Senior Design

Design Document

Narimdinda Robert Yann Bouda

Sahan Fernando

Sean Belieu

Ashok Paramasivam Rajan

Tianyu Wang

Zhaokui Wang

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Problem/Need Statement

Seedling growth chambers are able to house hundreds of seedlings, but are limited by the fact that each seedling is exposed to the same environmental conditions. The purpose of the chip-scale laboratory is to offer numerous individual seedling chambers that each house a single seed. The advantage is that each chamber can have a uniquely specified set of environmental conditions such as temperature, humidity and CO2 levels. In this way, optimal grown conditions can be found for multiple types of seedlings at a fraction of the time, space cost.

Our group's task consists of the design and integration of three main parts of the final product; A method for detecting temperature and humidity within individual growth chambers, a system that can interpret signals from the sensors to control an array of solenoids that use air pressure to direct liquid flow to a specific chamber, and a channel and chamber system that is designed to deliver liquid substances to the growth chambers

Hierarchy of our project/system

Due to the large scale of the final project, the project was broken into three sub-projects assigned to a sub-group composed of two members. During the first semester, each sub-group will strive to complete their individual objectives, then next semester integrate all of the sub-projects into a final system.

Objective

Sub-Project 1:

Create a control system using a microcontroller that will direct the behavior of the solenoid valves based on input received from sensors placed in individual growth chambers. The system must also implement a way for three solenoids to act as a peristaltic pump that will drive liquid throughout the system.

Sub-Project 2:

Design a channel and chamber system capable of delivering and receiving very small amounts of liquid. The process requires a specific photosensitive procedure used to fabricate SU-8 glass and using a mask process for laying out the glass in a PDMS design interface.

Sub-Project 3:

Through the use of an integrated temperature and humidity sensor, the individual environmental conditions of the individual growth chambers are monitored. The sensor is controlled by a microcontroller specifically designed to interface with the sensor and relay that data to relevant sub-systems.

System Block Diagram

The operation of the system, shown in Figure 1, is dependent on feedback from the sensor placed in each of the 128 seedling chambers. When a sensor is addressed by the system, its output is read and is compared to the preset conditions for that chamber. If a mismatch is found, the system works to correct the environmental conditions of that chamber. When the sensor output matches the preferred conditions, the next chamber is addressed.

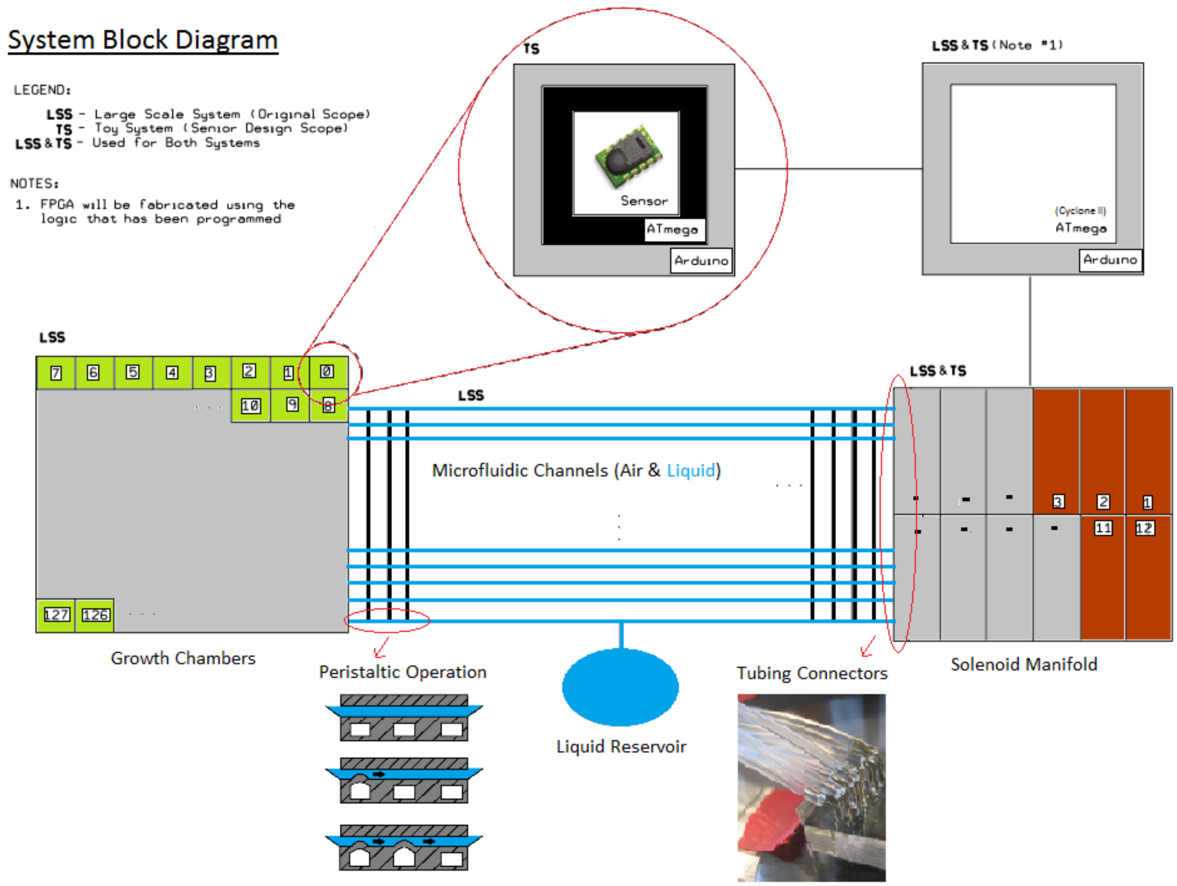


Figure 1: Block Diagram of the System

Requirements

Functional Requirements

1.) Sensor Array

a) Acquire a sensor with dimensions less than 100mm^2 that is capable of measuring both temperature and humidity with a tolerance of 0.5 C^o and 0.5% RH(Relative Humidity)
b) Design a circuit layout that is capable of receiving digital information from the sensor at the required resolutions stated above as well as the address of the individual chamber from which the data is received.
c) Program a control element that sends data in a serial digital format to a different system designed to regulate flow of liquid to the individual seed chambers to maintain correct environmental conditions.

2.) Solenoid Control System

a) Design a system using Verilog or VHDL capable of receiving and decoding a serial digital signal that contains chamber addresses and sensor information.
b) Using the address and sensor data, send control signals to a set of 7 solenoids that correspond to a 7-bit addressing scheme designed to restrict flow of liquid to one chamber at a time
c) If pumping of liquid is required, control 3 additional solenoids designed to work as a peristaltic pump until environmental conditions are corrected. If temperature correction is required, control of a heat exchanger until environmental conditions are corrected

3.) Water Flow Channels

a) Fabricate a flow channels capable of delivering liquid to individual chambers at volumes of 1µm^3.
b) Use air pressure generated by 7 solenoids to restrict flow of liquid to one chamber that all share a common reservoir.
c) Fabricate 7 air flow channels designed to depress and restrict flow through liquid channels using air pressure.

Non-Functional Requirements

a) Use of FPGA and Verilog/VHDL to program the control system for solenoids.
b) Provide documentation for any circuit elements to be submitted for review before any testing occurs.

Design Constraints

a) The thickness of control channels should be less than 1 mm on bottom.
b) The thickness of the flow channels should be 3 mm on top.

Equipment Constraints

a) The response time of the solenoid valves should be between 5-10 milliseconds
b) The solenoid valves should have a 105 psi max.
c) Solenoid valves should be normally off.
d) Solenoid valves should use a supply voltage of between 6 and 8 volts.
e) The sensor should a supply voltage of 2.4 to 5.5 volts.
f) The sensor should be able to sense a temperature between -20 Celsius to 100 Celsius.
g) The relative humidity operating range should be between 0 to 100%.
h) The sensor should have a response time of less than 10 seconds.

Detailed Design

Solenoids

The project will use a Clippard EMC-12-06-20 electronic manifold with 12 ET-2M-6 solenoids that are pre-mounted to it. The manifold has a 25 pin connector that will be used to interface with an Altera Cyclone II. The purpose of using an Altera Cyclone II is to provide an FPGA that provides operational instructions to the manifold.

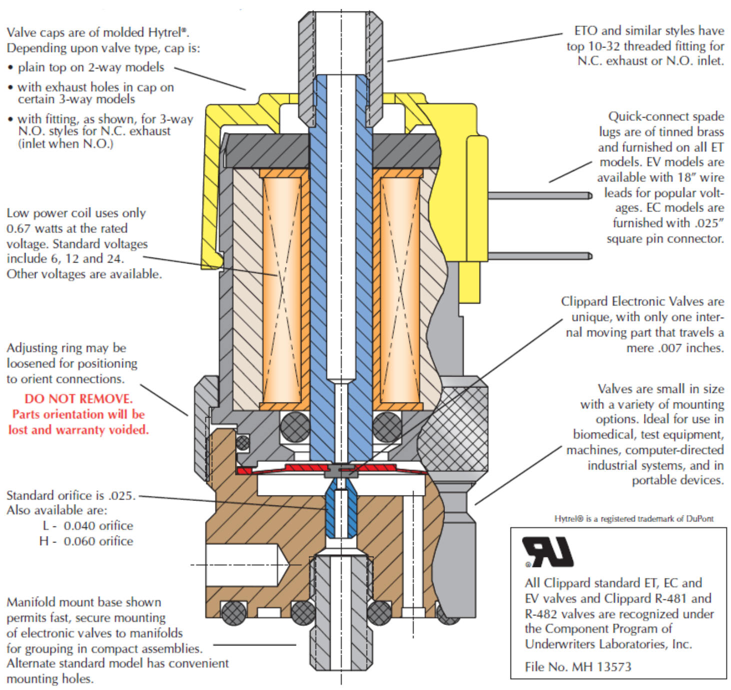


Figure 2: 12 ET-2M-6 solenoid.

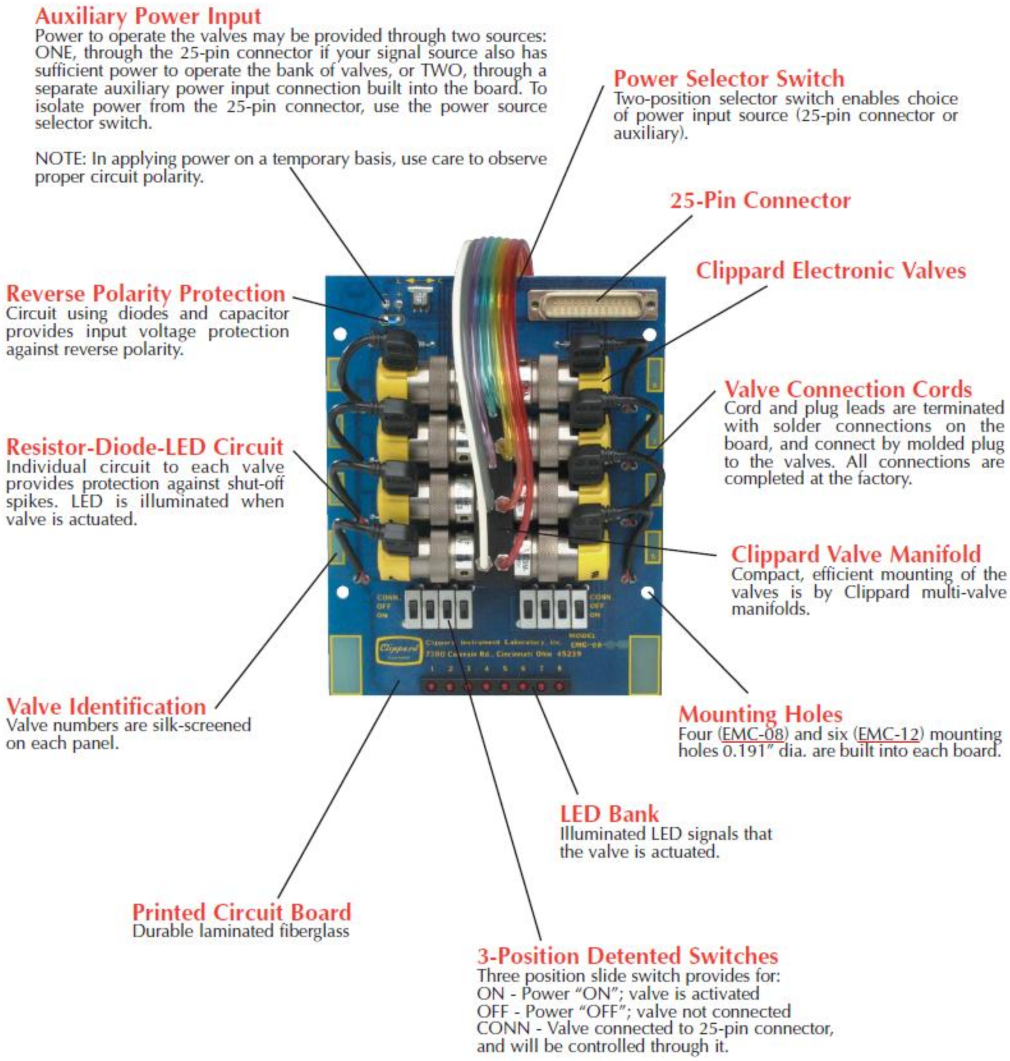


Figure 3: EMC-12-06-20 electronic manifold with ET-2M-6 pre-mounted solenoids

The solenoids pictured in Figure 2 and Figure 3 will correspond to a 7-bit addressing system designed to control flow to 128 different chambers, when a sensor detects an irregularity in any of the 128 chambers.

If pumping of liquid is required, 3 additional solenoids are designed to work as a peristaltic pump until environmental conditions are corrected. If temperature correction is required, the heat exchanger is controlled to obtain the necessary environmental condition.

Sensor

The temperature and humidity environmental variables are measured using the Sensiron SHT 11. This sensor was chosen because of its small profile and ability to measure both environmental parameters in one package. The Sensiron SHT 11 has environmental detection resolutions that meet and exceed those required by the project. The Sensiron SHT 11 is also self-calibrated and provides a serial digital output that will be easier to interface with a microcontroller.

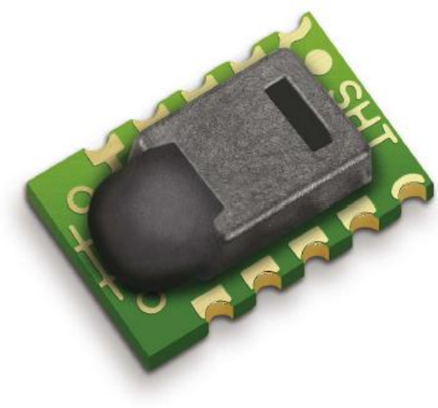


Figure 4: RH & T sensor, Sensiron SHT11

Features

- Energy consumption: 80uW (at 12bit, 3V, 1 measurement / s)
- RH operating range: 0 – 100% RH
- T operating range: -40 – +125°C (-40 – +257°F)
- RH response time: 8 sec (tau63%)
- Output: digital (2-wire interface)

- Maximal accuracy limits for relative humdity and temperature:

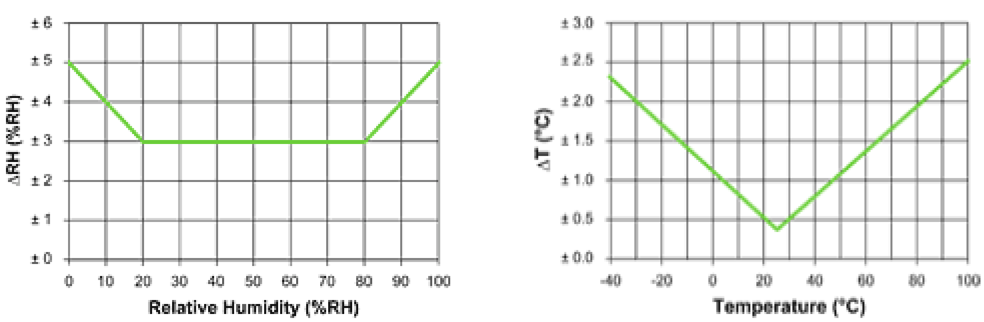


Figure5: Relative Humidity & Temperature features of SHT 11

The sensor uses a supply voltage in the range of 2.4- 5.5V. One drawback of the Sensiron SHT 11 is that it is essential to keep the temperature of the sensor at the same temperature as the air of which the relative humidity of the chamber to be measured for stable running condition. Arduino, an open-source electronics prototyping platform is used to create an interface that the Sensiron SHT 11 can operate through. An example is shown in Figure 6 in addition to all range readout shown in Figure 5.

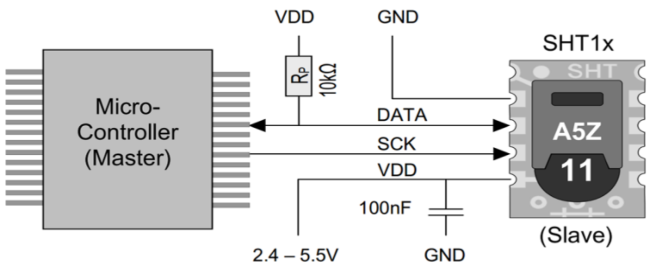


Figure 6: Typical application circuit

Micro fabrication

The fabrication process is done on SU-8, a negative photoresist polymer and Polydimethylsiloxane (PDMS) that is a type of polymeric organosilicon compound that is commonly referred to as silicone.

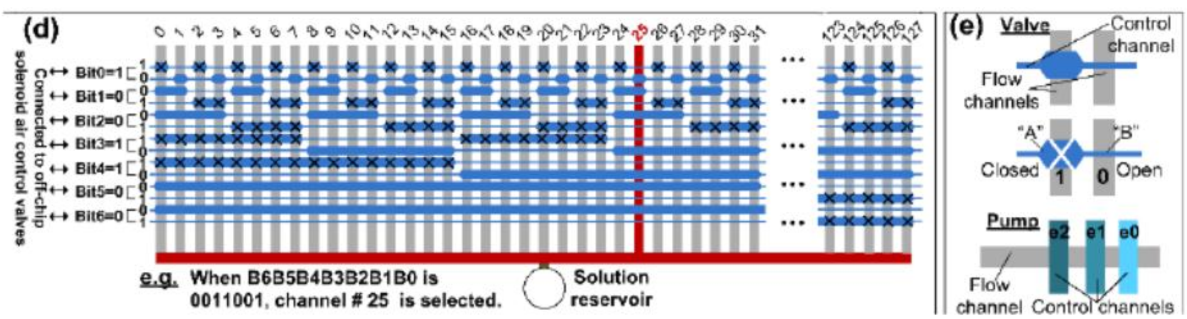


Figure 7: Logic diagram for Channel Selection

The fabrication process is as follows:

1) Clean the glass slides using IPA, ethanol, water, and a plasma cleaner for 40 seconds.
2) Then dry the glass slide for 2 hours at 95 C
3) Then, a spinner is used with 2-3 drops of SU8-25 solution on each glass slide with a pressure of 60
4) The SU8 is dried over 5 minutes at 60C and 45 minutes at 90C.
5) It is then exposed to UV light for 25 seconds over UV strength of 29.
6) After UV light we need to dry for glass for 1 minute at 60C and 3 minutes at 90C.

7) Wash the glass slides with SU8 developer, IPA and ethanol.
8) 20 g of PDMS is added on each glass slide.
9) Dry the devices for 2 hours at 90C and 4 hours at 60C.
10) The PDMS device is cut and the same process is repeated over the next layer.

Figure 8: Cleaning Station

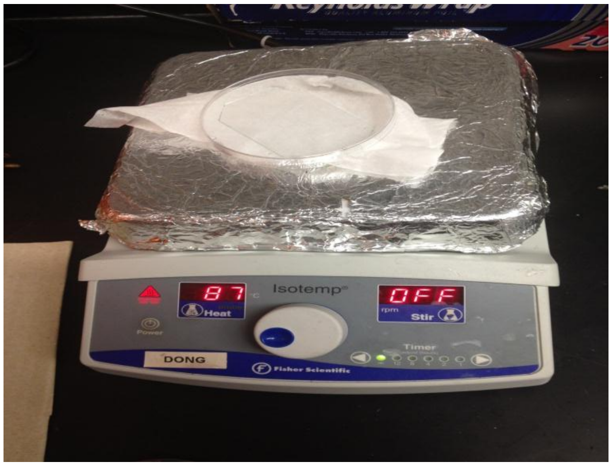


Figure 9: Dryer

Figure 10: UV Machine

Figure 11: Glass Slide

The final device has a number of glass slides that are micro fabricated with the above procedure. The glass slides are layered on each other to create the flow system, however it is important that one layer does not impede the layer underneath it as unintentional blocking of flow channels could occur.

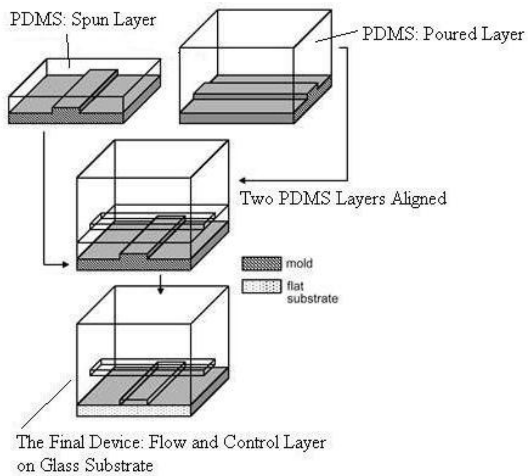


Figure 12: Glass slides layered on each other

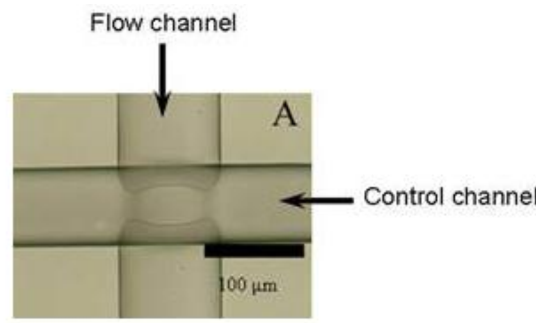


Figure 13: Flow and Control Channels

Testing Methods

Sensor Array

- Program Arduino using an individual sensor and check the accuracy of the output
- Add 3 sensors to the array and expand program to incorporate as many sensors as needed

Solenoid Manifolds

- Using MultiSim, verify code by using testbench code and observing for expected output in simulation
- Load code to Cyclone II and verify function by observing on/off condition of solenoids

Channel Overlay System:

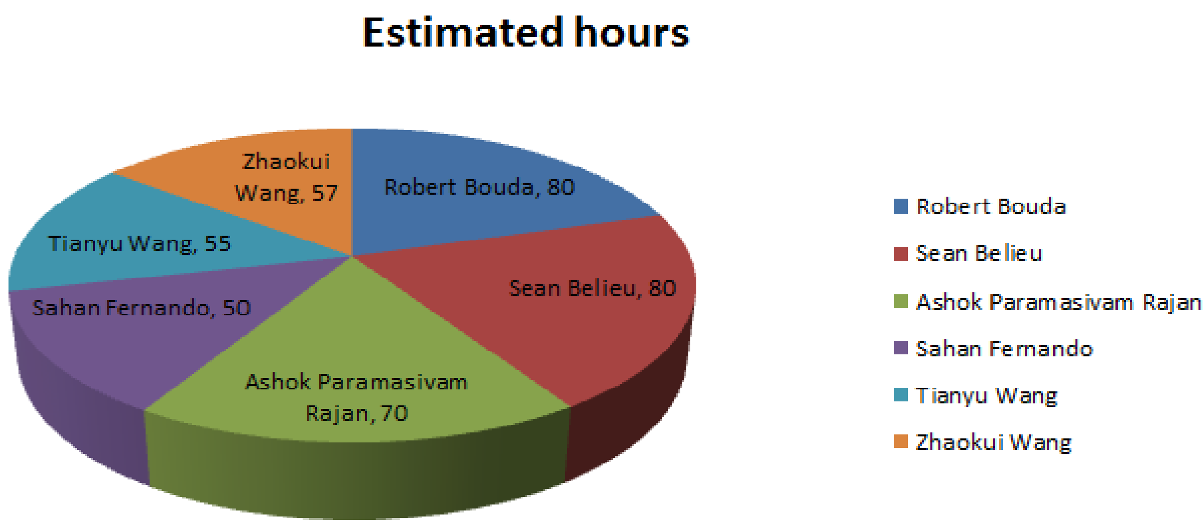
- Perform stress tests on material to verify proper layer bonding
- Apply air pressure and verify proper inflation of thin layer areas

Small Scale System:

- After verifying function of individual units, incorporate and check for expected operation

Estimated Time/Resources

Labor



Costs

Product	Quantity	Cost
SHT11X Sensor	4	$200
EMC-12-06-20 Solenoid Manifold	1 (12 Solenoids)	$500
MISC Cables/Connectors	Var.	$20
Altera Cyclone II	1	Provided
Total		**$720**

Contact Information

Faculty Advisor & Client

Dr.Liang Dong	ldong@iastate.edu

Team members

Narimdinda Robert Yann Bouda	nybouda@iastate.edu
Sahan Fernando	fernando@iastate.edu
Sean Belieu	spbelieu@iastate.edu
Ashok Paramasivam Rajan	ashok90@iastate.edu
Tianyu Wang	wty1987@iastate.edu
Zhaokui Wang	zhaokuiw@iastate.edu