

Calculate heart rate and respiration rate with g.MOBILab and Simulink

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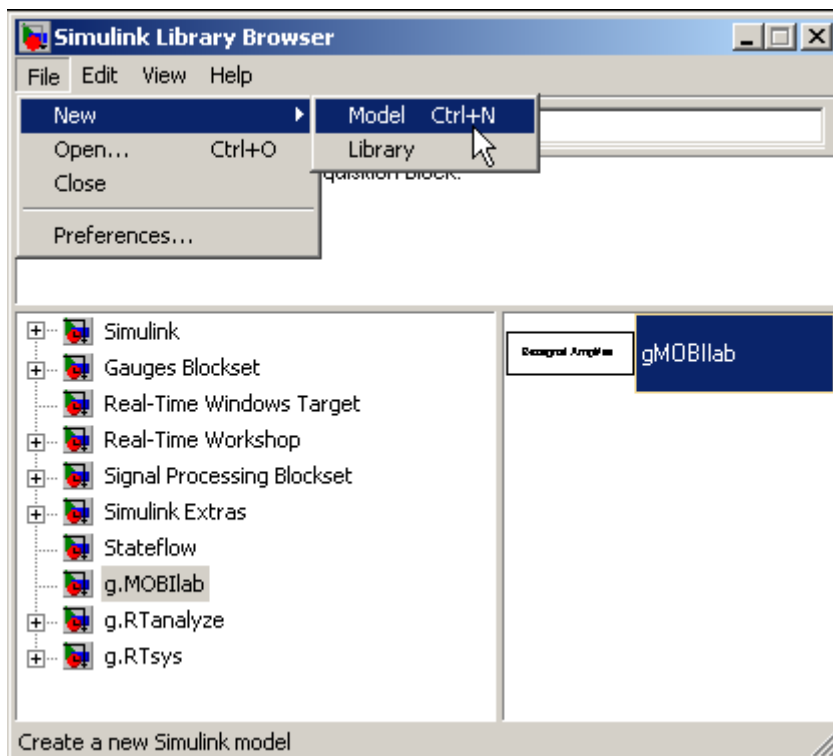
g.MOBILab is a biosignal acquisition system for EEG, ECG, EMG, EOG and other sensors. In this tutorial the recording of an ECG and a respiration signals will be discussed. Furthermore the usage of Simulink blocks for the detection of the heart rate and of the respiration will be shown.

DRIVER CONFIGURATION

Start MATLAB by double clicking on the MATLAB icon and type

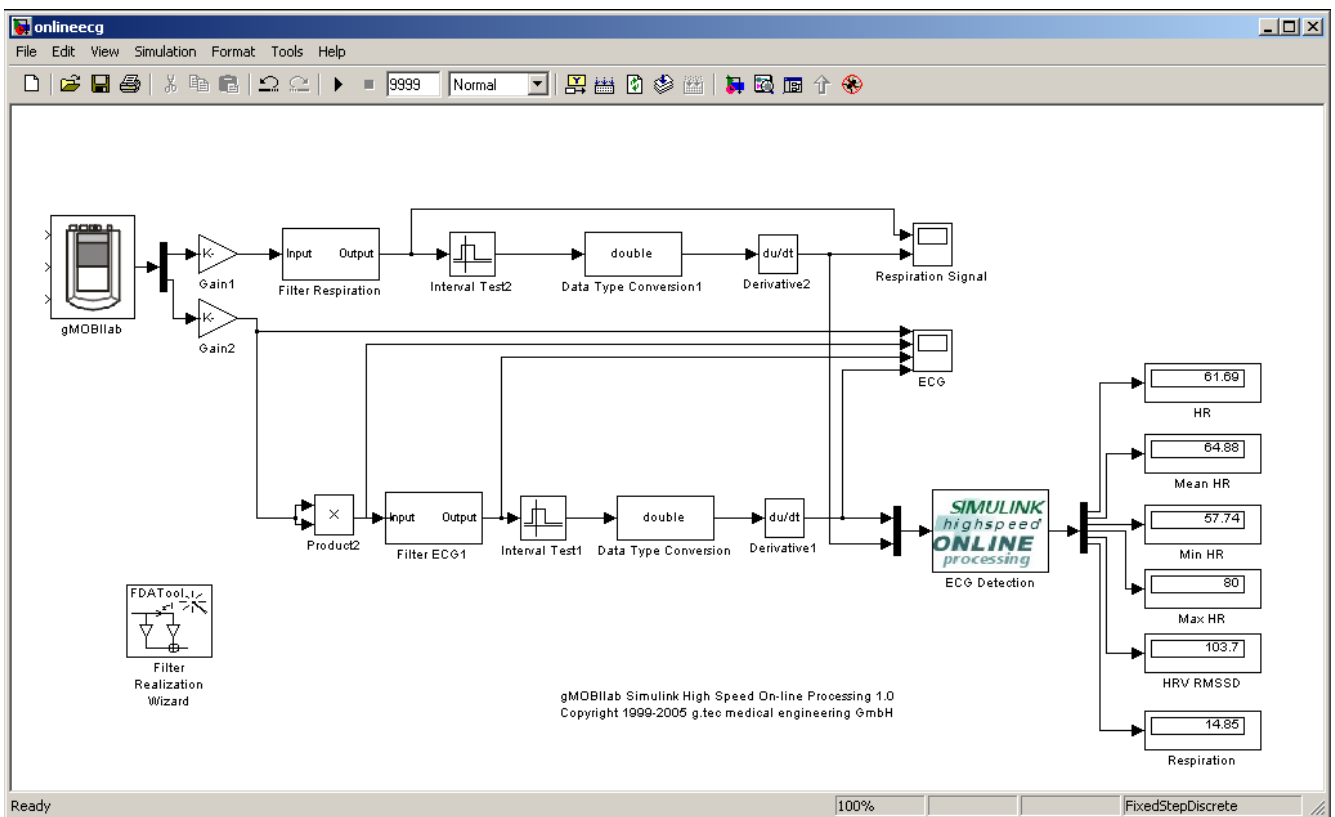
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simulink
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into the MATLAB command line to start up the **Simulink Library Browser**:

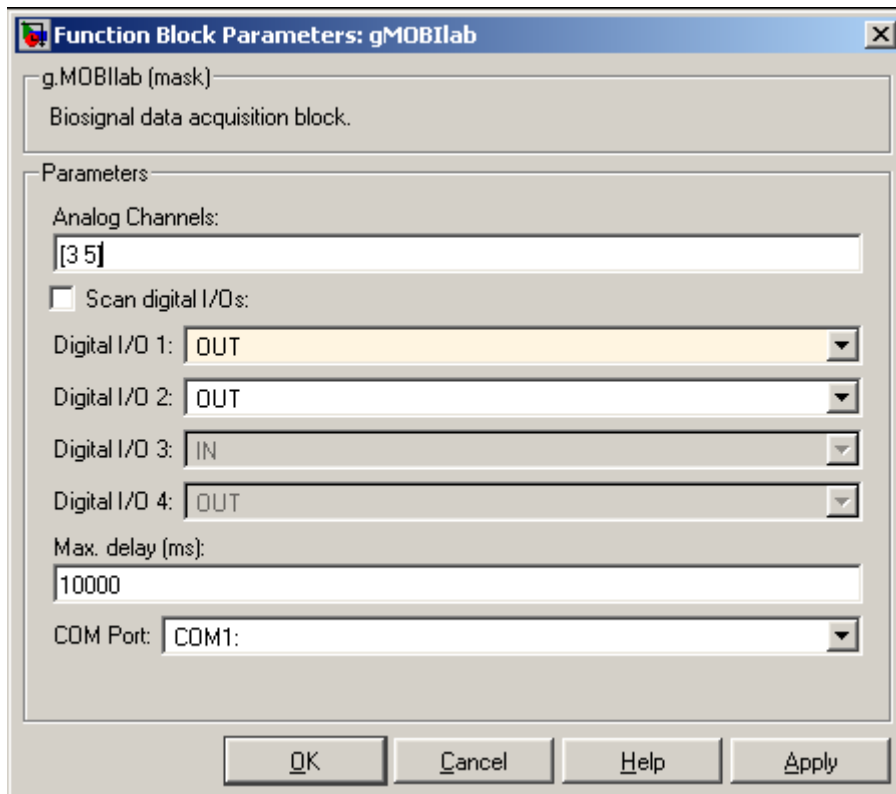


Open a new Simulink model from the **File** menu.

Then go to the `g.MOBILab` folder in the **Simulink Library Browser** and drag the block `gMOBILab` into the new Simulink model.



Double click onto the block to open the following window:



Editor box **Analog Channels** allows to specify the biosignal channels. Enter [3 5] to read in a DC channel with a lower cutoff frequency of 0.01 Hz and an ECG channel.

Check **Scan digital I/Os** if digital inputs or outputs should be used. Digital inputs 1 and 2 can be defined as inputs or outputs. **Digital I/O 3** is always an input and can be used to read in data from the external switch that can be connected to g.MOBILab. **Digital I/O 4** is always an output channel. Output channels are useful to send trigger signals to external devices for synchronization or to control an external device.

Max. delay (ms) allows to specify the maximum possible delay that the g.MOBILab driver block can have. The highly optimized driver block ensures that all data from the acquisition device is read into Simulink. If the PC is busy with other tasks and can not perform the Simulink operations fast enough, the driver stores the data in a hardware buffer. After returning to the Simulink task the operations are performed as fast as possible. If the driver block detects an overflow an error message is shown.

Pull-down menu **COM Port** can be used to select the appropriate serial port of your PC or notebook.

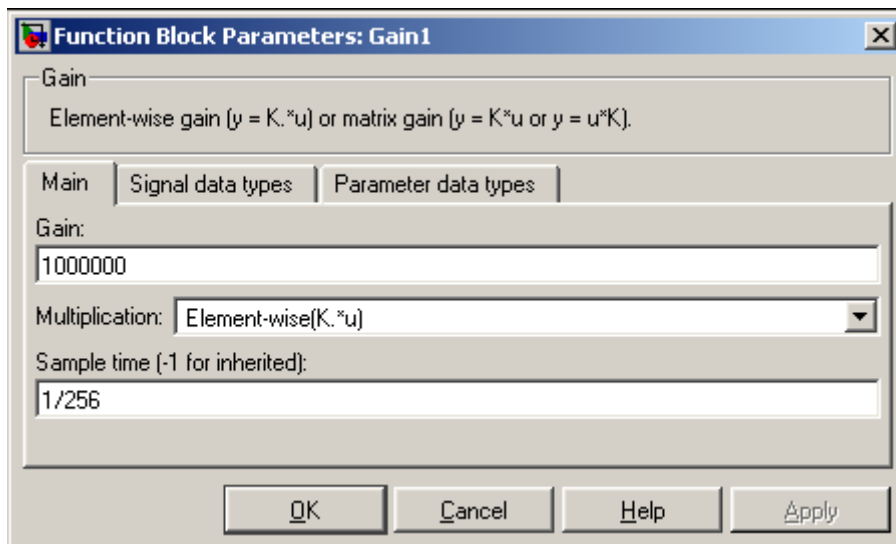
Now g.MOBILab is correctly initialized.

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

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 Volt. Set the gain for the DC channel to 1 . 000 . 000 to work with signals in the μV range and for the ECG channel to 1 . 000 in order to work with mV signals.

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

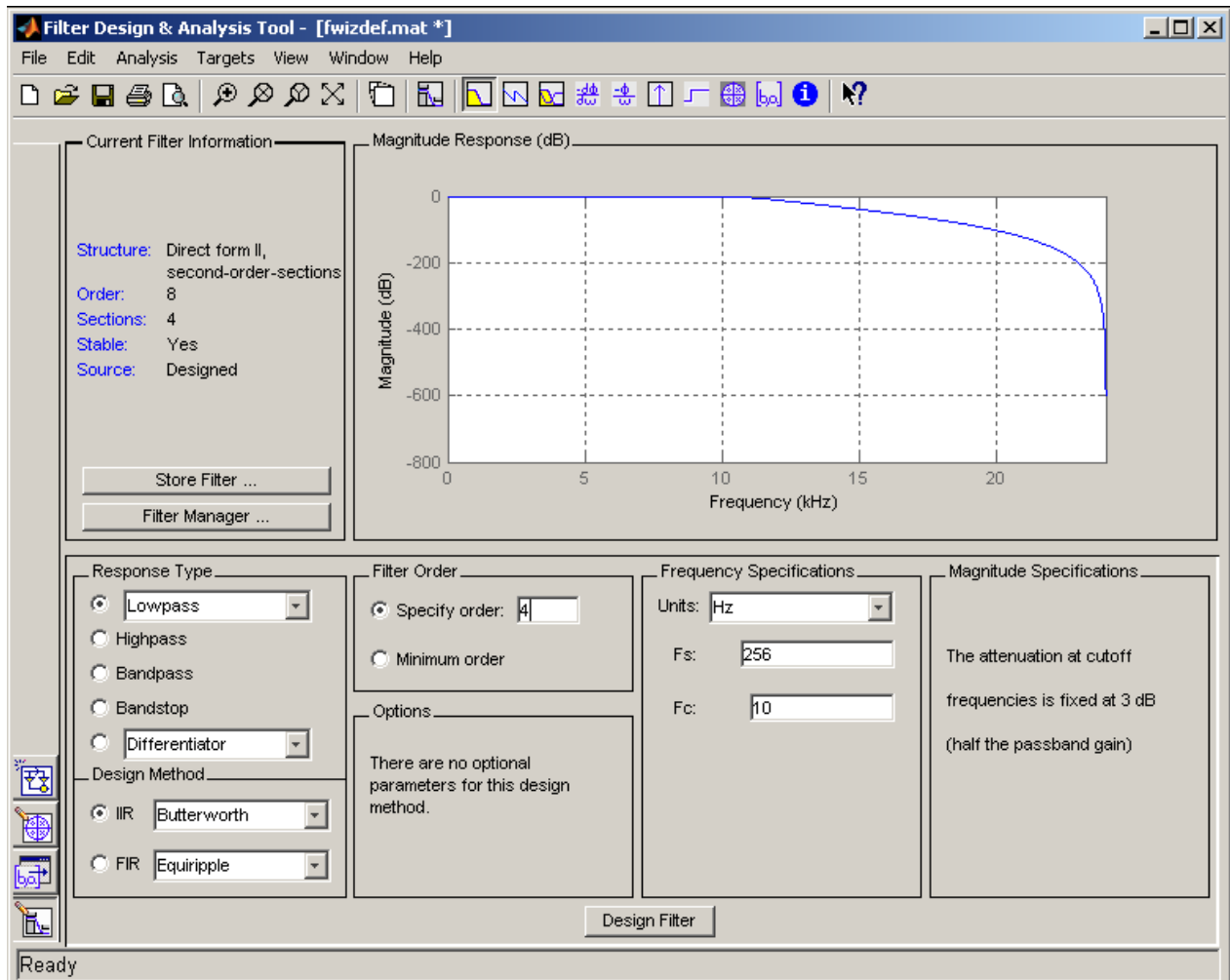


RESPIRATION

Copy the **Filter Realization Wizard** into your model to design a lowpass filter. The sampling frequency of g.MOBIIlab 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**.

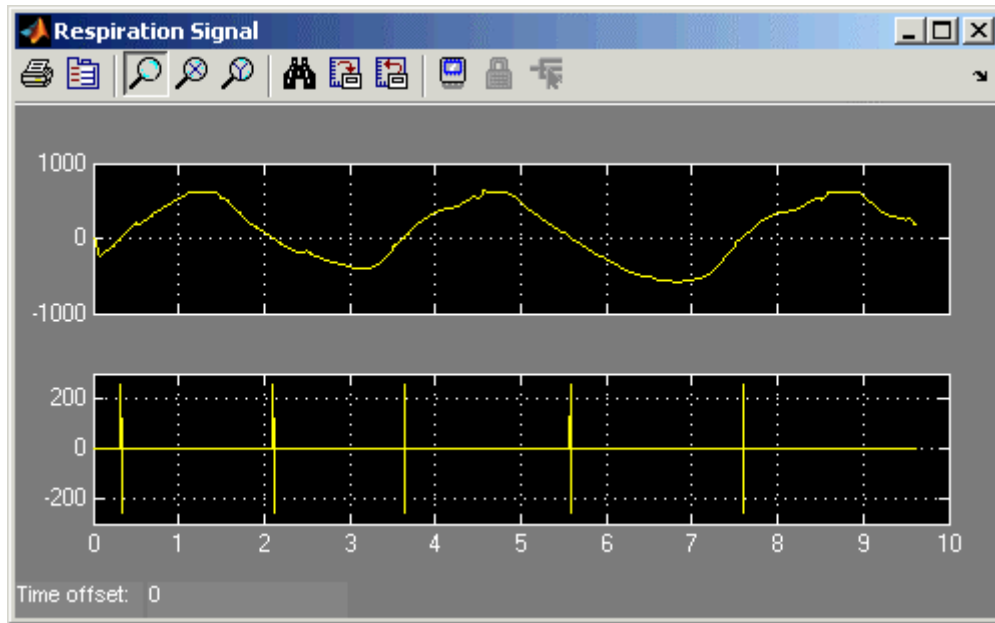
Click on **Realize Filter** to create a Simulink block with the settings.



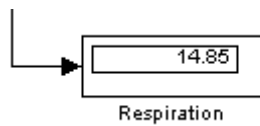
Connect the filter to the **Gain** block.

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.

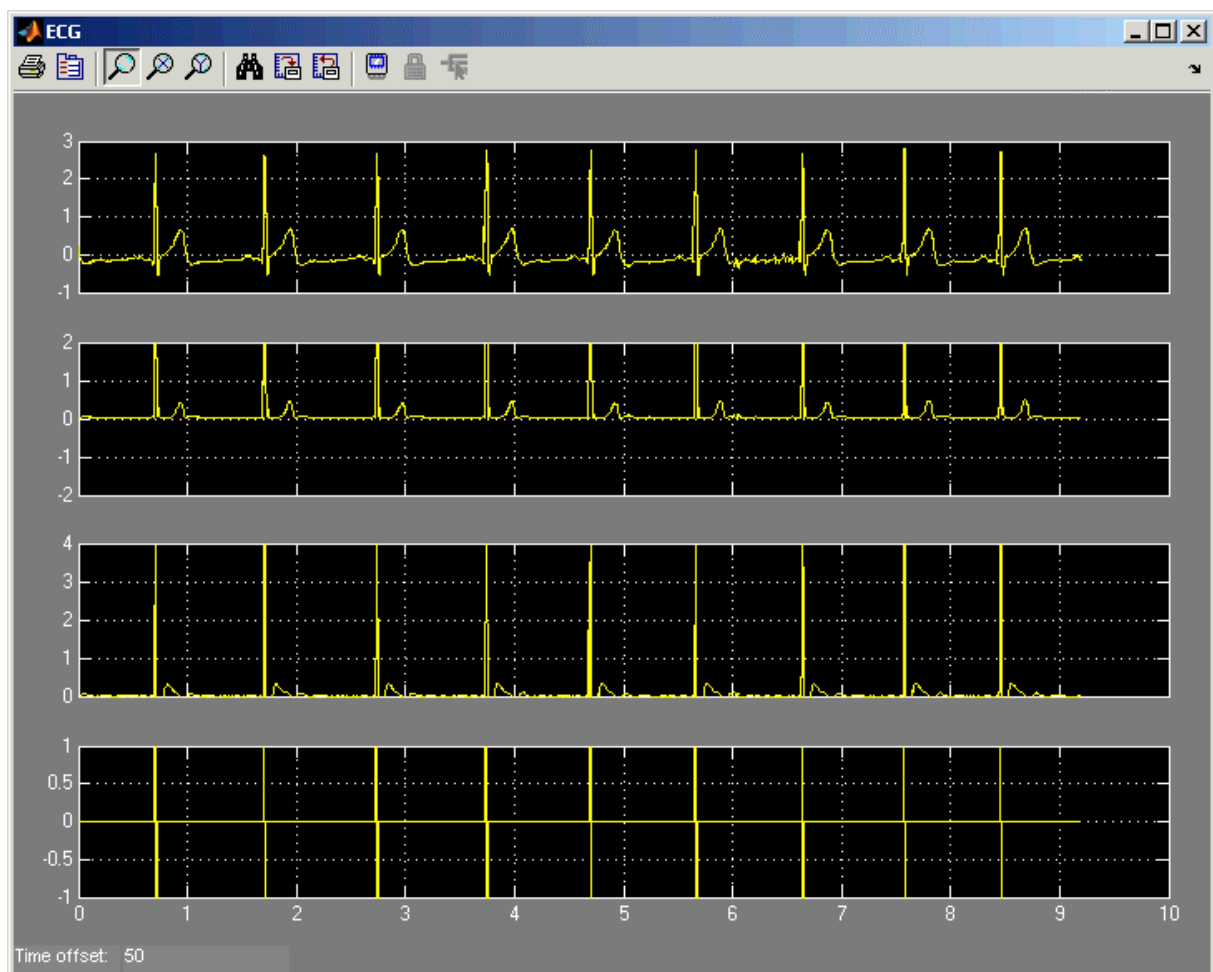
Click the **Design Filter** button to investigate the **Magnitude** and **Phase Response**.

Click on **Realize Filter** 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 in order to perform the first derivation in the next block.

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.

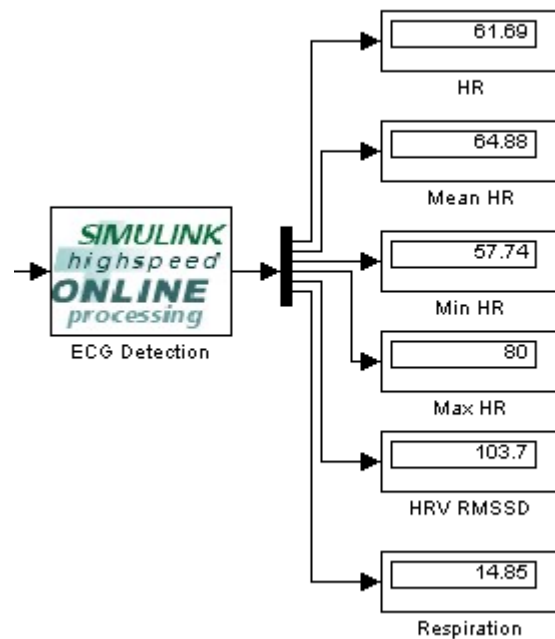


The block **ECG Detection** is a MATLAB S-Function that performs an error detection of the QRS complex detector and of the respiration signal. Input 1 reads in the QRS complex signal and channel 2 the zero-crossings of the respiration channel.

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



SUMMARY

To perform the tutorial the following components are required:

- g.MOBilab** biosignal acquisition device
- Simulink highspeed ONLINE processing** blocks for g.MOBilab
- ECG cable and ECG electrodes for g.MOBilab
- Respiration sensor for g.MOBilab
- PC or notebook with serial or USB connector
- MATLAB 7 and Simulink 6