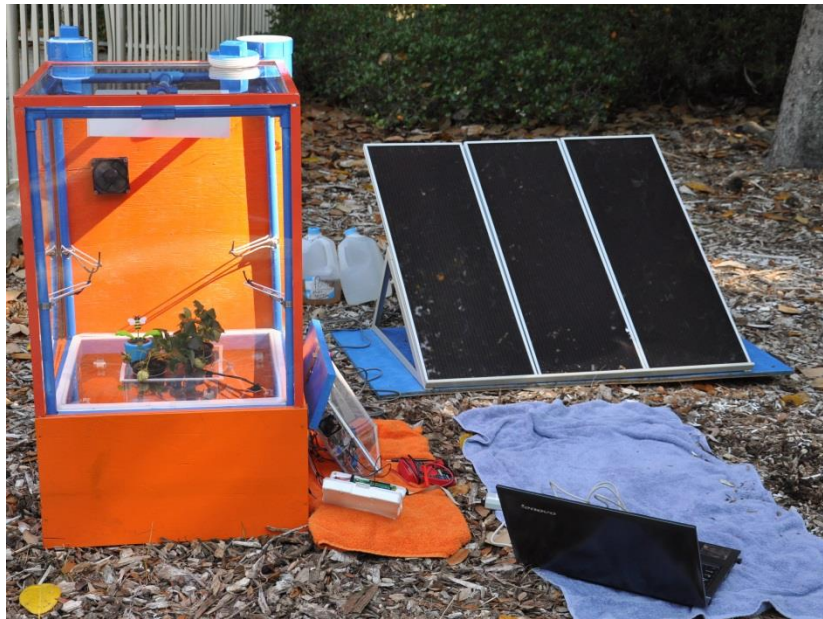


EEL 4924 Electrical Engineering Design 2 (Senior Design)

Final Design Report

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Project Title:
Hydrotronic Greenhouse

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Project Abstract

The goal of our project is to create an automated greenhouse that can be sent to the Moon or Mars on an expedition that plans to start a colony on either. A LCD screen will be used as a user interface on the greenhouse, but a XBee wireless module is used to remotely check on its status and to send commands. The greenhouse will have a solar panel that will charge the batteries that power it. To avoid having to transport soil into space, the plant will be grown hydroponically in the greenhouse. The greenhouse will control the amount of light the particular plant species that is being grown requires. The nutrient levels will also be regulated based on the plant type to avoid over absorption of nutrients into the roots. A solenoid valve will open to allow more nutrients to flow into the hydroponic solution and a pump will circulate this solution. The temperatures on Mars vary greatly from day to night much like a desert on Earth, only Mars receives a little less than half the light Earth does from the Sun. Therefore we plan to monitor the temperature of the greenhouse and will have a fan to blow hot and or humid air out, if either are over a preset value. The greenhouse will also have a water tank attached and a water sensor to ensure that the water level stays consistent. We plan to have a humidity sensor as well. For demonstration, we will be using a hydroponic nutrient solution.

Introduction

The Hydroponic Greenhouse's main application is to be sent into space to provide food and to lead towards the terraforming of either the Moon or Mars. The goal of our project is to create an automated greenhouse that can be sent on an expedition that plans to start a colony in space. The greenhouse will be responsible for monitoring what is most vital to growing a plant, temperature, water and nutrient levels, and amount of light, making the optimal adjustments based on the plant species.

The purpose of this project is to have the capability of growing plants in space without requiring much attention from the space colonists. The basics needs of plants and what need to be monitored include the following:

- **Water**
 - Water is the medium that plants use to absorb nutrients and to transport these nutrients from the roots through the stem and into the leaves.
- **Nutrient**
 - Plants need nutrients like we need food, and like humans need vitamins there are many micronutrients plants also need to grow healthily. Without some nutrients the plant may not grow at all.
- **Light**
 - Plants need light for their photosynthesis cycle to generate their energy to grow.

- **Temperature**
 - Most plants thrive within a range of temperatures that they are native to.
- **Humidity**
 - Most plants do best in humid environments, but also can't thrive in 100% humidity. When water evaporates off the leaves it pulls nutrient rich water from the roots to the leaves - a plant pump. Humidity can also lead to mildew and rot.

Competitive Products

There are several automated greenhouse varieties on the market none of which are under \$1000 for a completely automated grow system and none of which subsidize some of their power off solar. SuperCloset is one such company. Our automated greenhouse will be able to do all of this for cheaper and has the possibility of being retrofitted with an atmosphere module to regulate the atmosphere of the greenhouse for use on other planets or celestial bodies.

Project Features

The Hydrotronic Greenhouse will be able to grow plants autonomously or manually.

- Adjust LEDs to control light received in addition to the sun.
- Adjust the water level to keep the plant properly watered
- Real-time clock will control the timing of the system
- Control the amount of nutrient the plant receives
- Control air pump to oxygenize the water
- Turn on/off a fan to regulate temperature and humidity
- Solar panels to power and charge batteries

Concept/Technology

- **TI MSP430**
 - This microprocessor was chosen because it is cheap, low power, and we are familiar with it. It also has room for expansion in case we want to add more sensors or valves or anything else that strikes our fancy.



Figure 1: MSP430 Control Board

- **XBee 1mW Trace Antenna – Series 1 (802.15.4)**
 - XBee allows the greenhouse to be remotely monitored and controlled from a computer a short distance away.
- **Real-Time Clock – PCF8563**
 - A separate real time clock allows a low power solution to keeping time and will not tie up the microprocessor. Interrupts are sent from the real time clock at set chosen intervals to signal the lights on or off or to check the sensors.
- **3X 15W Solar Panels from Harbor Freight**
 - 45 watts of solar power will cover the current needs of the greenhouse as well as charge the batteries when there is full sun out.



Figure 3: 12V 24Ah Yuasa battery



Figure 2: 45W Solar Panel Array

- **2X 12V batteries**
 - The greenhouse will be powered by a pair of Yuasa 12V 24Ah batteries
- **HTM2500 Humidity/Temperature Sensor**
 - This sensor allows us to measure the humidity and temperature with high accuracy.
- **Voltage Regulators – 5A adjustable LDO Voltage Regulator – LM338T**
 - For 15V, 5V, and 3.3V regulation on power board. We chose to use a linear voltage regulator to make a simple modular power supply that could handle high currents and largely varying loads. Given more time, switch mode regulators would have been a great choice for the larger voltage drops in order to increase the power efficiency of the greenhouse.

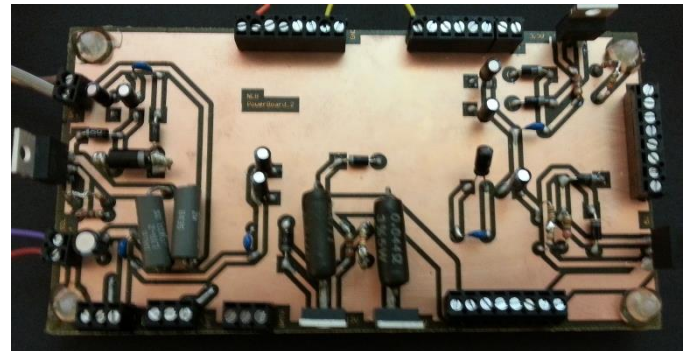


Figure 4: Completed Power Board: Solar charging circuit on the left with outputs for the battery voltage, regulated 12V, regulated 5V and regulated 3.3V

- **16x2 Serial LCD 5V**
 - Want to save pins on microprocessor. Will be used as display at the plant and for some manual configuration also at the plant.
- **X27 1W LED's**
 - X15 1W Red 630 nm X12 1W Blue 450 nm LEDs. Current research shows that these ranges are the light that plants need throughout their growth process. The LED arrays will be modulated depending on the light hitting the plant from the sun to meet the plant's light needs.

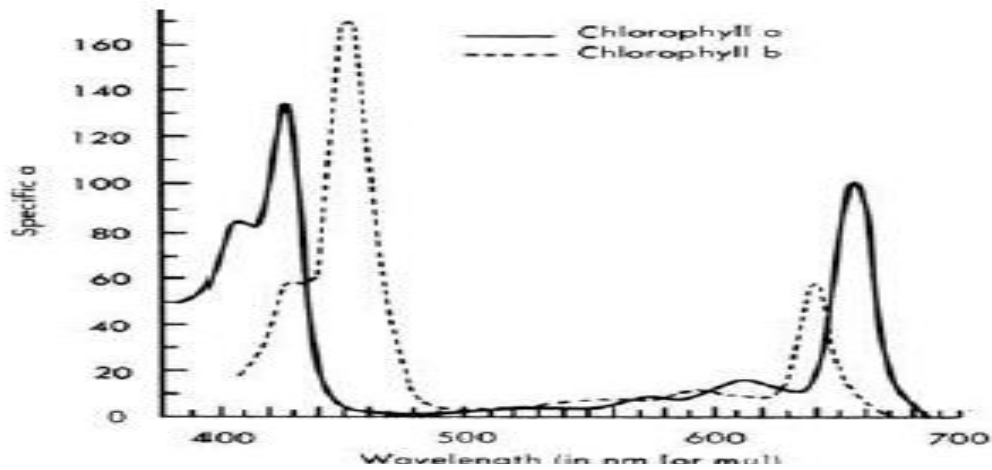


Figure 5: Graph of the Absorption of Chlorophyll a and b with respect to wavelength of light. "The final analysis is that the most successful growth is found at 420nm, 450nm, 630nm, and 660nm wavelengths" From: <http://www.blackstarled.com/102bl2wch.html>

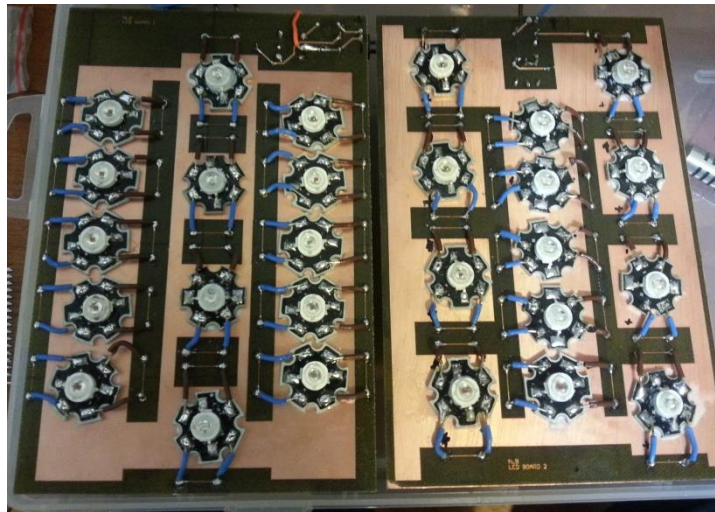


Figure 6: Completed LED boards

- **X2 Solenoid Valve – 0 psi capable**
 - Solenoid valves that can operate down to 0 psi so nutrients and water can be gravity fed.
- **Air pump and Air Stone**
 - Low power aquarium DC air pump. The air pump will pump through the air stone to keep the water oxygenated.
- **12V Solid state relays – IRLZ14PB-ND**
 - Power N-fets for solid state relays allow the microcontroller to turn on high power appliances like the LED's and the air pump. Thought about using optically isolated solid state relays, but they were slightly higher power, more expensive, and proved unnecessary after testing with the mosfets and seeing no significant change to the data signals being read in to the microprocessor.

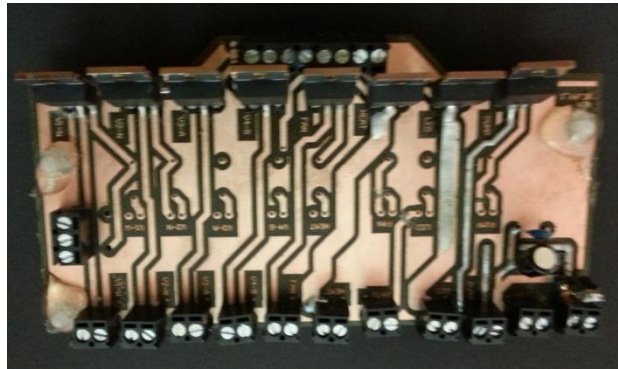


Figure 7: Completed Relay Board: Receives outputs from the microcontroller to control the higher current appliances of the greenhouse.

- **X4 Photoconductive Photocells – PDV-8104**
 - Measure light and determine how long led's need to be on to compensate for lack of sun. The four sensors will be averaged and the amount of light hitting the array will control be read into the microcontroller and the LED's will be modulated to have the light output adjusted to the correct time of day and the plant's light needs.

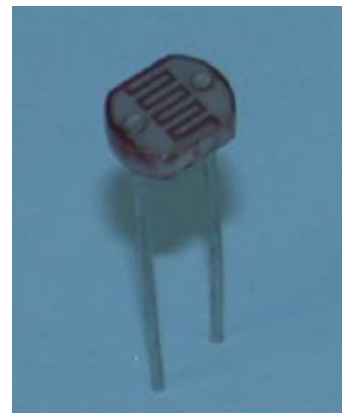


Figure 8:PDV-P8104

Project Architecture

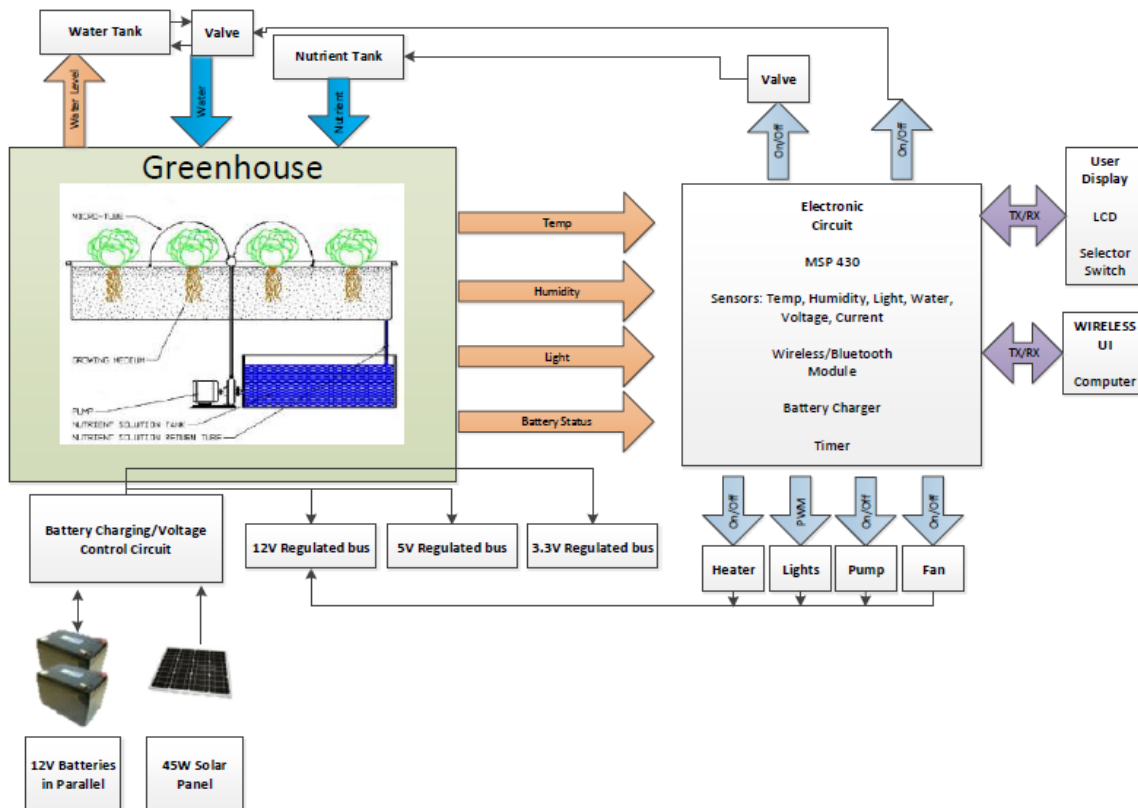


Figure 9: Block Diagram of the Greenhouse

Microprocessor

- MSP430 will monitor the sensors using an ADC. It will send out commands to adjust or control different parameters (ie. light, nutrient, water, temperature, ect) until they meet preset values. Figure 7 is a flow chart of how the microprocessor will control and monitor everything.
 - The MSP430 is being used because it is a very low power chip and that is how this system needs to operate.

Inputs

- The temperature and humidity sensor each output a voltage from 0 to 3V depending on the temperature and relative humidity of the air.
- The resistance of the light sensors changes with the amount of light incident on the sensor. Since the exact value of the resistance doesn't need to be known, but rather a range of values corresponding to full sun, partial sun, and darkness, a Wheatstone bridge is not necessary and the changes in voltage can just be monitored by using the resistor as part of a voltage divider and passing that voltage through an op amp to achieve a voltage range of 0 to 3V for shade and full sun respectively.

- The water level sensors either serve as an open circuit or a closed circuit depending if the water has reached the preset level.
- The timer chip sends an interrupt input to the microcontroller over i2c at times preset for checking the sensors or for turning on or off the LED lights.

Outputs

- The microcontroller outputs either a high or low, 3.3V or ground signal to the relay board to control the higher current and or voltage appliances that the microcontroller can't drive.
 - PWM will be used to control the intensity of the light to the plants when they are in partial sun or shade based on the input from the light sensor.
- A mux chip selects either the LCD or the XBee for the microcontroller to communicate with over UART. Data is then sent or received from whichever user interface is being looked at.

Power

- The 45 watt solar panels are regulated from 20V down to 15V where they keep the lead acid batteries floating at 14.3V after passing through a diode for protection of the charging circuit as well as to drop the voltage to a good charging level. The batteries can handle up to a 5A charge and the solar panels can't deliver that. The two batteries have a combined capacity of 48 Ah. In the worst case conditions with the solar panel not charging, the lights on for their full daily cycle, the fan and air pump on constantly, the greenhouse draws about 2 amps. The batteries would be able to last for a full day on this, but with the lights only on for a maximum of 8 hours a day, the power draw drops to around 1 amp worst case scenario. This would allow for around two days of zero sunlight charging the batteries before they began to fail.
- The 12V battery voltage is regulated down to 5V for the mux chip, LCD, and the temperature and humidity sensor. The 5V is then regulated down to 3.3V for the microcontroller, the XBee, the real time chip and the air pump.

Flowcharts and Diagrams

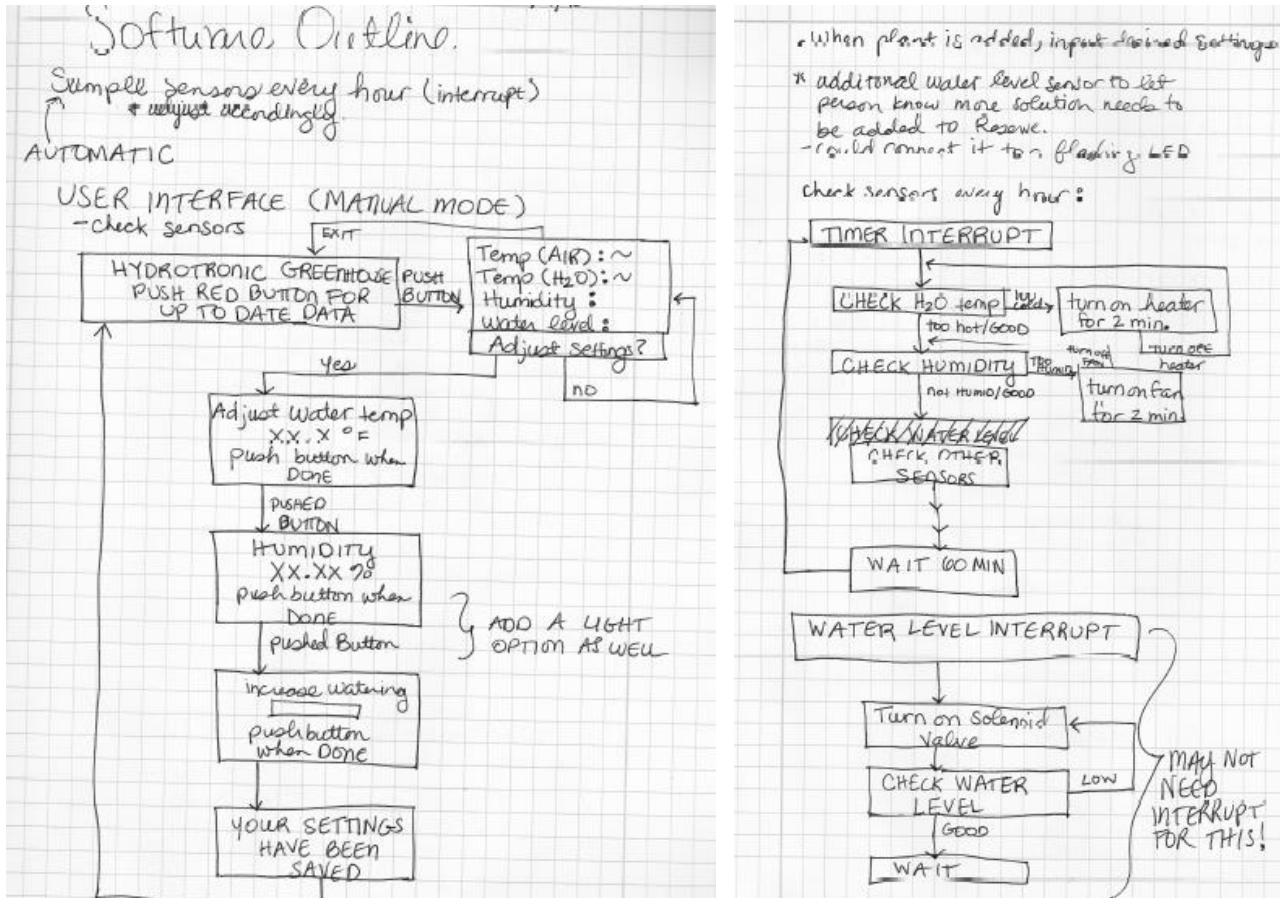


Figure 10: Software Flowchart

The software is written in a way that allows the microcontroller to be idling in a low power mode while it is waiting to check the sensors. The MSP430 waits for an interrupt from the real time clock. When it receives the interrupt it checks each of the sensors and compares the value to a preset or user defined value for that sensor. If the sensor is outside of the parameters then the valid periphery is turned on or off to assess discrepancy in the sensor value and desired condition in the greenhouse. The user can communicate the values through the XBee from a computer at a distance. The only nuance of this low power saving mode is that the LED's were not attached to a PWM line of the microcontroller and if the LEDs need to be modulated to reduce their output the microcontroller must do this through toggling a gpio pin and will no longer be idling in low power mode. This is somewhat countered by the thought that the LEDs are using less power during this mode of operation. If the board were redesigned the LEDs would be on a PWM output line.

Distribution of Labor

Sarah was responsible for the main PCB design and microcontroller programming as well as XBee communication and the real time clock. She has worked with Altium extensively and her computer engineering background makes her best suited to do the necessary program in order to save time.

Nolan was responsible for the design of the power board, relay board, signal conditioning board, and LED boards. He was also responsible for the physical design and assembly of the greenhouse.

Both members were responsible for research, circuit design, as well as testing and debugging of the sensors.

Bill of Materials

Description	Manufacturer	MF#	Supplier	Datasheet	Supplier #	Link	Price	QTY	Total
Temperature sensor	TI	LM-335	Mike	LM-335	LM335Z/NOPB		0.96	1	0.96
Wireless XBEE kit			Sparkfun	XBEE	Sparkfun	Pinout	100	1	100
Humidity/Temp Sensor	measurement sp	HTM2500	Mike	HTM2500				1	0
LCD	Sparkfun	ASM1602U	Mike	ASM1602U				1	0
12 Vdc Normally Closed Soleno	American Science	B007D1U64E	EBAY		BBTF-CD-12VDC		3.25	2	6.5
1W LEDs(red)	CHINA	620nm	EBAY	LEDs			0.33	15	4.95
1W LEDs(blue)	CHINA	460nm	EBAY	LEDs			0.5	12	6
12V Air pump			Amazon				12.36	1	12.36
Water level sensor	Sourcingmap	ZP3208-P	Amazon	Plastic Float	B005FDT02Q		5.22	2	10.44
Photocell Light sensor		PDV-P8104	Digikey	PDV-P8104			0.8	4	3.2
12V Fan	Gino	12V DC 80mm	Amazon	DC 12V Blac	B007PPETQO		5.39	2	10.78
Adjustable Voltage Regulator	National semicon	LM338T	Digikey	LM338T			2.01	5	10.05
Power N-Fet	vishay	IRLZ14PBF-ND	Digikey	IRLZ14PBF-ND			0.91	8	7.28
Op Amp	Microchip	MCP6002-I/P-ND	Digikey	MCP6002-I/P-ND			4	0.36	1.44
MSP430	TI	MSP430F2278	Digikey	MSP430F2278			6	1	6
PCB terminal 2h			Digikey				0.35	6	2.1
PCB terminal 3h			Digikey				0.45	4	1.8
PCB terminal 7h			Digikey				0.9	2	1.8
PCB terminal 8h			Digikey				1.15	1	1.15
PCB terminal 2h blue			RadioShack				0.55	4	2.2

.002Ω Shunt Resistor			design lab		0.5	5	2.5
0.03Ω LED Resistor			Digikey		0.3	5	1.5
10kΩ Resistor			design lab		0.05	10	0.5
0.1uF Capacitor			digikey		0.3	4	1.2
mux chip	motorola	MC74F157AN	digikey	MC74F157AN	1.12	1	1.12
toggle switch			Radioshack		2	2	4
10kΩ potentiometer			design lab		1.25	3	3.75
Diode		1n4001	digikey		0.28	8	2.24
Diode 3A		IR0211	design lab		0.9	1	0.9
Wood			Lowe's		35	1	35
PVC pipe/sealant			Lowe's		40	1	40
Plexiglass/sealant			Lowe's		100	1	100
Aluminum Angle Iron			Lowe's		6	2	12
Airstone			Petsmart		7	1	7
Paint			Lowe's		25	1	25
						Total	425.72

Figure 11: Bill of Materials

Gantt Chart

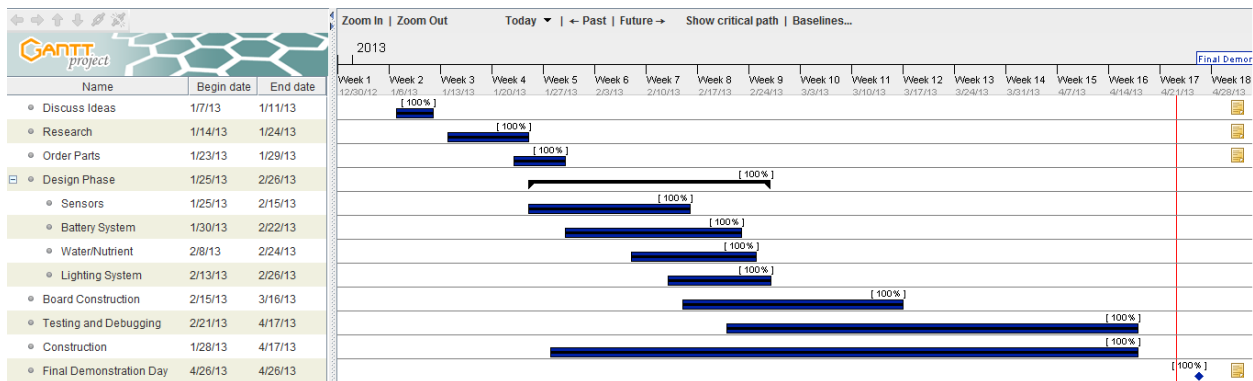


Figure 12: Gantt Chart

Appendix A Schematic Diagrams

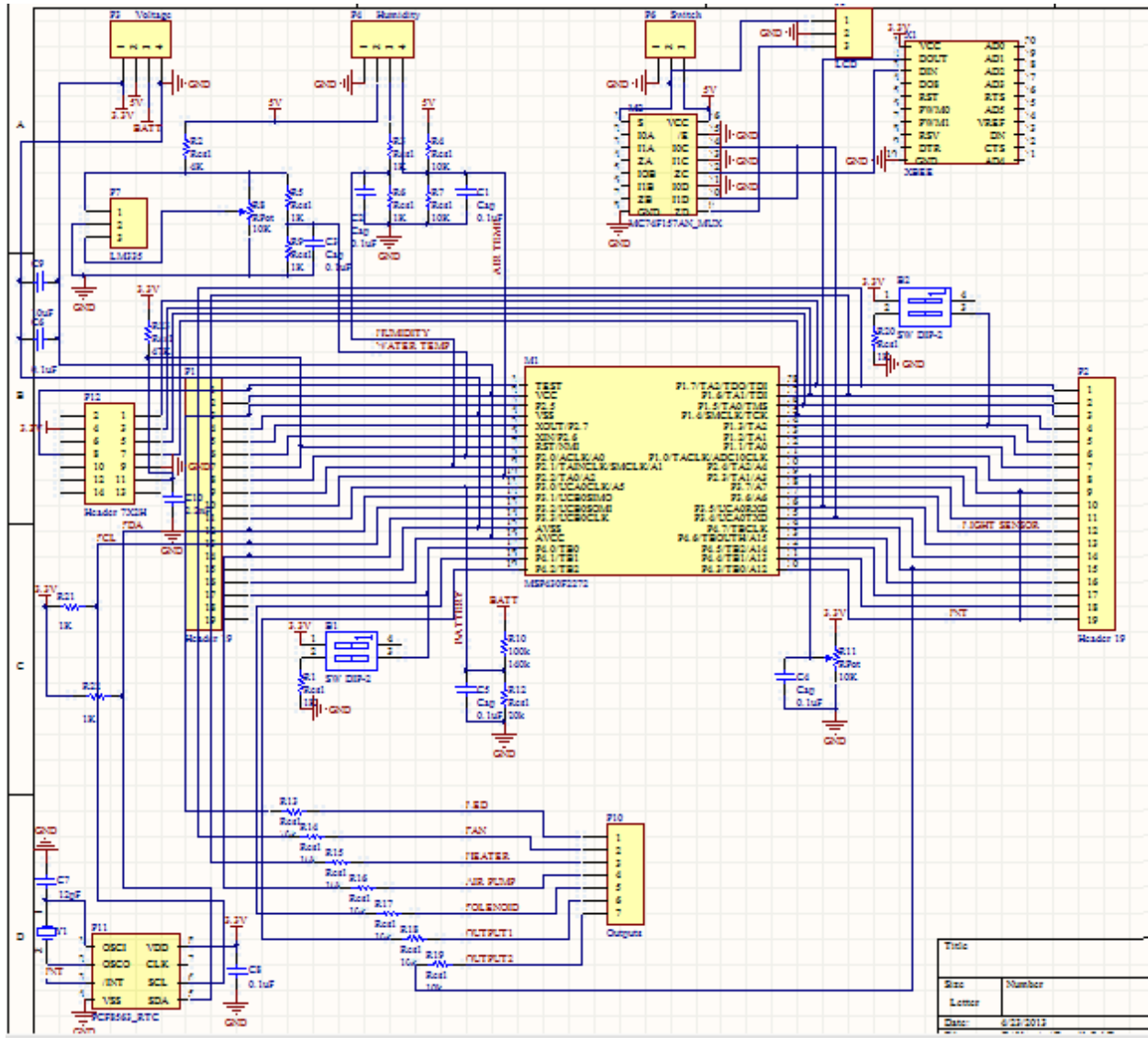


Figure 13: Main Control Board Schematic

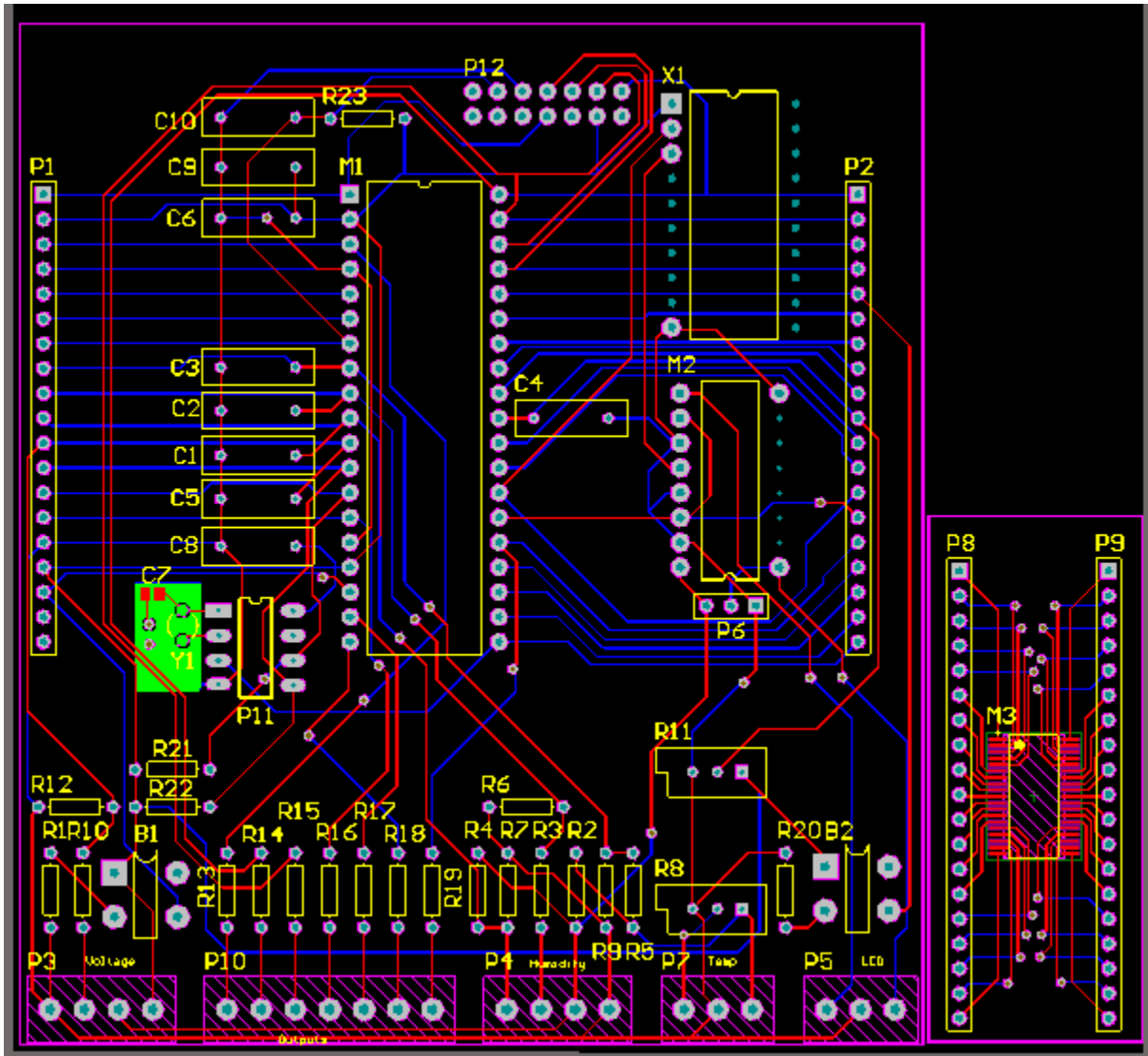


Figure 14: Main Control Board PCB

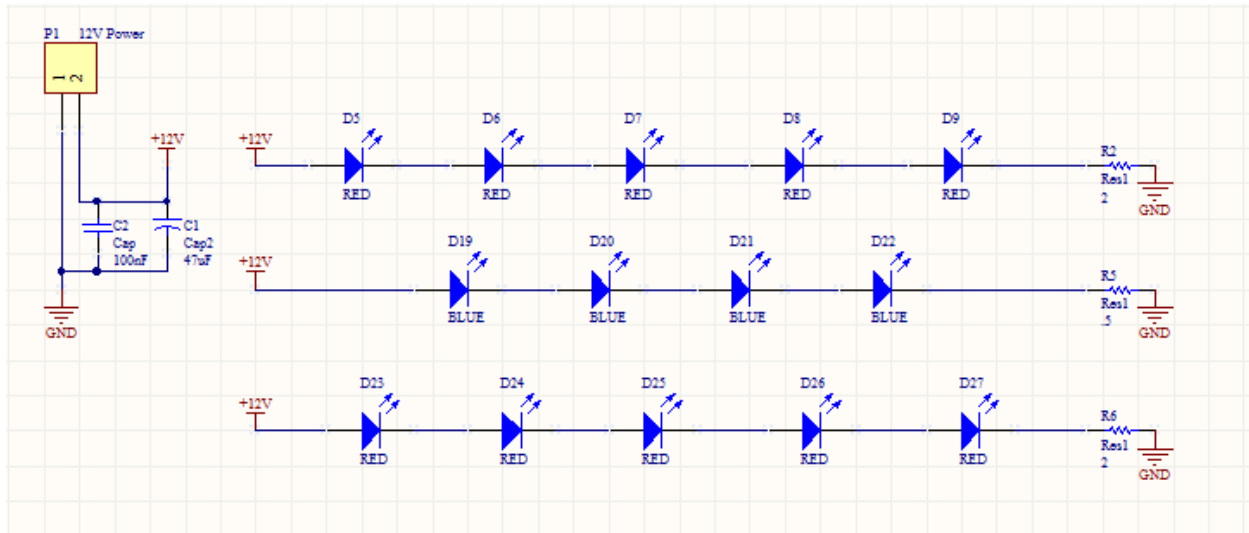


Figure 15: LED Board Schematic

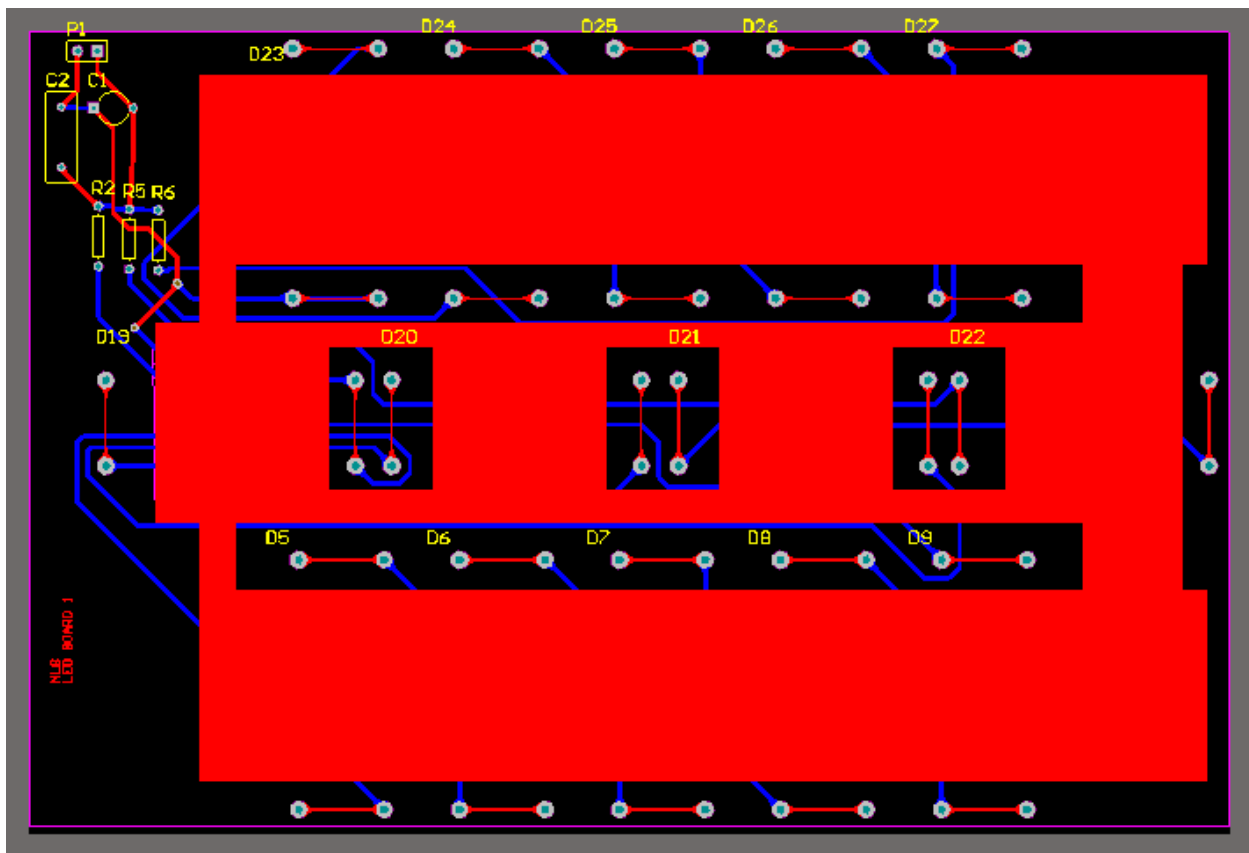


Figure 16: LED Board1 PCB

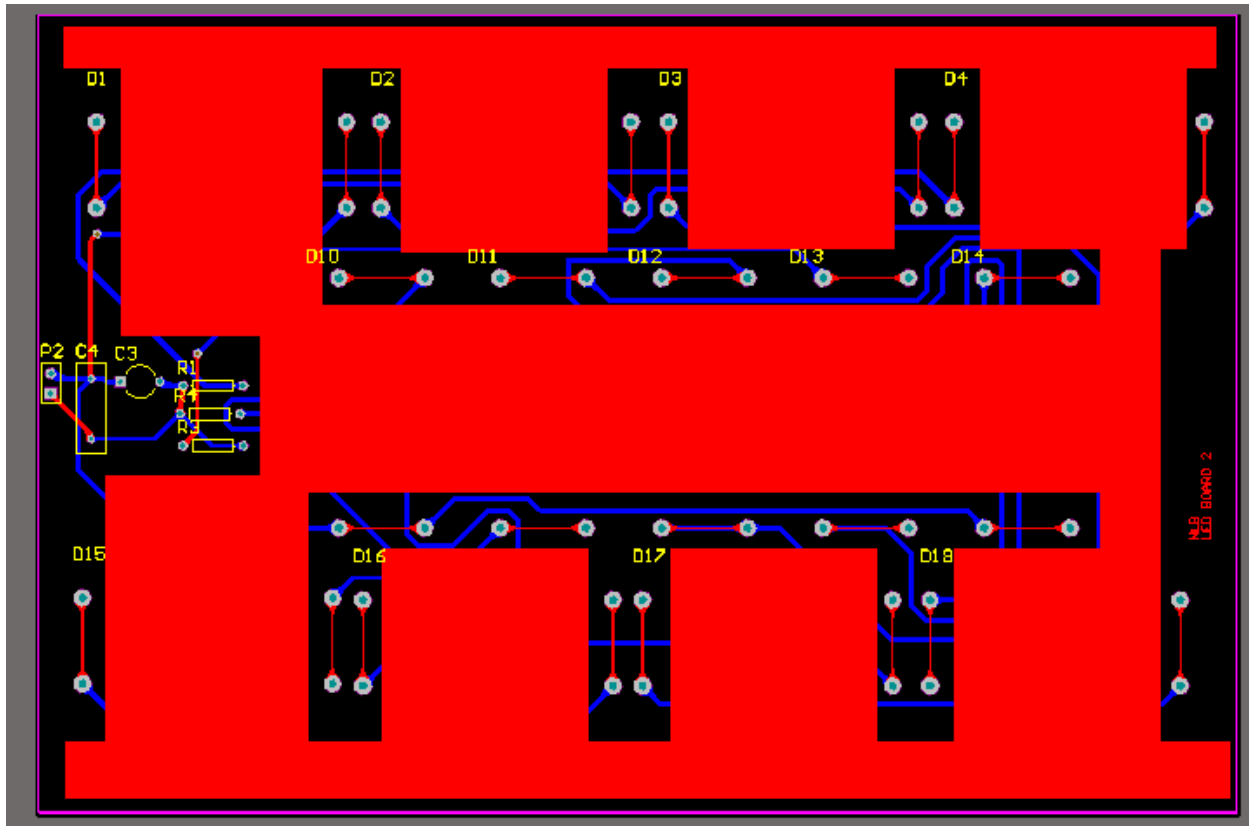


Figure 17: LED Board2 PCB

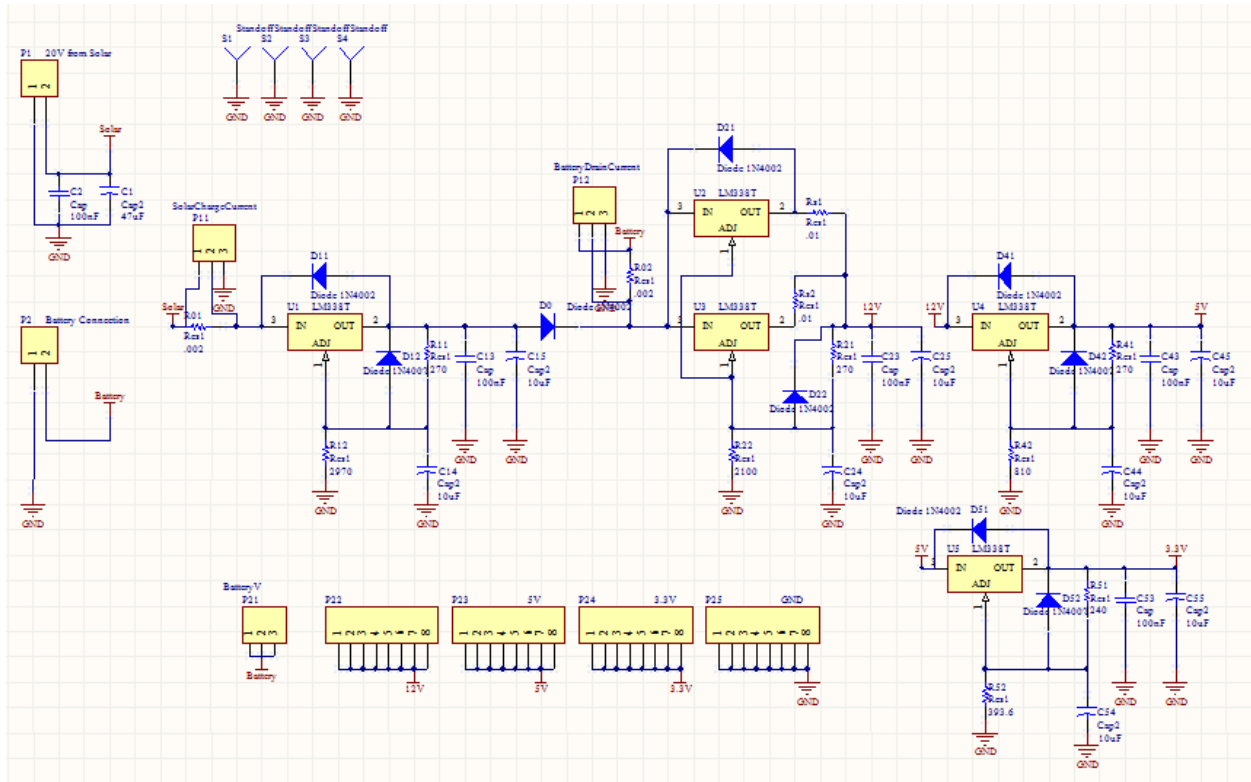


Figure 18: Power Board Schematic

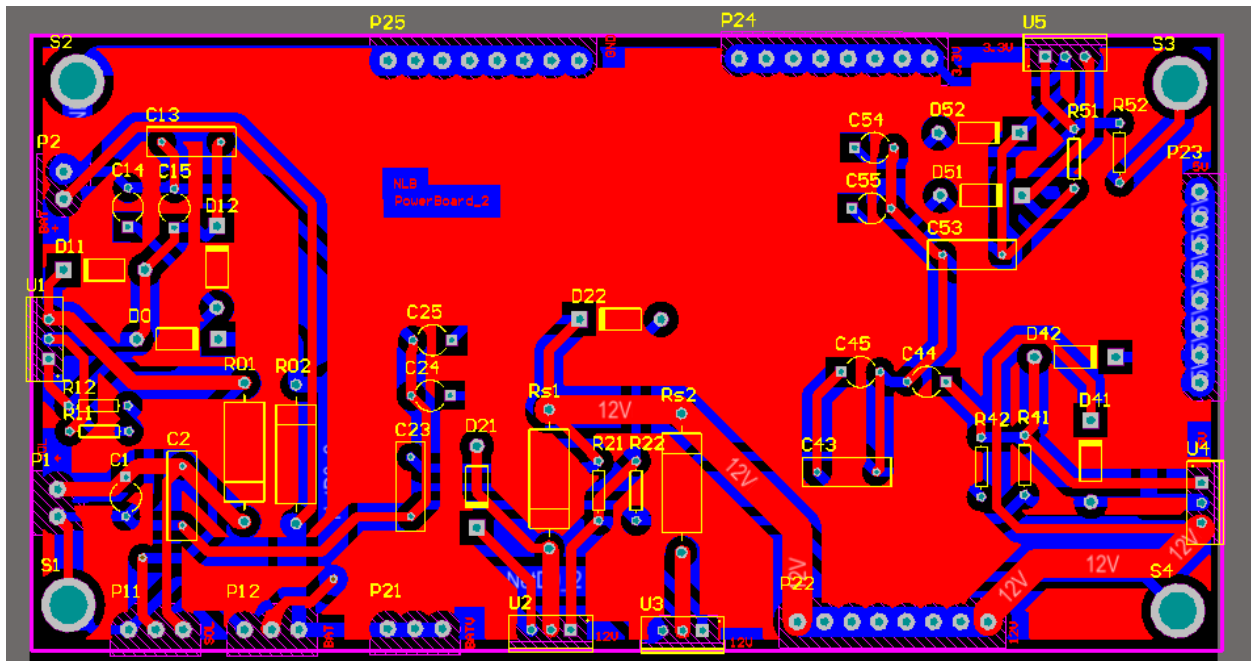


Figure 19: Power Board PCB

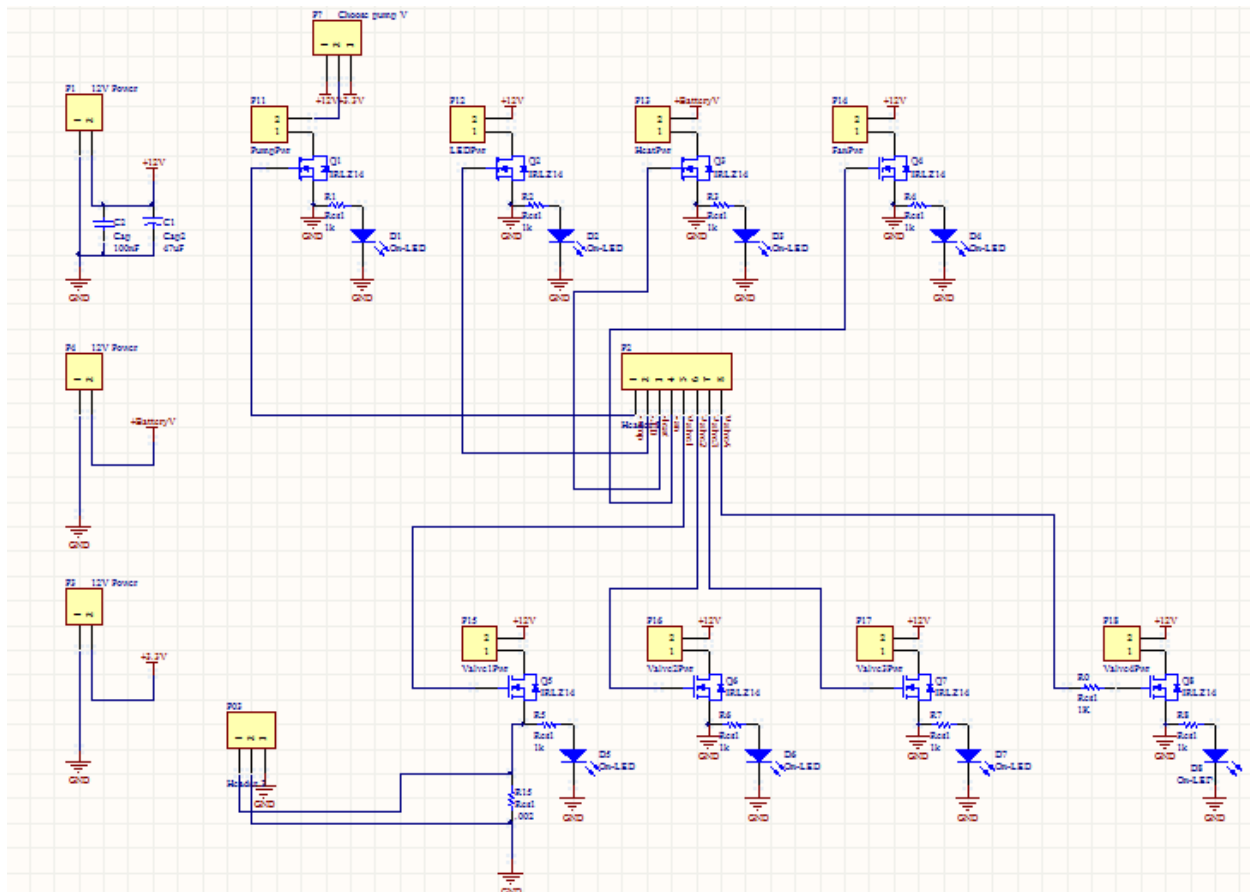


Figure 20: Relay Board Schematic

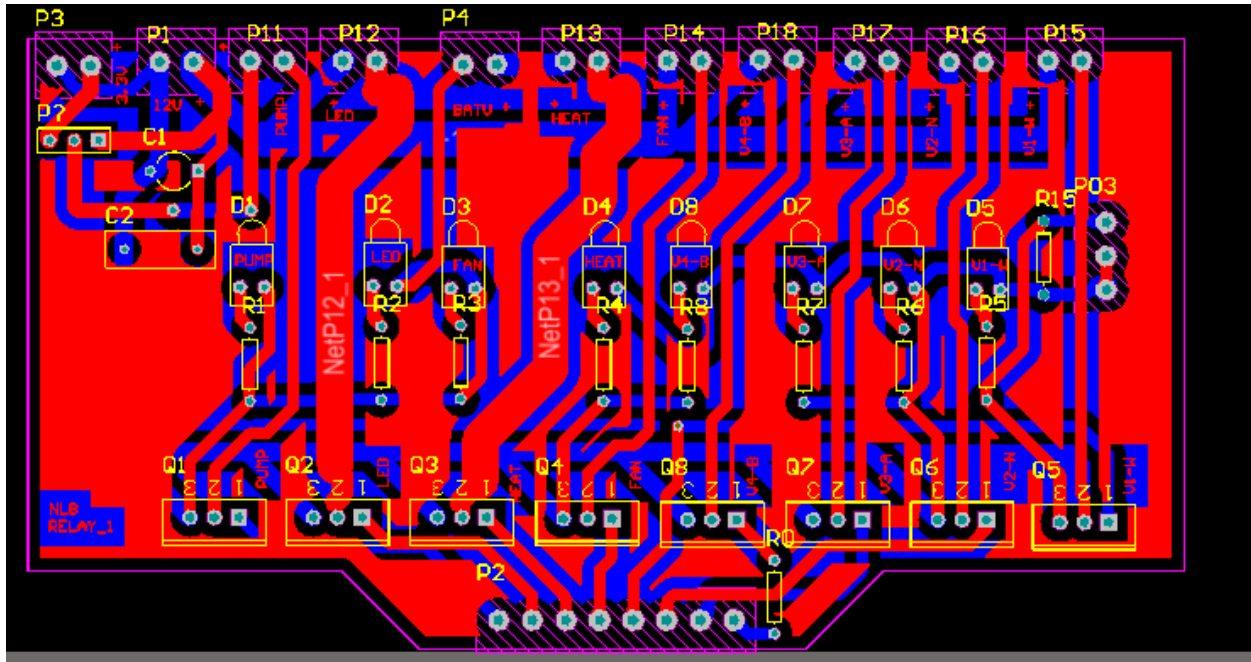


Figure 21: Relay Board PCB

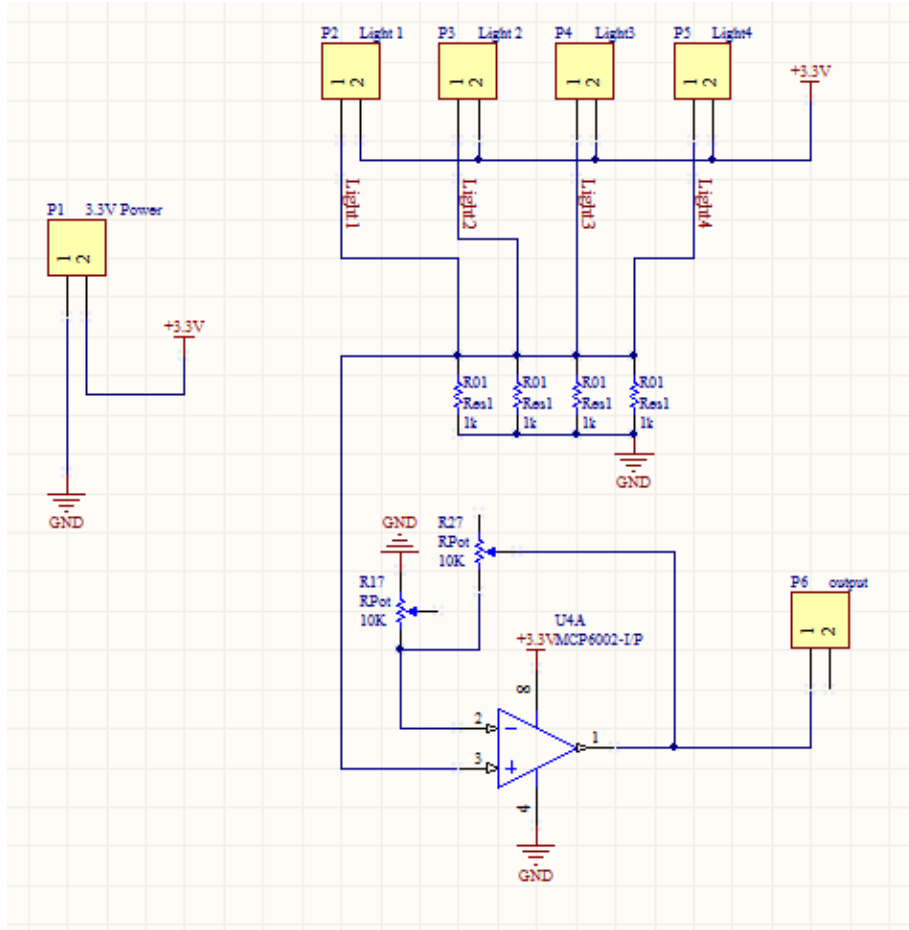


Figure 22: Signal Conditioning Board Schematic

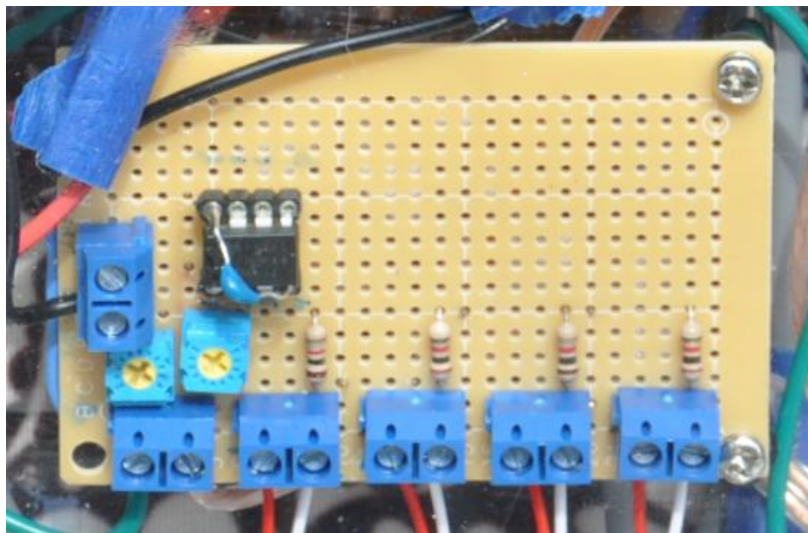


Figure 23: Signal Conditioning Board PCB