MIDDLE EAST TECHNICAL UNIVERSITY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE213 CIRCUIT LABORATORY 2016-17 FALL

ANALOG AIR CONDITIONING SYSTEM
Term Project Final Report

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1. Introduction

Air conditioning consists of process of cooling, heating, moisturizing, dehumidification and other processes, with a main purpose of creating a more comfortable interior environment. Therefore air conditioning is an indispensable comfort provider for the modern day's interior spaces. So our main purpose in this project is to design a functioning air conditioning system and understand and apply the practice of air conditioning systems from an engineering perspective.

Air conditioning units include a sensing unit which senses the ambient temperature and signals it accordingly, a temperature adjustment unit which the users set their desired temperature and a control unit which compares the signals from sensing and adjustment unit and deduces the action to be taken.

In this project, we designed an analog air conditioning system. The system is capable of carrying out heating and cooling functions; according to the ambient and desired temperatures. In order to compare the ambient and desired temperatures, pulse width modulation is used in the circuit; signals from the sensing unit and temperature adjustment unit are converted into duty cycles in order to be compared more effectively. In addition the PWM provides an obvious difference between duty cycles of subunits and enables continuous speed control for operations.

2.The Overall Circuit

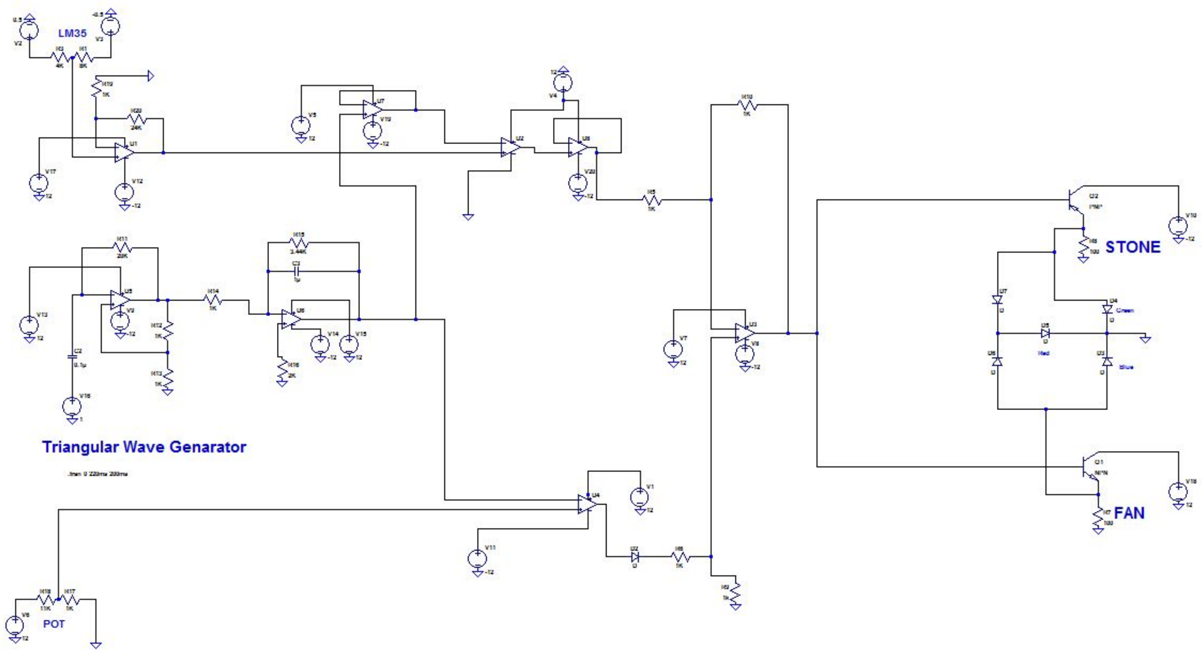

Figure 1: Overall schematic of the circuit

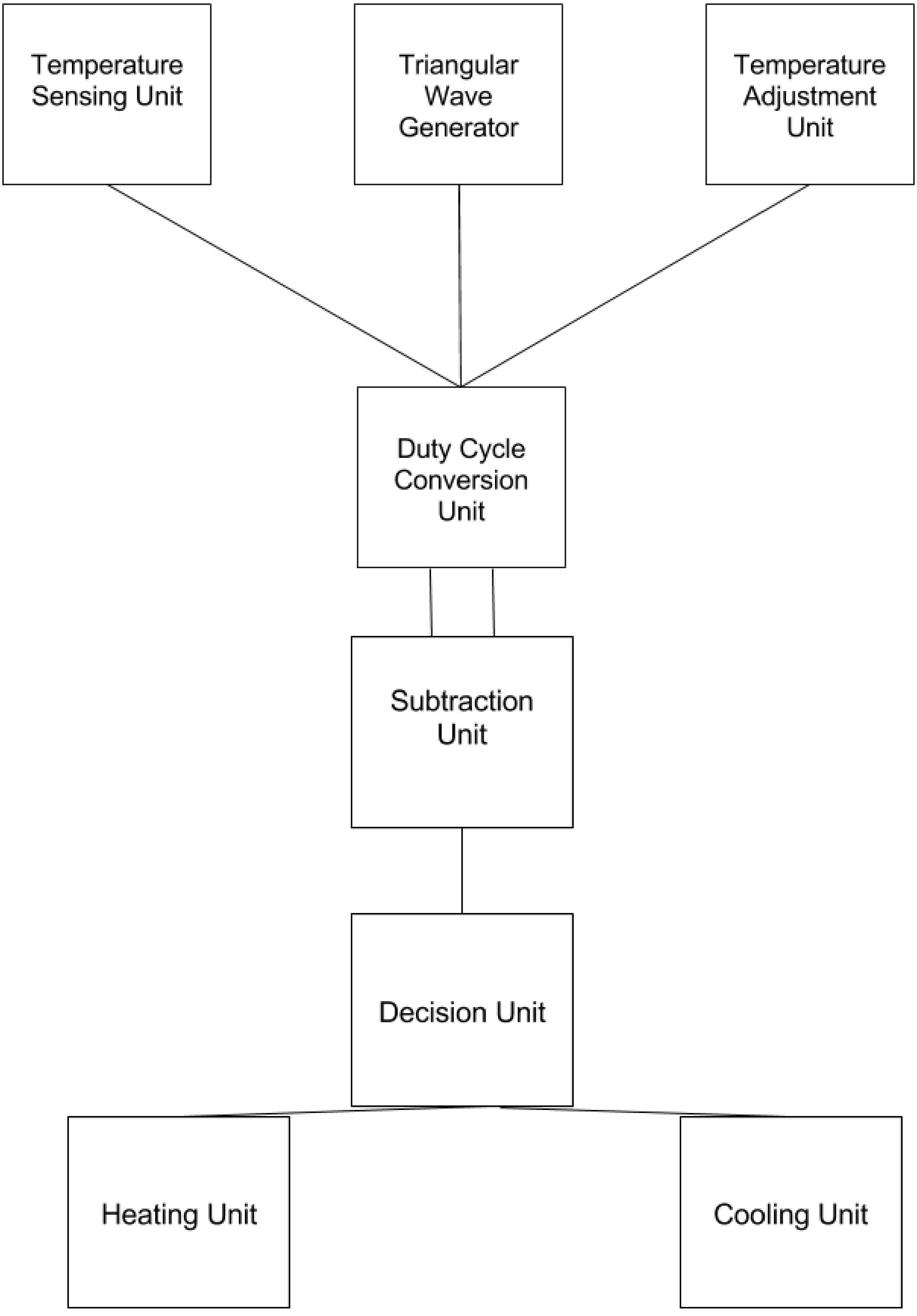

Figure 2: Overall Block Diagram of the Circuit

3. Description of the Circuit

In the first part of our circuit, we've built a square wave generator circuit and an integrator circuit. By using the integrator circuit, we converted the square wave from square wave generator to triangular wave. The triangular wave is to be used in the later part to obtain duty cycles, therefore the frequencies of the square wave and the triangular wave is irrelevant, because of the percent nature of PWM; the percent ratio of a duty cycle is independent of the frequency of the triangular wave used. Yet, the formulation for the waves are illustrated below along with their waveforms and the circuit schematics.(Figure 3,Figure 4 and Figure 5)

$$T = 2R_1 C \ ln(\tfrac{1+\lambda}{1-\lambda}) \text{ for } \lambda = \frac{R_3}{R_3+R_2}$$

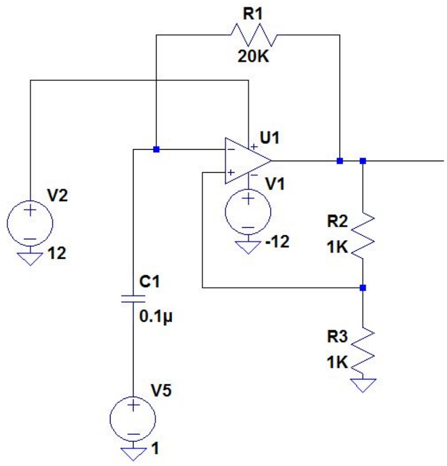

Figure 3: Square Wave Generator

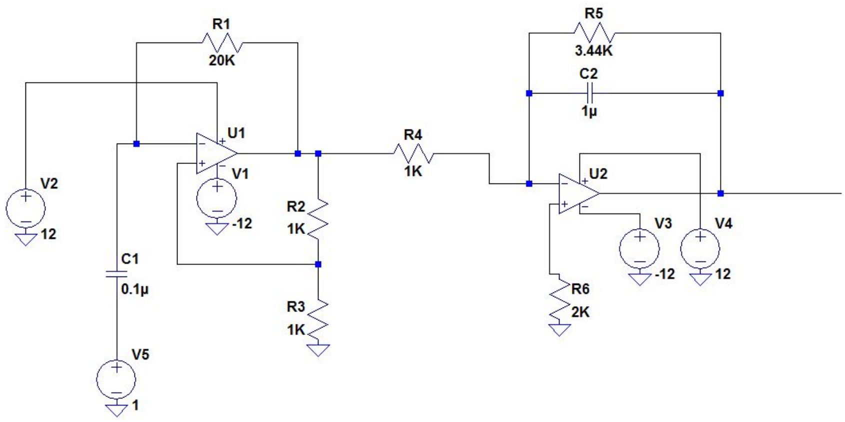

Figure 4: Triangular Wave Generator

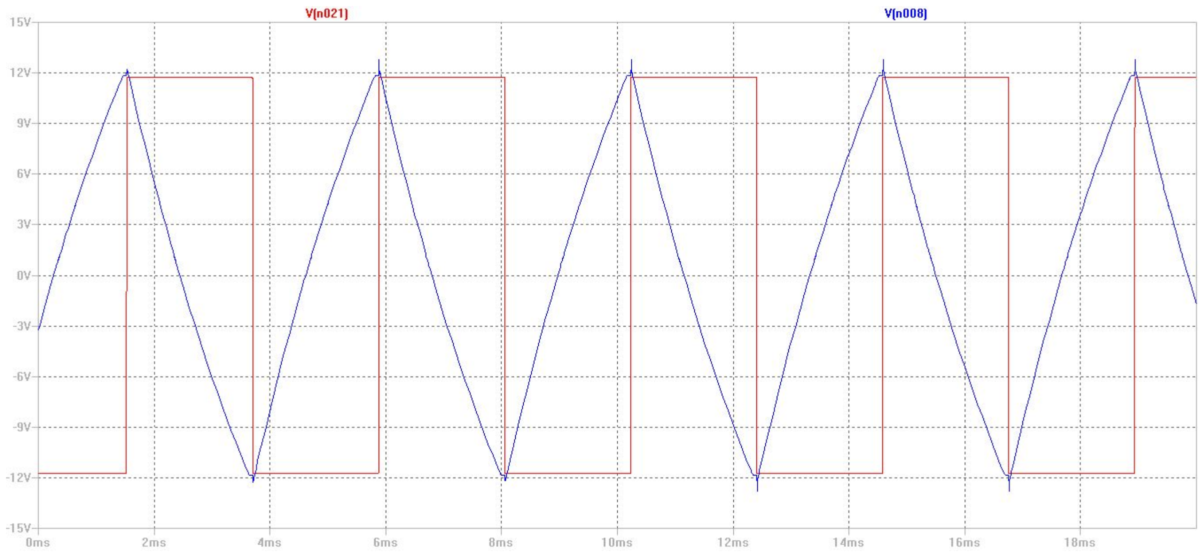

Figure 5: Waveforms of Square and Triangular waves (blue from output of Triangular Wave Generator and red for output of Square Wave Generator)

For the second part of the system, DC voltages are obtained from the Temperature Sensor LM35 and Temperature Adjustment Unit POT. The outputs from these units are results of voltage divisions. For the LM35's division, maximum and minimum voltages are -0.5 and +0.5. Therefore we used a non-inverting amplifier to amplify it to -12 to +12 range in order to have a fixed basis of comparable voltages.

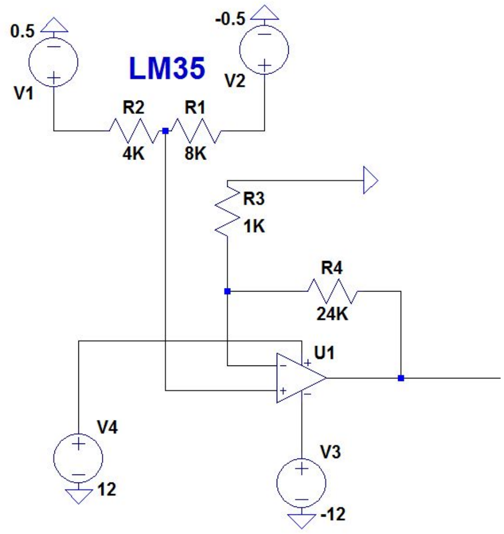

Figure 6 : Temperature Sensing Unit

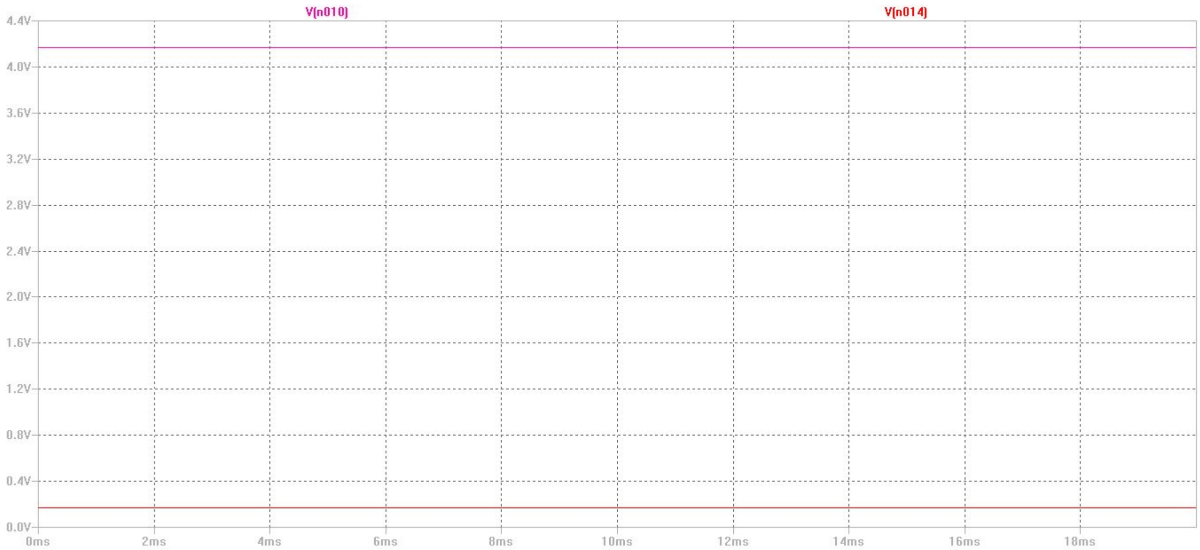

Figure 7 : DC voltage output of LM35 and non-inverting amplifier

For the temperature adjustment part, we used a potentiometer to adjust temperature. To do so, we set a simple voltage division circuit by using potentiometer and +/-12 V. By changing the internal resistance of the potentiometer we obtained a DC voltage corresponding to desired temperature. For the sake of simplicity, we adjusted the voltages so that 12V=50°C and -12V=-50°C. (Figure 8 and Figure 9)

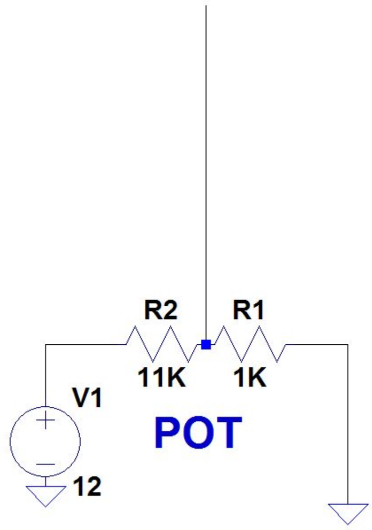

Figure 8 : Temperature Adjustment Unit

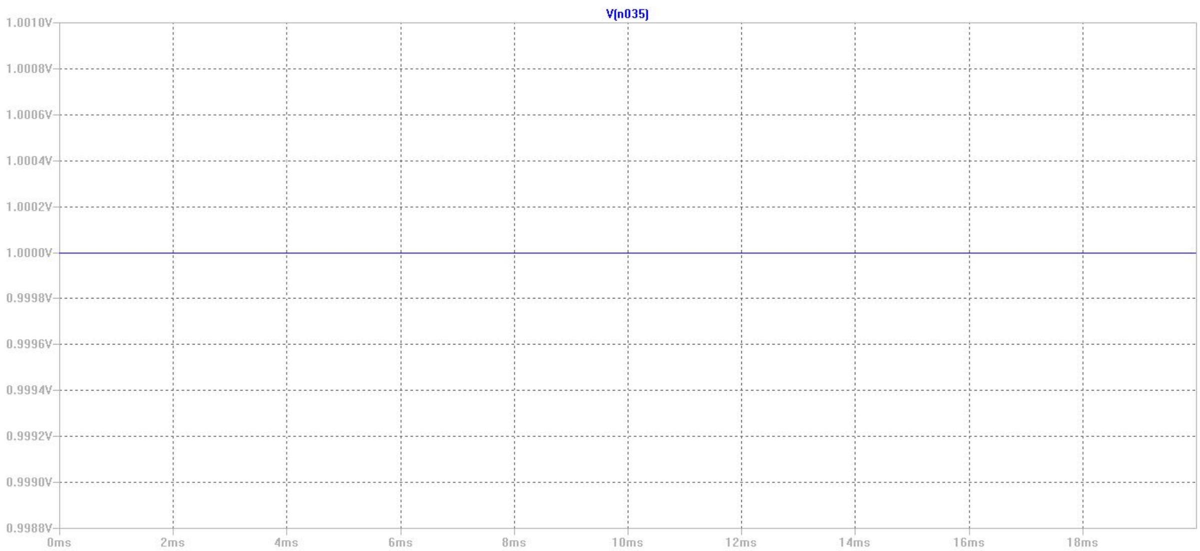

Figure 9 : DC voltage output of potentiometer

In this part, a comparator opamp is used to compare the amplified DC voltage from LM35 with Triangular Wave. Comparator mainly works by comparing its voltage input. When the DC voltage from LM35 is bigger than Triangular Wave, the output of Op-amp switches to -Sat that is 0V for our circuit. And likewise, when the DC voltage from LM35 is smaller than Triangular Wave, the output of Op-amp switches to +Sat that is +12V for our circuit. Moreover, we used two buffers in this part to protect LM35 and Triangular Wave from unwanted feedback voltages. (Figure 10 and Figure 11)

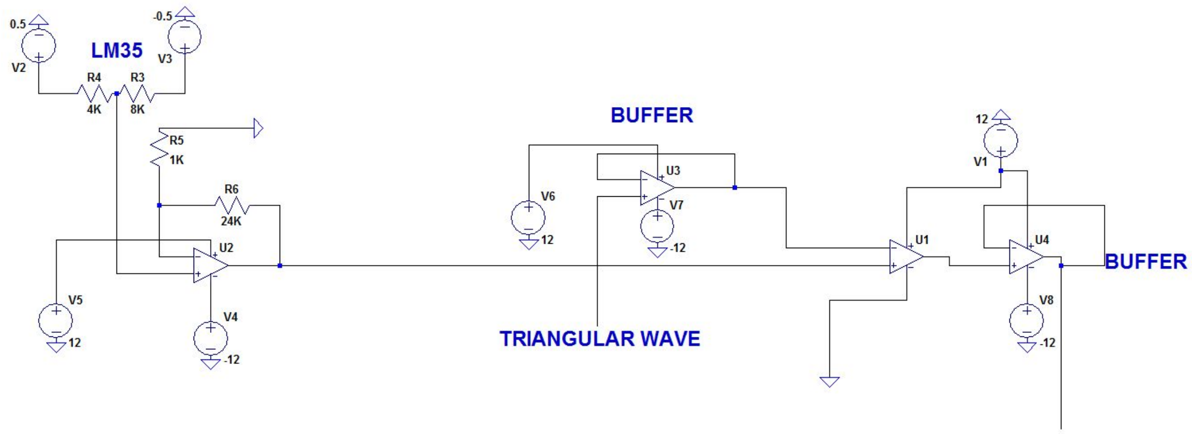

Figure 10 : Ambient Temperature to Pulse Width Modulation Unit

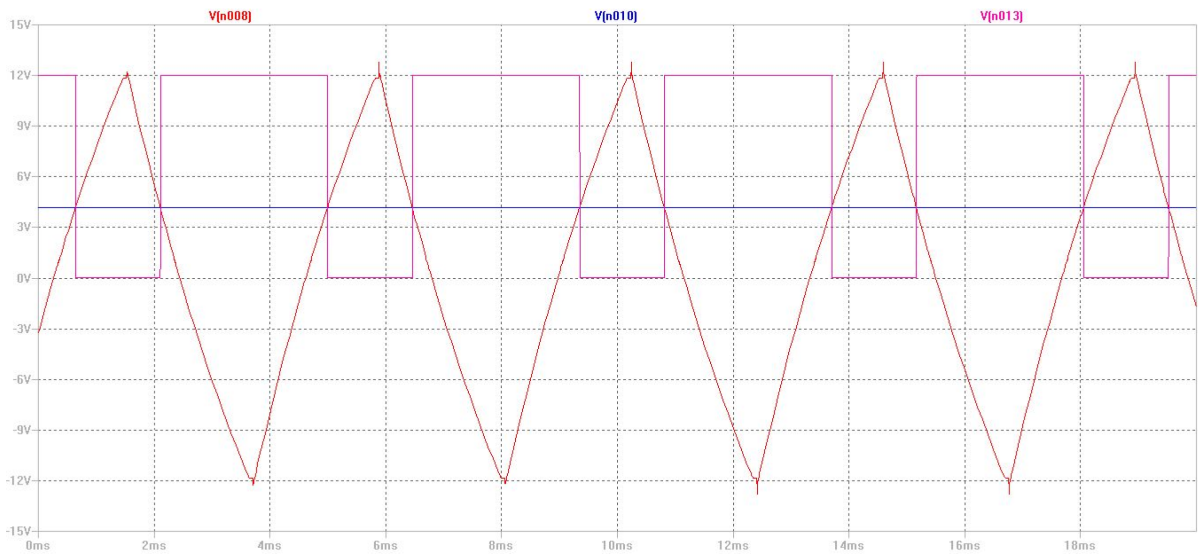

Figure 11 : Triangular Wave, Ambient Temperature Voltage and Outcome PWM

In this part, similar to previous part, a comparator op-amp is used to compare the DC voltage from Potentiometer with Triangular Wave. Because of the way comparator works, when the DC voltage from POT is bigger than Triangular Wave, the output of Op-amp switches to -Sat that is -12V for that part of the circuit. And likewise, when the DC voltage from POT is smaller than Triangular Wave, the output of Op-amp switches to +Sat that is +12V for our circuit. (Figure 12 and Figure 13)

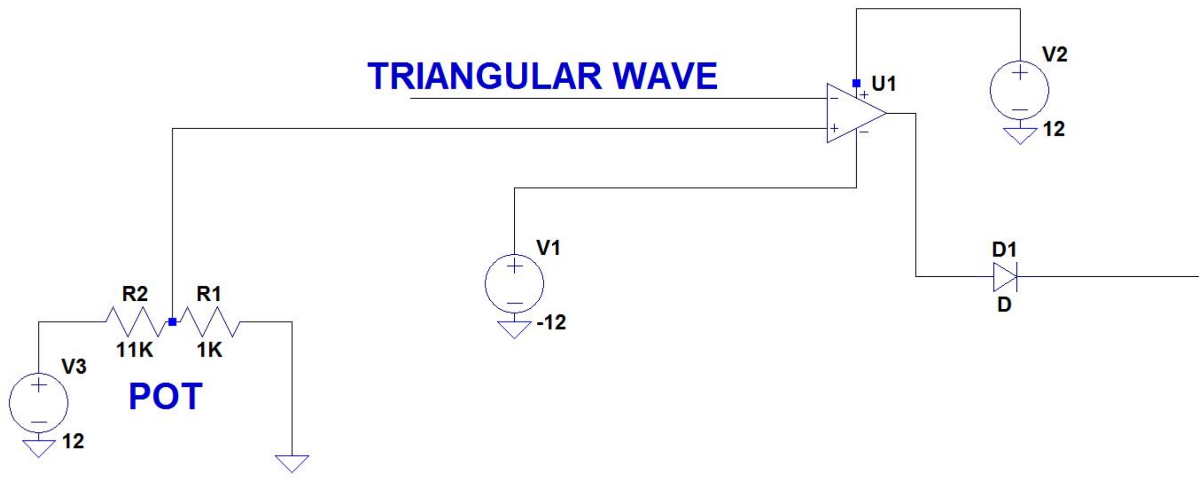

Figure 12 : Desired Temperature to Pulse Width Modulation Unit

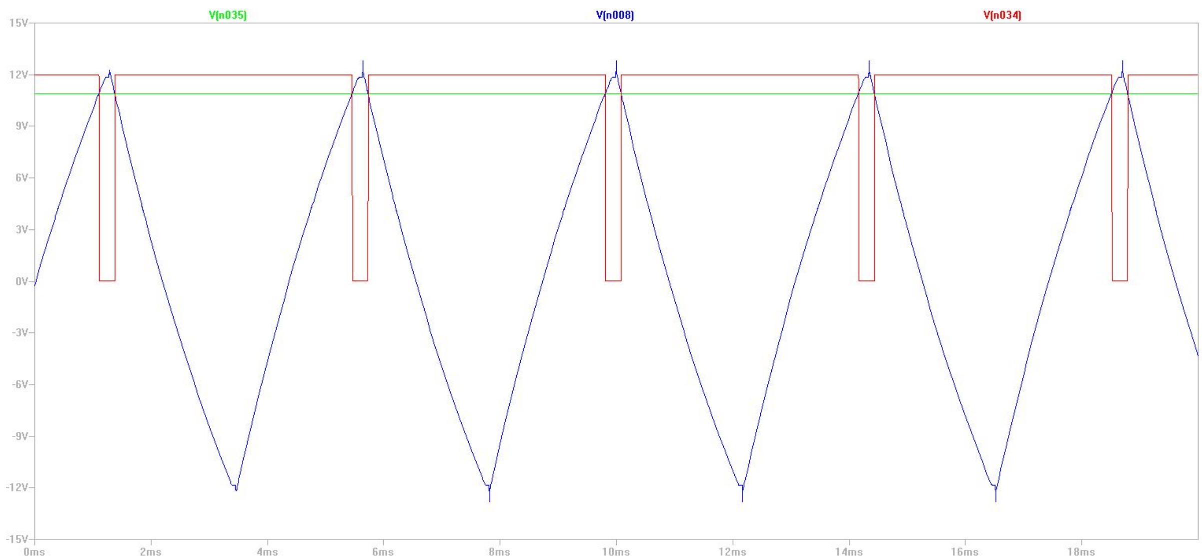

Figure 13 : Triangular Wave, Desired Temperature Voltage and Outcome PWM

In this part, a difference amplifier is used to subtract two duty cycles that are from LM35 and POT. For making calculations easier, we adjust the gain of this op-amp to one by using four equal resistors that are 1K Ohm resistors. When the desired temperature is bigger than ambient temperature that is DC voltage from POT is bigger than amplified DC voltage from LM35, the outcome voltage which we can call pulse width modulation (PWM)
is become negative. Similarly, when the desired temperature is smaller than ambient temperature that is DC voltage from POT is smaller than amplified DC voltage from LM35, the outcome voltage which we can call pulse width modulation (PWM) becomes positive. (Figure 14, Figure 15 and Figure 16)

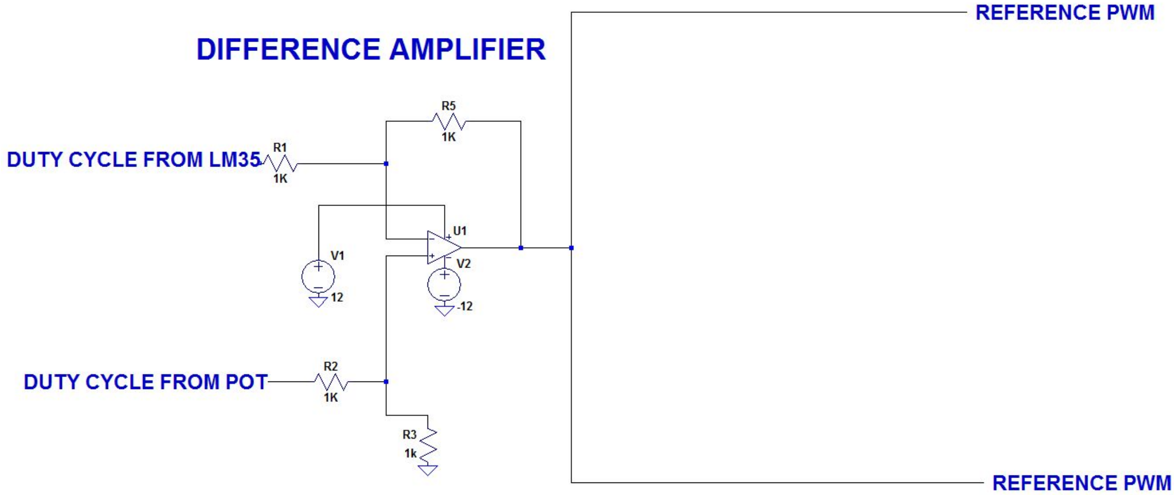

Figure 14 : Difference Amplifier

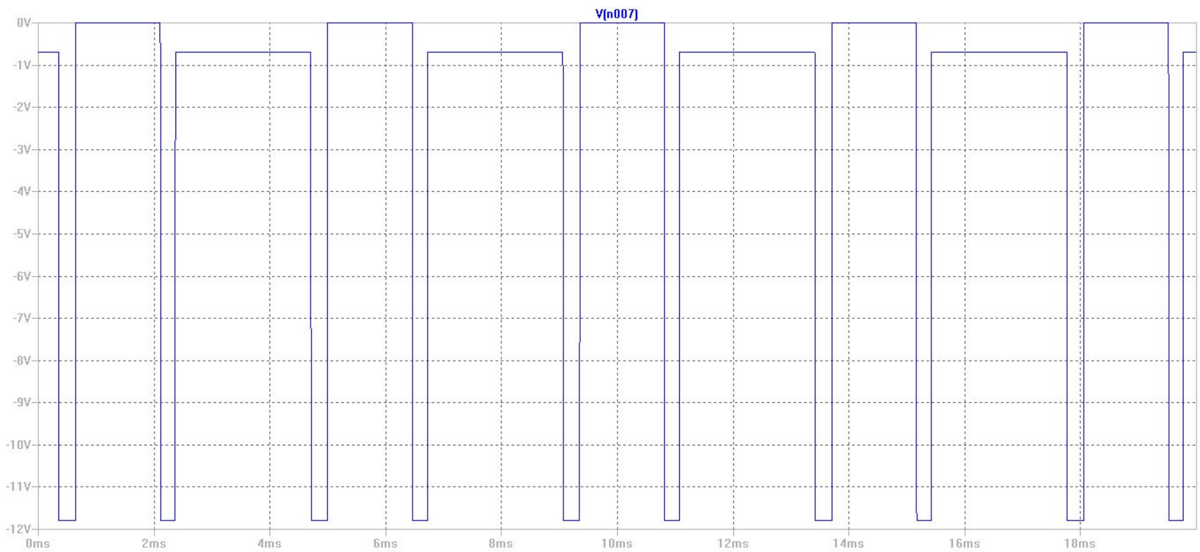

Figure 15 : Voltage Output of difference amplifier when desired temperature is bigger than ambient temperature

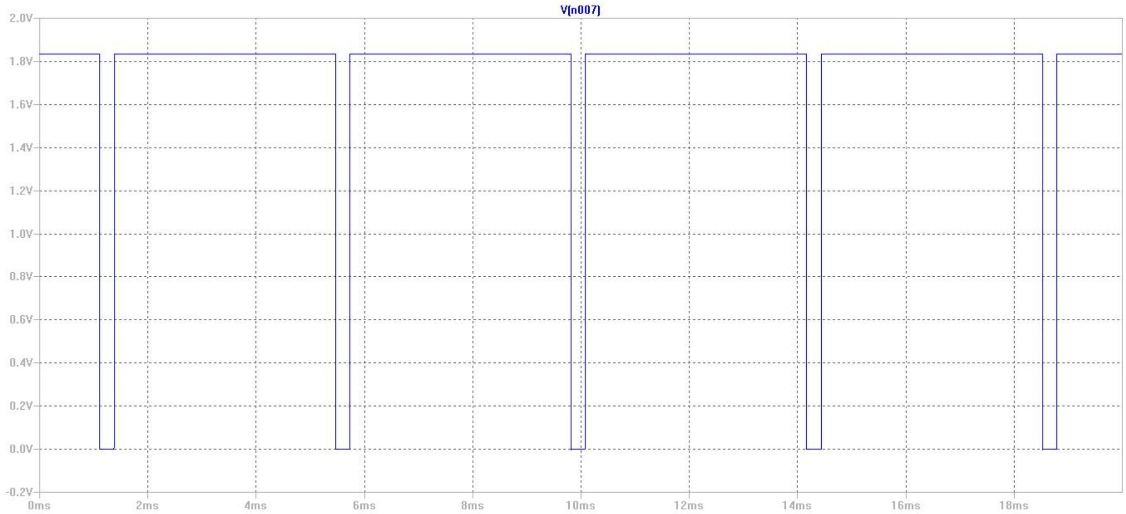

Figure 16 : Voltage Output of difference amplifier when desired temperature is smaller than ambient temperature

In this part, we used two transistors to drive fan and stone resistor and an RGB LED to indicate the operation. When the PWM from difference op-amp is negative, PNP transistor is activated because of the operation principle of PNP transistors, that is when the voltage difference between its base and emitter is lower than zero, current flows through it. Similarly, When the PWM from difference op-amp is positive, NPN transistor is activated because of the operation principle of NPN transistors, that is when the voltage difference between its base and emitter is higher than zero current flows through it. And finally, we connected a common cathode RGB led to our circuit to indicate the ongoing operation. To achieve this, we connected collector of PNP to green LED of RGB and collector of NPN to Blue. In addition to that, we connected the blue and green LED to red LED by diodes to obtain required colours yellow and purple. (Figure 17)

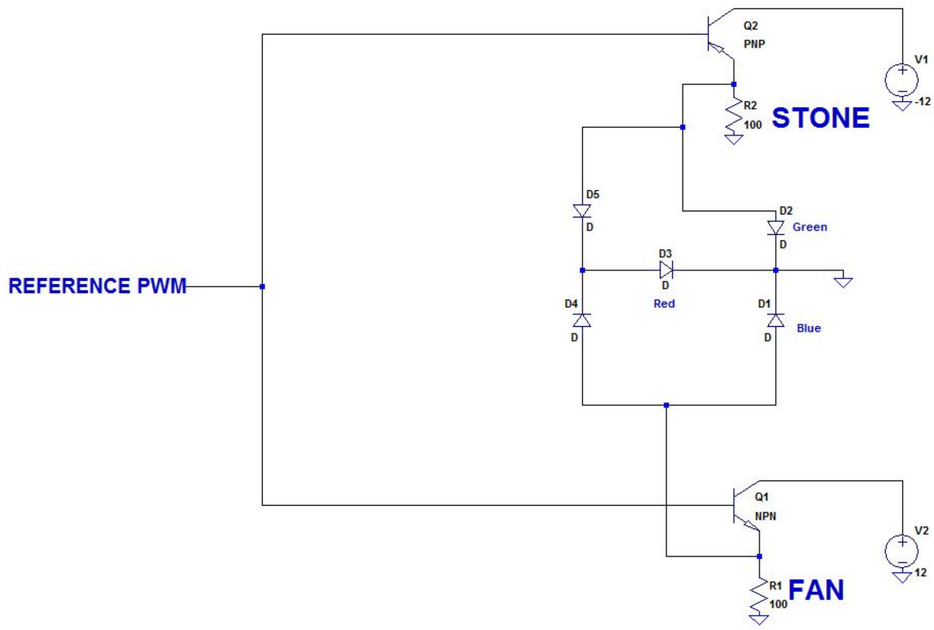

Figure 17 : Heater Unit, Cooler Unit and RGB LED

4. Selection of Equipment

Selecting the right equipments for intended purposes of a circuit is as important as the design. Therefore we did our best choosing the equipments properly. The simplest, yet most important component of our circuit is the op-amp. We used many of them as because they are capable of accomplishing various tasks, including comparing, amplifying and subtracting voltages. As a result they are indispensable from our system. Next, there is the LM35 temperature sensor, used to measure temperature. Although it's not our selection exactly, it performs adequately with just small mismeasurements. POT's were another selection of ours to accomplish voltage division, which let us to adjust the desired temperature. The last unordinary components of the control unit are PNP and NPN transistors, which are the logical decision units of the circuit. Besides these relatively special components, control unit consists of resistors with different resistances , depending on their role in the circuit. Also there is a single capacitor for the square wave generator.

Apart from the control unit, there is a stone resistor that conducts heating and a fan that conducts cooling. Although the stone resistor can't heat a centimeter away from it and the fan is obviously incapable of cooling up to -50°C, they are more than enough to represent operations of the system. Also an RGB LED indicates the operation that is carried out; either cooling or heating. Finally there is a breadboard that combines all these components and wires on it.

5 - Cost Analysis

Component	Quantity	Unit Price (TL)
LM35	1	5
Potentiometer	2	1
LM358	7	0.5
Transistor	2	0.75
Capacitor	2	0.25
Resistor	13	0.1
Fan	1	7.5
Stone Resistor	1	2.5
RGB LED	1	2
Diode	3	0.15

6 - Power Analysis

In our project, the current through voltage source varied from 0.065 to 0.093 ampere from +12 V and varied from 0.720 to 0.940 ampere from -12 V. Therefore; total power consumed in circuit as operational changed between

P= (12 V) * (0.065 A) + (12 V) * (0.720 A) = 9.42 W *and*

P= (12 V) * (0.093 A) + (12 V) * (0.940 A) = 23.373 W.

And for idle mode,the current through voltage sources was 0,020 ampere from both +12 V and -12V. Therefore, total power consumed during idle mode was

P= (12 V) * (0.020 A) + (12 V) * (0.020 A) = 0,480 W.

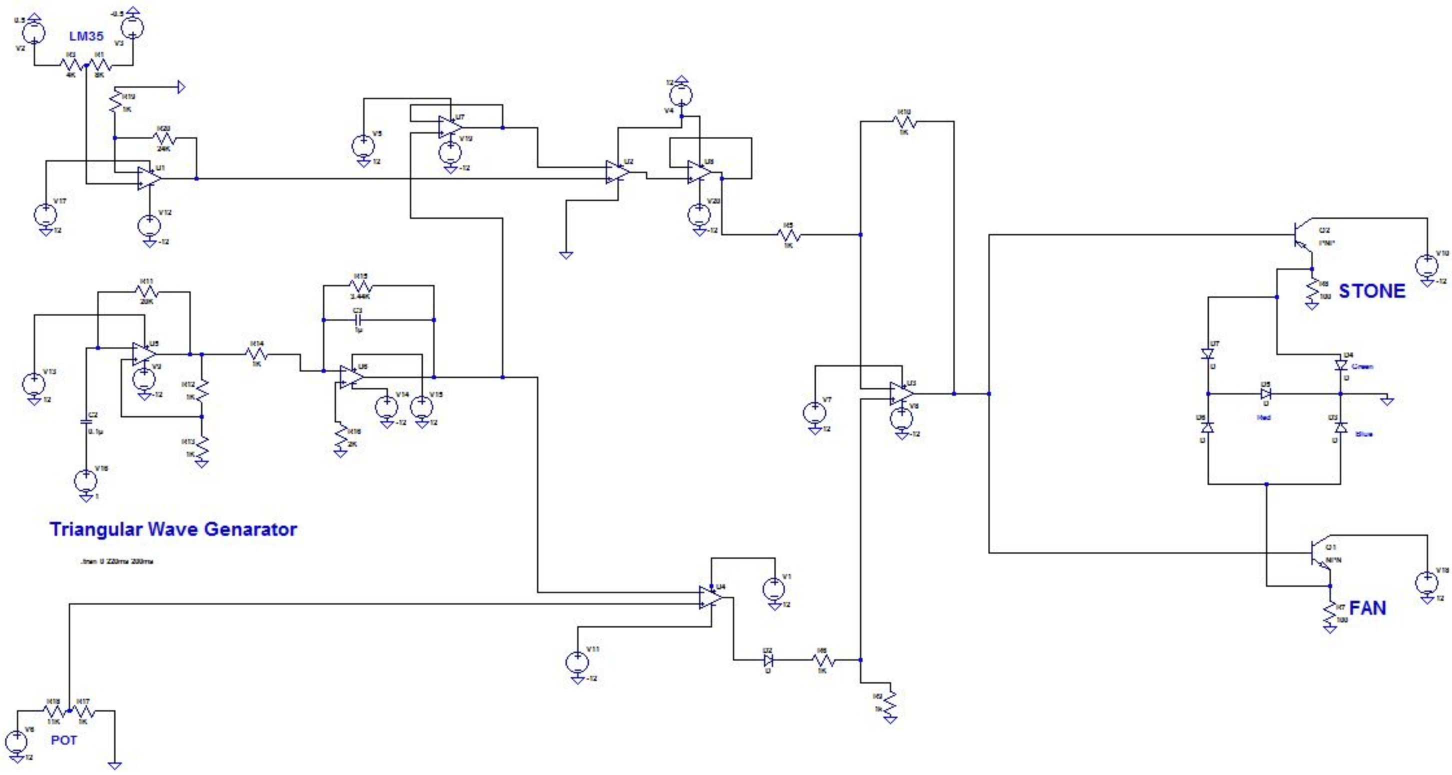

Figure 18 : Overall schematic of the circuit

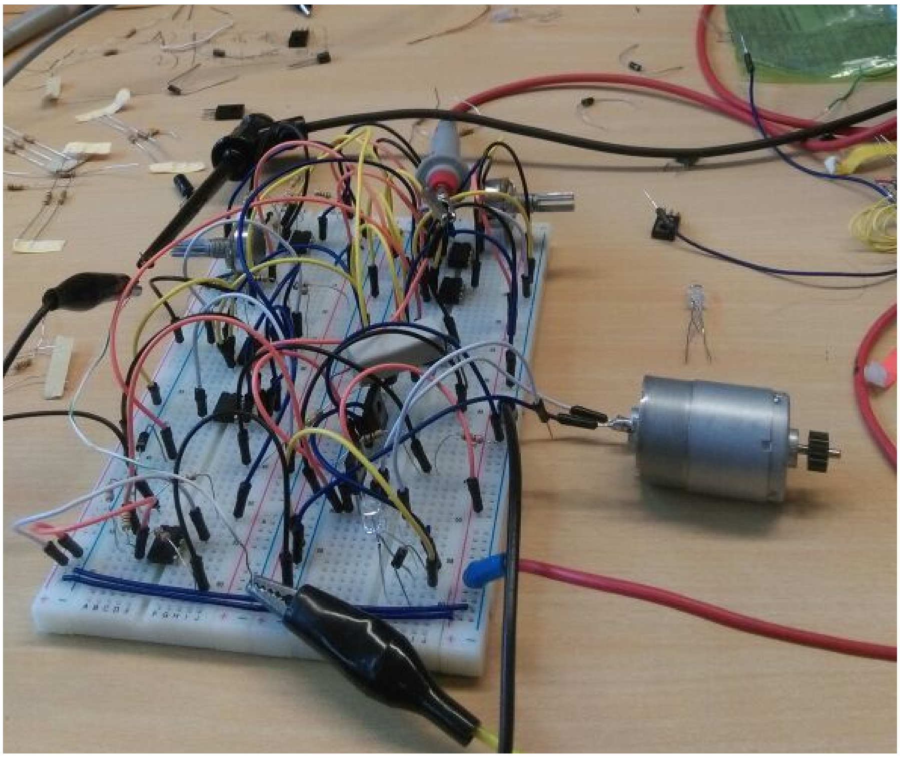

Figure 19 : Analog Air Condition System

7 - Conclusion

In this project, we designed an analog air conditioning system that can cool or warm up the room if necessary by measuring its ambient temperature. We mainly used two duty cycles, one of them represents the ambient temperature and the other one represents desired temperature. By subtracting this two duty cycles, we obtained a voltage that can be named pulse width modulation or PWM . The purpose of conducting the driving of the operation units with PWM, is to be able to speed control the operation. The greater the temperature difference,the greater the duty cycle, the faster the operation is carried out. Because the maximum output current of the LM358 was too low to drive Fan and Stone Resistor, a NPN and a PNP transistor was used to amplify the current. And because of the operation principles of PNP and NPN transistors, which we mentioned previously, transistors acted like switch between Stone Resistor and FAN. And finally, we used RGB LED to indicate whether heating or cooling operation is being carried out. Throughout the project we faced many difficulties which were caused by various reasons. The nonideality of our components caused us a lot of trouble. Our own miscalculations and logic mistakes were also some of the obstacles we faced.