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g.tec GUGER TECHNOLOGIES

g.USBamp USB BIOSIGNAL AMPLIFIER

SIMULINK highspeed ONLINE processing

Simulink Highspeed On-line Processing

USER MANUAL V3.15.01

CONTENT:

TO THE READER

Welcome to the medical and electrical engineering world of g.tec!
Discover the only professional biomedical signal processing platform under MATLAB and Simulink. Your ingenuity finds the appropriate tools in the g.tec elements and systems. Choose and combine flexibly the elements for biosignal amplification, signal processing and stimulation to perform even real-time feedback.

Our team is prepared to find the better solution for your needs.

Take advantage of our experience!

Dr. Christoph Guger Dr. Guenter Edlinger

Researcher and Developer

Reduce development time for sophisticated real-time applications from month to hours.
Integrate g.tec's open platform seamlessly into your processing system.
g.tec's rapid prototyping environment encourages your creativity.

Scientist

Open new research fields with amazing feedback experiments.
Process your EEG/ECG/EMG/EOG data with g.tec's biosignal analyzing tools.
Concentrate on your core problems when relying on g.tec's new software features like ICA, AAR or online Hjorth's source derivation.

Study design and data analysis

You are planning an experimental study in the field of brain or life sciences? We can offer consultation in experimental planning, hardware and software selection and can even do the measurements for you. If you have already collected EEG/ECG/EMG/EOG, g.tec can analyze the data starting from artifact control, do feature extraction and prepare the results ready for publication.

Related Products

g.tec provides several biosignal analysis elements that are especially relevant to the kinds of tasks you perform with g.tec Highspeed.

For more detailed information on any of our elements, up-dates or new extensions please visit our homepage www.gtec.at or just send us an email to office@gtec.at

Conventions

Item	Format	Example
MATLAB code	`Courier`	to start Simulink, type `simulink`
String variables	*Courier italics*	`set(P_C,'`*`PropertyName`*`',...)`
Menu items	**Boldface**	Select **Save** from the **File** menu

Installation and Configuration

This chapter includes the following sections:

Hardware and Software Requirements

Hardware Requirements

g.tec Highspeed requires a PC compatible desktop, notebook workstation running Microsoft Windows.

The table below lists optimal settings:

Hardware	**Properties**
CPU	Pentium working at 3000 MHz
Harddisk	100 gigabyte
RAM	8 gigabyte
USB 2.0 high speed port	One free USB port for each g.USBamp and one for the Hardlock Dongle

Software Requirements

g.tec Highspeed requires the installation of the g.USBamp driver which is shipped with the device, MATLAB, Simulink and Signal Processing Blockset. Make sure that the MATLAB installation works correctly before installing the g.tec Highspeed software. Depending on your Windows operating system administrator rights might be necessary for the installation.

Software	**Version**
g.USBamp Driver	3.14.00 (shipped with g.USBamp)
MATLAB	Release 2014a
Simulink	Release 2014a
Signal Processing Blockset	Release 2014a
Windows	Windows 7 Professional Service Pack 1 English Win64
Acrobat Reader	11.0.04
.net Common Language Runtime	4

Installation from a CD

The installation consists of three steps:

1. Installation of g.tec Highspeed

   Insert the g.tec product CD into the CD-drive and change to the `g.HIsys\g.HIsys Highspeed Online processing for SIMULINK` directory of your CD-drive and double-click on the `Setup.exe` file. The installation starts and displays the welcome message. Follow the instructions on the screen.

   Please read the License Agreement for g.tec Highspeed and if you agree with the terms, click **I Agree** and **Next**.

2. Installation of the Hardlock

   The driver software for the Hardlock is installed automatically via Windows update, when the computer is connected to the internet. For manual installation click the `HASPUserSetup.exe` in the `Prerequisites/HaspHL` folder on your g.tec CD.

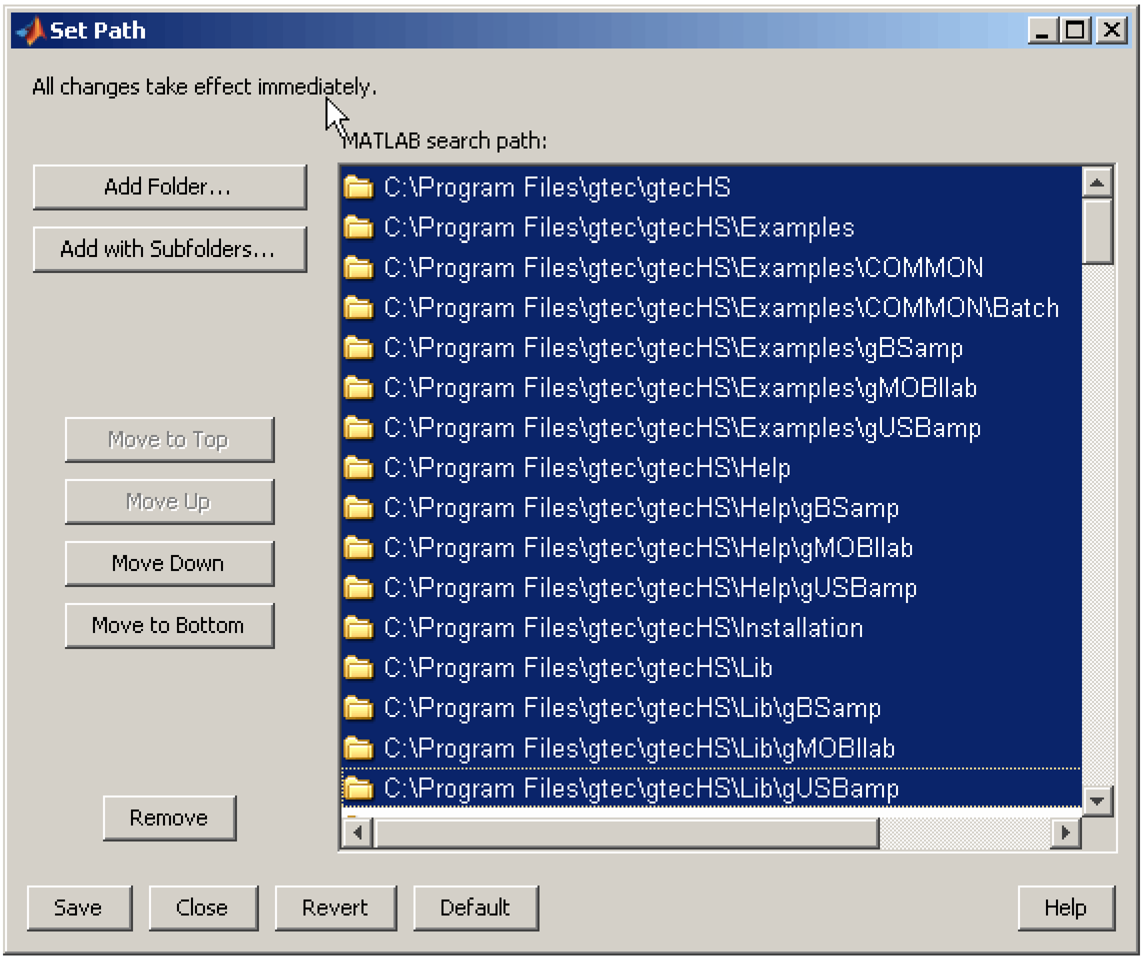
   Note that you have to uninstall the Hardlock driver separately if you uninstall the g.USBamp Highspeed On-line Processing software.

3. Set MATLAB path

To make the path settings start MATLAB and open the **Set Path** window from the **File** menu. Then click on the **Add with Subfolders** button and select

```
C:\Program Files\gtec\gtecHS
```

to add all subdirectories:



Click **Save** and **Close** to finish the installation.

Insert the Hardlock into a free USB slot of your PC or notebook. The light must be on if the installation was successful.

Files on your Computer

g.USBamp Highspeed files - are stored under (it is assumed that the default path setting is used)

```
C:\Program Files\gtec\gtecHS\Lib\gUSBamp
```

Example models - are stored in the subdirectory

```
C:\Program Files\gtec\gtecHS\Examples\gUSBamp
```

Help files - are stored under

```
C:\Program Files\gtec\gtecHS\Help\gUSBamp
```

Introduction to g.USBamp

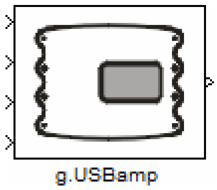
g®.USBamp is a multimodal biosignal amplifier for any type of electrophysiological signals like EEG, ECG, EOG, EMG, ECoG, ... and external sensors. It has an integrated 24-bit ADC and a floating point DSP and can be connected directly to the PC via USB. The device is characterized by excellent signal quality and a very low noise level. Multiple units (16 channels each) can be stacked to build multi-channel systems. A programming API is included and drivers for MATLAB are also available. It is a CE and FDA certified medical device. g.USBamp comes with 16 analog input channels, one trigger channel which is scanned with the analog inputs, 2 digital inputs and 2 digital outputs.

g.USBamp has 4 potential separated groups with 4 input channels each. Each group has its own reference and ground inputs.

Highlights

- CE certified medical device for use in humans according to medical normative EN 60601-1 (IEC 60601-1) and FDA approved
- EEG, ECoG, ECG, EMG and EOG recording via USB
- 16 analog inputs with 24 Bit and a sampling frequency of up to 38400 Hz per channel
- Digital filtering of the biosignal data (DC - 2.4 kHz)
- Over-sampling to achieve a high signal to noise ratio
- Simultaneous sample and hold for all channels
- Direct connection of electrodes with standard safety connectors or system connectors for a very fast electrode application
- can be used for recordings directly on the brain (ECoG) or heart (CF-System)
- on-line signal analysis under Simulink
- can be combined with g.BSanalyze for off-line biosignal analysis under MATLAB

g.USBamp Highspeed Block



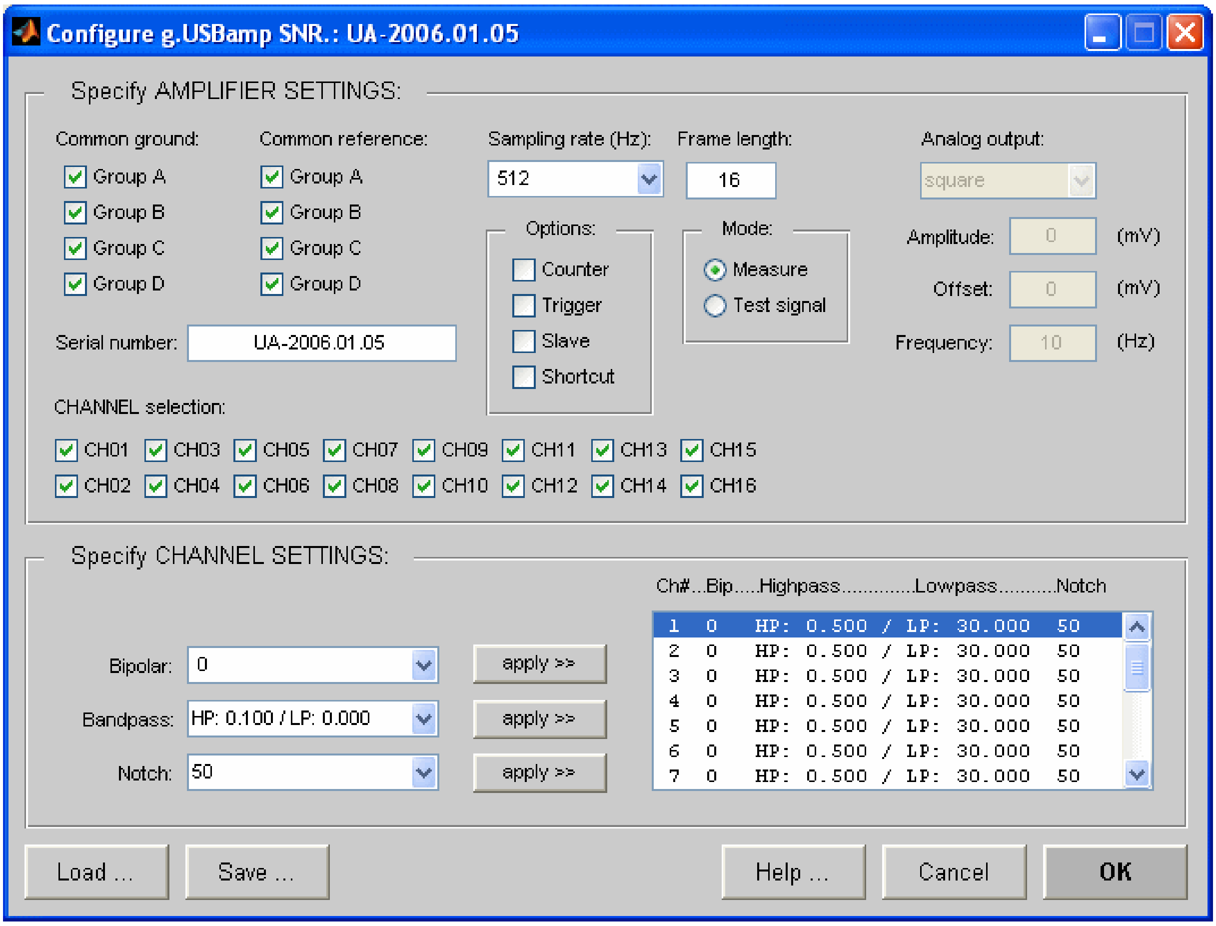
The g.USBamp Highspeed block provides a graphical interface to the g.USBamp hardware which can be used under Simulink to specify the amplifier properties and to acquire the data.

Description

The g.USBamp block output signal provides the biosignal data. The data format is single (float32) and it is scaled in µV. If all analog input channels (16) and the trigger signal (1) are acquired the line width is 17. Use a **Demux** block to de-multiplex the channels.

The g.USBamp block inputs are used to set the digital outputs of g.USBamp (two for g.USBamp version 2.0, four for g.USBamp version 3.0)

Dialog Box



Specify AMPLIFIER SETTINGS

Common ground	check the editor box to connect a specific group to common ground
Common reference	check the editor box to connect a specific group to common reference
Serial number	enter the serial number of the amplifier
CHANNEL selection	check the analog input channels that should be acquired
Sampling rate (Hz)	specify the sampling frequency of the g.USBamp in Hz
Frame length	specify the buffering block size

Options

Counter	show a counter on channel 16 which is incremented with every block transmitted to the PC
Trigger	scan the digital trigger channel with the analog inputs. The trigger channel is shown as channel 17 if 16 analog channels are used.
Slave	set the amplifier to slave mode if multiple units are used
Shortcut	enable the shortcut input

Mode

Measure	amplify the inputs and send the data to the PC
Test signal	apply internal test signal to all inputs NOTE: The test signal works for sampling rates equal or below 600 Hz
Analog output	generate a Sine-, Square-, Sawtooth- or Noise-signal as test signal
Amplitude	specify the amplitude of the test signal (max: 245 mV)
Offset	specify the offset of the test signal
Frequency	specify the frequency of the test signal

Specify CHANNEL SETTINGS

Bipolar	perform a bipolar derivation between 2 input channels
Bandpass	perform a digital bandpass filtering of the input channels
Notch	perform a bandstop filtering to suppress the power line frequency of 50 Hz or 60 Hz
Load	Load an amplifier configuration
Save	Save the amplifier configuration

Perform the following steps:

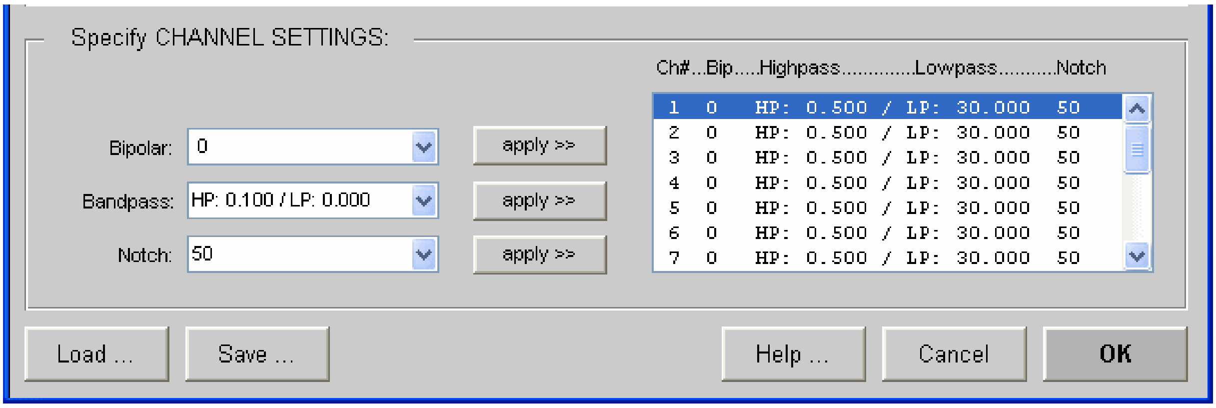
1. Select the channels in the listbox that should be edited. Use the Ctrl key or the Shift key to select multiple input channels.

2. Select the **Bandpass** filter `HP: 0.5 / LP: 30` and press the **apply** button to assign the bandpass to the specific channel. The selection is shown in the listbox.

3. Select the `50` Hz **Notch** filter to suppress the power line interference at 50 Hz and then press the **apply** button

4. To perform a bipolar derivation between channels 1 and 2 select the first channel in the listbox. Then select channel `2` under **Bipolar** and press the **apply** button. The settings appear in the listbox. This configuration subtracts channel 2 from channel 1 and the bipolar derivation will be visible on channel 1.

   NOTE: Select `0` under **Bipolar** and assign it to the channel if no bipolar derivation should be performed



5. Use the **Save …** button to store the configuration for the g.USBamp. The **Load …** button allows to import configurations.

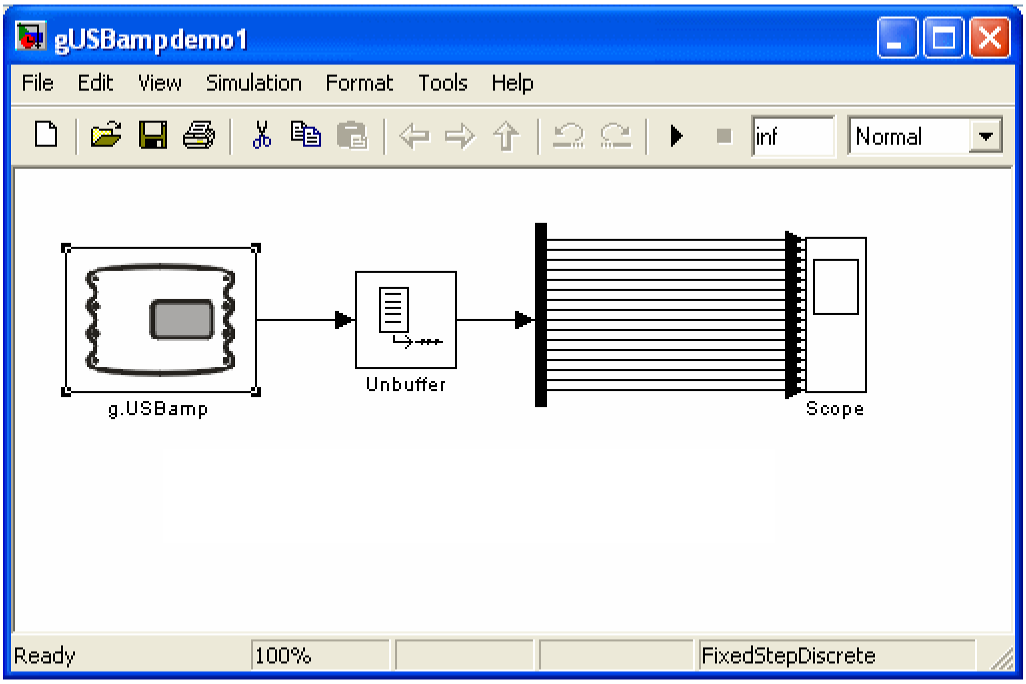
6. Press **OK** to close the window

Running g.USBamp Highspeed

To test the g.USBamp Highspeed configuration on your system please perform the following example:

1. Start the MATLAB command window. See your MATLAB documentation if you are not sure how to do this.

2. Open the Simulink model by typing `gUSBampdemo1` into the MATLAB command window. This command starts up Simulink and creates the following window:



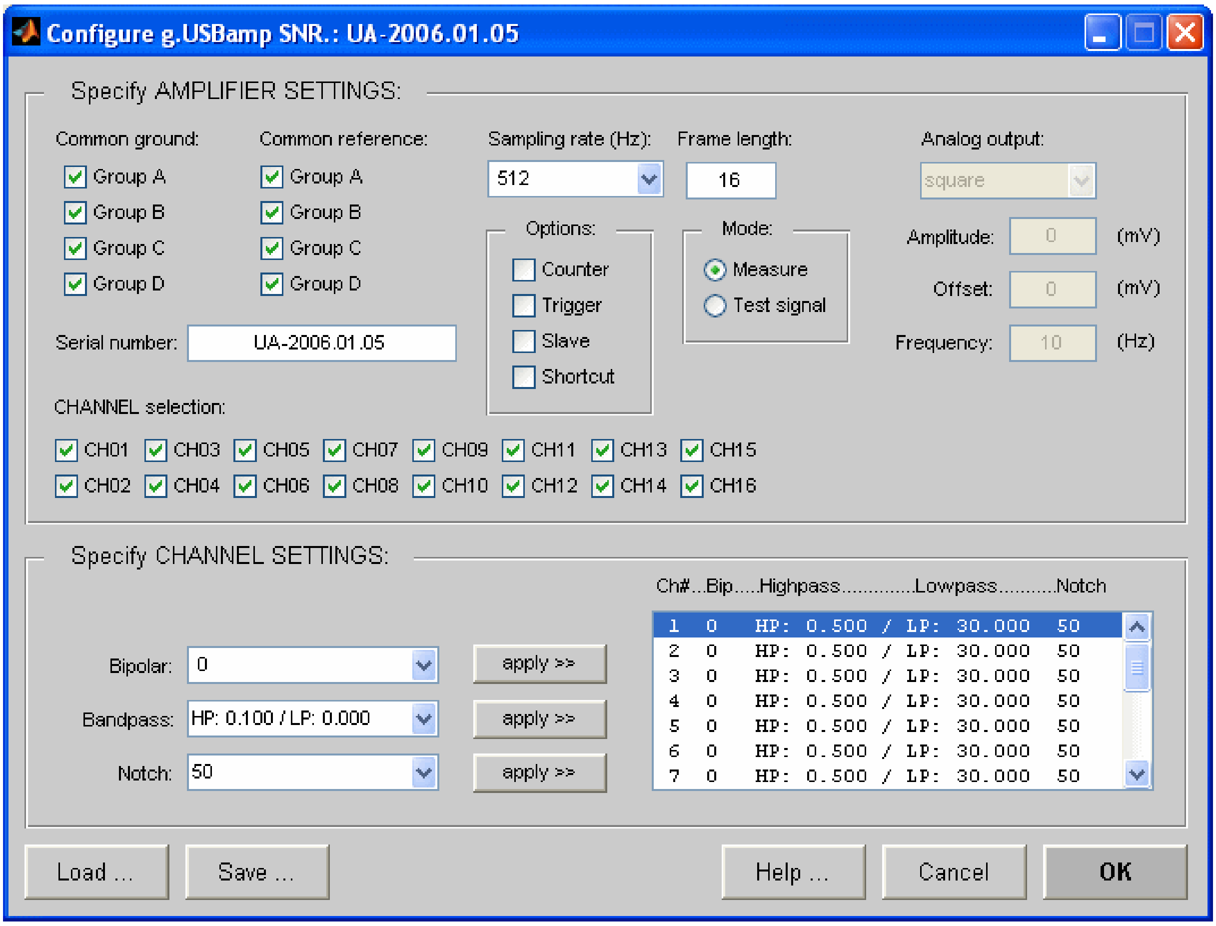
The Simulink model contains a **g.USBamp** block which reads in the data from the amplifier over USB.

3. Switch g.USBamp on and connect it to one free USB port. The power LED on g.USBamp must be on.

4. Connect a sine wave generator to channel 1 of g.USBamp. The sine wave should have an amplitude of ± 100 µV. This can be done e.g. with g.SIGgen.

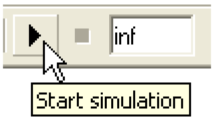
5. Double click on the **g.USBamp** block

6. Load the configuration file `gUSBampdemo1.cfg`. The following window appears:

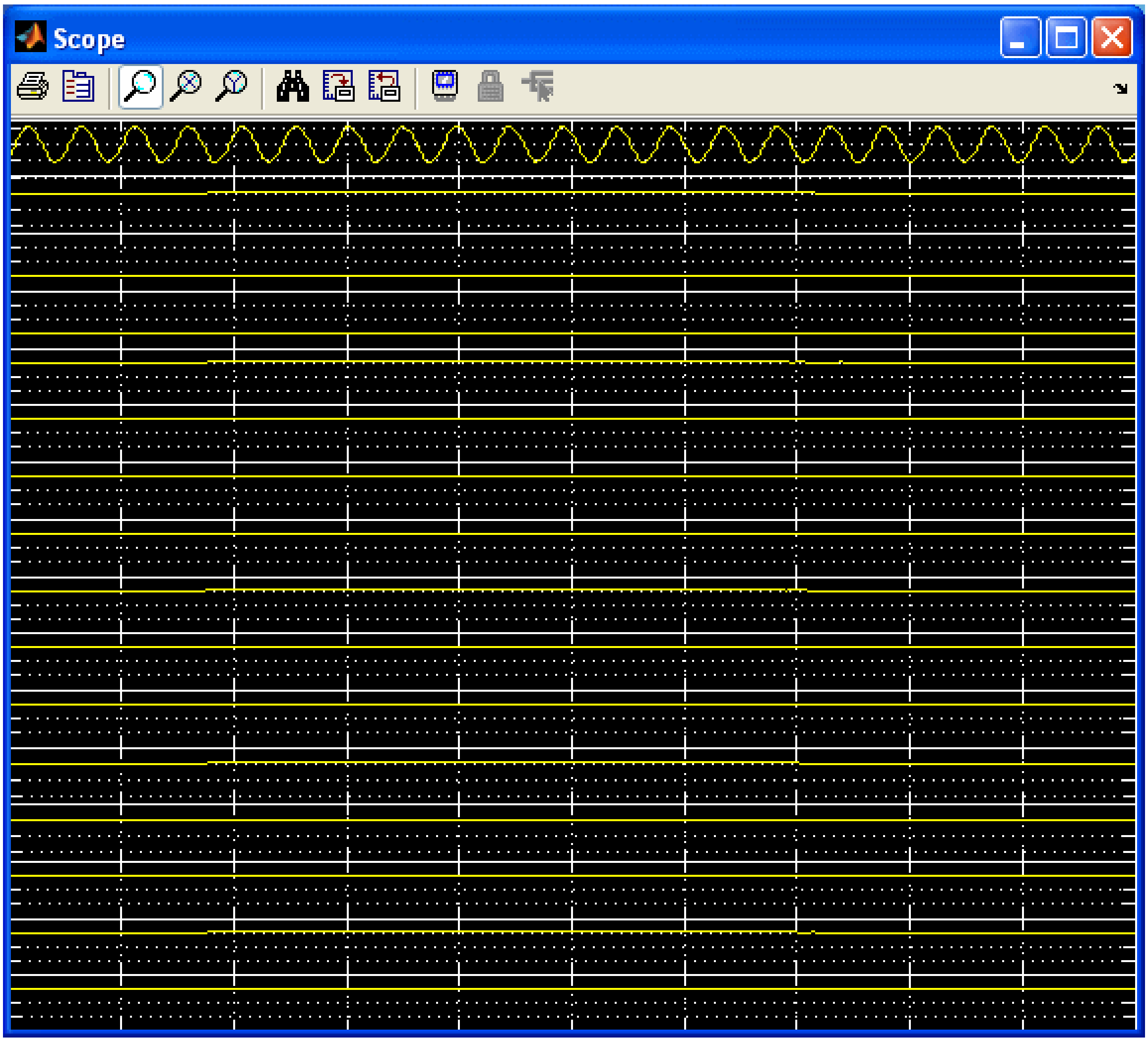


7. Enter the correct **Serial number** of the connected amplifier and press the **OK** button

8. Start the model by pressing the **Start** button in the Simulink model



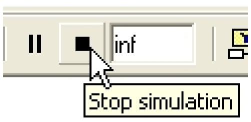
9. To view the signals double click on the **Scope** block. Click with the right mouse button into the first channel and select **Autoscale** to zoom into the axis.



Note that g.USBamp Highspeed reads in all biosignal data in µV

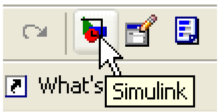
Channel 1 shows a ± 100 µV signal with a frequency of 10 Hz provided by g.SIGgen.

10. Stop the model with the **Stop** button and close it



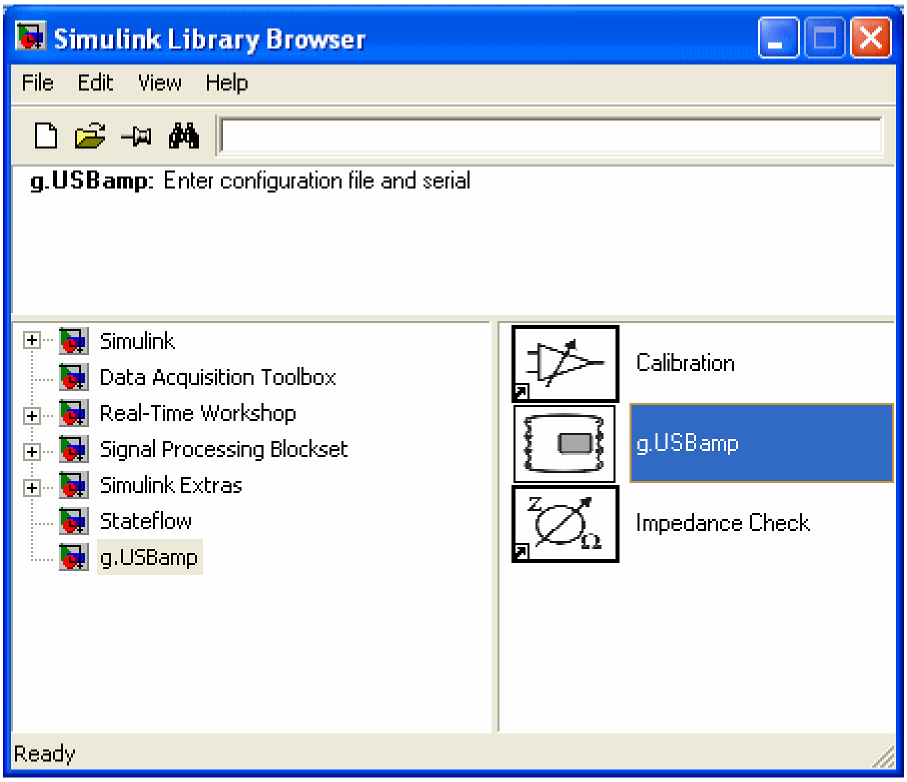
Creating a Simulink Model for Biosignal Acquisition

1. To create a new Simulink model click on the **Simulink** icon in the MATLAB window



or enter `simulink` into the MATLAB command window.

The **Simulink Library Browser** opens:

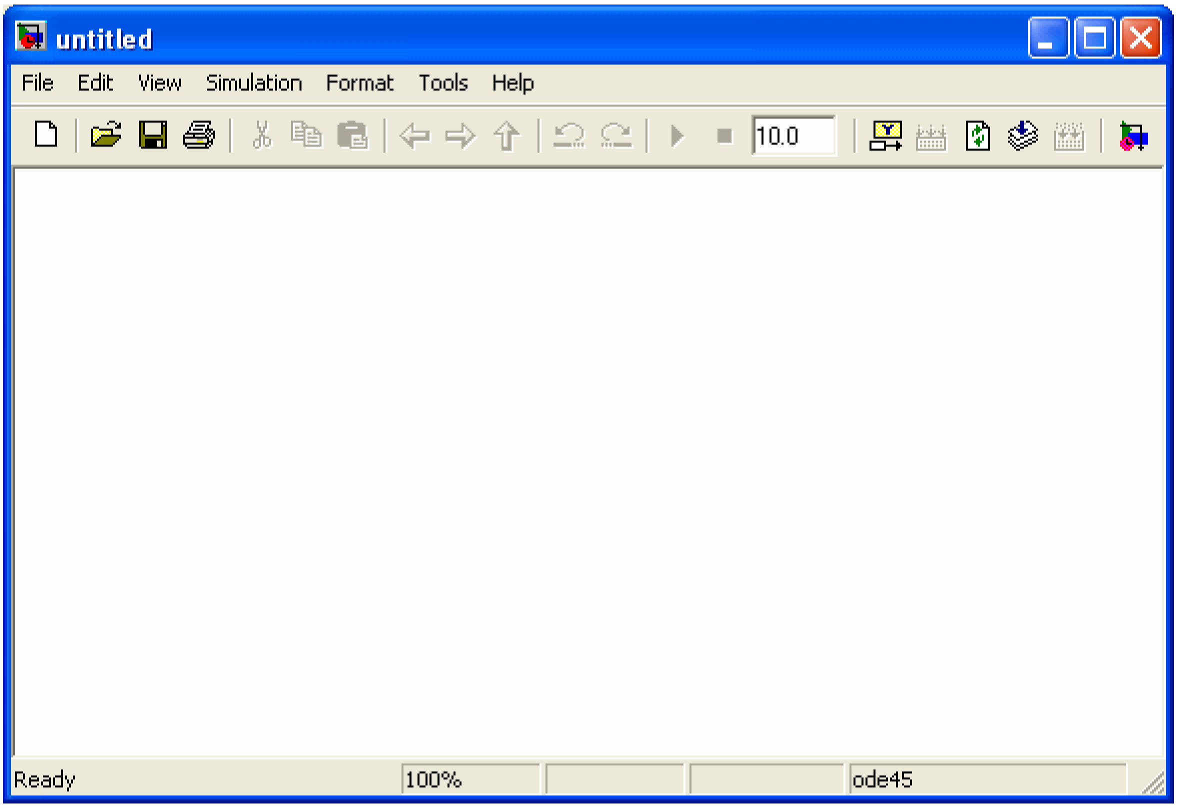


The **Simulink Library Browser** gives access to all Simulink based blocksets.

2. Scroll down to **g.USBamp** to show the biosignal data acquisition block.

3. Press the **Create a new model** icon in the **Simulink Library Browser**

to open an empty Simulink model:



4. Click on the **g.USBamp** block in the **Simulink Library Browser** and drag it into the new Simulink model

5. Open the **Signal Management\Buffers** path under **Signal Processing Blockset** in the **Simulink Library Browser** and copy the **Unbuffer** block into the new model

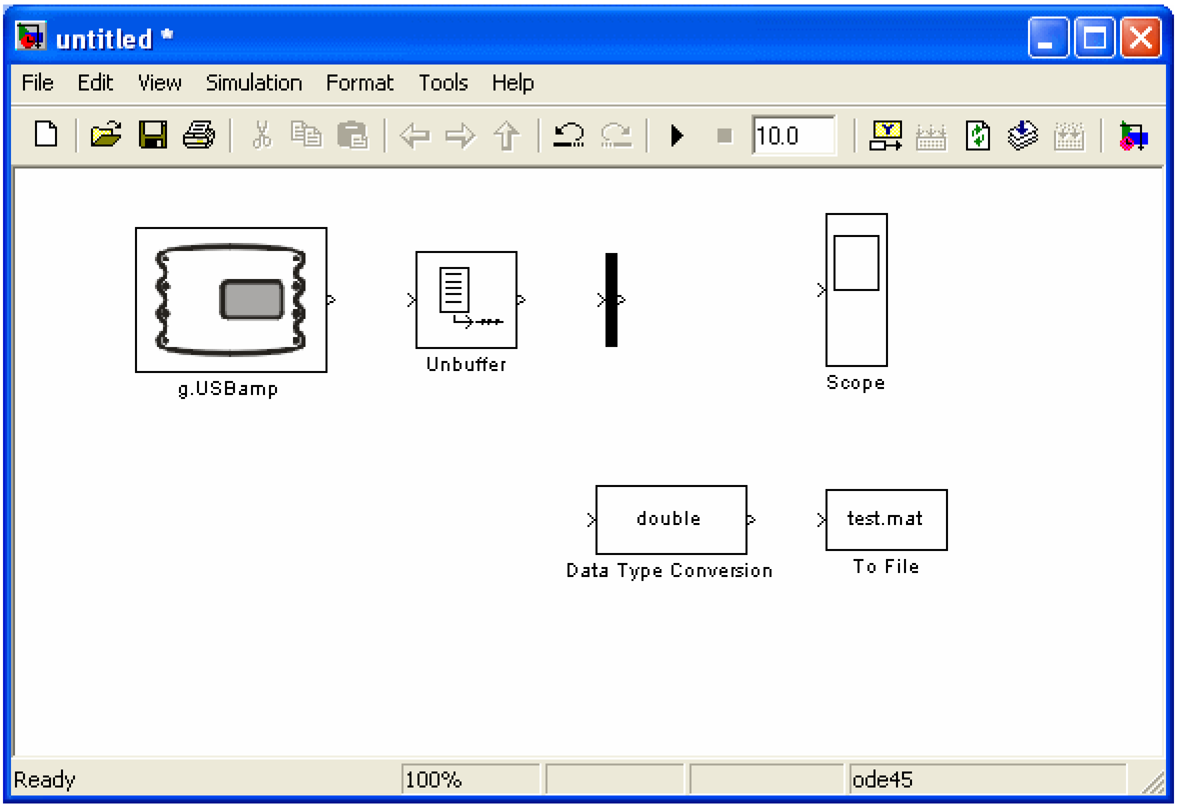
6. From the **Sinks** directory under **Simulink** copy the **Scope** block

7. From the **Signal Routing** directory under **Simulink** copy the **Demux** block

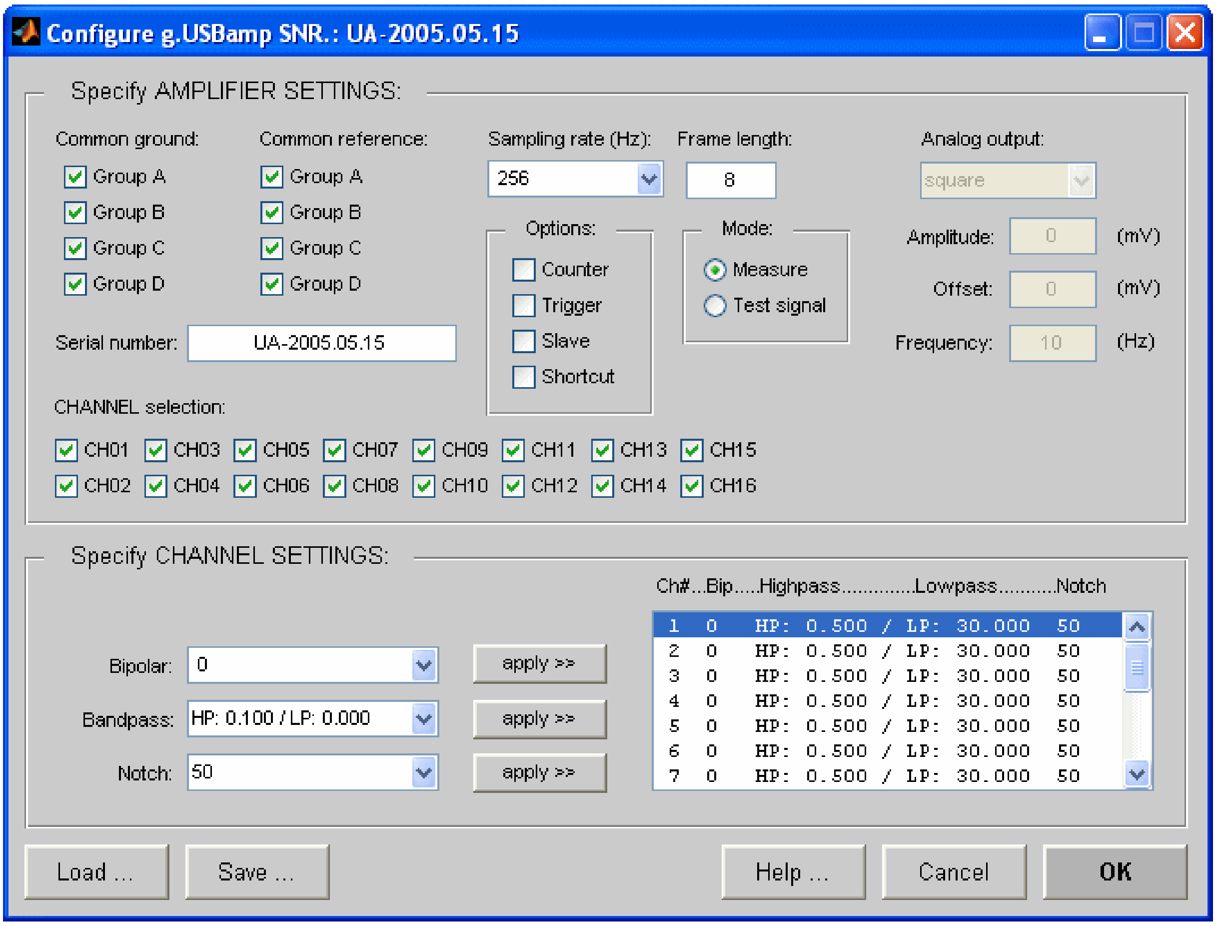
8. From **Sinks** under **Simulink** copy the **To File** block

9. From **Signal Attributes** under **Simulink** copy the **Data Type Conversion** block

Now your model should look like this:

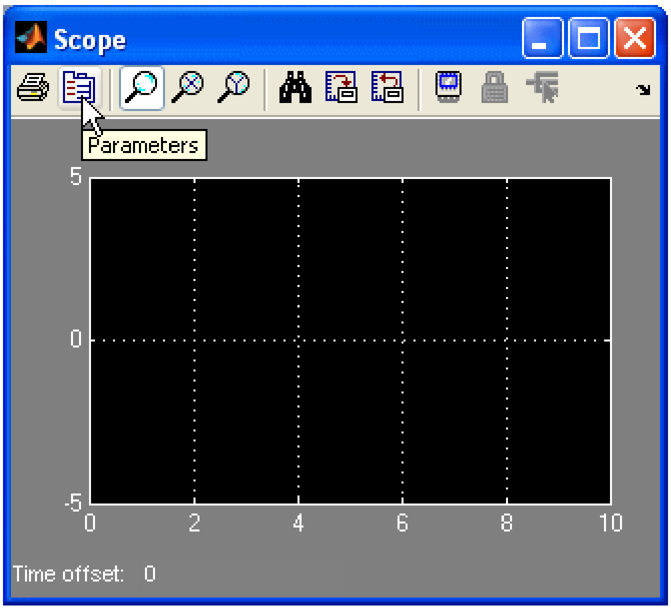


10. Double click on the **g.USBamp** block, load the configuration `gUSBampdemo2.cfg` and enter the serial number of your amplifier.

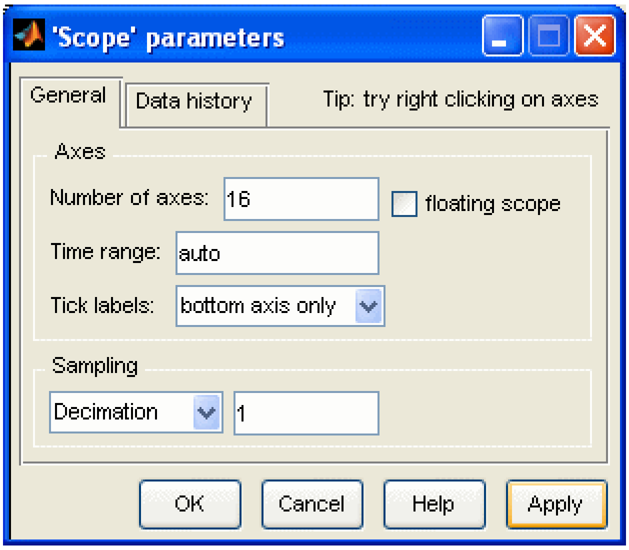


11. Double click on the **Demux** block and enter `16`

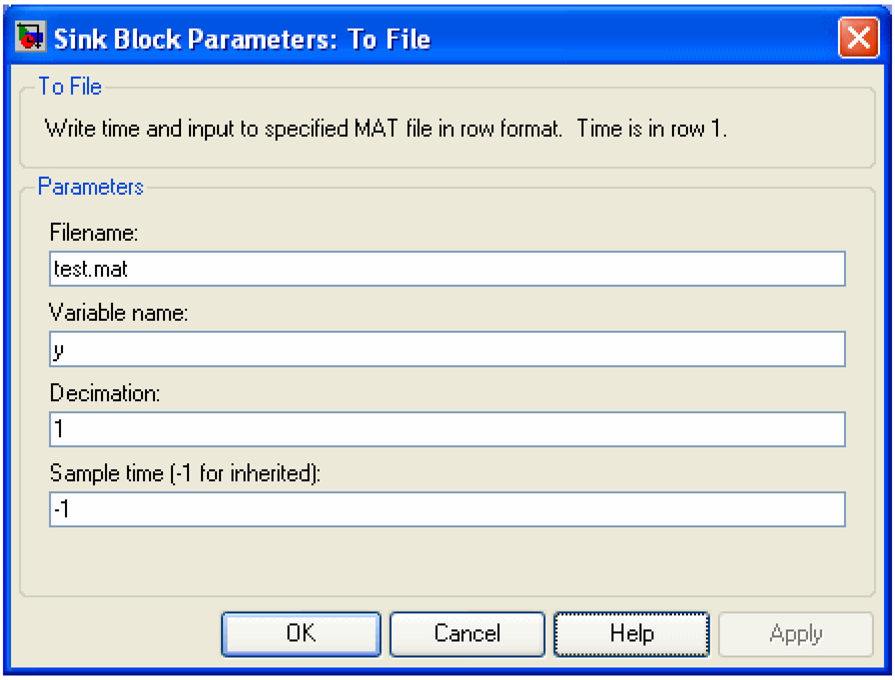
12. Double click the **Scope** block and select the **Parameters** icon:



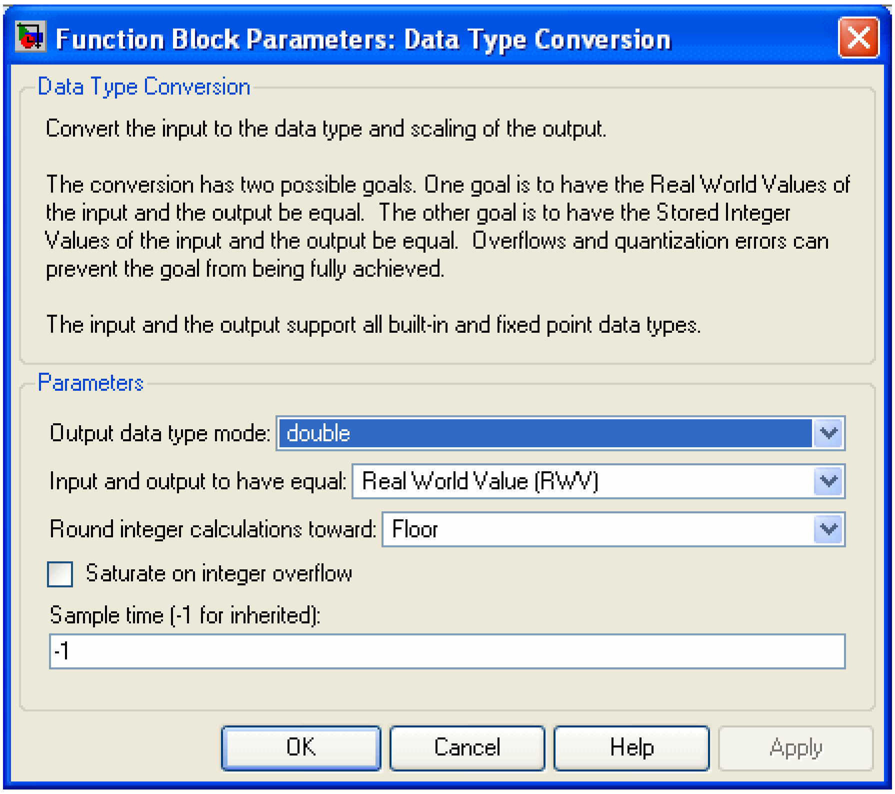
13. Set the **Number of axes** to `16` to visualize 16 analog input channels. Set the **Time range** to `5` seconds and the **Tick labels** to `none`. The **Sampling Decimation** should be `1`.



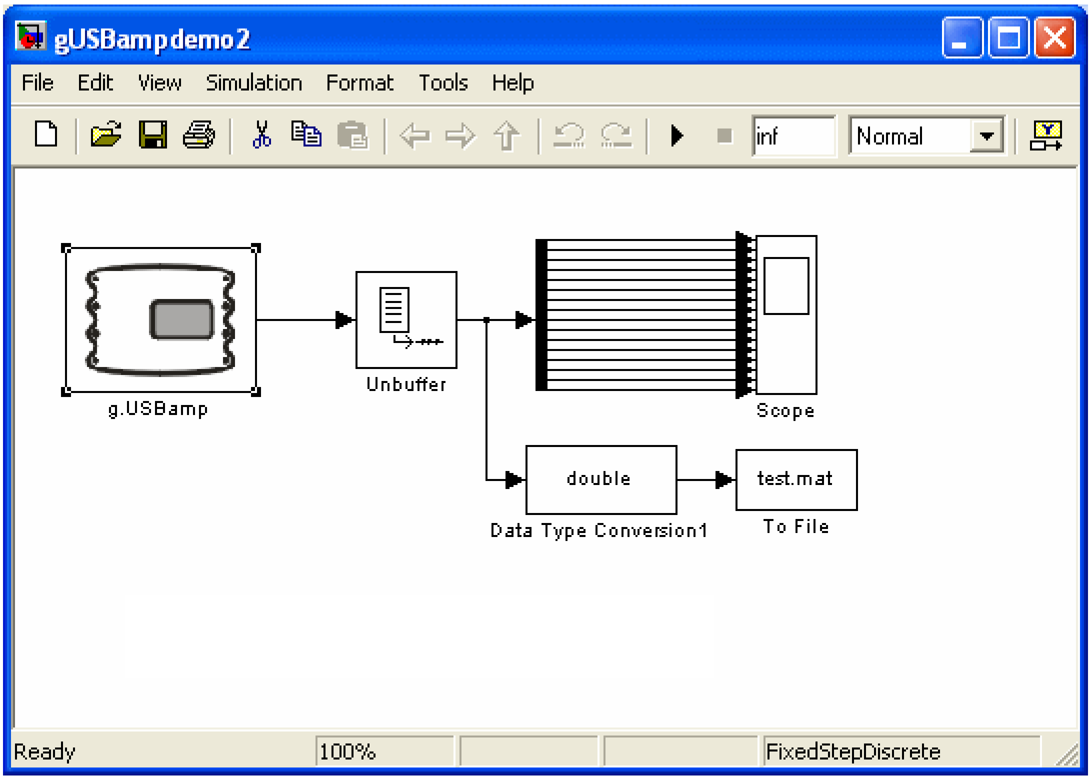
14. Double click on the **To File** block and enter the filename `test.mat` to store the data into variable `y`



15. Double click on the **Data Type Conversion** block and change the **Output data type mode** to `double` because **g.USBamp** is acquiring the data as float32.

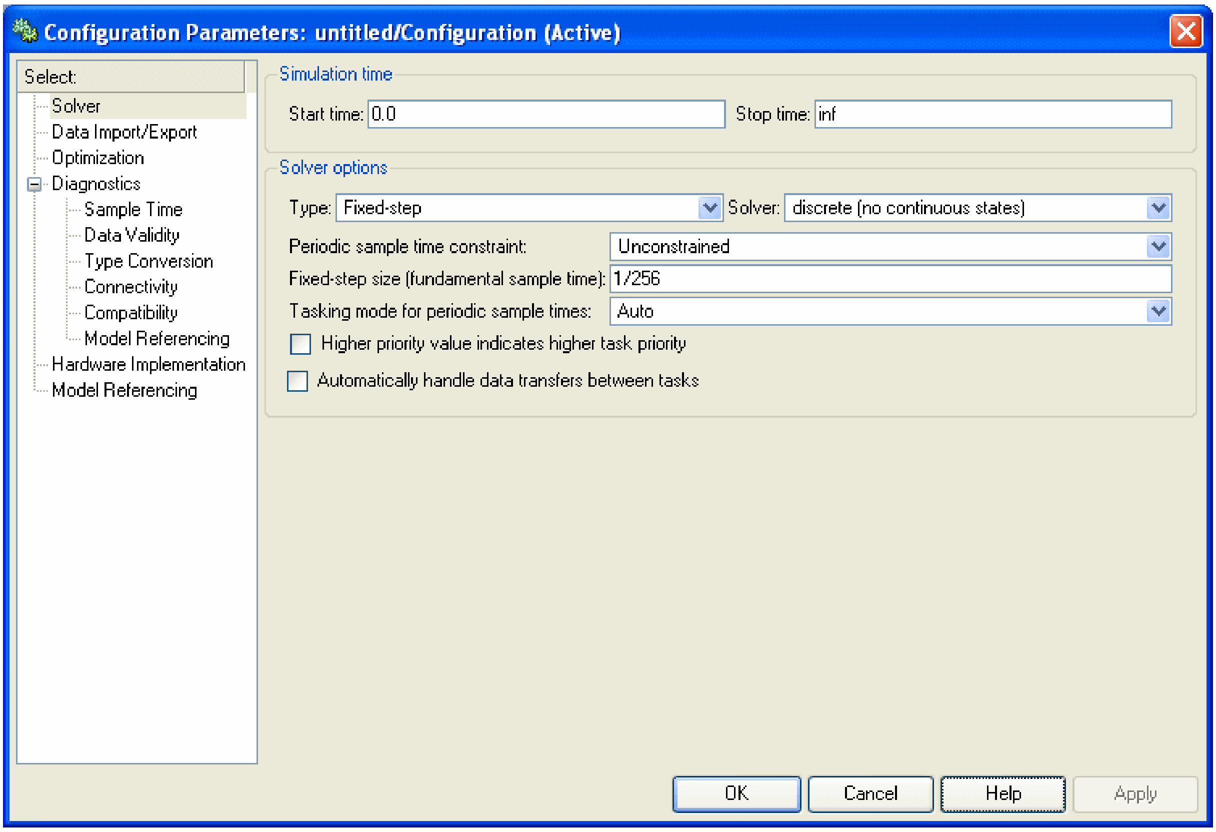


16. After configuring each block perform the connections as shown below:



17. Click on the **Simulation** menu and select **Configuration Parameters**

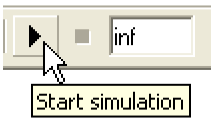
18. Set the **Stop time** to `inf` and the **Type** under **Solver options** to Fixed-step. The **Fixed-step size** must be set to `1/256` because **g.USBamp** samples the data with 256 Hz.



19. Confirm the settings and close the window with **OK**

20. Switch g.USBamp on and connect it to one free USB port. The power LED on g.USBamp must be on.

21. Start the model

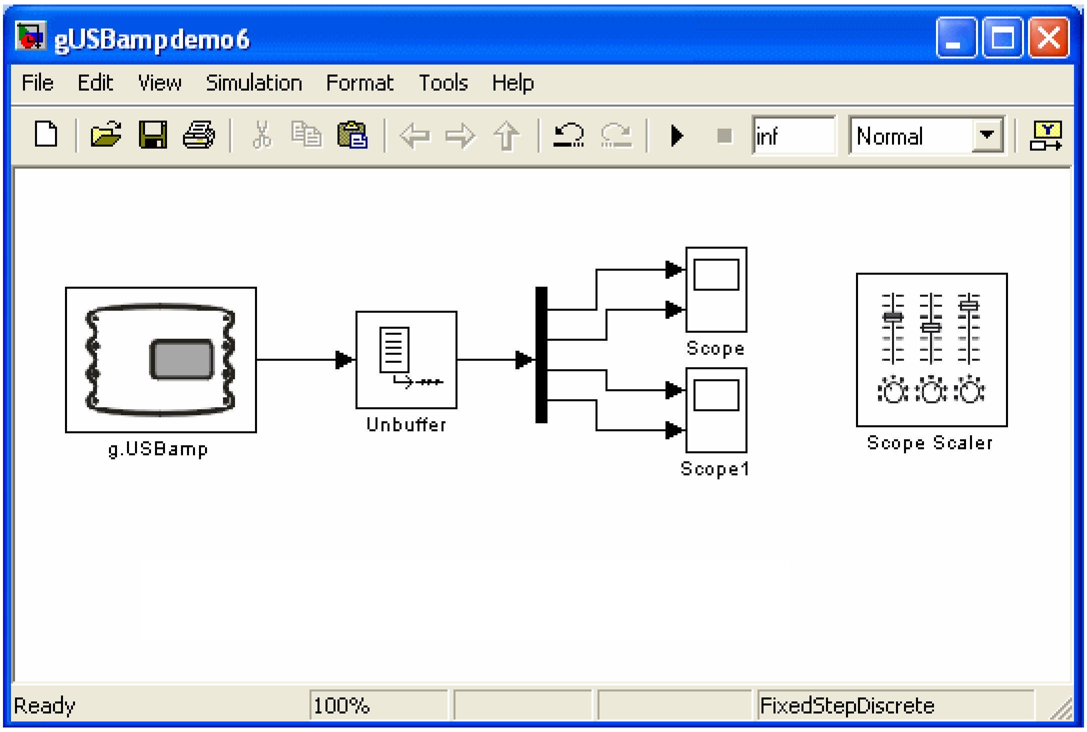


Using the Scope Scaler

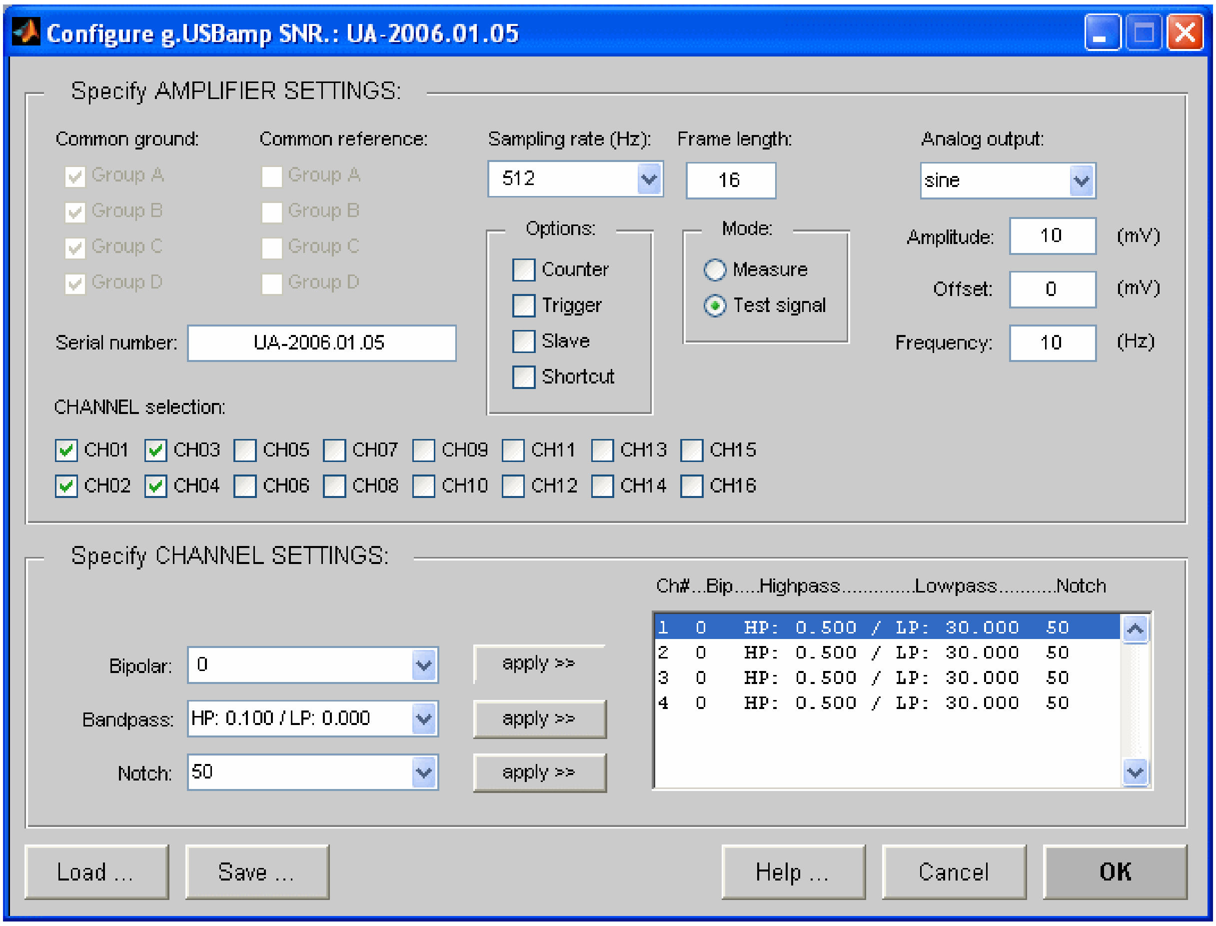
This section explains the function of the block **Scope Scaler** which can be copied from the example below or found in the `gUSBamplib.mdl` in the folder

`C:\Program Files\gtec\gtecHS\Lib\gUSBamp`

1. To run the example presented in this section type `gUSBampdemo6` into the MATLAB command window. This opens the Simulink model shown below.

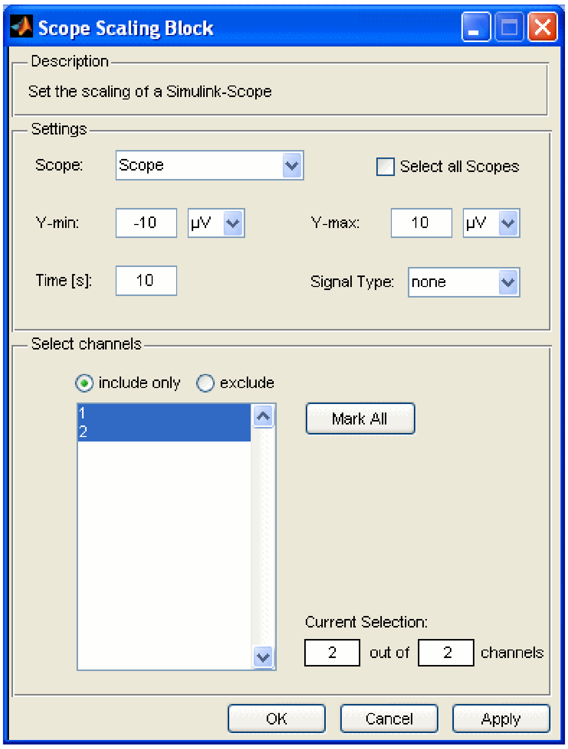


2. Double-click the **g.USBamp** block to review the g.USBamp configuration.

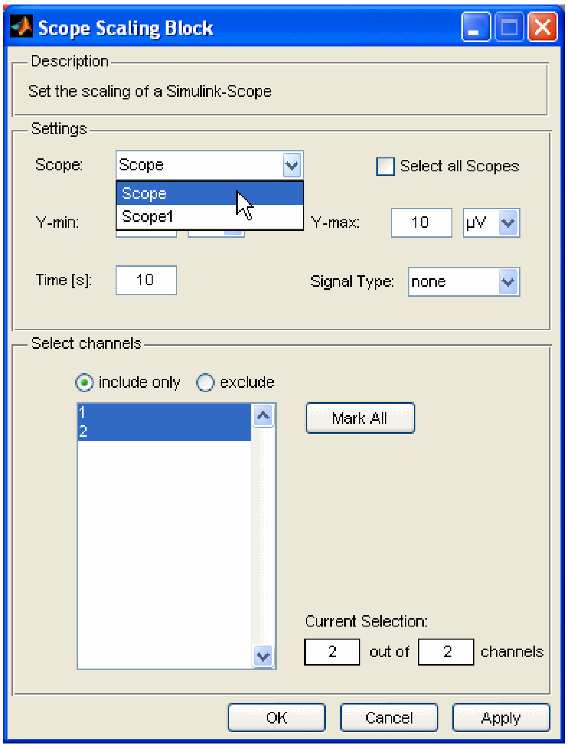


If the configuration for this example has changed you can reload the configuration by clicking the **Load** button and selecting the file `gUSBampdemo6.cfg`.
This example is configured to record channels 1 to 4 with a test signal at a frequency of 10 Hz, an offset of 0 mV and an amplitude of 10 mV.

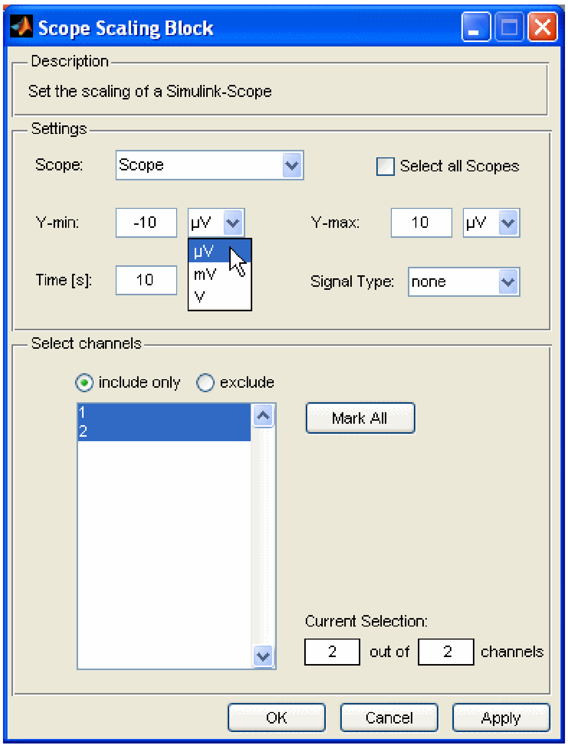
3. Double-click the **Scope Scaler** block to open the dialog below.



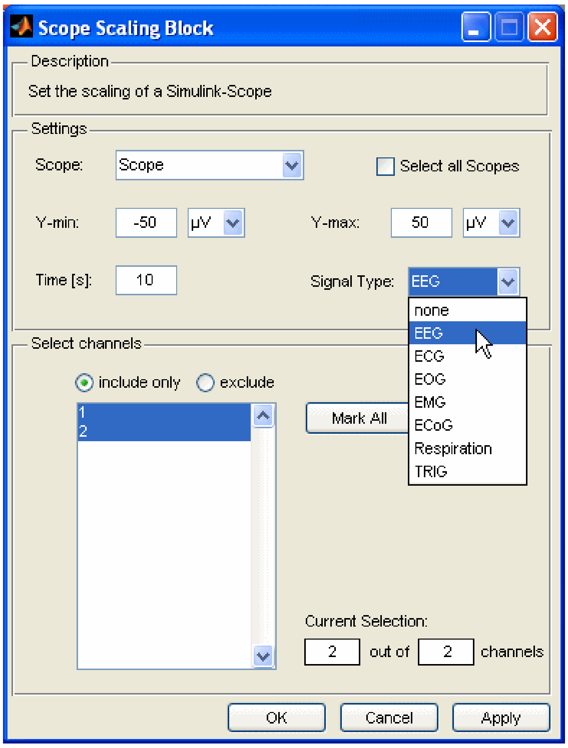
4. In the model there are 2 scope blocks, **Scope** and **Scope1**. In the **Scope** section you can either choose **Scope** or **Scope1**. With the **Select all Scopes** checkbox the settings can be applied to all scopes in the current model.



5. In the **Y-min** and **Y-max** editor boxes the maximum settings for the Y-axis can be set. With the listbox beside you can set the scale to either **µV**, **mV** or **V**.



6. In the **Time** editor box the displayed time range in seconds (the X-axis range) can be selected. With the **Signal Type** list box select a type of signal you are recording (e.g. EEG, ECG, etc.) The values for Y-min and Y-max change with the selected signal type.



7. In the **Select Channels** section the channels in the scope to be changed can be set. With the radio buttons **include only** and **exclude**, the selected channels are either included to be changed or excluded from being changed. The **Current Selection** is displayed at the bottom of this section. With the **Mark All** button you can select all available channels in the selected scope.

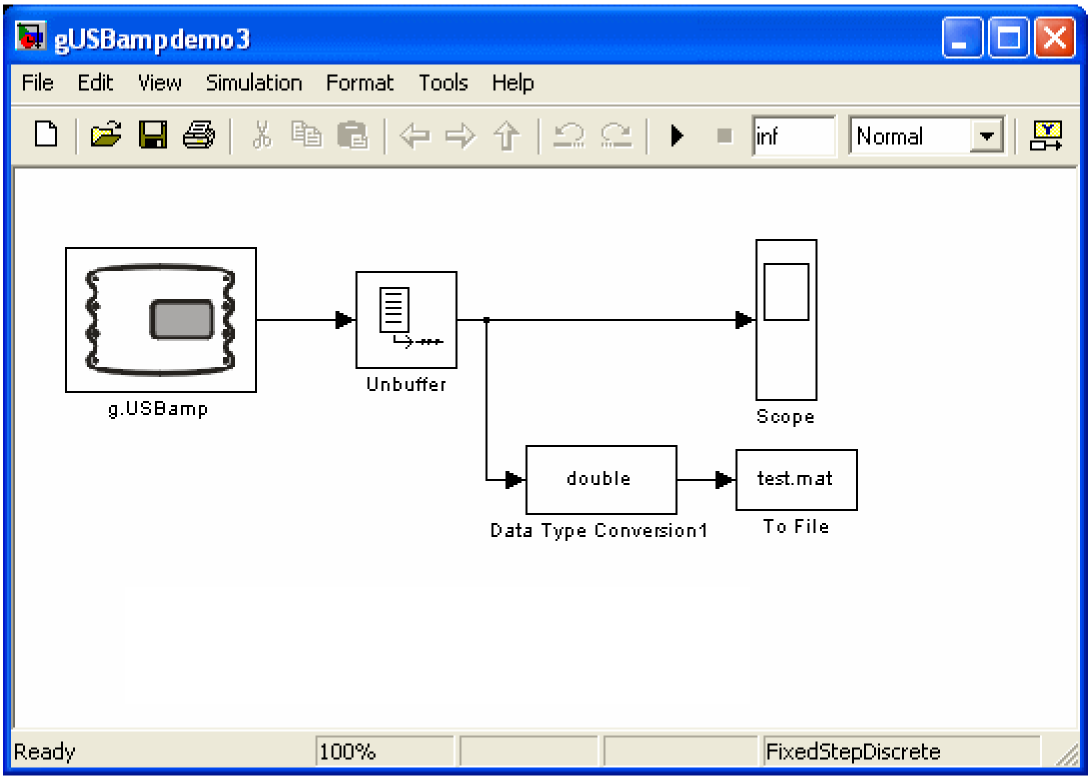
8. With the **Apply** button the changes are applied to the selected scope(s). Click **OK** to close the dialog.

Biosignal Acquisition and Visualization

This section shows the configuration of g.USBamp Highspeed for the acquisition of an ECG channel.

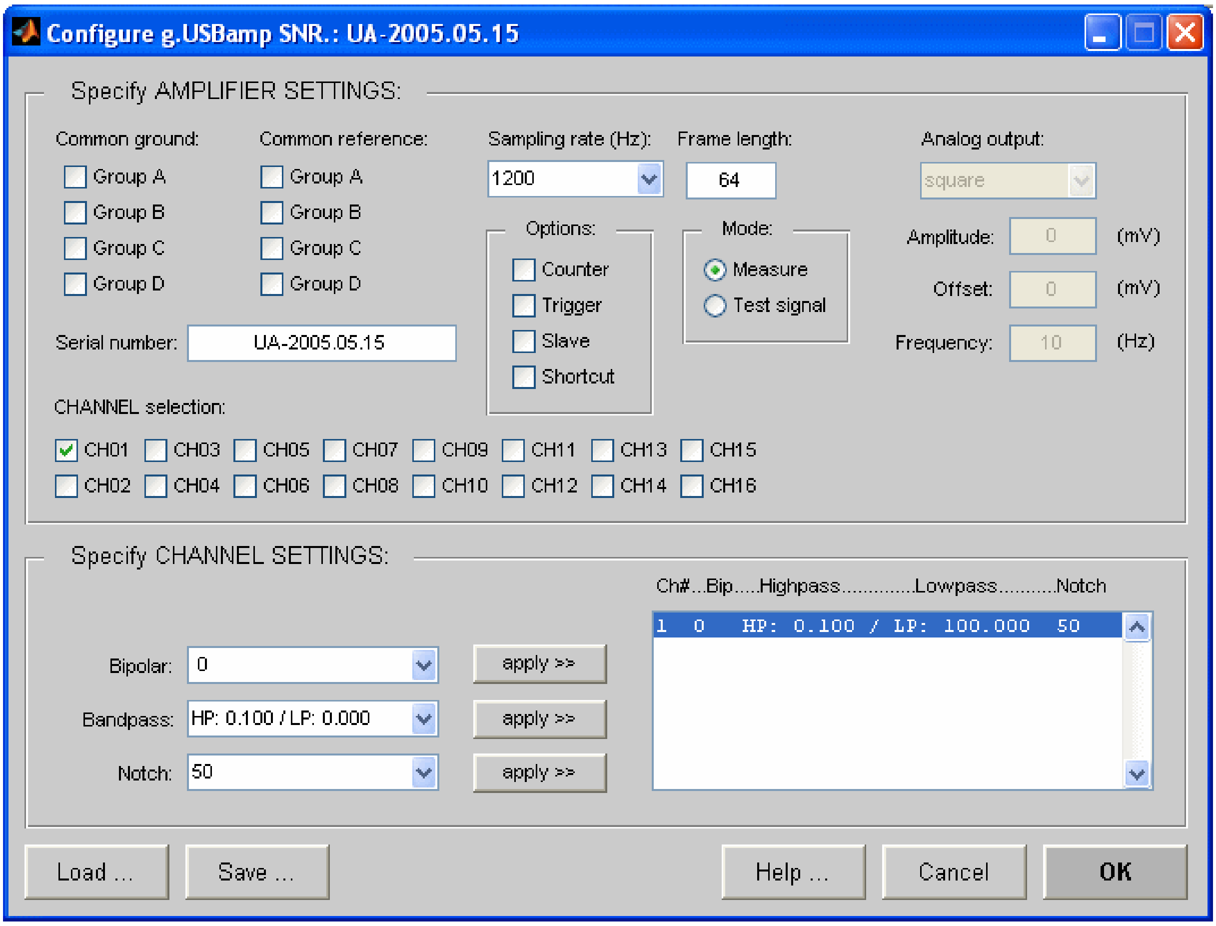
1. Start the MATLAB command window.

2. Open the Simulink model by typing `gUSBampdemo3` into the MATLAB command window. This command starts up Simulink and creates the following window:

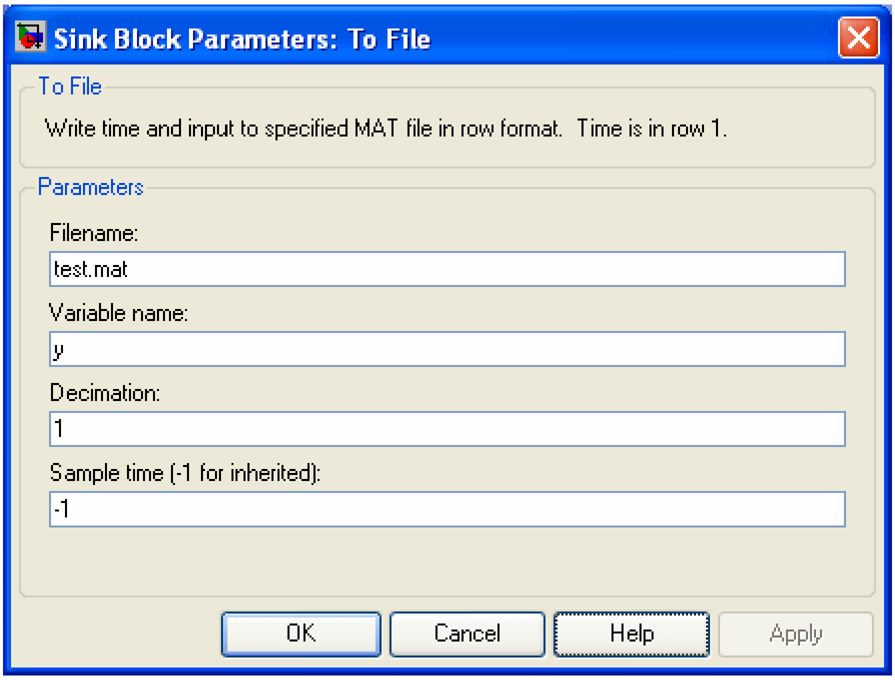


3. Double click on the **g.USBamp** block and select only channel **CH01**. Assign a **Bandpass** filter with a HP of `0.1` Hz and a LP of `100` Hz. The sampling frequency should be `1200` Hz.

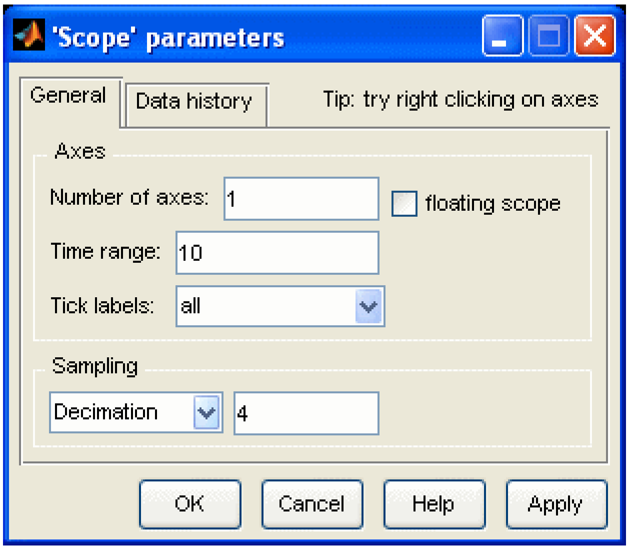
Note: The settings can also be loaded from the configuration file `gUSBampdemo3.cfg`



4. Double click on the **To File** bock and enter **Filename** `test.mat`. The data is stored into the variable `y`.



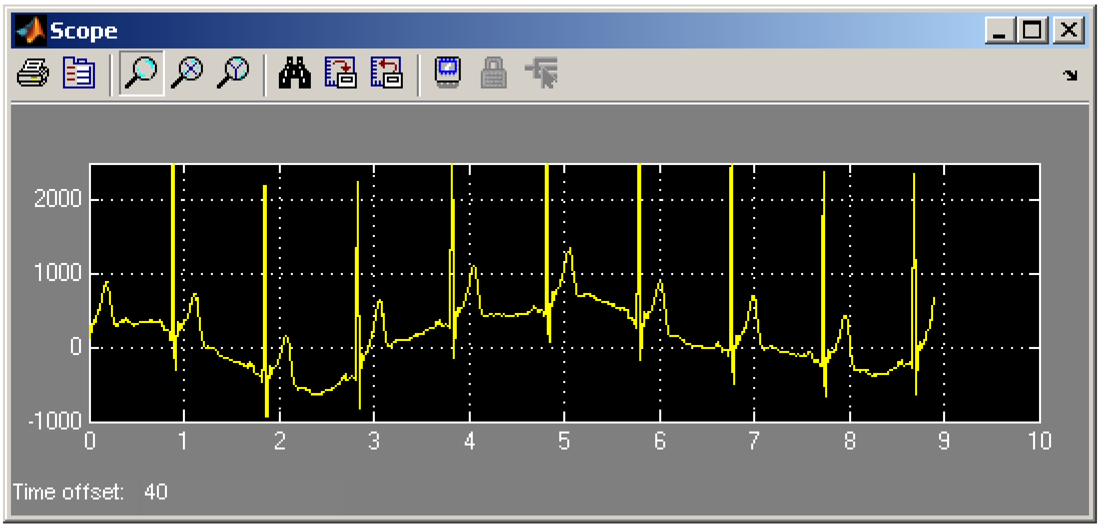
5. Double click on the **Scope** block and open the '**Scope' parameters** window. Enter under **Decimation** 4 to downsample the values for the visualization.



6. Switch g.USBamp on and connect it to one free USB port. The power LED on g.USBamp must be on.

7. Connect your ECG electrodes to the amplifier. Connect channel 1 to the center of the chest (upper side of breastbone/sternum), channel 2 to the left abdominal side and the ground electrode to the right abdominal side.

8. Press the **Start** icon

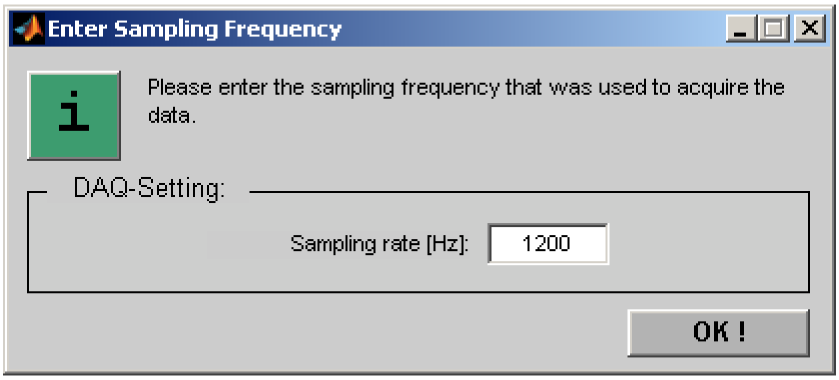


g.USBamp Highspeed reads in the data in µV. The ECG signal has therefore an amplitude of approximately 1-2 mV.

Viewing Data with g.BSanalyze

1. Start the biosignal processing toolbox g.BSanalyze and load the biosignal data file `ekg.mat` or the file `test.mat` which was recorded in the previous section into the Data Editor with the **Load data** function from the **File** menu

2. Enter the sampling frequency `1200` Hz



The Data Editor shows the ECG channel. Use the sliders to scroll through the data-set.

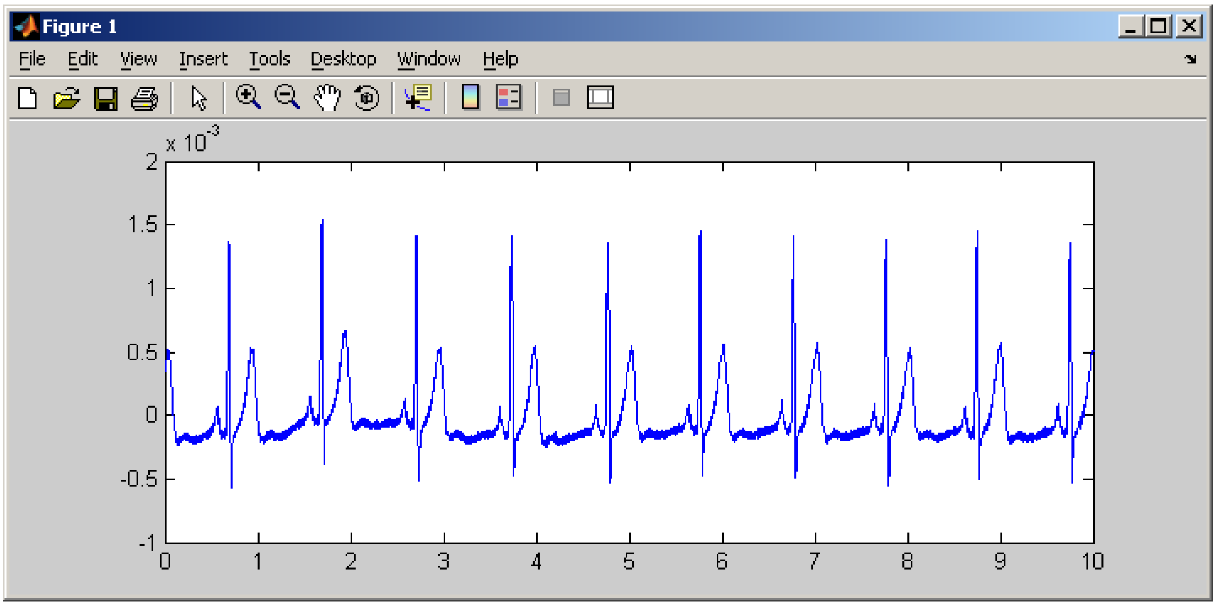
MATLAB Plot Function

You can use the MATLAB plotting functions for the visualization of acquired data. After running `gUSBampdemo3.mdl` and logging data to the hard disk perform the following steps:

1. Change to the directory where test.mat is stored and enter load test.mat in your MATLAB command line. Instead of `test.mat` the file `ekg.mat` can also be used.

2. Type `whos` to investigate the variable `y`. The first row is a time vector and the second raw the acquired ECG data.

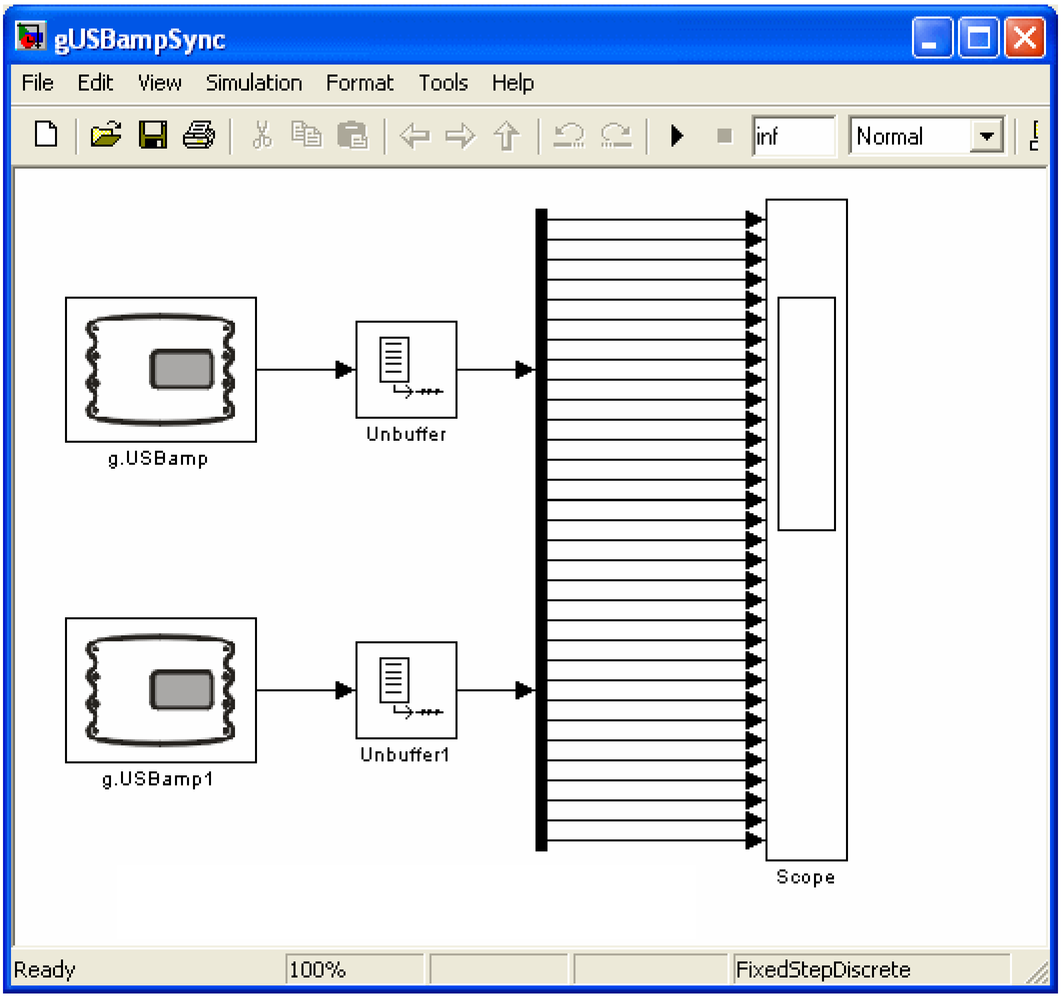
3. Enter `plot(y(1,:),y(2:end,:))` to create the following window:



Synchronization of Multiple g.USBamps

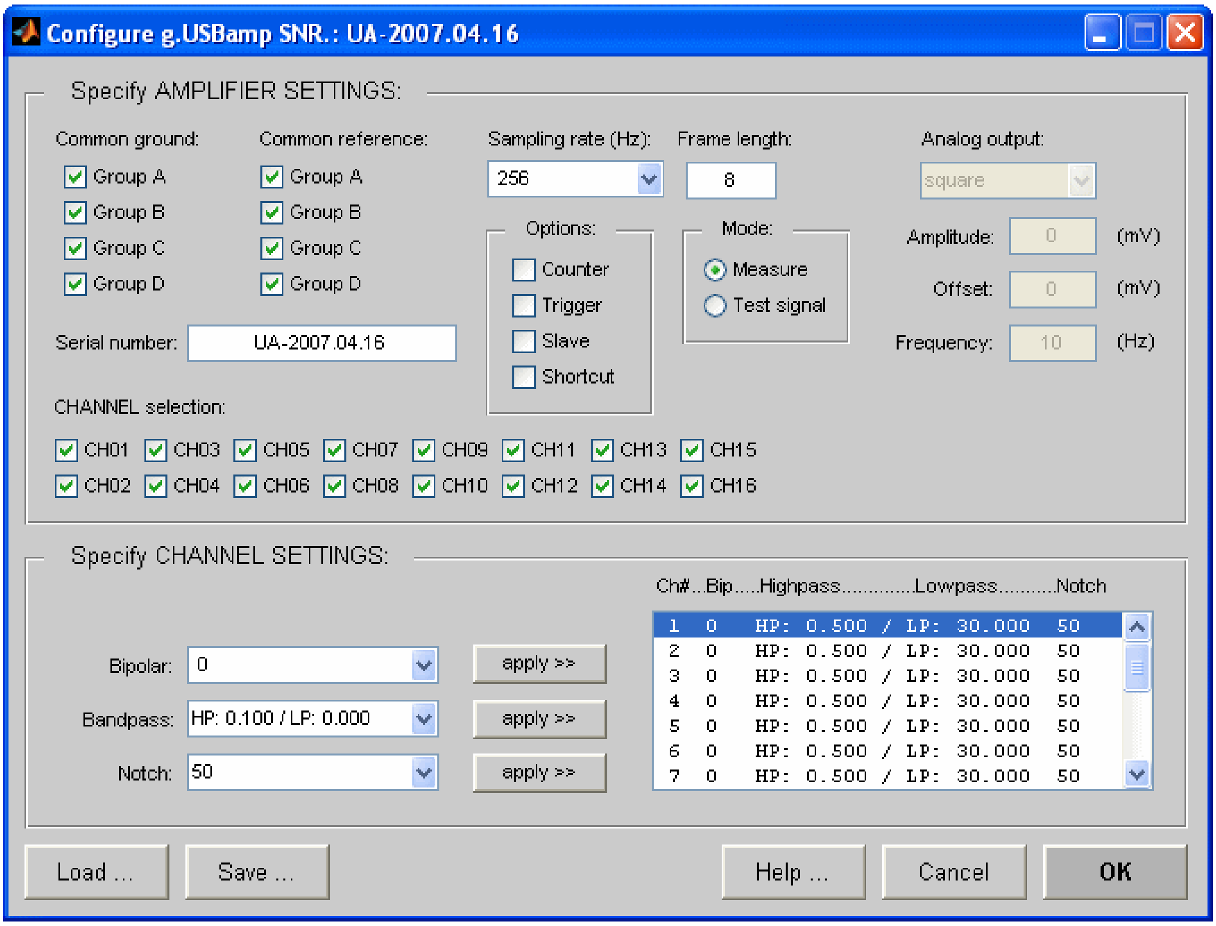
g.USBamp Highspeed can be used to acquire data from two g.USBamps. Perform the following steps:

1. Start the Simulink model `gUSBampSync.mdl` from the MATLAB command line to open the following model:

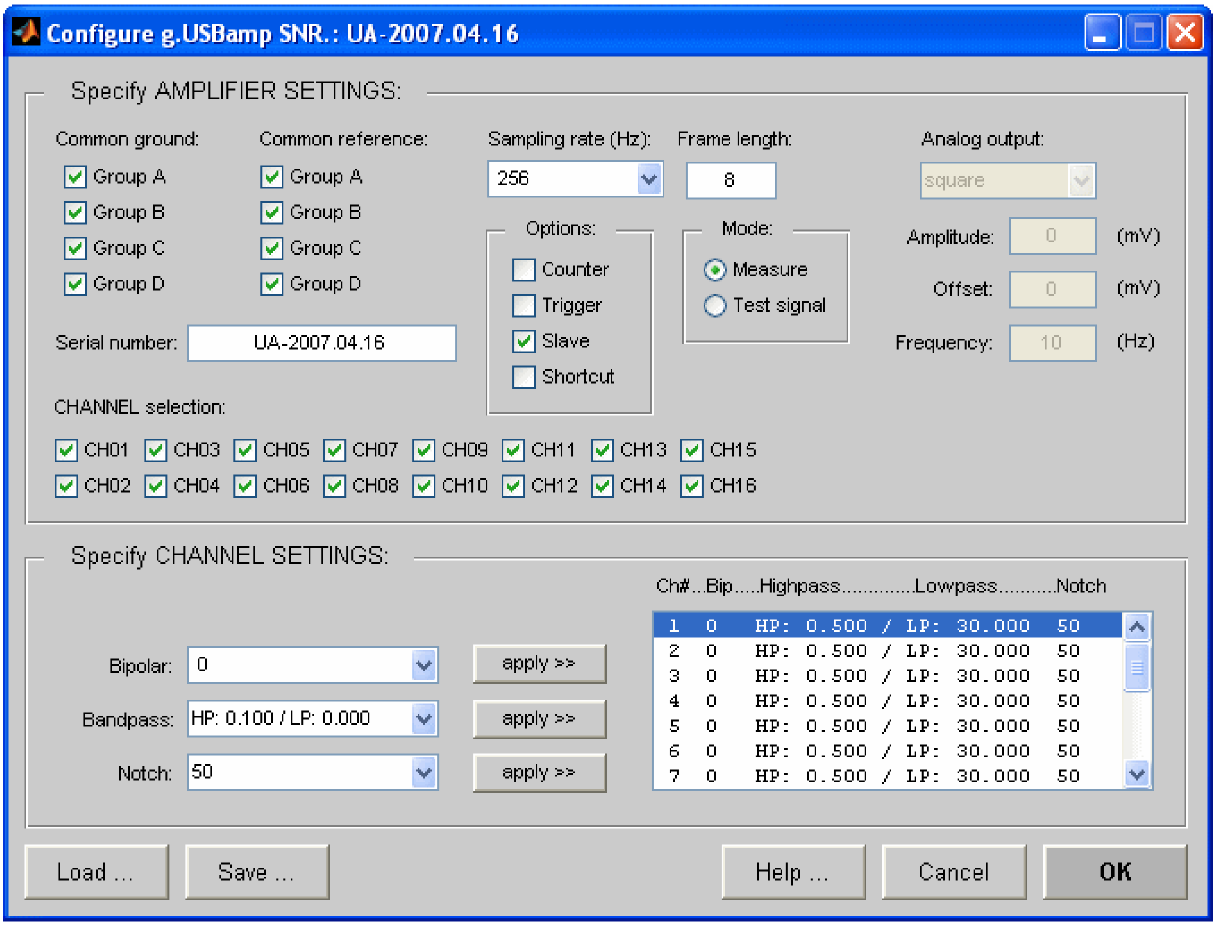


2. Double click on **g.USBamp** and load the configuration file `gUSBampSyncMaster.cfg`

3. Enter the **Serial number** of the MASTER device and connect the synchronization cable to the output **SYNC OUT** on the rear side of the device.

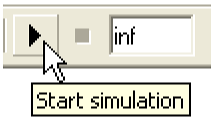


4. Double click on **g.USBamp1,** load the configuration file `gUSBampSyncSlave.cfg` and enter the **Serial Number** of the SLAVE device. Additionally check the **Slave** box under **Options**. Connect the synchronization cable to the **SYNC IN** connector on the rear side of the amplifier.



5. Switch on both amplifiers and connect the MASTER to the USB port. Then connect the SLAVE to the USB port.

6. Press the **Start** icon

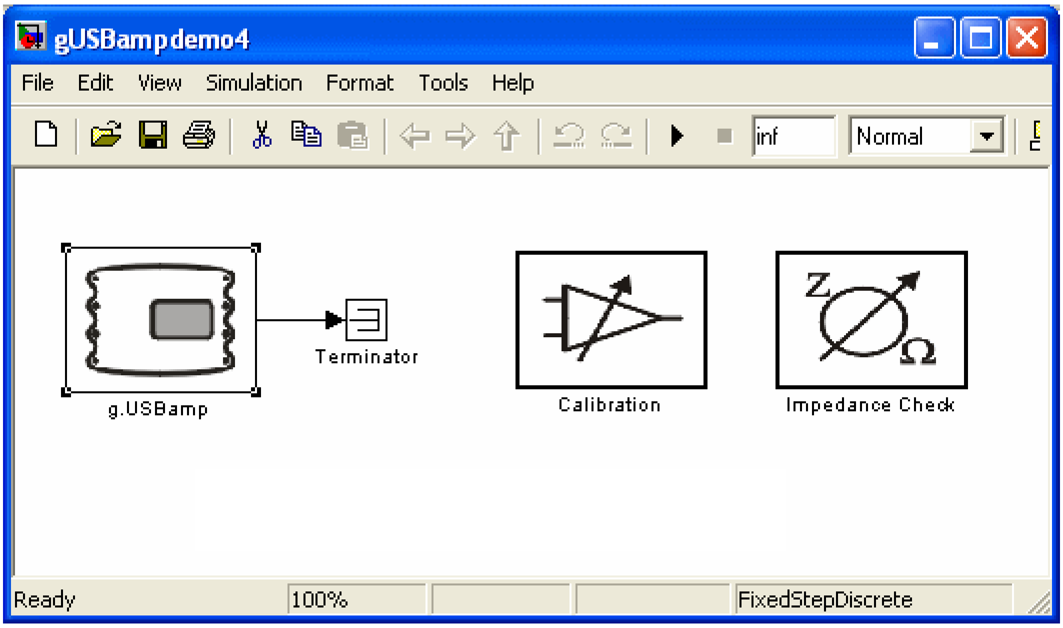


Start the Simulink model `gUSBampdemo5` from the MATLAB command line to open an example for the synchronization of four amplifiers.

Impedance Check

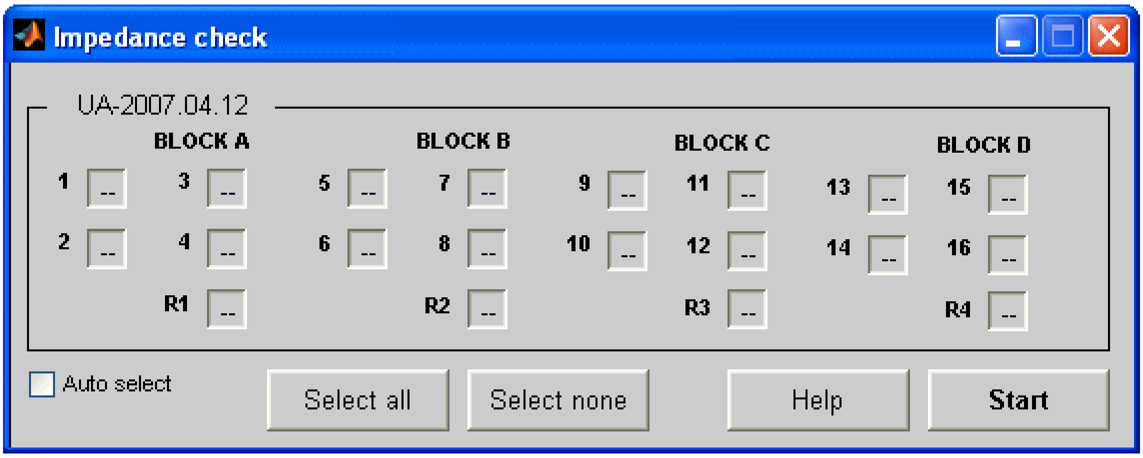
g.USBamp has a build-in impedance check unit. To measure the impedances of passive electrodes perform the following steps:

1. Start the Simulink model `gUSBampdemo4` from the MATLAB command line to open the model below:



2. Double click on **g.USBamp** and load the configuration file `gUSBampdemo4.cfg`. Enter the **Serial Number** of your amplifier.

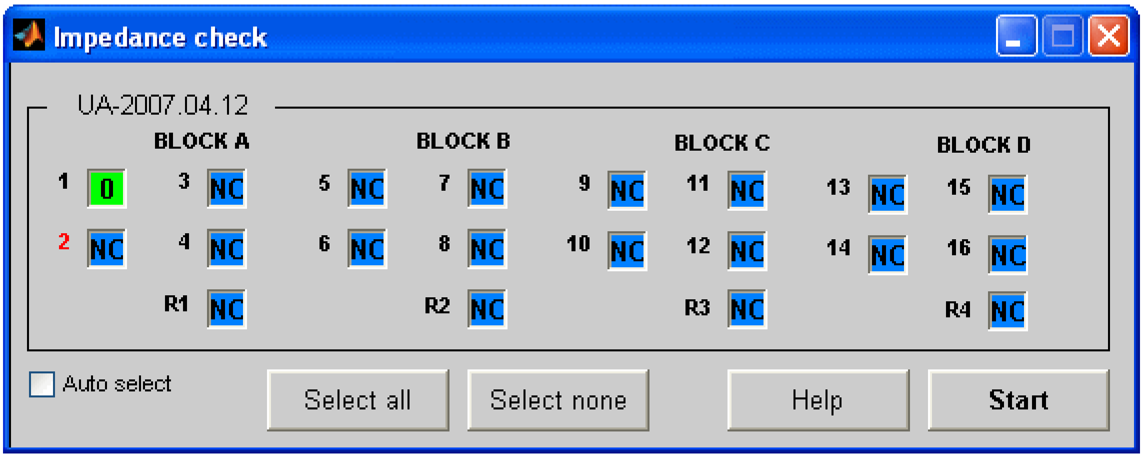
3. Double Click **Impedance Check** block. The following window will appear:



The system creates a panel for each amplifier in the current model. The channels are labeled **1** to **16** and the references **R1** to **R4**. If the corresponding toggle button is pressed the electrode impedance is measured. You can use **Select all** to select all electrodes or **Select none** to deselect all electrodes.
If **Auto select** is checked the system will measure only electrodes which are not below 5 kΩ.

4. Press **Start** to start the measurement. The label of the currently measured electrode is displayed red. Impedance values are displayed next to the corresponding channel labels. The colors indicate different ranges of the impedance values:

green	Impedance < 5 kΩ
yellow	Impedance between 5 and 7 kΩ
red	Impedance between 7 and 100 kΩ
blue	Electrode not connected



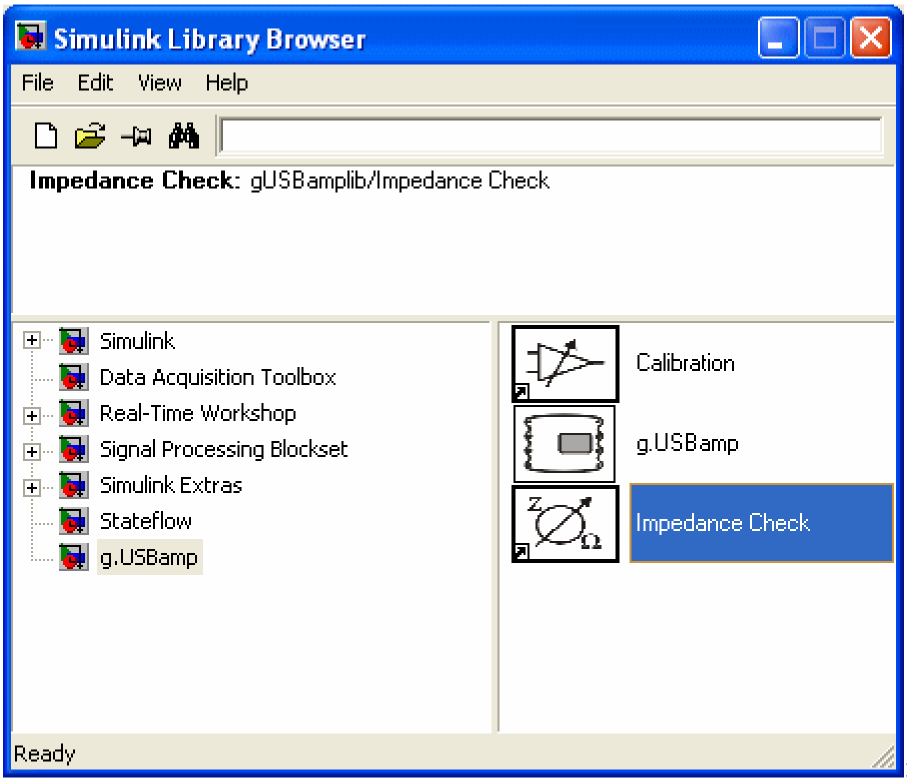
5. The system starts measuring the electrode impedance of channel 1 until channel 16. At the end the impedances of the reference electrodes are additionally measured. All impedances are measured against the common ground potential (all grounds of groups A to D are connected).

   The impedance is measured for 1 second for each channel with a 20 Hz signal. The impedance is shown in kΩ. For a good EEG recording the values should be below 5 kΩ (green).

6. To stop the impedance measurement press **Stop**.

NOTE: If one reference electrode and one ground electrode are used for all blocks A to D the reference and the ground must be connected to **Block D**.

If you want to add the Impedance measurement facility to your model type simulink to the MATLAB command line and select the **g.USBamp** library. Drag the **Impedance Check** block into your model:



:

Note:

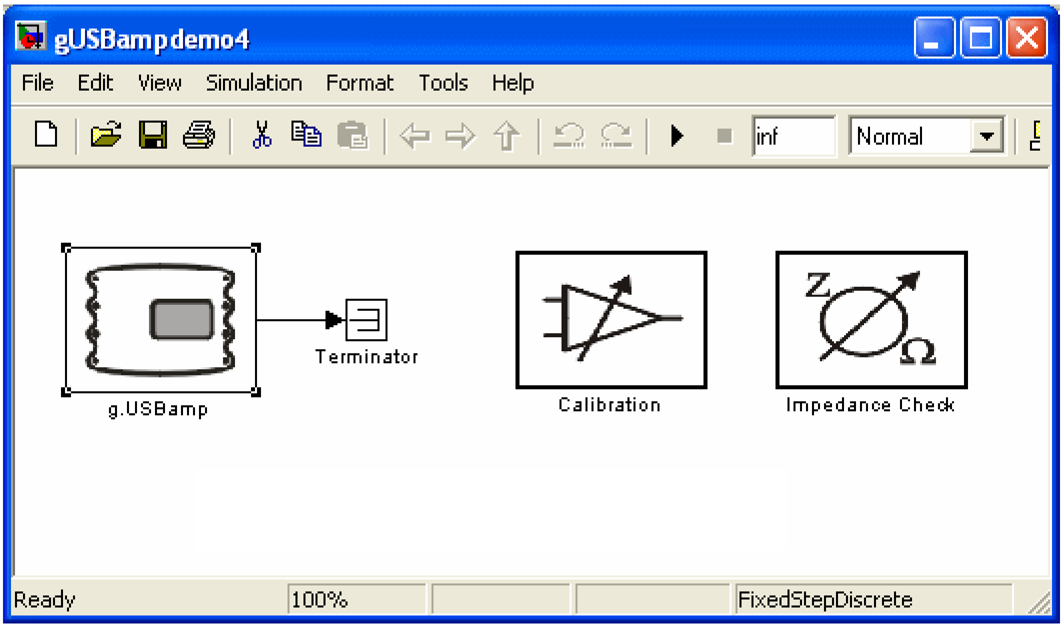
- **Any sensor or device has to be disconnected from the amplifier while the impedance of the electrodes is measured!**
- **The impedance cannot be measured for active electrodes!**

Calibration

g.USBamp has a build-in calibration unit, all analog channels have to be short cut to ground to calibrate g.USBamp.

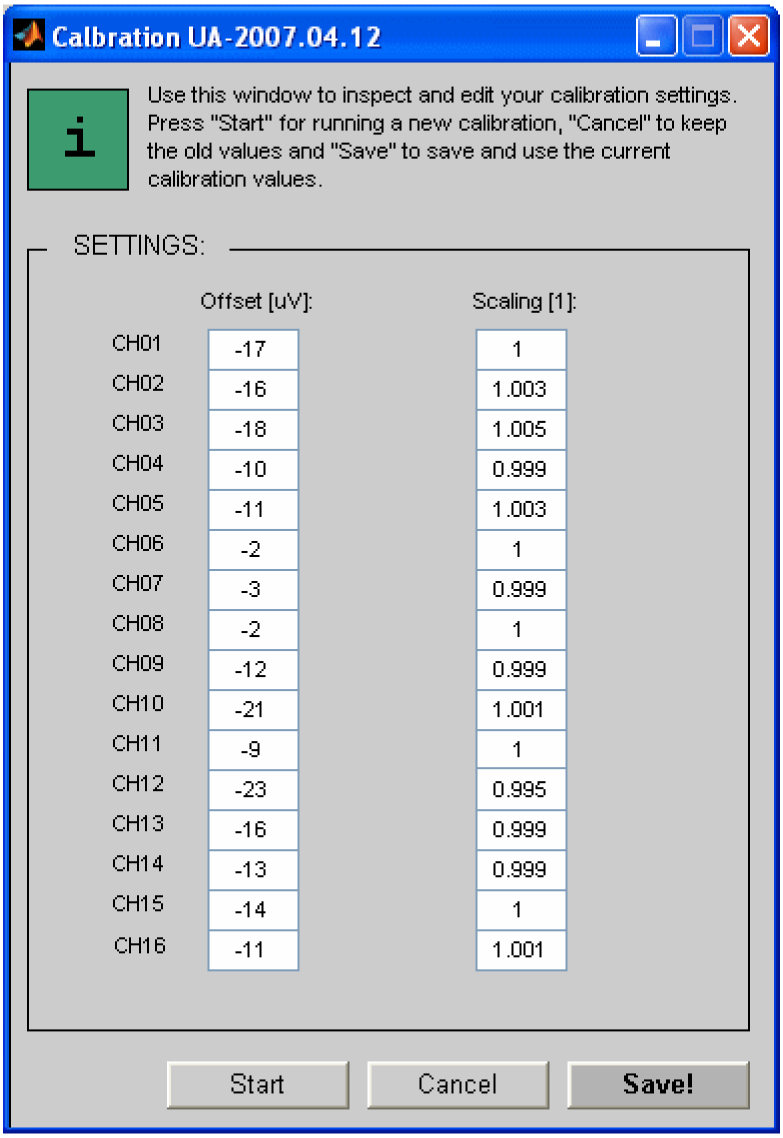
To calibrate g.USBamp perform the following steps:

1. Start the Simulink model `gUSBampdemo4` from the MATLAB command line to open the model below:



2. Double click on **g.USBamp** and load the configuration file `gUSBampdemo4.cfg`. Enter the **Serial Number** of your amplifier.

3. Double click on the **Calibration** block. The following window will appear:

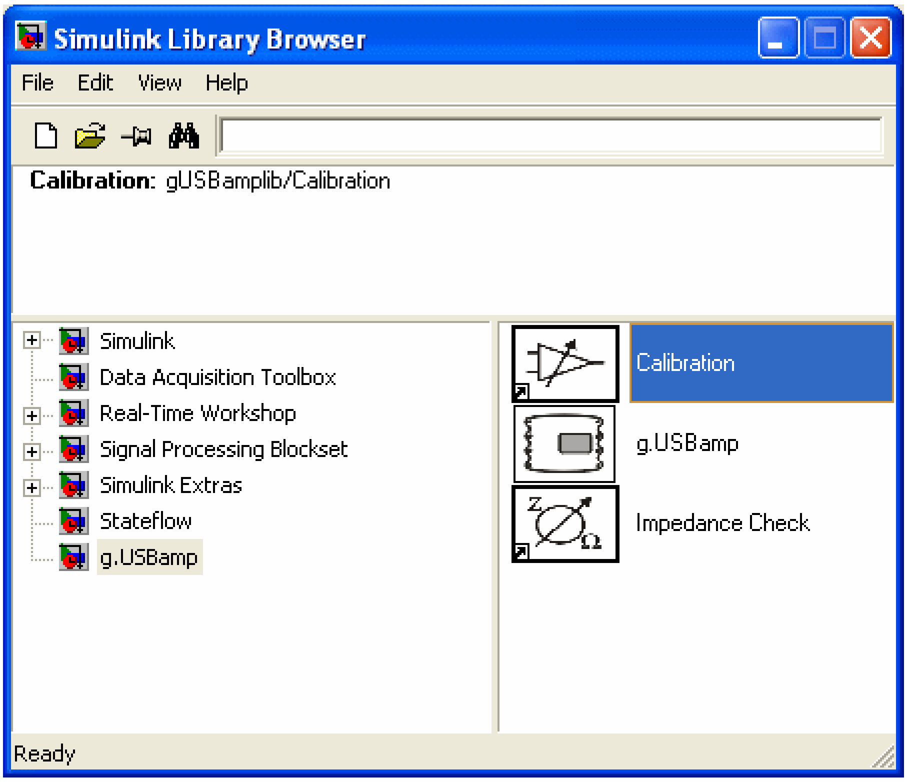


4. Press **Start** to perform the calibration and to get the **Offset** and **Scaling** values for each channel

5. Inspect the **Offset** and **Scaling** values. If you want to perform some changes use the editor boxes.

6. Press the **Save** button to store the calibration

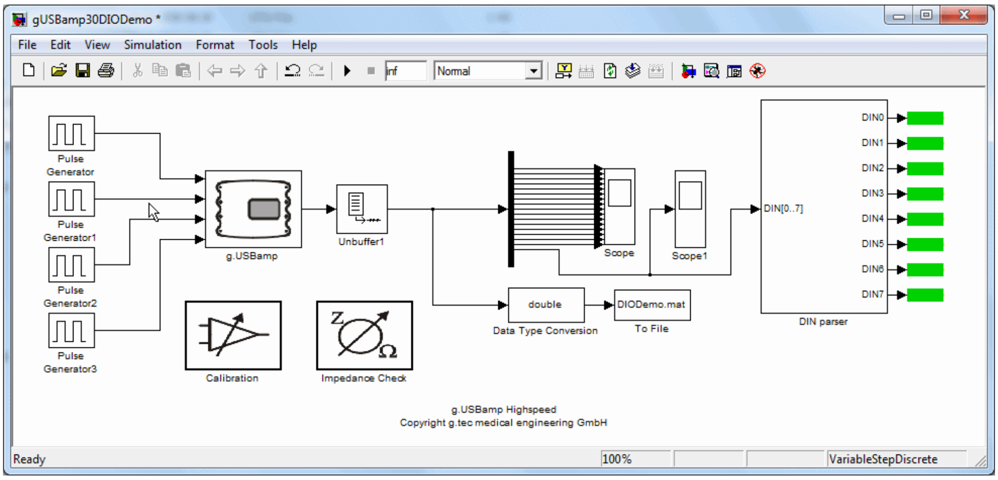
If you want to add the Calibration facility to your model type simulink to the MATLAB command line and select the **g.USBamp** library. Drag the **Calibration** block into your model:



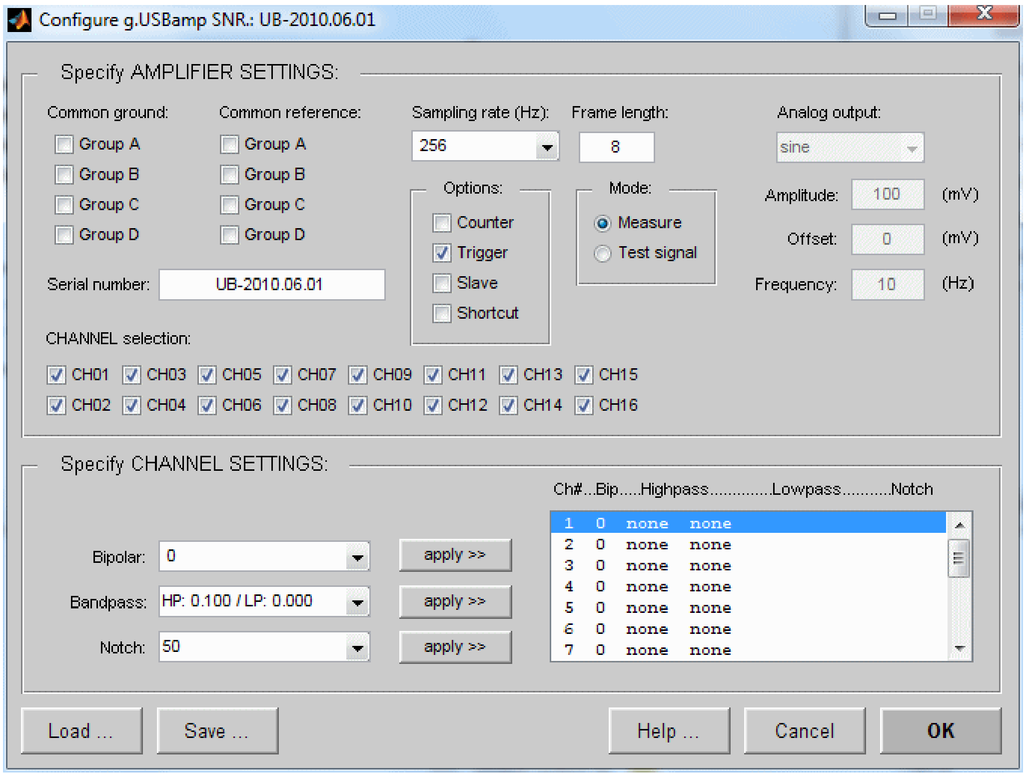
Using Digital In- and Outputs of g.USBamp (version 3.0 only)

g.USBamp version 3.0 provides 8 digital inputs and 4 digital outputs.

1. Open Simulink model `gUSBamp30DIODemo` from the MATLAB command line to open the following model:



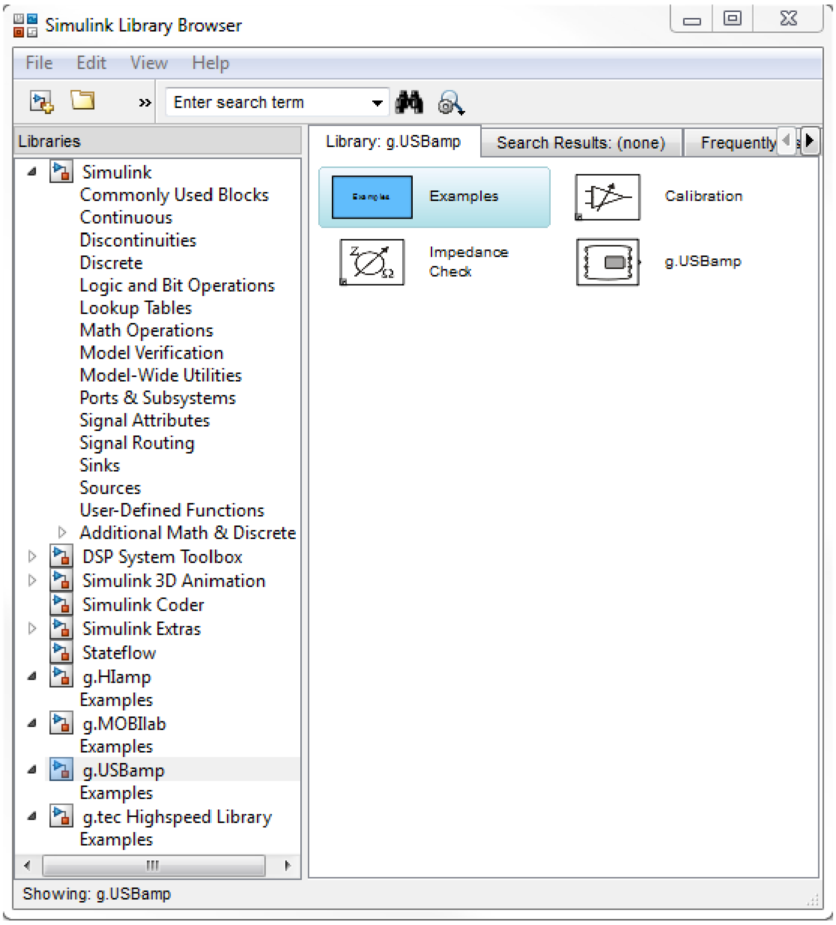
2. Double click the **g.USBamp** block to open the configuration dialog. Provide the configuration as shown in the dialog below or use the **Load…** button to load the stored configuration `gUSBamp30DIODemo.cfg`.



3. Start the model. Depending on the input signal provided for the digital inputs the outputs **DIN0** to **DIN7** from the **DIN parser** block will change from green (high) to grey (low).

Other Examples

g.USBamp Highspeed provides the **g.USBamp** library and three other useful examples. Open the **Simulink Library Browser** and either select **g.USBamp** or double click the **Examples** entry to see the examples:



g.USBamp starts a Simulink model with the driver block

gUSBamp Online ECG, Respiration starts a Simulink model which calculates the heart-rate, heart-rate variability and respiration rate

gUSBamp Brain Computer Interface starts a Simulink model which performs brain computer interface experiments

gUSBamp P300 Spelling Device starts a Simulink model which allows to spell with the single character flash speller

See the PDF helps under

`C:\Program Files\gtec\gtecHS\Help\gUSBamp`

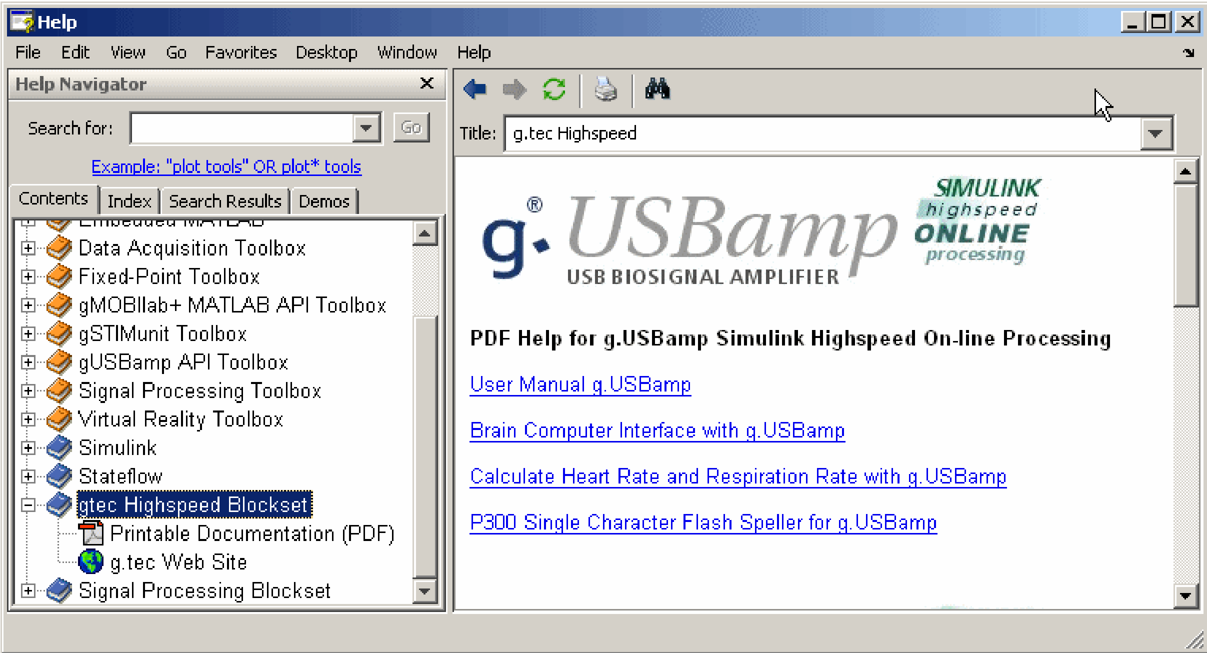
for a detailed description.

Help

g.tec Highspeed provides a printable documentation.

To access the help click on **MATLAB Help** in the **Help** menu of MATLAB. To access the help from command line type:

```
doc
```



The printable documentation is stored under

```
C:\Program Files\gtec\gtecHS\Help\gUSBamp
```

as `gUSBampHS.pdf`. Use Acrobat Reader to view the documentation.

Product Page

Please visit our homepage www.gtec.at for

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- Downloads
- Troubleshooting
- Additional demonstrations

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