DEPARTMENT OF ELECTRONIC & TELECOMMUNICATION ENGINEERING

UNIVERSITY OF MORATUWA

EN2090: LABORATORY PRACTICE – 2

LUX METER

PROJECT REPORT

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11th July 2018

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1. ABSTRACT

This report presents the implementation of a Lux Meter that can measure white and colored LED light under normal laboratory conditions. Defining high accuracy and steadiness in readings is the main problems when designing a lux meter. When dealing with biomedical instruments, photography, robot navigation, illumination engineering these error levels cause much deviation from expected results. Much like any other projects the biggest challenge for us is to make a lux meter close enough to compare with the commercial one. For this project, a photo-transistor was used for the sensing and the errors were corrected to optimum level using analog techniques. This document contains the methods, test results and full functionality of the lux meter we built.

2. INTRODUCTION

The lux value which was also called the illuminance is a measure of amount of luminous flux per unit area (1 m2). This value varies massively from location to location with a minute difference in illuminance. Though human eye is very sensitive to illuminance, the feature illuminance is immeasurable to the human eye. As a solution to this an instrument was needed which deals with wide range of lux values and which can reproduce the relevant lighting condition again and again and to measure the illuminance. This instrument is called lux meter.

Commercial lux meters are made from complicated parts and many advanced ICs. As instructed we had to use basic analogue electronic components such as operational amplifiers, transistors, diodes etc. to make the meter. So, we had to use a sensor for the light intensity sensing part, for that we tried several components and finally settled down on the TEMT6000 photo-transistor module. We chose it because it directly outputs a voltage proportional to the light intensity. Then for the processing part we used an Atmega328P microcontroller as it's the chip used in the Arduino UNO so we can easily reprogram it for our purpose. We also used a 16x2 LCD unit to display the lux value to the user.

Several types of amplifiers, rectifiers, clippers were analyzed and a combination of them was selected as the most appropriate circuit design to implement the concept. Finally, the practical problems faced while designing and implementing the design in several stages, selections and justifications, limitations of the device and many other issues were discussed and appropriate solutions were used to complete the device.

This report presents the method which we used to develop our device in several stages, the practical problems we faced, selections and justifications, limitations and measurements of our device with comparison to another commercially available lux meter which we used for the calibration of our device as well as the problems we encountered in the process of developing this device and the solutions.

3. METHOD

3.1 Components Used

I. TEMT6000 Photo-transistor
II. AD620 Instrumentation Amplifiers
III. LT1054 Switched-Capacitor IC
IV. TL072 Operational Amplifiers
V. 1N4001 Diodes
VI. L7808 & L7805 Regulators
VII. 2N2222A Transistors
VIII. Atmega328P Microcontroller
IX. 16 x 2 LCD Display
X. 3.7V Rechargeable Batteries
XI. Variable Resistors
XII. 16 MHz Oscillator
XIII. Capacitors, Resistors, LEDs
XIV. Connector Cables & Sockets

3.1.1 TEMT6000 Photo-transistor

Whole design is based on photo Transistor which is used to detect the intensity of light in different situations. Output of the photo transistor depends on the wave length of the light falling on it rather than frequency of the light falling outer surface which is used by some other sensors. These wave lengths fall in three regions in electromagnetic spectrum which are UV, Visible Light and IR. In some designs, it uses LDR and photo diodes as the

Figure 3.1.1.1

basis of detecting light intensity in lux meters. In LDR it uses changes of the resistivity in a light sensitive resistor. Photo diodes uses the change in diode reverse current with the intensity of light. But all the currents or generated voltages should be amplified to get more sensitivity. But when using photo transistor, it amplifies itself then an inbuilt sensitivity can be found. And the accuracy due to sensitivity was the main reason for choosing of photo transistor for the design. And the sensitivity of the photo transistor depends on dc current gain of the transistor.

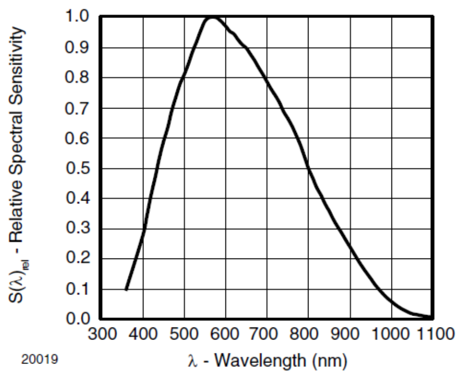


Figure 3.1.1.2

The response photo transistor is maximum at wave lengths between 500 nm to 700 nm.

3.1.2 AD620 Instrumentation Amplifier

AD620 is a high accuracy instrumentation amplifier which is ideal for use in precision data acquisition systems. The low noise, low input bias current, and low power of the AD620 make it well suited for our need and it requires only one external resistor to set gains of 1 to 10,000, so by using it we were able to make our design much simpler and easy to implement. In our design implementation, we used the IA with a gain of 4 using a 16.47K external resister.

3.1.3 LT1054 Switched-Capacitor IC

All the Operational Amplifiers which were used in the circuit are in dual supply mode. Therefore, LT1054 was used as a voltage inverter to generate a -8V using a +8V voltage regulator output. It was very easy to use and is able to output up to 100mA which was perfect for our need.

3.2 Hardware Development

The true challenge for us was the design. It was very important that our design is a unique one as well as the better one. In order to achieve that, we spent days coming up with different kinds of circuit designs and analyzing them for further optimizations. As mentioned above we used the TEMT6000 photo-transistor as its output voltage is proportional to the light intensity and we had to take account the availability of it in Sri Lankan stores. Though it was available at the time we made the decision, later when we were going to buy, it was out of stock locally and at the end we had to order it online.

In our design, what we basically did was dividing the 0-5V output of the sensor into 4 equal ranges and amplifying them separately so at the end each range would give a 0-5V output. Each range line would go five circuit elements consequently along the branch. After feeding those four inputs to four analog input pins of the microcontroller we summed the four voltages up so that in the end the 0-5V is effectively amplified into 0-20V only using low voltages. Five stages along a branch are consecutively as follows.

I. Instrumentation Amplifier
II. Opamp Rectifier (Negative Clipper)
III. Voltage Follower I
IV. 5V Clipper
V. Voltage Follower II

3.2.1 Instrumentation amplifier

The main purpose of using the Instrumentation Amplifier is to get the difference of two given voltages. As I have mentioned before the reference voltages for the four ranges are consequently 0V, 1.25V, 2.5V & 3.75V which are achieved by potential divider method. At each Instrumentation Amplifier, the output from the sensor is feed into one input and the relevant reference voltage is feed into the other input pin. So, the output will be 4 times the difference between the two voltages as the gain set to 4. But when the sensor output is lower than the reference voltage of a branch, the output becomes negative which indeed cannot be feed into the Atmega chip. The following element looks into that problem

3.2.2 Opamp Rectifier

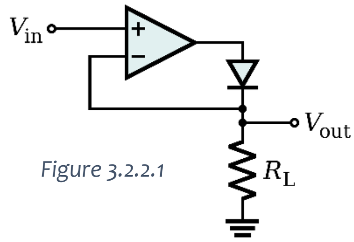


Figure 3.2.2.1

The main purpose of this element is to cut down the negative voltages and output them as zero voltages. So, whenever the sensor output is below a reference voltage the branch output will be zero.

3.2.3 Voltage Follower I

This is simply used to feed the output of the rectifier into the 5V clipper without drawing any current from the previous stage so the input voltage for the current stage remains the same as the output voltage of the previous stage.

3.2.4 5V Clipper

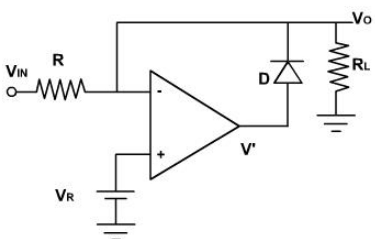


Figure 3.2.4.1

This element is used to limit the output of the branch to 5V as voltages above 5V will damage the Atmega chip. As the maximum effective voltage which can be achieved by the branch is also 5V, voltages exceeding that value are useless and hence can be represented by 5V.

3.2.5 Voltage Follower II

This is used to eliminate the output voltage variation which can be occurred due to the current drawn by the analog input pin of the Atmega chip from the branch.

3.3 Testing & Fabricating the PCB

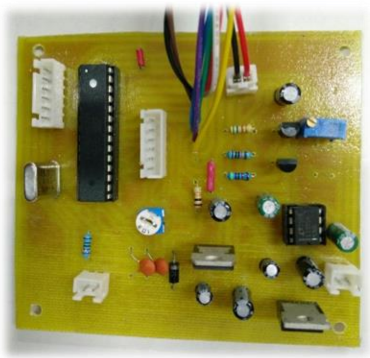


Figure 3.3.1

Designing the PCB was done using Altium software as recommended. Before making the PCB, it was thoroughly tested on bread board ensuring the correct functionality of it. For the testing, we made a small light box with

a LED array from a torch and used it directly above the meter, this was to eliminate unnecessary light from entering the sides to increase the credibility of the readings. This was important because our light sensor module was flat but on the other hand the commercial lux meter had a concave focusing cover over its sensor. After ensuring the

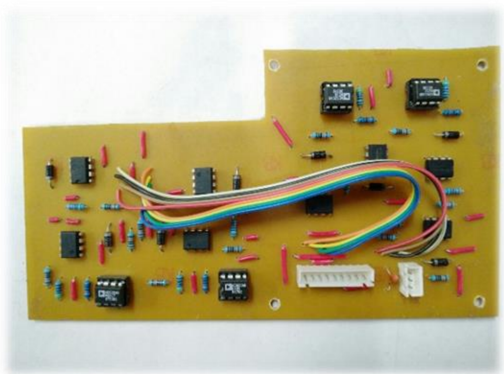


Figure 3.3.2

functionality the layout of the single sided PCBs was designed using Altium software.

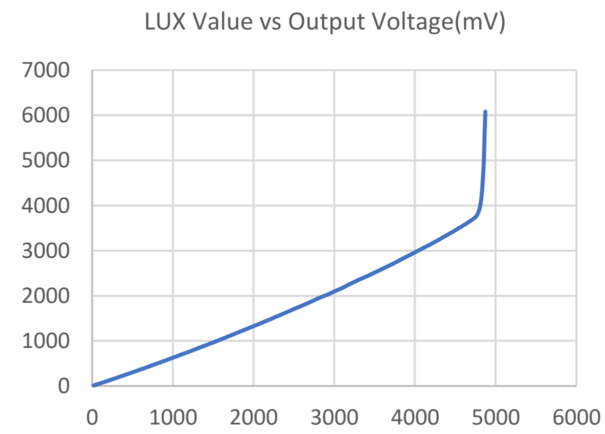
The PCB was manufactured using toner transfer ironing method which was easier and cheaper for the design. Also, it was etched with ferric chloride. Mounting of the components was done thereafter and the connections were checked several times as the equipment deals with sensitivity and accuracy much more.

3.4 Enclosure Design

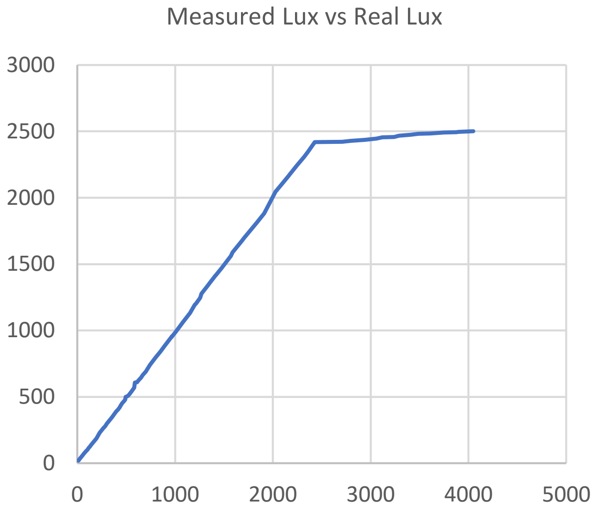
At the beginning of the project it was mentioned that we need to have a proper enclosure for the lux meter. So, we used Solidworks 3D modelling software to design the enclosure and used laser cutting technology to manufacture it.

4. RESULTS

The following is the graph of lux value vs output voltage of the sensor in millivolts obtained by us with the use of a commercial lux meter. The values were obtained for an emitter resister value of 10K on the sensor. It can be clearly observed that the there is a linear relationship between the two variables and the curve becomes vertical around 3500 lux because the photo-transistor gets saturated at that point. By decreasing the emitter resistor value, the measurable range can be further increased, but the accuracy will drop by a considerable factor.



The following is the calibration graph plotted between the measured lux value of our lux meter and the real lux value obtained from a professional lux meter. It can be observed that the two values are nearly equal in the 0-2500 range.



5. DISCUSSION

5.1 Power Supply Issue

At the earlier stages of the designing process we decided to use a 9V battery to power up the lux meter. It was our fault that we never checked the circuit to be powered up by an actual 9V battery. Until the last moment we used the laboratory power supply to power up the circuit as it was easier and safe to use. The circuit needed a minimum supply voltage of 8.8V and it drew a maximum current of 100mA. Later, when we connected a 9V battery to the circuit it failed to supply the power required and it was an utter failure. As a solution, we decided to use three high capacity 3.7V rechargeable Li-Ion batteries which were the easiest to use. Changing the batteries increased the supply voltage to 11.1V but it was not an issue as we have used a voltage regulator to regulate the supply to 8V.

5.2 Enclosure Dimension Errors

This was due to a silly mistake done at the enclosure design process which caused last minute changes to the designed enclosure. We had to remove some designed parts and assemble the enclosure as there was a 5mm error in a length.

5.3 Complexity of the Design

At the beginning, we were thinking of implementing the Instrumentation Amplifier using the standard three Opamp design but after a few attempts we understood that the size of the PCB would be massive which was inadequate for a lux meter. So, we decided to use the AD620 Instrumentation amplifier which would do the required job with much ease.

Also, we were having trouble with generating negative 8V for the negative supply of the Opamps. We tried to use several methods but each of them failed. At the end, we were left with the option of providing a high voltage and using the voltage divider rule and defining the mid voltage as the ground. But fortunately, we found the LT1054 IC and ordered it online so we could easily generate the required negative supply from a positive voltage.

Even after taking lots of measurements to simplify the design we faced some difficulties when designing the layout in Altium. As we could only make single sided PCBs, the routing of the layout was tedious. It was accomplished after dividing the circuit into three different PCBs and adding lots of jumpers.

5.4 Battery Voltage Indicator

As to be sure about the accuracy of our design we had to consider the battery drainage. So, we checked for absolute minimum voltage level required for the circuit to function properly and used a simple transistor low voltage indicator circuit to convey the message to the user that the supply voltage has dropped so that the reading of the lux meter is not accurate.

6. ACKNOWLEDGEMENTS

This project would not have been possible without the support of many individuals. We would like to give our special appreciation to the project supervisor Ms. Thavishi Illandara for her guidance and support throughout the project time period. Our special thanks go to the laboratory staff who kept the labs open until late in the night for the completion of our projects and indeed we are thankful for letting us borrow such an expensive commercial lux meter from the Department Workshop for calibration purposes.

Software Used

- Altium Designer 2016
- Solidworks 2016
- AutoCAD

7. REFERENCES

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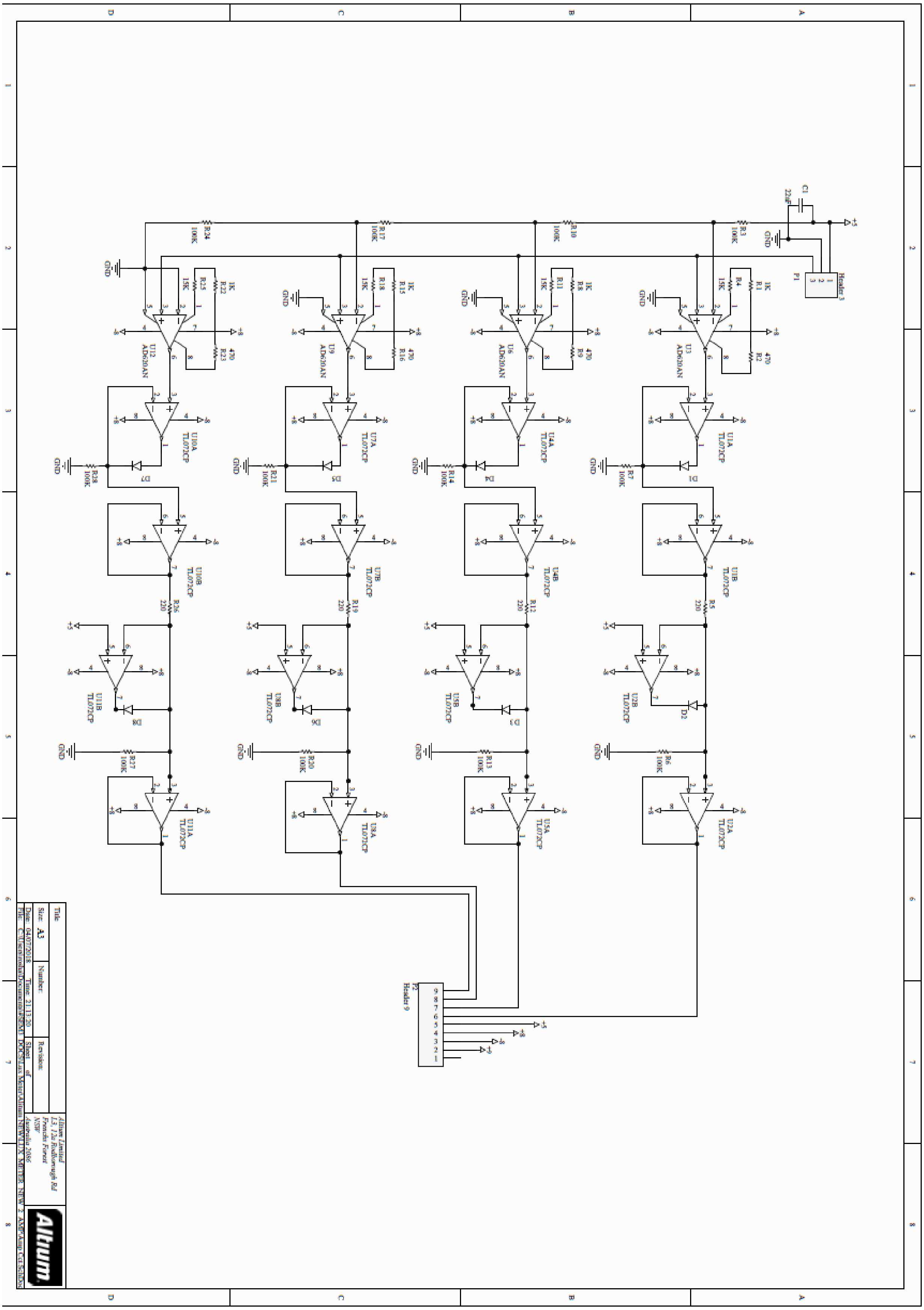
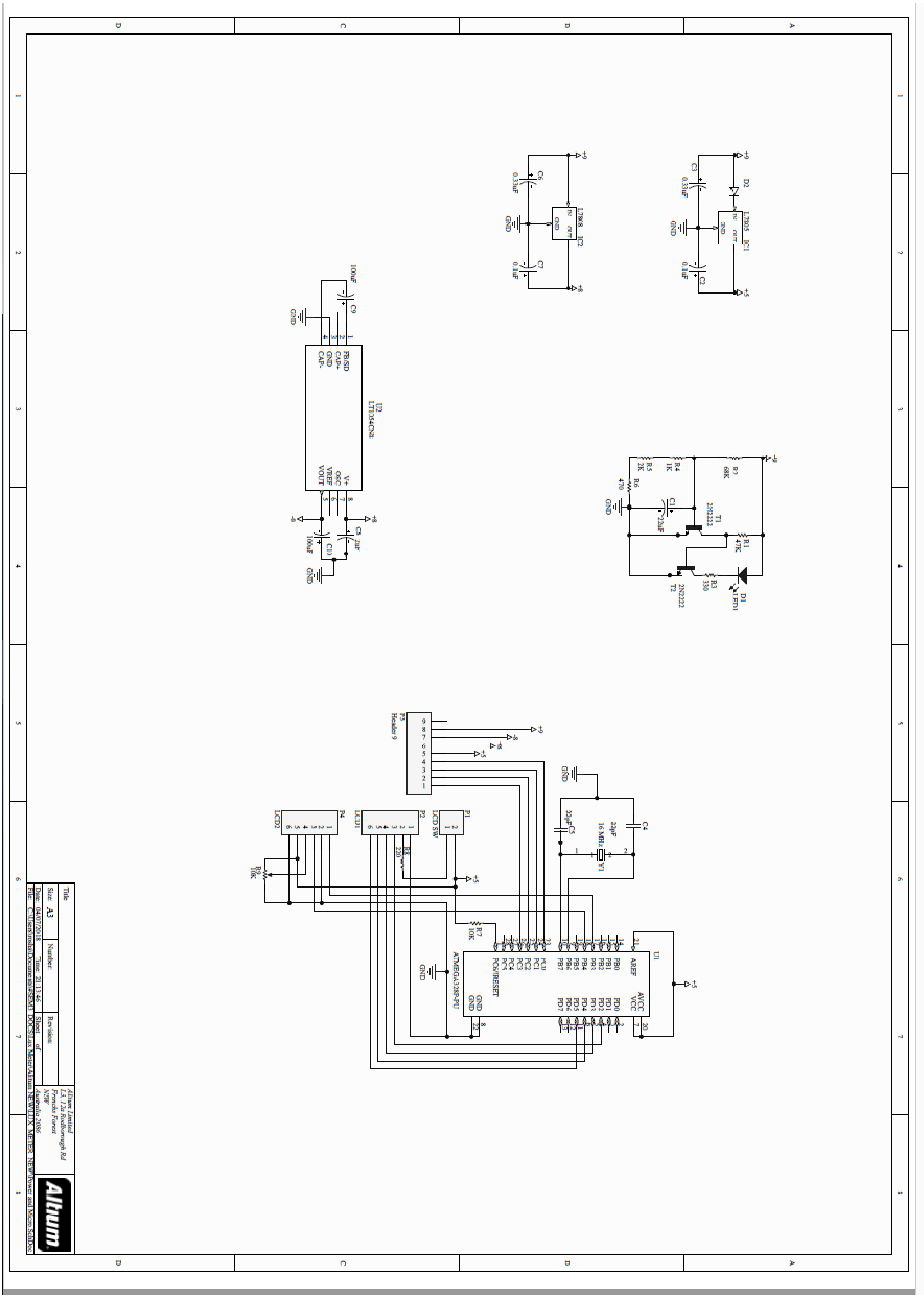
III. http://www.ti.com/lit/ds/symlink/lt1054.pdf
IV. http://www.analog.com/media/en/technical-documentation/data-sheets/AD620.pdf
V. https://www.arduino.cc/en/Tutorial/HelloWorld
VI. https://www.arduino.cc/en/Hacking/PinMapping168

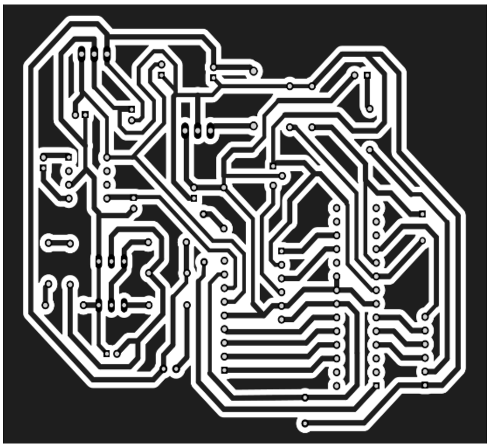
8. APPENDICES

8.1 Circuit Diagrams

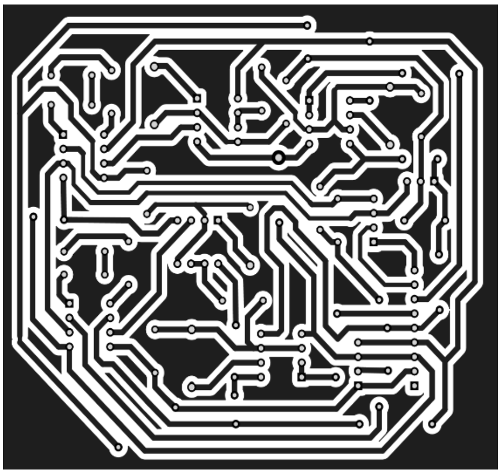




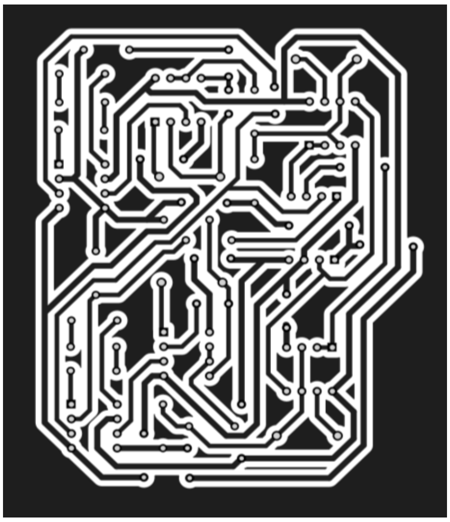
8.2 PCB Layouts



Microcontroller & Power supply

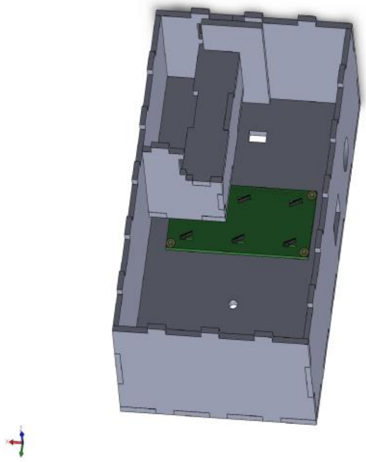


Amplifier Circuit 1

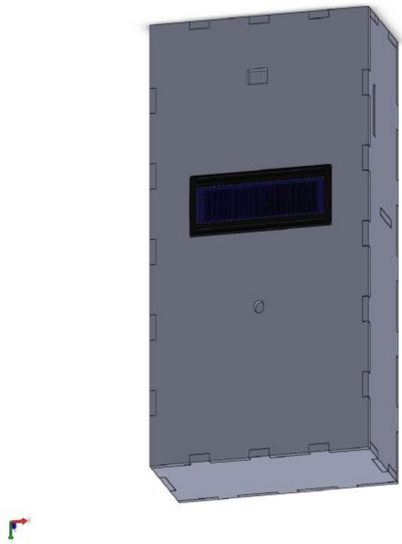


Amplifier Circuit 2

8.3 Enclosure Designs



Internal View



External View

8.3 Code

```
// include the library code:
#include <LiquidCrystal.h>
// initialize the library by associating any needed LCD interface pin
// with the arduino pin number it is connected to
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;
LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

void setup() {
 // set up the LCD's number of columns and rows:
 lcd.begin(16, 2);
 Serial.begin(9600);
 // Print a message to the LCD.
 lcd.print("Hi");
 pinMode(A0,INPUT);
 pinMode(A1,INPUT);
 pinMode(A2,INPUT);
 pinMode(A3,INPUT);          }

void loop() {
 // set the cursor to column 0, line 1
 // (note: line 1 is the second row, since counting begins with 0):
 lcd.clear();
 int a=analogRead(A0);
 int b=analogRead(A1);
 int c=analogRead(A2);
 int d=analogRead(A3);
 int tot=a+b+c+d;
 //Serial.println(a);
 float A=(tot+1)/1024.00*5/4;
 //Serial.println(A);
 int ans= A*500;
 Serial.println(ans);
 lcd.setCursor(0, 0);
 lcd.print(ans);
 // print the number of seconds since reset:
 lcd.setCursor(0, 1);
 lcd.print("Lux");
 delay(500);          }
```