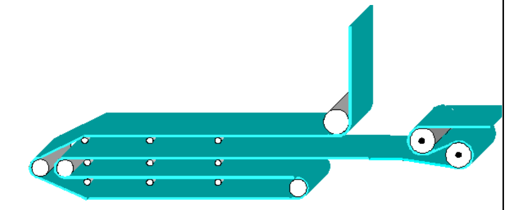
1.1 Mechanical description

A web accumulator works per definition as a material buffer. This functionality is needed for realizing reel changes of un- or rewinders without interrupting the process. By doing so the productivity of the machine is increased.

Typically, a web accumulator is found behind an unwinder or before a rewinder. With the web accumulator slowing down the winders it is possible to enable a reel change without stopping the machine.

Examples for web accumulators:

figure 1-1: variations of web accumulators

vertically	horizontally
	

Usually an accumulator consists of the accumulator axis, which buffers the material, accompanied with a feeder axis and a dancer roll or load measuring cell to maintain proper web tension. A web accumulator is made for decoupling the winder from the converting process. E.g. reel changes without varying the machine speed or stopping the machine are possible.

If the accumulator is driven by multiple mechanically coupled motors, the control technology coupling must be realized outside of the application, e.g. with a virtual axis, position gearing or velocity gearing.

1.2 Typical areas of the application

Machines, where an accumulator is required to enable material intake or uptake during winder coil change without stopping the converting process.

1.3 Prerequisites

It is necessary to have a good understanding of SIMOTION, SCOUT Engineering and at least a basic understanding of the technological function.

The application is available as a SIMOTION library programmed in the Structured Text programming language. The application strictly depends on the presence of the Converting Library LConLib, which is also available in SIOS (https://support.industry.siemens.com/cs/ww/en/view/48805235)

1.3.1 Target group

Projecting engineers, who have experience with SIMOTION and aim to implement accumulator functionality in a converting machine.

1.3.2 Technical environment

This application is intended to be used in a SIMOTION Motion Control environment.

1.4 Objective and purpose of this standard application

This SIMOTION standard application was developed with the objective of creating a flexible solution for controlling and automating converting machines where an accumulator is used. It can be fitted to ones needs by parametrization due to the fact, that it is open source.

1.5 Advantages of the standard application

When the standard application SIMOTION Web Accumulator is used, it offers users the following advantages.

- Reduction of engineering time
- Easy adaptation with parametrization
- Transparency (open source code)
- Worldwide support
- Continuous updates

2 Functions of the application

2.1 Core functions

The application SIMOTION Web Accumulator realizes storage functionality for automatic reel changes for winders. It calculates the speed setpoint for the accumulator and the infeed. It is working independently from the SIMOTION Winder standard application and is not included in it.

The core functionality is realized with a function block for controlling and calculating the necessary signals and setpoints. The function block must be parametrized correspondingly to its use.

The core functionality can/must be adapted outside of the function block.

In particular this this means:

- activating axes
- free jogging operations
- free positioning operations

NOTE For implementing basis axis functionality reference is made to the applications SIMOTION Axis Function Block or SIMOTION Line Axis. The mentioned functionality can be combined and expanded.

2.2 Accumulator modes

An accumulator can be used both in conjunction with an unwinder or a rewinder.

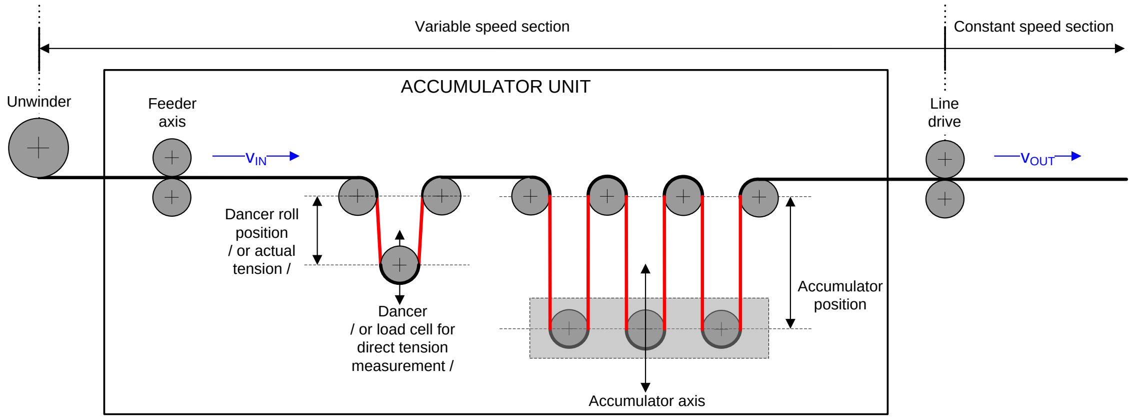
If it is used together with an unwinder it acts as material source during coil change, which means, that the buffer must be filled before the role change and refilled afterwards.

If it is used together with a rewinder, it is used to buffer the material while the rewinder is stopped for coil change, which means the buffer must be empty before the role change and be depleted afterwards.

In both modes the accumulator axis is working as a slave of the feed axis. Therefore, the different states are defined by the state of the feed axis. The accumulator axis has two states: standstill or moving – aside emergency stop.

2.2.1 Accumulator with unwinder

Figure 2-1: Accumulator with unwinder



In this mode the input speed of the accumulator is variable, and the output speed is constant. The converting process is located behind the accumulator.

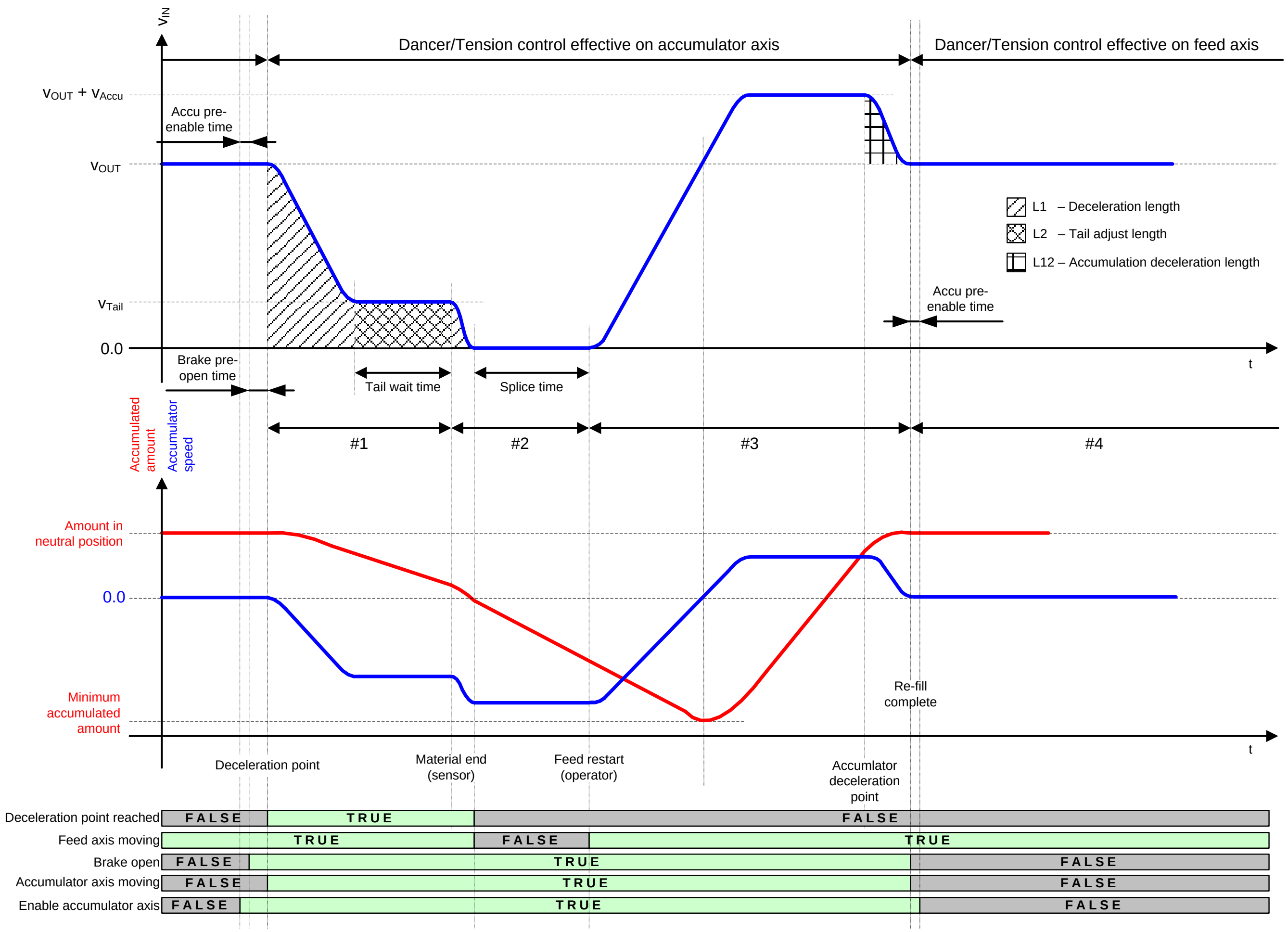
The accumulator is normally filled in its neutral position. After the rest length of the material on the unwinder reaches the brake point, the feed axis (and so the unwinder) will be decelerated. If format length accuracy is not required, it decelerates to standstill. If format length accuracy is required, it decelerates down to tail positioning speed. The brake point is equal to the material amount, which is transported by the feed during deceleration with specified dynamics and rest length.

If the configured tail velocity is valid, the material end must be detected and signaled to the accumulator. After the splice, the unwinder is restarted, the accumulator is re-filled with material. As long as the output speed is higher than the input speed, the amount of material in the accumulator is decreasing. Before the accumulator is completely refilled, the feed axis is decelerated to the output speed under consideration of deceleration length. If the accumulator is in neutral position and the output of the technology controller is below a defined threshold value, the accumulator will be locked into this position until the next reel change.

Before the accumulator axis starts movement, the brake must be opened. Since mechanical brakes cannot react instantly, the delay time must be considered. The axis must be enabled before opening the brake and stay enabled until the brake has closed. The brake can be controlled with an output signal.

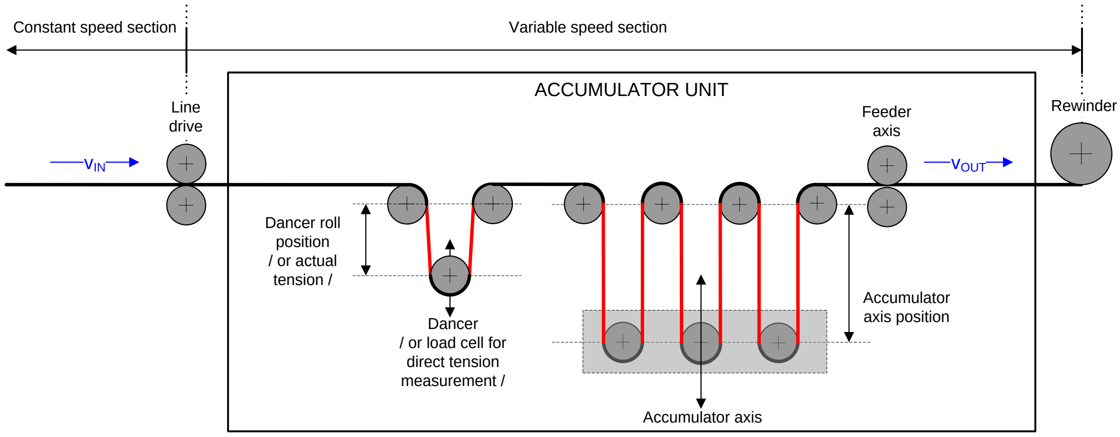
The changeover period is to be seen on the next time diagram in detail.

Figure 2-2: signal diagramm accumulator with unwinder



2.2.2 Accumulator with rewinder

Figure 2-3: Accumulator with rewinder



In this mode the output speed of the accumulator is variable, and the input speed is constant. The converting process is located in front of the accumulator.

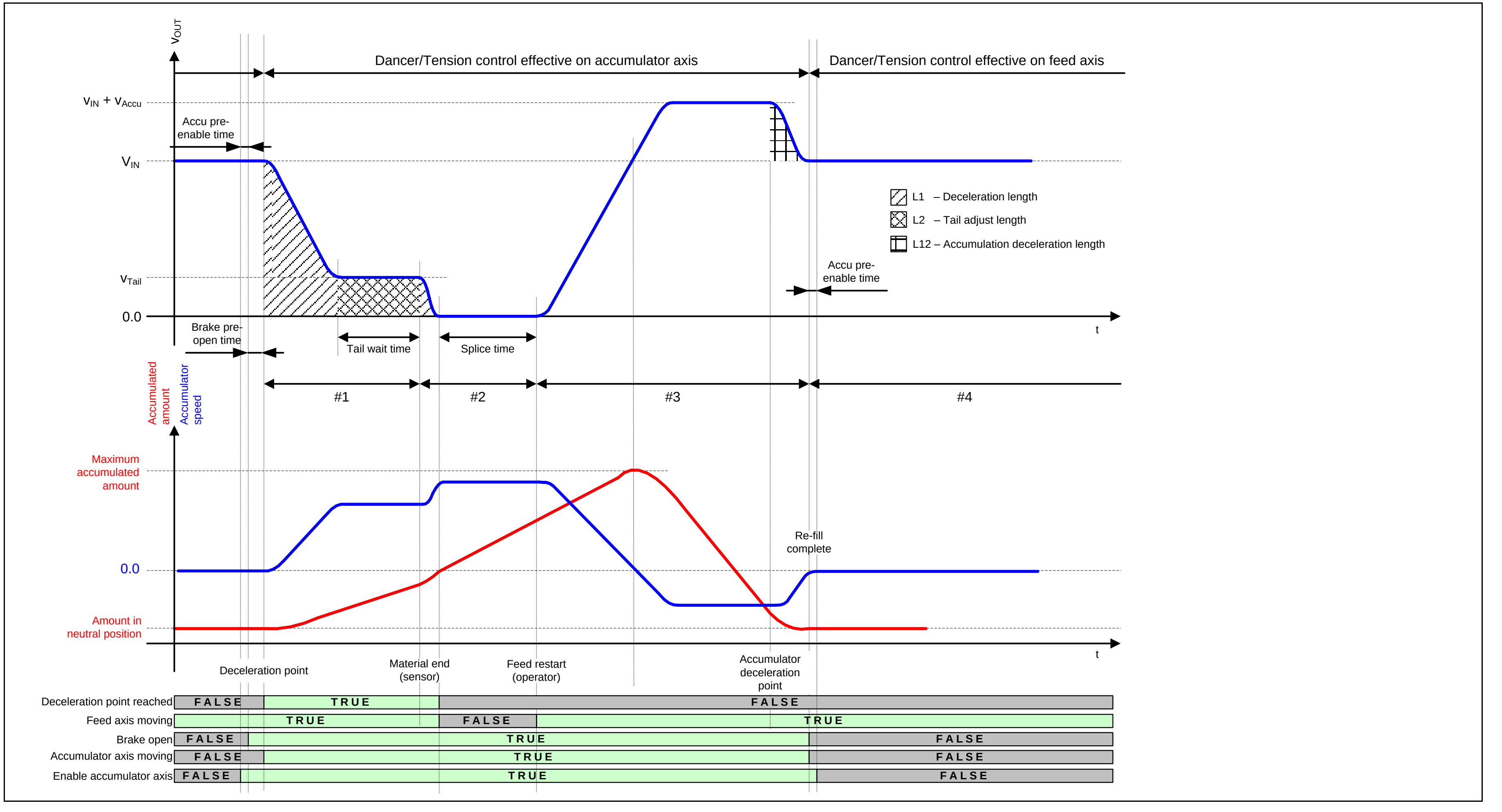
The accumulator is normally empty in its neutral position. After the material length of the rewinder reaches the brake point, the feed axis (and so the unwinder) will be decelerated. If format length accuracy is not required, it decelerates to standstill. If format length accuracy is required, it decelerates down to tail positioning speed. The brake point is equal to the material amount, which is transported by the feed during deceleration with specified dynamics and rest length.

If the configured tail velocity is valid, the material end must be detected and signaled to the accumulator. After the splice, the rewinder is restarted, the accumulator will be depleted. As long as the output speed is lower than the input speed, the amount of material in the accumulator is increasing. Before the accumulator is completely empty, the feed axis is decelerated to the intput speed under consideration of deceleration length. If the accumulator is in neutral position and the output of the technology controller is below a defined threshold value, the accumulator will be locked into this position until the next reel change.

Before the accumulator axis starts movement, the brake must be opened. Since mechanical brakes cannot react instantly, the delay time must be considered. The axis must be enabled before opening the brake and stay enabled until the brake has closed. The brake can be controlled with an output signal.

The changeover period is to be seen on the next time diagram in detail.

Figure 2-4: signal diagram accumulator with rewinder



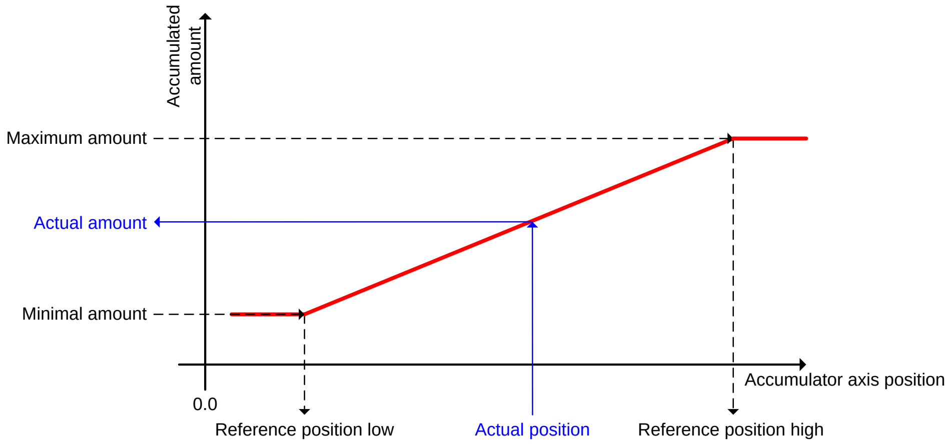
2.3 Properties and features of the core function

The most important function of the application is to calculate velocity setpoint for the feed and accumulator axes. Several other functions are also implemented in this application, some of these are necessary for accumulator control others are implemented to offer extended functionality. Setpoint calculation for feed and material axis is described in detail in chapter 4.3.4. Basically, the feed axis setpoint follows the line setpoint and the accumulator axis is standstill – unless the rest length for winding reaches a specific value. If this value is reached, the feed axis is decelerated, the accumulator axis temporary acts as an unwinder or rewinder. After the winding coil is changed, the feed axis is restarted, accumulator reaches neutral position and feed axis will follow the line speed again.

2.3.1 Material amount identification

One of the key functions is to monitor the material amount which is stored in the accumulator. This function is set up by determining the minimum and maximum material amount based on the mechanical construction and connecting it to the actual position of the accumulator. the actual amount is determined by (linear) interpolation between the configured values, based on the actual position. This method is not exact, but it is sufficiently accurate.

Figure 2-5: Material amount identification



2.3.2 Accumulator position monitoring

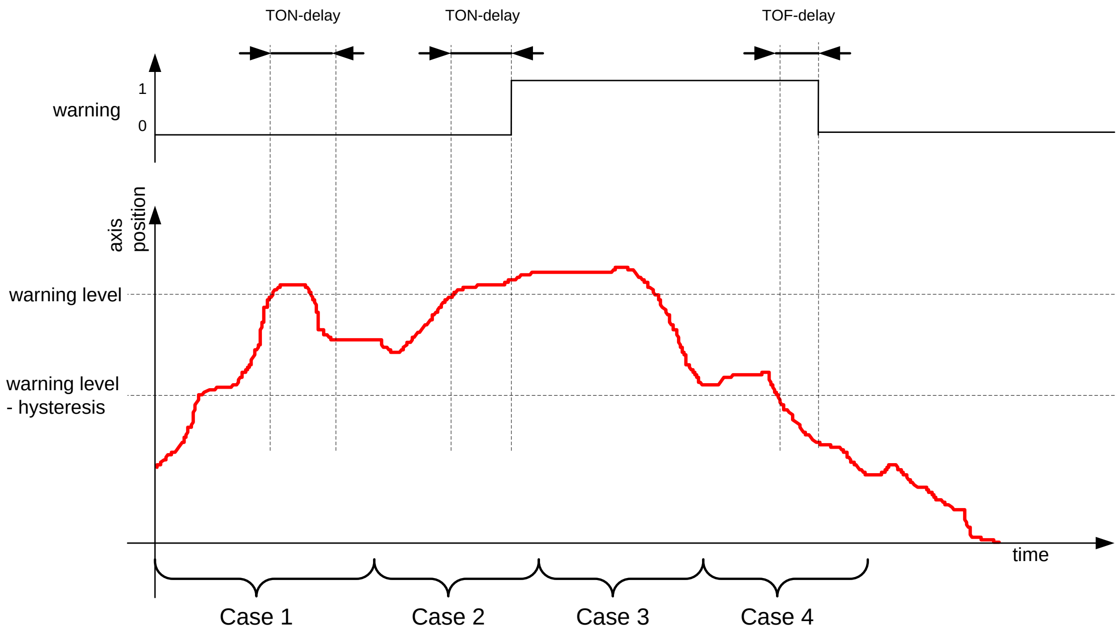
The accumulator axis has five specific positions:

- Upper endposition alarm (HW)
- Upper endposition warning (HW/SW)
- Neutral position (operating point, SW)
- Lower endposition warning (HW/SW)
- Lower endposition alarm (HW)

If the accumulator is filled or empty – depending on the location of the accumulator – it is in the neutral position. During depletion or fill the axis is moving between the endpositions.

If one of the endpositions for warning is reached, a respective signal is output. The warning signal can be an external sensor with a respective signal input or be a direct position limit which is monitored by the function block and in this case possibly delayed with a time-on delay function. Also, if the signal is produced by the function block based on software limits, the reset of the signal is delayed with a time-off delay, and a hysteresis can also be set. See the following figure for details.

Figure 2-6



Case 1: Position is above the warning level for less than the TON-delay.

Case 2: Position is above the warning level for a longer time than the TON-delay

Case 3: Position falls below the warning level, but not under the hysteresis.

Case 4: Position leaves the hysteresis and the signal is reset after the TOF-delay.

The reaction to this warning is to be defined by the user – outside of the function block.

If one endposition for alarm is reached, the accumulator and feed axes are stopped immediately. There is no delay time to alarm limits, and alarm limits can only be signal inputs.

2.3.3 Rest length monitoring

The residual material amount to unwind from or rewind on the coil is calculated internally (refer to function FCRLC, which is described in the User Manual Converting Library. The calculated length is evaluated by the accumulator unit and automatic deceleration for un- or rewinder side feed axis is initiated.

The precision of the calculated rest length is a key element for the determination of exact automatic stop for coil change.

2.3.4 Web tension or dancer position control

The web tension within the accumulator unit is controlled via (direct) tension control or dancer position control. This is realized with the technology controller. The technology controller is basically a PID controller with extended functionality. The controller function block is described in the User Manual Converting Library.

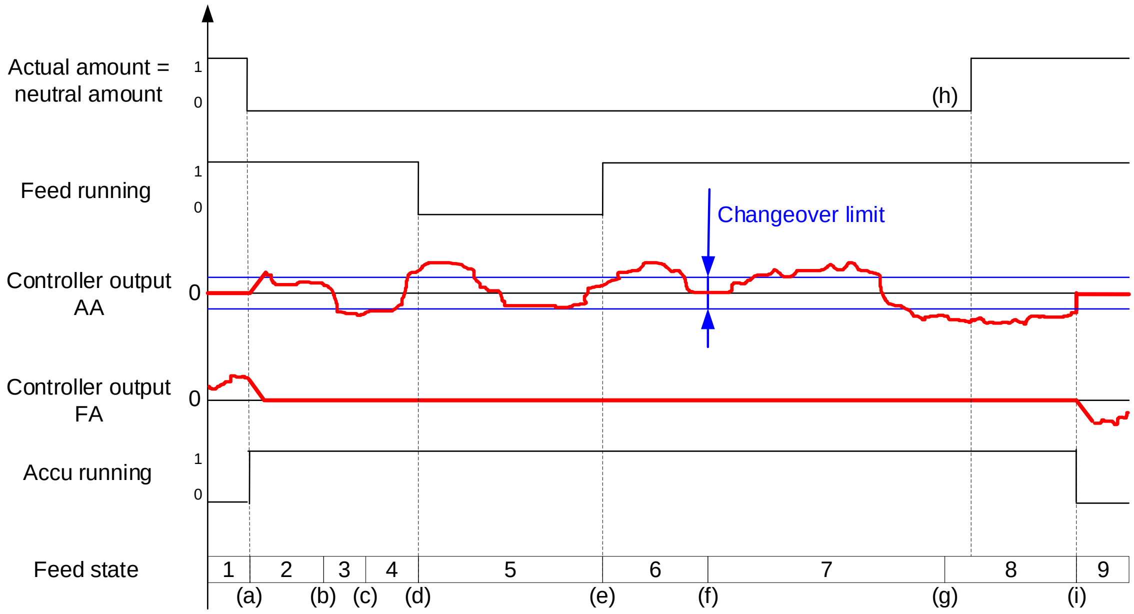
The web tension in this section is independent from the winder section tension.

There is a technology controller for each feed and accumulator, which can be parameterized differently. Depending on the actual state, only one of the two controllers is active at a time. The switchover takes place at the start and stop of the accumulator and is executed without sudden jumps in in speed setpoints.

If the accumulator is standstill, meaning it is in neutral position, the technology controller of the accumulator is active and its velocity is adapted, to control the tension. In case of an active reel change, the accumulator is moving, and the technology controller of the accumulator is activated. In this case, the speed of the accumulator is adapted to control the tension. The technology controller of the feed will be activated again, if the accumulator is in neutral position, the feed is moving with setpoint velocity and the output of the technology controller of the accumulator is below a parameterizable threshold.

NOTE In case there is no feed axis and the winder is responsible for tension control, the behavior is similar. While the accumulator is in operation, it takes over the tension control. Afterwards, the winder again is responsible for tension control. To coordinate this procedure, it is recommended using the output variable "accuRunning".

Figure 2-7: Technology controller switchover



a) The deceleration point is reached, feed axis is decelerated to tail end positioning speed. The output limit of technology controller which is effective on the feed axis is ramped to zero, the output limit of the technology controller which is effective on the accumulator axis is ramped to maximum value.

b) Tail end positioning speed is reached.

c) Material end is detected, feed axis is decelerated to standstill.

d) Feed axis is in standstill.

e) Feed axis is restarted and accelerated to accumulating speed.

f) Accumulating speed is reached.

g) Line speed deceleration point is reached, feed axis is decelerated to line speed.

h) Accumulated amount equals the neutral amount and feed axis reached line speed, but the output of the technology controller which is effective on the accumulator axis is above the specified switchover value.

i) The output of the technology controller which is effective on the accumulator axis falls below the switchover limit, web tension control is re-activated on the feed axis and the accumulator axis is stopped.

2.3.5 Web break detection

Web break detection compares the actual value of the technology controller (actual dancer position or actual tension) with parameterizable border values. If those values get exceeded, a reaction time gets activated and after expiration a responsive feedback is generated. Web break detection is optional and is activated by an input signal and a parametrizable velocity threshold.

The reaction to web break hast to be defined in the user program.

2.3.6 Accumulator and feed axis torque precontrol

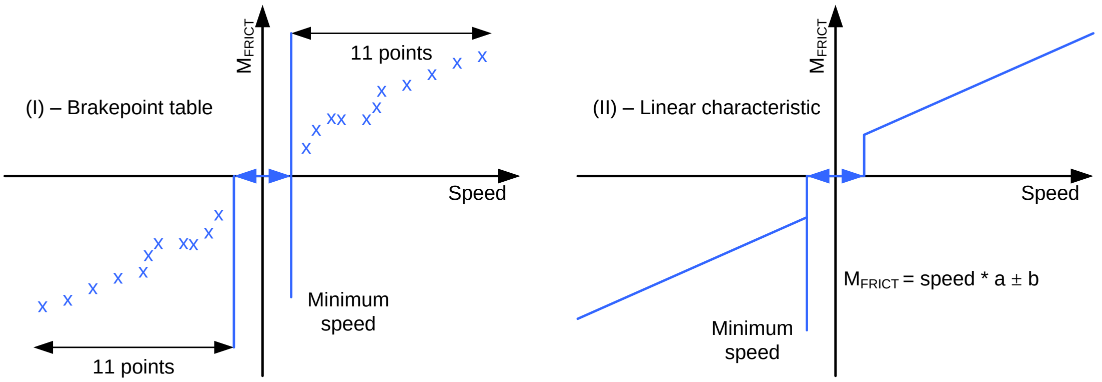
NOTE Pre control for feed axis is only available, if a real axis was assigned as reference at the input feedAxis.

The torque precontrol value consists of two components:

- Acceleration precontrol – this value is based on the inertia and the acceleration setpoint of the axis.
- Mechanical loss compensation – this value is based on the actual speed of the axis. The characteristic can be defined with a breakpoint table (I) or using a linear characteristic (II). For both methods a minimum speed can be defined, which is evaluated as an absolute value. If the axis is slower, this component of torque precontrol is zero.

Torque precontrol for both axes (feed and accumulator) works the same way, but the respective parameters must be set up correctly. The connection to the drive system has to be realised by the user.

Figure 2-8



The pre control calculation of bothes axes works with the same principle and therefore hast to be parametrized correctly. The connection to the drive hast to be configured additionally.

2.3.7 Tension setpoint ramping

This function conditions the tension setpoint using a Ramp Function Generator (FBRFG), this unit is described in the User Manual Converting Library.

There are two methods to maintain the tension of the material web:

- Dancer control, here the ramped tension setpoint can be used as a setpoint for air pressure or as setpoint for any other similar quantity which is associated with the force, that the dancer arm exerts on the material.
- Tension control with load cell, here the ramped tension setpoint output is to be connected to the respective input of the technology controller. This connection is not made automatically within the accumulator function block.

3 Program environment and interfaces

3.1 Program structure

This application consists of a single function block – FBLAccu_WebAccumulator. However, this function block does not cover all axis functions, homing, jog, enabling and disabling of the axis have to be realised outside of the FB. For such functions SAP SIMOTION Line Axis can be used for example, as a complete axis operation mode manager. In LAccuLib are three units (source files).

Table 3-1

UNIT	POU	Function
aVersion	-	Version history and changelog
dTypes	-	Type definitions for the interface of FBLAccu_WebAccumulator. No executable POU.
fAccu	FCLAccu_Conversion	Private function, not exported, used internally for defining conversion constants.
fAccu	FCLAccu_ReturnValueBuffer	Private function, not exported, used internally for saving return values of system functions if they are not zero.
fAccu	FCLAccu_FeedState	Private function, not exported, used internally to control state transitions.
fAccu	FBLAccu_WebAccumulator	Function block for accumulator (and optionally feed) axis control. This block is to be used in the user program.

3.2 Call environment

The unit FBLAccu_WebAccumulator must be instanced for every accumulator which is controlled by the SIMOTION controller. It is not possible to control more axes with the same block. If more motors are mechanically coupled within one mechanical accumulator unit, the coordination between these has to be realised outside of the FBLAccu_WebAccumulator (with a common virtual axis, with angular synchronism or with velocity gearing).

The function block must be called in a time synchronous task, these are:

ServoSynchronousTask

IPOSynchronousTask

IPOSynchronousTask_2

TimerInterruptTask

4 Program and function description

4.1 Information and warnings

WARNING	**Before carrying-out changes** Uncontrolled, incorrect changes and modifications to core functions can result in death and severe bodily injury! Before you carry-out changes to the components included in the core functions, you should get to know how the components function by referring to and reading the ST/MMC documentation.

Restrictions regarding support when changing components of the core functions

The Application Center can only provide support for core functions that have not been changed.

If changes have been made to the code, then support can no longer be provided for core functions.

This also applies for the revision and adaptation recommendations listed in this Chapter.

4.2 Function Block FBLAccu_WebAccumulator

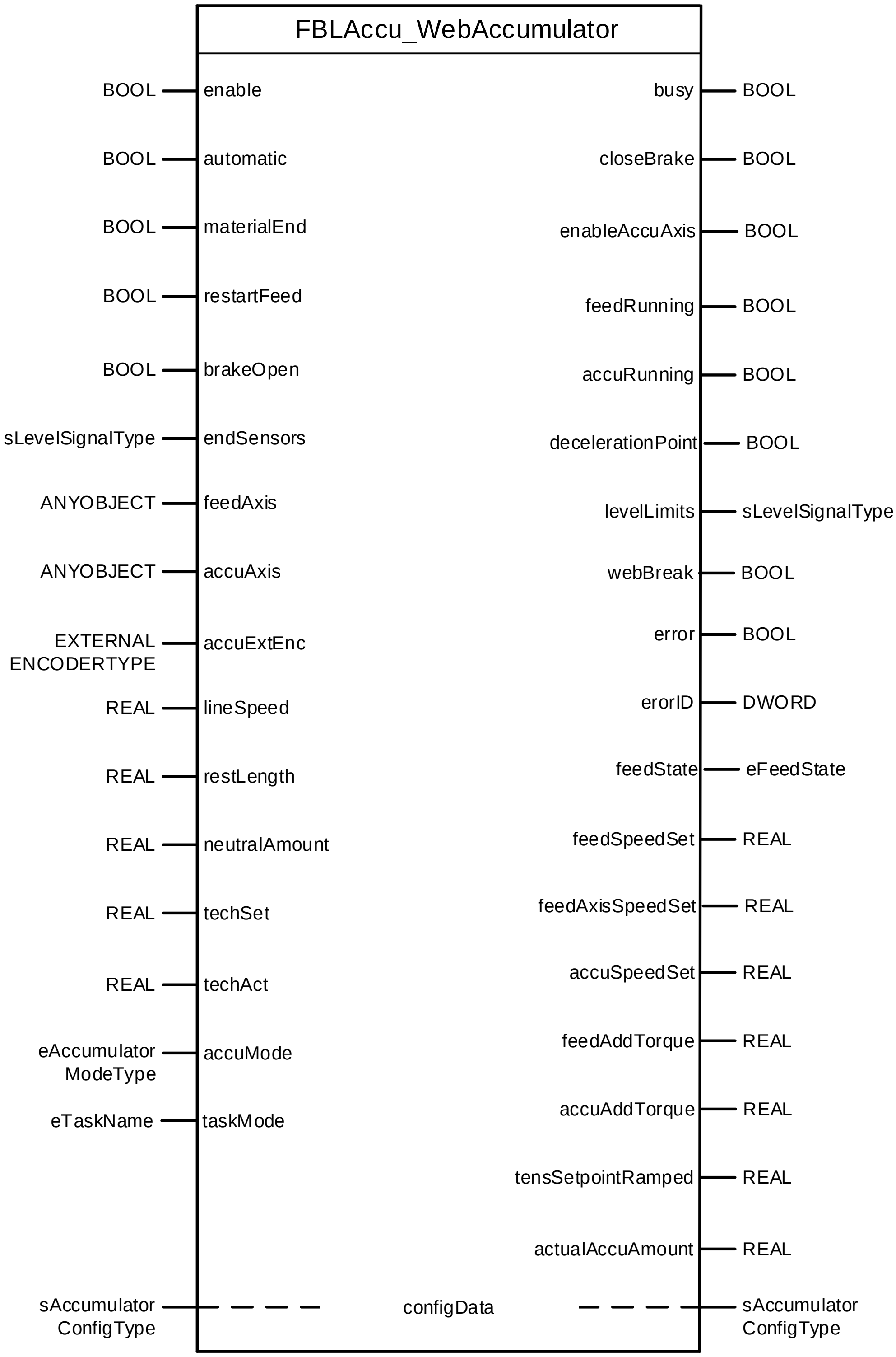
4.2.1 Task

In this function block the following functions are implemented:

- Controlling a web accumulator
- Calculation of velocity setpoints for feed and accumulator
- Calculation of torque pre control for feed and accumulator
- Line tension control in a web accumulator with dancer position control or load cell via feed and web accumulator
- Actual amount identification of the accumulator
- Control sequence based on rest length calculation and actual amount of the accumulator
- Monitoring accumulator position (externally or internally)
- Web break detection

4.2.2 Interface of the Function Block

Figure 4-1



4.2.3 Block parameters

Input parameters

Table 4-1

Name	Data type	Initial value	Description
enable	BOOL	FALSE	FALSE: FB deactivated completely Rising edge: initialisation, and then active TRUE: functions without automatic mode functions are active Falling edge: FB will be disabled, motionIn interface disabled immediately.
automatic	BOOL	FALSE	TRUE: functions for automatic mode (feed and accumulator speed setpoint calculation, technology (dancer or tension) control) are active FALSE: functions or automatic mode are disabled. Feed speed setpoint is ramped to zero. Feed axis motion interfaces deactivated, after speed setpoint ramping is done. Accumulator axis stopped immediately.
materialEnd	BOOL	FALSE	Rising edge: indicates the reach of the material end. Result is the deceleration of the feed axis to standstill.
restartFeed	BOOL	FALSE	Rising edge: feed axis is restarted, feed axis state is switched to accumulating. Only effective if feed axis is in standstill.
brakeOpen	BOOL	FALSE	Feedback, if brake of the accumulator axis is open. TRUE: The motor holding brake for the accumulator axis is open FALSE: The motor holding brake for the accumulator axis is closed. If the brake is closed when the accumulator should be moving, a warning is output.
endSensors	sLevelSignalType	-	Structure for signal input, for endposition monitoring. See description at the data type description for structure
feedAxis	ANYOBJECT	TO#NIL	Object reference for the feed axis. Can be TO#NIL, DRIVEAXIS or POSAXIS. If present, must be enabled all the time.
accuAxis	ANYOBJECT	TO#NIL	Object reference for the

Name	Data type	Initial value	Description
			accumulator axis. Can be DRIVEAXIS or POSAXIS. Must be enabled at start and when the enableAccuAxis output is true. If POSAXIS, must not be modulo.
accuExtEnc	EXTERNALENCODERTYPE	TO#NIL	Object reference for accumulator external encoder. Can be TO#NIL or EXTERNALENCODERTYPE. If TO#NIL (no external encoder is used) accuAxis must be a POSAXIS. Must not be modulo.
lineSpeed	REAL	0.0	[LI] [LU / vTU] Actual line speed setpoint. Unit is defined by the configData.sLineUnitSpec.
restLength	REAL	MAX_REAL	[FE] [LU] Actual rest length to be wound. Unit is defined by the configData.sFeedUnitSpec.
neutralAmount	REAL	0.0	[FE] [LU] Neutral (setpoint) material amount to be accumulated. Changes to this setpoint are effective during states other than V_LINE_DEC and V_LINE. Unit is defined by the configData.sFeedUnitSpec.
techSet	REAL	0.0	[TV] Setpoint for the technology controller. Unit is defined as „technology variable“. Has no direct connection to axis setpoints.
techAct	REAL	0.0	[TV] Actual value for the technology controller. Unit is the same as for the setpoint.
accuMode	eAccumulatorModeType	AT_UNWINDER	Definition of accumulator position. Options are AT_UNWINDER, AT_REWINDER. Input is saved at the enable rising edge, after that no change is possible.
taskMode	eTaskNameType	IPO_SYNCHRONOUS_TASK	Specification of the task in which the function block is called. SERVO_SYNCHRONOUS_TASK IPO_SYNCHRONOUS_TASK IPO_SYNCHRONOUS_TASK_2 TIMER_INTERRUPT_TASK

Input/Output parameters

Table 4-2

Name	Data type	Initial value	Description
configData	sAccumulatorConfigType	-	Configuration data for the accumulator application. See description at the data type description for structure

Output parameters

Table 4-3

Name	Data type	Initial value	Description
busy	BOOL	FALSE	FB is enabled and no error occurred.
closeBrake	BOOL	TRUE	Signal, which can be used to control the brake of the accumulator. TRUE: Brake for accumulator axis can be closed (axis is at standstill). FALSE: Brake for accumulator axis must be opened.
enableAccuAxis	BOOL	FALSE	Signal, which can be used to control accumulator. TRUE: Accumulator axis must be enabled. FALSE: Accumulator axis can be disabled.
feedRunning	BOOL	FALSE	Feed axis is not in standstill, speed setpoint <> 0.0
accuRunning	BOOL	FALSE	Accumulator axis is not in standstill, speed setpoint <> 0.0
decelerationPoint	BOOL	FALSE	TRUE: Automatic deceleration is active, will be set at the start of the deceleration, reset when standstill is reached, or feeder is restarted before standstill. Deceleration point is passed, if the internally calculated brake length exceeds restLength.
levelLimits	sLevelSignalType	-	Structure for signal output, for endposition monitoring. See description at the data type description for structure
webBreak	BOOL	FALSE	TRUE: Web break is detected. FALSE: No web brake detected.
error	BOOL	FALSE	FALSE: No error occurred TRUE: Error occurred
errorID	DWORD	16#0000_0000	Error identification, refer to error messages errorID < 16#000_8000: warning errorID >= 16#0000_8000: error
feedState	eFeedStateType	STANDSTILL	Actual state of feed axis within the application.
feedSpeedSet	REAL	0.0	[FE] [LU / vTU] Speed setpoint for feed axis without web tension correction. This setpoint is meant for diagnosis and is not effective on the TO, even if a valid reference at feedAxis is configured. Unit is defined by the configData.sFeedUnitSpec.
feedAxisSpeedSet	REAL	0.0	[FE] [LU / vTU] Speed setpoint for feed axis with web tension correction. This setpoint is effective on feedAxis.defaultMotionIn.velocity, if feedAxis was assigned a valid reference. Unit is

Name	Data type	Initial value	Description
			defined by the configData.sFeedUnitSpec.
accuSpeedSet	REAL	0.0	[ac LU / vTU] Speed setpoint for accumulator axis. Unit is defined by the configData.sAccuUnitSpec indirectly.
feedAddTorque	REAL	0.0	[FE] [M] Additive (precontrol) torque for feed axis. Unit is defined by the configData.sFeedUnitSpec indirectly.
accuAddTorque	REAL	0.0	[ac M] Additive (precontrol) torque for accumulator axis. Unit is defined by the configData.sAccuUnitSpec.
tensSetpoint Ramped	REAL	0.0	[Z] Ramped tension setpoint, unit is same, as tension setpoint in configData.r32TensSetpoint
actualAccuAmount	REAL	0.0	[FE] [LU] Actual accumulated material amount. Unit is defined by the configData.sFeedUnitSpec.

4.2.4 Error messages

Table 4-4

Error ID	Priority	Description
16#xxxx_0xxxx	Lowest priority	Warning
16#xxxx_4xxx	Low priority	Warning, cannot be executed
16#xxxx_8xxx	High priority	Error, can no longer be executed
16#xxxx_Cxxx	Highest priority	Critical error

Errors

Error messages are displayed using the state of the error and errorID output: error = TRUE and errorID <> 16#0000_0000.

Table 4-5

Error ID	Description
16#0000_0000	No error
16#0801_C001	Accumulator axis not defined or external encoder is not present but accumulator axis is not POSAXIS OR source for position feedback is modulo axis
16#0801_8001	FB is called in an invalid task
16#0801_8005	Invalid configuration data Number of wrappings is 0, configData.u8Wrappings = 0 or Feed axis unit specification is incomplete or invalid axis LU selected Feed axis diameter unspecified or negative and feed axis is present Accu axis unit specification is incomplete or invalid axis LU selected Accu axis diameter unspecified or negative Line unit specification is incomplete or invalid
16#0801_8051	Accumulator axis is not enabled when it supposed to be. OR Feed axis is present but not enabled.
16#0801_8100	Accumulator external encoder is present but could not be enabled
16#0801_8101	Error when the motionIn interface was to be deactivated for the accumulator or the feed axis.

Error ID	Description
16#0801_8105	Error when the motionIn interface was to be activated for the accumulator or the feed axis.
16#0208_8005	Configuration data for accumulator or feed axis technology controller is invalid.

Warnings

Warning messages are displayed using the state of the error and errorID output: error = FALSE and errorID <> 16#0000_0000.

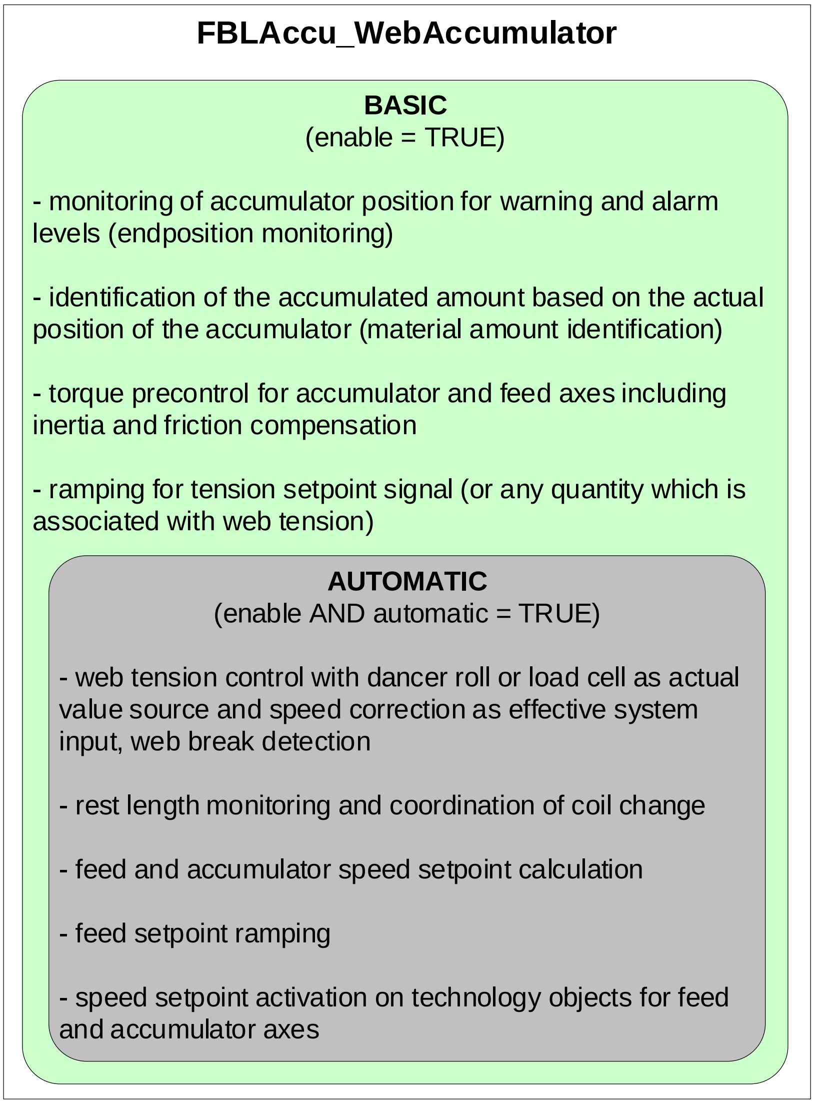
Table 4-6

Error ID	Description
16#0000_0000	No warning
16#0801_4009	Accumulator axis motor holding brake is closed when accumulator speed setpoint is not zero.

4.3 Function description

The functionality of the function block can be divided into two groups. These functions were briefly introduced in chapter 2 Functions of the application. One group – AUTOMATIC – includes the functions, which are only active if the FB is in automatic mode (and enabled), the functions from the other group – BASIC – are active, if the FB is enabled – regardless whether automatic mode is active or inactive. This can be seen in the following figure.

Figure 4-2



However, the accumulator position monitoring is one of the basic functions, there is no emergency reaction in basic mode, since axis control is inactive.

If no axis is specified as feedAxis, torque precontrol for the feed axis will not be calculated.

4.3.1 System of units

There are numerous quantities which depend on physical units – such as position, length, speed, acceleration, angular velocity, angular acceleration, torque, tension, moment of inertia, diameter. It is possible, that different axes and signals use different quantities. For example in most cases the line speed is defined as m/min, but the diameter for an axis defined in mm, the speed is in RPM. To have an unambiguous representation of these quantities the units must be defined. Signals, which can have different units – for example at accumulator speed setpoint – first all quantities are converted to the standard internal SI units (m, s, rad, kg as base units) and then converted into target axis units.

Axis units

In SIMOTION there are numerous possibilities to define axis units for different quantities. In this application not all of these combinations are supported. The following combination of units is possible:

Table 4-7

Axis type	DRIVEAXIS	POSAXIS ROT	POSAXIS LIN
Position	-	LU	LU
Velocity	1 / vTU	LU / vTU	LU / vTU
Acceleration	1 / aTU^2	LU / aTU^2	LU / aTU^2
Possible LU	rev	rad, deg, gon	m, mm, in, ft
Possible vTU/aTU	s, min		
Feature of quantites	Rotary (angular velocity) Diameter is used to calculate circumferential velocity and acceleration from axis variables		Linear (circumferential velocity) Diameter is used to calculate angular velocity and acceleration from axis variables
SI units	rad, rad/s, rad/s^2		m, m/s, m/s^2

Units which can be constructed with the use of Table 4-7 are available as axis units. One restriction applies: the same LU must be used for all axis quantities. TU can be chosen for speed and acceleration separately.

The units for feed and accumulator axis are defined by their configurations structures sFeedUnitSpec and sAccuUnitSpec.

NOTE Even if there is no feed existing and no axis reference was assigned to feedAxis, sFeedUnitSpec must be parameterized. In case of a missing axis reference at feedAxis, the application can not decide, whether there is no feed existing or if it is controlled outside of the application.

As line axis there is no technology object, which is connected to the accumulator function block, but some quantities and the actual line speed still have units. It is possible to define the units with the configuration structure sLineUnitSpec.

Units of parameters

Various parameters of the accumulator can be associated with an axis. In this case the units used for the axis also define the units of these parameters.

In the type descriptions and the IO list of FBLAccu_WebAccumulator the units are represented as [ac LU/vTU] for example. The abbreviations represent the following:

Prefixes:

- [AC] – unit is associated with the units of the accumulator axis
- [LI] – unit is associated with the units of the line “axis”
- [FE] – unit is associated with the units of the feed axis

Units:

- vTU – time unit of velocity
- LU – length unit

– if axis has rotary features, LU of diameter

– if axis has linear features, LU of axis position

- M – unit is the unit of torque (see Table 6-22)
- J – unit is the unit of the moment of inertia (see Table 6-22)

The unit of torque and inertia depend on the LU of the diameter (DRIVEAXIS, POSAXIS ROT) or the LU of the position (NOAXIS, POSAXIS LIN) of the respective axis.

Table 4-8

Definition LU	**Metric – m, mm**	**US imperial – ft, in**
Torque [M]	N * m	lbf * ft
Moment of inertia [J]	kg * m^2	lb * ft^2

Units without conversion

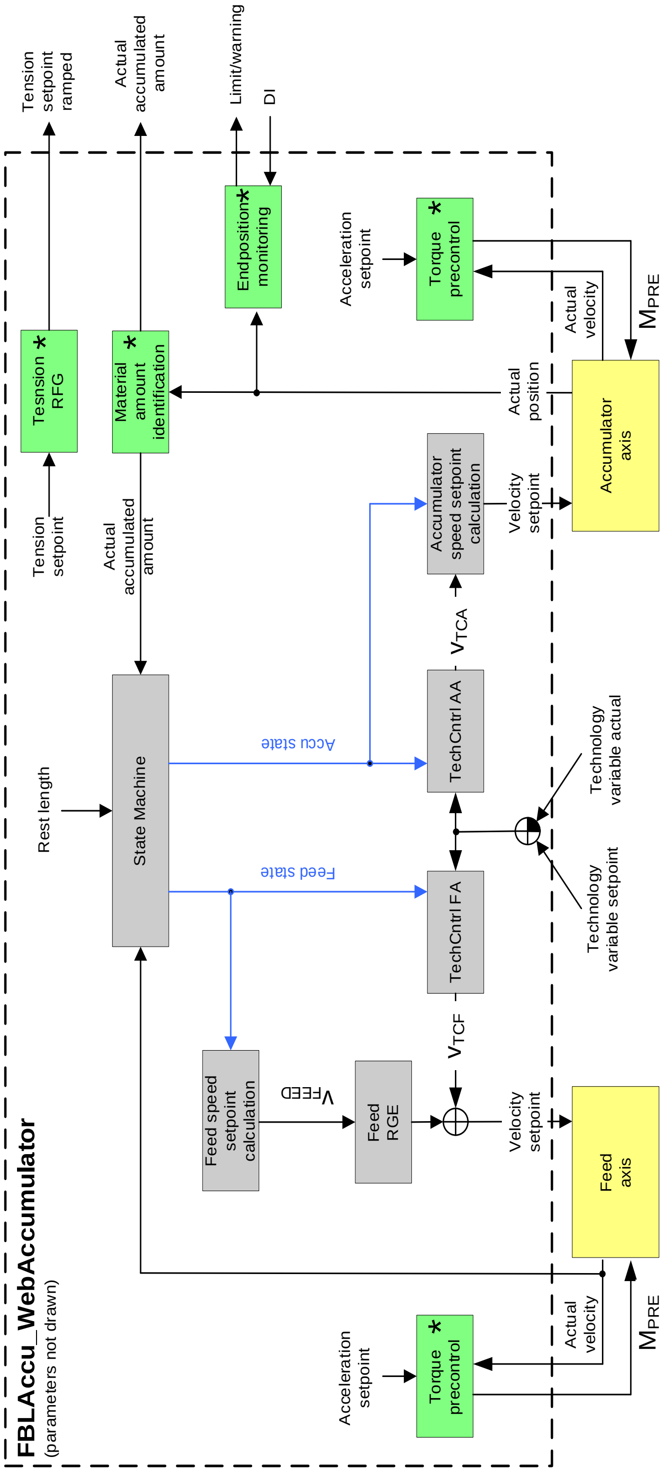
- TV – unit is the unit of the technology value (dancer position or tension), here no conversions are needed, unit is not to be set
- Z – unit is the tension setpoint unit (which is only ramped), here no conversion is needed, unit is not to be set.

4.3.2 Internal structure

The application structure can be seen on the next block diagram.

Blocks marked with a star represent basic functions (active independently from automatic mode). Other blocks within the dashed rectangle are only active, if the function block is switched to automatic mode. Blocks outside the rectangle represent the two axes, which are controlled by this application.

Figure 4-3



4.3.3 State machine

The accumulator axis is virtually the slave axis of the feed axis. For this reason the different states are coupled with the feed axis and are defined based on the speed setpoint and acceleration of the feed axis. The accumulator axis has fewer states than the feed axis, and an unambiguous translation from feed states to accumulator states is possible. This is not true vice versa.

There are four main segments for the feed speed setpoint, which are also marked on Figure 2-2 and Figure 2-4. The feed setpoint is ramped using a ramp function generator with jerk limiting, this divides every segment into sub-segments – these are the states of the feed axis – the deceleration and/or acceleration phase and the constant phase. This means a total of eight states for the feed axis in normal mode, and one additional state for emergency stop.

Table 4-9

States	Description
V_TAIL_DEC, V_TAIL	The segment begins when the deceleration point is reached. At this time the internal feed setpoint is switched to tail end positioning speed. The deceleration point detection is based on the actual rest length, feed velocity setpoint as well as deceleration rate and can be adjusted with a designated parameter.
STANDSTILL_DEC, STANDSTILL	The segment begins, when the deceleration point is reached and no tail end positioning is used or when material tail end is detected. Internal feed setpoint is switched to zero. When the feed axis reaches standstill, the signal for deceleration point is reset.
V_ACCU_ACC, V_ACCU, V_LINE_DEC	The segment begins with the direct restart of the feed axis. The internal feed setpoint is switched to the line speed plus an accumulating offset. When the difference between the actual accumulated amount and the neutral amount equals the accumulating deceleration length, the accumulating offset is deactivated.
V_LINE	The segment begins, when the actual accumulated amount equals the neutral amount and the dancer controller output is smaller than the adjustment parameter.
V_ACCU_ACC	The segment beings, if the accumulator is moving, and therefore the accumulator is filled or depleted.

Events for state transitions

The following events and options can influence the state transitions:

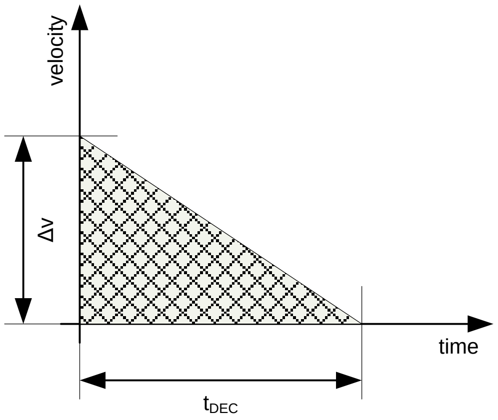
Table 4-10

Event/Option	Description
Deceleration point is reached	The deceleration point is reached, when the material length (brake length), which will still be transported by the feed axis during the normal deceleration – deceleration is defined by the ramp parameters – equals to the rest length which can be wound on the coil – this is the restLength input. This timing can be adjusted with the sConfigData.r32AutoStopAdj parameter. Positive adjustment values result in earlier detection of the deceleration point, meaning that there will be some material left on the unwinder or some free space on the rewinder. Negative adjustment value has an opposite effect.
Tail end positioning speed is used	Tail end positioning is used, if the sConfigData.r32tailSpeed parameter is positive
Material end is reached (sensor)	When material end is detected, this is signaled with the materialEnd input
Feed axis restart	Feed axis is restarted by the input signal restartFeed. The restart of the axis can be delayed using the sConfigData.u32restartDelay parameter.
Line speed deceleration point is reached	The line speed deceleration point is reached, when the material length (brake length), which will still be transported by the feed axis during deceleration from the accumulating speed to line speed – deceleration is defined by the ramp parameters – equals to amount difference between the actualAccuAmount and neutralAmount. This timing can be adjusted with the configData.r32fillStopAdj parameter. Positive adjustment values result in earlier detection of the line speed deceleration point, meaning that there will be less material accumulated than the neutral amount. Negative adjustment value has an opposite effect. Trigger is internal for the transition
Accumulated material amount is in neutral interval	The neutral interval detection depends on the accuMode and neutralAmount inputs, and the actual accumulated amount - actualAccuAmount. accuMode = AT_UNWINDER: actualAccuAmount >= neutralAmount accuMode = AT_REWINDER: actualAccuAmount <= neutralAmount
Feed setpoint ramping finished	Setpoint ramping is finished, if the input of the feed axis setpoint ramp function generator equals the ramped output.
Technology controller output is ready for switch	Since the web tension control is switched between the accumulator and feed axes, the changeovers must be smooth. For the switchover from accumulator to feed axis a threshold is defined – sConfigData.r32OutputChangeLimit – when the technology controller output drops below this value, switchover takes place.
Emergency stop	Emergency stop is triggered by the signals endSensors.boUpperAlarm and endSensors.boLowerAlarm for reaching the hardware endposition.

Calculation of brake length

The calculation of the brake length does not consider the settings for jerk limiting while assuming constant deceleration. This can be represented as a triangle, where the brake length is the area of the triangle.

Figure 4-4



The following equations are true:

$$\Delta v = t_{DEC} * deceleration$$

$$brake\_length = \frac{t_{DEC} * \Delta v}{2}$$

And therefore

$$brake\_length = \frac{\Delta v^2}{2 * deceleration}$$

For the detection of the deceleration point Δv = v_{LINE}, for the detection of the line speed deceleration point Δv = v_{ACCU}

Transition matrix

The following matrix shows all possible transitions, transitions are grouped based on the actual state and the trigger events. Transitions are divided into two groups, regular and irregular transitions.

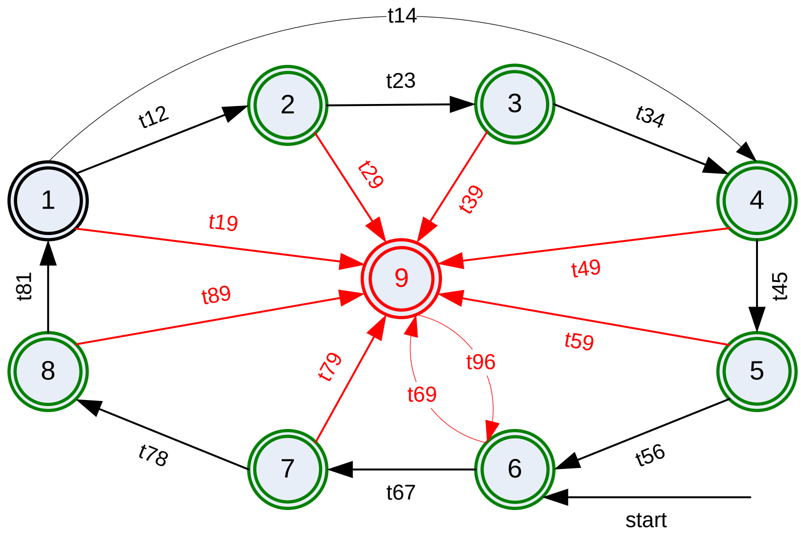
Table 4-11: Transition matrix

	Next STATE	V_LINE	T_TAIL_DEC	V_TAIL	STANDSTILL_DEC	STANDSTILL	V_ACCU_ACC	V_ACCU	V_LINE_DEC	ESTOP
Actual STATE		1	2	3	4	5	6	7	8	9
V_LINE	1	O	t_{12}	X	t_{14}	X	X	X	X	t_{19}
T_TAIL_DEC	2	t_{21}	O	t_{23}	t_{24}	X	t_{26}	X	X	t_{29}
V_TAIL	3	t_{31}	X	O	t_{34}	X	t_{36}	X	X	t_{39}
STANDSTILL_DEC	4	t_{41}	X	X	O	t_{45}	t_{46}	X	X	t_{49}
STANDSTILL	5	t_{51}	X	X	X	O	t_{56}	X	X	t_{59}
V_ACCU_ACC	6	X	t_{62}	X	t_{64}	X	O	t_{67}	t_{68}	t_{69}
V_ACCU	7	X	t_{72}	X	t_{74}	X	X	O	t_{78}	t_{79}
V_LINE_DEC	8	t_{81}	t_{82}	X	t_{84}	X	X	X	O	t_{89}
ESTOP	9	X	X	X	X	X	t_{96}	X	X	O

Transitions are coded with the numbers of actual and target state numbers. Transitions t12, t14, t23, t34, t45, t56, t67, t78, t81, t96 and tx9 are the regular, others are the irregular transitions. Where X is present, that is an invalid – not present –transition. The same transition can be triggered by different event and status combinations.

Regular state transitions

Figure 4-5: state machine with regular transitions



The following transitions are regular transitions, which follow each other if events occur in the expected order. The triggering events are:

t12: Deceleration point is reached AND Tail end positioning is used

t14: Deceleration point is reached AND Tail end positioning is NOT used

t23: Feed setpoint ramping finished

t34: Material end is reached (sensor)

t45: Feed setpoint ramping finished

t56: Feed axis restart AND Accumulated material amount is NOT in neutral interval

t67: Feed setpoint ramping finished

t78: Line speed deceleration point is reached OR Accumulated material amount is in neutral interval

t81: Feed setpoint ramping finished

tx9: Emergency stop

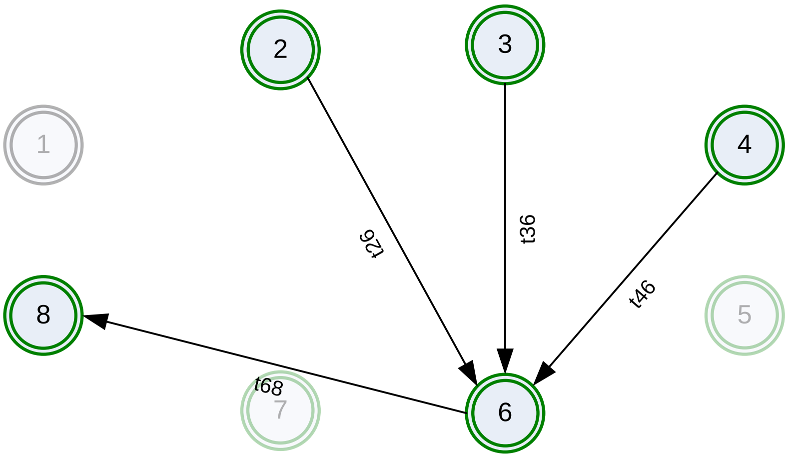
t96: Restart

Irregular state transitions

On the following diagrams, the various irregular transitions are symbolized. These diagrams and transitions are grouped by the triggering event.

Transitions with asynchronous feed restart and reach of neutral amount

Figure 4-6: irregular transitions for feed axis restart and early reach of neutral position



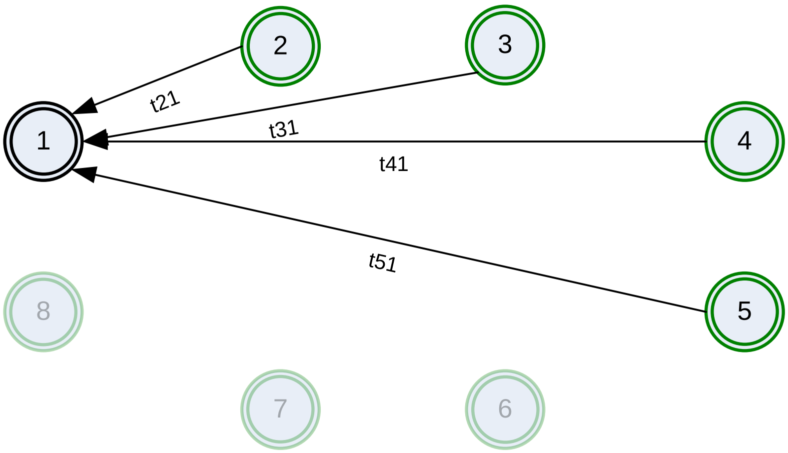
The following transitions are irregular transitions. The triggering events are:

t26, t36, t46: Feed axis restart AND Accumulated material amount is NOT in neutral interval

t68: Line speed deceleration point is reached OR Accumulated material amount is in neutral interval

Transitions with feed restart in neutral interval

Figure 4-7: feed axis is restarted, but accumulator is in neutral interval

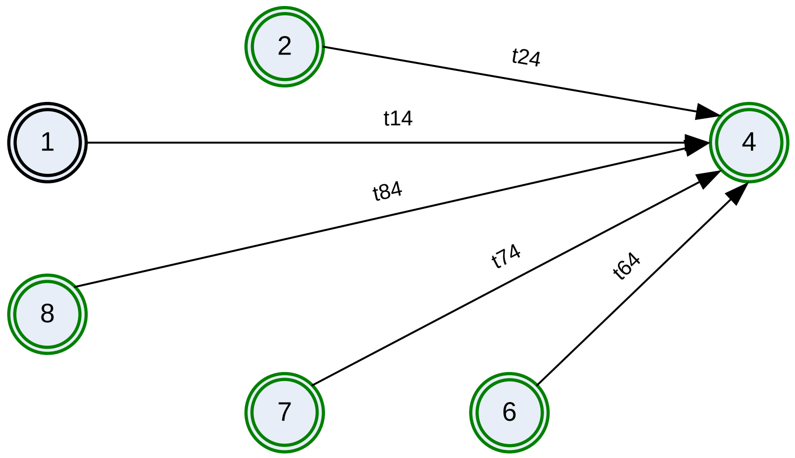


The following transitions are irregular transitions. The triggering events are:

t21, t31, t41, t51: Feed axis restart AND Accumulated material amount is in neutral interval

Asynchronous material end detection

Figure 4-8: end of material is detected (bogus automatic stop, web break)

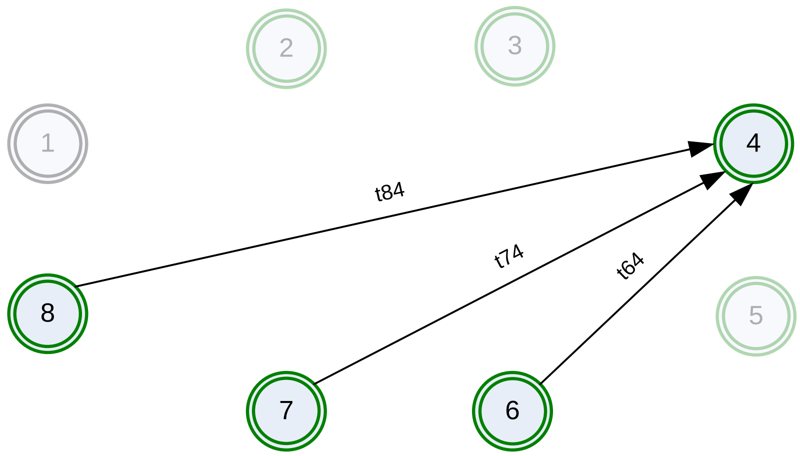


The following transitions are irregular transitions. The triggering events are:

t14, t24, t64, t74, t84: Material end is reached (sensor)

Deceleration point reached in state other than v_line without tail end speed

Figure 4-9: automatic stop is initiated in a state other than v_line and tail end positioning is not used

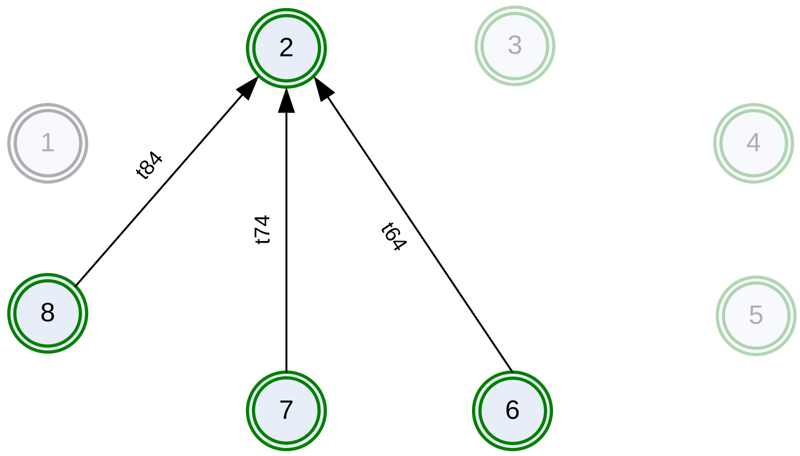


The following transitions are irregular transitions. The triggering events are:

t64, t74, t84: Deceleration point is reached AND Tail end positioning speed is NOT used

Deceleration point reached in state other than v_line with tail end speed

Figure 4-10: automatic stop is initiated in a state other than v_line and tail end positioning is used



The following transitions are irregular transitions. The triggering events are:

t62, t72, t82: Deceleration point is reached AND Tail end positioning speed is used

4.3.4 Speed setpoint calculation

The function block – in automatic mode – calculates speed setpoint for both accumulator and feed axes. The effective setpoint depends on the actual state of the respective axes and also the location of the accumulator unit (at rewinder or unwinder). In the following tables the formulas which are used in the setpoint generation are listed with the respective states. The meaning of the abbreviations can be found at Abbreviations.

Feed axis:

The feeder setpoint is always routed through a RFG (with jerk limiting), to avoid abrupt setpoint changes.

Table 4-12

	Feed state	Accumulator state	Feed setpoint (before RFG)
1.	V_LINE	STANDSTILL	$v_{FEED} = v_{LINE} + v^{*}{}_{TCF}$
2.	V_TAIL_DEC	IN_MOVE	$v_{FEED} = v_{TAIL}$
3.	V_TAIL		
4.	STANDSTILL_DEC		$v_{FEED} = 0$
5.	STANDSTILL		
6.	V_ACCU_ACC		$v_{FEED} = v_{LINE} + v_{ACCU}$
7.	V_ACCU		
8.	V_LINE_DEC		$v_{FEED} = v_{LINE}$
9.	ESTOP	ESTOP	$v_{FEED} = 0$

*The output of the technology controller is added to the speed setpoint after the RFG, and thus not ramped.

Accumulator axis:

The accumulator axis is virtually the slave axis of the feed axis, and its speed setpoint equally depends on the line speed too.

NOTICE	**There is NO RFG used to limit the change of the accumulator axis setpoint. This means, that every change in the line speed is immediately effective in the accumulator speed setpoint!**

- If accumulator is used with an unwinder, the feed axis acts as input, the output velocity is constant.

$$v_{IN} = v_{FEED}$$

$$v_{OUT} = v_{LINE}$$

- If accumulator is used with a rewinder, the feed axis acts as output, the input velocity is constant. Constant velocity is always line velocity.

$$v_{IN} = v_{LINE}$$

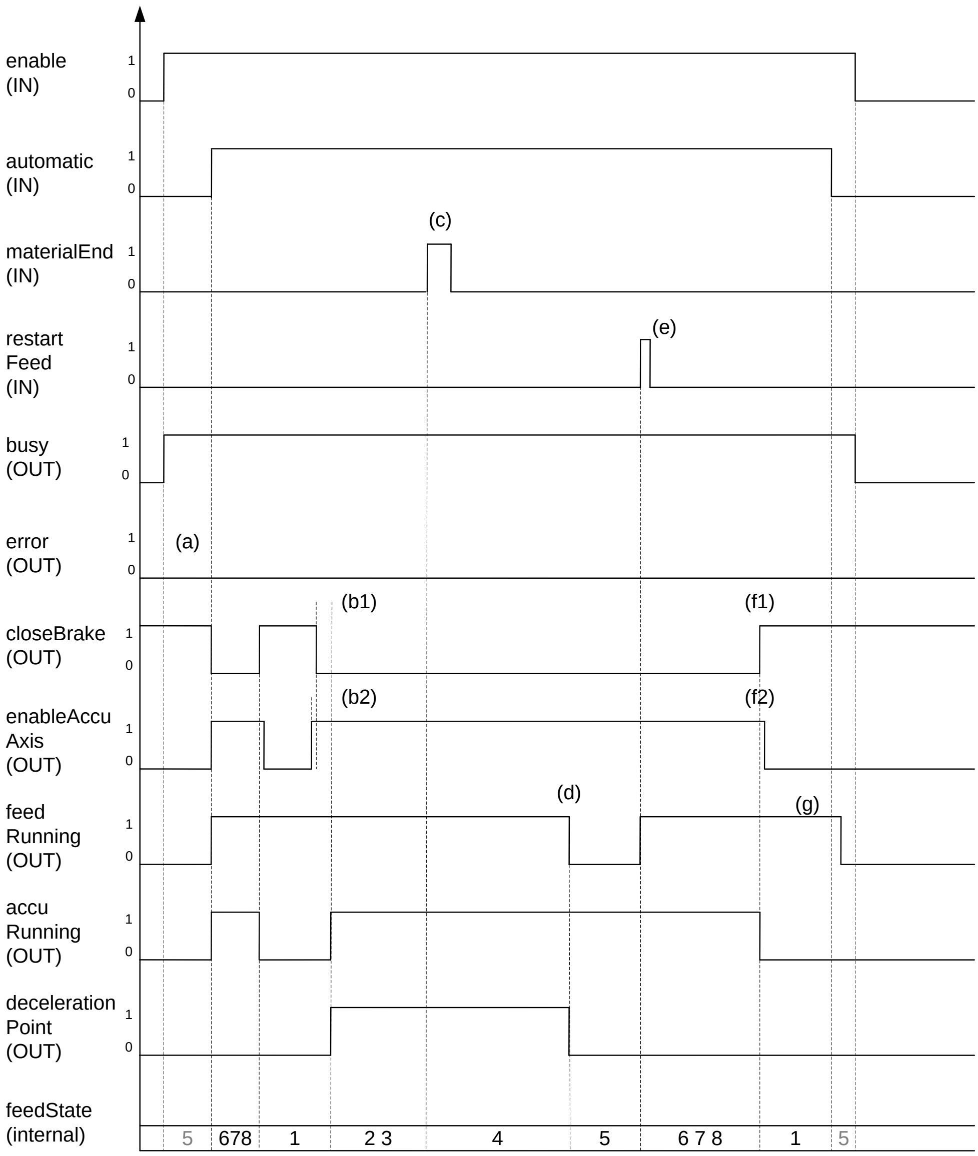
$$v_{OUT} = v_{FEED}$$

Table 4-13

	Accumulator state	Accumulator setpoint
1.	STANDSTILL	$v_{AA} = 0$
2.	IN_MOVE	$v_{AA} = \frac{v_{IN} - v_{OUT} + v_{TCA}}{n_{Wrappings} * 2}$
3.	ESTOP	$v_{AA} = 0$

4.3.5 Timing diagrams

Figure 4-11: timing without error and with tail end positioning speed



(a) After entering automatic mode, first state is V_ACCU_ACC (6) to reach neutral amount

(b1) Deceleration point was detected, brake was pre-opened, continue to tail end speed.

(b2) Accumulator axis is to be enabled prior to brake opening.

(c) Material end was detected, continue to standstill

(d) Feed axis reached standstill

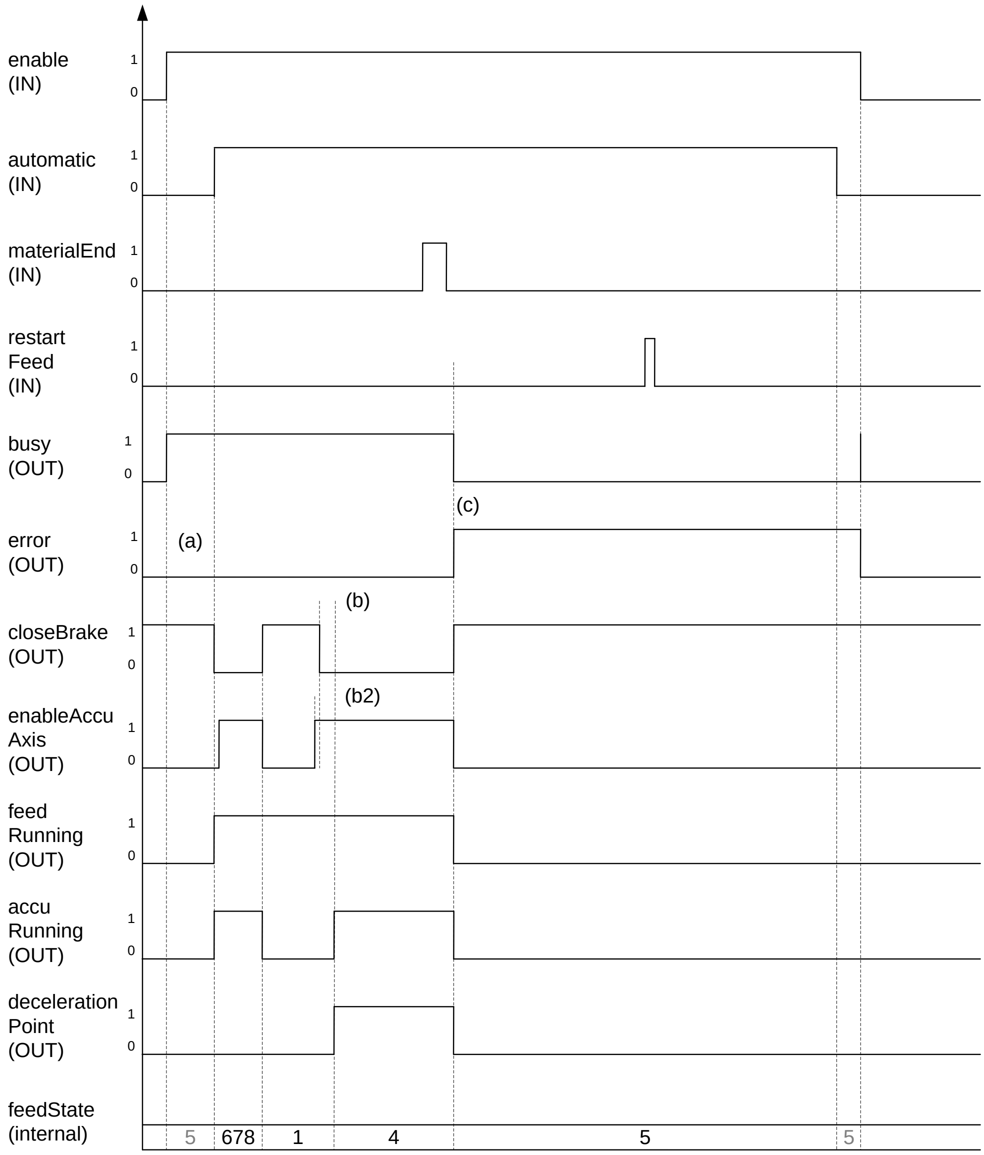
(e) feed axis is restarted

(f1) Neutral amount was reached

(f2) Accumulator axis can be disabled after brake closing

(g) Feed axis setpoint is ramped to zero after falling edge of automatic.

Figure 4-12: timing with error



(a) After entering automatic mode, first state is V_ACCU_ACC (6) to reach neutral amount

(b) Deceleration point was detected, brake was pre-opened, continue to standstill

(b2) Accumulator axis is to be enabled prior to brake opening.

(c) Error occurred, actual state for both axes is standstill, setpoints are zero, motion interface is deactivated. Acceleration is defined by the axis dynamic settings!

4.4 Data types

4.4.1 Overview

Enumeration types

Type declarations of enumeration types are provided for some of the input and output parameters of the function block. Various modes and properties can be preset using these parameters.

Data structures

The function block is mostly parameterized using data structures. These structures are described in detail.

4.4.2 Enumeration types

The following enumeration data types are defined and used in the application.

Table 4-14

Enumeration type name	Contents
eAccumulatorModeType	Defines the location of the accumulator unit. Declared in: LAccuLib\dTypes
eAxisTUType	Defines the time unit for axis velocity and acceleration. Declared in: LAccuLib\dTypes
eAxisLUType	Defines the length unit for axis position, velocity and acceleration. Declared in: LAccuLib\dTypes
eDiameterLUType	Defines the length unit for axis diameter. Declared in: LAccuLib\dTypes
eFrictionCharModeType	Defines the definition mode for the friction compensation. Declared in: LAccuLib\dTypes
eFeedStateType	Defines the actual application state (of feed axis). Declared in: LAccuLib\dTypes

eAccumulatorModeType

Table 4-15

Element	Description
AT_UNWINDER	Accumulator is located between the unwinder and the converting process. The output speed of the accumulator is constant.
AT_REWINDER	Accumulator is located between the converting process and the rewinder. The input speed of the accumulator is constant.

eAxisTUType

This data type is used to define the time unit for the axis acceleration and speed for the internal conversions.

Separate values can be used for acceleration and speed within the application for the same axis.

Table 4-16

Element	Description
UNDEFINED	Time unit is undefined, default value.
MINUTE	Time unit is one minute, speed is defined as LU/min and acceleration is defined as LU/min2
SECOND	Time unit is one second, speed is defined as LU/s and acceleration is defined as LU/s2

eAxisLUType

This data type is used to define the length unit for the axis. Same LU is used for position, speed and acceleration.

Table 4-17

<table>
<tr><th>Element</th><th colspan="2">Description</th></tr>
<tr><td>UNDEFINED</td><td colspan="2">Length unit is undefined, default value.</td></tr>
<tr><td>REV</td><td colspan="2">Only for DRIVEAXIS, where speed and acceleration is defined as revolution/TU. Has no direct interpretation as position.</td></tr>
<tr><td>M</td><td>Length unit is one meter.</td><td rowspan="4">For linear POSAXIS or signals with linear attributes.</td></tr>
<tr><td>MM</td><td>Length unit is one millimeter.</td></tr>
<tr><td>IN</td><td>Length unit is one inch.</td></tr>
<tr><td>FT</td><td>Length unit is one feet.</td></tr>
<tr><td>RAD</td><td>Length unit is one radian. 1 rev = 2 PI rad</td><td rowspan="3">For rotary POSAXIS.</td></tr>
<tr><td>DEG</td><td>Length unit is one degree. 1 rev = 360 deg</td></tr>
<tr><td>GON</td><td>Length unit is one gradian. 1 rev = 400 gon</td></tr>
</table>

eDiameterLUType

This data type is used to define the length unit for the axis diameter.

Table 4-18

Element	Description
UNDEFINED	Length unit is undefined, default value.
M	Length unit is one meter.
MM	Length unit is one millimeter.
IN	Length unit is one inch.
FT	Length unit is one foot.

eFrictionCharModeType

This data type is used to define the mode of friction compensation.

Table 4-19

Element	Description
TABLE	Friction compensation is defined with a breakpoint table (speed – torque) with 11-11 points both for positive and negative speeds.
LINEAR	Friction compensation is defined with a linear characteristic, with a user defined offset.

eFeedStateType

This data type is used to define the state for the state machine within the accumulator application.

Table 4-20

Element	Description
V_LINE	Feed axis follows line speed, web tension control is active on feed axis.
V_TAIL_DEC	Feed axis setpoint is ramped to tail end positioning speed.
V_TAIL	Feed axis follows tail end positioning speed.
STANDSTILL_DEC	Feed axis setpoint is ramped to standstill.
STANDSTILL	Feed axis is in standstill
V_ACCU_ACC	Feed axis setpoint is ramped to accumulating speed.
V_ACCU	Feed axis follows accumulating speed.
V_LINE_DEC	Feed axis setpoint is ramped to line speed.
ESTOP	Feed axis is in emergency stop, setpoint is zero, restart is required.

4.4.3 Data structures

The following structure data types are defined and used in the application.

Table 4-21

Data type	Description
sAccumulatorConfigType	Accumulator application configuration data. Declared in: LAccuLib.dTypes
sLevelSignalType	Structure for alarm and limit signals. Declared in: LAccuLib.dTypes
sAccuAmountCharType	Structure for accumulator characteristic definition. Declared in: LAccuLib.dTypes
sUnitSpecType	Axis unit definition type. Declared in: LAccuLib.dTypes
sFrictionCharType	Friction compensation definition type. Declared in: LAccuLib.dTypes
sMechDataType	Axis mechanical data type. Declared in: LAccuLib.dTypes

The following generally applies for designating/naming the structure elements:

[IN]: Values that the user must provide

[OUT]: Results or feedback signals

[IO]: Values, which depending on how the block is interconnected, are supplied by the user or written by the function.

sAccumulatorConfigType

This structure includes configuration data for the accumulator application.

Table 4-22

I/O	Element	Data type	Description
Unit specification			
IN	sLineUnitSpec	sUnitSpecType	Unit specification for line units. eAxisLU and eAxisVTU is relevant.
IN	sFeedUnitSpec	sUnitSpecType	Unit specification for feed axis.
IN	sAccuUnitSpec	sUnitSpecType	Unit specification for accumulator axis

I/O	Element	Data type	Description
Mechanical data			
IN	sFeedMechData	sMechDataType	Mechanical data of feed axis.
IN	sAccuMechData	sMechDataType	Mechanical data of accumulator axis.
Technology controller settings – detailed description is in User Manual Converting Library			
IN	sControllerDataAccu	sTechnologyControllerConfigType	Configuration data for the technology controller that is effective on the accumulator axis.
IN	sControllerDataFeed	sTechnologyControllerConfigType	Configuration data for the technology controller that is effective on the accumulator axis.
Accumulator characteristic			
IN	sAccuAmountChar	sAccuAmountCharType	Accumulated amount identification data.
Settings associated with accumulator			
IN	u8Wrappings	USINT	Number of wrappings in the accumulator unit. Internally saved with the enable rising edge.
IN	r32UpperSwLimit	REAL	[AC] [LU] Upper software limit for accumulator position – if overridden, warning is initiated.
IN	r32LowerSwLimit	REAL	[AC] [LU] Lower software limit for accumulator position – if overridden, warning is initiated.
Settings associated with line			
IN	r32TailSpeed	REAL	[LI] [LU / vTU] Tail end positioning speed. After the deceleration point is detected, feed axis will be decelerated to this speed until material end is detected.
IN	r32AccuSpeed	REAL	[LI] [LU / vTU] Accumulating speed offset added to the line speed setpoint, feed axis will be accelerated to this speed after the restart of the winder.
Fine adjustment settings (delays, corrections)			
IN	u32RestartDelay	UDINT	[ms] Delay time for feed restart after the coil change is signaled to the application.
IN	u32WarningOnDelay	UDINT	[ms] On-time delay for position warning signal output. If the axis position overrides the defined position levels for a shorter time, no signal is output.
IN	u32WarningOffDelay	UDINT	[ms] Time off delay for resetting the warning signal, after axis re-enters normal interval for position monitoring (with hysteresis).
IN	r32WarningHyst	REAL	[AC] [LU] Hysteresis value for resetting the warning signals (if software endsignals are used).
IN	u32BrakePreOpenTime	UDINT	[ms] Brake for the accumulator axis will be opened prior to the detection of the deceleration point.
IN	u32AccuPreEnableTime	UDINT	[ms] Adjustment time for enabling the accumulator axis prior to the opening, and after the closing of the brake.

I/O	Element	Data type	Description
IN	r32AutoStopAdj	REAL	[FE] [LU] Adjustment length for automatic stop, subtracted from the rest length value, resulting in an earlier stop as the material end and leaving material on the coil.
IN	r32FillStopAdj	REAL	[FE] [LU] Like AutoStopAdj but for the deceleration from the accumulating speed to the line speed.
IN	r32OutputChangeLimit	REAL	[AC] [LU / vTU / TV] Controller output limit for controller switchover. The web tension control is active on the accumulator axis while this axis is moving. The dancer or tension control will be re-activated on the feed axis, if the accumulator is in neutral position and the controller output for the accumulator axis is below this threshold.
IN	sWebBreakConfig	sWebBreakDetectionType	Configuration data for web break detection – detailed description is in User Manual Converting Library /1/
Settings for feed setpoint ramping			
IN	r32FeedNominalValue	REAL	[FE] [LU / vTU] Maximum value for feed axis setpoint (without technology controller output) and also reference value for rampup and rampdown times.
IN	r32FeedRampUpTime	REAL	[ms] Ramp up time for feed axis setpoint.
IN	r32FeedRampDownTime	REAL	[ms] Ramp down time for feed axis setpoint.
IN	r32FeedRoundingTime	REAL	[ms] Rounding time (jerk limiting) for feed axis setpoint. Acceleration from zero to maximal acceleration is reached within this time.
Settings for tension setpoint ramping			
IN	r32TensStallSpeedLimit	REAL	[LI] [LU / vTU] Speed limit for line speed, below this speed the tension setpoint is changed to stall tension.
IN	r32TensStallPercentage	REAL	[0..100%] Defines the stall tension in perentage of the main tension setpoint value.
IN	r32TensSetpoint	REAL	[Z] Main tension setpoint.
IN	r32TensRampTime	REAL	[ms] Ramping time for tension setpoint.
IN	r32TensNominalValue	REAL	[Z] Reference value for ramp time.

sLevelSignalType

This structure is used once as an input to deliver sensor signals to the accumulator control unit and also as output signals for software limit monitoring.

Table 4-23

I/O	Element	Data type	Description
IO	boUpperAlarm	BOOL	Sensor value or signal set by function for reaching upper alarm threshold.
IO	boUpperWarning	BOOL	Sensor value or signal set by function for reaching upper warning threshold.

I/O	Element	Data type	Description
IO	boLowerWarning	BOOL	Sensor value or signal set by function for reaching lower warning threshold.
IO	boLowerAlarm	BOOL	Sensor value or signal set by function for reaching lower alarm threshold.

sAccuAmountCharType

This structure is used to define the points for linear interpolation regarding the identification of the actual accumulated amount. Points are to be defined at commissioning.

Table 4-24

I/O	Element	Data type	Description
IN	r32PosLow	REAL	[ac LU] Accumulator axis lower position
IN	r32AmountLow	REAL	[FE] [LU] Amount associated with lower accumulator position.
IN	r32PosHigh	REAL	[ac LU] Accumulator axis upper position
IN	r32AmountHigh	REAL	[FE] [LU] Amount associated with upper accumulator position.

sUnitSpecType

This structure is used to define the unit for axis specific measures (position, speed, acceleration, diameter).

Table 4-25

I/O	Element	Data type	Description
IN	eAxisLU	eAxisLUType	Defines axis length unit – LU.
IN	eDiamLU	eDiameterLUType	Defines axis diameter unit – LU.
IN	eAxisVTU	eAxisTUType	Defines axis velocity time unit – vTU.
IN	eAxisATU	eAxisTUType	Defines axis acceleration time unit – aTU.

sFrictionCharType

In this structure the friction compensation data is defined.

Table 4-26

I/O	Element	Data type	Description
IN	eFrictionCharMode	eFrictionCharModeType	Chooses the definition mode (table/linear).
IN	ar32Speed	ARRAY OF REAL	[LU / vTU] Speed coordinates for table mode. 22 values. Array size is LCONLIB_MAX_IDX_B
IN	ar32Torque	ARRAY OF REAL	[M] Torque values for table mode. 22 values. Array size is LCONLIB_MAX_IDX_B
IN	r32FrictMinSpeed	REAL	[LU / vTU] Minimal axis speed in axis speed unit for friction compensation. Used as absolute value, both positive and negative direction.
IN	r32LinGrad	REAL	[M / LU / vTU] Gradient for linear friction compensation characteristic, used as absolute value.

I/O	Element	Data type	Description
IN	r32LinOffset	REAL	[M] Offset for linear friction compensation. With negative speeds sign is effective opposite.

sMechDataType

This structure defines the mechanical properties of an axis.

Table 4-27

I/O	Element	Data type	Description
IN	r32Inertia	REAL	[J] Total inertia – including motor – motor side.
IN	r32Diameter	REAL	[LU] Axis diameter
IN	r32SpeedAdjust	REAL	Speed fine adjustment factor. E.g. 1.05 is 5% overspeed.
IN	sFrictionChar	sFrictionCharType	Friction compensation data.

5 Integrating into the user program

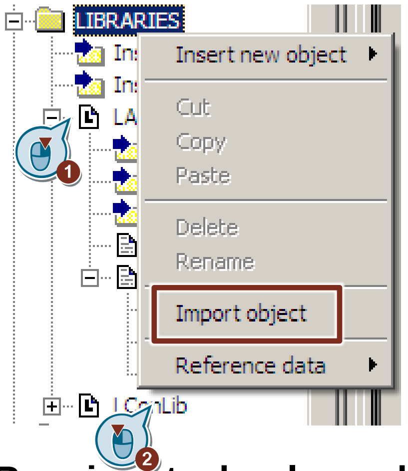
The following steps are necessary to successfully integrate the SIMOTION Web Accumulator standard application into a new project. Please keep in mind, that the integration of the application just by itself does not realise all typical machine functions.

5.1 Importing the source code

The accumulator functionality is part of the LAccuLib library. This library is available as standard “SIMOTION Web Accumulator” application as well as through an XML Export. In order to use the functionality of the library, this must be integrated into the corresponding user project. There are two possibilities to do so:

1. Dearchive and open the “SIMOTION Web Accumulator” project. In parallel, open a second SIMOTION SCOUT project which contains your user program and copy the LAccuLib library from the program library.
2. Import the LAccuLib library from the XML export, with right mouse button click on LIBRARIES in the project tree and browse for the respective file.

Figure 5-1



5.2 Required technology objects

The application can work in various combinations of the connected technology objects. Generally, three TOs can be connected to the function block. The connection to the accumulator axis is necessary.

Accumulator axis

The accumulator axis must always be present, can be set-up as DRIVEAXIS or POSAXIS, however this choice is not independent from the presence of an external encoder. This axis follows the speed setpoint calculated by the application – in automatic mode. The axis must be enabled and disabled outside of the accumulator application, since this application does not cover basic axis functions. The axis must **not** be a modulo axis.

Accumulator external encoder

This technology object may be used to determine the actual position of the accumulator instead of using the actual position of the accumulator axis. Using a machine encoder can improve the accuracy. The technology object type is EXTERNALENCODERTYPE. The presence of this external encoder also determines the permissible type of the accumulator axis, defined by the following table.

Table 5-1

		Accumulator external encoder	
		NOT_PRESENT	**PRESENT**
Accumulator axis type	**DRIVEAXIS**	ERROR	OK
	POSAXIS	OK	OK

The presence of an external encoder and the type of the accumulator axis is not irrelevant. If an external encoder is connected, that is used as position reference for the identification of the accumulated amount, a DRIVEAXIS can be used. If no external encoder is connected, the accumulator axis must be an axis with position interface, and this position will be used as position reference.

Modulo must **not** be enabled on the external encoder.

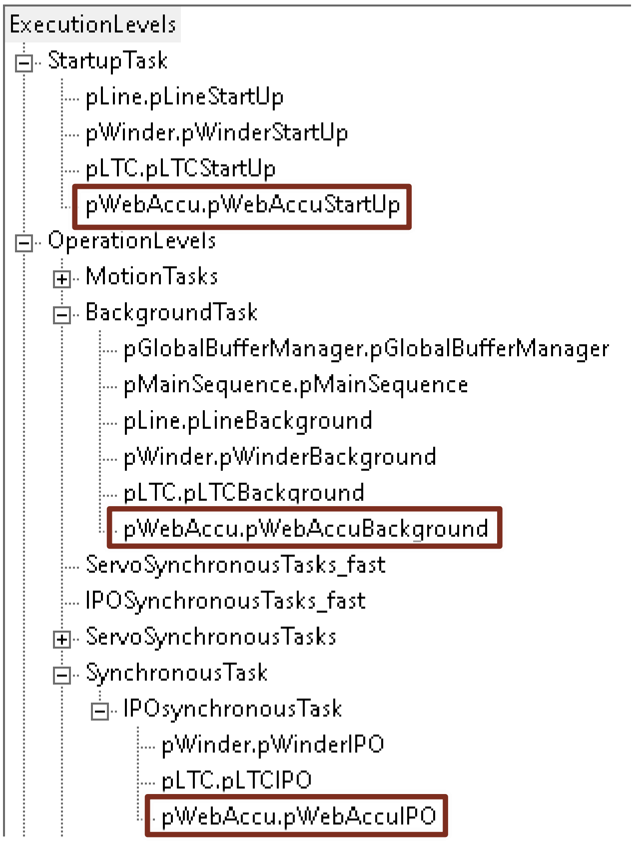
Feed axis

The presence of the feed axis is optional. If it is not present, torque precontrol for the feed axis is disabled, but in automatic mode the speed setpoint will still be calculated, but not activated on any axis. If the axis is present, it can be set-up as DRIVEAXIS or as POSAXIS. In this case, the speed setpoint is activated on the feed axis – in automatic mode.

5.3 Integrating the core function

Copy pWebAccu from the example project into the target project. It contains a StartUp program for parametrization, a background program with an example sequence and an IPO synchronous program which calls FBLAccu_WebAccumulator and the rest length calculation. Subsequently you can adapt the programs to your own needs. Lastly, integrate the programs into the execution system.

Figure 5-2



5.4 Information regarding the user program

The user is responsible for integrating the function blocks into his automation solution or his user program. This includes, among other things, activating, referencing, positioning and jogging the axes, the operating states of the machine, the data management and alarm handling. Also included are the emergency shutdown and where relevant, the implementation of monitoring functions.

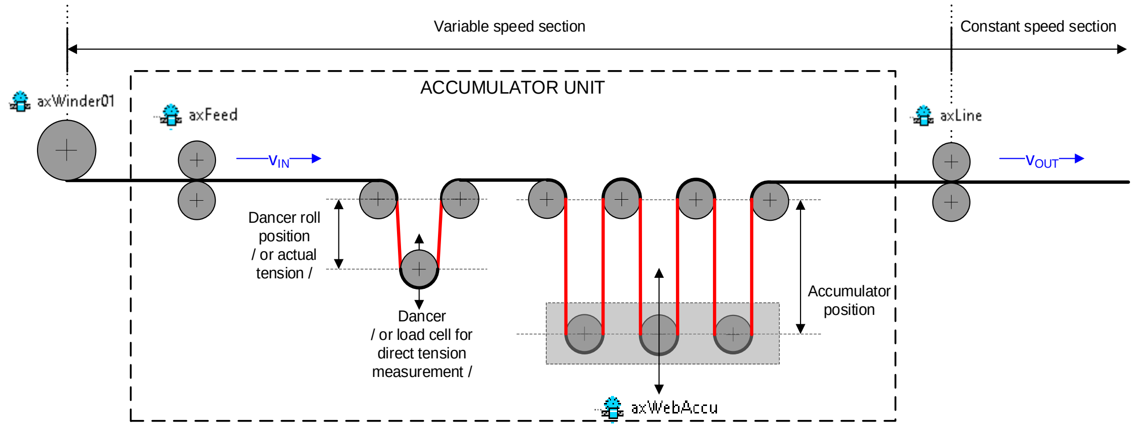
5.5 Example project

This chapter gives a closer look into the example project. The project is supposed to be an easy and fictive application example to deepen the understanding of the application and to pretest some aspects in the simulation with SIMOSIM. Therefore, no hardware is required.

5.5.1 Structure

The example project is built on the example project of the winder, thus containing the library LConLib. However, there is just one winder. The interaction between the different TOs is explained with the help of the example of a web accumulator at an unwinder.

Figure 5-3



The winder is operating in indirect tension control, because otherwise axFeed would work against the technology controller of the winder which would result in enormous web tension between those two axes. Dancer position control (or direct tension control with load cell) is usually done by axFeed. If axWebAccu is enabled, axWebAccu is taking over dancer position control. The switchover to the technology controller of axFeed happens automatically depending on the parametrizable threshold value r32OutputChangeLimit.

5.5.2 Description of the program units

The SIMOTION Web Accumulator example project contains the following program units, which are mostly identical to the ones of the SIMOTION winder example project.

- **pMainSequence**
  The unit pMainSequence contains the program
  - **pMainSequence**
    Example control sequence to control different modules.
    This sequence coordinates the sub-module sequences.
    The example project contains two modules (line axis and winder).
    Single modules can also be controlled directly via the respective module control sequence. In this case the main control sequence is not necessary.
    For testing the web accu application, the sequence was extended by a short sequence for a roll change.
-
- **pLine**
  The unit pLine contains the programs
  - **pLineStartUp**
    Pre-allocation of configuration data
  - **pLineBackground**
    Example control sequence to control a line axis.

- **pWinder**
  The unit pWinder contains the programs

  - **pWinderStartUp**

    Pre-allocation of configuration data
  - **pWinderBackground**

    Example control sequence to control a winder axis.
  - **pWinderIPO**

    FBLConWinder function block call as well as normalization of diameter sensors and dancer position sensor.

- **dConITDiag**

  This unit contains the global variable definition for usage of the **Fehler! Verweisquelle konnte nicht gefunden werden.**. The actual value copy to these parameters is done in the program pWinderBackground.

- **pWebAccu**

  The unit pWebAccu contains the programs
  - **pWebAccuStartUp**

    Pre-allocation of configuration data
  - **pWebAccuBackground**

    Example sequence to control a web accu.
  - **pWebAccuIPO**

    FBLAccu_WebAccumulator function block call as well as rest length calculation of the winder and normalization of dancer position sensor

- **pFault**

  Template programs for the tasks TechnologicalFaultTask and PeripheralFaultTask.

- **pStartupCheck**

  The application „SIMOTION StartupCheck“ (https://support.industry.siemens.com/cs/de/de/view/48947625/en) is part of the example project because of I/O data access to an ET200 in the program code.

  The application can be integrated to a user project with the SIMOTION Project Generator.

- **pGlobalBufferManager**

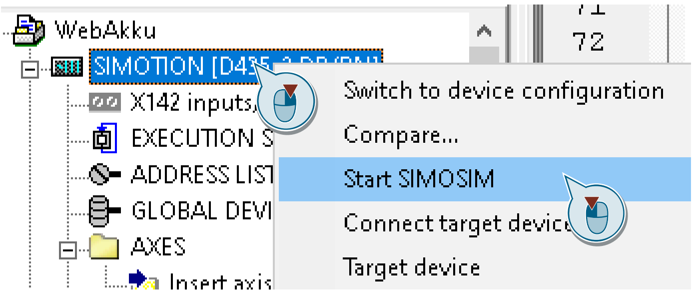
  This unit is part of the application „SIMOTION StartupCheck“.

5.5.3 Operating the example project

The example project is prepared for use in combination with SIMOSIM

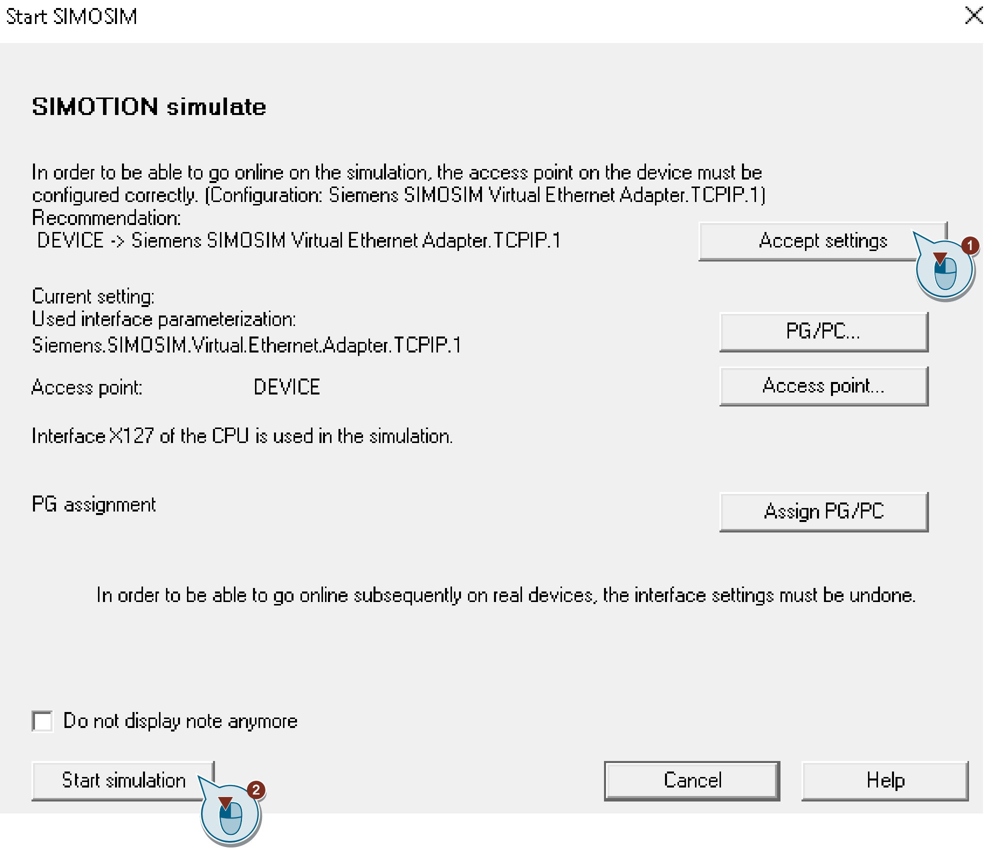
First start the SIMOSIM instance.

Figure 5-4



A pop up window appears, which refers to the interface configuration. With "Accept settings" all necessary settings are accepted automatically. Subsequently the SIMOSIM instance can be started with "Start simulation".

Figure 5-5



The SIMOSIM instance will start. Go online and download the CPU. Open the watch table "Control". It contains all necessary variables to operate the project and additional diagnosis variables.

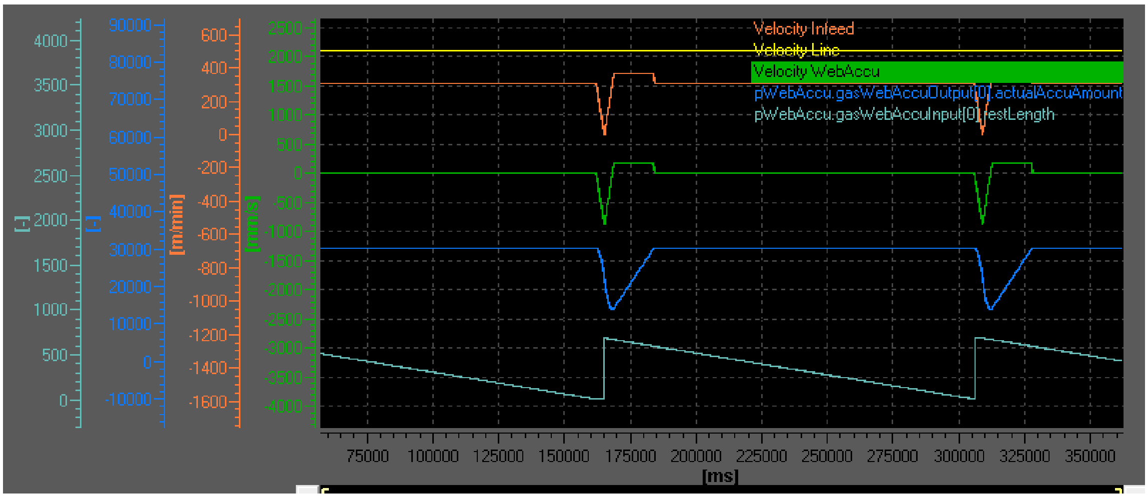
Figure 5-6

	⊞ Name	Information		Control v
	All	All		All
3	SIMOTION\pWinder.gboSetDiameter		☑	FALSE
4	SIMOTION\pMainSequence.gboStart		☑	FALSE
5	SIMOTION\pWinder.gaboEnableTensionWinder[0]		☑	TRUE
6	SIMOTION\pWebAccu.gasWebAccuInput[0].enable	Enable FB WebAccu	☐	
7	SIMOTION\pWebAccu.gasWebAccuInput[0].automa...	Start automatic operation of FB W..	☑	TRUE
8	SIMOTION\pLine.gboStartLine		☑	TRUE
9	SIMOTION\pLine.gar32LineVelocity[0]		☑	300.0000

A rising edge on gboSetDiameter will set the diameter of the winder to the value of gr32CoilStartDiameter. Afterwards, gboSetDiameter can be set back to FALSE. Subsequently the sequence can be started with gboStart. The enable bits of winder and web accu will be set to TRUE, the drives will be set in control. The setpoint of the technology controller of the winder as well as the ctrlEnable bit can be set with gaboEnableTensionWinder. By setting gasWebAccuInput[].automatic the web accu will start filling. Finally, the line can be started with gboStartLine. The material will be unwound until the winder runs empty. By calculating the brake length internally, the feed axis will stop in time and the web accu will output material to the process. The splice is simulated very simplistically by deactivating the winder and setting the diameter to the value of gr32CoilStartDiameter and restarting the feed axis. Afterwards the web accu fills up again by moving back to the neutral position and the process can be repeated indefinitely.

In the following trace the role change can be seen two times. If the material rest length is getting closer to 0, the feed axis will brake and the web accu puts out material by moving with negative velocity. This can also be seen by looking at the variable actualAccuAmount, which displays the actual amount stored in the accumulator. If the feed reaches standstill, it will restart briefly afterwards and accelerate. Consequently, also the web accu accelerates to go back to reach its neutral amount. As soon as it is reached, the web accu goes back to standstill and the feed axis is decelerating to line velocity.

Figure 5-7



5.6 Use in combination with Print Standard

The application can also be integrated into the concept of Print Standard. A format master can be used as line axis (axLine). The winder (axWinder01) is operated in the designated operation mode WINDER. To prevent unwanted interactions between Print Standard and the Web Accumulator application, accumulator (axWebAccu) and feed (axFeed) must use the operation mode

EXTERNAL_CONTROL. Due to the fact, that neither the operation mode nor the Web Accumulator application itself is taking care of enabling axes, the axes must be enabled outside of the application, e.g. with help of LMCBasic.

6 General information on the application

6.1 Scope of supply

The package „Web Accumulator with SIMOTION„ comprises the following:

- LAccuLib SIMOTION SCOUT library exported in XML format
- Sample ST source files for Startup task, global variable declaration and FBLAccu_WebAccumulator call
- Documentation in english language

6.2 Abbreviations

Table 6-1

Name	Description
AA	Accumulator axis
aTU	Time unit for acceleration
FA	Feed axis
FB	Function block
FC	Function
lbf	Pound-Force
Lib	Library
LU	Length unit
M_{PRE}	Precontrol torque
n_{PATH}	Accumulator path count
POU	Program organisation unit
RFG	Ramp function generator
RGE	Ramp function generator with jerk limiting
SAP	Standard Application
SCOUT	SIMOTION Controlling with Optimized Usability Toolbox
SI	Le Système International d'Unités – International system of units
ST	Structured text (IEC 61131-3 Standard programming language)
TO	Technology object
TU	Time unit
v_{AA}	velocity of the accumulator axis, zero in standstill
v_{ACCU}	velocity offset for accumulator fill/depletion
v_{FEED}	feed axis velocity, variable
v_{IN}	accumulator input velocity
v_{LINE}	line velocity, constant
v_{OUT}	accumulator output velocity
v_{TAIL}	tail end positioning velocity
v_{TCA}	technology controller output for accumulator axis
v_{TCF}	technology controller output for feed axis

Name	Description
vTU	Time unit for velocity/speed
XML	eXtensible Markup Language

7 Appendix

7.1 Service and support

Industry Online Support

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7.3 Application support

Siemens AG
Digital Factory Division
Factory Automation
Production Machines
DF FA PMA APC
Frauenauracher Str. 80
91056 Erlangen, Germany

mailto: tech.team.motioncontrol@siemens.com

7.4 Links and literature

Table 7-1

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to this entry page of this application example https://support.industry.siemens.com/cs/ww/en/view/109744604
\3\	Converting Library User Manual Converting Library (LConLib) https://support.industry.siemens.com/cs/ww/en/view/48805235
\4\	SIMOTION Axis Control (LMCBasic) https://support.industry.siemens.com/cs/ww/en/view/48816191
\5\	SIMOTION Print Standard (LPrint) https://support.industry.siemens.com/cs/ww/en/view/38195516

7.5 Change documentation

Table 7-2

Version	Date	Modifications
V 1.0.1	07/2009	minor changes in consistency
V 1.0.2	08/2016	compatibility for LConLib V2.x.x
V1.0.3	07/2017	compatibility for LConLib V2.2.3 (LCon Prefix)
V 3.0.0	12/2020	Incompatible update of the application