MegaSat
Assembly Manual

Description

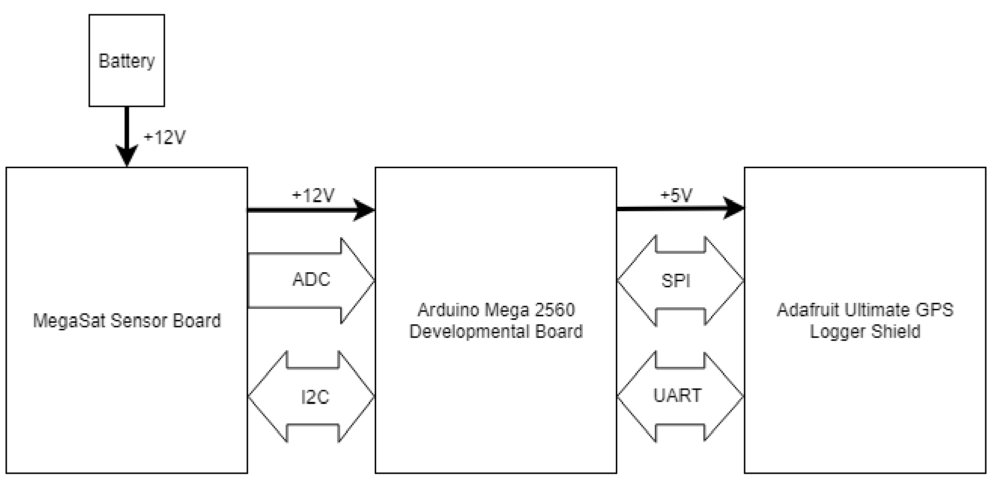
The ***MegaSat*** is a custom sensor interface shield to provide a baseline payload for use in LaACES program. It is designed to be combined with an Arduino Mega2560 and Adafruit GPS Logger shield. It includes an accelerometer/gyroscope breakout board, internal and external temperature sensors, humidity and pressure sensors, and a real-time clock (RTC). Power is provided to the ***MegaSat's*** sensors and circuits by a +9-12V supply. Teams have previously flown both 9V and 12V battery packs without issue, though a lithium 9V pack with greater than .

The ***MegaSat*** uses the ATmega2560 Rev3. The ***MegaSat*** provides a basic set of sensors to monitor atmospheric conditions, payload kinematics, and location during a balloon flight.

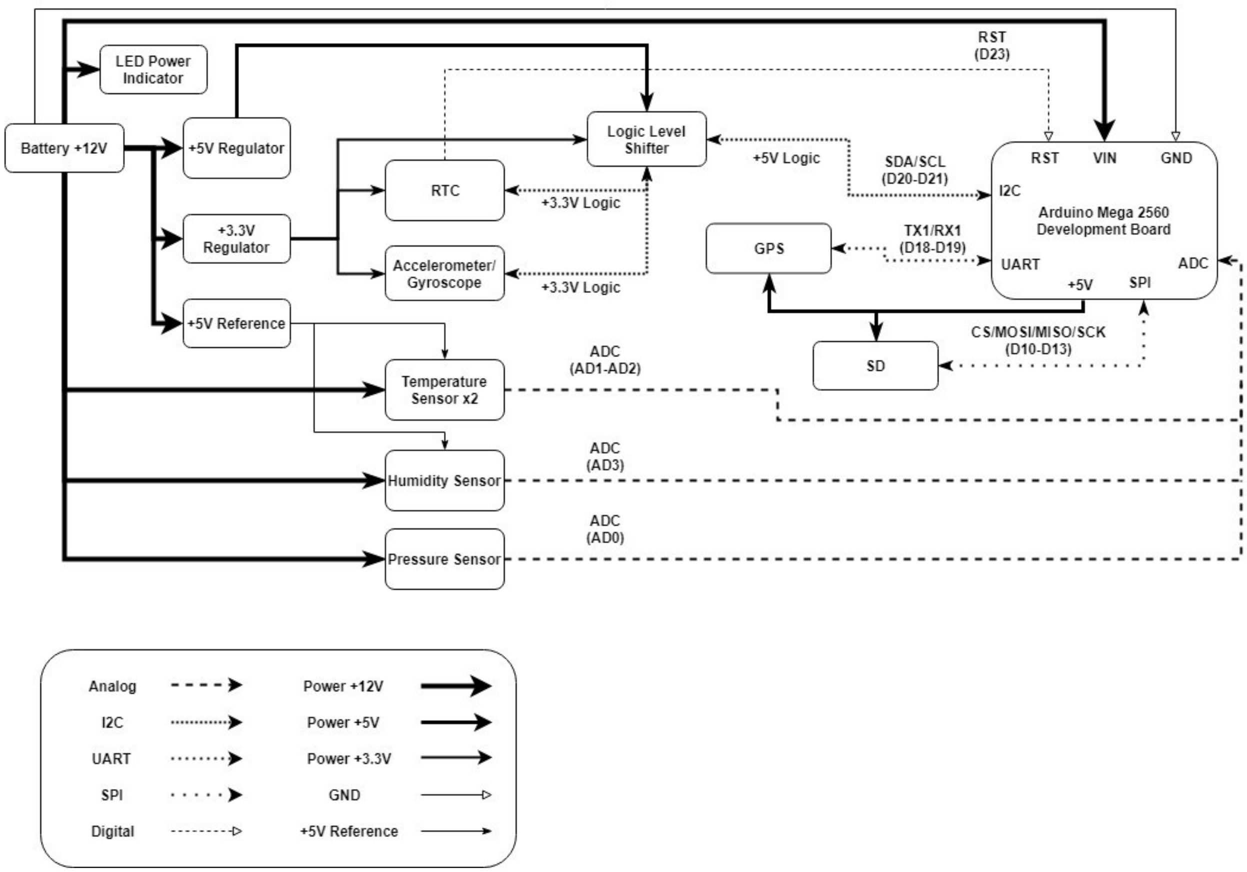
Theory of Operation

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 A2 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 aspecific 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!
- Solder can splash and clipped wires can fly.
- Soldering irons get hot...350 degrees Celsius to melt most solder…that's approximately 650 degrees Fahrenheit!
- Don't touch the solder tip while the unit is powered.
- Wait for the soldering iron to cool down before returning it to storage.
- Always keep your hair pulled back.
- Avoid loose, long-sleeve shirts or clothing that may come in contact with the iron.
- Never leave an iron unattended!
- Electrical components are sensitive to electrostatic discharge (ESD).
- 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 jumper J1. The screw terminal block plug P1 is provided for creating a connection to the voltage source.

The MegaSat was designed to be 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 accidentally 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 in sections.

Open your assembly kit and find and open the Power Module packet. Verify that all components listed in the Power Module list below are included. 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

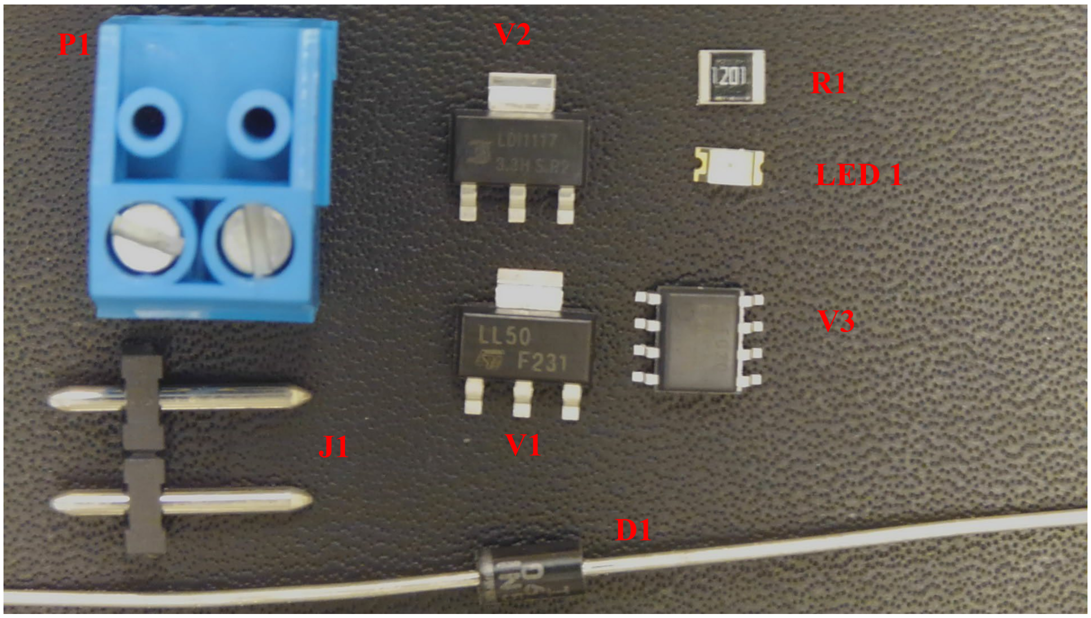


Figure 1: Power Distribution Parts

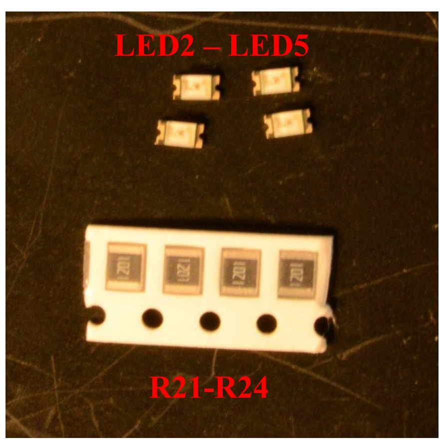


Figure 1: Power Distribution Parts

Power Module Schematics

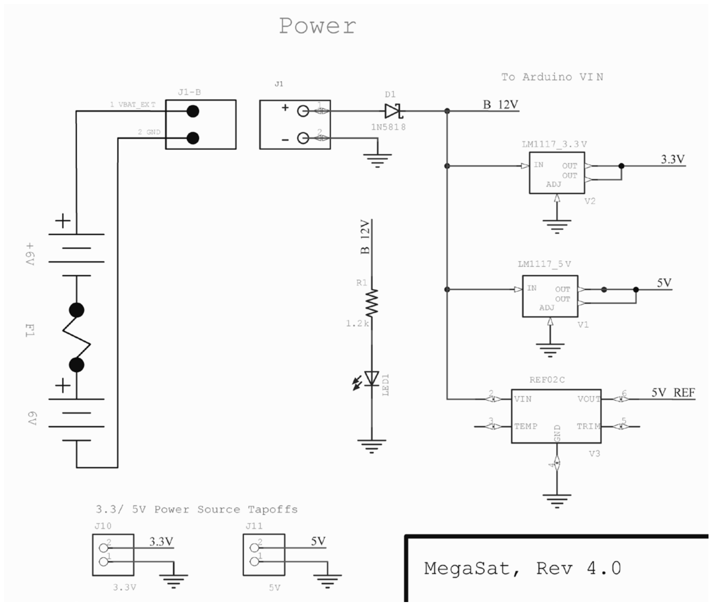


Figure 3: Power distribution circuit diagram

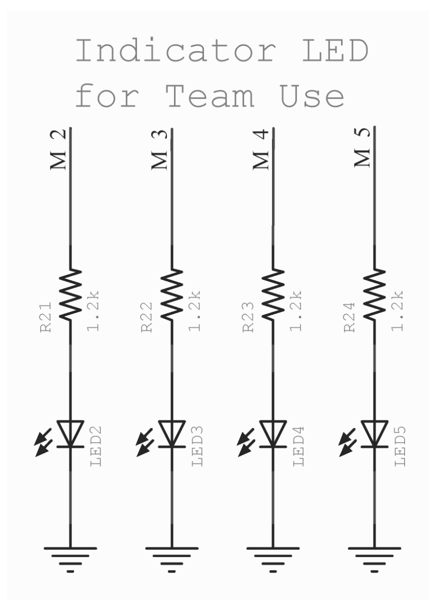


Figure 2: Diagnostic LED schematic

Power Module PCB Layout

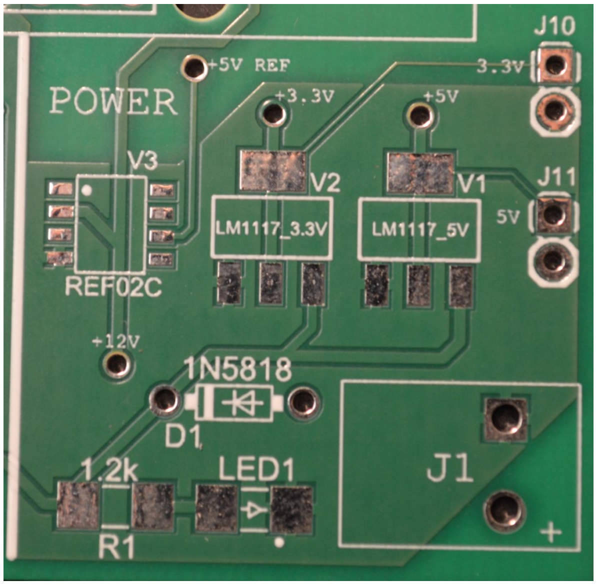


Figure 4: Bare PCB, power distribution section

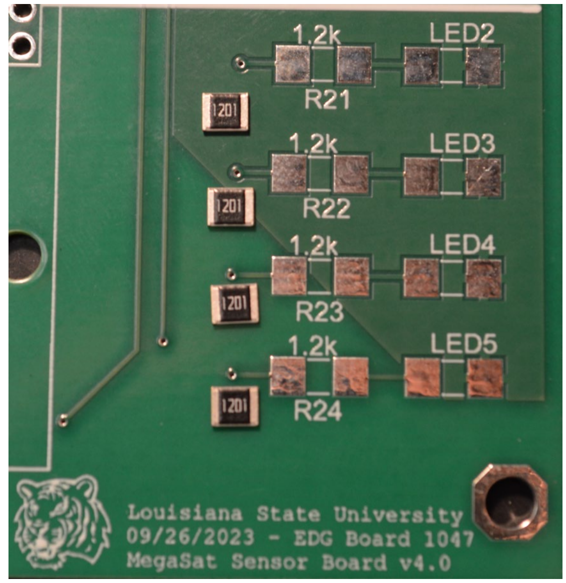


Figure 6: Bare PCB, diagnostic LEDs section

Power Module Assembly

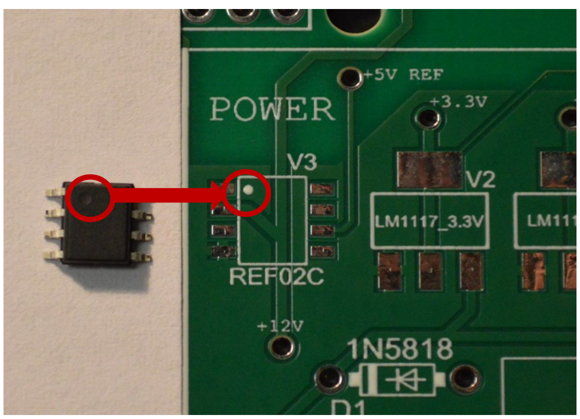


Figure 7: Alignment of V3 (5V reference)

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.

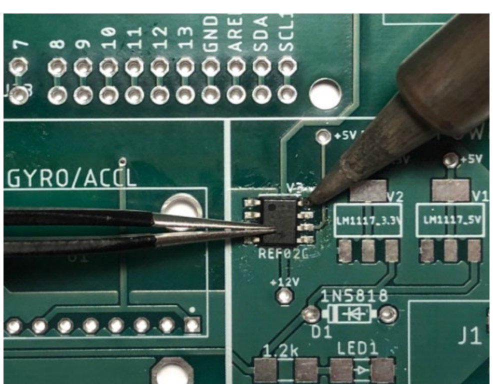


Figure 8: Holding SMT chip in place while soldering with tweezers

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.

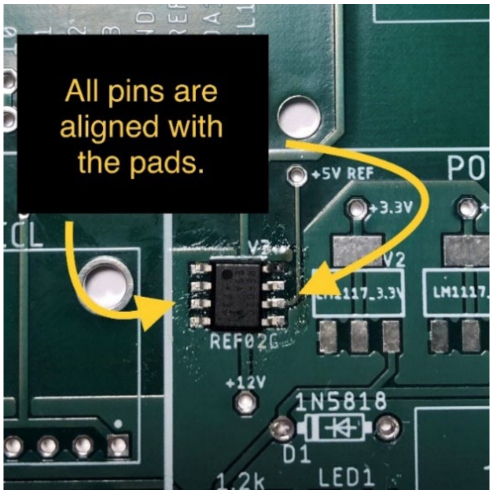


Figure 9: V3 Properly align with pads. Note: only the upper right big has been soldered.

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.

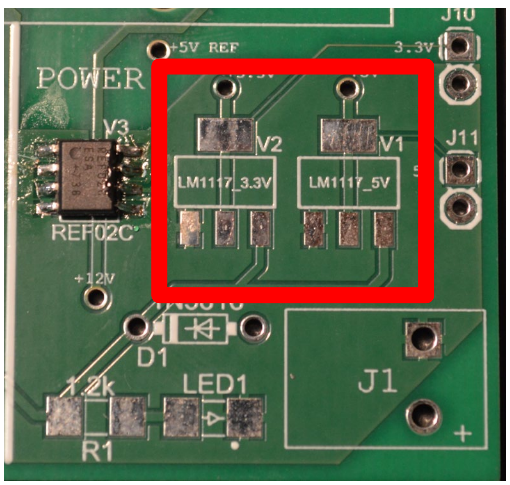


Figure 10: Pad Locations 3.3V and 5V regulators

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 marked with 3.3H for the 3.3V regulator.

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

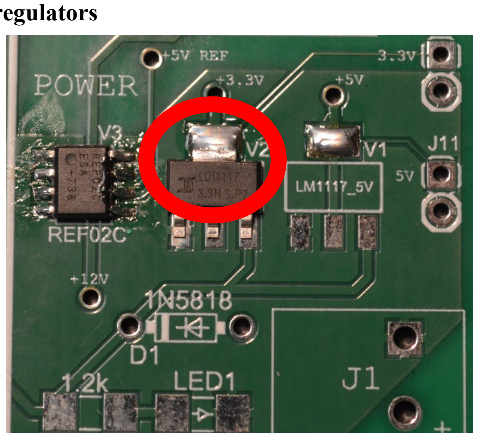


Figure 11: 3.3 V Regulator stored via the top pin

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.

Power Module Assembly Step 7

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

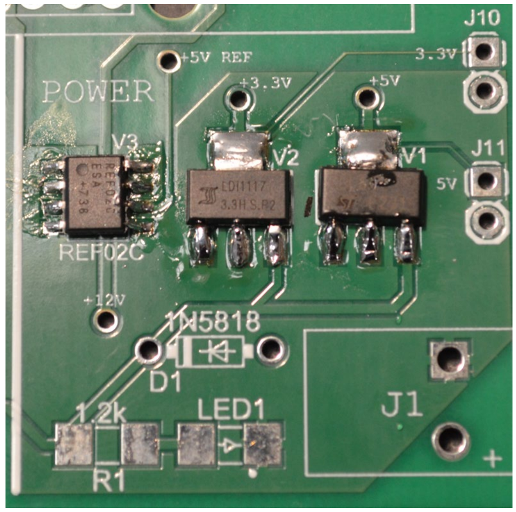


Figure 12: Power module after soldering 5V LM1117 regulator.

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. <u>Be sure to align the diode properly before soldering.</u>

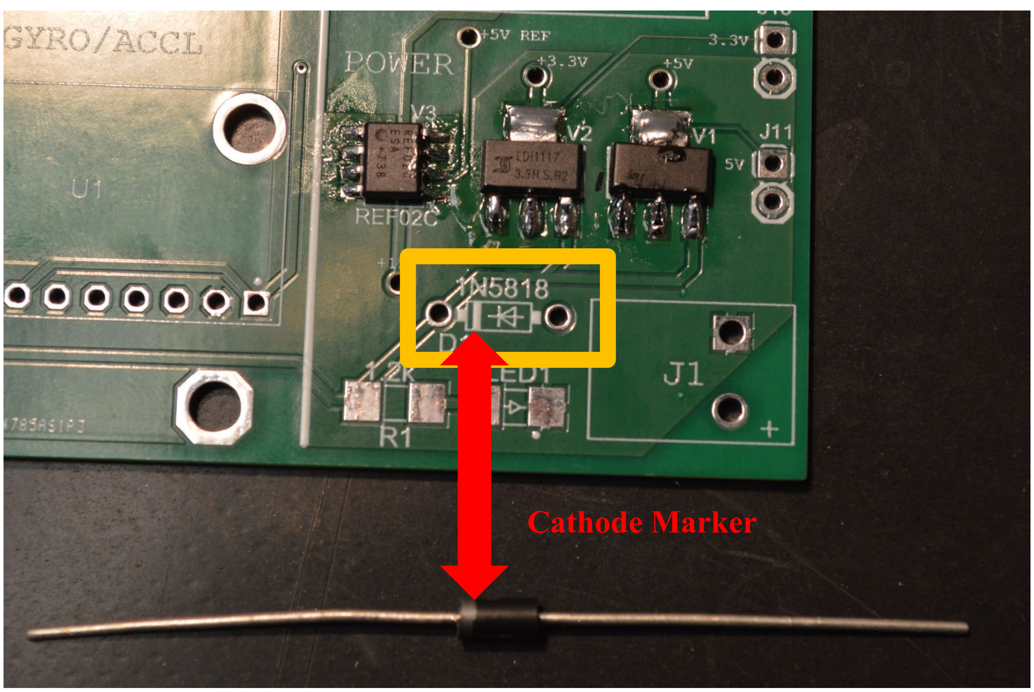


Figure 13: The diode pads for the D1 in the power module (yellow) and markings that identify the cathode (both on the PCB and diode itself)

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.

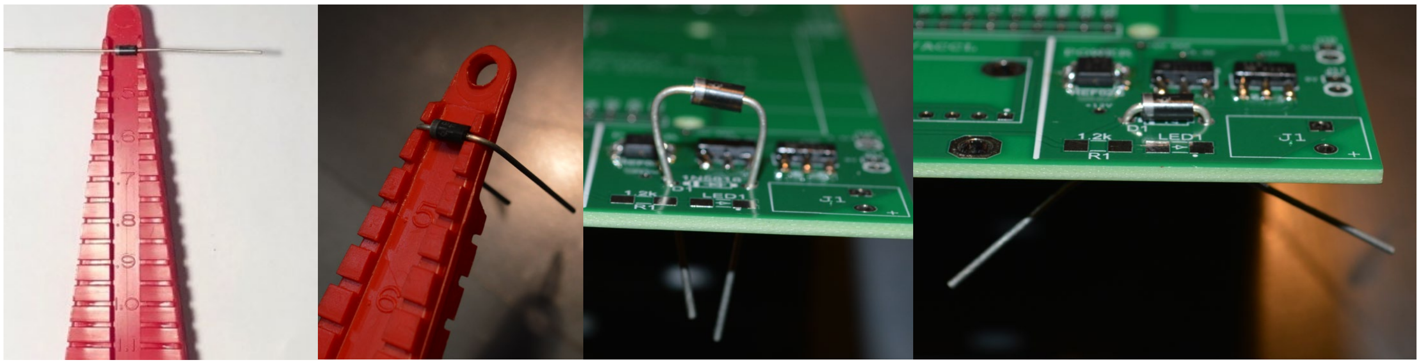


Figure 14: Bending and installing the diode D1 into the PCB

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.

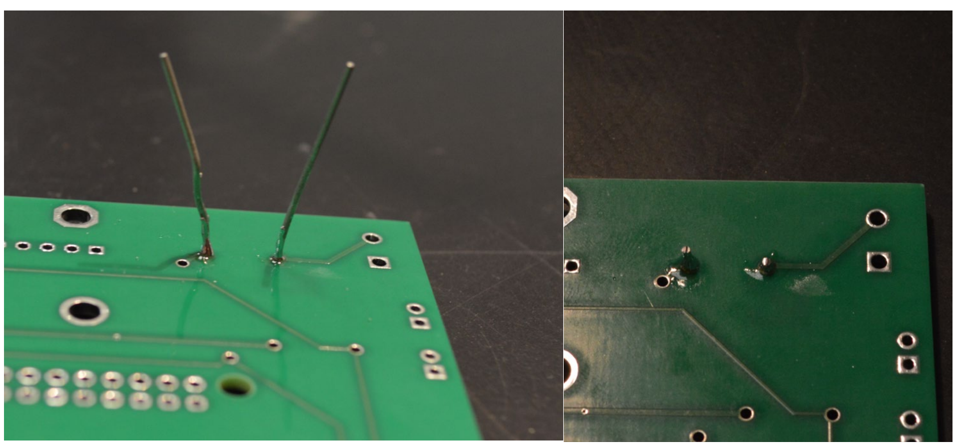


Figure 15 Left: Properly soldered leads of diode D1, Right: Leads trimmed above the solder joints.

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.

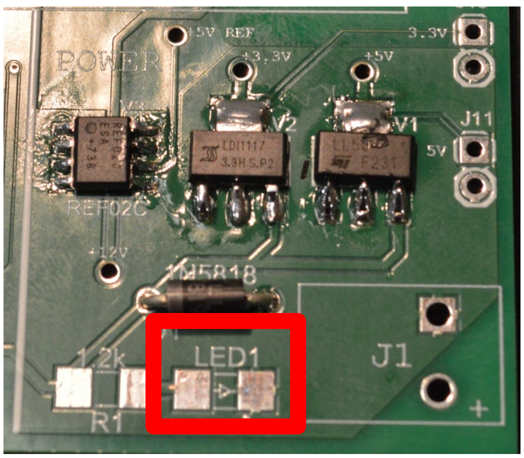


Figure 16 SMD LED Pad, notice the silkscreen indicating the right side as the negative/cathode.

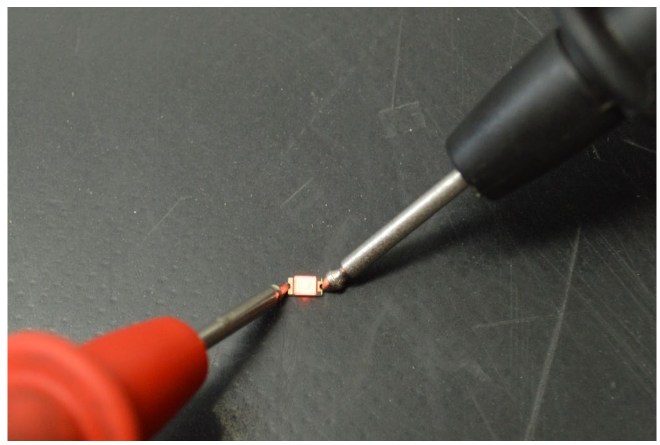


Figure 17 SMD LED being tested. Notice that dim light from the LED and the multimeter positive lead touching the left side and negative lead touching the right side.

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 or remove solder if needed.

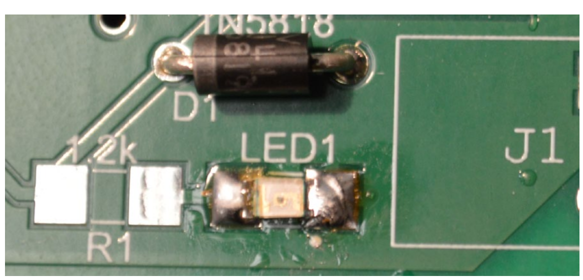


Figure 15: Completely soldered LED

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.

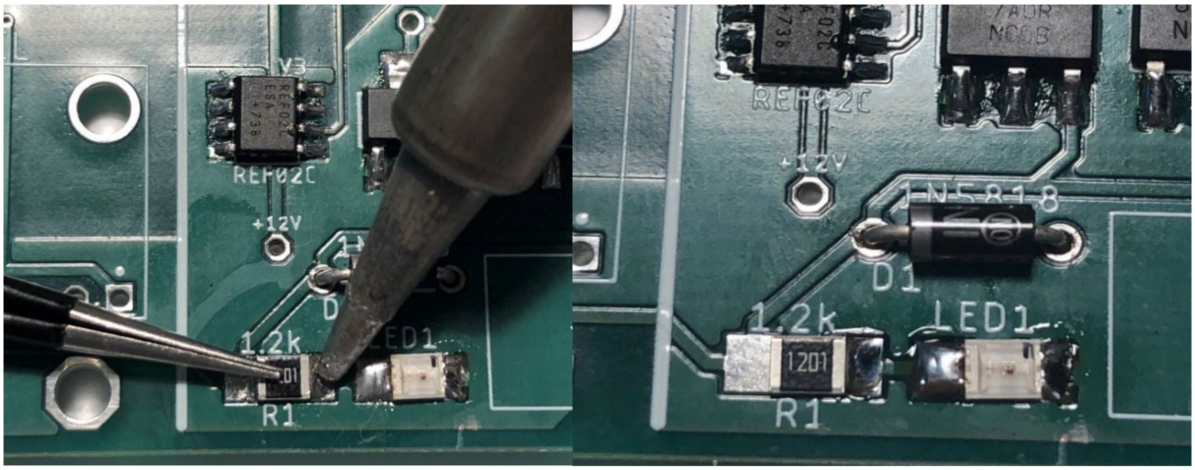


Figure 19: Soldering one pad of resistor R1, notice how the tweezers/forceps are used to hold the component in place while the solder is melted.

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.

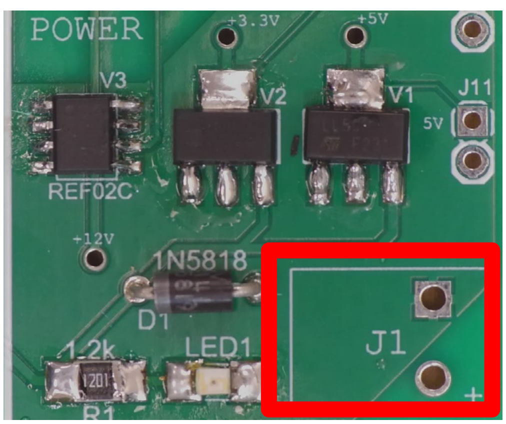


Figure 20: Where jumper J1 will soldered to the PCB

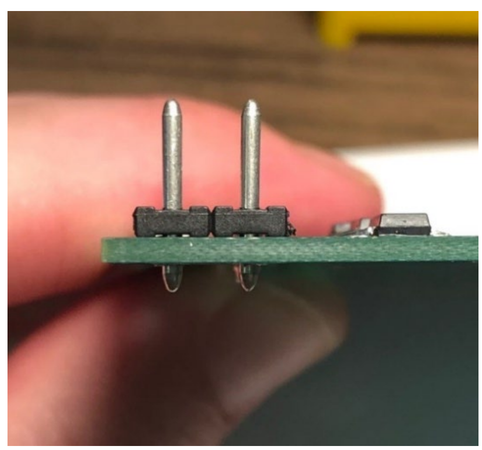


Figure 21: Jumper J1 sitting flush the board.

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 22: Backside of J1 with a single pin soldered.

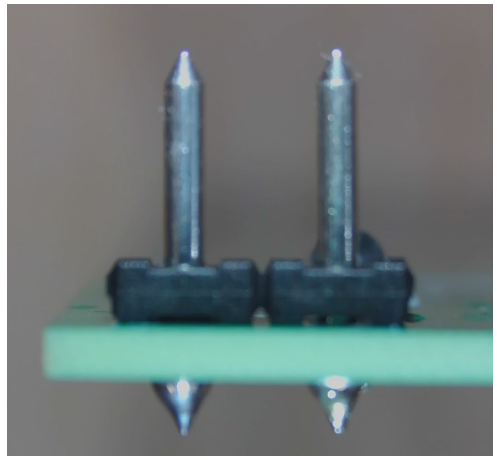


Figure 23: Properly aligned pins after soldering.

Power Module Assembly Step 16

Solder the other lead on the bottom side of the board. After this the power distribution section should be complete as shown in Figure 24: Completed power module.

Power Module - Complete Assembly

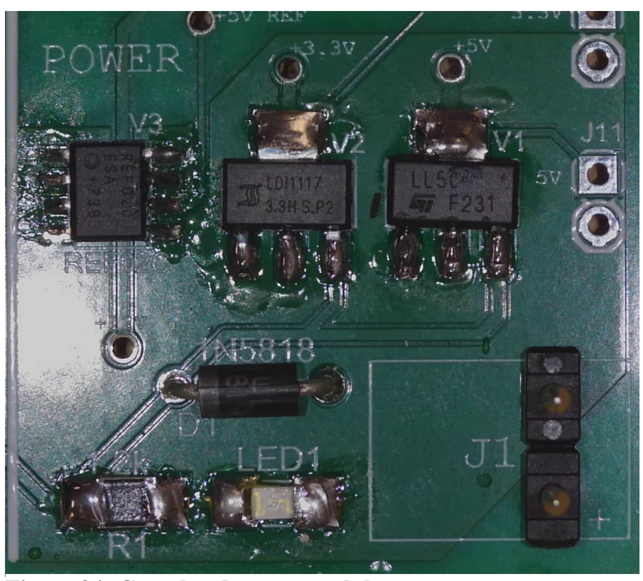


Figure 24: Completed power module.

Power Module Checkpoint – Voltage Checks

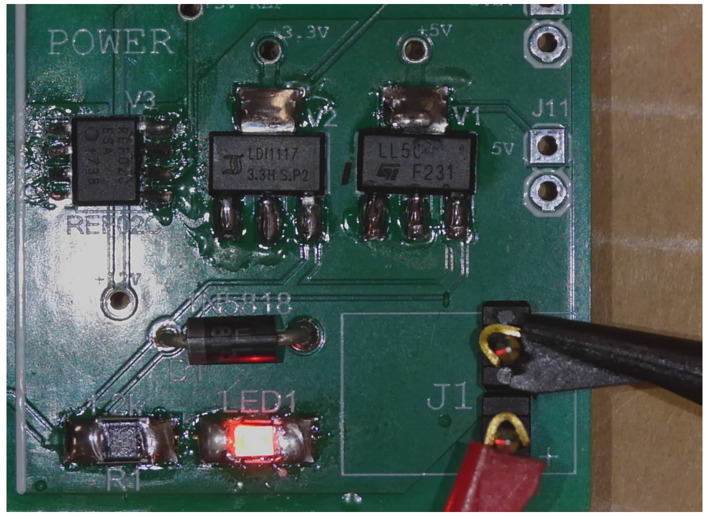


Figure 25: Power module connected to external power supply for voltage checks.

Using an external power supply, apply ~12V to the input power of the MegaSat making sure to connect positive terminal to the positive pin.

The power LED (LED1) should light up, indicating the board is powered. Then measure the voltage between one of the ground points on the board and the 3 voltage test points above the regulators and 1 below. 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 lit.

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 diagnostic LEDs labeled 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 their SD card was successfully detected at the start of their program, allowing them to ensure the card was properly mounted prior to launch.

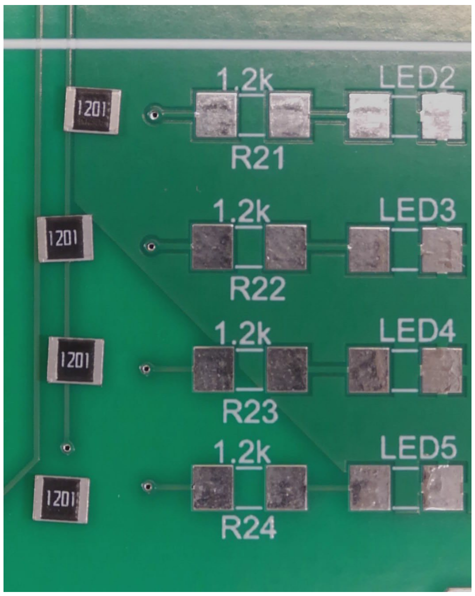


Figure 26: LED Resistors R21, R22, R23, R24.

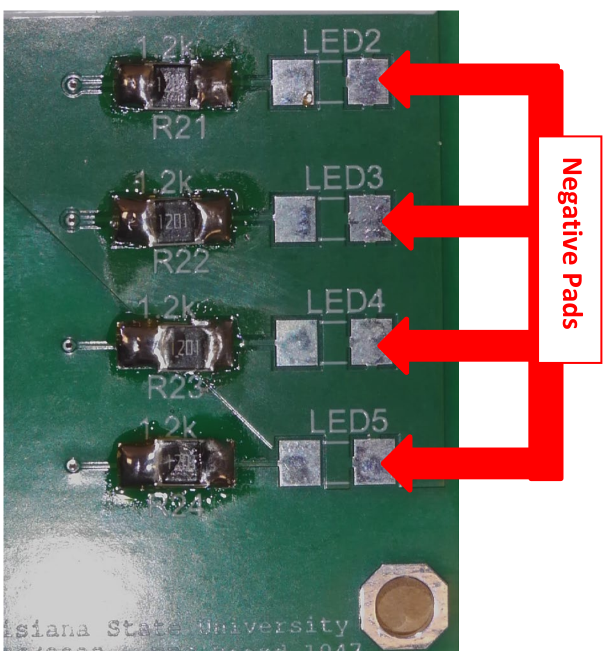


Figure 27 : Negative Pads for LED2, LED3, LED4, and LED5.

LED Assembly Step 1

Locate the section of the board containing resistors 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.

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).

Do them one at a time to determine the orientation of LEDs using 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 the orientation by 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.

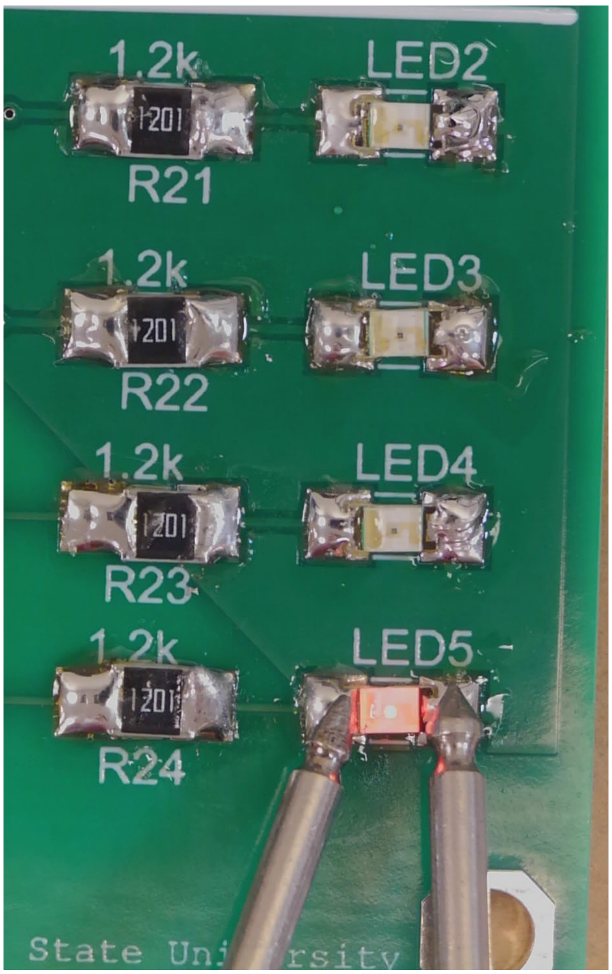


Figure 28: Verifying orientation of diagnostic LEDs after soldering in place.

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 and J3 will be assembled at a later step, C9 is found in the 4.0 Update module bag.

C9: 10 µF Electrolytic Capacitor (4.0

J3: Right-Angle Breakaway Header (2-Pin)

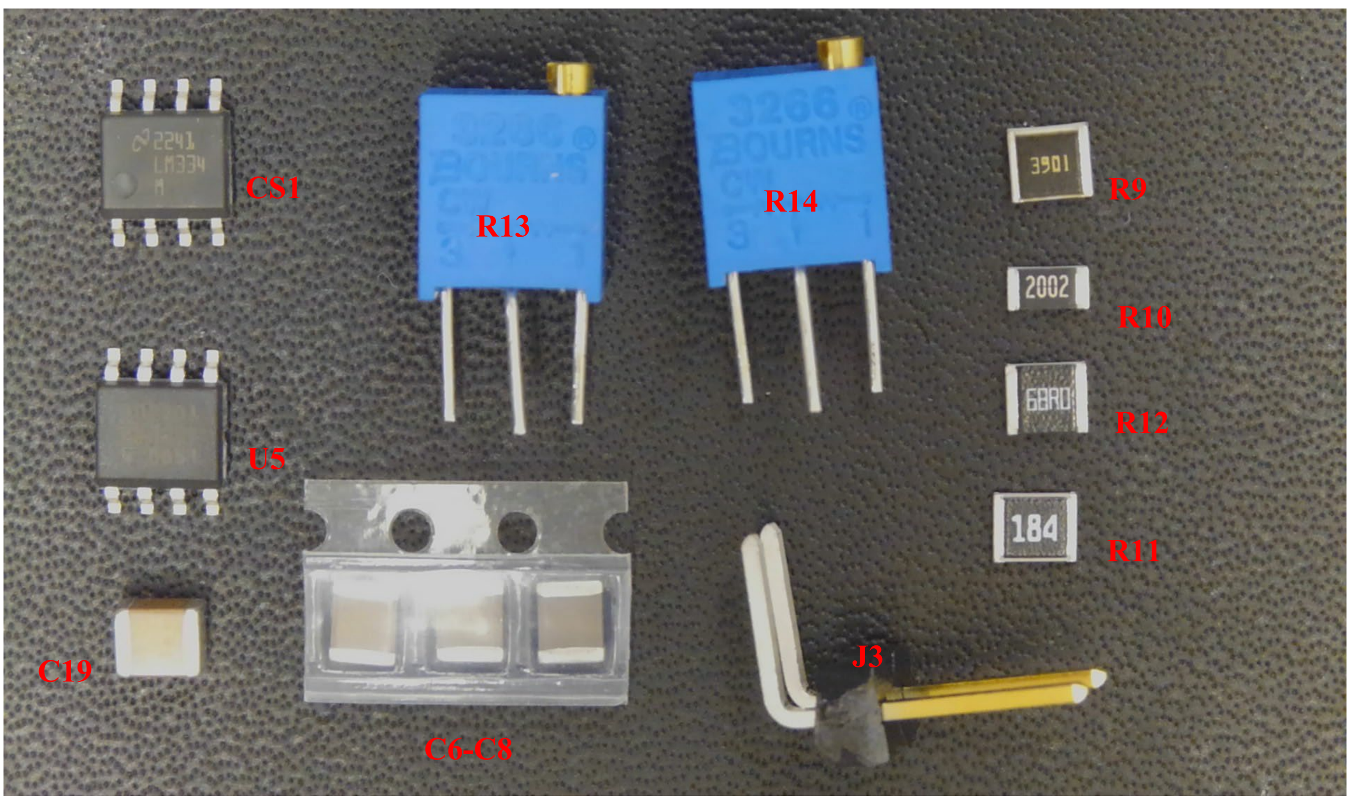


Figure 29: Internal Temperature circuit parts.

Internal Temperature Modules – Schematic

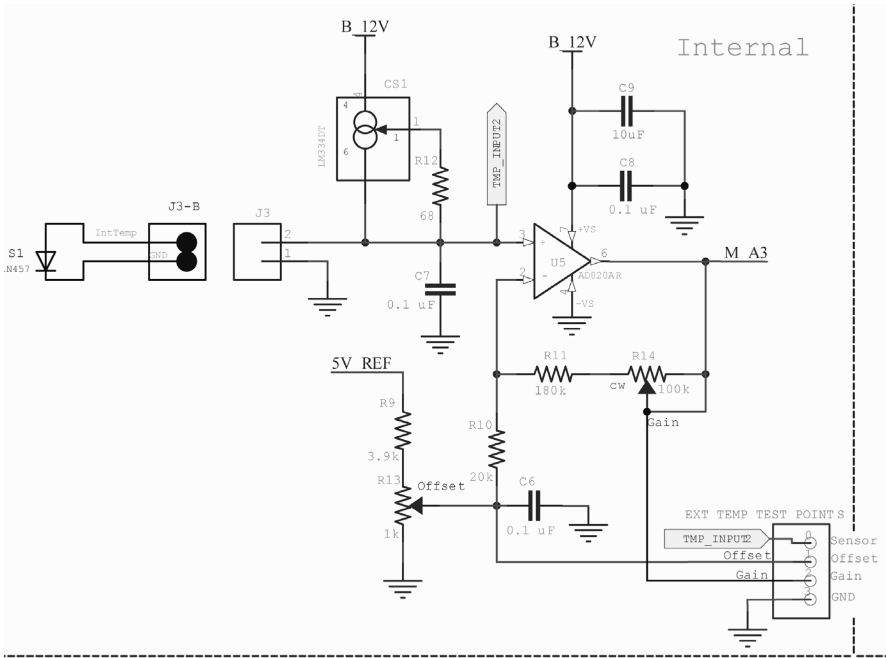


Figure 30: Internal temperature sensor schematic.

Internal Temperature Modules – PCB Layout

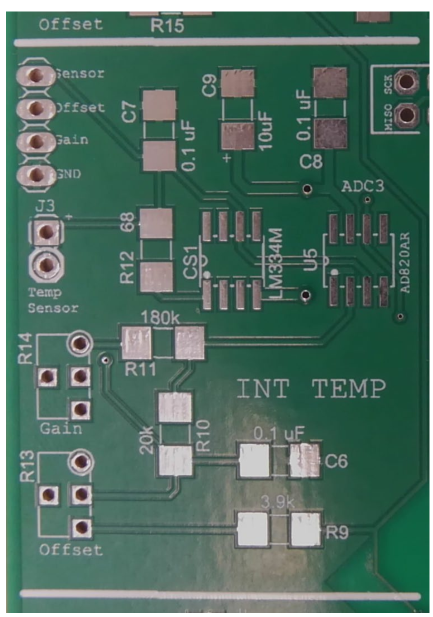


Figure 31: Bare PCB for internal temperature circuit.

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.

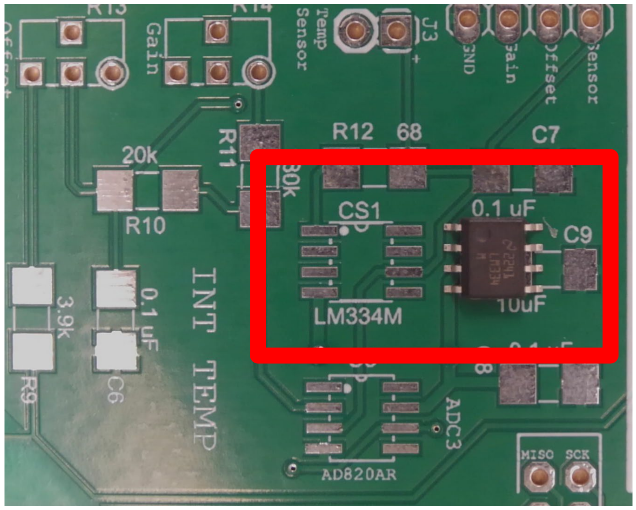


Figure 32: Alignment of the current source CS1.

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.

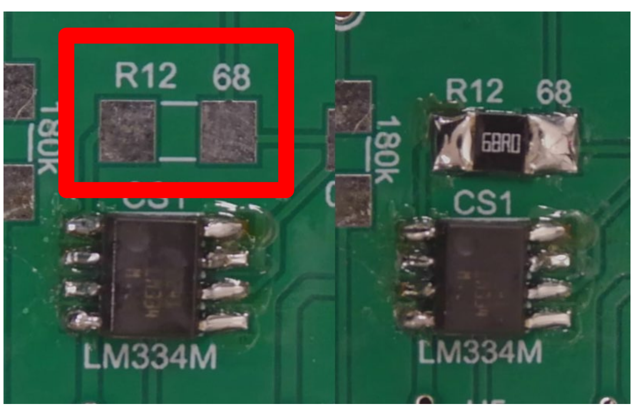


Figure 33: Soldering Resistor R12.

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 34: 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.

Table 2:Internal Temp Checks

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

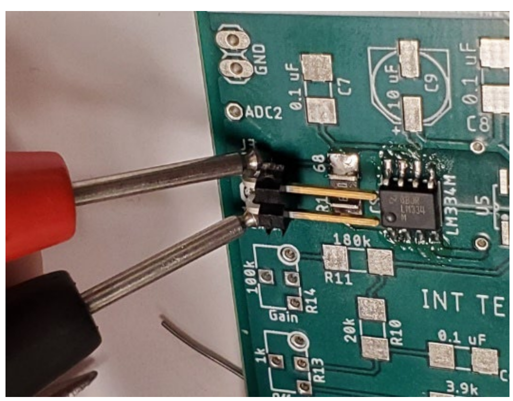


Figure 35: Measuring the current produced by CS1, note this photo has the jumper J3 already uninstalled but the process is the same without the jumper installed.

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.

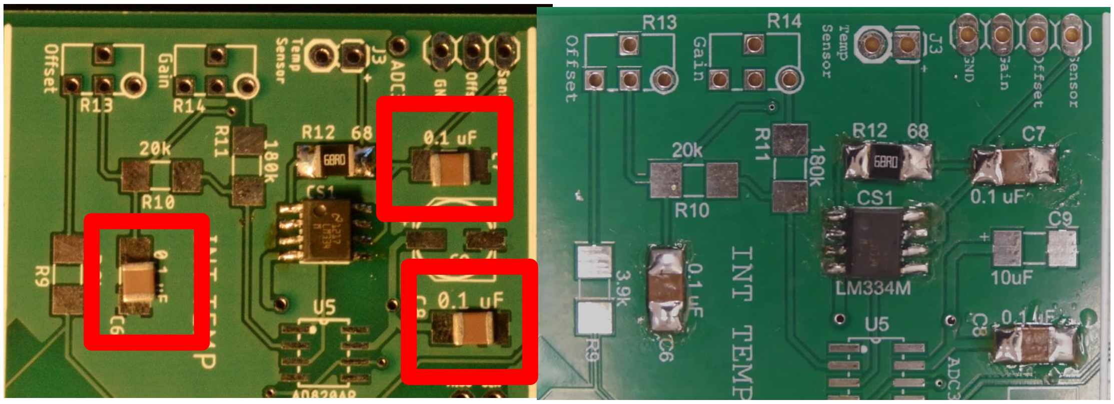


Figure 36: Soldering Capacitors C6, C7, and C8 for internal temperature circuit.

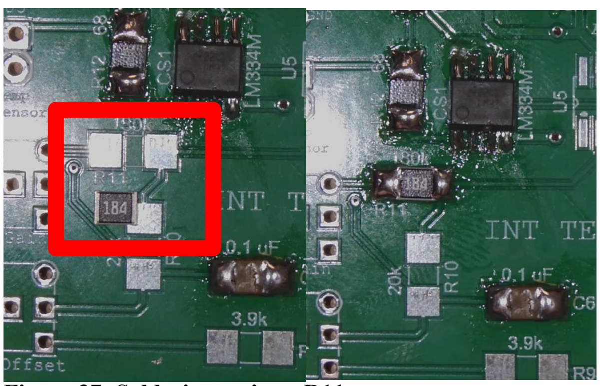


Figure 37: Soldering resistor R11

Temperature Module Assembly Step 5

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

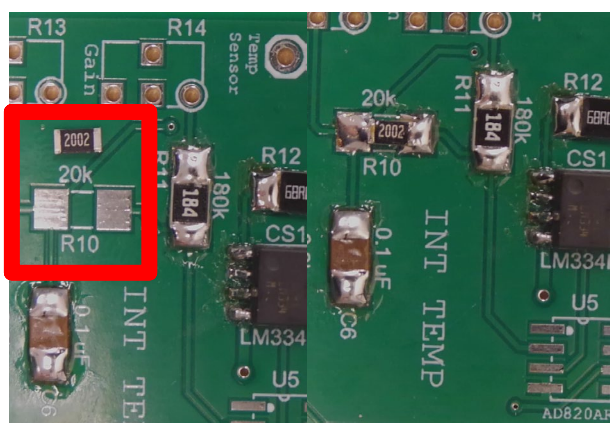


Figure 38: Soldering resistor R10

Temperature Module Assembly Step 6

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

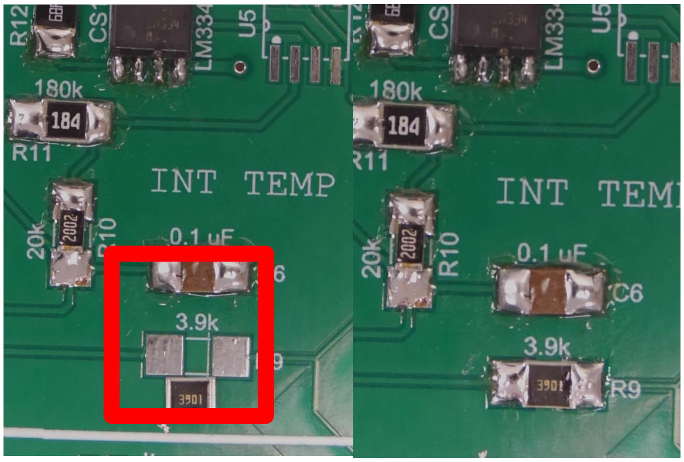


Figure 39: Soldering resistor R9

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(U6). Locate the matching pin 1 markings on the IC and the PCB. Then solder the chip into place.

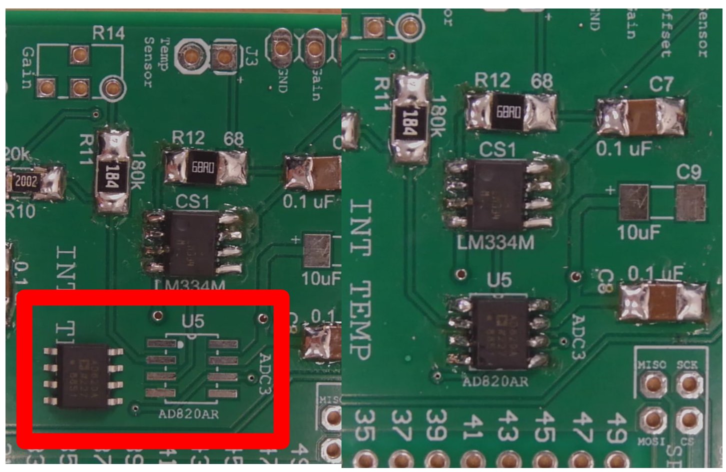


Figure 40: Soldering U5 Op amp in place.

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 41: Potentiometer markings for 1k and 10k resistors R13 and R14

Temperature Module Assembly Step 9

Locate the 100kΩ potentiometer. Record the minimum and maximum values.

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.

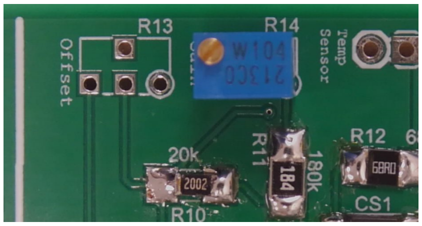


Figure 42: Resistor R14 soldered in place.

Temperature Module Assembly Step 10

Locate the 1kΩ potentiometer. Record the minimum and maximum values.

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.

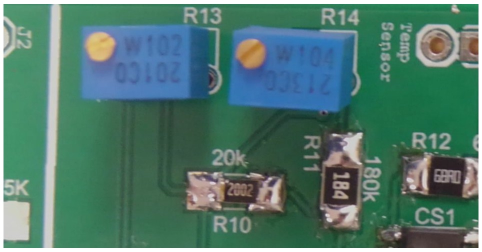


Figure 43: Both Potentiometers R13 and R14 Soldered in place.

Temperature Module Assembly Step 11

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

Figure 44: Potentiometer leads (R13 and R14) leads before and after trimming

Temperature Module Assembly Step 12

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 and J4 will be assembled at a later step, C9 is found in the 4.0 Update module bag.

C13: 10 µF Electrolytic Capacitor

J4: Right-Angle Breakaway Header (2-Pin)

External Temperature Module – Schematic

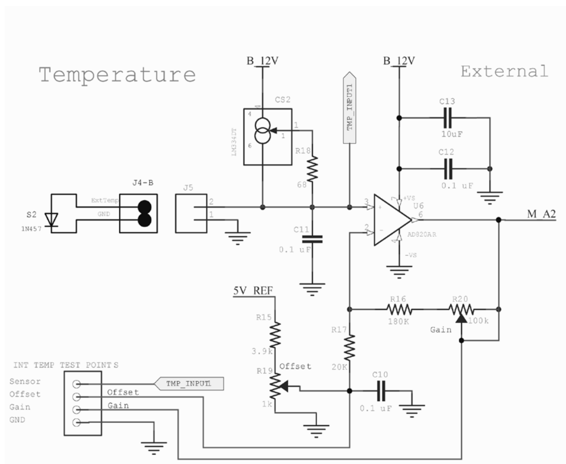


Figure 45: External temperature circuit schematic.

External Temperature Module – PCB Layout

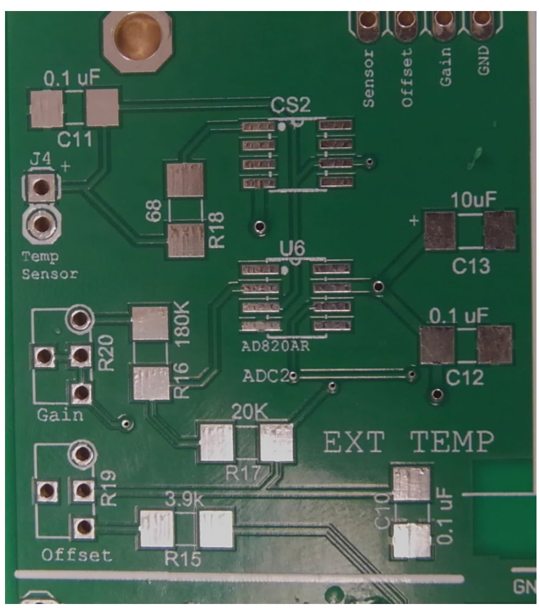


Figure 46: Unpopulated external temperature sensor PCB.

Assembled Temperature Modules

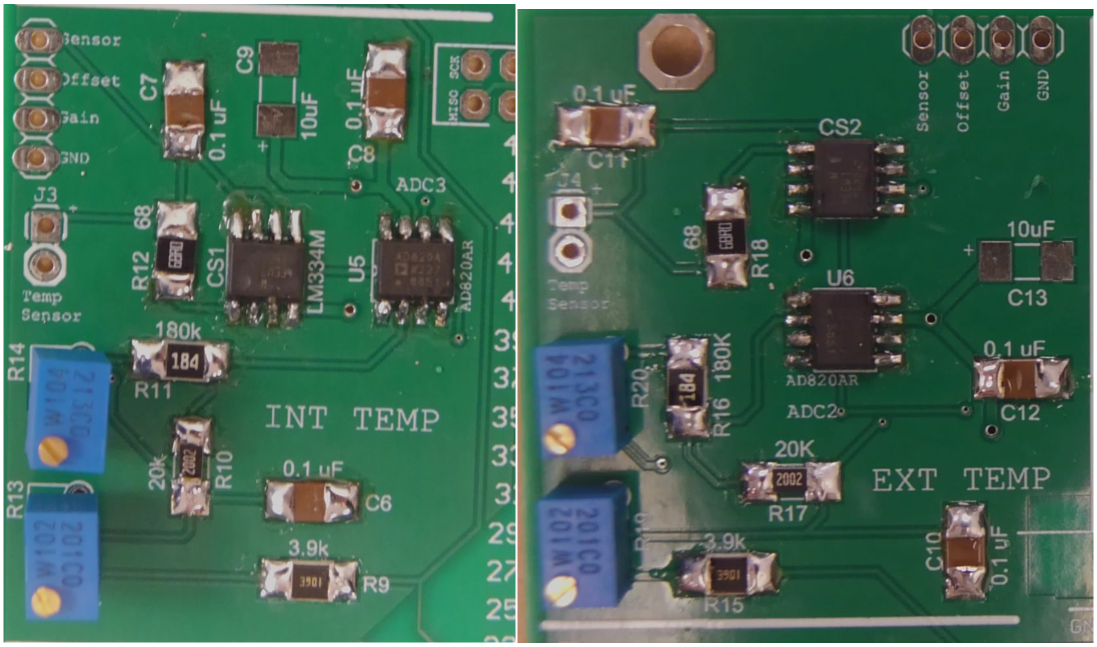


Figure 47: Assembled internal (left) and external (right) temperature circuits.

At this point both temperature circuits should be assembled except for capacitors C9 and C13 (located in a separate bag) 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 and J2 will be assembled at a later step, C9 is found in the 4.0 Update module bag.

C5: 10 µF Electrolytic Capacitor
J2: Right-Angle Breakaway Header (3 pin)

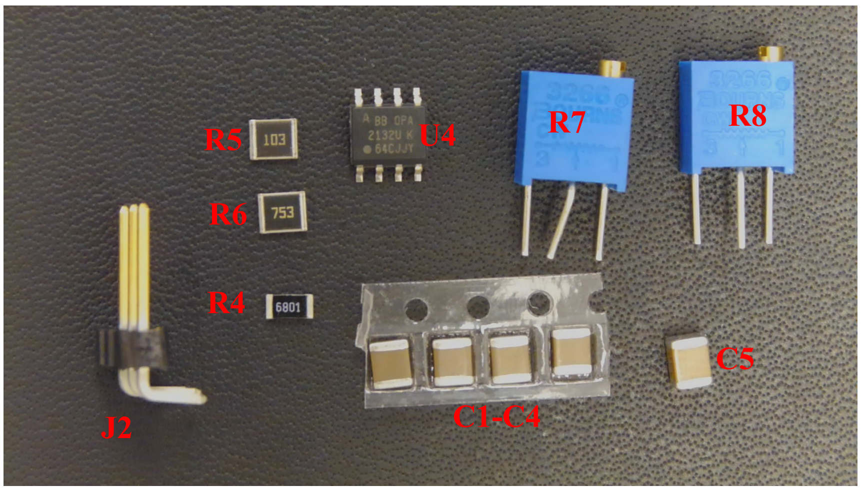


Figure 48: Humidity Module Parts

Humidity Module – Schematic

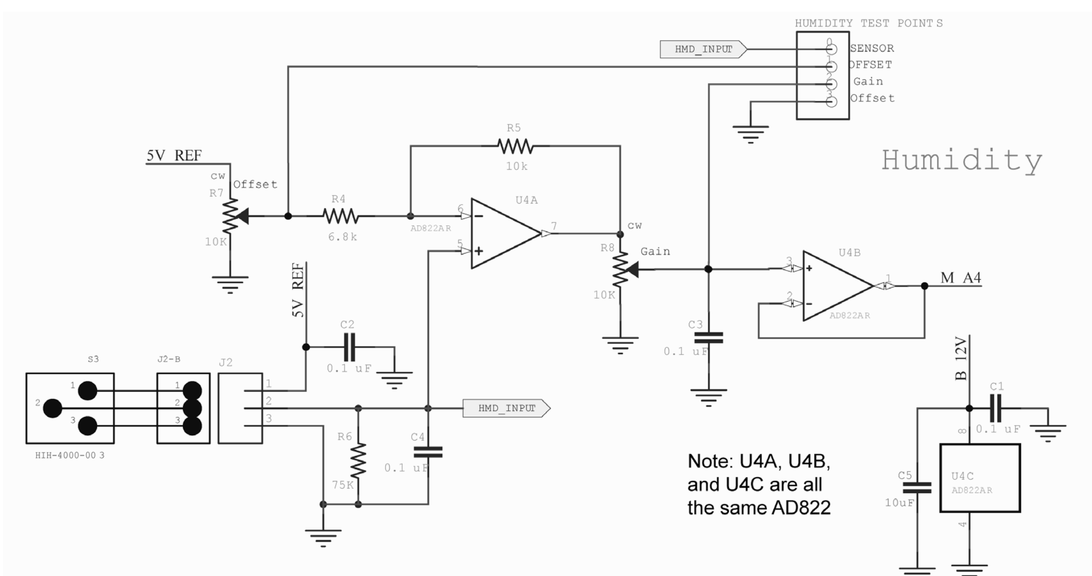


Figure 49: Humidity sensor circuit schematic.

Humidity Module – PCB Layout

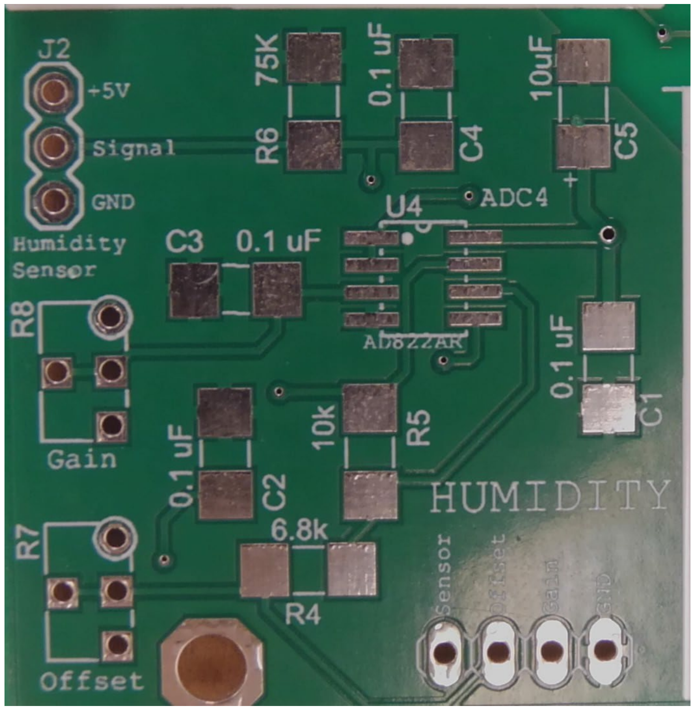


Figure 50: Humidity module bare PCB

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.

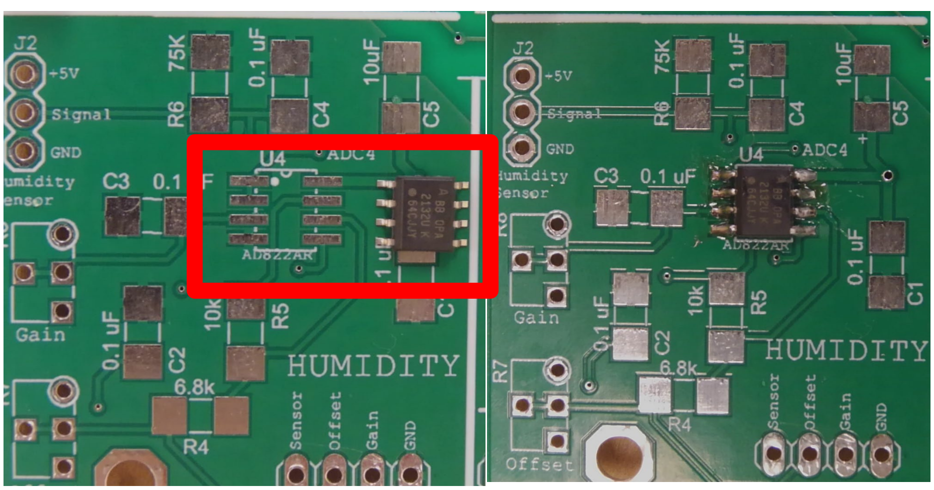


Figure 51: Soldering Dual Op amp U4 in place.

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.

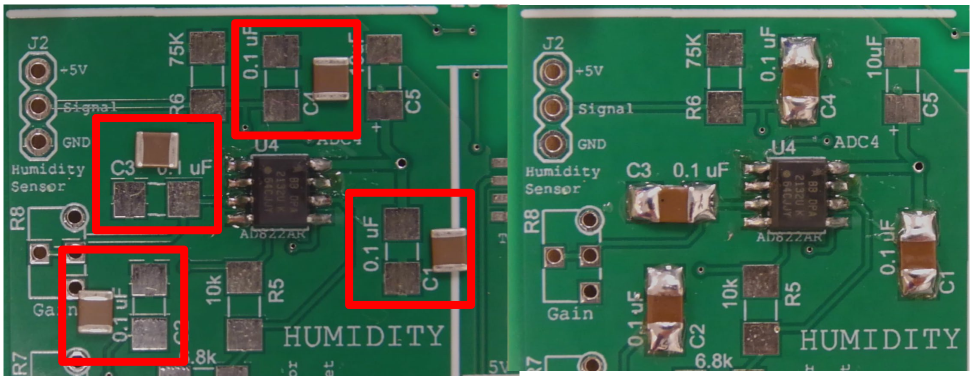


Figure 52: Soldering capacitors C1, C2, C3, and C4 in place.

Humidity Module Assembly Step 3

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

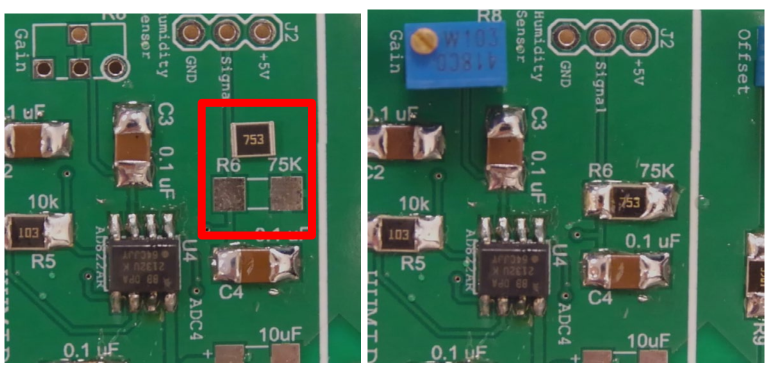


Figure 53: Soldering resistor R6 in place.

Humidity Module Assembly Step 4

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

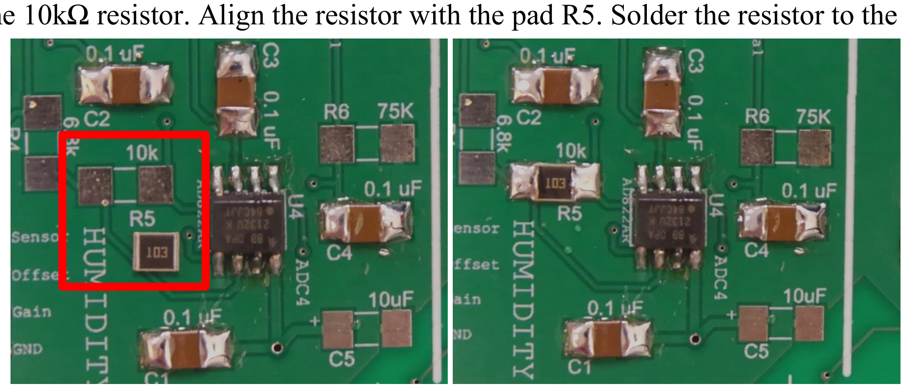


Figure 54: Soldering resistor R5 in place.

Humidity Module Assembly Step 5

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

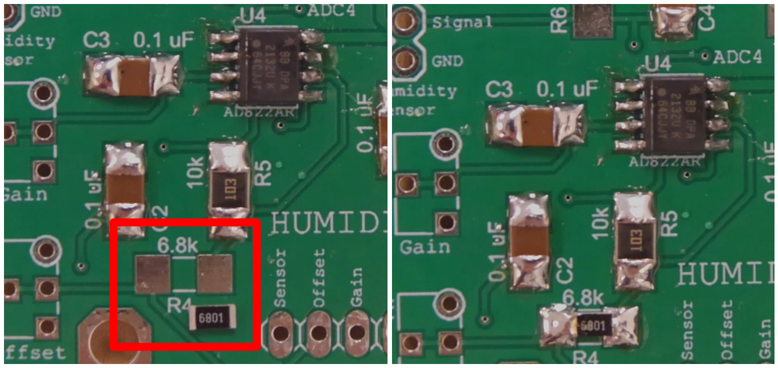


Figure 55: Soldering resistor R4.

Humidity Module Assembly Step 6

Locate the 10kΩ potentiometers. These will be marked with 103 for 10 x 10^3 on top. Record the minimum and maximum values of each.

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.

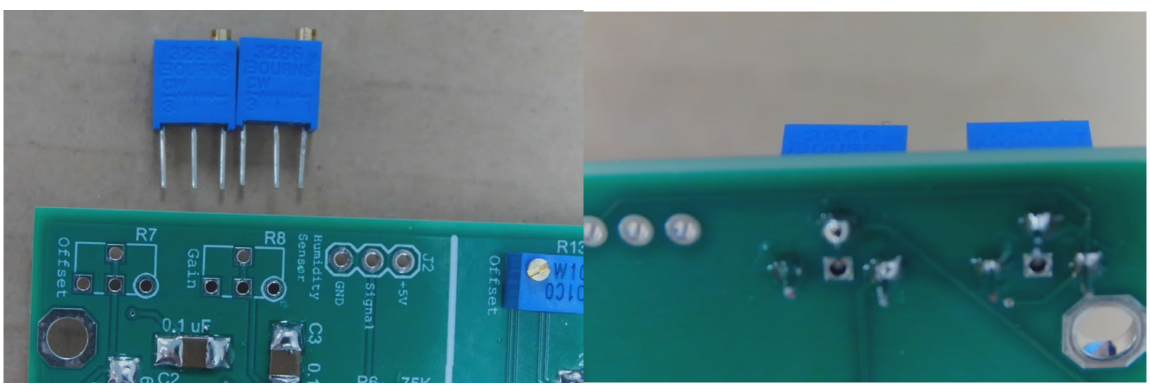


Figure 56: Solder potentiometer for humidity circuit.

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 capacitor C5 (located separately) and the right-angle header J2 for later. Your humidity circuit should the image shown below in Figure 60: Completed humidity circuit.

Assembled Humidity Module

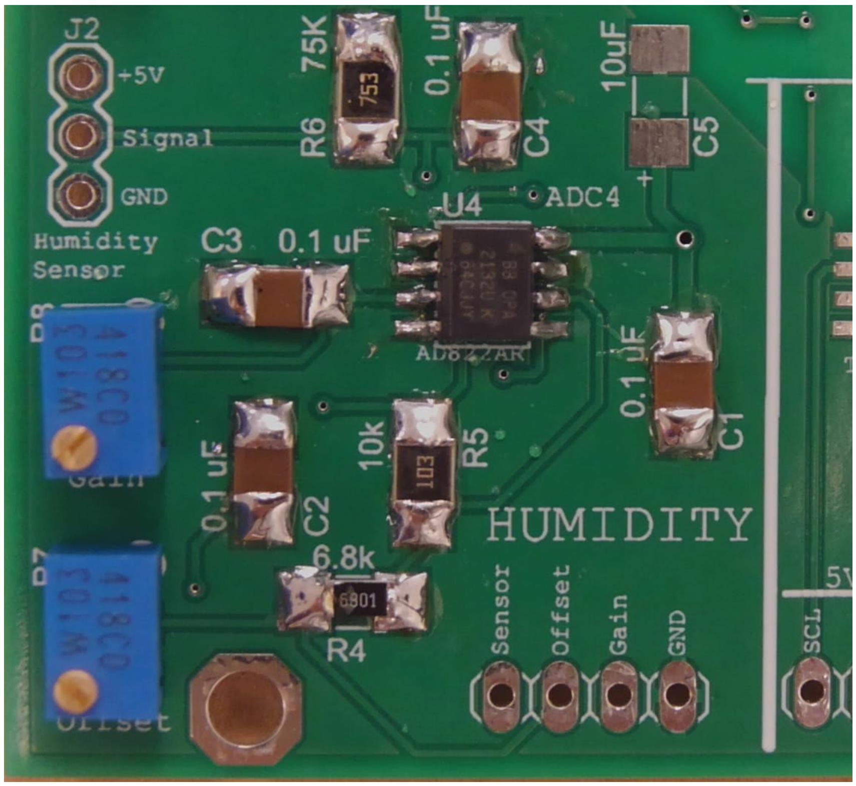


Figure 57: Completed humidity circuit.

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
- ☐ 8-Pin Socket

C9 will be assembled at a later step, C9 is found in the 4.0 Update module bag.

C15:10 µF Electrolytic Capacitor

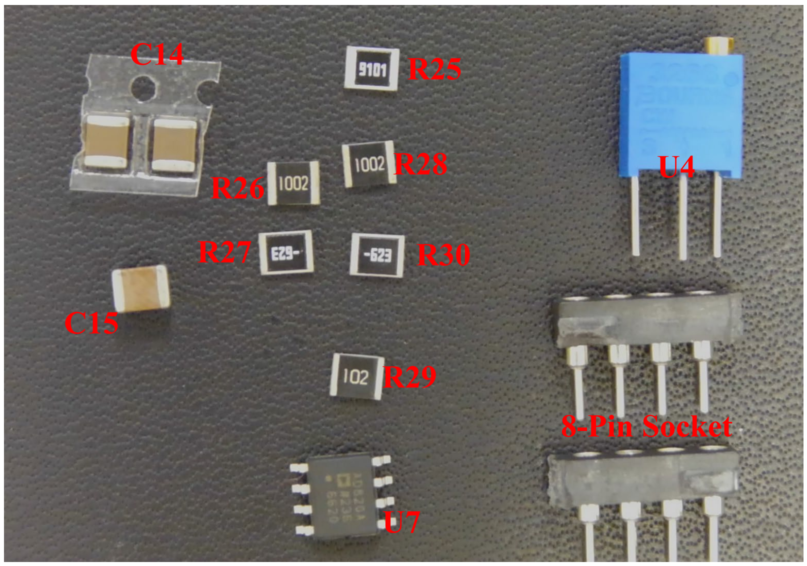


Figure 58: Pressure module parts.

Pressure Module - Schematic

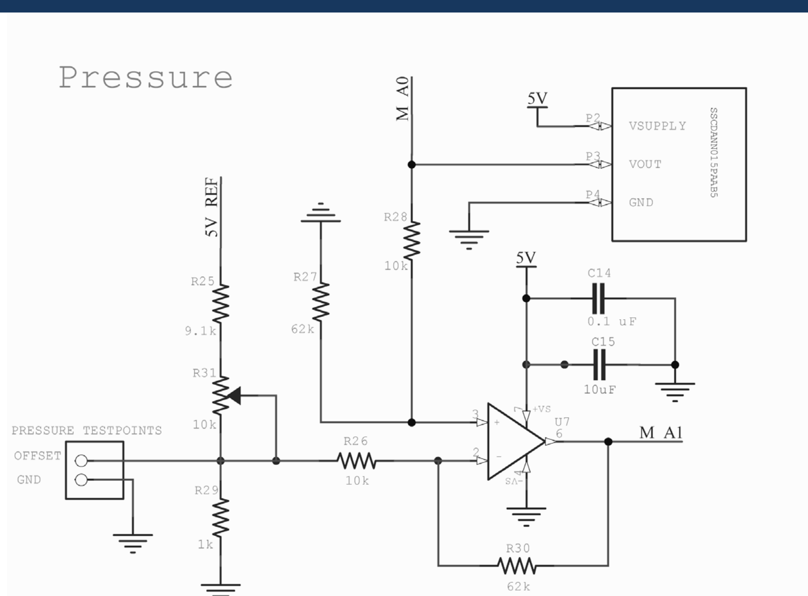


Figure 59: Pressure sensor schematic.

Pressure Module – PCB Layout

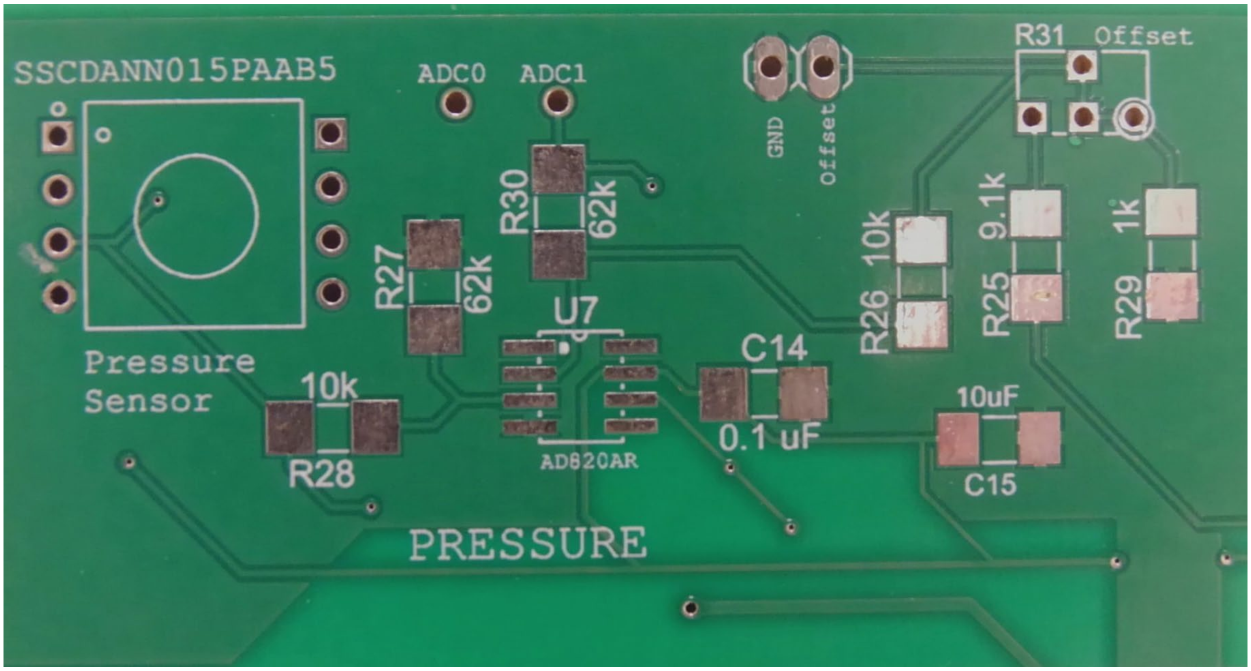


Figure 60: Pressure module bare PCB.

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.

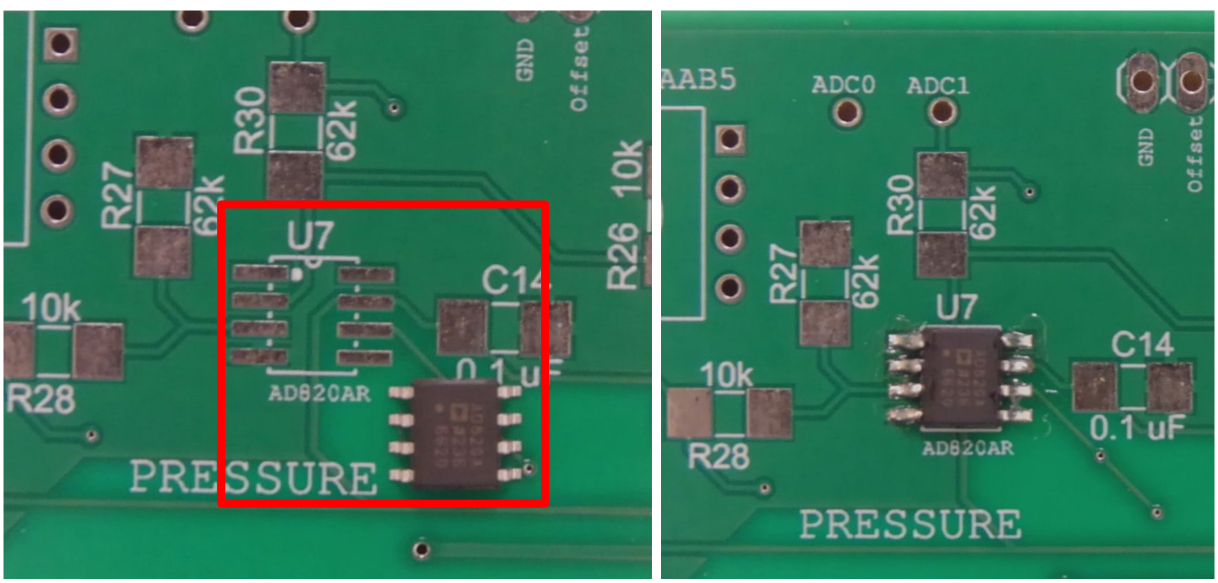


Figure 8: Soldering AD820 op amp to U7.

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.

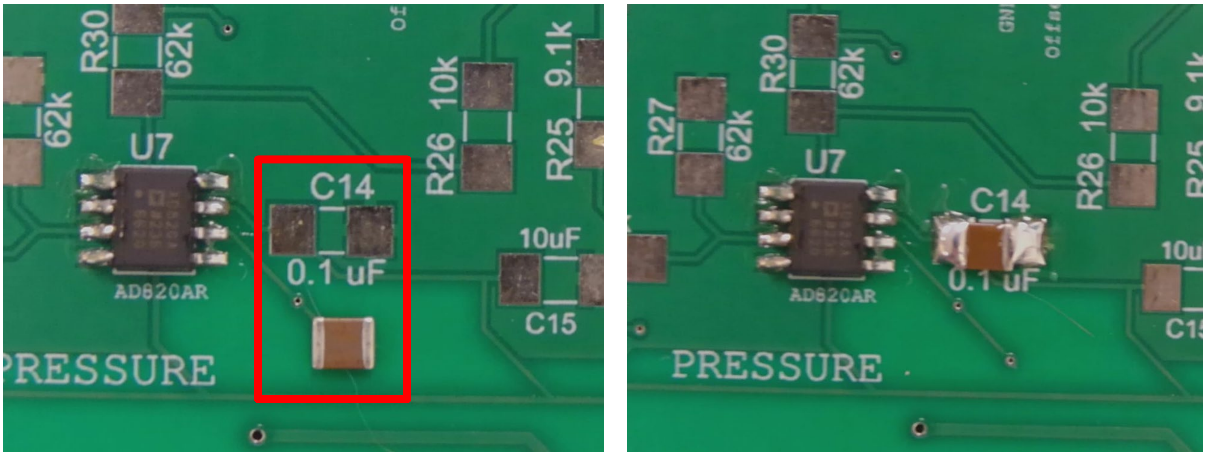


Figure 62: Soldering capacitor C14 to the board.

Pressure Module Assembly Step 3

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

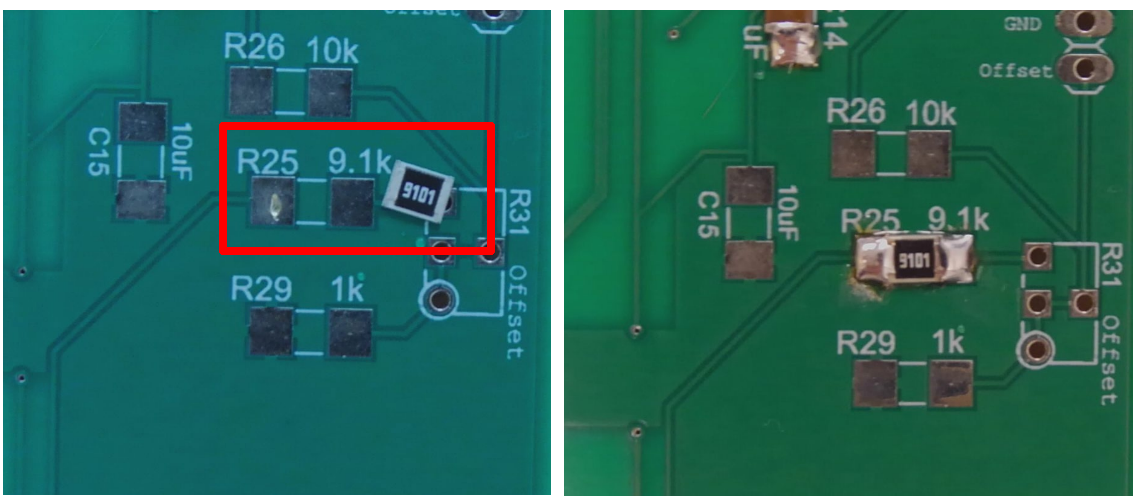


Figure 63: Soldering resistor R25 to the board.

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.

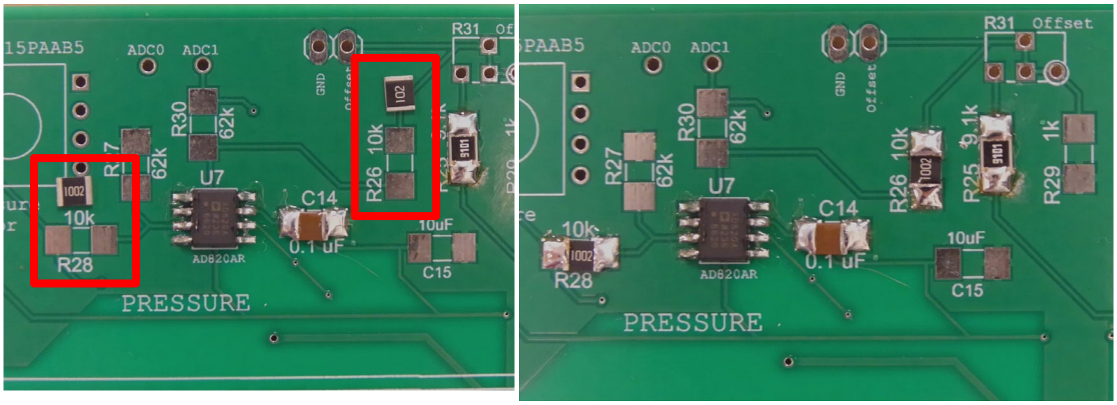


Figure 64: Soldering resistors R26 and R28 in place.

Pressure Module Assembly Step 5

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

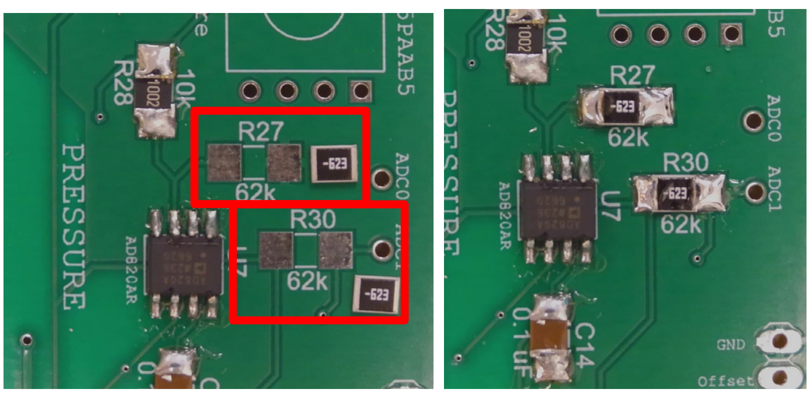


Figure 65: Soldering resistors R27 and R30 in place.

Pressure Module Assembly Step 6

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

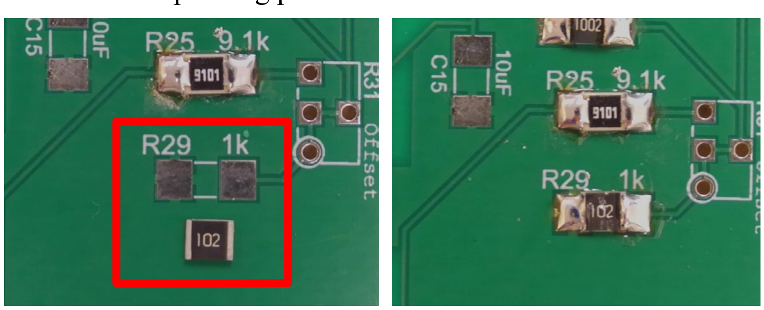


Figure 66: Soldering resistor R29 in place.

Pressure Module Assembly Step 7

Locate the 10kΩ potentiometer labeled 103. Record the minimum and maximum values.
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 wire cutters.

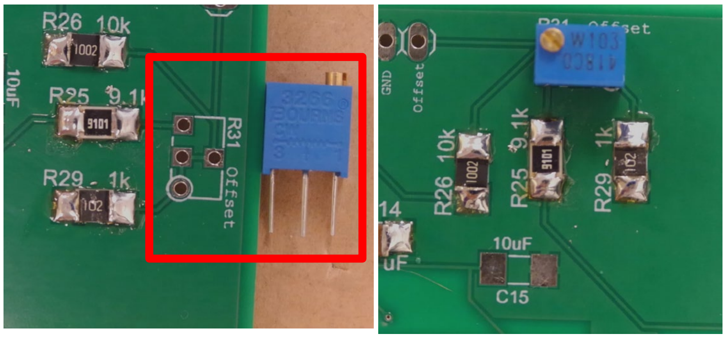


Figure 67: Soldering 10k potentiometer R31.

Pressure Module Assembly Step 8

Locate the IC socket. The socket may come in a 24-pin socket. Take a pair of wire cutters and cut the 24-pin socket into two 4 pin sockets (an 8 pin IC socket). Be careful when cutting the socket, pieces tend to fly. 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.

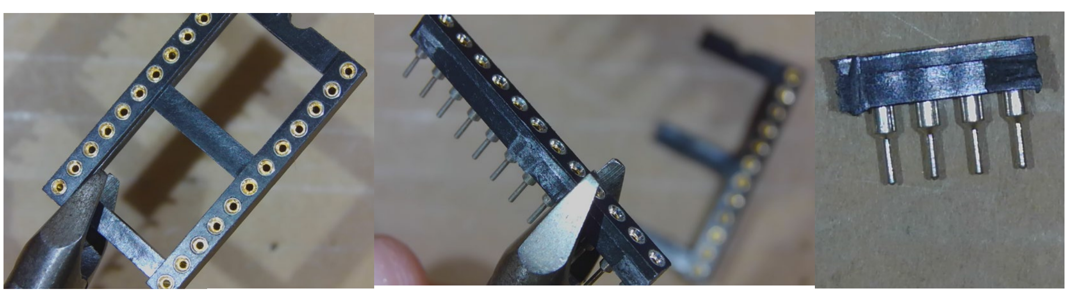


Figure 68: Cutting a 24 pin IC socket down to a 4 pin IC socket

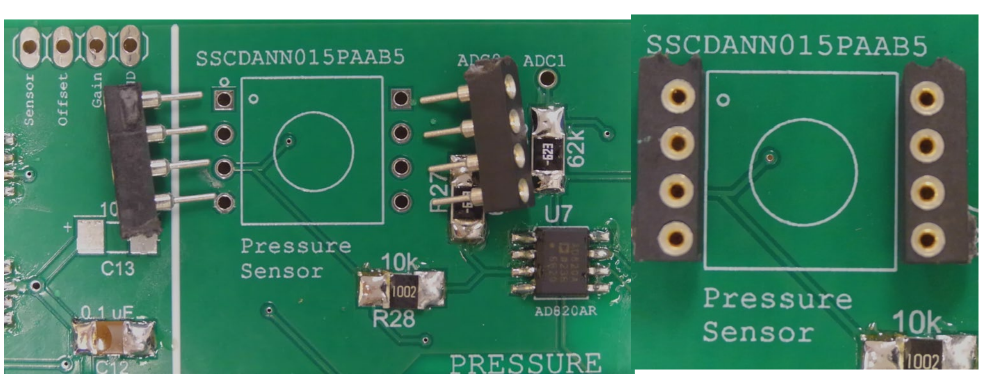


Figure 69: 8 pin IC socket for pressure sensor, placement (left) and soldered (right)

Pressure Module Assembly Step 9

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

Assembled Pressure Module

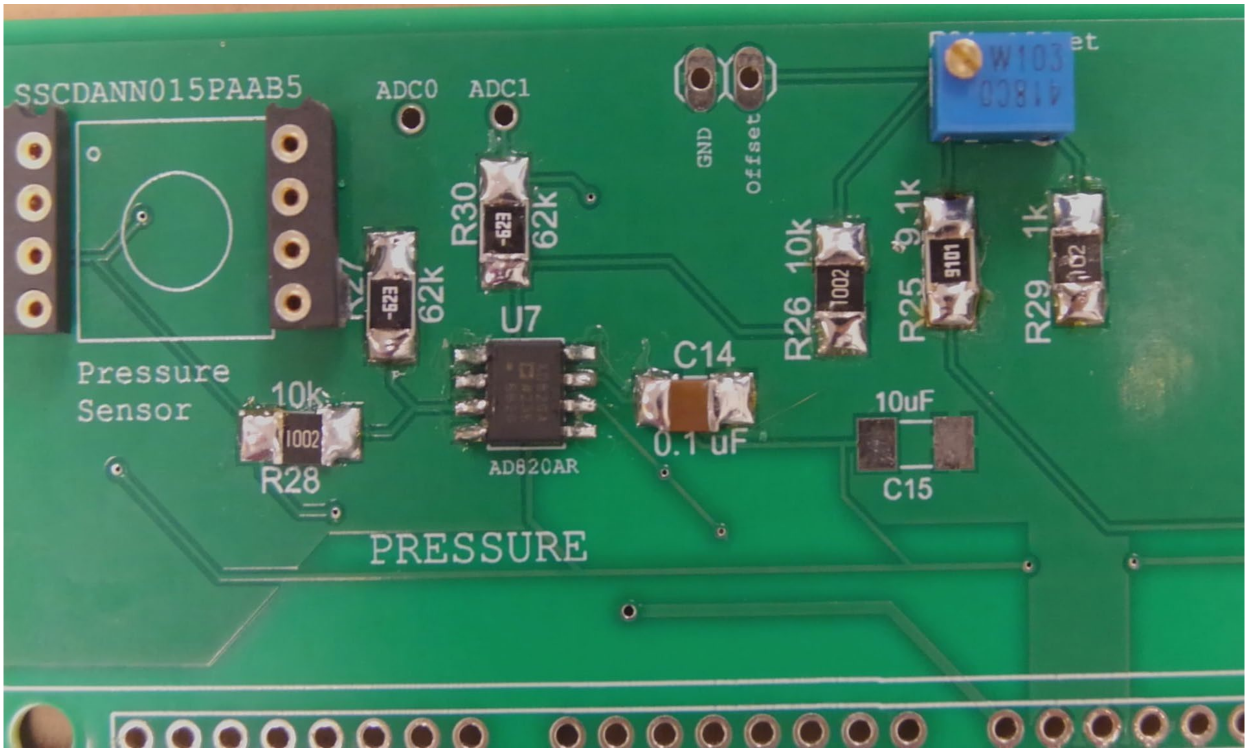


Figure 70: Completed pressure module.

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

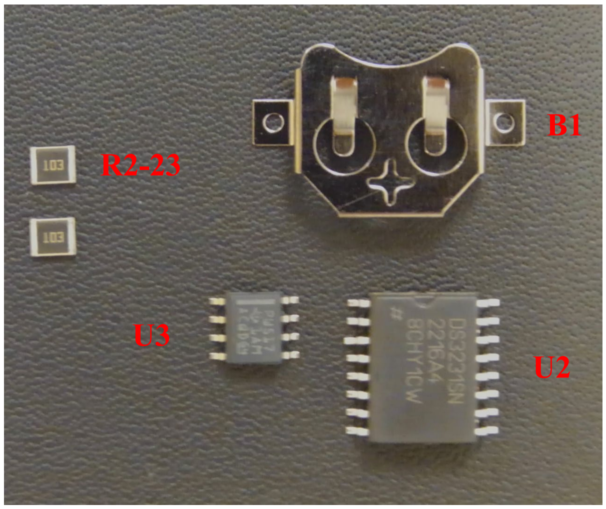


Figure 71: RTC Module Parts

RTC Module – Schematic

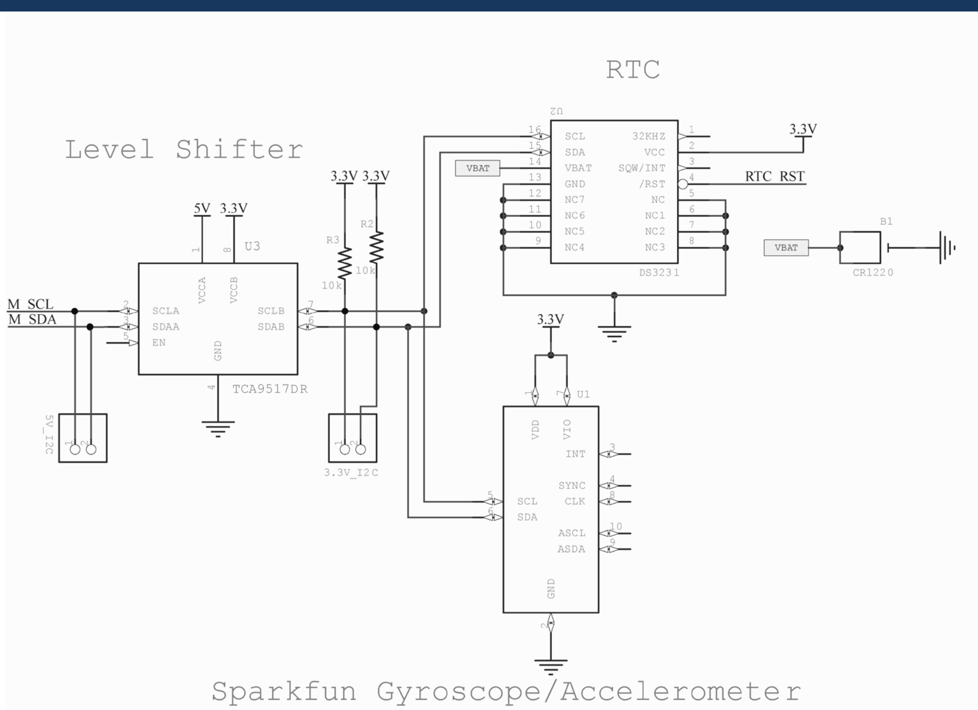


Figure 9: RTC and IMU Module Schematic

RTC Module – PCB Layout

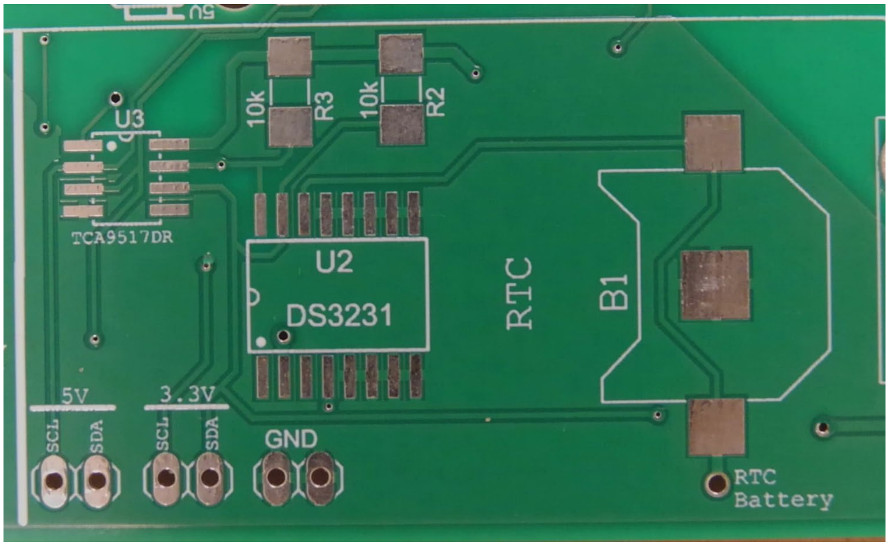


Figure 11: RTC module PCB layout.

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. Inspect all of your pins thoroughly as it is very easy to bridge the pins on this particular IC.

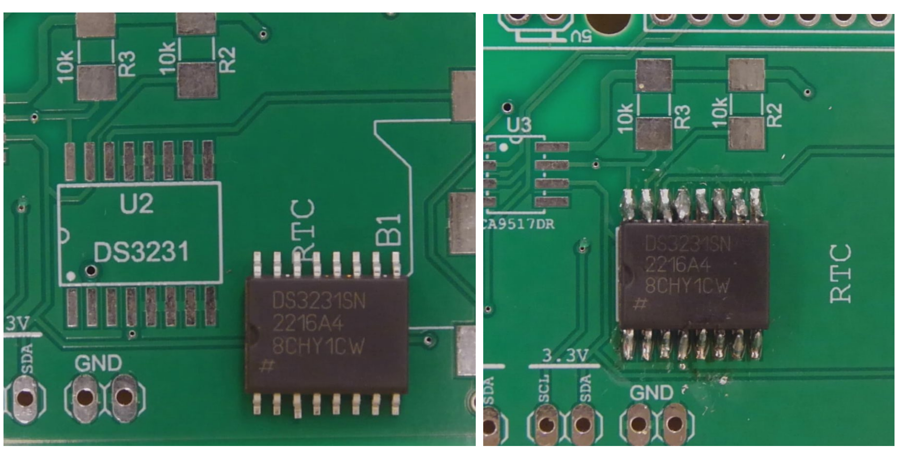


Figure 10: Soldering the RTC chip in place.

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.

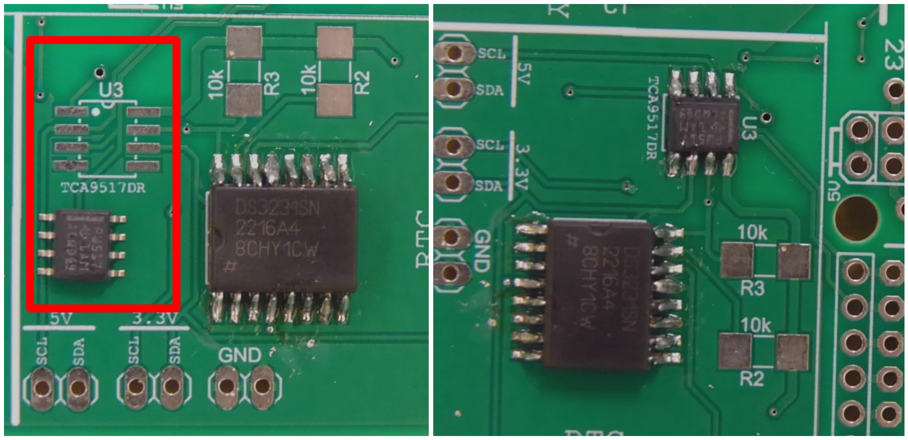


Figure 13: Soldering level shifter in place.

RTC Module Assembly Step 3

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

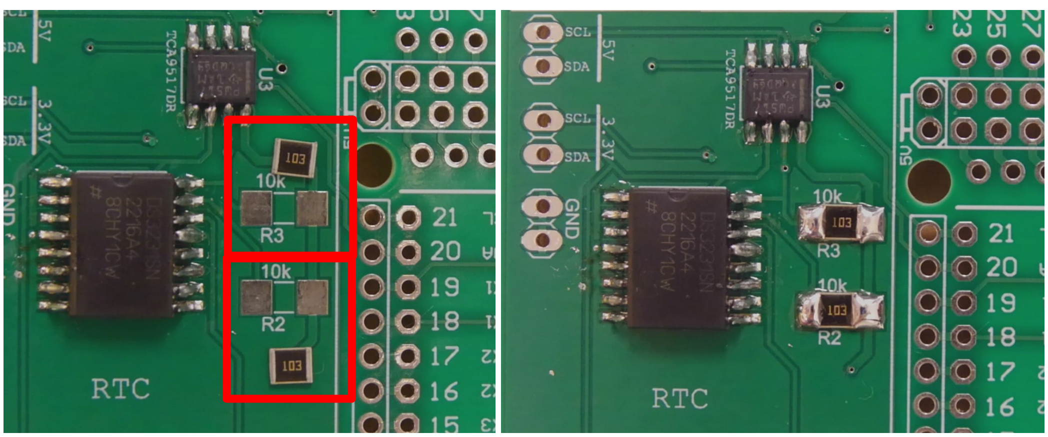


Figure 12: Soldering resistors R2 and R3 in place.

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 and make the contact with bottom side of the coin cell.

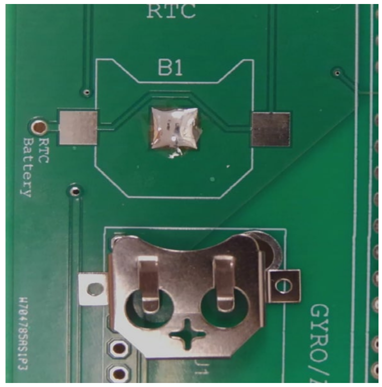


Figure 15: Adding solder to the center pad of the battery holder, be sure that the solder bead sticks out from the board.

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 needle nose 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.

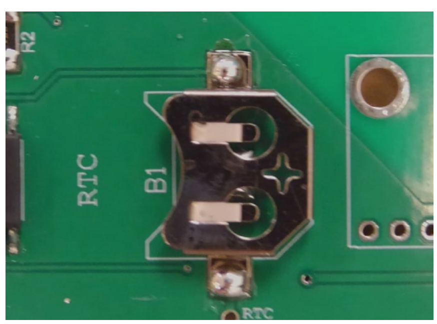


Figure 14: Completely soldered batter holder.

Assembled RTC Module

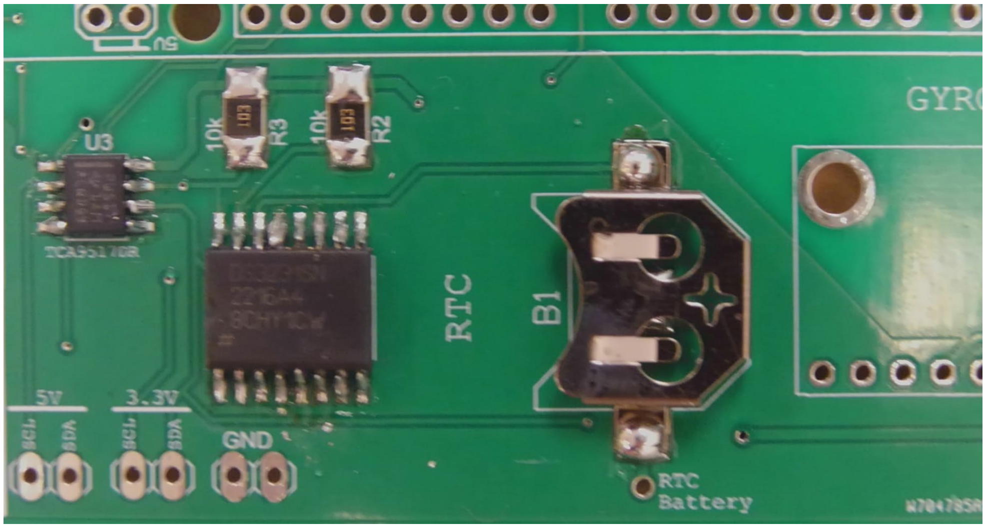


Figure 79: Completely soldered RTC Module

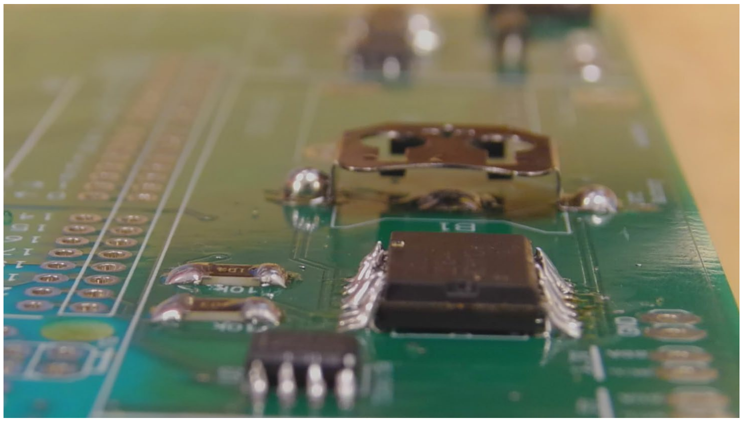


Figure 80: Notice how the solder of the center pad of battery holder sticks above the board.

MegaSat Assembly – Accelerometer / Gyroscope

Accelerometer / Gyroscope Module – Parts List

These parts are located inside the Sensor Module Bag

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

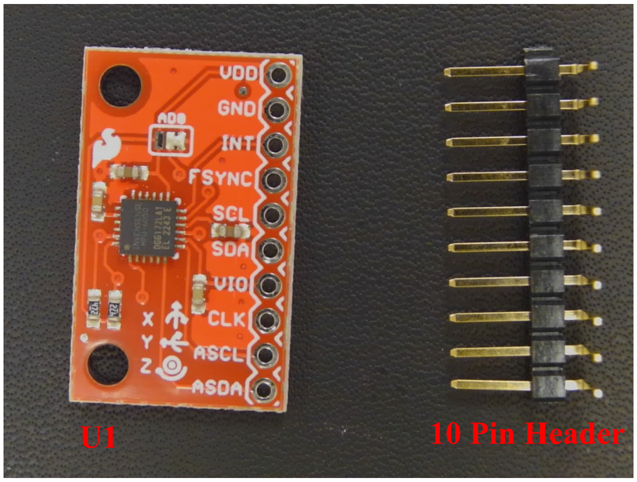


Figure 17: Accelerometer Gyroscope parts.

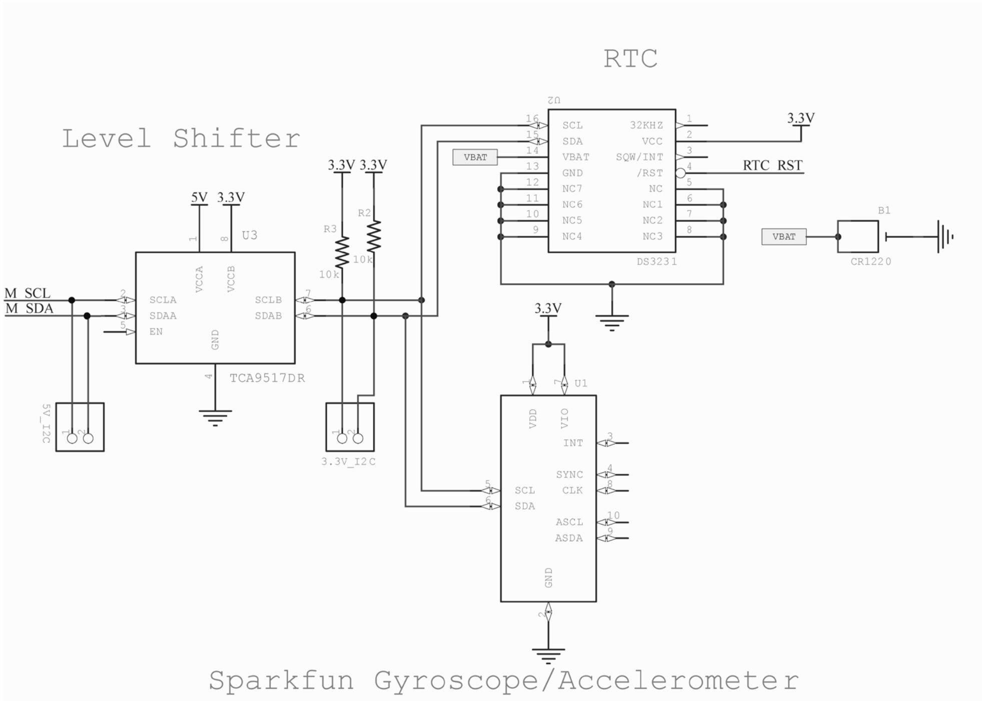


Figure 16: RTC and IMU Schematic.

Accelerometer / Gyroscope Module – Schematic

Accelerometer / Gyroscope Module – PCB Layout

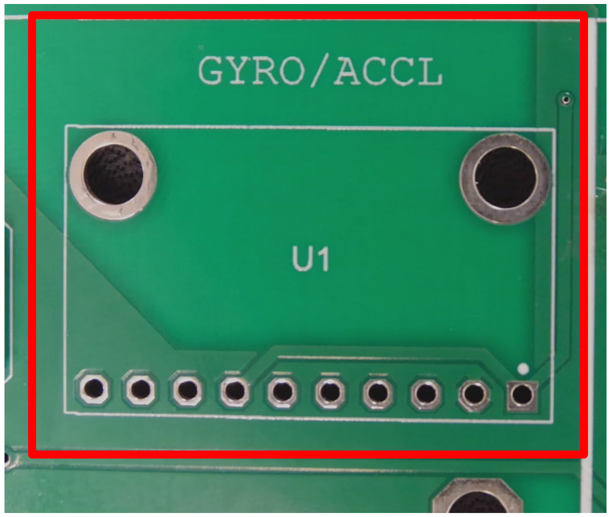


Figure 83: PCB location where the IMU will be soldered in.

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

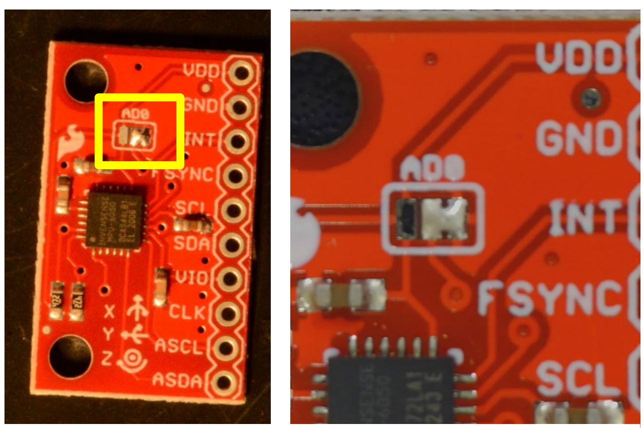


Figure 18: The AD0 jumper on the breakout board. The center pad is connected to and address select pin on the IMU chip. The right pad is connected to ground and the left to VDD (voltage supply). In the shown configuration this sets the address to 0x68

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 there is no longer a connection between the middle and left pin with a continuity test.

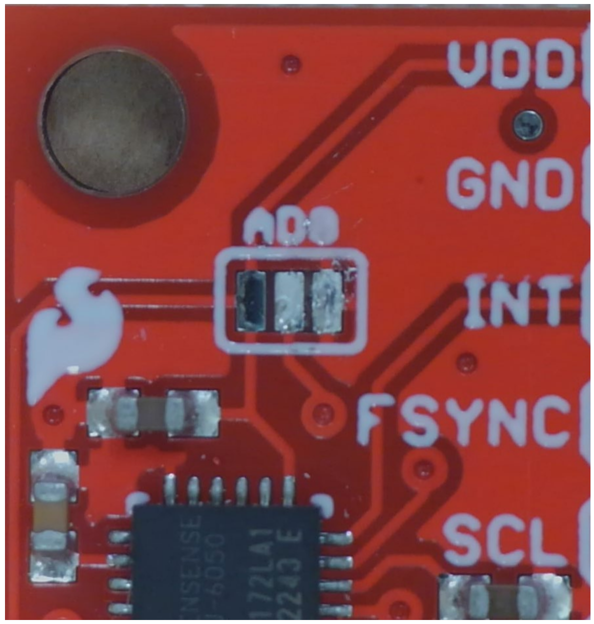


Figure 85: Address jumper AD0 after the connection between center and right pads has been removed.

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.

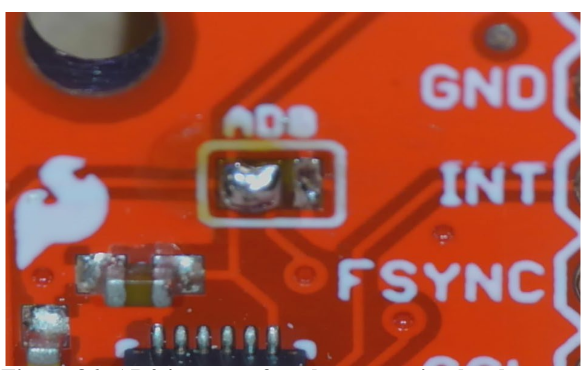


Figure 86: AD0 jumper after the connection has been made between the left and center pins. In this configuration the I2C address will be 0x69.

Accelerometer / Gyroscope Assembly Step 4

Correctly installing the IMU involves soldering the right-angle header twice. First, the header must be soldered to the IMU board. And then, the headers will be soldered to the MegaSAT

Take the right-angle head and install it in the holes on the side of the IMU breakout board with the IC visible. The plastic should be flush with the IMU PCB. Then, flip the breakout board over and solder each of the pins of the header to the breakout board. Be sure to check for bridging between the pins before proceeding since these pads will not be accessible after this section is complete.

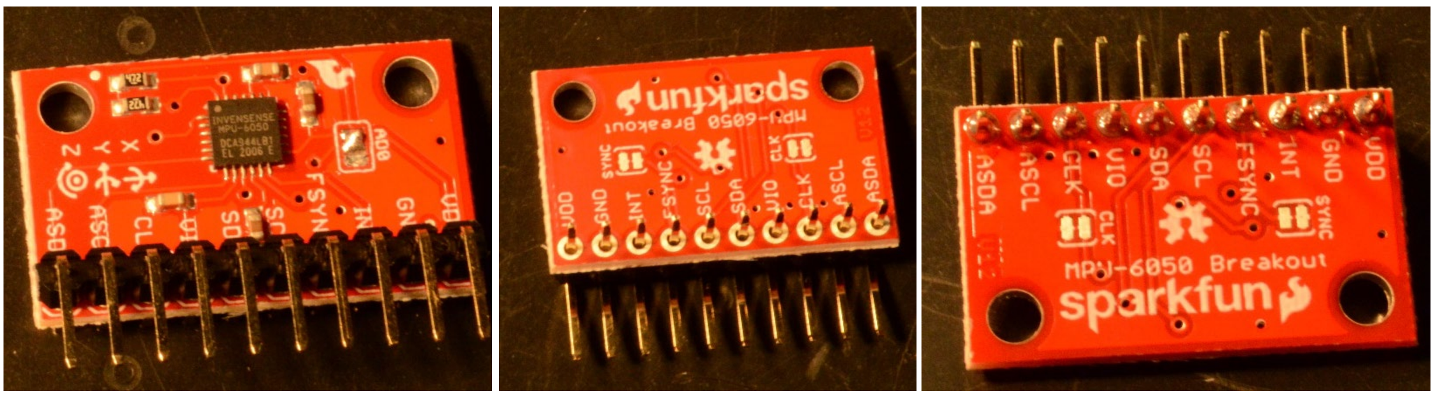


Figure 20: Installing header pins in breakout board and then soldering to the board.

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.

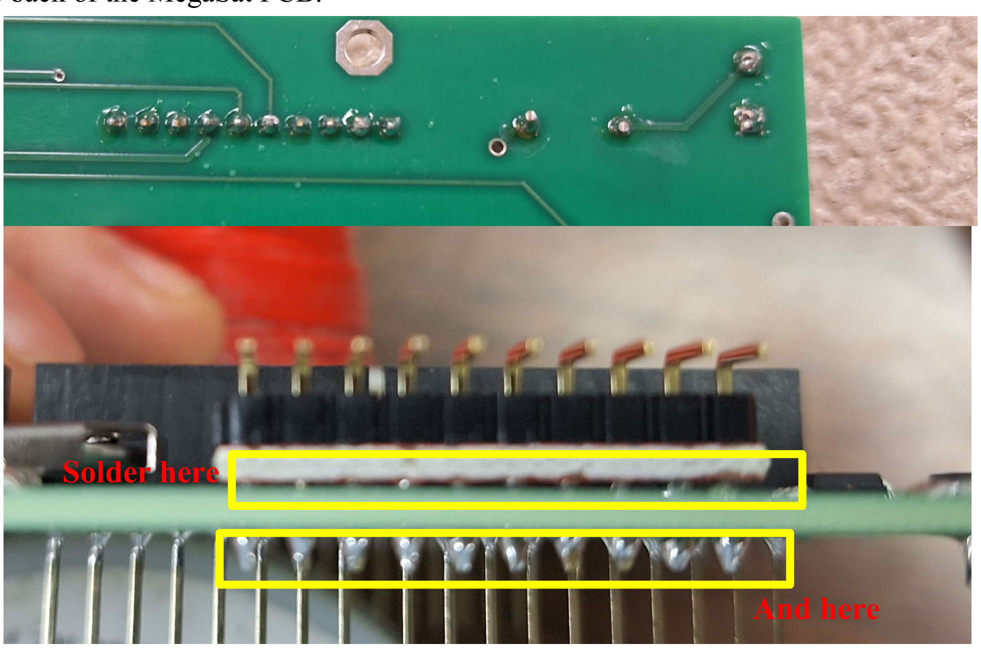


Figure 19: Top: IMU pins after soldering. There should be two set soldered joints as shown in the bottom image.

Assembled Accelerometer / Gyroscope Module

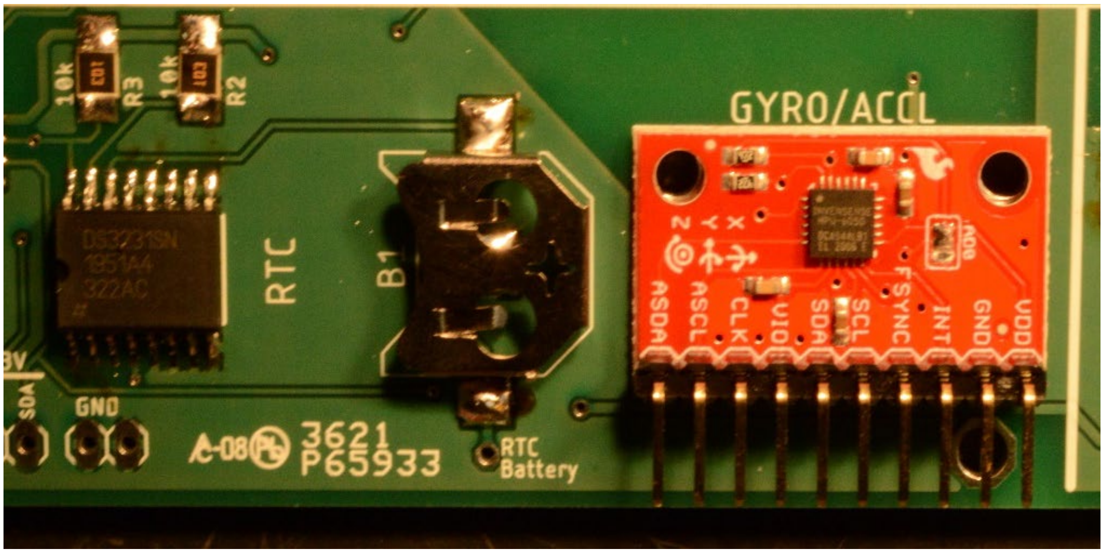


Figure 89: Assembled MPU Module.

MegaSat Assembly – Large Capacitors

We will now solder the capacitors we had previously set aside during assembly. You should have four large 10 uF capacitors, compared to the 0.1uF capacitors that have already been soldered on.

Four 10 uF capacitors are used in the Internal Temperature (1 capacitor), External Temperature (1), Humidity (1), and Pressure (1) circuits; these capacitors are in the **4.0 Update Module** bag.

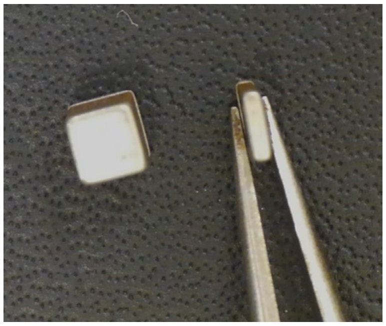


Figure 90: Size comparison between the 10uF capacitor and the 0.1uF capacitor . Note that the 10 uF is significantly taller than the 0.1 uF capactitor

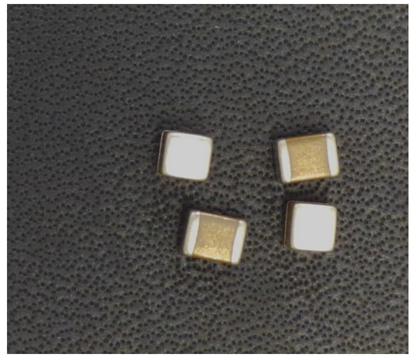


Figure 91: Four 10 uF capacitors.

Large Capacitor Assembly Step 1

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

These capacitors are not polarized.

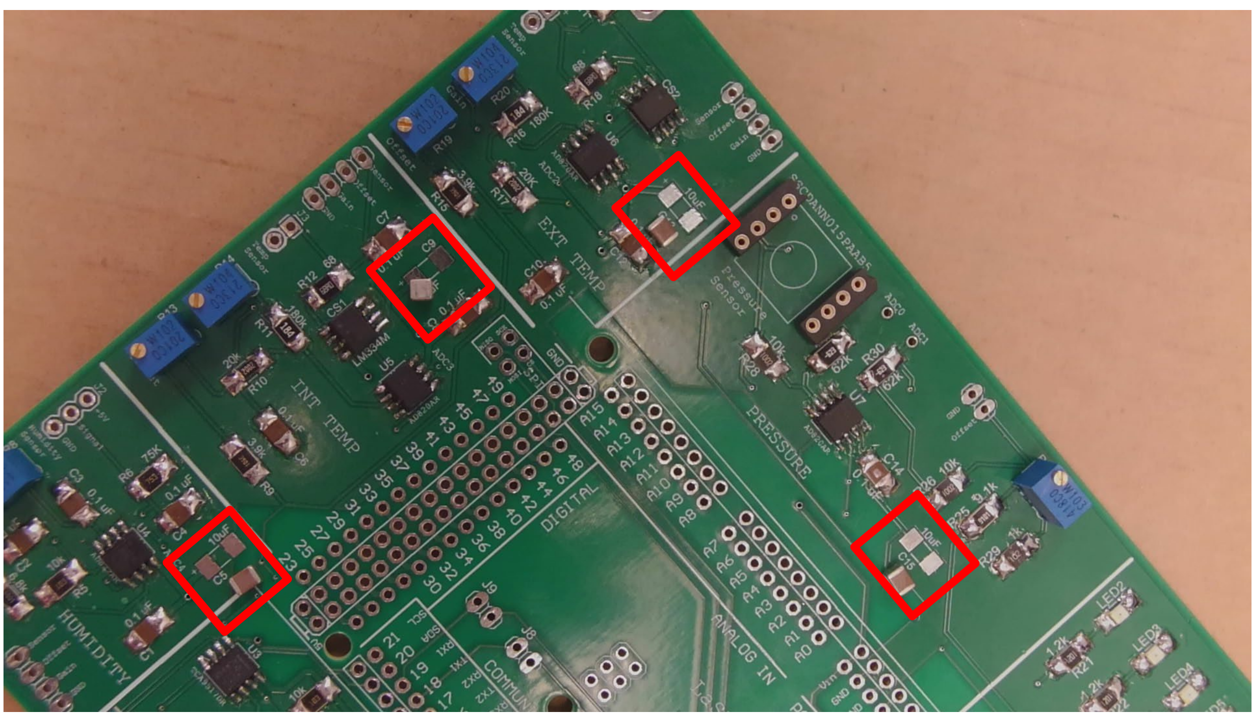


Figure 92: Locations of large capacitor pads C5, C9, C13, and C15 .

Large Capacitor Assembly Step 2

Starting with C5 (on the humidity circuit), solder these the same way the 0.1uF capacitors were soldered. Add a small solder to one of the pads. Then the remelt the solder while pressing the capacitor onto the pads using tweezers.

Verify correct alignment with the other pad making adjustments in necessary. Then add solder the other pad. Because of the larger size of the capacitor you may want to add more solder to the pads to ensure good contact.

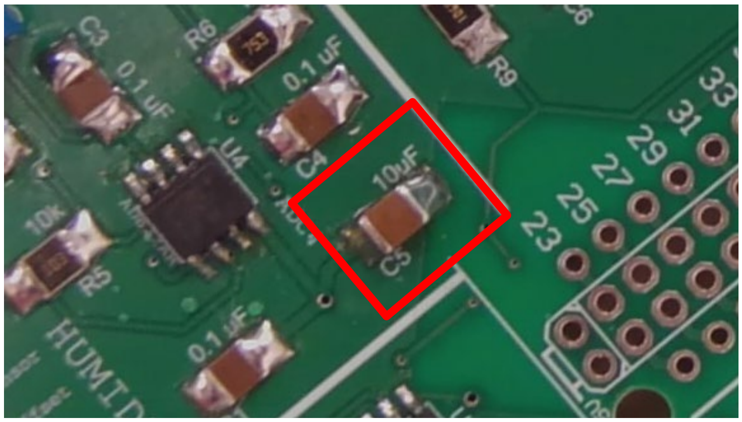


Figure 93: Completely soldered capacitor C5.

Large Capacitor Assembly Step 1

Repeat the above process for C9(internal temperature), C13(external temperature), and C15(pressure).

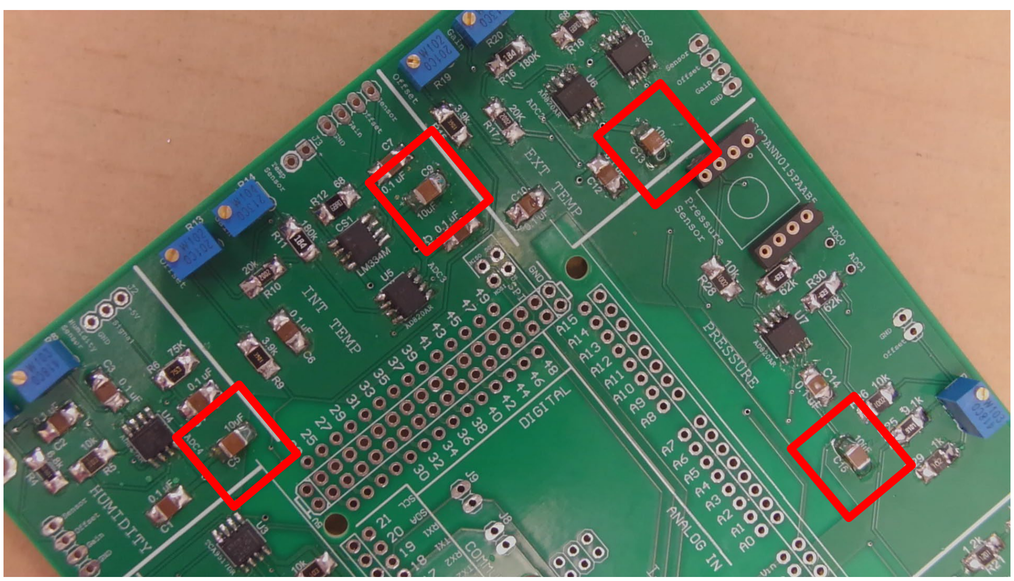


Figure 94: Completely soldered capacitors (C5, C9, C13, and C15)

MegaSat Assembly – Arduino Hardware

The Arduino Mega connects with the MegaSat PCB through stackable headers. There are seven stackable headers of differ pin counts 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.

Next to the pads for the headers there are a second set of pads so teams can easily solder wires to connect to Arduino pins. The set of pads for headers are surrounded by white boxes on the PCB. **MAKE SURE YOU SOLDER THE HEADERS INTO THE CORRECT PADS.**

Use caution when handling, installing and soldering the head pins. Because of the number of pins if pins become misaligned or bent it will be difficult to line up the Arduino.

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 (Used for temperature sensors)
- ☐ 3-Pin Receptacle Housing (used for the humidity sensor)
- ☐ Right angle breakaway header x 2 (used for 3.3V and 5V I2C connections)
- ☐ 22-24 AWG Female crimp x 11 (Used for the Receptacles) [10]

Arduino Hardware – PCB Layout

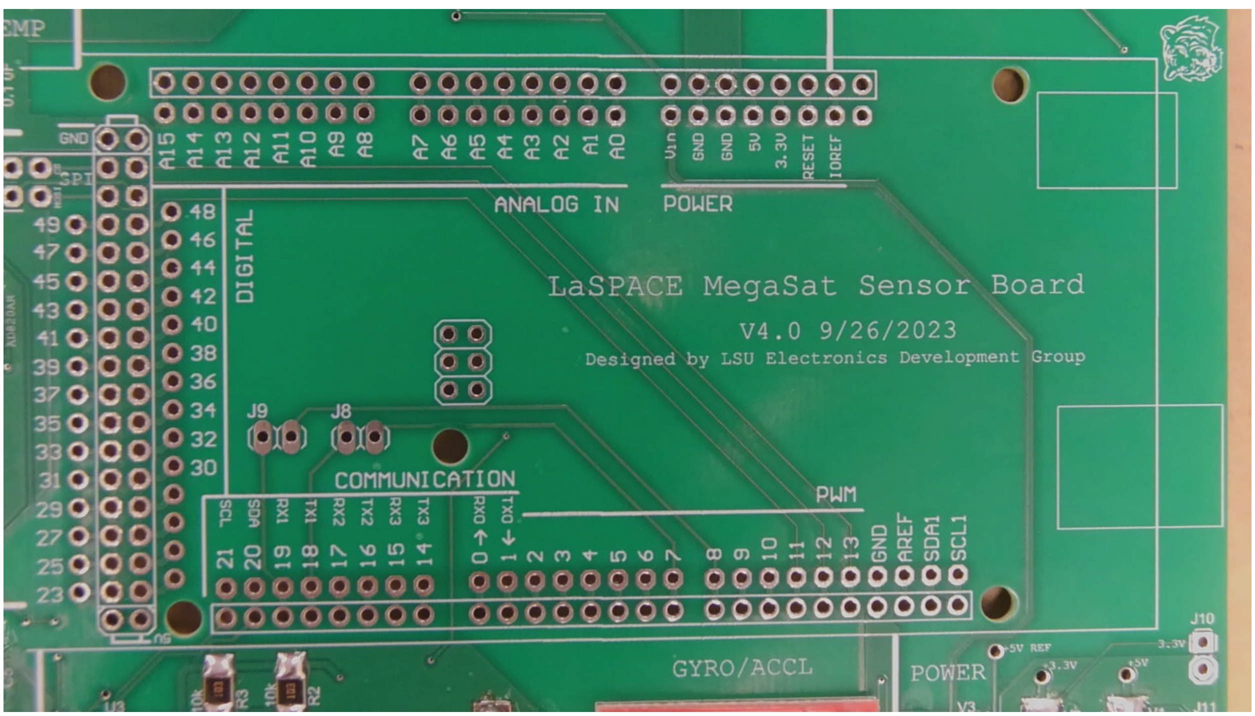


Figure 95: The location where the header pins shall be installed in the MegaSat board.

Arduino Hardware – Assembly

Arduino Hardware Assembly Step 1

We will first locate the location of each of the headers. Because of the difficulty in aligning the pins you will want to use a board a board that already has a of all of the headers soldered to hold the headers in alignment as you solder. You can use the Arduino, in which case it will need be below the MegaSat. As you add headers insert the pins through the MegaSAT board and into the headers of the Arduino. Leave a gap so you will be able to apply a small amount of solder the Arduino hold the headers alignment. the header pins.

Even better is if have an old MegaSAT. In that case you can place it on top the new MegaSAT and will line up the headers while leaving the pads clear for soldering.

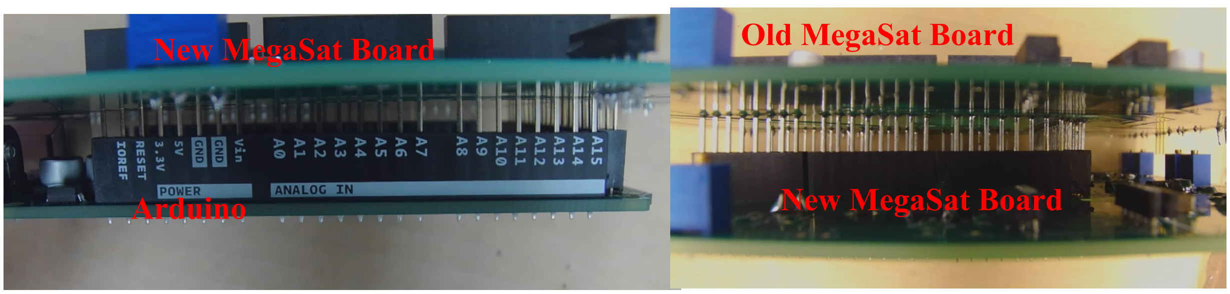


Figure 96: Adding solder the header pins while they are being aligned via the Arduino (left). Aligning the header pins with an old MegaSat Board (right)

Arduino Hardware Assembly Step 2

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 or pliers may be useful to slightly move the pins to get the pins to align with the holes.

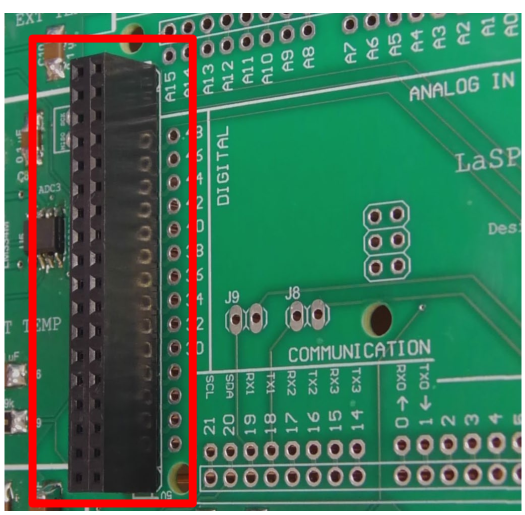


Figure 97: Location of 36-pin header.

Arduino Hardware Assembly Step 3

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

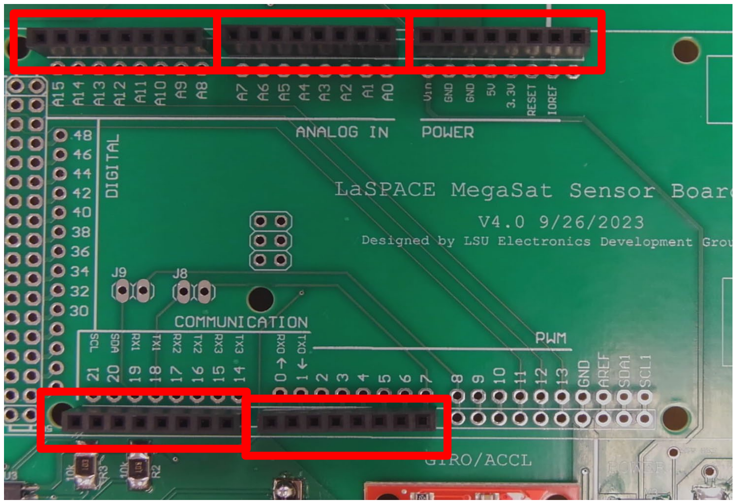


Figure 98: Installing the 8-pin headers in place.

Arduino Hardware Assembly Step 4

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

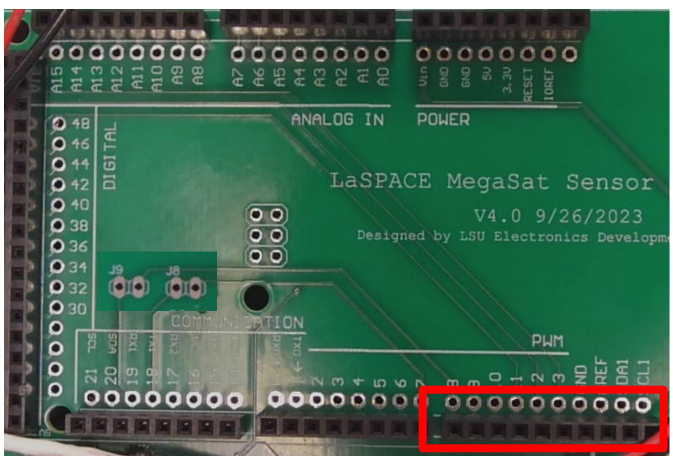


Figure 99: Location of the 10-pin header.

Arduino Hardware Assembly Step 4

Ensure that the headers are all aligned correctly. The headers should be flush with the top of the MegaSAT PCB. 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 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 just get the pins held in place.

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, taking care not to bend the pins.

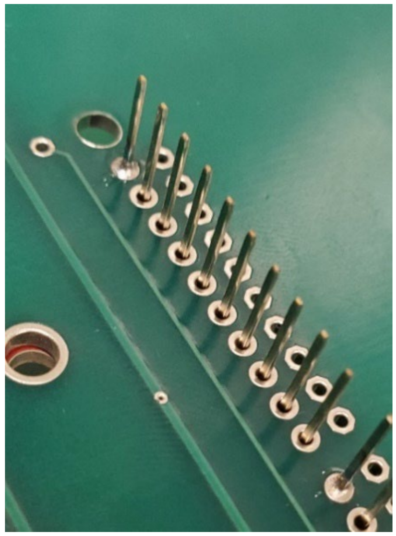


Figure 100: After removing Arduino should header with some solder holding header in place and majority of pins unsoldered.

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 solder bridges exist between adjacent pins.

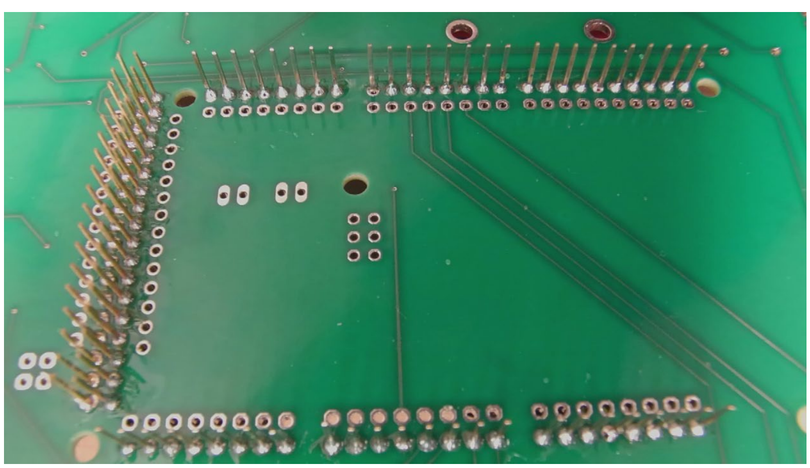


Figure 101: Completely Soldered Header Pins from bottom of the board.

Arduino Hardware Assembly Step 6

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

Assembled Arduino Headers

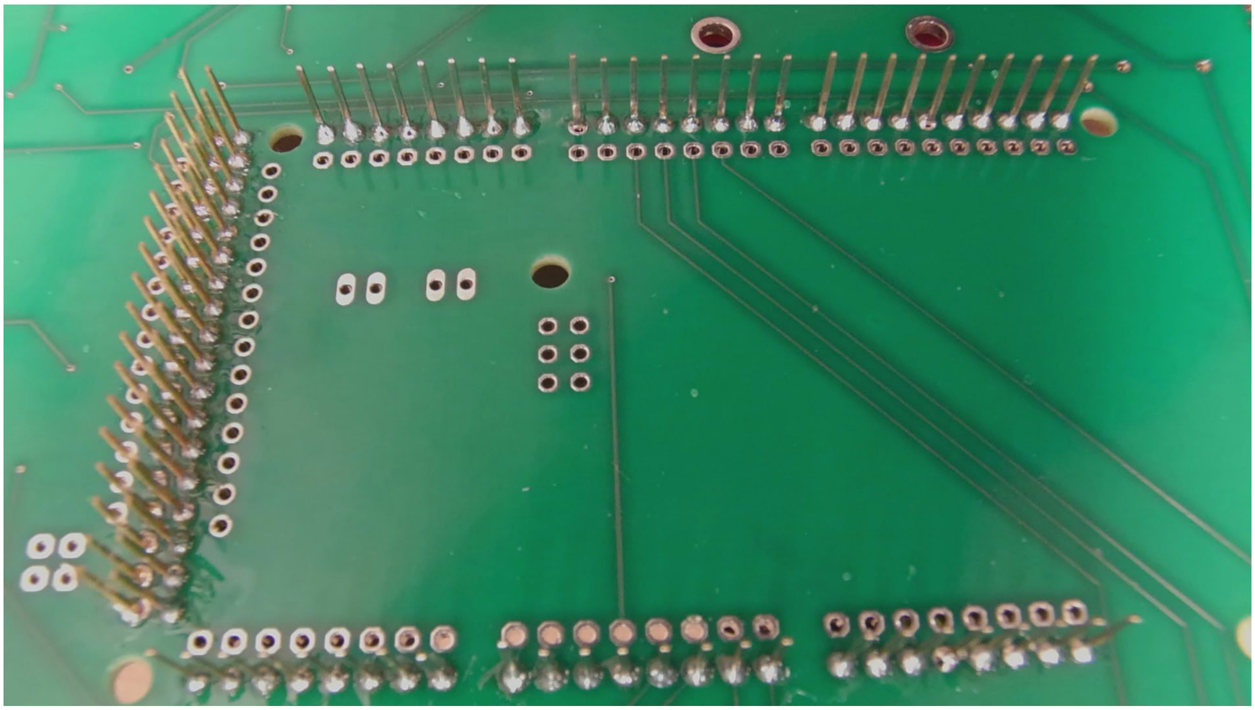


Figure 102: Completed Soldered Arduino Header Pins

MegaSat Assembly – GPS Logger Shield

The Adafruit Ultimate GPS Logger Shield will be included in MegaSAT Payload stack. Since the logger shield does not have the full set of header pins and only has single-sided header pins, the GPS shield be installed at the top of the payload stack. You should have previously assembled the shield, but refer to Activity 14.01 for assembly instructions.

The MegaSAT includes a set of jumpers that will connect the "Soft Serial" Pins of GPS (Arduino Pins 7 and 8) to the pins for Serial1 (Arduino Pins 18 and 19). These perform the same function as the wire jumpers you installed on the GPS shield, but provide a more permanent, stable connection.

GPS Logger Shield – Parts List (Located inside the 4.0 Update Module bag)

- ☐ Breakaway Headers (2-Pin) x2
- ☐ 2-pin Jumper x 2

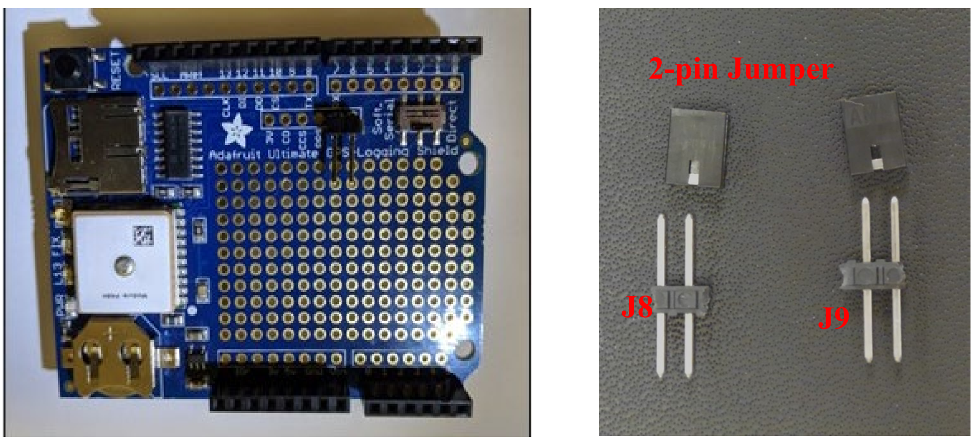


Figure 103: Adafruit GPS Logger Shield (left) and jumper connectors (right).

GPS Logger Shield Assembly Step 1

Locate J8, J9 and two 2-pin headers. Solder the header in place. Install these jumpers on the top side of the MegaSAT with the plastic flush against the board, soldering the pins to pads on the back side of the board.

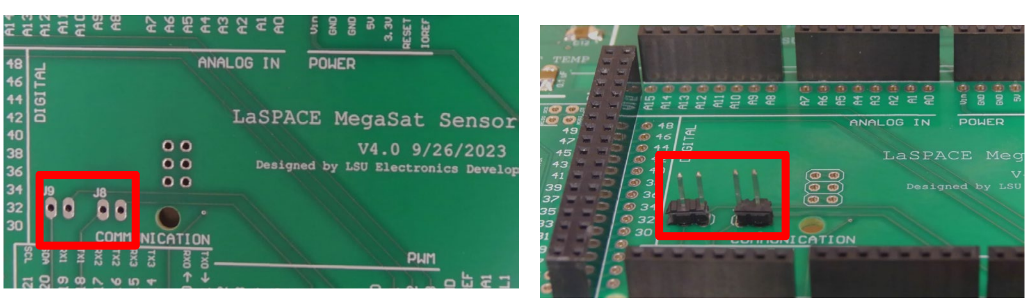


Figure 104: The installation location of jumpers J8 and J9 (left). Headers should be installed on top of the board with plastic flush with the surface of the PCB (right).

GPS Logger Shield Assembly Step 2

The headers themselves do not complete the electrical connection. By installing the jumper, you short the pins together and complete the connection.

The 2-pin jumper slides over the header pins and will function with either side up. If needed, you can remove the jumper to break the connection.

Remember that the GPS switch must be in "**Soft. Serial**" for this to operate correctly.

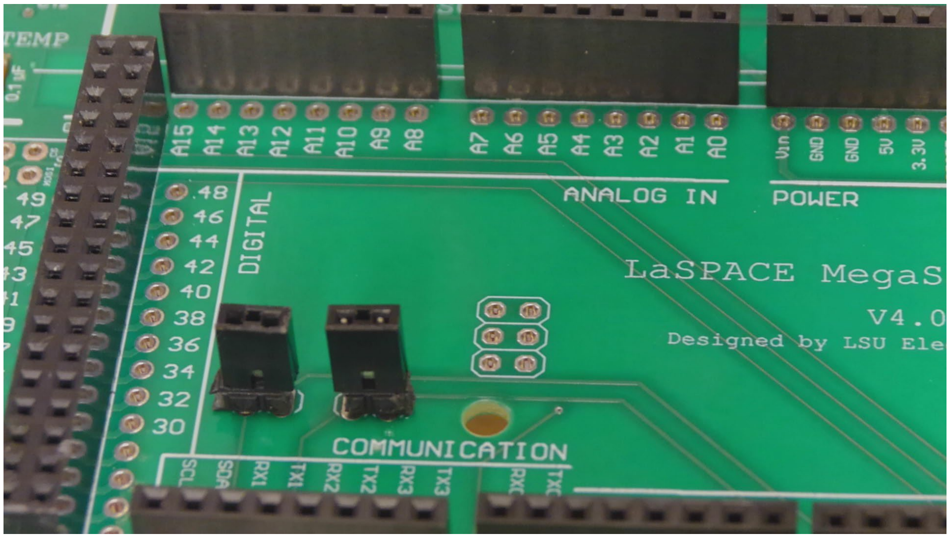


Figure 105: 2-pin jumper for GPS installed on J8 and J9.

Assembled GPS Logger Shield

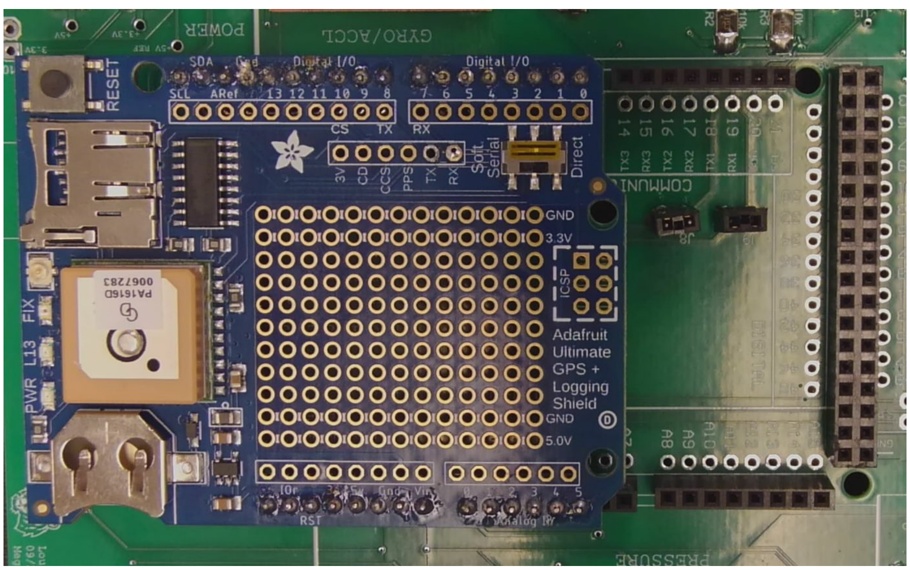


Figure 106: Assembled GPS Logger Shield

MegaSat Assembly – Sensors

It is now time to assemble 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 similar to what was done with diodes for the capstone temperature 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 expensive crimping tool [11].

If you do not have access to a crimping tool it is recommended to instead you solder your sensor lead wires directly into the MegaSAT board. Since you most likely want to cover with leads with heat shrink or liquid electrical tape, be sure to use different colored wire for each lead.

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 Module – Parts List

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

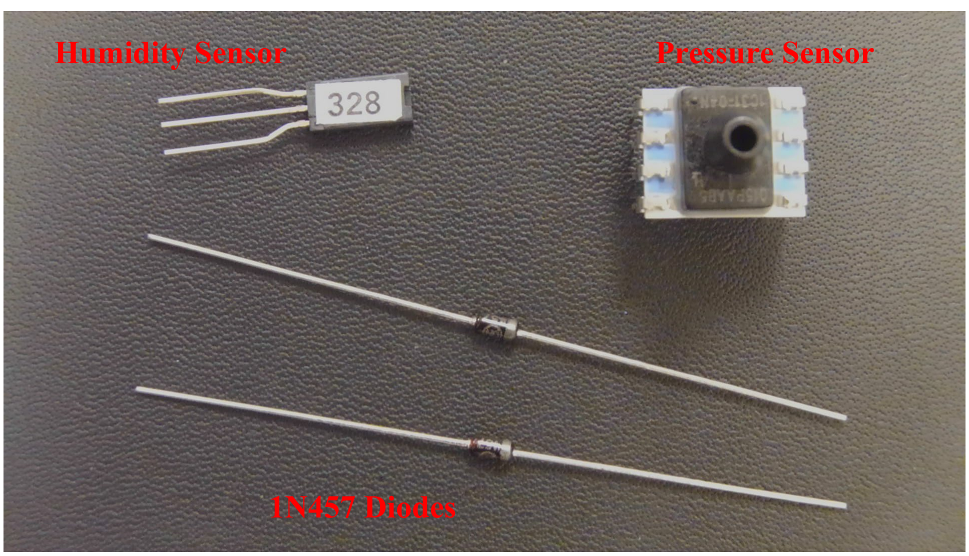


Figure 107: Sensors

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.

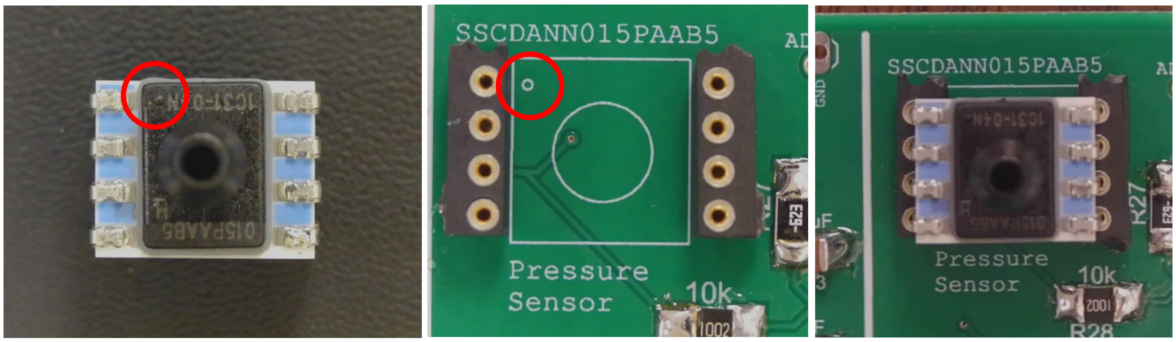


Figure 108: Alignment markings on the pressure sensor (left), silkscreen (center), and the correct orientation of the installed sensor in the socket.

Sensors Assembly Step 2

Locate the 1N457 diodes. These will be our temperature sensors, it is recommended to use one inside your payload and one outside.

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 is recommended you bend the lead of the diode in a 180 bend with a gentle large radius like in the figure below. While not required, this makes it less likely you will break the leads, while making the temperature sensor relatively compact.

Figure 109: Pre-bent diode for temperature sensor.

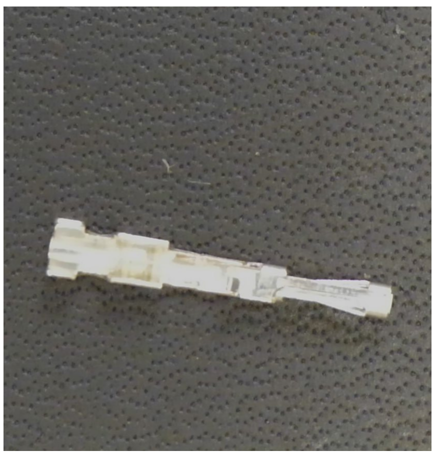
Sensors Assembly Step 4

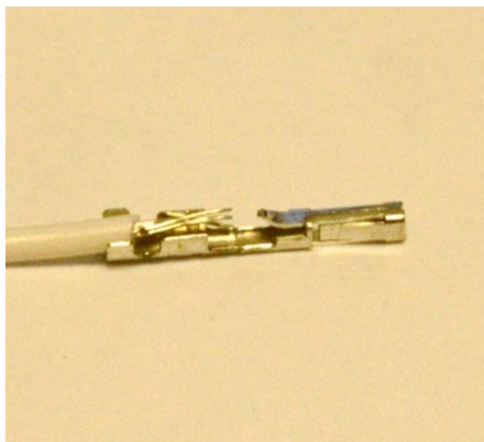
At this point it would be a good time to apply a waterproofing method such as heat shrink or liquid electrical tape to your sensor. You want your sensor waterproof to allow for calibration in a water bath and to protect against condensation.

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.

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.





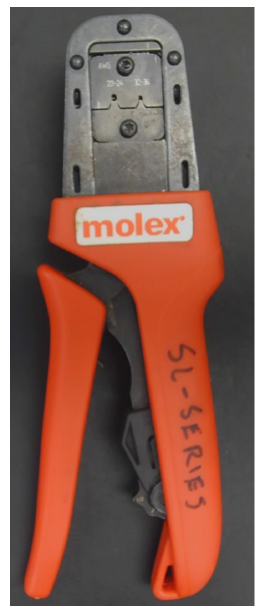


Figure 110: The crimps used for connecting sensors. Middle shows the approximate length of wire you should strip for crimping, notice the back set of tabs on the crimp should fold over insulation and the right front on bare wire. Right: shows the crimping tool.

Sensors Assembly Step 6 (Crimp Method Only)

Insert the crimp and wire into the correct size jaws and of the crimping tool. They will be labeled with a size(for example20-24AWG). Squeeze the the crimping tool until the ratchet releases. 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.

In the event of a bad or malformed crimp you should cut with wire just behind the crimp and reattempt to crimp.

Figure 111: Wire lead after crimping. Again, notice the back set of tabs on the crimp should fold over insulation and the right front on bare wire

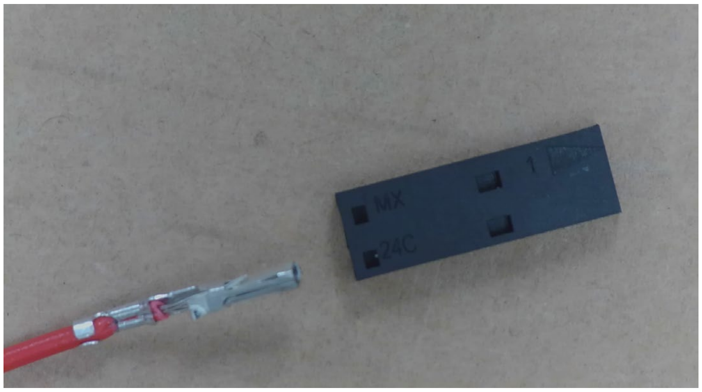
Sensors Assembly Step 7 (Crimp Method Only)

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.



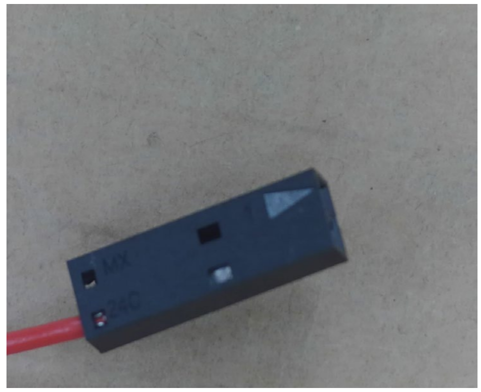


Figure 112: Inserting the crimp into the receptacle.

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.

The humidity sensor has three pins: input power, output signal, and ground. Checking the data sheet we can see (-) is on the left, (+) on the right and out in the middle when viewing the sensor (not the calibration number sticker).

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

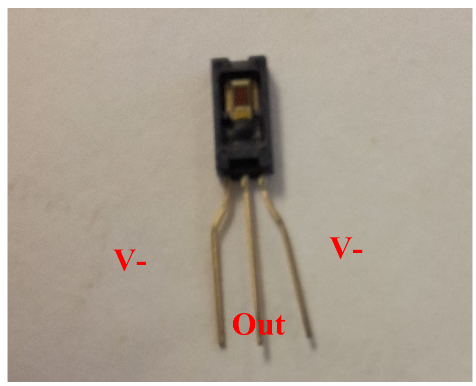


Figure 113: Humidity sensor with pin orientation when viewing sensor.

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.

Tips for Success

The right-angle headers have straight leads and bent leads. 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.

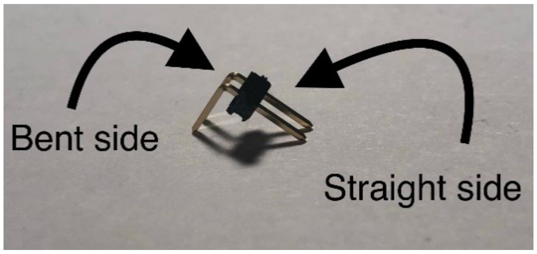


Figure 114: Straight and bent side of right angle headers.

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 16 (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 17 (Crimp Method Only)

Attempt to install one of your temperature sensors on the 2-pin header. Make sure there is enough clearance over the resistors and IC to connect your sensor.

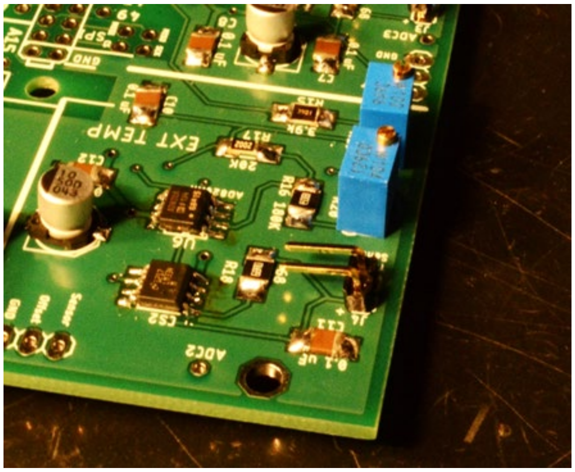


Figure 115: Installed 2-pin right angle header.

Sensors Assembly Step 18 (Crimp Method Only)

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

Sensors Assembly Step 19 (Crimp Method Only)

Repeat for the 3-pin connector and pad J2.

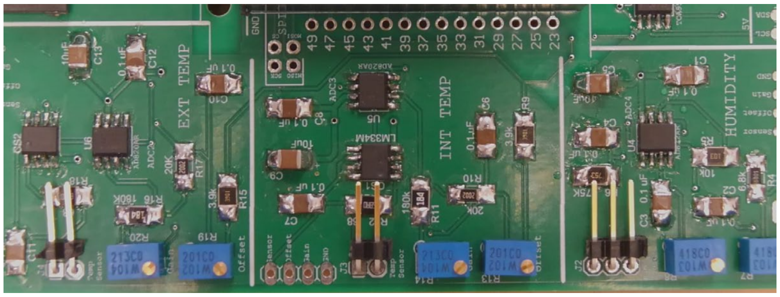


Figure 116: Note: The connections should still work with the connections soldered in either orientation but the orientation of figure 109 is recommended.

Sensors Assembly Step 18 (Crimp Method Only)

Install the assembled temperature and humidity sensors onto the connectors installed at J2, J3, and J4. Ensure that the orientation of each connector is correct and that you can feel solid contact, with no loose connections. It is recommended to use hot glue to secure connections immediately prior to flight.

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.

Assembled MegaSat

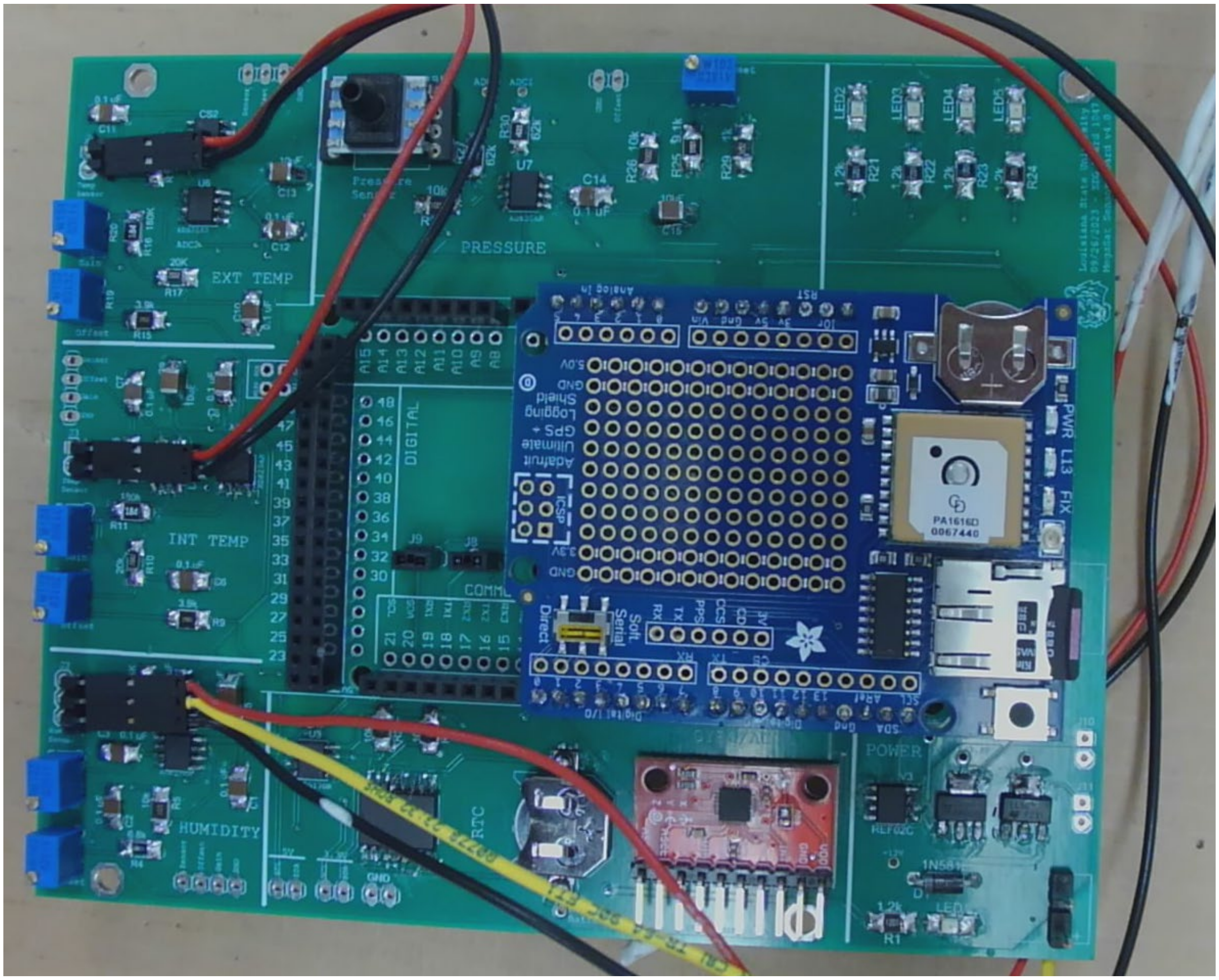


Figure 117: Assembled MegaSat board with all components installed.

Appendix A – Setting the Gain and Offset of Sensor Circuits

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

By combining series resistors or splitting potentiometers into two resistors we find that all three are a version of the non-inverting amplifier with offset circuit shown below.

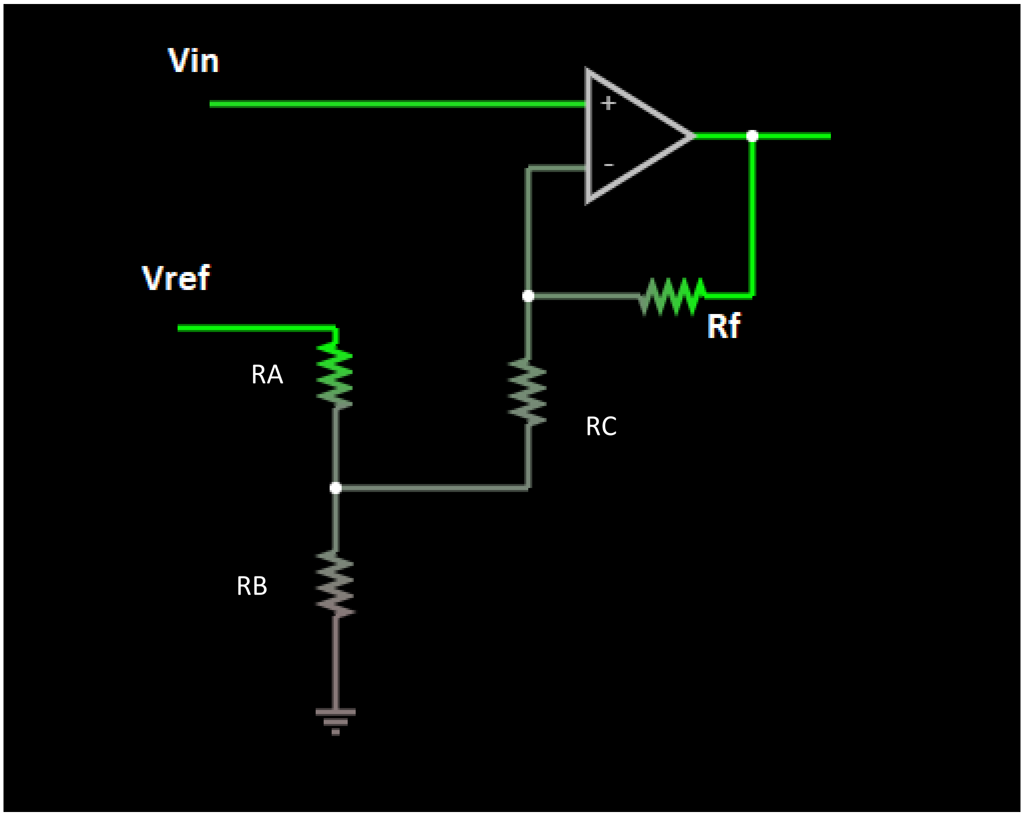


Figure 118: Simplified circuit for Pressure, Temperature and first stage Humidity amplifiers. Not the resistor numbers here are just generic designators and do not correspond to designators on the MegaSat Board. For example, R1 above has nothing to do with R1 on the MegaSat (part of the power circuit). Likewise the values for resistance and voltage should be ignored.

If we compare the above circuit to pressure, temperature, and humidity circuits we can determine which resistors in each real circuit are equivalent to the resistors in the generic circuit.

Table 3 Amplifying Circuit Equivalent Resistors

Generic Noninverting Op Amp with Offset	Internal Temperature	External Temperature	Pressure	Humidity First Stage
Rf	R11 + R14	R16+R20	R30	R5
RA	R9+Upper half of R13	R15 + Upper half of R19	R31+R25	Upper Half of R7
RB	Lower Half of R13	Lower Half of R19	R29	Lower Half of R7
RC	R10	R17	R26	R4

In this case “upper” and “lower” refer to the two resistance values of the potentiometer that change as we adjust the middle pin and refer to the orientation as shown in the schematics. For example “Upper-half of R19” means the resistance between R15 and the middle pin of R19, “lower half” means the resistance between the middle pin ground. Because the potentiometer has a fixed total resistance when you increase the upper half, you decrease the lower half.

Using circuit analysis, we can solve for the transfer equation of the generic circuit.

Equation 1: Generic Noninverting amplifier transfer equation.

$$V_o = \left[1 + \frac{\frac{R_f}{R_A} + \frac{R_f}{R_B}}{1 + \frac{R_C}{R_B} + \frac{R_C}{R_A}}\right] V_{in} - \left[\frac{R_f}{R_A} * \frac{1}{1 + \frac{R_C}{R_B} + \frac{R_C}{R_A}}\right] V_{ref}$$

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 obtained from the datasheets of circuits to determine an initial setting for our potentiometers.

As you can see the equations are quite complicated so solving for the settings of the potentiometer without using a computer solve is difficult.

Excel file R27.01_Megasat_AMP_tool.xlsx includes a calculator for each gain and offset based on potentiometer settings.

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 adjust the values to give 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 read 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.

The examples here will use the expected response to calculate values for the potentiometers.

Calculating the desired gain and offset for temperature circuits

Internal and External Temperature

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 lets assume we want -50 to 100 C. This corresponds to a diode voltage of 0.4125V (at 100C) to 0.7875V (at -50C) for the internal temperature. This to amplify those to 0V and 5V we need a gain of 13.3 and offset of -5.5

If we choose a range of -70C to 70C for the external temperature the values are 0.4875 (70C) to 0.8375V (-70C) and a gain of 14.3 and offset of -6.96

Note for your payload you should select the values based on the requirements you establish in your design reviews, as well as the performance of your diode to calculate your target gain and offset.

Table 4: Example Gain and offset values for temperature circuit.

Sensor	Min Temperature Value	Max Temperature Value	Minimum input Signal Voltage	Maximum input Signal Voltage	Gain	Offset
Internal Temp	**-50ºC**	**100ºC**	**0.4125V (@100ºC)**	**0.7875V (@-10ºC)**	**13.3**	**-5.5**
External Temp	**-70ºC**	**70ºC**	**0.4875V (@70ºC)**	**0.8375V (@-70ºC)**	**14.3**	**-6.96**

By plottingt the gain and offset values for all possible settings of the offset resistor (R19 or R13) and gain resistors (R20 or R14) we get a plot like the one below.

By looking at the shape we can see each of the potentiometers actually affects both the gain and offset. For example, if we look at the left side, we can see as we lower the offset from 0 to -9 we will also cause a small decrease in the gain.

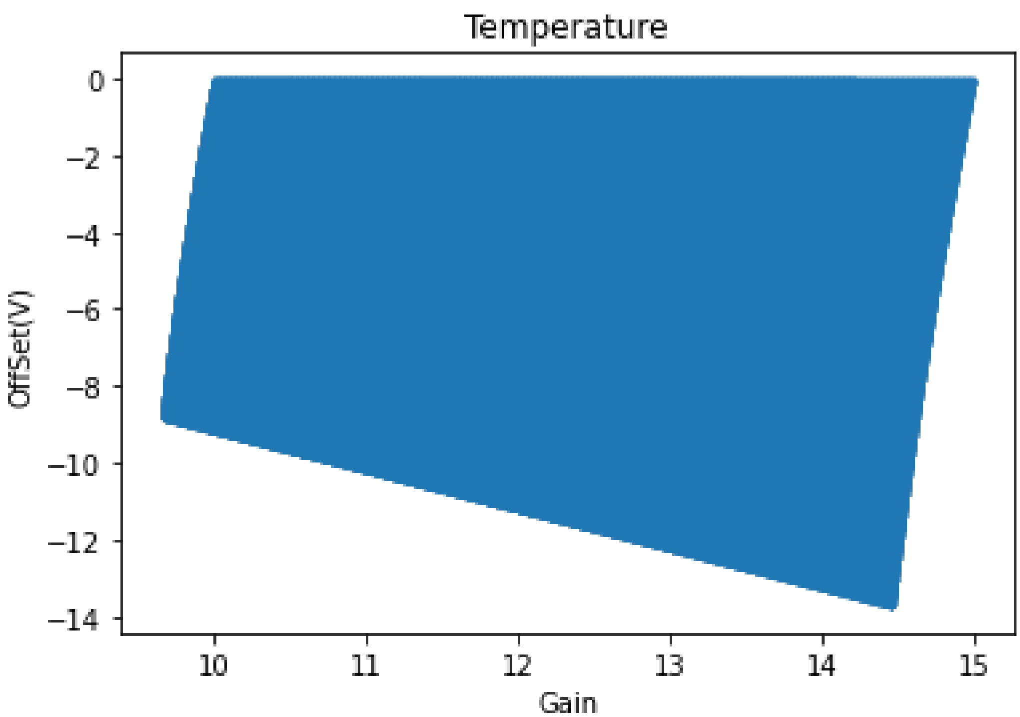


Figure 119: Range of possible values of gain and offset for internal and external temperature amplifiers.

If we solve for the resistance values to give the gains from table 4:

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.

Remember your diodes may behave differently and you may want different temperature ranges so you will likely need different settings. Since it can be difficult to solve for those values it is recommended to use the calculator in the **Excel R27** to tweak the values for the potentiometers until you get close to your desired gain and offset. Remember your amplfier components all have tolerances so the actual circuit behavior will vary slightly anyway.10

Calculating the desired gain and offset for humidity circuit

Humidity

If we look at the humidity circuit we see it has two amplifying stages. The first stage is similar to the temperature circuit and the generic noninverting amplifier. Therefore, Equation 1 and the substitutions of Table XX apply. With R7 being the only potentiometer that can be adjusted to affect the gain and offset.

The output voltage of that first stage is reduced by the voltage divider R8 and then sent to the second stage which is an amplifier of Gain 1. That combination acts like an amplifier with gain of less than 1.

Since the first stage of the humidity circuit just has the single potentiometer, if we plot the gain and offset as a function of R7, we see it is much simpler and forms a curve rather than a region. We can see also that R7 mostly affects the offset with the and the gain will be about 2.

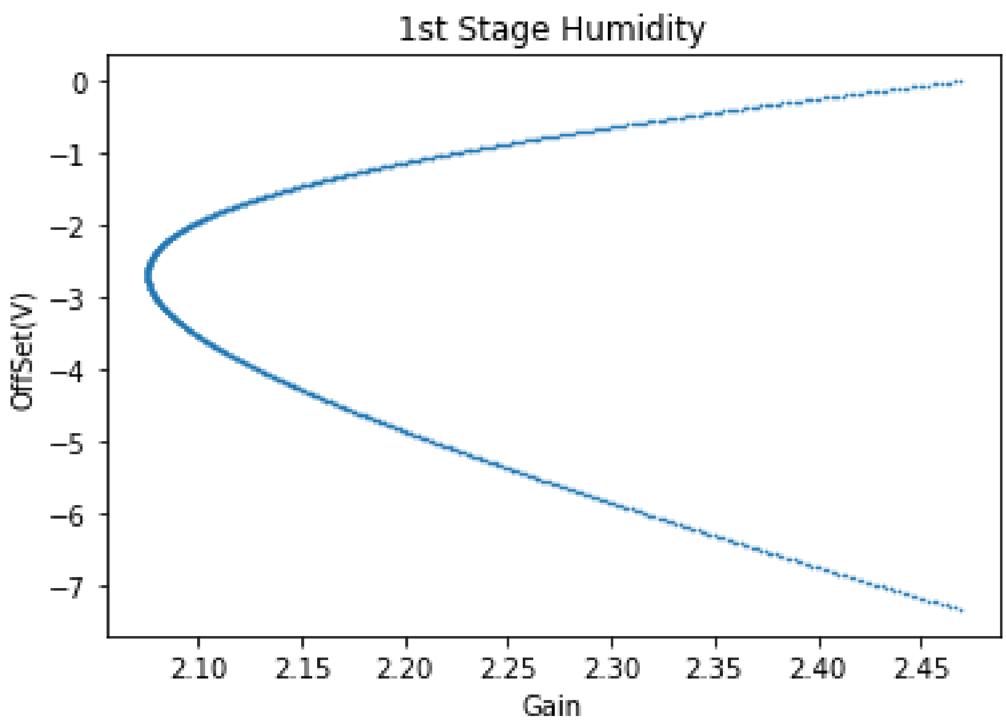


Figure 120: Gain and Offset of first stage of humidity circuit.

To determine how to set R7, we consider that the 2nd stage has no offset. This means we want to use the first stage to set our 0% humidity close to 0V output on the first stage because that will stay close to 0V after the 2nd stage. Then we will use R8 and the second stage to adjust the 100% voltage close to 5V

If we look at the calibration sheet that came with the humidity sensor, we see the value at 0% humidity is about 0.8V, and the value at 75% is about 3V. Since we know we will have a gain of about 2, we will want an offset of about 1.6 (2 * 0.8V).

So if we set the upper half of R7 to 7000 ohms we get the transfer equation of:

Equation 2: First stage humidity transfer equation when R7 Upper is set to 7000Ohm

$$V_{out} = 2.1 * V_{in} - 1.69$$

Plugging in 0.8V and 3.73 (the expected voltage) value at 100% we get 0.013V and 6.24V.

So now we will want to calculate the value of R8 upper so that 3.73V is close to 5V on the output of the second stage. We just divide 6.24V by 5V and see we want our voltage divider to reduce the output by a factor of 0.8. So we want to set R8 upper to 2000 ohm (or R8 lower to 8000).

Table 5: Gain and Offsets of humidity circuit.

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	3.73V	2.12	-1.69

Sensor	Min Physical Value	Max Physical Value	First Stage Output Min Value	First Stage Output Max Value	Gain	Offset
2nd Stage Humidity	0% RH	100% RH	0.8V	3.9V	0.8	0

Calculating the desired gain and offset for temperature circuits

High Gain Pressure

The high gain circuit for the pressure is like the humidity circuit in that it has one potentiometer that adjusts the offset and fixed gain.

The amplified pressure should give a range of ~ 2.8 psi from minimum pressure to max pressure. At -2.8V offset that range should be from ~-0.3-2.5 psia, and at -1.4V offset, the range is from -1.1 to +1.7 psia.
NOTE: Absolute pressure does not actually go negative, the numbers above are just what the minimum value would be if you extrapolated down to 0V.
Since the real ADC and amplifier will not go all the way to 0V it is recommended to set the offset to the smallest magnitude of -1.4V to prevent cutting off 0 psia. This occurs when R31 is at the max value of 10kOhm. Then the pressure range can then be slowly adjusted higher if desired.

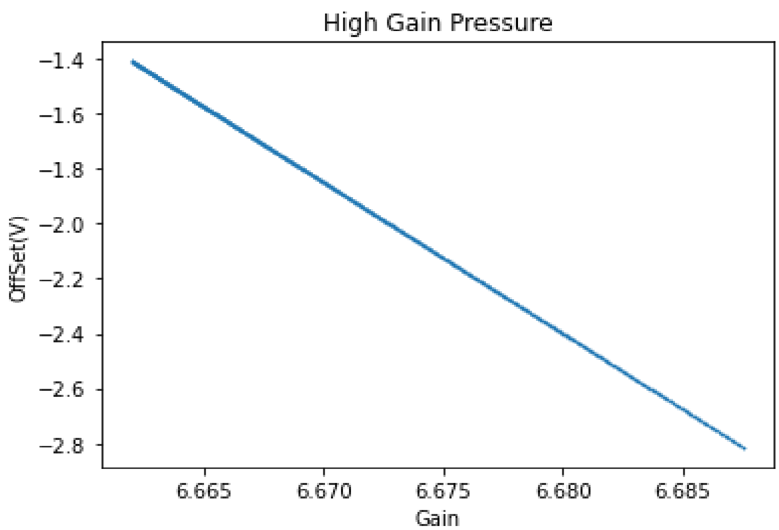


Figure 121: Gain and Offset ranges possible for high gain pressure range.

Table 6: Summary of Gain and Offset Calculation results.

Sensor	Resistor 1	Resistor 1 Value	Resistor 2	Resistor 2 value	Target Gain	Target Offset
Internal Temp	R14	71500	R13 Lower	437	13.3	-5.5
External Temp	R20	92000	R19 Lower	513	14.3	-6.96
1st Stage Humid.	R7 Lower	3000			2.221	-1.69
2nd Stage Humid.	R8 Lower	8000			0.8	0
High Gain Pressure	R31	10000			6.66	-1.4

We so now we have are ready to begin setting the resistors. It is recommended to have two people when setting the resistors so one person can hold the meter while a second adjusts the screwhead.

Setting Internal Temp Gain (R14)

To measure R14 place one probe on the testpoint labeled "Gain" and the other on the resistor going into the 100kΩ potentiometer, in this case R11. Make sure you are on the correct side of R14, if your measured resistance varies from 180-280Kohm instead of 0-100Kohm you are on the wrong side.

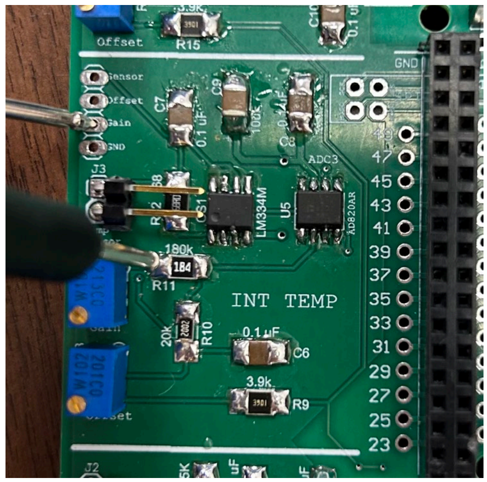


Figure 122: Positioning of multimeter leads to set gain of Internal Temperature Module.

Setting External Temp Gain (R20)

To measure R20 place one probe on the testpoint labeled "Gain" and the other on the resistor going into the 100kΩ potentiometer, in this case R11. Make sure you are on the correct side of R14, if your measured resistance varies from 180-280Kohm instead of 0-100Kohm you are on the wrong side.

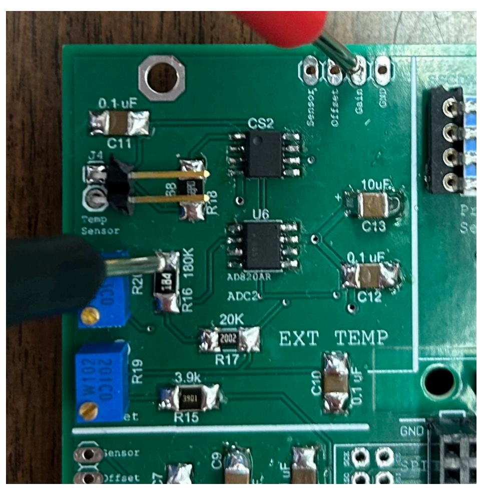


Figure 123: Positioning of multimeter leads to set gain of External Temperature Module.

Setting the Internal Temp Offset (R13)

Locate the two test points labeled “Offset” and “GND”. We will notice something strange as we adjust he values of the offset resistors like R13. You will find that you will be unable to adjust the potentiometer to its full value of 1000 ohms and it will instead max out at 870 ohms.

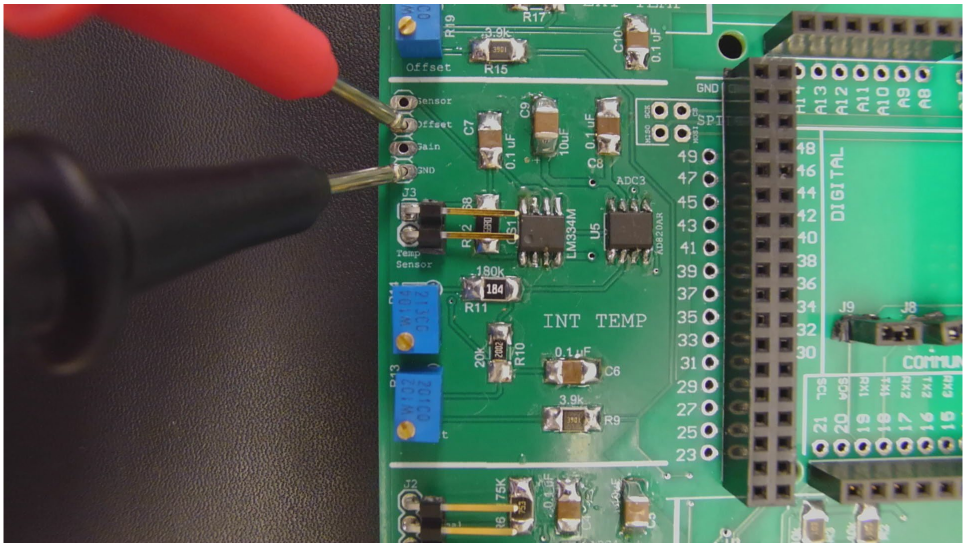


Figure 124: Positioning of multimeter leads to set gain of Internal Temperature Module.

Setting offsets – Parallel Resistances

Looking at schematic, notice that all of the offset resistors are connected to both the 5V reference and ground. This means when we are measuring that resist we a measuring the parallel combination of the resistor we are trying to set **AND** all of the other offset resistances.

$$R_{measured} = \left(\frac{1}{R_{lower}} + \frac{1}{R_{everything}}\right)^{-1}$$

The amplifier Excel R.27 includes calculators that will calculate the measured values of R13, R19, R7 and R31 based on the desired setting. You can change the desired value on each sheet to determine what your measured values should be.

For R13 lower half to get a value of 437 ohms we should adjust until the value reads 412 ohms on the meter

Setting the External Temp Offset (R19)

Repeat the process for R19, for a target value of 513 we should measure 479 ohms.

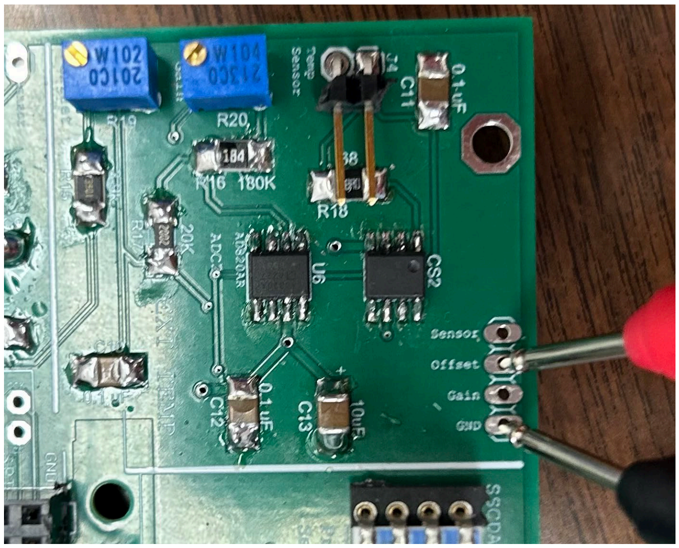


Figure 125: Positioning of multimeter leads to set gain of Internal Temperature Module.

Setting the first stage humidity amplifier (R7)

To set R7 we want the want our multimeter on the offset and GND test points. However if for this there is an addition complication. As you adjust R7 you will notice it will increase from 0 reach a maximum just over 2250 ohms and then decrease.

Because of this there are two different settings that give the same measured values. For example for our target value of 3000 ohms we want to read 2085 ohms on our meter. By looking at the plot we can see this is left of maximum.

So to set R7 we first adjust it 0 ohms (all the way left on the plot) and the increase it until we hit our desired value.

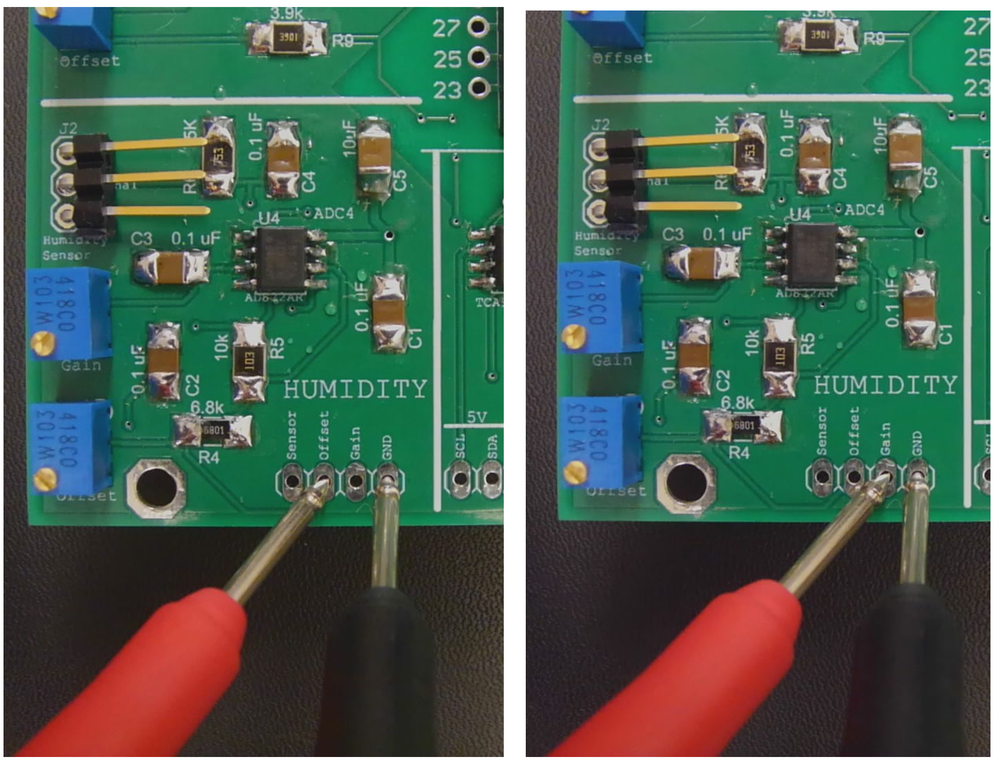


Figure 126: Positioning of multimeter leads to set gain (right) and offset (left) of Humidity Module.

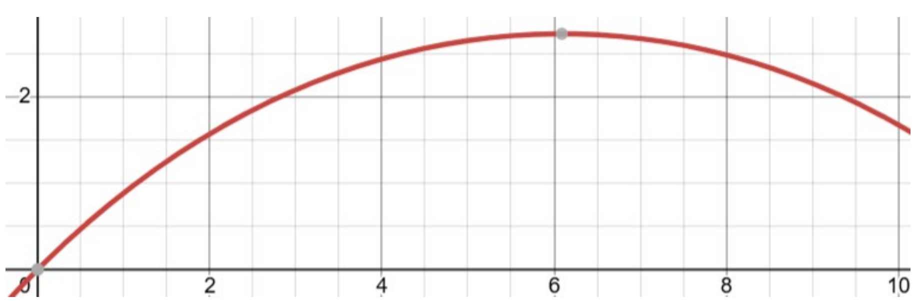


Figure 127: The measured resistance (y-axis) for R7 lower will actually rise, reach a maximum and then decrease as raise tis true value.

Setting the second stage humidity amplifier (R8)

Luckily R8 does not have any parallel paths and will measure the true value for the lower half. So we just need to adjust it to our target value of 2000 ohms.

Setting the pressure (R31)

Finally, we need to set R31. We want our probes on the offset test point and R29 as shown in the image. As previously stated the recommended initial value is to set R31 to its max value.

This should occur when the meter reads ~5500 ohms

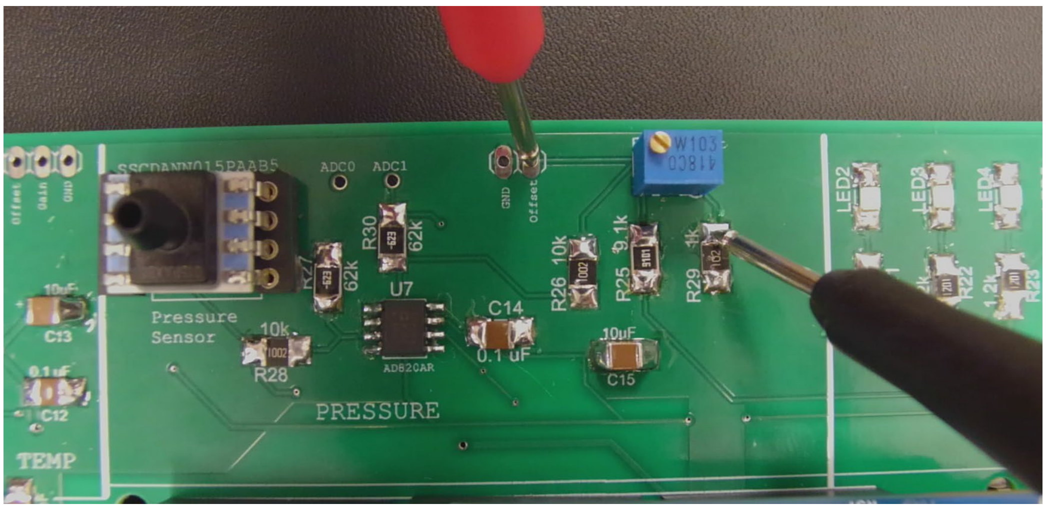
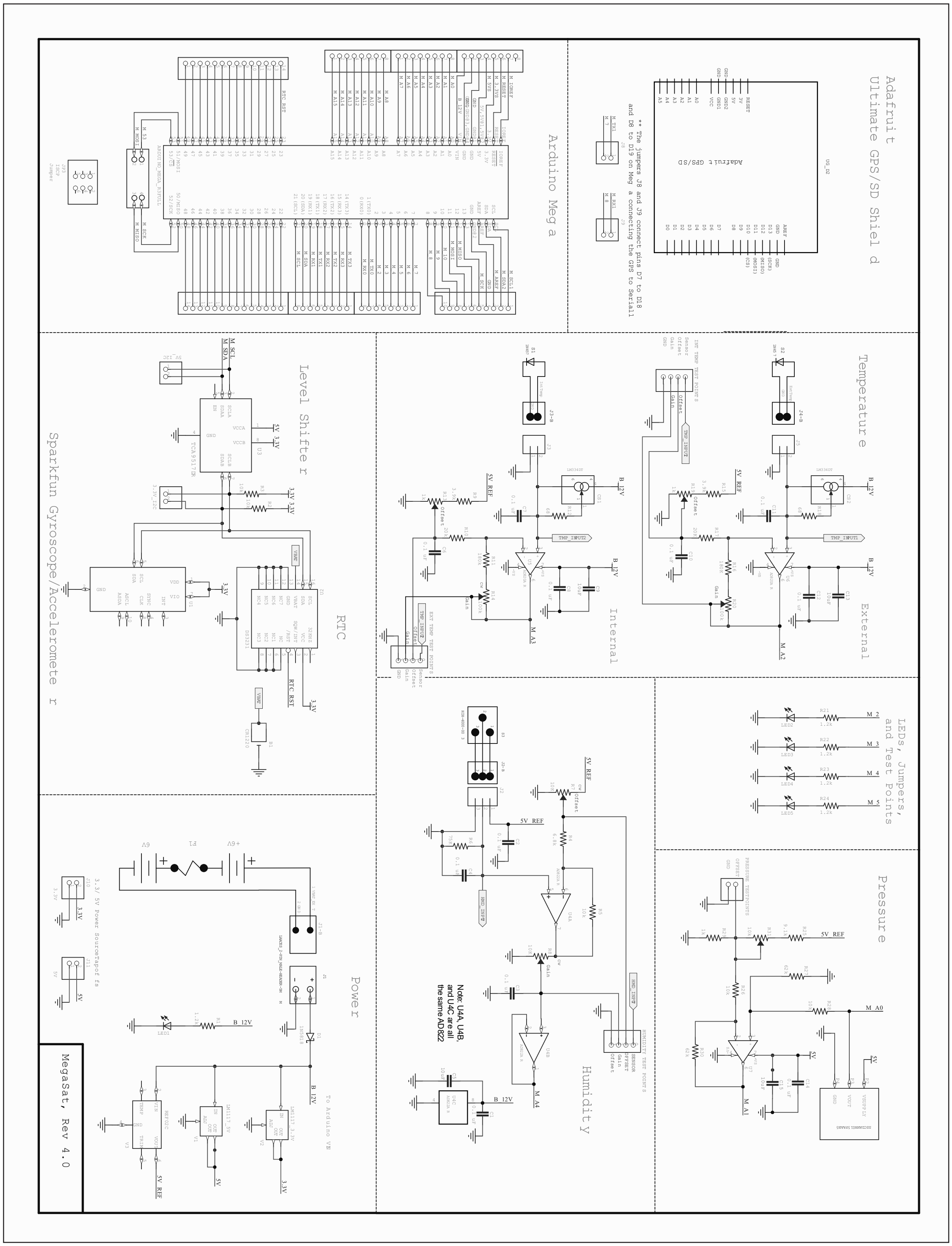


Figure 128: Positioning of multimeter leads to set and offset of Humidity Module.

Congratulations your MegaSAT should now be fully assembled

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**
Shared with IMU	**SDA**	**20**
Shared with IMU	**SCL**	**21**
IMU (I2C Address:0x69) Shared with IMU	**SDA**	**20**
Shared with RTC	**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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