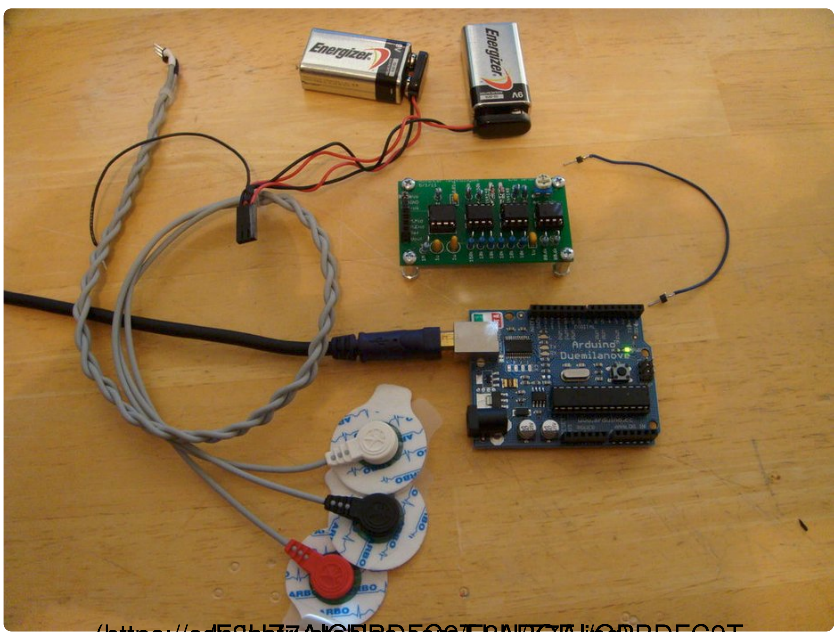
DIY MUSCLE SENSOR / EMG CIRCUIT FOR A MICROCONTROLLER

By Advancer Technologies (/member/Advancer+Technologies/) in Technology (/technology/) > Science (/technology/science/) 608,213 765 426 Featured

Published Jun. 27, 2011 Download Favorite



(/member/Advancer%20Technologies/)

By **Advancer Technologies**

Advancer Technologies
(http://www.advancertechnologies.com)

More by
the author:

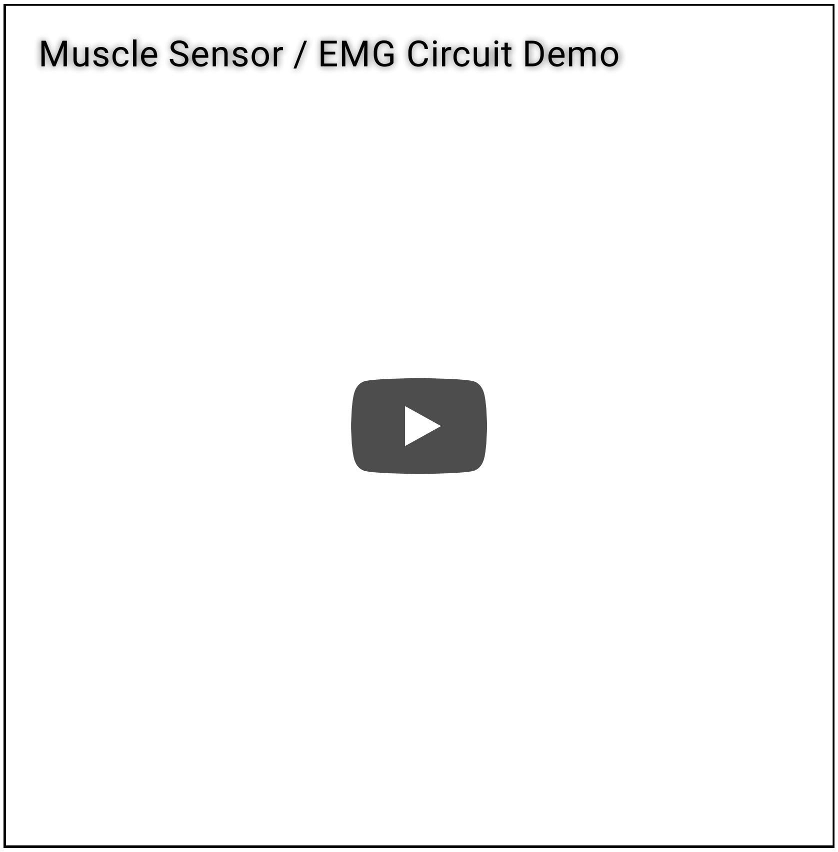


About: The bionics wizards at Advancer Technologies are changing the world by helping homegrown inventors flex their creative muscles. From robots to video games to prosthetics, their muscle sensor, MyoWare™,... More About Advancer Technologies » (/member /Advancer%20Technologies/)

Measuring muscle activation via electric potential, referred to as electromyography (EMG) (http://en.wikipedia.org /wiki/Electromyography) , has traditionally been used for medical research and diagnosis of neuromuscular disorders. However, with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into prosthetics, robotics and other control systems. Yet, EMG systems remain expensive and mostly outside the grasp of modern hobbyist.

This instructable will teach you how to make your own muscle sensor / EMG circuit to incorporate into your next project. Use it to control video games, robot arms, exoskeletons, etc.

Click on the video below for a demonstrations on how to hook up and use your EMG circuit board!



You can now also purchase EMG sensors, kits, cables and electrodes at [www.AdvancerTechnologies.com (http://www.advancertechnologies.com/p/shop_3.html)]!

[Muscle Sensor Kit (http://www.advancertechnologies.com/p/muscle-sensor-v3.html)] (now also on [SparkFun (https://www.sparkfun.com/products/11776)])

[Muscle Sensor Electrodes (http://www.advancertechnologies.com/p/muscle-sensor-electrodes.html)]

Note: This sensor is not intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation treatment, or prevention of disease, in a man or other animals.

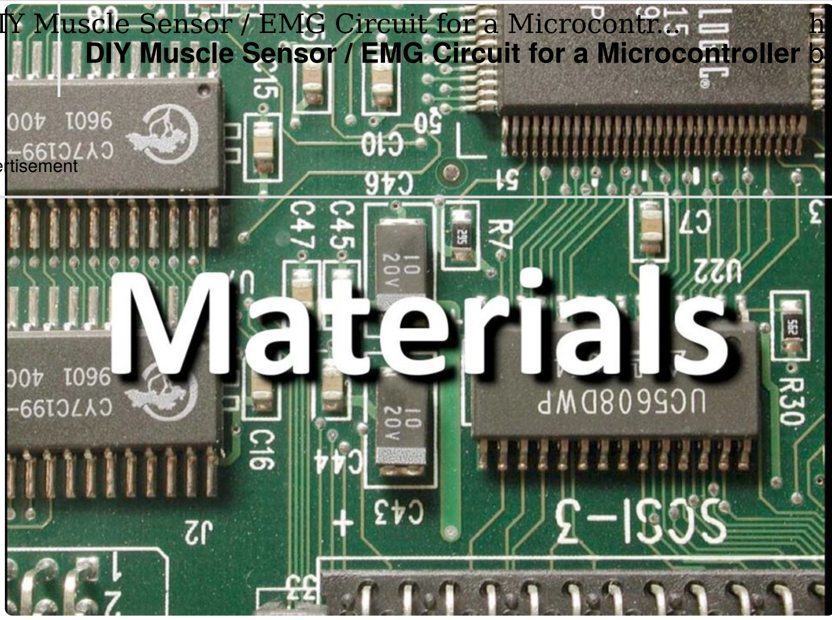
About Advancer Technologies

Advancer Technologies (http://www.advancertechnologies.com/) is a company devoted to developing innovative game-changing biomedical and biomechanical technologies and applied sciences. Additionally, Advancer Technologies (http://www.advancertechnologies.com/) promotes all forms of interest and learning into biomedical technologies. To help culture and educate future great minds and concepts in the field, they frequently post informative instructions on some of their technologies. For more information, please visit www.AdvancerTechnologies.com (http://www.advancertechnologies.com/) .

Add Tip Ask Question Comment

Download

Step 1: Materials



Click on the links to go to where you can buy items/order free samples.

Circuit Chips

3x TL072 IC Chip (http://focus.ti.com/docs/prod/folders/print/tl072.html) - Free Samples

1x INA106 IC Chip (http://focus.ti.com/docs/prod/folders/print/ina106.html) - Free Samples

Cables and Electrodes

1x EMG Cables (http://bio-medical.com/products/din-ekgemgeeg-snap-leads-24-inch.html) (set of 3)... Note: you could optionally connect the alligator clips directly to the electrodes.

3x EMG Electrodes (http://bio-medical.com/products/kendall-tyco-arbo-disposable-electrodes-50pkg-35mm.html)

Power

2x 9V Battery

2x 9v battery clips (http://www.radioshack.com/product/index.jsp?productId=2062218)

Capacitors
- 2x 1.0 uF Tant (http://search.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header=search_go&lang=en&site=us&keywords=399-3529-ND&x=0&y=0)
- 1x 0.01 uF Ceramic Disc (http://search.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header=search_go&lang=en&site=us&keywords=490-3812-ND&x=0&y=0)
- 1x 1.0 uF Ceramic Disc (http://search.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header=search_go&lang=en&site=us&keywords=399-4389-ND&x=0&y=0)

Resistors
- 3x 150 kOhm 1% (http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=150KXBK-ND)
- 2x 1 MOhm 1% (http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=RNF14FTD1M00CT-ND)
- 2x 80.6 kOhm 1% (http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=RNF14FTD80K6CT-ND) (Note: You don't need exactly 80.6k resistors. Anything around 80k should suffice. Our MyoWare sensor uses 82k resistors for

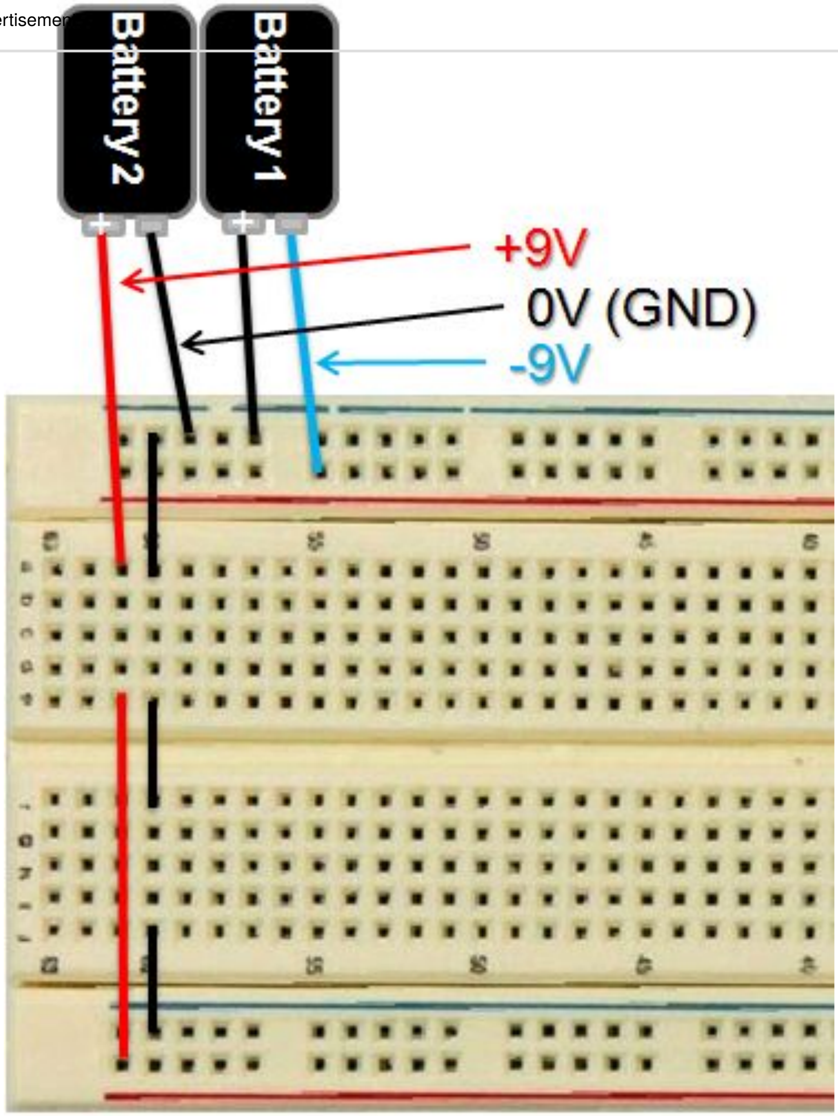
example)

• 6x 10 kOhm 1% (http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=10.0KXBK-ND)
• 1x 100 kOhm Trimmer (http://search.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header=search_go&lang=en&site=us&keywords=D4AA15-ND&x=0&y=0)
• 1x 1 kOhm 1% (http://search.digikey.com/scripts/DkSearch/dksus.dll?Detail&name=RNF14FTD1K00CT-ND)

Misc
• 2x 1N4148 Diode (http://search.digikey.com/scripts/DkSearch/dksus.dll?WT.z_header=search_go&lang=en&site=us&keywords=1N4148FS-ND&x=0&y=0)
• Jumper wires (http://www.radioshack.com/product/index.jsp?productId=2103801)
• 3x Alligator clip cables (http://www.sparkfun.com/products/8927)

Optional
• 1x Oscilloscope
• 1x Multimeter

Step 2: POWER SUPPLY



To start things off, you'll need both a positive and negative voltage power supply. We will make these using two 9V batteries.

Now, everyone knows what a positive voltage power supply is, (e.g. common battery) but how do you go about making a negative voltage power supply?

Common electrical circuit rule of thumb is when you connect two batteries in series (eg positive terminal of battery 1 connected to the negative terminal of battery 2) then measure the voltage from the negative terminal of battery 1 and the positive terminal of battery 2, the measured voltage is equal to the summation of the voltages of battery 1 and battery 2.

For this circuit we want a +9V and a -9V power supplies. If we connect our two 9V batteries in series, we will get a power supply of +18V. So how do we get the -9V from these two?

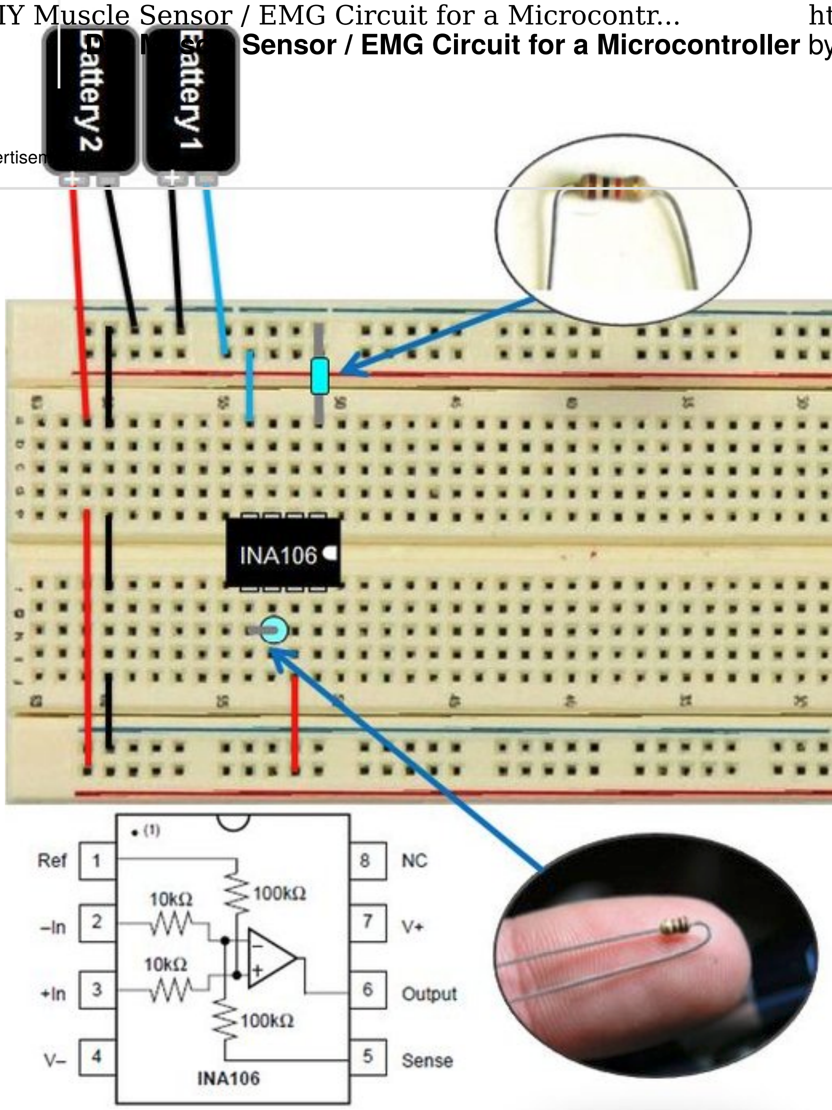
It might help to think about what voltage actually means... voltage is an electrical potential difference. The keyword here is difference. Voltages are only meaningful in terms of the reference point (or more commonly referred to as ground). A voltage is the electrical potential between this reference point and the point you are measuring. Do you see the answer yet?

We do indeed get a +18V voltage reading if we use battery 1's negative terminal as the reference point... but what if we choose the connection between battery 1's positive terminal and battery 2's negative terminal? If

we use this point as our reference or ground, then battery 2's positive terminals voltage will be +9V and battery 1's negative terminal will be -9V!

Using your breadboard, 9V batteries and battery clips, connect the battery clip wires as shown. *However, for the time being, disconnect the positive terminal of battery 2 and the negative terminal of battery 1. It is good practice to always disconnect your power while you assemble a circuit. At the end of the assembly we will reconnect these wires to power the circuit on. (You could also add switches to do this)*

Step 3: SIGNAL ACQUISITION



Next, we will work on the signal acquisition phase of your EMG circuit which we will use to measure your body's nervous system's electrical impulses used to activate muscle fibers.

First, get out your INA106 IC chip (chip A) and insert it into your breadboard as illustrated above. The INA106 is a difference amplifier which will measure and amplify (G=110) the very small voltage differences between the two electrodes you place on your muscle.

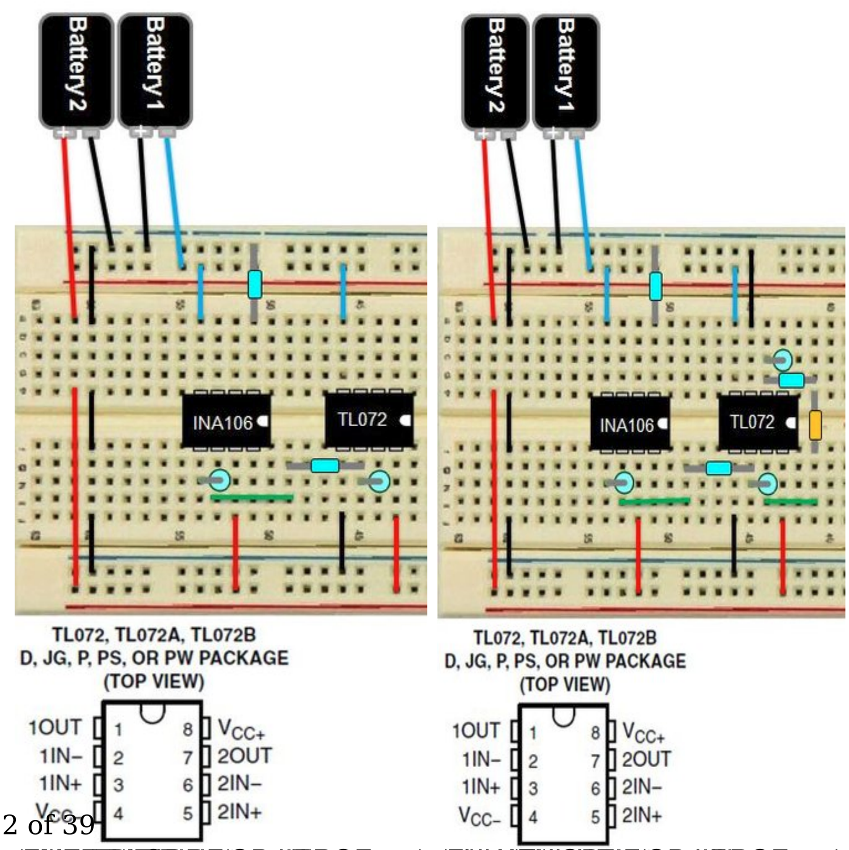
Next grab two 1 M ohm resistors, bend them and then plug them in to your breadboard like the two examples shown. One should connect pins 5 and 6 and the other should bridge pin 1 to your ground rail of your board.

Don't worry about the other pins of the INA106 for now; we'll come back to those later.

Add Tip Ask Question Comment

Download

Step 4: SIGNAL CONDITIONING - Amplification



DIY Muscle Sensor / EMG Circuit for a Microcontroller by Advancer Technologies (/member/Advancer Technolog

In this phase, we're going to take those very small signals measured in the SIGNAL ACQUISITION phase and amplify them.

Let's start first with two series of amplification; the first will be inverting amplifier with a gain of -15. An inverting amplifier does exactly what it sounds like. It amplifies your signal but also inverts it. You can find more info about inverting amplifiers here (http://en.wikipedia.org/wiki/Operational_amplifier_applications#Inverting_amplifier) .

We are going to first build an inverting amplifier with a gain of -15. To do this, we'll need one of the TL072 chips (chip B), one 150 kOhm resistor and a 10 kOhm resistor.

Place chip B as the picture indicates. Now use a jumper wire and connect pin 6 of chip A two rows past pin 8 of chip A. Grab one of the 10 kOhm resistors and plug one pin into this row as well. Connect the other pin to pin 6 of chip B. Bend a 150 kOhm resistor and connect one pin to chip B's pin 6 and the other to pin 7. You can calculate the gain by G=-R2/R1 or in this case G=-150 kOhm / 10 kOhm. (See image 1)

Next, we are going to add a capacitor to AC couple the signal. AC coupling is useful in removing DC error offset in a signal. Read

more about AC and DC coupling here

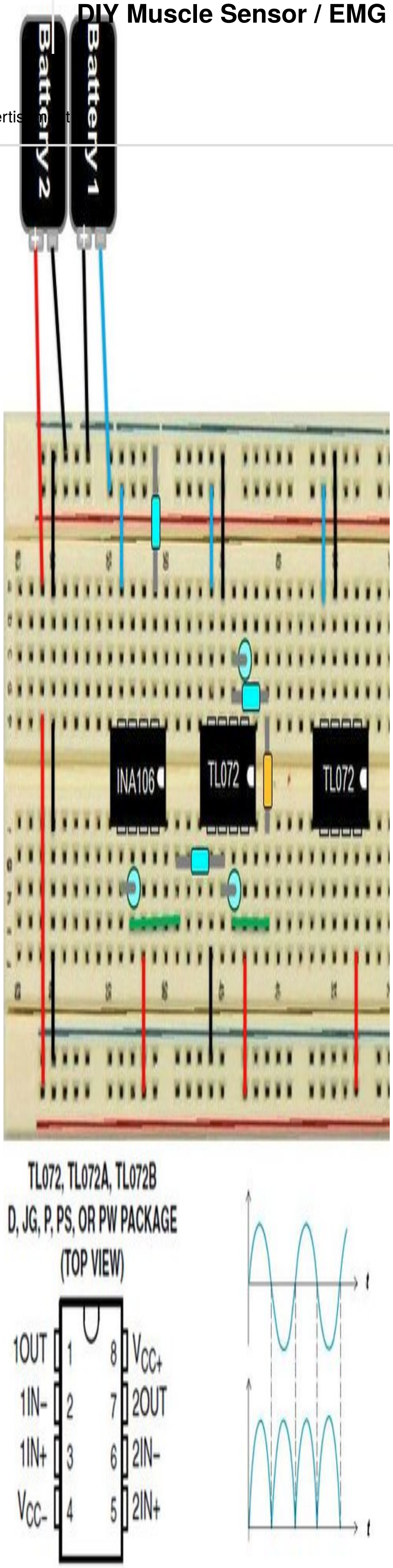
(http://zone.ni.com/devzone/cda/ph/p/id/9) .

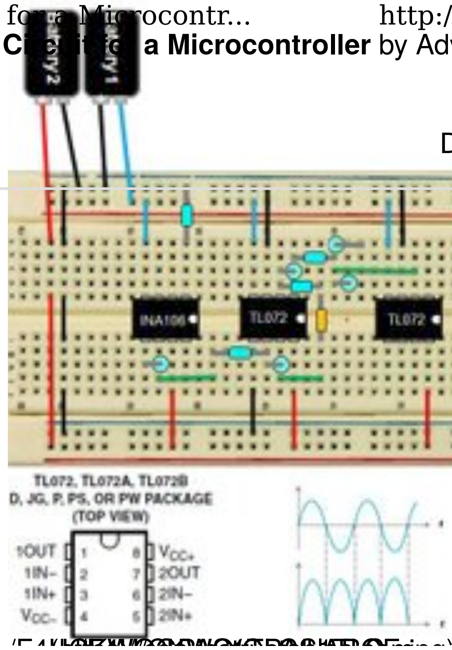
Continuing on, we are going to add an active high pass filter to get rid of any DC offset and low frequency noise. To do this you will need two 150 kOhm resistors and a 0.01uF capacitor. Use a jumper wire and the 0.01 uF capacitor to bridge the center gab of your breadboard as shown. (One end of the jumper wire should be connected to pin 7 of chip B). The 150 kOhm resistor will connect the capacitor you just placed to pin 2 of chip B. Now, bend the 150 kOhm resistor and push it into connect pins 1 & 2. (See image 2)

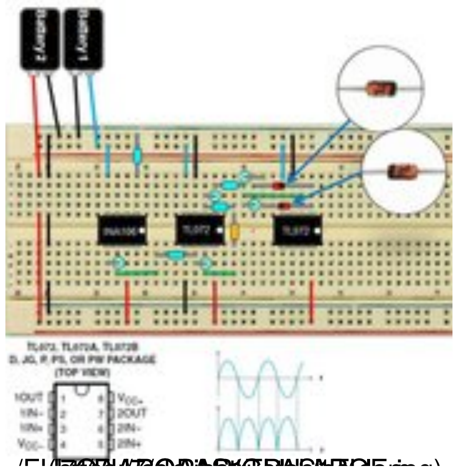
Also, go ahead and connect chip B's pin 4 to your -9V rail, pin 8 to your +9V rail, and pins 3 & 5 to your GND rail.

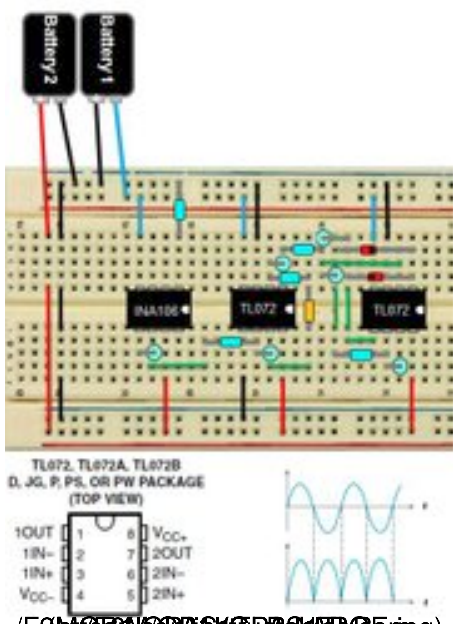
Add Tip Ask Question Comment
Download

Step 5: SIGNAL CONDITIONING - Rectification









In this phase, we will be rectifying the signal using an active full-wave rectifier (http://en.wikipedia.org/wiki/Rectifier#Full-wave_rectification) . Our rectifier will take the negative portion of our signal and turn it positive so the entire signal falls within the positive voltage region. We will use this coupled with a low pass filter to turn our AC signal in to a DC voltage; readying the signal to be passed to a microcontroller.

You will need five of the 10 kOhm resistors, both 1N4148 diodes, and a second TL072 chip. Warning... this will be the most difficult phase to assemble! Pay close attention to the pictures!

First, plug in a TL072 chip (chip C) and connect -9V rail to pin 4, the +9V rail to pin 8 and GND to pin 3, as shown in the first image.

Next, place a 10 kOhm resistor (let's call it resistor A) connecting pin 1 of the TL072 chip from the amplification phase and plug the other end into the row next to the 0.01uF capacitor's row. Use a jumper wire to connect this row to pin 2 of the second TL072 chip. The next 10 kOhm resistor we'll call resistor B. Resistor B's first pin should be plugged into the row where resistor A's second pin is plugged in and resistor B's other pin should be plugged into the row two down. Another 10 kOhm resistor's (resistor C) first pin should be plugged into the row where resistor A's second pin terminated (same as resistor B) but the other pin should be

plugged into the next immediate row over. (See

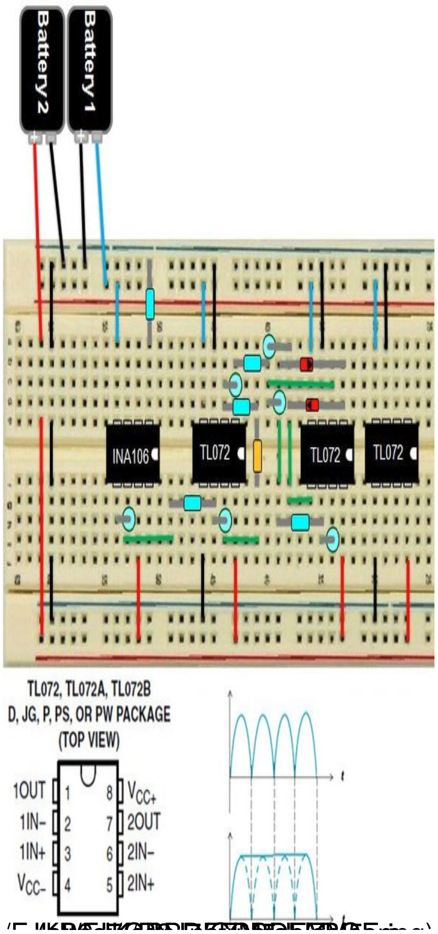
image #2)

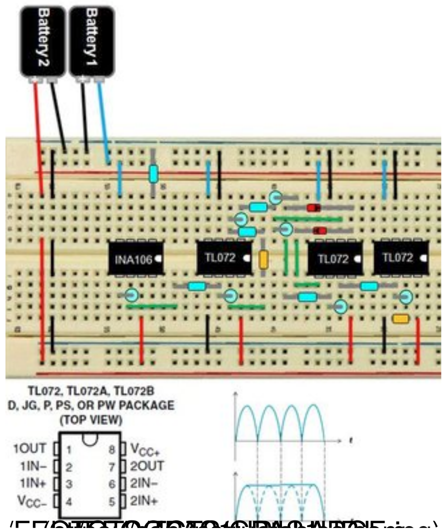
Now get out the two 1N4148 diodes. Diodes are polarized so be sure to pay attention what direction you plug them in! We'll call these diodes A and B. Plug diode A's positive end (end with black strip) into pin 1 of chip C and plug the negative end into the row of resistor C's second pin. Get diode B and plug the NEGATIVE end into pin 1 of chip c and plug the POSITIVE end into the row of resistor B's second pin. (See image #3)

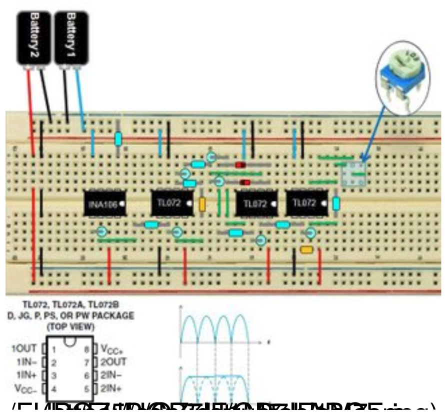
Next, use two jumper wires to bridge the center gap for resistor C and B's rows. Use another jumper wire to connect the jumper wire's row connected to resistor B's row to pin 5 of chip C. Use another 10 kOhm resistor to connect the jumper wire's row connected to resistor C's row to pin 6 of chip C. Finally, use the last 10 kOhm resistor to connect chip C's pins 6 and 7. (See image #4).

Phew... that is for the rectifying phase! Next is the filter phase.

Step 6: SIGNAL CONDITIONING - Smoothing + Amplification







In this last phase of circuit assembly, we will be using an active low-pass filter to filter out the humps of our signal to produce a smooth signal for our microcontroller.

You will need the last TL072 chip (chip D), the two 80.8 kOhm resistors, the 100 kOhm trimmer, the 1 kOhm resistor and the 1.0 uF ceramic disc capacitor.

First, plug in chip D and connect +9V to pin 8,

-9V to pin 4, and GND to pins 3 & 5. (image #1).

Now, grab one of the 80.6 kOhm resistors and connect one end to chip C's pin 7. Connect the other end to chip D's pin 6. Next grab the other 80.6 kOhm resistor use it to connect chip D's pin 6 and 7. Do the same thing for the 1.0 uF capacitor. (image #2)

That's the end of the filter circuit. However, since this is an active filter, there is a side effect of inverting the signal. We will need to invert the signal one more time (and have the ability to amplify it more if desired) using another inverting amplifier circuit with a trimmer configured as a variable resistor.

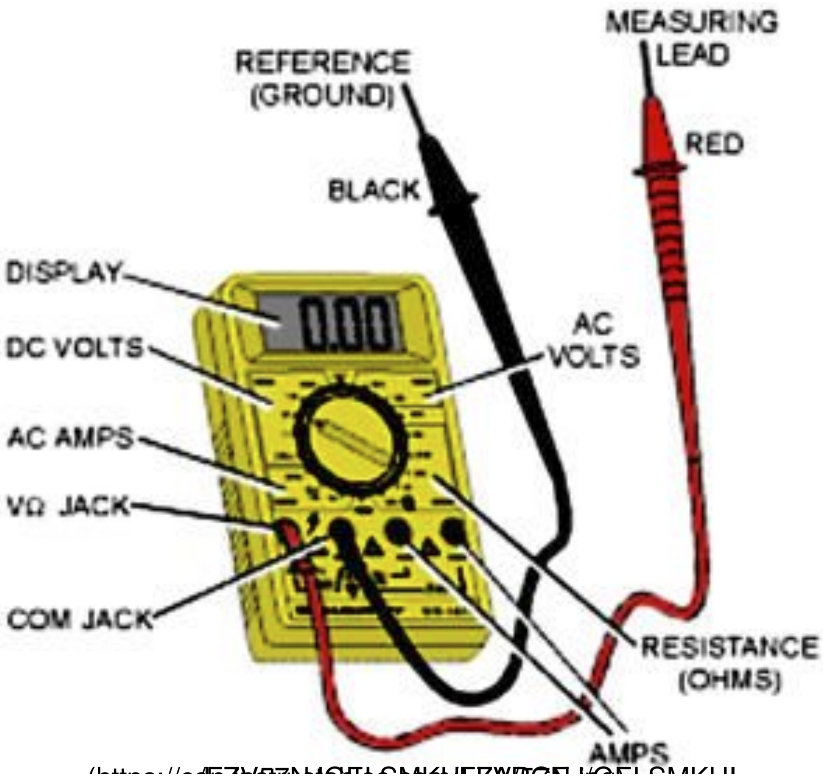
Use a jumper wire, connected to chip D's pin 7, and the 1 kOhm resistor to bridge the board's center gap. Use another jumper wire and connect the 1 kOhm resistor to chip D's pin 2. Next, place the trimmer one row over with the pins laid out and a jumper wire connecting two of the pins as pictured. Finally, place the last two jumper wires as indicated. (image #3)

By using a screw driver and turning the trimmer, you will be able to adjust the gain of your signal to account for different signal strengths from different muscle groups. Start out with it set pretty low and go up from there (~20 kOhms).

Add Tip Ask Question Comment

Download

Step 7: Circuit Review



(Optional) If you have an oscilloscope and a wave generator handy, now would be a good time to step through the circuit and test each phase.

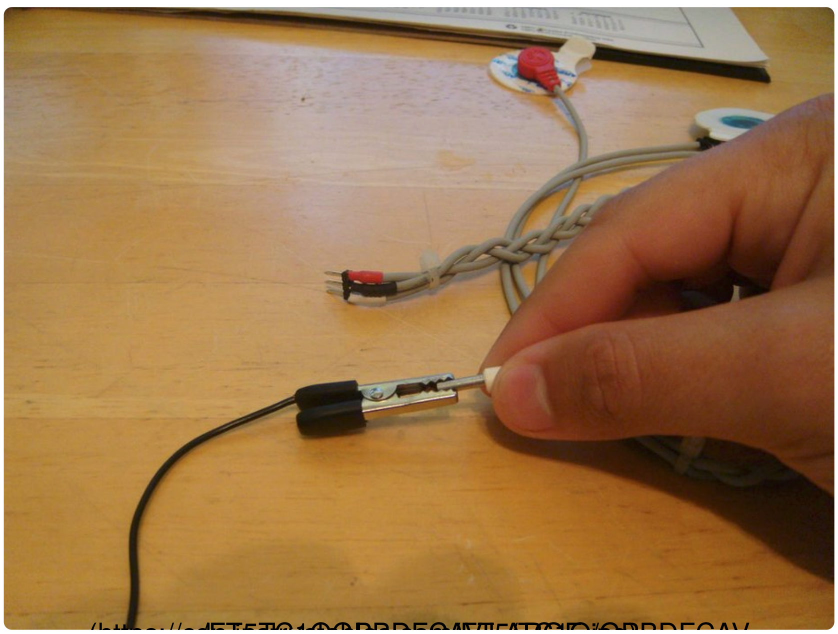
If you do not have an oscilloscope handy, go back and review your circuit connections step by step to make sure you have place each component correctly. Pay close attention to the

power pins and connections of your chips. If

you have these incorrect, you could burn out

your chips!

Step 8: Electrode Cables



Next, you'll need to make some changes to the EMG electrode cables since I have been unable to find a vendor who sells the cable's style DIN connector's female compliment. (if any one has a suggestion please let me know!)

Grab a pair of scissors, wire cutters, wire strippers, pocket knife, etc.... basically anything sharp and strip about a 1/4" of the end of the

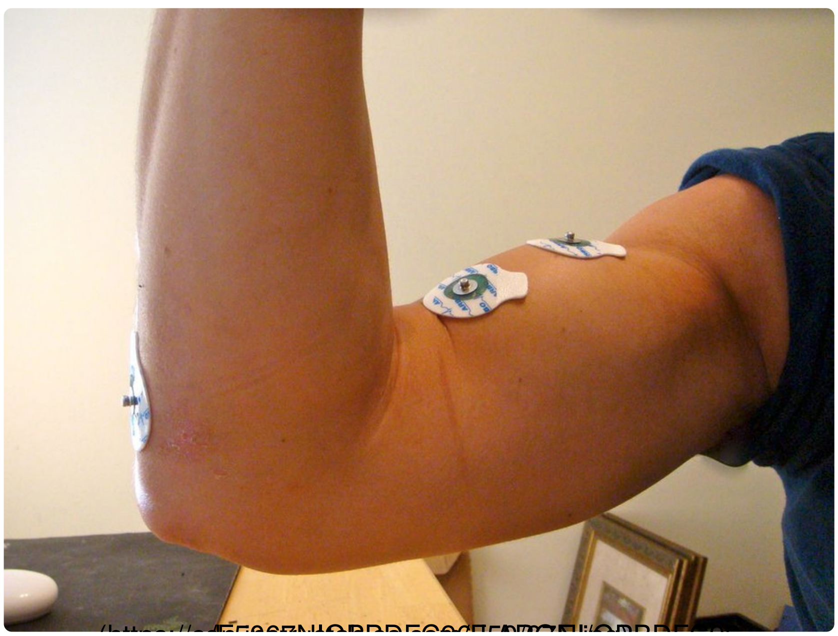
DIN plug on all three cables (the plug end not the snap end).

Next, clip an alligator cable to each of the wires. We will use these to connect the electrode cables to our breadboard with some jumper wire. You could do as I have done and strip the wire and then solder on terminal pins but it is not necessary and the alligator clips will do fine.

Add Tip Ask Question Comment

Download

Step 9: Surface Electrodes



For the electrode placement, you will need three surface electrodes.

After determining which muscle group you want to target (for example I will be using my right bicep) and cleaning the skin thoroughly, place one electrode on your skin above the middle of the length of the desired muscle. Let's call this the mid muscle electrode.

Next, place a second electrode at one end of the muscle. We'll call this the end muscle electrode.

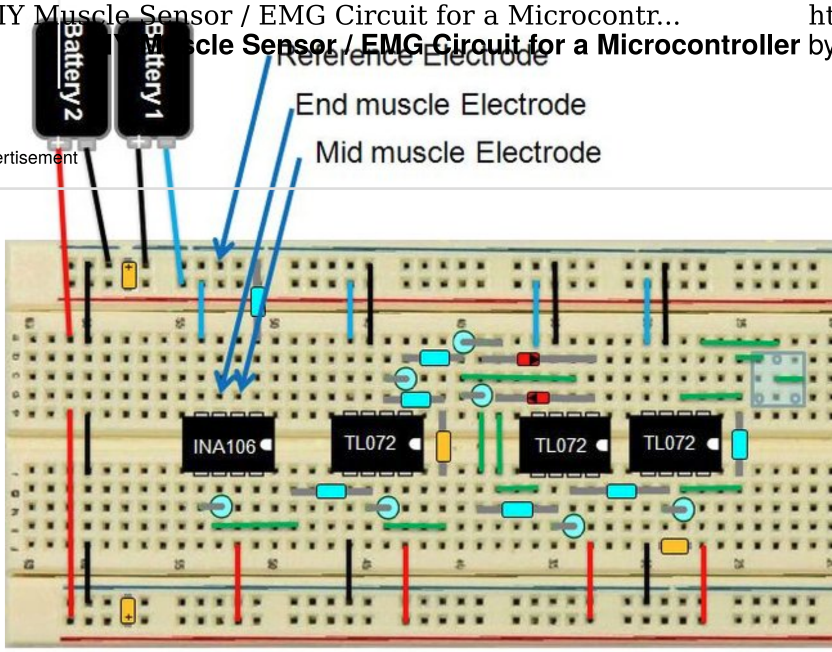
Last, place the third electrode on a bony part of your body nearby the muscle group. We'll call this the reference electrode. For example, for the biceps, I am placing the reference electrode on the bony end of my forearm close to my elbow.

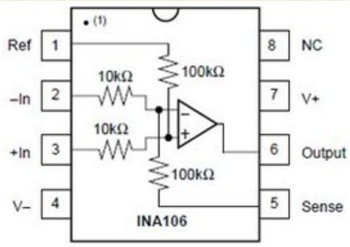
Using the snap connections of the electrode cables, snap each cable to each electrode. Make a mental note of which color cable is attached to which electrode.

Add Tip Ask Question Comment

Download

Step 10: Connecting Electrode Cables





Now you are ready to connect your electrode cables to your circuit. Remember those pins on chip A that we put aside till later?

Connect the reference electrode to the GND rail of your circuit.
Connect the mid muscle electrode to chip A's pin 2
Connect the end electrode to chip A's pin 3

Lastly, we need to add some circuit protection via capacitors. Tanthium capacitors are polarized like the diodes we used earlier. These are easier to tell which is the positive pin and negative pin since one is always marked with a + sign indicating positive pin. Connect one 1.0

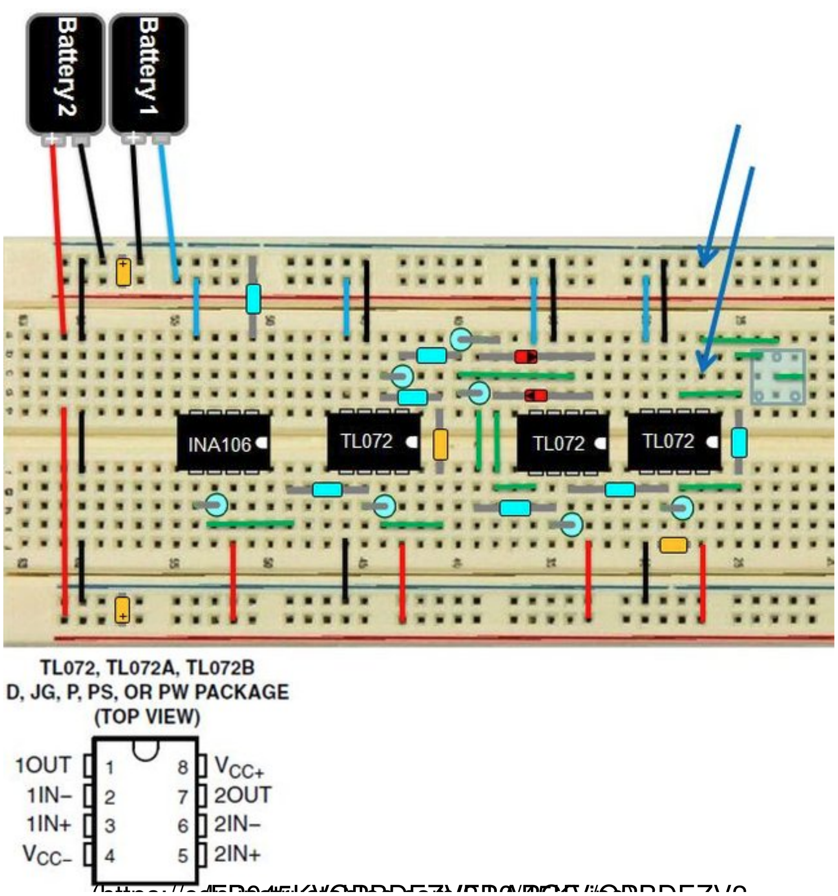
uF tant. capacitor between the +9V rail and GND rail, with the positive end connected to the +9V rail. Connect the other 1.0 uF capacitor to the -9V and GND rails, with the positive end connected to the GND rail.

Now you'll ready to power on your circuit!

Add Tip Ask Question Comment

Download

Step 11: Connecting to a Microcontroller



Before connect your circuit to your

microcontroller, you should power on your circuit (by connecting the battery wire's we disconnected earlier) and check the output voltage with a multimeter to make sure it is within your microcontroller's analog input pin's tolerances. To do this, connect the negative multimeter probe to your GND rail and connect the positive probe to pin 1 of chip D. Make sure the voltage measured is less than the max voltage of your input pin!

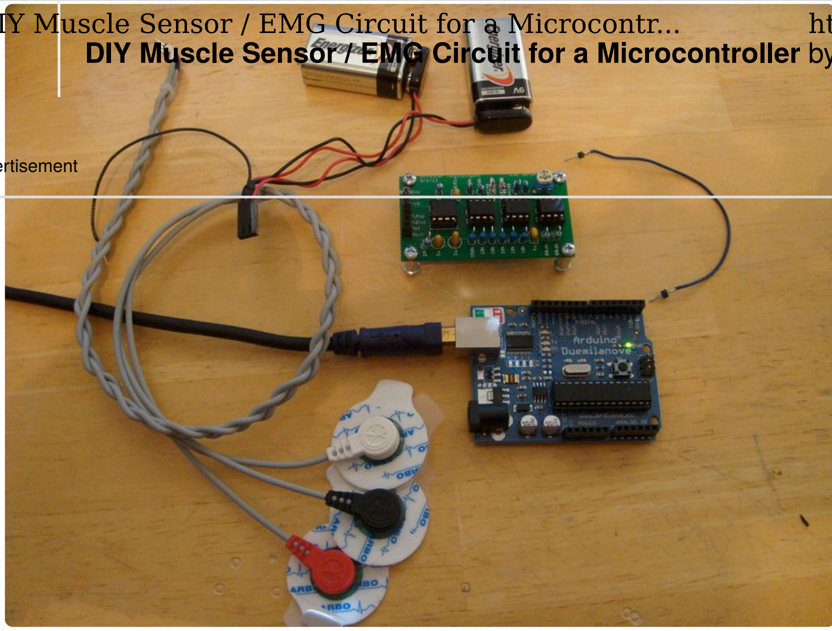
If you've done that check and everything thing looks fine, use jumper wires to connect pin 1 of chip D to an analog input pin of your microcontroller and your GND rail to the GND pin of your microcontroller.

Congratulations you're done!

Add Tip Ask Question Comment

Download

Step 12: Arduino Demo



For this demo, we used an Arduino Duemilanove microcontroller hooked up to a PC running Processing visualization software.

Remember to visit us at www.AdvancerTechnologies.com for kits and fully assembled sensors! (http://www.advancertechnologies.com/p/muscle-sensors.html)

DIY Muscle Sensor / EMG Circuit for a Microcontroller by Advancer Technologies (/member/Advancer Technolog

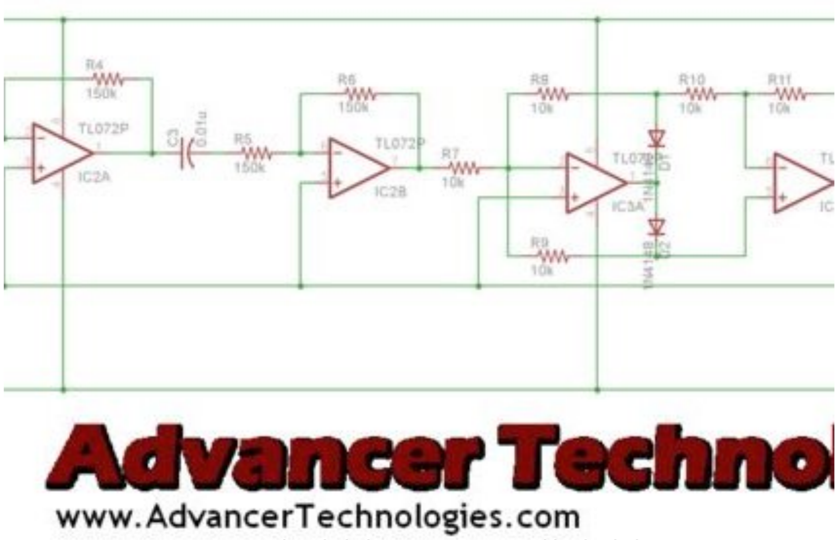
advertisement

Download Favorite

Add Tip Ask Question Comment

Download

Step 13: EMG Circuit Schematic



Click the i box in the top left to see a larger version... or go to our website and click on the

EMG schematic image (http://www.advancertechnologies.com/p/muscle-sensor-emg-circuit-kit-bronze.html) .

Add Tip Ask Question Comment

Download

11 People Made This Project!

Trainer665 (/member /Trainer665/) made it!

bobolgb (/member/bobolgb/) made it!

SiddharthG16 (/member /SiddharthG16/) made it!

Nour Abdel Latif Sanouree (/member /Nour+Abdel+Latif+Sanouree/) made it!

OzoneAmanda (/member /OzoneAmanda/) made it!

AhsanM18 (/member /AhsanM18/) made it!

MarcoP142 (/member /MarcoP142/) made it!

narendra1997 (/member /narendra1997/) made it!

DIY Muscle Sensor / EMG Circuit for a Microcontroller by Advancer Technologies (/member/Advancer Technolog

Download Favorite

See 2 more that made it

jerryliu (/member/jerryliu/)
made it!

Did you make this project? Share it with us!

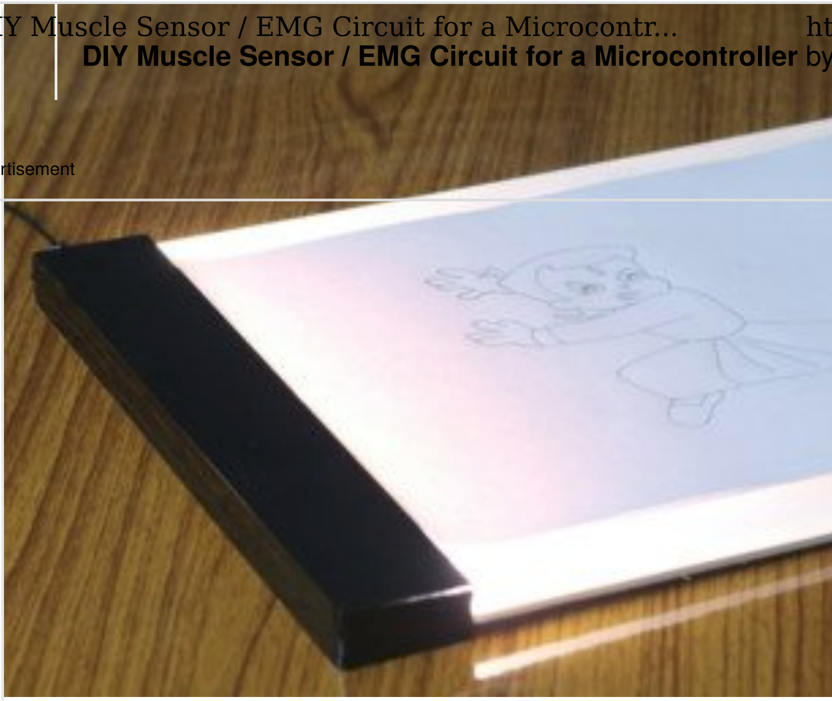
I Made It!

Recommendations

(/id/Electronic-Cricket-Game/)

Electronic Cricket Game (/id/Electronic-Cricket-Game/)

by lonesoulsurfer (/member/lonesoulsurfer/) in Technology (/techn...



(/id/LED-DRAWING-PAD/)

LED DRAWING PAD (/id/LED-DRAWING-PAD/)

by Creativity Buzz (/member/Creativity%20Buzz/) in Leds (/techno…

(/id/Weather-Forecast-Clock-Using-Old-Alarm-and-Arduino/)

Weather Forecast Clock Using Old Alarm and Arduino (/id/Weather-Forecast-Clock-Using-Old-Alarm-and-Arduino/)

by LenkaDesign (/member/LenkaDesign/) in Clocks (/technology/c…

Add Tip

Ask Question

Post Comment

We have a **be nice** policy.
Please be positive and constructive.

Add Images Post

426 Discussions

(/member/FLIPPtronics/) FLIPPtronics (/member/FLIPPtronics/)

2 years ago

Reply Upvote

How much do the meterials fot this cost in total? Is it cheaper than the pre-build myoware muscle sensors?

3 replies

 (/member/Rom%C3%A1nV1/) RomanV1 (/member /Rom%C3 %A1nV1/)

3 years ago

Reply ▲ Upvote

what programs and code for arduino you used for the data acquisition and the visual representation of the emg signals?, thanks for your time and for your project (:

1 reply

(/member/mosi0936/) mosi0936 (/member /mosi0936/)7 days ago

Reply ▲ Upvote

hi
im tring to make this circuit but i have question. could you tell me that which pins of this circuit should conect to arduinio? and if it is possible send me the picture of your arduino whent pins conected to it.
thanks
gmail: biopax.mirkazemi2016@gmail.com (mailto:biopax.mirkazemi2016@gmail.com)

 (/member/adityab98/) adityab98 (/member /adityab98/)

Question 24 days ago on Introduction

Answer ▲ Upvote

can you please suggest any replacement for INA106 because its not available here.

(/member/vaibhava31/) vaibhava31 (/member /vaibhava31/)5 months ago

hello sir,
your work is really appreciating. i just want to know what is use of 100 kohm trimmer
and can i use a regular 100k ohm resister insted of trimmer

(/member/shruikan27/) shruikan27 (/member/shruikan27/)7 months ago

Reply ▲ Upvote

Where can we actually get the Processing visualization software program used to test the completed device? We have downloaded the Arduino sample codes but when it comes to integrating it into the processing software we are receiving certain errors.

1 reply

(/member/6_run/) 6_run (/member/6_run/)
Question 5 months ago on Step 13

Answer ▲ Upvote

Hi, how does one control 5 robitic fingers individually using one muscle sensor.how (http://sensor.how) exactly does the sensor work with just 3 inputs.Won't the other muscles interfere and change the value that the sensor reads.

(/member/bakkkkkk/) bakkkkkk (/member/bakkkkkk/)6 months ago

Reply ▲ Upvote

I am trying to observe the EMG raw data (output from INA106), then the amplified data, rectified data and the smoothed data, on an oscilloscope. Need help! Can you or someone share the graph plots that are supposed to occur?

Thank you.

Download Favorite

 (/member/bakkkkkk/) bakkkkkk (/member/bakkkkkk/)6 months ago

Reply Upvote

Can you please share the graphs plots obtained from each IC's outputs?

 (/member/AhmedT125/) AhmedT125 (/member/AhmedT125/)

6 months ago

Reply Upvote

good

 (/member/AhmedT125/) AhmedT125 (/member/AhmedT125/)

6 months ago

Reply Upvote

thanks

 (/member/psuthar1/) psuthar1 (/member/psuthar1/)7 months ago

Reply Upvote

which model of INO106 is used in this project. There are 5 different models are available on the site whose link you have given.

http://www.ti.com/product/INA106/samplebuy

 (/member/shaon1333/) shaon1333 (/member/shaon1333/)7 months ago

Reply Upvote

sir can you give me the data sheet of this project...and what is the voltage and frequency range of this project?

(/member/safsafg1/) safsafg1 (/member/safsafg1/) 8 months ago

Reply ▲ Upvote

What I would like to know about calculations, is how you set the values for C1 and C2
Thank you before

(/member/safsafgassim6/) safsafgassim6 (/member/safsafgassim6/)
8 months ago

Reply ▲ Upvote

What a benefit C1 and C2

More Comments Post Comment

Categories

Technology (/technology/)
Workshop (/workshop/)
Craft (/craft/)
Home (/home/)
Food (/food/)
Play (/play/)
Outside (/outside/)
Costumes (/costumes/)

About Us

Who We Are (/about/)
Why Publish? (/about/create.jsp)
Jobs (/community/Positions-available-at-Instructables/)
Contact (/contact/)

Resources

Residency Program (http://www.autodesk.com/pier-9/residency/home)
Community (/topics/)
Sitemap (/sitemap/)
Help (/id/how-to-write-a-great-instructable/)

Find Us

(http://www.instagram.com/instructables/)

(http://www.pinterest.com/instructables)

(http://www.facebook.com/instructables)

(http://www.twitter.com/instructables)