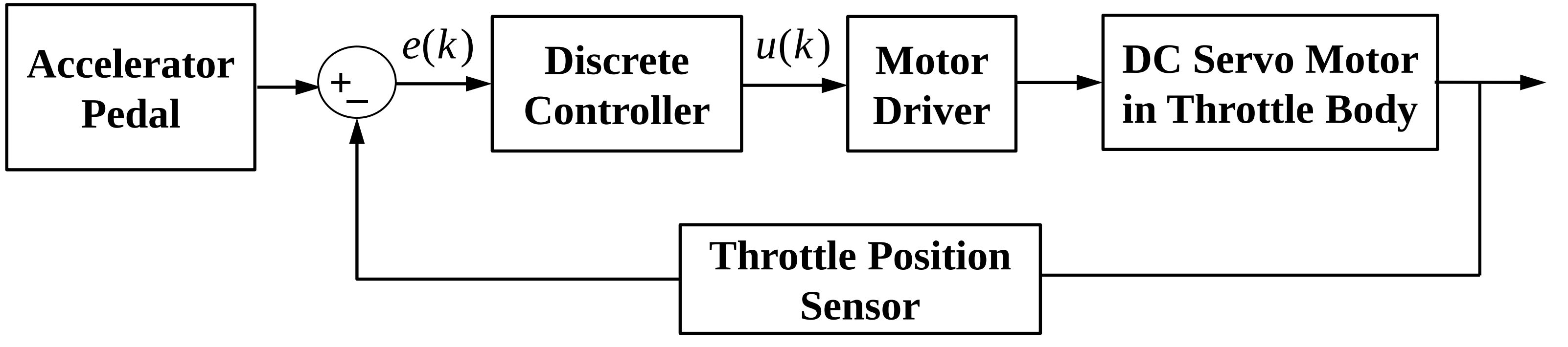
Lab 4: Closed-Loop Electronic Throttle Control (ETC)



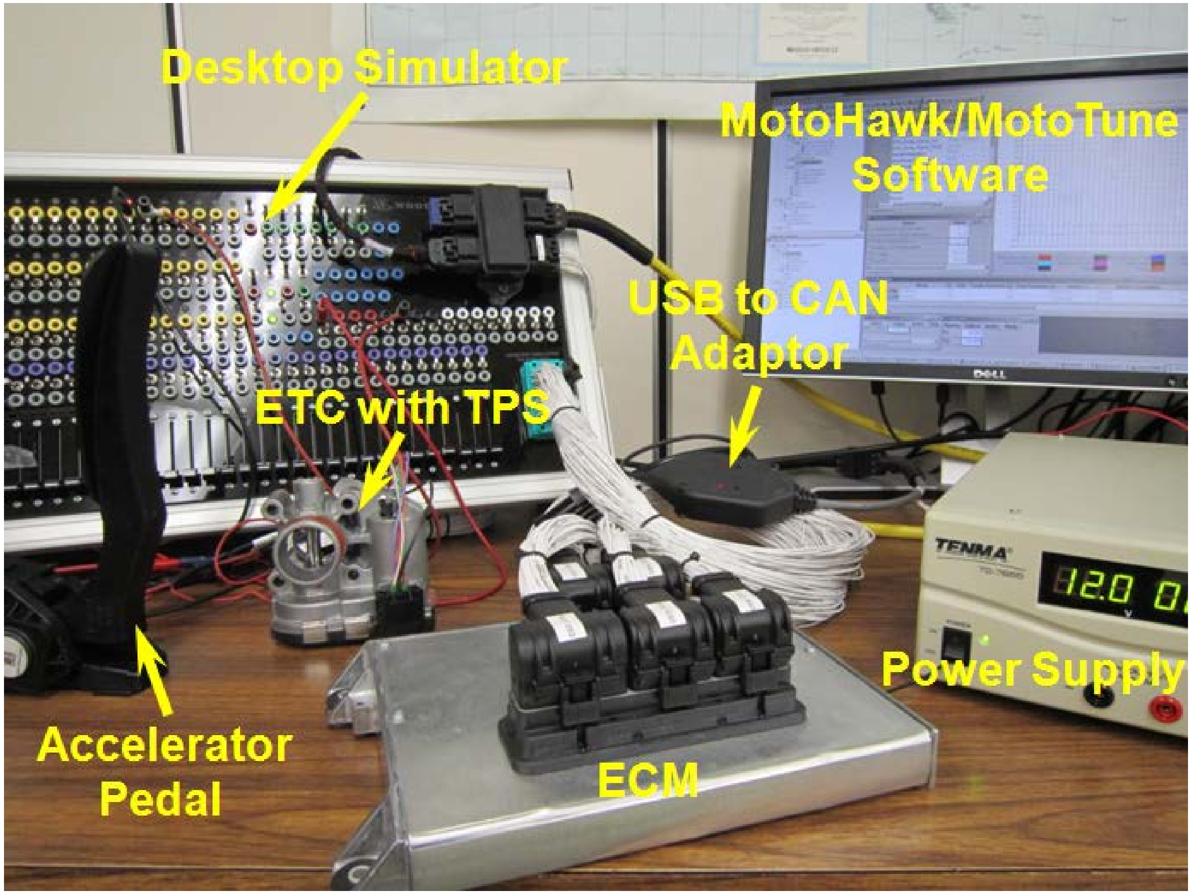
Objectives

1. Develop a feedback position control system for an electronic throttle body using a discrete controller.
2. An accelerator pedal position sensor (PPS) is used as a throttle command. The PPS is simulated by a potentiometer on the desktop simulator.
3. The servo motor of the throttle body is driven by a H-bridge in the MotoTron ECM.
4. A throttle position sensor (TPS) is used as a feedback signal of the control system.

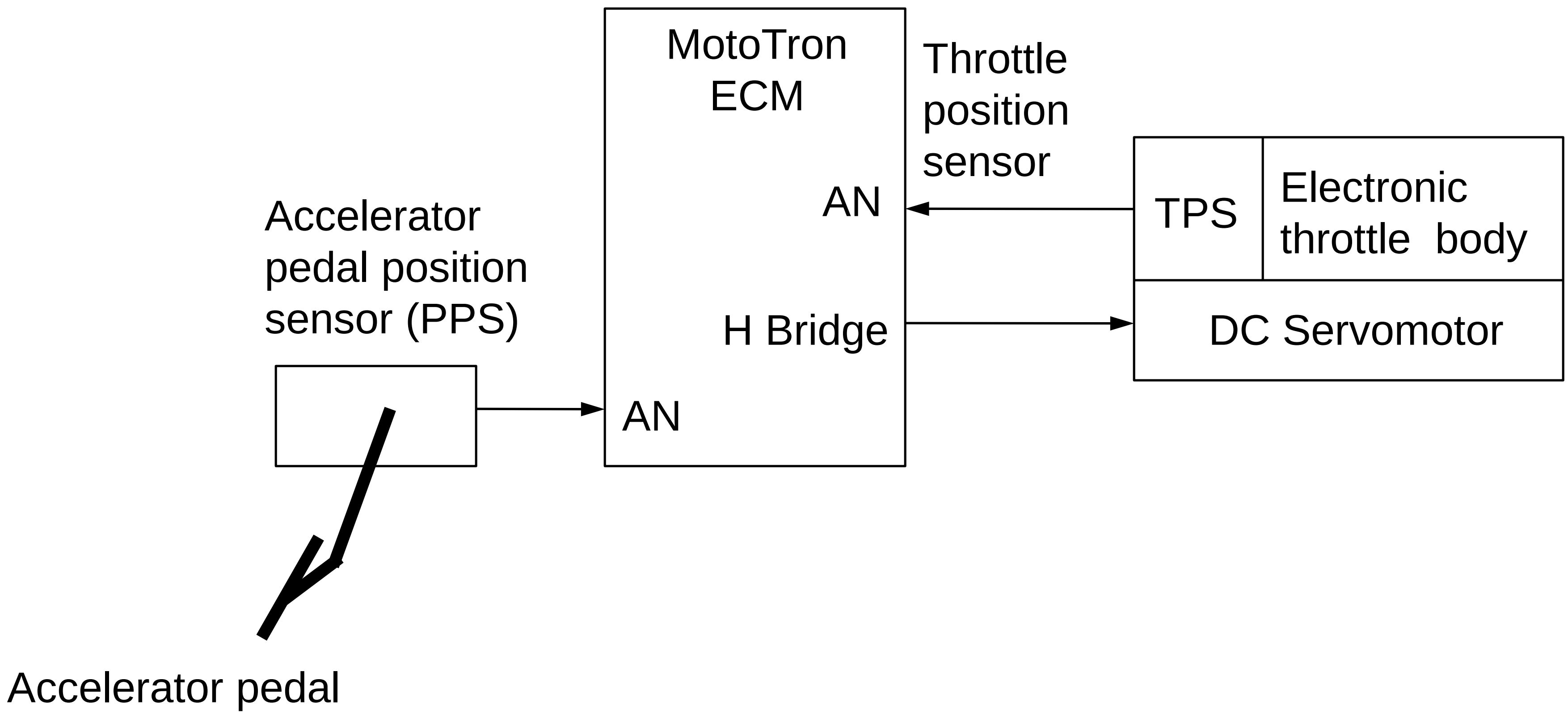
Objectives (Cont.)

5. Read the analog voltages of the PPS and TPS from analog input channels. Design linear interface models to relate PPS and TPS signals with throttle opening, which is determined by the duty cycle of the PWM control signal of the throttle servo motor.
6. Use a discrete controller to control the opening of the throttle body based on received throttle command (PPS signal).
7. Compare the performance of the control system with various controller design (different combination of P, I, and D terms) and the integration algorithms.
8. Perform real-time calibration to find out optimal controller design and controller gains.

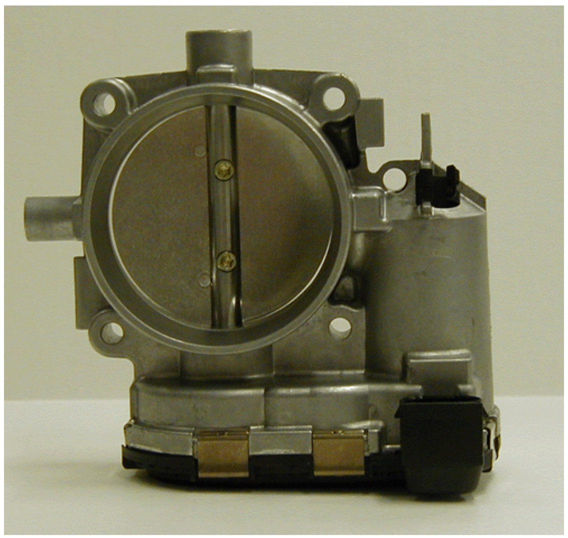
Lab Setup

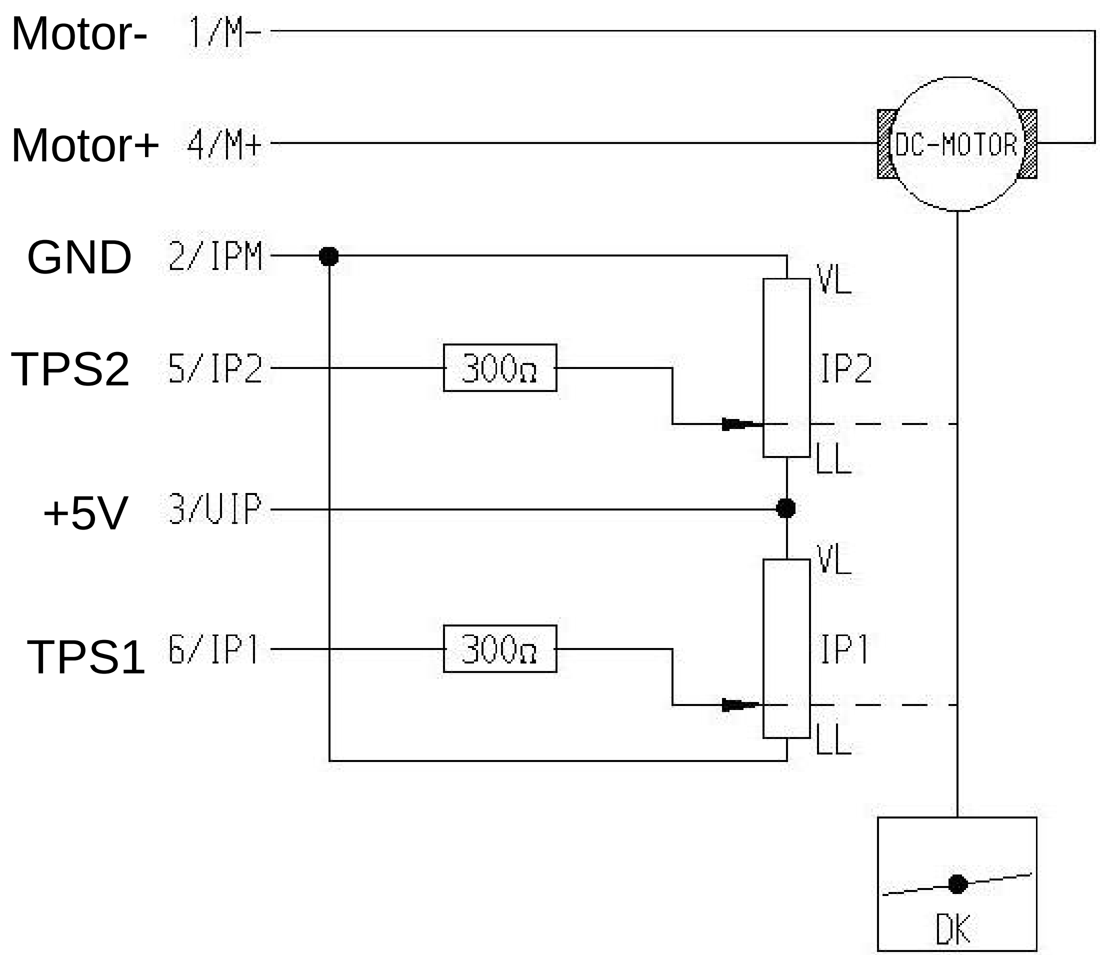

Desktop Simulator
MotoHawk/MotoTune Software
USB to CAN Adaptor
ETC with TPS
TENMA
12.0
Power Supply
Accelerator Pedal
ECM

Electronic Throttle Control (ETC)

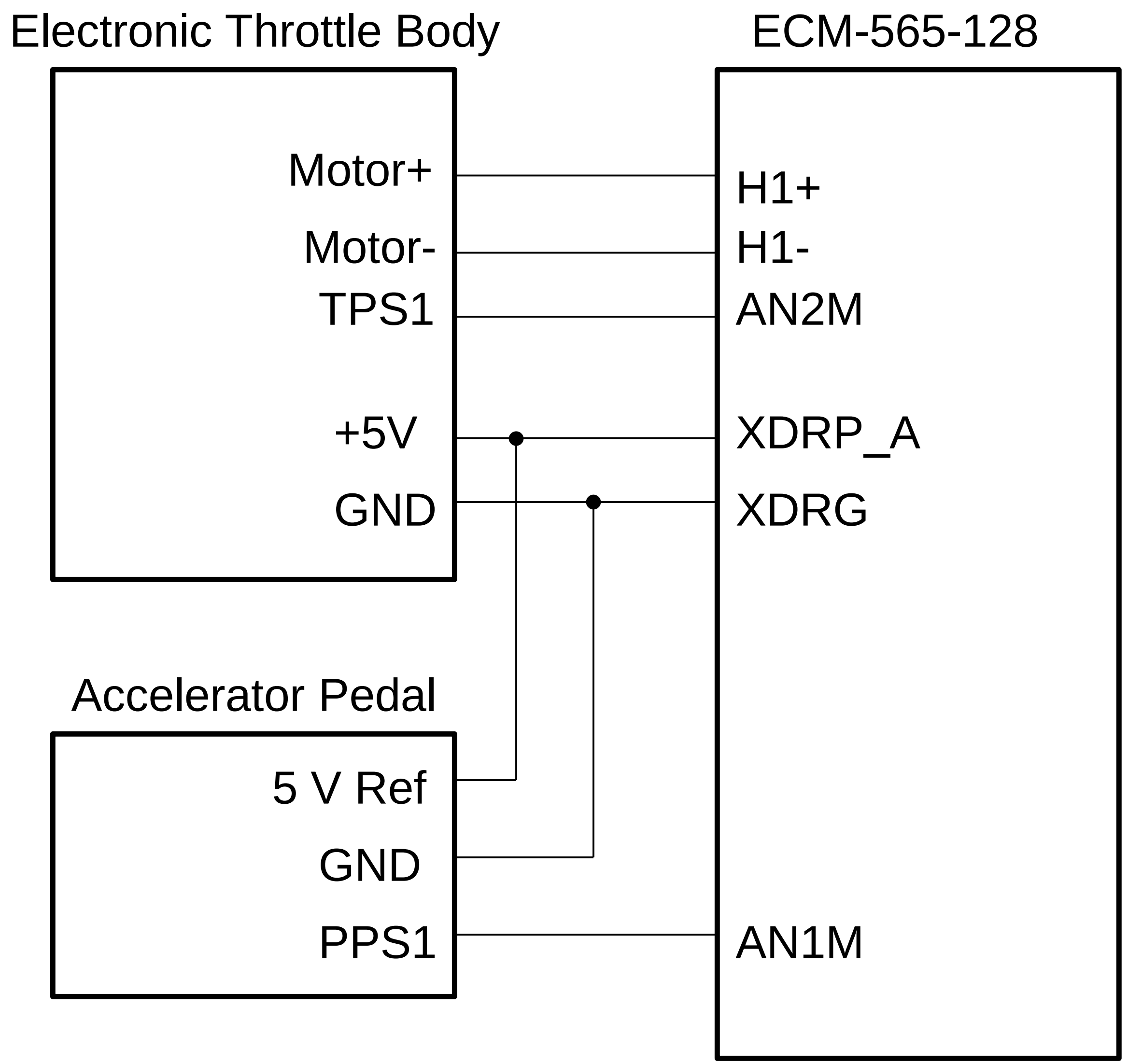


Electronic Throttle Body (Bosch)



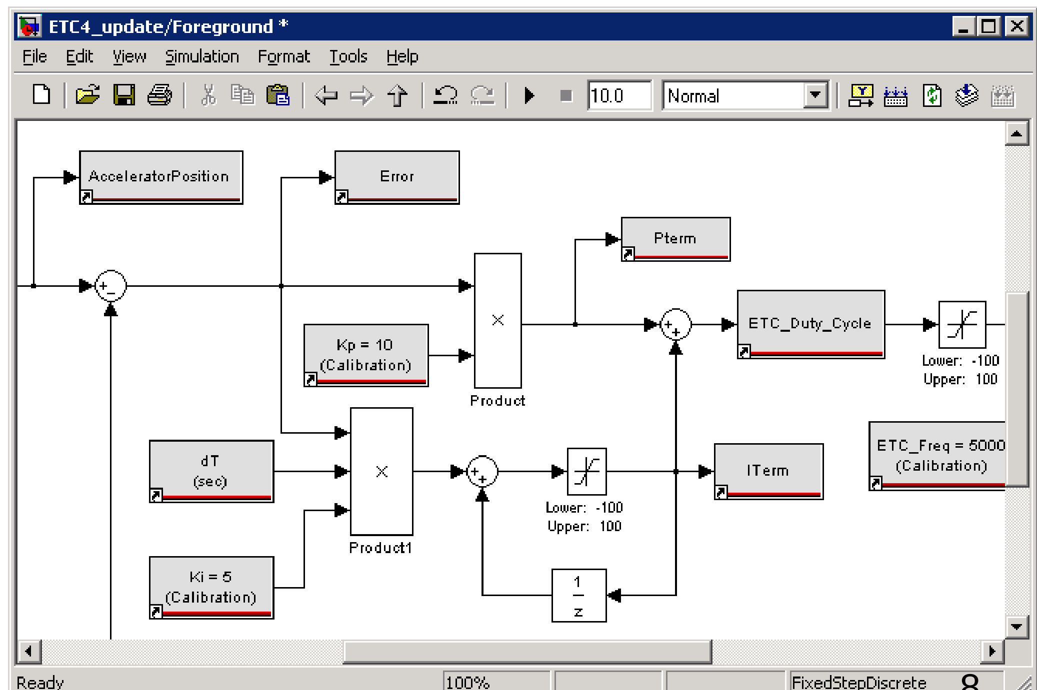


ETC Using MotoTron



Build ETC Model

1. Use analog input blocks and Data Type Conversion blocks to read in PPS and TPS signals.
2. Use Calibration blocks, Product blocks, and Add blocks to model linear interface models between the duty cycle of throttle servo motor and PPS (TPS) signals.
3. Model a discrete controller. The model at the right is a sample implementation of a discrete PI controller (dT block can be found in the MotoHawk Library: Extra Development Blocks).



Build ETC Model (Cont.)

4. Add a saturation block for the PWM duty cycle command and another saturation block for the I term.
5. Use a motohawk_pwm block (select H1 as the resource) to generate PWM signals for the DC servo motor in the throttle body.
6. Verify data types: From the Format menu select Port/Signal Displays and check Port Data Types. The data type appears adjacent to each wire. This is a convenient way to verify that your data types are consistent in your model.
7. Add Display blocks to show critical values in your model.

Special Attention in Modeling

- Add a PWM duty cycle override block between the output of the controller and the duty cycle input of the motohawk_pwm block. This override block can be used to calibrate the upper limit of the PWM duty cycle for the wide open throttle (WOT).
- In the motohawk_pwm block parameter window, check the "Output Current" option. With this option, you are able to monitor the H bridge current in MotoTune through a probe. The H-bridge current should be less than 1.5 A.
- Set the frequency of the PWM output block to 5000 or 6000 Hz.
- Set the initial value of $\mathrm{K_p}$, $\mathrm{K_i}$, or K_d to 0, respectively.

Calibration

- Set the lower limit of the PWM duty cycle saturation block to 0 (corresponding to closed throttle).
- Calibrate the upper limit of the PWM duty cycle saturation block: increase the PWM duty cycle using the override block until wide open throttle. Use WOT duty cycle as the upper limit of the saturation block. During this calibration process, monitor the H-bridge current. The maximum current should be less than 1.5A.
- Calibrate the gain and offset of the accelerator pedal position (PPS) sensor input, the lower limit of the slider corresponds to 0% throttle opening and the upper limit of the slider corresponds to WOT.

Calibration (Cont.)

- Calibrate the gain and offset of the throttle position sensor (TPS) by setting the value of the PWM duty cycle override block to two values, one for closed throttle and the other for the WOT.
- Note that the displayed current value on power supply should be about 1-2 A. If the current is too large, STOP lab immediately and consult TA for further diagnosis.

Basic Requirement of Lab and Report

1. Describe the principle of electronic throttle control using model-based method, including hardware, model development, and real-time calibration.
2. Connect an electronic throttle body and a potentiometer (PPS) to ECM based on the connection diagram on slide 7.
3. Design a discrete controller for the closed-loop throttle position control.
4. Change the accelerator pedal position command by adjusting a potentiometer on the desktop simulator. Observe the response of the throttle position.
5. Include charts showing the response of the throttle position to accelerator pedal command signals. Include corresponding Display windows and Calibration windows.

Basic Requirement of Lab and Report

6. Discuss the impact of individual P, I, or D term on the performance of throttle position control.
7. Discuss the effects of controller types (different combination of P, I, and D terms) and integration algorithms on the performance of the throttle position response and steady state performance. Include display charts corresponding to different controller designs. Identify the best controller design.
8. Tuning controller gains to find out optimal controller gains with regard to throttle position response (rise time, settling time, overshoot, and etc).

Basic Requirement of Lab and Report

9. What are the factors that impact the steady state performance of the system? How do you minimize the steady state error? Explain your approach to improve the steady state performance of the system.
10. Add additional control features to your system.
11. Describe what other real-time calibration you did. What are the effects when you change the values of the calibration variables? Include the pictures of Display windows, Calibration windows, charts, or log files for your discussion.
12. Submit your MotoHawk ETC model with your lab report.