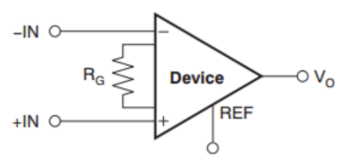
Analog Front End (ECG Amp)

The Analog front end of this system is comprised of a differential amplifier (**INA826**) followed by a second order low pass filter (Implemented using **OPA4171**). The design of these components is shown below:

Head Stage

The head stage was implemented using the INA826 instrumentation amplifier. The primary reason for choosing this device was the fact that the common mode signal was easily accessible and will be needed in the calculation ECG signals later in the design.



Assuming a signal with a maximum value of 1mV, a gain of 100 the needed R_G resistor can be calculated using the supplied equation:

$$G = 1 + \left(\frac{49.4k\Omega}{R_G}\right) \rightarrow R_G = \frac{49.4k\Omega}{100 - 1} = 498.99\Omega \sim \mathbf{500\Omega}$$

At this gain the signal will be linear up to 60 kHz which gives more than adequate room for the signal to pass undistorted.

Low Pass Filter

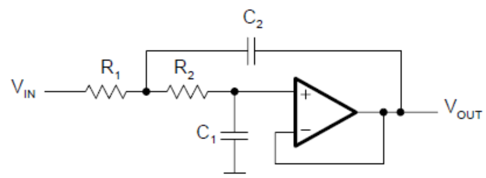
When designing the anti-aliasing filter the following parameters where chosen:

$f_c = 1500Hz$ (Nyquist criteria of ADC requires $f_c \max < 2kHz$)

Butterworth Coefficients ($a_1 = \sqrt{2}\,, b_1 = 1$).

$C_1 = 4.7nF\;, C_2 = 9.4nF$

Using the Sallen and Key topology shown below, other values could be picked as follows using the design process outlined in *Active Filter Design* by Texas Instruments.



The first step in this process is the validation of capacitor vales:

$$C_2 \geq C_1 \frac{4b_1}{a_1^2}$$

$$9.4\,x10^{-9} \geq (4.7\,x10^{-9})\frac{4(1)}{(1.4142)^2} \rightarrow 9.4\,x10^{-9} \geq (4.7\,x10^{-9})\,2 \rightarrow \mathbf{9.4\,x10^{-9} \geq 9.4\,x10^{-9}} \surd$$

With the capacitors validated, the resistors for this topology can be found by solving the following equation:

$$R_1, R_2 = \frac{a_1 C_2 \mp \sqrt{a_1^2 C_2^2 - 4b_1 C_1 C_2}}{4\pi f_c C_1 C_2}$$

With all parameters known, the resistor values were found as follows:

$$R_1 = \frac{(1.4142)(9.4x10^{-9}) - \sqrt{(1.4142)^2(9.4x10^{-9})^2 - 4(1)(4.7\,x10^{-9})(9.4\,x10^{-9})}}{4\pi(1500)(4.7\,x10^{-9})(9.4\,x10^{-9})} = 15.963\,k\Omega$$

$$R_2 = \frac{(1.4142)(9.4x10^{-9}) + \sqrt{(1.4142)^2(9.4x10^{-9})^2 - 4(1)(4.7\,x10^{-9})(9.4\,x10^{-9})}}{4\pi(1500)(4.7\,x10^{-9})(9.4\,x10^{-9})} = 15.963\,k\Omega$$

The cut-off frequency needs to be set for anti-aliasing purposes and as such does not need to be exact. The ADCs used in this application have a lower sampling limit of 4 kHz implying a maximal cut off frequency of 2 kHz to satisfy Nyquist criteria.

Choosing $\boldsymbol{R_1 = R_2 = 15k\Omega}$ results in a cut-off frequency of roughly 1.6 kHz which is still acceptable.