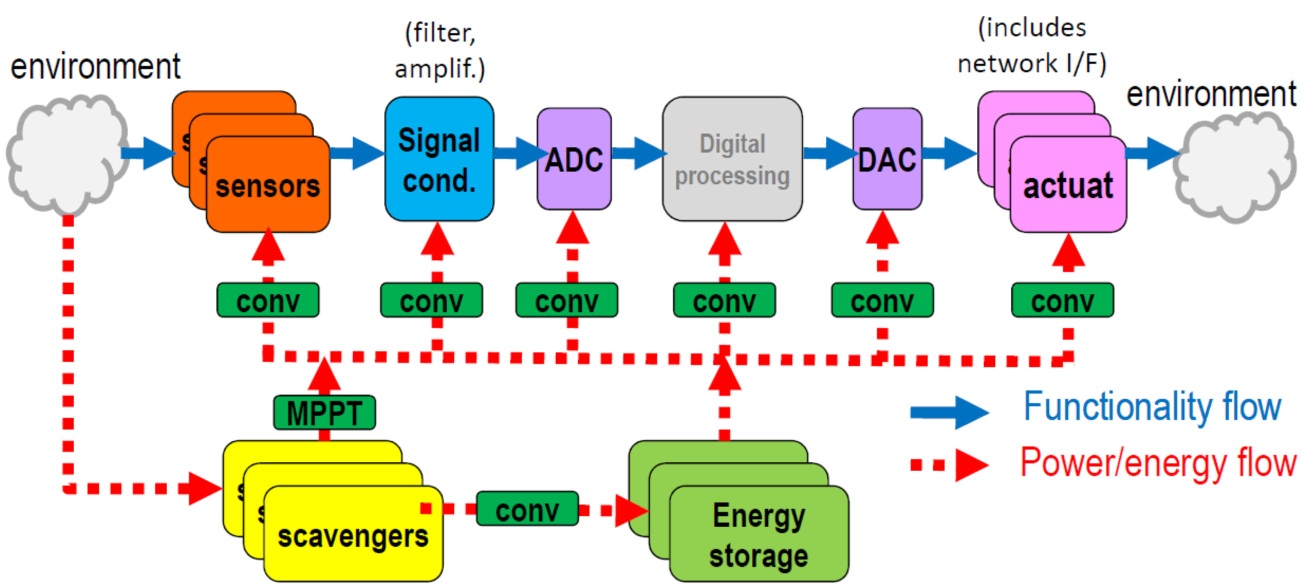
Lab 3
Energy storage, generation and conversion

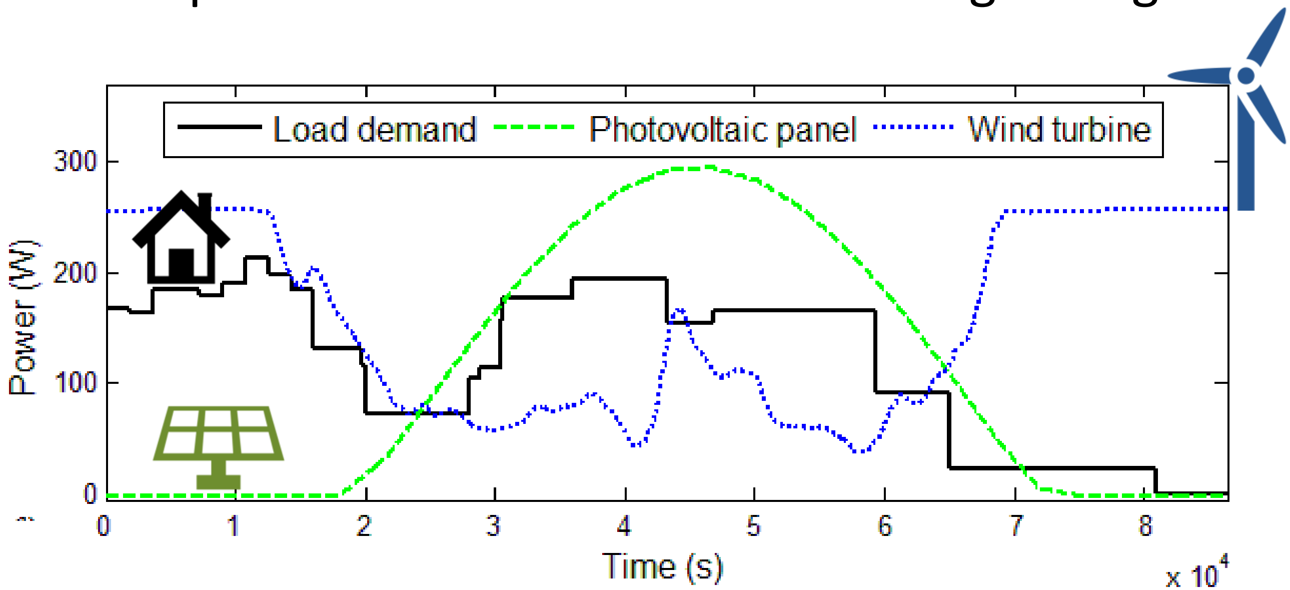
Energy storage, generation and conversion

- Focus: **power perspective of the system**
  - Energy storage: appropriate size to sustain loads?
  - Generation: how much provided by power sources?
  - Any loss due to conversions?



Energy storage, generation and conversion

- Crucial to model and simulate the overall system to validate and estimate the behavior of single components and of the overall system beforehand
  - On any scale of system!
  - Even more crucial when autonomousness must be guaranteed
    - Ensure operation of the IoT device for long enough…

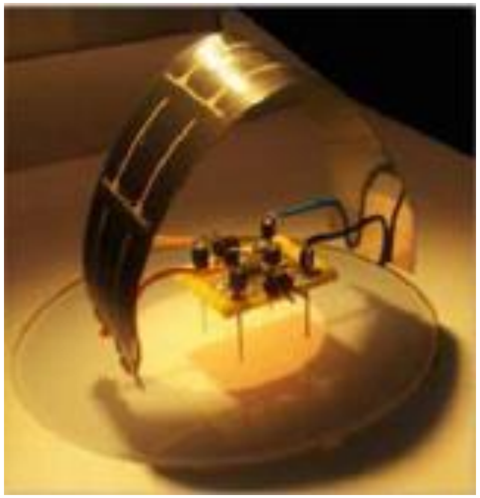


Energy storage, generation and conversion

- Crucial to model and simulate the overall system to validate and estimate the behavior of single components and of the overall system beforehand
  - On any scale of system!
  - Even more crucial when autonomousness must be guaranteed
    - Ensure operation of the IoT device for long enough…
  - Need to create models for the components
    - And to launch simulations to trace quantities

Objective and organization

- Goal of this lab is to simulate an IoT device made of:
  - 4 sensors
  - Memory and control unit
  - A module to transmit data over ZigBee
  - A battery with a DC-DC converter
  - A thin-film photovoltaic module



Objective and organization

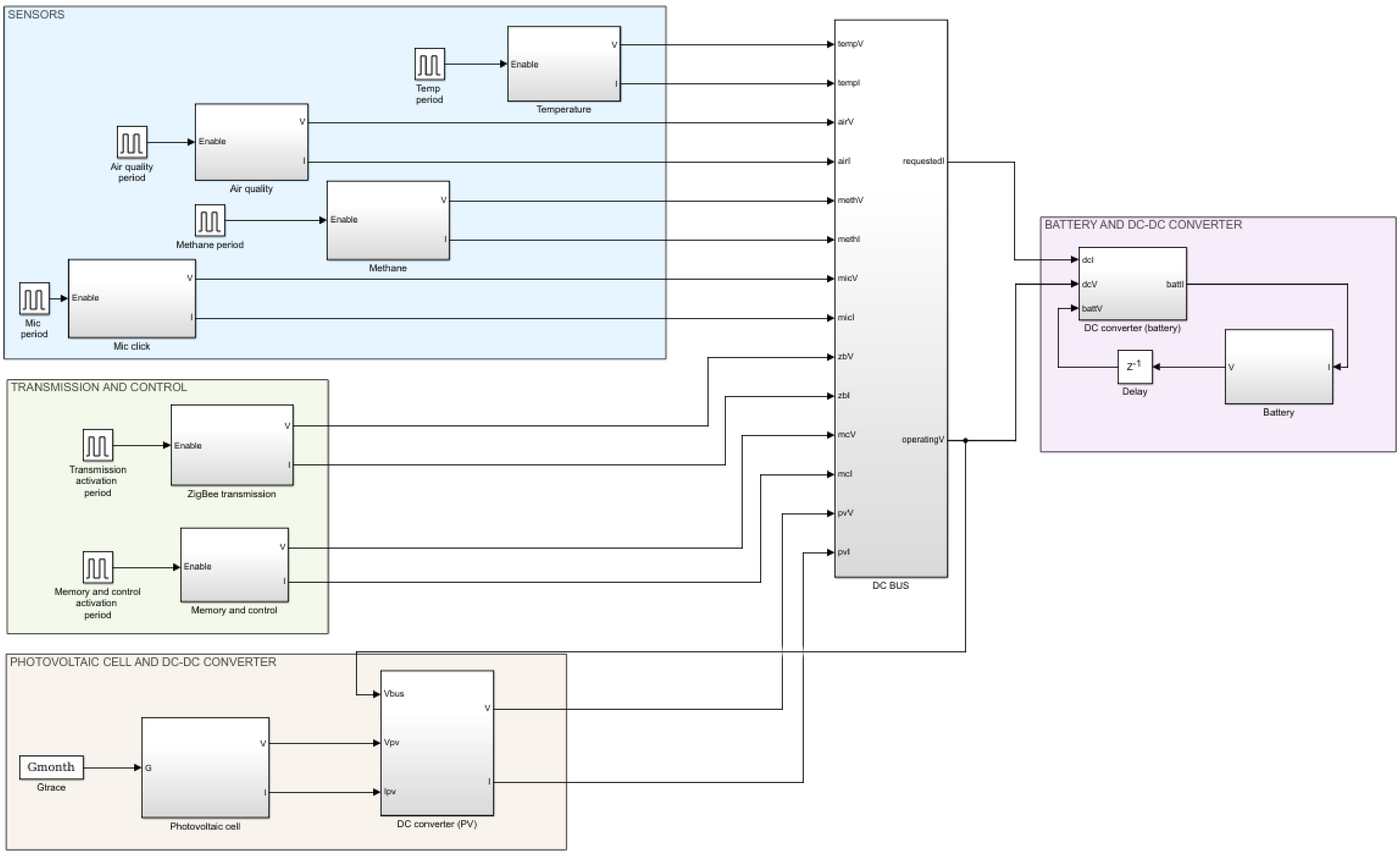
- Goal of this lab is to simulate an IoT device:
  - Implemented in Matlab/Simulink
    - Stardard-de-facto for energy simulation
    - Predefined simulation skeleton
    - To be populated with models for the components
  - 4 labs to populate the system, analyse and optimize its behavior

Objective and organization

- Organization
  - 1 assignment to deliver
  - 4 days
    - Jan 8th 2:30pm-4pm room 13
    - Jan 10th 8:30am-11:30am room 21A
    - Jan 13th 4pm-7pm room 10I
    - Jan 15th 2:30pm-4pm room 13
  - Required software: Matlab, Simulink
  - Required hardware: a mouse
  - Reference person: Sara Vinco (sara.vinco@polito.it)

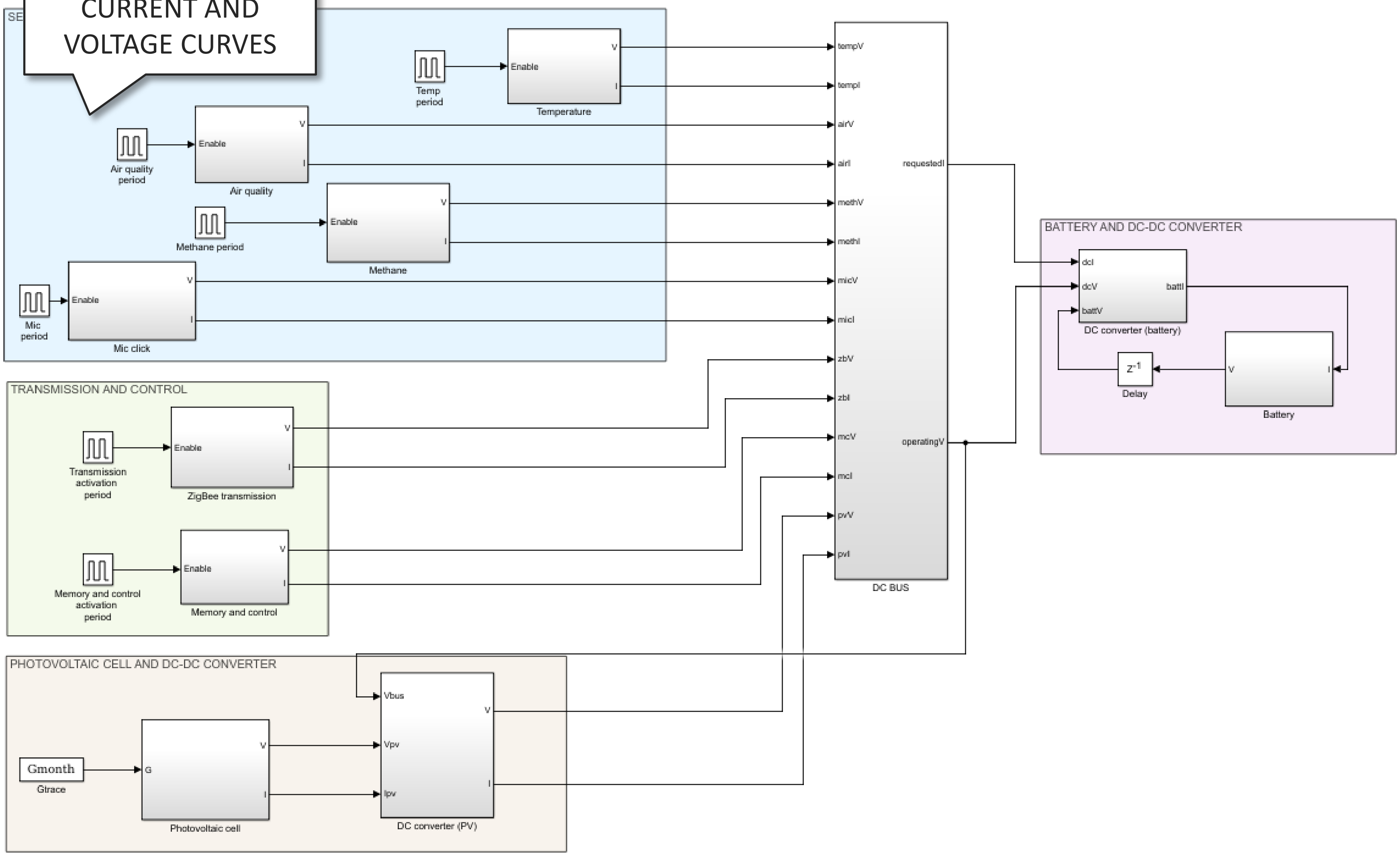
Simulink implementation

Simulink implementation

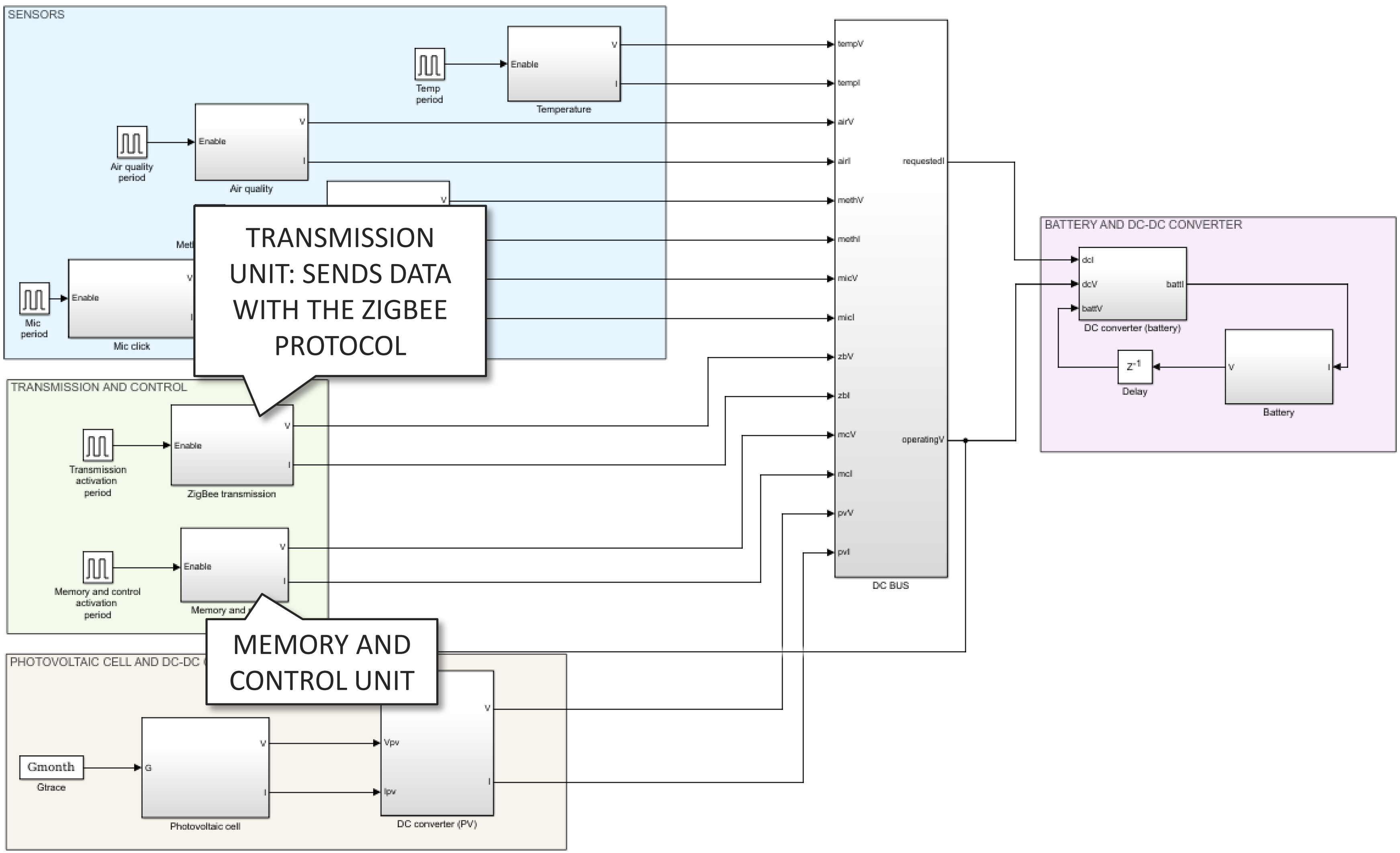


Simulink implementation

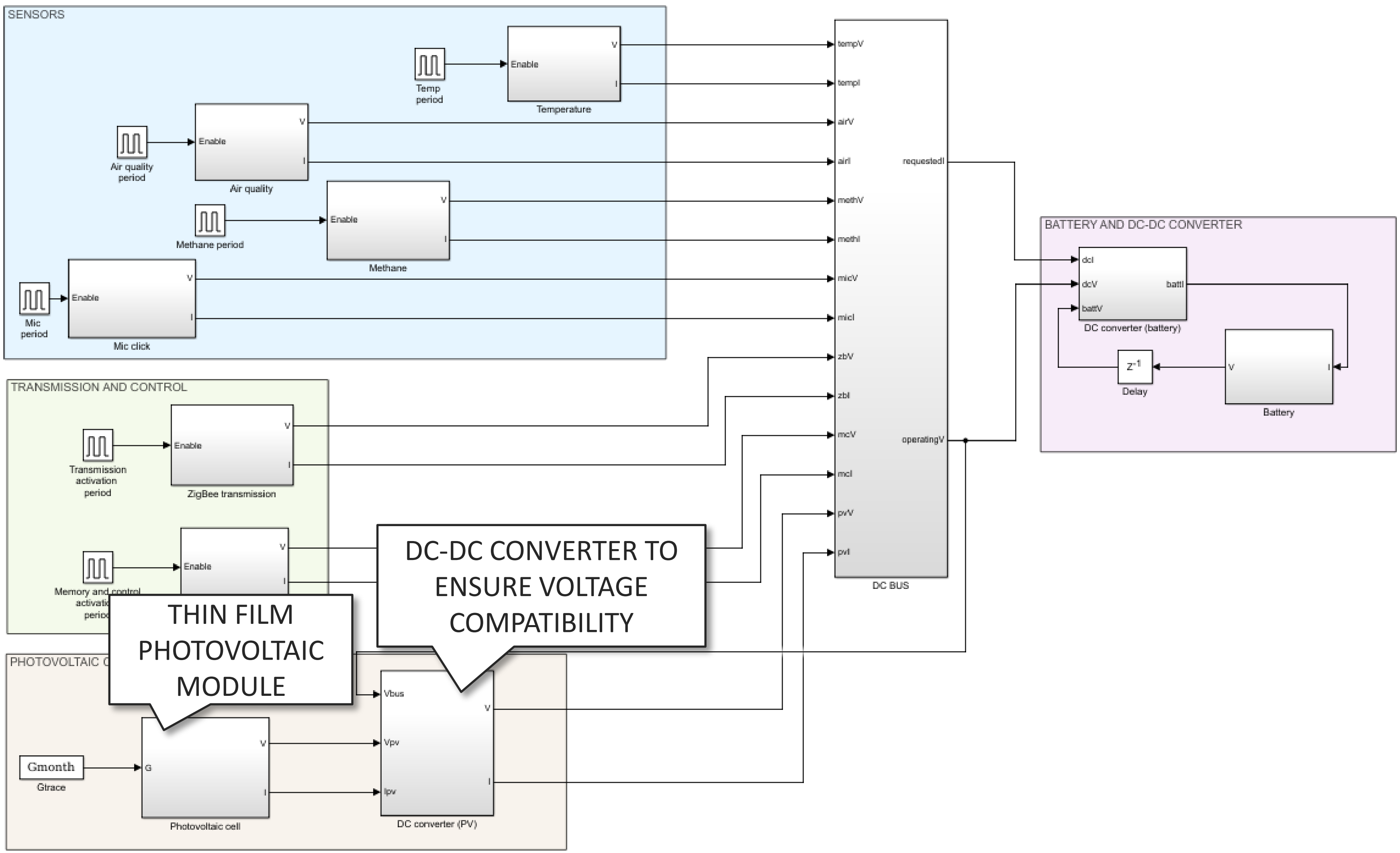
4 SENSORS: MODELED AS CURRENT AND VOLTAGE CURVES



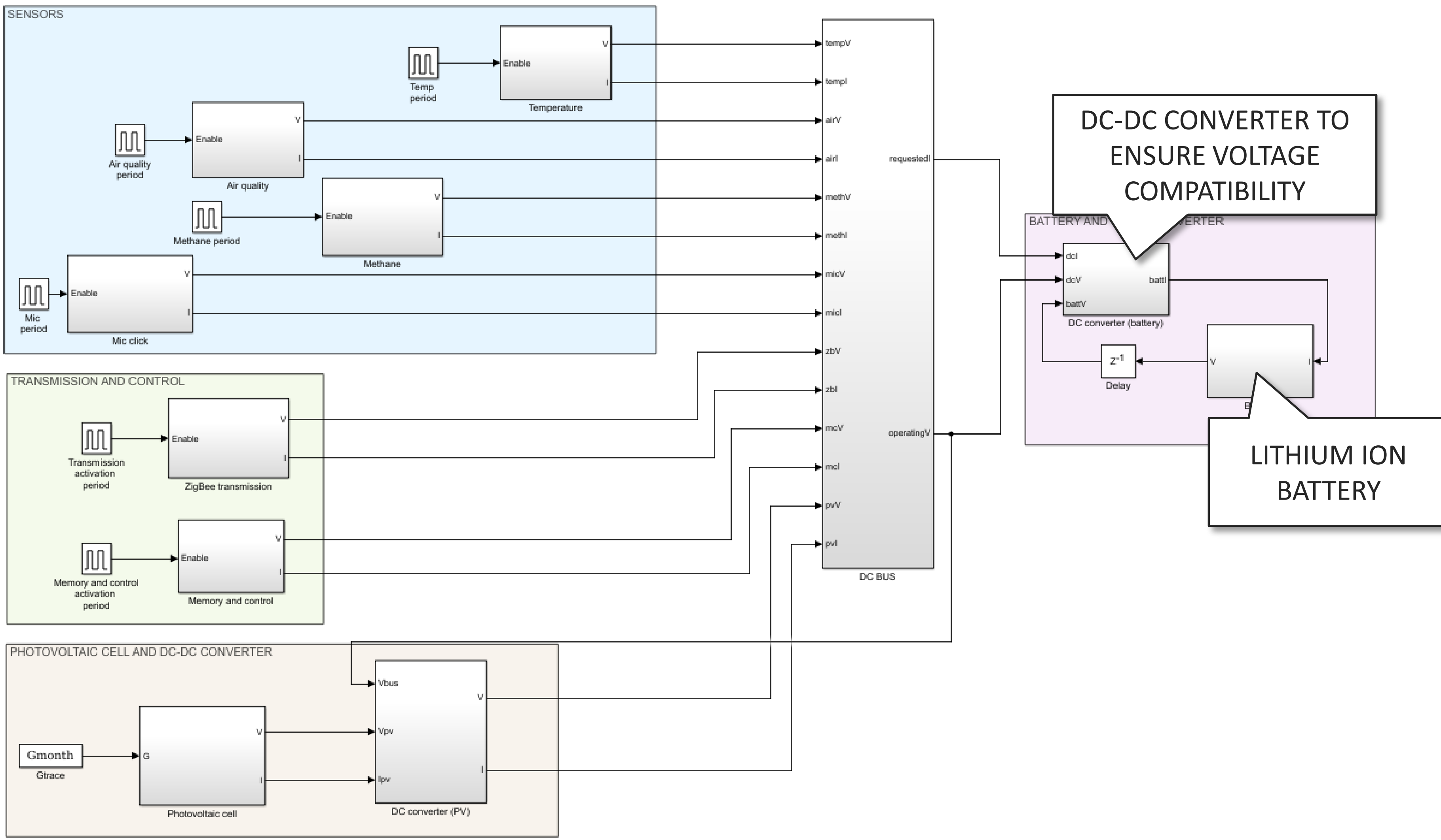
Simulink implementation



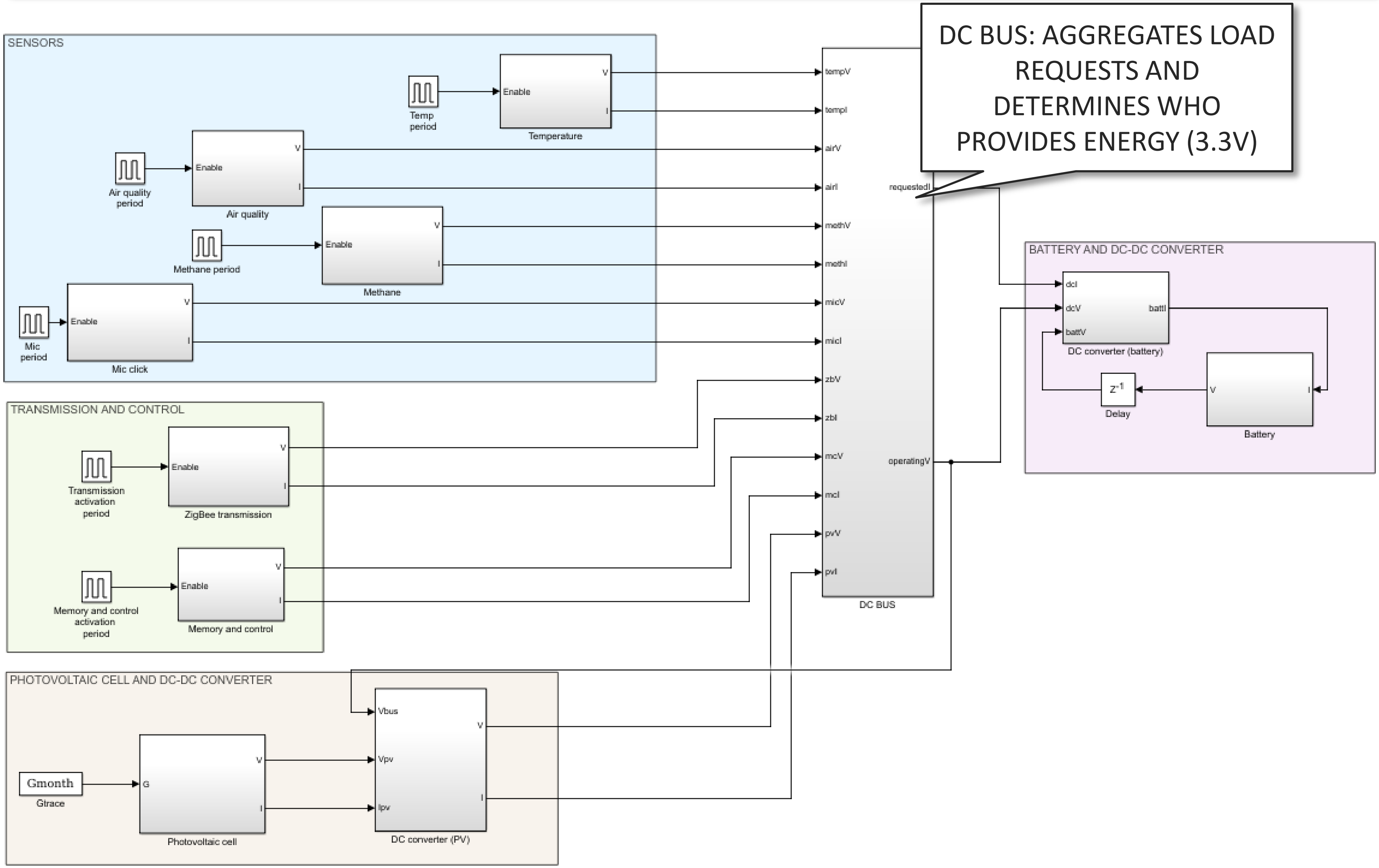
Simulink implementation



Simulink implementation

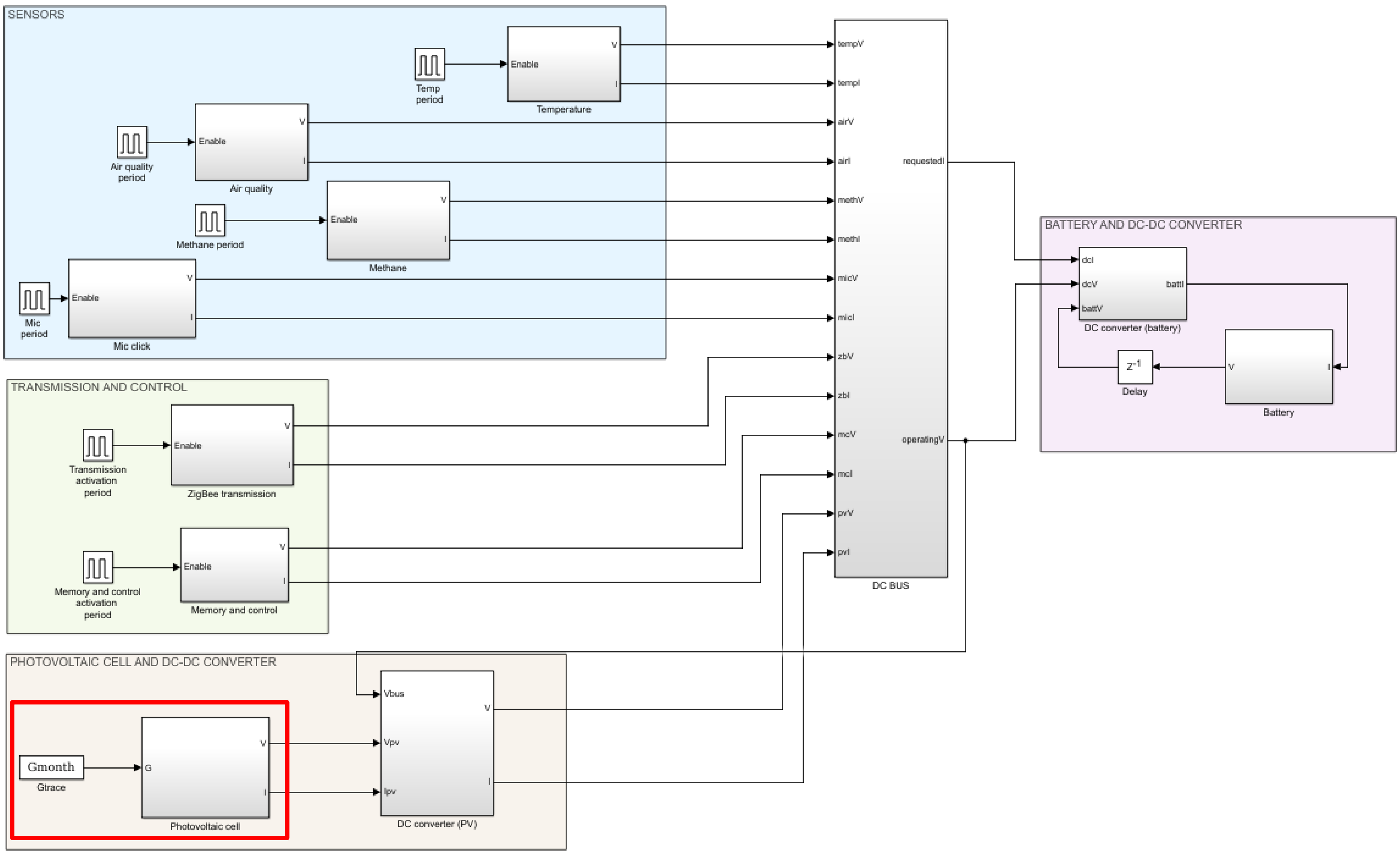


Simulink implementation



Lab 3 – Day 1
Model of the photovoltaic module

Simulink implementation



Photovoltaic cell block

- Gmonth
  - Variable loaded from workspace
    - To load it, type:
      - `load('gmonth.mat')`
  - Values of irradiance over time
    - Input of the photovoltaic cell
    - Two columns matrix:
      - First column: time (in seconds)
      - Second column: irradiance value (in W/m^2)
      - Each line corresponds to a new value of irradiance at a given time

Editor - panel.m

Gmonth

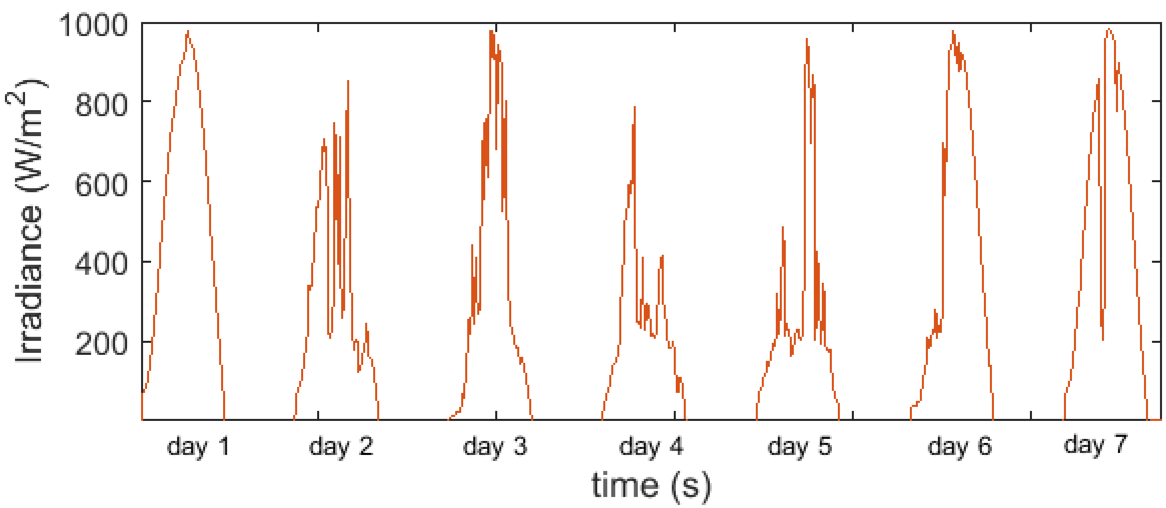
1590x2 double

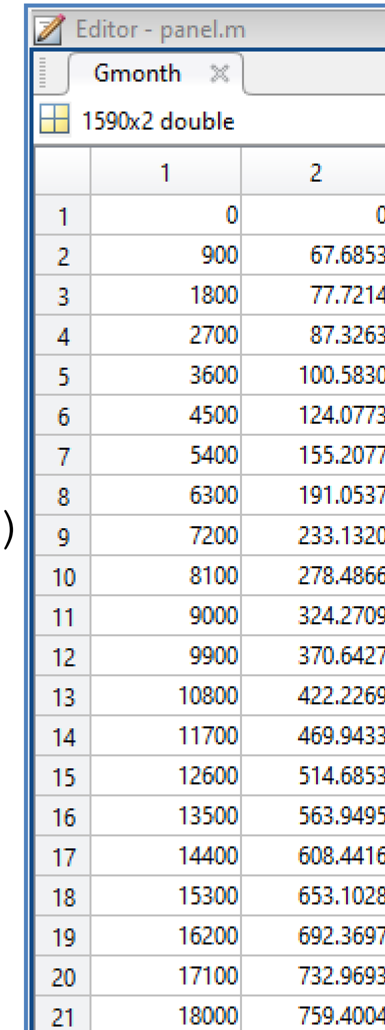
	1	2
1	0	0
2	900	67.6853
3	1800	77.7214
4	2700	87.3263
5	3600	100.5830
6	4500	124.0773
7	5400	155.2077
8	6300	191.0537
9	7200	233.1320
10	8100	278.4866
11	9000	324.2709
12	9900	370.6427
13	10800	422.2269
14	11700	469.9433
15	12600	514.6853
16	13500	563.9495
17	14400	608.4416
18	15300	653.1028
19	16200	692.3697
20	17100	732.9693
21	18000	759.4004

Photovoltaic cell block

- Gmonth
  - Irradiance of one month
    - 30 irradiance curves (allows a one month long simulation, i.e., 2,592,000 s)
    - Irradiance varies depending on weather (sunny/rainy/cloudy)
    - E.g.:

```
figure
plot(Gmonth(:,1), Gmonth(:,2))
```




Editor - panel.m

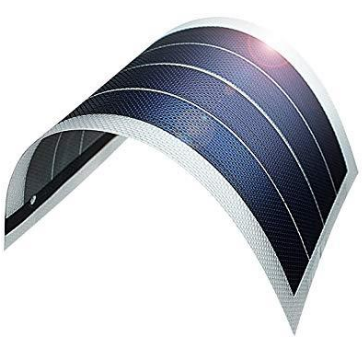
Gmonth

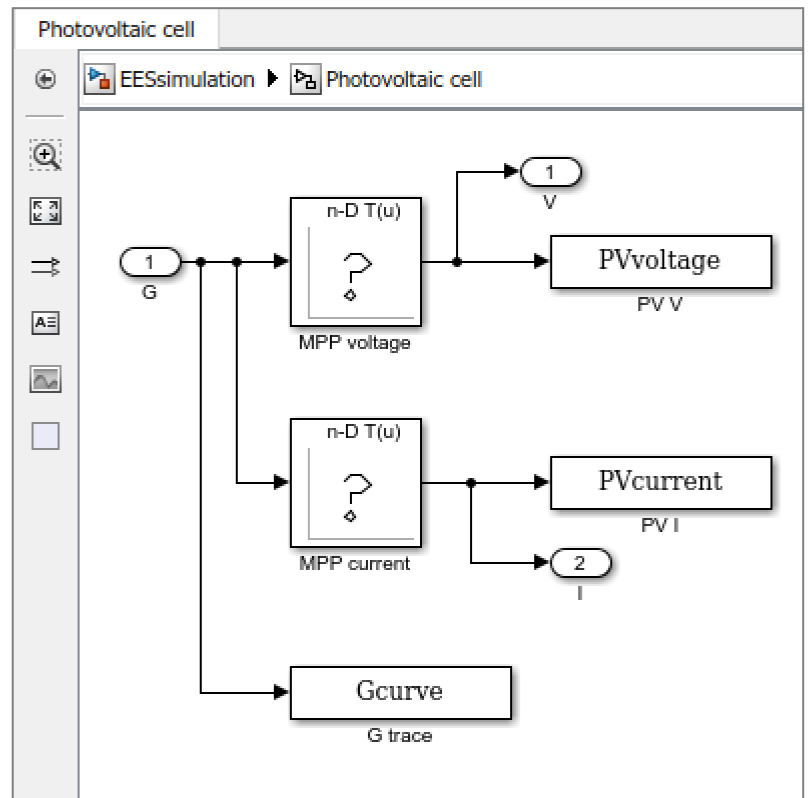
1590x2 double

	1	2
1	0	0
2	900	67.6853
3	1800	77.7214
4	2700	87.3263
5	3600	100.5830
6	4500	124.0773
7	5400	155.2077
8	6300	191.0537
9	7200	233.1320
10	8100	278.4866
11	9000	324.2709
12	9900	370.6427
13	10800	422.2269
14	11700	469.9433
15	12600	514.6853
16	13500	563.9495
17	14400	608.4416
18	15300	653.1028
19	16200	692.3697
20	17100	732.9693
21	18000	759.4004

Photovoltaic cell block

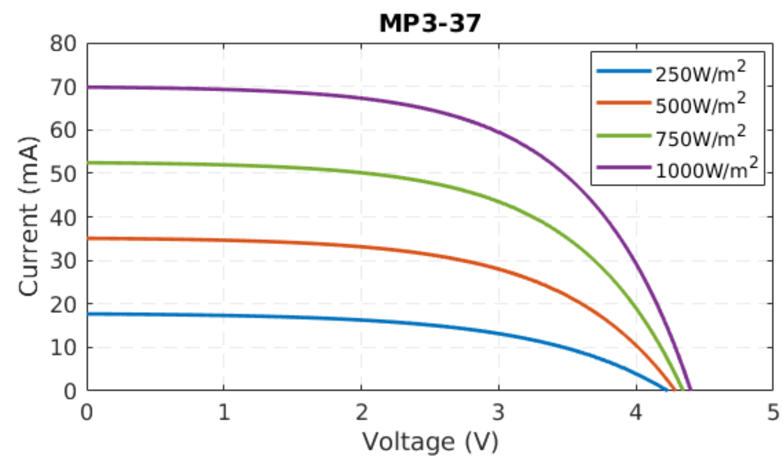
- Photovoltaic cell block
  - Open the subsystem by double-clicking on block
  - Two lookup tables
    - Voltage and current at the MPP given irradiance in input
    - Must populate the lookup tables!





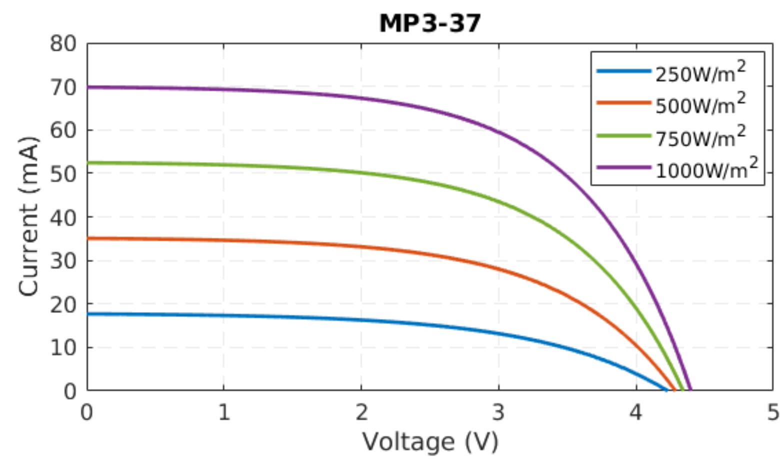
Photovoltaic cell block

- Open the PVdatasheet.pdf file
- Provides a graph of current versus voltage given different irradiance values
- How to:
  - Save the image
  - For each curve:
    - Digitize the curve
      - Can use the digitizer tool
    - Determine the voltage and current at the MPP for that irradiance value
    - Use the sample for the lookup table



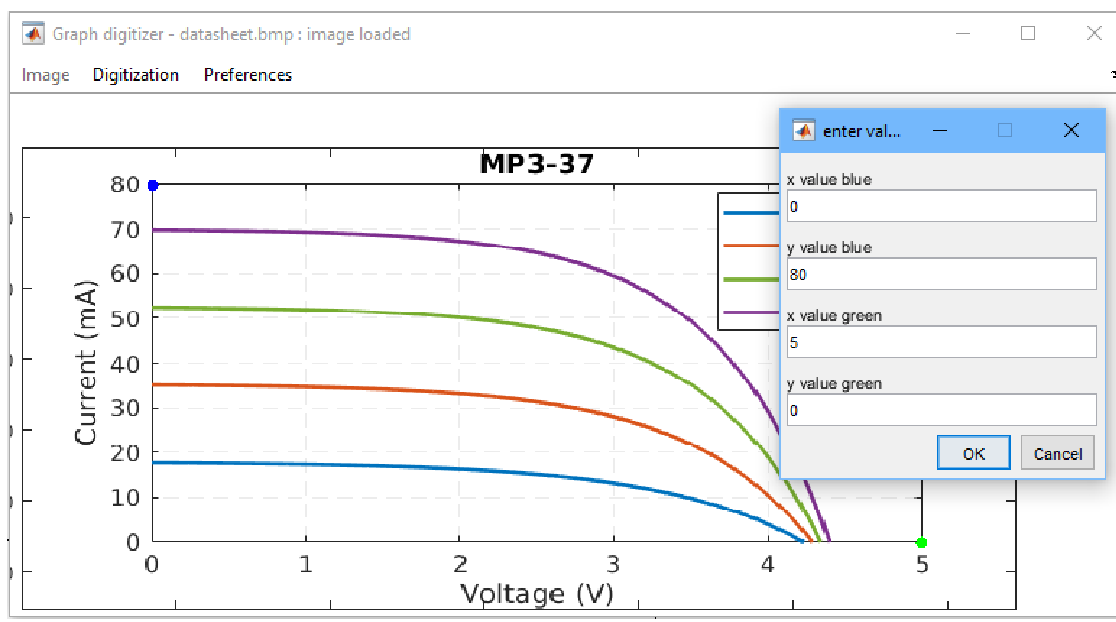
Photovoltaic cell block

- Open the PVdatasheet.pdf file
- Provides a graph of current versus voltage given different irradiance values
- How to:
  - Save the image
  - For each curve:
    - Digitize the curve
      - Can use the digitizer tool
    - Determine the voltage and current at the MPP for that irradiance value
    - Use the sample for the lookup table



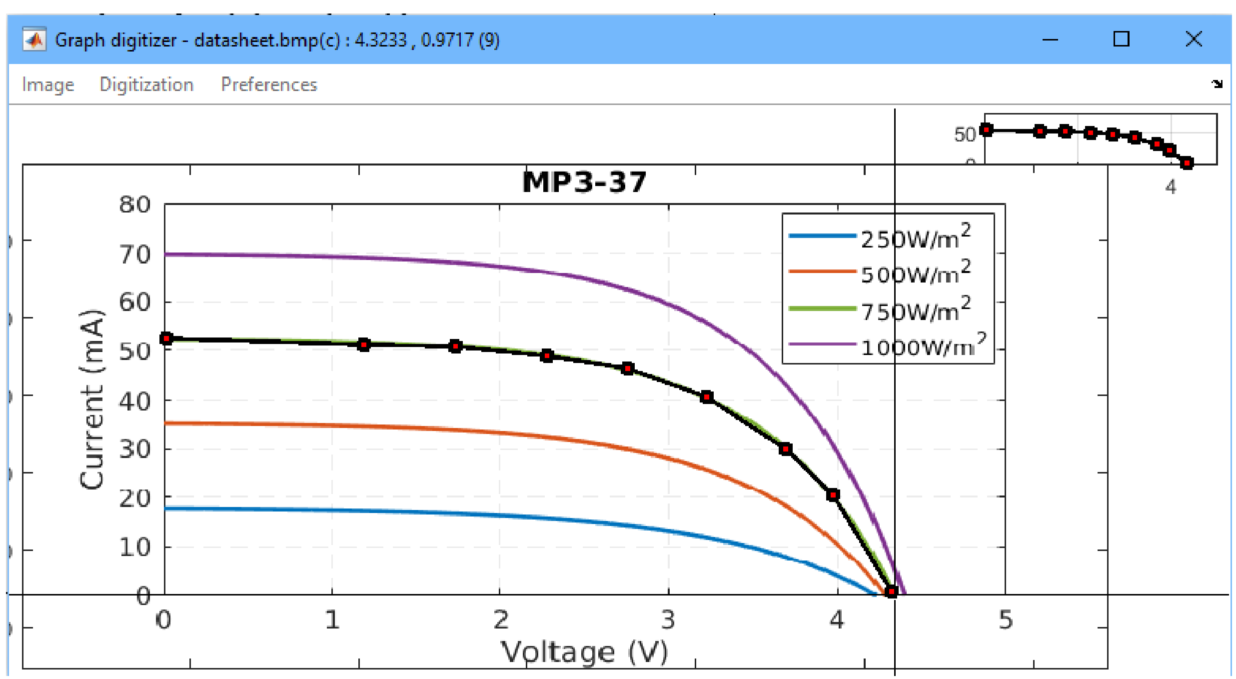
Photovoltaic cell block

- How to use the digitizer tool:
  1. Load the image
  2. Calibrate the image
     - Select two points and give corresponding x and y values
     - Conversion factor 1
     - 4 decimals precision



Photovoltaic cell block

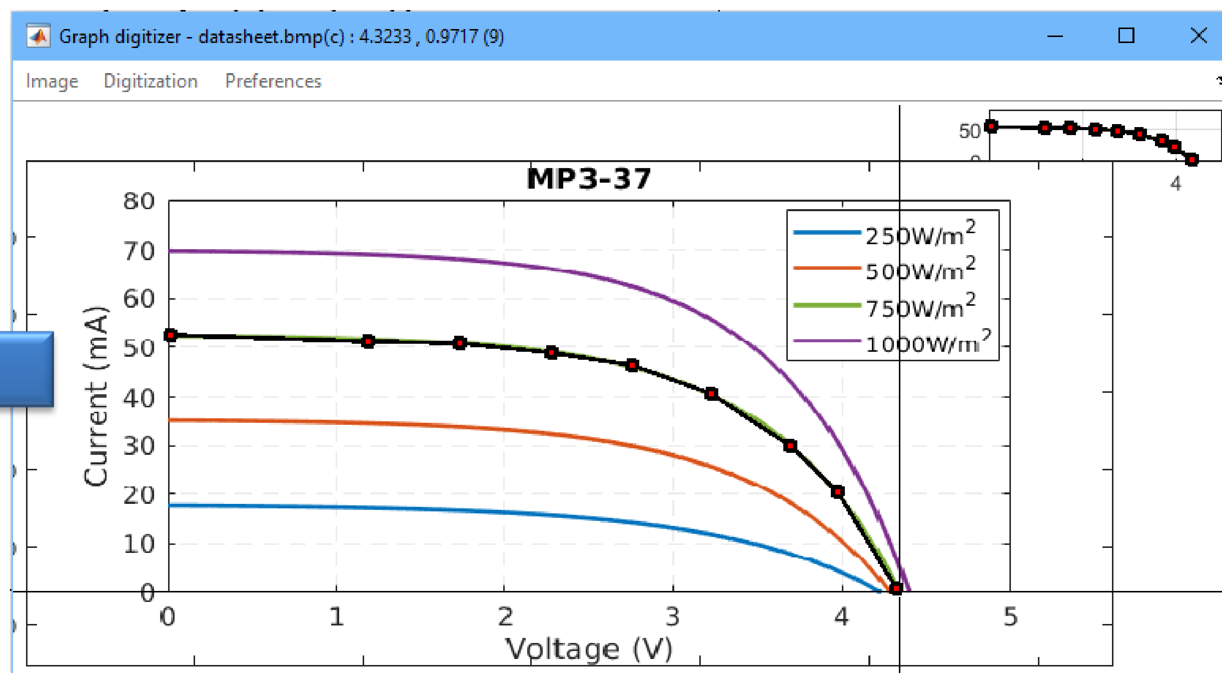
- How to use the digitizer tool:
  3. Select samples of one curve
     - Mouse left button = new sample
     - Mouse middle button = stop inserting samples
  4. Save to file



Photovoltaic cell block

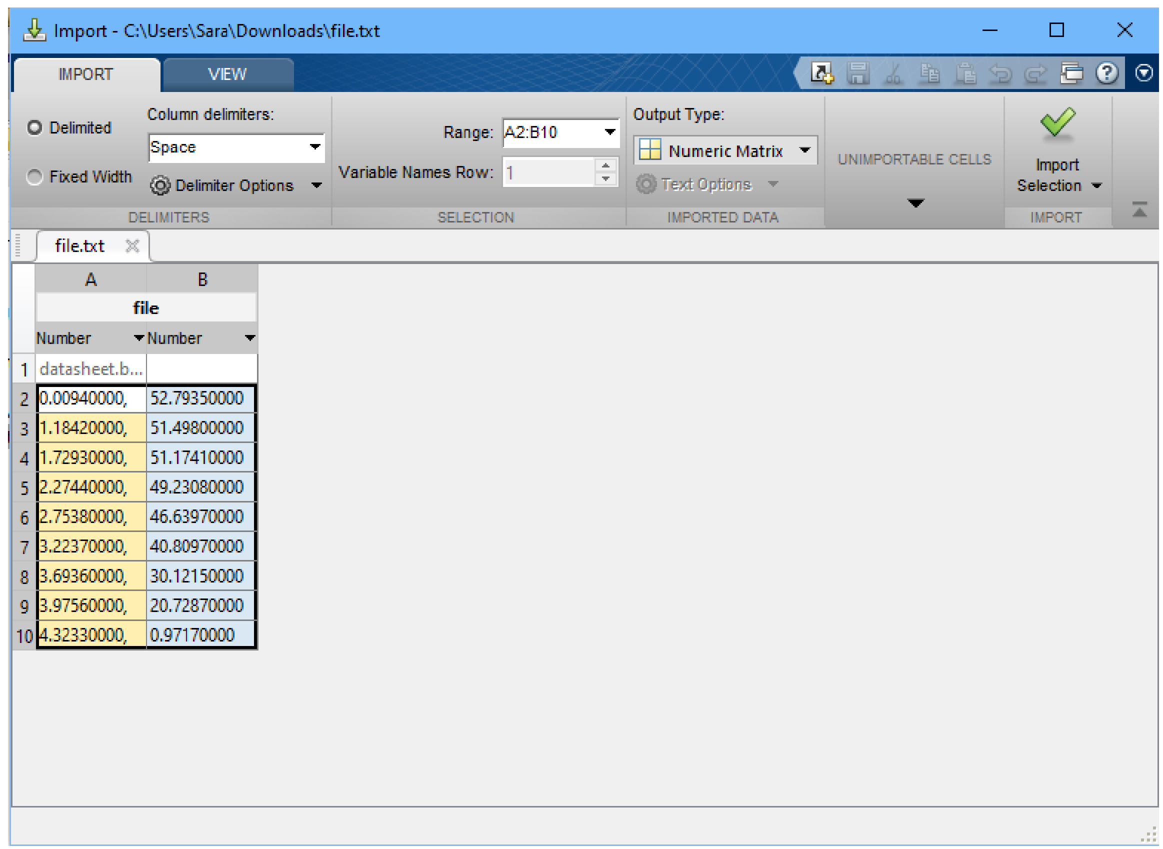
- How to use the digitizer tool:
  3. Select samples of one curve
     - Mouse left button = new sample
     - Mouse middle button = stop inserting samples
  4. Save to file

```
datasheet.bmp
 0.00940000, 52.79350000
 1.18420000, 51.49800000
 1.72930000, 51.17410000
 2.27440000, 49.23080000
 2.75380000, 46.63970000
 3.22370000, 40.80970000
 3.69360000, 30.12150000
 3.97560000, 20.72870000
 4.32330000,  0.97170000
```



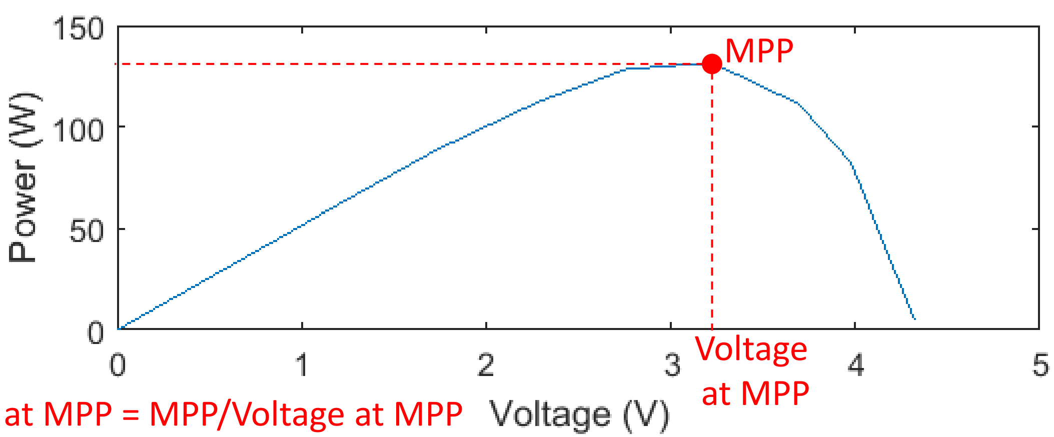
Photovoltaic cell block

- Each file represents one curve
- Import the file in Matlab:
  - Home > Import data > Select the file
  - File as a matrix variable



Photovoltaic cell block

- Each file represents one curve
- Import the file in Matlab
- To extrapolate MPP:
  - Build the corresponding power curve
  - Extrapolate V and I at the MPP
    - I.e., voltage and current corresponding to the maximum value of power for this curve



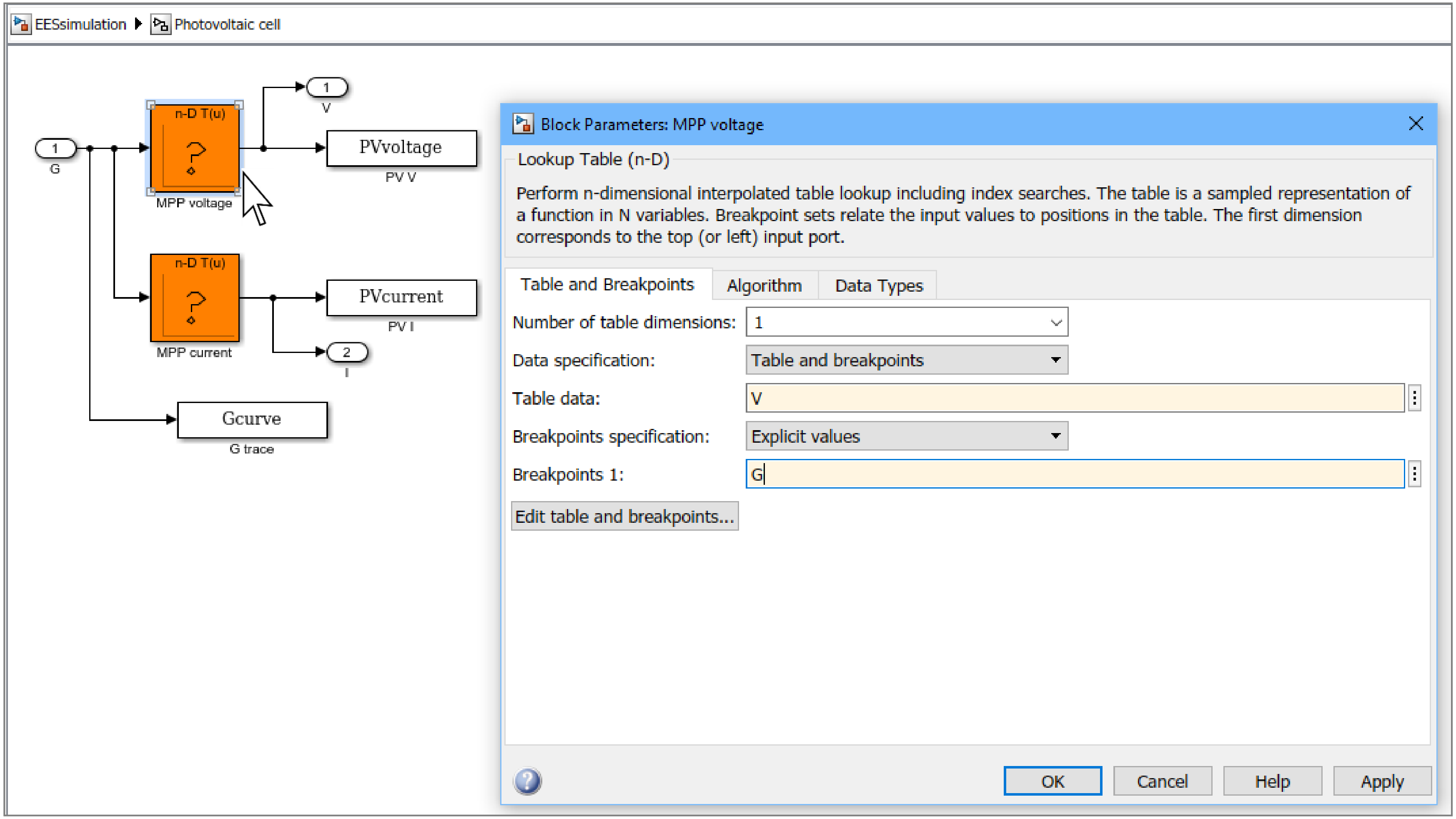
Current at MPP = MPP/Voltage at MPP
e.g., 131.56/3.22 = 40.81

datasheet.bmp
0.00940000, 52.79350000
1.18420000, 51.49800000
1.72930000, 51.17410000
2.27440000, 49.23080000
2.75380000, 46.63970000
3.22370000, 40.80970000
3.69360000, 30.12150000
3.97560000, 20.72870000
4.32330000, 0.97170000

Photovoltaic cell block

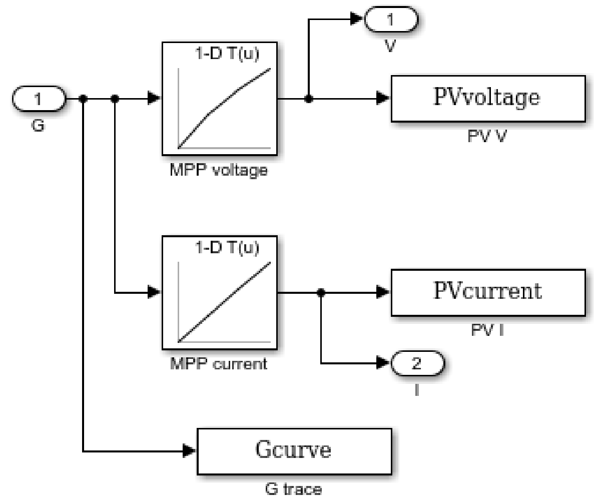
- Populate the lookup tables:
  - Vector of values of G:
    - `G = [250; 500; 750; 1000];`
  - Vector of corresponding values of current at the MPP
    - `I = [I250; I500; I750; I1000];`
  - Vector of corresponding values of voltage at the MPP
    - `V = [V250; V500; V750; V1000];`
  - Write the name of the variables in the configuration pane of the loopup tables
    - Breakpoints = G
    - Table values = V or I (corresponding values)

Photovoltaic cell block



Photovoltaic cell block

- If everything went well, your lookup tables should now look like:



- Lookup table output:
  – If input irradiance is one of the sampled values, the lookup table outputs the corresponding value of voltage/current
  – Else, the lookup table interpolates between the available samples and estimate the value of voltage/current