Engine Control Workstation Using Simulink / DSP Platform (COOLECW)

SENIOR PROJECT PROPOSAL

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and

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Project Summary

Cooling control systems used in vehicles have become more sophisticated in recent years due to demands for lower fuel or energy consumption. A thermostat has been the common control element but better accuracy, system speed, and minimization of fan and pump energy can be achieved with a proportional actuator. Multiple temperature sensors can also improve system performance.

An Engine Control Workstation will be designed to simulate the thermal environments found in liquid-based cooling systems. The workstation will allow users to design, test and implement controllers to more precisely regulate the thermal dissipation of a motor-generator system with the goal of reducing energy use. A user friendly GUI for temperature and engine control will be designed using MATLAB and Simulink software. Workstation controller and monitoring application software will be auto-code generated within the same program with the processing of the data being done on a DSP board.

Detailed Description

The proposed engine control workstation will consist of a total of 5 subsystems: (1) motor-generator system to mimic an engine, (2) an active thermal load for the engine, (3) a liquid cooling system consisting of a pump, tank, radiator, fan, cooling block, flow meter, and multiple temperature sensors, (4) a fixed-point DSP evaluation board and software for controller implementation, and (5) interfaced electronics. A high-level system block diagram is shown in Fig 3-1.

The system will interface with the user via a GUI developed using Simulink and MATLAB. There will be several parameters that the user will be able to input and simulate, with the hopes of designing an engine control system due to the user's desired specifications. These inputs are, but not limited to: command velocity, controller parameters, controller types – proportional, integral, derivative, (P, PI, PID) and their perspective values for Kp, Ki, and Kd, and load changes to the system.

Based upon these inputs, system identification can be performed to obtain a mathematical model of the system. The developed closed-loop controller for velocity and acceleration will be active for load and no load conditions on the system. This will be implemented using auto-code generation and real-time control in Simulink interfaced with a fixed-point 32-bit TMS320F2812 DSP Evaluation board. The outputs of the system are, but not limited to: output velocity, motor current, SS error, transient response – analyzing down to overshoot percentage, settling time, and time to first peak, PWM percentage, and controller signal. These outputs will be organized on a GUI that group these outputs in order to analyze desired specifications or continue design iterations.

From a hardware level, the system will also require a DSP to motor interface utilizing similar design techniques as in the 2008 Mini Project. Also, a deliverable of this project is to explore all areas of Simulink and DSP Evaluation board interfacing and document controller limitations, performance, and enhancements needed. From this another goal was created, to minimize both C-code and its execution time – down to an assembly level to ensure there are no possible real-time execution constraints created by the Simulink auto-code generation.

The Thermo control portion of the project will focus on developing controllers for the pump and the fan of the system. Multiple types of controllers are to be developed and implemented. These controllers will then be used to control the temperature of the coolant and/or the plant to a specific value.

In order to develop controllers to control temperature it is crucial to develop a transfer function and model of the thermo portion of the project by system identification. The system block diagram for the thermo system is shown in Fig 3-2.

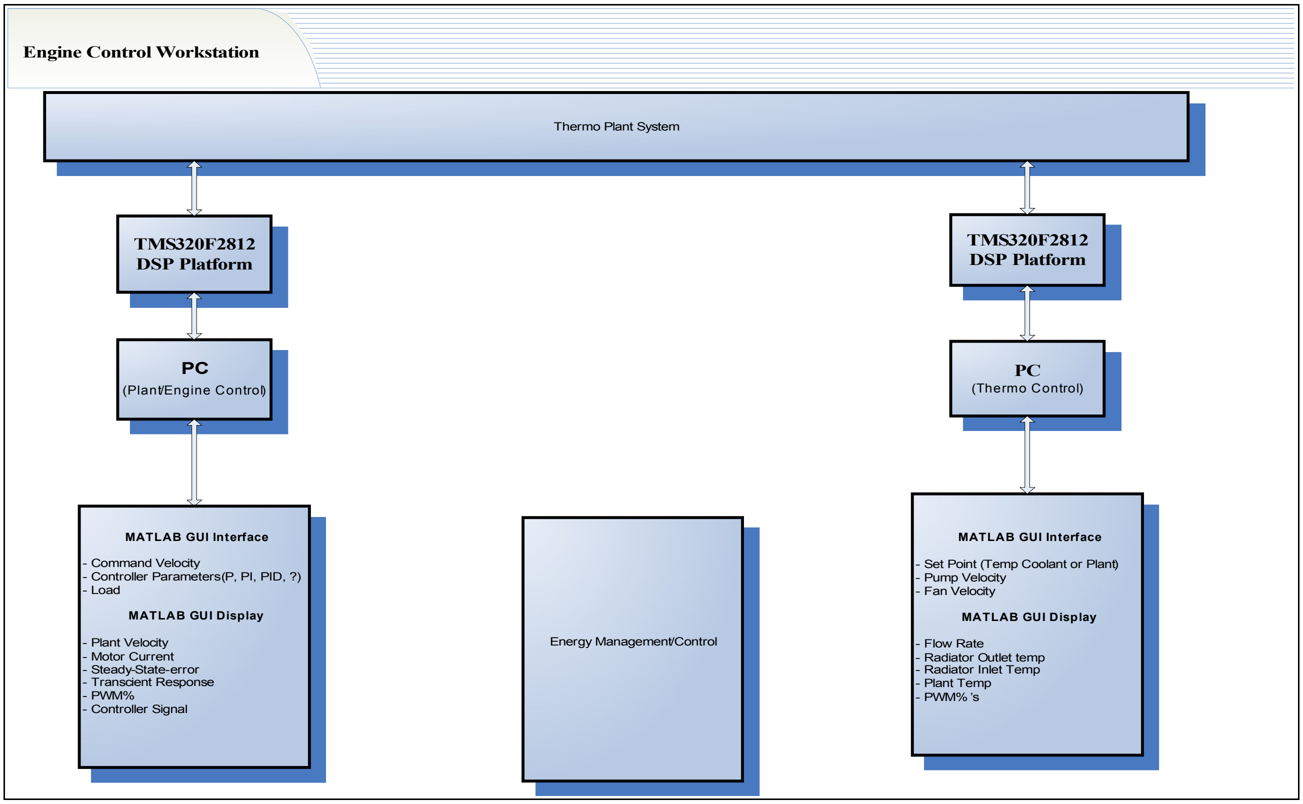

Fig 3 – 1 (System Block Diagram)

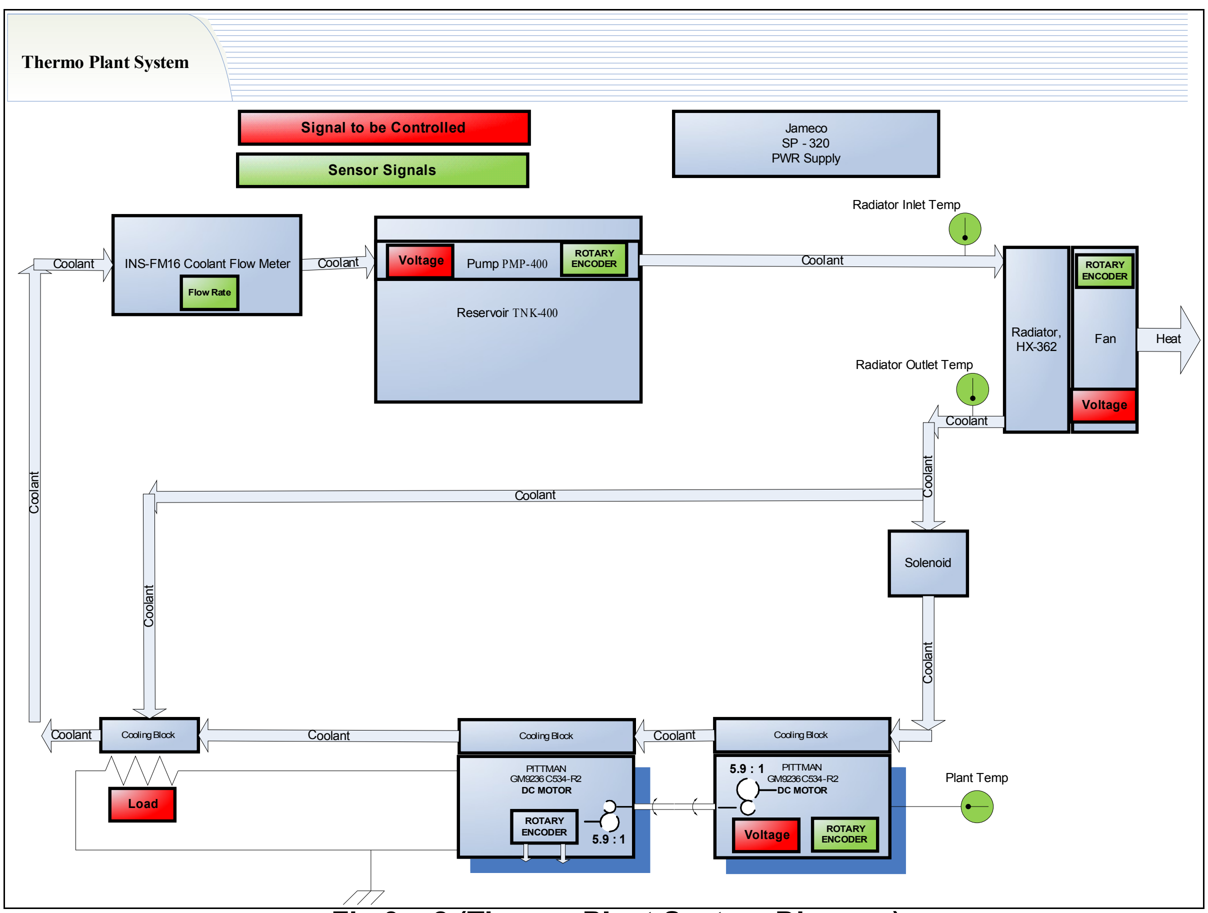

Fig 3 – 2 (Thermo Plant System Diagram)

Performance Specifications

The motor velocity control system will be designed with the following specifications for a command step input of 100 RPM for no-load and full-load conditions.

Steady State Error = +/- 5 RPM
Percent Overshoot =15 %
Rise Time = 30mS
Settling time = 100 mSec
Stability (Phase Margin) = 60 degrees

The closed loop control shall be operational over a command input range of 50 to 750 RPM. The command input shall consist of step only commands and/or combinations of steps and ramps. The tracking error for ramp inputs shall be less than 5% over the command range of 50 to 750 RPM.

The thermal regulator control system will be designed with the following specifications for a step input.

Steady State Error = +-2 degrees C
Percent Overshoot = 30 %
Rise Time = 1 Sec
Settling time = 10 Sec
Stability (Phase Margin) = 45 degrees

Under normal operating conditions the thermal control system shall maintain the motor and generator case temperature to less than 150 degrees F. The maximum cooling fluid temperature will be limited to 120 degrees F at the radiator outlet. The thermal control system's power consumption shall be maintained by independent control of the pump and radiator fan.

Proposed Circuits

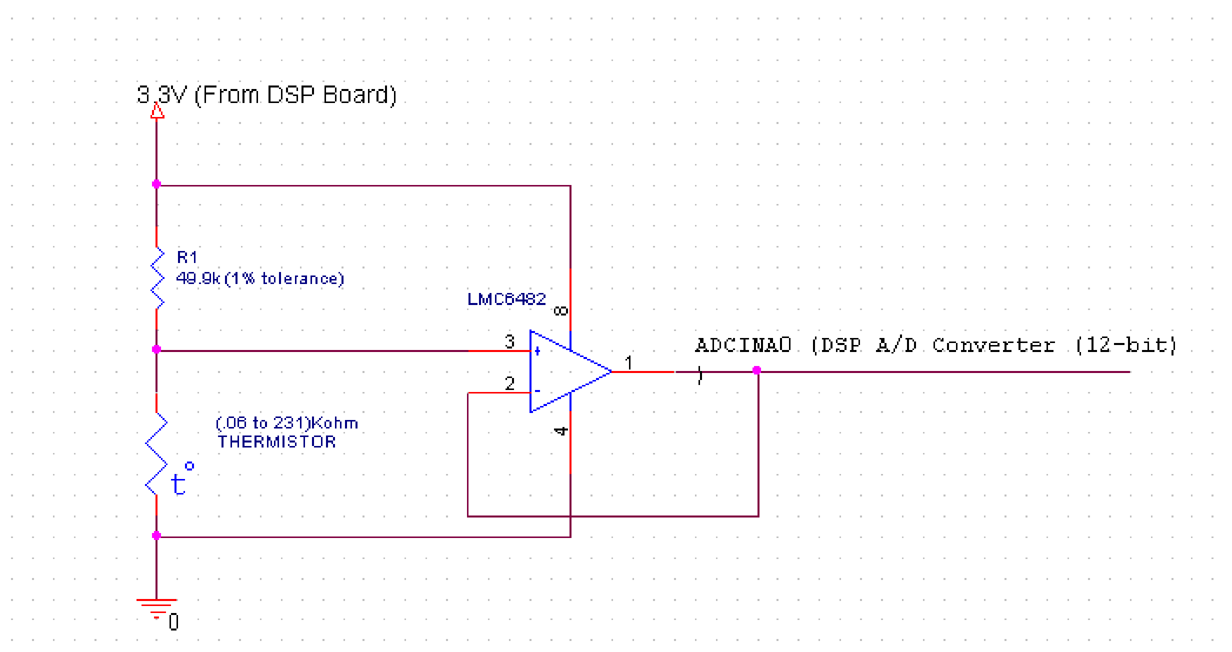

Fig 4 – 1 (Thermistor to DSP interfacing circuit)

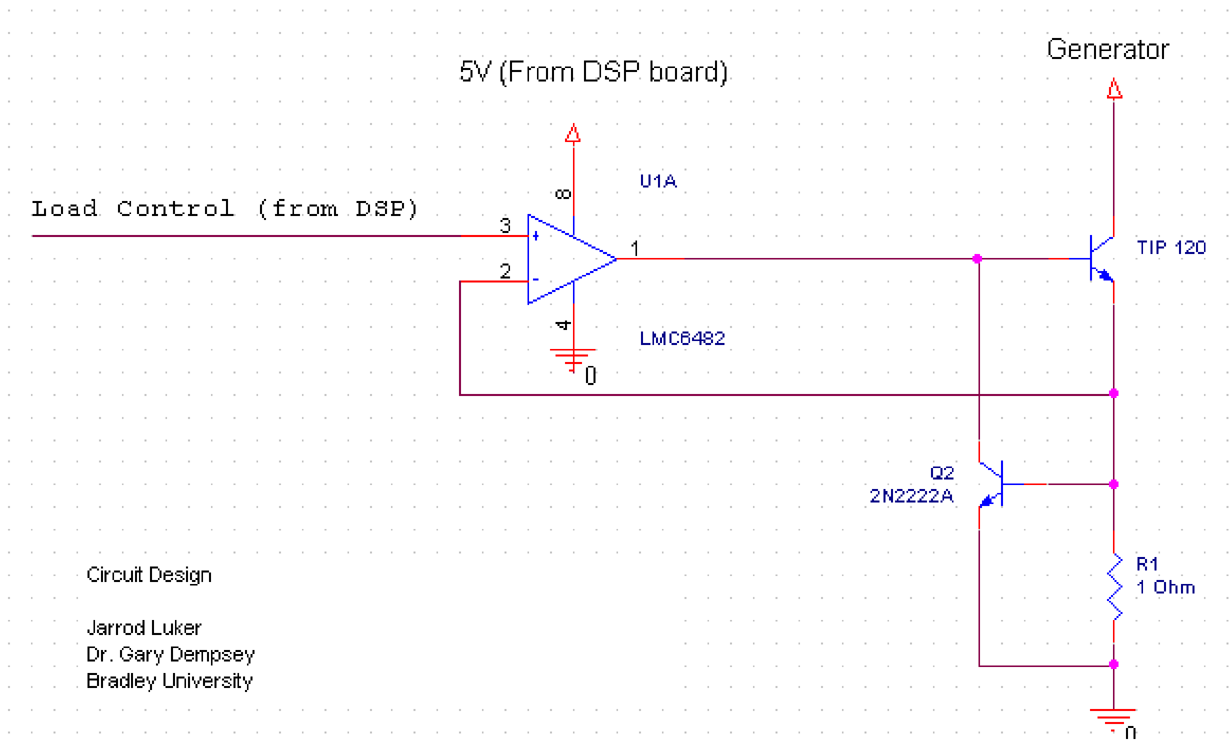

Fig 5 – 1 (Active-Load Circuit [1])

Task Schedule

Week	Mark Bright (Engine control)	Mike Donaldson (Thermal Control)
1	PWM Control	Hardware testing/interfacing + Simulink
2	Quadrature Encoder Pulse + GUI	Hardware testing/interfacing + Simulink
3	Quadrature Encoder Pulse + GUI	Active load testing + GUI
4	Closed Loop Control (P & PI (tuned))	System I.D. Thermal T.F.
5	Closed Loop Control (P & PI (tuned))	System I.D. Thermal T.F.
6	FF Control + GUI	Pump / Fan control + GUI
7	FF Control + GUI	Pump / Fan control + GUI
8	Digital Control Analysis	Digital Control Analysis
9	Digital Control Analysis	Digital Control Analysis
10	Complete GUI	Energy Management MIMO
11	Advanced Control MIMO	Energy Management MIMO
12	Advanced Control MIMO	Energy Management MIMO
13	Final Report/Presentation Prep	Final Report/Presentation Prep
14	Final Report/Presentation Prep	Final Report/Presentation Prep

References

[1] Jarrod Luker. “Component Oven Temperature Control”, Senior Project, Electrical and Computer Engineering Department, Bradley University, Oct 2000, http://cegt201.bradley.edu/~gld/mini_detail_00.pdf