Observer-Based Engine Cooling Control System

Students:
Andrew Fouts
Kurtis Liggett

Advisor:
Dr. Dempsey

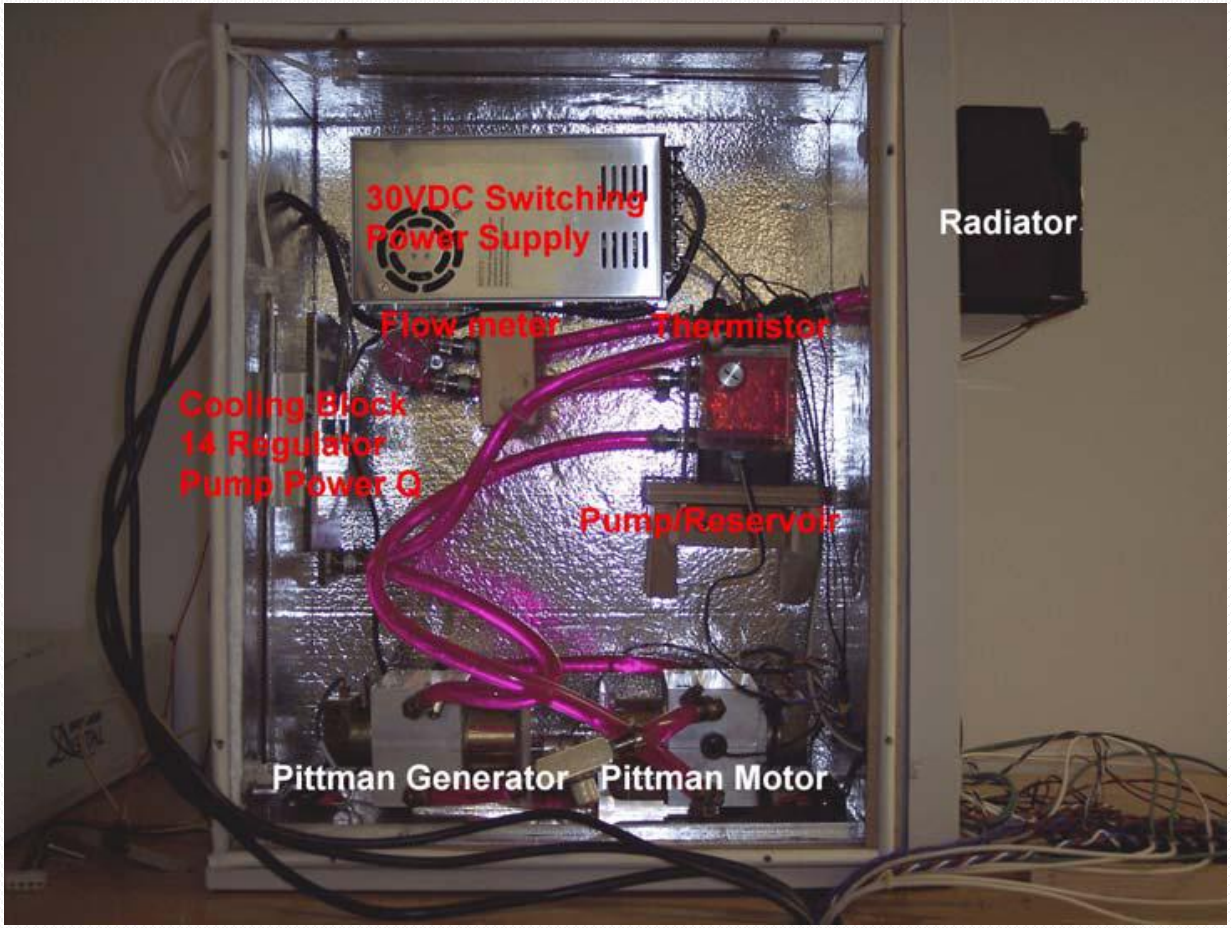
Presentation Overview

- Project Summary
- Observer-based control
- Previous Work
- Project Goals
- System Block Diagram
- Functional Requirements
- Preliminary Results
  - Engine Subsystem
  - Thermal Subsystem
- Schedule & Equipment

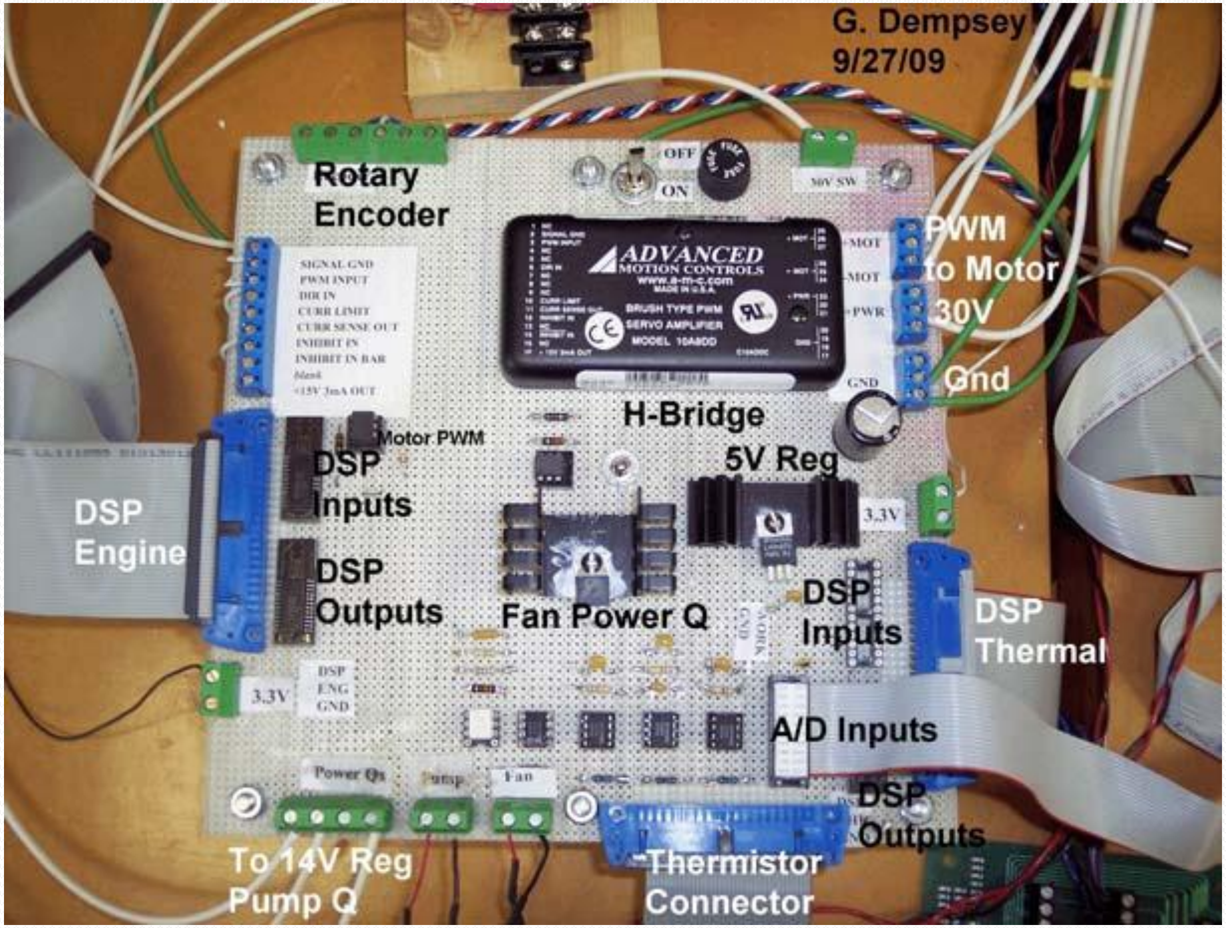
Project Summary

- Engine cooling control workstation
- Several control methods
  - Proportional control
  - PI control
  - A different advanced method
- Observer-based control
- CAN bus communication

Project Workstation



Power Electronics



Observers in Controls

- Overview
- Advantages
  - Reduced number of sensors
  - Increase stability
- Disadvantages
  - Added complexity
  - Computational Resources
  - Response to plant changes
- George Ellis. “Observers in Control Systems”, Academic Press, 2002.

Previous Work

- Nick Schmidt
- Chris Mattus
- Hardware design – Mike Donaldson and Mark Bright
- Thermal cooling redesign – Dr. Dempsey
- Advanced software – not used

Overall Project Goals

- Learn software packages for auto-code generation and real-time control via Simulink/DSP interface
- Design energy management control system in Simulink environment to regulate voltage/current to each subsystem
- Evaluate controller performance based on system accuracy, speed, and energy use
- Determine the limitations of the Simulink/DSP interface in terms of real-time execution and program memory

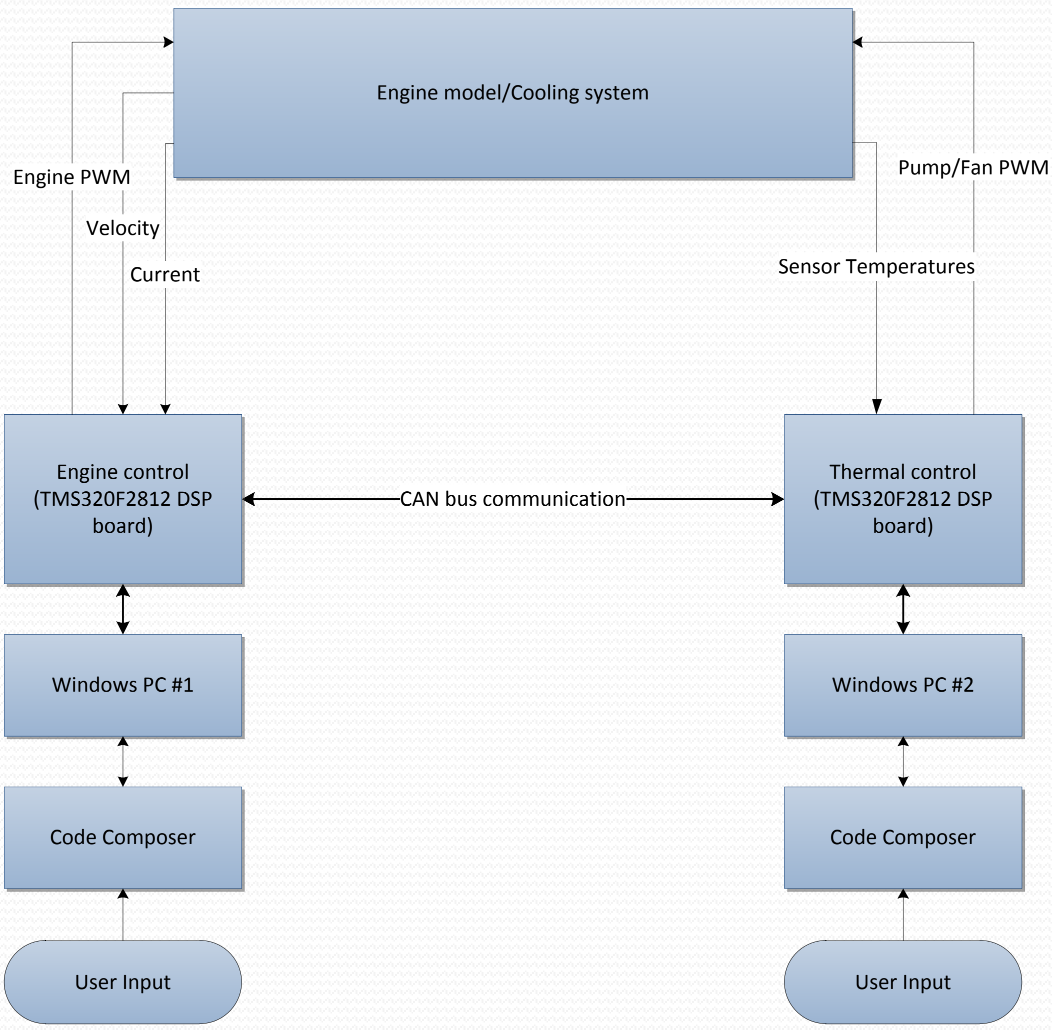
Engine Subsystem Goals

- Understand DSP/motor hardware interface
- Design software for PWM generation and velocity calculation from rotary encoder
- Design closed-loop controllers for velocity control using observer-based system
- Design observer-based system to acquire low noise current and velocity signal with minimal phase lag
- Design energy management software to limit engine power output based on Thermal DSP data via CAN bus interface and motor power calculation based on observer outputs of velocity and current
- Provide engine data to Thermal DSP via CAN bus

Thermal Subsystem Goals

- Understand DSP/cooling system hardware interface
- Obtain a mathematical model of the cooling system
- Design closed-loop controllers for temperature regulation of cooling system using observer-based system and energy management software for control of pump and fan
- Provide temperature data to Engine DSP via CAN bus interface

System Block Diagram



Functional Requirements

Engine control system:

- Steady-state error = ± 5 RPM
- Percent overshoot ≤ 10%
- Rise time ≤ 30 ms
- Settling time ≤ 100 ms
- Phase margin = 45°

Thermal control system:

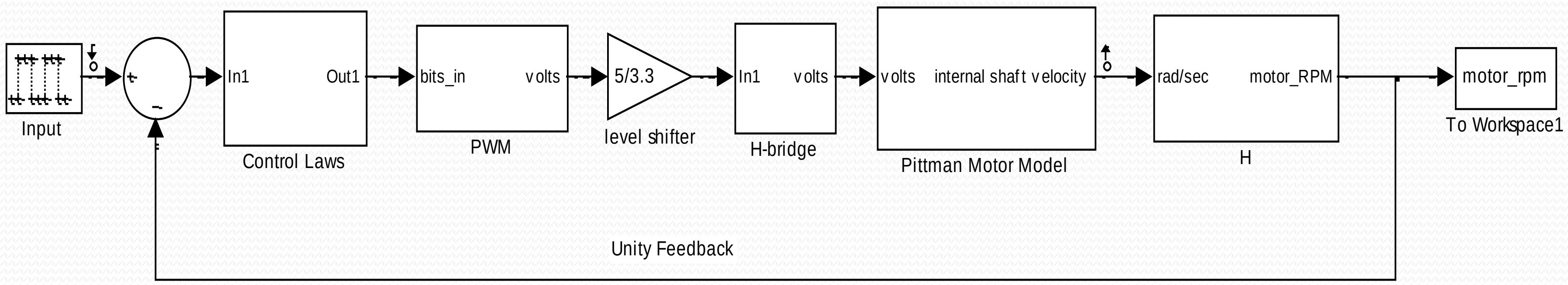
- Steady-state error = ±2° Celsius
- Percent overshoot ≤ 25%
- Rise time ≤ 2 seconds
- Settling time ≤ 10 seconds
- Phase margin = 45°

Preliminary Work - Engine

- Block diagram
- Pittman motor model
- Simulink models
- Control System Toolbox models
- eZdsp DSP Board

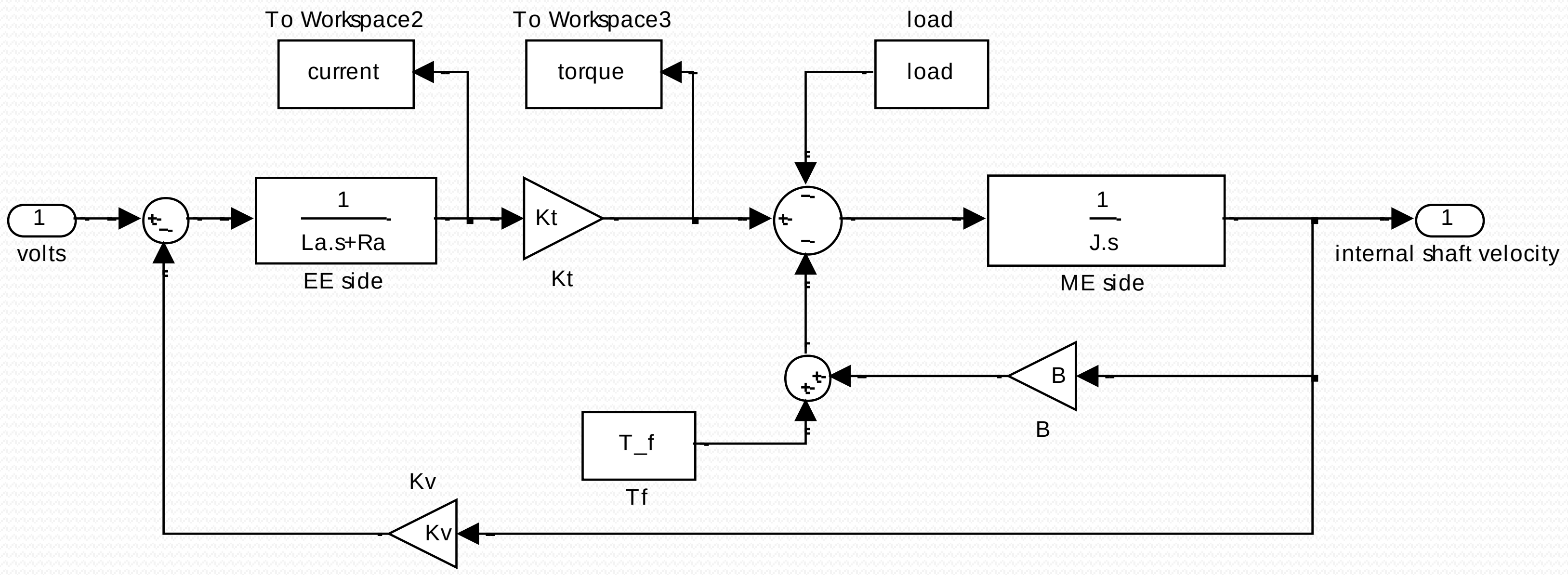
Preliminary Work - Engine

Block Diagram



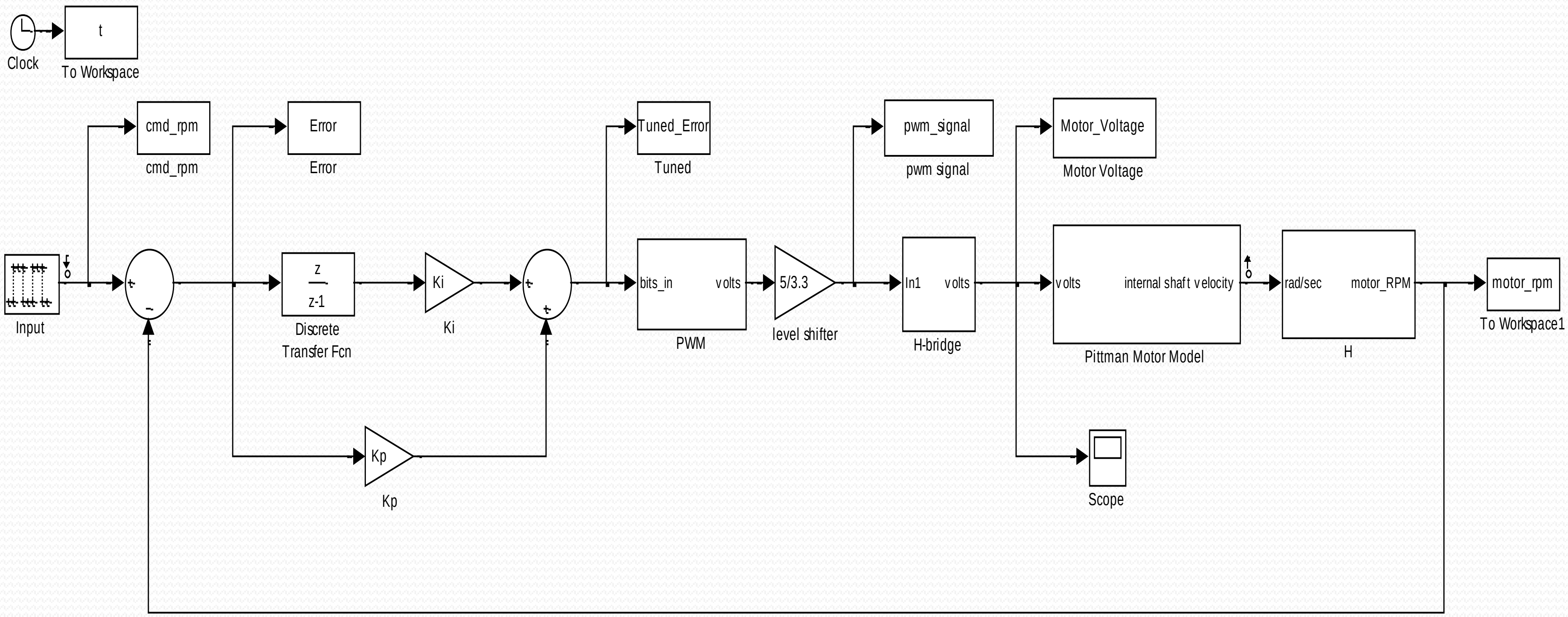
Preliminary Work - Engine

Pittman Motor Model



Preliminary Work - Engine

Simulink System Model



Preliminary Work - Engine

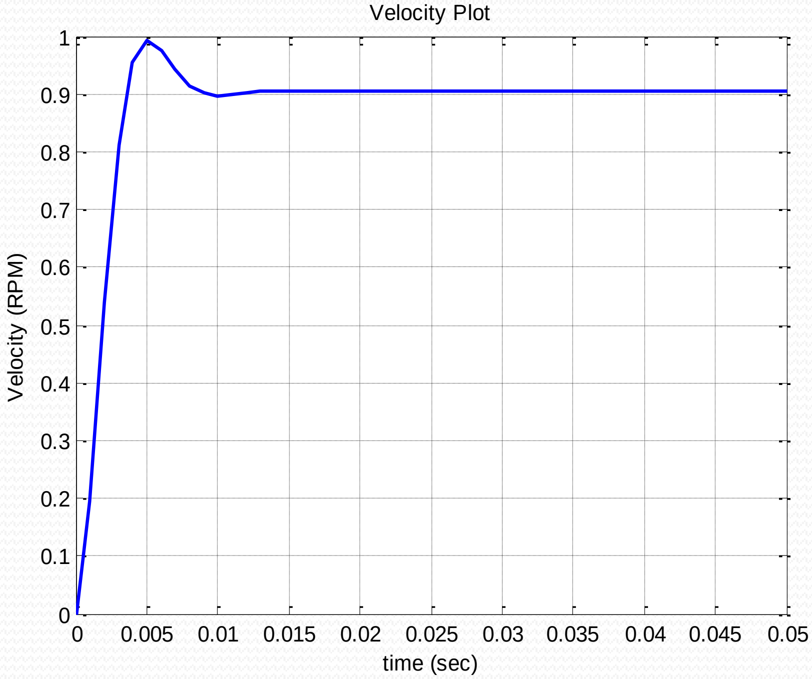
Control System Toolbox

- Must account for time delay
- Frequency domain design
- Compare Simulink model and Control System Toolbox results
- Design using Control System Toolbox

Preliminary Work - Engine

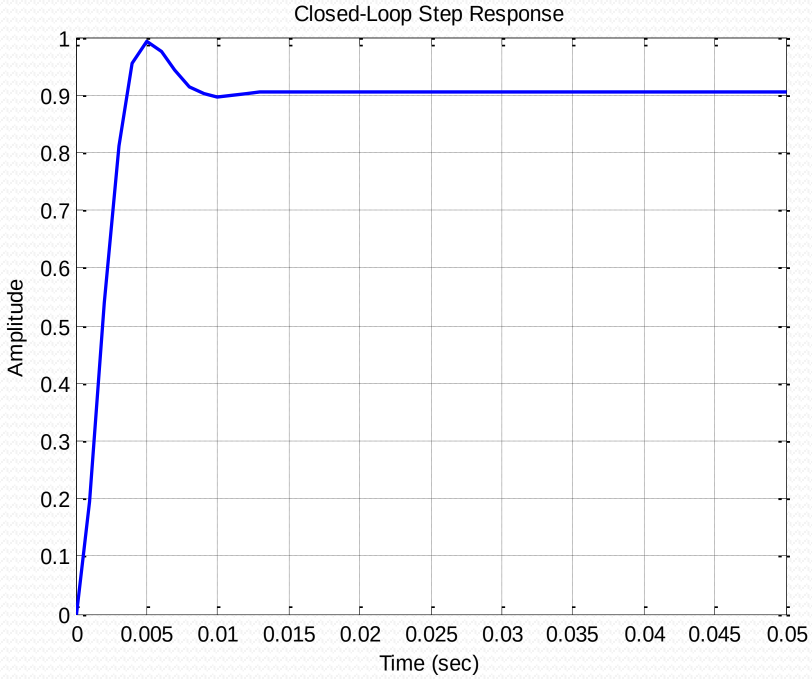
Simulink

Step Response



Control System Toolbox

Step Response



Preliminary Work - Engine

DSP Board

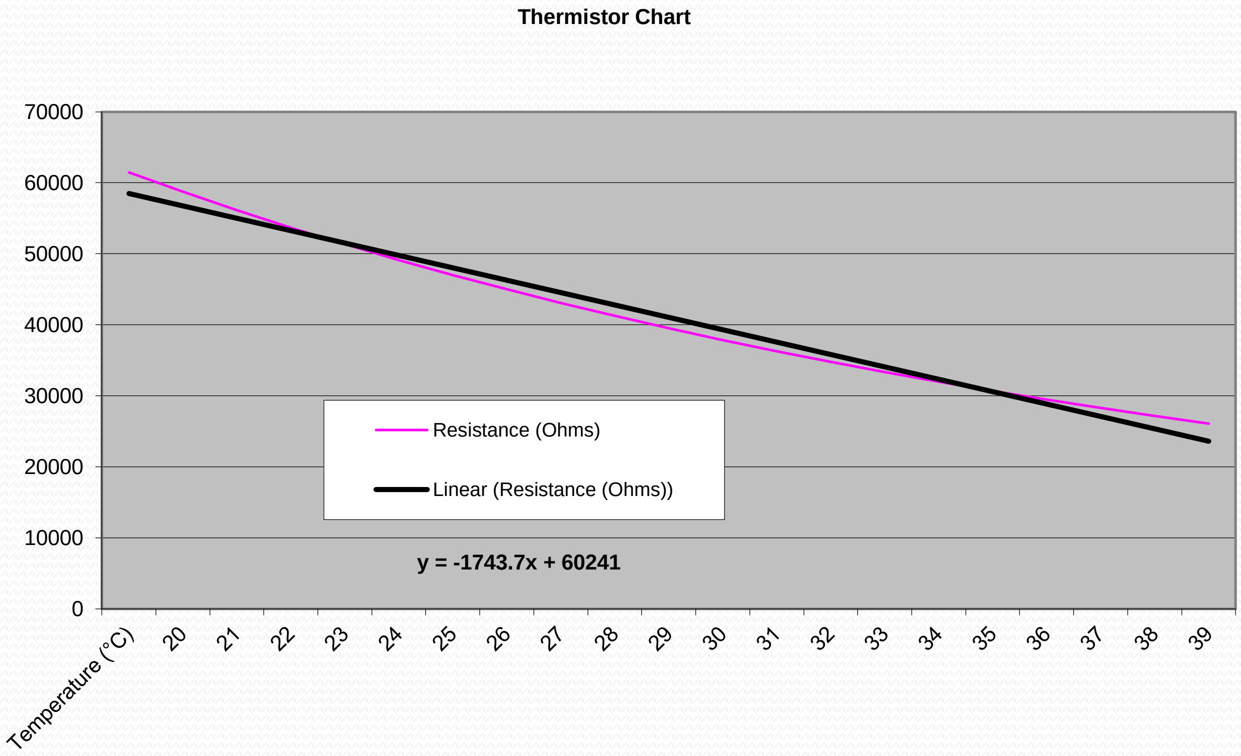
- PWM, Quadrature Encoder, and A/D Tutorials
- Mini-project implementation
- Proportional control
- PI control

Preliminary Work - Thermal

- Thermistor-temperature calculation
- Proportional/Proportional-integral controller (1st iteration)
- System identification
- Proportional-integral controller (2nd iteration)

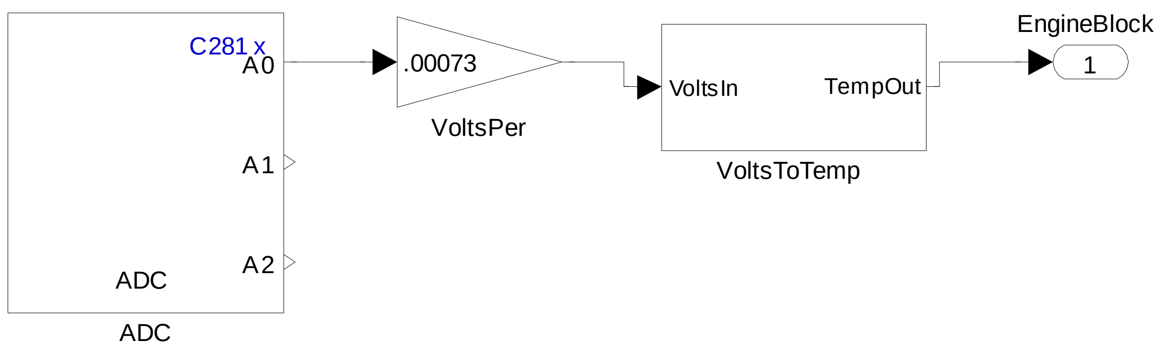
Preliminary Work - Thermal

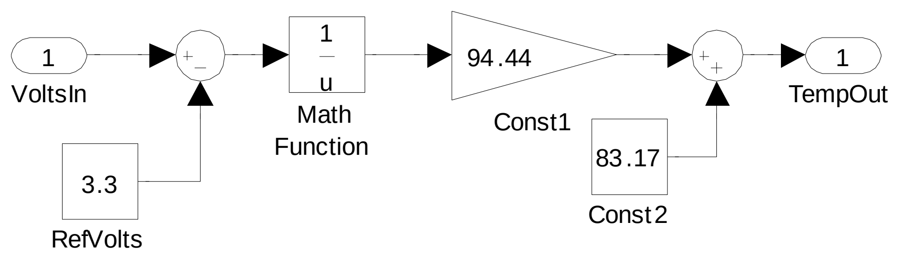
- Thermistor-temperature calculation
  - Required linearization of thermistor vs. temperature



Preliminary Work - Thermal

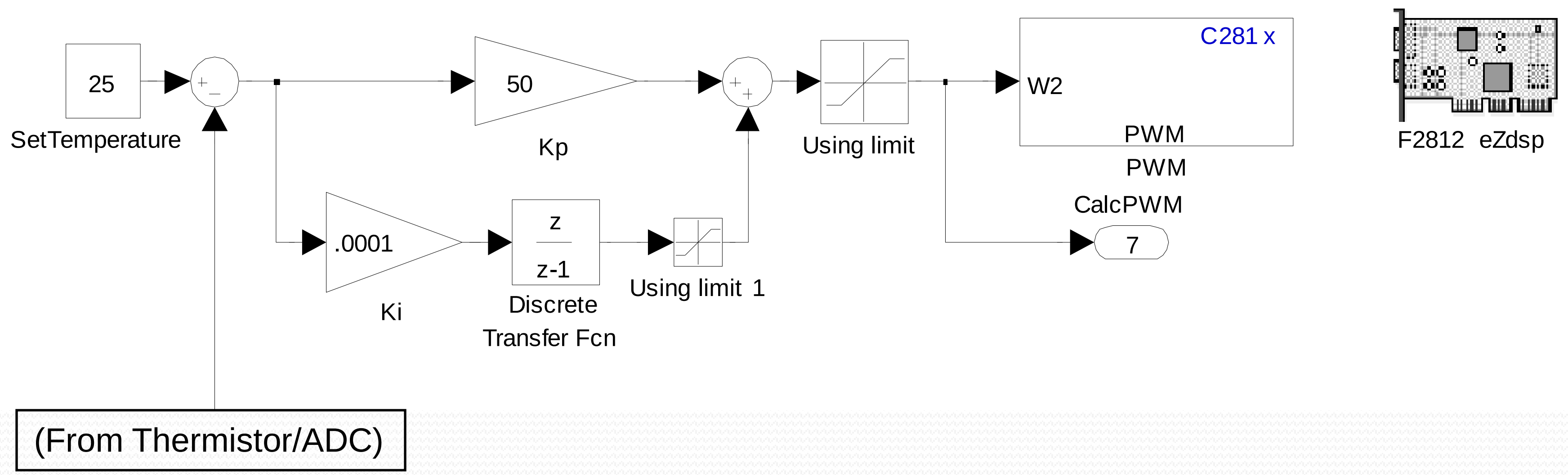
- Thermistor resistance to temperature conversion





Preliminary Work - Thermal

- Proportional/Proportional-integral controller (1st iteration)
  - Kp = 50; Ki = .0001
  - Early problems with windup

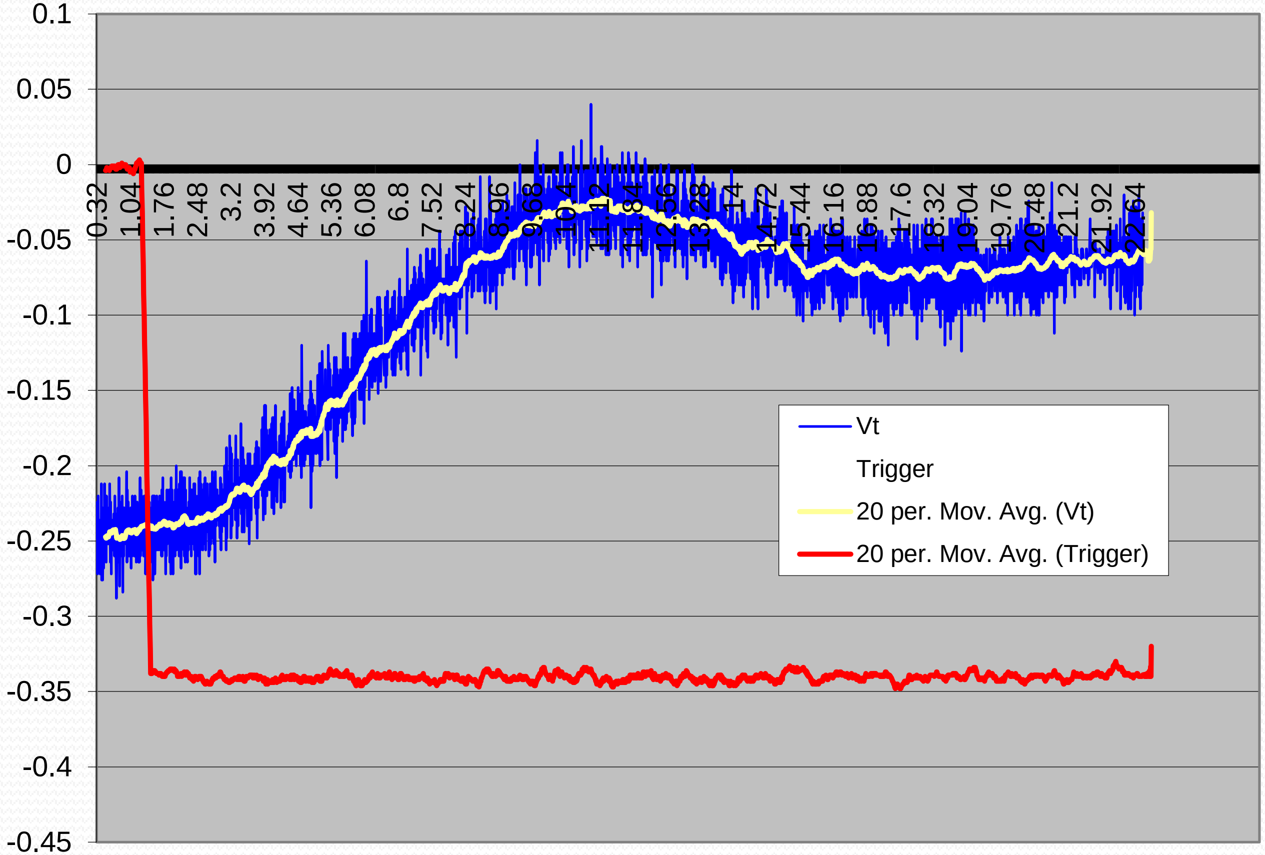


Preliminary Work - Thermal

- System identification
  - Pump PWM from 50% to 90%
  - Temperature change too small to measure; used small amplification circuit & recorded on scope

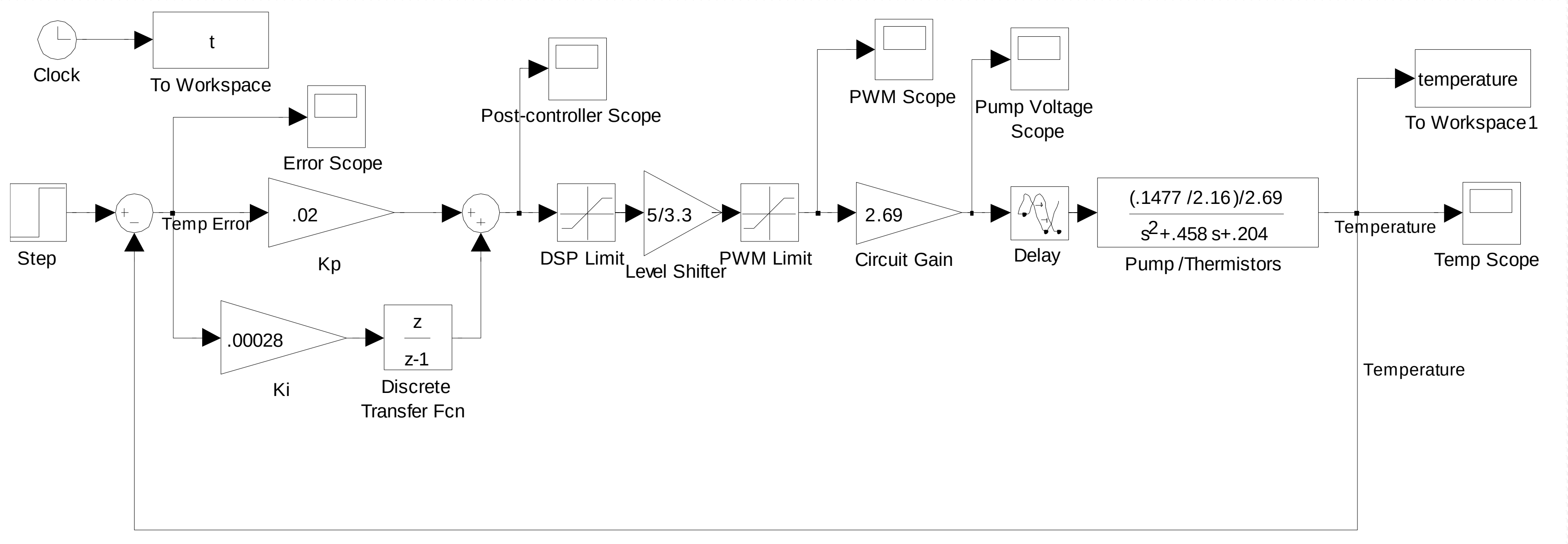
Preliminary Work - Thermal

- System identification – Pump step graph example



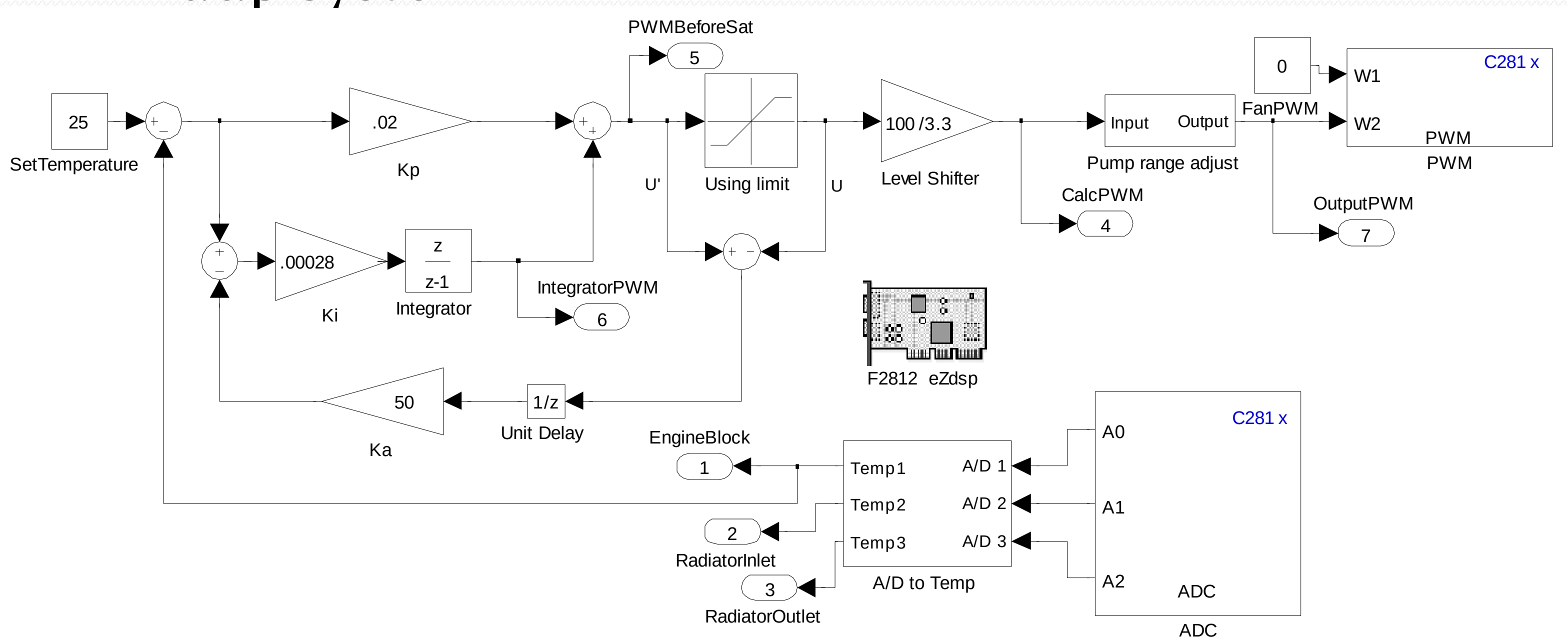
Preliminary Work - Thermal

- System identification – pump system model
  - Created using data from pump step graphs & control theory



Preliminary Work - Thermal

- Proportional-integral controller (2nd iteration)
  - Kp = 0.02; Ki = 0.00028
  - Windup problem still prevalent; implemented anti-windup system



Spring Semester Schedule

Week	Thermal Control System	Engine Control System
1	P/PI Control	PI Control
2	P/PI Control	Feed-Forward Control
3	Alt. Advanced Control	Feed-Forward Control
4	Observer-based Control	Observer-based Control
5	Observer-based Control	Observer-based Control
6	Observer-based Control	Observer-based Control
7	Energy management & power calculations	Engine governor & power dissipation calculations
8	Energy management & power calculations	Engine governor & power dissipation calculations
9	CAN Bus	CAN Bus
10	CAN Bus	CAN Bus
11	Performance Evaluations	Performance Evaluations
12	Performance Evaluations	Performance Evaluations
13	Final Report & Presentation	Final Report & Presentation
14	Final Report & Presentation	Final Report & Presentation

Equipment

- Pittman motors (2)
- Motor Heat Sinks
- H-bridge
- 30 volt, 315 watt switching power supply
- eZdsp F2812 TI DSP boards(2)
- Control and interfacing circuitry
- Fan
- Radiator
- Cooling block
- Reservoir and pump
- Flow meter
- Coolant
- Code Cathode
- Temperature Sensors (4)
- Tubing, clamps

Questions