Arduino Based Algea Incubator

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Abstract

This document provides a detailed guide for assembling and operating an algae incubator designed for controlled algae cultivation. It covers the complete setup, and operation, utilizing cost-effective materials and components to ensure both affordability and accessibility. The design incorporates an Arduino-based control system to regulate light cycles and internal airflow, critical for maintaining optimal growth conditions. Although the system does not include precise temperature controls, it effectively uses fans to manage internal heat generated by LED lights, maintaining a balance between internal and external temperatures.

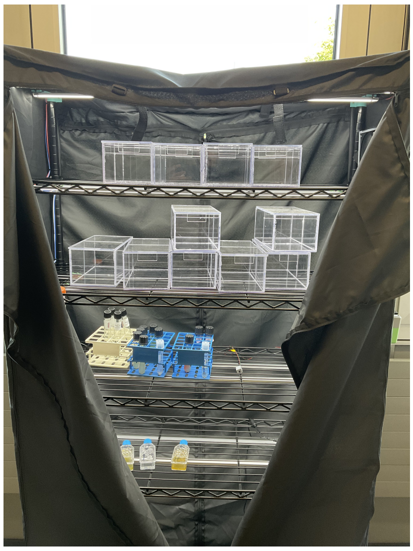


Figure 1: Algea incubator, with the air flow from bottom left to top right

1 Introduction and System Overview

The Algae Incubator is designed to optimize algae cultivation by providing a controlled environment with cost-effective materials. This system is specifically tailored for users looking to efficiently manage and simulate natural growth conditions. The core of this incubator is an Arduino-based control system, which integrates components such as LED strips, temperature sensors and fans to ensures a balance of light and temperature.

Shelf: The base of the incubator is configured with five shelves measuring 910 x 360 mm. This structure accommodates all essential components of the incubator efficiently, including

LED strips, fans, and control systems. It is enclosed in a dark housing designed to ensure complete darkness inside when the LED lights are off.

Light Management: The algae incubator utilizes LED strips that emit cool white light at a color temperature of 6000K operating at 12V and a power rating of 16W/m. The installation comprises slightly more than 8 meters in total, ensuring even light coverage throughout the growth area. Programmable light cycles, controlled via the Arduino interface, allow for precise adjustments of lighting times to simulate natural daylight conditions.

Temperature Control: Temperature regulation is managed by the *DS18B20* sensor enabling the Arduino to adjust fan modes. Airflow is facilitated by *Be Quiet! Pure Wings 2 120mm* fans, which are arranged to create a flow sucking air using two fans positioned at the bottom to introduce fresh air, and two fans at the top to exhaust warm air out. Such an arrangement is crucial for dissipating the heat generated by the LED lights. Figure 7 illustrates the impact of LED lighting on the temperature inside the incubator over time. This graph underscores the significant heat dissipation from the LEDs and highlights the critical need for effective air circulation through the shelving unit to maintain constant conditions for algae growth.

Figure 2: Control box mounted on the side of the shelf

2 Materials

2.1 Bill of materials

Component	Number	Cost/unit [CHF]	Total cost [CHF]	Source (hyperlink)
Fan, Be Quiet! Pure Wings 2 140mm	4	12.5	50	Galaxus
LED strips (5m), High Density, Cold White 6000K	2	119.9	239.8	Lumina Swiss
LED Profile, Standard, Matte 100cm	10	12.25	122.5	Lumina Swiss
Arduino UNO	1	25.86	25.86	Conrad
Relay Shield V3.0	1	36.96	36.96	Conrad
Temperature Sensor, DS18B20	1	5.6	5.6	Conrad
Real-Time Clock Module	1	5	5	Conrad
LCD Screen 20x4	1	10.95	10.95	Digikey
Proto Shield for Arduino UNO	1	8.2	8.2	Digikey
Transformer 230V to 12V	1	30	30	Brack
3-Pin Power Cable	1	5.4	5.4	Brack
Shelf, Steel Wire, Black	1	195	195	Kaiser Kraft
Housing	1	45	45	Formosa Covers
Total			**780.27**	

Table 1: Comprehensive parts list and procurement sources for the algae incubator.

2.2 CAD files

To construct the incubator, various custom components are designed using 3D printing (Prusa i3 MK3S) or created using a laser cutter and acrylic sheets (optional for the fans enclosure). The table below outlines the different parts required. All CAD files are accessible and can be modified as needed, available through our lab's GitHub repository.

File name	Number needed	File type	Material
Top Arduino box	1	STL file	PLA
Bottom Arduino box	1	STL file	PLA
Fan Cover	4	SVG file	Acrylic
Cover Temp Sensor	1	STL file	PLA
Enclosure Temp Sensor	1	STL file	PLA
Fan Enclosure Side Long	2	STL file	PLA
Fan Enclosure Side Short	4	STL file	PLA
Support Fan Male	2	STL file	PLA
Support Fan Female	2	STL file	PLA
Pin Fan	8	STL file	PLA

Table 2: List of 3D printable parts and their specifications for the algae incubator.

3 Building

3.1 Electrical design

This section outlines the electrical architecture of the algae incubator, focusing on the connectivity and power management of the LED strips, fans, and control systems. Given the different voltage requirements and the total power consumption of the system, special attention is given to safely converting and distributing electrical power.

Power Supply and Distribution: The incubator uses a transformer to step down the Swiss standard 230V AC mains power to 12V DC, suitable for powering the LED strips and the fans. This ensures that all high-power components operate safely within their electrical specifications. The Arduino, which operates at 5V, cannot directly handle the 12V required by the LEDs and fans. Therefore, it manages these components via a relay shield, which acts as an intermediary, safely switching the higher voltages and currents involved.

LED Configuration: Three LED strips are connected in parallel to ensure consistent brightness and uniform power distribution across all strips. Each strip operates at 12V with a power rating of 16W/m. Given the substantial power requirements of the LED strips, which extend slightly more than 8 meters, the total power draw is significant. A relay shield is employed to manage the power per LED strips. The shield's capacity to handle up to 70W per channel is suitable for the combined wattage of the strips, ensuring that the maximum power capacity is not exceeded and providing an extra layer of protection against electrical overloading.

Fan Setup: Four fans, essential for maintaining airflow and temperature within the incubator, are connected through the fourth channel of the relay shield. Their overall power consumption is relatively low, allowing all four to be safely connected to the same relay channel. This setup is not only efficient but also simplifies the wiring and reduces the number of control channels required. These fans collectively function to exhaust warm air from the top and draw cooler air in from the bottom, creating an effective air circulation system that is vital for temperature stability within the incubator.

Figure 3: Fan enclosure at the top of the incubator blowing air out

3.2 Arduino mounting

The connection diagram for the Arduino setup integrates various components such as the real time clock DS1302N, the I2C 20x4 LCD screen, the two DS18B20 temperature sensors, the two push buttons, and the 3-position switch, the relay shield and the Proto shield for easy soldering. The Figure 4 gives a representation of the whole electronical system. In this configuration, pins 4-7 are reserved for the relay shield, with each relay assigned to a specific pin. Pins 2 and 3 are utilized for Arduino interrupts, allowing the push buttons to change the desired times without needing to be in the loop at the exact moment of pressing. The Normally Open (NO) and Common (COM) entries are connected with the power supply: 12V goes to COM, and NO goes to the fans or LED strips. The grounds (GND) of the fans and LED strips are directly connected to the 12V transformer's GND. The Arduino Uno, relay shield, and Proto shield are stacked together for compactness, though for better visualization, they are shown separately in the sketch.

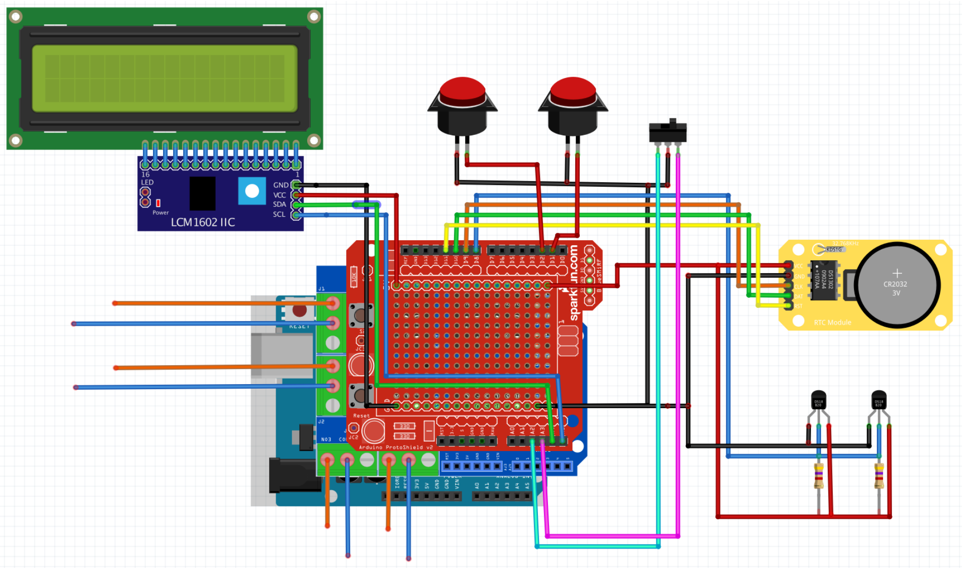


Figure 4: Schematic diagram of Arduino connections

3.3 Software and control logic

This section outlines the control logic embedded within the Arduino software, which plays a pivotal role in managing the operational dynamics of the algae incubator. The Arduino sketch is designed to integrate seamlessly with the hardware setup, providing precise control over the LED lighting, temperature monitoring, and fan operations.

3.4 Light Management Logic

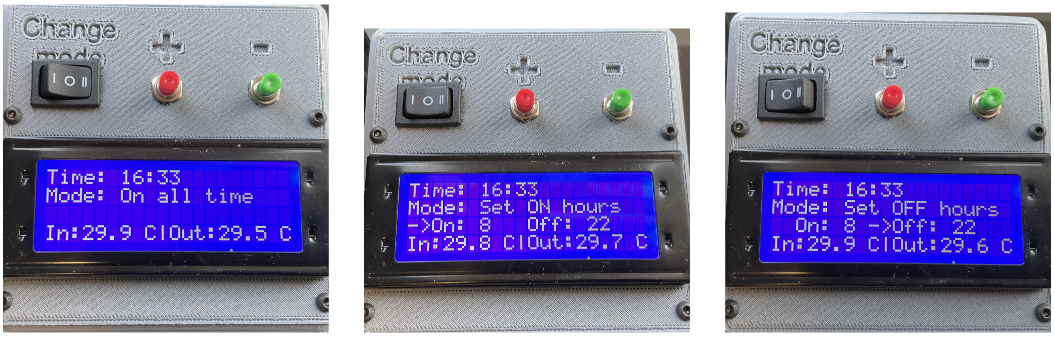
This subsection details the control logic for the LED lighting system. The Arduino code allows users to choose from three distinct lighting modes to best suit their specific needs.

1. **Constant Illumination**: In this mode, the LED lights remain on continuously, providing constant light exposure ideal for phases of growth that require prolonged lighting.

2. **Adjustable Start Time**: Users can set a specific start time for the LED lights, enabling them to customize when the lights turn on each day. This mode is useful for simulating sunrise or for gradually adjusting the light cycle to experiment with different photoperiod strategies.

3. **Adjustable End Time**: Similarly, the end time for when the LEDs turn off can also be customized, allowing users to simulate sunset or extend light exposure as required by the growth conditions or experimental design

A three-position switch on the control box (see Figure 5) enables the user to select between the lighting modes. An LCD display screen shows the current settings, including start and end times for the lights. A small arrow appears before the time value being adjusted, pointing at either the ON or OFF time, to clearly indicate whether the user is setting the start or end time. Two buttons allow for easy adjustment of the designated hours. The left button **(+)** increases the hours, while the right button **(-)** decreases them, both in increments of one hour. This setup ensures users can make precise adjustments quickly and efficiently.



(a) mode 1 (b) mode 2 (c) mode 3

Figure 5: Three different lighting modes

3.5 Temperature Monitoring and Fan Control

Regarding the temperature control, the system is based on a dual sensor setup. The incubator employs two DS18B20 temperature sensors to monitor temperature gradients effectively. One sensor is located on the control box, exposed to the ambient room temperature, while the other sensor is placed inside the shelf, directly within the algae cultivation area. This setup allows the system to accurately gauge the temperature differential between the internal environment of the incubator and the external room environment.

The fan activation logic is to stabilize the internal temperature by enhancing air circulation. For this, the Arduino software is programmed to activate the fans at full speed when the temperature inside the shelf exceeds the external temperature by a predetermined threshold, set at 0.3°C to keep a temperature inside close from the room temperature without a need of being to close and needing the fans to be turned ON at all time.

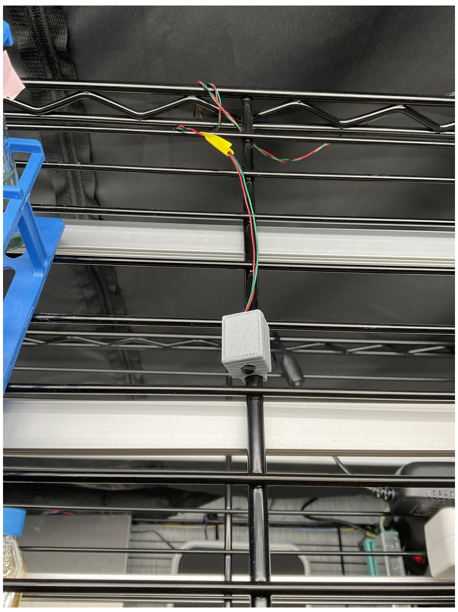


Figure 6: Temperature sensor inside the incubator

4 Performances

The Performance evaluation shows that the incubator is doing a great job managing airflow and keeping things cool, thanks to the fans that push about 223 m^3/h of air both in and out. This setup keeps the temperature just right and runs super quietly. On top of that, the incubator is pretty cost-effective (see table 1), utilizing affordable components.

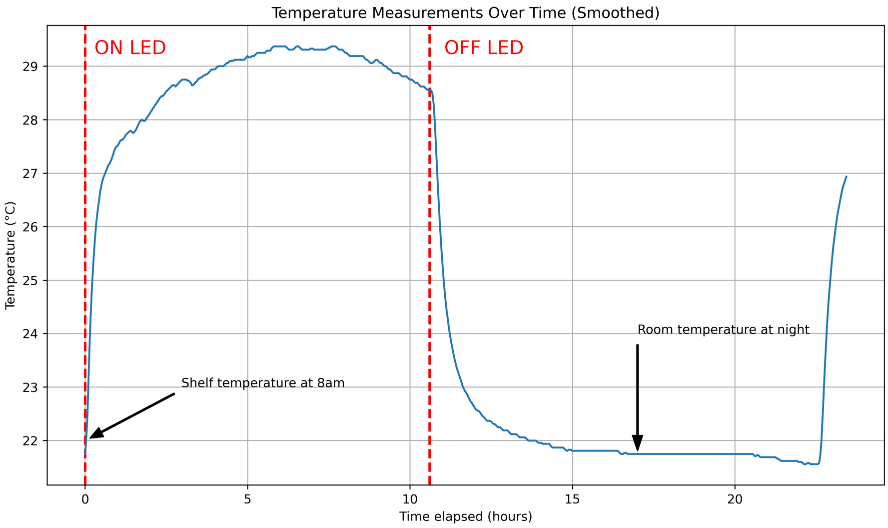


Figure 7: LED heat dissipation with no cooling fans