MegaSat
Assembly Manual

Description

The ***MegaSat*** is a custom sensor interface shield which serves as the platform for learning to use and apply the Arduino Mega 2560 development board. It includes an accelerometer/gyroscope breakout board, internal and external temperature sensors, humidity and pressure sensors, and a real-time clock (RTC). Power is provided to the ***MegaSat's*** sensors and circuits by a +12V supply. Voltage regulators are used to supply +3.3V and +5V. There is also a +5V reference onboard. The ***MegaSat*** includes a datalogger shield that provides GPS, micro-SD for storage, and a small prototyping area.

The ***MegaSat*** is a shield that interfaces with the Arduino Mega 2560 development board. It features a 16-channel, 10-bit analog-to-digital converter (ADC) with 16 analog input/output (I/O) pins. It has 54 digital I/O pins, 15 of which are designated for pulse width modulation (PWM) with 6 interrupts, and 4 are designated universal asynchronous receiver-transmitter (UART) hardware serial ports. It has a 16 MHz processor with 8 kB static random-access memory (SRAM), 256 kB of flash memory, and 4kB electrically erasable programmable read-only memory (EEPROM).

MegaSat can be used as a compact data acquisition system in the laboratory or integrated into a student-designed balloon payload where it can serve as the payload flight computer. ***MegaSat*** is programmed with the Arduino integrated development environment (IDE) using the Arduino programming language, which is a C/C++ variation. The IDE runs on a personal computer where programs (referred to as sketches) are written, edited, and then uploaded to the microcontroller. Several different versions of the Arduino Mega are available. The ***MegaSat*** uses the ATmega2560 Rev3.

Background

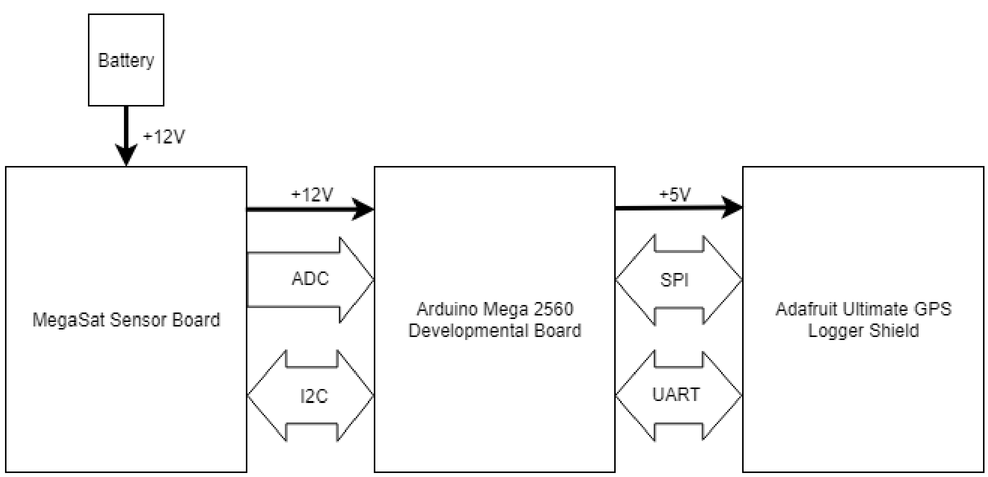
The ***MegaSat*** evolved from the ***BalloonSat***, which was an adaptation of the ***CanSat***. ***CanSat*** was a project conceived by Professor Bob Twiggs at Stanford University's Space Science Development Laboratory in the late 1990s. The original ***CanSat*** included an auxiliary EEPROM memory chip for data storage and a modem (modulator-demodulator) to allow connection to an external radio transmitter and receiver.

In the early 2000s, S.B Ellison and Jim Giammanco at Louisiana State University (LSU) Department of Physics and Astronomy designed the ***BalloonSat*** as an adaptation of ***CanSat*** for the Louisiana Aerospace Catalyst Experiences for Students (LaACES) program. ***BalloonSat*** eliminated the modem, but provided a number of enhancements including a 4-channel ADC, a voltage reference, temperature sensor and four on-board LED's for use as visual indicators. It also provided pins for connecting external hardware. Furthermore, a prototyping area with ground and supply buses was provided to allow students to incorporate additional components or circuits into their payload.

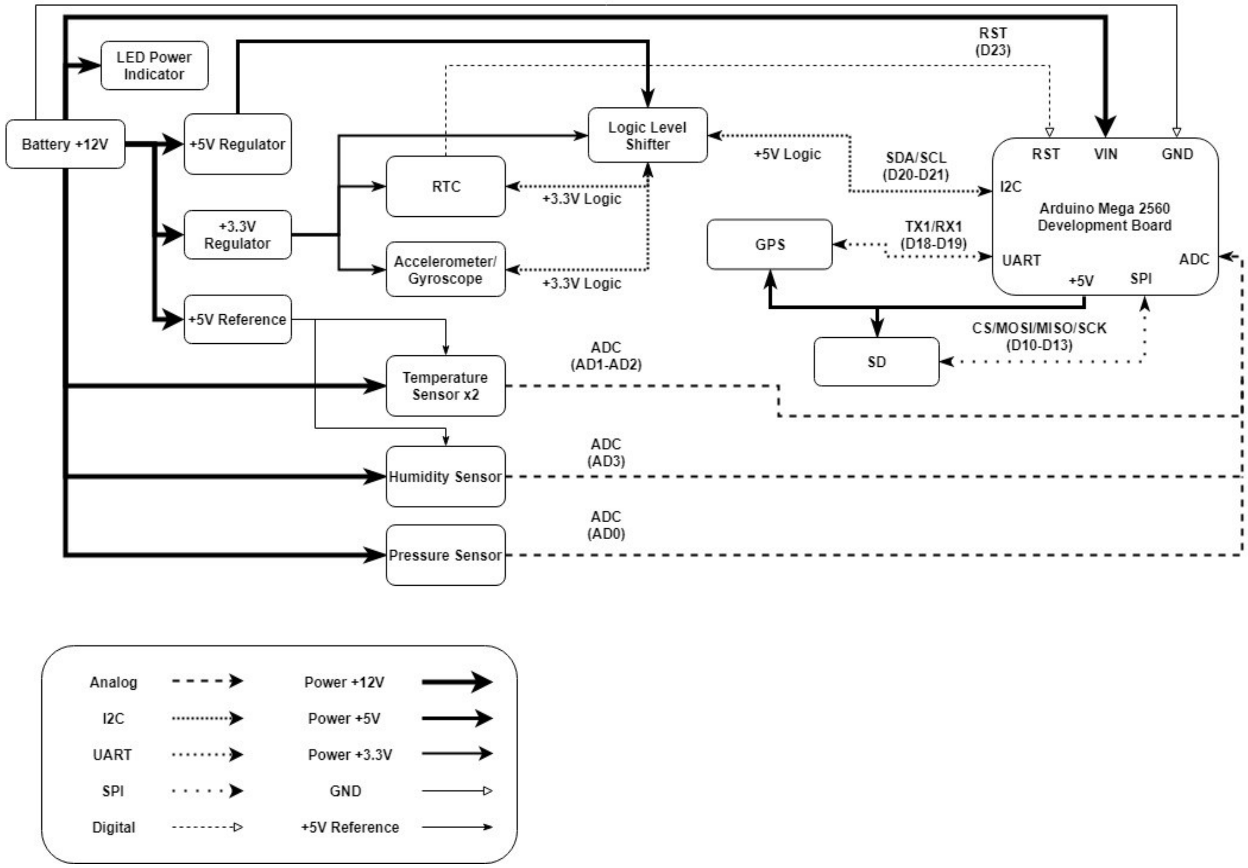
The ***MegaSat*** modernizes the ***BalloonSat*** and provides more versatility. It moves away from traditional through-hole components and introduces students to surface mounts which are more commonly seen in today's market. By replacing the Parallax BASIC Stamp with the Arduino Mega, the ***MegaSat*** can operate more sensors and devices. Students can utilize extra peripherals and take advantage of Arduino shields for advanced projects. The ***MegaSat's*** basic build provides everything needed to monitor atmospheric conditions, payload kinematics and location during a balloon flight.

Theory of Operation

The ***MegaSat*** incorporates multiple printed circuit boards (PCB) connected using extended headers. These include the ***MegaSat*** sensor board, an Arduino Mega 2560 development board, and an Adafruit Ultimate GPS Logger shield. The Arduino functions as the central controller for the entire ***MegaSat***.



The major functional subsystems of the ***MegaSat*** are depicted in the high-level block diagram above. The mid-level diagram on the next page shows how each subsystem breaks down. All the components and electrical connections are shown in the full schematic (Appendix B).



For power, the ***MegaSat*** will accept an external DC source between +9 VDC and +15 VDC. The circuit is protected by a Schottky diode, which prevents damage if the supply is accidentally connected backwards (reversing the polarity). A resettable fuse is connected between the cells of the power supply to prevent damage from short circuits. The sensors and integrated circuits require a clean, stable +5V or +3.3V power source under conditions of changing input voltage or amount of current required by the ***MegaSat***. This is provided by voltage regulators V1 and V2, respectively.

Both temperature sensors (internal and external) and the humidity sensor require a reference voltage with higher precision than the voltage regulators can provide. Voltage reference V3 is used to maintain a constant +5V reference for these sensors. The power converters supply enough current for all of the ***MegaSat's*** onboard components. The Arduino Mega and GPS shield also have their own internal voltage regulations.

The Arduino Mega 2560 development board is a microcontroller breakout board for the ATmega2560 microchip. Programs are written in the Arduino IDE and uploaded from a personal computer to the Arduino Mega using a USB cable. Once programmed, the Arduino Mega can be disconnected from the personal computer and will execute the uploaded program every time it is powered on.

Appendix C summarizes the I/O pins associated with each device. The Arduino Mega always serves as the master [sic] device in synchronous serial communication. The master [sic] initiates all operations and generates the required serial clock signal. Caution must be exercised not to apply negative voltages or voltages greater than +5V to any Arduino pin.

Various protocols have been established in the industry for synchronous serial I/O. Some common protocols are the Inter-Integrated Circuit (I^2C) developed by Phillips Semiconductor, Microwire from National Semiconductor, Serial Peripheral Interface (SPI) created by Motorola, and the Dallas Semiconductor OneWire protocol. Component datasheets will usually describe the protocol used in sufficient detail for writing and debugging user programs. Example circuits and programs are often available from the chip manufacturer's datasheets or websites.

The Arduino Mega contains onboard flash memory for storing the executable program (your sketch). Flash memory is nonvolatile, which means it retains the program even if the power is lost. There is a limited amount of SRAM to create and work with variables and data. The SRAM is volatile and will therefore lose data when the power is turned off.

EEPROM is also available onboard. This is nonvolatile memory that is similar to a hard drive in a computer. EEPROM can be erased and used again, but it does have a limited number of write cycles before it "wears out." This is usually on the order of 50,000 writes. It is possible to "wear out" the EEPROM if a user program "runs away" and repeatedly writes to the EEPROM chip. Inadvertently placing a write routine in an endless loop is a common programming mistake.

The ***MegaSat*** has a dedicated RTC that continuously runs regardless of what other tasks the Arduino Mega microcontroller may be performing. It uses a Maxim Integrated DS3231 timekeeping chip with provisions for an external backup battery. The external battery can be connected to P3 on the ***MegaSat*** sensor board. The current requirements are so small that a backup battery will typically last its shelf life for this type of application.

For extreme environmental conditions, the choice of battery does require some care. Review the DS3231 datasheet for voltage and current requirements. Note that this backup battery only serves the RTC. The other systems of the ***MegaSat*** still require their respective supplies for proper operation.

The DS3231 uses a simple two-wire serial interface with an integrated temperature-compensated crystal oscillator and crystal which enhances long-term accuracy of the device. I/O pin D20 (SDA) is the bidirectional data line, and I/O pin D21 (SCL) is the serial clock. Together, these make up the I^2C interface which allows multiple peripherals to share the same clock and data lines, yet operate independently of one another.

The Sparkfun MPU-6050 accelerometer/gyroscope breakout board shares the I^2C bus with the RTC, where it also uses I/O pins D20 (SDA) for data and D21 (SCL) for the serial clock. In order for both components to operate independently of one another, they must have different slave [sic] addresses. The RTC operates under a permanent address which is b1101000 and the MPU-6050 has a programmable address that is set to b1101001.

The breakout board incorporates the InvenSense MPU-6050 microchip which contains a 3-axis gyroscope, a 3-axis accelerometer, and a digital motion processor. It allows for precise tracking of both slow and fast motion by using a programmable accelerometer that can scale the range of ±2*g*, ±4*g*, ±8*g*, and ±16*g*. There are three onboard 16-bit ADCs for digitizing the accelerometer outputs.

To monitor the inertial reference, it has a gyroscope with a programmable full-scale range of ±250, ±500, ±1000, and ±2000 dps (degrees per second). For better customization, the sampling rate can be programmed from 3.9 to 8000 samples per second. It also has three on-board 16-bit ADCs for digitizing the gyroscope outputs.

Both the RTC and the MPU-6050 have logic levels of 3.3V. The Arduino Mega supports a 5V logic. To allow for easy communication between these devices, a voltage level shifter is used to step up the 3.3V logic to a 5V logic that the Arduino can process.

The temperature sensors use ordinary PN junction silicon diodes to measure the change in temperature. With a constant current applied, the voltage will decrease at a rate of approximately 1 to 2 mV/ºC. This change occurs in a near-linear fashion which makes it easy to correlate the change in voltage with the change in temperature. A constant current of 1 mA is provided by two constant current sources.

The internal temperature sensor produces a very small output voltage and requires amplification. Resistors are used to determine the voltage gain of this stage. Variable resistors provide offset and gain and can be adjusted by a small screwdriver for fine tuning. The amplified output is connected to analog channel A3 on the Arduino microcontroller.

The external temperature circuit is identical except the output is connected to channel A1 on the Arduino microcontroller.

The HIH-4000 humidity sensor is designed to produce a near-linear voltage output that correlates to changes in relative humidity. It uses a thermoset polymer capacitive sensing element with integrated signal conditioning. Changes in sensor capacitance relate directly to changes in relative saturation. Relative saturation, when at ambient temperature, is the same as ambient relative humidity. Therefore, changes in the sensor capacitance can be used to measure changes in relative humidity. The sensor is sensitive to light and must remain shielded or it will produce inaccurate readings.

The humidity sensor is ratiometric with respect to its supply voltage, so a well-regulated +5V supply is required. This is provided by precision 5V reference. The sensor output is amplified by an op amp. Variable resistors for offset and gain can be adjusted by a small screwdriver for fine tuning. The output of the amplifier is connected to analog channel A4 on the Arduino Mega microcontroller.

The pressure sensor is a SSC series TruStabality sensor from Honeywell. The full part number is SSCDANN015PAAB5. The SSC indicates the series. The D indicate is a DIP package component. The AN indicates the pressure port is a single axial barbed port. The next N indicates it is for use with dry gasses only. 015PA means 0-15 psi absolute pressure sensor. The next A indicates analog output. The B means the output is 5-95% of the supply voltage. And the 5 means the 5V supply version.

Two outputs are provided for the pressure sensor. Since the sensor has a working output range of 0.25V to 4.75 (5-95% of 5V) the output is connected directly to analog channel (A0) on the Arduino Mega microcontroller. An additional amplified output is connected to channel A1 to provide a high sensitivity pressure reading at low pressures.

The Adafruit Ultimate GPS Logger shield contains both a GPS chip and a microSD card reader. The GPS uses UART for asynchronous serial communication. It has a switch that toggles between software serial and direct serial. The Arduino Mega communicates through pins D18 (TX) and D19 (RX). At nearly any location on or near Earth's surface, the GPS should be able to receive a signal from at least four GPS satellites. This information is used to trilaterate the signal and determine the location of the GPS receiver within 5 to 10 meters of accuracy in only a couple of seconds.

Data is received in a sentence which follows the format set by the National Marine Electronics Association (NMEA) 0183 protocol. The datasheet explains this information in detail, including how to customize what the information received based on the experiment's specific needs.

The GPS has a sensitivity of -165 dBm (decibel-milliwatts), a 10 Hz refresh rate, and 66 channels. It includes built-in datalogging to flash memory. There is an onboard patch antenna and a connection provided for an external antenna. It has low power consumption compared to other GPS devices with only a 20 mA current draw.

The shield also offers a microSD card reader. The card reader uses the SPI protocol for synchronous serial communication. The designated pins are D10 for chip select (CS), D11 for master out slave in (MOSI), D12 for master in slave out (MISO), and D13 for serial clock (SCK).

Getting Started

Tips for Success

- When soldering surface mounts, it may be helpful to begin by heating a small amount of solder onto one pad, then aligning the component properly on top. After which, heat can be applied to the pad with the solder. This helps keep the component in place allowing you to more easily solder the other pins to their corresponding pads.
- It can be helpful to start soldering components inward and work your way out, soldering smaller components before larger ones. Allow yourself enough space to work in and avoid blocking access to areas or pads you may need to reach later on.
- A via is a small hole drilled into the circuit board. If a via is near a solder pad you are working with, be mindful not to solder over it. This can create a short circuit and prevent the circuit from functioning properly.
- There is a silkscreen outline of each component on the printed circuit board (PCB) that shows the part ID as well as orientation and alignment of the component to help guide you through proper installation.
- A footprint is the arrangement of pads or drill holes where you solder the components to the PCB. These also help with orientation and proper placement for each component.
- Refer to datasheets to identify the location and function for each pin of the components you are working with. This will help prevent accidentally soldering a component in backwards.
- Check resistor values prior to installing (see the user's manual for your multimeter to obtain detailed instructions on how to measure resistance).
- The footprints for the potentiometers were designed to accommodate both linear and triangular pin configurations, so you will always have one unused hole regardless of which potentiometer you use. The triangular configuration is recommended due to the additional support it offers.
- When soldering electronic components, verify if the component is polarized. Diodes, electrolytic capacitors, and many other electronics require a specific orientation for successful operation. There are indicators on the board and details in the instructions to identify the correct orientation of parts.
- Staying organized while you work can help prevent mistakes. Use the check boxes provided to mark off the components once they have been installed. It is also helpful to highlight the schematic as each step is complete.
- The ***MegaSat*** will be assembled in stages. For each stage, you will be provided module-specific information such as inventory, schematic, images of the PCB (both assembled and unassembled), and assembly instructions. This document is meant to be self-sustaining; however, you may find it useful to reference the accompanying lectures and activities for additional assistance. For component-specific information, always refer to the datasheet for that specific component.
- At the end of each assembly module, you will find a checkpoint, troubleshooting steps and when applicable an exercise. It is recommended to complete all of these steps and record your findings in a lab notebook.

Expanding the MegaSat

- Sometimes, there is a need to create a custom circuit as part of MegaSat. This can be done without the time and expense of a separate circuit board by using the prototyping area on the GPS shield. This provides space for soldering components directly onto the circuit board. It is best to draw the desired circuit and layout a tentative component placement plan prior to soldering components to the MegaSat.

- The stacking headers on the GPS shield connect directly to the MegaSat and can be used for expansions (be mindful not to use a port that is already in use by another component). Additional pads are provided on the sensor board for all of the Arduino Mega's I/O pins, as well as I2C connections through the bidirectional level shifter.

- If high current devices such as some incandescent lamps, motors, or relays are connected to MegaSat, a separate power source for high current loads is recommended.

- If you incorporate expansions to your sensor board, it might be necessary to disable some of the ***MegaSat's*** internal devices if they are not needed for a specific application. This will free I/O pins for use by external peripherals.

- Caution must be exercised not to apply negative voltages or voltages greater than +5 VDC to any Arduino pin. Devices with +5 VDC logic can connect directly to the Arduino Mega. Devices with +3.3 VDC must go through the bidirectional logic level shifter and the address must be changed as to be different than the RTC and accelerometer/gyroscope.

Checkpoints

Throughout the manual, there will be various checkpoints. The checkpoints help identify any potential issues. It is much easier to troubleshoot and debug problems as they occur rather than wait until the entire board has been complete.

It is recommended to use a bench supply for testing as opposed to a battery pack. If it is a current-limiting supply, set the current to no more than 200 mA. The current will rarely reach 200 mA and will stabilize around 160 mA with the ***MegaSat*** in full operation. Set the voltage between +9 VDC and +12 VDC. Do not exceed +15 VDC. This will damage the Arduino and the op amps.

It is helpful to become familiar with normal operating values for the circuit. Knowing how things should work can help you better determine what is not responding appropriately if you need to troubleshoot something later on. Note that values are approximate. See datasheets for specific tolerance ratings of individual components.

You will be provided a table stating the location of the test point along with the expected value. This will be accompanied by an empty column where you can document the measured value from your circuit.

Safety First!

- ∞ Remember to wear safety goggles!
  - o Solder can splash and clippec wires can fly.

- ∞ Soldering irons get hot...450 degrees Celsius to melt most solder…that's approximately 842 degrees Fahrenheit!
  - o Don't touch the solder tip while the unit is powered.
  - o Wait for the soldering iron to cool down before returning it to storage.
  - o Always keep your hair pulled back.
  - o Avoid loose, long-sleeve shirts or clothing that may come in contact with the iron.
  - o Never leave an iron unattended!

- ∞ Electrical components are sensitive to electrostatic discharge (ESD).
  - o When possible, it is recommended to use ESD wrist straps and mats.

MegaSat Assembly - Power Module

The MegaSat is powered via an external voltage source connected at the jumper J1. The screw terminal block plug P1 is provided for creating a connection to the voltage source.

The MegaSat was designed to powered by a 12V battery pack but should operate correctly with 9-20V input supply.

A Schottky-barrier diode, D1(1N5818) [1], protects the system from damage should the battery be accidently connected backwards, which would reverse the polarity.

Two linear voltage regulators are used to provide the necessary +5V and +3.3V needed for the components of the MegaSat to function. The voltage regulators are used to step the input supply down to +5V and +3.3V, provided by V1 (LM1117_5V) [2] and V2 (LM1117_3.3), respectively.

The temperature and humidity sensors must have a precisely regulated reference voltage to ensure that measurements are stable and accurate. A precision, temperature-compensated voltage reference is provided by V3 (REF-02CESA) [3].

An LED (LED1) provides a visual indication that the board is receiving power.

Four additional diodes, LED2, LED3, LED4, and LED5 are connected to Arduino Digital Pins D2-D5. These LEDs are not used as part of the power regulation system but are instead for teams to use for visual feedback in their payload. We will be assembling these components as in section.

Open your assembly kit and find and open the Power Module packet. Verify that all components listed in the Power Module list below are include. Check off each component after you have located each component.

Power Module Parts List

- ☐ V1: LM1117 5V Regulator [2]
- ☐ V2: LM1117 3.3V Regulator [2]
- ☐ V3: REF02-CESA 5V Reference [3]
- ☐ D1: 1N5818 Schottky Diode [1]
- ☐ LED1: Red LED
- ☐ R1: 1.2 kΩ Resistor
- ☐ J1: Two-Pin 5 mm Vertical Male Headers
- ☐ P1: Two-Pin Term Block Plug
- ☐ LED2-LED5 Diagnostic LED
- ☐ R21-R24 1.2 kΩ Resistor

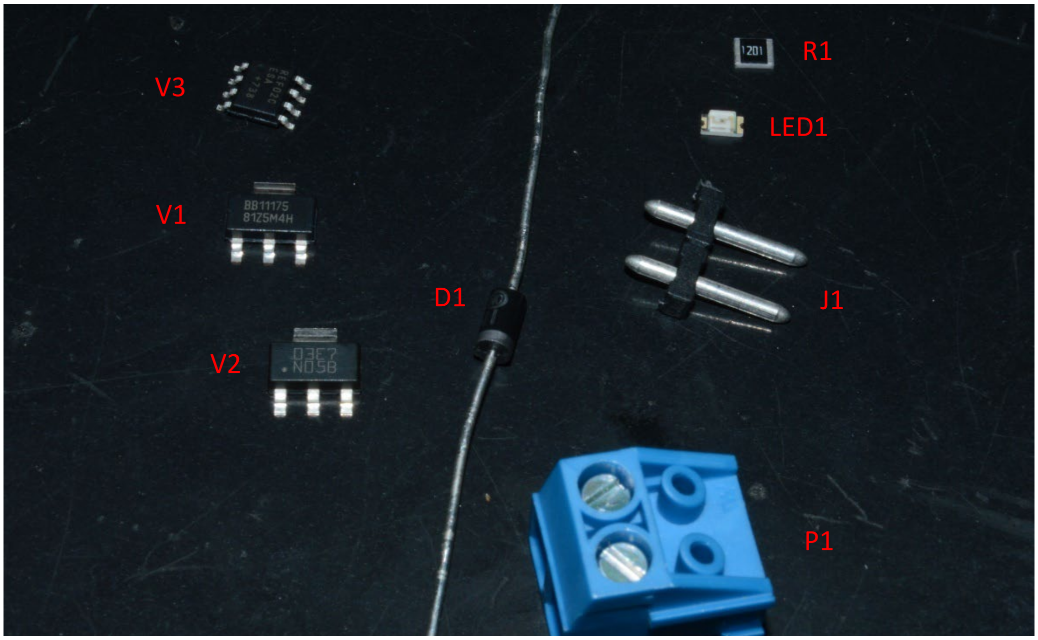


Figure 1: Power Distribution parts

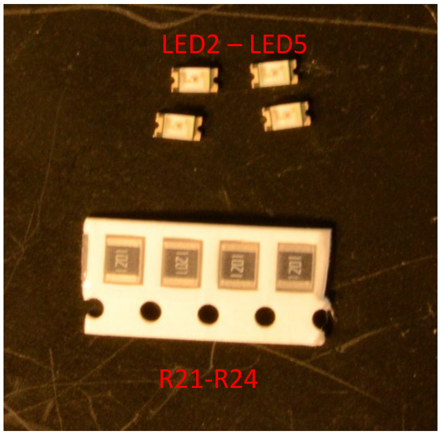


Figure 2: Diagnostic LED Parts

Power Module Schematic

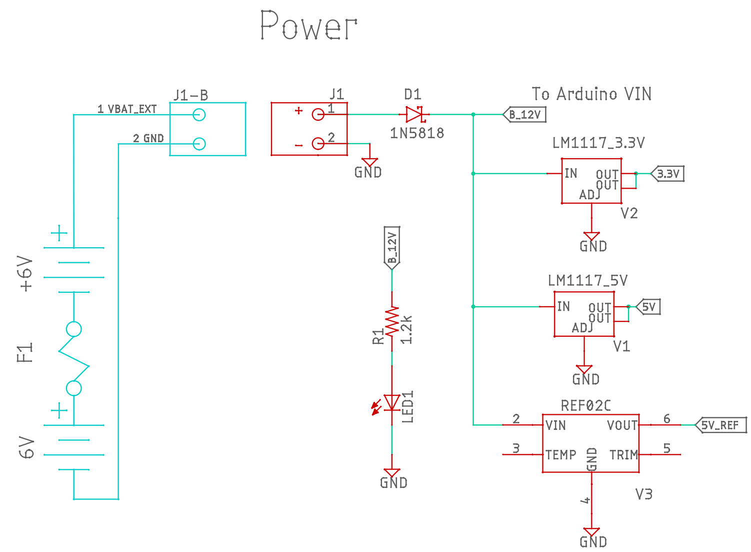


Figure 4: Power distribution circuit diagram

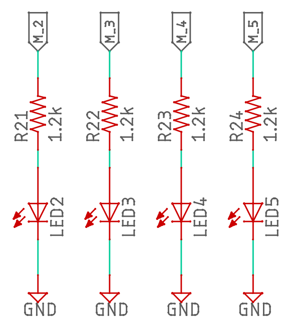


Figure 3: Diagnostic LED schematic

Power Module PCB Layout

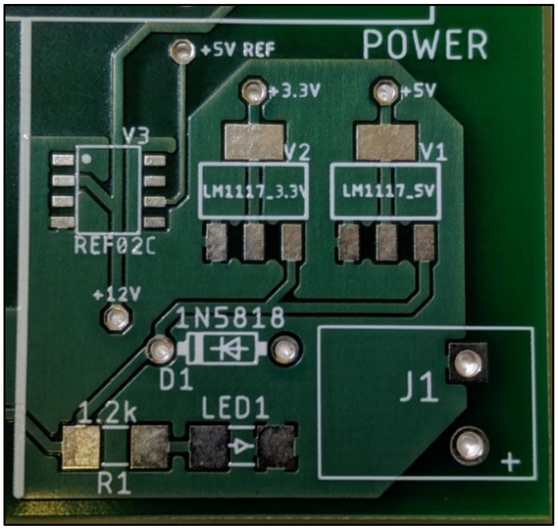


Figure 6: Bare PCB, power distribution section

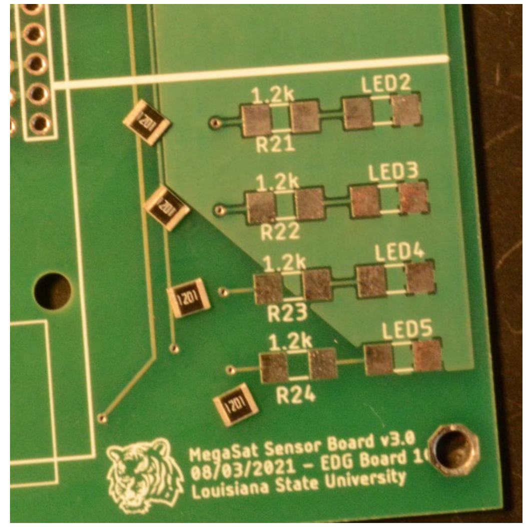


Figure 5: Bare PCB, diagnostic LEDs section

Power Module Assembly

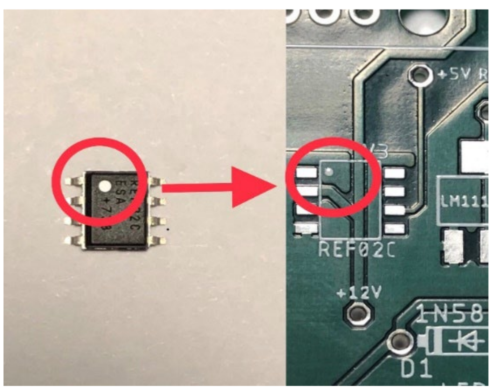


Figure 8: Alignment of V3 (5V reference)

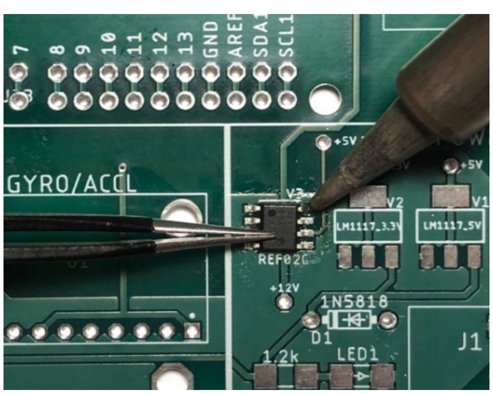


Figure 7: Holding SMT chip in place while soldering with tweezers

Power Module Assembly Step 1

Locate the REF02-CESA chip. Locate the matching set of pads labelled V3 REF02C on the PCB.

Tips for Success

Pay attention to the orientation of the chip! There is a white dot on the board for Pad 1 that matches the dot on the chip for Pin 1.

Power Module Assembly Step 2

Add a small amount of solder to one of the pads by heating the pad and applying solder. Press down on the IC gently with tweezers to hold it in place and remelt the solder. While continuing to hold the pad in place with tweezers remove the iron and allow the solder to cool.

Power Module Assembly Step 3

Check to make sure all the other pins are aligned with their respective pads. If the pins are not aligned, melt the solder and adjust the alignment of the chip until it is properly aligned with all pads.

Power Module Assembly Step 4

Tin your soldering iron. For each remaining pad use the soldering iron to heat the pad. Then add a small amount of solder to the pad.

Do not let the iron "sit" on the pad/pin for too long as the heat can damage the board and the IC.

After soldering all pads check for bridges and proper adequate solder on all the pins. Do not forget to add additional solder to the first pin if necessary.

While the solder pump or solder wick can be used to remove solder, if necessary you can use a clean solder tip to wick small amounts of solder.

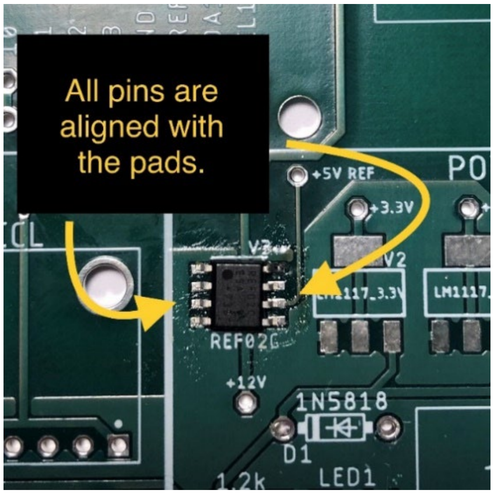


Figure 9: V3 Properly align with pads. Note: only the upper right big has been soldered.

Power Module Assembly Step 5

Locate the LM1117 3.3V Regulator and the pad at V2.

Tips for Success

Be careful not to install the 3.3V where the 5V goes, or vice versa. The 3.3V and 5V look almost identical so double-check that you have the correct IC.

Be sure to verify by looking up the device marking as the same part from different manufacturer may have different markings. The device marking in these photos is N05B for the 3.3V regulator.

However, for the 5V regulator two different versions are shown in this document, one marked N06B another marked BB1175.

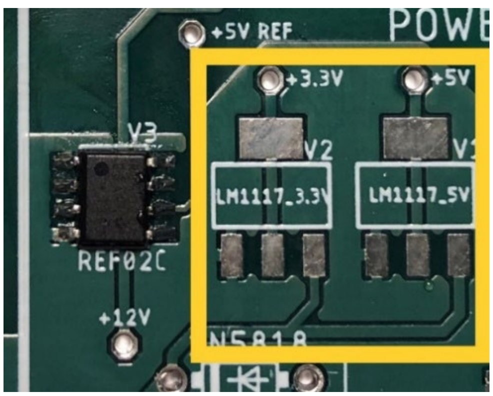


Figure 10: Pad Locations 3.3V Regulator.

Power Module Assembly Step 6

Using the same method as previously described, solder a single pin of IC to hold the chip in place. Once properly aligned solder the remaining pins and then inspect your solder joints and correct as necessary. For the LM1117 regulators V2 and V1 we recommend using the large upper pin for the first pin.

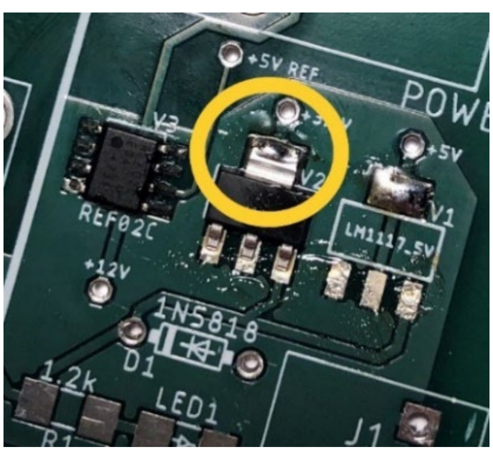


Figure 11: 3.3V Regulator soldered via the top pin.

Power Module Assembly Step 7

Locate the LM1117 5V Regulator and the matching pad V1. Align and solder the 5V regulator in place.

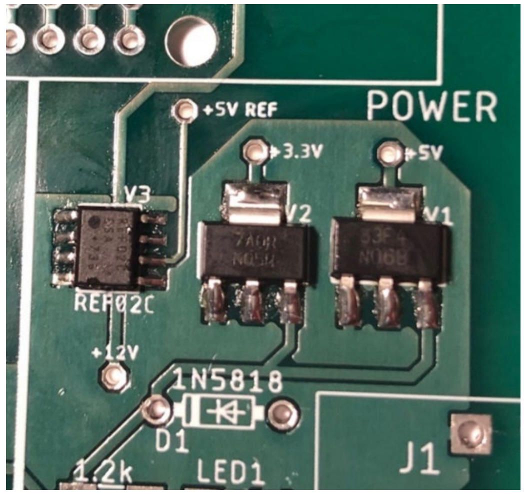


Figure 12: Power module after soldering 5V LM1117 regulator.

Power Module Assembly Step 8

Locate the 1N5818 Schottky diode and the matching solder pads labelled D1. The silkscreen on the printed circuit board has a white line marking that corresponds to the silver line on the diode both indicate the cathode. Be sure to align the diode properly before soldering.

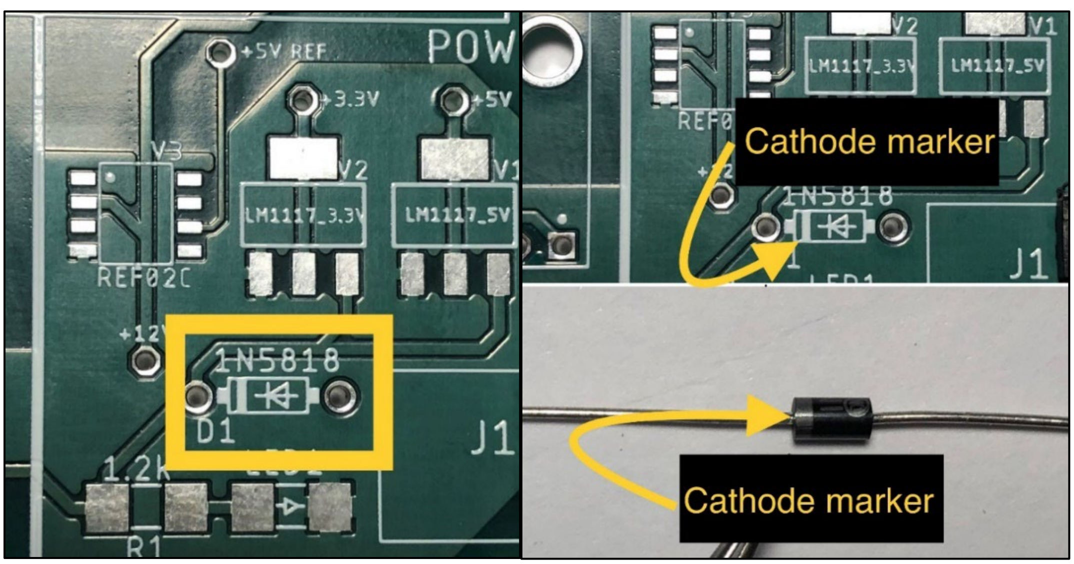


Figure 13: Left: the pads for diode D1 in the power module, right: the cathode marking on the PCB (upper) and diode(lower).

Power Module Assembly Step 9

Bend the leads of the diode. Insert the leads into the holes of the PCB at D1. Using needle nose pliers or a lead bending tool can be used to properly bend the leads. Then push the diode also close to the board as possible.

While the goal should be to get the diode flush with the board, having the diode slightly above the board is ok. The clearance of the holes is close and pushing too hard could break the diode leads.

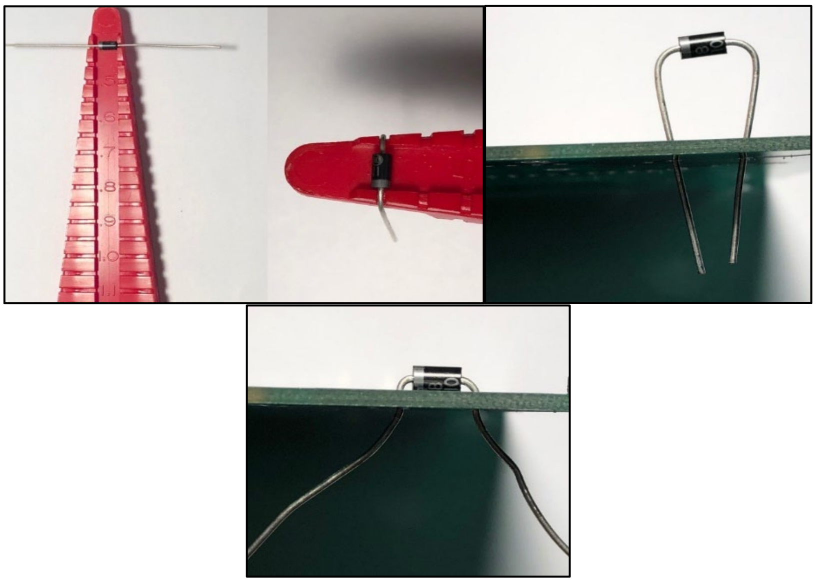


Figure 14: Bending and installing the diode D1 into the PCB.

Power Module Assembly Step 10

On the backside of the board, place the tip of the soldering iron on the pad and lead to heat the join and then apply solder. The solder should melt and form a small "Hershey Kiss" on the joint. Repeat for the second lead. Trim the leads down to the solder joint.

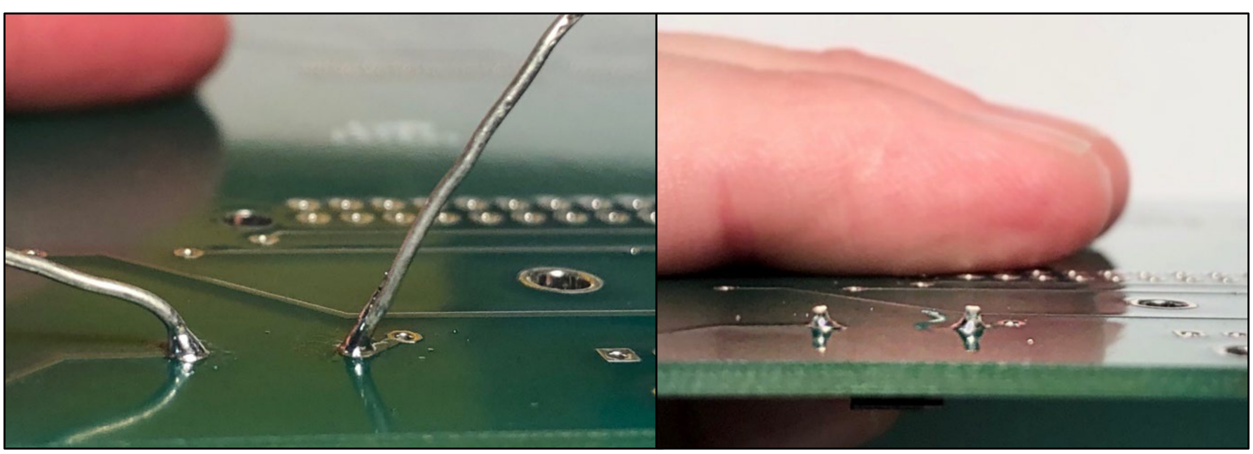


Figure 15: Left: Properly soldered leads of diode D1, Right: Leads trimmed above the solder joints.

Power Module Assembly Step 11

Locate the red SMD LED. Find the matching pad LED1. The silkscreen on the board has an arrow and that points in the direction of the cathode's alignment and a white dot that aligns with the cathode (negative terminal) on the LED. While some SMD LEDS have cathode markings they are very small and difficult to see.

Instead, it is best to use the diode testing function of your multimeter. Place the multimeter on the setting that matches the diode symbol and measures out in volts. Then touch the two leads of the LED. If you have lined up the positive lead of the multimeter to the positive lead of the LED and negative to negative the LED will dimly light up and you will read ~1.7V. If it does not work switch your positive and negative leads.

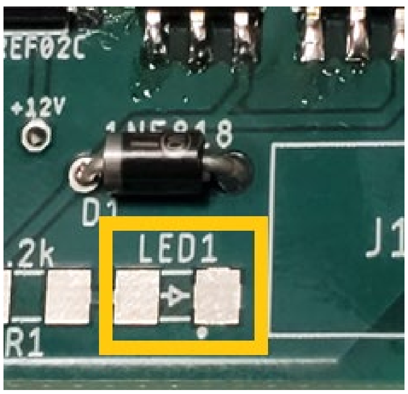


Figure 17: SMD LED Pad, notice the silkscreen indicating the right side as the negative/cathode.

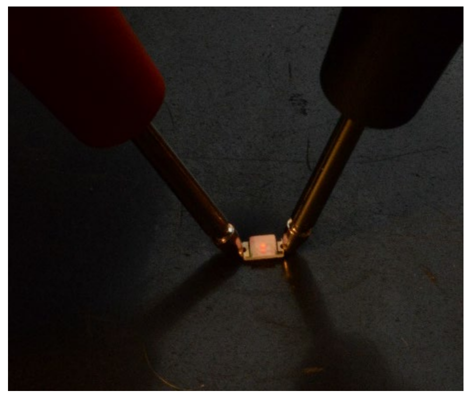


Figure 16: SMD LED being tested. Notice that dim light from the LED and the multimeter postive lead touching the left side and negative lead touching the right side.

Power Module Assembly Step 12

Add a small amount of solder to one of the LED pads. Then, place the LED on top of both pads and press down on the LED gently with tweezers to hold it in place. Remelt the solder on the initial pad then remove the iron and allow the solder to cool while holding the LED in place. Check that the LED is flush with the board, and that the other side of the LED is making contact its respective pad. If not, melt the solder and reposition the LED. When satisfied with the position, solder the other side of the LED to its pad. As always inspect your solder joints and add additional or remove excess solder if

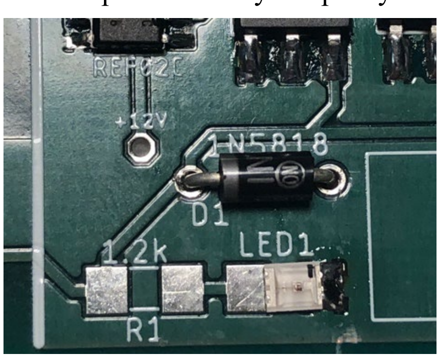


Figure 19: LED with right pad soldered

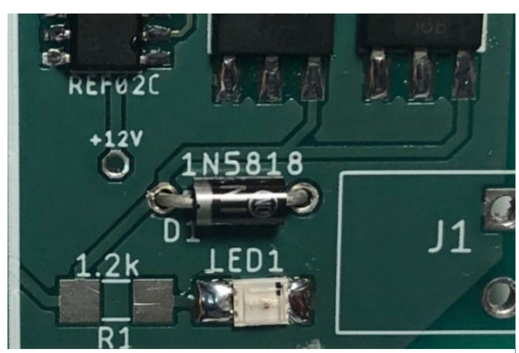


Figure 18: Completely soldered LED

Power Module Assembly Step 13

Locate the 1.2kΩ SMD resistor and matching pads R1. Repeat the same technique used for LED. Add solder to one pad, pace the resistor on top, remelt the solder while holding the resistor down and allow solder to cool. Then solder the other pad and inspect the solder joints.

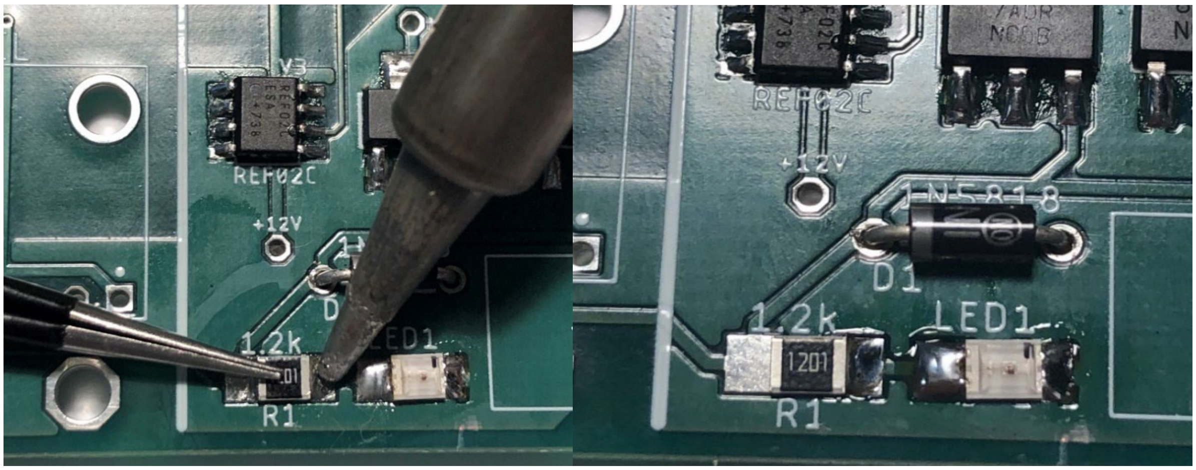


Figure 20: Soldering one pad of resistor R1, notice how the tweezers/forceps are used to hold the component in place while the solder is melted.

Power Module Assembly Step 14

Insert the shorter leads of jumper J1 header into the board. Make sure the black plastic is flush with the board. While there is a polarity marking this is for connected a voltage source or battery the jumper itself has no polarity.

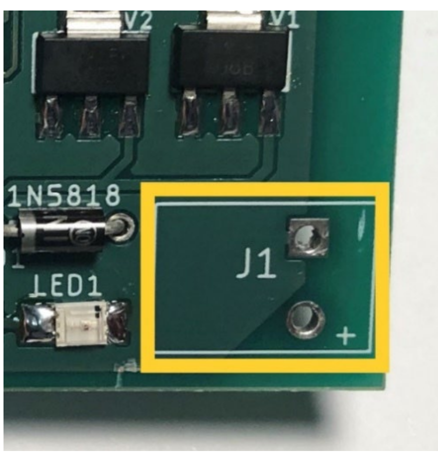


Figure 22: Where jumper J1 will soldered to the PCB

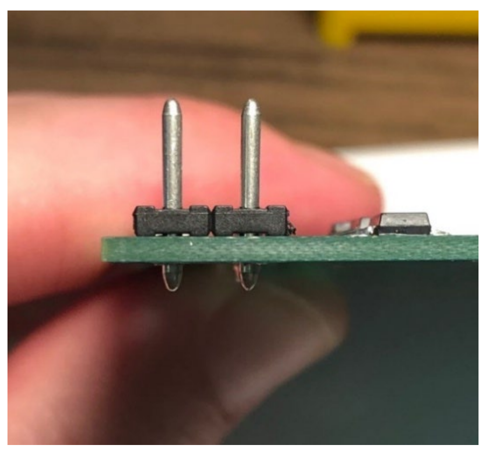


Figure 21: Jumper J1 sitting flush the board.

Power Module Assembly Step 15

On the back side of the board, solder one of the pins to the board. Check that the plastic is still flush with the board and pins are pointing straight up. If not, remelt the solder using the iron and realign the pins while the solder remains melted. Remember the pin you have soldered will be extremely hot so use pliers or tweezers to move the jumper while the solder is melted.

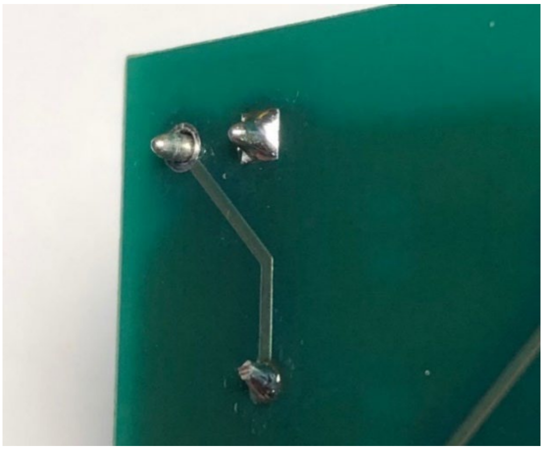


Figure 24: Backside of J1 with a single pin soldered.

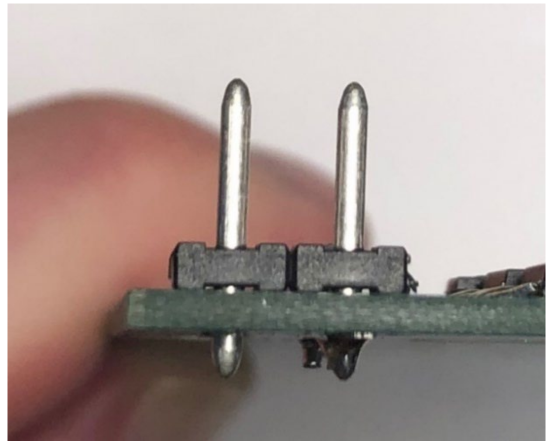


Figure 23: Properly aligned pins after soldering.

Power Module Assembly Step 20

Solder the other lead on the bottom side of the board. After this the power distribution section should be complete as shown in Figure 27: Completed power module.

Power Module - Complete Assembly

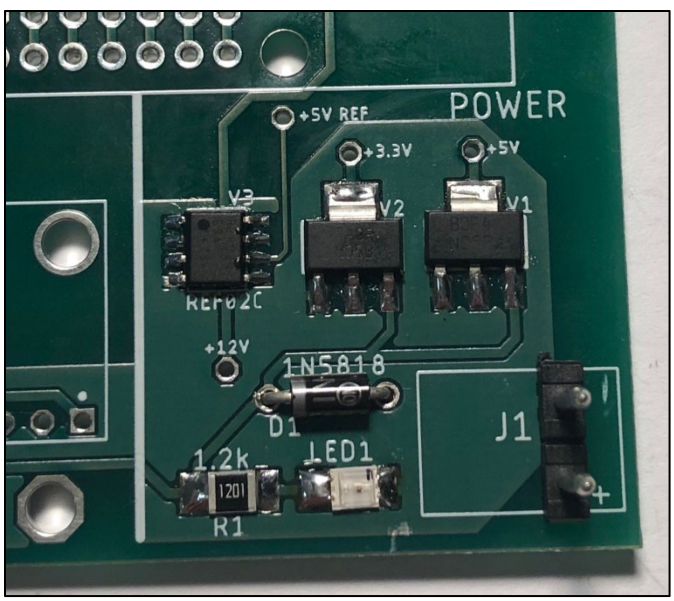


Figure 25: Completed power module.

Power Module Checkpoint – Voltage Checks

Using an external power supply, apply ~12V to the input power of the MegaSat making sure to

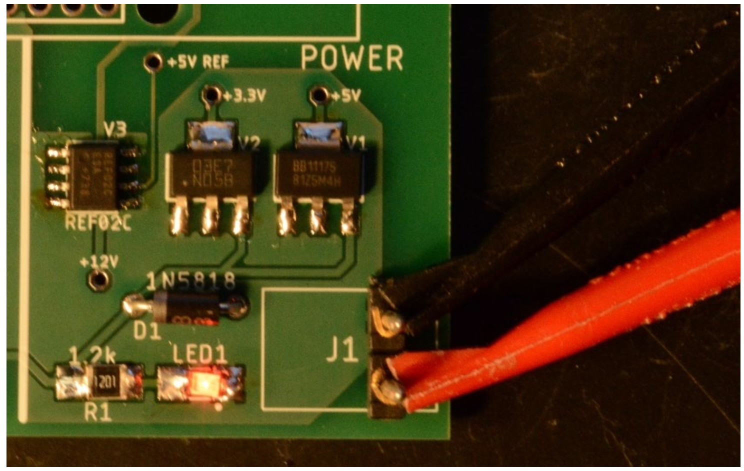


Figure 26: Power module connected to external power supply for voltage checks.

The power LED LED1 should light indicating the board is powered. Then measure the voltage with between one of the ground points on the board and the 3 voltage testpoints above the regulators. The values should match those in the table below.

Note: If the LED does not light still make the voltage checks, it is possible for the LED to be installed backwards, in which case the regulators will be operating correctly without the LED being on.

Table 1: Power Module Voltage checks.

Power Module Checkpoint – Voltage Check			
ID	**Name**	**Expected Value**	**Measured Value**
+12V	Input Power	+12 V (Match input Voltage)	
+5V	5V Linear Regulator	+5 V	
+3.3V	3.3V Linear Regulator	+3.3 V	
+5V REF	5V Reference	+5 V	
LED	Power LED	Lit	

MegaSat Assembly – Diagnostic LEDs

We will now install the LEDs LED2-LED5 and their associated resistors. These LEDS do not have a designated purpose but are intended for MegaSat users to provide visible feedback as they design in their payload.

For example, a team could turn LED2 on if they SD card was successfully detected at the start of their program, allowing them to ensure the card was properly mounted prior to launch.

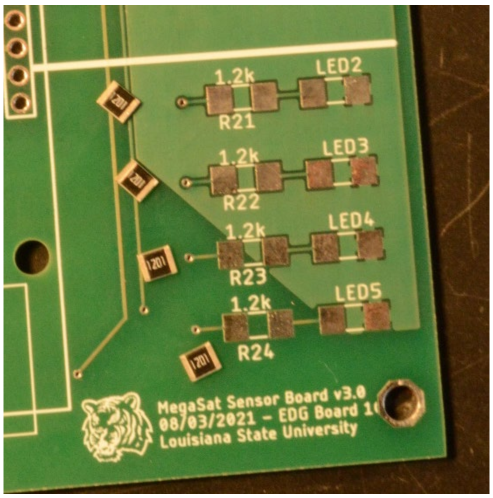


Figure 27: LED Resistors R21, R22, R23, R24.

LED Assembly Step 1

Locate the section fo the board containing resitors R21-R24 and LED2-LED5.

Find the remaining 1.2K Resistors from the power module envelope and the corresponding pads.

Using the same technique as before solder all 4 resistors in place.

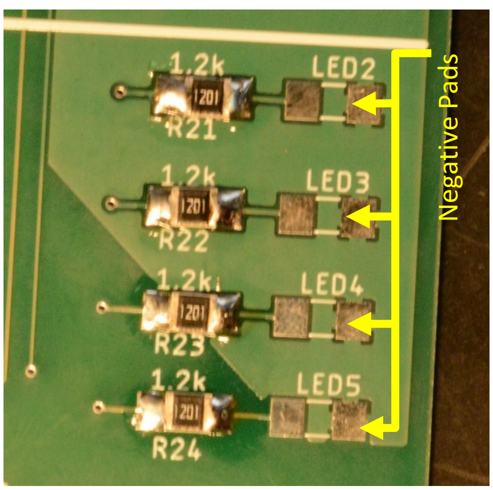


Figure 28: Negative Pads for LED2, LED3, LED4, and LED5.

LED Assembly Step 2

Get the four remaining SMD LEDs from the Power Module envelope.

The pads for LED2, LED3, LED4, and LED5. The pad further from the resistor is the negative terminal (cathode).

The one at a time so determined the orientation of LEDs with a multimeter as in Power Module Assembly step 11. Solder that LED in to place before moving on to the next one to ensure you do not mix up the polarization.

Repeat this until all four of the LEDs are soldered into place.

LED Assembly Step 3

Once all of the LEDS are soldered in place you can verify they orientation in place using a multimeter the same way we did when the LEDs were free.

With the multimeter on diode test mode and the positive lead applied to the positive pin and the negative lead applied to the negative pin you should see a faint lighting of the LED as shown in the figure below.

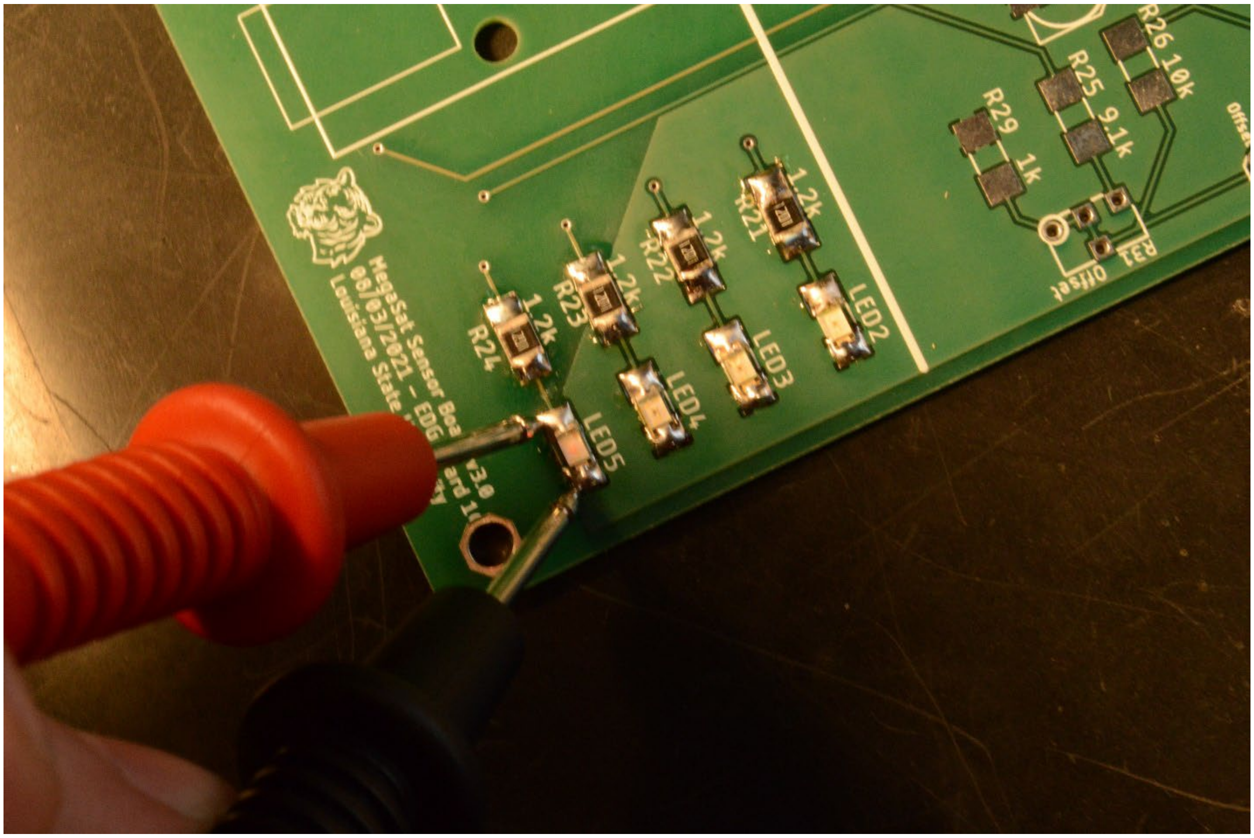


Figure 29: Verifying orientation of diagnostic LEDs after soldering in place.

MegaSat Assembly - Temperature Modules

There are two temperature modules present on the MegaSat PCB. One is designated external and the other to internal. The circuits for both modules are identical. The idea is that teams can use one temperature circuit to monitor the internal temperature of their payload and the other to monitor the temperature outside the payload. These instructions will guide you through assembling the internal temperature module.

The process is identical for the external temperature module with different component numbers. Refer to the inventory list, schematic, and PCB layout for the external temperature module when assembling the module to determine the correct component numbers for the second temperature module. In the steps component numbering in parenthesis will refer to the External Temp. Circuit.

Locate and open one of the Temperature Module packets, there will be two. Identify the following components. Check off each component after you have installed and inspected its solder connections.

Internal Temperature Module – Parts List

- ☐ CS1: LM334M Current Source [4]
- ☐ U5: AD820ARZ Single Op Amp [5]
- ☐ R9: 3.9 kΩ Resistor
- ☐ R10: 20 kΩ Resistor
- ☐ R11: 180 kΩ Resistor
- ☐ R12: 68 Ω Resistor
- ☐ R13: 1 kΩ Potentiometer
- ☐ R14: 100 kΩ Potentiometer
- ☐ C6-C8: 0.1 µF Ceramic Capacitors
- ☐ C9: 10 µF Electrolytic Capacitor
- ☐ J3: Right-Angle Breakaway Header (2-Pin)

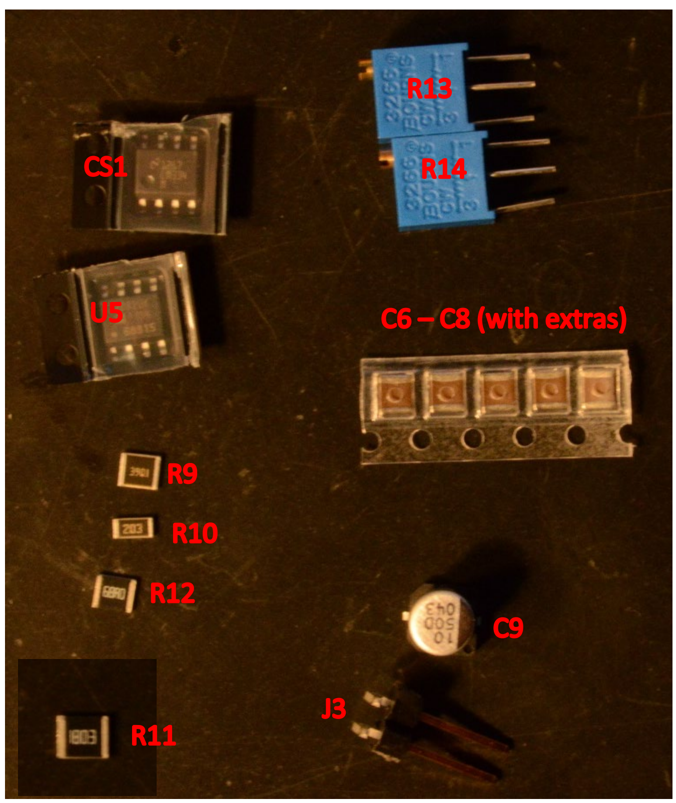


Figure 30: Internal Temperature circuit parts.

Internal Temperature Modules – Schematic

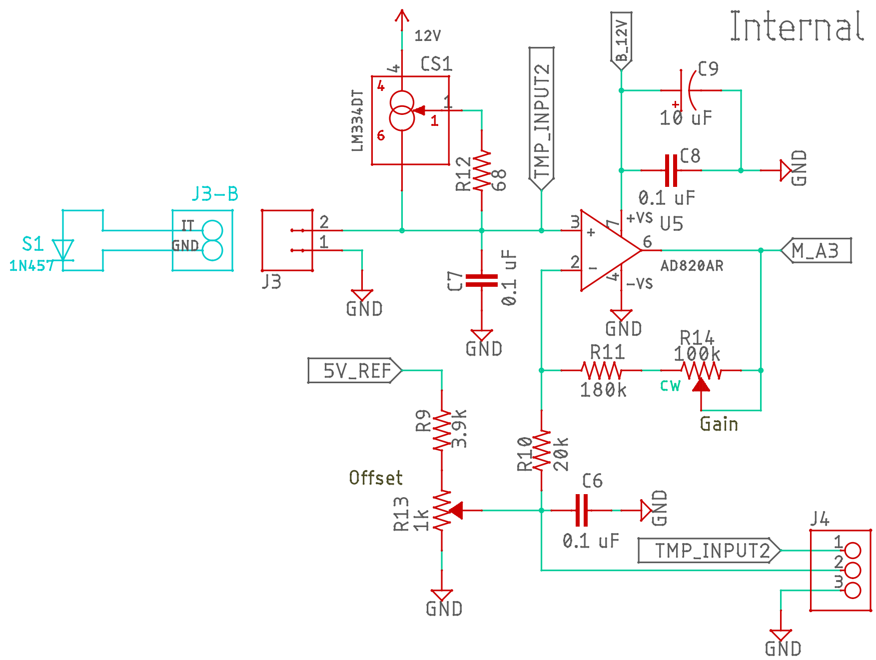


Figure 32: Internal temperature sensor schematic.

Internal Temperature Modules – PCB Layout

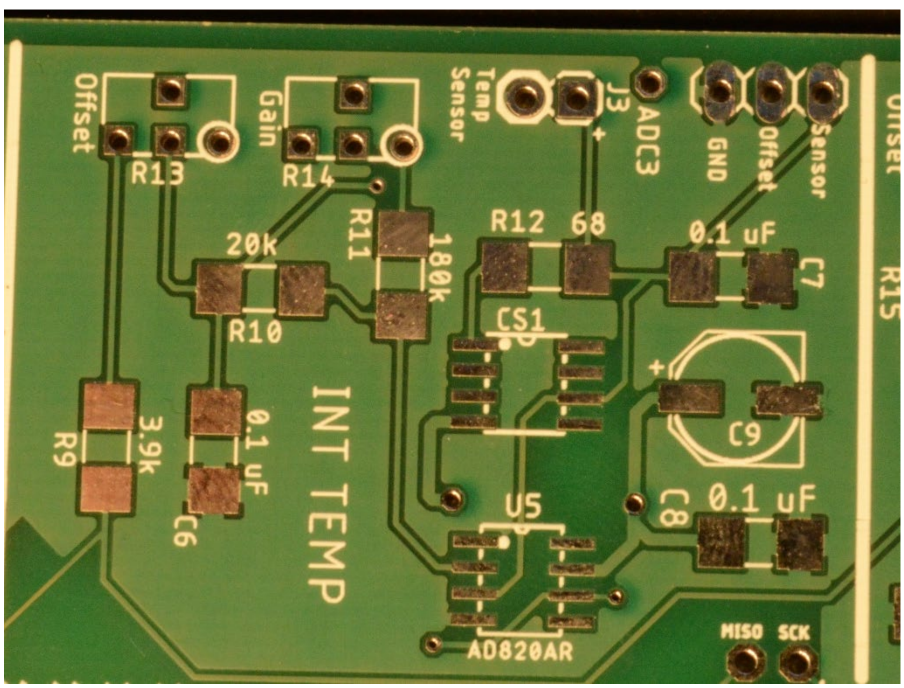


Figure 31: Bare PCB for internal temperature circuit.

Temperature Module Assembly Step 1

Locate the LM334 chip. Align the chip with the pad at CS1(CS2). Notice the matching orientation marker on the chip and silkscreen.

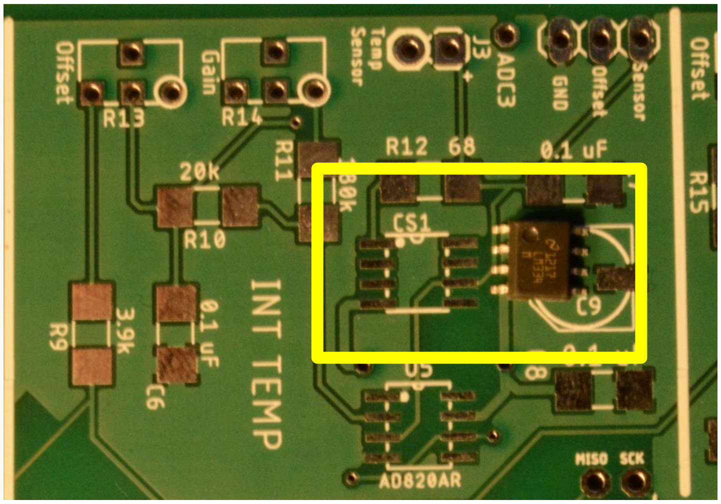


Figure 34: Alignment of the current source CS1.

Temperature Module Assembly Step 2

Using the same technique as previously solder the chips CS1(CS2) in place. Remember as always to check your solder job for adequate solder or bridging and correct as necessary.

Temperature Module Assembly Step 3

Locate the 68Ω resistor and matching pad R12 (R18). Solder the resistor in place on the pads.

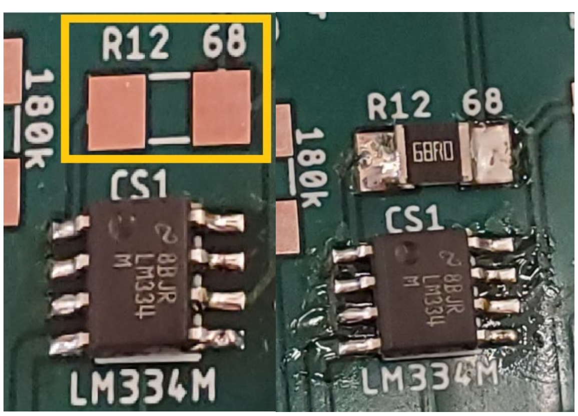


Figure 33: Soldering Resistor R12.

Identifying SMD Resistors

Surface mounted resistors are labeled with a three or four digit code. The first two or three digits identify the resistance. The last digit always identifies the power of 10 to multiply the earlier digits by to determine the resistance. R's are sometimes added in the middle of the code to identify the component as a resistor. For example, a resistor labeled 68R0 is a 68 x 10^0 or 68 Ω, 3901 is 390 x 10^1 or 3.9kΩ.

Temperature Module Checkpoint – Constant Current Source

The LM334 chip is a constant current source designed to output 1 mA of current through the sensor. If the current is not held constant at 1 mA, the sensor may not function as designed.

Connect 12V power to the MegaSAT and measure the voltage at pin 4 of the LM334 with respect ground. This is the input power for the chip. It should match the supplied voltage. Record the value on the table below.

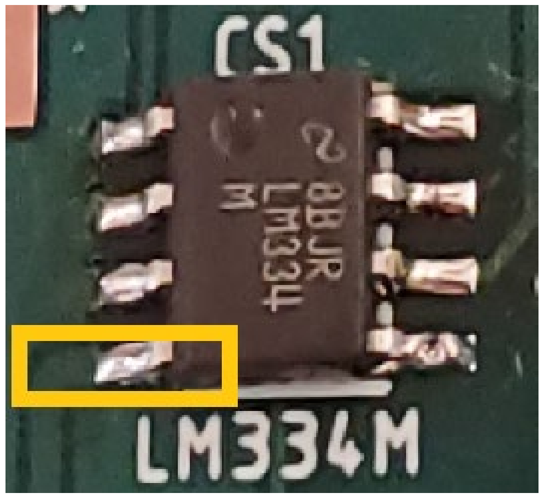


Figure 35: Voltage supply pin fo CS1.

Next, measure the current output the LM334. Set the multimeter to measure DC current. Connect the multimeter to the pads for J3(J4). Connect the negative lead to the opposite lead. The multimeter should read a value of 1 mA. Record the value.

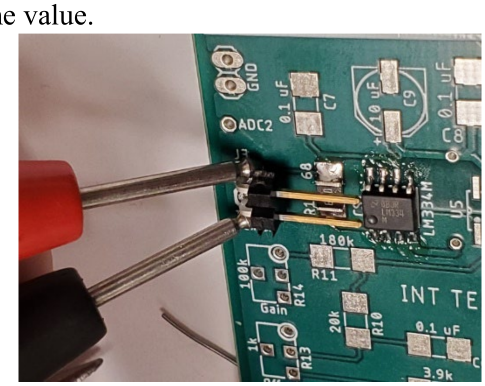


Figure 36: Measuring the current produced by CS1, note this photo has the jumper J3 already uninstalled but the process is the same without the jumper installed.

Internal Temperature Module Checkpoint – Constant Current Source			
Test	**Component**	**Expected Value**	**Measured Value**
Voltage Check	CS2 – Pin 4		
Current Check	J4		

Temperature Module Assembly Step 4

Locate the 0.1uF SMD capacitors. These capacitors have a light brown casing with no label and no polarity. Install the 0.1 uF ceramic capacitors to C6, C7, and C8(C10, C11, and C12). Solder the capacitors to their pads.

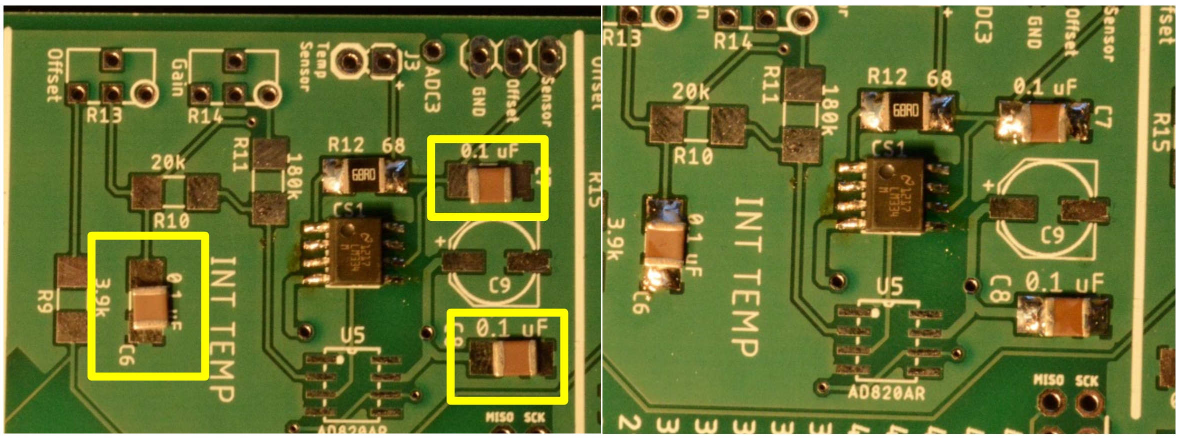


Figure 37: Soldering Capactitors C6, C7, and C8 for internal temperature circuit.

Temperature Module Assembly Step 5

Locate 180kΩ Resistor and its matching pads R11 (R16). Solder the resistor in place.

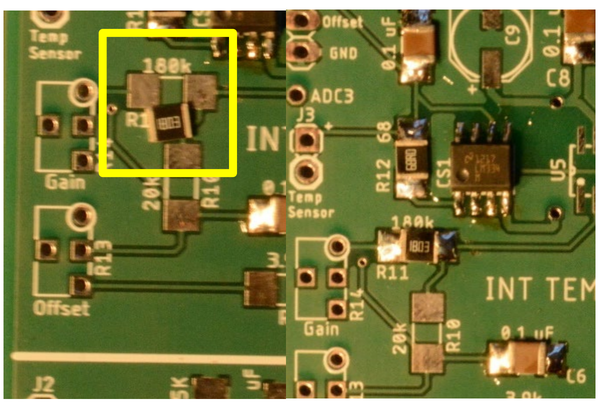


Figure 38: Soldering resistor R12

Temperature Module Assembly Step 6

Locate the 20kΩ resistor and matching pad R10(R17). Solder resistor to pad.

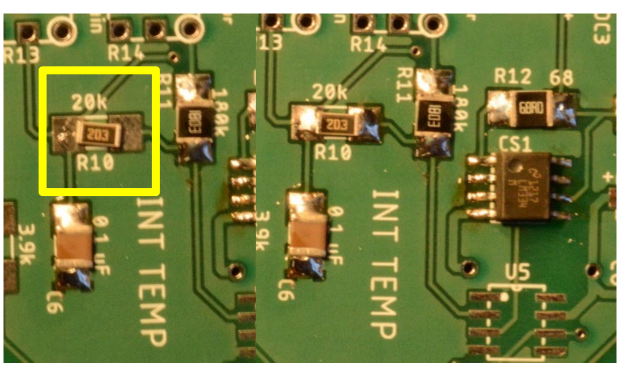


Figure 39: Soldering Resistor R10

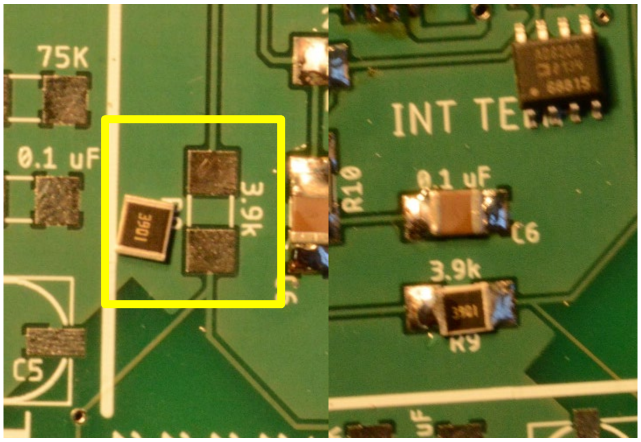


Figure 40: Soldering resistor R9

Temperature Module Assembly Step 7

Locate the 3.9kΩ resistor and matching pad R9(R15). Solder resistor to pad.

Temperature Module Assembly Step 8

Locate the AD820 Op Amp Chip and its matching pad U5. Locate the matching pin 1 markings on the IC and the PCB. Then solder the chip into place.

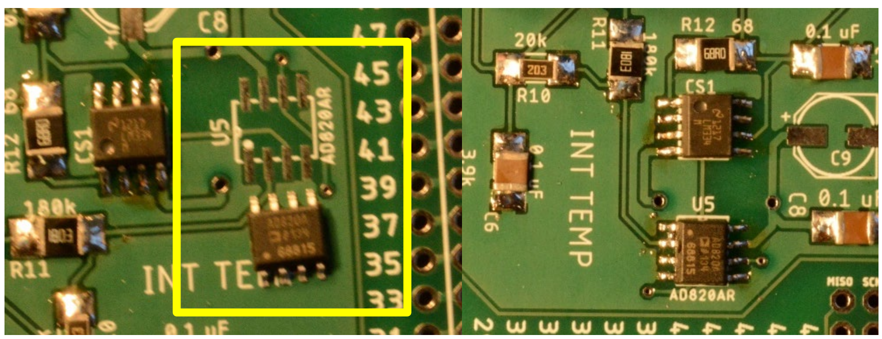


Figure 41: Soldering U5 Op amp in place.

Tips for Success

In the next few steps, you will be installing potentiometers. The potentiometers have similar packages and are easily mixed up. The 1kΩ potentiometer is labeled W102. The 100kΩ potentiometer is labeled W104. Double check the part number before soldering to ensure you don't accidentally install the wrong part in the wrong place!

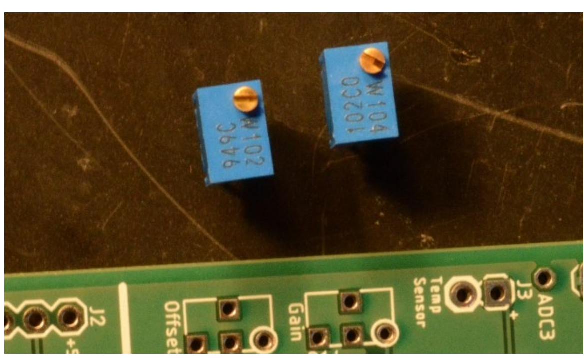


Figure 42: Potentiometer markings for 1k and 10k resistors R13 and R14

Temperature Module Assembly Step 9

Locate the 100kΩ potentiometer. Insert the potentiometer to R14(R20). Bend the leads outwards so that part remains secure on the board. Solder one pin and check that the potentiometer is flush with the board. If it is not, remove the solder and adjust the component. Then solder the other two pins.

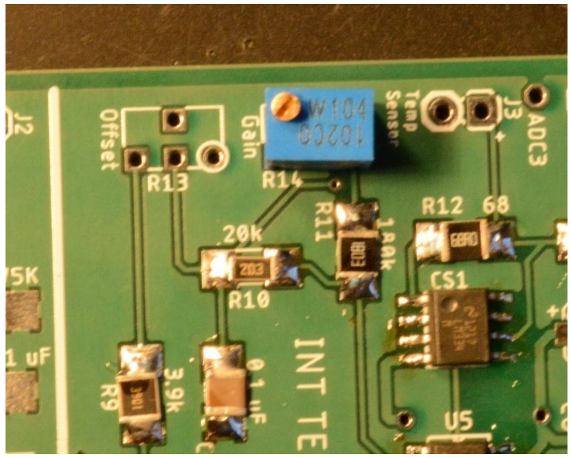


Figure 44: Resistor R14 soldered in place.

Temperature Module Assembly Step 10

Locate the 1kΩ potentiometer. Insert the potentiometer to R13(R19). Bend the leads outwards so that part remains secure on the board. Solder one pin and check that the potentiometer is flush with the board. If it is not, remove the solder and adjust the component. Then solder the other two pins.

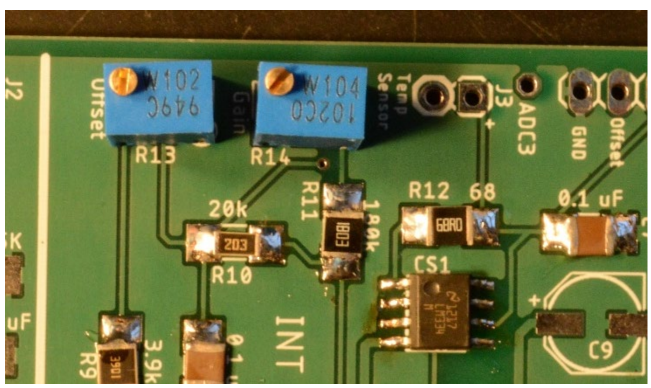


Figure 43: Both Potentiometers R13 and R14 Soldered in place.

Temperature Module Assembly Step 11

Flip the board over and trim the potentiometer leads using a wire clipper. \

Temperature Module Assembly Step 20

Locate the other Temperature Module Packet. Open the packet and repeat steps 1 – 11 for the external module. Refer to the inventory list, schematic, and PCB layout below as necessary.

External Temperature Module – Parts List

- ☐ CS2: LM334M Current Source
- ☐ U6: AD820ARZ Single Op Amp
- ☐ R15: 3.9 kΩ Resistor
- ☐ R16: 180 kΩ Resistor
- ☐ R17: 20 kΩ Resistor
- ☐ R18: 68 Ω Resistor
- ☐ R19: 1 kΩ Potentiometer
- ☐ R20: 100 kΩ Potentiometer
- ☐ C10-C12: 0.1 μF Ceramic Capacitors
- ☐ C13: 10 μF Electrolytic Capacitor
- ☐ J4: Right-Angle Breakaway Header (2-Pin)

External Temperature Module – Schematic

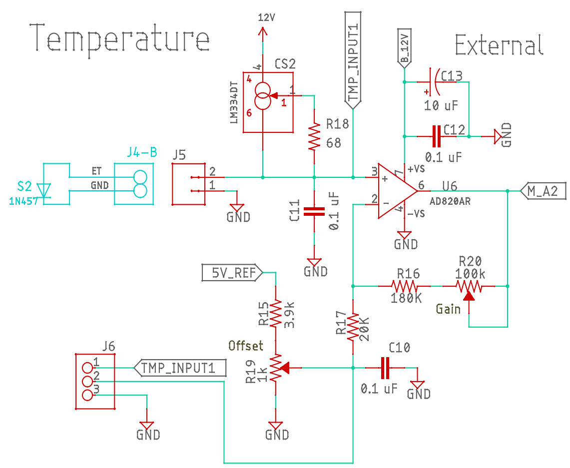


Figure 45: External temperature ciruit schematic.

External Temperature Module – PCB Layout

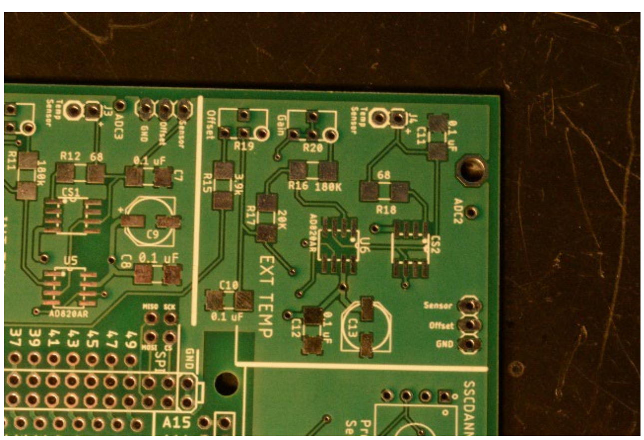


Figure 46: Unpopulated external temperature senesor PCB.

Assembled Temperature Modules

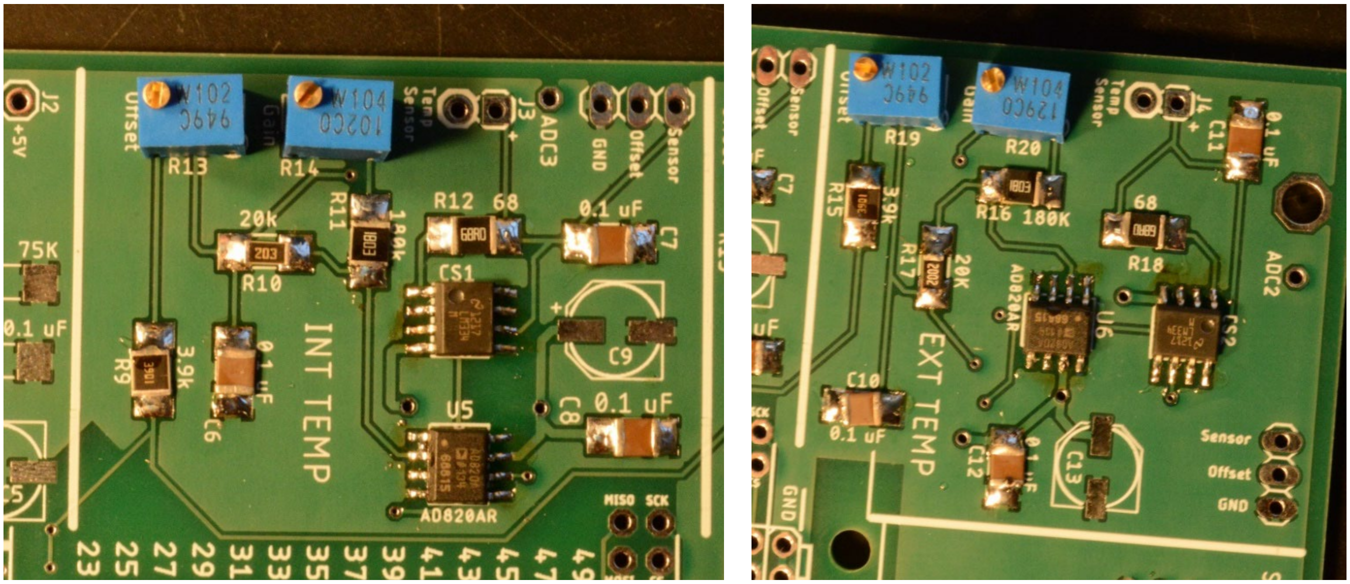


Figure 47: Assembled internal (left) and external (right) temperature circuits.

At this point both temperature circuits should be assembled except for the large capacitors C9 and C13 and the right angle headers J3 and J4. Save those parts which will be soldered at a later point in the assembly.

MegaSat Assembly - Humidity Module

Humidity Module – Parts List

- ☐ U4: AD822ARZ Dual Op Amp [6]
- ☐ R4: 6.8 kΩ Resistor
- ☐ R5: 10 kΩ Resistor
- ☐ R6: 75 kΩ Resistor
- ☐ R7-R8: 10 kΩ Potentiometer
- ☐ C1-C4: 0.1 µF Ceramic Capacitors
- ☐ C5: 10 µF Electrolytic Capacitor
- ☐ J2: Right-Angle Breakaway Header (3 pin)

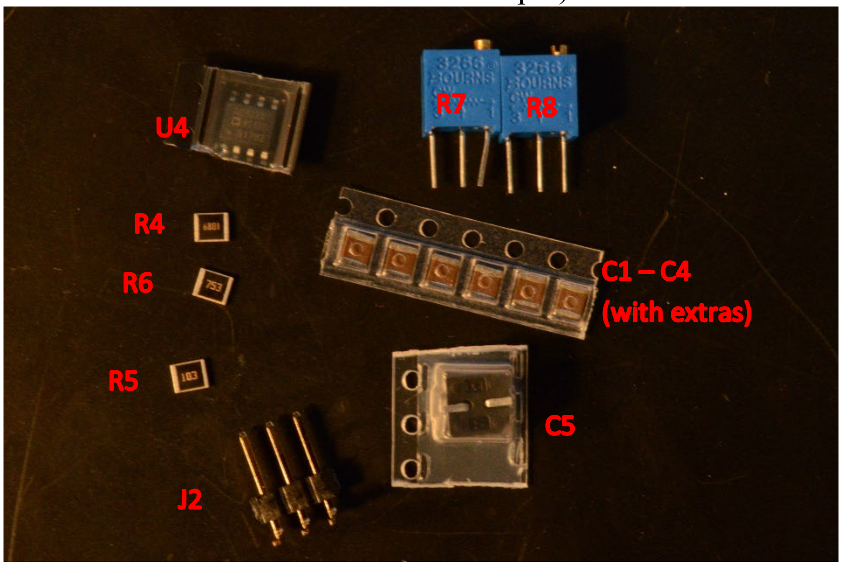


Figure 48: Humidty Module Parts

Humidity Module – Schematic

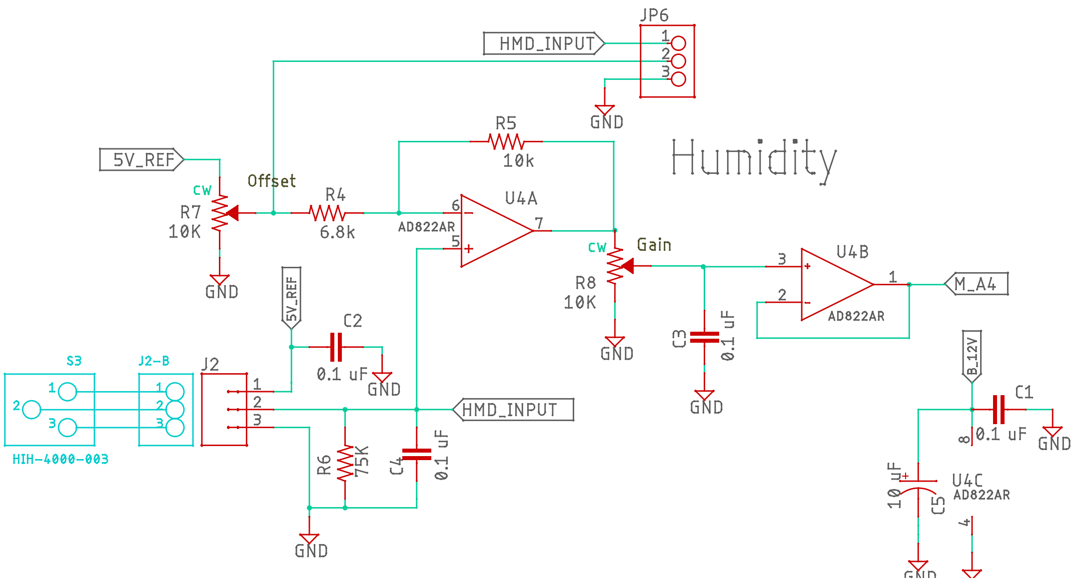


Figure 49: Humidty sensor circuit schematic.

Humidity Module – PCB Layout

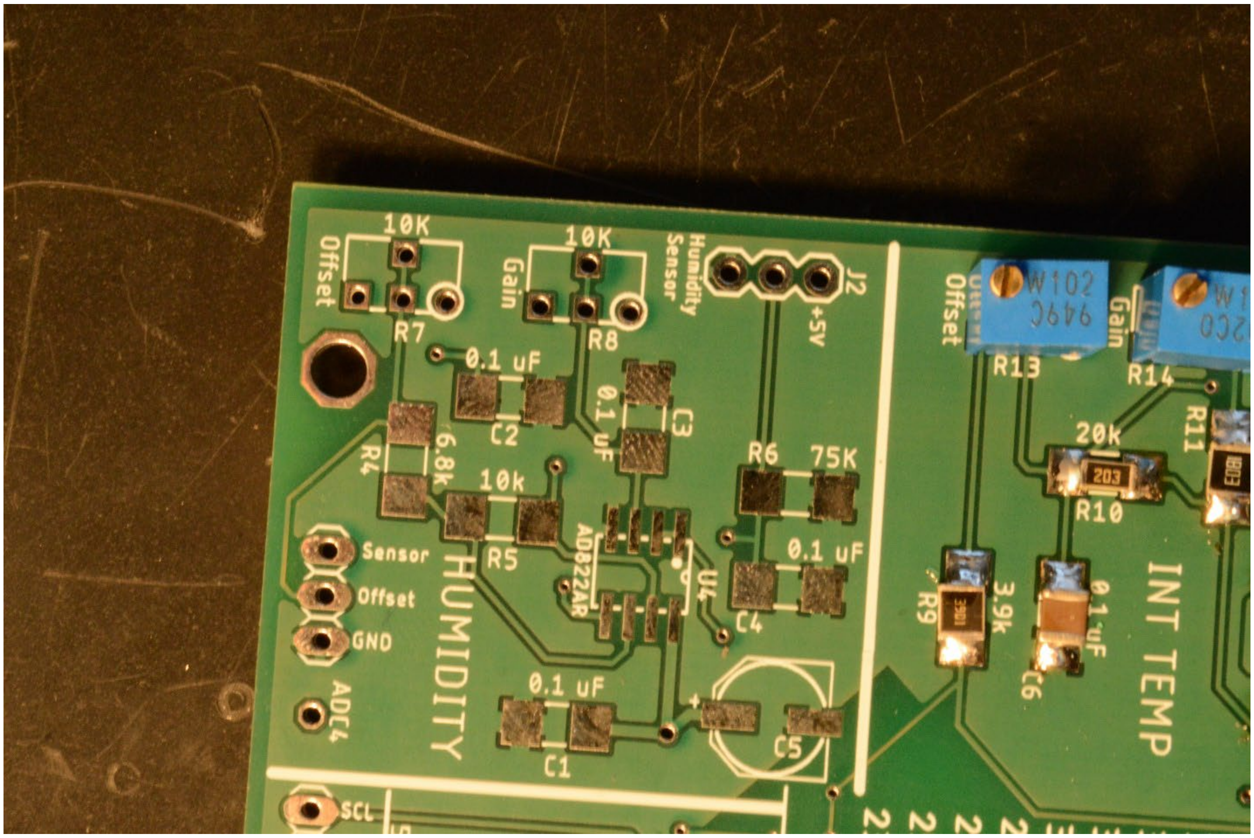


Figure 50: Humidity module bare PCB

Humidity Module Assembly Step 1

Locate the dual op amp AD822 and its matching pad U4. Locate the pin 1 marking on both chip and PCB to determine orientation and then solder IC in place.

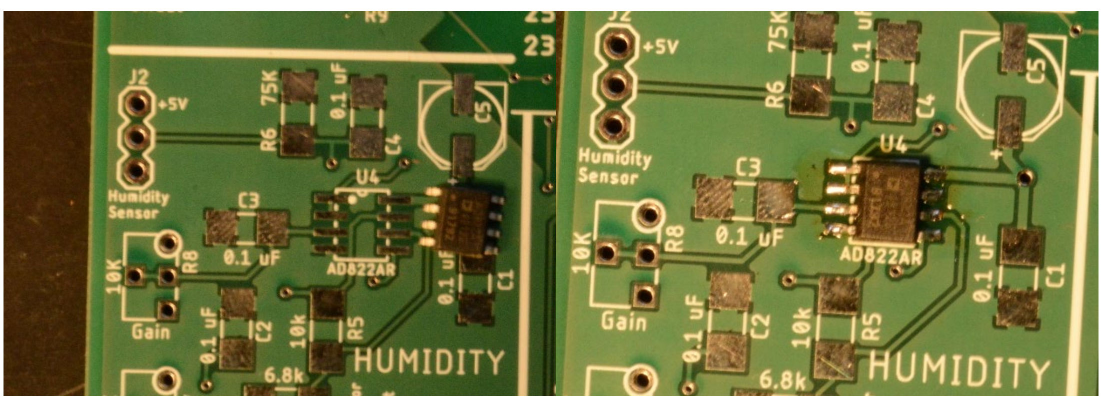


Figure 51: Soldering Dual Op amp U4 in place.

Humidity Module Assembly Step 2

Locate the locate four 0.1 uF capacitors and matching pads C1, C2, C3, and C4. These capacitors do not have any value marking or orientation. Solder all four capacitors to their pads.

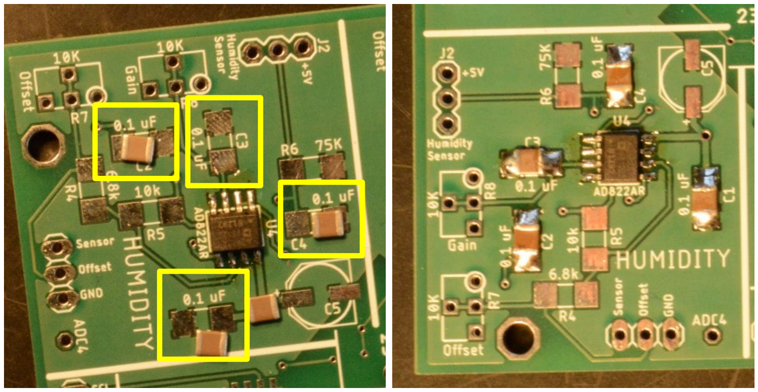


Figure 52: Soldering capacitors C1, C2, C3, and C4 in place.

Humidity Module Assembly Step 3

Locate the 75kΩ resistor. Align the resistor with the pad R6. Solder the resistor to the pad.

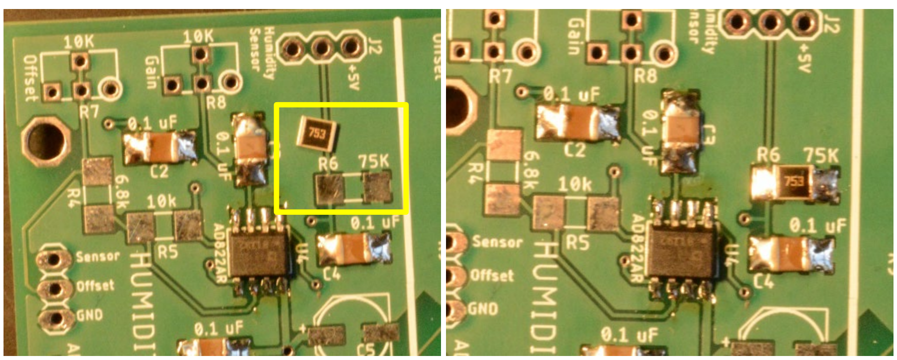


Figure 53: Soldering resistor R6 in place.

Humidity Module Assembly Step 4

Locate the 10kΩ resistor. Align the resistor with the pad R5. Solder the resistor to the pad.

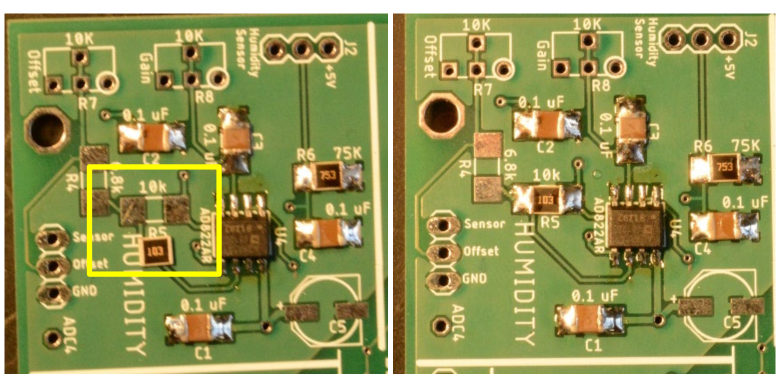


Figure 54: Soldering resistor R5.

Humidity Module Assembly Step 5

Locate the 6.8kΩ resistor. Align the resistor with the pad R4. Solder the resistor to the pad.

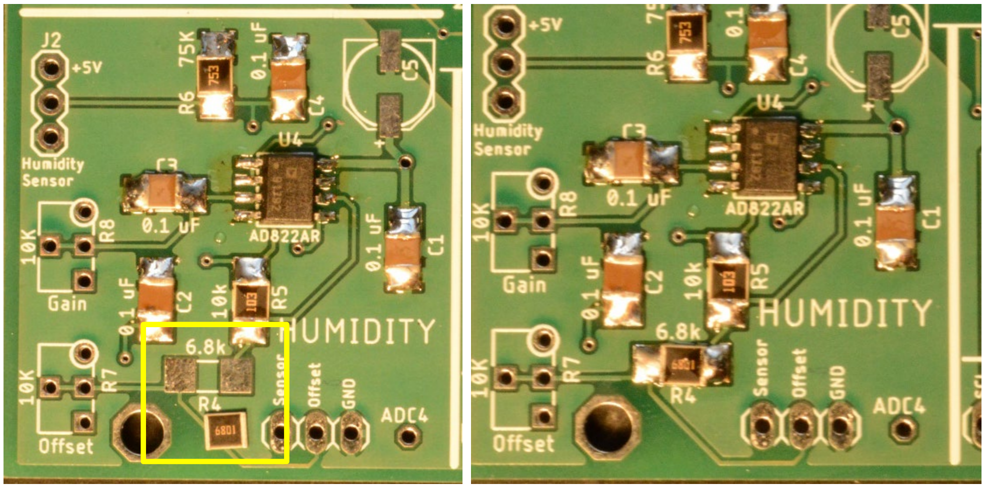


Figure 55: Soldering resistor R4 in place.

Humidity Module Assembly Step 6

Locate the 10kΩ potentiometers. These will be marked with 103 for 10 x 10^3 on top. Insert the potentiometer to R7. Bend the leads outwards so that part remains secure on the board. Solder one pin and check that the potentiometer is flush with the board. If it is not, remove the solder and adjust the component. Then solder the other two pins.

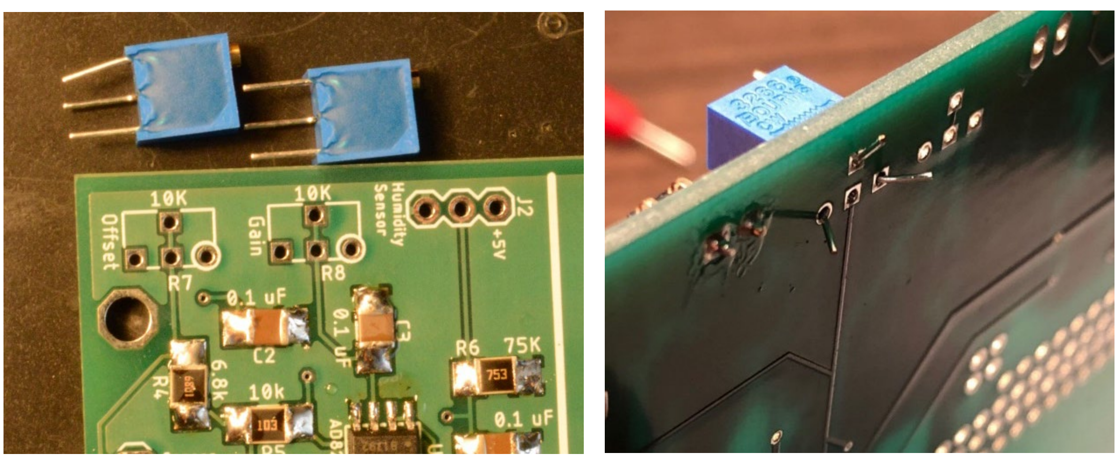


Figure 56: Solder potentiometer for humidity circuit.

Humidity Module Assembly Step 7

Repeat step 6 above for the second 10kΩ potentiometer and R8. Then trim the excess leads from the back of the board using wire cutters.

Humidity Module Assembly Step 8

Once again set aside the large capacitor C5 and then right-angle header J2 for later. Your humidity circuit should the image shown below in Figure 60: Completed humidity circuit.

Assembled Humidity Module

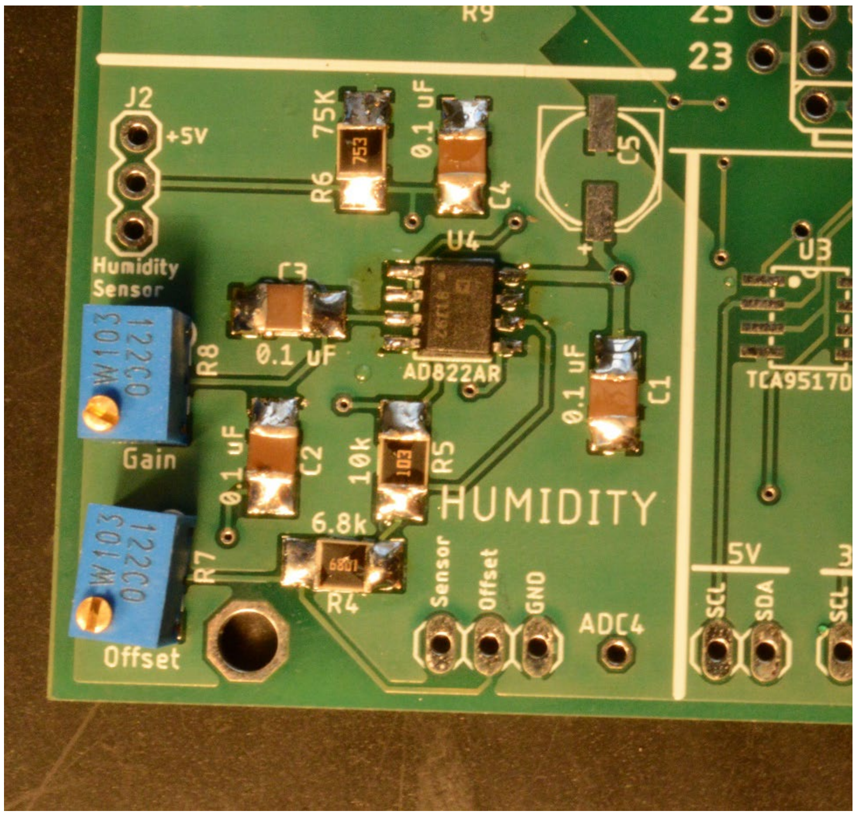


Figure 57: Completed humidity circuit.

MegaSat Assembly - Pressure Module

Pressure Module – Parts List

- ☐ U7: AD820ARZ Single Op Amp [5]
- ☐ R25: 9.1 kΩ Resistor
- ☐ R26, 28: 10 kΩ Resistor
- ☐ R27, R30: 62 kΩ Resistor
- ☐ R29: 1 kΩ Resistor
- ☐ R31: 10 kΩ Potentiometer
- ☐ C14: 0.1 µF Ceramic Capacitors
- ☐ C15: 10 µF Electrolytic Capacitor
- ☐ 8-Pin Socket

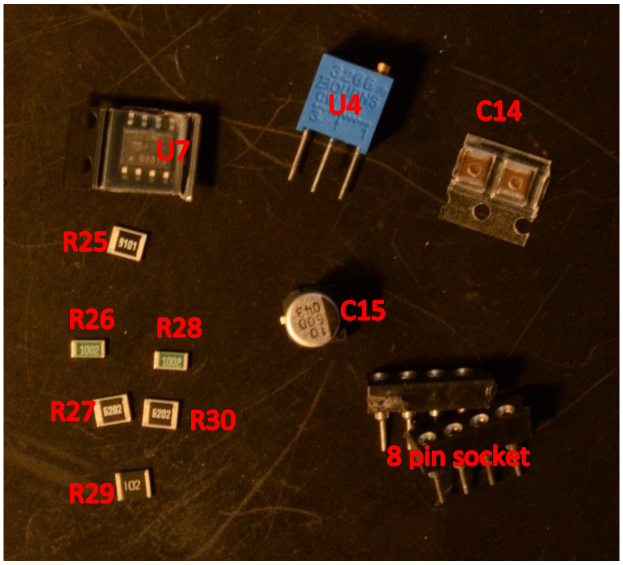


Figure 58: Pressure module parts.

Pressure Module - Schematic

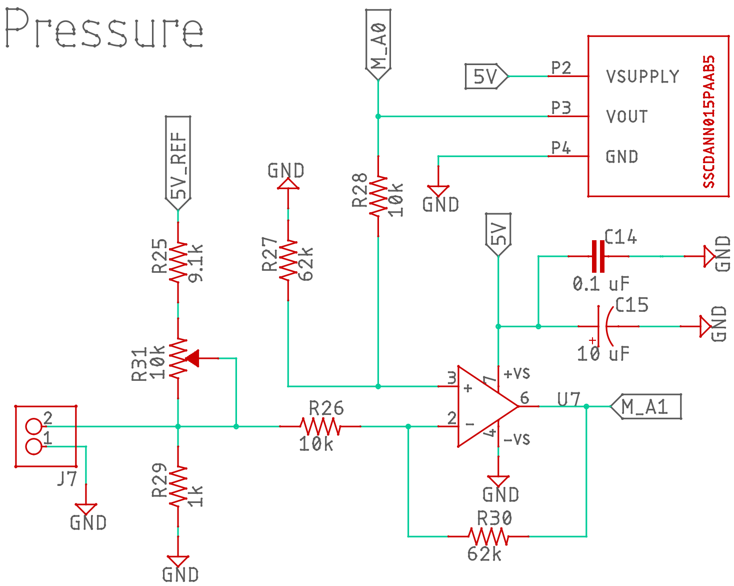


Figure 59: Pressure sensor schematic.

Pressure Module – PCB Layout

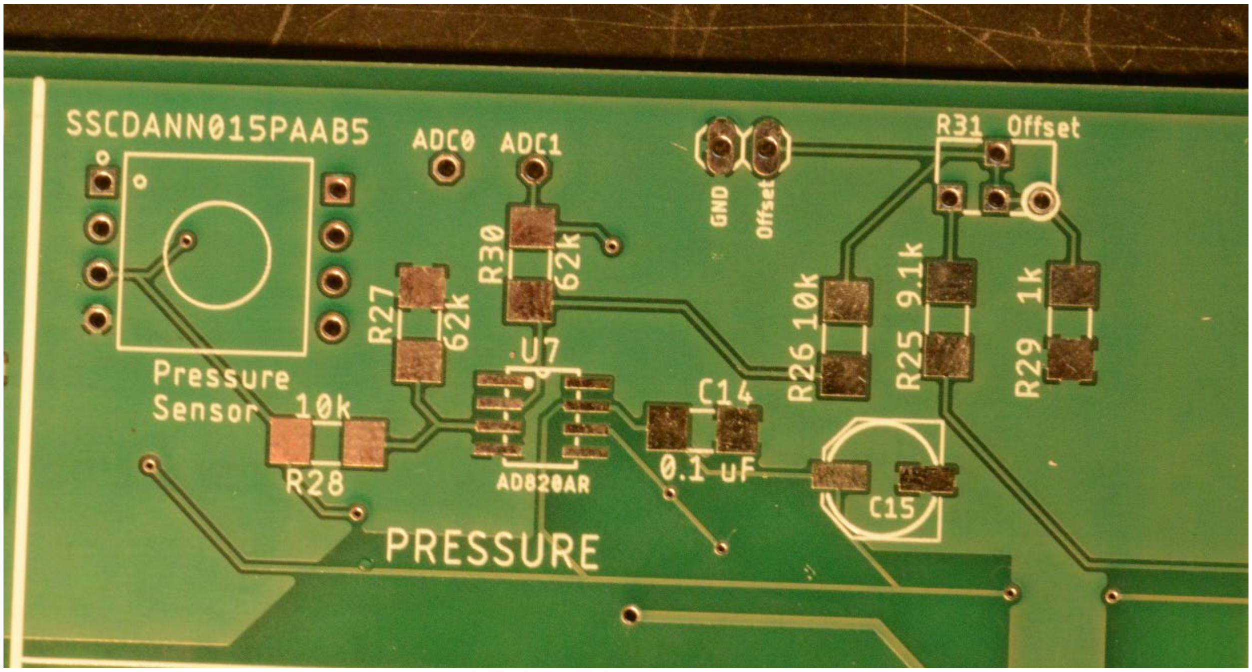
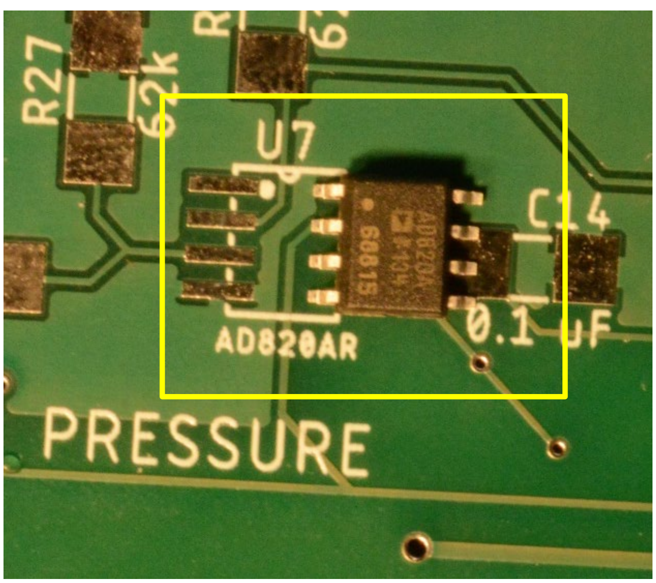


Figure 61: Pressure module bare PCB.

Pressure Module Assembly Step 1

Locate op amp AD820A and PCB pads U7. Locate the pin 1 marking on the IC and on the PCB to determine the orientation. Then solder the IC to the board.



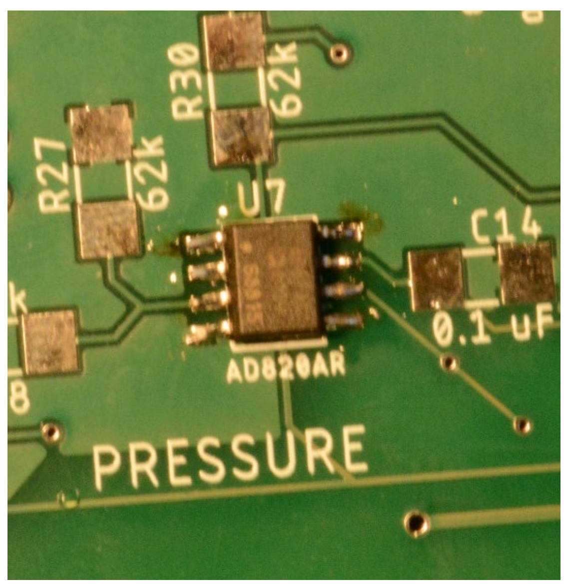


Figure 60: Soldering AD820 op amp to U7.

Pressure Module Assembly Step 2

Locate the 0.1 uF capacitor. Again, this capacitor has not markings and is not polarized. Locate the pad C14 for the capacitor and solder the capacitor to the board.

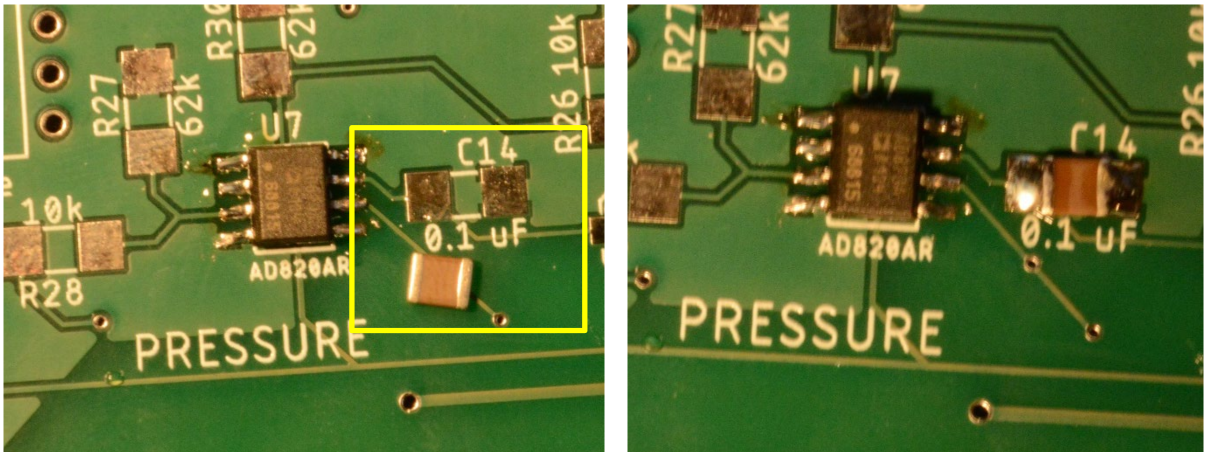


Figure 62: Soldering capacitor C14 to the board.

Pressure Module Assembly Step 3

Locate 9.1 kΩ resistor and pad R25. Solder the resistor in place.

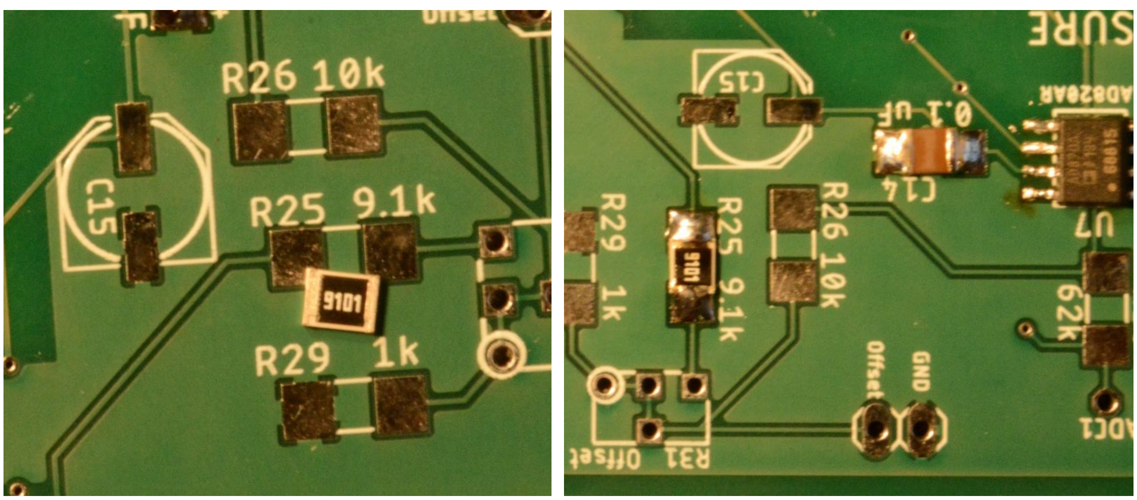


Figure 63: Soldering resistor R25 to the board.

Pressure Module Assembly Step 4

Locate the two 10kΩ resistors and the matching pads R26 and R28. Solder both resistors in place on the PCB.

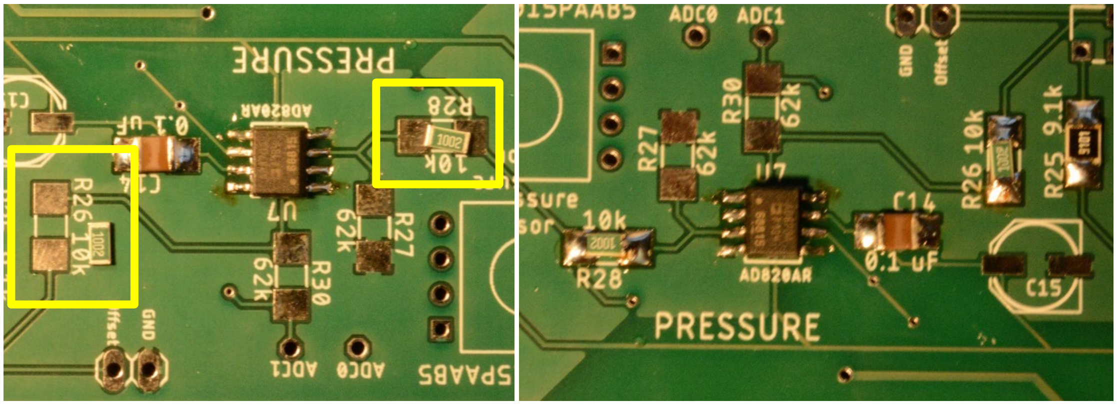


Figure 64: Soldering resistors R26 and R28 in place.

Pressure Module Assembly Step 5

Locate the two 62 kΩ resistors and their matching pads R27 and R30. Solder both resistors to the board.

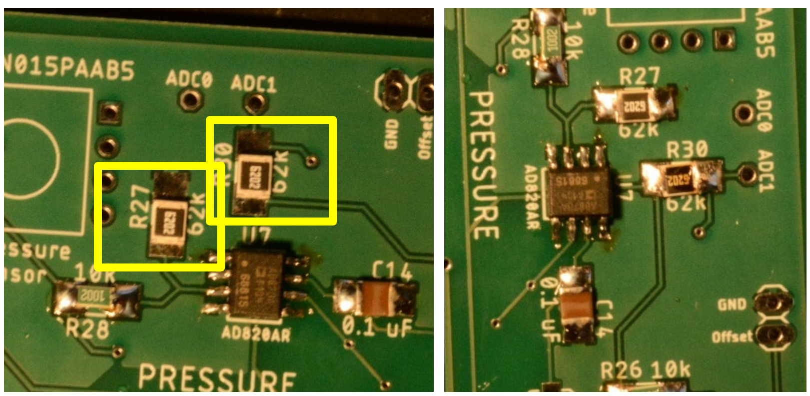


Figure 65: Soldering resistors R27 and R30 in place.

Pressure Module Assembly Step 6

Locate 1kΩ resistor and the corresponding pad R29. Solder resistor to the board.

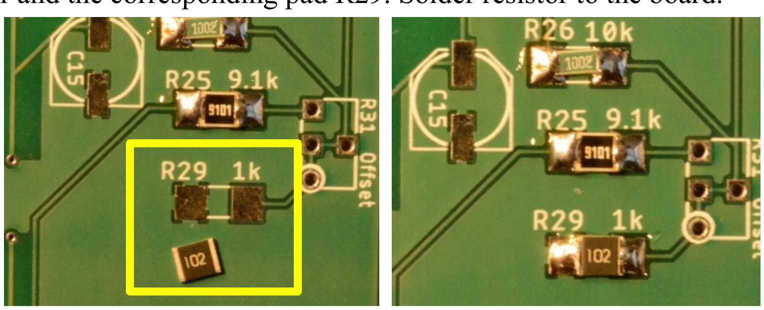


Figure 66: Soldering resistor R29 in place.

Pressure Module Assembly Step 7

Locate the 10kΩ potentiometer labeled 103. Insert the potentiometer to R31. Bend the leads outwards so that part remains secure on the board. Solder one pin and check that the potentiometer is flush with the board. If it is not, remove the solder and adjust the component. Then solder the other two pins. Then trim the leads on the back side of the board using wirecutters.

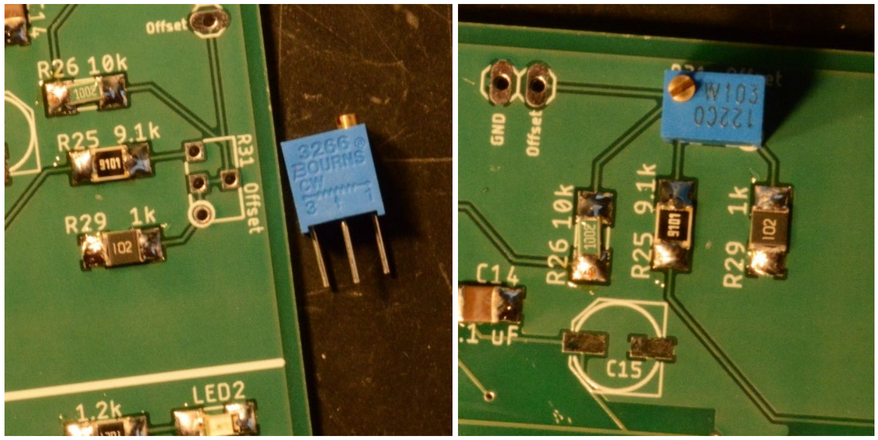


Figure 67: Soldering 10k potentiometer R31.

Pressure Module Assembly Step 8

Locate the 8 pin IC socket. Insert the socket to the pad labelled pressure sensor. Make sure the header is flush with the board. Flip the board over and solder one pin. Check and adjust the header as needed before soldering the rest of the pins.
Note: The header may come in two pieces, if so just solder each side one at a time.

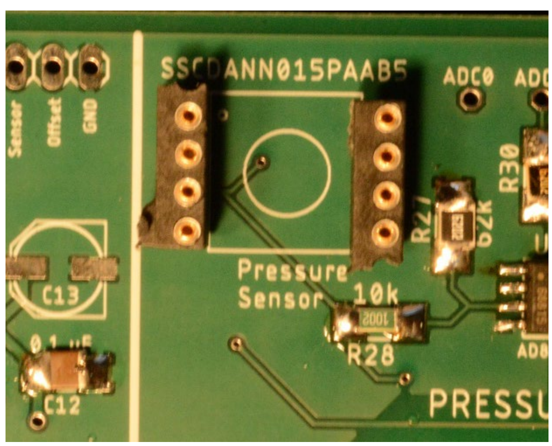


Figure 68: 8 pin socket for pressure sensor.

Pressure Module Assembly Step 9

Once again set the large capacitor C15 aside for later. Your completed pressure sensor should now look like Figure 72: Completed pressure module.

Assembled Pressure Module

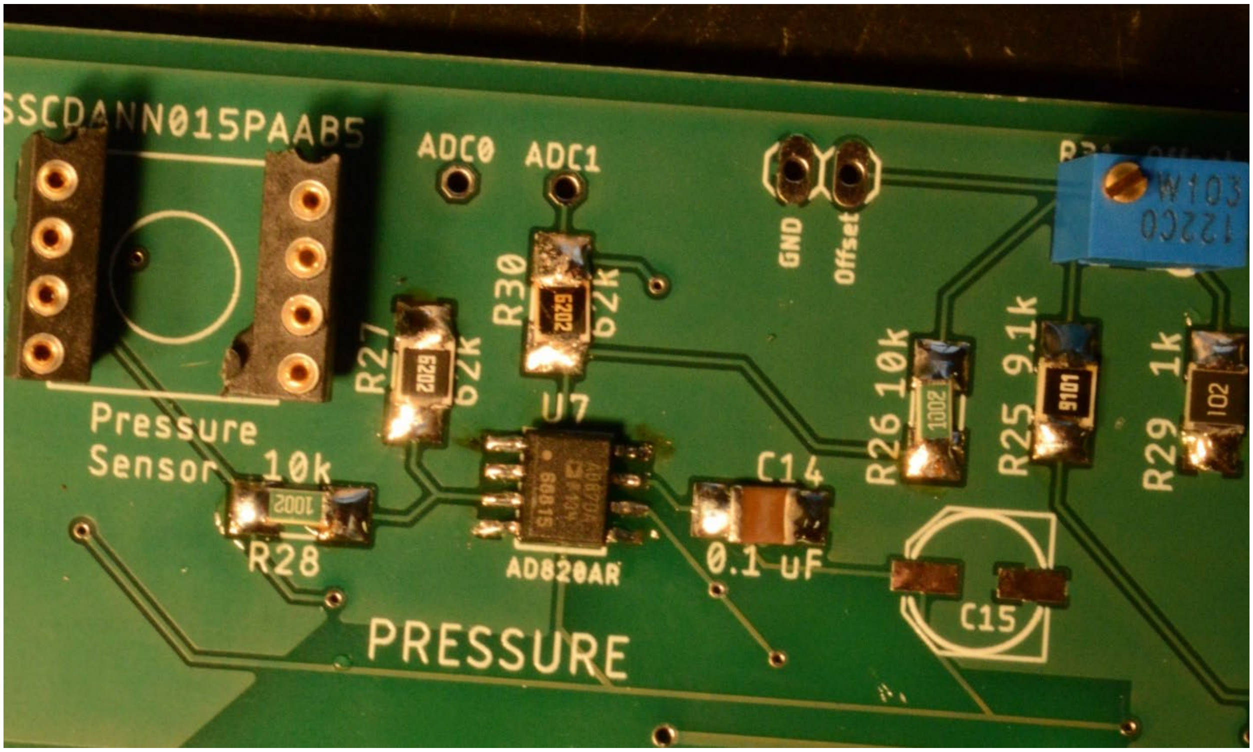


Figure 69: Completed pressure module.

MegaSat Assembly - RTC Module

RTC Module – Parts List

- ☐ U2: DS3231SN RTC [7]
- ☐ U3: TCA9517DR Bidirectional Level Shifter [8]
- ☐ R2-R3: 10 kΩ Resistor
- ☐ B1: 3000TR Coin Cell Battery Holder

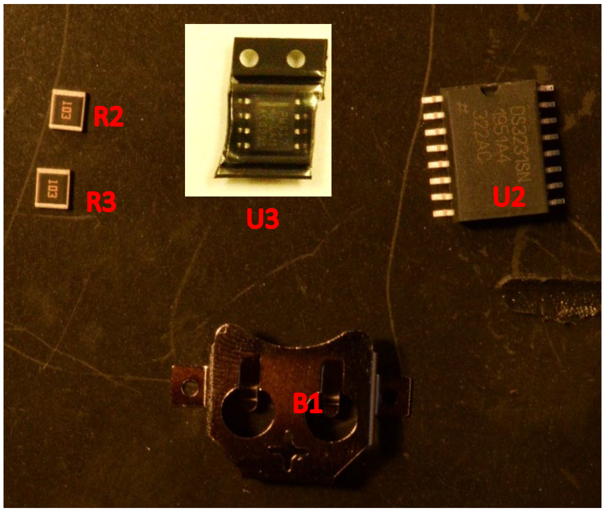


Figure 70: RTC Module Parts

RTC Module – Schematic

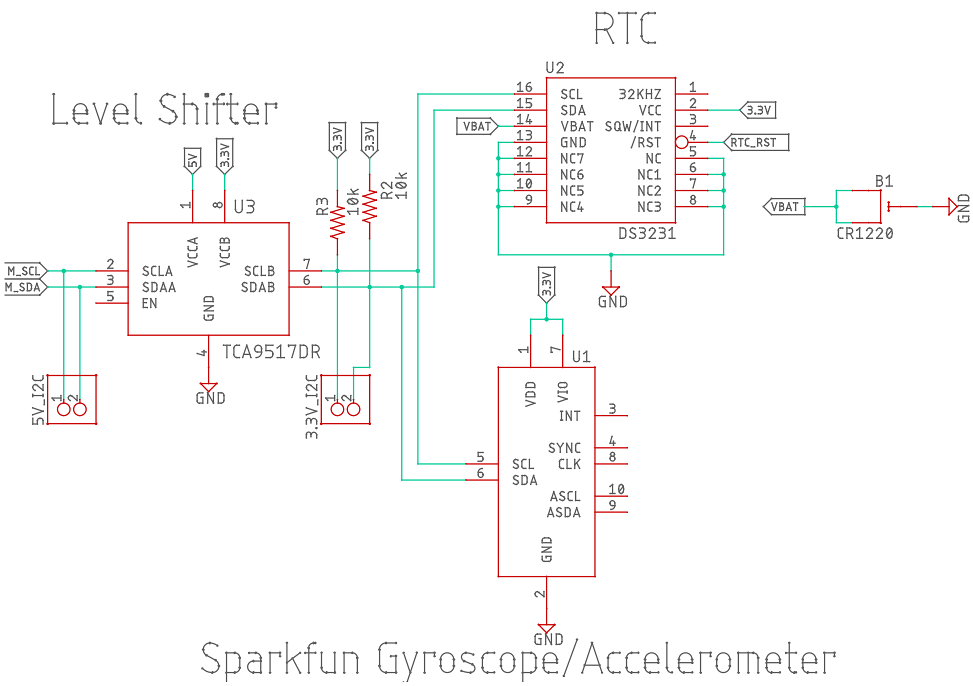


Figure 71: RTC and IMU Module Schematic

RTC Module – PCB Layout

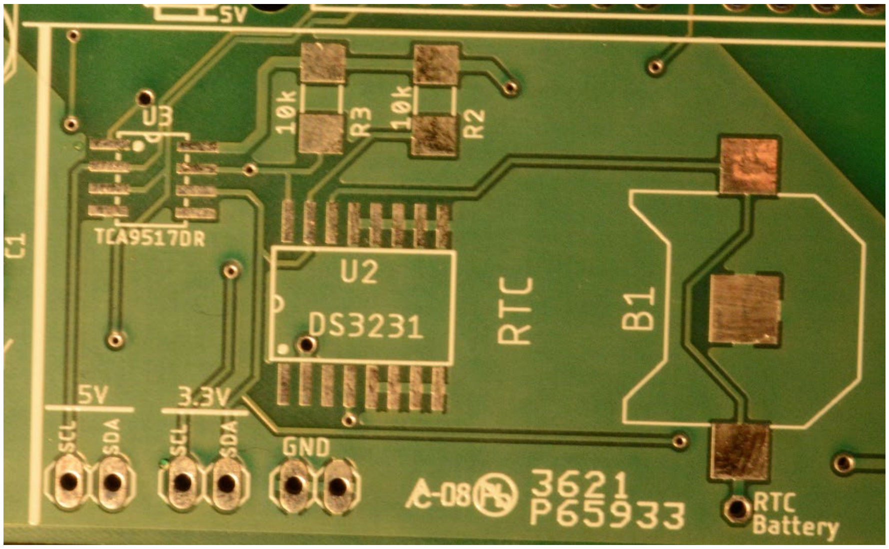


Figure 72: RTC module PCB layout.

RTC Module Assembly Step 1

Locate the DS3231 chip. Align the chips with the pad U2. There is a dot on the silkscreen pattern that matches a dot on the chip itself. Apply the solder to one of the pads first before attempting to solder the chip. While holding the IC in place with tweezers, solder one of the pins onto the board. Next, check to make sure all the other pins are aligned with their respective pads before soldering anymore pins. If not, melt the solder and realign the IC.

Once the chip is properly aligned solder the remaining pins. Be inspect all of your pins thoroughly as it is very easy to bridge the pins on this particular IC.

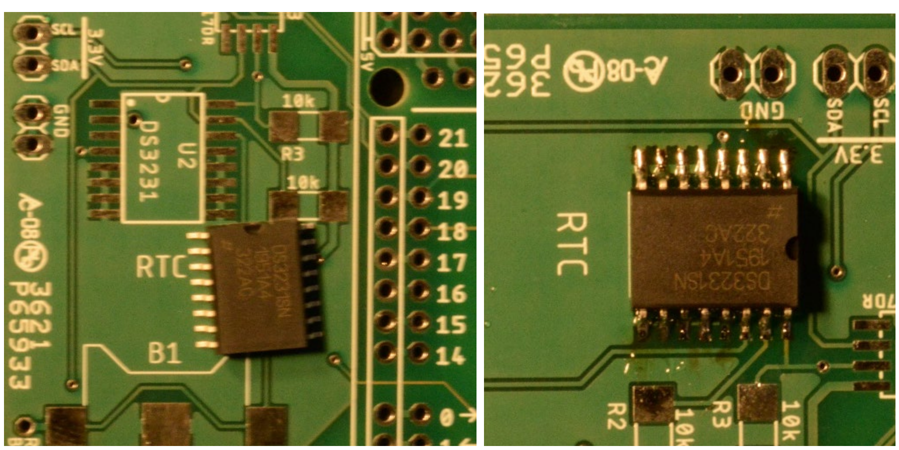


Figure 73: Soldering the RTC chip in place.

RTC Module Assembly Step 2

Locate the TCA9517 chip. Align the chips with the pad U3. There is a dot on the silkscreen pattern that matches a dot on the chip itself. Solder the IC in place.

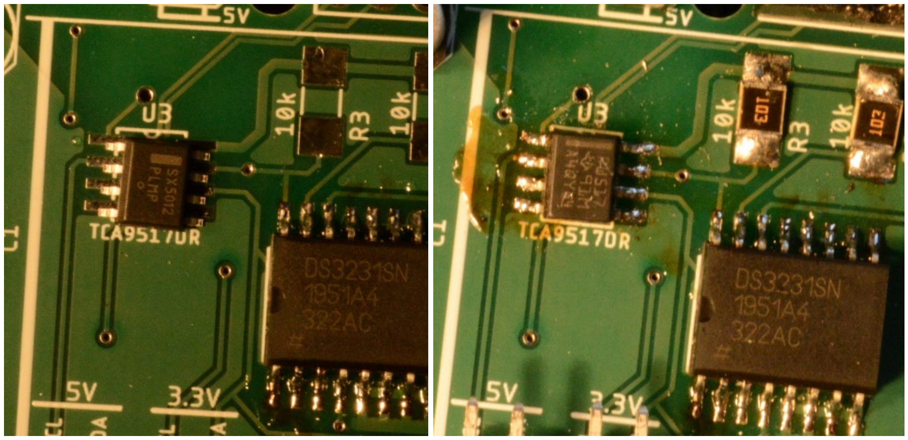


Figure 74: Soldering level shifter in place.

RTC Module Assembly Step 3

Locate the 10kΩ resistors. Align the resistor with the pad R2 and R3. Solder both resistors to the pads.

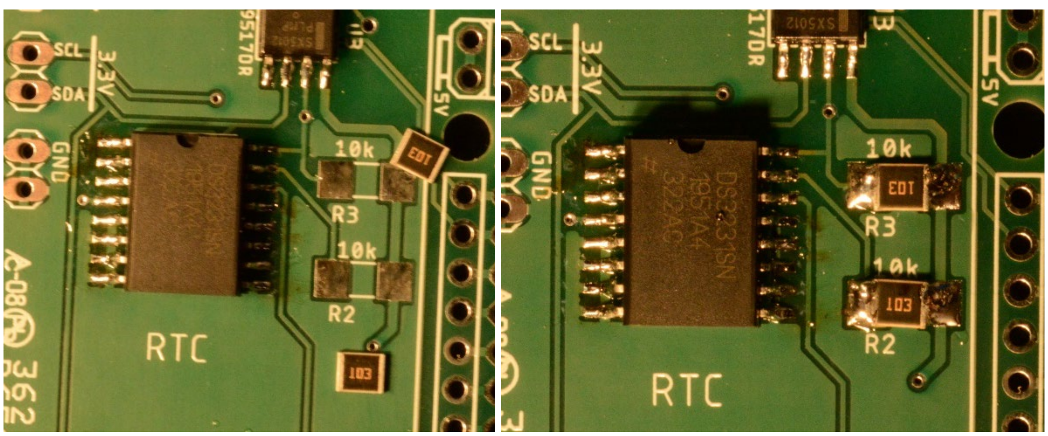


Figure 75: Soldering resistors R2 and R3 in place.

RTC Module Assembly Step 4

Locate the pad for the battery holder located at B1. Add solder to the center pad of B1. You want to add enough solder to create a small bead of solder that sits out from the board. This is bead will hold the battery in place an make the contact with bottom side of the coin cell.

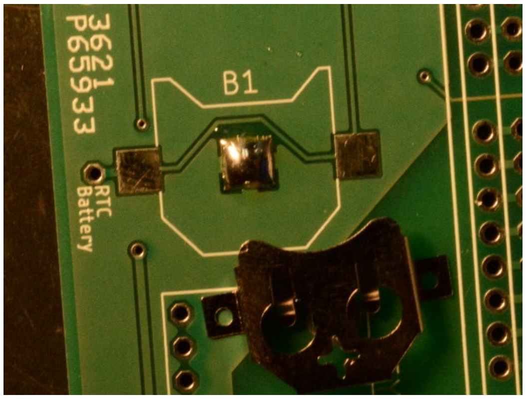


Figure 76: Adding solder to the center pad of the battery holder, be sure that the solder bead sticks out from the board.

RTC Module Assembly Step 5

NOTE: The battery holder is a single piece of metal and the entire holder will be hot when it heated with the soldering iron, use tweezers or needlenose pliers to handle while soldering.

Locate the battery holder. Add solder to one of the side pads of B1. Align the battery holder with the pads at B1. The battery holder should match the silkscreen. Remelt the solder while pressing the battery down into the pad. Check the alignment of the other bracket. If it is aligned with the pad, solder the other bracket down. Otherwise, remelt the solder and realign the battery holder. You will likely need to add additional solder to the first pad after it is in place.

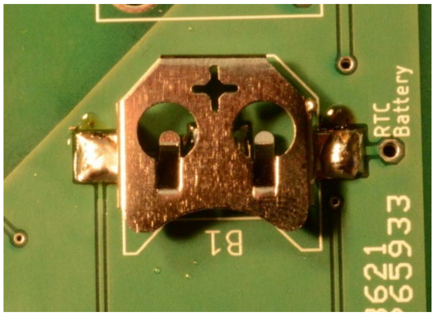


Figure 77: Completely soldered batter holder.

Assembled RTC Module

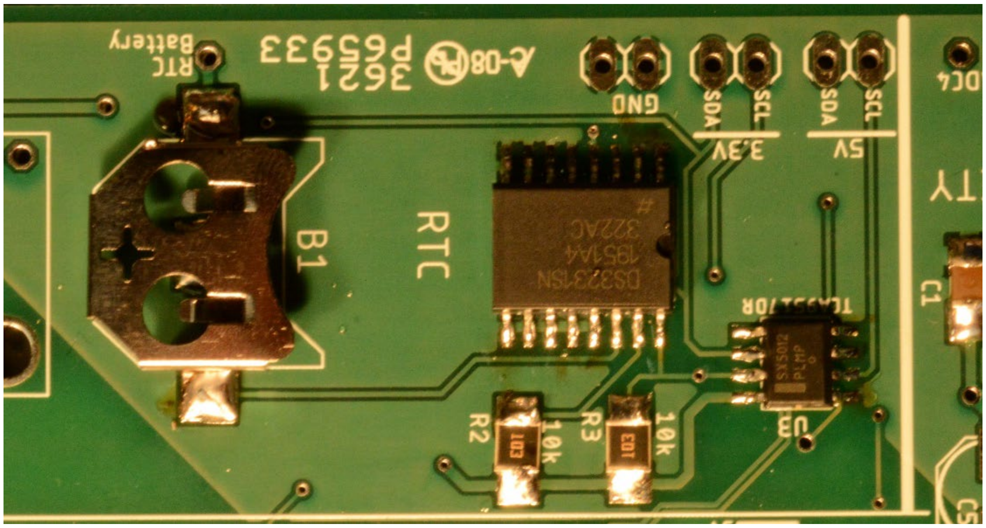


Figure 79: Completely soldered RTC Module

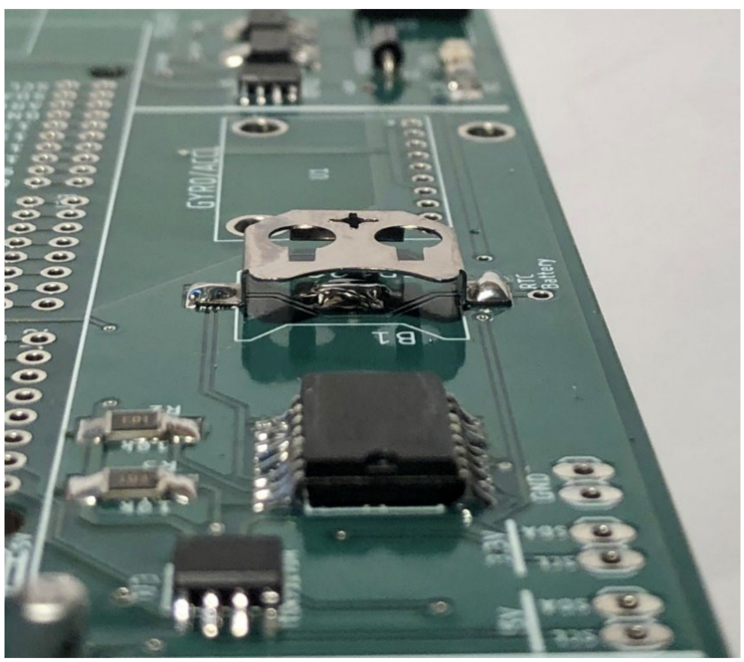


Figure 78: Notice how the solder of the center pad of battery holder sticks above the board.

MegaSat Assembly – Accelerometer / Gyroscope Module

Accelerometer / Gyroscope Module – Parts List

- ☐ U1: Sparkfun Triple Axis Accelerometer/Gyroscope Breakout Board [9]
- ☐ Right Angle Breakaway Headers (10-pin)

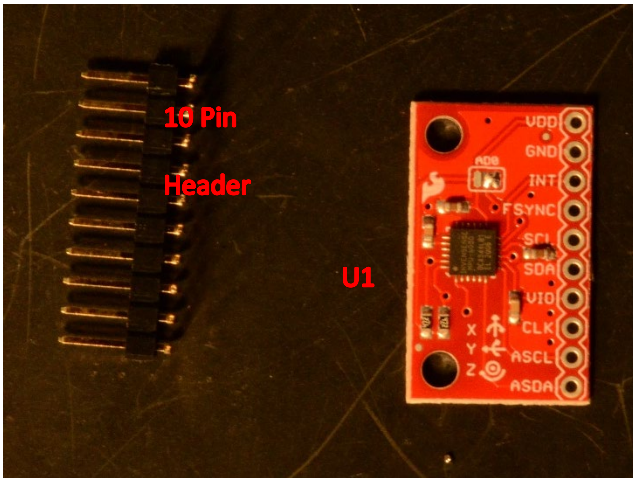


Figure 80: Acclerometer Gyroscope parts.

Accelerometer / Gyroscope Module – Schematic

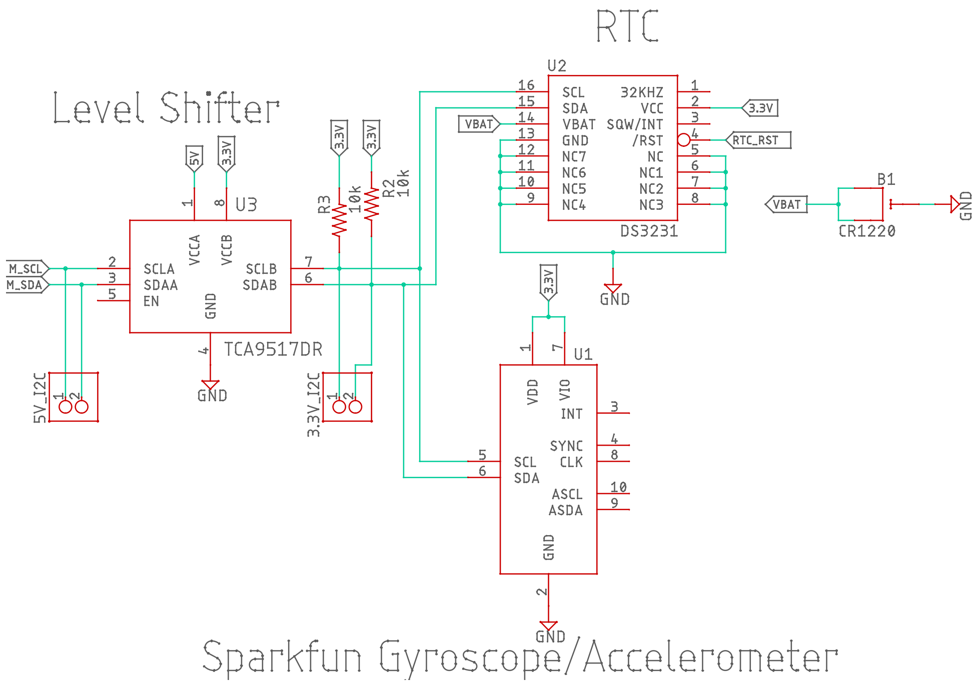


Figure 81: RTC and IMU Schematic.

Accelerometer / Gyroscope Module – PCB Layout

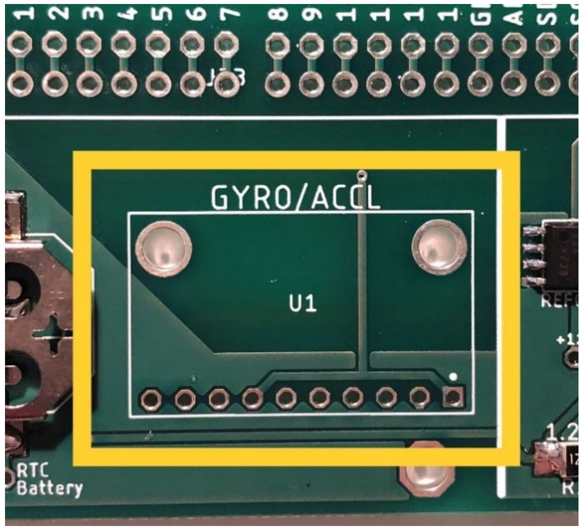


Figure 82: PCB location where the IMU will be soldered in.

Accelerometer / Gyroscope Assembly Step 1

From the Sensors module get the breakout board and 10 pin header.

By default the IMU has an I2C address of 0x68. This is the same address used by the RTC so we will need to change it. The last bit of this address is controlled by the AD0 jumper on the breakout board.

By default the AD0 connects the bit select pin on the IMU to ground setting the last bit of the address

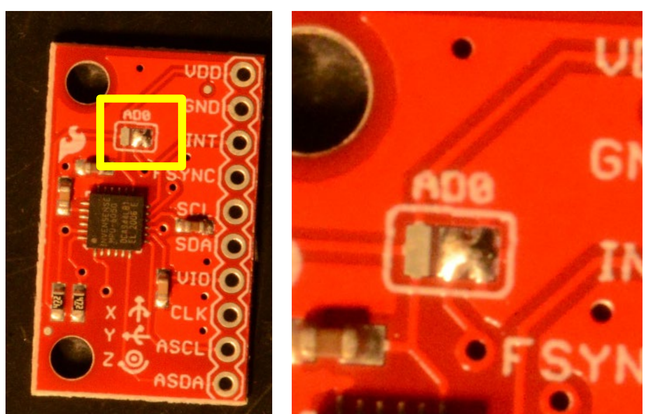


Figure 83: The AD0 jumper on the breakout board. The center pad is connected to and address select pin on the IMU chip. The right pad is connected to ground and the left to VDD (voltage supply). In the shown configuration this sets the address to 0x68

Accelerometer / Gyroscope Assembly Step 2

Using soldering iron, solder wick, and/or a solder pump remove the solder from the AD0 jumper pads. Be careful not to damage the pads. When you believe you have removed the solder verify ther is no longer a connection between the middle and left pin.

Figure 85: Address jumper AD0 after the connection between center and right pads has been removed.

Accelerometer / Gyroscope Assembly Step 3

Now add a solder to the left pad and then intentionally create a bridge between the center and left pads. Be careful to not create a bridge to the right pad as this will create a power to ground short on the breakout board. After you have finished verify that there is continuity from VDD to the center pad and no continuity between VDD and ground using a multimeter.

Figure 84: AD0 jumper after the connection has been made between the left and center pins. In this configuration the I2C address will be 0x69.

Accelerometer / Gyroscope Assembly Step 4

Take the right-angle head and install it in the holes on side of the IMU breakout board. Then flip the breakout board over and solder each of the pins of the header to the break out board.

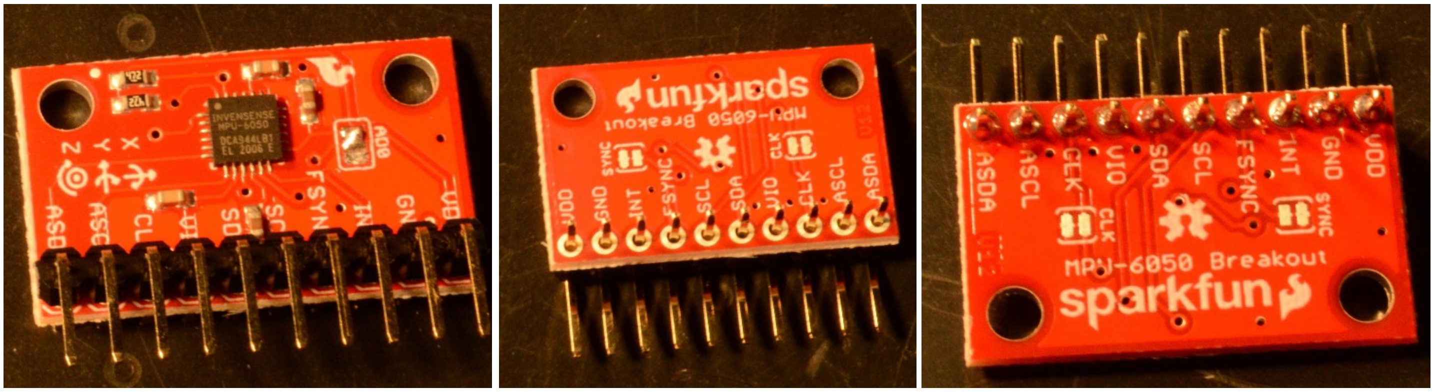


Figure 86: Installing header pins in to breakout board and then soldering to board.

Accelerometer / Gyroscope Assembly Step 5

Now put the assembled breakout board into the MegaSAT PCB in the spot labelled GYRO/ACCEL. The VDD pin should be closest to the power module section. Now flip the board over and solder the pins to the back of the MegaSat PCB.

Assembled Accelerometer / Gyroscope Module

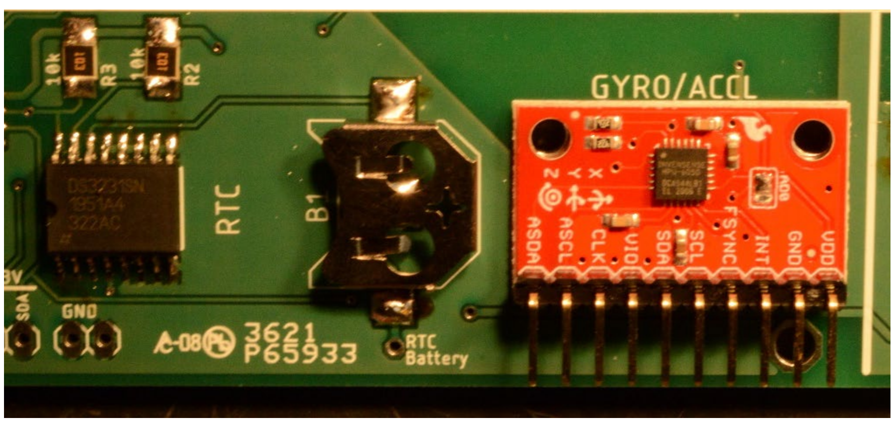


Figure 87: Assembled MPU Module.

MegaSat Assembly – Large Capacitors

We will now solder the large capacitors we had previously set aside during assembly. You should have four (relatively)large 10 uF capacitors, one from each temperature module, one from humidy, and one from pressure.

Figure 88: Four 10 uF capacitors.

Locate pads C5, C9, C13, and C15. This is where the capacitors will be soldered.

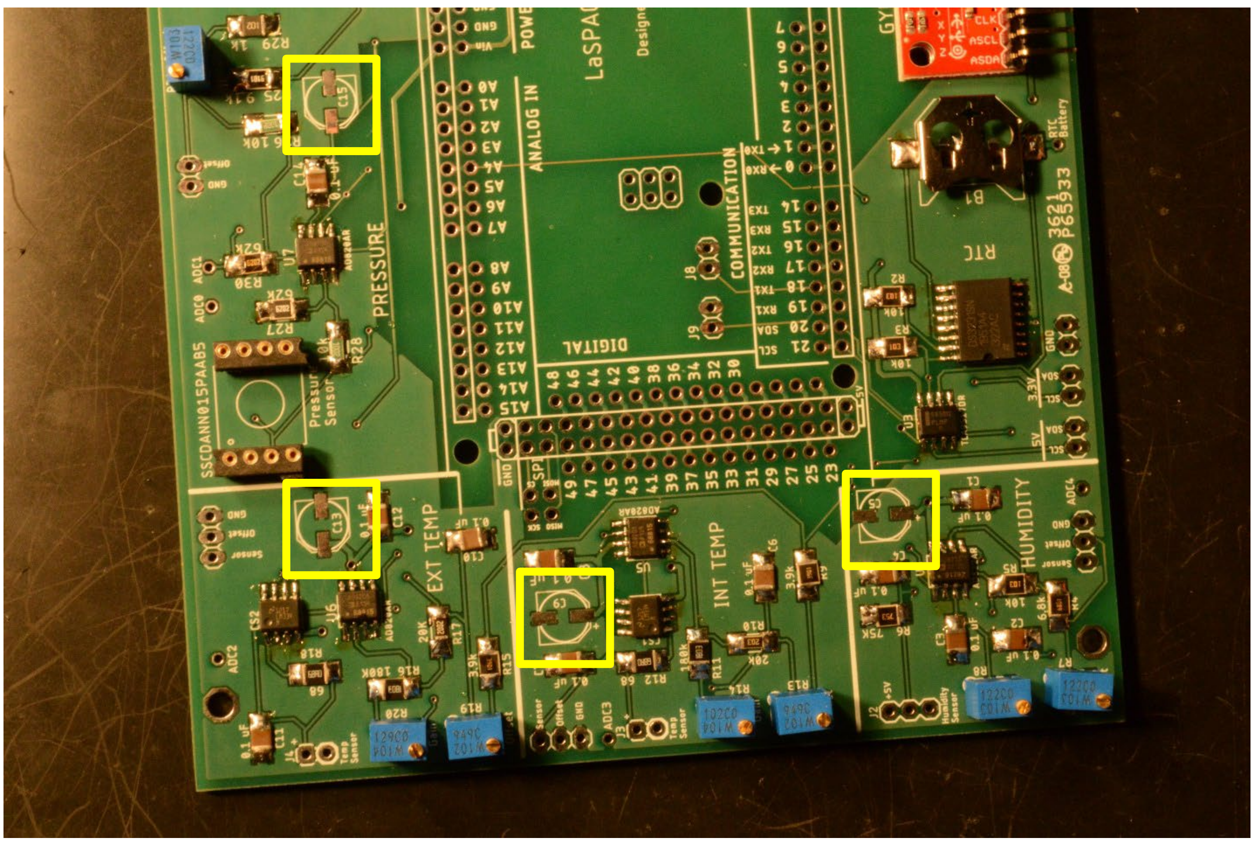


Figure 89: Locations of large capacitor pads C5, C9, C13, and C15 .

These capacitors are polarized. The black strip on the top of the capacitor indicates the cathode, the negative pin. Looking at the pads for these capacitors you see the one pad is marked with a positive sign and the other side has flat side to line up roughly with the black strip.

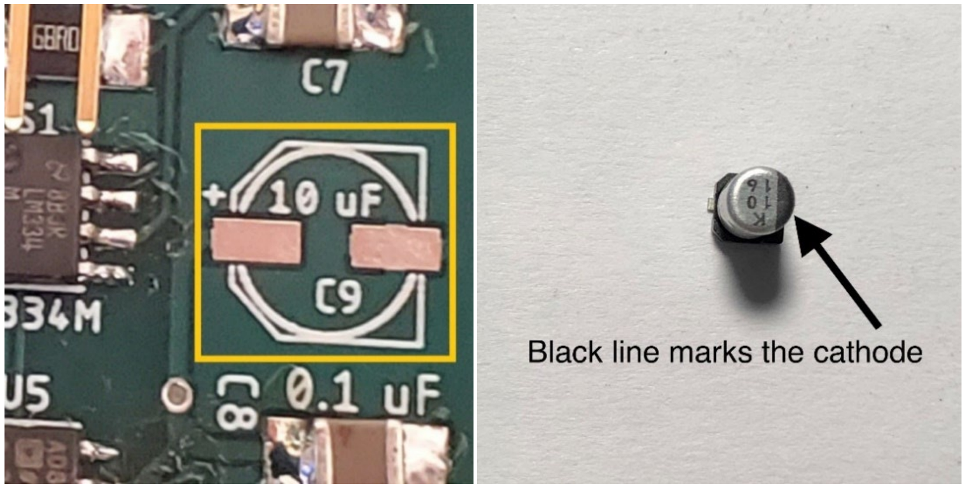


Figure 90: Polarity markings for the 10uF capacitors on the PCB and capacitor itself.

Starting with C5 add a small solder to one of the pads. Then hold the remelt the solder and press the capacitor on the melted solder and remove the iron while continuing to push down on the capacitor. Because of the large size of the capacitor this time the component may be held with your fingers.

Verify correct alignment with the other pad making adjustments in necessary. Then solder the other side by heating the pad and ping with the iron and adding solder.

Finally if neccisary add additional solder to the first pin.

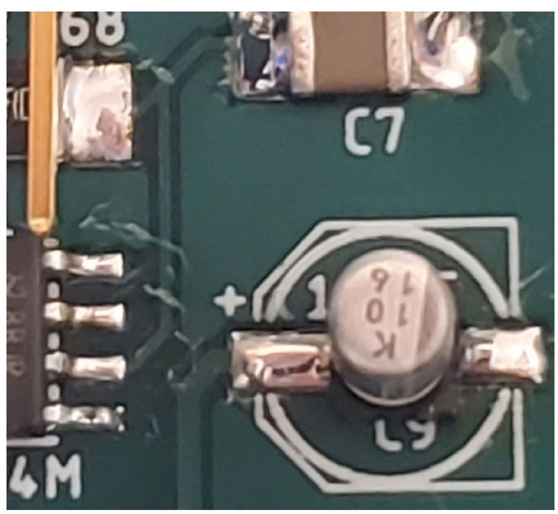


Figure 91: Completely soldered capacitor C9.

Repeat the above process for C9, C13, and C15.

MegaSat Assembly – Arduino Hardware

The Arduino Mega connects with the MegaSat PCB through stackable headers. There are seven stackable headers that act as the interface. It is important that the headers line up properly and remain straight. If the headers are misaligned or crooked, the Arduino Mega may not fit properly.

Additional connection pads to the Arduino pins have been included on the MegaSat PCB to make it easier to access the signals on those pins if needed.

It is important to install the headers into the proper location on the board. The Arduino Mega will not fit if the headers are installed in these expansion pins. The headers should be installed in the pads with the white boxes around them on the silkscreen.

Locate the follow components from the Arduino Hardware packet. You will install and solder the following components. Check off each component after you have installed and inspected its solder connections. An Arduino itself can be useful for alignment during this assembly.

Arduino Hardware – Parts List

- ☐ 8-Pin Stackable Headers x5
- ☐ 10-Pin Stackable Headers
- ☐ 36-Pin Stackable Headers
- ☐ 2-Pin Receptacle housing x 4
- ☐ 3-Pin Receptacle housing
- ☐ Right angle breakaway header x 2
- ☐ 22-24 AWG Female crimp x 11 [10]

Arduino Hardware – PCB Layout

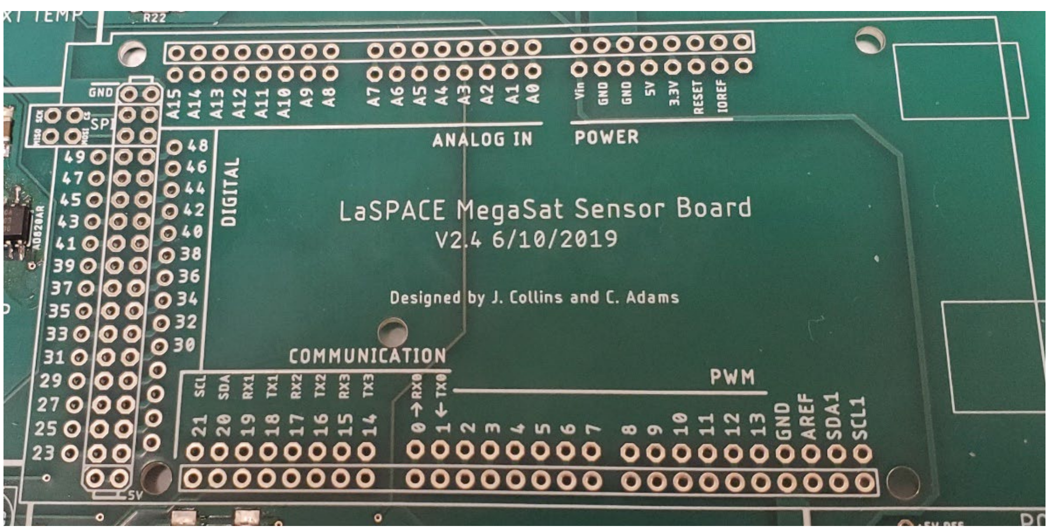


Figure 92: The location where the header pins shall be installed in the MegaSat board. Note shown is an older version of the board but position and installation of the headers remains unchanged.

Arduino Hardware – Assembly

Arduino Hardware Assembly Step 1

We will first locate the location of each of the headers. It can be quite difficult to try and hold all of the headers in place while manipulating the board. Instead we recommend putting an Arduino below the MegaSat. Then as you add headers insert the pins through the MegaSAT board and into the headers of the Arduino. This way the Arduino will align the header pins.

Locate the 36-pin headers. Insert it into the board. Due to the large amount of pins, it may prove difficult to insert the header into the board. Tweezers may be useful to slightly move the pins to get the pins to align with the holes.

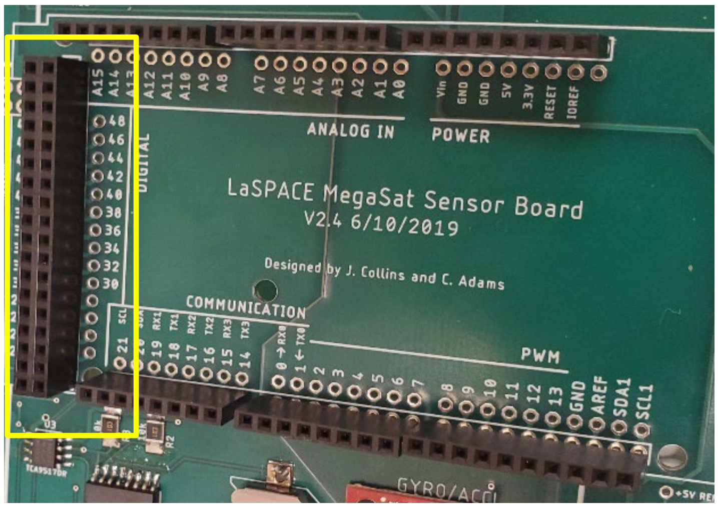


Figure 93: Location of 36-pin header.

Arduino Hardware Assembly Step 2

First Locate the five 8-pin headers. Insert them into board.

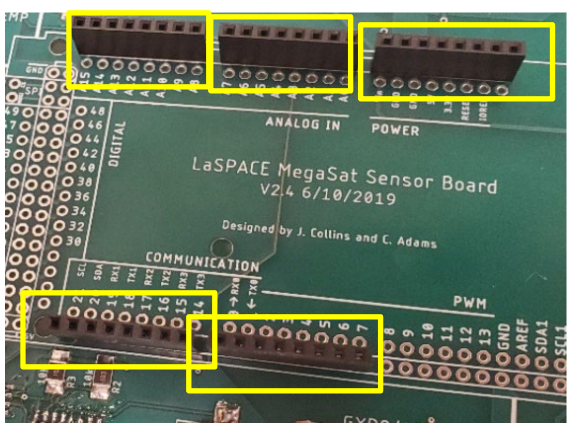


Figure 94: Installing the 8-pin headers in place.

Arduino Hardware Assembly Step 3

Locate the 10-pin headers. Insert it into the board.

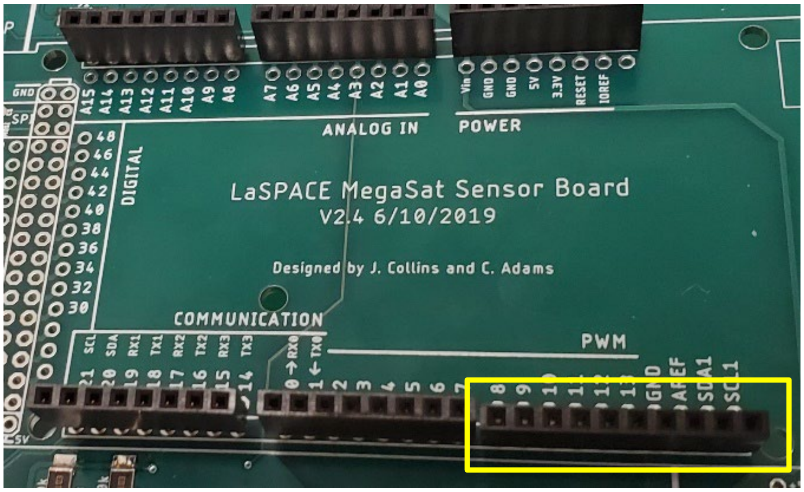


Figure 96: Location of the 10-pin header.

Arduino Hardware Assembly Step 4

Ensure that the headers are all aligned correctly. The headers should be flush with the top of the board with the leads exiting the holes. It is important to ensure the leads are all straight. There should be a gap between the bottom of the MegaSat board and the top of Arduino headers.

Now take the carefully solder a couple of pins on each header by inserting the iron and solder in through the gap. Take care not to melt the plastic of the Arduino headers. Do no worry about getting perfect solder joints on these pins as we are just trying to get the pins held in place.

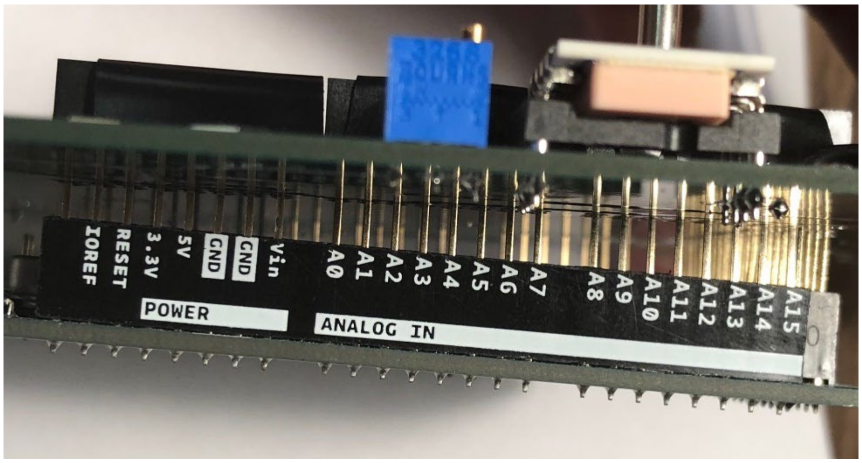


Figure 95: Adding solder the header pins while they are being aligned via the Arduino.

Arduino Hardware Assembly Step 5

Inspect the alignment of the headers and ensure they are flush with the board. If they are not, heat or remove the solder and adjust the alignment. When all the headers are flush and aligned, separate the MegaSat shield and Arduino, take care not to bend the pins.

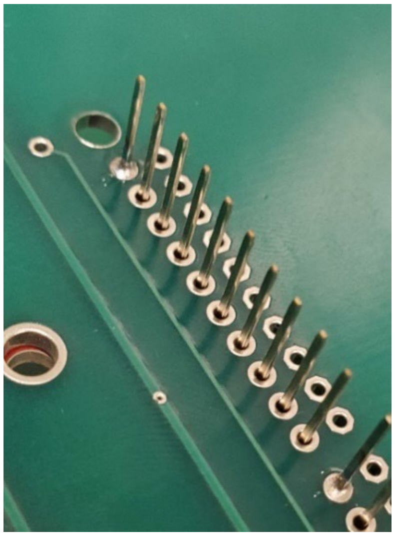


Figure 98: After removing Arduino should header with some solder holding header in place and majority of pins unsoldered.

Arduino Hardware Assembly Step 5

Solder the remaining pins on all headers to the board. Double check all pins to ensure none are skipped. After you have soldered the other pins on the header be sure to double check the original pins and add solder or remelt as necessary to get a good joint.

Also be sure to verify no bridges exist between adjacent pins.

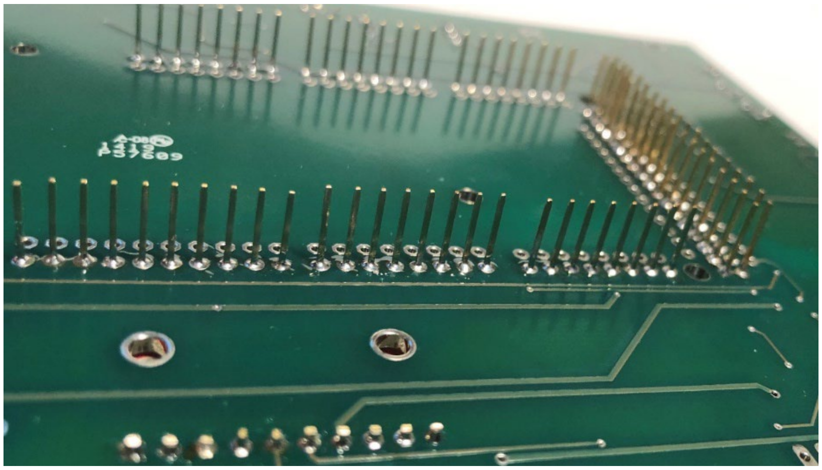


Figure 97: Completely Soldered Header Pins from bottom of the board.

Arduino Hardware Assembly Step 6

Save the Receptacle housings, crimps, and right-angle headers for later.

Assembled Arduino Hardware

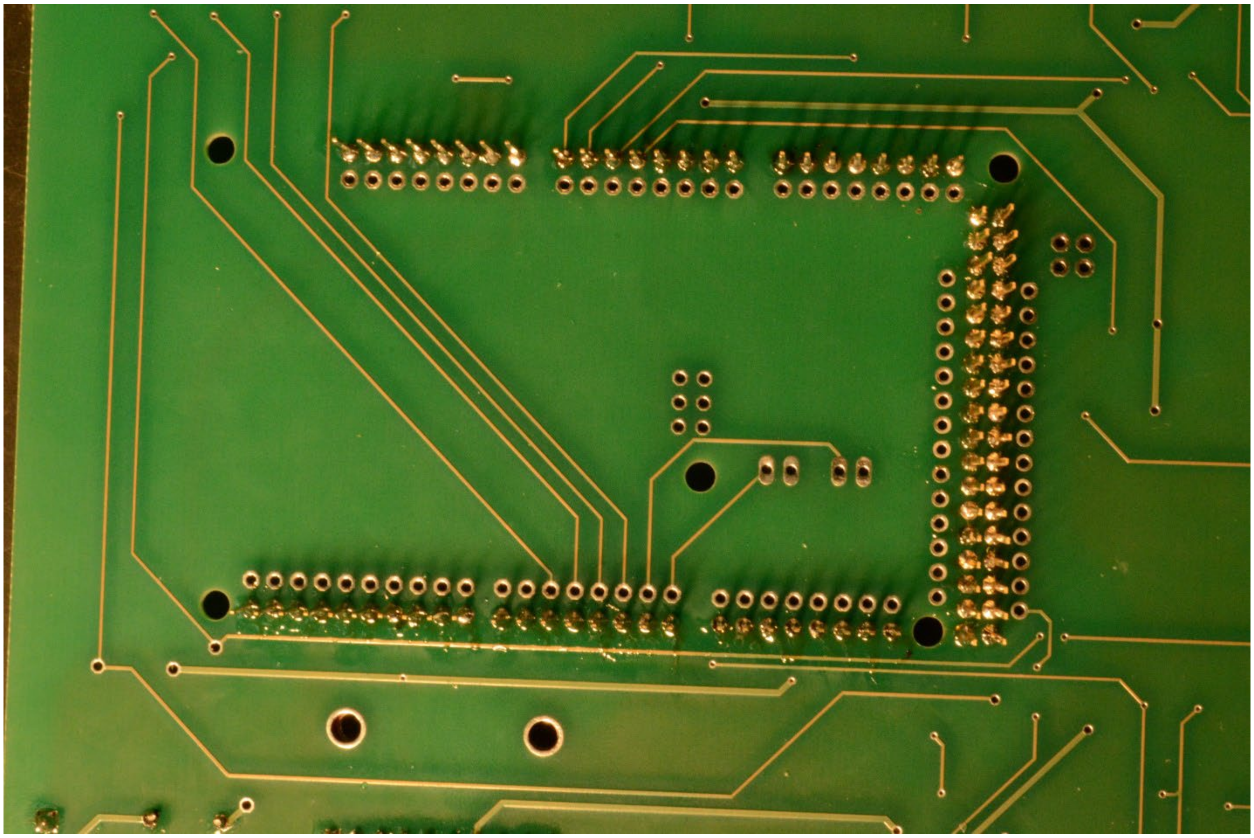


Figure 99: Completed Soldered Arduino Header Pins

MegaSat Assembly – Sensors

It is now time to attach the sensors to the MegaSat. The orientation of each sensor is important. If the sensors are installed backwards, it may cause damage to the sensors and not function correctly.

The pressure sensor is mounted on the socket installed in the Pressure Module.

The humidity and temperature sensors will require soldering wires to the leads of the sensors similarly to what was done during the SkeeterSat and the benchtop sensor. Then you will have 2 options for connecting these sensors to the board.

The crimps, receptacles, and right-angle headers we set aside earlier can be used connect the sensors to the board. This has the advantage of making our sensors easily removable from our payload board. However, correctly crimping the crimps to the wire is very difficult to do unless you have access to the relatively expensive proper crimping tool [11].

If you cannot properly install your crimps instead you may instead solder your sensor lead wires directly in to the MegaSat board.

Locate and open the Sensors packet. You will install the following components. Check off each component after you have installed and inspected its connections.

Sensors – Parts List

- ☐ SSCDANN015PAAB5 Pressure Sensor [12]
- ☐ 2 x 1N457 Diode [13]
- ☐ HIH-4000-003 Humidity Sensor [14]

Sensors – Assembly

Sensors Assembly Step 1

Find the Pressure Sensor. Align it with the socket installed in the pressure module. On the silk screen there is a small circle indicating pin 1. On the black plastic portion of the pressure sensor there is a small bump indicating the pin 1. Aligning the sensor by matching pin 1, slowly insert the sensor into the socket until the sensor is secured.

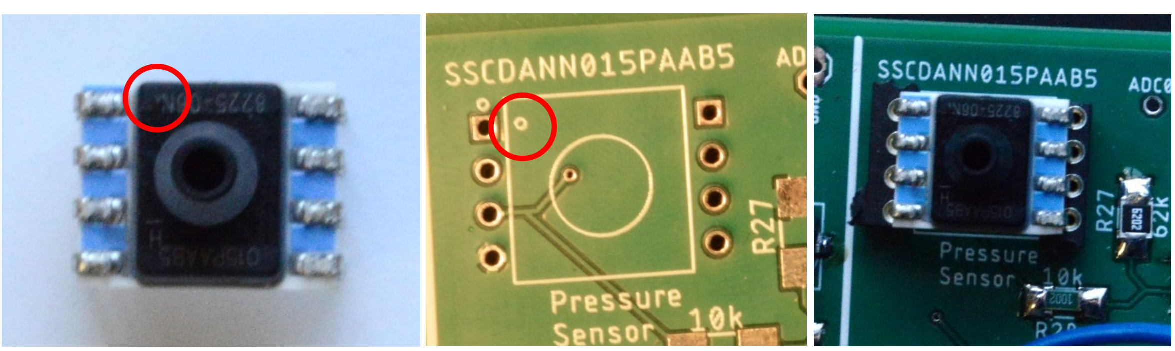


Figure 100: Alignment markings on the pressure sensor (left), silkscreen (center), and the correct orientation of the installed sensor in the socket.

Sensors Assembly Step 2

Locate the 1N457 diodes.

Solder hookup wire to the leads of the diode. It is recommended to use different color wires such as red wire for the anode and black wire for the cathode to provide a visual cue to the polarity of the diode. Remember that the stripe indicates the cathode.

Remember to give your lead wires sufficient length to allow you to place your sensor where you want for you final payload. If you plan on using the sensor internal to your payload a shorter lead will work but for sensors outside the payload you will need longer wires.

Sensors Assembly Step 3

Once you have soldered wire to both leads it recommended you bend the lead of the diode in a 180 bend like in the figure below. While not required this makes your pre-bending makes it less likely you will break the leads, while making the temperature sensor relatively compact.

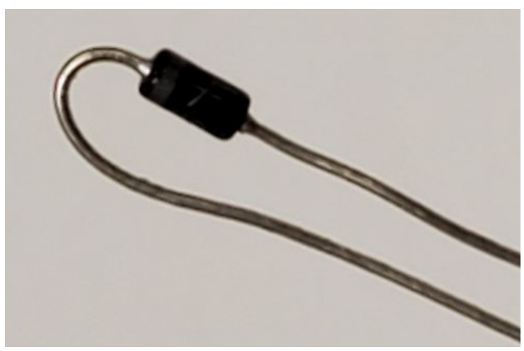


Figure 101: Pre-bent diode for temperature sensor.

Sensors Assembly Step 4

At this point it would be a good time to apply a waterproofing method such as heat shrink or liquid electrical tape to your sensor. You want your sensor waterproof to allow for calibration in a water bath and to protect against condensation.

Sensors Assembly Step 5 (Crimp Method Only)

Strip a small section of wire from the end of the sensor lead. This should not be an excessive length. If you look at the crimp, there are 2 sets jaws that get bent over the wire. The rear set of jaws is meant to clamp on to the bare wire providing the electrical connection.

So you want to strip enough wire to allow for a good electrical connection but not so much that you cannot get the get the uninsulated portion over under the rear jaws.

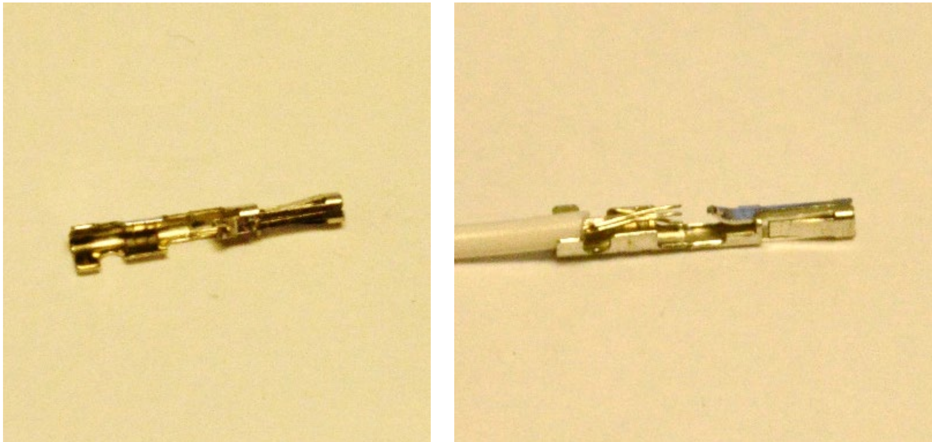


Figure 103: The crimps used for connecting sensors. Right shows the approximate length of wire you should strip for crimping.

Sensors Assembly Step 6 (Crimp Method Only)

Crimp the crimp to end of the wire using the crimping tool. The crimp and wire should be relatively straight and both set of crimp jaws should be clamped on to the appropriate part of the wire.

Figure 102: Wire lead after crimping.

Sensors Assembly Step 7 (Crimp Method Only)

Repeat the crimping steps for the other lead of the wire.

Sensors Assembly Step 8 (Crimp Method Only)

Now insert the crimped wire into one of the two pin receptacles. Note on the back of the crimp there is a tab designed to stick up into a matching hole in the receptacle. This holds the crimp in the receptacle when inserted.

Align the crimp with the receptacle and insert until a click is heard. Then repeat with the other wire.

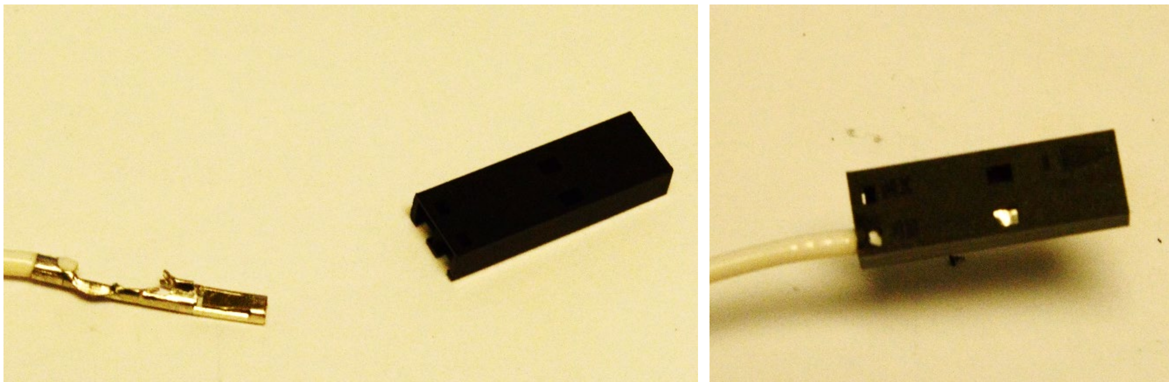


Figure 104: Inserting the crimp into the receptacle.

Sensors Assembly Step 9

Repeat steps 2-8 for the second diode, adjusting wire lead length as desired..

Sensors Assembly Step 10

Locate the humidity sensor and its calibration sheet. Record the calibration information as this provides a conversion from humidity to voltage. The calibration sheet is unique for each humidity sensor and cannot be replaced if lost.

Sensors Assembly Step 11

The humidity sensor has three pins: input power, output signal, and ground. Solder hookup wire to the three pins on the humidity sensor. It is recommended that you use color-coded wires to provide a visual cue to the polarity of the sensor wires.

Sensors Assembly Step 12

Apply either heat shrink or liquid electrical tape to the bare leads of the humidity sensor.
Note: The humidity sensor must be open to the air to function so be careful not to cover the sensor itself with heat shrink or other waterproofing.

Sensors Assembly Step 13 (Crimp Method Only)

Crimp the three leads of the humidity sensor and install the crimped leads in to the 3-pin receptacle. Make sure that the signal pin is the middle pin of the receptacle

Tips for Success

The right-angle headers have straight leads and bent leads. If solder the straight leads to the board the plastic piece will provide the clearance to keep the connector pins above the board. The header should be installed such that the leads overhang the installed resistor and chip.

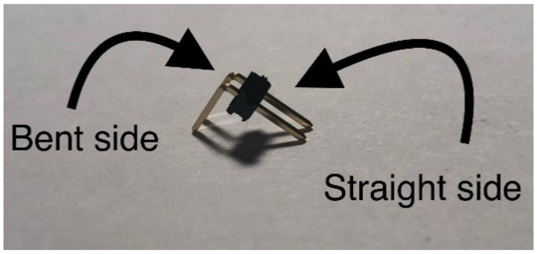


Figure 106: Straight and bent side of right angle headers.

Sensors Assembly Step 15 (Crimp Method Only)

Locate one of the two-pin headers set aside earlier. Then locate the jumper J3 on the internal temperature module.

Sensors Assembly Step 15 (Crimp Method Only)

Solder the header to the board on the bottom side just as you have with all through hole components before. Solder one pin, check the alignment, adjust if necessary, and then solder the other pin.

Sensors Assembly Step 15 (Crimp Method Only)

Attempt to install one of your temperature sensors on the 2-pin header. There should be adequate clearance over the resistor and IC to connect your sensor.

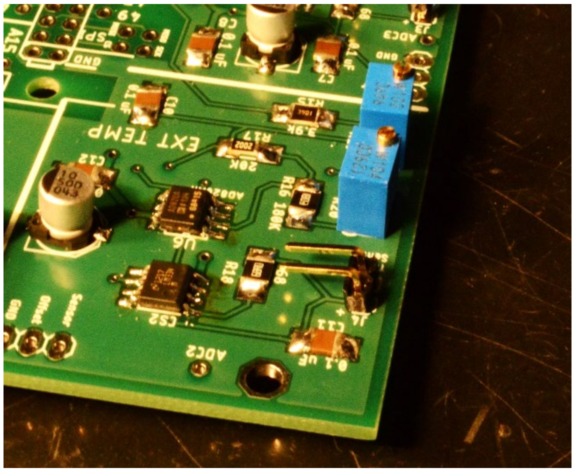


Figure 105: Installed 2-pin right angle header.

Sensors Assembly Step 15 (Crimp Method Only)

Attempt to install one of your temperature sensors on the 2-pin header. There should be adequate clearance over the resistor and IC to connect your sensor.

Sensors Assembly Step 16 (Crimp Method Only)

Repeat for a second 2-pin connector and pad J4.

Sensors Assembly Step 17 (Crimp Method Only)

Repeat for the 3-pin connector and pad J2.

Sensors Assembly Step 18 (Crimp Method Only)

Insert the assembled temperature and humidity sensors onto the connectors installed at J4. Ensure that the orientation of each connector is correct.

Sensors Assembly Step 19 (Non-Crimp Method Only)

If you do not have access to the proper tools to crimp leads, strip a small amount of wire from the end of the leads for your two temperature sensors and the humidity sensor.

Sensors Assembly Step 20 (Non-Crimp Method Only)

Solder the internal temperature sensor directly to the jumper J3, the external sensor to J4, and the humidity sensor to J2.

Be sure that the orientation is for all sensor wires is correct (positive, negative, and signal).

Do not forget to trim the excess lead from the bottom of the board after you have soldered the sensors to the board.

MegaSat Assembly – GPS Logger Shield

Installation of the Adafruit Ultimate GPS Logger Shield is the final step in the assembly process. It is designed to connect directly to the Arduino with very little assembly involved. The headers that were installed previously function as the interface between the shield, the MegaSat PCB, and the Arduino.

Here we discuss installing a wired jumper using crimps to connect the GPS to the MegaSat. This replaces the existing jumper wires with a removable jumper.

GPS Logger Shield – Parts List

- ☐ Right-Angle Breakaway Headers (2-Pin) x2
- ☐ 2-pin Receptacle x 2
- ☐ 22-24 AWG Female crimp

GPS Logger Shield – Assembly

GPS Logger Shield Assembly Step 1

Locate the 2-pin header provided in the Hardware packet. Insert and solder the header into the GPS shield at the TX and RX pins shown in the figure below. You may need to desolder existing jumper wires.

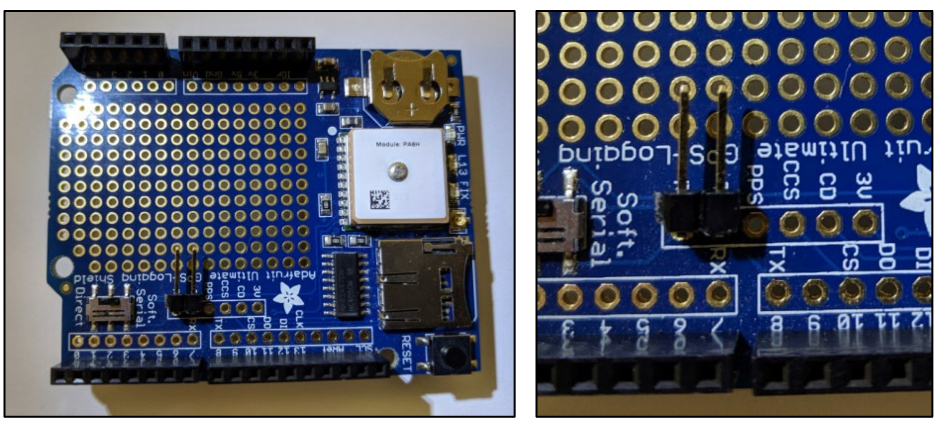


Figure 107: Installing 2 pin jumper to GPS shield.

GPS Logger Shield Assembly Step 2

Do the same with the TX1 and RX1 pins on the MegaSat board (pins 18 and 19).

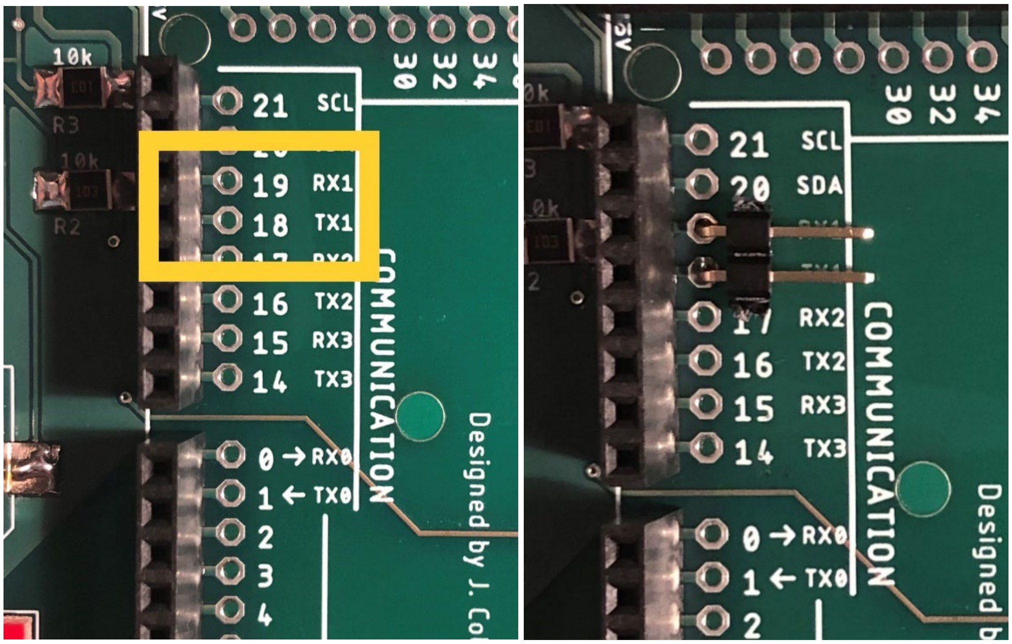


Figure 108: Installing 2-pin jumper for GPS on MegaSat Shield.

GPS Logger Shield Assembly Step 3

Measure and cut two lengths of hookup wire that can reach between the installed header and the header installed on the MegaSat board.

GPS Logger Shield Assembly Step 4

Install crimps on both ends of the new wire jumper and then insert each end into a 2-pin receptacle. You now have a removable jumper you can use to connect the GPS to the Arduino via the MegaSat board.

Remember that the GPS switch must be in Soft. Serial and you need to connect RX to TX for this to operate correctly.

Assembled GPS Logger Shield

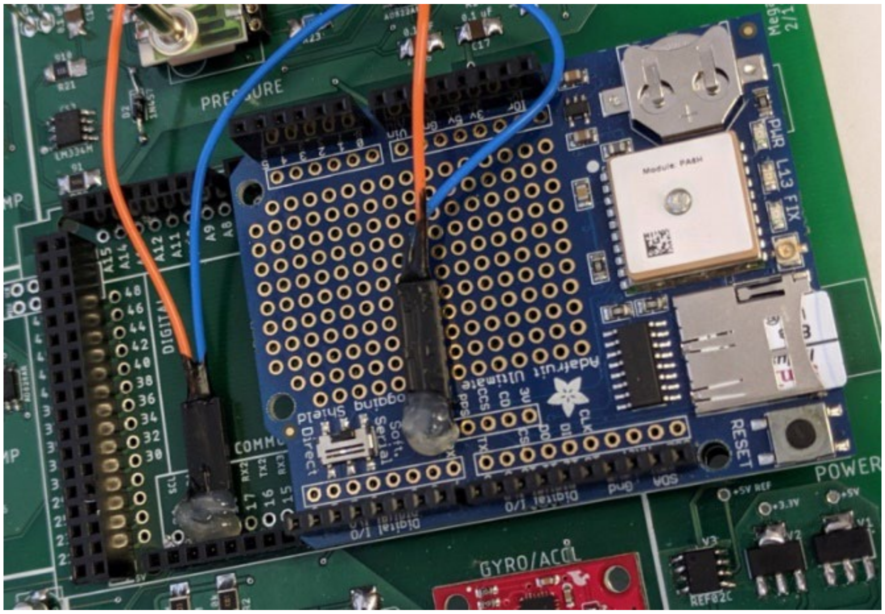


Figure 109: GPS shield with removable jumper.

Appendix A – Setting the Gain and Offset of Sensor Circuits

If we look closes at the amplifying circuits use in the sensors of the MegaSat we can see three of the amplifying circuits are of the same type. The temperature circuits, the first stage of the humidity amplifier, and the high gain pressure circuit are all similar.

In fact if we combing the resistors to simplify the circuit we find that all three can be reduced to circuit shown below.

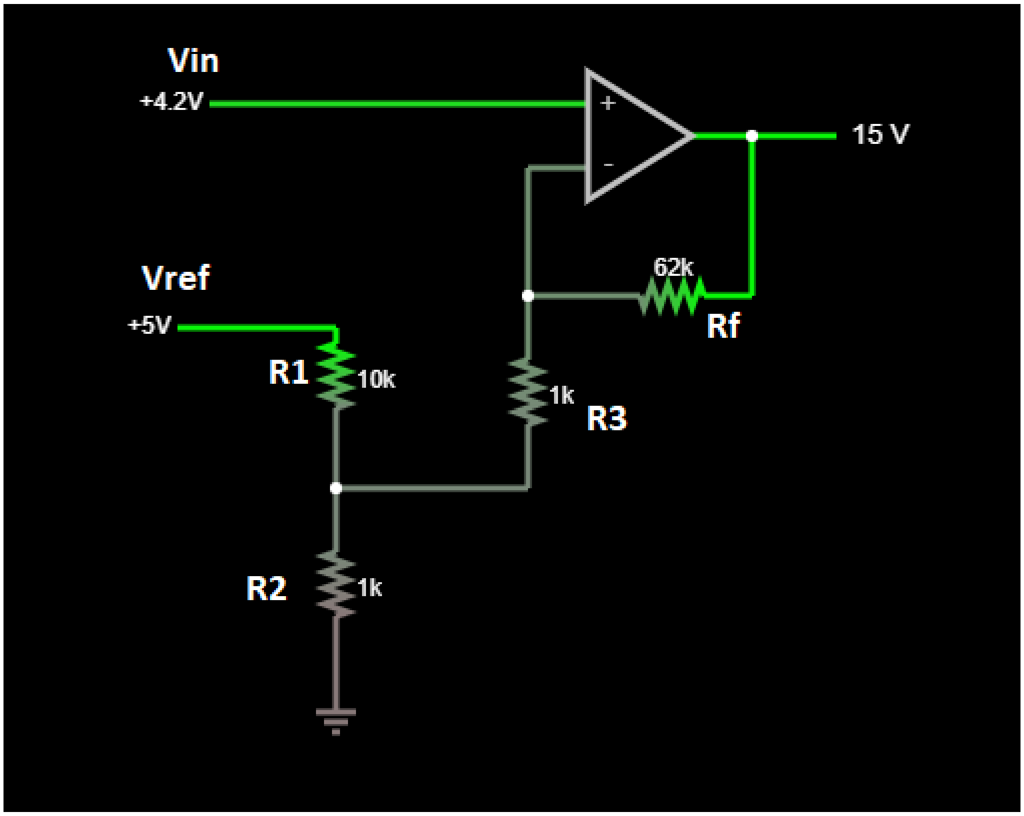


Figure 110: Simplified circuit for Pressure, Temperature and first stage Humidity amplifiers. Not the resistor numbers here are just generic designators and do not correspond to designators on the MegaSat Board. For example, R1 above has nothing to do with R1 on the MegaSat (part of the power circuit). Likewise the values for resistance and voltage should be ignored.

If we match the above circuit to pressure, temperature, and humidity circuits we can find which resistors in each circuit corresponds to the resistors in the generic circuit.

Doing so we find: (Resistors to the left of equal sign correspond to fig. 110 and right to specific amplifying circuit on the MegaSat)

Internal Temperature
Rf=R11+R14
R3 =R10
R1 =R9 + upper part of R13
R2 =lower part of R13

External Temperature
Rf=R16+R20
R3=R17
R1=R15+upper part of R19
R2=lower part of R19

1st Stage Humidity
Rf=R5
R3=R4
R1=upper part of R7
R2=lower part of R7

High gain pressure
Rf=R30
R3=R26
R1=R31+R25
R2=R29

We use circuit analysis to solve for the transfer equation of the generic circuit.

$$V_o = \left[1 + \frac{\frac{R_f}{R_1} + \frac{R_f}{R_2}}{1 + \frac{R_3}{R_2} + \frac{R_3}{R_1}}\right] V_{in} - \left[\frac{R_f}{R_1} * \frac{1}{1 + \frac{R_3}{R_2} + \frac{R_3}{R_1}}\right] V_{ref}$$

We can then use the values of the resistors in each circuit to calculate a gain or offset for the possible range of values for gain and offset for each of the circuits.

We can then use expected signal values from obtained from the datasheets of circuits to determine an initial setting for our potentiometers.

Note: We should expect our actual signal values to vary somewhat from the values determined from the datasheet. The goal at this point is to set the values so we are in the right neighborhood. After that we can do adjust the values to give a us the desired range of output values. Once we have finalized those values, we perform the calibration to give us the conversion from ADC to physical measurement.

In general we are trying to from minimum signal voltage to 0V and maximum signal voltage to 5V. We also want to have some extra “padding” to ensure we do not max out our signal.

Internal and External Temperature

The internal and external temperature circuits are identical, but we want to select different input voltages based upon the temperature limits we want each to be able to monitor.

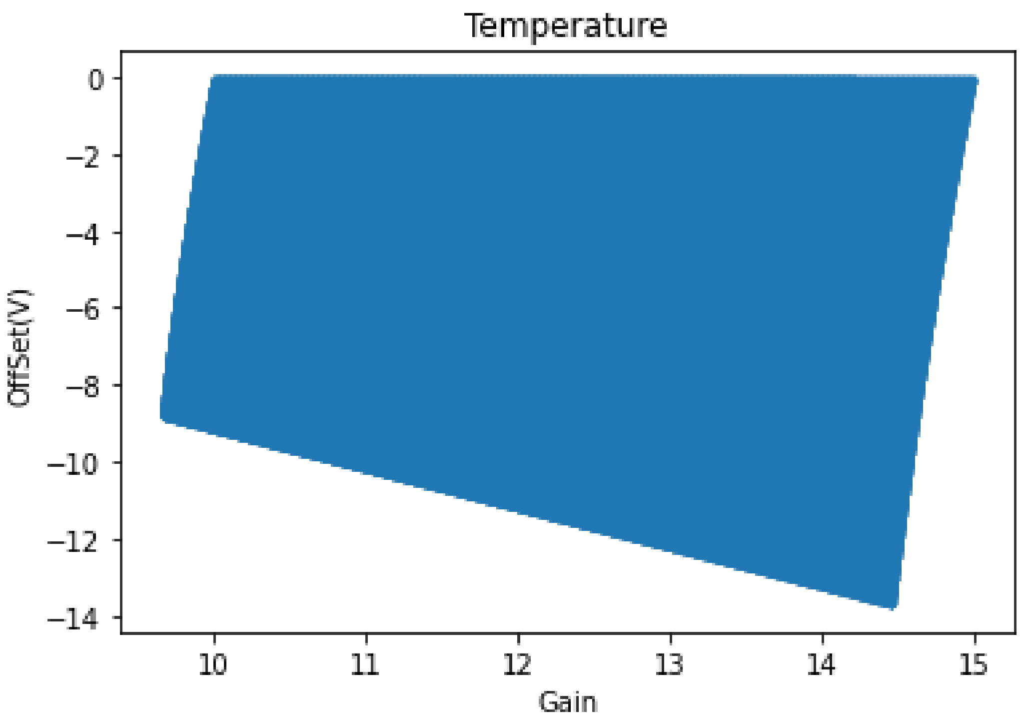


Figure 111: Range of possibe values of gain and offset for internal and external temperature amplifiers.

First from the datasheet [2] we can use the "typical" values for the diode. The values listed are 0.6V at 25C and a temperature coefficient of -0.0025V/C.

Next, we select our minimum and maximum temperatures. For internal start with -10 to 70 C and -70 to 70 C. This corresponds to an input signal of 0.4125 (100C) to 0.7875V (-50C) for the internal temperature. For external temperature the values are 0.4875 (70C) to 0.8375V (-70C). We want to set the gain for so that these values correspond to 0 and 5V output. Also, remember these values are approximate and we will adjust later.
Note for your payload you should select the values based on the requirements you establish in your design reviews.

Sensor	Min Physical Value	Max Physical Value		Minimum input Signal Voltage	Maximum input Signal Voltage	Gain	Offiset
Internal Temp	**-50ºC**	**100ºC**		**0.4875V (@70ºC)**	**0.6875V (@-10ºC)**	**13.3**	**-5.5**
External Temp	**-50ºC**	**50ºC**		**0.4875V (@70ºC)**	**0.8375V (@-70ºC)**	**14.3**	**-6.96**

For the internal temperature this solving for the values we find we want R14 set to 71.5KΩ and R13 set so that the upper half is 562 Ω and the lower half is 437Ω.

For the external temperature this solving for the values we find we want R20 set to 92KΩ and R19 set so that the upper half is 487 Ω and the lower half is 513Ω.

Humidity

The first stage of the humidity circuit is much simpler as it only has the single potentiometer. If we plot the gain and offset as a function of R6 we see it is much simpler and forms a curve rather than a region. Also we can see that R7 mostly affects the offset.

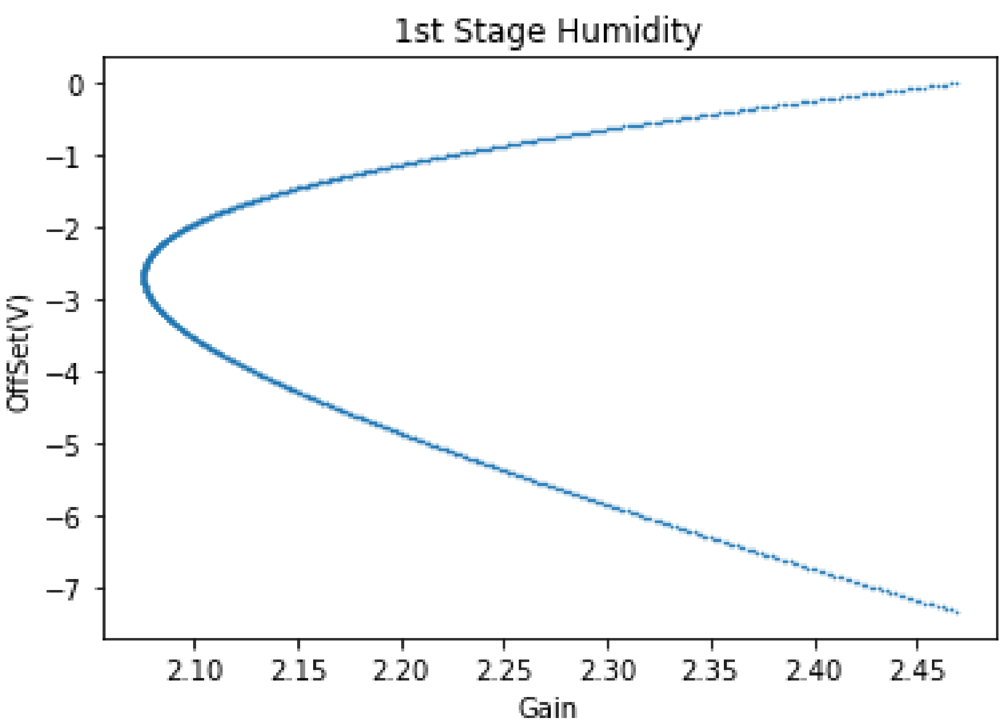


Figure 112: Gain and Offset of first stage of humidity circuit.

If we look at the calibration sheet we should see minimum value at 0% humidty slightly higher than 0.8V so to preven going below that. And then select 3.9V as our upper limit.

If we look at the 2nd stage of the of the humidity circuit we see that it is really just a voltage divider and unity gain op amp, so it is circuit of 0-1 Gain with no offset. So we will set R7 so that 0.8V. The adjust R8 so that 3.9V is close to 5V on the output.

Solving for the 0.8V to 0 after the first stage gives the values of 6977 KΩ for the upper half of R7. This will give a gain 2.12 and offset of -1.70.

Sensor	Min Physical Value	Max Physical Value	Minimum input Signal Voltage	Maximum input Signal Voltage	Gain	Offset
1st Stage Humidity	**0% RH**	**100% RH**	**0.8V**	**3.9V**	**2.12**	**-1.70**

A input signal of 3.9V with this gain and offset will yield an output signal of 6.57V. We need to set R8 so that we get a gain of 0.76. Since R8 is just a simple voltage divider the gain is just the lower half of R8 over 10KΩ. We want to set R8 so the lower half is 7.6 KΩ.

High Gain Pressure

The high gain circuit for the pressure is similar to the humidity circuit. There is a single variable resistor that can be used to adjust the offset voltage and the gain is relatively fixed. Since the minimum expected signal is expected to be 0.25V at 0 psia we will set the offset so that the amplifier outputs 0V at a 0.2V input signal. This gives a bit of buffer so we do not prematurely reach 0 at low pressure.

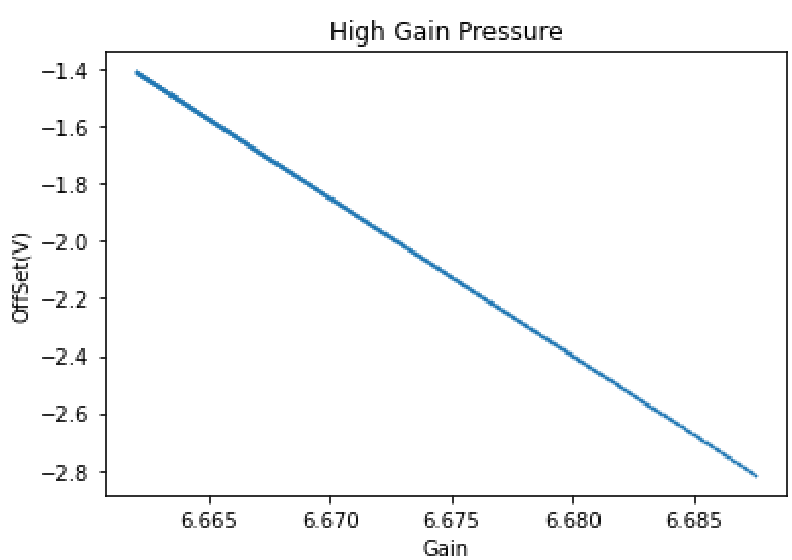
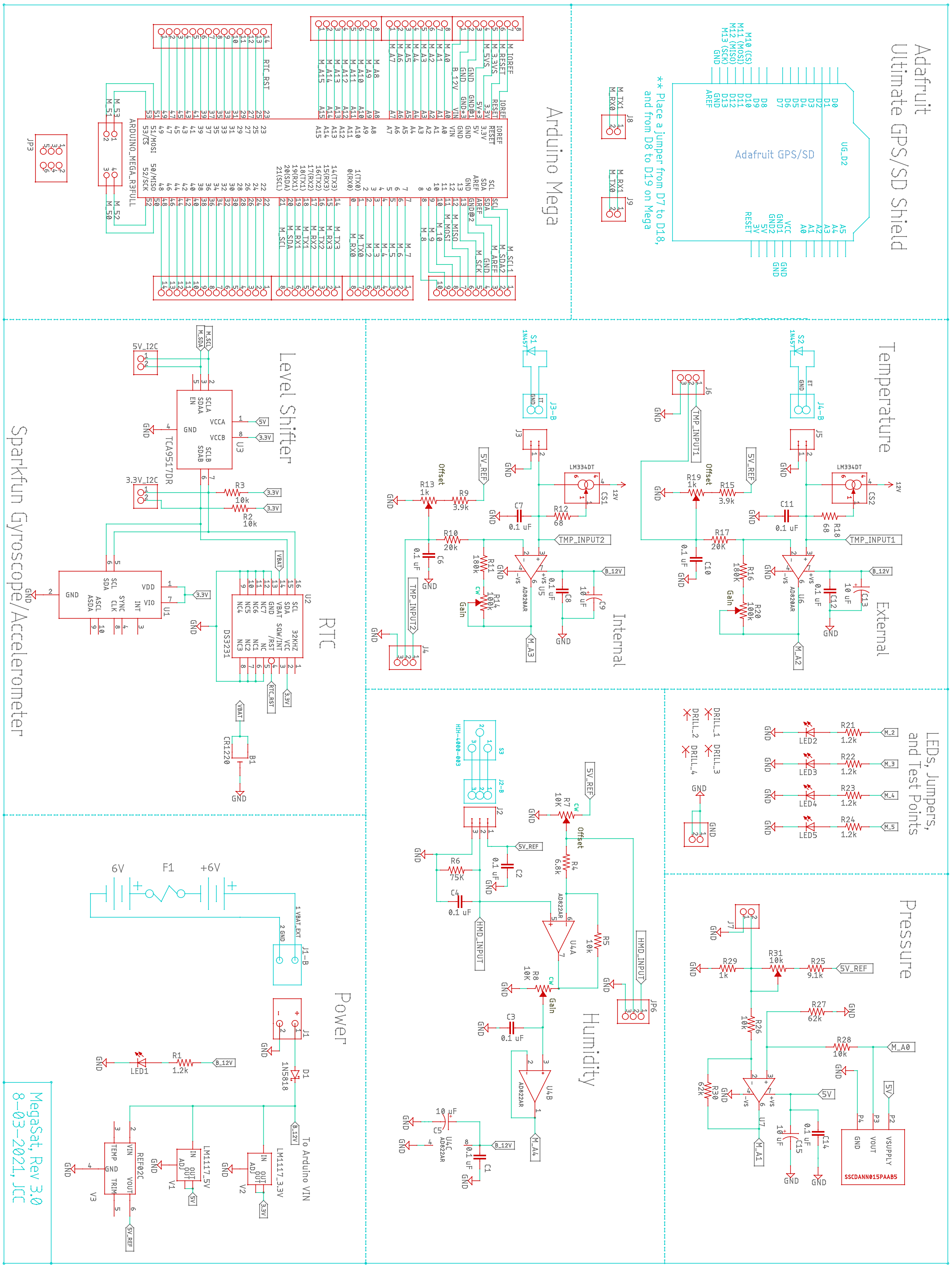


Figure 113 Gain and Offset ranges possible for high gain pressure range.

After we have set that we can determine what our pressure at 5V will be. This is the point at which the low pressure (high gain) circuit will be readable and active. To do so we want to set R31 to its maximum value 10kΩ. This will give a circuit that outputs 5V at ~0.98V input. This corresponds to a pressure of ~2.4 psia. Note R31 can be adjusted to increase the setpoint, which will raise the upper limit on the pressure but could potentially cut off the 0 psia point.

Sensor	**Min Physical Value**	**Max Physical Value**	**Minimum input Signal Voltage**	**Maximum input Signal Voltage**	**Gain**	**Offset**
High Gain Pressure	**0 PSIA**	**~2.4 psia**	**0.25V**	**0.98V**	**6.66**	**-1.53**

Appendix B – MegaSat Full Schematic



Appendix C – MegaSat Pin Usage

The MegaSat Pin Layout		
Microcontroller: Arduino Mega 2560		
Component	**Function**	**Pin #**
Pressure (Non-Amplified)	**ADC**	**A0**
Pressure (High Gain)	**ADC**	**A1**
External Temperature	**ADC**	**A2**
Internal Temperature	**ADC**	**A3**
Humidity	**ADC**	**A4**
RTC (I2C Address:0x68)	**Reset**	**23**
	SDA	**20**
	SCL	**21**
IMU (I2C Address:0x69)	**SDA**	**20**
	SCL	**21**
GPS TX	**RX1**	**19**
GPS RX	**TX1**	**18**
SD(Software SPI)	**CS**	**10**
	MOSI	**11**
	MISO	**12**
	SCK	**13**
LED2		**2**
LED3		**3**
LED4		**4**
LED5		**5**

Appendix D – References

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