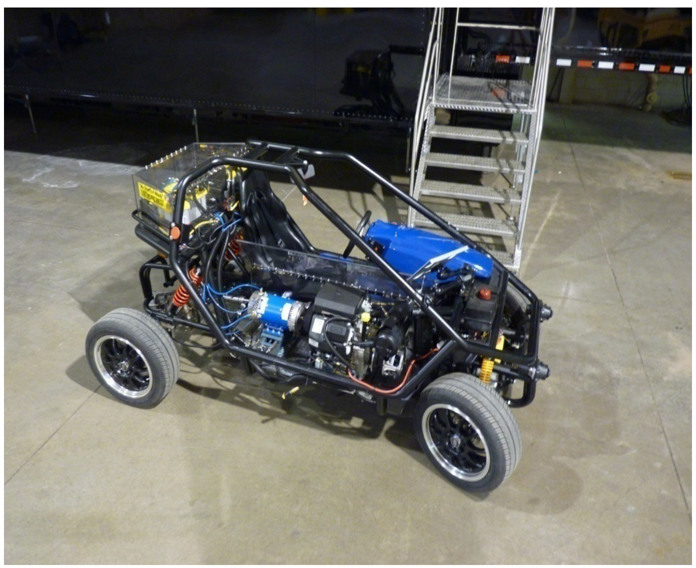
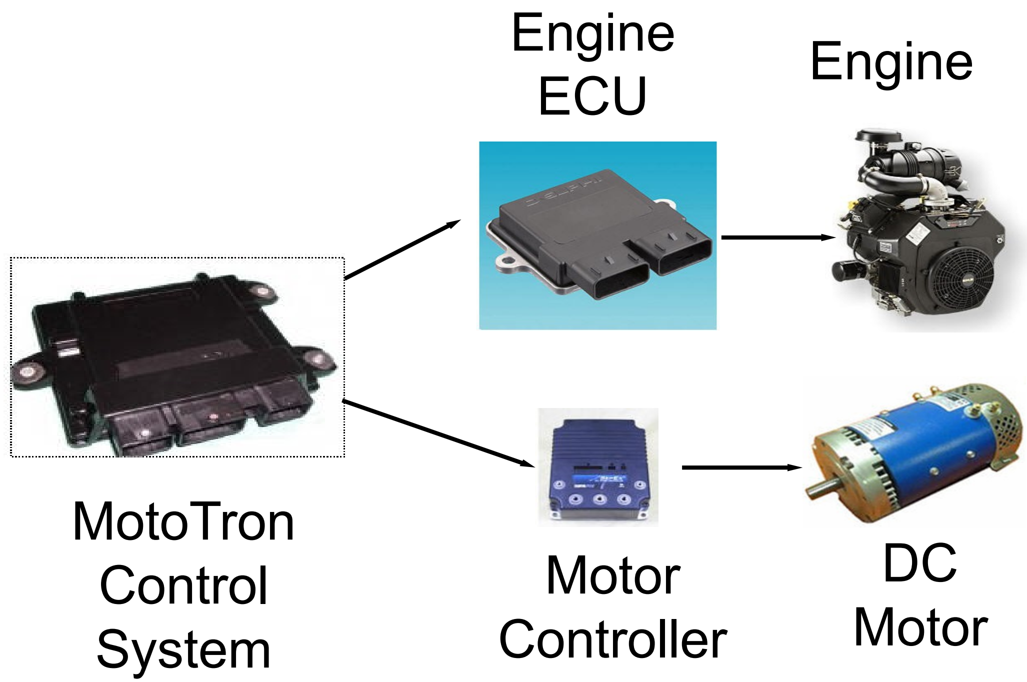
MEEM/EE 5750

Course Project Model Development and Validation in MotoTron

Project Objectives

1. Develop a high-level controller (MotoTron Control System) for a configurable hybrid electric learning modules (CHELM) as shown below using model-based embedded control system design approach.



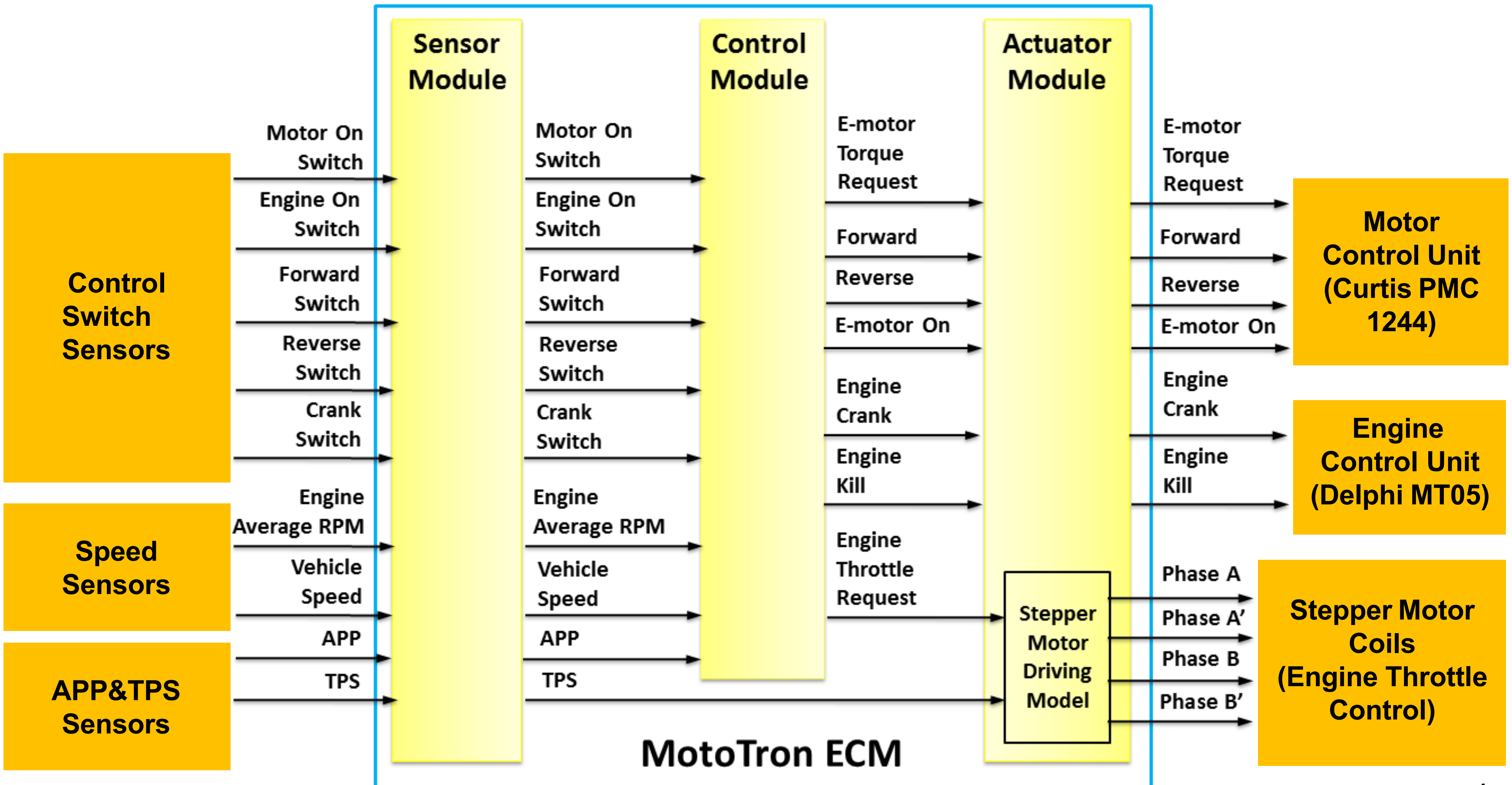


Project Objectives

2. The high-level controller generates control signals for the engine controller and the motor controller, such as engine and motor on/off, engine state control, and the amount of torque the engine and motor should provide.
3. The high-level controller also needs to provide driving signals for the coils of a step motor, which controls the engine throttle.

Overview of the MotoTron Control System

Figure below shows the basic modules, input, and output signals of the MotoTron control system (APP = PPS).



Input Signals

- Motor On Switch: Electric Solo Mode
- Engine On Switch: Engine Solo Mode
- Forward Switch: move forward switch in Electric Solo Mode
- Reverse Switch: move backward switch in Electric Solo Mode
- Crank Switch: vehicle key switch
- Engine Average RPM: engine speed sensor input
- Vehicle Speed: vehicle speed sensor input
- Accelerator Pedal Position (APP = PPS): vehicle speed/torque request command
- Throttle Position Sensor (TPS): throttle position sensor input

Output Signals

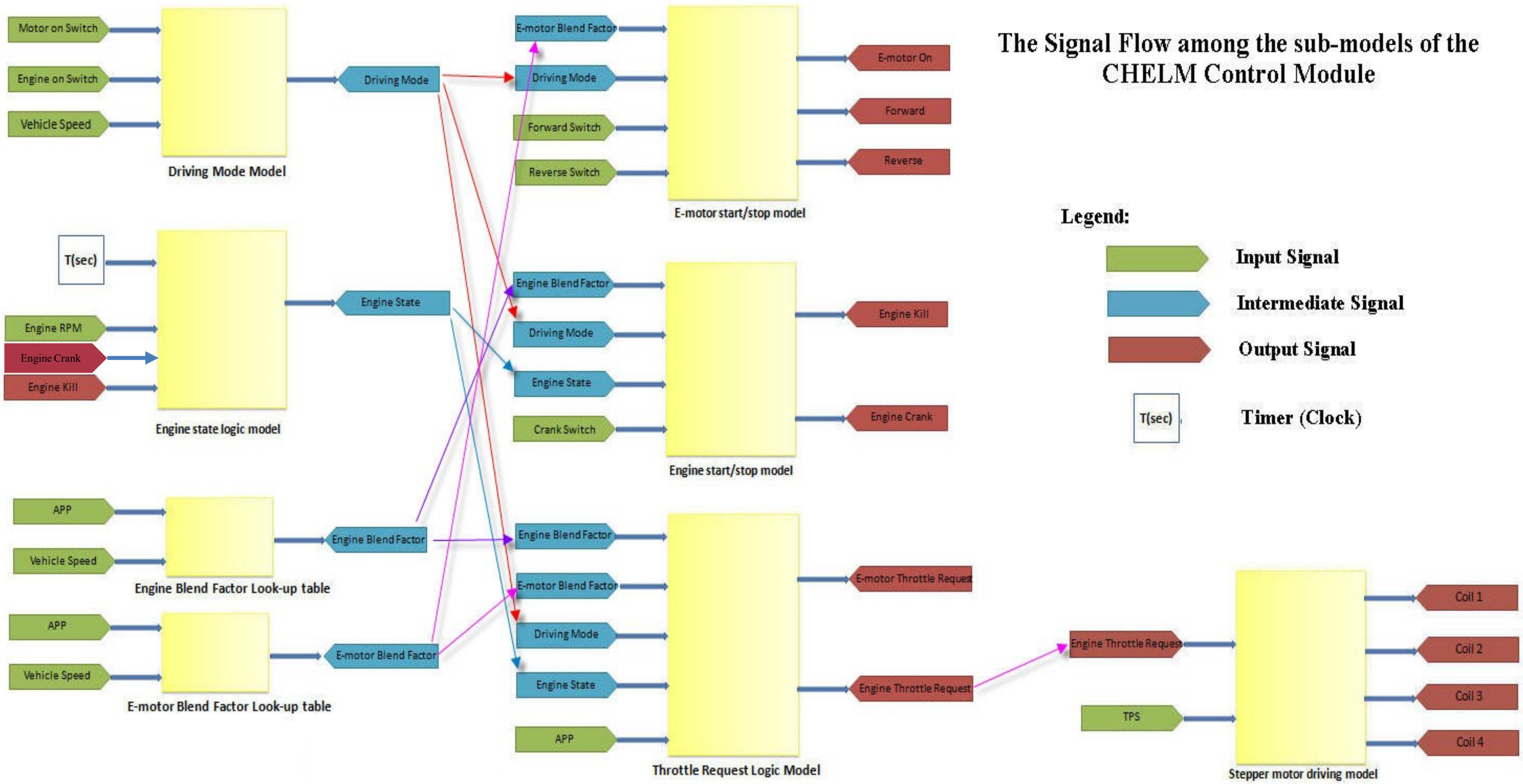
- E-motor Torque Request: the power control signal of the E-motor
- Forward: the motor moves forward
- Reverse: the motor moves backward
- E-motor On: a control signal to turn on the E-motor
- Engine Crank: a control signal to start engine
- Engine Kill: a control signal to stop engine
- Driving signals for four stepper motor coils

Model Development

You are required to develop at least six sub-models in the control module and one sub-model in the actuator module. The logic of these sub-models and the relation among these models are provided in a separate file, the control logic of the MotoTron controller.

1) Driving mode model: determines the driving model of the vehicle based on switch inputs.
2) Two look-up tables for the blend factors in the blending mode. Your improvement of power split between the engine and motor in the blending mode.
3) Engine state logic model: determines the state of the engine.
4) Engine start/stop model: determines when to start and stop the engine.
5) Motor torque request and engine throttle request model: determines motor torque and engine throttle request based on the driving mode, APP request, blend factors, and engine states.
6) E-motor start/stop model: determines when to start and stop the motor.
7) Stepper motor driving model: generates driving signals for four stepper motor coils.

Signal Flow among Sub-models



Sensors and Actuators for Mototron Validation

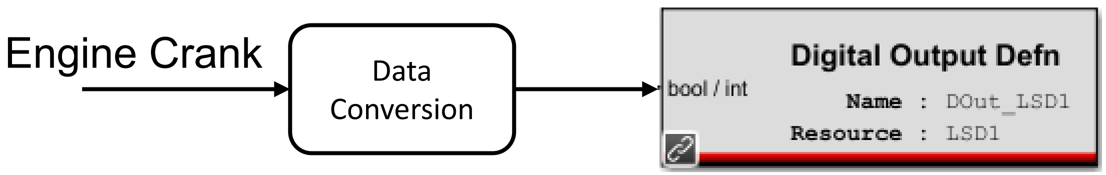
1. Use potentiometers as switch inputs for Engine On Switch, Motor On Switch, Forward Switch, Reverse Switch, Crank Switch and input signals of APP(PPS1), TPS, Engine Average RPM, and Vehicle Speed.
2. Use Low Side Drivers and LEDs on the desktop simulator to display Engine Crank, Engine Kill, Forward, Reverse, and E-motor On output signals.
3. Use a servo motor shaft to show the range of the E-motor Torque Request. The 0-90 degree of the servo motor shaft represents the minimum to the maximum values of the E-motor Torque Request. Use TACH on the desktop simulator to output a PWM signal to drive the servo motor.
4. Use four Low Side Drivers to form a unipolar driving circuit for the stepper motor.

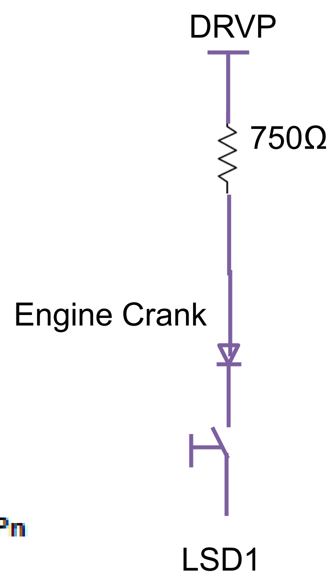
The Connection of Input/Output Signals to the Mototron ECU

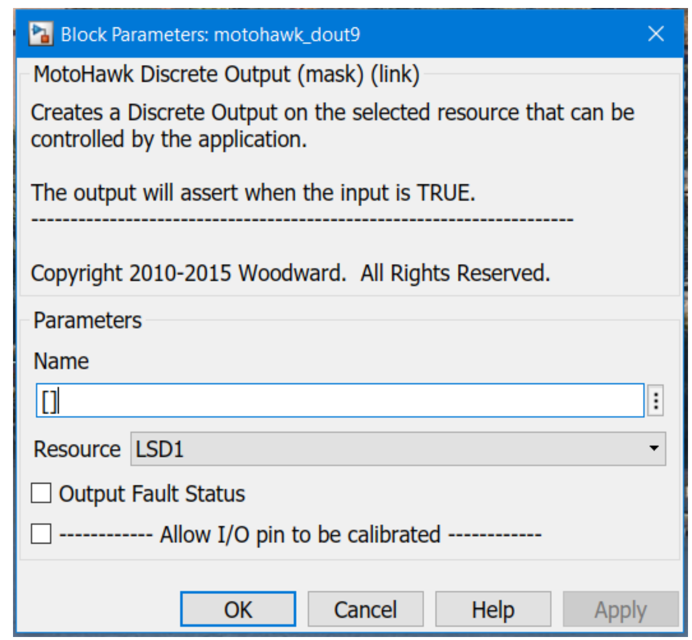
Input Signal	ECU Pin	Output Signal	ECM Pin
Engine On Switch	AN5M	Engine Crank	LSD1
Motor On Switch	AN6M	Forward	LSD2
Forward Switch	AN7M	Reverse	LSD3
Reverse Switch	AN8M	E-motor On	LSD4
Crank Switch	AN9M	Engine Kill	LSD9
APP(PPS1)	AN1M	E-motor Torque Request	TACH
TPS	AN2M	Stepper Motor Driving Signals	Coil 1 – LSD 5 Coil 2 – LSD 6 Coil 3 – LSD 7 Coil 4 – LSD 8
Engine Average RPM	AN3M		
Vehicle Speed	AN4M		

Note: If the defined channel number does not work in the desktop simulator, you can change to other input/output channels. Include the actual input/output channels in your report.

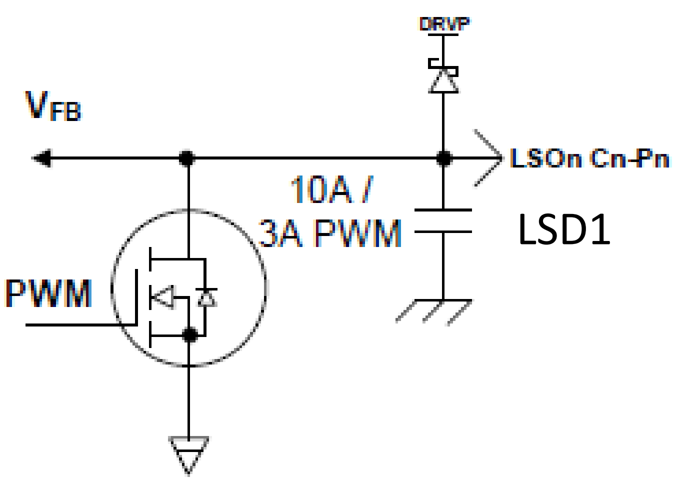
LED Output Control







Engine Crank



SG90 Micro Servo Motor

Control system: Pulse Width Control (1500us NEUTRAL)

Required pulse: 3-5 Volt peak to peak pulse wave

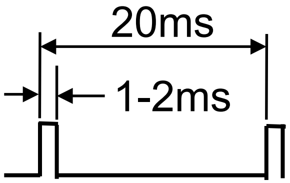
Operating voltage range: 4.8V to 6.0V

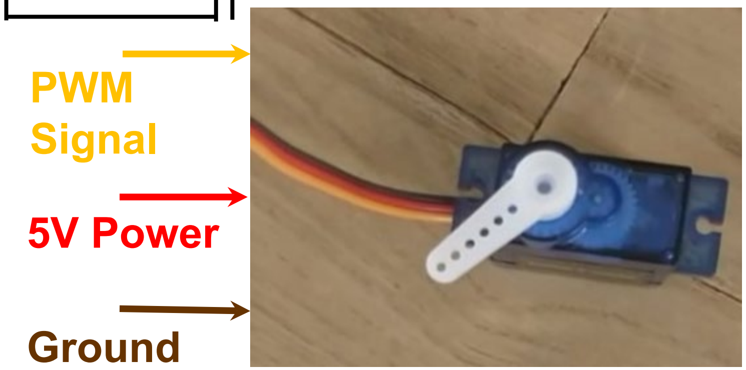
Operating angle range: 90^0

Operating speed (4.8V): 0.12 sec/60^0 at no load

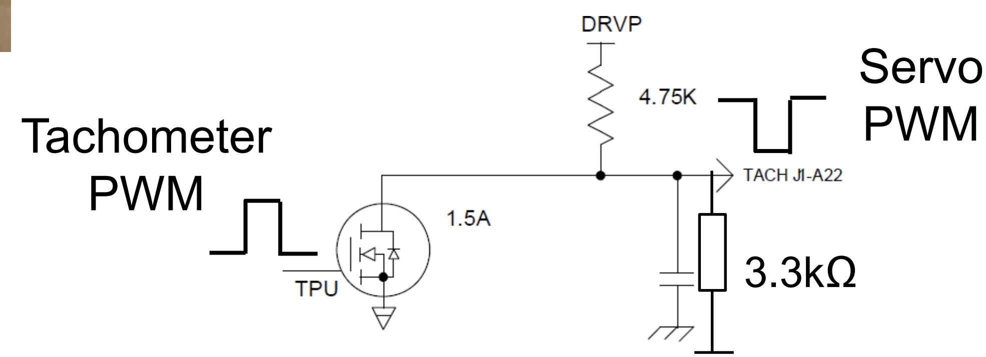
Torque : 2.5 kg/cm

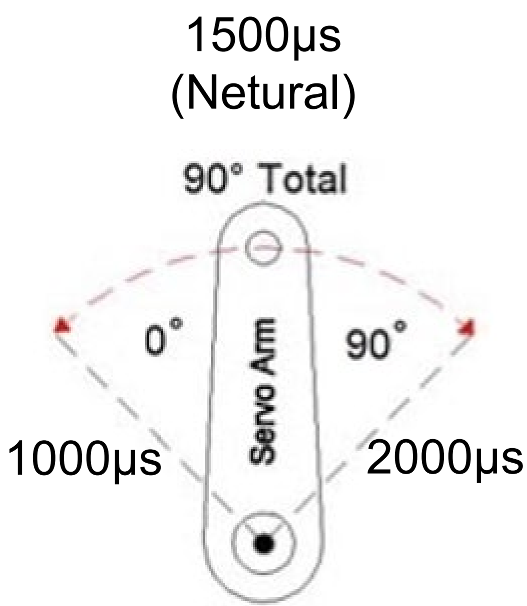
SG90 Micro Servo Motor Control





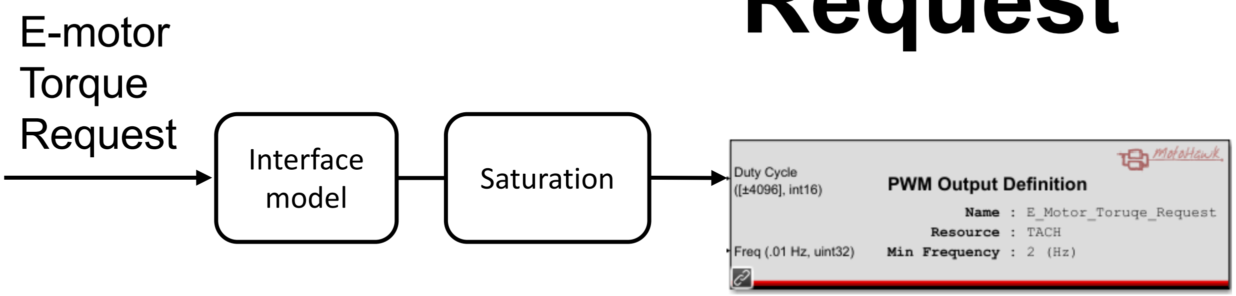
The period of the PWM signal is 20ms. Wider or thinner pulses command the servo arm moving to a designated position, either clockwise or counterclockwise from the center.

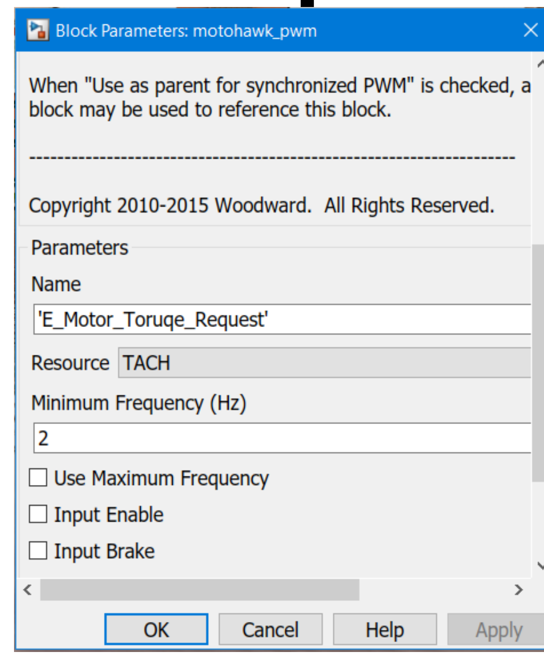


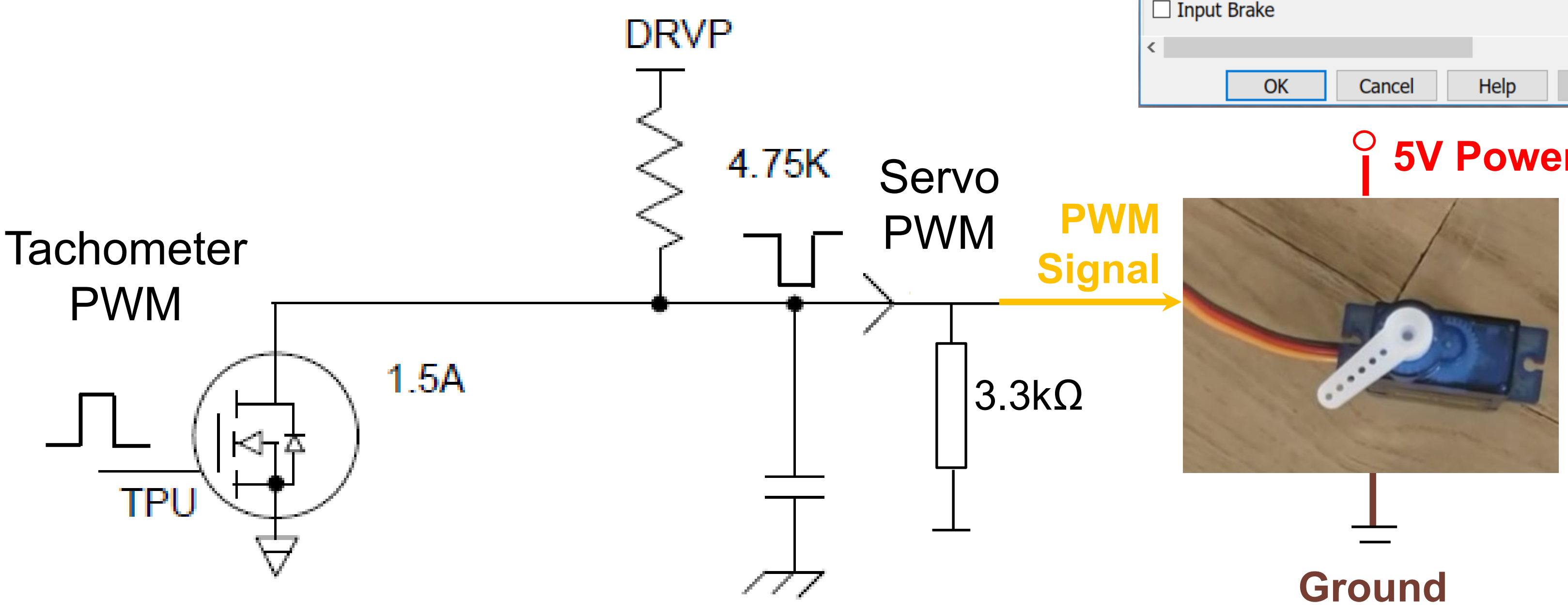


Calibration Value	Servo Rotation Angle (°)	Servo PWM Duty Cycle	Tachometer PMW Duty Cycle
Minimum E-motor Torque Request	0	0.05 (1ms/20ms)	0.95
Maximum E-motor Torque Request	90	0.1 (2ms/20ms)	0.90

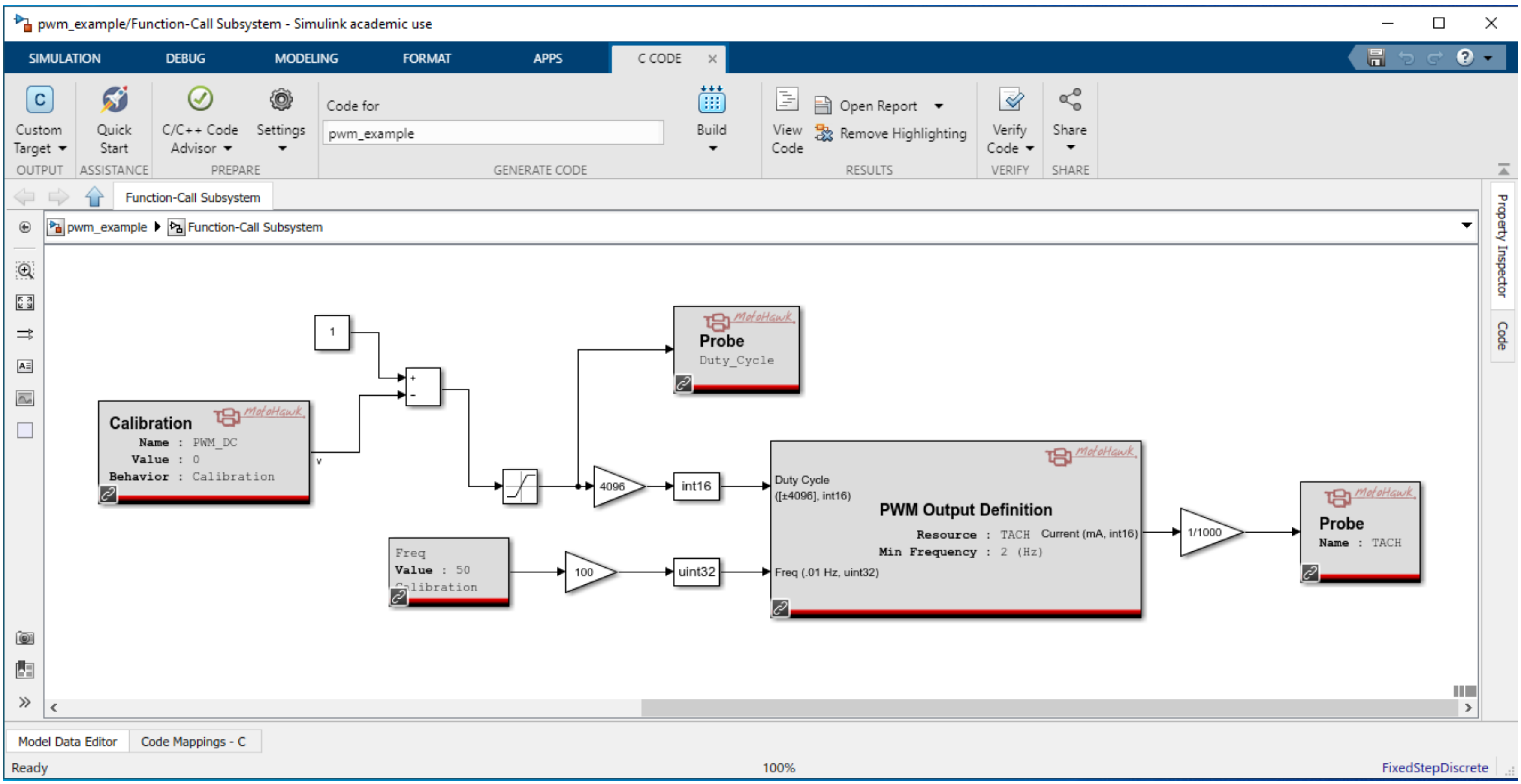
Output Control of E-motor Torque Request





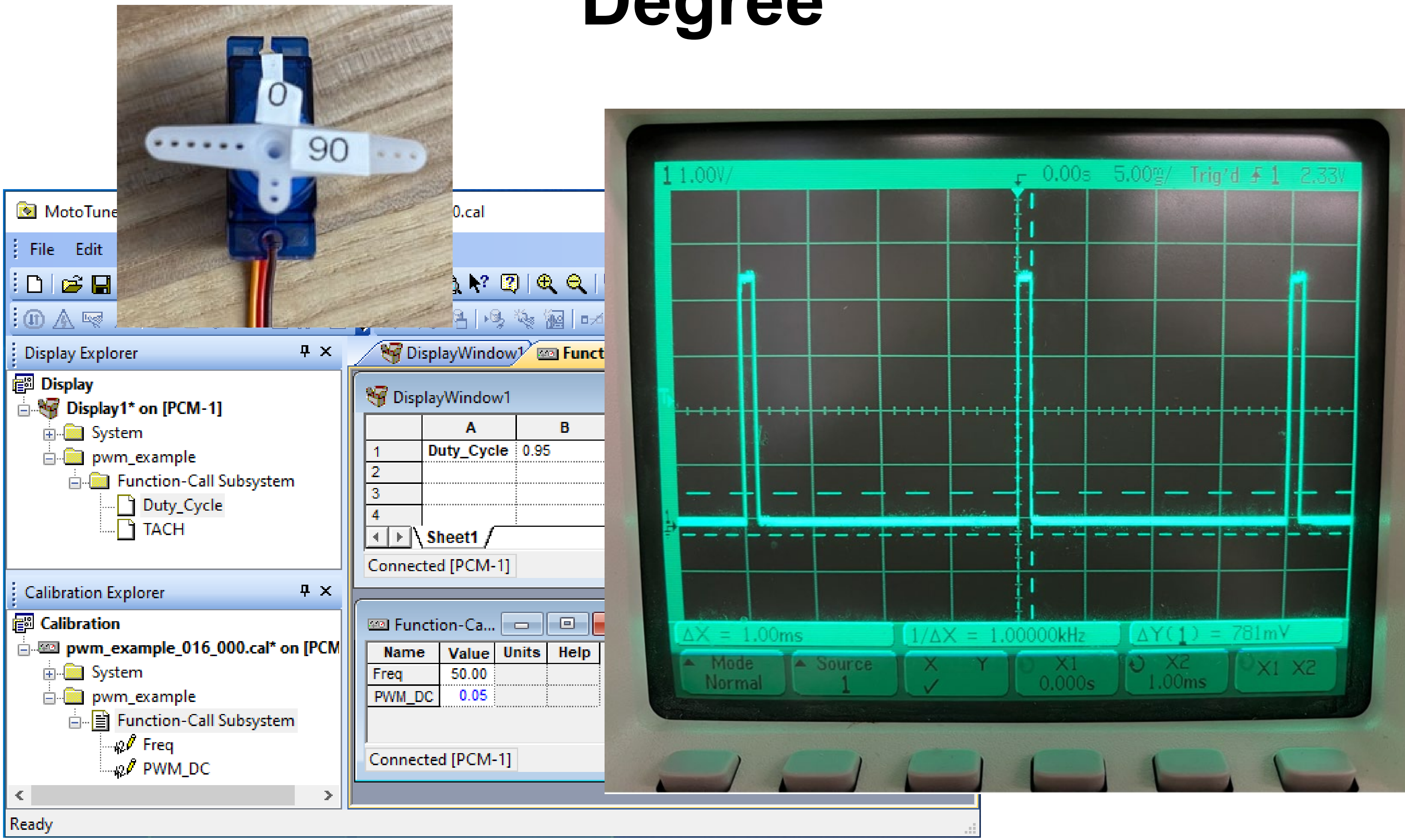


An Example of Generating PWM Signals for a Servo Motor



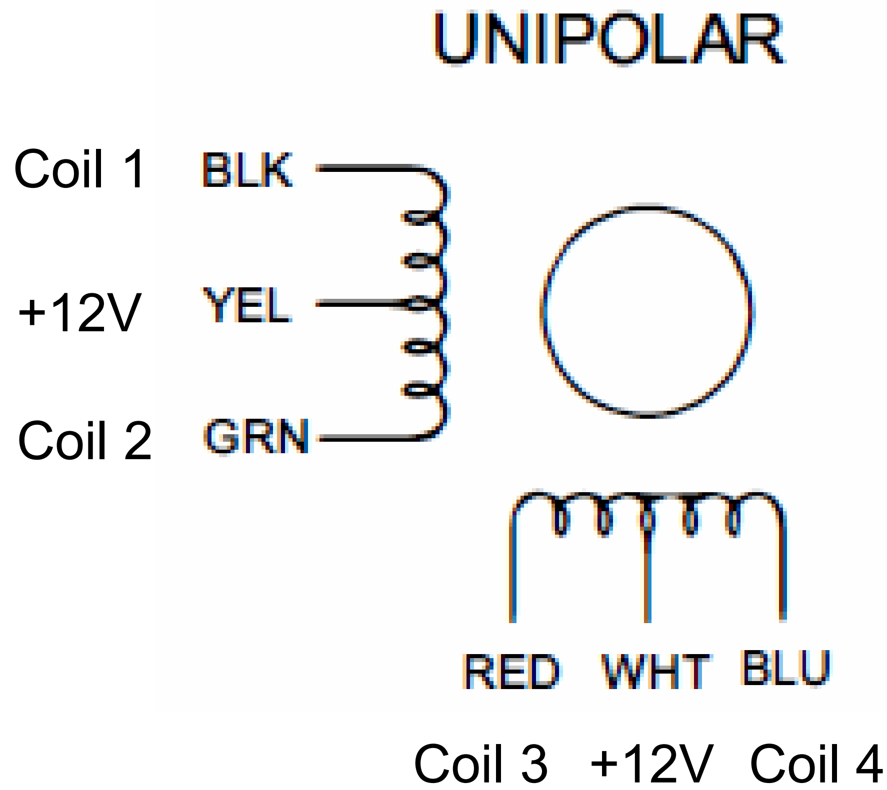
Saturation Block - Upper limit: 0.95, Lower limit: 0.9

PWM Signal for Servo Shaft at Zero Degree



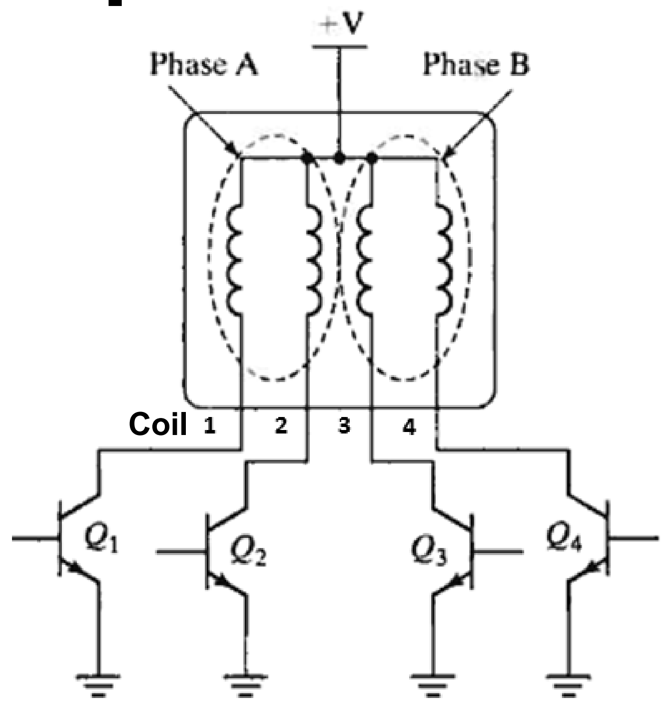
Stepper Motor

Stepper Motor



Only connect stepper motor to the desktop simulator when you test the functions of the stepper motor.

The Step Sequence of Driving Signals

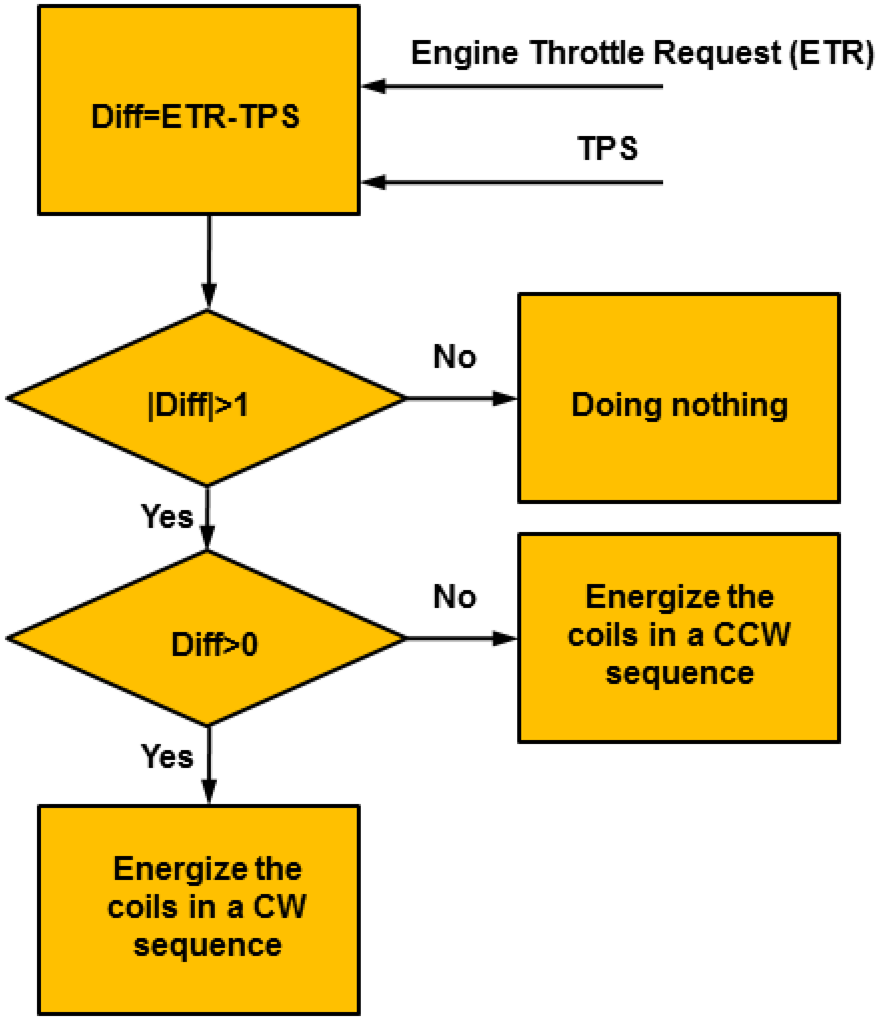


Unipolar Drive

CW ↓ / ↑ CCW

Step	Q_1	Q_2	Q_3	Q_4
1	On	Off	On	Off
2	On	Off	Off	Off
3	On	Off	Off	On
4	Off	Off	Off	On
5	Off	On	Off	On
6	Off	On	Off	Off
7	Off	On	On	Off
8	Off	Off	On	Off
1	On	Off	On	Off

Stepper Motor Control Logic



Tasks and Report Requirement

Task 1: Build and Submit Models

1. You are required to develop at least six sub-models in the control module and one sub-model in the actuator module. The logic of these sub-models and the relation among these models are provided in a separate file, the control logic of MotoTron controller.
    1) Driving mode model: determines the driving mode of the vehicle based on switch inputs.
    2) Two look-up tables for the blend factors in the blending mode. Your improvement of power split between the engine and motor in the blending mode.
    3) Engine state logic model: determines the state of the engine.
    4) Engine start/stop model: determines when to start and stop the engine.
    5) Motor torque request and engine throttle request model: determines the motor torque and engine throttle request based on the driving mode, APP request, blend factors, and engine states.
    6) E-motor start/stop model: determines when to start and stop the motor.
    7) Stepper motor driving model: generates the driving signals for four stepper motor coils.

Tasks and Report Requirement

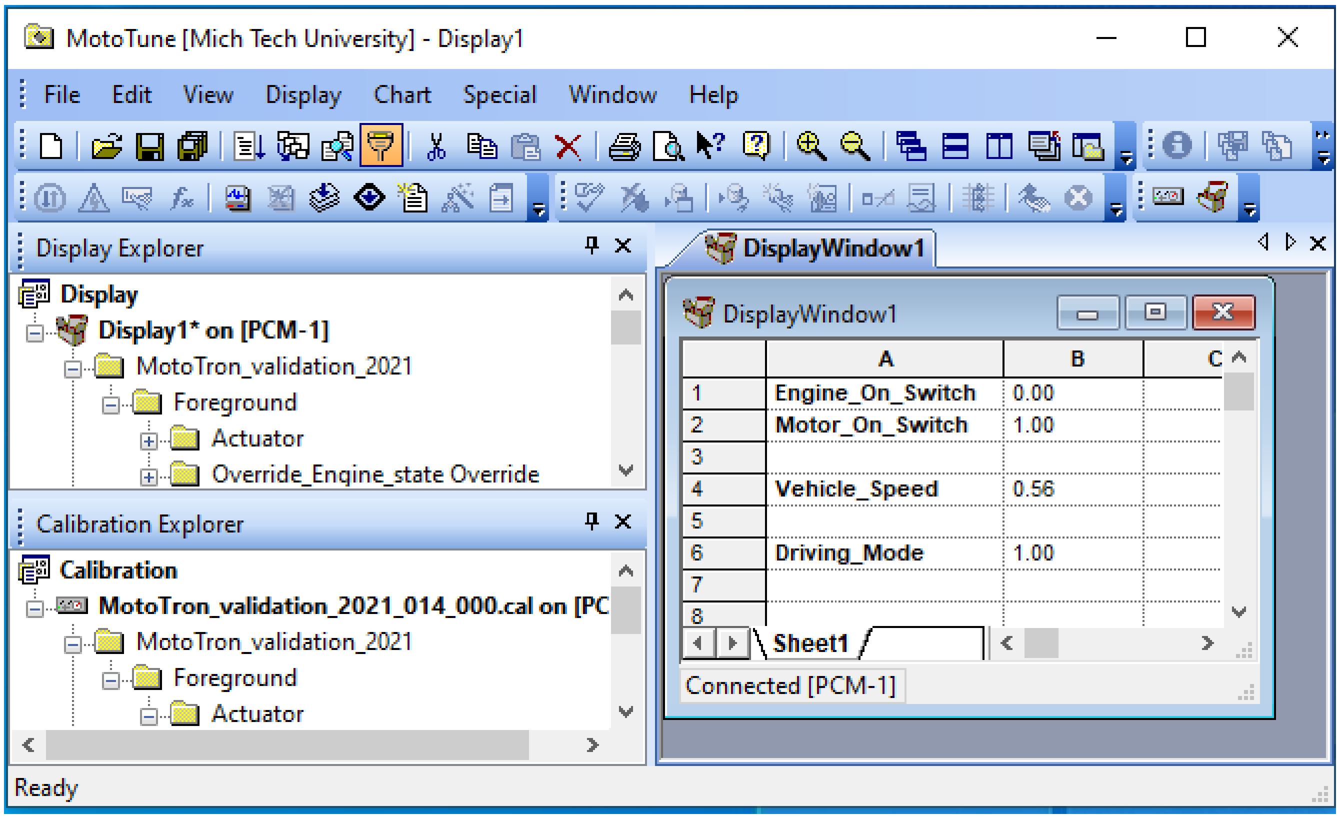
Task 2: Calibration

2. Perform calibration for the following variables.
   1) Vehicle speed: 0-19 mph.
   2) Engine average RPM: 10-3000 rpm
   3) APP: 0-100%
   4) TPS: 0-100%
   5) Servo motor shaft: 0 degree is corresponding to E-motor Torque Request=0. Shaft location of 90 degrees is corresponding to E-motor Torque Request=100%. It will be easier to perform this calibration in electric solo mode.

Tasks and Report Requirement

Task 3: Validation of the Driving mode model

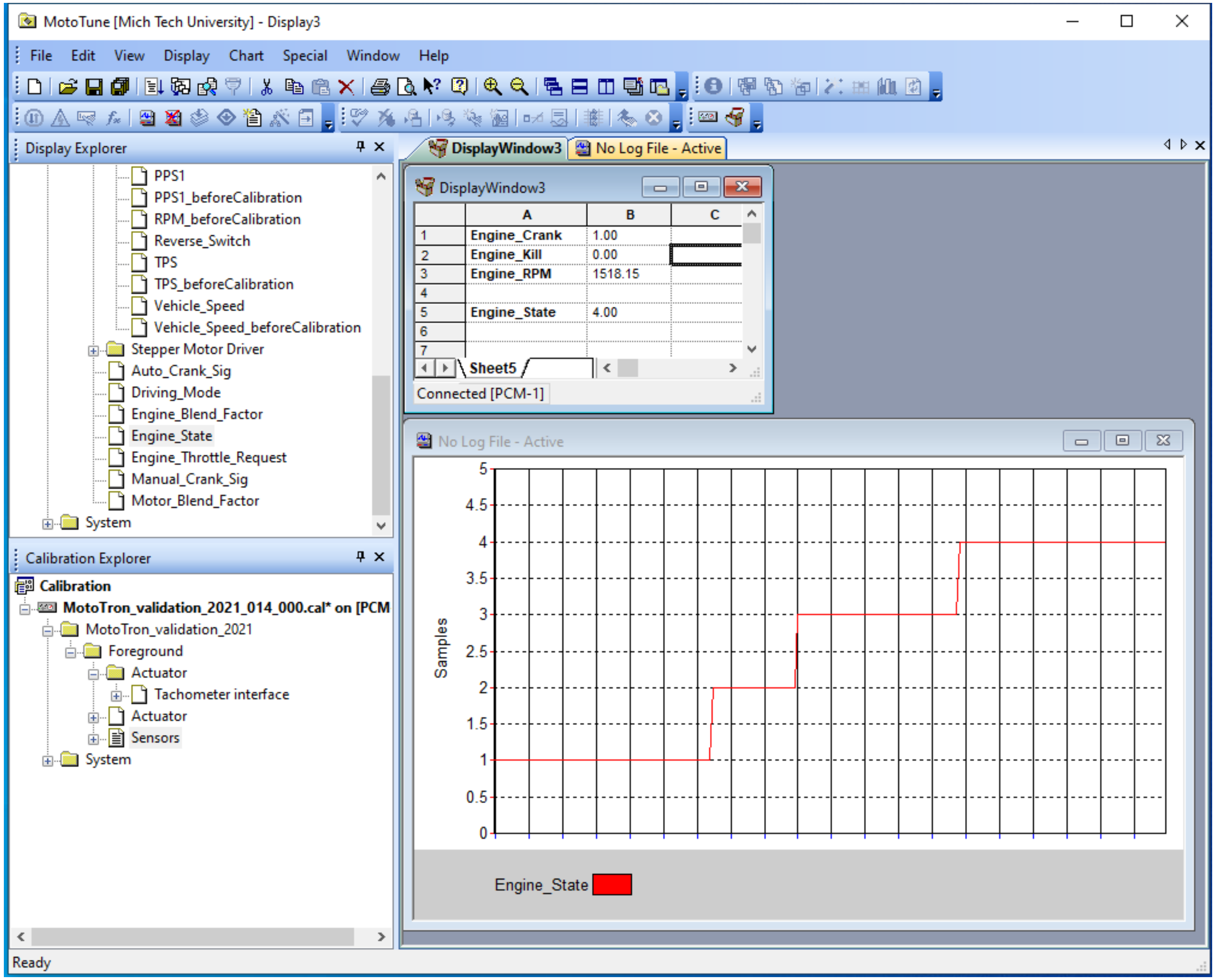
3. Test Driving mode model for all the possible input/output combinations. Below is one example.



Tasks and Report Requirement

Task 4: Validation of the Engine state logic model

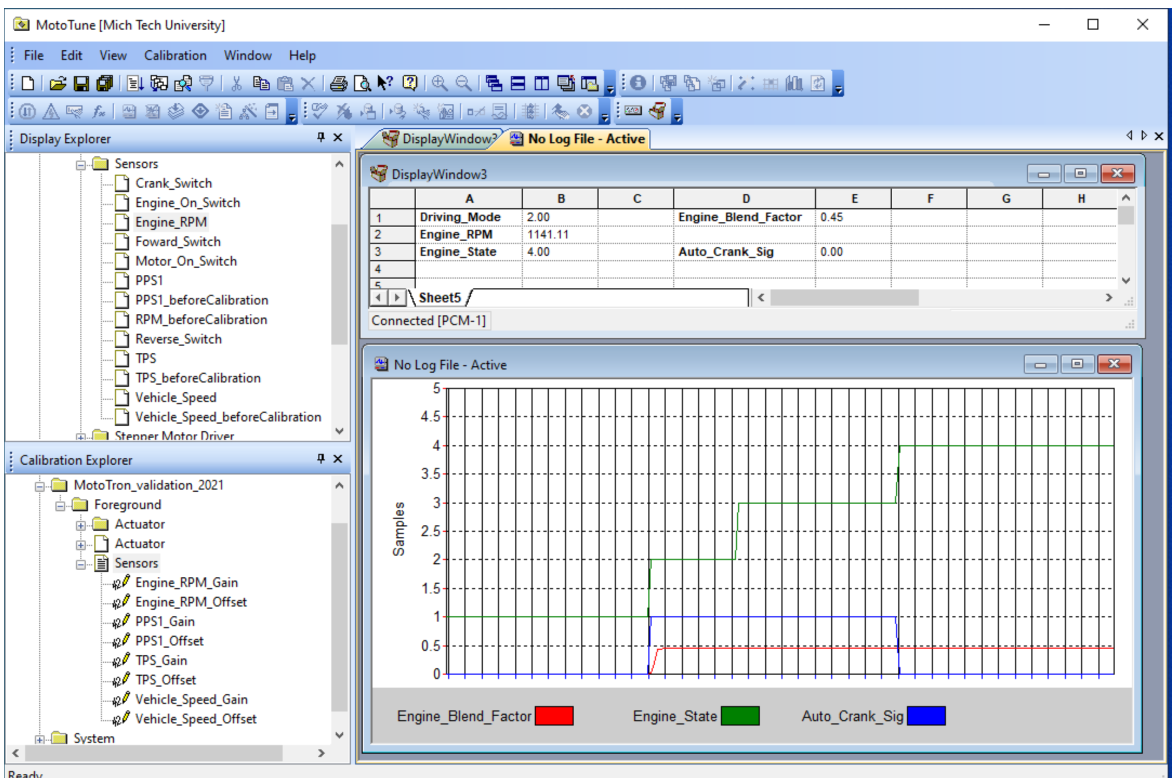
4. Test requirement for engine state model: include the input values and the state transition chart as shown on the right. Test for all possible state transitions described in the control logic documentation for the course project.



Tasks and Report Requirement

Task 5: Validation of the Engine start/stop model

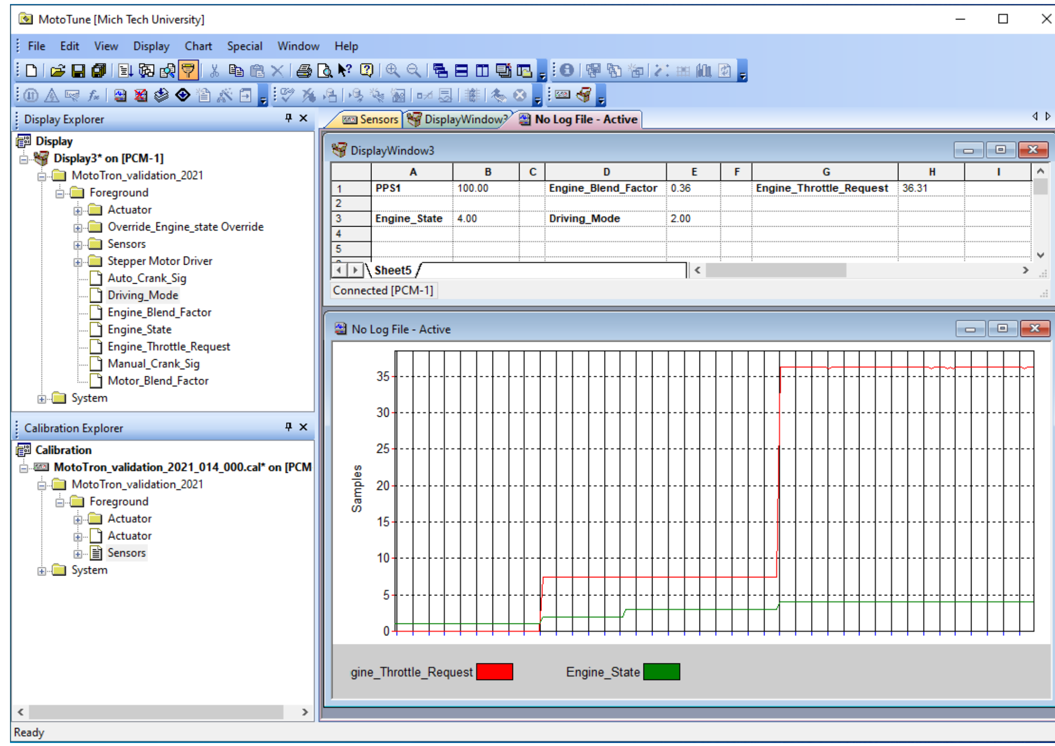
5. Test requirement for Engine start/stop model:
   1) Test all the combinations of inputs/outputs for Engine Kill and Engine Crank signals. Include MotoTune and Desktop Simulator test results.
   2) Include a chart for the transition of Automatic Crank signal, engine state, and Engine Blend Factor in “Blending mode.”



Tasks and Report Requirement

Task 6: Validation of Engine throttle request

6. Test requirement for engine throttle request:
   1) Test all the combinations of inputs/outputs to determine the Engine throttle request.
   2) For the Engine throttle request in the Blending mode, include a chart of Engine throttle request with respect to the Engine State. The Engine throttle request in the chart should be the same as defined in Table 6. One example is given on the right.



Tasks and Report Requirement

Task 7: Validation of Motor torque request

7. Test requirement for Motor Torque Request:
   1) Test Motor torque request for all driving modes with changing of APP values. In blending mode, consider different APP values and vehicle speeds. Include MotoTune test results in your report.
   2) In Electric solo mode, calibrate the servo motor interface model to match the 0 degree of shaft angle with Motor Torque Request=0 and 90 degrees of the shaft angle with Motor Torque Request=100% (Set APP =100%).
      a) Use an oscilloscope to observe the PWM signal of the servo motor. Capture oscilloscope screen when the servo motor shaft is at 90 degrees. Include this PWM signal, corresponding servo motor photo, and MotoTune windows in your report (refer slide 16 where the servo shaft is at 0 Degree).
      b) Submit a video of the servo motor with your report. The video should show the match of the APP, Motor Torque Request, PWM duty cycle, and the servo shaft angles. One video example is provided.

Tasks and Report Requirement

Task 8: Validation of E-motor start/stop model

8. Test E-motor start/stop model: Test E-motor On, Forward signal, and Reverse signal for all the possible input/output combinations. Include MotoTune and Desktop Simulator test results in your report.

Task 9: Validation of Stepper motor driving model

9. Test requirement for stepper motor driving model.
   1) Test the sequence of the stepper motor driving signals and the rotation of the stepper motor when the difference of APP and TPS changes. Test both clockwise and counterclockwise rotation scenarios.
   2) Create a video showing the clockwise and counterclockwise rotation of the stepper motor and the corresponding MotoTune window. One video example is provided.

Tasks and Report Requirement

Task 10: Validation of your blend strategy improvement

10. Test the performance improvement of your blend strategies in the blending mode.

Note: All the MotoTune and Oscilloscope figures included in this slide deck are for demonstration purpose. Please don’t use these figures in your report. Generate your own figures for your report.

The total points of the course project are 100. The course project grade makes up 25% of your course grade. The breakdown points of the course project are as follows.

Course Project Submissions	**Points**
Model and description (no more than one page) submissions	10
Week 11: Driving mode model, Blend factor look-up tables, Engine state logic model, Engine start/stop model, Motor torque request and engine throttle request model and the required input/output interface model	
Week 12: The entire model including E-motor start/stop model, the stepper motor driving model and the required input/output interface model	
Course project presentation	20
Course project report	70
Total	100

Report grades will be based on the table below. Note that the discussion of lab results and your observations are important.

Course Project Report and Presentation	Points (70)
Introduction (system description), conclusions, references, and the quality of the presentation of results and report	5
Task 1: The correctness and the quality of the model	15
Task 2: Results and discussion	5
Task 3: Results and discussion	5
Task 4: Results and discussion	6
Task 5: Results and discussion	6
Task 6: Results and discussion	6
Task 7: Results and discussion	6
Task 8: Results and discussion	5
Task 9: Results and discussion	6
Task 10: Results and discussion	5
Total	70