Fan Speed Control with Microcontrollers

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1 Abstract

Utilizing an msp430 microcontroller, a voltage regulator's temperature was able to be regulated to a desired temperature using a fan. The voltage regulator's temperature was measured with a PTAT, and this value was processed through an analog-to-digital converter to transform the output voltage into a readable temperature. The speed of the fan was controlled utilizing pulse-width-modulation.

2 Introduction

In many electronic components, heat is a major factor for optimal operating conditions as heat changes the electrical properties of said components. While just turning on a fan to cool them off might be a simple solution, most components have an optimal operating temperature where the efficiency of the system is highest, so the fan needs to be controlled to regulate the heat. Before the fan can control heat, it first needs to know what the temperature is, and its relative value to the desired temperature.

3 Background

To put together a temperature controlled fan requires a couple different steps to be undertaken to get different aspects of the circuit to provide useful information. To get the fan with only an on and off state requires the use of Pulse Width Modulation to squeeze out many different operating states. To get a usable temperature from the PTAT requires an equation to convert the voltage into a temperature.

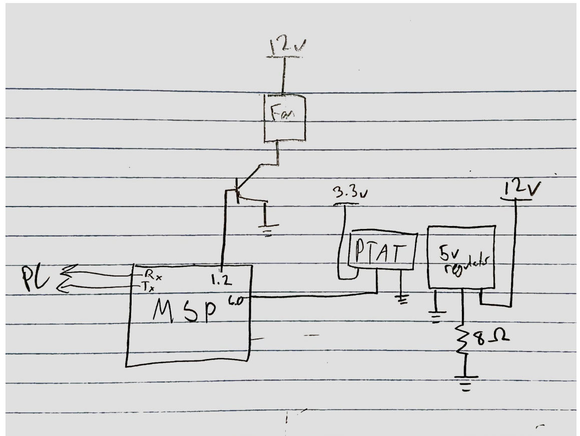

Figure 1: Higher Level Circuit Diagram

3.1 Pulse Width Modulation (PWM)

The concept of pulse width modulation (PWM) can be simplified as turning a light switch on and off at a certain speed. A duty cycle for PWM, using the light switch analogy, is how long the switch stays on before shutting back off. As depicted in Figure 2, the lower the duty cycle, the quicker the light turns on and off, providing a lower amount of overall light to the room.

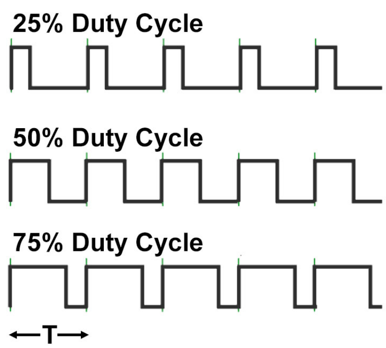

Figure 2: Duty Cycle Comparisons

Transferring that analogy to the fan, a lower duty cycle will provide less overall power to the fan, while a higher duty cycle will provide more. At 100% duty cycle the fan is running at full power, which is the same as just having the fan on. Utilizing PWM is very important for controlling the temperature of the Voltage Regulator as it will allow the fan to blow more or less air depending on the temperature. By creating different states of fan power using PWM, it is possible to constantly adjust fan speed with the temperature of the voltage regulator relative to the desired temperature.

3.2 Proportional to Absolute Temperature (PTAT)

A "PTAT" or "Proportional to Absolute Temperature" is an electrical component that outputs a voltage linearly proportional to temperature of the unit. In Figure 3; 1 is Voltage input, 2 is Voltage Output, and 3 is Ground.

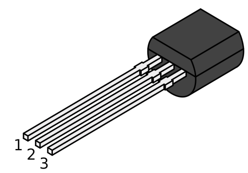

Figure 3: PTAT Model Diagram

For this lab we used a PTAT and for this component the input voltage used was 3.3 V whereas it can handle up to 7 V input, but from here the unit starts by sending out a voltage compared to the control voltage of the unit. For this the unit will output 750 mV at 25 °C and for every degree Celsius different from that the voltage would be 10 mV different in the same direction a the temperature.

3.3 Analog to Digital Converter (ADC)

The MSP430F5529 acted as our analog to digital converter by taking in the analog signal from the output of the PTAT and converting it to the correct temperature. From here the program can decide what the PWM to the fan should be to better control the fan speed for proper cooling.

4 Evaluation and Results

The circuit had its final test by connecting the circuit to the power supply with 12 volts running through it while the micro-controller was connected to the laptop to allow for quick temperature shifting. See the physical setup in Figure 4 and a diagram of the setup in Figure 1, as shown previously.

When first testing for steady state, we set the desired temperature to 30°C. Due to the power resistor of 11Ωthe heat generated by the voltage regulator quickly rose the voltage output of the PTAT, which after utilizing the ADC in the micro-controller read a value of 60 (the output within our system gives double the actual readout for temperature, so whatever the micro-controller outputs in the system is double what it actually is) and held steady within 1°C. The code within the micro-controller is made such that when the temperature deviates too far in either direction the duty-cycle linearly increases or decreases until the requirements are met. This creates a system that reacts very quickly to changing conditions, but if the conditions themselves change very

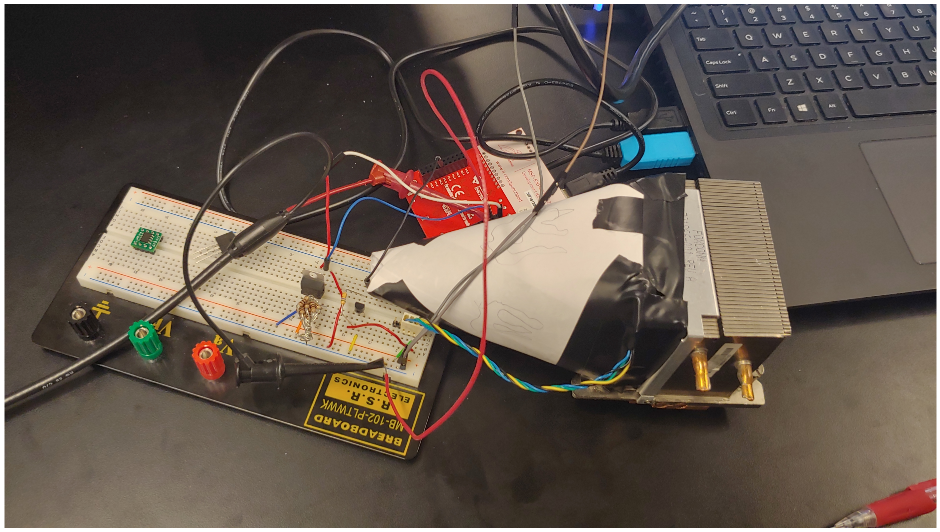

Figure 4: Testing setup

quickly, as in the case for rapid heat generation, there will be a degree of visible oscillation around the desired temperature. The circuit successfully kept the temperature within 1°C of the desired temperature.

For the next portion of the lab, the desired temperature of the system was set to 60°C, and performed similarly to the 30°C test. The results for which can be seen in Figure 5.The circuit successfully kept the temperature within 1°C of the desired temperature.

4.1 Measurement Uncertainty

Over the course of this lab there were some sources of inaccurate or incorrect data due to multiple different reasons such as part tolerances especially on the resistors, or the fans ability to cool the parts or even the physical contact between the PTAT and the voltage regulator.

Resistors are a common blame for results not being exact to theoretical results as the most common lab resistors are rated to $\pm 5\%$ error. For larger Ohm resistors this can mean 50 or more Ohms difference. For this lab we made a makeshift power resistor using 9 separate 100 Ωresistors to get a equivalent resistance of one 11 Ωresistor. The issue that can happen from this is that each resistor is $\pm 5\%$ off. We found that this resistor could have been nearly $\pm 6\%$ off. However this could only happen if all of the resistors were off by the same amount either all positive or all negative. In practice, this might actually prove to help get lower tolerances because it would be more probably to have resistances varying in ohmic signage.

Another possibly cause for bad data would be the PTAT's connection to the voltage regulator. For lab testing we just bent the pins from the bottom to try and position the

Figure 5: Oscilloscope Readings During Testing (60°C Test)

two components as closely as possible, but a more solid connection would most likely yield more accurate readouts of the PTAT.

Lastly a big source of the inability to cool the circuit was the fan setup. At first we had a large fan that moved a big volume of air, but after using this we found that a smaller fan that was more channeled to move less air faster and more directly helped maintain the circuits temperature. The fan also had its own momentum to the blades, so if the circuit wanted the fan to be off, there would be time that the fan has to slow to a stop, since there are no brakes or stopping ability.

5 Discussion/Conclusions

While demoing the circuit, as seen in Figure 5, the output temperature consistently oscillating from directly above the desired temperature, by about 1 °Celsius, to below by about 1 °Celsius. The 5 Volt Voltage Regulator was outputting roughly 3.125 Watts. The reason for this type of oscillation is the duty cycles were set to linearly increase when the read temperature was higher than the desired temperature, while it did the opposite when the read temperature was lower than the desired temperature. The increments for PWM are very rapid, causing the oscillation. This was caused by the sampling rate being very high, as due to the rapid PWM changes, the fan would go from off to full power in less than a second. The Voltage Regulator was also heating up very quickly due to the 11 Ohm power resistor generating heat rapidly. Another reason for the oscillation was because the fan itself was very powerful, cooling it at a very rapid rate. If the rapid sampling rate as well as the fan power was reigned in more, it would be possible to nearly eliminate the oscillation.

Due to the 1 °C margin of the desired temperature, the Fan circuit successfully met the parameters of regulating heat generated by the Voltage Regulator.