Motion Lab Systems

Whisper User Manual

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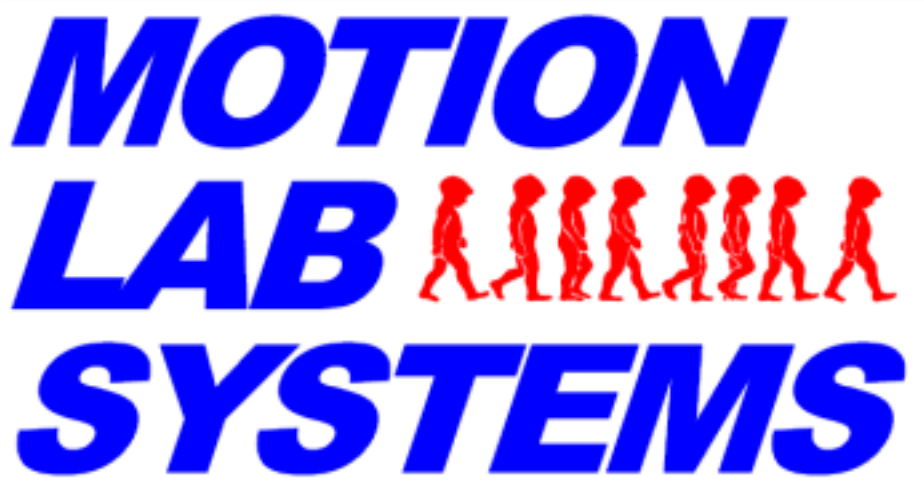

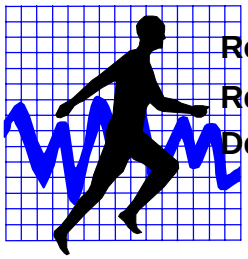

Roessingh
Research and
Development

Whisper User Manual
Published February, 2001
Revision 1.51
Intended Audience This manual is written for anyone using the Roessingh Research and Development Whisper EMG Test Set. It is assumed that the user is familiar with the principals of the Electromyography equipment that they use, and any associated EMG data collection system. Separate manuals for these products are available from their manufacturers.

Y2K compliance statement

The Whisper is Year-2000 compliant. It will not produce errors in date data related to the year change from December 31, 1999 to January 1, 2000. It will handle leap years correctly.
All MLS products either do not use internal date codes or utilize specific, non-ambiguous representation, handling and interpretation of centuries.

Electrical Safety

The Whisper is a battery operated electronic signal source that generates a sequence of test signals that simulate some characteristics of an electromyographical (EMG) signal. The unit is not designed to perform any electrical safety tests on your EMG system or replace any subject safety tests that are performed by a biomedical engineering safety check.

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Contents

Introduction

The Whisper

Congratulations on your purchase of the Whisper EMG equipment test package, manufactured by Roessingh Research and Development and distributed in the United States by Motion Lab Systems, Inc. From now on you can use the Whisper to test your EMG instrumentation in an easy, fast, and reliable, standardized manner. The Whisper can be used in seconds to perform a quick functional test or can perform a specification check and comparison with previous test results.

A quick functional test of EMG equipment is based on the idea that a faulty EMG system, and a normal system, will produce different EMG records when tested with a known, reproducible EMG input signal. The inspection of a system's response to a standardized EMG signal is therefore a good way to verify the performance of an EMG instrument or an EMG data collection system. The Whisper generates this standardized test signal for your EMG instrumentation and software included with the Whisper helps you interpret the results.

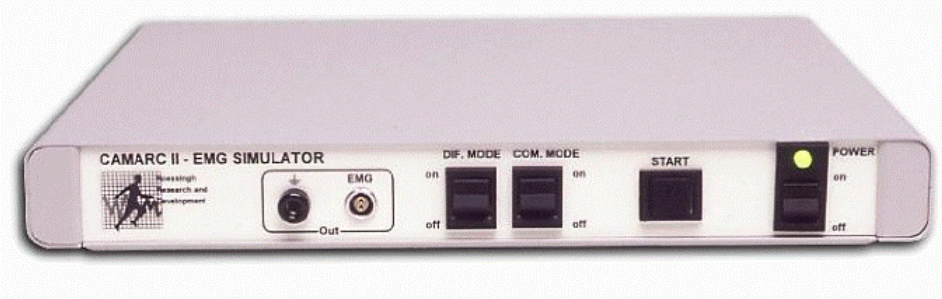


Figure 1 - The Whisper is a compact, easy to use, system.

This manual provides complete information to enable you to connect the Whisper to your EMG instrumentation and verify that the installation was successful.

The standardized test signal generated by the Whisper is described together with the information that can be calculated from the signal. The manual describes each of the Test Modes possible with the Whisper. Recording protocols and test parameter calculation algorithms are discussed to allow you to determine the test parameter values of your EMG instrumentation. After reading this manual you will be ready to use the Whisper to obtain many useful insights into the performance of your EMG instrumentation.

The Whisper can be connected to any mono-polar or bi-polar EMG system that generates either *smoothed, rectified EMG* signals or *raw EMG* signals and provides a means of recording these signals to a disk file in a format that the EMG-Equipment-Tester software (supplied with the Whisper) can read.

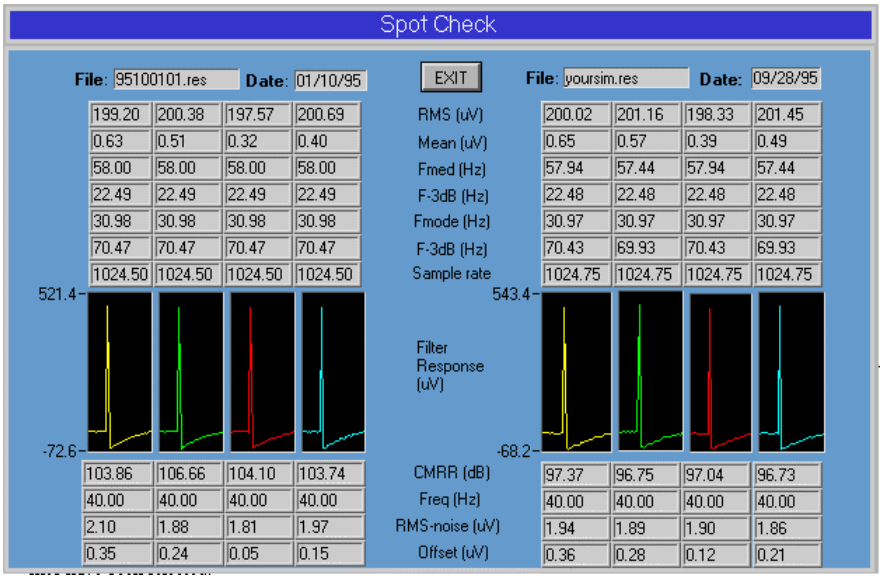


Figure 2 - A typical EMG test report generated using Whisper test data.

RData2 reads many common binary recording formats and generates the ASCII files required for analysis by the EMG-Equipment-Tester Software.

The Whisper package supplied by Motion Lab Systems includes two software tools to help the user analyze their recorded EMG signals. The *EMG-Equipment-Tester software* (written by Roessingh Research and Development) which performs the EMG test signal analysis, and also generates a report of the Whisper test results. The package also includes *RData2*, a file translation application from Motion Lab Systems, that generates the DST files (required by the *EMG-Equipment-Tester software)* from C3D and Dataq binary data files.

CE

The Whisper is CE-marked. The CE mark is the official marking required by the European Community for all electronic equipment sold or put into service for the first time, anywhere in the European community. It proves to the buyer or user that the Whisper fulfills all essential safety and environmental requirements as they are defined in the European Directives.

Electrical Safety

The Whisper is a battery operated electronic signal source that generates a sequence of test signals that simulate some characteristics of an electromyographical (EMG) signal. The unit is not designed to perform any electrical safety tests on your EMG system or replace any subject safety tests that are performed by a biomedical engineering safety check. Testing an EMG system with the Whisper must be in addition to your regularly scheduled safety testing and is not a substitute for regular biomedical equipment tests.

Installation

Getting started

The best way to avoid problems during installation of the Whisper is to read this entire chapter before you start the installation. The chapter lists all of the items that you should receive with the Whisper and describes the simple process of connecting the Whisper to your EMG instrumentation.

In order to be able to install the Whisper properly, the package contains the following items:

- The Whisper – an EMG signal generator.
- Four AA batteries.
- An EMG signal cable with LEMO connector.
- A ground reference cable.
- The EMG-Equipment-Tester software.
- The Whisper User manual (this document).

RData2 is a powerful binary to ASCII conversion utility supplied by Motion Lab Systems, Inc.

In addition to the Whisper equipment and software, Motion Lab Systems includes a copy of the RData2 file translation software. This software package can be used to generate the DST files required by the EMG-Equipment-Tester software supplied with the Whisper. RData2 reads C3D and Dataq data files and converts them to CAMARC standard DST files. The items supplied with RData2 are:

- RData2 Software.
- RData2 User Manual.
- Customer Registration code.

Please check that you have all the Whisper and RData2 items before continuing the installation. Please contact Motion Lab Systems if you can not find any of the items listed. Our mail address, phone numbers and email address can be found at the front of this manual.

Setting up and testing the Whisper

The Whisper is powered by four AA alkaline batteries (supplied) – these are easily obtained at any hardware store. If you plan to make extensive tests with the Whisper then you may want to purchase additional batteries.

Start by examining the Whisper and becoming familiar with the layout of the front panel connections and controls.

Figure 3 - The Whisper front panel

The front panel of the Whisper is simple - from the left to right you find:

- EMG Ground (Signal Reference)
- EMG Signal Output
- Differential Mode Signal On/Off Switch
- Common Mode Signal On/Off Switch
- Start Button
- Power On/Off Switch
- LED indicator: Simulator On/Off/Active

The rear of the Whisper provides access to the battery compartment.

Figure 4 - The Whisper back panel showing the battery compartment.

Start the installation by checking that the POWER switch, on the front of the Whisper is in the off position. The battery holder can be removed from the back of the Whisper by pressing the two clips together in the direction shown by the two arrows.

Figure 5 – The Whisper Battery pack

Remove the battery holder from the Whisper and insert the four AA batteries, paying particular attention to the polarity of the batteries.

Once the battery pack is inserted firmly into the back of the Whisper you are ready to generate EMG signals. The Whisper can be checked by turning on the POWER switch at the right side of the front of the unit. The LED will glow green if the batteries have been inserted correctly. If the LED does not light up then check that the batteries are inserted correctly and that the battery pack has been firmly inserted into the Whisper

If the batteries are inserted into the Whisper correctly and the LED lights when the power switch is turn on then you can test that the unit is functioning by turning the POWER switch on and pressing the START button, located to the left of the POWER switch. The LED will change from green to orange-red as the Whisper starts to generate an EMG test sequence.

The Whisper is now operational.

Two cables are supplied to enable you to connect the Whisper to your EMG system – you will need to connect both of them to you EMG system. These are the EMG signal cable and a ground reference cable.

Figure 6 – The EMG signal cable with LEMO connector.

LEMO p.n. FGG OB 302 CLA D45 Z w/ GMA OB 045 D6

The EMG signal cable has a LEMO connector at one end that connects to the EMG OUT connector on the left side of the Whisper front panel. The two output leads of the EMG signal cable have spade connectors.

The ground reference cable has a single connector that mates with the black ground reference jack on the left of the EMG OUT connector, while the other end has a standard safety DIN connector.

Figure 7 - The Whisper ground reference cable.

The ground reference cable should be connected to the to the grounded input of your EMG measurement chain – normally the EMG ground or indifferent reference

connector. The EMG signal cable is connected to the input of your EMG measurement chain. The EMG signal cable is supplied with two simple spade connectors that are suitable for most common EMG surface preamplifiers. You may need to modify this cable if your particular EMG input device does not interface to these connections.

The standard Whisper test signal starts with 5 leading pulses that check the recording system polarity.

The EMG signal connector has a positive and negative lead. The cable should be connected in such a way that the red lead on the EMG signal cable is connected to the positive input of the EMG system. If you don't know which of the inputs of your EMG instrument is the positive one, then connect the cable in the most convenient manner. A test will be described later that will check that the EMG signal cable has been connected correctly.

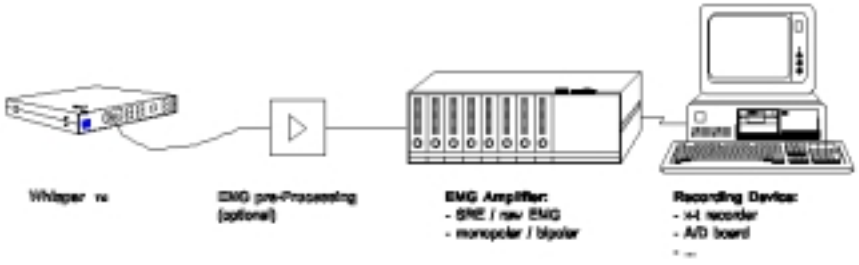


Figure 8 – A typical EMG test setup

It's a good idea at this point to connect the Whisper to your EMG recording system in order to test that the Whisper installation has been successful. EMG systems and recording configuration vary considerably so these instructions are quite general. You may need to read the instruction manual for your EMG system and recording system in order to complete this test.

Prepare your EMG recording instrumentation to record a signal during at least 22 seconds. Choose the gain of your EMG instrumentation channel such that your EMG instrumentation will not saturate when the standard Whisper test signal is applied. Your EMG instrumentation should expect to see a maximum EMG test signal amplitude of 1 mV.

If your EMG system has high and low pass filters then they should be set to allow the maximum bandwidth signal to pass with minimum attenuation.

Set both the DIF. MODE (Differential Mode Signal) and COM. MODE (Common Mode Signal) switches in the on position if you have bi-polar EMG instrumentation. If your EMG instrumentation is mono-polar then set the COM. MODE switch off.

When the Whisper LED is green the unit is ready to start generating an EMG test signal.

Now the Whisper is ready for use - you can switch on the Whisper using the POWER switch on the right side of the front panel. The LED above the switch should light up green. At this point the Whisper is ready to generate a signal at surface EMG levels when you press the start button.

The Whisper will start generating an EMG test sequence as soon as you push the START button, located to the left of the POWER switch. You will need to start your EMG recording system at the same time as you press the Whisper START button.

It's a good idea to turn off the Whisper when you have finished an EMG test to preserve the batteries.

With the Whisper turned on, and the power LED green, press the START button on the Whisper and start you EMG data collection recording system. The LED above the Whisper power switch will turn orange / red and your EMG recording instrument will record a standard EMG test signal from the Whisper for the next twenty two seconds. At the end of the EMG test sequence the Whisper LED turns green again and you can stop your recording device and store your data.

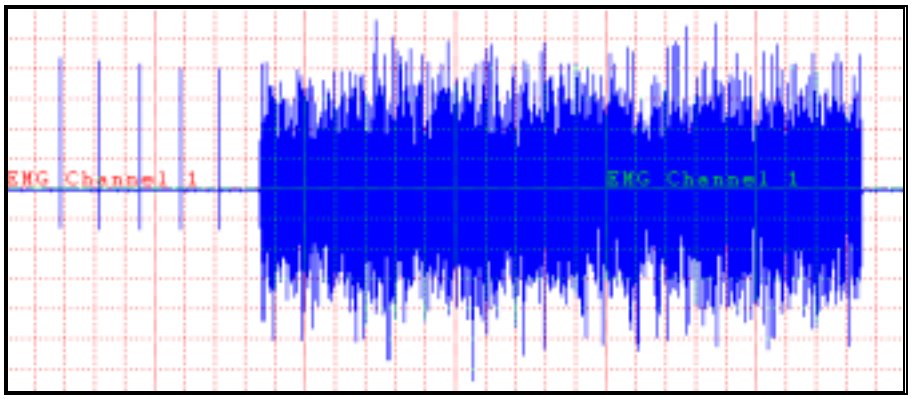


Figure 9 - The standard test signal recorded by raw EMG instrumentation

Once you have completed an EMG test recording you can view the recorded EMG data using your normal methods. If your EMG instrumentation records raw EMG then your recording should look like the signal that is shown in Figure 9.

If your EMG instrumentation records a rectified and filtered EMG signal (also called "envelope" EMG) then your recording should look like the signal that is shown in Figure 10. Both illustrations show highly compressed EMG signals to illustrate the entire EMG test sequence – each illustration covers a period of about twenty-two seconds.

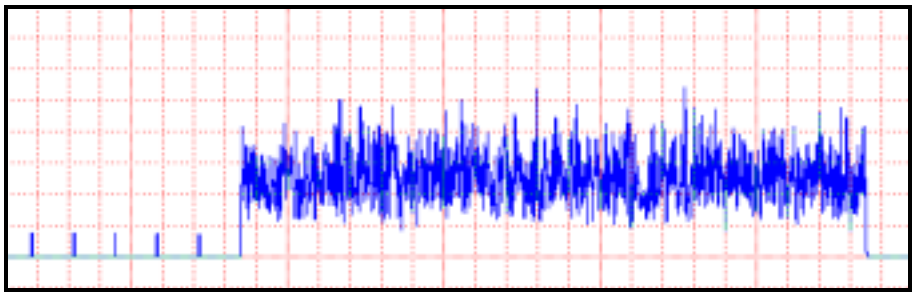


Figure 10 - The standard test signal recorded by "envelope" EMG instrumentation.

The Whisper is working and has been installed correctly if an EMG recording from a known working EMG systems is comparable to the EMG signals illustrated in either Figure 9 or Figure 10. Please consult the troubleshooting guide in Appendix A2 at the end of this manual if you do not see these signals.

The Test Signal

A Functional description

Roessingh Research and Development have developed the Whisper as a tool for quality assurance and routine checking of the performance of EMG instrumentation in a biomechanics laboratory. Its primary goal is to detect degradation in the performance or malfunctioning of the equipment in order to alert the users to any problems with their system at an early stage. Information generated by the Whisper allows the laboratory engineers and technicians to schedule regular maintenance to avoid making invalid EMG measurements and /or recordings.

The basic idea of an equipment test is that a standardized EMG test signal will be applied to the EMG instrumentation on a regular basis. The output of the EMG instrumentation will be recorded and test parameter values will be calculated from the recorded signal in order to obtain a record of the performance of the EMG instrumentation and recording system.

By comparing the test results from a Whisper test with the results of earlier tests it is possible to check that the EMG system and EMG recording channels for any signs of degradation. A faulty EMG system will produce a different EMG record from a functioning EMG system when both systems are presented with a standard EMG test signal such as generated by the Whisper.

The standardized test signal is stored in EPROM's inside the Whisper. Each Whisper contains an identical set of EPROM's and thus every Whisper generates an identical EMG signal for each test. The signal consists of two components – these are:

- A differential mode component.
- A common mode component.

The differential component consists of five, positive, leading pulses that are followed by a digitized EMG signal. The common mode component consists of a 40 Hz sine wave. Each of the two components can be generated and applied to the EMG output signal independently via the two DIF. and COM. mode switches on the front of the Whisper.

Both signals are generated as soon as the START button is pushed and released to allow the Whisper to produce a range of test signals under control of the user. The ability to combine and separate the differential and common mode components of the EMG test signal is invaluable in fault finding and testing EMG systems and components.

The standard test signal

The standard Whisper test signal consists of a differential mode signal with a common mode component superimposed on the signal. This allows a number of different EMG instrumentation parameters to be observed in a single test signal.

The differential mode signal

The differential mode signal consists of five leading pulses, followed by fifteen seconds of standard EMG generated from a signal stored in the Whisper EPROM's. The pulses are spaced 1 second apart. Their duration is one millisecond, their amplitude is 500 µV. There is one second between the release of the START button and the first pulse and one second between the fifth leading pulse and the stationary EMG signal. The stationary EMG signal is fifteen seconds long. The Whisper stops one second after the stored EMG signal has finished. Figure 11 shows a sample of the differential mode EMG signal while Figure 9 illustrates the entire fifteen-second sequence.

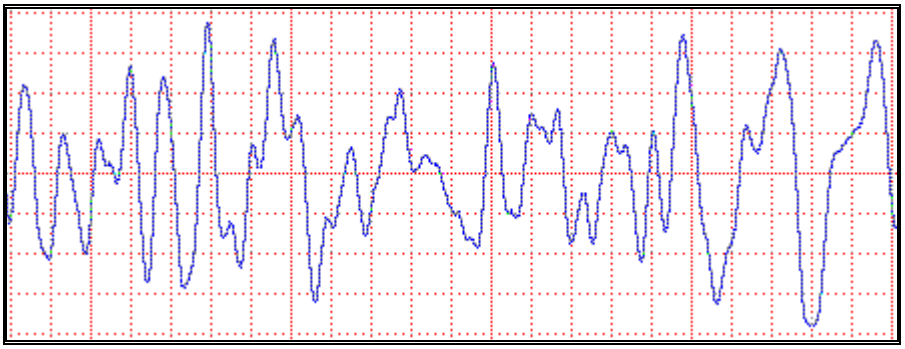


Figure 11 - Differential mode EMG signal.

The differential mode EMG signal, that is stored within each Whisper, is a simulated signal so that it has a precise amplitude and known frequency components. This avoids the problems inherent in recording a long, continuous burst of EMG from a human subject. In *Frequency parameters of the myoelectric signal as a measure of muscle conduction velocity* (IEEE Trans. Biomed. Eng. Vol. 28 (1981), p. 515-523), Stulen, F.B. and De Luca, C.J. show, that a stationary EMG signal can be obtained by band-pass filtering a white noise random sequence. The fifteen seconds of EMG used by the Whisper were obtained by low-pass filtering and then high-pass filtering fifteen seconds of white noise. The low-pass filter was a 2nd order, 80 Hz filter and the high-pass filter was a 1st order, 40 Hz filter. The digital filter used a 1024 Hz sample rate.

The resulting EMG test sequence has been scaled such that the standard deviation of the amplitude of the sequence equals 200. The overall z-transfer function of the digital band-pass filter is:

$$H(z) = \frac{0.035719(z^3 + 1.0022(z^2 - z) - 1)}{z^3 - 1.9792 z^2 + 1.2948z - 0.2804}$$

The simulated EMG data is provided in the file EPROM_e1.DST on the diskettes supplied with the Whisper. This file is a standard ASCII file and can be read by many common spreadsheet programs such as Lotus, Quattro, and Excel etc). If the DST data is read into any of these products and plotted then you should get a display that is similar to that illustrated in Figure 9. The y-scale values correspond to the amplitude of the differential mode signal at the output of Whisper (in microvolts). Thus a value of 345 in the data file is converted into an output of 345 µV at the EMG

signal output. The file *EPROM_e1.DST* thus provides you an exact description of the standard differential mode test signal.

The common mode signal

The common mode signal generated by the Whisper consists of three parts. During the first six seconds, the common mode signal remains 0.0 Volt. As soon as the differential mode signal starts to output the stored EMG signal, the common mode signal becomes a sinusoidal signal with an amplitude of 1.00 Volt at a frequency of 40 Hz. This common mode signal remains present for fifteen seconds and then returns to 0.0 Volt during the last second of each simulation.

The common mode signal is stored in the same way as the differential mode signal and is also converted on a one-to-one basis to each differential output of the Whisper.

EMG signal specifications

The standard EMG test signal, used by the Whisper to test the performance of your EMG recording instrumentation has the following characteristics. These can be verified from the file *EPROM_e1.DST* that is installed in the data subdirectory to the EMG-Equipment-Tester software. A full description of the format of this file is given in File Descriptions later in this manual.

Test parameter	Value		Unit
EMG signal – RMS Value	200	[+/- 5 %]	µV
EMG signal – Mean Value	0.1	[+/- 5 %]	µV
EMG signal – Fmed	59	[+/- 1 %]	Hz
EMG signal – Fmode	31	[+/- 1 %]	Hz
Leading Pulse Width	1	[+/- 1 %]	ms
Leading Pulse Amplitude	500	[+/- 2 %]	µV
Interpulse time	1.0	[+/- 1 %]	seconds
Common Mode Amplitude	1.0	[+/- 5 %]	Volt
Common Mode Frequency	40	[+/- 1 %]	Hz

Table 1 - Standard Test signal values

- RMS-value indicates the Root Mean Square value of the fifteen seconds of digitized EMG signal.
- Mean is the mean value of the 15 seconds of digitized EMG signal.
- Fmed is the median frequency of the power spectrum of the first two seconds of the digitized EMG signal.
- Fmode indicates the frequency at which the power spectrum of the first two seconds of the digitized EMG signal is at its maximum.
- Pulse width and Amplitude refer to the 5 leading pulses. The interpulse time is the time between 2 successive leading pulses.
- Common Mode Amplitude is the amplitude of the sine wave.
- Common Mode Frequency is the frequency of the sine wave.

Using the Whisper

Standardized EMG testing

The Whisper has been developed to provide a well-defined, reproducible test signal for standardized EMG equipment testing. Standardized testing can be performed in a number of separate steps. First the EMG test signal from the Whisper is applied to the input of the EMG instrumentation under test. The output of the Whisper is then recorded through the EMG instrumentation. The recording is then evaluated and parameters calculated from the recorded data. Finally, the calculated values can be either compared to the known input values or compared with the results of prior tests in order to be able to draw conclusions about the performance of the EMG recording system and EMG instrument under test.

In order to be able to draw reliable conclusions about the performance of the EMG instrumentation, it is important that each of these steps is performed in exactly the same standardized way each time the equipment is tested. This chapter will discuss how all this can be achieved.

Since the differential mode and common mode component of the Whisper EMG test signal can be selected independently, the standard test signal can take any one of four different configurations. Each of the four configurations can reveal different aspects of your EMG instrumentation.

Standard EMG test modes

The standard EMG test signal, stored within the Whisper, has been chosen so that several EMG instrumentation features can be quickly tested. Since both the differential and common mode components of the EMG test signal can be controlled independently, it is possible to define four operation modes.

Mode	Dif. mode	Com. mode	Test options	recording length
0	On	On	Bi-polar EMG: EMG and timing parameters.	> 22 sec
1	On	Off	Mono-polar EMG: EMG and timing parameters.	> 22 sec
2	Off	On	Bi-polar EMG: Common Mode Rejection Ratio	> 15 sec
3	Off	Off	Bi/Mono-polar EMG Noise and offset parameters	> 10 sec

Table 2 - Operation Modes and Test Features.

It is worth noting at this point that all the Whisper tests produce results that measure not only the EMG system but also the data recording and measurement system that is used to access the EMG data. The results reported from a series of Whisper tests may provide as much information about the performance of the analog EMG recording system as the EMG instrumentation that is used to acquire the EMG signal. It is important that the Whisper user considers all possible error sources before evaluating the results of a series of Whisper tests.

Mode 0: EMG and Common Mode

In mode 0 the EMG parameters, the timing parameters and the dynamics of any bipolar EMG instrument can be tested – this includes almost all common surface EMG preamplifiers. Mode 0 applies a differential EMG signal to the EMG instrument under test and superimposes a common mode component over the EMG signal. This tests the response of your EMG instrumentation to a differential mode signal in the presence of a large common mode signal. Modern EMG preamplifiers should reject the common mode component and amplify only the differential EMG signal.

Mode 1: EMG only

Mono-polar EMG instrumentation (often used with traditional needle electrodes – not to be confused with fine wire electrodes) can not reject common mode disturbances. Therefore this mode does not include a common mode signal and only applies the differential EMG component during tests to determine the EMG parameters, the timing parameters and the dynamical properties of the EMG instrumentation.

Mode 2: Common Mode

Mode 2 allows testing of the Common Mode Rejection Ratio (CMRR) by applying a large common mode signal to both EMG signal lead simultaneously. Since mono-polar EMG instruments can not reject common mode disturbances, this mode is only of interest for bipolar EMG systems.

Mode 3: Noise and Offset

Mode 3 allows testing of the noise and offset properties and can be applied to any EMG recording instrument. It does not produce any output signal other than the background noise level of the Whisper, which is present in all other tests. This allows us to calculate the signal to noise ratio of the EMG instrumentation.

Testing EMG instrumentation

The most important task of an EMG recording instrument is to measure and process EMG signals in a reliable and reproducible manner. Using the Whisper Mode 0 and Mode 1 EMG test signals it is possible to check that your EMG instrumentation is working correctly, since in these modes the differential mode component will be applied to the EMG instrument under test. From the fifteen seconds of recorded EMG a number of parameters can be determined. The most important parameters are:

- The RMS value of the recorded EMG signal.
- The mean value of the recorded EMG signal.
- Median and mode frequency of the power spectrum of the recorded EMG signal.

Since the precise values of the EMG signal, stored in the Whisper, are known, we can calculate the expected parameter values and compare them to the values that we measure. A regular EMG instrumentation test using the Whisper allows verification of the gain, the offset and the frequency characteristics of any EMG instrumentation.

Timing and Dynamics

The timing and the dynamics of the EMG instrumentation and recording system can be tested using the Whisper Mode 0 and Mode 1 EMG test signals by studying the five leading pulses in the differential EMG signal. Since the shape and the time between the leading pulses is exactly known, they can be used to check the:

- The sample rate of the EMG recording system.
- The dynamic response of the EMG recording system.

Common Mode Rejection Ratio

By applying only the common mode component (a Mode 2 test) to an EMG instrumentation system, it is possible to evaluate:

- The Common Mode Rejection Ratio of the EMG instrument.

The CMRR test (Mode 2) can be very informative if you are able to view the live output of the EMG system under test. Poor CMRR performance is easy to spot as it produces a large signal output during this test and instantly identifies a problem EMG channel.

During a Mode 2 test the common mode signal component is applied to a bipolar EMG instrument. Since this signal is present at each of the differential outputs of the Whisper, the EMG instrument should reject this signal (a 40 Hz sine wave). It is known that the amplitude of the sinusoidal signal from the Whisper equals 1.0 Volt. Thus a simple measurement of the amplitude of the sinusoidal present in a Mode 2 recording enables us to measure the extent to which the Common Mode signal has been suppressed. This is called the Common Mode Rejection Ratio and is important because it is the primary method by which bi-polar EMG recording systems eliminate line frequency signals (50 or 60 Hz depending on your location) from the EMG signal present on the subject.

It is worth noting that there is also a common mode component to the standard bi-polar EMG test signal (Mode 0) and that any EMG instrument that performs poorly with a Mode 2 test will probably need to be evaluated with Mode 1 EMG test signals instead of Mode 0 test signals.

Noise and Offset

It is possible to test:

- The noise and any DC offset in the EMG instrumentation

This is done by applying neither a common mode nor a differential mode signal to the input of the EMG instrument (Mode 3). Although it seems unusual to use the Whisper for this, it is very useful since the input of your EMG instrumentation will be forced to 0.0 Volt (ground) if you switch off both signals.

The signal from the Whisper will, however, still contain the same noise and frequency components that may be present during the other EMG tests. Thus, by recording the null output signal from the Whisper, you can measure any noise or other electrical disturbances, which are present in your EMG measuring and recording chain and are superimposed on your EMG recordings.

You can evaluate the noise contribution of the Whisper by comparing two Mode 3 tests – one test sessions being recorded with power applied to the Whisper and the second test session with the Whisper turned off.

Protocols for standardized testing

A standardized measurement protocol is of major importance for reproducible equipment testing. It is therefore recommended to use the following protocol every time you execute an equipment test:

1. Connect the Whisper to your EMG instrumentation as described earlier.
2. Select the test mode. Set the differential mode and common mode switches in the appropriate positions.
3. Prepare your recording instrumentation such that it can record the standard test signal without saturating for at least twenty-two seconds.
4. Switch the Whisper on.
5. Push the Start button, and commence recording the EMG signal, release the Start button within one second and check that the LED turns orange / red.
6. Wait until the LED turns green again.
7. Store the recorded data for future analysis.
8. Switch the Whisper off.

This protocol can be used in every test mode. In order to be able to extract test parameter values from a recording, it is necessary to verify whether the recording has been made in an appropriate way. For the following test modes the recording should therefore satisfy the following criteria:

Mode 0 / mode 1:

- Be sure that you have recorded each of the five leading pulses.
- Be sure that you have recorded fifteen seconds of digitized EMG.

Mode 2:

- Be sure that you can see a sine wave in the recording after six or seven seconds.

If your recording satisfies the particular criteria it is possible to determine the values of the test parameters. If your recording does not satisfy the particular criteria you need to execute another recording following the protocol described above.

Interpreting the Test Results

The results of the Whisper tests contain a lot of information about the performance of the EMG instrumentation under test. In this section we will explain how the various results can be evaluated.

Sample Rate

The sample rate of the recording device can be determined by counting the average number of samples between any two consecutive leading pulses produced at the start of a Mode 0 or Mode 1 recording. Since the five leading pulses repeat at a fixed rate the average of the number of EMG data samples between the five pulses must equal the sample rate of the recording device.

The measured sample rate of a Whisper test should equal the sample rate of your EMG data collection system.

Amplitude parameters

Since the Whisper generates exactly the same EMG test signal during every Mode 1 and Mode 2 test you can easily measure the gain and any DC offset in your EMG instrumentation and data collection system. The RMS and the Mean values of the input EMG signal are known – these are 200 μV RMS with a Mean of 0 μV. By measuring these values from the recorded EMG data, after it has passed through the EMG instrumentation and data recording system, you can learn a great deal about the performance of the entire EMG instrumentation and recording system.

In order to measure the EMG amplitude parameters reliably it is important that the RMS and Mean values are measured correctly from the EMG portion of the recorded signal. If the five leading pulses and the recording system sample rate have been determined, it is simple to locate the start of the EMG signal since it starts exactly one second after the last leading pulse and is exactly fifteen seconds long.

By calculating the RMS and Mean values of the fifteen seconds of standard EMG test signal in a Whisper Mode 0 or Mode 1 recording you can determine the gain and DC offset parameters of the EMG instrumentation and data recording system under test.

Frequency parameters

An EMG recording instrument can be regarded as a chain of filter and amplifier stages. In general the settings of these stages can be changed (gain, cutoff frequencies, bandwidths, etc.). Each of these stages has its particular task and together they ensure that an EMG signal will be recorded without distortion, with minimum noise or disturbances and maximum common mode rejection.

The power spectrum of the standard test signal produced by the Whisper is known and consequently the value various frequency parameters of the power spectrum (Fmed, Fmode etc.) are known. In order to be able to record the EMG signal without distortion, the bandwidth of the EMG power spectrum has be equal to or preferably less than the bandwidth of the whole recording chain. By calculating the frequency parameters of the recorded EMG signal produced by the Whisper, it is easy to check that the various filter stages of the EMG instrumentation have been set correctly.

The frequency parameters are calculated from the first two seconds of digitized EMG signal this is generated in any Mode 0 or Mode 1 recording. Once they have been measured the smoothed Power spectrum can be calculated. Smoothing yields multiplication of the power spectrum with a Papoulis window. The median and the mode frequency can be determined from the power spectrum.

Dynamic response

In theory, the impulse, or dynamic response, of any electronic system contains all the information about the dynamics of a system. Any changes in the dynamic response of the system will change the shape of the impulse response. The impulse response is therefore a useful tool to evaluate the dynamic response of any data recording system.

You must obey the Nyquist sampling theorem when recording data from the Whisper to test the impulse response of any system.

In order to measure the impulse response of your EMG instrumentation you must make either a Mode 0 or a Mode 1 recording. The response of your data recording system and EMG instrumentation to each of the five leading pulses reveals the impulse response of the entire EMG instrumentation and recording system to a one millisecond, 500 μV pulse.

Common Mode Rejection Ratio

The Common Mode Rejection Ratio (CMRR) indicates the extent to which any common mode components of a recorded signal will be rejected by a differential amplifier. The differential mode component will be amplified by the EMG instrumentation measuring chain and can be used to calculate the overall system gain. The Common Mode Rejection Ratio can therefore be determined by dividing the amplitude of the Whisper's common mode sine wave (40 Hz, amplitude 1.0 Volt) by the amplitude of the sine wave recorded in a Whisper Mode 2 recording. The Common Mode Rejection Ratio of your EMG instrument is the 20-log value of this ratio. In general most EMG systems should have a Common Mode Rejection Ratio of greater than 80 dB.

The Whisper generates a test signal for Common Mode Rejection Ratio calculation in Mode 2. The first five seconds of a Mode 2 signal consists of a quiet baseline followed by a low-level sine wave. The amplitude of this sine wave will depend on the ability of your EMG amplifier to reject Common Mode signals.

Noise and offset parameters

A Whisper Mode 3 recording enables you to measure the noise and DC offset parameters of your EMG instrumentation. In this mode the output of the output of the Whisper is 0.0 volts and contains only the internal noise that is inherent in any signal system. By measuring the RMS and Mean values of the recorded EMG signal in Mode 3, it is possible to calculate the amount of noise and the offset of the EMG instrumentation and data recording system.

While the internal noise generated by the Whisper is very small it is not zero. This is possible to measure the internal noise of the Whisper by comparing the results of a Mode 3 recording with the results of a similar recording made when the Whisper is switched off.

Whisper Applications

The Whisper can be used to perform a number of different tests within any clinical gait or biomechanics laboratory:

- Multi channel equipment test
- System performance test
- System specifications test
- System comparability test

Each of these tests will be described shortly in the following sections.

The multi-channel equipment test

The goal of a multi-channel equipment test is to compare the performance of a number of EMG channels in a measurement chain with each other. This allows you to determine if the performance of any particular channel has changed or is different from another channel under test. In general, each EMG channel is a separate unit in the recording chain. As a result, errors or defects in an EMG instrumentation system tend to affect only one channel rather than every channel in the system. A multi-channel equipment test is therefore a useful tool to detect problems in individual EMG channels that might otherwise be missed.

In a multi-channel equipment test the Whisper is connected to each EMG channel under investigation and the response of each channel to the standardized EMG test signal is recorded simultaneously. You can make a quick assessment of the EMG channel quality by looking at these recordings. If the recordings are in phase and the amplitude of the individual signals is similar then it's likely that the performance of the EMG channels will be acceptable.

In order to obtain a more precise measurement, we can calculate a number of standard parameter values for each EMG channel. By comparing these values to each other, it is easy to draw evaluate your EMG channel performance.

A full multi-channel equipment test consists of a number of recordings. For a bipolar EMG instrument it is necessary to make three recordings: a Mode 0 recording to test the timing properties and the dynamic properties of each channel, a Mode 2 recording to test the Common Mode Rejection Ratio of each channel and a Mode 3 recording for noise and offset testing. Figure 12shows an example of the results of a full equipment test of a bipolar raw EMG instrument using the EMG-Equipment-Tester software, supplied with the Whisper.

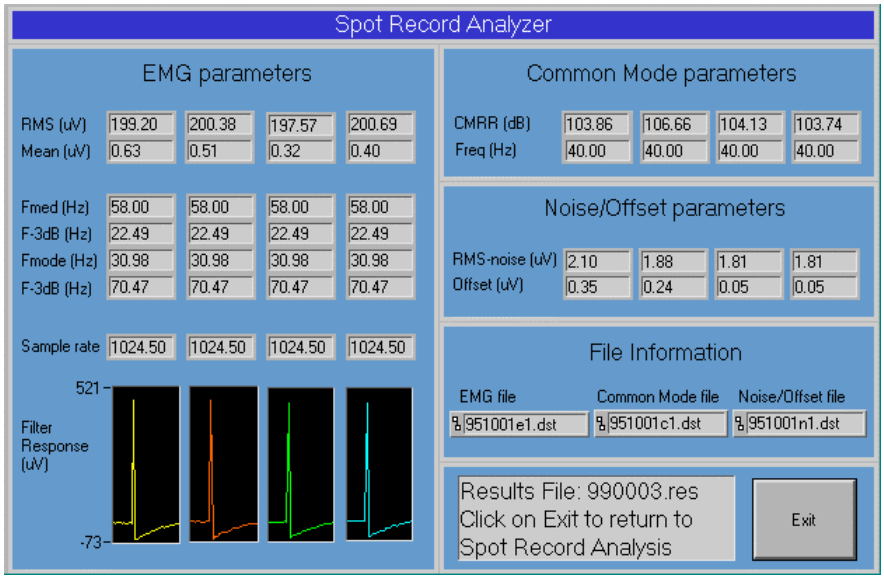


Figure 12 - Test results of the full equipment test of a 4 channel raw-EMG instrument.

As you can see, four separate EMG channels have been tested. Eleven unique parameter values have been calculated for each channel and the impulse response has been recorded. This report may be printed out and saved as a record of the test and the EMG system functionality.

The system performance test

The goal of a system performance test comparison to detect any degradation, malfunction, or change in the EMG system and recording instrumentation in order detect these problems at an early stage. Therefore, a system performance test will compare the results of a recent EMG system test to the results of an earlier test. In this way, invalid EMG measurements can be avoided and appropriate maintenance actions can be undertaken.

The starting point of a systems performance test are the results from an earlier recorded test of the EMG instrumentation. The saved results can be compared to the results of a new equipment test. If you perform a full EMG system performance test on a regular basis (for example once a week), you should find that the week to week

changes of the test parameter values are very small (< 1.0 %), indicating the EMG instrumentation and data collection system are working properly.

It is recommended that the Whisper tests be run on a regular basis in order to maintain a history of the performance of your EMG instrumentation.

Any large deviation in the test parameter values will suggest that the performance of your EMG instrumentation has changed in some way. It is almost impossible to make any general statements here about the values of specific deviations in parameter values since they depend a lot on the type of instrumentation and the environment in which you execute your measurements, etc. When any potential problem is observed, the test data produced by the Whisper is invaluable in assisting the biomedical engineer in determining the cause of the problem.

The system specifications test

The system specifications test is similar to the system performance test, but instead of comparing the test result of an equipment test with results from earlier recordings made in your own laboratory, you compare your test results with results provided by the EMG instrumentation manufacturer.

If you obtain a set of Whisper tests that have been recorded by the EMG system manufacturer then you can use these to confirm that the EMG system conforms to the specifications. Such a recording can be used as a 'standard' for verification of the specifications of your EMG instrumentation. This is especially useful when an EMG system is first installed in a laboratory since this allows you to verify that the EMG instrumentation has been installed properly and is functional.

The system comparability test

The system comparability test allows users in separate laboratories with different EMG systems and data collection instrumentation to verify the performance of their systems and determine if the instrumentation in both laboratories is functionally similar enough to allow exchange of EMG records. This test is based on the concept that the separate laboratories apply the same standardized test signal to their equipment, calculate the same test parameters from the recordings and compare the values of these test parameters with each other. Differences between test parameter values can only be attributed to differences in the EMG instrumentation in both laboratories.

If you conclude that the output of the instrumentation of the separate laboratories is different, you may conclude that the equipment is functionally different and that data recorded and processed in these two laboratories may not be directly comparable.

If you conclude that the output of the separate EMG instruments is the same, then you can consider this as a reasonable indication that the equipment is functionally similar and that the data recorded and processed in these two laboratories may be directly comparable.

A Whisper Tutorial

Introduction

It is very simple to record EMG test data from the Whisper but care must be taken to ensure that all the parameters of the recording are carefully controlled in order to produce meaningful results. This chapter will illustrate this using a pair of different EMG systems (Motion Lab Systems MA-100 and Motion Lab Systems MA-300 EMG systems) together with a Dataq analog data acquisition system on an IBM compatible PC (100MHz 486 with Windows 95 and 64Mb of memory).

The Whisper can also be used as a quick check of an EMG system by simply reviewing the output of a Mode 0 EMG test signal via any convenient display device such as an oscilloscope or analog signal monitor.

Analog data recording is a complex subject and it is very helpful to consider all the parameters that may affect your test data before you start to use the Whisper. This is especially helpful as most of the parameters that affect the test recordings that you make with the Whisper will also affect your day to day analog recordings in the laboratory. It is important to remember that the tests that you will be performing will allow you to investigate the performance on not only your EMG system but also your analog data acquisition system as well as the parameters that you use to sample your analog data during your normal day to day operations.

Setting the Gain

Many EMG systems have a number of different gain settings and it is important to select the optimal gain setting to record the test signals that are produced by the Whisper. The largest EMG test signal is produced when the Whisper is in Mode 0 or 1, depending on the type of test that you are performing. For a typical surface EMG system this will be a Mode 1 signal which has a maximum differential EMG signal amplitude of 500uV. There are three factors that must be considered:

Electrode gain

Both the EMG systems used in this tutorial use pre-amplified surface electrodes that have an internal gain (amplification) factor (MA-100 pre-amplified electrodes have a gain of x320 while the MA-300 pre-amplified electrodes have a gain of x20). It is important to know the gain of any pre-amplified electrode.

When testing any EMG system that uses pre-amplifiers you must connect the Whisper EMG test set directly to the electrode disks that are normally placed on the subjects skin. If you are testing an EMG system that uses passive electrodes then you must connect the Whisper directly to the EMG system inputs that would normally connect to Gel or other passive electrodes on the subject.

System Gain

Both the MA-100 and MA-300 systems support a range of different gain settings for each EMG channel.

The MA-100 EMG system uses an individual variable potentiometer gain control for each EMG channel on the back-pack to allow the user to adjust the EMG level that the system detects on the subject. This gain control is adjusted by the user to record an optimum maximal EMG signal on each channel, as determined by the individual LED displays. As a result, the channel gain control must be set by generating a Mode 0 EMG test signal from the Whisper and adjusting the gain control so that the maximal signal is recorded without overloading the system. Once the gain control is set, the precise channel gain can be calculated by making a test recording from the internal calibration source built into the MA-100 back-pack.

The MA-300 EMG system uses preset switches to determine the individual channel gains. Channel gain settings are marked in terms of the maximum peak to peak input that can be applied for a given switch setting. The MA-300 switch setting #3 indicates that this setting can handle EMG input signals of up to ±875μV peak to peak. This is the optimum input range on an MA-300 system for the Whisper tests which generate a differential EMG signal in the range of +742μV to -670μV.

ADC input range

The analog recording system must be able to accurately record the signals generated by the equipment under test. The maximum output signal generated by an MA-300 EMG system is ± 5 Volts which means that the recording ADC sub-system must be set for a range that will handle signals of this amplitude. Most common ADC sub-systems will handle signals in the range of ± 5 Volts or ± 10 Volts. Depending on the ADC system, you may be able to directly select a range of ± 5 Volts, or have a fixed range of ± 10 Volts and the option to apply a gain of x2 to provide an equivalent range.

The Dataq analog data acquisition system supports the sampling of analog data with a range of ± 5 Volts – this is appropriate for the EMG signal levels that are produced by both the MA-100 and MA-300 systems.

Frequency Response

It is important to consider the frequency response of both the Whisper test signal and the EMG system under test as both of these items will determine the minimum sampling rate that will be required from your data recording system. Many EMG systems include a set of user-adjustable filters that allow the user to tailor the frequency response of the system to match the analog recording system or filter the EMG signal to remove noise and other artifact before recording and measurement.

High Pass Filters

If the EMG system contains variable High Pass filters (these remove low frequency artifact components from the raw EMG) then they should be set to the lowest frequency setting available. The MA-100 contains a variable High Pass filter that is controlled via a connector on the rear of the unit (CONTROL) or via an optional switch box. The filter should be set to the minimum value of 20Hz. The standard MA-300 system does not contain a High Pass filter so this setting can be disregarded unless you are using the optional High Pass filter or an external filter. In either case the High Pass filter should be set to the lowest frequency available or turned off.

Low Pass Filters

If the EMG system contains variable Low Pass filters (these remove high frequency noise and other components from the raw EMG signal) then they should be set to an appropriate value. Figure 13 shows the spectral content of the test signal generated by the Whisper and demonstrates that the signal does not contain any components above 300Hz. If you only consider the spectral response of the EMG signal then you could choose a Low Pass filter point that is too low and removes part of the Whisper test signal.

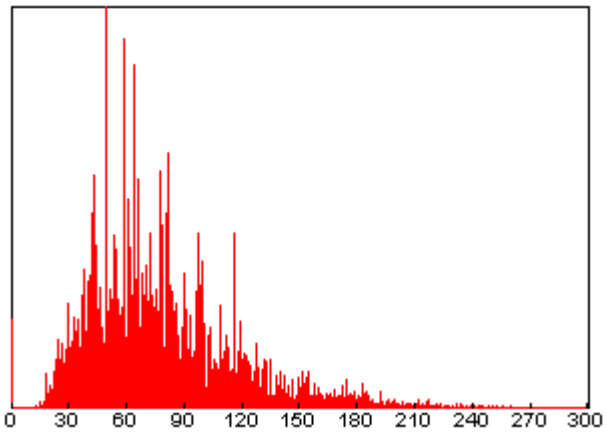


Figure 13 - Whisper EMG spectrum (Hz)

However, the test signal generated by the Whisper also contains a number of short timing pulses that are also affected by this filter setting. As a result it make sense to choose a higher filter setting to avoid unnecessarily attenuating the five leading pulses that precede the EMG test signal. A suitable setting for the internal MA-300 Low Pass filter would be #5 (750Hz) or #4 (1,000 Hz) while the MA-100 can be set to either 600 Hz or 1,300 Hz via an optional filter control box.

Some EMG systems do not have adjustable Low Pass filters in which case you can consider the entire EMG system to have a Low Pass frequency response that is equivalent to the maximum frequency that the system can reproduce. You may need to consult the manufacturers literature to determine the exact bandwidth of the EMG system under test.

Choosing a Sample rate

It is important to select a suitable sample rate to record the test signals generated by the Whisper. In order to do this you must know the distribution of the signal spectrum that you intend to sample. Figure 13 shows the spectral content of the test signal generated by the Whisper and demonstrates that the signal does not contain any components above 300Hz. Given this information, analog sampling theory dictates that the EMG signal must be sampled at a rate of at least 600Hz to prevent the generation of aliasing artifact in the recorded signal. Since you intend to analyze the recorded EMG signal you should select an analog sampling rate that is at least double the minimum required. If at all possible you should set your analog recording system to sample the EMG data at a rate of at least 1800 to 2000 samples per second to provide a signal bandwidth of 900 to 1000Hz in practice.

Sampling Characteristics

There are a wide range of different sampling techniques and methods and it is important to understand the different options that your ADC card offers in order to generate clean and accurate data recordings. Many of these options are unique to particular manufacturers or data collection cards so it is quite possible that you may have additional options to those discussed below. In addition, many inexpensive ADC cards offer only a simple interface without any of these options.

Oversampling

Many Analog Data Collection systems allow you to sample the analog data at very high rates – often much higher than you would normally record the sampled data. This is a very useful feature that allows the ADC card to provide some measure of anti-alias filtering of the input data as the system can process a larger number of analog samples to generate a single sample for recording. Oversampling usually offers a number of options for selecting a data sample:

- Average – a number of data points are averaged together to generate a sample data point. This method is very effective in removing high frequency noise from the sampled data that would otherwise appear as aliasing artifact.
- Last Point – this simply returns the most recent data point as a sample.
- Maximum – this returns the data point with the greatest amplitude as the sample point.
- Minimum – this returns the smallest data point as the sample point.

When recording test data for use with the Whisper you will find that the Average and Maximum sampling methods produce the most accurate data. The Maximum method will usually provide a better record of the five timing pulses when your data recording sample rate is low. In general the Average method is the most appropriate for day to day EMG recording.

Differential Inputs

Most Analog Data Collection systems offer the option to recording the data using a differential input – this is generally only appropriate if the EMG system under test produces a differential output signal. Most common ADC systems will use a single ended input arrangement.

Preparing for an EMG Test

If you use an EMG system in regular day to day data acquisition then all you should have to do in order to make a recording is to connect the Whisper *EMG Out* cable to the two differential EMG inputs and connect the separate ground lead to a suitable ground connection on the EMG unit. In the case of the MA-100 and MA-300 EMG systems used in this tutorial this means connecting the EMG Out cable to the pre-amplifier inputs (stainless steel disks on the pre-amplifier body) and connecting the separate ground lead to the green DIN connectors on the subject back-back. This is illustrated in Figure 8 on page 6.

Checking the Signal Levels

If this is the first time that you've made a recording using the Whisper then you may want to connect up the system and try a few trial recordings to check that you have the Whisper *EMG Out* cable polarity correct. The correct signal is shown in Figure 14 where the five leading pulses in a Mode 0 or Mode 1 test signal are positive going signals although you may see some overshoot of the signal depending on your EMG system characteristics. In general the positive leading edge of the signal will have a greater amplitude than the –ve going overshoot.

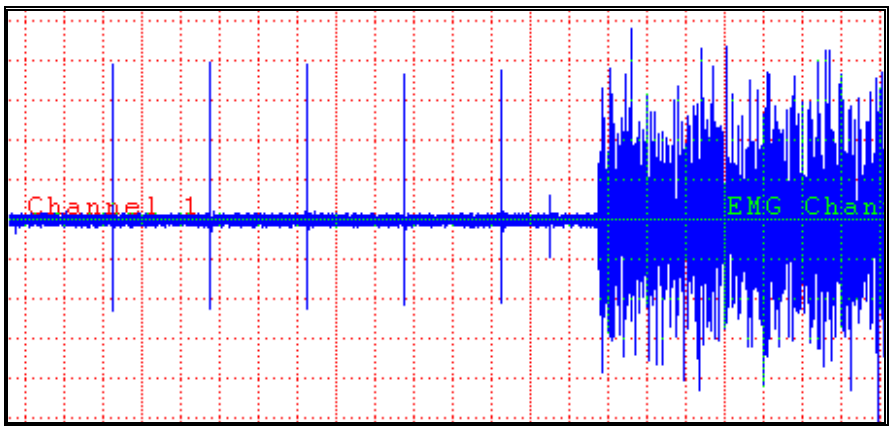


Figure 14 - the five leading pulses of a Mode 0 or Mode 1 signal should be +ve.

Because the signal levels generated by the Whisper are very low it is essential that all the equipment used in the test is grounded and shielded.

For first time recordings it is also a good idea to make a trial Mode 0 or Mode 1 recording and check that the recorded signal levels are correct – the Whisper EMG test signal should be clearly seen and should utilize a significant portion of the ADC input range as shown in Figure 14 if the EMG system gain is set correctly and the analog data acquisition system is setup correctly.

There are two possible problem areas with the EMG test signal at this point – the gain may be too high or it may be too low. In each case you should check that the analog data acquisition system is set up for the expected EMG system output range before adjusting any part of the EMG system. Both the MA-100 and MA-300 EMG systems used in this tutorial have user adjustable gain controls and these can be adjusted if necessary to produce a good test signal.

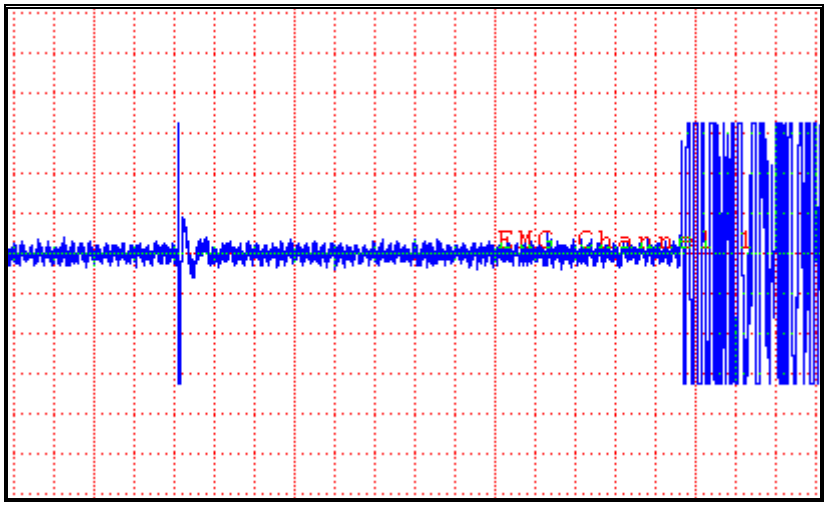


Figure 15 - Too much gain causes signal clipping

If the EMG system gain is set too high then the EMG test signal generated by the Whisper will be clipped as shown in Figure 15 – note the extremely flat appearance of the EMG signal. This produces distortion of the test signal and will cause the EMG testing software to produce erroneous results that do not accurately reflect the system performance. Signal clipping can be caused by an incorrect choice of data acquisition input levels as well as by the selection of too large an EMG channel gain.

If the EMG system gain is insufficient then the EMG signal will appear to be very low as shown in Figure 16. While this is not so much of a problem as having too much gain it is still not an optimal situation for either day to day operation of your EMG system or testing with the Whisper EMG system. If your EMG system has variable gains for the EMG channels then you should increase the gain to try and obtain a signal closer to that illustrated in Figure 14. This problem can also be caused by an incorrect choice of data acquisition input levels where the ADC card range is much greater than the output level of the EMG system.

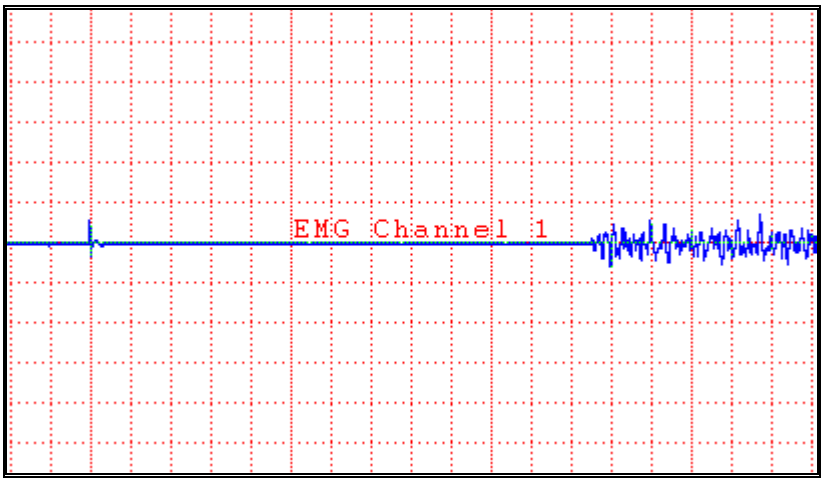


Figure 16 - Too little gain causes the signal to be lost in the background noise.

If you are working with an EMG system that does not have adjustable gain controls then it is likely that you will either see a signal that is the correct level or you will see a signal that appears to be too low. While it is possible to use the Whisper and obtain accurate results with a low EMG test signal this is not an optimal configuration for either testing or regular use.

Gain Calibration

One of the principal test performed by the Whisper is to report the EMG recording channel gain. This test requires that the recording levels are correctly set for the entire EMG signal recording chain. In other words, we expect that an input signal of one millivolt will be reported as a signal level of one millivolt. This would be a simple task except that most EMG systems produce an output level that is set at a convenient level for computers to record. Both the MA-100 and MA-300 EMG systems used in this tutorial produce output signals in the range of ±5 Volts so this signal must be scaled to accurately represent the original input level.

This tutorial will discuss the methods used to calculate this scaling factor for each of the two EMG systems (MA-100 and MA-300) in two different recording situations:

- Stand-alone tests using a Dataq ADC card recordings where the EMG information is recorded directly to a PC file.

- System tests using a Motion Capture system that generates a C3D file – this is a common file format standard that is in use in many biomechanics and gait analysis laboratories worldwide.

Stand-alone Tests

This section will discuss the gain calibration of sample recordings made with the MA-100 and MA-300 EMG systems using a stand-alone Dataq ADC card. For the purposes of this tutorial, these two EMG systems differ in their treatment of the signal in that the MA-100 system has a continuously variable signal gain while the MA-300 system offers a number of discrete switched gain levels. While this example uses a Dataq ADC card the principals described here can be applied to almost any analog data collection system.

Variable Gain Systems

The MA-100 has a continuously variable gain control for each EMG channel. This allows the user considerable flexibility in selecting an optimal EMG recording level but means that the amplitude of the recorded signal is not accurately known. Any variable gain system like this can be calibrated by applying a known input to the system and measuring the output level using the Dataq software.

The MA-100 includes a built-in calibration source that generates an 87Hz sine wave calibration signal at a level that is equivalent to 200µV RMS at the EMG pre-amplifier inputs. This calibration source can be used to calculate the system gain after the variable gain control has been adjusted to produce a suitable EMG test signal as discussed earlier. Once the variable gain controls have been set to the desired position they must not be moved or adjusted unless you are prepared to repeat the gain calibration procedure.

The calibration procedure is simple. A calibration recording is made once the individual gains have been set. The MA-100 uses its internal calibration source when the "CAL" button is pressed applies a known calibration source to each EMG input. Since we know the input signal (200µV RMS sine wave) and can directly measure the recorded level of the resulting output signal we can easily calibrate the system to record data scaled in µV or directly calculate the system gain.

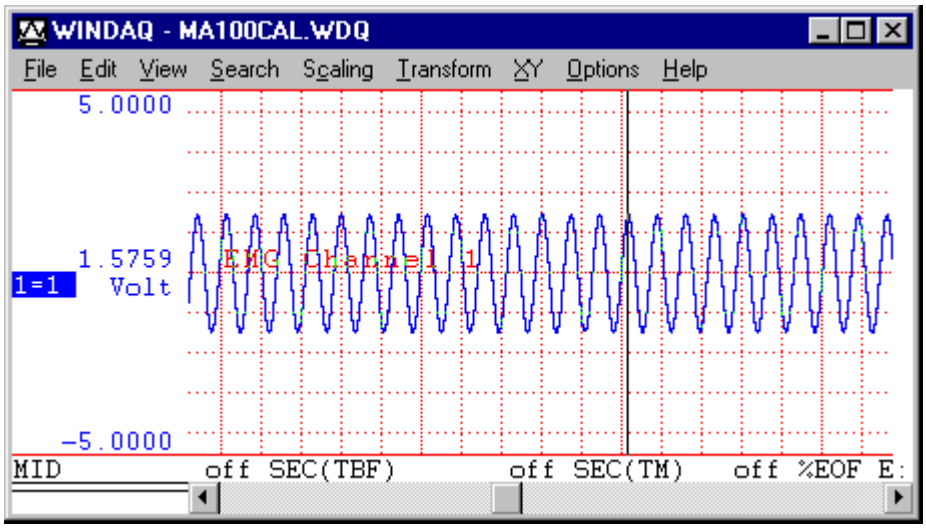


Figure 17 - A calibration level recording using a 200uV RMS input.

The calibration recording shown in Figure 17 using the Dataq Browser software that is supplied free of charge with the Dataq ADC cards. It shows the recorded signal from an MA-100 calibration signal - at this point the ADC system is calibrated in Volts – the ± 5 Volt range is shown on the left side of the display. The cursor has been moved to measure the maximum signal present in the display (Ctl-K using the Dataq software) and this value (1.5759 Volts) is displayed in the center of the range display on the left. We can use the built-in calibration function of the Dataq software (Function key F11 or assessable via the Edit menu) to scale the signal. We know that the input signal is 200µV RMS and that the output signal is 1.5759 Volts Peak.

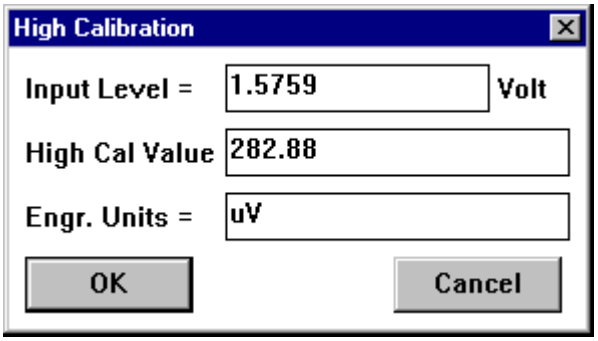


Figure 18 - Dataq peak level calibration.

It is vital that you do not calibrate a measured "peak" value with an RMS value.

Applying the RMS conversion factor (1.4144) give us a peak input signal of 282.88µV so we can use the Dataq Browser software to directly re-scale the recorded signal and display the new data units. This is done by entering a "High Calibration" value that is equivalent to the peak value of the input signal and changing the "Engr. Units" display to "uV".

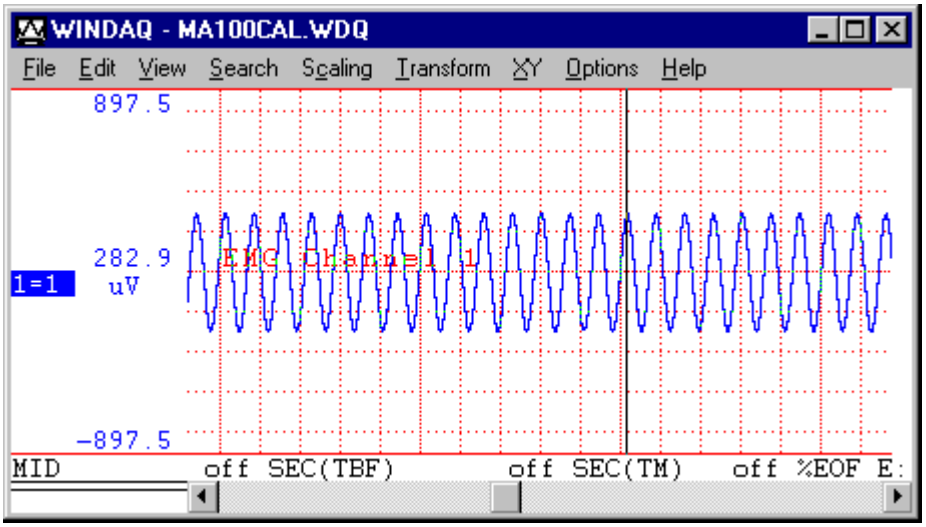


Figure 19 - The Dataq Browser calibrated in uV.

Since the MA-100 EMG System has individual gain controls on each channel, this procedure must be performed on each channel that is to be evaluated using the Whisper. Once the "High Calibration" has been performed, the Dataq Browser software will directly indicate the range of recorded signal for the channel in µV at the skin surface or pre-amplified electrode input – in the case of the illustration in Figure 19, this range is ± 897.5µV.

It is important to note that the actual "calibration" of the EMG system for data collection is performed when the range values are entering in the Dataq Analog Data Acquisition software.

This value can be entered into the Dataq Data Acquisition software as a pair of "Fixed Calibration" values (Function F12 or accessible via the Edit menu) to allow the Dataq Acquisition system to create output data files that contain test data that is scaled directly in microvolts (µV) as required by the Whisper EMG test software. Dataq files that are recorded in microvolts can be quickly converted by RData2 to create the DST files required for analysis and reporting.

Fixed gain systems

Fixed gain EMG systems may offer no user gain adjustment or may offer a limited number of preset gains, The gains may be chosen as a single value that applied to all the EMG channels or may be individually preset for each EMG channel.

MA-300 EMG Systems offers a range of individual gain settings for each EMG channel – these may either be preset to record a fixed level or preset to individual levels that are considered optimal for the EMG source under investigation. This allows the user a great deal of flexibility in selecting an optimal EMG recording level while maintaining a known gain for each EMG signal that is recorded.

The calibration procedure for fixed gain systems is very quick when using the Dataq Data Acquisition software. All that needs to be known is the input range of the signal for a given channel gain setting – in the case of an MA-300 EMG system, this value can be read directly from the manual.

If the EMG system under test provides a channel gain factor (rather than an input range) then the input range can be calculated by dividing the output range of the device by the gain. For a system with a gain of 8,000 and an output range of ± 5V this figure would be 5 Volts / 8,000 = 0.000625 Volt or 625µV peak. This value can be used to set a fixed calibration for the EMG channel by entering the values as the positive and negative limits for the data in the Dataq Data Acquisition software.

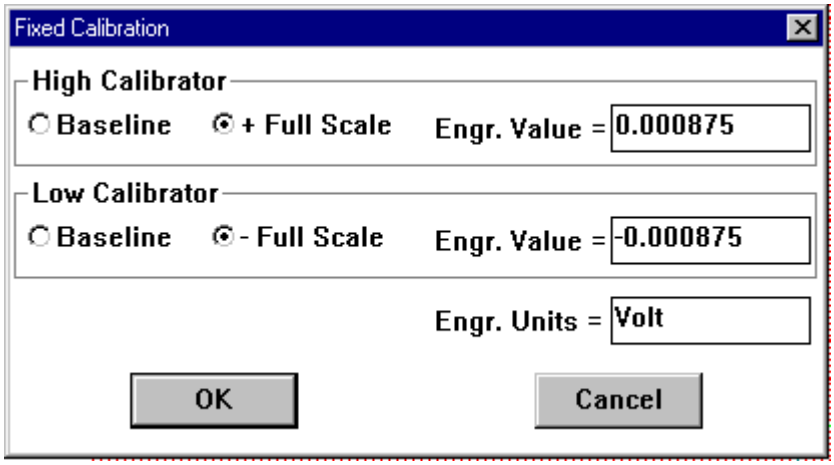


Figure 20 - The fixed Calibration can scale the data directly in uV.

The Fixed Calibration is accessed via the F12 function key or via the Edit menu option. Your ADC system is ready to record calibrated data in microvolts (µV) once this value has been set for each EMG channel that is to be tested. Remember that a system with individual gain controls for each channel will require the correct fixed calibration values for each channel.

An MA-300 system with a gain switch setting of #3 (a gain of x5714) and connected to a ±5 volt ADC will require a Fixed Calibration value of 0.000875 Volts which can be entered as shown in Figure 20.

C3D Recordings

This section will discuss the gain calibration of sample recordings made with the MA-100 and MA-300 EMG systems using a commercial motion capture system with a proprietary ADC card. For the purposes of this tutorial, the two EMG systems differ in their treatment of the EMG signal as the MA-100 system has a continuously variable signal gain while the MA-300 system offers discrete switched gain levels. This section assumes that the reader is familiar with the stand-alone calibration protocols described in the preceding pages and as a result, descriptions of the individual features of the example EMG systems will not be repeated.

Full details of the public C3D file format description together with common parameter information is available from the C3D web site at http://www.c3d.org

C3D files are a common biomechanics standard that allows analog and 3D data to be recorded in data files, together with various parameters that describe the data. A standard analog channel consists of a number of analog samples together with two gain factors that are applied to the analog signal to transform the binary samples into real-world values. These gain factors are called GEN_SCALE and SCALE. There is a single GEN_SCALE parameter that is applied to every analog channel – the value of the GEN_SCALE parameter is usually set when the data capture system is installed. Since this scale factor is applied to all analog data it is usually not changed very often – we will need to know its value but will not change it when we calibrate our individual analog channels.

The calibration for each analog data channels in a C3D file is controlled by an SCALE factor parameter – this parameter has an individual value for each channel that is directly related to the gain or input range of the channel in combination with the GEN_SCALE value. While the GEN_SCALE and individual SCALE parameters can take any value, it is normal to choose these parameters such that results in the analog channel are scaled in some known value – normally this will default to Volts. The C3D analog parameter UNITS should normally describe the measurement system for each channel.

Common values for GEN_SCALE are:

- 0.0048828 – the value of a single bit of data from a 12-bit ADC that is measuring a ± 10V input range. An individual channel SCALE value would then be 1.00 to obtain the analog data scaled in Volts.
- 0.0024414 – the value of a single bit of data from a 12-bit ADC that is measuring a ± 5V input range. An individual channel SCALE value would then be 1.00 to obtain the analog data scaled in Volts.
- 1.000000 – individual channel SCALE values must be set to 0.0048828 or 0.0024414 to obtain analog data scaled in Volts when sampled by a 12-bit ADC that is measuring a ± 10V or ± 5V input range respectively.

Many commercial motion capture systems use a standard naming procedure for data recording trials that may not allow you to specify the standard names used by the EMG Testing software. If you are using one of these systems then it may be necessary to copy and rename the C3D files after recording to facilitate the use of the Whisper EMG test software.

Variable Gain Systems

As described earlier, the calibration procedure is for an MA-100 system is simple. A calibration recording is made using the internal calibration source to apply a known calibration source to each EMG input. Since we know the input signal level (200µV RMS sine wave) all we need to do is directly measure the recorded level of the resulting output signal to calculate a scaling factor to record data scaled in µV. The exact method of generating a C3D file will vary depending on your data collection software however it is important that the analog parameters GEN_SCALE and

SCALE are correctly set to produce a calibration file output scaled in Volts as well will need to be able to read the system output levels directly.

The contents of the C3D files are easily viewed using the MLSviewer software from Motion Lab Systems web site http://www.motion-labs.com.

The exact method for setting these values will depend on the motion capture system that is used to collect the data – questions about controlling and viewing these parameters via your system software must be addressed to your data collection system manufacturer. However, independent software is available from Motion Lab Systems, Inc. that displays the values of the parameters and data within any C3D file (MLSviewer) and allows the user to edit any parameter or other component of a C3D file (C3dEditor).

The C3D file displayed in Figure 21 contains a calibration signal recorded by an MA-100 system – the C3D file has a GEN_SCALE parameter value of 1.00 and an analog SCALE value of .00488 to produce an analog display that can be read directly in Volts. The scale illustrates that the peak calibration signal is 2.23 Volts.

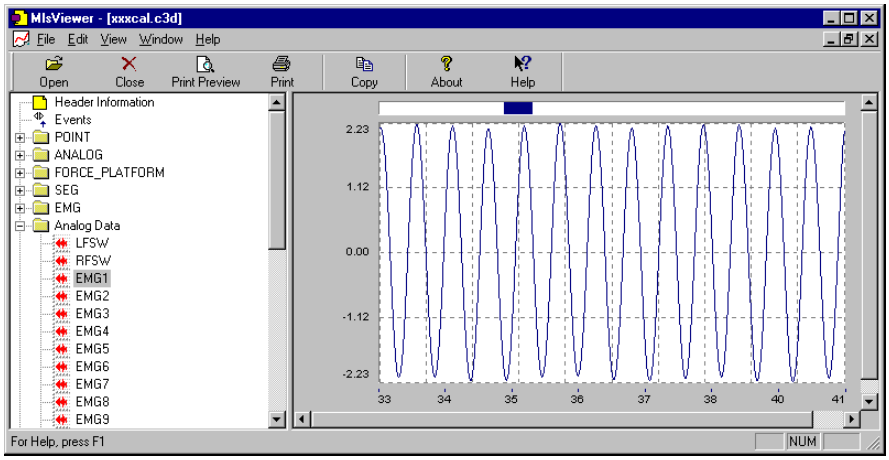


Figure 21 - Viewing an EMG calibration signal in a C3D file.

Since we know that the calibration signal is 282.88µV peak (200µV RMS) we can calculate the correct value for the ANALOG:SCALE parameter for this channel using the following formula:

$$SCALE = \frac{ADCrange}{\frac{resolution * ADCgain * EMGgain}{GENSCALE}}$$

Where:

EMGgain = (Vout / Vin) = 2.23 / 0.00028288 = 7883

ADCrange = 20 Volts

ADCgain = x1

resolution = 4096 (12-bit resolution)

Warning: At the time of writing, Oxford Metrics Vicon Workstation applications have a bug that causes all SCALE factors of less than 0.000001 to be stored incorrectly. Please contact Motion Lab system or your supplier if you encounter difficulties creating the correct SCALE values.

Using an ADCrange of 20 (the ADC channel range is ± 10Volts), an EMG system gain of 7883 (Vout / Vin) and a GEN_SCALE values of 1.00 yields a value of 0.00000062 for the ANALOG:SCALE parameter to calibrate this channel in microvolts at skin surface. You should change the ANALOG:SCALE value in the C3D file to this value using the facilities provide in your C3D file creation software. This calculation must be performed for each channel in the C3D file that is to be calibrated. Note that this calculation should only be done for the EMG channels – the ANALOG:SCALE parameter for force platforms and other analog channels should not be altered without careful consideration of the effects of any change.

Normally the analog SCALE parameters are created with the correct values when the C3D file is created using the software application supplied by your vendor. The SCALE parameter, and other parameters may also be directly modified using programs such as C3dEditor, available from Motion Lab Systems, Inc.

Fixed Gain Systems

An Excel spreadsheet is available from Motion Lab Systems that documents the precise calculations needed to calculate C3D scale factors.

MA-300 EMG Systems offer individual gain settings for each EMG channel that may be preset to record specific gain levels for each EMG channel. This type of system, with a known gain factor for each channel or switch setting can be used to generate calibrated C3D file data very quickly. All that needs to be known is the input range of the signal for a given channel gain setting – in the case of an MA-300 EMG system, this value can be read directly from the manual or calculated using the formula recommended by your C3D data collection system manufacturer.

As in calculations for variable gain systems, the calibration scaling factor used for a fixed gain EMG system will be applied to the individual ANALOG:SCALE parameters for the channels under investigation while leaving the universal ANALOG:GEN_SCALE parameter unchanged as this affects all the analog channels in the C3D file.

For C3D file recordings made with an MA-300 using the #3 gain setting using an ADC with a ±5 volt range, and a GEN_SCALE parameter value of 0.00488, the individual channel ANALOG:SCALE factors should be set to the value of 0.00009083 to scale the recorded EMG test signal from the Whisper in microvolts.

The #3 gain setting is selected because this is the optimum input range on an MA-300 system for the Whisper tests which generate an EMG signal in the range of +742µV to -670µV. A higher gain setting would cause the Whisper test signal to exceed the input range of the EMG system under test (see Figure 15 on page 25 for an example of this type of problem).

The individual SCALE value for the EMG channels can be determined from information provided with the EMG system user manual or calculated directly as follows:

$$SCALE = \frac{ADCrange}{\frac{resolution * ADCgain * EMGgain}{GENSCALE}}$$

Where:

EMGgain = 5508

ADCrange = 20 Volts

ADCgain = x2 (±5 volt range)

resolution = 4096 (12-bit resolution)

Thus:

$$SCALE = \frac{\frac{20.0}{4096*2.0*5508.0}}{1.0} = \frac{20.0}{4096*2.0*5508.0} = 0.0000004$$

The *EMGgain* figure is the total amount of amplification applied to the signal from skin surface to output of the EMG system, as applied to the input of the ADC. If any additional signal processing equipment is placed in-line between the EMG system output and the ADC data sampling system then the gain (if any) of this item must be included in the EMGgain figure. Note that the gain figure used here is a nominal gain – due to component tolerances this figure may vary from the typical quoted gain value for a specific setting. Consult your EMG system manual or equipment manufacturer for details of acceptable tolerances for this figure.

Note that the value of the system gain of the EMG system being tested is easily estimated by dividing the maximum output voltage of the system by the maximum input voltage for a given gain setting – in this case 10 Volts divided by 0.00175 Volts or 5,714 – however, in this case various component tolerances are known to reduce the gain for this setting to a figure of 5508.

The ADCrange is considered to be 20 Volts in this instance although the actual range of the ADC card is quoted at ±5 volts. This is due to an ADCgain factor of x2 that is applied within the ADC card. This has the effect of amplifying the incoming signal to effectively reduce the ADC input voltage range to 10 volts (+5 Volts to –5 Volts) which accounts for the manufacturers quoted range of ±5 volts.

The ADC card has 12 bits of sampling resolution resulting in a total resolution of 4096. GEN_SCALE is a (usually fixed) universal scaling factor in the C3D file and usually has a value of 0.00488 or 1.00 although other values are acceptable.

It is important that the SCALE value is calculated and entered correctly as this determines the scaling of the EMG signals that are recorded in the C3D file although it does not otherwise affect the quality of the signal. Incorrect scaling of the test signals from the Whisper is a common problem when users first start to examine the EMG signals. It is recommended that anyone using the C3D file format should carefully examine the data scaling and verify that it is correct before attempting to analyze the data with the Whisper EMG Analysis Software. A C3D and DST file viewer (MLSviewer, illustrated at the end of this chapter) is available from the Motion Lab Systems, Inc web site at http://www.motion-labs.com.

Recording the Test Signals

Once you have made some initial basic tests to verify the correct connections, gain levels and the recording parameters, you are ready to start making some test runs or recordings. The Whisper Mode 0 provides the best test signal to the initial set up of your recording or test environment. This mode produces five leading pulses at intervals of one second. Each pulse is a single positive going square wave with an amplitude of 500µV and a duration of one millisecond. These timing pulses are used by the Whisper EMG Test Software to determine the sample rate of the system under investigation.

Note that the high frequency component of the rising and falling edges of the square wave timing pulse will be altered by the frequency response of the system components under test. As the timing pulse contains a DC component you will not be able to measure the pulse amplitude accurately with any EMG system that incorporates a High Pass filter.

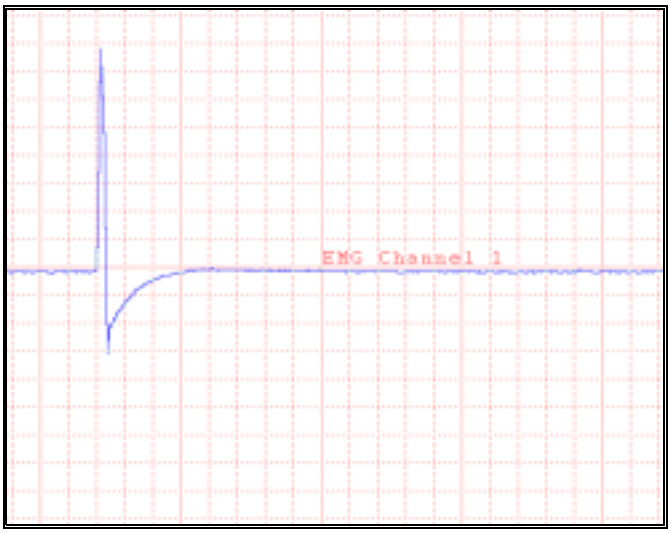


Figure 22 - Whisper timing pulse (20Hz - 2,000Hz bandwidth)

A brief switching transient may be seen halfway between the last timing pulse and the start of the EMG signal – this is normal and can be ignored.

The digitized Whisper EMG signal starts exactly one second after the fifth timing pulse and includes a common mode component. Select Whisper Mode 1 to generate a test signal that does not contain any common mode signals – this is useful if you are testing an EMG system that has a mono-polar input or has a very low common mode rejection ratio.

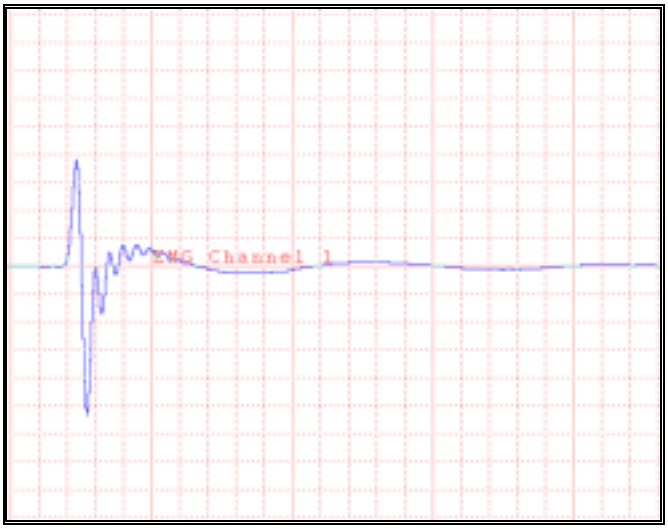


Figure 23 - Whisper timing pulse (20Hz - 500Hz bandwidth)

The following items are good indicators of a quality EMG test recording using a test signal generated by the Whisper in either Mode 0 or Mode 1.

- Five positive going timing pulses should appear at one second intervals prior to the start of an EMG signal. The amplitude of the timing pulses is not critical as this will be affected by the frequency response of the system under test. If the timing pulses appear to be negative then you will need to reverse the EMG signal connections to the inputs of the device that is being tested.
- The EMG signal should start one second after the last timing pulse and last for fifteen seconds followed by a quiet baseline signal. If you have

recorded five timing pulses then this will require a recording that is at least twenty two seconds long.

- The EMG signal should be clean and should not clip at the maximum and minimum recording signal range. There should be no significant difference in EMG amplitude between a Mode 0 and Mode 1 EMG test signal. If you find that Mode 0 EMG test signals are very large while Mode 1 signals appear to be much lower in amplitude then the equipment under test may have a common mode problem.
- The peak EMG signal amplitude should be approximately

Once you have established that the signal generated by the Whisper appears to be appropriate for testing the system you will need to make three separate data recording for the EMG testing software. These will normally be:

- Mode 0 – five timing pulses followed by fifteen seconds of EMG with a common mode component.
- Mode 2 – fifteen seconds of common mode signal without any EMG signal.
- Mode 3 – ten seconds of baseline without and common mode or EMG signal.

You must use the correct file name format for your EMG data files if you wish to use the EMG-Equipment-Tester software to analyze the data.

If you are testing an EMG system that does not have a differential input and cannot reject a common mode signal, or has problem with large common mode inputs then you should substitute a Mode 1 test for the Mode 0 test. If you want the EMG testing software to automatically recognize the file types then you should choose file names that end in ***En*** for Mode 0 tests (EMG), ***Cn*** for Mode 2 tests (CMRR) and ***Nn*** for Mode 3 tests (noise/offset) where ***n*** is a number from 0 to 9 that can indicate the test number for multiple tests. It is common to use the date of the test as part of the filename so a typical set of filenames for a test would be:

000618E1.C3D – EMG test data recorded on 18th June, 2000.

000618C1.C3D – CMRR test data recorded on 18th June, 2000.

000618N1.C3D – Noise and offset test data recorded on 18th June, 2000.

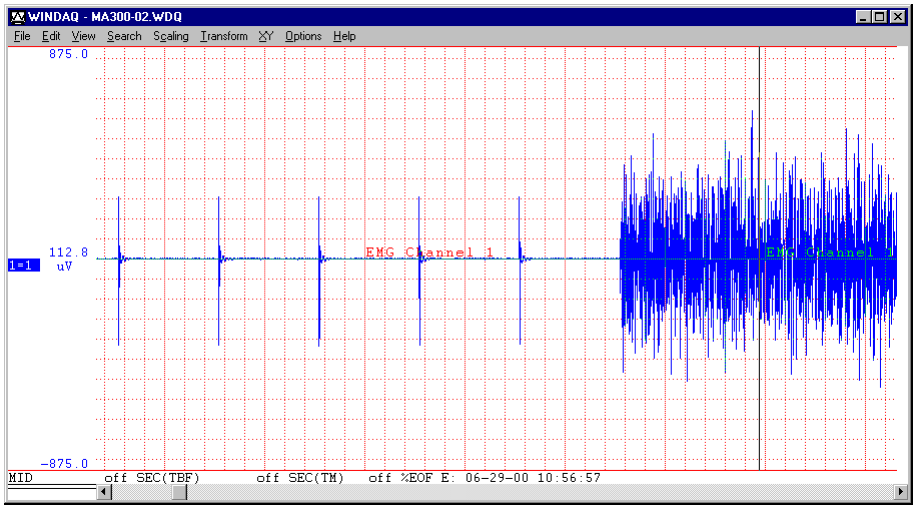


Figure 24 - EMG showing the first 5 timing pulses.

The raw data files can be reviewed using any suitable data file viewer – the contents of C3D files may be checked using software supplied by your data capture system

manufacturer or by using the MLSviewer software available from Motion Lab Systems web site at http://www.motion-labs.com. Data recorded using Dataq software can be viewed using the Codas WINDAQ browser software. A quick check of the start of any Mode 0 or Mode 1 test should produce an EMG data display similar to that shown in Figure 24 – it may be necessary to adjust the horizontal time-base to view the entire trial.

Converting the data

DST files use a standard file format developed by CAMARC in the 1980's. Detailed information on the file format and the various lexicons is available from the Motion Lab Systems web site. http://www.motion-labs.com

The EMG Equipment Test Software supplied with the Whisper requires that the data files submitted to it are in DST format. This is a standard ASCII text file format that can be used to describe a broad range of data with the exact format of the contents of a DST file being specified by a *lexicon*. In this case the Whisper *lexicon* describes a header that must exist at the start of the file to provide some basic information about the test situation while the test data is stored as a series of integers with a count of "1" representing one microvolt. An example of this format can be found on page 63 in Appendix A1 at the end of this manual. If your data recording and collection system produces data in this format then you can immediately start using the *EMG-Equipment*-Tester software supplied with the Whisper.

However, while the DST format commonly used for storing processed data, it is not widely used to store raw data so we must usually convert the recorded EMG data from the Whisper before we can use the *EMG-Equipment*-Tester software to analyze the information and produce a report. Many common file formats, including C3D and Dataq CODAS formats, can be converted by RData2, an ASCII software conversion tool that is included with your purchase of the Whisper from Motion Lab Systems. RData2 can read many common binary biomechanics data formats and generate a wide range of ASCII output data, including DST file using the Whisper lexicon.

Configuring RData2

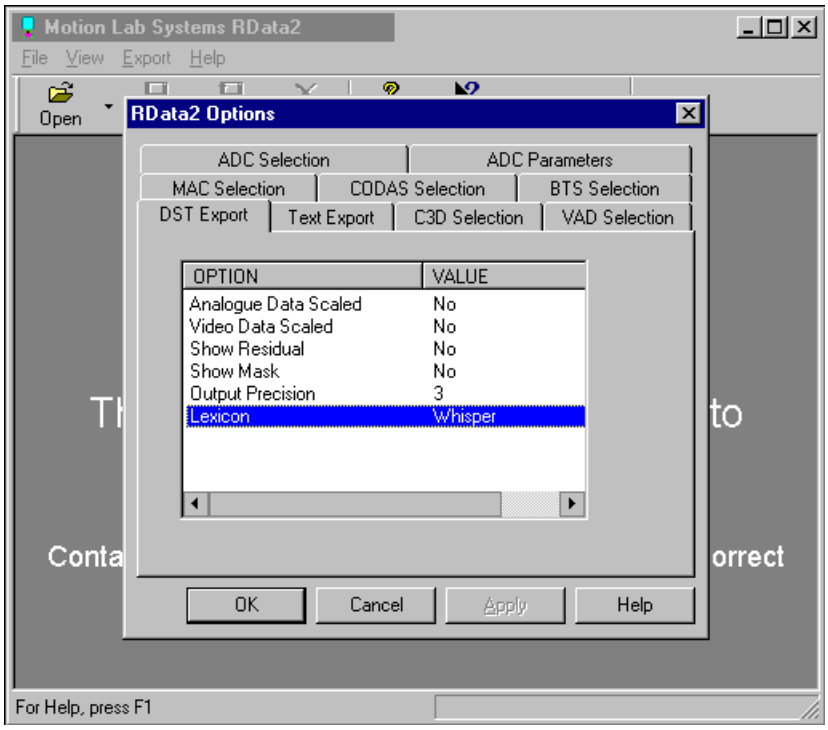
At the time of writing, RData2 supports the generation of Whisper DST files from C3D files, Motion Analysis Corporation .ANA files, and Dataq ADC files only.

The RData2 application from Motion Lab Systems Inc., is supplied with its own user guide and registration information and must be installed separately from the Whisper *EMG-Equipment*-Tester software. The registration information provided with your copy of RData2 must be entered as described in the RData2 User Manual before you can use the application to generate DST formatted data files suitable for analysis. Once the RData2 application has been registered you will need to specify the DST lexicon to be used (RData2 supports several different lexicons) and customize it with information about your testing environment and location.

Selecting the Whisper Lexicon

Start the RData2 application and select "Defaults…" from the "Export" menu and choose the "DST Export" option tab. In this tab you will find the Lexicon option which will initially default to "MLS". Click on the "Lexicon" option until it displays "Whisper" – Rdata2 will now default to producing DST files using the Whisper lexicon whenever a data file is exported.

DST files generated using the "Whisper" lexicon will have a specific file header and contain EMG data scaled in microvolts (μV). An illustration of this file lexicon can be found in this manual in Appendix A1 on page 63.



In addition to selecting the Whisper lexicon, make sure that the Export option "DST File" is checked so that the application will produce DST format files and not plain ASCII text files.

Using RData2 with Motion Analysis data files

In addition to selecting the Whisper lexicon, Motion Analysis users who are recording data in the ANA file format will need to select an appropriate scaling factor for the data. This is set in the "MAC Selection" tab in the options menu.

Entering your Test Information

The final configuration option that is need is the information for the Whisper DST file header. The only required item in this menu (ADC Resolution) is set by default to "12" – a common value. The remaining information is optional and can be entered as required via the RData2 "Export" menu selection "Whisper Information…"

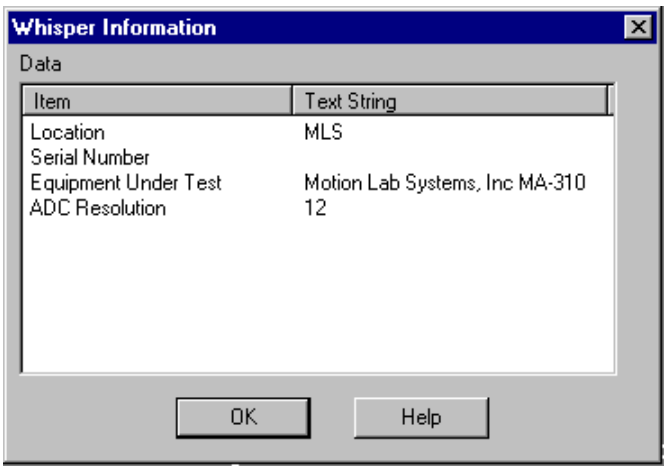


Figure 25 - The RData2 "Whisper Information" menu.

The menu also contains a setting for "ADC Resolution" which is set to the value of 12 by default when RData2 is installed. If your data collection hardware is not a 12-bit resolution system then you must change this value to reflect your specific ADC capabilities.

All of the data in the Whisper Information menu can be changed by double clicking on the item and entering the appropriate information.

The menu allows you to enter some information about the location of the testing site, a serial number and a description of the testing configuration. This information is saved in all Whisper formatted DST files and can be used for quality control and configuration purposes. Full details of these header options can be found on page 57 in the chapter on File Descriptions.

Using RData2

It is a simple process to generate the files required by the *EMG-Equipment*-Tester software once RData2 has been registered and configured to generate DST formatted files using the Whisper lexicon. The process is very simple and consists of opening the raw EMG data file and then saving the file – this process automatically exports the data to a DST format file with the same file name in the same directory as the original data file. The original data file is unchanged.

A progress bar is displayed in the bottom status line of RData2 during all data export operations.

You can use the "Save As" option to change the file name and the location of the exported data and change the type of data file that will be written out. RData2 can be closed once you have converted all the raw Whisper data files to DST file. The resulting DST files can be viewed using the MLSviewer software, available from Motion Lab Systems, and can be opened by the *EMG-Equipment*-Tester software.

Note, that for C3D files and Dataq WDQ files, it is essential that all required scaling factors have been applied to the raw EMG data file before RData2 is used to export the Whisper DST file. If you find that you have to change an EMG channel scaling factor then this must be done in the original data file and the data exported again to overwrite the older DST file.

Using RData2 with ANA files

ANA files, collected with a Motion Analysis Corporation system require that a specific gain factor is entered into RData2 before generating a Whisper DST file.

EMG data files generated using a Motion Analysis Corporation system must be in the "ANA" compressed ASCII format in order to be read by RData2. This file format does not have any provision for scaling the individual data channels and so the scaling factor must be determined and entered in the RData2 "MAC" format options tab. In general, data collected on a Motion Analysis Corporation system in the .ANA format uses a fixed gain range – normally this is ±5 Volts although gains corresponding to ±10V, ±5V, ±2.5V and ±1.25V can be used.

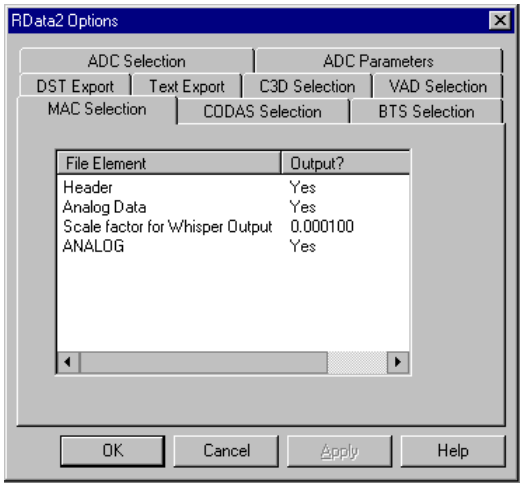


Figure 26 – The MAC selection tab includes a specific scale factor for Whisper output.

Viewing the Whisper DST file

The EMG-Equipment-Tester software can be run once a DST file has been created. This software application provides the ability to view (via the Quickview option) the contents of any suitable DST file. However, if the DST file contains data or parameters that are out of the expected range then the EMG-Equipment-Tester software may have problems opening and viewing the data. This type of problem typically occurs if the DST file has been created with the wrong format or scaled incorrectly so that it contains data that is outside the range that the software is expecting to analyze.

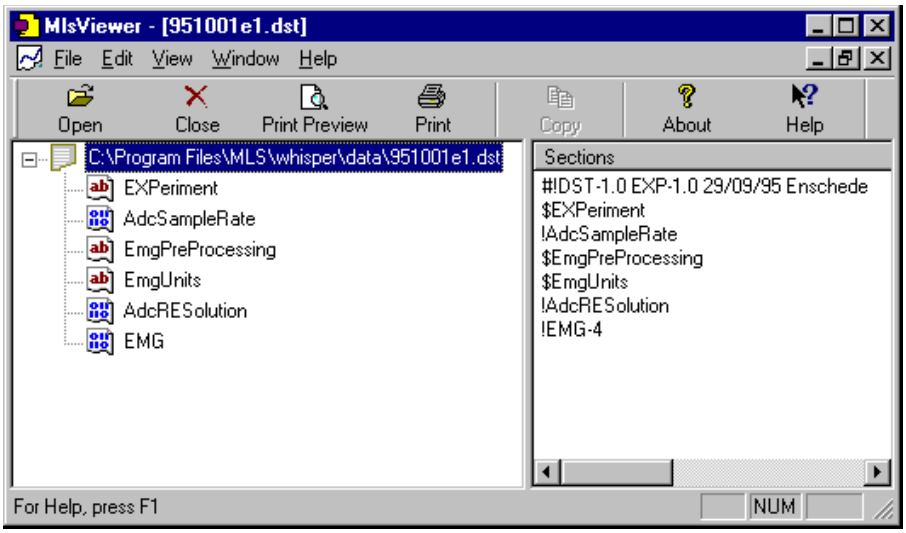


Figure 27 - MLSviewer can display the DST file structure, parameters and file header.

MLSviewer is a general purpose DST file viewer that can open almost any DST formatted file and display the contents of the header and all parameters and data within the file. This application can often be useful if the EMG-Equipment-Tester software fails to open a new DST file for any reason.

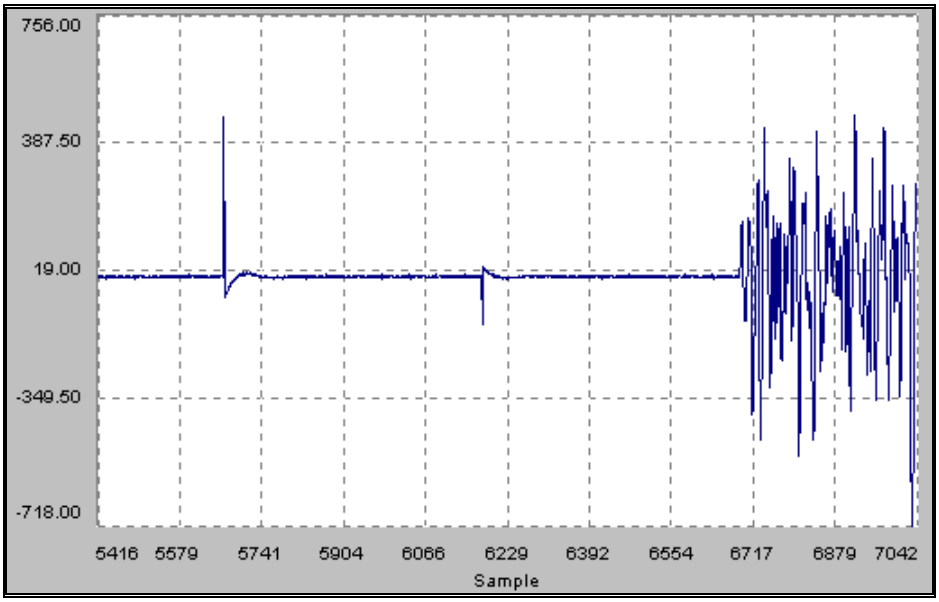


Figure 28 - MLSviewer can display the raw data in an easy to understand view.

This allows the user to check any DST file to verify that the format is correct and that the DST file header contains accurate information about the data. A typical Mode 0 or Mode file should contain EMG data in the range of +800 to –800 µV and be preceded by five positive going timing pulses. The MLSviewer has a flexible viewing mode that can be used to display the entire data recording as well as allowing the user to zoom in to view individual data samples in an easy to use graphical display.

The MLSviewer data display is auto-scaled and allows the user to rapidly determine that the Whisper data has been scaled correctly - Figure 28 illustrates the transition

from the initial Whisper timing pulses to the start of the simulated EMG signal. The data in this illustration (a DST file) is shown scaled in the range of +756 to –718 (vertical scale) over a sample range of 5416 to 7042.

Most of the initial problems with generating DST files from raw Dataq or C3D files can be traced directly to errors in the file format or the scaling of the data. The MLSviewer is a very useful tool that can provide a great deal of useful information about any DST file, as well as its built-in ability to display the contents of industry standard C3D files.

The EMG Test software

Introduction

This manual and tutorial uses, as an example, data from a Whisper EMG signal generator recorded and analyzed using an EMG amplifier in the R.R.D. laboratory in Enschede, the Netherlands.

The EMG-Equipment-Tester software has been developed by Roessingh Research and Development as a tool to analyze test records of *EMG-Equipment* using the standardized EMG signals generated by the Whisper. The software is able to view and analyze the data from up to four EMG channels simultaneously and displays the EMG, common mode, noise, and DC offset parameters. The software also allows the user to compare the current test results with any prior test results using the same equipment or with test results obtained in a colleague's laboratory. As such it is not only possible to test the performance of your own equipment but it is also possible to compare the performance of your system with other EMG recording systems or environments.

The following chapters explain how to use the EMG-Equipment-Tester software and assumes that you have read the earlier chapters explaining the Whisper EMG signal generator. If you have not done so, please read the earlier chapters that explain the Whisper functionality and operating modes as this information will not be repeated here.

The EMG-Equipment-Tester software reads EMG data that has been stored in files using the DST file format defined by CAMARC. If your data collection system does not produce EMG data files that can be stored in the DST format then you may need to use the accompanying RData2 software package. This creates DST files in the correct format from C3D files and WDQ files created by Dataq data acquisition software programs (CODAS and WinDaq/Pro).

Software installation

The best way to avoid problems during installation is to read the manual before you start the installation.

The EMG-Equipment-Tester software has been developed under LabVIEW and runs under the Microsoft Windows 95, Windows 98 and Windows NT operating systems. Before installing and using the EMG-Equipment-Tester software, you therefore need to understand the basic skills for working with your version of the Microsoft Windows operating system.

The typical requirements for an IBM compatible PC to run this software are:

- At least a 100MHz Pentium processor with a minimum of 32 Mb of main RAM memory and 10 Mb of free disk space - the software may be installed on a network drive.

- An SVGA monitor and graphic adapter that supports at least 256 colors and a color printer supported by the operating system.

You can use the Windows Add/Remove Programs option in the Control Panel to install the application from a floppy disk. This will install the program on your system together with some example files that you can use to demonstrate the program.

If you accept the default options during installation, then you will have created a short-cut in the Gait Lab menu group called Whisper together with a desktop short-cut and icon.

Getting Started

The EMG-Equipment Tester is the analysis tool which comes with the Whisper and was developed specifically to analyze the data recordings produced by the Whisper. The analysis results from equipment tests can be stored in files on disk – up to four EMG channels can be analyzed simultaneously.

Each stored analysis is informally known as a *Spot Check* and the results of the analysis are stored in a *.res* file. A sample results file called *YOURSIM.RES* is included with the software and is documented in Appendix A1.

The EMG-Equipment Tester is able to compare two different *.res* file analysis records with each other. The *Spot Check* feature can be used to provide a history of EMG equipment tests of your EMG instrumentation as well as documenting the performance of your EMG instrumentation against the EMG equipment in another laboratory.

The structure of the EMG-Equipment-Tester software is reflected in the diagram shown below:

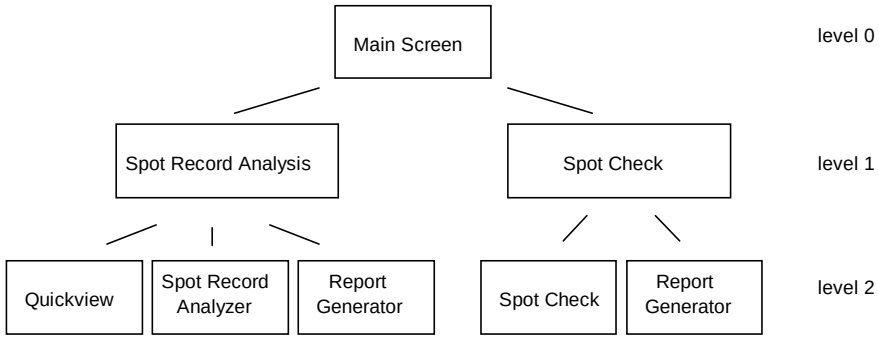


Table 3 - Function Diagram of the EMG-Equipment-Tester software.

From the main menu you can choose to do a *Spot Record Analysis* or to do a *Spot Check*.

Within a *Spot Record Analysis* you are able to:

- View the data files recorded using the Whisper (*Quickview*).
- Make a Spot Record of a data file which has been recorded using the Whisper. You can extract a number of EMG parameters from the data and store these parameters into a file for further investigation (*Spot Record Analyzer*).

- Print the results of a Spot Record to the default Windows printer (*Report Generator*).

Spot Record Analysis will analyze data from up to four different EMG channels at one time for multi-channel equipment tests.

Within a Spot Check you are able to:

- Compare two Spot Records with each other in order to check the performance of your EMG instrumentation (*Spot Check*).
- Print the results of this Spot Check to the printer (*Report Generator*).

The Spot Check allows you to analyze data that provides detailed information about your system performance and specifications. Data from independent tests made over a period of time can be compared to verify continued system performance.

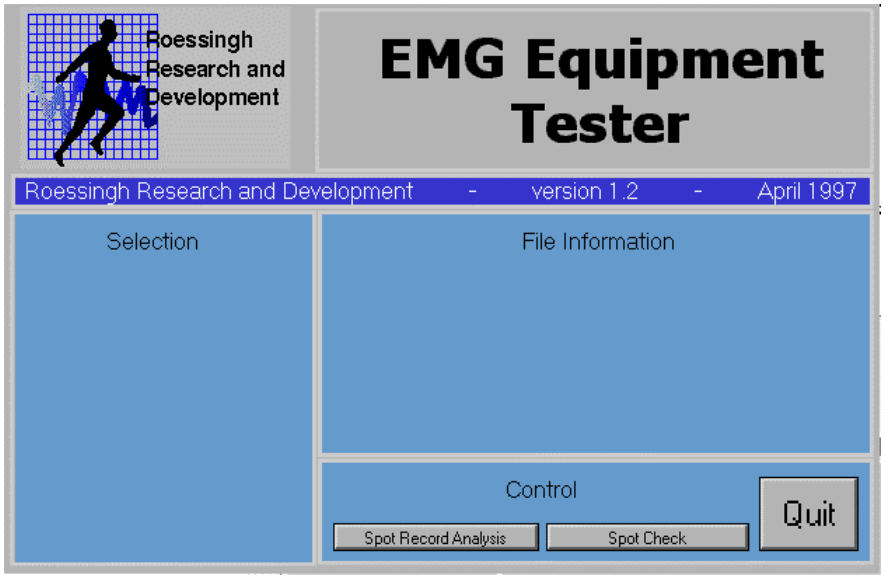


Figure 29 – The main screen of the EMG-Equipment-Tester software.

If the EMG-Equipment-Tester software has been installed correctly, it can be run by double clicking on the EMG-Tester icon on the desktop or by running it from the Start menu applications group that you specified when the program was installed. This is normally the *Gait Lab* group.

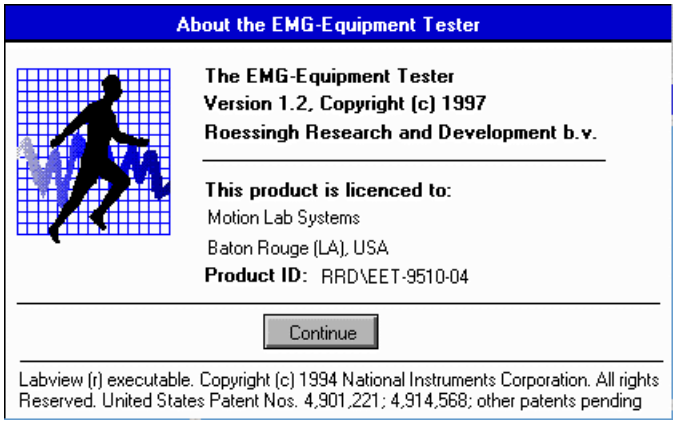


Figure 30 - The software "splash" screen showing the licensing information.

When the application first starts it will display a "splash" screen that displays some information about the software such as the registration number and site location. This screen will disappear after twenty seconds, or as soon as the *Continue* button is pressed. The EMG-Equipment-Tester software will then display the main screen as shown in Figure 29. You are now ready to analyze test recordings that have been collected using the Whisper.

Using the EMG-Equipment-Tester software

This chapter is a tutorial in the use of the EMG-Equipment-Tester software that uses a number of sample data files that are provided as part of the software installation. This tutorial starts from the main screen of the EMG-Equipment Tester shown in Figure 29. This screen contains three windows, the Selection window, the File Information window and the Control window.

You can exit the EMG-Equipment Tester by clicking on the Quit *button in the main menu. The software will then return you to the Windows operating system.*

While using the EMG-Equipment-Tester software, you can expect buttons and selection switches to pop-up in the Selection window. These buttons and switches allow you to select the task and data-analysis operations that you want the software to perform. Depending on the analysis or operation requested, the EMG-Equipment Tester will prompt the user for the data files needed to complete the operation. These requests will appear in the File Information window. The analysis operation can not start until the appropriate information is supplied. Buttons in the Control window allow you to start the analysis or move to a different application option.

The next two sections discuss the basics to perform the *Spot Record Analysis* and *Spot Check* options which are entered by clicking on the corresponding button in the Control window.

The Spot Record Analysis screen

Click on the *Spot Record Analysis* button in the Control window of the Main Screen to enter the Spot Record Analysis – you should see the screen shown in Figure 31. The *Exit to Main* button in the Control Window allows you to return to the Main screen to switch to *Spot Check* option or exiting the application if you wish.

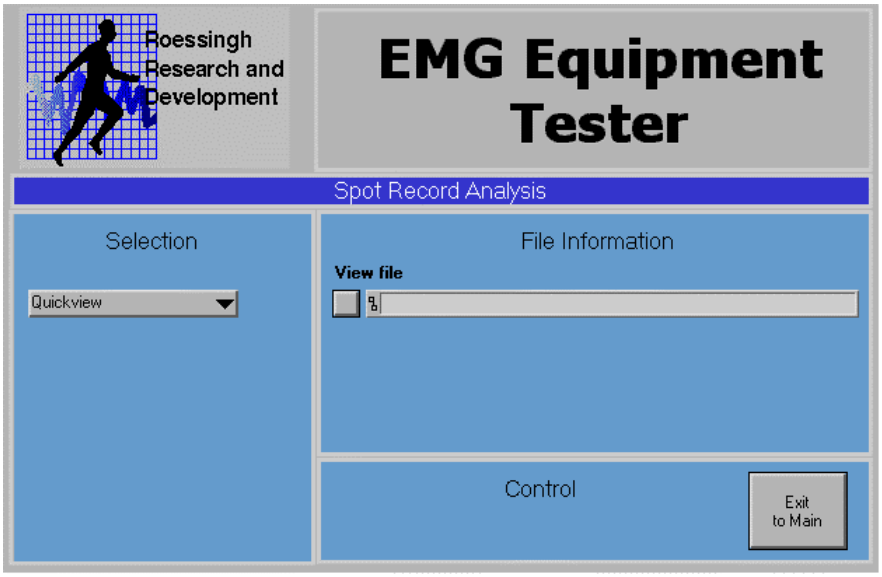


Figure 31 - Spot Record Analysis screen of the EMG-Equipment Tester

The default *Spot Record Analysis* option is *Quickview* and this is the option that is initially displayed on the selection button in the *Spot Record Option*. Clicking on this button will display a menu that allows you to select one of three possible *Spot Record Analysis* options: *Quickview*, *Spot Record Analyzer* and *Report Generator*.

Viewing a file in Quickview

If you select *Quickview* in the Selection window, the File Information window will contain a single file request dialog. Enter the name and the path of the file that you want to view by typing it directly into the space provided or use the control on the left of the dialog box to open a window and browse for the file.

When using the browse file selection method the "open" window will only display data files with the appropriate file type – in this case only .dst filenames will be shown.

For the purposes of this tutorial select the file *951001e1.dst* which has been installed in the \data sub-directory. To select the file you must click on the file and then click the open button. The EMG-Equipment-Tester software will then select this file for display and will cause the "Start Analysis" button to appear at the bottom of the control window. If any problems are detected in the selection procedure then the Message <*Not A Path*> will appear in the File Information dialog box. If this happens the *Start Analysis* button will not appear. In that case you have to repeat the file selection procedure until the file has been selected.

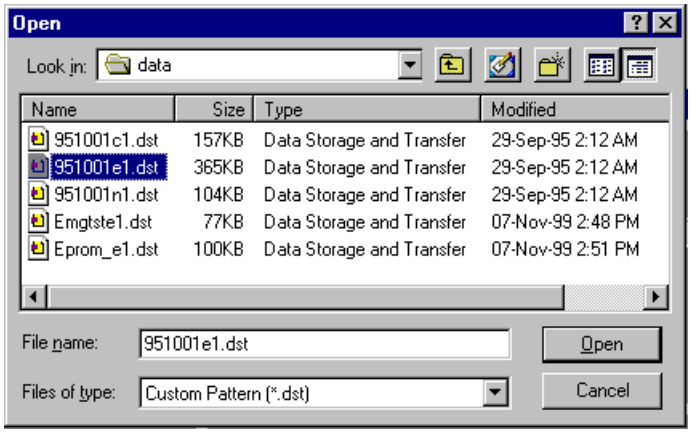


Figure 32 - The file open dialog.

Once the file has been selected the EMG-Equipment-Tester software is ready to view the data contained within file. Click *Start Analysis* to start the Quickview option. The selected EMG data file will then be loaded and the Quickview screen displayed. After a brief pause (depending on your CPU and computer speed), four graphs will be drawn on the screen.

The demonstration file that you have selected contains raw EMG data recorded from a four-channel equipment test. Therefore, you will see four graphs in the Quickview screen as soon as the data loads. The display will show the first second of each data recording on the screen. The Y-values of all graphs are in the same range. The minimum and maximum values of this range are shown.

The initial view of the sample file will display four flat lines as the start of each channel of the sample recording containing the five timing pulses that occur in each Mode 0 or Mode 1 Whisper signal.

Quickview allows you to easily check that all the channels have recorded the standard test signal in the same way.

Quickview allows you to scroll quickly through your recordings. It can be used to get a quick overall view of the data quality and allows the user to check that the recorded EMG signals are appropriate to be used in the *Spot Record Analyzer*. It has an easy to use interface containing only three buttons. By clicking on the <<< or the >>> button the graphs will scroll to the left or the right.

If you scroll through the sample recording by continuously clicking on the >>> button, you will easily see that the standard Whisper test signal has been recorded correctly. The start of the recording will display the timing pulses, one second apart, quickly followed by the digitized EMG signal. Note that the signal has been recorded at very similar levels in each channel.

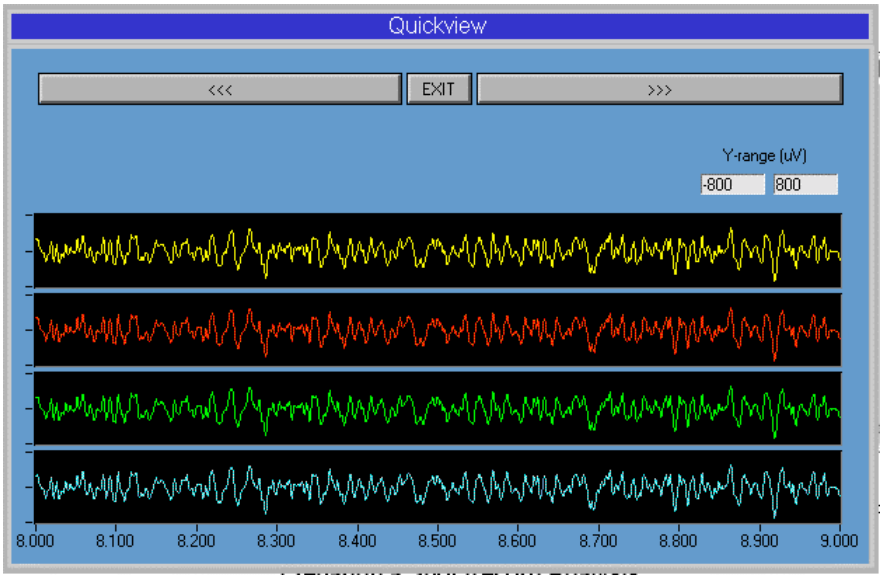


Figure 33 - Quickview screen of the EMG-Equipment Tester.

You can leave *Quickview* by clicking on the *EXIT* button in the center of the top three buttons. Then you will return to the *Spot Record Analysis* screen.

Preparing a Spot Record Analysis

You can perform a multi-channel equipment test by selecting the *Spot Record Analyzer* option in the pop-up-menu button in the Selection window of the Spot Record Analysis screen. Selecting the *Spot Record Analyzer* causes five buttons to appear in the Selection window.

The five buttons allow you to select which parameters, which you want to measure and display. For the tutorial please select all parameters by clicking on each button. As you select the buttons you will see the appropriate filename dialog boxes appear in the File Information window. Note that when you have selected all five parameters there will be three separate file name dialog boxes displayed. These are *EMG file*, *Common Mode file* and *Noise/Offset file.* You can either type the filename and path into each dialog box directly or use the browse feature to point and click on the appropriate filename.

The *EMG file* is the file that contains the Mode 0 / Mode 1 EMG test recording from the Whisper. A Mode 0 or Mode 1 recording provides information on EMG frequency and amplitude data properties, as well as timing and dynamic information.

The EMG-Equipment-Tester software will only open files with the correct filename format, e.g. nnnnnnEn.DST

As a result selecting any one or more of the first three buttons will display a single filename dialog request for the EMG file. By convention the EMG filename will have the format *??????E?.DST* and only filenames with this format will appear in the file open window.

To display the sample data supplied with the EMG-Equipment-Tester software you should select the file name 951001E1.DST that is provided with the installation.

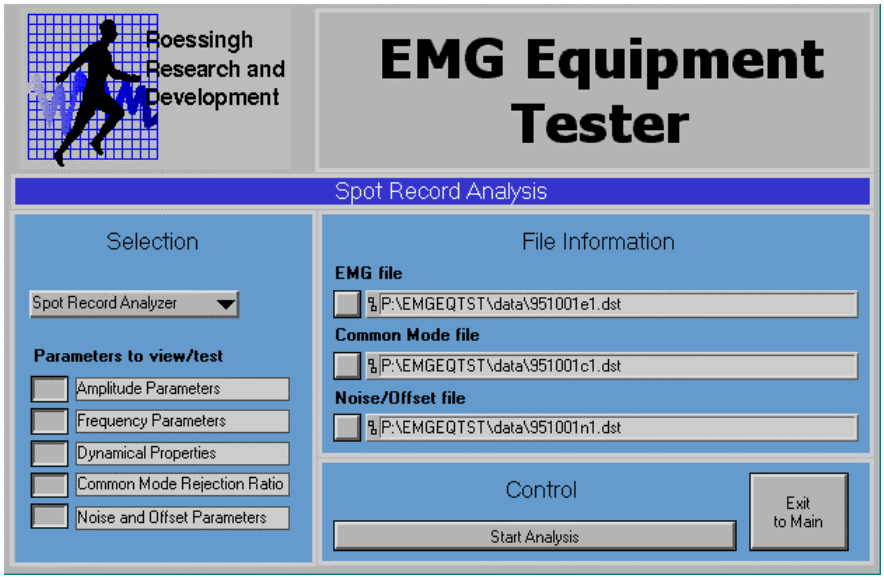


Figure 34 - Spot Record Analysis window when preparing a Spot Record Analysis.

The *Common Mode file* is the file that contains the Mode 2 Whisper recording. This file is generated when the Whisper is used to apply a common mode test signal to the EMG instrumentation. This test enables the Common Mode Rejection Ratio (CMRR) to be measured.

The dialog box requesting the Common Mode File will appear as soon the Common Mode Rejection Ratio button is selected in the Selection window. You should enter a filename in the Common Mode file dialog box – by convention, only those files which have the format *??????C?.DST* will be displayed in the file open browse window. A file can be selected by double clicking on its name – for the purposes of this tutorial select the file 951001C1.DST that can be found in the data directory that is created when the application is installed.

The *Noise/Offset file* is the file that contains a Mode 3 recording. This recording is used to measure the noise and DC offset levels the EMG instrumentation. The dialog box for this filename will appear as soon as you select the Noise and Offset Parameters option in the Selection window. Only files that have names in the format *??????N?.DST* will be displayed. A file can be selected by double clicking on its name.

In order to demonstrate a full *Spot Record Analysis*, 3 demonstration files have been provided on the data diskette that comes with your Whisper. These are *951001e1.DST*, *951001c1.DST* and *951001n1.DST*. These 3 files contain EMG data, Common Mode data and Noise/Offset data measured with bipolar raw EMG instrumentation.

Select all five test parameter options and select the three demonstration files. As soon as all three filenames are loaded, the software will display the *Start Analysis button* in the Control window. Click on this button in order to start the *Spot Record Analyzer*.

The Spot Record Analyzer screen

Use the "Spot Record Analyzer" to view the data analysis results and the "Report Generator" to send copies of the analysis results to the current default printer.

As soon as the *Spot Record Analyzer* is started, the screen which is shown in Figure 35 should pop up and will be initialized. The screen is divided into five windows: the EMG parameter window, the Common Mode parameter window, the Noise/Offset parameter window, the File Information window and a message/controller window. The first three windows will show the results of the data analysis. Each column relates to one separate EMG channel and each window is related to one of the files which has been selected in the Spot Record Analysis screen. The names of these files are shown in the File Information window.

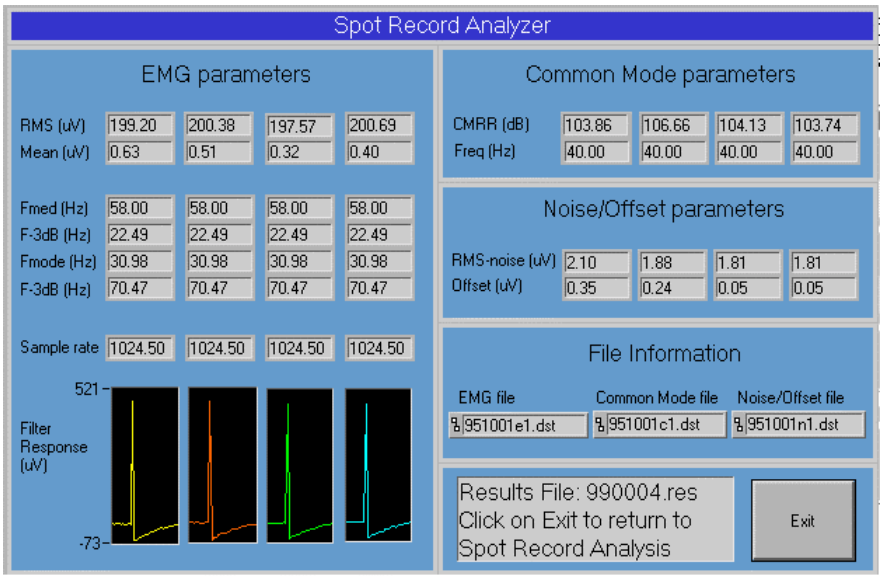


Figure 35 - The Spot Record Analyzer screen at the end of an analysis.

During an analysis these files are loaded and the selected parameters will be calculated and will appear on the screen. The message box in the message/controller window shows which task is under execution. Since a complete test analyzes three files with lengths varying from ten to twenty-two seconds, each containing the data of up to four EMG instrumentation channels, it can take up to several minutes before a *Spot Record Analysis* will be completed if you do not have a fast computer.

During a complete *Spot Record Analysis,* performed with all three data files, the following parameters will be calculated:

Amplitude parameters

- The Root Mean Square (RMS) value of the recorded EMG signal (in microvolts)
- The Mean value of the recorded EMG signal (in microvolts)

Both parameters will be calculated over the fifteen seconds of data in the EMG file that contain the EMG signal. The EMG data is located by first reading the file and looking for the five leading pulses. The position of the five pulses within the file is measured and the average number of samples between successive pulses is calculated. The Whisper generates these pulses at one-second intervals so the average number of samples measured enables us to determine the EMG sample rate.

Since we know that the EMG signal starts exactly one second after the last leading pulse and that the EMG signal is 15 seconds long, it is easy to extract the EMG signal data from the EMG file and calculate the RMS and Mean values.

Frequency parameters

- The Median frequency (F_{med}) of the Power Spectrum of the recorded EMG signal (in Hz)
- The Mode frequency (F_{mode}) of the (smoothed) Power Spectrum of the recorded EMG signal (in Hz)
- The -3 dB points of F_{mode} ($F_{-3dB\ left}$, $F_{-3dB\ right}$) of the (smoothed) Power Spectrum of the recorded EMG signal (in Hz)

These parameters are calculated from the first two seconds of the EMG signal in the EMG file. The two seconds are extracted from the EMG file using the same algorithm as the amplitude parameters discussed above.

The Power Spectrum is calculated, and by integrating the Power Spectrum, the total power is calculated. The median frequency can be determined by integrating the Power Spectrum until the frequency at which the integrated power equals half of the total power. This median frequency F_{med} thus cuts the Power Spectrum in two pieces of equal power.

F_{mode} is the frequency in the smoothed Power Spectrum at which the spectrum is maximal. Smoothing yields multiplication of the Power Spectrum with a Papoulis window.

The F_{-3dB} points are related to F_{mode}. Two points can be separated: $F_{-3dB\ left}$ and $F_{-3dB\ right}$. They can be defined as follows: for any frequency below $F_{-3dB\ left}$ and above $F_{-3dB\ right}$, the value in the Power Spectrum will never exceed $F_{mode}/2$. The frequency bands outside the F_{-3dB} points therefore indicate frequency ranges in which the power will never increase half of the maximum Power ($F_{mode}/2$). The frequency band between the -3dB points can therefore be regarded as a measure of the bandwidth of the spectrum.

Dynamic properties

- The sample rate of the EMG instrument under test (in Hz)
- The dynamic response of the EMG instrument under test (in microvolts)

The sample rate of the EMG instrument under test is calculated from the leading pulses in the EMG record (as mentioned above).

The dynamic response that is shown in the Spot Record Analyzer screen after an analysis is the response of the EMG instrument to the first leading pulse in a Mode 0 or Mode 1 recording. The graphs that are plotted show the shape of the filter responses start 10 samples before the pulse arrives and show the response of the system as long as the absolute value of the amplitude is more then 1 % of its maximum value.

It is important to note that the leading pulses are only 1mS wide – as a result they may not always be accurately recorded if the frequency response of the EMG instrumentation does not extend to the higher frequencies or the analog data collection sample rate is low.

Common Mode parameters

- The Common Mode Rejection Ratio (CMRR) of the EMG instrument under test (in dB)
- The frequency of the recorded common mode signal (in Hz)

Both parameters are calculated from the Common Mode file, a Whisper Mode 2 recording. Two seconds of data is extracted from the middle of the file (ten to twelve seconds after the start of the recording) and used to calculate the Power Spectrum of the data.

The frequency at which the Power Spectrum is maximal is determined first. Since the common mode signal is a pure 40 Hz sine wave, the maximal frequency should also be 40 Hz. This is displayed as the estimated frequency of the recorded common mode signal.

Once the maximal frequency has been determined the common mode signal can be reconstructed from the same two seconds of Common Mode file data by first performing a Fast Fourier Transform (FFT) on the signal. The FFT signal is then bandpass filtered (bandwidth = 25% of F_{mode} around F_{mode}) and from this signal the Inverse Real FFT will be calculated. This signal should be a 40 Hz sine wave. The Whisper generates a known 1.0 volt common mode signal during a Mode 2 test. Since we know the amplitude of the common mode signal at the input of the EMG instrument, the Common Mode Rejection Ratio can be calculated by dividing 1.0 by the estimated amplitude and taking the 20-log of this result.

Noise/Offset parameters

- The RMS noise of the EMG instrument under test (in microvolts)
- The DC offset of the EMG instrument under test (in microvolts)

These parameters are calculated from the Noise/Offset file. Since in a Noise/Offset test does not produce any differential or common mode signal during the test, the Noise and Offset parameters can be calculated over the complete file. The RMS noise is determined by the RMS value of the recording while the Offset is equal to the Mean value of the recorded signal.

The Results File

As soon as the *Spot Record Analyzer* has finish an analysis, it stores the results of the analysis in a *results file*. This file will be written in ASCII (text) format. The name of this file will automatically be generated and has the format *YYnnnn.RES,* where YY = Year, and nnnn is a number that is incremented each time a results file is created. The results file will be written to the same directory as the data.

The *Spot Record Analysis* is complete as soon as the application has completed writing the results file to disk. Once the *Spot Record Analysis* is completed the *Exit* button will appear in the message/controller window. If you click on this button you will return to the *Spot Record Analysis* screen.

Printing a Spot Record (Report Generator)

The *Report Generator* option from the *Spot Record Analysis* menu works in exactly the same way as the *Spot Record Analyzer* option. The only difference is that the Report Generator will print the results to a printer at the end of each analysis.

You can select the *Report Generator* option from the Selection window in the *Spot Record Analysis* screen. The analysis will proceed in exactly the same manner as the Spot Record Analysis, using the same five buttons to select the Whisper test files as

described above. Once a Report Generator analysis has been selected, and the *Start Analysis* button pressed, an analysis will be performed and a report printed on the default Windows printer attached to your computer.

Interpretation of the Results

The EMG-Equipment Test software has been developed test the performance of an EMG recording system using a Whisper generated EMG test signal. In addition it the basic test and quality assurance functions, the EMG-Equipment Test software can be used to compare the behavior of different EMG systems and data collection instrumentation in separate laboratory or data collection environments.

When you are evaluating the performance of an EMG system it is important to know what results you expect to obtain from the tests in order to determine the operational status of the equipment. Since the characteristics of the Whisper generated test signals are well known it is possible to predict the results of many of the tests.

The characteristics of the standard EMG test signals generated by the Whisper are covered in extensive detail in Using the Whisper of this manual. Using the Whisper to generate Mode 0 or Mode 1 test signals applied a signal to the equipment under test that has well known amplitude and frequency parameters of the EMG signal. These values are shown in Table 4.

The Whisper Mode 0 and Mode 1 test signals are appropriate when testing systems that record raw EMG signals.

If the EMG instrumentation under test records *raw EMG*, then the system should record the standard Whisper Mode 0 and Mode 1 test signals without significantly changing the signal properties. If you run a series of Whisper tests and find that the results reported from a *Spot Record Analysis* shows values comparable with those of Table 4 then you can reasonably conclude that your EMG data collection and recording system is functioning correctly.

However, if your EMG instrumentation generates smoothed, rectified EMG then you will find that a *Spot Record Analysis* reports different numbers. In the ideal case the RMS value of the recorded EMG has to be compensated with a factor $\sqrt{2/\pi}$ and the average RMS value should be equal to 159.68 microvolts. The Common Mode frequency has to be equal to the frequency that is shown in Table 4. It is also difficult to predict the values of F_{med}, F_{mode} and F_{-3dB} since they depend too much on the bandwidth properties of your smoothed, rectified EMG system. In practice the F_{med}, F_{mode} and F_{-3dB} parameters are not very useful if the recording instrument produces smoothed, rectified EMG.

test parameter	value	unit
RMS (EMG)	200.13	microvolt
mean (EMG)	0.09	microvolt
Freq (Com. mode)	40	Hz
F_{med}	59.00	Hz
$F_{-3dB\ (left)}$	23.00	Hz
F_{mode}	31.00	Hz
$F_{-3dB\ (right)}$	70.50	Hz

Table 4 - Test parameter values of the standard test signal

The sample rate is determined by the number of samples recorded between the leading pulses in Mode 0 and Mode 1 test signals.

The sample rate at which the EMG test signals will be recorded is set by the data sampling system that is used to record EMG signals. The sample rate reported by the *Spot Record Analyzer* must match the value that has been set for the data sampling system, regardless of the type of EMG system (raw or smoothed, rectified EMG recordings).

The filter response, Common Mode Rejection Rate (CMRR) and the Noise and Offset of the EMG system depend a lot of the quality and type (raw EMG or smoothed, rectified EMG) of the EMG system under test. This makes it difficult to suggest an "ideal" set of numbers for the *Spot Record Analyzer* to report. The shape of the dynamic filter response depends on the type of EMG system – raw and smoothed, rectified EMG systems will produce radically different displays due to the pre-processing inherent in a smoothed, rectified EMG system.

The CMRR should be as high as possible (usual between 80 to 120 dB). The Noise and Offset of the EMG instrument under test should be as low as possible (a few microvolts).

Figure 37 shows the results of a multi-channel Equipment Test of an EMG recording instrument that records bipolar raw EMG (sample rate 1024 Hz). If you compare these results with Table 4, you should be able to conclude that the EMG instrument is functional and behaving as expected.

Spot Check

The Spot Check and Report Generator options function in the same way except the Report Generator will create a printed copy of the analysis results on the default Windows printer.

The *Spot Check* option allows you to run system performance, specification and comparison tests. You can enter the *Spot Check* option by clicking on the *Spot Check* button in the Control window of the Main menu screen. The *Spot Check* option will display a selection button in the Selection Window – this has two selections, which are *Spot Check* and *Report Generator*. *Spot Check* will display the results on the screen while *Report Generator* will also send the results to the default Windows printer.

The File Information window displays two file selection dialog boxes – these expect you to enter the names of two *result* files (.res). A new result file is created by the *Spot Record Analyzer* (see page 50) whenever a *Spot Analysis* is performed and contains a record of the analysis results.

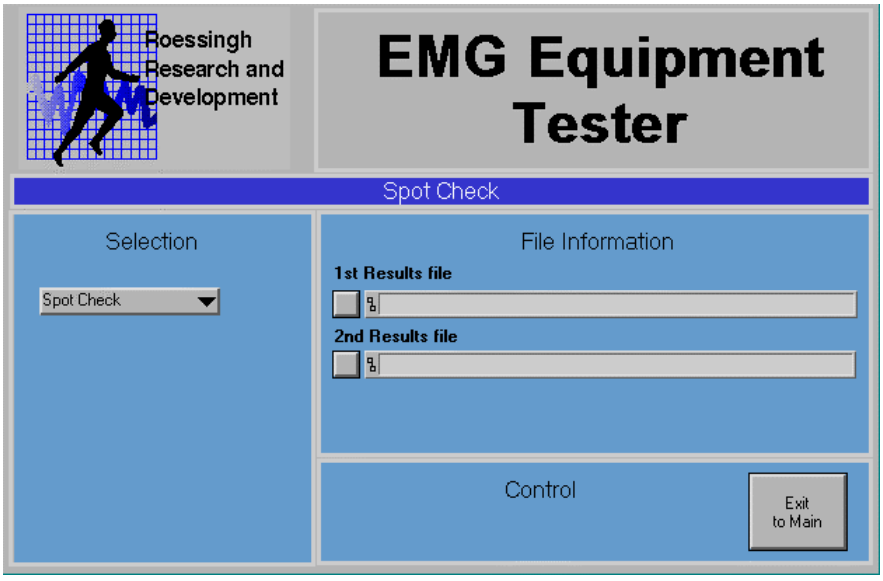


Figure 36 - The Spot Check option.

Executing a *Spot Check* is very easy - first select either the *Spot Check* or *Report Generator* option from the pop up menu in the Selection window. Then switch to the File Information window then and load the name of the 1st Results file. A pair of sample results file are provided with the EMG-Equipment-Tester software - these are

the files *95100101.RES* and *YOURSIM.RES*. Load *95100101.RES* as the name of the 1st file and *YOURSIM.RES* as the name of the 2nd result file.

As soon as both filenames have been loaded the *Start Analysis* button will be displayed in the Control window. Click on the *Start Analysis* button to start the *Spot Check* (or the *Report Generator*) and the screen shown in Figure 37 will appear. Note that if the file selection procedure is not completed properly the error message *<Not A Path>* will appear in the File dialog box. Repeat the file selection procedure until both files have been selected.

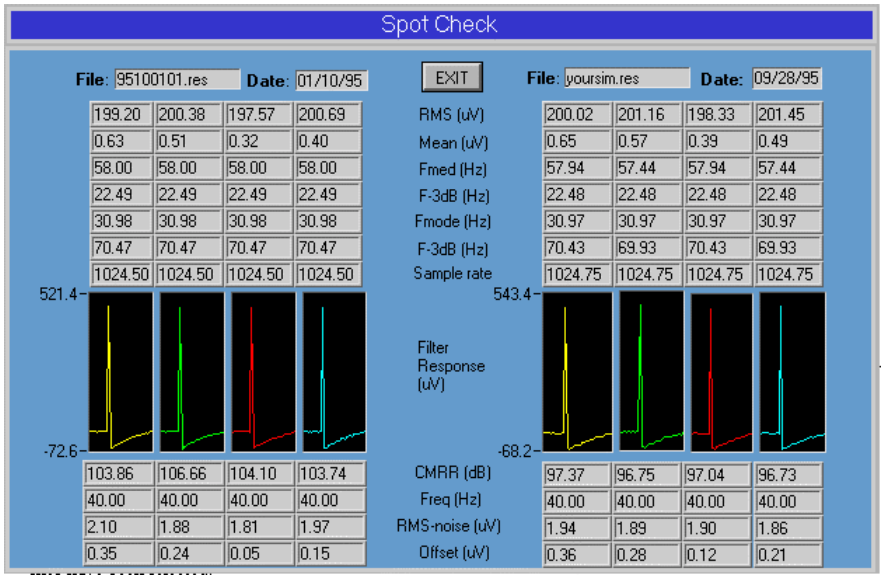


Figure 37 - Spot Check screen of the EMG-Equipment tester.

The *Spot Record* screen displays the results of two prior *Spot Record Analysis* operations. Each *Spot Record Analysis* results file can contain details from one to four EMG channel analysis tests. The left side of the window displays the contents of the first *results* file - each column displayed in this half of the screen contains the test results of one EMG channel. At the right of the screen you will find the contents of the second *results* file. Again each column contains the test results of a separate EMG channel.

The *Spot Record* screen provides an easy way to compare two result files. If an equipment test has been done according to a standardized measurement protocol, the contents of two different results files relates to the same EMG channels of the instrument under test. In that way, the performance of the EMG instrument under test can be tested by simply comparing the corresponding results in two different *results* files. Thus the quality of an EMG system can be checked on a regular basis by comparing data from tests made several days or weeks apart.

For example, by examining two *results* files that have just loaded you could conclude that the performance of the EMG instrument under test has not changed since both Results files contain very similar test values.

As soon as you have compared two result files, the *Spot Check* has been completed. You can leave the *Spot Check* screen by clicking on the *Exit* button. If you click on *Exit to Main* and on *Quit* then, you will leave the EMG-Equipment-Tester software and return to the Windows operating system.

File Descriptions

Protocol standardization

The EMG-Equipment-Tester software has been developed to automate the analysis of standardized EMG test signals generated by the Whisper EMG signal generator. It analyzes recordings from the output of EMG system instrumentation using an automated, standardized procedure that is guaranteed to be repeatable at any time. EMG instrumentation can be tested at any time and in any location with the certainty that the results of the tests can be compared in a meaningful way.

In addition to the basic quality assurance features of the Whisper, the instrument also allows users of EMG instrumentation in separate laboratories to check that their data collections systems and EMG equipment is comparable.

It is important that the data recorded from the Whisper is maintained according to a standard protocol if the Whisper will be used for equipment testing. The signal data protocols have been discussed earlier in Using the Whisper on page 16 of this manual however the storage of the information needs to be defined to some extent if the EMG-Equipment-Tester software will be used to analyze the recordings.

This chapter will therefore discuss the protocols that must be followed in order to use the EMG-Equipment-Tester software. These are:

- The data format the EMG-Equipment-Tester software can read and analyze.
- The three basic Whisper data modes - Mode 0/1, Mode 2 and Mode 3 signals.

This chapter will end with a description of a full equipment test and some recommendations for proper use of the EMG-Equipment-Tester software.

The CAMARC DST format

The following description of the Whisper file formats is provided for the benefit of anyone who is unable to generate native DST file by either directly exporting them from their data collection software or by using the Motion Lab Systems program RData2 that is supplied with the Whisper. The Rdata2 program can generate Whisper compatible DST files from any C3D or Dataq EMG data file in seconds.

Full details of the CAMARC DST file formats may be found in the files distributed with the Motion Lab Systems MLSviewer application. that is available from the web site: http://www.motion-labs.com

In order to be able to analyze your test data with the EMG-Equipment Tester, it is necessary to write your data in the appropriate data format. The format which will be used is an ASCII text format and origins from the CAMARC II DST/EXP lexicon. This means that each test data file should have a header in which the kind of test data will be described, followed by the actual test data. The following shows an example of such a header followed by the first 5 data lines of a test data file.

```
#!DST-1.0 EXP-1.0 01/10/95 Enschede
$EXPeriment
EMG source: Whisper TM
serial number: RRD/CES-9412-01
Equipment under test: 8 channel EMG amplifier
Employee performing test: BF
Date of test: 01-10-95
Test sequence starts at: 13.24
Channels tested: 1 2 3 4
!AdcSampleRate
1024
$EmgPreProcessing
raw
$EmgUnits
microvolts
!AdcRESolution
12
!EMG-4
7   8   3  -1
7   2   7   9
9  -3   1   4
5   4   1  -2
14  1  12   8
.   .   .   .
.   .   .   .
```

This header is provided in the data directory as the file *HEADER.TXT*. I you are generating DST files using a text editor it is recommended that you copy this header to the start of the file, above your test data, and then change the information in the header so that it matches the recorded data.

In order to be able to edit the header in the appropriate way you should know that:

- The header consists of a *file-header-line* (first line; starts with #!), *text-section-header-lines* which indicate the beginning of a text section (these lines begin with $ and are followed by text lines) and *data-section-header-lines* which indicate the beginning of a data section (these lines begin with ! and will be followed by data lines)
- The *file-header-line* contains information about the CAMARC II lexicon and about the date and the place of the experiment.
- The *text-section-header-lines* and the text lines contain comments on the experiment. The contents of *text-section-header-lines* may not be changed and is case sensitive. The contents of the text lines needs to be edited in order to fit your test data.
- The *data-section-header-lines* indicate parameters. The value of these parameters can be found in the data-line following the *data-section-header-line*. The contents of *data-section-header-lines* may not be changed and is case sensitive. The contents of the data lines needs to be edited in order to fit your test data

- The lines in the header are separated by EndOfLine characters (EOL = CR (Carriage Return) + LF (Line Feed) = ASCII 13 + ASCII 10)
- The order of the *file-header-line*, the *text-section-header-lines* and the *data-section-header-lines* as shown above is the prescribed order. If you change this order, your EMG-Equipment-Tester software may not be able to analyze your Test date automatically.

In order to avoid problems with the EMG-Equipment-Tester software, it is recommended that you only change the following information in the header of a Test date file:

- The name of the city and the date of the experiment in the *file-header-line*. Be sure that you have written the date in the appropriate format and that you separate the date and place by only 1 SPACE (ASCII 32).
- The text in text lines following the *text-section-header-lines*. You may include any comment over as many lines as you want in order to describe the experiment as clear as possible. Be sure that you use the appropriate EndOfLine characters.
- The sample frequency of your recording system in the line following *!AdcSampleRate*. Replace *1024* by the sample rate (in Hz) of your recording system.
- The resolution (in bits) of your recorded data in the line following *!AdcRESolution*. Replace *12* by the resolution (in bits) of your recording system.
- The number of EMG channels of which your test data file contains the recorded data. Replace *4* in the line *!EMG-4* by the number of EMG channels in your Test date file (maximum number of channels = 4).

The header is followed by the actual test data. The test data should be written as follows:

- Each column contains the data of 1 separate EMG channel. TABs (ASCII 9) separate the columns.
- Each row contains 1 sample value of each recorded EMG channel. Each line ends with an EOL character (ASCII 13 + ASCII 10).
- The data should be written as text integers (the file is an ASCII text file). Each test integer should indicate the measured value in microvolt.
- At the end of the test data an EndOfFile marker (EOF = ctrl z) should be included.

If you have written a test data file in the appropriate format, you can save the file to disk. This file should have a name according to the following format:

*YYMMDD**t**N.DST*

in which:

- *YY* stands for Year (95 for 1995, 00 for 2000)
- *MM* stands for Month (01 for January, 12 for December)
- *DD* stands for Date (01 ... 31)
- ***t*** indicates the type of the test date file (*e* for EMG file; *c* for Common Mode file; *n* for Noise/Offset file)
- *N* stands for the files (serial) number (0 ... 9)

EMG Test Protocol (Mode 0, Mode 1)

The amplitude parameters, the frequency parameters and the dynamic properties of your EMG instrument can be tested as follows:

- Connect the Whisper to your EMG system.
- Setup your EMG recording instrumentation such that it can record the standard test signal without saturating during at least 22 seconds.
- Select the test mode (mode 0, mode 1) and set the signal switches (DIF and COM) on the Whisper in the appropriate positions.
- Switch the Whisper on .
- Push the Whisper Start Button, start your EMG data recording instrumentation and release the Start Button within one second.

Write the data that you have recorded in the appropriate DST-data format and name the file according to the following format: *YYMMDDeN.DST*.

- Run the EMG-Equipment-Tester software
- View the file in Quickview and be sure that y*ou have recorded the 5 leading pulses and that* ***the first and only the first leading pulse*** *occurs in the first 2 seconds of the recording*

If both criteria are satisfied, your file is suitable to be analyzed by the EMG-Equipment-Tester software.

Common Mode Test Protocol (Mode 2)

The test protocol for Common Mode can be used to measure the Common Mode Rejection Ratio of your EMG instrumentation.

- Connect the Whisper to your EMG instrumentation.
- Setup your EMG recording instrumentation such that it can record the standard test signal without saturating during at least 15 seconds.
- Select only the common mode signal of the simulator by switching the COM switch on and the DIF switch off.
- Switch the Whisper on.
- Push the Start Button and start recording the EMG data within one second.

Write the data that you have recorded in the appropriate DST data format and name the file as follows: *YYMMDDcN.DST*.

- Run the EMG-Equipment Tester
- View the file in Quickview and be sure that y*ou* ***don't*** *see the 40 Hz sinusoidal signal during the first 6 seconds of the recording and that the 40 Hz sinusoidal signal is present during the 10th .. 12th second of the recording*

If both criteria are satisfied, your file is suitable to be analyzed by the EMG-Equipment-Tester software.

If you have calculated the CMRR, you need to verify that the estimated frequency of the Common Mode signal is indeed 40 Hz before you can be sure that the CMRR calculation is a reliable measurement.

Noise and Offset Test Protocol (Mode 3)

The test protocol for Noise and offset testing can be used to test the Noise and Offset of the EMG instrument under test.

- Connect the Whisper to your EMG instrumentation.
- Prepare your recording system to record the standard test signal with out saturating during at least 10 seconds.
- Set both the COM and DIF switches off.
- Switch the Whisper on.
- Start your recording device after pushing the Start Button.

Write the data that you have recorded in the appropriate DST data format and name the file as follows: *YYMMDDnN.DST*.

- Run the EMG-Equipment-Tester software and select the noise and offset analysis.

If you use the protocol in this manner, the total amount of Noise/Offset that you will find indicates the Noise/Offset of both your EMG recording instrument and the Whisper. This amount of Noise/Offset is superimposed on all your test data.

A full Equipment Test

When making connections to the Whisper take special care to avoid introducing any AC noise into your EMG system under test.

A full Equipment Test yields that all facilities of the EMG-Equipment-Tester software will be used simultaneously such that a single analysis is able to show you the overall performance of up to four EMG-channels. This means that you have to develop a connection board that can be used to connect the output of the Whisper to four EMG channel inputs simultaneously.

In case of a bipolar EMG instrument, a full Equipment Test consists of three recordings (mode 0, mode 2 and mode 3). In case of a mono-polar EMG instrument the full Equipment Test consists of only two recordings (mode 1 and mode 3). After you have made the recordings and transformed the data in the appropriate data format, you present them to the EMG-Equipment-Tester software. Before you are able to analyze them you should verify in *Quickview* whether the EMG file (mode 0, mode 1) and the Common Mode file (mode 2) are indeed suitable to be analyzed. If this is the case, you can start the analysis. We recommend doing this analysis using the *Spot Record Analyzer (Report Generator)*. If your EMG recording system records raw EMG you can select all five parameters to view/test. If your EMG system records *smoothed, rectified EMG*, it is useless to select *Frequency parameters* and the *Common Mode Rejection Ratio*.

As soon as the analysis has been done you can compare the behavior of your EMG recording instrument with a previous recording. We recommend doing this with the *Spot Check (Report Generator)*. After this check the full Equipment test has been done and the EMG-Equipment-Tester software can be left.

At the R.R.D. laboratory in Enschede, the Netherlands, a full Equipment Test has been done with a Whisper using a Klab SPA20 pre-amplifier, a KL100 (raw) EMG amplifier and a TRI 815 AD-board. The results of this test are provided in the \data directory of the software *YOURSIM.RES* and are also shown in Appendix A1.

Appendix A1

EMG-Equipment Tester Output

This appendix shows the outcome of a full equipment test of a Whisper EMG signal generator at the R.R.D. laboratory in Enschede, the Netherlands. The results of this test can also be found in the file *YOURSIM.RES* at the data diskette, which is provided with the Whisper package.

```
!#!DST-1.0 EXP-1.0 09/28/95 Enschede
$EXPeriment
CAMARC II Specimen Test Result file, 09/28/95
Ampl/Freq/DynTest file: 950928E2.DST
Common Mode Test file: 950928C2.DST
Noise/Offset Test file: 950928N2.DST
!Results-4[11111]
 2.000167E+2  2.011645E+2  1.983335E+2  2.014467E+2
 6.542840E-1  5.730922E-1  3.880684E-1  4.920955E-1
 5.794341E+1  5.744390E+1  5.794341E+1  5.744390E+1
 2.247805E+1  2.247805E+1  2.247805E+1  2.247805E+1
 3.096976E+1  3.096976E+1  3.096976E+1  3.096976E+1
 7.043122E+1  6.993171E+1  7.043122E+1  6.993171E+1
 1.024750E+3  1.024750E+3  1.024750E+3  1.024750E+3
 3.300000E+1  3.300000E+1  3.300000E+1  3.300000E+1
 2.000000E+0 -1.000000E+0  0.000000E+0 -1.000000E+0
 2.000000E+0 -1.000000E+0  1.000000E+0  2.000000E+0
 2.000000E+0  1.000000E+0  1.000000E+0  1.000000E+0
-2.000000E+0  0.000000E+0  0.000000E+0  1.000000E+0
 3.000000E+0  2.000000E+0  0.000000E+0  0.000000E+0
-3.000000E+0  0.000000E+0  0.000000E+0 -1.000000E+0
-2.000000E+0  4.000000E+0  0.000000E+0  0.000000E+0
 0.000000E+0 -2.000000E+0 -2.000000E+0 -1.000000E+0
 0.000000E+0  2.000000E+0  0.000000E+0  2.000000E+0
 1.000000E+0  3.000000E+0 -1.000000E+0 -2.000000E+0
 4.900000E+2  4.920000E+2  4.890000E+2  4.940000E+2
-5.500000E+1 -5.700000E+1 -5.900000E+1 -6.100000E+1
-6.200000E+1 -6.200000E+1 -6.100000E+1 -6.000000E+1
-5.500000E+1 -5.600000E+1 -5.400000E+1 -5.900000E+1
-5.200000E+1 -5.200000E+1 -5.200000E+1 -5.300000E+1
-4.900000E+1 -4.800000E+1 -4.800000E+1 -4.700000E+1
-4.400000E+1 -4.600000E+1 -4.500000E+1 -4.300000E+1
```

```
-4.500000E+1 -4.400000E+1 -4.100000E+1 -4.000000E+1
-3.800000E+1 -3.800000E+1 -3.900000E+1 -4.000000E+1
-3.500000E+1 -3.400000E+1 -3.400000E+1 -3.400000E+1
-3.200000E+1 -3.300000E+1 -3.200000E+1 -2.800000E+1
-2.900000E+1 -2.900000E+1 -3.000000E+1 -2.900000E+1
-2.500000E+1 -2.700000E+1 -2.700000E+1 -2.500000E+1
-2.400000E+1 -2.100000E+1 -2.300000E+1 -2.600000E+1
-1.900000E+1 -2.100000E+1 -2.100000E+1 -2.100000E+1
-1.600000E+1 -1.800000E+1 -1.800000E+1 -1.600000E+1
-1.600000E+1 -1.700000E+1 -2.000000E+1 -2.000000E+1
-1.500000E+1 -1.600000E+1 -1.300000E+1 -1.400000E+1
-1.200000E+1 -1.300000E+1 -1.400000E+1 -1.600000E+1
 0.000000E+0 -1.100000E+1 -9.000000E+0 -9.000000E+0
 0.000000E+0 -8.000000E+0 -9.000000E+0 -9.000000E+0
 0.000000E+0 -1.100000E+1  0.000000E+0 -6.000000E+0
 0.000000E+0  0.000000E+0  0.000000E+0 -5.000000E+0
 9.736605E+1  9.674984E+1  9.703971E+1  9.673129E+1
 4.000000E+1  4.000000E+1  4.000000E+1  4.000000E+1
 1.937604E+0  1.892821E+0  1.895600E+0  1.859045E+0
 3.582031E-1  2.833984E-1  1.171875E-1  2.051758E-1
```

Appendix A2

Technical Issues

Service and Support

The Whisper and the EMG-Equipment-Tester software are guaranteed and supported for one year from the date of purchase. This means that in case of problems and questions you can always contact us by mail, phone, fax or e-mail.

It is suggested that US customers who purchased the Whisper through Motion Lab Systems should first contact Motion Lab Systems to resolve any problems. Please mention the serial number of your Whisper when you contact us:

US distributor:

Motion Lab Systems, Inc.
4326 Pine Park Drive, Baton Rouge, LA 70809 USA
Tel: +1 225 928-4248
Fax: +1 225 928-0261
e-mail: support@motion-labs.com
Internet: http://www.motion-labs.com

Manufacturer:

Roessingh Research and Development
Roessinghsbleekweg 33, 7522 AH Enschede, The Netherlands
Tel. :+31 53 4875777
Fax :+31 53 4340849
e-mail: rrd@rrd.nl
Internet: http://www.rrd.nl

Electrical Specifications

Power Source	4 AA batteries, 1.25 Volt, 500 or 720 mAh.
Average current dissipation	stand-by mode: 50 mA
	run mode: 300 mA
Output Impedance	22 Kohm [+/- 2 %]
Common mode output level	[-1.0, +1.0] Volt [+/- 5 %]
Differential mode output level	[-2.048, +2.047] millivolt [+/- 5 %]

Table 5 - Whisper technical specifications.

Troubleshooting the Whisper

The Whisper is a precision EMG signal generator and should give many years of trouble free service. The following fault finding instructions are provided in the unlikely event that you experience problems with your Whisper.

The LED does not light when you switch on the Whisper:

- Check that the batteries are not discharged.
- Check that the batteries are placed correctly in the battery compartment (see the illustration on page 4).
- Check the size of the batteries. If you are using rechargeable batteries (not recommended) you may find that they are shorter then regular AA batteries. This may give some problems.

The Whisper does not produce a test signal:

- Check that the Whisper has been switched on and the LED is illuminated.
- Check that the batteries are charged – the LED will not turn on if the batteries are discharged.
- Check that the LED on the power switch turns red / orange as soon as you release the START switch.
- Check that the START switch releases after being pressed – if the switch sticks down then the LED will stay red /orange and no output will be produced.
- Check that at least one of the COM and DIF mode switches was set on. The Whisper only produces a differential output signal in Mode 0 or Mode 1.
- Check the connections between the Whisper and your EMG instrumentation.
- Check that the Whisper and your EMG instrumentation have been grounded correctly. Incorrect grounding could short-circuit the test signal.
- Check that your EMG instrumentation has been setup correctly and responds to an EMG level input.

The EMG signal does not look like EMG:

- Check all the connections between the Whisper, your EMG instrumentation and pay special attention to the ground connections.
- Check that you are using an appropriate gain level for your EMG system and recording or data sampling equipment.
- Check that you are using an appropriate sampling rate. If in doubt use a rate close to 1,000 samples per second per channel. If you are sampling multiple channels then the total sample rate must be increased appropriately.

The leading pulses in Mode 0 and Mode 1are negative:

- The connection cable between the Whisper and your EMG instrumentation is not correct. Disconnect the Whisper signal cable (Figure 6 on page 1) and connect the cable the other way around.

The test signal saturates your EMG system:

- Check all the connections between the Whisper, your EMG instrumentation and ground.
- Verify whether the connection cable between the Whisper and your recording EMG instrumentation is symmetrical. Even the smallest (common mode) asymmetry at the input of your EMG instrument can cause your EMG instrument to saturate.
- Check that your EMG instrumentation has been set correctly.
- If the EMG system appears to work in Mode 1 but not Mode 0 then you may have a very poor CMRR – perform a Mode 2 test to determine your systems CMRR response.

The recording contains line frequency signals:

- There is a lot of common mode interference. Check all the connections between the Whisper, your EMG instrumentation and the laboratory ground.
- If you are running a Mode 0 test then check that your EMG inputs are actually differential inputs. If the system appears to work with a Mode 1 test but fails a Mode 0 test then it is likely that your EMG system is either not a differential input system or does not have a good CMRR.

The recording is very noisy:

- Check all the connection between the Whisper, your EMG instrumentation and ground.
- Verify that the Whisper and/or your recording instrumentation have not been placed near to noise sources such as computer screens or equipment which generates electrical or magnetic fields.

Your recording contains more than five leading pulses:

- If you see a spike 1/2 second after the 5th leading pulse this is due to an internal switch in the Whisper. This spike will not cause any problems.
- If you see a spike at the beginning of your EMG recording this is due to pushing the start button. You probably did not push the Start Button before you started your EMG recording instrument. If you only view your EMG recording this won't be a problem. If (in a later stage) you are going to use the EMG-Equipment-Tester software, the spike will cause problems if its amplitude exceeds the amplitude of the leading pulses.

Your recording contains less then the five leading pulses:

- The sample rate of your recording device is low compared to the impulse response of your EMG instrumentation. Increase the sample rate of your recording device.
- Check to see if you started the Whisper prior to starting recording. Some recording systems may take a second or so after the commond to start before they actually record any data.

When you start the EMG-Equipment-Tester software a window pops containing the message: *Could not allocate the total amount of memory requested [20480000 bytes]. Continuing with ... bytes.*

- This message indicates that you have less than 20 Mb of RAM memory available – this may not cause too much of a problem unless you have less than 16 Mb. The EMG-Equipment-Tester software may run into serious memory problems if there is not enough memory to perform the software analysis functions.

While processing data an error message appears Application memory full. Saving and closing other applications (for instance a mail program running in the background) can free memory. You may need to increase the Total Memory allocated to LabVIEW from the EMGEQTST.INI file. This message can be followed by another message that indicates the location of the memory conflict.

- Restart the computer and run the analysis again using fewer data files.
- Sample the EMG data at a lower sample rate if possible.
- Add more memory to the computer system that you are using.

The EMG-Equipment Tester will fails to open a data file to perform an Analysis.

- Check that the data files are in the appropriate data format. The EMG-Equipment Tester will only open DST in the correct format. You can use the *MLSviewer* (from Motion Lab Systems) to view the contents of a DST file and confirm that the format is correct.
- Check that you have named the data files in an appropriate format. The EMG-Equipment Tester will not open files that have names that do not conform to its naming convention.
- The EMG-Equipment Tester does not open binary data files – check that you data file is viewable in *Quickview* or *MLSviewer*.

The EMG-Equipment Tester reports the wrong sample rate.

- If you do not find the correct sample rate, this can be due to your Mode 0/1 data file containing less than five leading pulses
- Check the data file in *Quickview* or *MLSviewer* to make sure that the data file does not contain any unexpected spikes that could interfere with the software measurements.
- Check that your data collection sampling rate is high enough in comparison with the length of the recorded filter response. If the time between two samples is more than the filter response time (at least a few milliseconds), the analysis software may not see every pulse.
- Check that the EMG signal gain is appropriate – excessive gain can cause the software to detect an erroneous sample rate.

The *Spot Analysis Report* is missing some parameter reports for some channels in a multi-channel analysis.

- Make sure that each Test data file contains the same number of EMG channels if you analyze an EMG file, a Common Mode file and a Noise/Offset file simultaneously.

Unexpected files appear in the EMG-Equipment Tester directory.

- The EMG-Equipment Tester creates some **.vi* and **.rsc* files under certain circumstances. These files can safely be deleted after each analysis.