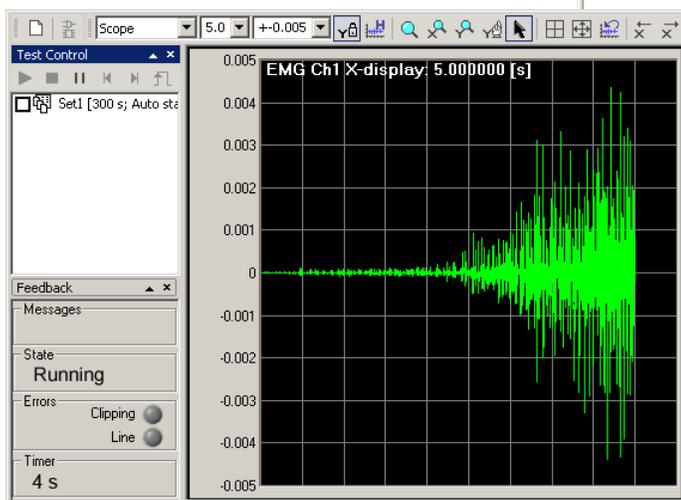
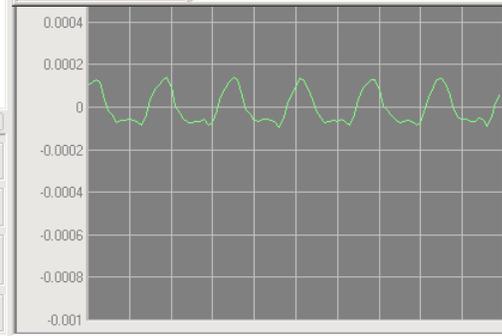
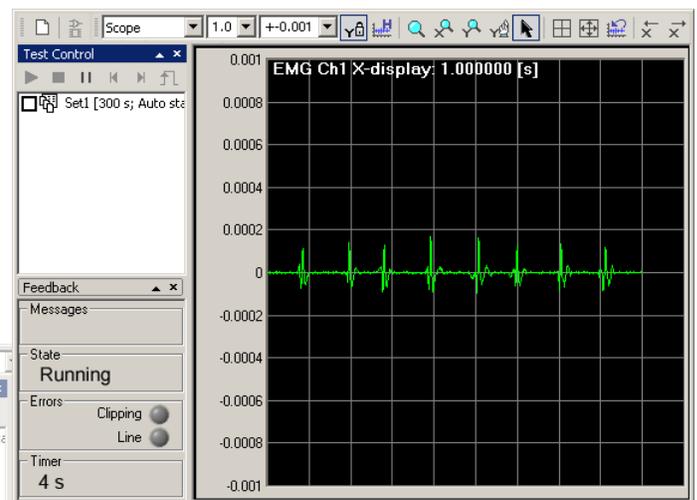


Purpose

This technical note addresses factors that must be considered in verifying that quality EMG data is being acquired. It assumes that the EMG sensor has already been located properly. Please see **Technical Note 101: EMG Sensor Placement** for more details.

Hardware Concepts

- Baseline Noise
- Line Interference
- Clipping
- Amplifier Gain



Software Concepts

- Error Indicators
- Domain
- Range

Introduction

This document is one of a series of technical notes designed to address important concepts dealing with Delsys® hardware and software. The goal of this technical note is to address a number of practical issues dealing with the acquisition of quality EMG data. It focuses on the use of EMGworks Data Acquisition software and real-time evaluation of data.

Determining the Noise Baseline of the EMG Signal

The first step in examining the quality of the EMG signal is to establish the noise baseline of the system. This is done with a Bagnoli system by turning the knob for the channel being studied to the **0** position as portrayed in the diagram to the right. With the Myomonitor, this is done by shorting the two EMG sensor bars with the Reference Electrode. When data acquisition is initiated in EMGworks with the default domain and range, the recorded signal should appear as a flat line as shown in *Figure 1A*. The default domain in EMGworks is 5 seconds, meaning that 5 seconds of data are shown in the plot area at a time. The default range is +/- 0.005 V, which corresponds to +/- 5 mV. These scales are typically optimal for viewing gross EMG activity, but they are not appropriate for detecting noise or for studying the details of the EMG signal. It is necessary to zoom in on the plot or to change the domain and range in order to view the noise baseline in detail as shown *Figure 1B*.

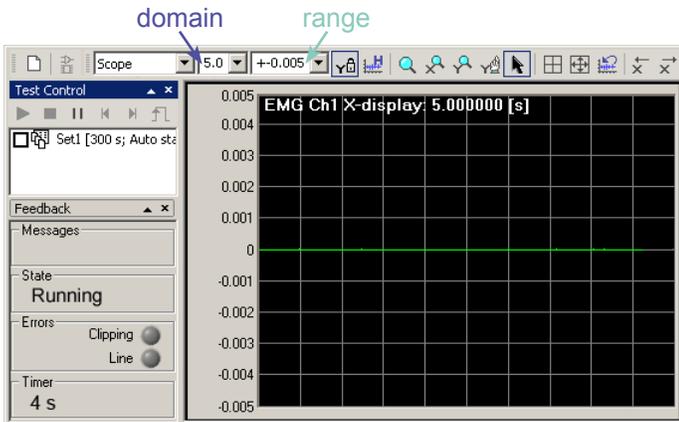
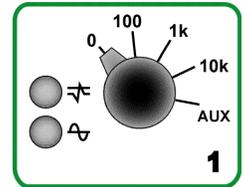


Figure 1A: Noise baseline of EMG system with EMGworks default scale: domain = 5 s, range = +/- 5 mV.

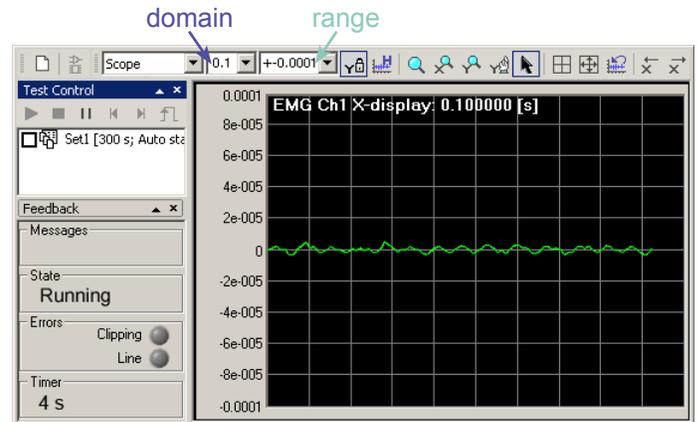
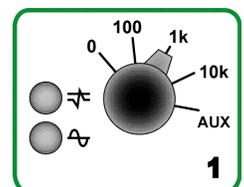


Figure 1B: Noise baseline of EMG system with appropriate scale: domain = 0.1 s, range = +/- 0.1 mV.

Delsys EMG systems exhibit a 5 to 10 μV peak-to-peak noise baseline. If the noise baseline is significantly greater in amplitude than this, make sure that the data acquisition device is properly installed and that all cables connecting the EMG system to the data acquisition device are properly connected. Once the EMG system gain is set and the EMG sensor and Reference Electrode are affixed to the skin, the noise baseline for the system increases as much as 5 μV , depending on the impedance characteristics of the skin. This low baseline is observable only when the skin has been carefully prepared, the sensor is attached with an adhesive interface, and the muscle is completely relaxed.

Choosing an Appropriate System Gain

The majority of EMG acquisition should be performed with the EMG system gain set to **1k**. Acquisition should only be started with smaller or larger gains in special circumstances. It is typically more appropriate to start with a gain of 1k and to adjust if necessary. Make sure that the **Gain** parameter is set properly in the Test Configuration being used in EMGworks so that the signal is scaled properly. See the **EMGworks User's Guide** for more information.



Ensuring Minimal Line Interference

Any EMG system is susceptible to ambient noise that originates from electromagnetic sources in the recording environment. The most important component of ambient noise is line interference. This refers to noise that originates from power line sources (power supplies, electrical wire, light bulbs, fluorescent lamps, etc.) that is undesirably recorded with the EMG signal. In North America, line interference appears as a cyclic signal with a fundamental frequency of 60 Hz. In Europe and other international countries, this cyclic signal has a fundamental frequency of 50 Hz

In order to minimize line interference, the EMG system and the subject should be isolated as much as possible from power line sources. That being said, it is impossible to completely avoid exposure to electromagnetic radiation, and, in fact, the magnitude of noise from these sources on the patient's skin is often orders of magnitude greater than the EMG signal.

The differential recording technique used by Delsys EMG Sensors is critical in removing line interference and other ambient noise sources from the recorded EMG signal. An unconnected sensor or poor sensor to skin contact is, therefore, an important cause of line interference. The Reference Electrode also plays an important role in minimizing line interference. An unconnected Reference Electrode or poor electrode to skin contact will also cause line interference. Please see **Technical Note 101 - EMG Sensor Placement** for important information on skin preparation and proper sensor placement.

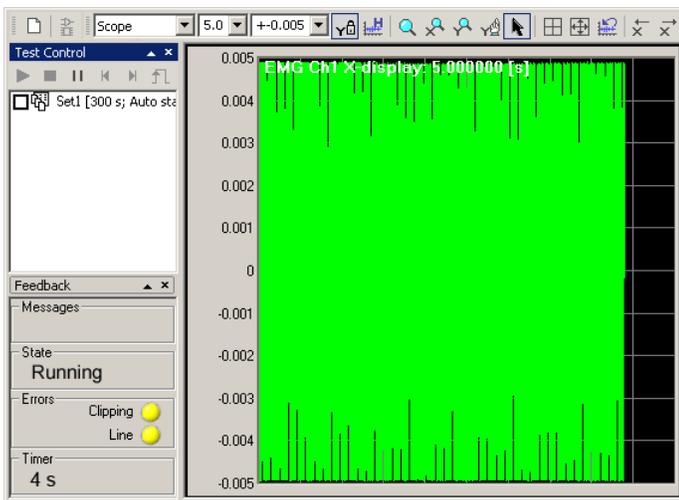


Figure 2A: Line interference due to an unconnected reference electrode. Default scale: domain = 5 s, range = +/- 5 mV.

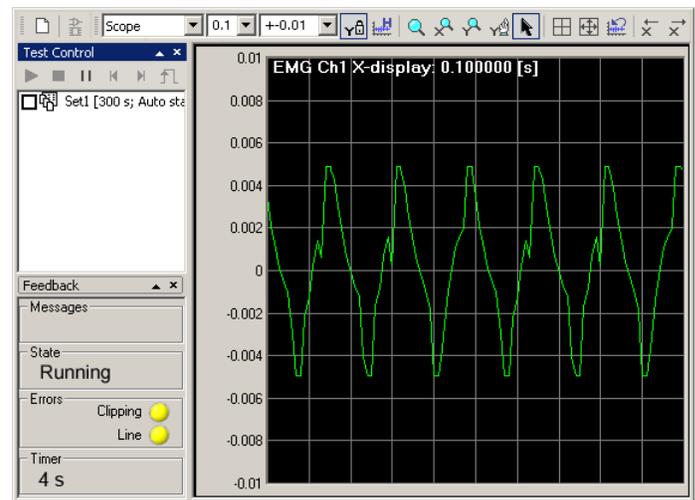
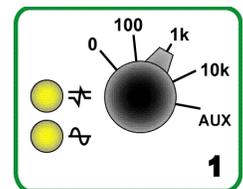


Figure 2B: Line interference due to an unconnected reference electrode. Scale: domain = 0.1 s, range = +/- 10 mV.

The screenshots above show an example of data recorded with an unconnected reference electrode. In Figure 2A with the default domain and range, there is obviously a large amplitude signal, but the source is unclear. The **Line** error indicator is illuminated, however. Upon changing the domain and range as in Figure 2B, it is clear that there is 60 Hz cyclical noise corresponding to line interference. Due to its large amplitude, the signal is also being clipped at 5 mV and the **Clipping** error indicator is illuminated.



The large amplitude line interference shown above could also be seen in the case when only one bar of the EMG sensor is in contact with the skin. It is important to monitor for line interference not only at the beginning of data acquisition but also throughout a recording. When the subject is physically active, it is possible for an EMG sensor or Reference Electrode to become partially or completely unattached.

Large amplitude line interference is difficult to overlook since it is difficult to clearly see EMG activity within this signal. Low amplitude line interference is sometimes not detected, however. The example below shows low amplitude line interference due to poor EMG sensor to skin contact. The hair was not shaved at the detection site and no skin cleaning was performed. The same signal could result from an unconnected EMG sensor or poor Reference Electrode to skin contact. In *Figure 3A*, a low amplitude signal is present, but the source is not clear. The **Line** error indicator is illuminated, however. Upon zooming as in *Figure 3B*, it is clear that there is 60 Hz cyclical noise corresponding to line interference.

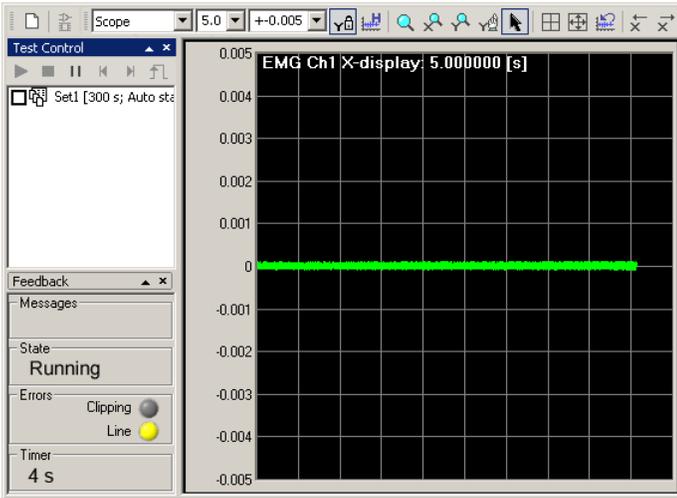


Figure 3A: Line interference due to poor EMG sensor to skin contact. Default scale: domain = 5 s, range = +/- 5 mV.

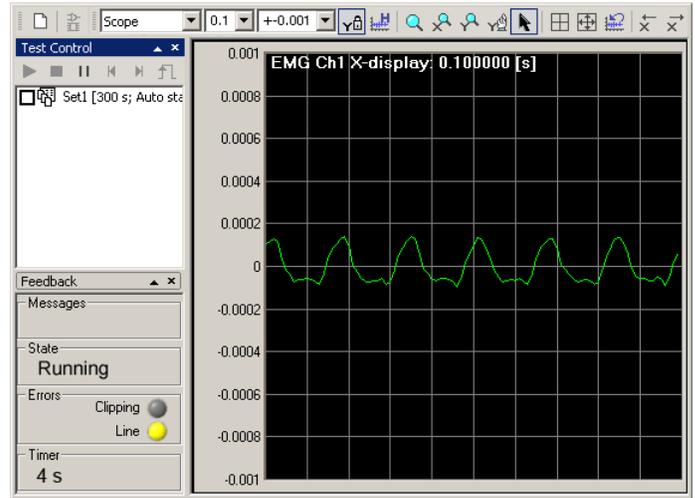


Figure 3B: Line interference due to poor EMG sensor to skin contact. Scale: domain = 0.1 s, range = +/- 1 mV.

The screenshots below show how low amplitude line interference could be overlooked. If the user is not vigilant about checking the quality of the baseline signal prior to recording contractions and is not careful to avoid line interference, this noise could be mistaken for low level EMG activity between contractions. *Figure 4A* shows contractions with low amplitude line interference due to poor skin preparation and *Figure 4B* shows contractions in a quality surface EMG recording. Always be careful to look for the **Line** error indicator in EMGworks and on the EMG system. The **Audible Buzzer Alarm** on the EMG system can be enabled as a reminder.

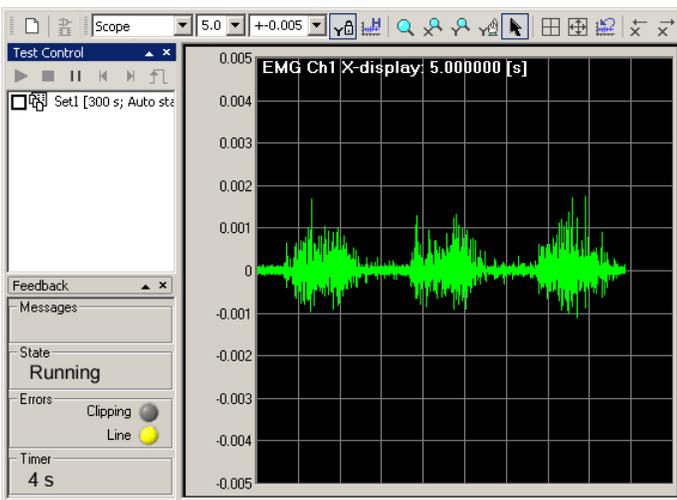
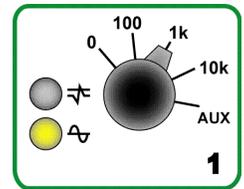


Figure 4A: EMG data with low amplitude line interference. Default scale: domain = 5 s, range = +/- 5 mV.

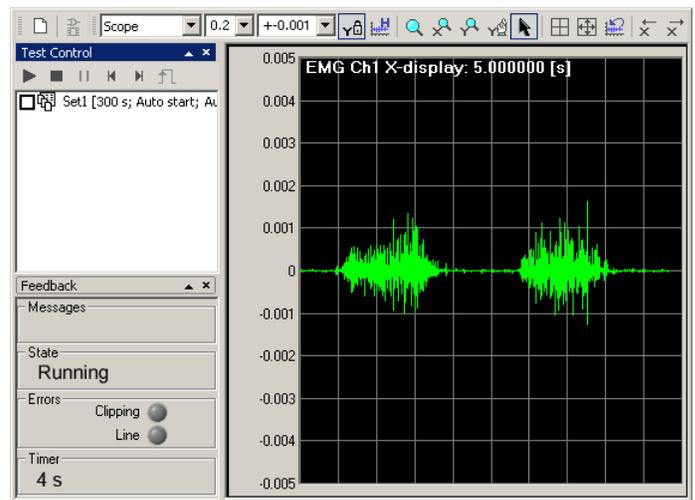


Figure 4B: Quality EMG data with no significant line interference. Default scale: domain = 5 s, range = +/- 5 mV.

Examining the Quality of the EMG Signal

Once the noise baseline of the EMG signal has been studied and it has been assured that there is no significant line interference, the quality of the EMG signal can be examined. It is important not to immediately proceed to large amplitude contractions in assessing the quality of the EMG signal. It should first be confirmed that the recording is of sufficient quality that individual motor unit action potentials (MUAPs) can be discerned (See **Technical Note 101** for more information). As soon as a few muscle fibers underneath the EMG sensor become activated, MUAPs can be recorded. *Figure 5A* shows the baseline signal with the muscle completely relaxed. *Figure 5B* shows the EMG signal with minimal muscle contraction.

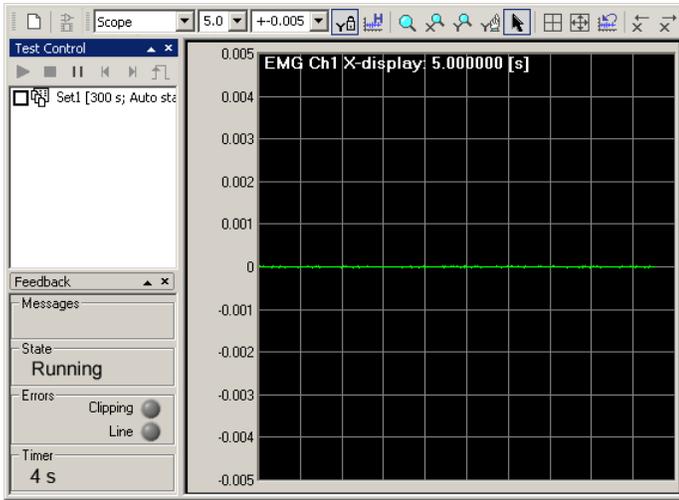


Figure 5A: Baseline signal with muscle completely relaxed. Default scale: domain = 5 s, range = +/- 5 mV.

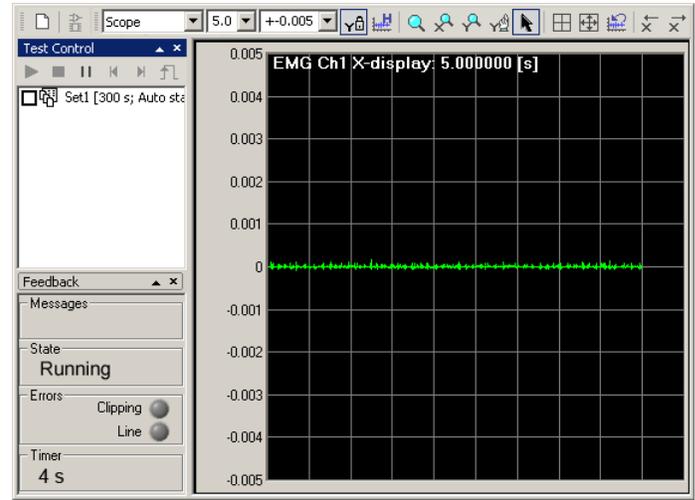


Figure 5B: EMG activity during minimal muscle contraction. Default scale: domain = 5 s, range = +/- 5 mV.

With the EMGworks default scale shown above, the low level EMG activity could be mistaken for noise or noise could just as easily be mistaken for low level EMG activity. It is important to understand the characteristics of a MUAP at the skin surface to ensure that these mistakes do not happen. The amplitude of a MUAP can range from as low as 20 μV to as high as 2 mV and the typical duration is between 20 and 40 ms. In *Figure 6*, the domain was changed to 1 s and the range was changed to 1 mV. In this case, it is clear that quality motor unit action potentials are being recorded.

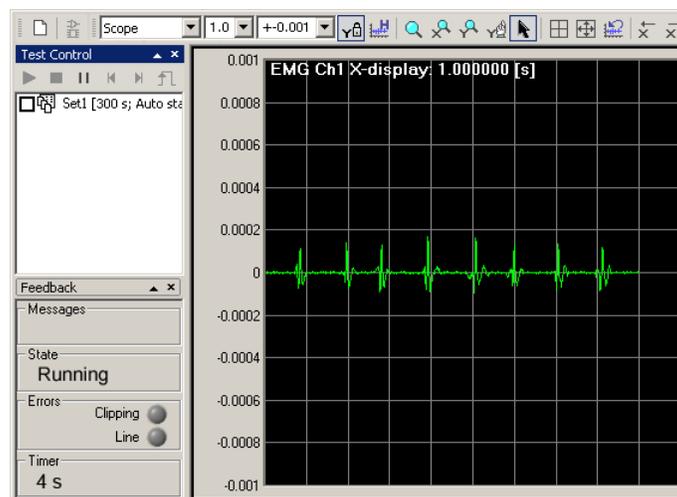


Figure 6: Motor unit action potentials during minimal muscle contraction. Scale: domain = 1 s, range = +/- 1 mV.

Once it has been confirmed that quality motor unit action potentials are being recorded, the full range the EMG signal can be examined. In *Figure 7*, the subject began with the muscle being studied completely relaxed. The amount of contraction was then gradually increased from a level where individual MUAPs could be observed to the level of maximal contraction.

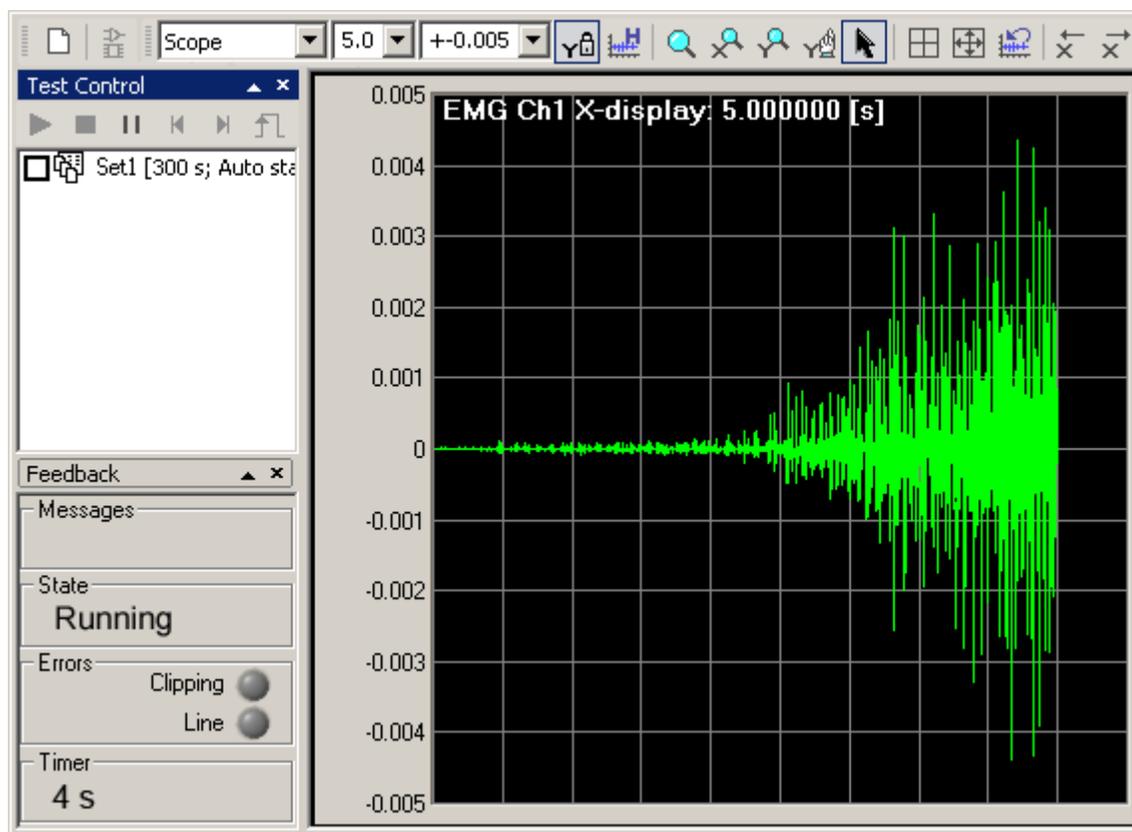
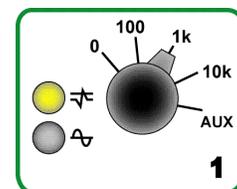


Figure 7: EMG activity during a task of increasing muscle activity. Individual motor unit action potentials are noticeable in the early recording and could be clearly seen if zoomed. Maximal EMG amplitude never exceeds 4.5 mV. Default scale: domain = 5 s, range = +/- 5 mV.

Adjusting the System Gain and Avoiding Clipping

In the case above, it can be seen that the EMG system gain is appropriate since the maximal EMG amplitude never exceeds 4.5 mV. If it had exceeded this value, distortion of the signal may have occurred. If the values exceeded 5 mV, then the signal would be clipped since this would exceed the range of the EMG system. The **Clipping** error indicator would have illuminated as portrayed in the diagram to the right. It would be necessary to turn down the gain of the EMG system to **100**. If, on the other hand, the muscle being studied produced EMG activity that was so small in amplitude that the maximum amplitude was below 0.5 mV, then it would be necessary to turn the gain of the EMG system up to **10k**.



This technical note addressed the most important concepts in evaluating EMG signal quality. Please consult the Knowledge Center at www.delsys.com for more details.