DEPARTMENT OF ELECTRONIC AND TELECOMMUNICATION ENGINEERING
UNIVERSITY OF MORATUWA

EN2090 - Laboratory Practise II

Lux Meter Report

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1. Abstract

This report represents the implementation of a lux meter that is able to measure white and coloured LED light under normal laboratory conditions. Lux meter uses in photography, biomedical instruments, robot navigations etc. Therefore, accuracy and steadiness of readings is very important. Those are the main problems that we faced in designing the lux meter. We had to implement this as to reduce those issues to get expected results. We used commercial lux meter to calibrate. Therefore, getting accuracy as commercial lux meter was a huge challenge. We used a photodiode for the sensing and used some analog parts to increase the resolution. Methods, testing, results and functionality of our lux meter include in this report.

2. Acknowledgements

We would like to express our gratitude to our supervisor Mr.Dulara De Zoysa for giving us technical advice and guidance.
We pay our gratitude to all the lecturers, instructors and other academic staff who intimately welcomed us to share their knowledge and experiences. We are very grateful to the personnel who are in charge of laboratories for allowing us to use the laboratories when needed and for the support given to solve technical problems.

CONTENTS

3. Introduction

The lux meter is a device that measures the intensity of illumination as distinguished by the human eye in lux which is luminous flux per unit area. The captured light by the photo element of the lux meter is then converted into an electric current which the device uses to calculate the lux value. This measurement varies with the light's intensity and distance.

In this project, we were instructed to build a lux meter using basic analogue components such as amplifiers, transistors, diodes etc. The main component of the lux meter is the component that is used to sense light after testing many phototransistors and photodiodes we decided to use the photodiode TEMD5510. For the processing part, we used the Atmega32 microcontroller and the calculated lux value is displayed through an LCD display.

To design a circuit for the lux meter we tested many operational amplifier applications and finally built a circuit using a differential amplifier and three non-inverting amplifiers. When testing the whole circuit together we faced many issues and after a thorough discussion and research, we overcame these issues to build a complete properly functioning circuit.

This report presents the method we used to build a lux meter, the different problems we encountered and the applicable solutions we applied to complete the project. A comparison of the final outcome of the lux meter and the commercial lux meter shows the achieved targets of this project.

4. Methodology

4.1 Components Used

1. TEMD5510 Photodiode
2. LF353 Dual JFET Input Amplifier
3. LT1054 Switched Capacitor IC
4. ATMega32 microcontroller
5. 16x 2 LCD Display
6. LM 2596 Simple Switcher Power Converter
7. 16 MHz Oscillator
8. 9V Battery
9. Resistors, Capacitors

4.1.1 TEMD5510 Photodiode

TEMD5510 is a photodiode with high photosensitivity. As the task was to design a lux meter which responds to visible light this photodiode was suitable as it has a suppression filter for near-infrared radiation and it is sensitive to visible light much like the human eye(Fig.1). This diodes photocurrent shows a linear relationship with the illuminance as well(Fig.2).

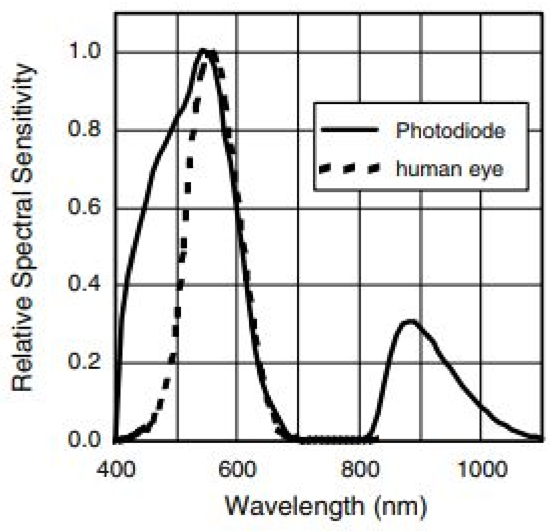

Fig.1 - Relative Spectral Density vs Wavelength

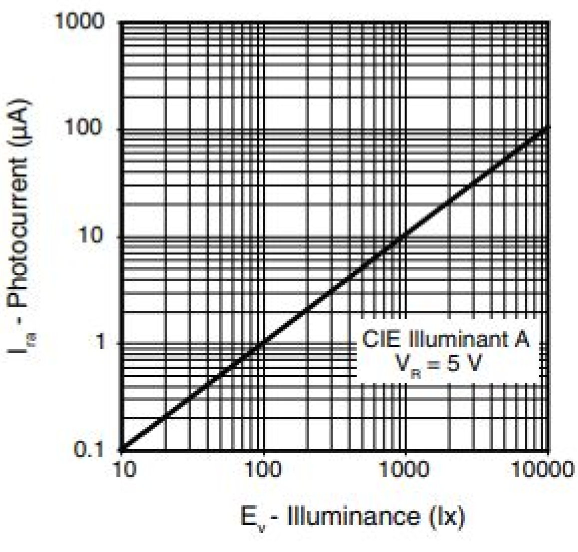

Fig.2 - Reverse Light Current vs Irradiance

4.1.2 LF353 Operational Amplifier(OpAmp) IC

LF353 is a high speed, dual input JFET operational amplifier with an internally trimmed input offset voltage. As this IC consists of two opamps our circuit design became less complex with the use of only two ICs. This device has a low input bias current of 50pA. Low input bias current op amps are required whenever the difference of currents or voltage is small and needs to be measured accurately. As the signal does not get loaded down by the input of the opamp we decided to use this opamp for amplification purposes.

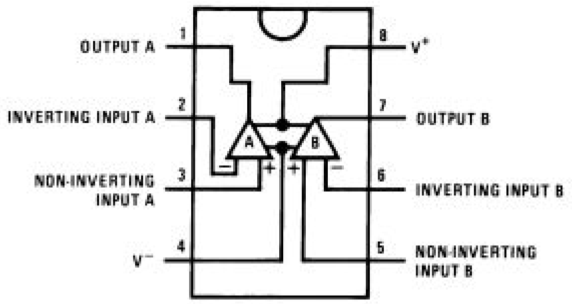

Fig.3 - 8 pin SOIC

4.1.3 LT1054 Switched Capacitor IC

LT1054 is a switched capacitor voltage converter with regulator. This device has a low loss of 1.1V at 100mA. As all the LF353 opamps were used in the dual supply mode LT1054 was used as the inverter to supply -5V for the negative supply pin.

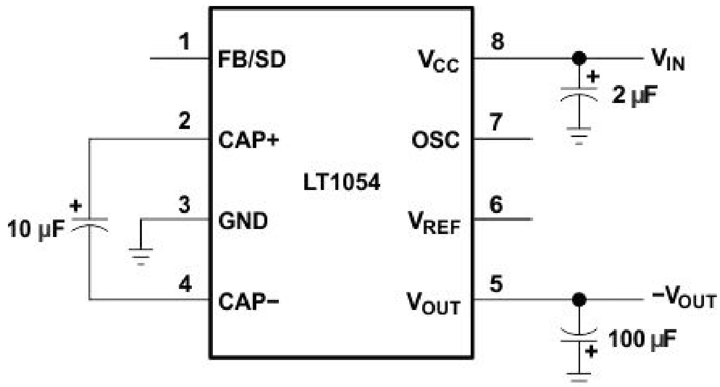

Fig.4 - Inverter IC Schematic

4.1.4 ATMega32 microcontroller

The ATmega32 is a low power high performance atmel AVR 8-bit microcontroller. The AVR Minimum system board along with the AVR serial programmer was used to program the microcontroller.

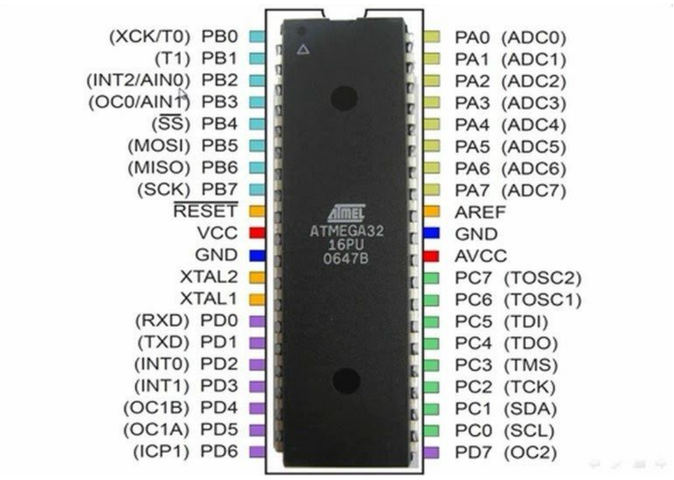

Fig.5 - Atmega 32 microcontroller

4.2 Block Diagram

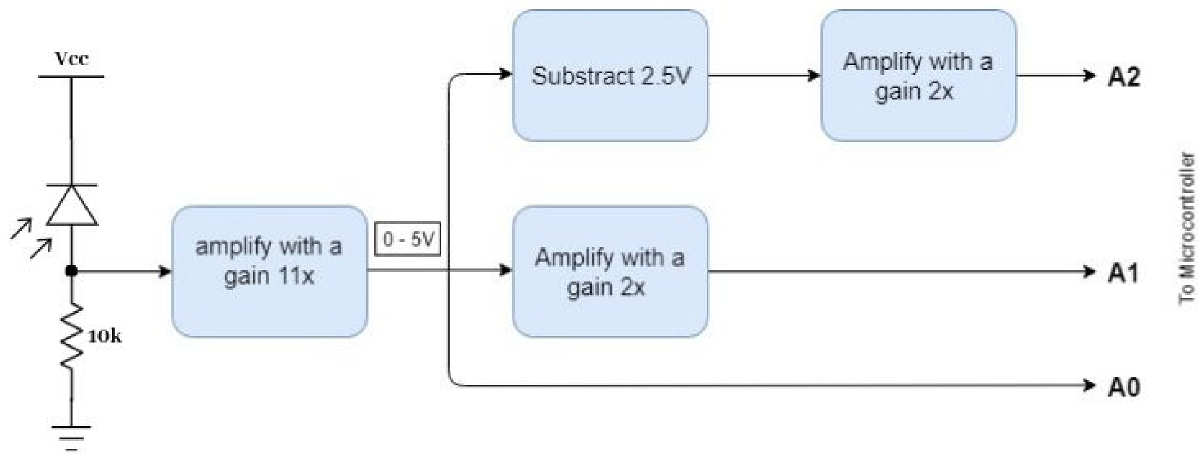

Fig.6 - Functional Block Diagram

4.3 Hardware Development

The main part of the project was to develop the hardware. In the circuit design the operational amplifier LF353 was used both as a non-inverting amplifier and a subtractor. The TEMD 5510 photodiode could not directly be used and we had to surface mount it onto a dot board.
In our design the amplified photodiode output which is in the range 0-5V was divided into two ranges 0-2.5V and 2.5-5V and is amplified in order to be mapped to 0-5V.

4.3.1 Subtractor Circuit

The LF353 operational amplifier was used with the suitable resistors as a subtractor to subtract 2.5V from the output of the 1st stage amplifier circuit with a unity gain.

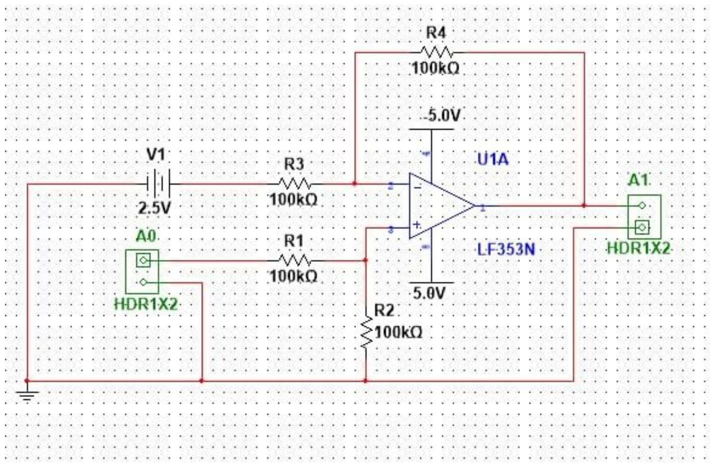

Fig.7 - Subtractor Circuit

4.3.2 Non-Inverting Amplifier

Three non-inverting amplifiers were designed to achieve gains of 11 and 2. The voltage across the 10k resistor which is in series with the photodiode was first amplified by non-inverting amplifier of gain 11, through which we were able to bring the voltage to 0 - 5V. In this initial amplification we noticed that the output signal was corrupted with noise and it resulted a varying signal. Therefore a feedback capacitor was inserted to limit the bandwidth in order to reduce noise.

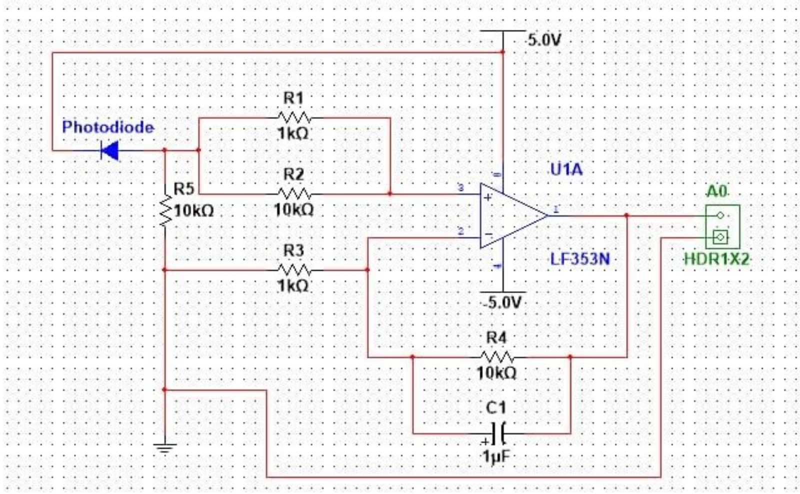

Fig.8 - Non-inverting amplifier with gain 11

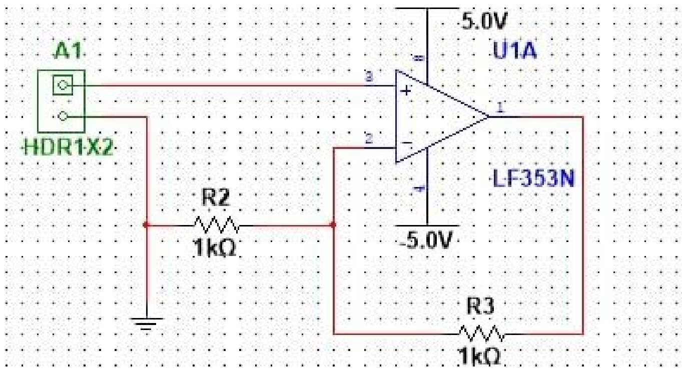

Fig.9 - Non-inverting amplifier with gain 2

4.4 Testing and Fabricating the PCB

Altium software was used to design the PCB. We tested the circuits many times by using breadboards in order to get the correct circuit design before manufacturing the PCB. After finalizing the circuit, the double sided layout was designed by using Altium. The finalized PCB design was sent to China for manufacturing.After that we soldered the components and checked the PCB several times. After ensuring the functionality, we calibrated the lux meter. For that we made a light box with a LED array. We set the LED array directly above the lux meter to increase the credibility of readings. We used a commercial lux meter to calibrate. Since lux value changes with the distance we got some readings by changing the distance when calibrating..

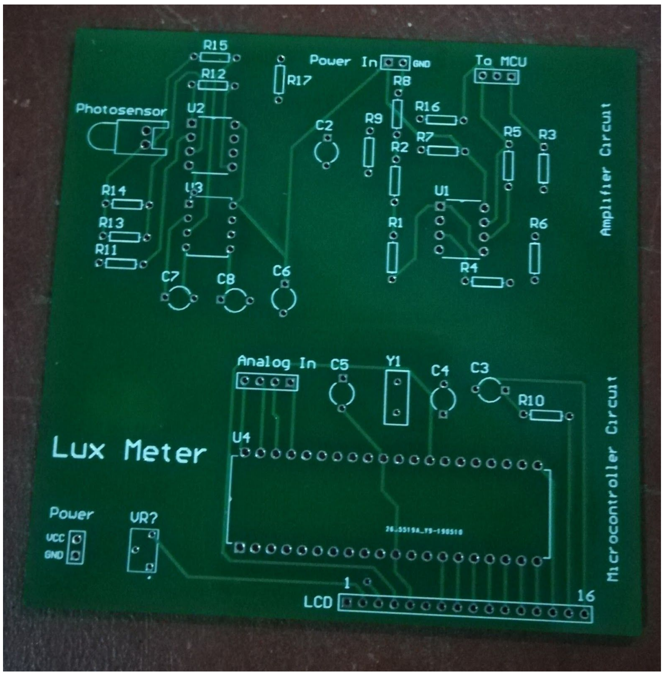

Fig.10 - Final PCB Design

4.5 Enclosure Design

We decided to make a proper enclosure for the lux meter to mount the circuit, LCD display and the photodiode in an organized manner and to make the product look more appealing. Also it helps to keep the PCB safe. For designing the enclosure, we used the Solidworks software. After that we used laser cutting method to manufacture the enclosure.

5. Results

The lux meter was calibrated using a commercial lux meter. In our design the initial voltage that determines the lux value is the voltage across the 10k resistor(V_1) which is in series with the photodiode. The graph below shows the plot of the lux value observed from the commercial lux meter vs the 0 -1023 mapped 11x V_1 voltage (A_o). It can be observed that the relationship between the real lux value vs A_o shows a much linear relationship.

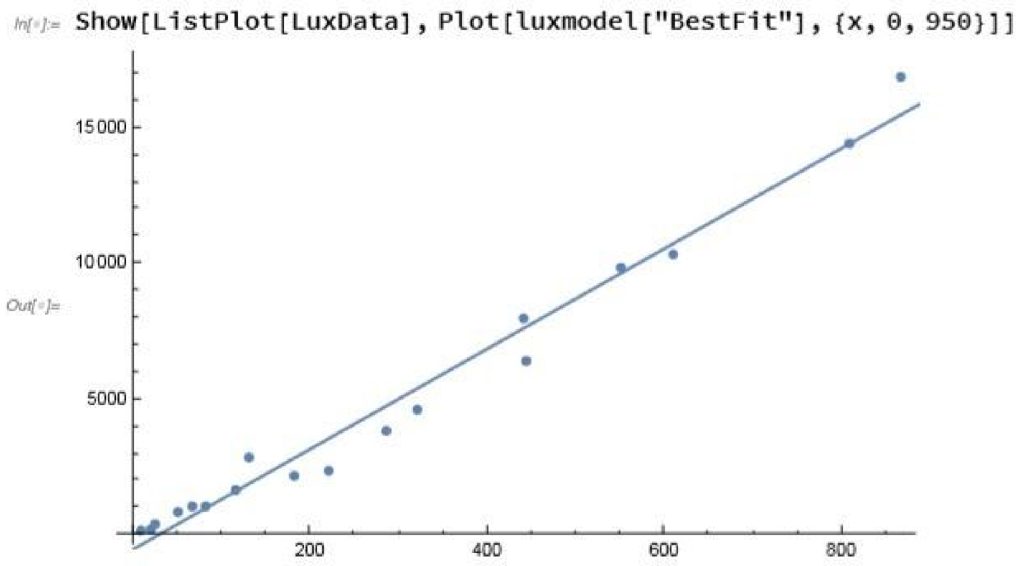

Fig.11 - Lux Value vs A_o

The three different inputs to the microcontroller (A_o , A_1 , A_2) calculates the final lux value. A_o value determines the relevant equation to be used to calculate the lux value depending on if $A_o \lessgtr 400$.

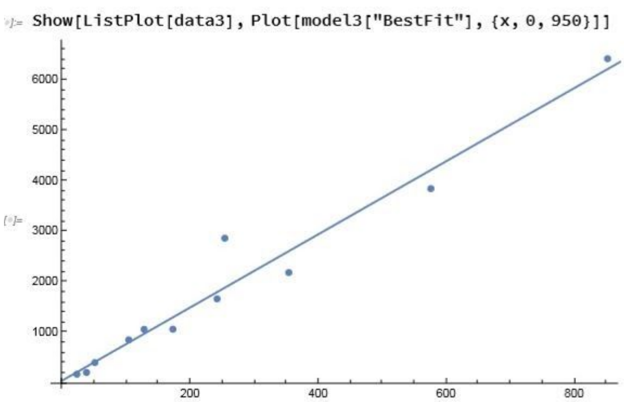

Fig.12 - Lux Value vs A_1

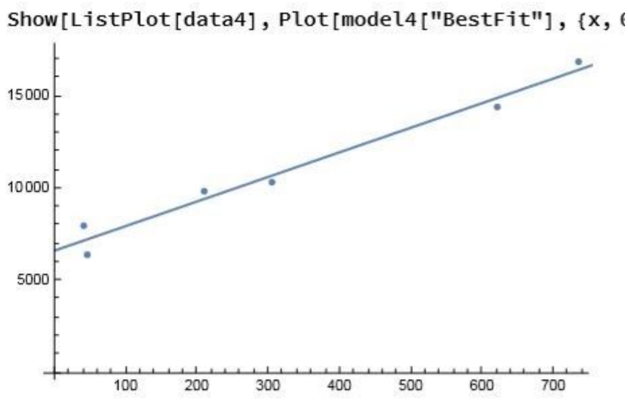

Fig.13 - Lux Value vs A_2

6. Discussion

6.1 Selecting the most applicable sensor

The sensor is the most important component in a lux meter. We first ordered a few phototransistors and photodiodes in order to test and select the most applicable sensor. The sensors we tested was SFH 3310, TEMT 6000, TEMD 5510. As it was important to use a sensor that adopts to the human eyes responsivity we observed the datasheets of each sensor and compared the spectral sensitivity curve of the sensor with the human eye. We also considered the radiant sensitivity area of each sensor as it is better to use a sensor with a wide sensitivity area. After taking into account all these conditions we decided to use the photodiode TEMD 5510 for our lux meter.

6.2 Noise Reduction

When testing the whole circuit on the breadboard we noticed that the final output signal is not a constant but a signal varying sinusoidally with a high frequency. To reduce this effect which was caused due to noise a feedback capacitor of 47μF was added to the initial amplification stage opamp.

6.3 Precision Issues

In the subtractor circuit the voltage to be subtracted(2.5V) from the input had to be given to the inverting input of the opamp. In the PCB design we obtained this 2.5V through a voltage divider using two 100k resistors and a supply voltage of 5V. When the components were soldered to the PCB it was noted that the voltage in the middle of the divider was not exactly 2.5V but a lesser value. This issue would have been overcome by the use of a variable resistor but as the PCB was already printed the issue was not fixed. Even though the subtractor did not subtract 2.5V but a lesser value this did not affect the final output in a large scale.

7. Appendices

7.1 Circuit Diagrams

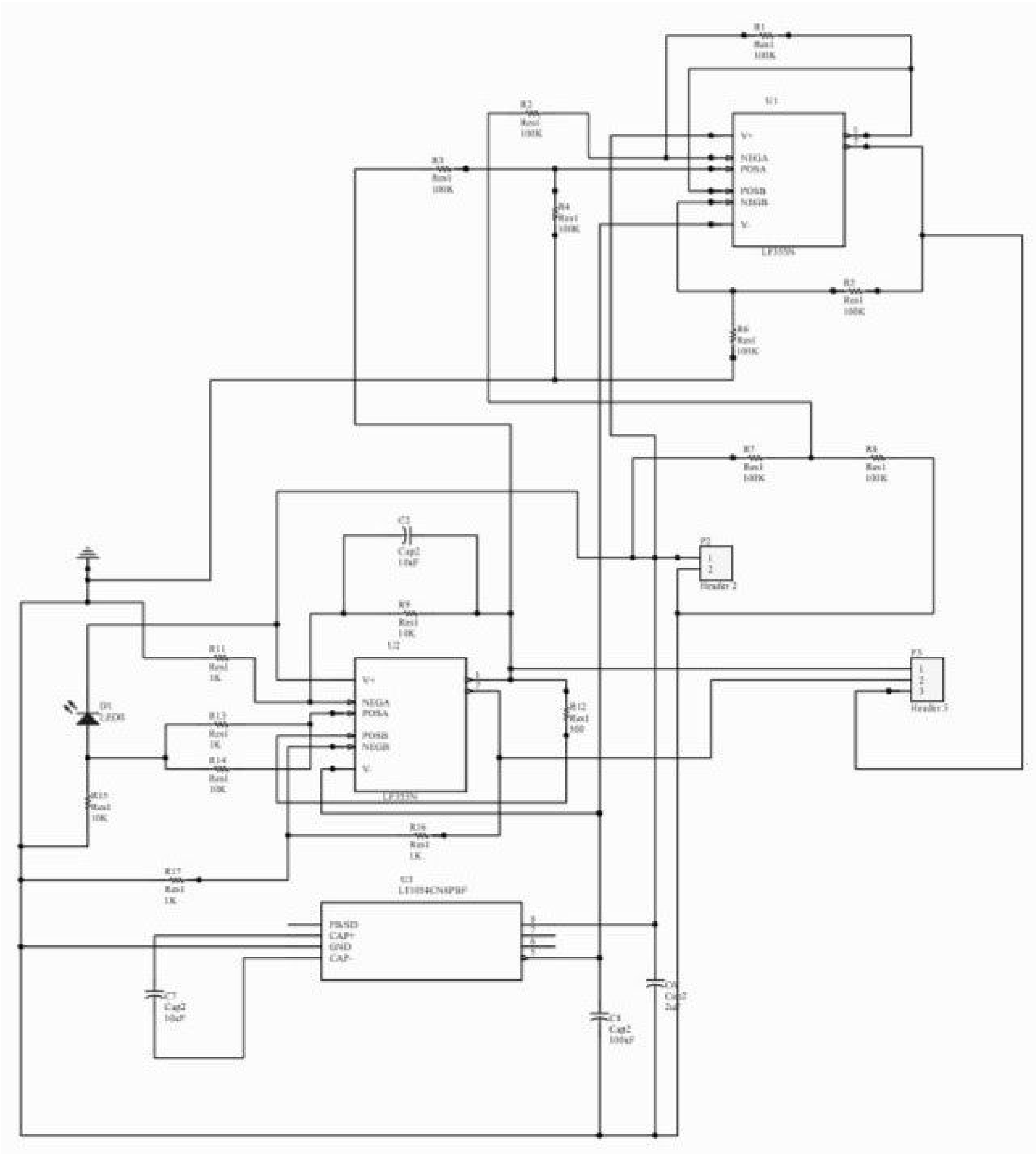

Fig.14 - Schematic

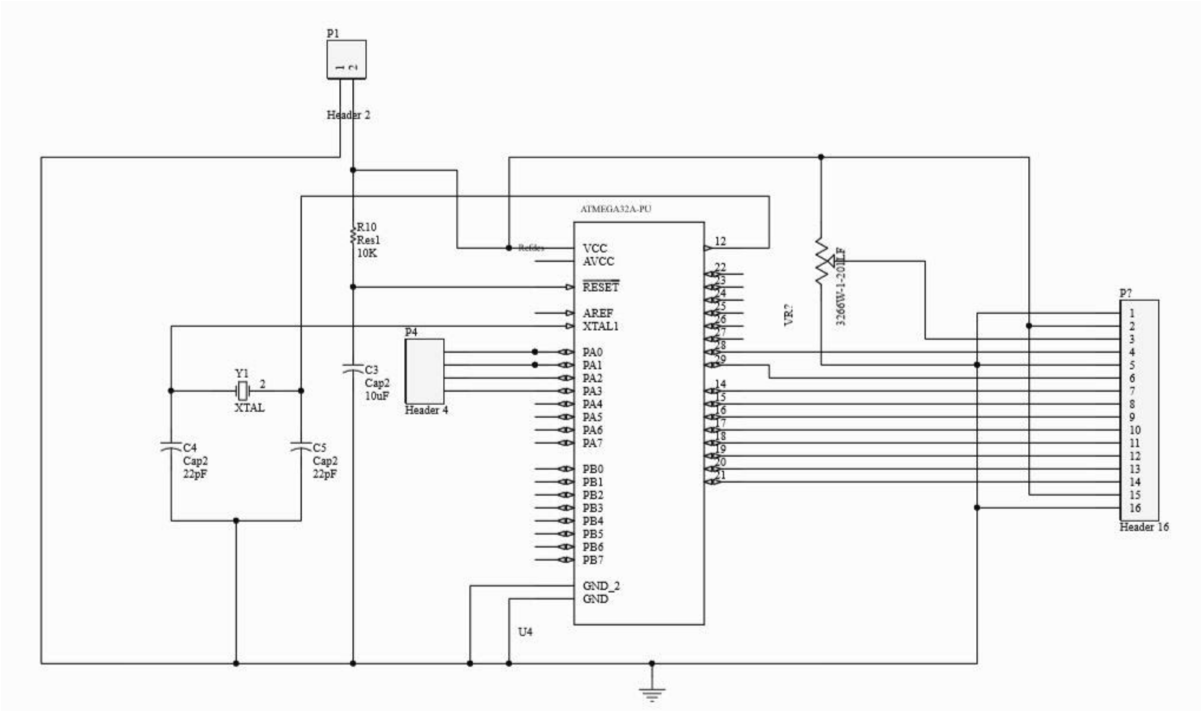

Fig.15 - Microcontroller Schematic

7.2 Enclosure Design

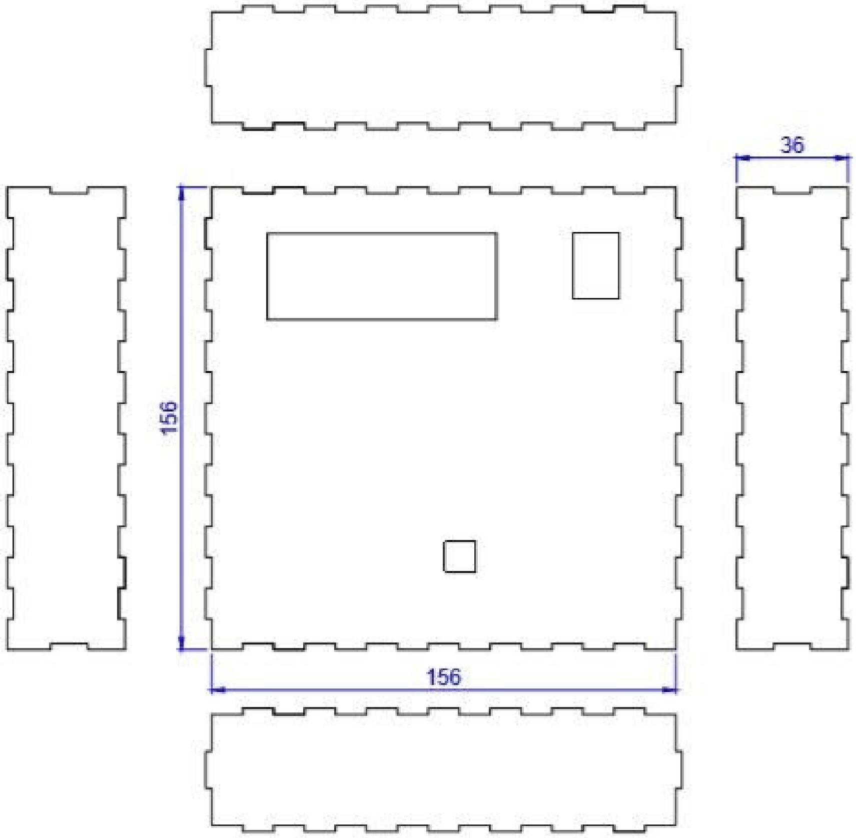

Fig.16 - Enclosure Drawing

Fig.17 - Final Enclosure

7.3 Microcontroller Source Code

```
/*  Group 9 | UoM | ENTC 17Batch  */
/*#ifndef F_CPU
#define F_CPU 16000000UL // 16 MHz clock speed
#endif
*/
#define D0 eS_PORTD0
#define D1 eS_PORTD1
#define D2 eS_PORTD2
#define D3 eS_PORTD3
#define D4 eS_PORTD4
#define D5 eS_PORTD5
#define D6 eS_PORTD6
#define D7 eS_PORTD7
#define RS eS_PORTC6
#define EN eS_PORTC7

#include <avr/io.h>
#include <util/delay.h>
#include "stdlib.h"
#include "string.h"
#include "lcd.h"

char disp[16]="0000000000000001";
char result[8] = "00000001";

void lcd_disp(char data_points[],int r,int c,char w[]){
        if(w=="clear")Lcd8_Clear();
        Lcd8_Set_Cursor(r,c);
        Lcd8_Write_String(data_points);
}

void ADC_Init(){
        DDRA=0x0;                       /* Make ADC port as input */
        ADCSRA = 0x87;                  /* Enable ADC, fr/128  */
        ADMUX = 0x40;                   /* Vref: Avcc, ADC channel: 0 */
}

int ADC_Read(char channel){
        int Ain,AinLow;
        ADMUX = 0x40;
        ADMUX=ADMUX|(channel & 0x0f);   /* Set input channel to read */

        ADCSRA |= (1<<ADSC);            /* Start conversion */
        while((ADCSRA&(1<<ADIF))==0);   /* Monitor end of conversion interrupt */
        _delay_us(10);
        AinLow = (int)ADCL;             /* Read lower byte*/
        Ain = (int)ADCH*256;            /* Read higher 2 bits and
                                        Multiply with weight */
        Ain = Ain + AinLow;
        return(Ain);                    /* Return digital value*/
}

int main(void){
   DDRD = 0xFF;  // #
        DDRC = 0xFF;  //for lcd
```

```
	DDRA = 0x00;  //Analog input

	ADC_Init();
	//ADMUX = 0b01100000; // Configure ADC to be left justified, use AVCC as reference, and select ADC0 as ADC input
	//ADCSRA = 0b10000111; // Enable the ADC and set the prescaler to max value (128)


	Lcd8_Init(); //Initializing the LCD screen
	lcd_disp("Starting Lux ~)",1,1,"");
	lcd_disp("Meter *_*",2,1,"");

	_delay_ms(1000);

	lcd_disp("Initializing",1,1,"clear");
	lcd_disp("Sensor",2,1,"");
	_delay_ms(1000);

	lcd_disp("Initializing ~",1,1,"clear");
	lcd_disp("Sensor",2,1,"");

	_delay_ms(1000);

	while(1){
		char val[4]; //temporary variable for itoa
		char val1[6]; //temporary variable for itoa
		char val2[4]; //temporary variable for itoa
		Lcd8_Clear();
		int a0=ADC_Read(0);
		int a1=ADC_Read(1);
		int a2=ADC_Read(2);

		int LuxValue=0;

		if(a0<400){
			LuxValue=7.23006*a1+61.2736;
		}else{
			LuxValue=6651.64+13.33*a2;
		}

			itoa(LuxValue,val1,10);
			lcd_disp("Reading Value...",1,0,"");
			lcd_disp(val1,2,0,"");
			lcd_disp(":lux",2,6,"");

		_delay_ms(600);

	}

}
```

8. References

1. https://en.wikipedia.org/wiki/Lux
2. https://www.vishay.com/docs/81293/temd5510.pdf
3. http://www.ti.com/lit/ds/symlink/lf353-n.pdf
4. https://www.ti.com/lit/ds/symlink/lt1054.pdf