Informatik 11
Embedded Software

RWTH AACHEN UNIVERSITY

Introduction to

Embedded Systems

Prof. Dr.-Ing. Stefan Kowalewski | Julius Kahle, M. Sc.
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Exercise 3 – Programmable Logic Controllers

Overview

- Running in Circles
- Never too late
- Fun with Functions
- Good Timing
- Choosing the right path (IL)
- Secret ingredients (SFC)

Running in Circles

Task 1: a) – c)

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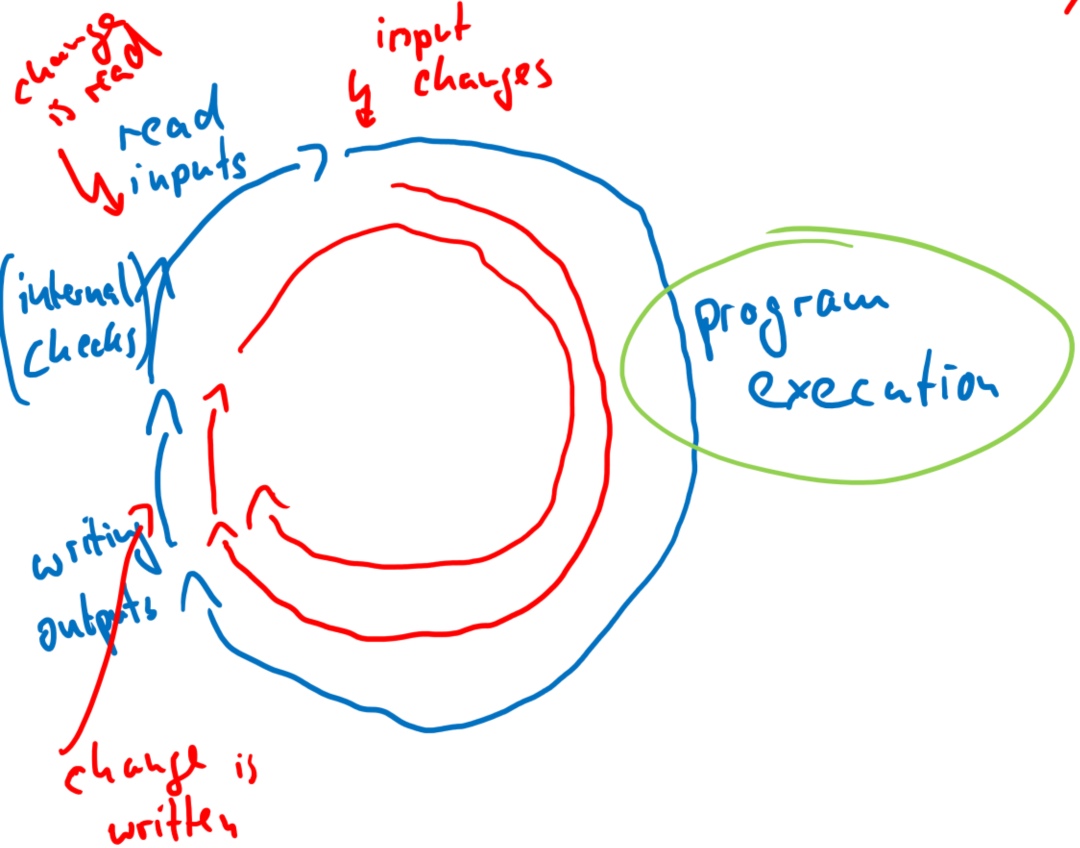
Task 1: a)

a) Explain the term cyclic execution. / cyclic scanning mode



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Task 1: b) + c)

b) What are the two worst-case assumptions that are made when calculation the maximum reaction time?

1 • input changes right after inputs were read

2 • our execution time is the longest/maximum time in both program execution

c) How are maximum cycle time and maximum reaction time linked?

max. reaction time = 2 * max. cycle time

1 2

Never too late

Task 2

Task 2

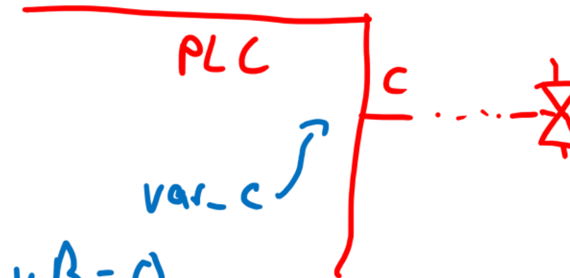
CR → current result

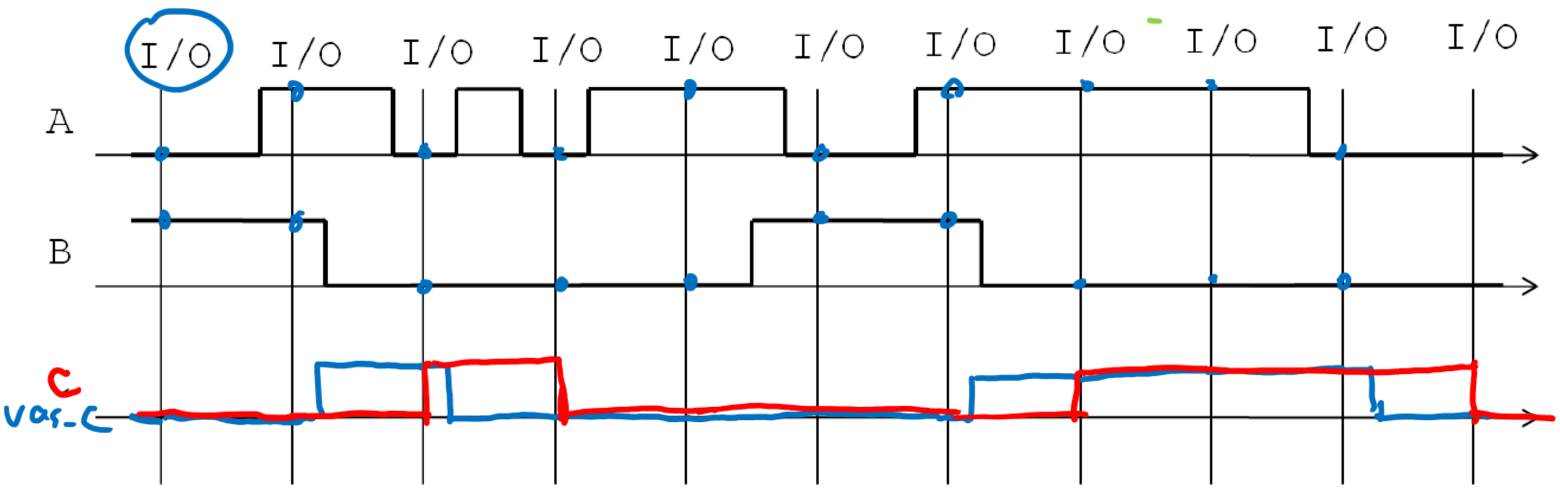
Complete the signal diagram below for the following IL program. A and B are inputs while C is an output.

```
LD A
AND B
S C
LDN A
ANDN B
R C
```

$\Rightarrow \begin{cases} C := 1 & \text{if } A \wedge B = 1 \\ \text{NOP} & \text{otherwise} \end{cases}$

$\Rightarrow \begin{cases} C := 0 & \text{if } \neg A \wedge \neg B = 1 \iff A \vee B = 0 \\ \text{NOP} & \text{otherwise} \end{cases}$





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Fun with Functions

Task 3

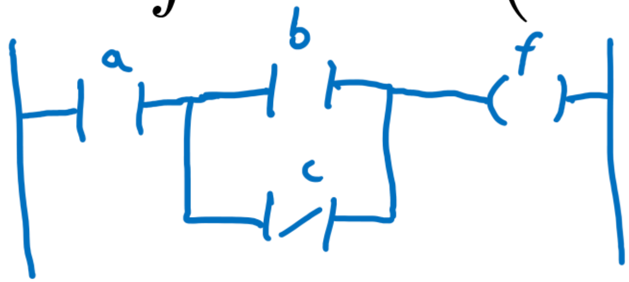
Task 3

serial parallel

Implement the function $f = a \wedge (b \vee \neg c) = f$

- Ladder diagram
  left-to-right
- Function block
  in-to-out
- Instruction list

LD:



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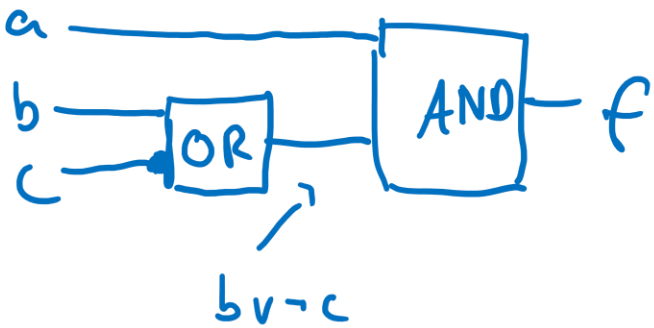
FB:



IL:

```
LD   b          LD   a
ORN  c          AND( b
AND  a          ORN  c
ST   f          )
                ST   f
```

Task 3

$$f = a \wedge (b \vee \neg c)$$

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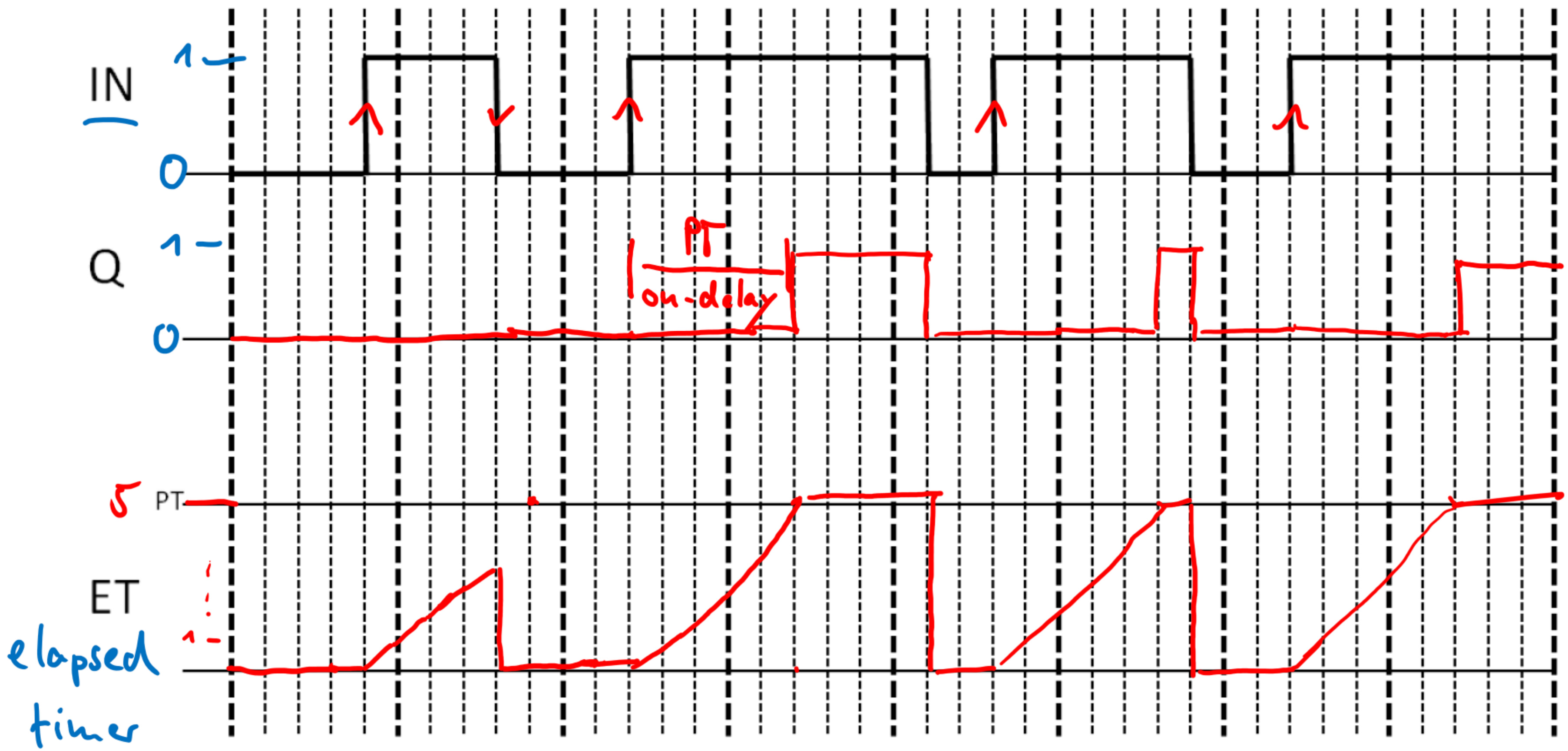
Good Timing

Task 4

Task 4

Complete the following diagram of a TON. ET needs five time units to reach PT. = 5

TOF , TP



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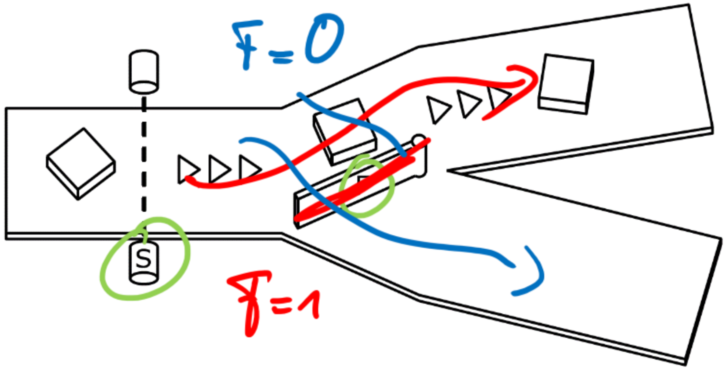
Choosing the right path

Task 5

Task 5

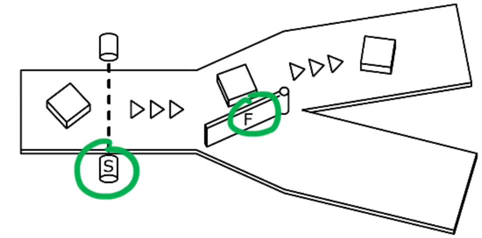
The following sketch shows a branch in a conveyor belt. The belt transports objects, which are directed either to the upper or to the lower branch by a separator flap (F). Write a controller for the flap in IL code with the following behaviour and briefly explain what each line of your code does: The flap shall pass the first two objects to the lower branch, then five to the upper one, then two to the lower one, five to the upper, and so on. To count the objects, there is a light barrier switch (S). Assume that there can only be up to one object passing per cycle and that objects passing the light barrier also pass the flap in the same cycle. In other words: When the light barrier variable fires, the object has already passed the flap.



Task 5

Name	Type	Description
S	input	Equals one for a single cycle when an object passed the light barrier, zero otherwise.
F	output	Controls flap. Directs objects to lower branch when F equals zero, otherwise to the upper branch. Initialized with zero.
C	in/out	Use this to count the objects (increment when S is true). Initialized with zero.

ADD X	Adds an integer X to CR.
MOD X	Computes CR modulo X (for an integer X).
RETC	If CR is true, skips the rest of the program (equivalent to jumping to the end of the program).
RETCN	Same as RETCN, but only jumps if CR is false.
GT X	Checks if CR is greater than an integer X.
LT X	Checks if CR is less than an integer X.




```
LD S        check whether object passed
RETCN       NOP if not
LD C
ADD 1
ST C        increment counter if object passed
```

```
GT 1        check C≥2
S F         set F=1
LD C
GT 6        check c≥7
R F         set F=0
R C         reset counter
```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Task 5 (ctd.)

reading inputs

LD C
ADD S

LD S
RETCN
LD C
ADD 1
ST C

GT 1
S F
LD C
GT 6
R F
R C

MOD 7
ST C
GT 1
ST F

writing outputs

internal checks

Secret ingredients

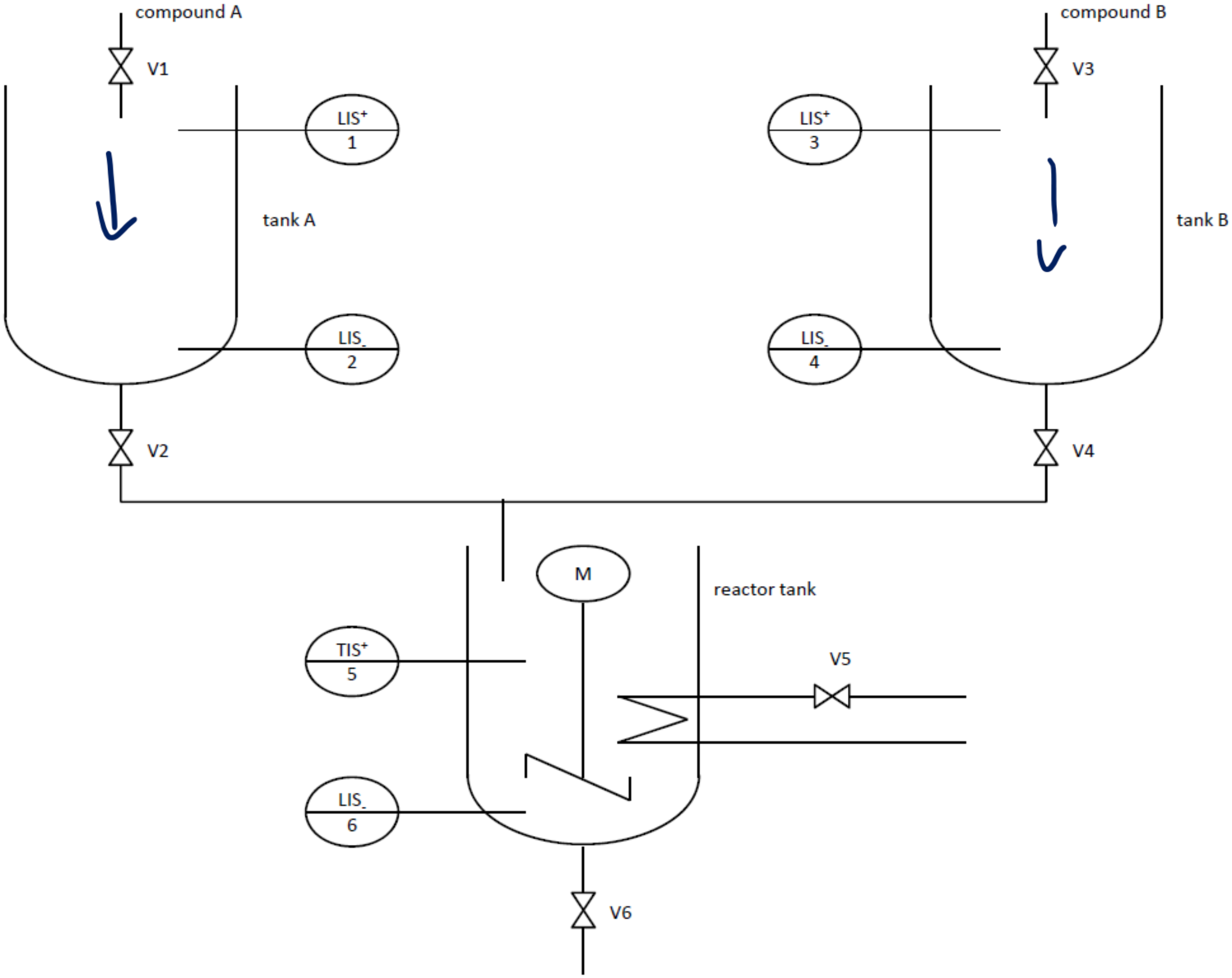
Task 6

Task 6

Given the P/ID, which shows a pipeline and instrumentation diagram of a very simple chemical plant. Two top secret compounds have to be mixed and heated to produce an even more secret compound. As everything is classified your system is completely independent of all other systems. You have been assured that there will always be enough compound A and B to fill your tanks and that you can empty your reactor at any time. You, therefore, only have to follow these important rules:

- The reactor tank can exactly hold the volumes of tank A and tank B combined. There must be no way that the reactor overflows.
- Compound A must never be poured in compound B.
- As timing is highly classified you cannot use timers.
- Tank A and tank B are at the same height. Opening V2 and V4 at the same time might force a backflow causing massive damage to the plant.
- Heating is very delicate and may only be applied when the stirrer is running.
- As soon as the reactor reaches critical temperature the product must be drained.

Task 6



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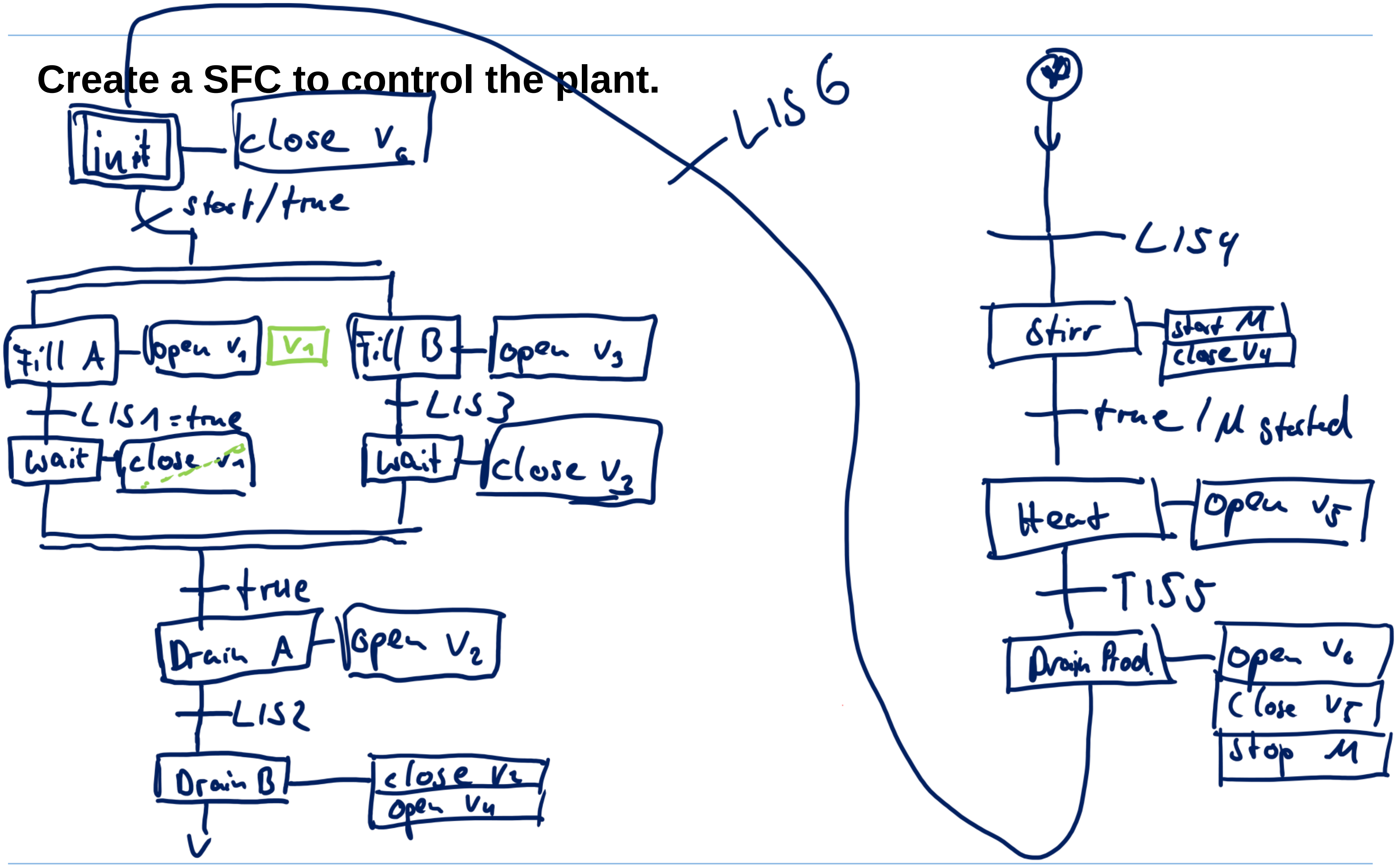
Task 6

Create a SFC to control the plant.



Task 6 (ctd.)