Closed Loop Temperature Control

Brian Harlow and David Gaffney
Rowan University

December 3, 2018

1 Design Overview

In this milestone, an MSP430F5529 microcontroller was used to receive a desired temperature through UART communication and use that temperature to alter the speed of a fan. This was done to control the temperature of an ”environment,” or in this case a thermistor. The thermistor is cooled down by the fan and heated up by a nearby 5 V voltage regulator that produces large amounts of heat. The thermistor changes resistance based on its temperature. As the resistance changes, different voltages are measured and input into the microcontroller's ADC in order to calculate the current temperature. That temperature is returned to the sender over UART to see the current temperature of the thermistor.

1.1 Design Features

This design features the following:

- Desired temperature control accurate to within 2 degrees celsius
- Analog to digital voltage conversion for temperature reading
- Serial UART communication between user and microcontroller
- Hardware PWM integration to control fan speed
- 2^8 steps of PWM based fan speeds
- Implementation on MSP430F5529 microcontroller

1.2 Featured Applications

A list of different technologies this system could be applied to:

- Temperature control of an isolated environment
- Custom heat sinks for device cooling

1.3 Design Resources

For all relevant resources and files, visit the linked repository:

Scrumbology Repository

1.4 Block Diagram

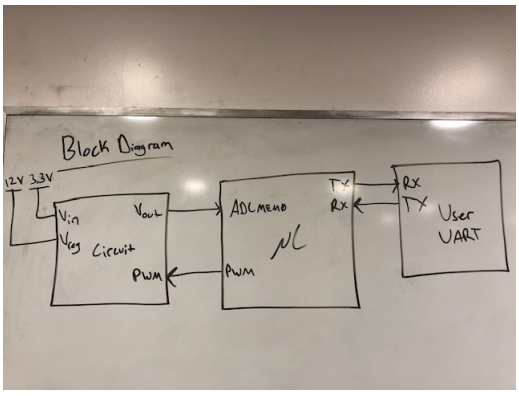

Figure 1: Simple diagram of Temperature Control System

1.5 Board Image

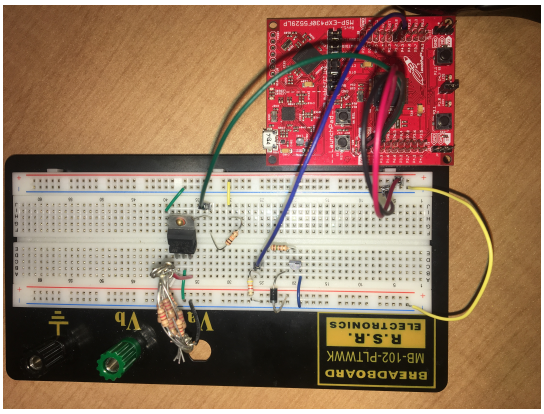

Figure 2: Image of microcontroller connected to Thermistor Circuit

2 Key System Specifications

Parameter	Specification	Description
Voltage	12V Power Supply	12V power input to the fan.
CCRx	16 Bit Registers	16 bit registers that store the values that control the PWM period and pulse width.
Baud Rate	Data Transmission Frequency	The baud rate is the rate at which data is transferred between two UART devices. If the baud rates are not the same frequency, the data will not transfer properly and there will be timing issues.
12 Bit ADC	Thermistor Temperature Reading	The ADC takes in the analog voltage at one node of the thermistor to convert to a digital signal. This value is read and stored in the ADC12MEM0 register. Using this value, the temperature of the thermistor is calculated.
RX/TX Buffer	Data In/Out 8 Bit Registers	The RX Buffer is a register which stores a byte of data to be taken in by the microcontroller. The TX buffer stores the data to be transferred to the user.

3 System Description

This system is designed to control the temperature of an isolated environment using a 5V voltage regulator, an NTC thermistor, and a 12V Fan. It utilizes the user input in

the form of a desired temperature that is sent over UART to the microcontroller. This temperature is used to calculate the change in temperature which is calculated from the goal temperature minus the current temperature. The current temperature is found using an NTC thermistor which is implemented in a voltage divider circuit connected to the microcontroller. The thermistor is set up in close proximity to the 5v voltage regulator so that it continually heats it, so that the fan will counteract it. The fan is set up in a circuit that uses a mosfet to control the fan, and a diode to combat feedback.

3.1 Detailed Block Diagram

The ”User” block is the Realterm program that the user utilizes to send and receive temperatures to and from the system. This is done over the MSP430F5529’s UART interface. The circuitry is designed to control the fan to blow towards the thermistor to cool it down. The voltage regulator, though not shown in the circuit diagram, is in contact with the thermistor for good heat transfer.

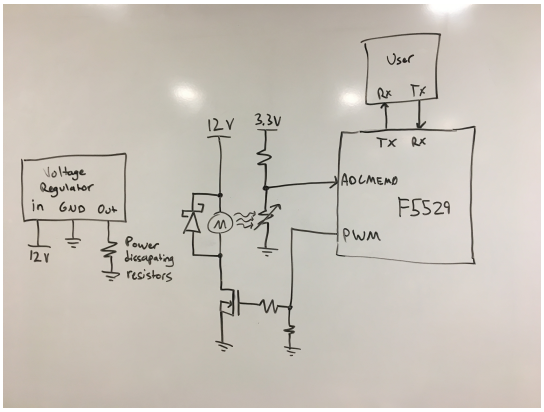

Figure 3: A detailed diagram of the Temperature Control System

3.2 Highlighted Devices

Essential components list:

- MSP430F5529
- NTC Thermistor
- L7805 5 V Voltage Regulator
- 12 V Fan

3.3 MSP430F5529

The device being used is the MSP430F5529. Inside of the processor, a couple of different components were used: The timer module and its corresponding CCRs, UART communication with RX and TX buffers, and the Analog to Digital Converter (ADC). The timer A module was used to control the duty cycle of the 1kHz PWM which allowed a varying fan speed. The UART protocol was used to allow communication between the user and the system and set different temperatures. Finally, the RX and TX buffers were used to capture the data being sent from the user, and to send back to the user the current temperature.

3.4 NTC Thermistor

The thermistor used was an NTC, or negative temperature coefficient, thermistor. This means that as the temperature of the thermistor increases, the resistance decreases. This part is essential to be implemented within a voltage divider circuit. It allows an output voltage to vary depending on temperature. This voltage is sampled by the ADC to be converted to a digital signal to calculate the temperature.

3.5 Voltage Regulator

The 5V Voltage Regulator was used with 10 parallel 120 Ohm Resistors to heat up the thermistor. The 10 resistors are used to dissipate the 2 Watts used to power the voltage regulator.

3.6 Fan

The fan used was a 12 V fan. Its speed would vary depending on the PWM output of the microcontroller determined by the program itself.

4 SYSTEM DESIGN THEORY

The main components of this project that allow the system to work are the ADC, UART communication and the Fan PWM. These components are used in specific ways that are described in sections 4.1, 4.2, and 4.3.

4.1 Fan Pulse Width Modulation Control

The Pulse With Modulation Control was used to create the duty cycle that controls the speed of the fan. The timer that was originally running at 1 MHz was divided by 4 using the internal divider. This set the clock at a value of 250 kHz. Using two CCR's set to 255, this allowed the PWM to operate at a frequncy of 1 kHz. The output mode was set to three which is used for set and reset.

4.2 UART Communication

The serial UART communication protocol interface implemented in the MSP430F5529 was essential for relaying information from the user to the system and vice versa. The microcontroller was configured to receive and send data from the user and to the user using a terminal program called Realterm. A desired temperature would be sent from the user to the system. This temperature would be used to calculate the change from the current temperature, and the PWM duty cycle would change based on that delta. Then the current temperature would be sent back to the user.

4.3 Analog to Digital Converter

The Analog to Digital Converter was used to input a resistance value based on the temperature that the thermistor was reading. This value was then needed to be converted from an analog value to a digital value, and then converted into a resistance used to find the current temperature. This was integral to the project because without it there wouldn't be any environment control.

5 Getting Started/How to use the device

This program is used to control the environment created using a 12V fan, a 5V Voltage Regulator, and a thermistor on an MSP430F5529. The way that the program works is first the circuit using the fan, regulator, and thermistor must be set up. The thermistor is set up in a voltage divider where the input output goes to the ADC on the MSP430.The fan is set up to be controlled using a mosfet, a feedback diode, and 2 resistors. The regulator is set up using a circuit with a combination of parallel resistors with the capability to disperse 2 Watts. This circuit can be found in Figure 3. Then using a terminal program, set it up for a baud rate of 9600, and make sure it is set up for the correct com port that your microcontroller is connected to. Then use the terminal program to send integer temperature values in degrees Celsius.

6 Test Setup

Connect the device as described in section 5, and pictured in Figure 2.

6.1 Test Data

Temperature Low	30 degrees Celsius
Temperature High	60 degrees Celsius
Temperature Variance	+/- 2 degrees Celsius