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

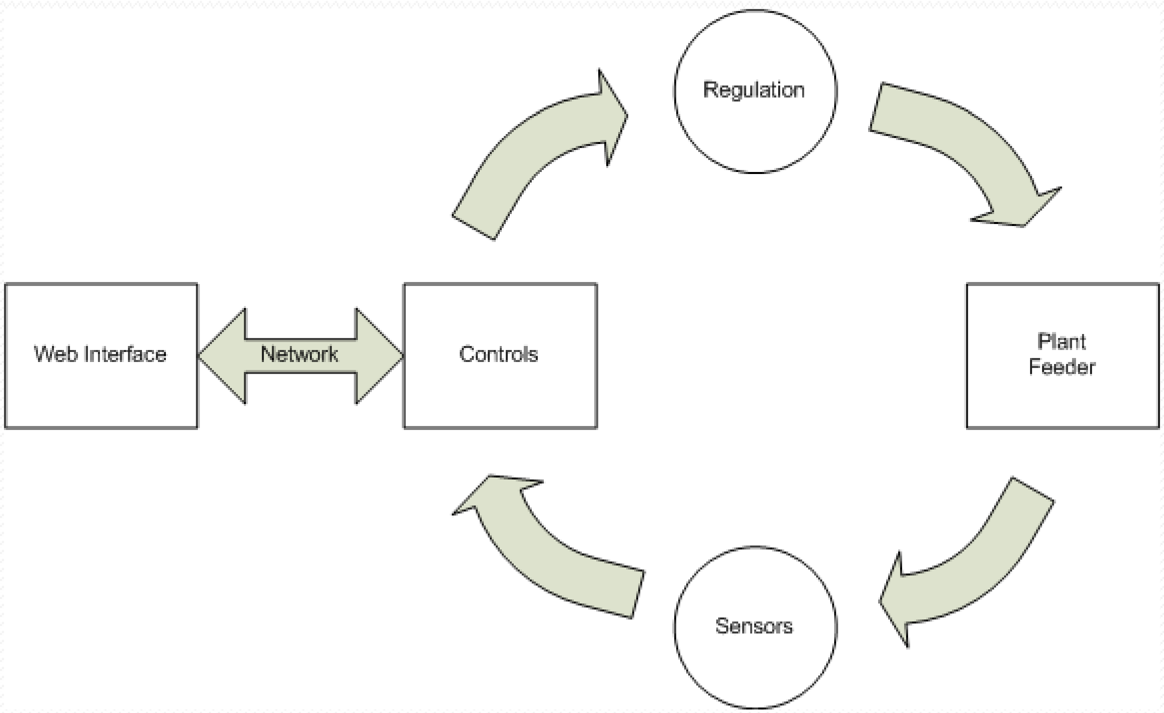
Requirements

- 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

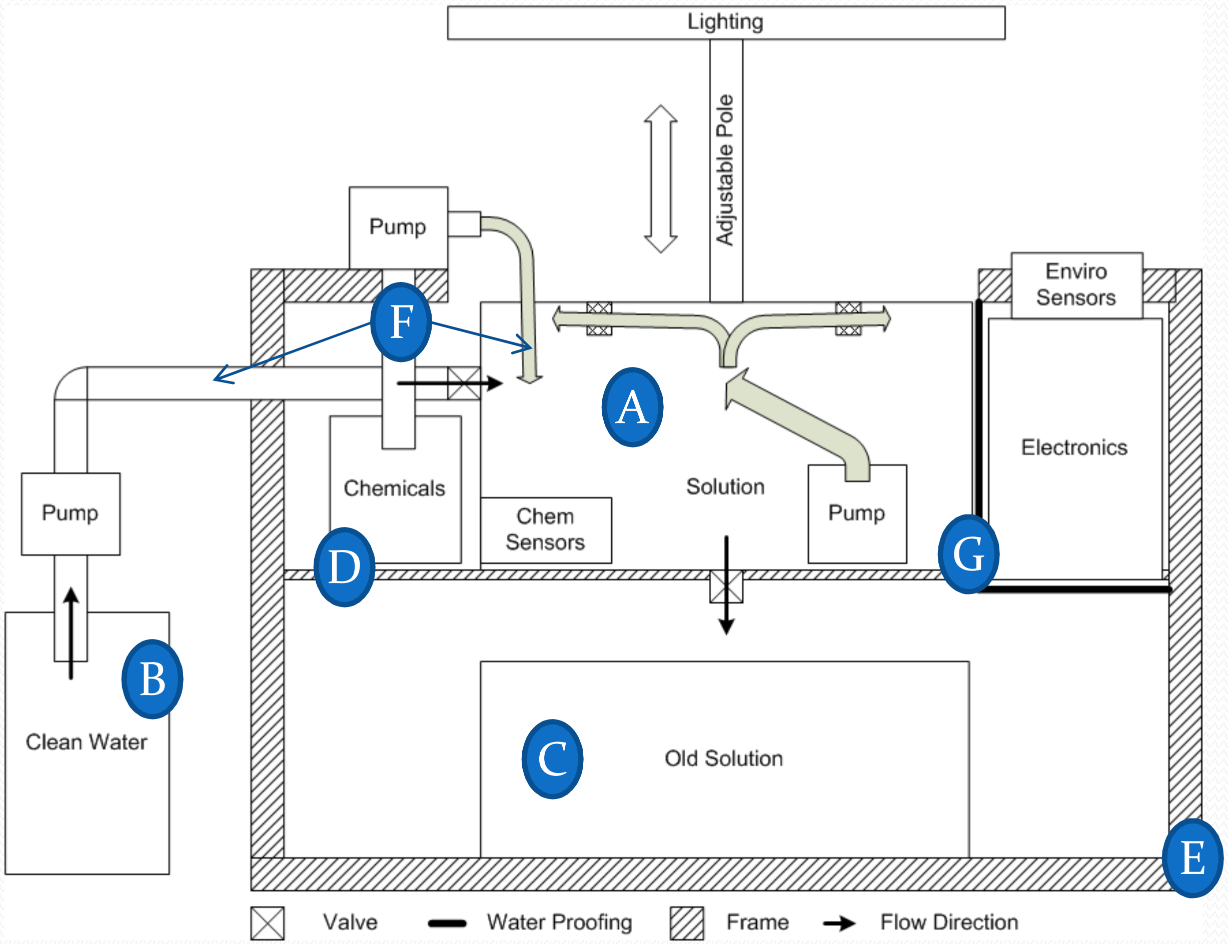
- The structure shall allow for a maximum of 10 gallons and a minimum of 0 gallons
- The humidity sensor shall have a range of 0 to 100% RH and a precision of 3%
- The temperature sensor shall allow for a range of 0 to 80^0 C and a precision of 1^0 C
- The liquid level sensor shall have a minimum range 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 CO_2 sensor shall allow for 0-1000ppm with a precision of 1ppm
- 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



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
  - CO_2
  - Optical Sensor
  - Contact Sensor

INTERNAL ENVIRONMENT

EXTERNAL ENVIRONMENT

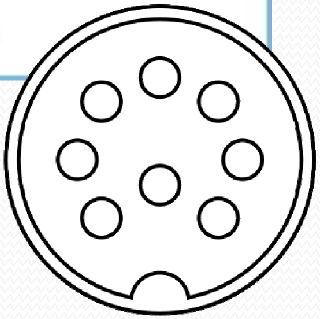
LIGHTING

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

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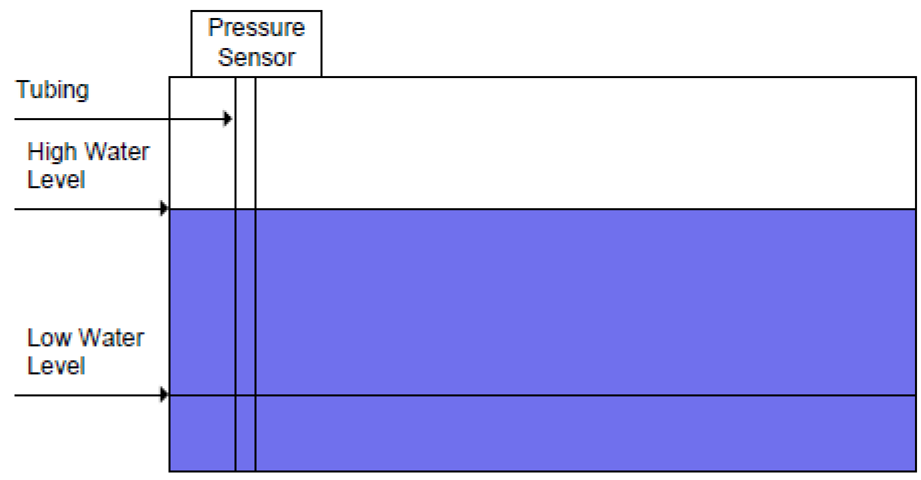
DC5 Possibly insert analysis of accuracy
Doug Cooper, 5/31/2009

Sensors: Internal Environment

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

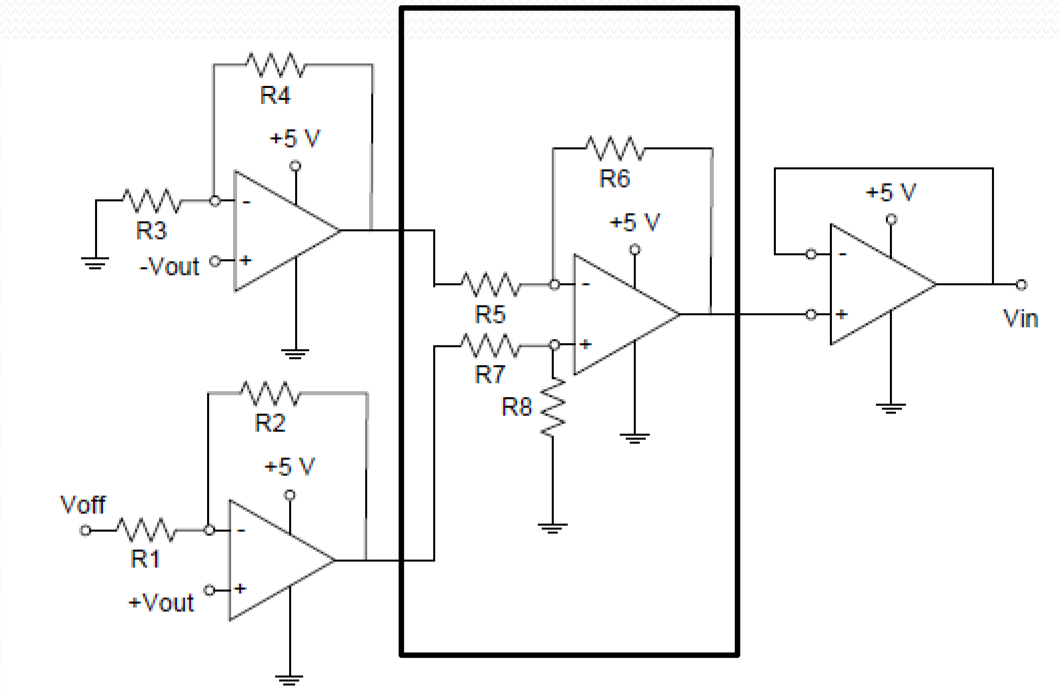
$$h = \frac{P}{dg}$$

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



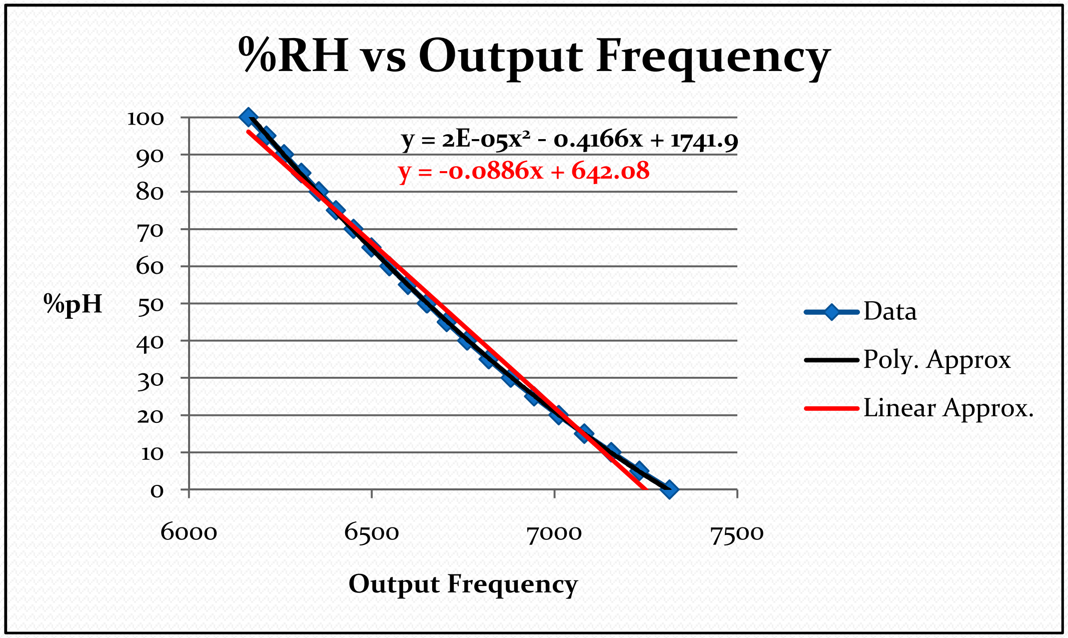
Difference
Amp

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)

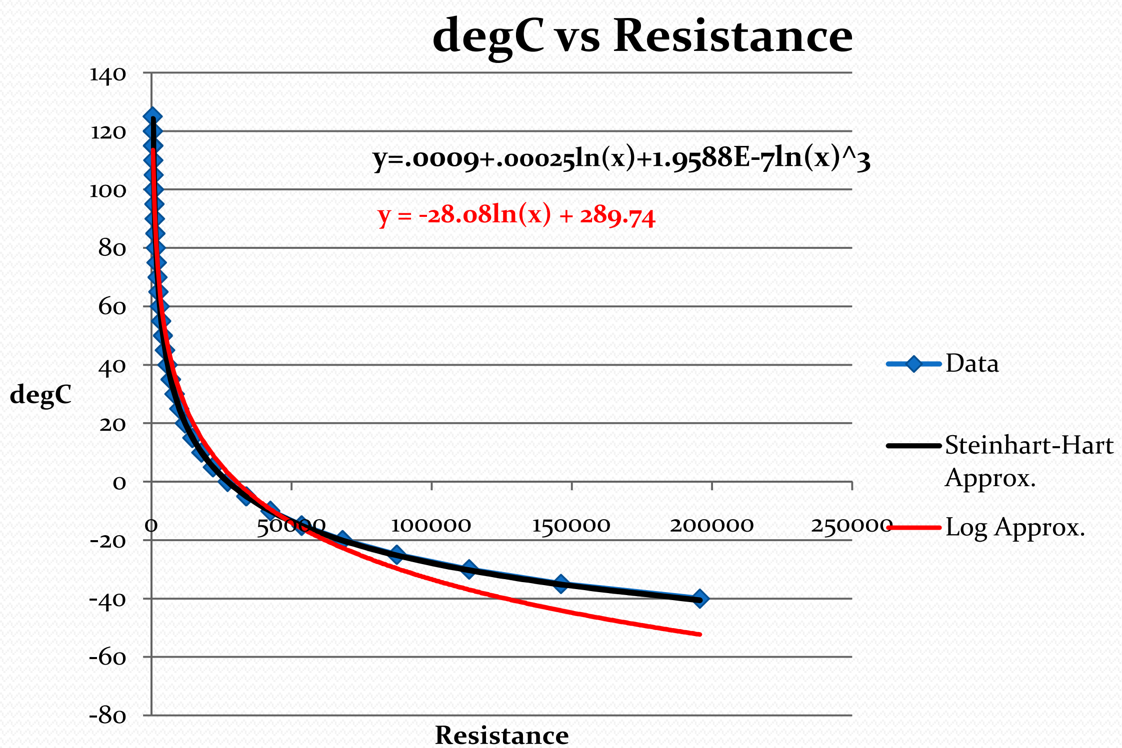
Sensors: External Environment

- Humidity: Curve Fitting (based on Manufacturer data)



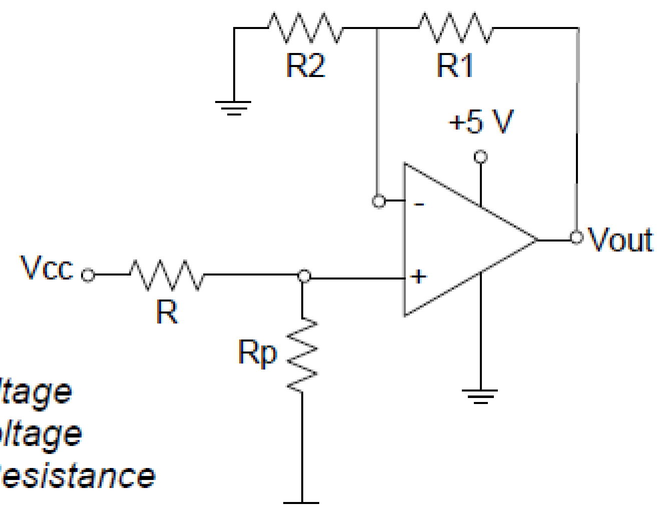
Sensors: External Environment

- Temp: Curve Fitting (based on Manufacturer data)



Sensors: External Environment

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



$$Vout = Vcc\left(\frac{Rp}{R + Rp}\right)\left(1 + \frac{R1}{R2}\right)$$

Vcc - Supply Voltage
Vout – Output Voltage
R – Thermistor Resistance

Sensors: External Environment

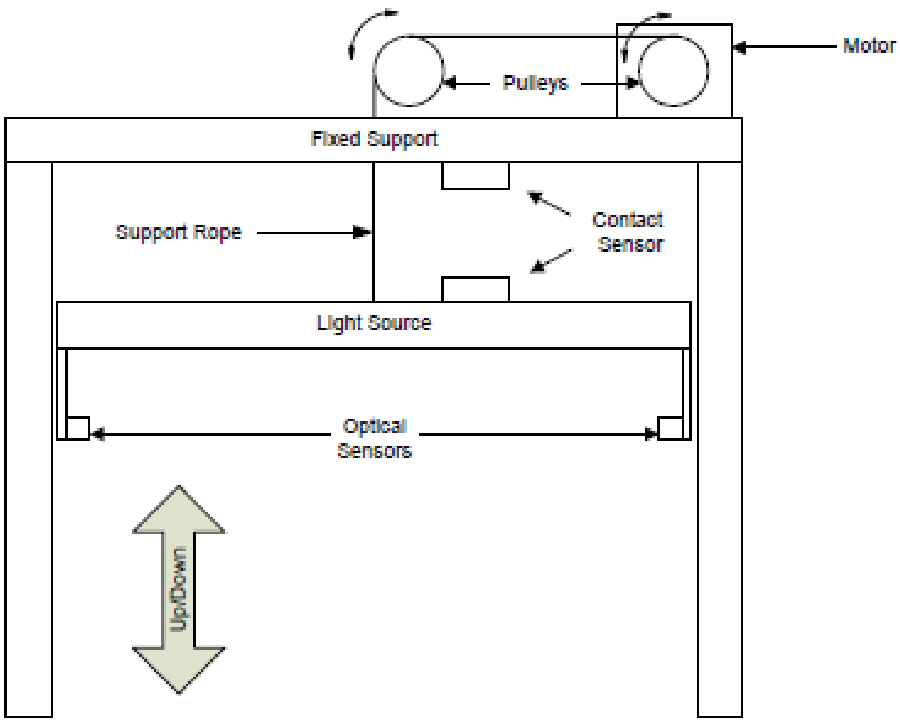
- CO_2
  - Range: 0 – 1000 ppm
  - Accuracy: 1 ppm
  - Cost: Free
  - Linear Analog Output
    - 0 to 5 V
    - No additional circuitry required
  - No calibration required due to onboard algorithms

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

DC2

Lighting System

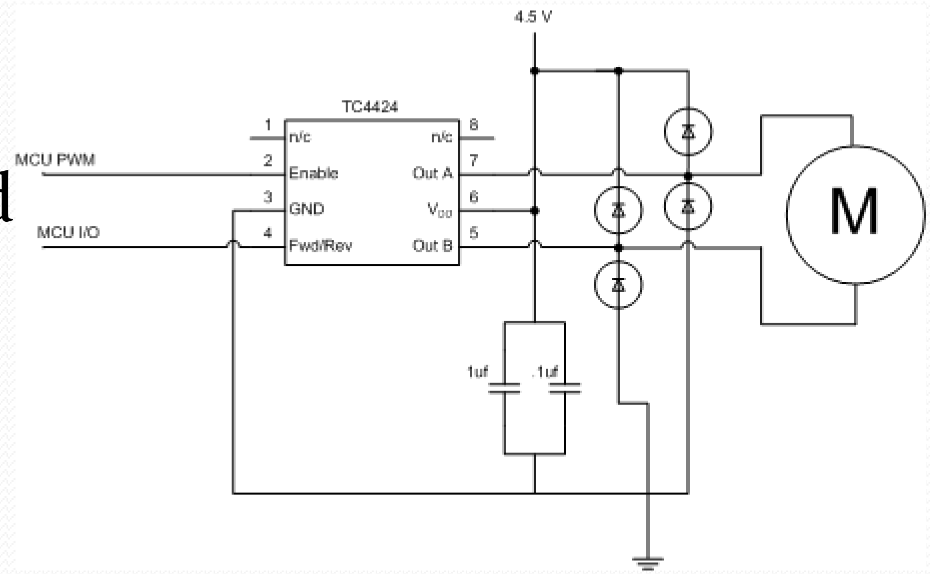
- Worm Gear Assembly

Slide 23

DC2 Discuss the advantage to using te worm gear over the typical gear
Doug Cooper, 5/31/2009

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

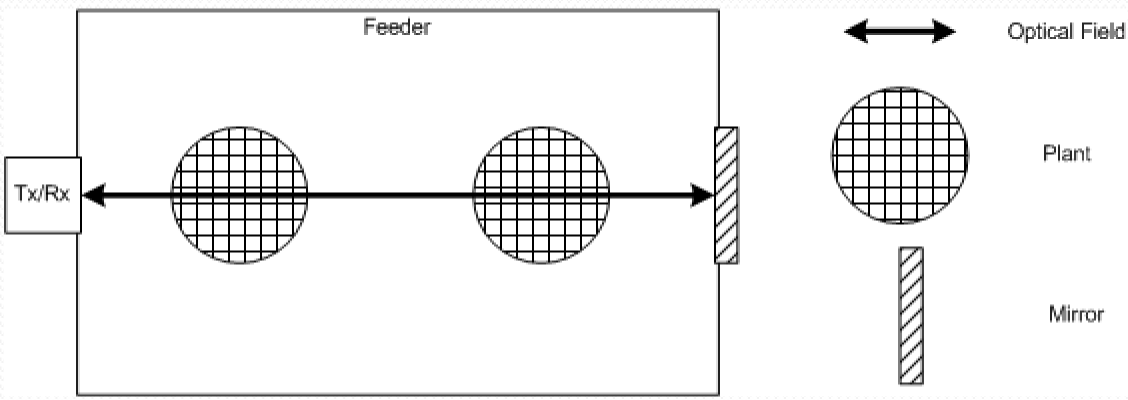


Lighting System

- 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

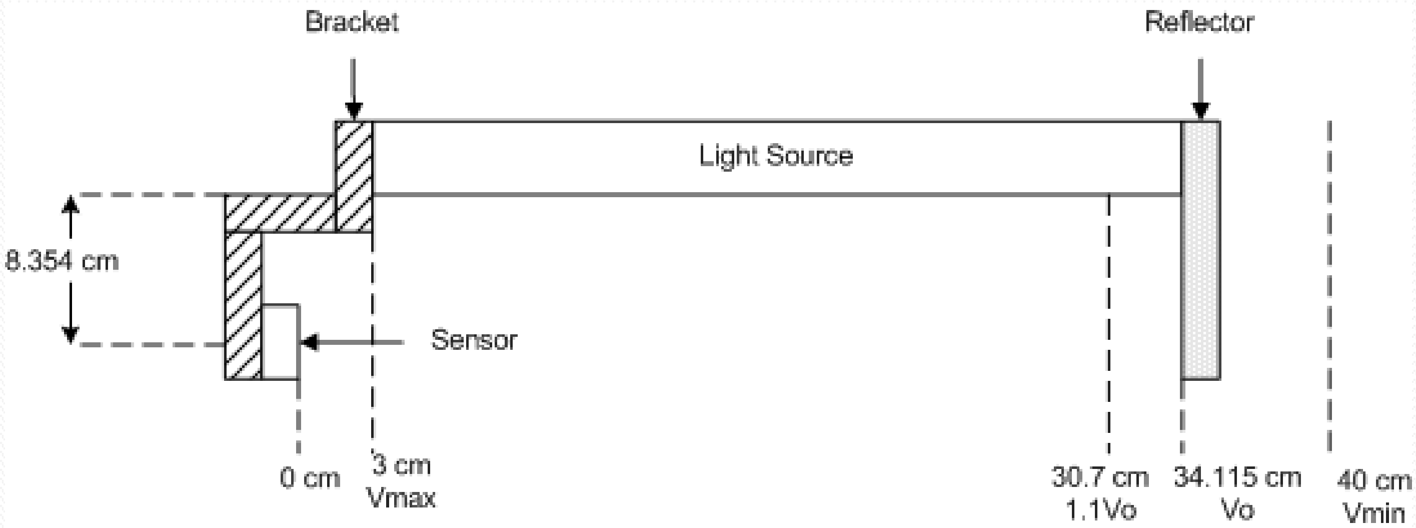
Lighting System

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



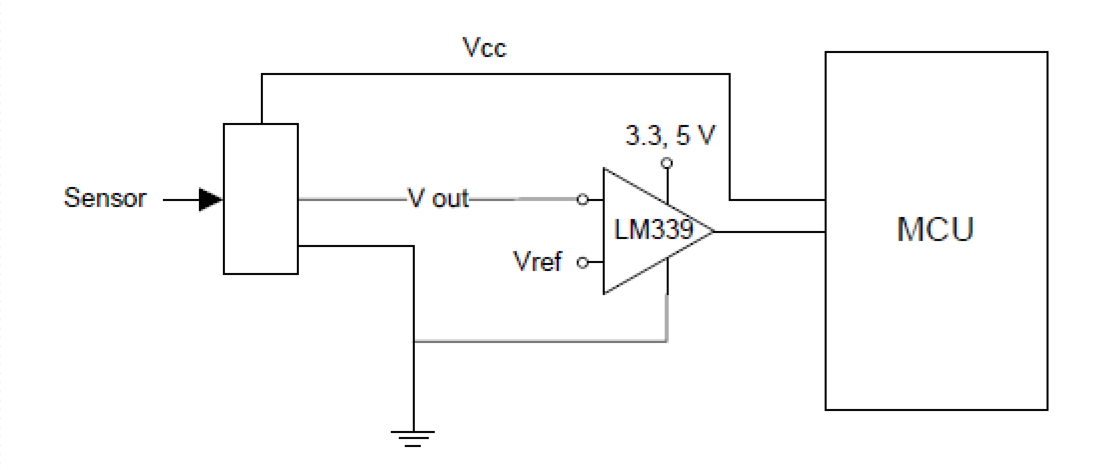
Lighting System

- Side view of Optical sensor configuration



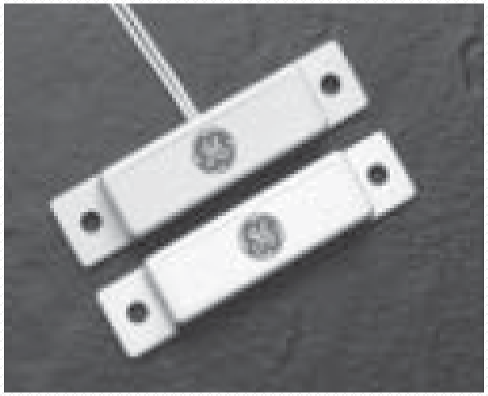
Lighting System

- 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} >Vref, signals MCU to move motor



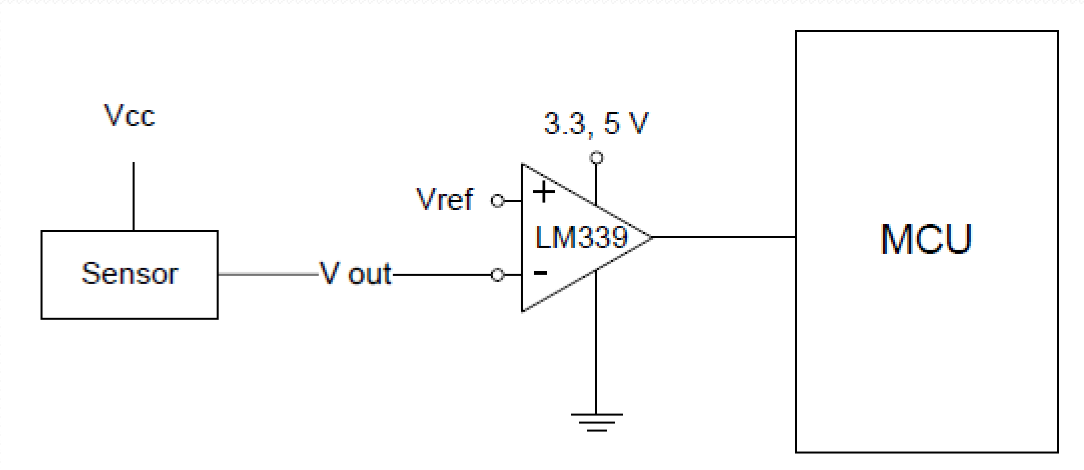
Lighting System

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



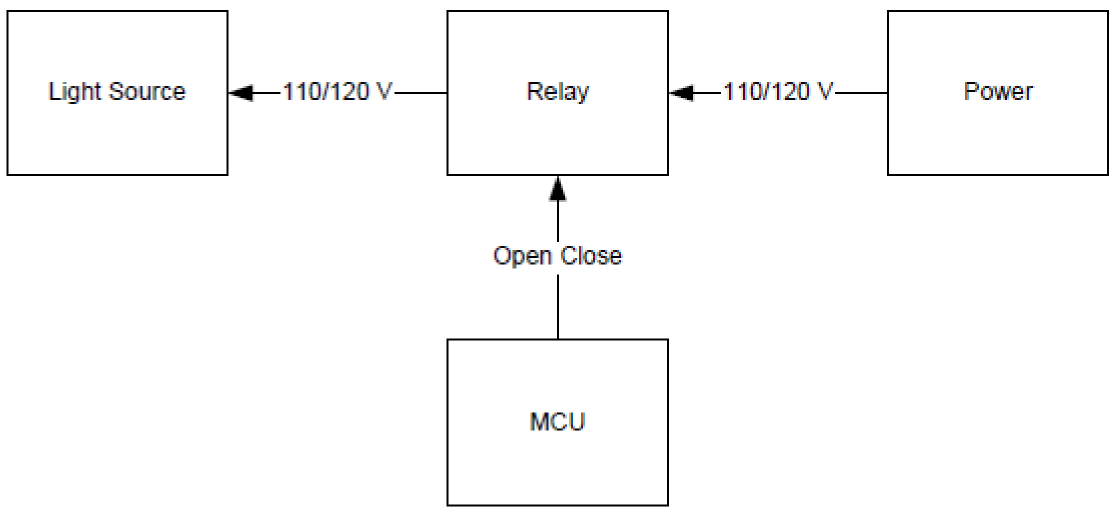
Lighting System

- Contact sensor connection diagram
  - Vref = 1 V
  - With no contact, Vout goes high and connects MCU input to GND
  - On contact, Vout = 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

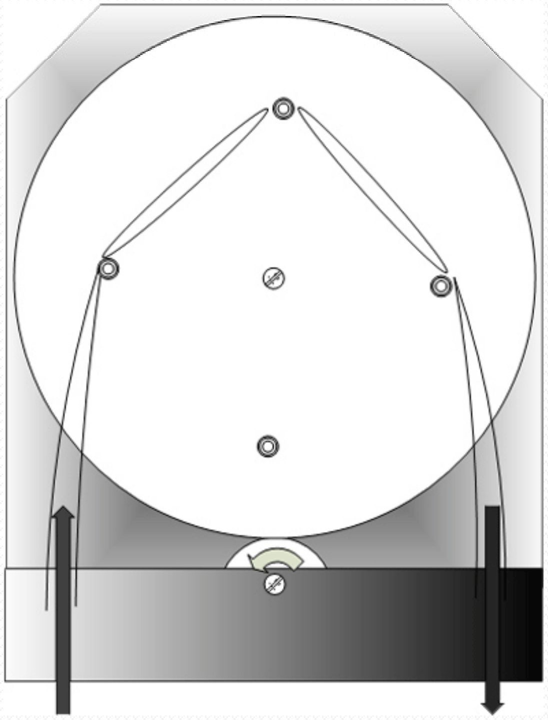


Lighting System

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

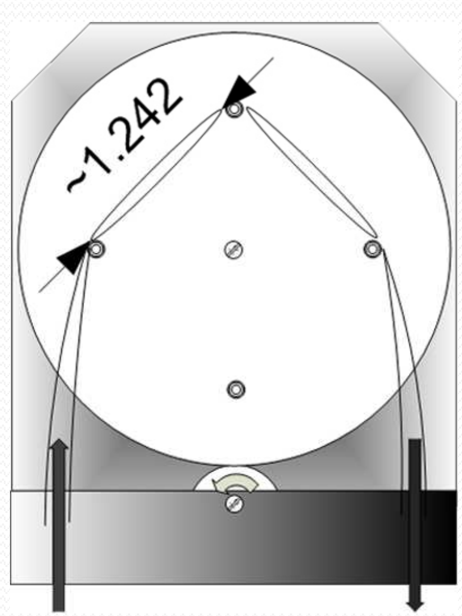
Feeding System

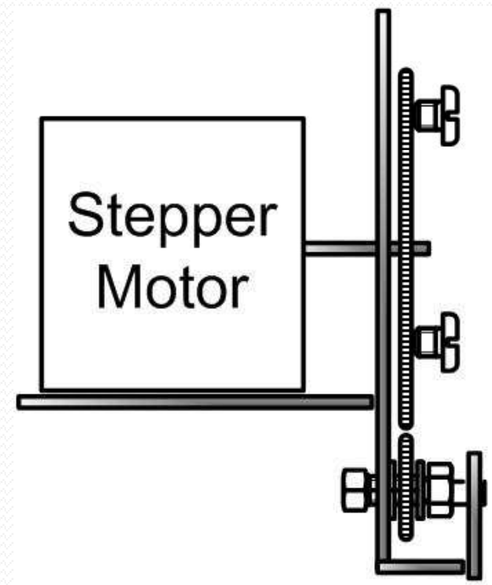
- Nutrient and pH regulation
  - 3 Peristaltic Pumps
    - Nutrients
    - ph up
    - ph down
  - Each 45º rotation will give 1 mL output of chemical solution
  - 25 steps are needed for a full 45° rotation



Feeding System

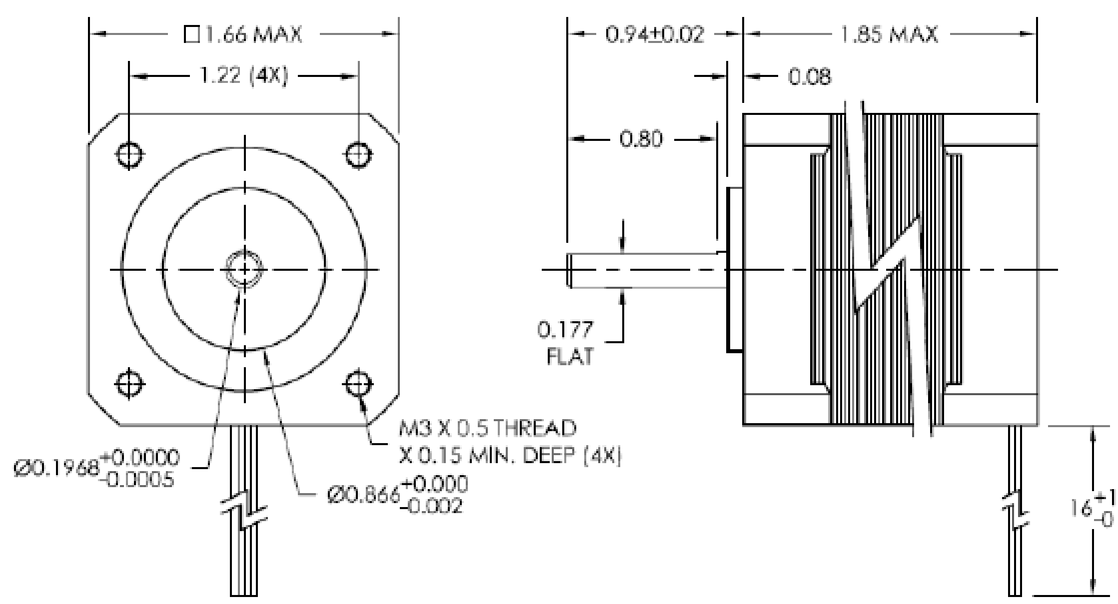
- Peristaltic Pumps
  - Spacing between the screws on the wheel should be approx 1.24 inches apart which has been calculated to provide 1 mL/rotation with a ¼” ID tubing.





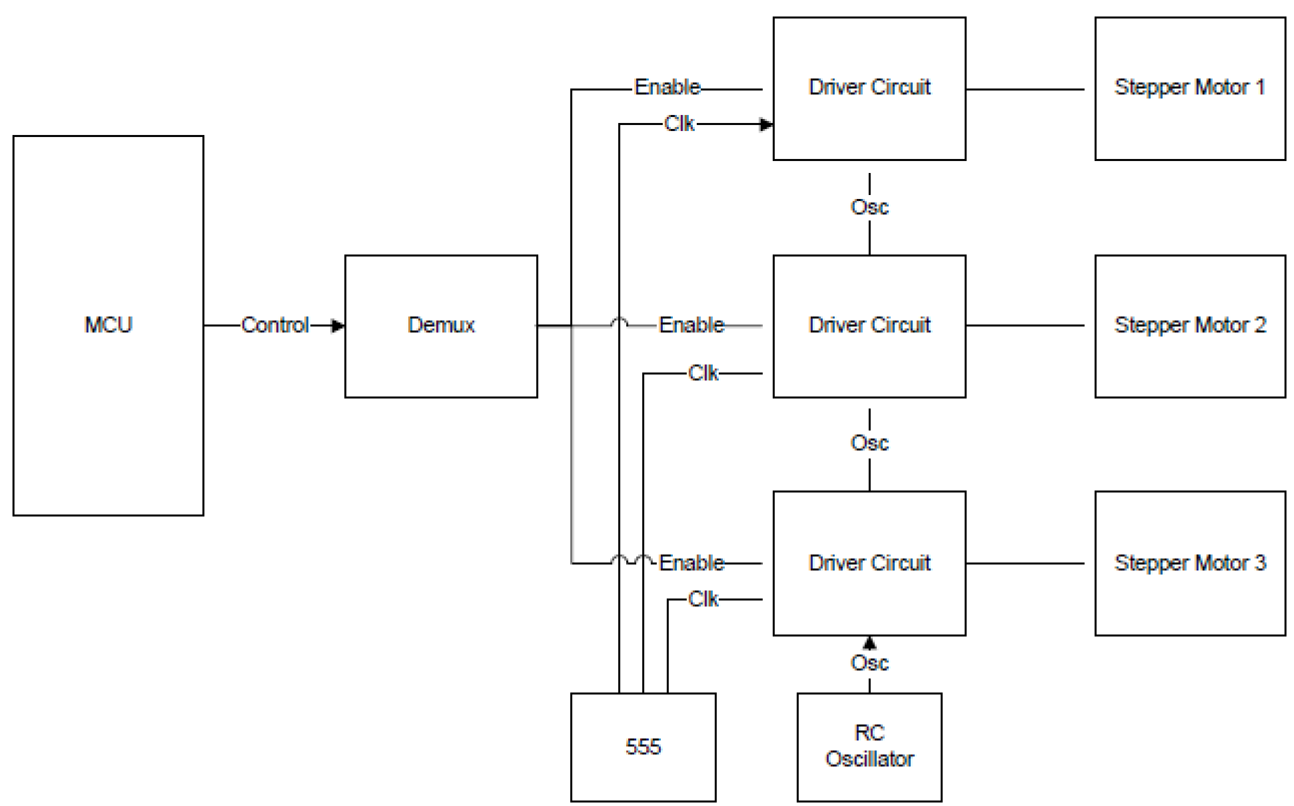
Feeding System

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



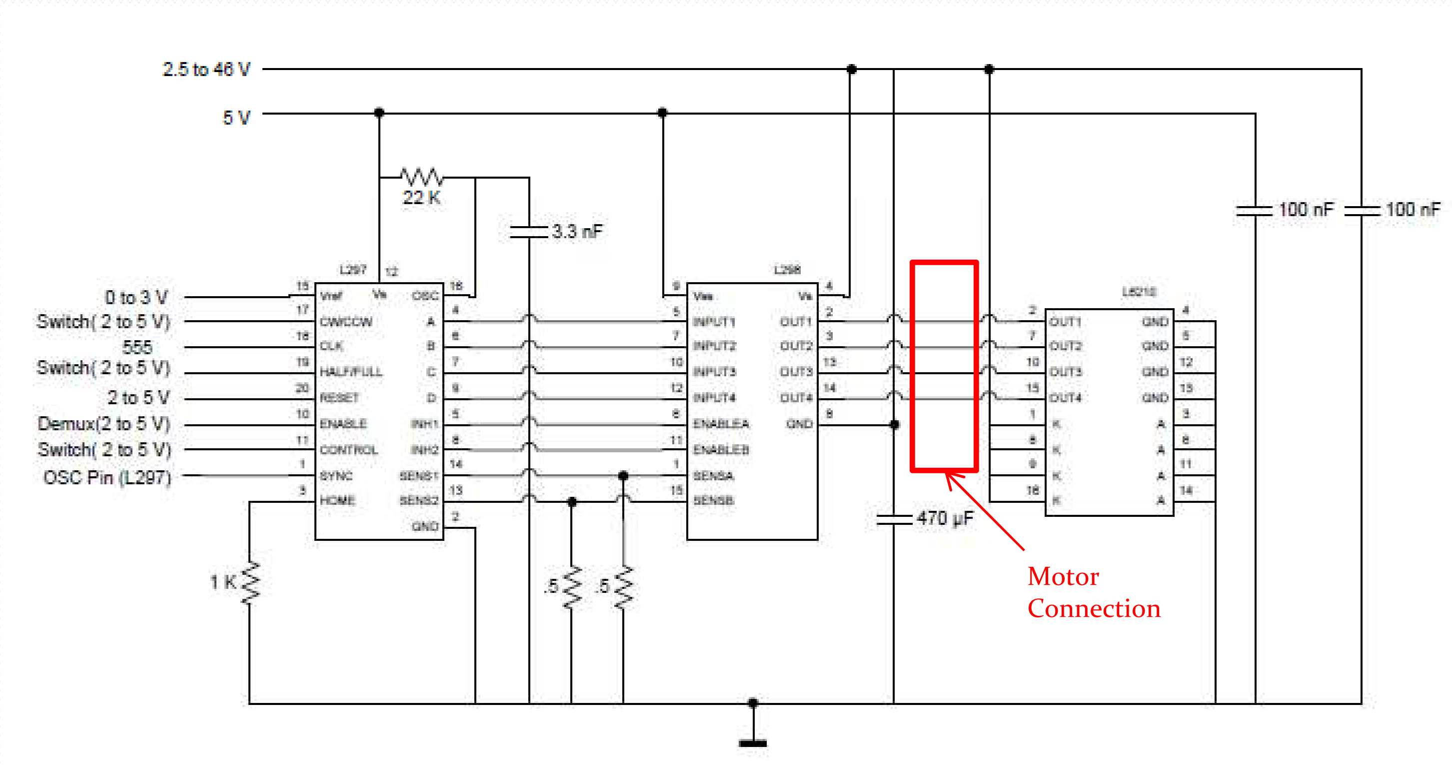
Feeding System

- Stepper Motor Connection Diagram



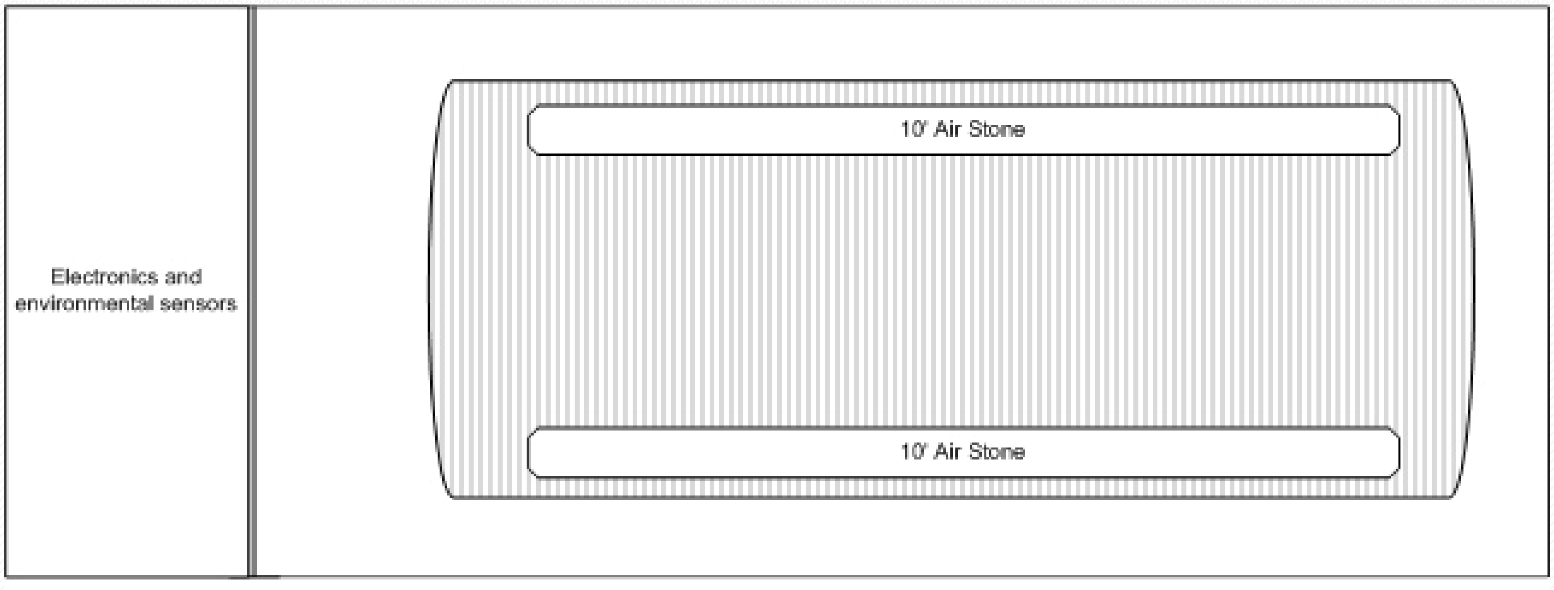
Feeding System

- Stepper Motor Circuit Diagram



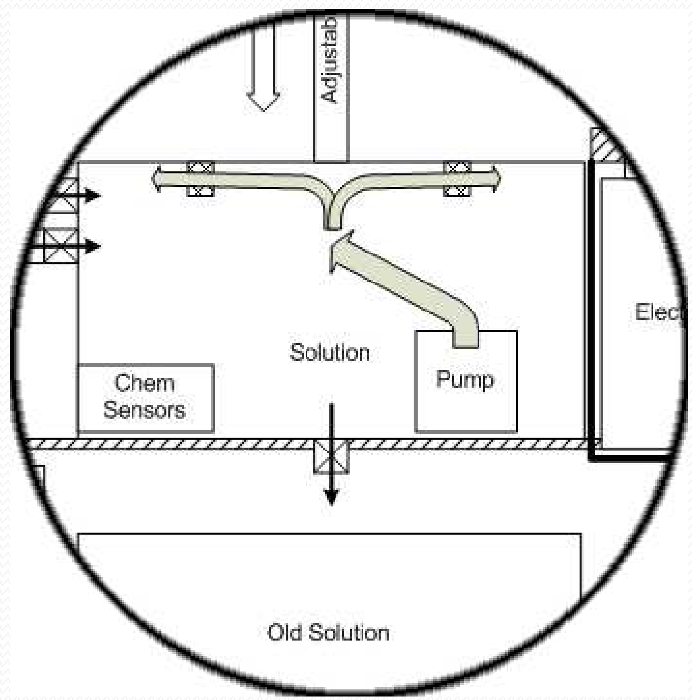
Feeding System

- 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



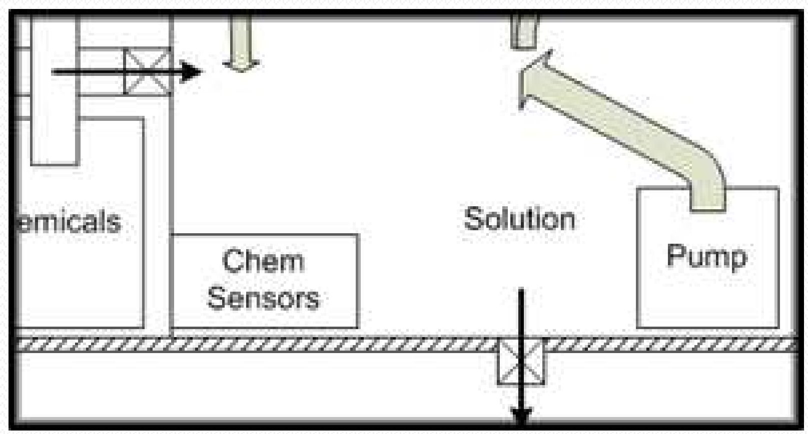
Feeding System

- 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

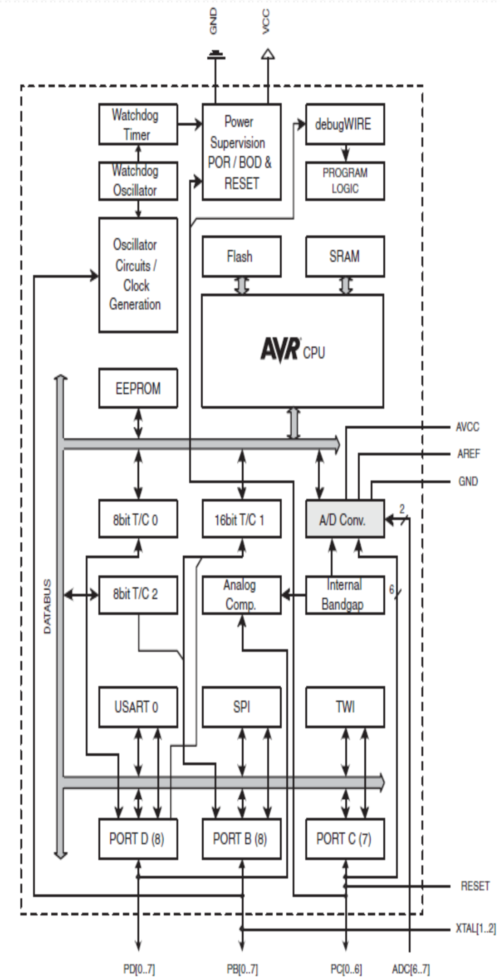


Feeding System

- 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

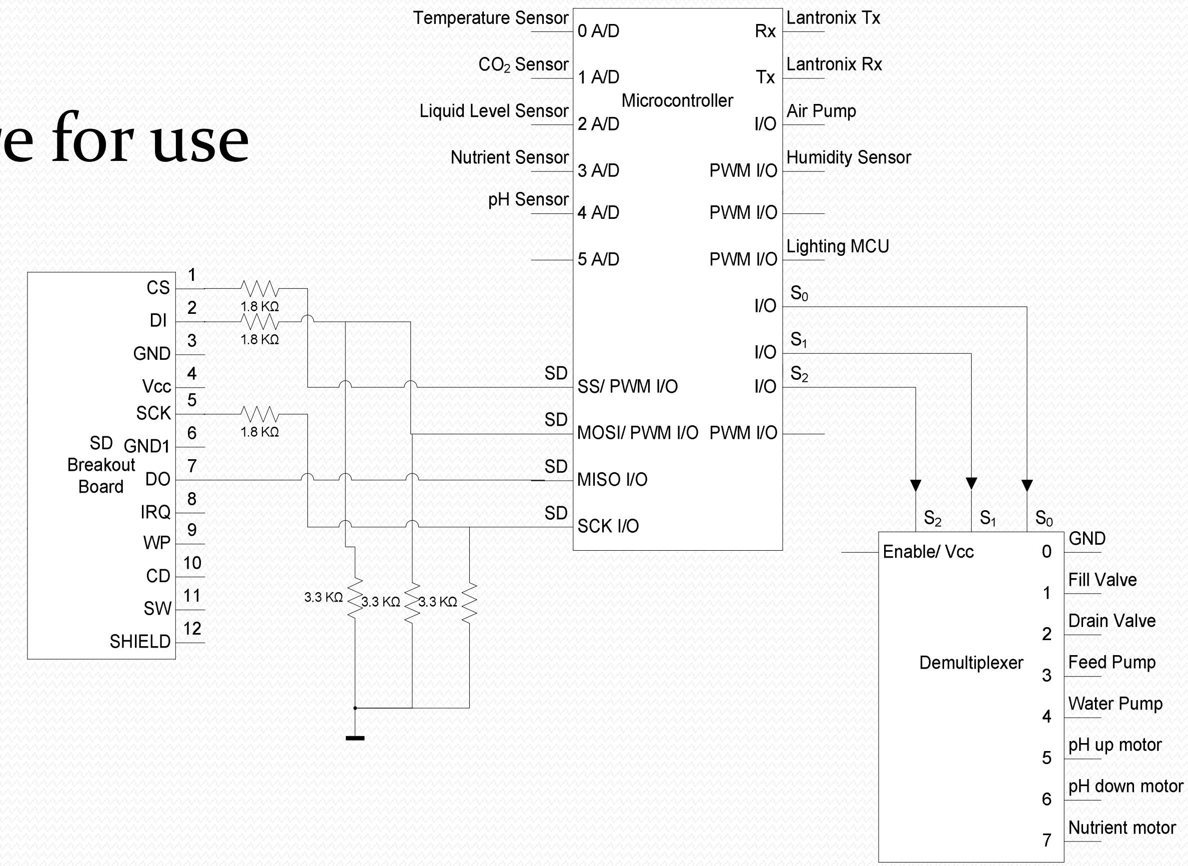
Controls

- 2 Atmel 168 MCU's
  - Lighting
  - Sensors
  - Pumps
- Usages:
  - Serial Interface
  - A/D inputs
  - PWM I/O's
  - Digital I/O's



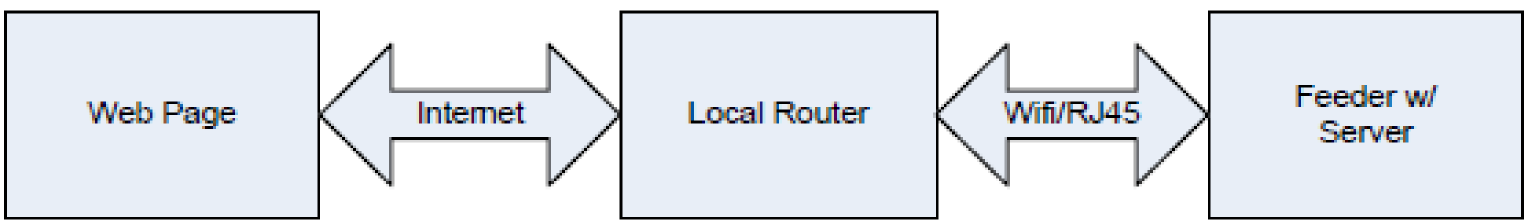
Wiring of Control System

- 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

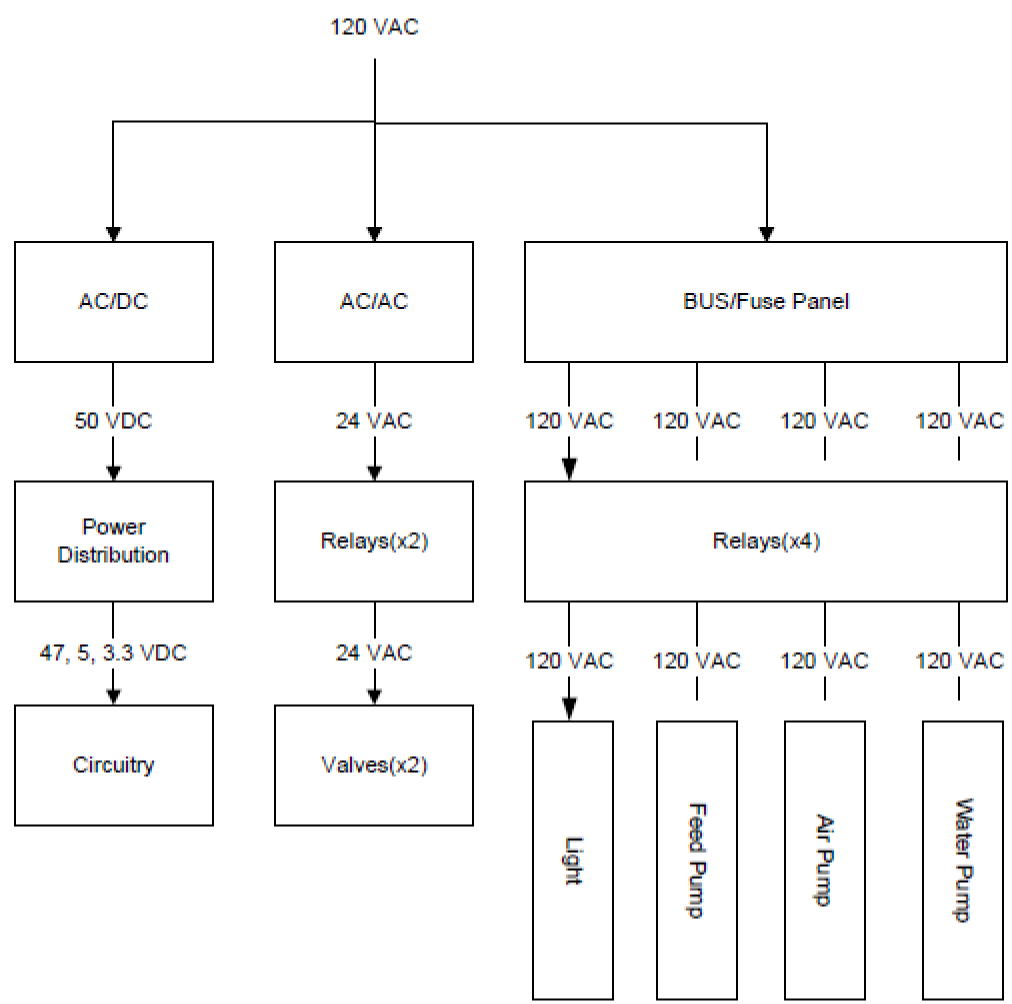
- Main interaction with the user
- HTML & JAVA based coding
- Passes data to control system over serial interface
- Regulates user inputs
  - Ensures the inputs are within expected values
  - Lets user know anticipated input values
  - Will not update unless specific actions are taken (i.e. button click)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

	Budget	Retail Cost	Actual Cost	Savings
Total	$900	$1057	$660	$397
Total/Person	$300	$352	$220	$132

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

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)