IoT Hardware & Firmware

Building an IoT Clock

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IEEE COMPUTER SOCIETY
Student Branch Chapter at the University of South Florida

UNIVERSITY of SOUTH FLORIDA
College of Engineering

Agenda

- IoT Recap
- Hardware
  - Voltage / Resistance / Current
  - Breadboard and Connecting Pins
- Firmware
  - Definition
  - Platforms
- Board Setup
  - Registration
  - Circuit Building
- Coding

IoT Recap

Internet of Things

Network of physical objects or “things” that are embedded with sensors, software, and other technologies to collect and exchange data with other devices and systems over the internet.

Examples of IoT Devices

- Fitness tracking devices
- Hospital call buttons

- Smart light bulbs
- Smoke Detectors (w/ internet)

- Automatic traffic lights
- Car computers (w/ internet)

IoT Systems

Microcontrollers:

- Nordic Semiconductor nRF
- Microchip Atmega

Development Boards:

- Particle Argon
- Arduino BLE

Platforms:

- Particle IO
- Amazon Web Services
- Cisco IoT

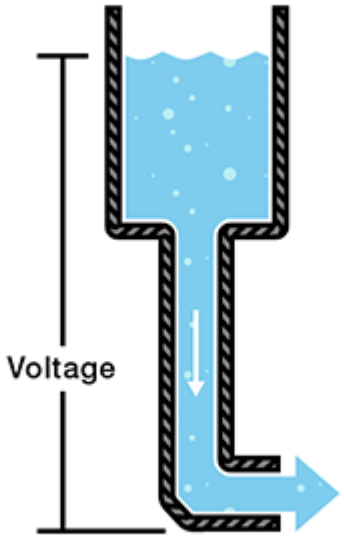
Hardware

Voltage

- Voltage is *Potential Energy*
- Similar to pipe water pressure
- All our hardware needs voltage

Common DC voltage levels:

- 5 V (max provided by most USB)
- 3.3 V (for lower power hardware)
- 3 V (coin cell battery)
- 1.5 V (AA & AAA battery)



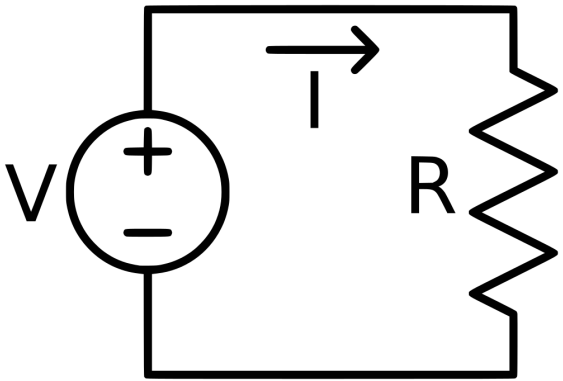
Resistance

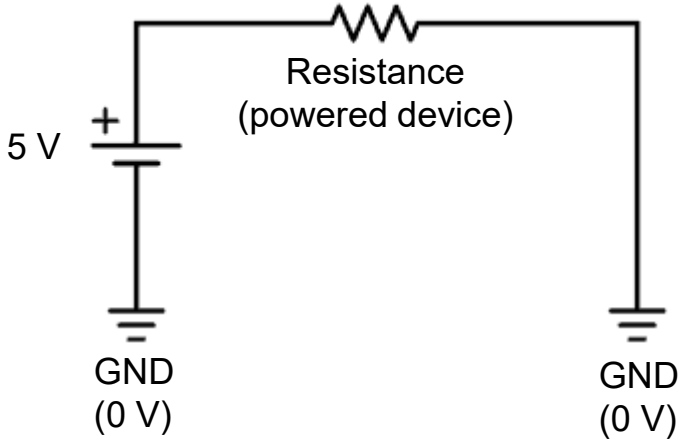
- Things we power have / need *Resistance*
- Similar to a garden hose faucet
- Having no resistance causes short circuit
- Your resistance will “spend” your energy

$$P = \frac{V^2}{R}$$

Current

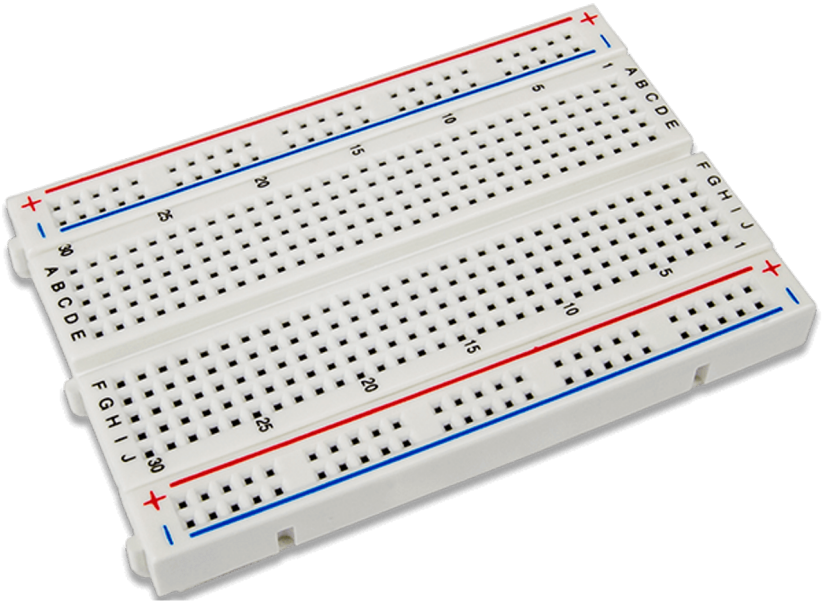
- Current is like the water which flows in our garden hose
- The base reference that voltage relates to is called *ground*
- We have to “drain” our voltages to ground voltage to get current



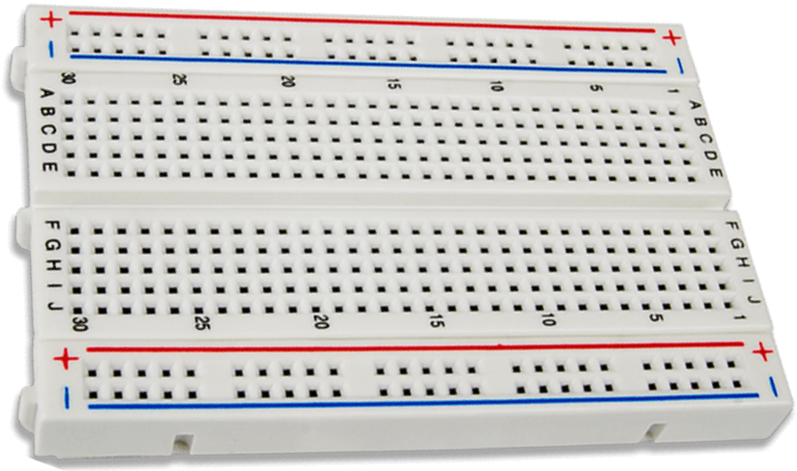


Breadboard

- Help develop without soldering
- Easy swapping of components
- Hidden “wires” to connect parts
- Slot in pins to make a circuit



Breadboard



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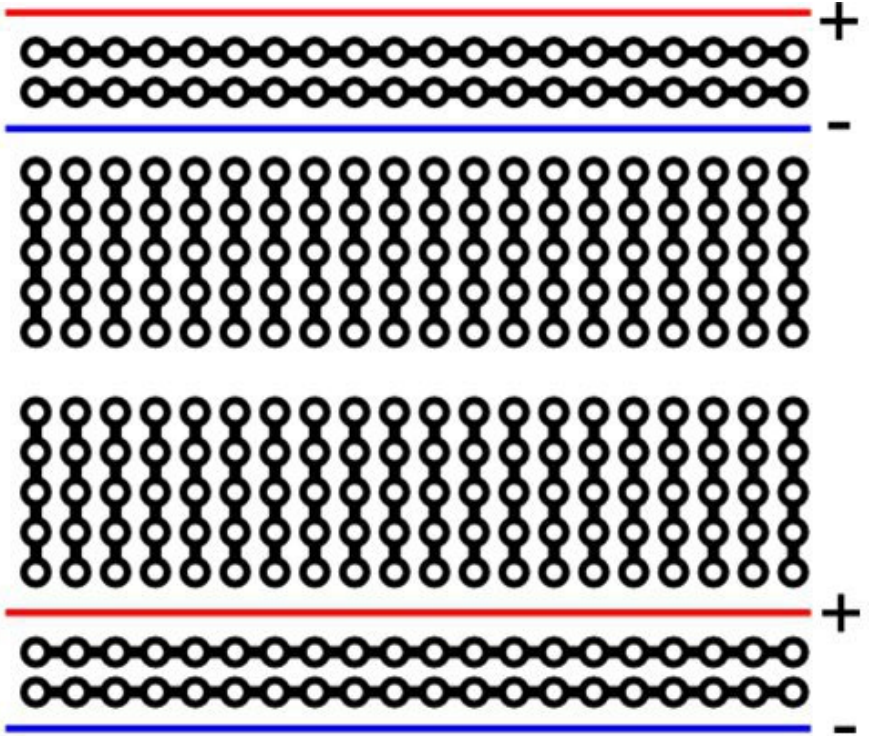
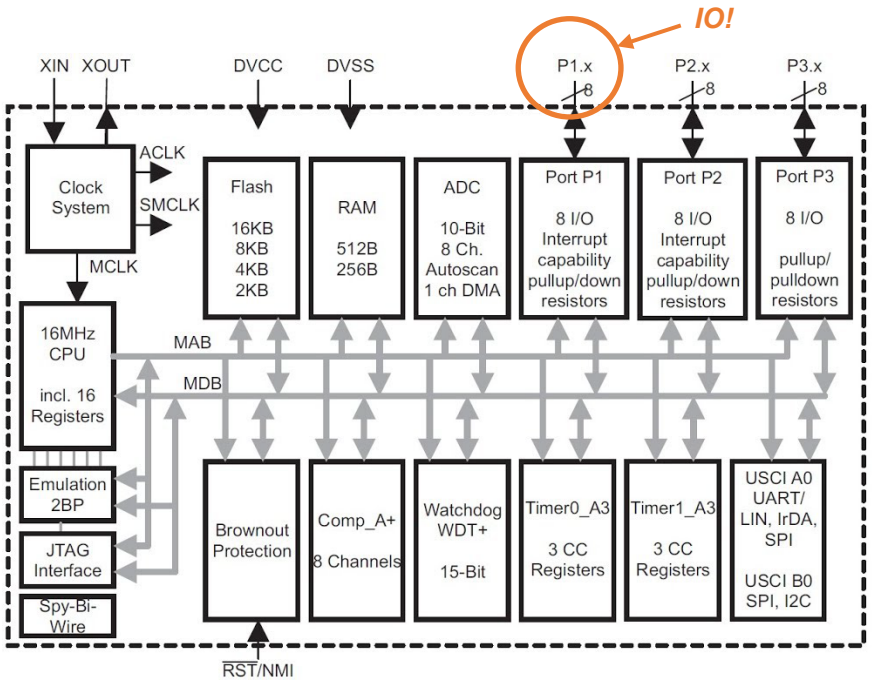


Firmware

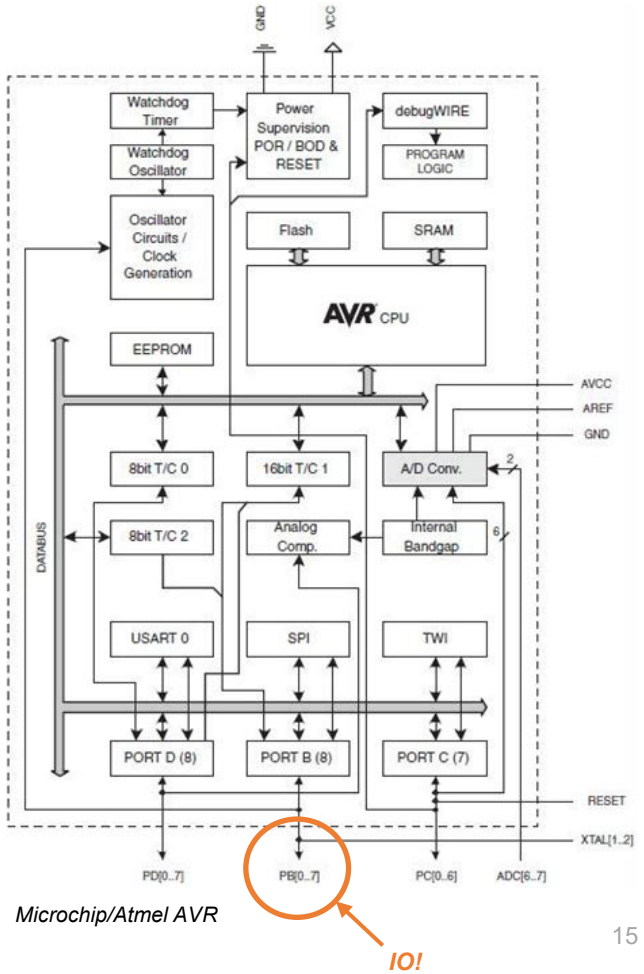
Firmware

- Code that directly controls hardware
  - Memory, interrupts, data transfer, boot process
- Most often programmed in C, but Rust use is growing
- Firmware is everywhere!
  - BIOS, SSDs, keyboards, IoT devices etc.
- To write firmware, you must first understand the hardware
- Every processor architecture requires specific firmware

Chip Architectures



Texas Instruments MSP430



Microchip/Atmel AVR

Embedded C

- The same thing as C, but with compiler-specific macros
- No libraries, you must read the chip's documentation!

```c
#include <msp430.h>

int main(void) {
    // Stop the watchdog timer
    WDTCTL = WDTPW | WDTHOLD;

    // Set P1.0 as an output pin
    P1DIR |= BIT0;

    while (1) {
        // Set P1.0 to HIGH (3.3V)
        P1OUT |= BIT0;

        // Wait for a while
        __delay_cycles(1000000);

        // Set P1.0 to LOW (0V)
        P1OUT &= ~BIT0;

        // Wait for a while
        __delay_cycles(1000000);
    }
    return 0;
}
```

Texas Instruments MSP430

```c
#include <avr/io.h>

int main(void) {
    // Set PB0 as an output pin
    DDRB |= (1 << DDB0);

    while (1) {
        // Set PB0 to HIGH (5V)
        PORTB |= (1 << PORTB0);

        // Wait for a while
        _delay_ms(1000);

        // Set PB0 to LOW (0V)
        PORTB &= ~(1 << PORTB0);

        // Wait for a while
        _delay_ms(1000);
    }
    return 0;
}
```

Microchip/Atmel AVR

Firmware Frameworks

- Abstract the manual bitwise operations with a header file
- The Arduino framework is widely used and works with most chips

```c
#include <avr/io.h>

int main(void) {
    // Set PB0 as an output pin
    DDRB |= (1 << DDB0);

    while (1) {
        // Set PB0 to HIGH (5V)
        PORTB |= (1 << PORTB0);

        // Wait for a while
        _delay_ms(1000);

        // Set PB0 to LOW (0V)
        PORTB &= ~(1 << PORTB0);

        // Wait for a while
        _delay_ms(1000);
    }
    return 0;
}
```

Embedded C AVR

```c
const int ledPin = 8;

void setup() {
    // Set the LED pin as an output
    pinMode(ledPin, OUTPUT);
}

void loop() {
    // Set the LED pin to HIGH (5V)
    digitalWrite(ledPin, HIGH);

    // Wait for a while
    delay(1000);

    // Set the LED pin to LOW (0V)
    digitalWrite(ledPin, LOW);

    // Wait for a while
    delay(1000);
}
```

Arduino Framework

Firmware to Cloud

- When working with IoT applications you will typically use frameworks
- Particle uses the Arduino framework with added functionality, such as cloud variables and functions
  - Cloud variables and functions can be accessed from the web interface!
- NuvIoT and Arduino also offer cloud specific libraries for IoT applications

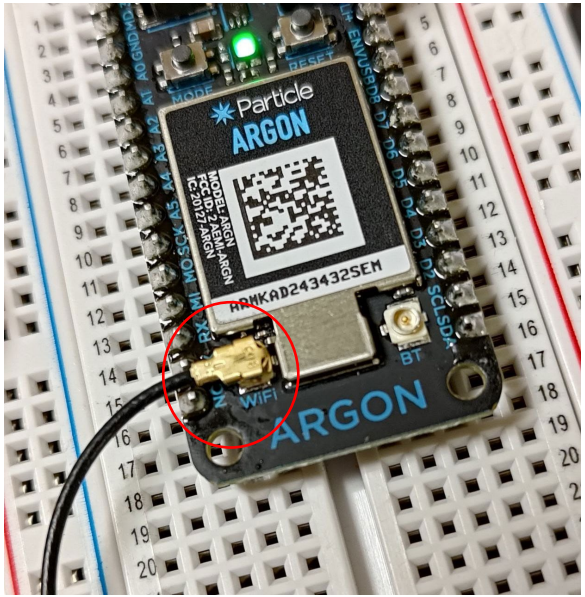
Board Setup

Getting Ready

1. docs.particle.io/quickstart/argon/
2. “Set up your Argon”
3. “Get Started”
4. Make Account (required)

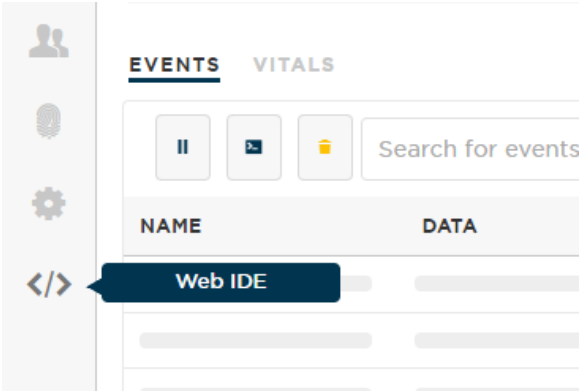
Updating

1. Attach antenna to Argon board “Wi-Fi” port
2. “Start setting up my device”
3. Attach board with USB cable to laptop
4. “Select Device,” pick device, and “connect”
5. “Continue,” pick device, and “connect”
6. “Continue” and “Update Device”



Registering

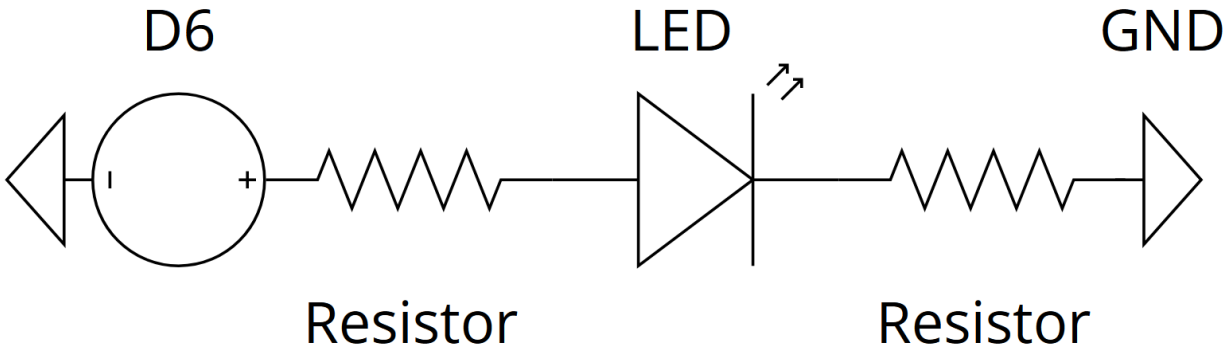
1. “Or create a new product” and give a name
2. “Add to product” and gave a device name
3. “Name Device”
4. Choose Wi-Fi network (Not school Wi-Fi, try phone hotspot)
5. Activate Device
6. “Go to Console”
7. Open Web IDE

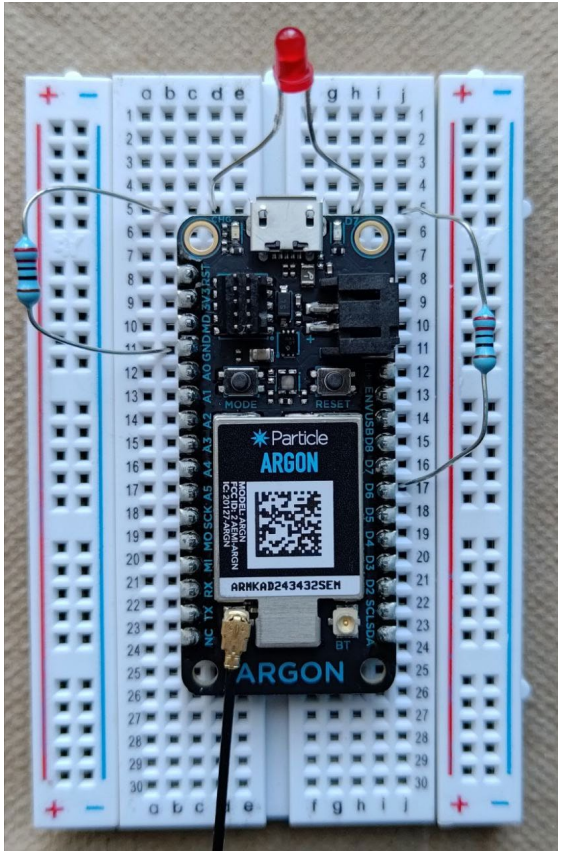


Circuit Assembly

3v3 voltage to long leg of LED

GND to short leg of LED





Coding

Code – Beginning

```
1  // Allows code to run without internet
2  SYSTEM_THREAD(ENABLED);
3
4  // This is where your LED is plugged in.
5  // Other side goes through a resistor to GND.
6  const pin_t LED_PIN = D6;
7
8  //declaration of functions
9  int timeSet(String inputT);
10 int alarmSet(String inputS);
11
12 int alarmTime; // declaration of alarm variable
13 int timer;  // declaration of timer variable
```

Code - Setup

```
15  void setup()
16  {
17      // First, declare all of our pins. This lets our device know which ones
18      // will be used for outputting voltage, and which ones will read
19      // incoming voltage.
20      pinMode(LED_PIN, OUTPUT); // Our LED pin is output (lighting up the LED)
21      digitalWrite(LED_PIN, LOW);
22
23      // We are going to declare a Particle.variable() here so that we can
24      // access the value of the timer variable from the cloud.
25      Particle.variable("time", timer);
26
27      // We are also going to declare Particle.functions so that we can
28      // set the clock time and alarm time from the cloud
29      Particle.function("set the time", timeSet);
30      Particle.function("set the alarm", alarmSet);
31
32      int alarmTime = -1;
33      int timer = 0;
34  }
```

Code - Loop

```
36  void loop()
37  {
38
39      if (timer == 86400) // number of seconds in a day
40      {
41          timer = 0; // reset timer
42      }
43      else
44      {
45          timer = timer + 1; // increment second
46      }
47      if (timer == alarmTime)
48      {
49          digitalWrite(LED_PIN, HIGH); // turn light on
50      }
51
52      delay(1000ms);
53  }
```

Code – Functions

```
55  // This function is called when the Particle.function is called
56  int timeSet(String inputT)
57  {
58      timer = inputT.toInt();
59      digitalWrite(LED_PIN, LOW);
60      return 1;
61  }
62
63  int alarmSet(String inputS)
64  {
65      alarmTime = inputS.toInt();
66      digitalWrite(LED_PIN, LOW);
67      return 1;
68  }
```

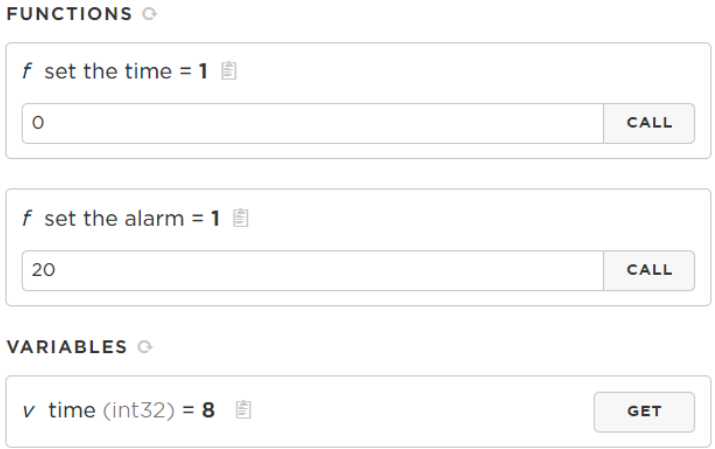
Code – Dashboard Interface

You can now:

- Set the clock and timer remotely
- Check the current time

Also possible:

- Change output to hours & minutes
- Using a mobile app to access the dashboard and notifications remotely



More tutorials and code are available at

https://docs.particle.io/getting-started/hardware-tutorials/hardware-examples/

Questions?

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