

Hand-On Model Physical System in various fidelity level

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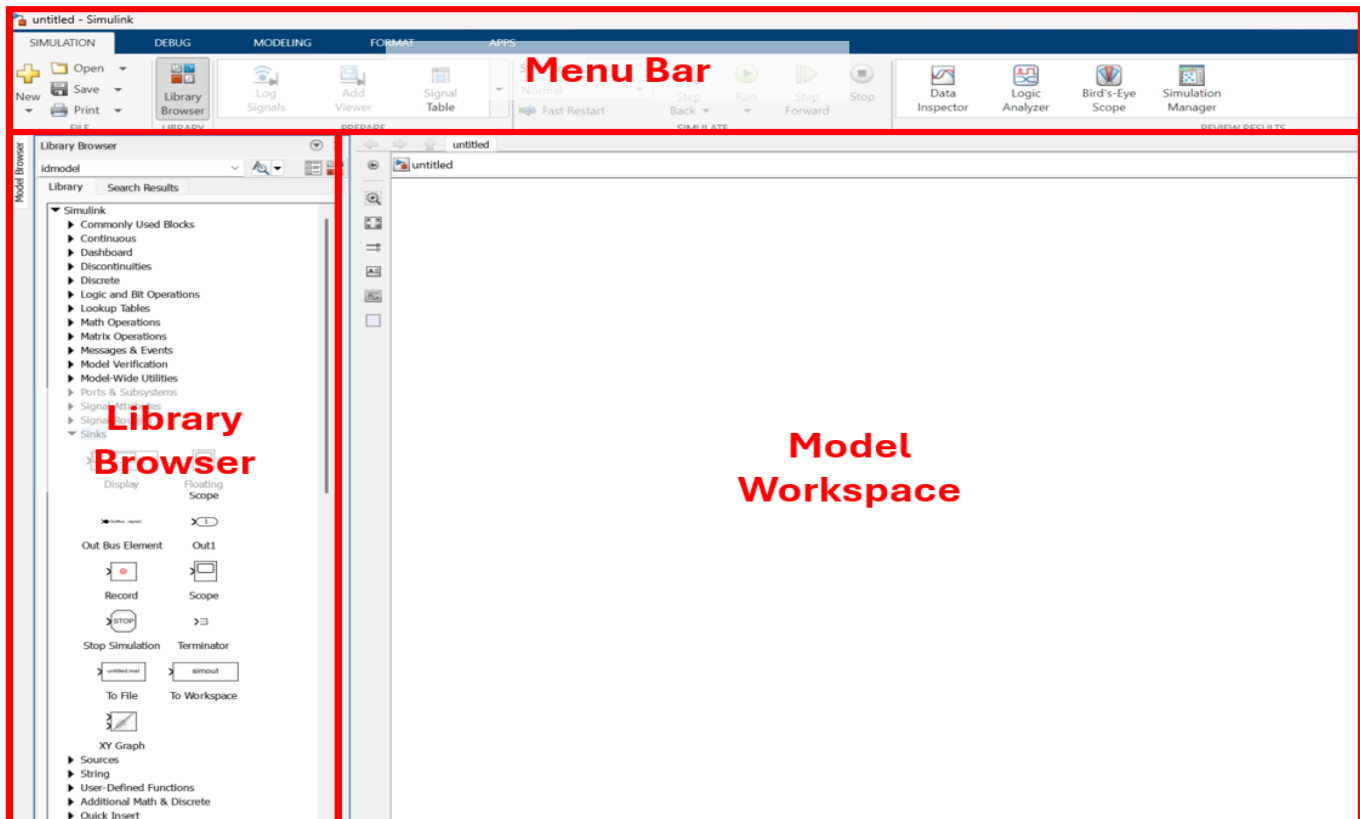
Optional Across the Domain (Rotational + Multibody)

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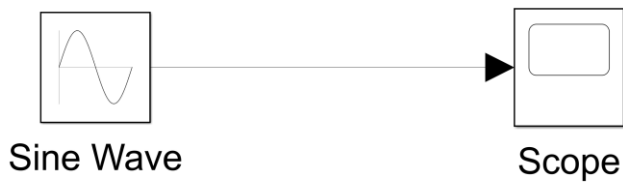
Introduction to Simulink

Simulink

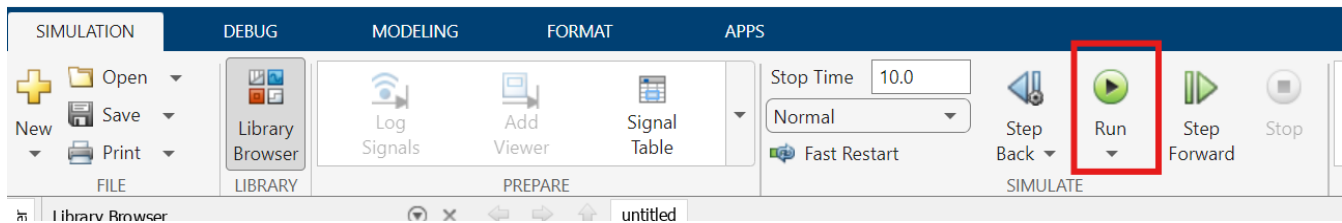


Task 0-1: Simulink block and Simulation

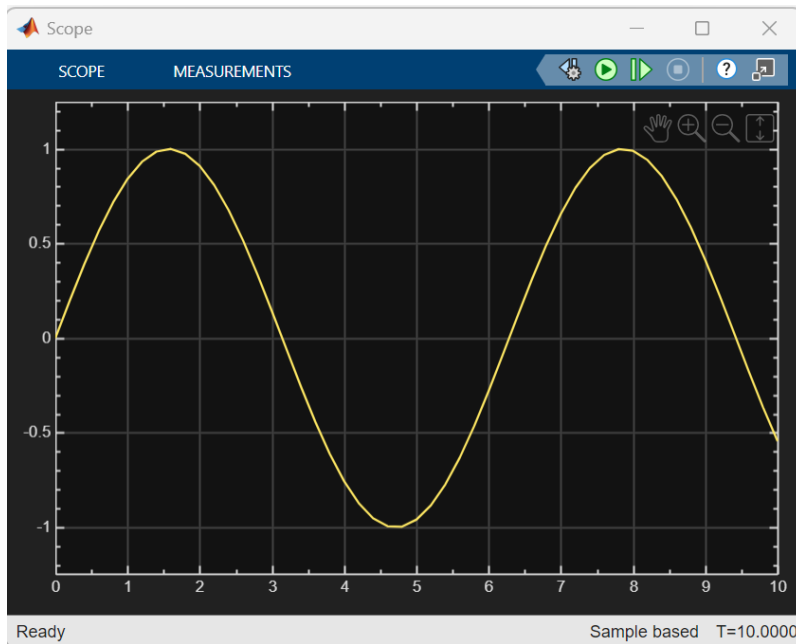
- Drag and Drop "**Sine Wave**" block from "**Simulink>Sources**" to the workspace
- Drag and Drop "**Scope**" block from "**Simulink>Sink**" to the workspace
- Connect the signal from "**Sine Wave**" to "**Scope**"



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

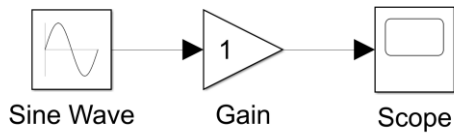


- Check the output by double click at "**Scope**"

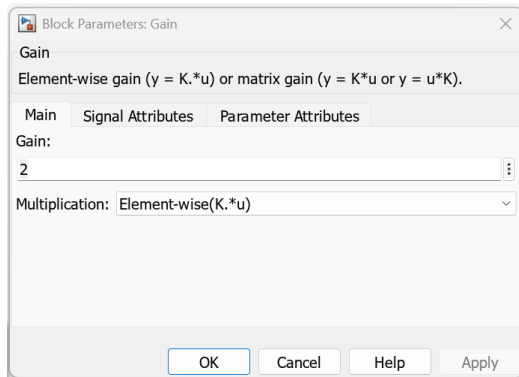


Task 0-2: Math calculation

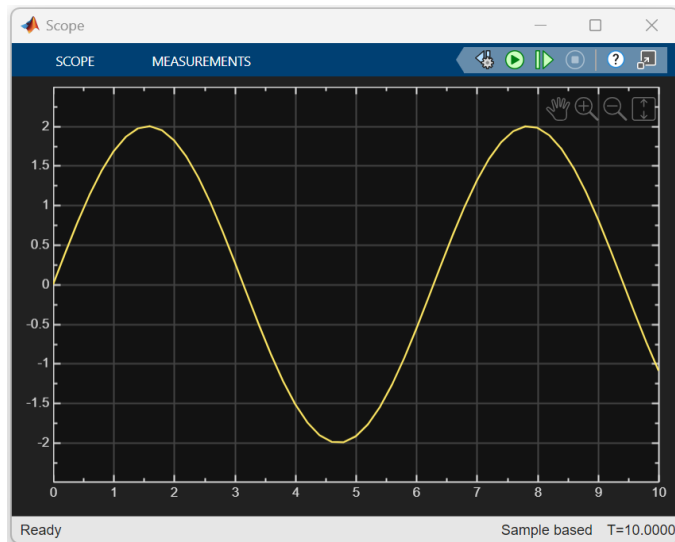
- Drag and Drop "**Gain**" block from "**Simulink>Math Operations**" to the workspace
- Place the "**Gain**" block in the signal line between "**Sine Wave**" and "**Scope**" block



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

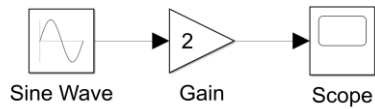


- Start simulate the system by clicking "**Run**" at Simulate section
- Check the output by double click at "**Scope**"



Task 0-3: Dashboard control

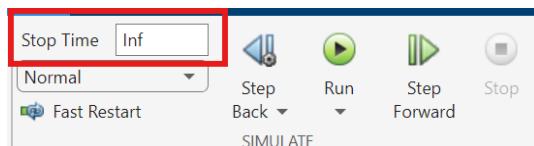
- Drag and Drop "**Slider**" block from "**Simulink>Dashboard**" to the workspace



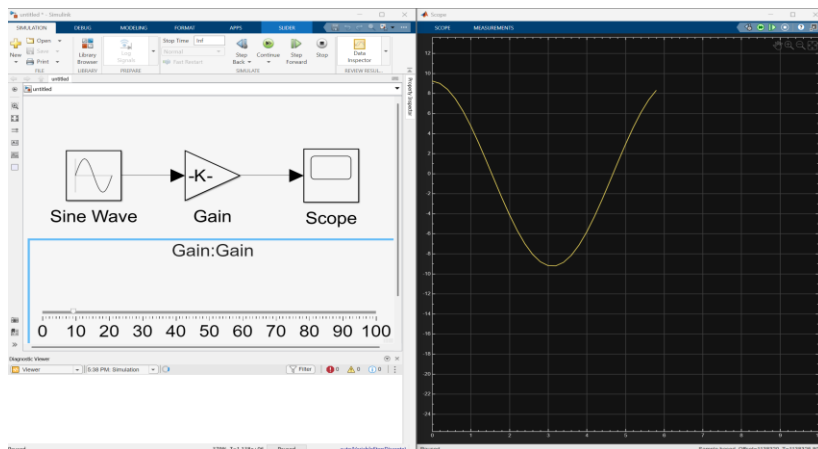
- Double click at "**Slider**" --> Select "**Gain**" block --> Click at "**Connect**" check of the gain value --> Click "**OK**" to confirm



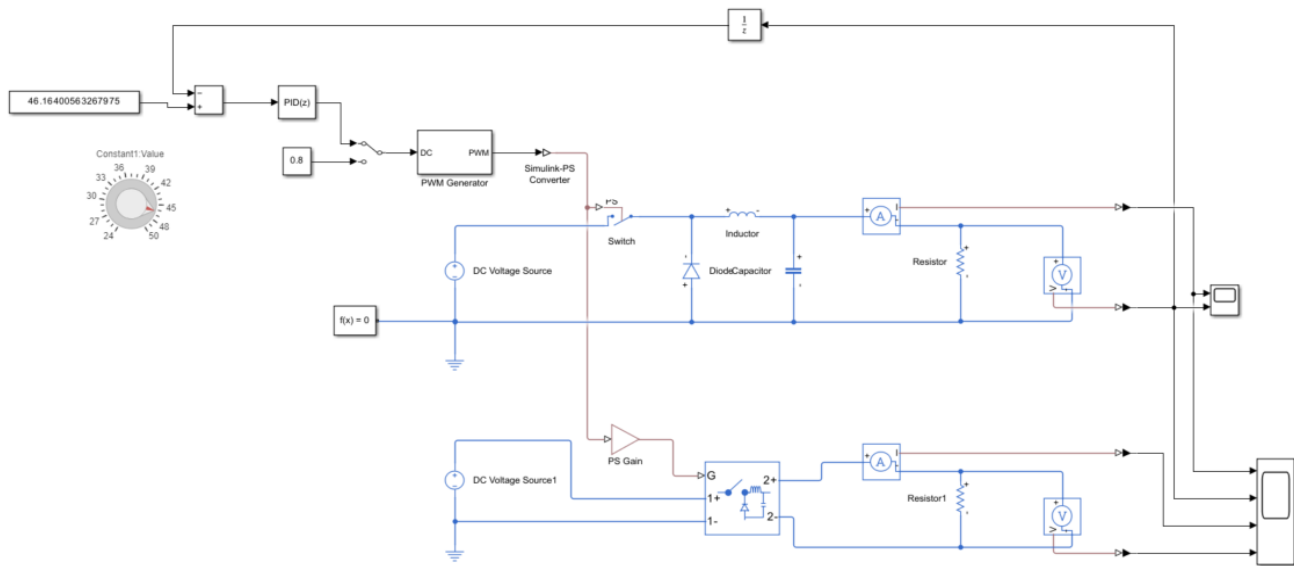
- Change "**Stop Time**" to "Inf"



- 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



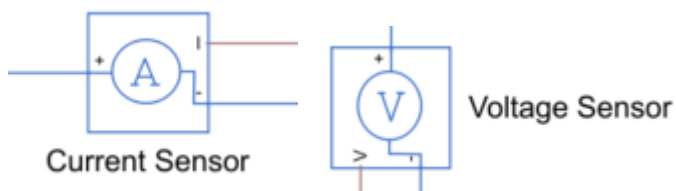
Simscape>Foundation Library>Electrical Element



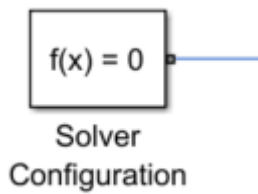
Component Values

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

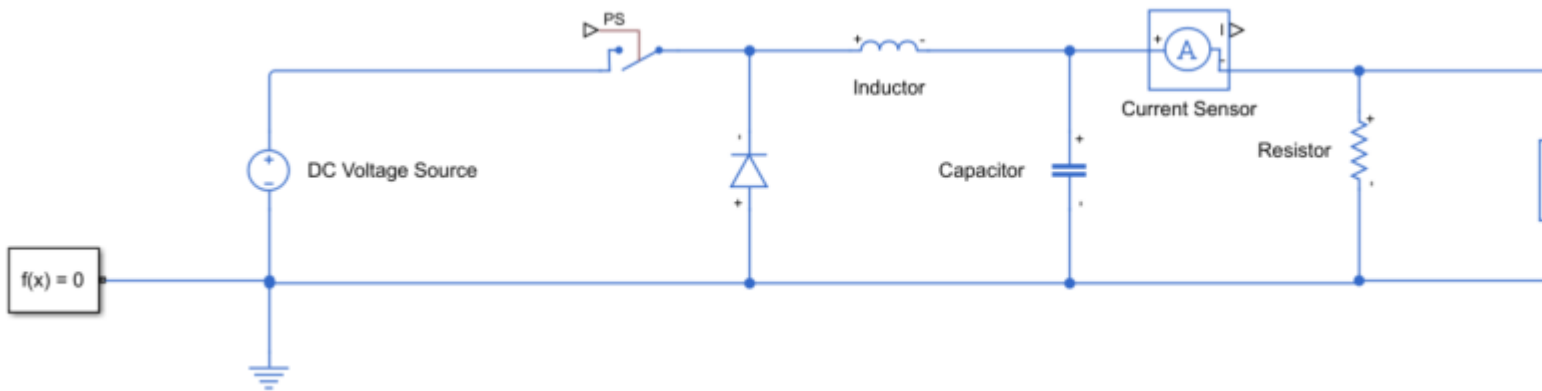
Simscape>Foundation Library>Electrical Sensor



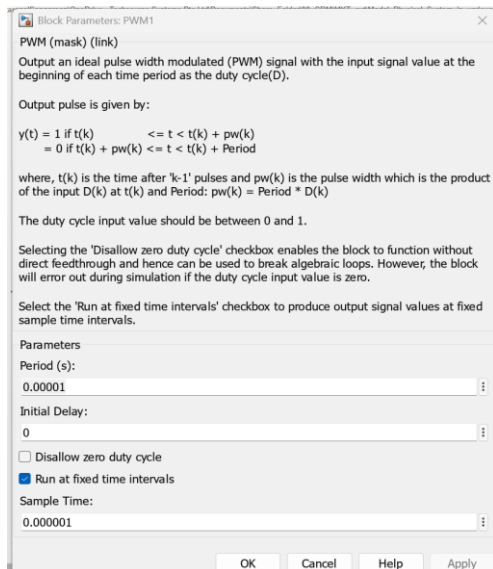
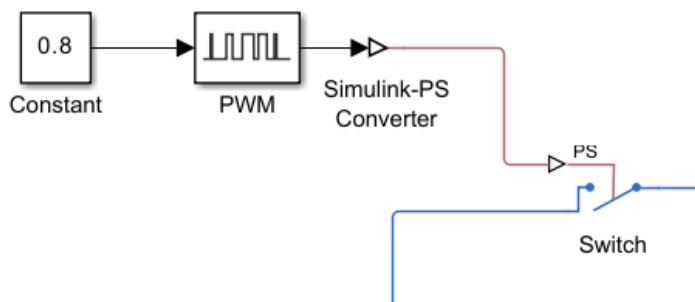
Simscape>Utilities



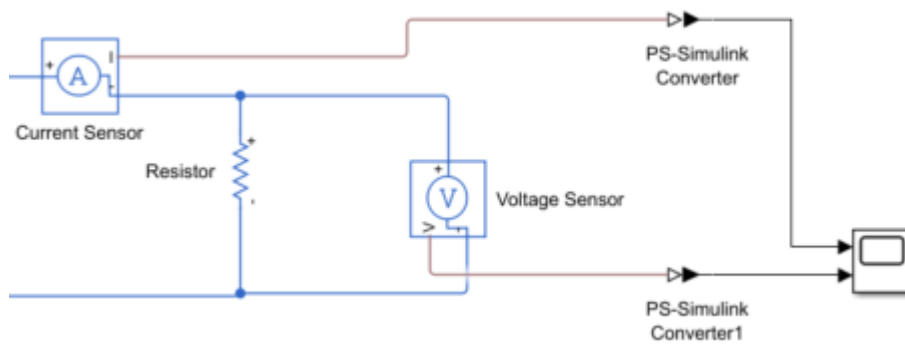
2. Connect Buck converter circuit



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

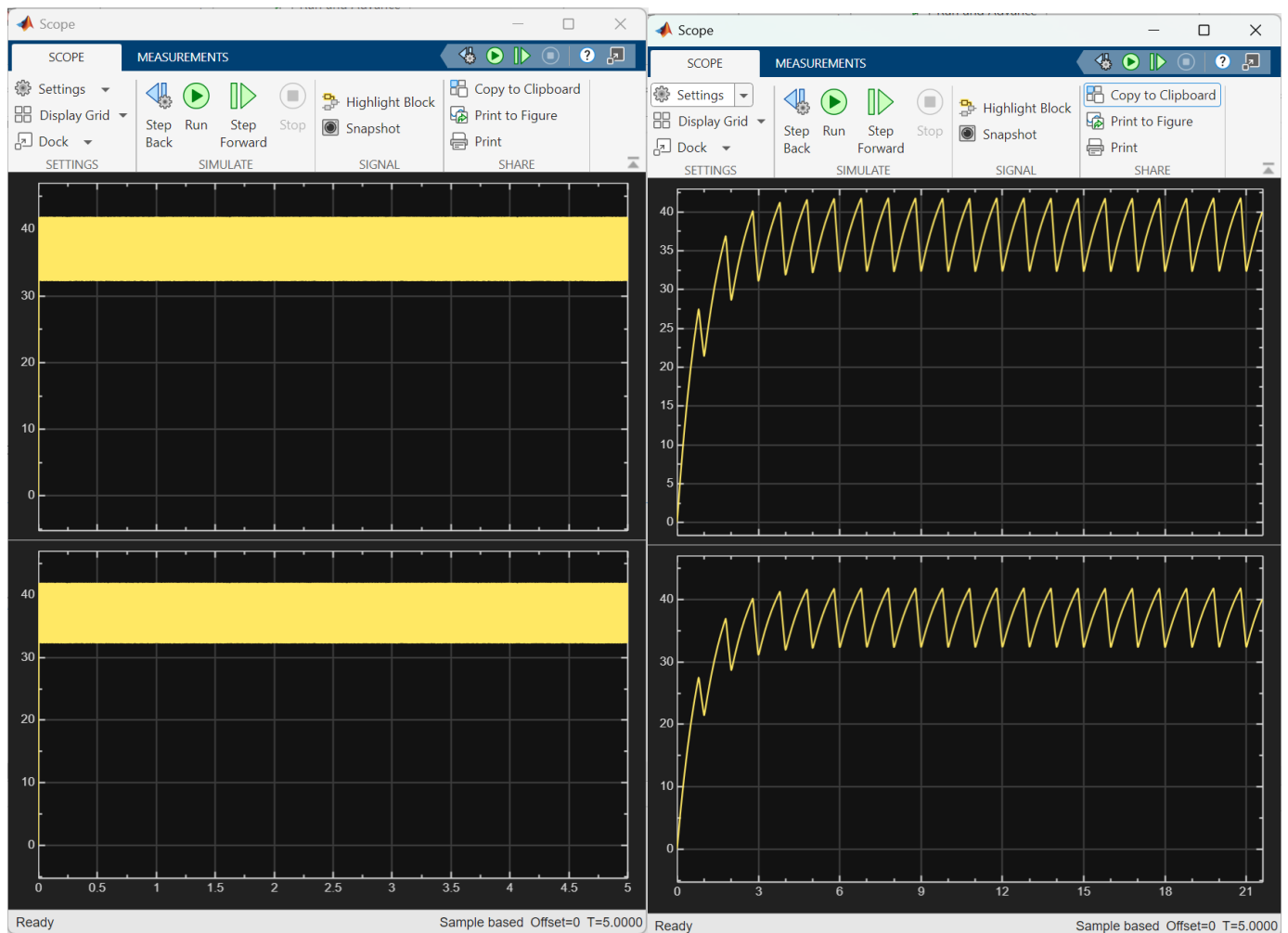


4. Adding "Scope" Block to see the output



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

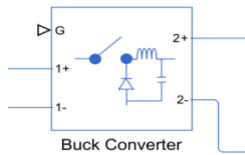
*You may zoom in to scope down the time at 0 - 0.005 to see the transient response



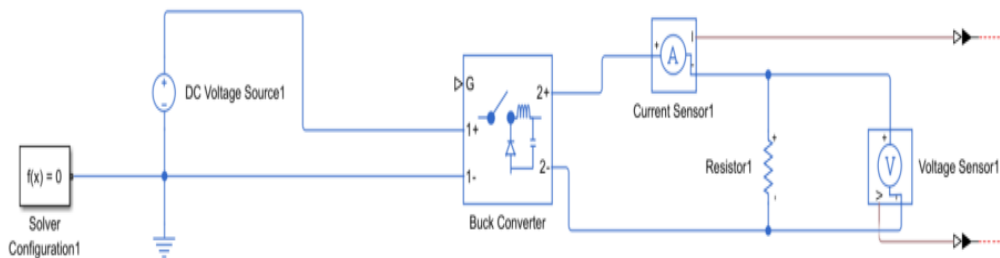
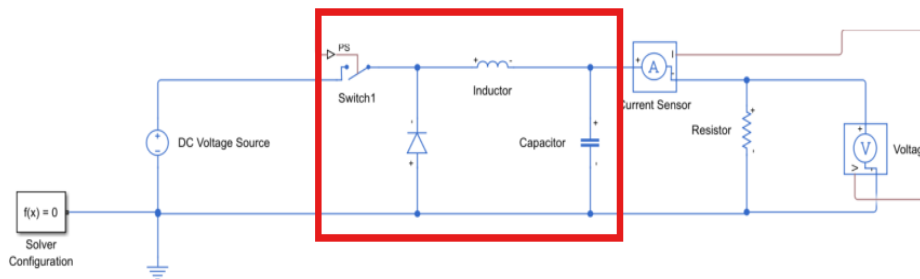
Task 2: Create built-in Buck converter circuit from Simscape Electrical

1. Drag the block from

Simscape>Electrical>Semiconductors & Converters>Buck Converter



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

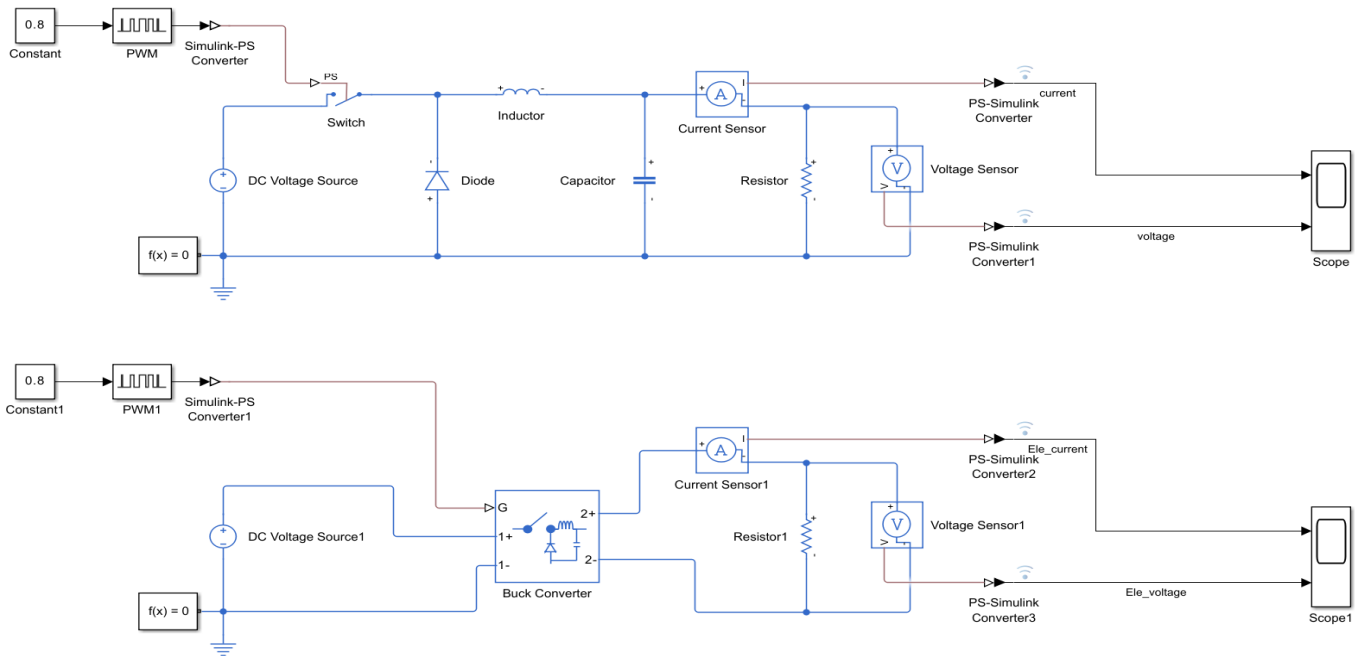
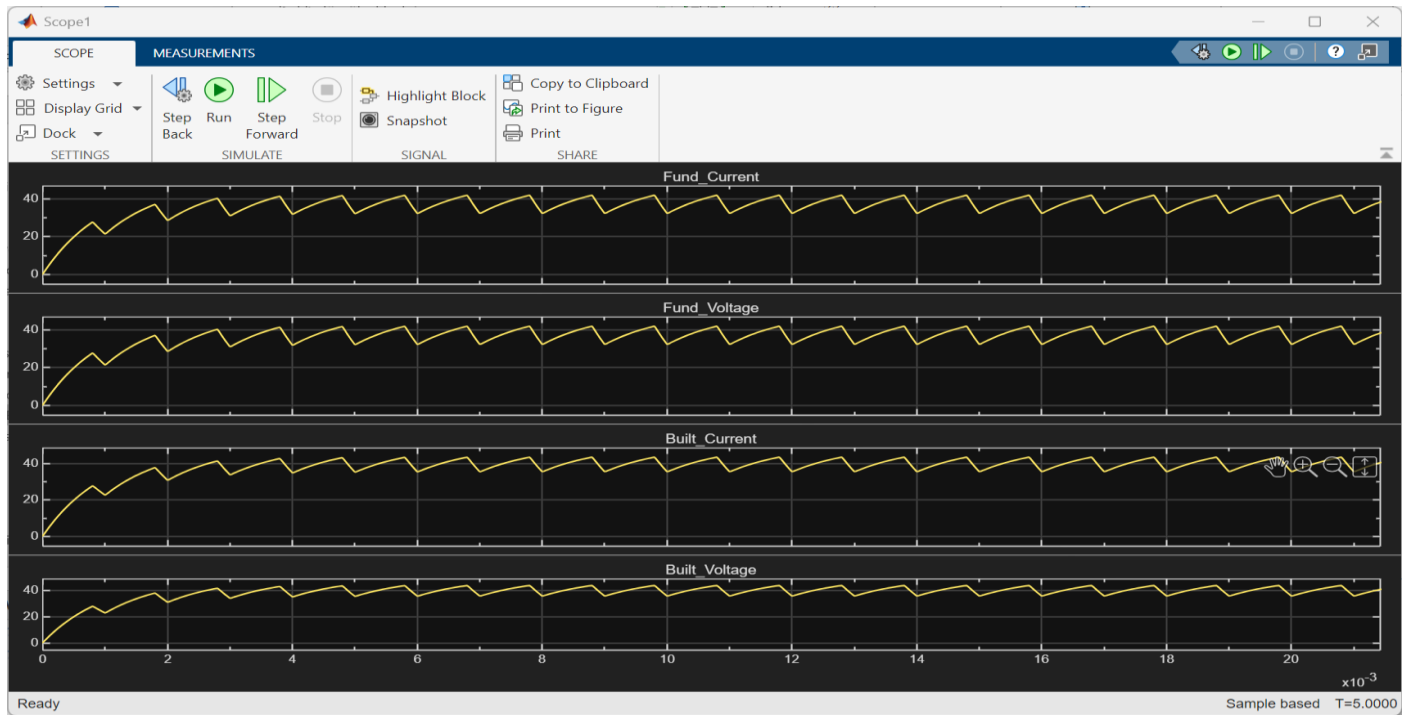


3. Set the parameter as setting in the previous model

Block Parameters: Buck Converter		
Buck Converter Auto Apply		
Settings	Description	
NAME	VALUE	
Modeling option	Nonsynchronous converter	
Switching Device		
Gate-control port	PS	
Switching device	Averaged Switch	
> On-state resistance	0.001	Ohm
> Integer for piecewise constant ...	0	
Diode		
Forward voltage	0.8	V
On resistance	0.001	Ohm
Off conductance	1e-5	1/Ohm
LC filter		
> Inductance	1e-3	H
> Inductor series resistance	0	Ohm
> Capacitance	1e-5	F
> Capacitor effective series resist...	1e-6	Ohm
Initial Targets		
> <input type="checkbox"/> Inductor current		
> <input type="checkbox"/> Capacitor voltage		
Priority	High	
Value	0	V
Nominal Values		

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 approach 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"

Block Parameters: Buck Converter

Buck Converter

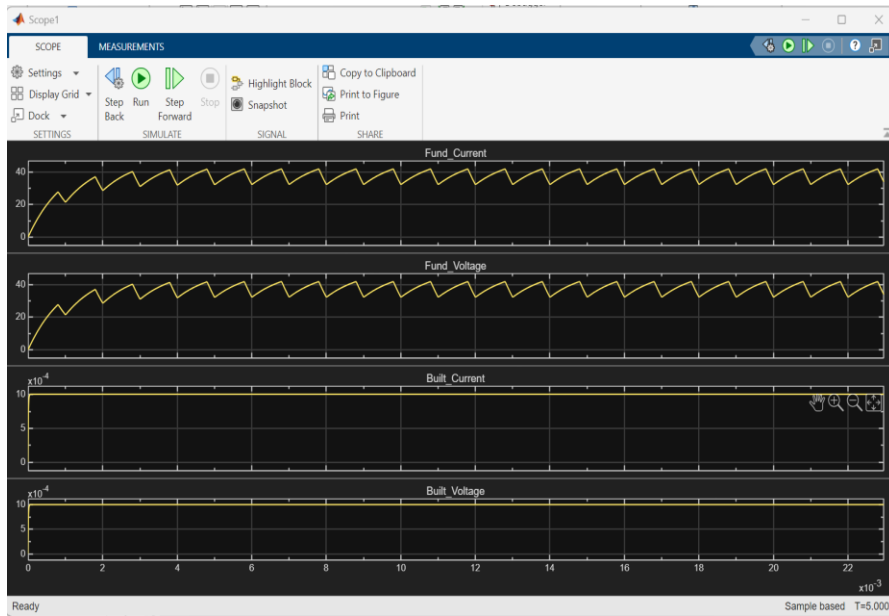
Auto Apply

Settings

Description

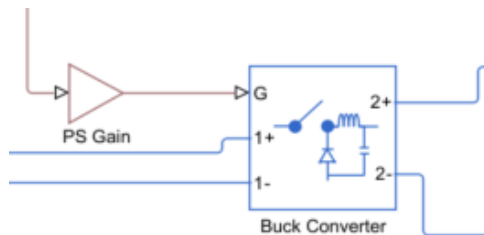
NAME	VALUE	
Modeling option	Nonsynchronous converter	
Switching Device		
Gate-control port	PS	
Switching device	Averaged Switch	
> On-state resistance	GTO	
> Integer for piecewise constant ...	Ideal Semiconductor Switch	
	IGBT	
	MOSFET	
	Thyristor	
Diode	Averaged Switch	
Forward voltage		
On resistance	0.001	Ohm
Off conductance	1e-5	1/Ohm
LC filter		
> Inductance	1e-3	H
> Inductor series resistance	0	Ohm
> Capacitance	1e-5	F
> Capacitor effective series resist...	1e-6	Ohm
Initial Targets		
> <input type="checkbox"/> Inductor current		
> <input type="checkbox"/> Capacitor voltage		
Priority	High	
Value	0	V
Nominal Values		

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

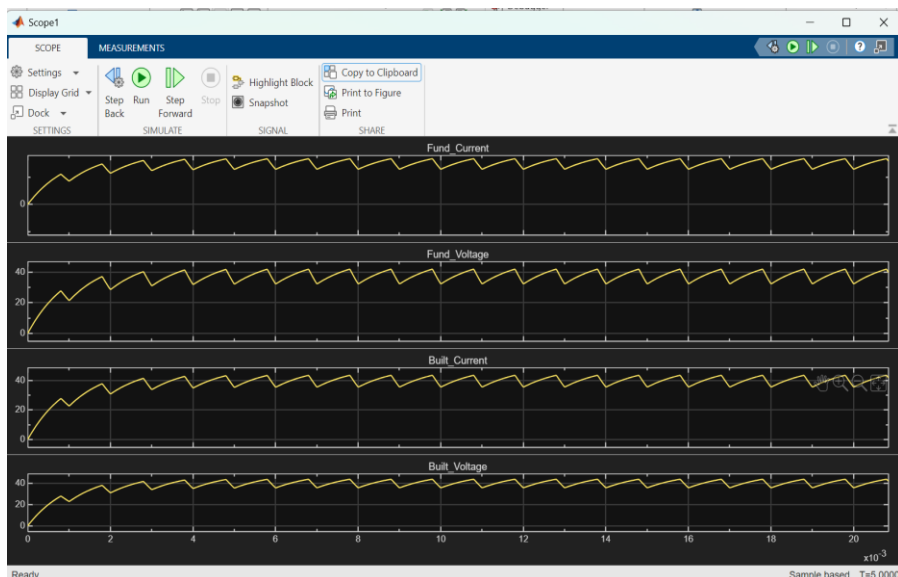


3. Add "PS Gain" from **Simscape>Foundation Library>Physical Signals** between PWM signal to Gate of "Buck Converter" --> Set the gain at 12

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

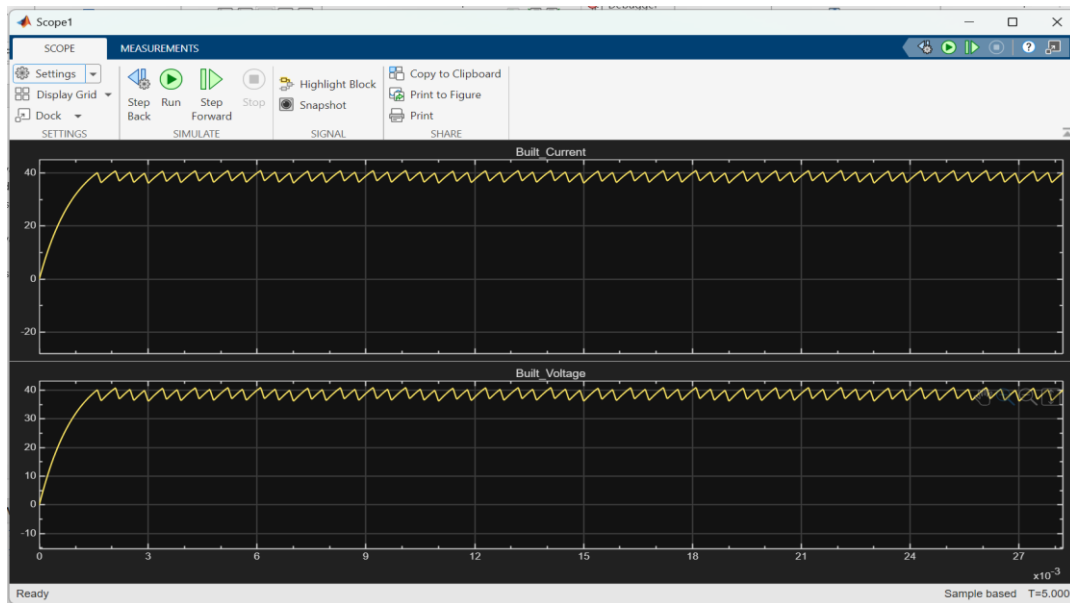
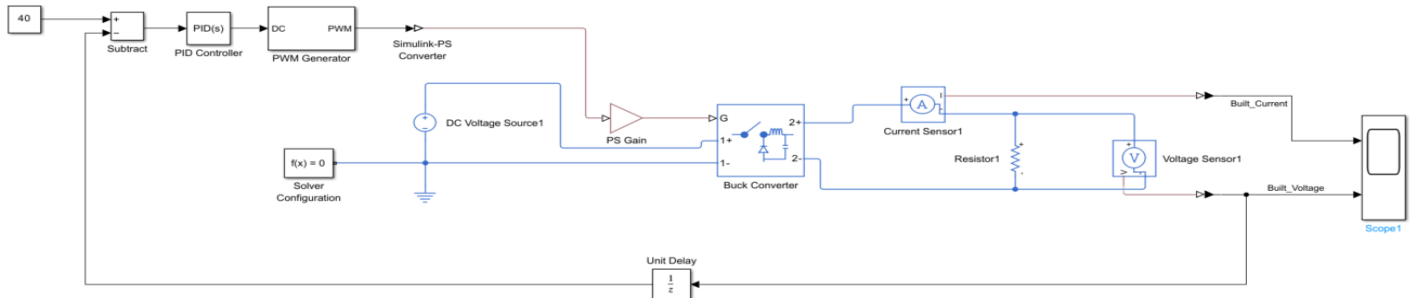


4. Simulation again and checking the scope

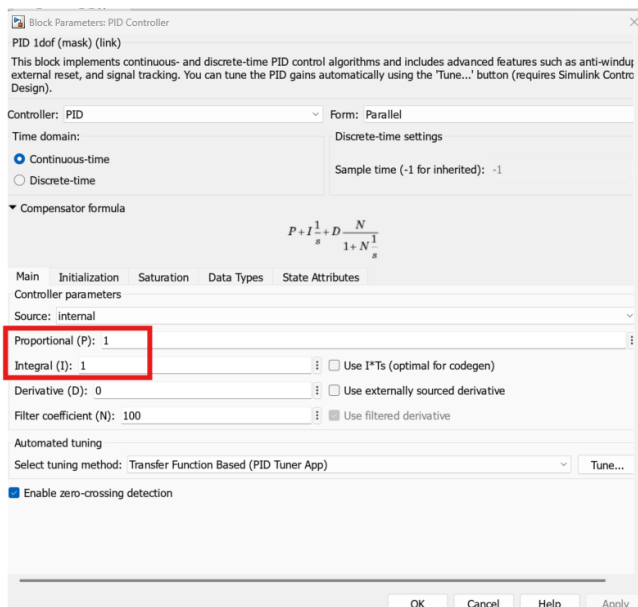


Task 4: Voltage control with PID controller

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

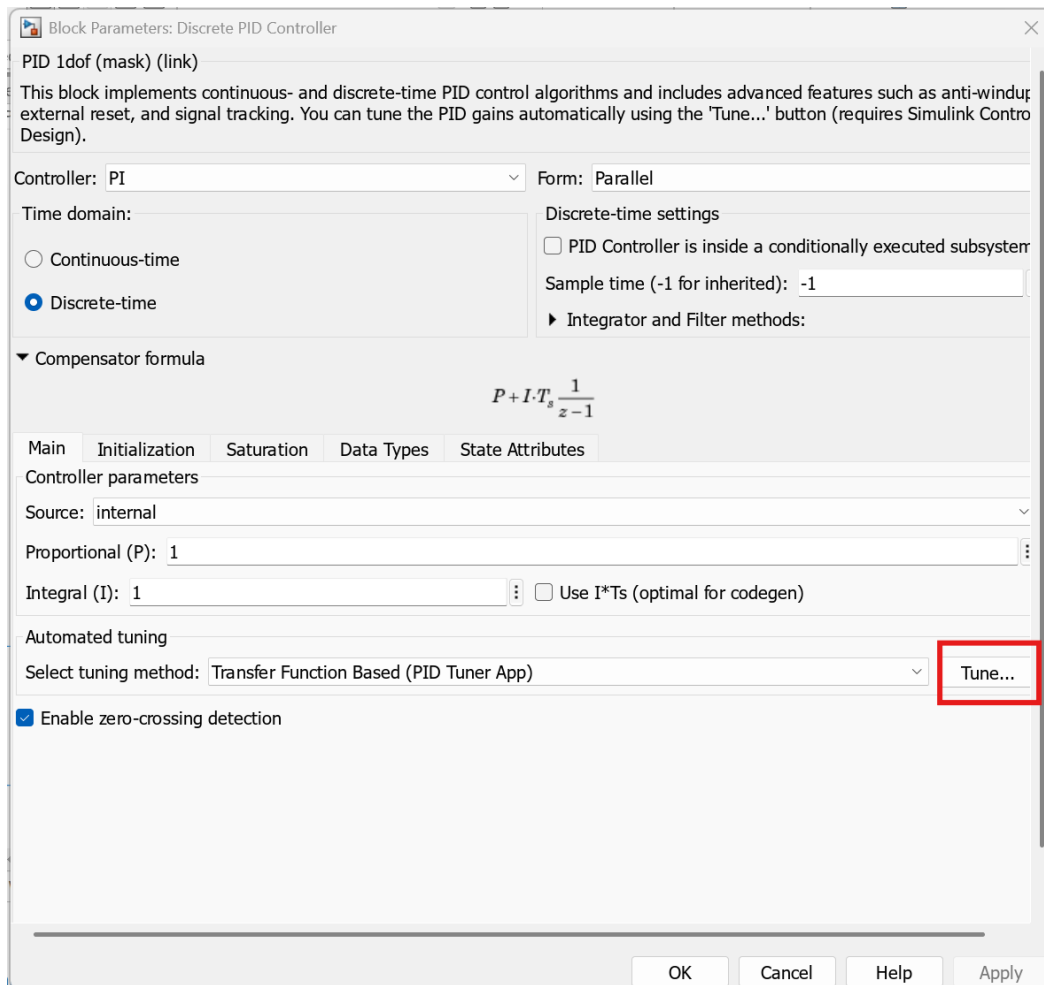


*You may try to change the value of PID gain by double click at "PID controller"



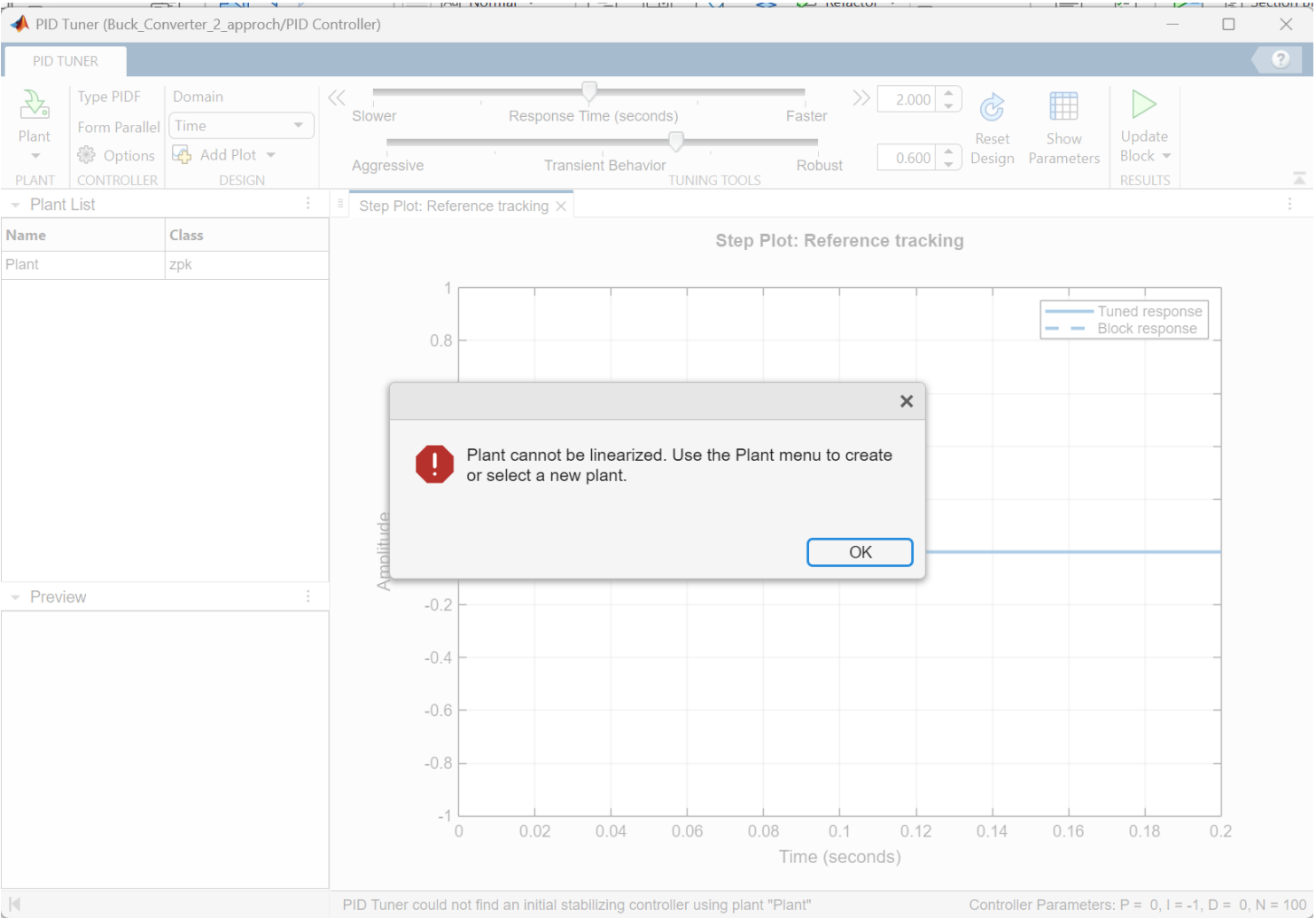
Task 5: Tuning Controller with PID tuner

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

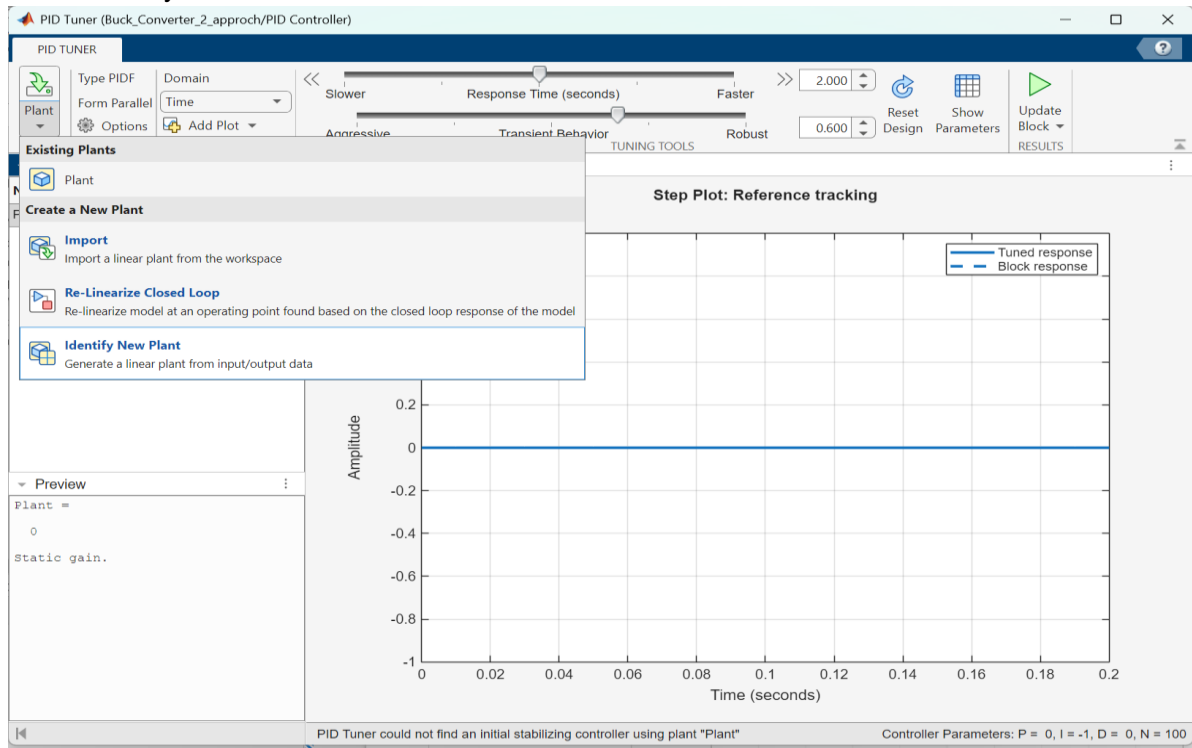


- PID tuner window will pop-up. You can try to tune your controller's "**Response time**" and "**Transient Behavior**" by sliding the bar in picture below --> Click "**Update Block**" after you finished

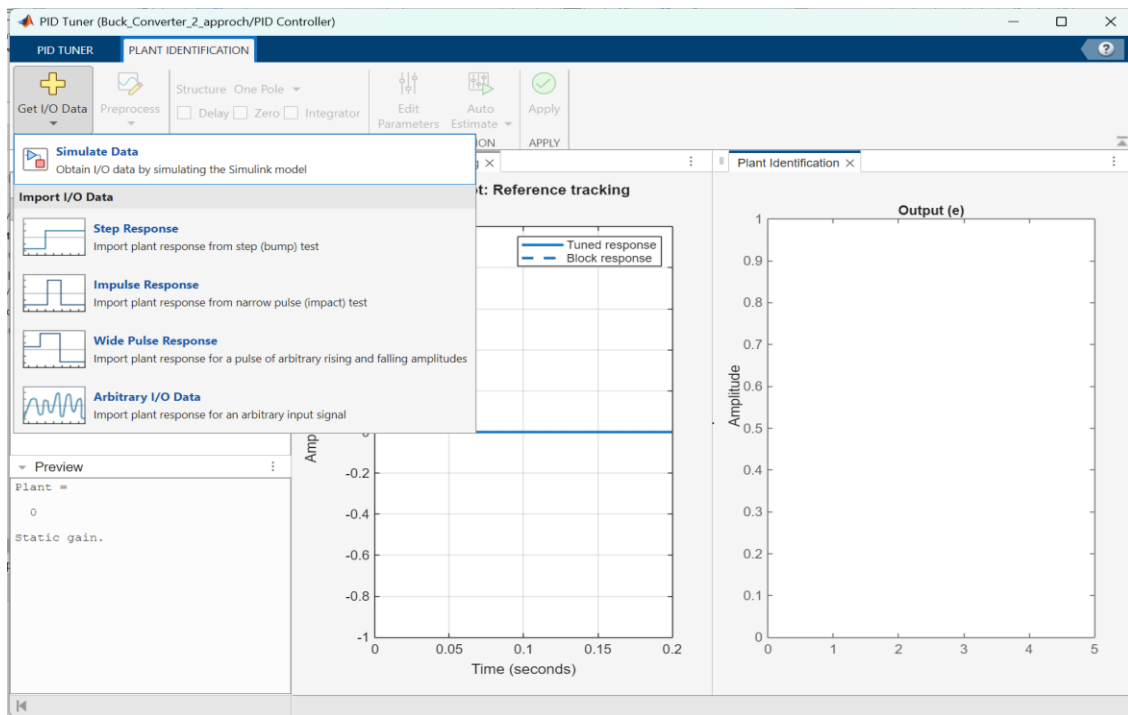
*In this case you may face that "Plant cannot be linearized. Use the Plant menu to create or select a new plant." --> Because the system cannot be linearized --> Linearize manually by selecting the operating point.



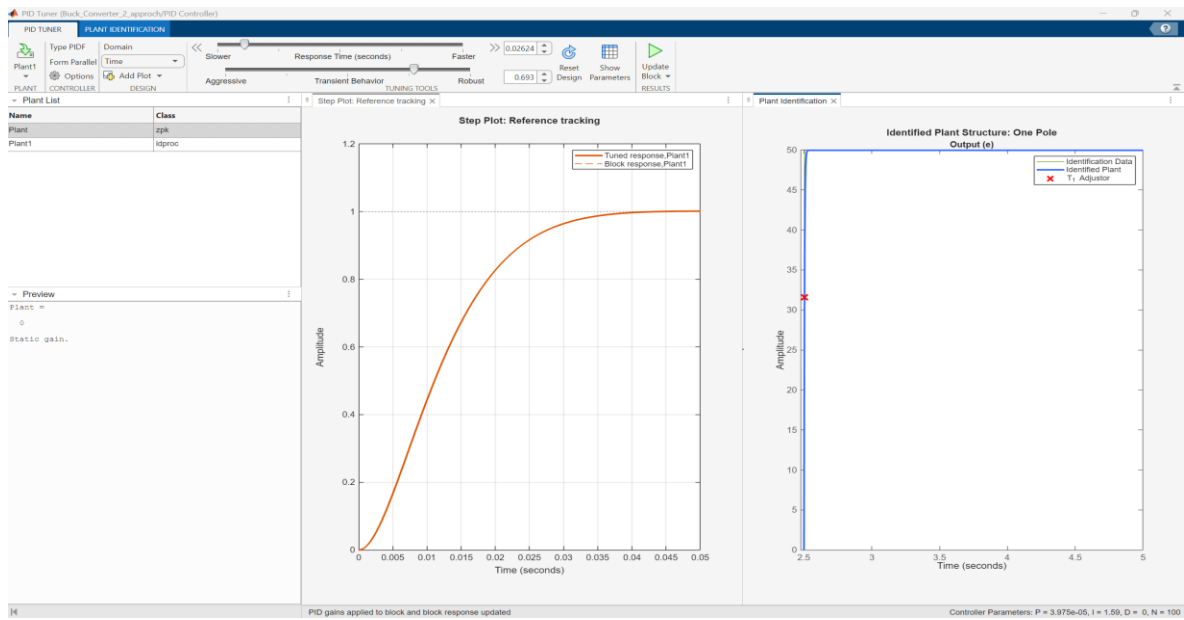
Goto "Identify New Plant"



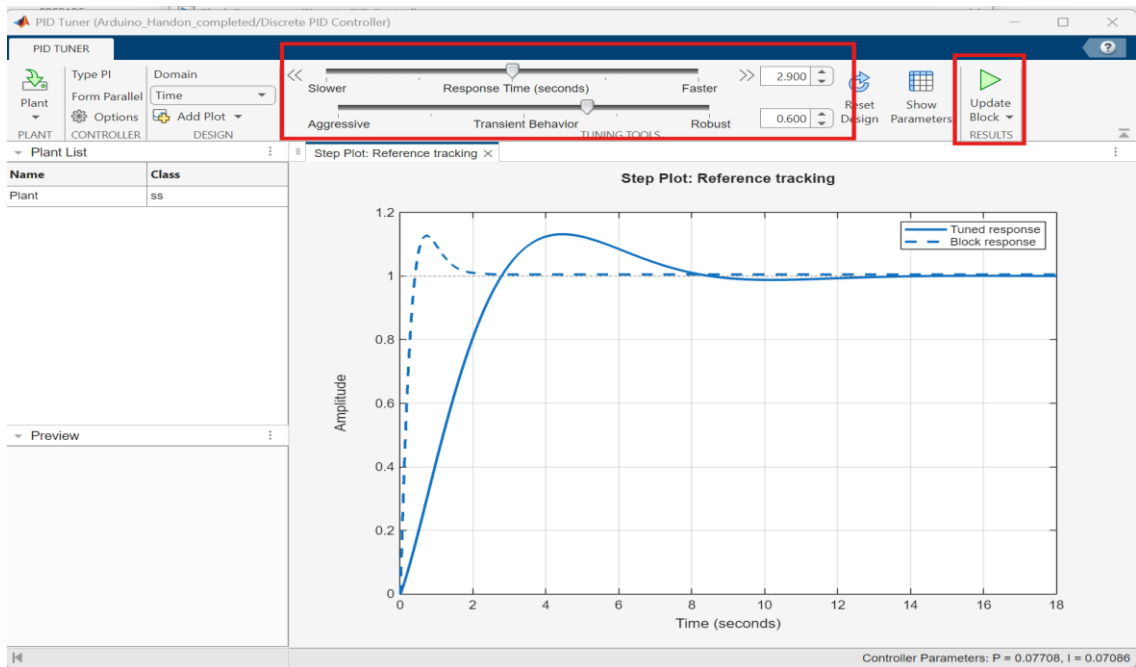
Go to "PLANT IDENTIFICATION" --> "Get I/O Data" --> Simulate Data



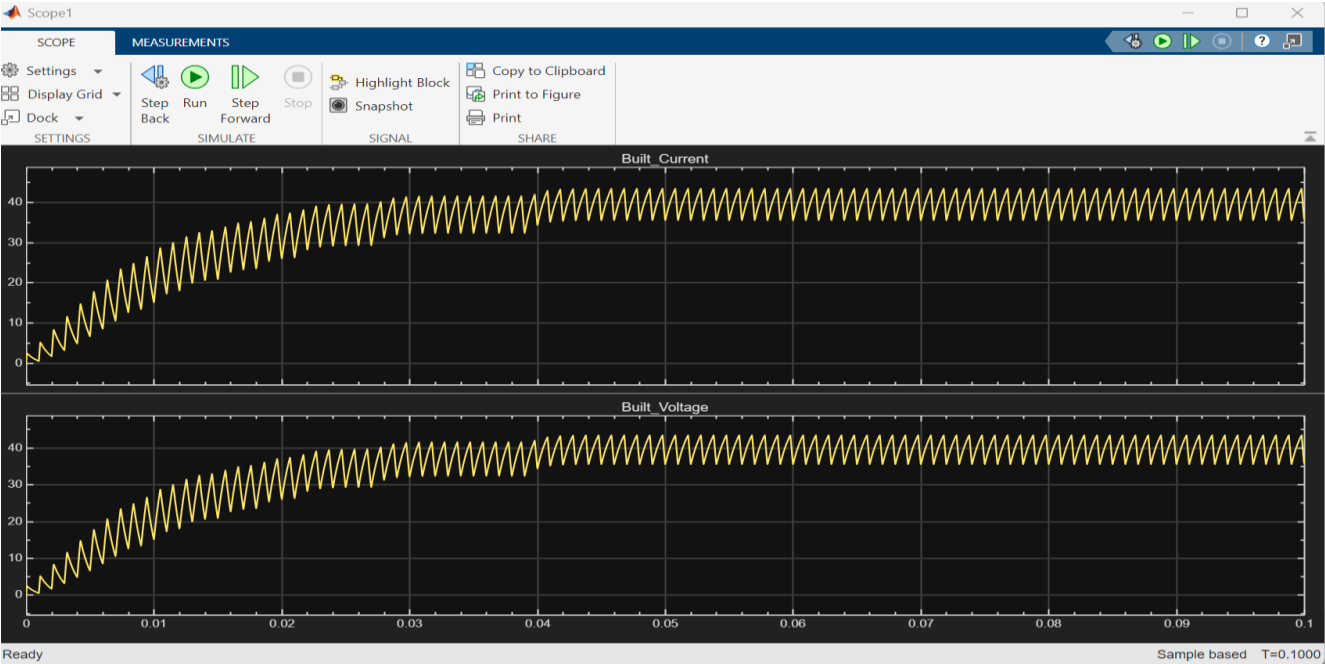
Identify the model and click "Accept" it



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

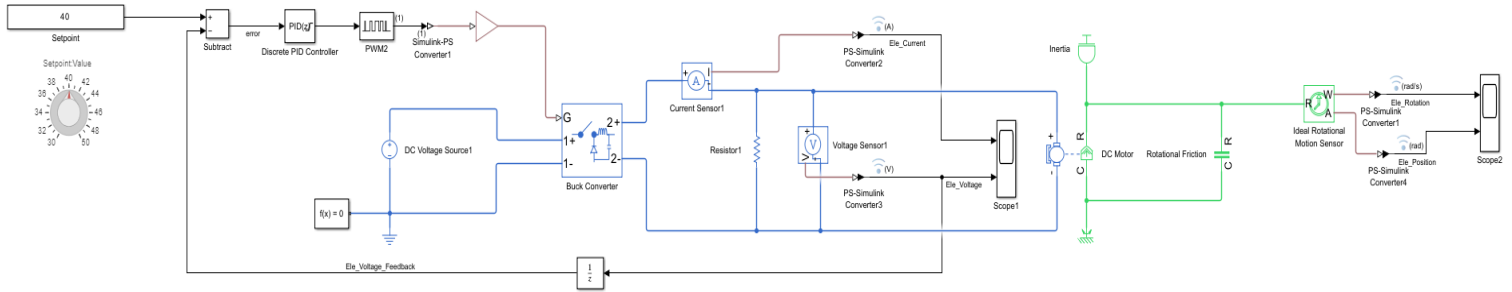


Try to "Run" simulation again to see the chage after you tunning



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

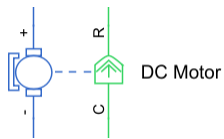
***Optional* Across the Domain (Rotational + Multibody)**




Task 6: Connect to another domain (Rotational)

1. Drag the block from

Simscape>Electrical>Electromechanical>Brushed Motors

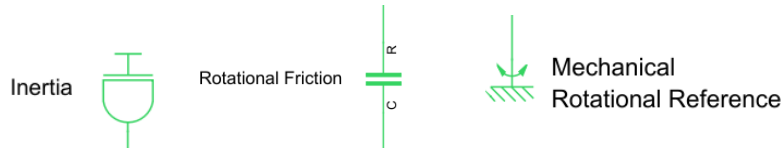



Block Parameters: DC Motor

DC Motor
Auto Apply

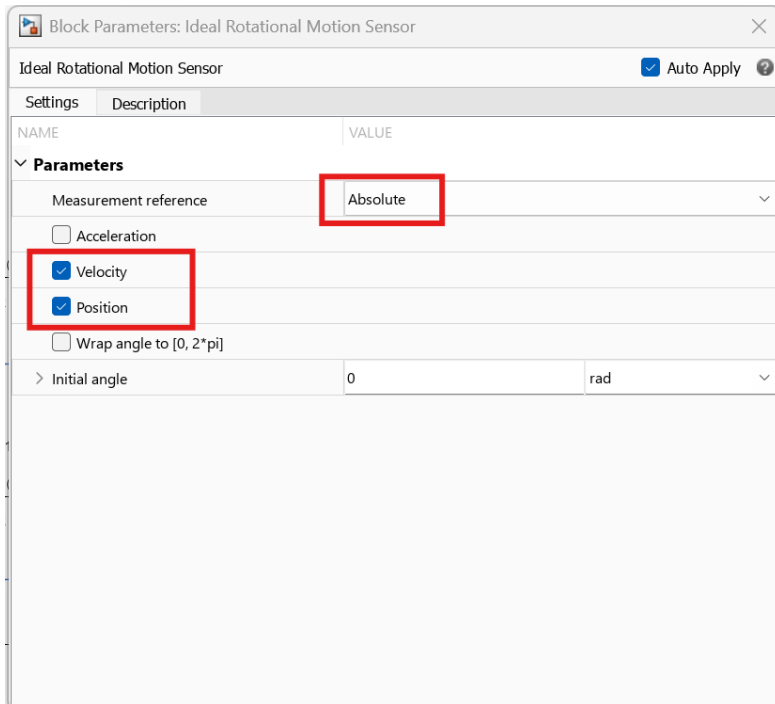
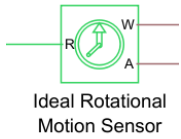
Settings	Description	Value
NAME		
Modeling option		No thermal port
Selected part		<click to select>
Electrical Torque		
Field type		Permanent magnet
Model parameterization		By rated load and speed
Armature inductance		12e-6 H
> No-load speed		19100 rpm
> Rated speed (at rated load)		15000 rpm
> Rated load (mechanical power)		80 W
> Rated DC supply voltage		50 V
Rotor damping parameterization		By damping value
Mechanical		
Faults		

Simscape>Foundation Library>Mechanical>Rotational Elements

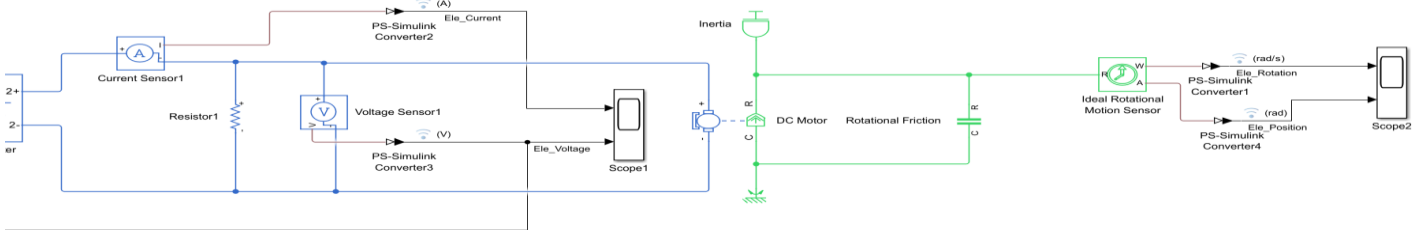


$$J = 1 \times 10^{-5} \text{ kg m}^2, \quad T_{\text{breakaway}} = 0.1 \text{ N m}, \quad T_{\text{Coulomb}} = 0.1 \text{ N m}$$

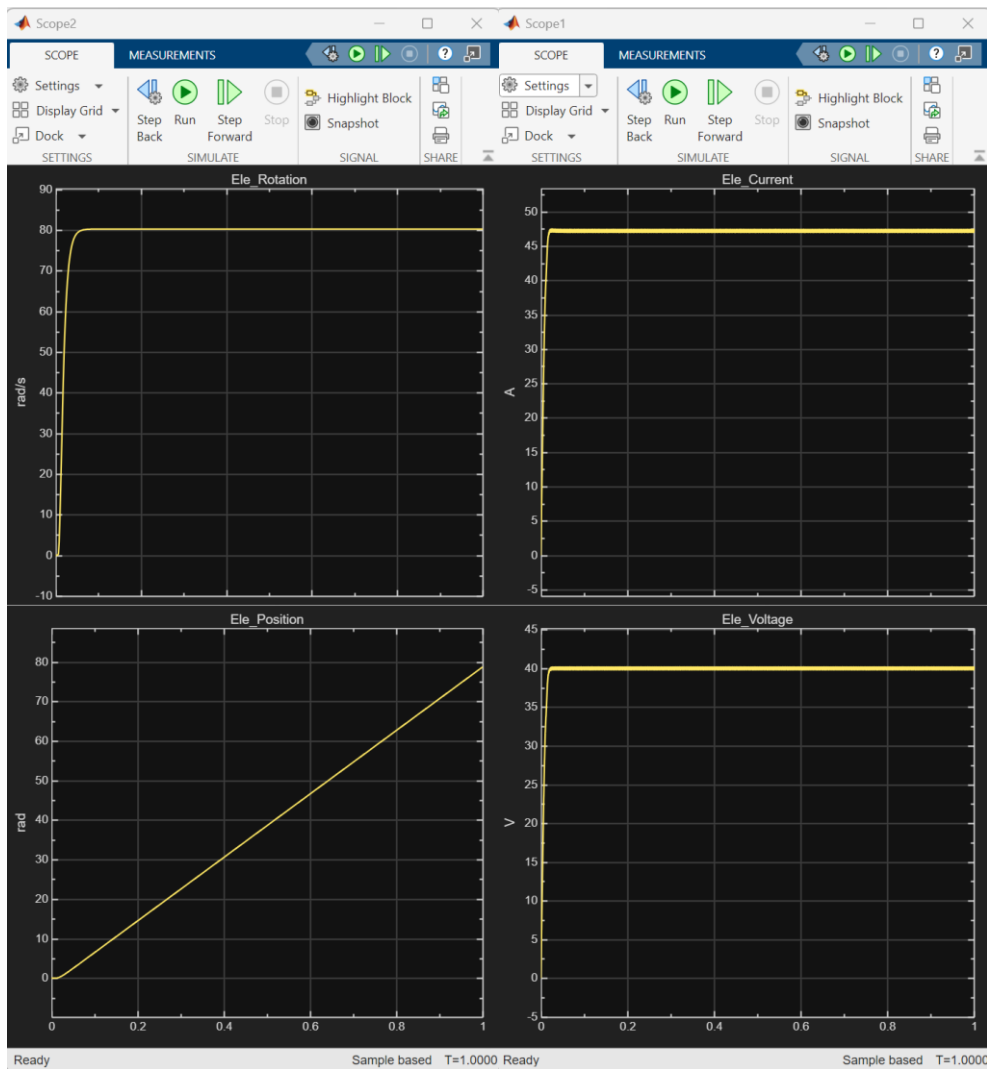
Simscape>Foundation Library>Electrical Sensor



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

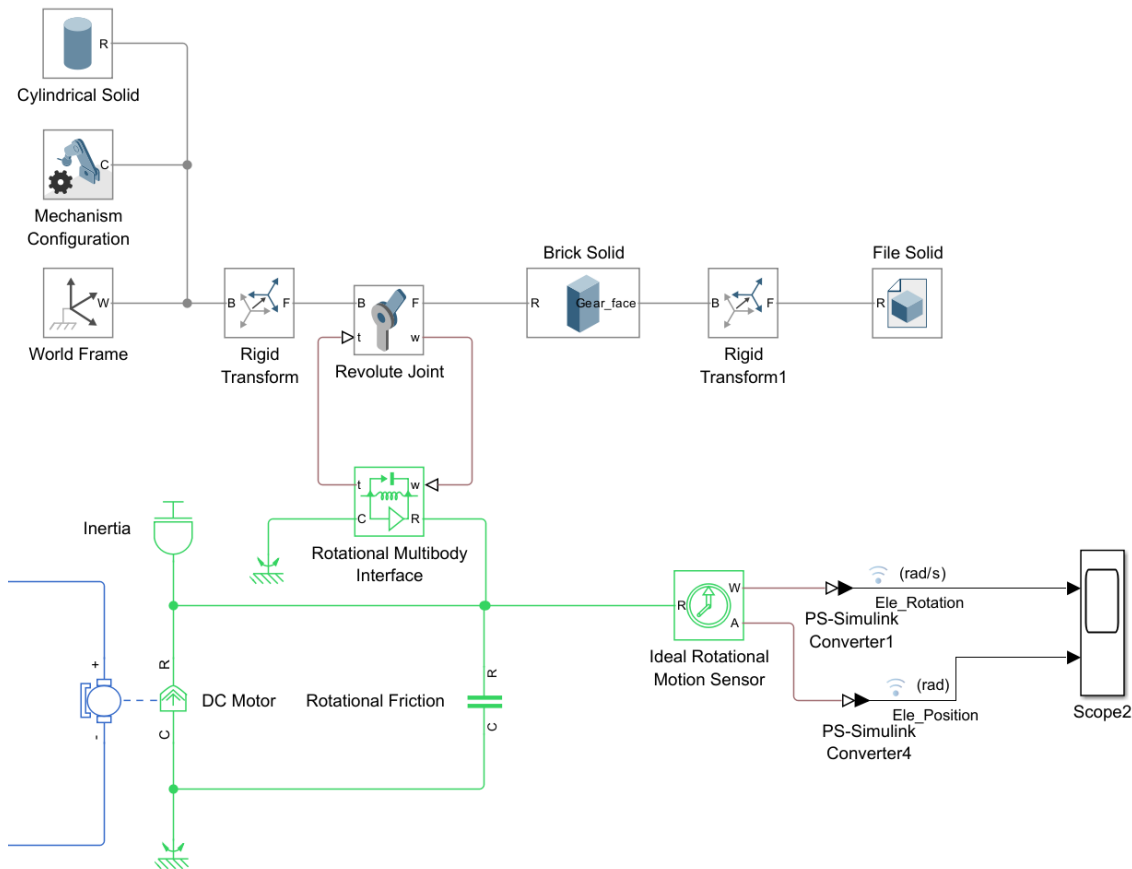


3. Simulate at 1 seconds



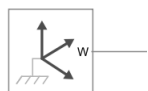
```
open("Buck_Converter_2_PID_Tune_Rotational.slx")
```

Task 7: Connect to another domain (Multibody)



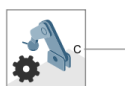
1. **[Create Reference]** Drag the block from

Simscape>Multibody>Frame and Transforms



World Frame

Simscape>Multibody>Utilities



Mechanism Configuration

Simscape>Multibody>Body Elements

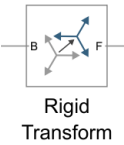


Cylindrical Solid

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

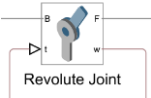
2. [Create Joint] Drag the block

Simscape>Multibody>Frame and Transforms



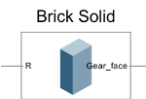
Translation		
Method	Cartesian	
Offset	[0 0 0.5]	cm


Simscape>Multibody>Joints



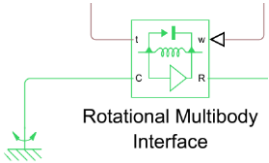
Actuation	
Torque	Provided by Input
Motion	Automatically Computed
Sensing	
<input type="checkbox"/> Position	
<input checked="" type="checkbox"/> Velocity	

Simscape>Multibody>Body Elements

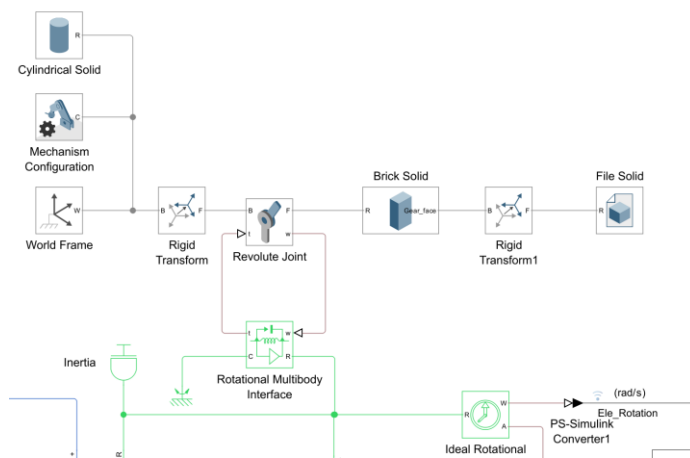


Solid				
Settings		Description		
NAME		VALUE		
▼ Geometry				
Dimensions	[1 1 1]	cm	▼	Compile-time ▼
➤ Export				

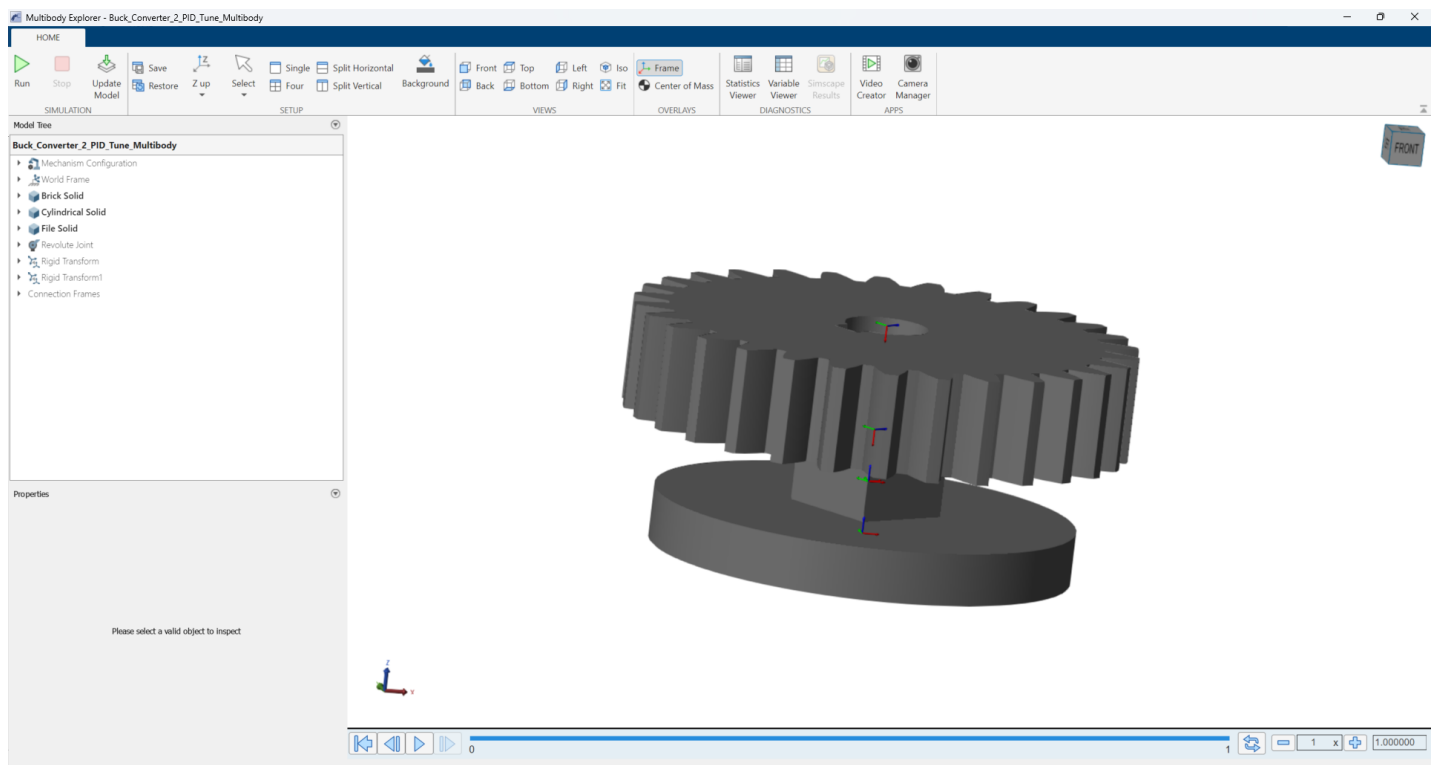
Simscape>Simscape Mechanical Interfaces



3. Connect model together



4. Simulate at 1 seconds



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