EE313 ANALOG ELECTRONIC LABORATORY 2021-2022 FALL TERM PROJECT FINAL REPORT

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***Abstract* - In this project report, first of all, a brief description is made for the purpose of the study. General circuit diagrams are shown, circuit operation principles are explained, and formulas used in the project are given. Second, simulation results and the test results are provided and compared. Third, power consumption of the circuit is mentioned. Finally, comments and conclusions are made.**

INTRODUCTION

This project aims to design a micro air conditioner that monitors the ambient temperature and raises or lowers the ambient temperature to the desired level. This project consists of four main parts: a sensing unit, a control unit, an operation unit, and a display unit. The sensing unit senses the ambient temperature, and the output of this unit is the input of both the operation and display units. In the control unit, the desired temperature of the environment is set. The output of the control unit is sent as input to both operation and display units. In the operation unit, the data coming from the sensing unit is compared with the data coming from the control unit; and the operation point, which is cooling, heating or idle mode, is decided. The display unit shows the ambient or desired temperature level according to the switch position by the help of RGB LED to the user. While designing this project, OP-AMPS, resistors, transistors, LEDs, RGB LEDs, diodes, potentiometer, LM35, and DC motor are used.

Specifications for this project are below:

- One RGB Led displays both the ambient and the desired temperature level according to switch position.
- The RGB Led display only blue color when the temperature is 24 °C or below, display only green color when the temperature is 32 °C and display only red color when the temperature is 40 °C or above. Color transition occurs continuously and scans all visible spectrum.
- Cooler operation stars when the ambient temperature is 1 °C lower than the desired temperature and it stops when the ambient and the desired temperature levels equalized.
- Heater operation starts when the ambient temperature is 1 °C higher than the desired temperature and it stops when the ambient and the desired temperature levels equalized.
- While heater operation in progress a red LED lights and indicates the heater operation. Similarly, while the cooler operation in progress a blue LED lights and indicates the cooler operation.

DESIGN FORMULATION

As mentioned above, this project consists of four main parts. In this section this parts are going to explained.

The Sensing Unit

The aim of the sensing unit is to sense the ambient temperature level and transmit this information to both the display and operation unit.

LM35 Precision Centigrade Temperature Sensor is used for sensing the ambient temperature. According to datasheet, LM35 operates between -55 °C and 150 °C. Since this project aims to operate between 24 °C and 40 °C, basic sensor set up is used which is shown in Figure 1. In this configuration, LM35 is giving 10mV output per 1°C.

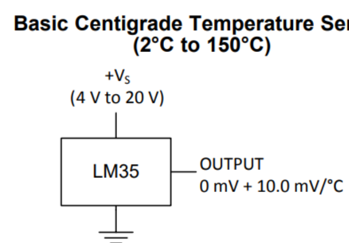

Figure 1: Basic LM35 Temperature Sensor Set Up

According to datasheet +Vs can be between 4V to 20V. Since +6V, +12V and -12V power supplies are used for this project, +12V is connected to the LM35 as Vs.

The sensing unit configuration is shown in Figure 2. In the sensing unit, first, output of the LM35 is connected to a basic OP-AMP buffer. On the other hand, simple voltage division technique is applied to +12V by using 300 kΩ and 8.2 kΩ resistors. 0.32V is obtained by this voltage division and this output is connected to a basic OP-AMP buffer. After these buffer operations, output of the LM35 buffer is subtracted from the 0.32V by using difference amplifier. At that point when the ambient temperature is 24 °C – 40 °C, 80 mV and - 80 mV output is obtained. Since this range is too small to operate, output of the difference amplifier is multiplied with -75 by using inverting amplifier. Therefore, an output between -6V and 6V is obtained for the temperature range 24 °C to 40 °C. This output is sent to the both the display and the operation unit.

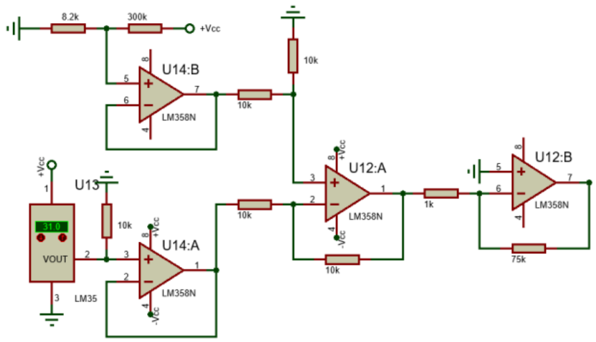

Figure 2: Sensing Unit Configuration

The Control Unit

The aim of the control unit is to take the desired temperature level from the user and sent this information to both the display and the operation unit. In order to get the desired temperature level information from the user a potentiometer is used. A potentiometer consists of three pins and a rotating button. First and third pins of the potentiometer is connected to the +12V supply and the ground respectively. By turning the button clockwise or counterclockwise, a voltage level between 0-12V is taken as an output from the second pin of potentiometer. On the other hand, 2 same valued resistors (100kΩ) are connected in series between the +12V supply and the ground. The voltage level 6V between the resistors is obtained and this voltage level is connected to the OP-AMP buffer. After this operation, the difference between the output of the potentiometer and the 6V is taken by the help of difference amplifier. Finally, a voltage level between -6V and 6V is obtained. This voltage range represents the operation temperature level linearly which means while -6V represents the 24 °C, +6V represent the 40 °C. Every 0.75V rise on the output represents 1 °C rise on the desired temperature level. Configuration of the control unit is shown in Figure 3. The output of the control unit is sent to the both the display and the operation unit.

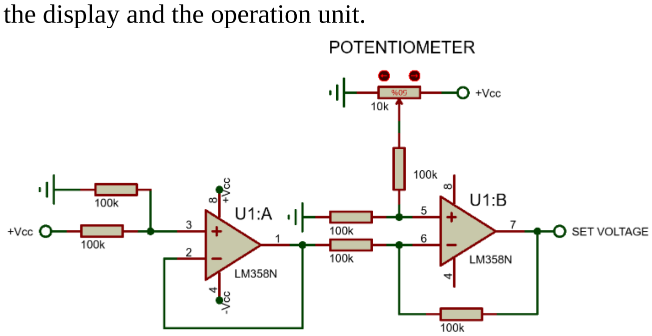

Figure 3: Configuration of the Control Unit

The Display Unit

The aim of the display unit is to show both the ambient and the desired temperature level by RGB LED. When the ambient/desired temperature is 24°C or lower, RGB will only show a blue light. When the ambient/desired temperature is 40°C or higher, RGB will only show red light. When the ambient/desired temperature is 32°C, RGB will only show a green light. When the ambient/desired temperature is between 24 °C and 32 °C, RGB displays blue and green lights with different brightness levels depending on the temperature. As the temperature rises, the brightness of the green light increases, and the brightness of the blue light decreases. Similarly, RGB displays green and red lights with different brightness levels when the desired/ambient temperature is between 32°C and 40°C. As the temperature rises, the brightness of the red light increases, and the brightness of the green light decreases.

The display unit has two inputs which are coming from the control and the sensing unit. These inputs are both between -6V and 6V. By connecting a switch at the beginning of the display unit only one of the inputs is activated. As explained above, while the temperature level is between 24 °C and 32 °C, blue and green color is desired with the appropriate ratio. On the other hand, when the temperature level is between 32 °C and 40 °C, only green and red color is desired with appropriate ratio.

In order the achieve this, RGB LED is assumed like it consists of 3 ideal blue, red and green LED which do not have opening voltage and their brightness are same for same voltage.

First, the voltage range is decreased to between -2.5 to 2.5 by using inverting amplifier in order to nut to burn the LEDs. After this operation 2.5V for 24 °C and -2.5V for 40 °C obtained. This voltage is directly connected to the blue LED and connected to the red LED by multiplying with -1. In that way blue LED receives 2.5V when the temperature is 24 °C and this voltage decreases linearly with the increasing temperature value. When the temperature is 32 °C the blue LED receives 0V. When the temperature is higher than 32 °C blue LED receives negative voltage which is not important since LEDs are operating with positive voltage. Just the opposite of this situation is valid for the red LED. When the temperature is 40 °C red LED receives 2.5V and this voltage decreases linearly with the decreasing temperature level and reaches 0V when the temperature is 32 °C. In order to feed the green LED, absolute value of the input which is in the range of -2.5V to 2.5V is taken by using two OP-AMPs, diodes and resistors. After this absolute value is subtracted from 2.5V and the resulting voltage is connected to the green LED. In this way, when the temperature is 32 °C, green LED receives 2.5V and this voltage decreases linearly with the increasing or decreasing temperature. Configuration of this ideal RGB LED assumption is shown in Figure 4.

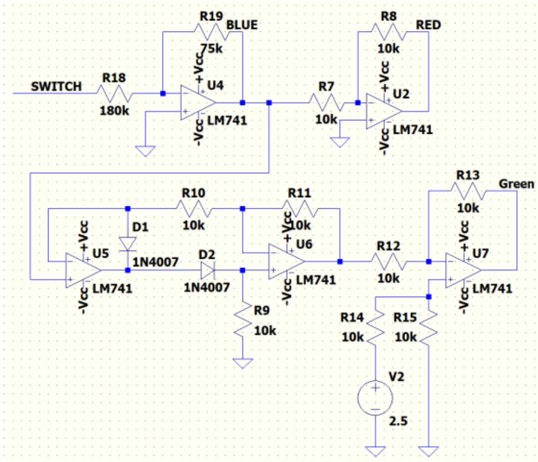

Figure 4: Configuration of the Ideal RGB Assumption Display Unit

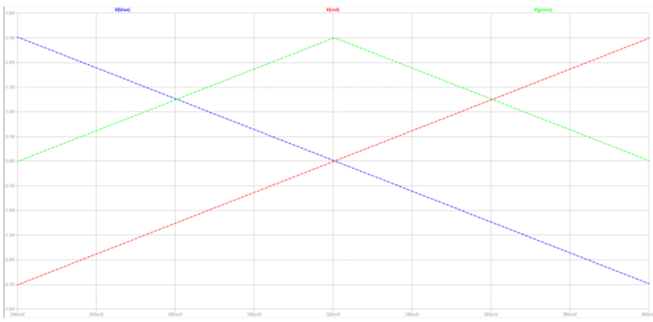

Figure 5: Simulation Result for Ideal RGB Assumption Display Unit

In Figure 5 simulation result of this design is shown. As can be seen from the figure, result is desired result. However, in reality RGB LED is not ideal. All three LEDs in the RGB have different opening voltages and different level of brightness for the same current. Therefore, opening voltages of these LEDs are added by summing amplifier and different valued resistors are used. This opening voltage values and resistor values are determined by experimentally. 1.6V for red, 2V for green and 2.3V for blue LED are added. 51 Ω for red, 68 Ω for green and 48 Ω for blue LED are used as current control resistors. In the following figures, final configuration of the display unit is shown.

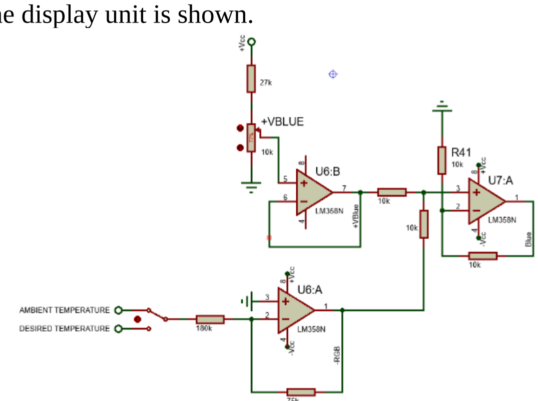

Figure 6: Configuration of the Display Unit for Blue LED

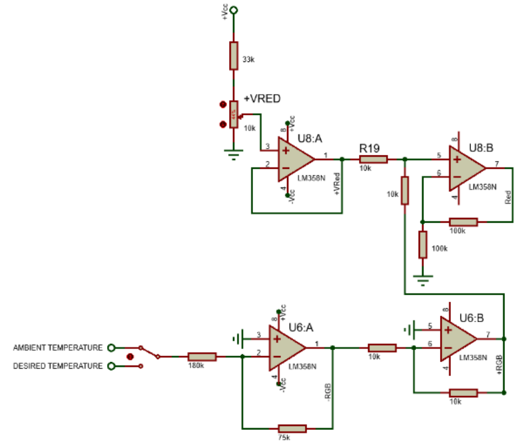

Figure 7: Configuration of the Display Unit for Red LED

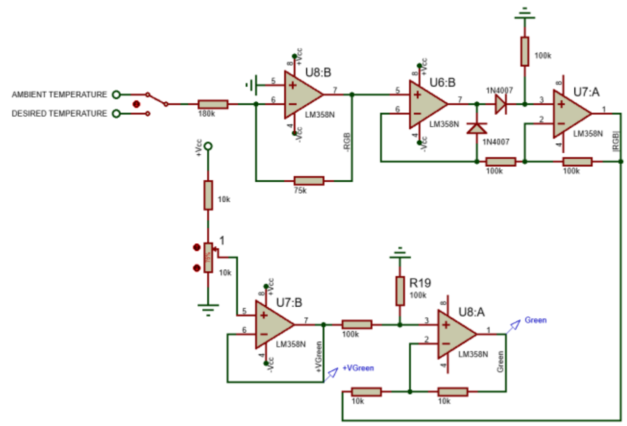

Figure 8: Configuration of the Display Unit for Green LED

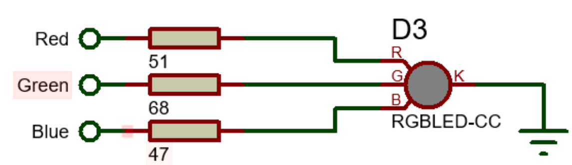

Figure 9: Configuration of the Common Cathode RGB LED

The Operation Unit

The aim of the operation unit is the control the operation point of the micro-air conditioner. If the difference between the desired temperature is 1 °C higher than the ambient temperature, the operation unit runs the heater until both temperature levels are equalized. If the difference between ambient temperature is 1 °C higher than the desired temperature, the operation unit runs the cooler until both temperature levels are equalized. If the desired and the ambient temperature level is less than 1 °C, the operation unit provides the idle mode.

In the operation unit, firstly the difference between desired and the ambient temperature level is taken by difference amplifier and multiplied with -1. By this operation both desired temperature level minus ambient temperature level and ambient temperature level minus desired temperature level is obtained. This operation is shown in Figure 9.

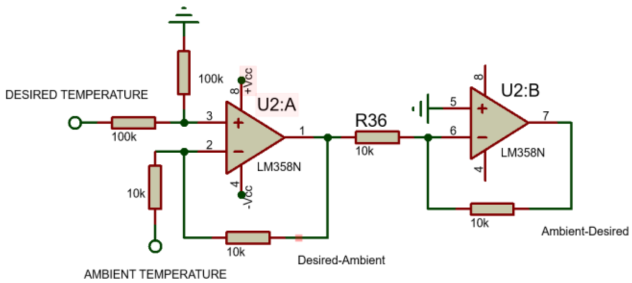

Figure 9: Getting Desired-Ambient And Desired-Ambient Values

In order to run the cooler or the heater, the difference must be larger than 1 °C which is represented by 0.75V and in order to stop the operation, the difference must be equal to zero. In order to achieve this specification, a comparator OP-AMP is used with positive feedback which provides the hysteresis loop. Vcc of the OP-AMP is connected to the +12V supply and the Vee of the OP-AMP is connected to ground. Therefore, when the comparator is in +SAT, +12V output and when the comparator is in -SAT, 0V output is provided. This comparator OP-AMP with hysteresis loop is shown in the Figure 10. The comparator on the left is for heater operation and the right for cooler operation.

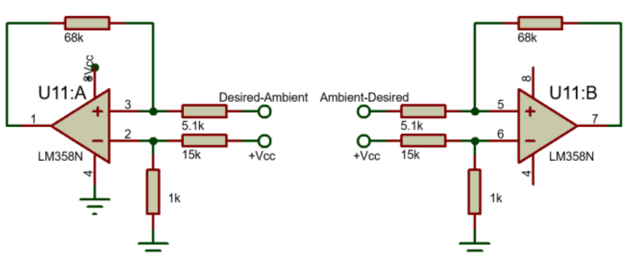

Figure 10: Comparator with Hysteresis Loop

The resistor values 15 kΩ and 1kΩ are provide the 0.75V reference voltage for the hysteresis loop. 5.1 kΩ and 68 kΩ resistors provide the hysteresis loop which is shown in Figure 11.

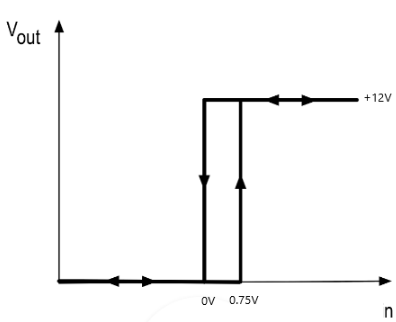

Figure 11: Provided Hysteresis Loop By OP-AMP

The output of the comparator is connected to the gate of the n-channel enhancement type MOSFET so that when the comparator is in +SAT, the MOSFET behaves like closed switch and when the comparator is in -SAT, the MOSFET behaves like open switch.

For heating operation, a red LED and 2.2Ω stone resistor is connected in parallel between the +6V supply and the drain of the MOSFET. The source of the MOSFET is connected to the ground. The reason why +6V supply is used is to separate the high-power consumption from the rest of the circuit. When the comparator is in +SAT, the MOSFET let the current flow through the resistor and the red LED. Red LED indicates the heating operation occurs and 2.2Ω stone resistor ensures the heating.

Similar to heating operation, a blue LED and a DC motor is connected in parallel between the +6V supply and the drain of the MOSFET. The source of the MOSFET is connected to ground. Same reason is valid for using the +6V supply. When the comparator is in +SAT, the MOSFET lets the current flow through DC motor and blue LED. Blue LED indicates the cooling operation, and the DC motor ensures the cooling. Overall structure of the operation unit is shown in Figure 12.

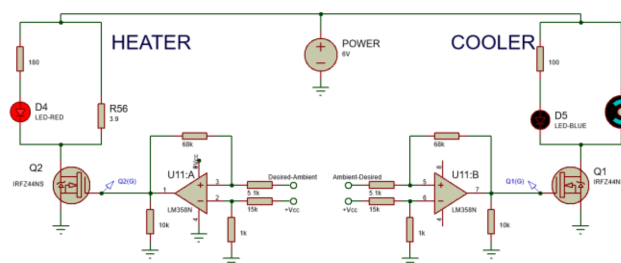

Figure 12: Overall Structure of the Operation Unit

Selection of The Equipment

LM358 is chosen for OP-AMP because it includes 2 OP-AMPS per package, and it is cheaper than the OP-AMPS used in EE313 laboratory.

All resistors except heater resistor are 1/4W resistors since they do not carry high current. Heater resistor is 11W stone resistor because it carries high current.

IRFZ44N MOSFET is used because it is the cheapest MOSFET which satisfies the design requirements.

Common cathode RGB is used since it was appropriate for this design.

Trimpots are used for adding voltages to RGB LED, since it is set with the help of screwdriver and hard change by environmental effects.

Cost Analysis

- 10 LM358 are used: 10 x 2 = 20 TL
- LM35 Temperature Sensor: 25 TL
- RGB: 1.5TL
- 3 Trimpots are used: 3 x 2 = 6 TL
- Potentiometer: 2 TL
- 2 Diodes, 2 LEDs and resistors: 5TL
- 2 Breadboard: 2 x 15 = 30 TL
- Stone Resistor: 3TL
- 2 IRFZ44N: 2 x 8 = 16 TL

- Switch: 1 TL
- DC Motor: 15 TL

  Overall Cost: 124.5 TL

TEST RESULTS

The circuit is tested in the laboratory where the ambient temperature is nearly 27 °C. Heater mode achieved the warmup the sensor to 40 °C from 27 °C in less than 3 minutes. Cooler mode achieved the cool the sensor from 40 °C to 27 °C in 10 seconds, however minimum 26 °C is observed. Cooler mode failed to cool down to circuit below to room temperature.

When the control unit is set to heater mode, heater mode operates correctly, however when the current flow through heating resistor stops, it still continued to heat the sensor since it has already warmed up. Therefore, sometimes sensor is heated above 1°C from the desired temperature and cooler mode is on.

Hysteresis loop worked correctly, when the difference between two temperature value is 0.75V operation starts and when the two temperature levels are equalized, operation stops. However, cooler mode works unexpectedly fast which means DC motor cools the sensor very fast. Therefore, observing the idle mode in cooler mode was not possible.

POWER ANALYSIS

While the operation unit is in idle mode, no power consumption is observed on +6V supply. 20mA current flow is observed from +12V supply and 10 mA current flow is observed from -12V supply. Therefore, total power consumption in idle mode is 0.36W.

While the operation unit is in cooler mode 1.6 A current flow is observed from +6 V supply. Current flow through +12 and -12V supply did not change. Therefore, total power consumption in cooler mode is 9.96W.

While the operation unit is in heater mode 1.4 A current flow is observed from +6 V supply. Current flow through +12 and -12V supply did not change. Therefore, total power consumption in cooler mode is 8.76W.

COMMENT AND CONCLUSION

In this project, we were able to do what was asked. We have established a circuit that detects the temperature in the environment and displays it in RGB LED, offers the opportunity to set the desired temperature, and displays this temperature in the same RGB LED as the switch. We made a micro air conditioner that can adjust the ambient temperature to the desired temperature with cooling and heating systems. While doing this project, we tried to use our knowledge in line with the demands and to find solutions to the problems. In lab experiments, we had the opportunity to try to solve a big problem, which is different from problem-solving done piecemeal, in small pieces, and try to combine these pieces. We built the desired circuit with theoretical calculations. While building the circuit in the lab, we made new calculations and assumptions to correct for differences due to non-ideal elements. We have completed and presented the project.