Hand-On Model Physical System in various fidelity level

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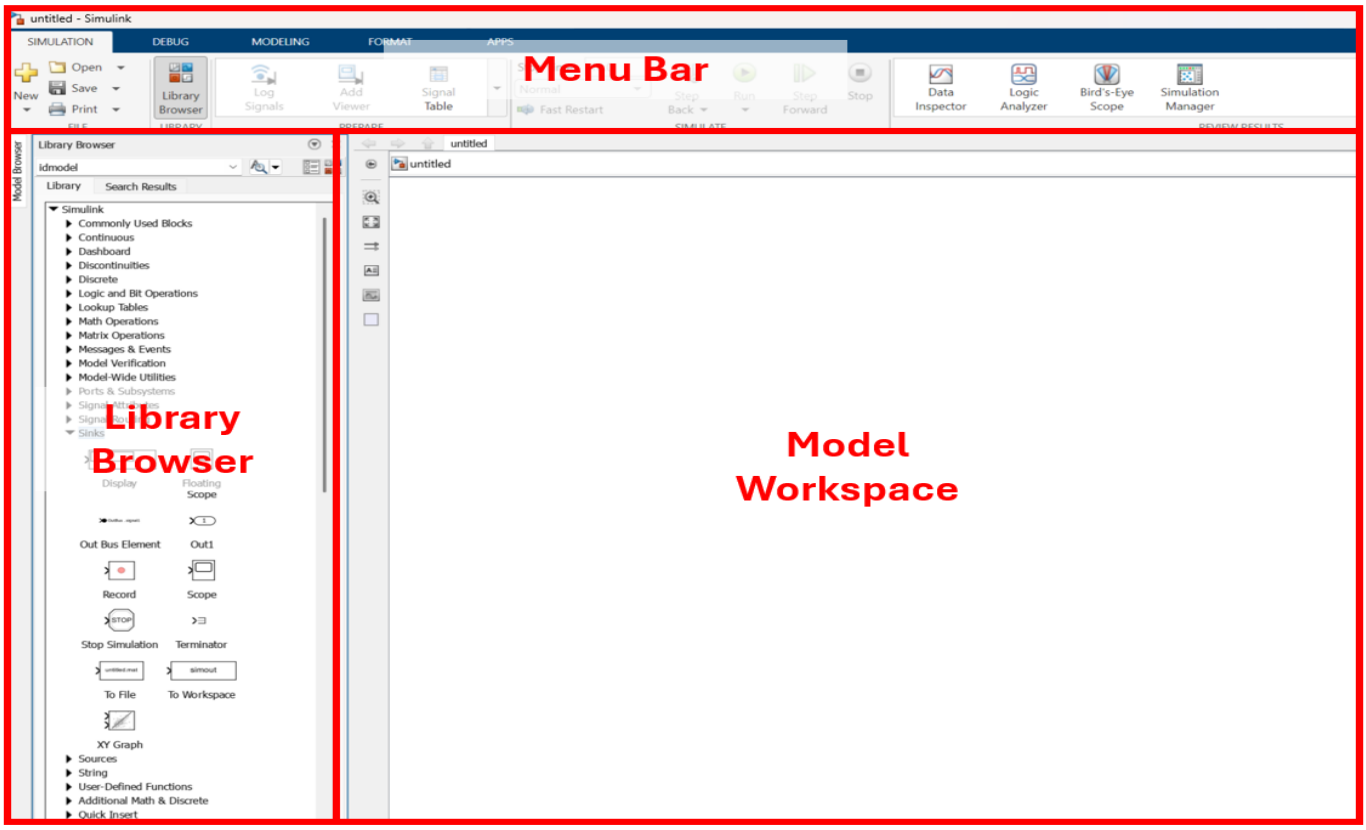
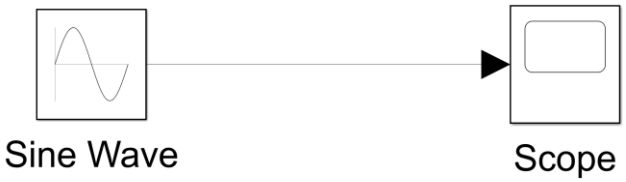
Introduction to Simulink

Simulink

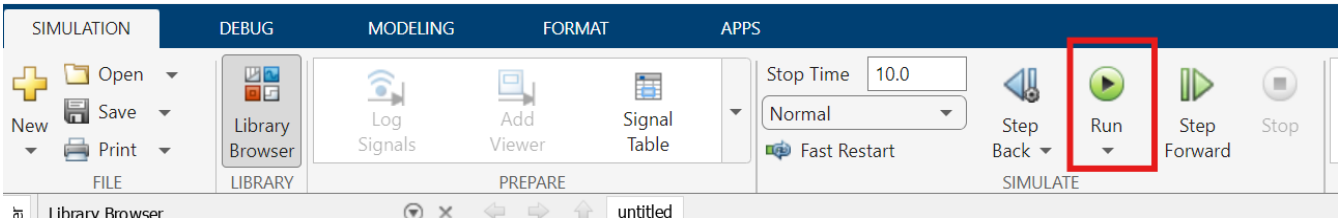


Task 0-1: Simulink block and Simulation

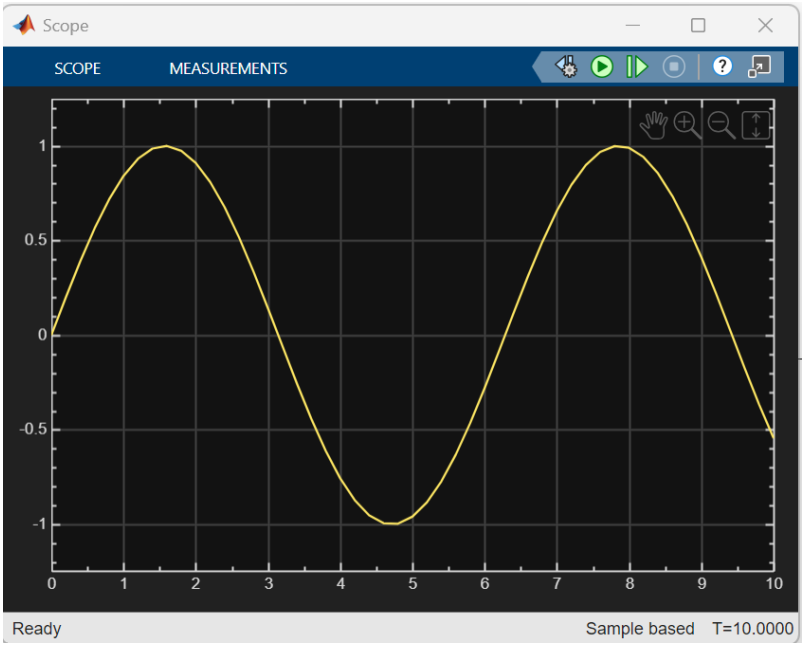
- Drag and Drop "**Sine Wave**" block from "**Simulink>Sources**" to the workspace
- Drag and Drop "**Scope**" block from "**Simulink>Sink**" to the workspace
- Connect the signal from "**Sine Wave**" to "**Scope**"



- Start simulate the system by clicking "**Run**" at Simulate section

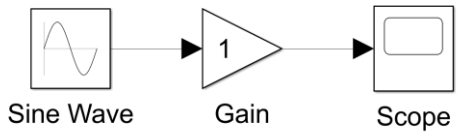


- Check the output by double click at "**Scope**"

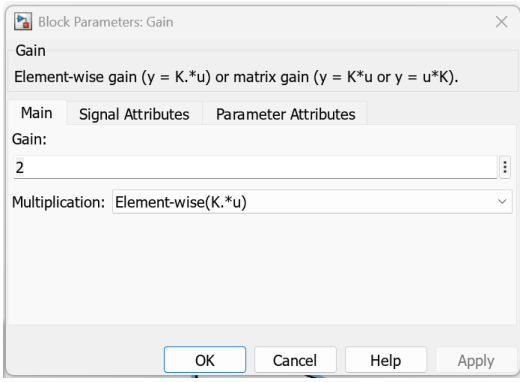


Task 0-2: Math calculation

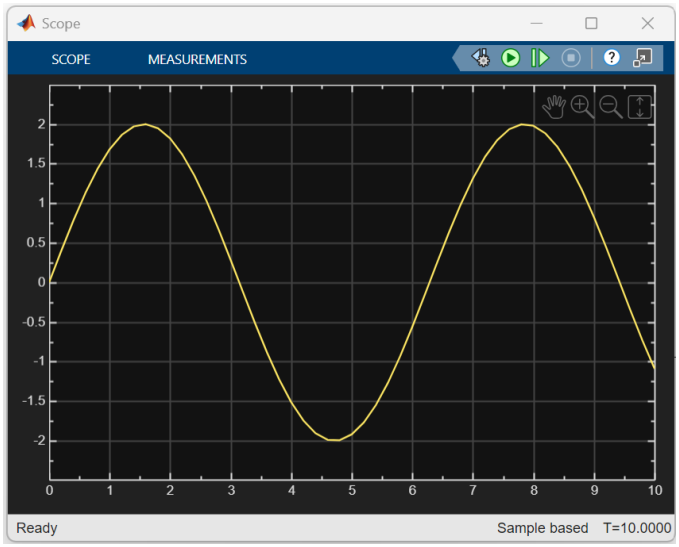
- Drag and Drop "**Gain**" block from "**Simulink>Math Operations**" to the workspace
- Place the "**Gain**" block in the signal line between "**Sine Wave**" and "**Scope**" block



- Double click at "Gain" block and Change the gain value to 2

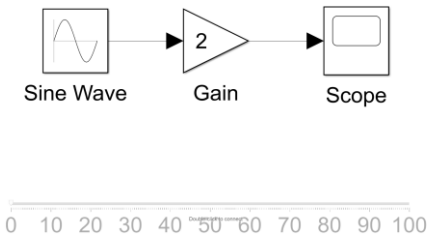


- Start simulate the system by clicking "**Run**" at Simulate section
- Check the output by double click at "**Scope**"

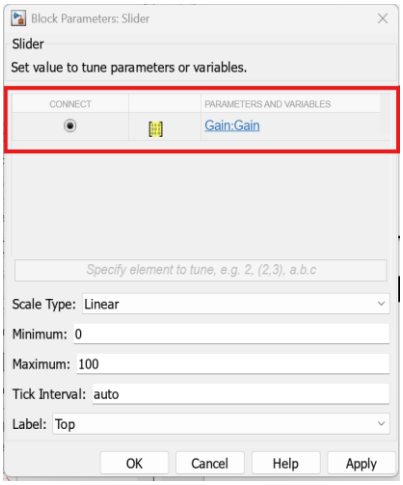


Task 0-3: Dashboard control

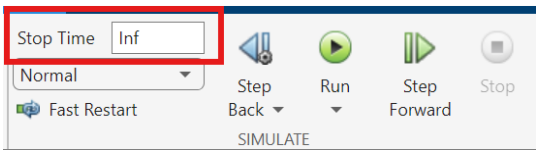
- Drag and Drop "**Slider**" block from "**Simulink>Dashboard**" to the workspace



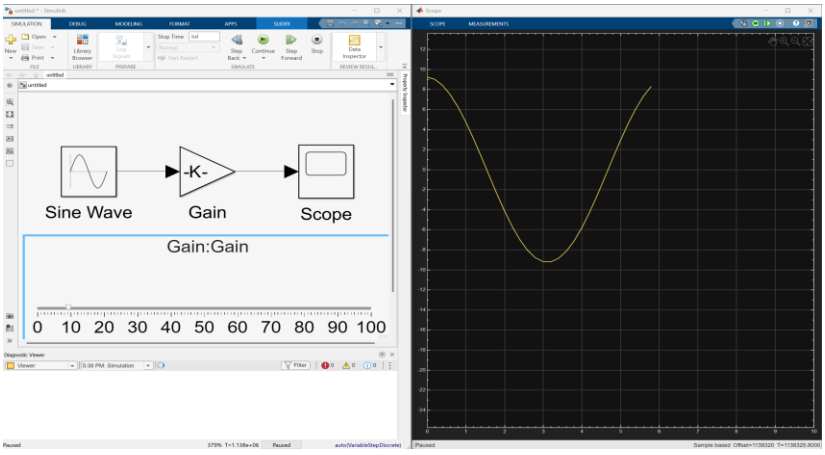
- Double click at "**Slider**" --> Select "**Gain**" block --> Click at "**Connect**" check of the gain value --> Click "**OK**" to confirm



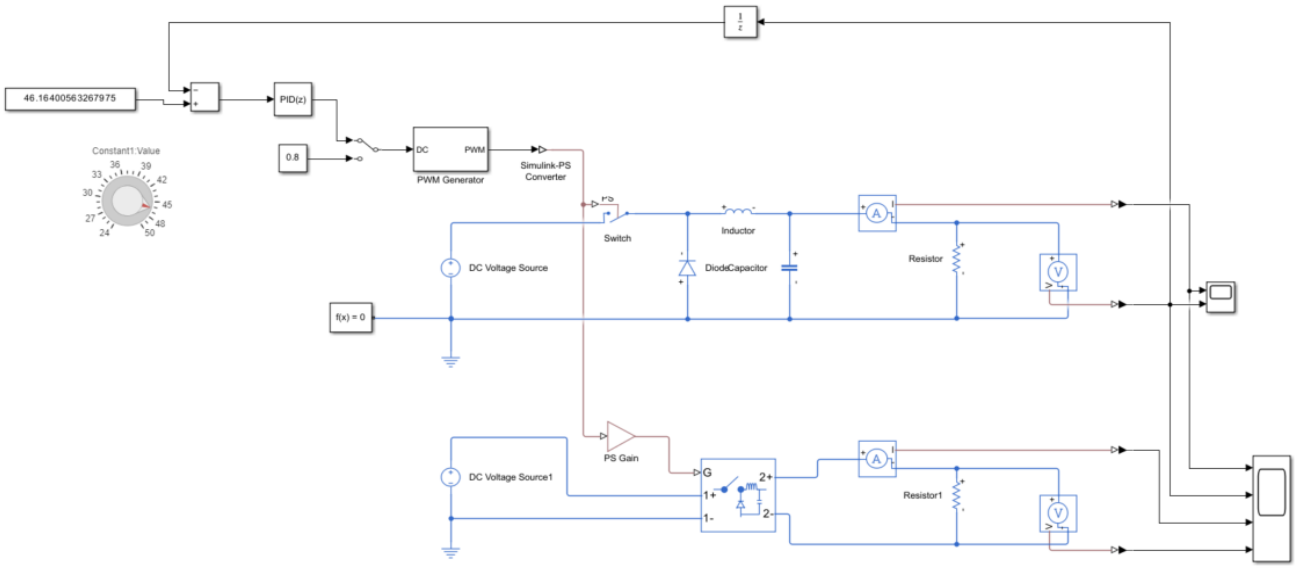
- Change "**Stop Time**" to "**Inf**"



- Try to Slide the "**Slider**" bar and see the changed of Sine Wave at "**Scope**"



Model Physical System in various fidelity level



Task 1: Create fundamental Buck converter circuit

1. Drag the block from

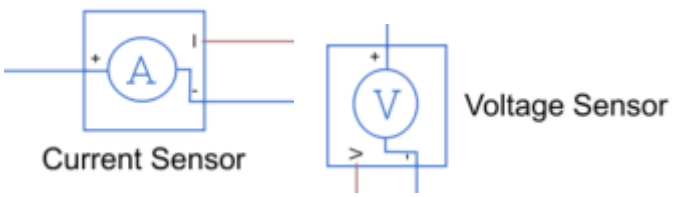
Simscape>Foundation Library>Electrical Sources

Simscape>Foundation Library>Electrical Element

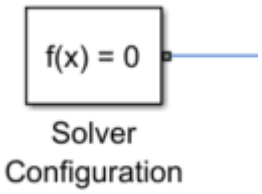
Component Values

$$R = 1\,\Omega, \quad L = 3\,\text{mH} = 3 \times 10^{-3}\,\text{H}, \quad C = 10\,\mu\text{F} = 10 \times 10^{-6}\,\text{F}$$

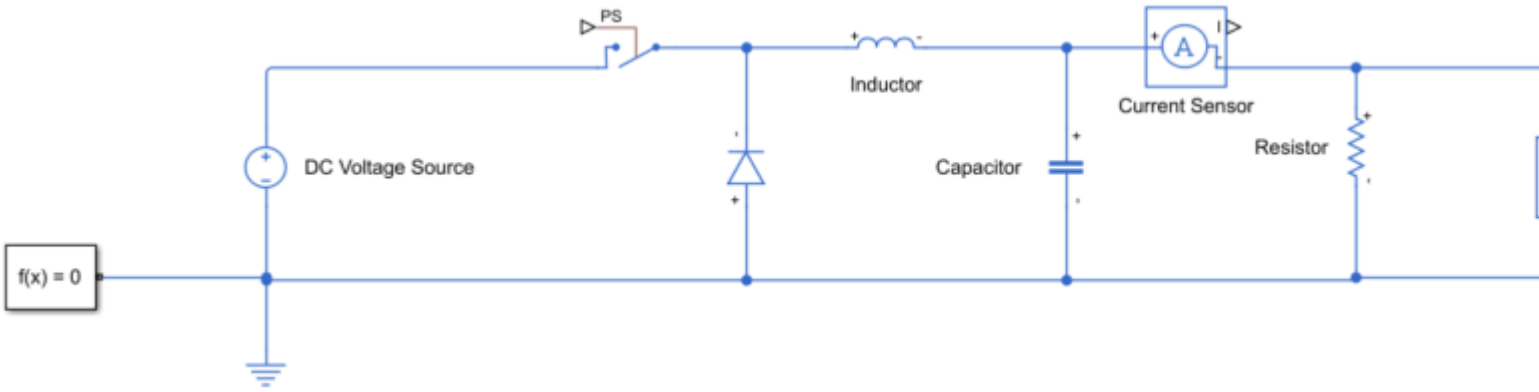
Simscape>Foundation Library>Electrical Sensor



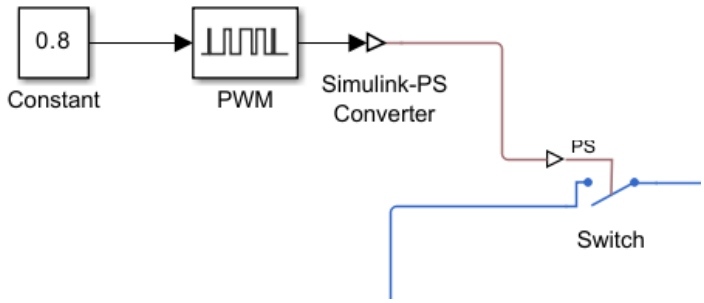
Simscape>Utilities

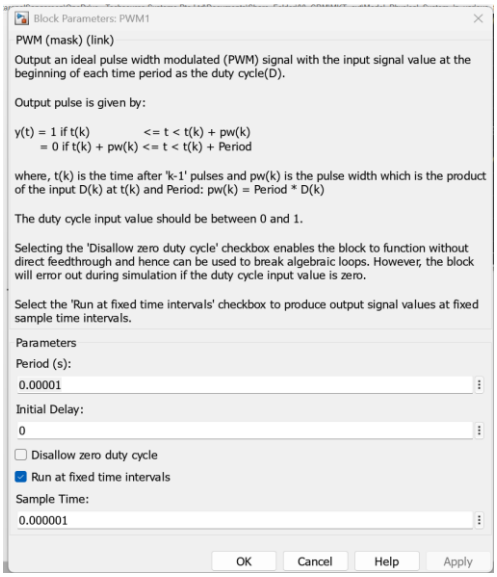


2. Connect Buck converter circuit

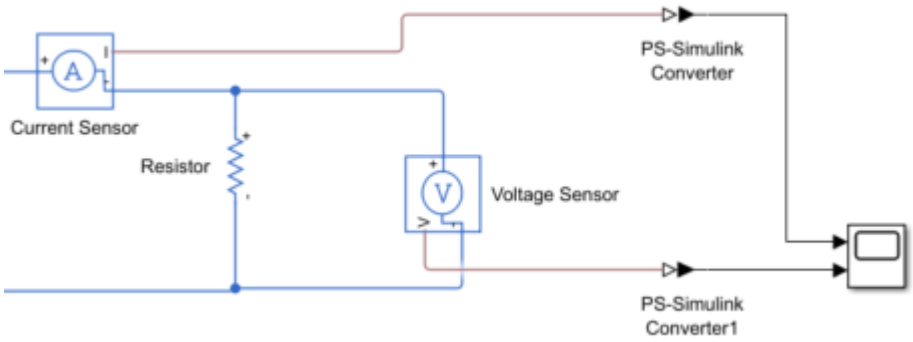


3. Adding "PWM" to input "Switch" Block, Set up constant at 0.8 for duty cycle, Set Period to 1e-5, Sample time at 1e-6



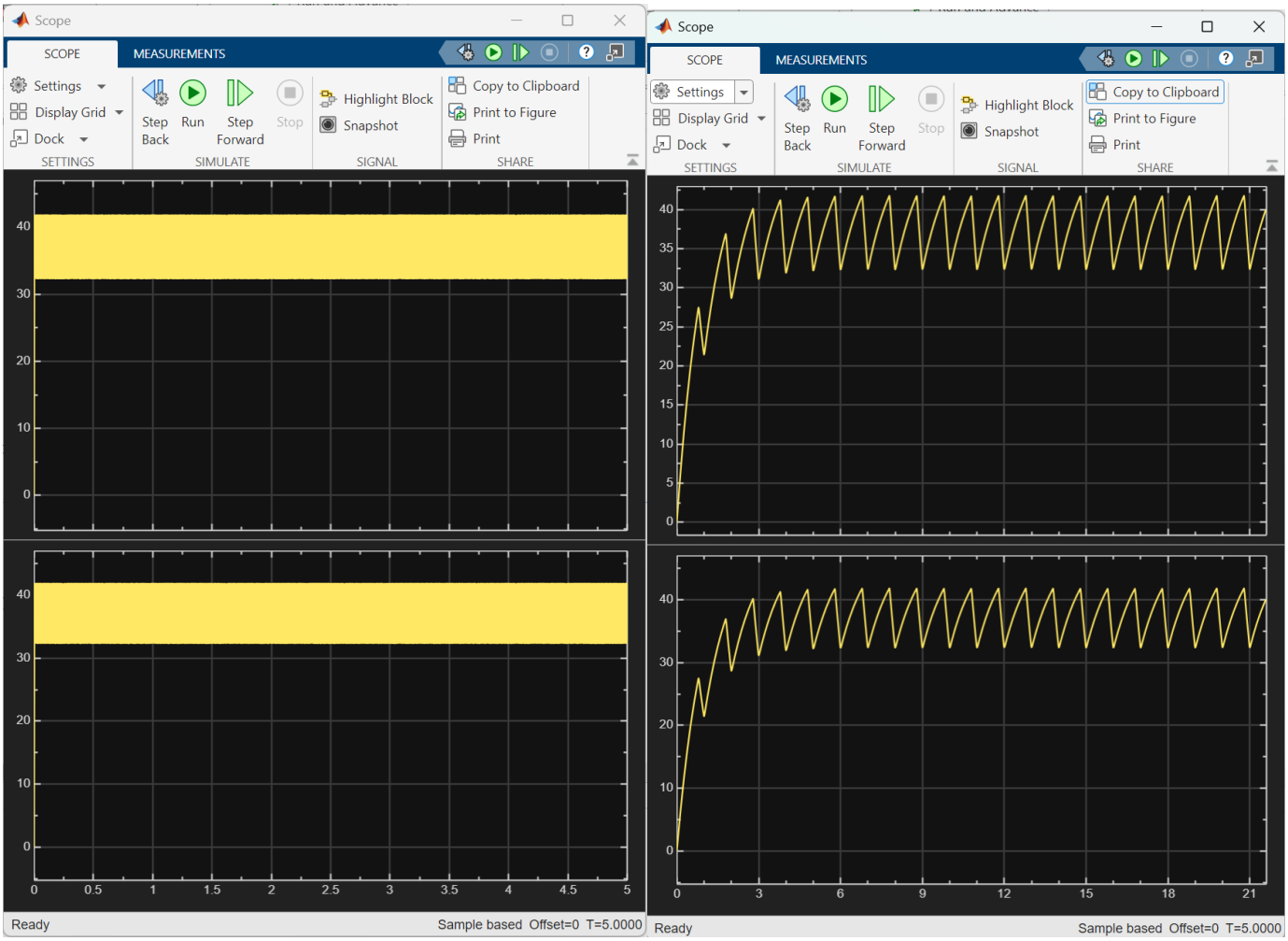


4. Adding "Scope" Block to see the output



5. Change simulation stop time to 5 second and click "Run" to start the simulation --> Check the result at "Scope" block

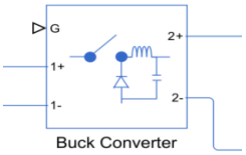
*You may zoom in to scope down the time at 0 - 0.005 to see the transient response



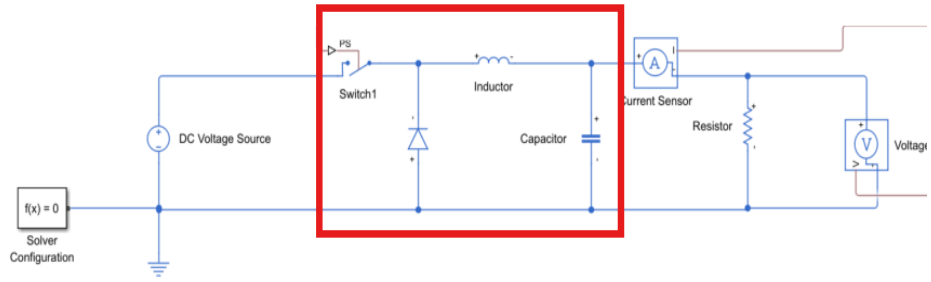
Task 2: Create built-in Buck converter circuit from Simscape Electrical

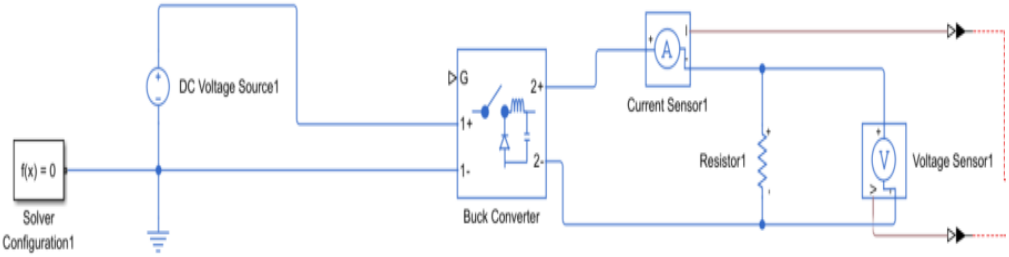
1. Drag the block from

Simscape>Electrical>Semiconductors & Converters>Buck Converter

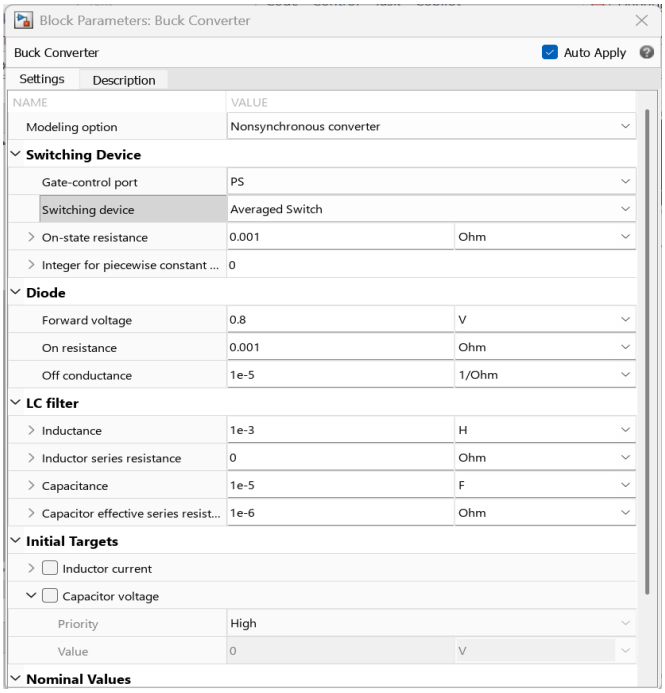


2. Replace the "Buck Converter" block to the previous circuit



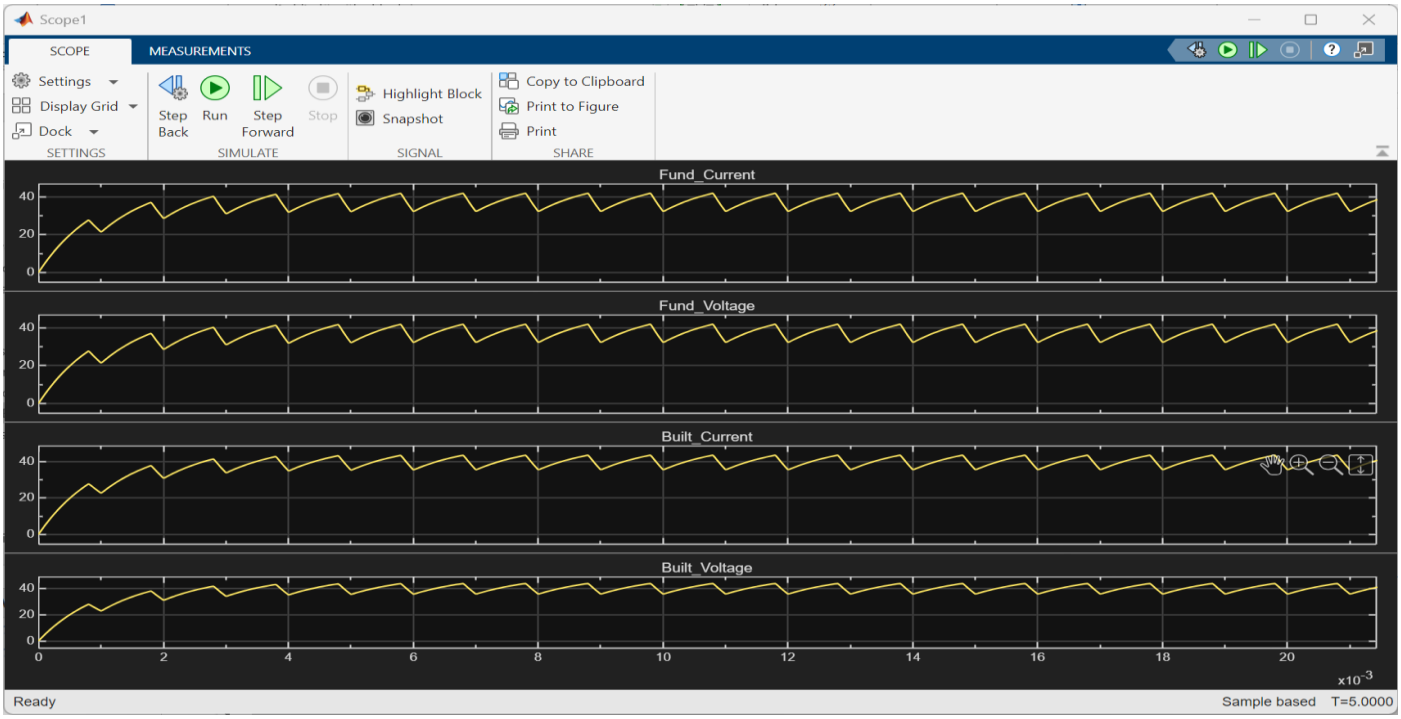


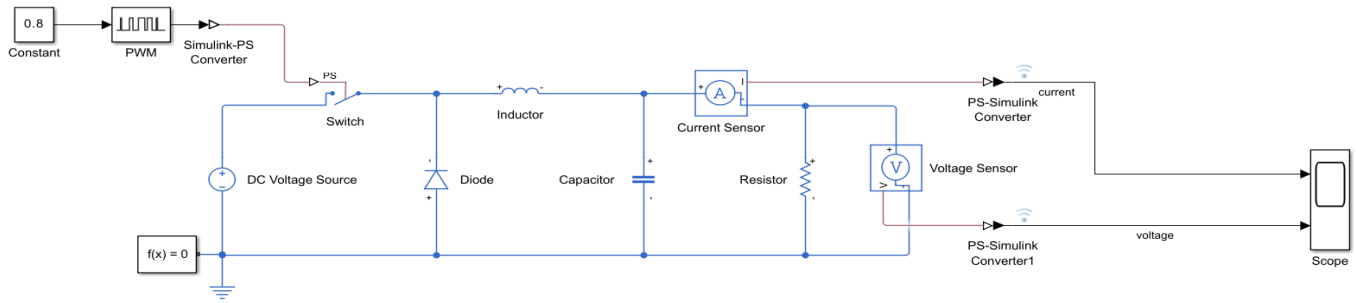
3. Set the parameter as setting in the previous model

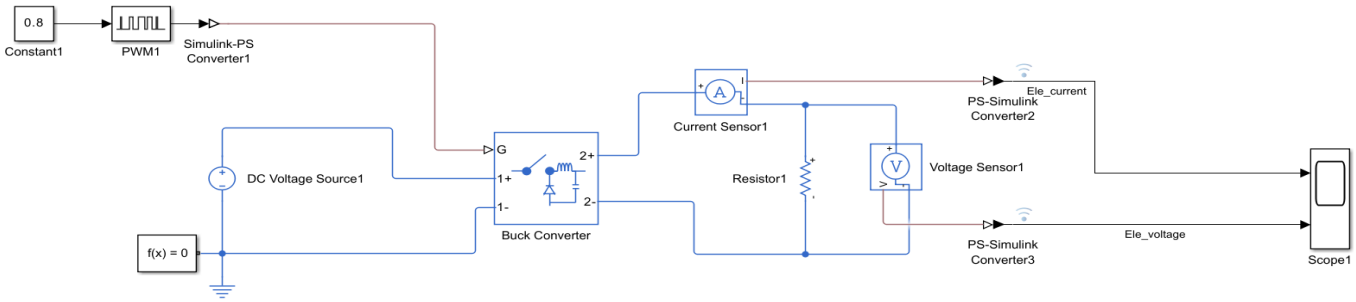


4. Change simulation stop time to 5 second and click "Run" to start the simulation --> Check the result at "Scope" block

*You may compare the different between 2 approch model by merge the signal to the same scope



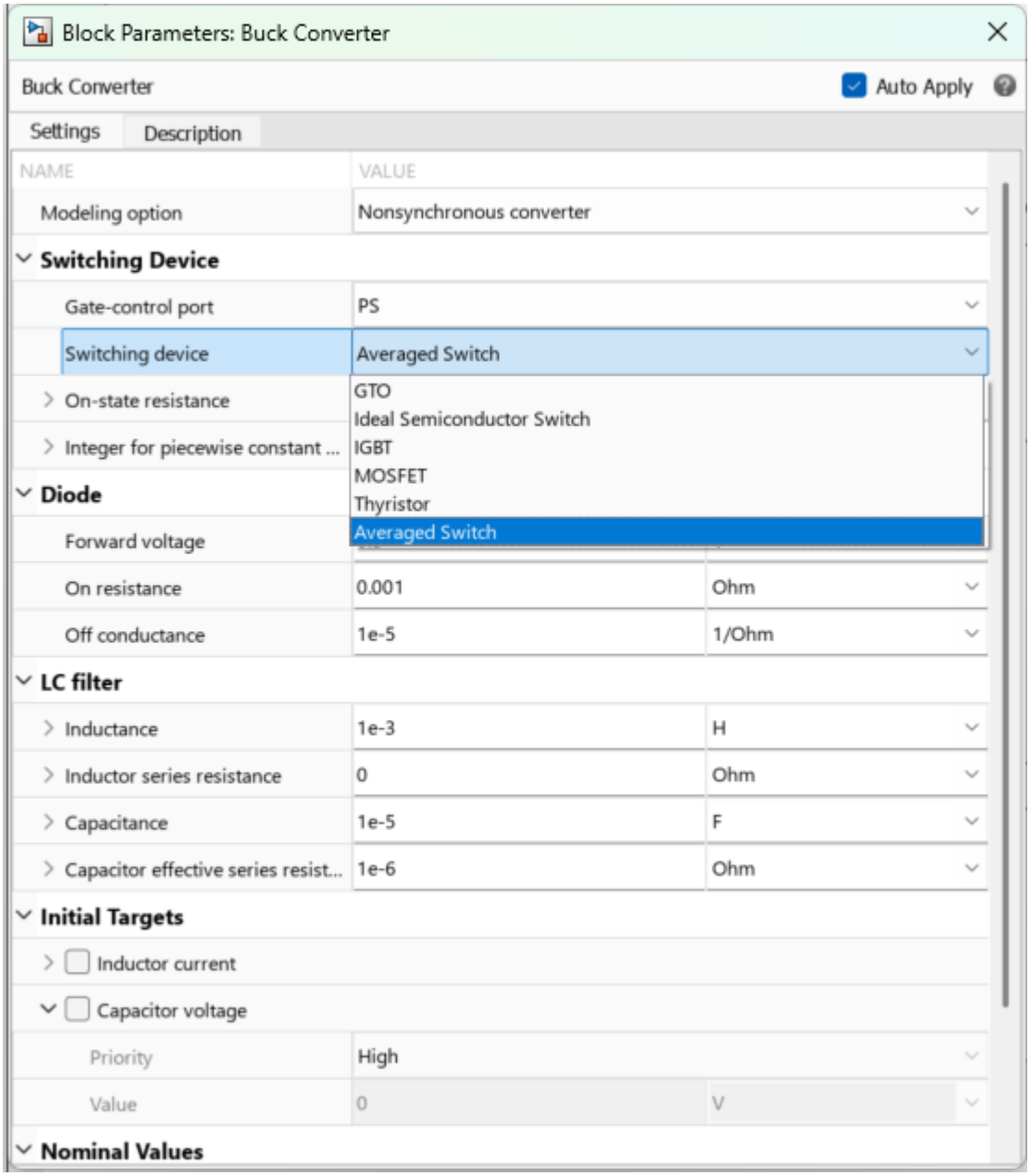




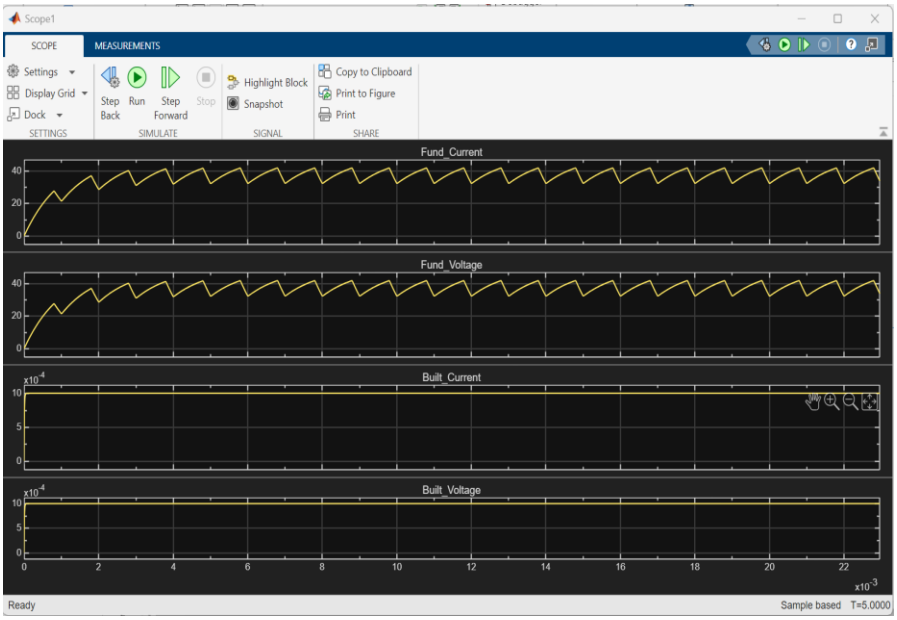

```
open("Buck_Converter_2_approch.slx")
```

Task 3: Achieve higher fidelity model by configuration parameter

1. Checking "Buck Converter" Block parameter --> Checking "Switching device" --> Change to "Ideal Semiconductor Switch"

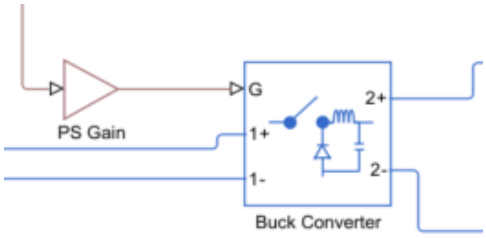


2. Change simulation stop time to 5 second and click "Run" to start the simulation --> Check the result at "Scope" block compare to the fundamental circuit

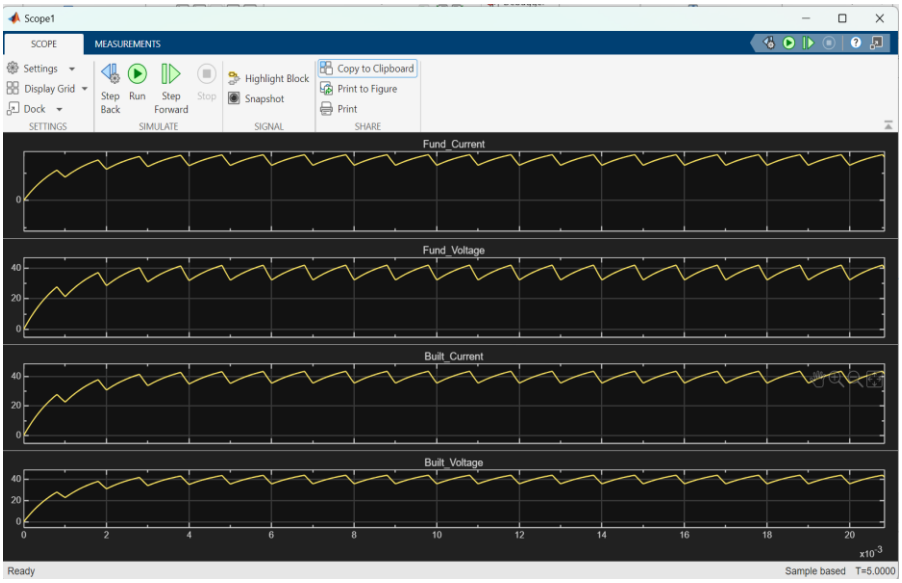


3. Add "PS Gain" from **Simscape>Foundation Library>Physical Signals** between PWM signal to Gate of "Buck Converter" --> Set the gain at 12

*PWM voltage signal need to be more than threshold to drive the gate open (More fidelity)

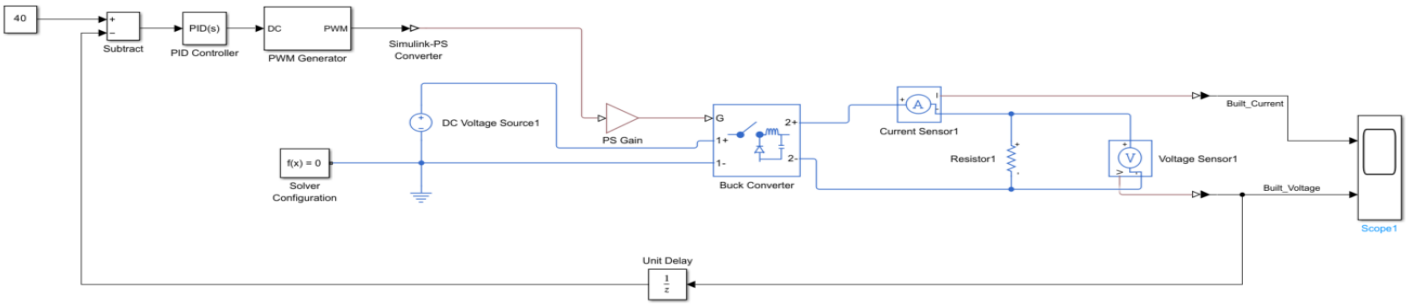


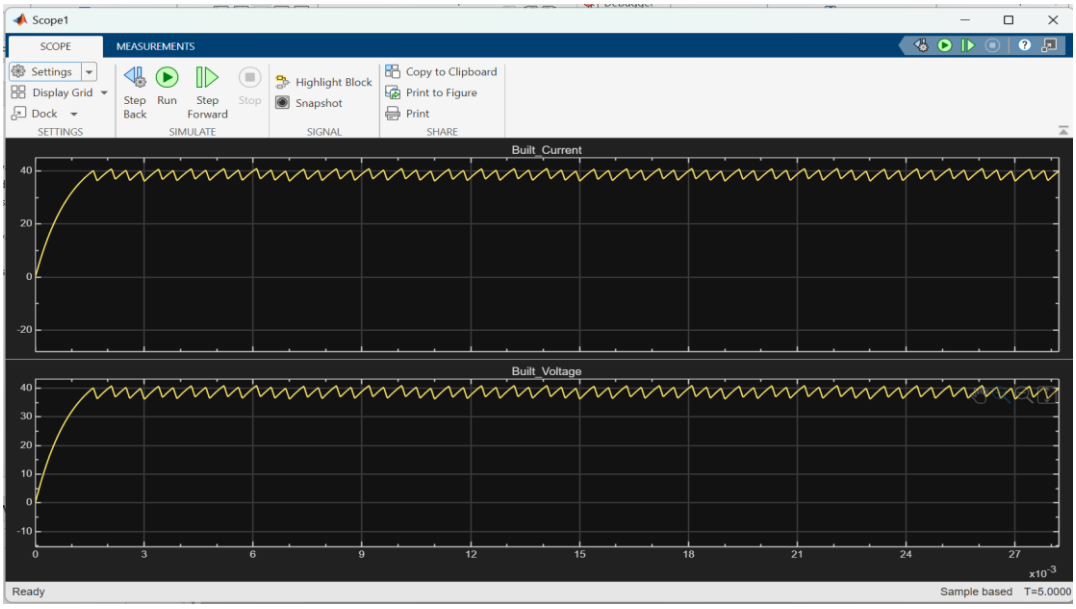
4. Simulation again and checking the scope



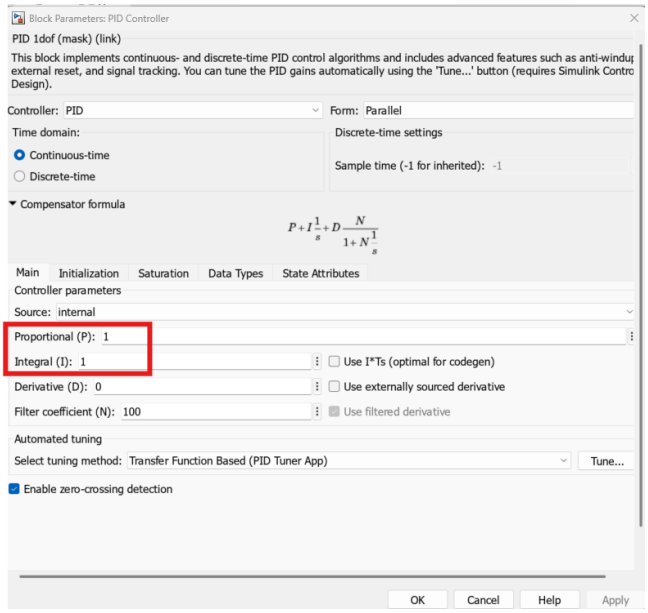
Task 4: Voltage control with PID controller

1. Adding "Unit Delay" block to feedback the Output volage of Buck converter
2. Adding "Subtract" block --> Subtract "Feedback voltage" with constant (Set as 40 for the default setpoint) to get the error value
3. Adding "PID controller" to make the PID control --> Sending the PWM control to PWM Generator



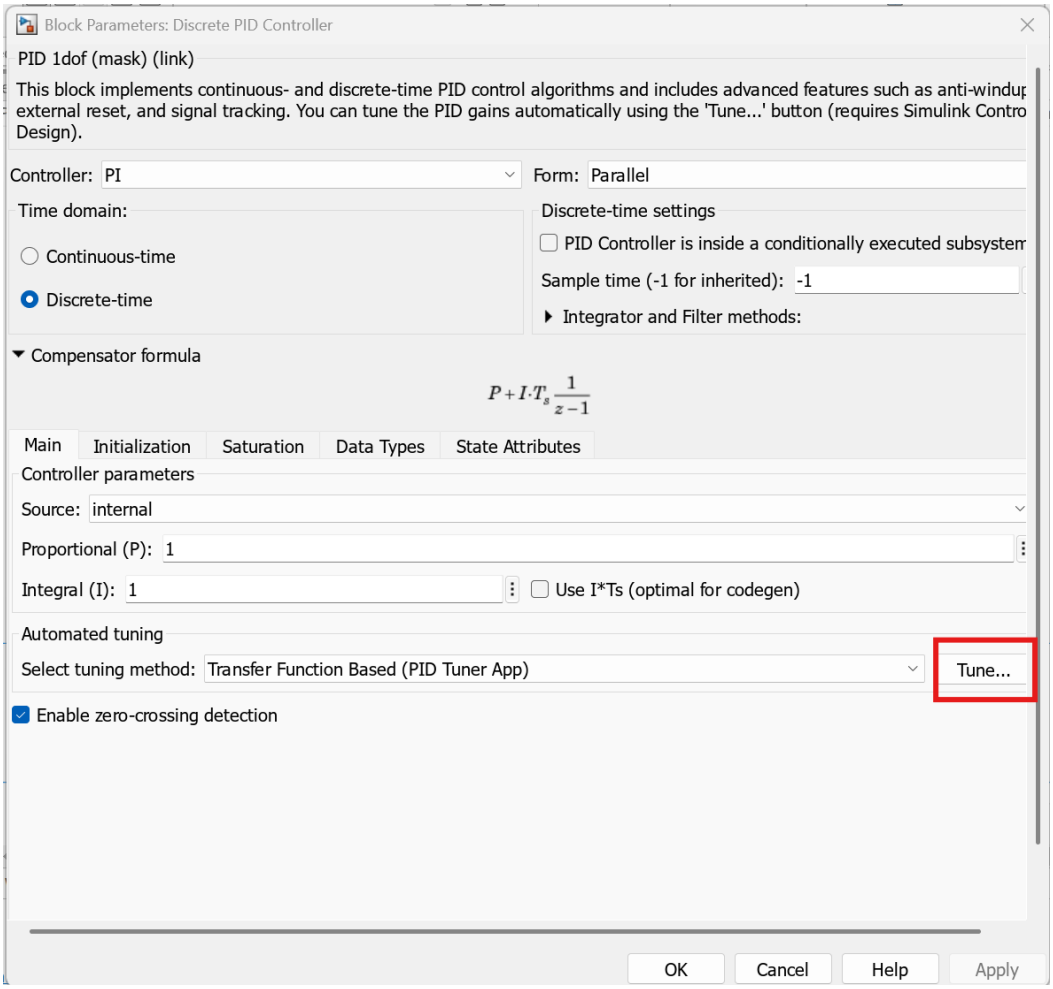


*You may try to change the value of PID gain by double click at "PID controller"



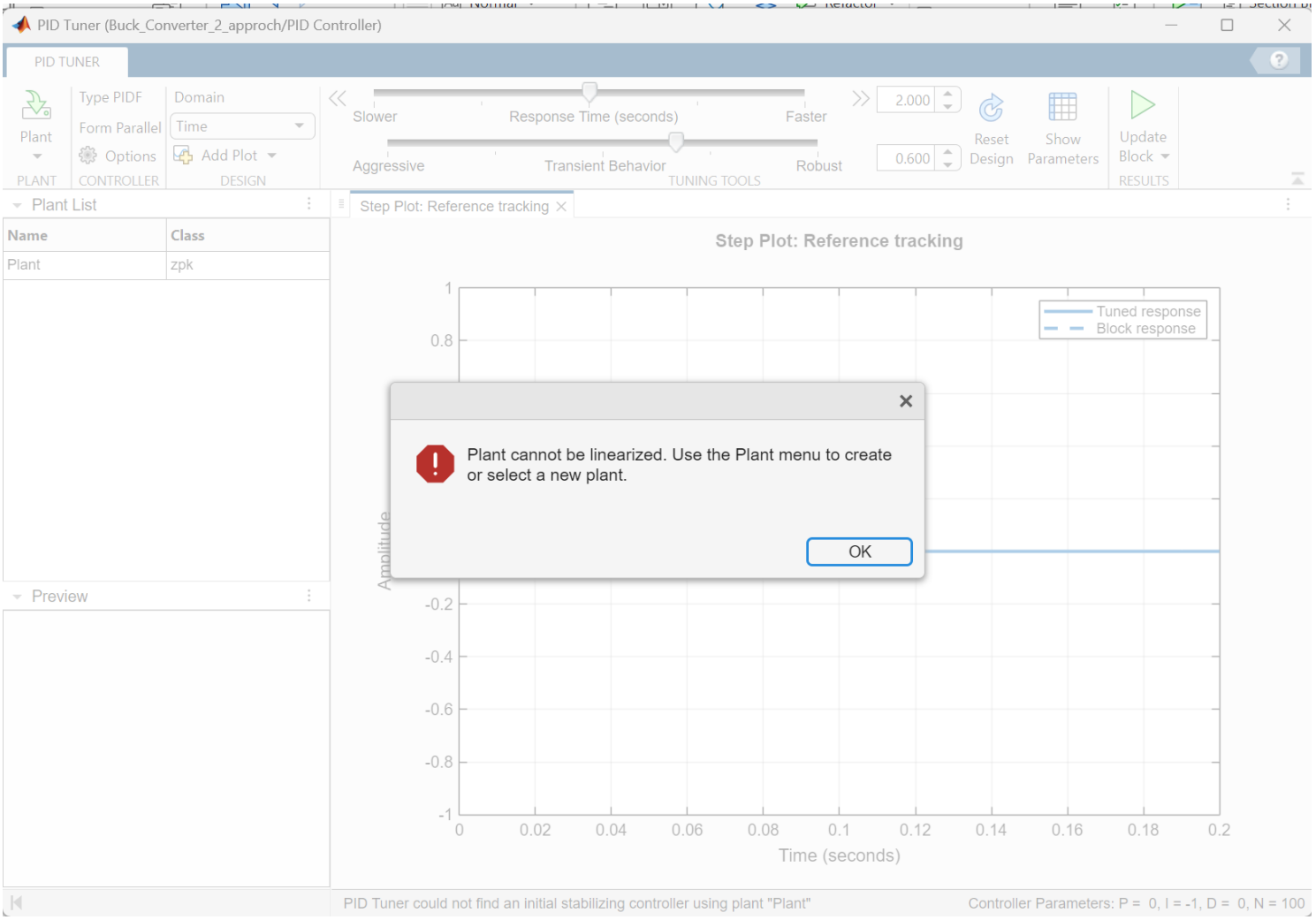
Task 5: Tunning Controller with PID tunner

- Double click at "**Discrete PID Controller**" --> Click "**Tune**" button

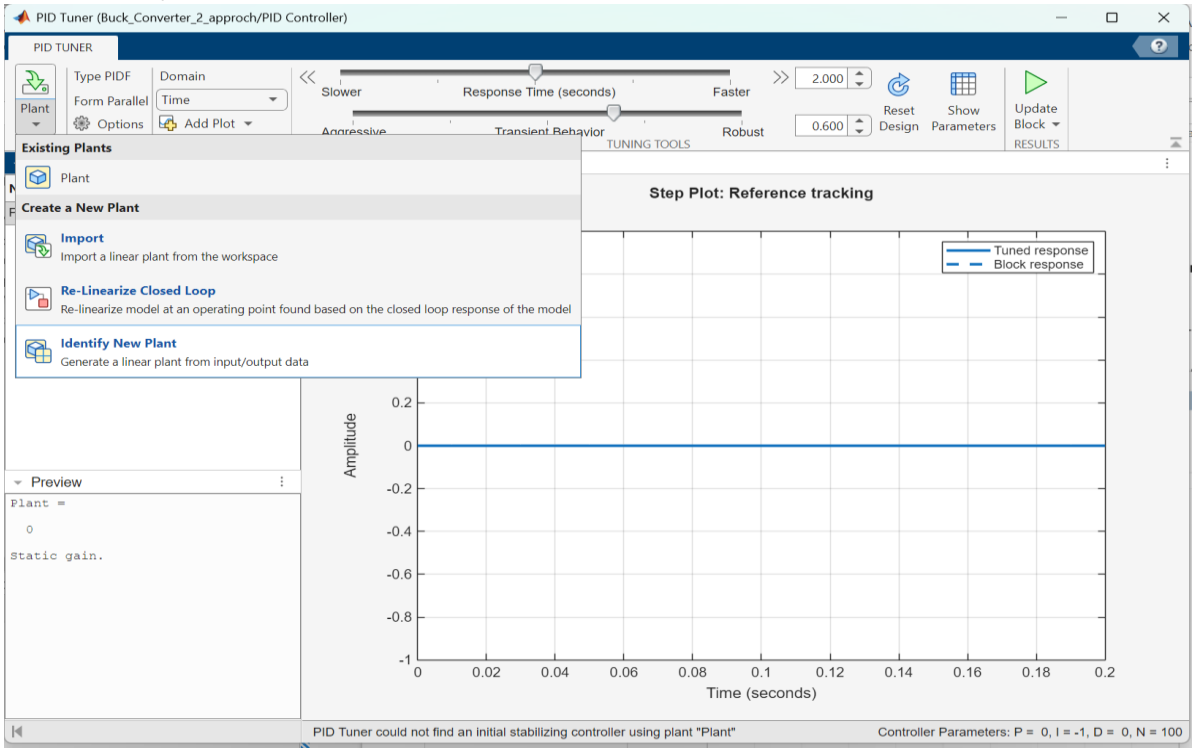


- PID tuner window will pop-up. You can try to tune your controller's "**Response time**" and "**Transient Behavior**" by sliding the bar in picture below --> Click "**Update Block**" after you finished

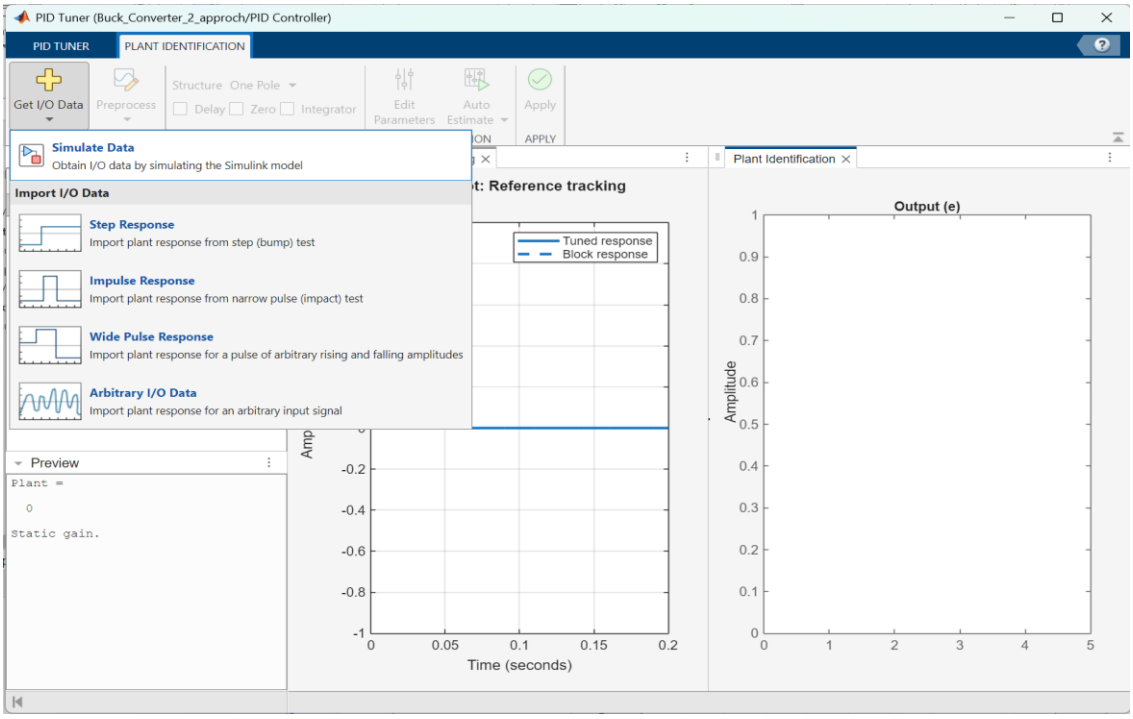
*In this case you may face that "Plant cannot be linearized. Use the Plant menu to create or select a new plant." --> Because the system canot be linearized --> Linearize manually by sellecting the operating point.



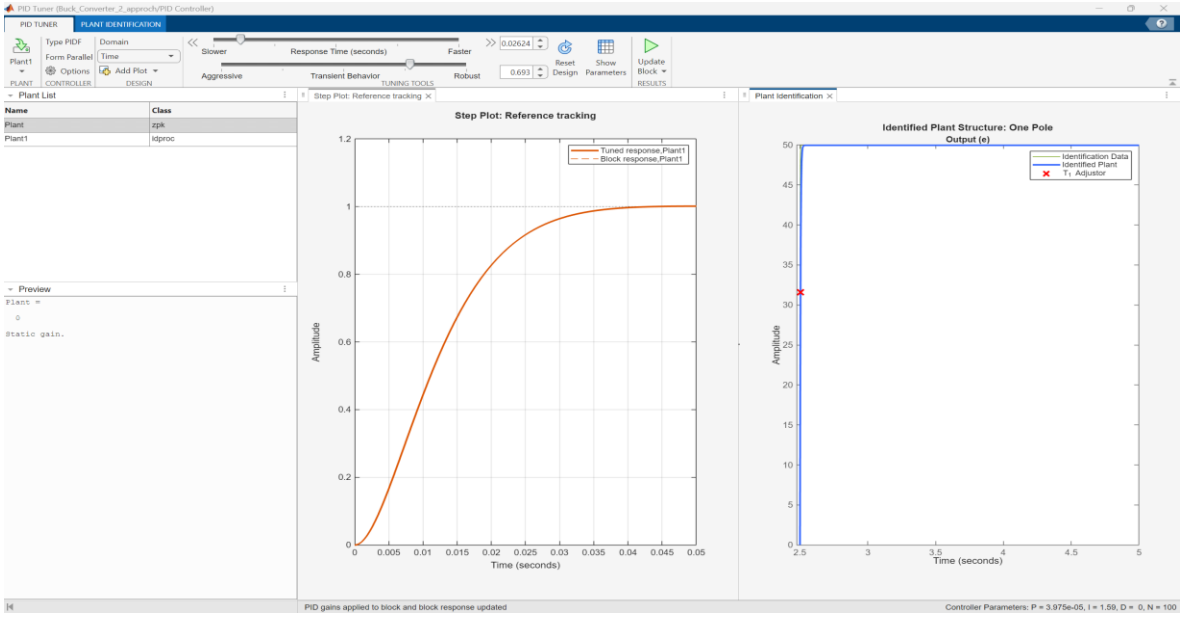
Goto "Identify New Plant"



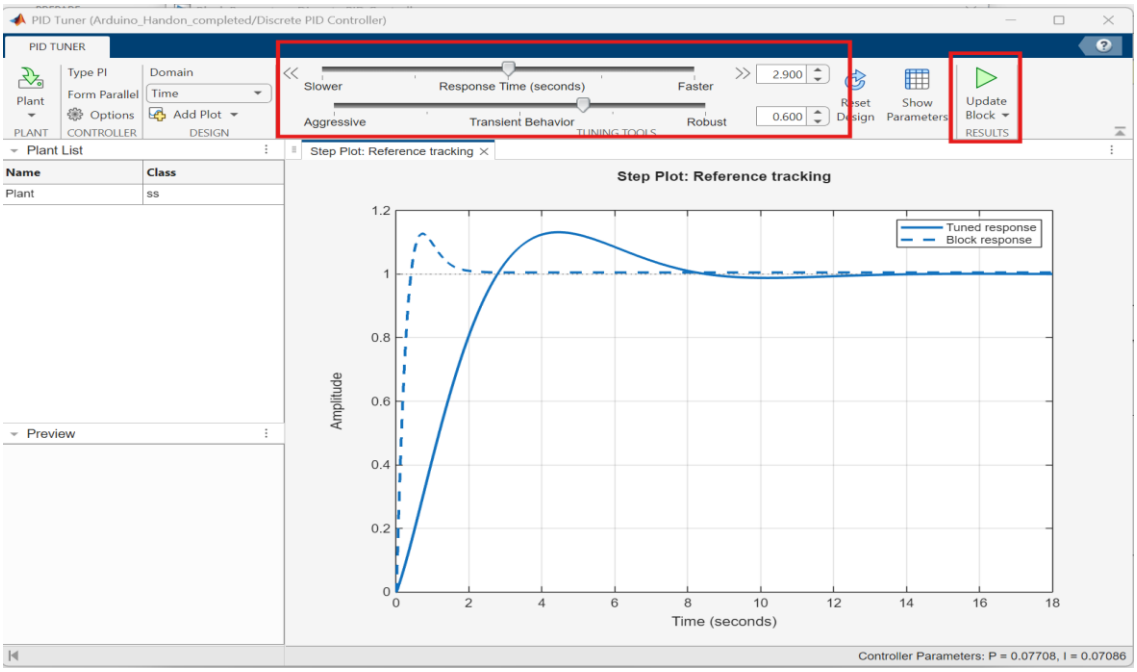
Go to "PLANT IDENTIFICATION" --> "Get I/O Data" --> Simulate Data



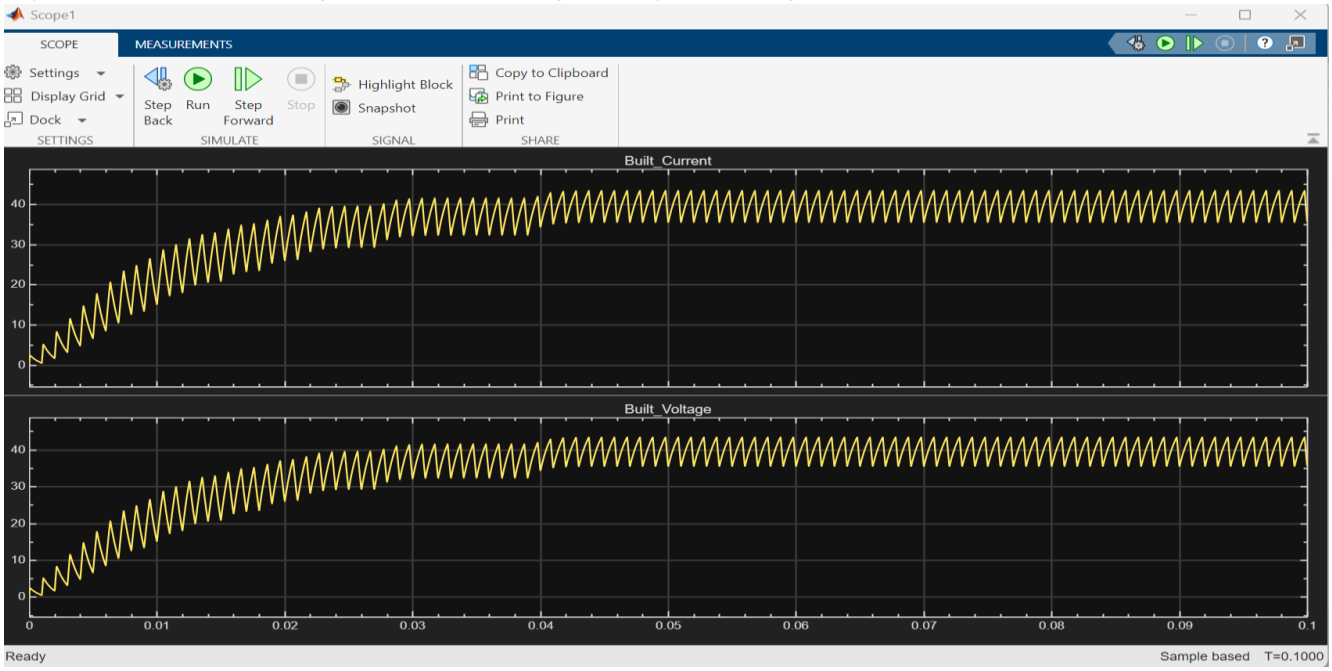
Identify the model and click "Accept" it



You can try to tune the response by using sliding bar.

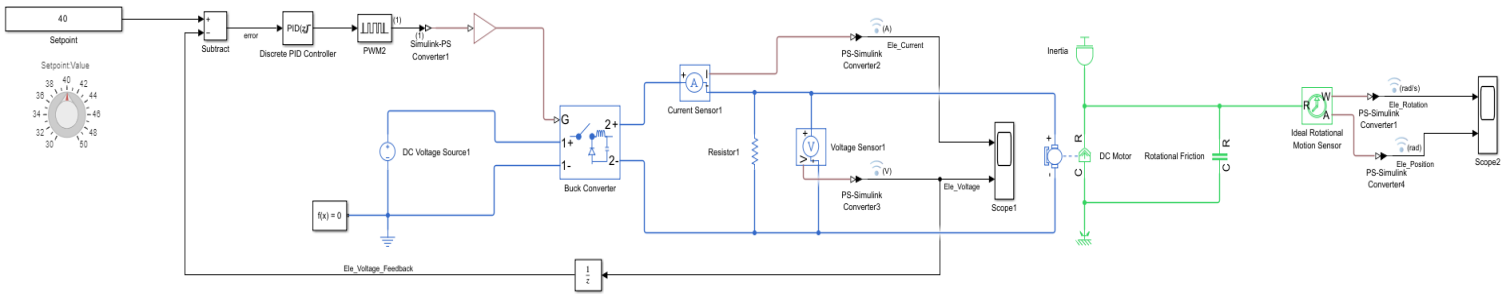


Try to "**Run**" simulation again to see the chage after you tunning




```
open("Buck_Converter_2_PID_Tune.slx")
```

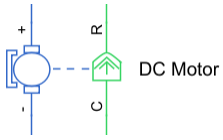
Optional Across the Domain (Rotational + Multibody)

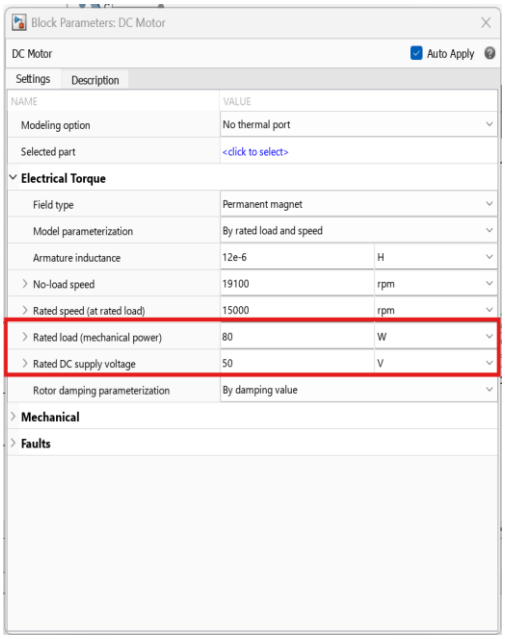


Task 6: Connect to another domain (Rotational)

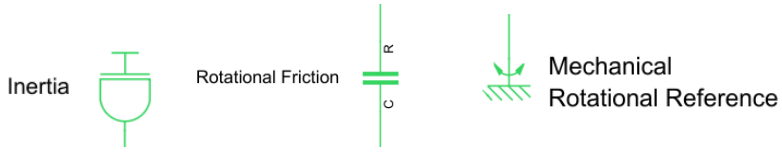
1. Drag the block from

   Simscape>Electrical>Electromechanical>Brushed Motors



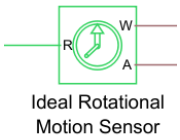


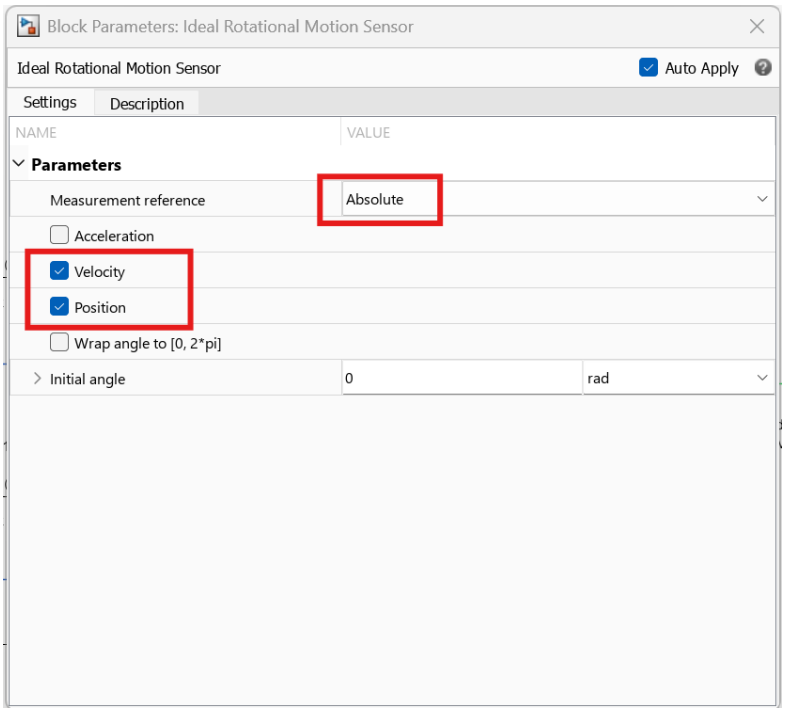
Simscape>Foundation Library>Mechanical>Rotational Elements



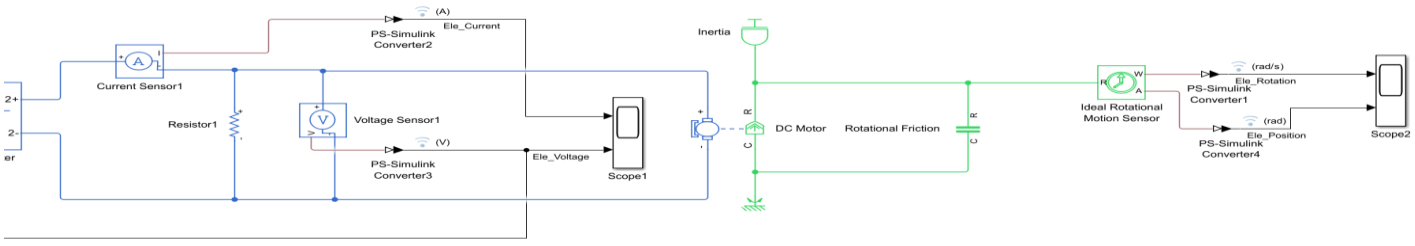
$$J = 1 \times 10^{-5}\ \mathrm{kg\ m^2}, \quad T_{\mathrm{breakaway}} = 0.1\ \mathrm{N\ m}, \quad T_{\mathrm{Coulomb}} = 0.1\ \mathrm{N\ m}$$

Simscape>Foundation Library>Electrical Sensor

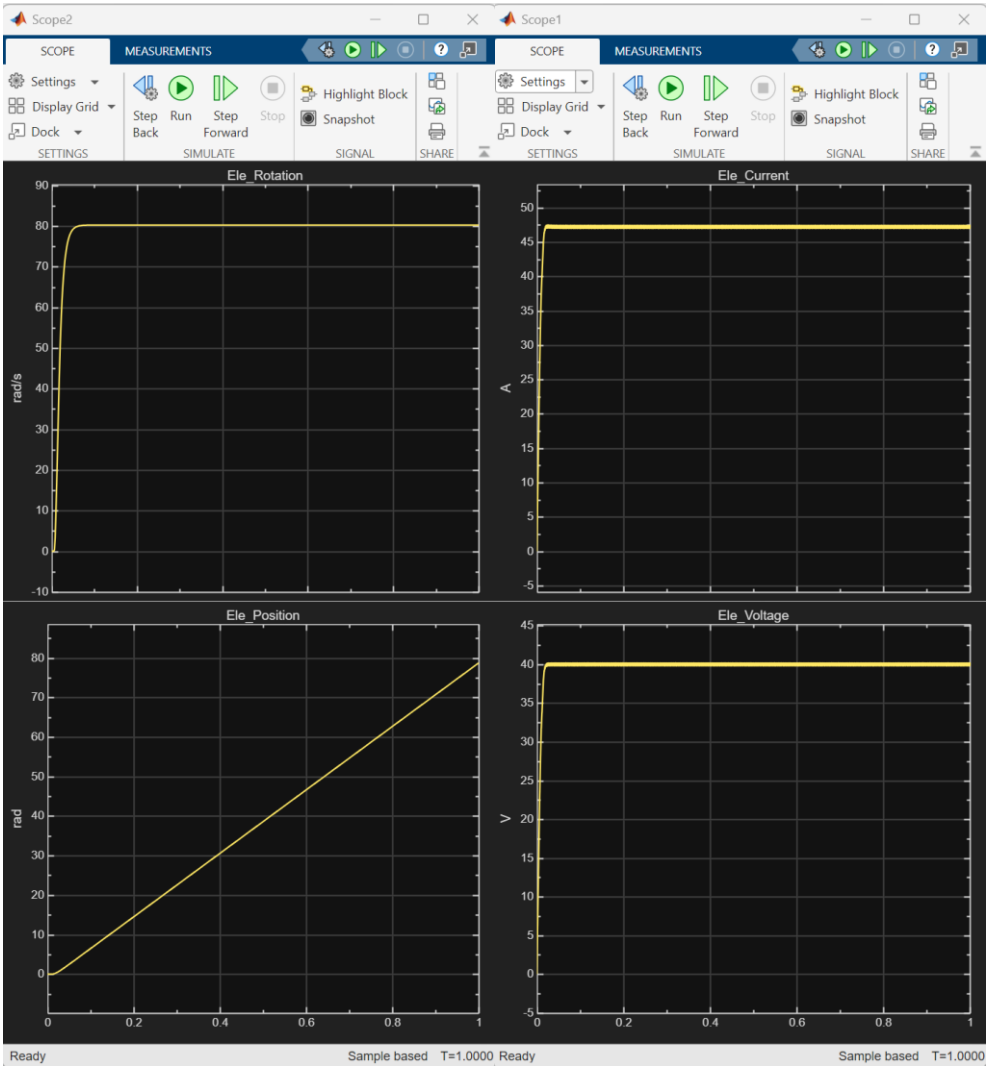




2. Connect "DC Motor" cascading to the "Buck converter" + Connect the scope to the sensor

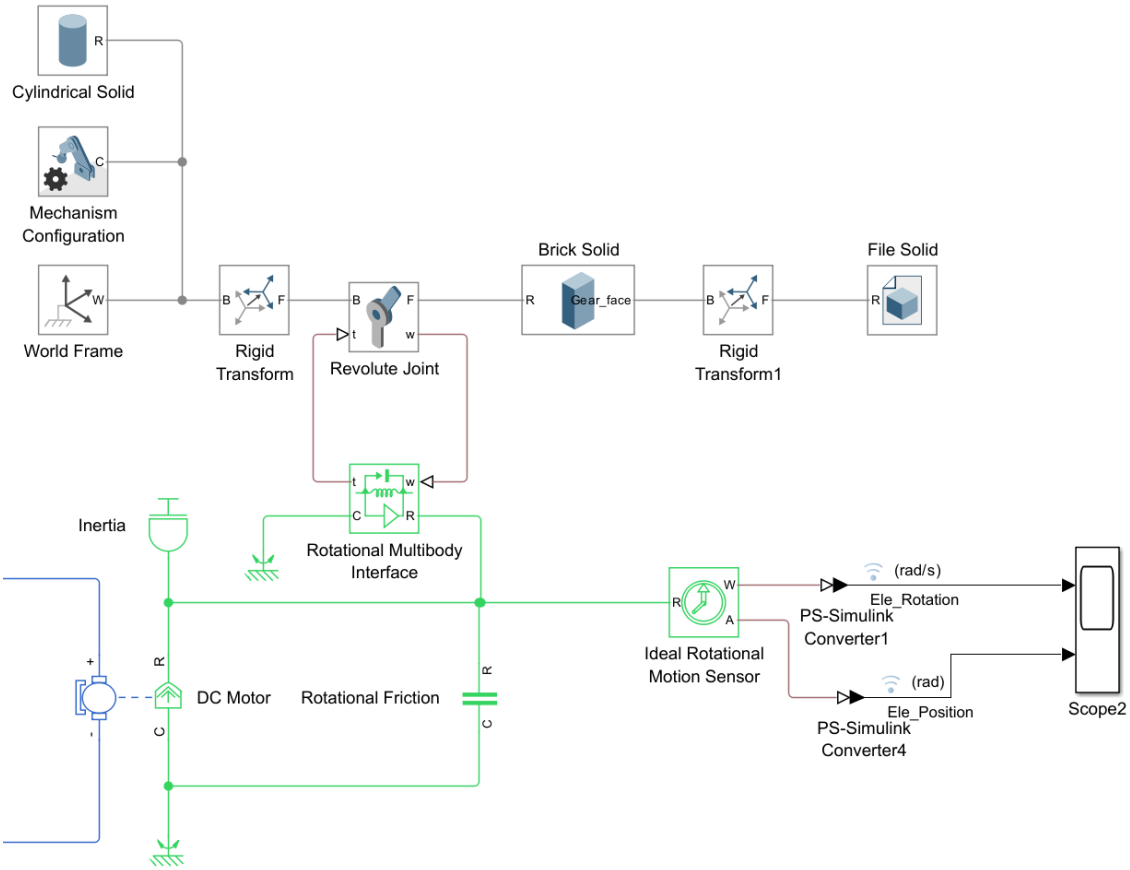


3. Simulate at 1 seconds



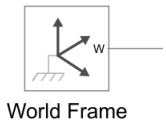

```
open("Buck_Converter_2_PID_Tune_Rotational.slx")
```

Task 7: Connect to another domain (Multibody)

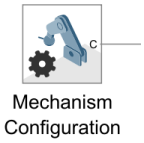


1. **[Create Reference]** Drag the block from

   Simscape>Multibody>Frame and Transforms

   Simscape>Multibody>Utilities

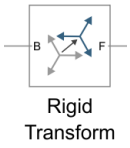
   Simscape>Multibody>Body Elements

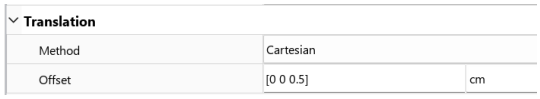
   

   $r = 2\ \text{cm}, \quad L = 0.5\ \text{cm}$

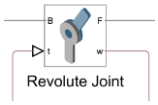
2. **[Create Joint]** Drag the block

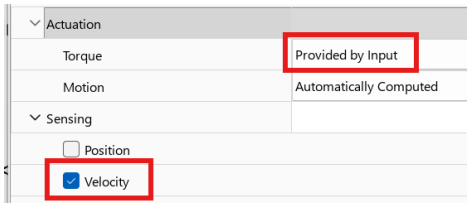
Simscape>Multibody>Frame and Transforms



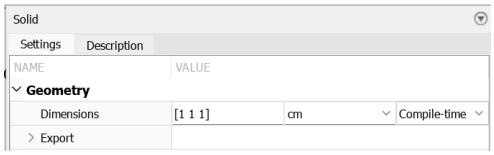


Simscape>Multibody>Joints

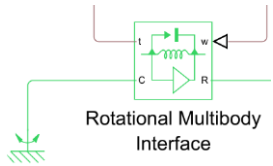




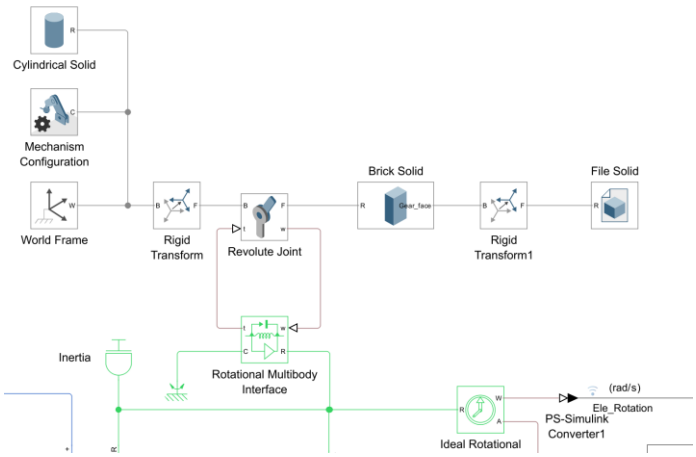
Simscape>Multibody>Body Elements



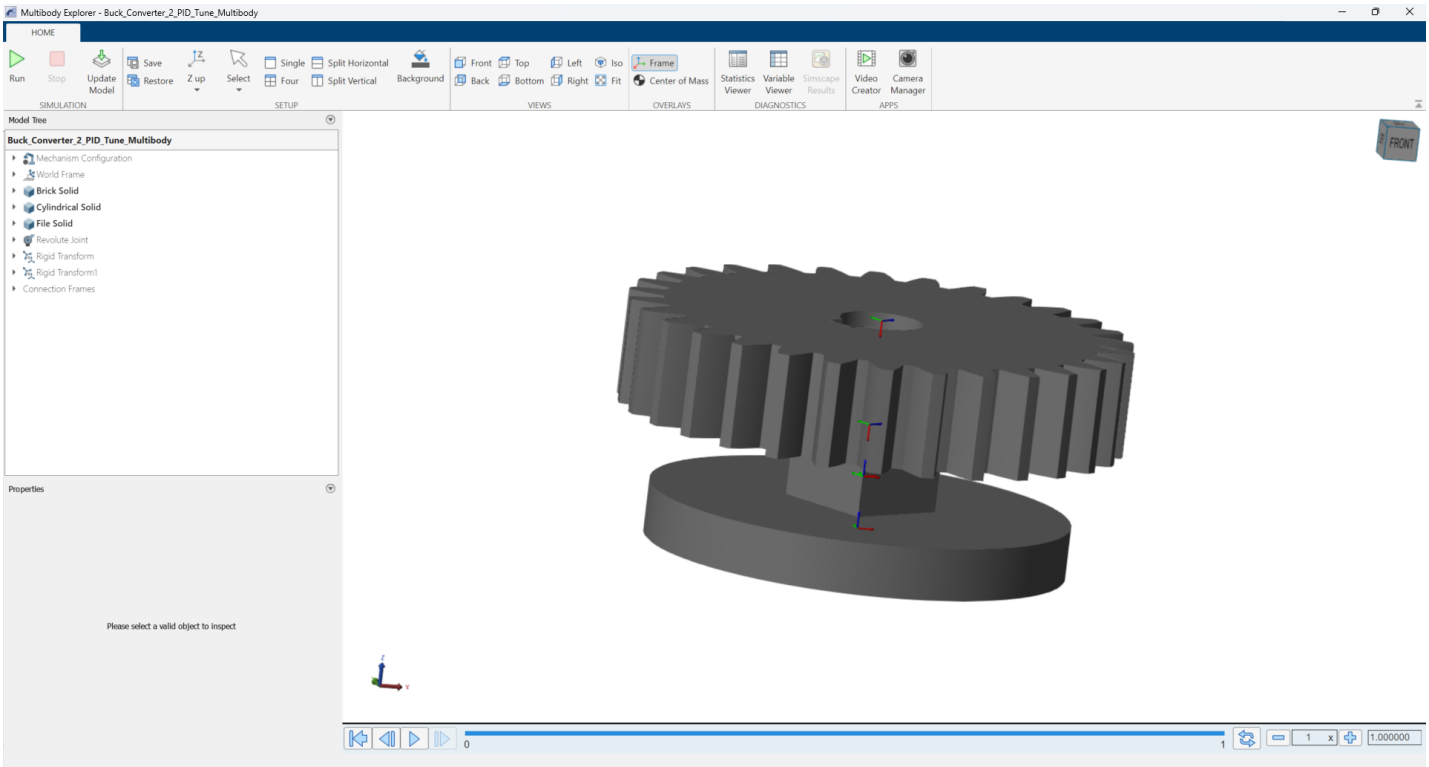
Simscape>Simscape Mechanical Interfaces



3. Connect model together



4. Simulate at 1 seconds




```
open("Buck_Converter_2_PID_Tune_Multibody.slx")
```