

BME 2081C: Electric Circuits
Ninetales Soldering and Testing Guide

Name: _____

Grade: out of 100 points and worth 1% of your final grade. However, you will need a successfully soldered board in order to complete the other parts of this assignment which are worth a larger percentage of your grade.

Objectives: Solder Ninetales so you can utilize it for your lab project.

NOTE: There is no partial credit for this assignment. Your circuit board either works or it doesn't. If it works, you get all the points. If it doesn't work, you get 0 points.

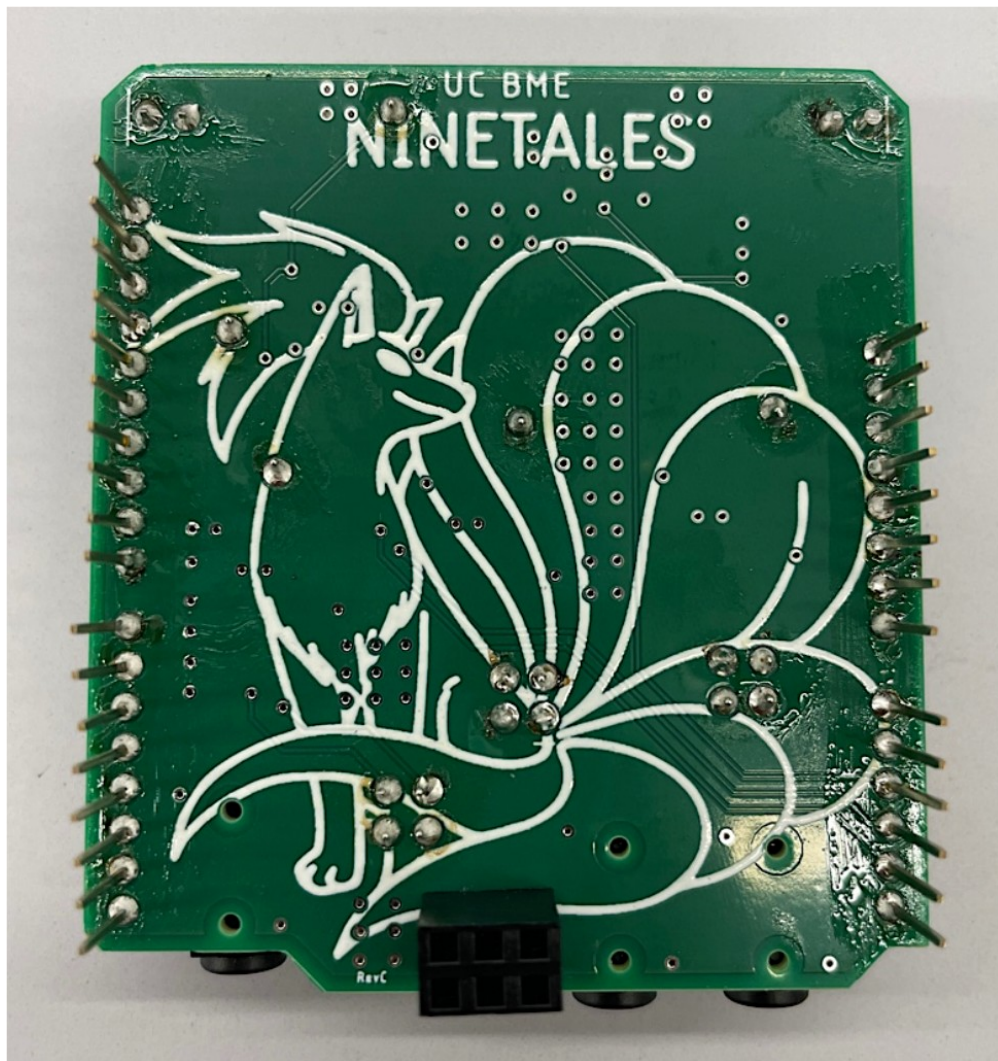


Figure 1. Image of Ninetales.

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Table 1. Abbreviations.

Acronym	Meaning
ECG	Electrocardiogram
EEG	Electroencephalogram
EMG	Electromyogram
EOG	Electrooculogram
INA	Instrumentation Amplifier
LED	Light-Emitting Diode
PCB	Printed Circuit Board

Part I: Please adhere to these safety guidelines

1. Read and abide by the CEAS Solder Safety guidelines (Canvas: Home/Modules -> Soldering). In particular, please wear pants, closed-toed shoes, and a natural fiber long-sleeved shirt to the soldering session. Wear the safety glasses provided to you by your instructor for the duration of the soldering session, even if you're not currently soldering.
2. Only use the lead-free solder provided to you by your instructors.
3. The soldering iron is hot. Please hold the iron by the black handle and not the silver tip.
4. Do not leave your iron on for more than 10 minutes even if you're in between soldering joints. If you leave the iron on for too long, you will oxidize the tip, rendering the tip useless. You can try to "tin" your tip by applying a small amount of solder to it and cleaning it with the brass sponge. However, if your tip is too corroded, it will need to be replaced.
5. Use a fume extractor while you're soldering to avoid the fumes from entering your respiratory system. The fume extractors are equipped with activated carbon filters which break down the organic molecules that cause respiratory irritation.
6. If you use isopropyl alcohol to clean the flux off your board, wear gloves.

Part II: Setting up your soldering iron

Figure 2. Picture of the soldering station control unit indicating the location of the ON/OFF switch.

1. Turn your soldering iron on using the switch at the bottom, right side of the machine.
2. Set your soldering iron to 660 degrees Fahrenheit. (The units on the machine are °F, not °C.)
 - a. Press and hold the ENTER button until the hundreds digit starts flashing on the display. Use the UP button to change the hundreds digit (the numbers wrap around from 7 back to 0).

- b. Once the hundreds digit is set, press (don't hold) the ENTER button again to switch to the tens digit. Then repeat step 3a. (The tens digit wraps around from 9 to 0.)
 - c. Once the tens digit is set, press (don't hold) the ENTER button to switch to the ones digit. Then repeat step 3b.
 - d. Once the ones digit is set, press ENTER to finish.
3. Allow your iron 2-3 minutes to warm up.
4. You may increase the temperature of your soldering iron to 680 degrees Fahrenheit if your solder isn't readily melting.

Part III: Helpful soldering tips

1. Solder surface mount components before through-hole components.
2. Solder lowest profile components before taller components.
3. Solder passives (components that don't need power, i.e., resistors, capacitors, inductors) before other components.
4. You should **CONSTANTLY** be cleaning your soldering iron tip. Your instructors clean their irons every time they solder a single new connection. If you don't have a clean tip (it's not shiny), the solder won't stick to the iron very well, and you'll have quite a bit of difficulty getting anything done.
5. Your soldering iron is not a writing utensil (pen or pencil). You want to place the iron so that you get good surface area contact between the iron and the components. So, hold your iron roughly sideways while soldering. Do not hold the iron like you're using it as a pen or pencil. You won't get good heat transfer and won't be able to get anything done.
6. Flux is your friend. Use it liberally. There shouldn't be a pool of flux on your board, but the boards should be very damp.

Part IV: Gather Your Components

You've been provided with a 3D printed component box to store your components along with some sharpies and labeling tape. Since you'll solder Ninetales over the course of a few weeks, please start by organizing your components into your component box. You will also be provided a larger project box to store your components and your in-progress PCB over the course of the next few weeks. **The PCB will not fit inside the component box.**

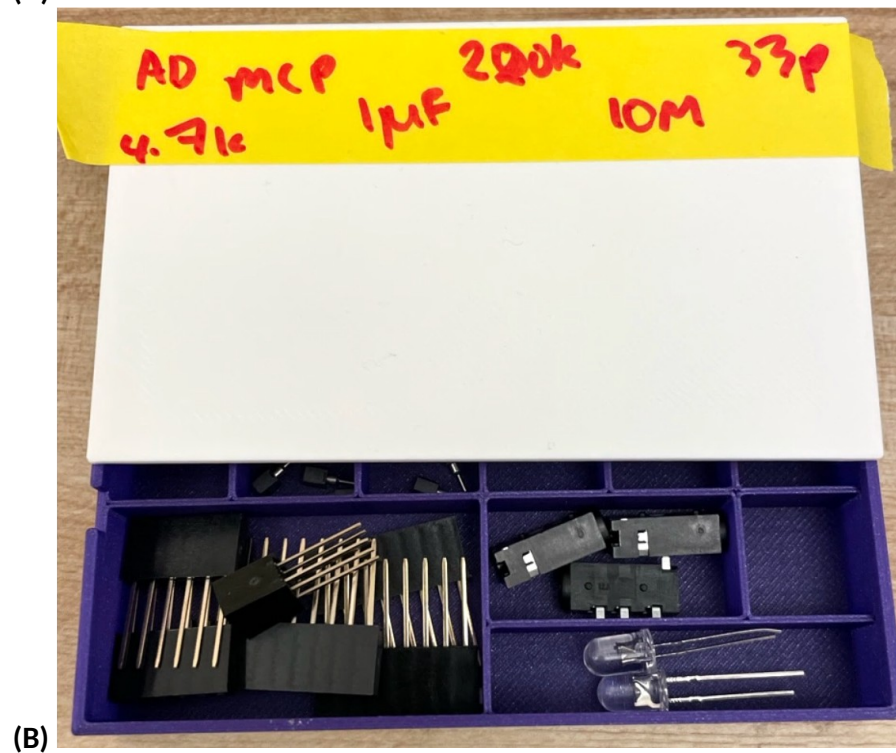
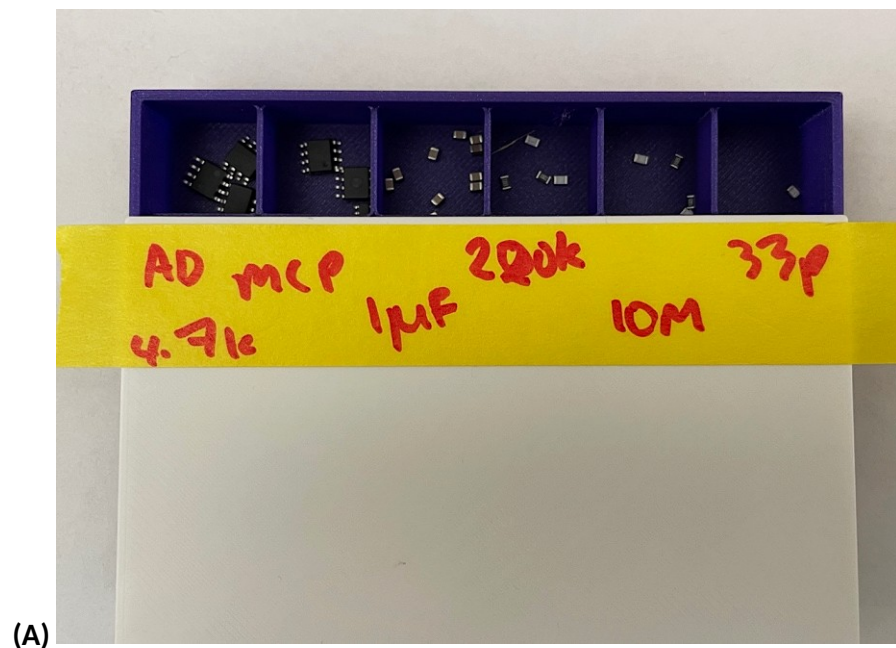


Figure 3. (A and B) The component box, labeling tape, and marker to organize your components.



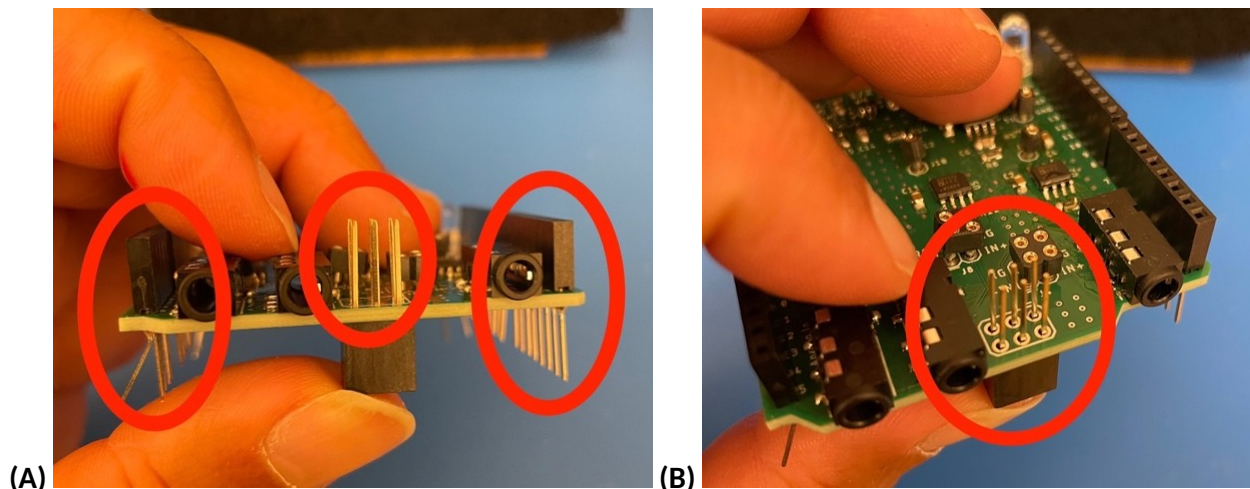
Figure 4. (A and B) Components for Ninetales at the designated instructor area.

Table 2. List of components for Ninetales.

1 x Component box	3 x AD8226
1 x Ninetales PCB	2 x MCP6002
5 x 4.7k resistor	1 x MCP6001
6 x 220k resistor	3 x 4-position headers or 6 x 2-position headers
4 x 10 M resistor	5 x 1-position headers
10 x 1 μ F capacitor	3 x 3.5 mm jack
3 x 330 pF capacitor	1 x stackable headers kit
1 x 33 pF capacitor	2 x your favorite color LED (<i>or feel free to mix and match. You don't need to stick with one color like you did with Firefly</i>)

PLEASE READ BEFORE YOU START SOLDERING

1. **DO NOT CUT THE PINS OF THE STACKABLE HEADERS.** The pin headers are long and should protrude from the board as shown in Figure 5 below. However, you may cut the leads of the LEDs.
2. **NOTE THE ORIENTATION OF THE STACKABLE HEADERS.** These can be a bit challenging to fix. Yes, The 2x3 pin header is oriented opposite the others as shown in Figure 5B below.
3. **When soldering the 8-pin operational amplifiers** (MCP6002 and AD8226), there are images (Figure 8 and Figure 9) a few pages below that help you orient the op amp on the PCB correctly. Yes, the images were originally made for the LM358; however, the general principles from the images still hold for the 8-pin op amps you'll use in Ninetales.
4. When soldering the LEDs, please consult the images a few pages (Figure 10) below.

**Figure 5. (A and B)** Orientation of the header pins that stack the board on top of the Arduino.

Part V: Soldering Ninetales

Steps

1. Please read all the steps in their entirety before you start soldering.
2. Obtain a Ninetales printed circuit board (PCB) from your instructors along with the components to solder to the board (Figure 3, Figure 4, and Table 2). The PCBs and other components may also be in a pick-up area designated by the instructor.
3. Solder the components in the following order: resistors, capacitors, operational amplifiers, 4-position headers (or 2, 2-position headers), 1-position headers, J9, J2, J3, LEDs, stackable headers. Consult the designator reference list on the final page of this document and the images in the proceeding pages.
4. When you are soldering J1, J8, J4, J5, J6, J7, J10, J11, etc., insert the header pins into the designated vias. Tape the header pins down. Flip the board over, then solder the components to the board. It would be helpful to solder J1, J8, and J4 (4-position headers, or 2, 2-position headers) at the same time and J5, J6, J7, J10, and J11 (1-position headers) at the same time.
5. When soldering the 8-pin operational amplifiers, please consult Figure 8 and Figure 9 a few pages below.
6. When soldering the LEDs, please consult Figure 10 a few pages below.
7. When soldering the header pins, please consult Figure 11 a few pages below.
8. A few reminders.
 - a. **Resistors:** The black side of the resistor should face upwards. Also, the resistor is non-polar. It doesn't matter how you rotate it (along its long axis).
 - b. **Capacitors:** The capacitors are non-polar. It doesn't matter which side you solder them along their long axis. The capacitor is also the same all the way around. It doesn't matter how you rotate it around its center axis.
9. Please have your instructors inspect your soldering job before you proceed.
10. If instructors think your soldering job looks good, they will hand you three sets of sensor cables and ECG electrodes (Figure 6). The sensor cables will plug into the corresponding receptacle on Ninetales based on which biosignal you are measuring. The locations for the electrodes and sensor cables are shown in Table 3 on the following page.

Part VI: Testing Ninetales

Table 3. Electrode Locations.

Biosignal	Red	Blue	Black
Electrocardiogram (ECG)	Volar (palm) side of left wrist	Volar (palm) side of right wrist	Right ankle or lower left abdomen
Electromyogram (EMG)	Opposite sides of a muscle		Unrelated part of your body away from the muscle
Electrooculogram (EOG)	For detecting blinks, looking up, and looking down: Above and below one eye. It doesn't matter which cable goes where. ¹ For detecting looking left and right: Above both eyes. It doesn't matter which cable goes where. ¹		Behind right or left ear.
Electroencephalogram (EEG)	We'll save this one for a later time.		

¹ Changing which cable goes where changes the polarity of your signal. For example, let's assume the red electrode is above your right eye and the blue is electrode is below your right eye. Let's assume that when you close your eye, your signal has a positive polarity (e.g. Figure 7D). When you flip the electrodes (red electrode is below your eye and blue electrode is above your eye), your signal would have a negative polarity (goes downwards) when you close your eye. The polarity of your signal has physiological meaning but will likely be irrelevant for what most students do with this project.

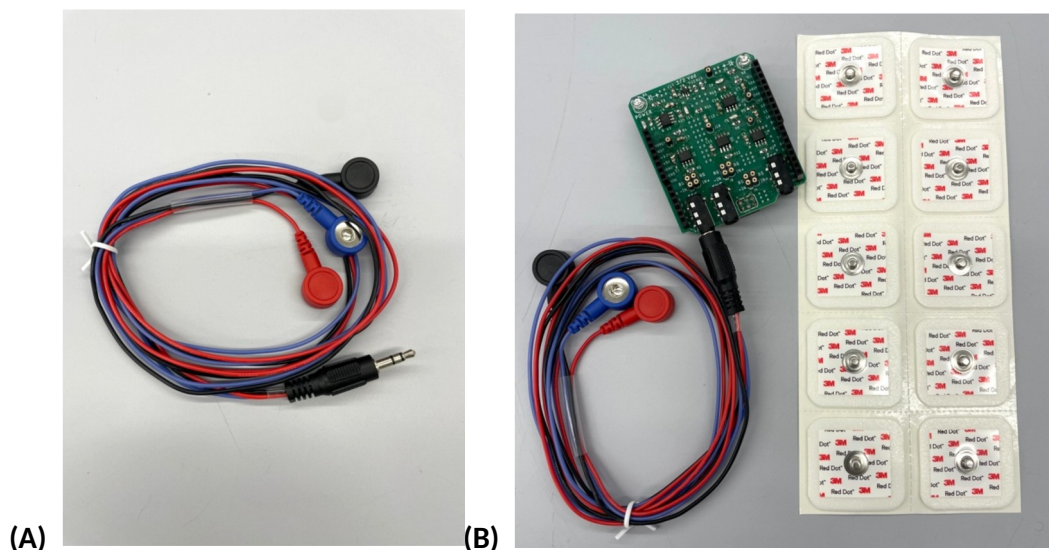


Figure 6. (A) Sensor cables (B) plugged into Ninetales ECG channel.

Steps

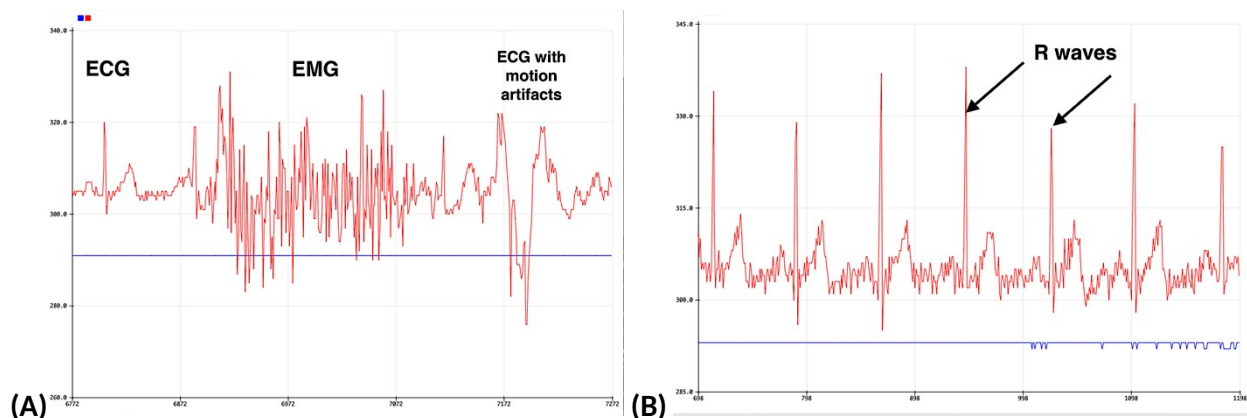
1. When testing Ninetales, **disconnect your computer from the wall outlet or anything that is connected to a wall outlet (like an external monitor).**
2. To test Ninetales, please find the example codes under the Home/Modules -> Ninetales on Canvas. You will need the following codes: EXAMPLE01_Blink.ino

and `EXAMPLE03_MultiSample.ino`. If there are additional example codes on Canvas, you'll use those at a later time (or they may just be for reference), but you don't need them for this step.

3. **Please follow the instructions in the comments in each file.** You should test `EXAMPLE01_Blink.ino` first and then `EXAMPLE03_MultiSample.ino` and demonstrate each to your instructor. Your instructors will monitor you closely during this step, since the physiological signals are fairly nuanced, and we want to make sure they're being acquired correctly.
4. For the `MultiSample` test, we can essentially test the electrocardiogram (ECG) on all 3 channels for convenience. The channels "overlap," with which biosignal they are sensitive to (as explained in the `MultiSample` code). But be sure you read the instructions in each code as there is quite a bit of background information in each.
5. Please see examples of what the physiological signals will look like in Figure 7.
6. You may find that braiding the sensor cables helps to reduce noise.

Once the instructors say your board works...

1. You are complete when the instructors inform you that your board is working as expected. Keep Ninetales, the sensor cables, and ECG electrodes. You'll need them for your project. There's nothing for you to submit on Canvas. Your instructors will mark your grade on Canvas themselves.
2. Clean up your soldering station. Put everything you took out of the soldering kit, back inside the kit **EXCEPT** the physical iron (and the iron holder). We need to let the iron cool down before we put the hot iron back inside a plastic tote (for obvious reasons). **Leave the kit on your desk, unplug the soldering station control unit, and place the unit back inside your kit.**



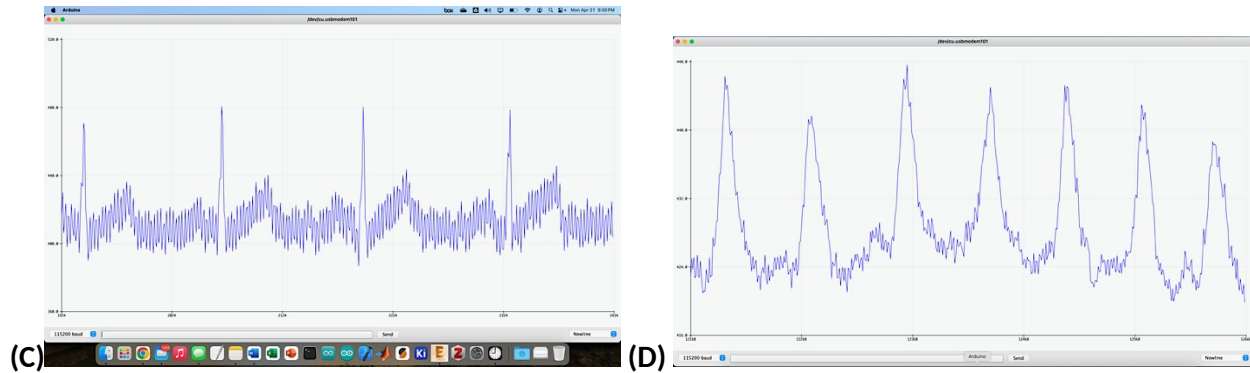


Figure 7. Example outputs. Sample (A) electrocardiogram (ECG), electromyogram (EMG), ECG with motion artifacts, (C) ECG with 60 Hz noise, and (D) electrooculogram (EOG). The ECG from the bandpass filter should have relatively little 60 Hz noise and should look more like B. If you were to sample your ECG directly from the instrumentation amplifier (for whatever reason), your ECG might look more like C.

Appendix A: Information on Biosignals

Here is some background information on each biosignals. The links are also posted on Canvas under Home/Modules -> Ninetales:

- Electrocardiography: <https://en.wikipedia.org/wiki/Electrocardiography>
- Electrooculography: <https://en.wikipedia.org/wiki/Electrooculography>
- Electromyography: <https://en.wikipedia.org/wiki/Electromyography>
- Electroencephalography: <https://en.wikipedia.org/wiki/Electroencephalography>

You don't need to commit this information to memory. They are just good references for this project.

Appendix B: Example Projects

Here are some fun videos to give you some ideas for your project. The links are also posted on Canvas under Home/Modules -> Ninetales. You don't need to commit this information to memory. They are just good references for this project.

- <https://youtu.be/rSQNi5sAwuc?si=-KV495ya7C4e6at1> (**NOTE: You can't control anyone else's muscles for your project for safety reasons.** But you can control a motor, LED, or some other inanimate object.)
- <https://youtu.be/pvBISFVmoaw?si=Pa6Mk-fDZRtAfB1H>
- <https://youtube.com/shorts/txhxElO8aqA?si=8jDMgpoRVJZIB8jv>
- <https://youtube.com/shorts/iC7-0uNzdgk?si=OIUuCPM9JNiMGTWG>
- <https://www.instructables.com/Bionic-Clicker-MKI/>
- <https://youtu.be/PlIjb5hp1u8?si=Eil6fgdkqVxldHpY>
- <https://youtu.be/b7BxFyMrpJo?si=ItOW0iU0z54CYVIA>

Appendix C: Visual Guide for Soldering Operational Amplifiers

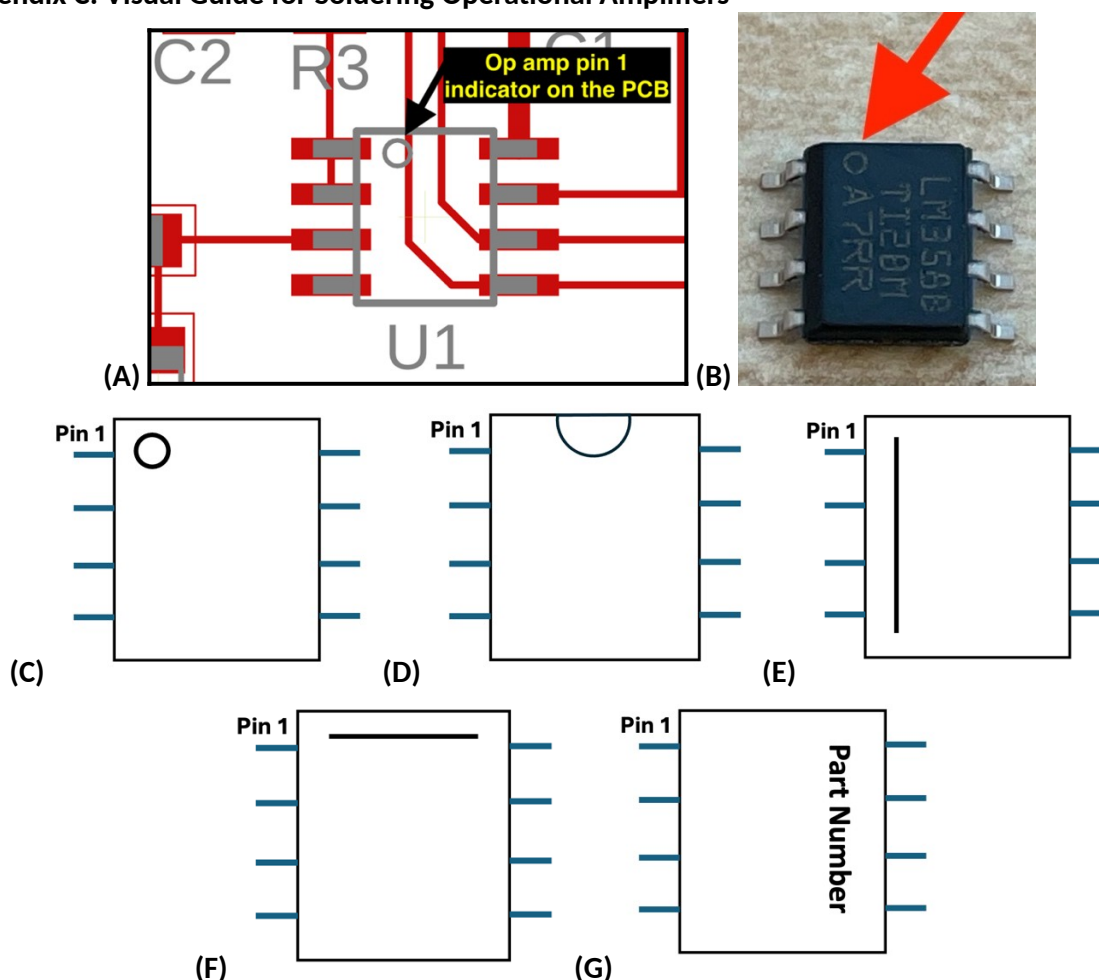


Figure 8. Possible locations of the op amp's pin 1 indicator. Images are showing the LM358; however, you will be using the MCP6002 and AD8226. The guide still holds for the MCP6002 and AD8226 op amps, but of course, the writing on the op amp will be different than Fig. 5B.

1. When soldering the operational amplifiers (op amps), place flux on all the op amps pads on the PCB. Align your op amps on the pads with pin 1 placed in the top left corner (as indicated in Figure 8 and also detailed below). Apply flux on top of the op amp's pins (in addition to the flux you added directly to the pads on the PCB earlier). Then solder the pin to the board.

The pin 1 indicator for the op amps is indicated by either:

- i. a circle in the top left corner, right next to pin 1 (or a circular indent or "dimple") (Figure 8A-C)
- ii. a notch in the top center of the op amp. Pin 1 is to the left of the notch if you position the notch to the top side of the op amp (Figure 8D).
- iii. a line (or indent) on the left side of the op amp. Pin 1 is in the top left corner

- if the line (or indent) is on the left side of the op amp (Figure 8E).
- iv. by a line at the top of the op amp. Pin 1 is to the left of the line (Figure 8F).
 - v. if you have the part number oriented such that you can read it from right to left, pin 1 is going to be to the bottom left of the part number (Figure 8G).
2. Then, add more flux to the top of the remaining 7 pins of the op amp (yes, in addition to the flux you added directly to the pads of the PCB earlier) and solder the remaining 7 pins. Yes, you must solder all 8 pins of the op amp for the op amp to function correctly. **And, no, you're not just adding one big blob of solder that's connecting all the pins together.** That's called a "solder bridge" or a short.

If you have any "solder bridges" (Figure 9) (connecting two pins together accidentally) between the pins of your op amp, please add more flux, then apply heat. That can often remove the bridges. If that doesn't work, try using desoldering wick. Place the wick on top of the solder bridge. Then apply the soldering iron on top of the wick. Wait for 5-10 seconds. It's often helpful to have the soldering iron at slightly higher temperature (maybe an additional 50 °F) since the heat now must transfer from the iron to the wick, and then to the pin and pad.

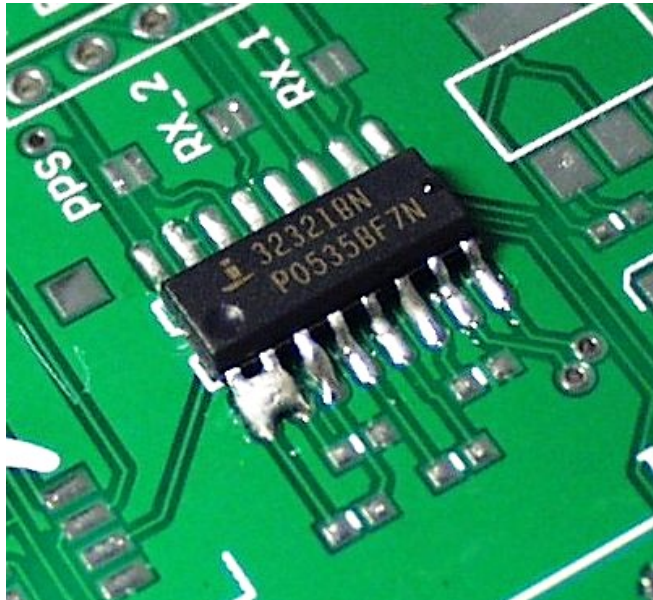


Figure 9. Notice the solder bridge between the two pins of the op amp. **DON'T DO THIS.**
 Image courtesy of All About Circuits and SparkFun Electronics.

Appendix D: Soldering LEDs and Header Pins

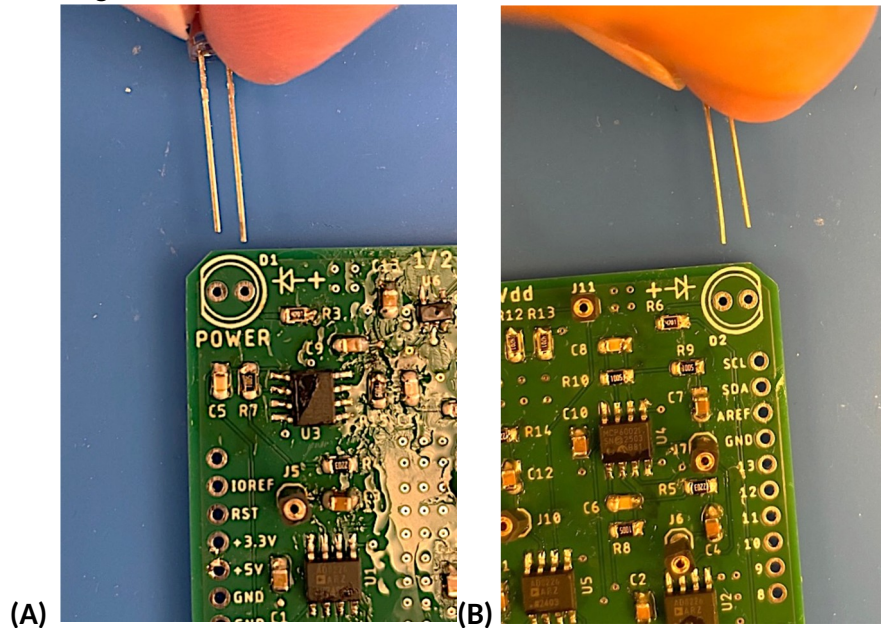


Figure 10. Orientations of the LEDs on the (A) left and (B) right sides of the board.

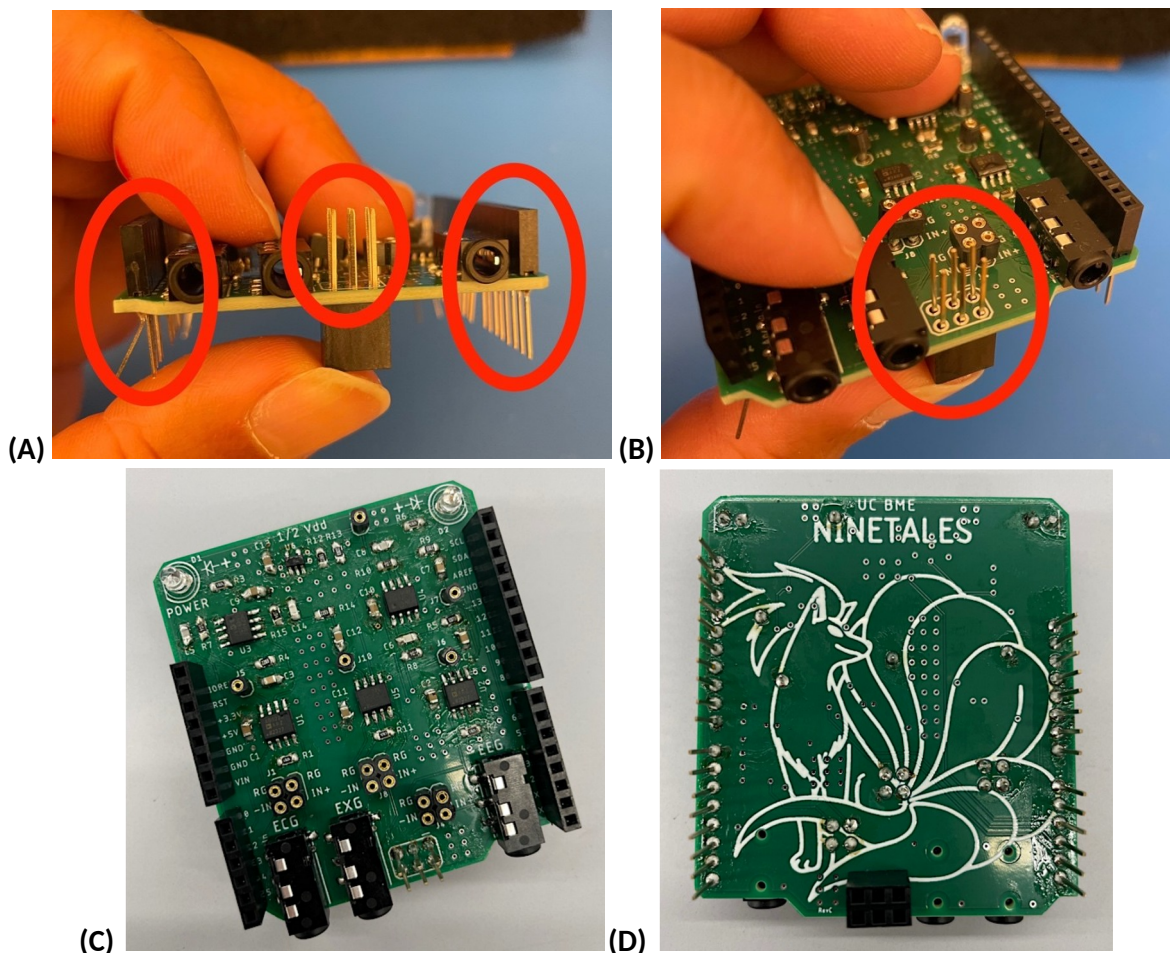


Figure 11. (A-D) Orientation of the header pins that stack the board on top of the Arduino.

Appendix E: Component Soldering Guide

Solder these first

R1 – 4.7k
 R2 – 4.7k
 R3 – 4.7k
 R4 – 220k
 R5 – 220k
 R6 – 4.7k
 R7 – 10 M
 R8 – 10 M
 R9 – 220k
 R10 – 10 M
 R11 – 4.7k
 R12 – 220k
 R13 – 220k
 R14 – 220k
 R15 – 10 M

Solder these second

C1 – 1 μ
 C2 – 1 μ
 C3 – 1 μ
 C4 – 1 μ
 C5 – 330 pF
 C6 – 330 pF
 C7 – 1 μ
 C8 – 330 pF
 C9 – 1 μ
 C10 – 1 μ
 C11 – 1 μ
 C12 – 1 μ
 C13 – 1 μ
 C14 – 33 pF

Then these...

(please consult the images
 for soldering the op amps)

U1 – AD8226
 U2 – AD8226
 U3 – MCP6002
 U4 – MCP6002
 U5 – AD8226
 U6 – MCP6001 (the
 orientation for this one
 should be obvious)

J1, J8, J4 are the 4-position
 headers (or 2, 2 position
 headers).

J5, J6, J7, J10, J11 are the 1-
 position headers. (Fig. 4C).
**These are NOT the header
 pins on the outer edge of
 the board.**

Then this

J9 – 3.5 mm jack (**solder J9
 before J2 or J3**)

Then these

J2 – 3.5 mm jack
 J3 – 3.5 mm jack

D1 – LED (any color,
 POWER indicator)

D2 – LED (any color, general
 purpose LED)

Solder these last and **NOTE
 the orientation:**

The stackable headers (the
 ones on the outer edge of
 the board) (Fig. 4A-4C.)