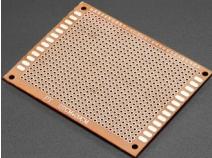
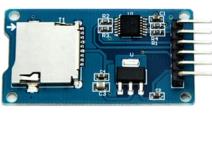
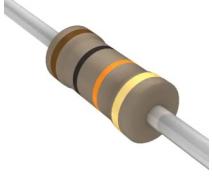
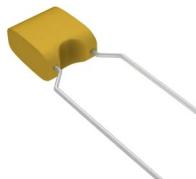


# Wave Gauge Circuit Board Assembly Guide

## Electronic Component List

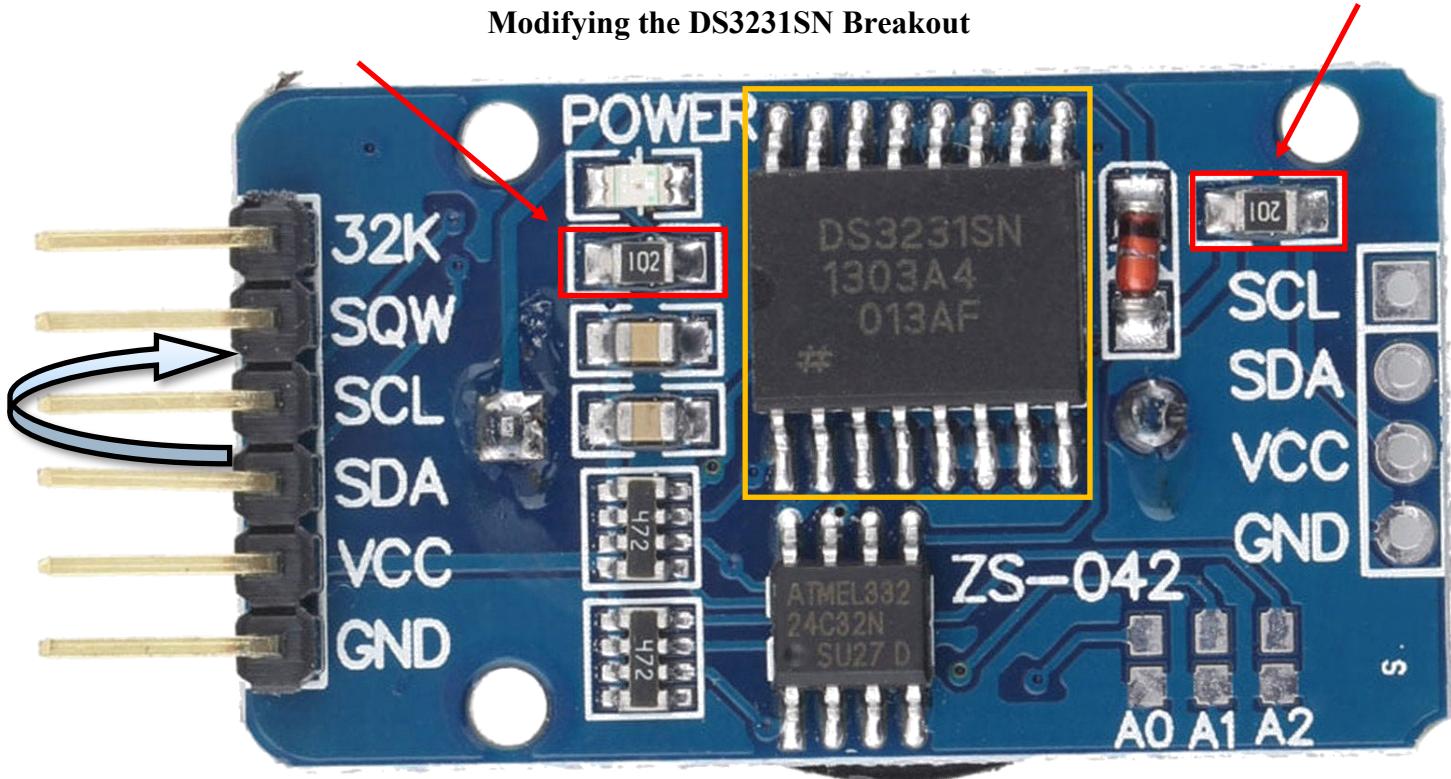
Image	Part	Quantity	Image	Part	Quantity
	Perfboard	1		3V Linear Voltage Regulator	1
	DS3231SN Breakout	1		Red LED	1
	MicroSD Breakout	1		2 Pin Male JST Connector	1
	28 Pin Dip Socket	1		1 $\mu\text{F}$ Capacitor	1
	10 K $\Omega$ Resistor	2		0.1 $\mu\text{F}$ Capacitor	3
	130 $\Omega$ Resistor	1		Female 3 Pin Header	1
	MS5803-14BA	1		Female 4 Pin Header	1
	SMT Breakout PCB for SOIC-8, MSOP-8 or TSSOP-8	1		(Preferably Blue) Lengths of Wire	1 x ~1 in. 1 x ~1.5 in.

## Notes

- Practice soldering on an empty breadboard before starting this build if you aren't very comfortable with it. These are the essential skills for putting together the board:
  - Attempt to make lines of solder next to each other without shorting them together. One method of doing this is to first fill in the holes you wish to be connected using solder, without worrying about connecting them together. Then, place your soldering iron over each pair of adjacent holes to be connected and apply additional solder until they bridge together. Remove your soldering iron in a quick, straight up motion for best results.
  - When a short is inevitably created between two lines that aren't supposed to be connected, also practice fixing the connection: either wait for it to cool and then apply heat only to one hole (melted solder is attracted to heat), or use solder wick to remove solder from the board.
  - Finally, practice soldering components' leads / pins or wire to the board. Desoldering components with several leads can be very difficult with just a soldering iron, so it's important to place them in the right holes the first time. To solder a lead in place, rest the tip of the soldering iron against both the pin of the component and the copper ring on the board. Then, simply apply solder to the ring, close to your iron, until the entire hole is filled.
- The board can be put together in *almost\** any order, but the steps below are organized for ease of soldering.

\* Two jumper wires are used in the build: these wires will be covered when the RTC and SD breakout boards are placed on the board, so they must be at least placed in the proper holes before soldering the RTC and microSD breakouts.
- All components and jumper wires are placed on the front of the perfboard, and soldering is done on the back. The back can be identified by the copper rings around each of the holes.

## Modifying the DS3231SN Breakout



The two resistors (red boxes) should be removed from the module. Do this by applying heat using a soldering iron to one pad of the resistor and pushing until it moves off the pad, or by repeatedly applying heat to both pads and pushing. We won't be using these resistors later, so it's alright if they are damaged.

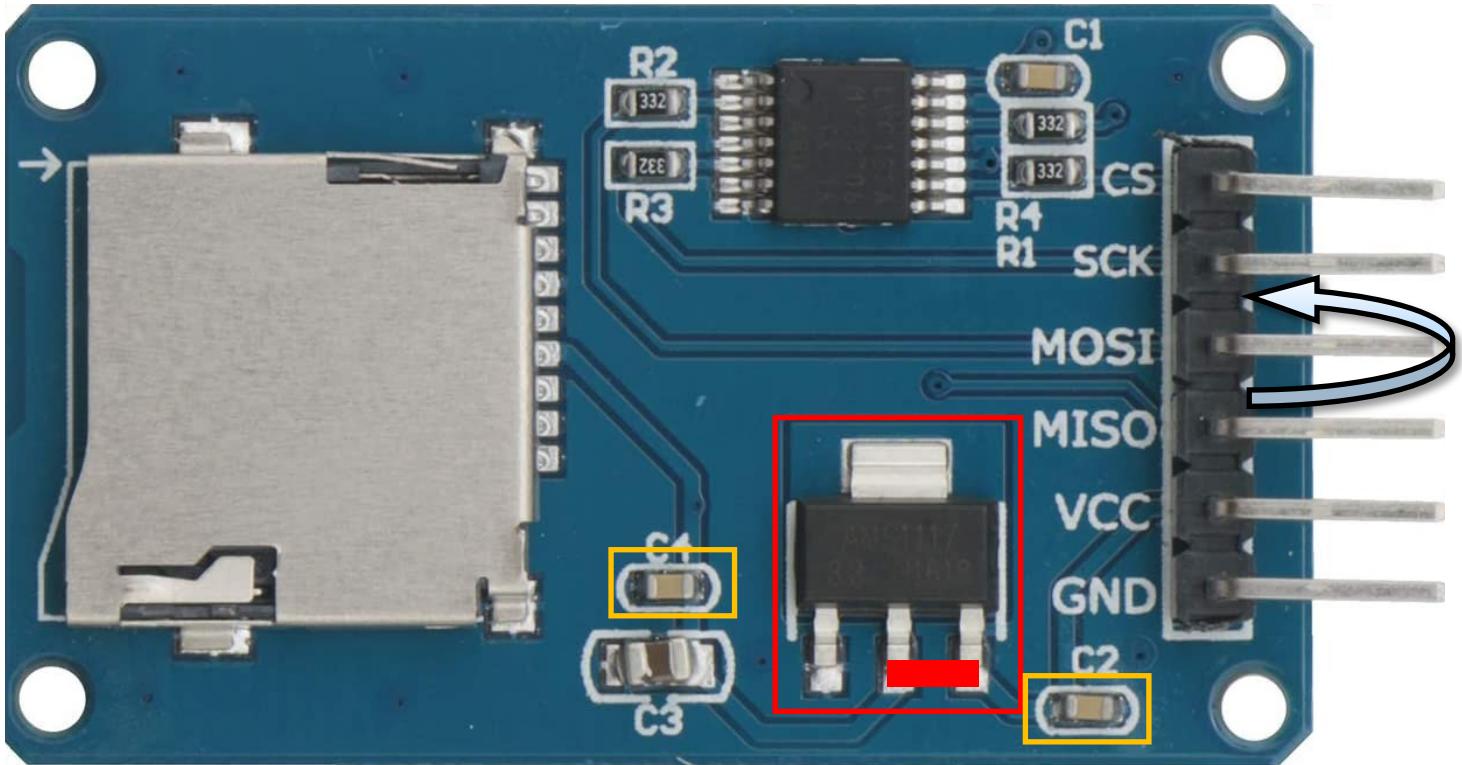
- We remove the left resistor to open the circuit to the power LED above it, which is unnecessary and wastes battery power in our setup. The power LED can also be optionally removed, but since the circuit is already open it makes no difference to power consumption.
- The right resistor is used to allow a small amount of current from VCC to trickle charge the coin cell. We remove it to open this battery charging circuit, as we are using non-rechargeable batteries which would be damaged by it. Even if you use rechargeable batteries, our VCC voltage of 3V may not be high enough to charge them properly. The red diode to the left of this resistor can also be optionally removed.

After removing the components, bend the 6 pins on the left so they come straight out of the board, rather than being parallel to it as shown in the picture.

It is also important to observe the type of DS3231 chip on the board (orange box). Notice this chip is labelled as "DS3231SN". This is the variant we want.

- The "SN" variant of the chip can be used as both a RTC (real time clock) and TCXO (temperature compensated crystal oscillator); both of these features are necessary for our sensor design. Other versions of the chip exist, all of which can be used as a RTC of course, but some lack the ability to be used as a TCXO and are less accurate time keepers, primarily the DS3231M variant. These variants cannot be used, and this seems to be one of the tradeoffs of buying these boards so cheaply: sellers will not always guarantee or even mention what variant of chip you will receive.

## Modifying the MicroSD Breakout



First, the voltage regulator (red box) must be removed from the module. Since our design already includes a voltage regulator (3V), this one is unnecessary and wastes power.

- To remove it using a soldering iron, repeatedly apply heat and force to the 4 pins (3 on the bottom, 1 on the top) until it can be pushed loose. We won't be using this part later, so it's alright if it is damaged. Another way is to only apply heat to the pins on one side while using your iron (or another slim object) to leverage that side into the air by pushing up from beneath the leads.

Once removed, there is no longer a path for power to reach the card reader. To fix this, we will short the voltage regulator's input pad to its output pad (the smaller filled in red rectangle).

- This is safe since our input is already at 3V, but using a higher voltage could damage the SD card. Place your soldering iron over both pads and apply solder until they bridge together (this may require some fiddling). Once bridged, remove your soldering iron straight upwards in a swift motion for the best chance of the pads staying together. Make sure that NO path is formed to the leftmost or top pads (GND), as this will create a short circuit.

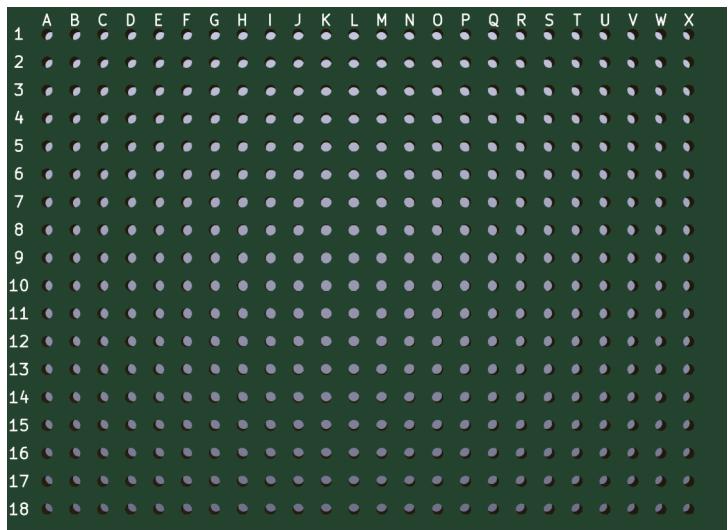
Next, we can remove capacitors C2 and C4, marked with the orange boxes. This isn't necessary for the board to function, but may save a small amount of power.

- These capacitors can be removed similarly to the resistors from the RTC module: either apply heat to both sides repeatedly or stick to one side and push until it levers upward. These components won't be used later.

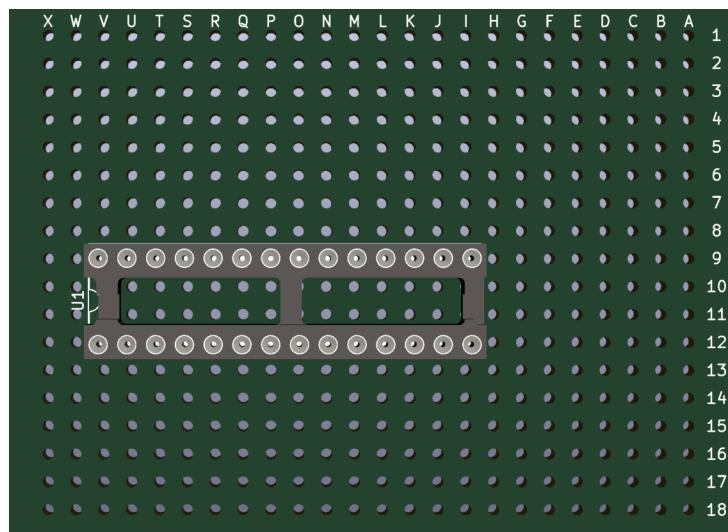
Finally, we again bend the 6 pins on the right so they are perpendicular to the board.

## Board Assembly

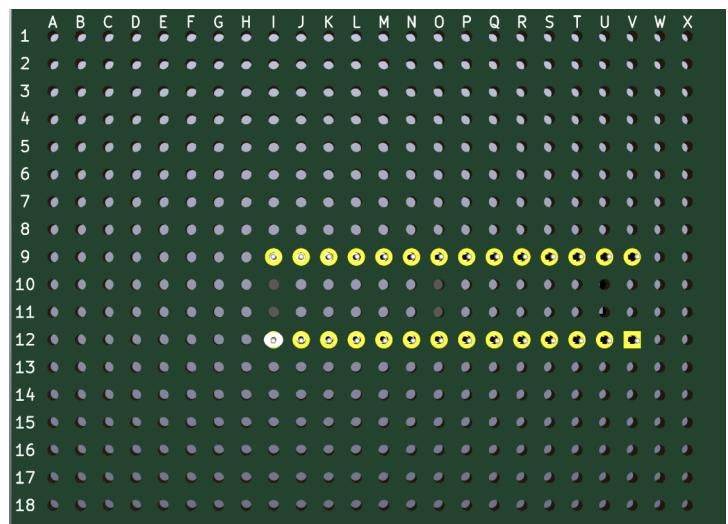
**Step 1:** Start with a blank piece of Perfboard.



**Step 2:** Place the 28 Pin DIP Socket through holes V9, V12, K12, K9. The orientation of this piece does not matter.



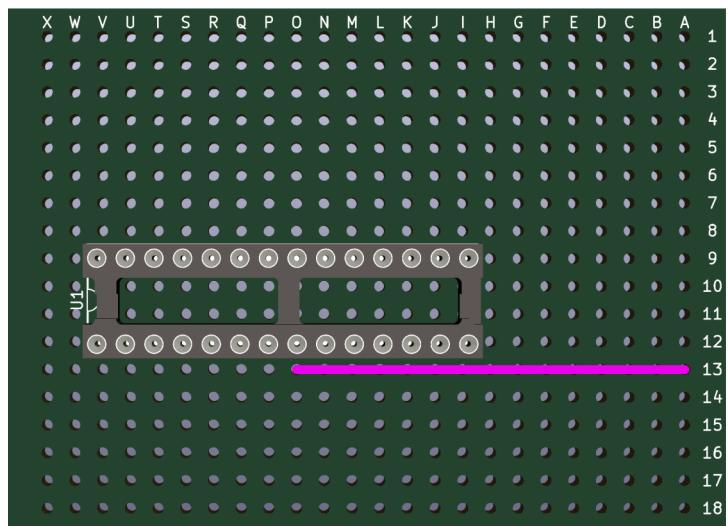
**Step 3:** Solder pin I12 to hold the socket in place.



## Board Assembly

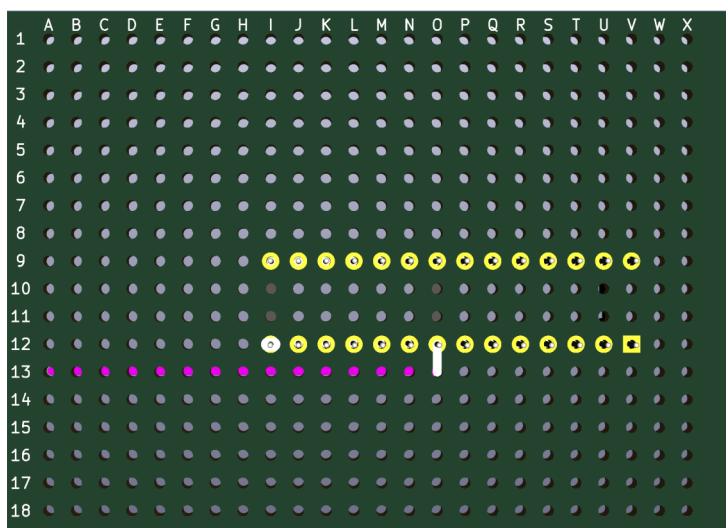
**Step 4:** Place a jumper cable between O13 and A13.

Make sure the cable is on the front of the perfboard, and that the wires are long enough to poke through each hole.



**Step 5:** Solder connections:

O12 to O13



**Step 6:** Place the MicroSD Breakout onto the perfboard:

GND goes through A12

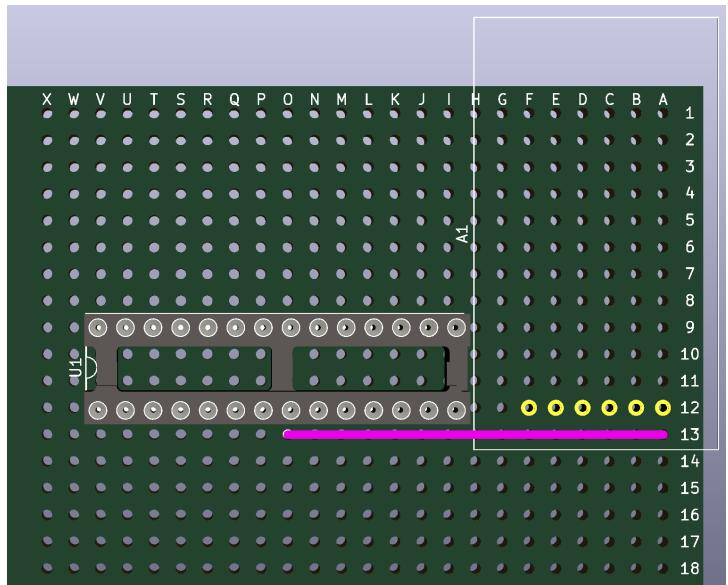
VCC goes through B12

MISO goes through C12

MOSI goes through D12

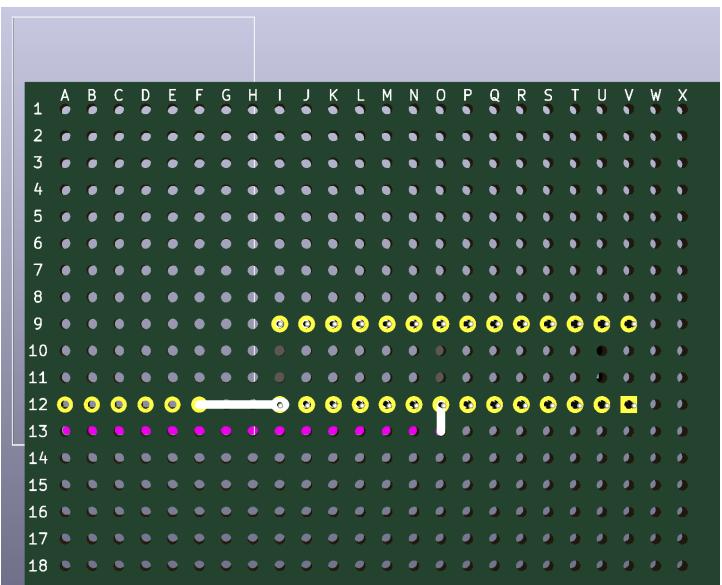
SCK goes through E12

CS goes through F12

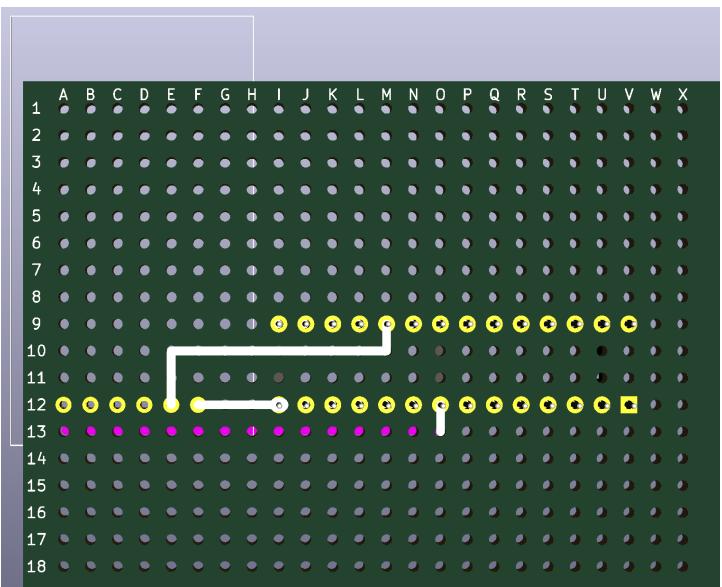


## Board Assembly

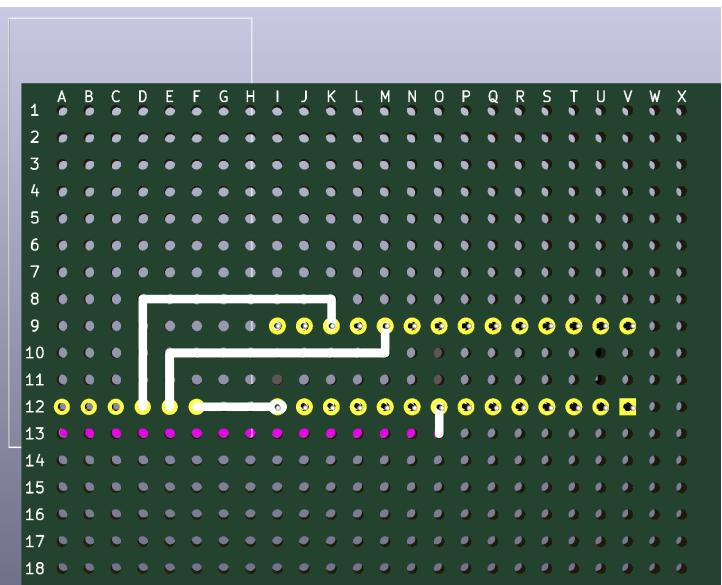
**Step 7:** Solder connections:  
F12 to I12



**Step 8:** Solder connections:  
E12 to E10 to M10 to M9

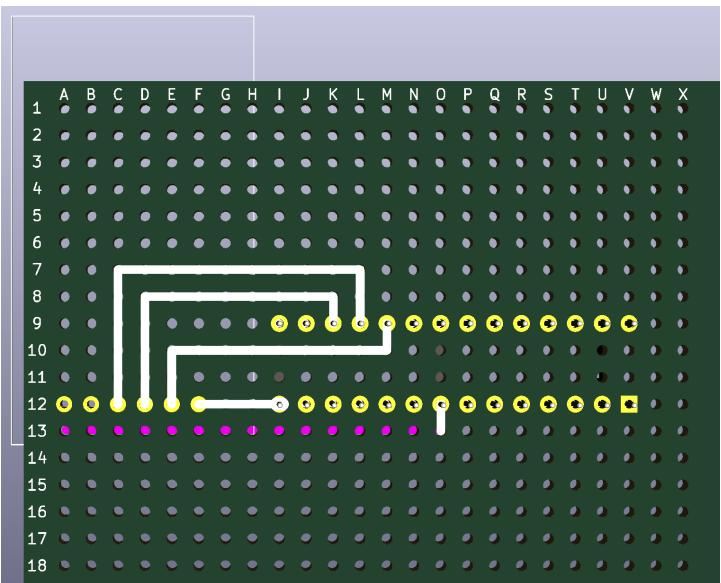


**Step 9:** Solder connections:  
D12 to D8 to K8 to K9

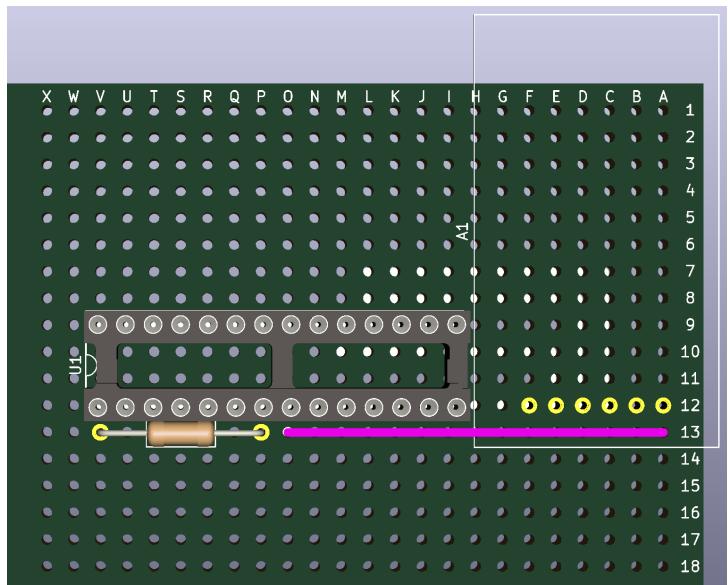


## Board Assembly

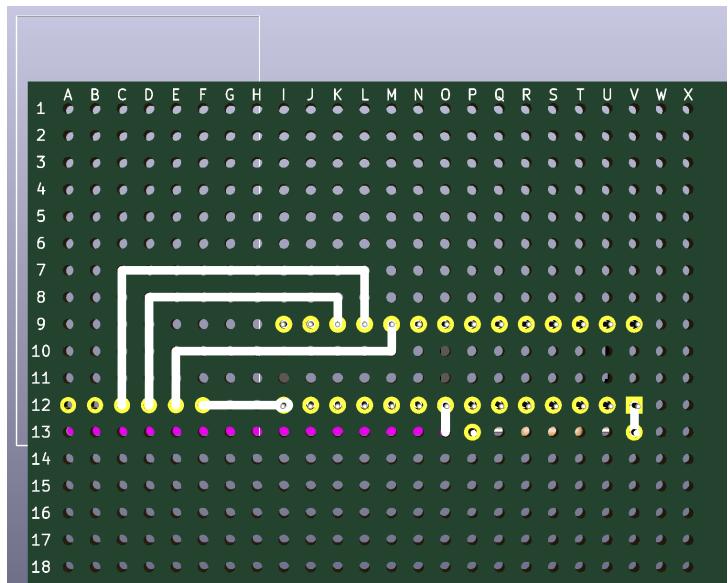
**Step 10:** Solder connections:  
C12 to C7 to L7 to L9



**Step 11:** Place a 10 KΩ Resistor between V13 and P13. The orientation of this piece does not matter.

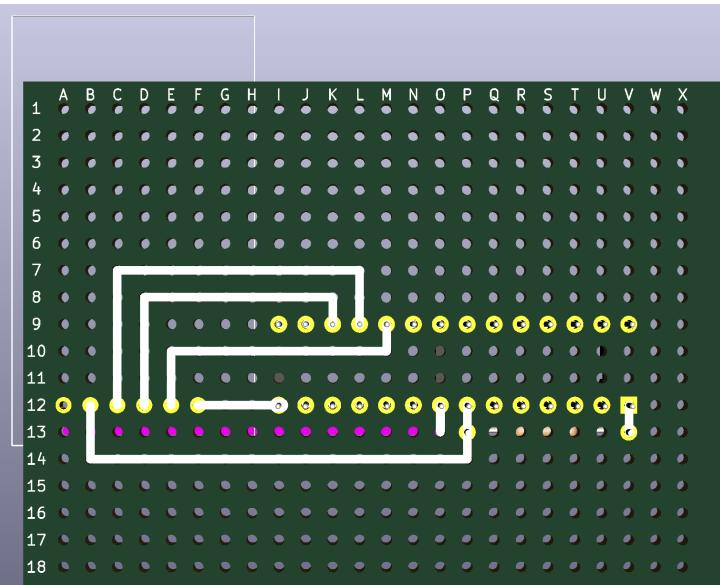


**Step 12:** Solder connections:  
V12 to V13

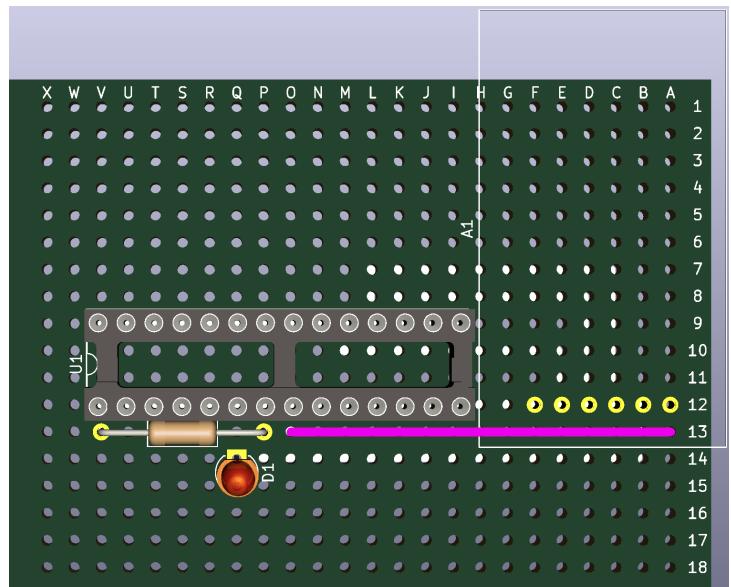


## Board Assembly

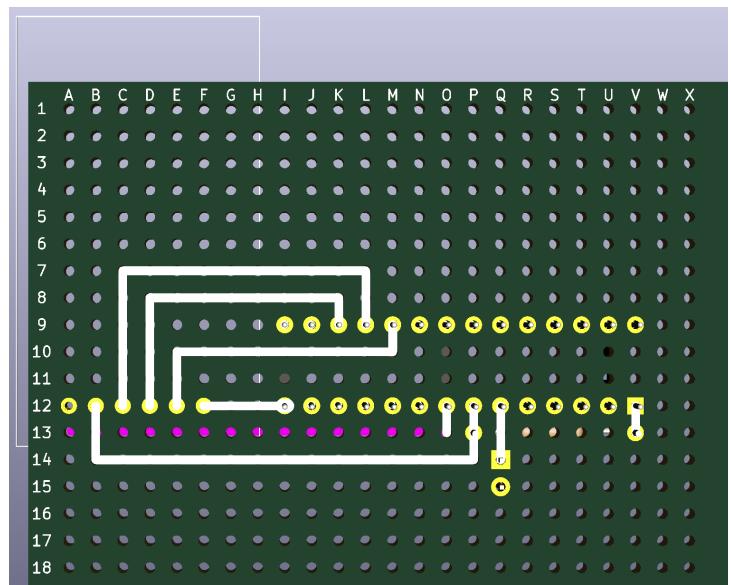
**Step 13:** Solder connections:  
B12 to B14 to P14 to P12



**Step 14:** Place the Red LED on the board, with the longer lead going through Q14 and the shorter lead going through Q15. The orientation of this piece DOES matter.

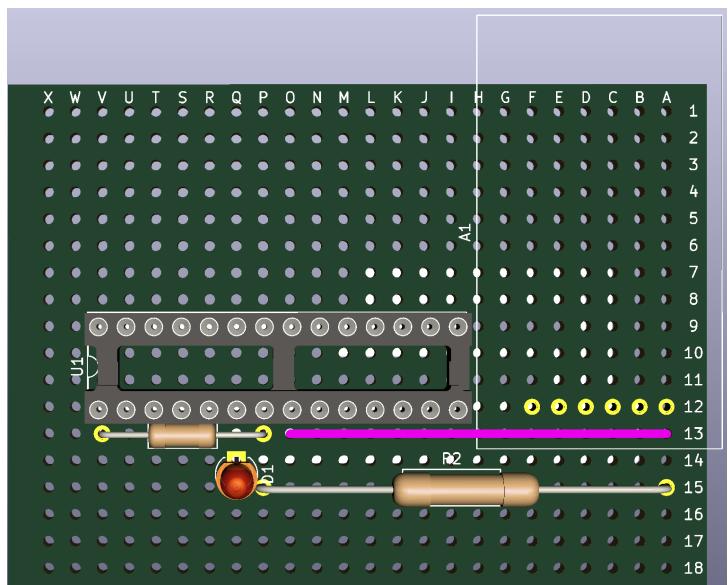


**Step 15:** Solder connections:  
Q12 to Q14

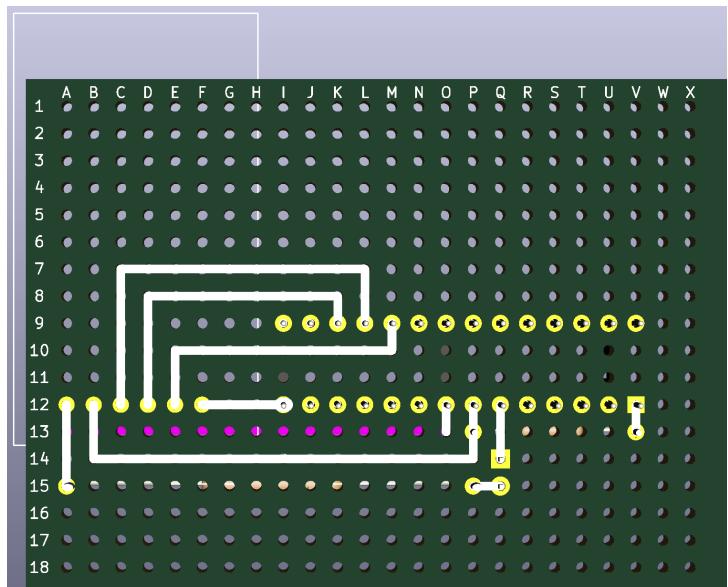


## Board Assembly

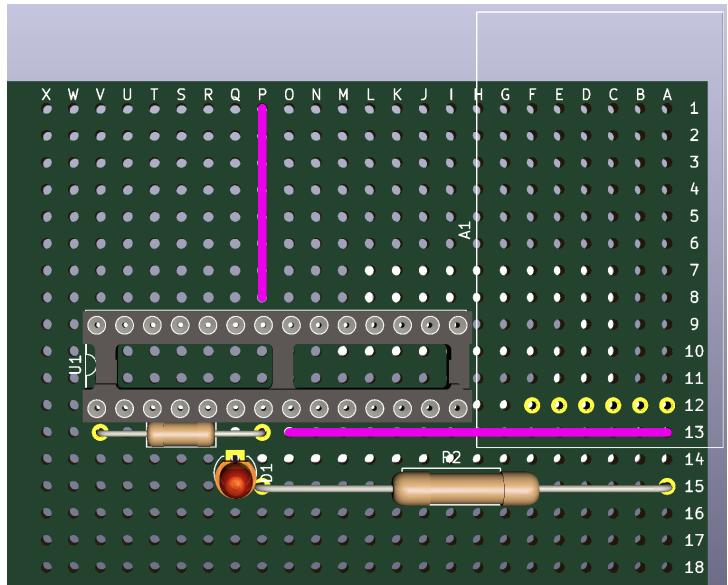
**Step 16:** Place the  $130\ \Omega$  Resistor across pins P15 and A15. The orientation of this piece does not matter.



**Step 17:** Solder connections:  
P15 to Q15  
A12 to A15

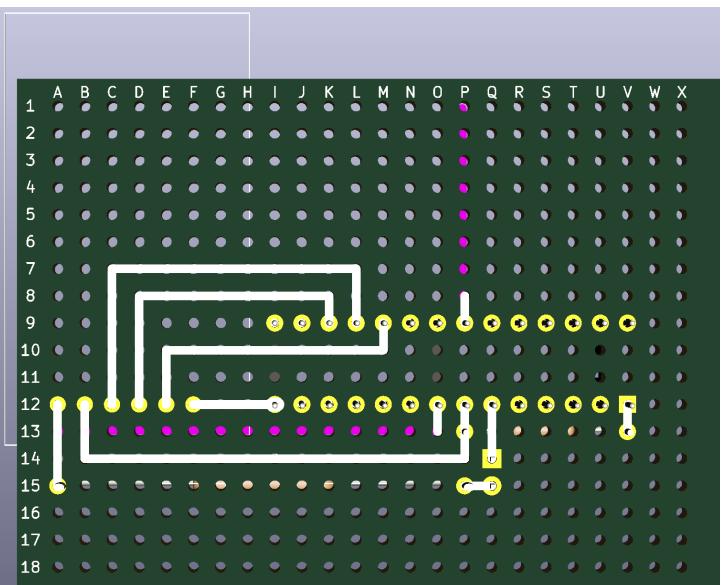


**Step 18:** Place a jumper cable between P1 and P8.  
Make sure the cable is on the front of the perfboard,  
and that the wires are long enough to poke through  
each hole.

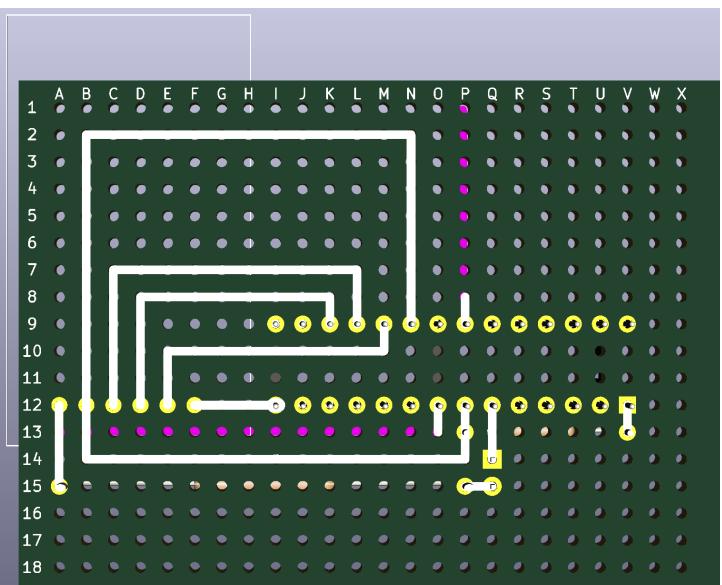


## Board Assembly

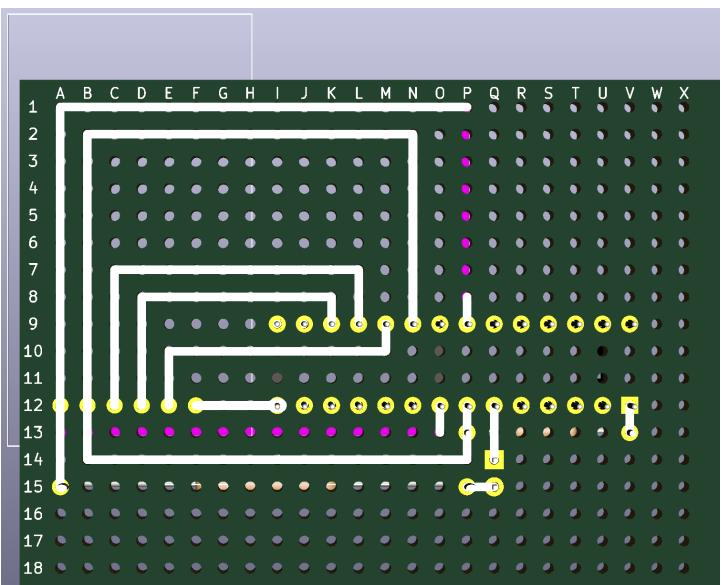
**Step 19:** Solder connections:  
P8 to P9



**Step 20:** Solder connections:  
B12 to B2 to N2 to N9

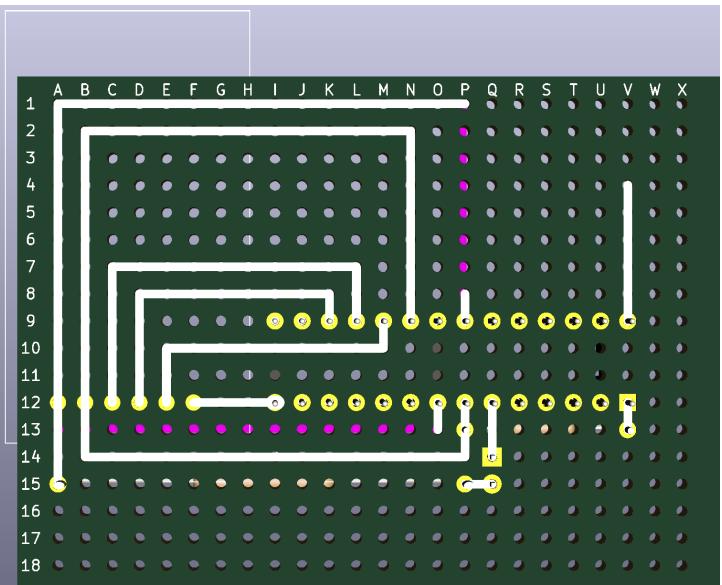


**Step 21:** Solder connections:  
A12 to A1 to P1

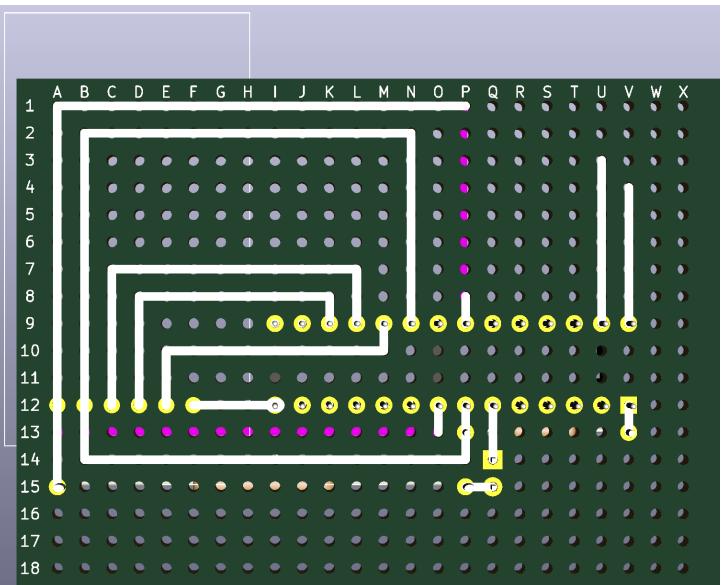


## Board Assembly

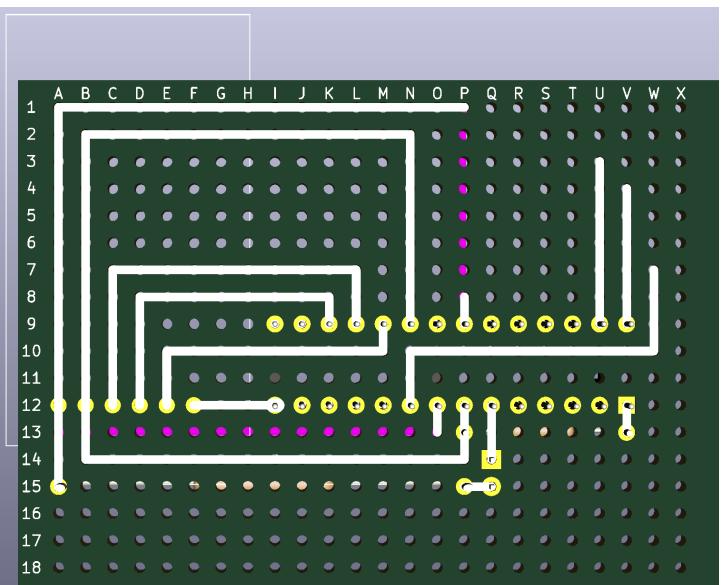
**Step 22:** Solder connections:  
V9 to V4



**Step 23:** Solder connections:  
U9 to U3

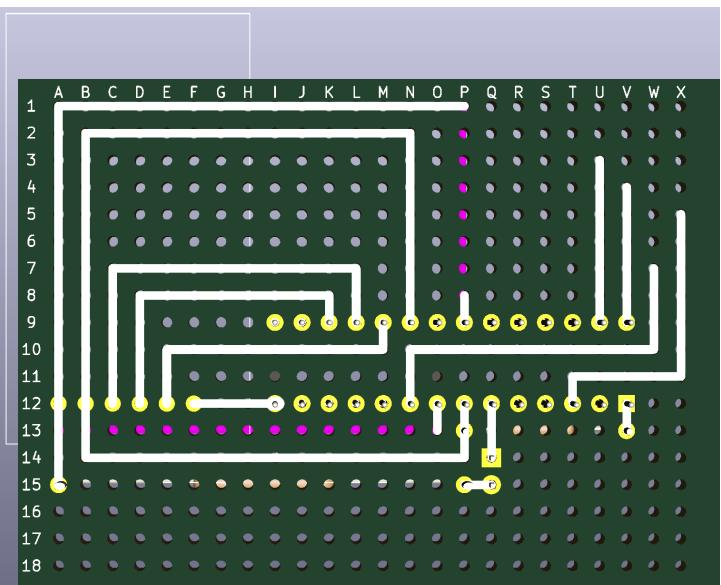


**Step 24:** Solder connections:  
N12 to N10 to W10 to W7

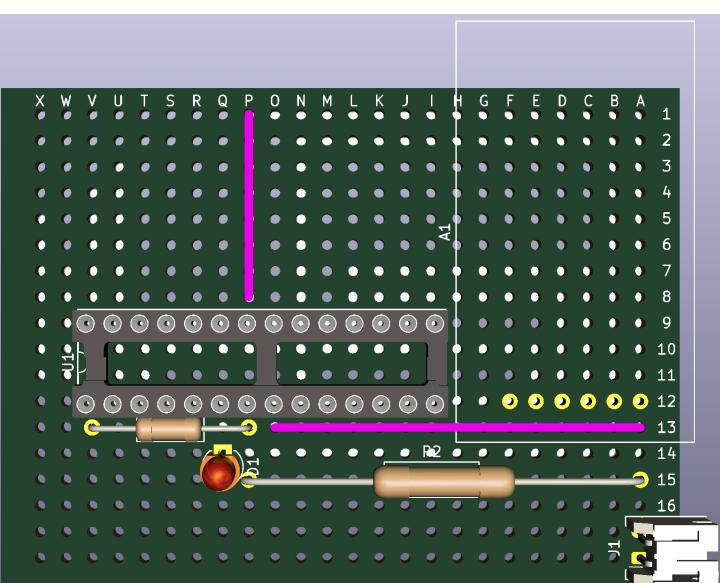


## Board Assembly

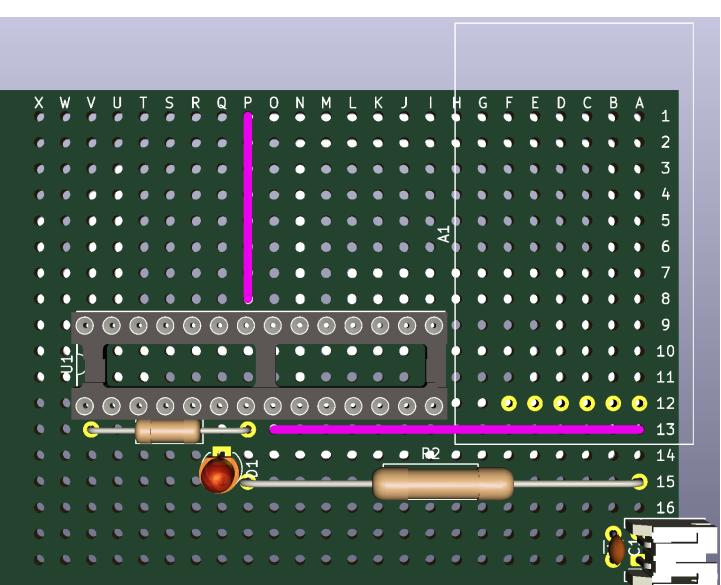
**Step 25:** Solder connections:  
T12 to T11 to X11 to X5



**Step 26:** Place the 2 Pin Male JST Connector on pins A17 and A18 such that it is facing away from the board. The orientation of this piece DOES matter.

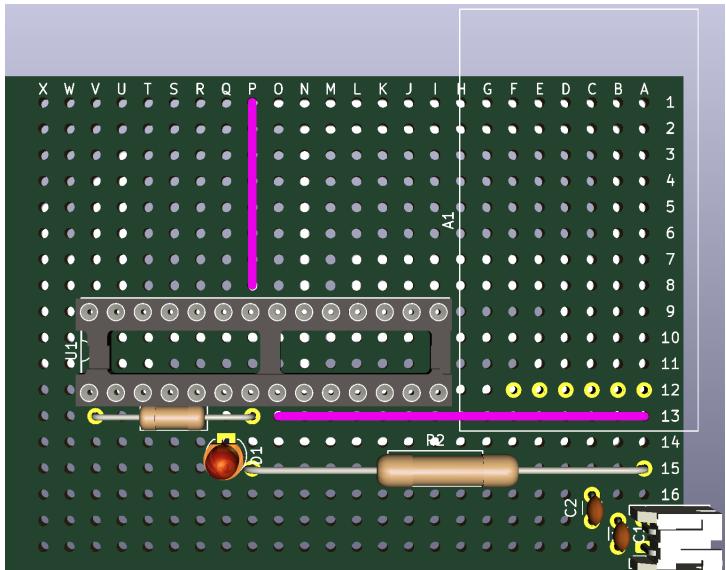


**Step 27:** Place a  $1 \mu\text{F}$  Capacitor across pins B17 and B18. The orientation of this piece does not matter.

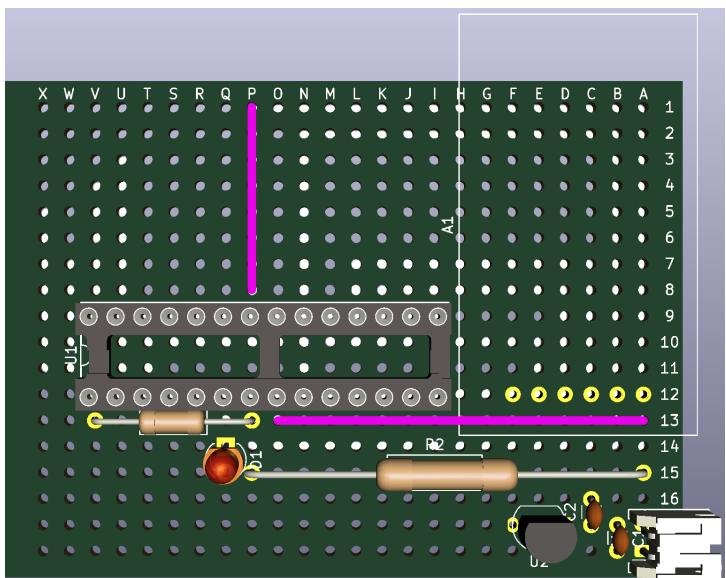


## Board Assembly

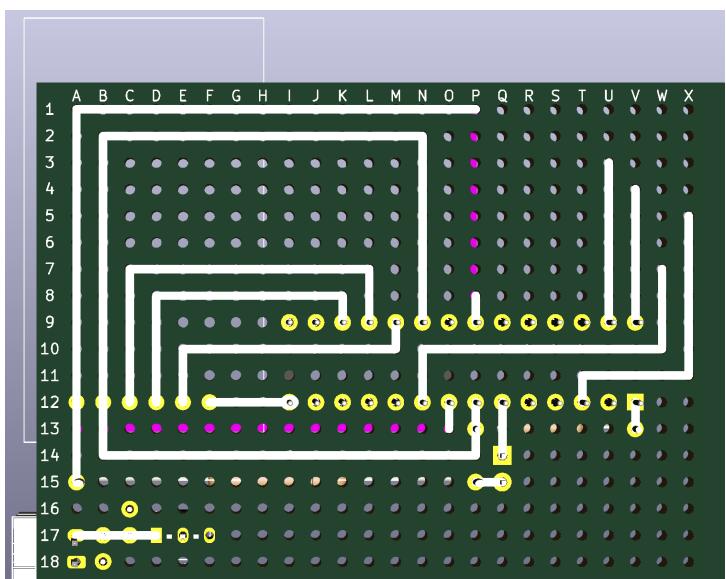
**Step 28:** Place the other 1  $\mu$ F Capacitor across pins C16 and C17. The orientation of this piece does not matter.



**Step 29:** Place the 3V Linear Voltage Regulator on pins D17 (GND), E17 ( $V_{IN}$ ), and F17 ( $V_{OUT}$ ). The orientation of this piece DOES matter. The flat side of the component should face into the board.

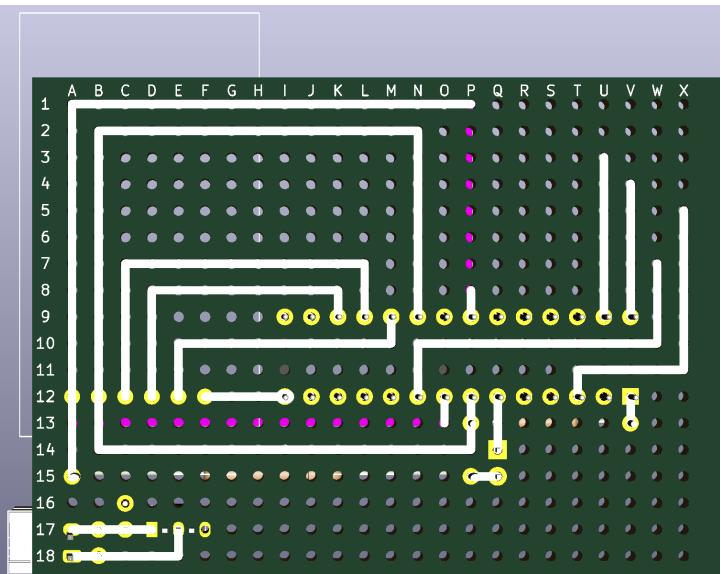


**Step 30:** Solder connections:  
A17 to D17

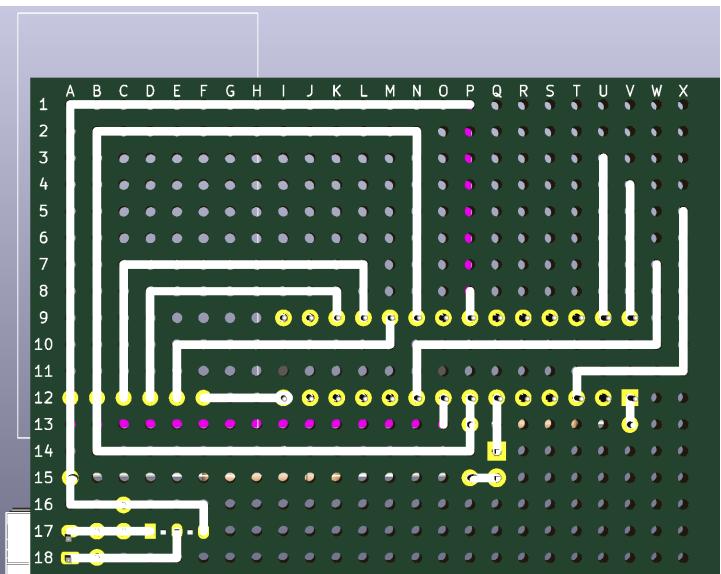


## Board Assembly

**Step 31:** Solder connections:  
A18 to E18 to E17

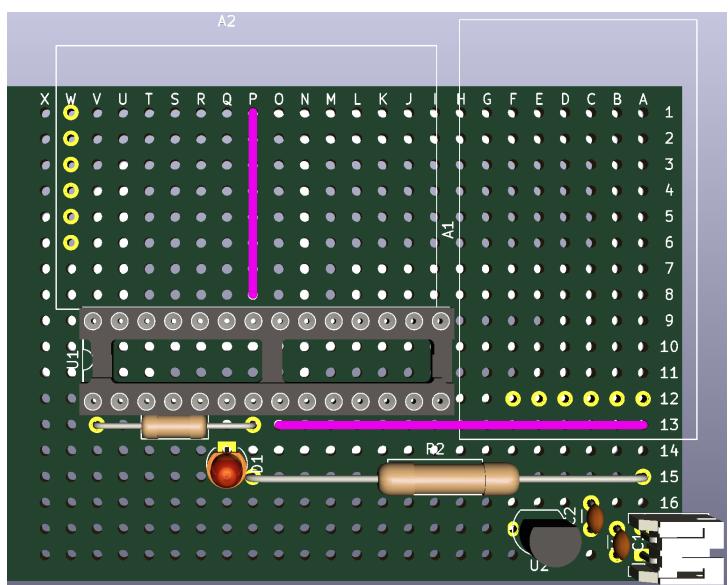


**Step 32:** Solder connections:  
F17 to F16 to A16 to A15



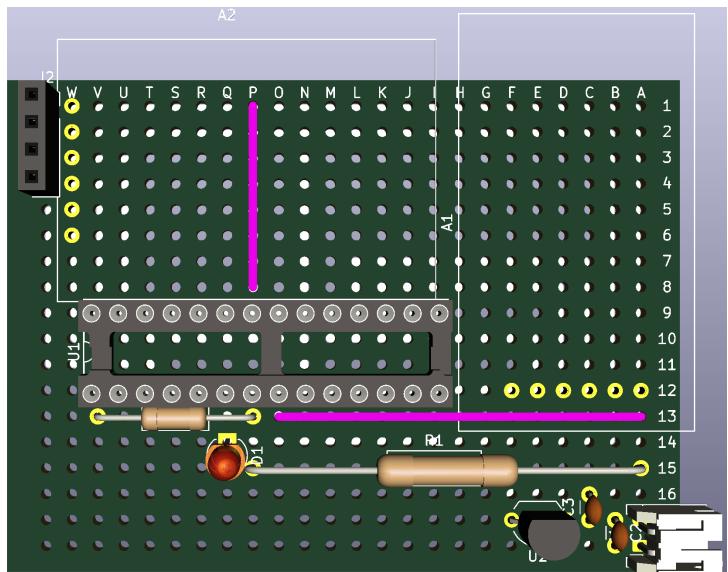
**Step 33:** Place the DS3231SN Breakout onto the perfboard:

GND goes through W1  
VCC goes through W2  
SDA goes through W3  
SCL goes through W4  
SQW goes through W5  
32K goes through W6

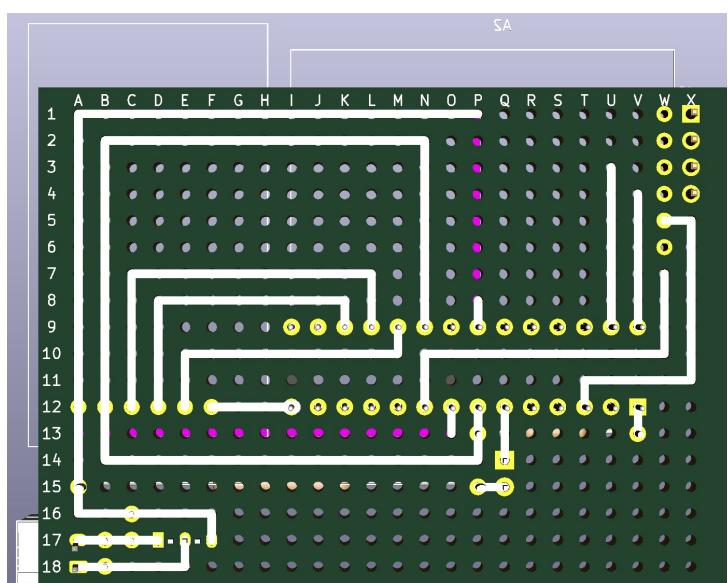


## Board Assembly

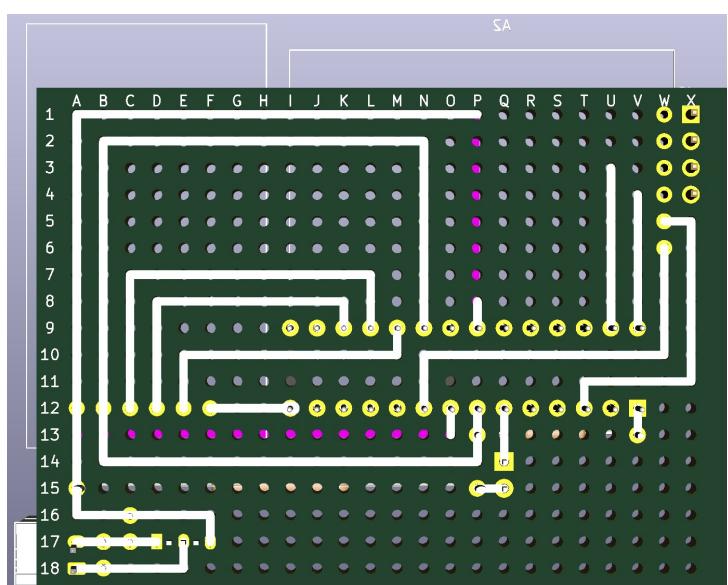
**Step 34:** Place a set of 4 Female Header Pins through X1, X2, X3, and X4. The orientation of this piece does not matter.



**Step 35:** Solder connections:  
X5 to W5

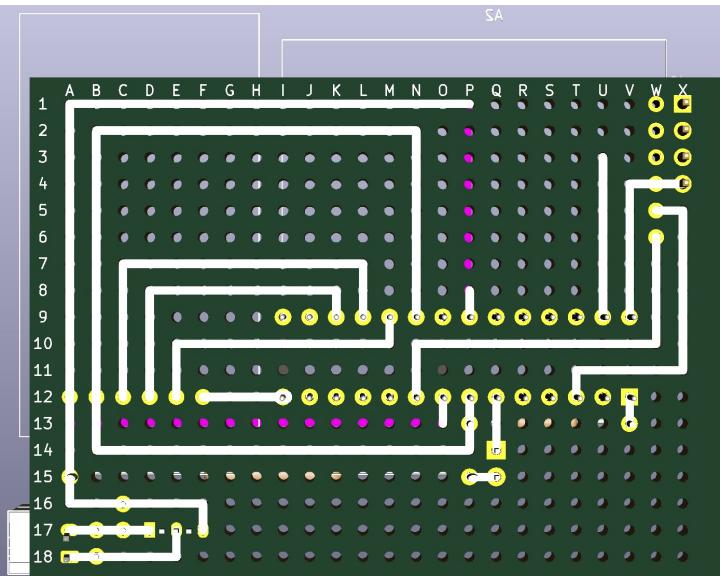


**Step 36:** Solder connections:  
W7 to W6

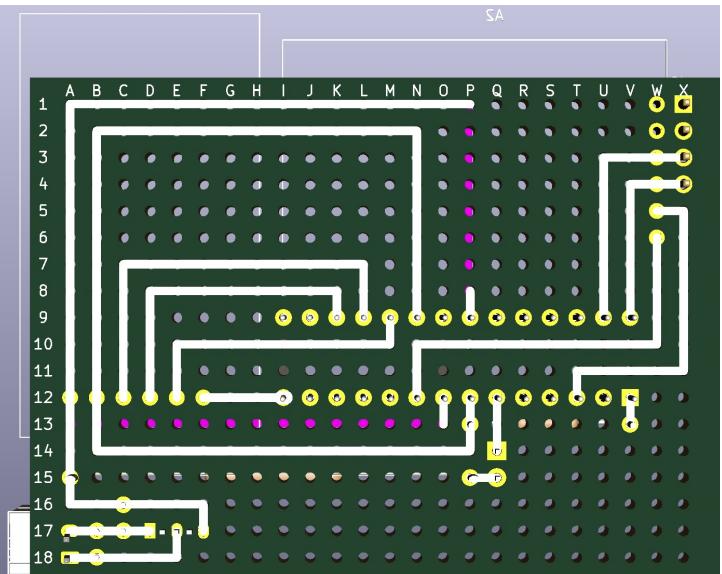


## Board Assembly

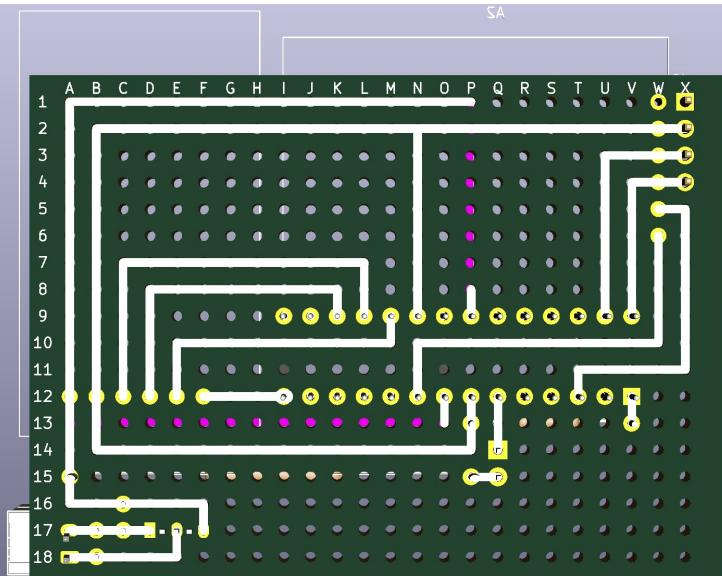
**Step 37:** Solder connections:  
V4 to X4



**Step 38:** Solder connections:  
U3 to X3

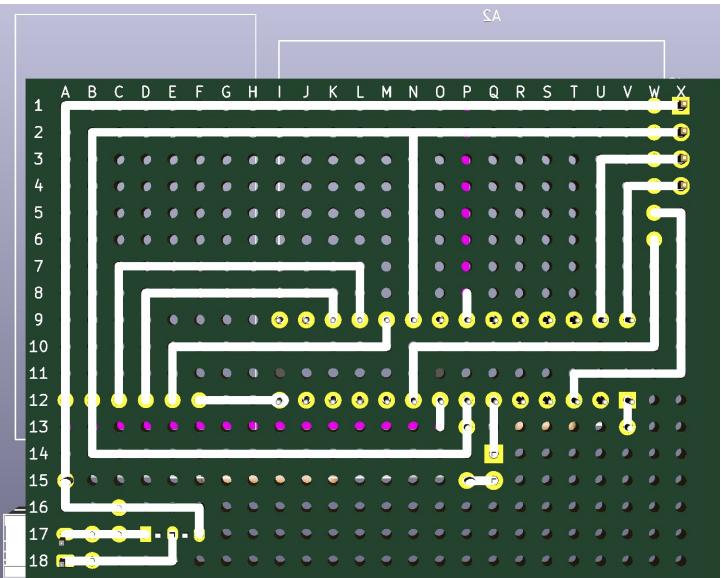


**Step 39:** Solder connections:  
N2 to X2

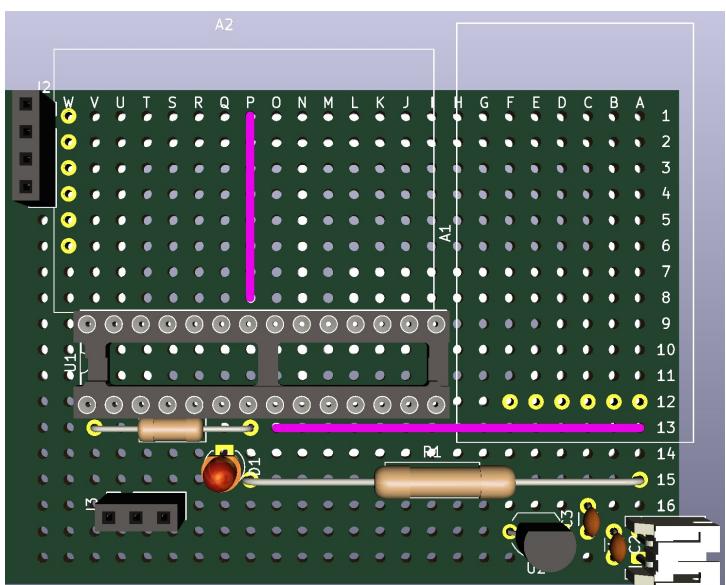


## Board Assembly

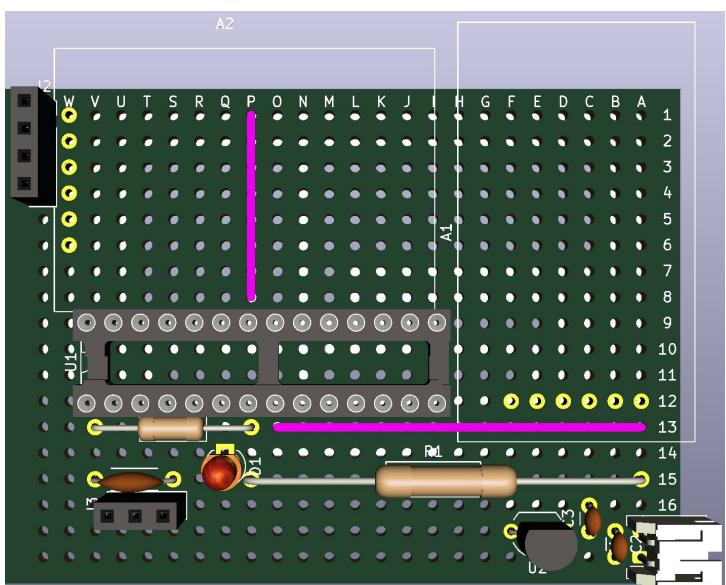
**Step 40:** Solder connections:  
P1 to X1



**Step 41:** Place a set of 3 Female Header Pins through U16, T16, and S16. The orientation of this piece does not matter.

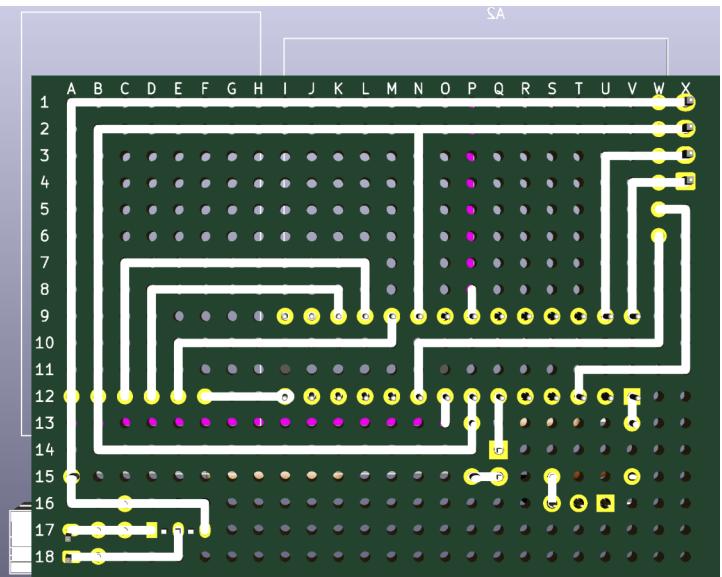


**Step 42:** Place a 0.1  $\mu\text{F}$  Capacitor across pins S15 and V15. The orientation of this piece does not matter.

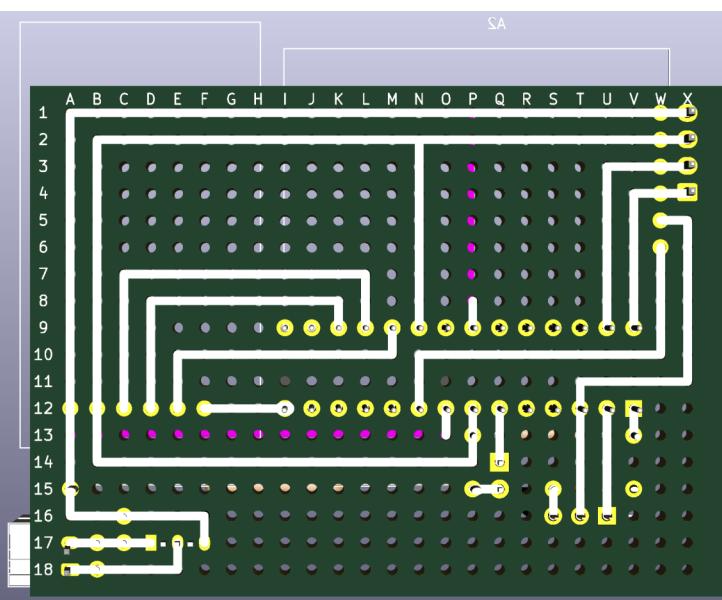


## Board Assembly

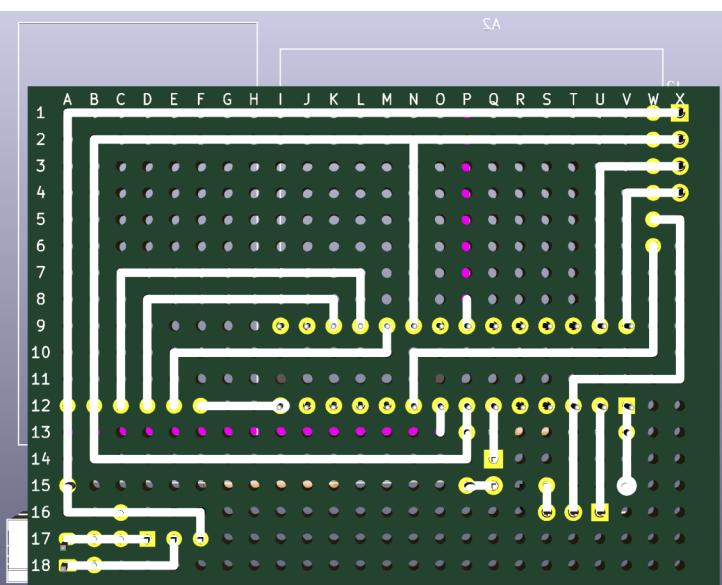
**Step 43:** Solder connections:  
S16 to S15



**Step 44:** Solder connections:  
T16 to T12  
U16 to U12

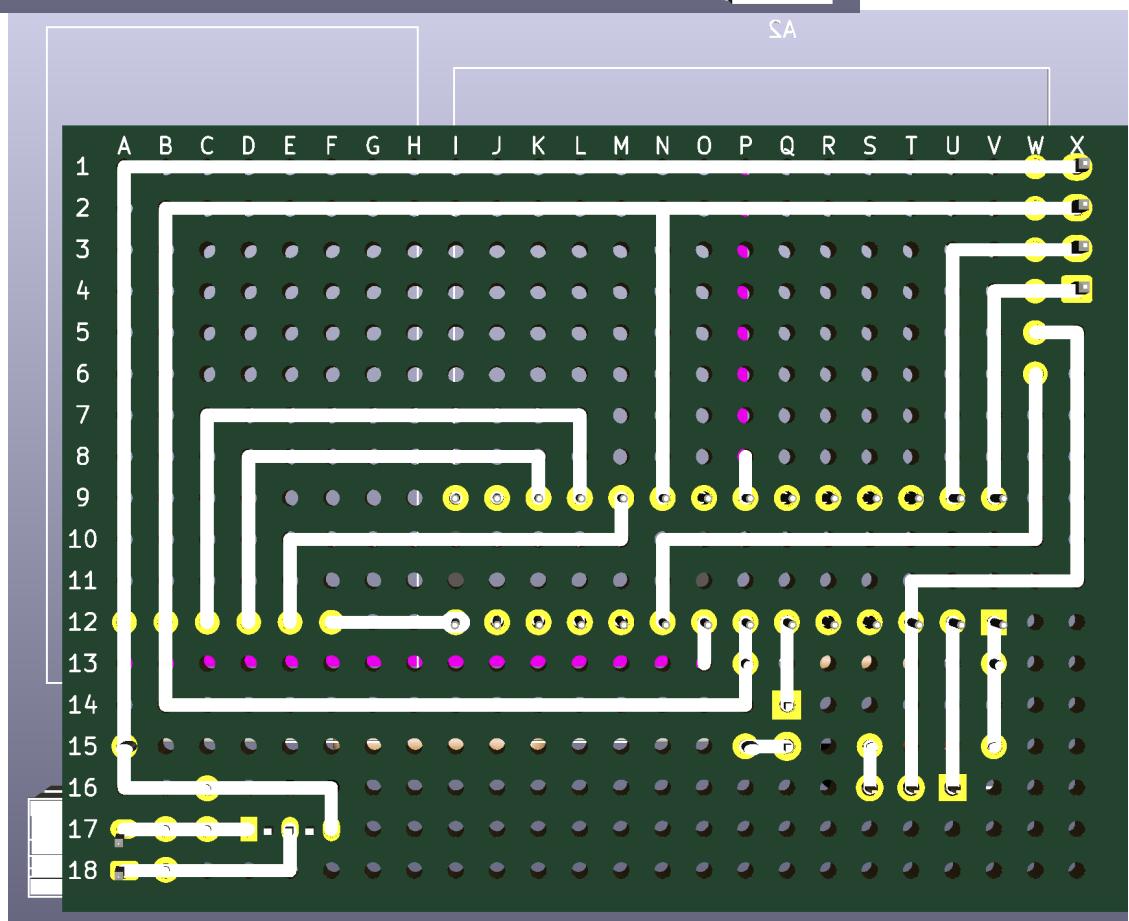
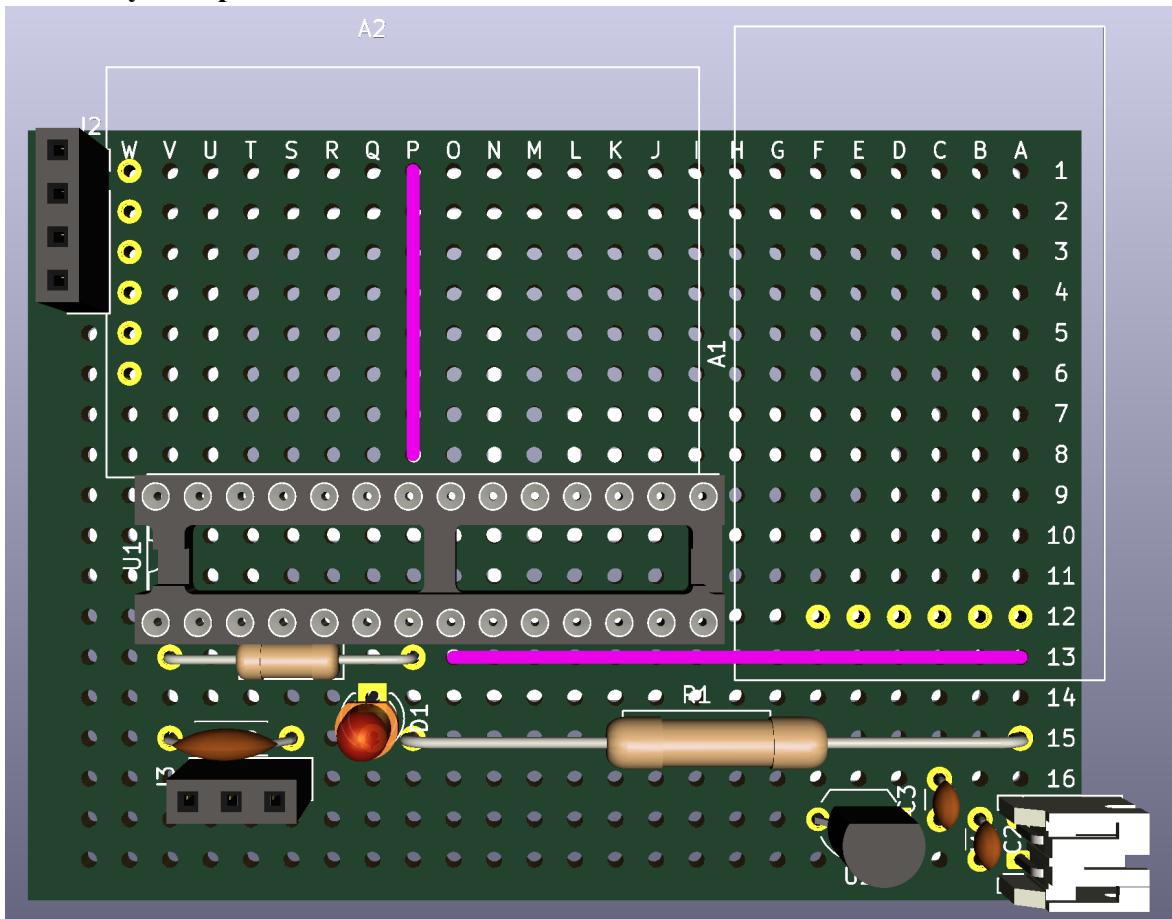


**Step 45:** Solder connections:  
V15 to V13



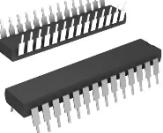
## Board Assembly

Assembly Complete!



## Programming the ATmega328P

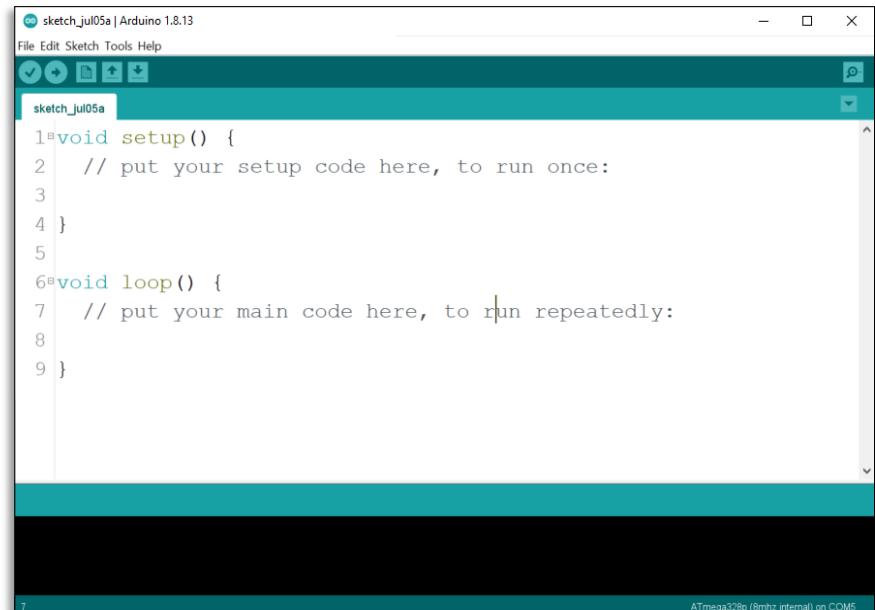
This portion of the guide will explain how to upload a bootloader and code onto the ATmega328P chip using the Arduino IDE. These steps will require the following equipment:

Image	Part	Quantity	Image	Part	Quantity
	Arduino Uno	1		USB Type A to USB Type B Cable	1
	3.3V FTDI USB to TTL Serial Adapter	1		USB Type A to USB Type B Mini	1
	Breadboard	1		ATmega328P	1
	10 KΩ Resistor	1		1 μF Capacitor	1
	Male to Male, Male to Female, and Female to Female Jumper Wires	*depends on wiring*			

## Downloading and Setting Up the Arduino IDE

The Arduino IDE is the software used to develop code for and program Arduinos.

Although this pressure logger does not use a full Arduino, it does use the same chip as the Arduino Uno (the ATmega328P). This means the user friendly and free Arduino IDE can still be used to interact with the standalone ATmega328P.

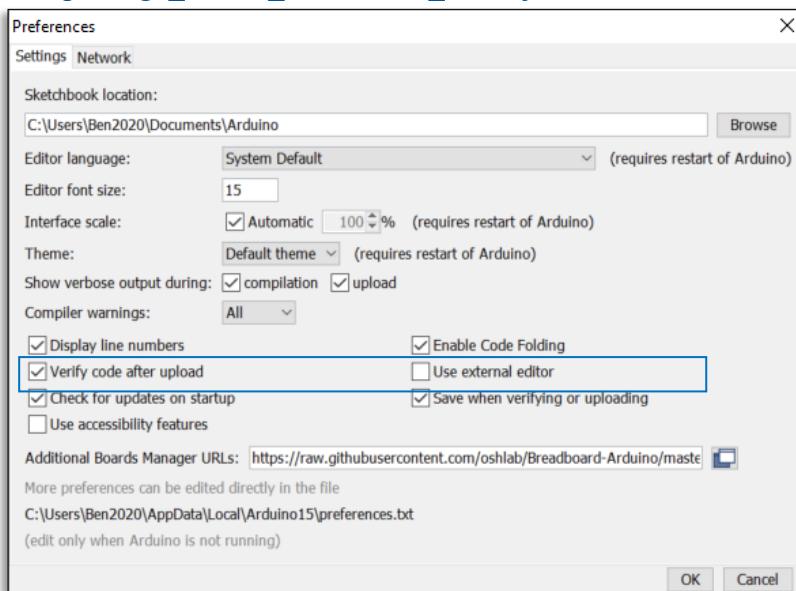


```
sketch_jul05a | Arduino 1.8.13
File Edit Sketch Tools Help
sketch_jul05a
1 void setup() {
2 // put your setup code here, to run once:
3
4 }
5
6 void loop() {
7 // put your main code here, to run repeatedly:
8
9 }
```

ATmega328p (8MHz internal) on COM5

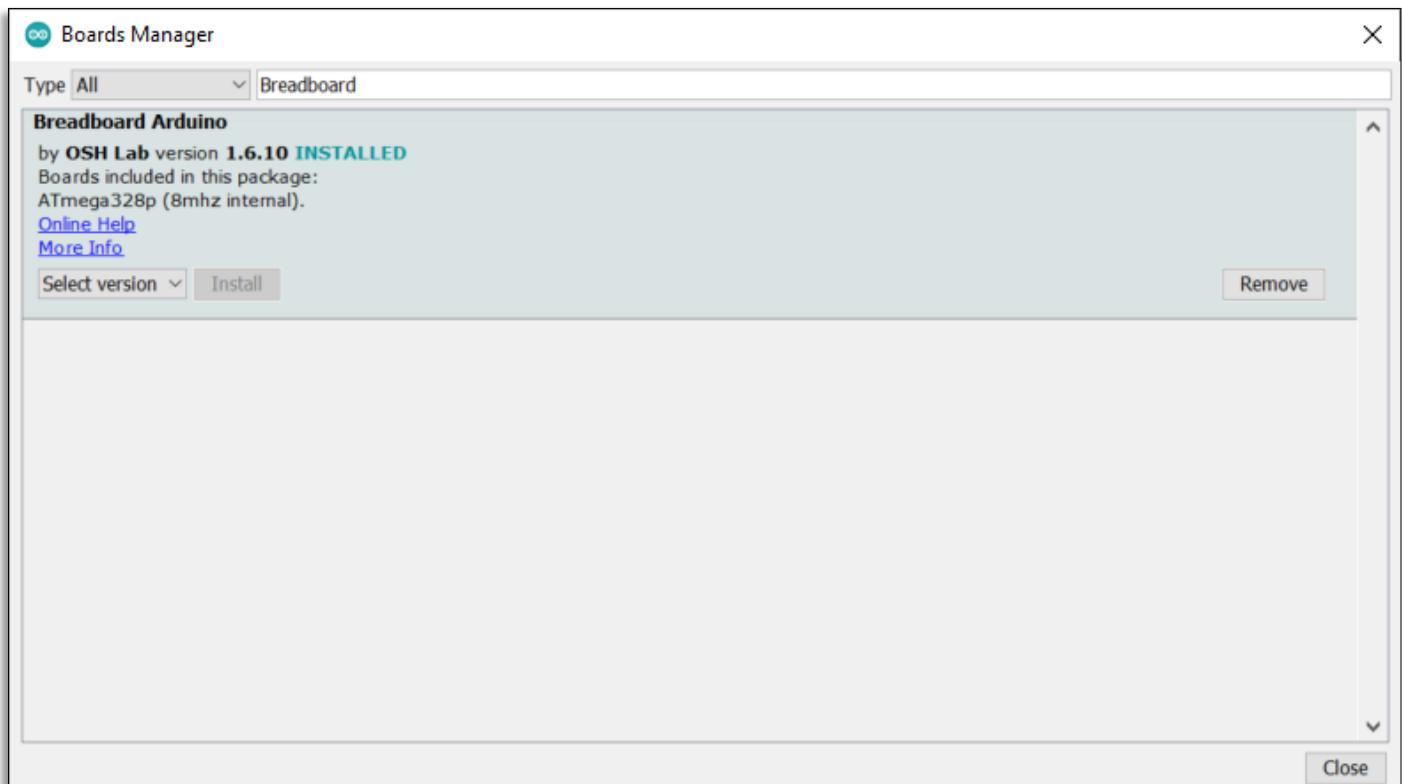
## Programming the ATmega328P

1. To download the IDE, navigate to <https://www.arduino.cc/en/software> and download the appropriate installer for your OS. See the “Install the Arduino Desktop IDE” section at <https://www.arduino.cc/en/Guide> for more details. This guide is based off of version 1.8.13 of the IDE. Once the IDE has been downloaded, install and run it. You should be greeted with a window similar to the one on the previous page.
2. In the IDE, go to File -> Preferences and paste the following link in the “Additional Boards Manager URLs” box:  
[https://raw.githubusercontent.com/oshlab/Breadboard-Arduino/master/avr/boardsmanager/package\\_oshlab\\_breadboard\\_index.json](https://raw.githubusercontent.com/oshlab/Breadboard-Arduino/master/avr/boardsmanager/package_oshlab_breadboard_index.json)



This link points to a board configuration that will be downloaded next for the ATmega328P, specifically one that uses the 8MHz internal clock of the chip. It can be found on the unofficial list of 3rd party Arduino boards at <https://github.com/arduino/Arduino/wiki/Unofficial-list-of-3rd-party-boards-support-urls>. This allows us to run the chip at 3V. The other settings here can be customized.

3. Navigate to Tools -> Board -> Boards Manager. Find the “Breadboard Arduino” configuration (search for “Breadboard”) and install it.



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4. Navigate to Sketch -> Include Library -> Manage Libraries. Three external libraries are needed: “SdFat”, “RTCLib”, and “SparkFun MS5803-14BA Pressure Sensor”. Find each one in the library manager and install it. The version of each library used by this guide is shown in the images below; if the most recent version of the library causes issues during later steps, try using the versions shown here.

The image displays three separate instances of the Arduino Library Manager window, each showing a different library installed:

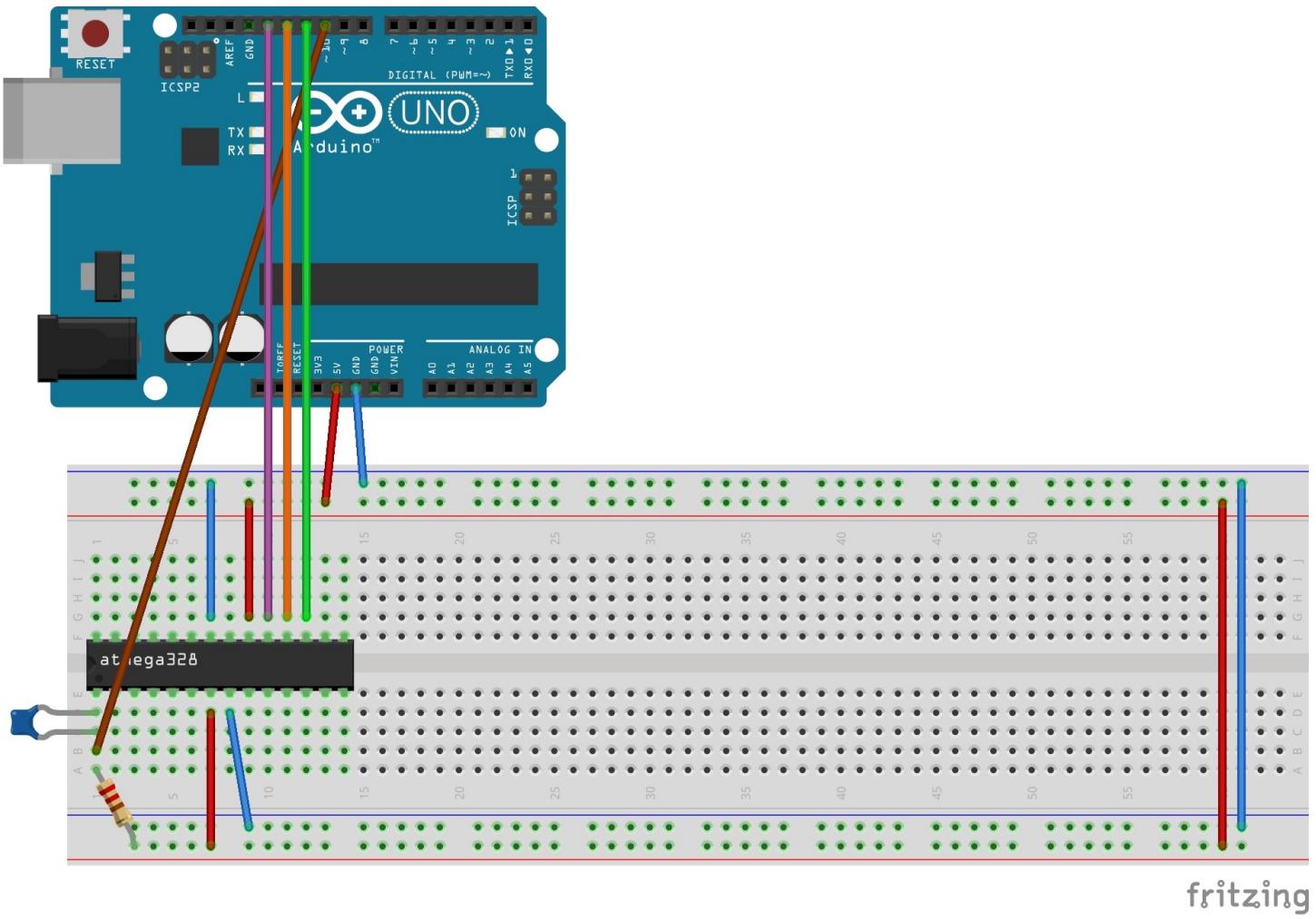
- SdFat**: Version 2.0.7 (INSTALLED). Description: Low-power general-purpose data logger library, written for the Arduino-based ALog but expandable to other devices. This toolkit handles power management, the clock, and the SD card for a lightweight field data logger, and contains pre-made functions for a range of sensors.
- DS3231**: Version 1.13.0 (INSTALLED). Description: Arduino library for the DS3231 real-time clock (RTC) Abstracts functionality for clock reading, clock setting, and alarms for the DS3231 high-precision real-time clock. This is a splice of Ayars' (<http://hacks.ayars.org/2011/04/ds3231-real-time-clock.html>) and JeeLabs/Ladyada's (<https://github.com/adafruit/RTCLib>) libraries.
- SparkFun MS5803-14BA Pressure Sensor**: Version 1.1.2 (INSTALLED). Description: Library for MS5803-14BA Pressure Sensor. Provides I2C communication protocol for measuring water depth, altitude, or other pressure readings.

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## Uploading the Bootloader

- This step is only required for fresh ATmega328P chips. After the bootloader has been burned into the chip once, it will not need to be burned again.
  - There are many ways to burn a bootloader onto a chip, and this guide only briefly describes one possible approach.

First, the ATmega328P must be set up on a breadboard. This breadboard setup will allow the “ATmega328p (8mhz internal)” bootloader to be burned onto the ATmega328P using an Arduino. The following image shows the necessary wiring. The blue capacitor has a value of  $1 \mu\text{F}$  and the resistor has a value of  $10 \text{ K}\Omega$ ; their orientations do not matter. Do note the orientation of the ATmega328P, however, as the notched end must face away from the breadboard (as shown dimly in the image).



Double check all wiring before plugging the Arduino Uno into your computer using the USB Type A to USB Type B Cable.

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The Arduino IDE will be used for the following steps:

1. In order to use the Arduino Uno to upload a bootloader, the Uno must be programmed with the “ArduinoISP” sketch. Navigate to File -> Examples -> ArduinoISP and select ArduinoISP to open the desired sketch.
2. Navigate to Tools -> Board -> Arduino AVR Boards and select Arduino Uno.
3. Navigate to Tools -> Port and select the port with the Arduino Uno attached.
4. Navigate to Tools -> Programmer and select AVRISP mkII.
5. Upload the sketch using the “Upload” button found at the top of the window and in the Sketch menu.  
The output should look similar to either of the following:

```
Done uploading.

Sketch uses 4354 bytes (13%) of program storage space. Maximum is 32256 bytes.
Global variables use 482 bytes (23%) of dynamic memory, leaving 1566 bytes for local variables. Maximum is 2048 bytes.

<
1

Done uploading.

avrduude: reading on-chip flash data:

Reading | #####| 100% 0.57s

avrduude: verifying ...
avrduude: 4354 bytes of flash verified

avrduude done. Thank you.

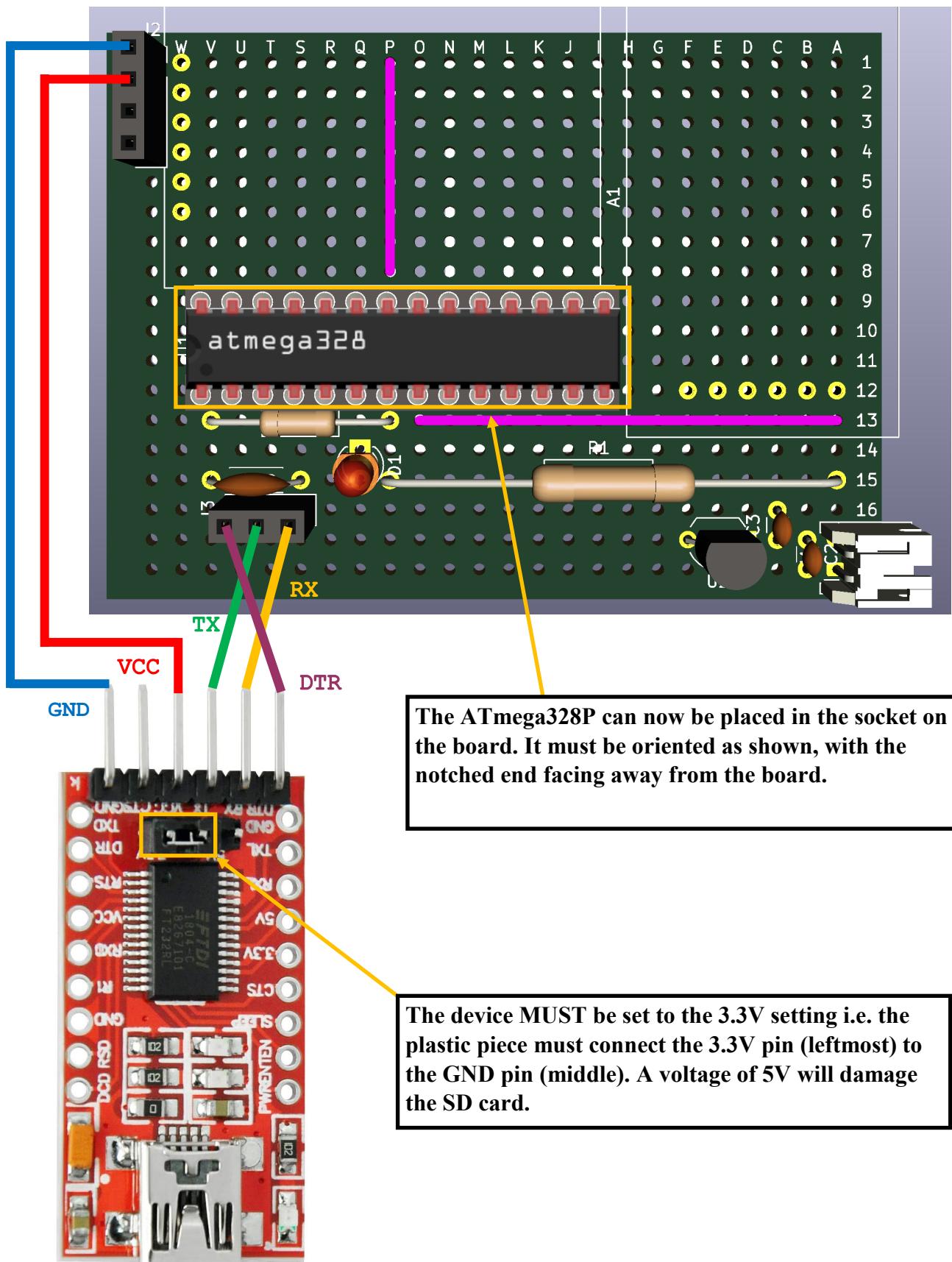
<
1
```

6. Now that the Uno is ready, the bootloader can be uploaded. Navigate to Tools -> Board -> Breadboard Arduino (OSHLAB.com) and select ATmega328p (8mhz internal).
7. Navigate to Tools -> Programmer and select Arduino as ISP.
8. Burn the bootloader to the chip by pressing the “Burn Bootloader” button in the Tools menu. If the operation is successful, a light will blink once per second on the Uno.

## Programming the ATmega328P

### Uploading Code

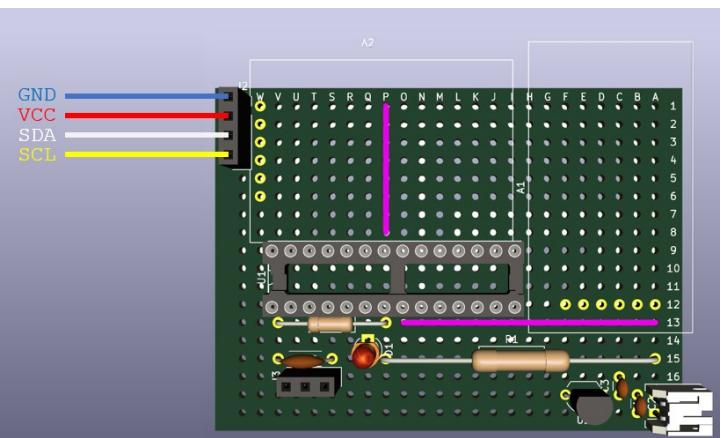
The following circuit must be set up in order to upload code to the ATmega328P. Once ready, one program will be uploaded to set the time on the RTC before uploading the main code used by the device.



## Operation Details

### Initialization:

Once the housing and the circuit board have been assembled, the ATmega328p microchip has been programmed, and the DS3231SN Real Time Clock (RTC) has been set to the correct time, the pressure sensor is ready to collect data. Before powering a sensor, ensure the DS3231SN Breakout is fitted with a CR2032 coin cell battery, the microSD Breakout has a microSD card in the slot, and the wires from the MS5803-14BA pressure sensor are plugged into the correct ports on the board, as shown on the right.



When the device is powered by plugging a battery into the connector in the lower right, it will immediately initialize the RTC, microSD card, and MS5803-14BA pressure sensor; there is no on/off switch. If any of these initializations fail, the device will stop and the error LED will blink at a rate indicating the issue:

- 1 blink repeating: issue with RTC
- 2 blinks repeating: issue with microSD card / breakout
- 3 blinks repeating: failed to create file on SD card

Warning blinks may also be seen:

- 1 short blink indicates that the RTC has lost power at some point, and needs to be reset to the correct time. The device will still function properly, but its time will not be accurate and will not be synchronized with other sensors.
- 2 short blinks indicate that there was an issue reading data from the configuration file on the SD card (see below), and that the device will be using default (hardcoded) settings.

### Creating a configuration file:

The device has 4 configurable settings which can be modified by creating a `config.txt` file in the root directory of the SD card. This makes it easier to modify deployment parameters, as it does not require the sensor to be reprogrammed in order to make the changes. The settings are the following:

`startMinute`: The minute-hand value when the sensor should begin taking the first sample. A value greater than 59 will cause the sensor to begin sampling immediately. This can be used to start multiple sensors at the same time, assuming their clocks are accurately synchronized. The device goes into a low power sleep while waiting.

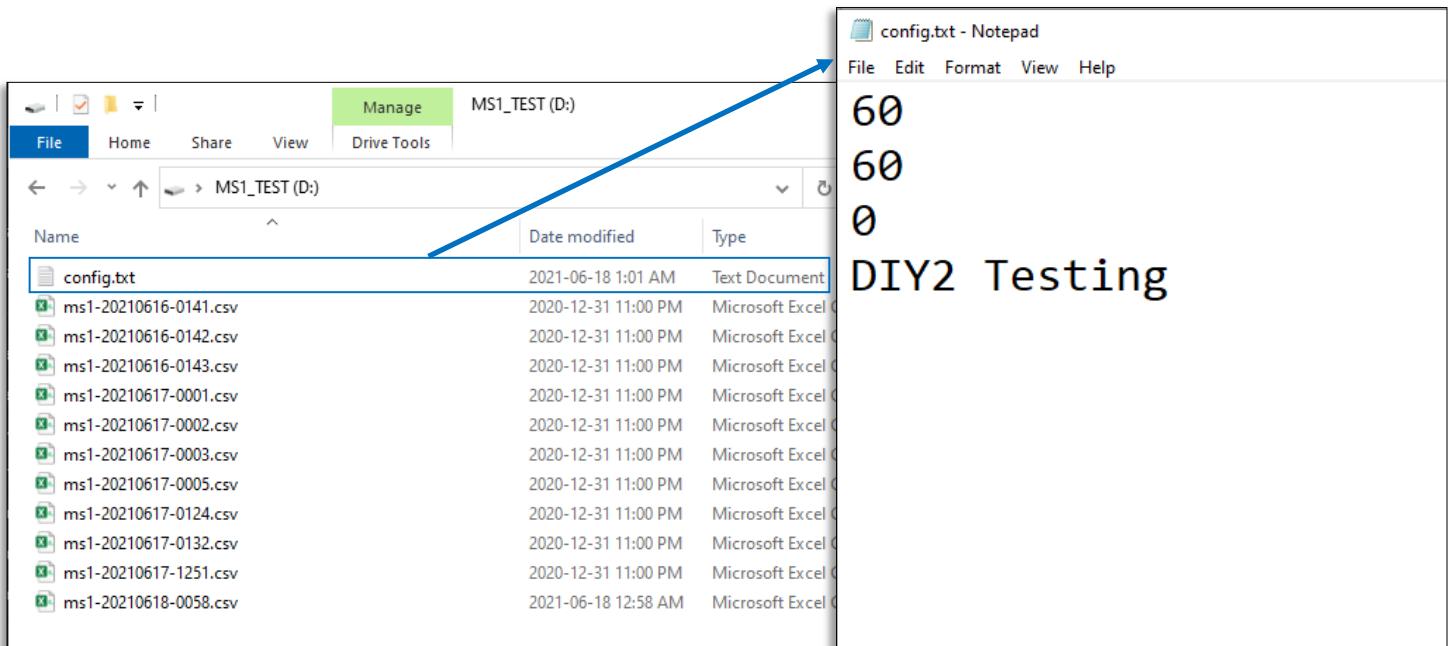
`sampleDuration`: The duration of time (in minutes) spent sampling before the device should sleep during a single cycle. This value will have no effect if `sleepDuration` is set to 0, since the device will be sampling continuously.

`sleepDuration`: The duration of time (in minutes) to spend in a low power sleep before resuming sampling during a single cycle. If the value is set to 0, the device will sample continuously (no deep sleeping).

`infoString`: A short piece of text to place in each CSV file. This can be used to identify the specific sensor and site (63 characters max).

## Operation Details

The below example of a configuration file shows the following: startMinute=60, sampleDuration=60, sleepDuration=0, infoString="DIY2 Testing". This means the sensors will begin sampling immediately after being powered, and will sample continuously (without sleeping). The text "DIY2 Testing" (without quotes) will be present in the second row of each CSV file created by the device. Note that only the values are present in the text file, and each value is separated by a new line in the order described above (startMinute, sampleDuration, sleepDuration, infoString).



## Sampling

After the device has been initialized and the start time has been reached (if a start time was set), the device is ready to begin sampling. The LED will then flash for 3 seconds to notify the user. At the beginning of sampling and at the start of each day, a new CSV file will be created on the SD card. Depending on the sleepDuration value, the device may sample continuously or temporarily go to sleep after the time specified by samplingDuration. For example, using samplingDuration=17 and sleepDuration=3, the device will first sample for 17 minutes, then go into a low power sleep for 3 minutes, then repeat. The device will remain active until the voltage provided by the battery drops sufficiently low or the power is removed.