Automated Plant Growth System

Sponsorships:
Lantronix
Senseair
Sunstone Circuits

Group 04

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Desmond Persaud

Samael Reyna

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. The system will provide feedback for key environmental conditions surrounding the plant.

Goals & Objectives

- 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

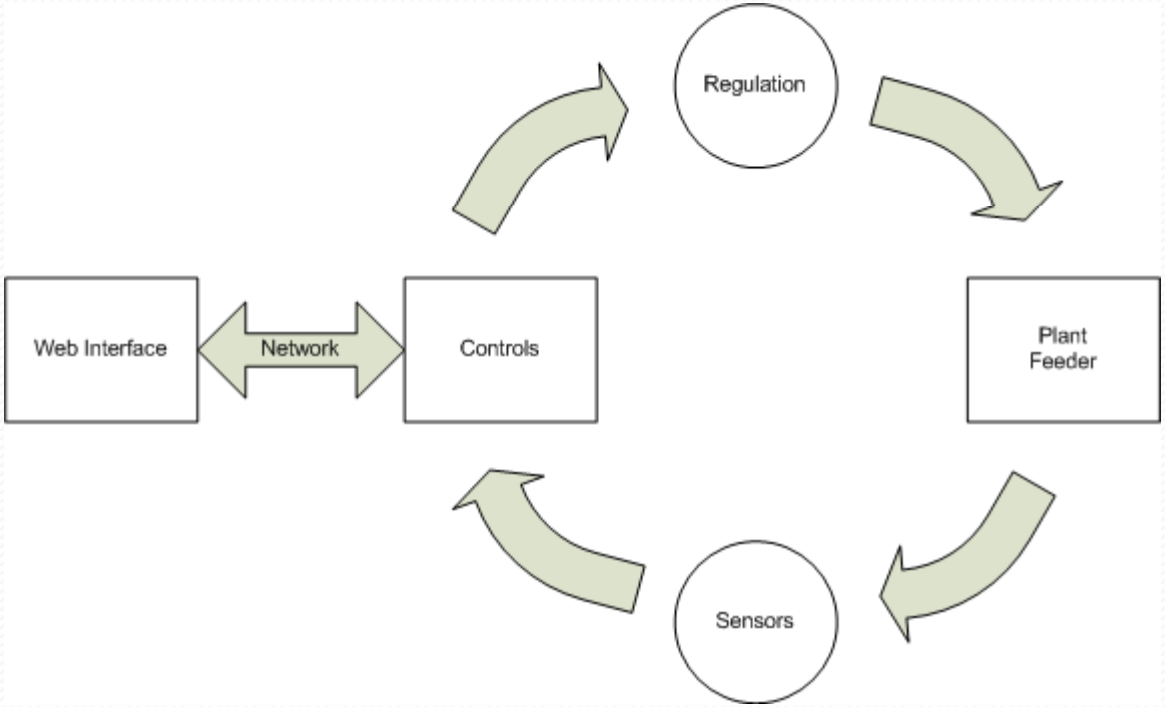
Requirements & Specifications

- 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 85° C and a precision of 1° C
- The liquid level sensor shall have a minimum range of 0 to 21.5 centimeters with a precision of at least .5 cm
- The pH sensor shall have a range of 0 to 14 with a precision of 1 pH
- The CO_2 sensor shall allow for 0-2500ppm with a precision of 10 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

Work Distribution

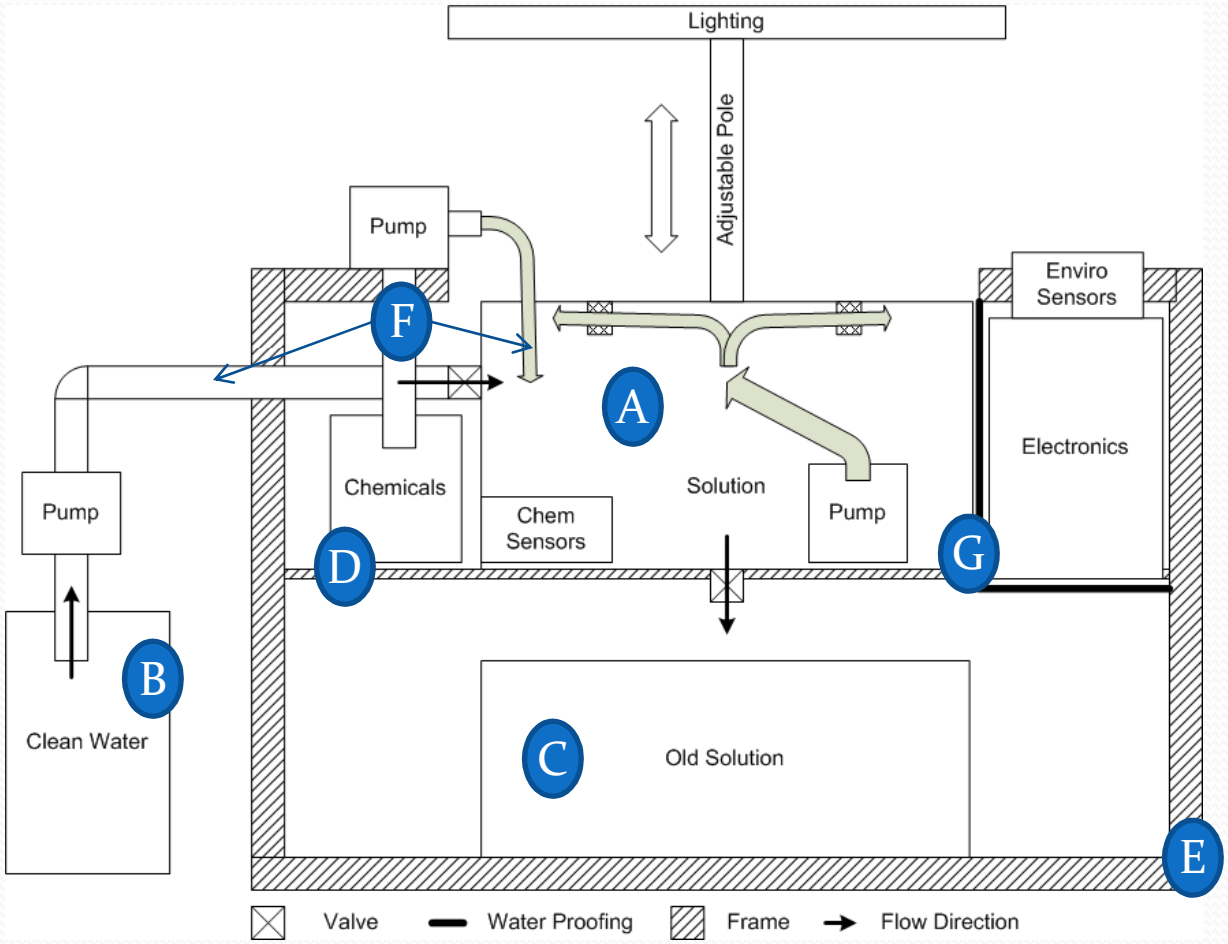
- Doug – Lighting System; Liquid Level, Humidity, Temperature and CO_2 sensors
- Desmond – Microcontroller programming; Web-site interface; Sensor interfacing
- Samael – Water regulation; Chemical regulation
- Doug and Sam – Peristaltic Pumps
- Group – PCB layout and fabrication; wiring and construction; mechanics; troubleshooting and testing

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

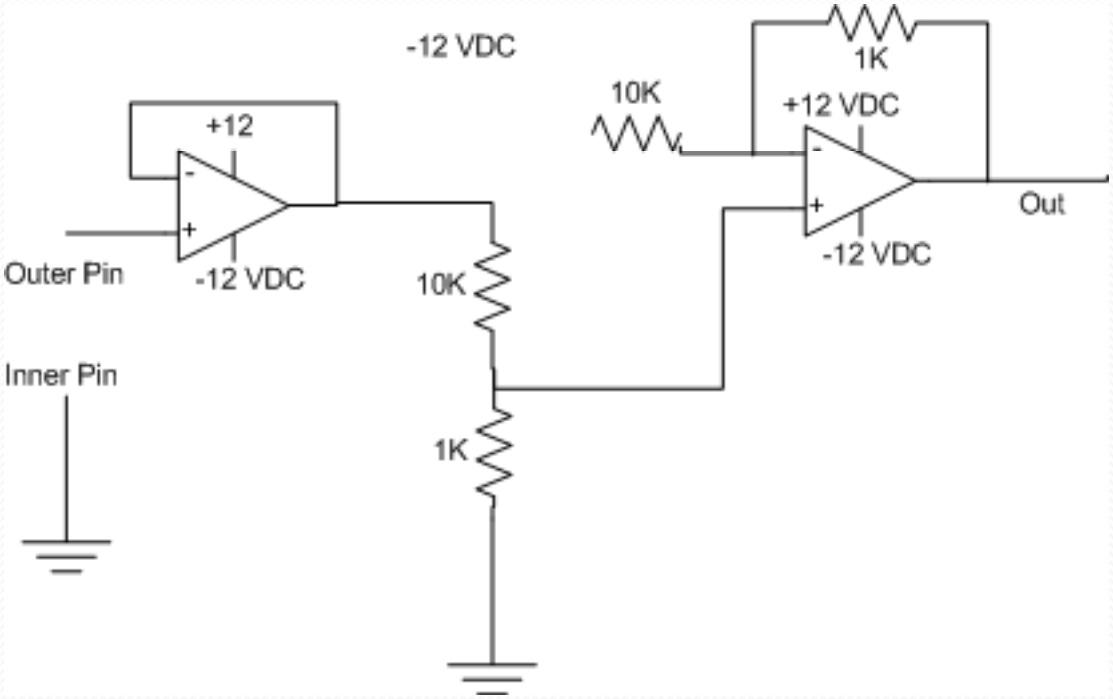
LIGHTING

Sensors: Internal Environment

- pH Electrode
  - Range: 0 – 14 pH
  - Accuracy: .01 pH
  - Cost: $17
  - BNC Connector (Analog)
  - *Provides internal voltage based on pH of solution*

Sensors: Internal Environment

- pH electrode: Circuit Diagram



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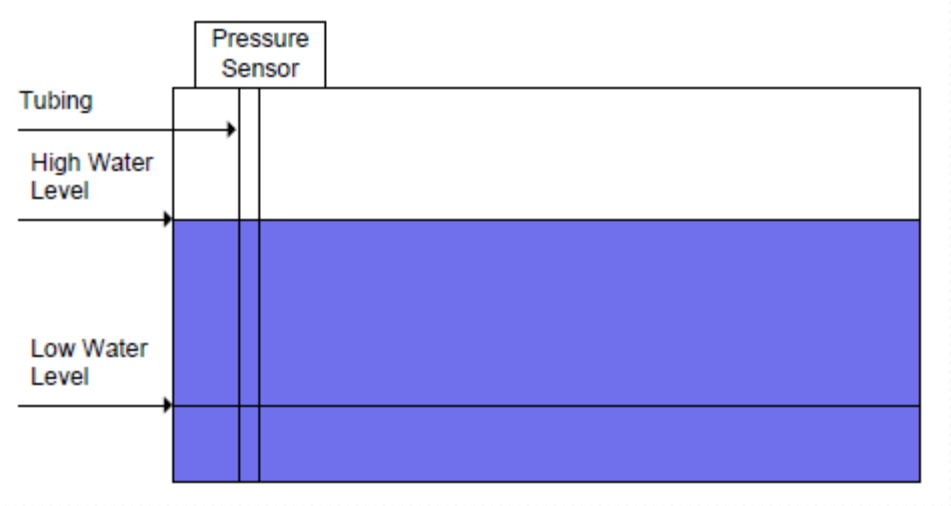
DC5 Possibly insert analysis of accuracy
Doug Cooper, 5/31/2009

Sensors: Internal Environment

- Liquid Level: Application Diagram
  - Measurement range:
    - 0 to 21.5 cm
    - 0 to 2 kPa

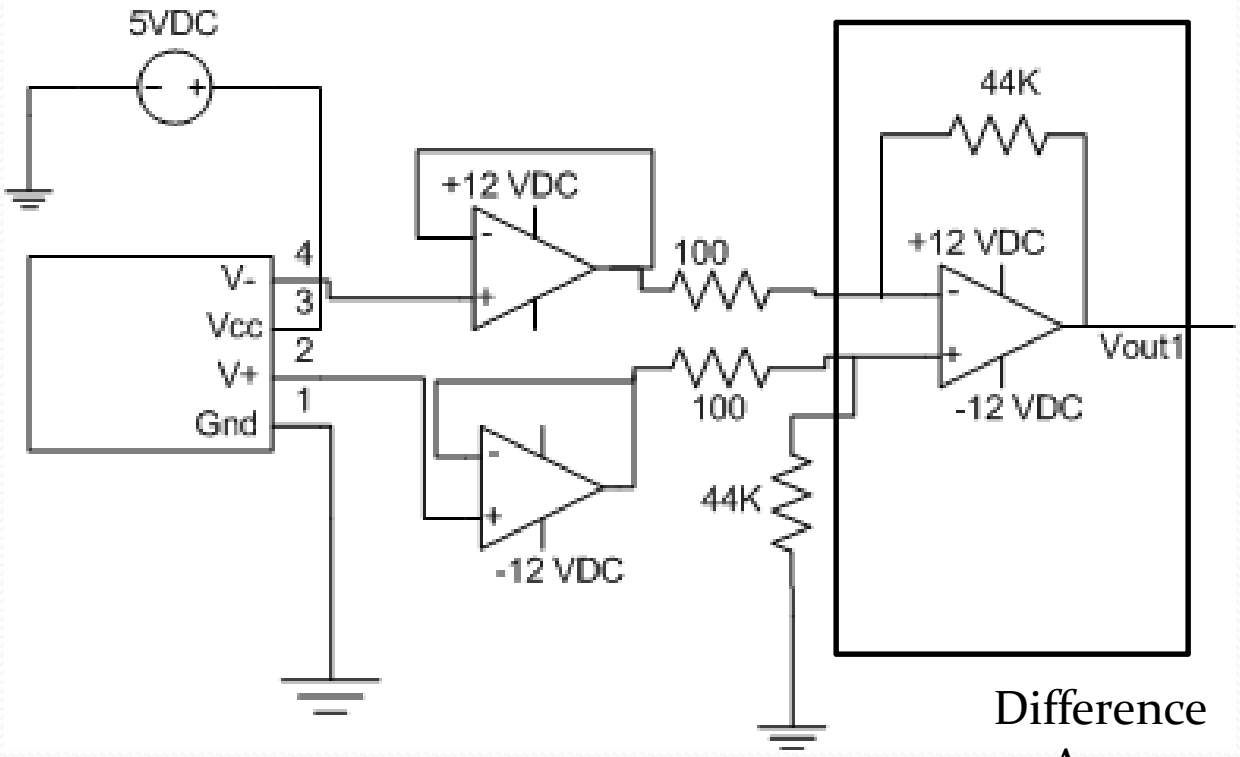
$$h = \frac{P}{dg}$$

h - height of the liquid
P - measured pressure
d – density of the liquid
g – force due to gravity



Sensors: Internal Environment

- Liquid Level: Circuit Diagram
  - Provides output of 1 to 2.5 V over 21.5 cm range

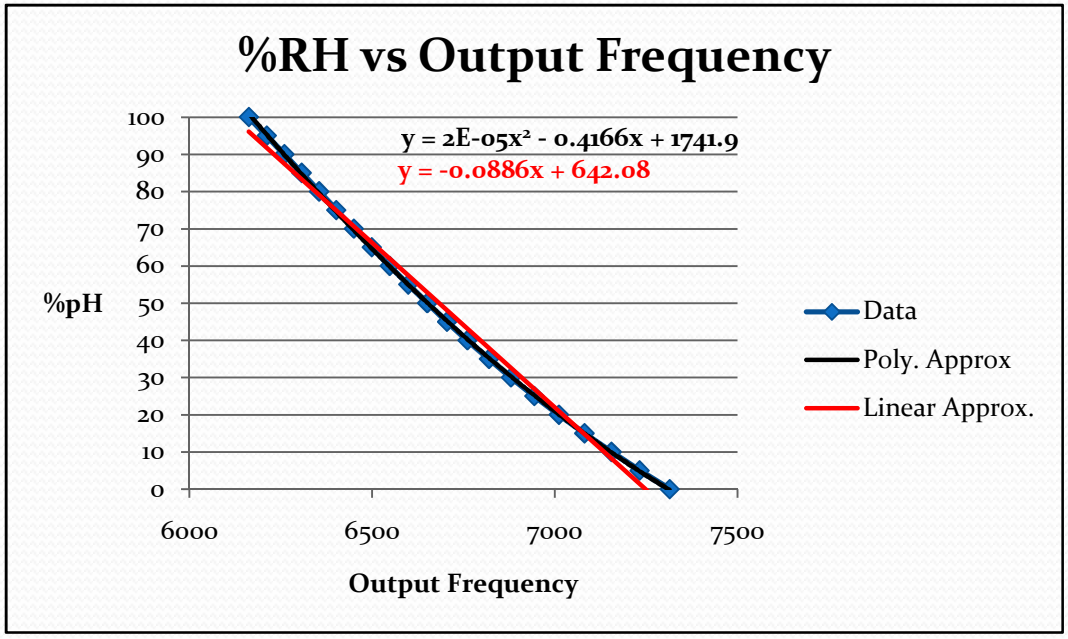


Sensors: External Environment

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

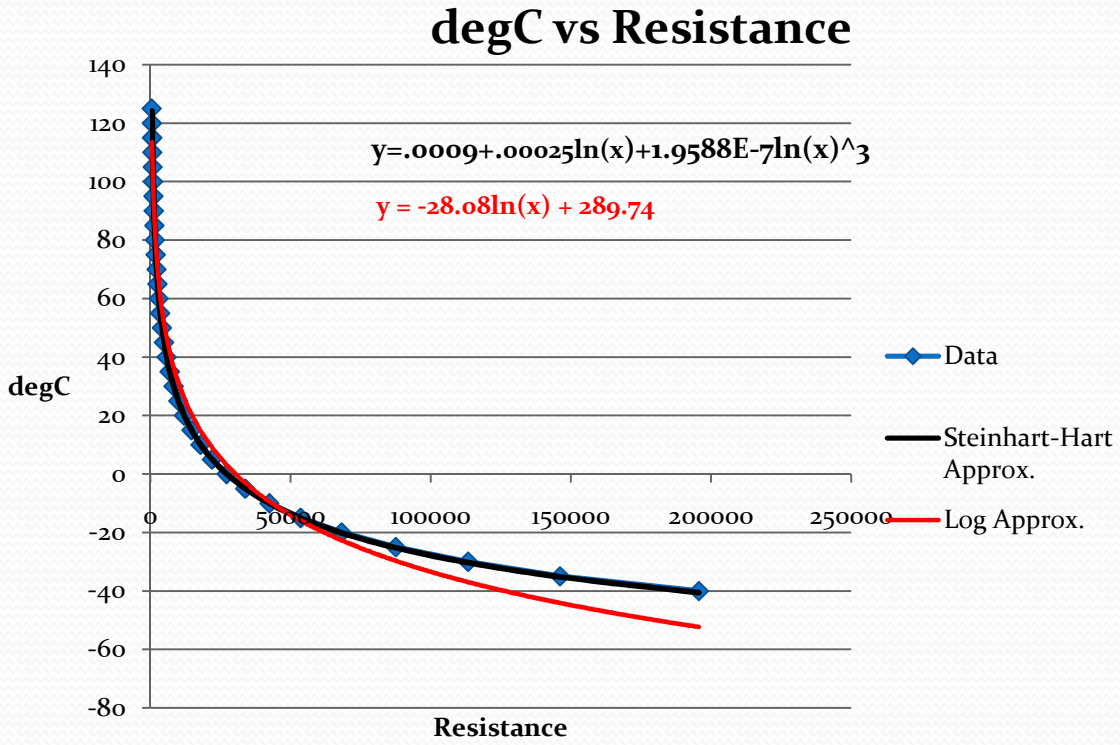
Sensors: External Environment

- Humidity: Curve Fitting (based on Manufacturer data)



Sensors: External Environment

- Temp: Curve Fitting (based on Manufacturer data)



Sensors: External Environment

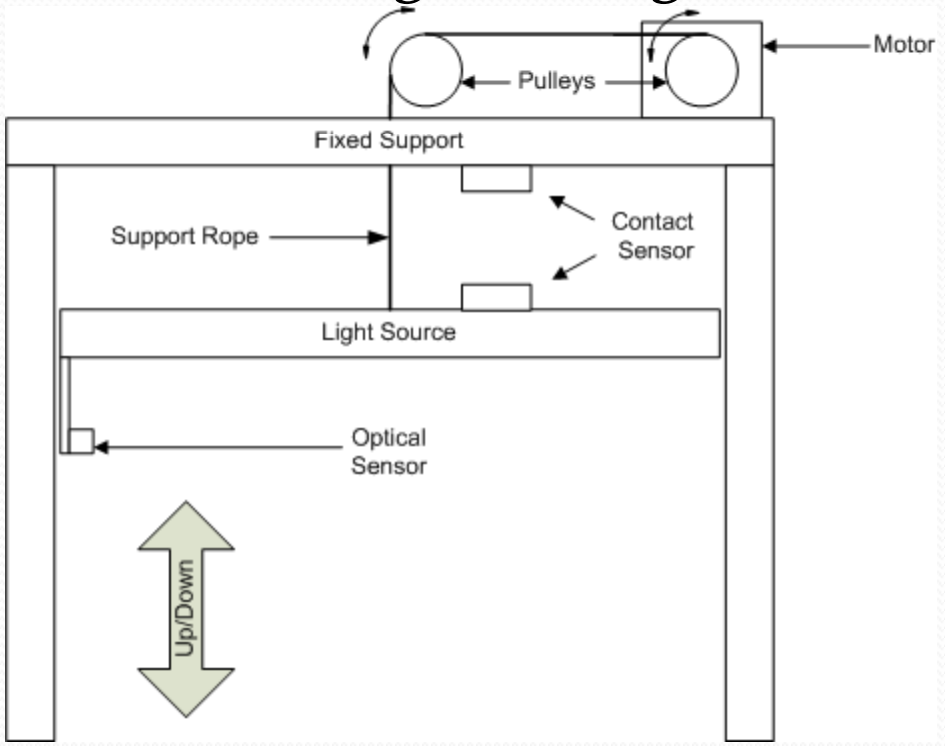
- CO_2
  - Range: 0 – 2500 ppm
  - Accuracy: 10 ppm
  - Cost: Free
  - Linear Analog Output
    - 0 to 5 V
    - No additional circuitry required
  - No calibration required due to onboard algorithms

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)

Lighting System

- Stepper Motor + Worm Gear Assembly →
  DC Motor w/ Worm Gear Assembly

- Specs:
  - High Torque (value not avail)
    - made for car windows
  - ≈1 rev/s @ 5 VDC, 1.2 A

DC2

Lighting System

- Worm Gear Assembly

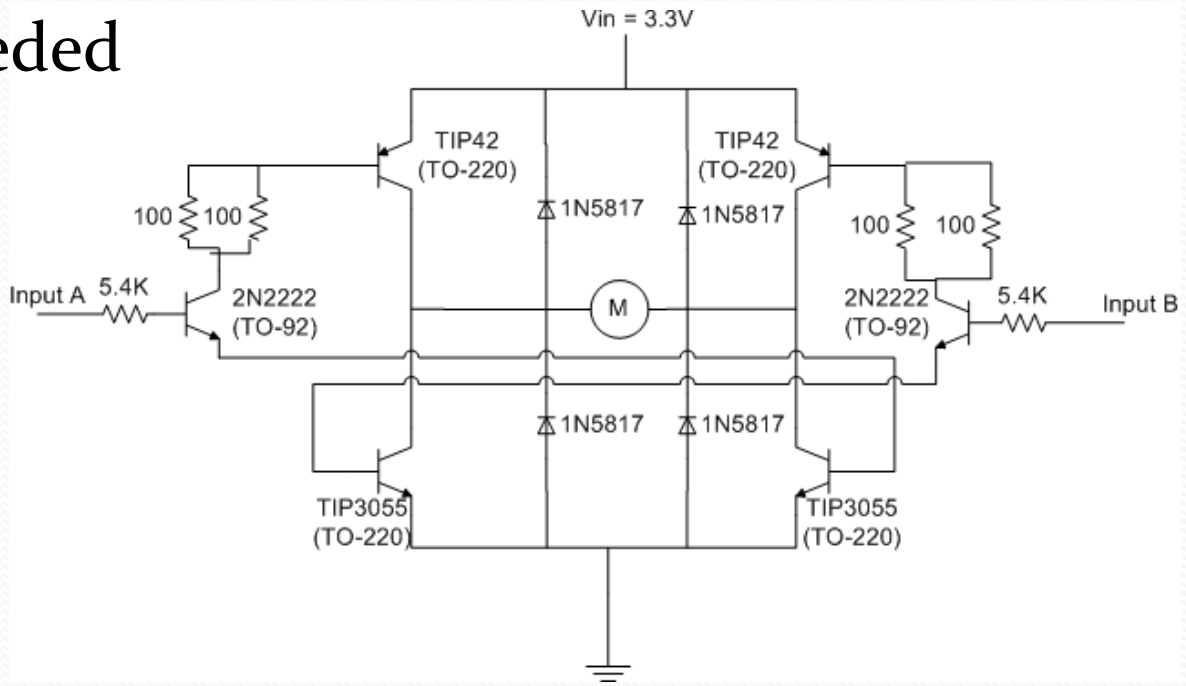
Slide 22

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
- Fwd/Rev control
- On/off functionality
- Shottky diodes needed to protect against kickback from the motor

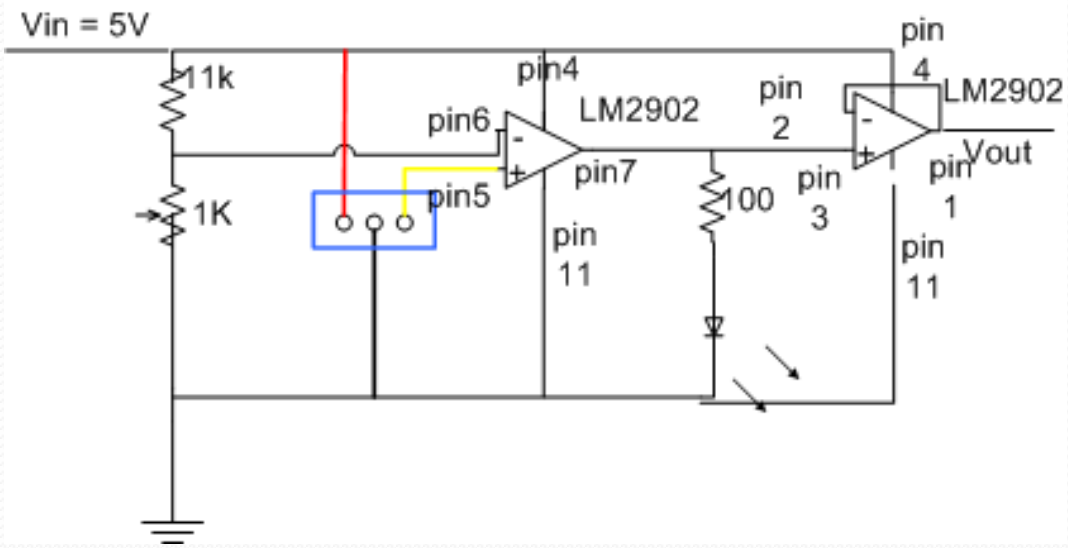


Lighting System

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

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

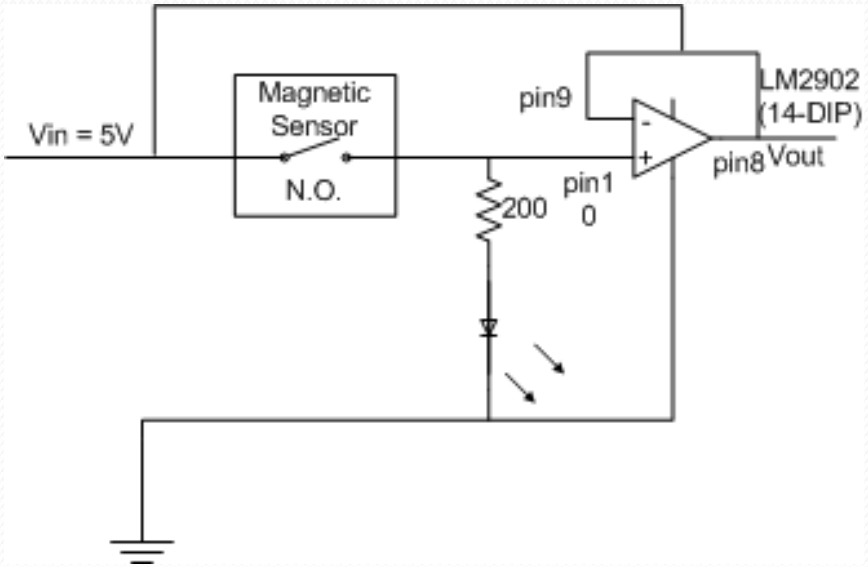


Lighting System

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

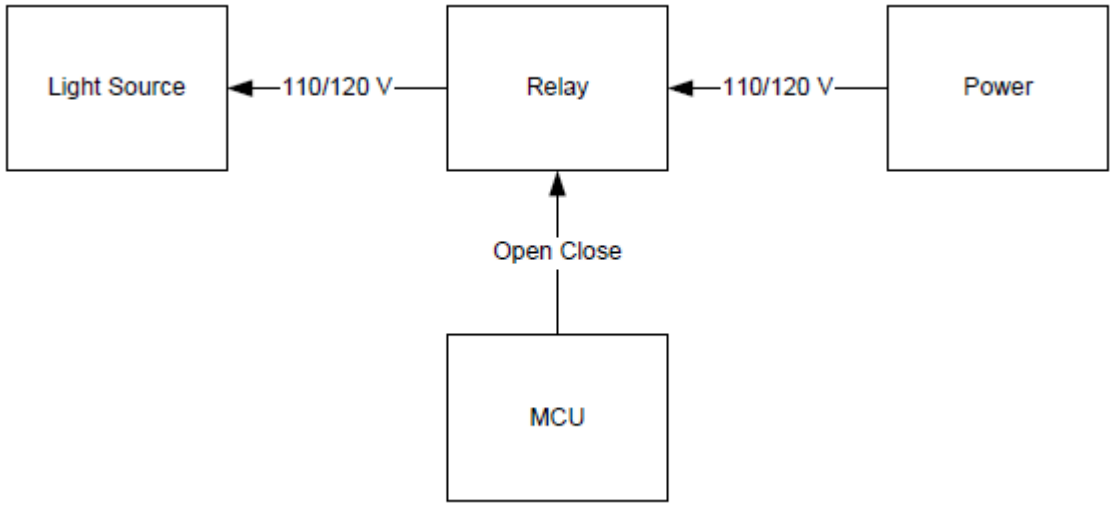
Lighting System

- Contact sensor connection diagram
  - With no contact, connects MCU input goes Low
  - On contact, 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

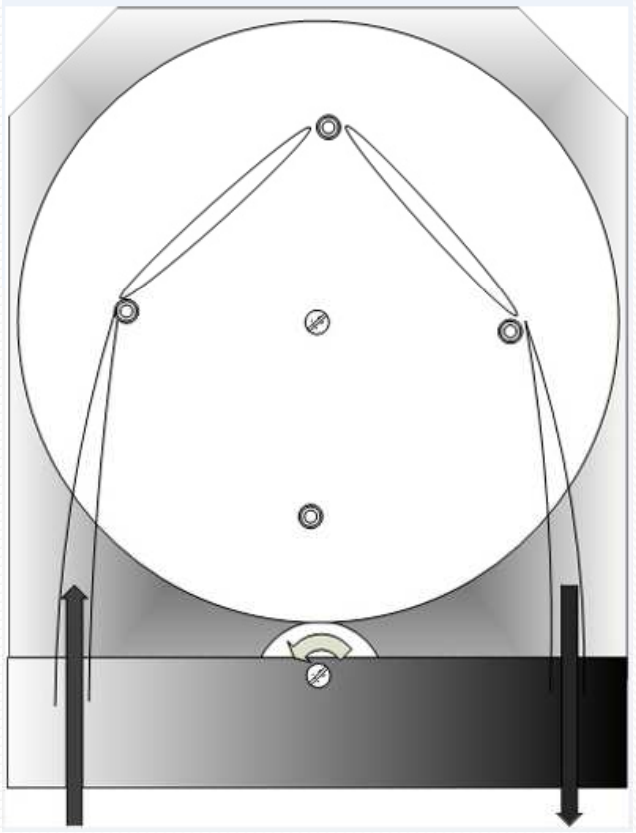


Lighting System

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

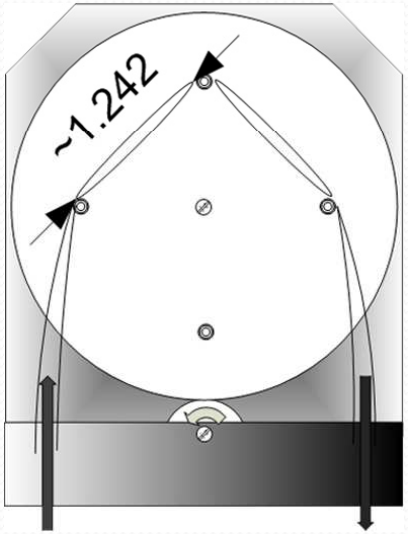
Feeding System

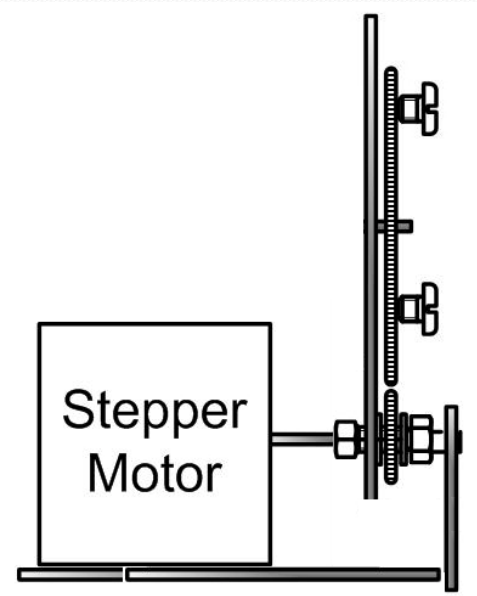
- Nutrient and pH regulation
  - 3 Peristaltic Pumps
    - Nutrients
    - ph up
    - ph down
  - Each 45° rotation will give 1 mL output of chemical solution
  - 25 steps are needed for a full 45° rotation



Feeding System

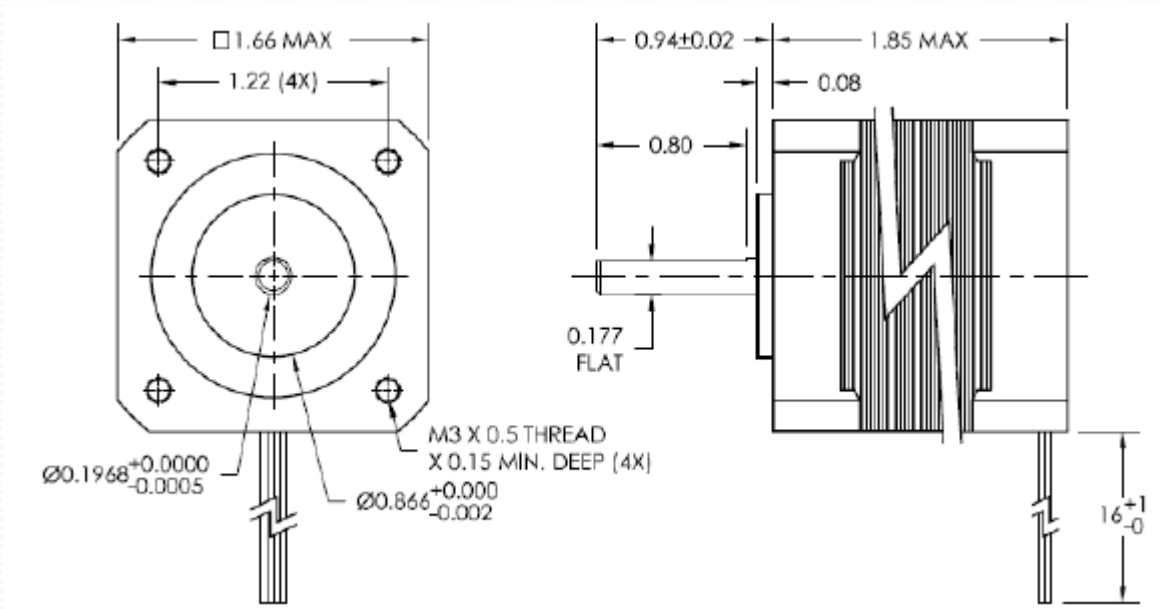
- Peristaltic Pumps
  - Spacing between the screws on the wheel should be approx 1.24 inches apart which has been calculated to provide 1 mL/rotation with a ¼" ID tubing.





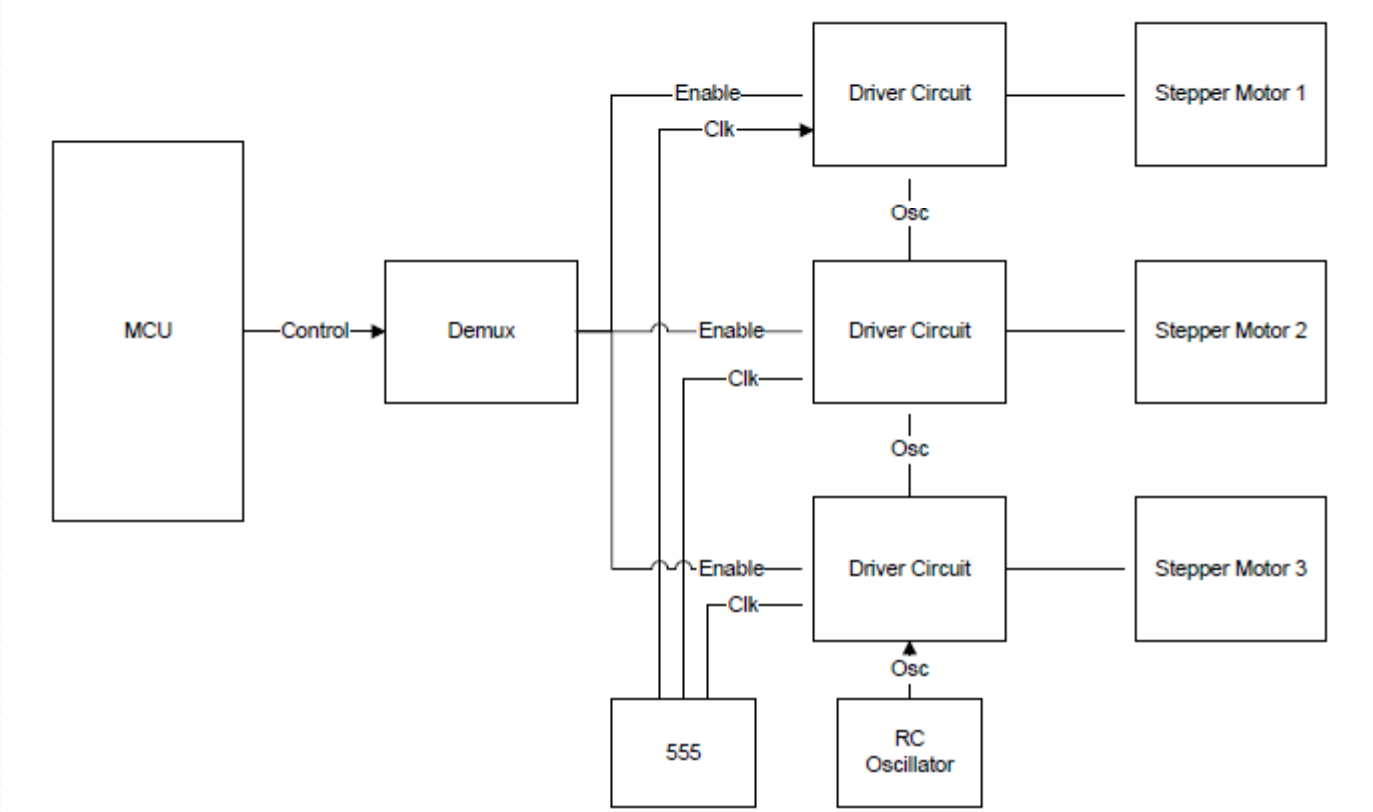
Feeding System

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



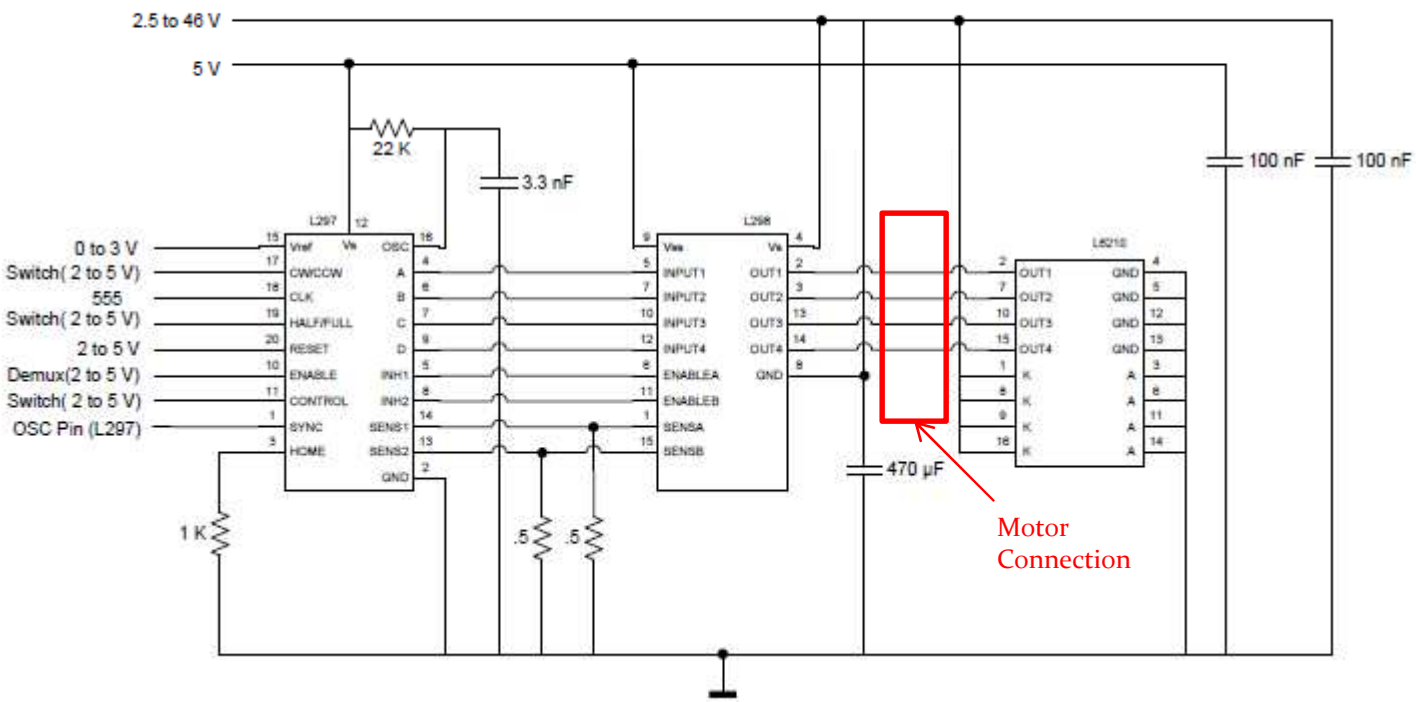
Feeding System

- Stepper Motor Connection Diagram



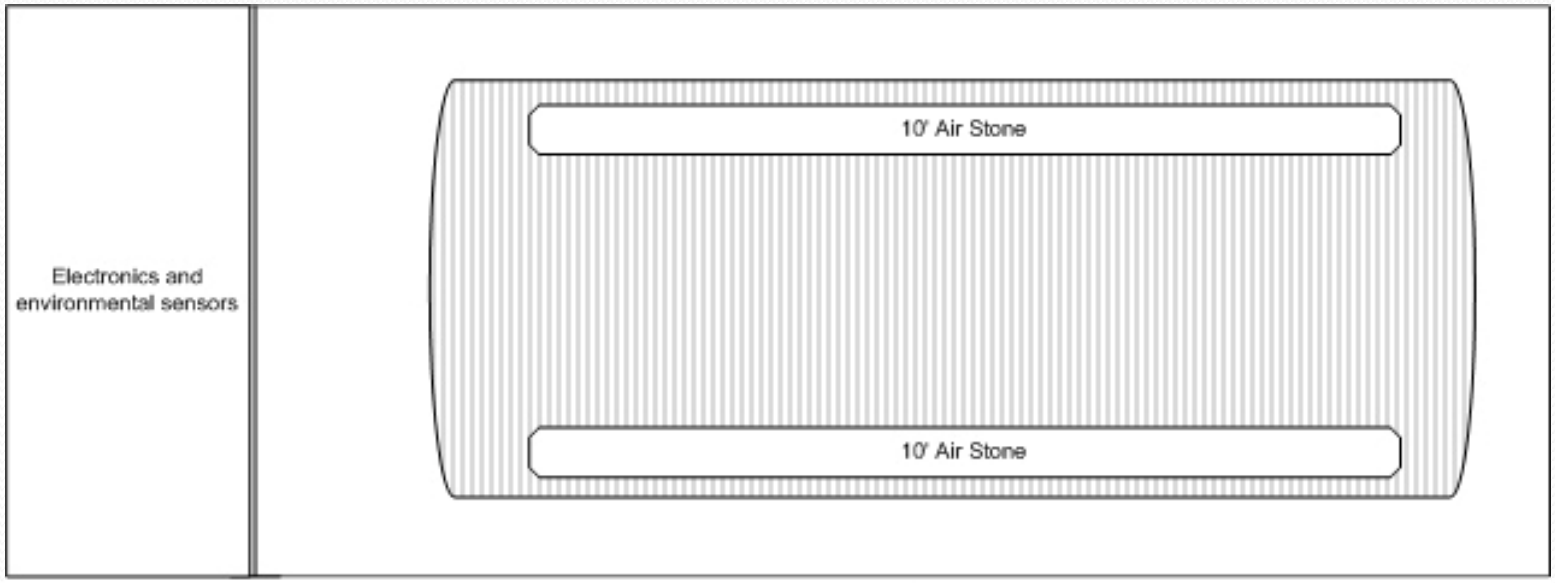
Feeding System

- Stepper Motor Circuit Diagram



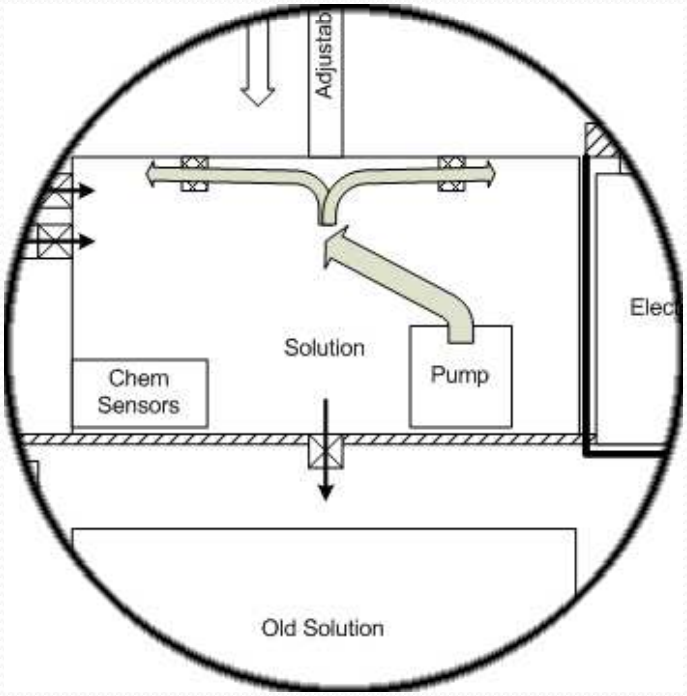
Feeding System

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



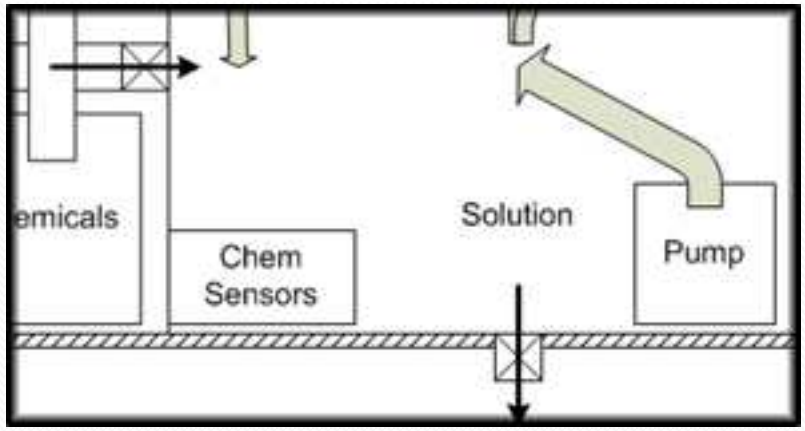
Feeding System

- 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.

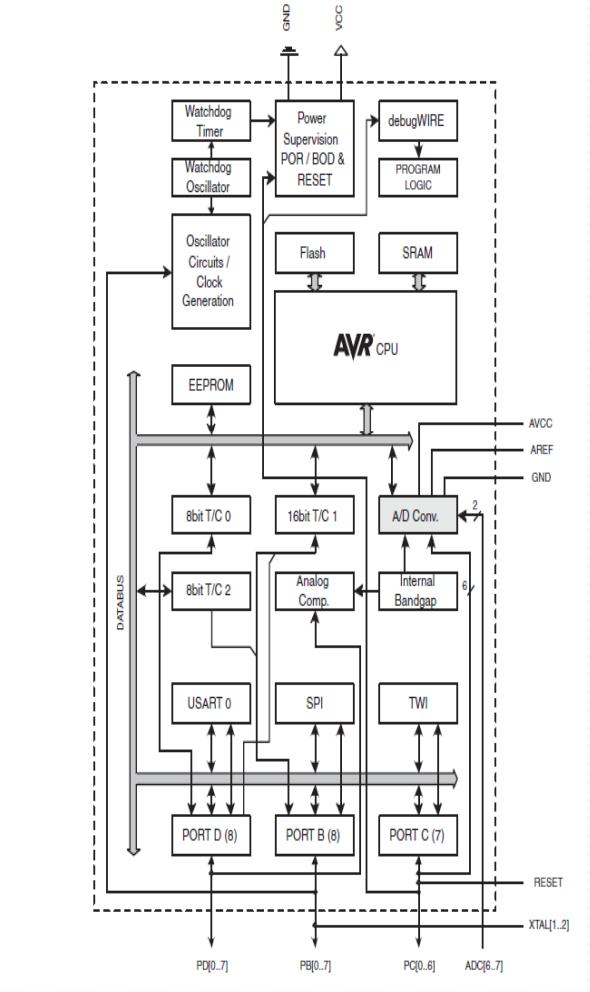


Feeding System

- Drain Valve
  - Needs 24 VAC to open and allow water to drain to bottom container. No minimum pressure required to function properly
- Inlet Pump
  - If a hose is not available a pump and an additional reservoir can be added to the system
- Inlet Valve
  - Same specifications as Drain Valve. Supplying voltage will input water to system.

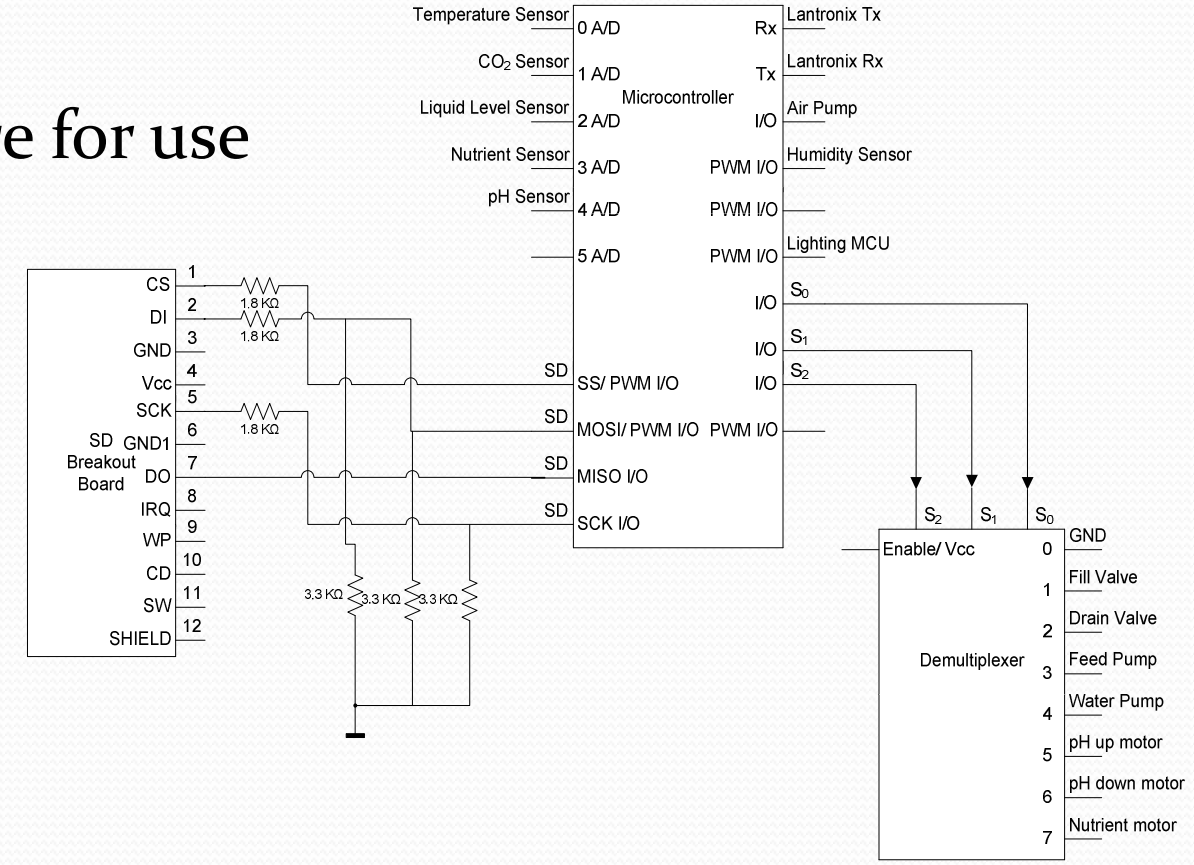
Controls

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



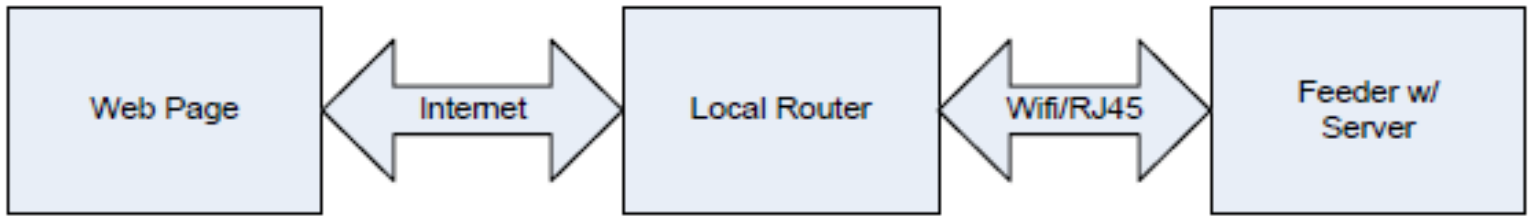
Wiring of Control System

- 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 connection



Web Interface

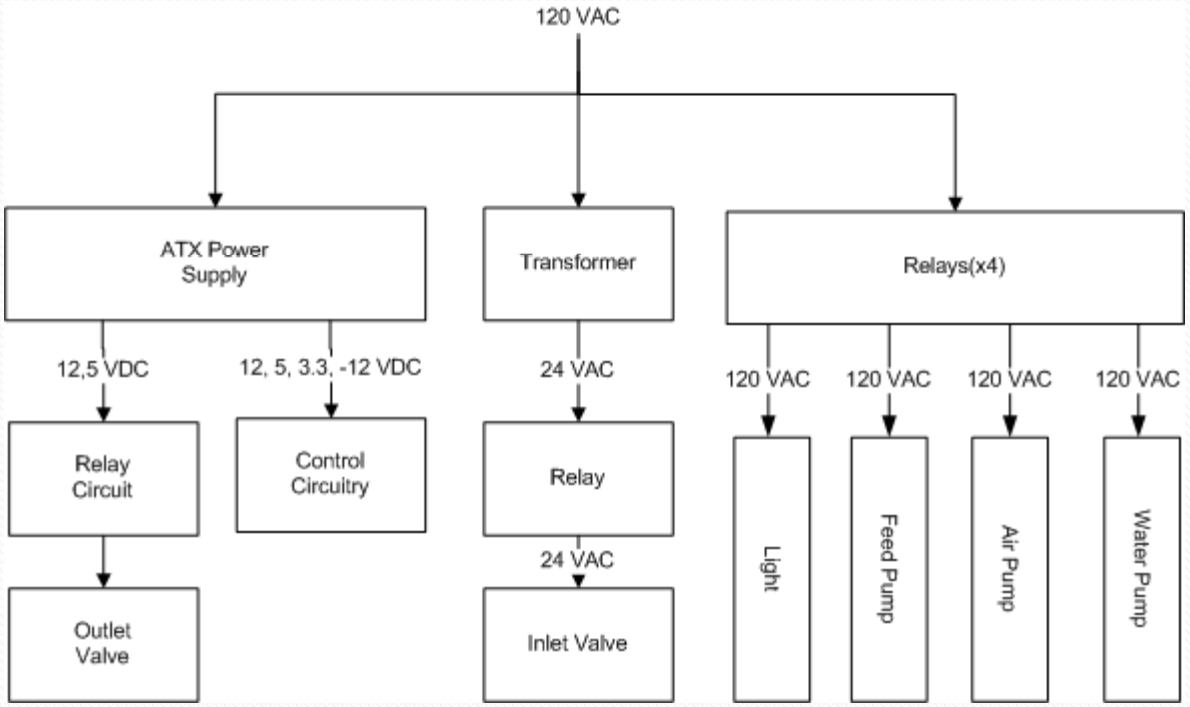
- 2 Serial ports
- No RF fabrication required
  - Antenna connects directly to the ufl connector on rear of unit
- Ethernet capabilities (if needed)
- Module Cost: Free
- Eval kit: Free

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

Power

- Overview
  - 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
- A computer power supply to power the electronics

Budget

Controls

Component	Actual	Retail	Reproduction	Manufacturer	Supplier
Microcontroller	$0	$4	$4	Atmel	Friend
Web Server module	$0	$90	$90	Lantronix	Manufacturer
Web Server Dev. Kit	$0	$120	$0	Lantronix	Manufacturer
Antenna	$0	$6	$6	Lantronix	Manufacturer
Demux	$1	$1	$1	National Semi.	Mouser
SD Breakout Board	$18	$18	$18	Sparkfun	Sparkfun
SD Card	$14	$14	$14	Best Buy	Sandisk
Arduino Dev Kit	$0	$30	$0	Arduino	Friend
Total	***$33***	***$283***	***$133***		

Sensors

Component	Actual	Retail	Reproduction	Manufacturer	Supplier
CO_2	$0	$130	$130	SenseAir	Manufacturer
Humidity/Temp.	$30	$30	$30	Humirel	Digikey
Pressure	$0	$3	$3	STMicroelec.	Manufacturer
pH	$15	$15	$15	HANNA	eBaY
Total	***$45***	***$178***	***$178***		

Budget

Lighting

Component	Actual	Retail	Reproduction	Manufacturer	Supplier
LED Light	$40	$40	$40	Unknown	California Nursery
Optical Sensor	$24	$24	$24	Sharp	SparkFun
Contact Sensor	$0	$10	$10	Cherry Corp	Manufacturer
Motor	$8	$8	$8	Lin Engineering	eBay
Microcontroller	$4	$4	$4	Atmel	Mouser
Stepper Motor Components	$2	$6	$6	STMicroelectronics	Manufacturer
Hardware	$10	$10	$10	Home Depot	Home Depot
Total	***$88***	***$102***	***$102***		

Frame

Component	Actual	Retail	Reproduction	Manufacturer	Supplier
Frame	$40	$40	$40	Home Depot	Home Depot
Small Reservoirs (x3)	$15	$15	$15	Zevro	Wal-Mart
Medium Reservoirs (x3)	$30	$30	$30	Sterilite	Wal-Mart
Waterproofing	$10	$10	$10	Home Depot	Home Depot
Hardware	$20	$20	$20	Home Depot	Home Depot
Hydro Rocks	$5	$5	$5	Hydroton	HydroponicGarden
Pots (x4)	$4	$4	$4	Unknown	eBaY
Total	***$134***	***$134***	***$134***		

Budget

Pumps

Component	Actual	Retail	Reproduction	Manufacturer	Supplier
Valves (x2)	$36	$36	$36	Toro	Home depot
Feed Pump	$13	$13	$13	Unknown	Unknown
Air Pump	$20	$20	$20	Coleman	Camping Comfortably
Motors (x3)	$24	$24	$24	Lin Engineering	eBay
Timers (x3)	$18	$18	$18	Taylor	Amazon
Tubing	$20	$20	$20	Home Depot	Home Depot
Relays (x5)	$50	$50	$50	Skycraft	Skycraft
Total	***$191***	***$191***	***$191***		

PCB

Component	Actual	Retail	Reproduction	Manufacturer	Supplier
Control Board	$60	$140	$40	PCBExpress	PCBExpress
Lighting Board	$10	$10	$10	Skycraft	Skycraft
Motor Board	$60	$60	$60	4PCB	4PCB
CO_2/Humidity/Sensor Board	$10	$10	$10	Radioshack	Radioshack
Total	***$140***	***$220***	***$120***		

Total

	Budget	Retail Cost	Actual Cost	Savings
Total	$631	$1108	$858	$250
Total/Person	$210	$370	$286	$84

Issues

- Keeping focus on the Electrical Engineering aspect of the project and not the Plant Growing processes
- Mechanical Aspects (i.e. fluids, motors, gears)
- Keeping cost down (i.e. Conductivity sensor)
- Power issues with all loads connected
  - Liquid level sensor fluctuations
  - Spontaneous system resetting
- pH probe measurement consistency