CRITICAL DESIGN REVIEW: Automated Plant Growth System

Group 04

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Introduction

- This system utilizes a *hydroponic environment* which offers a solution to automatically monitor and regulate basic and critical elements that can optimize growth of plants. System will *provide feedback* for key environmental conditions surrounding the plant.
Objectives and Goals

- Minimize user interaction – “Set it and forget it!”
- Allow for automated feeding portions & times
- Control chemical and water level
- Control lighting cycles and distance from plant
- Provide environmental measurements
- Provide a web-based GUI
Requirements

- The system shall utilize a soilless hydroponic environment
- The system shall be designed for small plants
- The system shall be able to regulate the pH level of the feeding solution
- The system shall be able to regulate the nutrient level of the feeding solution
- The system shall be able to regulate the water level of the feeding solution
- The system shall be able to regulate the day and night lighting cycles
- The system shall regulate the height of the light source from the plant
- The system shall implement a web-based interface of user interaction
- The system will utilize an onboard data server with the capability of hosting a web interface that displays: real time display of all measurements, predefined database and user defined growth characteristics, data log of plant growth history
Specifications

- The structure shall allow for a maximum of 10 gallons and a minimum of 0 gallons.
- The humidity sensor shall have a range of 0 to 100% RH and a precision of 3%.
- The temperature sensor shall allow for a range of 0 to 80°C and a precision of 1°C.
- The liquid level sensor shall have a minimum range of 0 to 40 centimeters with a precision of at least 1 millimeter.
- The pH sensor shall have a range of 0 to 14.
- The CO₂ sensor shall allow for 0-1000 ppm with a precision of 1 ppm.
- The day and night lighting cycles shall allow for a user defined interval for cycles.
- The pumps shall allow for a minimum output of 1 mL.
System Overview

Diagram:
- Web Interface
- Network
- Controls
- Sensors
- Regulation
- Plant Feeder

The diagram illustrates the flow of information and control between these components.
Plant Feeder Structure

- Considerations:
  A. Plant Reservoir
  B. Optional Clean Water Reservoir
  C. Drain Reservoirs
  D. Chemical Reservoirs
  E. Wood Frame
  F. Piping/Tubing
  G. Main Electronics Encasement
## Sensors

- **8 Sensors**
  - pH
  - Nutrient
  - Liquid Level
  - Temperature (Environment)
  - Humidity
  - CO₂
  - Optical Sensor
  - Contact Sensor

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<tr>
<th><strong>INTERNAL ENVIRONMENT</strong></th>
<th><strong>EXTERNAL ENVIRONMENT</strong></th>
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**LIGHTING**
Sensors: Internal Environment

- pH Electrode
  - Range: 0 – 14 pH
  - Accuracy: .01 pH
  - Cost: $17
  - BNC Connector (Analog)
  - Currently on order
  - Provides internal voltage based on pH of solution
  - Will need to do voltage testing in order to design a circuit for A/D interface
Sensors: Internal Environment

- Nutrient
  - Range:
    - 0 – 2000 ppm
    - -5 to 50 °C
  - Accuracy: .5 ppm
- DIN Connector (Analog)

CURRENT ISSUES:
- Test Probe and meter is costly generally over $150 for a simple system
- Measured voltages may not match up to other probes that are less expensive
- Too much RISK!!
- Need to focus more on timed dispensing based on user input
- Meter obtained from Biology Department
Sensors: Internal Environment

- Liquid Level
  - Differential pressure sensor
  - Range:
    - 0 to 100 cm
    - 0 to 10 kPa
  - Accuracy: 1 mm
  - Response time: 1 ms
  - Cost: Free
Possibly insert analysis of accuracy
Doug Cooper, 5/31/2009
Sensors: Internal Environment

- Liquid Level: Application Diagram
  - Measurement range:
    - 0 to 40 cm
    - 0 to 4 kPa

\[ h = \frac{P}{d \cdot g} \]

- \( h \) - height of the liquid
- \( P \) - measured pressure
- \( d \) - density of the liquid
- \( g \) - force due to gravity
Sensors: Internal Environment

- Liquid Level: Connection Diagram
  - Provides output of 2.5 to 5 V over 40 cm range
Sensors: External Environment

- Temperature and Humidity
  - Combined in single module
  - Range:
    - 0 – 100% RH
    - -40 to 85 °C
  - Accuracy:
    - +/- 3% RH
    - +/- 1 °C
- Cost: $25
- PWM Out (RH)
- Analog Out (°C)
Sensors: External Environment

- Humidity: Curve Fitting (based on Manufacturer data)

\[
y = 2E^{-0.05x^2} - 0.4166x + 1741.9
\]

\[
y = -0.0886x + 642.08
\]
Sensors: External Environment

- Temp: Curve Fitting (based on Manufacturer data)

\[
y = 0.0009 + 0.00025 \ln(x) + 1.9588 \times 10^{-7} \ln(x)^3
\]

\[
y = -28.08 \ln(x) + 289.74
\]
Sensors: External Environment

- RH output is directly connected to PWM input on MCU
- Because the Thermistor resistance changes with Temp:
  - Voltage at + terminal of op-amp is varied from 24 mV to 500 mV
  - Output is amplified between 0.24 V and 5 V range for A/D
  - (Gain of 10)

\[ V_{out} = V_{cc} \left( \frac{R_p}{R + R_p} \right) \left( 1 + \frac{R_1}{R_2} \right) \]

- **Vcc** - Supply Voltage
- **Vout** - Output Voltage
- **R** - Thermistor Resistance
Sensors: External Environment

- **CO₂**
  - Range: 0 – 1000 ppm
  - Accuracy: 1 ppm
  - Cost: Free
  - Linear Analog Output
    - 0 to 5 V
    - No additional circuitry required
  - No calibration required due to onboard algorithms
Regulation

- 2 Main Systems:
  - Lighting System
    - Automated height adjustment
    - Day/Night Cycling
  - Feeding System
    - Nutrient Dispensing
    - pH Up/Down Dispensing
    - Timed Feeding capabilities
    - Water Level adjustment
Lighting System

- Automated height adjustment
  - Allows the light to maintain a fixed height during growth
    - LED Light Source
    - Stepper Motor (change)
    - Driver Circuit (change)
    - Optical Sensor
    - Contact Sensor
    - MCU I/O
Lighting System

- LED Light Source
  - Provides correct spectrum of light used by most plants
  - Voltage: 110/120 VAC
  - Current: 115 mA
- Dim: 12.25 x 12.25 x 1.25 in (34.115 x 34.115 x 3.481 cm)
- Min. Distance from Plant: 3 in (8.354 cm)
- Cost: $43.00
Lighting System

- Stepper Motor + Worm Gear Assembly → DC Motor w/ Worm Gear Assembly
  - ISSUE: Finding a worm gear assembly separate from the motor
- Specs:
  - High Torque (value not avail)
    - made for car windows
  - ≈.5 rev/s @ 3 VDC, 1 A
Lighting System

- Worm Gear Assembly
Discuss the advantage to using a worm gear over the typical gear

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Lighting System

- Stepper Driver Circuit → DC Motor H-Bridge
  - ISSUE: Need a new design for a different type motor
- Fwd/Rev control
- On/off functionality
- Shottky diodes needed to protect against kickback from the motor
Lighting System

- Optical Sensor
  - Purpose: Detect when the plant has reached the minimum level of the light source distance
  - Infrared detection
  - Range: 3 – 40 cm
  - Cost: $14
  - Analog output used as a digital input
Lighting System

- Top view of Optical Sensor configuration
- Provides a reference voltage at a fixed distance
Lighting System

- Side view of Optical sensor configuration
Lighting System

- Optical sensor connection diagram
  - $V_{ref}$ is 1.1 times the voltage measured at the other end of the light source. Provides buffer for small fluctuations.
  - When breached, $V_{out}>V_{ref}$, signals MCU to move motor
Lighting System

- Contact Sensor
  - Purpose: Detect when the light source has reached max. height
  - On/Off output
  - Normally Open (contact)
  - Cost: Free
Lighting System

- Contact sensor connection diagram
  - $V_{ref} = 1\, \text{V}$
  - With no contact, $V_{out}$ goes high and connects MCU input to GND
  - On contact, $V_{out} = 0$, input on MCU goes High
Lighting System

- Day/Night Cycling
  - Provide the ABSENCE of light needed for the plant to grow properly
  - Relay
  - MCU Output
Lighting System

- Atmel 168 (8-bit) MCU
  - Inputs: Optical, Contact Sensor
  - Outputs: Motor control, Lighting Relay
  - Reason for use: obtained free development board
Feeding System

- Nutrient and pH regulation
  - 3 Peristaltic Pumps
    - Nutrients
    - pH up
    - pH down
  - Each 45° rotation will give 1 mL output of chemical solution
  - 25 steps are needed for a full 45° rotation
Feeding System

- Peristaltic Pumps
  - Spacing between the screws on the wheel should be approx 1.24 inches apart which has been calculated to provide 1 mL/rotation with a ¼” ID tubing.
Feeding System

- Stepper Motor
  - Nema 17 – 1.8° Step Motor
  - High Torque
  - 2 Amp Rating
  - Low Cost: $7
Feeding System

- Stepper Motor Connection Diagram
Feeding System

- Stepper Motor Circuit Diagram
Feeding System

- Air pump
  - On the side of the solution reservoir we would have two air stones to mix the solution when chemicals are added.
  - Possibly leave them on to both continuously mix and stop water from getting stagnant
  - Circuit for air pump will only require on/off output
Feeding System

- Timed Feeding
  - Pump located at bottom of tank.
  - Will be turned on for specified amount of time as determined by the size, and stage of growth of the plant.
  - Needs only on/off function.
Feeding System

- **Water Level**
  - By controlling the two main valves in our system we can adjust the volume of water
  - System would be flushed generally once every two weeks through plants life cycle.
  - The response time of the water level sensor and valves will give a generally accurate volume of water. Accuracy to be determined through testing
Feeding System

- **Valves**
  - **Drain Valve**
    - Needs 24 VAC to open and allow water to drain to bottom container. No minimum pressure required to function properly.
  - **Inlet Valve**
    - Same specifications as Drain Valve. Supplying voltage will input water to system. In combination with water level sensor will give an accurate volume of water. ¾” input is available on unit to connect a hose.
- **Inlet Pump (Optional)**
  - If a hose is not available a pump and an additional reservoir can be added to the system.
Controls

- 2 Atmel 168 MCU’s
  - Lighting
  - Sensors
  - Pumps
- Usages:
  - Serial Interface
  - A/D inputs
  - PWM I/O’s
  - Digital I/O’s
Wiring of Control System

- Demultiplexer allows for more outputs from fewer inputs
- Rx and Tx lines are for use of web interface (UART connection)
- Sensors on A/D and PWM inputs
Web Interface

- Lantronix 802.11 Data Server
  - Hosts custom web pages
  - Wireless to Serial Interface
  - Ad-hoc, LAN or WAN connection
    - Final connection type TBD
Web Interface

- 2 Serial ports
- No RF fabrication required
  - Antenna connects directly to the ufl connector on rear of unit
- Ethernet capabilities (if needed)
- Module Cost: Free
- Eval kit: Free
Web Interface: GUI

- Main interaction with the user
- HTML & JAVA based coding
- Passes data to control system over serial interface
- Regulates user inputs
  - Ensures the inputs are within expected values
  - Lets user know anticipated input values
  - Will not update unless specific actions are taken (i.e. button click)
- Displays current values from control system
External Storage Device

- Secure Digital interface
  - Used for data logging
  - Wires directly into the control system
  - Uses MOSI, MISO, SS, SCK on control device
  - Will store sensor values for selected time intervals
  - Values will be retrievable through the website by the user if requested
- Cost: $11
Power

- Overview
  - Not the focus of the project
  - Basic power strip will be used to distribute power to the system
Power

- **AC/DC & AC/AC Conversion**
  - Supplied through off-the-shelf power converters that are suited for the various pumps and valves
- **Relays**
  - 5 VDC, 40 mA control (from MCU)
  - 240 VAC, 5A operation
  - Cost: $1/unit
- **Power distribution to motors**
  - Tests will be performed to determine exact voltage for each motor
  - A low voltage (5V) will be used and increased accordingly
- Possible to use a computer power supply to power the electronics
Budget

- Approximate values
- Some costs have increased and some have decreased
- On target

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<tr>
<th></th>
<th>Budget</th>
<th>Retail Cost</th>
<th>Actual Cost</th>
<th>Savings</th>
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<tbody>
<tr>
<td>Total</td>
<td>$900</td>
<td>$1057</td>
<td>$660</td>
<td>$397</td>
</tr>
<tr>
<td>Total/Person</td>
<td>$300</td>
<td>$352</td>
<td>$220</td>
<td>$132</td>
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Current Status

- Successfully connected to a simple web page via ad-hoc
- Coding for communication between web interface and controller determined
- Simple code written for A/D and digital input/output processes
- Materials for structure obtained
- Build/Test for stepper motor circuit in progress
- Obtained/ordered all major components
Possible Issues

- Keeping focus on the Electrical Engineering aspect of the project and not the Plant Growing processes
- Mechanical Aspects (i.e. fluids, motors, gears)
- Water-proofing electronics
- Keeping cost down (i.e. Conductivity sensor)