



engineeringworldhealth

PRESSURE CALIBRATION KIT

Assembly Instructions

Pressure Calibration Kit Assembly Instructions

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engineeringworldhealth

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Pressure Calibration Kit Assembly Instructions

Overview

Blood pressure is an important contributor to our health as high blood pressure can be indicative of heart disease, which is the leading cause of death worldwide (<https://www.who.int/news-room/fact-sheets/detail/the-top-10-causes-of-death>). Monitoring blood pressure is one of the most basic techniques medical practitioners can use to ensure their patients are healthy and maintaining habits that keep them so, including eating a balanced diet and exercising regularly. Therefore, it is very important that the devices used to measure the blood pressure are accurate, as an inaccurate measurement may lead to an incorrect diagnosis or oversight of a major health issue. Thus, healthcare workers need to make sure that their instruments are well calibrated so that they know the results obtained from patients are accurate and a correct diagnosis may be given. This Kit will guide students through building their very own pressure sensor, which may then be calibrated so that the Kit may be used to measure “unknown” pressures, including the blood pressure of the students.

Currently, this Kit is only available as a solderable version. Because the Kit has many pieces and may be relatively complicated for students who have no experience soldering, it is recommended that the solderable Kit be used for advanced high school or college classrooms. A later version of the Kit may come with many components pre-assembled, allowing for more of a plug-and-play utility and extending the use of the Kit to middle and high school students.

Purchase of this Kit comes with all of the Kit components listed in Table 1. It does not include soldering materials (Table 2). For classrooms that need these materials, they can support Engineering World Health even more by purchasing them from EWH’s Amazon page, <https://www.amazon.com/shop/engineeringworldhealth>.

Kit Disclaimer

Engineering World Health’s Pressure Calibration Kit is **an educational tool only and is not to be used for any other purpose, including any medical, diagnostic or other laboratory applications.**

Assembled Kits may be used for future projects, or returned to EWH to be recycled.

EWH tried to choose low-cost components available in resource-poor areas, so that BMETs in training can repair their Kits if necessary. Nevertheless, EWH Chapters are welcome to improve the equipment, for example, changing switches or building a case. Thank you for purchasing EWH Kits, which helps EWH improve health care in resource-limited settings by training biomedical engineering technicians and which gives STEM practice to the next generation of engineers.

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Important Guidelines and Safety Measures

General

- Never assemble or disassemble the circuit while it is turned on. To ensure safety, it is recommended that the batteries be left out until the entire circuit is assembled and ready to test.
- Safety goggles should be worn when assembling the Kits.
- Be extremely cautious with all materials, especially as the components' legs may be sharp.
- Be wary of electrostatic discharge while handling components, as this may damage the board. This is most concerning in cold, dry climates. To keep oneself and the components safe, keep components in their antistatic protection bags until you are ready to install them.
 - For extra precaution, one may wear an ESD strap connected to a proper ground when handling parts if available. If it is not available, touch some metal object just before handling the electronic components to discharge.
- Each component comes in labeled bags (Figure 1). To avoid confusing the components, only open each bag when you are ready to assemble that component.



Figure 1 – Component description, value, and schematic ID is on each bag

Soldering

- Always wear safety goggles when soldering.
- Make sure the circuit is OFF before beginning soldering.
- Solder in a well ventilated space to prevent fume buildup that may cause irritation
- Soldering can be dangerous due to the temperature required to melt the solder
 - Always be cognizant of where the soldering iron is. Make sure to put it back in the holder when not in use. Do NOT put it directly on a work surface.
 - Melted solder is hot but will cool rapidly; to be safe, give it 10 seconds to cool.
 - Never catch a soldering iron if it falls! A soldering iron tip can be replaced.
 - Never leave flammable items (paper, clothing, etc.) near a soldering iron.
- Unplug the iron when it is not in use.






























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Parts List








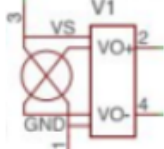




The parts provided by EWH as shown in Table 1. It is recommended that one does not remove the parts from their bags (see Figure 1) until it is time to assemble them in order to simplify the assembly process. Note that all of the resistors come in the same bag; in order to determine the values of each, use a multimeter to measure the resistance or Figure 2 to read the colored bands on the resistor to determine the resistance: then, use Table 1 to determine where to place each resistor.

Please note that EWH does not supply solder materials (see Table 2), goggles, or batteries. Each assembled Kit will need a 9 V battery to operate.

Table 1: Pressure Calibration parts list

Description	Value	Quantity	Schematic ID	Schematic Symbol	Image*
Printed Circuit Board	N/A	1	N/A	N/A	
Resistor	680 Ω	1	R38		
Resistor	1 k Ω (1,000 Ω)	11	R1, R11, R21, R22, R23, R24, R25, R26, R27, R28, R29		
Resistor	1.5 k Ω	1	R37		
Resistor	2.4 k Ω	1	R36		
Resistor	3.3 k Ω	1	R35		
Resistor	4.7 k Ω	1	R34		
Resistor	6.2 k Ω	1	R33		
Resistor	8.2 k Ω	1	R32		
Resistor	10 k Ω	13	R2, R3, R10, R12, R13, R14, R15, R16, R17, R18, R19, R20, R31		
Resistor	13 k Ω	1	R30		
Resistor	220 k Ω	6	R4, R5, R6, R7, R8, R9		
Capacitor	100 nF (0.0000001 F)	8	C1, C2, C3, C4, C5, C6, C7, C8		
Potentiometer	22 k Ω	1	RTRIMM1		
Potentiometer	470 k Ω	1	RTRIMM2		

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Integrated Circuit (IC)	N/A	3	IC1, IC2, IC3	 (for amplifier in IC)	
Socket for IC	N/A	3	IC1, IC2, IC3	N/A	
LED (green)	N/A	1	PWR		
LED (red)	N/A	9	LED1, LED2, LED3, LED4, LED5, LED6, LED7, LED8, LED9		
Pressure Sensor	N/A	1	Pressure Sensor		
Voltage Regulator	N/A	1	LDO		
Battery Connector	N/A	1	N/A	N/A	
PCB Rubber Feet	N/A	4	N/A	N/A	

*Component color and shape may vary depending on supplier availability; images are for illustrative purposes only.

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Band 1 Coding	Band 2 Coding	Band 3 Coding	Band 4 Coding
	0	x1	
1	1	x10	
2	2	x100	±2 %
3	3	x1k	
4	4	x10k	
5	5	x100k	
6	6	x1M	
7	7		
8	8	:10	±5 %
9	9	:100	±10 %

According to IEC 60062

(a)

Standard EIA Color Code Table 5 Band: ±1%, ±25%, ±5%, ±1%

Color	1st Band (1st figure)	2nd Band (2nd figure)	3rd Band (3rd figure)	4th Band (multiplier)	5th Band (tolerance)
Black	0	0	0	10 ⁰	
Brown	1	1	1	10 ¹	±1%
Red	2	2	2	10 ²	
Orange	3	3	3	10 ³	
Yellow	4	4	4	10 ⁴	
Green	5	5	5	10 ⁵	±5%
Blue	6	6	6	10 ⁶	±25%
Violet	7	7	7	10 ⁷	±1%
Gray	8	8	8	10 ⁸	
White	9	9	9	10 ⁹	
Gold				10 ⁻¹	

Chart Provided by

(b)

Figure 2: Resistor identification chart for resistors with 4 bands (a) and 5 bands (b). It's always smart to check the resistance with a multimeter, if available.

Soldering Instructions

Tools List

The tools needed for soldering are shown in Table 2. These tools are NOT provided by EWH but may be purchased at <https://www.amazon.com/shop/engineeringworldhealth>.

Description	Image*
Soldering Iron	
Solder	
Eye goggles	
Cutting pliers	
Solder flux	
9V battery	

Table 2: Tools needed for soldering

Please review the soldering safety instructions and guidelines (Page 4) before continuing.

Pressure Calibration Kit Assembly Instructions

Solder Technique

The best way to learn how to solder is to practice! For a beginners' guide on how to solder, these Youtube videos are a good place to start:

- http://www.youtube.com/watch?v=l_NU2ruzyc4
- <http://www.youtube.com/watch?v=eU4t0Yko9Uk>

The main steps to soldering components are shown in Table 3. For the best results, apply solder flux to the hole on the back of the board (Step 5) , heat the connection with the iron, then gently touch the solder to the hot connection (not to the soldering iron). Remove the solder, remove the iron, and allow to cool. An example of a successful joint is shown in Figure 3.

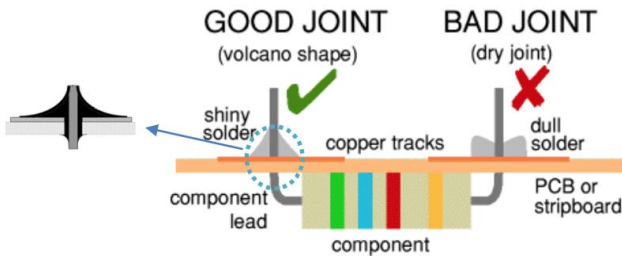

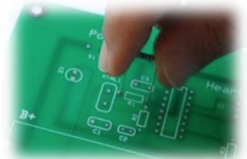
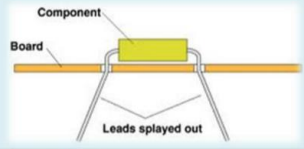
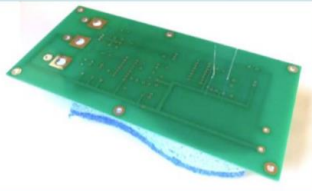




Figure 3: Cross section view of PCB with good and bad soldered joints.

Make sure to *avoid* applying too much solder so that two holes are joined by the solder as this will create a short in the circuit. In order to help support the board during soldering, it is recommended to use a clamp (Panavise) or sponge to hold the PCB while both hands are busy soldering (Figure 4).

Table 3: Steps to assemble solderable components.

Component Assembly Steps	
1 Bend the component wires 90°.	
2 Insert component pins into corresponding holes on circuit board. The resistor must rest on the top, labeled side of the board.	
3 Gently bend the leads under the board when installing to get a good mechanical connection.	
4 Turn the PCB over so that the component is face down and the wires are exposed.	
5 Solder each component leg to the board.	
6 Using the wire cutters, cut the excess length of resistor wires as close to the board as possible. <i>Protect your eyes from wire pieces that may fly from the board!</i>	

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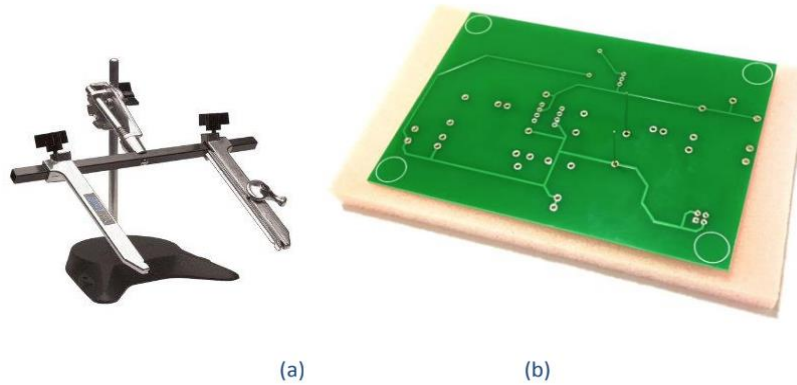


Figure 4: Support for PCB using Panavise (a) or dry sponge (b).

Assembly Steps

Printed Circuit Board

The baseline for our circuit is a printed circuit board (PCB). The PCB contains the necessary connections for our components, which are visualized as black lines on the top and bottom layers of the board (Figure 5). The PCB also contains silkscreen symbols and text to assist in placing each component.

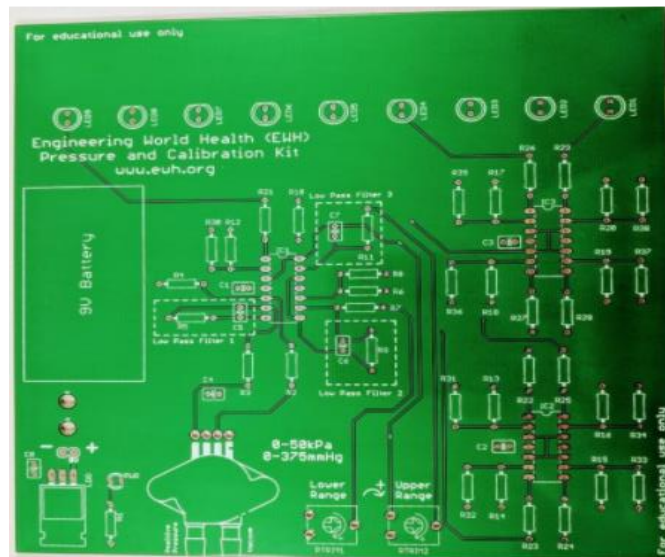


Figure 5: Top layer of PCB. Note the silkscreen marks to assist in placement of components.

While the PCB may seem intimidating at first due to the sheer number of components, this guide will contain step-by-step instructions to place components correctly and will make the process much less daunting.

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Resistors

The first components to place on the board are the resistors, and they form the bulk of the components to be soldered. It is very important that the resistors involved in the comparators are placed correctly so that the order of the LEDs is correct (Figure 7). Use Figure 2 or a multimeter to determine the value of each of the resistors. Note that the bag containing the resistors and Table 1 indicate the board placement for each resistor (Figure 6).

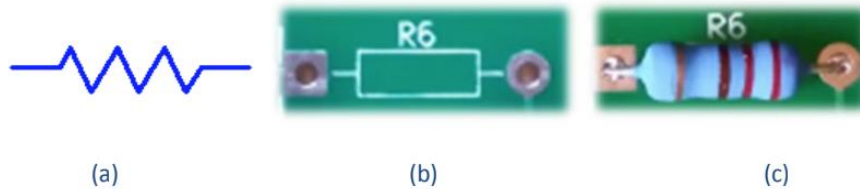


Figure 6: Resistor circuit diagram symbol (a), silkscreen placement (b), and component (c).

Follow the soldering steps in Table 3; as they become routine, it is possible to place several resistors (Steps 1-3) at once before soldering them at a later time (Steps 4-6). When choosing this option, make sure the components legs are bent so that they don't all fall out when the board is turned upside down.

Begin by soldering the 220 k Ω resistors to the board. The board should now look like Figure 9a.

Next, solder the 1 k Ω resistors. The board should now look like Figure 9b.

Next, solder the 10 k Ω resistors. The board should now look like Figure 9c.

At this point, the only resistors left are those to be used for the comparators. Again, it is very important that these are installed in the correct order; use Figure 7 to confirm placement. After all the resistors have been placed, the board should look like Figure 9d.



Figure 7: Comparator resistors in increasing order of resistance: 680 Ω , 1.5 k Ω , 2.4 k Ω , 3.3 k Ω , 4.7 k Ω , 6.2 k Ω , 8.2 k Ω , and 13 k Ω . Clever observers might note that there are only eight resistors, but nine LED indicators. This is because the ninth comparator uses a 10 k Ω resistor, which was already soldered on at R31.

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Capacitors

The next components to solder are the capacitors. Because all of the capacitors have the same value (capacitance), there are no special instructions to placement of these components. Also note that, unlike Figure 8, these capacitors do not have polarity and therefore have no preferred orientation.

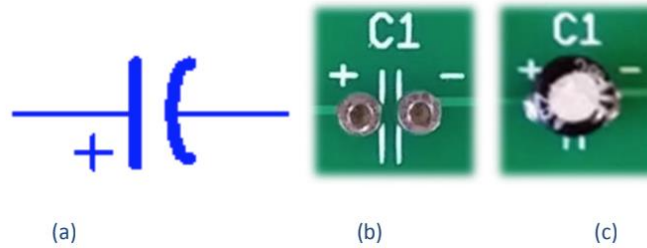
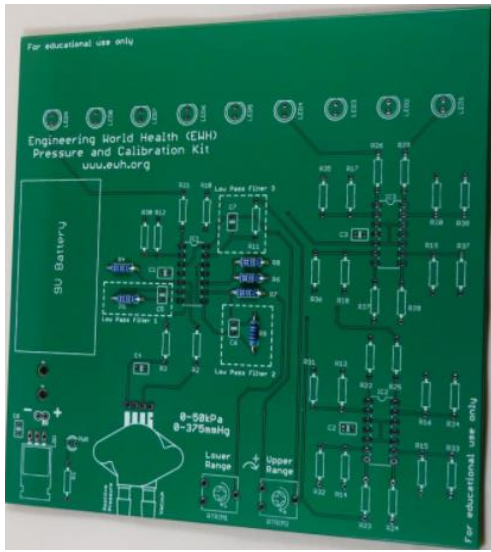


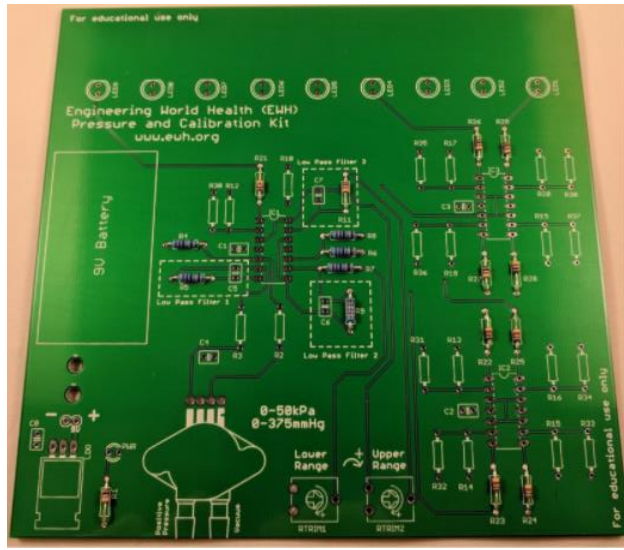
Figure 8: Capacitor circuit diagram symbol (a), silkscreen placement (b), and component (c).

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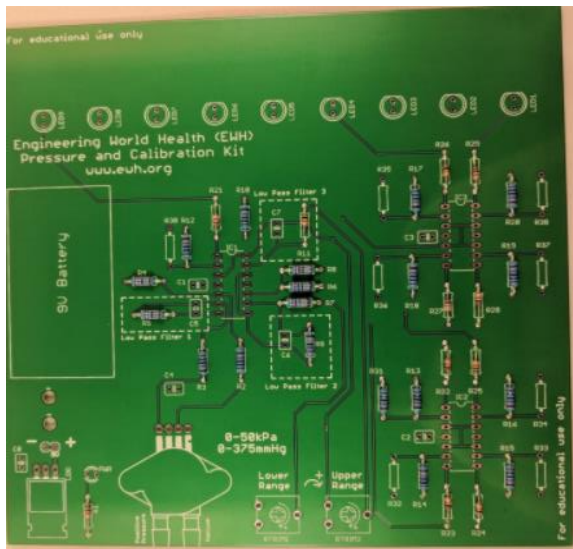
(a)



(b)



(c)



(d)

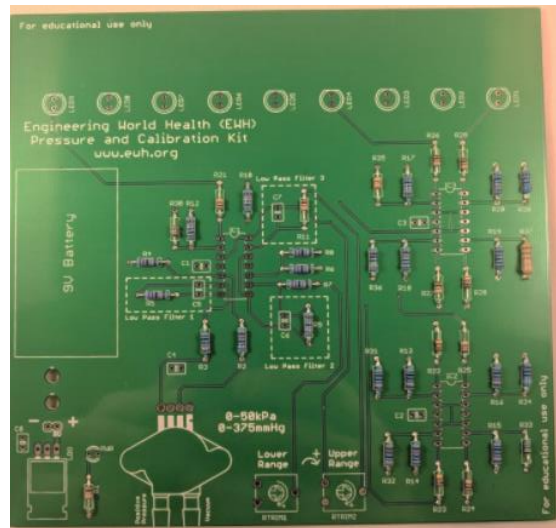


Figure 9: PCB after placement of 220 kΩ resistors (a), and 1 kΩ resistors (b), and 10 kΩ resistors (c), and all remaining resistors (d).

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Amplifier Sockets

Solder the amplifier sockets into IC1, IC2, and IC3. Make sure that the notch of the sockets matches the notch on the silkscreen (Figure 10). When plugging the ICs into the sockets, make sure the notches match again.

Figure 10: The amplifier socket notch should match that on the silkscreen, facing the top of the board.

Potentiometers

The next step is to solder in the potentiometers. Make sure that the 22 k Ω potentiometer is soldered to the Lower Range (RTRIM1) and the 470 k Ω to the Upper Range (RTRIM2).



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LEDs

LEDs are the next component to assemble. Note that the LEDs have polarity, and therefore must be installed in the correct orientation to work properly. This may be done by matching the notch on the LEDs to the notch on the silkscreen and/or closely following Figure 11.

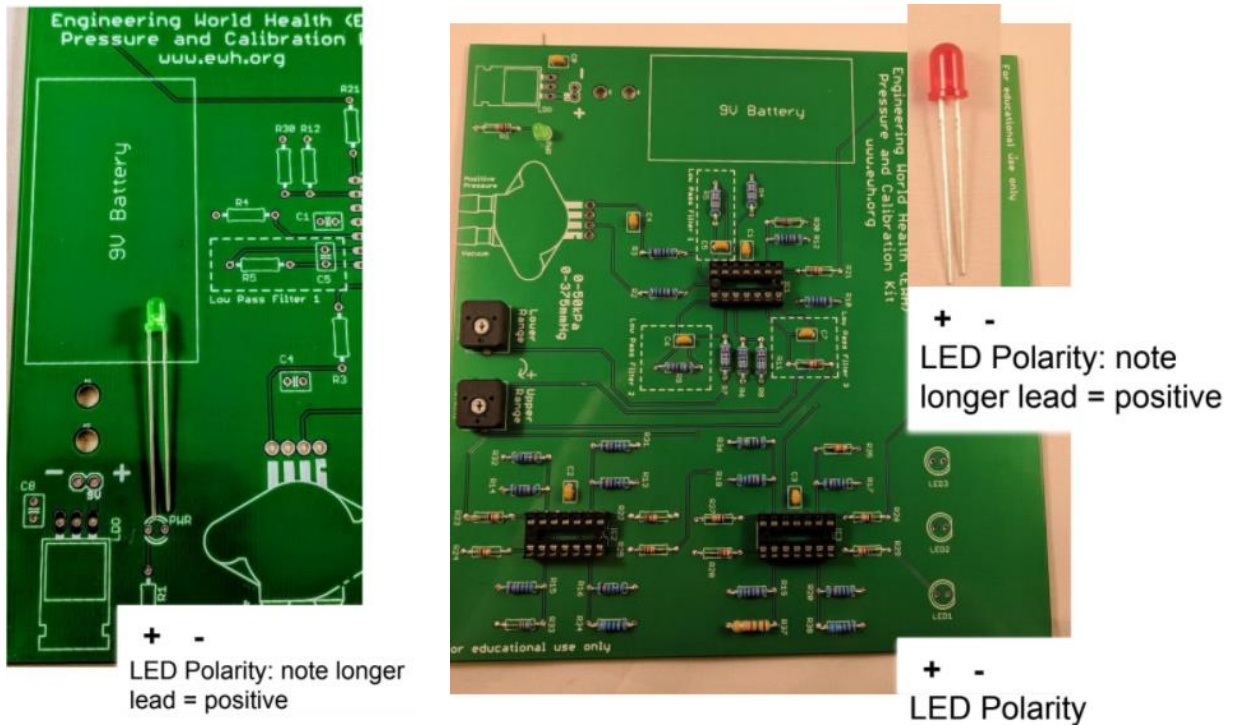


Figure 11: Placement and orientation of the LEDs. The longer component leg corresponds to the anode (+) and the notch at the base of the bulb corresponds to the cathode (-).

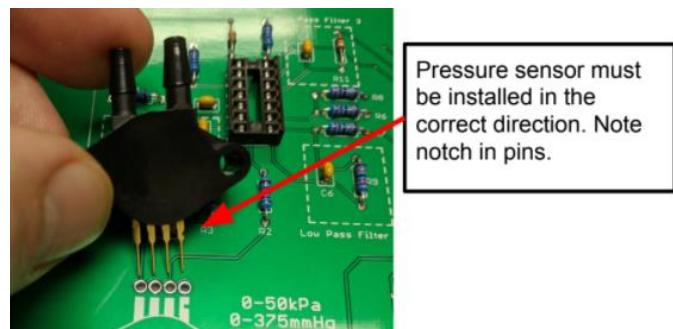
Pressure Sensor

Now install the pressure sensor. Make sure that the notch of the pressure sensor matches that on the PCB (Figure 12). Figure 12: (Above) Match the notch on the pressure sensor to that on the PCB. (Left) PCB after pressure sensor has been installed.



One of the last steps is to solder the battery connector and the voltage

Battery Connector and Voltage Regulator



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regulator. Make sure that the red wire of the battery connector goes to the (+) side and the black wire to the (-) (Figure 13). There are two holes to weave the connector through in order to reduce the stress on the soldered connection when the heavy 9V battery is connected. Additionally, solder in the voltage regulator so that its orientation matches the outline on the PCB (Figure 13).

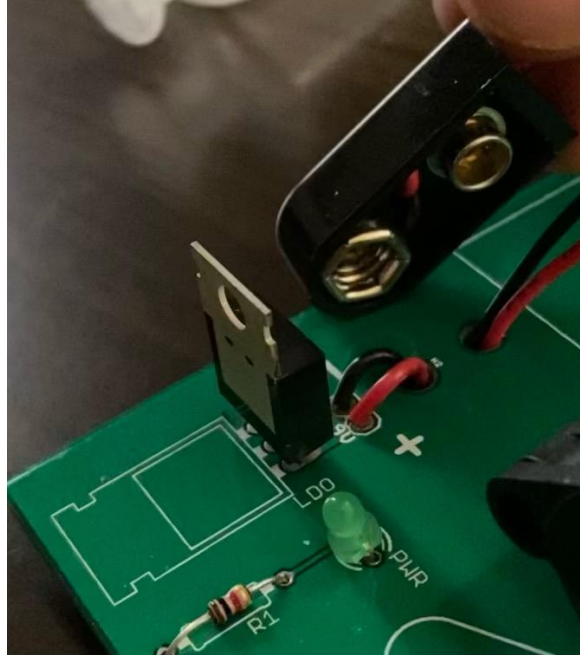


Figure 13: Battery connector (right) and voltage regulator (left) connected. Note that the polarity of both is important for the Kit to work properly.

Final Steps

Finally, add the integrated circuits (ICs) into the previously installed sockets if not done already. When doing this, be sure that the orientation of the IC is such that the notches face the top of the board and align with the notches in the socket and the silkscreen (Figure 10).

Attach the rubber feet at the bottom of the board at each of the corners (Figure 14).



Figure 14: Rubber feet placed underneath corners of PCB.

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Congratulations!! The Pressure Calibration Kit has been completed. Compare the constructed circuit to Figure 15 to ensure that all of the components are in the correct space. Additionally, look to Figure 16 to see a complete circuit diagram of the circuit that was just completed.

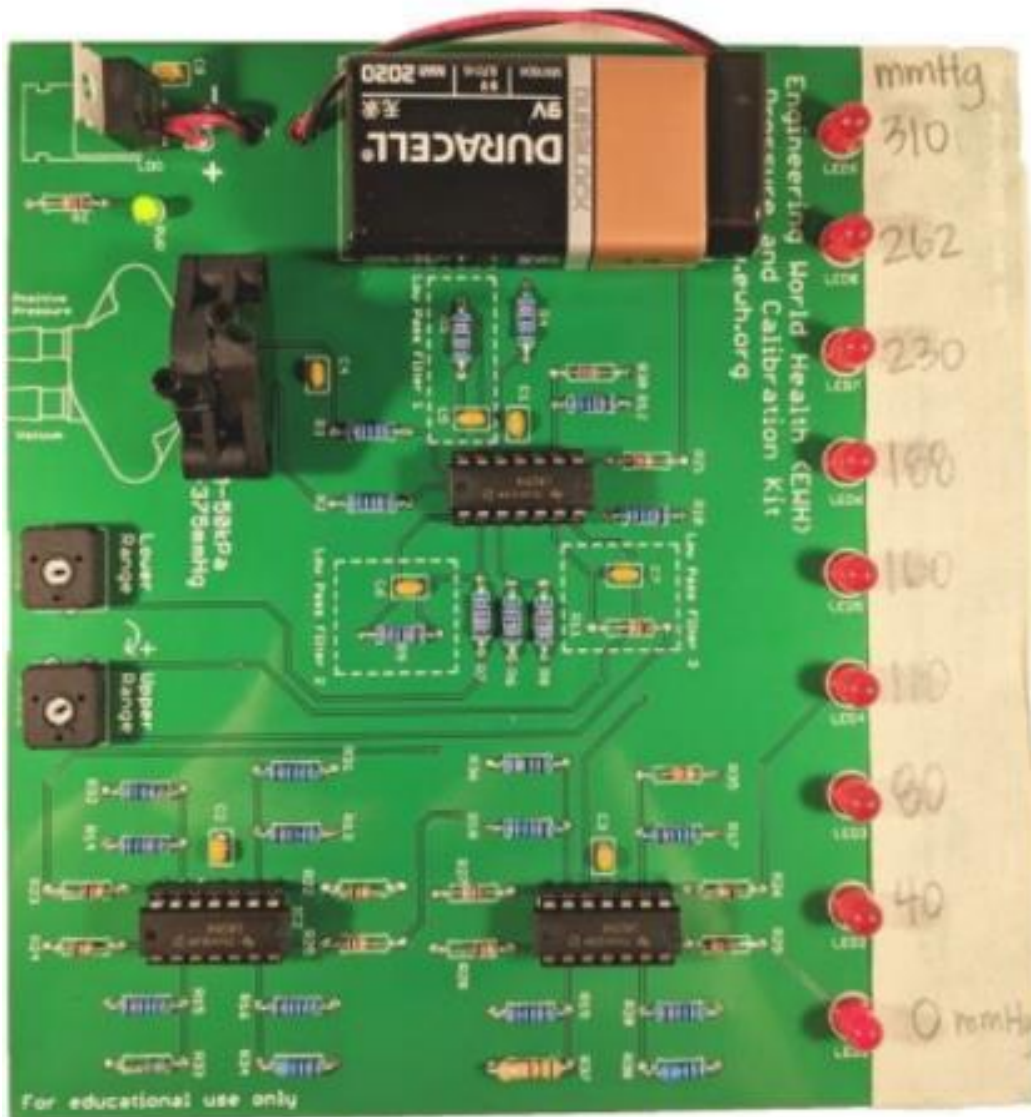


Figure 15: Completed Pressure Calibration circuit.

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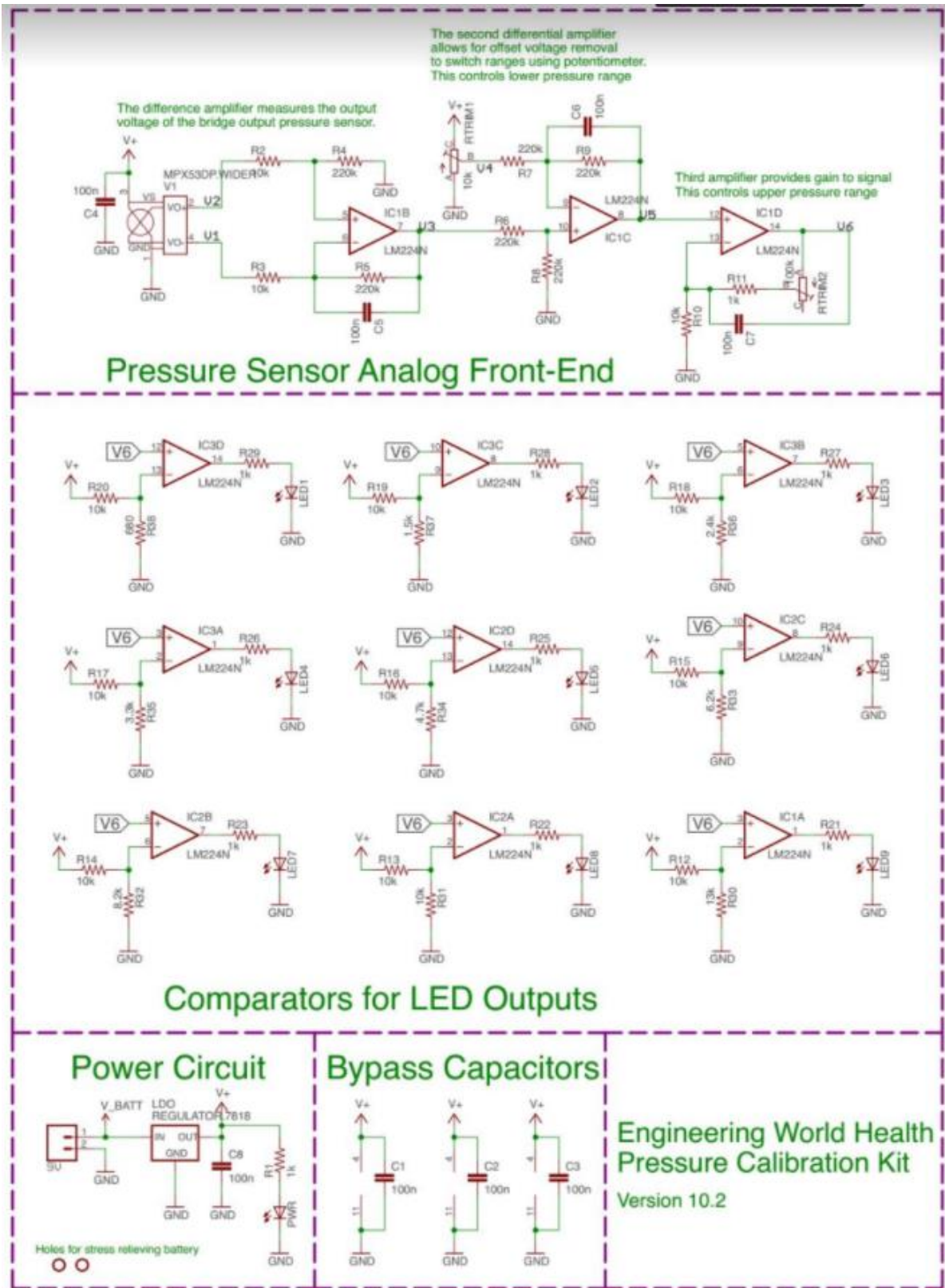


Figure 16: Circuit diagram of the completed Pressure Calibration circuit.

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Testing Instructions

In order to test the circuit, plug a 9V battery into the battery connector. The green “PWR” LED should light up when this is done, indicating that the circuit is live. Attach a way to increase the pressure, such as a gauge, syringe, or manometer to the positive pressure inlet of the pressure sensor (Figure 17). Slowly increase the pressure; the red LEDs should light up in turn. One may adjust the pressure at which these turn on by adjusting the potentiometers with a small screwdriver. The next lesson will focus on calibrating this Kit in order to get an accurate pressure reading from the LEDs when the pressure is unknown.



Figure 17: Gauge connected to the pressure sensor ‘positive pressure’ inlet.

Troubleshooting Steps

The circuit is rather complicated and will not work properly if any one of the components was not installed correctly. Consider these steps or consult with the instructor if the circuit is not working properly.

- First, make sure all components are in the correct place (Figure 15) and electrically connected by gently trying to pull each one out of their sockets. If the components move, consider re-soldering the connection. Use a multimeter to confirm that voltage is present as expected across select points.
- If the green LED doesn’t light when the battery is connected, there may be a power issue. Check with a different battery, or consider re-soldering the battery connector or voltage regulator.

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- If the red LEDs won't change with a change in pressure, check the ICs. Make sure that everything is oriented properly. Make sure that the sockets are soldered well (no shorts between the socket legs, this is easy to do since they are very close together) and that all the legs of the ICs are straight and enter the socket.
- Check for shorts. This may happen if too much solder was applied to a hole and caused two holes to become electrically connected together. If this happens, remove the excess solder with a desoldering pump.
 - This is especially easy to occur with components that have legs close together, such as the pressure sensor, voltage regulator, or IC sockets. Check these components first.
- If the red LEDs turn on but are out of order, consider adjusting the potentiometer so that they turn on more gradually. If they are still out of order, check that the comparator resistors were placed in the right positions. Use Figure 16 to trace which LEDs correspond to which resistors to check those first. Use a multimeter to make sure the correct resistance is measured across the resistor.