Closed Loop Systems

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1 Design Overview

The closed loop PID control of a fan will be accomplished by using the MSP430F5529. To implement this, we will be incorporating skills we became familiar with in previous labs. The skills include, interrupts, PWM, UART, and finally analog to digital conversion. The processor will be calculating the temperature of a mass that disperses heat while controlling the speed of a fan to dynamically change the temperature to match the temperature given over UART.

1.1 Design Features

The following features will be utilized and displayed in the lab.

Each are for the MSP430G2553:

- PID
- Steinhart and Hart Equation
- UART
- PWM
- C Programming
- Circuit Analysis

1.2 Featured Applications

- Closed loop system
- Transmitting Data
- Receiving Data

1.3 Design Resources

- Closed Loop Systems
- Main.c

1.4 Block Diagram

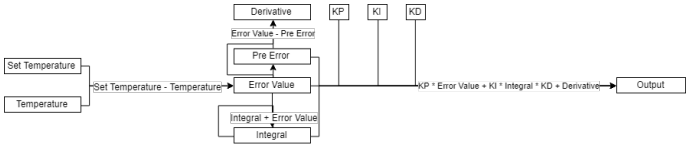

Figure 1: PID Block Diagram

1.5 Board Image

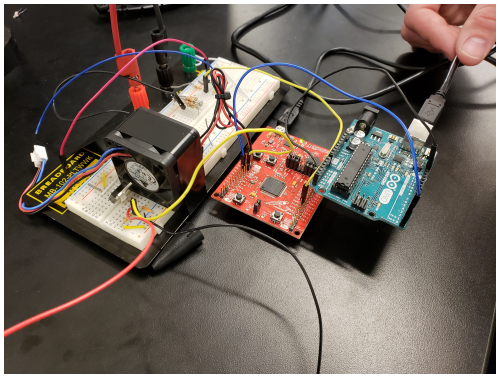

Figure 2: Fan and Supporting Circuit

2 Key System Specifications

PARAMETER	SPECIFICATIONS	DETAILS
Correct temperature of mass	Correct amount of bits are sent	Temperature of mass cannot fluctu below the target temperat

3 System Description

A UART message will be transmitted to the processor and the processor will receive the data as the target temperature for the voltage regulator. The processor will calculate the temperature of the voltage regulator and determine the necessary duty cycle of the fan to cool down the mass. The system will then actively monitor the temperature of voltage regulator. The active monitoring is to ensure the temperature does not travel too far above or below the specified temperature. This is accomplished by dynamically changing the duty cycle of the fan.

3.1 Detailed Block Diagram

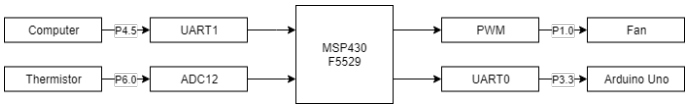

Figure 3: Closed Loop System

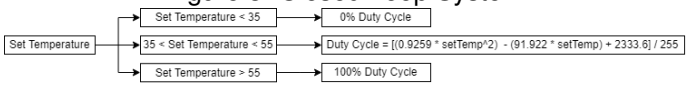

Figure 4: Open Loop System

3.2 Highlighted Devices

- MSP430F5529
- PWM Fan
- Thermistor
- Voltage Regulator

3.3 Device - MSP430G2553

The MSP430F5529 is used in this lab for analog to digital conversion, controlling an output with PWM, and calculating the temperature of the voltage regulator.

3.4 Device - Fan

The fan used is a PWM fan which are typically used to cool electronics such as processors and computer parts. It is important the fan has a data pin to allow for control over the speed.

3.5 Device - Thermistor

A 10k Ohm thermistor was utilized. A thermistor varies in resistance based on the temperature of the environment or devices it is near. In order to derive the temperature of the thermistor, a voltage divider was utilized.

3.6 Device - Voltage Regulator

The voltage regulator takes a 12V input and regulates the voltage to 5V. This is achieved by having a load connected to the input that dissipates heat. The load attached is a composition of 10, 120 Ohm, 1/4 watt resistors in parallel. This circuit resulted in an equivalent resistance of 12 Ohms and drew 0.417 amps and a load of 2.08 watts. These numbers caused the voltage regulator to reach a peak temperature of 75 degrees Celcius.

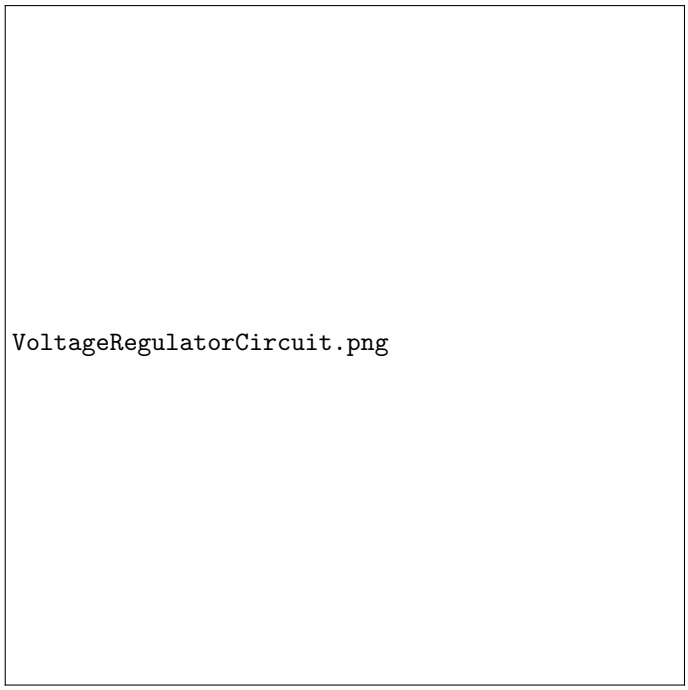

Figure 5: Voltage Regulator Circuit

4 SYSTEM DESIGN THEORY

The system to control the temperature of the voltage regulator is composed of two major parts, the processor and the supporting circuit. The responsibility of the processor is to receive data, process the data, actively monitor the data received by the

ADC12, and translate the data into a duty cycle for the fan. The circuit is necessary to calculate the temperature of the thermistor and communicate with the MSP430F5529. The following sections will go into more detail about the functions of each unit.

4.1 Design Requirement 1

The processor used in the closed loop circuit is the MSP40F5529. The pins addressed in the code are P6.0, P1.0, P1.2 as well as the TXD and RXD for UART communication. P6.0 is configured as the ADC12 input. Therefore, the pin will be reading the voltage of the voltage divider. The voltage is then converted into a hexadecimal, 12 bit number. This number is stored in the ADC12MEM0 register and will be used in an equation to calculate the actual voltage. Once the actual voltage is calculated, the resistance of the thermistor can be found. Next, since the resistance of the thermistor is know, the Steinhart and Hart equation is used to find the temperature of the voltage regulator. The temperature is then stored in the UCA0TXBUF and transmitted through UART0 to the terminal. The duty cycle of the fan is determined by a Proportional, Integral, Derivative control, or PID control equation. The proportional portion of the controller compares the desired temperature with the actual temperature. The resulting error is then multiplied with a constant (KP) to get a portion of the output. The integral portion of the controller integrates the error until the error value reaches zero. The integral control decreases its output when negative error takes place and limits the speed of response. The integral is multiplied with a constant (KI) to get another portion of the output. The derivative portion of the controller anticipates the future error of the value. The derivative is multiplied with a constant (KD) to get the last potion of the output. The constants, KP, KI, and KD can be adjusted in order to better tune the closed loop control and minimize oscillation of the temperature. The code is included below.

void PID() errorValue = setTemp - temperature; integral = integral + errorValue; derivative = errorValue - preError; output = kp * errorValue + ki * integral + kd * derivative; TA0CCR1 = output; preError = errorValue;

4.2 Design Requirement 2

The supporting circuit for the fan is composed of the fan, a thermistor, a voltage regulator and voltage divider. The fan is a typical PWM controlled fan. To control the fan a low side switch was utilized to take the hardware PWM signal from P1.2 of the MSP430F5529 and control the fan. An N-Mos was utilized to connect and disconnect the fan to and from ground based on the received signal, this controlling the speed of the fan. The thermistor is 10k Ohms and is placed in a voltage divider to calculate the voltage of the thermistor. From this information, the resistance of the thermistor is calculated by the processor. The voltage regulator takes 12V and regulates it to 5V. This is accomplished by resistors that dissipate the voltage in a form of heat. The heat affects the resistance of the thermistor. In this instance, the heat from the resistors lowers the resistance of the thermistor, causing the voltage to increase. The voltage becomes the analog input for the ADC on the processor.

5 Getting Started/How to use the device

In order to interface with the processor it must be connected via USB to a computer. Once connected to the computer you must open a terminal, such as RealTerm. The COM port that the MSP430 is connected to will be sent a package of data that will be the target temperature for the voltage regulator. The processor must be connected to the circuit via P6.0 which is the input for the ADC.

The electrical circuit must be set up on a breadboard. The circuit diagrams may be used as a reference.

5.1 Hardware Design

The hardware design aspect of this project was using a voltage divider to calculate the temperature of a thermistor. The thermistor reads the temperature of a voltage divider that takes 12V and regulates it to 5V. A thermistor was used due to the cost of the device. If this was impemented into a larger system that required hundreds of sensors to regulate the temperature, the cost of materials would have a more significant impact. The fan in the circuit is used to regulate the temperature of the voltage divider to a specific temperature.

6 Design Files

6.1 Bill of Materials

- MSP430F5529
- Resistors
  - 10x 120 Ohm 1/4 Watt
- Breadboard
- Fan
- Jumper cables
- Thermistor
- Thermal compund

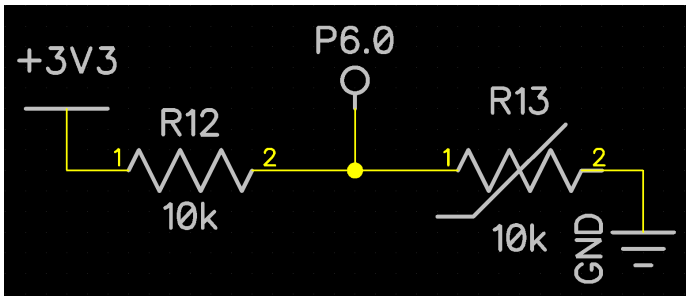

Figure 6: Thermistor Circuit Design

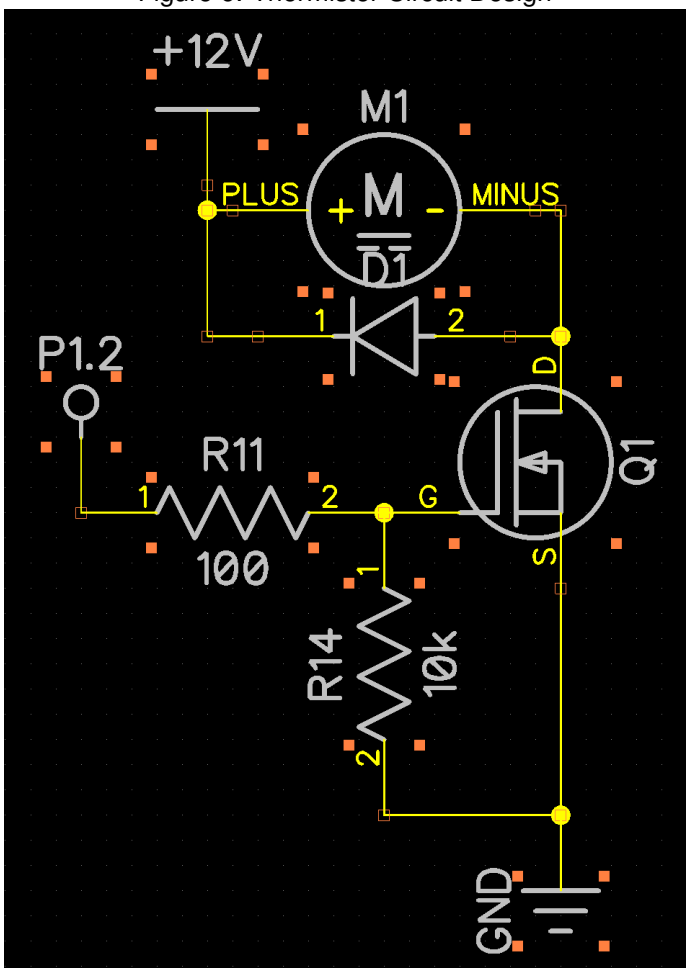

Figure 7: Fan Circuit Design