Milestone 2: Closed Loop Systems - Hardly Working

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1 Design Overview

The intent of this project was to create a system in which the temperature of a voltage regulator is regulated to a target temperature using a fan controlled by an MSP430F5529. To implement this, a voltage regulator was given 12v and a 6 ohm load, causing it to heat up, and a thermistor was placed adjacent to detect the temperature. A target temperature was sent to the MSP via UART, and the board would utilize PWM to actuate the fan, cooling the regulator down to the target temperature.

1.1 Design Features

These are the design features:

- Able to receive and execute UART signals
- Able to display thermistor temperature via UART
- Cool voltage regulator to desired temperature using PWM and a fan
- Able to change target temperature over UART

1.2 Featured Applications

- Desktop/Laptop CPU temperature regulation
- HVAC room temperature control

1.3 Design Resources

Here's a link to our code.

1.4 Block Diagram

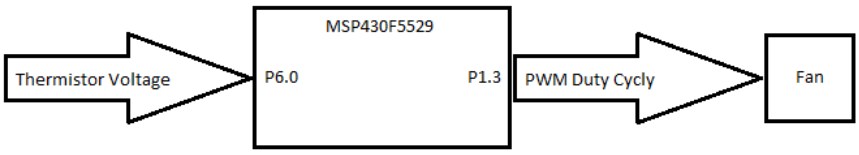

Figure 1: System Block Diagram

1.5 Board Image

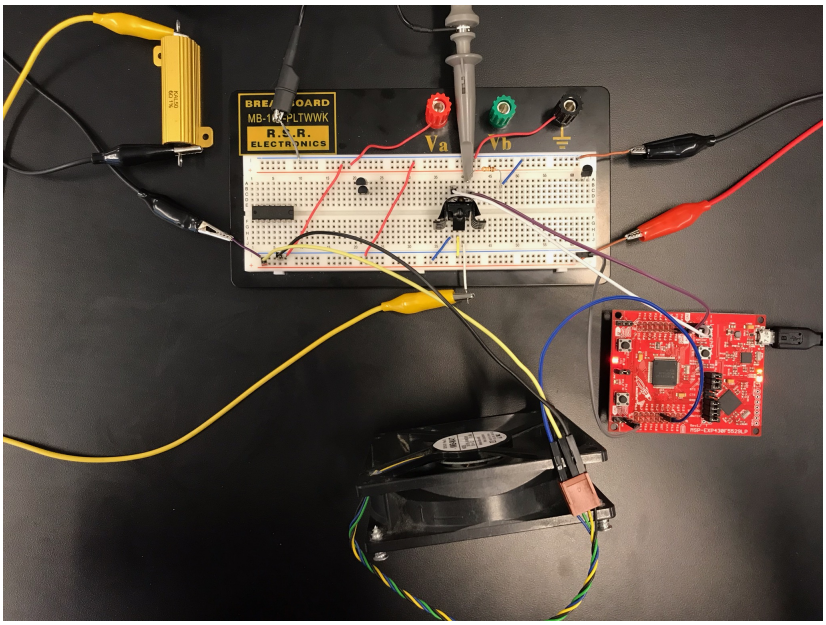

Figure 2: Circuit setup with fan and MSP430F5529

2 Key System Specifications

For this system there are two main parameters. The first parameter is a temperature reader which uses a thermistor in the voltage divider circuit to get a temperature reading. The second parameter sets the target temperature to be maintained by the PWM controlled fan.

PARAMETER	SPECIFICATIONS	DETAILS
Reading Temperature	15 C to 65 C	Reads temperature using the thermistor based on the voltage reading from the ADC port message
Setting Temperature	20 C to 65C	Sets temperature through UART and maintains that temperature by controlling the fan speed of the fan using PWM

3 System Description

For this project, a program was created that could be loaded on to an MSP430 processor to regulate the temperature in a system. For this purpose, timers, PWM, and UART protocol were all utilized. In the original code the target temperature could be set to a specific temperature, then utilizing UART this target temperature can be changed. For example, we can set the target temperature to 60 degrees Celsius then use UART to set the target to 30 degrees Celsius. The fan speed will increase to cool the voltage regulator down to the desired temperature and it will keep the temperature at or below the target once it reaches the desired temperature.

3.1 Detailed Block Diagram

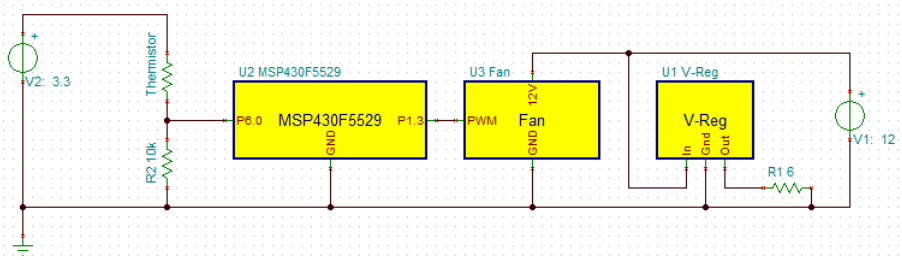

Figure 3: Voltage Regulator Temp Sensing Diagram

3.2 Highlighted Devices

- Computer with Realterm - Loads program onto MSP430 board, allows for temperature monitoring and target temperature adjustment
- MSP430F5529 - Receives/transmits UART signals, PWM fan speed to regulate temperature

3.3 MSP430F5529 Processor

The MSP430F5529 microprocessor is the heart of the system. It is responsible for receiving and processing the UART signal that determines the PWM for the fan. The MSP430F5529 is also responsible for calculating the temperature of the voltage regulator using a thermistor. This board was chosen due to there being more capture/compare registers for a single timer, and the fact that UART backchannel would not have to be used.

3.4 Circuitry

For our circuit a voltage divider was used for the thermistor, this is because the ADC can't take in resistance values, but can take in voltage values. Because a voltage divider was used, resistance can be calculated from the voltage and converted to temperature by the program. The voltage divider uses a 10k resistor in series with a thermistor connected to the 3.3V power source on the MSP430. The voltage divider was connected to Pin 6.0 between the resistor and thermistor. Pin 6.0 is the ADC12 port of the MSP430.
The voltage regulator is fed with a separate 12V power source. The IN port is connected to a 12V power source, the OUT is connected to a 6 power resistor connected to ground. Using the power resistor allows the circuit to draw enough current to heat up the voltage regulator. COM is then connected to ground. The fan is also supplied with 12V like the voltage regulator, connected to ground, and pin 1.3 for PWM to adjust fan speed.
A UART connection was also needed. This was done by connecting to Port 16 on the laptop and setting a baud rate of 9600. The temperature was sampled using the MSP430 which allows the user to see the current temperature. The target temperature could also be changed by sending a UART signal to the board from RealTerm.

4 SYSTEM DESIGN THEORY

The MSP430F5529 was picked over the other boards for multiple reasons. The F5529 was chosen due to it making UART communication easier by using a USB cable, and simpler implementation of the PWM thanks to pins P1.2, P1.3, P1.4 and their corresponding CCRs. The FR2311 only has timer B, and a UART USB back channel would have to be used.

4.1 PWM

PWM, or pulse width modulation, is used to control speed of the fan. By using PWM, the fan speed can be changed according to the temperature given by the thermistor. With a target temperature set, the PWM will increase fan speed to cool the voltage regulator if the thermistor is registering higher temperatures, and slow down to maintain the target temperature when it is reached. A timer module was used to control

the PWM for the fan. The timer clock was set to SMCLK in UP mode at 1 MHz. This sets the clock period to full cycle.

4.2 UART

UART stands for Universal Asynchronous Receiver/Transmitter. UART is needed to send and receive signals from/to the device. In this case UART is used to change the target temperature. To use UART, the pins associated with it must be enabled. On the MSP430F5529, those are pins 4.4 for transmit and 4.5 for receive. Next, the state machine is initially set to reset so it is not used till it is needed. Then the BAUD rate was set to 9600. The modulation is set after and these values are stored in corresponding registers. Once this has all been done, the state machine is ready to be initialized.

4.3 ADC12

The state machine is used to control the fan's PWM and pushes information to the processor. The ADC12 is also important for this to work. Because a thermistor was used the thermistor has a different resistance when the temperature changes. The ADC12 converts analog signals to digital signals. The ADC doesn't take in resistance values, but does take in voltage values. Because of this a voltage divider was built so the resistance can be calculated and converted to temperature by the program. This is then used by the PWM to set the fan speed to maintain the voltage regulator's temperature.

5 Getting Started/How to use the device

To use this program an MSP430F5529 must be obtained. The code is designed for this board and will not work with other boards due to different pin assignments and timer modules. To use this fan-modulating voltage regulator temperature control system, multiple programs must be downloaded and installed and a basic understanding of using them is needed. A breadboard, resistors, a thermistor, voltage regulator, and a computer fan are needed to build the circuit to be connected to the MSP430F5529. Once the circuit is constructed, connected, and operational, the fan will automatically cool the voltage regulator to the target temperature, and new target temperatures can be input using UART via Realterm.

5.1 Software needed

Texas Instruments' Code Composer Studio software is needed to load the firmware onto the MSP430F5529. This can be downloaded from TI's website. Once downloaded, follow the install wizard and be sure to install the package for the MSP430. Now the code can be input into Code Composer Studio and flashed to the board.

The other piece of software needed is Realterm. Realterm is a serial capture program that can be used for UART. Once this is downloaded and installed you are ready to connect to the MSP430F5529. First plug the board into the computer using a USB cable. The port that the device is connected to must be determined, which can be done by going into Device Manager and checking Ports (COM & LPT). The one needed is MSP Application UART1 (PortXX), in our case it was port 16. Once this information is obtained, go to the port tab of RealTerm, set the BAUD rate to 9600, select your port, set it to open, and click change. Once done, the processor is ready to receive messages over UART.

5.2 Circuit Setup

There are two circuits that need to be constructed for this system. The first is the thermistor circuit. This circuit is essentially a voltage divider; the thermistor is connected to power and then a 10K ohm resistor is placed in series to ground. A voltage sensing wire is placed between these two components and run to pin 6.0 of the MSP430. Next is the voltage regulator circuit, which consists of a 12V to 5V voltage regulator that is supplied with 12 volts, ground, and a 6 ohm load. It is important that the thermistor head makes good contact with the heat sink of the voltage regulator for accurate measurement. Finally, a fan is supplied with 12V power, ground, and connected to pin 1.3 of the MSP430 for PWM.

5.3 Communicating with the Device

Communicating with the device is done using UART via a program called Realterm. While the system is active, Realterm will display and continuously update the current temperature of the thermistor. Using the send tab of Realterm, a new target temperature can be input to the MSP430 by entering the desired numerical value in Celsius.

6 Test Setup

To setup testing of the program, the code must first be flashed to the MSP430 processor. For this purpose we used Code Composer, and the specific board that was flashed was the MSP430F5529. Once the code is flashed to the board it is ready to be interfaced with.

To communicate with the board, UART is used. To accomplish this the program Realterm was used. Once Realterm is opened go into the port tab and set the port to the port the MSP430 board is on. For our case it was port 16. The BAUD rate must be set to 9600 and the port must be set to open. Once this is done we are ready to send information to the board.

To send information to the board to change the target temperature we must go to the Send tab within Realterm. Setting the target temperature is as simple as inputting the numerical temperature value in Celsius and pressing send. The MSP430 will then

modulate the fan speed until target regulator temperature is reached, and maintain that temperature as needed.