Smart Industrial Irrigation

Team 208

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Dr. Shawn Jordan

Problem Definition

Problem Statement

In the future of agriculture, water rapidly becomes a scarce resource with a steeply rising demand. As the demand for water grows, water conservation methods become important both to minimize water costs, and reduce the energy draw on the environment. In this future, the irrigation systems will need to be more carefully regulated to ensure that crops are not being overwatered. This device will monitor soil saturation to ensure crops are thoroughly watered and water is not wasted exceeding that.

Customer Impact Statement

In an agricultural future where there is higher demand for water, there is significant interest in using at an effective amount of water for irrigation, but not exceeding the minimum effective amount. If the cost for water was significantly higher than it is now, there could be either a financial need or government regulation to irrigate based on soil saturation and time of day, rather than distinctly by time.

In the present day, many solutions exist that attempt to reduce the consumption of water for irrigation by disabling irrigation during rainfall, using weather forecasts or weather stations to identify it. The current demand for water, however, is not high enough to warrant the use of in-ground sensors to identify and stop an irrigation system when the soil is adequately watered. But with a steep increase in the cost of water, and with a higher demand for agricultural products in the future, this could change.

This system would result in the increased ability to minimally water, without underwatering crops during specific times of the day or at certain brightness levels. This would help reduce food production costs in areas with high cost of water, resulting in cheaper food for people in everyday life. One way this device could negatively affect people in everyday life is by temporarily raising the irrigation costs to install the system. For agricultural communities to install a soil-monitoring irrigation system would cost initial capital, which could be passed on to every-day food consumers.

Specifications

Table 2: Performance-based criteria

Metric No.	Metric	Unit	Marginal Value	Ideal Value	Rationale	Status
1	Field Coverage	acre	1-10	10	Commercial farm land can typically span anywhere between 500-1000 acres. The prototype built will not have that large of coverage	FAIL
2	Saturation Detection	%	>80	50-80	Saturation sensor can detect saturation values of above 80% and use the data as input to determine irrigation necessity	PASS
3	Installation Time	hr	<2	1	Device should take between 1 and 2 hours to install.	PASS
4	Yield Strength	MPa	>19.3	>55.2	The team will probably use a thermoplastic for irrigation tubing. The lowest tensile strength for a thermoplastic is 19.3MPa and the highest is 55.2MPa.	PASS
5	Points of Failure	#	<10	<5	There will always be points of failure when it comes to water hose systems. Ideally, the device will minimize these connection points to decrease the possibility for leaks and escaped water to most efficiently irrigate a field.	PASS

Table 3: Project specific constraints

Metric No.	Metric	Unit	Marginal Value	Ideal Value	Rationale	Status
1	Supply Voltage	V	110-240	115	Standard mains AC voltage supplied to device.	PASS
2	Hose Diameter	in	½ -1 ½	⅝	Typical irrigation systems can be connected to pressurized water sources with ⅝” connectors.	PASS
3	Water Pressure	psi	80	40-60	Standard water lines are pressurized at between 40-60 PSI, however they can sometimes reach as high as 80, and the irrigation system must sustain that.	PASS

Table 4: Instructor-defined constraints

#	Metric	Unit	Marginal Value	Ideal Value	Status
1	Prototype budget ● Does not include development kits, components, or PCBs from PRLTA, components from outside of ASU, or free samples.	$	$40 / team member	< $40 / team member	FAIL (Sutton lost parts so we had to reorder)
2	Power supply design ● AC adapter, battery, or solar panel connected to a custom-designed voltage regulator circuit. No USB power packs. ● This counts as a subsystem	#	≥ 1	# justified by design	PASS
3	Cypress BLE Microcontroller ● Cypress Bluetooth Low Energy (BLE) Pioneer Kit (CY8CKIT-042-BLE-A), PSoC 4 Pioneer Kit (CY8CKIT-042), and/or Prototyping Kit (CY8CKIT-049-42xx)	#	≥ 1	# justified by design	PASS
4	Sensor(s) read by a microcontroller ● Must have a custom-designed hardware signal conditioning circuit ● These count as subsystems	#	≥ 1	# justified by design	PASS
5	Actuator(s) controlled by a microcontroller ● These count as subsystems	#	≥ 1	# justified by design	PASS
6	Bluetooth Low Energy (BLE) communications with a phone, computer, or other device using a Cypress BLE kit	#	≥ 1	# justified by design	PASS
7	Functioning custom printed circuit board ● Must be created in Cadence ● No commercial boards	#	≥ 1	# justified by design	PASS

8	Surface mount components ● Size 0805 or larger recommended	#	≥ 0	≥ 1 per team member	PASS
9	Programming language	programmed in C or C++			PASS
10	Electrical subsystem (#2, #4, or #5) designed and used in the final device	#	1 by each team member	∞	PASS
11	Functioning at Innovation Showcase	%	50% functioning (100 points)	100% functioning (200 points)	75%

Team Member Accomplishments

Ben Levine:

Responsibilities:

In charge of the solenoid subsystem to open and close based on saturation sensor value. The subsystem was needed to water the soil so the saturation values change. Responsibilities also included designing the first housing mechanism and skeleton code, as well as updating the block diagrams and other documents following TA and professor feedback. The first housing mechanism was used to determine how the team could include incorporate the saturation sensor, solenoid, linear actuator, power supply, and PSoC into one single housing unit. The skeleton code was designed to be a proof-of-concept to show that the subsystems could be integrated together. It is important to continually update documents so the team is on the same level of understanding as the project progressed.

Accomplishments:

The individual subsystem assignments were great introductions to the industrial programs of Cadence and PSoC. The solenoid subsystem was simple to put together and integrate with the other subsystems of the project. Learned how to create a PCB and design a fully-functional circuit that integrated a mosfet and diode to control a solenoid. The skeleton code was able to control both the linear actuator and solenoid, but did not incorporate the saturation sensor. Additionally, the course was an introduction to the group environment in a professional setting. The design review introduced presenting project ideas and documents to industrial professionals to receive constructive feedback.

Ben Seeger:

Responsibilities:

Create a functional subsystem with accurate documentation. The subsystem needed to insert and retract a sensor into the ground by control of a microcontroller. The subsystem needed to be compatible with the sensor physically and electronically. The documentation included a full schematic of components and pin connections as well as a functional digital layout for a printed PCB board.

Accomplishments:

Researched, selected, and purchased components that would complete the desired function and were within our budget. These components were a linear actuator, an H-bridge driver, and some commonplace electrical parts such as capacitors. Created a detailed schematic in Cadence illustrating the relationship and wiring between components and their connection to the microcontroller. Created a digital PCB layout with ASU-specific specs that was electrically accurate to the schematic. Created a fully functioning subsystem on a PCB board using custom PSoC code. Integrated that subsystem into our groups system. Contributed to multiple documents such as a software diagram, a power budget, and a bill of materials.

Emmanuel Romanous:

Responsibilities:

I was in charge of designing and fabricating a working Power Supply subsystem. The subsystem needed to take an input of 12 volts from a Mean Well Power supply system that is directly hooked up to a wall outlet and regulate it down to a 5 volt output. Half of the overall system required 12 volts while the other half such as the the driver circuits and the sensor and PSoC required 5 volts. There was no code corresponding with the power supply itself so I was not responsible for any PSoC code with this particular subsystem.

Accomplishments:

The Power Supply was successfully put together on the individual subsystem PCB, then eventually integrated into the final PCB design. For the Final and individual subsystem PCBs, the voltage regulator was successfully able to take the input voltage and regulate it down to 5 volts. For the overall integration of my subsystem and the mechanical aspects of the project, I was able to assist in the cutting of the acrylic box. As for putting the acrylic together, I pinpointed acrylic glue and made sure that the box was assembled correctly with the PCBmounted and located on the north acrylic panel.

Ryan Sparks:

Responsibilities:

The individual subsystem which I was responsible for was the saturation sensor subsystem. The saturation sensor subsystem works by approximating a voltage output using a digital potentiometer as a voltage divider, and comparing that with the voltage created by the saturation sensor. The saturation sensor is effectively a voltage divider, with two stainless steel bars inserted into soil as one of the resistors. As the saturation level of the soil changes, the resistance between the stainless steel bars will decrease, causing a digital signal into the microcontroller. This subsystem has been thoroughly tested, and its functionality confirmed.

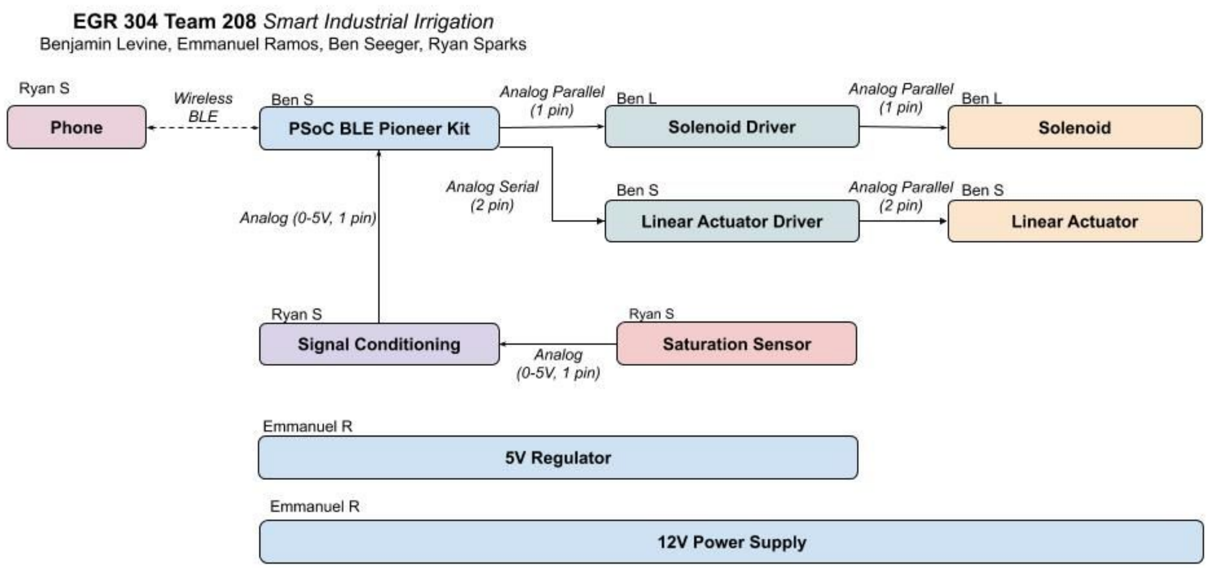
In addition to completing my own individual subsystem, I was also responsible for coordinating project assembly near the end of the semester. I was responsible for cutting the acrylic and manufacturing needed 3D printed parts, as well as helping to ensure timely completion of the deliverables.

Accomplishments:

The subsystem which I was responsible for was completed both individually and on the team board. I ensured that most subsystems worked together to the best of my ability, and strived to test and ensure the functionality of the final board in a timely manner. I also completed the Bluetooth component of the project, developing a method of communication between the project and a phone or other BLE device. One other accomplishment that I contributed to the team is the efficient and well-structured PCB routing on our project. While routing the PCB, I made sure that our project contained no extra vias, and all traces were appropriately distanced from the ground and 5v plane. This PCB routing is something I enjoy doing and that I believe greatly contributed to the success of the team.

Hardware Design

Block Diagram



Description

Sensor Subsystem

The sensor subsystem works by setting a threshold voltage of "saturation" using a digital potentiometer. The microcontroller communicates with the digital potentiometer to set an output voltage between 0 and 2.5v, depending on calibration. This threshold voltage is considered the threshold level, or the reference.

Another critical component of the saturation sensor subsystem are two stainless steel rods which are inserted into the soil. These two rods comprise one of the two resistors in a voltage divider to produce a voltage depending on the resistance between the rods. The voltage produced by this voltage divider is the input, or the saturation level.

An LM393 comparator compares these voltages, both very close to zero, and outputs a digital signal depending on whether the saturation level has exceeded the threshold level. This output signal directly indicates to the microcontroller whether the soil is saturated or not.

Solenoid Subsystem

The solenoid is being used to water the soil to increase its saturation levels. The saturation sensor determines whether or not the solenoid needs to be opened or closed by reading and retrieving saturation levels. The solenoid needed to be powered directly from the 12V power supply because it would not run below 10V. The driver circuit was connected to the PSoC so the solenoid could be actuated.
An n-channel mosfet is used to drive the solenoid circuit because of its simplicity and efficiency. N-channel mosfets are designed to connect the source to ground, drain the load, and turn on when there is a voltage at the gate. The structure of the n-channel mosfet was necessary for controlling the solenoid because the load was connected to 12V and could not receive a signal directly from the PSoC. The mosfet was able to control the actuation state of the solenoid. A 10k pull-down resistor was used.

Linear Actuator Subsystem

The system required a method of inserting the saturation sensor into the soil, allowing it to read the saturation level, and then retrieving it. The most efficient way to do this was to attach the sensor to a linear actuator. The actuator forces the sensor directly downward into the soil, holds it still for as long as needed, and then extracts it directly upward. This method is simple, fast, causes minimal disturbance to the soil, and is suited to repeated use.
The actuator is driven by an H Bridge, which uses switches to supply power in reversing polarity. This allows the actuator to extend and retract based upon the inputs of our microcontroller. The microcontroller takes the reading of the sensor and turns that into commands for the H Bridge that will cause the actuator to extend or retract.

Power Supply Subsystem

The Subsystem required that it takes an input voltage of 12V and regulate it down safely to 5V. The reason being was because half of the components require 12V and the other half needed 5V inorder to function. The voltage is being dropped from 12V to 5V through a 5V voltage regulator that simply takes the input of 12V from one pin and releases an output of 5V through the opposite ending pin. A fuse was incorporated into the design as a safety precaution in case of a short circuit that would cause an excess of amps to run through the circuit board which would render it useless. The fuse was never blown through testing on the individual subsystem level and when tested and integrated on the final PCB, also did not blow. Bypass capacitors were also incorporated in so that AC voltage can be separated for the DC output, however the

Mean Well power supply already does this so the bypass capacitors embedded into the design are a safety precaution as well.

Overall

The system combines the functions of the individual subsystems to create a device that can self-sufficiently keep soil saturated. It inserts a sensor when it is time, dispenses water if it is needed, and retracts the sensor for longevity of the components. The device is compact and causes very minimal soil disturbance. The device requires no manual input after installation and its settings can be updated via bluetooth.

Major Component Selection

Solenoid Subsystem

Solution	*Pro*	*Con*
Solenoid Valve ST-DA ¼" brass ($27.25) 	- Direct operation (no differential pressure required) - EPDM seal protects the internal components of the solenoid well	- ¼" hose diameter - Expensive
Solenoid Valve PRE ½" Nylon ($17.39) 	- ½" inch hose diameter - Inexpensive - NBR seal is suitable for most water temperatures	- Indirect valve operation (differential pressure required) - Not designed for extended use because it can be damaged by extended exposure to dirt.

[USSOLID Electric Solenoid Valve 1”](#) ($28.99)  	- 1” hose diameter - Flow rate of 12 gallons per minute - Operational pressure from 0-101psi	- No downloadable datasheet - Solenoid has potential to overheat despite normal operating conditions

Selection: Third option; US Solid solenoid valve

Rationale: The US Solid valve appears to be a better option than the nylon or brass valves because of its hose diameter and flow rate. The team is not concerned with the potential for overheating because it will not be activated for extended periods of time. The increased diameter creates an increased flow rate, which allows for quicker irrigation times.

Solenoid Driver

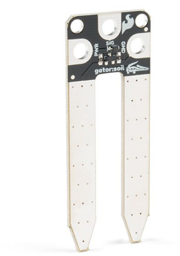
Solution	*Pro*	*Con*
MC33152PG IC Driver MOSFET Dual HS 8DIP ($1.39) 	- Easy to use - Output 1.5A - Operates up to 20V	- Fragile - Optimum switching speed at 10V
Infineon IRL520NPBF ($0.78)	- Drain up to 10A - Gate threshold voltage 1-2V	- No listed lead time - Fragile

	(PSoC @ 5V) - Overheats at 175 Celsius	- May be too powerful
ROB-14451 TB6612FNG Motor Driver Board ($4.95) 	- Outputs 15V - Average output 1.2A	- Expensive - Complicated internal structure - May require PWM

Selection: Second option; Infineon IRL520NPBF

Rationale: The Infineon IRL520NPBF is the most powerful of the three options and the easiest to implement because of the quantity of pins it contains. Its ability to dissipate up to 10A reduces the chance for a short circuit or unforseen electrical problems. The Infineon can easily work with the power supplies and microcontroller to easily provide information to the solenoid.

Saturation Sensor Subsystem

Solution	*Pro*	*Con*
Develop custom PCB that can serve as a soil probe. PCB can be inserted into soil and exposed traces detect soil saturation.  Example (solution would be custom fabricated but similar)	- Probes would be inexpensive and require few parts. Little thought would be required into separating probes as they are cut to shape in PCB fabrication. - Easy to mount to a mechanical system raising probes up and down. Mounting points could be built-in to PCB. - Signal conditioning circuitry can be built directly onto the probe resulting in easier fabrication and greater probe accuracy.	- Exposure to water could cause copper pads to stop adhering to FR4 board material - Probe depth is limited by PCB fabrication size constraints. Can't measure very deep into the soil. - Signal conditioning circuitry built onto the probe would be exposed to the elements and may degrade with exposure to water.
Attach two 2ft stainless steel rods together with 3D printed plastic dielectric spacers. These rods can be inserted in the soil and connected to system with wire.  Stainless steel rods ($1.25/ft) can be found fastened together with 3D printed spacers.	- Probes can be made at nearly any length and can be used to identify saturation at deeper soil levels. - Resistant to wear and corrosion. Stainless steel conducts electricity and resists corrosion. - Easy insertion into soil. Small rod diameter results in low friction when probe is in contact with soil.	- Probe does not have on-board signal conditioning, increasing distance to signal conditioning and introducing noise. - More difficult to mount and thought must be put into separating probes with dielectric.

Selection: Second option; stainless steel rods

Rationale: The major factor detracting from using a PCB or a different style of probe is probe life. With the insertion and removal of a PCB into soil, the copper traces that serve as the “sensor” could be dislodged from the PCB and the sensor could stop working. Stainless steel rods, however, can be easily inserted and removed from soil with no wear issues. They are corrosion resistant and could be made at a length such that they measure soil saturation deeper in the soil. To separate the two rods required for the probe, 3D printed hardware and a zip tie can be used. This would keep the probes apart and alligator clips could be used to attach wire to the probes.

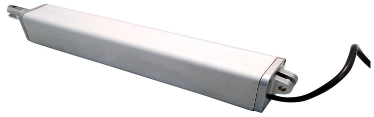
Saturation Sensor Signal Conditioning Subsystem

Solution	*Pro*	*Con*
LM393N Comparator ($0.91 ea) 	- Detection of 2mV voltage difference allows for precise measurement of soil resistance and saturation. - Designed for operation on one power supply and can detect near-ground voltage without a negative rail (designed for CMOS voltages) - Two op amps in one package!!	- More expensive than more generalized component. - Requires external circuitry to operate successfully. More complex than a simple transistor.
2N3904 Bipolar Junction Transistor ($0.21 ea) 	- Relatively simple signal conditioning network where probe current is amplified by BJT. - Highly available and very inexpensive transistor. - Datasheet includes information on circuit setup to use BJT as a comparator.	- Documentation only discusses operation with signal greater than 400mV. This may not be precise enough for soil saturation. - Current controlled and not voltage controlled. Probes need to be closer together. - Not designed specifically for signal conditioning and could introduce noise and error.

Selection: First option, LM393N comparator

Rationale: The datasheet of the LM393N comparator advertises its usage in an application very similar to the one described by our project. The device specifically mentions that it can be used with a single power supply and it can detect near-ground voltages even without a negative rail. It also indicates that it's designed specifically to interface with TTL and CMOS. Between the accurate near-ground voltage detection and the lack of a need for dual power supplies, the LM393 is an excellent choice for this application.

Sensor Insertion Subsystem

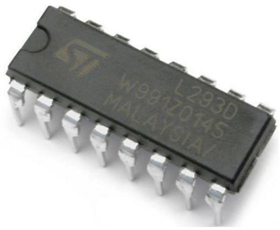
Solution	*Pro*	*Con*
PA-07-12-5 Micro Linear Actuator ($69.99) 	- 12 inch extension is perfect for the scale of our build. - Extensive data sheet will provide us with precise calculations. - The size and shape of the actuator will fit well in our build.	- Price is much higher than its value to the build. - The 5 lbs of force provided may struggle to break ground.
PA-14 Mini Actuator ($108.99) 	- The 12 inch extension is perfect for the size of our build. - Extensive data sheet will provide us with precise calculations. - The size and shape of the actuator will fit well in our build. - The 150 lbs of applied force will easily break ground.	- Price is much, much higher than its value to the build. - The added force output is not necessary for our build.
FA-05-S-12-6 Tubular 6 Inch Stroke Linear Actuator ($65.00) 	- The force provided is sufficient to break ground smoothly. - The size and shape of the actuator will fit well in our build.	- 6 inch stroke is slightly too small for the scale of our build. - Price is much higher than its value to the build. - Datasheet is not professional and not easily accessible.

Selection: First option, micro linear actuator

Rationale: The additional range of extension will allow us more room to mount a ground-breaking tool and saturation sensor. The extensive and accurate datasheet will allow us to make precise calculations for its individual use as well as its cooperative use and power consumption within the build.

Linear Actuator Driver

<table>
<tr><td>Solution</td><td>Pros</td><td>Cons</td></tr>
<tr><td>AC-27-10-12 Relay (12V, 10A) ($16.99)
</td><td>- Does not require any manual input.
- Data sheet is helpful in terms of values, calculations, and wiring.
- Device is simple.
- Device is designed for use with microcontrollers.</td><td>- Lack of customization.
- May be difficult to configure automatic current reverse.</td></tr>
<tr><td>AC-21 Digital Programmable Timer Switch (12V, 16A) ($37.50)
</td><td>- Multiple timers can be set.
- Is its own input and only provides an output signal.</td><td>- Times will need to be set manually.
- Our build would benefit from a timer that communicates to the whole system, not just the actuator.
- Price is higher than its value to the build.</td></tr>
<tr><td>AC-14 DC Speed Controller (10A) ($31.99)
</td><td>- Provides precise movement and speed control.
- Easy to use.
- High Efficiency.</td><td>- Speed Control isn’t necessary, only on/off and direction.
- Price is higher than its value to the build.
- Requires manual input.</td></tr>
<tr><td>L293D H Bridge ($2.95)</td><td>- Inexpensive
- Simple
- Requires no manual input
- Designed for use with microcontrollers</td><td>- Device is small and difficult to work with.
- Device is malleable and may become deformed.</td></tr>
</table>

Selection: Last option, L293 H Bridge

Rationale: It requires no manual input, and can enact extension and retraction. The wiring is very simple. The H bridge is also the least expensive option.

Power Subsystem

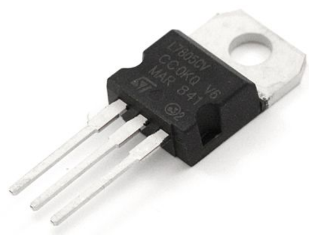
Solution	Pros	Cons
RHINO switching power supply, 12 VDC output ($52) 	- Stationary Power Supply - Protections type against short circuits and “overload” - Voltage monitoring to keep an eye on how much voltage is being emitted	- Very costly compared to the other two power supplies - Only has one output voltage port - No remote on/off switch

MEAN WELL RD-35A dual output switching power supply- enclosed type ($11.95 - above 9 pins) 	- Cost efficient - Can have two output voltages, one at 5V and the other at 12V - High reliability: 105°C long life electrolytic capacitors - Protection types against short circuit and “overloads” - High operating temperature range: -25~+70°C	- Unknown reliability in regards to the amount of pins (higher pin count is less expensive) - Open frame body cover design makes cooling convenient but exposes internal components to environmental harms
Triad Magnetics WSU120-1000 ($9.61) 	- Easily pluginable wall mount power supply that is extremely portable - Enclosed body design - AC to DC voltage type - Least expensive power supply out of the competition	- Only has one output - Would need to modify the connected wire in order to be able to plug into system

Selection: Second option, MEAN WELL RD-35A

Rationale: Since cost is a factor, it makes it clear that an inexpensive yet efficient power supply was needed to be selected. The MEAN WELL power supply is the smallest power supply that supplies 12 DC Voltage just like the other two competing power supplies for a relatively low price. Its compact body makes portability and installation easy. This power supply provides 4A of current while the Triad Magnetics only outputs 1A. If the Triad Magnetics power supply output around the same current as the MEAN WELL then that would have been the power supply of choice.

Voltage Regulators

Solution	Pros	Cons
[COM-00107]() ($0.95) 	- 5V fixed output voltage - Can output maximum of 1.5A of current - Thermal overload, short circuit protection	- Price is relatively high for one regulator - Fragile
[L7815CV]() ($0.49) 	- 1.5A output current - Thermal overload, short circuit protection - Output voltage up to 24 volts - Relatively low cost	- Quality is unknown - Price might be very low for poor quality of device
[LM2940CT-5.0/LF01]() ($1.56)  	- Very high voltage input of 26V - Output current of 1A - Outputs 5 Volts	- Very expensive for one regulator - Design might cause complications with PCB

Solution: First option, COM-00107

Rationale: Since all the regulators have almost identical specs, and relative to other parts regulators are inexpensive so investing in a more reliable part will be worth it in the long run. The 5V fixed output voltage is what we'll need for the microcontroller so this voltage regulator is perfect for this specific design.

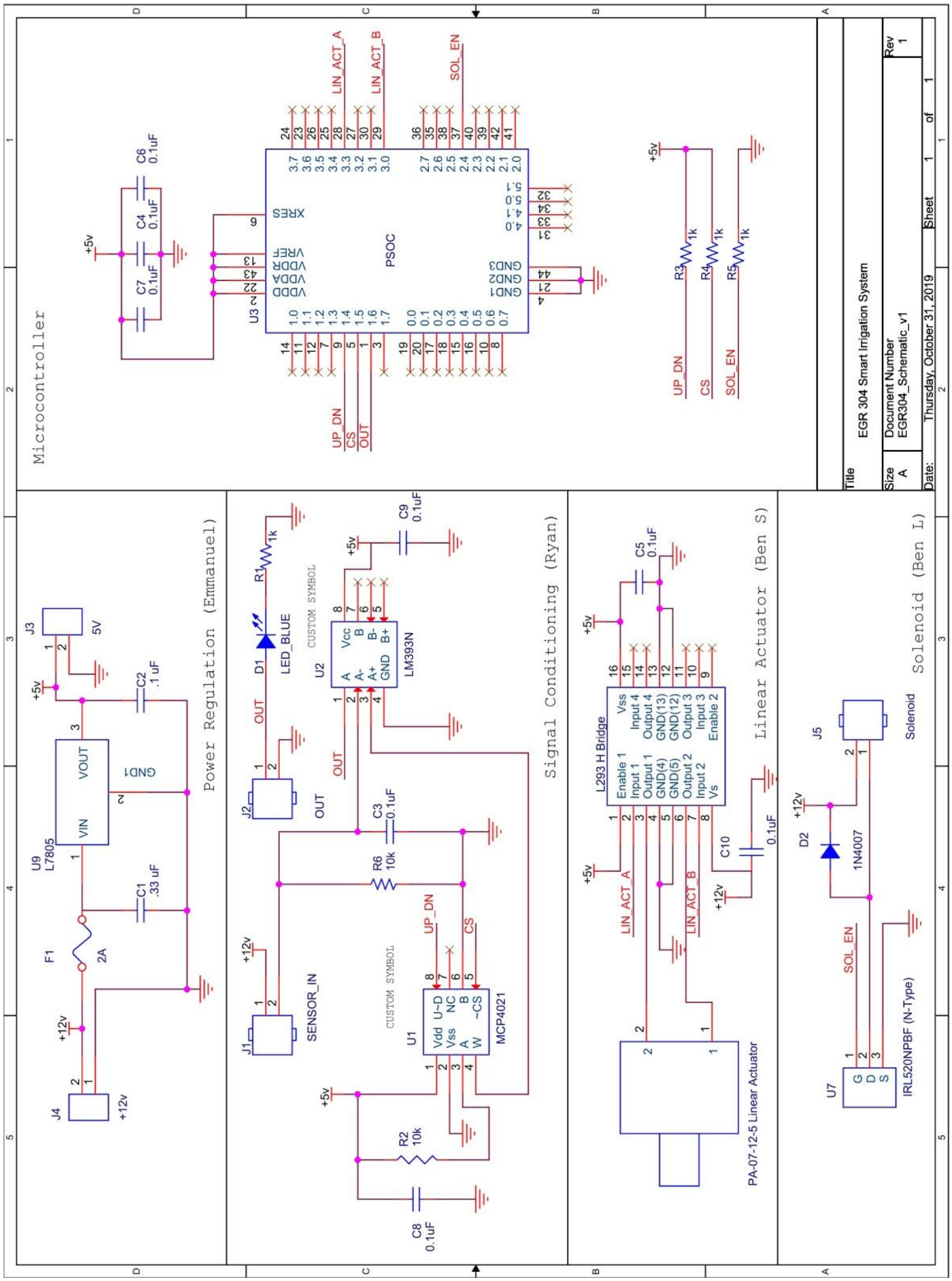
Power Budget

a. List ALL major components (active devices, integrated circuits, etc, but no resistors, capacitors, or passive elements)							
All Components	**Component Name**	**Part Number**	**Supply Voltage Range**	**#**	**Absolute Maximum Current (mA)**	**Total Current (mA)**	
	Solenoid	JFSV00003	10.8 - 13.2 V	1	1670	1670	
	LM393N Comparator	LM393N	1 - 18 V	1	1	1	
	PSoC 4 BLE Module	CY8CKIT-042-BLE	1.7 - 5.5 V	1	100	100	
	Linear Actuator	PA-07	12 V	1	200	200	
	12V Relay	G6E-134P-US DC5	3 - 48 V	1	40	40	
b. Assign each major component above except for voltage regulators to ONE power rail below. Try to minimize the number of different power rails in the design. Add additional power rails if needed.							
12V Power Rail	**Component Name**	**Part Number**	**Supply Voltage Range**	**#**	**Absolute Maximum**	**Total Current (mA)**	

					Current (mA)		
	Solenoid	JFSV00003	10.8 - 13.2 V	1	1670	1670	
	Linear Actuator	PA-07	12 V	1	300	300	
					Subtotal	1970	
					Safety Margin	25%	
					Total Current Required on 12V Rail	2462.5	
5V Power Rail	**Component Name**	**Part Number**	**Supply Voltage Range**	**#**	**Absolute Maximum Current (mA)**	**Total Current (mA)**	
	PSoC 4 BLE Module	CY8CKIT-042-BLE	1.7 - 5.5 V	1	100	100	
	LM393N Comparator	LM393N	1 - 18 V	1	1	1	
	12V Relay	G6E-134P-US DC5	3 - 48 V	1	40	40	
					Subtotal	141	
					Safety Margin	25%	
					Total Current Required on 5V Rail	176.25	
c. For each power rail, select a specific voltage regulator. List the working input voltage range and absolute maximum current specifications. Group regulators by supply (e.g., a specific rectified transformer, unregulated power supply, or battery). In the right-hand columns, link to the requirements for each power rail from step (b) above, and provide a subtotal for each power supply.							
Supply	**Regulator**	**Part Number**	**Input Voltage Range**		**Absolute Maximum**	**Required By Rail(s) (mA)**	**Problem?**

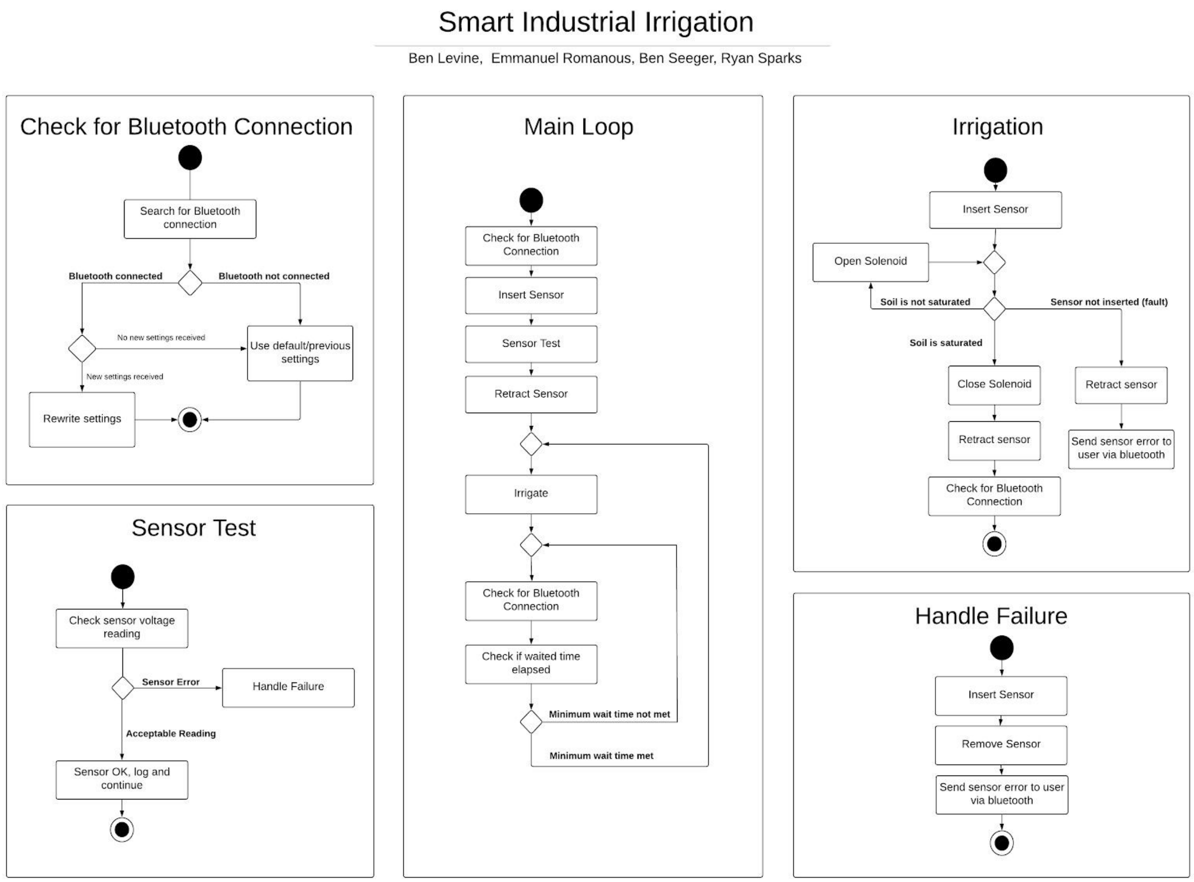
					Current (mA)		
Plug in power supply	5V Regulator	COM-00107	5V-18V		1500	176.25	no
					Subtotal	**176.25**	
d. Calculate power supply requirements. For each supply, identify the input voltage (if applicable), output voltage, and absolute maximum output current. Different batteries have different current output capabilities and should be identified from the datasheet or researched based on the chemistry you select. Compare against the subtotals calculated in step (c).							
External Supplies	**Component Name**	**Part Number**	**Input Voltage (if applicable)**	**Output Voltage**	**Absolute Maximum Output Current (mA)**	**Required By Regulators**	**Problem?**
	Mean Well 12V Power Supply	RD-35A	120 VRMS	12 V	4000	2462.5	no
					Subtotal	2462.5	no
Notes							
External Supply Voltage should be determined by the dropout voltage for highest-voltage regulator (e.g., 14V for a 12V regulator).							
If you have multiple units in your design (e.g., a base unit and remote unit) then you need a separate power budget for each unit							

Schematic


Microcontroller
Power Regulation (Emmanuel)
Signal Conditioning (Ryan)
Linear Actuator (Ben S)
Solenoid (Ben L)
PSOC
U3
L7805
LM393N
MCP4021
L293 H Bridge
PA-07-12-5 Linear Actuator
IRL520NPBF (N-Type)
1N4007
LED_BLUE
SENSOR_IN
LIN_ACT_A
LIN_ACT_B
SOL_EN
UP_DN
CS
OUT
Title
EGR 304 Smart Irrigation System
Size
A
Document Number
EGR304_Schematic_v1
Rev
1
Date:
Thursday, October 31, 2019
Sheet
1
of
1

Software Design

Software Diagram



Rationale

The central function of the software is the Irrigation function. This function inserts the sensor and reads the saturation level. If the soil is not saturated, the solenoid will open and dispense water. The sensor will read the saturation level until the soil is saturated and will then close the solenoid. Once the soil has become saturated, the sensor will retract out of the soil and wait until the next time the saturation level needs to be read.

Before the Irrigation function, the system attempts to establish a bluetooth connection, then performs a test to ensure that the insertion/extraction is working correctly, as well as ensuring that the sensor is reading the saturation level correctly.
After the Irrigation function, the system goes into a resting period while it waits until the inputted next time to insert the sensor. During this resting period, the system will attempt to establish a bluetooth connection and will take inputs for the delay period and saturation threshold.

Mechanical Design

Rationale

The housing structure is constructed out of ¼” acrylic so the components can be viewed externally so the subsystems can be monitored. Along with the transparency of the acrylic, there are ventilation slots for the power supply that also act as a mounting mechanism. These slots provide an avenue for the heat generated by the power supply to be released outside of the general housing structure. Additionally, there are two 3D printed mounting mechanisms: one for the PCB and another for the saturation sensor. The mount for the PCB allows for quick access and easy removal. The bolt heads are on the outside to allow for easy access. To assist with the access of the parts, the bottom of the box is empty. The empty bottom also allows for the saturation sensor to be mounted to the inside of the box with the linear actuator. The linear actuator extends below the box, so it is important to have the bottom of the box open.

- Acrylic is transparent
- Ventilation holes are also used to mount power supply
- 3D printed PCB mount
- 3D printed saturation sensor mount
- Open bottom

Relation to specs:

- Few points of failure
- Low detection radius of saturation
- Quick installation time
- Low field coverage
- Meets supply voltage
- Meets hose diameter (1” hose diameter for solenoid)

Project in Context

Figure 1: Overall System 1

Photos

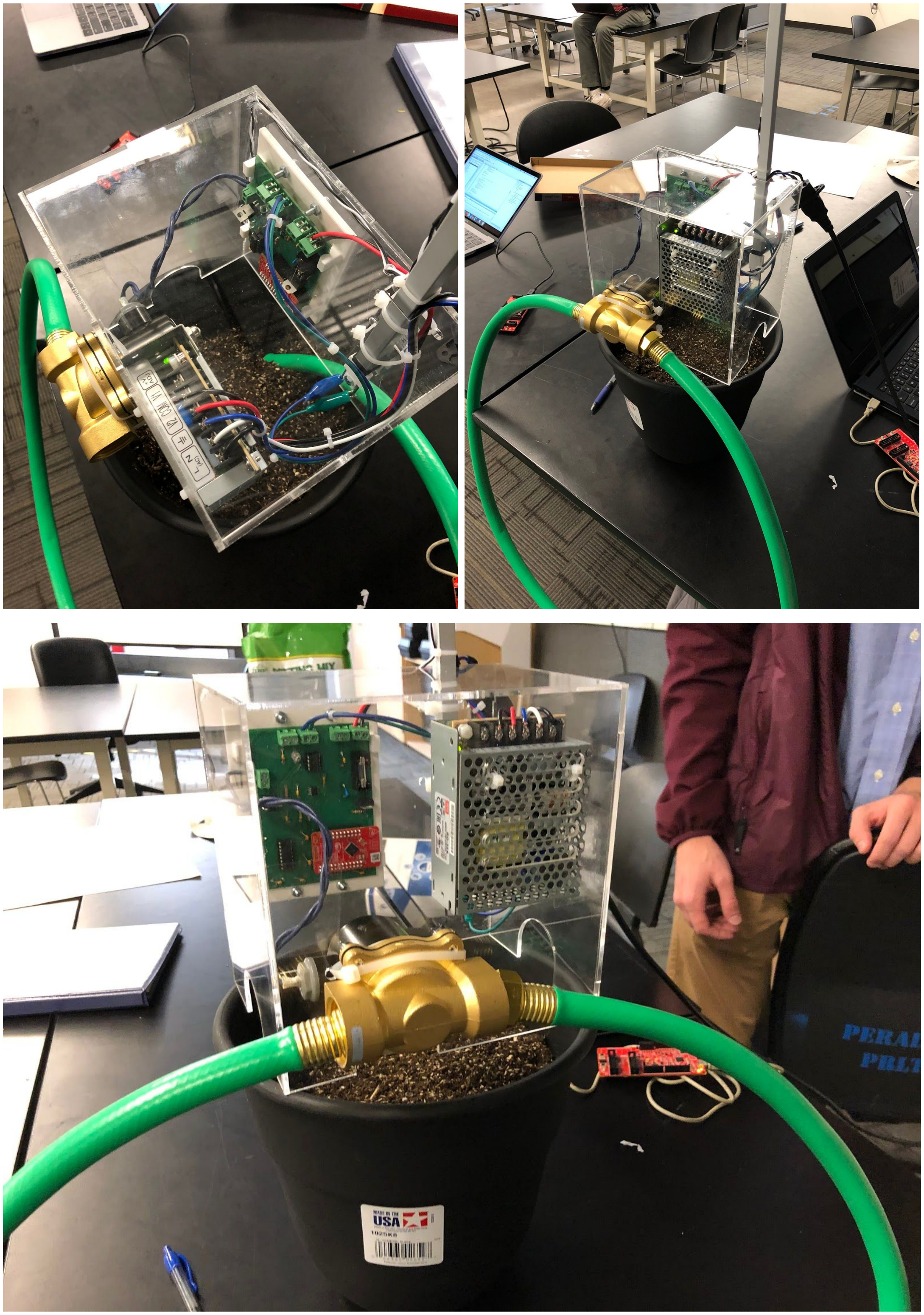


Figure 2: Overall System 2

V2.0+ and Lessons Learned

Hardware Design

The risk of the linear actuator outweighs its benefits. The actuator is by far the component most likely to break, and therefore compromises the whole system. If any component breaks, then the system's self-sufficiency is destroyed and will need to be manually fixed. The actuator also creates other failure points, such as the possibility of failure to breach the soil and insert the soil. This would cause the entire system to operate incorrectly. An alternate way of creating the system could be to permanently insert the sensor into the ground. The sensor would now be the most likely component to need replacing, but replacing the sensor would be much easier and cheaper than the actuator. If this change were implemented, the system would now require very little power. The current system requires an AC power input, which could be inconvenient if the user wanted to install the device in a field. Because the device is generally designed for outdoor use, it is very possible that the little power required to read the saturation and dispense water could be produced by a solar panel. Another component could have been added that would greatly increased the coverage of the water. Our current range of saturation is fairly small because our output of water is stationary. A sprinkler system would have greatly increased the range of our device.

Software Design

Our software is ill-equipped to handle failures and variations. Our code works as intended under ideal conditions, but does not have functions to handle varying results. For example, the device would benefit from the ability to catch itself from infinitely dispensing water. If the sensor become disconnected or is not able to correctly read the soil and reports that the soil is constantly under saturated, the system will infinitely dispense water. If the device is installed in a field, it could be a very long time before this error is caught and could cause damage, loss of crops, and waste of water. This error could be caught by the device by adding a timer override, where the device will automatically cut off water supply after x seconds if the sensor is not reacting to the dispensed water. The user would also benefit from bluetooth updates and error cases from the device. This way the user could be alerted remotely of things such as amount of water used or a failure to insert the sensor. The device would consume much less power if it went into a low power rest mode in between readings. The device is idle for much of its lifetime and only occasionally consumes power to perform readings and dispense water. The rest of the time, the device only needs the power to establish a Bluetooth connection and receive commands.

Mechanical Design

The mechanical design could be improved to mount the solenoid closer to the saturation sensor. Currently, the design has the saturation sensor and solenoid on opposite sides of the box, which means the hose needs to be routed to reach the soil. If the solenoid were closer to the saturation sensor, we can receive more accurate measurements. The spacing of the solenoid makes it difficult to route wires efficiently because the wires for the solenoid need to be fully extended in order for them to reach the PCB. Another improvement to the mechanical design should be the dimensions of the housing. In our current model, the linear actuator is taller than the acrylic used to create the box. This results in there being a hole at the top of the box for the saturation sensor attached to the linear actuator to rest at the bottom of the housing unit. The hole at the top of the box allows for more potential damages to the PSoC and other electrical components. In order to protect such sensitive equipment, the housing unit should be able to fit all components. To make the device more user-friendly, the housing unit should have a hinge on the top panel to allow for easy access to all the internal components. The current design does not have a bottom panel so the linear actuator can extend the saturation sensor into the soil while being mounted to the internal walls of the housing structure. Allowing the top panel to rotate on a hinge would allow the user to access the different components without disrupting the general setup of their irrigation system. The PSoC will come with different pre-set options of saturation that the user can choose from (Low, Regular, High). If the user wishes to change the thresholds on the saturation levels, the top hinge will allow them easy access to the microcontroller.

Lessons Learned

1. Cadence software
2. Creating a schematic
3. How to design/create PCB
4. Working on a tight budget
5. How to design software diagram
6. Testing matrix
7. Determining what components to use and why
8. System integration
9. Troubleshooting electrical layout
10. Importance of surface-mount versus through-hole components

Appendix:

Benchmarking of Related Solutions

Table 1: Benchmarking of existing irrigation systems

Solution	Description	Pros	Cons
Rachio 16ZULW-C Smart Sprinkler Controller, 16 Zone ($253.85)  https://www.amazon.com/	The Rachio Smart Sprinkler Controller solves the problem of irrigating many types of fields by having 16 zones that can be used to irrigate residential properties. The sprinkler system has the ability to detect rainfall and will not irrigate during the rain.	● Detects rainfall to disable use of irrigation during rain ● Programmable and can can be scheduled from a smartphone via Bluetooth/WiFi ● Delivers appropriate amount of water for grass type.	● Does not receive direct sensor feedback from soil to detect saturation ● Residential system for non-industrial irrigation. Used for lots of different types of soil.
Orbit 57946 B-hyve Smart Indoor/Outdoor 6-Station WiFi Sprinkler System Controller ($89.99)  https://www.amazon.com/	The Orbit system solves the problem of mobile irrigation by connecting to WiFi to allow your phone to control it from anywhere. It can be set as a timer or you can use “smart watering” settings. It looks at weather forecasts and disables irrigation during rain.	● Helps to save water by avoiding raining during rainfall ● Can be set to water an appropriate amount depending on soil type ● Can be controlled from anywhere with internet	● Does not receive direct sensor feedback from soil to detect saturation ● Rural areas without WiFi (even in the future) would be unable to use this system. ● Requires internet weather forecast to disable for rain.
Rain Bird 32ETI Easy to Install In-Ground Automatic Sprinkler System Kit ($137.50) 	The Rain Bird sprinkler system solves the problem of uneven watering by having an automated watering system to uniformly water the lawn.	● Easy to install ● In-ground sprinkler with retractable heads	● System not designed to expand; fixed size ● Inconsistent parts/durability

https://www.amazon.com/			
Elecrow Arduino Plant Watering System with Soil Moisture Sensor and Pump ($69.97)  https://www.amazon.com/	The Elecrow Arduino system solves the problem of pre-programmed sprinklers by allowing hobbyists to program their controller.	• Maintains a certain quantity of soil saturation • Allows for expandable programming and control over watering cycle • Offers multiple zones for water management	• Does not allow for a simple user interface. No bluetooth or wireless system. • Assembly required • Water is pumped instead of pressurized. Not good for industrial irrigation
Netro Smart Sprinkler Controller, WiFi, Weather aware, Remote access, 6 Zone, Compatible with Alexa ($109.99)  https://www.amazon.com/	The Netro Smart Sprinkler Controller solves the problem of uniform watering schedules by adjusting the water schedule from different plants.	• Adjustable watering schedules • Has weather forecasting technology • Easy installation	• System runs while it is raining • Poor wifi connectivity

Bill of Materials

Line #	Designator	Manuf.	Manuf. Part #	Item Desc.	Qty	Dev Cost (USD)	Ext. Dev Cost (USD)	Prod Cost (USD)	Ext. Prod Cost (USD)
1	C1	Kemet	C322C104K5 R5TA7301	0.33uF Capacitor	1	$0.18	$0.18	$0.15	$0.15
2	C2-8	Kemet	C330C334K5 R5TA	0.1uF Capacitor	7	$0.18	$1.26	$0.15	$1.05
3	D1	Broadcom Ltd	HLMP-4700-C 0002	LED	1	$0.00	$0.00	$0.00	$0.00
4	F1	Littelfuse	0477002.MXP	2A Fuse	1	$1.52	$1.52	$0.69	$0.69
5	F1	Littelfuse	10207101009	2A Fuse Holder	2	$0.24	$0.48	$0.12	$0.24
6	J1-2	Phoenix Contact	1935161	Screw terminals	2	$0.43	$0.86	$0.30	$0.61
7	J3-5	Harwin Inc	M20-9990246	0.1" Header Pins (male)	3	$0.11	$0.33	$0.04	$0.11
8	R1-5	Stackpole Electronics	CF14JT1K00	1k Resistor	5	$0.10	$0.50	$0.01	$0.04
9	U1	Analog Devices	AD5220BNZ1 0	10k Digital Potentiometer	1	$3.60	$3.60	$1.90	$1.90
10	U2	Texas Instruments	LM393N/NOP B	LM393 Comparator	1	$0.91	$0.91	$0.39	$0.39
11	U3	Cyprus Semiconductor	PSOC4-BLE	PSOC Bluetooth Low Energy Kit	1	$0.00	$0.00	$0.00	$0.00
12	U4	ST Microelectronics	L7805ABV	Linear 1.5A voltage regulator	1	$0.51	$0.51	$0.20	$0.20
13	U5	ST Microelectronics	L293D	L293D H Bridge	1	$3.91	$3.91	$2.06	$2.06
14	U6	Infineon Technologies	IRL520NPBF	N-channel enh mode MOSFET	1	$0.86	$0.86	$0.39	$0.39
15		McMaster Carr	8984K1	1/2ft 304 stainless steel rod	2	$0.75	$1.50	$0.75	$1.50
16		MEAN WELL USA Inc	RD-35A	32W 12V power supply	1	$17.25	$17.25	$15.28	$15.28
17		Progressive Automations	PA-07-12-5	Micro Linear Actuator	1	$69.99	$69.99	$69.99	$69.99
18		US Solid	JFSV00003	Solenoid Valve	1	$28.99	$28.99	$28.99	$28.99
19		ON Semiconductor	MC33152PG	Low-Side Gate Driver IC Non-Inverting 8-PDIP	1	$1.39	$1.39	$0.63	$0.63
20		Acrylic	N/A	8x6x12”	1	$18.99	18.99	$18.99	$18.99
21		Misc. Assembly Equipment	N/A	Zip ties, wires, nuts and bolts	1	$4.99	$4.99	$4.99	$4.99

Final PCB Layout

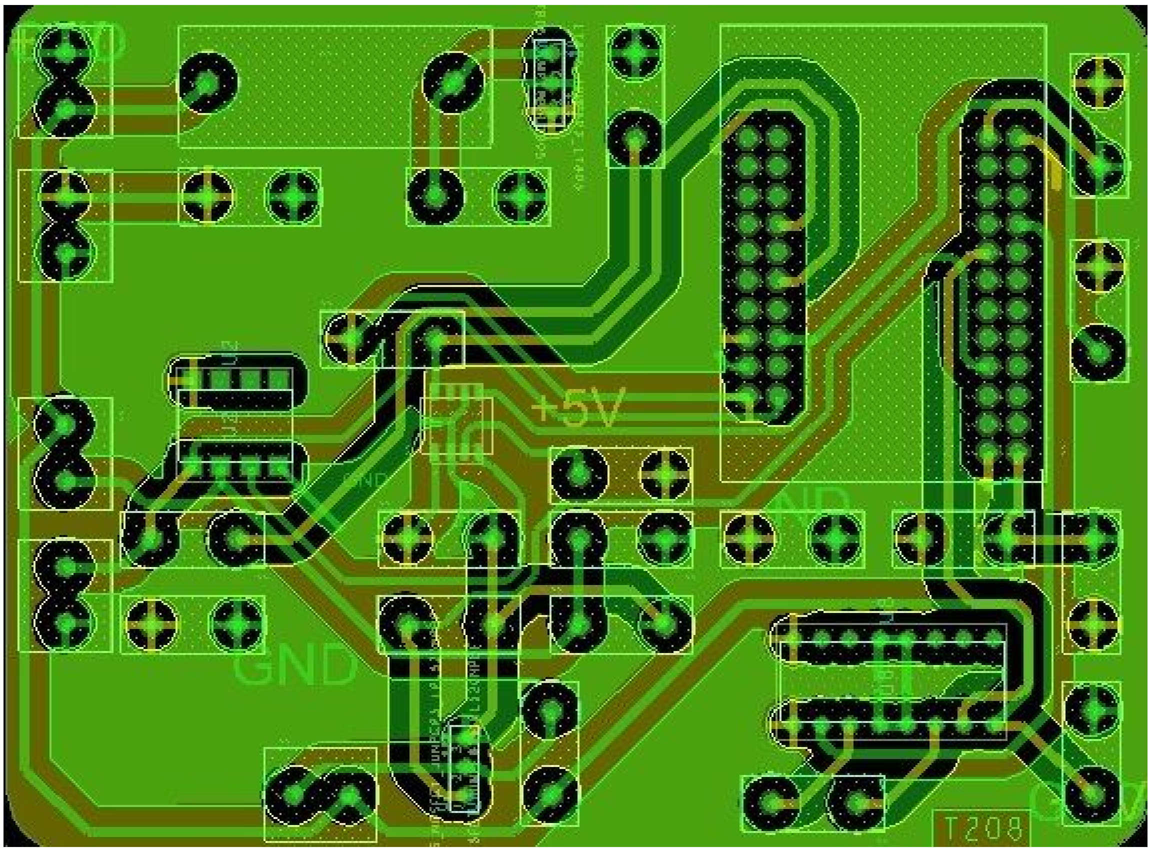


Figure 3: Final PCB

Code

```
#include <project.h>

#define NO_ALERT            (0u)
#define MILD_ALERT          (1u)
#define HIGH_ALERT          (2u)

#define NO_ALERT_COMPARE    (0u)
#define MILD_ALERT_COMPARE  (250u)
#define HIGH_ALERT_COMPARE  (500u)

void StackEventHandler(uint32 event, void* eventParam);
void IasEventHandler(uint32 event, void* eventParam);
void HandleAlertLEDs(uint8 status);
```

```
int main()
{
    CyGlobalIntEnable;

    CyBle_Start(StackEventHandler);

    PWM_Start();

    CyBle_IasRegisterAttrCallback(IasEventHandler);

    Sat_UP_DN_Write(0u);
    CyDelay(5);
    Sat_CS_Write(0u);
    for(int i = 0; i < 65; i++) {
        CyDelay(5);
        Sat_UP_DN_Write(1u);
        CyDelay(5);
        Sat_UP_DN_Write(0u);
    }
    CyDelay(5);
    Sat_CS_Write(1u);

    CyDelay(1000);

    Sat_UP_DN_Write(1u);
    CyDelay(5);
    Sat_CS_Write(0u);
    for(int j = 0; j < 30; j++) {
        CyDelay(1);
        Sat_UP_DN_Write(0u);
        CyDelay(5);
        Sat_UP_DN_Write(1u);
        CyDelay(5);
    }
    CyDelay(5);
    Sat_CS_Write(1u);
    Sat_UP_DN_Write(0u);

    while(1)
    {
        /* Process all the pending BLE tasks. This single API call to
```

```
         * will service all the BLE stack events. This API MUST be
called at least once
         * in a BLE connection interval */
        CyBle_ProcessEvents();


    }
}

void StackEventHandler(uint32 event, void *eventParam)
{
    switch(event)
    {
        /* Mandatory events to be handled by Find Me Target design */
        case CYBLE_EVT_STACK_ON:
        case CYBLE_EVT_GAP_DEVICE_DISCONNECTED:
            /* Start the BLE fast advertisement. */
            CyBle_GappStartAdvertisement(CYBLE_ADVERTISING_FAST);
            break;

        default:
         break;
    }
}

void IasEventHandler(uint32 event, void *eventParam)
{
    uint8 alertLevel;

    /* Alert Level Characteristic write event */
    if(event == CYBLE_EVT_IASS_WRITE_CHAR_CMD)
    {
        CyBle_IassGetCharacteristicValue(CYBLE_IAS_ALERT_LEVEL,
sizeof(alertLevel), &alertLevel);

        /*Based on alert Level level recieved, Drive LED*/
        HandleAlertLEDs(alertLevel);
    }
}

void HandleAlertLEDs(uint8 status)
{
```

```
    /* Update Alert LED status based on IAS Alert level 
characteristic. */
    switch(status)
    {
        case NO_ALERT:
            PWM_WriteCompare(NO_ALERT_COMPARE);
            Lin_Act_Fwd_Write(1u);
            CyDelay(8000);
            Lin_Act_Fwd_Write(0u);
            break;

        case MILD_ALERT:
            PWM_WriteCompare(MILD_ALERT_COMPARE);
            break;

        case HIGH_ALERT:
            PWM_WriteCompare(HIGH_ALERT_COMPARE);
            Lin_Act_Rev_Write(1u);
            CyDelay(4000);
            Lin_Act_Rev_Write(0u);
            CyDelay(5000);
            Lin_Act_Fwd_Write(1u);
            CyDelay(4000);
            Lin_Act_Fwd_Write(0u);
            break;
    }
}
```

User Manual

Setting up the Device

1. Connect hose to one end of solenoid
2. Loosen the soil around the location the sensor probes will enter to ensure the probes do not have any problems measuring into the soil
3. Connect phone to bluetooth
4. Select saturation level

Troubleshooting

1. Carefully scrape off the soil that clings to the saturation sensor probes to ensure data is accurate
2. If an error message is received, check to make sure the linear actuator remains vertical and the probes can enter the soil

CAD

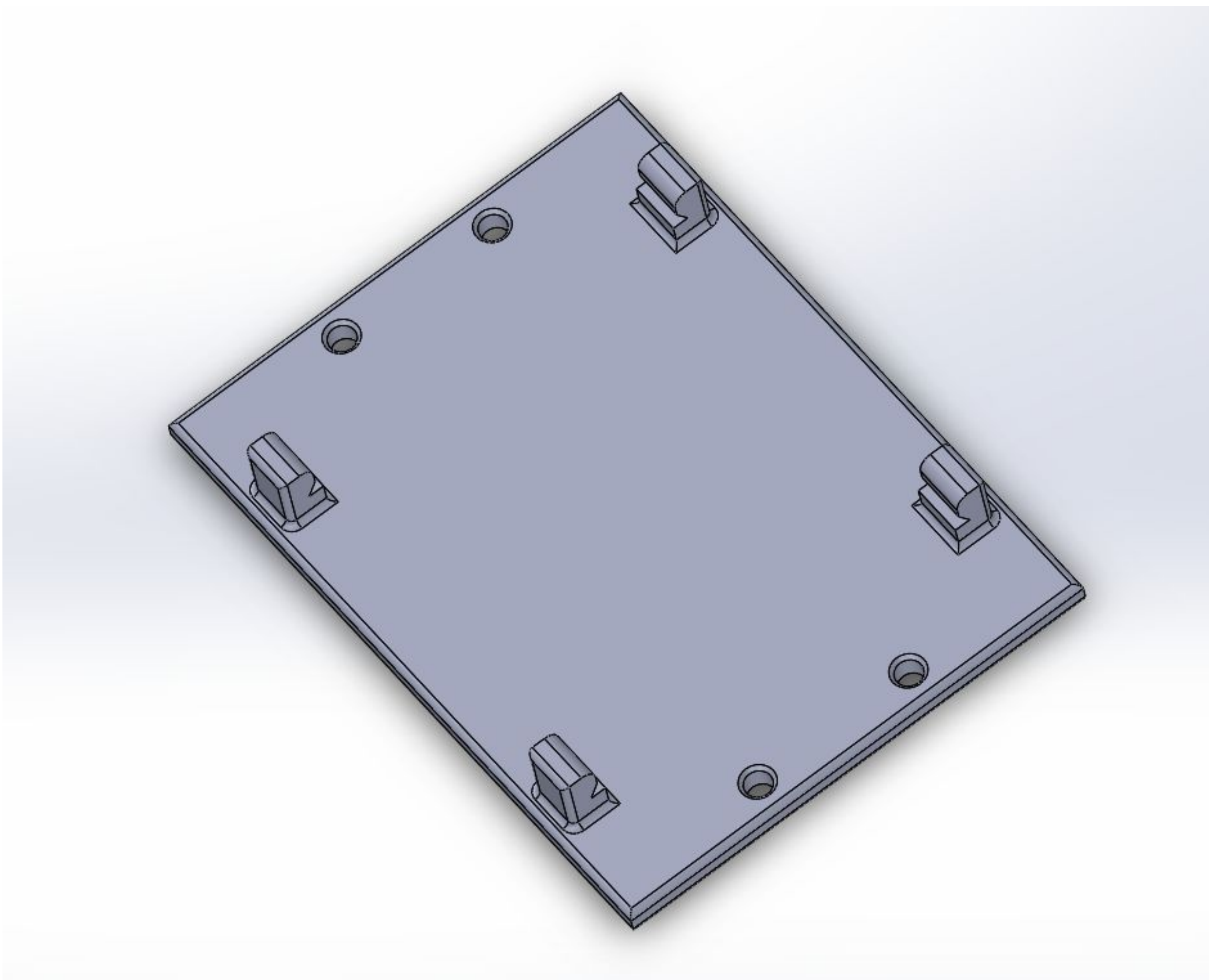


Figure 4: CAD Part 1

Figure 5: CAD Part 2

References

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