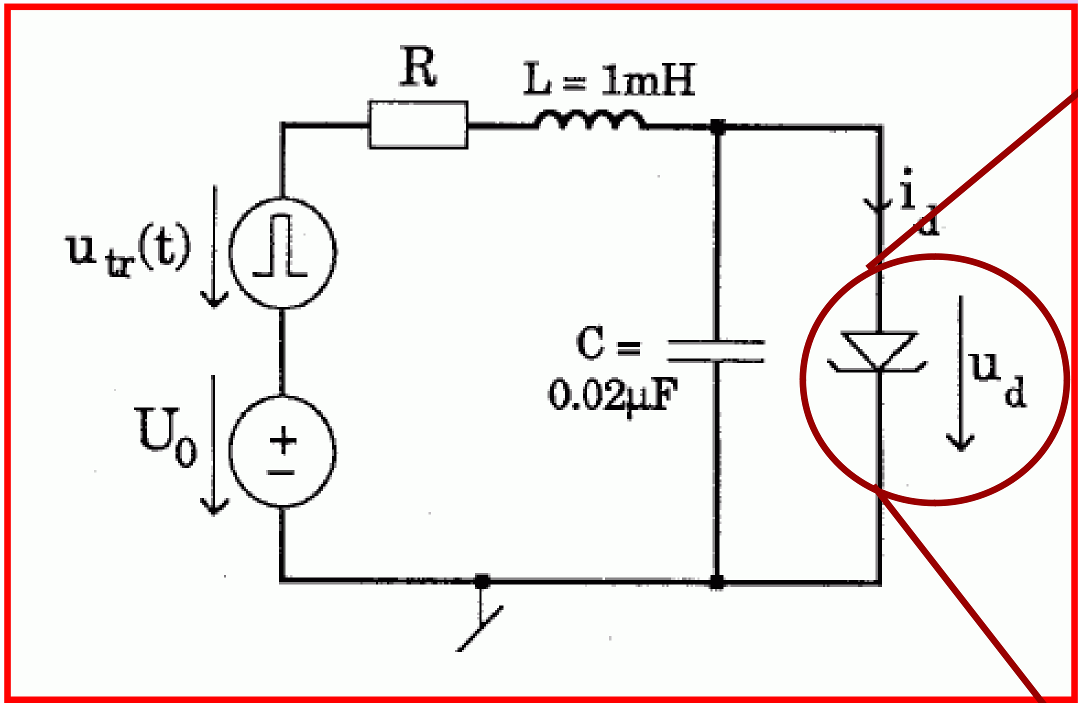
7th Homework – Solution

- In this homework, we shall model and simulate a discontinuous system as well as train the incorporation of tabular functions.
- We shall first model an electrical oscillatory circuit containing a tunnel diode.
- We shall then model a fly-back electronic power converter circuit with current overprotection.

- Free-running tunnel diode circuit
- Pulsed tunnel diode circuit
- Fly-back electronic power converter circuit

Free-running Tunnel Diode Circuit I

- Given the following electronic circuit:



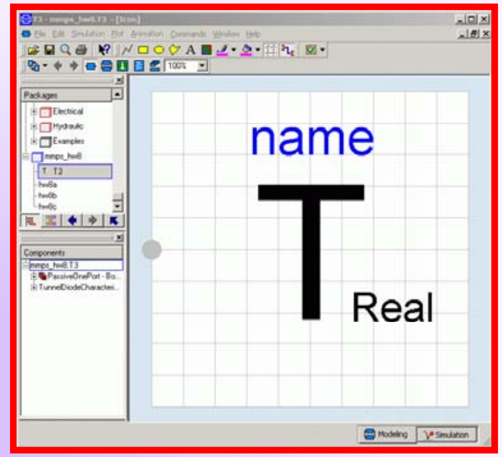
Voltage u_d [V]	Current i_d [mA]
0.00	0.00
0.05	1.70
0.10	2.90
0.15	4.00
0.20	4.75
0.25	5.00
0.30	4.90
0.35	4.25
0.40	3.20
0.45	2.35
0.50	2.00
0.55	2.20
0.60	2.70
0.65	3.50
0.70	4.35
0.75	5.30
0.90	9.00

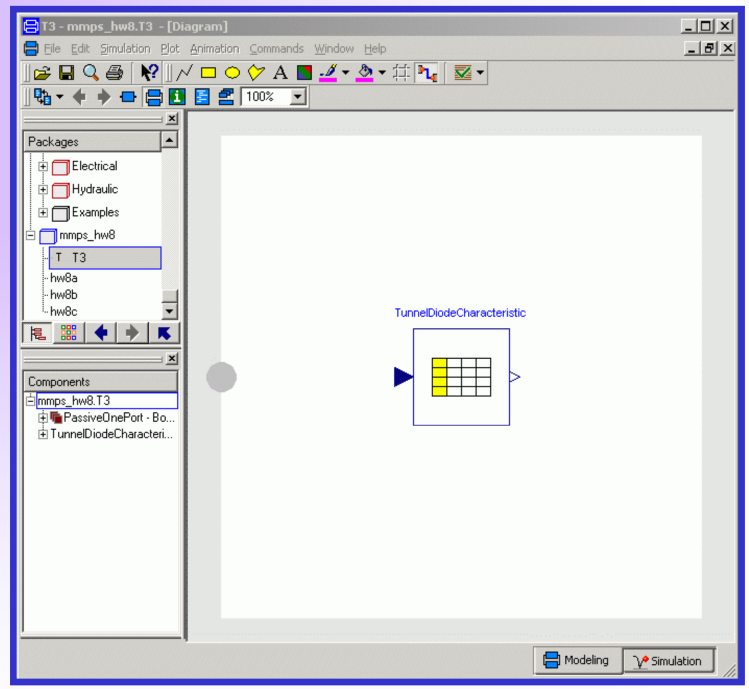
Free-running Tunnel Diode Circuit II

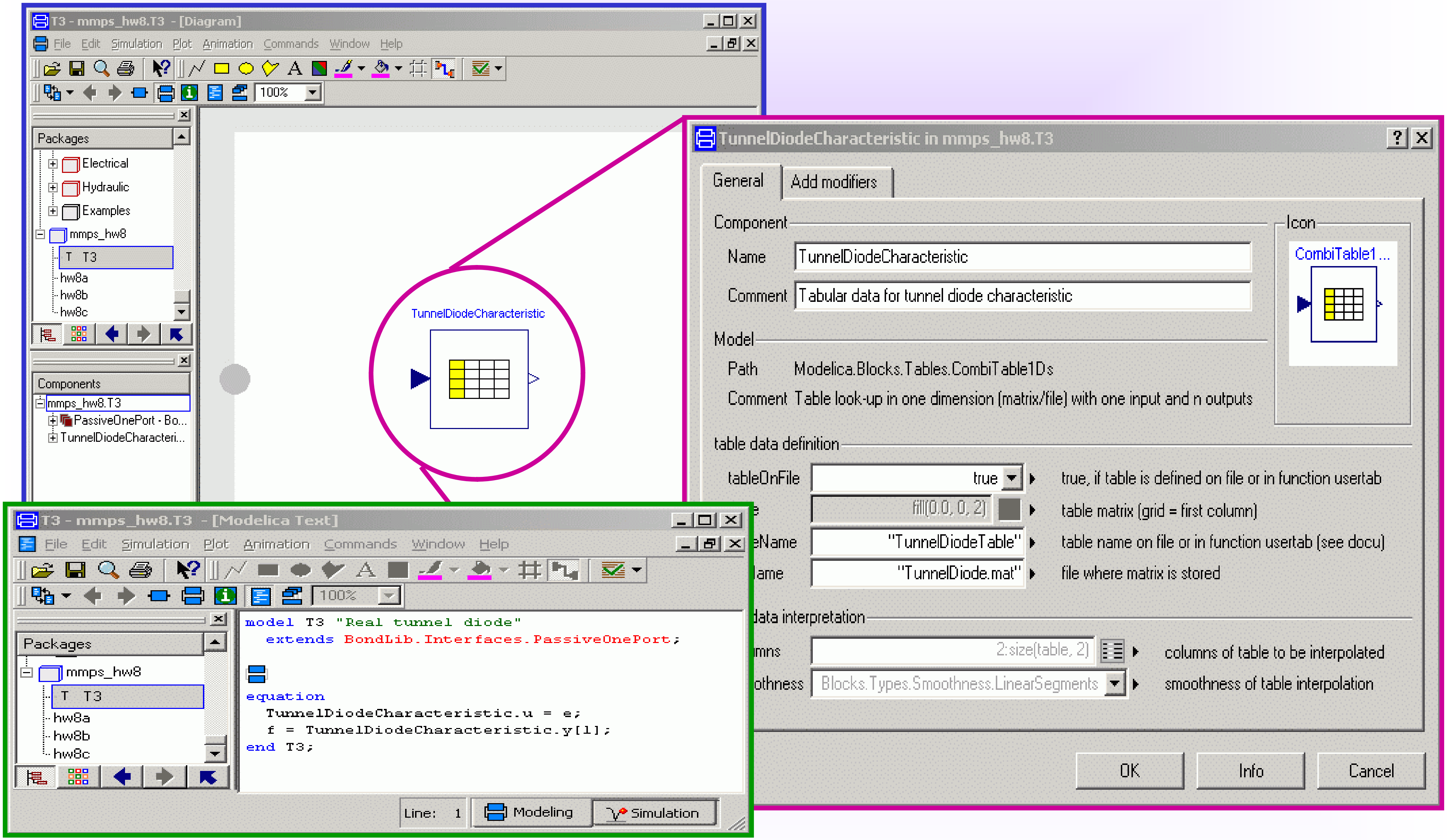
- Let us set $U_{tr} = 0$. We select a resistor with a value of $R = 25\ \Omega$. We choose a DC bias of $U_0 = 0.48\ V$.
- Create a bond graph (without wrapping) of the circuit. Use causal bonds whenever possible.
- Create a model *T3* representing the tunnel diode. The tabular function is incorporated by dragging the corresponding table-lookup block into the diagram window.
- Use Matlab to save the table onto a binary file, and reference that table from within the parameter window of the table-lookup block. Make sure to assign the correct causality to the table-lookup function. You can determine the correct causality from the bond graph of the overall circuit.

C:\Cellier\Classes\Ece449\Hw_8\TunnelDiode.m

```
% Convert the tunnel diode data to a table usable by Dymola
% -----------------------------------------------------------
%
x_vals = [0:0.05:0.75,0.9];
y_vals = 0.001*[0,1.7,2.9,4,4.75,5,4.9,4.25,3.2,2.35,2,2.2,2.7,3.5,4.35,5.3,9];
TunnelDiodeTable = [ x_vals' , y_vals' ];
%
save TunnelDiode.mat TunnelDiodeTable -V4
%
return
```

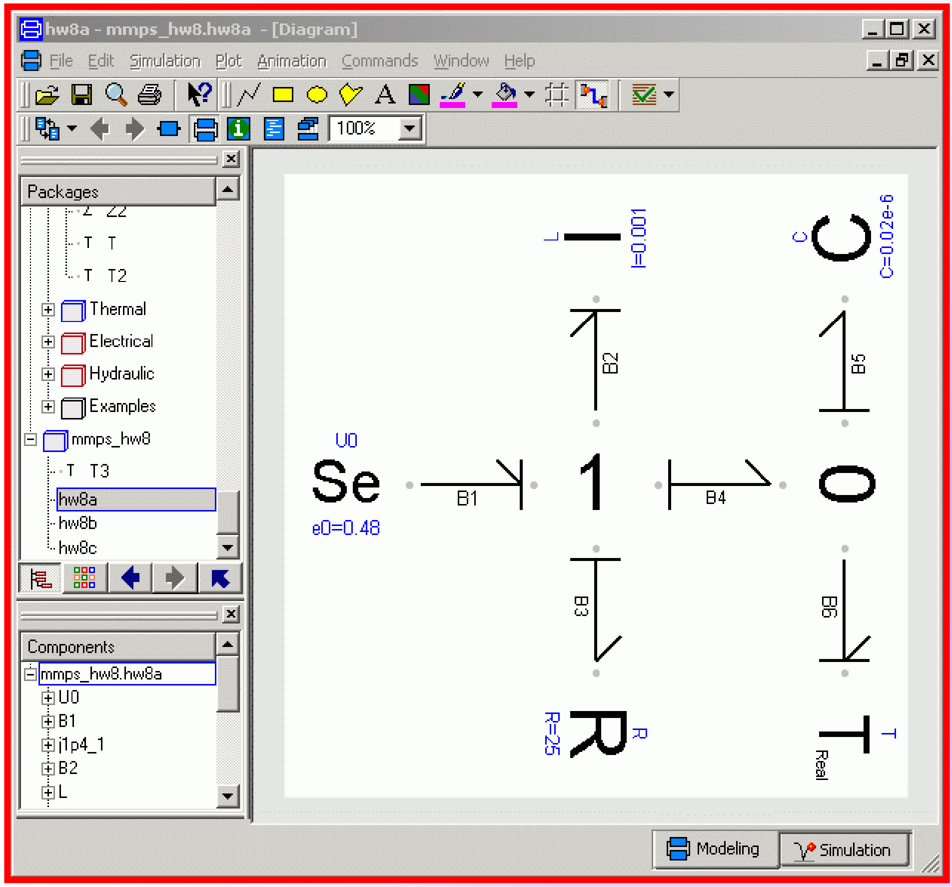


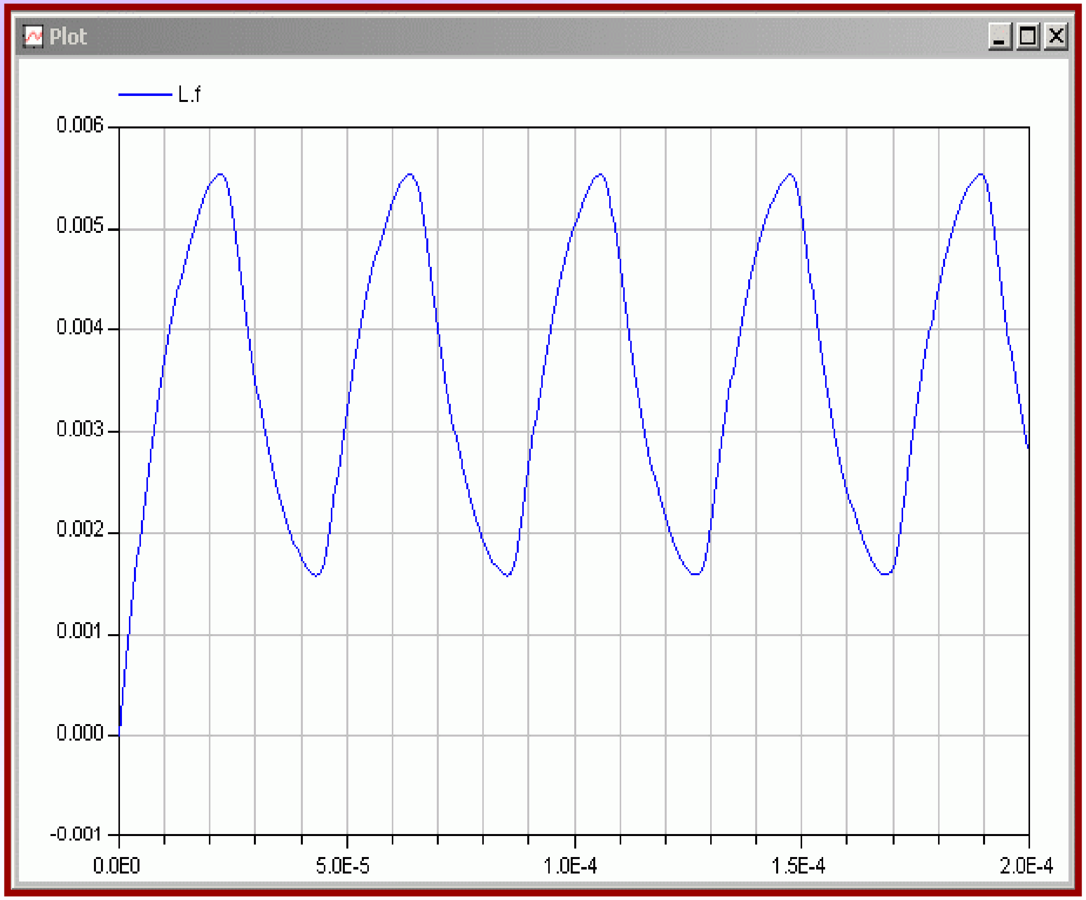



T3 - mmps_hw8.T3 - [Diagram]
File Edit Simulation Plot Animation Commands Window Help
100%
Packages
Electrical
Hydraulic
Examples
mmps_hw8
T T3
hw8a
hw8b
hw8c
Components
mmps_hw8.T3
PassiveOnePort - Bo...
TunnelDiodeCharacteri...
TunnelDiodeCharacteristic
TunnelDiodeCharacteristic in mmps_hw8.T3
General
Add modifiers
Component
Name TunnelDiodeCharacteristic
Comment Tabular data for tunnel diode characteristic
Icon
CombiTable1 ...
Model
Path Modelica.Blocks.Tables.CombiTable1Ds
Comment Table look-up in one dimension (matrix/file) with one input and n outputs
table data definition
tableOnFile true
true, if table is defined on file or in function usertab
fill(0.0, 0, 2)
table matrix (grid = first column)
"TunnelDiodeTable"
table name on file or in function usertab (see docu)
"TunnelDiode.mat"
file where matrix is stored
data interpretation
2:size(table, 2)
columns of table to be interpolated
Blocks.Types.Smoothness.LinearSegments
smoothness of table interpolation
OK
Info
Cancel
T3 - mmps_hw8.T3 - [Modelica Text]
model T3 "Real tunnel diode"
extends BondLib.Interfaces.PassiveOnePort;
equation
TunnelDiodeCharacteristic.u = e;
f = TunnelDiodeCharacteristic.y[1];
end T3;
Line: 1
Modeling
Simulation

Free-running Tunnel Diode Circuit III

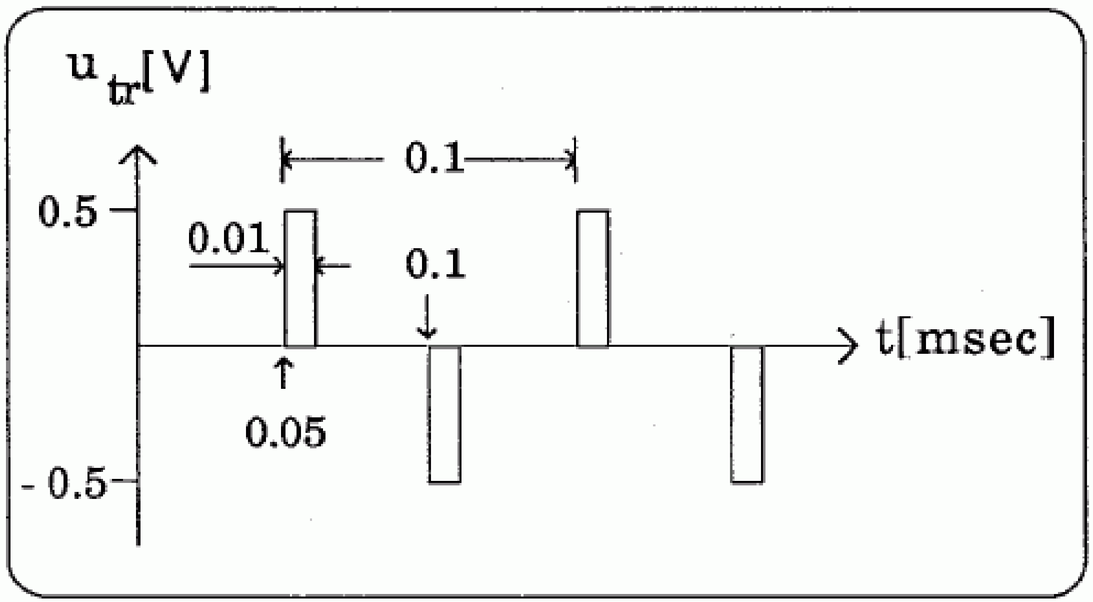
- Now create a model of the overall circuit (without wrapping) in Dymola using the ***BondLib*** library as well as the previously coded ***T3*** model.
- Simulate the circuit across ***0.2 msec*** of simulated time.
- Plot the current through the tunnel diode.
- Interpret the results obtained.


hw8a - mmps_hw8.hw8a - [Diagram]
File Edit Simulation Plot Animation Commands Window Help
100%
Packages
T T
T T2
Thermal
Electrical
Hydraulic
Examples
mmps_hw8
T T3
hw8a
hw8b
hw8c
Components
mmps_hw8.hw8a
U0
B1
j1p4_1
B2
L
U0
Se
e0=0.48
B1
1
B4
0
I
I=0.001
B2
C
C=0.02e-6
B5
B3
R
R=25
B6
T
Real
Modeling
Simulation


Plot
L.f
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
0.0E0
5.0E-5
1.0E-4
1.5E-4
2.0E-4

Pulsed Tunnel Diode Circuit I

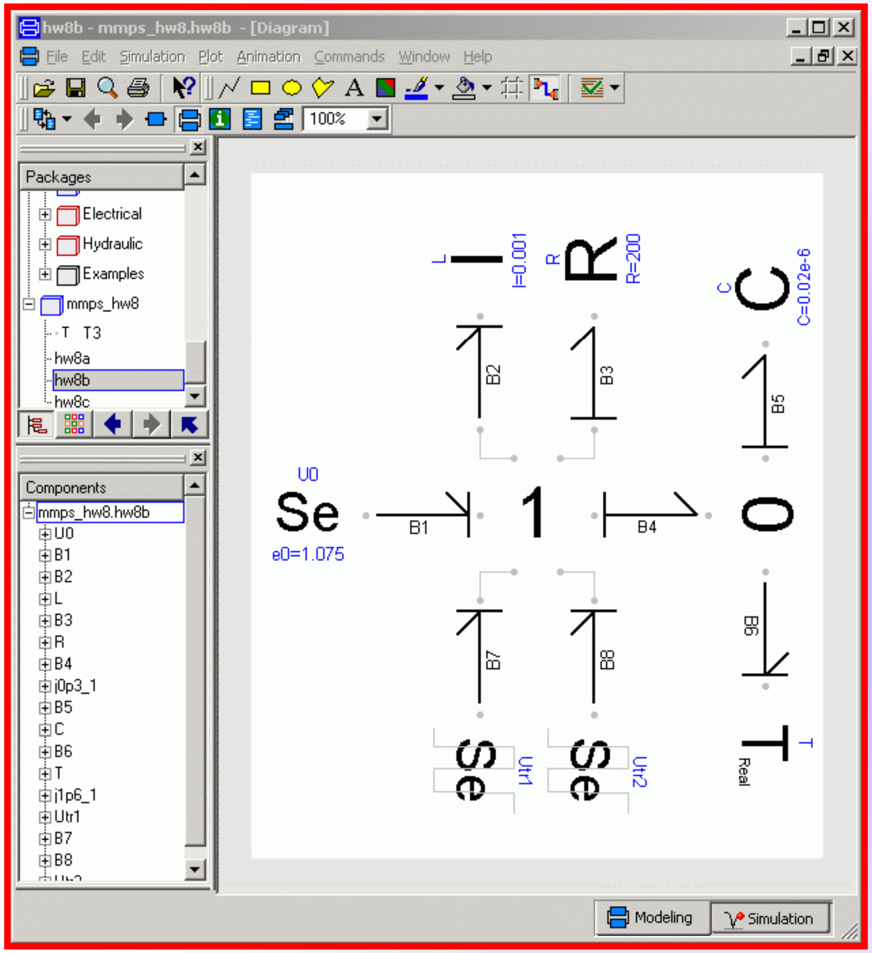
- In a second experiment, we include the following pulsed trigger signal, U_{tr}.



- You can easily create the trigger voltage out of the super-position of two of the pulsed voltage sour-ces provided in the standard bond graph library.

Pulsed Tunnel Diode Circuit II

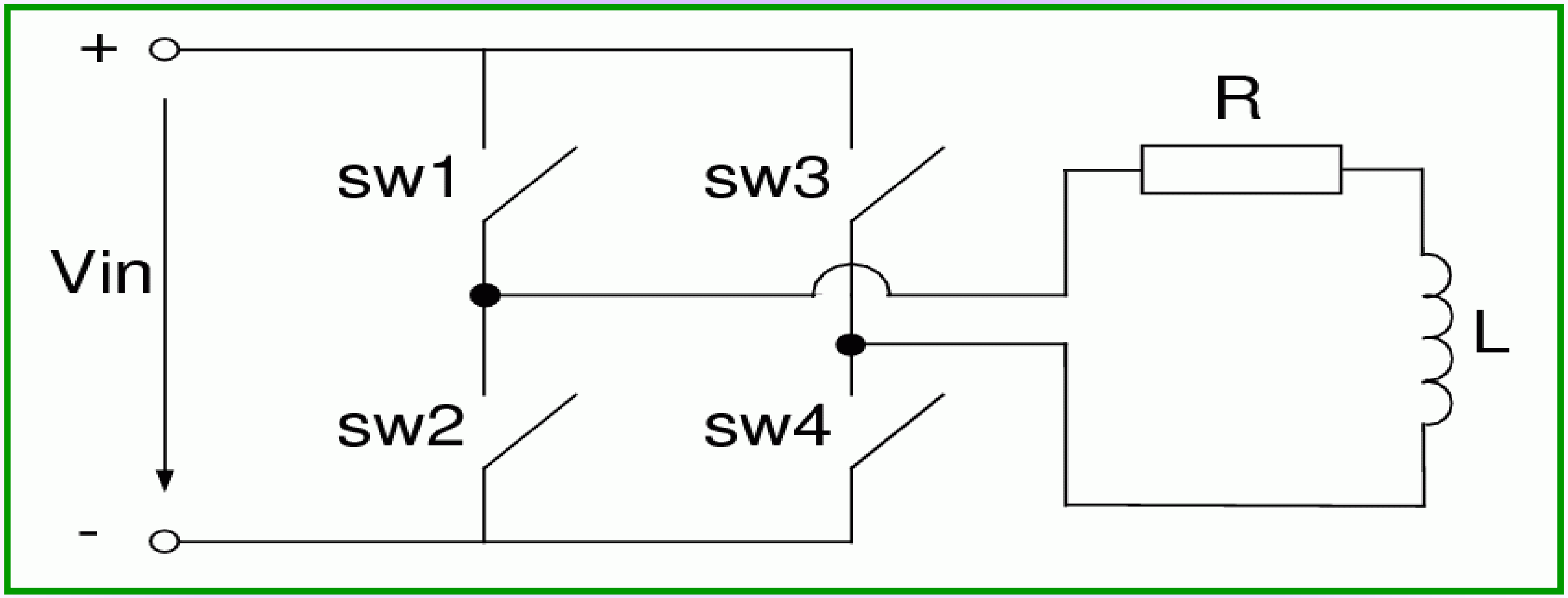
- For this experiment, we select a resistor with a value of ***R = 200 Ω***. We now choose a DC bias of $U_0 = 1.075\ V$.
- Simulate the modified circuit across ***0.2 msec*** of simulated time.
- Plot the current through the tunnel diode.
- Interpret the results obtained.


hw8b - mmps_hw8.hw8b - [Diagram]
File Edit Simulation Plot Animation Commands Window Help
Packages
Electrical
Hydraulic
Examples
mmps_hw8
T T3
hw8a
hw8b
hw8c
Components
mmps_hw8.hw8b
U0
B1
B2
L
B3
R
B4
j0p3_1
B5
C
B6
T
j1p6_1
Utr1
B7
B8
U0
Se
e0=1.075
B1
1
B4
0
L
I
I=0.001
R
R
R=200
C
C
C=0.02e-6
B2
B3
B5
B6
B7
B8
Se
Utr1
Se
Utr2
T
Real
T
Modeling
Simulation


Plot [1*]
L.f
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
-0.001
0.0E0
5.0E-5
1.0E-4
1.5E-4
2.0E-4

Fly-back Power Converter Circuit I

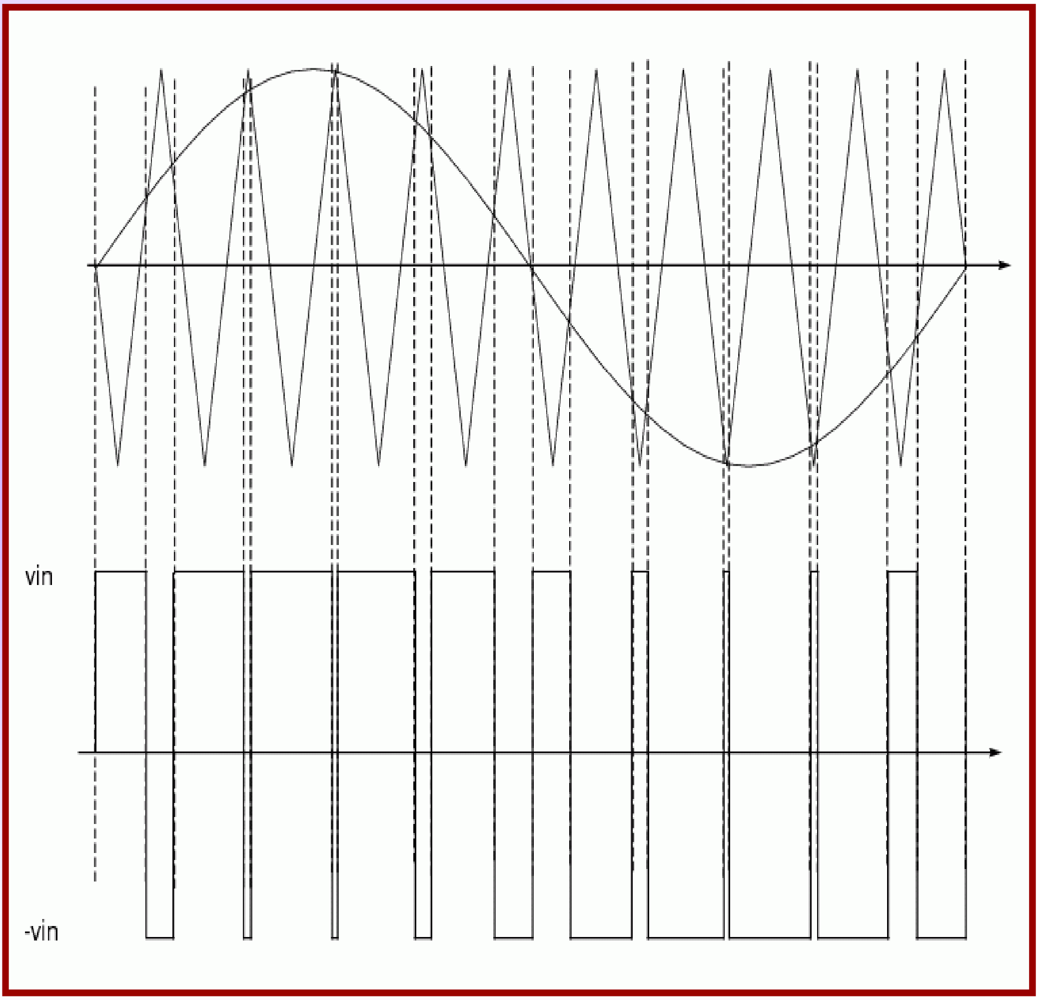
- Given the electronic circuit:



- The purpose is to create an inductor current that is approximately sinusoidal.

Fly-back Power Converter Circuit II

- To this end, we use pulse width modulation.
- The four switches are controlled in such a way that sometimes V_{in} is being applied to the ***RL*** circuit, and at other times ***-Vin***.
- The logic is explained in the graph to the right.



Fly-back Power Converter Circuit III

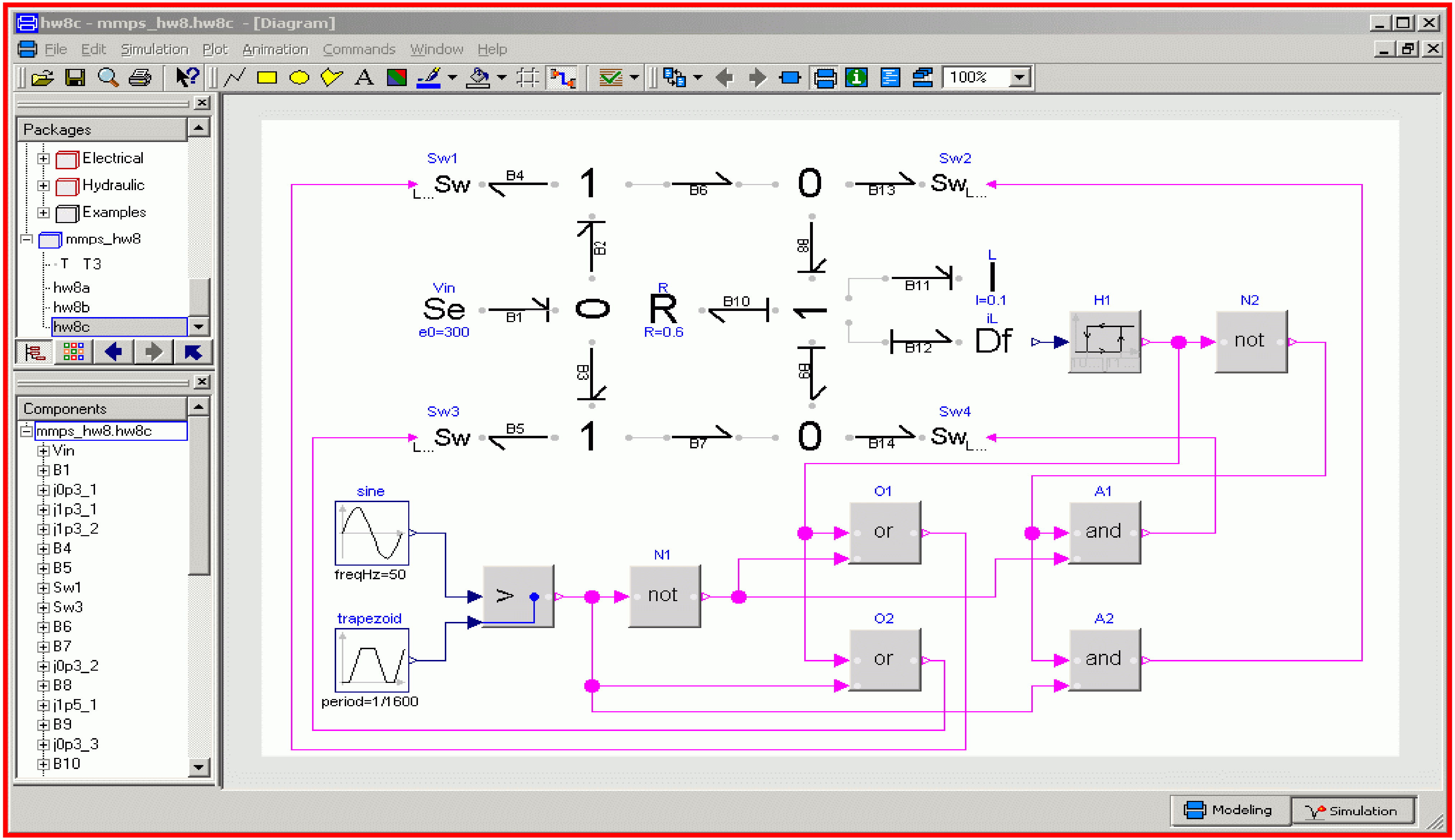
- If the sine-wave signal is larger than the triangular signal, switches #1 and #4 must be closed, whereas switches #2 and #3 must be opened.
- If the sine-wave signal is smaller than the triangular signal, switches #2 and #3 must be closed, whereas switches #1 and #4 must be opened.

Fly-back Power Converter Circuit IV

- We also want to implement a over-current protection circuit.
- When the inductor current becomes larger than ***11.05 A***, switches #2 and #4 must be closed, and switches #1 and #3 must be opened, irrespective of what the previous logic indicated.
- When the inductor current becomes smaller than ***10.95A***, the previous logic takes precedence once again.
- The hysteresis around the threshold current of ***11.0 A*** is necessary to avoid chattering.

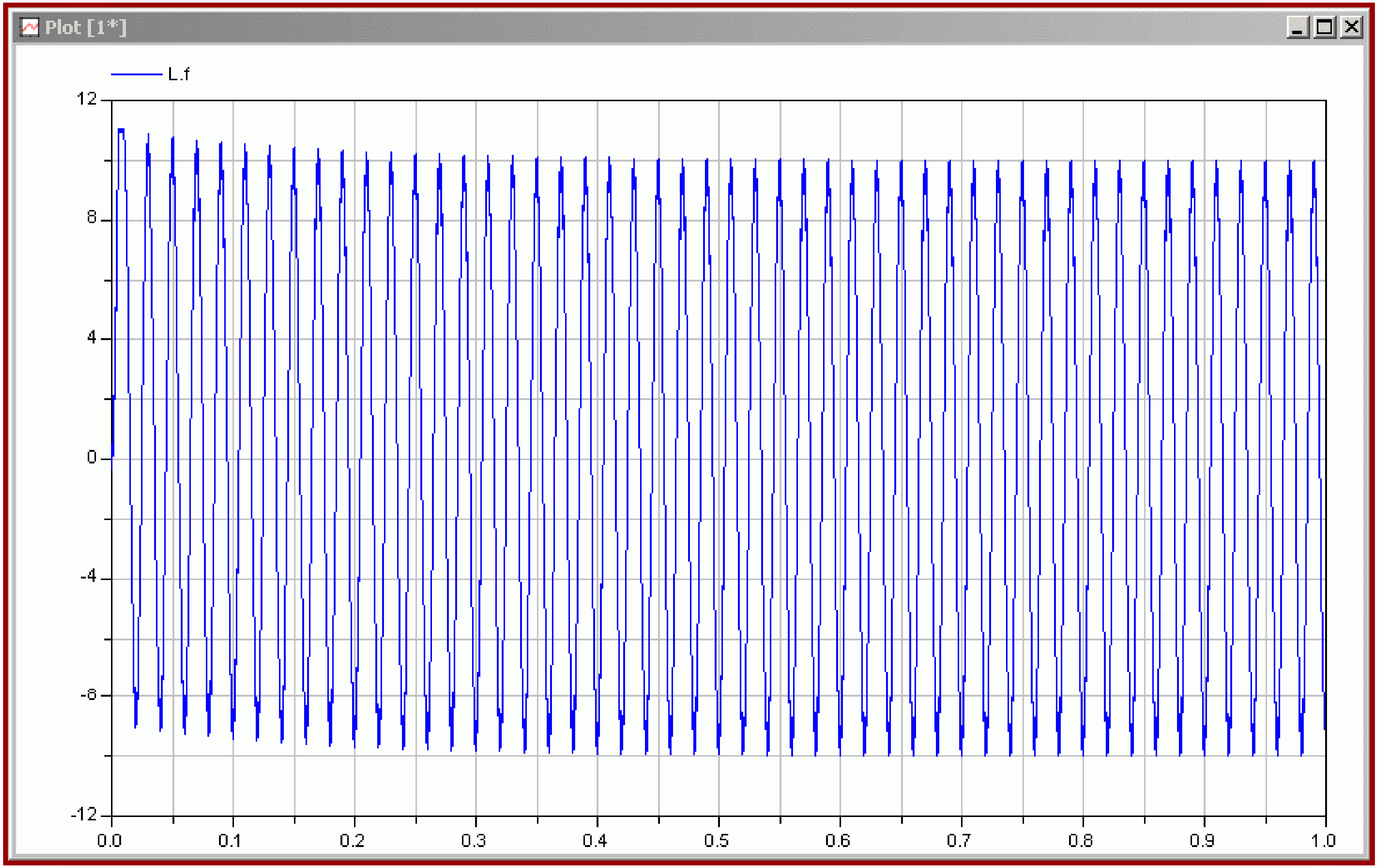
Fly-back Power Converter Circuit V

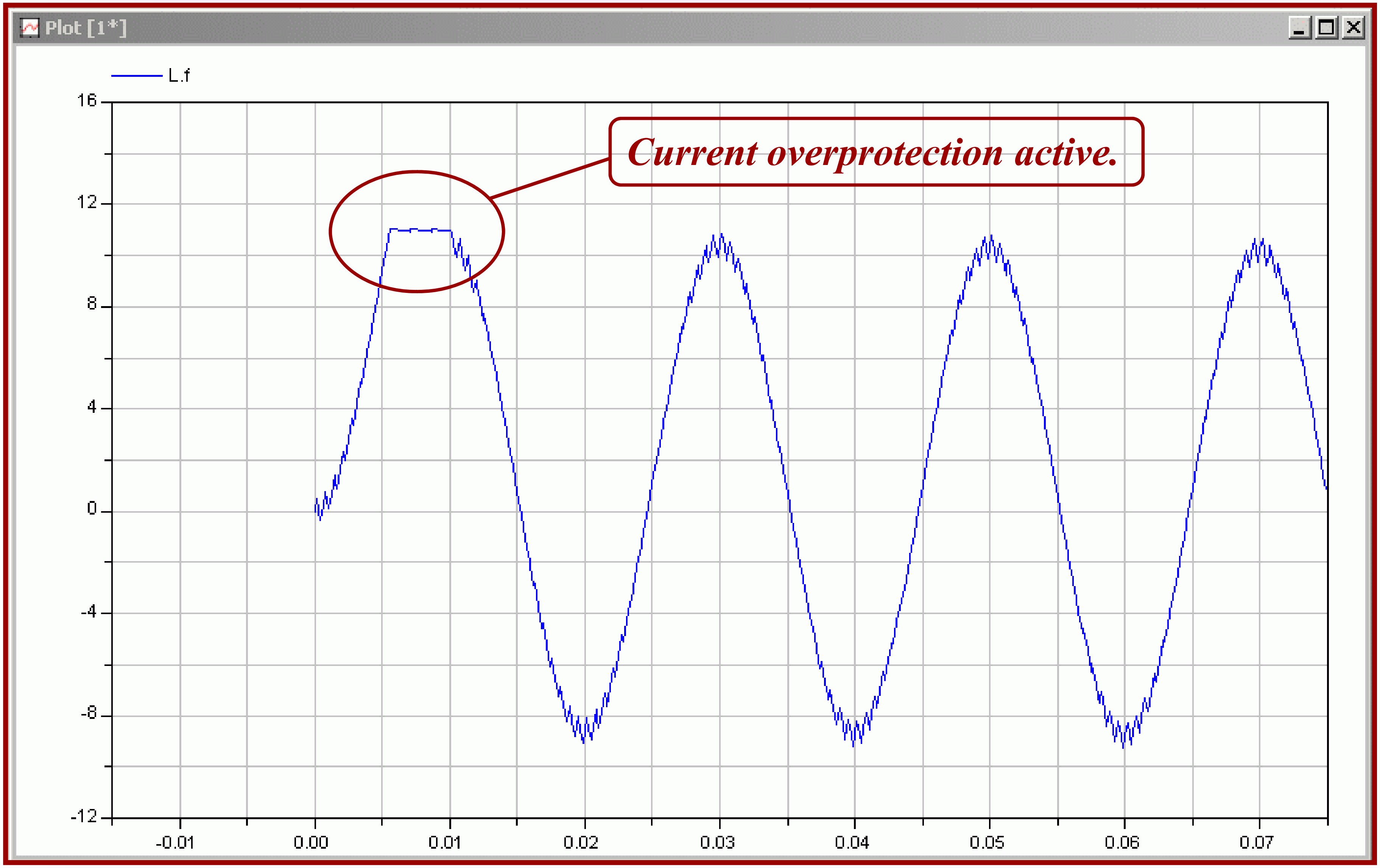
- Without the hysteresis, the switches would switch back and forth with infinite frequency. This phenomenon is called chattering.
- Create a bond graph model of the fly-back converter circuit. Use causal bonds wherever the causality is fixed, and use a-causal bonds elsewhere.
- Make use of four "leaky" switches to avoid divisions by zero.
- Program the logic of the four switches graphically using the standard ***Modelica*** blocks library.

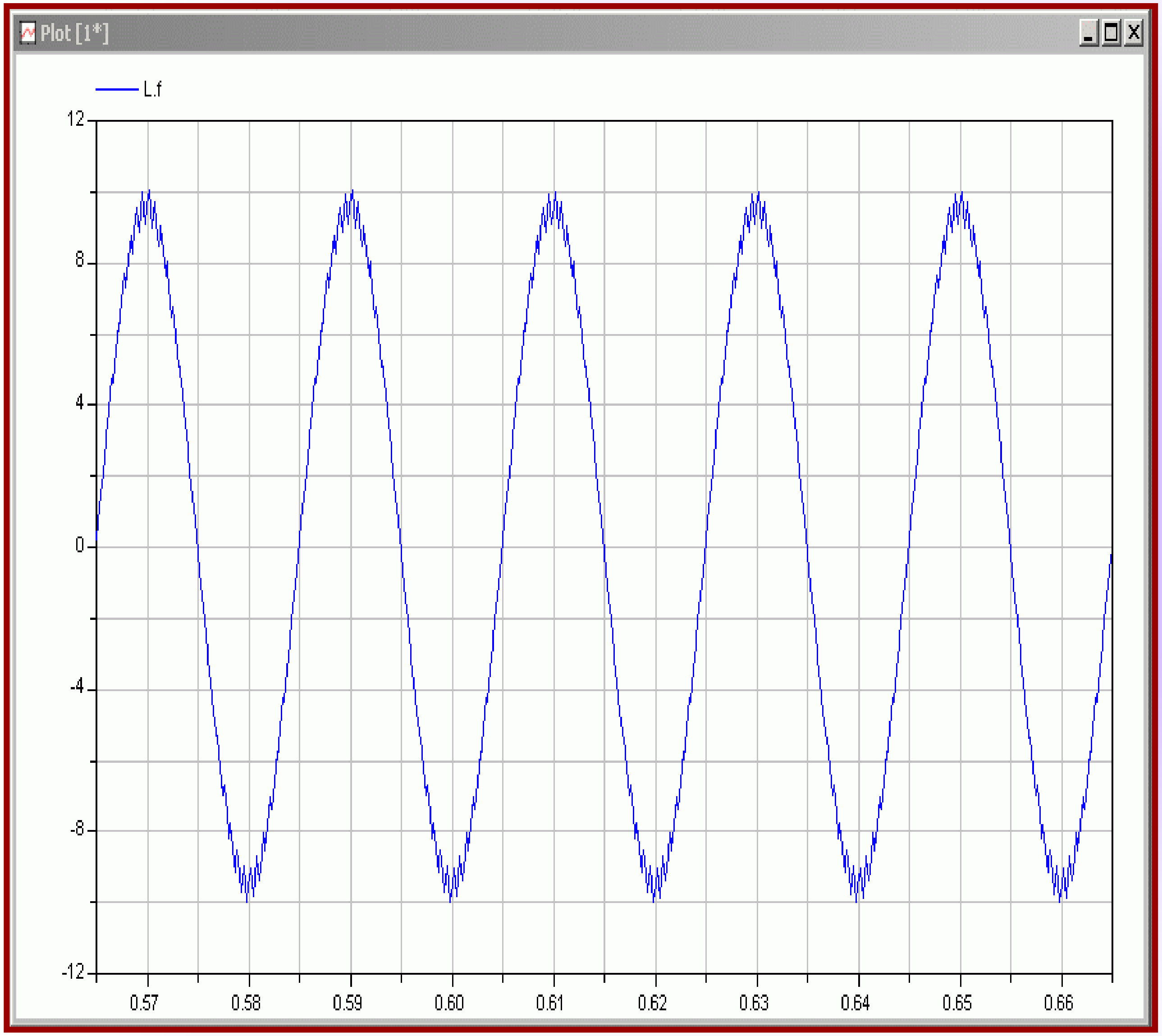

hw8c - mmps_hw8.hw8c - [Diagram]
File Edit Simulation Plot Animation Commands Window Help
Packages
Electrical
Hydraulic
Examples
mmps_hw8
T T3
hw8a
hw8b
hw8c
Components
mmps_hw8.hw8c
Vin
B1
j0p3_1
j1p3_1
j1p3_2
B4
B5
Sw1
Sw3
B6
B7
j0p3_2
B8
j1p5_1
B9
j0p3_3
B10
Sw1
Sw2
Sw3
Sw4
Vin
Se
e0=300
R
R=0.6
L
I=0.1
iL
Df
H1
N1
N2
not
O1
O2
or
A1
A2
and
sine
freqHz=50
trapezoid
period=1/1600
Modeling
Simulation

Fly-back Power Converter Circuit VI

- Simulate the circuit across ***1 sec*** of simulated time using ***R = 0.6 Ω*** and ***L = 100 mH***.
- Plot the inductor current over the entire period, and also over two smaller time windows, namely at an early period, when the over-current protection is active, and during steady-state operation.


Plot [1*]
L.f
12
8
4
0
-4
-8
-12
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0


Plot [1*]
L.f
16
12
8
4
0
-4
-8
-12
-0.01
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Current overprotection active.



- The current is almost sinusoidal.
- There are only a few high-frequency components that could easily be filtered out using a low-pass filter.