

Motion control unlimited

FM 458 in SIMATIC S7-400



In many machines, mechanical shafts and gears are increasingly being replaced by software, and individual, intelligently controlled drives.

This means that modern machine designs have to meet exacting requirements in terms of processing speed and precision, not to mention flexibility.

Mechatronic solutions with fast cycle speeds are becoming increasingly widespread, especially when it comes to machinery for production, packaging and printing.

The FM 458 application component is available within the SIMATIC® S7-400® range for exactly this range of applications. Together with the new CFC function blocks for Motion Control, it has all the necessary mechatronic functions.

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Technology functions with FM 458 and CFC modules

The FM 458 application module enables demanding technical functions to be achieved using the SIMATIC S7-400. In particular, complex and highly dynamic motion controllers can be produced simply and easily in conjunction with the appropriate CFC function blocks.

Its unlimited functionality means that the FM 458 is flexible and can be used for a wide range of applications. As well as motion control, completely different technological functions can be achieved using the FM 458, such as winder or hydraulic controls or other controllers.

The FM 458 is Siemens' top-of-the-range module for motion control.

The FM 458 is based on more than 15 years of experience with high-performance control systems and incorporates the benefits of SIMATIC – which has been the world's leading automation system for decades.

With its high-performance RISC processor, the FM 458 can control the position and synchronization for up to several hundred drives, even at extremely fast cycle times. The replaceable serial and analog ports also make it possible to connect a range of different drive types.

Every partial function of a motion control system is carried out by means of a CFC function block. There are over 300 blocks available, from simple mathematical or logical operations through to complex functions to take over all the motion control for the axes. The motion functions can be chained and combined at will.

A centralized control solution using the FM 458 has a number of benefits:

- Cost savings when using a large number of axes through the use of a single controller
- Simple, concise engineering
- User-friendly, manageable monitoring and diagnostics

The FM 458 application module is fully integrated into Totally Integrated Automation® TIA - the Siemens concept which enables three-way consistency of engineering, data storage and communications.

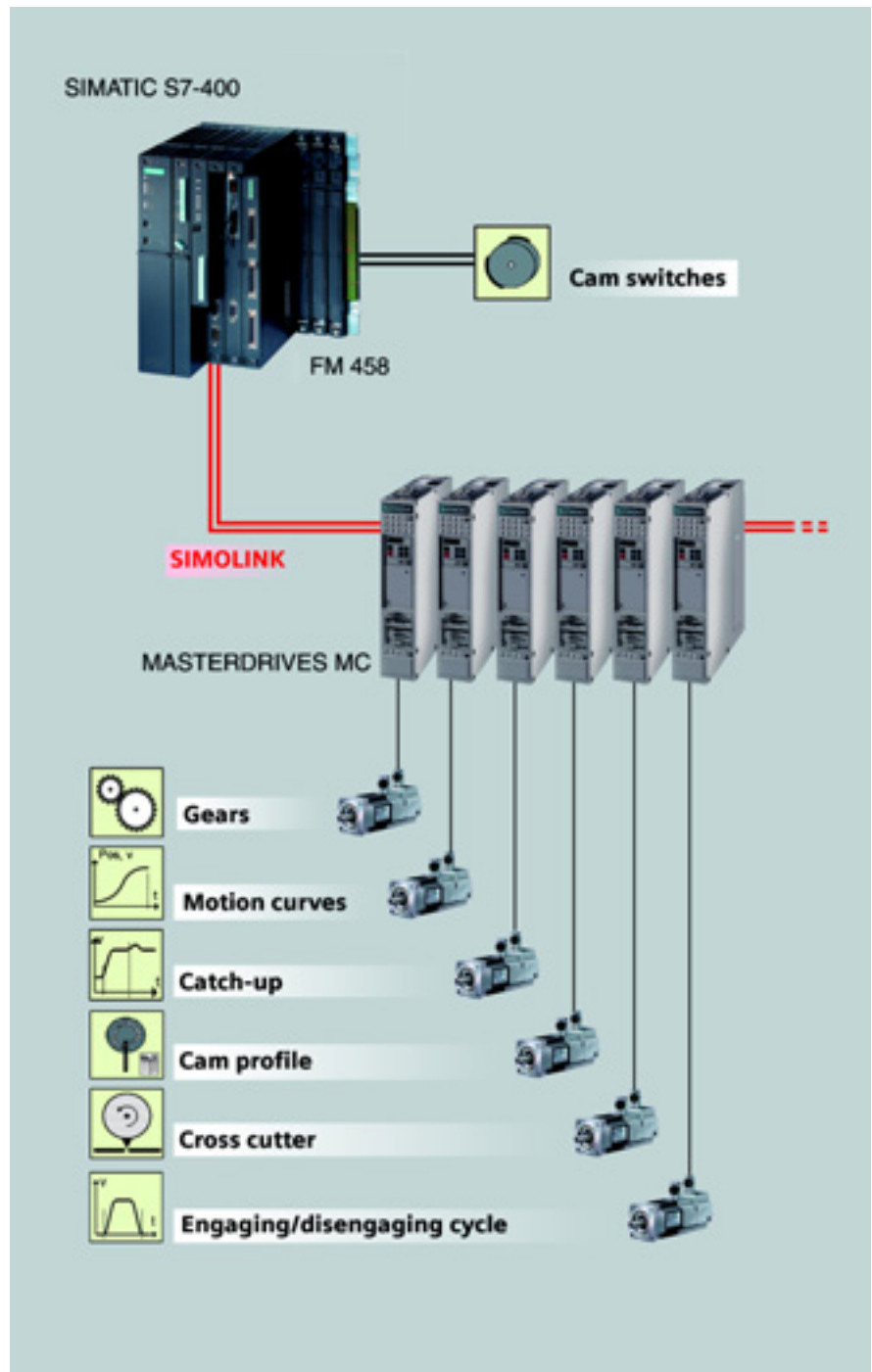


Fig. 1: Motion control with no limits using FM 458 and CFC function blocks

This means that tried and tested SIMATIC standard tools are used to configure the applications:

- STEP® 7 and the SIMATIC Manager for project administration and HW-Config for hardware configuration

- Continuous Function Chart CFC – the graphical function chart editor – to configure technological functions
- Sequential Function Chart SFC (optional) for combining CFC programs with a user-friendly sequence control system which is easily manageable and configurable

Configuration and startup

Efficient using CFC function charts

The control functions are configured using the SIMATIC engineering tool Continuous Function Chart. CFC is an object-oriented, simple-to-learn Windows application which is intuitive to use.

Using CFC to create automation programs minimizes the work required:

- You can retrieve technological function blocks from a block catalog just by clicking with the mouse and then connect their inputs and outputs later. Finally, all you need to do is set the application-specific parameters and the configuration is complete
- Creating a function by connecting standard blocks is quicker and less error-prone than programming
- The function charts automatically provide detailed documentation for the program created

CFC has a whole range of high-performance functions which considerably reduce engineering and startup work:

- Test mode to enable quick startup and signal monitoring using a graphics-based system
- Special online functions: Simple viewing and permanent changing of values and connections between function blocks, and insertion of new functions in the form of additional function blocks while the system is live
- Frequently used program components (plans) can be compiled into a module which can be reused and modified on a central basis
- Hierarchical CFC plans ('plan in plan' technology) provide the option of increasing the transparency of extremely complex programs or structuring programs ('top-down')

If the standard blocks available are not sufficient for specialist applications, you can use the user-friendly 'user function block generator'. This allows you to develop user-specific function blocks in C which can then be used in CFC without any further work.

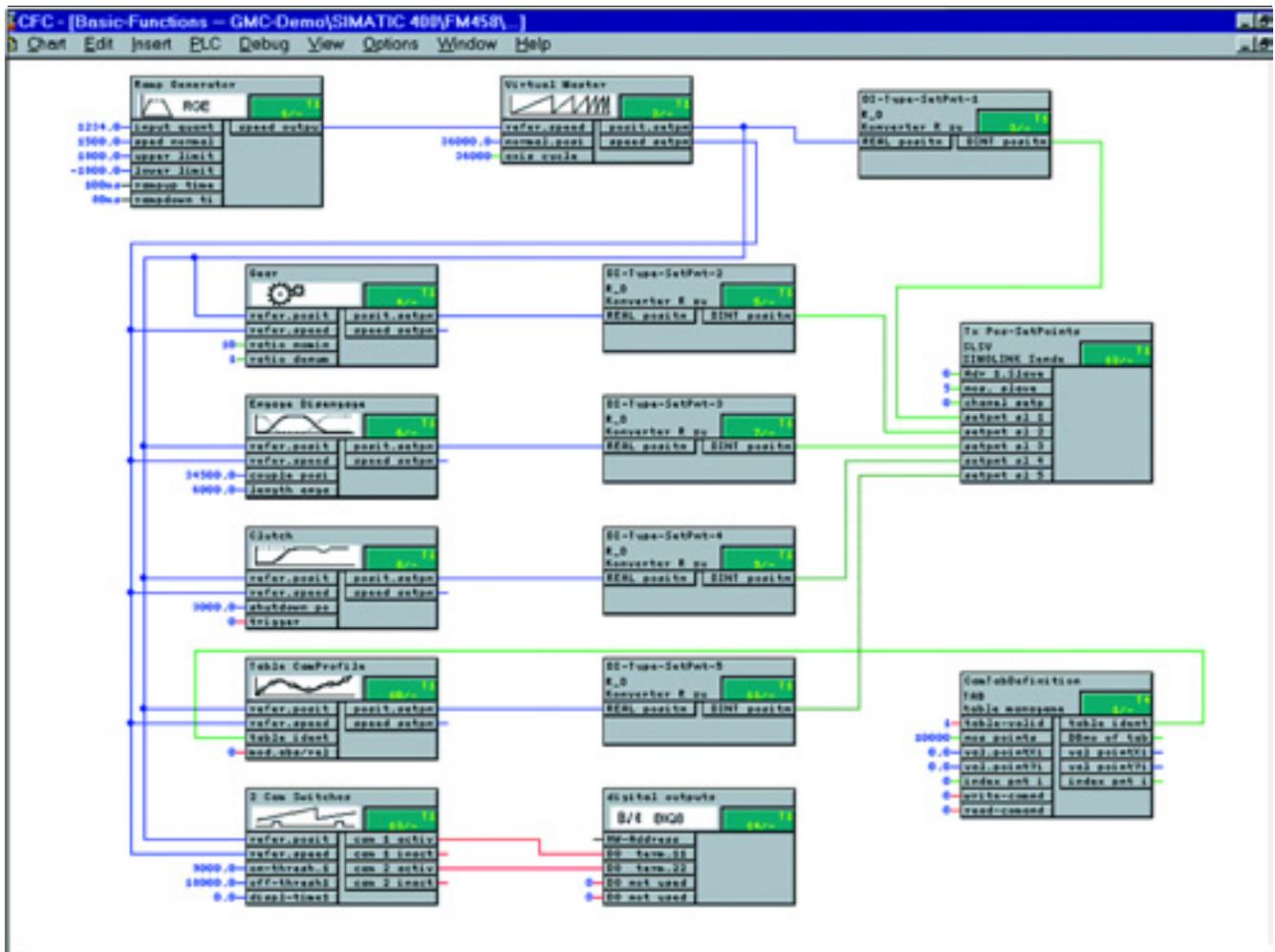


Fig. 2: CFC function chart with connected function blocks for controlling, for example, 5 drives

Connecting drives to FM 458 using serial or analog interfaces

Connection using serial ports

MASTERDRIVES frequency converters are connected to the FM 458 using serial interfaces.

The high-speed SIMOLINK fiber optical ring is used for data transfer.

In MASTERDRIVES MC, the position controller with position detection is used to determine a speed setpoint.

The FM 458 also provides a speed pre-control value to ensure increased dynamic and stability.

The minimum position controller cycle time is 1 ms, which is a real advantage for applications which require high production speeds and precision. A pulse frequency of 8 kHz can then be set to minimize motor noise.

In the future, the PROFIBUS®-DP clock synchronized will also be available on the FM 458 as well as the SIMOLINK.

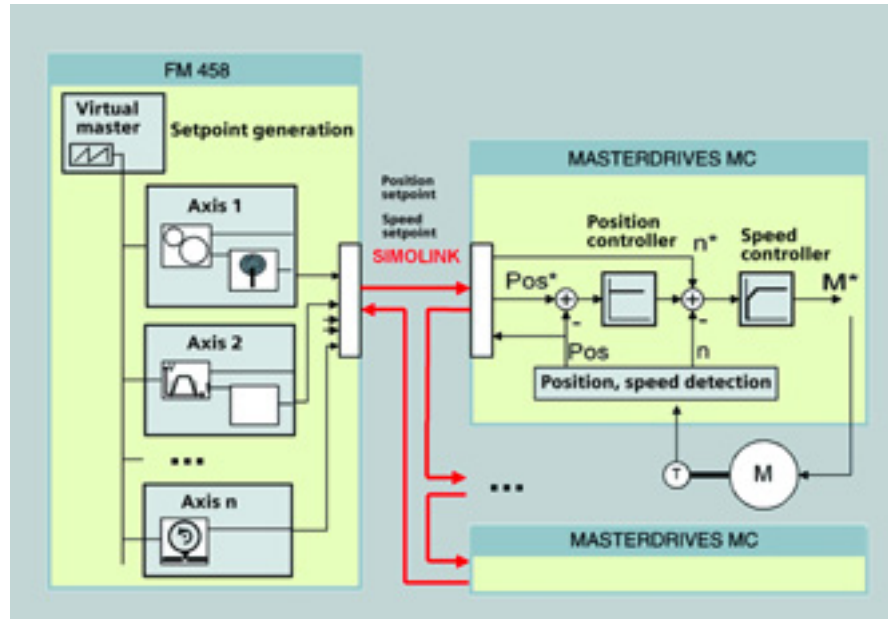


Fig. 3: Control structure of an FM 458 axis controller with SIMOLINK and MASTERDRIVES MC

Connection using analog ports

Drives with no SIMOLINK or PROFIBUS-DP serial link can be connected via analog ports. In this case, the FM 458 executes the set point and also takes on the function of the position controller for the drives.

Speed setpoints are supplied to each of the drives. Current speed and position values are sensed on the FM 458 using the NAVMC block.

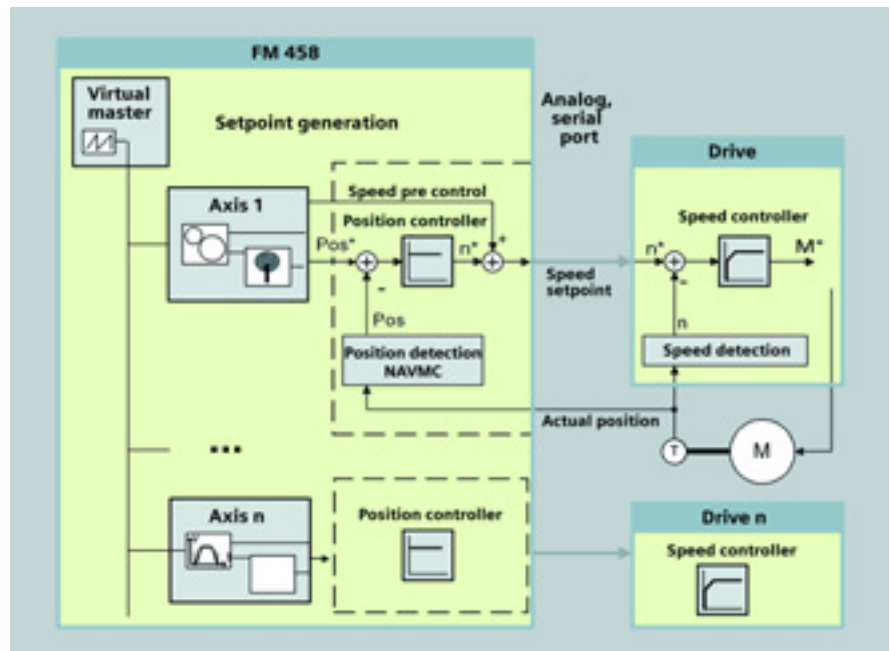


Fig. 4: Control structure of an FM 458 axis controller for other drives

Function blocks for motion control

Virtual master, coupling function

Machines, especially those used for production, packaging and printing, require a wide range of drive-specific functions, e.g.

- Virtual master
- Catch-up/stop
- Gear synchronization
- Positioning

- Engaging/disengaging cycle
- Cam switches
- Motion curves
- Cross cutters/sealers
- Cam profiles
- Reference runs, alignment
- and many more

These motion control functions are carried out by CFC function blocks. They are suitable for both rotary and linear axes and can be combined together in any formation. The individual modules are described below.

INT_MR: Virtual master

The virtual master generates the main setpoint for the drives on the basis of the machine speed required. The main setpoint consists of the saw-tooth like position setpoint and the speed pre control for the position controller. Depending on the machine type, it can be replaced by a real master. With a connected additional ramp function generator (RGJ block) a gentle startup is possible.

The axis cycle length at which the actual position value and position setpoint are reset is also an important variable. This length could relate to the length of the product to be processed in the machine. If, for example, it takes 3 rotations of the motor to process the product, the axis cycle could be three times the increments of the motor position encoder, i.e. $3 \times 360^\circ$.

This ensures that the program is extremely transparent and easy to modify.

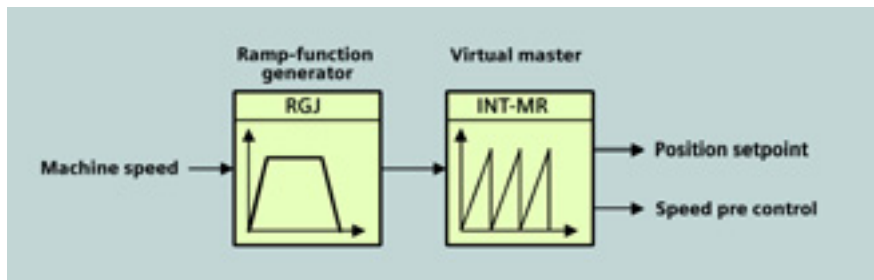


Fig 5: Virtual master with RGJ und INT_MR function blocks.

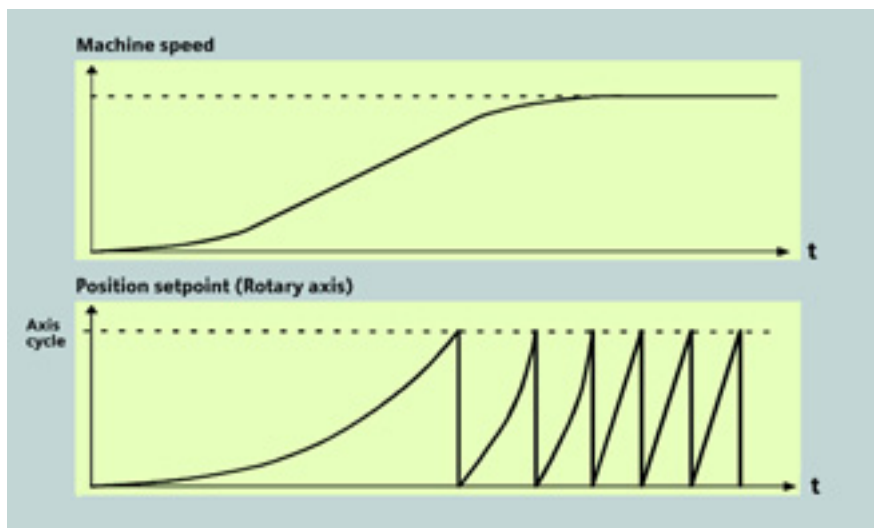


Fig. 6: Generation of the saw-tooth like position setpoint based on the machine speed

CLUTCH: Clutch function

The clutch function enables the synchronization of a drive on an axis which is already moving. For this, the axis can either be moved at the same speed or synchronized on a position-controlled basis.

In addition, the axis can also be controlled and stopped or decelerated to an adjustable speed.

For the clutch process, you can adjust the maximum speed/acceleration and the maximum jerk.

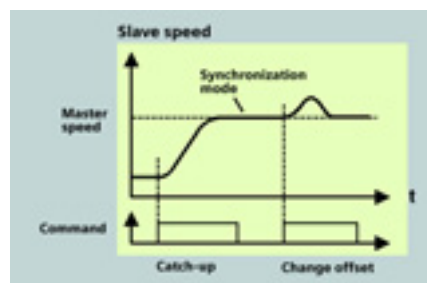


Fig.7: "Catch-up" function with CLUTCH block

Function blocks for motion control

Gear function, positioning

GEAR: Gear function

A drive can modify the speed of a following drive by using the gear function block. The relationship between the two speeds is defined by entering a gear ratio (32 bit nominator and denominator). Thus the gearing steps can be precisely defined, which enables compensation for drum wear, for example.

The block can also be used to change the axis cycle. This makes sense, for example, if the machine is used to assemble lots of small products into a longer product, which is then processed further. For example the axis can be extended from 180° to 360°.

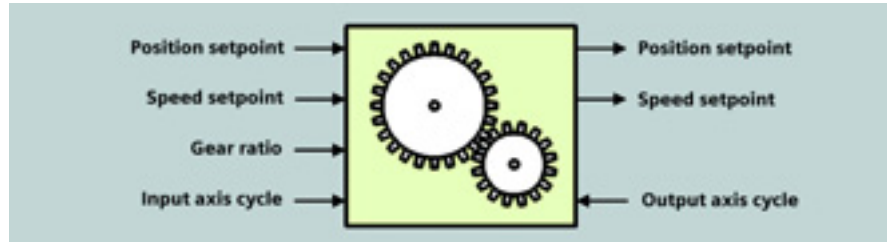


Fig.8: The most important inputs and outputs of the GEAR block

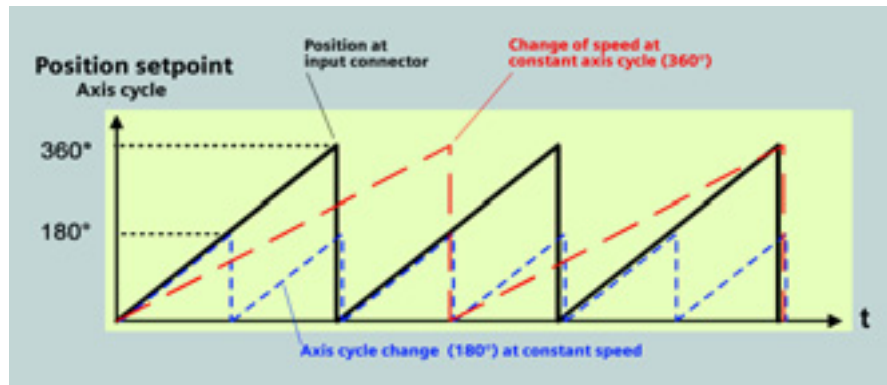


Fig. 9: Position setpoints for the different gear functions

POSMC: Positioning

The positioning block generates the setpoint for the relevant position and also the associated pre control variables, such as speed and acceleration. This means a high level of dynamics.

The positioning process can be optimized to meet the application requirements. The following can be set:

- Maximum speed
- Maximum acceleration
- Maximum jerk

The target position can either be reached in the quickest time, or by avoiding an overshoot. As well as the absolute positioning, a relative positioning function is also possible for chained movements.

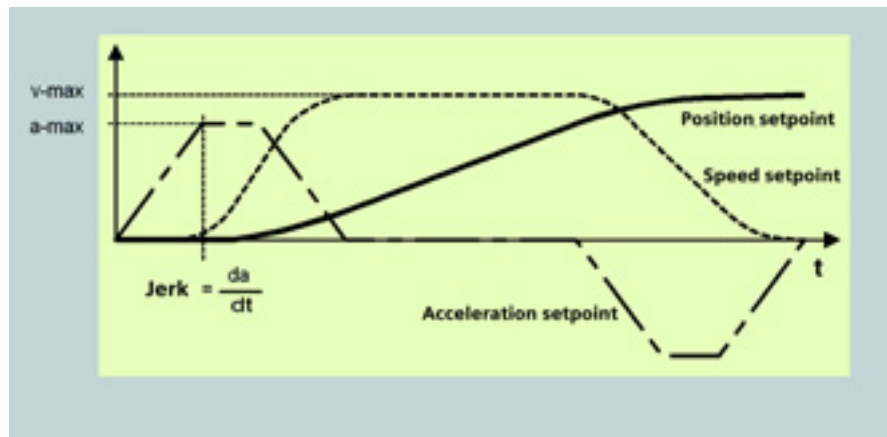


Fig. 10: Adjustable characteristics for positioning using POSMC block

Function blocks for motion control

Engaging/disengaging cycle, cam switches

EDC:

Engaging/disengaging cycle

The engager moves the axis from standstill for the defined engage cycle time.

The disengager brakes a drive until it stops and, once the disengaging cycle is complete, accelerates it back up to the master speed.

Engaging and disengaging cycle lengths are adjustable and can be extended "on the fly". Roundings can also be defined for the movements.

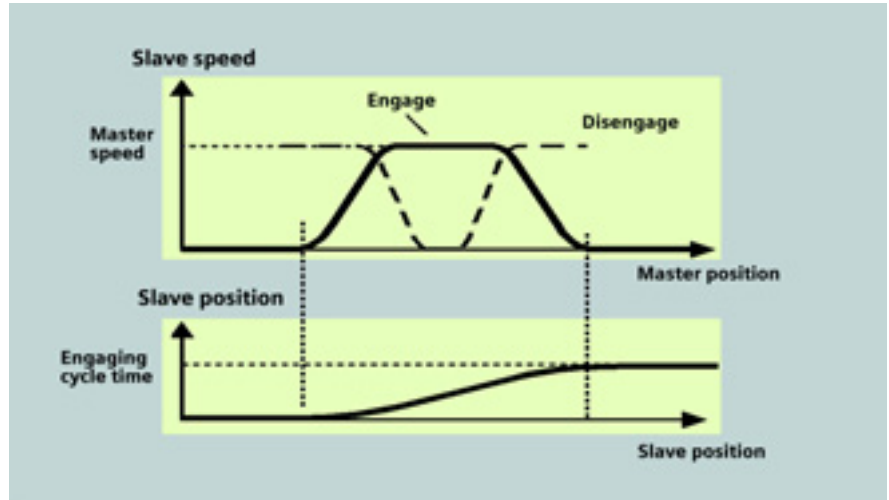


Fig. 11: Engaging and disengaging cycle functions using the EDC block

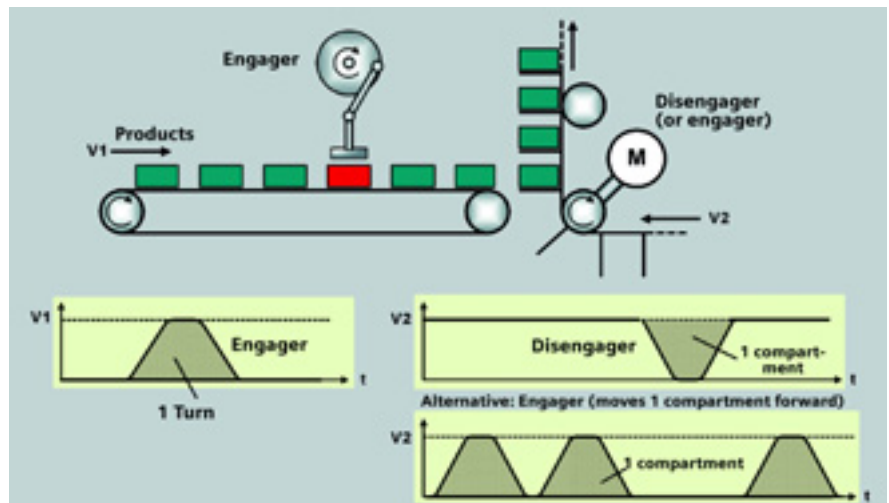


Fig. 12: Engaging and disengaging cycle functions in a packaging machine

CAMSW:

Cam switches

Cam blocks give a position-dependent digital signal to control connected process or machine peripherals. The switch signals can be generated early or late to compensate the switching times of connected final controlling elements.

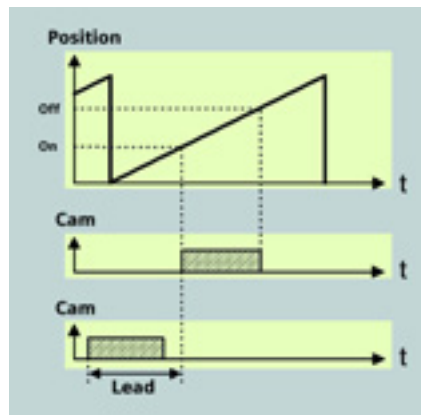


Fig. 13: Position-controlled cam output using CAMSW block

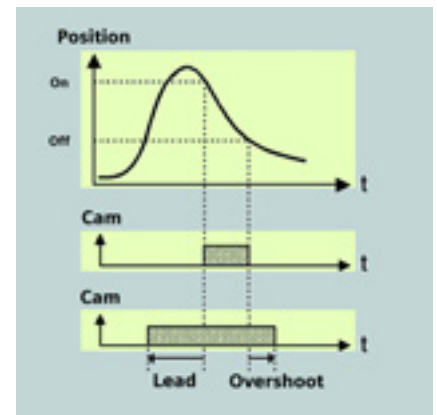


Fig. 14: Cam output with time adjustment control using CAMSW1 block

Function blocks for motion control

Motion curves, cross cutter, motion functions

MCSB, MCSS: Motion curves

In many applications, position-dependent speed profiles need to be used in addition to time-dependent speed and position setpoints.

The MCSB/MCSS and CAMD blocks can be used to define individual motion segments, which can simply be chained together for complex motion.

For each segment, start and stop conditions can be defined for the position, speed and acceleration.

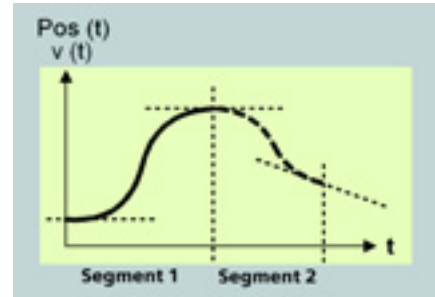


Fig. 15: Definition of motion curves using MCSB and MCSS blocks

SHEAR: Cross cutter/sealer

In many modern production and packaging machines, rotary shears or cross sealing functions are required. The SHEAR function block incorporates nearly all the calculations necessary for this, which makes configuration significantly easier.

Depending on the current position of the material and the length of the product to be processed, the block calculates the position setpoint as a 4th order curve and the speed setpoint as a 3rd order curve. This guarantees the blade and the material are moving at the same speed when the cut is made. The cut length can also be changed at any time while the system is running.

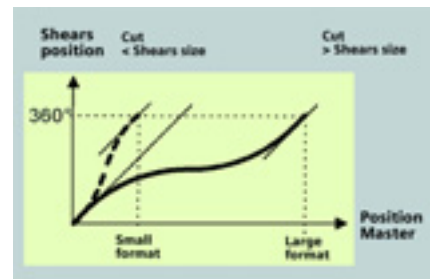


Fig. 16: Transfer curves for the SHEAR block

MDCMP: Other motion functions

In order to provide high-performance and flexible machine designs, changes of setpoint channels or operating modes must be incorporated.

For example, it can be worthwhile to switch from an electronic gearbox to a cam profile while the system is running, or to switch from inching mode to normal mode as quickly and smoothly as possible.

For all applications where these sort of changes bring about jumps in the setpoints and actual values, the smoothing blocks MDCMP and MDCMP1 can be used to compensate for these changes. They enable a smooth transition between two sources of setpoints.

The module MDCMP1 generates additional setpoints for special motion functions, e.g. inching, aligning, referencing or pass mark synchronization. The resulting changes in speed and acceleration can be configured for all transition functions.

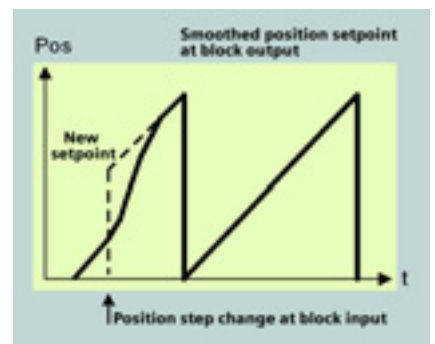


Fig. 17: Smoothing a position step change using MDCMP block

Function blocks for motion control

Cam profiles using tables

Cam profiles

The cam profile is a variable gear for which any relation can be defined between the movement of the master and the slave, even a nonlinear relation.

This means that the gear ratio factor (gradient) can be, for example, a function of the position of the master.

On the FM 458, cam profiles can be stored as tables or other mathematical functions.

TAB, TABCAM: Table synchronization

Cam profiles as tables are stored on the FM 458 in the TAB block. The tables contain between around 16,000 and 250,000 interpolation points.

The tables are read out by the TABCAM block. This determines the slave position and speed applicable for a specific master position on the basis of the table. There is a linear interpolation between two interpolation points.

It is also possible to switch between different tables while the system is running using a multiplexer block.

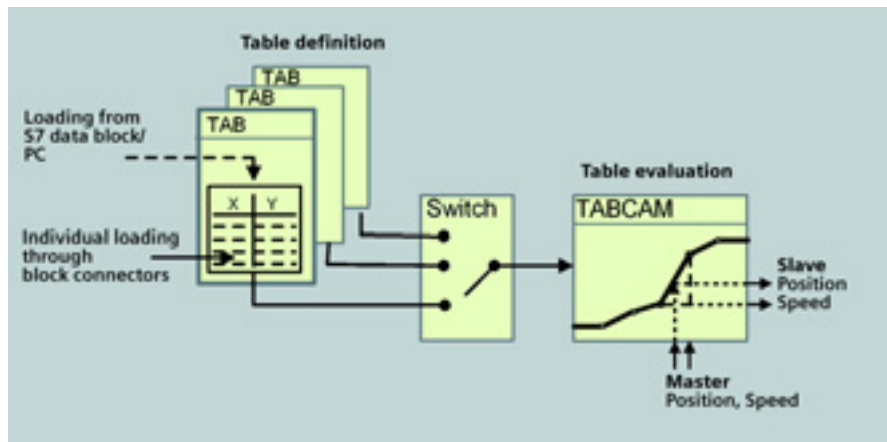


Fig. 18: Loading and reading out tables using TAB and TABCAM blocks

Generating and loading large tables

There are various ways of loading tables onto the FM 458:

- Direct loading and reading of each individual interpolation point by means of block connectors
- Copying of SIMATIC S7 data blocks from the S7-400 CPU or the engineering PC
- Loading PC files (e.g. Excel, Text) from the engineering PC onto the Memory Card of the FM 458

The tables can even be overwritten with new values while the system is running.

The table blocks are not only used for motion control. They can also be used as a simple way of loading large volumes of data from S7 data blocks or the PC onto the FM 458.

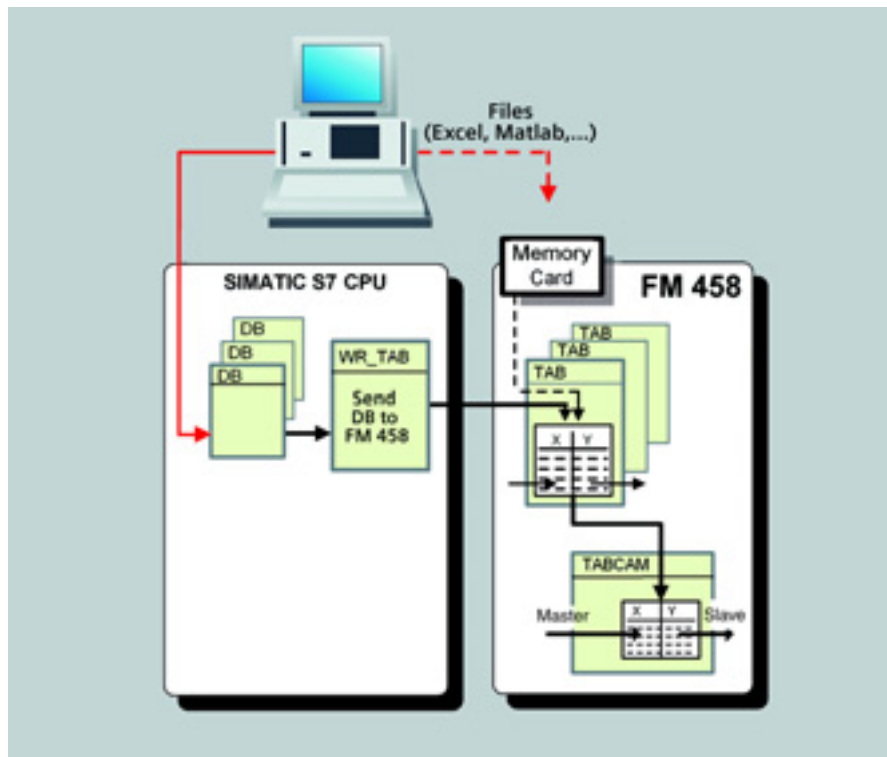


Fig. 19: Loading tables from S7 blocks and PC

Function blocks for motion control

Cam profiles using splines

SPLINE:

Cam profiles using splines

Cam profiles can also be stored as mathematical functions (splines). These splines are loaded into the SPLINE block on the FM 458 via the serial port on the PC (Spline Editor). As with the processing of the tables, the slave position required for a given master position are loaded from the SPLINE block using a subsequent block (e.g. CAMD). Here, too, you can switch between different cam profiles while the system is running.

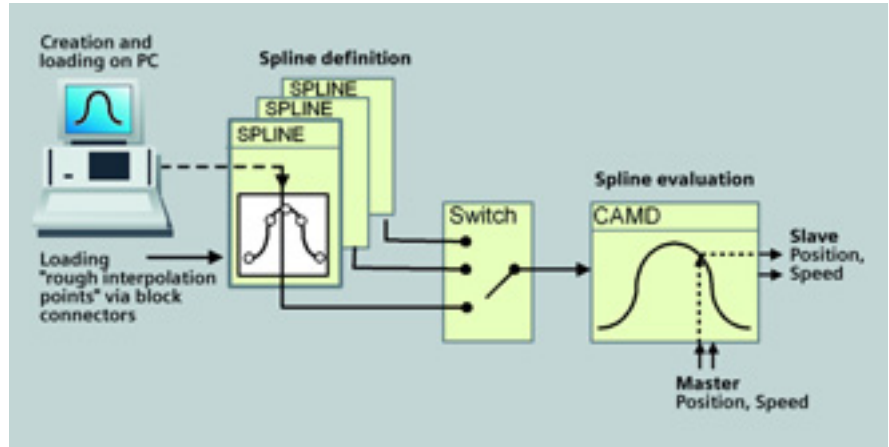


Fig. 20: Loading and reading out splines using SPLINE and CAMD blocks

Creating cam profiles using the Spline Editor

The Spline Editor PC program enables you to define cam profiles in the form of mathematical equations up to the 3rd order, using a quick, user-friendly interface. The Spline Editor generates rounded curves on the basis of a few 'rough' interpolation points.

The first derivation of this movement function between the master and the slave axis can be displayed and used to optimize the motion of the slaves.

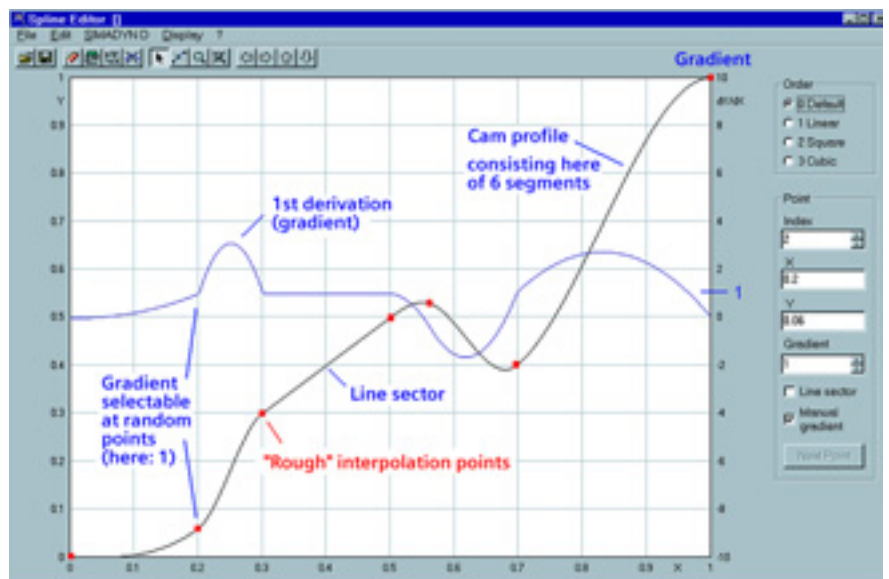


Fig. 21: Creating cam profiles graphically using the Spline Editor

Digital storage oscilloscope

Online trace

symTrace as an optional software package

symTrace is an add-on module for the online trace. It enables precise, real-

time recording and analysis of, for example, dynamic processes and the interaction between multiple axes.

symTrace is an extremely effective tool for commissioning and optimizing the facility.

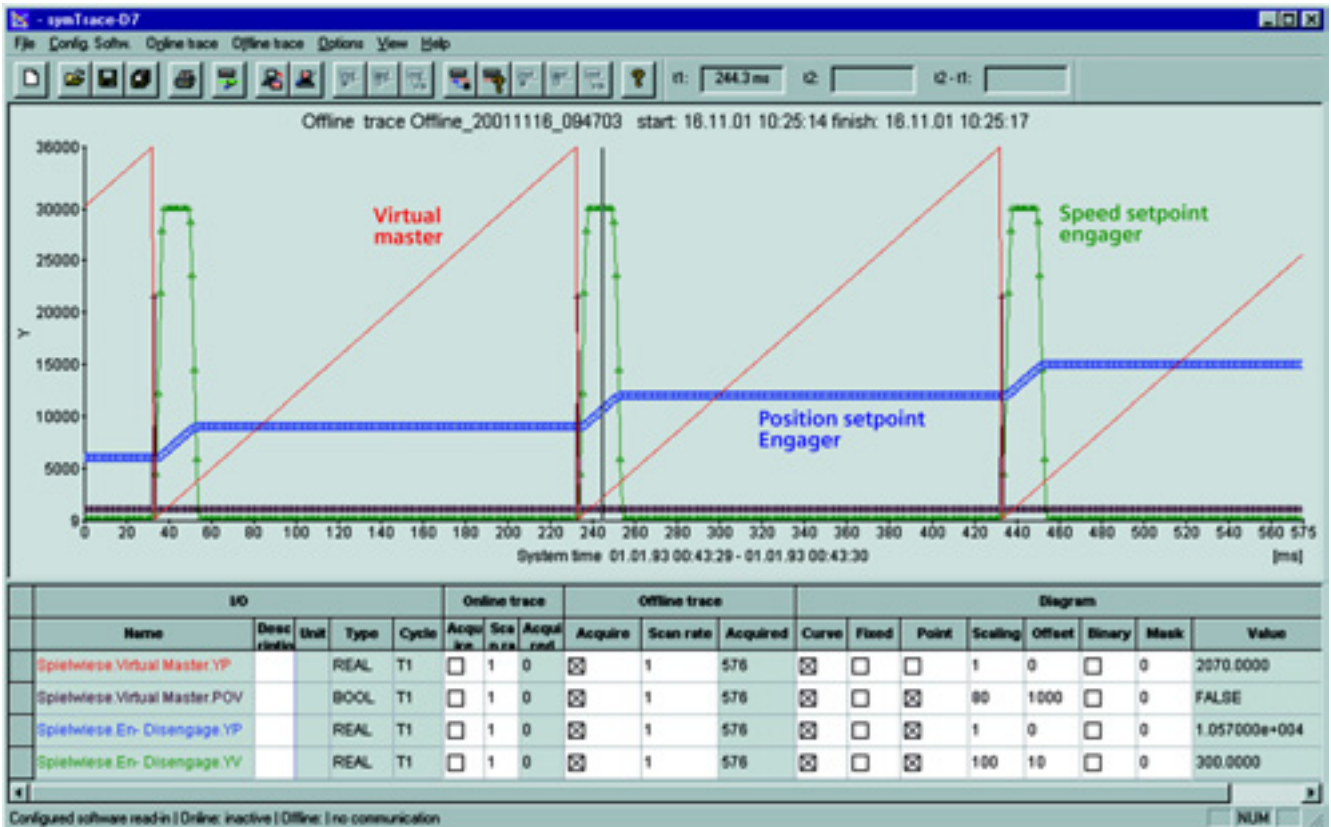


Fig. 22: Online trace for 3 engaging cycles

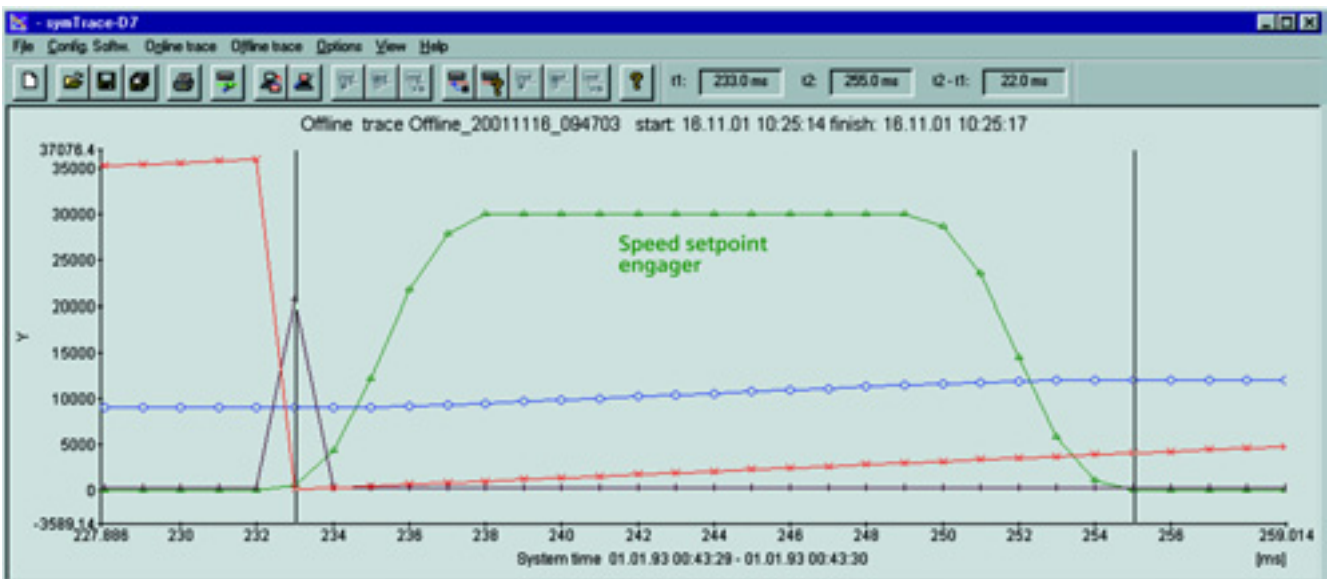


Fig. 23: Trace detail function for a single engaging cycle (scanning rate 1 ms, scanning values highlighted)

Function blocks for motion control

Overview

CFC function blocks for motion control with FM 458		
FB name	Function	Average execution time for FM 458
INT_MR	Virtual master	6 μ s
CLUTCH	Catch-up/stop (clutch)	7.5 μ s
GEAR	Gear	9 μ s
POSMC	Positioning	12 μ s
EDC	Engaging/disengaging cycle	9 μ s
CAMSW	2 cams switches with speed-controlled dead time compensation	9 μ s
CAMSW1	Cam switch with time-controlled dead time compensation	3.5 μ s
MCSB/MCSS	Generate motion sequences, time-dependent	7/3 μ s
SHEAR	Cross cutter/sealer	5.5 μ s
MDCMP1	Various basic and compensation functions (smoothing, inching, positioning, referencing)	7.5 μ s
TAB	Loading of table from SIMATIC data blocks or PC file (e.g. for cam profile)	15 μ s
TABCAM	Cam profile, reading out of table-defined values	12 μ s
SPLINE	Cam profile definition with mathematical functions	2 μ s
CAMD	Cam profile, reading out of splines-defined values	12 μ s
ADDAZ	Adder with axis cycle handling	2 μ s
DRVINT	Interface to (MASTERDRIVES) drive	5 μ s
NAVMC	Actual-value acquisition for speed/position	10 μ s
OFSGEN	Offset generation	10 μ s
OFSSAV	Offset calculation	0.3 μ s
PHSFT	Phase shift	3 μ s
POSREG	Additional position value acquisition for NAVMC block	1 μ s
WEBSFT	Position-dependent output of measured values (shift)	5 μ s

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