GCSE Electronics Controlled Assessment

Part 1 - Project Brief and Specification

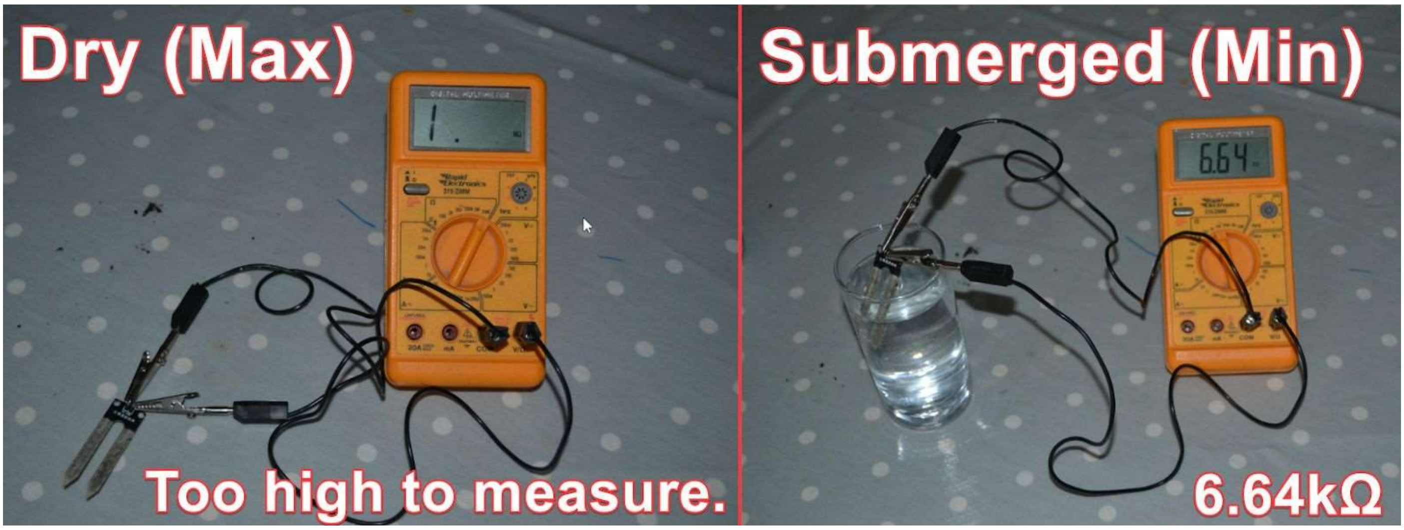
Project Title: Plant Irrigation System

Statement of problem to be solved:

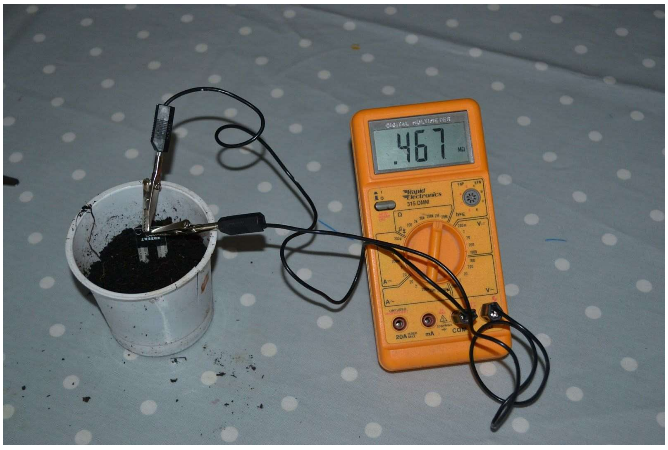
When growing plants, it is often hard to keep track of their health. Usually, an owner will water their plants at an inconsistent rate and often leave them out in unsuitable conditions. When an owner does check up on their plant it is often difficult to tell whether it needs more watering. My electronics controlled assessment will try to solve this by automating some of these repetitive tasks such as checking whether the soil moisture levels are suitable and whether the plant is receiving enough light.

Investigation

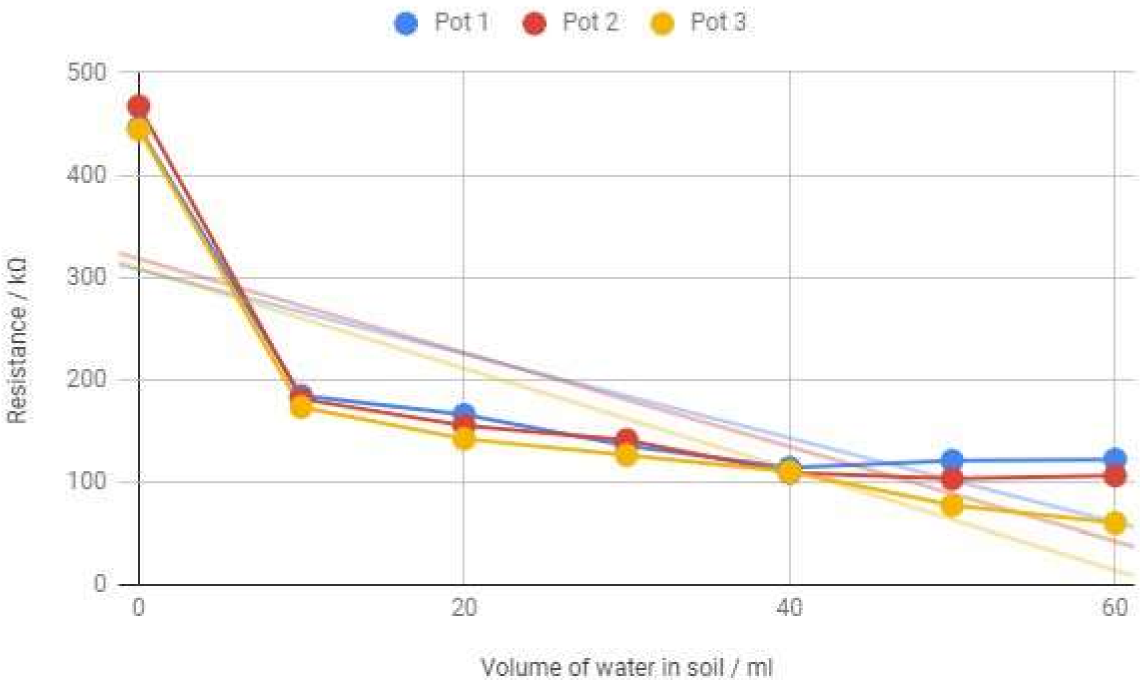
For my project, I needed to measure the varying levels of resistance the soil moisture probe would give. To do this, I simply connected a multimeter to the two probes on the resistance setting. The soil moisture probes act as a sensor by measuring the resistance across the two probes. My first experiment was to see what readings the multimeter would give at its theoretical maximum and minimum values. I measured the max resistance value by leaving the probes completely dry and the minimum by completely submerging the probes in water. The outcome is shown below:



From this experiment, I have been able to gather that there is a large range of resistance when using soil moisture probes like these. The lowest reading I was able to get on the multimeter was 6.64kΩ, this was when the probes were submerged fully in water. Due to normal water found in the environment (not pure) being a good conductor of electricity it has a low resistance compared to air (a poor conductor). These readings are useful for getting a threshold, however, I still do not know how the resistance will vary between these two points and how it will behave in the soil. To find out more about the resistance from the moisture probes I set up the following experiment (on the following page):



I gathered 3 samples of the same volume of dry soil and pushed the moisture probes in the same distance each time to ensure my readings were reliable. Between each reading, I added 10 ml of water to the soil in the same location. I used a digital multimeter to ensure there was little chance of user error and to ensure accuracy. The readings I gathered are displayed in the graph and table below.



Blank Space

		Resistance / kΩ	
Vol / ml	Pot 1	Pot 2	Pot 3
0	445.9	467	444
10	184.1	181	173
20	165.55	155	142
30	135.45	141	126
40	113.75	109	110
50	120.75	103	77
60	121.8	106	60

Conclusion

From these readings I have concluded that the effective resistance range of the moisture probe is 0-470kΩ.

Blank Space

Record of 1st Research

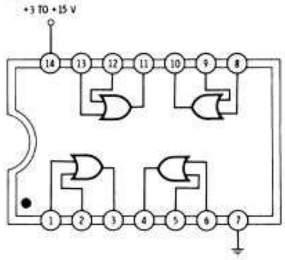
I used the internet to find an ideal solution for visually displaying the soil moisture level. After some browsing, I found the following IC: https://www.ti.com/lit/ds/symlink/lm3914.pdf (27/01/19). This chip contains several op-amps for each LED which allows an analogue signal to be inputted and visually displayed as a bar chart. Which is ideal for my application as it can be used in conjunction with a 10 Segment LED Display to display the soil moisture level at a glance.

Record of 2nd Research

I used the CMOS Cookbook (ISBN: 9780750699433) to lookup the pin layout of the 4071, a Quad 2-Input OR Gate. This allowed me to see where I could connect my inputs and outputs plus where the voltage supply pins were located. It also explains the basic functionality of the IC in which if **either** inputs are high then the output will go high. It also gave me information on the Propagation delay which is approx 80 nanoseconds which is more than suitable for my application as this is faster than any human being's reaction time.

4071

QUAD 2-INPUT OR GATE



TOP VIEW

All four positive-logic OR gates may be used independently.

On any one gate, with *either* or *both* inputs *high*, the output will be *high*. With both inputs *low*, the output will be *low*.

Device is functionally equivalent to the 7432 (TTL) and the 74C32 (CMOS) devices.

Propagation delay is 80 nanoseconds at 10 volts and 190 nanoseconds at 5 volts. Total package current at 1 megahertz is 0.5 milliampere at 5 volts and 1 milliampere at 10 volts.

Record of 3rd Research

I looked around on the internet to get a better idea of what volume of water a plant needed per day. I found the following extract from Greenhouse Management (https://www.greenhousemag.com/article/gmpro-0310-water-plants-automating-irrigation/) (10/02/19). It suggests that an average plant only needs a tablespoon (17ml) of water a day. I will use this to calculate how long the pump needs to be on for.

A tablespoon per day

We have studied how different irrigation set points affect a variety of plants. Petunias were grown at substrate water levels ranging from 5-40 percent for three weeks. In a peat-lite substrate, a 5-10 percent substrate water level is the lowest most plants could survive and 50 percent is near container capacity. Plant growth increased with increasing substrate water content, although there was little difference between 25-, 30-, 35- and 40-percent treatments. Even in the substrate maintained at 40 percent water level, there was no leaching.

A higher substrate moisture set point resulted in more frequent waterings, so the amount of water that the plants received increased with increasing substrate moisture levels. Over a three week period, plants received anywhere from 3½ to 22 ounces.

A substrate moisture content of 20 percent was enough to grow quality plants. For a three week period, these plants received about 16 ounces of water per plant. This is a little more than 1 tablespoon per day. Water use was not constant during the study; small plants used 1 tablespoon per day, while large plants used slightly less than 2 tablespoons per day. Overall, there was a good correlation between plant growth and the amount of water applied. The study indicated that controlling irrigation can be an effective method of controlling growth.

Qualitative Specification

1. The circuit will have a 10 segment display to convey to the user the moisture level of the soil at a glance. This is because it is often difficult to tell by glance by looking at a plant how long ago you watered it. With this 10 segment display it will make it a lot easier for the user to tell whether their plant needs more water.
2. The alarm and pump should turn on when the moisture and light levels are below the optimum level. This will attract the user's attention so they can check the plant and ensure it is under the correct conditions and act accordingly (e.g. water the plant if pump is not functioning or move it into sunlight).
3. The circuit will need to be able to water the plant when the moisture level is below a set value by the user. This will mean even when the customer is away the plant will be able to look after itself. It also adds a level of convenience to the circuit as it means the user does not need to worry about constantly watering their plant.

4. The user should be able to easily test if the alarm + pump are functional. This will allow the user to check if the pump is functional incase it becomes blocked or burns out. It will also allow for testing of the speaker if the user doubts the circuit is working properly.

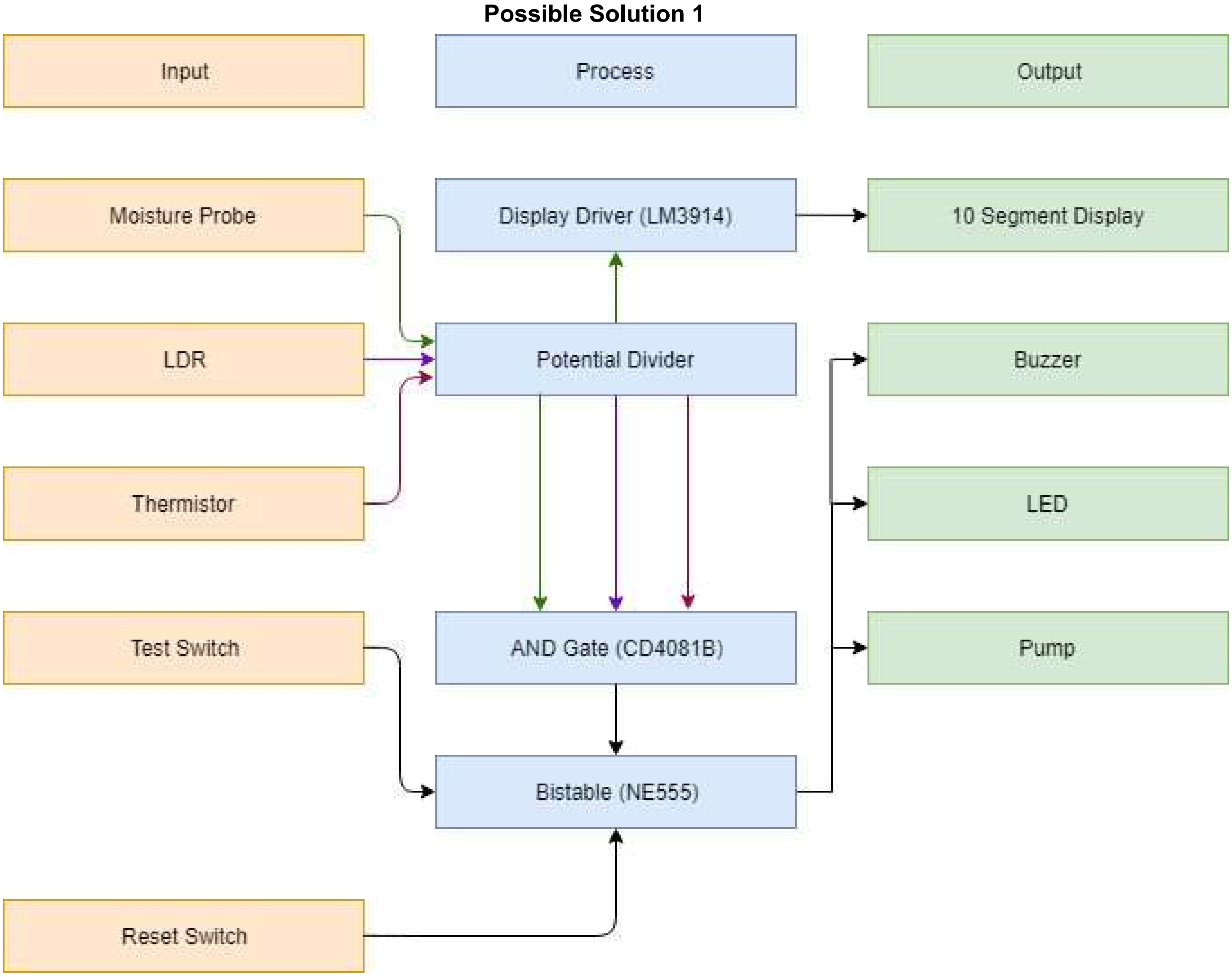
Quantitative Specification

1. The circuit will need to work when powered by a 5V±1V power supply to allow the product to be used in conjunction with a USB cable (5V). This is so the circuit is convenient to use for the average user as most people have a USB power supply in their home. A fixed power supply of another voltage in the range could also be used if the user wanted to power a more powerful pump.
2. The circuit will need to be able to turn on a pump (0.200l/min) for 5s to provide 17ml of water. From my research, I found out that 17ml is the ideal volume of water a plant should get per day. I then worked out the length of time the pump would need to be on to provide this amount of water which came out as being on for approximately 5 seconds. This will ensure the plant gets the water it needs.
3. The circuit will need to set off an alarm at a frequency of 11600 Hz±1000 Hz (due to electrolytic capacitors having such high tolerances) with a loudness level of 70 db±10 db at 1m. From testing with a signal generator, I found the frequency of 11600 Hz to be the most alarming and attracting the most attention. I also ensured the pitch was lower than something like a fire alarm as this may cause distress to some users. The loudness level of 70 db is enough to attract attention from across the home without sounding like an immediate threat.
4. The circuit must be able to power a pump which draws 2A at 5V. This will ensure that the pump gets the power it needs to pump the water from a tank to the plant pot. The motor I will be using for the testing of this product is rated for a 2A supply so I will need to supply this amount of current.

Blank Space

Part 2 - Project Planning

Possible Solutions



The three different sensors are connected to potential dividers which are fed into an AND gate. If either the soil is dry, not enough light is present or the room is not warm enough, the outputs of all 3 potential dividers will be high, causing the AND gate to also turn high. This causes the trigger on the bistable to go high causing the pump to turn on, the LED to be lit and the buzzer to sound. The user can then reset the system by pressing the reset switch causing the bistable to reset and turn low. The user can also test the alarm system by pressing the test switch.

Advantages

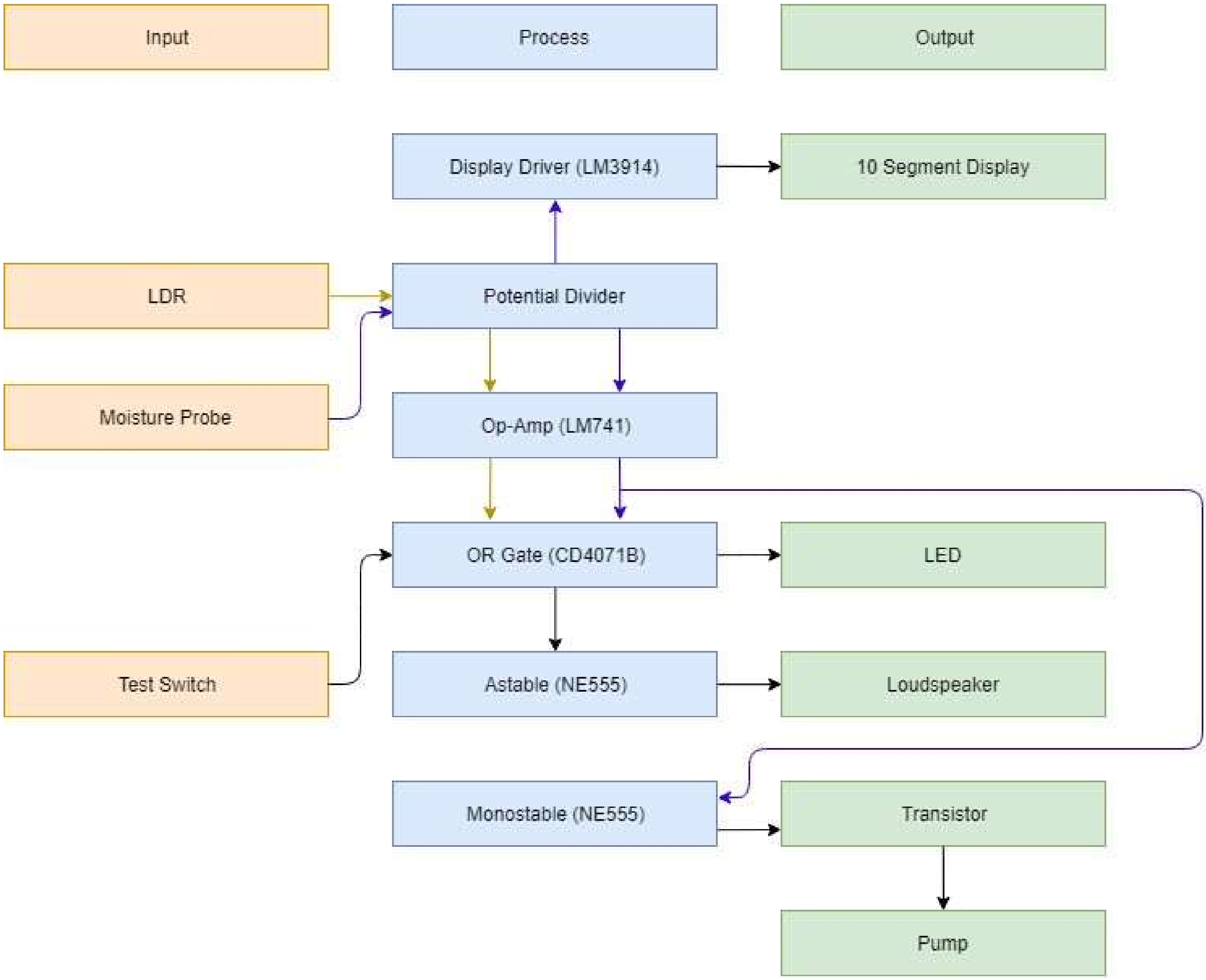
- The system takes three sensors into account meaning all aspects of the plant are monitored.
- Relatively easy to make
- Fulfils most of the specification
- Bistable means the system latches.

Disadvantages

- Thermistor is relatively expensive and does not have much effect on a plant's health and adds more complexity to the logic system.

- The pump is connected to the bistable meaning it would be left running overfilling the plant pot significantly causing the plant to die.
- AND gate means that all criteria needs to be met however one variable may be fine but two might be significantly below what is needed meaning the plant would not be watered effectively.
- Standard buzzers are fairly quiet.
- The pump would need to be low current due to the AND gate meaning the system would be less efficient.
- User is unable to adjust sensitivity of sensors.

Possible Solution 2



The moisture sensor and light dependent resistor are connected to potential dividers which are fed into two Op-Amps in a comparator configuration. When either the soil is dry or not enough light is present the outputs of the potential dividers will be below the reference voltage provided by the user on the Op-Amps potentiometer, causing the Op-Amps to turn high. The Op-Amps are fed into an OR gate so if either output is high then the output of the gate will also be high, causing the astable for the loudspeaker to be triggered causing the alarm to sound. An LED indicator is also turned high. A monostable is also triggered when the Op-Amp for the moisture probe is high causing a transistor to switch, turning on the pump. The user can also test the alarm system by pressing the test switch.

Advantages

- An astable is fed into the loudspeaker to create a more distinctive sound that will attract the users attention.
- The two sensors are connected to Op-Amps in a comparator configuration allowing the user to adjust the sensitivity level of the sensors.

- An OR gate is used to ensure that if either sensor is below the value specified by the user then the alarm will trigger.
- The pump is connected separately to the moisture probe Op-Amp so the plant is only watered when it really needs it.
- Less sensors are used meaning less logic complexity.
- A transistor is used to power a high current draw pump.
- Monostable used to ensure plant gets suitable amount of water instead of immediately shutting off due to sensor picking up water.

Disadvantages

- Increased number of subsystems.
- More power draw due to high current devices such as loudspeaker and high power pump.
- Pump water time is not adjustable.

Chosen system

I have decided to go ahead with Solution 2 as it is much more suitable for the Specification. It also involves less sensors meaning less parts are likely to fail. Solution 2 also allows more customizability for the user allowing the circuit to be used in a wide range of applications.

Calculations

1. Working out resistor and capacitor values for the astable circuit to pulse the loudspeaker at a regular interval.

   Frequency = $\frac{1.44}{(R1 + 2R2) \times C}$

   I want the astable to oscillate at a frequency of 11600 Hz

   Let C = 10nF

   $$R1 + 2R2 = \frac{1.44}{11600 \times 10 \times 10^{-9}} = 12400\Omega$$

   Let R1 = 10kΩ

   $$2R2 = \frac{12400 - 10000}{2} = 1200\Omega$$

   $$R2 = 1.2k\Omega$$

   1.2 is in the E24 series so no rounding is required.

2. Working out value of resistor to protect an LED.

   Measuring the potential difference across my school's standard LED I get a reading of 2V, I will use this for my calculation. I am presuming the current of my LED is 14mA.

   Voltage Power Supply - Voltage LED = 5 - 2 = 3V

   $$Find\ R = \frac{V}{I} = \frac{3}{0.014} = 214\Omega$$

   214 is not in the E24 series so I will use the next value up which is 220. Therefore for all the unprotected LEDs in my circuit I will use a 220 Ω resistor.

3. Working out resistor and capacitor values for the monostable circuit to produce a signal to last for a duration of 5s.

   T = $1.1RC$

   I want the monostable to have a time high for 5s.

   Let C = 47μF

   $$5 = 1.1 \times 47 \times 10^{-6} \times x$$

   $$5 = 5.17 \times 10^{-5}x$$

   $$x = 96.7k\Omega$$

967 is not in the E24 series so I will use the next value up which is 100. Therefore for the resistor value in my monostable circuit I will use the resistance value 100kΩ.

Risk Assessment

Hazard	Probability / 5	Consequence / 5	Risk*Consequence /25	Hazard avoidance strategy	Action to be taken in event of accident
Working Alone - No one to get help in an emergency.	3	2	6	Ensure I am always within proximity of a student/teacher.	Call for help
Working on circuits while switched on - Danger from heat and stored charge	3	4	12	Ensure circuits are always turned off before performing any modifications. Do not touch circuitry while power is on.	If major, call 999. If minor, perform relevant first aid.
Coming into contact with mains electricity	2	5	10	Always use low voltage supplies provided by school which have passed relevant safety checks.	Switch off supply. Administer First aid. Get Help.
Trips and Falls due to loose cabling	4	3	12	Ensure there are no trailing cables across the floor. Tidy away all cables after use.	If major, call 999. If minor, perform relevant first aid.
Injury from cutting wire	1	2	2	Ensure cutting equipment is safe to use and fit for purpose.	If major, call 999. If minor, perform relevant first aid.
Water and Electricity causing short circuit.	4	3	12	Only bring water near to the circuit when testing. Ensure moisture probe is isolated from rest of circuit.	Switch off supply. Check for damage.

Blank Space

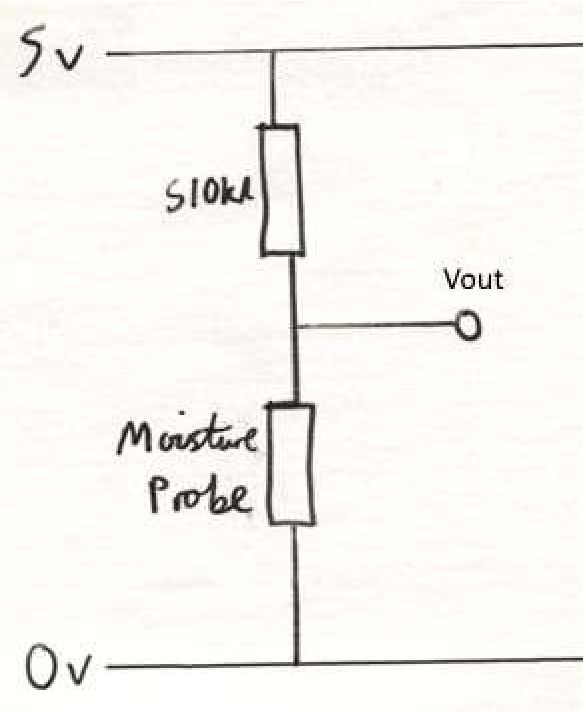
Part 3 - Project Development

Subsystem 1

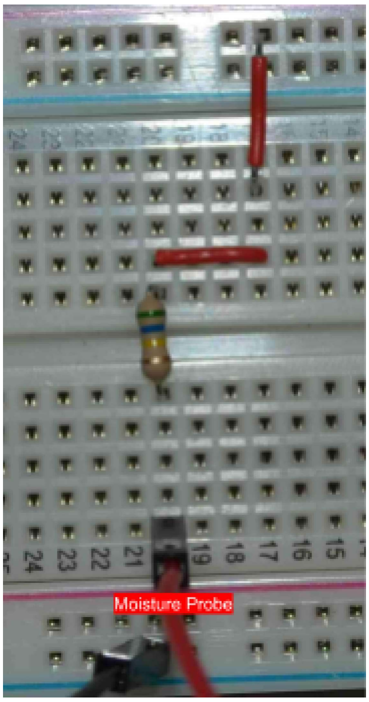
Potential Divider - Moisture Sensor

The subsystem will vary the voltage of the potential divider output according to the resistance of the moisture probe. When the moisture probe is in water there is a low resistance, when the moisture probe is dry there is a high resistance. This allows the potential divider to be used so the circuit is able to detect when the soil is too dry. I used the results from my investigation to pick the resistance (510kΩ) for the potential divider.

Circuit Diagram



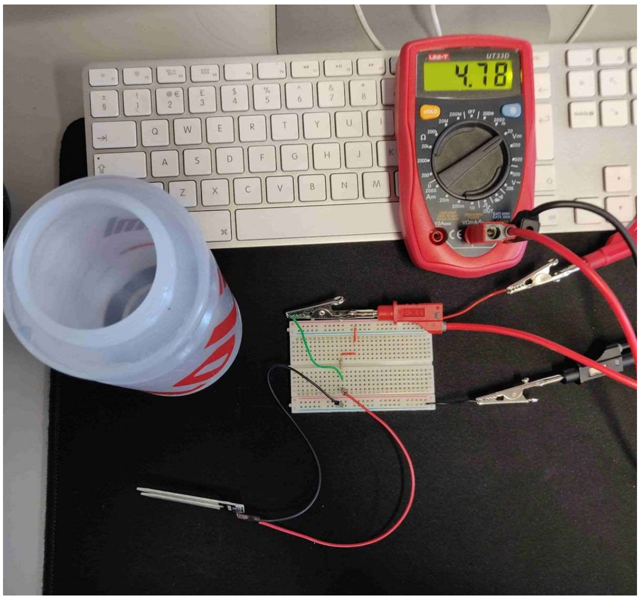
Circuit Picture

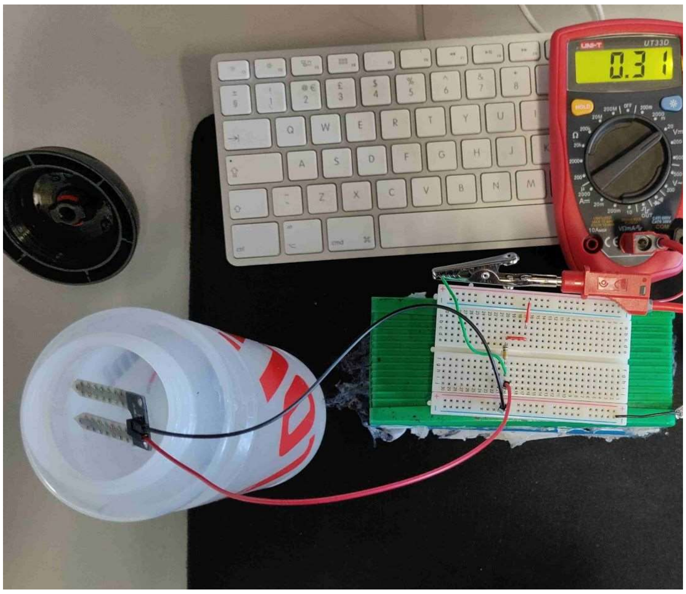


Blank Space

Test

I used a multimeter to measure the voltage being produced by V_{out} to ensure that when the probe was in water the output would be low and that when the moisture probe was dry the output would be high.





The pictures show that when the moisture probe is in water the output of V_{out} is low (0.31V) and when the moisture probe is out of water the voltage goes high (4.78V).

Evaluation

The subsystem functions as expected. When the moisture probe is dry the resistance goes low causing the voltage at V_{out} to go high (4.78V). The readings are always the same meaning the subsystem is reliable. The subsystem can also be used for the LDR as this also measures light by changing its own resistance. This subsystem will feed into an Op-Amp in a comparator configuration (pin 3) to allow the user to adjust the sensitivity of the sensor.

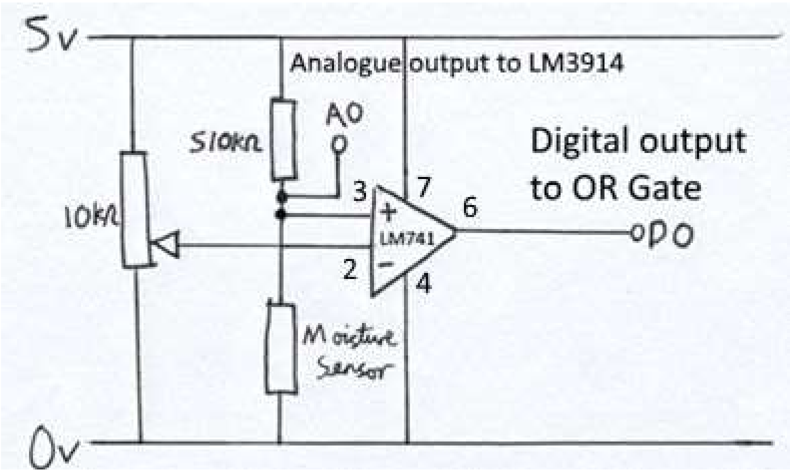
Blank Space

Subsystem 2

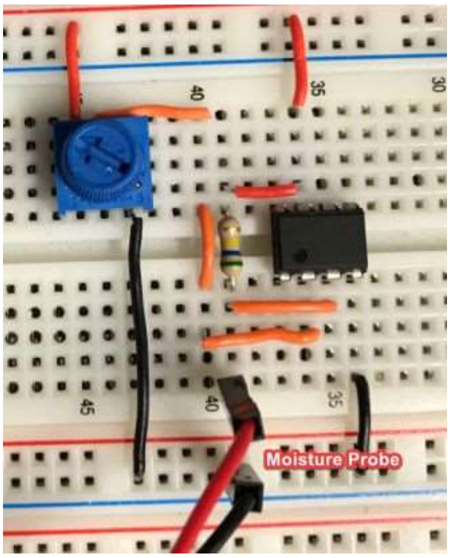
Op-Amp - Moisture Sensor

An operational amplifier is used in a comparator configuration to allow the user to adjust the sensitivity of the moisture probe. A similar circuit was also built for the LDR to detect when the light levels were below a set level by the user. The output of V_{out} from the Op-Amp is connected to pin 3 and this is compared to a reference voltage from pin 2 which is a 10kΩ potentiometer. The output at pin 6 is either high or low indicating whether the potential divider voltage is above or below the reference voltage.

Circuit Diagram



Circuit Picture



Test

I used a multimeter and a logic probe to test if the subsystem was working effectively. The multimeter was connected to the output of the potential divider (pin 3) and the logic probe was connected to the output (pin 6) of the LM741 to check that the output voltage was high when the moisture probe was dry and the voltage was low when the moisture probe was in water.

The desired outcome was that if the moisture level of the probe was below the specified the voltage of the user the output of the Op-Amp would go high. As you can see by the pictures above, when the probe is left dry the output of the Op-Amp is high as shown by the logic probe. When the probe is submerged, the output shown by the logic probe is low. This shows that the subsystem is functioning as intended.

Evaluation

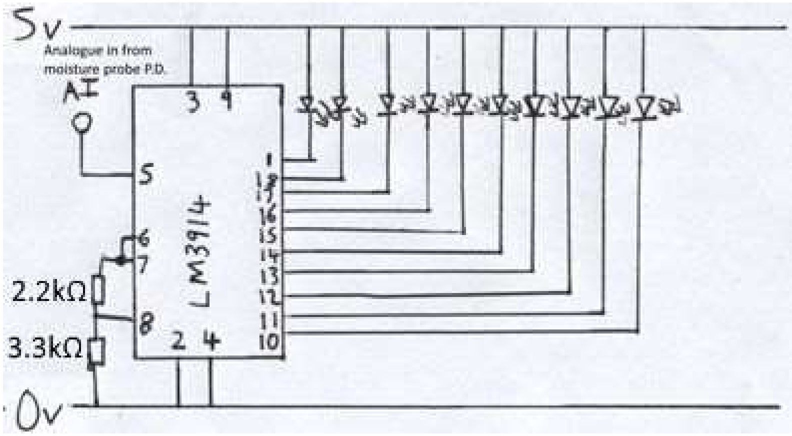
The subsystem functions as expected. The voltage at which the output goes high is adjustable by the user. The Op-Amp is reliable and switches at the set reference voltage every time. This subsystem will feed into an OR gate (pin 13) to trigger alarm circuitry.

Subsystem 3

10 Segment Bar Display for Moisture Level

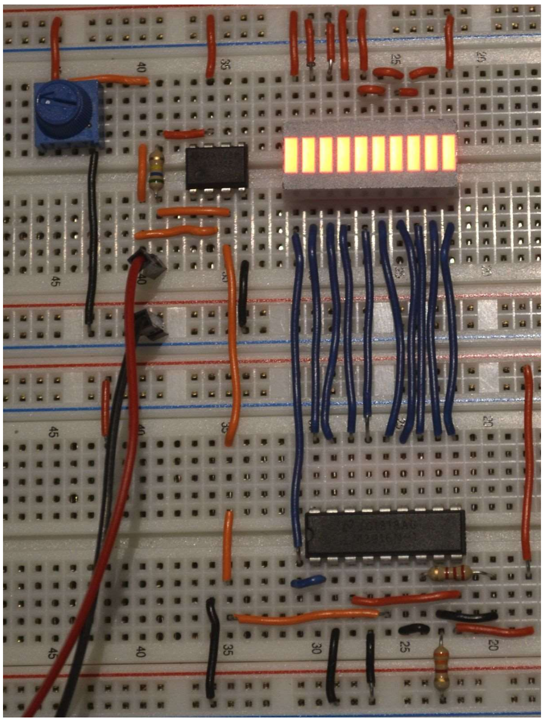
In this subsystem, a LM3914 IC is used to convert the analogue signal out of the potential divider (V_{out}) for the moisture probe and display the reading on a series of LEDs as a visual guide to the user on the dryness of their plant's soil.

Circuit Diagram



NB: The 10 segment display I was using already had a protective resistance in series with each LED meaning I did not have to add any extra protective resistance myself.

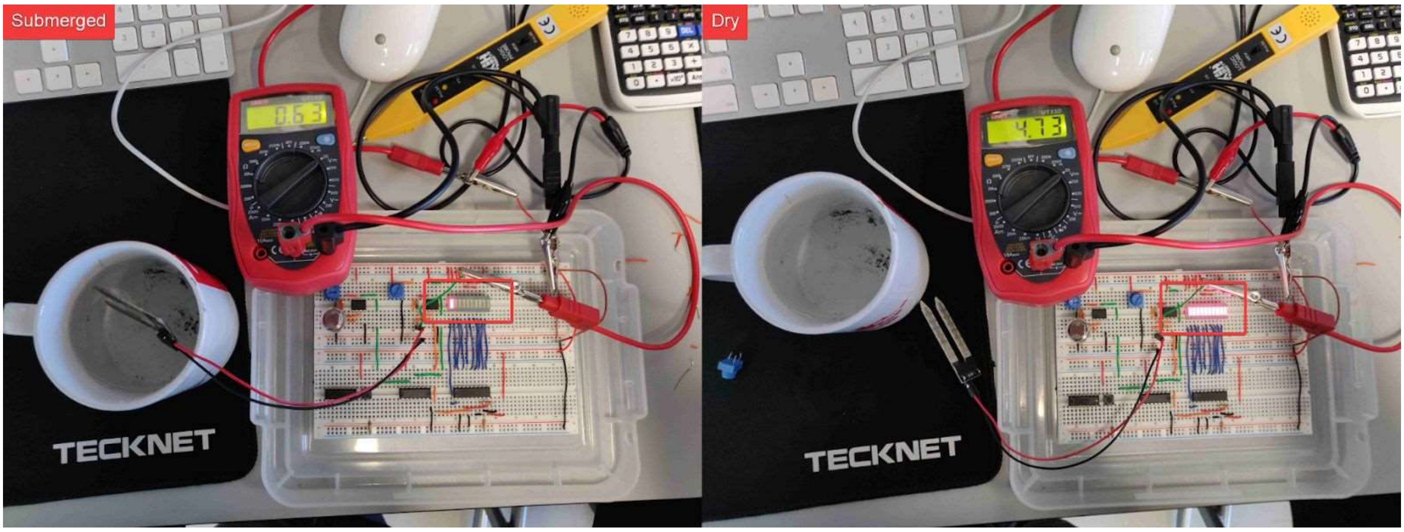
Circuit Picture



Blank Space

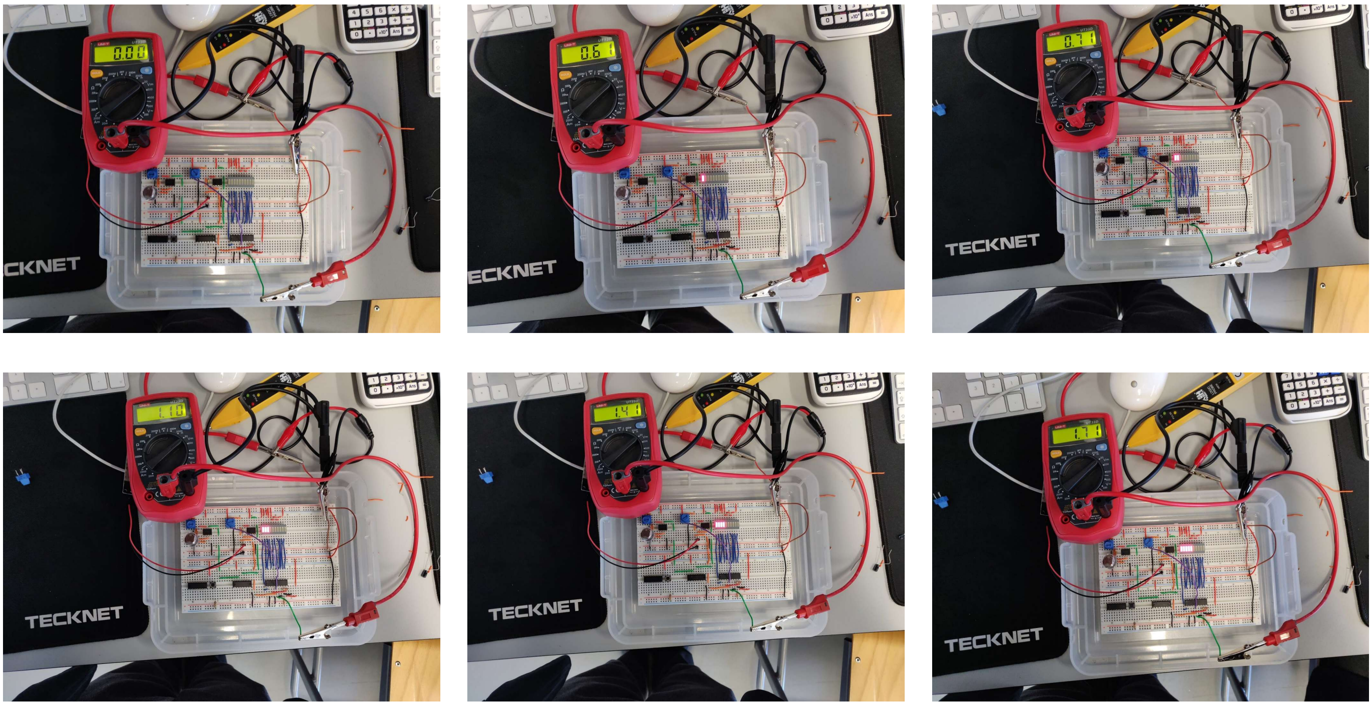
Test

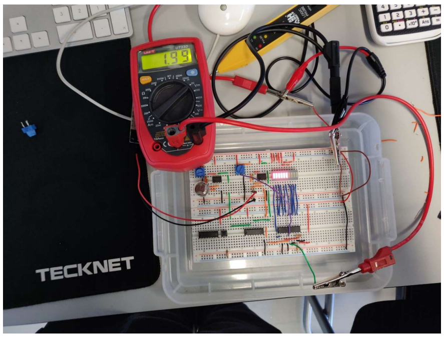
I tested the subsystem by connecting a multimeter to the output of the potential divider and observing the output that was displayed on the 10 segment display connected to the LM3914. The expected outcome of the testing was that when the moisture probe was in water the 10 segment display would only show 1 segment but when the moisture probe was dry all 10 segments should be lit.

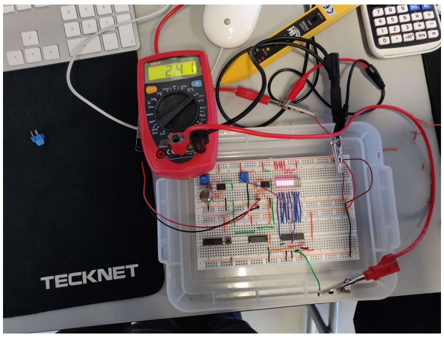


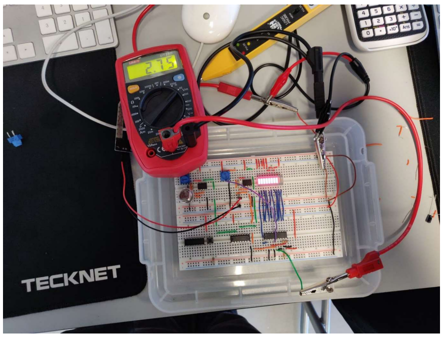
As shown by the photos, the 10 segment display displayed the expected output. It illuminated all 10 segments when the probe was completely dry and only illuminated 1 segment when the moisture level was high.

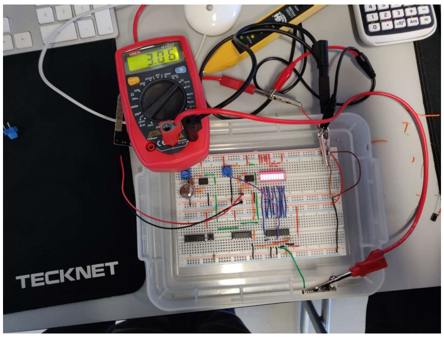
I performed further testing to ensure that all the levels on the 10 segment display were functioning. I performed this test by temporarily connecting the input of the LM3914 to a potentiometer. Below are the results.











As shown by the photos, all 10 segments of the displays are functional and vary according to the input voltage. This means that the user can quickly estimate how much time is left before their plant needs watering.

Evaluation

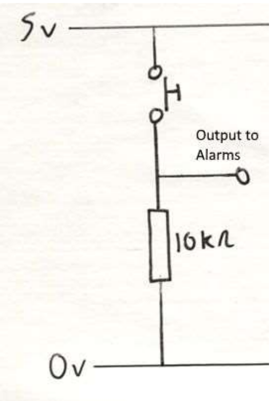
My tests show that the 10 segment display is reliable and switches at the same voltage each time. However the subsystem is not perfect as the LM3914 is setup to only have the voltage range from 0V to ~3V which means that part of the soil moisture level is cut off. However this does not affect the system majorly because if a user was to get to this voltage level when they haven't watered their plants they would definitely need to water them so additional segments would not serve much purpose.

Subsystem 4

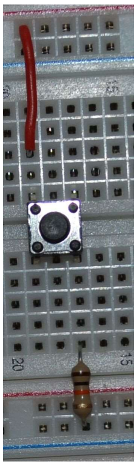
Push Switch

This subsystem will give a high signal when the push-to-make switch is pressed and a low voltage when released to be fed into the alarm circuitry to test the alarm system is fully functional.

Circuit Diagram

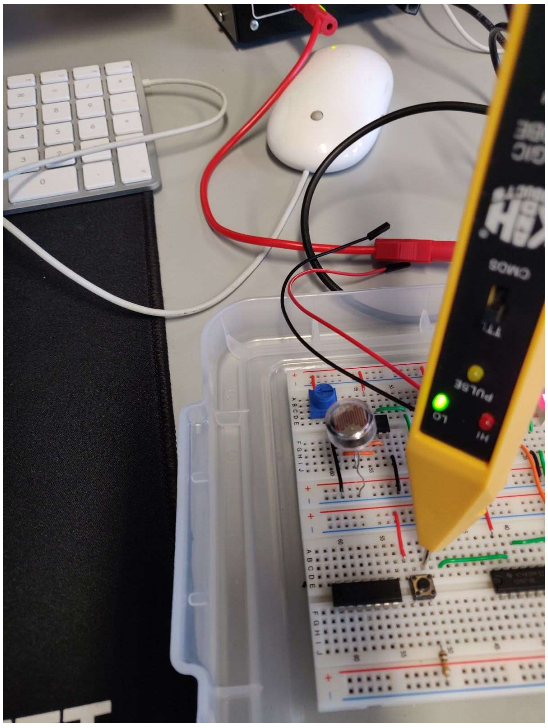


Circuit Picture

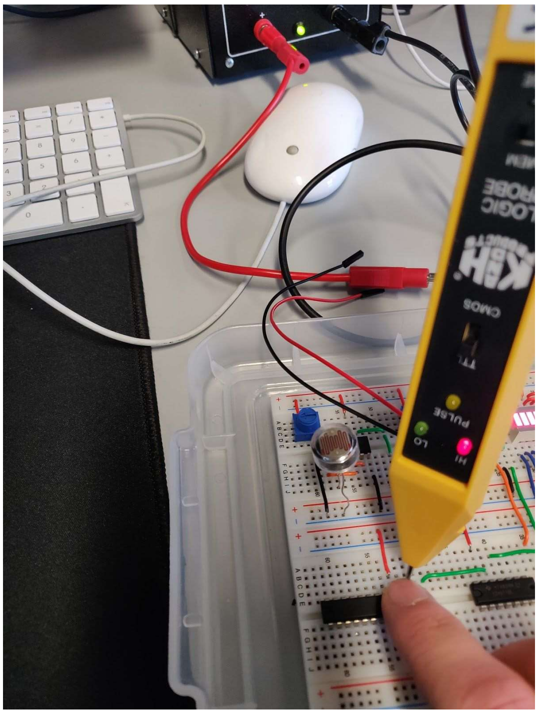


Test

To test if the push button was functional, I used a logic probe to test the output.



Switch Open



Switch Closed

The photos show that when the switch is pressed, the output is high and when the switch is released the output is low.

Evaluation

The subsystem functions as expected. The button reliability switches from low to high every time it is pressed. The output will be fed into pin 13 (the moisture Op-Amp) on an OR gate to test if the pump and alarm are functional.

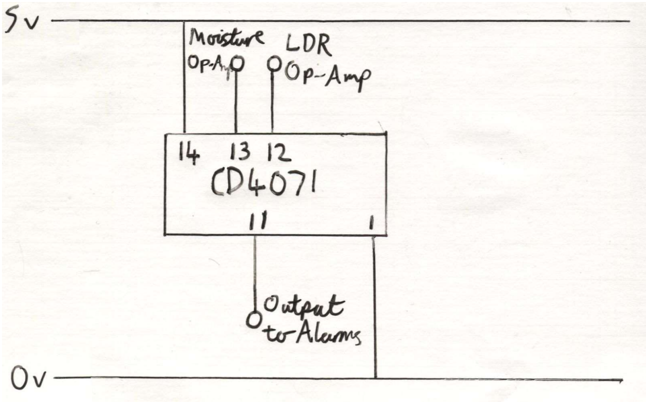
Subsystem 5

OR Gate

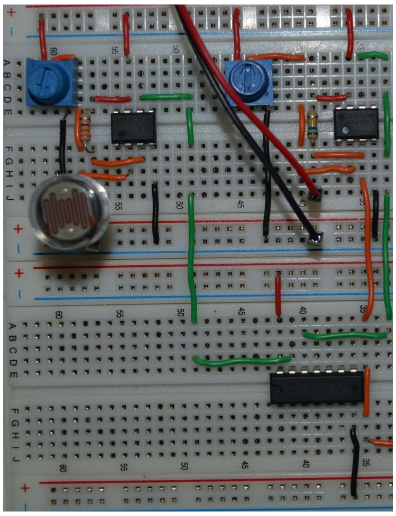
In this subsystem, an OR logic gate (CD4071) is used to ensure that if **either** the temperature of the soil (measured by the thermistor) or the soil moisture level (measured by the moisture probe) is below the required criteria set by the user, the alarm will sound. The inputs of the OR gate (pins 13 and 12) are connected to the two sensor Op-Amps V_{out}.

Blank Space

Circuit Diagram



Circuit Picture

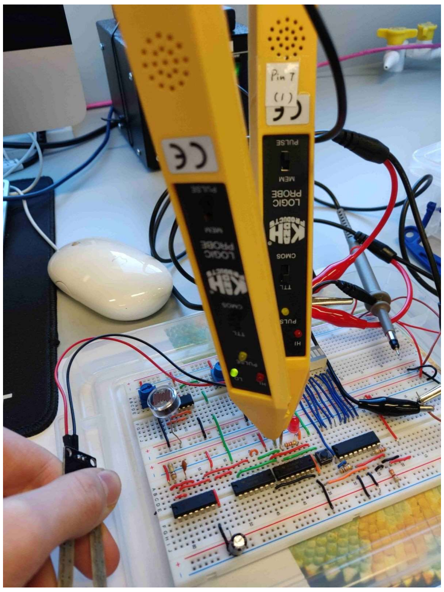


Test

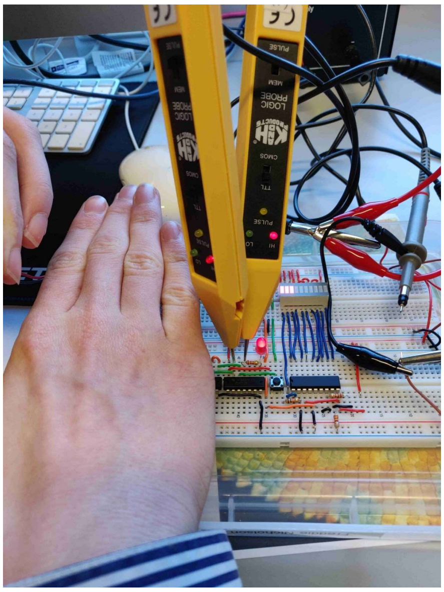
The expected truth table output of the OR gate would be:

Moisture Op-Amp (A)	LDR OP-Amp (B)	Output (A+B)
0	0	0
1	0	1
0	1	1
1	1	1

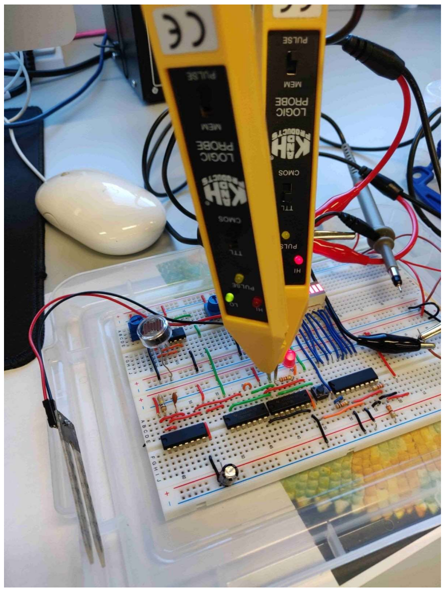
To test if this was the case, I tested the OR gate with two logic probes connected to the inputs (pins 13 and 12) and a LED connected to the output (pin 11). The output is shown below:



Moisture Low, LDR Low
Output: Low



Moisture High, LDR High
Output: High



Moisture High, LDR Low
(or Moisture Low, LDR High)
Output: High

The photos show that the OR gate follows the truth table output that was expected. When either of the sensor Op-Amps go high then the output will also go high. Only if **both** the sensors are low then the output will also be low (indicated by the LED).

Evaluation

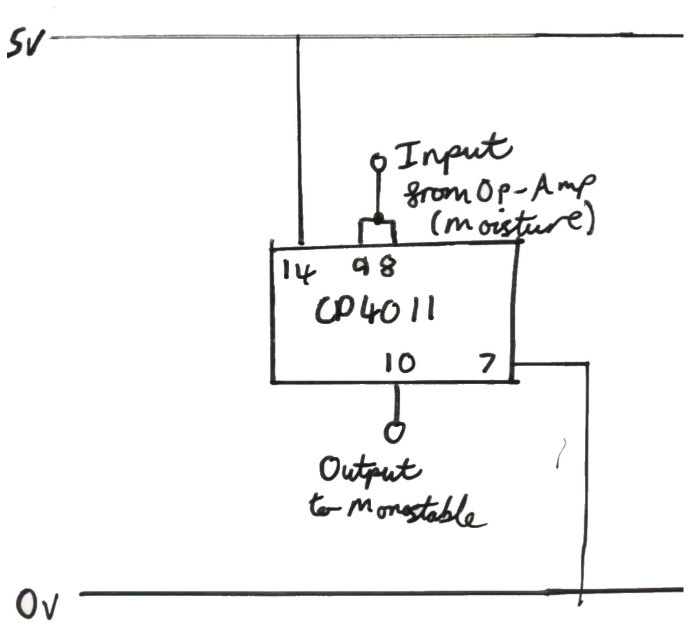
The subsystem functions as expected. The OR gate reliably follows the expected output and switches within the propagation delay found in my research which is almost instantaneous to the human eye. I will feed the output (pin 11) into the LED pictured above and an astable for a loudspeaker (pin 4).

Subsystem 6

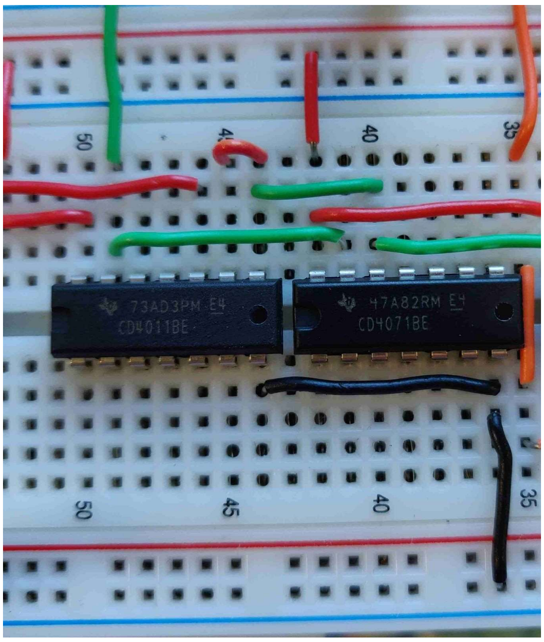
NOT Gate (NAND)

A monostable requires a falling edge to be triggered, to achieve this, I used a NOT gate connected to pin 13 of the OR gate which was connected to pins 9 and 8 on the NAND gate. Instead of using a CD4049, I used a NAND chip (CD4011) and utilised it as a NOT gate by wiring the two inputs together as pictured below.

Circuit Diagram



Circuit Picture

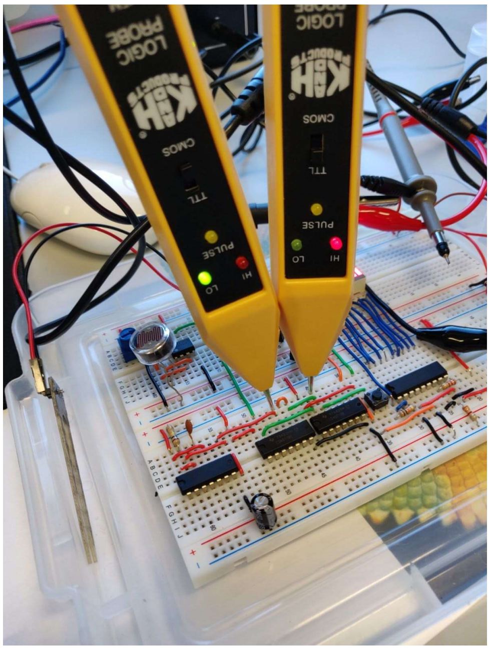


Test

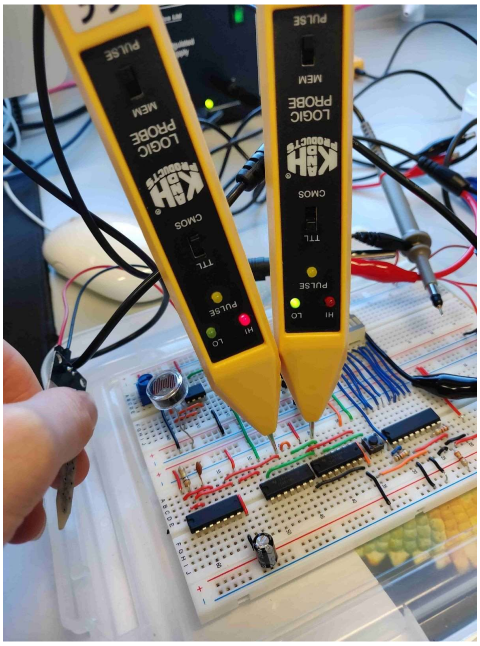
The expected truth table output of the NOT gate would be:

Moisture Op-Amp (A)	Output ($\overline{A}$)
0	1
1	0

To test if this was the case, I tested the NOT gate with two logic probes connected to the input (pins 9/8) and output (pin 10) pins of the CD4011. The output is shown on the next page:



Moisture Low
Output: High



Moisture High
Output: Low

The photos show that the NOT gate follows the truth table output that was expected. When the Moisture Op-Amp is high, the output of the NOT gate (pin 10) is low.

Evaluation

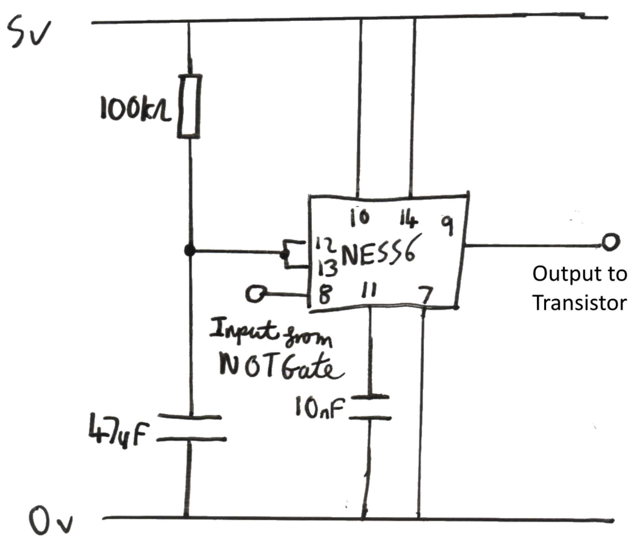
The subsystem functions as expected. The NOT gate reliably follows the expected output. I will feed the output (pin 10) into a monostable (pin 8 on a NE556).

Subsystem 7

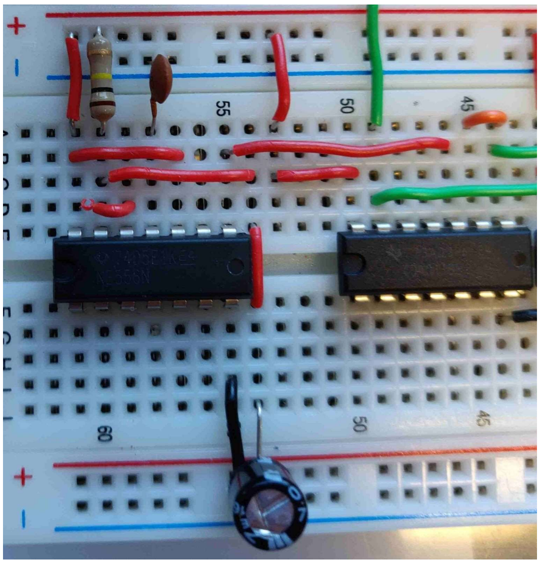
Monostable

This monostable is used to create a signal with a time period of 5 seconds to power the pump for the right amount of time to pump the right amount of water into the plant. From my calculations I have worked out the resistor value (100kΩ) and the capacitor value (47μF) for a time period of approximately 5s (5.17s). I used a NE556 due to me knowing in advance I would also be building an astable. The trigger pin (pin 8) is connected to the NOT Gate output pin (10) so that when the moisture level was below the set level the pump would turn on for the set amount of time.

Circuit Diagram

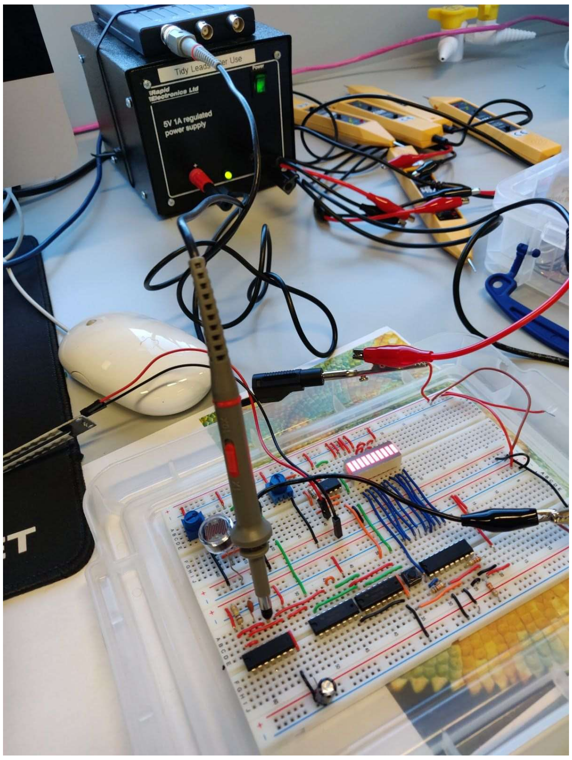


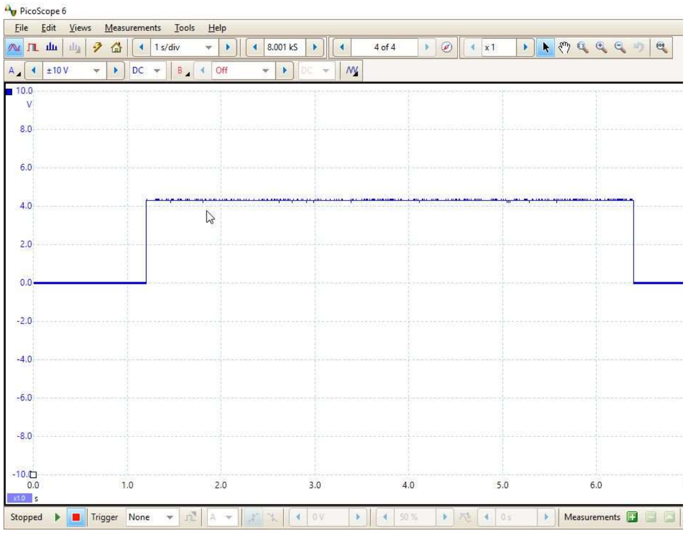
Circuit Picture



Test

To test if the subsystem was functional I connected a digital oscilloscope to the output pin (pin 9) of the NE556.





Output on digital oscilloscope showing a signal with a time period of 5 seconds.

The photos show that the time period of the monostable lasts approximately 5s which is enough time for 17 ml of water to be pumped on a 0.200l/min pump. The output is just under 5V (high) which is enough to switch the transistor to switch the relay to turn on the pump.

Evaluation

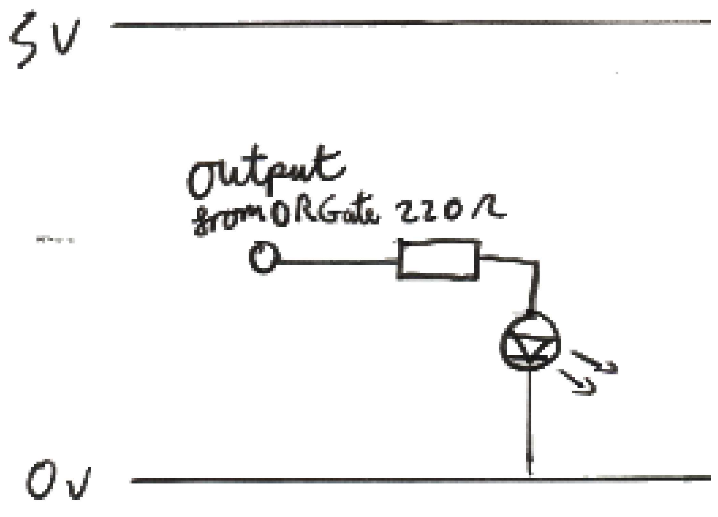
The subsystem functions as expected. The time period is as calculated and in this case, there seems to be no significant difference from the calculated value which means the electrolytic capacitor values were accurate. The output (pin 9) will be fed into the base of a TIP120 transistor.

Subsystem 8

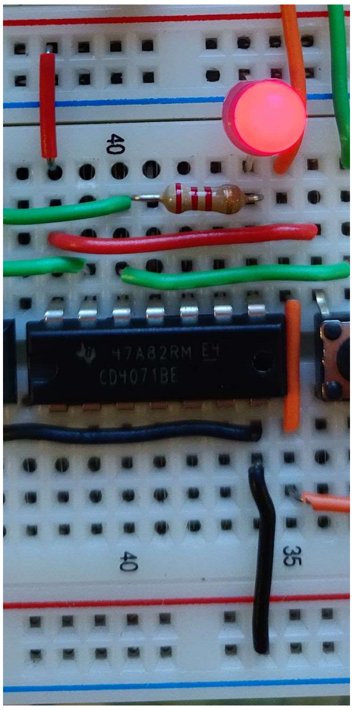
LED

A LED is used to visually indicate to the user when there is a problem with their plant. It is connected to the output (pin 11) of the OR gate. I used the value of 220Ω from my calculations to act as a protective resistance.

Circuit Diagram

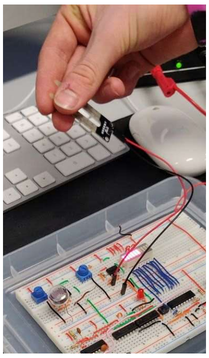


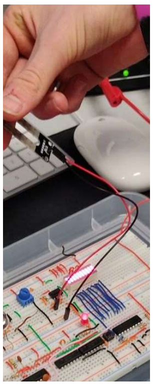
Circuit Picture



Test

To test the subsystem, I observed the output when varying the output of the OR Gate by adjusting the moisture sensor level.





As you can see from the photos, when I apply pressure to the soil moisture sensor (the moisture on my skin is enough to switch the Op-Amp) the LED turns off and when I remove pressure the LED turns back on.

Evaluation

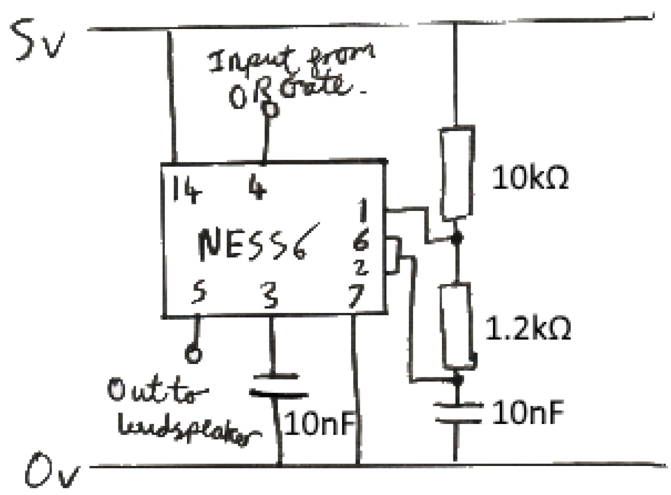
The LED works as expected. The LED is bright enough to be seen by the user at a glance and not too dim as I calculated the protective resistance correctly for the voltage supplied.

Subsystem 9

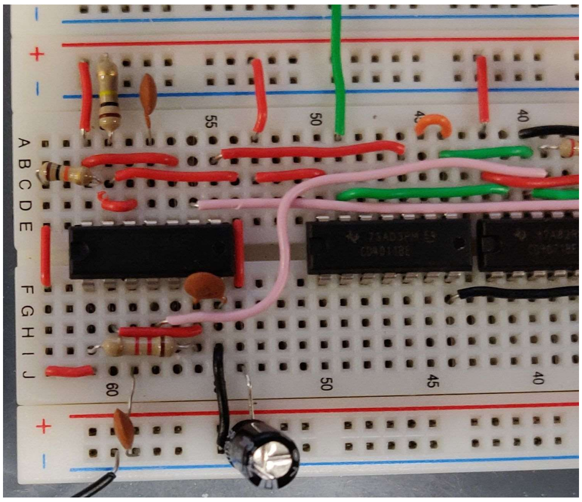
Astable

This astable should produce a signal with a frequency of 11600 Hz as specified in my specification. I am adding the circuit onto the NE556 used for the monostable. I have connected the reset pin (pin 4) to the output from the OR gate (pin 11) so the frequency is only generated when the OR gate output signal is high.. The function of this subsystem is to produce a frequency which can be fed into a loudspeaker to sound an audible tone to alert the user that their plant either needs water or light. I used a 10kΩ resistor as R1, a 1.2kΩ resistor as R2 and a 10nF capacitor for C1. I gathered these values from my calculations.

Circuit Diagram



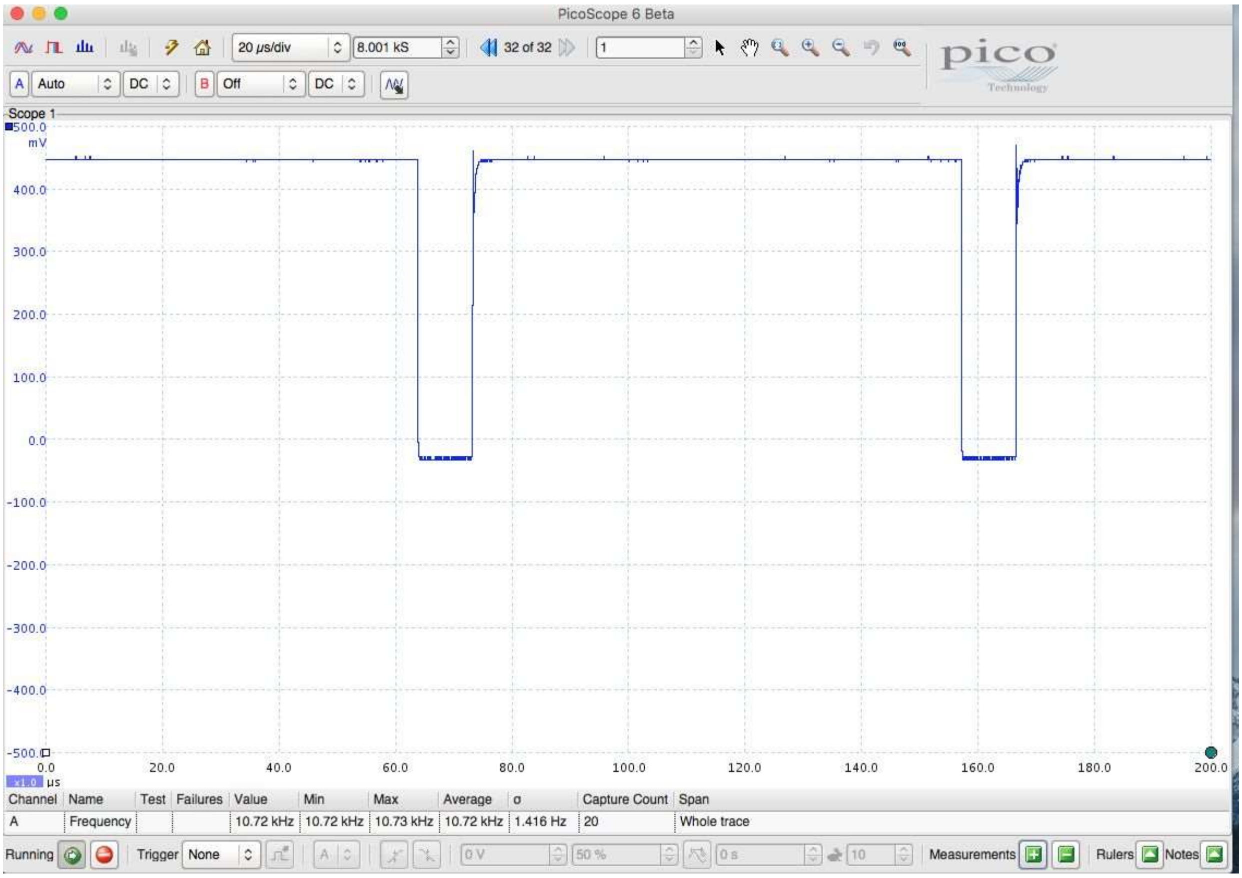
Circuit Picture



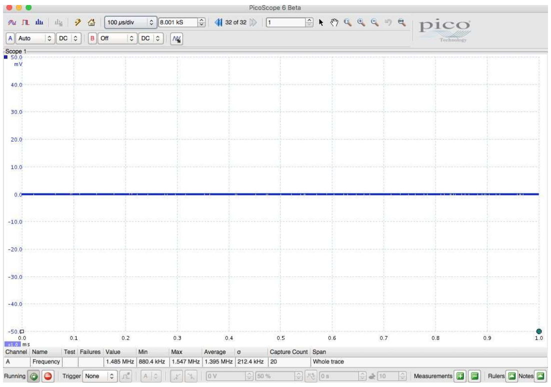
Test

To perform the test on the astable to ensure there was a oscillating signal I connected a digital oscilloscope to the output (pin 5) of the NE556. The output is shown on the following page.

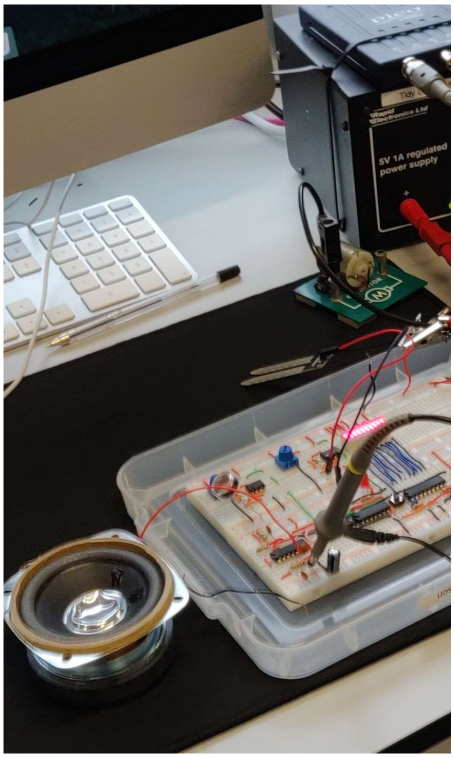
Blank Space



Output when signal at reset (pin 4).



Output when no signal at reset (pin 4)



Channel	Name	Test	Failures	Value	Min	Max	Average	σ	Capture Count	Span
A	Frequency			10.72 kHz	10.72 kHz	10.73 kHz	10.72 kHz	1.416 Hz	20	Whole trace

Measurement facility in oscilloscope software showing frequency generated as 10.72kHz

These photos show that the astable is functioning as would be expected. However the frequency measurement is significantly above the calculated value. This is probably due to the capacitor's value being off due to the high tolerances on electrolytic capacitors.

Evaluation

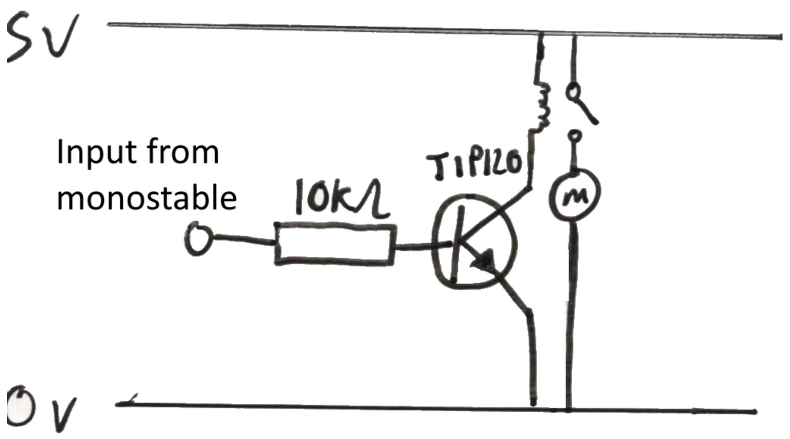
The astable functions as expected however the frequency is off by a significant amount (900 Hz almost) which is due to the tolerances on either the capacitor or resistors. In this case even being just 1nF off can mean the entire frequency is shifted by 1000 Hz. The tone produced by the loudspeaker however is still very audible and would alert a user that their plant needs watering.

Subsystem 10

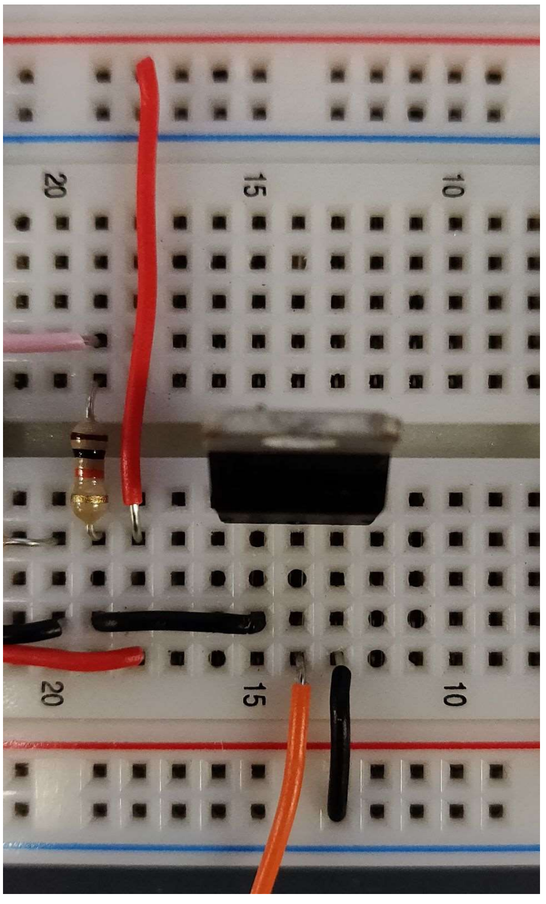
Transistor

This transistor will be used to trigger a relay to power a pump for the specified amount of time by the monostable. It is used as the monostable is not able to supply the high current that the motor requires to run at the correct RPM. This is why a relay is used to act as a switch to turn the motor on and off.

Circuit Diagram

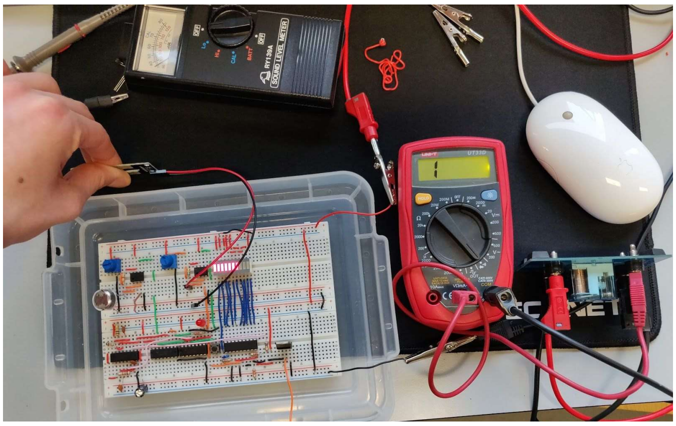


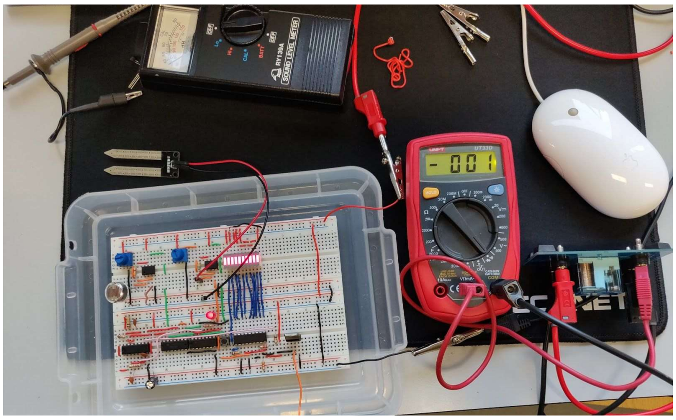
Circuit Picture



Test

To test the transistor, I connected a multimeter in continuity mode to test if the switch was closed when required.





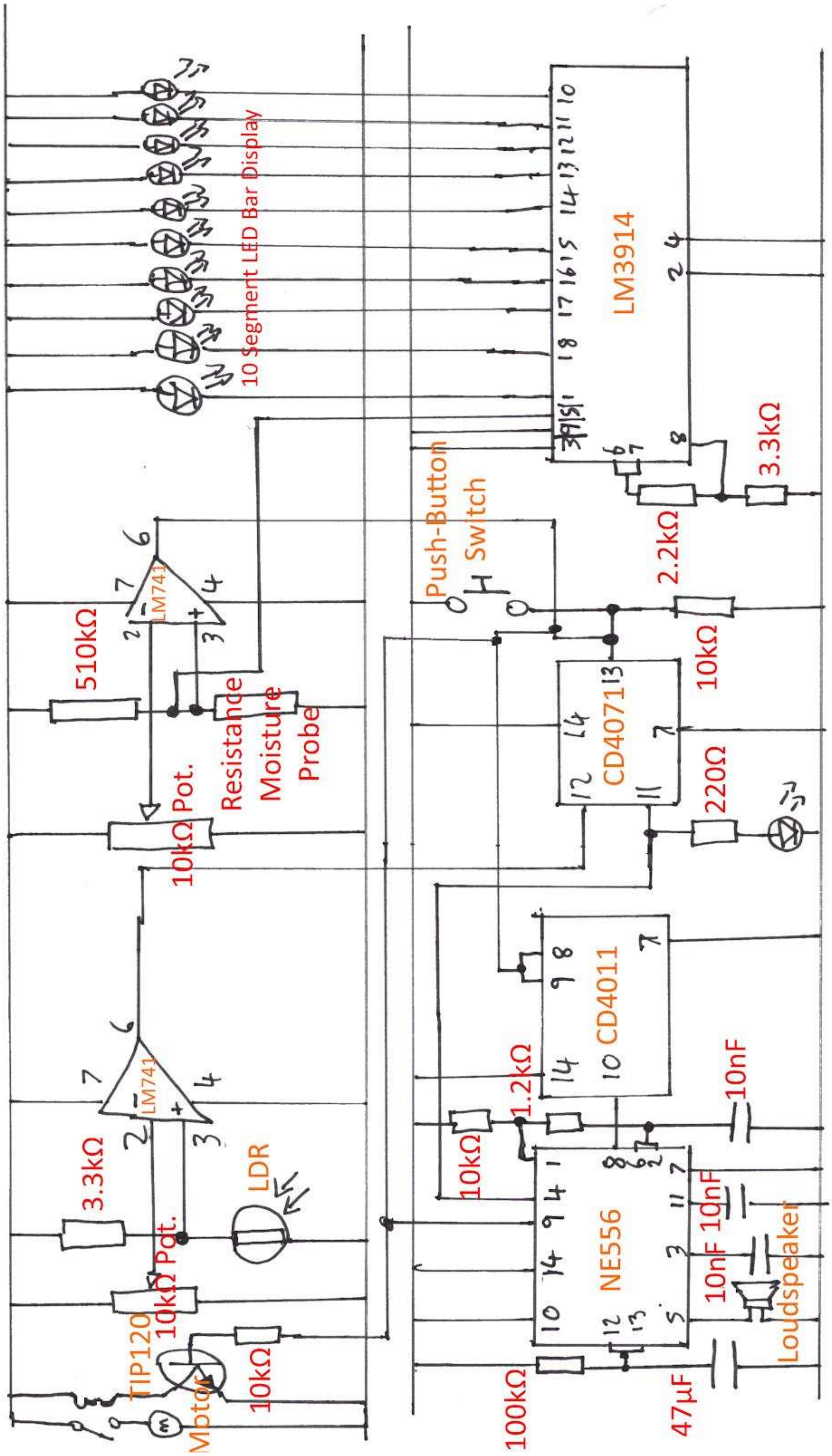
As you can see from the photos, when I apply pressure to the sensor the switch is open and no continuity is detected on the multimeter as the relay is open. However when I remove pressure and leave the sensor dry, a continuity is detected and a reading is displayed (a audible tone also sounds).

Evaluation

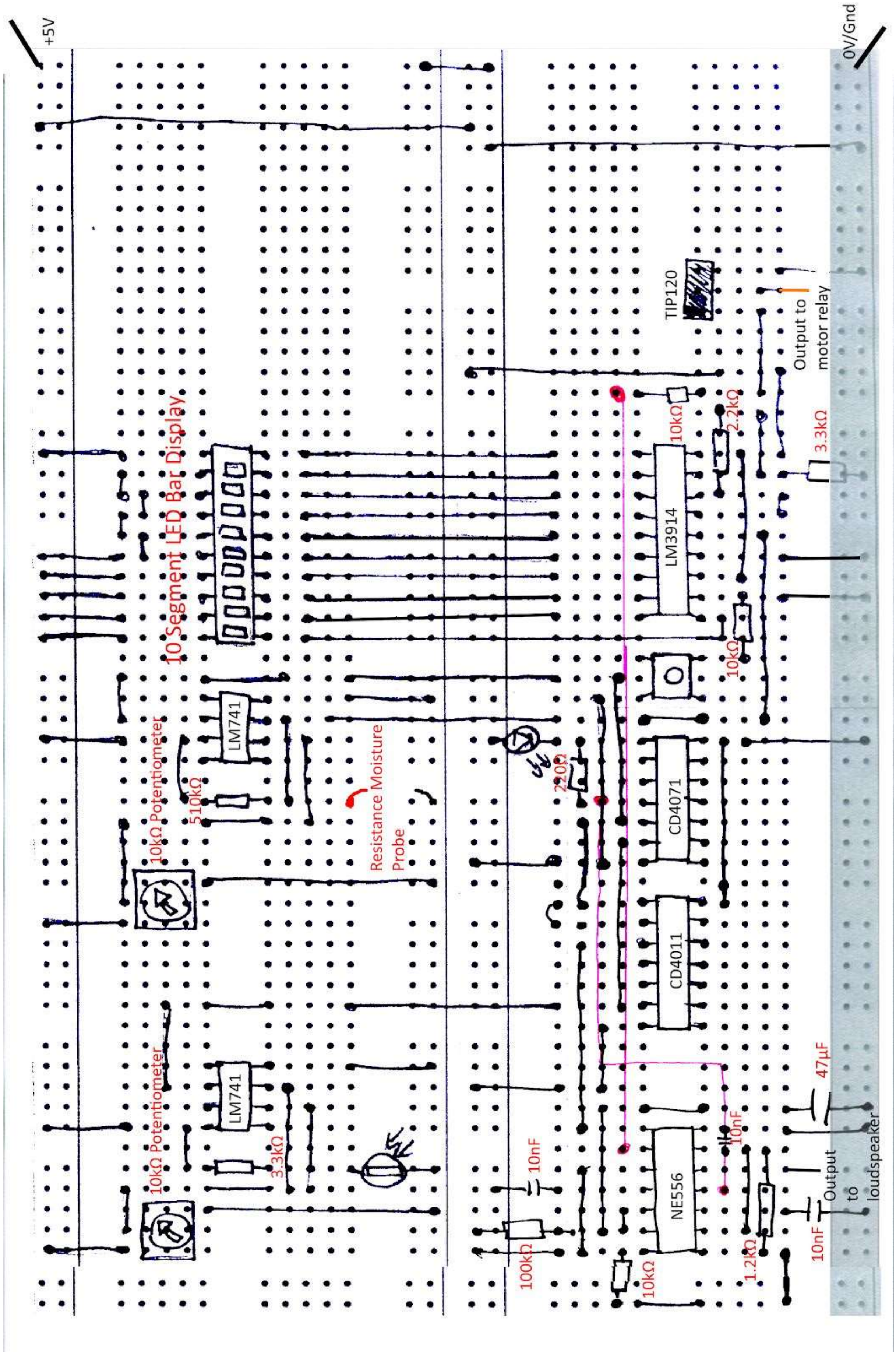
The transistor functions as expected. The switch is reliable and works every time allowing the pump to turn on exactly when it is required.

Blank Space

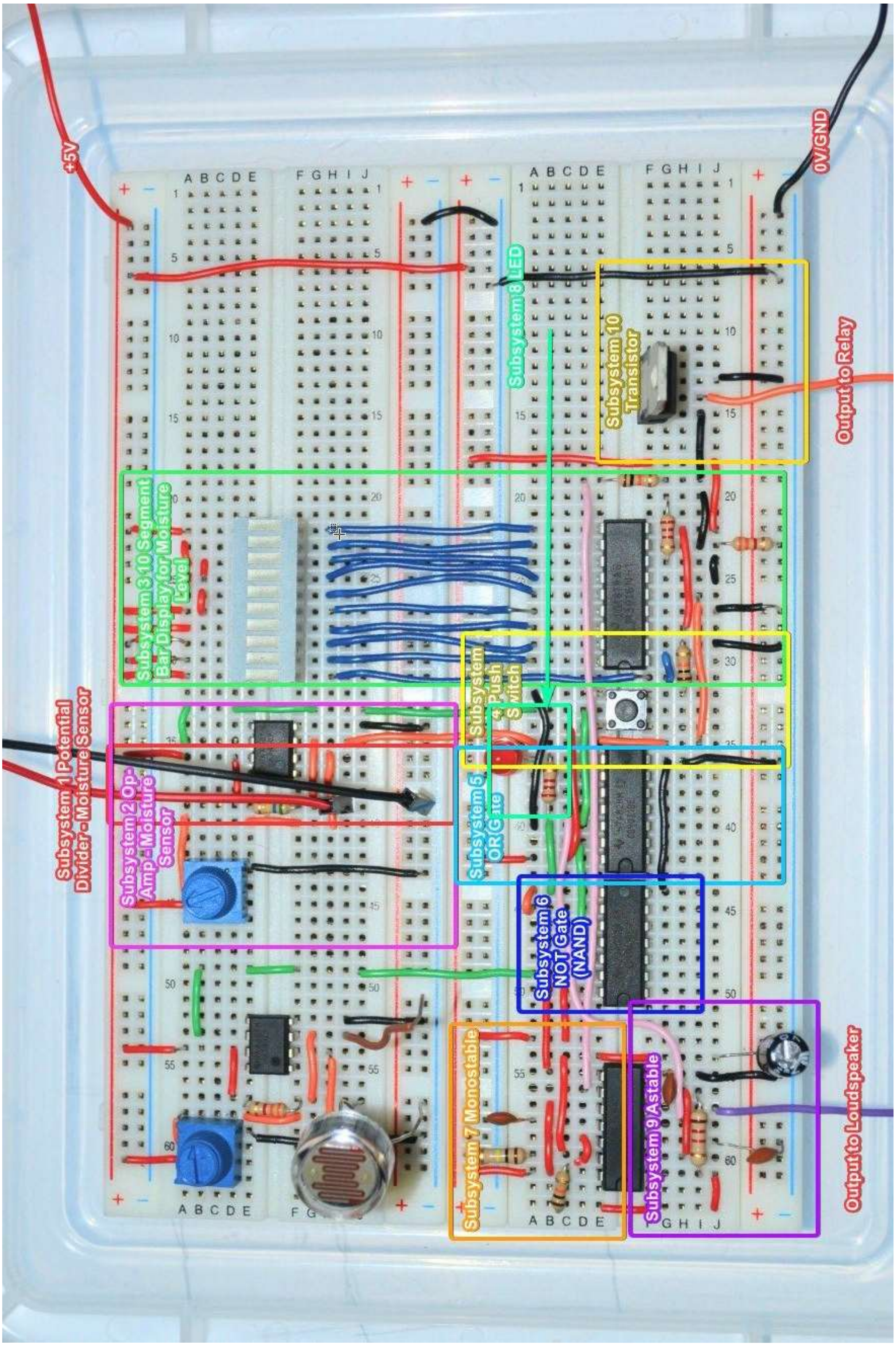
Final circuit diagram

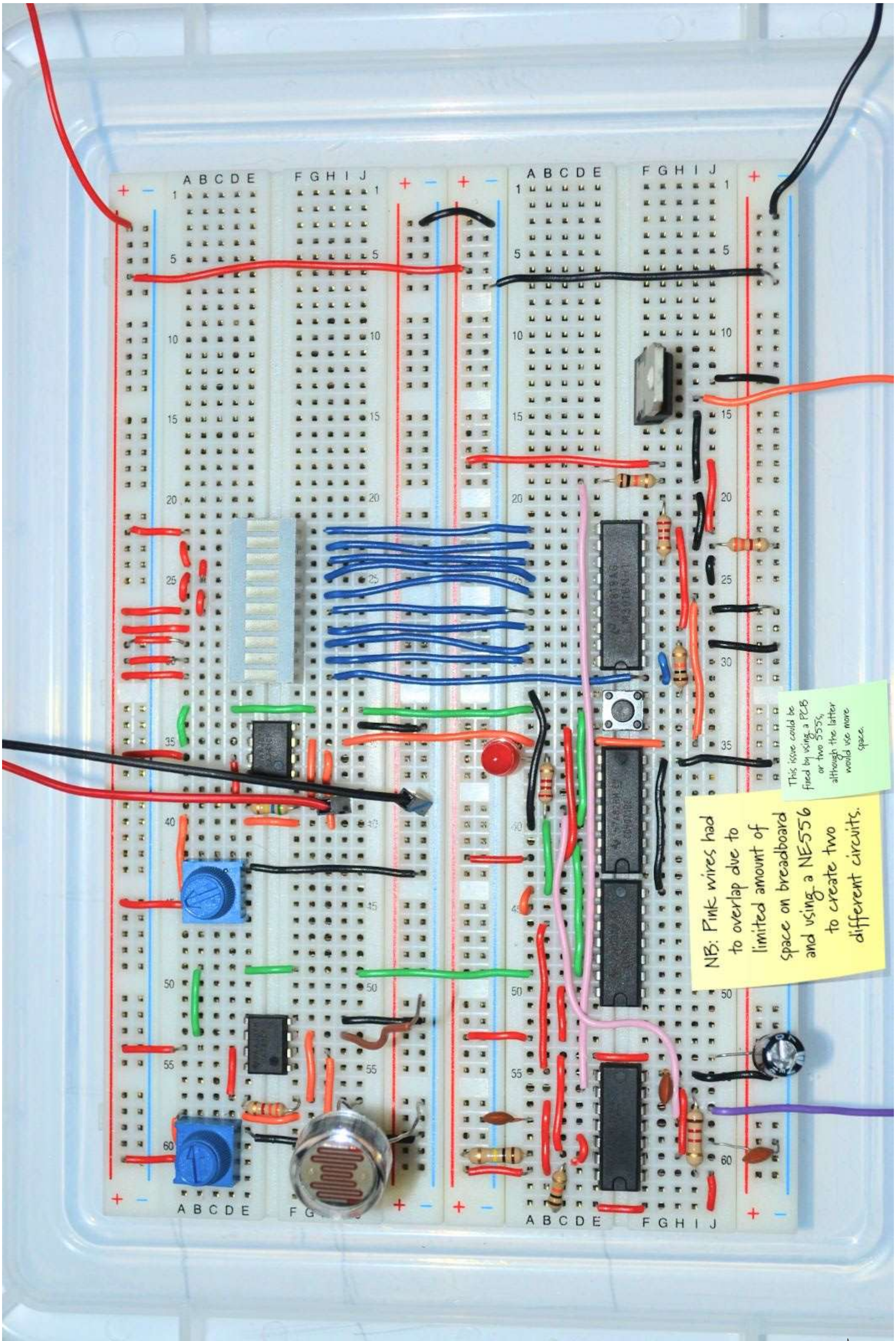


Component Layout Diagram



Circuit Photo with subsystems labeled (unlabeled on following page)



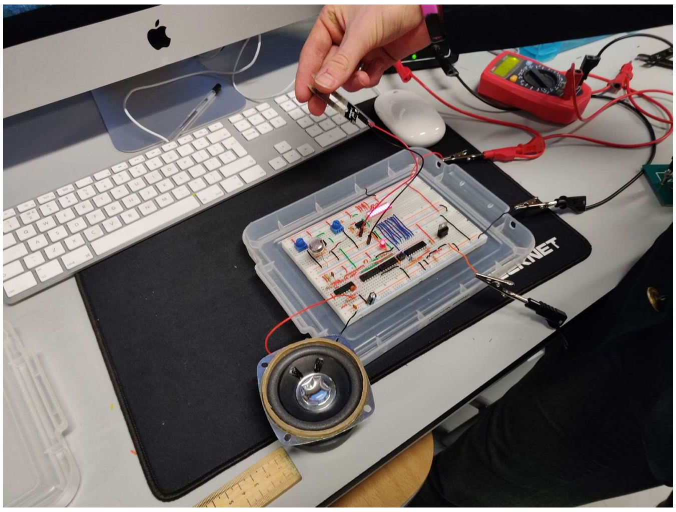

NB: Pink wires had
to overlap due to
limited amount of
space on breadboard
and using a NE556
to create two
different circuits.
This issue could be
fixed by using a PCB
or two 555s,
although the latter
would use more
space.

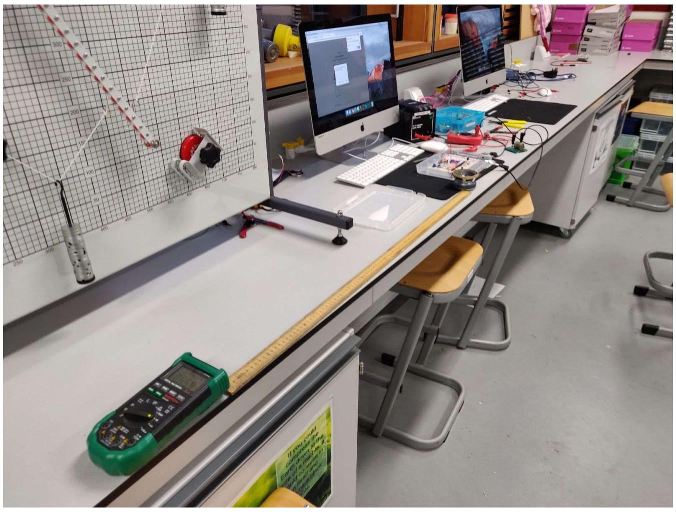
Testing the prototype of the complete hardwired system

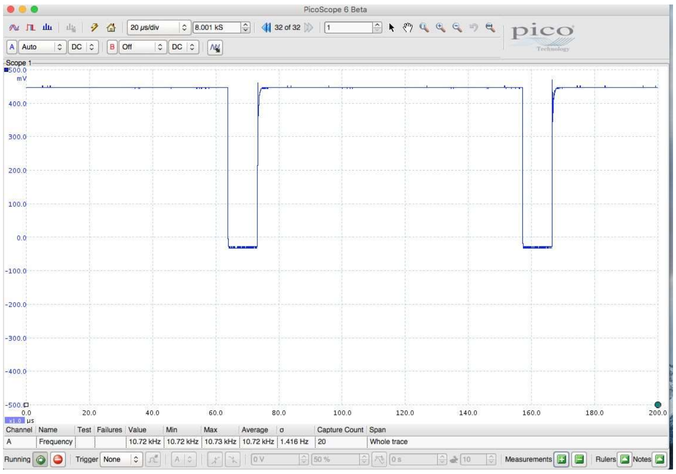
In my specification I set the following criteria:

5. *The circuit will need to set off an alarm at a frequency of 11600 Hz±1000 Hz (due to electrolytic capacitors having such high tolerances) with a loudness level of 70 db±10 db at 1m.*

To ensure I met this criteria, I set up some test equipment that was either connected or setup around the circuit's loudspeaker. I made sure that the circuit was in alarm mode by leaving the soil moisture sensor dry.



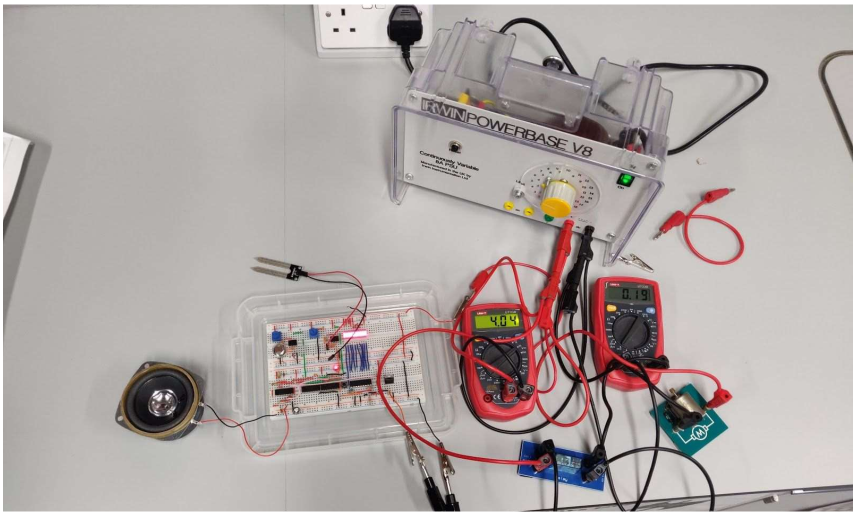
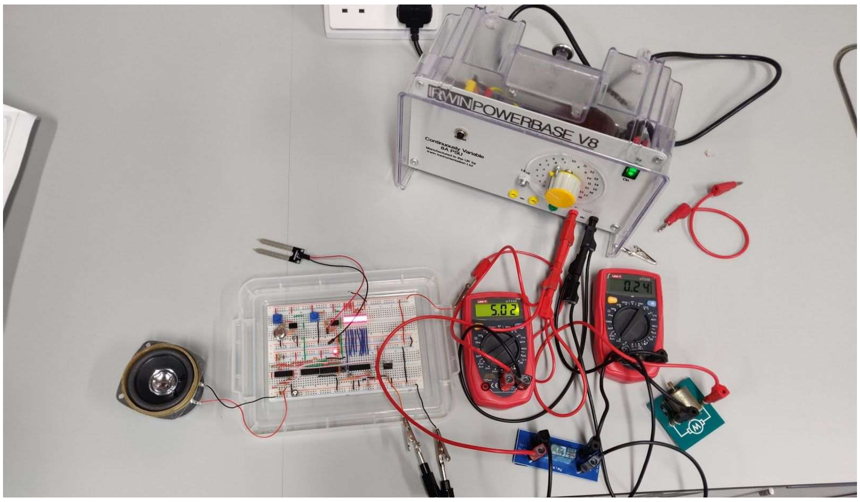
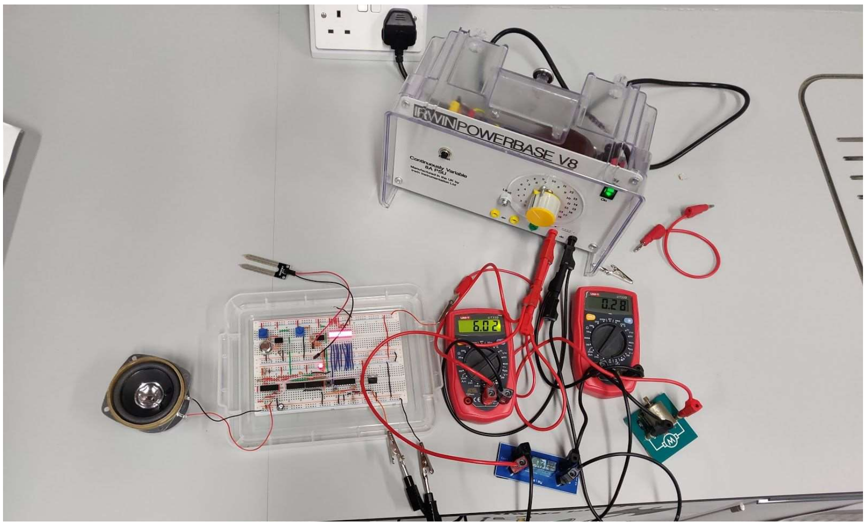




- **Loudspeaker Loudness Test**
  For this test I setup a multimeter in decibel mode to measure the decibel level of sound. I positioned the multimeter exactly one meter away from the loudspeaker as set out in the criteria. I then let the alarm tone play and observed the reading on the multimeter which came out as 75.8db. My specification set out that it should be 70 db±10 db so this test passed.
- **Loudspeaker Frequency Test**
  For this test I connected a digital oscilloscope to the loudspeaker (pin 5 of NE556) to view the frequency being played. The frequency was measured by the oscilloscope software as being 10.72kHz. My specification said that it should be 11600 Hz±1000 Hz. The frequency was off by 900 Hz however this is acceptable in this case due to the tolerances of the resistors and capacitors being so broad.

I also set the following criteria around the circuit power supply:

6. *The circuit will need to work when powered by a 5V±1V power supply to allow the product to be used in conjunction with a USB cable (5V).*

4V	
5V	
6V	

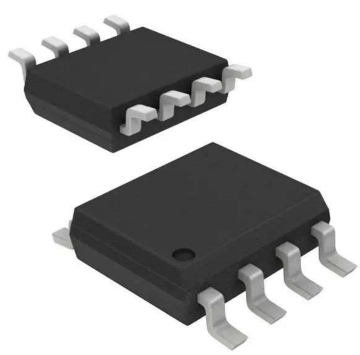
- **Circuit Voltage Range Test**
  I checked the voltage range of the circuit by hooking up a variable power supply with a voltmeter in parallel so I could see the exact voltage the supply was providing. I then changed the power supply to three set voltages within the range (4V, 5V and 6V) to see if the circuit was fully functioning by checking that the alert tone was still playing and that all the LEDs were functioning. As you can see from the pictures all the systems were functioning as expected at each voltage.
- **Circuit Current Test**
  I hooked up a multimeter in series with the supply and the circuit to measure the amount of current flowing through the circuit. The current in the circuit was proportional to the voltage being supplied and did not exceed the maximum rated amperage of the supply (8A).

Improvements

Use of a Microcontroller to send a text alert
A microcontroller could be used in conjunction with the circuit by connecting something like an Arduino with a GSM shield to the output pin of the OR gate and writing a program to send a text alert to the user so they are able to know their plants health status remotely.

Use of a RF module to pair multiple sensors together.
RF modules could be connected to the output and inputs of the OR gate to allow multiple sensors to be used in conjunction with each other. When one unit would set off, the others would also be able to set off allowing the user to know there is a problem. As there would be multiple units the range of the alert would be wider making this suitable for use in a industrial environment.

Using two NE555s instead of one NE556
Initially I thought using a NE556 would be a good space saver in terms of building the circuit, however in the end it meant that some wires had to overlap which is not ideal for a prototype. Using a 556 would be fine for a PCB but it was not ideal for prototyping. If I was able to do the project again I would use two 555s to allow for more working space in terms of wiring.



Using a PCB instead of a breadboard
A printed circuit board could be used instead of a breadboard to mount the components using a more efficient use of space as there are no wire routing issues which I experienced quite a lot of when working with a breadboard. Breadboards are also not effective in mass production so if the circuit was to go in production a PCB would be required. Contacts with components are also more reliable meaning there would be no issues with wiring coming loose or components falling out, which is another issue I faced.

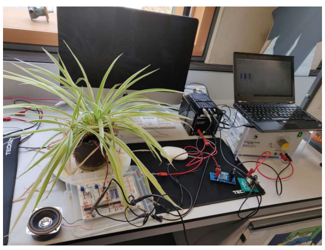
Part 4 - Performance of the Hard Wired System

Reliability

When building the circuit I found two main faults which led to reliability issues. The first was an issue to do with the NE556 chip. As it was placed in a breadboard and so many cables were being connected and my testing with an oscilloscope probe lead to it often became fairly loose meaning some connections were not being made causing the whole circuit to behave erratically. I corrected the issue by bending the pins straighter to make a stronger connection between the breadboard and the NE556 so it did not become loose.

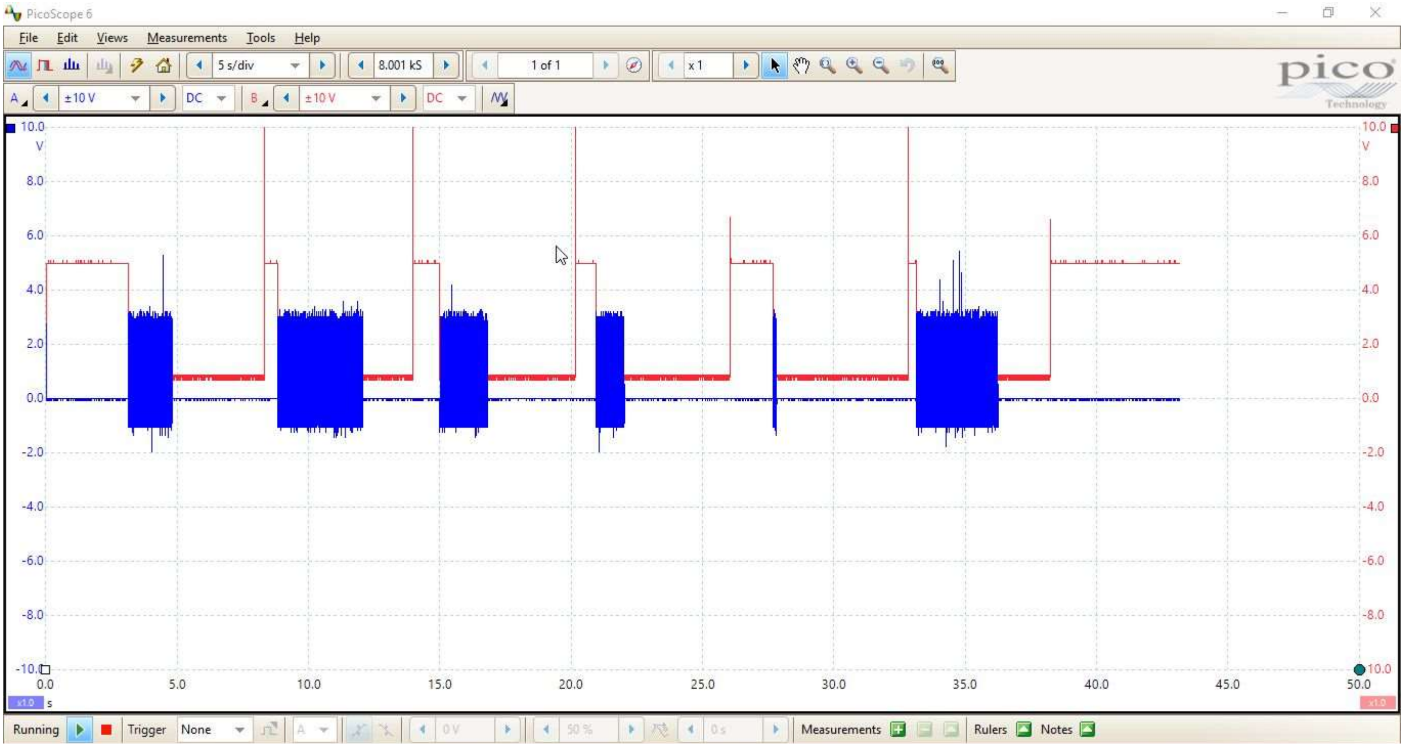
Another issue I faced was when I was testing with the transistor and the motor. When the transistor switched on and tried to drive the motor the circuit struggled to function with subsystems failing and the loudspeaker tone becoming distorted. I quickly found out that this was due to the motor consuming all of the circuits current which is why I added a relay into the circuit which could then be controlled by the transistor. This allowed the motor to be powered by a completely separate power supply with a higher current output.

To test the reliability of the circuit I repeatedly removed and replaced the moisture probe to mimic the soil moisture level going below the required soil moisture level. I did this for random intervals to check the pump would always run for the set amount of time the plant required. I connected a digital oscilloscope to pin 5 of the NE556 (loudspeaker pin) and the emitter pin on the TIP120 (relay pin) to check the alarm output was as expected. The expected output was that the oscillating loudspeaker frequency would be on for the amount of time that the probe was in the soil and that the pump transistor signal would last for 5 seconds from the point of time which the probe was removed.


■ ■ ■

(6 times)



An oscilloscope trace showing oscillating loudspeaker signal (blue, pin 5 of NE556) and 5s pump signal (red, emitter pin of transistor) ***NB:*** *Pump is on when transistor is low due to the way in which it is wired to the relay.*

The oscilloscope trace shows that the alarm system is functioning reliably and as expected. The pump signal goes low for the 5 seconds required when the moisture probe is placed back into the soil (which is shown by the time the loudspeaker is playing a tone). This value is always the same and there is no delay distinguishable between each test. There was never any issue with the circuit not responding or giving an unexpected output.

Final Evaluation

Apart from the problems listed above, I had no other issues with the construction of my circuit. I have tested the circuit extensively over a period of one day to ensure the circuit can operate reliably over a fairly long length of time. The circuit met the criteria set at the beginning of the project with no problems. The circuit has not broken in any way. If I was to construct another version, I would incorporate Microcontrollers to allow for additional functionality for more advanced use cases.

Part 5 - Other Documentation

Component list

Quantity Needed	Component
2x	10kΩ Potentiometer
2x	3.3kΩ Resistor
1x	510kΩ Resistor
1x	LDR (NORPS-12)
2x	LM741 Op-Amp

1x	10 Segment LED Display (YSLB-10251B5-10)
1x	LED (YSL-R531R3D-D2)
1x	LM3914
1x	220Ω Resistor
3x	10kΩ Resistor
1x	2.2kΩ Resistor
1x	TIP120 Transistor
1x	Loudspeaker 8Ω 10W (TQ-077FM-R)
1x	Relay (G5LE)
1x	Push Button Switch
1x	CD4071
1x	CD4011
1x	NE556
1x	100kΩ Resistor
3x	10nF Capacitor
1x	47μF Capacitor
1x	1.2kΩ
1x	Pump
1x	Resistance Moisture Probe

Comparison to Specification

Specification Criteria	Test Performed	Criteria Met?
The circuit will have a 10 segment display to convey to the user the moisture level of the soil at a glance.	See tests on Subsystem 3 for the LM3914 and 10 Segment Display. This test fulfilled the criteria.	✔
The alarm and pump should turn on when the moisture and light levels are below the optimum level.	See tests on Subsystem 5 for the OR Gate for alarms. This test fulfilled the criteria.	✔
The circuit will need to be able to water the plant when the moisture level is below a set value by the user.	See tests on Subsystem 2 for the Op-Amp for the moisture sensor. This test fulfilled the criteria.	✔
The user should be able to easily test if the alarm + pump are functional.	See User Guide images step 4. These photos show the circuit fulfills the criteria.	✔

The circuit will need to work when powered by a 5V±1V power supply to allow the product to be used in conjunction with a USB cable (5V).	See voltage range test in "Testing the prototype of the hardwired system". This test fulfilled the criteria.	✔
The circuit will need to be able to turn on a pump (0.200l/min) for 5s to provide 17ml of water.	See tests on Subsystem 10 for the Transistor connected to a relay. This test fulfilled the criteria.	✔
The circuit will need to set off an alarm at a frequency of 11600 Hz±1000 Hz (due to electrolytic capacitors having such high tolerances) with a loudness level of 70 db±10 db at 1m.	For frequency, see tests on Subsystem 9 for the Astable connected to a loudspeaker + digital oscilloscope. This test fulfilled the criteria. For loudness, see test loudspeaker loudness test in in "Testing the prototype of the hardwired system". This test fulfilled the criteria.	✔
The circuit must be able to power a pump which draws 2A at 5V.	See tests on Subsystem 10 for the Transistor connected to a relay. As the motor is connected to a relay, this means the circuit can control a power supply of any voltage/amperage. This fulfills the criteria.	✔

Evaluation

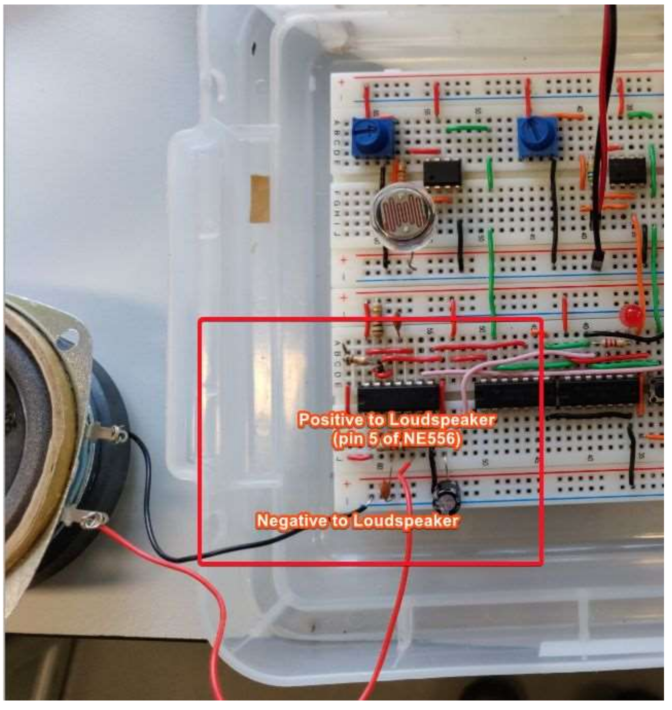
The table above shows that the circuit meets all the given criteria by the specification. The only slight discrepancy with the criteria is the frequency being 900 Hz however this is still within the specification tolerance.

Blank Space

User Guide

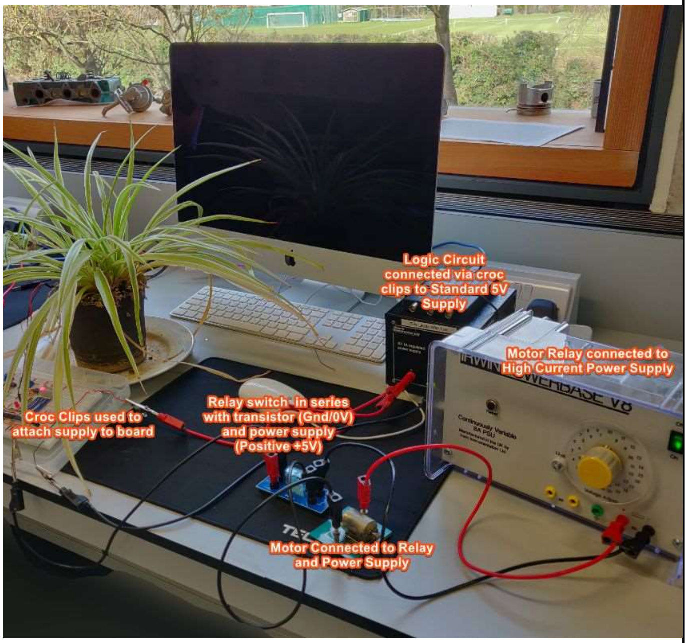
1. Insert the soil moisture probe into a potted plant/soil and ensure both contacts are firmly pushed in. The circuit will not function if there is not a secure connection. Feed your pump output into the soil.

2. Connect a loudspeaker to the circuit board by connecting the negative lead to the negative rail and the positive lead to pin 4 on the NE556 chip (pictured) and connect the relay (connected to your pump) to the emitter pin of the transistor (pictured) and the positive rail of the circuit.

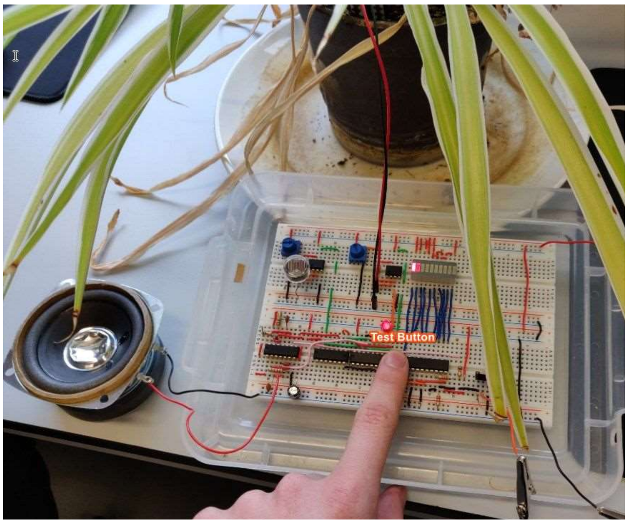


3. To provide power to the device, connect the positive and negative connections of a supply within the range of 4-6V to the circuit board in the positions shown. (The positive and negative rails)

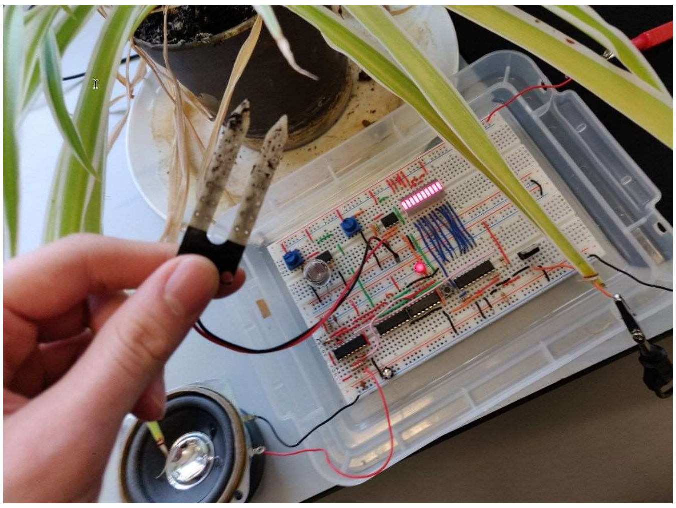
   The motor needs to be connected to a seperate power supply rated for it's requirements and connected to the relay as shown so that when the relay is switched the circuit between the motor and power supply will be complete.



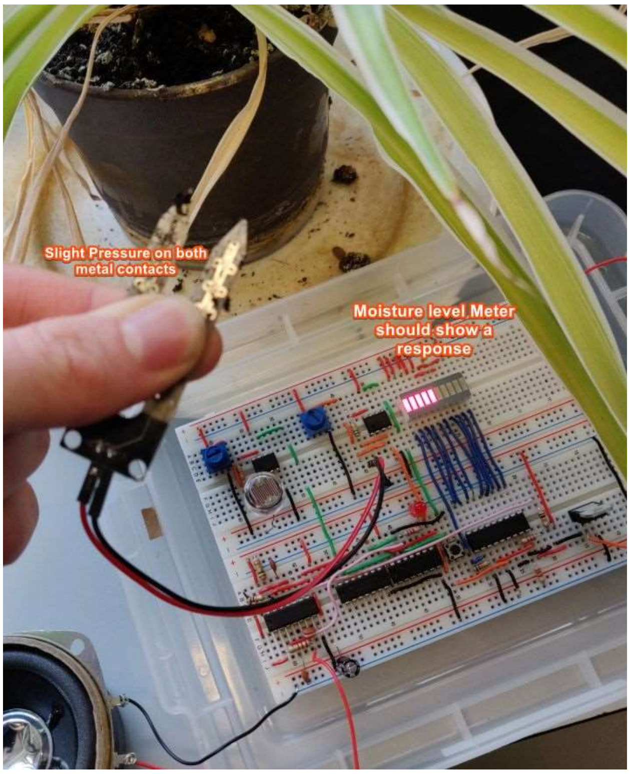
4. Ensure all the systems are functional by pressing the test button (pictured to the right). The pump should run, the LED should light and the loudspeaker should play an alert tone.



5. Check the moisture probe by removing it from the soil and observing for an alert tone to indicate there is not enough moisture. Observe to check if any corrosion has occured on the sensor due to electrolysis, if it has the sensor needs replacing. To replace, remove current module from positive and negative lead and plug in to new module.



6. To test the 10 Segment Moisture Meter, apply slight pressure using your fingers on the two metal contacts on the resistance moisture sensor and observe the output given on the 10 segment display. It should vary with the pressure you apply.

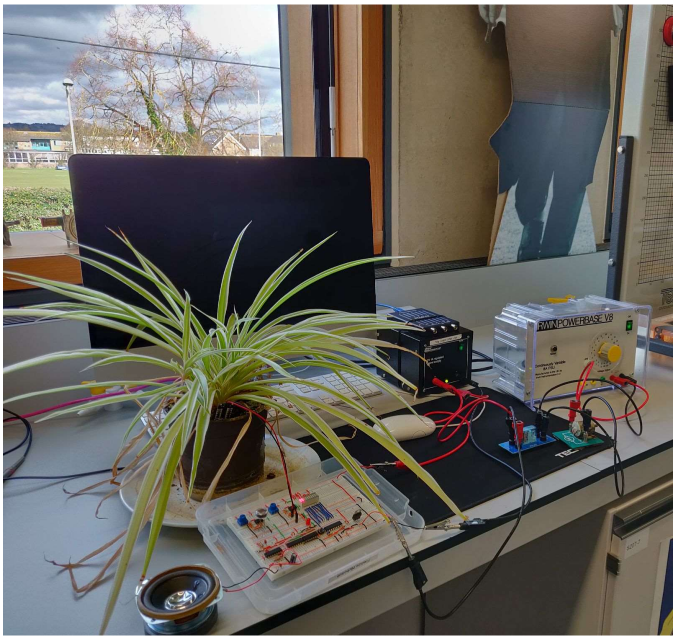


7. Leave the circuit to look after your plant, you should perform a maintenance check of the circuit by following steps 4-6 every fortnight.

   The sensitivity of either sensors can be adjusted using the blue potentiometers.

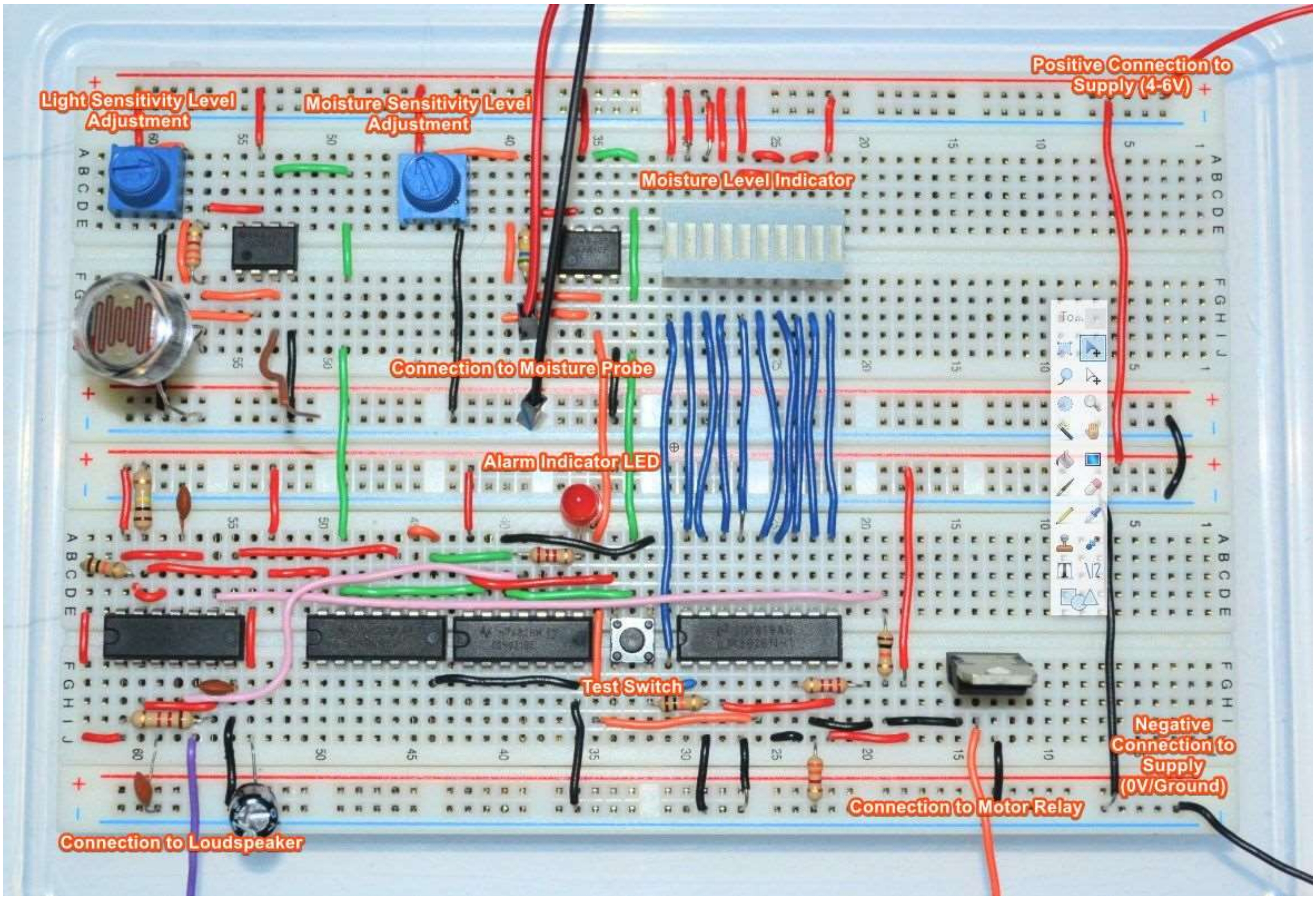
   While the circuit is on if either it is too dark or the soil moisture level is too dry the alarms will sound.

   If the moisture level is below the reference voltage set on the right hand side potentiometer then the pump will turn on for 5 seconds to pump a tablespoon (17ml) of water.



Blank Space

Labeled Diagram for User Guide



Blank Space

END OF BOOKLET