SEQUENTIAL FUNCTION CHART

OBJECTIVE

The students will be able to successfully implement sequential controls using step sequences. The students understand the structure and effect of step sequences, and are introduced to corresponding design methods. Knowledge about operating modes and protective measures is expanded for sequential controls. The students understand the interaction between the programs for basic automation and the sequential controls. They know how to generate sequential controls in **PCS7**.

THEORY IN SHORT

Sequential controls allow for processing sequential and parallel operations in a mode that is discrete with respect to time or events. They are used to coordinate different continuous functions as well as controlling complex process sequences. Depending on defined states or events, operating and mode changes are generated in the existing logic control systems and as a result, the desired sequential performance is implemented. They are implemented through one or several *step sequences* (in English: *sequential function charts*).

A step sequence is the alternating sequence of **steps** that trigger certain actions respectively, and **transitions** that cause a step to change into another one as soon as the corresponding **step enabling condition** is met. Each step sequence has exactly one **start step** and one **end step** and in addition any number of intermediate steps that are connected respectively through oriented edges by means of interposed transitions. The diagrams may also generate feedback through loops within the step sequence. They also can include parallel or alternative branches. However, in this case it has to be ensured during the design that the sequence does not contain segments that are unsafe or unavailable.

To design sequential controls, particularly the formal design methods of *state diagrams* or *Petri's networks* are available. State diagrams are easily learned, make automatic error diagnosis possible and can be converted without a problem into many existing programming languages for sequence controls. However, designing parallel structures is not possible, since state diagrams have only exactly one state.

Petri's networks are considerably more complex and more demanding mathematically. But all structures that are permitted in sequential controls can be modeled and extensively analyzed. Thus, required control properties can be proven formally. Likewise, Petri's networks allow for no-problem implementation in sequential controls.

Sequential controls parameterize and activate lower level logical control systems by setting corresponding global control signals. These control signals can have a brief or a lasting, a direct or a delayed effect. Sequential controls as well as logical control systems have to support different operating modes. Particularly manual control of the transitions and temporary or permanent interruptions of the process sequences has to be possible In addition, process specific protective functions are implemented with sequence controls.

In *PCS7*, sequence controls are implemented with *Sequential Function Charts* (*SFC*). SFCs provide for efficient operating mode management, high controllability through several switching modes as well as extensive parameterizability through different sequence options. The SFCs and CFCs interact and are linked in *PCS7* by means of process variables and control variables. The interactive behavior can also be controlled in detail.

THEORY

CONTINUOUS AND SEQUENTIAL CONTROLS

Within the scope of basic automation, different logic control systems are developed that implement a limited, clearly defined function. The functions continuously process input signals and generate corresponding output signals. By means of different control signals, the functions can also be activated and parameterized. To implement complex process sequences -for example, manufacturing *recipes* for products- it is necessary to coordinate the different functions and to activate them at the right time with the correct parameters. This task can be handled using sequential controls.

Sequential controls make step by step, event-discrete processing of sequential and parallel operations possible using *step sequences*. Depending on defined states or events, they generate operating and mode changes in the existing logic control systems and thus implement the desired sequential behavior. Step sequences are also referred to as *sequential function charts*.

STRUCTURE OF STEP SEQUENCES

A step sequence is the alternating sequence of *steps* and *transitions*. The individual steps activate certain actions. The transitions control the change from one step to the next.

The first step of a step sequence is referred to as the *start step*. It is the unique entry point in the sequence and is always executed. The last step in a step sequence is correspondingly referred to as the *end step*. It is the only step in the sequence that does not have a sequence transition. After the end step is processed, the step sequence is terminated, or processing starts anew. The latter case is also referred to as sequence loop.

Steps and transitions are connected to each other with oriented diagrams. It is possible to connect a step with several sequential transitions; the reverse is possible also. A transition is enabled if all series connected steps are active and the step enabling condition is met. In this case, first the immediately preceding steps are deactivated and then the immediate subsequent steps are activated.

The simplest form of a step sequence is the unbranched sequence. Each step is followed by exactly one transition, and the transition in turn by exactly one subsequent step. This implements a purely sequential process run. Figure 1 shows the corresponding graphic basic elements.



Figure 1: Basic elements of sequential function charts

Loops within the step sequence occur when by sequencing several steps a cyclical run within a sequence is possible. The sequence loop represents a special case of a loop where all steps are run cyclically.

Another option for structuring step sequences is jumps. When a jump mark is reached, processing continues with the step to which the jump mark points. Jumps within the step sequence can also result in loops. Since such a structure is difficult to follow, jumps should be dispensed with if possible.

In many cases it is necessary from the process view to respond differently to different events when the program is executed. This structure is referred to as **alternative branching**. The step is linked with each possible subsequent step by means of its own transition. To ensure that at any time at most one of these transitions is enabled (and the branches are actually alternative), the transitions should be mutually locked or clearly prioritized. Otherwise, in most control systems the transitions are evaluated from left to right, and the first transitions whose step enabling condition is met is enabled.

Figure 2 shows, in principle, the structure of alternative branching with two branches. It is represented by bordering horizontal single lines with protruding ends. As can be seen, the alternative branches always start and end with transitions.



Figure 2: Alternative and parallel branches

It is often required that after a step, several subsequent steps are to be processed simultaneously. In this case, the initial step has one transition exactly that activates several subsequent steps at the same time. We call this structure *parallel branching*. The subsequent steps of the individual branches are processed independent of each other and are then merged again. All branches end in a joint transition. Only after all branches are processed completely and the step enabling condition for the subsequent transition is met is it possible to activate the joint subsequent step.

Figure 2 also shows the sequence of a parallel branch with two branches. They are represented with bordering horizontal double lines and protruding ends. As can be seen, the parallel branches always start and end with actions.

A particular control engineering problem is the possibility to generate -by unfavorably using jumps and branches- faulty step sequences. We are distinguishing three possible cases.

- Uncertain sequence: A step sequence contains a structure whose availability is not ensured through the defined sequential performance.
- *Partially stuck*: A step sequence contains an internal loop that is not exited. Although the steps within this loop are executed, the steps outside the loop are not. This makes parts of step sequence unavailable.
- Totally stuck: A step sequence contains a structure for which no permissible step enabling condition exists. In this case, the step sequence remains permanently in one state and all other steps are unavailable.

Such structures are not permitted in step sequences and have to be excluded with corresponding design methods. Figure 3 shows examples of two step sequences with impermissible structures.

In the left sequence we can't ensure that Step S6 is available since the alternative branch after Step S3 prevents -when transition t3 is enabled- that the parallel branch is merged again in transition t4. For that reason, this sequence is uncertain. The right sequence, on the other hand, is executed exactly once and then stops at Step S4. Since Step S2 is not active in this state, the parallel branch can no longer be merged in transition t3. It is totally stuck; Step S5 is unavailable.



Uncertain structure

DESIGN OF SEQUENCE CONTROLS

There are numerous formal design methods for sequence controls. In practice, however, particularly the *state diagrams* and *Petri's network* have proven themselves.

A **state diagram** is a connected, oriented diagram. States are represented as circles and the state transitions as arrows that connect exactly two states. In a state diagram, always exactly one state is active at a time. The states can be linked to certain actions. A certain sequence performance can be assigned to these actions. They can be performed once when entering the state or when leaving it, or cyclically as long as the state is active. State transitions can be subject to transition conditions.

State diagrams can be arranged hierarchically, and linked to each other. State diagrams are considered easy to learn and make automatic error diagnosis possible -for example, through pair, time or state monitoring. They can be converted into many existing programming languages for sequence controls, without a problem.

Petri's networks are particularly suitable for modeling concurrent processes. Petri's network consists of locations and transitions that are linked to each other with oriented edges. This generates an oriented diagram also. A location is represented as a circle, a transition as a rectangle (often also reduced to a cross bar). Active locations are identified with labels which are represented by a dot within the circle for the corresponding location.

In contrast to function diagrams, in Petri's network the state is determined by the number of active locations in the entire network. The dynamics of the system is modeled by the movement of the labels within the network. The significance of the locations and transitions for the modeled process (i.e., the *semantics* of Petri's network) is not defined and has to be specified depending on the application case. Petri's networks whose semantics is specified are referred to as *interpreted Petri's networks (IPN)*. For the control design, *control engineering interpreted Petri's networks (CIPN)* are used as a rule.

Petri's networks can be extensively examined analytically. They also permit the conversion into existing programming languages for sequence controls without a problem. There are numerous expansions for Petri's networks that are optimized for certain application cases respectively, or permit a more detailed modeling of the process. For that reason, Petri's networks can become quite complicated which makes them rather demanding as design models. Because of their structural similarity to step sequences and the option of modeling parallel sequences, Petri's networks offer clear advantages, however.

Which design method is used depends ultimately on the requirements of the design task as well as on the developer's preference. For additional information, we refer to the pertinent technical literature.

INTERACTION OF SEQUENCE CONTROLS AND LOGIC CONTROL SYSTEMS

As described above, certain actions can be assigned to each step in step sequence. Generally, these actions consist of the parameter assignment and the activation of logic control systems. To this end, corresponding control signals are set.

Process and control signals used by step sequences have to be declared globally so that they are <<a>available equally? something missing in original>> to the programs of the sequence and logic controls. Usually, the signals are contained in a symbol table.

Control signals always are effective as long as the corresponding step is active. To implement more complex function sequences, it is possible to vary the processing of a control signal itself (latching or non-latching, delayed or limited).

Usually, process specific functions are implemented with sequence controls, while logic controls implement all device specific functions.

PROTECTION FUNCTIONS AND OPERATING MODES IN SEQUENCE CONTROLS

Just as for the individual drive functions, adequate protection functions and operating modes have to be implemented for sequence controls. It has to be possible to operate sequence controls manually if there is a fault. To this end, corresponding operating modes have to be provided for in the control.

- Automatic mode: The action of the step sequence is executed if the preceding transition is enabled.
- Manual mode: The operator triggers the action of step sequence, even if the preceding transition is not enabled.
- Mixed mode: The action of the step sequence is executed if the preceding transition is enabled, or the operator triggered it. As an alternative, operator activation as well as enabling the preceding transition may be required.

The manual mode prevents that the sequence control may be permanently blocked because of a fault. The mixed mode allows for the manual interruption of the sequence for testing or commissioning. The step enabling conditions of all transitions of the sequence control have to be expanded accordingly.

Step sequences have to be able to react to faults in the controlled devices. To this end, continuous fault monitoring is required. It recognizes and signals faults in the controlled devices. It makes automated safety of the plant possible by stopping the step sequence automatically if there is a fault. In addition, it has to be possible for the operator to stop and cancel the step sequence if there is a fault.

In both cases corresponding protection functions have to be activated to take the plant to a safe state. If a sequence is stopped, it has to be ensured that it can be continued safely and in a way that is permissible regarding process engineering, even if the interruption was of a longer duration. In the sequence controls, process specific protection functions are implemented, such as sequential locking of several devices if there is a fault in the process.

SEQUENCE CONTROLS IN PCS7

In *PCS7*, sequence controls are implemented with *Sequential Function Charts* (*SFC*). They contain the step sequences and define their sequence topology, the conditions for the transitions and the actions of the steps. It is possible to define and prioritize the start conditions and the sequence characteristics separately for each step sequence. In addition, the preprocessing and post-processing steps can be defined that are executed once before or after processing the step sequence.

Operating Modes and Switching Modes

The performance of a sequence control in **PCS7** depends on the following: the selected operating mode, the specified switching mode, its current operating mode, and the sequence options. Two different operating modes can be selected for sequence controls:

- **Auto:** The program controls the sequence.
- Manual: The operator controls the sequence through commands, or by changing the sequence options.

In the manual mode, the following commands are available to the operator: *Start, Stop, Halt, Exit, Cancel, Continue, Restart Reset* and *Error*, to operate the sequence control manually. Depending on the selected operating mode, the behavior of a step sequence can be controlled through different switching modes when further switching active steps to the subsequent steps.

- Switching Mode T: The sequence control is running process controlled; i.e., automatically. If a transition is enabled, the preceding steps are deactivated and the subsequent steps are activated. (T = transactions)
- Switching Mode O: The sequence control is running operator controlled; i.e., manually. The transition is enabled by an operator command. To this end, each

subsequent transition of an active step automatically sets an operator prompt (O = Operator).

- Switching Mode T or O: The sequence control is running process controlled or operator controlled. The transition is enabled either through an operator command or a step enabling condition that was met.
- Switching Mode T and O: The sequence control is running process controlled and operator controlled. The transition is enabled only based on an operator command and if the step enabling condition is met.
- Switching Mode T/T and O: In this switching mode we can specify for each step individually whether the sequence is controlled by the process or the operator. In the test mode, this allows for defining stop points in the sequence control (T/T = Test Transactions)

In the operating mode *Auto*, only the switching modes *T* and *T/T* and *O* can be selected. The operating mode of the sequence control indicates the current state in the sequence and the resulting performance. A corresponding operating mode logic defines the possible modes, the permissible transitions between the modes as well as the transitional conditions for a mode change. *PCS7* defines a separate operating mode logic for sequence controls and for step sequences respectively. It is possible to run step sequences depending on the mode of the sequence control.

Sequence Options

By using sequence options, it is possible to control the execution time performance of sequence controls. For example, we can specify whether a sequence control is processed once or cyclically (option *cyclical mode*) or whether the actions of the active step are actually performed (option *command output*). In addition, time monitoring for the individual steps of a step sequence can be activated which signals a step error if there is a timeout (option *time monitoring*).

Interaction Performance

In the **PCS7**, CFCs and SFCs interact by means of process values and control values. These values are linked by means of the desired signals either from the global symbol table or by entering the absolute signal address. Controlling the processing of the control signals is possible by means of the SFC characteristics. In the **SFC Library**, the **PCS7** makes available preassembled step sequences for different standard scenarios. These templates can be used and adapted to current projects.

LITERATURE

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STEP BY STEP INSTRUCTIONS

TASK

Based on the recipe in the chapter 'Process Description' we are setting up and programming an SFC step sequence.

For this chapter, we reduced the recipe to the following sequence:

- 1. First, 350ml are to be drained from educt tank =SCE.A1.T1-B003 to reactor =SCE.A1.T2-R001.
- 2. When reactor =SCE.A1.T2-R001 is filled, the liquid it contains is to be heated to 25°C and the stirrer is to be switched on.
- 3. When the temperature of the liquid in reactor =SCE.A1.T2-R001 has reached 25°C, this liquid in this reactor =SCE.A1.T2-R001 is to be stirred another 10 seconds at 25°C.
- 4. Now, the liquid in reactor =SCE.A1.T2-R001 is to be heated to 28°C with the stirrer being switched on.
- 5. When the temperature of the liquid in reactor =SCE.A1.T2-R001 has reached 28°C, this liquid is then to be drained into product tank =SCE.A1.T3-B001.

OBJECTIVE

In this chapter, the student learns the following:

- Setting up and editing SFC step sequences
- Establishing logic operations between SFC step sequences and CFCs
- Establishing logic operations between SFC step sequences and the operands in the symbol table
- Testing sequence step programs

PROGRAMMING

- 1. To start, we are setting up a new SFC in the plant view in the folder 'A1_multipurpose_ plant'.
 - $(\rightarrow A1_multipurpose_pant \rightarrow Insert New Object \rightarrow SFC)$



2. Next, we are selecting the SFC properties.

 $(\rightarrow SFC(1) \rightarrow Object Properties)$

SIMATIC Manager - SCE_PCS7_MP				
File Edit Insert PLC View Options Window He	elp			
D 😅 \$? 🥽 X 🖻 🛍 🖆 🗣		🗄 🏢 🔁 🖂 N	o Filter >	💽 🏹 🔡 🛍
SCE_PCS7_MP (Component view) D:\Pro	ogramme\	SIEMENS\STEP 7\	IN IN INTERNET	
📄 🗃 🎒 SCE_PCS7_Prj	T3_pro	iduct_tanks 🚡 T4_	rinsing	
Shared Declarations Sec factory	SFC(1	Open Object	Ctrl+Alt+O	
🖻 📓 A1_multipurpose_plant		Open External Vi	ew	
⊕ T1_educt_tanks ⊕ T2 reaction		Cut	Ctrl+X	
⊡ 📴 T3_product_tanks		Сору	Ctrl+C	
⊕ 🔂 T4_rinsing		Paste	Ctrl+V	
E-SCE_PCS7_Lib		Delete	Del	
		PLC	•	
		Print	,	
		Charts	ŀ	
		Plant Hierarchy	•	
		SIMATIC BATCH		
		Rename	F2	
Displays properties of the selected object for editing.		Object Properties	Alt+Return	-

- 3. Under General, we change the name to 'SFC_Produkt01'.
 - $(\rightarrow \text{General} \rightarrow \text{SFC}_{Produkt01})$

Properties SFC chart		×		
General AS Operating Par	rameters DS Version			
Name:	SFC_product01	-		
Project path:	SCE_PCS7_Prj\SIMATIC 400(1)\CPU 414-3 DP\S7			
Technological path:	SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant			
Storage location of project:	D:\Programme\SIEMENS\STEP7\s7proj\SCE_PCS7\SCE_Prj			
Author:		-		
Date created:	12/06/2010 12:23:49			
Last modified:	12/06/2010 12:23:49			
Comment:				
	≊			
Write-protected				
ОК	CancelHelp			

 We are keeping the operating parameters; they can be changed later in the online mode (→ AS Operating parameters)

Properties SFC chart		×
General AS Operating Parameters	OS Version	-
Step control mode:	Operating mode:	
Command output Cyclic operation	SFC startup after CPU restart Initialize SFC Retain SFC state	
Start options C Autostart Use default operating paramete	rs when SFC chart starts	
OK	CancelHelp	

- 5. Regarding the tab OS it is important that the checkmark is set so that the SFC will be available later in visualization.
 - $(\rightarrow OS \rightarrow Transfer chart to the OS for visualization)$

Properties SFC chart		X
General AS Operating Parameters OS Version		
✓ Transfer chart to OS for visualization		
ОК	Cancel	Help

6. Under the tab Version, we accept all parameters with OK.

 $(\rightarrow \text{Version} \rightarrow \text{OK})$

Properties SFC ch	art		
General AS Operati	ng Parameters OS Version		
Version:	0.0001		
Data version:	V7.1 SP2		
		Cancel	Help

 Now, with a double click, we open the step sequence 'SFC_Produkt01' in the SIMATIC Manager. (→ SFC_product01)

SIMATIC Manager - SCE_PCS7_MP			
File Edit Insert PLC View Options Window He	∲ <u>• ∵ ⊞ ∰ €</u>	< No Filter >	- V 2 @
SCE_PCS7_MP (Component view) D:\Pro			
SCE_PCS7_Prj SCE_PCS7_Prj Shared Declarations SCE_factory SCE_fact	In T1_educt_tanks T1_educt_tanks T2_reaction T3_product_tanks T4_rinsing SFC_product01 ¬↑ Picture(3)	SIMATIC 400(1)\CPU SIMATIC 400(1)\CPU SIMATIC 400(1)\CPU SIMATIC 400(1)\CPU SIMATIC 400(1)\CPU 	
SCE_PCS7_Lib	<	2	,
Press F1 to get Help.		PC internal (local)	

8. In the SFC editor, it is now possible to set up the sequence control with the following symbols from the tool bar.

ħ	Button Switch on Select
ŧ	Button Insert Step and Transition
韓	Button Insert parallel branch
÷	Button Insert alternative branch
中	Button <i>Insert loop</i>
\$₽	Button <i>Insert jump</i>
abl	Button <i>Insert text field</i>

🛃 SFC - [SFC_product01 SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant] 💦 🔲 🔀
🖸 SFC Edit Insert CPU Debug View Options Window Help 🛛 🗕 🗗 🗙
D 😂 🎒 🐁 🖻 🖻 🗉 🕅 🎰 😗 🥦 🐹 🐼 🔍 🔍 🍳 🖷 🖻 👀 🕺
▶ 中 韓 母 玲 玲 abl
START
END
Press F1 for help OB35 SFC_product01

9. We need additional steps and transitions for our task. To insert both, we select the

button 📑	and then select the location where we want to insert them. $(\rightarrow \textcircled{\mp})$	

SFC - [SFC_product01 SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant]	
SFC Edit Insert CPU Debug View Options Window Help	
D 🚅 🎒 🐰 🖻 🖻 🔳 🕅 🏙 🕑 🦉 🔀 🐼 🐼 🔩 Q 🖷	Long a start
▶ 中韓 む む は = = = = = = = = = = = = = = = = =	
· │구 ፡芊 단 단 tā au	
	-
START	
END	
	·
Press F1 for help 0835	SFC_product01

10. After we inserted five steps and transitions in this way, we click on the symbol \mathbf{N} to edit normally again. (\rightarrow)



$\underline{\mathbb{A}}$

Note: Step and transition numbering is of no impotance for the sequence in which the step sequence is processed.

11. Now, we first want to be able to change the properties of a step. Right click on the step and then select Object Properties. (\rightarrow 3 \rightarrow Object Properties)



12. For greater clarity, each step is assigned a name in the object properties. (\rightarrow eductB003toR001 \rightarrow Close)

lun times Minimum: Maximum:	
Minimum	
Comment:	
	\sim
DS comment:	0
	100
	1000
Acknowledgment	~

13. As for the steps, for the transitions also the properties have to be changed. Right click on the transition and then select Object Properties. ($\rightarrow 1 \rightarrow$ Object Properties)



14. Here also, first only the name is changed. (\rightarrow Init_OK \rightarrow Close)

Properties - 1 SCE_F	PCS7_Prj\SCE_factory\A1	_multipurpose_p	olant\\SFC_product01	X
General Condition 0	S Comment			
Name:	[init_OK]	Number:	1	
Comment:				<u>^</u>
				~
Close	y ← ↑ ↓ →	Print Brows	se Go to	Help

15. Repeat the previous steps until our SFC looks like this. It is important to enter at the step 'hold 25°C stir' also the minimum execution time of 10 seconds. (→ T#10s)



16. Now we have to implement the actual function of the step sequence. We start by double clicking on the step 'START'. (\rightarrow START)



17. To establish logic operations with the CFCs or symbols, we are selecting the first field and then click on 'Browse'. (→ Browse)

1	:=	
2	:=	
3	:=	
4	:=	
5	:=	
6	:=	
7	:=	
8	:=	
9	:=	
10	:=	

18. Then, in a selection window in the familiar clearly laid out plant view we select the connection of a desired block.

 $(\rightarrow$ SCE_factory \rightarrow A1_multipurpose_plant \rightarrow T1_educt_tanks \rightarrow A1T1S003 \rightarrow A1T1S003 \rightarrow AUT_ON_OP)

		1/0:	s <filtered< th=""><th>></th><th></th></filtered<>	>	
E B SCE factory	Name	/ Data t	I CFC	interconnection	SFC acc
🖻 🙆 A1_multipurpose_plant	AUT L	BOOL	I.		
FC product01	AUT_ON_OP	BOOL	1.		
E 🙆 T1 educt tanks	AUTO_ON	BOOL	I		
	AUTOP_EN	BOOL	1.		
	AUX_PR04	ANY	L		
🖻 🌆 A1T1S003	AUX_PR05	ANY	1.		
	AUX_PR06	ANY	I.		
2	AUX_PR07	ANY	1.		
	AUX_PR08	ANY	1.		
	AUX_PR09	ANY	L		
5	AUX_PR10	ANY	I		
7	BA_EN	BOOL	1.		
	BA_ID	DW0	1.		
	BA_NA	STRI	L		
9	CSF	BOOL	I. x		
ERROR	EN	BOOL	1.		
	FAULT_OFF	BOOL	L.		
	FB_ON	BOOL	L x		
pump A1T1S003	L_RESET	BOOL	I,		
	LIOP_SEL	BOOL	1.		
	LOCK	BOOL	L x		
	LOCK_ON	BOOL	L x		
🗈 🙆 T3_product_tanks	MAN_ON	BOOL	I		
💼 🛅 T4_rinsing	MANOP_EN	BOOL	1.		8
	LIGHTOD .	2001	1.51	1	>

19. On the right side, this parameter can be assigned either the value of another parameter again from the plant view or, as here, simply a constant. (\rightarrow Auto \rightarrow Close)

1		A1T1S003\pump_A1T1S003.AUT_ON_OP	:=	= Auto
2			:=	Auto Manual
3			:=	
4			:=	=
5	1		:=	=
6			:=	=
7	9		:=	=
8			:=	=
9]되		:=	-
10			:=	_

20. Now we are editing the next step 'heat 25°C stir' by first opening it with a double click. (\rightarrow heat 25°C stir)



21. To establish connections, we highlight the first field and then click on 'Browse'. (\rightarrow Browse)

1	5	:=	
2		:=	
3		:=	
4		:=	
5		:=	
6		:=	
7		:=	
8		:=	
9		:=	
10	V	:=	

22. Next, in the selection window in the plant view, we select the matching connection in the plant view. (→ SCE_factory → A1_multipurpose_plant → T2_reaction → A1T2T001 → A1T2T001 → PIDTemp_A1T2T001 → SP_EXT)



23. On the right, again a constant is assigned to this parameter. (\rightarrow 25.0 \rightarrow Close)

1	VA1T2T001\PIDTemp_A1T2T001.SF	2_EXT := 25.0	
2		:=	_
3		:=	
4		:=	
5		:=	
6		:=	
7		:=	
8		:=	
9		:=	
10		:=	

24. Now we specify the step enabling conditions. To do this, we open the first transition by selecting it with a double click.

 $(\rightarrow \text{Init}_\text{OK})$

🕏 SFC - [SFC_product01 SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant]	_ 🗆 🛛
🚯 SFC Edit Insert CPU Debug View Options Window Help	×
	Ⅲ № ?
▶ 中韓 む む \$p abl	
START	
init_OK [1]	

25. To again establish logic operations, we highlight the first field and then click on 'Browse'. (\rightarrow Browse)

1		
2		
3		&
4		
5		
6		&
7		&
8	•	&
9		
9		

26. This time, we select an operand under Symbol.

 $(\rightarrow \text{Symbol} \rightarrow \text{A1.A1H001.HS+-.START})$

			Symbols			
Symbol	Address	Data t	Comm			
A1.A1H001.HS+-START	11 00	BOOL	Main			1
A1.A1H002.HS+OFF	1 0.1	BOOL	emerg			
A1.A1H003.HS+LOC	1 0.2	BOOL	local			
A1.T1.A1T1L001.LSA+.SA+	1 1.0	BOOL	level			2
A1.T1.A1T1L001.LSASA-	1 1.1	BOOL	level			
A1.T1.A1T1L002.LSA+.SA+	1 2.0	BOOL	level			
A1.T1.A1T1L002.LSASA-	1 2.1	BOOL	level			
A1.T1.A1T1L003.LSA+.SA+	1 3.0	BOOL	level			
A1.T1.A1T1L003.LSASA-	1 3.1	BOOL	level			
A1.T1.A1T1S001.S0+.0+	1 1.2	BOOL	pump			
A1.T1.A1T1S001.SV.C	Q 0.1	BOOL	pump			
A1.T1.A1T1S002.S0+.0+	1 2.2	BOOL	pump			
A1.T1.A1T1S002.SV.C	Q 0.2	BOOL	pump			
A1.T1.A1T1S003.S0+.0+	1 3.2	BOOL	pump			
A1.T1.A1T1S003.SV.C	Q 0.3	BOOL	pump			
A1.T1.A1T1X001.G0+0+	1 1.3	BOOL	valve			
A1.T1.A1T1X001.G0+0-	I 1.5	BOOL	valve			
A1.T1.A1T1X001.XV.C	Q 0.4	BOOL	valve			
A1.T1.A1T1X002.G0+0+	1 2.3	BOOL	valve			
A1.T1.A1T1X002.G0+0-	1 2.5	BOOL	valve			
A1.T1.A1T1X002.XV.C	Q 0.5	BOOL	valve			
A1.T1.A1T1X003.G0+0+	1 3.3	BOOL	valve			
A1.T1.A1T1X003.G0+0-	1 3.5	BOOL	valve			0
A1 T1 A1T1X003 XV C	0 06	ROOL	valve			2

27. To the right, we again enter a value, and in the center we specify the type of operation. Here, we are querying the equality of the values. (\rightarrow TRUE \rightarrow = \rightarrow Close)

1 "A1.A1H001.HS+STA	RT" = TRUE	
2		
3		& -
4		
5		
6		&
7		
8		&
9		
10		

28. As the next step enabling condition we open 'R001 350ml' with a double click.

 $(\rightarrow R001 \ 350 ml)$

🕱 SFC - [SFC_product01 SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant] 💦 🔲 🔀
🚯 SFC Edit Insert CPU Debug View Options Window Help 🛛 🗕 🗗 🗙
▶ 中華中寺 abl
START
eductB003toR001
R001 350ml [2]

29. For the operations, we again highlight the first field and then click on 'Browse'. (\rightarrow Browse)

1	
2	
3	&
4	
5	
6	&
7	&
8	&
9	
10	

30. This time, we select a connection in the selection window in the plant view. (\rightarrow SCE_factory \rightarrow A1_multipurpose_plant \rightarrow T2_reaction \rightarrow A1T2L001 \rightarrow A1T2L001 \rightarrow LISA+_A1T2T001 \rightarrow V)

T2_reaction\A1T2L001\\A1T2L001\LISA+_A1T2L001.		1/Os	<filtered></filtered>	
Image: Stell actory Image: Stell actory Image: Stell actory Image: Stell actory </th <th>Name VLRANGE VHRANGE VALUE V_LAST_1 V_LAST V_DELTA VUELTA VUELTA</th> <th>REAL I. REAL I.</th> <th></th> <th>SFC acce</th>	Name VLRANGE VHRANGE VALUE V_LAST_1 V_LAST V_DELTA VUELTA	REAL I. REAL I.		SFC acce
ie·í函 A1T2×003 ⊕·í函 T3_product_tanks ⊡·í函 T4_rinsing	QCHF_LL QCHF_HL QBAD OVLRANGE OVHRANGE MODE LAST_DN	BOOL C BOOL C BOOL C REAL C REAL C DWO I. BOOL I		

31. To the right, we enter a value and in the center, we again specify the comparator type. Here, we query for larger or equal to.

$(\rightarrow 350.0 \rightarrow \geq = \rightarrow \text{Close})$	
---	--

Properties - R001 350ml SCE_PC57_P General Condition OS Comment	rj\SCE_fact	cory\A1_multipurpose	_plant\\SF	C_prod 🔀
1 1\\A1T2L001\LISA+_A1T2L001.V 2 3 4	= ▼ 350. = < > <= <>	0	&	
6 7 8 9 10	• • •			& - & - +
Close Apply ← ↑ ↓	→ Prin	tBrowse	Go to	Help

- 32. Just as shown in the previous steps, we now program the entire step sequence. In the result, the steps of the completed step sequence should look like this:
- Step START

1	1	\A1T1S003\pump_A1T1S003.AUT_ON_OP ;= Auto
2		\A1T2S001\stirrer_A1T2S001.AUT_ON_OP := Auto
3	v	\A1T2S003\pump_A1T2S003.AUT_ON_OP := Auto
4	-	\A1T2X003\valve_A1T2X003.AUT_ON_OP := Auto
5	1	\A1T1X006\valve_A1T1X006.AUT_ON_OP := Auto
6	1	1T3X001\VALVE_A1T3X001.AUT_ON_OP := Auto
7		A1T2T001\PIDTemp_A1T2T001.LMN_SEL := FALSE
8	1	T001\PIDTemp_A1T2T001.LIOP_INT_SEL := TRUE
9	1	001\PIDTemp_A1T2T001.LIOP_MAN_SEL ;= TRUE
10	1	1T2T001\PIDTemp_A1T2T001.SPEXON_L := TRUE
11	1	ion\A1T2T001\\A1T2T001\OR_AUT_L.IN2 := TRUE
12		:=

- Step EductB003inR001

1	1	3\\A1T1S003\pump_A1T1S003.AUT0_ON	:= 🗖	TRUE	
2	1	3\\A1T2X003\valve_A1T2X003.AUT0_OC	:=[]	TRUE	
3		6\\A1T1X006\valve_A1T1X006.AUT0_OC	:=[1	TRUE	-
4		1	:=[
5	1		:=[
6			:=[
7			:=[
8			:=[
9	1		:=[
10			:=[-

- Step Heat25°CStir

1	1	\\A1T2T001\PIDTemp_A1T2T001.SP_EXT	;= 25.0
2	1	3\\A1T1S003\pump_A1T1S003.AUT0_ON	:= FALSE
3	1	3\\A1T2X003\valve_A1T2X003.AUT0_OC	:= FALSE
4		6\\A1T1X006\valve_A1T1X006.AUT0_OC	;= FALSE
5	1	ion\A1T2T001\\A1T2T001\OR_AUT_L.IN2	2 := FALSE
6		1\\A1T2S001\stirrer_A1T2S001.AUT0_ON	:= TRUE
7	1	1	:=
8			:=
9			:=
10			:=

- Step Hold25°CStir

nitialization			
Name:	hold 25°C stir	Number: 5 🗌 Con	firmation
Run times			
Minimum:	T#10s	Maximum:	
Comment:			
Lomment.			~
			~
OS comment:			1
			~
Acknowledgment			
information:			<u></u>
			\sim

No.					CE_factory	\A1_multipur	pose_plant\\	SFC_pro🔀
Gener	al Initia	alization Pri	ocessing T	ermination				1
1					:=			<u> </u>
_2					:=			
3					:=[
4					:=			
5					:=			
6					:=			
_7	N				:=			
8					:=[
9					:=			
10	9				:=			
-			7					
Clo	ose	Apply	<u>+</u> +	+ →	Print	Browse	Go to	Help

- Step heat 28°C stir

1	VA1T2T001\PIDTemp_A11	12T001.SP_EXT := 28.0	
2		:=	
3		:=	
4		:=	
5		:=	
6		:=	
7		:=	
8		:=	
9		:=	
10		:=	

- Step R001inProdB001

1		\\A1T2T001\PIDTemp_A1T2T001.SP_EXT	:=	0.0
2	1	ion\A1T2T001\\A1T2T001\OR_AUT_L.IN2	:=	TRUE
3	•	1\\A1T2S001\stirrer_A1T2S001.AUT0_ON	:=	FALSE
4	1	3\\A1T2S003\pump_A1T2S003.AUT0_ON	:=	TRUE
5	1	\\A1T3X001\VALVE_A1T3X001.AUT0_OC	:=	TRUE
6			:=	
7	1		:=	
8	1		:=	
9	1		:=	
10			:=	

- Step END

1		3\\A1T1S003\pump_A1T1S003.AUTO_ON := FALSE	
2		6\\A1T1X006\valve_A1T1X006.AUT0_OC := FALSE	-
3	V	1\\A1T2S001\stirrer_A1T2S001.AUT0_ON := FALSE	
4	1	3\\A1T2S003\pump_A1T2S003.AUT0_ON := FALSE	
5	1	3\\A1T2X003\valve_A1T2X003.AUT0_OC := FALSE	
6	1	\\A1T3X001\VALVE_A1T3X001.AUT0_OC := FALSE	
7	1	\\A1T2T001\PIDTemp_A1T2T001.SP_EXT := 0.0	_
8		ion\A1T2T001\\A1T2T001\OR_AUT_L.IN2 := TRUE	_
9	1	:=	
10		:=	_

The transitions of the completed step sequence look like this:

Transition Init_OK

General Condition OS Comment	j\SCE_factory\A1_multipurpose_pla	nt\\SFC_product01 🖻
1 "A1.A1H001.HS+.START"	= TRUE	
2 "A1.A1H002.HS+OFF"	= TRUE	—
3 "A1.A1H003.HS+LOC"	= FALSE	&
4		_
5		
6	•	&
7		- & -
8		&
9		- -
10		
Close Apply 🗲 🕇		Go to Help

- Transition R001 350ml

<mark>opertie</mark> General	s - R001 350ml SCE_PC57_Prj\SCI	E_factory\A1_multipurpose_pla	nt\\S	FC_prod
	1\\A1T2L001\LISA+_A1T2L001.V >= ▼	350.0		
2				
3	· · · · · · · · · · · · · · · · · · ·]	& _	
4				
5				
6]		& -
7]		& -
8]	&	
9	•			
10				+
		7 1		
Close	e Apply ← ↑ ↓ →	Print Browse Go	to	Help

Transition 25°C OK

1	ction\A1T2T001\\A1T2T001\10.V	>= 💌	25.0		
2		<u> </u>			
3				&	-
4		-			
5		•			
6		-			&
7		-			8
8		-]	&	
9		-			
10	1	-	1	-	I

- Transition hold ready

1			
2			
3		&	
4			
5			
6			&
7			8
8		&	
9			
		&	

- Transition 28°C OK

1	ction\A1T2T001\\A1T2T001\10.V	>= 💌	28.0		
2					
3		-		&	_
4		- <u>-</u>			
5		-			
6		-			&
7		-			8
8		-		&	
9		-			
10	[-	[1

- Transition ready

	\\A1T2L001\LISA+_A1T2L001.V	<= 💌	50.0		
2		<u> </u>			
3		-		& -	-
4		-			
5		-			
6		-			&
7		-			8
8		-		- &	, u
9		-		_	
10		T	(_	I

33. Before we can test our program with the step sequence in the SFC, we have to again compile and download the objects from the component view.

 $(\rightarrow$ SIMATIC Manager \rightarrow Component view \rightarrow SIMATIC 400(1) \rightarrow PLC \rightarrow Compile and Download Objects)

SIMATIC Manager - SCE_	PCS7_MP					
File Edit Insert PLC View	Options Window H	telp				
🗋 🗅 🥔 🕌 🚟 🚟 🛛 🕹 🛍 🖡	2 🚵 9 🗣		🚺 主 🛛 < No Filter :	>	• 70	22 📾
SCE_PCS7_MP (Compor	nent view) D:\P	rogramme\SIE	MEN 🔳 🗖 🔀			
SCE_PCS7_MP	Hardware Hardware CP 443-1	📕 CPU 4	114-3 DP	nt		
🚊 🔣 CPU 414-3	Open Object	Ctrl+Alt+O				
⊡ ST Prog ⊡ ST Prog ⊡ Sou ⊡ Blo ⊡ Blo @ Cha	Cut Copy Paste	Ctrl+X Ctrl+C Ctrl+V		(1)\CPU (1)\CPU (1)\CPU		
⊕ +∰+ CP 443-1 ⊕ - 9 SIMATIC PC St	Delete	Del		(1)\CPU		
🗄 🧰 Shared Declara	PLC	Þ	Download		Ctrl+L	
<	Print	F.	Compile and Downlo	oad Objects	ń.	
	SIMATIC BATCH		Hardware Diagnost Compare	ics		
	Rename Object Properties	F2 Alt+Return				
Compiles/downloads the objects to	be celected under th	a biabliabled abia				

34. In the tool for compiling and downloading, we now check the settings for the charts. (\rightarrow Charts \rightarrow Settings for Compilation/Download \rightarrow Edit)

Dbjects	Status	Operating Mode	Compile	Download
SIMATIC 400(1)				
Du Hardware	undefined		X	 Image: A state of the state of
🖃 – 📕 CPU 414-3 DP		STOP		1
Blocks				
Charts	undefined			✓
Connections	undefined			4
Settings for Compilation/Download Update		w Log Single Object All	Select Objects	Deselect All

35. For the scope during compiling we select 'Entire program' and have the module drivers generated once more.

(Compile Charts as Program \rightarrow Scope: Entire program \rightarrow Generate module drivers)

Compile Program /	Download to Tar	get System	
Compile Charts as Pro	gram S7 Download		
CPU:	CPU 414-3 DP		
Program name:	SIMATIC 400(1)	\CPU 414-3 DP\S7 Program(1)	
_ Scope			
Entire program			
C Changes only			
Generate module	drivers	Block Driver Settings	
🔲 Generate SCL sc	urce		
ОК		Abbrechen	Hilfe

- 36. We download the entire program also.
 - (S7 Download \rightarrow Download mode: Entire program \rightarrow Generate module drivers)

mpile Program / Do	wnload to Target System	
Compile Charts as Program	S7 Download	
CPU:	CPU 414-3 DP	
Program name:	SIMATIC 400(1)\CPU 414-3 DP\S7 Program(1	1)
Download mode		
Entire program		
C Changes only		
C To test CPU (entire	programj	
	Show Changes	
Include user data blo	cks.	
	entire program, the CPU is set to STOP and all b download the S7 program?	blocks are
1		
Read the notes in the on	line help about possible effects Abbrechen	

\triangle

Note: Downloading the entire program is possible only if the CPU is in the 'STOP' mode.

37. After we set the check marks at 'Compile' and 'Download', we can start compiling and downloading. (→ Charts → Compile → Download → Start)

Compile and Download Objects					
Selection table:					
Objects		Status	Operating Mode	Compile	Download
E- SIMATIC 400(1)					X
🛄 Hardware		undefined		Z	
🖂 - 📓 CPU 414-3 DP			STOP		V
Blocks					
Charts		undefined			
Connections		undefined			1
Settings for Compilation/Download Edit Test	Update	Viev	VLog	Select Objects	Deselect All
	d if compilation error is detected		Alt		Destection
Start Close					Help

38. After reading the warnings, confirm with OK.

 (→ OK → OK)
 Compile and Download Objects (3280:826)
 No
 Downloading program changes during operation can, in the case of malfunctions or program errors, cause serious damage to personnel and equipment! Make sure also that downloading to the individual CPUs is not done simultaneously after compilation. Make sure that no dangerous situations could occur before executing this function!
 OK Cancel
 Compile and Download Objects (3280:822)
 If you want to download changes online, please make sure that the prerequisites have been met (e.g. correct settings selected, no previous complete compilation from the OS). A complete download is only possible if the PLCs are not in RUN. Do you want to continue?
 Yes No

39. If compiling and downloading was successful, it is displayed in a log ($\rightarrow \boxtimes \rightarrow \boxtimes$)

📸 Compile and Download Objects					
Selection table:					
Objects	Status	Operating Mode	Compile	Download	
			V		
Du Hardware	downloaded			V	
🖃 🖳 📴 CPU 414-3 DP 🗾 Compile and Download Objects - Ec	litor		V		
Datei Bearbeiten Format Ansicht ?					
Charts					
Connections Date: 12/06/2010 time: 01:11 Compile:	¹⁸ Date: 12/06/2010 time: 01:11:46 PM				
SCE_PCS7_Prj\SIMATIC 400(1)\H. -> Object was compiled withou	ardware				
-> Object was compiled without	t errors				
Date: 12/06/2010 time: 01:11 Compile:	Date: 12/06/2010 time: 01:11:51 PM				
SCE_PCS7_Prj\SIMATIC 400(1)\C >> Object was compiled withou	PU 414-3 DP\C	onnections			
-> Object wás compiled withou	t errors 🏾 🏾				
Date: 12/06/2010 time: 01:11	:54 PM				
compile: SCE_PCS7_Prj\SIMATIC 400(1)\CI	PU 414-3 DP\S	7 Program(1)\Ch			
		· · · · · · · · · · · · · · · · · · ·			
Settings for Compilation/Download Update	Viev	Log	Select Objects		
Edit Test Status Operating Mode		Single Object All	Select All	Deselect All	
	·				
🗌 🗌 Status during Open					
Compile only 🔽 Do not load if compilation error is detected					
Start Close				Help	

40. We now switch again to our step sequence 'SFC_product01' to test and watch the

program there. Start the test mode by clicking on the symbol \square . (\rightarrow \square)



41. Now we can watch how the step sequence is processed, and we can also operate it.

For example, our step sequence has to be started by clicking on $\boxed{}$ Start (\rightarrow)

SFC - [SFC_product01 -- SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant_ONLINE] - 8 × 🚯 SFC Edit Insert CPU Debug View Options Window Help D 🗃 🕘 X 🖻 🖻 🗉 🕅 🎽 ষ 🧏 🔀 🔍 🔆 🍳 🍳 🖷 🖿 📢 ▶ | 幸 韓 母 點 abl * START init_Ol eductB003toR001 R001 350ml heat 25°C stir 25°C OF RUN/ I + RUN 🕨 Run T -MANUAL 0.00 Command Output MANUAL Start П Hold ID Cyclic Operation AUTO X Abort 1 Stop Time Monitoring 5 4 8 5 Restart Reset Error Press F1 for help RUN(Process)

42. In the test mode, we can monitor the condition of the logic operations in the transitions, and the actions active in the steps at the moment. To this end, we only have to click on the respective step or the transition.

	uct01 SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant_ONLINE]	
SFC Edit Insert	CPU Debug View Options Window Help	- 8 ×
D 🗳 🍜 🕺 🖪	n 🖻 🖻 🗉 🕼 📩 🛐 雅 🎇 🖾 🗟 - 🗞 🔍 🍳 🖺 🖪 🖽 🕅	
▶ 幸 幸 む む	· ‡ _* abi	
	START	
Properties - START(I(ACTIVE) SCE_PCS7_Prj\SCE_factory\A1_multipurpose_plant\\SFC_pX	
OS comments (ir	initialization) OS comments (processing) OS comments(closing)	
General	Initialization Processing Termination	
1 Auto	mp_A1T1S003.AUT_ON_OP := Auto	
2 Auto	SCE_factory\A1_multipurpose := Auto Auto	
3 Auto	SCE factors\A1_multinumose := AutoAutoAutoAuto	
4 Auto	Properties - init_OK(FALSE) SCE_PCS7_Prj\SCE_factory\A1_multipurpose_p	lant\\SFC_pr🔀
5 Auto	General Current Cond. OS Comment Previous Cond. Cond. after Error	
6 Auto	0 H001.HS+.START" = TRUE 1	1
7 0	0 .A1H002.HS+.OFF" = TRUE 1	
8	0 A1H003.HS+.LOC" = FALSE 0 - &	
9 <mark>1</mark> 10 <mark>1</mark>		
10]1		& - 1
Close		
		& -
	╖ <u>╢</u> ╎┝─────┝─────┝─┝────┝─┝────┝──┝────	
🕨 Run 🕨		
MANUAL		*
MANUAL Start		b Help
AUTO X Abort		
Press F1 for help.	t Reset Error Time Monitoring	
ness i norneip.	ייייים איניים ייייייים איניייים איניייים איניייים איניייים איניייים איניייים איניייים אינייים אינייים אינייים אינייים אינייים אינייים איניים איניטים איניים איניטים איניטיטיטיטיטיטיטיטיטיטיטיטיטיטיטיטיטיטי	///

EXERCISES

We are going to apply to the exercises what we learned in the theory part and the step by step instructions. We are going to utilize and expand on the existing multi-project provided in the step by step instructions (PCS7_SCE_0107_R1009.zip).

This exercise is intended as a complex exercise, where the technical knowledge presented in the entire Module P01 is repeated. The tasks below are to be an aid to incorporate with Reactor R002 the second line that was missing so far into the project.

TASKS

The following steps are based on the step by step instructions. For each task, the corresponding steps in the instructions can be used as an aid.

- 1. For the second line, the corresponding plant hierarchy has to be implemented. Set up a folder for each of the individual drive functions listed in Table 1.
- 2. Implement the individual drive functions in the associated folder of the plant hierarchy. Use the functions that are already implemented from the previous exercises. When you implement the individual drive functions, don't omit to carry out the required steps for plant safety.
- 3. Based on the step by step instructions, implement in the SFC step sequence a second line that includes the required steps for Reactor R002. The objective is implementing the recipe according to the process description. In the step by step instructions, all steps in reference to Reactor R001 are already implemented.

Name	Туре	
A1T1S001	Motor	
A1T1S002	Motor	
A1T1X004	Valve	
A1T1X005	Valve	
A1T2H004	Manual operation	
A1T2H005	Manual operation	
A1T2H009	Manual operation	
A1T2H016	Manual operation	
A1T2L002	Measure level	
A1T2S002	Motor	
A1T2S004	Motor	
A1T2X004	Valve	
A1T2X005	Valve	
A1T2X008	Valve	

Table 1: Required individual drive functions