Compact Plant Sensor for Data Collection and Actuation

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***Abstract*—This paper presents the design and implementation of an autonomous plant monitor. In order to have a successfully healthy plant, this smart plant pot actively monitors the light, temperature, humidity, and soil moisture conditions of its plant. Using a RaspberryPi and custom sensors, the essential needs of any plant are covered. The pot includes an OLED display screen that displays in real time the current status of the plant and the appropriate actions the user should take to ensure the best care.**

I. Introduction

In today's modern society, creating and maintaining the appropriate conditions for plant health is not straightforward. Many people do not have regular access to the basic needs of plants. For instance, those residing in apartments or low-light housing will not have adequate access to the necessary sunlight for plant survival. Furthermore, the majority of people today simply have no idea how to take proper care of a plant. The basic questions of how much to water the plant, how much sunlight is no longer commonplace. We propose a device that will answer all of these questions without having to be explicitly asked.

The compact plant sensor for data collection and actuation will take care of all steps in the plant care process. This includes measuring the specific specs of the plant - from light, moisture, to temperature levels. From this, the system will determine and actuate the best course of action to ensure optimal care of the plant. In addition, this product is great for data lovers, since the system will have WiFi capability, enabling users to track the success and failure of their plant over time. This makes the product ideal for all levels of plant care takers. Ranging from the knowledgeable owner who may just not have time to water their plant, to the very beginner who needs to reverse image search a picture of their plants to determine what the species even is.

There are many options for products which allow users to remotely monitor and care for their plants. Two of the systems which had the most success on the market, although their success was short-lived, are the Edyn and the Parrot.

The Edyn is a complex, two part system. The Garden Sensor tracks light, humidity, temperature, soil nutrition and moisture and cross references the information with plant, soil science and weather databases. The Water Valve automatically controls watering based on the Garden Sensor while adapting to weather forecast and also has a manual watering option through the app. This system is entirely solar powered, WiFi-connected and uses machine learning to analyze sensor data. The Edyn App can be used from a cell phone over WiFi. This product is mostly intended for large outdoor gardens rather than for indoor plants [3].

Parrot has two types of products, a pot with sensors and a stand-alone sensor which can be placed into an existing pot. The Parrot Pot Sensors include capacitive soil moisture sensor, fertiliser level sensor, light sensor, and air temperature sensor. Connection via Bluetooth and has an app to download on your phone. It also uses "Perfect Drop" irrigation system to water plants when sensors deem necessary. Works indoors or outdoors, but is a full pot to buy. The Parrot Flower Power sensor is a wireless Bluetooth smart plant sensor that works through an app. It has the ability to chart data over time and tells the user what to change in a to-do list which is does not get automatically updated as tasks are completed. The sensor gives specific data about the status of the plant, but does not indicate what the ideal levels for the specific plant are. These Parrot products are no longer sold and one of the main challenges was that in order to obtain any data from the Flower Power sensor you must be physically close to the device which limits monitoring and the Pot had too many direct competitors such as the Edyn, which was able to secure a contract with Home Depot and control the market [10].

Aside from products, such as those made by Edyn and Parrot, that have made it to market, there is a lot of research and development of technologies in this space. As a result, there are a plethora of patents for plant specific sensors such as Soil Moisture Sensors [12], Plant Growth with LED Lights [9] and more general Environmental Sensors [8].

The EcoDuino [2] platform is a useful kit which can be used to automatically water plants and message plant data through wireless communication. This kit is similar to the model which will be implemented in this project; however, the sensors and actuators in this project will have more objective data points to collect and compare to the ideal values as determined from a database and will also have room for more user interaction with a live-stream video of the plant which will accompany the data.

The EcoDuino is the closest product on the market that features parts of what our system hopes to achieve, as discussed above. However, it requires the user to preprogram the desired actions for which it will take through the Arduino interface. Therefore, a prior knowledge of implementation is required of the user before they can use the product. In addition, it only has the capability to measure soil moisture and temperature, where we propose the addition of the light sensor to ensure a higher quality of care for the plants. Furthermore, the device does not allow for plant specific parameters to be implemented. For example, the EcoDuino does not distinguish between shade loving and sun loving plants, which can cause key differences in care taking. In summary, we hope to present a product that is more user friendly than what is already available.

The metrics of speed and environmentalism (use of plastics, minimal over watering) are all fairly comparable for the various products being considered, since they all respectively act at a need to need basis, use plastics, and aim not to over water the plants. This leaves the cost comparison as the final metric to consider. The Edyn rings in at $170, EcoDuino costs $53. This leaves our product with a hard target to beat in order to stay competitive in the market. However, though the cost of product testing and design will may exceed $50, over time the amortized cost of producing our product aims to be lower. Further research will need to be done to determine the final costs.

II. Component Architecture

This section will address the architecture to be implemented for each of our component sensors. The goal of our design is to eliminate the use of breadboards and pre-bought parts through the use of custom PCB designs.

A. Soil Moisture Sensor

The soil moisture sensor to be implemented is very simple and designed to be used in conjunction with a microcontroller. It effectively measures the conductivity of the soil, because with a higher water (ion) content a stronger electrical connection is formed. This leads to the obvious question: how does one account for the salt level in the soil? Residual salts in the in the soil are common, and could cause a false positive reading. However, the design to be implemented [13] uses a resistor designed to be tuned to the correct level of sensitivity to match the soil content. We acknowledge that though there will always be outliers in soil types used, the average soil can be accounted for in this design. With the above discussion in mind, the schematic was tested at the bench and noted very reliable. The schematic is shown in Figure 1, and the operating specs are given in Table I.

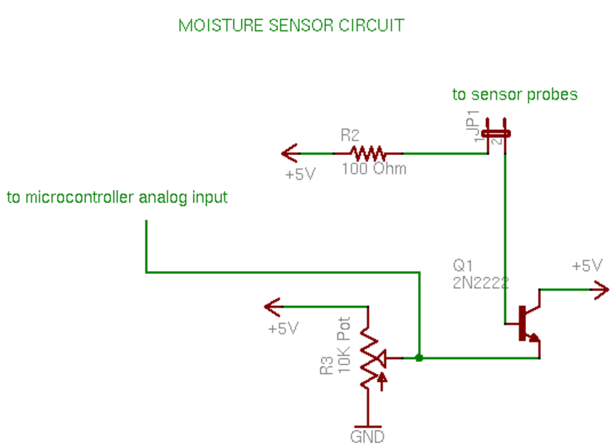

Fig. 1. Schematic of the Soil Moisture Probe [4]

The probes are constituted of a metal material, such as a stainless steel rod. Together, they act as a variable resistor. The more water that is in the soil means the better the conductivity between the pads will be and will result in a lower resistance,

Variable	Voltage Range
VCC	3.3V - 5.0V
SIG	0.0V - 5.0V

TABLE I
Soil Moisture Sensor Specs

and a higher signal out (SIG). The transistor is intended to amplify the very small amount of current that goes through the soil. In order to preform the salt content calibration, one needs to trim the variable resistor so that it is just low enough that it does not pull the output to ground. The length and spacing of the rods are not variables of much concern, as long as they are not touching.

B. Light Sensor

The light sensor to be implemented is relies on UV/Ambient Light Sensor (Si1145/46/47) designed by Silicon Labs[11]. The Si1145 is a low-power, reflectance-based, infrared proximity, UV index and ambient light sensor with I2C digital interface and programmable-event interrupt output. This device offers excellent performance under a wide dynamic range and a variety of light sources including direct sunlight[5].

One salient design feature of this device is its autonomous operation mode, which allows measurements to be taken automatically without any external commands. The device features an analog to digital converter. Using the SCL and SDA output pins, the amount of UV, IR, and Vis light can be determined. Further information on testing and wiring can be found at its Adafruit host site[7]. The functional block diagram and the schematic of the device are shown below in Figures 2 and 3.

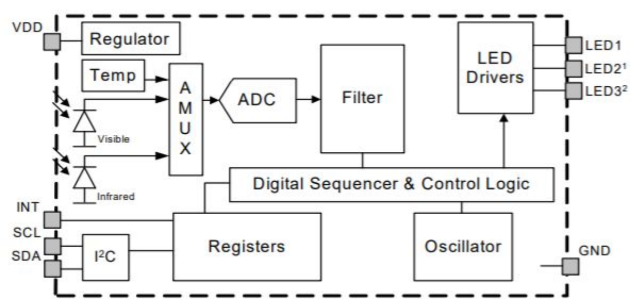

Fig. 2. Si1145 Functional Block Diagram [11]

With the workhorse of the light sensor examined, we can now build the supporting circuitry presented in Section III. The overall specs of the chip in Table II.

Variable	Range
Operating Voltage	3.0V - 5.5V
Working Current	3.5mA
Wave Length	280-950nm
Operating Temperature	-45-85^oC

TABLE II
Light Sensor Specs[5]

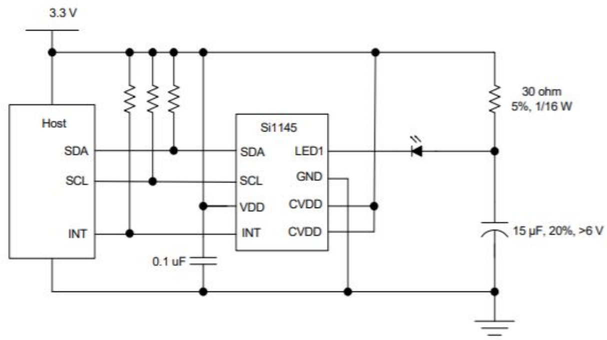

Fig. 3. Si1145 Basic Application [11]

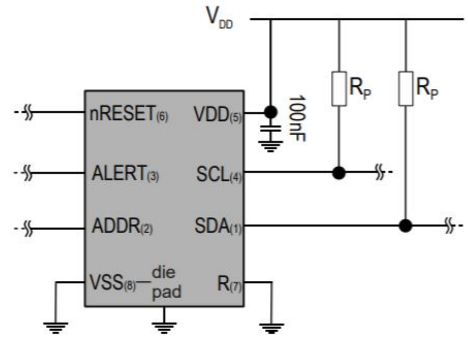

Fig. 5. SHT31 Basic Application [6]

C. Temperature Sensor

Because the temperature of an indoor environment is fairly stable, it is important to use and design a sensitive device. We will base our design on the popular temperature and humidity sensor SHT31 from Seeed Studios[6]. The PCB design of the device is in the public domain, and we will replicate their design and fabricate it ourselves. The SHT31 sensor is extremely accurate, and also has the capability to measure humidity levels. The functional block diagram and schematic are shown below in Figures 4 and 5.

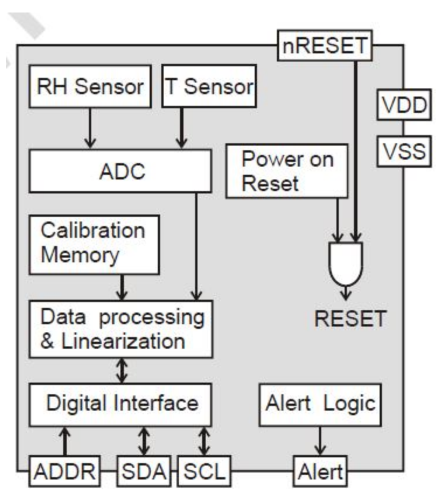

Fig. 4. SHT31 Functional Block Diagram [6]

Due to the compactness and usability of the proposed device, it should be easy to interface with our design and microcontroller. The specs are given in Table III.

Variable	Range
Operating Voltage	3.3V - 5.5V
Current Consumption	$3.5\mu A$
Operating Temperature	-45-125^oC
Accuracy	$\pm 2\%$

TABLE III
TEMPERATURE SENSOR SPECS[6]

III. DESIGN IMPLEMENTATION

The goal of our design is to create a modular system which can rely on different combinations of sensors to allow user customization with respect to the different sensors used. The sensors which are being considered for PCB design are the Moisture Sensor, the UV/IR/Light Sensor, and the Temperature Sensor. The customer may elect to incorporate as many or as few of these sensors as they wish. The project will incorporate all of the sensors, whether or not the PCB is able to be designed in the allotted time.

The pot design entails two compartments: the top which will have the sensors and the plant (the components which will be exposed in this compartment will be waterproof) and the bottom which will house the Raspberry Pi and will remain dry. One critical design challenge is allowing the sensors in the top compartment to communicate with the Raspberry Pi in the bottom compartment.

All of the code and PCB designs governing the project are uploaded to GitHub in our EDL repository at [1].

Fig. 6. Visualization of Final Product

A. PCB Design

The three sensors selected to implement were the temperature sensors, the UV/IR/Visible light sensor, and the soil moisture sensor. To preserve the modularity of our design, each sensor was placed on its own seperate PCB board. This allows for the sensors to be independently placed from each other. Parts and footprints were download from the open source DigiKey master library.

Below, the schematic and layout for the soil moisture sensor is displayed in Figures 7 and 8.

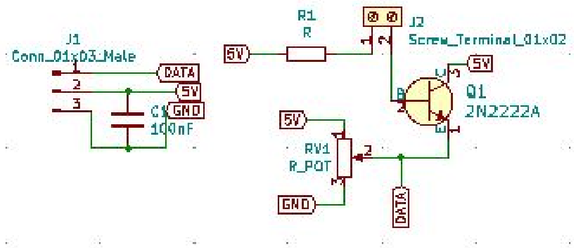

Fig. 7. Schematic of the soil moisture sensor

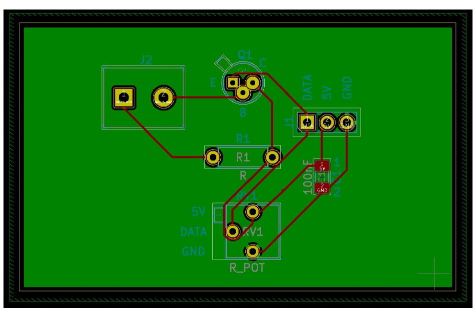

Fig. 8. Layout of the soil moisture sensor

Next, the schematic and layout for the temperature sensor is displayed in Figures 9 and 10. The design is very simple, relying solely on the IC as the hub of the PCB, and placing headers to allow us to interface the chip with the RaspberryPi.

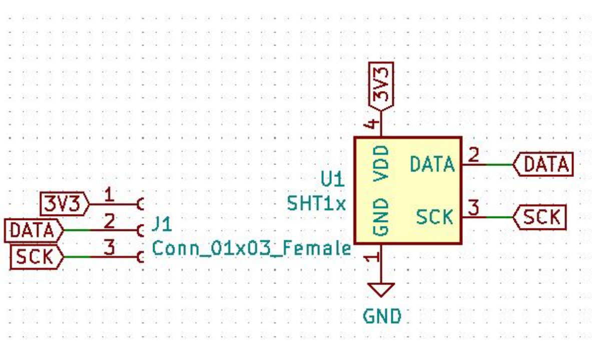

Fig. 9. Schematic of the temperature sensor

Finally, the schematic and layout were designed for the light sensor and are given in Figures 11 and 12.

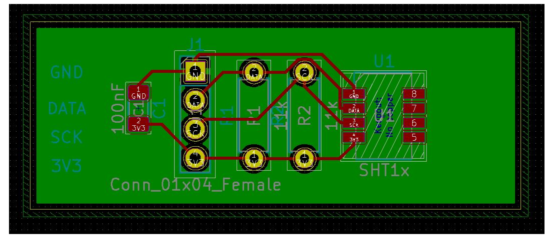

Fig. 10. Layout of the temperature sensor

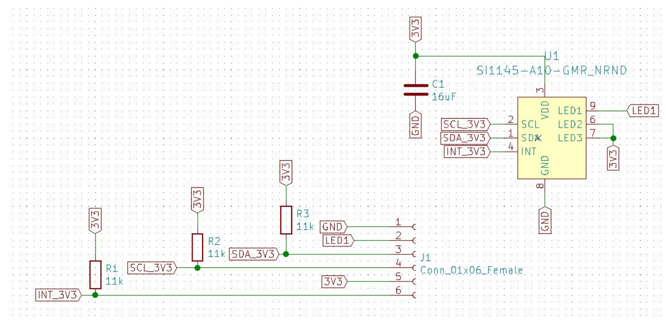

Fig. 11. Schematic of the light sensor

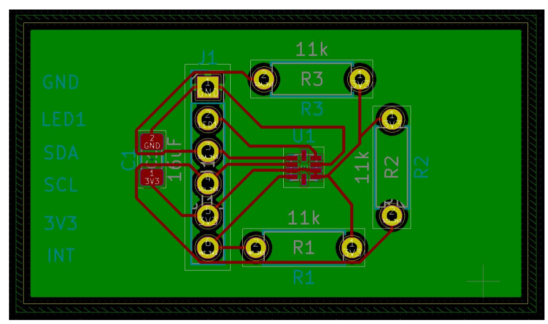

Fig. 12. Layout of the light sensor

B. Software

The Raspberry Pi will be programmed to work for all three of the sensors. The sensors will collect data points continuously and send the information to the Raspberry Pi. The Raspberry Pi will be processing the data as it is received and tracking it over time. Once the predetermined thresholds are met indicating low levels of moisture, a need for more light or an unsuitable temperature, the Raspberry Pi will send a message to the user via an LCD screen.

C. User Commands and Actuation

Using the data collected from the three sensors, we can list the commands given in response to the current environment. We begin by giving the commands for the soil moisture sensor in Table IV. Because we read in an analog value, the potential values range from 0.0V to 5.0V. Therefore, we tune the system to have a threshold of 2.5V to determine if sufficient water is present in the plant or not.

Next, we list the commands given to the user based off of the temperature of the environment in Table V.

Value	Command
mois > 2.5	'Water Levels Sufficient'
mois < 2.5	'Needs Water'

TABLE IV
MOISTURE VALUES AND COMMANDS

Value	Command
temp > 100	'Too Hot'
$55 <$ temp < 100	'Temperature Sufficient'
temp < 55	'Too Cold'

TABLE V
TEMPERATURE VALUES AND COMMANDS

Finally, we list the commands given to the user based off of the light levels in the environment in Table VI.

Value	Command
vis > 300	'Light Levels Sufficient'
mois < 300	'Needs Light'

TABLE VI
MOISTURE VALUES AND COMMANDS

IV. RESULTS

To fully capture the final product, a video highlighting its features is posted to my GitHub at [1]. In the video, there is a demo displaying the functionality of each sensors. It is demonstrated the effects of having the probes in a water and un-watered plant to show the soil moisture sensors and appropriate commands. It demonstrated the effect of shining a light on and off the pot to portray the effects f appropriate sunlight. Finally, an ice pack is used to display the effects and resulting commands of moving the pot into too cold of an environment. The stats are successfully shown in real time on the OLED display screen during the demo.

In Figure 13, a snapshot of the final product is displayed. The product is currently off, and the sensors and display can be seen on the rim of the product. As shown in the demo video, the final product is fully functional and ready to be put to use to any user who does not have much plant-based knowledge!

V. CONCLUSION

This project successfully demonstrated our working knowledge of many core concepts of Electrical Engineering. Ms. Abella was in charge of all systems engineering and software design, as well as spear-heading the documentation of this project. Ms. Cohn demonstrated apt knowledge in the principles of PCB design and hardware engineering, as well as being in charge of the assembly of this project. In the future, there is work to be done to bring this product to the shelves of consumers, but a working prototype has been presented in this paper. In the future, work can be done to make the pot give care recommendations specific to plants and climate, as well as being able to send data to the user's computer.

Fig. 13. Image of Final Product

VI. ACKNOWLEDGEMENT

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