Bee Hive Monitoring System Prototype

Harrison Fletcher

1.0 Introduction

The interior climate of a beehive is vital for a healthy colony and efficient honey production. Knowing the interior temperature and humidity will give the beekeeper an indication of colony health. A healthy colony will work to strictly regulate the temperature of the brood nest (the part of the hive where eggs are laid and developed into young bees) (Figure 1). The bees heat the brood nest by pressing their thoraxes to the brood cells. In summer, bees achieve a cool air flow by fanning their wings near the entrance of the hive.

Figure 1: Brood Nest Frame Removed from a Langstroth Hive

Any deviation from optimal brood nest temperature (32-35 °C) could be due to loss of brood production or inadequate hive setup (e.g. poor ventilation or insulation). Loss of brood production can occur due to loss of queen, disease, pests, abandonment etc.. A prudent beekeeper must act quickly and effectively to restore the hive to health and mitigate further losses. Being able to track the temperature and humidity of the brood nest will allow beekeepers to monitor for any abnormal conditions that will require a hive inspection.

2.0 Prototype Objectives

The prototype project will aim to achieve the following.

- Measure the interior hive temperature and humidity of a standard 10 frame Langstroth hive (Figures 2 and 3)
- Transmit data to the internet with a Wi-Fi transmitter
- Supply power with rechargeable battery's
- Recharge battery with solar energy

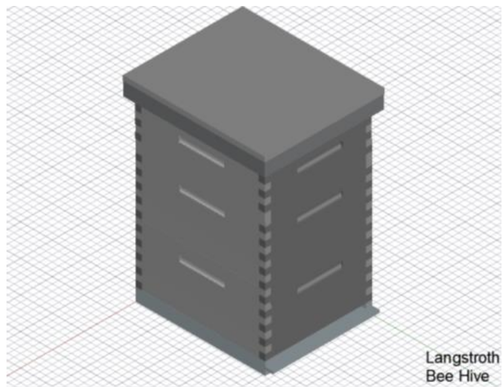

Figure 2: Langstroth Hive

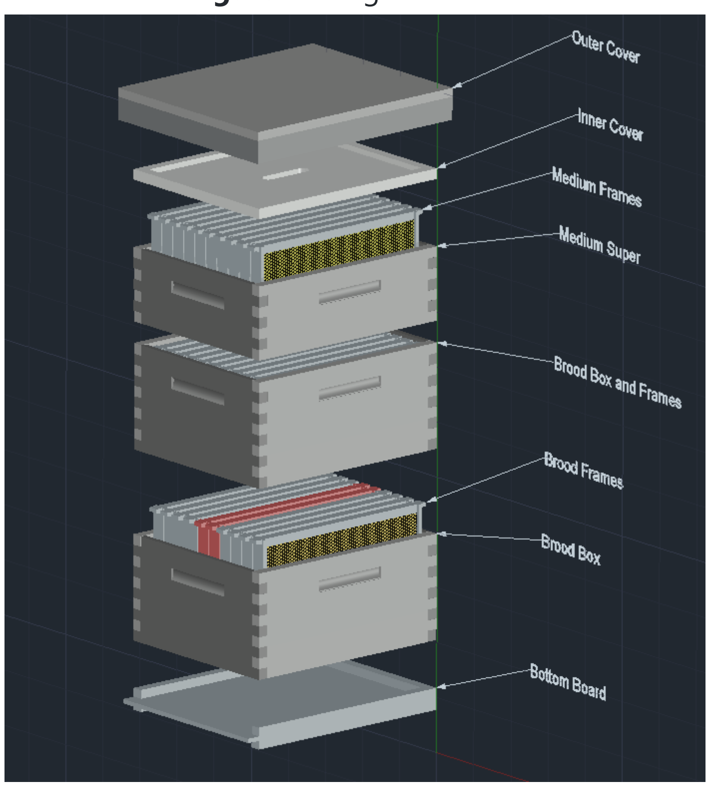

Figure 3: Langstroth Beehive Components

3.0 Constraints

The following constraints are imposed by the nature of bees and the beehive environment. They must be considered when designing the prototype.

- Bee Space
    - Bee space refers to the dimensions of open space which occur between the combs and interior walls of a natural bee hive
    - Bee space is commonly said to be between 4.5 mm and 8.0 mm, which is approximately the gap bees require to pass freely (Figure 4)
    - Violating bee space (i.e. creating open space dimensions greater than 8.0 mm or smaller than 4.5 mm) can cause bees to fill the space with extra comb, making hive inspection more difficult
    - Violating bees space may also provide pests such as the small hive beetle an area unreachable by worker bees, allowing the pests to multiply uncontrolled within the hive.

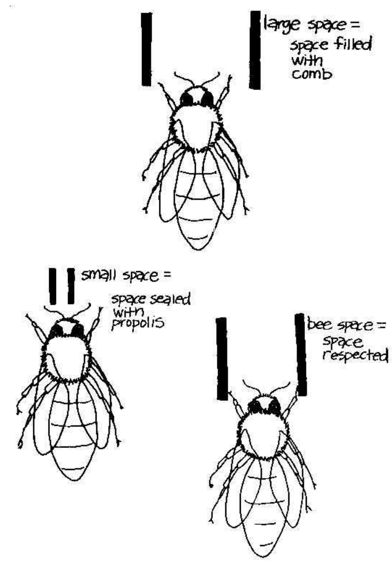

Figure 4: Bee Space [1]

- Size
    - The interior of a Langstroth hive provides little free space for the prototype to be mounted.
    - In the 10 frame Langstroth hive that this prototype is designed to function in, approximately 1.54 cm between each frame and 2.63 cm between frame the top of the lower frames and bottom of the upper frames.

4.0 System Implementation

The following section details the prototype's components, circuits, software and power system

4.1 System Overview

The prototype will be based on a low cost ESP8266 Wi-Fi Module. The ESP8266 has become exceedingly popular amongst makers due to its affordability, small size and plethora of features. The following block diagram displays the system components and connections required to satisfy the proposed objectives. (Figure 5.) For storing energy, a lithium ion battery has been chosen due to high energy densities the lithium ion chemistry can offer. High energy density is necessary for maximizing the amount of stored energy while also maintaining the required compact size. Charging a lithium ion battery requires additional circuitry to prevent overcharging and discharging power while the battery supplies less than the specified cutoff voltage.

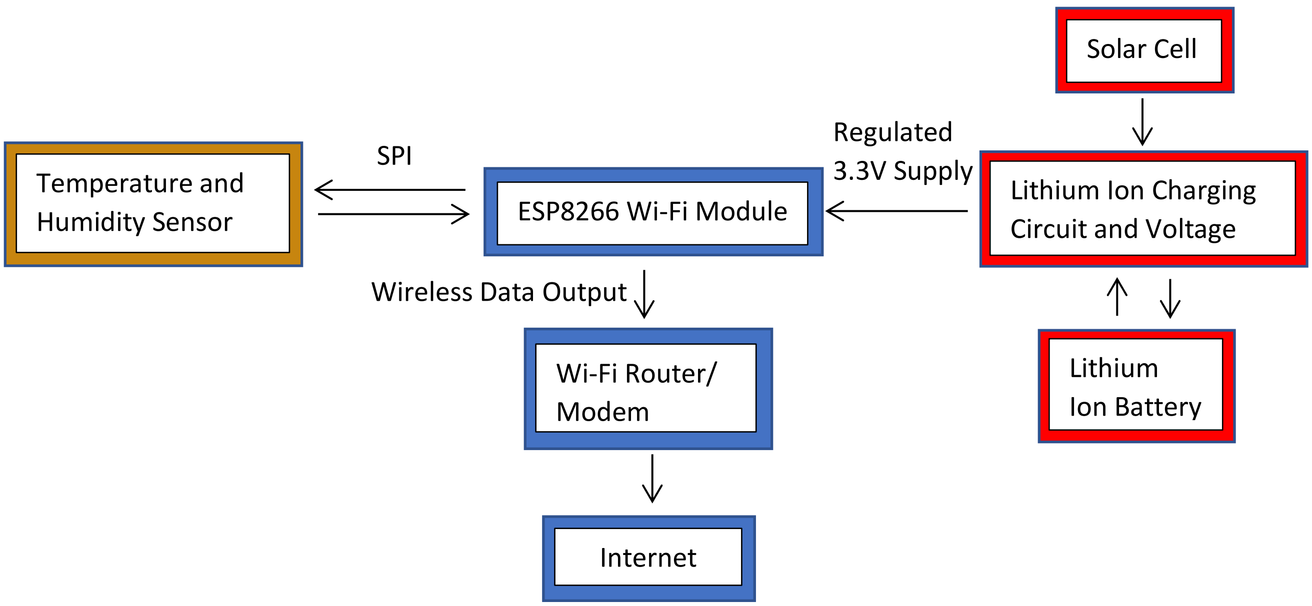

Figure 5: Block Diagram

Temperature and humidity measurements will be achieved with a digital sensor and communicated to the ESP8266 through the integrated serial peripheral interface (SPI). The measured data is transmitted to a local Wi-Fi router and sent to the appropriate internet address to be read by the user.

3.2 Power System Design Considerations

To maximize efficiency a low drop out regulator has been selected. Initially a LM1117T regulator was used to regulate the 5V supplied to the prototype from a USB connection. While the LM1117T is ideal for this application, it will not be able to supply the required 3.3 V to the ESP8266 when connected to a 3.7 V lithium ion battery. This is because the LM1117T has a drop out of 1.2 V, meaning that if the battery supplies 3.7 V, the regulator will output a maximum of 2.5 V [2]. Therefore, the selected voltage regulator must have a drop out less than 0.4 V.

As stated earlier, charging a lithium ion battery requires additional circuitry to avoid overcharging and discharging below cut off voltage. In addition to these situations the variable voltage and current supplied by the solar panel must also be considered. Many lithium ion charger integrated circuits (ICs) are available which can provide the required protection to avoid these situations.

Under normal operating conditions, the prototype draws 83 mA with peaks of 110-120 mA when transmitting (Figure 7). According to the data sheet, the ESP8266 draws its maximum current of 215 mA when transmitting with 802.11b protocol [3].

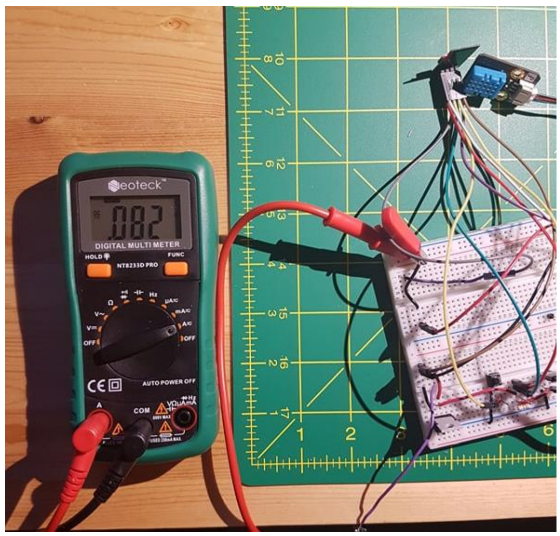

Figure 7: Measured Input Current Under Normal Operating Conditions

The regulator and solar charging IC should therefore be rated to supply a maximum of 250 mA. For prolonged operation the ESP8266 can enter deep sleep mode between measurements. In this state the ESP8266 only consumes about 10 µA. With measurement intervals set to every 5 min, the prototype will an average current of about 8.3 mA. In this case a 500 mAh battery should allow the prototype to sustain operation for about 60 hours.

3.3 Build of Materials

The following section provides a brief description of the primary components.

3.2.1 ESP8266 Wi-Fi Module

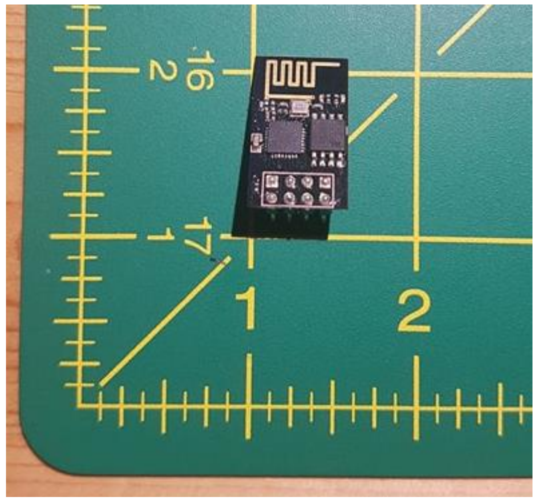

Figure 8: ESP8266 Wi-Fi Module

Often the ESP8266 is utilized as a Wi-Fi transmitter for an externally connected processor. However, with integrated features such as an onboard 80 Mhz RISC processor, 1MB of flash memory, programmable GPIO pins and a 10-bit ADC, the ESP8266 can operate as a standalone microcontroller unit. The ESP8266 comes equipped to communicate with other Wi-Fi devices with 802.11 b/g/n protocols [3].

3.2.2 DHT11 Temperature and Humidity Sensor

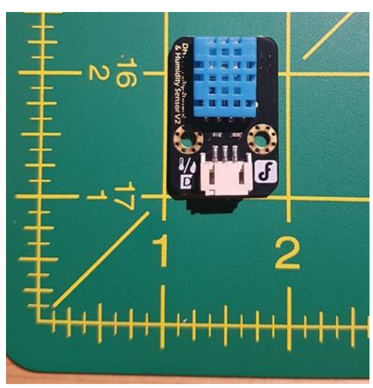

Figure 9: DHT11 Temperature and Humidity Sensor Module

The DHT11 is a low cost digital temperature and humidity sensor (Figure 9). This sensor has been selected for its low power consumption (maximum of 2.5 mA consumed when active) and long-term stability [4]. The sensor can easily be connected to the ESP8266 through the SPI. A minimum supply of 3V is required for operation.

3.2.3 Voltage Regulator

As stated in the provided data sheet, the ESP8266 module requires a 3.3 V supply to function properly. The MCP1825 3.3 V low drop out regulator is capable of regulating voltages up to 5.0 V with a typical voltage drop out of only 210 mV [5]. The rated maximum current output of 500 mA is more than enough to accommodate

3.2.4 Solar Cell

Power is generated with a 1W solar panel. The panel dimensions measure to be 100 mm x 75 mm. A clear epoxy coating seals the exterior of the panel, making it suited for outdoor applications [6].

3.2.5 Lithium Ion Battery

Figure 10: Lithium Ion Battery

Currently the prototype utilizes a 500 mAh lithium ion battery (Figure 10). This specific battery is especially compact with dimensions of 6.0 cm x 1.5 cm x 0.6 cm. Further testing is required to determine if a 500 mAh capacity can sustain the prototype indefinitely.

3.2.6 DFR0264 Lithium Ion Solar Battery Charger

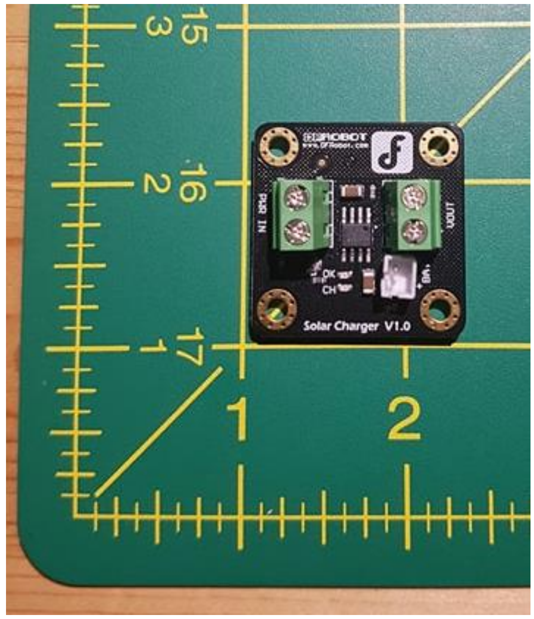

Figure 11: DR0264 Charger

The DR0264 is a solar powered lithium ion battery charging module based on a CN3083 charger IC (Figure 11 and 12). The provided terminal blocks and pin headers provide convenient, solder free, connections to the solar panel, battery and load circuit. This feature is particularly useful for testing and troubleshooting as batteries and solar panels may be swapped out with ease. The DR0264 can supply a maximum charge current of 500 mA and is configured to operate with only 3.7 V lithium ion batteries [7].

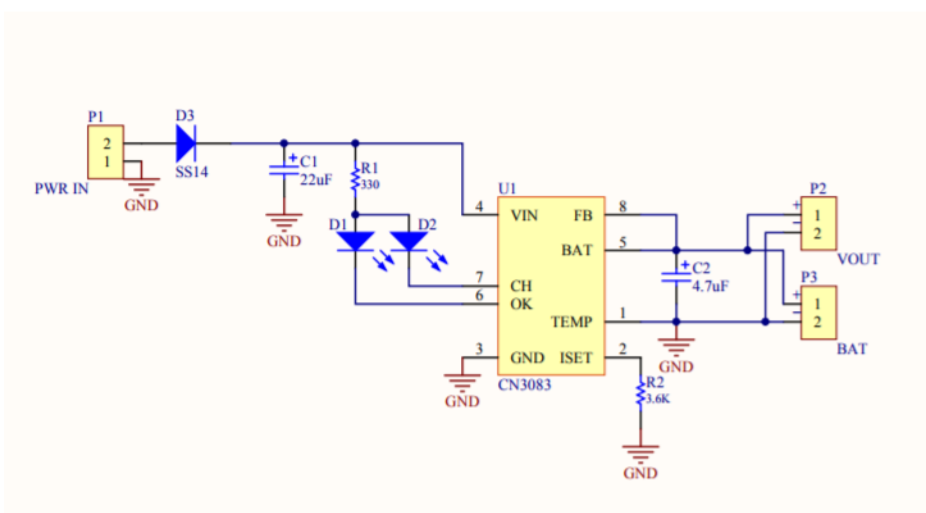

Figure 12: DR0264 Charger Schematic [8]

3.4 Circuit

The following KiCad schematic displays the circuit prototype (Figure 13). A push button is provided to easily choose between boot modes when power is applied (Table 1). Pin headers allow for external serial connections. This allows the user to issue software revisions the on board flash memory.

GPIO 0	GPIO 2	Boot Mode
Low	High	Download code from UART connection
High	High	Boot from flash storage

Table 1: ESP8266 Boot Modes

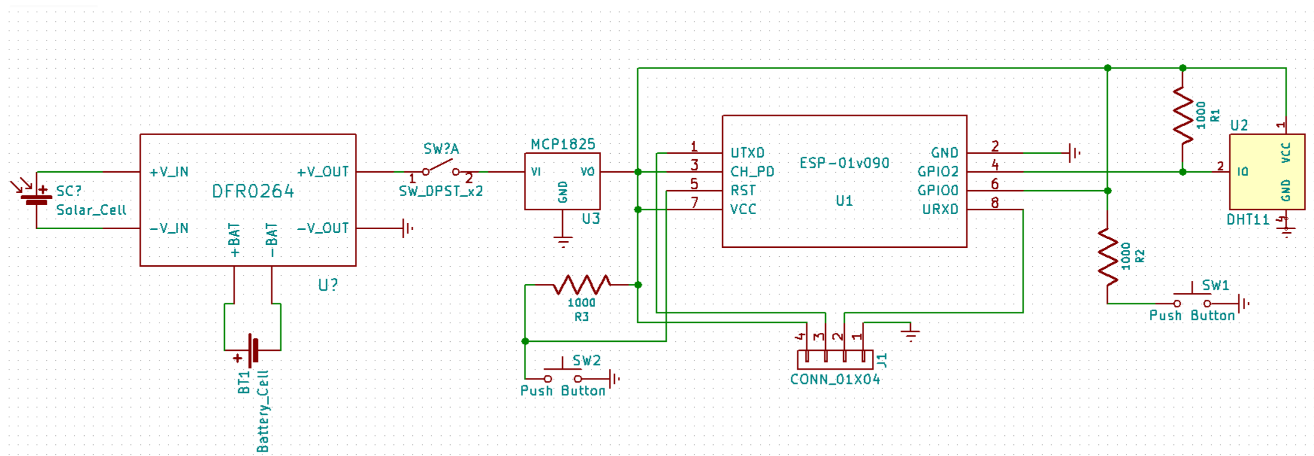

Figure 13: Circuit Schematic

3.5 Software

Currently there are many options for programming the ESP8266 with languages such as C/C++, Basic, LUA and Python. This prototype executes C++ code written and compiled with the Arduino IDE [9]. After executing all instructions required to achieve and transmit temperature and humidity values, the code puts the ESP8266 into a timed deep sleep state. After the specified time has elapsed, code execution resumes from the beginning of the program. The provided ESP8266WiFi library contains a plethora of functions required to achieve Wi-Fi connections and transmit data. Additionally, Adafruit Industries has provided a library for the DHT range of temperature and humidity sensors [10]. This library allows measurements to be achieved with single function calls. The data acquired is transmitted to a ThingSpeak channel via a connection to the local Wi-Fi network. ThingSpeak is a internet of things (IoT) platform which allows users to analyze and track data transmitted from IoT devices [11]. ThingSpeak is perfect for this prototype because it is extremely easy to implement, provides a slick interface with built in analytics and is free of charge.

Please visit the following Github repository for the current code:
https://github.com/hpfletch/BeeHiveMonitoring

7.0 References

[1] http://www3.telus.net/conrad/5.htm
[2] http://www.ti.com/lit/ds/symlink/lm1117.pdf
[3] https://nurdspace.nl/images/e/e0/ESP8266_Specifications_English.pdf
[4] http://image.dfrobot.com/image/data/DFR0067/DFR0067_DS_10_en.pdf
[5] http://ww1.microchip.com/downloads/en/DeviceDoc/22056b.pdf
[6] http://wiki.seeedstudio.com/index.php?title=1w_Solar_Panel_75*100
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[10] https://github.com/adafruit/DHT-sensor-library/blob/master/DHT.h
[11] https://thingspeak.com/