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March 3, 2004

Lucky One
School of Engineering Science
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RE: ENSC 440 Project Lord of the Seeds Design Specification

Dear Mr. One,

The attached document, Design Specification of Lord of the Seeds (LOTS), details the design specification of our proposed ENSC 440 project previously submitted. Our product cares for hydroponics crops by accurately measuring and controlling the pH and electro-conductivity (EC) level in the hydroponics solution.

This product design specification provides a comprehensive discussion of the design and testing aspects of our project.

Please feel free to contact us if you have any questions, comments or concerns. We can be reached by email at poseidon-microsys@sfu.ca or by cell phone at 604-726-5989.

Sincerely,

Abdul Haseeb Ma

Abdul Haseeb Ma
CEO and President
Poseidon Microsystems

Enclosure: Design Specification for the Lord of the Seeds

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Design Specification for Lord of the Seeds

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Abstract

Hydroponics, or soil less gardening, has been taken up by more than 1 million gardeners world wide over the traditional in-soil gardening since it was first popularized by the astronauts.

Poseidon Microsystems brings together the joy of planting and maximum yield available in a single user-friendly package for growers of all levels everywhere. Control of electrolytic conductivity (EC) and pH (acidic levels in the water) level is the cornerstone in hydroponics, hence maintaining a constant desired level of EC and pH is essential. EC and pH sensors in the automated system will feedback readings of EC and pH levels of the nutrient solution in the system. Other than conductivity and pH levels, our system is to monitor air and water temperatures, humidity and water levels.

These sensors can be categorized to air sensors and water reservoir sensors. The air sensors unit would include air temperature and humidity sensors, while the water reservoir unit will contain control valves, pumps, pH, EC, water temperature and water level sensors.

Essentially, the output of these sensors is analog and will be driven by an amplifier circuit before it reaches the A/D of our microcontroller. The microcontroller will then relay the information to a transceiver module. Via long range RF, the information is sent to a central PC unit where the user will be able to view sensor readings and change control constants at the PC via a GUI. The central PC unit will consist of a transceiver, microcontroller and PC. The microcontroller receives information from the RF module then communicates with the PC by the means of the RS232 technology. The automated control algorithm will also reside at the PC and thus communication between the central unit and the sensor units is essential.

Testing will be done vicariously on device interfaces and communication signals to ensure that accurate information is transmitted to the PC. The GUI will allow the users to accurately read sensor readings, while RF communication to the PC will allow users to view these readings without setting foot into the growing environment.

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Glossary

AC	Alternating Current
ACK	Acknowledge Packet
A/D	Analog to digital conversion
EC	Electro-Conductivity: ion concentration in liquid; measured in µSiemens/cm^3
FSK	Frequency Shifting Key
GUI	Graphical User Interface
ISM	Industrial, Scientific and Medical equipment
LED	Light Emitting Diode
LOTS	Lord of the Seeds: our product, plant monitoring system for hydroponics
NAK	Not Acknowledge Packet
NRZ	No Return Zero
pH	potential of Hydrogen
RF	Radio Frequency
RS232	Serial communication connection
SIMO	Slave In Master Out
SOMI	Slave Out Master In
SPI	Serial Peripheral Interface
TC	Temperature Compensation
TDMA	Time Division Multiple Access
TI	Texas Instruments

1 Introduction

Lord of the Seeds is an automated hydroponics control system for home growers and hobbyists. The system will enhance plant growth by monitoring and controlling the temperature, pH and nutrient level of the solution. The information of air temperature and humidity data are collected through sensing devices and logged into our innovative software for a convenient history resource. Liquid sensing and control allows total freedom for planters, since the automated system will be controlling the nutrient solution constantly. The *Design Specification of Lord of the Seeds* will include a thorough discussion of the design requirements of assembling this system.

1.1 Scope

The document describes the design specification of the LOTS system to meet the specifications listed in the Functional Specification. Note that the design specification in this document applies only to the prototype system.

2 System Overview

The LOTS system will automate two major tasks of growers: adjusting the nutrients in the solution and adjusting for the correct pH. Aside from controlling, the unit will monitor air temperature, air humidity, water EC, water pH and water temperature. When the water level is below a certain threshold, the system will be able to alert the user to add water. Valves will be used to control acid, base and nutrient solutions entering into the reservoir. Below is a basic functional diagram of our integrated system and the intended interfacing methods.

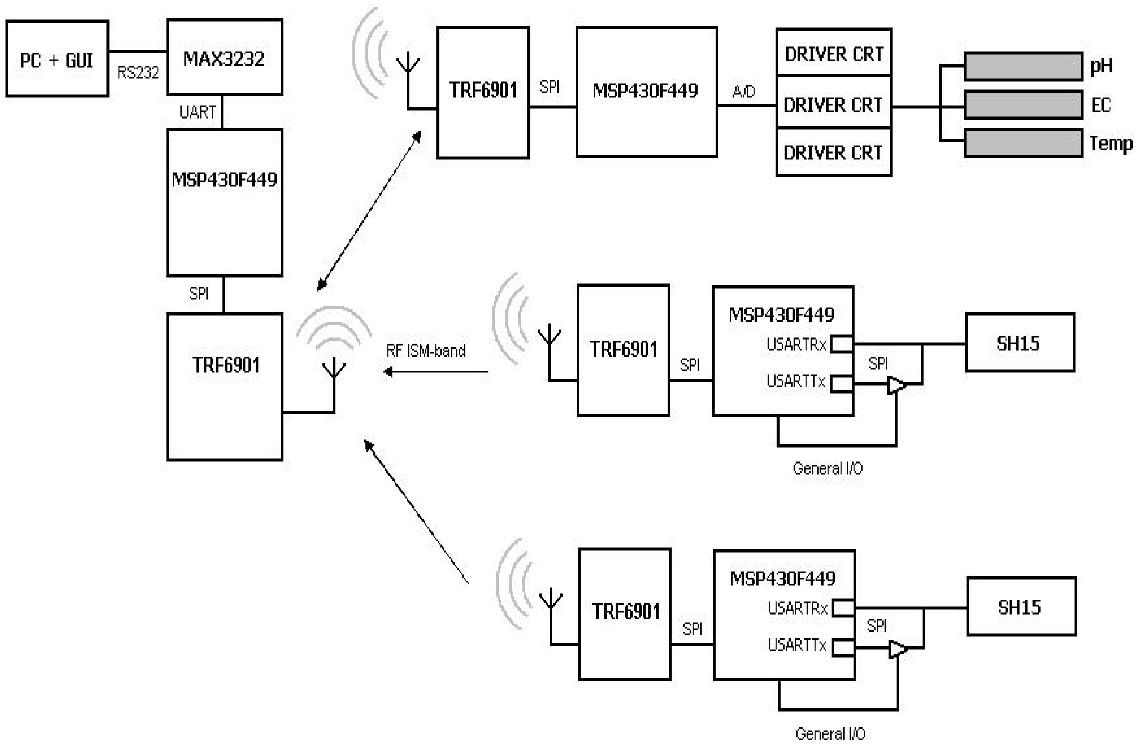

Figure 1: Block Diagram for LOTS

Additional air sensor modules can be produced to provide extra monitoring when required. For the purpose of our prototype, however, we will be developing only two. Poseidon Microsystems will be using the TI TRF6901 Demonstration and Development Kits as the basis for the LOTS prototype. Each module shown above in Figure 1 is built on a single TRF6901 Demonstration board. Each demonstration board contains the MSP430F449 microcontroller and the TRF6901 RF transceiver, along with necessary interface and software to perform basic RF communication. The GUI interface should provide an easy to use and user-friendly interaction with the control and monitoring system.

3 System Requirements

The environmental specification listed in this section pertains to the overall system. The specifications of the individual components of the LOTS system will be discussed in the subsequent sections.

3.1 Environmental Specifications

In order to accommodate the environmental conditions of various plants, the LOTS system must be able to operate in the 10 to 40°C environment with 0 to 98% non-condensing humidity. To achieve this, all components used in the system must be resistant to corrosion due to moisture.

4 RF Communication

Communication between each of the four modules of the Lord of the Seeds system is performed through a 900MHz wireless link. The Texas Instrument TRF6901 transceiver is used in all four modules to process both send and receive RF operations. The TRF6901 is programmed and driven by a TI MSP430F449 microcontroller via SPI. All RF settings are initialized by the microcontroller by writing the appropriate control parameters into the TRF6901 registers. Multipoint to point communication is used in Lord of the Seeds, the three sensor modules shall transmit sensor data towards the central module, and the central module shall transmit command data to the liquid module. See Figure 1 for a high level diagram of the multipoint to point communication implementation.

4.1 Wireless Protocol Architecture

The wireless communication protocol implementation is identical to the pre-installed TI protocol. The TRF6901 is preconfigured to operate in the US ISM-band (900MHz – 930MHz). Data communication protocol is performed through digital FSK running at 38400 bits per second with no-return-zero (NRZ). Preamble, start bits, and word-synchronization-bits are used in the communication protocol to ensure data integrity. Figure 2 shows how the RF messages are organized.

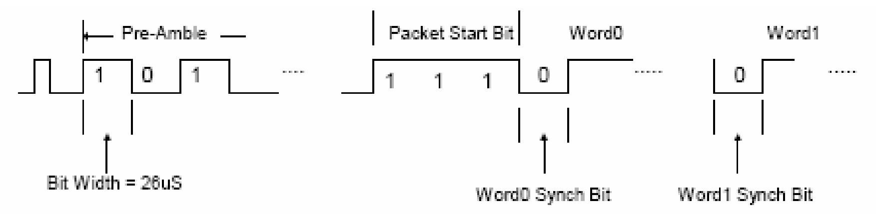

Figure 2: RF Data Structure [5]

Preamble bits are used to initiate a RF data transfer. The TI implementation generates 100 bits of alternating 1s and 0s. The bit stream allows the TRF6901 receiver to set the proper threshold to the extract binary RF patterns. The packet start bit indicates the beginning of the data. Along with the synch bit, the communication protocol allows the receiver to adjust synchronization timing while the message is in transmission. Change in phase between transmitter timing and receiver timing will inevitability occur over time. Thus the synchronization bit allows the receiver to adjust its sampling timer. The protocol implementation uses a synchronization bit after each word rather than after each byte in order to make the message transfer more data-efficient.

4.2 RF Message Transfer Protocol

Data transfer will be initiated by the central module. When a particular sensor reading is needed, the central unit will broadcast an RF message with a specific address. The liquid module and the air modules will then decode this message and verify that the address corresponds to the particular module. The corresponding module will then send the requested data to the central unit. Every message transfer will be followed by an acknowledge message (ACK) from the receiver. If the transmitter does not receive an ACK within 500ms, then the message will be retransmitted. A total of three 500ms timeouts will be allowed before the transmitter stop sending the particular message.

The air and liquid modules will all be initialized in receive mode, waiting for a data request message from the central unit. After the central module receives an ACK from a sensor module after a data request message has been sent, it will go into receive mode and wait for data to be sent from the corresponding sensor module. If the central module does not receive data within 3 seconds, the central module will cancel the data request. The transmission error will be noted by the central module and will be logged by the PC software.

4.3 RF Data Packet Structure

All data packets being transferred through RF will have a data structure shown in Figure 3 Each packet will start with a header byte, followed by 6 data bytes, then end with a checksum byte. Therefore each packet will comprise of a fixed length of 8 bytes.

Header Byte	Address Byte	Data Bytes					Checksum Byte
0xFE	ADDR	DATA4	DATA3	DATA2	DATA1	DATA0	CKSM

Figure 3: 8-byte RF Data Packet Structure

Since RF transmission is used, all modules will receive the same message during transmission. There fore it is essential for each module to decode the message and verify that the address byte is referring to the correct module. Table 1 below shows the individual address of each module.

Table 1: RF Data Packet Address Byte

Address Byte (in hex)	Module
0x00	Central Module
0x01	Liquid Module
0x02	Air Module 1
0x03	Air Module 2

The checksum byte is used to verify data integrity. It is calculated by summing the first 7 bytes of the data packet. Any overflow in the summation is ignored. Receivers will automatically calculate the checksum of the received message and compare it with the checksum byte. If checksum fails, then a not-acknowledged packet (NAK) will be sent to indicate a transmission error. For the LOTS prototype, the transmitter does not need to retransmit the message if a NAK is received. In the case of the central module, if the sensor data it has received fails its checksum calculation, the error will again be noted and the PC software will record such an error. The ACK packet and the NAK packet structures are shown in Figure 4 and Figure 5 respectively.

ADDR	0x06	0x06	0x06

Figure 4: 4-byte ACK packet

ADDR	0x90	0x90	0x90

Figure 5: 4-byte NAK packet

The address byte in the ACK and the NAK packet will contain the address of the transmitting device. For example, if the liquid module sends an ACK signal in response to a data request from the central module, then the address byte in the ACK packet will contain the address of the liquid module itself.

4.4 Antenna

The TRF6901 demonstration boards are preconfigured to use a small onboard PCB antenna. External quarter-wave dipole antennas with matched impedance will be installed in order to achieve greater range. To operate in the ISM-band, the antenna length will be 8.1 cm. Each dipole antennas will be mounted perpendicularly to a TRF6901 demonstration board by a standard SMA connector. SMA solder pad is already made available by the demonstration board; therefore the SMA connector will be bought and soldered onto the board.

In order to disable the onboard PCB antenna, the connection between pin2 and pin3 of Jumper 1 of the TRF6901 demonstration board will be removed. Pin1 and pin3 will then be shorted with a 0-ohm resistor in order to allow the demonstration board to connect to the SMA connector.

5 RS232 Interface

A RS232 serial interface is used to transmit data asynchronously between the LOTS system and a user PC. The TI MSP430F449 microcontroller on the central module will put all sensor readings into packet form. A TI MAX3232 driver chip will receive these data packets via the microcontroller’s UART0 port and send the data to the PC via the RS232 interface. The PC will also transmit control commands to the Lord of the Seeds system via the same RS232 link. Again, the central module microcontroller will read these data packets and reroute them to the appropriate modules.

The serial communication protocol LOTS system will be utilizing a simple 8N1 protocol (i.e. 8 bits of raw data, no parity bit, and 1 stop bit). With a close physical proximity between central module and the user PC, parity checking is not implemented since there is a very low possibility of data corruption during transmission. Flow control is also unnecessary because both the microcontroller and the PC will be operating at very high speed and will thus be able to handle all serial communication easily. Transmission speed will be set at a constant 38400 bps. Baud rate selection is performed by setting the appropriate control bits in the microcontroller and also in the GUI software.

Currently, there are a total of eight sources of data, namely the LOTS system has eight difference sensors. All sensor data processed by LOTS are twelve bits raw data. With these constraints, data sent from the microcontroller towards the PC requires two bytes. Structural design of single data packets is illustrated in Figure 6 below.

ADDR2	ADDR1	ADDR0	-	DATA11	DATA10	DATA9	DATA8

Structure of First Byte

DATA7	DATA6	DATA5	DATA4	DATA3	DATA2	DATA1	DATA0

Structure of Second Byte

Figure 6: Structure of Serial Data Packet

Three bits are used for the address bits in order to allow the PC to determine which of the eight sensors data is coming from. First four bits of the 12-bits data are then sent after a reserve bit. The second data packet contains the rest of the 12-bits data. The following Table 2 shows how the address bits are used to represent the eight sensors.

Table 2: RS232 Data Packet Address Bits

Address Bits	Corresponding Sensor
000	EC
001	pH
010	Liquid Temperature
011	Water Level
100	Air Temperature (1)
101	Air Humidity (1)
110	Air Temperature (2)
111	Air Humidity (2)

Commands issued from the PC software to the central unit will fit within a single 8-bits data packet. A second data packet is therefore not needed.

6 Air Sensor

The purpose of the air modules is so that users can obtain remote temperature and humidity readings from different parts of the room. There will be two air modules to allow multiple air detectors to be placed in a room. Each air module consists of one sensor that includes both the temperature and humidity sensor. The information obtained from the sensor will be processed and sent as raw bytes to the PC via RF. It is important to note here, that raw data is being sent to the PC, further calculation must be done on the PC side to convert this data to useful numerical values. This section will entail a discussion on how the interfacing with the air sensor and microcontroller will be carried out.

6.1 Temperature and Humidity Sensor

A single chip relative humidity and band-gap temperature sensor comprising a calibrated digital output will be used. The sensor is SHT15 made by Sensirion shown in Figure 7. The chip converts analog signal to a digital 14 bit temperature output and 12 bit humidity output. The chip consists of 4 pins: a bidirectional data line, clock signal (SCK), voltage and ground. From the V_{ref} pin on the microcontroller, we can use the 3V to power up the sensor.

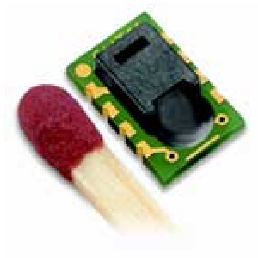

Figure 7: SHT15 Sensor [6]

The sensor has very specific communication method with the microcontroller. First of all, a transmission start sequence is required before any command can be sent to the sensor. The following figure shows a lowering of the data line while SCK is high followed by a low pulse on SCK and raising the data line again while SCK is high.

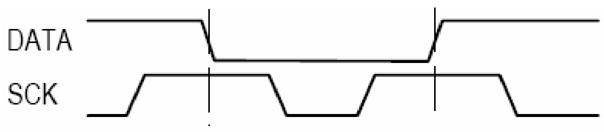

Figure 8: Transmission Start [6]

Eight designated command bits are necessary to carry out jobs shown in the table below:

Table 3:Command Bits

Command	**Code**
Measure Temperature	0000 0011
Measure Humidity	0000 0101
Read Status Register	0000 0111
Write Status Register	0000 0110
Soft reset	0001 1110

For the purpose of the project, only the measuring temperature and humidity commands will be used. A separate reset code will be created in C since the software reset only clears registers; and reset of the connection is required.

The sensor indicates proper reception of a command by pulling the data pin low after the falling edge of the 8^{th} SCK clock. Measurement takes approximately 11 ms and the controller must wait for the sensor to pull the data line low before starting to toggle the clock again. Two bytes of measurement data will be transmitted and the controller must acknowledge each byte by pulling the data line low [6].

6.2 Integrating SHT15 with MSP430F449

The problem with designing the communication aspect between the sensor and microcontroller is that the MSP430 microcontroller does not support bidirectional data lines. The SHT15 does not support I^2C either. At first, it would seem intuitive to use one I/O bit and configure that to be input or output according to necessary conditions since we did not need dual concurrent communication. However to apply SPI mode, it is impossible to configure the same bit to be SIMO and SOMI. The MSP430 specifically states when in SPI mode, port 3.2 will be SIMO and port 3.1 will be SOMI. It is of great importance to be designing in SPI mode because of the internal clock signal and the ease of manipulating serial inputs and outputs. After careful studying, tying the ports together to simulate a bidirectional port from the view of the sensor seems to be a legitimate solution. The I/O pin is not tri-stated so we must use an external tri-state buffer. The following diagram illustrates this concept.

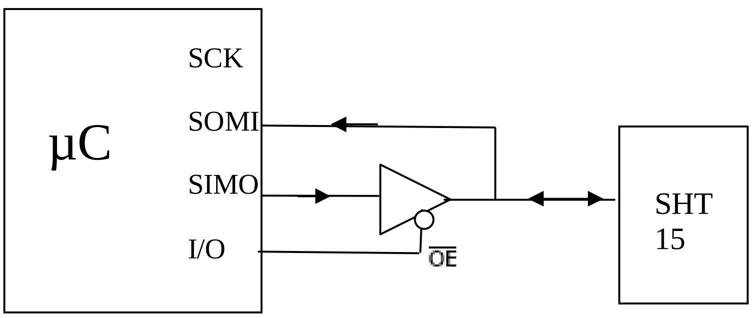

Figure 9: Sensor-Microcontroller Interface

To ensure that the output port does not get damaged, the buffer must be at high impedance at all times except when the controller is manipulating the data line. A free I/O port will be used as the output enabler. The input port should not be of concern as long as appropriate information from the data line is used at correct times. The high level flow chart of usage of the sensor is shown below.

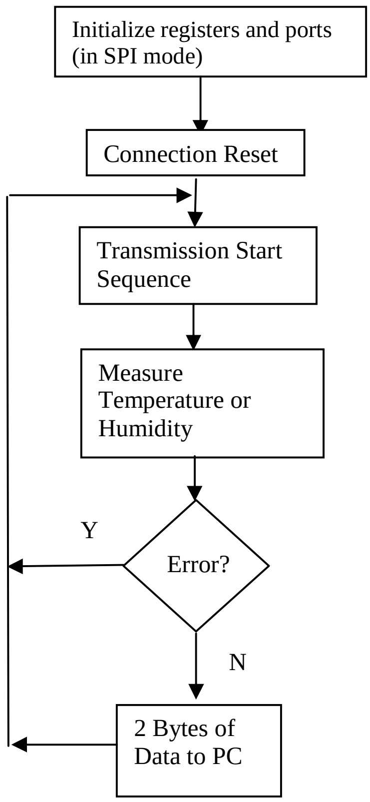

Figure 10: Flowchart of Sensor Logic

If there is no acknowledgement from the sensor to flag reception of a command, an error will be flagged. The two bytes of data from the sensor can be calculated into temperature data and humidity data using a linear temperature or humidity equation respectively. The PC will be responsible for performing these calculations.

6.3 Converting Output to Physical Values

6.3.1 Relative Humidity

The following formula converts and compensates for the non-linearity of the humidity sensor:

$$RH_{linear} = c_1 + c_2 \bullet SO_{RH} + c_3 \bullet SO_{RH}^2$$ *Equation 1*

SO_{RH}	c_1	c_2	c_3
12 bit	-4	0.0405	-2.8 * 10^{-6}

[6]

c_1, c_2 and c_3 are constants and SO_{RH} is the 12 bit sensor output
For further accuracy when operating temperatures are significantly different from 25°C, the following equation should be used:

$$RH_{true} = (T_{°C} - 25) \bullet (t_1 + t_2 \bullet SO_{RH}) + RH_{linear}$$ *Equation 2*

SO_{RH}	t_1	t_2
12 bit	0.01	0.00008

[6]

t_1 and t_2 are constants, SO_{RH} is the 12 bit sensor output, $T_{°C}$ is the temperature measured by sensor and can be calculated from the equation to follow.

$$Temperature = d_1 + d_2 \bullet SO_T$$ *Equation 3*

VDD	d_1 [°C]	d_1 [°f]
5V	-40.00	-40.00
4V	-39.75	-39.50
3.5V	-39.66	-39.35
3V	-39.60	-39.28
2.5V	-39.55	-39.23

SO_T	d_2 [°C]	d_2 [°f]
14bit	0.01	0.018
12bit	0.04	0.072

[6]

The constants d_1 and d_2 varies for different V_{DD}. For our case, we are using 3V and 14 bit output.

6.3.2 Testing Specifications

To ensure the module performs as designed, the following test will be carried out. Before integrating with the PC, reading from the air sensor is converted to corresponding temperature or humidity through the set of mathematical calculations by the microcontroller. The numerical value will be compared to a hand held thermometer and humidity meter. If results are comparable, it assures raw bytes contain accurate information and can be passed on to the PC.

7 Liquid Sensor

This section will outline the design of the reservoir water monitoring system which consists of a pH sensor, EC sensor, water level detector, and water temperature sensor (thermistor). In general, the output of these sensors will be passed to the A/D converter of our microcontroller via signal conditioning circuits. The values of these sensors will then be sent via RF to the main PC unit for further interpretation.

7.1 pH Sensor

The pH sensor that will be utilized is the S200C from Sensorex. The length is about 6 inches long and has a BNC receptacle as an output which makes for simple hardware interfacing. The S200C is shown in figure below:

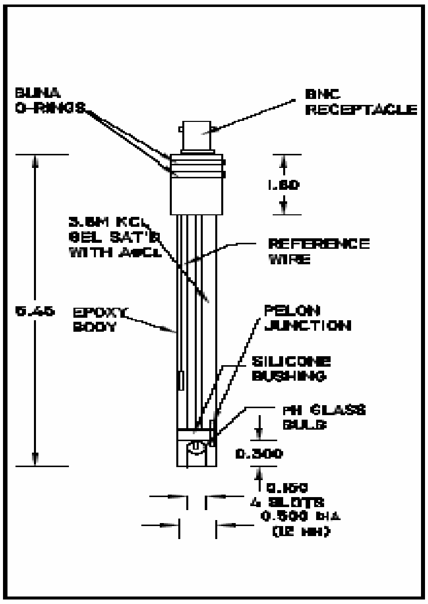

Figure 11: S200C pH Electrode [8]

The S200C is light in weight, and its durable epoxy body will ensure a prolonged life while submerged into out highly electrolytic water environment. Like most pH electrodes used in the industry, it is a high impedance galvanic generator. Essentially, it is a battery and will generate its own voltage due to electrochemical reactions. The output at a pH of 7.00 is defined as 0.00 mV. For each increment of pH from 7, the electrode will generate a 59.16 mV per unit change in pH hence the output can be easily read by the A/D. This output is straightforward to interpret since it is linear. The output of this sensor ranges from 0 to 14 pH with a resolution of 0.01 pH. [4]

7.2 EC Sensor and Thermistor

Conductivity electrodes are devices that measure the conductivity of water samples. Conductivity is simply a measurement of how well a material carries current. An electrode is inserted into a sample liquid to determine the concentration of ions which will be vital in the success of our nutrient monitoring system. [4]
The conductivity sensor employed is the CS150TC, a low cost conductivity sensor for industrial usage. This particular sensor has water temperature sensor built in. The temperature sensor is also used as temperature compensation for the CS150TC sensor. The CS150TC is shown in Figure 12 below. [7]

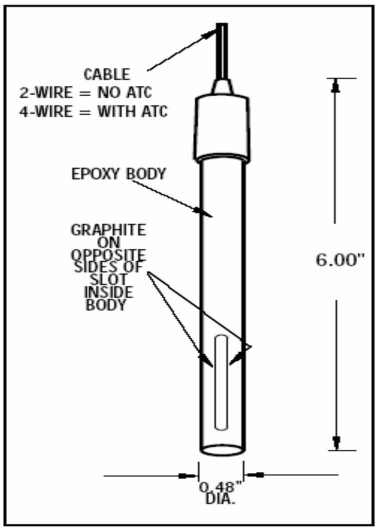

Figure 12: CS150TC Conductivity Sensor with Thermistor [7]

The conductivity sensor is a static device with no output of its own. It is required to build a driver circuit in order to interpret the data, which will be explained in the following section. The conductivity sensor can be thought of as just two pennies, with a lead wire attached to each. The pennies are immersed in water while being kept parallel to each other at a constant distance. A current will pass through the circuit loop once a voltage is applied to the two leads, and thus the resistance can be calculated.

The conductivity sensor's measurement depends on the temperature. Thus it is imperative that this temperature effect is compensated for. This temperature compensation will be done in the software. The temperature sensor, or thermistor, will provide the temperature of the water and the true conductivity can be calculated from the fact that conductivity will be skewed by 2% per degrees Celsius.

7.3 Water Lever Detector

For water level detection, Honeywell's LL103000 water level sensor will be used. This sensor operates at low voltage of 5V and outputs logic high when there is no liquid surrounding the sensor. The sensor will be mounted inside the reservoir at ¼ of the reservoir height. Thus, the sensor will send a high signal to the general I/O port of the microcontroller when the water level falls below 25%. Then the GUI will indicate that the water level has fallen below 25%, and prompts the user to refill the reservoir.

7.4 Hardware Interfacing

As mentioned above, the pH electrode, conductivity sensor and thermistor will require signal conditioning before their outputs are passed on to the A/D converter on the microcontroller. For all driving circuits, a simple ±12 volt power supply will be built. It will consist of a wall transformer, a rectifying circuit and voltage regulators.

The pH electrode provides a mV output via a BNC cable. The driving circuit will take the existing output and amplify it to sufficient level for the A/D converter on the microcontroller. The amplifying circuit will be a regular non-inverting operational amplifier. [4]

As for the conductivity sensor, the output is simply the resistance. To measure this resistance an inverting amplifier can be configured as follows:

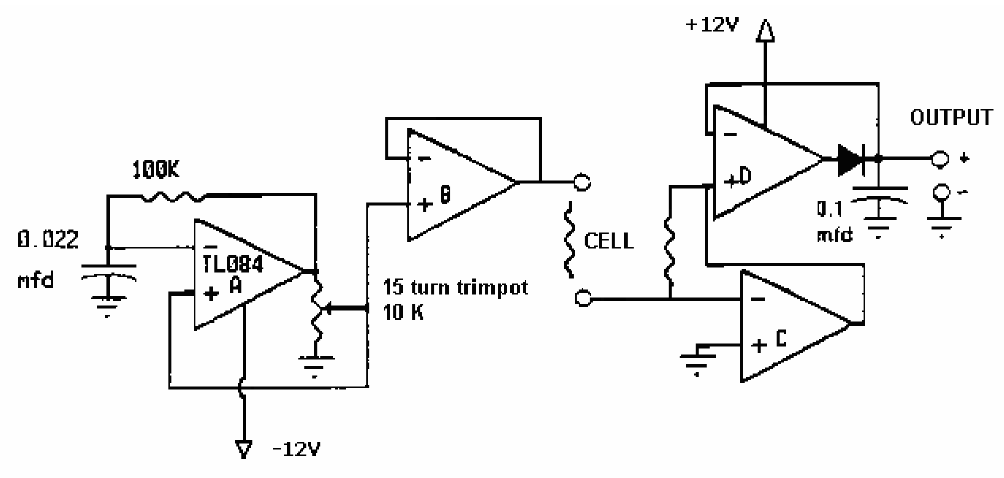

Figure 13: Conductivity/Thermistor Driving Cicuit [7]

As shown above, the conductivity meter consists of 4 units (A B C and D). Unit A is a square wave oscillator with a frequency of about 1 kHz and peak voltage of 12 volts. A multi-turn potentiometer is used as a voltage divider to reduce the peak voltage to 1 volt at the input of unit B where unit B is a voltage follower. Unit C is the conductance meter which is simply an inverting amplifier with voltage gain given by -Rf/Rin. Rin is the conductance cell. Thus, if we know the output voltage and Rf, Rin is apparent. Lastly, unit D is a peak detector used to convert the square wave output of unit C into a DC voltage, which is then fed into our microcontroller. [7]

Finally, the water level detector will be connected to the microcontroller through voltage buffer and divider to accommodate the microcontroller specification.

7.5 A/D Conversion

The signal processing circuitry will provide the A/D converter with readable signals from the three sensors. Hence, 3 of the A/D port on the microcontroller will be occupied with the output signals from the pH, EC and temperature sensors. An internal timer in the microcontroller will be set to trigger an interrupt at a specified time interval. When one of the interrupt is triggered; the output signals will be read into the A/D converter for conversion. Once the conversion is complete, the values will be stored in a buffer until further implementation. At this point, a global flag will be triggered. A while loop in the main program will then run the sequence for the transfer of these values to the RF.

8 Reservoir Liquid Control

The implementation and volume control for the reservoir liquid control will be described in the following sections. Three types of liquids are used to control the water quality of the reservoir: Acid, base and nutrient solution.

8.1 Implementation

Acid, base and nutrients solutions used to control the pH and the EC levels of the reservoir will be stored in plastic containers. Each container will be connected to a solenoid valve via garden hose to control the flow of the solutions. Orbit's sprinkler system valve, model 91704, will be used because it is low priced and can be easily attached to an ordinary garden hose. The Figure 14 below shows how the valves will be connected to the microcontroller on the liquid module.

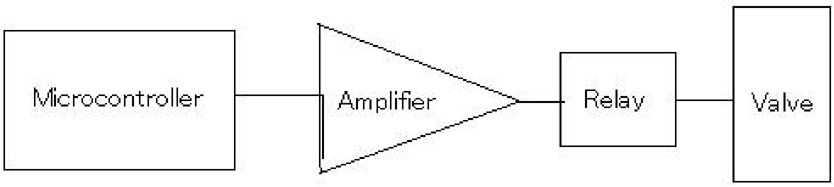

Figure 14: Valve Connection

When the valve needs to be turned on to pour in the needed solution, the microcontroller will send a logic high signal, which is 3V. Then the amplifier will amplify the signal to 5V, which is needed to activate the relay. 0.3A current, which is needed turn on the valve, will be provided to the valve through the relay from an external 24 V power source. Lastly, logic low from the microcontroller will turn the valve off.

The connection shown in Figure 14 will be implemented to the each of the three solutions.

8.2 Volume Control

The GUI program is responsible for determining when to control the pH and EC levels. The program will take the received EC and pH data and compare them to the user defined pH and EC levels. If the level received is not the same as the level set, the GUI will send a command to the central module to either dispense acid, base or nutrients into the reservoir.

The important factor when controlling the pH and the EC is to prevent excessive dispensing of the solution so that the pH and the EC do not go beyond the desired level. The volume of solution dispensed into the reservoir is controlled by the timer in the microcontroller. The dispense time is determined depending on current pH and EC level, and will be calculated in the GUI program.

8.2.1 EC Control

The dispense rate for the nutrient solution, or t_{EC}, can be approximated by the dilution equation:

$$t_{EC} = \frac{(EC_{Set} - EC_{Current})V_{res}}{D(EC_{sol})} \qquad \textit{Equation 4}$$

EC_{Set} = Desired EC level (μSiemens/mL)
$EC_{current}$= Current EC level
EC_{sol} = EC level of the solution
V_{res}= Current volume of the reservoir (mL)
D = Dispense rate of the valve (mL/s)

Since our system does not have the functionality to measure the current reservoir level, V_{res} is set to 20% of the reservoir capacity because the system can warn the user when the reservoir level falls below 25%. Thus to be conservative, 20% was chosen. By under estimating the current reservoir volume, the system can increase the EC level gradually to prevent excessive increase in EC. EC_{set} and EC_{sol} are set by the user through the GUI.

The valves will be tested to determine the dispense rate, D. The testing will involve opening the valve for 1 minute to determine the average volume of liquid dispensed by repetition

8.2.2 pH Control

First, the GUI needs to determine if the reservoir is acidic or basic to calculate the dispense rate for the acid and the base, t_{acid} and t_{base}.

$$A = 10^{-pHset} - 10^{-pHcurrent} \qquad \textit{Equation 5}$$

pH_{set} = Desired pH
$pH_{current}$ = Current pH

If A is positive, this means the reservoir is basic compared to the desired pH level, so acid needs to be added. If A is negative, reservoir is acidic and base will be added. Thus t_{acid} and t_{base} are calculated by the following equations:

If A>0,

$$t_{acid} = \frac{AV_{res}}{(10^{-pH_{acid}})D} \qquad \textit{Equation 6}$$

If A<0,

$$t_{base} = \frac{-AV_{res}}{(10^{-pH_{base}})D} \qquad \textit{Equation 7}$$

V_{res}=Current reservoir volume (L)
D= Dispense rate of the valve (L/s)
pH_{acid}= pH of acid solution
pH_{base}= pH of base solution

Similar to the EC control, V_{res} will be set to 20% of the reservoir capacity, and pH_{acid}, pH_{base}, and pH_{set} will be set by the user though the GUI.

9 Graphical User Interface

The main functionality of the GUI is to read, process, and display data for the user to see. It also controls the EC and pH levels of the reservoir according to the calculations described in the previous section.

The GUI will be written in LabVIEW 6i. LabVIEW will generate an executable file which the user can double-click and run on any Windows 98/2000/NT/XP operating system.

When the GUI is executed, the default menu will be the Main menu. From there, the user can select which menu they would like to display: option, water or air. Figure 15 below shows the flow of the user interface.

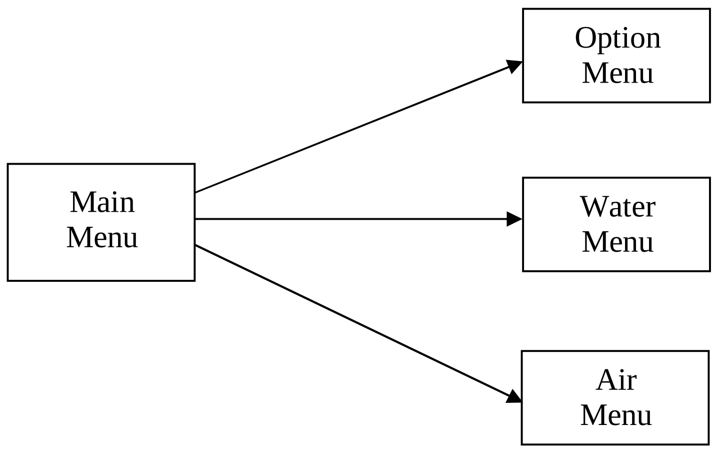

Figure 15: User Interface flowchart

Each of the menus will be written in separate VIs, which are similar to the functions in C programming. Shared operations, such as writing the data to a file, will be written in the main menu VI while operations such as graphs will be contained in their respective VIs.

9.1 Main Interface

The design for the main interface will consist of numeric displays of the current sensor readings of pH, EC, water and air temperature and humidity. These displays will refresh whenever new data has arrived from the sensor modules. Six digital LED indicators will light up when the respective data received is out of the indicated range. Providing that pH control and EC control options are selected, digital control boxes for setting the pH and EC level will also be available for the user to either type in or select their desired pH and EC level with arrows. In addition to these data displays, there will also be an option to select which additional menus to display. There will be a button to start the LOTS system. Figure 16 shows the main menu prototype.

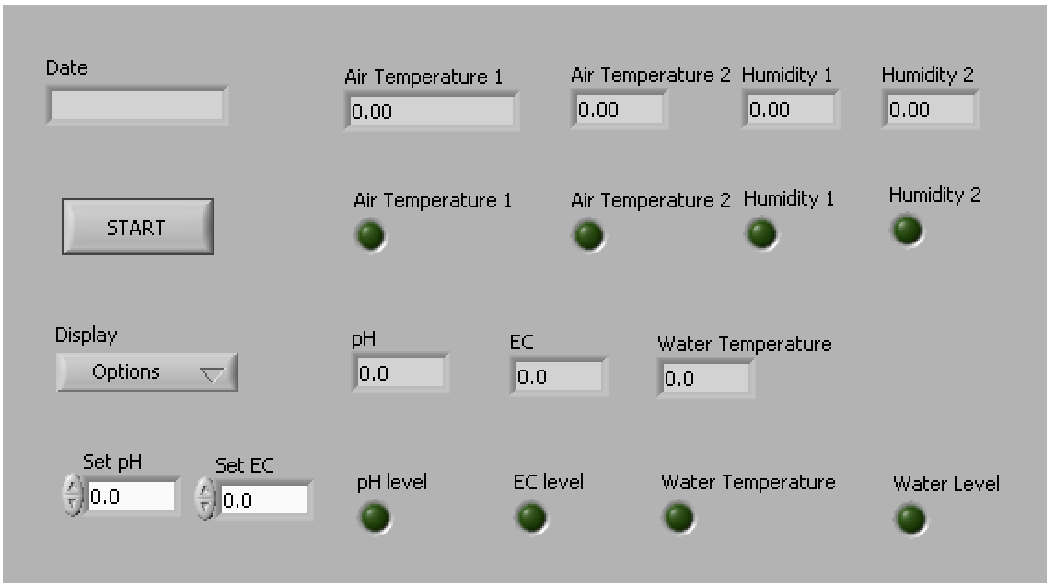

Figure 16: Main menu prototype

9.2 Option Menu

In the option menu, there will be option boxes to control either the pH or EC levels will be located. The digital control boxes for setting the pH and EC levels will also be available. There will be an option to set the desired operating range for the sensors. When the sensor reading is outside this designated range, the LED indicator on the other menus will be lit. There will also be an option to select the file in which to save the data. Figure 17 shows the option menu prototype.

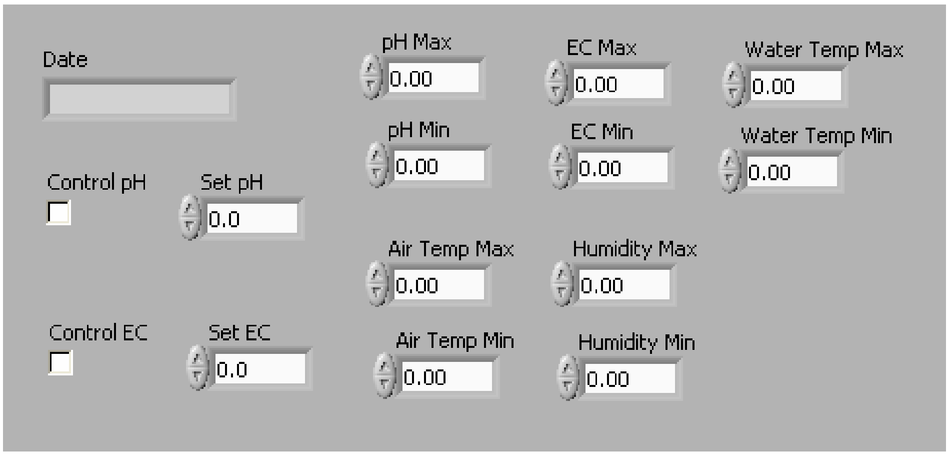

Figure 17: Option menu prototype

9.3 Water Interface

The water interface menu will have digital numeric displays of the current water sensor readings of pH, EC and water temperature. There will also be four LED indicators that light up when the respective data is out of the indicated range. Providing the option to control the pH and EC levels is selected, the two control boxes will allow the user to select the desired pH and EC level. In addition, there will be graphs located below the numeric sensors displays, tracking the history of the data readings. Figure 18 shows the water menu prototype.

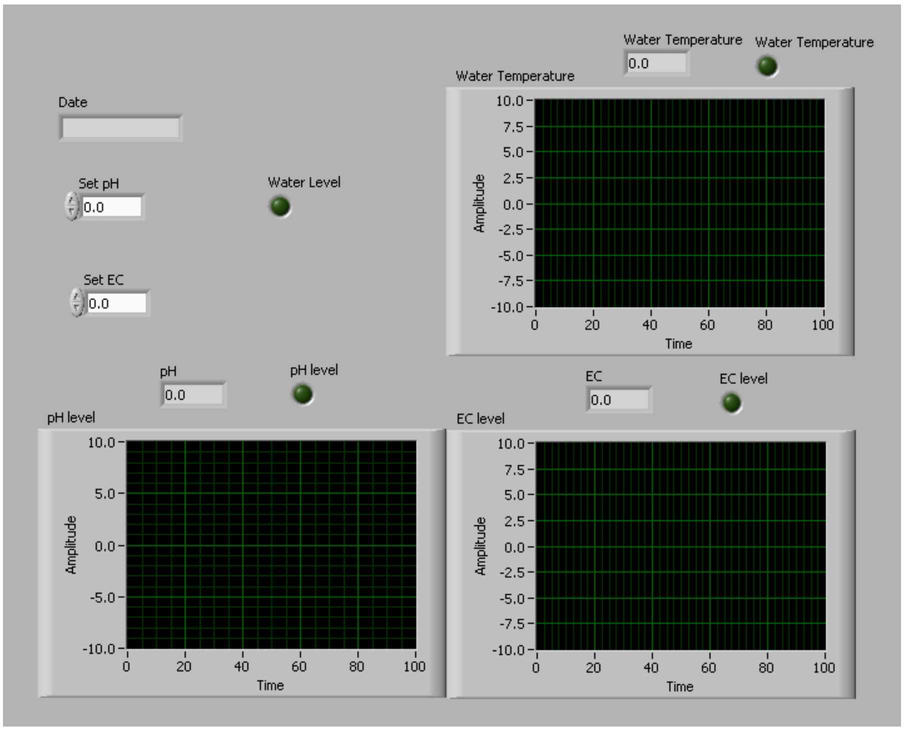

Figure 18: Water menu prototype

9.4 Air Interface

The air interface menu will have digital numeric displays of the current air sensor readings of air temperature and humidity. There will also be two LED indicators that light up when the respective data is out of the indicated range. In addition, there will be graphs located below the numerical sensor displays, tracking the history of the data readings. Figure 19 shows the air menu prototype.

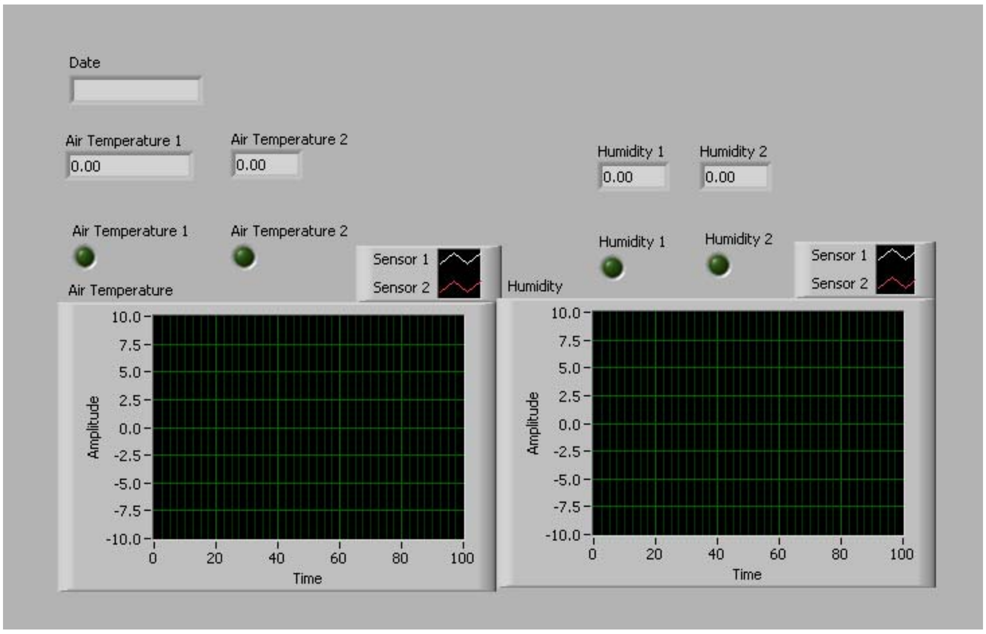

Figure 19: Air menu prototype

The user interface will write the data received from the RF module to a file. The date and the time of when the data is taken will also be written to the file.

10 System Test Plan

This section outlines the system test plan to ensure the operation of the design.

RF range testing will be done on the system in an indoor environment. The sensor units will be moved away from the central module until the sensor unit can no longer communicate with the central module. In addition to RF range testing, the system will also undergo RF interference testing. Cellular phones and 900 MHz cordless phones will be introduce and used in the vicinity of the system.

The pH control of the system will undergo disturbance and user control testing. In order to test how the system will respond to a drastic change in the system's pH, the pH of the system reservoir will be changed by approximately 1 pH unit. The pH in the reservoir will be monitored with an external pH meter to observe how fast the system can change the pH back to the level indicated in the user interface. This will also help monitor the accuracy of the GUI's pH display. For the user control testing, the desired system pH level will be indicated on the GUI and the reservoir will be monitored with an external pH meter to check the accuracy and speed of the pH control system.

The EC control system will undergo tests similar to the tests that were performed on the pH control system except this time, the EC will be changed.

In addition to pH and EC control testing, the GUI will also be tested for its pH and EC monitoring accuracy. The readings displayed on the GUI will be compared to an external pH and EC meter.

The water level sensor will also be tested. Water will be removed from the reservoir until the water level sensor is exposed. When the water level sensor is exposed, the water level LED indicator on the GUI interface will be lit.

The water and air temperatures displayed on the GUI will also be compared to external thermometer located in close proximity to the temperature sensors.

The humidity readings will be tested in the same way as the water and air temperatures except that a humidity sensor will be used instead of a thermometer.

11 Conclusion

The Design Specification document contains an outline of the technical design requirements and implementation that the Lord of the Seeds prototype system must achieve in order for it to be a viable product. The discussion has covered some justifications of the choices of solutions that are made. Specification of the overall system shows how the product as a whole should perform, while component specification shows how the system works internally. By having an exhaustive test plan, we can check the reliability of our product in the real world.

12 References:

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