Switch Calibration Procedures and Instruction Manual v1.0

Design of an Electromyographic Switch
for Communication System Access
Version 1.0
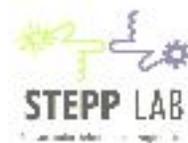
TABLE OF CONTENTS

BASIC OVERVIEW

This project delivers a surface electromyography (sEMG)-based switch, which directly replaces the use of a mechanical push-button switch for augmentative and alternative communication (AAC) system access. The sEMG-based switch is intended for use in patients who lack the muscle strength and coordination to activate a traditional push-button switch, but retain residual muscle control over one or more muscle groups. The following procedures detail the recommended method for determining the proper electrode placement and calibration method for such a patient.
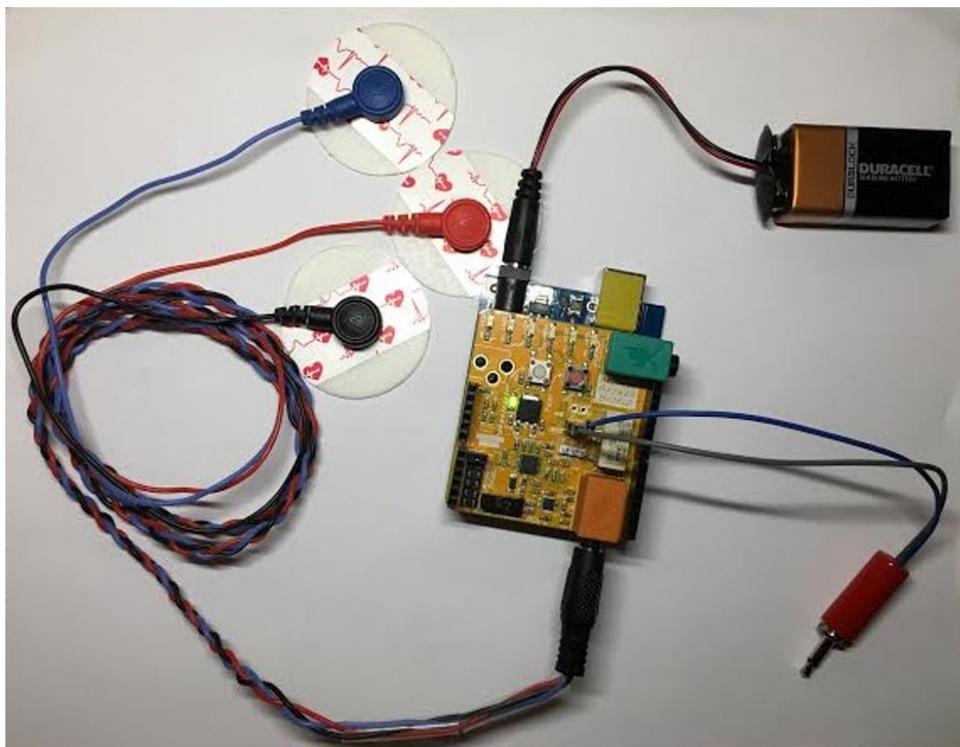
SELECTING THE INNERVATED MUSCLE GROUP

This switch is designed to work by capturing the signal from the electrical activity of innervated muscles or muscle groups on a patient through sEMG electrodes placed on the surface of the skin. Innervated muscles are those that are controlled by healthy nerves; the electrodes must be placed over a voluntary muscle group of which the patient has volitional control.

Locate and isolate the patient's control of a singular muscle group. For the expected target population of the switch, the residual, active muscles will often be found in the upper extremities and neck. If the active muscle group is known, the following steps may be skipped. Otherwise, begin by asking the patient to attempt to move different regions of their body.

1. Ask the patient to turn or raise his/her head to one side. As they do this, palpate the region of the **neck** above the left and right shoulder. Feel for muscular contractions, small movements/twitches or a tightening of the muscular tissue. Ask the patient to repeat voluntary contractions and continue to palpate.
2. Ask the patient to raise his/her eyebrows. Gently feel for muscle contractions on the **forehead** above both eyebrows.
3. Ask the patient to raise their lower lip. Palpate the muscles of the **chin**.
4. Check the extremities for residual motor control by asking the patient to lift a leg and palpating the upper **thigh** (quadriceps) or to lift their arm/hand and palpate the **forearm** or **bicep**.
5. Continue with small, controlled muscle movements until a target, active muscle group can be identified. Note the location, size and strength of the muscle group.

If more than one voluntary muscle group has been identified, determine the optimal target muscle for the switch based on the following criterion:

- sEMG is best suited to capture signal from long, parallel muscle fibers closest to the skin (for example, the forearm contains many long, parallel muscle fibers, while the back and abdomen are constructed of many short, overlapping muscle fibers).
- Areas with the least subdermal fat and least muscle fiber overlap are optimal.
- Muscles with the greatest strength and best volitional coordination will ease the calibration process and increase the accuracy of the switch.

SELECTING THE INNERVATED MUSCLE GROUP *CONTINUED*

Note that the location of the active muscle group will vary from patient to patient due to the origin of their condition. This switch may not be appropriate for use with patients who have spastic, involuntary muscle movements, such as those common in neurodegenerative disorders (i.e. ALS, PD).

Ultimately, it is at the discretion of the hospital staff to determine the optimal muscle group to harness for use of this sEMG-based switch on a patient-by-patient basis. Trial and error testing of muscle group selection may be necessary.

PREPARING THE PATIENT

Once the active, voluntary muscle group has been determined, the patient should be prepared for an AAC communication session. This will entail positioning of the patient, attachment of the sEMG-based switch device housing, and preparation of the patient's skin for electrode placement

1. Positioning the Patient

Position the patient in an orientation that is comfortable for them which also provides them the greatest accessibility to activate the muscle group which has been determined for switch control. The selected muscle region should be visible and open to the air to allow for the electrode placement, and the patient must be able to view the user interface of the AAC system with which they will interact. The hospital staff must determine the orientation of the patient primarily based on the safety and comfort of the patient.

2. Attachment of the Switch Device Housing

The sEMG-based switch, once completely constructed, rests inside a protective housing. This housing must be secured and immobile during switch use to reduce noise and variation in the sEMG signal captured. The housing includes a self-adhesive Velcro strap, which can be secured either to the patient or nearby equipment. The optimal placement of the switch is closest to the active muscle group of the patient.

For example, accessing an active muscle group in the neck may be most secure if the strap is secured around the upper arm or chest of the patient, or the railing of the hospital bed.

3. Preparing the Patient's Skin

The last step of patient preparation prepares the active muscle group to be most accessible for the electrodes.

1. Reposition or remove any clothing, bedding or other objects that could obstruct the skin over the active muscle group
2. Gently wipe the skin clean with a washcloth or alcohol swabs in order to clean off the dead skin cells that may be on the surface of the skin. Ensure that any area where the electrodes may be placed is cleaned **(both along the muscle fiber and on the bony, grounded area).**


3. Allow the cleaned area to dry completely (about 45 seconds)

PLACING THE ELECTRODES

Proper electrode placement is key to the efficacy of the sEMG-based switch for communication system access. Gather three sterile adhesive sEMG electrodes to begin a new communication session with a patient.

1. Begin by attaching each metal stud on the top of the three adhesive electrodes to the three snap fittings on the ends of the electrode lead wires (red, blue and black).
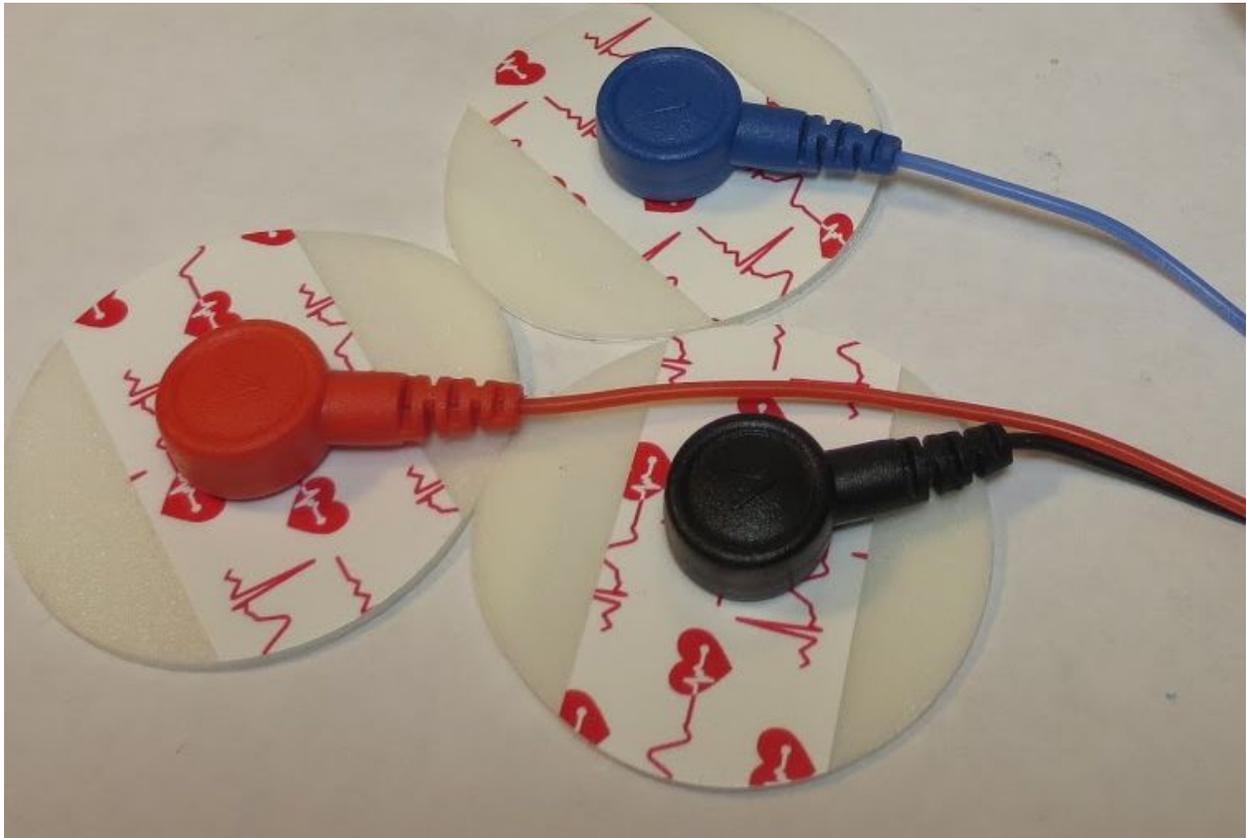
Be sure to complete this step *before* adhering the electrodes to the patient, or the pressure of applying the snap to the electrode while on the patient could cause bruising.

PLACING THE ELECTRODES *CONTINUED*

2. Determine the best electrode placement along the active muscle fibers by the following criterion:
   - The **red and blue (positive and negative)** electrodes should be placed along the active muscle fiber, such that they are oriented along a line which is in parallel to the muscle fibers. In many anatomical images these long muscle fibers are illustrated in a group, as in the forearm example on the following page. The red and blue electrodes must run up and down the length of the muscle fiber. For additional help identifying muscle fibers in parts of the body a human anatomy textbook description of superficial musculature may be consulted. A physician or registered nurse can also help identify proper placement.
   - The **black (ground)** electrode should be placed in the nearest non-muscular region to the active muscle group. These regions are **bony** processes, tendon, or cartilaginous regions such as the elbow, clavicle, or earlobe. This is shown in the images below, where the black, ground electrode is positioned directly on the bony area of the elbow and spine.

Note that the ordering of the red and blue electrodes does not affect the signal. Refer to the images and figures below for exemplary electrode placements in active regions of the forearm and neck.

PLACING THE ELECTRODES *CONTINUED*

Forearm
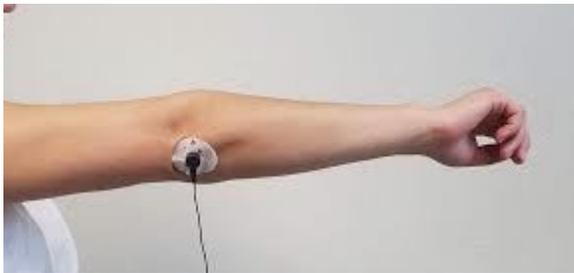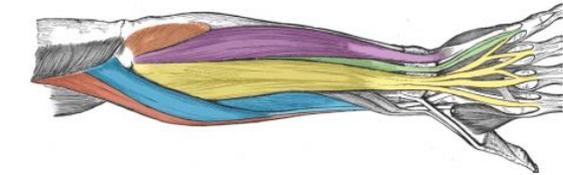
PLACING THE ELECTRODES *CONTINUED*

Neck
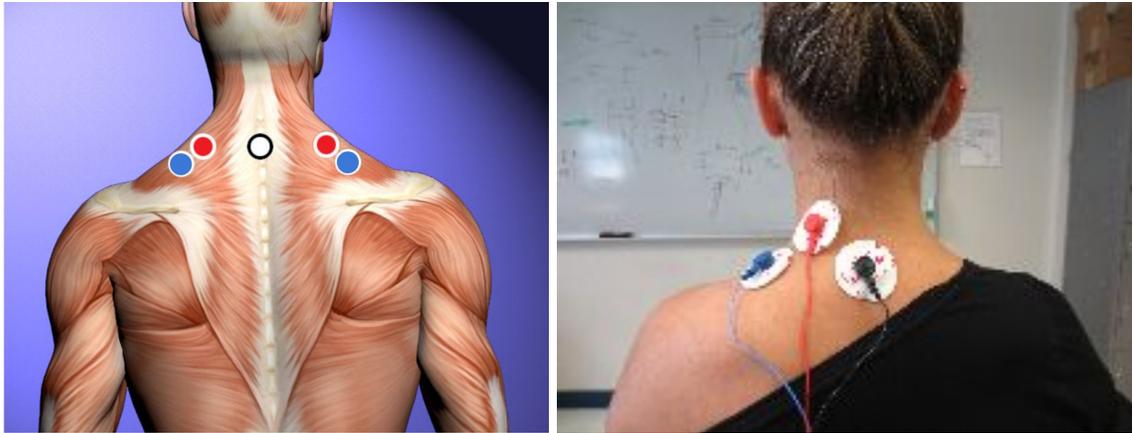
If it is unclear where the innervated muscle group may be, refer to the "Selecting the Innervated Muscle Group" section on page 4.

3. One-by-one, peel the plastic covering off of the back of the adhesive electrodes, and adhere them to the clean surface of the skin over the active muscle group in the determined, optimal locations.

   > Note that the relay of the switch may go off during the electrode placement. This causes a sporadic clicking noise, but is not harmful to the device.

4. Gather the wires of the electrode leads to the side closest to the switch hardware housing. Secure any excess wire around the housing, such that it will not be disturbed during use. Any wire movement during switch use can cause huge variations and noise in signal.

DETERMINING OPTIMAL SWITCH SENSITIVITY

This sEMG-based switch is designed to work for a wide range of patients in the target population. In order to accommodate varying strength of muscle groups, strength of signal and individual patient changes over time, the switch is equipped with an array of sensitivity levels to meet different needs.

The Arduino Software program, as downloaded from the Stepp Lab informational site, is equipped with 18 sensitivity levels. Higher sensitivity levels work best with stronger muscle groups while lower sensitivity levels should be applied to weaker muscles. The program cycles through the sensitivity levels from 18 to 1, in order to optimize for increasingly weaker signals throughout the cycle. The current sensitivity level is indicated by the LED lights on the Muscle SpikerShield immediately following the press of one of the sensitivity buttons.
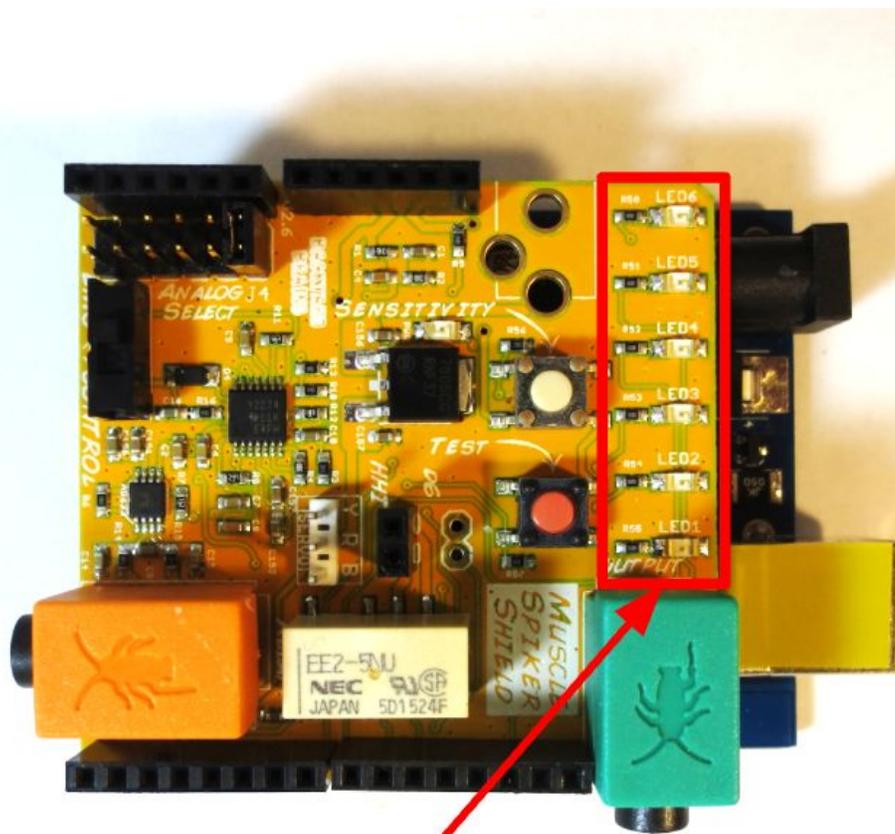
LEDs

DETERMINING THE OPTIMAL SENSITIVITY *CONTINUED*

The Arduino Software is initially preset to the highest sensitivity: level 18. It is likely that this sensitivity level will not work on atrophied muscle of a weakened patient. The instructions on the next page describe a method for iterating through the sensitivity levels to optimize the sEMG signal for a patient, once the previous steps for selecting the innervated muscle group, preparing the patient, and placing the electrodes have been successfully completed. Each sensitivity is indicated by a different LED illumination pattern.

White Sensitivity Increment Button

Red Sensitivity Decrement Button
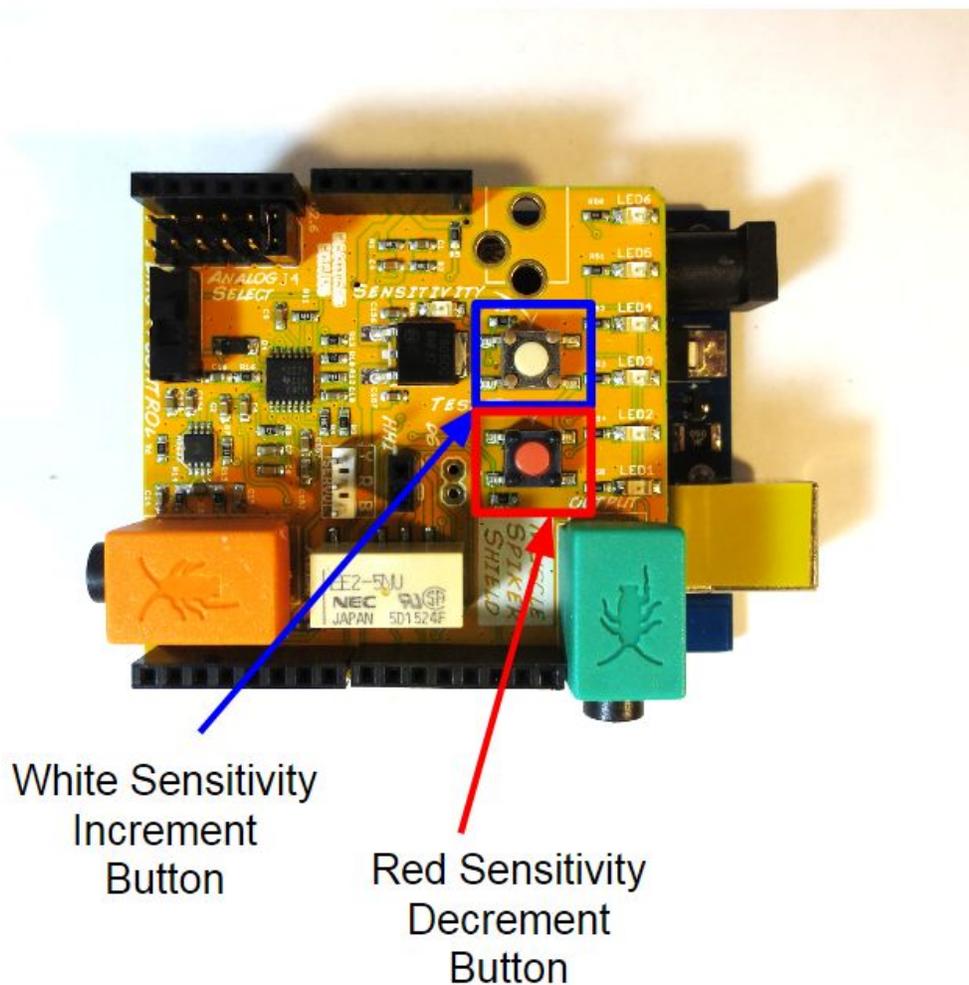
DETERMINING THE OPTIMAL SENSITIVITY *CONTINUED*

1. Beginning with sensitivity level 18, ask the patient to **maximally** flex the active muscle group, and watch the six indicator LEDs on the Muscle SpikerShield.

   > Note that the patient flexing maximally during each step of the calibration process is *integral* to achieving the proper calibration level. Rest the patient between steps as needed.

2. If *all six* LEDs do not illuminate, click the **red** sensitivity decrement button once to decrement the sensitivity level by 1. Note each time the sensitivity level changes by making a check in the appropriate box on the table--the first check is at level 18 because this is the initial sensitivity setting.

3. Watch the pattern of LED light blinking and note the current sensitivity level being implemented based on the sensitivity level chart attached to this section. The LEDs will blink according to the sensitivity level the switch is set to, not from muscle activity.

4. Ask the patient again to **maximally** flex the active muscle group. Continue to iterate through sensitivity levels following these steps until the patient's **maximal** flex illuminates all six LEDs.

   > Pressing the red sensitivity decrement button once lowers the sensitivity level by 1. Pressing the white sensitivity increment button raises the sensitivity level by 1. Raising the sensitivity above level 18 loops the sensitivity level back to 1, and lowering the sensitivity below level 1 returns the sensitivity level to 18.

5. Record the patient's final, optimized sensitivity level. Now the device is ready for use with an AAC system.
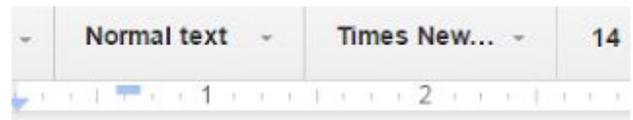
Sensitivity Level	LED Signal	
18	3 blinks of LED 6 (red)	✓
17	3 blinks of LED 5 (red)	
16	3 blinks of LED 4 (yellow)	
15	3 blinks of LED 3 (yellow)	
14	3 blinks of LED 2 (green)	
13	3 blinks of LED 1 (green)	
12	2 blinks of LED 6 (red)	
11	2 blinks of LED 5 (red)	
10	2 blinks of LED 4 (yellow)	
9	2 blinks of LED 3 (yellow)	
8	2 blinks of LED 2 (green)	
7	2 blinks of LED 1 (green)	
6	1 blink of LED 6 (red)	
5	1 blink of LED 5 (red)	
4	1 blink of LED 4 (yellow)	
3	1 blink of LED 3 (yellow)	

14

DETERMINING THE OPTIMAL SENSITIVITY *CONTINUED*

Note that the optimal sensitivity level for a given patient may vary between each use case due to the following factors:

- Small variations in electrode placement over the same active muscle group
- Increasing atrophy of the muscle group over time
- Increasing strength of the muscle group due to repeated use of the active muscle group
- Environmental noise

It is recommended that this calibration is performed before each patient use, beginning always with sensitivity level 18 and decrementing as required using the red sensitivity decrement button. The white sensitivity increment button may be used to correct an error or more efficiently return to the appropriate sensitivity level for the patient.

NOTE: During use with an AAC system, the patient must flex such that the first 3 lights turn on in order to accurately "click" or select something with the sEMG based switch.

TROUBLESHOOTING

The following activity may indicate that something is wrong with the device software:
- No LED activity
- Spastic clicking
- Rhythmic clicking
- Constant, full LED illumination

Before altering the device software check the following:
- The Muscle SpikerShield is set to capture sEMG signals in RAW mode: the small black toggle switch should be pushed farthest toward the corner of the device, towards the arrow labeled EMG (note: the Arduino Software programs provided will *not* work if the hardware is in CONTROL mode).

- The electrode lead wires are secure and do not move during use, and the housing is securely fastened to the patient or a stable surface nearby.
- The hardware construction is consistent with the Hardware Setup section of the Initial Device Setup Instructions Manual (especially the wire pin placement).
- The 9V battery is fully charged or replaced. The lifetime of a 9V battery running a shield-equipped Arduino UNO is approximately 2 hours.

If the above troubleshooting methods are unsuccessful, it may be beneficial to re-upload the default software. This poses no risk to the device. Follow the instructions to download the default Arduino program off of the Stepp Lab's sEMG-based Switch website and upload to the Arduino as outlined in the Software Setup section of the Initial Device Assembly Instructions Manual.

TROUBLESHOOTING *CONTINUED*

If both hardware and software troubleshooting do not solve the problem, check the physical components of the device for abnormalities; replace any damaged parts. Note that electrically noisy hospital or clinic environments can negatively affect the efficacy of the device; try to reduce the electrical equipment in the immediate surroundings. Motion in the electrode cable may also cause sporadic noise. If the patient is in motion, i.e. in a wheelchair, be sure to coil any excess cable such that the wires are effectively as short as possible.