DIY Muscle Sensor / EMG Circuit for a Microcontroller

by **Gundanium** on June 21, 2011

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Brian graduated from North Carolina State University with a BS in Biomedical Engineering with a concentration in Biomechanics in May, 2006. While at North Carolina State University, Brian was involved in projects relating to biomechanics, biomaterials, tissue engineering, biomodeling, and biorobotics.

In December of 2007, Brian received an MS in Mechanical Engineering from the University of Michigan. His graduate studies emphasized biomechanics, mechanical design, and robotics.

Brian currently resides in Raleigh, North Carolina with his wife, Catherine, and two dogs, Bella and Lion.

Intro: DIY Muscle Sensor / EMG Circuit for a Microcontroller

Measuring muscle activation via electric potential, referred to as electromyography (EMG) , 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 contol 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!

CLICK TO PLAY VIDEO

You can now also purchase EMG circuit boards, sensors, kits, cables and electrodes at www.AdvancerTechnologies.com!
Muscle Sensor / EMG Circuit Kit - Bronze Package....Kit includes all circuit parts
Muscle Sensor / EMG Circuit Kit - Silver Package.......Kit includes PCB circuit board and all circuit parts
Muscle Sensor / EMG Circuit Kit - Gold Package........Fully assembled sensor
Muscle Sensor / EMG Circuit Board............................PCB circuit board only

Note: this sensor is not intended for nor to be used for any medical purposes.

About Advancer Technologies
Advancer Technologies is a company devoted to developing innovative game-changing biomedical and biomechanical technologies and applied sciences. Additionally, Advancer Technologies 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 .
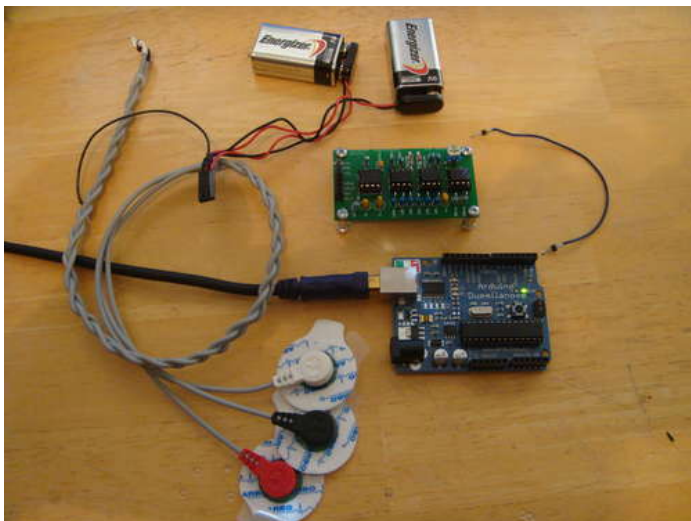
Step 1: Materials

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

Circuit Chips
3x TL072 IC Chip - Free Samples
1x INA106 IC Chip - Free Samples

Cables and Electrodes
1x EMG Cables   (set of 3)
3x EMG Electrodes

Power
2x 9V Battery
2x 9V battery clips

Capacitors
• 2x 1.0 uF Tant
• 1x 0.01 uF Ceramic Disc
• 1x 1.0 uF Ceramic Disc

Resistors
• 2x 150 kOhm 1%
• 2x 1 MOhm 1%
• 2x 80.6 kOhm 1%
• 7x 10 kOhm 1%
• 1x 100 kOhm Trimmer
• 1x 453 kOhm 1%

Misc
• 2x 1N4148 Diode
• Jumper wires
• 3x Alligator clip cables

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)*
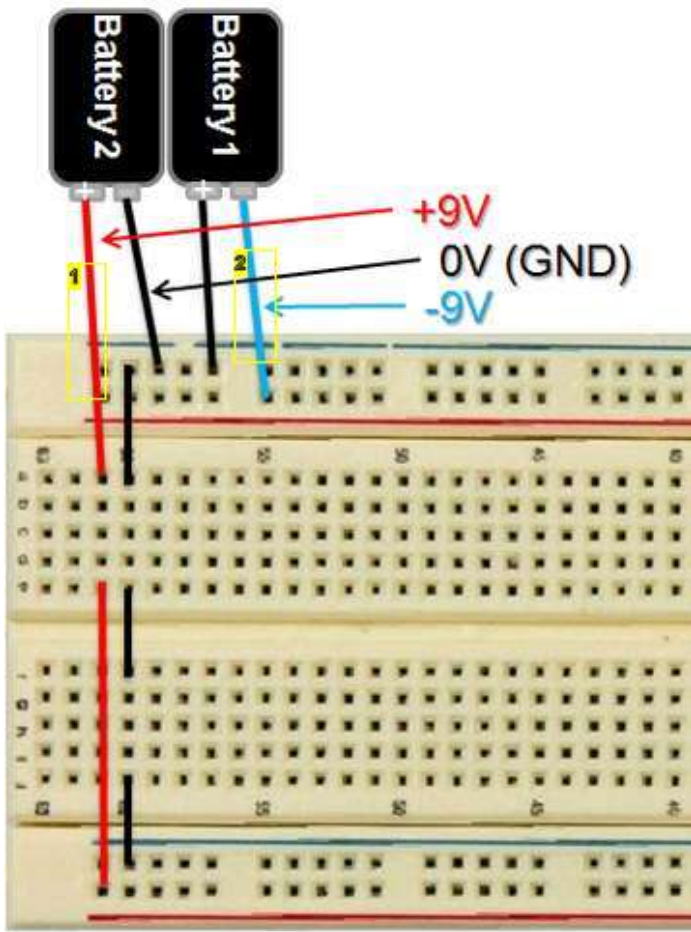
Image Notes
1. Disconnect until your ready to use the circuit!
2. Disconnect until your ready to use the circuit!

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 slightly amplify the very small voltage differences between the two electrodes you place on your muscle.

Next, grab two 1 M& 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.
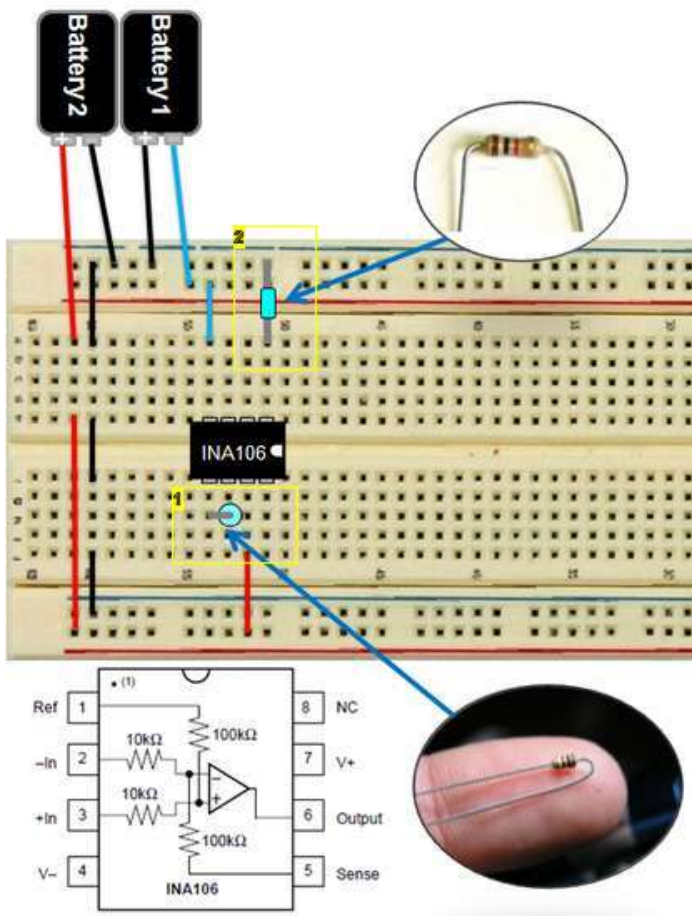
Image Notes
1. 1 MOhm resistor
2. 1 MOhm Resistor

Step 4: SIGNAL CONDITIONING - Amplification

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 .

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.
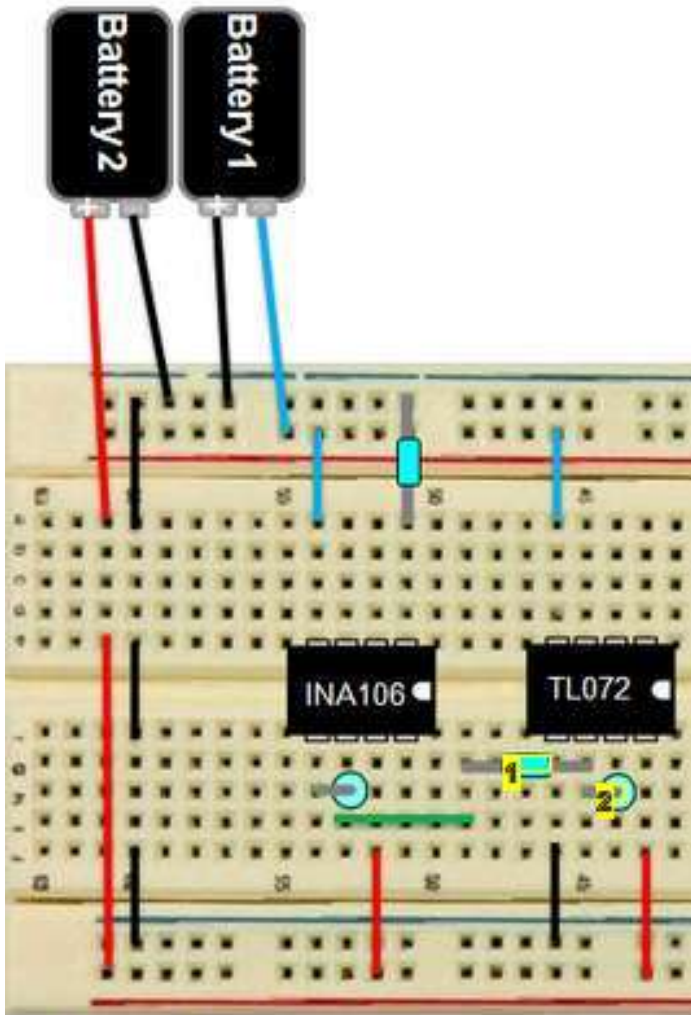
Place chip B as the picture indicates. Now use a jumper wire and connect pin 6 of chip A two rows past pin 8 of chip A. Grab one of the 10 kOhm resistors and plug one pin into this row as well. Connect the other pin to pin 6 of chip B. Bend a 150 kOhm resistor and connect one pin to chip B's pin 6 and 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 .

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).

Continuing on, we are going to add another inverting amplifier with a gain of appox. -3. To do this you will need a 453 kOhm and another 150 kOhm resistor. The 150 kOhm resistor will connect the capacitor you just placed to pin 2 of chip B. Now, bend the 453 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.

TL072, TL072A, TL072B
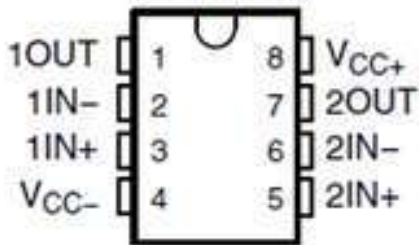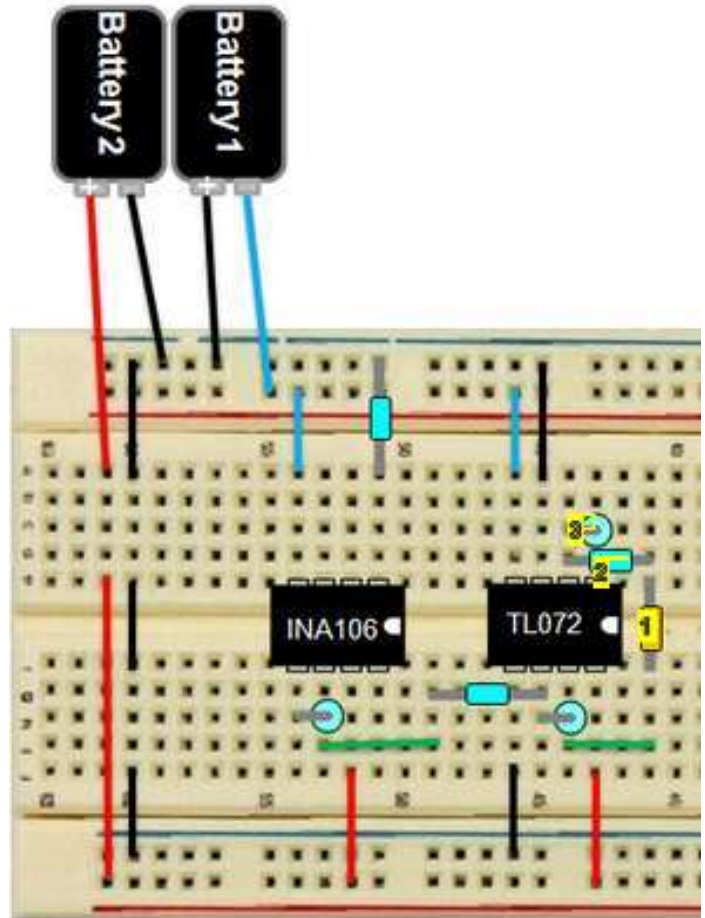D, JG, P, PS, OR PW PACKAGE
(TOP VIEW)

1OUT	1	8	V_{CC+}
1IN−	2	7	2OUT
1IN+	3	6	2IN−
V_{CC-}	4	5	2IN+

Image Notes
1. 0.01 uF ceramic disk capacitor
2. 150 kOhm resistor
3. 453 kOhm resistor

TL072, TL072A, TL072B
D, JG, P, PS, OR PW PACKAGE
(TOP VIEW)

1OUT	1	8	V_{CC+}
1IN−	2	7	2OUT
1IN+	3	6	2IN−
V_{CC-}	4	5	2IN+

Image Notes
1. 10 kOhm resistor
2. 150 kOhm resistor

Step 5: SIGNAL CONDITIONING - Rectification

In this phase, we will be rectifying the signal using an active full-wave rectifier . 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)

http://www.instructables.com/id/Muscle-EMG-Sensor-for-a-Microcontroller/

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.
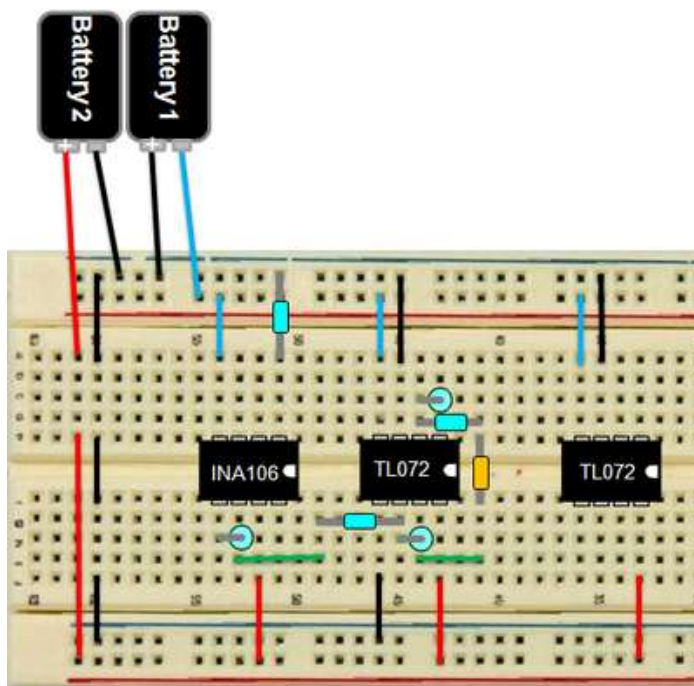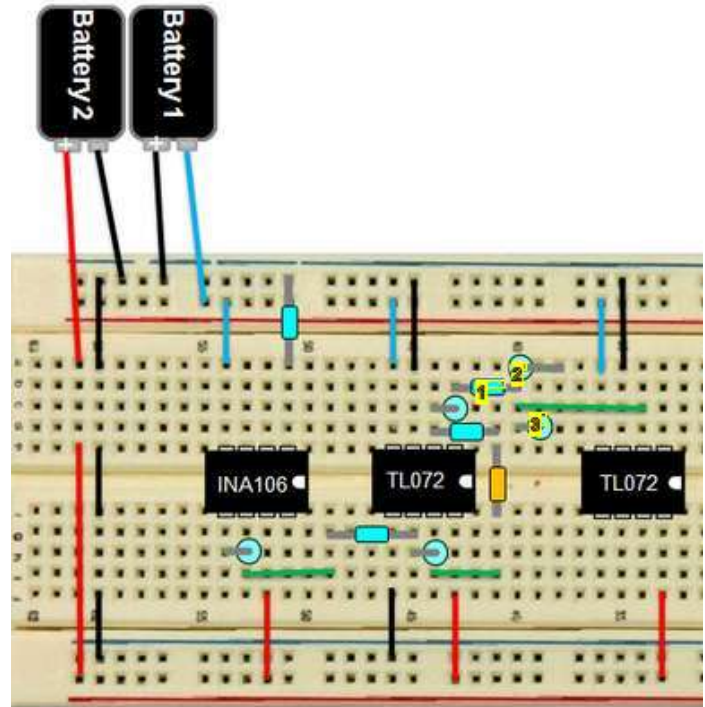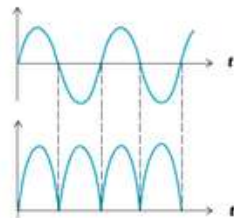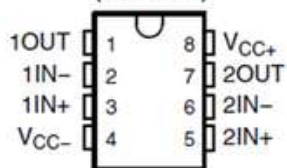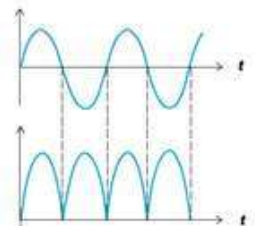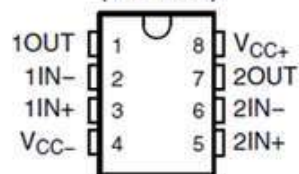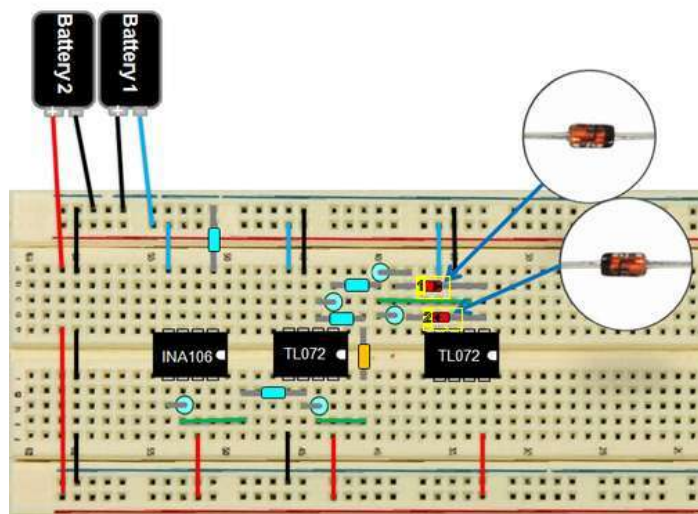
Image Notes
1. 10 kOhm resistor
2. 10 kOhm resistor
3. 10 kOhm resistor

TL072, TL072A, TL072B
D, JG, P, PS, OR PW PACKAGE
(TOP VIEW)

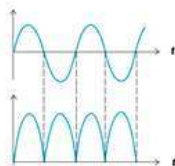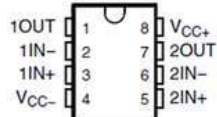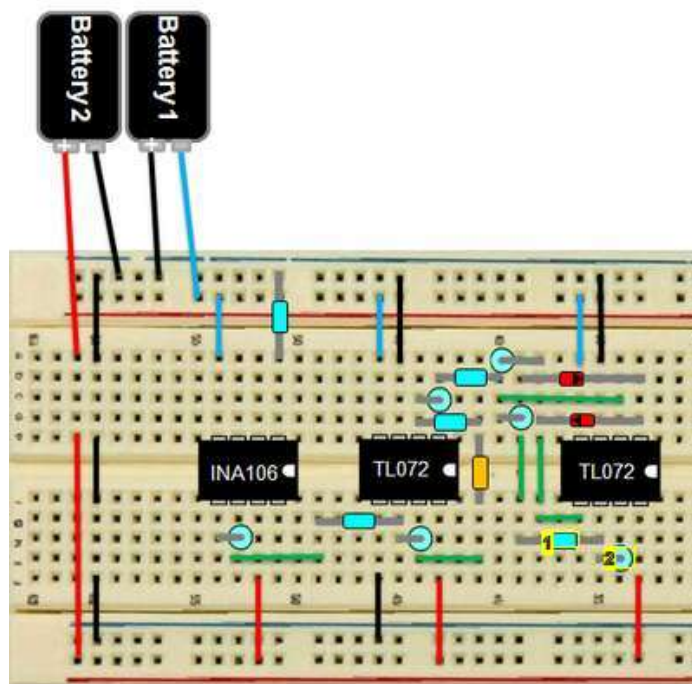| 1OUT | 1 | 8 | V_{CC+} |
1IN–	2	7	2OUT
1IN+	3	6	2IN–
V_{CC-}	4	5	2IN+

Image Notes
1. 1N4148 Diode
2. 1N4148 Diode

TL072, TL072A, TL072B
D, JG, P, PS, OR PW PACKAGE
(TOP VIEW)

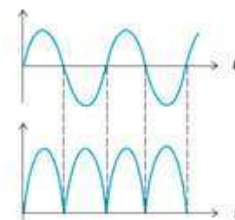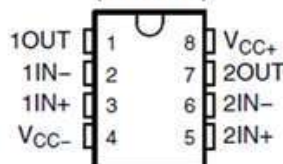| 1OUT | 1 | 8 | V_{CC+} |
1IN–	2	7	2OUT
1IN+	3	6	2IN–
V_{CC-}	4	5	2IN+

Image Notes
1. 10 kOhm resistor
2. 10 kOhm resistor

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 last 10 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 last 10 kOhm resistor to bridge the board's center gap. Use another jumper wire and connect the 10 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).
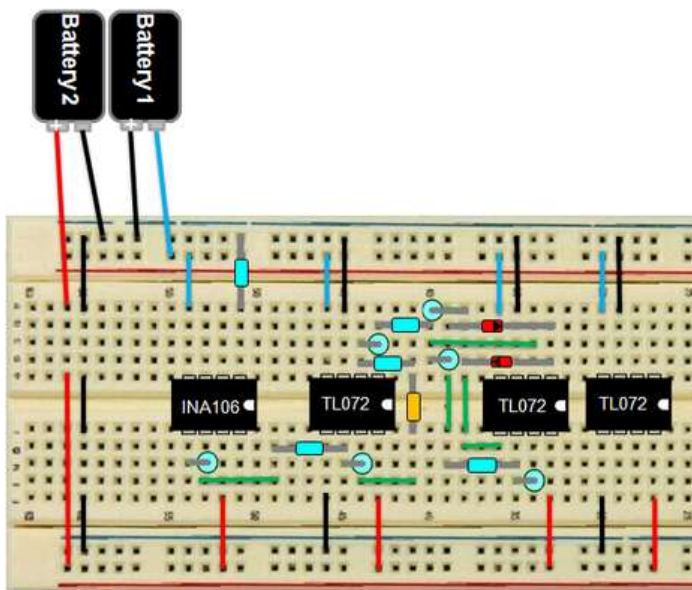
TL072, TL072A, TL072B
D, JG, P, PS, OR PW PACKAGE
(TOP VIEW)

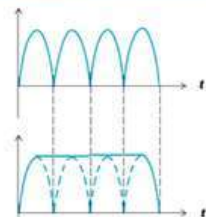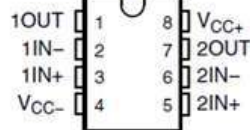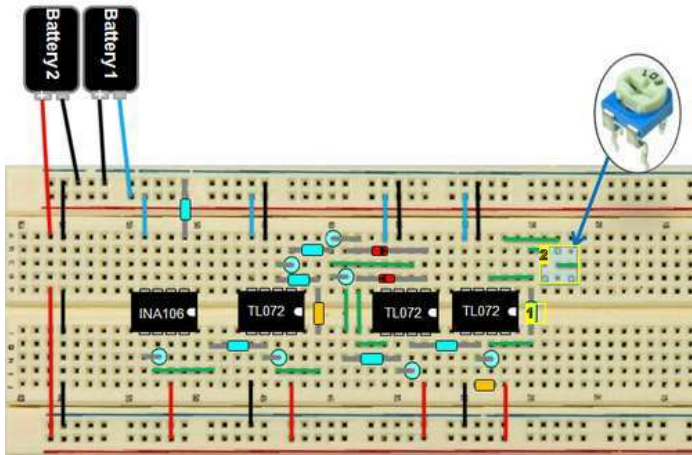|			
1OUT	1	8	V_{CC+}
1IN−	2	7	2OUT
1IN+	3	6	2IN−
$V_{CC−}$	4	5	2IN+
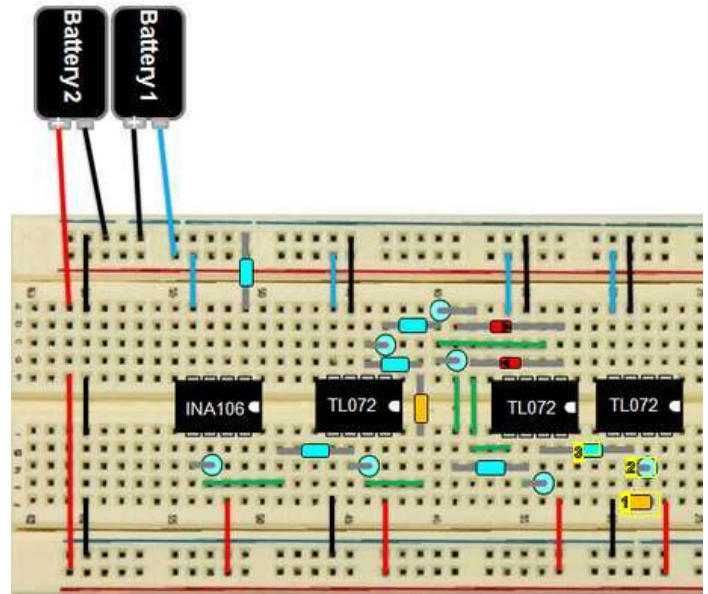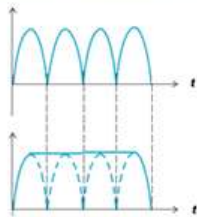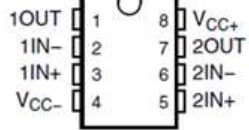
Image Notes
1. 1.0 uF ceramic disc capacitor
2. 80.6 kOhm resistor
3. 80.6 kOhm resistor

TL072, TL072A, TL072B
D, JG, P, PS, OR PW PACKAGE
(TOP VIEW)

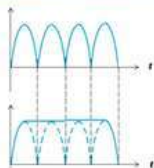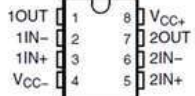|			
1OUT	1	8	V_{CC+}
1IN−	2	7	2OUT
1IN+	3	6	2IN−
$V_{CC−}$	4	5	2IN+

Image Notes
1. 10 kOhm resistor
2. 100 kOhm trimmer

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!
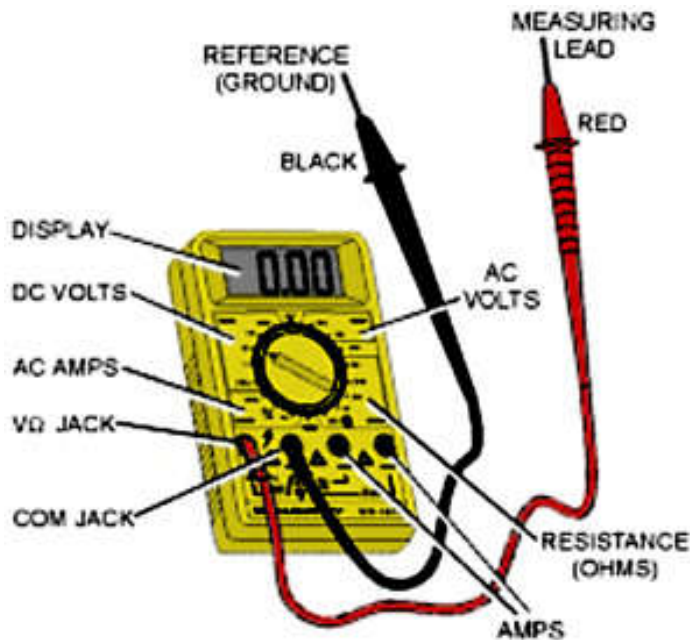
Step 8: Electrode Cables

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.
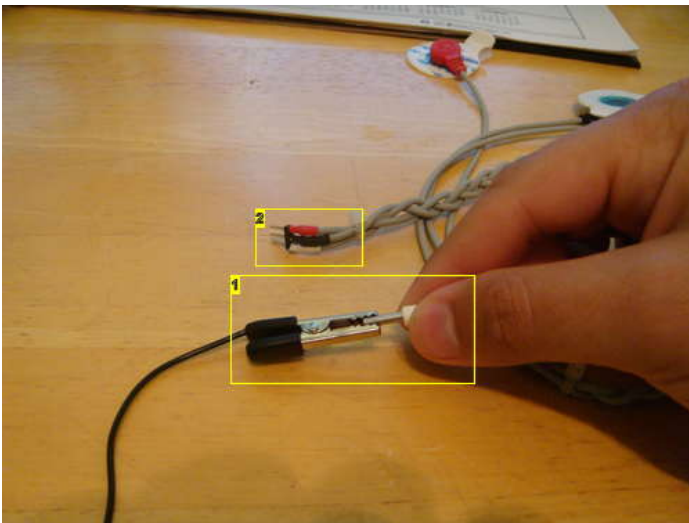

Image Notes
1. Alligator clip with stripped cable plug
2. Soldered terminal pins

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.
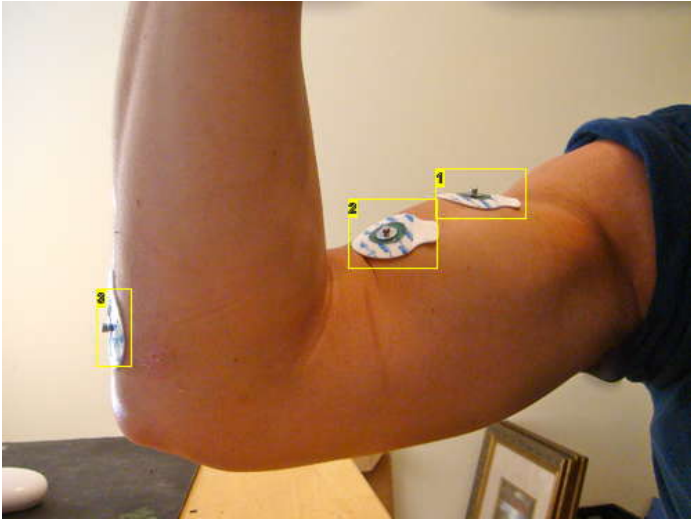
Image Notes
1. Mid muscle electrode
2. End of muscle electrode
3. Reference electrode

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!
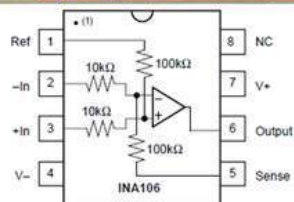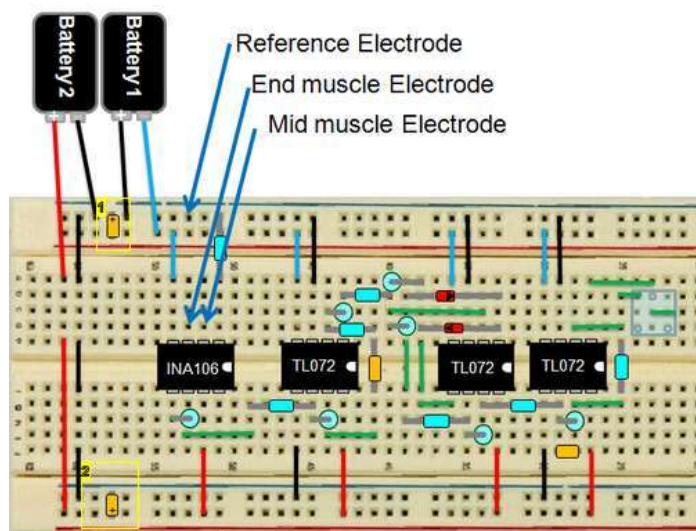
Image Notes
1. 1.0 uF tant. capacitor
2. 1.0 uF tant. capacitor

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!
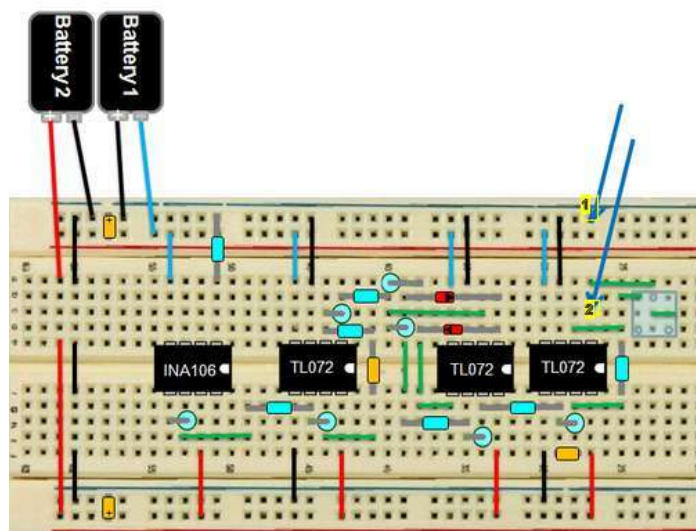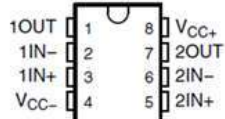
Image Notes
1. Connect your ground rail to your microcontroller ground pin

2. Connect pin1 of chip D to an analog input pin of your microcontroller

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!

CLICK TO PLAY VIDEO
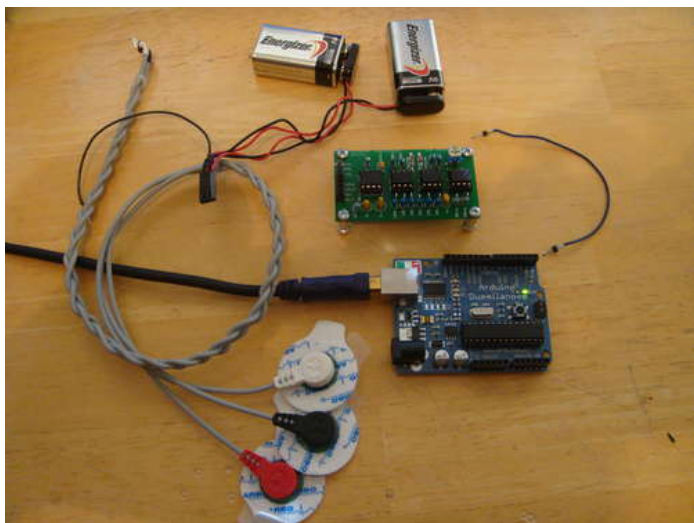
Step 13: EMG Circuit Schematic

Click the i box in the top left to see a larger version... or go to our website at http://www.advancertechnologies.com/p/muscle-sensor-emg-circuit-kit-bronze.html and click on the EMG schematic image.

Schematic - EMG Circuit v7.1
www.AdvancerTechnologies.com
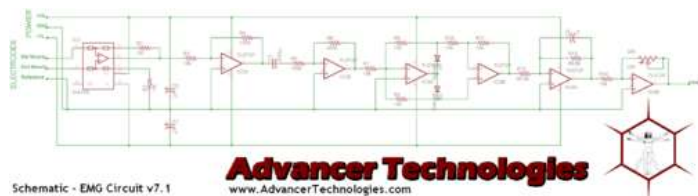
Related Instructables

Soft-Circuit Position Sensing Glove by Gundanium

Using Humidity sensor with 8051 Microcontroller (video) **by** ashoksharma

Xanboo/Homesite Laser Break Beam Sensor by krich

How to Demonstrate Temperature Properties of Muscle Wire (Nitinol) (video) **by** kentchemistry.com

Neoprene Bend Sensor IMPROVED by Plusea

How to make an All in One Detector by willbill808

Comments

Add Comment

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wilgubeast says: Jun 27, 2011. 10:25 AM **REPLY**

Awesome. Along with the heartrate sensor that was added last week, the Instructables community is well on its way to a DIY medical office. This is excellent.

Chrizlax says: Jul 4, 2011. 3:27 PM **REPLY**

Any chance of the schematic for this? Im just interested to see how it works.

---

oscarcar says: Jul 6, 2011. 2:16 PM **REPLY**

Can this be adapted to get the raw waveform and not a rectified EMG envelope?

Is there enough gain to leave of the rectifying components?

Gundanium says: Jul 6, 2011. 3:31 PM **REPLY**

Sure can. Leave off the rectifier and low-pass filter portion.

You'll also have to give it a DC offset voltage such that the resting voltage is around the middle of your ADC range. You'll need this if you want to see the negative portion of the unrectified signal.

Gundanium says: Jul 6, 2011. 3:32 PM **REPLY**

I'll try and put something together for you.

Chrizlax says: Jul 8, 2011. 2:39 PM **REPLY**

Thanks, much appreciated

Gundanium says: Jul 12, 2011. 10:40 AM **REPLY**

The schematic can now be found at: http://www.advancertechnologies.com/p/muscle-emg-sensor-kit-bronze-package.html

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Gundanium says: Jul 19, 2011. 7:20 AM **REPLY**

Hmm I'm not sure I've got a clear understanding of the situation.

An external power supply for this circuit shouldn't effect any other sensors interfaced with your Arduino as long as your power supply's ground is connected to the Arduino ground pin.

However, if you're sure an external power supply won't work for your circuit, then you could split your 3.3V power supply using a voltage divider to power this circuit. This would give you +-1.15V. Your signal resolution would be severely effected though since your drastically reducing the number of valid ADC steps.

Does the Arduino FIO have 10bit ADCs? If so you'd be reducing your sample points from 1024 down to ~235. If its 8bit, it would be even less.

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nitta says: Jul 21, 2011. 1:38 AM **REPLY**

My plan was to use only one power supply unit...my intention is to build a "wearable" system so i would like to keep it simple and small...

Thanks anyway for your advices ;)

Gundanium says: Jul 21, 2011. 9:36 AM **REPLY**

I just looked up the specs for the Arduino Vio . You could power both this circuit and the Arduino with the +-9V setup described in my instructions since the Arduino Vio's input voltage range is 3.35V to 12V.

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robomaniac says: Jun 29, 2011. 6:19 PM **REPLY**

Why don't you sell those EMG electrode on your site?

It is wrtting on your site "Advancer Technologies is now selling low-cost muscle (EMG) sensors to be used with microcontrollers."
When I read that, it means that you sell the EMG sensor aka the electrodes.

What you call "sensor" is no a sensor it's a interface board, amplifier board. Confusing.

You should mention and give the link to those electrode on your product page.

I want to build a EXOSKELETON with it!!!!

Gundanium says: Jun 30, 2011. 6:01 AM **REPLY**

Good point.

Check out our new product line up at http://www.advancertechnologies.com/p/muscle-sensors.html . We've added a new kit and added the ability to include a set of EMG cables and electrodes to all our kits.

Awesome. I'm a big fan of exoskeletons. Our ExoGlove and HARE boots are both powered exoskeletons in essence. Please keep me posted if you get around to building one!

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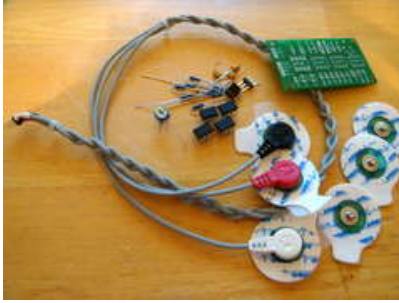
karanuna says: Aug 3, 2011. 12:58 AM **REPLY**

hi
i m unable to download pdf file for "DIY Muscle Sensor / EMG Circuit for a Microcontroller"

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nitta says: Jul 19, 2011. 3:37 AM **REPLY**

Hi. I would like to interface this EMG circuit with an Arduino FIO but i have the power supply issue since the arduino runs at 3.3V....any chance you could give some hints on how to do it?
Thanks

Gundanium says: Jul 19, 2011. 4:21 AM **REPLY**

You should be fine if you use the power supply described in step 2. I wouldn't suggest powering this circuit with any of the arduino power pins since you still need a negative voltage source.

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nitta says: Jul 19, 2011. 6:28 AM **REPLY**

Thanks for your quick answer!
Yeap that's the thing...i have another sensors interfaced with the Arduino and i would like to add the EMG recording to the project...preferable without the need of an extra power supply unit...any suggestions?