ESP3903 Major Design Project II

Optimizing Air Flow for Cooling Indoor and Al Fresco Dining Areas

Group 7: Lock Mei Lin, Goh Kheng Xi Jevan, Toh Wei Wen

Engineering Science Programme, National University of Singapore

Abstract

This project aims to optimise the airflow for cooling indoor and Al Fresco dining areas. Using temperature sensors, damping and variable speed fan systems are prototyped to illustrate indoor and outdoor cooling, respectively.

A central unit collects data from all indoor and outdoor sensors and sends back relevant feedback control signal to the corresponding microcontrollers to drive their respective temperature control actuators.

For indoors, the cooling systems are dampers that varies their angle to control the airflow from a fixed cool air source (simulating a diffuser).For outdoors, the cooling systems are DC fans that varies their speed according to the temperature.

Design of Sensor

- **Design of Temperature Sensor**
  - Resistance of diodes drops as zone temperature increases and thus, voltage difference across points 'a' and 'b' in Fig. 2 increases in accordance with the formula:

$$V_b = V_a + \left(\frac{V R_1}{R_1+R_2}\right) \quad ; \quad V_c = V_a + \left(\frac{V R_{diodes}}{R_{diodes}+R_3}\right)$$

  - This voltage difference value is input into the differential amplifier
  - Wheatstone bridge configuration to measure small voltage changes more precisely
  - The differential amplifier steps up this value for more sensitive readings, while attenuating unwanted noise

Fig. 1. LM358 differential op-amp

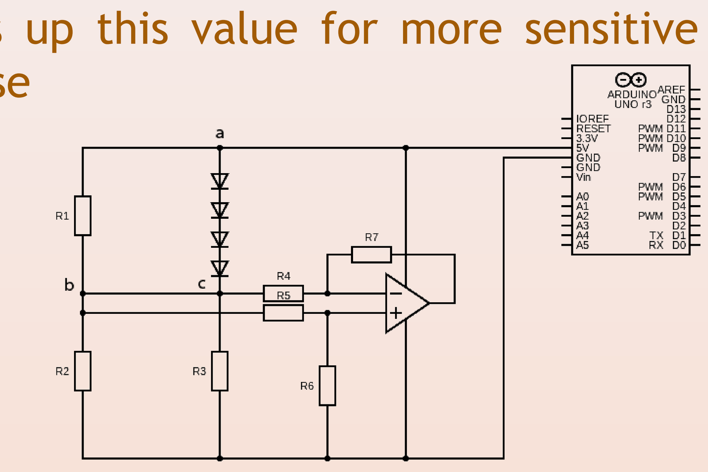

Fig. 2. Circuit of temperature sensor

Calibration of Sensor

Calibration of Temperature Sensor

- External temperature sensor was used to obtain control measurements
- Infrared Radiation (IR) lamp emitted heat of up to 300W
- Output voltage was mapped linearly to measured temperature difference to produce the following relation: Temperature = 0.0159Vout + 3.3016

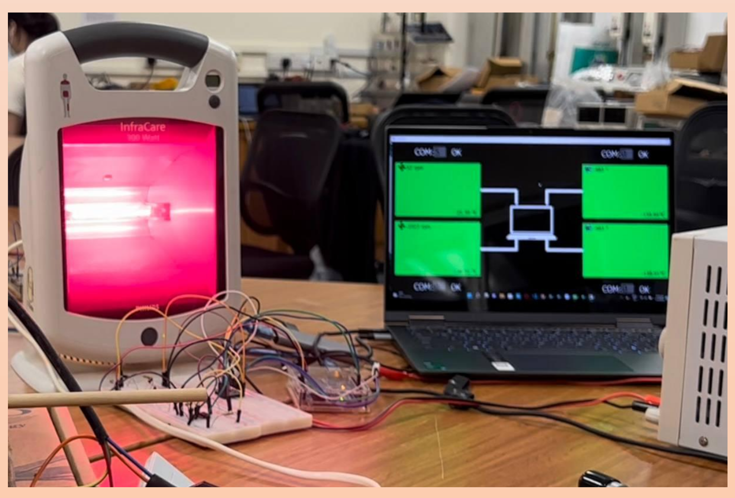

Fig. 3. Calibration process for temperature sensor

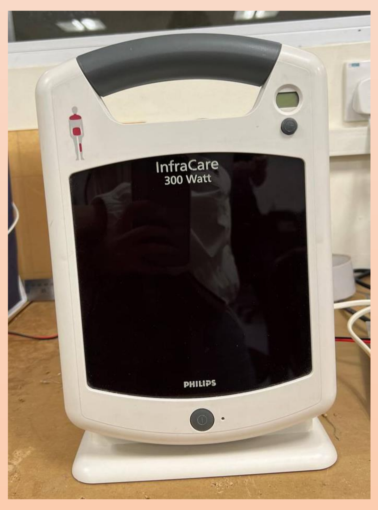

Fig. 4. 300W IR lamp

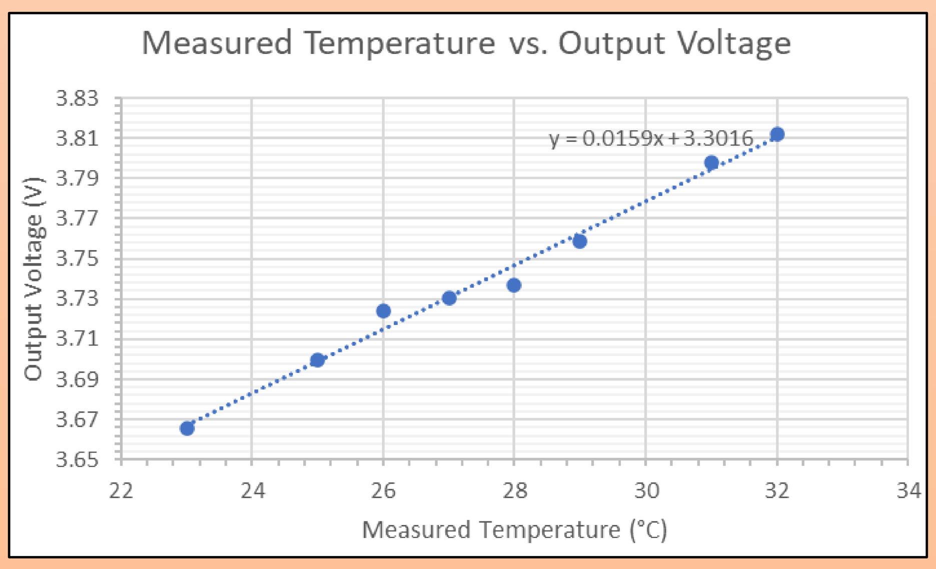

Fig. 5. Calibration graph of temperature sensor

Design of Outdoor Variable Speed Fan System

Fig. 6. Variable speed DC fan

- A 12V DC fan is controlled by an Arduino Uno
- 1000 - 2000 rpm
- Arduino PWM (Pin 9) is connected to the fan
- Arduino Ground is connected to the fan
- The fan is connected to a 12V DC power supply

- The fan speed is directly proportional to the value of the applied PWM duty cycle
- When temperature increases, the control algorithm increases the fan's duty cycle
- This then increases the speed of the DC fan, increasing the outdoor cooling effect

Design of Indoor Damping System

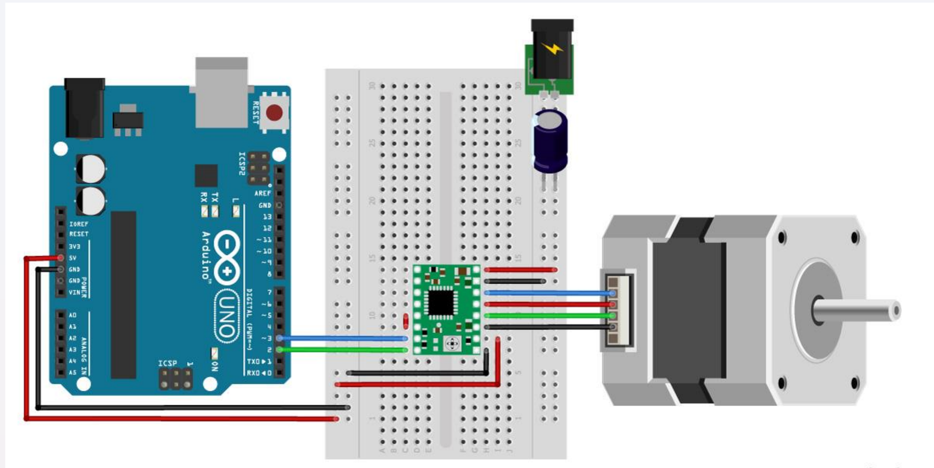

Fig. 6. Circuit of PWM-controlled DC motor

- A round Volume Control Damper (VCD) is placed in front of a fan simulating the airflow from the A.H.U.
- The circular damper is connected to a stepper motor that is controlled by an Arduino Uno
- The motor is used to turn the damper, thus adjusting the airflow

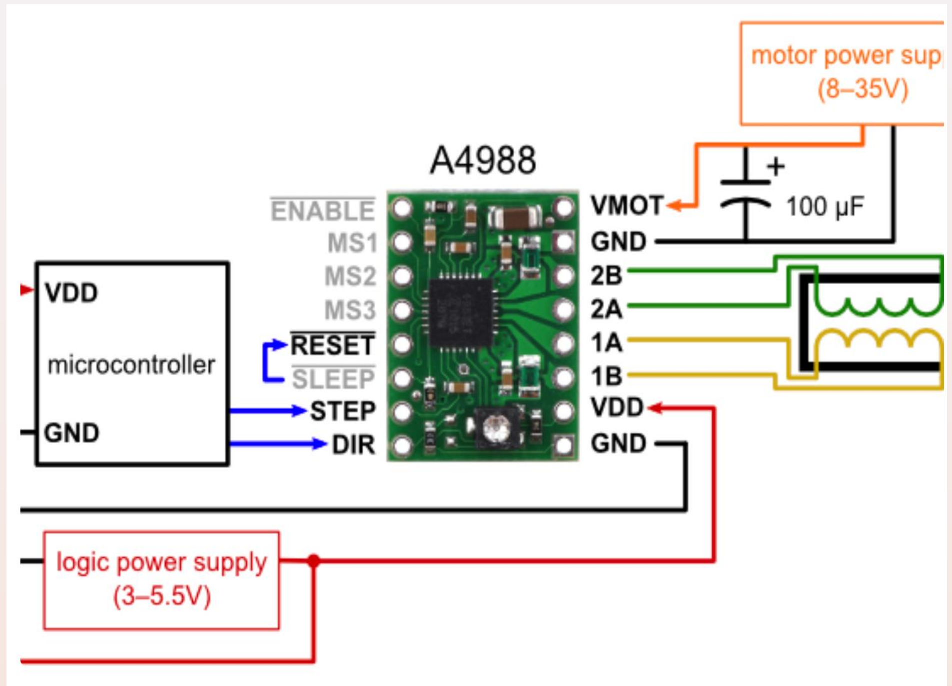

Fig. 8. A4988 motor driver

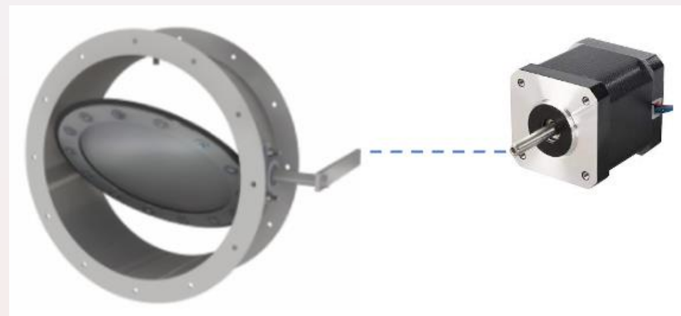

Fig. 7. Damper connected with stepper motor

- Stepper motor is full step mode, 200 steps per revolution
- The Arduino Uno sends a pulse width modulation (PWM) signal to control the rotation of the motor.

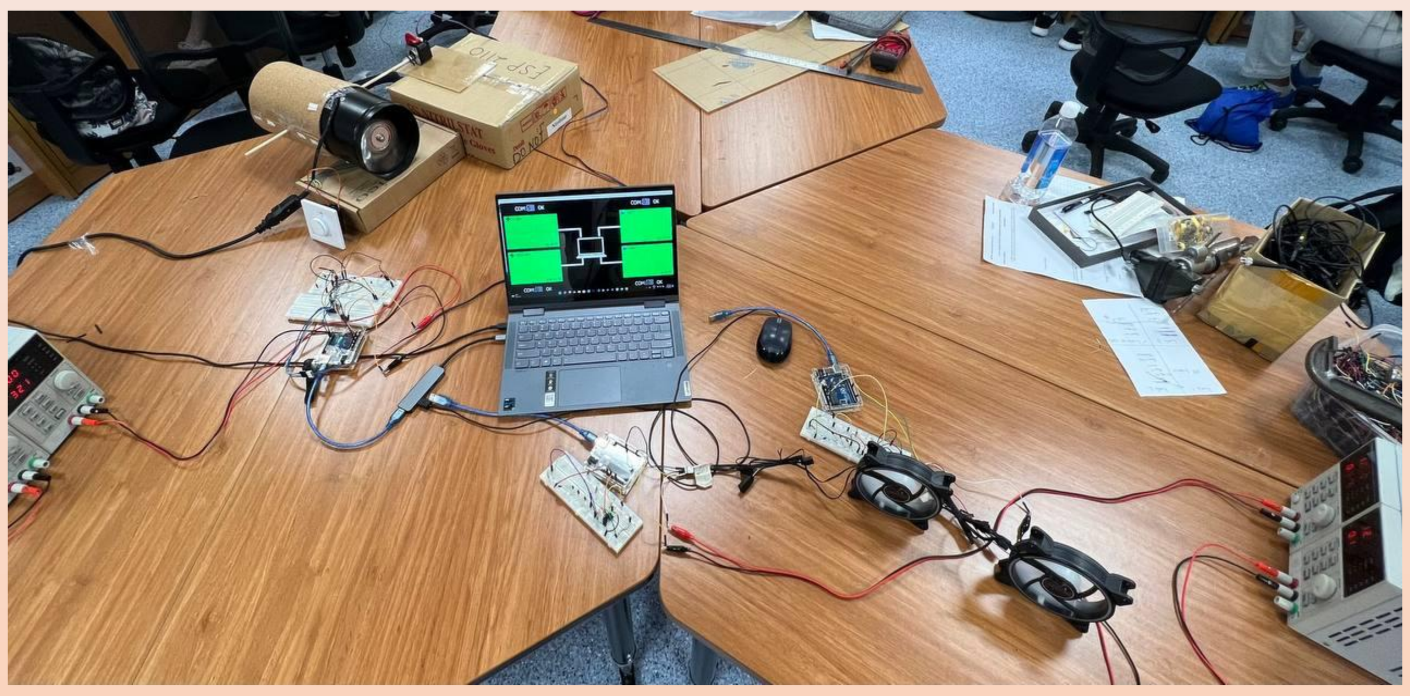

Fig. 9. Overall setup

System Design

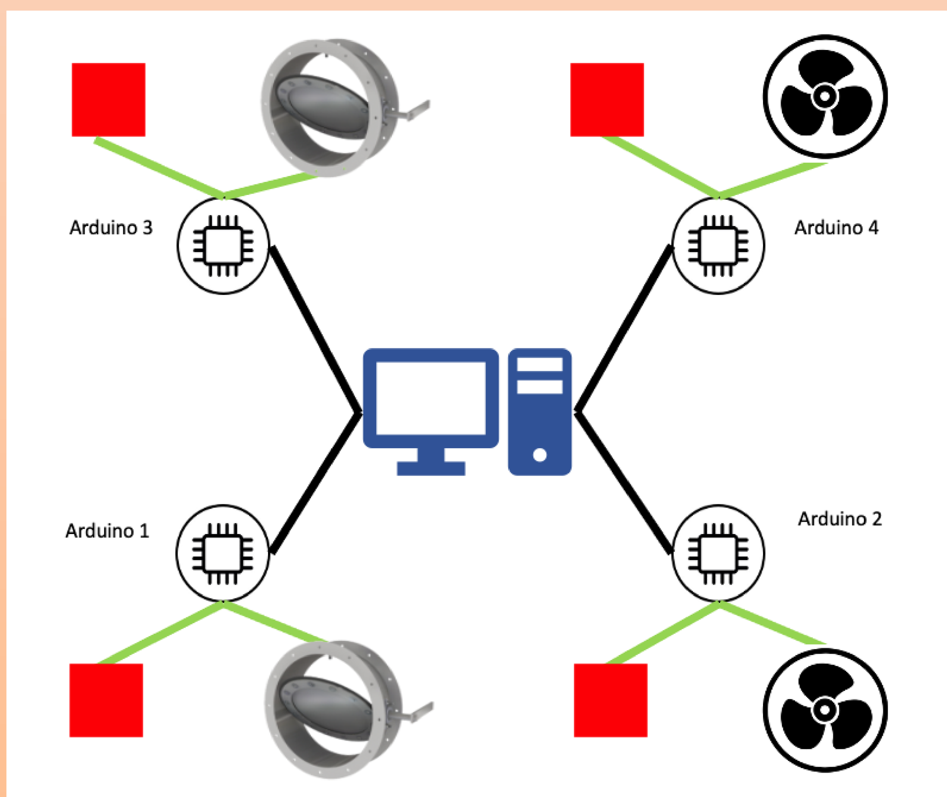

Fig. 10. System design

- The four temperature sensors are placed at different locations in a room to better represent the temperature distribution
- For the indoor cooling system, each Arduino is connected to a stepper motor and a thermal sensor
- For the outdoor cooling system, each Arduino is connected to a DC fan and a thermal sensor

Conclusions

Through calculations, the smart ACMV (Air Conditioning and Mechanical Ventilation) system can save up to 25%. The sensors have to be recalibrated frequently due to the materials used. Improvements can be made by soldering components onto proto-boards or using PCBs.

Furthermore, the thermocouple available are not accurate which might have caused inaccuracy during calibration. While the system might not meet commercial standards due to insufficient budget and time, it successfully reduced energy wastage.

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