**Group Member Names**: Abdul Ali, Bryce Nelson, Ali Bibi, Nicholas Lekas

**Course and Quarter:** ENGR 114 Fall 2019

**Date:** 12/09/2019

## Automatic Water Shut-off Valve

#### Problem Statement:

Water damage claims are the leading cause of property insurance claims in the USA. Water damage and freezing account for almost 22 percent of all homeowners insurance claims, and average $4,024 per claim, according to the Insurance Information Institute. There are many products and preventative maintenance strategies/guides designed to mitigate the risks posed by water supply lines. Products include heat trace tape, pipe insulators, piping material designed to expand and stretch without bursting, etc. Preventative maintenance and these types of products are defensive in nature. Our system offers an offensive approach in that when a pipe burst, a sensor sends a signal to a device capable of shutting the water supply off.

#### Hardware Setup:

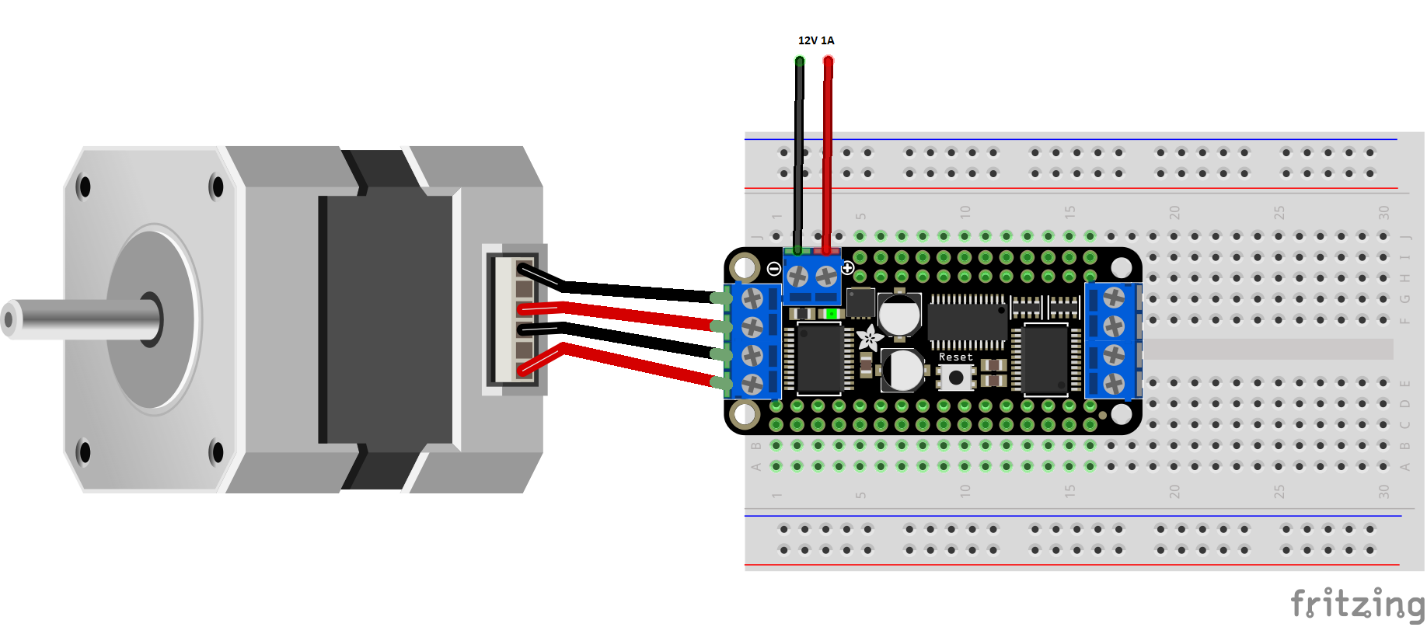
Bill of Materials

<https://docs.google.com/spreadsheets/d/1_x6ZGH3ySJbsKaVvGHzYyC4p7wBCZ06N/edit#gid=1461949826>

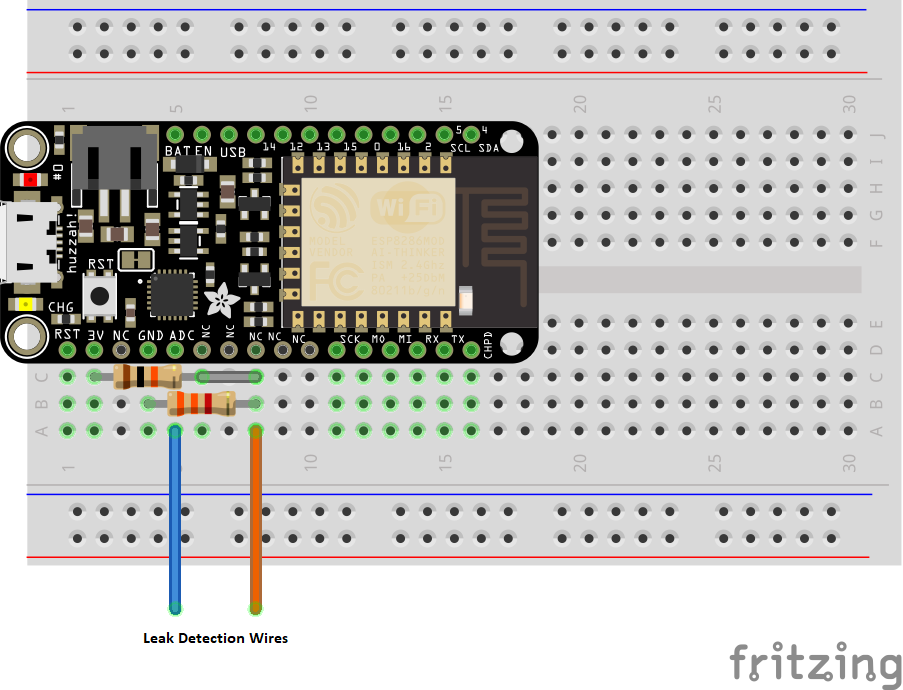
|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Part Name | Quantity | Unit Price | Sub-Total | Source |
| 1" PVC Male Adapter | 2 | $0.78 | $1.56 | HomeDepot |
| 1" SCH 40 PVC Pipe (10 ft. Stick) | 1 | $3.97 | $3.97 | HomeDepot |
| 1" Gate Valve | 1 | $12.61 | $12.61 | HomeDepot |
| ESP8266 board | 2 | $16.95 | $33.90 | Adafruit |
| USB Cable | 2 | $4.99 | $9.98 | Amazon |
| Stepper motor driver | 1 | $19.95 | $19.95 | Adafruit |
| Breadboard pack | 1 | $6.99 | $6.99 | Amazon |
| Jumper Wire Pack | 1 | $5.79 | $5.79 | Amazon |
| Stepper Motor | 1 | $20.99 | $20.99 | Amazon |
| 12V 2A power supply | 1 | $7.99 | $7.99 | Amazon |
| 10k ohm resistor | 1 | $0.10 | $0.10 | DigiKey |
| 3.3k ohm resistor | 1 | $0.10 | $0.10 | DigiKey |
|  |  |  |  |  |
|  |  | Total | $123.93 |  |

Hardware Schematic

Valve Hub



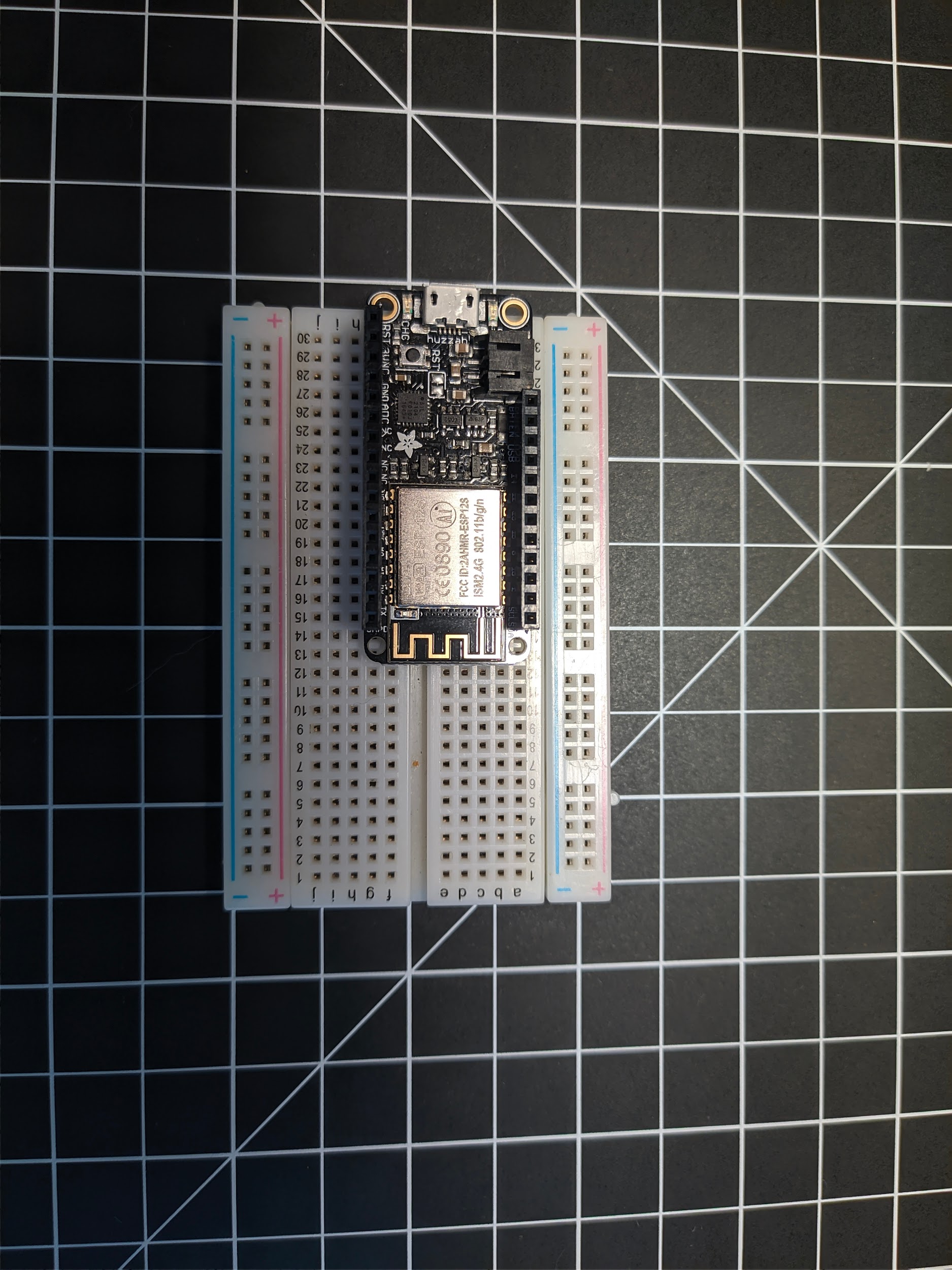
Leak Detector



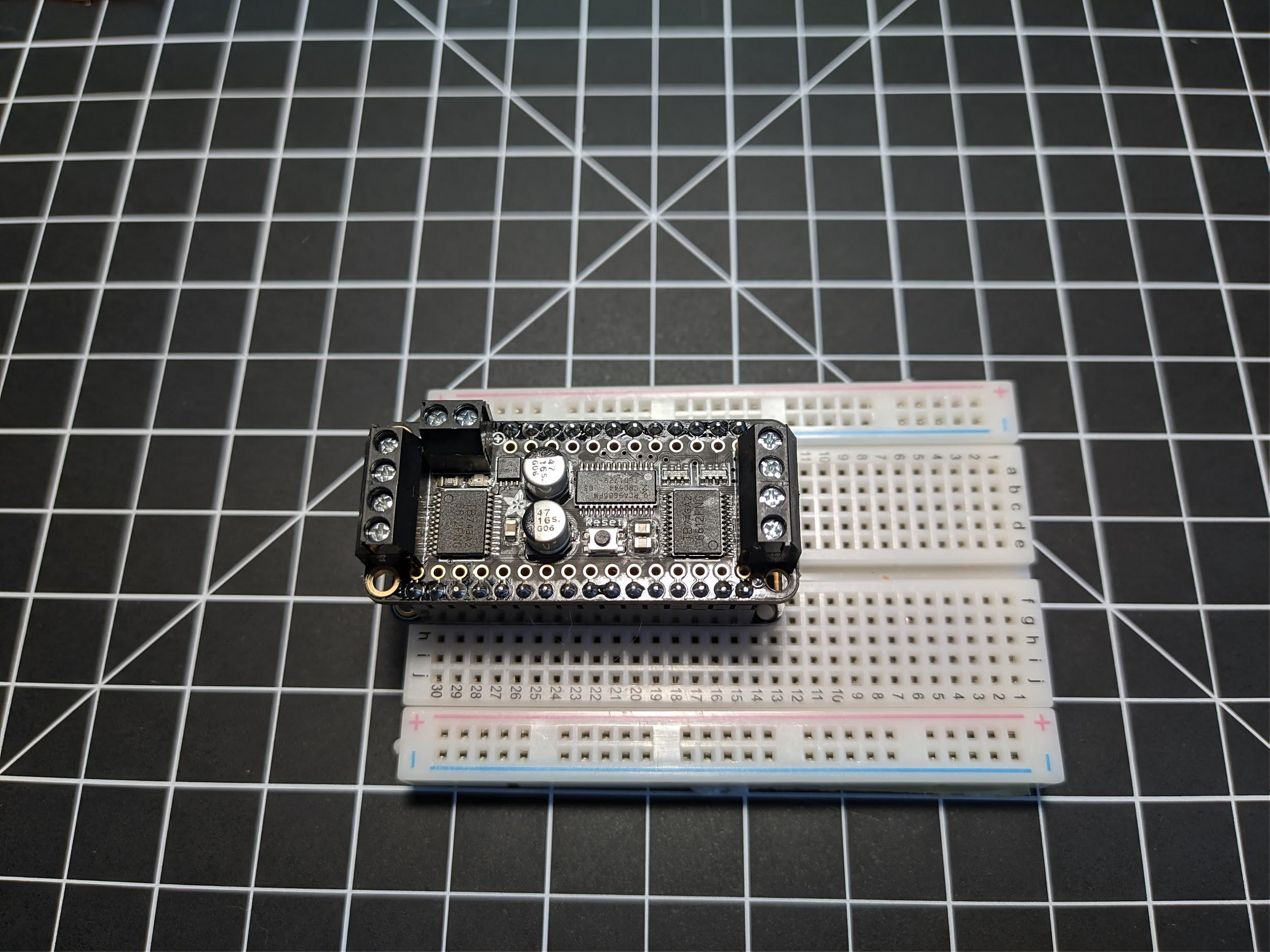
Hookup Guide

Valve Hub

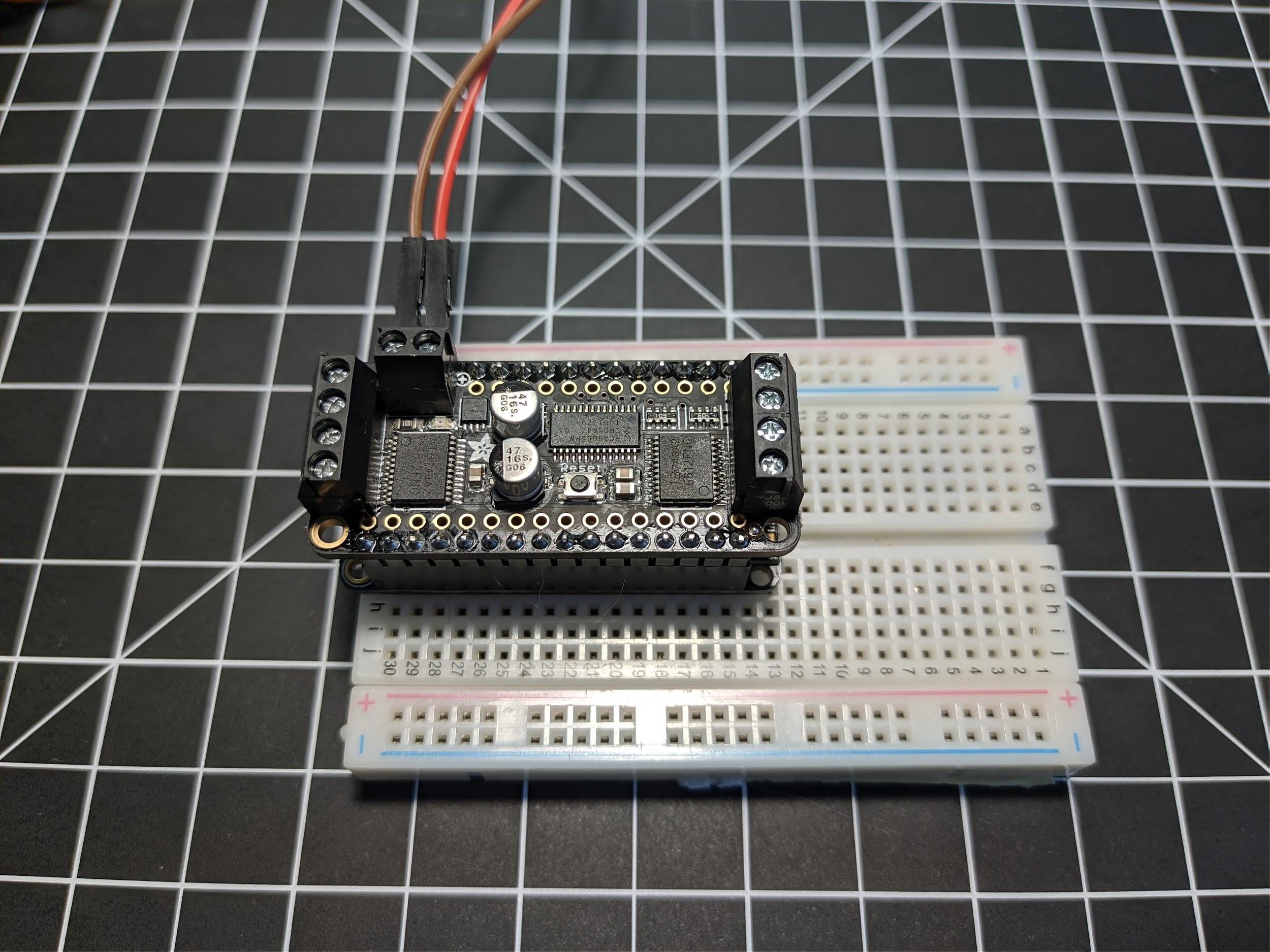
Step 1: Place your ESP module into a breadboard. In this guide, an Adafruit Feather HUZZAH ESP8266.



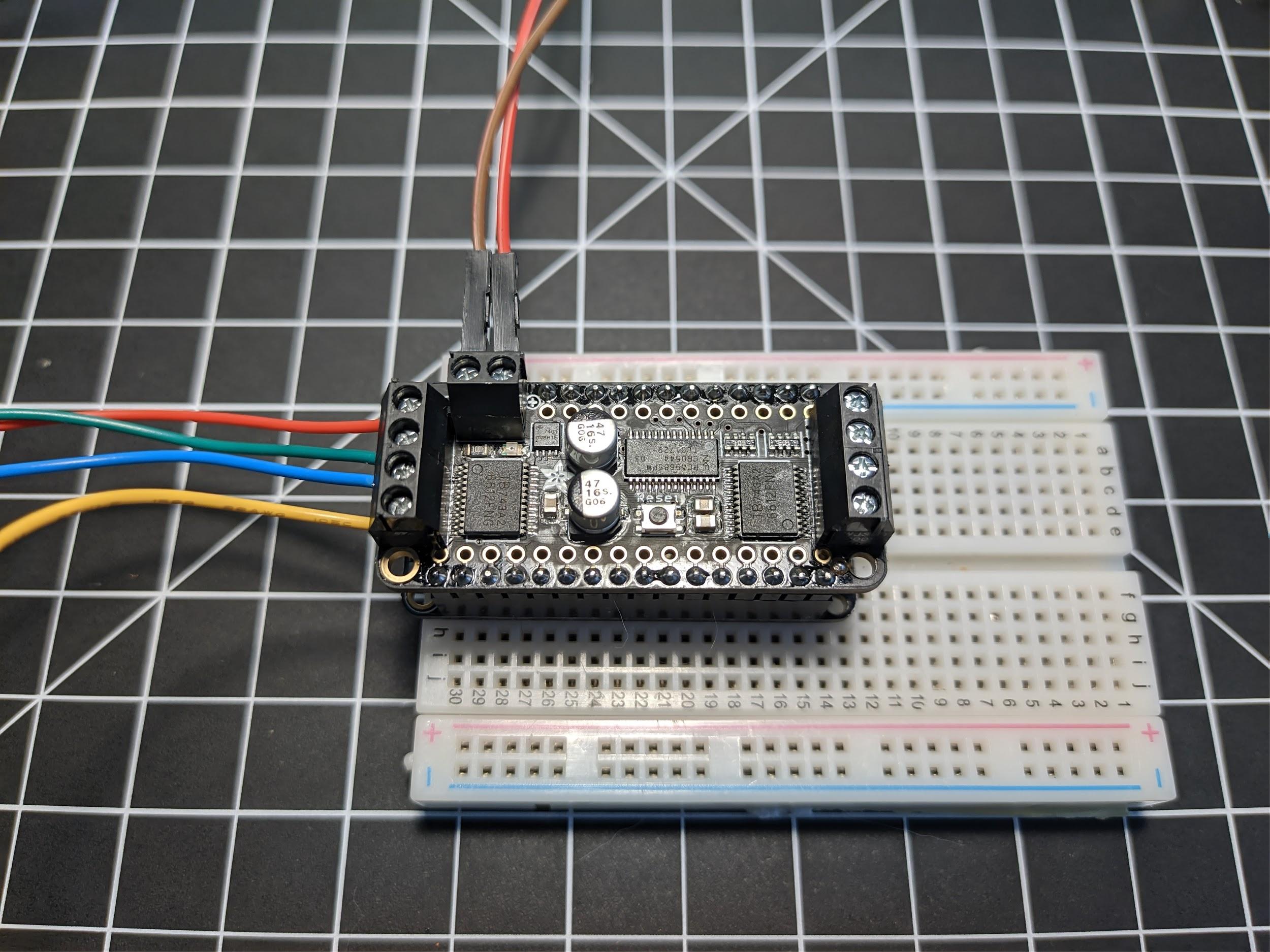
Step 2: Attach your stepper motor driver. In this guide an Adafruit DC Motor + Stepper FeatherWing is used and it connects to the top of the Adafruit Feather HUZZAH ESP8266.



Step 3: Connect 12V power to the stepper motor driver, on this Adafruit driver, power is connected to the single 2 wire terminal block.

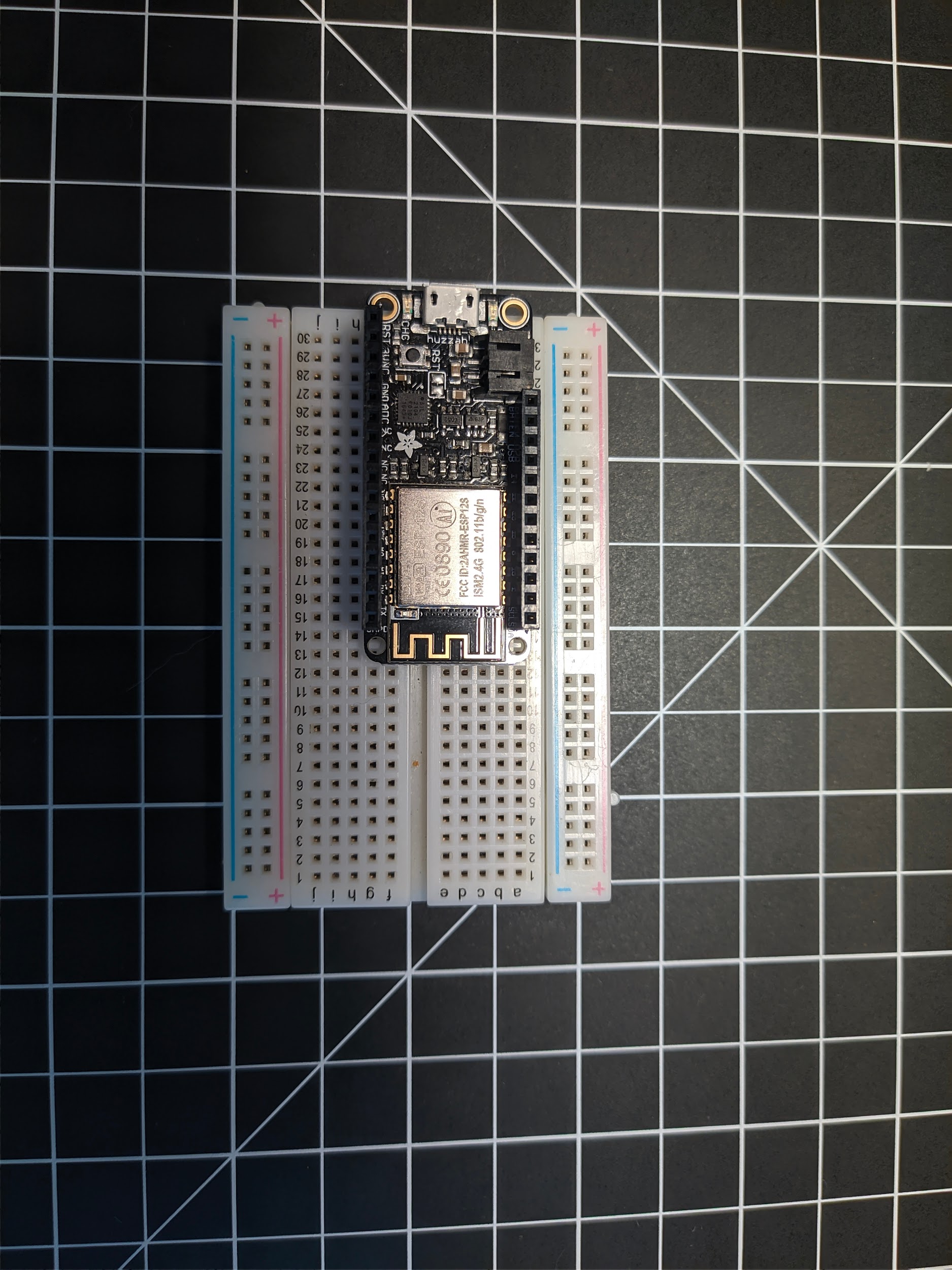


Step 4: Connect the stepper motor, make sure you know which wires belong to each coil in the motor. If you’re not sure, choose 2 of the 4 wires, hold the exposed ends together and turn the output shaft of the motor. If there is resistance, then you have the wires for 1 coil, if there is no resistance swap 1 wire out for another and test again.

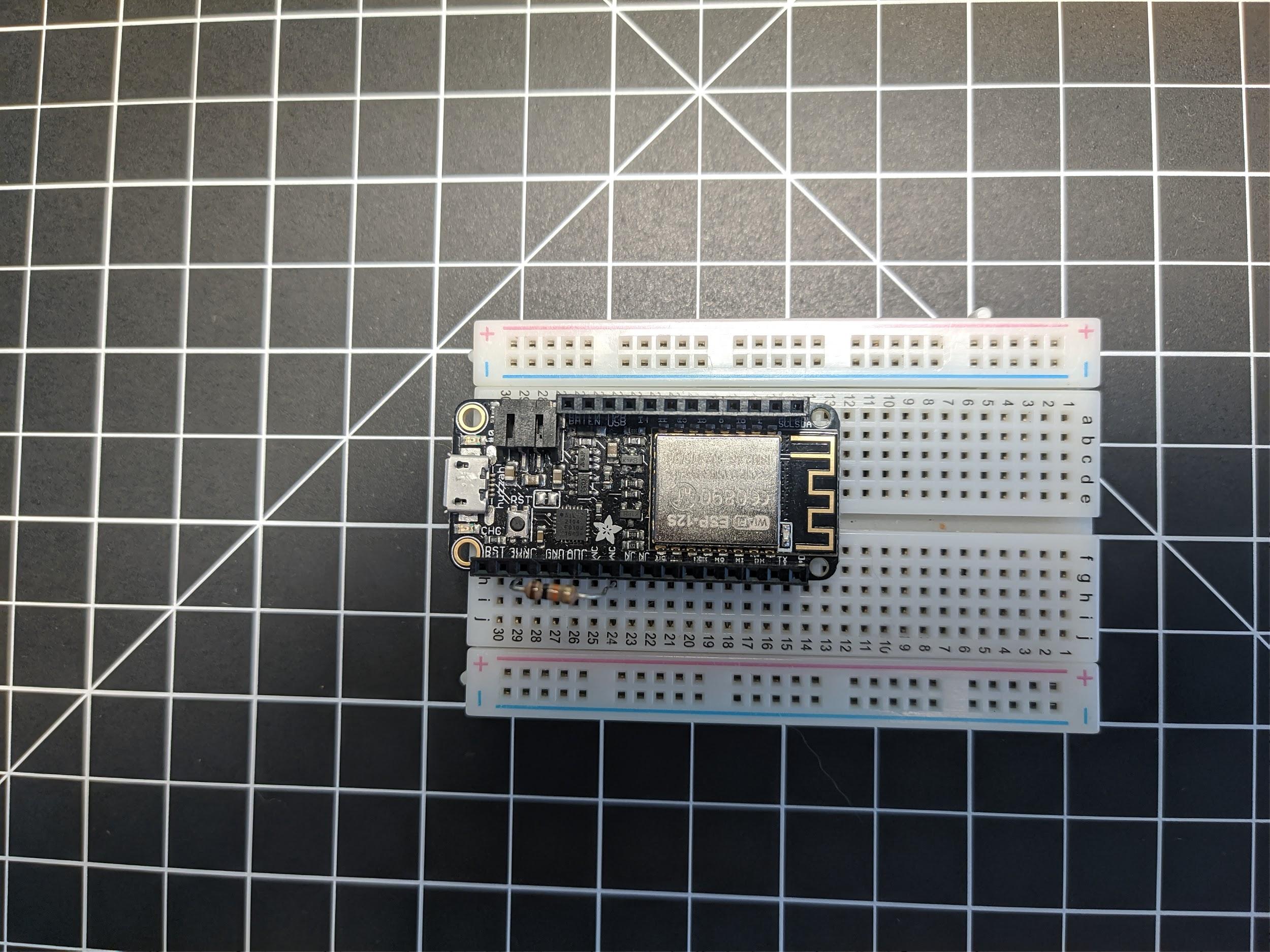


Leak Detector

Step 1: Place your ESP module into a breadboard. In this guide, an Adafruit Feather HUZZAH ESP8266.



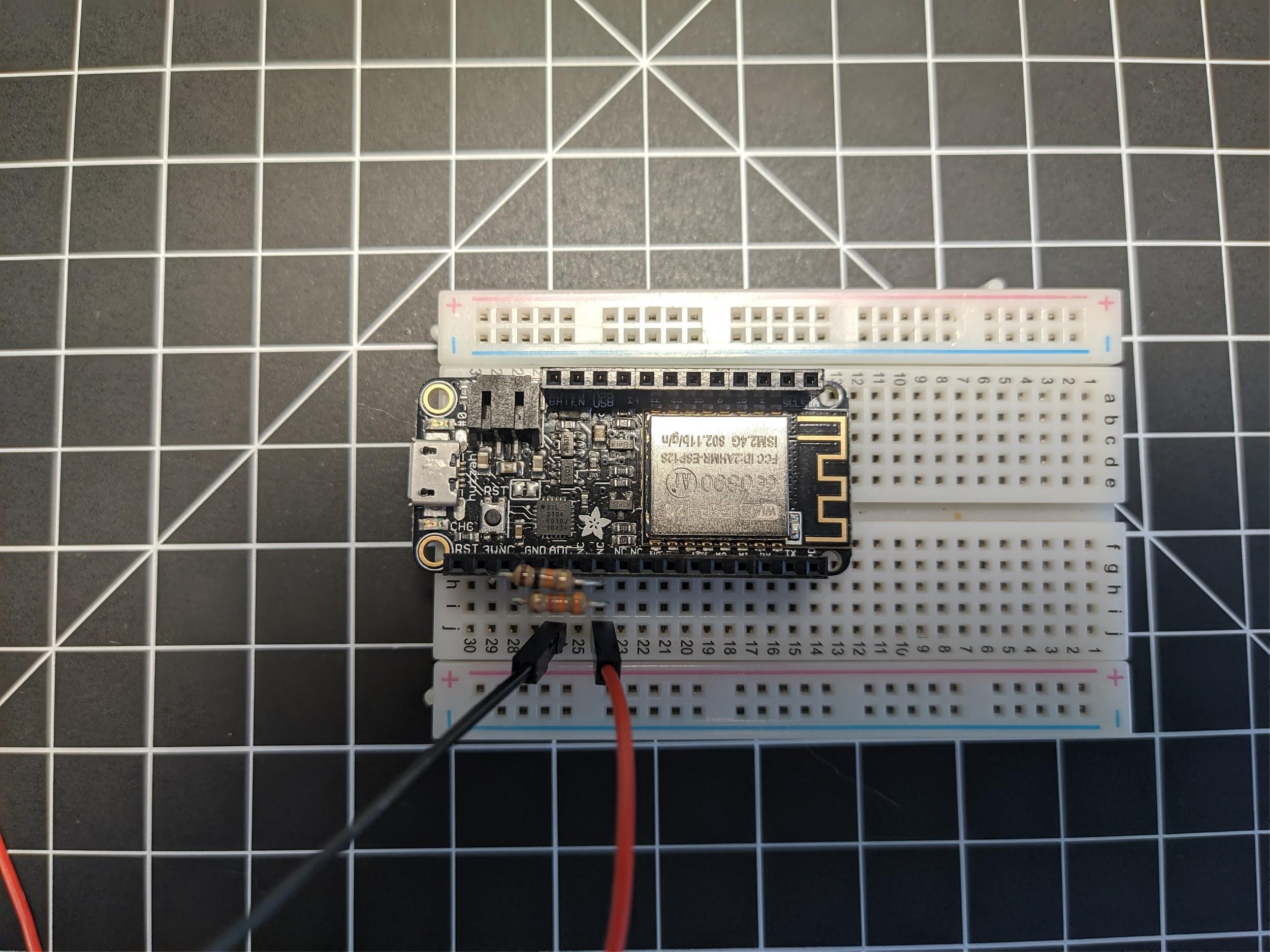
Step 2: The ESP8266 operates at 3.3V, but the ADC can only read from 0-1V. Because of this a voltage divider is needed. Take the 10kΩ and connect one end to the 3.3V out of the ESP to an NC (No Connection) pin on the ESP.



Step 3: Connect the 3.3kΩ resistor to the ground pin on the ESP and the NC pin that you connected the 10kΩ resistor to.



Step 4: Connect one of the jumper wires to the NC pin that the 2 resistors are connected to and the other jumper wire to the ADC pin on the ESP. These wires are used to detect water when both are touching the same puddle



#### Code:

This project was developed using the Visual Studio Code plugin PlatrofrmIO. Code is provided in both the PlatfromIO and Arduino IDE format. If you’re using the Arduino IDE follow the instructions in the ino file. If you’re using PlatformIO, follow the instructions in the ‘Readme.txt’ that is in the ‘src’ folder for each device.

The source code is available at [https://github.com/NickLekas/Leak-Detector-and-Valve-Shutoff](https://github.com/NickLekas/Leak-Detector-and-Valve-Shutoff.git)

Valve Hub

main.cpp

/\*

This code is for the valve hub processor

developed by: Mauve Grinders

\*/

#include <ESP8266WiFi.h>

#include <WiFiUDP.h>

#include <Adafruit\_MotorShield.h>

#include "config.h"

#include "pins.h"

void setWifi(); //sets up the wifi network

void handleClients(); //process data from clients and responds

void leakCheck(char\* isLeak); //process received data from handleClients and turns the valve if needed

void ready(int flashes); //flashes the LED a number of times when the main code is running using a set number of flashes from the user

//sets up the stepper motor

Adafruit\_MotorShield AFMS = Adafruit\_MotorShield();

Adafruit\_StepperMotor \*valveMotor = AFMS.getStepper(200, 1);

//IP setup

IPAddress APlocal\_IP(192, 168, 4, 1);

IPAddress APgateway(192, 168, 4, 1);

IPAddress APsubnet(255, 255, 255, 0);

//local port that will be listened to

unsigned int UDPPort = 2390;

//enables udp communication

WiFiUDP Udp;

//buffer to hold incoming packet

char packetBuffer[255];

char result[10];

bool valveClosed = false;

void setup() {

  //enables serial monitor output

  Serial.begin(115200);

  //sets the LED pin to an output and turns off the LED

  pinMode(led, OUTPUT);

  digitalWrite(led, 0);

  // Setting Up A Wifi Access Point

  setWifi();

  //enables the stepper motor

  AFMS.begin();

  //sets the stepper motor to 20rpm

  valveMotor->setSpeed(20);

  //flashes the LED 3 times once the main program is running

  ready(3);

}

void loop() {

  handleClients();

}

//processes the data received from a client and responds with the current uptime

void handleClients(){

  unsigned long tNow;

  //stores the size of the received packet

  int packetSize = Udp.parsePacket();

  //if a packet is received, process it.

  if (packetSize) {

    //prints the size of the packet to the user

    Serial.print("Received packet of size ");

    Serial.println(packetSize);

    //prints which the device sent the data

    Serial.print("From ");

    Serial.print(Udp.remoteIP());

    Serial.print(", port ");

    Serial.println(Udp.remotePort());

    //reads the packet into the packet Buffer

    int len = Udp.read(packetBuffer, 255);

    if (len > 0) {

      packetBuffer[len] = 0;

    }

    //prints the contents of the packet

    Serial.println("Contents:");

    Serial.println(packetBuffer);

    //searches the packet for a '1' indicating there is a leak

    char\* isLeak = strchr(packetBuffer, '1');

    leakCheck(isLeak);

    //gets the current uptime of the controller

    tNow=millis();

    //converts a number into ASCII so it can be sent over UDP

    dtostrf(tNow, 8, 0, result);

    //sends the time to the client device

    Udp.beginPacket(Udp.remoteIP(), Udp.remotePort());

    Udp.write(result);

    Udp.endPacket();

  }

}

void leakCheck(char\* isLeak) {

  //if a '1' if found in the packet turn on the LED and turn the motor

    if(isLeak != NULL) {

      //turn on the LED

      digitalWrite(led, 0);

      //turn the motor if it has not yet been moved

      //this is so the motor does not try to turn the vale off again and damage the valve or itself

      if(valveClosed != true) {

        valveMotor->step(50, FORWARD, MICROSTEP);

        valveClosed = true;

      }

    }

    else {

      //if there is no leak detected, turn off the LED

      digitalWrite(led, 1);

    }

}

//sets up the wifi network

void setWifi(){

  //stop active previous WIFI, if there is

  //this is mainly a safety check

  WiFi.disconnect();

  //sets the WiFi mode

  WiFi.mode(WIFI\_AP\_STA);

  Serial.println("WIFI Mode : AccessPoint Station");

  //starts the AccessPoint

  WiFi.softAPConfig(APlocal\_IP, APgateway, APsubnet); //softAPConfig (local\_ip, gateway, subnet)

  WiFi.softAP(SSID, PASSWORD, 1 ,0, MAXSC); //WiFi.softAP(ssid, password, channel, hidden, max\_connection)

  Serial.println("WIFI < " + String(SSID) + " > ... Started");

  //waits a bit to make sure things start properly

  delay(50);

  //gets the server IP

  IPAddress IP = WiFi.softAPIP();

  //prints the server IP Address

  Serial.print("AccessPoint IP : ");

  Serial.println(IP);

  //starts the UDP Server

  Udp.begin(UDPPort);

  //tells the user the server has started

  Serial.println("Server Started");

}

//flashes the LED a number of times when the main code is running using a set number of flashes from the user

void ready(int flashes) {

  int i;

  //loops double the times the user enters to create the number of flashes the user has set

  for(i = 0; i < flashes \* 2; i++) {

    //if the current cycle is divisible by 2, turn the LED on, if not, turn the LED off

    if(i % 2 == 0) {

      digitalWrite(led, 0);

    }

    else {

      digitalWrite(led, 1);

    }

    //wait 300ms so the LED flashes visibly

    delay(300);

  }

}

config.h

#ifndef CONFIG\_H

#define CONFIG\_H

    char\* SSID = "Valve Hub";

    char\* PASSWORD = "9454d858-0f13-11ea-8d71-362b9e155667";

//maximum number of clients

const int MAXSC = 6;

#endif

pins.h

#ifndef PINS\_H

#define PINS\_H

    const int led = 0;

#endif

Leak Detector

main.cpp

/\*

This code is for the leak detector processor

developed by: Mauve Grinders

\*/

#include <ESP8266WiFi.h>

#include <WiFiUDP.h>

#include "config.h"

#include "pins.h"

void leakDetect(); //determines if there is a leak based on the voltage to the analog input

void checkWifiAndConnect(); //checks for the specified wifi network and connects to it

void sendDataToServer(); //tells the hub if there is or is not a leak detected

void ready(int flashes); //flashes the LED a number of times when the main code is running using a set number of flashes from the user

//wifi Module Role & Port

IPAddress APlocal\_IP(192, 168, 4, 1);

IPAddress APgateway(192, 168, 4, 1);

IPAddress APsubnet(255, 255, 255, 0);

//local port to send and listen to

unsigned int UDPPort = 2390;

//enables UDP

WiFiUDP Udp;

//buffer big enough for 7-character float

char result[16];

//buffer for incoming data

char packetBuffer[255];

//leak detection cycle count

int count = 0;

//leak detection flag

bool isLeak = false;

void setup() {

  //sets up the serial communication

  Serial.begin(115200);

  //enables the LED and turns it off

  pinMode(led, OUTPUT);

  digitalWrite(led, 0);

  //establishes a wifi connection with the hub

  checkWifiAndConnect();

  //flashes the LED to indicate the device is ready

  ready(3);

}

void loop() {

  //checks for a leak and sends data to the hub

  sendDataToServer();

  //verifies wifi connection and will attempt to reconnect if lost

  if (WiFi.status() != WL\_CONNECTED) {

    //flashes the LED and then holds it on

    ready(3);

    digitalWrite(led, 0);

    //attempts to reconnect to the hub

    checkWifiAndConnect();

    //flashes the led to indicate the connection to been reestablished

    ready(3);

  }

}

//tells the hub if there is or is not a leak detected

void sendDataToServer() {

  unsigned long tNow;

  //checks for a leak

  leakDetect();

  //converts a number into ASCII so it can be sent over UDP

  dtostrf(isLeak, 8, 0, result);

  //establishes what port and ip address to send the leak data, sends is, then closes the connection

Udp.beginPacket(APlocal\_IP, UDPPort);

Udp.write(result);

Udp.endPacket();

  while(1) {

    //reads the size of the incoming packet

    int packetSize = Udp.parsePacket();

    //if there is a packet size, there is data to be processed

    if (packetSize) {

      //prints out the size of the packet

      Serial.print("Received packet of size ");

      Serial.println(packetSize);

      //prints out which ip sent the packet and on what port

      Serial.print("From ");

      IPAddress remoteIp = Udp.remoteIP();

      Serial.print(remoteIp);

      Serial.print(", port ");

      Serial.println(Udp.remotePort());

      //reads the packet into the packet Buffer

      int len = Udp.read(packetBuffer, 255);

      if (len > 0) {

        packetBuffer[len] = 0;

      }

      //prints the contents of the packet

      Serial.print("Contents:");

      Serial.println(packetBuffer);

      break;

    }

    //if there is no received data for 1000ms, a timeout message is printed

    if((millis()-tNow)>1000) {

      Serial.println("timeout");

      break;

    }

  }

}

//determines if there is a leak based on the voltage to the analog input

void leakDetect() {

  //rads the analog input

  int val = analogRead(leakSense);

  //if the analog input is greater than 800 there is a leak

  //a leak condition will not trigger until 100 consecutive loops to filter false readings

  //if a false reading is detected the cycle count will be reset

  if(val >= 800) {

    count++;

    if(count > 50){

      isLeak = true;

      digitalWrite(led, LOW);

    }

  }

  else {

    count = 0;

    isLeak = false;

    digitalWrite(led, HIGH);

  }

}

//checks for the specified wifi network and connects to it

void checkWifiAndConnect(){

  //checks for no established wifi connection

  if (WiFi.status() != WL\_CONNECTED) {

    //starts searching for the specified wifi connection

    WiFi.begin(SSID, PASSWORD);

    //tells the user that a connection is attempting to be established

    Serial.println();

    Serial.print("Wait for WiFi");

    //prints a '.' every 0.5 seconds while waiting for a connection

    while (WiFi.status() != WL\_CONNECTED) {

      delay(500);

      Serial.print(".");

    }

    //tells the user a connection has been made and what the ip address is

    Serial.println("");

    Serial.println("WiFi connected");

    Serial.println("IP address: " + WiFi.localIP().toString());

    //starts the UDP connection

    Udp.begin(UDPPort);

  }

}

//flashes the LED a number of times when the main code is running using a set number of flashes from the user

void ready(int flashes) {

  int i;

  //loops double the times the user enters to create the number of flashes the user has set

  for(i = 0; i < (flashes \* 2); i++) {

    //if the current cycle is divisible by 2, turn the LED off, if not, turn the LED on

    if(i % 2 == 0) {

      digitalWrite(led, 1);

    }

    else {

      digitalWrite(led, 0);

    }

    delay(300);

  }

}

config.h

#ifndef CONFIG\_H

#define CONFIG\_H

    char\* SSID = "Valve Hub";

    char\* PASSWORD = "9454d858-0f13-11ea-8d71-362b9e155667";

//maximum number of clients

const int MAXSC = 6;

#endif

pins.h

#ifndef PINS\_H

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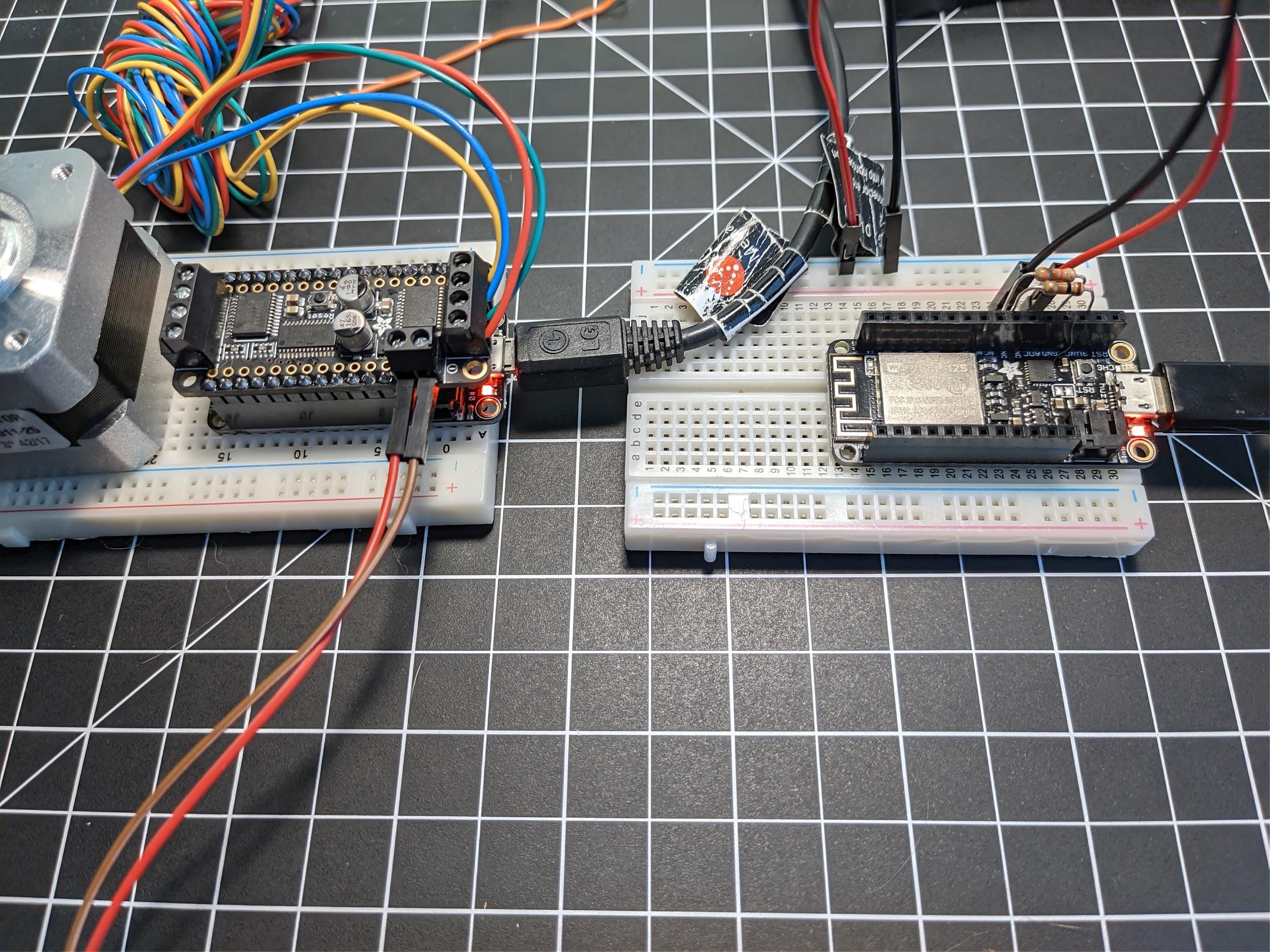
    const int led = 0;

    const int leakSense = 17;

#endif

#### Results:

Once the leak detector detects a leak, the valve hub is notified within a few milliseconds and closes the valve it is attached to. If another leak detector were to detect a leak, the valve hub will not attempt to close the valve again to prevent damage to the valve or motor. Once the leak is repaired, the reset button will need to be pressed for the valve hub to close the valve again in the future. Below is a picture of a valve hub on the left and a leak detector on the right. On both controllers you can see a red LED illuminated indication that the leak detector detected a leak and that the valve hub received the notification that a leak was detected and closed the valve.



#### Future Work:

* **Use a bigger motor capable of producing enough torque to turn a valve**
* **Provide a secondary means of validating water intrusion/ pipe burst in order to minimize false positives**
* **Design a system that allows this device to be attached to various valve types**
* **Integrate the product into an app that notifies interested parties and allows for feature development**
* **Develop a network that allows valves to share information and communicate with one another**
* **Track water usage information**

For this project we underestimated the amount of torque that was needed to turn the valve. The motor that we chose to use was significantly undersized for this application. With the use of this undersized motor were unable to successfully shut the gate valve.

If another group decides to continue this project we suggest spending more time researching and testing the motor. We suggest that they look at the specifications for the valve being used to see how much torque is required to turn the valve. Once the torque value is known, the correct sized motor can then be determined.

In order to solve this problem we thought that using a smaller gate valve such as a ¾” or ½” would require less torque to close. After doing some testing we determined that there was not a noticeable difference in the torque required to close a smaller gate valve when turning the valve by hand. We believe that the 28Nm motor we used might have been able to work if we geared it. However, it is probably more advisable to get a higher torque motor to start and then using some gearing as needed instead of creating a small gearbox just to make it work. We would recommend sticking with a stepper motor because of the precise control to make sure the valve is never overturned.

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Version 3, 29 June 2007

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