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Calculate Heart Rate and Respiration Rate With g.USBamp and Simulink V3.12.03

Introduction

g.USBamp is a biosignal acquisition system for EEG, ECG, EMG, EOG and other sensors. In this tutorial the recording of an ECG and a respiration signal will be discussed. Furthermore the usage of Simulink blocks for the detection of the heart rate and of the respiration will be shown.

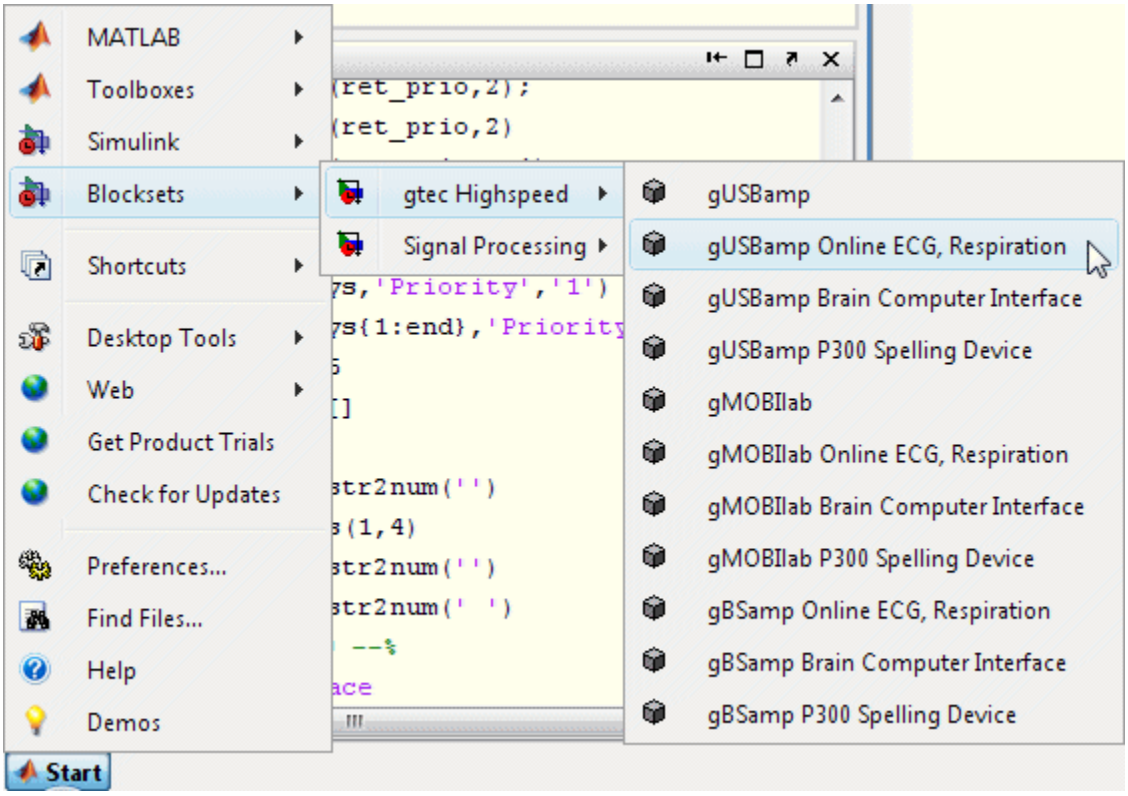
Required components

To perform the tutorial the following components are required:

- **g.USBamp** biosignal acquisition device
- **Simulink Highspeed On-line Processing** blocks for g.USBamp
- ECG cable and ECG electrodes for g.USBamp
- Respiration sensor for g.USBamp
- PC or notebook with serial or USB connector
- MATLAB, Simulink and Signal Processing Blockset Release 2012a

Start-up

The corresponding Simulink model can be started from the MATLAB **Start** button



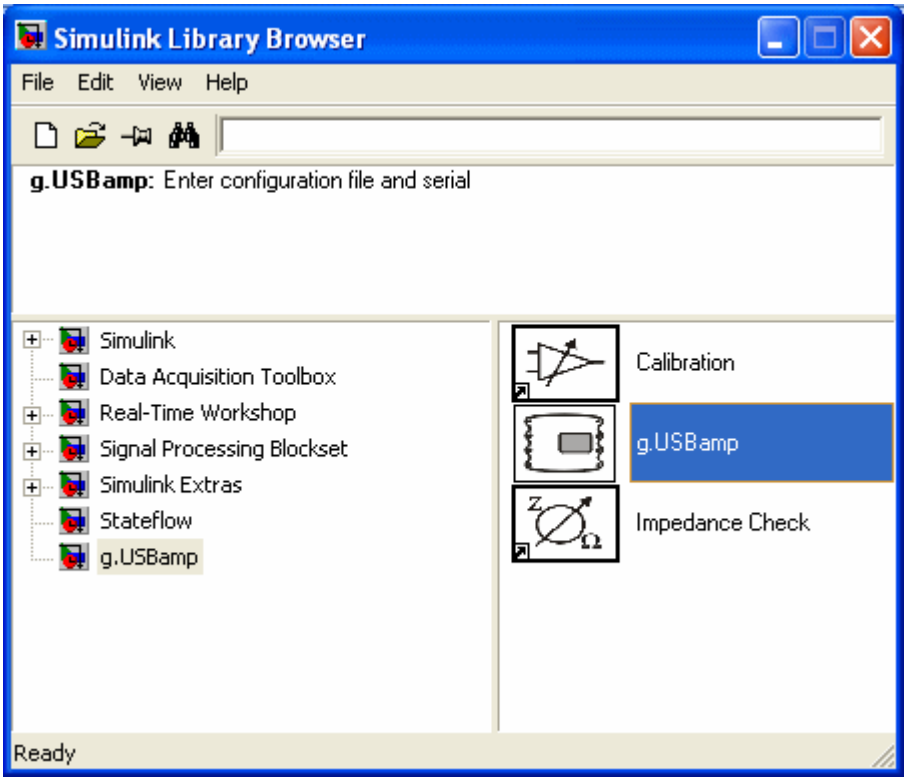
or by typing `gUSBampECG` into the MATLAB command line.

Driver configuration

Start MATLAB by double clicking on the MATLAB icon and type:

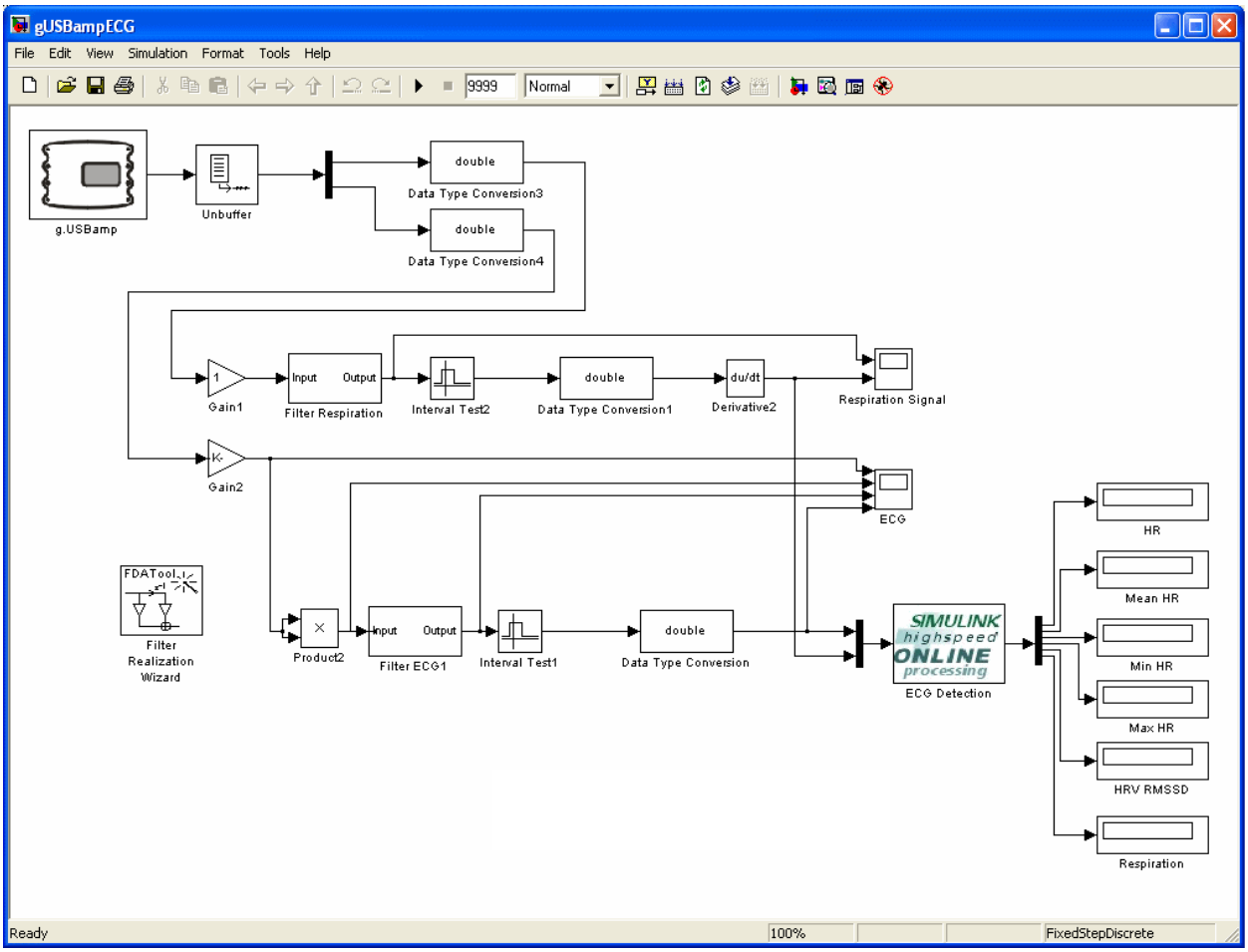
```
simulink
```

into the MATLAB command line to start up the **Simulink Library Browser:**

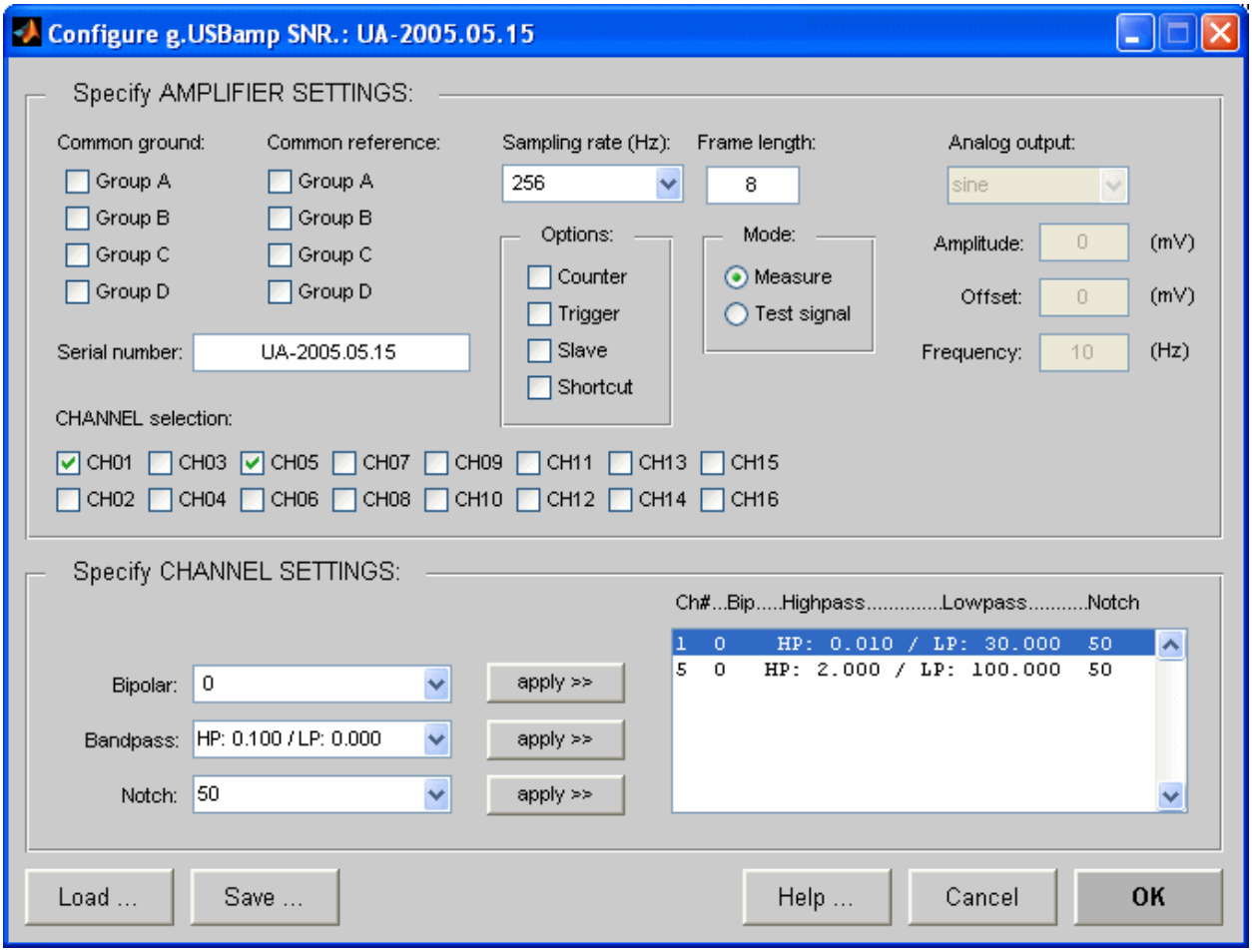


Open a new Simulink model from the **File** menu.

Then go to the g.USBamp folder in the **Simulink Library Browser** and drag the block **g.USBamp** into the new Simulink model and build the following model.



Double click onto the block to open the following window:



CHANNEL selection allows specifying two channels for the measurement of the ECG and of the respiration signal. Assign a **Bandpass** filter of `2` to `100` Hz for ECG channel 5 and `0.01` to `30` Hz for respiration channel 1. Set the **Sampling rate** to `256` Hz.

Enter the **Serial numbe**r of g.USBamp.

Now g.USBamp is correctly initialized.

Press **OK** to accept the settings and to close the window.

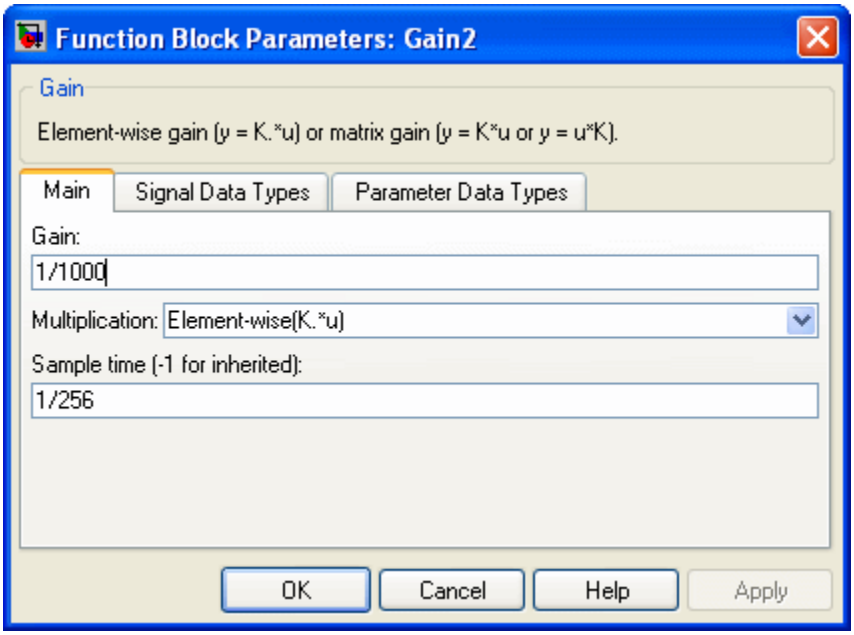
Note: The configuration can be loaded by clicking on the **Load …** button and selecting `gUSBampECG.cfg`.

Connect **g.USBamp** to the **Unbuffer** block.

Connect a **MUX** block to split the DC and ECG channels. Then connect both channels to a **Gain** block to correctly calibrate the signals.

The driver block reads in the data in µV. Set the gain for the respiration channel to `1` to work with signals in the µV range and for the ECG channel to `1/1000` in order to work with mV signals.

Set the **Sample time** to `1/256`.



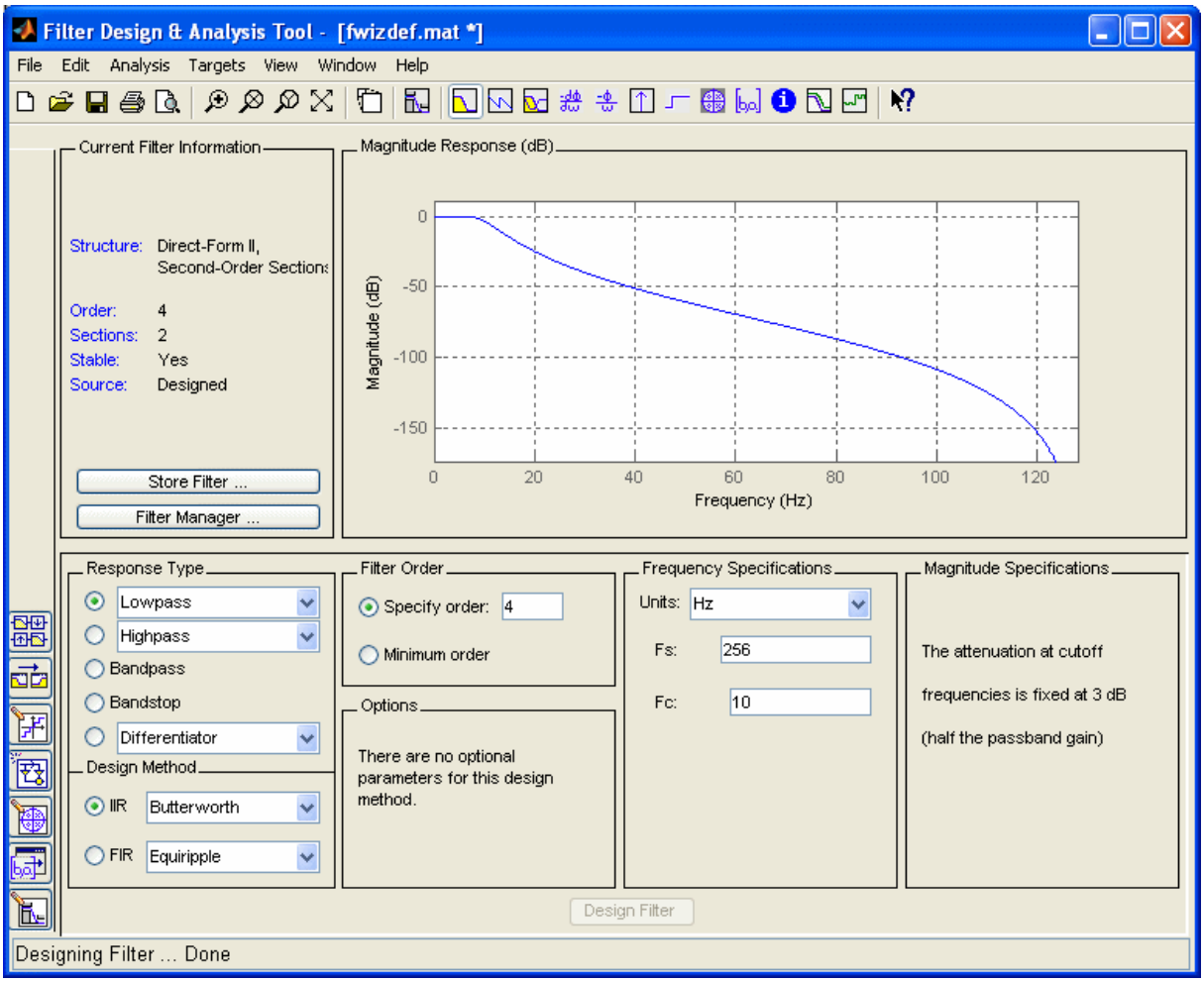
g.USBamp reads the data with single precision (float32). Use the **Data Type Conversion** block to work with doubles.

Respiration

Copy the **Filter Realization Wizard** into your model to design a lowpass filter. The sampling frequency of g.USBamp is 256 Hz for all channels. Enter `256` in the editor box **Fs** and set the cut-off frequency **Fc** to `10` Hz. Set the order of the lowpass filter to `4` under **Specify order**.

Click the **Design Filter** button to investigate the **Magnitude** and **Phase Response**.

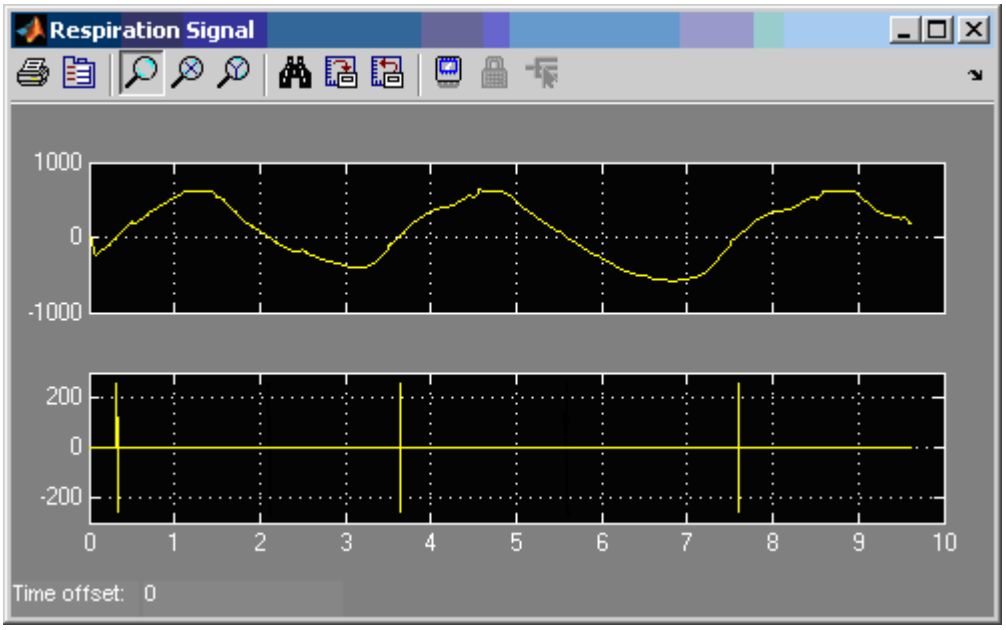
Click on **Realize Model** to create a Simulink block with the settings.



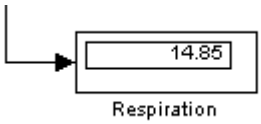
Connect the filter to the **Gain** block.

Copy the **Interval Test** block into the model. The block detects zero-crossings of the respiration signal. The **double** block converts the boolean output of the **Interval Test** block into doubles in order to perform the first derivation in the next block.

Use the **Respiration Signal** scope to investigate the respiration signal in channel 1 and the detected zero-crossings in channel 2.



The **Respiration** display block shows the respiration cycles per minute.



ECG Processing

Copy the **Product** block into the model and connect it to the **Gain** block of the ECG signal. This block is used to square each input sample.

Start again the **Filter Realization Wizard** to design a bandpass filter for the ECG signal. Design a Butterworth bandpass filter with a lower cut-off frequency of `5` Hz and an upper cut-off frequency of `100` Hz. Set the order to `4`.

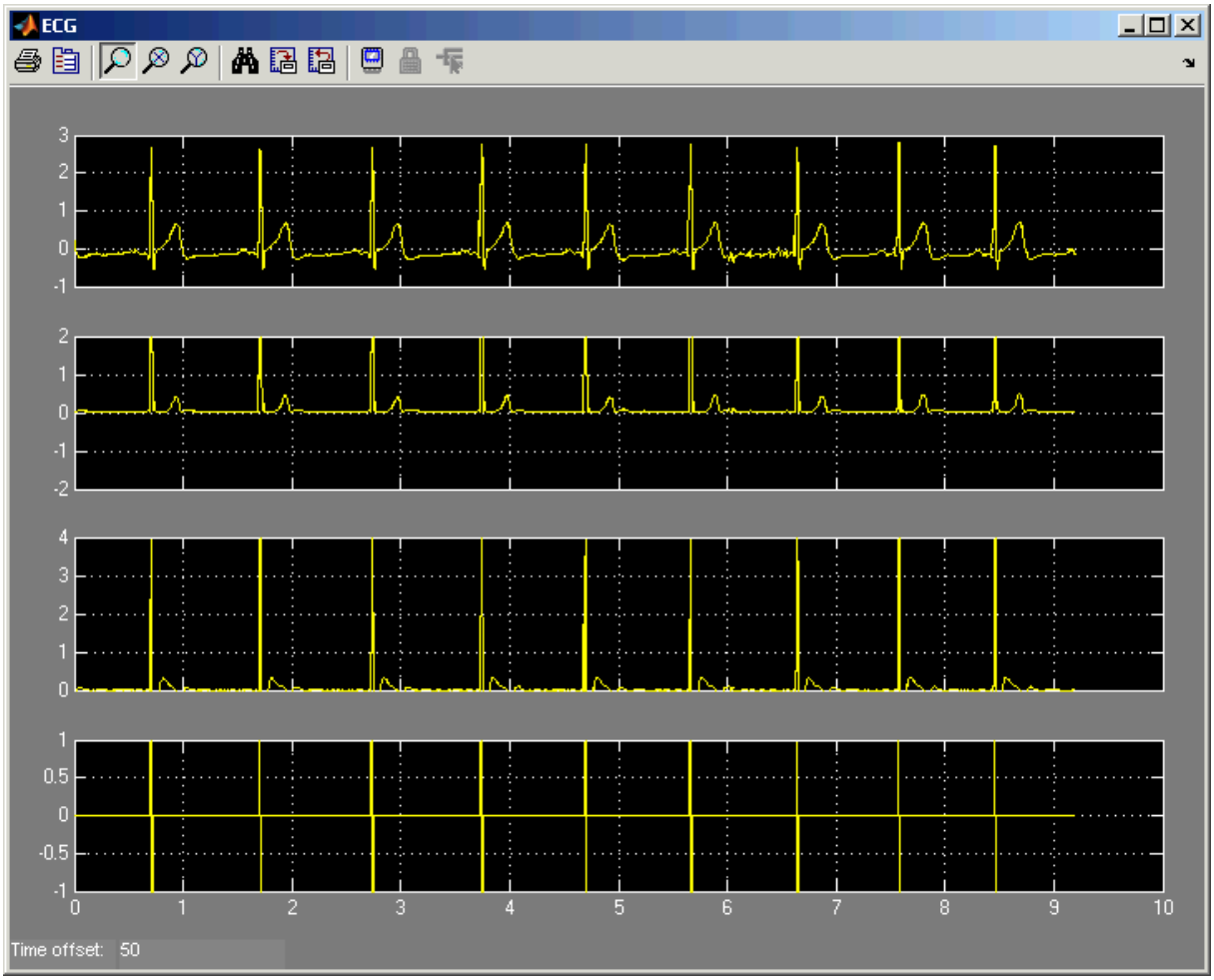
Click the **Design Filter** button to investigate the **Magnitude** and **Phase Response**.

Click on **Realize Model** to create a Simulink block with the settings.

Connect the filter block to the **Product** block.

Copy the **Interval Test** block into the model. The block detects amplitudes above 2 mV and below 10 mV. The **double** block converts the Boolean output of the **Interval Test** block into doubles.

Use the **ECG** scope to investigate the ECG signal on channel 1, the squared signal on channel 2, the bandpass filtered signal on channel 3 and the detected QRS complexes on the last channel.

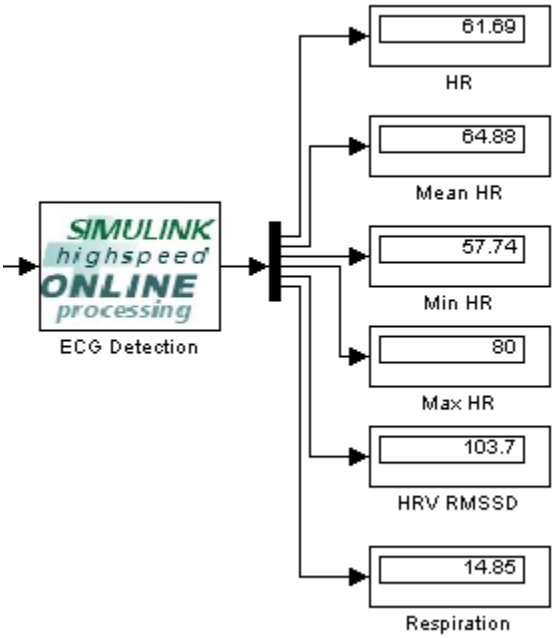

ECG
Time offset: 50

The block **ECG Detection** is a MATLAB S-Function that performs error detection of the QRS complex detector and of the respiration signal. Input 1 reads in the QRS complex signal and channel 2 the zero-crossings of the respiration channel.

If the interval from the last heart beat to the current heart beat (RR interval) exceeds the previous interval by 150 % or is smaller as 50 % than the interval is not accepted.

The block has 6 outputs which are connected to the display blocks:

HR	actual heart rate in beats per minute
Mean HR	mean HR of the last 10 beats
Min HR	minimum HR of the last 10 beats
Max HR	maximum HR of the last 10 beats
HRV RMSSD	heart rate variability in ms of the last 10 beats. RMSSD is the root mean square of the squared difference of successive RR intervals.
Respiration	respiration cycles per minute

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