

NANYANG TECHNOLOGICAL UNIVERSITY  
SCHOOL OF ELECTRICAL & ELECTRONIC ENGINEERING  
EE4341/EE6341 ADVANCED ANALOG CIRCUITS  
TUTORIAL 9

1. Based on the bi-quadratic filter shown in Fig. 1, design the following active filters with other necessary circuits:
  - (a) Second-order low-pass filter with specifications:  $Q = \sqrt{2}$  and attenuation = 18.36 dB at 60 kHz. 2000 pF capacitors are preferred in the design. Draw the final circuit and indicate the values of all the resistors and capacitors.
  - (b) Second-order band-pass filter with specifications:  $-3$  dB bandwidth of 0.95 kHz and centre frequency of 1.9 kHz. 1000 pF capacitors are preferred in the design. Determine its upper and lower cut-off frequencies. Draw the final circuit and indicate the values of all the resistors and capacitors.

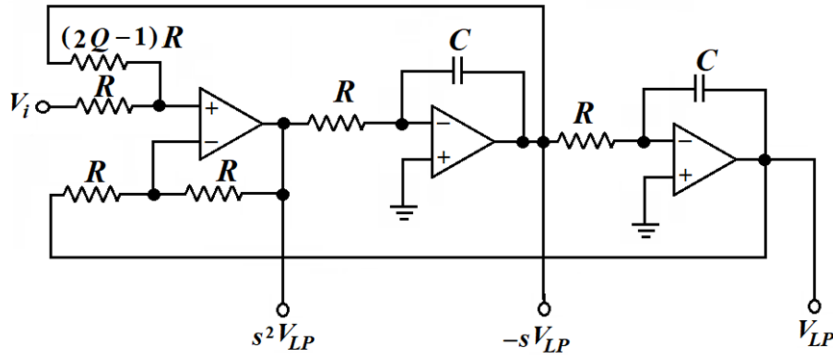


Figure 1

2. Design a low-pass Butterworth filter that has a  $-3$  dB cut-off frequency of 2 kHz and at least 43 dB attenuation at 7 kHz. 10 k $\Omega$  resistors are preferred in the design. Implement the circuit using Sallen-Key second-order low-pass filters and other necessary circuits. The transfer function of the Butterworth filter is given by:

$$T(s) = \frac{1}{B(s)}, \text{ where } B(s) \text{ for } n^{\text{th}} \text{ order Butterworth filter is given in Table 1.}$$

Table 1

$n$	Factors of $B(s)$
1	$(s + 1)$
2	$(s^2 + 1.4142s + 1)$
3	$(s + 1)(s^2 + s + 1)$
4	$(s^2 + 0.7654s + 1)(s^2 + 1.8478s + 1)$
5	$(s + 1)(s^2 + 0.6180s + 1)(s^2 + 1.6180s + 1)$
6	$(s^2 + 0.5176s + 1)(s^2 + 1.4142s + 1)(s^2 + 1.9318s + 1)$