Milestone 2: Closed Loop Systems

Nate Hoffman and DJ Stahlberger
Rowan University

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1 Design Overview

In this milestone, the simple problem of controlling the temperature in a closed loop system was observed and solved. The purpose of this milestone was to use a thermistor, an MSP430F5529, and a fan to regulate the temperature of the thermistor. This was achieved using the on board analog to digital converter on the MSP430 and using PWM to power the fan in correspondence with the closed loop feedback provided by the thermistor.

1.1 Design Features

Due to PWM control and the serial communications protocol UART, here are the design features:

- Closed loop temperature control using PWM to power a fan
- Reading data from an NTCLE100E3 thermistor
- Data transmission to any device that utilizes UART

1.2 Featured Applications

- Temperature Control
- Analog to Digital Conversion
- UART Communications

1.3 Design Resources

Here are a few links to the GitHub repository and a few useful documents

- Here is the GitHub repository containing the design files
- NTCLE100 Thermistor DataSheet
- MSP430F552x DataSheet
- MSP430x5xx Family Users Guide

1.4 Block Diagram

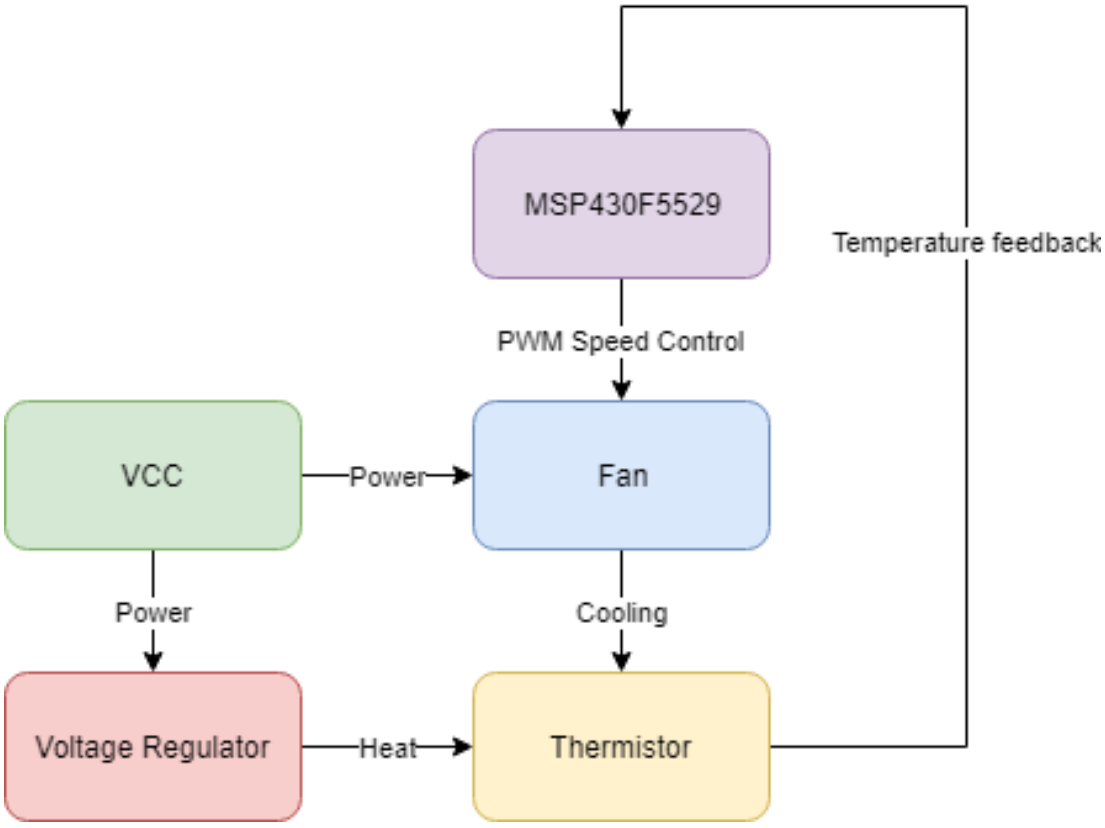

Figure 1: Closed Loop Block Diagram

1.5 Board Image

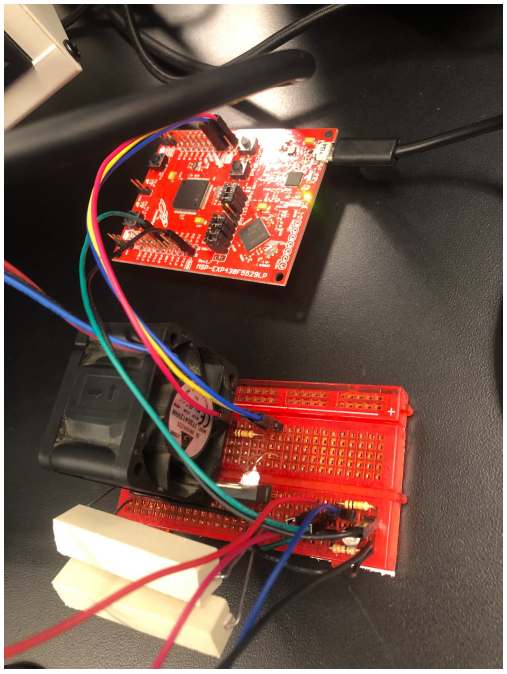

Figure 2: Breadboard setup containing all components as well as the MSP430F5529

2 Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Baud Rate	9600	Bits per second being transferred between systems
ADC	12-bit	Analog to Digital converter with 12-bits of resolution
PWM	1kHz	Speed of the pulse width modulation used to control the fan
Temperature	30C - 60C	Range of temperatures the system is capable of holding

3 System Description

The problem being solved is controlling the temperature of a closed loop system. The problem is that a voltage regulator is being heated up by resistors drawing current and a thermistor is attached to the regulator. This thermistor needs to be cooled off by a fan in a controlled fashion.

3.1 Detailed Block Diagram

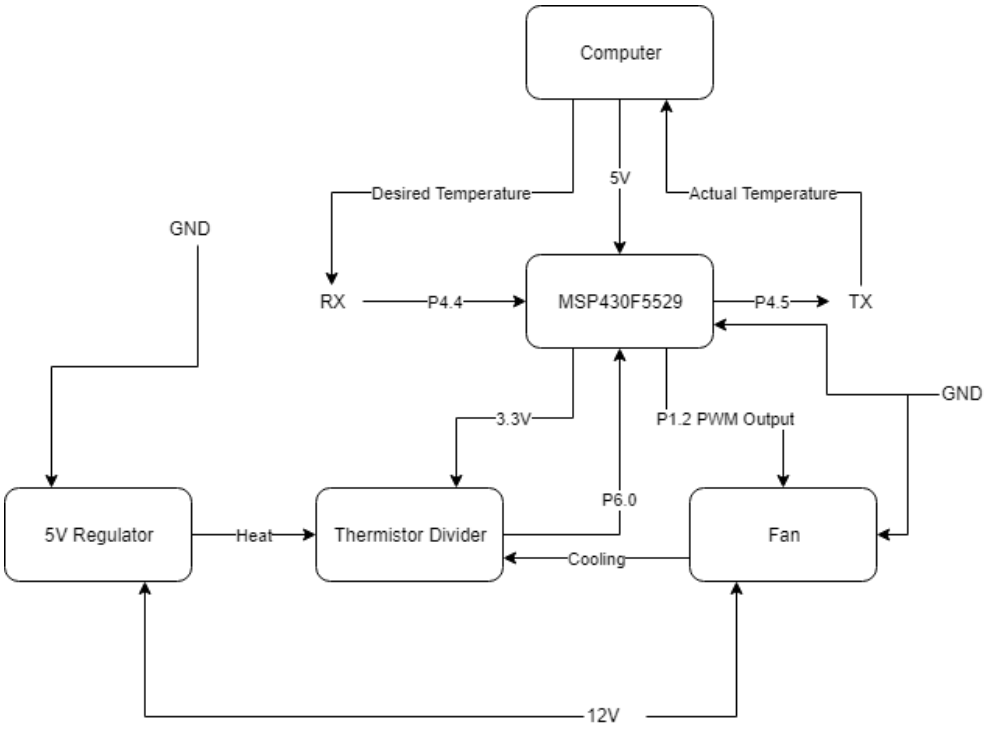

Figure 3: Detailed System Diagram

3.2 Highlighted Devices

- MSP430F5529
- Low-Side Driver
- Voltage Regulator
- Thermistor

3.3 MSP430F5529

This device has a 12-bit ADC, hardware PWM, and UART connections. These are the features required for this milestone. Connections to the other parts of the system were made.

3.4 Low-Side Driver

The low-side driver controls whether the fan is on or not using an N-channel MOSFET. This allows a microcontroller or other device with low output current to control higher powered devices. The driver can even be controlled with PWM to provide varying voltage to the device it is connected to.

3.5 Voltage Regulator

Designed to generate heat, this 5 Volt regulator (powered by 12 Volts) was connected to two 50 Ohm 10 Watt resistors in parallel. The amount of power from the regulator generates a lot of heat that needs to be cooled down.

3.6 Thermistor

The NTC thermistor decreases its resistance as its temperature goes up. It was placed in the bottom half of a voltage divider. The top half is a 10 kOhm resistor. At 25 degrees Celcius the thermistor measures 10 kOhm.

4 Circuit Setup

One 12 Volt power supply is used to both drive a cooling fan and power the voltage regulator. The cooling fan speed is controlled by a low-side driver. This is then pointed at the voltage regulator. The voltage regulator is setup to generate heat driving a high wattage load (2 Watts). A NTC thermistor was used to measure the temperature of the voltage regulator. It is important to maintain good thermal contact between the regulator and thermistor to accurately measure the temperature, so the use of thermal paste is suggested.

5 Getting Started Software

To interface with the board, the USB connection was utilized. Serial data running at 9600 bps was transmitted over USB to and from the computer. The board transmitted the temperature read from the thermistor in degrees Celcius with two decimal places of precision. The format is ASCII, and each line ended with a newline character.

When transmitting data from the computer to the board, the raw data value is used. A single byte is used to set the target temperature of the voltage regulator in degrees Celcius. No newline characters or other delimiting bytes were used.

6 Test Setup

To confirm the accuracy of the system, the circuit setup was followed. Multiple temperatures were set and the system was monitored to confirm that the desired temperature was reached on the voltage regulator.

In addition to confirming the temperature read by the MSP430F5529, the voltage across the thermistor was monitored separately. This confirmed the temperature reading was in the correct range, and did not oscillate more than plus or minus 3 degrees Celcius.

6.1 Test Data

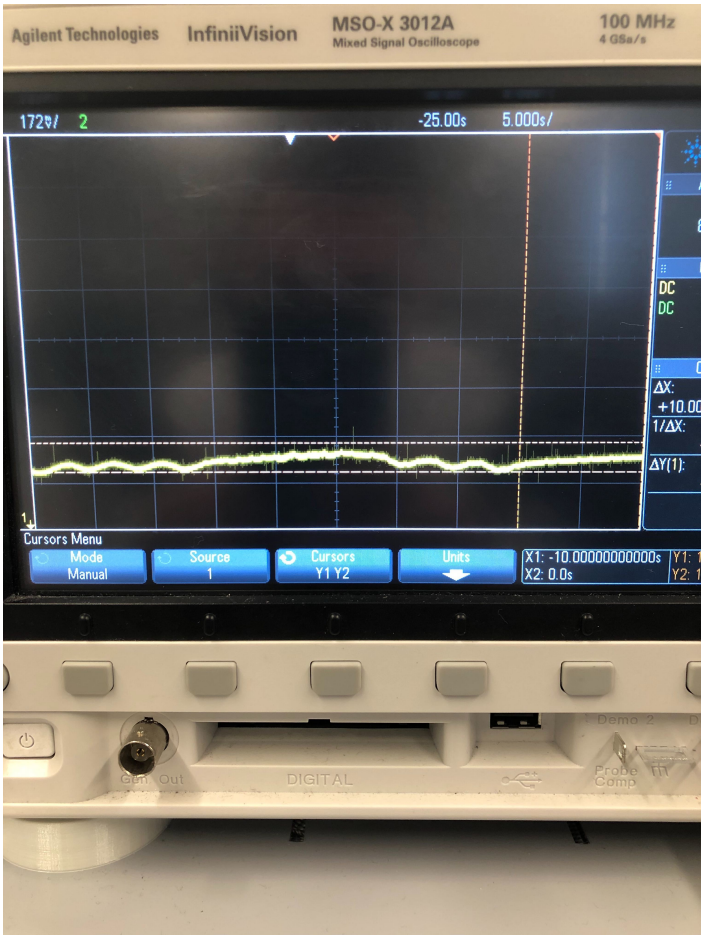

Figure 4: Voltage reading of the thermistor in steady state

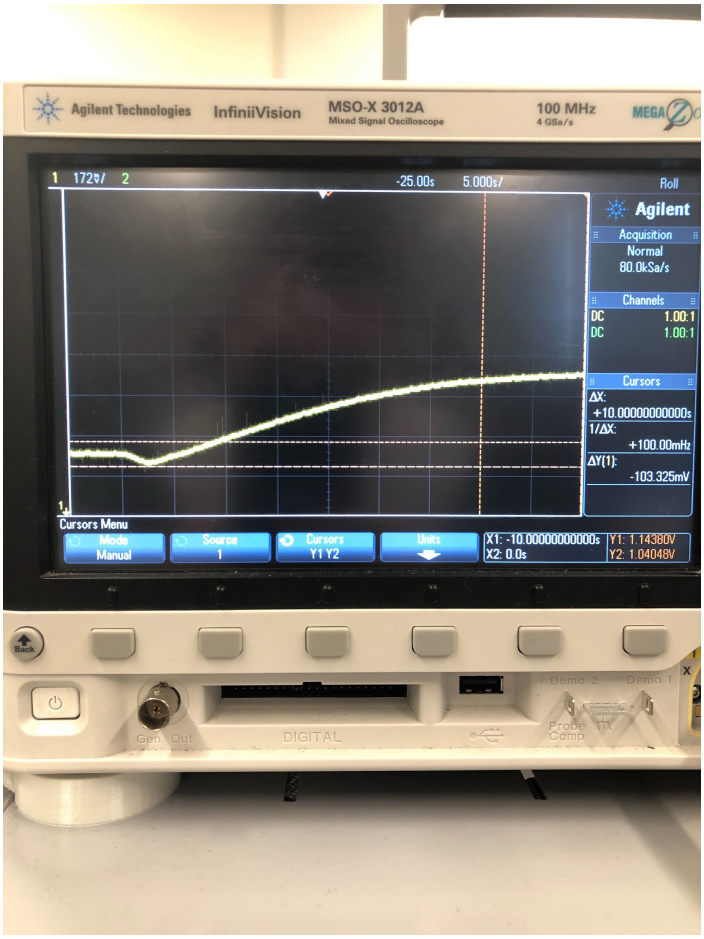

Figure 5: Voltage reading of thermistor in transition state

7 Design Files

7.1 Schematics

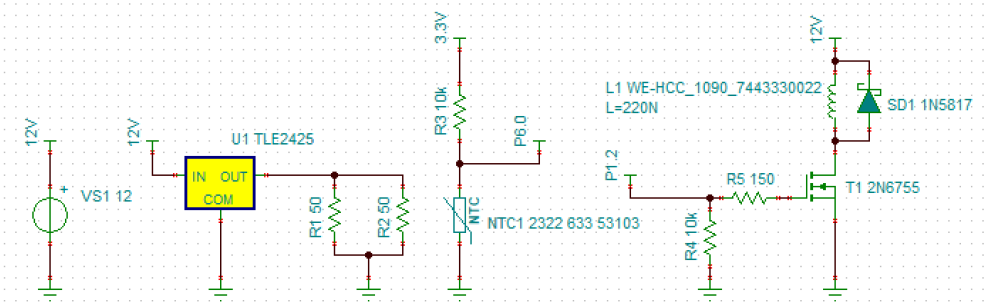

Figure 6: Schematic of closed loop system

7.2 Bill of Materials

- 150Ω resistor
- 2x 10kΩ resistors
- 1.5 Amp 5 Volt Voltage regulator
- 1N5817 Schottkey Diode
- 2N7000 NMOS
- NTCLE100 Thermistor
- 2x 50Ω 10 Watt resistors
- Delta FFB0412VHN Fan