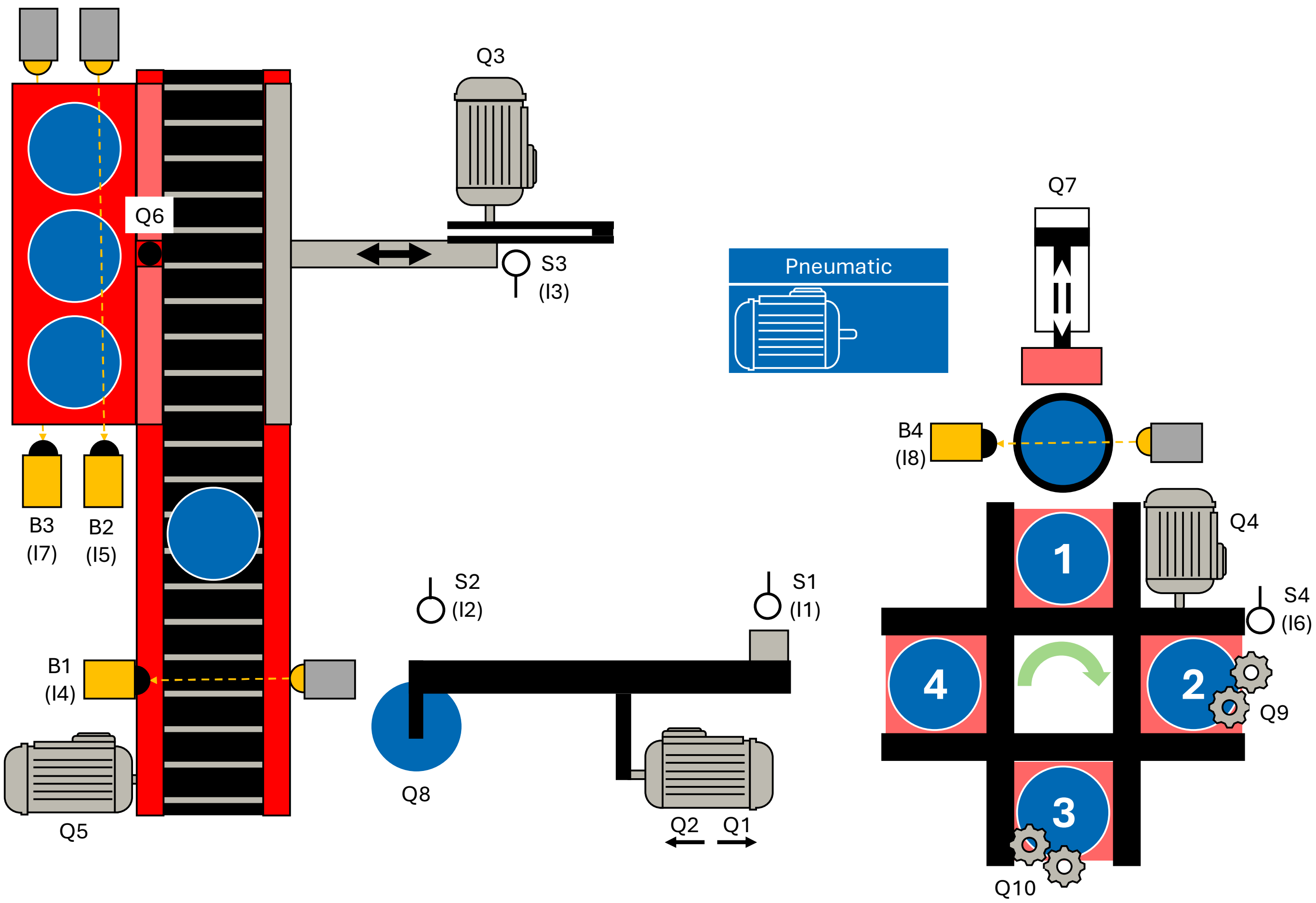
24V production line

GRAFCET



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4 GRAFCET

4.1 Introduction

GRAFCET, also known as "Graphe Fonctionnel de Commande Étape-Transition" or "Sequential Function Chart" (SFC), is a standardized graphical modelling tool for the description and specification of control and regulation tasks in automation technology. It was defined in the IEC 60848 standard and is an essential tool for programming and documenting programmable logic controllers (PLCs).

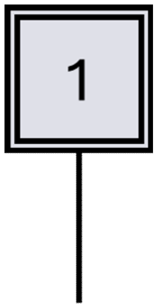
In modern industrial automation, it is crucial to plan and implement complex control tasks in a clear and structured manner. GRAFCET offers a standardized method that enables engineers to model control processes in an easily understandable and verifiable way. The function of a system is represented with steps and switching conditions (= transitions).

Many people from a wide range of disciplines are involved in the development of a machine or system. GRAFCET serves as a kind of language that can be understood by everyone, regardless of their area of expertise. The aim is for all employees to be able to understand the function and control behavior of the system very quickly. It does not matter what type of control system is later used in the production area.

4.2 Rules for creation

4.2.1 Initial step

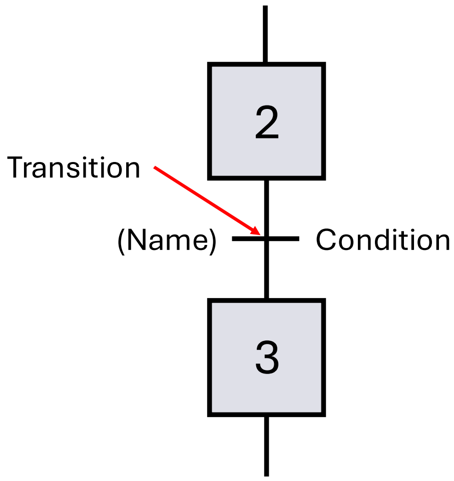
Each step chain must start at a specific point, and the initial step is used for this. This can be recognized by the double frame. After switching on, the controller is automatically in the initial step, but before the START command. The standard refers to this state as the "initial situation". This is why the initial step is usually at the beginning of the step chain In the following illustration, step 1 is shown as the initial step, but the initial step can also be given a zero or another number. Only the double frame is important. When creating a GRAFCET, however, every developer should assign the numbering of the initial step and all further steps not arbitrarily, but in line with the system logic.



Picture 1 Initial step

4.2.2 Transition

In order to move from the current step to the next, a condition must be fulfilled, which is referred to as a transition condition. If the current step is activated and the transition to the next step is fulfilled, the current step is deactivated and the next step is activated. Transitions are represented by a horizontal bar on a top-to-bottom line (connection between two steps). The name of the transition can appear to the left of the dash, but does not have to be assigned. The actual transition condition is to the right of the dash and can be displayed in text form, as a Boolean expression or even graphically. However, the transition condition is usually displayed as a Boolean expression.



Picture 2 Transition

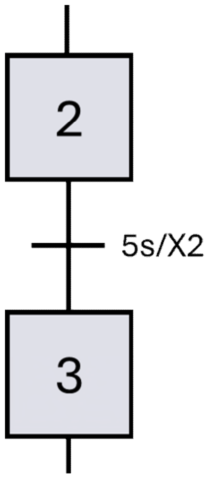
The logical operations AND, OR and NOT are completely sufficient to represent any Boolean operation. The AND operation is represented in GRAFCET by " - ". As this character is not contained in the ASCII character set, " * " can also be used. The OR

operation is represented by " + " and the NOT operation is represented by a slash above the binary variable.
To query a change of state (edge) of a switching condition, simply place an arrow pointing vertically upwards or downwards in front of it.
By using brackets, the symbols can be combined with each other as required.

Representation	Meaning
$S1 \bullet S2$	S1 AND S2
$S1 + S2$	S1 OR S2
$\overline{S1} \bullet \overline{S2}$	not S1 and not S2
$\uparrow S1$	Rising edge of S1
$\downarrow S2$	Falling edge of S2
$(S1 \bullet S2) + (S3 \bullet S4)$	S1 AND S2, OR S3 AND S4
$(S1 + S2) \bullet (S3 + S4)$	either S1 OR S2, AND additionally S3 OR S4
$(\overline{S1} \bullet S2) + (S3 \bullet \overline{S4})$	S1 not AND S2, OR but S3 AND S4 not
$\uparrow(S1 \bullet S2) + \downarrow(S3 \bullet S4)$	rising edge from the logic operation (S1 AND S2), OR but falling edge off (S3 AND S4)

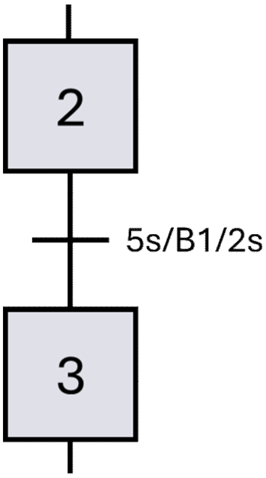
Table 1 Bit links

Times in transition



Picture 3 Time-dependent transition

A step is represented by an "X" with the corresponding number.
The X is prescribed by the standard, the number is freely selectable, but should always be assigned sensibly.
Meaning of the transition: 5s after the start of step 2, the system switches to step 3.

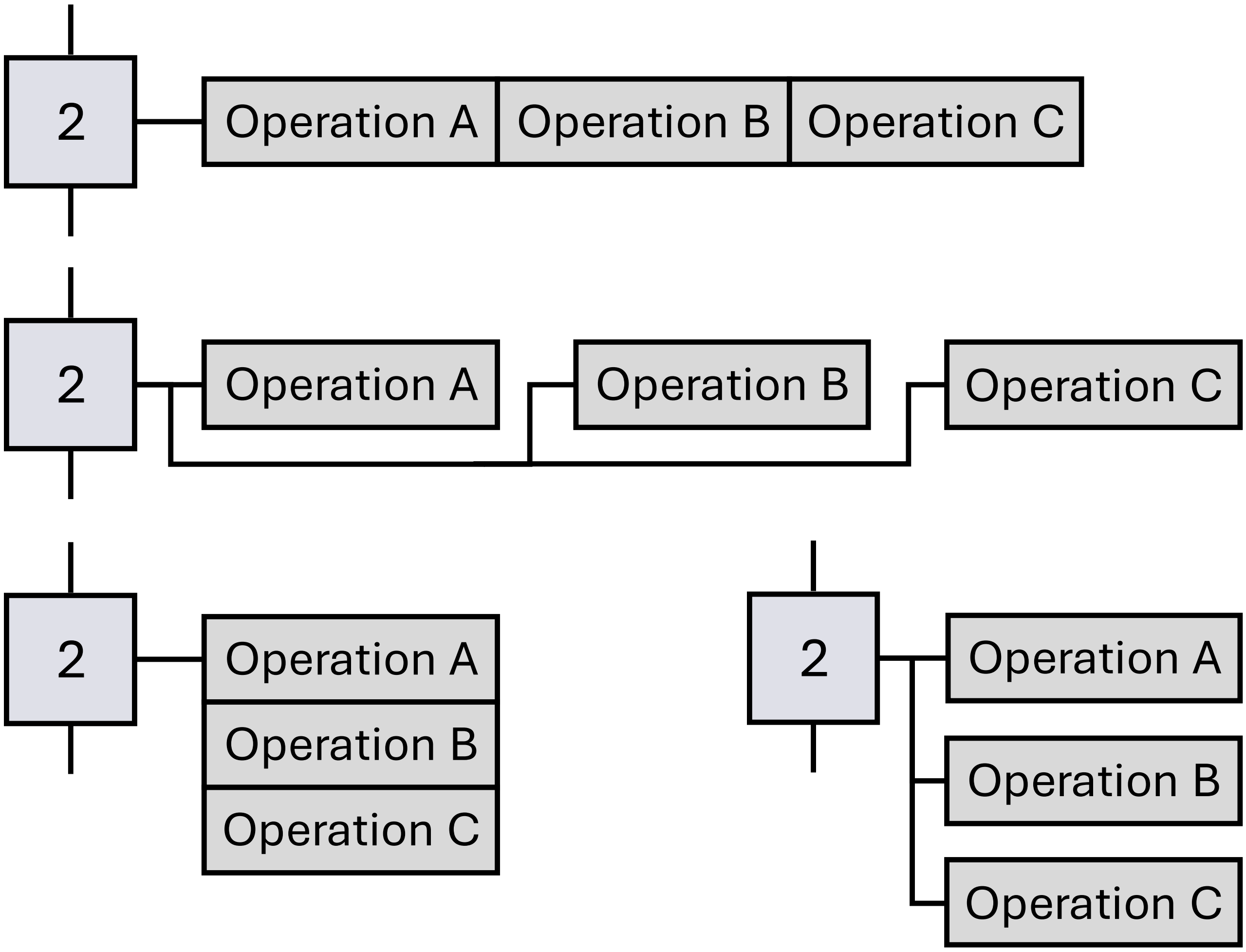


Picture 4 Transition with 2 time specifications

Time specifications to the left of the transition condition act as a switch-on delay, time specifications to the right of the condition act as a switch-off delay.
This results in the following meaning of the transition: B1 must supply a 1 signal for at least 5 seconds (switch-on delay) for the switch-on condition to be fulfilled; if B1 is no longer actuated, the transition remains fulfilled for a further 2 seconds (switch-off delay).

4.2.3 Actions

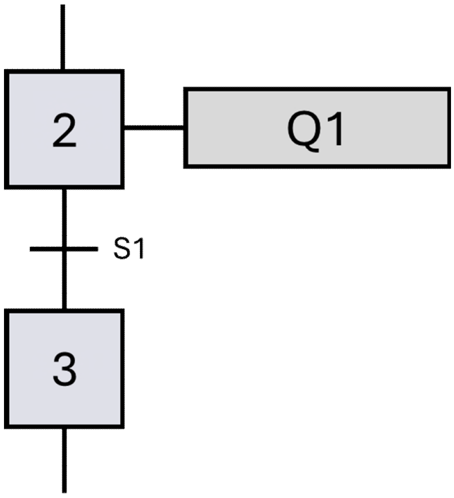
If a step is active, the action assigned to it is executed (provided no additional conditions need to be observed). However, several actions can be assigned to a step, all of which are executed simultaneously.
Which of the variants described is used is basically irrelevant.
Sometimes, however, the choice of GRAFCET variant simply depends on the space available.



Picture 5 Display options for actions

Actions A - C all take place simultaneously, so there is no chronological order!

Continuous action
The "continuously acting action" must be distinguished from the "continuously acting action with assignment". With the continuous action, the variable described in the action box is assigned the value 1 as long as the associated step itself is active; an inactive step assigns the value zero to a variable of a continuous action.

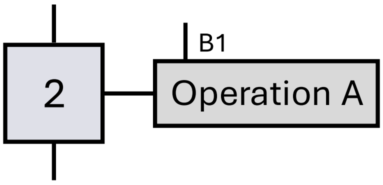


Picture 6 Continuous action

As long as step 2 is active, the contactor coil remains energized.
In step 3, the contactor coil is assigned the value 0, as step 2 is inactive.

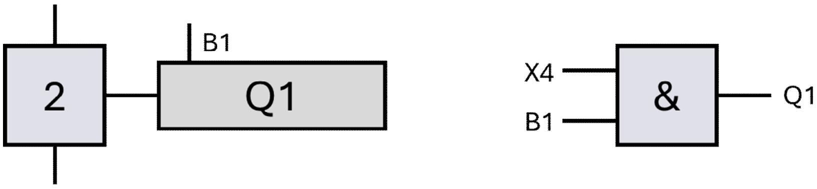
If a variable is described by a continuously acting action, it may no longer be described elsewhere with a storing action!

Continuous actions with condition
Continuous actions are always executed when the associated step is active. An additional condition can also be specified.



Picture 7 Continuous action with condition

The variable in the action is assigned the value 1 if the corresponding step is active and the assignment condition is fulfilled. In all other cases, the variable receives the value 0.

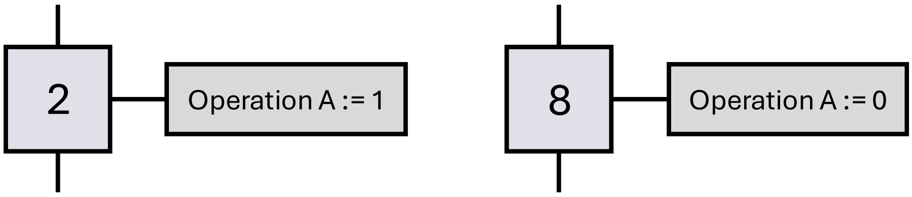


Picture 8 Comparison of GRAFCET and FUP

Storing action

In contrast to a continuous action, which is only active as long as the associated step is active, a saving action retains its value until it is overwritten or reset (usually in another step).

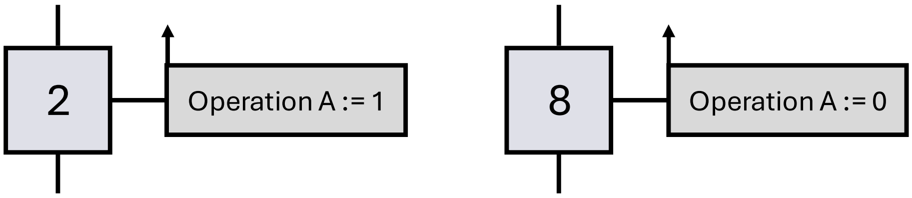
":=" indicates that it is a saving action.



Picture 9 Storing action

Action when activating/deactivating a step

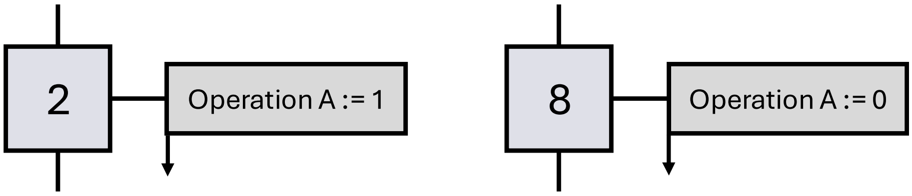
If the value is assigned when the step is activated, i.e. when there is a rising signal edge of the step variable, the action is indicated by an arrow pointing upwards.



Picture 10 Storing action on activation of the step

As soon as step 2 becomes active, "Action A" is assigned the value 1 and saved. "Action A" retains this value even if step 2 is no longer active. If step 8 becomes active, the value 0 is assigned to "Action A". The variable retains this value until the value is overwritten by another action.

If the value is assigned when the step is deactivated, i.e. when there is a falling signal edge of the step variable, the action is indicated by a down arrow.

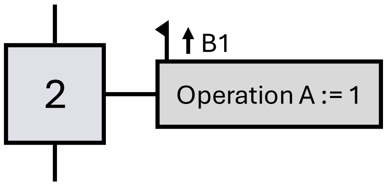


Picture 11 Saving action when deactivating the step

As soon as step 2 is deactivated, "Action A" is assigned the value 1 and saved. "Action A" retains this value. If step 8 is exited, the value 0 is assigned to "Action A". The variable retains this value until the value is overwritten by another action.

Saving action for an event

A flag pointing to the side indicates that the action will be saved as soon as a certain event occurs.

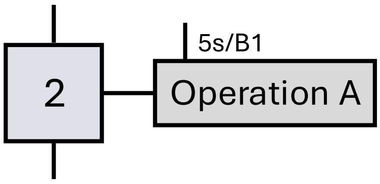


Picture 12 Storing action for an event

The variable "Action A" described in the action only receives the specified value if the event (B1) has a rising edge and the step is active.

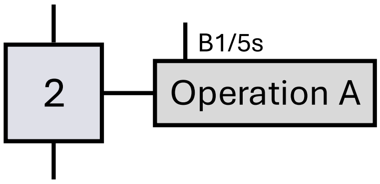
Actions and times

Continuous action with time-dependent assignment condition



Picture 13 Action with time-dependent condition (switch-on delay)

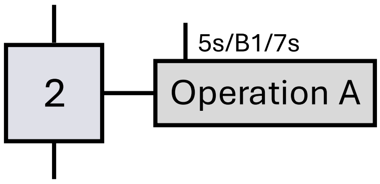
The time specified to the left of the condition (5 seconds) is started as soon as the condition returns a rising edge. (An arrow is not required here).
The action is only executed after the time has elapsed.
This behavior therefore corresponds to a switch-on delay.



Picture 14 Action with time-dependent condition (switch-off delay)

The time specified to the right of the condition (5 seconds) is started as soon as the condition returns a falling edge. (An arrow is not required here).
The action is thus extended by 5 seconds.
This behavior corresponds to a switch-off delay.

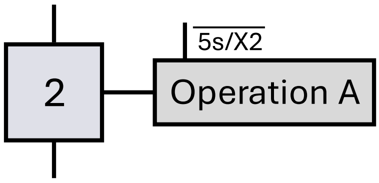
Switch-on and switch-off delay can also be combined:



Picture 15 Action with combined time-dependent condition

B1 must supply a 1 signal for at least 5 seconds. Action A is then executed. If B1 then drops out, the action remains active for a further 7 seconds.

Time-limited actions are indicated by a negation bar above the condition.



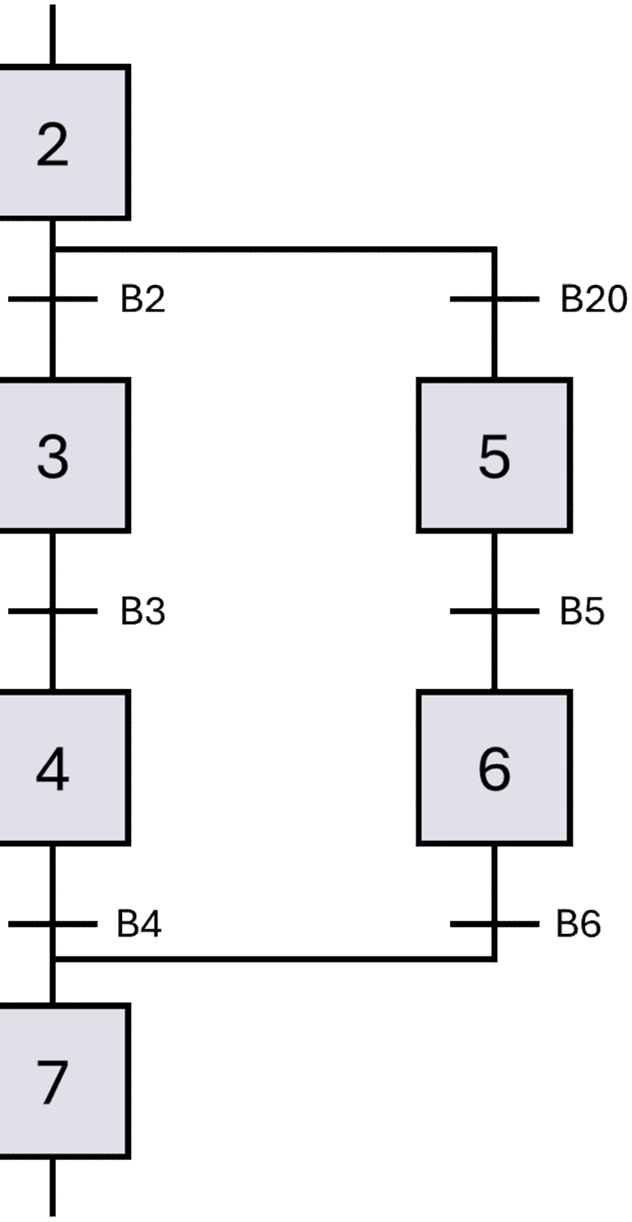
Picture 16 Time-limited action

After activating step 2, "Action A" is assigned the value 1 for 5 seconds.

4.2.4 Alternative branching

With a sequence selection (also called alternative branching), various alternative branches are available for switching on. It is important that the various transition conditions are formulated in such a way that two (or more) alternative branches can never be started at the same time. The different branches are mutually exclusive. If a step of a sequence branch is active, no other step of another branch may be active.
At the end of the sequence selection branches, a sequence merge takes place, after which a common step follows again, regardless of which sequence branch was executed.

An alternative branch always begins and ends with a transition.

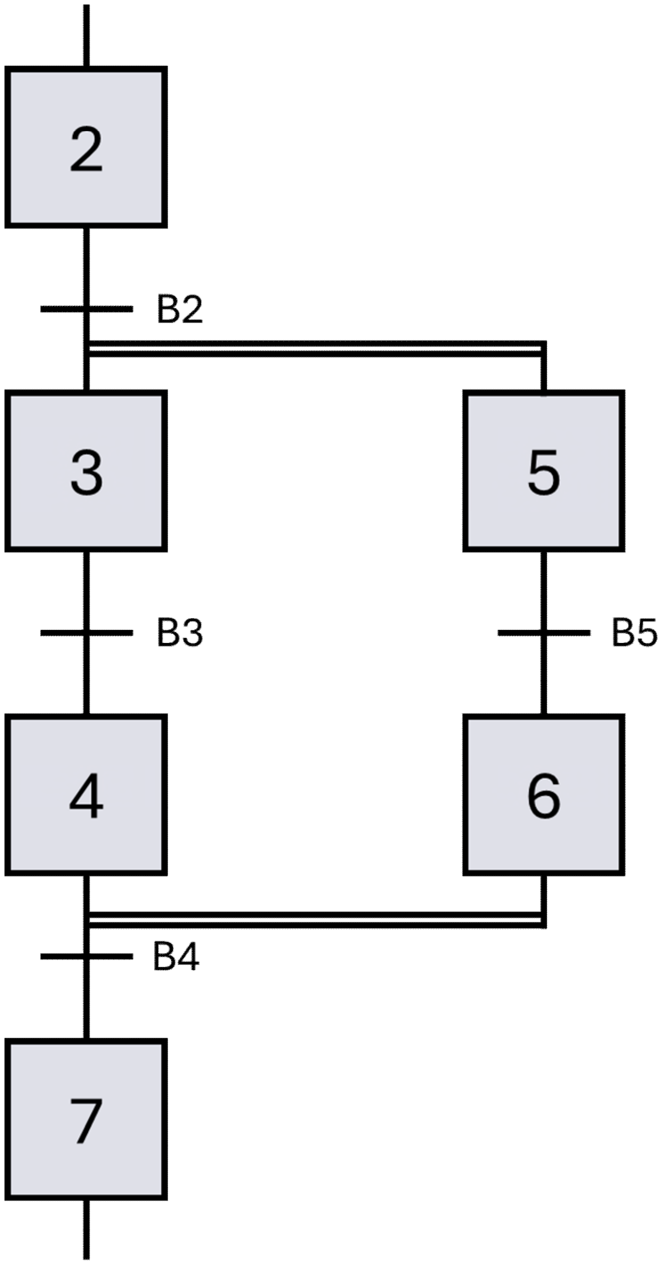


Picture 17 Alternative branching

4.2.5 Simultaneous branching

During synchronization, several parallel branches run simultaneously. To do this, of course, a branch must first be split into several parallel branches. The first steps of all parallel branches start simultaneously, so there is only one transition condition before the sequence splitting, after which all parallel steps are started simultaneously. However, the parallel chains run independently of each other.

At the end of the parallel sequence chains, they must be merged again. In order for the transition to the common step after the merge to take place, the last steps of the parallel sequence chains must be active and the common transition condition must be fulfilled.



Picture 18 Simultaneous branching

4.3 Exercise: Planning the process chain with GRAFCET

Target:

I can create a GRAFCET sequence chain based on a functional description.

Task:

Create a sequence chain for the agitator tank in GRAFCET so that the function shown below is implemented.

Function:

Two liquids are mixed and heated in a mixing bowl.
The liquids can be fed into the tank via valves Q1 and Q2 and drained via valve Q3.
The fill levels are recorded via the level sensors B1 to B3. B1 supplies a 1 signal when not actuated. B2 and B3 provide a 1 signal when actuated.
The M1 motor drives the agitator.
The liquid can be heated with the E1 heater.
The start button and the indicator lights P1 to P3 are available for operation and monitoring.

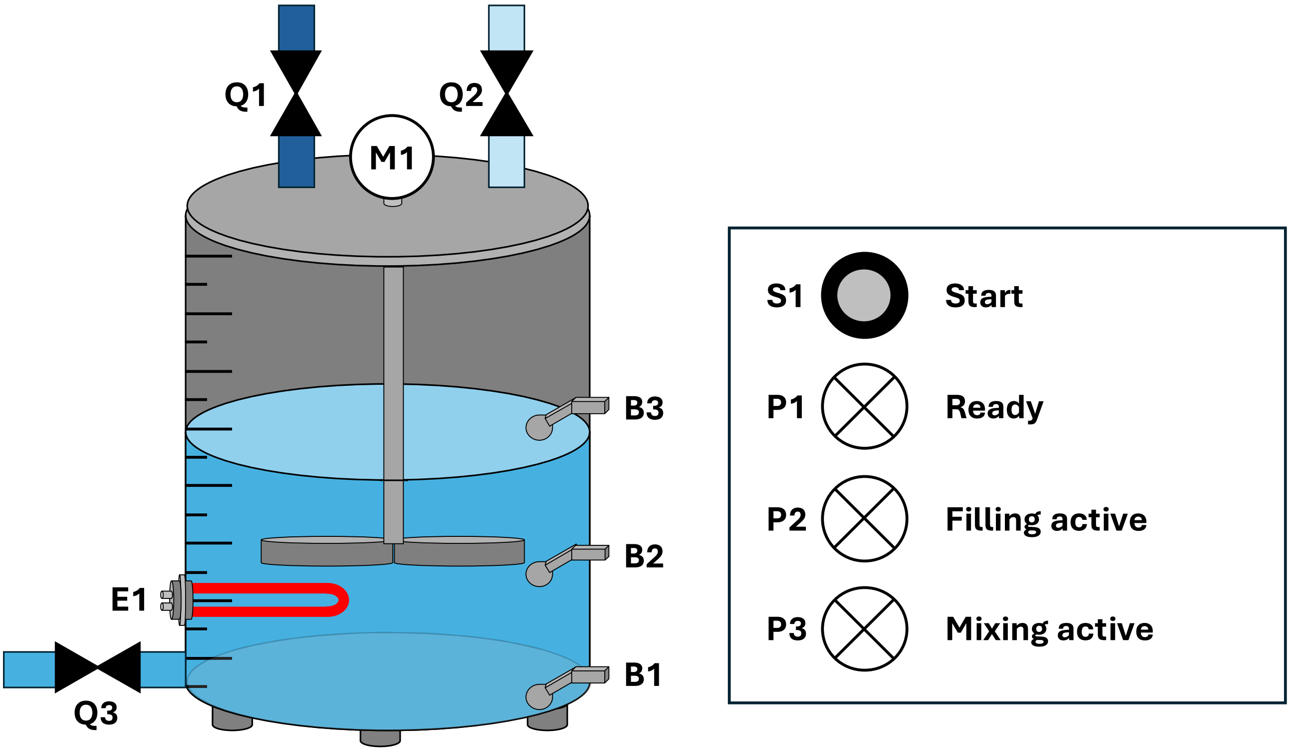


Image 19 Stirring tank

1. initial step

The process can be started with the start button (S1) when the system is ready for operation.
The system is considered ready for operation when the agitator tank is empty (B1 supplies 1 signal).
Operational readiness is indicated by the indicator light P1.

2. fill in liquid 1

After actuating S1, valve Q1 is opened to feed liquid 1 into the tank. When the required fill level is reached (B2 supplies 1 signal), the valve is closed again.
The indicator lamp P2 is switched on when the valve is opened.

3. fill in liquid 2

Once the fill level has reached the required level, the second liquid is introduced by opening valve Q2. When the level of B3 is reached, the valve is closed again.
When the valve is closed (leaving the step), the indicator lamp P2 is switched off.

4. heating and stirring

To obtain a homogeneous mixture, the two liquids must be mixed together for 25 seconds while heat is applied. The mixer motor is controlled by M1 and the heater by E1.
The mixing process is indicated by P3.

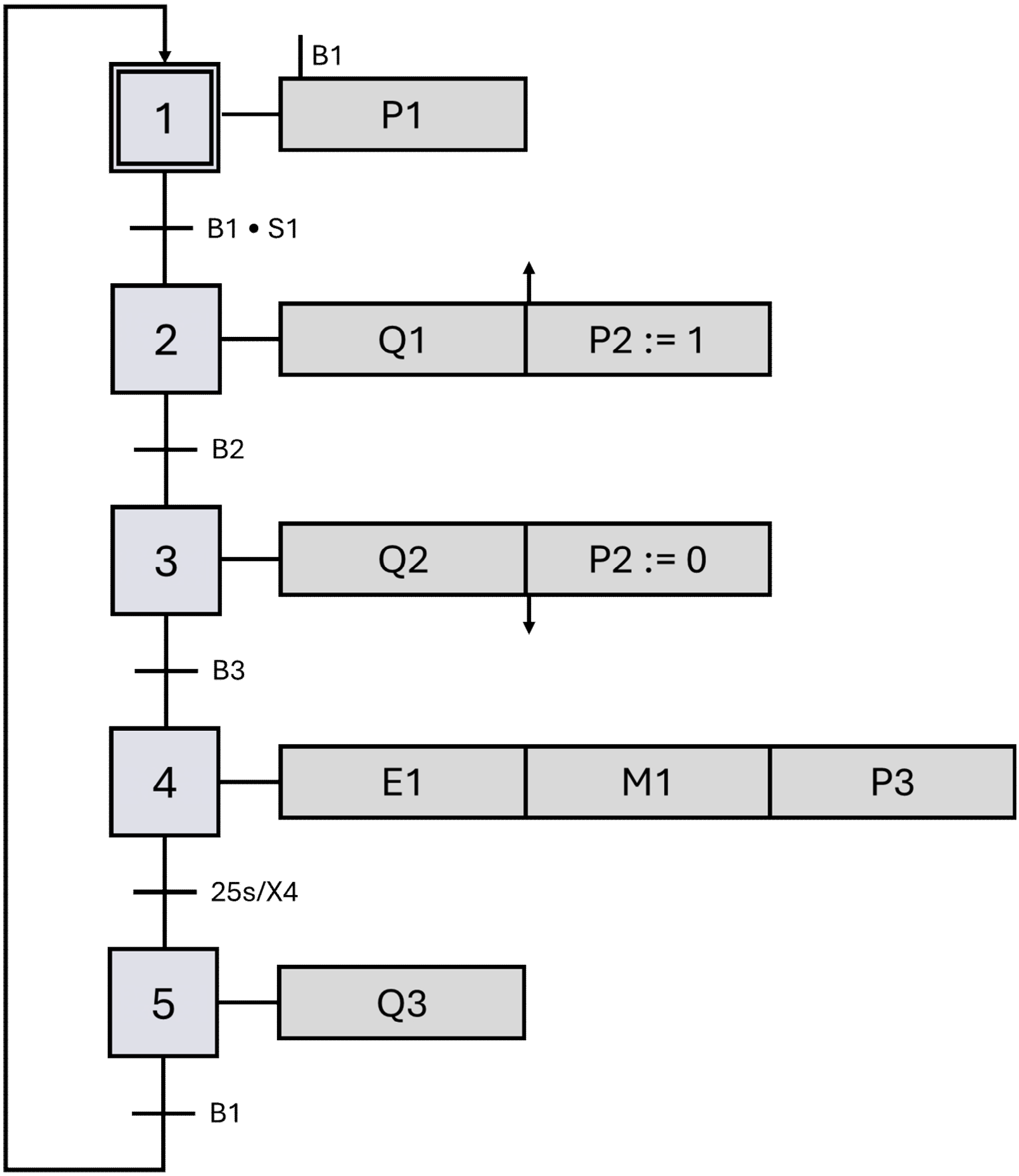
5. empty the container

The mixture is then drained from the tank. To do this, the drain valve (Q3) is opened until the tank is completely empty (B1 supplies 1 signal).

The process can be restarted by closing Q3.

Solution

Solution:



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