University of Michigan
EECS 311: Electronic Circuits
Fall 2009

PROBLEM SET 2

Issued 9/16/2009
Due in Lecture 9/23/2009

For background information, refer to the Sallen and Key paper on the website:

http://www.eecs.umich.edu/courses/eecs311/f09/handouts/1955_sallen_key.pdf

P2.1 Refer to the S&K paper, and the circuit in Fig. 7 (top-right of page 77) to answer the following questions.

a) What is the form of the transfer function of this circuit as given in the paper?

b) What type of filter is this: high-pass, low-pass, band-pass, or band-stop?

c) What is the equation given in the paper for parameter h?

d) What is the relationship between parameters T_1 and T_2 given in the paper?

e) Given you would like to specify the ratio of capacitors $\gamma = C_2/C_1$ and the parameter T_1, what formula group should you use to solve for d? What is the equation given for d in this formula group, and what is x in this equation?

f) Should you instead wish to solve for K in terms of d, what is the equation for K assuming the same formula group as in part e)?

P2.2 Refer to the S&K paper, and the circuit topology in Fig. 1 on page 76. Each of the following transfer functions satisfies the normalized form given by this circuit:

$$H(s) = \frac{h}{s^2 + ds + 1}$$

For each part below, find the values of ω_n, h and d for the normalized transfer function. Then, assuming $C_1 = C_2$, find the normalized values of T_1 and T_2 required to synthesize each transfer function. Finally, assuming $C_1{}' = C_2{}' = 10nF$, calculate the un-normalized values of $R_1{}'$ and $R_2{}'$ and K for the circuit.

a) $H(s) = \frac{1}{(1+s/10^2)(1+s/10^4)}$

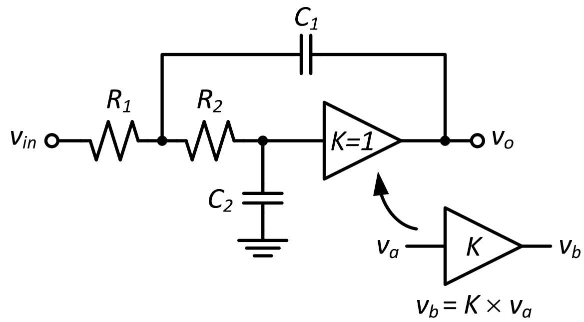
b) $H(s) = \frac{10}{s^2/10^{10}+s/10^6+1}$

c) $H(s) = \frac{1}{\left(1+\frac{s}{100+j100}\right)\left(1+\frac{s}{100-j100}\right)}$

d) $H(s) = \frac{10^3}{10^4+200s+s^2}$

P2.3 Use the circuit below to answer the following questions. Assume the amplifier is ideal (zero input current, infinite bandwidth) with a gain of $K = 1$.

a) Find the transfer function $H(s) = v_o/v_{in}$ of the following circuit.



b) What type of filter is this: high-pass, low-pass, band-pass, or band-stop?

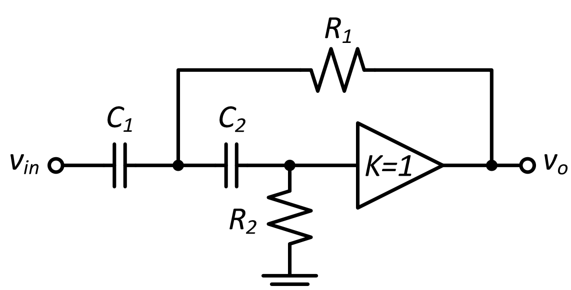
c) Assume $R_1 = R_2$, and $C_1 = 100C_2$, find a numerical value for Q of the filter. What is the peak gain of the filter?

$$H(s) = \frac{1}{1 + s\dfrac{1}{\omega_n Q} + s^2\dfrac{1}{\omega_n^2}}$$

d) Refer now to the S&K paper, and the circuit in Fig. 1 on page 76. Assuming the same R and C ratios given in part c) of this problem, use the table to calculate the value of parameter d. What is the relationship of d to Q from part c)?

P2.4 Use the circuit below to answer the following questions. Assume the amplifier is ideal (zero input current, infinite bandwidth) with a gain of $K = 1$.

a) Find the transfer function $H(s) = v_o/v_{in}$ of the following circuit.



b) What type of filter is this: high-pass, low-pass, band-pass, or band-stop?

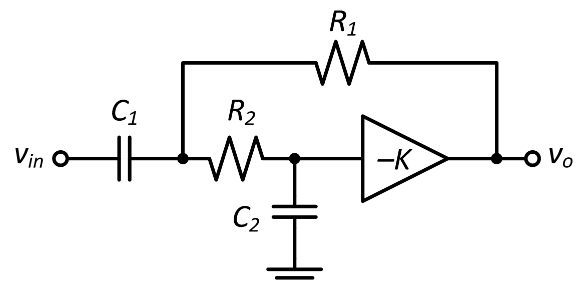
c) Refer now to the S&K paper, and the circuit in Fig. 3 on page 76. Calculate the value of parameter d when $R_1 = R_2$ and $C_1 = C_2$.

P2.5 Design a bandpass audio filter having a zero at the origin, and two poles at frequencies of 100Hz and 10kHz so that only the audible frequencies are passed through the filter. The filter can have arbitrary midband gain h. The desired transfer function is as follows.

$$H(s) = \frac{hs}{\left(1 + \frac{s}{2\pi 100Hz}\right)\left(1 + \frac{s}{2\pi 10kHz}\right)}$$

a) Calculate ω_n for this filter, and then find the normalized value of d.

b) Use Sallen and Key filter topology given below (page 77 of S&K paper) to realize this filter. Assume $C_1 = C_2$, and determine the values of T_1, T_2, $\rho = R_1/R_2$, and K to achieve the desired value for d. Multiple solutions exist, therefore you will have to make reasonable choices for your solution.



c) Assume $C_1 = C_2 = 10nF$, calculate the un-normalized values of R_1 and R_2 for your filter.

d) Derive the transfer function for the circuit in part b).

e) Plug in your component values to the TF found in part d), and plot the frequency response of your filter with Matlab. Turn in this plot.