Observer-based Engine Cooling Control System (OBCOOL)

Functional Description & System Block Diagram

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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 [3].

Our project consists of researching observer-based control systems and applying this knowledge to design closed-loop controllers for temperature regulation and velocity control 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 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/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

Functional Description

The engine control workstation consists of the following subcomponents:

- Engine model simulated by a motor-generator system
- Variable load for engine
- Cooling system consisting of a fan, radiator, cooling block, reservoir, pump, flow meter, and three temperature sensors
- Two eZdsp F2812 DSP boards
- PC software GUI (MATLAB/Simulink and Code Composer)

A closed-loop control system will be implemented for both the engine system and the thermal system. While the initial control systems will be developed using EE 431 (“classical”) control methods, the final system will incorporate observers to improve the systems’ responses.

The overall system functions as follows:

1. Using the PC GUI, the user sets the system inputs (engine RPM, etc.) for the engine.
2. The PC sends data to the DSP boards through Code Composer.
3. The engine control DSP board sets the engine RPM to the desired value using the implemented control algorithm and PWM signals.
4. The thermal control DSP board adjusts the temperature of the engine by changing the pump & fan motor speeds using the implemented control algorithm and PWM signals.
5. The engine control output information and the thermal control output information are sent back to the PC and are displayed in the GUI.

Inputs / Outputs	
Engine	
Inputs	**Outputs**
RPM	RPM
Power Limiter	Current
	Power dissipated
	Output power
	Observer RPM
	Observer current
Thermal	
Inputs	**Outputs**
Temperatures	Temperature of radiator inlet
	Temperature of radiator outlet
	Engine block temperature
	Power of each subsystem
	Observer temperatures

Table 3-1
System Inputs/Outputs

Functional Description, cont.

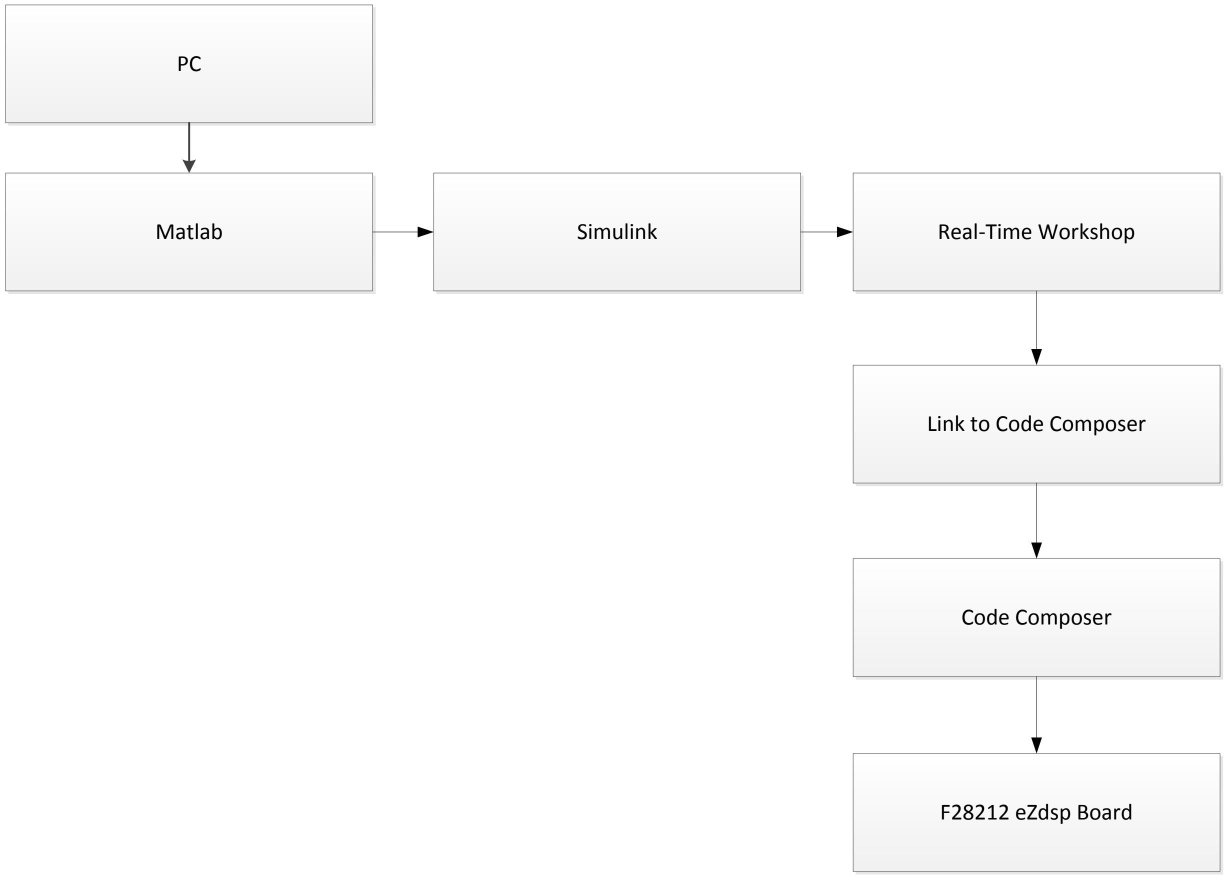

Fig. 4-1
General Software Flow Chart [2]

The eZdsp F2812 DSP board will be used in both the motor control subsystem and the cooling control subsystem. The design and implementation of these control systems is done through the PC. The software packages that will be used are MATLAB, Simulink and Realtime Workshop, and Code Composer 3.

- MATLAB is the main program associated with the project. It will be the host to other software, such as Simulink.
- Simulink is used to build the models of the subsystems.
- The Realtime Workshop is used to convert the Simulink model into C code using Code Composer.
- Link to Code Composer is used to link the Real-time Workshop to Code Composer

System Block Diagrams

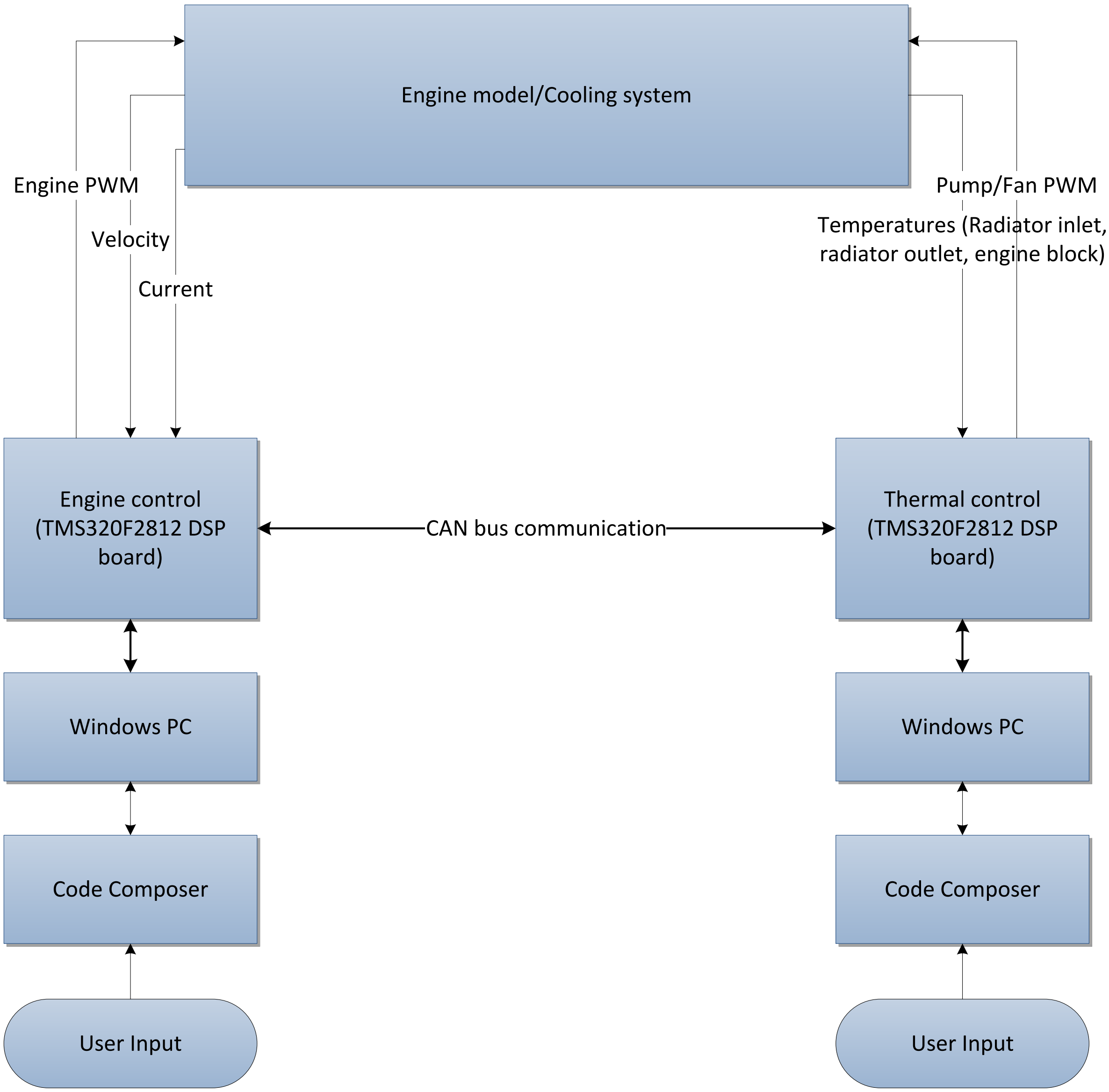

Fig. 5-1
Overall Block Diagram

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.

System Block Diagrams, cont.

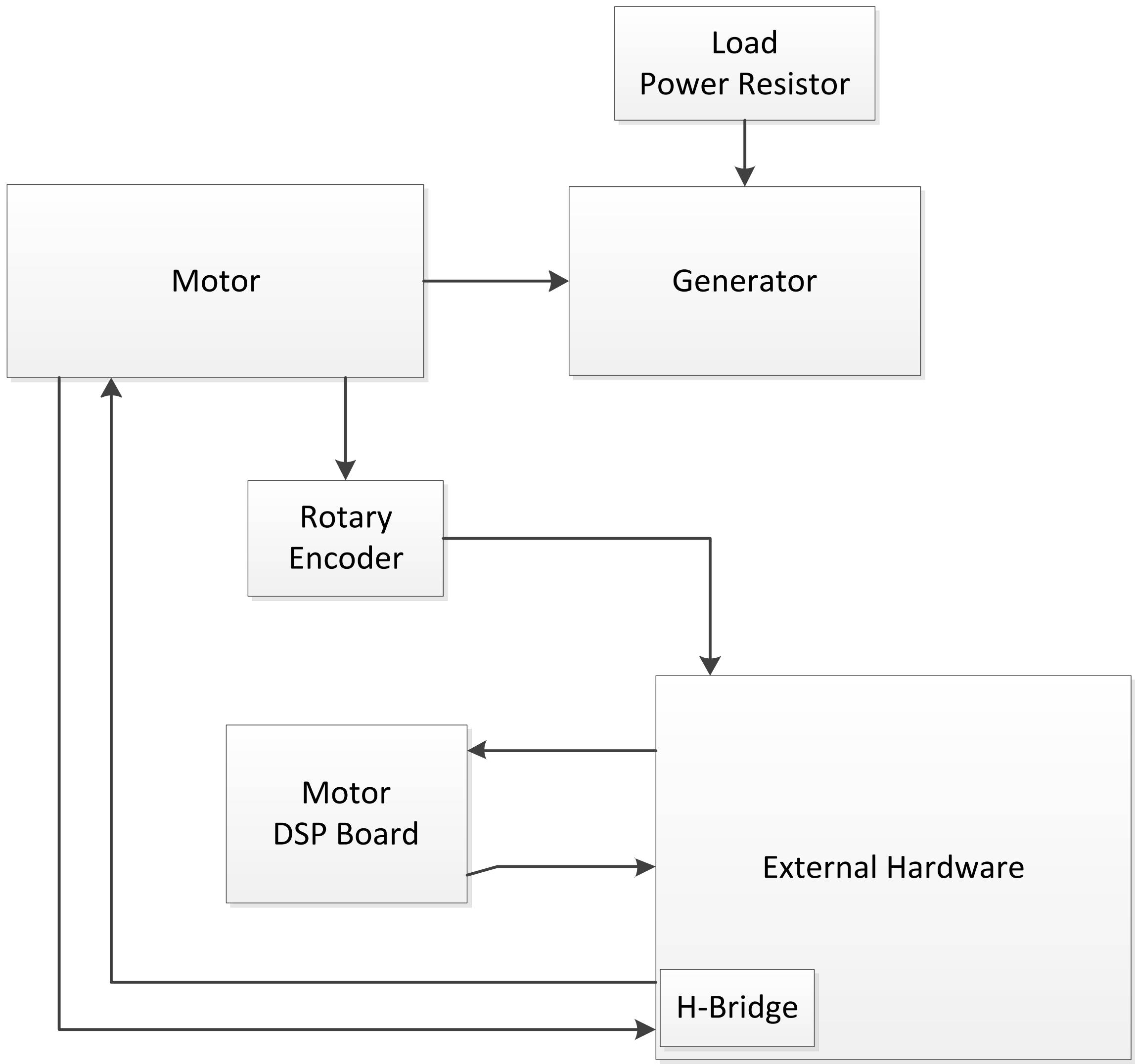

Fig. 6-1
Engine Block Diagram

The engine subsystem includes the motor, generator, load, rotary encoder, external hardware, and one DSP board. [1]

- The load is simulated using a power resistor. This will load the generator, which will load the motor. The system will be designed to accommodate varying loads.
- The rotary encoder is used to detect the speed of the motor, which will be used in the observer calculations
- The H-bridge provides a means to control the motor using a PWM signal from the DSP board.
- The DSP board allows computations to be done quickly. The observers will be done in software on the DSP board.

System Block Diagrams, cont.

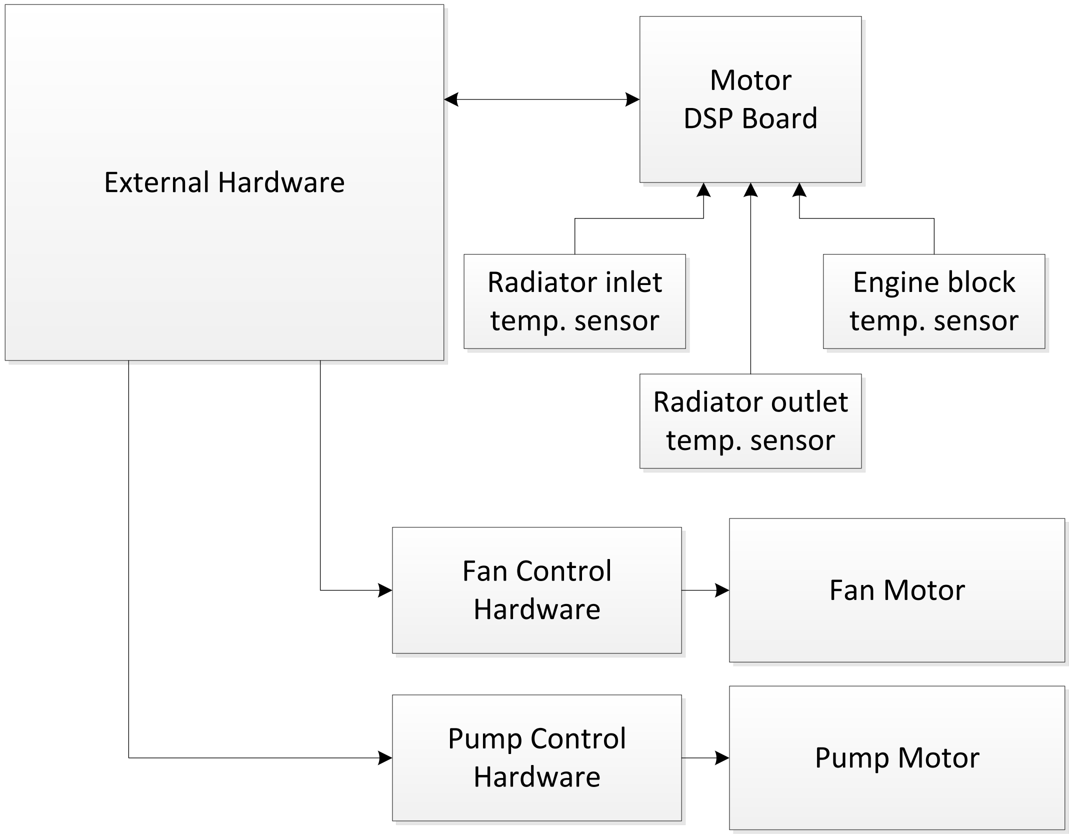

Fig. 7-1
Thermal Control Block Diagram

The thermal subsystem includes the fan & pump motors, hardware for controlling each motor, three temperature sensors, and one DSP board. [1]

- The temperature sensors each contain one thermistor for measuring the temperature. The thermistor's resistance varies with temperature, causing the voltage output of each sensor to change.
- The DSP board converts the voltage levels from the temperature sensors into digital values and calculates the required fan/pump motor speeds required to cool the system.
- The DSP board outputs a PWM signal (through the external hardware) to the fan/pump motors and adjusts their speed.
- The DSP board allows computations to be done quickly. The observers will be done in software on the DSP board.

Circuit Schematics

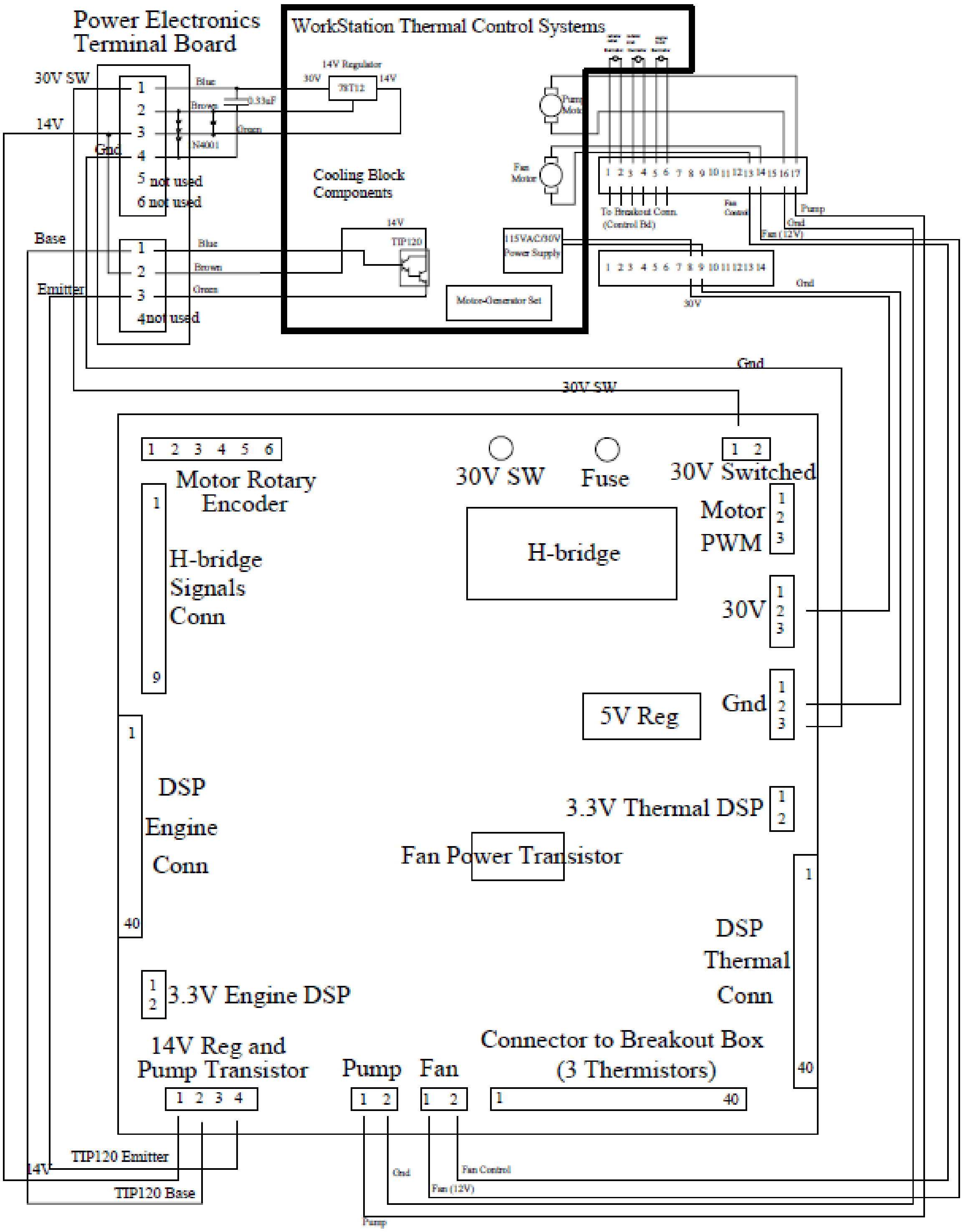

Fig. 8-1

High Level Schematic of Power Electronics [1]

The circuitry of figure 10-1 is of the power electronics for both the engine and thermal subsystems. The main components of the engine subsystem in integrated into the left half of the bored. The thermal control components are integrated into the right half of the bored. Each subsystem has been isolate from the other and, therefore, each subsystem also has its own ground.

Circuit Schematics, cont.

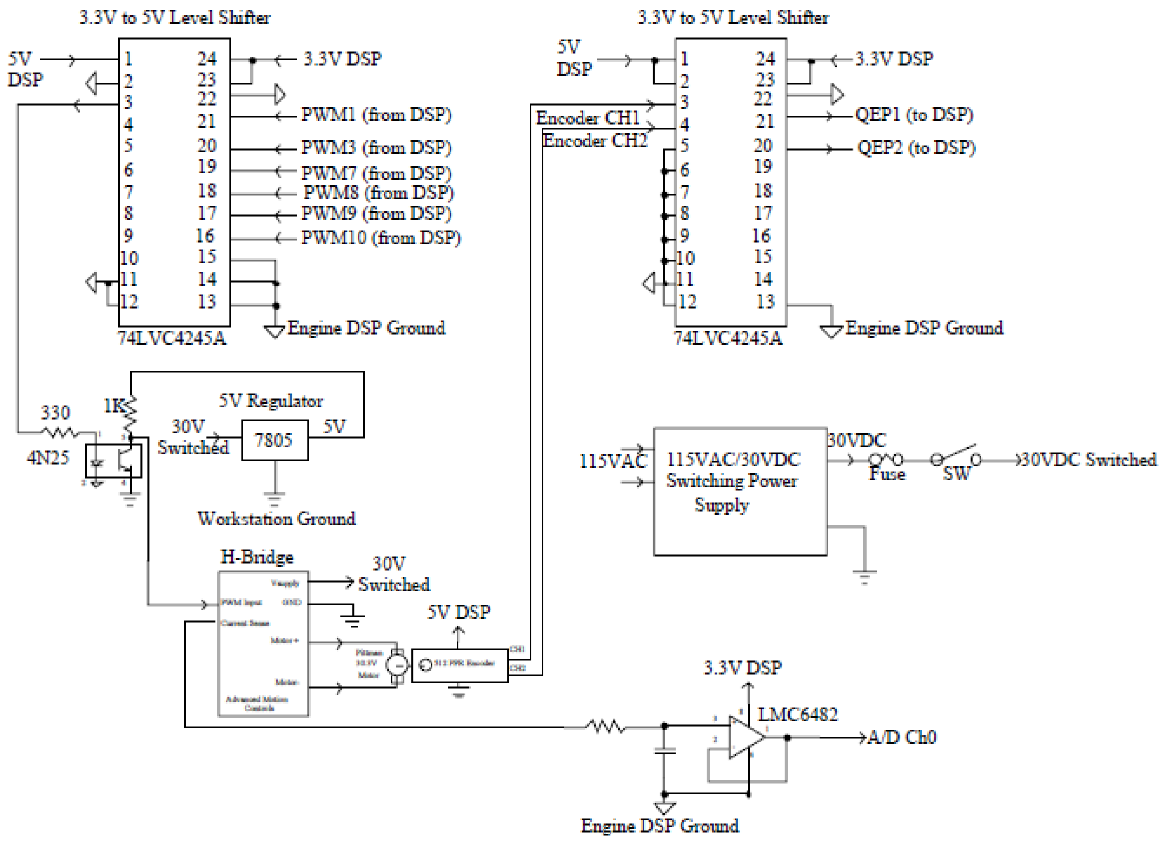

Fig. 9-1
Engine Control Circuty [1]

The circuit schematic for the engine control subsystem is shown in figure 8-1. The components include the motor, a DSP board, a 3.3V to 5V level shifter, an H-bridge, and A/D conditioning circuitry. This circuitry has already been implemented in a previous senior project.

Circuit Schematics, cont.

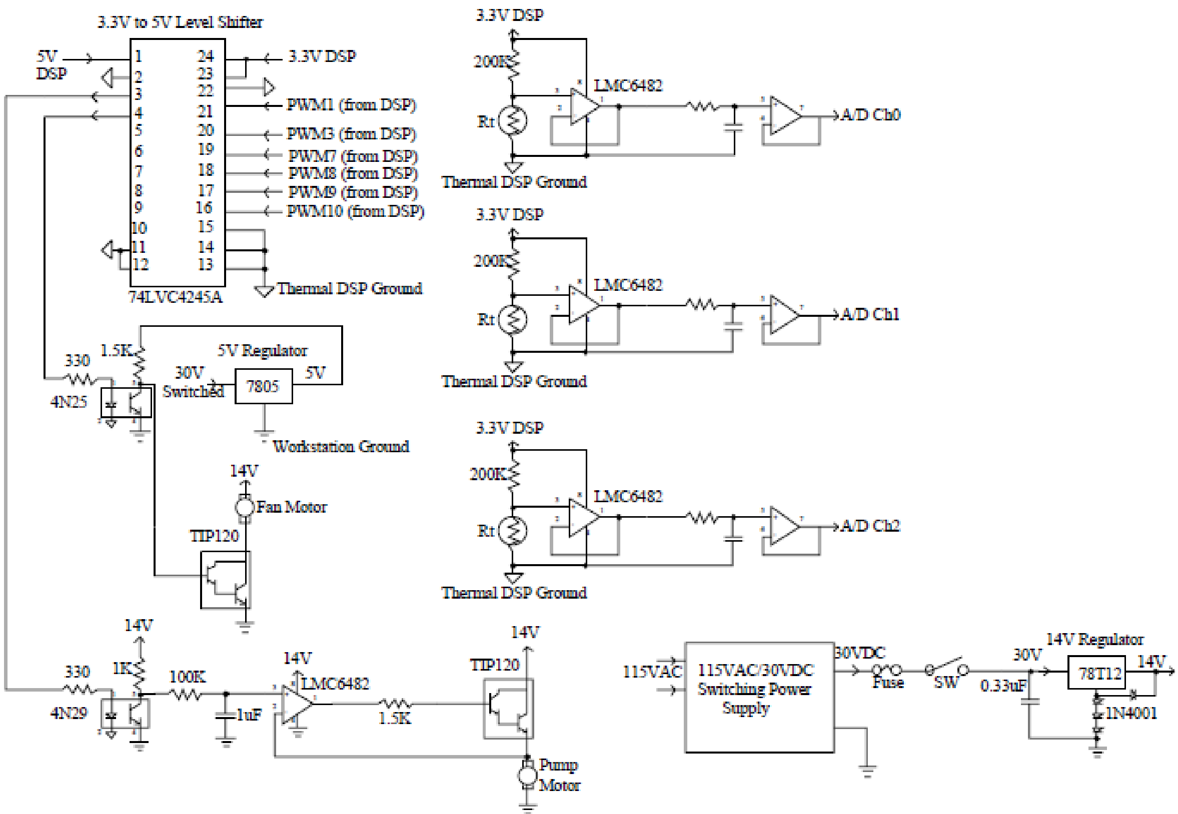

Fig. 10-1
Thermal Control Circutry [1]

Figure 9-1 shows the circuit components for the thermal control subsystem. The components include a 3.3V to 5V level shifter, transistors, and A/D conditioning circuitry. This circuitry has been implemented in a previous senior project.

Conclusion

Several control schemes will be implemented throughout the time of the project. The last method will be observer-based control. The methods will be compared to determine which method is the most suitable for the engine cooling control system.

References

[1] Gary Dempsey. “Engine Control Workstation System Overview”, Electrical and Computer Engineering Department, Bradley University, September 2010
[2] Gary Dempsey. “Observer-based Engine/Cooling Control System”, Electrical and Computer Engineering Department, Bradley University, August 2010
[3] George Ellis. “Observers in Control Systems”, Academic Press, 2002.