# Analog/IC Filter Design (ELEC 441/6081)
## Mid-Term Test#1 (Winter 2011-2012)

Electrical and Computer Engineering Department
Concordia University
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**NOTE to UG students:** Answer ONLY THREE questions. If you answer *more than three* questions, the last answer will be discarded (i.e., NOT marked).

**Student id#**

**Time:** 60 minutes

**Q.1**: Figure 1 shows a filter circuit with a voltage amplifier (VCVS) of gain K. Derive the expression for the voltage transfer function (VTF) $V_2(s)/V_1(s)$.

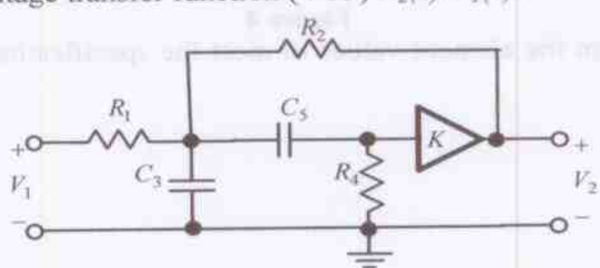


**Figure 1**

**Q.2**: Determine the transfer function of a *maximally flat* low-pass filter with a loss of 1dB at the pass-band edge frequency $f_c$ =10 kHz, and an attenuation of at least 25 dB at $f_a$= 40 kHz.

**Q.3**: You are required to design a BPF with the pass-band extending from $\omega=10^5$ rad/sec to $\omega=4\times10^5$ rad/sec. The filter has *equal ripple* characteristic in the pass-band with peak-to-peak value not exceeding 1 dB. At $\omega=15.263\times10^5$ rad/sec, the response must be at least 60 dB down relative to the pass-band.

(a) Synthesize the *normalized low-pass filter function* associated with the intended band-pass filter.

(b) Show the L, C ladder realization of the *normalized low-pass filter* terminated in a 1 ohm resistance and fed from an *ideal* voltage source.

**Q.4:** Consider the band-pass filter network of figure 4. It combines both positive and negative feed-back around an ideal OA. The voltage transfer function is given by:

$$\frac{V_2}{V_1}=\frac{-s(K+1)/(R_1C_2)}{s^2+s[1/(R_2C_2)+1/(R_2C_1)-K/(R_1C_2)]+1/(R_1R_2C_1C_2)}, \text{ with } K=R_A/R_B.$$

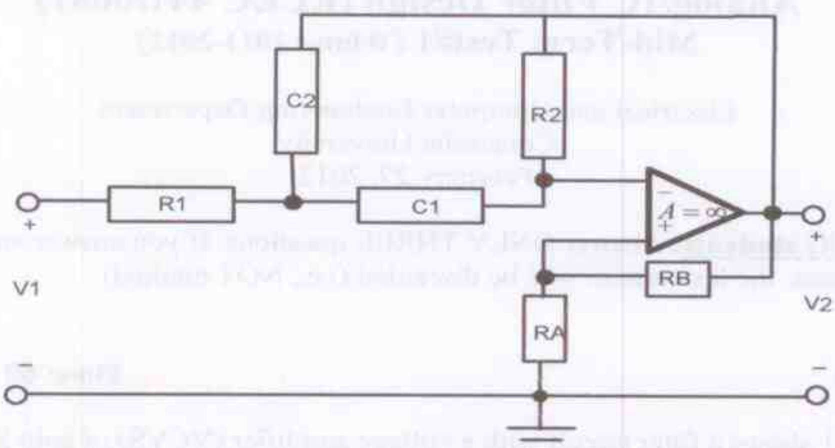


**Figure 4**

Assuming $K=1$, design the element values to meet the specifications: $f_p$=10 kHz, $Q_p$ =5 and C=0.1 μF each.

**Filter Function Tables**

(next page)

## Filter Function Tables

**A.1:** Coefficients of denominator polynomial, in the form $s^n + a_1 s^{n-1} + a_2 s^{n-2} + ... + a_{n-2}s^2 + a_{n-1}s + 1$, for Butterworth filter function of order $n$, with pass-band from 0 to 1 rad/sec[+].

| $n$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ |
|---|---|---|---|---|---|---|
| 2 | 1.4142 | | | | | |
| 3 | 2.0000 | 2.0000 | | | | |
| 4 | 2.6131 | 3.4142 | 2.6131 | | | |
| 5 | 3.2361 | 5.2361 | 5.2361 | 3.2361 | | |
| 6 | 3.8637 | 7.4641 | 9.1416 | 7.4641 | 3.8637 | |
| 7 | 4.4940 | 10.0978 | 14.5918 | 14.5918 | 10.0978 | 4.4940 |

**A.2:** Coefficients of denominator polynomial, in the form $s^n + a_1 s^{n-1} + a_2 s^{n-2} + ... + a_{n-2}s^2 + a_{n-1}s + a_n$, for Chebyshev filter function of order $n$, with pass-band from 0 to 1 rad/sec[+].

| Pass-band ripple $A_p$ | $n$ | $a_1$ | $a_2$ | $a_3$ | $a_4$ | $a_5$ | $a_6$ |
|---|---|---|---|---|---|---|---|
| 0.5 dB $\varepsilon$=0.3493 | 1 | 2.863 | | | | | |
| | 2 | 1.425 | 1.516 | | | | |
| | 3 | 1.253 | 1.535 | 0.716 | | | |
| | 4 | 1.197 | 1.717 | 1.025 | 0.379 | | |
| | 5 | 1.1725 | 1.9374 | 1.3096 | 0.7525 | 0.1789 | |
| | 6 | 1.1592 | 2.1718 | 1.5898 | 1.1719 | 0.4324 | 0.0948 |
| 1.0 dB $\varepsilon$=0.5089 | 1 | 1.965 | | | | | |
| | 2 | 1.098 | 1.103 | | | | |
| | 3 | 0.988 | 1.238 | 0.491 | | | |
| | 4 | 0.953 | 1.454 | 0.743 | 0.276 | | |
| | 5 | 0.9368 | 1.6888 | 0.9744 | 0.5805 | 0.1228 | |
| | 6 | 0.9282 | 1.9308 | 1.2021 | 0.9393 | 0.3071 | 0.0689 |
| 2.0 dB $\varepsilon$=0.7648 | 1 | 1.308 | | | | | |
| | 2 | 0.804 | 0.637 | | | | |
| | 3 | 0.738 | 1.022 | 0.327 | | | |
| | 4 | 0.716 | 1.256 | 0.517 | 0.206 | | |
| | 5 | 0.7065 | 1.4995 | 0.6935 | 0.4593 | 0.0817 | |
| | 6 | 0.7012 | 1.7459 | 0.8670 | 0.7715 | 0.2103 | 0.0514 |

[+] R. Schaumann et al, "Design of Analog Filters- Passive, Active RC, and Switched Capacitor", Prentice-Hall Inc., © 1990