

Scratch for Arduino (S4A) and the Electromyography (EMG) Sensor

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INSIGHT Summer Institute 2014

Cyber-Physical Systems (CPS)

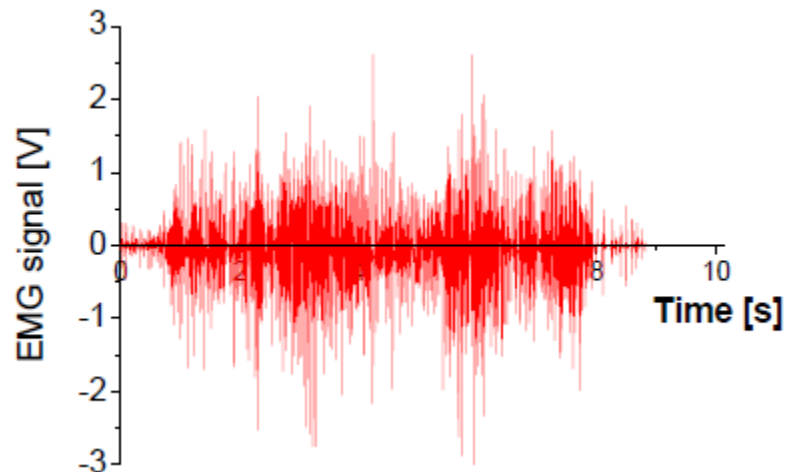
- A **cyber-physical system (CPS)** is a system of collaborating computational elements controlling physical entities –wikipedia.
- The pre-cursor generation of cyber-physical systems are often referred to as real-time embedded systems.
- In embedded systems the emphasis tends to be more on the computational elements, and less on an intense link between the computational and physical elements.
- Unlike traditional embedded systems, a full-fledged CPS is typically designed as a network of interacting elements with physical input and output instead of as standalone devices.[\[1\]](#)
- Closely related areas are robotics and sensor networks.

CPS Future Potential

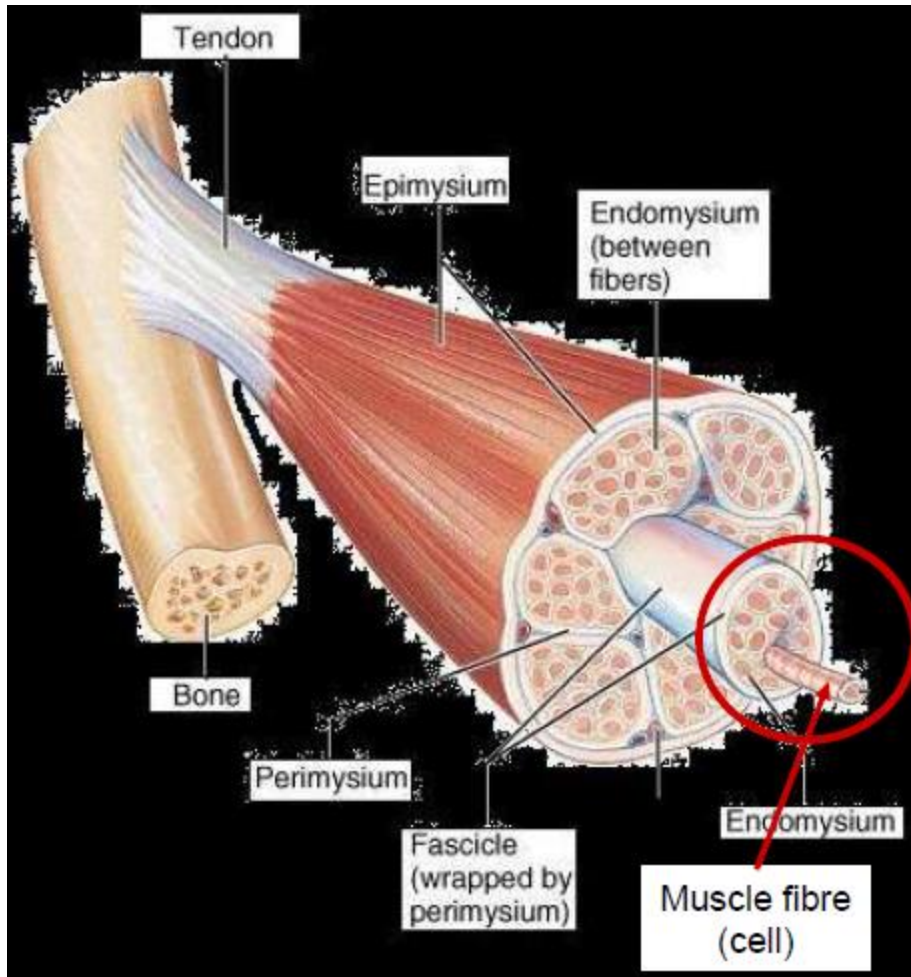
- Ongoing advances in science and engineering will improve the link between computational and physical elements, dramatically increasing the adaptability, autonomy, efficiency, functionality, reliability, safety, and usability of cyber-physical systems.
- This will broaden the potential of cyber-physical systems in several dimensions, including:
 - intervention (e.g., collision avoidance);
 - precision (e.g., robotic surgery and nano-level manufacturing);
 - operation in dangerous or inaccessible environments (e.g., search and rescue, firefighting, and deep-sea exploration)
 - coordination (e.g., air traffic control, war fighting);
 - efficiency (e.g., zero-net energy buildings); and
 - augmentation of human capabilities (e.g., healthcare monitoring, prosthetics, etc.).[\[2\]](#)

Electromyography (EMG)

- **Electromyography (EMG)** is a technique for evaluating and recording the electrical activity produced by skeletal muscles – from wikipedia
 - Study that deals with the detection, analysis, and use of electrical signals that emanate from contracting muscles – from “The physiology background of EMG” by Lida Mademli



Skeletal Muscle Organization

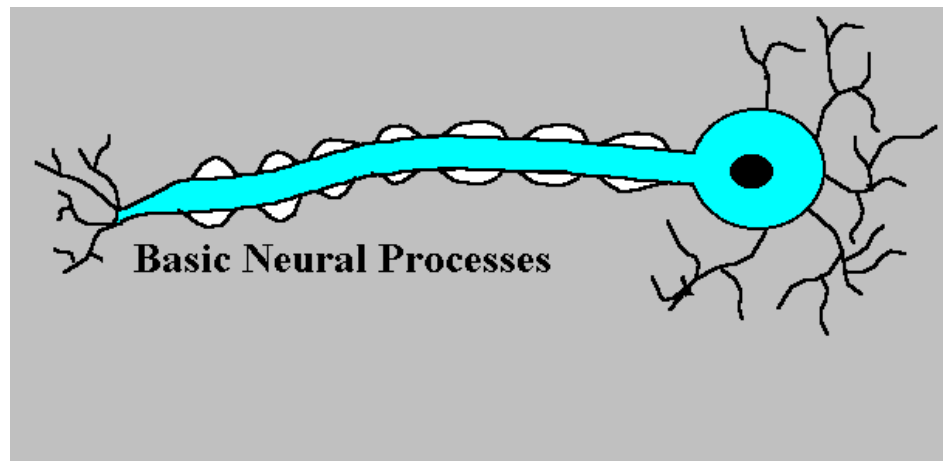


Muscle consists of:

- Muscle fascicles (bundles of muscle fibres)
- Muscle fascicles are wrapped by perimysium
- Muscle fascicles consist of
 - Muscle fibres (muscle cell)
 - Muscle fibres are wrapped by endomysium
- **The muscle fibre is what contracts**

Motoneuron

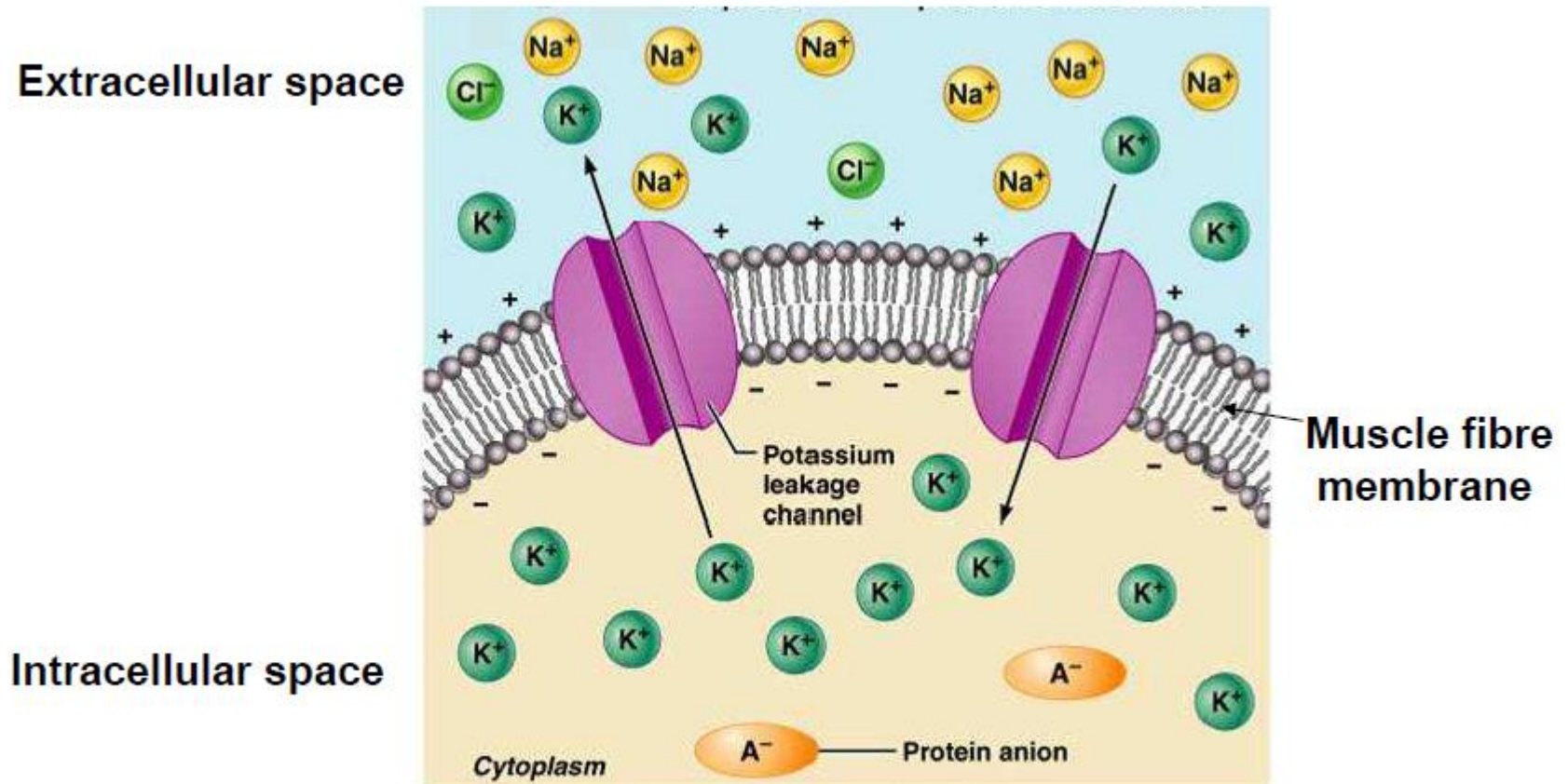
- **How the electrical stimulus travels down the motoneuron to innervate (activate) the muscle fibre.**
- The change in polarity travels down the neuron (**action potential**)
- Neurotransmitter (**acetylcholine**) is released from terminal end



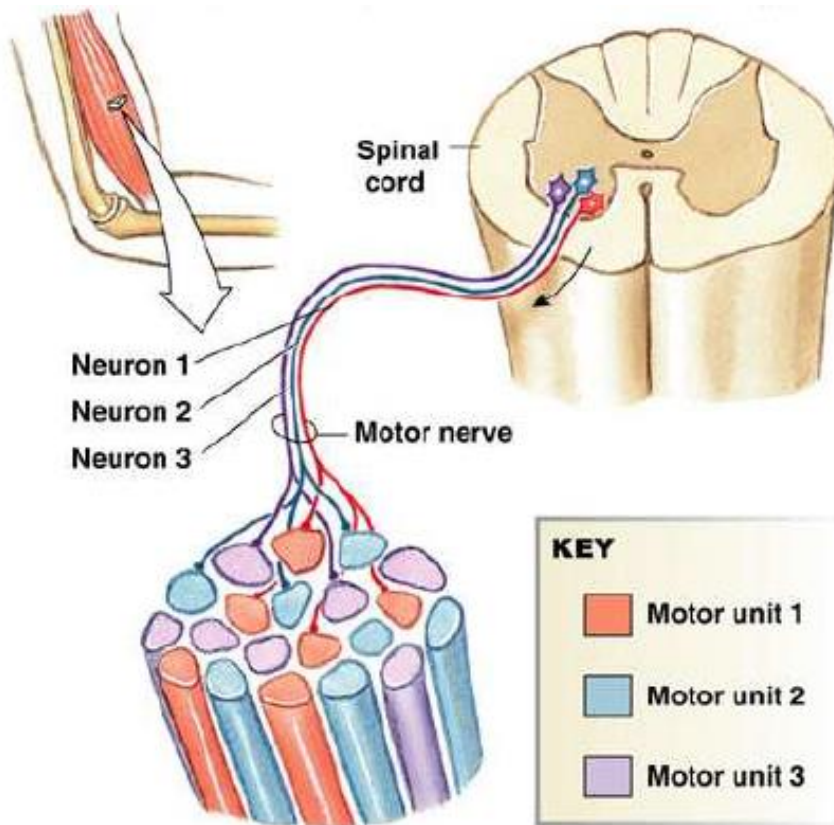
Muscle at Rest

Resting potential of muscle = $\sim -90\text{mV}$ (Purves et al 2001)

- In the absence of an impulse, the inside is electrically negative and the outside is positive



Muscle and Nerve

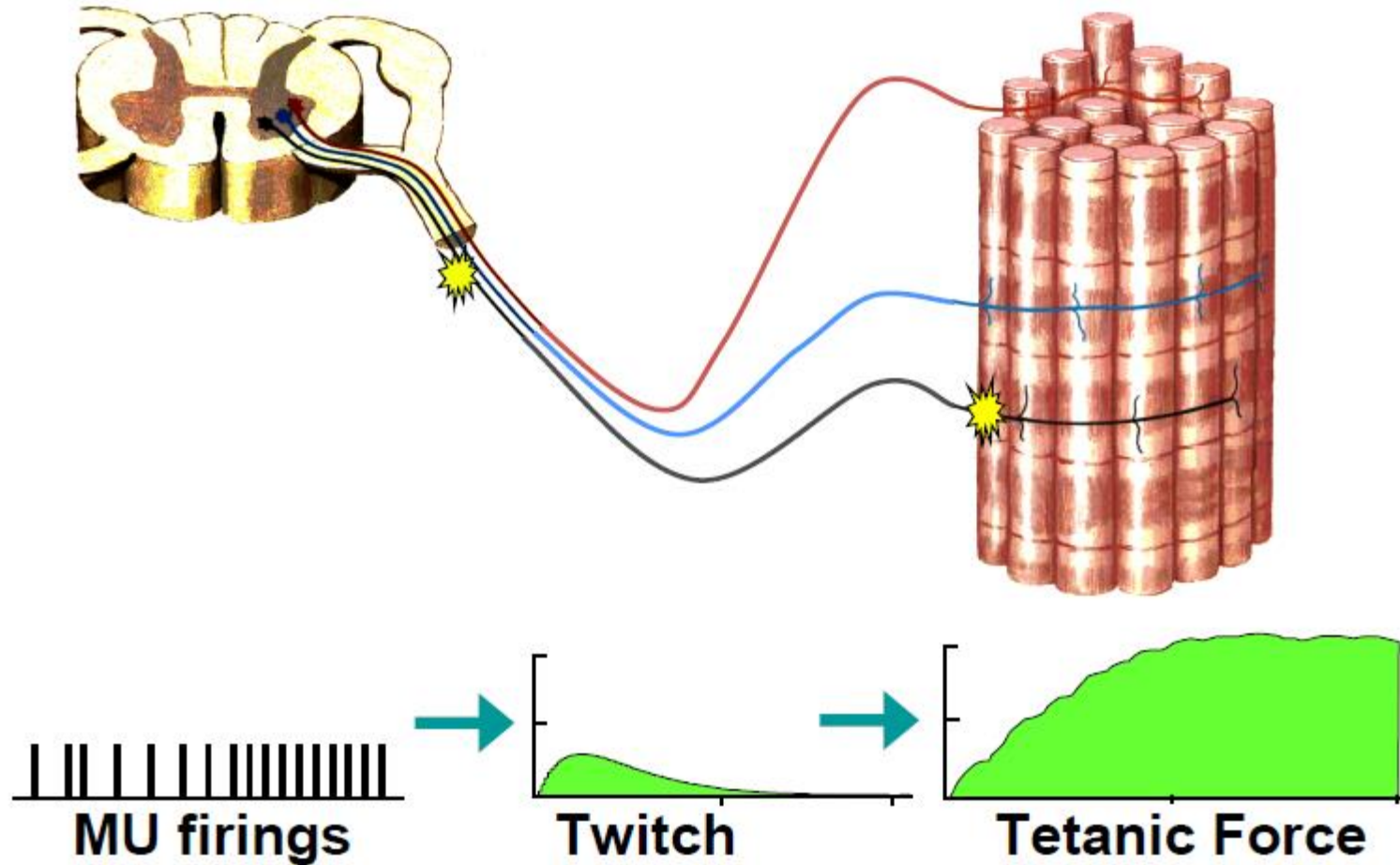


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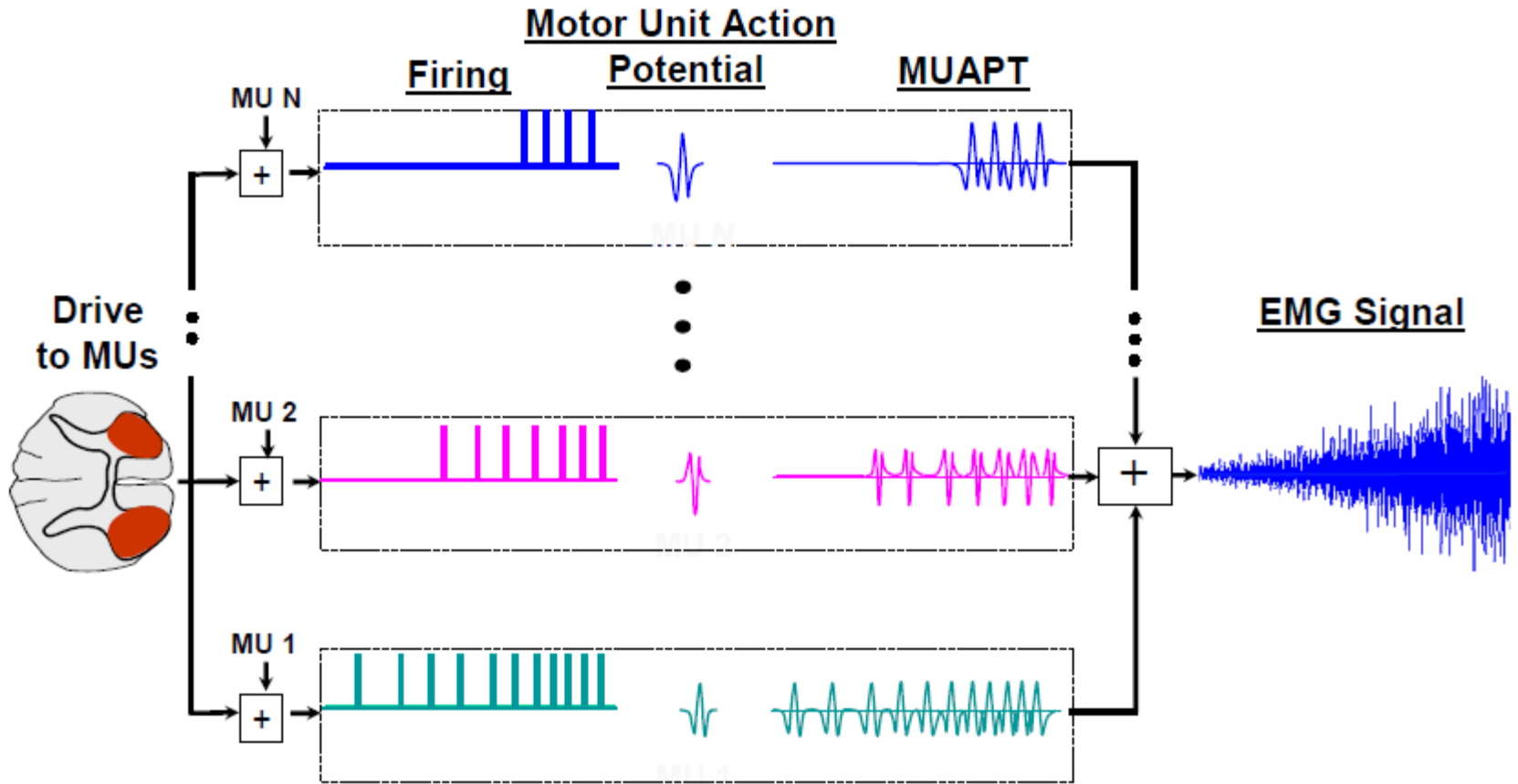
The Motor Unit (MU)

- One muscle may have many motor units of different fibre types (slow or fast twitch)
- One motor unit can have from 5 to few thousands muscle fibres.
- The motor unit is the brain's smallest functional unit of force development control.

Motor Units and Force

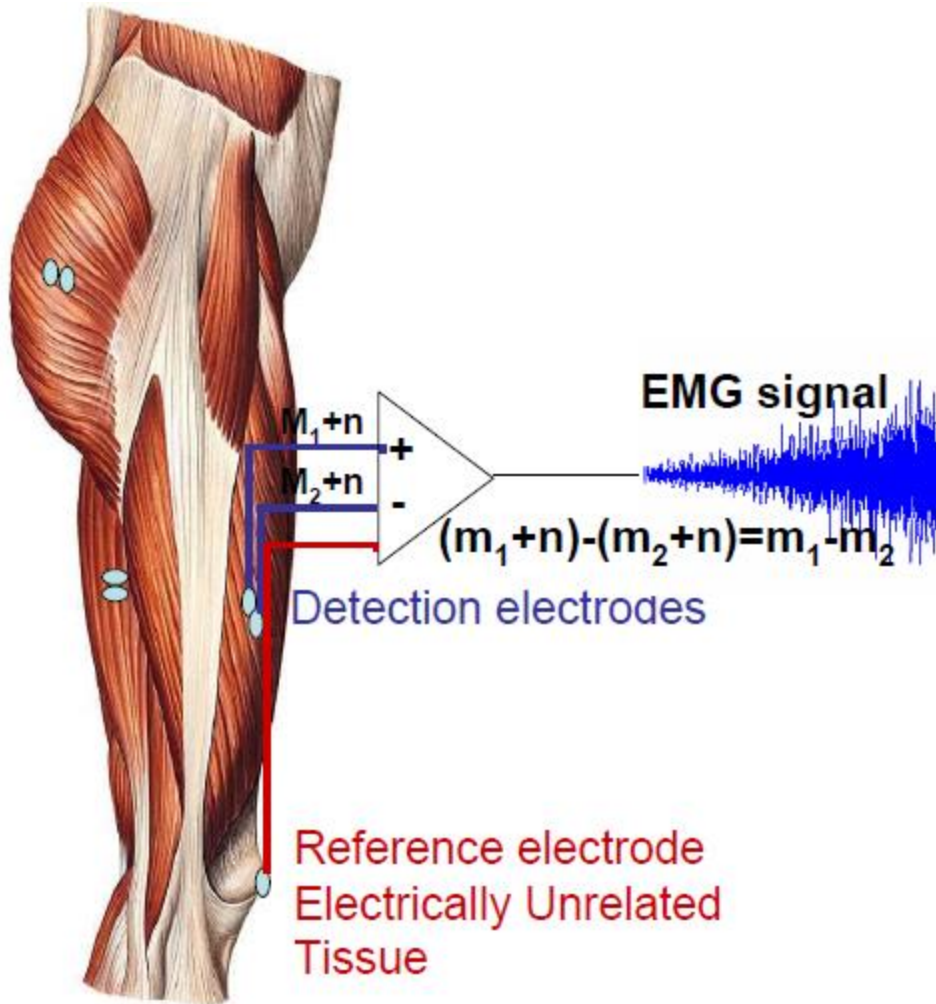


EMG Signal



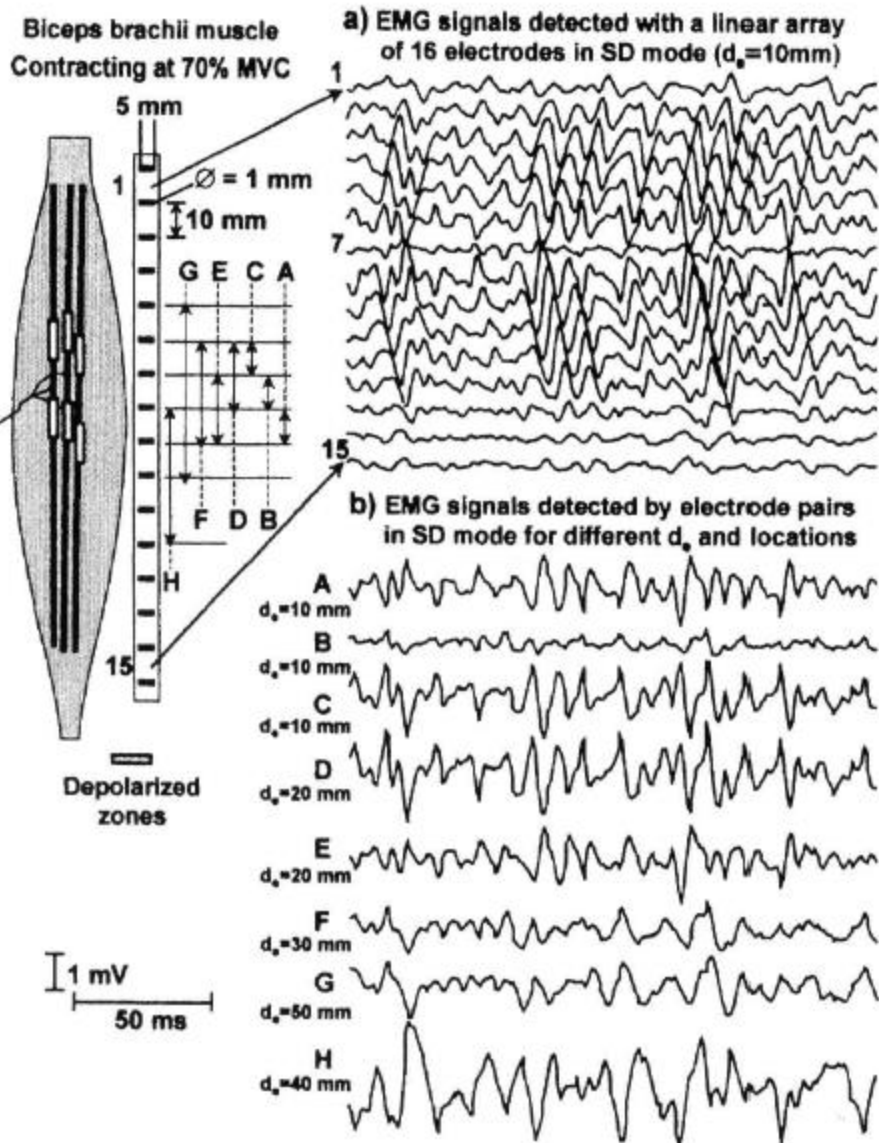
(De Luca CJ and Erim Z. Common drive of motor units in regulation of muscle force. Trends in Neuroscience, 17: 299-305, 1994.)

EMG Signal Capture



- Differential amplifier
- Input from two different points of the muscle
 - Close (usually 1-2cm)
 - Electrode alignment with the direction of muscle fibres implies increased probability of detecting same signal
- Subtracts the two inputs
- Amplifies the difference
- Optionally, rectify and smooth signal

Physiology of the EMG



- Above the innervation zone, electrode 7 small amplitude.
- Above the myotendinous junction, more tendon tissue, electrodes 14 and 15 small amplitudes.
- Others radiate out from electrode 7.

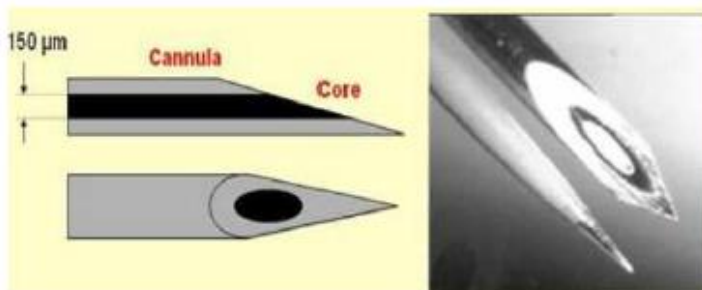


electrode

Types of EMG Sensors

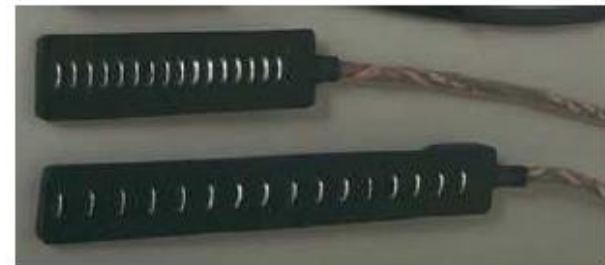
Inserted

- Fine-wire (Intra-muscular)
- Needle



Surface

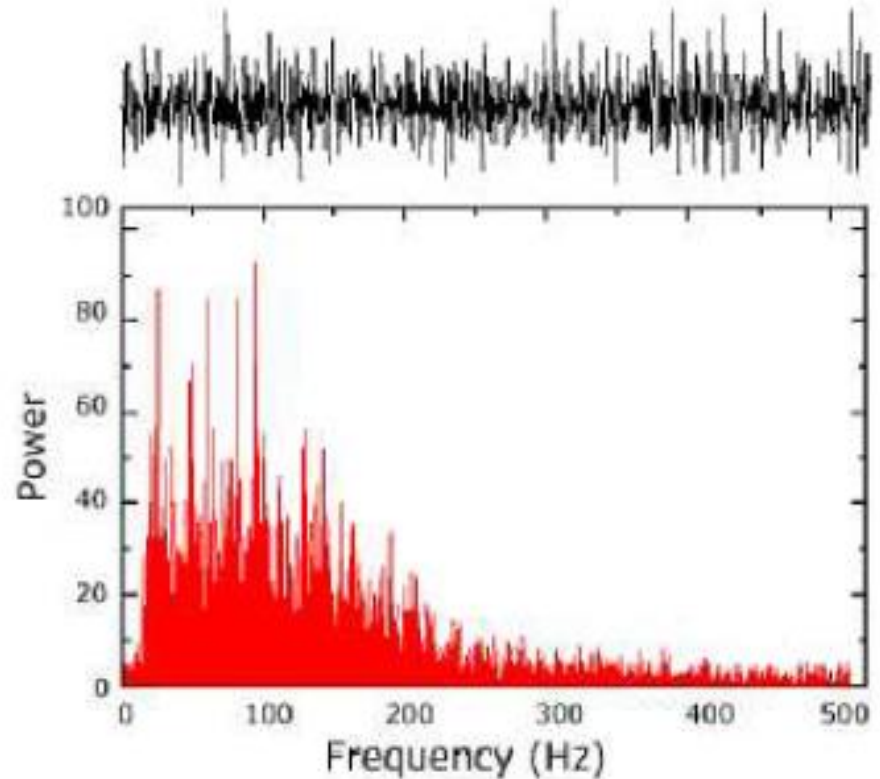
- Bipolar (wired or wireless)
- Array (wired)



sEMG = surface EMG

Characteristics of EMG Signal

- Amplitude range:
0 - 10 mV (+5 to -5) prior to amplification
- EMG frequency:
range of 10 - 500 Hz
- Dominant energy:
50 - 150 Hz
- Peak in the neighborhood of
80 - 100Hz



EMG Frequency

- Motor Units
 - Slow twitch: 75 - 125 Hz (twitches/sec)
 - Fast twitch: 125 - 250 Hz

Most Usual Parameters in Biomechanics or Physiology

- Time domain:
 - RMS or average of rectified EMG
- Frequency domain:
 - FFT analysis (spectral analysis)
 - Power density
 - Mean power frequency
 - Median power frequency

EMG During Fatigue

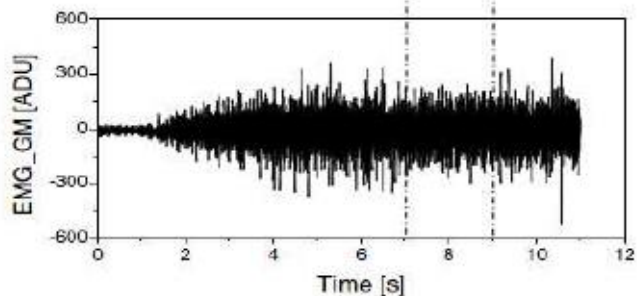
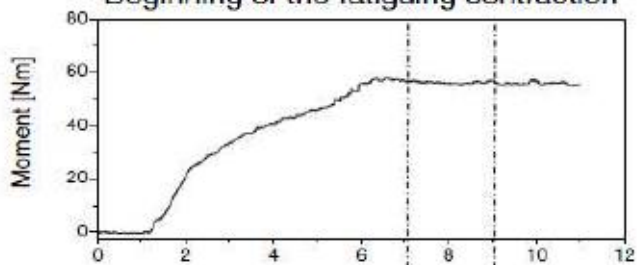
– from Physiology of EMG, Mademli

- During fatigue:
The EMG signal was analysed for a 2s plateau of the moment.

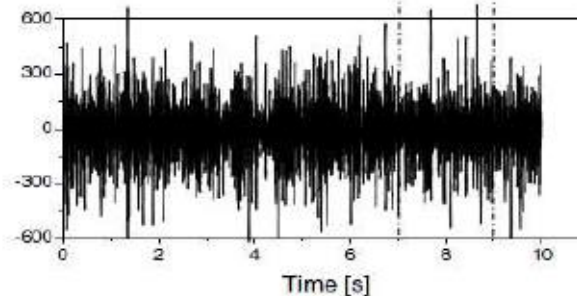
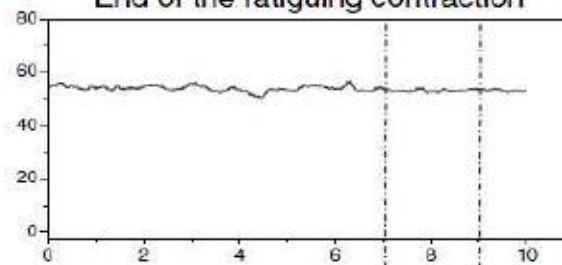


Young subject

Beginning of the fatiguing contraction

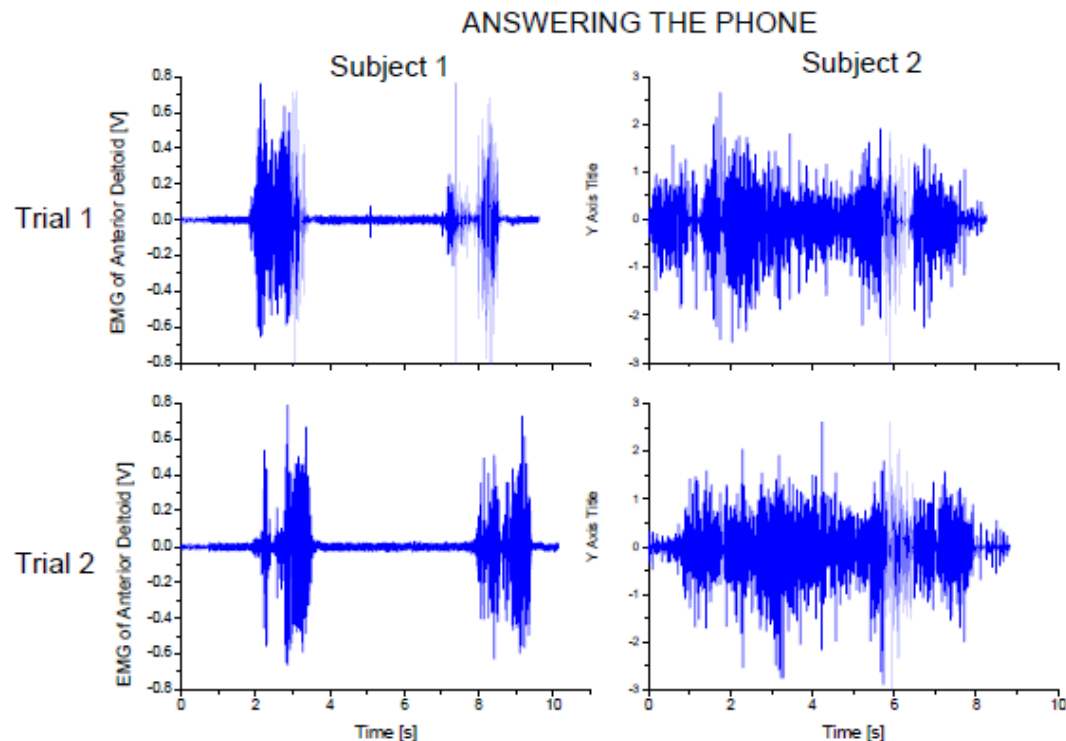


End of the fatiguing contraction



Potential Use of EMG

- It is possible that the EMG signal during a specific movement will demonstrate inter-individual differences. This can be used in user authentication systems (ACTIBIO).



Potential Use of EMG

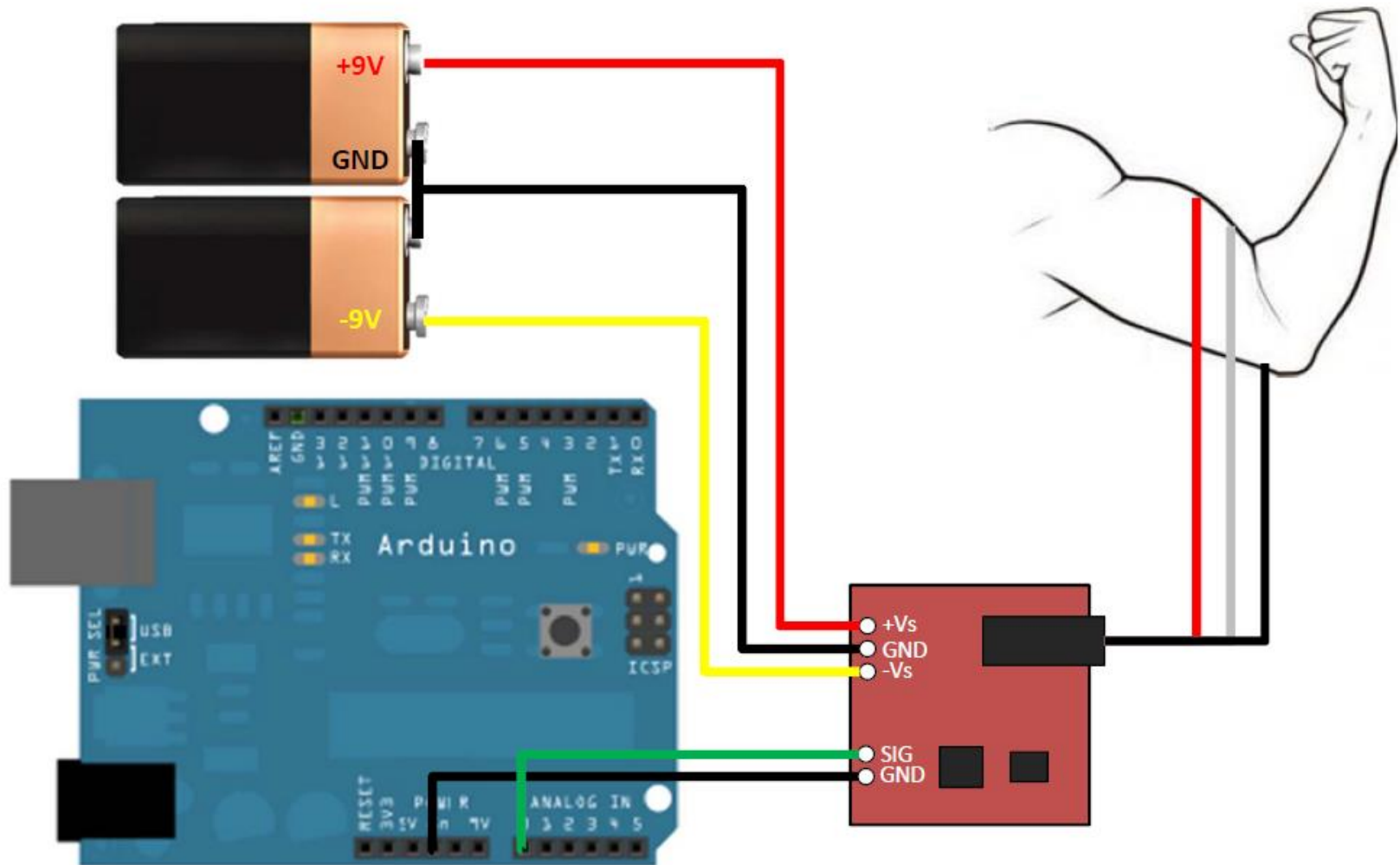
- The muscle activity recorded using sEMG can be useful as an input signal to the system which can control devices such as keyboard, mouse or computer. (Arjunan, et al., 2007)
- “The strength of sEMG is a good measure of the strength of contraction of muscle”. (Arjunan, et al., 2007)
 - **Not always true! E.g., EMG During Fatigue**

Muscle Sensor

- Advancer Technologies Muscle Sensor v3:
<http://www.advancertechnologies.com/p/muscle-sensor-v3.html>



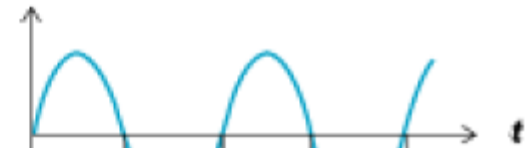
Hardware Configuration



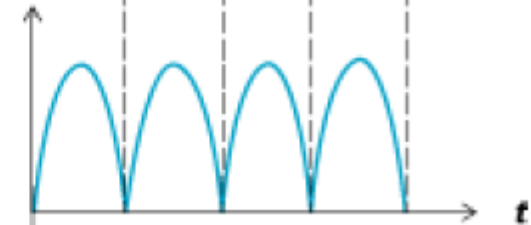
Rectified and Smoothed Signal

- These sensors do not output a RAW EMG signal, but rather an amplified, rectified, and smoothed signal the can be used directly with a microcontroller's analog-to-digital converter.
- This difference can be illustrated using a simple sine wave as an example.

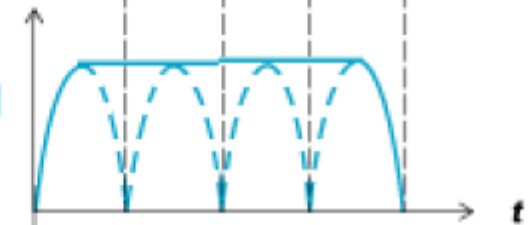
RAW Sine Wave



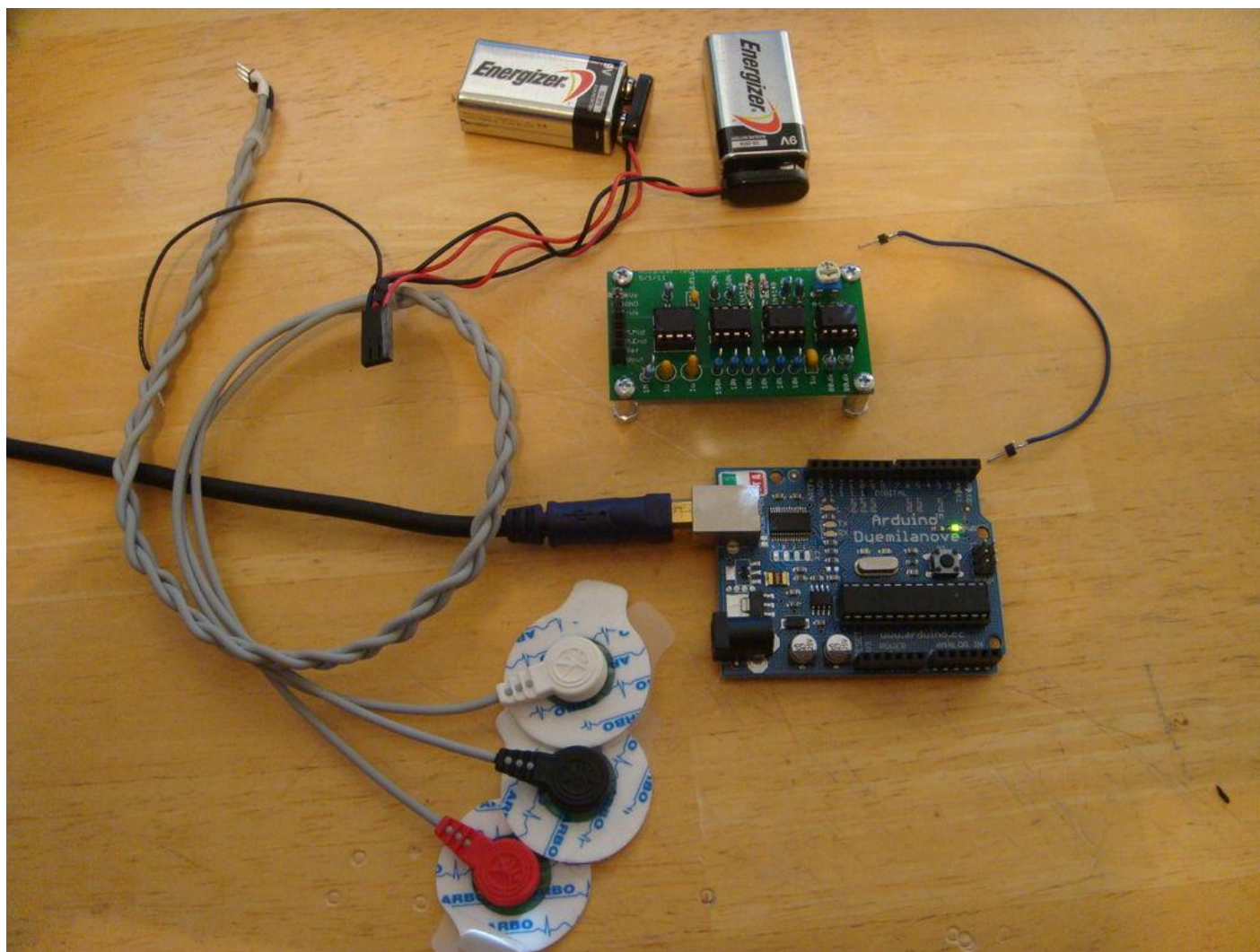
Full Wave Rectified Sine Wave



Rectified & Smoothed Sine Wave



Muscle Sensor Kit



Connect Sensors

- See http://www.youtube.com/watch?v=VnrsWdA6dzE&feature=player_embedded



Connect to Arduino

- Simple Scratch4Arduino Example

The screenshot displays the Scratch4Arduino interface. The main workspace shows a script for an Arduino board named "Arduino1". The script is as follows:

```
when clicked
  set x to -200
  set y to 0
  clear
  forever
    wait 1 secs
    set y to value of sensor Analog0 - 200
    set pen color to blue
    pen down
    change x by 2
    if x position = 200
      set x to -200
      clear
```

The right-hand panel, titled "EMGplot", shows a blue line graph representing the sensor data. Below the graph is a button labeled "Arduino1 Searching board..." and a small image of an Arduino board. The bottom right corner of the interface includes a "New sprite:" section with a search icon and a button labeled "Arduino...".

Arduino to Drive Relay

The image shows the Scratch IDE interface for a project titled "relayController- S4A 1.4". The main workspace features an "Arduino 1" sprite with the following script:

```
when green flag clicked
  forever loop
    if key space pressed?
      analog 9 value 255
    if key down arrow pressed?
      analog 9 value 0
```

The left sidebar contains various Scratch categories: Motion, Control, Looks, Sensing, Sound, Operators, Pen, and Variables. The right sidebar displays the "relayController" object with a status of "Searching" and a table of sensor values:

Arduino 1 Searching	
Analog0	0
Analog1	0
Analog2	0
Analog3	0
Analog4	0
Analog5	0
Digital2	false
Digital3	false

At the bottom right, there is a "New sprite:" section with a search icon and a "New" icon, and an "Arduino" sprite icon.

Now, put the two together

- If the muscle activity reaches a sufficient level, then turn on the external device...
- If the muscle activity drops below a certain level, then turn the external device off...

Conductive Fabric Electrode Sleeve

- Cut out three rectangular strips of the conductive fabric. Two of the strips should be W $5/8$ " x L $1\ 3/4$ ". The third strip should be W $5/8$ " x L 2".
- Take the forearm sleeve, turn it inside out, and put it on the opposite arm that it is intended to go on.
- Using fabric pins, pin the two shorter strips on your forearm muscle such that one is in the middle of the muscle body and the other is about an inch apart. Pin the third strip along the back side of your forearm (on the bony part). Check out the pictures to see how to orient the strips.
- Carefully take the sleeve off and you're ready to sew.

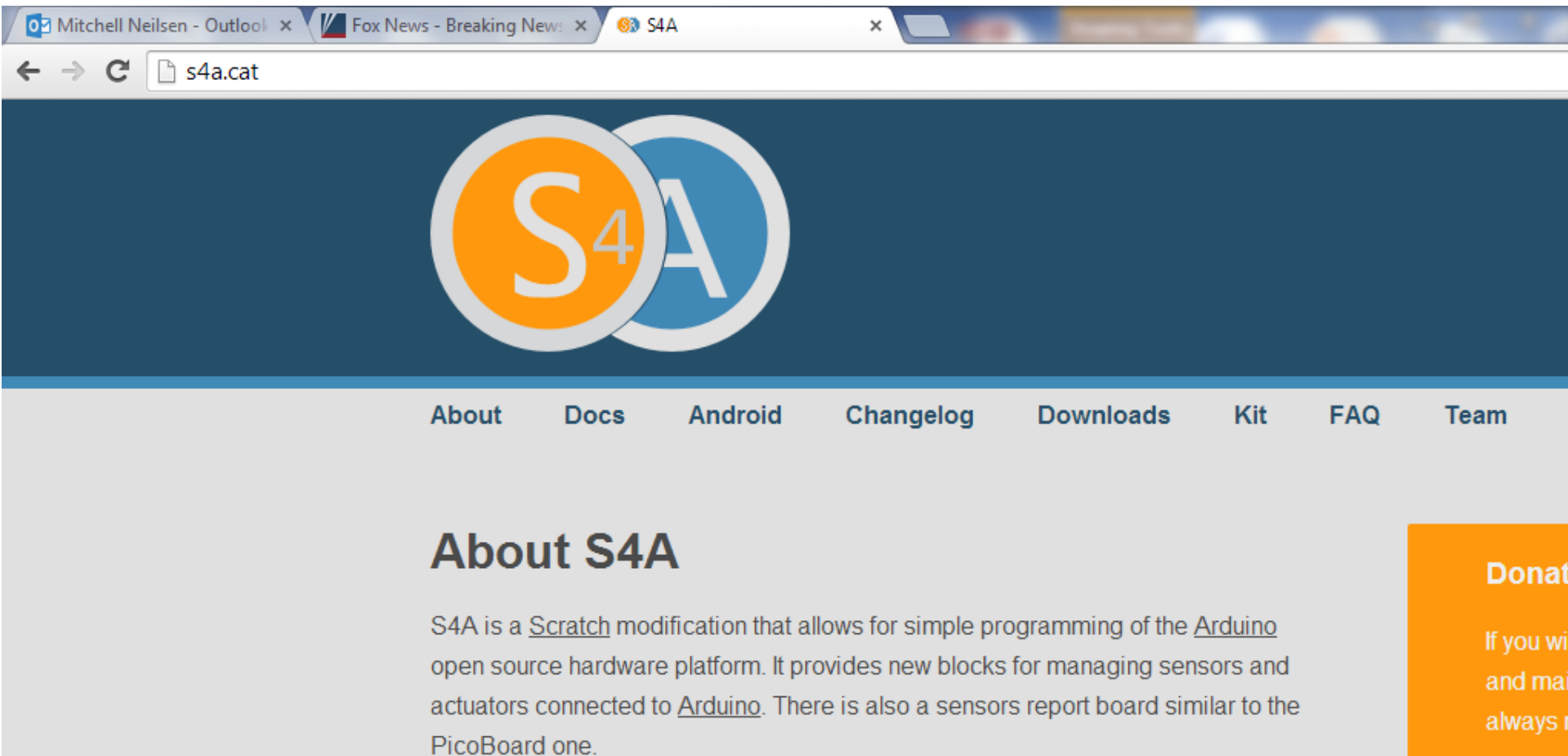


Conductive Fabric Material

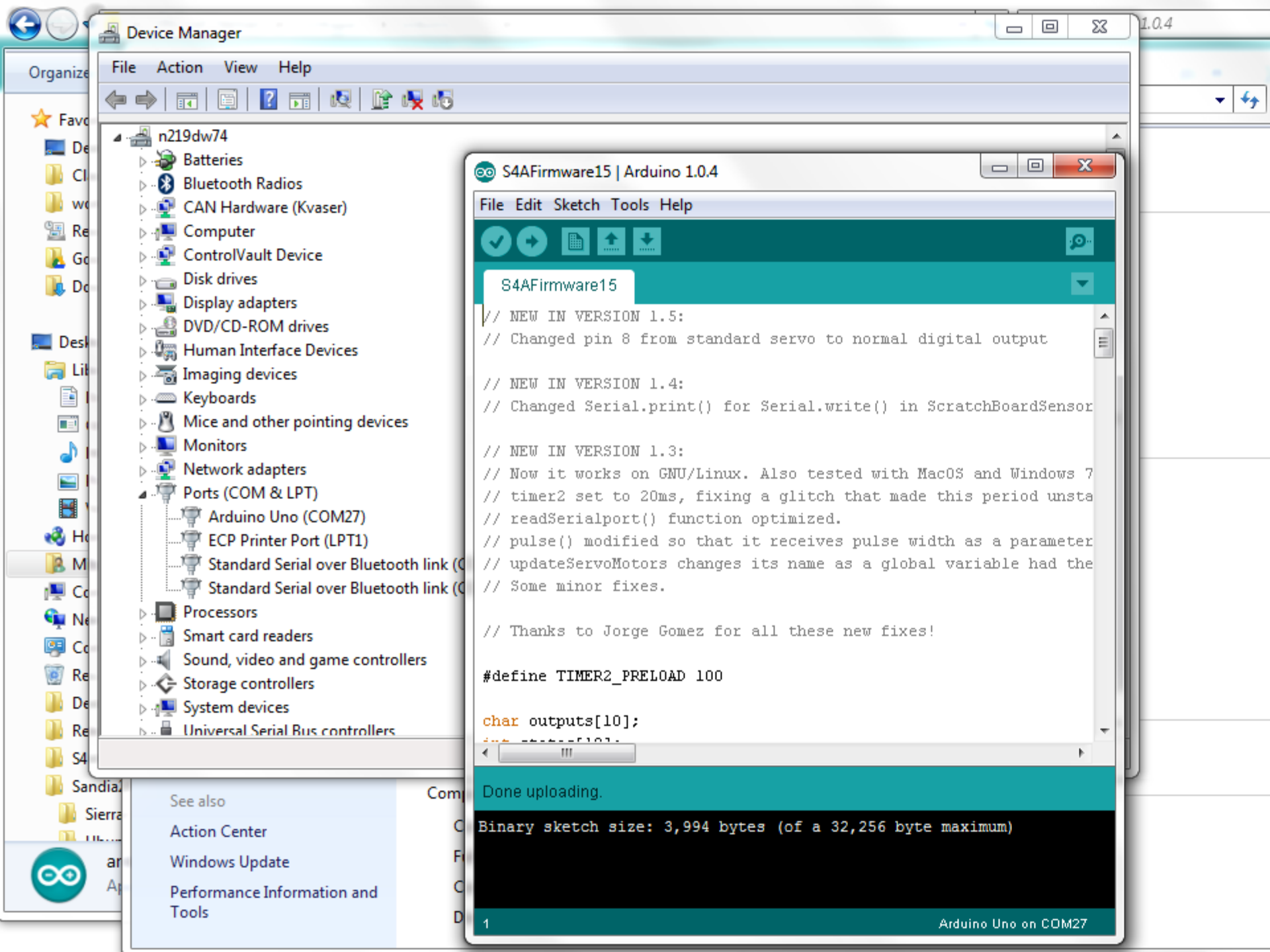
- "This medical grade Silver plated 76% Nylon, 24% elastic fiber fabric offers the unique ability to stretch in both directions.
- Can be used as an antibacterial wound dressing (note: our material is not sterile) but it also makes a great material for electrode contacts, stretchy hats, socks, gloves, or other garments.
- Highly conductive, and conductivity increases as it stretches in one direction, and decreases as it stretches in the other direction.
- Silver coating is 99.9% pure. Silver/gray color. “
– lessemf.com

S4A Download

- <http://s4a.cat/>



The image shows a browser window with the URL `s4a.cat` in the address bar. The page features a dark blue header with the S4A logo, which consists of two overlapping circles: an orange one with a white 'S' and a blue one with a white 'A'. Below the header is a navigation menu with links for 'About', 'Docs', 'Android', 'Changelog', 'Downloads', 'Kit', 'FAQ', and 'Team'. The main content area has a heading 'About S4A' followed by a paragraph: 'S4A is a [Scratch](#) modification that allows for simple programming of the [Arduino](#) open source hardware platform. It provides new blocks for managing sensors and actuators connected to [Arduino](#). There is also a sensors report board similar to the PicoBoard one.' On the right side, there is a partial view of an orange box with the text 'Donat' and 'If you wi and ma always n'.



- n219dw74
 - Batteries
 - Bluetooth Radios
 - CAN Hardware (Kvaser)
 - Computer
 - ControlVault Device
 - Disk drives
 - Display adapters
 - DVD/CD-ROM drives
 - Human Interface Devices
 - Imaging devices
 - Keyboards
 - Mice and other pointing devices
 - Monitors
 - Network adapters
 - Ports (COM & LPT)
 - Arduino Uno (COM27)
 - ECP Printer Port (LPT1)
 - Standard Serial over Bluetooth link (COM...)
 - Standard Serial over Bluetooth link (COM...)
 - Processors
 - Smart card readers
 - Sound, video and game controllers
 - Storage controllers
 - System devices
 - Universal Serial Bus controllers

- See also
- Action Center
- Windows Update
- Performance Information and Tools



```
S4AFirmware15
// NEW IN VERSION 1.5:
// Changed pin 8 from standard servo to normal digital output

// NEW IN VERSION 1.4:
// Changed Serial.print() for Serial.write() in ScratchBoardSensor

// NEW IN VERSION 1.3:
// Now it works on GNU/Linux. Also tested with MacOS and Windows 7
// timer2 set to 20ms, fixing a glitch that made this period unsta
// readSerialport() function optimized.
// pulse() modified so that it receives pulse width as a parameter
// updateServoMotors changes its name as a global variable had the
// Some minor fixes.

// Thanks to Jorge Gomez for all these new fixes!

#define TIMER2_PRELOAD 100

char outputs[10];
int status=101;
```

Done uploading.

Binary sketch size: 3,994 bytes (of a 32,256 byte maximum)

1 Arduino Uno on COM27