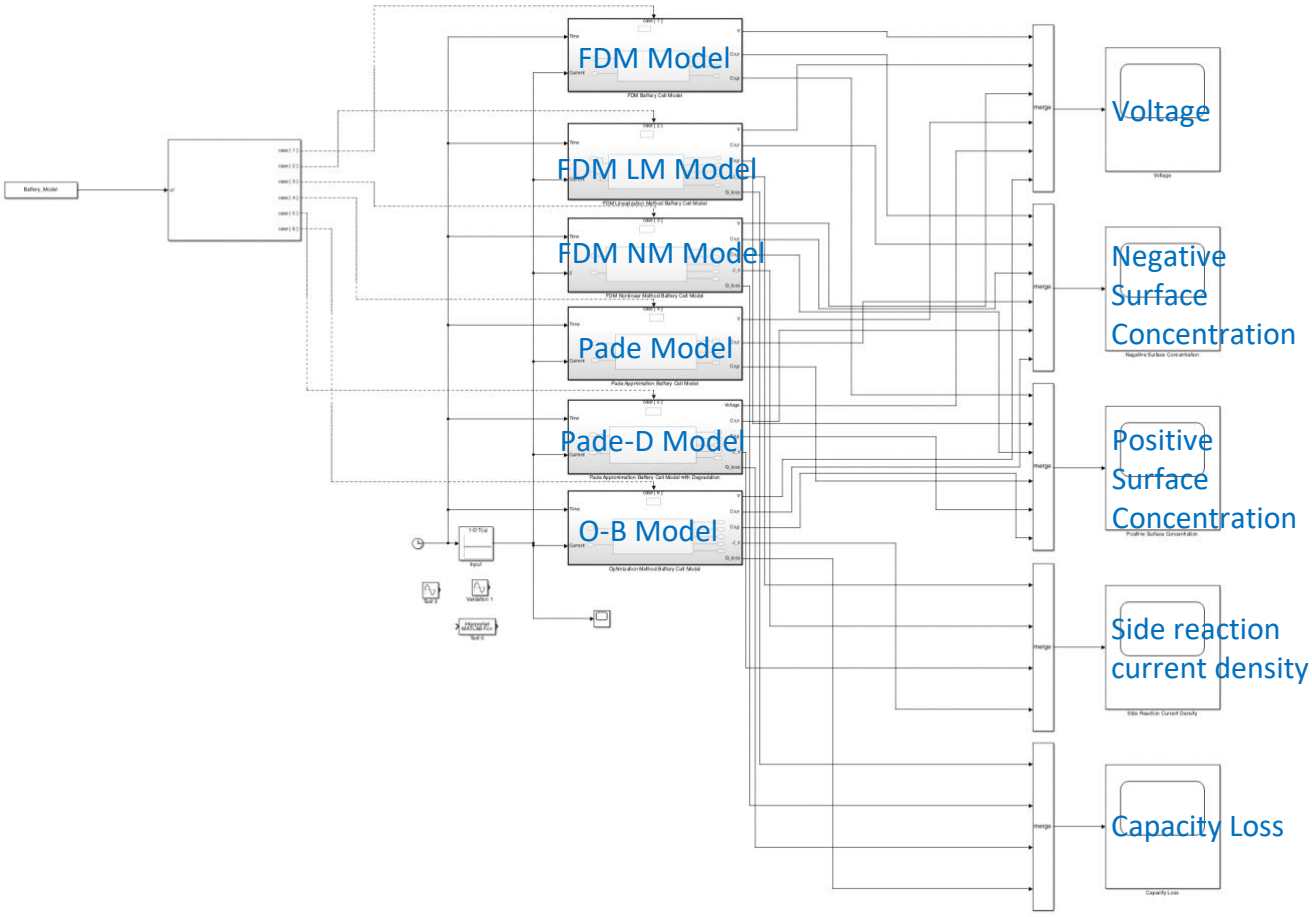
Lithium-Ion Battery Single Particle Model Tutorial

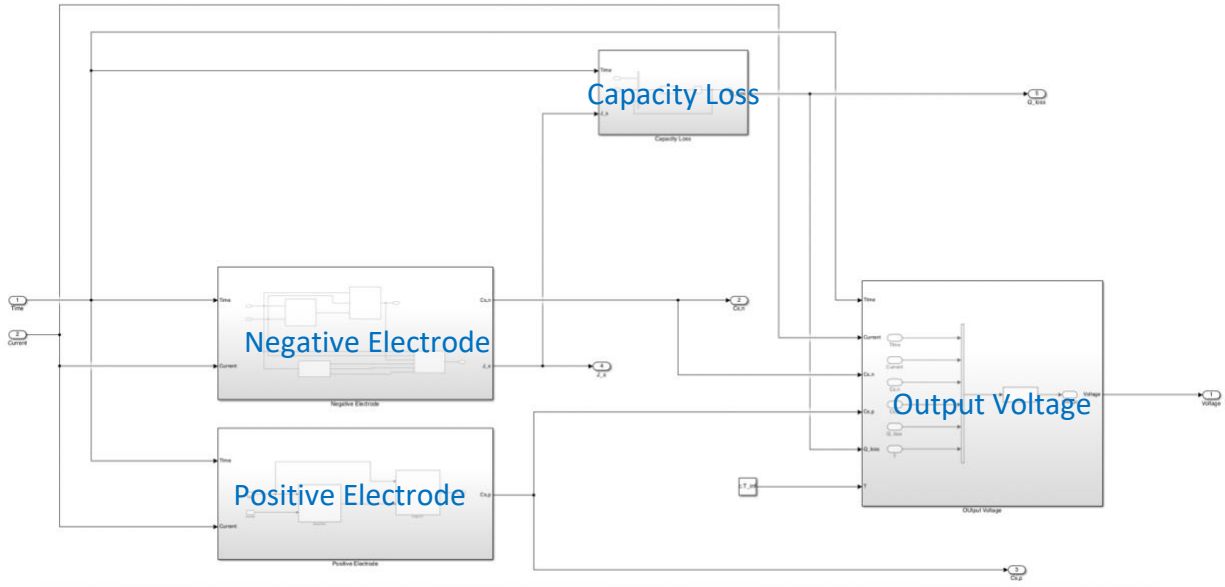
Lithium-Ion Battery Single Particle Model is the code to simulate the lithium-ion battery cell model.
The code contains various models.

(1) Finite Difference Method Model without Degradation. (FDM Model)
(2) Finite Difference Method Model with Linearized Degradation. (FDM LM Model)
(3) Finite Difference Method Model with Nonlinear Degradation. (FDM NM Model)
(4) Pade Approximation Model without Degradation (Pade Model)
(5) Pade Approximation Model with Degradation (Pade-D Model)
(6) Optimization-Based Model (O-B Model)

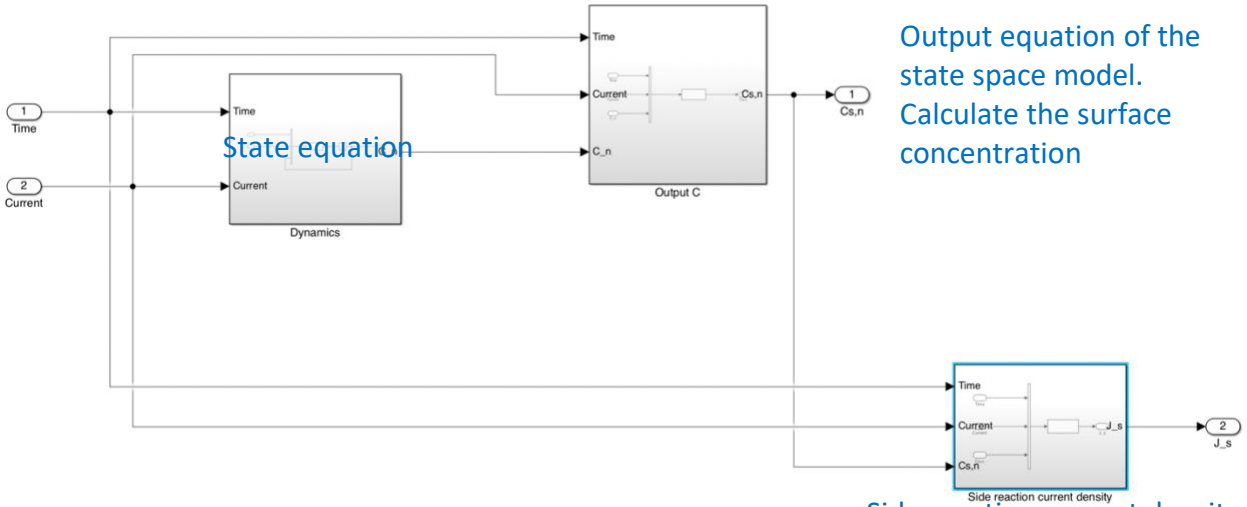
1) Simulink (Open “battery_cell_model.slx”)



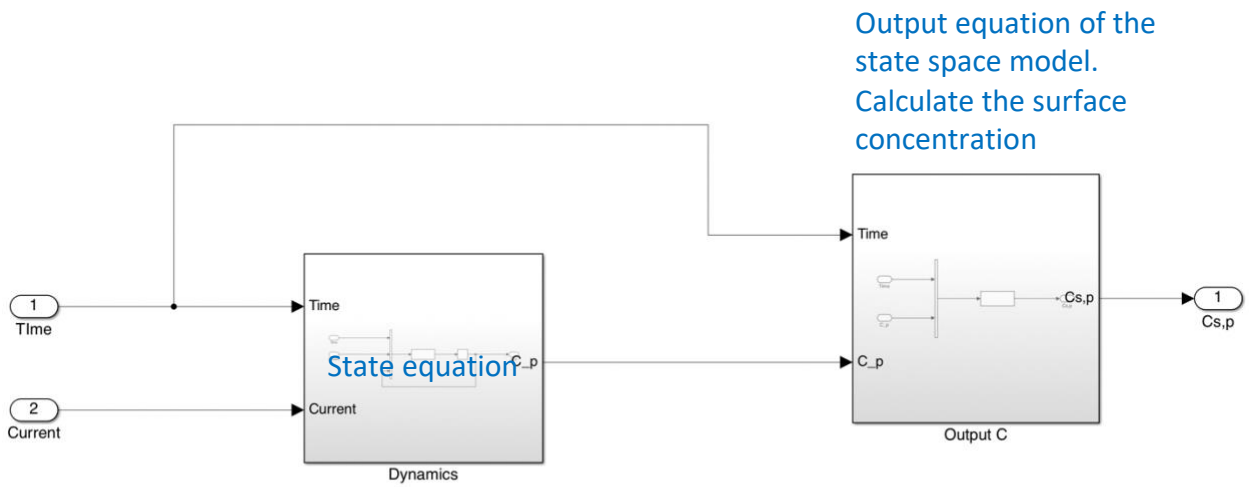
Battery Cell



Negative Electrode



Positive Electrode



2) MATLAB File

To run the code, open the file "RUN_ROM_battery_cell.m"

Following steps are the setup to run the battery cell model.

(1) You have to choose what model you are going to run. (FDM Model, FDM_LM Model, FDM_NM Model etc.)

```
%%Choose what model are you going to run
Battery_Model = 2; % 1: FDM Model without Degradation (FDM)
                   % 2: FDM Model with Linearized Degradation (FDM LM)
                   % 3: FDM Model with Nonlinear Degradation (FDM NM)
                   % 4: Pade Model without Degradation (Pade)
                   % 5: Pade Model with Degradation (Pade-D)
                   % 6: Optimization Model (O-B Model)
```

(2) After you choose the battery cell model, you have to select what parameters you are going to use. Skip this part if you select the model that does not contain a degradation model

In this code, we have two options. First is 'SD' (General Parameters). Second is 'BD' (Increased Parameters)

```
Parameters = 'SD'; %SD: General Parameters
                   %BD: Increased Parameters (Boosted Parameters)
load([Parameters,'.mat'])
```

(3) Select the model's order

FDM Model & FDM LM Model

```
%%select which order model are you going to simulate
%_____________________________________________________________________

%FDM Model
FDM_N = 33;

%_____________________________________________________________________

%FDM LM Model (Lin)
FDM_LM_N = 50;
```

FDM NM Model

```
%FDM NM Model
%load NM Map
NM_map = ['degradation_map_',Parameters,'.mat'];


FDM_NM_N = 50;
```

In FDM NM Model, we have to load the nonlinear map to calculate the negative surface concentration. There are two nonlinear maps. `'degradation_map_SD.mat'` is for 'SD'. `'degradation_map_BD.mat'` is for 'BD'.

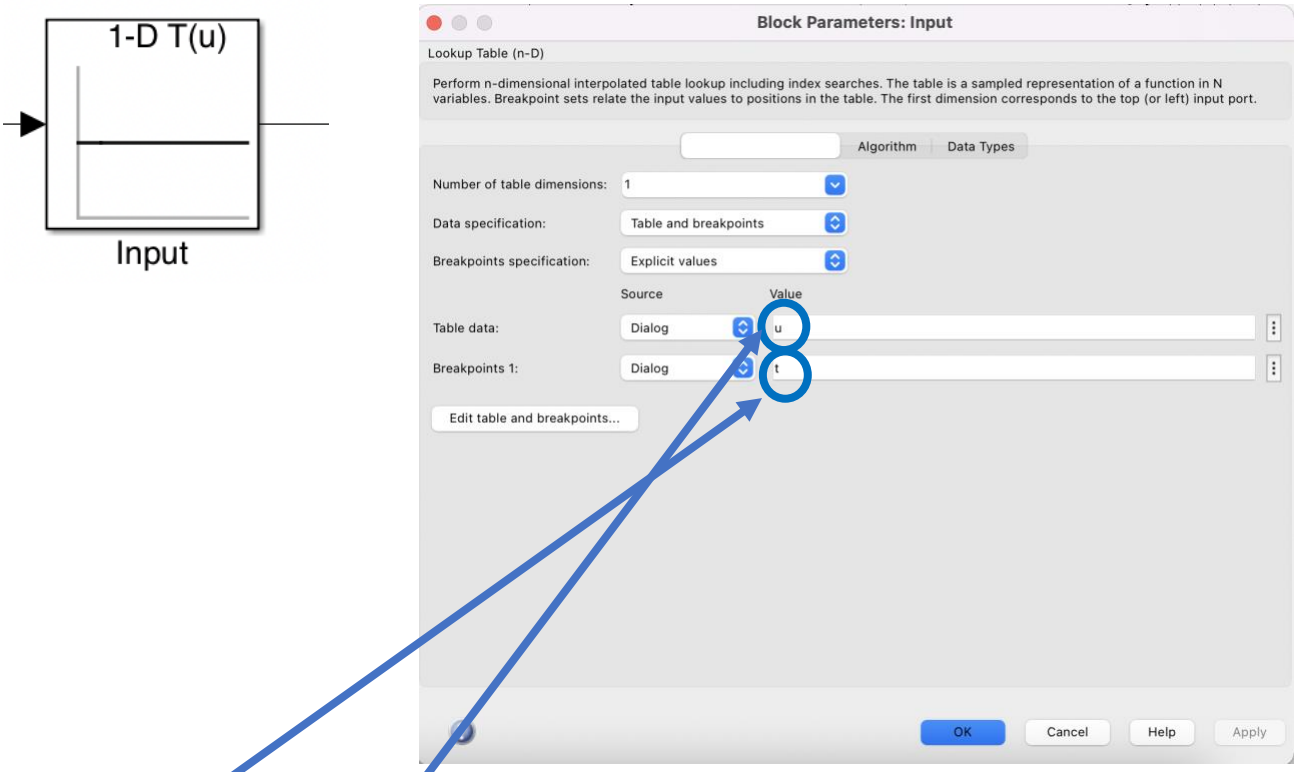
Pade Model & Pade-D Model

```
%Pade Model
%Pade Model Coefficients
load('Pade_coefficients.mat')

Pade = 6;
PN = Pade_6_n; %negative electrode pade approximation coefficients
PP = Pade_6_p; %positive electrode pade approximation coefficients

%_____________________________________________________________________

%Pade-D Model
%Pade-D Model Coefficients
load(['Pade_D_coefficients_',Parameters,'.mat'])

Pade_D = 4;
PN_D = Pade_4_n_D; %negative electrode pade approximation coefficients
PP_D = Pade_4_p_D; %positive electrode pade approximation coefficients
```

O-B Model

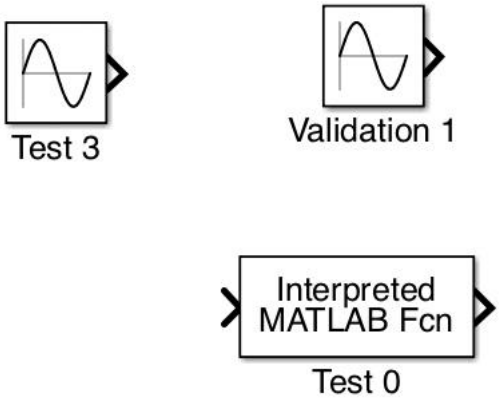
```
%O-B model
%O-B Model design variables
load(['design_variables_data_',Parameters,'.mat'])

ROM_order = 4;
theta_n = n4; %negative electrode design variables data
theta_p = p4; %positive electrode design variables data
```

(4) Setup the input current




```
%_____________________________________________________________________
%%input current
t = [0 1000 7000];
u = [-1  -1 -1];

% file_name = 'UDDS_current_profile_7000.mat';
% test_data = load(file_name);
% t = test_data.time;
% u = test_data.UDDS_current_profile;
```

If you want to use the 1-D look up table block you have to setup the ‘t’ and ‘u’ variables.



Or you can setup the various input current using Simulink block as shown above. (Sinusoid wave, square wave etc.)

(5) Initial Condition

In initial condition part, the only thing you have to change is “line 137”.

```
137 -    x1_initial = 0.5*Q_nom; %charge level
```

(6) Linearized side reaction current density coefficients (minor step)

```
%If you want to linearized the side reaction current density in different
%value you have to change below parameters.
c.c_bar = n.c_max_n*0.5;
c.u_bar = 0;
```

Remind below equation.

$$J_s \approx \bar{J}_s + \alpha\left(c_{s,n} - \bar{c}_{s,n}\right) + \beta(I - \bar{I})$$

$$\alpha = \left.\frac{\partial J_s}{\partial c_{s,n}}\right|_{\bar{c}_{s,n},\bar{I}} \quad and \quad \beta = \left.\frac{\partial J_s}{\partial I}\right|_{\bar{c}_{s,n},\bar{I}}$$

Line 174 – Line 197 is the code to calculate the $\alpha, \beta, and\ \bar{J}_s$.

(7) Setup the time range

```
t_final = 10;

sim('battery_cell_model.slx',t_final)

save ROM_battery_cell_SD_v2_lt_3.mat
```