Project Plan

Micro-Greenhouse Environmental Controls System | Group May 14-36

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Summary

The project goal is to design a control system that regulates two important environmental conditions inside micro-sized greenhouses.   These two conditions are air temperature and relative humidity.

The serves as a proof of concept implementation for an ongoing research project of the Lab-Chips group lead by Liang Dong. This team works to develop biological research laboratory tools on small electronics chips. The ultimate goal of the project is to design a full miniature control system, sensors and actuators on a chip.

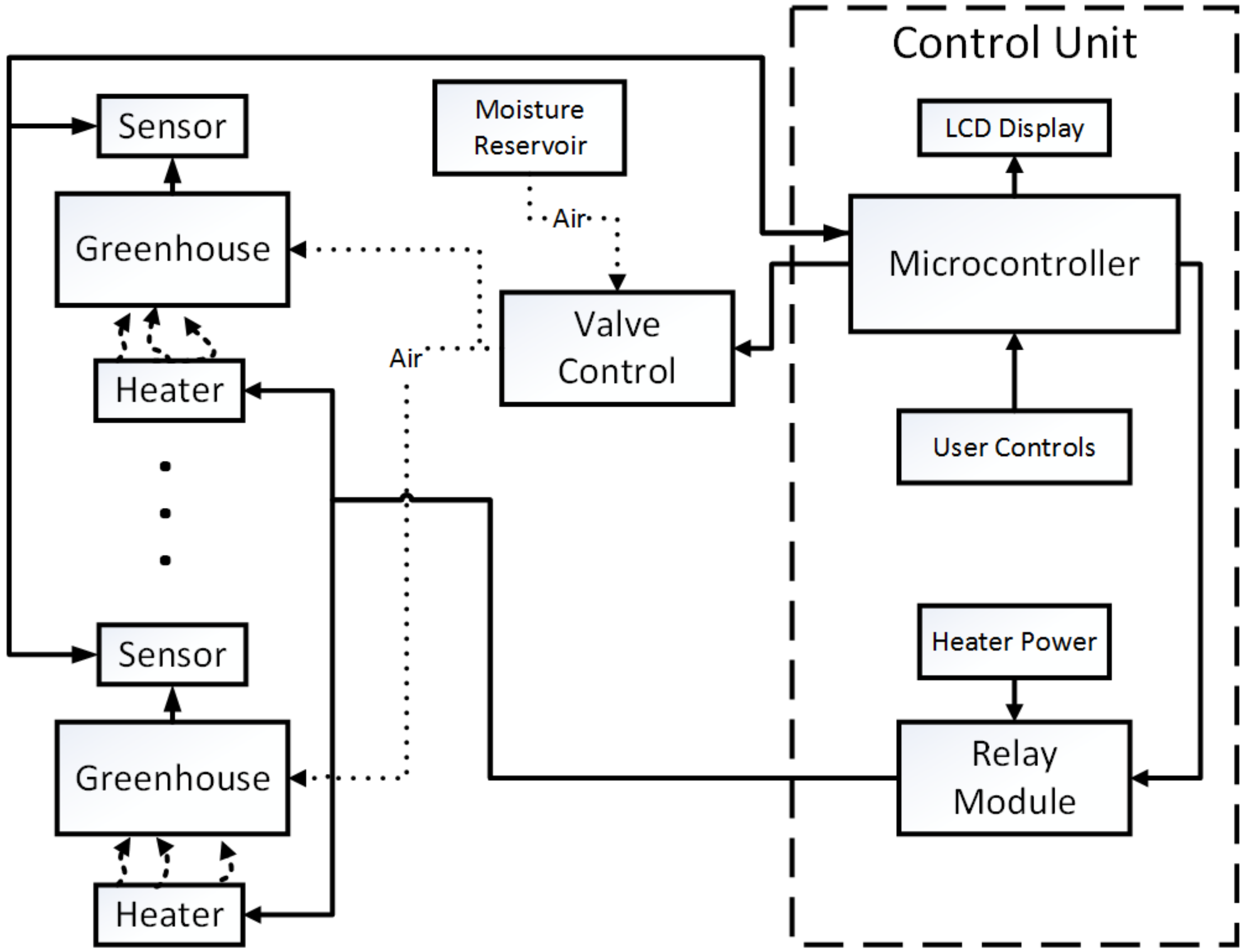
Concept

Implementing a greenhouse controller there must be a logic processor which takes in measurements and scales the output to reach the appropriate levels. Duplicate this several times to have multiple channels and add an interface to change values in the output scaling computation.

System Description

The system will consist of a controller unit that monitors current humidity and temperature of micro-sized greenhouses. As needed the controller will apply additional heat and inject humidity into the greenhouses to bring conditions into desired ranges. The controller must host user controls, some kind of display, communication subsystem for sensor, and system to signals to actuators. Users must be able to dial in target levels and change performance tuning. The system must have capacity to regulate multiple of these greenhouses and provide independent zone control.

System Block Diagram



Operating environment

The system is intended to be operated in a lab setting, by researchers to grow small biological samples. It should always be in climate controlled environment and most components shall remain on the exterior, not exposed to the contained biological elements. Given this there should always be a reliable power source available as well as a source of compressed air, common to many chemical and bio labs. Electromagnetic emissions should be not be any major concern.

User Interface

As the unit is intended for research lab purposes an aesthetically pleasing and integrated user interface is not a requirement and any user interface of the controller is beyond the scope of this project.

The sensor devices should have the capability to be calibrated easily. Additionally, both for testing purposes and later setup it would be prudent that this calibration procedure work with and without the controller present.

Functional requirements

The sensor system must stabilize temperature to within +/-1℃ and +/-1% relative humidity of the desired target level.

Response time to changes in environmental conditions must be immediate, but speed it not paramount.

Temperature and humidity levels should have minimal overshoot when stabilizing at target levels. This is of highest concern with temperature as too much heat could damage biologic sample and invalidate experiments.

The system must maintain long term operation stability, maintaining measurement accuracies for a reasonable growth cycle, allowing periodic recalibration.

The system must be able to support at least 4 separate units.

Allowances for swappable components and tuning must be made.

Stable temperature range should be 20℃ - 50℃.

Stable humidity range should be 10%– 90%.

Non-functional requirements

System must be relatively power efficient.

Small physical footprint.

Easy to use interface.

Market and Literature Survey

Research into current controllers was done. As a further investigation and to develop an immediate working control solution a market available digital temperature controller was setup. This controller uses a "PID (Proportional + Integrator + Derivative) auto-tuning" and functional works by sending switching signal for relays in a PWM (Pulse Width Modulation) scheme. This PWM allows for variable power application with binary actuation. From this test system configuration important lessons and caveats were gained for system design.

Project Subsystems Details

Controller Logic

There are several factors to account for when designing the control logic of the system. With an array of accurate sensor that directly measure the controlled states some form of classically direct feedback seems logical. As the desired response would have minimal overshoot and speed of response is not important it seems that an integrator element is not necessary. This also allows the system to be much simpler as differentiation is much simpler to implement in a digital system than integration.

Associated Risks

There should be some way to quickly freeze or shut down the system in emergency in situations.

Sensor Communication

There are available a series of digital temperature and humidity sensors, the Sensirion SHT11. The system should have a digital communications system to gather readings from these sensors. SHT11 use a serial protocol similar to I^2C, but with a few differences. Sensirion makes publicly available C++ libraries for interfacing with their sensors and this functions can be used as a framework for designing a communications module's subroutines

Temperature Actuation

There are a series of thin flexible heater elements that will be used to apply addition thermal energy to the greenhouses.

Associated Risks

The initial plan was to apply these heaters to the base of glass substrates hosting moisture reservoirs, however through tests it became clear that it was very inefficient and impractical to heat the glass them air temperature is the ultimate target. To diffuse heat directly into the air the heaters were given small aluminum heat sinks and placed inside slightly larger greenhouses.

Humidity Actuation

Humidity can be injected into the greenhouse using an existing valve control system. This module connects via USB to FTDI chip that decodes the serial signals and addressed a specific solid state relays to open its corresponding valve. Pressured air passed through the valve and then into a reservoir. The reservoir containing water and moist air is connected to the greenhouse. Pressure forces this moist air into the greenhouse increasing humidity.

Associated Risks

The air valves are driven by a high 24V and this could pose a risk with liquid water in reservoir. To mitigate the rick the reservoirs should be sealed well and not be close in proximity to the circuit.

Additionally, there is a possibility that liquid is inadvertently forced into the greenhouse. This can be avoided by having the intake tubes far for the liquid water level, as well as a possible splash guard that would block liquid water but allow air to pass.

Deliverables

End of Semester I

First semester the team focused on designing sensors and signal conditioning system for other environmental characteristics—ambient light, oxygen concentration, CO_2 concentration, and relative humidity. Each measurement required a separate sensor and a different subsystem was designed to formulate the readings into consistent signals—square waves with frequency encoding. Instrumentation insulation and signal conditioning stages were necessary. A multiplexing solution was also necessary to allow a controller access to all the units' sensors with fewer input channels.

At the end of the first semester test circuits and PCB designs were completed and most initial tests were competed. At this time the focus of the project began to shift.

End of Semester II

At the end of the second semester a prototype system should be completed that is capable of all measurements and controls on each greenhouse unit. The system should be run through performance tests on response, accuracy and usability. As time allows a long term operation test should be completed to examine drift and stability.

Resource Requirements

The current valve controller, sensors and resistive heater will be used as actuators for the system.

Passive components and logic component must be purchased to construct prototypes. For ease of testing and stability PCB boards and case for prototype should be designed and manufactured.

Funds for component will be provided by Dr Dong's allocated project budget.

Workflow

The first semester work was broken down by team member. For the second semester the team will be working more closely together on the integrated system.

Research and Planning

Week 1-3

During the first three weeks the main goals and scope of the project were better defined. Research of current sensor technologies was done with consideration to how these could be implemented on a small scale. Comparisons of the benefits and limitations was done to select the best method for obtaining that desired measurement. Rough cost analysis was completed.

Week 4

Rough circuit design layouts developed with basic idea of major components and how they will interact.

Design and Simulation

Week 5-7

Circuit designs run through simulation in software testing operation. Simulations go to full team review.

Week 8-10

PCB layout designs completed and go into full team review.

Week 10-12

Begin design of multiplexing for multiple sensor signals.

Prototyping

Week 9-10

Final PCB designs out for fabrication.

All necessary components ordered.

Week 9-10

Build and test breadboard sensor prototype circuits as parts arrive

Week 11

Manufactured PCB boards return. Construct units on PCB.

Week 12-14

Testing of stand-alone subsystem units.

Spring Semester Schedule

Reevaluation and Planning

Week 1-2

During the first weeks the main goals and scope of the project were refocused. Research of current what is currently available in market. Comparisons of the benefits and limitations was done for possible methods of control and platforms. Cost analysis was completed.

Week 4-6

Test implementation with an off-shelf module was built. Testing on this unit was performed to examine the systems response.

Design

Week 5

Initial tests of the Altera Cyclone II development board as control platform. Tested ability to drive actuation outputs, hold and address control variables, display variables.

Week 5-11

Coding of control logic in Verilog built on the Altera development board.

Week 12

Abandoned development board for Arduino microcontroller platform.

Design & Prototyping

Week 12-14

Porting code to new platform improving the control logic.

Week 13-15

Build enclosure.

Week 13

Design breakout PCB

Week 11

Manufactured PCB boards return. Construct units on PCB.

Testing

Week 13

Initial heater tests.

Week 14-15

Full system tests