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## CPE 301 Swamp Cooler Project

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This repository contains the code and documentation for the CPE 301 Swamp Cooler Project. Swamp coolers are devices that cool air by evaporating water. Water has a high latent heat of vaporization, which means it can absorb a lot of heat from the air before turning into vapor. This makes swamp coolers an effective and energy-efficient way to cool indoor spaces, especially in dry climates where the humidity is low.

The swamp cooler system in this project uses an Arduino Atmega2560 and various sensors and actuators (described in the section below) to monitor and control the operation of the swamp cooler.

It can monitor temperature, humidity, and water level, and adjust the fan speed accordingly. It has an LCD screen to display the temperature and humidity of the past minute, as well as the current system status. It also logs data with timestamps using a real-time clock module through the serial monitor.

If you are a student looking to study or reuse parts of this code, please read the License section at the bottom of this document.

## Components Used

- **Microcontroller:** Arduino Atmega2560
  - This is the main controller for the swamp cooler system.
- **Temperature and Humidity Sensor:** DHT11
  - Used to monitor both temperature and humidity levels.
- **Analog Water Level Detection Sensor**
  - Monitors the water level in the reservoir. If the water level is too low, the system will enter a non-operational state until the user refills the reservoir and presses the reset button.
- **LCD Display:** LCD1602
  - Displays current temperature, humidity, and system status.
- **Stepper Motor:** 28BYJ-48
  - Used for the vents to control airflow direction.
- **Stepper Motor Driver:** ULN2003

- Drives the stepper motor for vent control.
- **Real-Time Clock Module:** DS1307
  - Used to keep track of real-time for logging.
- **3-6V Motor with Propeller Fan Blade**
  - Provides airflow for the swamp cooler.
- **Motor Driver:** L293D
  - Used by the microcontroller to control the fan motor speed.
- **Power Supply Module**
  - Delivers the necessary power to the motors.
  - Note that the rest of the system is powered via USB from the microcontroller.
- **Push Buttons**
  - Used for user input to control vent direction, system reset, and system disable/enable.
- **LEDs**
  - Used for status indication.
- **Breadboard, jumper wires, and resistors**
  - Used for connecting components and building the circuit.

## System Overview

The swamp cooler system is designed to monitor environmental conditions and adjust its operation accordingly. It uses a DHT11 sensor to measure temperature and humidity, and an analog water level sensor to ensure there is sufficient water in the reservoir. If the water level is too low, the system will not operate until the user refills the reservoir and presses the reset button.

Note that the motors (fan and stepper motor for vents) are powered separately from the microcontroller using a separate power supply module. There are two breadboards used in this project: one for the microcontroller and sensors, and another for the motors and their drivers. The motor breadboard and the microcontroller breadboard are not electrically connected but share a common ground. This separation is to prevent cases where the power supply for the motors turns off while the microcontroller is still powered, which will cause the motors to draw power from the microcontroller and potentially damage it.

## System States

The system has the following states:

- **Idle:** The system is powered on but not actively cooling.
  - Transitions to **Idle** state only during initial power-on. This is an implementation-specific detail where the state machine is designed so that each state has enter logic that runs once upon entering the state. When the system is powered on, it starts in the Idle state by default, but has to enter the Idle state again to run the enter logic.
  - Transitions to **Running** state if temperature exceeds threshold and water level is sufficient.
  - Transitions to **Error** state if water level is too low.
  - Transitions to **Disabled** state if user presses the enable/disable toggle button.
- **Running:** The system is actively cooling based on sensor readings.
  - Transitions to **Idle** state if temperature drops below threshold.
  - Transitions to **Error** state if water level is too low.
  - Transitions to **Disabled** state if user presses the enable/disable toggle button.
- **Error:** The system has detected an error condition (low water level) and is not operational. No cooling will occur until the user refills the reservoir and presses the reset button.
  - Transitions to **Idle** state if the user presses the reset button.
  - Transitions to **Disabled** state if user presses the enable/disable toggle button.

- **Disabled:** The user has manually disabled the system using the disable button. No cooling will occur until the user re-enables the system.
  - Transitions to **Idle** state if user presses the enable/disable toggle button.

## Circuit Image

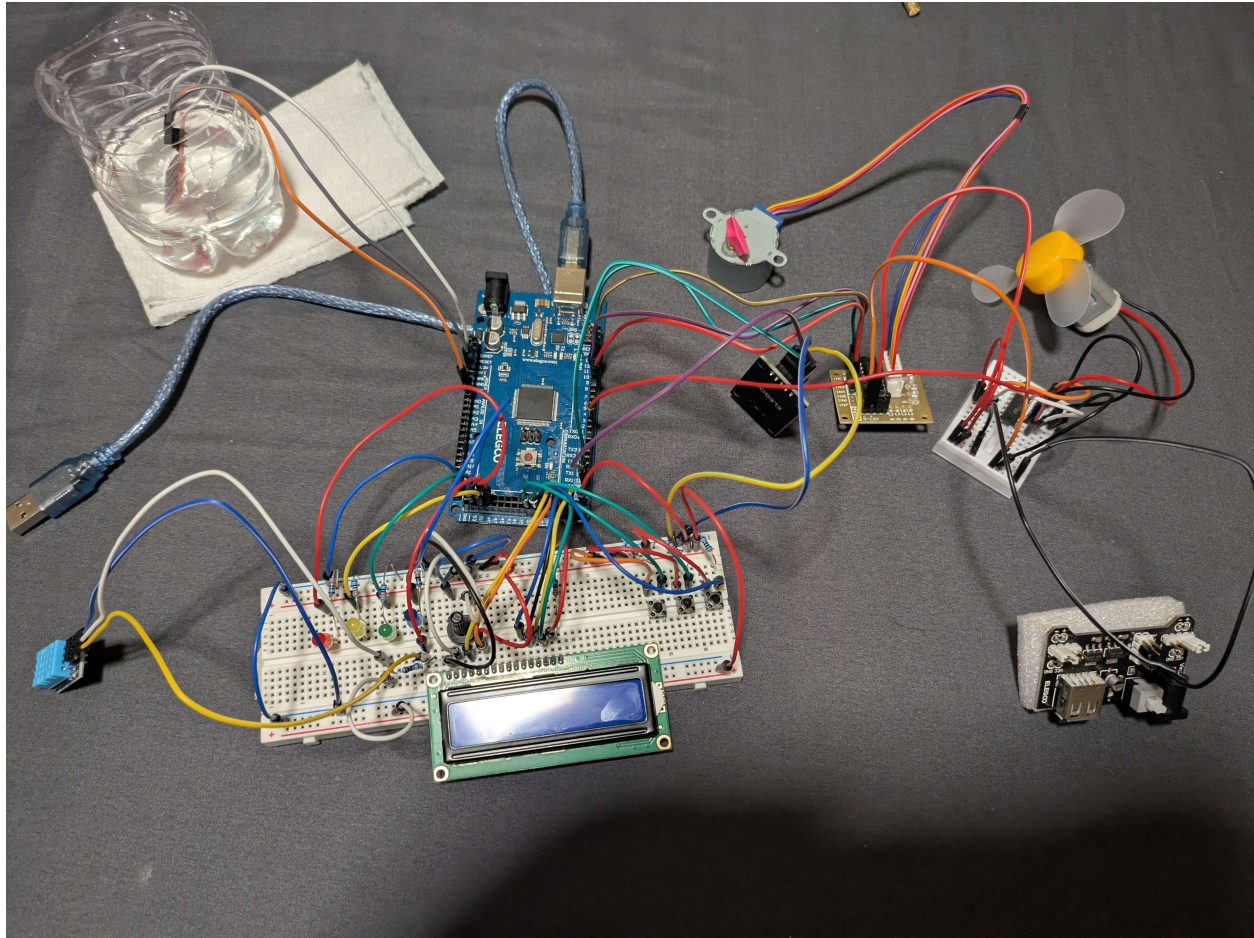


Figure 1: Circuit Image

## Schematic Diagram

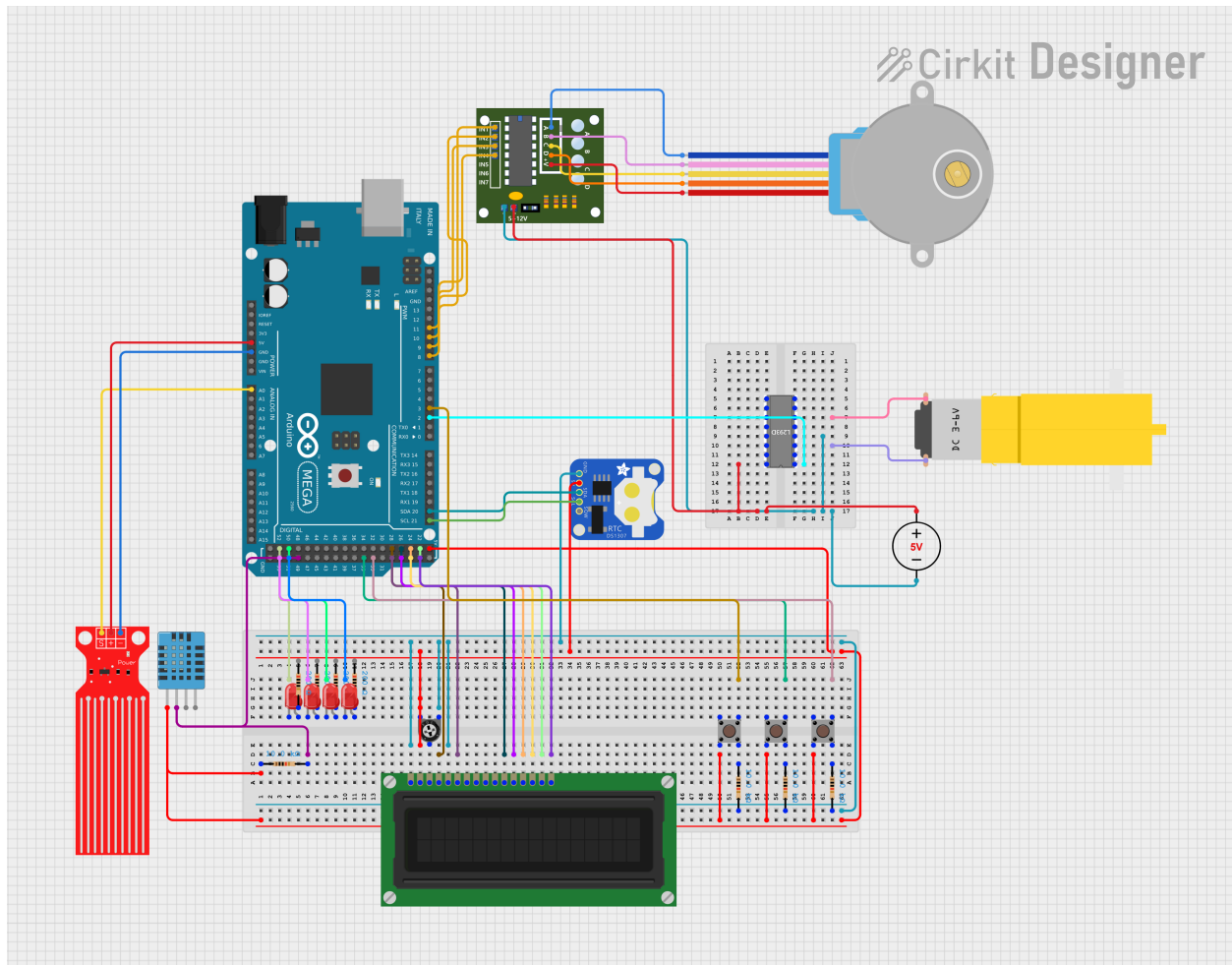
Components used are described in the Components Used section above.

## System Demonstration

Below is a video demonstration of the swamp cooler system in operation:

<https://drive.google.com/file/d/1CNwVBzageFXINSoOLmAduGrb4Q404aej/view?usp=sharing>

Addendum: the video demonstrates logging with real-time clock timestamps. It included hour/minute/second, but it did not include the year/month/day. A new commit was added to include year/month/day in the log output. Here is an updated screenshot of the log output with the full date and time:



```
[2025-12-13 01:18:03] Fan motor enabled
[2025-12-13 01:18:03] RTC time adjusted.
[2025-12-13 01:18:03] STATE CHANGE: IDLE -> IDLE
[2025-12-13 01:18:03] STATE CHANGE: IDLE -> RUNNING
[2025-12-13 01:18:03] Fan motor enabled
```

## **Environmental Impact**

### **Energy Efficiency**

The swamp cooler system is designed to be energy efficient by only operating when the temperature exceeds a certain threshold and if there is sufficient water in the reservoir. This minimizes any unnecessary energy consumption.

In addition, the fan speed is controlled by how much the temperature exceeds the threshold. This allows the system to adjust its cooling power based on the current environmental conditions, only using minimal power when the temperature is just above the threshold. This is seen in the `startMotor()` method in the source code.

### **Design Safety**

As described in the System Overview section, the motors are powered separately from the microcontroller using a separate power supply module. This design choice prevents damage to the microcontroller in case the motor power supply is turned off while the microcontroller is still powered.

In addition, the error state requires manual intervention from the user to reset the system after a low water level condition is detected. This ensures that the user is aware of the water level issue.

### **Affordability**

The components used in this project are chosen to be affordable. The total cost of the kit containing all of the components used in this project is around \$60-\$70. This makes it accessible for hobbyists who want to replicate or build on this project.

In addition, I reduced the number of components needed by reusing them for different but similar functions of the system. For example, the enable button is the same physical button as the disable button; it toggles the system state between enabled and disabled. By having the start/enable functionality be implemented as an ISR, the user can press the button to disable the system without worrying of holding the button too long and accidentally re-enabling it.

The vent button also toggles the vent direction between two preset positions, which simplifies the two vent states into a single button.

### **Sustainability**

The design of the swamp cooler system emphasizes sustainability by using components that are widely available and can easily be replaced or upgraded. Especially because the water level sensor is at risk of corrosion over time due to constant exposure to water, it is important that the sensor can be easily replaced. The water sensor used in this project is an inexpensive analog water level detection sensor that can be easily swapped out if it fails, only requiring to reconnect the jumper wires. Any water sensor that provides an analog voltage output based on water level can be used as a replacement.

### **Accessibility**

Most of the user interface is placed in front of the user, while most of the sensors and wiring are placed on the side or back of the system. This allows the user to easily access the buttons and view the LCD display. In addition, the wiring is mostly organized to allow for easy rebuilding or modification of the circuit.

## License (read me if you are a student)

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An example of proper attribution of part of this code, such as reusing the print integer function (`U0putint(int)` in the source) in your own code, would be:

```
/*
 * U0putint function
 *
 * Originally written by Justin Juera
 * Source: https://github.com/jjuera-unr/cpe301-swamp-cooler
 * Licensed under GPLv3 or later
 *
 * This function has been reused here with attribution in accordance
 * with the original license.
 */
void U0putint(int, int = 0);
void U0putint(int value, int leadingZeros) {
    // render negative numbers correctly by prepending negative sign and printing
    // as positive
    if (value < 0) {
        U0putchar('-');
        value = -value;
    }

    const char digits[] = "0123456789";
    int temp = value;
    int count = 0;

    // count number of digits for leading zeros
    if (temp == 0) {
        count = 1;
    } else {
        while (temp > 0) {
            temp /= 10;
            count++;
        }
    }
}
```

```
while (leadingZeros > count) {  
    U0putchar('0');  
    leadingZeros--;  
}  
  
if (value >= 10) {  
    U0putint(value / 10, 0);  
}  
  
U0putchar(digits[value % 10]);  
}
```