Temperature Gauge

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TABLE OF CONTENTS

Introduction:

We wanted to have a quick and simple way to read the temperature of an object or system that we are monitoring. For example, I own an older motorcycle with an air cooled engine. This motorcycle does not come equipped with an engine temperature gauge like a modern high end motorcycle, and I would like to have a means to monitor engine temperature. We developed our analog temperature gauge to serve as a quick temperature reference for equipment or devices that do not have a way to monitor temperature. The main objective of our project is to create a temperature gauge that will display the intensity of the measured temperature with an assortment of LEDs. We decided the best approach would be to utilize a temperature sensor in conjunction with multiple comparators. Once we began constructing the schematics for the circuit we realized we need a different reference voltage at each comparator inorder to trigger a LED at several different temperatures. This led to the construction of a voltage divider that features multiple resistors in series that will divide the input voltage at five stages, at each stage we will send a reference voltage to the comparator which will then compare the reference voltage with the output voltage of the temperature sensor and send a output signal to the LED only if the output voltage is higher than the reference voltage. The next step of constructing the circuit was to determine what voltage to set the voltage divider to at each temperature stage. We decided that our temperature range would begin at 20℃ and increment by 20° for each comparator, resulting in the final temperature to be 100℃. Using the V_{OUT} formula given by the AD22100 temperature sensor we were able to calculate the output voltage at each of our target temperatures (20℃, 40℃, 60℃, 80℃, 100℃). Once we calculated the V_{OUT} of the sensor at each of our target temperatures we were able to find our resistor values for our voltage divider. By using the voltage divider equation. The final step in constructing our circuit was to configure all of our components onto a breadboard and supply 5V to our temperature sensor, voltage divider, and each comparator, as well as provide V_{OUT} of our temperature sensor and all of our voltage references, to each comparator. We connected our LEDs to each comparator by using the output and ground pin outs from each respective comparator.

Description of System Design:

The Hardware used in this project consists of four distinct components. These components are listed down below:

- 5 - AD8561 Comparators
- 7 Resistors
- 5 - Light Emitting Diodes
- 1- AD 22100 Temperature Sensor

The AD8561 is a comparator with separate input and output sections. Separate supplies enable the input supply of 5V. This comparator will have the task of comparing two voltage levels and returning a voltage output only if the input voltage is greater than the voltage reference. This can be better seen in Figure 1. In Figure 1, we can see that the Pin 1, V+, will be our power imputed such as the 5 volts. Pin 4, the V-, pin 5, the latch, and pin 6, the ground, will all need to be referenced to the ground since we are only using a single power source. The Pin 2 or +In will symbolize the voltage generated by our AD22100 sensor. Meanwhile, Pin 3, the -In configuration, will be the voltage level generated by our resistors and will serve as the baseline the sensor must overcome for the comparator to turn positive.

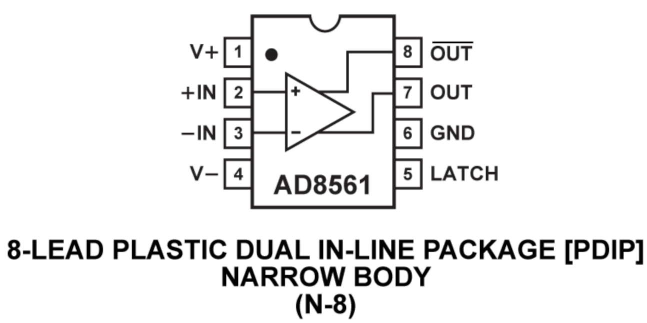

Figure 1: AD8561 Comparator Schematic.

The AD22100 is a series board mount temperature sensor with a maximum temperature range of 150 ℃ and a minimum range of -50 ℃. The AD22100 temperature sensor is an easy and cost-effective sensor that will allow us to measure temperature by outputting a voltage. We can predict the voltage output by the temperature sensor using this Equation: $V_{OUT} = (V+/5\ V) \times [1.375\ V + (22.5\ mV/°C) \times T_A]$. The way the AD22100 sensor should be configured can be seen in Figure 2. We can accurately see that V+ will be our 5V powering system, while GND symbolizes our ground, and Vo symbolizes our voltage output.

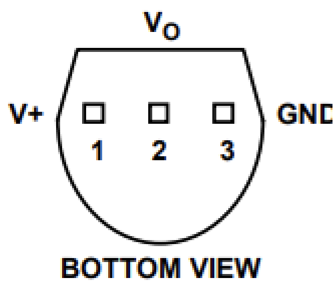

Figure 2: Schematic for the connections for the AD22100 Temperature Sensor

We will also be analyzing the resistance values needed to accurately convey the voltage reference needed for the comparator's -IN pin. We will be able to determine this by first analyzing the voltage needed at each voltage drop across the resistor for the given temperature threshold. This means we were tasked with finding the voltage output at each temperature shown in Table 1, using the equation shown in the passage above pertaining to the AD22100 Temperature Sensor.

Table 1: Table used to indicate voltage output at each Temperature Threshold.

Temperature °C	Voltage Output
100 °C	3.625 V
80 °C	3.175 V
60 °C	2.725 V
40 °C	2.275 V

20 °C	1.825 V

Once we have the desired voltage references we will be able to calculate each resistor drop by setting our current to 1mA. We will then use the equation: $\frac{Va-Vb}{1\,mA}$. For example, if we want the resistor that will get us the 100 °C voltage we will have to set Va to 5V and Vb to the calculated voltage at that temperature which is 3.625 V. This will result in a resistor value of 1.38kΩ. However, if we want the resistor value in series with this resistor for the 80 °C temperature we will have to set the new Va to 3.625 V and the Vb to 3.175 V. This will result in a 450Ω resistance in series. The result of our calculation is better shown in Figure 3.

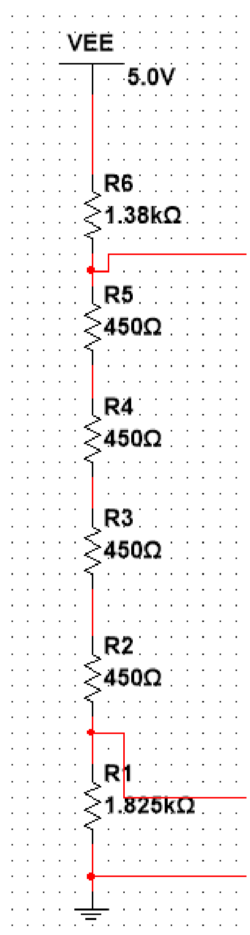

Figure 3: Resistor values generated for each temperature threshold.

We will need 7 resistors even though we see 6 resistors in the figure above, this is due to not having the 1.38kΩ in stock and having to connect two other resistors that add up approximately to this value.

The software we utilized in this project is very minimal and obsolete. The software used would be multisim, a software program that allows us to electronically create a circuit as well as to simulate test runs. We utilized Multisim to visually represent how our circuit will look like, however, some major components are not connected properly such as the AD22100. In Multisim, there was no temperature sensor AD22100, therefore for visual presentation we will replace the AD22100 for the TEMP1000 only for visual illustration. The schematic created using this software can be seen in the Figure below.

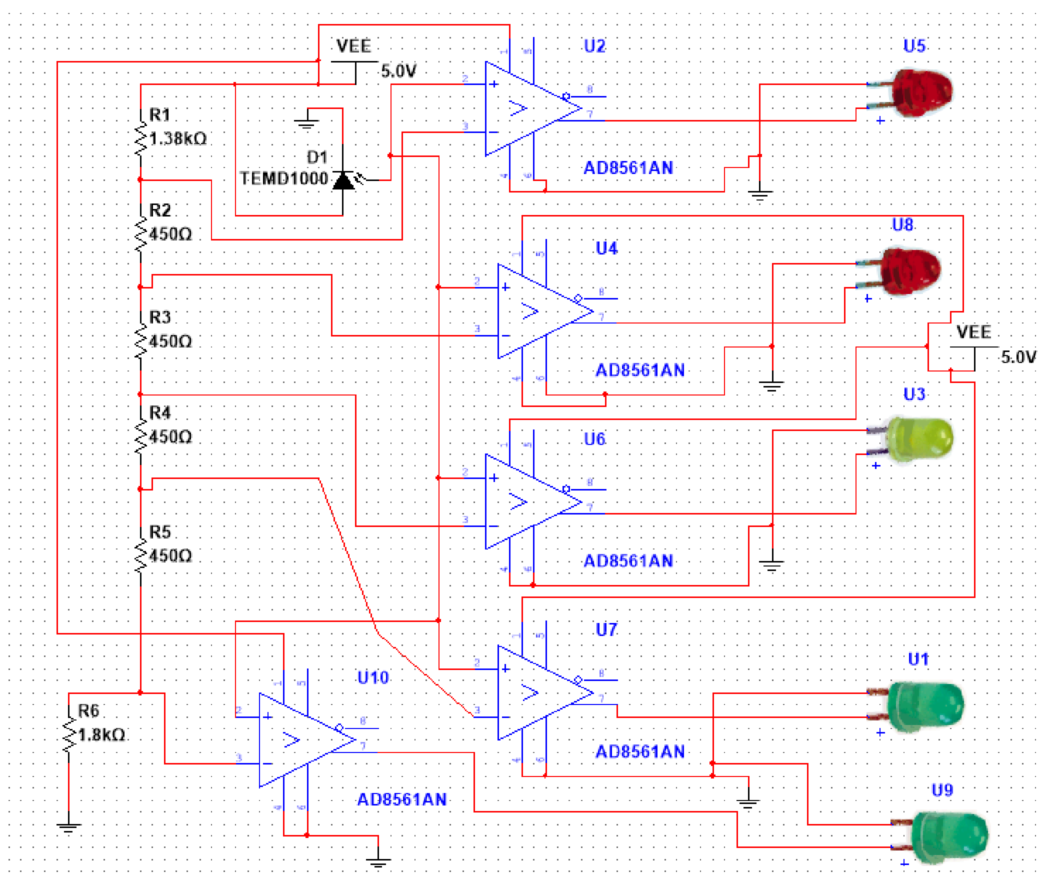

Figure 4: Schematic made using Multisim for the whole circuit.

The figure above is how we will be connecting all the hardware components using a breadboard. The schematic is an appropriate approximation of the circuit we will build for this project.

Test Plan and Results

The first thing we tested was our AD22100 temperature sensor. Once we solved for our target temperatures using the equation provided in the data sheet we verified our calculations by probing the V_{OUT} pin of the temperature sensor. We accomplished this by applying 5V to the V+ pin and ground to the ground pin. We probed the V_{OUT} pin while adding heat to the sensor using a heat gun and monitoring the temperature using a thermocouple. When the sensor reached one of our target temperatures we recorded the output voltage of the sensor at that point, we recorded the output voltage for each target temperature and compared the measured voltages with our calculated values. We found that our calculated values and measured values were similar enough to one another, so we decided to use the calculated values when constructing our voltage divider.

The second thing we tested was the comparator, we did this by first sending 5V to the positive power rail and ground to the negative power rail. We then provided two different voltages to the comparator inputs and probed the output signal. At first, all seemed to be functioning correctly however, when we switched the inputs of the comparators we noticed that the comparator output was still showing the same signal as before. This puzzled us since we couldn't get the comparator to switch outputs. After further investigation, we found that the latch pin needed to be grounded in order to allow the comparator to switch between a high and low output according to the voltage inputs.

We then decided to test a single portion of the circuit to verify it functionally, we did this by connecting our temperature sensor output to one of the comparator inputs and providing a voltage divider at a target temperature of 40℃. Once all the components were connected correctly we used a heat gun to apply heat to the temperature sensor, we monitored the temperature outputted by the heat gun using a thermocouple. We observed that the temperature rose to 40℃ and the LED powered on. Now that we confirmed the operation of the circuit we placed all our components on the breadboard and applied heat to the temperature sensor and observed each LED powering on once their respective temperature was met.

We then allowed the sensor to cool down and we saw each LED power off once the temperature decreased past their respective temperature.

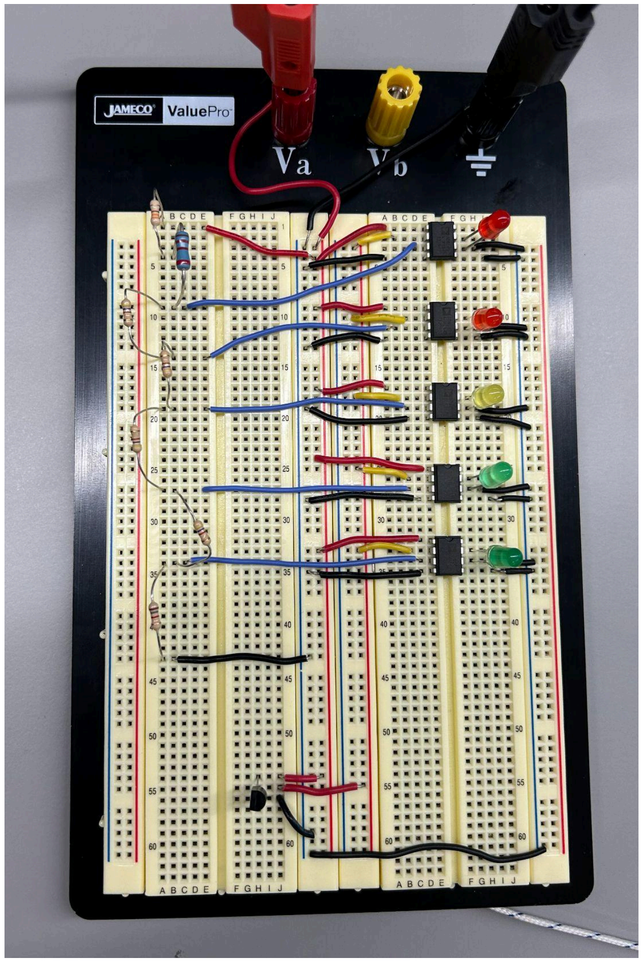

Figure 5: Completed Circuit

<u>Description of System Operation</u>

In order to use the temperature gauge you must first provide a five-volt power supply to the positive port of the breadboard, you must also supply a ground from that same power supply to the negative port of the breadboard. Once power has been supplied to the circuit, the temperature sensor will immediately send an output signal to the comparators. Depending on the temperature of the environment you are in, the LED set at 20℃ might power on as soon as you power the circuit. From this point the circuit is operating as designed, and the temperature sensor can be influenced by supplying a heat source. Depending on the temperature each corresponding LED will power on.

Conclusion

Lastly, we would like to recommend several details that we could have improved upon in this project if the time had allowed for this intervention. The first component we believe will increase heavily on our board would be the installation of a 5 V battery pack. This will allow us to make our project a mobile one, making it a more versatile temperature gauge. Another recommendation we would have wished to implement would be the addition of a feature that would allow for the temperature gauge to be turned off independently if the maximum temperature was reached. These two simple but effective recommendations will allow our project to be more safe as well as transportable.

In conclusion, we learned a lot of various analog components and how to properly connect them to make them work together. A major point/reason to do this project was due to the fact that we had very little experience with comparators. However, we believe that we have grown a quick but detailed understanding of how the AD8561 comparators work, and the same could be said with the utilization of the AD22100 temperature sensor.