31654 Introduction to Biomedical engineering

Guide to EMG measurements

Ørsted•DTU, Ørsteds plads, building 348

Technical University of Denmark

2800 Kgs. Lyngby

1 Introduction

In this guide you will find instructions and diagrams to set up the two electromyography (EMG) experiments in the course 31654. The software as well as the hardware setup and measurement procedure are described thoroughly in this guide.

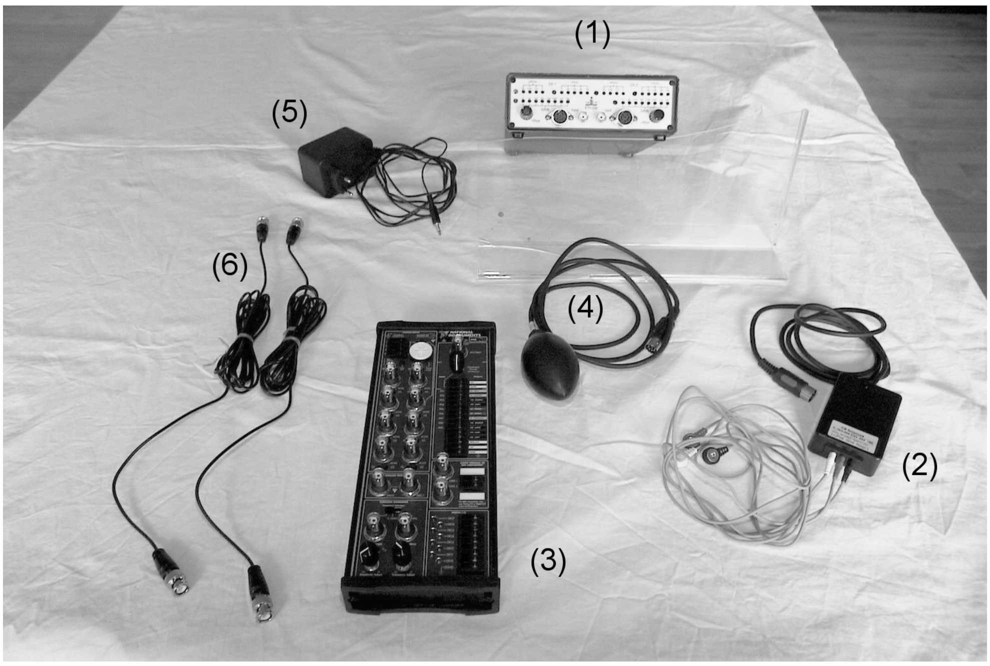
2 Equipment

The experimental setup consists of transducers, amplifiers/filters, digitalization equipment as well as a data recording software running under LabView on a PC.

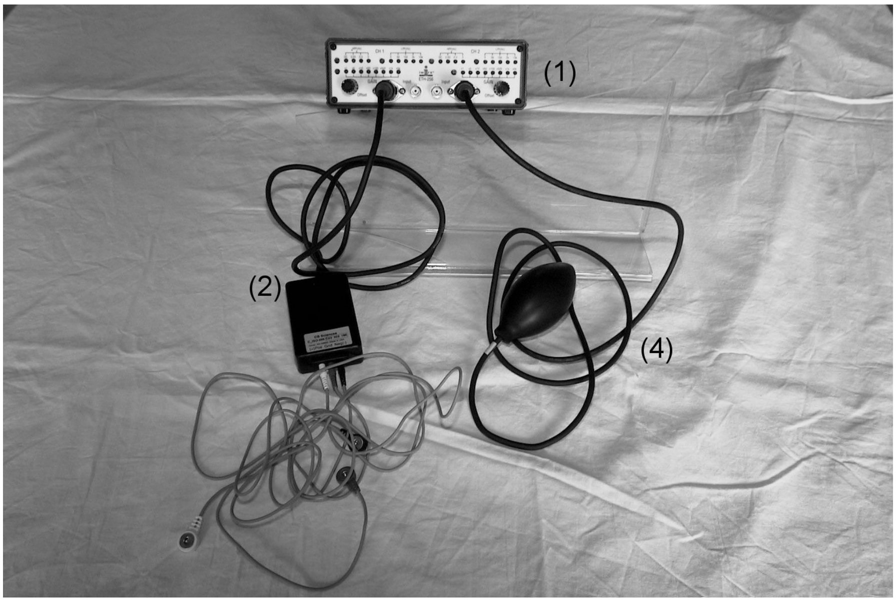
2.1 Components

The components used in the measurements (mainly from iWorx[1]) are as follows and can be seen in Figure 1:

1. Bridge/bioamplifier (CB Sciences/iWorx type ETH-256) (*bioforstærker*). Details in [3].
2. Isolation amplifier (CB Sciences type C_ISO-255) (*isolationsforstærker*)
3. Connection box (NI, type BNC-2120) (*BNC-forbindelsesboks*)
4. Hand dynamometer (iWorx/CB type FT325). Details in Appendix C in [3] (*hånddynamometer*).
5. AC/AC Power supply (*strømforsyning*)
6. Connecting cables (*Coaxialkabler*)



Figur 1 Main equipment for EMG measurements.



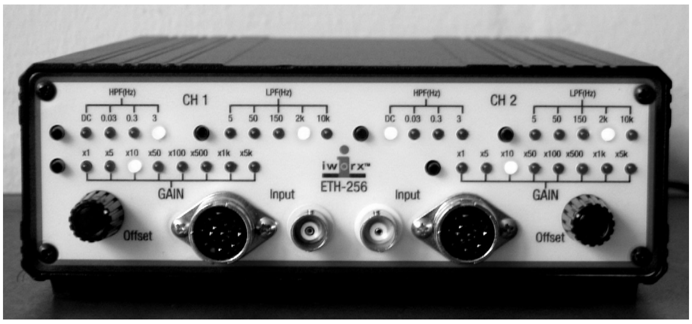
Figur 2 Dynamometer on the right connected to channel 2 of the bioamplifier. Electrodes are connected through the isolation amplifier (black box to the left), which is connected to channel 1 of the bioamplifier.

In addition to that, the measurement setup needs a computer with a NI PCI-6040E 12 bit data acquisition card (*dataopsamlingskortet hvor det analoge signal samples til et digitalt signal*) which is connected to the connection box with a NI SH68-68-EP shielded cable.

2.2 Setup

First connect the isolation amplifier (2) to channel 1 of the bioamplifier (1) and the dynamometer (4) to channel 2 as seen in Figure 2. Next connect the power supply (5) to the bioamplifier (1) and turn it on so that the red diodes light up on the front panel of the bioamplifier. Next connect channel 1 from the bioamplifier to channel 0 of the connection box (3), and channel two from the bioamplifier to channel one of the connection box as shown in Figure 3. Finally, take the cable from the computer and check

Figur 3 Connections between rear of bioamplifier and the connection box. Channel 1 from the bioamplifier is connected to channel 0 of the connection box, while channel 2 is connected to channel 1.



Figur 4 Photo of front panel of the bioamplifier. The settings shown here are close to the recommended settings.

that all the pins are straight. Then gently connect it to the end of the connection box (3) and tighten both screws (it must be firmly attached to work properly). Now the green LEDs on (3) should light up.

This means that channel 0 of the digital signal that we will see in LabView will correspond to the signal measured from the electrodes, and channel 1 in LabView will correspond to the signal originating from the dynamometer (4).

For your reference, Figure 4 shows a photo of the bioamplifier.

With respect to component 3 in Figure 1 (the BNC-2120): In order to obtain reliable results, it is of outmost importance that you remember to set the two switches right below the input channels to the "FS"-position!

3 Preparing the PC

In order to do the measurements, you must log on to the computer (see section 9.1) and then run a LabView program.

3.1 Downloading the LabView measurement program

The measurement program (or the right version of it) might not be on the computer. To store it on the computer, do the following:

1. Go to the course homepage under "Programs and data". Go to the Labview directory and download the Labview library EMG_Force_version<n>.llb, where <n> is the version number (minimum 4). Download the latest version, unless otherwise told. Place the library on you network drive.
2. Copy the library to the desktop of the computer (you need to have the program on the local disk of your computer, since running it over the network is not always stable).
3. Run Labview and open the MainToFile.vi. Now your measurement program should be on the screen.

Table 1: Settings of the bioamplifier.

	Electrode channel (1)	Pressure channel (2)
Highpass frequency	3 Hz	DC
Lowpass frequency	2 kHz	50 Hz
Gain	10	10

4 Settings of hardware

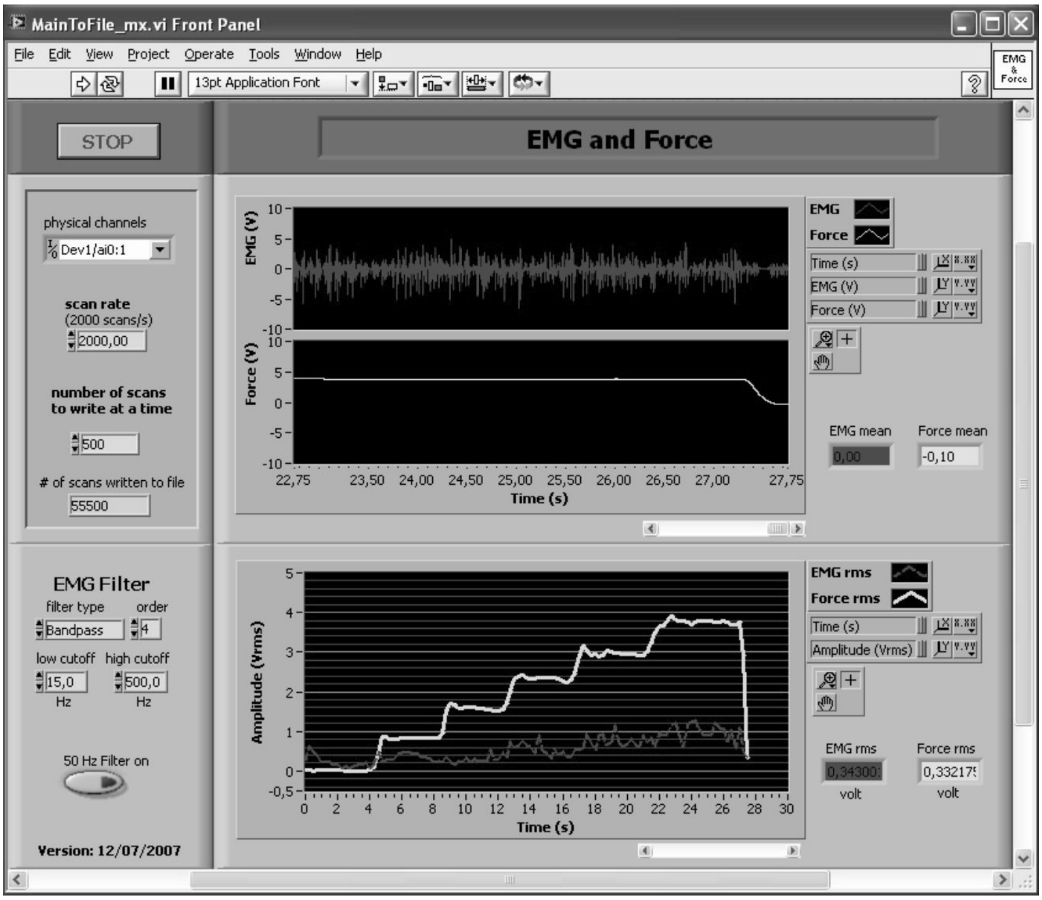
The isolation amplifier has a gain of 50 which is fixed. The bioamplifier, which has a variable gain, is considered in this chapter. The setting given here should only be used as a guideline, since the amplitude of the EMG signals will vary from person to person depending on the electrode placement, the amount of adipose tissue etc. Try to start with the settings in Table 1, and for each channel adjust the gain if your signal amplitude is too low or too high. The voltage range of the analog-to-digital converter is ±10V. If the signal amplitude is much lower than ±10V, the signal will be noisy. On the other hand, if the amplitude is much higher than ±10V, the signal will be “clipped” at this value. It is OK, that the signal occasionally reaches beyond ±10V.

5 Settings of, and notes on, software

Figure 5 shows a screen dump of the measurement program MainToFile.vi, which is used for all three exercises.

The program controls both the sampling and digitalization of the measured signals as well as some of the processing of the data prior to display. The raw electrode signal from the analog to digital converter is displayed in the upper black graphical window (in red) and then filtered with the 50 Hz notch filter (on/off) as well as the EMG filter (lowpass/highpass/bandpass/bandstop, low cut-off, high cut-off). This filtered signal is displayed in the second black graphical window (in yellow). The raw force signal (from the second analog to digital converter) is displayed in the third black graphical window (in white). In the lower black graphical window with the green horizontal lines, the rms value of the two latter signals is show.

The most important initial settings are shown in Table 2.



Figur 5 Screen dump of measurement program MainToFile.vi. The program is started by the right-arrow at the upper left corner. The settings shown here are not nescessarily correct!

The output file that the Labview program writes, has three columns. The first column contains the raw electrode signal. The second column contains the digitally filtered electrode signal (after both filters) and the third column contains the force signal. The very first line contains the sampling frequency, while the remaining lines contain the actual signal. The sampling frequency is in hertz while the signals are in volts.

Table 2: Initial settings of the measurement program. See text for details. For the first three figures, keep ratio between numbers.

Item	Initial value
Sampling frequency (scan rate)	5 000 Hz
Buffer size (in memory)	20 000 scans
Number of scans to write at a time	5 000
Notch filter (48-52 Hz)	Off
Bandpass filter	15 Hz and 500 Hz

There is another LabView program that allows reading the first column of the data file and performing the filtering, before the data is written to a new file. This program is called MainFromFile.vi. If you for some reasons need to re-apply the filters on data already saved to file, then this program can be used.

The three first parameters in Table 2 are described in detail in Appendix 9.3.2. If any of these values are changed, the program should be stopped and started again.

6 Measurements

The instructions here are not strictly written step by step, since your measurements will be an interactive effort from your side, in the sense that you might have to repeat different parts of the measurements a number of times. So after you have read Section 6.1, you must try to create a mental picture in your head about what is going on, and why.

6.1 Staircase exercise (the first measurement day)

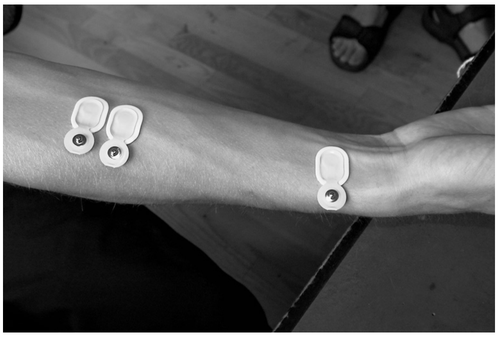
6.1.1 General

In order to measure the EMG signal, three electrodes should be placed on the forearm of the subject as shown in Figure 6. Remove all jewelry from the arm in use. The active area of the electrodes Pos (+) and Neg (-) are placed as close as possible (approximately 1-2 cm apart center to center) near the midline of the belly of the muscle (musculus flexor digitorum superficialis) since this is the area where the most muscle fibers will be intersected. In the other direction the electrodes should be on the long-axis of the muscle. A third reference electrode should be placed on electrically neutral tissue (say over a bony prominence) on the wrist of the subject as shown in Figure 6. To ensure good connection, these areas should preferably be cleaned with alcohol and dried prior to placement of the electrodes. If you are sensitive to the glue, then do not clean the skin where the glue goes. More details on electrode placement can be found in [2].

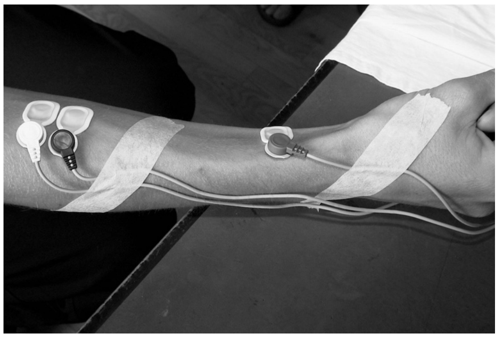
Then connect the electrodes to the equipment but relax the muscle completely. Let the forearm rest on the table, in order to relax other muscles located nearby. Do not touch the dynamometer. Look at the computer screen and consider the signals. Both should have no offset and be reasonable small (maybe zero) in amplitude. If not, adjust the offset and maybe gain to obtain this. Be sure you understand where on the LabView program you can observe this. Many knobs can be adjusted, and you might need to ad-

1) Clean with alcohol

2) Dry to ensure good connection



3) Place the electrodes



4) Connect cables to electrodes and fasten with tape

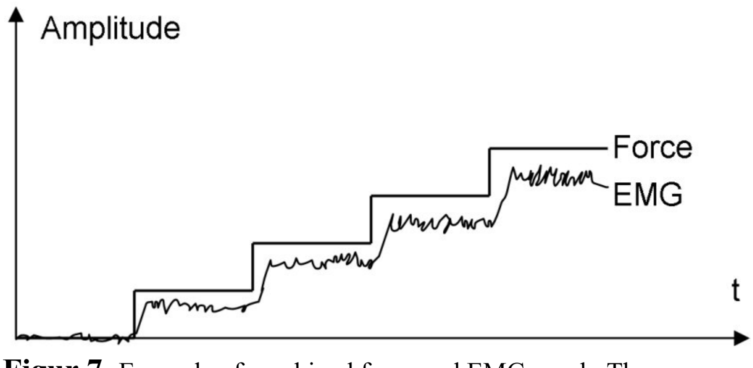
Figur 6 Proper application of electrodes

just some of them again later. Now play with the digital lowpass, highpass and notch filters, to see their effect on the amplitude of the signal. You can also remove (set to “off”) these digital filters and play with the analog filters, but remember to put them back into the optimal state. Be sure that you understand all "knobs" on the computer screen.

About offset: After you change gain, you cannot be sure that the offset remains correctly adjusted. Try the following: Relax completely and do not touch the ball. Set gain to unity (one) for both channels. Adjust the offset to zero (see the voltage at the blue, lower right hand window in Figure 5). Now, observe possible changes in the voltage level as gain is increased (up to about 50). If the voltage level is not constant, it means that you will have to adjust the offset *after every change in gain*.

For your reference: The electrodes must be placed on the skin and connected to the isolation amplifier. If not, you will get a highly fluctuating signal and will not be able to adjust any settings.

Suggestions for initial settings of the analog and digital equipment are stated in Table 1 and 2.



Figur 7 Example of combined force and EMG graph. The curves show the rms values.

Finally, a small but important detail: check if the readout on the front panel of the Labview program (Figure 5) is done with a period as the decimal seperator (as done in the US). If it is a comma, then data will also be written to disk with a comma, which will make reading into MATLAB more cumbersome. Ask a teaching assistant (*hjælpelærer*) to help you changing the comma to a period in the LabView configuration panel.

6.1.2 Recording the staircase data

When the equipment is properly setup, force should be applied to the dynamometer in a step-wise fashion as sketched in Figure 7, in order to make interpretation of the measurements easy. As the dynamometer is a delicate piece of equipment you should avoid squeezing your fingertips or any jewellery into the dynamometer, since this can damage it. Try squeezing with your fingers as extended as possible.

The software is designed to both save the measured data to a file and present the data on screen. It is recommended to use a consistent and easy recognizable file name *e.g.,*

<person>_<gain_ch1>_<gain_ch2>.txt

when you save your data. Example: sofie_50_10.txt. Remember to change the value if you later adjust the gain. In this way, you will be able to remember your gain settings for the different persons and easily identify the data later on. You should also try to get some “screen shots” of the graphs for later reference. You can do this by pressing "Alt-Print Screen", go to a program that can handle images and press "Ctrl-V" to paste the screen shot into that program. Now save this in a file that match the file name of the data you save (i.e. your files with the screen shot and data has the same *first name*, but different *last names*). Be very careful about naming files, it is difficult to remember a week or two later, and your written notes could be unclear or get lost.

Data should always be saved in `c:\users\31654`.

Look at the signals from both the dynamometer and the electrodes. Also pay attention to the rms-values of the signals, which are shown on the screen. The rms-value is calculated from the entire signal in the buffer. If the buffer is 500 points, then the corresponding time period is $500/f_s$, where f_s is the sampling frequency. f_s is identical to “scan rate” at the upper right hand corner of Figure 5. The concept of sampling will be considered during the lectures.

One of the important things about these measurements is to use the equipment efficiently, as was also stated in Section 4. This means that your gain should be appropriate to make the measured signals be just within the ±10V of the digitalization board (down to ±4V is OK). Especially, check the red signal: if it is strongly clipped, you will have to record a new signal with lower gain. Likewise, it is important to adjust the zero point, so that the signal oscillates symmetrically around zero at all times!

When the program runs (after pressing the arrow bottom), all data is simultaneously saved to a file. Remember to press "stop", before the file gets too large! *This file should be saved on a local harddisk*, maybe under "C:\Documents and Settings". Be sure to move the files that you need, to your network drive and delete other files that your program has created. Try to figure out, why do we do it this way? Be sure you find the answer, possible by asking the teaching assistant.

On your network drive, you can consider making a directory called `31654\trappe` where you store the data from this measurement. Later you can make another one called `31654\fatigue`.

6.1.3 Overview of what data files you need

In summary, you should have done the following exercises and saved the following data:

- A data file where you try to "replicate" Figure 7 as well as possible. One file per person. Example of name: sofie_50_10.txt
- Directly afterwards and with exactly the same settings as above, record a data file where you relax completely, so that you can see the noise level. This file might also be useful for other things (as we will come back to in the course). One file per person. Example of name: sofienoise_50_10.txt

Before you leave the laboratory, it would be a good idea to re-check the block diagram showing the individual components and how they were interconnected. This will help you considerably when having to write the report. Remember to indicate the blocks with a meaningful title, company and type number.

And finally, are you data files on your network drive and deleted on the local computer?

6.2 Fatigue exercise (second measurement day)

This is the last exercise! Thus, you should be sure that you have all the data that you need; otherwise this is the time to record what you might be missing from the previous measurement.

The present exercise is carried out as in the previous exercise, with the exception that you squeeze the dynamometer with a constant force. It is difficult to apply a constant force during long time. Use the rms value of the force curve as a visual feedback to ensure constant force. When you have a curve where the rms value is rather constant but then falls at the end (no matter how red your face becomes (☺), then you can save this data.

7 Wrapping up

When the exercise has been carried through and all data is obtained you should remove the electrodes and rinse your arm with water. Also remember to clean up after yourself, dispose off your garbage (including sheets of paper) in the trash can, disassemble all hardware, bring it back to the shelf and log off the computer.

8 References

[1]http://www.iworx.com

[2] Surface electromyography: Detection and recording. Delsys Inc. 1996.

[3]IWORX ETH-256 manual (pdf available via course home page).

9 Appendix

9.1 How to log on to PCs in ES-lab (005) in building 349 and the group PCs in building 327

1. When the computer has completed the boot process log on as "stud" using the password "stud".
2. After Windows has opened activate the Internet Explorer window and log on using your student ID and password; this validates you and enables you to save data at your student account. Minimize Internet Explorer.
3. Now go to the small login window and log on, again using your data bar student ID and password, and you are ready to go.
4. To access your personal data bar home directory right click on the Start Button in the lower left corner and select Explorer. Your data bar home directory has been mapped as the Z drive.

9.2 Trouble shooting

Signal missing on screen:

- Make sure that the program is reading from the correct channels of the connection box (channels 0 and 1) and
- verify that the switches below the channels are set to “FS” and
- verify that the cable to the connection box is really fastened.

The bioamplifier seems not to react to changes in settings on the front panel:

- Turn power off, wait 30 s and turn back on.

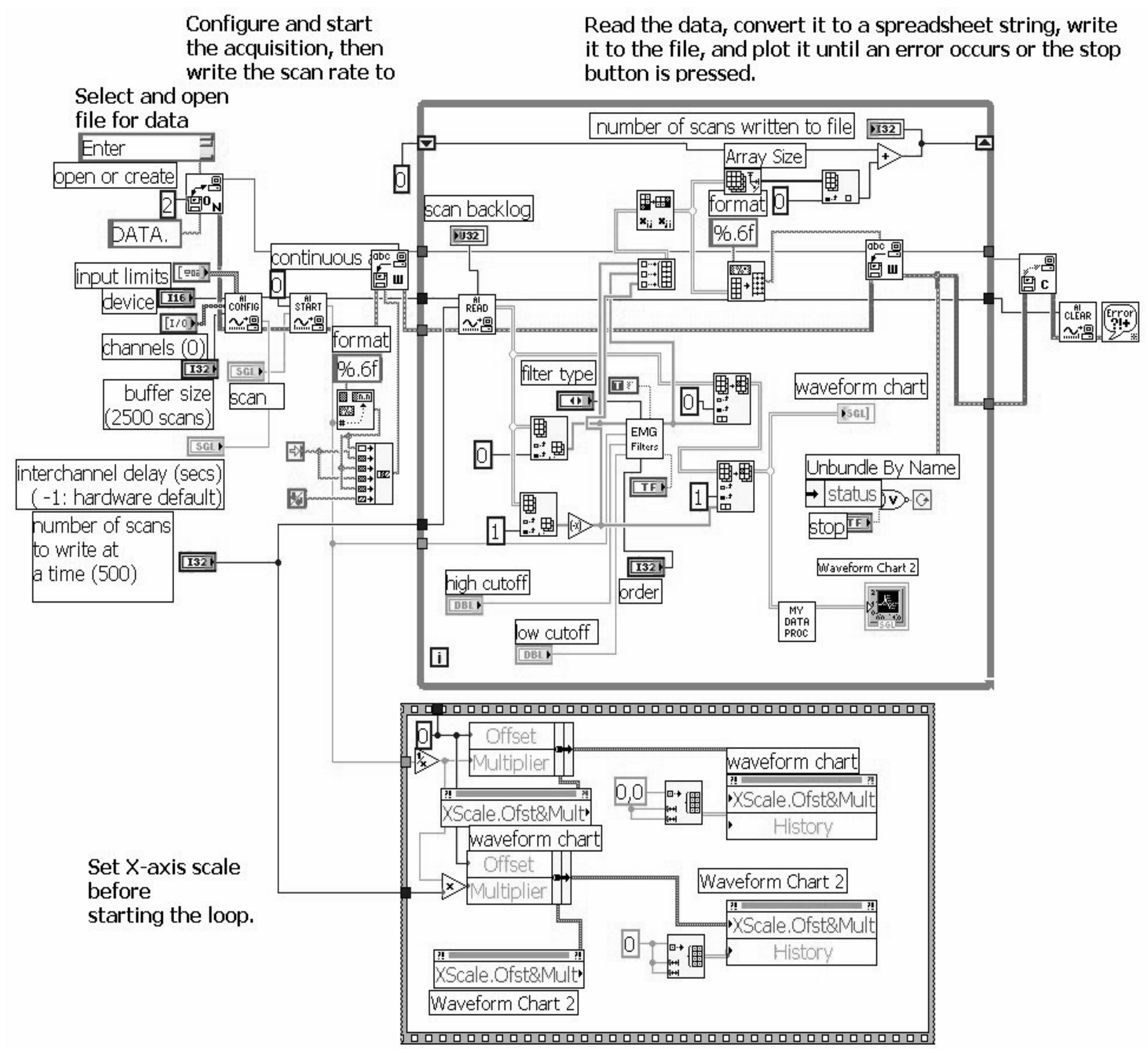
Error on the ADC or in the cable to the computer:

- Consider using another set of channels, maybe from (0,1) to (4,5) and do the same in the LabView program. (switch termo to BNC on connector box).

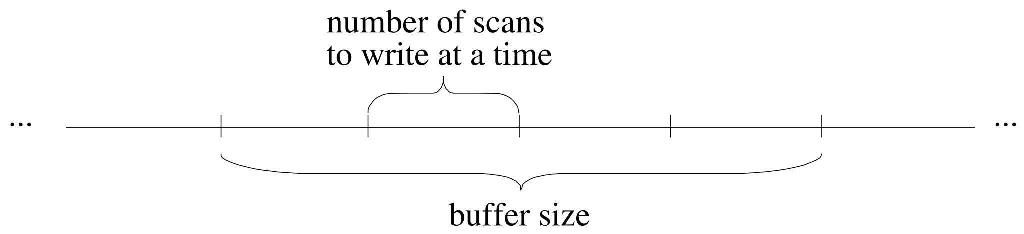
9.3 Details of LabView program MainToFile.vi

9.3.1 Functionality and block diagram

This VI reads EMG and Force channels in from the data acquisition card. It can be used to save recorded data to an ascii file. In addition to general filtering of the EMG channel there is an option to dampen



Figur 8 Block diagram of data acquisition program for LabView, MainToFile.vi (v3).



Figur 9 Schematic illustration of part of the RAM in the computer. The analog to digital converter card in the computer is continuously writing to the part of the ram corresponding to “buffer size”. Howerver, in this case, only a fourth of the buffer size is written at a time.

50 Hz interference from the power lines (only on the EMG channel). The need to remove power line interference is confirmed if the EMG rms curve has a high baseline value. In that case one should compare the result with and without filtering the EMG signal.

The hand dynamometer used to record contractile force in the muscles of the lower arm generates a negative voltage deflection upon compression. The program inverts the force signal in order to obtain an upward deflection.

Using the magnifying glass to the right of the graph one can zoom out and include the entire data sequence inside the graph window or zoom in to see the details of the emg signal.

With respect to the file written to disk: Check if the decimal point in your data files is the symbol you want (period or comma). If this is not the case you must alter the Windows setting in Control Panel.

9.3.2 Data transfer

The data transfer in the computer is determined by these three parameters which are also illustrated in Figure 9:

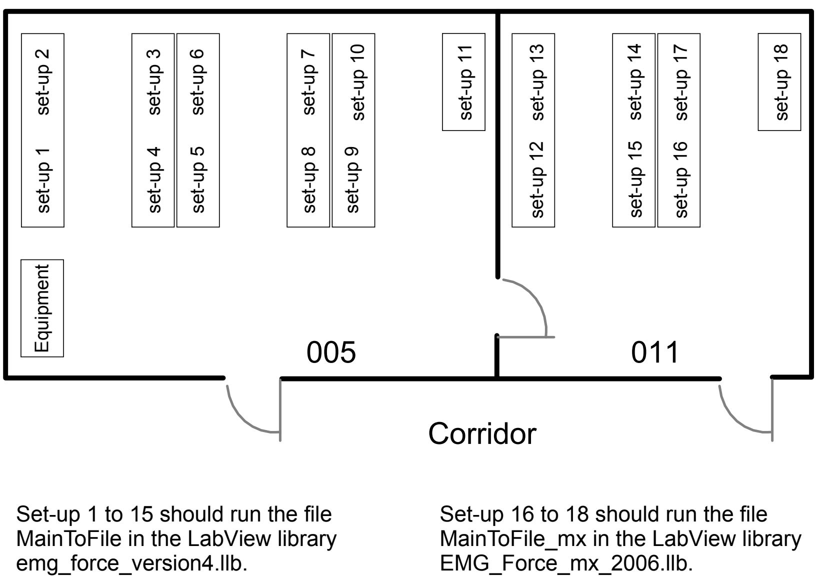
Buffer size: The number of floating point numbers that the ADC (analog to digital converter) can store in the PC memory before overwriting old values.

Scan rate: The number of floating point “number-sets” that the ADC writes to the buffer per second. If there are *two* channels, there are *two* floating point numbers in a ”number-set”. The scan rate is equal to the sampling frequency.

Number of scans to write at a time: The number of floating point numbers that the LabView program reads from the buffer and writes to an array in a single “buffer read operation”. In Figure 5, these data are (maybe partly) displayed in the upper graphs or used in the rms calculation and shown as a single dot in the lower graph.

Because the ADC writes continuously, the buffer size should be a good deal larger than “number of scans to write at a time“, to have some safety margins. In the long run, however, the sampling frequency should also be so low that the buffer can emptied faster than it is filled up. Error messages occur, if this is not the case.

9.4 Set-up assignment



Figur 10 Overview of the laboratory facilities. For MedTek1: Team 1 should sit at Set-ups 1, 2, 3 and 4. Team 2 at Set-ups 4, 5, 6 and 7, etc. For MedTek2: Team 6 should sit at Set-ups 1, 2, 3 and 4. Team 7 at Set-ups 4, 5, 6 and 7, etc.