FURTHER QUESTIONS: IIR Filter

1. Distinguish between direct, canonical and parallel structures for the implementation of digital filters of the form:

$$y(n) = \sum_{p=0}^{N-1} a_p x(n-p) + \sum_{q=1}^{M} b_q y(n-q)$$

where $x(n)$ and $y(n)$ are input and output samples respectively at time n, a_i and b_i are filter coefficients, N and M are integers ≥1. Describe the advantages and disadvantages of each structure.

2. Discuss the advantages and disadvantages of Infinite Impulse Response (IIR) filters in relation to Finite Impulse Response (FIR) filters.

3. Define Bilinear Transform and discuss the effects of this transform on the frequency response of the IIR digital filter.

4. Design a digital filter equivalent of a 2nd order Butterworth low-pass filter with a cut-off frequency $f_c = 25\text{Hz}$ and a sampling frequency $f_s = 250$ samples/sec. Derive the finite difference equation and draw the realisation structure of the filter. Given that the analogue prototype of the frequency-domain transfer function $H(s)$ for a Butterworth filter is:

$$H(s) = \frac{1}{s^2 + \sqrt{2} \cdot s + 1}$$