Climate Control Grow Box

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Abstract

In this project we worked to create a Climate Controlled Grow Box. To do this we wanted to maintain control over the system's humidity, lighting, and the amount of water received by the plant. By using a variety of sensor inputs we were able to control when the power went to each of these systems, and to change the operation based on the current conditions.

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1. Introduction

1.1 Problem

Many houseplants struggle to survive due to the indoor environmental conditions they are brought into, which often do not match their specific climate needs. Often times these plants which may not be native to the region even if they could benefit from the natural climate control of the new location by boeing planted outside often have to deal with the indoor environment where factors like too high or low humidity levels, excessive or lack of lighting, and water availability all contribute to a plants deteriorating ability to thrive or even the plants death.

1.2 Purpose

The goal of this project was to design a box which could work as an indoor environment for plants.Our solution is to design a small climate controlled grow box that is designed with the space constraints of a typical residential home. This box will have the ability to regulate and modify the current humidity percentage, airflow through the enclosure, light intensity levels, along with watering amount. By controlling these variables we can create a better suited environment for the plant than that provided by the average interior climate for the plants being grown. We will do this by having Humidity Control, Lighting Control, Water Control, Power control, and a control subsystem that will work together to create a small self contained climate.

1.3 Report overview

This report will go over the key points of this project's creation first starting with the design of the subsystems integrated within the project, why we chose them, and what we learned when designing. Next we will cover our verification stage where we will explain some of the steps taken to verify the previously designed subsystems worked as expected and if not why not. Additionally we will be explaining the costs associated with this work before discussing our accomplishments and future work in the summary.

2. Design

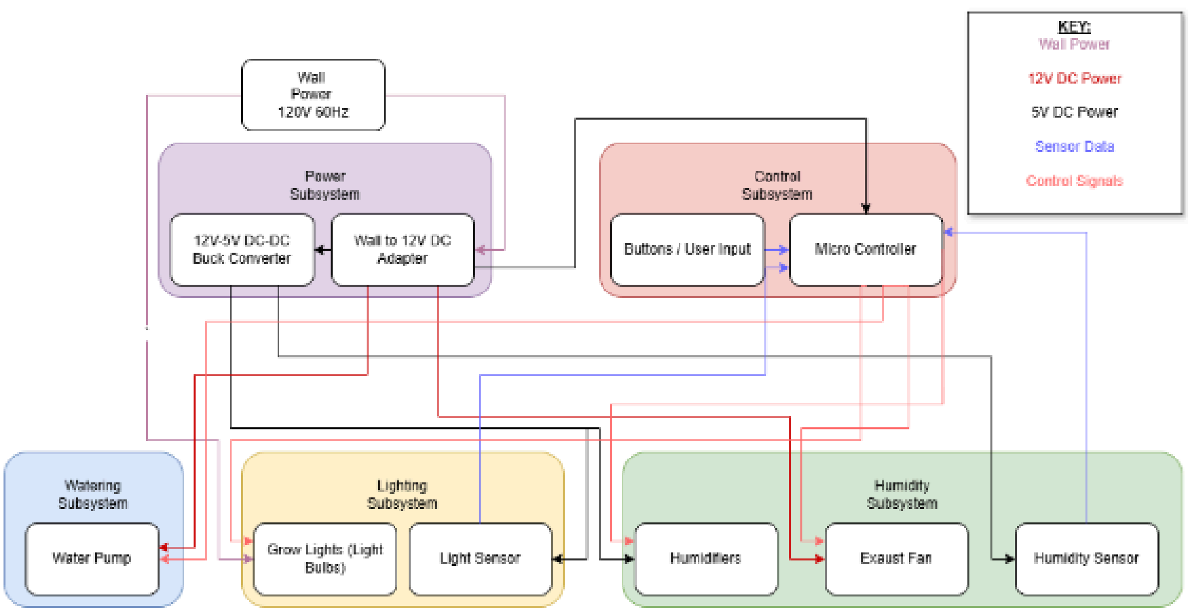

Figure 1: Block Diagram

2.1 The Control System

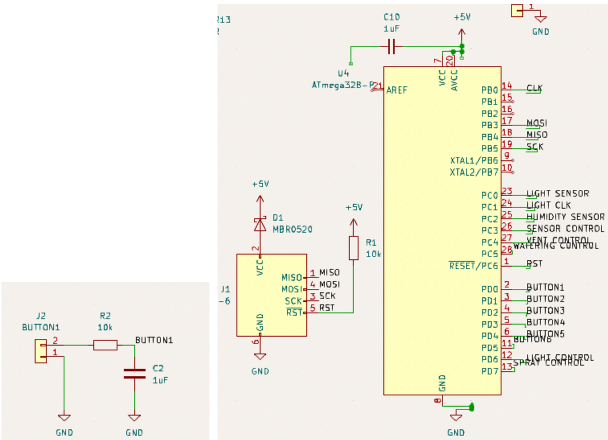

Figure 2: Control PCB

This subsystem consists of an ATMega328P microprocessor, buttons used as user input, and the connections to the light and humidity sensors. The ATMega328P accepts inputs from the buttons and the sensors to be sent through a logic flow and conditionally output signals to the power system's buck converter as well as mosfet controls to control the other components in the system.

2.1.1 Control Design Logic

On startup the control system's code starts the output signals to the lowest initial state, low humidity, low, light, low water. Then using the buttons the user can increase these states as desired for the plant's needs. This updates internal variables that will be used to redefine reference points from a set group of parameters, for the humidity or light sensor data to determine if a new output state is needed.

2.2 Humidity System

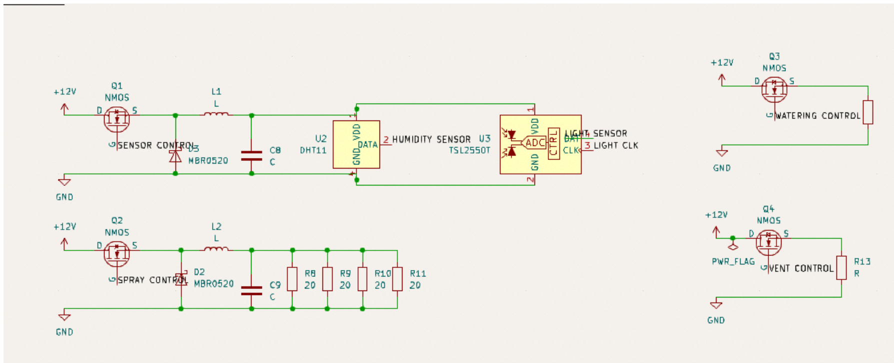

Figure 3: Humidity PCB

The Humidity subsystem's goal is to control the relative humidity level within the box. This subsystem contains a four inch 12V DC Vent Fan, a set of four 5V Atomization Disc humidifiers that fill from the water reservoir, and a DHT22 Temperature and water sensor to monitor the current conditions. The humidity sensor reads the current humidity within the enclosure and sends the data to the control system. The sprayers which add humidity to the box or turn on the vent to remove humidity by circulating the air.

2.3 The Lighting System

The point of the lighting system is to ensure that the plants have an adequate amount of light. The light sensor detects the amount of light which the system is seeing in Lux(lumen per square meter), this value is compared to the value which is selected by the user input. When the value in Lux is lower than that desired value the system will turn on the lights, when the Lux value is higher the lights will turn off.

2.4 Power System

The different units of our project required different voltage levels as an input, and due to the fact that these systems will operate at a higher power level we choose to build our own DC-DC buck converter to reduce the input 12 volts to the desired 5 volts. This converter was chosen because it is easier and safer to construct compared to a boost converter going from 5 volts to 12 volts.

When designing the system, we chose to use a simple buck converter controlled by a switching frequency added into the MOSFET. As long as there is a consistent current flow in the inductor the duty ratio for the system is the desired voltage divided by the input, in this case it is 41.667%, or 42%.

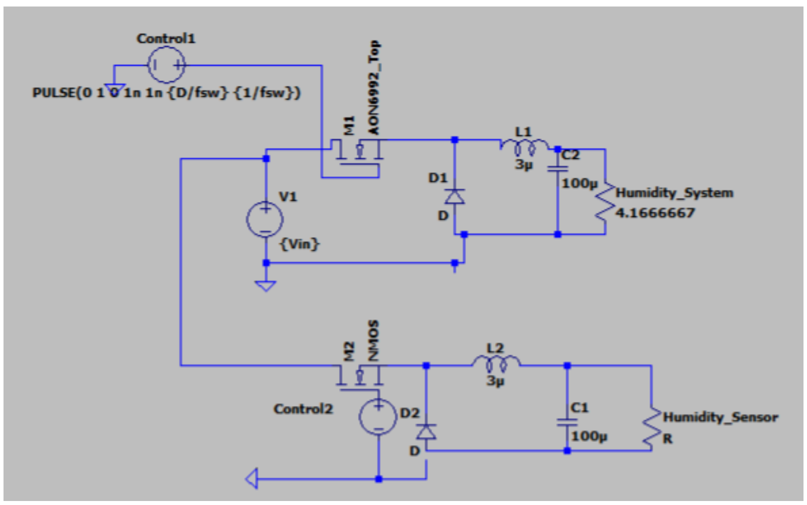

Figure 4:Power Schematic

2.5 The Watering System

This system has only two major components: a water pump with tubing connecting its inputs and output to a water reservoir that is shared with the humidity subsystem and the plant enclosure respectively. The water pump is activated by the control subsystem and will be programmed to release 1/4 cup of water increments at a determined time interval as set by the user. The control system is also responsible for determining the time needed to run the pump to reach this volume of water distributed.

2.6 Design Flaws

One of the issues in the operation of the whole system was due to the fact that the MOSFETs which were selected were made for systems which operated at 100 volts. This meant that they required a larger current to turn on current compared to MOSFETs which were made to handle closer to 20 volts. The main reason at the start that we chose the larger MOSFETs was due to them being able to handle the higher currents that the system would pull. This did cause issues in running the processor, we attempted to add the gate drivers which we were going to add to the control onto the lighting system. The 12V input from our power source was not enough to fully operate the gate drivers effectively due to the drivers requiring a higher input to operate as desired.

When we were attempting to control the power system there was also a period of time where we had inverted the duty ratio. Instead of providing a wave that was on for 20% of the time and off the rest of the time , the wave was on 80% of the time and off for 20%. This caused our inductor's core to saturate due to the high current. This was caused by the increase of current within the system due to the higher duty ratio. The core saturation went unnoticed in the later tests, but we noticed when results differed with a new inductor.

3. Design Verification

3.1 Power System

The primary goal of the power system was to maintain a 5V DC value, with a ripple of less than 5%. So the system stays within the range 5.25V and 4.75V. The system operated at an average of about 5.1V and we saw a ripple of 300mV, this kept us in the desired ranges.

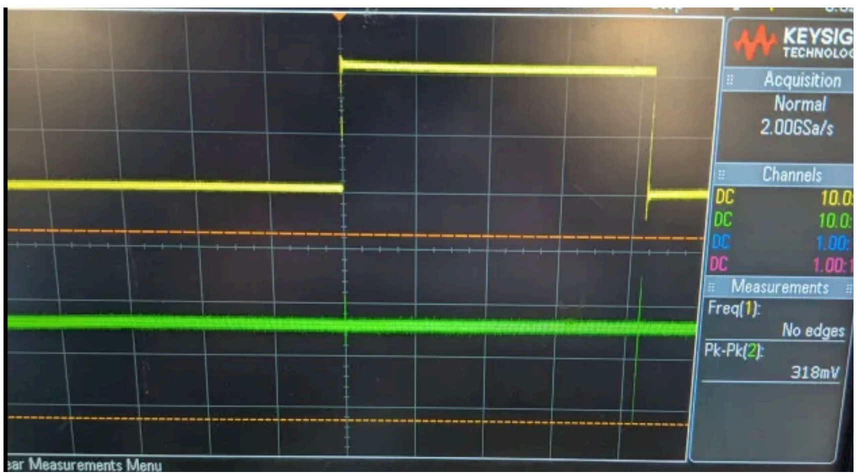

Figure 5: Readings from the oscilloscope of the power output(lower) and the cycle driving the Mosfet(upper)

3.2 Humidity

One of our requirements for the humidity subsystem was that "'We must be able to raise the humidity within the enclosure by 10% in comparison to the external humidity level" even though we were unable to test within the enclosure itself. However we were able to estimate the change in humidity by observing the change in water volume within a reservoir over a period of time, which I determined to be ten minutes.

	Water Before	Water After	Water dispersed in 10 minutes

Humidifier 1	47.5g	42.8g	3.6g
Humidifier 2	44.7g	39.9	4.2
Average water dispersed per humidifier			3.8g

With our final box having an internal volume of one cubic foot or roughly 0.028 cubic meters along with an average room temperature of 72° Fahrenheit (20° Celsius) we were able to do the following calculations to determine if thesprayers would have been enough to raise the humidity.

To calculate Relative Humidity (RH) from Absolute Humidity (AH) and temperature, use the formula assuming At this temperature the saturation point of the air is 2.34 kPa. :

RH = (AH / Saturation Vapor Pressure at given temperature) x 100

Absolute Humidity [AH] (g/m^3) = (Mass of Water Vapor (g) / Volume of Air (m^3))

where "Saturation Vapor Pressure" is the maximum amount of water vapor the air can hold at a specific temperature, and is typically found using a table or a formula based on temperature.

Our humidifiers can atomize water at a rate of 22.8 ml/h and with six of them active at once that provides approximately 91.2 g/hr of water being added to the air or 4-5 g/minute

22.8 ml/h * 4 sprayers = 91.2 ml/hr = 91.2 g/hr = 1.5 g/m

On the lower bound of 4g/m

$\Delta AH = 1.5 \text{ (g/min)} / 0.028 \text{ (m}^3\text{)} = 53.57 \text{ ((g/m}^3\text{)/min)}$

We can find the change relative humidity per minute by

$$\Delta RH = (\Delta AH/\text{Saturation Vapor Pressure})*100$$

$$= (53.57/ 781.95730806)*100$$

$$= 6.85 \text{ humidity } \%/m$$

With a volume of 0.028 cubic meters to increase the humidity level within the enclosure 10% it would take approximately 1.45 minutes.

3.3 Water Timer

Due to the water pump malfunctioning, we were unable to calibrate the timing. For the calibration we would have run the pump for a set period of time and measured the water pumped. From that we would calculate the rate in which the water was moved and use that to calculate the amount of time it would take to reach the desired water quantity.

4. Costs

Working within the University of Illinois at Urbana Champaign has allowed us to reduce some of the costs associated with the project due to our ability to access the Student Self Service and to obtain parts at a discounted price from the University.

4.1 Parts

The total that we spent on the system will be $95.15 for the hardware. There were many components that we were able to find through the supply in the Self Service within ECEB. These components were not considered in our costs, these components cost $6.82. The total materials cost would be $101.97 when those totals are combined.

Description	Vendor	Quantity	Price	Link
Exhaust Fan	Amazon	1	$30.99	link
LED 50W Plant Grow Lights	Amazon	1	$6.50	link
Input voltage 120AC 60 Hz to 12VDc 6A	Amazon	1	$13.59	link
Humidity Sprayers: pack of six	Amazon	6	$13.99	link
3μH Power Inductors	Mouser	2	$1.84	link
GRAVITY: I2C IP68 WATERPROOF AMB	Mouser	1	$8.13	Link
IC MCU 8BIT 32KB FLASH 32TQFP	Digi-Key	2	$2.47	
Temperature and Humidity Sensor		1	$9.80	
100 uF Tantalum Capacitor rated for 6V	Self Service	2	$1.52	N/A
Schottky Diode	Self Service	2	$0.40	N/A
NMOS	Self Service	5	$4.90	N/A

4.2 Labor

We needed to consider the cost that comes from the labor that we will be putting into this project. According to the UIUC Financial Wage site, we would qualify as paraprofessional employees and would make between $15.00-$22.50 an hour[1]. Since this group comprises entirely seniors, we qualify for the greater end of that scale. With this the total cost of labor would be 100(hr)*22.50($/hr) = $2250.00.

In the end the total cost of this project would be $2351.97, this includes the components which we did not need to purchase.

5. Conclusion

5.1 Accomplishments

We were able to determine that all of the systems worked independently. The control signals were shown to activate and deactivate on our command, and we were able to set the needed square wave for the power systems.

When testing the power system some of the inductors broke, we got the chance to wind our own inductors. To do this we needed to review equations regarding magnetics and look into the cores which were available for us in the Electronics Service shop. During this process we had to look into the saturation limits of each of these cores as well as the permeability to see if they would be able to handle providing the needed inductance without saturating.

5.2 Uncertainties

A lot of the tests we were unable to complete or calculate correctly, a primary concern that we would have would be within the power system. By the time we had reached the end of the design the inductors were made by the team. While the necessary inductance calculations were performed, we were not able to test the capacitance that was within the device, nor the thermal limits. If the system were to run for an extended period of time and get hot the inductor could fail.

5.3 Ethical Considerations

There are a few areas of concern we had for the development of this project. These include connecting the operating system directly to the power grid and operating and designing electronics near water. If we were not careful with how we handled these issues they can cause harm to the person who is using the product, which would go against the IEEE code of ethics [2]. To maintain the health and safety of those who will use our system we will take measures to ensure that no harm will come to the persons who will be operating the system. To do this we worked with the workshop to make sure that the system was fully waterproofed, to prevent leakage of the water into the electrical systems.

The primary issue when working with power connected to the grid is the chance for a severe electric shock. We managed this by ensuring that when we connected to the grid it was on an extension cord . If we are able we will work with a system that will have a fuse as a layer of protection to prevent current from connecting to a human. The second thing we will do is ensure that the connectors to the lights which require the larger voltage and power are secured and closed from the system. There will also be steps taken to ensure that the system remains separated from the other systems.

5.4 Future Work

The current power system, if it had worked, would have relied on two input lines from the power grid. In an ideal system we would have drawn power from the grid and used transformers and a full-wave rectifier circuit with a high frequency filter to provide 5 volts and 12 volts to the system. This would have been a fully passive power system and not have required any controls from the processor to operate. It would be ideal if this system were to go onto the market since there would have been no direct connection to controlling the power from the converter.

Appendix

Humidity Table	
Requirement	Verification
The humidity must be sensed with an accuracy of +-5%	We will verify these readings with a Reliable Hygrometer We will place our humidity sensor next to a calibrated hygrometer and compare the readings between the two sensors over that span of several minutes while changing the humidity in the environment and comparing the expected results.
We must be able to raise the humidity within the enclosure by 10% in comparison to the external humidity level	We can verify this by taking an external read of the current humidity, if the reading is less than 70% we can continue the verification, else we must find an environment with less than 70% humidity. In an environment with less than 70% humidity we will then activate the humidifiers within the enclosure and measure how long and if it is possible to increase the humidity by 10%.
We must be able to lower the humidity within the enclosure by 10% in comparison to the external humidity level	We can verify this by taking an external read of the current humidity, if the reading is greater than 30% we can continue the verification, else we must find an environment with greater than 30% humidity. In an environment with greater than 30% humidity we will then activate the ventilation fan within the enclosure and measure how long and if it is possible to decrease the humidity by 10%.

Light Table	
Requirement	Verification
The luminosity level must be sensed with an accuracy of +-5lx	We will verify these readings with a Reliable luminosity sensor We will place our luminosity sensor next to a calibrated luminosity sensor and compare the readings between the two sensors over that span of several minutes while changing the light levels in the environment and comparing the expected results.
The lights must turn on with an external signal sand increase the light in an environment with less than 1000 lx	We can verify this by taking an internal read of the current light level, if the reading is less than 1000 lx we can continue the verification, else we must find an environment with less than 1000 lx. In an environment with less than 1000 lx we will then activate the lights within the enclosure and measure the new light level.

Water Table	
Requirement	Verification
Must be able to accurately dispense water using timed dispension in ¼ cup intervals up to dispensing the entire reservoir	We will verify this by measuring the water dispensed with a weight scale to verify that it is within the tolerance of 10g of water per dispensation of water into the enclosure.
Must be able to stop dispersal of water within three seconds after the signal to dispense water has ended	We will test this by starting and stopping the water at varying intervals and ensuring that the water flow stops within the three second interval by timing the time it takes to stop flowing

Control Table	
Requirement	Verification
Must be able to create the control variables for humidity and light	Test to see if the user inputs are being stored accurately and see if the signals are getting through to the sensors
Must be able to operate timer control for the water subsystem	Test to see if the water being dispensed is the correct amount
The controls must correctly activate the MOSFETs	To check if the MOSFETs are being correctly controlled first connect a multimeter to the drain and source legs of the MOSFET(the two which are not connected to the signal). Add a voltmeter to the gate to where the chip is providing the signal. The signal produced by the ATmega should be seen on this device. When the signal is high we should see on the multimeter that there is a resistance of around zero in the MOSFET when the gate sees a high pulse. A large resistance should be seen when the gate is receiving a signal of zero. By doing this we can test to see if the MOSFETs are working as anticipated.

Power Table	
Requirement	Verification
Buck converter is required to provide a 5 volt DC output from a 12 volt DC source with a voltage ripple of 5%.	To Test this a 5 ohm or greater resistor should be placed into the position where the system will be. If the resistor value is less than 5 ohms you run the risk of overloading the current which the system can handle.

	On this resistor hook up the oscilloscope, when powered on the viewer should see a signal that sits within 5.25V and 4.75V.

References

[1]“Wages – Office of Student Financial Aid,” *Illinois.edu*, 2024.

https://osfa.illinois.edu/types-of-aid/employment/regulations/wages/ (accessed Mar. 06, 2025)

[2]IEEE, “IEEE Code of Ethics,” ieee.org, Jun. 2020.

https://www.ieee.org/about/corporate/governance/p7-8.html (accessed Mar. 06, 2025)