Op Amp Circuits Practice 2

1. For the circuit below determine an optimum value for $R_{\text{offset}}$ to minimize offset and drift. Determine the output offset voltage if $V_{os}=3\text{mV}$ and $I_{os}=100\text{nA}$. $R_i=2k$, $R_f=40k$, $R_{\text{load}}=20k$.

2. For the circuit below, determine the approximate input noise voltage and output noise voltage. If the nominal signal output is 1 $\text{lt RMS}$, determine the signal-to-noise ratio in dB. $R_i=1k$, $R_f=10k$, $R_l=20k$, $F_{\text{unity}}=1.5\text{MHz}$. Bandwidths: Curve A = 20Hz-150kHz, curve B = 50Hz-50kHz, curve C = 100Hz-10kHz
3. Determine the input impedance and gain of each channel of the circuit below. \( R_1 = 10 \text{k}\), \( R_2 = 2 \text{k}\), \( R_3 = 5 \text{k}\), \( R_f = 20 \text{k}\).

4. Design a unity gain 5 kHz 4\(^{th}\) order Butterworth low pass filter.
1. \[ \text{Roffset} = \frac{R_i}{R_f} = \frac{2k}{40k} = 1.9k \]
\[ \text{Anoise} = 1 + \frac{R_f}{R_i} = 1 + 40k/2k = 21 \]
\[ \text{Vout-offset} = V_{os}*\text{An} + I_{os}*R_f \]
\[ \text{Vout-offset} = 3\text{mv}*21 + 100\text{nA}*40k = 63\text{mV} + 4\text{mV} = 67\text{mV} \]

2. \[ \text{Anoise} = 1 + \frac{R_f}{R_i} = 1 + \frac{10k}{1k} = 11 \]
\[ f_2 = \frac{f_{\text{unity}}}{\text{Anoise}} = \frac{1.5\text{MHz}}{11} = 136kHz \]
\[ R_s \text{ is } R_i \text{ for this circuit, } 1k. \]
\[ \text{Curve A is the closest to the desired 136kHz (this curve would be just below A so you might wish to imagine this curve). The corresponding input noise would be around 6.5uV.} \]
\[ \text{Vout-noise} = \text{Anoise*Vin-noise} = 11*6.5uV = 71.5uV \]
\[ \text{S/N} = \frac{\text{Vout}}{\text{Vout-noise}} = \frac{1V}{71.5uV} = 13.99E3 = 82.9 \text{ dB} \]

3. The input impedance of each channel is set by the associated input resistor. The gain of each channel is set by \( \frac{R_f}{\text{inputR}} \). Thus,
\[ \text{Channel 1: } A = -\frac{20k}{10k} = -2, \text{ Zin} = 10k \]
\[ \text{Channel 2: } A = -\frac{20k}{2k} = -10, \text{ Zin} = 2k \]
\[ \text{Channel 3: } A = -\frac{20k}{5k} = -4, \text{ Zin} = 5k \]

More channels may be added in a similar fashion. Non-inverting summers are also possible. One way is to simply add inverting stages to the inputs (i.e., invert the inversion). Gain is best adjusted via separate pots (such as an output volume control) rather than replacing \( R_f \) or the input resistors directly with pots.

4. For Butterworth, \( f_c = f_{3\text{dB}} \) (i.e., 5kHz). 4\text{th} order unity gain LP will require two second order sections of the type found on page 433 (Fig 11.14). From the table on page 445, the damping factor for the first section is 1.848, and for the second section .765. Therefore for the first section, \( C_1=1.082F \) and \( C_2=.924F \). For the second section, \( C_1=2.614F \) and \( C_2=.3825F \). The frequency scaling factor is \( 2\pi5000 = 31,416 \). To raise \( f \), decrease \( R \) or \( C \). Therefore, \( C_1=34.4uF, C_2=29.4uF \) for the first section and for the second, \( C_1=83.2uF \) and \( C_2=12.2uF \). For practical impedances, scale \( R \) up and \( C \) down by the same factor. 10k would be convenient and reasonable. Therefore, all \( R_s \) are 10k (except the feedback resistors which would be 20k, if used). The caps are \( C_1=3.44nF, C_2=2.94nF \) and for stage two \( C_1=8.32nF \) and \( C_2=1.22nF \). Of course, in order to use standard values, the \( R \) and \( C \) values may need to be adjusted slightly (\( R \) and \( C \) are adjusted by inverse factors, i.e. if \( C \) is increased by 10% then \( R \) is decreased by 10%).