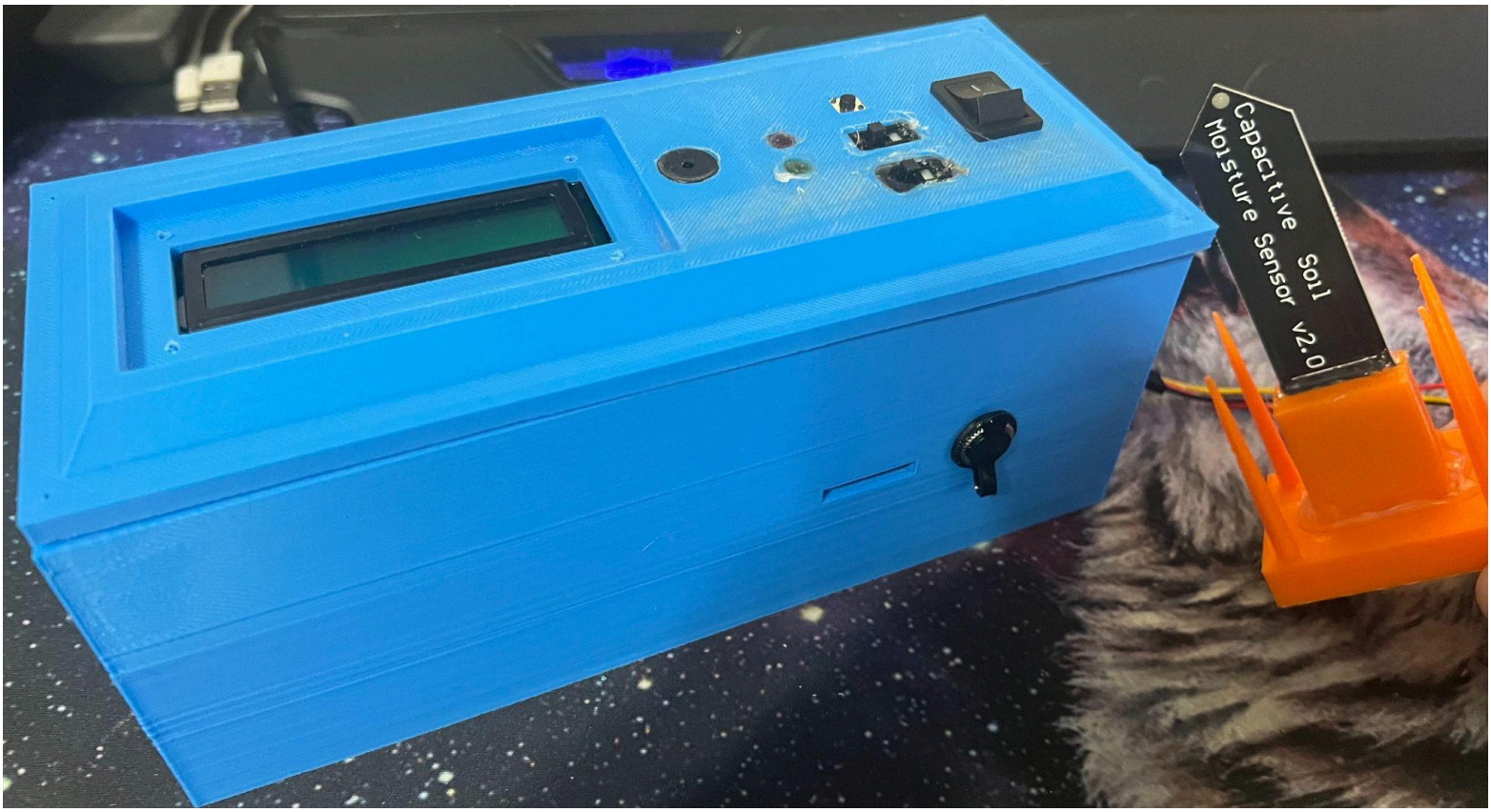
Soil Moisture Sensor

Quick Start Guide



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Introduction:

The product uses a capacitive sensor, a type of moisture sensor that works similarly to a capacitor–changes in the dielectric (caused by the soil and moisture) cause a voltage change, which in turn allows the user to detect moisture levels. Features that support the sensor include a display rate button, recording switch, mode switch, charging port, display screen, and more.

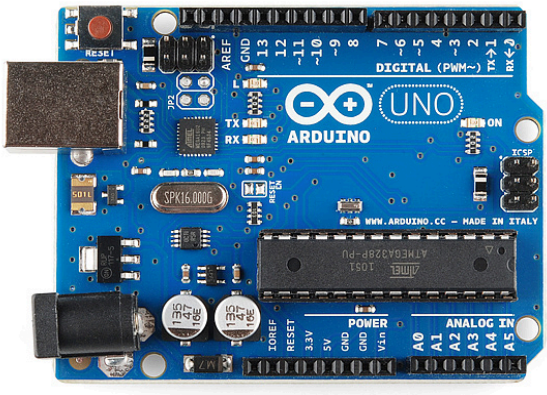


Image 1. Capacitive sensor design.
Image 2. An Arduino microcontroller. A component that helps perform various tasks.

The design is meant to serve a few purposes: to act as a guide when watering crops, verify if planted crops are at appropriate moisture levels, and record data for experimentation purposes. View the “Getting Started” section on how to prepare the sensor for the desired intention.

Getting Started:

Depending on the sensor usage, separate steps must be taken. Choose the options below, separated by letters, to ensure the product functions as intended. Remember to charge the product (around 1 ½ to 2 ½ hours) to full power over several short uses or a long interval.

Option A: I want to use the sensor as a guide to finding the general ideal moisture level for vegetable crops.

1. Flip the power switch on and change the measuring unit to percent moisture (indicated by a water droplet icon).
2. When measuring moisture, ensure the sensor (the black probe) is fully submerged in the soil.

Option B: I want to record moisture with acceptable accuracy (requires calibration).

1. Follow the section on "Calibration" to measure moisture content in gravimetric water content (GWC). Read about the mode switch in "Design Functions" to learn more about GWC.
2. Once the sensor is calibrated, turn it on and activate the measurement for GWC.
3. Change the rate at which the sensor will record data depending on how long it will be recording. Set the refresh rate to 300 seconds (or five minutes) if recording for 3-12 hours, 60 seconds (or one minute) if recording for 10 minutes-2 hours, and adjust the rate based on preference below 10 minutes.
4. When using the sensor, ensure the black probe is fully submerged in the soil. Flip the recording switch when ready.
5. When finished recording, turn the device off and insert the micro SD card into a micro SD reader for your computer.
6. Access the DATALOG Excel file.
7. To graph the data, select all the data points (including the header) and click the *Insert* tab in Excel. Then click on the scatterplot icon in the *Charts* group.

Option C: I want to record moisture without calibrating (expect unacceptable % error readings).

1. Turn the sensor on and activate the measurement for % moisture, indicated by a water droplet.
2. Start from step 3 in Option B.

When finished using the sensor, turn off the device and clean it off using wet wipes. Use a dry towel afterward, store it indoors, and let it charge if needed.

Design Functions:

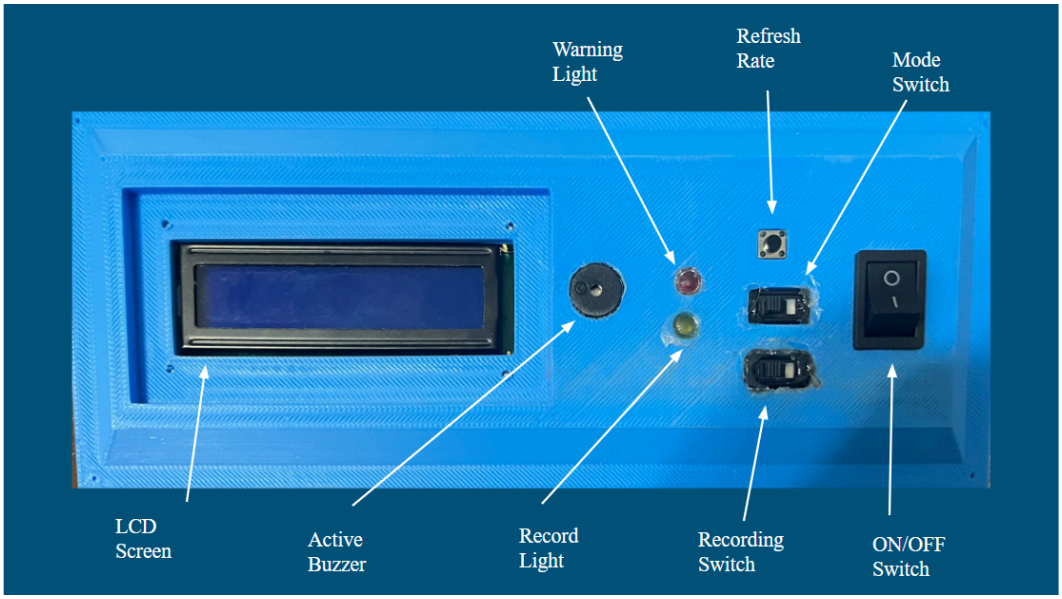


Image 3: Visual to identify all visible switches, LEDs, buttons, buzzers, and screens.

Refresh rate: A toggleable button that changes the rate at which the sensor displays data. Options include 0.5, 1, 5, 60, and 300 seconds. You can see the current rate option on the LCD screen.

Recording switch: An Excel file will gather data on the time (sec) and moisture level of only one mode upon recording. Access the file using the micro SD card reader. **Remember that turning back on the recording switch will remove previously stored data**. The recording state is signaled at the top-right of the LCD screen or by the yellow LED.

Mode Switch: A switch that controls what mode the sensor will record in. There are two options: a % moisture mode and a calibration mode. The former displays a water droplet on the LCD screen, and the latter displays gravimetric water content (GWC) as an acronym.

- The % moisture mode reads the moisture content in the soil from dryness to saturation. It does not need calibration but provides less accuracy than the second mode. It also provides general qualitative data, which is more suitable when checking the moisture content of vegetable crops.
- The second mode measures gravimetric water content (GWC). GWC is the mass of water in a unit mass of a substance (soil, in this case). Though this mode requires calibration for each soil type to maintain accuracy, it can provide up to a 2% error for finer soils. Refer to the section called “Calibration” to learn how to set up this mode. This mode is more suitable for logging data.

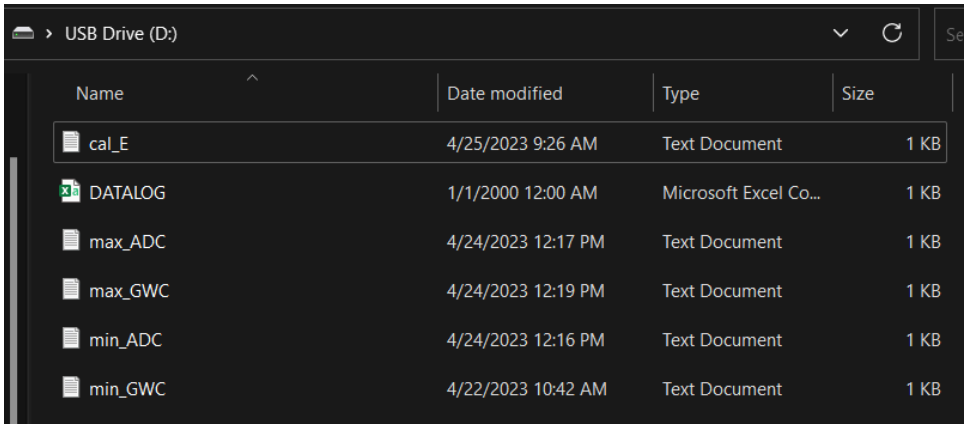


Image 4. Micro SD card files for viewing recorded data or adjusting calibration data.

Memory card file:

- cal_E: The calibration enable file allows the user to change the measuring option for mode two to either GWC or ADC. If cal_E = 0, mode two will display the ADC value; if cal_E = 1, GWC will be displayed instead.
- DATALOG: an Excel file to view recorded data of time (sec) and moisture level (which changes depending on the mode option before recording.
- min_ADC: the ADC value where GWC is 0 for a particular soil type when dry.
- max_ADC: the ADC value where GWC > 0 for a particular soil type. Preferably where GWC is a positive integer, if possible, to avoid any additional error.
- min_GWC: should always be set to 0.
- max_GWC: the percentage GWC which correlates with the max_ADC value on the line of best fit for a GWC vs. ADC graph (when calibrating).

Image 5: Visual to identify the charging port and the micro SD module for data logging.

Charging port: A barrel connector port that is compatible with standard outlets. Charge the sensor for 1 ½ to 2 ½ hours for every use.

Calibration:

The calibration mode does not consider qualitative moisture levels as the saturation point for each soil type differs.

To improve sensor accuracy, calibration for each soil type is necessary. The percent error of the sensor for a specific soil type after calibration is up to 2% for finer soils. The calibrated mode does not measure in % moisture but gravimetric water content (GWC), which is the mass of water in a unit mass of dry soil. Use Equation 1 to help with the calibration process.

$$GWC = \frac{0.997 \frac{g}{mL} * V_w}{m_s}$$

Equation 1. GWC using the volume of water and soil. V_w = volume of water in grams and m_s = mass of soil in grams.

Materials:
A tarp/cloth to cover the workspace, a 100 mL burette/10 mL graduated cylinder, a pipet, one 500 mL beaker (for water), one 300 mL beaker, an analytical/digital balance, potting soil, and a glass stirring rod.

Calibration Procedure:

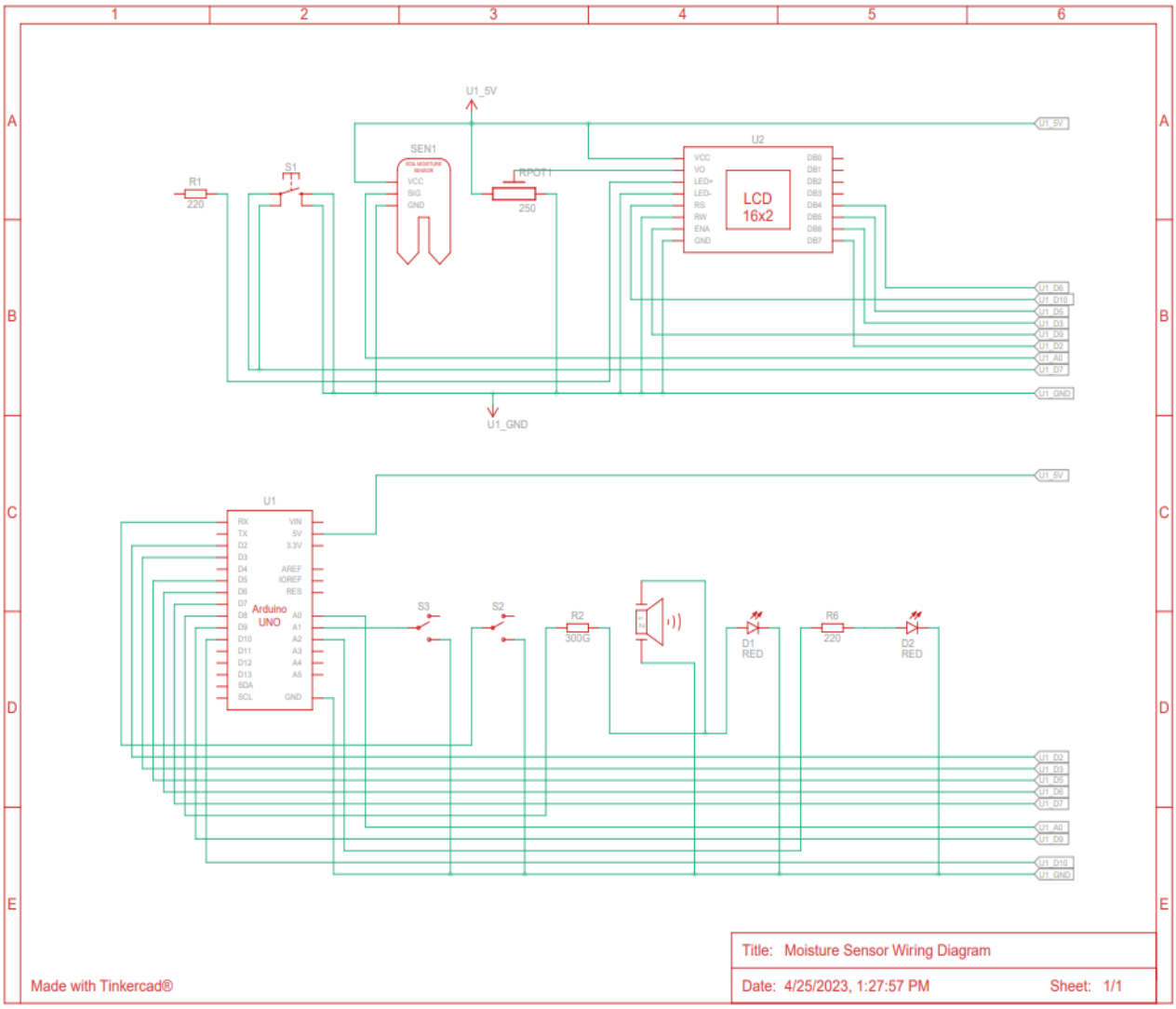
1. Prepare the workspace by covering it with a tarp/cloth.
2. Record the mass of a dry 300 mL beaker.
3. Fill the beaker with 300 mL of soil and record its mass (not including the beaker's mass).
4. Let the beaker dry at consistent room temperature for 1-2 days.
5. Prepare the 100 mL buret by filling it with water to the 100 mL line. Refill when needed. If you will use a graduated cylinder, fill it to 10 mL (use a pipet if needed).
6. Change the cal_E text file in the micro SD card to 0 (for recording in ADC). Refer to the "Design Functions" section on how to do this.
7. Insert the sensor into the cup so the black probe is fully submerged in the soil. Record the ADC value and the total volume of water in the soil (start at 0 mL).
8. Pour 10 mL into the cup so that the surface is uniformly distributed with water (using a buret or a graduated cylinder). Wait 10 seconds.
9. Repeat steps 6 and 7 until a total of 50 mL has been dispensed or the soil is saturated (all parts of the soil are moist, and no water is seeping to the bottom of the glass).
10. Create a scatterplot of % GWC vs. the sensor's ADC values and create a line of best fit (Excel is preferred). Use Equation 1 to find GWC (and multiply by 100 for a percentage value).

11. Use the line of best fit to find at what ADC value the calibrated sensor would read at 0% GWC (when x = 0 on the line of best fit equation).
12. Use the line of best fit to find at what ADC value the calibrated sensor would read at any % GWC point on the line of best fit (that's greater than 0). Preferably, find a point where GWC is a positive integer to avoid any additional error.
13. The values from steps 11 and 12 can then be used to map the equation the calibrated sensor will use. The following text files should be changed/set: min_ADC, max_ADC, min_GWC (should be 0), and max_GWC. **Ensure the input values in the memory card are positive integers.**
14. Change the text file called "cal_E" to 1 on the micro SD card.

Once the calibration procedure is completed, turn the sensor on and flip the mode switch to display moisture in its calibrated mode.

Wiring Diagram:

Schematic 1 displays most of the wiring and components that make up the design and functionality. Although the schematic does not include the micro SD adapter, it would be connected to VCC, GND, and digital pins 4, 11, 12, and 13. It also does not include the wiring for the lithium batteries as a power source.



Schematic 1. Wiring diagram for the moisture sensor. This does not include the micro SD adapter.