engineeringworldhealth

OPTICAL HEART RATE MONITOR KIT

Assembly Instructions

Contents

Overview

Devices that measure the heart rate can be found in almost all hospital areas and are important tools for diagnosing and monitoring health issues. Although doctors and nurses can hear cardiac sounds in a patient's chest with a stethoscope, the body's extremities are better locations for continuous monitoring. This is possible because even small arteries in the body's extremities expand with the heart's contractions. The small volume variation can be detected with an optical sensor that measures the amount of red light absorbed by the arteries. Figure 1 shows how light reflectance in the human finger is measured by the EWH Optical Heart Rate Monitor Kit to indicate the heart rate. After sampling the signal, the device amplifies the signal and displays the heart beats through outputs such as indicating lights.

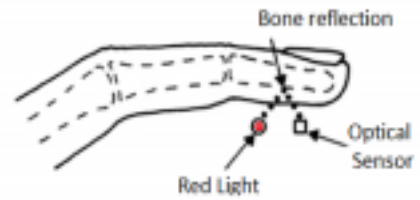


Figure 1 – Heart Rate measurement principle through the finger tip.

There are two possibilities to assemble the Optical Heart Rate Monitor kit. The first is to order the plug-and-play kit, which comes with the battery holder, switches and sockets already soldered (Figure 2b). This approach allows users to connect and remove the components as many times as desired without soldering and is suitable for middle school, high school and college students activities that require the measure of each circuit block separately. If one loses some of the components, one can order a replacement package with only the resistors, capacitors, amplifier, LED and optical sensor from http://www.ewh.org/students/2013-12-06-15-44-37/stem-kits prices.

The second option is to solder all of the parts directly on the board as shown in Figure 2a. This solderable kit is best for classrooms that have access to soldering equipment (which can be purchased from https://www.amazon.com/shop/engineeringworldhealth) and wish to teach their students how to solder. This kit is to be used for one lecture only.

These instructions will follow the order of assembly for a plug-and-play kit. The directions for the soldering kit are largely the same: instructions for soldering and the (few) additional steps for this kit are included in the appendix.

(a)

(b)

Figure 2 – Optical Heart Rate Monitor kit assembled with solder (a) for only one lecture and with sockets for plug-and-play (b), which allows it to be used many times.

Kit Disclaimer

Engineering World Health's Optical Heart Rate Monitor Kit is **an educational tool only and is not to be used for any other purpose, including any medical, diagnostic or other laboratory applications.**

EWH University Chapters may construct Optical Heart Rate Monitor Kits to give students an opportunity to practice hands-on technical skills.

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.

Important Guidelines and Safety Measures

- 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 4). To avoid confusing the components, only open each bag when you are ready to assemble that component

Figure 4 – Component description, value, and schematic ID is on each bag

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 4) until it is time to assemble them in order to simplify the assembly process (this is especially important for resistors as they are easy to get confused). If one does mix up the resistors, Figure 5 details how to read the colored bands on the resistor to determine the resistance of the resistor: then, compare to Table 1 to determine where to place each resistor.

Please note that EWH does not supply solder materials (see Appendix), goggles, or batteries. Each assembled kit will need two 1.5 V AAA batteries to operate.

Table 1: Optical Heart Rate Monitor parts list

Description	Value	Quantity	Schematic ID	Schematic Symbol	Image*
Printed Circuit Board	N/A	1	N/A	N/A	
Resistor	220 Ω	3	R1, R4, R6		
Resistor	10 kΩ (10,000 Ω)	2	R2, R3		
Resistor	2.7 MΩ (2700,000 Ω)	1	R5		
Capacitor	10 µF (0.00001 F)	2	C1, C2		
Operational Amplifier	MCP6273	1	U1		
LED + Photodetector	OPB608R	1	U2		
LED	3 mm green	1	X1		
Switch	N/A	1	S1		
Battery Holder	N/A	1	N/A	N/A	
PCB Rubber Feet	N/A	4	N/A	N/A	
One Pin Socket	N/A	23	N/A	N/A	
Socket for Amp Op	N/A	1	N/A	N/A	

*Component color and shape may change according with supplier availability; images are for illustrative purposes only.

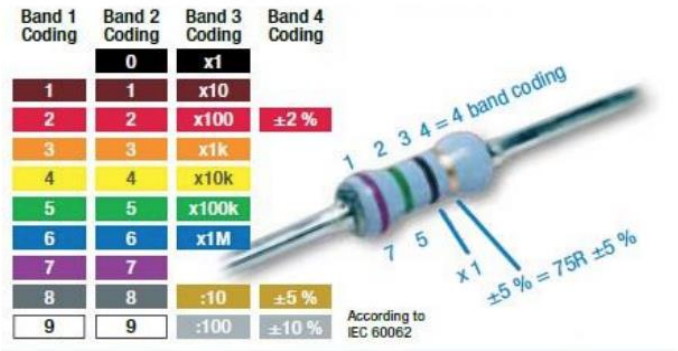


Figure 5: Resistor identification chart.

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 white lines on the top layer of the board (Figure 5). If curious, one can observe the +3V and the ground (⏚) connections on the back layer of the PCB. The PCB contains silkscreen symbols and text to assist in placing each component as well as labels for the high-pass filter (HPF) and low-pass filter (LPF).

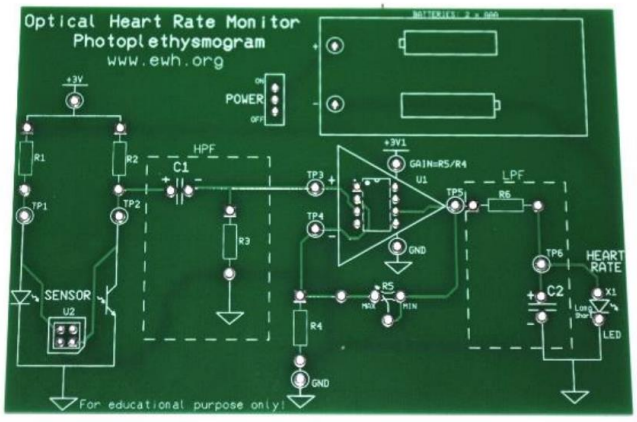


Figure 6: Top layer of PCB. Note the silkscreen marks to assist in placement of components.

Note: If using the solderable kit, continue to the appendix to learn soldering techniques. If not, continue on to the next section. **Remember, make sure the circuit is turned off when assembling.** It is optional to clip the legs of the components to make them shorter and easier to push into the socket. If one does this, keep track of polarity of capacitors and LEDs!!

Resistors

There are three different types of resistors, as noted in Table 1. Being careful to not mix up the different resistors, place the legs of each resistor into the sockets surrounding the marked positions on the PCB (Figure 7). Be sure that legs are firmly in the sockets by gently tugging on the resistor and ensuring that it remains in place.

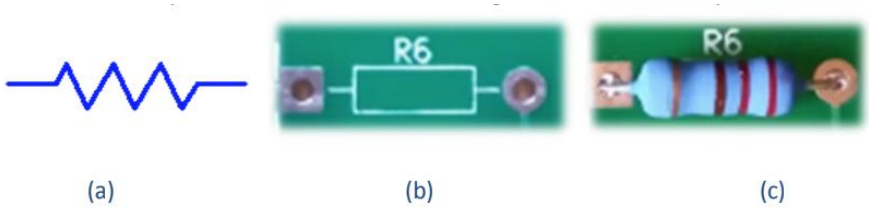


Figure 7: Resistor circuit diagram symbol (a), silkscreen placement (b), and component (c).

Remember, if one accidentally confuses the different resistors, use Figure 5 to determine the correct resistance for each (**Optional activity: Mix the resistors and use Figure 5 to find their resistances.**)

Capacitors

Once all of the resistors are in place, it is time to move on to the capacitors. Be careful, as capacitors have polarity, which means that they will only work if placed in the correct direction. Make sure that the anode (longer leg) is connected to the (+) side and the cathode to the (-). (Cathodes should also be marked by a silver stripe.)

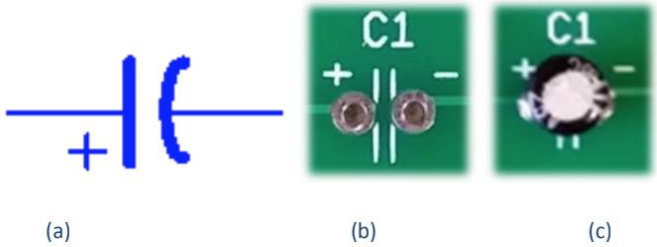


Figure 8: Capacitor circuit diagram symbol (a), silkscreen placement (b), and component (c).

Light Emitting Diode (LED)

The next component to assemble is the LED indicator light. Note that, like capacitors, the LED has polarity. The anode (longer leg, +) should go to the upper end of the board (Figure 9).

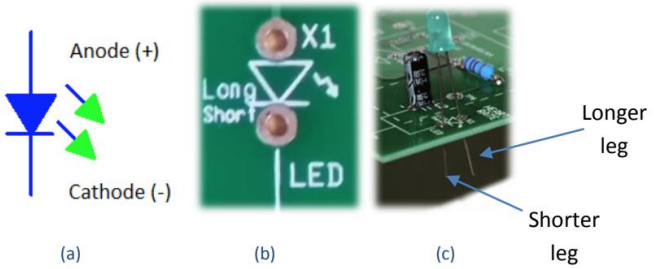


Figure 9: LED circuit diagram symbol (a), silkscreen placement (b), and component (c).

Operational Amplifier (Op-Amp)

The Op-Amp comes as an integrated circuit (IC) component and will go in the position marked U1 on the PCB. Again, this component has polarity; it is important to place the component so that the notches match that on the PCB facing the top of the board.

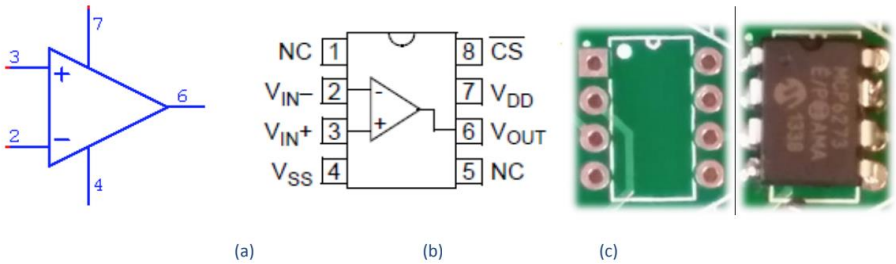


Figure 10: Op-Amp circuit diagram symbol (a), silkscreen placement (b), and component (c). Take particular note that the notch on the component matches the notch on the PCB.

Photosensor

The second IC to be placed on the board is the photosensor. It will go into the position marked U2. Again, placement is key as this component contains a red LED that serves to illuminate the finger and an optical sensor to pick up the signal after the light has passed through the finger (Figure 1). Match the notch on the component to the notch on the board (Figure 11).

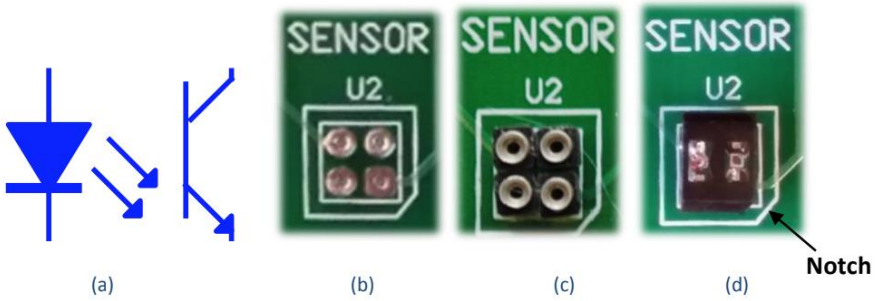


Figure 11: Diode and optical sensor circuit diagram symbols (a), silkscreen placement (b), sockets (c) and component (d). Take particular note that the notch on the component matches the notch on the PCB.

PCB Support

The final step is to make sure that the PCB is well-supported. Four rubber feet have been supplied and should be placed underneath the four corners of the board (Figure 12).

Figure 12: Rubber feet placed underneath corners of PCB.

Congratulations!! The Optical Heart Rate Monitor has been built. Check the constructed circuit against Figure 13 to make sure that all the components are in the right place.

(**Optional Activity: Draw the circuit diagram for the circuit that was just constructed. The symbols for each of the components can be found in the previous two pages. Make sure to draw the connections between the components as lines. Check your answers against Figure 14 on the next page.**)

(a) (b)

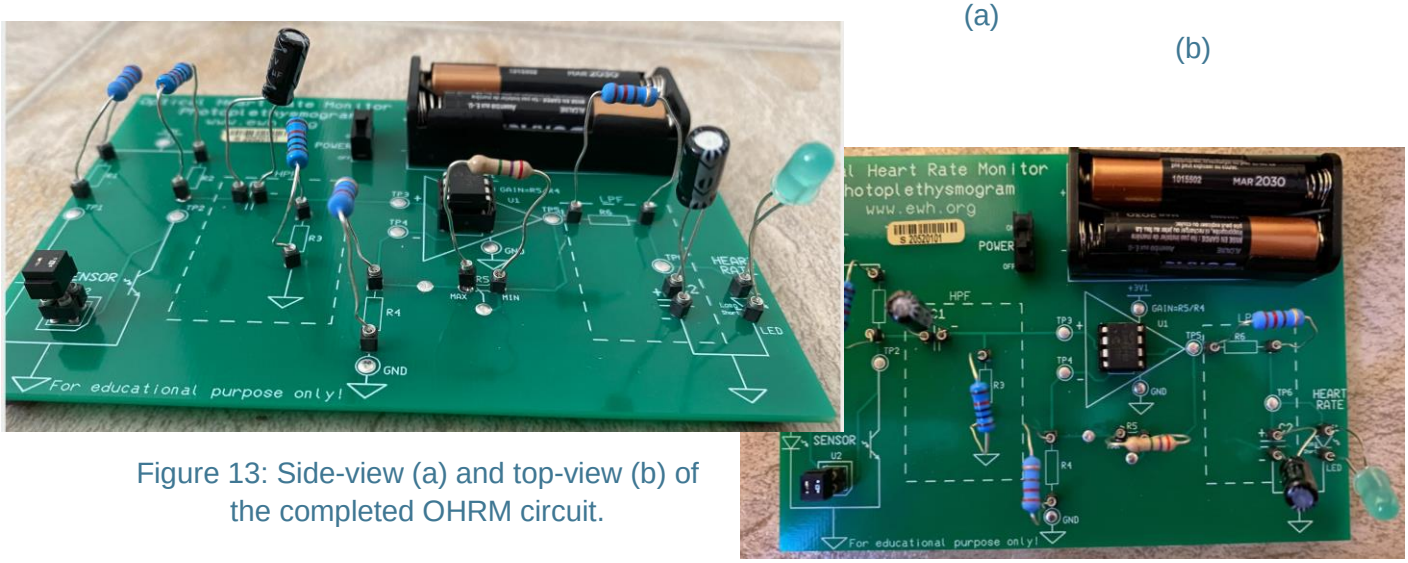


Figure 13: Side-view (a) and top-view (b) of the completed OHRM circuit.

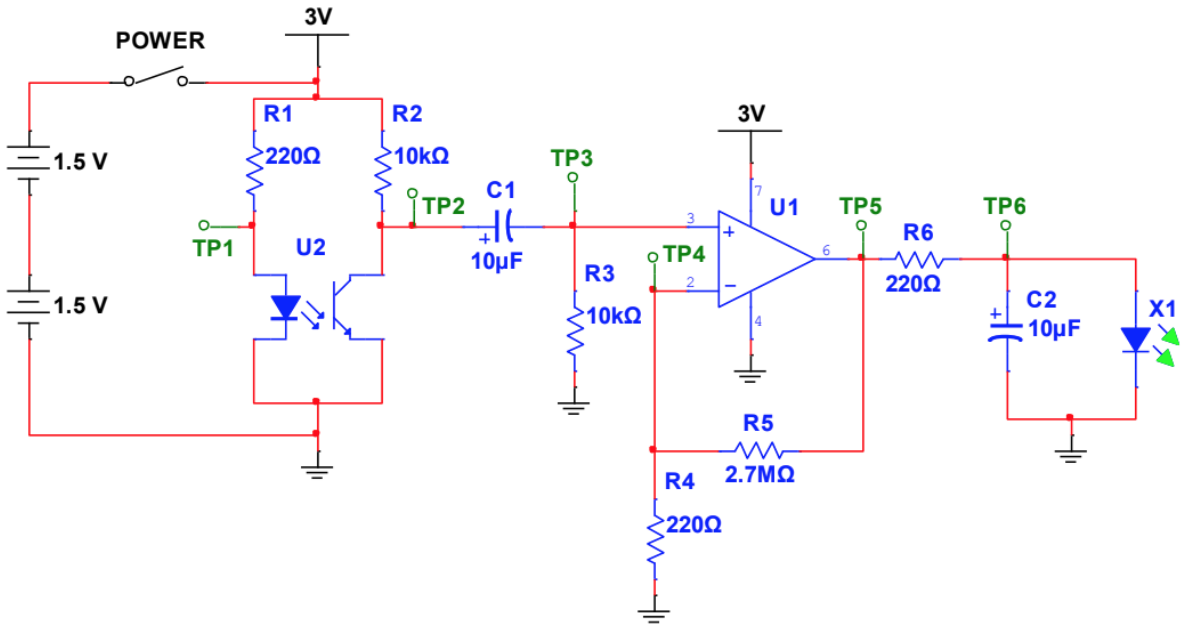


Figure 14: Circuit diagram for the Optical Heart Rate Monitor. It may look complicated, but one should be able to trace each of the components and connections to the board using the circuit symbols provided.

Testing Instructions

In order to test the circuit, plug 2 AAA batteries into the battery holder and turn the circuit ON. Gently place the tip of one's finger over the photosensor (Figure 15). It is very important that the pressure of the finger does not vary as it is resting on the sensor. To optimize reliability, rest one's hand and other fingers on the table. Observe the LED sensor. Meanwhile, take one's other hand and manually measure one's pulse. The LED should light with one's cardiac pulse.

Figure 15: OHRM fingertip measurement. Make sure that all other fingers and elbows lay on the table.

The circuit can be very sensitive to external conditions. If one has trouble getting the LED to match the heartbeat, then try these troubleshooting steps:

- Make sure all components are in the correct place (Figure 13) and secure by gently trying to pull each one out of their sockets.
- Move one's fingertip around the photosensor. In this author's experience, the best location on the finger was right at the center of the swirl of the fingerprint.
    - Try different pressures of one's finger. Too much pressure will generally prevent any light from reaching the optical sensor and the LED will remain dark. Too little and the LED is nearly always lit. Try and find a sweet spot in between.
    - Try a different finger or even the other hand. Although other body parts (such as one's toes or wrists) also theoretically work, these have not been tested, but could be an alternative option as needed. This sensor was designed to work with fingers but can be accessible for all students.

- Try different external lighting. The lights in the room may affect the background noise.

Appendix: Soldering Instructions

Safety Guidelines

- 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.

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.

Table 2: Tools needed to complete the solderable kit.

Description	Image
Soldering iron	
Solder	
Eye goggles	
Cutting pliers	
Long nose pliers	
2 x **1.5 V AAA batteries**	

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=I_NU2ruzyc4
http://www.youtube.com/watch?v=eU4t0Yko9Uk

The main steps to soldering components are shown in Table 3. For the best results, heat the connection first, 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 16.

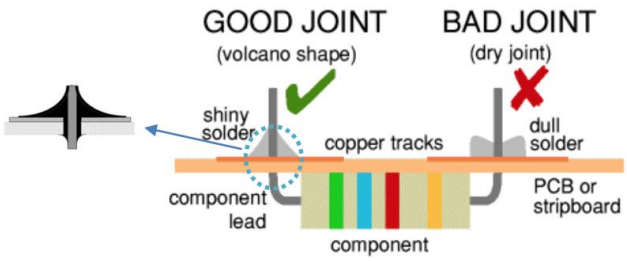
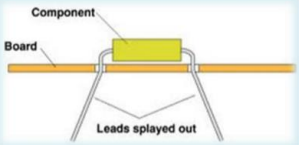
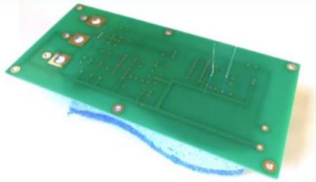
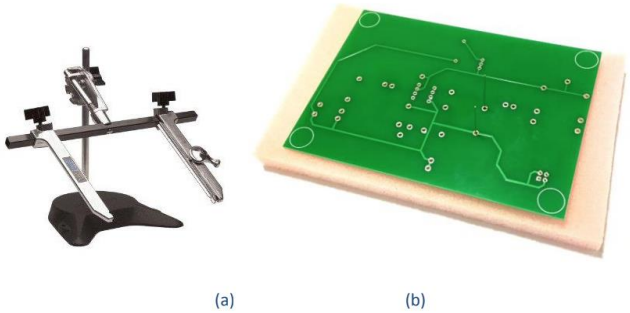


Figure 16: Cross section view of PCB with good and bad soldered joints.

Make sure to *avoid* applying too much solder so that two joints 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 17).

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.** ***Protect your eyes from wire pieces that may fly from the board!***	



(a) (b)

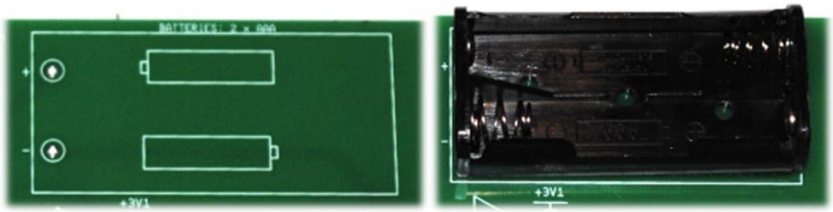
Figure 17: Support for PCB using Panavise (a) or dry sponge (b).

Assembly Steps

Follow the assembly steps that start on Page 7, practicing good solder technique. Finally, attach and solder the power slide switch (Figure 18) and battery holder (Figure 19).

(a) (b) (c)

Figure 18: Power switch circuit diagram symbol (a), silkscreen placement (b), and component (c).



(b) (b)

Figure 19: Battery holder silkscreen placement (a), and component (b).

Plug in batteries and follow testing instructions to operate the circuit (Page 11).