Thema 8: Chem. Digitalcomputermodell modulo-Operation auf 3-Bit-Operanden

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    b. Ermitteln & Vereinfachen der Schaltfunktion (Quine-McCluskey-Algorithmus)
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Aufgabenbeschreibung

Aufgabenbeschreibung

- entwerfen eines chemischen Digitalcomputermodells für die modulo-Operation auf 3-Bit-Operanden
- modulo-Operation k mod n berechnet den Divisionsrest von [k/n]
- Pathologischen Fällen:
  - k mod 0 = k,
  - k mod 1 = 0,
  - 0 mod n = 0
- Beispiel: 7 mod 4 = 3

Lösung

Erstellen der Schaltbelegungstabelle

x2	x1	x0	x BIN	x DEC	y2	y1	y0	y BIN	y DEC	z2	z1	z0	z BIN
0	0	0	000	0	0	0	0	000	0	0	0	0	000
0	0	0	000	0	0	0	1	001	1	0	0	0	000
0	0	0	000	0	0	1	0	010	2	0	0	0	000
0	0	0	000	0	0	1	1	011	3	0	0	0	000
0	0	0	000	0	1	0	0	100	4	0	0	0	000
0	0	0	000	0	1	0	1	101	5	0	0	0	000
0	0	0	000	0	1	1	0	110	6	0	0	0	000
0	0	0	000	0	1	1	1	111	7	0	0	0	000
0	0	1	001	1	0	0	0	000	0	0	0	1	001
0	0	1	001	1	0	0	1	001	1	0	0	0	000
0	0	1	001	1	0	1	0	010	2	0	0	1	001
0	0	1	001	1	0	1	1	011	3	0	0	1	001
0	0	1	001	1	1	0	0	100	4	0	0	1	001
0	0	1	001	1	1	0	1	101	5	0	0	1	001
0	0	1	001	1	1	1	0	110	6	0	0	1	001
0	0	1	001	1	1	1	1	111	7	0	0	1	001
0	1	0	010	2	0	0	0	000	0	0	1	0	010
0	1	0	010	2	0	0	1	001	1	0	0	0	000
0	1	0	010	2	0	1	0	010	2	0	0	0	000
0	1	0	010	2	0	1	1	011	3	0	1	0	010
0	1	0	010	2	1	0	0	100	4	0	1	0	010

...

1	0	1	101	5	0	0	1	001	1	0	0	0	000
1	0	1	101	5	0	1	0	010	2	0	0	1	001
1	0	1	101	5	0	1	1	011	3	0	1	0	010
1	0	1	101	5	1	0	0	100	4	0	0	1	001
1	0	1	101	5	1	0	1	101	5	0	0	0	000
1	0	1	101	5	1	1	0	110	6	1	0	1	101
1	0	1	101	5	1	1	1	111	7	1	0	1	101
1	1	0	110	6	0	0	0	000	0	1	1	0	110
1	1	0	110	6	0	0	1	001	1	0	0	0	000
1	1	0	110	6	0	1	0	010	2	0	0	0	000
1	1	0	110	6	0	1	1	011	3	0	0	0	000
1	1	0	110	6	1	0	0	100	4	0	1	0	010
1	1	0	110	6	1	0	1	101	5	0	0	1	001
1	1	0	110	6	1	1	0	110	6	0	0	0	000
1	1	0	110	6	1	1	1	111	7	1	1	0	110
1	1	1	111	7	0	0	0	000	0	1	1	1	111
1	1	1	111	7	0	0	1	001	1	0	0	0	000
1	1	1	111	7	0	1	0	010	2	0	0	1	001
1	1	1	111	7	0	1	1	011	3	0	0	1	001
1	1	1	111	7	1	0	0	100	4	0	1	1	011
1	1	1	111	7	1	0	1	101	5	0	1	0	010
1	1	1	111	7	1	1	0	110	6	0	0	1	001
1	1	1	111	7	1	1	1	111	7	0	0	0	000

Ermitteln und vereinfachen der booleschen Schaltfunktion

- Quine-McCluskey Optimierung
- aufteilen der Schaltfunktion nach den einzelnen Ausgabe-Bits von z
  - f = z2,
  - g = z1,
  - h = z0
- bilden der disjunktiven Normalform aus den Mintermen
- verschmelzen der Konjunktionsterme

f = z2

Minterme:

(100000, 100101, 100110, 100111, 101000, 101110, 101111, 110000, 110111, 111000)

Schaltfunktion:

$(a \wedge \neg b \wedge \neg c \wedge d \wedge f) \vee$
$(a \wedge \neg c \wedge d \wedge e \wedge f) \vee$
$(a \wedge \neg d \wedge \neg e \wedge \neg f) \vee$
$(a \wedge \neg b \wedge d \wedge e)$

g = z1

Minterme:

(010000, 010011, 010100, 010101, 010110, 010111, 011000, 011100, 011101, 011110, 011111, 101011, 110000, 110100, 110111, 111000, 111100, 111101)

Schaltfunktion:

(a ∧ ¬b ∧ c ∧ ¬d ∧ e ∧ f) ∨
(¬a ∧ b ∧ ¬c ∧ e ∧ f) ∨
(b ∧ ¬c ∧ d ∧ e ∧ f) ∨
(b ∧ c ∧ d ∧ ¬e) ∨
(b ∧ ¬e ∧ ¬f) ∨
(¬a ∧ b ∧ d)

h = z0

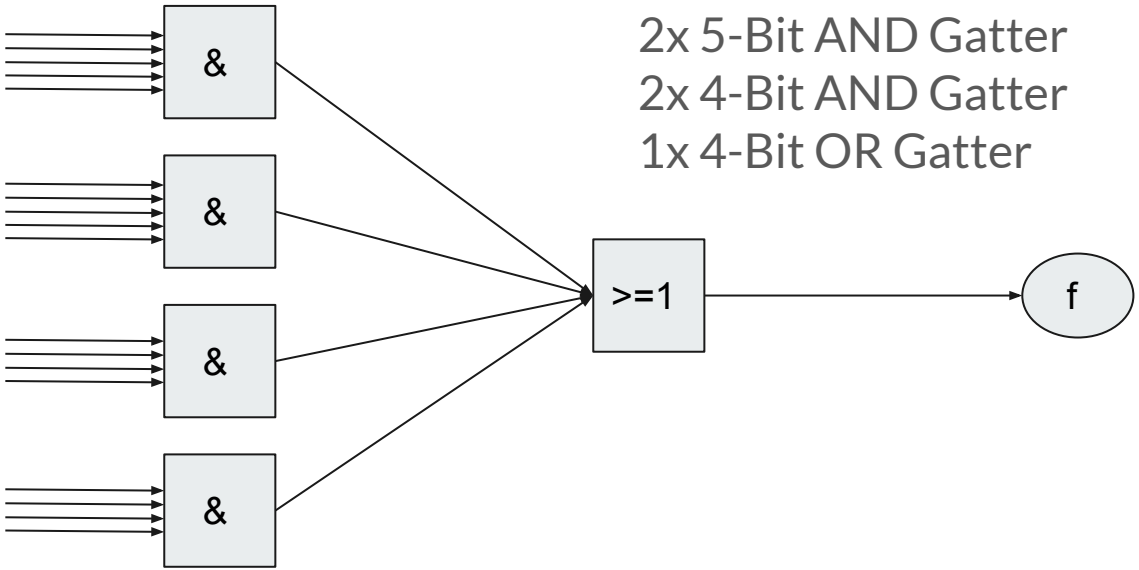
Minterme:

(001000, 001010, 001011, 001100, 001101, 001110, 001111, 011000, 011010, 011100, 011101, 011110, 011111, 100011, 101000, 101010, 101100, 101110, 101111, 110101, 111000, 111010, 111011, 111100, 111110)

Schaltfunktion:

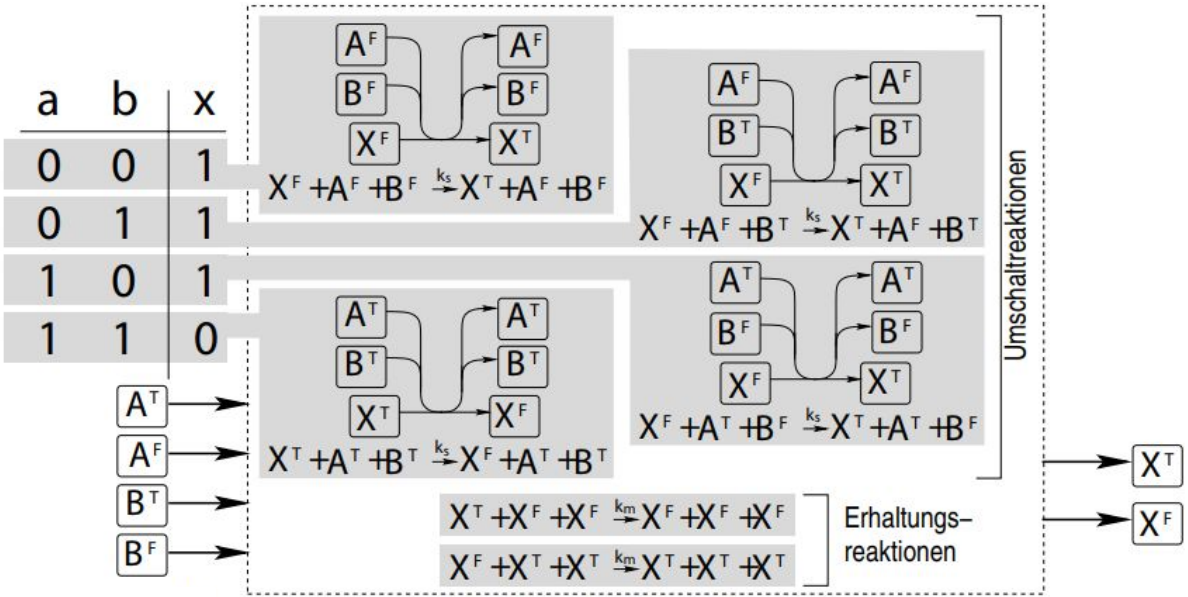
(a ∧ ¬b ∧ ¬c ∧ ¬d ∧ e ∧ f) ∨
(a ∧ b ∧ ¬c ∧ d ∧ ¬e ∧ f) ∨
(a ∧ b ∧ c ∧ ¬d ∧ e) ∨
(¬a ∧ ¬b ∧ c ∧ e) ∨
(¬b ∧ c ∧ d ∧ e) ∨
(¬a ∧ c ∧ d ∨ c ∧ ¬f)

Schaltung für f = z2



2x 5-Bit AND Gatter
2x 4-Bit AND Gatter
1x 4-Bit OR Gatter

Rückblick 2-Bit NAND Gatter



Quelle: Thomas Hinze, “Computer der Natur”

4-Bit OR Gatter

yT + x3F + x2F + x1F + x0F -> yF + x3F + x2F + x1F + x0F
yF + x3F + x2F + x1F + x0T -> yT + x3F + x2F + x1F + x0T
yF + x3F + x2F + x1T + x0F -> yT + x3F + x2F + x1T + x0F
yF + x3F + x2F + x1T + x0T -> yT + x3F + x2F + x1T + x0T

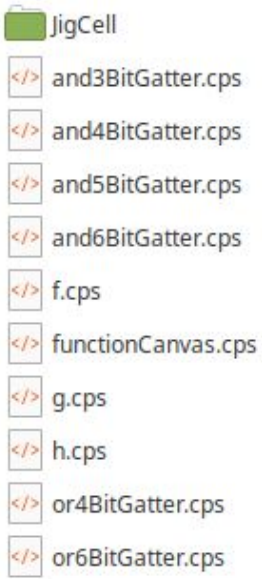
...

yF + x3T + x2F + x1T + x0T -> yT + x3T + x2F + x1T + x0T
yF + x3T + x2T + x1F + x0F -> yT + x3T + x2T + x1F + x0F
yF + x3T + x2T + x1F + x0T -> yT + x3T + x2T + x1F + x0T
yF + x3T + x2T + x1T + x0F -> yT + x3T + x2T + x1T + x0F
yF + x3T + x2T + x1T + x0T -> yT + x3T + x2T + x1T + x0T

Umsetzung Reaktionsnetzwerk - Idee !

- alle Gatter mit Copasi modellieren
- mit Jig Cell Model Connector modulare Modells zusammenfügen
- zusammengefügtes Modell exportieren und wieder in Copasi importieren --> Simulation

Aufgabe: alle Gatter mit Copasi modellieren



Umsetzung Reaktionsnetzwerk - Umsetzung !

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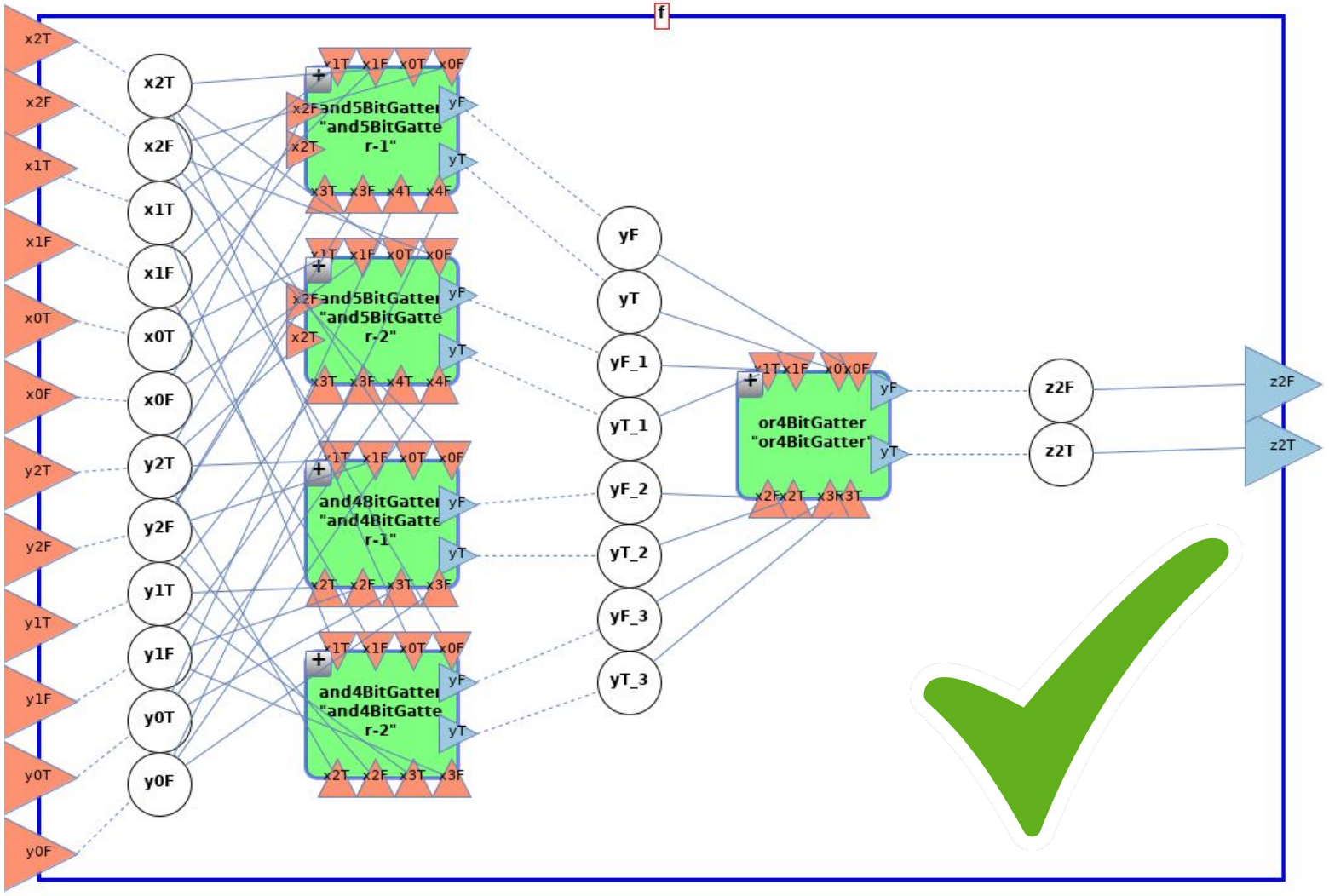
f
x2T
x2F
x1T
x1F
x0T
x0F
y2T
y2F
y1T
y1F
y0T
y0F
and5BitGatter "and5BitGatter-1"
and5BitGatter "and5BitGatter-2"
and4BitGatter "and4BitGatter-1"
and4BitGatter "and4BitGatter-2"
yF
yT
yF_1
yT_1
yF_2
yT_2
yF_3
yT_3
or4BitGatter "or4BitGatter"
z2F
z2T

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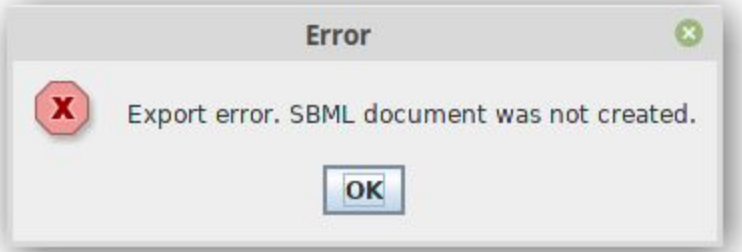
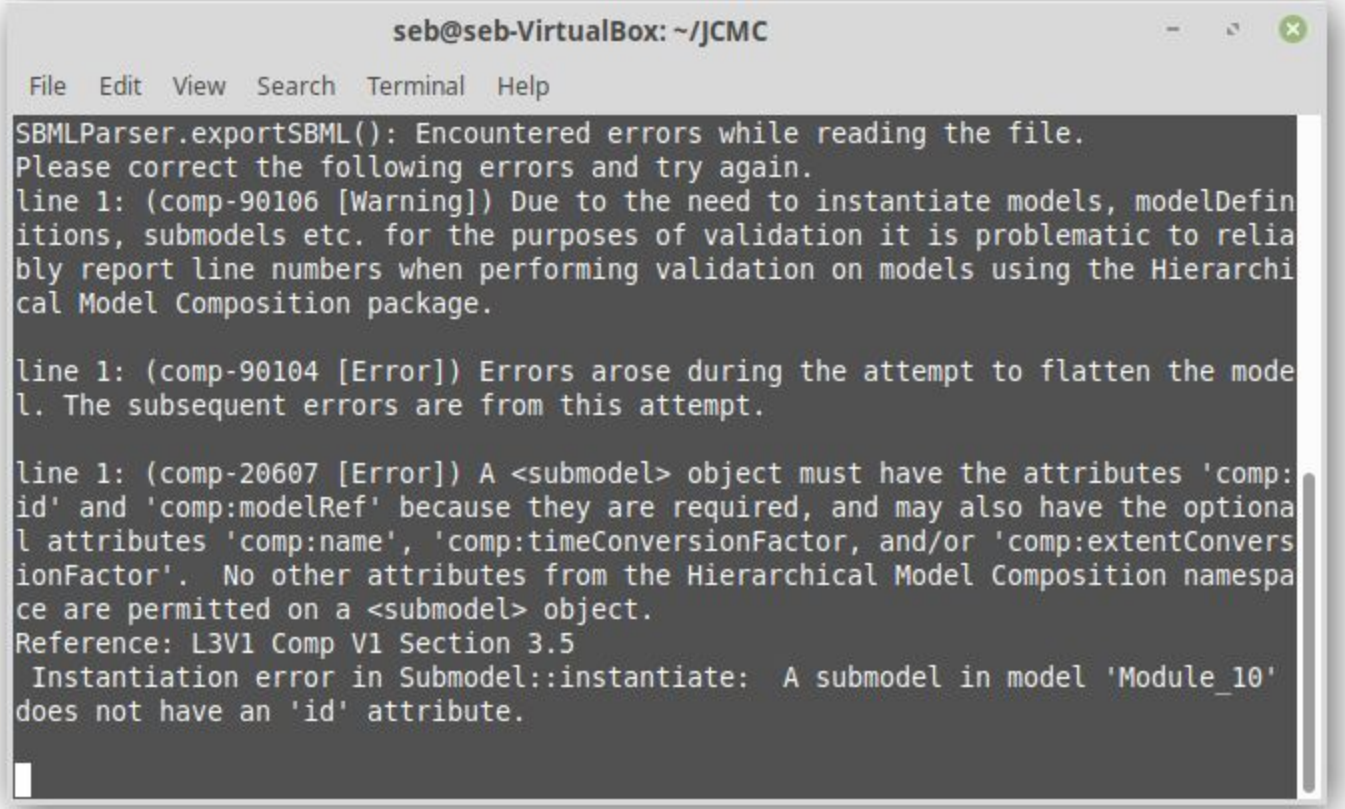
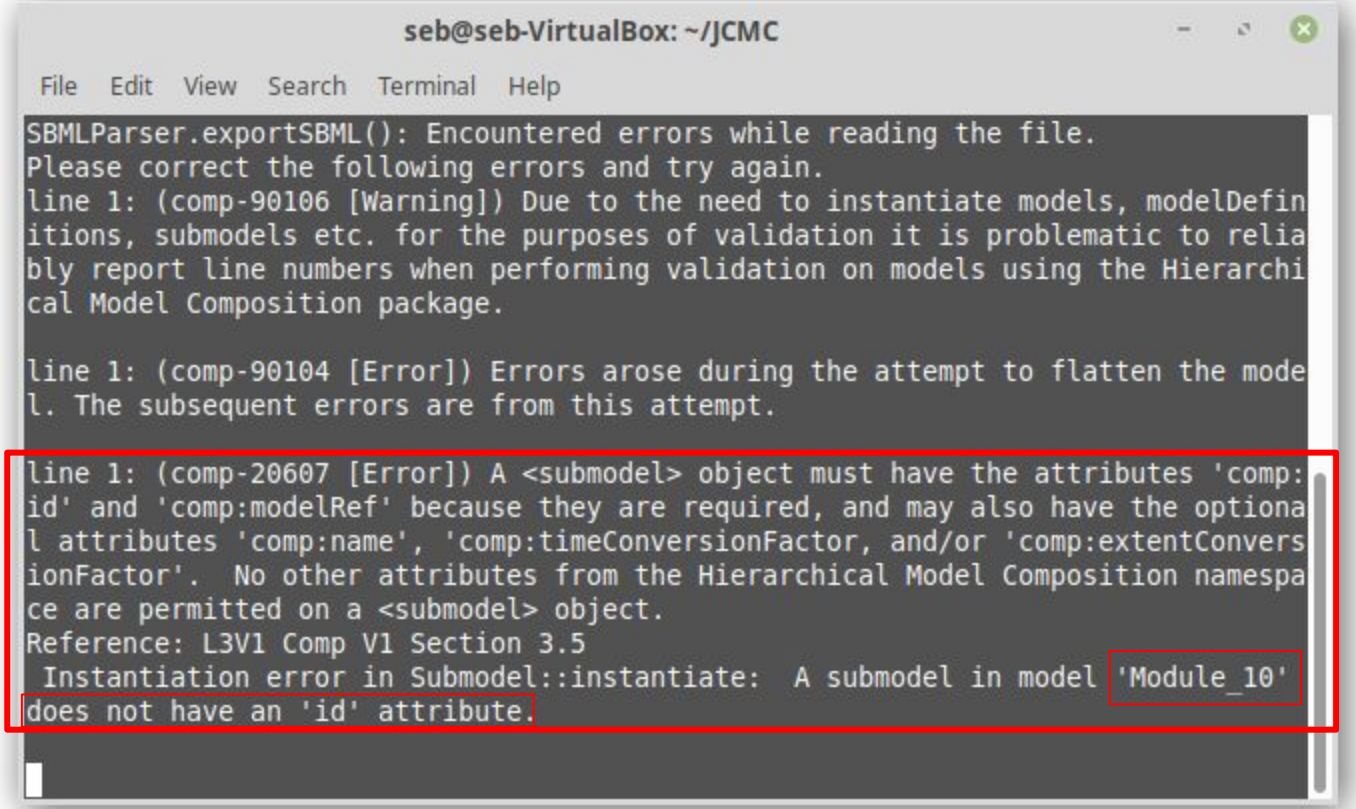

Error
Export error. SBML document was not created.
OK


seb@seb-VirtualBox: ~/JCMC
File Edit View Search Terminal Help
SBMLParser.exportSBML(): Encountered errors while reading the file.
Please correct the following errors and try again.
line 1: (comp-90106 [Warning]) Due to the need to instantiate models, modelDefin
itions, submodels etc. for the purposes of validation it is problematic to relia
bly report line numbers when performing validation on models using the Hierarchi
cal Model Composition package.
line 1: (comp-90104 [Error]) Errors arose during the attempt to flatten the mode
l. The subsequent errors are from this attempt.
line 1: (comp-20607 [Error]) A <submodel> object must have the attributes 'comp:
id' and 'comp:modelRef' because they are required, and may also have the optiona
l attributes 'comp:name', 'comp:timeConversionFactor, and/or 'comp:extentConvers
ionFactor'. No other attributes from the Hierarchical Model Composition namespa
ce are permitted on a <submodel> object.
Reference: L3V1 Comp V1 Section 3.5
Instantiation error in Submodel::instantiate: A submodel in model 'Module_10'
does not have an 'id' attribute.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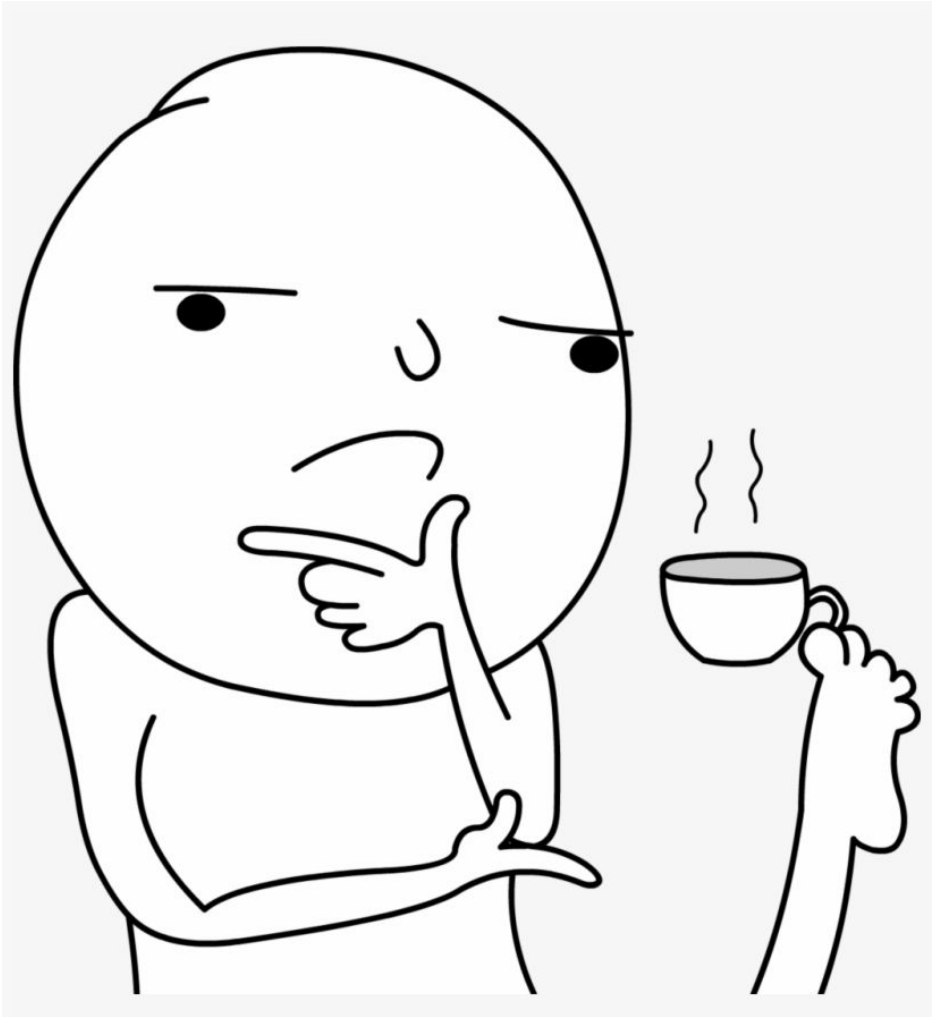


Lösungsansatz V2

- Erstellen der Schaltbelegungstabelle
- Ermitteln ~~& Vereinfachen~~ der Schaltfunktion
- Aufstellen des Reaktionsnetzwerkes
  - ~~alle Gatter mit Copasi modellieren~~
  - ~~mit Jig Cell Model Connector modulare Modells zusammenfügen~~
  - ~~zusammengefügtes Modell exportieren und wieder in Copasi importieren~~
- Simulation des Netzwerkverhaltens

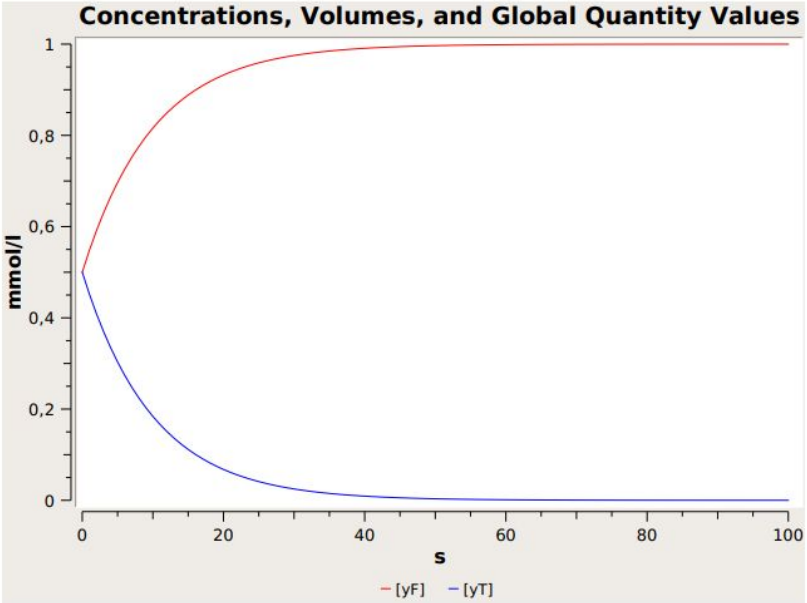
Ergebnisse

Fallstudie (000 mod 011 = 000)

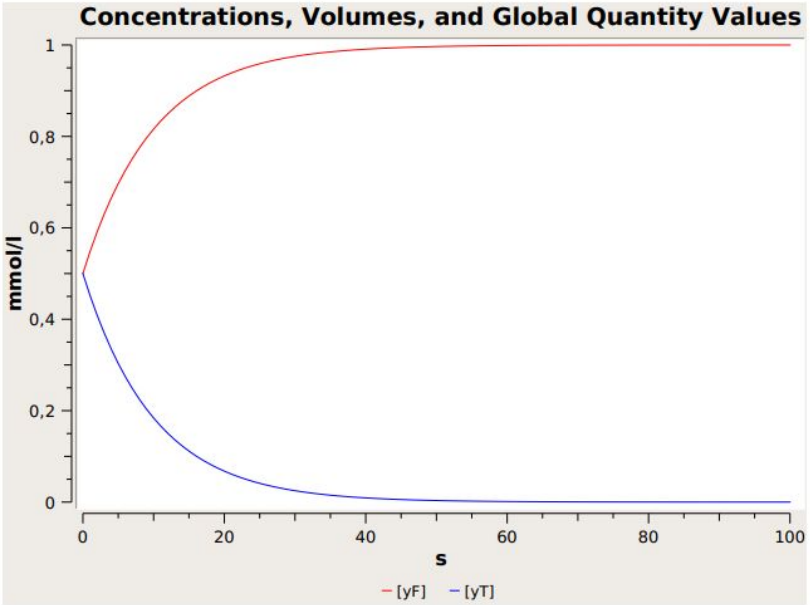
Parameter Setting (000 mod 011 = 000)

#	Name	Compartment	Type	Unit	Initial Concentration [Unit]
1	x0F	compartment	reactions	mmol/l	0
2	x1F	compartment	reactions	mmol/l	0
3	x2F	compartment	reactions	mmol/l	1
4	x3F	compartment	reactions	mmol/l	1
5	x4F	compartment	reactions	mmol/l	1
6	x5F	compartment	reactions	mmol/l	1
7	yF	compartment	reactions	mmol/l	0,5
8	yT	compartment	reactions	mmol/l	0,5
9	x0T	compartment	reactions	mmol/l	1
10	x1T	compartment	reactions	mmol/l	1
11	x2T	compartment	reactions	mmol/l	0
12	x3T	compartment	reactions	mmol/l	0
13	x4T	compartment	reactions	mmol/l	0
14	x5T	compartment	reactions	mmol/l	0

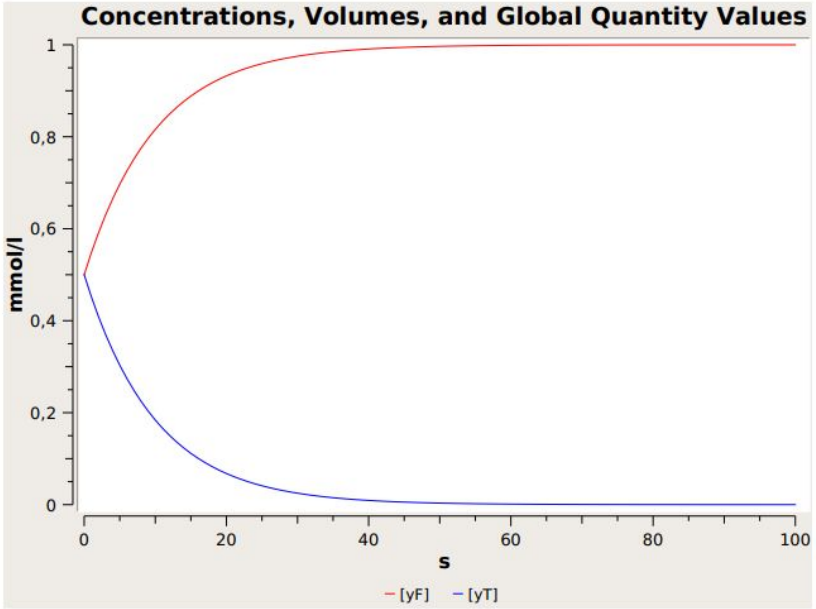
000 mod 011 = 000 (z2=0)



000 mod 011 = 000 (z1=0)



000 mod 011 = 000 (z0=0)



99%-Genauigkeit
für 000 mod 011 = 000

Worst case: f=z2

Time	yF	yT
0	0.5	0.5
1	0.5475812947	0.4524187053
	...	
36	0.9863381748	0.0136618252
37	0.9876382708	0.01236172917
38	0.9888146457	0.01118535427
39	0.9898790748	0.01012092515
40	0.9908422083	0.009157791662
41	0.9917136889	0.008286311055
42	0.9925022357	0.007497764335
43	0.9932157437	0.006784256314

EOF