FAULHABER

Programming Manual

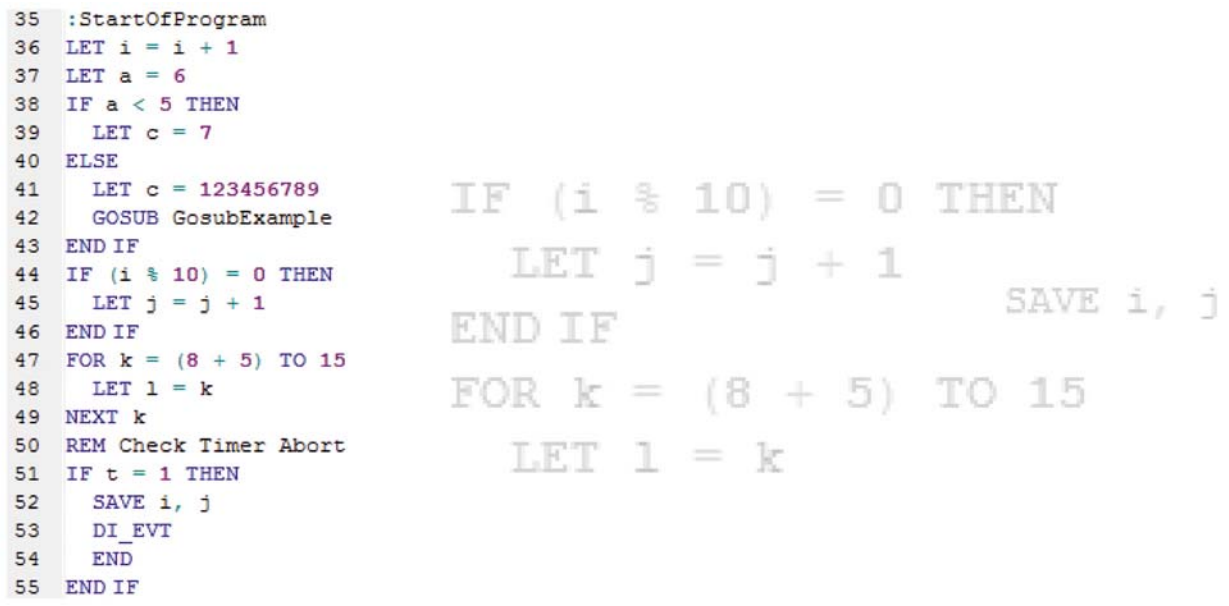
Motion Controller

MC 5010

MC 5005

MC 5004

MCS



```
:StartOfProgram
LET i = i + 1
LET a = 6
IF a < 5 THEN
  LET c = 7
ELSE
  LET c = 123456789
  GOSUB GosubExample
END IF
IF (i % 10) = 0 THEN
  LET j = j + 1
END IF
FOR k = (8 + 5) TO 15
  LET l = k
NEXT k
REM Check Timer Abort
IF t = 1 THEN
  SAVE i, j
  DI_EVT
  END
END IF
```

```
IF (i % 10) = 0 THEN
  LET j = j + 1
END IF
FOR k = (8 + 5) TO 15
  LET l = k
SAVE i, j
```

WE CREATE MOTION

EN

Imprint

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The relevant regulations regarding safety engineering and interference suppression as well as the requirements specified in this document are to be noted and followed when using the software.

Subject to change without notice.

The respective current version of this technical manual is available on FAULHABER's internet site:
www.faulhaber.com

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1 About this document

1.1 Validity of this document

This document describes the programming of sequence programs for controllers of the Motion Controller and Motion Control systems family V3.0, using the FAULHABER Motion Manager.

This document is intended for software developers with programming experience, and for drive technology project engineers.

All data in this document relate to the standard versions of the drives. Changes relating to customer-specific versions can be found in the attached sheet.

1.2 Associated documents

For certain actions during commissioning and operation of FAULHABER products additional information from the following manuals is useful:

Manual	Description
Motion Manager 6	Operating instructions for FAULHABER Motion Manager PC software
Quick start guide	Description of the first steps for commissioning and operation of FAULHABER Motion Controllers
Drive functions	Description of the operating modes and functions of the drive

These manuals can be downloaded in pdf format from the web page www.faulhaber.com/manuals.

1.3 List of abbreviations

Abbreviation	Meaning
BASIC	Beginner’s All-Purpose Symbolic Instruction Code
EEPROM	Electrically Erasable Programmable Read-Only Memory
Sxx	Data type signed (negative and positive numbers) with bit size xx
Uxx	Data type unsigned (positive numbers) with bit size xx

1.4 Symbols and markers

NOTICE!
Risk of damage.

▶ Measures for avoidance

Instructions for understanding or optimising the operational procedures

✓ Pre-requirement for a requested action

1. First step for a requested action

   ↳ Result of a step

2. Second step of a requested action

↳ Result of an action

▶ Request for a single-step action

2 Introduction

Sequence programs can be transferred to controller by the FAULHABER Motion Manager and can be executed directly by the controller. This enables e.g. stand-alone operation without a supervisory controller or semi-autonomous execution of smaller program sequences.

Sequence programs are programmed in the BASIC programming language, with FAULHABER-specific extensions.

8 independent memory areas for user programs are available. Optionally, one program can also be started automatically at boot-up.

3 Characteristics of the programming language

- BASIC interpreter with FAULHABER-specific extensions
- Function calls
- No line numbers; jumps are to jump labels
- Jump labels are placed at the beginning of a line and start with a colon
- Distinction between upper and lower case characters (commands always in upper case)
- Read and write access to objects in the object dictionary
- Capability to respond to events during normal execution of a program
- Timer for time measurement and wait loops
- Arithmetic, comparison and bit operators
- Special character **$** for values expressed as hexadecimal numbers
- Maximum length of one program: 8 kByte
- Maximum length of all programs: 16 kByte
- 26 global standard 32-bit variables a…z (can be stored permanently)
- 26 global symbolic 32-bit variables (can be freely named)
- Local symbolic variables (can be freely named)

3.1 Command set

Tab. 1: Standard BASIC command set

Command	Function	Example
REM…	Comment. Placed at the beginning of a line and applies until the end of the line.	REM comment
END	End program	END
GOTO…	Jump to the specified jump label. The following constructs may not be exited with GOTO: ▪ IF…THEN…ELSE…END IF ▪ GOSUB…RETURN ▪ FOR…TO…NEXT… GOTO jumps are not supported in sub-functions (FUNCTION…).	GOTO Start
GOSUB… … RETURN	Jump to a sub-program at the specified label. After execution, jump back to the calling position. No GOTO jump may be performed from a sub-program.	GOSUB Step1 … :Step1 RETURN
FOR…TO… … NEXT…	Programming a loop. No conditional GOTO jump may be performed from a FOR loop.	FOR i = 1 TO 10 … NEXT i
DO … LOOP UNTIL…	Loop with check of the loop condition at the end of the loop.	DO … LOOP UNTIL a = 5
DO … LOOP	Loop without check of a loop condition. Exit the loop with EXIT.	DO … LOOP
DO … LOOP WHILE…	Loop with check of the loop condition at the end of the loop.	DO … LOOP WHILE stop = 0
DO WHILE… … LOOP	Loop with check of the loop condition at the start of the loop.	DO WHILE speed > 500 … LOOP
EXIT…	Jump from a loop without having reached the end of the loop. The keyword of the loop must be specified.	EXIT FOR EXIT DO

IF…THEN…
ELSEIF…THEN…
ELSE…
END IF
	Programming a branch.
	No GOTO jump may be performed from an IF instruction.
		IF a > 3 THEN
		  b = 1
		ELSE
		  b = 0
		END IF

IF…THEN GOTO…
IF…THEN GOSUB…
IF…THEN <Name>()
	Conditional jump or branch into a sub-program. Used in a line without END IF.
	The following constructs may not be exited with GOTO:
	▪ IF…THEN…ELSE…END IF
	▪ GOSUB…RETURN
	▪ FOR…TO…NEXT…
		IF z=1 THEN GOSUB Step1

Characteristics of the programming language

Command	Function	Example

IF…THEN EXIT FOR
IF…THEN EXIT EVT
	Jump out of a FOR loop or an event routine. Used in a line without ENDIF.
	May not be used in the following constructs:
	▪ IF…THEN…ELSE…END IF
	▪ GOSUB…RETURN
		FOR a = 1 TO 5
		  IF x = 1 THEN EXIT FOR
		NEXT a

IF…THEN EXIT GOSUB	Jump out of a sub-program. Used in a line without ENDIF.
	May not be used in the following constructs:
	▪ IF…THEN…ELSE…END IF
	▪ GOSUB…RETURN
		:Sub1
		IF x = 1 THEN EXIT GOSUB
		RETURN

FUNCTION…
…
RETURN…
END FUNCTION
	Definition of a sub-function. The function is called in the program text via its name.
	Local variables can be allocated via the key word DIM.
	Parameters can be passed as numbers or with variables.
	The sub-function can return a numeric result with the key word RETURN.
	GOTO jumps are not supported.
	Each sub-function must be ended with the key word END FUNCTION.
		Defintion
		FUNCTION <Name> (Parameter1, Parameter2)
		DIM result
		…
		RETURN result
		END FUNCTION
		Call
		<Name> (1, 5)

DIM…	Allocates a variable with symbolic name. ▪ If DIM is used outside of a sub-function (FUNCTION), a global variable is allocated that can also be used under this name by all sub-functions. Global symbolic variables can be read and changed in the development environment integrated in the Motion Manager via their name. ▪ If DIM is used within a sub-function (FUNCTION), a local variable is allocated that is valid only within the sub-function. Local variables can be read and changed in the development environment integrated in the Motion Manager as long as the sub-function itself is active (e.g., stopped at a breakpoint or in single-step mode).	DIM Statusword

Characteristics of the programming language

Tab. 2: FAULHABER command extension

Command	Function	Example
SETOBJ…	Write an object in the object dictionary. Syntax: SETOBJ <Index>.<Subindex> = <variable or value>	SETOBJ $6083.$00 = 500
GETOBJ…	Read an object in the object dictionary. Syntax: <variable> = GETOBJ <Index>.<Subindex>	a = GETOBJ $6083.$00
DEF_EVT_VAR…	Defines a variable which, when the event occurs, returns the value of the event status bit mask.	DEF_EVT_VAR e
EN_EVT…	Activation of an event routine which is triggered by the device state signalled by a change in the object 0x2324.01 (event handling). Note: Only one event routine can be active. Syntax: EN_EVT <bit mask>,<event mark>	EN_EVT $ffffffff, EvHandler
DI_EVT	Deactivation of all events for processing that is being performed in parallel. Syntax: DI_EVT	DI_EVT
RET_EVT	Jump back from an event routine. Syntax: RET_EVT	: EvHandler RET_EVT
SAVE…	Permanent saving of one or more variables in the EEPROM (comma-separated list). Syntax: SAVE <variable1<,variable2,...>>	SAVE a, b, z
LOAD…	Loading one or more previously saved variables from the EEPROM (comma-separated list). Syntax: LOAD <variable1<,variable2,...>>	LOAD a, b, z
DEF_TIM_VAR…	Defines a variable to be used as a timer. Syntax: DEF_TIM_VAR <variable>	DEF_TIM_VAR t

START_TIM…	Starts the timer with a value in ms (or stops the timer if the value = 0).
	Syntax: START_TIM <variable or value>
	When the specified time has elapsed, the timer variable is 1, otherwise it is 0 (timer still running).
		START_TIM 3000
		
		IF t = 1 THEN
		ENDIF

DEF_CYC_VAR…	Defines a variable to be used as a 1 ms cycle counter. This can be used to, e.g., perform time measurements. The counter runs a maximum of 24 days and then stops with -1. Syntax: DEF_CYC_VAR <variable>	DEF_CYC_VAR z
START_CYC	Starts the cycle counter with the value 0. Syntax: START_CYC	START_CYC
STOP_CYC	Stops the cycle counter. The current counter state is retained in the variable defined for this purpose and can be processed further. Syntax: STOP_CYC	STOP_CYC
DELAY…	Waiting time in ms. The program is not processed further during the waiting time. Syntax: DELAY <variable or value>	DELAY 200

Command	Function	Example
#DEFINE…	Assigns a value to a symbolic designation. Syntax: #DEFINE <symbol> <value> This key word can also be used to define more complex macros that can be used in the program text via the macro names. Syntax: #DEFINE <macro> <expression> If a macro name is prefixed with "MC.", the macro is available in the autocompletion of the Motion Manager editor. The list of available macros appears after entering "MC."	#DEFINE MaxSpeed 2000 #DEFINE MC.IsTargetReached ((GETOBJ $6041.00 & $400) = $400) If MC.IsTargetReached THEN…
#INCLUDE…	Instructs the development environment to link another file to the program (Basic-Include file *.bi). Sets of pre-defined symbolic names or function libraries can thereby be linked and reused. If no path is specified, include files are searched for in either the Motion Manager ProgramData directory or in the same folder as the corresponding .bas file. Include files from other folders can be referenced by specifying an absolute path. Syntax: #INCLUDE <[path] filename>	#INCLUDE "MotionParameters.bi"

3.2 Operators and special characters

Arithmetic operators	
Addition	+
Subtraction	-
Multiplication	*
Division	/
Modulo (remainder)	%

Logic operators	
And operation	AND
Or operation	OR
Inversion	NOT

Comparison operators	
Greater than	>
Less than	<
Equal to	=
Not equal to	<>
Greater than or equal to	>=
Less than or equal to	<=

Bit operators	
Bit-wise AND	&
Bit-wise OR	|
Bit-wise inversion	~
Bit-wise moving of a variable to the left	<<
Bit-wise moving of a variable to the right	>>

Assignment operator	
Assignment operator	=

Special character	Meaning
()	Used for mathematical operators
,	Used in EN_EVT and SAVE/LOAD
.	Delimiting characters in SETOBJ /GETOBJ
$	Hexadecimal numbers
:	Jump label, placed at the start of the line

3.3 Variables

Three variable types are available in sequence programs:

- Global variables with fixed address (see chap. 3.3.1, p. 13)
- Allocated global variables (see chap. 3.3.2, p. 13)
- Allocated local variables (see chap. 3.3.2, p. 13)

3.3.1 Global variables with fixed address

Variables that are referenced via letters a…z are available globally in all program areas. Each change is visible globally.

Variables with fixed address have the following properties:

- They can be saved and loaded in the EEPROM using the LOAD and SAVE commands.
- They can be used as timer variables (DEF_TIM_VAR) or event variables (DEF_EVT_VAR) (only applies to variables with fixed address).
- They can be addressed via object 0x3005 directly via the communication interface.
- They can be mapped to PDOs.
- They can be assigned a symbolic name via #DEFINE. These symbolic names can be used everywhere in the program text.

Example:

```
#DEFINE RefSpeed a
#DEFINE MC.TagetVelocity SETOBJ $60FF.00

RefSpeed = 2000
MC.TagetVelocity = RefSpeed
…
SAVE RefSpeed
```

3.3.2 Allocated global and local variables

With the key word DIM <variable name>, a variable can be created with a symbolic name.

Example:

```
DIM Statusword
```

- Global variables:

  If `DIM` is used outside of a sub-function, a variable from a set of a maximum of 26 global variables is thereby allocated. The variable can be used by all functions. The symbolic name can be used as a number in all expressions.
- Local variables:

  If `DIM` is used within a sub-function, only a local variable valid within this sub-function is thereby allocated. Transfer parameters of sub-functions are handled as local variables. The maximum number of local variables is 26 per sub-function.

Allocated variables cannot be used as timer variables (DEF_TIM_VAR) or event variables (DEF_EVT_VAR). They cannot be directly initialised via LOAD or SAVE from the EEPROM nor can they be stored there.

In the Motion Manager, it is possible to access allocated variables via their symbolic names. Local variables can only be accessed within the function in which the variable is defined.

3.4 Instructions for creating programs

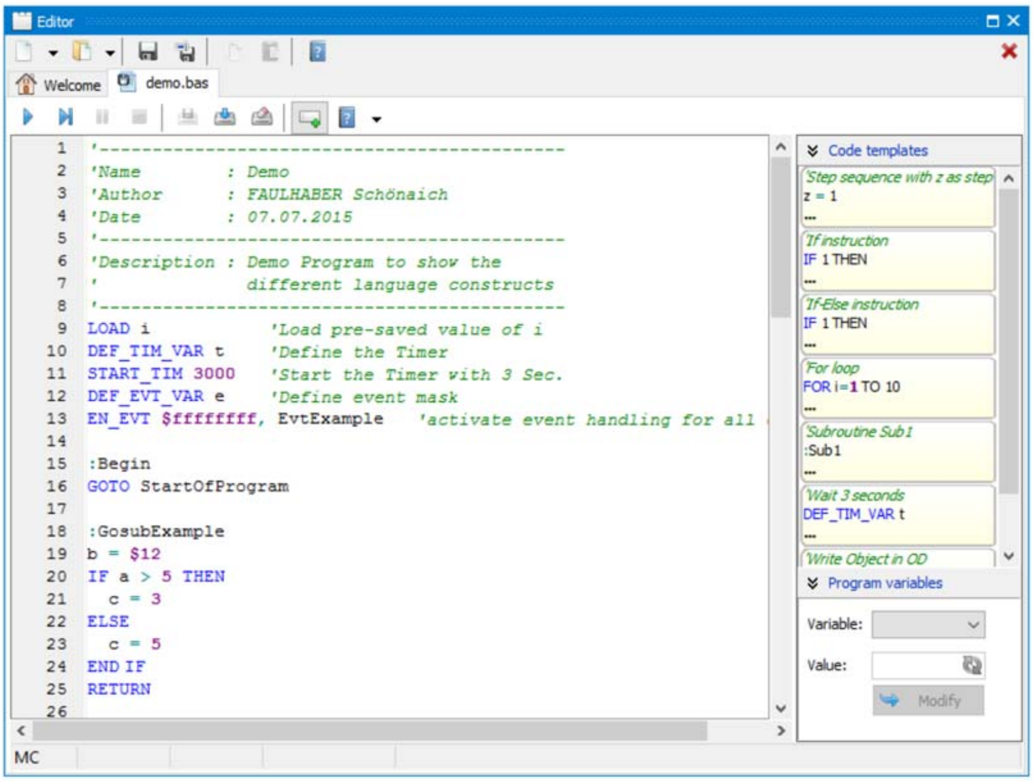
- A sequence program must always be constructed as a sequence of steps with a main loop that encompasses the entire execution code (see chap. 1, p. 1). Wait loops cannot contain conditional jumps governed by specific events.
- Sequence programs are created and edited using the FAULHABER Motion Manager.
- Before downloading a sequence program on to the controller, the FAULHABER Motion Manager performs a pre-processing step in order for instance to determine the addresses of the jump labels and the necessary memory area.
- FAULHABER Motion Manager offers the capability not only to create sequence programs, edit them and transfer them to the controller, but also to check for programming errors and correct them (debugging options).
- Own function libraries can be developed and linked as basic include files (*.bi) in a sequence program.

  It is recommended that these libraries first be created as a BAS file and the functions outsourced to an include file only after completion of development and testing. The Motion Manager offers no debugging options for include files.

4 Developing sequence programs using the Motion Manager

The FAULHABER Motion Manager Editor window offers an integrated development environment for sequence programs. The development environment offers the following facilities:

- Syntax highlighting
- Displaying and editing up to 8 user program
- Load and display user programs from the device memory and the PC memory
- Start individual sequence program
- Stop the active sequence program
- Pause the active sequence program
- Single step execution
- Definition of a breakpoint
- Display the current program status and the current program line
- Monitor and change the contents of variables
- Read protection by means of an access code
- Code modules for use in your own programs
- Autocompletion
- Automatic syntax check in the background



```
'-------------------------------------------
'Name        : Demo
'Author      : FAULHABER Schönaich
'Date        : 07.07.2015
'-------------------------------------------
'Description : Demo Program to show the
'              different language constructs
'-------------------------------------------
LOAD i              'Load pre-saved value of i
DEF_TIM_VAR t       'Define the Timer
START_TIM 3000      'Start the Timer with 3 Sec.
DEF_EVT_VAR e       'Define event mask
EN_EVT $ffffffff, EvtExample   'activate event handling for all

:Begin
GOTO StartOfProgram

:GosubExample
b = $12
IF a > 5 THEN
  c = 3
ELSE
  c = 5
END IF
RETURN

```

```
'Step sequence with z as step
z = 1
...
'If instruction
IF 1 THEN
...
'If-Else instruction
IF 1 THEN
...
'For loop
FOR i=1 TO 10
...
'Subroutine Sub1
:Sub1
...
'Wait 3 seconds
DEF_TIM_VAR t
...
'Write Object in OD
```

Tab. 3: Function of the buttons (editor environment)

Button	Designation	Function
▶	Run	Download sequence program to the control and execute it.
⏭	Step	Execute the sequence program in single steps or continue.
⏸	Halt	Pause the sequence program.
■	Stop	End the sequence program.
💾	EEPROM-Save	Save currently loaded sequence program in EEPROM.
📥	Download	Download sequence program to the control and save it in EEPROM.
✎	Delete	Delete the sequence program from the control EEPROM.
➕	Extras	Display the code template and offer the facility to investigate the contents of variables, and change them.

4.1 Editing a program

- The command ***File - New - Motion Control file MC V3.x*** creates a new program.
- The command ***File - Open*** followed by selection of the desired .bas file loads an existing program.
- When a new file is created, an empty .bas file with a pre-prepared file header is generated. After it has been edited, the file can be saved to any desired memory location.
- Saved files that have already been downloaded to the controller can be opened from the **sequence programs** directory of the active node by double clicking in the Node Explorer.

  The Node Explorer contains links to the program files that are stored in device program memories P1 to P8.

  Irrespective of the declared program links, there is also the possibility by double clicking on the **Upload** node to load all the programs saved in the controller. If an appropriate file link exists in the programs that have been uploaded, the file content is shown in Node Explorer. Otherwise the program content read from the device is shown.

If it is desired to view the content of the device memory instead of the linked file, the file link must be deleted in Node Explorer (***Del*** key). On the next download of the file previously stored on the PC, the link will be re-established in the Node Explorer.

- Comment lines that start with ' are saved in the file only for purposes of documentation and are not downloaded to the controller.
- The content of the files that are referenced via `#INCLUDE` is merged with the actual program code prior to transfer to the control.
- Macro commands and symbolic variables specified in the program are replaced with the expressions stored with `#DEFINE` and the internal variables allocated with `DIM` prior to transfer to the control.
- For user support a column can be displayed at the right-hand side of the editor window (***Extras*** button) with code templates that can be dragged into and adapted in the current program using the mouse.
- If the automatic syntax check is activated (Help icon in the File tab), detected syntax errors are displayed underlined in red.
- A context menu for further Editor functions can be opened with the right mouse button. It is possible in this way to, e.g., open an include file specified in the program code or to jump to a function or macro definition.

4.2 Load the program to the controller and execute it

- Pressing the ***Run*** button downloads the finished program to the controller and immediately executes it.
- If this is a new program that has not yet been saved to the controller, a program number between 1 and 8 must be assigned to it. The program is saved to the controller under this program number.
- If the file had already been saved into a desired directory, the link to this file is generated in Node Explorer under **sequence programs** of the active node. This also shows the assigned program number (e.g. P1 for program number 1).
- After execution has been started, the editor area switches into debug mode (with a different background colour). This mode does not allow program editing. The following information is shown in the status line of the editor window:
  - The currently loaded program number.
  - Current program line
  - Program status (e.g. Running)
- If errors occur whilst running the program, execution is interrupted and the last line executed is highlighted in red.
- To return to program editing mode, program execution must be ended by pressing the ***Stop*** button.
- A program that is loaded by means of the ***Run*** button is stored in the non-volatile memory only if a program number is assigned to it. Subsequent changes are saved only to the working memory. To save changes permanently on the controller, press the ***EEPROM Save*** button.
- When the ***Download*** button is pressed, a program can be saved to any program number.
- Pressing the ***Delete*** button deletes programs that are no longer required from the device memory.
- Program links that are no longer required in Node Explorer can be deleted by pressing the ***Delete*** button or via the context menu.

i If a program link is deleted in the Node Explorer, this has no effect on the device program memory. Programs from the device program memory can only be deleted via the ***Delete*** button in the editor.

4.3 Debugging a program

The following debugging options are available for troubleshooting in sequence programs:

- Pause the program at the current execution position (***Pause*** button):
  - The active line is highlighted in the editor. If the program is currently processing a function in a linked file, the calling location in the main file is marked.
  - The edit area remains inactive.
  - After a ***Pause*** the program can either be continued via ***Run*** or executed further in single steps via ***Step***. Pressing ***Stop*** reverts to program edit mode.
- Executing the program further in single steps (***Step*** button):
  - Only the next program line is executed.
  - The new active line is highlighted in the editor.
  - The edit area remains inactive.
  - After ***Step*** the program can either be continued via ***Run*** or executed further in single steps via ***Step***. Pressing ***Stop*** reverts to program edit mode.
- Pausing the program at a breakpoint:
  - A breakpoint can be established by clicking on the desired line number at the left-hand edge of the window.
  - Program execution is paused when it reaches this line. It can then be continued via ***Run*** or ***Step***. Pressing ***Stop*** reverts to program edit mode.
  - Clicking on the breakpoint at the left-hand edge of the window deletes the breakpoint. Until this has been done, no further breakpoint can be established.
  - A breakpoint can be established before a program is started and also during program execution.
- Investigating and changing the contents of variables:
  - If the Extras column on the right-hand edge of the Editor is displayed (***Extras*** button), the **Program variables** area is also displayed there. The globally defined symbolic variables and the standard variables a…z can be selected at any time from the variable list and displayed and changed there. Local variables can only be accessed if the program has stopped in the respective function.
- Examining the call stack:
  - If the Extras column on the right-hand edge of the Editor is displayed (***Extras*** button), the **Call stack** area is also displayed there. In addition to the current line of a stopped program, the numbers of the lines in the call sequence of functions are also displayed.

5 Control of sequence programs

A saved sequence program can be started by a host computer via the interface, or automatically when the controller is booted up.

5.1 Controller via the interface

The execution of sequence programs can be controlled and monitored by a supervisory computer, via the object 0x3001.

Tab. 4: Current Control Parameter Set

Index	Subindex	Name	Type	Attr.	Meaning
0x3001	0	Number of Entries	U8	ro	Number of object entries
	1	Program Control	U8	rw	Control of the sequence program activated via 0x3001.02 or 0x3002.00: ▪ 1: Load the activated program from the EEPROM (Load) ▪ 2: Start or continue the loaded program (Run) ▪ 3: Execute the individual program line (Step) ▪ 4: Pause the running program (Break) ▪ 5: End the running program (Terminate)
	2	Program Number	U8	rw	Activate the sequence program at program number
	3	Actual Position	U16	ro	Address of the line currently being executed
	4	Actual Program State	U8	ro	Current status of the program: ▪ 0: No reaction (Idle) ▪ 1: Program is currently being loaded from the EEPROM (Reading) ▪ 2: Program is currently being saved to the EEPROM (Saving) ▪ 3: Program is currently being deleted (Deleting) ▪ 4: Program is currently being executed (Running) ▪ 5: Program paused (Halted)
	8	Error State	U8	ro	Error status: ▪ 0: No error (No Error) ▪ 1: Syntax error (Parsing Error) ▪ 2: Error accessing the EEPROM (EEPROM Access Error)
	9	Error Code	U16	ro	Detailed error code in the event of a syntax error (see chap. 5.2, p. 21)

Before a new program is loaded, any program already running must be ended.

Pseudo-code:

- If 0x3001.04 = 4 (Running) or 0x3001.04 = 5 (Halted), then 0x3001.01 = 5 (Terminate)
- Wait until 0x3001.04 = 0 (Idle)

Example for loading and running a sequence program in program number 1:

1. Select program 1:
   - 0x3001.02 = 1 (P1)
2. Load program:
   - 0x3001.01 = 1 (Load)
   - Wait until 0x3001.04 = 0 (no longer Reading).
3. Run program:
   - 0x3001.01 = 2 (Run)

↳ Program 1 is loaded and will be run.

5.2 Error handling

Errors that occur during program execution are returned as an error code in object 0x3001.09.

If an error occurs, the following actions are triggered automatically:

- Program execution is ended.
- The detailed error code is returned in object 0x3001.09 (see Tab. 5).
- A calculation error (bit 12) is set in FAULHABER error word 0x2320.00.

When starting a new program, the error code in object 0x3001.09 and calculation error in error word 0x2320.00 are reset.

Error word 0x2320.00 can be used to automatically trigger further actions in the event of an error. For example, the drive can be switched off automatically.

Tab. 5: Error codes for 0x3001.09

Code	Error	Meaning	Remedy
0	No error	No error	–
1	Generic error	General error	Check syntax.
3	Unexpected token	The character was not expected at this location.	Check syntax.
4	Missing return value	A function was ended without RETURN even though a return value was expected.	Add RETURN instruction.
6	End of parsing memory	Nested function calls using too much memory.	▪ Reduce nesting depth. ▪ Use shorter calling lines.
7	Too many variables	The chain of called functions results in too many local variables being used.	Reduce program complexity
8	Illegal variable type	No variables created via DIM can be used for the following functions: ▪ Special functions of the timer ▪ Special functions of event processing ▪ SAVE ▪ LOAD	Use manually created variables a…z.
9	Function stack overflow	The nesting depth of the function calls is too high. Maximum 15 call levels are supported.	Reduce nesting depth.

Code	Error	Meaning	Remedy
10	Nested condition overflow	The nesting depth of conditions such as IF is too high. A depth of max. 15 levels is supported.	Reduce nesting depth.
11	Division by 0		
12	Event while in Event	An event was triggered while event processing was still active. The event cannot be processed.	Reduce trigger frequency.
13	RET_EVT while not in event	RET was used outside of an event.	Only use RET to jump out of events.
14	ELSE or END IF without IF	The ELSE or END IF command was detected without the corresponding IF.	Check syntax.
15	Wrong variable used in NEXT token	The variable used to call NEXT does not correspond to that from the FOR call.	Check syntax.
16	GOTO not supported here	GOTO is not supported within functions.	Do not use GOTO in functions.
17	Illegal object	The object used for GETOBJ or SETOBJ does not exist or does not support the access.	Check syntax.
18	RETURN while not in SUB or FUNCTION	A RETURN was detected without first having entered in a sub-function.	Check syntax.

5.3 Start the sequence program automatically

Object 0x3002.00 allows input of a program number; when the controller is booted up this program will be started automatically.

Tab. 6: Autostart Program Number

Index	Subindex	Name	Type	Attr.	Meaning
0x3002	0	Autostart Program Number	U8	rw	Program number of the sequence program that will be started automatically.

This function is also available via the drive functions dialogue in the Motion Manager (**Device control - sequence programs**).

5.4 Protecting sequence programs

With object 0x3003.00, a 32-bit key can be set that protects the programs stored in the controller against unauthorised access.

If a 0x3003.00 ≠ 0 code was set and the parameters of the controller then saved, the stored sequence programs can then only be read out if the code is entered again.

Tab. 7: Access Code

Index	Subindex	Name	Type	Attr.	Meaning
0x3003	0	Access Code	U32	ro	32-bit key for protecting the programs stored in the controller against unauthorised access.

5.5 Data exchange with sequence programs

Data exchange via object 0x3004

The program variables a to z can also be used for data exchange between the sequence program and the supervisory computer. Object 0x3004.01 can be used to select a variable and object 0x3004.02 to read or write its value.

Tab. 8: Variable Access

Index	Subindex	Name	Type	Attr.	Meaning
0x3004	0	Number of entries	U8	ro	Number of object entries
	1	Variable index	U8	rw	Variable index ▪ 0…25 = standard variables a…z ▪ 32 + (0…25) = global internal variables ▪ 128 + (0…25) = local internal variables
	2	Variable value	S32	rw	Variable value

Data exchange via object 0x3005

Individual standard variables can be directly accessed via the sub-indices of object 0x3005. The variables can thereby be, e.g., recorded or mapped to a PDO. Not included here are variables that are used for event handlers, timers or counters.

Tab. 9: Debug User Program

Index	Subindex	Name	Type	Attr.	Meaning
0x3005	0	Number of entries	U8	ro	Number of object entries
	1…26	User prog variable a…z	S32	rw	Values of variables a…z

6 FAULHABER Motion library

Beginning with version 6.5, three supporting files are delivered with the FAULHABER Motion Manager:

File	Description
MotionParameters.bi	Pre-defined assignment of symbolic parameter names with values, e.g., #DEFINE Statusword $6041.00. See chap. 6.1, p. 24.
MotionMacros.bi	Pre-defined macros for directly accessing parameters of the Motion Controller, e.g., for drive control and status check. See chap. 6.2, p. 25.
MotionFunctions.bi	Pre-defined functions for typical drive tasks of the Motion Controllers. See chap. 6.3, p. 25.

6.1 MotionParameters

The *MotionParameters.bi* file contains symbolic definitions for typical parameters, e.g.:

```
#DEFINE Statusword $6041.00
```

The file is stored in the installation area of the Motion Manager and is automatically linked in new program files:

```
'--------------------------------------------
'Author:
'Date:
'--------------------------------------------
'Description:
'--------------------------------------------

#INCLUDE "MotionParameters.bi"
#INCLUDE "MotionMacros.bi"
```

In the program, access can then take place via the symbolic names.

Example:

```
DIM DeviceStatus
DeviceStatus = GETOBJ Statusword
```

6.2 MotionMacros

The *MotionMacros.bi* file contains pre-defined access to parameters of the drive system. Like the MotionParameters file, it is stored in the installation area of the Motion Manager and is automatically linked in new program files.

The macros always start with code `MC`.

Example:

```
#DEFINE MC.GetStatusword GETOBJ $6041.00
…

DIM DeviceStatus
DeviceStatus = MC.GetStatusword
```

6.3 MotionFunctions

File *MotionFunctions.bi* contains a set of pre-defined functions that can be used to set up your own processes.

The file is stored in the **Examples** directory of the Motion Manager installation. To be able to use the pre-defined sub-functions, a copy of the file must be stored in the directory in which the newly created program is stored.

FUNCTION Enable ()
The `Enable` function tries to bring the drive state machine into the *Operation Enabled* state.

Only once the *Operation Enabled* state has been reached does the function return to the calling context. If the state cannot be achieved, e.g., because a blocking error is pending, the function does not return. This is, thus, a blocking call.

FUNCTION Disable ()
The `Disable` function first switches the drive to the *Switched On* state. This brings the drive to a stop via the ramp set in object *Disable Operation Option Code* (0x605C). Afterwards, it switches back to the initial state *Switch On Disabled*.

FUNCTION QuickStop ()
The `QuickStop` function switches the drive from the *Operation Enabled* state to the Quick Stop Active state. This brings the drive to a stop via the ramp set in object *Quick Stop Option Code* (0x605A).

FUNCTION MoveAbs (TargetPos, Immediate)
The `MoveAbs` function passes parameter *TargetPos* as new absolute set value.

Prerequisite: Operating mode PP is set.

Parameter *Immediate* forces the drive to accept the new set value even during running positioning.

The function immediately returns to the calling context and does not wait until the passed target position is reached.

FUNCTION MoveRel (TargetPos, Immediate)
The `MoveRel` function passes parameter *TargetPos* as new relative set value. Thus, the new movement takes place relative to the previous movement.

Prerequisite: Operating mode PP is set.

Parameter *Immediate* forces the drive to accept the new set value even during running positioning.

The function immediately returns to the calling context and does not wait until the passed target position is reached.

FUNCTION WaitPos ()
The `WaitPos` function waits until the drive signals via the Target Reached bit in the status word that a target has been reached.

Prerequisite: A new positioning operation was first started in operating mode PP with `MoveAbs` or `MoveRel`.

7 Examples of programs

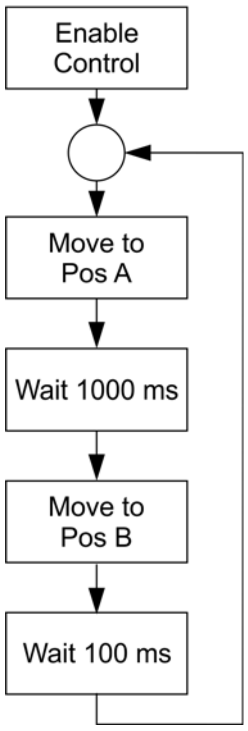
A number of example programs that illustrate the use of the supported methods are located in the Motion Manager installation directory. The examples folder can also be opened via the Help icon in the editor area.

7.1 Simple cyclic movement using the library functions

In this example, the Profile Position Mode (PP) is first set. Two positions are defined symbolically. The motor control is started explicitly via the `Enable()` function.

With the library functions from *MotionFunctions.bi*, the position then alternates between the two positions.

Prerequisite: The motor was successfully commissioned and the control was adapted to the application.



```
'-----------------------------------------------
'Author: MCSupport
'Date: 2018-09-14
'-----------------------------------------------
'Description: Test of the Libs
'-----------------------------------------------

#INCLUDE "MotionParameters.bi"
#INCLUDE "MotionFunctions.bi"

#DEFINE PosA 0
#DEFINE PosB 10000

SETOBJ ModesOfOperation = OpModePP

Enable ()

DO
    MoveAbs (PosA, 0)
    WaitPos ()
    DELAY 1000
    MoveAbs (PosB, 0)
    WaitPos ()
    DELAY 100
LOOP

END
```

7.2 Use of sequences of steps for program design

In many cases, sequences consist of individual steps that are to be processed in sequence or depending on other conditions.

Examples:

- **First,** start the control
- **Next,** execute a reference run
- **Then,** change to positioning operation
- **If** … is actuated, change to inching mode

The key words that identify the sequence of steps are in bold in the examples.

In all of these cases, it is useful to collect the steps in a table and organize them into a sequence. It must be noted for each step what is to occur during the step and what the condition is for advancing to the next step.

Implementation

```
DIM StepCounter

StepCounter = 1

…
DO
    IF StepCounter = 1 THEN
        DoSomething ()

        IF FirstCondition THEN
            StepCounter = 2
        END IF
    ELSEIF StepCounter = 2 THEN
        DoWhatever ()

        IF NextCondition THEN
            StepCounter = 3
        END IF
    ELSEIF … THEN
    …
    END IF
LOOP
```

7.2.1 Reference run with subsequent automatic change to positioning operation

In this example, the Motion Controller is configured so that the motor control is started automatically.

A check is first performed in the sequence program to determine whether the output stage is already activated. Afterwards, the previously configured reference run is started.

After the drive has been successfully referenced, it switches to active operation. DigIn1 can be used to switch between position control with analogue setpoint specification and torque control.

Prerequisites

- The motor was successfully commissioned and the control adapted to the application.
- The desired type of reference run was configured in object 0x6098.00.
- The analogue setpoint specifications are appropriately scaled via objects 0x2313 and selected as sources for the position set value (0x2331.04) or the torque set value (0x2331.02) via object 0x2331.
- The motor control was automatically activated via bit 2 in object 0x233F.00.

Sequence

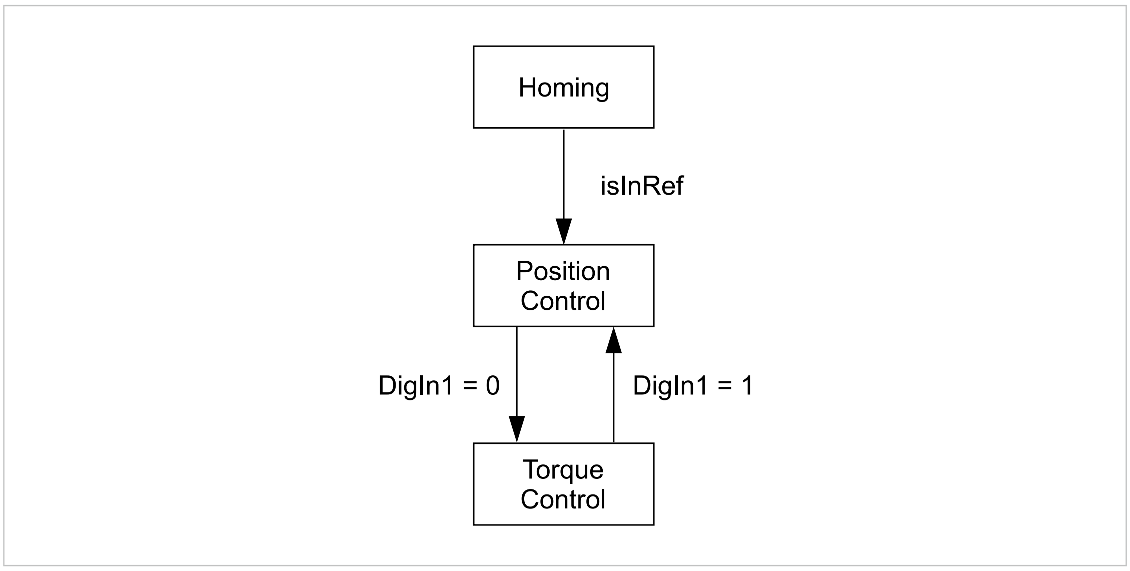


Fig. 1: Sequence for reference run with subsequent change to positioning operation

Implementation

```
'---------------------------------------------------------------
'Author: MCSupport
'Date: 2018-09-14
'---------------------------------------------------------------
'Description: Test of the Libs
'---------------------------------------------------------------

#INCLUDE "MotionParameters.bi"
#INCLUDE "MotionFunctions.bi"
```

```
:Init
DIM StepCounter
DIM DigInStatus

StepCounter = 0

:MainLoop
DO
    DigInStatus = GETOBJ DigitalInputLogicalState

    IF StepCounter = 0 THEN
        IF isEnabled() THEN
            'Drive is enabled: start Homing

            StartHoming()

            StepCounter = 1
        END IF
    ELSEIF StepCounter = 1 THEN
        IF isInRef() THEN
            'can start the applicaton now1

            StepCounter = 2
        END IF
    ELSE
        Run()
    END IF
LOOP

END

'-----------------------------------------------------------------

'local functions

FUNCTION isEnabled()
    DIM DriveStatus

    'DriveStatus is the lower bits of the statusword

    DriveStatus = (GETOBJ Statusword) & $6F

    IF (DriveStatus = CiAStatus_OperationEnabled) THEN
        RETURN 1
    ELSE
        RETURN 0
    END IF
END FUNCTION


FUNCTION StartHoming()
    SETOBJ ModesOfOperation = OpModeHoming

    SETOBJ Controlword = (CiACmdEnableOperation | CiACmdStartBit)
END FUNCTION

FUNCTION isInRef()
    DIM DeviceStatus

    DeviceStatus = GETOBJ Statusword

    'check for IsInRef bit

    IF (DeviceStatus & $1000) > 0 THEN
        RETURN 1
    ELSE
        RETURN 0
    END IF
END FUNCTION
```

```
FUNCTION Run()
    'check for DigIn1
    IF (DigInStatus & $01) > 0 THEN
        SETOBJ ModesOfOperation = OpModeAPC
    ELSE
        SETOBJ ModesOfOperation = OpModeATC
    END IF
END FUNCTION
```

7.2.2 Reference run with subsequent automatic change to positioning operation and start-stop function

This example builds on the example in chap. 7.2.1, p. 29.

Control is not activated automatically here. Control is activated from within the program if DigIn2 is active.

After the first switch-on procedure, the reference run is performed first followed by a change to normal operation. Control can also be deactivated again at any time via DigIn2. The reference run does, however, only occur after being switched on for the first time.

Prerequisites

- The motor was successfully commissioned and the control adapted to the application.
- The desired type of reference run was configured in object 0x6098.00.
- The analogue setpoint specifications are appropriately scaled via objects 0x2313 and selected as sources for the position set value (0x2331.04) or the torque set value (0x2331.02) via object 0x2331.

Sequence

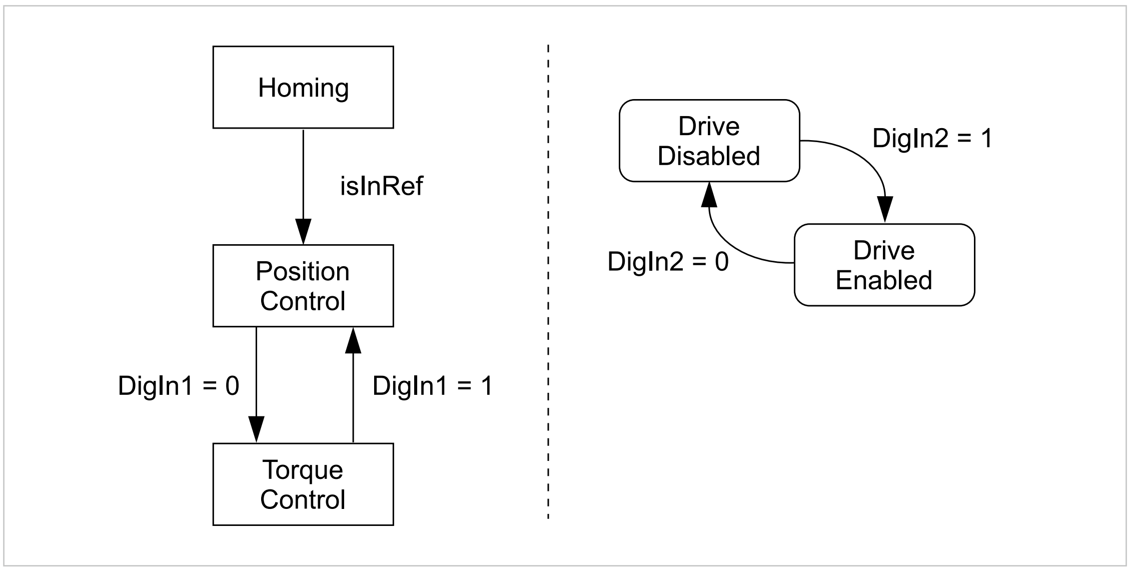


Fig. 2: Sequence for reference run with subsequent change to positioning operation and start-stop function

Implementation

The sequence for reference run with subsequent change to positioning operation (left side in Fig. 2) is taken over, including the sub-functions from the example in chap. 7.2.1, p. 29.

The check and reaction to DigIn2 is amended to the loop. Prerequisite for this is the implementation of the sequence as a sequence of steps without any blocking queries.

```
'-----------------------------------------------------------------
'Author: MCSupport
'Date: 2018-09-14
'-----------------------------------------------------------------
'Description: Test of the Libs
'-----------------------------------------------------------------

#INCLUDE "MotionParameters.bi"
#INCLUDE "MotionFunctions.bi"

:Init
DIM StepCounter
DIM DigInStatus
DIM DriveStatus
DIM isStarted

StepCounter = 0
isStarted = 0

:MainLoop
DO
    'cyclic check of status
    'DriveStatus is the lower bits of the statusword
    DriveStatus = (GETOBJ Statusword) & $6Fe
    DigInStatus = GETOBJ DigitalInputLogicalState

    'check application status
    IF StepCounter = 0 THEN
        IF isEnabled() THEN
            'Drive is enabled: start Homing
            StartHoming()
            StepCounter = 1
        END IF
    ELSEIF StepCounter = 1 THEN
        IF isInRef() THEN
            'can start the applicaton now1
            StepCounter = 2
        END IF
    ELSE
        Run()
    END IF
    'check DigIn2 for start/stop oft he powerstage
    IF isStarted THEN
        'check for stop command
        IF (DigInStatus & $02) = 0 THEN
            'drive shall be stopped
            IF StopDrive() THEN
                isStarted = 0
            END IF
        END IF
    ELSE
        'check for start command
        IF (DigInStatus & $02) > 0 THEN
            'drive shall be started
            IF StartDrive() THEN
                isStarted = 1
            END IF
        END IF
    END IF
LOOP

END

'-----------------------------------------------------------------
'local functions

FUNCTION isEnabled()
    IF (DriveStatus = CiAStatus_OperationEnabled) THEN
        RETURN 1
    ELSE
        RETURN 0
    END IF
END FUNCTION


FUNCTION StartHoming()
    SETOBJ ModesOfOperation = OpModeHoming
    SETOBJ Controlword = (CiACmdEnableOperation | CiACmdStartBit)
END FUNCTION


FUNCTION isInRef()
    DIM DeviceStatus
    DeviceStatus = GETOBJ Statusword

    'check for IsInRef bit
    IF (DeviceStatus & $1000) > 0 THEN
        RETURN 1
    ELSE
        RETURN 0
    END IF
END FUNCTION


FUNCTION Run()
    'check for DigIn1
    IF (DigInStatus & $01) > 0 THEN
        SETOBJ ModesOfOperation = OpModeAPC
    ELSE
        SETOBJ ModesOfOperation = OpModeATC
    END IF
END FUNCTION
```

7.3 Event handling

The following program extract shows how the program can respond to the event **Temperature warning limit reached**.

```
DEF_EVT_VAR e 'Define event mask
EN_EVT $00030000, EvtOverTemp 'activate event handling for over temperature


:EvtOverTemp
IF e & $00020000 THEN
    END
ELSE
    w = 1 ‘temperature warning, set variable w
END IF
RET_EVT
```

DR. FRITZ FAULHABER GMBH & CO. KG
Antriebssysteme

Daimlerstraße 23 / 25
71101 Schönaich • Germany
Tel. +49(0)7031/638-0
Fax +49(0)7031/638-100
info@faulhaber.de
www.faulhaber.com

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