Problem 1.
The specifications for a switched-capacitor sigma-delta modulator are given as follows:

a) Signal bandwidth of interest 80kHz. Input signal however, has the following spectrum:

\[ |H(f)| \]

\[
\begin{array}{c|c}
0dB & -50dB \\
0.2MHz & 0.5MHz \\
\end{array}
\]

b) Required minimum SNR 90dB - Input signal range (Δ) is 2V

c) The settling of the opamp designed is slew limited (ignore settling time) and the
slew rate is defined by Iy/Cintg

d) The first integrator power consumption is estimated as 2VDDxIy where VDD=2.5V

e) The following integrators consume half the power compared to the 1st integrators
and the power dissipation for the comparator and the rest of the associated
circuitry is about 10% of the power dissipated in the 1st integrator

f) An anti-aliasing filter is required in front of the converter. The out-of-band aliased
signal should be kept <-95dB with respect to inband signal.

The goal is a preliminary study to choose between a 2nd order sigma-delta modulator
architecture and a cascaded (2-1) configuration. The choice is based on minimum total
power dissipated by the converter and the required prefilter. Assume that a first order
filter can be built with a simple passive RC with no power dissipation and the power
dissipation of filters with order larger than one is give by \( P = (n-1)(2Iy) VDD \) where \( n \) is
the filter order.

In your over-sampling ratio computations, for ease of the decimator filter design, choose
\( M \), the oversampling ratio, to be \( 2^m \) with \( m \) an integer number. Ignore noise contributed
by the opamp and make sure that all other noise sources added to the quantization noise are -90dB lower compared to the converter full-scale signal. Also, note that it is desirable to have the in-band thermal noise exceed in-band quantization noise for dithering purposes.

Submit your computations and the estimated power dissipation for the two architectures. Use the table below to show the final results:

<table>
<thead>
<tr>
<th></th>
<th>2nd Order ΣΔ Modulator</th>
<th>Cascaded (2-1) ΣΔ Modulator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oversampling ratio (M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-band quantization noise power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-band thermal noise power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st integrator Cintg value</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1st integrator power dissipation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total integrator + comparator power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anti-aliasing filter order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anti-aliasing filter power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Power Dissipation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Problem 2.**

Compute the required sampling frequency for an oversampled ADC converter built to handle in-band signal ranging from DC to 20kHz with 18-bit resolution (HiFi audio applications). Consider these three cases:

a) No noise-shaping, just pure oversampling, 1-bit quantization

b) 1st order noise shaping ΣΔ (1-bit quantizer)

c) 2nd order noise shaping ΣΔ (1-bit quantizer)

What are the reasons you would choose option c) for the implementation?