<u>EGB348 Electronics</u>
<u>Tutorial 5 – Op Amps and Filters</u>

Q1. First Order Low Pass Filter

Design a first order low pass filter to have a gain of 5 in the passband, and with a 3dB cutoff of fp=1kHz, as shown in Figure 1.

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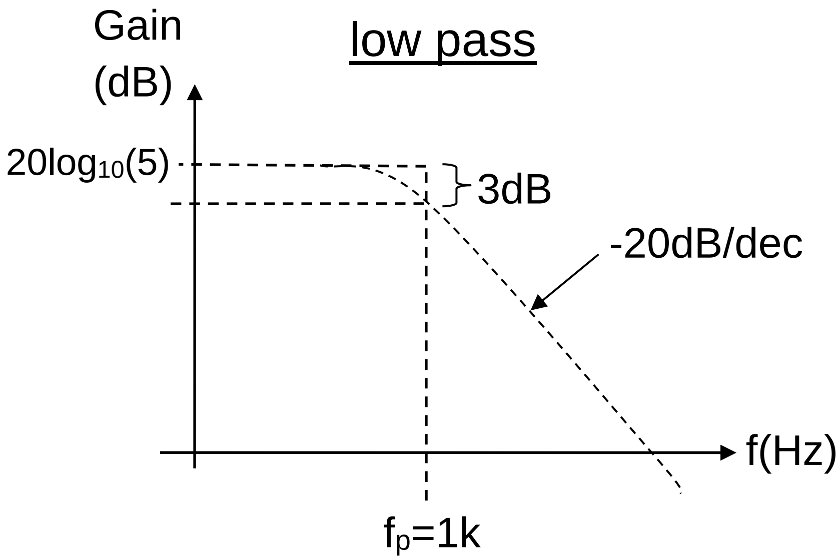

Figure 1: Filter for Question 1.

(a) Draw a first order Voltage Controlled Voltage Source (VCVS) style of circuit that could be used to implement this filter.

(b) Using C_1 = 1F, and a prototype Ωp of 1 rad/s, derive prototype values for the circuit components.

(c) If a capacitor value of 10nF is to be used, determine frequency and magnitude scale factors (K_f and K_m), and determine scaled values of all circuit components.

Q2. Filter Order

The specifications for a low pass filter are:

- maximum attenuation in the passband (Amax) = 1dB.
- minimum attenuation in the stopband (Amin) = 35dB.
- passband edge frequency (fp) = 500 Hz
- stopband edge frequency (fs) = 1.5 kHz

(a) What order of Butterworth filter is required to meet this specification?

(b) What order of Chebyshev filter is required to meet this specification?

Q3. Fifth Order Low Pass Filter

A circuit for a fifth order low pass filter is shown in Figure 2.

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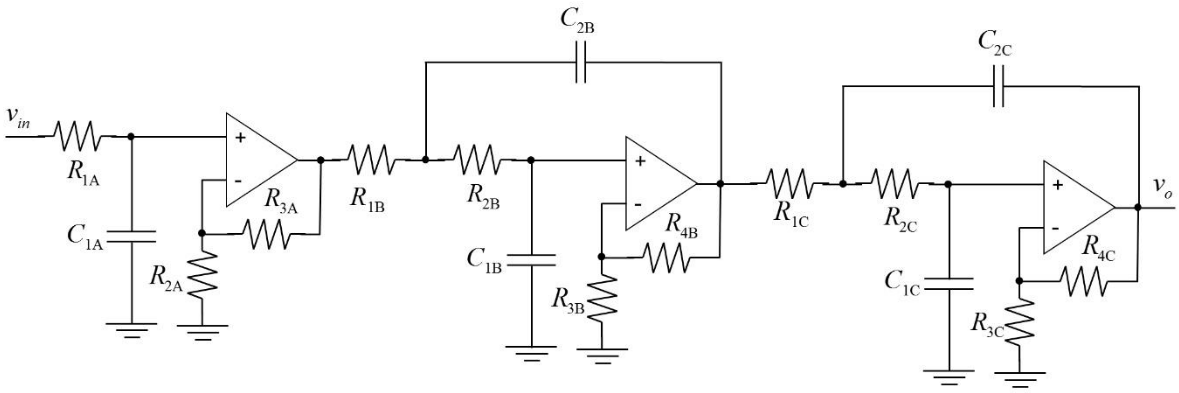

Figure 2: Fifth order low pass circuit.

The filter is to have an overall gain of G = 6 in the passband, with the gain of each stage set to K_1 =2, K_2 = 3 and K_3 = 1 respectively.

(a) Using the attenuation specification from Q2, derive the Butterworth transfer function to realise this specification, normalised to have a passband cutoff frequency of 1 rad/s.

(b) Using C = 1F for all capacitors, derive prototype values for the circuit components.

(c) If a value of 22nF is to be used for capacitor C_{1A}, determine frequency and magnitude scale factors (K_f and K_m), and determine scaled values of all circuit components.

<u>Q4. Fourth Order Low Pass Filter</u>

A circuit for a fourth order low pass filter is shown in Figure 3.

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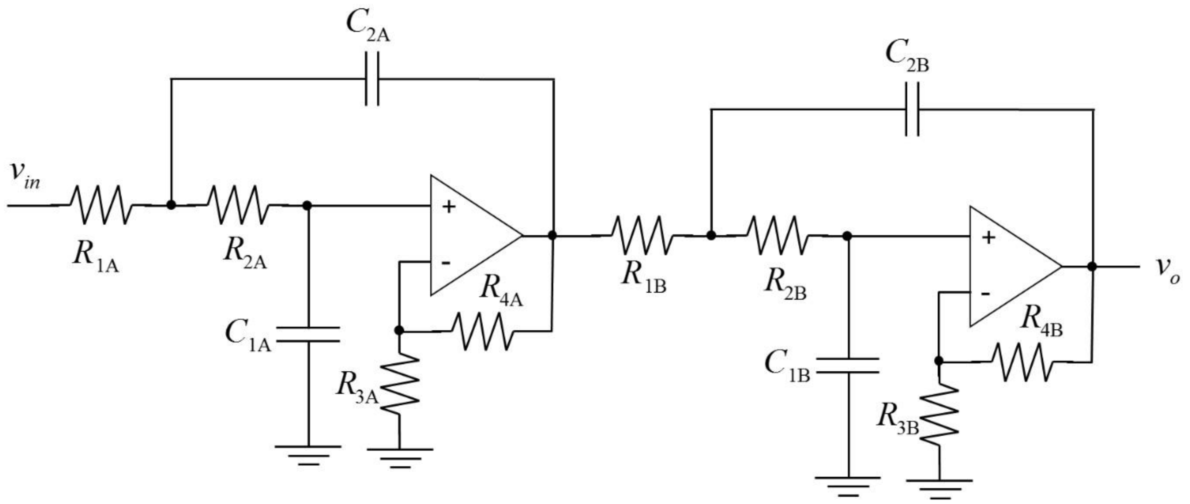

Figure 3: Fourth order low pass circuit.

The filter is to have an overall gain of G = 6 in the passband.

(a) Using the attenuation specification from Q2, find the Chebyshev transfer function to realise this specification, normalised to have a passband cutoff frequency of 1 rad/s.

(b) Using C = 1F for all capacitors, derive prototype values for the circuit components.

(c) If a value of 22nF is to be used for all capacitors in the circuit, determine frequency and magnitude scale factors (K_f and K_m), and determine scaled values of all circuit components.

Q5. Filter Order – High Pass

The specifications for a high pass filter are:

- maximum attenuation in the passband (Amax) = 0.5dB.
- minimum attenuation in the stopband (Amin) = 30dB.
- passband edge frequency (fp) = 2 kHz
- stopband edge frequency (fs) = 500 Hz

(a) Convert the high pass specification to an equivalent low pass specification.

(b) What order of Butterworth filter is required to meet this specification?

Q6. Fourth Order High Pass Filter

A circuit for a fourth order high pass filter is shown in Figure 4.

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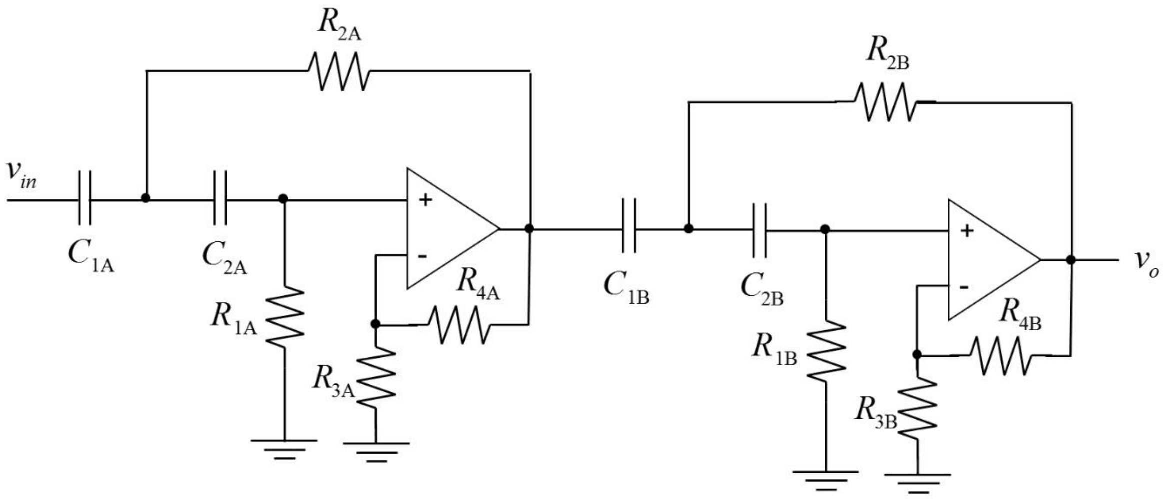

Figure 4: Fourth order high pass circuit.

The filter is to have an overall gain of G = 6 in the passband, with the gain of each stage set to $K_1 = 2$ and $K_2 = 3$ respectively.

(a) Using the attenuation specification from Q5, derive the Butterworth transfer function to realise this specification, normalised to have a passband cutoff frequency of 1 rad/s.

(b) Using C = 1F for all capacitors, derive prototype values for the circuit components.

(c) If a value of 22nF is to be used for all capacitors in the circuit, determine frequency and magnitude scale factors (K_f and K_m), and determine scaled values of all circuit components.

Q7. Tow-Tomas Biquad

The circuit for the Tow-Tomas biquad is shown in Figure 5.

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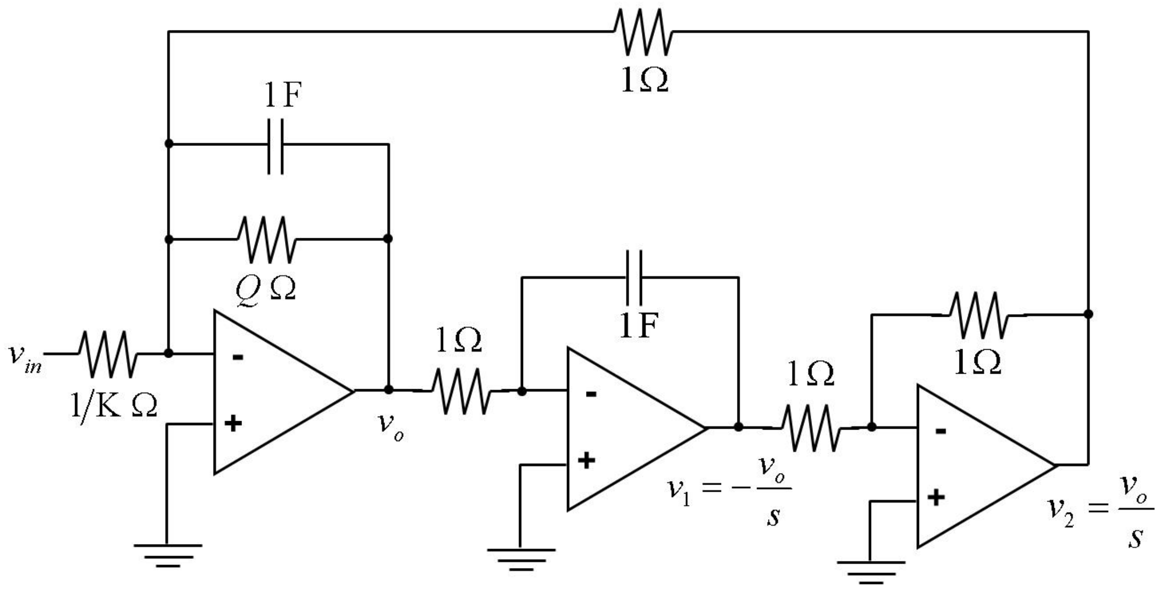

Figure 5: Tow-Tomas Biquad.

We wish to use this circuit to implement a second order Butterworth low pass filter with a gain of 2. The low pass output will be given by:

$$\frac{v_2(s)}{v_{in}(s)} = \frac{2}{s^2 + \sqrt{2}s + 1}$$

(a) Find prototype values for the circuit components.

(b) If a value of 0.1μF is to be used for all capacitors in the circuit, and 3dB cutoff freq = 1kHz, determine frequency and magnitude scale factors (K_f and K_m), and determine scaled values of all circuit components.

Q8. Filter Order – Band Pass

The specifications for a band pass filter are:

- maximum attenuation in the passband (Amax) = 3dB.
- minimum attenuation in the stopband (Amin) = 20dB.
- stopband edge frequency1 (fs1) = 100 Hz
- passband edge frequency1 (fp1) = 1 kHz
- passband edge frequency2 (fp2) = 2 kHz
- stopband edge frequency2 (fs2) = 20 kHz

(a) Convert the band pass specification to an equivalent low pass specification.

(b) What order of Butterworth filter is required to meet this specification?

Q9. Second Order Band Pass Filter – extension question

A circuit for a second order band pass filter is shown in Figure 6.

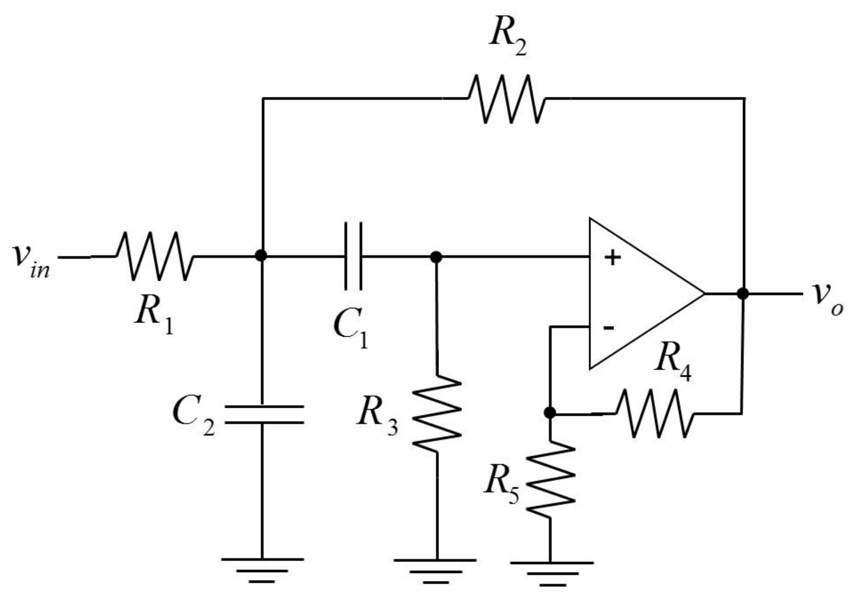

Figure 6: Second order band pass circuit.

The filter is to have an overall gain of K = 2.

(a) Using the attenuation specification from Q8, derive the Butterworth transfer function to realise this specification, normalised to have $\omega_0 = 1$ rad/s.

(b) Using $C_1 = C_2 = 1$F, derive prototype values for the circuit components.

(c) If a value of 0.1µF is to be used for all capacitors in the circuit, determine frequency and magnitude scale factors (K_f and K_m), and determine scaled values of all circuit components.