P1 $V_{LSB} = \frac{5}{2^4} = 0.3125V$

$V_{out} = \left\lfloor \frac{0.33}{V_{LSB}} \right\rfloor \cdot V_{LSB} = 0.3125V$

$\therefore$ error $= 0.33 - 0.3125 = 0.0175V$

P2 $f_{max} \le \frac{f_s}{2} = \frac{10kHz}{2} \doteq 5kHz$

P3 $f_s = 2K$ $f_{in_1} = 100Hz$ (input: $2.5 + 1.5\sin(200\pi t + \theta_1) + 0.25\sin(6400\pi t + \theta_2)$

$f_{in_2} = 3.2kHz$

aliasing: $\frac{k-1}{2} f_s < f_{in_2} < \frac{k}{2} f_s \Rightarrow k = 4$

$\Rightarrow f_{aliased} = 800Hz.$

Output: $2.5 + 1.5\sin(200\pi t + \theta_1) + 0.25\sin(1600\pi t + \theta_2')$

P4 $H(s) = \left(\frac{2\pi \cdot 3k}{s + 2\pi \cdot 3k}\right)^3$ input: $2.5 + 1.5\sin(200\pi t + \theta_1) + 0.25\sin(6400\pi t + \theta_2)$

$A_1 = |H(j\omega)|_{\omega = 200\pi} = 0.9983$

$A_2 = |H(j\omega)|_{\omega = 6400\pi} = 0.3199$

output: $2.5 + 1.5 \cdot A_1 \sin(200\pi t + \theta_1 + \alpha) + 0.25 \cdot A_2 \sin(6400\pi + \theta_2 + \beta$

$\alpha = \angle H(j\omega)_{\omega = 200\pi} = -0.1$ rads/s

$\beta = \angle H(j\omega)_{\omega = 6400\pi} = -2.4529$ rads/s

P5 $f_{max} = \max(1K, 2.5k, 4k) = 4k$

$\therefore f_s \geq f_{max} \cdot 2 = 8kHz$

P6 The quantization noise is $\frac{X_{LSB}}{\sqrt{12}}$ RMS

The RMS value of the signal is $\frac{100mV}{\sqrt{2}}$

$$\therefore SNR = \frac{\frac{100mV}{\sqrt{2}}}{\frac{X_{LSB}}{\sqrt{12}}} = \frac{\sqrt{6} \cdot 100mV}{5} \cdot 2^{12} = 200.6$$

or $SNR = 46\,dB$

P7 The quantization noise is $\frac{X_{LSB}}{\sqrt{12}} = 0.352mV$

The RMS value of the signal is $\frac{0.75}{\sqrt{2}} = 0.53V$

$$\therefore SNR = \frac{0.53V}{0.352mV} = 1506.4 \quad \text{or } SNR = 63.56\,dB$$

$$\therefore ENOB = \frac{SNR_{dB} - 1.76}{6.02} = 10.27 \quad \text{hence } 11 \text{ bits}$$

P8 The quantization noise is $\frac{X_{LSB}}{\sqrt{12}} = 1.410mV$

The RMS value of the signal is $\frac{4}{2\sqrt{2}} = 1.414V$

device noise:

$$SNR = \frac{1.414V}{21.5mV} = 65.78 \quad \text{or } SNR = 36.36\,dB$$

$$ENOB = \frac{36.36 - 1.76}{6.02} = 5.75 \quad \text{hence } 6 \text{ bits}$$

only quantization noise:

$$SNR = \frac{1.414V}{1.410mV} = 1003 \quad \text{or } SNR = 60.03\,dB$$

$ENOB = 9.68$ hence 10 bits

4 bits loss due to device noise