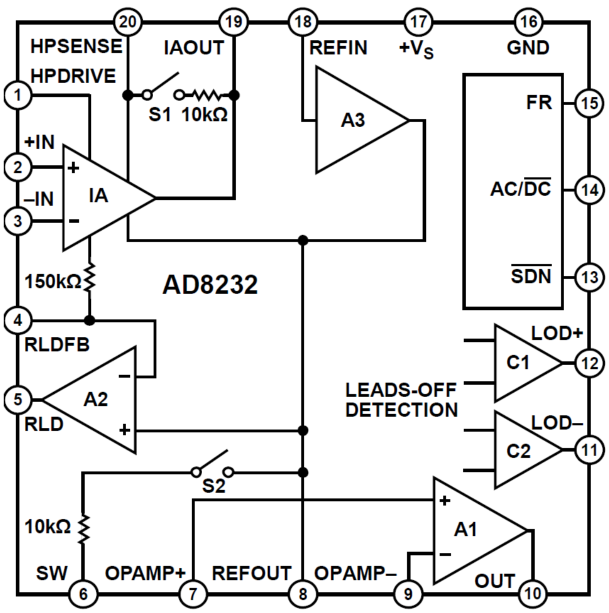
AD8232 FILTER DESIGN TOOL USER MANUAL

AD8232. THE PART

The AD8232 is an integrated signal conditioning block for ECG and other biopotential measurement applications. It is designed to extract, amplify, and filter small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement.

Figure 1- AD8232 Block Diagram



Please read AD8232 datasheet (available at www.analog.com/AD8232) for a detailed explanation of the part and a full set of specifications.

In summary, the AD8232 features an instrumentation amplifier, a reference buffer, a spare amplifier, an amplifier to inject back the common mode voltage and several digital features such as shutdown mode, AC or DC leads-off detection and Fast Restore.

The first stage is a high impedance instrumentation amplifier that amplifies the small biopotential signal by a factor of 100 while removing differential near-DC offsets up to ±300mV. This first stage is therefore a High Pass Filter and makes the the AD8232 front end an AC coupled system.

The second stage is formed by a spare amplifier that is usually configured as a single or second order Low Pass Filter with (or seldom without) additional gain.

Therefore the overall system will most likely look as a bandpass front end.

Figure 2- AD8232 Filter Design Tool. Main Blocks

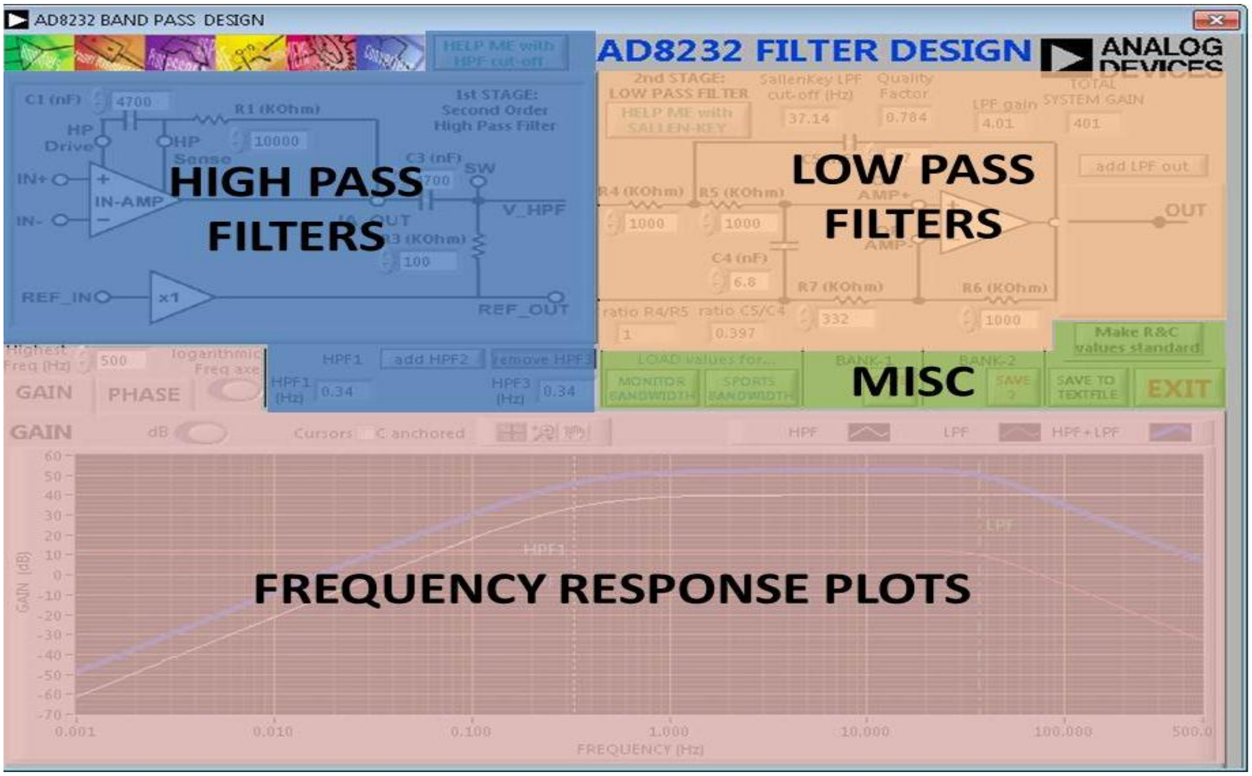
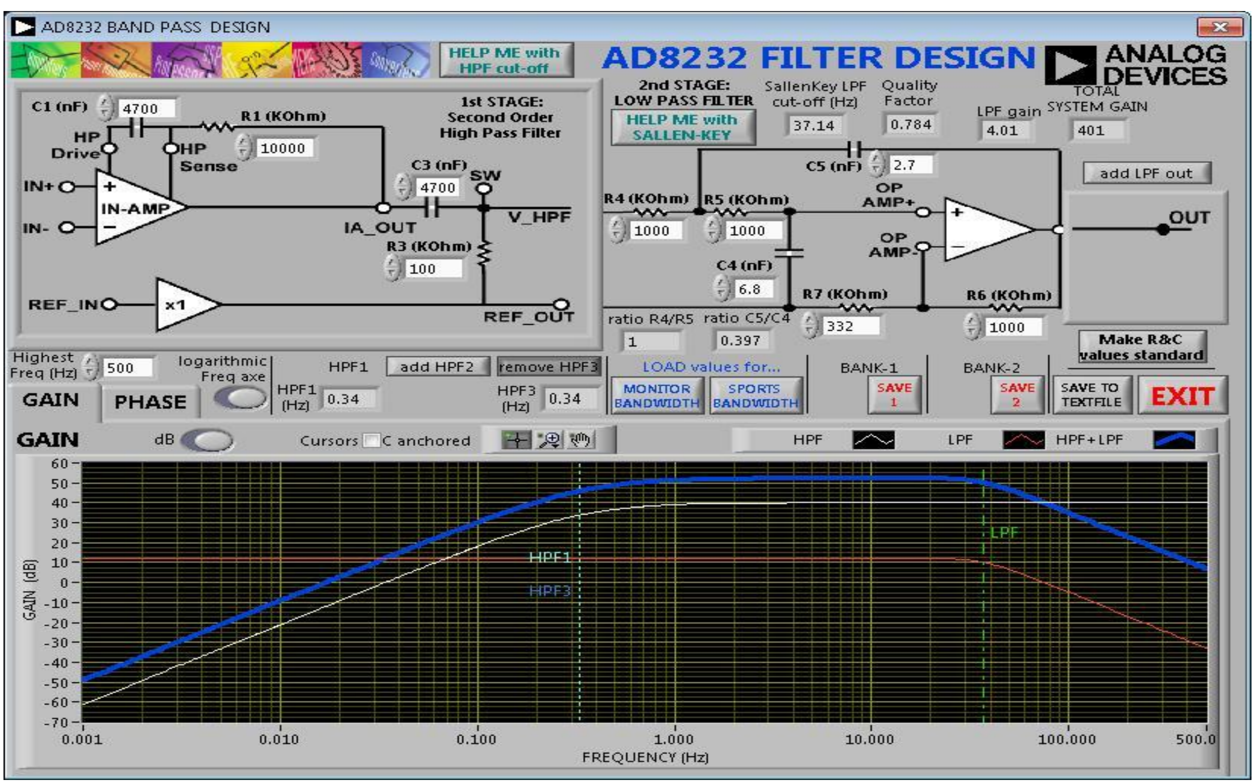


Figure 3- AD8232 Filter Design Tool



THE SOFTWARE TOOL

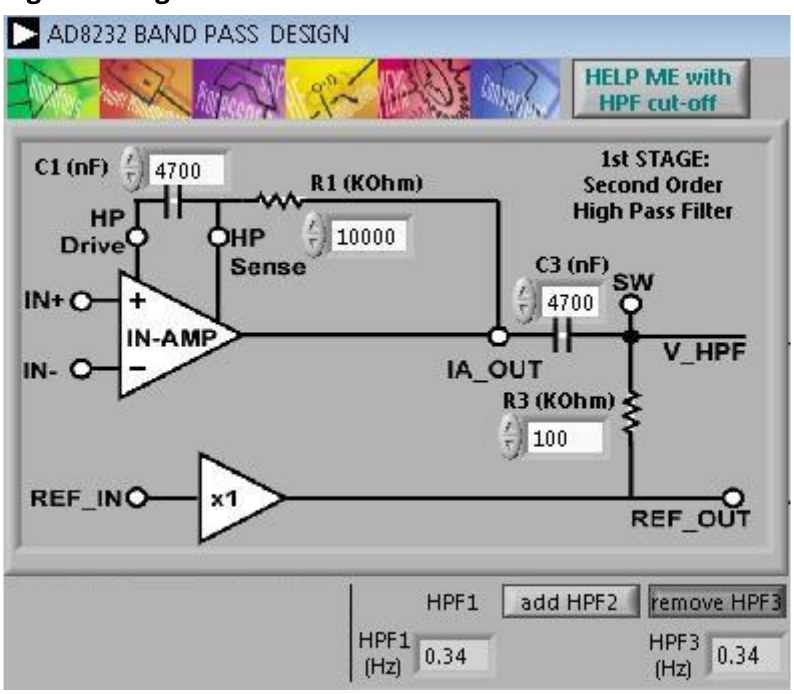
This software tool calculates the theoretical frequency response of such a system taking care of details that are specific to the AD8232. This system frequency response calculator helps the designer choose the right values for the external resistors and capacitors that will result in the desired frequency response. This tool does not include second order effects in the calculations and is provided as a visual tool to speed up the design process. Both an actual implementation and overall frequency characterization is highly recommended.

This program leaves out the digital features, the reference buffer and the Right Leg Drive Amplifier since the design of the bandpass is not affected by them.

THE FILTERS

High Pass Filters: Four implementation options are offered for the design of the High Pass Filter. One single pole based on R1 and C1 (HPF1), two dual poles that add one pair (R2/C2 or R3/C3) to the first pole or a three pole high pass filter comprised by the three passive pairs.

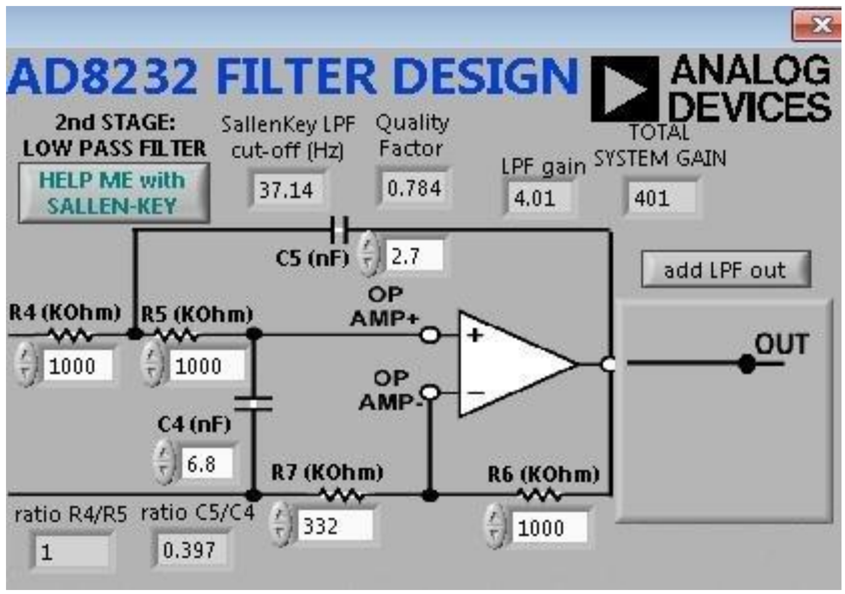
Figure 4- High Pass Filter Section



The first High Pass Filter (HPF1) is defined by R1 and C1 and is always present. Press ´add/remove HPF2´ (or HPF3) to enable or disable the other two optional High Pass Filter poles.

Low Pass Filters: A Sallen-Key cell is offered as a second order Low Pass Filter. This stage adds to the signal path an extra gain set by R7 and R6. Care must be taken when designing this block since changing the gain changes the Quality Factor and therefore the overall response of the system, and may even lead to instability. See ´HELP ME with SALLEN-KEY´ below.

Figure 5 Low Pass Filter Section



Please note that this block is given by default and is not removable within the tool. But in a real implementation there is no reason why R4 could not be made a short circuit and C5 an open circuit to make this block a first order low pass filter (instead of second order), saving some external components.

An additional first order passive low pass filter can be added to the simulated signal chain with an optional final RC pair (R8 and C8). Press 'Add/Remove LPF out' to enable/disable this option.

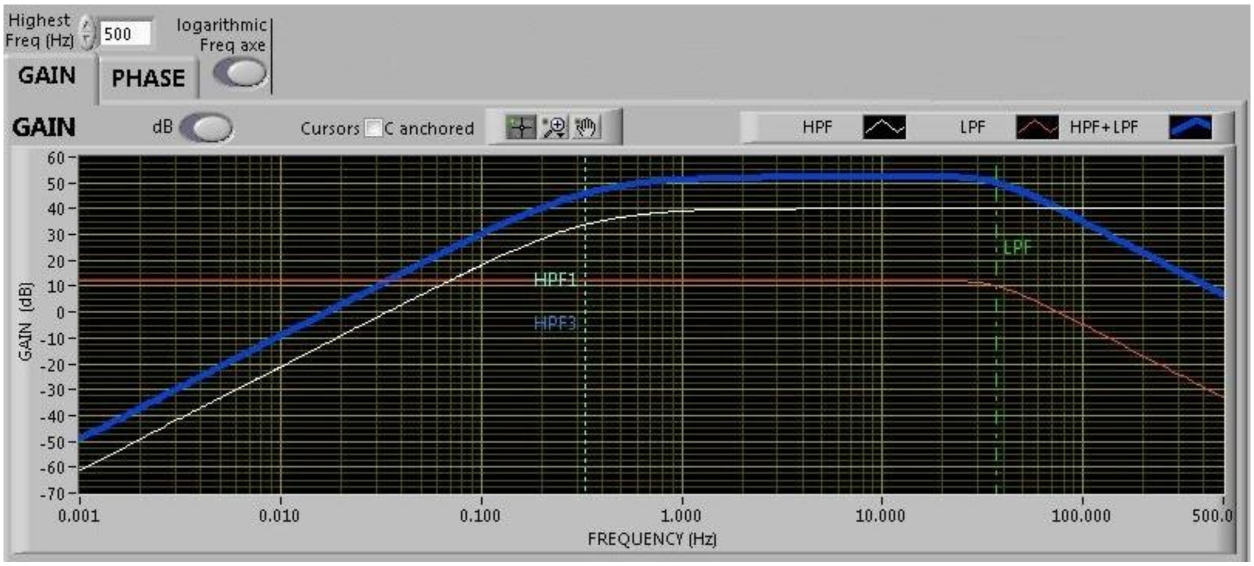
Pressing button ´HELP ME with HPF cut-off´ or ´HELP ME with SALLEN-KEY ´ will show a pop-up window where the decision making is guided. This is especially helpful to design the gained Sallen-Key.

THE RESULTING FREQUENCY RESPONSE

The GAIN versus Frequency plot is shown by default in the bottom half of the window. Select the ´PHASE´ tab in order to switch to the overall PHASE response versus Frequency plot.

Changing the values of the enabled resistors and capacitors accordingly changes the overall frequency response of the system and instantly updates the GAIN and PHASE plots.

Figure 6 Frequency Response Section



Dragging the -3dB cursors associated with each filter will also change the associated R (or C) values to make the resulting cut-off frequency match the cursor´s. Tick box ‘Cursor R (or C) Anchor’ fixes one of the two values (R or C) while the other (C or R) changes to accommodate the cut-off frequency set by the cursor being dragged

The vertical units can be changed from dB to V/V and from radian to degree using the available sliding switches.

The maximum frequency shown on the X axes of the plots can be changed with the ´Highest Freq (Hz)´ control. The X axes can be switched between logarithmic and linear mode with the ´Freq axe´ control.

MISCELLANEOUS FEATURES

STANDARISE R&C VALUES: The selected passive values can be tuned back to standard values by pressing the button labeled ´Make R&C values standard´ on the right side of the window. Please note a resistor will be tuned to its closest value in the E192 series while a capacitor will be to the closest value in the E24 series.

SAVE CURRENT CONFIGURATION: The current enabled filter configuration and passive values can be saved for later comparison by pressing the SAVE buttons shown in red. Up to two configurations can be saved (SAVE-1 and SAVE-2). Please note these values will be erased on program exit.

Figure 7 Miscellaneous Features

LOAD previously saved CONFIGURATION: Once any one of the two SAVE buttons just mentioned has been exercised a corresponding LOAD button will be made visible for the user to load the previously saved configuration.

LOAD DEFAULT VALUES: Two sets of filters are proposed by default. They can be loaded at any time by pressing the ´MONITOR (or SPORTS) BANDWIDTH´ buttons. Both sets configure a second order filter both at the High and Low pass sections. Monitor bandwidth sets the corner frequencies at 0.34Hz and 37Hz. Sports bandwidth sets a narrower passing band where the cut-off frequencies can be found at 7Hz and 25Hz.

SAVE to TEXT FILE: Both the current passive values and the overall frequency response can be saved to a text file. This information cannot be loaded back to this simulator. It is intended for later reference and higher quality printing.

EXIT: The EXIT button shuts down the software tool.