

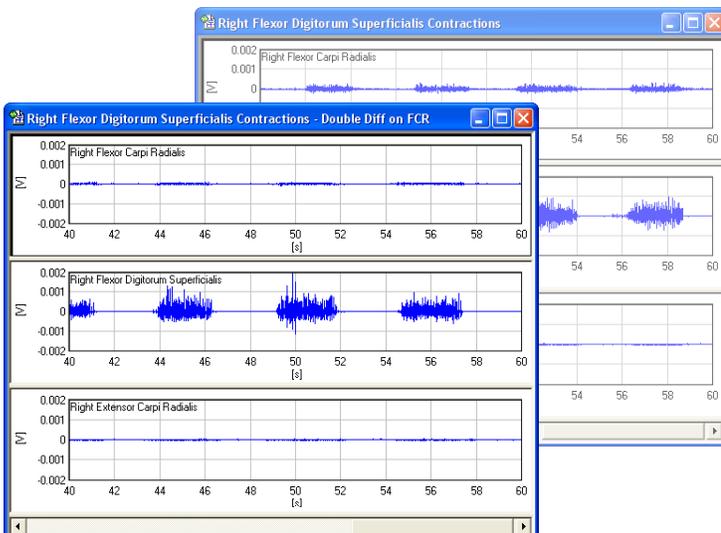
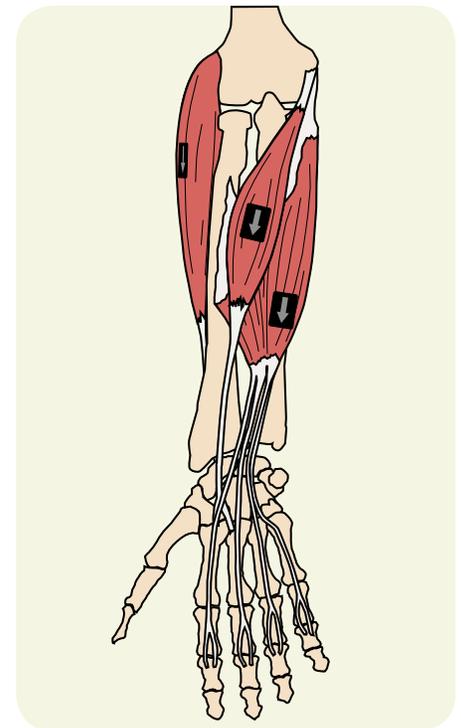
Purpose

This technical note addresses proper placement technique for Delsys Surface EMG Sensors. The technique is demonstrated through an experiment in which EMG data is recorded from several forearm muscles.

Dimensions	CMRR (0-500 Hz)	Noise
41 x 20 x 5 mm	-92 dB (typical)	1.2 μ V (RMS, R.T.I.)

Hardware Concepts

- The Surface EMG Signal
- Delsys EMG Sensors
- EMG Sensor Location and Placement
- Experimental Set-up



Software Concepts

- Test Configuration Design
- Data Acquisition
- Refinement of Sensor Location

Introduction

The key to achieving a successful EMG recording resides in understanding how to use and where to place the EMG sensors. This document presents important concepts in this regard, that relate to both Delsys® hardware and software. These concepts are presented from the vantage point of an experimental protocol and the ensuing analysis of the data. The intention of this structure, which is consistent throughout our Technical Notes Series, is to provide guidelines for working with Delsys products, and to promote creativity and sound judgement during the experimental design phase.

The Surface EMG Signal

The surface electromyographic (EMG) signal is the minute electrical signal that emanates from contracting muscles. The most fundamental component in motor control is known as the motor unit, consisting of a single alpha motor neuron and the muscle fibers that it innervates. Similarly, the most fundamental component of the surface EMG signal is the motor unit action potential, consisting of the electrical activity that arises from the contraction of a single motor unit. A continuous muscle contraction produces a train of motor unit action potentials, and a gross muscle contraction produces a signal that is the spacial and temporal summation of all of the motor unit action potential trains that are active. Finally, the surface EMG signal is the component of this signal that can be detected at the skin after it has been affected by filtering properties of the tissues through which it has traveled. Please visit the knowledge center at www.delsys.com for more detail about the origin of the surface EMG signal and the factors that affect it.

The Delsys Surface EMG Sensors



Delsys Surface EMG Sensors are the foundation for unmatched signal quality and reliability in all of the Delsys EMG Systems. The patented fixed parallel bar design, contoured shape, and convenient adhesive skin interfaces allow for consistent and hassle-free recordings. The sensors come in single and double differential models.

CAUTION: The Delsys Surface EMG Sensors should not be used for diagnostic purposes.

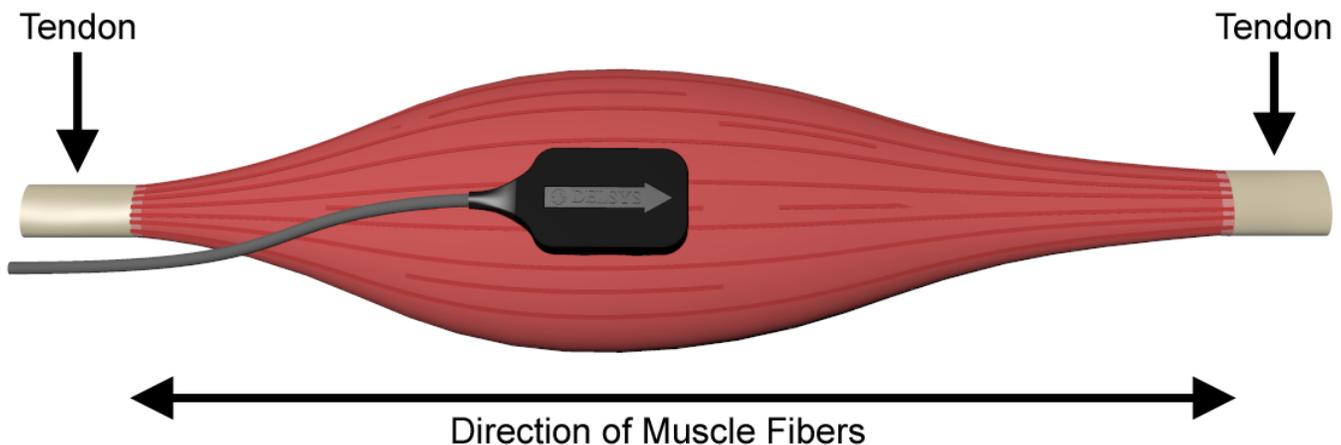
An understanding of the design of the Delsys Surface EMG Sensors is crucial for their proper use. The first concept to consider is that the sensors rely on differential amplification. This means that the signal is detected at two sites, the signals are subtracted, and the difference is amplified. As a result, any signal that is “common” to both detection sites will be removed, and signals that are different at the two sites will be amplified. Most noise is “common” to both detection sites and is removed. The desired surface EMG signal is different at the two sites and is amplified. In the double differential model, the signal is detected at three sites and the subtraction procedure is performed twice to allow even greater focus on the desired muscle and to eliminate crosstalk.

The second concept to consider is the fixed parallel bar arrangement of the skin contacts. Muscle fibers run longitudinally in a muscle. As a result, the electrical activity of the muscle also propagates predominantly along the length of the muscle. Each Delsys EMG Sensor has an arrow on top that should be aligned along the length of the muscle so that the parallel bar detection sites transect the muscle fibers. The parallel bar arrangement, in contrast to circular contacts, ensures that a maximum number of muscle fibers are monitored in a given location. The fixed distance between the contacts ensures that measurements are reproducible since changes in the distance between detection surfaces would affect the detected signal.

EMG Sensor Location

Proper EMG sensor location is critical for detecting quality surface EMG signals. The user should consult an anatomical atlas to determine the precise location, origin, insertion, and function of the muscle being studied as well as any nearby muscles that may produce underivable signals (crosstalk).

1. Place the sensor along the longitudinal midline of the desired muscle with the arrow parallel to the muscle fibers.
2. **DO NOT** place the sensor at the outside edges of the muscle. In this region, the sensor is susceptible to detecting crosstalk signals from adjacent muscles.
3. Place the sensor between a motor point (innervation zone) and the tendon insertion or between two motor points.
4. **DO NOT** place the sensor on or near the motor point. The motor point is that point on the muscle where the introduction of minimal electrical current causes a perceptible twitch of the surface muscle fibers. This point usually, but not always, corresponds to that part of the innervation zone of the muscle with the greatest neural density. This is a poor location for a surface EMG sensor because the electrical activity propagates in multiple directions and, therefore, cancels itself out when differential amplification is used.
5. **DO NOT** place the sensor on or near the tendon of the muscle. As the muscle fibers approach the fiber of the tendon, the muscle fibers become thinner and fewer in number, reducing the amplitude of the EMG signal. Also in this region the muscle is physically smaller, which makes it difficult to accurately place the sensor and to avoid crosstalk from adjacent muscles.



6. Once the general location for the sensor is determined, contractions of the muscle should be performed to ensure that quality signals are being detected. A significant advantage of the Delsys Surface EMG Sensor is that it requires no skin preparation or adhesive for basic function. For this reason, it is possible to use a sensors as a probe. The location can be easily adjusted to find the optimal position. As the desired muscle is contracted, the location of the sensor is slightly shifted until the detected signal is maximized. In the same way, the sensor can be moved to minimize the detection of surface EMG activity from adjacent muscles.

EMG Sensor Placement

Although the Delsys Surface EMG Sensor can be used as a probe without skin preparation or adhesive, the following simple steps are needed to assure optimal signal detection once the final location is determined.

1. Wipe the surface of the sensor and the silver detection bars with an isopropyl alcohol pad to remove residue. Allow the sensor to air dry for a few seconds.
2. Shave excessive hair from skin at the detection site.
3. Wipe the skin at the site with an isopropyl alcohol pad to remove oils and surface residues. Allow the skin to air dry for a few seconds.
4. Apply the sensor to the skin using a Delsys Adhesive Sensor Interface.
 - A. Peel an interface from the sheet and apply it to the sensor taking care to align the silver detection bars through the holes.
 - B. Remove the adhesive backing from the interface.
 - C. Apply the sensor to the skin at the prepared site.



EMG Sensor Experiment - Hardware Setup

The goal of this experiment is to record three channels of surface EMG data from a subject while performing different wrist and finger movements. The EMG data will be recorded from the right flexor carpi radialis, right flexor digitorum superficialis, and the right extensor carpi radialis longus. Since these muscles are all in close proximity, a thorough understanding of their anatomy and function is necessary, and proper EMG sensor location and placement is critical. In the experiment, each muscle will be contracted individually with Delsys Single Differential Surface EMG Sensors on all three muscles. The location of each sensor will be adjusted to maximize the detection of activity from the desired muscle and to minimize the detection of activity from the other muscles. Then, since a significant portion of the flexor digitorum superficialis muscle lies deep to the flexor carpi radialis, the sensor over the flexor carpi radialis will be changed to a Delsys Double Differential Surface EMG Sensor to determine if this reduces the unwanted detection of activity from the flexor digitorum superficialis.

The experimental setup is illustrated below. The table lists where to plug in each sensor in the auxiliary box and how to set the gain for each channel on the Bagnoli EMG System.



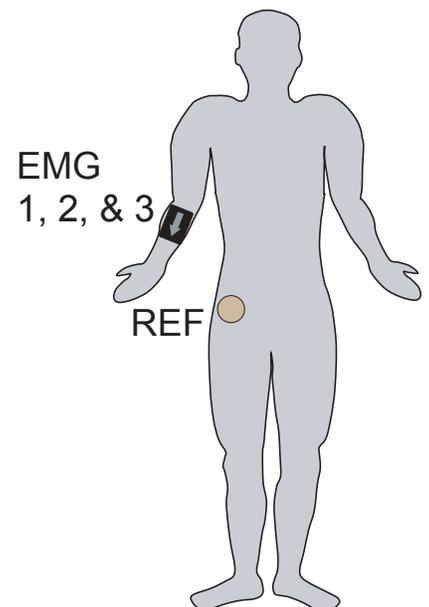
Bagnoli Amplifier Configuration

Sensor	Channel	System Gain
EMG 1	CH 1	1 K
EMG 2	CH 2	1 K
EMG 3	CH 3	1 K
Reference	REF	Not Applicable

Note: Myomonitor Systems do not require external settings of any kind.

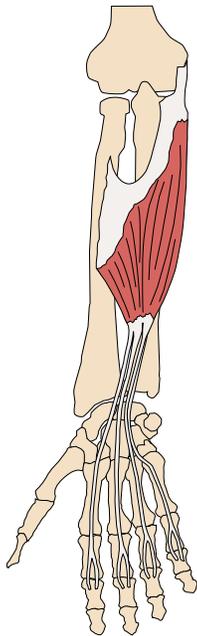
To the right is a simplified diagram of sensor placement. The EMG sensors are placed over the right flexor carpi radialis, right flexor digitorum superficialis, and the right extensor carpi radialis longus. The precise location of the sensors with careful attention to anatomical detail is covered on the next page

The reference electrode is placed on the anterior superior iliac spine. This location on a bony prominence is chosen to minimize the EMG activity exposed to the reference.

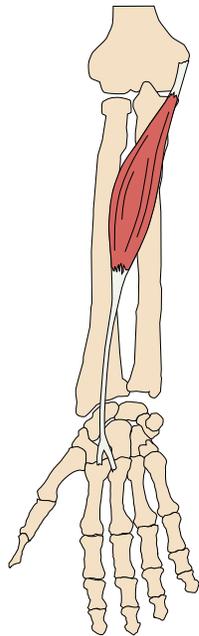


EMG Sensor Experiment - Sensor Location Details

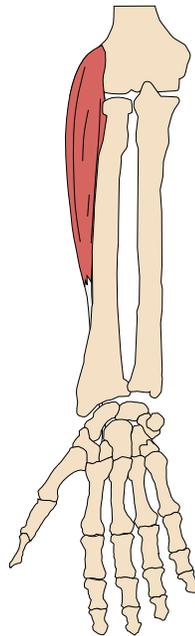
The illustrations below show the ventral (palmar) aspect of the right forearm. Each depicts one of the muscles of interest including its tendons of origin and insertion. The flexor digitorum superficialis shares its origin on the radius, ulna, and the distal humerus. Its tendons insert on the proximal aspect of each of the middle phalanges of the fingers. The flexor carpi radialis originates from the medial epicondyle of the humerus. It inserts at the proximal aspect of the second and third metacarpals. The extensor carpi radialis longus originates from the lateral epicondyle of the humerus and inserts at the proximal aspect of the second metacarpal on the dorsal aspect of the hand. This muscle lies predominantly on the lateral and dorsal aspect of the forearm rather than the ventral aspect like the other two muscles.



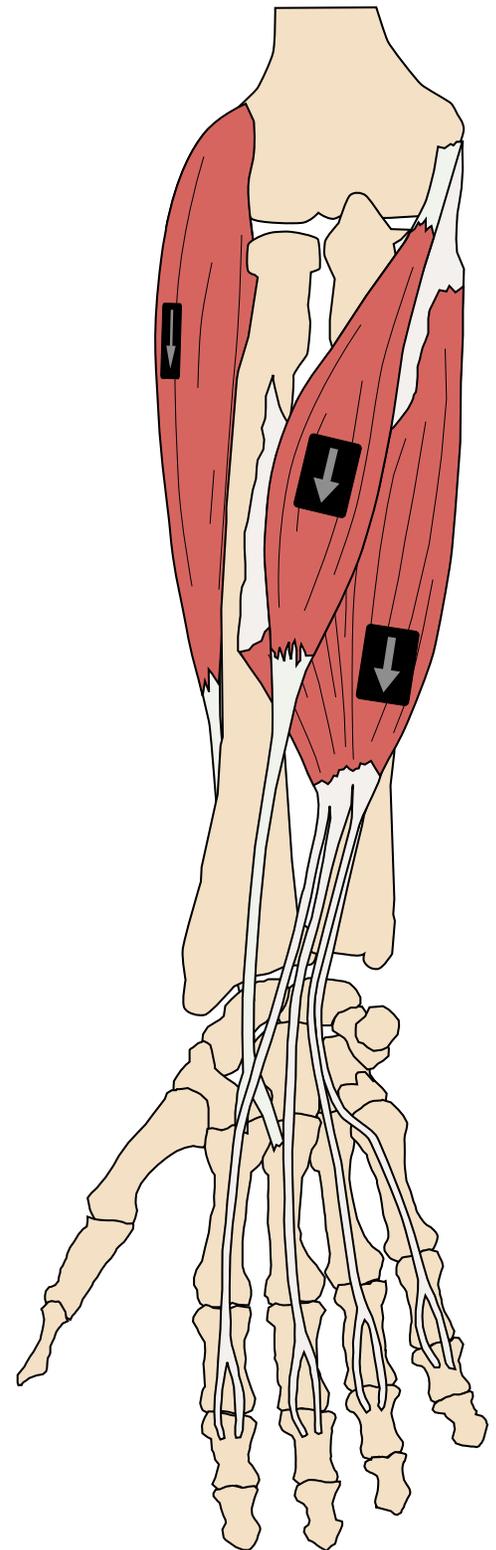
Flexor Digitorum Superficialis



Flexor Carpi Radialis



Extensor Carpi Radialis Longus



The illustration to the right shows all of the muscles and their anatomical relationships as well as the suggested locations for each of the EMG sensors. The most important relationship to note is that a significant portion of the flexor digitorum superficialis lies deep to the flexor carpi radialis. Each of the sensors is located as close to the longitudinal midline of the muscle as possible and in the portion of the muscle belly with maximal mass. In the case of the flexor digitorum superficialis, however, the sensor had to be positioned slightly more lateral and inferior in order to avoid overlying the flexor carpi radialis and other muscles not pictured. In the case of the extensor carpi radialis longus, note that the sensor is placed on the lateral/dorsal aspect of the forearm.

EMG Sensor Experiment - Software Setup

EMGWorks Acquisition requires the user to specify a Hardware Configuration and a Test Configuration to use for recording data. Please consult the EMGWorks manual for more details on the procedure for creating these.

Hardware Configuration

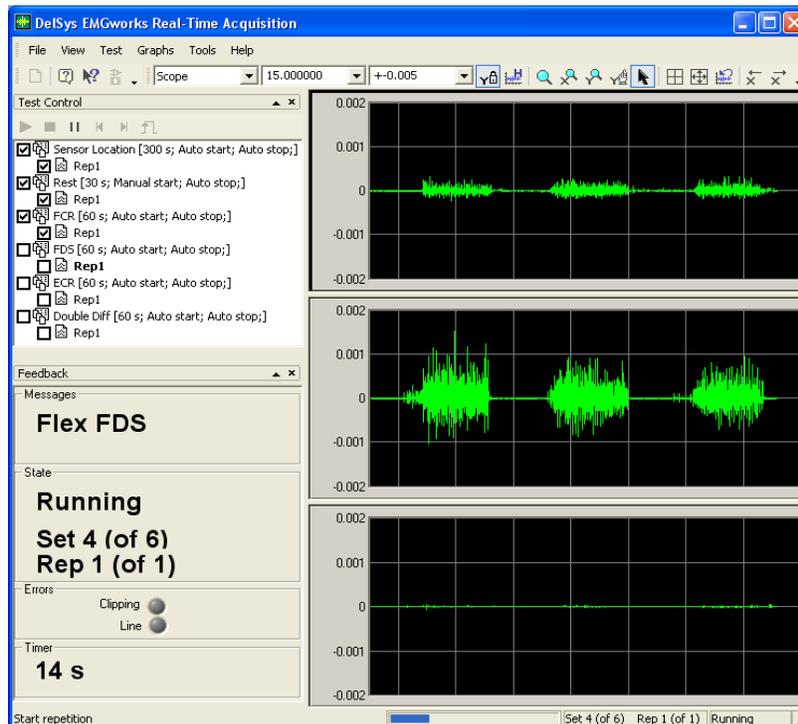
A Hardware Configuration should be created according to the hardware that you are using. In this case, the configuration was created for a Bagnoli 16-Channel EMG System and a National Instruments M-Series A/D Card.

Test Configuration

A Test Configuration should be created consisting of 6 Sets. The **Test Control** window in the screenshot below summarizes the Test. The first Set will be for refining the location of each of the EMG sensors. Each of the muscles being studied will be contracted individually and the location of the corresponding sensor will be adjusted to maximize the detected signal. The location of the other sensors will be adjusted to minimize the detected signal (i.e. crosstalk). After the first set, each of the sensors will be properly affixed to the skin. For the second Set, resting data will be collected to be sure that no undesired activity or noise is detected by the sensors. For the third through fifth Sets, each of the muscles being studied will be contracted individually. Before the sixth Set, the sensor over the flexor carpi radialis should be changed to a double differential sensor. For the sixth Set, the subject should then contract the flexor digitorum superficialis again by flexing the fingers at the metacarpophalangeal joints.

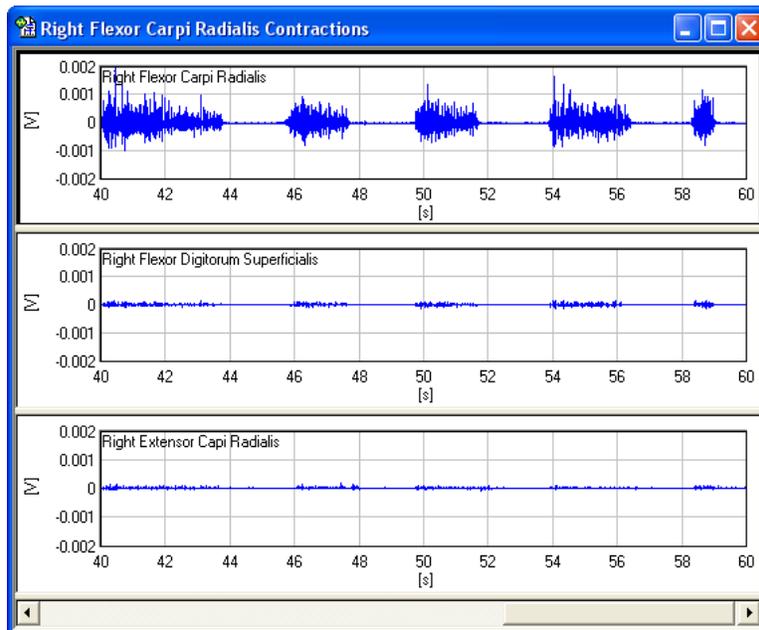
EMG Sensor Experiment - Data Acquisition

Data acquisition will proceed according to the Test Configuration after clicking the **Play** button in the **Test Control** window. The screenshot below shows an example of the EMG data during the performance of the experiment.

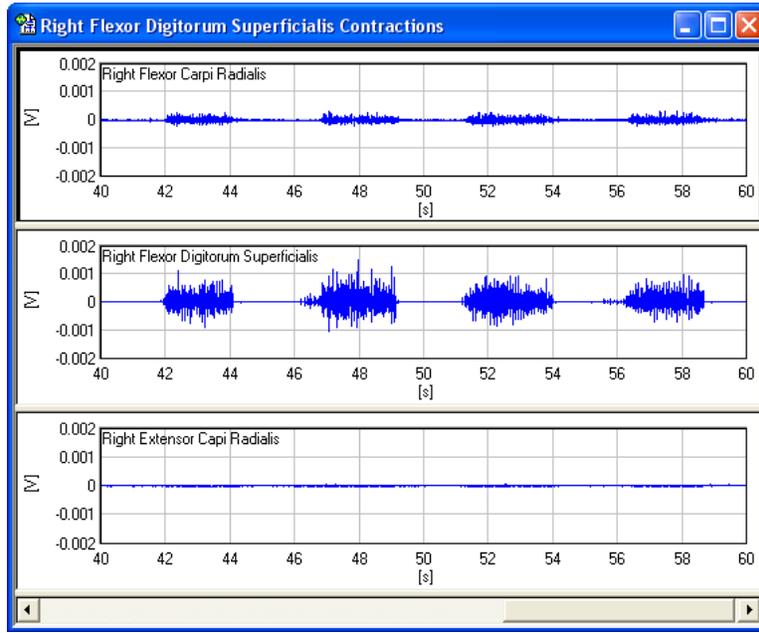


Data Analysis

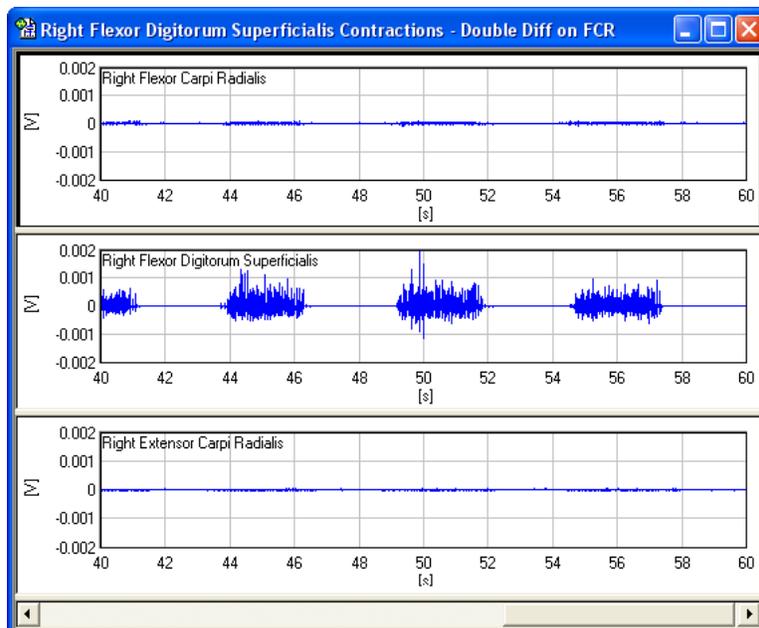
The screenshot below shows the recordings from all three EMG sensors during contractions performed by the right flexor carpi radialis. It can be seen that the surface EMG activity from the right flexor carpi radialis is obviously of the greatest magnitude. There is, however, low amplitude surface EMG activity detected by the sensors over the right flexor digitorum superficialis and the right extensor carpi radialis longus as well. This detected activity was minimized by adjusting the locations of the sensor. This activity may be crosstalk from the right flexor carpi radialis. Many situations require the precise placement of the EMG sensor so that it only detects activity from one muscle, especially in locations like the forearm where there are many muscles which overlap. This is why studying the appropriate anatomy before designing an experiment is very important. Often it is difficult or impossible to design tasks that use only one specified muscle. Other nearby muscles may have postural, agonist, or antagonist activity. Despite this low amplitude activity from the other EMG sensors, the results suggest that the sensor over the right flexor carpi radialis is detecting quality data.



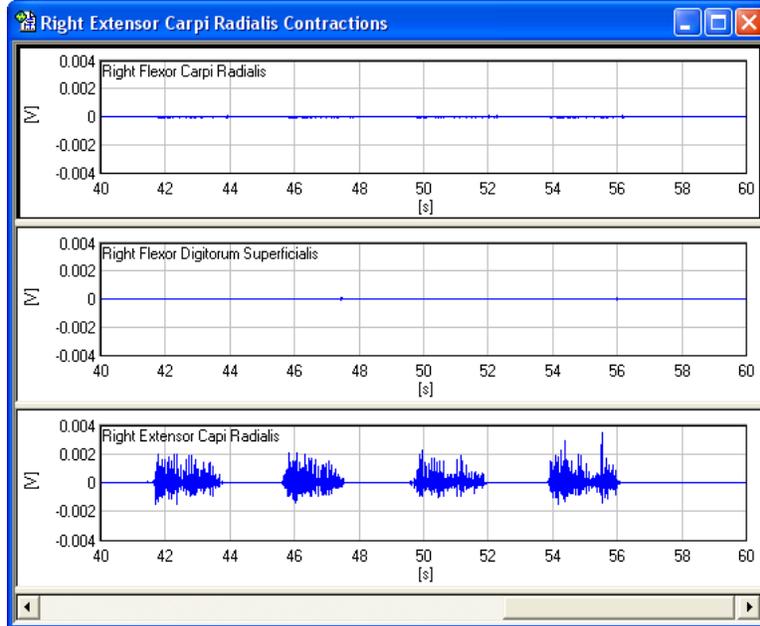
The screenshot below shows the recordings from all three EMG sensors during contractions performed by the right flexor digitorum superficialis. Again, it can be seen that the surface EMG activity from the desired muscle is obviously of the greatest magnitude. In this case, however, there is actually significant activity being recorded by the EMG sensor over the right flexor carpi radialis. Considering that the flexor carpi radialis overlies much of the flexor digitorum superficialis, this activity is most likely crosstalk.



This hypothesis can be tested by studying the data that were recorded with the double differential EMG sensor over the right flexor carpi radialis. This sensor should more effectively cancel out surface EMG activity emanating from deeper muscles, and, therefore, decrease the amplitude of the activity from the right flexor digitorum superficialis muscle that is undesirably detected. The screenshot below shows that this is indeed the case.



The screenshot below shows the recordings from all three EMG sensors during contractions performed by the right extensor carpi radialis longus. In this case, there is some low amplitude surface EMG activity being recorded from the EMG Sensor over the right flexor carpi radialis. Considering that these two muscles are anatomically distant from each other, this is likely true activity. The flexor carpi radialis likely has some antagonist involvement in wrist extension.



This document covers the most important concepts to understand for the proper location and placement of EMG Sensors. Please visit the tutorial section of the knowledge center at www.delsys.com for more details.

EMG Sensor Additional Information

- Single Differential EMG Sensor for Bagnoli System, Catalogue Number - SP-E04
- Double Differential EMG Sensor for Bagnoli System, Catalogue Number - SP-E06
- Single Differential EMG Sensor for Myomonitor, Catalogue Number - SP-E07

Dimensions	CMRR (0-500 Hz)	Noise
41 x 20 x 5 mm	-92 dB (typical)	1.2 μ V (RMS, R.T.I.)