SEVENTH FRAMEWORK PROGRAMME

SPLENDID
Personalised Guide for Eating and Activity Behaviour for the Prevention of Obesity and Eating Disorders

Seventh Framework Programme

CallFP7-ICT-2013-10

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Abbreviations

DOW	Description of Work (Technical Annex to Grand Agreement with EC)
WP	Work Package
PDA	Personal Digital Assistant

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Executive Summary

Within the context of WP2 of the project SPLENDID, the two main objectives of Task 2.1 have been the selection or the design of a sensor capable of detecting chewing events and of an activity sensor.

During the first stage of the project, a preliminary non-integrated prototype of chewing sensors has been realized. The prototype consists of two microphone-based acoustic sensors and an optical sensor associated with its data logger. A series of measurements have been carried out at CSEM in order to assess whether the signals acquired by the developed sensors are good enough to be used to extract useful information on mastication. The prototype will be delivered in July to Wageningen University for the first validation study which is planned to be executed from July 28th to August 15th 2014 within the context of Task T6.2 and T6.3. The sensors will be evaluated and the comfort of wearing of sensors will be tested as well.

A specific activity sensor previously developed by CSEM, has been sent in Month 3 to Mando and AUTH for their evaluation for tasks T6.2 and T3.1 respectively. This sensor is capable of indicating either user's different activities such as resting, walking, running or the user presence or absence. It allows Mando and AUTH to extract raw data of the accelerometer in three directions. It has been assessed by the two partners with measurements at different positions on subjects. A new activity sensor, based on the delivered one, will be probably embedded into the future data logger.

The design of the prototype will be detailed in the next deliverable D2.2 entitled "Complete architecture of Sensing equipment Hardware and Software" in Month 18. The current document aims at giving a step-by-step description on use of the prototype dedicated to the validation study which will be carried out in Wageningen University in July 2014. The way the data acquired by the chewing sensors is converted to be further processed in Matlab is described as well.

1. Introduction

Based on the user requirements, health evaluation protocols and the complete system design, the work package 2 (WP2) in the project SPLENDID mainly involves the definition of the measurement techniques, the choice or design of the necessary sensors, the design of an electronic device capable of acquiring, enhancing, and processing the sensor signals, transmitting the extracted parameters wirelessly to a Smartphone, PDA or equivalent equipment.

Task 2.1 is the first task of WP2. One of the goals of Task 2.1 has been the selection or the design of a sensor capable of detecting chewing events with a recall and precision good enough (WP1) for the application that is at the same time small and smart enough to be integrated together with the loudspeaker of an earphone set [1].

During the first stage of the project, a preliminary non-integrated prototype of chewing sensors has been realized. The prototype consists of two microphone-based acoustic sensors and an optical sensor associated with its data logger. A series of measurements have been carried out at CSEM in order to assess whether the signals acquired by the developed sensors are good enough to be used to extract useful information on mastication. The design of the prototype will be presented in detail in the next deliverable D2.2 entitled "Complete architecture of Sensing equipment Hardware and Software".

This prototype will be delivered as a set of two units to Wageningen University – WP6 leader – for the first validation study within the context of tasks T6.2 and T6.3.

Another goal of Task 2.1 has been the selection of an activity sensor. A specific activity sensor previously developed by CSEM, has been sent in Month 3 to Mando and AUTH for their evaluation for tasks T6.2 and T3.1 respectively. This sensor is capable of indicating either user's different activities such as resting, walking, running or the user presence or absence. It allows Mando and AUTH to extract raw data of the accelerometer in three directions. It has been assessed by the two partners with measurements at different positions on subjects.

The present document serves as supplementary material to the chewing sensor prototype that has been realized within the context of Deliverable D2.1 entitled "Preliminary non-integrated prototype realization". It aims at providing a consistent description on how to use the chewing sensor prototype and on how to handle the data acquired by the developed chewing sensors to be further processed in Matlab.

1.1 Methodology

Task T2.1 has been carried out in the following procedure:

- study of the state of the art of the mentioned sensors in the field of dietary monitoring
- definition of the sensor system requirements
- development of the sensors' electronics
- experiences and recordings
- assessments of the recorded data
- development in parallel of the future data logger

During this first stage of the project, the emphasis has been put, following the DoW, on the choice and then on the design of prototypes of sensors in such a manner that rapid data acquisition could be performed to facilitate notably the work of WP3.

At the same time, designs on future integrated version of the system have also been carried out in parallel.

1.2 Document audience

The intended audience is all the SPLENDID partners, among which WP3, WP4 and WP6 partners are especially addressed.

1.3 Document structure

The document is organized as follows: an executive summary is given at the beginning of the document. The user manual of the prototype is described in Section 2. Handling of acquired raw data for further processing is presented in Section 3. Conclusion will be drawn at the end of the document.

2. User manual of the first sensor prototype for the validation study

2.1 Introduction

In this section, the use of the non-integrated prototype of chewing sensors is presented. The current section will serve as the User Manual dedicated to the first validation study which will be performed at Wageningen University in July 2014.

Separated and independent modules will be used for the first evaluation and data base campaign. During this phase, there is no need of large integration. Additionally, up to 9 electrodes for EMG acquisition for validation purposes will be used and attached to the subjects.

Two microphone-based acoustic sensors and one optical sensor will be used in parallel at the same time. Two sets of materials will be provided to Wageningen University for the validation study.

Each set is composed of the following modules:

- 1 audio module Alesis iO2 EXPRESS
- 2 power and polarization boards,
- 1 air microphone FG-23329 connected to an audio cable with XLR[4] audio connector
- 1 bone conduction microphone BU-21771-000 connected to an audio cable with XLR audio connector
- 1 PPG sensor with its data logger
- 1 Bluetooth USB dongle
- Software : CSEM Matlab viewer “Commander”

The whole prototype of chewing sensors is shown in **Figure 1**.

[4] Primarily found on professional audio, XLR connectors are available from a number of manufacturers and are covered by an international standard for dimensions, IEC 61076-2-103

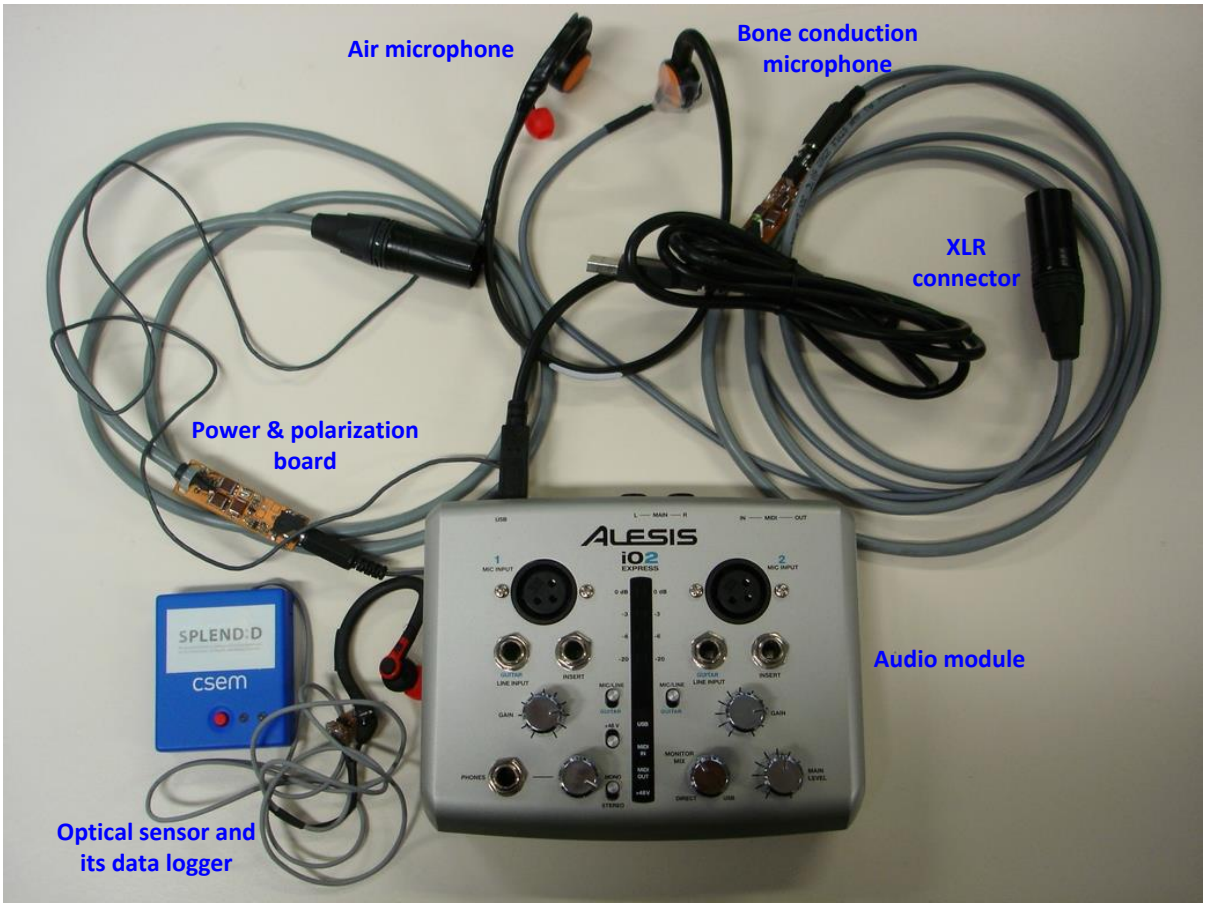


Figure 1: Overview of the chewing sensors prototype

The main feature of the specifically designed circuits for powering and polarize the two types of microphone is its capability of driving and converting the Phantom power of 48 V delivered from the audio module. This results in easy manipulation of the users since no additional power supply will be needed for recordings. Each of the two PCB, very small in dimension, is connected to the audio module through electrical cables. A green LED has been integrated to indicate the presence of the power supply when it is lighted.

2.2 Acoustic sensors

2.2.1 Setup of the audio module

The Alesis audio interface iO2 EXPRESS is a plug-and-play device, which means that no additional drivers need to be installed to use it with the PC, as shown in **Figure 2**.

Figure 2: Audio recording interface device and associated USB cable[5]

To enable the iO2 EXPRESS to receive audio to the PC, follow the instructions below:

Windows7:

1. Use the provided USB cable to connect the iO2 EXPRESS to the PC. Once the cable is plugged, a green LED is lighted just on the black rectangle screen on the device indicating that the device is power on.
2. Go to **Start menu → Control Panel → Hardware and Sound → Sound**
3. Click the **Recording** tab and select **Microphone / iO2** as the default device, as shown in **Figure 3**.

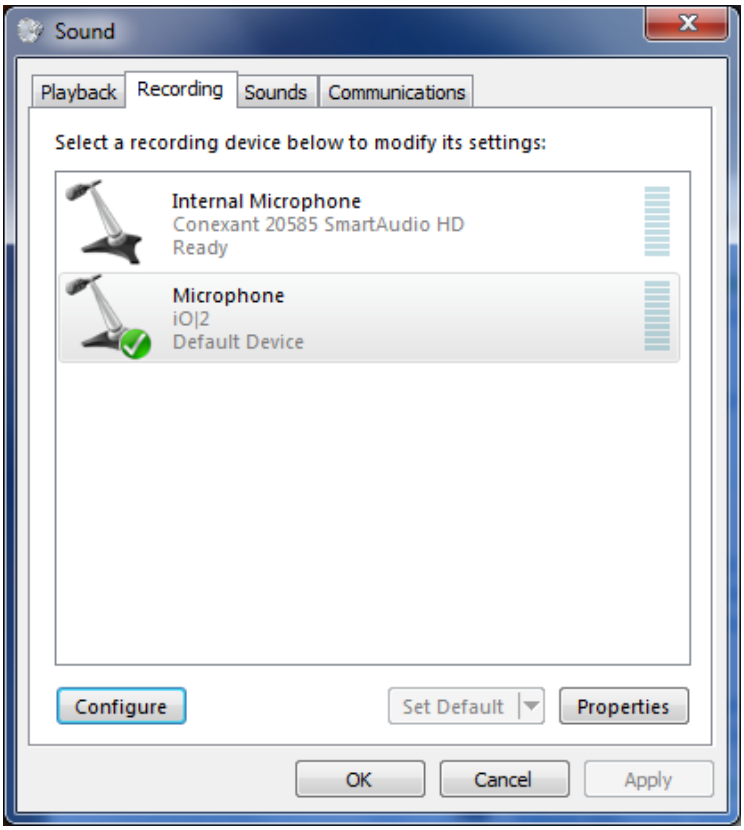


Figure 3: Audio recording interface device and associated USB cable[6]

[5] Photos taken from http://www.alesis.com/io2express

4. Click the **Playback** tab and keep your default device.
5. Click **Properties** in the lower right-hand corner.
6. In the new window, click the **Advanced** tab and select **2-channel, 24-bit, 44100 Hz (Studio Quality)** as the default format.

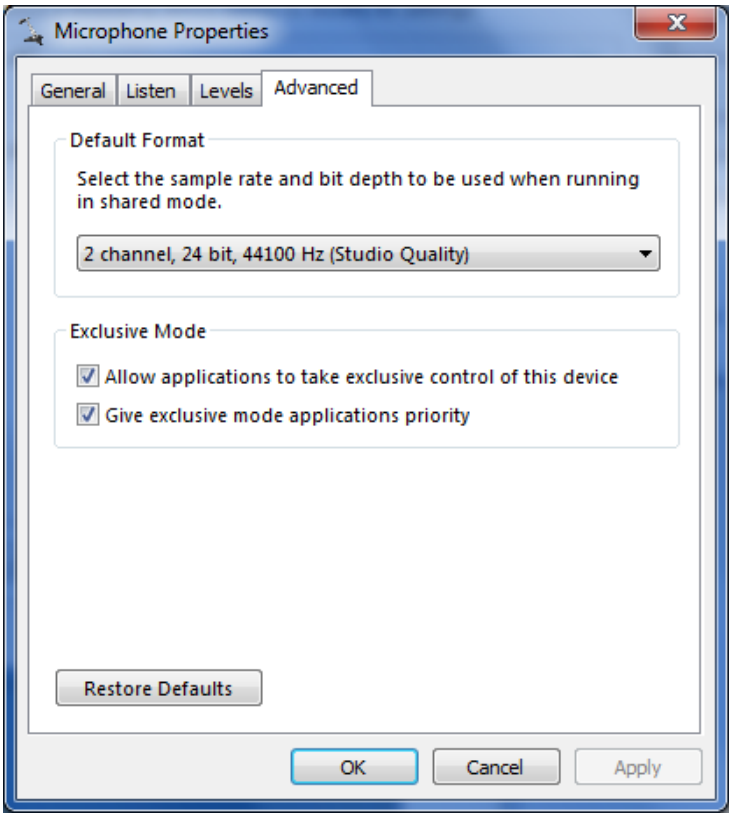


Figure 4: Audio recording interface device and associated USB cable

7. Uncheck both boxes under **Exclusive Mode**
8. Click the **Levels** tab and set the slide to **50**
9. Click **OK** to close the **Properties** window.
10. Click **OK** to close the **Sound** control panel.

Windows XP:

1. Use the provided USB cable to connect the iO2 EXPRESS to the PC
2. Go to **Start Menu → Control Panel → Sounds and Audio Devices**
3. Click the **Audio** tab
4. Under **Sound Recording**, select **USB Audio Codec** as the default device
5. Click **OK**.

[6] Photos taken from http://www.alesis.com/io2express

MAC

1. Use the provided USB cable to connect the iO2 EXPRESS to the PC
2. Go to **Applications → Utilities → Audio MIDI setup**
3. In the **Audio Devices** tab under **Systems Settings** select **USB Audio Codec** as the Default Input.
4. Close the window.

2.2.2 Connection of microphones to the audio module

1. In any case, care must be taken to insure that no signal saturation occurs. Adjust the volume (gain) of the audio device in the middle position.

Figure 5: Volume setting of the audio module

2. Connect the two microphones to the audio module by cables with XLR connector
3. Select **+48 V**
4. Select **Stereo**
5. Connect the audio module to a PC or a laptop by plugging the provided USB cable. The greed LED will be lighted.

2.2.3 Wearing of the microphones

A headphone from AfterShokz is used as support on which the air microphone and the bone conduction microphone are fixed. On the same headphone, two types of microphones are fixed, as shown in **Figure 6**.

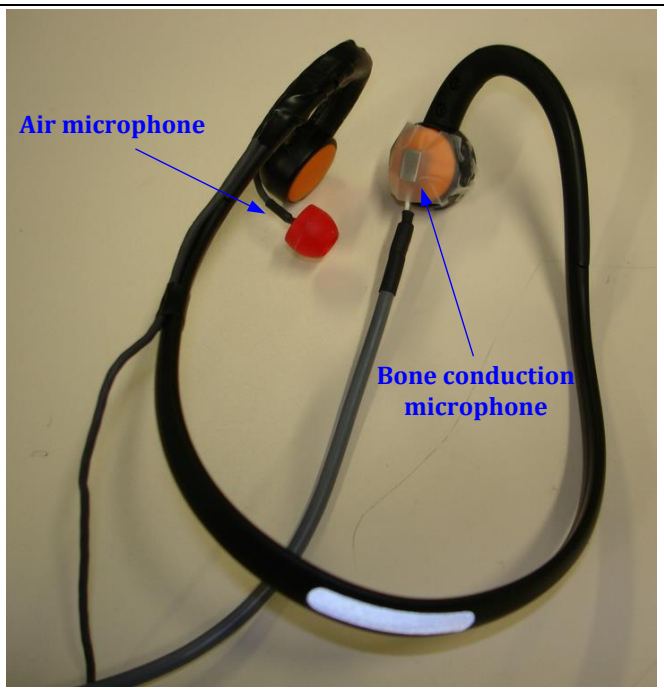


Figure 6: Headphone with two microphones

The headphone is worn in a normal way, as shown in **Figure 7.** Ensure that the microphone is inserted into a deep position in the ear canal in order to have a minimal influence of ambient noise.

Figure 7: Wearing of two microphones. Left: air microphone, right: bone conduction microphone

2.2.4 Signal acquisition

For an easy utilization, the proposed software for sound recording is "Sound Recorder" under Windows. It can be found under "Start Menu → All Programs → Accessories → Sound Recorder". The application is shown in **Figure 8**.

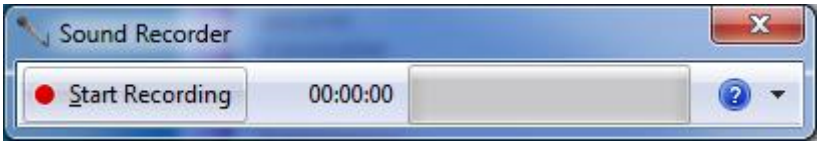


Figure 8: Sound Recorder under Windows 7

The user has to ensure that the correct audio input is selected. This can be checked under "Control Panel → Hardware and Sound → Sound" under the "Recording" tab.

A recording can be started by clicking the "Start Recording" button, which turns into a "Stop Recording" button while recording.

When the "Stop Recording" button is pressed, a window automatically pops up and allows the user to save the recording as a Windows Media Audio (WMA, *.wma extension) file.

2.3 Optical sensor

2.3.1 Pairing of the data logger to the PC

2.3.1.1 Installation of Bluetooth dongle

The data logger is wirelessly communicating to the PC by Bluetooth™. It is necessary to pair the device to the PC.

If no Bluetooth dongle is plugged in the PC, please insert the provided Bluetooth dongle and proceed to its installation. If the installation is successful, a message window like **Figure 9** will appear. If the installation is failed, re-install the Bluetooth dongle until the message "Your device is ready to use" appears.

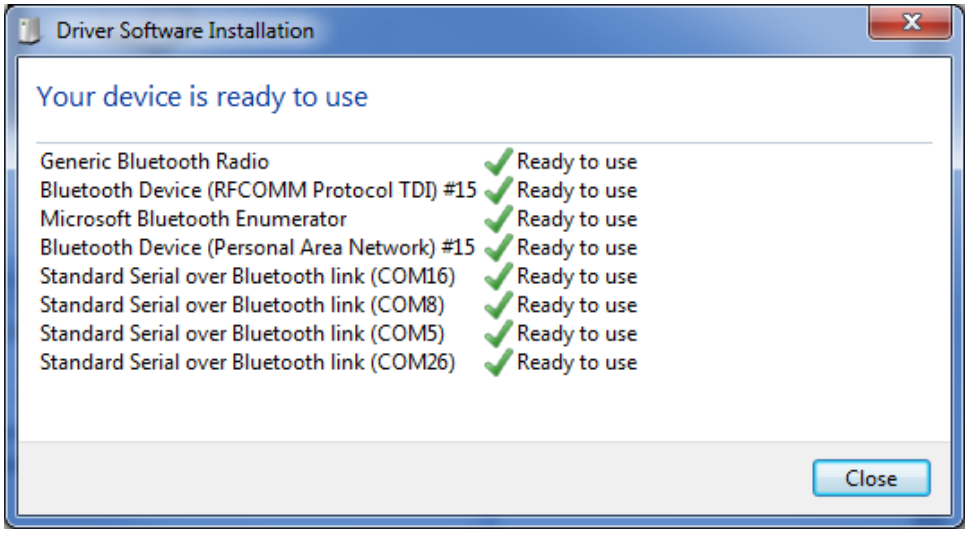


Figure 9: Installation of Bluetooth dongle

- **Paring of Bluetooth device**

1. Turn on the data logger by pressing the red pushbutton. The green LED will be blinking slowly.
2. Click the icon of Bluetooth
3. Click "Add a device", as shown in **Figure 10**.

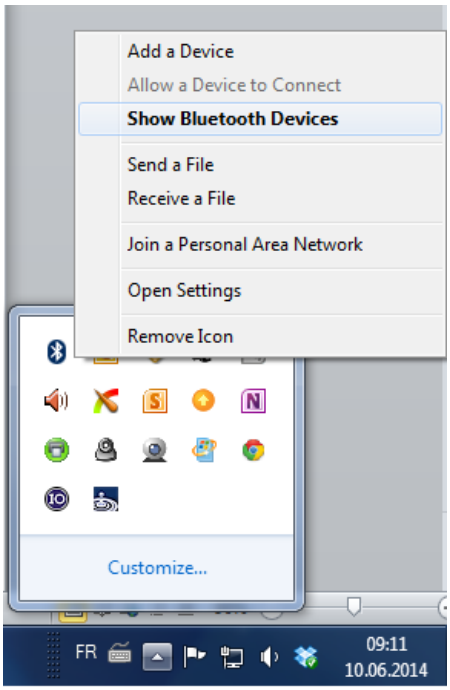


Figure 10: Add a Bluetooth device

4. Select "SPLENDID_n1" then click "Next", **Figure 11**.

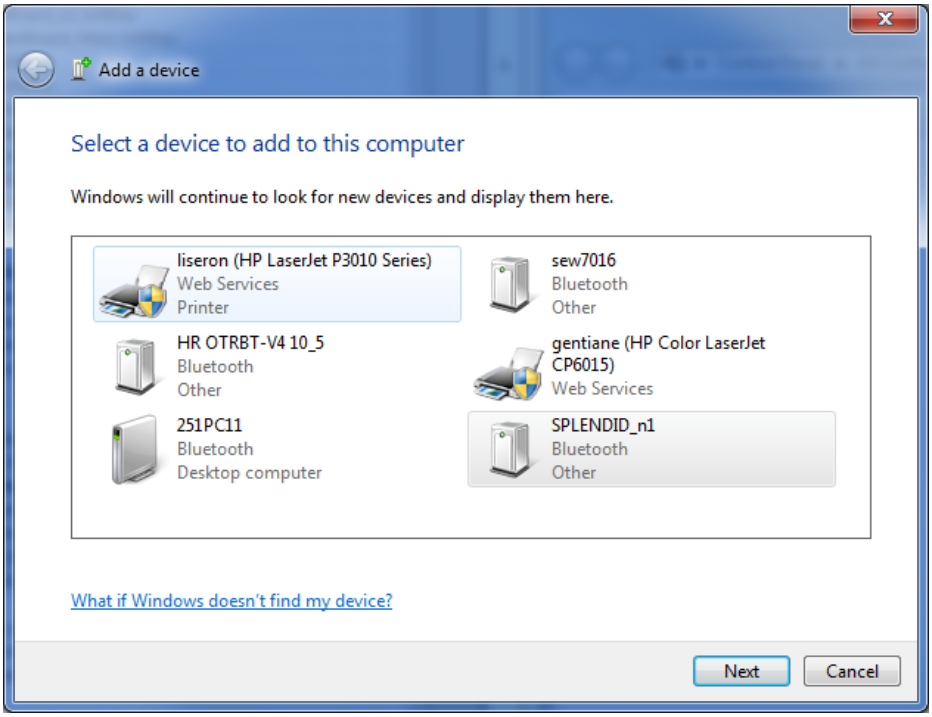


Figure 11: Selection of "SPLENDID_1" to add as a Bluetooth device

5. Click the second option "Enter the device's pairing code" and type "**2002**" to pair the device, as shown in **Figure 12**.

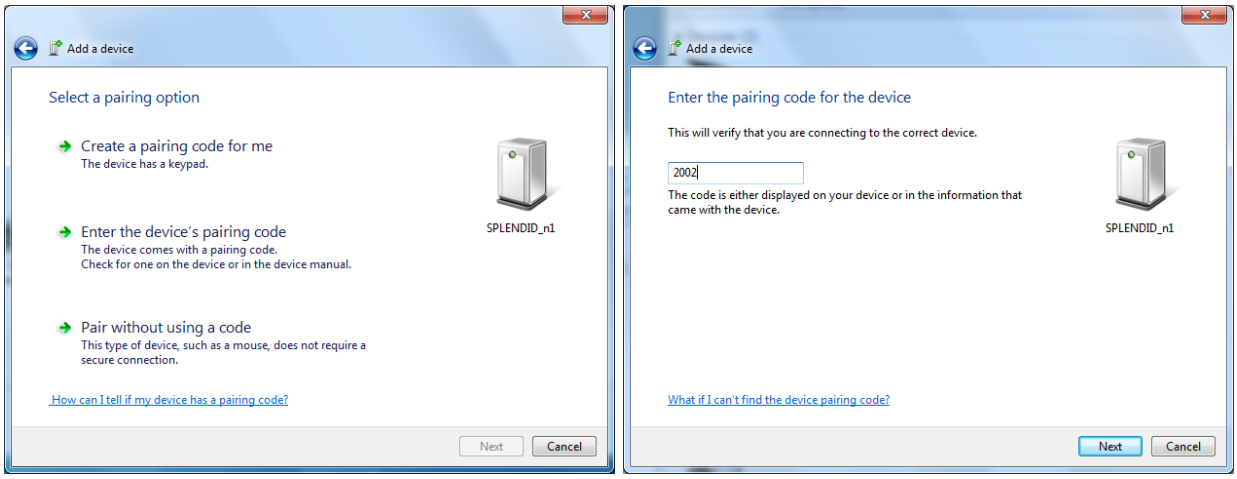


Figure 12: Paring of the SPLENDID_1 device to the PC

6. The icon of the data logger is shown in the "Bluetooth Device" window, **Figure 13**.

Figure 13: The data logger successfully paired to the PC

7. Right click on the icon and click the "Services" tab. Note down the communication port number, as shown in **Figure 14**.

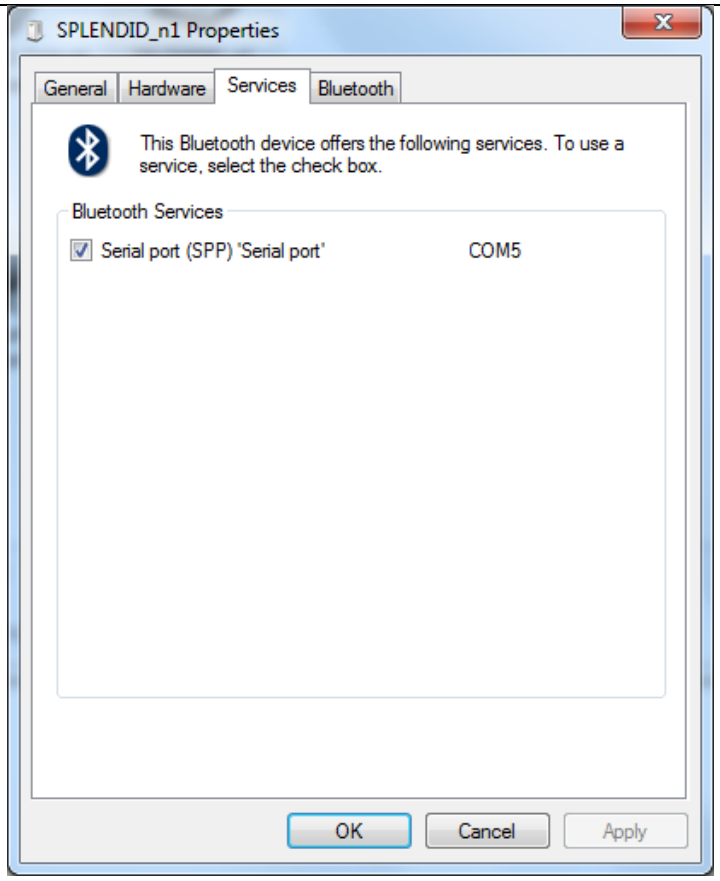


Figure 14: Communication port number of the connected device

2.3.1.2 Installation of the PC application – CSEM Matlab Viewer

1. Install the Matlab Runtime Environment
2. Decompress the executable file "Sense2_pkg.exe" into a known folder.
3. Check the contents of the created installation folder, as listed in **Figure 15**.

Name	Date modified	Type	Size
Database	11.06.2014 09:45	File folder	
Sense_mcr	11.06.2014 09:45	File folder	
default	11.06.2014 10:04	Microsoft Access ...	1 KB
DefaultSettingsViewerSigma	11.06.2014 10:02	Microsoft Access ...	1 KB
MCRInstaller_R2014aWin32.exe	21.02.2014 01:22	Application	550'062 KB
PC_Loader.exe	10.04.2014 16:39	Application	874 KB
readme.txt	14.05.2014 10:53	Text Document	2 KB
Sense.bat	14.05.2014 10:49	Windows Batch File	1 KB
Sense.ctf	14.05.2014 10:53	CTF File	906 KB
Sense.exe	14.05.2014 10:53	Application	380 KB
Sense_pkg_20140514_R2014aWin32.exe	14.05.2014 10:56	Application	1'601 KB
Sigma_DefaultSerialPortConfig	11.06.2014 09:52	Microsoft Access ...	1 KB

Figure 15: Installation folder

2.3.2 Wearing the PPG sensor

Wearing of the PPG sensor is shown in **Figure 16**. Ensure that the photodiode is positioned so that it is faced towards the LED. The LED is integrated into the red soft foam cushion that is inserted in the ear canal. It might be necessary to use scotch in order to fixate the sensor.

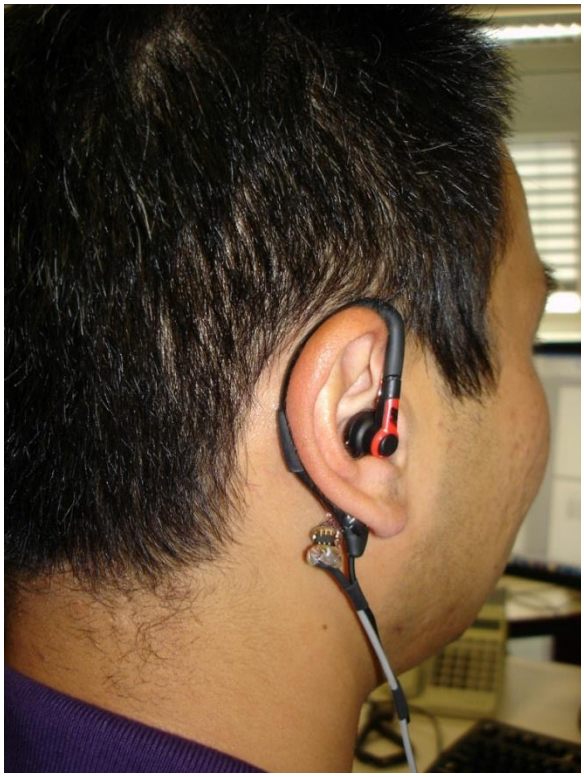


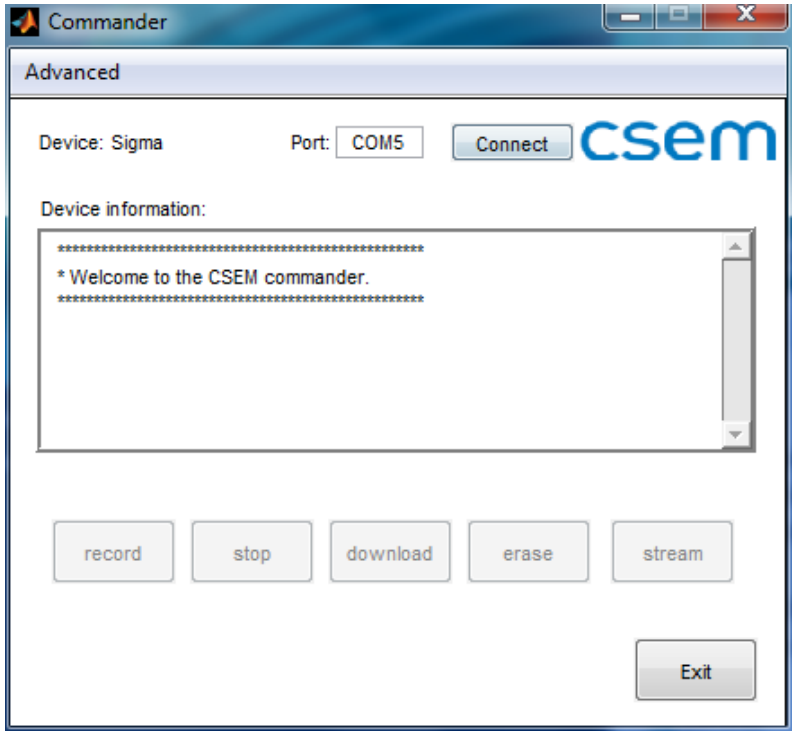
Figure 16: Position of the PPG sensor

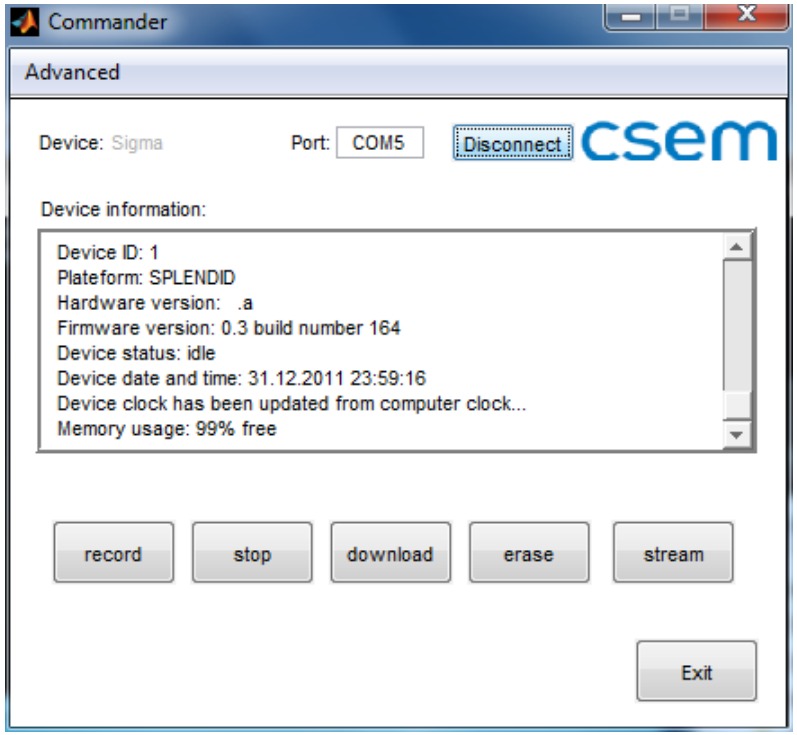
2.3.3 Signal acquisition with "Commander"

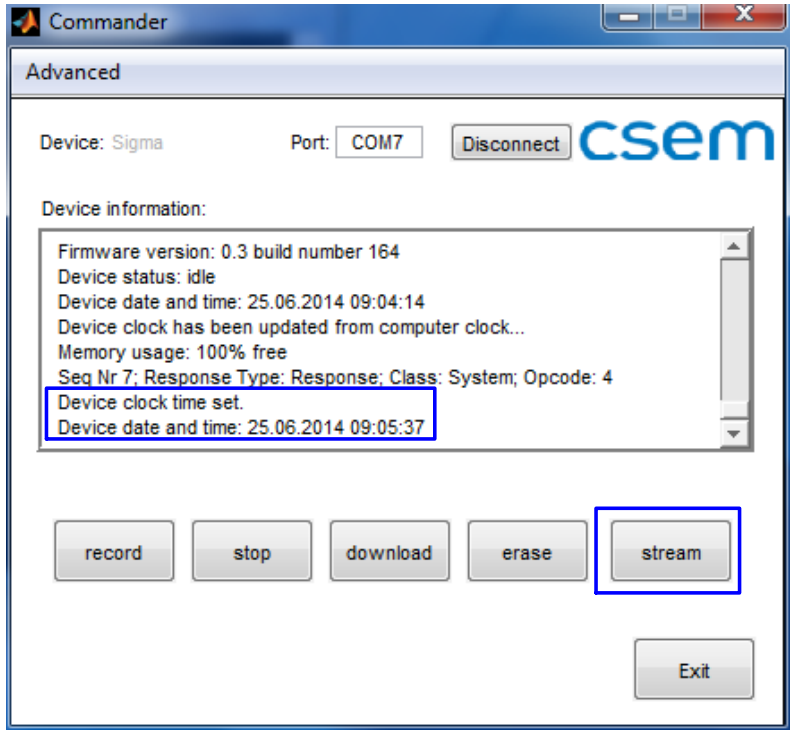
The PC application "Commander", developed by CSEM, allows to stream and display signals captured by the PPG sensor and to download recorded sessions from the embedded memory into PC.

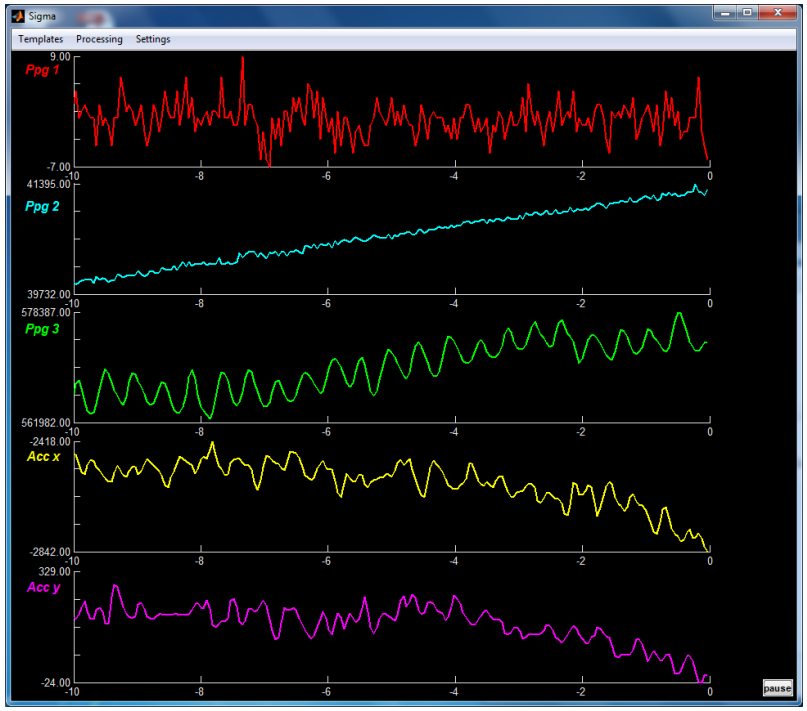
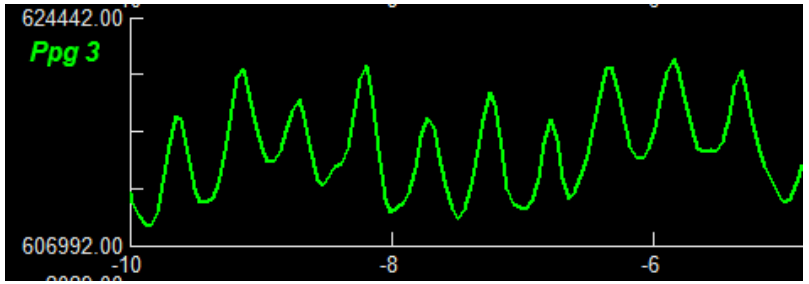
The following instructions listed in **Table 1** should be followed to record.

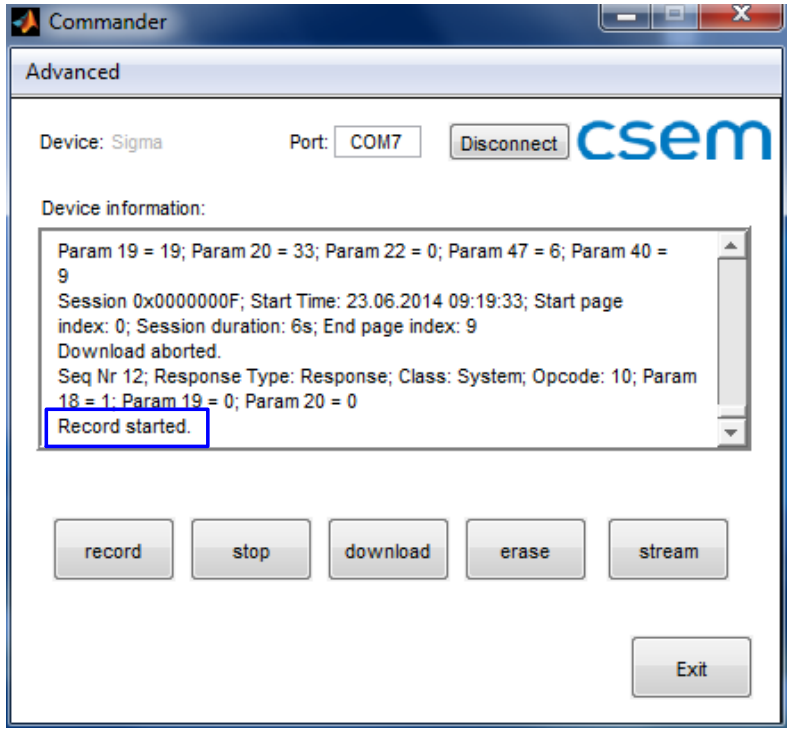
Table 1 – Instructions for recording with application "Commander".

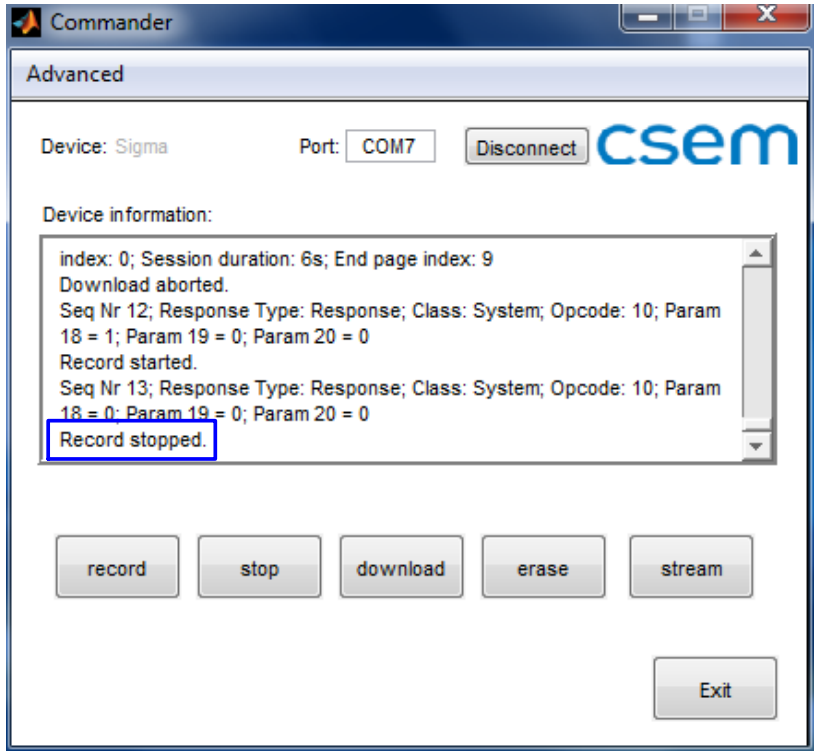
N°	Action	Description	Illustration
1	Turn on the data logger	Turn on the PPG sensor data logger by pressing the red pushbutton	
2	Launch the application "Commander"	Double click the batch file « Sense.bat ». Wait a while before the « Commander » window appears	

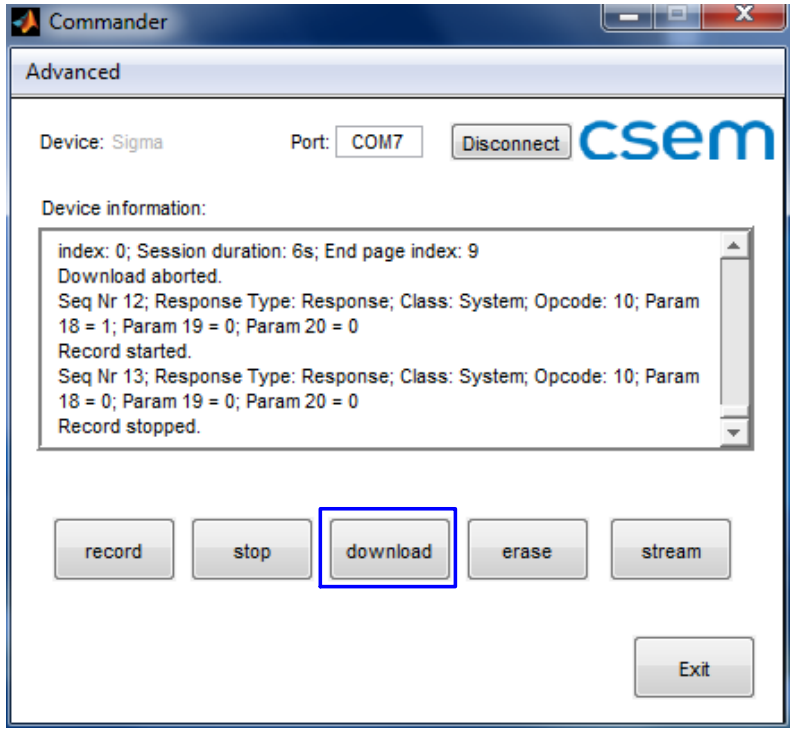
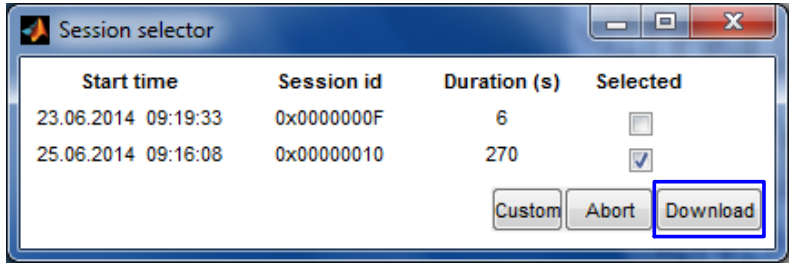
3	Connection of the data logger to PC	Click **Connect** and when the data logger is successfully paired, the next window appears	

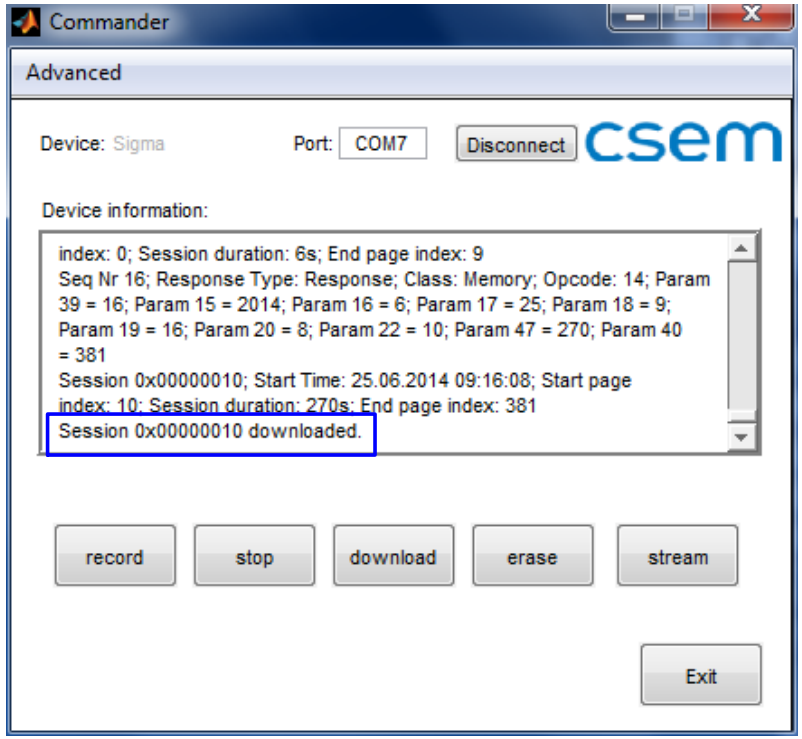
4	Set date and time	If the clock displayed in the window is not the current clock. Set clock by executing **Advanced → Custom cmd → SetClockTime**. To display the current date and time, execute **Advanced → Custom cmd → GetClockTime**	

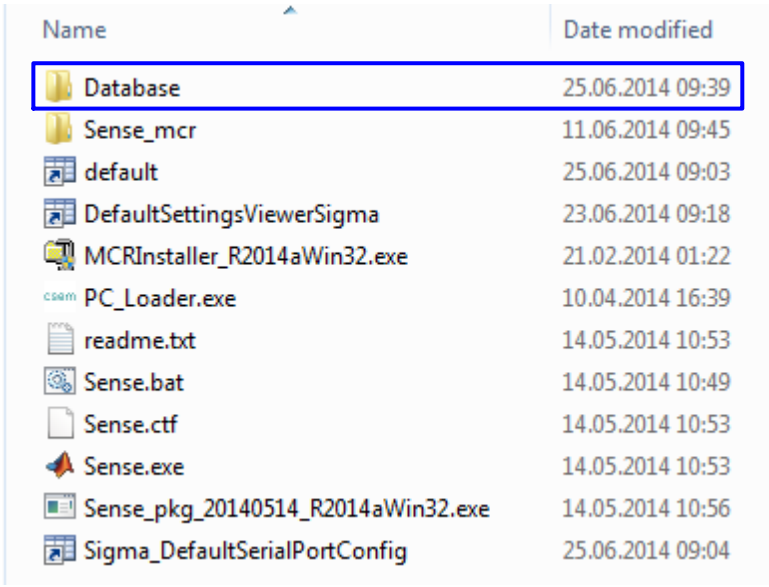
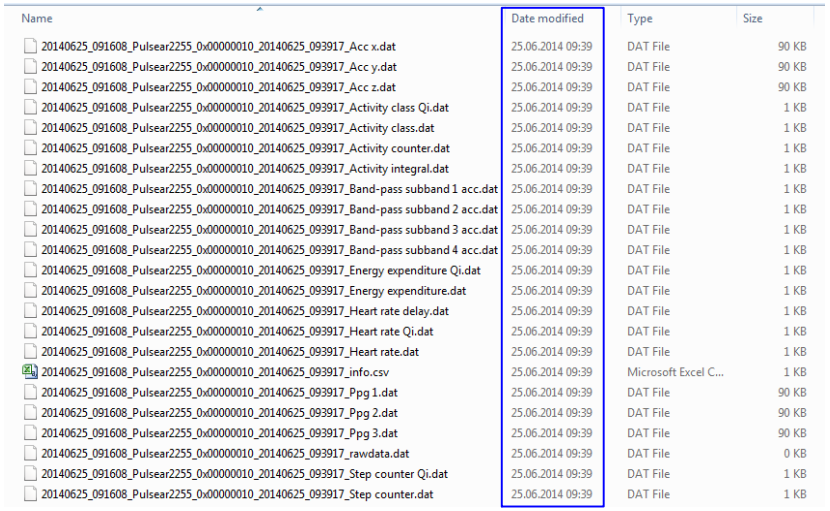
5	PPG signal streaming	To verify if the sensor is well connected and positioned in the ear, it is recommended to enter into streaming mode to view waveform of PPG signal. Click **stream** button, as shown in the previous figure, PPG signals are streamed and can be seen in a new window, as shown in the upper figure. Only "**Ppg 3**" represents the captured signal by the PPG sensor. Verify the waveform of PPG3 is somehow like what is shown in the lower figure.	 
6		Close the streaming window by clicking the red "X" button on the top right corner of the display window.	

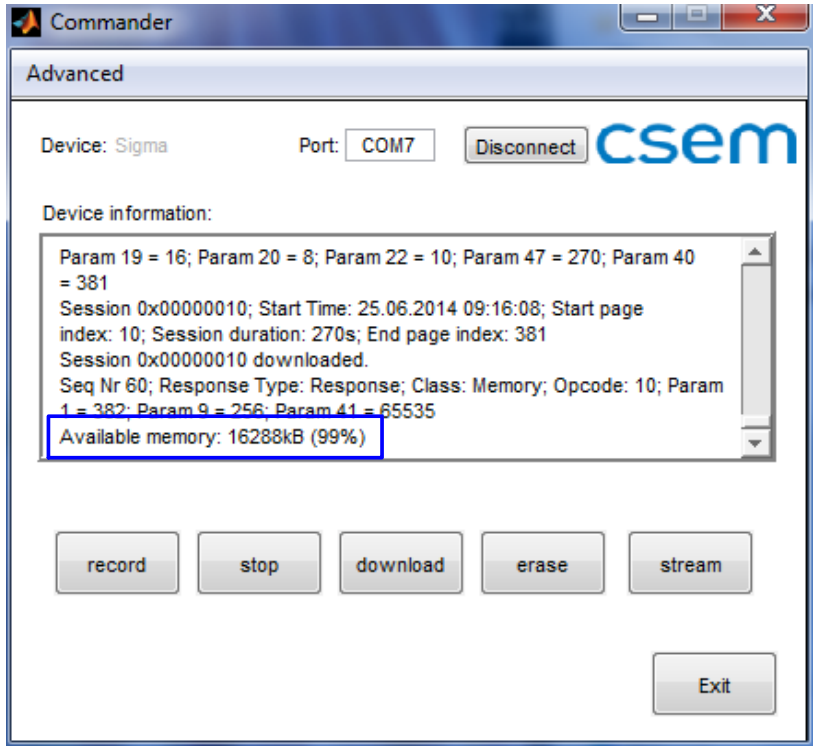
7	Start recording	Click "**record**" button to launch a recording. Verify that "**Record started**" is displayed in the interface window.	

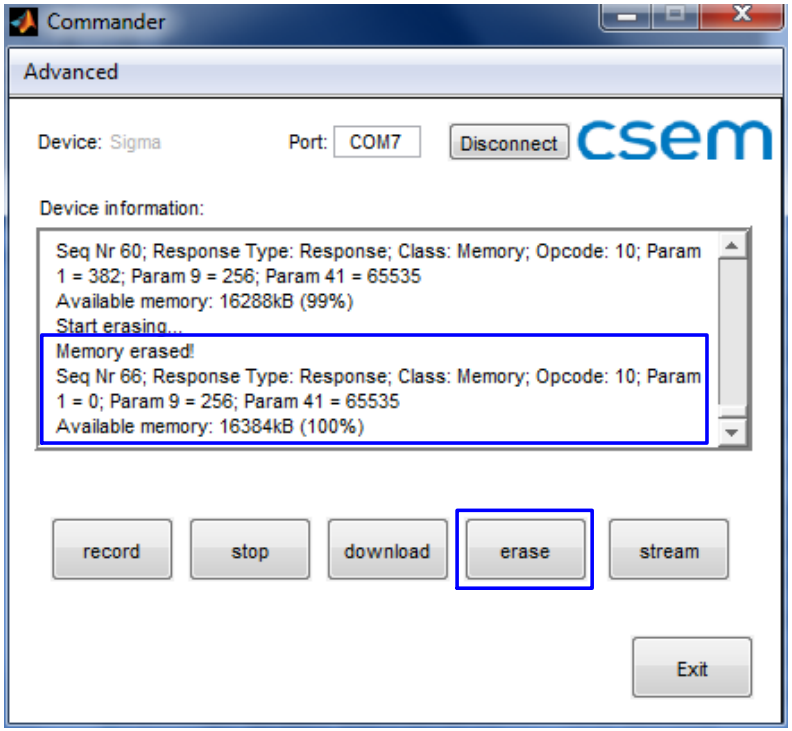
8	Stop recording	Click "**stop**" button to stop the recording. Verify that "**Record stopped**" is displayed in the interface window	

9	Download sessions	Click **download** button. A list of recorded sessions is then displayed in a new window	 

10	Successful download of sessions	Select recorded sessions to be downloaded and then click "**Download**". Verify the message "Session 0x0000xx downloaded" is displayed	

11	Folder containing the downloaded sessions	The downloaded files are put into the folder "**Database**" automatically generated during the installation of the viewer, which is located in the installation folder.	
12	Downloaded files in the "Database" folder	For each recording/session, a total of 23 files containing raw data are generated. All recorded data of different sessions are stored under the "Database" folder. In the Windows Explorer, the column "Data modified" can be used to distinguish the files related to each session. In fact, the showed date and time correspond to the recording time.	

13	Check of available memory	To check the resting internal memory, execute **Advanced → Custom cmd → MemoryStatus.** The percentage of available memory is displayed.	

14	Erase the memory	To erase the recorded sessions from the internal memory, click **erase** button. The available memory should be now 100%	
15	Disconnect Bluetooth	To disconnect the Bluetooth link, click **Disconnect.**	
16	Exit "Commander"	To close the application, click **Exit**	
17	Turn off the data logger	To turn off the data logger, press the red pushbutton and hold more than 3 seconds.	

2.4 Battery recharging of the data logger

If the data logger is running on low battery, the red and green LEDs will be slowly blinking. And if the battery is nearly empty, only the red LED will be fast blinking and the green one is OFF.

In these cases, the battery of the device needs to be recharged using a USB cable with a mini-B plug connected to a PC or a laptop. During recharging, the green LED is always ON and the red LED blinks, as shown in **Figure 17**.

Figure 17: Recharging of the data logger

When the battery is completely recharged, the green LED will remain ON and the red LED turns OFF. Remove the USB cable and press again the pushbutton.

3. Handling of data acquired by the sensors

For further digital processing of recorded data in Matlab, the raw data need to be converted into acceptable data format. In this section, the procedure of data conversion is described.

Note that the information provided in the section is particularly addressed to the WP3 team who will carry out signal processing.

3.1 Acoustic sensors

3.1.1 Data import in MATLAB

The present section details how the raw data acquired by the various sensors can be imported in MATLAB for further processing.

The raw audio file for both the bone and air microphone is a WMA file, when using Sound Recorder as recording application. The following two-step procedure is proposed to import the data to be handled in MATLAB:

1. The WMA file should first be converted to a Waveform Audio File Format (WAV, *.wav extension) file. To do so, the use of the free software Format Factory (available at http://www.pcfreetime.com/index.html) is suggested. The installation file will be provided jointly to this document. The procedure for converting a WMA file into a WAV file using Format Factory is detailed hereunder.

    a. In the "Audio" tab on the left, click on the "→ WAV" button.

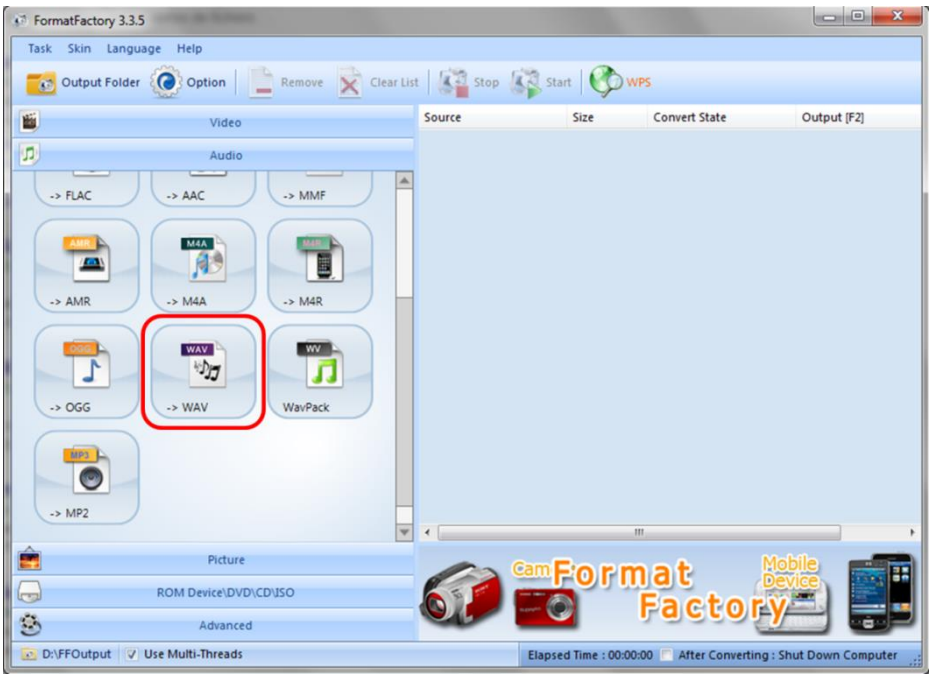


Figure 18: Format Factory interface

    b. In the new window as shown in **Figure 19**, add the WMA file using the "Add File" button, then specify an output folder for the WAV file with the "Change" button.

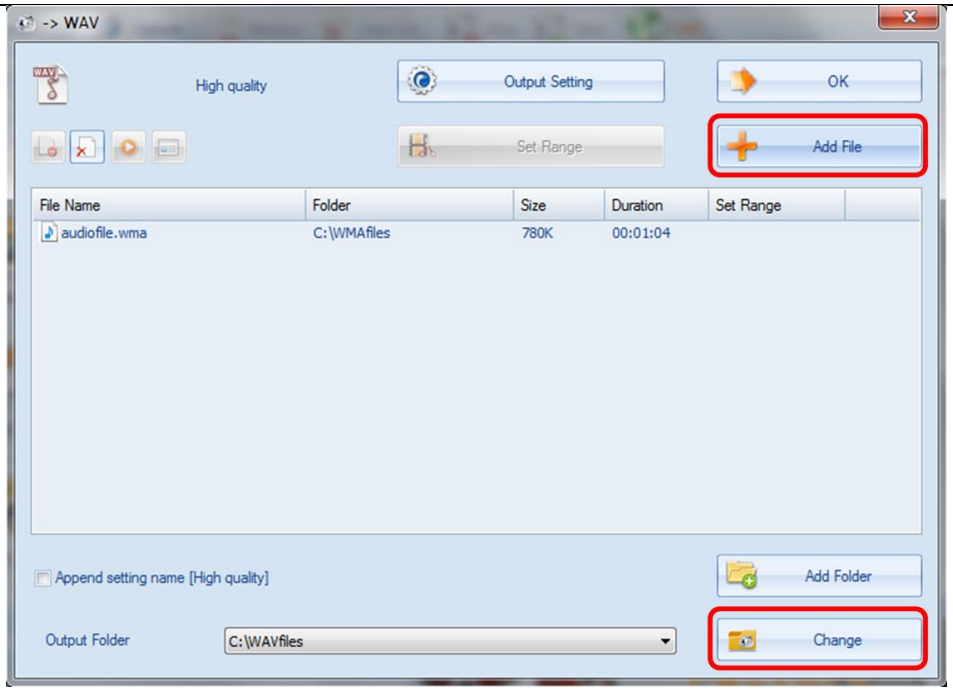


Figure 19: Conversion of audio format

c. Click OK. The new window closes. To start the conversion process, either click the "**Start**" button at the top or at the bottom.

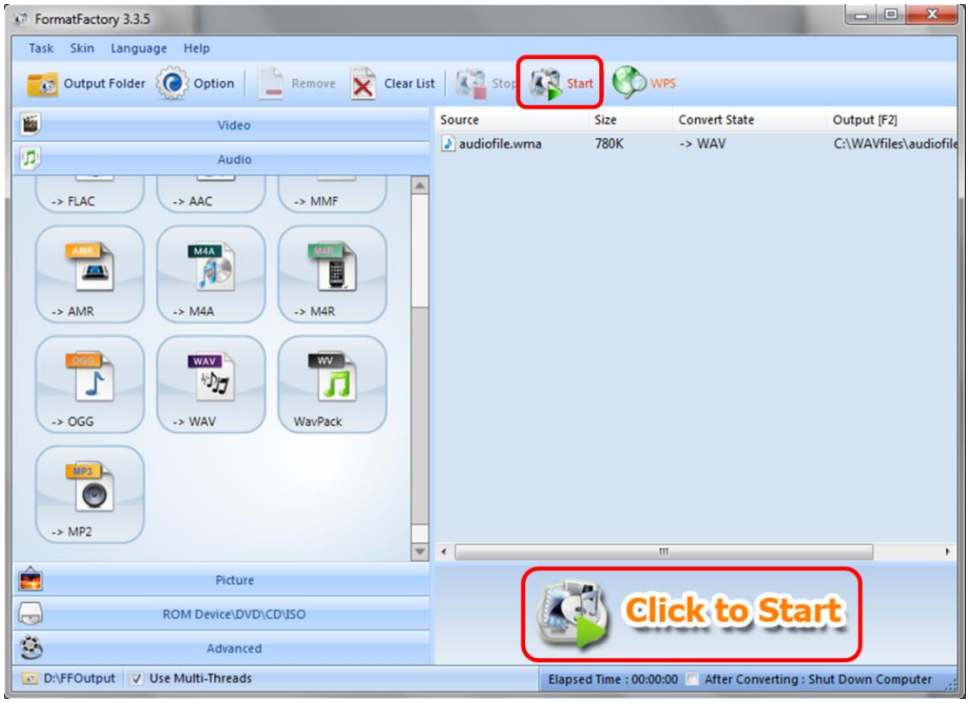


Figure 20: Start of conversion

d. The WAV file is now available in the specified output folder.

2. The so-obtained WAV file can then be read via MATLAB's command:

```
[Signal,Fs] = wavread(Filename);
```

where `Signal` is a two-column matrix containing the desired audio signal in the first column, `Fs` is a scalar containing the sampling frequency and `Filename` should be a string containing the name (with its full path and extension) of the WAV file to be imported.

3.2 PPG sensor

The raw data obtained from the PPG data logger is a Comma-Separated Values file (CSV, *.csv extension) and a collection of Data files (DAT, *.dat extension). All these files should be kept together in the same folder. The following command is proposed to import the data they contain in MATLAB:

```
[Ppg,Fs] = readPPGsignal(PathToCSVfile, CSVfile);
```

where `Ppg` is a vector containing the desired PPG signal, `Fs` is a scalar containing the sampling frequency, `PathToCSVfile` and `CSVfile` should be strings containing respectively the path and the name of the CSV file to be imported (with its extension).

The source code of the "**`readPPGsignal`**" function is provided in Annex **Error! Reference source not found.**.

4. Conclusion

The main objectives of Task 2.1 are to design a sensor which allows detecting mastication events and to select or design an activity sensor. During the first stage of the project, a preliminary non-integrated chewing sensor prototype has been developed. Research on adequate commercial off-the-shelf headsets which could physically support either the acoustic sensors or the optical sensor has been carried out. A series of recordings using the designed sensors in a fully controlled environment have been done. As mentioned above, detailed description of design and verification of the current prototype will be given in the next deliverable D2.2.

The prototype will be delivered in July to Wageningen University for the first validation study which will be executed from July 28th to August 15th 2014 within the context of Task T6.2 and T6.3. The sensors will be evaluated on subjects and a data base will thus be obtained. The comfort of wearing of sensors will be tested as well. During the further work, more effort will be done on mechanical design in order to build fashionable ear-worn sensors.

Aiming at the first integrated version (V1) of the prototype, the next step of the development consists in continuing the on-going work of designing an analog front end for the acoustic sensor, a more robust optical sensor and the data logger. New experiments have already been planned and signal quality assessment will be again carried out. Meanwhile, a new activity sensor, based on the one delivered to Mando and AUTH, will be directly embedded into the future data logger.

References

[1] SPLENDID Consortium, "Grant agreement for : Collaborative project Annex I - ' Description of Work ,'" pp. 7 – 9, 2013.