Observer-based Engine Cooling Control System (OBCOOL)

Functional Requirements List & Performance Specifications

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Introduction

Control systems exist in many applications today, from home thermostats and vehicle cruise controls to engine temperature regulation and missile-guidance systems. Many control system designs exist, and one of the newer, more sophisticated concepts in modern control systems is the concept of observers. Observers are algorithms used to predict a system's response. While complex, observers are a powerful addition to a control system and greatly improve the system's performance [1].

Our project will consist of researching observer-based control systems and applying this knowledge to design closed-loop controllers for velocity control and temperature regulation of an engine cooling system. The controllers will be implemented using DSP boards with Simulink code generation. In addition, energy management and controller performance will be evaluated.

Goals

- General
    - Learn software packages (Simulink/Code Composer) 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
- Thermal Control
    - 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
- Engine Control
    - Understand DSP/engine 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 engine power calculation based on observer outputs of velocity and current
    - Provide engine data to Thermal DSP via CAN bus

System Block Diagrams

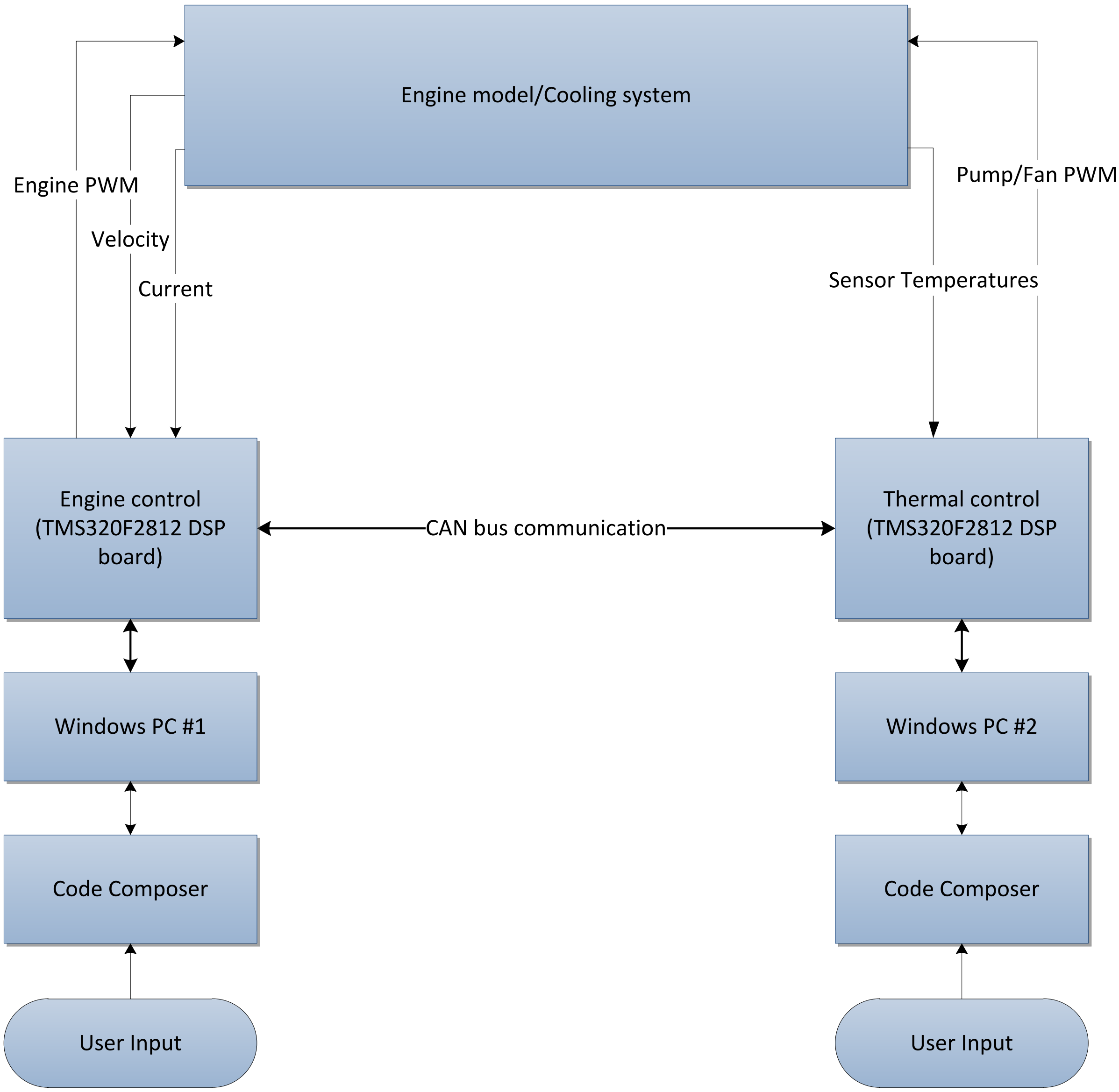

Fig. 3-1
Overall Block Diagram

The overall system consists of the plant (engine/cooling system), the engine & thermal controls (DSP boards), and two Windows PCs with Code Composer interfaces. The user's input will be sent to the DSP boards for processing. After the boards have executed the user's commands, the resulting output will be sent back to the Code Composer interface and displayed.

Functional Requirements & Performance Specifications

<u>Engine control system</u>

The engine control system will go through multiple designs. A basic proportional controller will be implemented first, followed by PI & PID controllers. The final controller will be observer-based.

The final engine control system shall meet the following specifications using a step input:

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

The data for these specifications will be collected for each method of control. This data will then be compared to make conclusions on the advantages and disadvantages for each control method. Each method will then be implemented in the engine control system. Both theoretical and experimental data will be collected. The control method command input range will vary based on the method used.

<u>Thermal control system</u>

The thermal control system will go through several design iterations. A basic proportional controller will be implemented first, followed by PI & PID controllers. The final controller will be observer-based.

The final thermal system shall meet the following specifications using a step input:

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

During system operation, the thermal control system shall ensure that the engine temperature remains below 40° C (104° F). The power consumed by the thermal control system shall remain at a minimum level. Each controller method listed above will be tested against the defined requirements. The method that best meets these requirements will be used in the final thermal control system.

Conclusion

Our engine cooling system will go through several design iterations with the last method will be observer-based control. The methods will be compared to determine which method best meets the requirements defined above. This system will be used in the final version of the control system.

References

[1] George Ellis. “Observers in Control Systems”, Academic Press, 2002.