Module 6: Neuro- & Biomechanics

Description: Organisms use feedback and control systems to dynamically interact with their environment and by investigating these biological systems we can learn more about animal physiology, locomotion, and neuromechanics.

Smartphone oscilloscope (oscillophone)

Goal: Build an EMG circuit using the provided diagrams and to convert your smartphone into an oscilloscope using the audio jack as the signal input. Then, record your muscle response during different activities and use MATLAB to analyze the signal. BONUS: 3D print a box to make it portable!

Materials

- function generator
- oscilloscope
- 9V battery
- 9V battery snap clip
- breadboard
- jumper wire kit
- 3.5mm TRRS audio connector (4-conductor connector)
- 4.7uF (10V) ceramic capacitor
- 6V (0.5W) zener diode
- LM741, operational amplifier (2)
- INA128, instrumentation amplifier
- alligator clips (3)
- surface electrodes (3)
- 22k ohm resistor (2)
- 1.5k ohm resistor (2)
- gain resistor (resistor value determines gain of INA128)

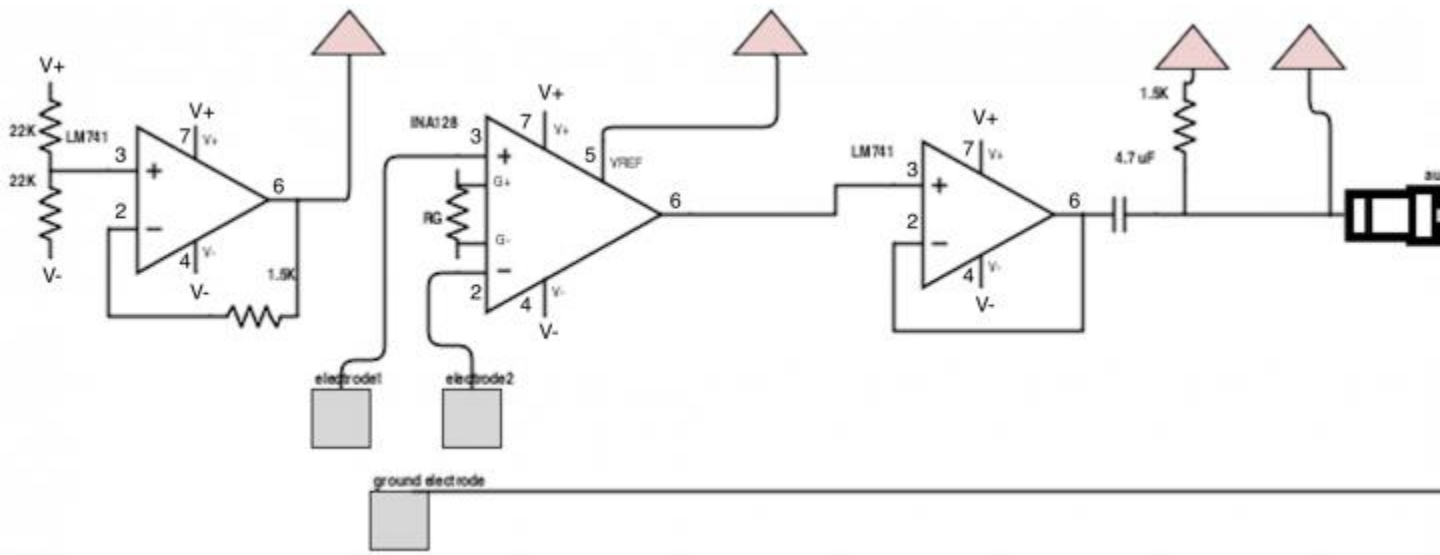
Procedure

1. Determine the TRRS connections for your smartphone and download an oscilloscope app.
    a. Make sure the app uses the audio jack as the signal input.
2. Follow Step 2: Wiring the TRRS Audio Connector in the pre-amplifier Instructable (see Resources).
3. Build the EMG amplifier/oscillophone circuit according to the diagram below or the pre-amplifier Instructable.
4. Power the circuit with the 9V battery and test it with the function generator and oscilloscope to ensure it's working correctly before plugging it into your phone.
    a. Check that the oscilloscope and the oscilloscope app both give the correct output.
5. Stick electrodes onto the target muscle and connect them to the circuit with alligator clips.
    a. Place one electrode on a bony area (e.g. knee or back of the hand) to act as a ground.

b. Place the other two electrodes over the same muscle, but with their centers at least 2cm apart to create a potential difference.

6. Test the circuit by recording your own muscle activity on your phone.

Circuit diagram[edit]



The first op-amp group forms the voltage divider which outputs a 4.5V virtual ground. The second op-amp group forms the gain circuit. The final op-amp group is a low-pass filter that protects the smartphone from a surge (you can calculate the cutoff frequency from the RC-constant).

Notes:

- V+ means the positive side of the battery
- V- refers to the negative side of the battery
- Triangles represent common (virtual ground)
- V (+, -): pins 7, 4
- signal inputs (+, -): pins 3, 2
- signal output: pin 6

Smartphone TRRS connections[edit]

Device	Tip (T)	Ring 1 (R1)	Ring 2 (R2)	Sleeve (S)

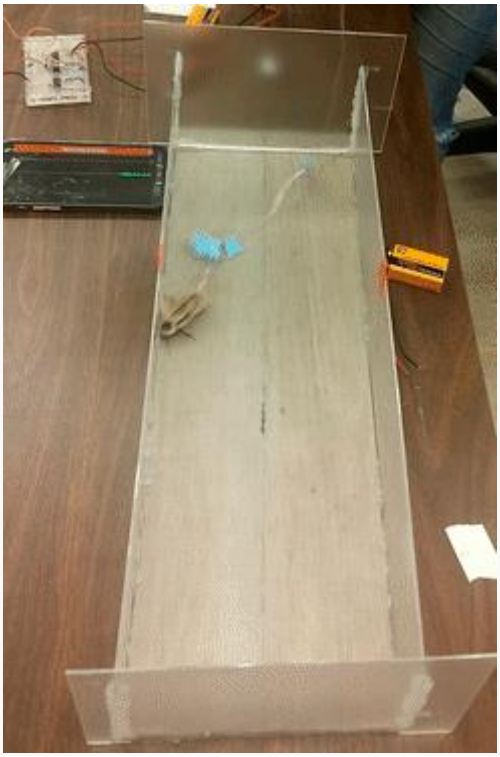
old Nokia (and also Lumia starting from the 2nd gen), old Samsung (2012 Chromebooks), old Sony Ericsson (2010 and 2011 Xperias), Sony (PlayStation Vita), OnePlus One	Left audio	Right audio	Microphone	Ground
Apple, HTC, latest Nokia (including 1st gen Lumia as well as later models), latest Samsung, Jolla, Sony (Dualshock 4), Microsoft, most Android phones	Left audio	Right audio	Ground	Microphone

Resources

- Virtual ground circuit
- Pre-amplifier Instructable
- 3.5mm headphone jack connector explained

Cockroach ("Blaberus") wiring

Goal: Implant silver wire electrodes into specific muscles in the leg of a cockroach (*Blaberus*) in order to record muscle signal (neuron firing) during various behaviors, e.g. running or climbing.



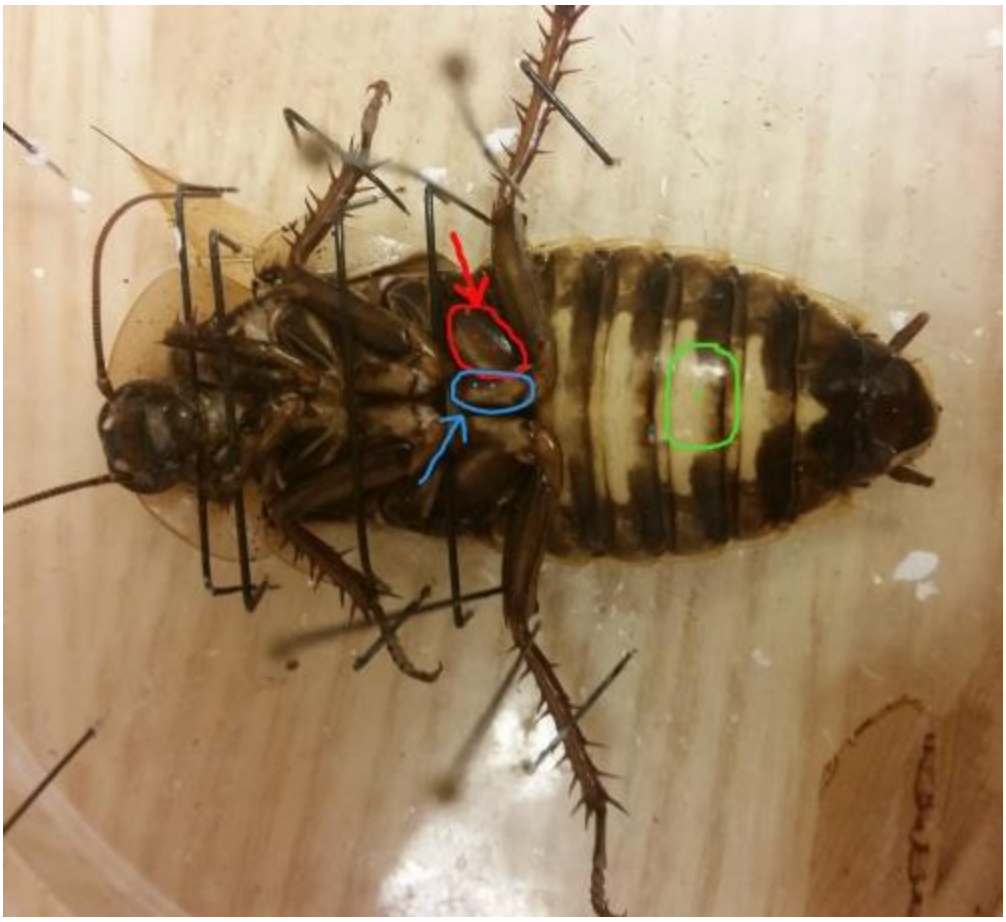
Materials

- dissecting microscope
- forceps set
- gel super glue
- stainless steel dissection pins
- baking soda
- toothpicks
- silver wire (gauge)
- lighter
- XX plate
- insect pins
- whiteout
- gloves
- air duster
- ice (optional)

Procedure

1. Anesthetize the cockroach in the refrigerator for ~30 minutes.
    a. (optional) Fill a bucket with ice to have in case the cockroach starts to wake up during surgery.
2. While waiting, prepare the electrodes/tether:
        i. Cut three (or five) equal lengths of silver wire and label the top and bottom of two (or three) wires with small pieces of tape (two different colors).
        ii. Tightly wind the wires together, leaving the ends split and long enough for implantation and attachment to the EMG circuit.
        iii. Burn the tips of the wires on both ends to remove insulation.
3. After the animal is anesthetized, start with the head and pin it (see picture below) to the XX plate.
    a. Make sure to leave the target muscle(s) exposed.
4. Using a stainless steel dissection pin score the areas the of the cockroach that will be super glued.
5. Gently drill holes in the target muscle(s) and abdomen.
6. With the dissecting microscope and forceps, insert the wires into the holes made first in the target muscle(s) and then in the abdomen.
7. Apply super glue to the wires and the immediate surrounding area (avoiding joints or other muscles).
8. Place a pinch of baking soda over the super glue to cure it.
9. After a few seconds, blow away excess baking soda with the air duster.
10. Gather all wires and super glue them together (curing with super glue).
11. Glue the cluster of wires to the abdomen (below the ground wire) with some slack, so the animal won't rip them out.
12. When unpinning the animal, unpin the head last.

Leg muscles



- Red circle: flexor muscle ("bicep")
- Blue circle: extensor muscle ("tricep")
- Green circle: abdomen
- Number of dots corresponds to the number of inserted wires