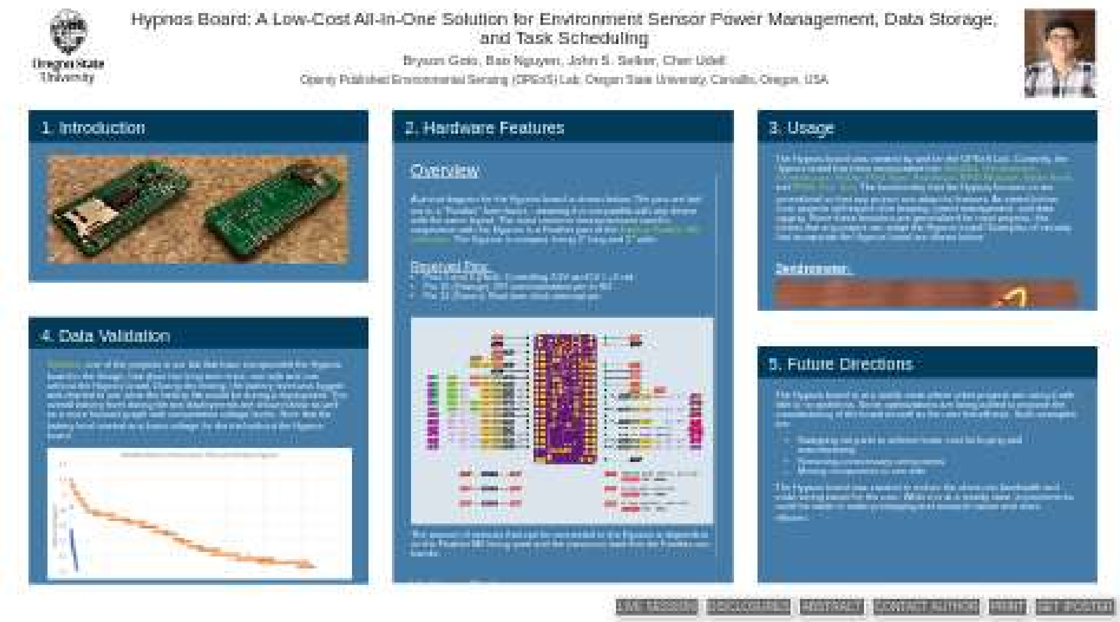
Hypnos Board: A Low-Cost All-In-One Solution for Environment Sensor Power Management, Data Storage, and Task Scheduling



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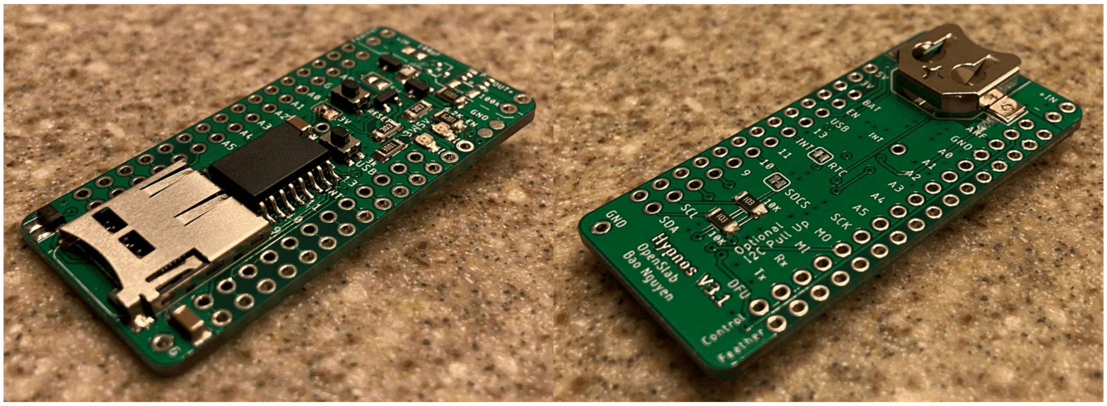
PRESENTED AT:

1. INTRODUCTION



Sensors deployed in the field need to measure and record data at known, pre-determined times for the desired period of collection. To meet these objectives, sensing systems typically require a suite of tools such as microprocessors, real-time clocks, SD card holders, power relays, and specialized software. Off-the-shelf hardware (e.g. Adafruit FeatherWings (https://learn.adafruit.com/adafruit-feather/overview)) and software (e.g. Adafruit's Sleepydog library (https://github.com/adafruit/Adafruit_SleepyDog)) are available individually to create such systems

In contrast, the Hypnos board was designed as an add on to a microprocessor (Adafruit M0) to incorporate these common functionalities into one electronic package with the added capabilities of providing different levels of voltage and complete shut off of sensors-- reducing the amount of required hardware as well as power consumed.

Resources:

GitHub Wiki (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/Hypnos)

Zenodo Repository (https://zenodo.org/record/4015581)

4. DATA VALIDATION

SitkaNet (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/SitkaNet), one of the projects in our lab that have incorporated the Hypnos board in the design, has done two long term tests: one with and one without the Hypnos board. During the testing, the battery level was logged and charted to see what the battery life would be during a deployment. The overall battery level during the two deployments are shown below as well as a more focused graph with comparative voltage levels. Note that the battery level started at a lower voltage for the trial without the Hypnos board.

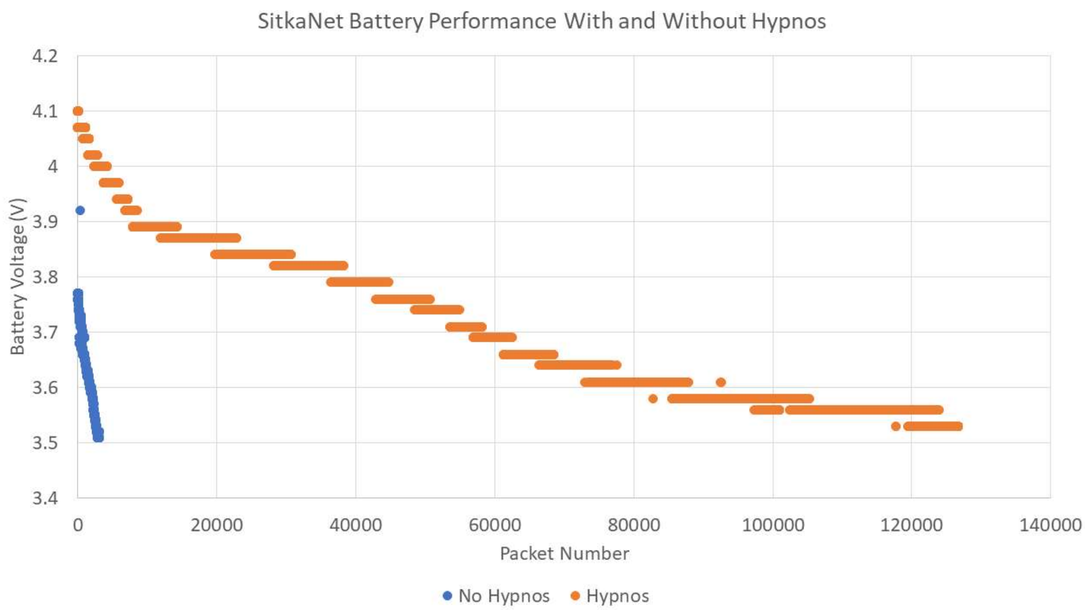


Figure 1: SitkaNet Deployment Battery Levels

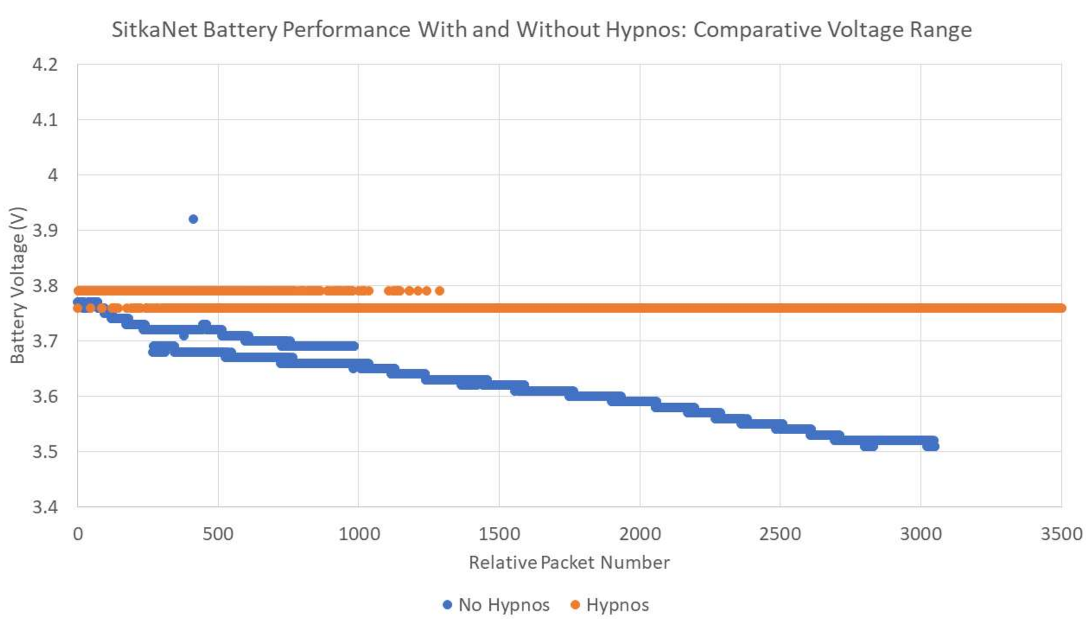


Figure 2: Relative Battery Level

Data Analysis:

The duration of the deployment over these tests were different, which can be seen through the difference in packets charted. However, the data can be compared through relative voltage levels as shown in Figure 2. There was a 5 minute interval in between samples for both tests.

For a comparative range of voltages (3.76/3.77 V to 3.53/3.51 V), the system using the Hypnos took 82,282 samples while the system without the Hypnos took 3,050 samples or 25x more samples-- meaning the trial with the Hypnos took over 25x more samples with the same amount of battery usage. This can be seen in the chart from the much steeper slope for the No Hypnos data. With the reduced sleep current (current between sample times), much less power is wasted and the battery levels last longer.

	Hypnos	No Hypnos	
Starting Comparative Voltage	3.76	3.77	V
Ending Comparative Voltage	3.53	3.51	V
Comparative Voltage Drop	0.23	0.26	V
Comparative Samples	83,282	3,050	
Average Voltage Drop / Sample Cycle	2.8	85	µV
Full Battery Voltage	4.1		V
Ending Battery Voltage	3.53		V
Total Voltage Drop	0.57		V
Total Samples	126,705		
Average Voltage Drop/Sample Cycle over entire Hypnos battery life:	4.50		µV

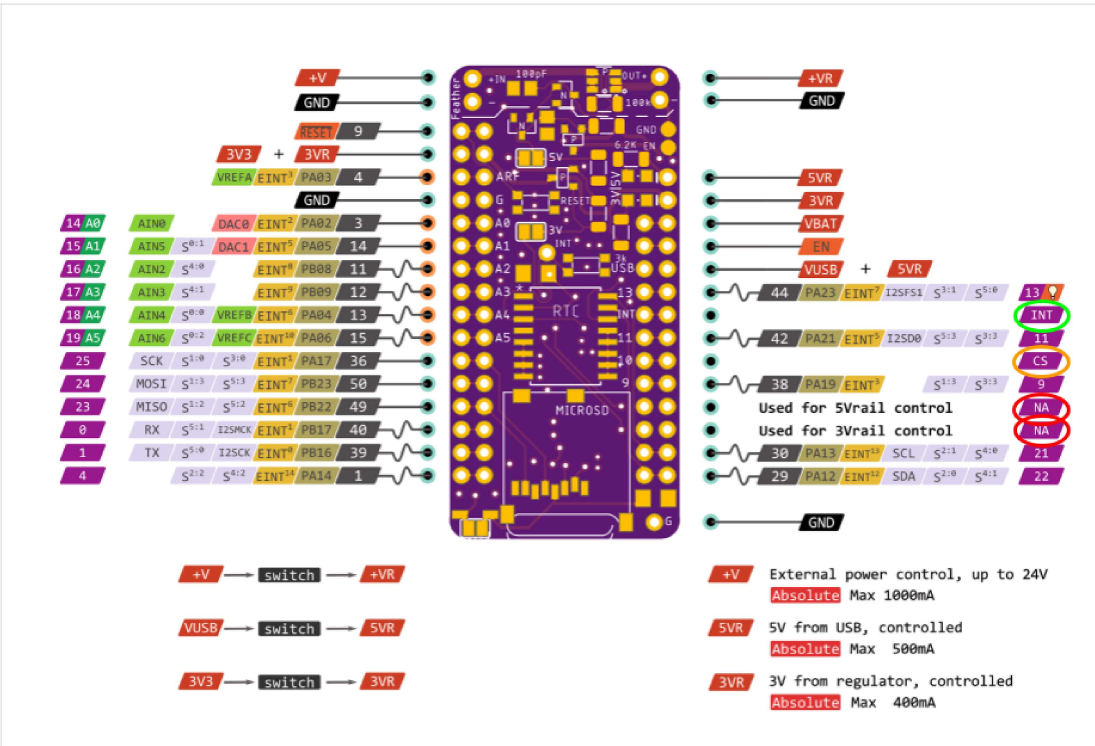
2. HARDWARE FEATURES

Overview

A pinout diagram for the Hypnos board is shown below. The pins are laid out in a "Feather" form factor-- meaning it is compatible with any device with the same layout. The most common microprocessor used in conjunction with the Hypnos is a Feather part of the Adafruit Feather M0 collection (https://www.adafruit.com/feather). The Hypnos is compact, being 2" long and 1" wide.

Reserved Pins:

- Pins 5 and 6 (Red): Controlling 3.3V and 5V / +V rail
- Pin 10 (Orange): SPI communication pin to SD
- Pin 12 (Green): Real time clock interrupt pin

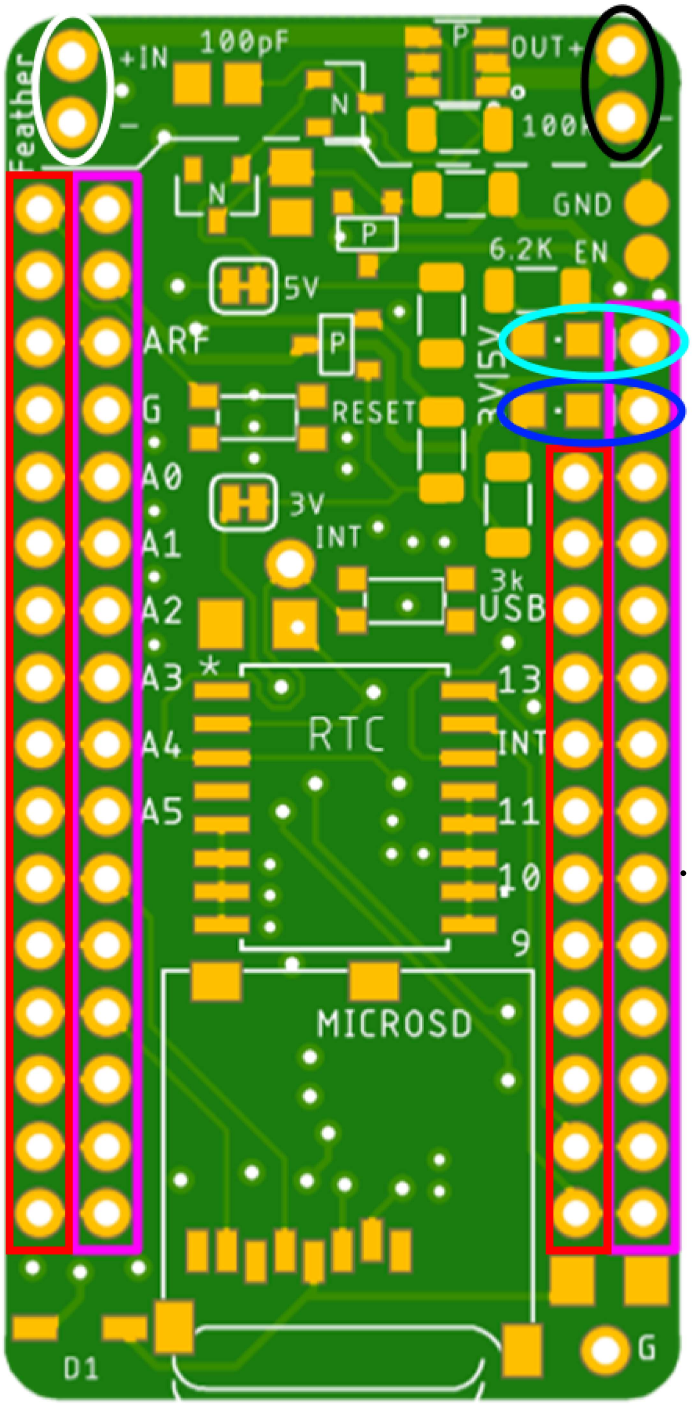


The amount of sensors that can be connected to the Hypnos is dependent on the Feather M0 being used and the maximum load that the Feather can handle.

Voltage Rails:

The Hypnos connects to other primary components using 2 different rails: the Feather rail (red boxes) and the sensor rail (purple boxes). The Feather rail connects to the Feather M0 microcontroller.

The sensor rail, shown in purple boxes, is where the sensors connect to. Any connection that would be connected to the Feather can be alternatively powered through the Hypnos board. There are a few exceptions to this rule where specific pins can not be used to connect to sensor, which is explained in the "Reserved Pins" section above. The most important aspect of the sensor rail is the controlled voltage rails that power the sensors: dark blue ellipse: 3V, light blue ellipse: 5V, black ellipse: +V, white ellipse: input for +V. These rails can be powered on and off at the developer's discretion-- which are specialized in power management.



There are three voltage rails to power sensors: a 3.3V rail (dark blue), 5V rail (light blue), and an extra voltage rail (+V rail, black). +V rail requires an external battery source (white ellipse) which may be rated at a maximum of 24V. The 3.3V rail and 5V rail are powered through a 3.7V LiPo battery connected to the Feather. However, the 3.7V LiPo battery only supports the 3.3Vrail. Without a power booster, the 5Vrail will display the voltage of the battery, not 5V. To use the 5Vrail with the 3.7V LiPo battery, a power booster should be connected to boost the voltage coming from the rail.

Real Time Clock (RTC) + SD:

For timekeeping and task scheduling, the Hypnos board includes a Real Time Clock (red box) and backup coin cell battery (not shown):

- DS3231 (https://datasheets.maximintegrated.com/en/ds/DS3231.pdf) (I2C Protocol):

o Precision: ±3.5ppm from -40°C to +85°C

o Time keeping: Times from years to seconds

- 1220 Coin Cell Battery (https://data.energizer.com/PDFs/cr1220.pdf):

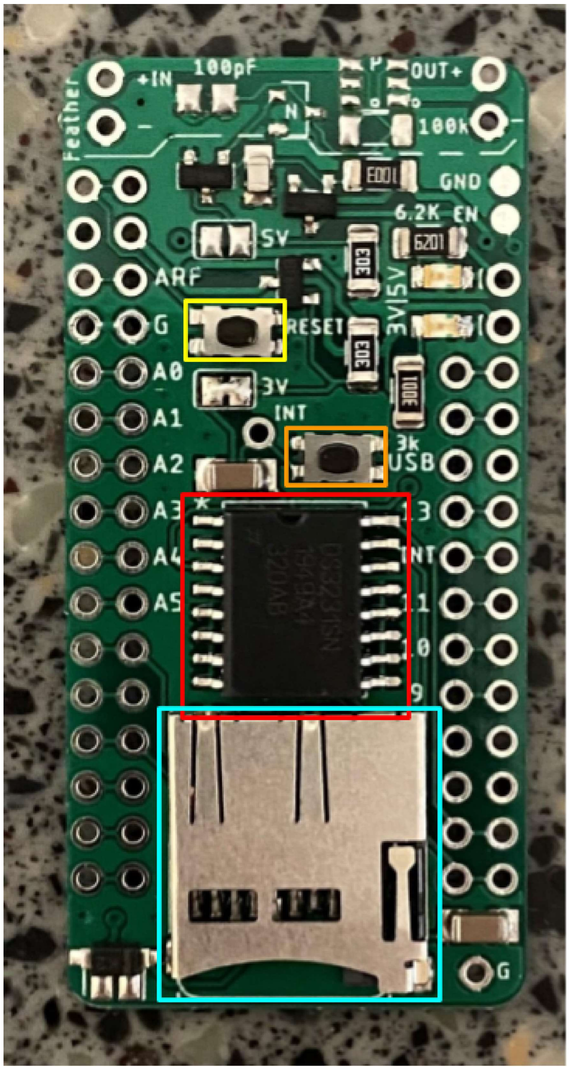
o 3.3V Lithium Battery

o Powers RTC for a minimum of 6 months (depending on temperature conditions)

For data logging and software storage, the Hypnos board includes a microSD card holder (https://www.adafruit.com/product/1660) (blue box) placed toward the bottom on the top of the board for convenient access

- Reset + Interrupt Button

o Reset button (yellow box): Sends reset signal to microprocessor

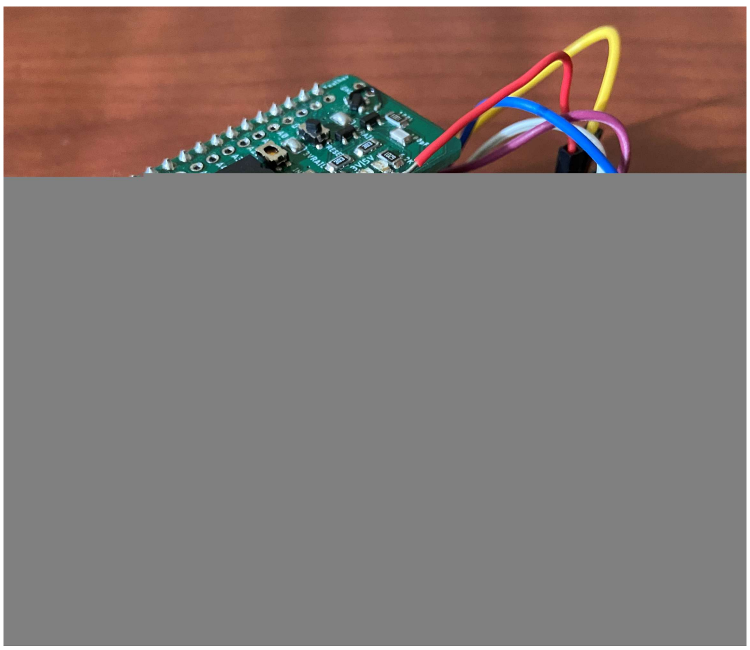


o Interrupt button (orange box): Sends interrupt signal to RTC-- waking it up from sleep

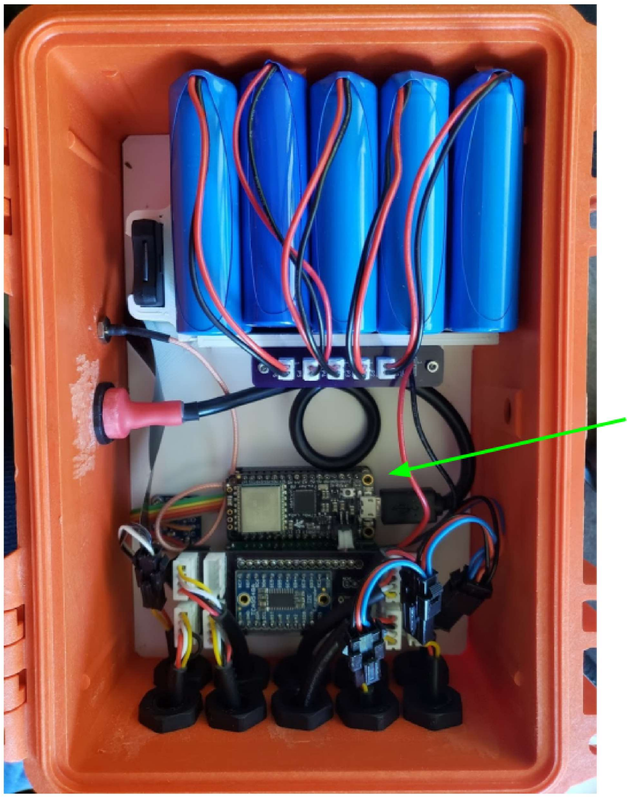
3. USAGE

The Hypnos board was created by and for the OPEnS Lab. Currently, the Hypnos board has been incorporated into SitkaNet (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/SitkaNet), Dendrometer (https://github.com/OPEnSLab-OSU/Dendrometer), eGreenhouse (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/eGreenhouse), FloDar (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/FloDar), Pied Piper (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/Pied-Piper), RainSavor (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/RainSavor), RFID Moisture (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/RFID-Moisture), Smart Rock (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/Smart-Rock), and PNNL Flux Tool (https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/PNNL-Flux-Tool). The functionality that the Hypnos focuses on are generalized so that any project can adapt its features. As stated before, most projects will require time keeping, power management, and data logging. Since these functions are generalized for most projects, this means that any project can adapt the Hypnos board! Examples of circuitry that incorporate the Hypnos board are shown below.

<u>Dendrometer:</u>



<u>SitkaNet:</u>



Software Considerations:

Using the Hypnos can be done through the Arduino IDE software. The 3V rail and 5V rail are controlled through the Feather's digital pin 5 and 6. Setting these pins as an output will set them to output power. To power the rails, the 3V rail should be set low and the 5V rail should be set high. The code should look like what is shown below. These lines are written in the Arduino setup function.

```
pinMode(5, OUTPUT);
digitalWrite(5, LOW); // Sets pin 5, the pin with the 3.3V rail, to output and enables the rail
pinMode(6, OUTPUT);
digitalWrite(6, HIGH); // Sets pin 6, the pin with the 5V rail, to output and enables the rail
```

During the loop function, the voltage rails are powered on and off at the user's discretion. In order to turn off the power rails, the following code needs to be written. This turns off the voltage rails and disables communication to the SD before going into deep sleep mode.

```
digitalWrite(5, HIGH); // Disabling all pins before going to sleep.
digitalWrite(6, LOW);
pinMode(23, INPUT);    // Disables SPI communication to SD before going to sleep
pinMode(24, INPUT);
pinMode(10, INPUT);
```

In order to reactive the power rail, the reverse needs to be done.

```
digitalWrite(5, LOW); // Enabling all pins after wake up has completed.
digitalWrite(6, HIGH);
pinMode(10, OUTPUT);  // Enables SPI communication to SD after going to sleep
pinMode(23, OUTPUT);
pinMode(24, OUTPUT);
```

Awakening the Hypnos requires an interrupt service routine to ensure all of the sensors and peripherals are awaken at the proper time. Each project will have their own service routine so programming that is relative to each project.

5. FUTURE DIRECTIONS

The Hypnos board is at a stable state where other projects are using it with little to no problems. Some optimizations are being added to improve the manufacturing of the board as well as the user friendliness. Such examples are:

- Swapping out parts to achieve lower cost for buying and manufacturing
- Removing unnecessary components
- Moving components to one side

The Hypnos board was created to reduce the electronic bandwidth and make wiring easier for the user. While it is at a steady state, improvements could be made to make prototyping and research easier and more efficient.

DISCLOSURES

This work is supported by the USDA National Institute of Food and Agriculture, Hatch project NI18HFPXXXXXG055, and the National Science Foundation award #1832170.

ABSTRACT

Open source in-situ environmental sensor hardware continues to expand across the geosphere to a variety of applications. These systems typically perform three fundamental tasks: sample sensors at a specified time or period, save data onto retrievable media, switch power to components on and off in between sample cycles to conserve battery energy and increase field operation time. This is commonly accomplished through integrating separate off-the-shelf components into the desired system such as: power relays, SD card hardware, Real-Time Clocks (RTCs), and coin cell batteries. To enable faster prototyping, the Openly Published Environmental Sensing Lab abstracted all of these requirements into a single PCB that can be dropped into any project to achieve these commonly-required capabilities. The hardware is laid out in a "Feather" form factor, a popular configuration in the open-source hardware community, to easily mate with other industry standard products. The onboard RTC acts as an alarm clock that wakes a user-attached micro controller from low-power sleep modes in between sample cycles. By integrating all these components into a single PCB, we save cost while significantly reducing physical system size. The design as well as a suite of code functions that enable the user to configure all the Hypnos board features are detailed. For more information, please visit

OPEnSLab-OSU/OPEnS-Lab-Home

This is the homepage for the Oregon State OPEnS Lab. - OPEnSLab-...

github.com

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