Myomonitor® III EMG system

User Manual

December 2004
Edition
(PM-M04A)

Specifications and procedures outlined in this manual are subject to change without notice.

IMPORTANT INFORMATION

Intended Use

The Myomonitor EMG Systems are designed for research, investigational and scholarship purposes only. Delsys products are not intended for measurement purposes or for use in the treatment and diagnosis of humans.

Warnings and Precautions

Delsys products are not designed to be used in conjunction with any devices not approved by Delsys Inc. Please contact Delsys for further information.

Connecting a patient to high-frequency surgical equipment while using Delsys EMG systems may result in burns at the site of the EMG sensor contacts.

Immediately discontinue device use if skin irritation or discomfort occurs.

Immediately discontinue device use if a change in the device's performance is noted. Contact Delsys technical support for assistance.

Do not use Delsys products in the presence of any liquid or during conditions where the device or the user(s) may become exposed to liquids. The presence of liquids may compromise the safety features of the device.

Delsys EMG amplifiers are extremely sensitive to electrical disturbances. Avoid static discharges and electromagnetic fields.

Delsys Inc. guarantees the safety, reliability, and performance of the equipment only if assembly, modifications and repairs are carried out by authorized technicians; the electrical installation of the relevant room complies with the appropriate requirements; and the equipment is used in accordance with the instructions for use.

Disclaimer

DELSYS INC. makes no warranties, express or implied, as to the quality and performance of this product including but not limited to, any implied warranty of applicability for other than research uses by qualified individuals. DELSYS INC. shall not be liable to any person for any medical expenses or any direct or

consequential damages resulting from any defect, failure or malfunction, whether a claim for such damages is based upon theory of warranty, contract, tort or otherwise. No representative, agent, or licensed practitioner is authorized to waive this disclaimer. DELSYS INC. makes no diagnosis or prescription by virtue of anything about this product.

Limited Warranty

The Myomonitor®III Portable EMG Systems are warranted against failure of materials and workmanship for a period of 1 year from the date of delivery, provided that the product is given proper care and has not been subject to abuse during this period. This warranty is in lieu of all other warranties expressed or implied. Operation of this device outside specified power supply or input voltage ranges specified by DELSYS INC. or use with any other input devices other than DELSYS INC. electrodes constitute an invalidation of this limited warranty. This warranty is not transferable.

All devices to be returned require a return authorization number issued by DELSYS INC. All authorized returned merchandise must be shipped prepaid to DELSYS INC. If authorization for the return of a device is given, please insure the product in transit for any loss or damages that may occur.

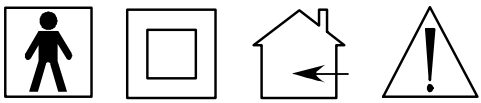
Technical Support

Visit our web site at:

http://www.delsys.com

Tel: (617) 236-0599

Fax: (617) 236-0549



Myomonitor® III Portable EMG System

General Description

The Myomonitor System is a portable electromyographic (EMG) data acquisition system. The device comes in two configurations:

- Myomonitor Wireless, which transmits data to a host computer nearby for storage and real-time viewing.
- Myomonitor Datalogger, which acquires and stores data in onboard memory. It can display a specified channel in real time.

Each configuration is available in 8 or 16 channels.

The Myomonitor EMG System is designed to make the acquisition of EMG signals hassle-free and reliable. The active electrodes are specifically designed to optimally detect EMG signals at the skin surface, while rejecting common noise signals such as motion and cable artifacts, yielding an excellent signal-to-noise ratio. In addition, the Myomonitor EMG System's portable design allows experiments to be conducted that would be impossible with conventional systems.

The Myomonitor III Portable EMG System is comprised of the following items:

- •1 Myomonitor Main Unit
- •1 512 MB Memory (Datalogger)
- •1 WLAN Transmitter (Wireless)
- •1 WLAN Receiver (Wireless)
- •8 (16) DE-2.3 EMG Electrodes
- •1 (2) Belt mounted Input Module
- •1 (2) Input Module Cable
- •1 Docking Module
- •1 7.2V 4300 mAh Li-Ion Battery
- •1 9V Power Supply
- •1 USB cable, 2m
- •1 Lumbar Pack
- •1 Carrying Case
- •1 Reference Cable, alligator
- •1 Reference Cable, tip
- •1 Package of Small Reference Electrodes
- •1 Package of Large Reference Electrodes
- •1 Package of Skin Interfaces

Myomonitor System Components

Main Unit

The Main Unit powers the EMG electrodes and digitizes the EMG signal. In Datalogging mode, the EMG data are stored on internal flash memory (512 MB standard), which will keep data secure even in the case of power loss. In Wireless mode, the EMG data are sent over the wireless local area network (WLAN) to the host computer for storage and real-time display. The Main Unit is shown in Figure 1.

The front of the Main Unit contains the touch screen, where the application program is executed.

The top of the Main Unit has the connectors for the Input Modules and to the Docking Module. For subject safety, the design prevents the Input Module and the Docking Module to be connected at the same time.

The bottom panel of the Main Unit has the controls for Power on/off and the reset button. It also has the Trigger Connector, the speaker and the status LEDs.

Figure 1. The Myomonitor Main Unit

DE-2.3 Differential Surface Electrodes

The differential electrode subtracts EMG potentials detected at two distinct locations on the surface of the skin, directly above an active muscle. The EMG potentials are always measured with

respect to the electric potential of a neutral site located away from the EMG muscle source.

The electrodes are designed using a parallel-bar contact geometry for ensuring signal stability, repeatability between recordings and optimal frequency content representation. These versatile electrodes are well-suited for most EMG applications, ideal for both large and small muscles.

Figure 2. DE-2.3 Single Differential Surface EMG Electrode.

Input Modules

The Input Modules (see Figure 3) host the EMG electrodes and the Reference Electrode cable. Up to eight electrodes can be connected to an Input Module. The EMG signals detected by the electrodes are communicated to the Main Unit via the Input Cable. The Input Modules have a clip on one side, which simplifies fastening to the waist belt or lumbar pack.

Figure 3. The Input Module

Input Cable

The Input Cable connects the Input Modules with the Main Unit, supplying power to the active EMG electrodes and transmitting EMG data back to the Main Unit.

Figure 4. The Input Cable.

Reference Electrode Cable

Two types of reference electrode cables are provided with the system in order to support several reference electrode options (see Figure 5). Both cables are single-conductor wires with a “banana” connector on one end and either an “alligator clip” or a “tip plug” on the other end. The banana plug is hosted by a receptacle located in the Input Module. Although two cables are provided, only one reference connection shoud be used when collecting EMG.

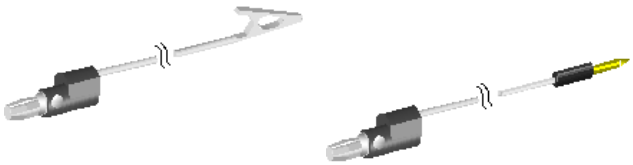


Figure 5. (a) The Alligator Reference Electrode Cable. (b) The Tip Reference Electrode Cable.

Power Supply

The power supply is fitted with a universal IEC 320 input plug so as to accept power cables from all countries. The power supply accepts input voltages ranging from 100-240V, 50 or 60 Hz.

Delsys strives to supply the correct power cable for each destination however, it may at times be necessary to separately purchase power cords, suitable for the local receptacles in use.

Figure 6. The universal input power supply (100-240 VAC, 50-60 Hz.).

Docking Module

The docking module provides connections to the power supply and to the PC, through the Universal Serial Bus (USB). It connects to the top of the Main Unit. For safety, the docking module design prevents the EMG electrodes from being connected to the subject when the Main Unit is connected to external power or USB.

Figure 7. The Docking module.

Getting Started with the Myomonitor System

Please be sure to read the Release Notes that came with the system before continuing with the instructions below. These contain important additional information regarding the configuration and operation of the system.

Charging the Battery

Before using the system, the battery should be fully charged. Connect the Docking Module to the Main Unit.

Connect the External Power Supply to the electrical outlet and to the Docking Module (see Figure 8)

Figure 8. The Main Unit connected to the Docking Module and the Power supply for charging purposes.

The charging of the internal Li-Ion Battery starts immediately and completes within 6 hours. Delsys recommends that the device is left plugged into external power when not in use so as to keep the battery fully charged at all times.

Connecting the Input Modules

The Input Cable connects the Input Module with the Main Amplifier Unit. Insert the cable into the receptacle on the Input Module and make sure that the latching mechanism secures the connection.

For the 8-channel version, make the connection to bank A on the Main Unit.

For the 16-channels version (see Figure 9), connect one Input Module to bank A (channel 1-8) and the other Input Module to bank B (channel 9-16).

Figure 9. Connecting the Main Unit and Input Modules via the Input Cable.

Connecting the Reference Electrodes

Connect the Reference Electrode cable to the Input Module using the "banana" jack. Attached the Reference Electrode to the skin considering the points below:

- A high quality electrical connection between the Reference Electrode and the skin is as important for obtaining reliable EMG signals as a high quality EMG Electrode-skin connection. Be sure to clean the skin prior to affixing the reference.
- Only one reference connection is required when collecting EMG signals. The site should be an electrically inactive area on the skin surface.
- Delsys EMG Systems are supplied with two examples of disposable reference electrodes, shown in Figure 10. The small tab electrodes are an economical solution, while the large conductive disc electrodes provide a better connection. Both types are lined with a conductive medical grade adhesive. Conductive electrodes other than the examples supplied can be used as substitutes.

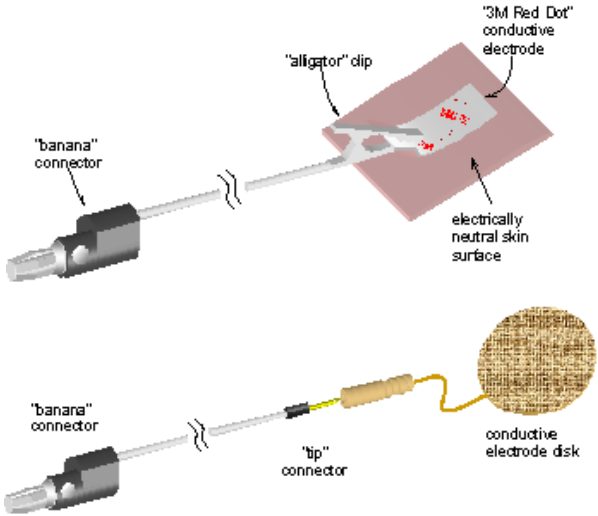


Figure 10. The Reference Electrode. The "banana" connector is mated with the Input Module, while the "alligator" or "tip" is used to connect to conductive adhesive electrodes.

Connecting the EMG Electrodes

The Myomonitor EMG System is supplied with DE-2.3 Surface EMG electrodes. These plug into the receptacles labeled Ch. 1-8 on the Input Modules. The connectors have a key so that they can only be inserted with a specific orientation. The order of the electrodes can be interchanged with no consequences to the performance of the EMG System. The electrode cables are five feet in length so that they can be placed on any part of a user's body when the Input Modules are mounted at waist level.

CAUTION: Never use any EMG electrode other than the DE-2.3 Surface EMG Electrode as an input to the Myomonitor EMG System. Connecting anything other than Delsys specified electrode/sensor as an input to the Myomonitor EMG System constitutes an invalidation of the Delsys Warranty and may result in personal injury and/or permanent damage to the system or the electrodes.

Orienting the EMG electrodes on the Skin

The DE-2.3 Surface EMG Electrode is fitted with two silver bar contacts for detecting the EMG signal at the skin surface. It is crucial that the orientation of these bars be perpendicular to the muscle fibers for maximum signal detection. The top of the

electrode is stamped with an arrow to aid in the determination of this orientation. The arrow should be placed parallel to the muscle fibers underneath the electrode as demonstrated in Figure 11. It is important that the electrode and the skin are clean and free of oil and other resides before placement of the electrodes. It is advised to remove excessive hair from the EMG site. The electrodes are easily attached to the skin with the Delsys Electrode Interface.

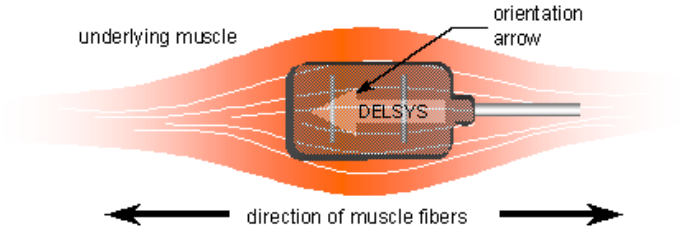


Figure 11. Electrode orientation with respect to the muscle fibers. It is important that the orientation of the arrow on the electrode be parallel to the underlying muscle fibers.

Using the Delsys Electrode Interface

The Delsys Interfaces are made from medical grade adhesive specifically designed for dermatological applications. Usage of the interface promotes a high quality electrical connection between the electrode bars and the skin, minimizing motion artifacts and the ill-effect of line interference. To ensure a strong bond with the skin, it is advised to shave excessive hairs and wipe the skin area with isopropyl alcohol, to remove oils and surface residues. Allow the skin to dry completely before applying the interfaces. Figure 12 illustrates the correct application of the Interface.

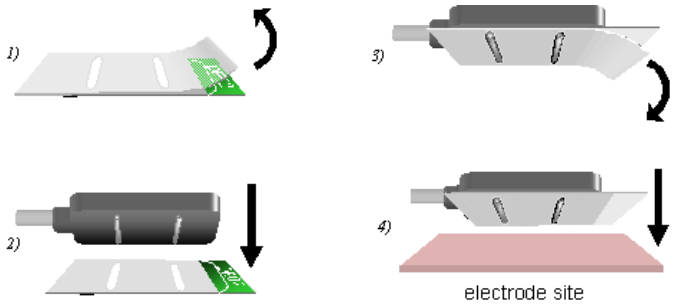


Figure 12. Application of the Delsys Electrode Interface. 1) Peel the top clear liner to expose the first layer of adhesive. 2) Mount the interface on the electrode, taking care to align the electrode contacts through the interface slots. 3) Peel the white liner located on the bottom side of the interface, to expose the second layer of adhesive. 4) Attach the electrode to the desired muscle site on the skin surface. Discard after using.

Starting the Myomonitor Main Unit

Start the Myomonitor by pressing the ON/OFF button on the bottom panel of the Main Unit. The first time you use the device, you will have to start the applicable program from the desktop of the system by double-clicking with the stylus. The next time the device is used, it will automatically launch the program last used.

For details regarding software operation, see the Software section below.

Myomonitor Hardware Features

Connecting to a PC computer

Consult the Release Notes that came with the system for Microsoft ActiveSync installation instructions prior to attempting to connect the Myomonitor to the PC.

To connect the Myomonitor to a PC computer, first connect the Docking Module to the Main Unit.

Using the USB cable provided with the system, connect the Docking module to a free USB port on the host computer.

Power and Reset

To activate the Myomonitor, press the On/Off button. This will bring the device from the Suspended state to the active state. Press the On/Off button again to suspend the device. Power to the memory is still maintained in the suspended state so that user settings are preserved.

To reset the device, push the reset button on the bottom panel of the Main Unit using the stylus. This will reset the device, clearing the memory on the device.

To bring the device back to the factory state, you should perform a cold reset. From the active mode, press the On/Off button. With the On/Off button depressed, push the reset button with the stylus. A succesful cold reset is indicated by the initiation of the touch screen calibration. Follow the instructions on the screen to complete the calibration.

Trigger Connector

The trigger connector on the bottom panel of the Main Unit allows the user to input and output triggering signals to manage and synchronize data collection. The four trigger signals are:

Start In – Initiates data collection on a +5V rising edge

Stop In – Ends data collection on a +5V rising edge

Start Out – Outputs a +5V rising edge once data collection is initiated

Stop Out – Outputs a +5V rising edge once data collection is stopped

The pinout diagram of the trigger connector is shown in the table below.

Pin	Signal
1	Stop In
2	GND
3	Stop Out
4	Start Out
5	+5V
6	Start In

Battery

The Main Unit has an internal Li-Ion battery and an internal battery charger. To maintain the charge of the battery, the Main Unit should be connected to external power when not in use.

CAUTION: Never use any battery other than the one supplied with the system. Connecting anything other than the specified battery constitutes an invalidation of the Delsys Warranty and may result in personal injury and/or permanent damage to the system.

Replacing the Battery

To replace the battery:

1. Press the On/Off button to turn off the device. It is important that the device is in suspend mode while replacing the battery to preserve what is stored in memory.
2. Place the Unit upside down, taking care not to scratch the display.
3. Remove the Phillips screws (cross slot) and remove the battery panel (see Figure 13).
4. Remove the old battery and replace with the new battery. Note, this should be done as quickly as possible to preserve the memory. The orientation of the battery does not matter as long as the battery's contacts mate with the Main Unit's contacts.

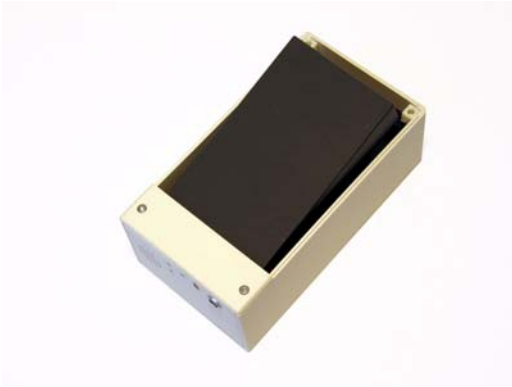


Figure 13. Open the battery compartment at the back of the Myomonitor to replace the battery.

Myomonitor III Software

Introduction

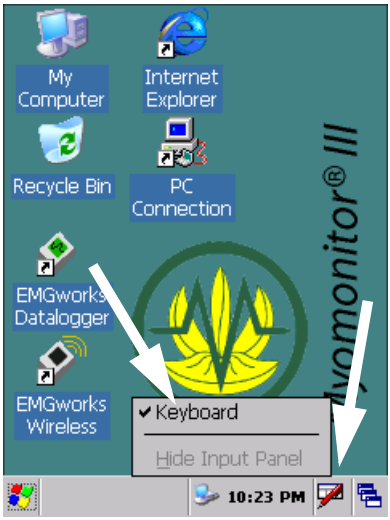
The Myomonitor III comes in two configurations, wireless transmission and onboard datalogging. “EMGworks Wireless Software” on page 32 describes the details for the wireless operation and “EMGworks Datalogger Software” on page 23 describes details regarding the datalogger operation.

Consult the Release Notes that came with the system for additional information.

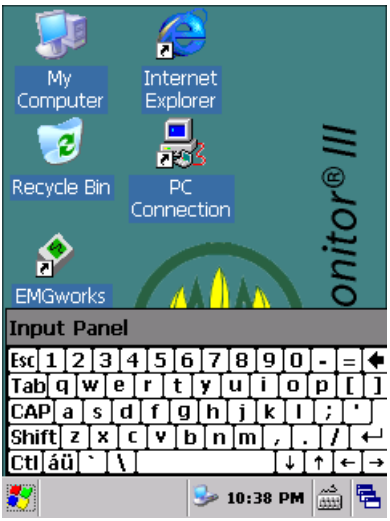
Using the stylus and the virtual keyboard

The “virtual keyboard” can be usd any time it is required to enter information.

To show the “virtual keyboard” tap the pen icon in the task bar at the bottom right of the screen:



Tap “Keyboard” in the pop-up menu:



Text can now be entered by tapping the different characters individually.

To hide the virtual keyboard, tap the “Keyboard” icon in the taskbar and tap “Hide Input Panel”.

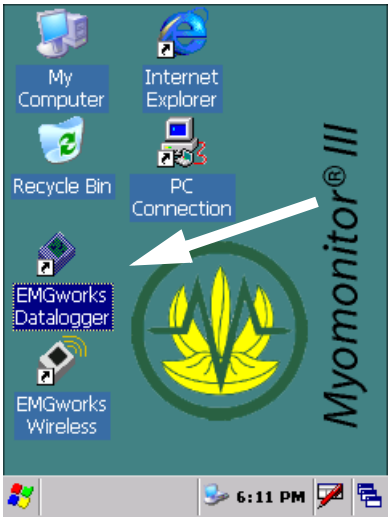
EMGworks Datalogger Software

The EMGworks Datalogger software is used to control the data acquisition process. Two versions are available, one for 8 channels and one for 16 channels of EMG data. The data is stored on board and can later be downloaded to a host computer for analysis. The EMGworks Datalogger software is also equipped with signal acquisition protocols that can be defined by the user. Protocols permit the automatic acquisition of multiple data sets without user intervention.

Before proceeding in the document, make sure that Microsoft AcitveSync has been properly installed. Refer to the Release Notes for ActiveSync installation instructions.

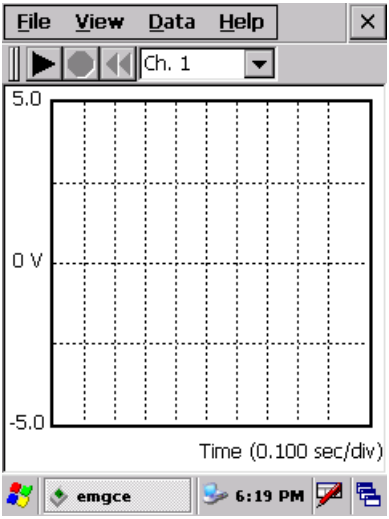
Starting the Myomonitor Datalogger Software

Double tap the EMGworks Datalogger icon on the Myomonitor desktop display to start the software.



EMGworks Datalogger Program Layout

When the EMGworks Datalogger software is opened, a new data acquisition session will automatically open, as shown below.



File Menu

Provides options for data acquisition and protocol management.

New…Opens a new data acquisition session. If data was recorded in the previous session, the user will be prompted to save the data. The new session will inherit the properties of the previous session by default.

Open Protocol File…Allows the user to open an existing EMG protocol file (*.epf) or to create a new protocol. See "Using Data Acquisition Protocols" on page 27.

Close Protocol File…Closes an open protocol.

Save, Save As…Saves the data in the data acquisition session.

When using a data collection protocol, only the data for the current repetition can be saved. In addition, recording should be paused before attempting to save the data.

Note: It is important to save all data in the folder "\My Computer\Storage Card". The location has persistent memory, which retains the data in the event of power loss. See "Transferring Acquired EMG Data for Analysis" on page 30 for information on how to download the data from the device.

Exit Closes the EMGworks Datalogger software.

View Menu

Provides options for workspace viewing during data acquisition.

Chart/Plot Properties Allows the user to select the background colors for the display.

Voltage Allows the user to select the desired voltage range for the display (±5, ±2.5, ±1, ±0.5, ±0.2, or ±0.1 Volts). Note that this range is only for display purposes. All data is saved with a ±5 Volts range.

Time Base Allows the user to select the desired time scale for the display (5s, 2s, 1s, 500ms, 250ms). Note that this scale is only for display purposes.

Protocol Toggle menu that, when enabled, displays a protocol status window during data acquisition.

Data Menu

Provides control for data acquisition.

Start Initiates the data acquisition. This function can be accessed directly from the play (▶) recording control at the top of the session.

Stop Pauses all data acquisition including protocols. This function can be accessed directly from the stop (■) recording control at the top of the session. Data acquisition can be resumed by selecting ***Data*** **>** ***Start*** or pressing the play (▶) recording control.

Rewind Erases all data in the session. In the case of an active protocol, only the current repetition will be erased. This function can be accessed directly from the rewind (◀◀) recording control at the top of the session workspace. Data acquisition can be resumed by selecting ***Data*** **>** ***Start*** or pressing the play (▶) recording control.

Properties Opens the ***EMG Properties*** dialog box. This allows the user to specify the number of channels of EMG data to acquire and the duration of acquisition in seconds. Note that properties can only be changed before recording is initiated.

External Trigger Synchronizes start of data acquisition with an external input. After selecting ***External Trigger*****,** press play

(▶) or select ***Data*** > ***Start*** to begin data collection. The program will wait for the rising edge of a +5 volt signal on the trigger input to begin data acquisition.

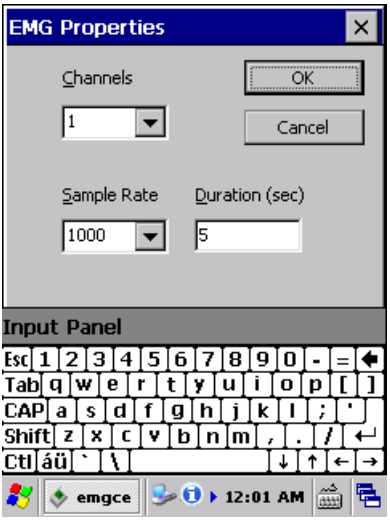
Reset Re-initializes the Data Acquisition hardware..

Recording EMG Data

There are three simple steps for recording EMG data:

1. Change the Recording Properties

   There are two properties that must be set for an EMG data recording. These properties can only be set before the recording is initiated. If they are not set, the properties that were specified for the previous recording will be used by default. Select ***Data*** > ***Properties*** to display the ***EMG Properties*** dialog box, as shown below.



   From the dropdown list, select number of ***Channels*** to record, the ***Sample Rate*** and type the desired ***Duration*** in seconds for the recording. Tap ***OK*** to continue

2. Initiate Data Acquisition

   Press the play (▶) recording control at the top of the screen or select ***Data*** > ***Start*** to initiate data acquisition. Acquisition will automatically stop when the end of the specified duration is reached. The other recording controls described in the Data Menu section on the previous page can also be used to control data acquisition.

3. Save the EMG Data

   EMG data must be saved after it is recorded. Select ***File > Save As…***, choose the file location, and type in the desired file name to save the data from the data acquisition workspace.

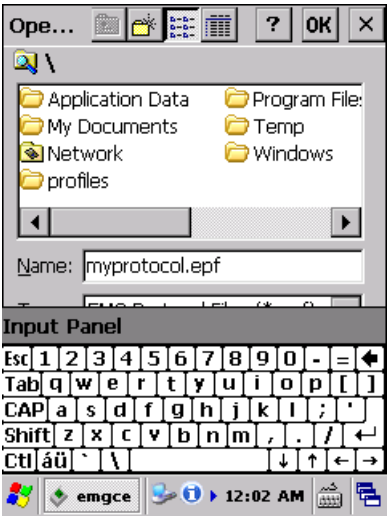
Using Data Acquisition Protocols

EMG data can be recorded with the Myomonitor III using structured data collection protocols. These protocols consist of a number of "protocol sets" each consisting of a number of repetitions with the same duration and the same rest time.

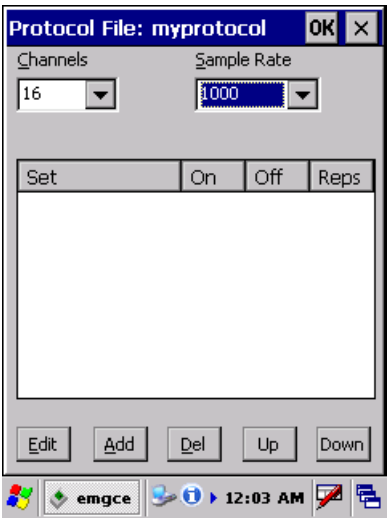
Creating a New Protocol

1. Select ***File > Open Protocol File…***

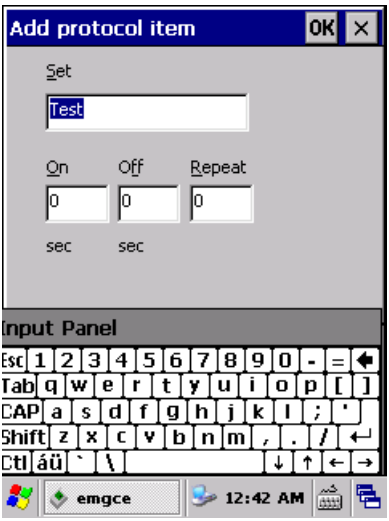
   The ***Open Protocol*** dialog box will open.:



2. Using the Virtual Keyboard, type a unique protocol name in the ***Name*** field and tap "OK".



3. Select the number of ***Channels*** to record and the ***Sample Rate*.**
4. Tap ***Add*** to add a new protocol set. The ***Add Protocol Item*** dialog box will open, as shown below:



5. Enter the set parameters:

   Type a unique protocol ***Set*** name.

   Type the duration for each repetition in the ***On*** field.

   Type the duration for each rest period in the ***Off*** field.

Type the number of repetitions in the ***Repeat*** field.

6. Tap ***OK*** when done; this will revert to the protocol dialog.
7. Repeat steps 4-7 to add additional protocol sets.

- Edit a protocol set by selecting it and tapping ***Edit***.
- Delete a protocol set by selecting it and tapping ***Del***.
- Move a set in the protocol order by selecting it and tapping ***Up*** or ***Down***.

8. To exit the protocol setup and specify where the acquired data files should be stored, tap "OK". This opens the Data Directory dialog. Select a directory. The data from the protocol recording will be saved in the specified directory. Each repetition will be saved as a separate file with its protocol set name and repetition number. A copy of the protocol will also be saved in the directory.

Opening an Existing Protocol

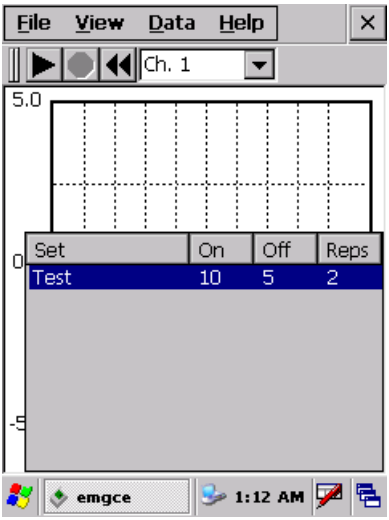
1. Select ***File > Open Protocol File...***
2. The ***Open Protocol*** dialog box will open.
3. Find and select an existing EMG protocol file (*.epf).
4. Tap ***OK***.
5. The ***Protocol File*** dialog box will open.
6. If desired, edit the protocol using the instructions from "Creating a New Protocol" on page 27.
7. When the protocol is complete, tap ***OK***.
8. The ***Data Directory*** dialog box will open.
9. Select a location and type a unique folder ***Name***. The data from the protocol recording will be saved in this specified folder. Each repetition will be saved as a separate file with its protocol set name and repetition number. A copy of the protocol will also be saved in the directory.
10. Tap ***OK.***

Recording EMG Data with a Protocol

Once a data acquisition protocol has been created or opened, it is possible to begin collecting data.

Press the play (▶) recording control at the top of the workspace or select ***Data > Start*** to initiate data acquisition.

If ***View > Protocol*** is checked, the protocol status window will be displayed in the lower right hand corner of the screen and the current protocol set will be highlighted in blue, as shown below:



In addition, the Myomonitor III will provide audible cues to indicate the protocol status. It will produce a tone at the end of the recording for each repetition. It will also count down the last five seconds of each rest period with audible ticks.

The recording controls described in "Data Menu" on page 25 can be used to control data acquisition for each repetition of the protocol.

The repetitions will automatically be saved as they are completed. It is also possible to save the current repetition when recording is paused by selecting ***File > Save As…***

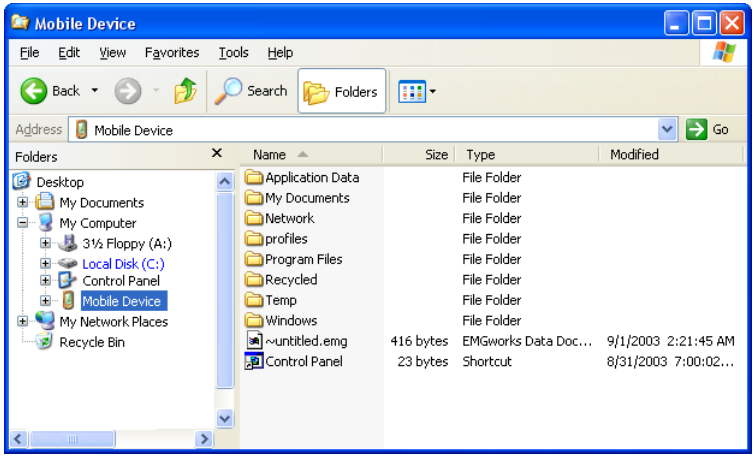
Acquisition will be automatically stopped when the end of the protocol is reached.

Transferring Acquired EMG Data for Analysis

Follow the instructions under "Connecting to a PC computer" on page 17 to prepare the Myomonitor for file transfer. The Myomonitor automatically connects when the cable is inserted and Microsoft ActiveSync is installed.

The Myomonitor III is accessible directly from Windows Explorer. Open a new Windows Explorer window and tap

"Mobile Device" in the left hand pane to browse the Myomonitor.



The saved files can then be copied or moved from the Myomonitor III to the host computer. Once the data files are transferred to the PC they can be analyzed using EMGworks Analysis software.

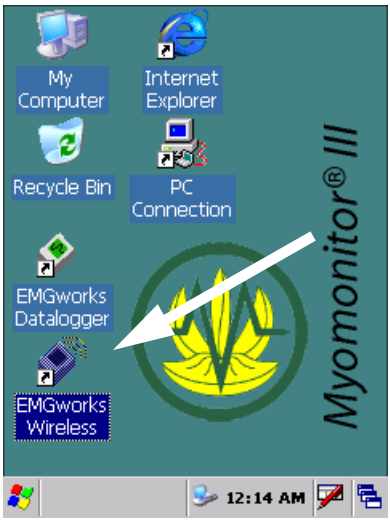
EMGworks Wireless Software

This section describes how to use the Myomonitor III as a wireless real time EMG data acquisition system. The EMGworks Wireless client application on the Myomonitor interfaces directly to EMGworks Acquisition on the host PC enabling the Myomonitor III device to exchange information with the host computer.

Before proceeding, make sure that a wireless connection between the Myomonitor III and the host computer has been setup and established. Refer to the Release Notes for wireless network installation instructions.

Starting the EMGworks Wireless application

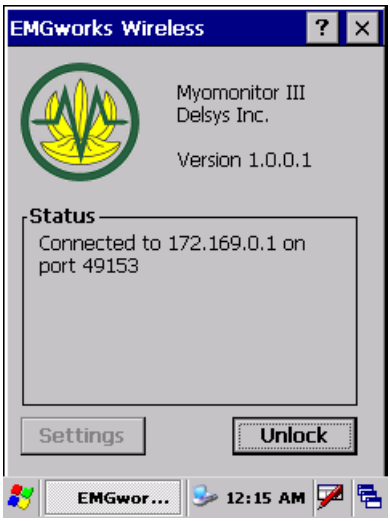
To start the wireless application, double tap the "EMGworks Wireless" icon on the desktop.



Double tapping the icon opens the EMGworks Wireless main screen:

EMGworks Wireless will instantly attempt to connect to the default host computer on the Myomonitor network. If EMGworks Acquisition is running on the host computer and the network has been setup using the default parameters, the Myomonitor III should instantly connect.

Please refer to the Release Notes if a connection can not be established.



The Myomonitor III is now ready and connected to EMGworks Acquisition. The data acquisition is controlled by EMGworks

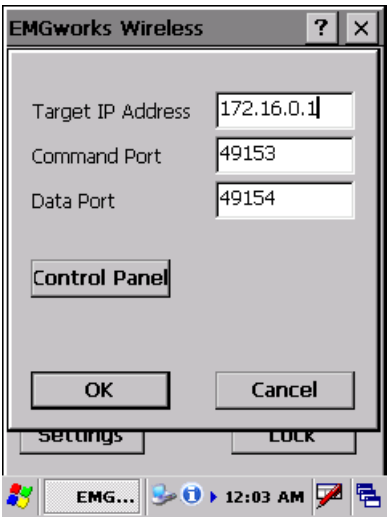
Acquisition on the host computer. Refer to the EMGworks manual for details.

Setting up Myomonitor III manually

The Myomonitor III is configured to connect to the server application at IP address 179.16.0.1. To meet specific end user networking requirements, there may be reasons for changing the network settings. Under those circumstances, the address of the host computer must be set manually.

Chaging the Myomonitor settings manually is not a standard procedure and is not recommended.

To access Myomonitor's manual settings, tap "Unlock" once to enable the "Settings" button and then tap "Settings". This opens Myomonitor's network setup dialog:



- Target IP Address

  Specifices the IP address of the host computer
- Command Port

  Do not change.
- Data Port

  Do not change.
- Control Panel

  Tapping "Control Panel" brings up Windows' control panel.

Troubleshooting EMG Recordings

Problem: Excessive Presence of Line Interference

Power line interference from surrounding sources is always an issue to contend with when recording body potentials on the surface of the skin. This interference is due to the presence of a 60 Hz (or 50 Hz) displacement current flowing on the skin surface due to the capacitance between the body and ground and between the body and surrounding power sources (refer to Figure 14). People are exposed to this surface current on a continual basis, as it is present anytime a body is near an AC power source. This current cannot be sensed or felt, and poses no risk to the body it is flowing on.

The surface potentials resulting from this displacement current on the skin can be orders of magnitude larger than the EMG potentials being detected by the electrodes. If the EMG system is working correctly, however, the detected amplitude of these interfering potentials are negligible when compared to the detected EMG potentials. Recall that the output of the EMG electrode is a subtraction of the potentials detected at the electrode contacts. The interfering potentials are large signals and change very little as they propagate across the space of the electrode contacts. The EMG potentials, on the contrary, change drastically as they propagate between the electrode bars. Ideally, the result is a differential EMG signal with a complete subtraction of the line interference (refer to Figure 14 (b)).

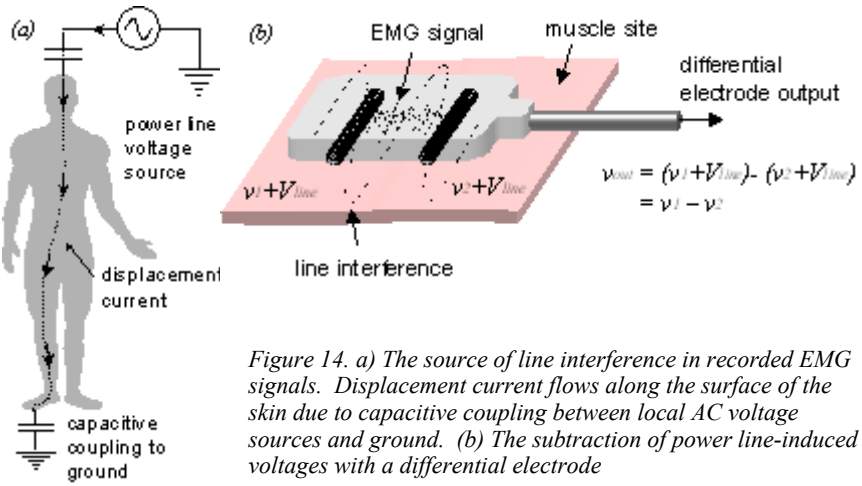


Figure 14. a) The source of line interference in recorded EMG signals. Displacement current flows along the surface of the skin due to capacitive coupling between local AC voltage sources and ground. (b) The subtraction of power line-induced voltages with a differential electrode

Line interference becomes overwhelmingly apparent if either of the following conditions arises: (a) the electrode does not subtract signals in an ideal fashion, (b) the quality of one or more electrode-skin contacts becomes compromised. The interference will appear as a high amplitude cyclic signal with a frequency of 60 Hz (for North American AC sources) or 50 Hz (for European, Australian and other international AC sources).

The first condition is intrinsic to the construction of the electrode preamplifier. The parameter used to gauge the electrode's ability to subtract signals ideally is called the common-mode rejection ratio (CMRR) and is measured in decibels. Most surface bio-potential applications require a minimum CMRR of 80 dB. An electrode capable of subtracting signals perfectly would have an infinite CMRR.

The second condition is within the user's control, and is attributable to most instances of excessive line interference. It is crucial that the reference electrode and all the silver bars of the EMG electrodes make a high quality electrical connection with the surface of the skin. Failure to establish a high quality connection will drastically increase the probability of observing line interference. The following checklist should help in eliminating potential problem areas.

1. ***Turn "off" surrounding power sources***. While it is generally not feasible to completely cut all the power in the ambient experimental area, all electronic equipment not in use should be turned off. The more AC power sources in the experimental area there are, the higher the probability of line interference. Pay careful attention to high current devices which radiate strong magnetic and electric fields such as motors, transformers, lights and equipment power supplies. If a portable computer is being used, it is advisable to disconnect the power supply (as these tend to be quite noisy) and run the machine from battery power for the data acquisition portion of the experiment.
2. ***Check electrode-skin contact.*** Ensure that all the electrodes are aggressively attached to the skin. The electrodes should not be easily dislodged when pulled by the connecting cables. Any portions of the electrode contacts not firmly pressed against the skin will result in line interference. The use of the Delsys Electrode Interfaces is recommended for this purpose. Refer to the section on "Poor Electrode-Skin Adhesion" if this is a problem.

3. ***Clean the skin.*** Ensure that the skin under all the electrodes is clean and free from hair. The area should be wiped with isopropyl alcohol swabs before the electrodes are applied. If necessary, hair can be removed with a safety razor or with commercially available hair removing lotions such as "Neet" or "Nair".
4. ***Allow the electrode to settle.*** When first applied to the skin, the electrode may display high levels of noise and interference. Allow the electrode to settle for a few minutes, giving time for the ionic currents between the electrode and the skin to become established. Wetting the electrode bars with water will expedite this process.
5. ***Use surfactants.*** On particularly dry skin, it may be necessary to wet the EMG electrode contacts with water or to line them with electrode gel so as to promote the necessary ionic flow. For this purpose, it is recommended to use medical grade conductive gel, similar to those used for EKG and TENS applications. A very small amount should be applied to the electrode bars prior to attaching them to the skin. Cotton swabs can be used to spread a very thin layer on the silver bars. Take care not to smudge the gel on the skin when the electrodes are placed. Any connection between the electrode bars through the conductive gel will short circuit the input of the EMG electrodes and result in erroneous readings. Ionic soap is also an excellent surfactant of this purpose. As with the gels, it should be used in extremely small quantities.
6. ***Check the Reference Electrode.*** It is crucial to have a well-established reference electrode contact. It may be necessary to use large reference electrodes to ensure a high quality connection. Various samples of reference electrodes are provided with the system. Test them to determine which is best for your application.
7. ***Uncoil cables.*** Any cable carrying EMG signals (electrode cables, input module cables, A/D cables) should be uncoiled and allowed to drape freely. Cables that are arranged in coils act like antennae, promoting the induction of line interference.

Note that it is extremely difficult to eliminate all presence of line interference. In most situations a residual amount will always be present due to the finite electrode CMRR and the imperfect electrical connections between the skin and the electrode contacts. However, with proper use of the EMG System, this

residual amount should be insignificant and in most cases not detectable when compared to the amplitude of the EMG signal.

Problem: Poor Electrode-Skin Adhesion

For best results, it is recommended to use the Delsys Interfaces to attach the DE-series EMG electrodes to the skin. Alternatively, surgical tape may be used. If the electrodes persistently fail to adhere to the skin, the following points should be addressed:

1. ***Clean and dry the skin.*** It is imperative that the skin be thoroughly cleaned before applying any type of adhesive. Allow the skin to completely dry after cleaning. Adhesive will not stick to wet or oily skin. Be sure to remove all hairs under the observation sites. This can be easily done with a safety razor or with commercially available hair removing lotions and waxes.
2. ***Remove dry skin cells.*** The human body is constantly generating skin tissue. New skin cells originate on the inner layer of the skin and grow outward towards the surface, progressing through several distinct layers and levels of activity. By the time the cells reach the skin surface, they become inactive on a cellular level and are generally considered to be dead. The body is constantly shedding this outermost cell layer, as it is replaced by the new cells from underneath. Since these inactive cells are easily dislodged from the skin, adhesives tend not to function properly when placed in contact with them. To avoid this problem, it is useful to remove the outermost layer of skin cells. This can be easily done by lining the skin with strips of surgical tape. When the tape is removed, most of these dry cells will be dislodged. This process can be repeated until satisfactory electrode adhesion is achieved.
3. ***Check the shelf life of the interfaces or the tape.*** The Delsys Electrode Interfaces have a shelf life of 24 months. If the interfaces are not used within this period, the medical grade skin adhesive may begin to dry and deteriorate. The date of manufacturing can be found on the front of the package. Ensure that the time limit has not expired. Keep in mind that other adhesives such as surgical tape have similar time limitations on their shelf life.
4. ***Use elastic bandages.*** If difficulty in attaching the electrodes persists after addressing the above points, then one remaining

alternative is to wrap the electrodes to the body with elastic bandages. Commercially available athletic wraps and bandages are suitable for this purpose if, obviously, the recording sites allow their use. Note that this method of electrode attachment is highly discouraged and should only be used as a last resort.

Problem: Excessive Presence of Motion Artifact

Motion Artifact is characterized by large amplitude, low frequency spikes which may saturate the sensitive EMG amplifiers. This type of electrical interference is usually associated with jarring motions, excessive stretching of the skin under the electrode sites and other forms of mechanical vibrations which cause movement of the electrode with respect to the skin. It is caused by a temporary fluctuation in the DC skin potential. While, the Delsys EMG systems and electrodes are specifically designed to be insensitive to fluctuations in DC skin potentials, complete immunity to motion artifact is impossible. The following points should be addressed when excessive motion artifact is present:

1. ***Strong electrode-skin adhesion.*** Ensure that the electrodes are robustly attached to the skin. It is crucial that there not be any electrode movement with respect to the skin at the recording site. Delsys Electrode Interfaces are specifically designed for this purpose. See the Troubleshooting section on "Poor Electrode-Skin Adhesion" if this is problem.
2. ***Provide sufficient cable slack.*** It is important that the electrode never be tugged by its cable. Some movements throughout an experiment may result in electrode cable tension. Take care to provide the necessary relief from cable-tension so that the electrode is not disturbed in any way.
3. ***Minimize jarring motions.*** Some types of activities (such as jogging) may cause vibration of the tissue located at the recording site. If possible, keep these activities to a minimum or modify them so as to reduce tissue vibration.
4. ***Keep clothes clear.*** If electrodes are being used underneath loose clothing, ensure that body movements do not cause the clothes to disturb the electrodes or the skin in their vicinity. Note also that many fabrics can build high electrostatic charges, which may pose operational problems for the electrodes.
5. ***Ensure high quality electrical contacts.*** In extreme cases it may be necessary to wet the electrode bars or use conductive

gel to enhance the stability of the electrode-skin electrical connection. See the Troubleshooting section on “Excessive Presence of Line Interference” for methods to ensure a high quality electrode-skin contact.

Specifications

Myomonitor III Main Unit System

General	
Typical Operating Range	35 m (closed office) 270m (open space) unlimited (Datalogger)
Data Capacity	host PC dependent (Wireless) 512 MB standard (Datalogger)
Medical Device Conformity	IEC 601
Classification	Class 1 (93/42/EEC), Type BF
Dimension	165 x 91 x 61 mm (6.6 x 3.6 x 2.5 “)
Mass	900g (2 lbs.)
Enclosure Material	ABS
Temperature Range	0-40° C

Electrical	
Signal Resolution	16 bits
Signal Input Range	±5 V
Sampling Rate	1024 Hz/ channel (minimum)
Number of Channels	8 or 16
Screen Size	240 x 320 pixels
Battery Requirements	7.2V, 4.2Ah, Li-Ion
Battery Duration per charge	6 hours (wireless) 8 hours (datalogger)

DE-2.3 EMG electrodes

General	
Number of Contacts	2
Contact Dimension	10 x 1 mm.
Contact Material	99.9% Ag
Case Dimension	41x20x5 mm
Cable Length	1.5 m.
Connector	LEMO 4 pin male
Case Material	Polycarbonate plastic

Electrical	
Gain	1000 (±1%)
Bandwidth	20±5 Hz to 450±50 Hz, 12 dB/oct
Overall Channel Noise	<1.2uV (RMS, RTI)
CMRR	>80 dB

Input Module

General	
Number of Sensor Input	8
Sensor Input Connector	LEMO 4 pin female
Case Dimension	81 x 46 x 23 mm (3.2 x 1.8 x 0.9")
Mass	85 g.(3 oz.)

Input Module Cable

General	
Connector	Honda 14-pin male.
Length	2.5 ft.

Reference Electrode Cable

General	
Connector	“Banana” plug to “Alligator Clip” or “Tip” plug
Conductor	Single
Length	1.67m 5 ft

Glossary of Commonly Used Terms

A/D System: "Analog to Digital" System. These devices are commonly used in conjunction with computers for translating continuous (i.e. analog) voltage signals into binary (i.e. digital) data. Once in digital format, the data can be viewed, manipulated and stored on digital media devices such as disk drives and CD ROMs.

Aliasing: A condition arising when digitally sampling a signal at a frequency less than twice the highest frequency content of the signal. Aliasing inhibits the faithful reconstruction of a digitally sampled signal. It can be avoided by ensuring that the Nyquist Criterion is not violated, which forces the representation of any frequency component in the signal with at least two samples.

BNC: "Bayonet-locking coupling" is a standard connector configuration providing quick connect and disconnect coaxial connections between instruments. The conducting cable is completely surrounded by a flexible shield, and insulated with specially designed dielectric materials. BNC cables are commonly designed with a 50 ohm impedance.

Channel Crosstalk: In the context of this manual, this term is used to describe the electrical interference present in a particular channel as a result of the electrical signals present in other channels. This situation may arise in physically adjacent channels, and becomes more noticeable as the signal amplitude increases. This problem may be resolved by lowering the channel gains. Channels on A/D cards with unconnected (floating) inputs will typically experience channel crosstalk or "phantom" electrical signals caused by signals in other channels. This problem can be resolved by terminating all unused A/D channels to the A/D ground potential. A/D saturation may also cause channel crosstalk talk due to long recovery times of the internal A/D amplifiers. In this case, it is necessary to ensure that the amplitude of the signals input to the A/D card is never in excess of the A/D card's rated specifications.

EMG Signal Crosstalk: This term is specific to the EMG signals being recorded at the electrode site. The EMG signal detected at the skin surface is a composition of hundreds of action potentials. These action potentials can come from muscle fiber located directly below the electrode detection surface, as well as muscle fibers located adjacent to and farther away from the

electrode detection surface. When the electrode detects EMG signals not only from a muscle directly beneath it, but also from surrounding muscles which may not necessary be of interest, then crosstalk from adjacent muscles is said to be present. Note that single differential electrodes have limited capacities for minimizing EMG signal crosstalk. Double differential electrodes significantly reduce this type of crosstalk as EMG signals originating from distance sources are cancelled, while those with more immediate sources remain.

D-Subminiature (D-Sub) Connectors: Multiple-contact assemblies commonly used for connecting multi-conductor cable between equipment. These connectors are in the shape of a "D", and come with standard 0.100" inter-contact spacing as well as high-density versions with 0.050" inter-contact spacing.

Floating Signal: This term refers to the indeterminate voltage state of a terminal when it remains unconnected. If the signal terminal is not connected to any established potential (for example the Reference Potential), then it is said to be "floating". A floating signal at the input of recording devices is typically characterized by a wandering baseline voltage and may contain an inconsistent presence of line interference. Output signals of the Bagnoli EMG System will float if either the EMG Electrode or the Reference Electrode is not properly connected.

Ground Potential: This the electric potential sometimes referred to as "Earth" and is connected to the metal chassis of many electrical instruments. It can act as a current sink for any line potentials which may come in contact with the chassis of instruments. Note that the Ground Potential is different than the Reference Potential. The BNC outputs and the output connector on the rear panel of the Bagnoli EMG System are typically connected to the Ground Potential when recording instruments are used. The Reference Potential used in the differential EMG recordings is separated from the Ground Potential via channel-independent isolation transformers.

LED: "Light Emitting Diode". This is a semiconductor device which illuminates when current is allowed to flow through it. The Bagnoli EMG system contains LEDs which appropriately illuminate when either a "line error" or a "hi error" is detected in any one of the channels.

Line Interference: The contamination of electrical signals by the superposition of cyclic noise induced by surrounding AC power lines and sources. In North America line interference has

a fundamental frequency of 60 Hz, while in most European and other international countries the line interference has a fundamental frequency of 50 Hz. It is extremely difficult to completely remove the presence of line interference in noisy environments. In most cases, the optimum scenario is to keep line interference to unobservably low amplitudes when compared to the EMG signal amplitude.

Motion Artifact: A transient disturbance in the detected EMG signal caused by the movement of the electrode with respect to the skin surface. Motion artifacts are undesirable and can be minimized by attaching the electrode to the skin with aggressive adhesive, by providing sufficient cable slack and by avoiding jarring motions and disturbances. Other types of transient disturbances include stimulus artifacts (caused by the applied voltage to a skin area for the purposes of eliciting a biological response) or electrostatic artifacts (caused by static discharges detected in the vicinity of the electrode).

Reference Potential: An arbitrary voltage potential on the surface of the body used in establishing differential potential recordings. All voltages measured by the surface electrodes and propagated throughout the Bagnoli EMG System have significance only when measured with respect to a well-defined Reference Potential. Note that the reference potential is not the same as, and is completely isolated from the Ground Potential.

Sampling Frequency: This is an important parameter characterizing A/D systems. It is defined by the number of digital samples taken of an analog signal per second. According to the Nyquist criterion, it is crucial that the sampling frequency (expressed in Hertz) be at least twice the highest frequency component of the signal being sampled, in order to correctly capture all the information in the signal, and to avoid aliasing. The Bagnoli EMG Systems has a maximum bandwidth of 15 Hz to 500 Hz. It is thus imperative that the sampling frequency be at least 1000 Hz.

Signal Clipping: The non-linear distortion of a signal due to excessive channel amplification for the given input signal. Signal clipping on the Bagnoli EMG System is indicated by the "HI" LED warning light, and can be observed when the output signals appear to be truncated at ± 5 Volts. This phenomenon is almost always caused by amplifier saturation present either in the EMG System or the AD System. The only solution is to

reduce the channel gain so that the output signals are within the ± 5 Volt specification.

Signal-to-Noise Ratio: This is a mathematical technique used to express the energy of the EMG signal compared to the energy of the noise present. The SNR is defined as Vemg/Vnoise (expressed as a unitless number) or 20 log[Vemg/Vnoise] (expressed in dB). Obviously, the higher the SNR, the better the quality of the recorded EMG signal.

Surfactant: This class of substances are also called surface active agents or wetting agents, and are used to reduce the surface tension of some types of cleaning solutions. Their presence in certain types of soaps can be used to facilitate ion transfer across the skin to the EMG electrode contacts.