**TO THE STUDENT: ALWAYS CHECK THE ERRATA on the web.**

## RAY'S READING SUGGESTIONS FOR BROADENING YOUR EDUCATIONAL FOUNDATION

### ON LEADERSHIP:

*The Leadership Pill* by Ken Blanchard and Marc Muchnick (Short and sweet—laying out a triple bottom line for achievement while setting forth the humane and affirming road to achieve success communally—not individually. Success is a communal effort.)

*The John Deere Way* by David Magee (Did you know that during the depression era, The John Deere Company carried the loans of farmers and dealers often forgiving interest.

*Team of Rivals* by Doris Kearns Goodwin (Challenging and long. Abraham Lincoln took his competitors, a diverse group of over achievers and political office seekers, and using his wit, story telling ability, good humor, and love of neighbor, glued them together into his presidential cabinet, demonstrating the qualities of a true leader.)

*Squirrel Inc*. by Stephen Denning (A fascinating fable about a company resisting a plan for moving from a nut burying technology to a not storing technology.)

### ON TEACHING

*Teacher Man: a Memoir* by Frank McCourt (A great story about teaching in the NYC school system. The pages are filled with humor, wit, pathos, and innovation. One technique he used in his creative writing class was to have the students each write a note to their teacher for an unexcused absence from school, something most had already done without having it formally graded. ☺ I listened to the book on CD read by the author—terrific.)

*Teach Like your Hair's on Fire* by Rafe Esquith (Highly innovative teaching techniques—learned much that I didn't know and wish I could do. I wish all of us would have had or will have the experience of a teacher like Rafe Esquith.)

### ON SCIENCE AND ENGINEERING

*A Illustrated Brief History of Time, Updated and Expanded Edition* by Stephen Hawking (Listened to this on tape also—I thought it quite accessible and thought provoking.)

*The Mathematical Theory of Communication* by Warren Weaver and Claude Shannon. (Didn't find the first part by Warren Weaver very interesting and have executed a core dump. Loved the part by Claude Shannon. Rumor has it that Claude Shannon was not considered good enough for MIT's Ph.D. program in EE. So he went to the Math Dept and invented among many things **Information Theory**, the basis for modern (coded) digital communication. His article therein explains his basic ideas on information theory while showing that each symbol in the English language contains one bit of information, making English perfect for cross word puzzles.)

*The Feynman Lectures* by Richard Fineman, Nobel Laureate. (Audio Books. Basic physics as the best series of lectures on any topic I have ever heard. I wish I could lecture like Richard Fineman.)

**ON BECOMING MEN AND WOMEN**

*Reviving Ophelia* by Mary Pipher (For gals. Rented the audio book and listened to this with my daughters. A very challenging and illuminating book for their dad.)

*Fire in the Belly:On Being a Man* by Sam Keen (The first half was the most interesting for me.)

*Iron John* by Robert Bly (Bly, a poet, uses a Grimm Brothers' Fairy Tale to explore what it means to become a man setting forth stages that one must GROW through on the way. Another difficult and challenging book. Listened to this on CD, read by the author.)

**QUOTE**: (The need for uniqueness.) Anybody, who is any good, is different from anybody else.
–Felex Frankfurter

**DUE FRIDAY MARCH 27**

**SUGGESTED DERIVATION—NOT TO BE TURNED IN**. Recall equation 21.2, i.e.,

$$\left|H\left(j\omega\right)\right|^2 = \frac{1}{1+\varepsilon^2\left(\frac{\omega}{\omega_p}\right)^{2n}} = \frac{1}{1+\left(\frac{\omega}{\omega_c}\right)^{2n}},$$

This equation induces a relationship between the coefficient $\varepsilon$, $\omega_p$, and $\omega_c$. Show that for any LP brickwall specification the range of $\varepsilon$ is given by

$$\frac{\sqrt{10^{0.1A_{\min}}-1}}{\left(\frac{\omega_s}{\omega_p}\right)^n} = \varepsilon_{\min} \le \varepsilon \le \varepsilon_{\max} = \sqrt{10^{0.1A_{\max}}-1}$$

**49.** For this problem, do all calculations in MATLAB and use comments to explain your steps. Turn in your MATLAB printout – no copies. Note, it is often useful to write your program in WORD or some text file and then paste it into MATLAB as this allows you to easily correct your errors. The printout is NOT to have your errors in it. Design a Butterworth LP filter transfer function when $A_{\max} = 0.75$ dB, $f_p = 550$ Hz, and $f_s = 2200$ Hz as follows:

(a) find the largest integer value of $A_{\min}$ so that the filter order is 3; use the calculated value of $A_{\min}$ for the remainder of the problem. You must show how you came up with your value of $A_{\min}$—otherwise no credit. Hint: for-loop.

(b) find the range of allowable $\omega_c$ and the range of allowable $f_c$;

(c) find the poles, zeros, and gain constant of the 3 dB NLP transfer function and verify that they lie on the unit circle by computing their magnitude;

(d) find the 3 dB NLP transfer function as a product of a second and a first order section;

(e) using $\omega_{c,\min}$ find the zeros, poles, and gain constant of the actual LP transfer function; do the poles lie on a circle about the origin? DO NOT COMPUTE THE ACTUAL TRANSFER FUNCTION!

(f) Compute the dB loss, $-20\log_{10}\left|H_{3dBNLP}\left(j\Omega\right)\right|$, associated with Amax and Amin, i.e., $\Omega = 1, \frac{\omega_s}{\omega_p}$.

(g) Use MATLAB to plot $-20\log_{10}\left|H_{3dBNLP}\left(\frac{\omega}{\omega_{c,\min}}\right)\right|$ vs $0 \le f = 2\pi\omega \le 2f_s$.

(h) Use MATLAB the magnitude (gain) response of your filter, i.e., $\left|H_{3dBNLP}\left(\frac{\omega}{\omega_{c,\min}}\right)\right|$ vs frequency in Hz for $0 \le f = 2\pi\omega \le 2f_s$. Does your filter response meet the given brickwall specs at $f_p$ and $f_s$?

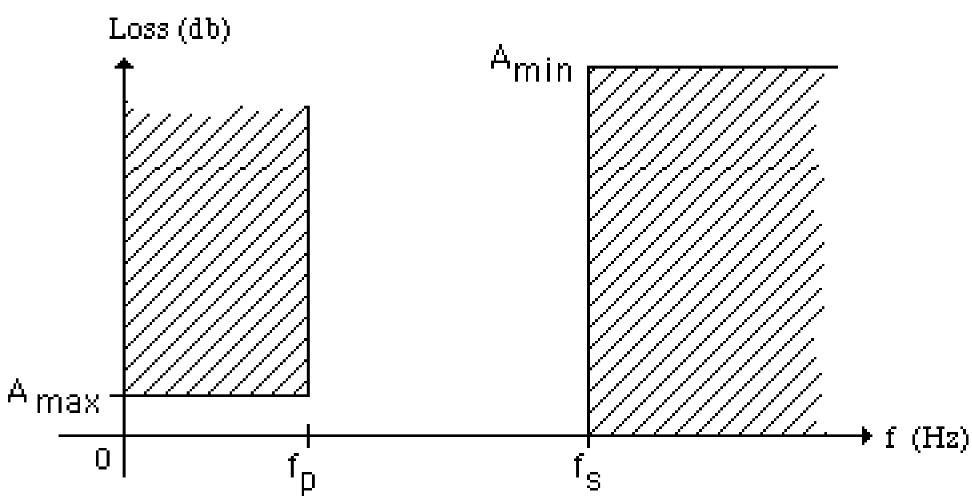



Figure P21.8

USEFUL MATLAB CODE:

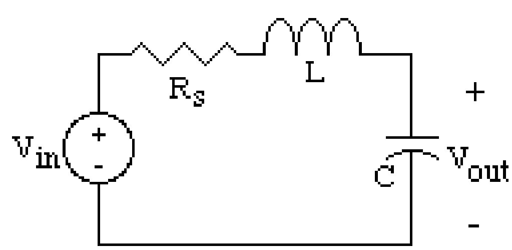
```
fp = ???; fs = ????;Amax = ???; Amin = ????;
n = buttord(fp,fs,Amax,Amin,'s')
fcmin = fp/((10^(0.1*Amax)-1)^(1/(2*n)))
fcmax = ???????
wcmin = ???
wcmax = ????
wc = wcmin;
fc = fcmin;
[z,p,k] = buttap(n)
```

```
zplane(p)
grid
pause
znew = z*wc
pnew = p*wc
knew = k*wc^n
f = 0:fp/100:2*fs;
h = freqs(knew*poly(znew),poly(pnew),2*pi*f);
plot(f,abs(h))
xlabel('Frequency Hz')
ylabel('Gain')
grid
pause
plot(f,180*angle(h)/pi)
grid
xlabel('Frequency Hz')
ylabel('Phase, degrees')
?????  Obtain Magnitude Plots in dB ??????
```

50. (a) Find the 3dB NLP Butterworth transfer function meeting the specs: $(\omega_p, A_{\max}) = (2\pi 500, 2\,dB)$ and $(\omega_s, A_{\min}) = (2\pi 2000, 20\,dB)$. Then find $\omega_{c,\min}$ and $\omega_{c,\max}$.

(b) Using the circuit below,
 (i) Compute the transfer function in terms of the parameter values, and
 (ii) realize the 3dBNLP transfer function obtained in part (a).

(c) Magnitude and frequency scale the circuit so that the gain is 3 dB down at $\omega_{c,\min}$ and $C_{final} = 10$ nF after magnitude and frequency scaling.

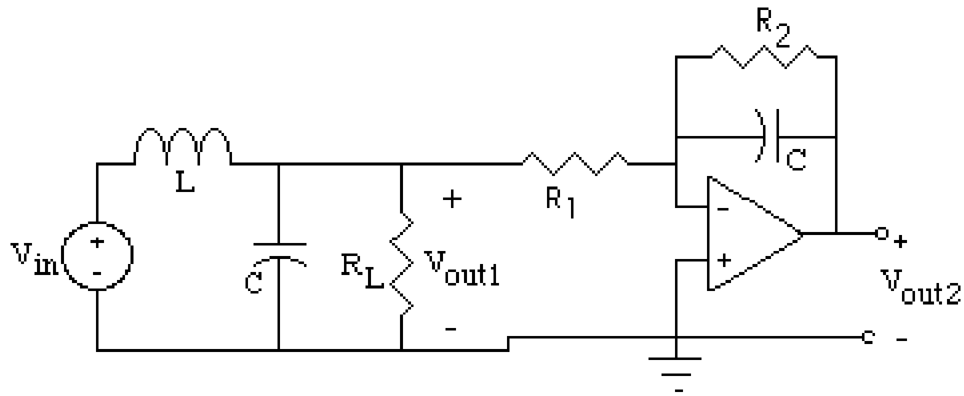



51. In this problem, you are to realize with a circuit, the filter designed in problem 49 using the circuit below.

(a) Compute the transfer functions, $H_1(s) = \dfrac{V_{out1}(s)}{V_{in}(s)}$, $H_2(s) = \dfrac{V_{out2}(s)}{V_{out1}(s)}$, and $H(s) = \dfrac{V_{out2}(s)}{V_{in}(s)}$ of the circuit below. in terms of the literal element values.

(b) Realize the 3dBNLP transfer function computed in part (d) of problem 49.

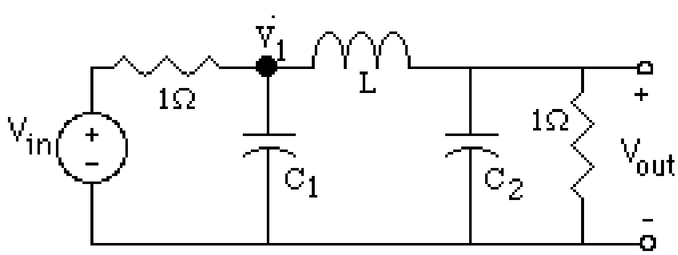
(c) Frequency scale and magnitude scale your circuit so that the 3dB down point is at $\omega_{c,\min}$ as computed in problem 49, AND so that $R_1 = 20$ kΩ and $R_L = 100$ Ω. Magnitude scaling requires two separate magnitude scale factors—why is this permissible?




52. Consider figure below.
   (a) Show that the transfer function is

$$H_{cir}(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{\frac{1}{LC_1C_2}}{s^3 + \frac{C_1 + C_2}{C_1C_2}s^2 + \frac{C_1 + C_2 + L}{LC_1C_2}s + \frac{2}{LC_1C_2}}$$

   (b) Determine values so that the circuit realizes a third order (3 dB NLP) Butterworth gain characteristic denominator. Note that the dc gain is 0.5 and would have to be increased by either a transformer (to be covered later) or by an op amp circuit. Thus one can only match the denominator coefficients.
   (c) Find new parameter values of a third order low pass Butterworth filter having the specs of the filter in problem 49 and $C_{2\,final} = 10$ nF after magnitude and frequency scaling.
   (d) Use SPICE to verify the frequency response of the circuit.



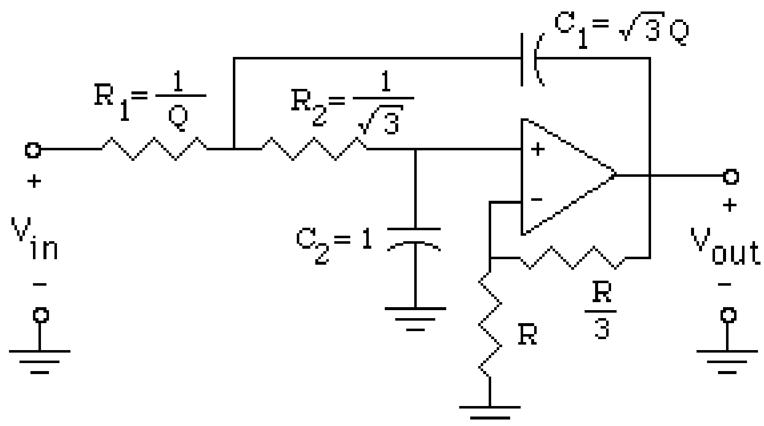

**QUOTE**: Far and away the best prize that life offers is the chance to work hard at work worth doing. – Theodore Roosevelt

**DUE WEDNESDAY APRIL 1—NO FOOLING**

53. A 2nd order normalized Butterworth filter can be realized by the Sallen and Key circuit described in the notes and shown below. In the final design, the filter is to have a dc gain of 1, a 3 dB down frequency of $f_c = 2000$ Hz, and largest capacitor of 5 nF.
   (a) Write down the 2nd order NLP Butterworth transfer function $H_{3dBNLP}(s)$.

(b) The transfer function of the Sallen and Key circuit is given by $H_{cir}(s)=\dfrac{\frac{4}{3}}{s^2+\frac{1}{Q}s+1}$.

Determine Q. Then determine the values of $R_1, R_2, C_1,$ and $C_2$ for the 3dBNLP filter. The value of $R$ can be chosen independently, 20 kΩ being a reasonable value.
(c) Determine $K_f$ and $K_m$. Then determine the final values of all resistors and capacitors in the circuit.




54. (a) Realize a 3rd order 3dB NLP using a cascade of the Sallen and Key circuit (Saraga design) of problem 53 and a 1st order active circuit such as the leaky integrator.
(i) Write down the 3nd order NLP Butterworth transfer function $H_{3dBNLP}(s)$ as a product of a first order and second order section.
(ii) Using the leaky integrator, your circuit transfer function should be

$$H_{cir}(s)=\frac{\frac{4}{3}}{s^2+\frac{1}{Q}s+1}\times\frac{G_3}{Cs+G_4}$$

(iii) Determine Q. Then determine the values of $R_1, R_2, C_1,$ and $C_2$ for the Sallen and Key circuit recalling that $R$ can be chosen independently. Next determine the values of $G_3, G_4,$ and $C$ for the leaky integrator circuit.
(b) In the final design, the filter is to have a dc gain of 1, a 3 dB down frequency of $f_c = 2000$ Hz, and largest capacitor of 5 nF. Determine the final values of all circuit parameters.
(c) (optional) Do a SPICE frequency sweep simulation of your circuit. Does your design meet specs?

55. A 2nd order Butterworth HP filter has 3 dB down point at $f_c = 2000$ Hz. The 2nd order Butterworth normalized LP prototype is given in the figure below and has transfer function

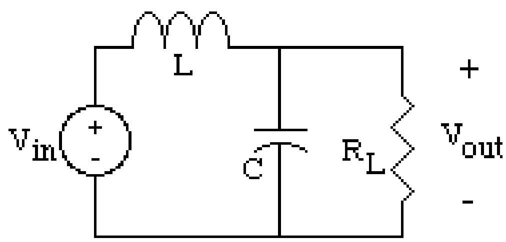
$$H_{cir}(s)=\frac{\frac{1}{LC}}{s^2+\frac{1}{R_LC}s+\frac{1}{LC}}$$

(a) With $R_L = 1\ \Omega$, compute L in H and C in F to realize the normalized 2nd order prototype. Check: $C = 1/\sqrt{2}$ F.

(b) Using (a), construct a NHP circuit with $R_L = 1\ \Omega$ and $\Omega_{c,HP} = 1$ rad/s. This is the so-called 3 dB normalized HP filter (3dBNHP).

(c) Now construct the final HP design if $R_L = 100\ \Omega$.

(d) Do a SPICE simulation to verify your design.




56. A 3rd order Butterworth HP filter has 3 dB down point at $f_c = 4200$ Hz. The 3rd order Butterworth normalized LP prototype is given in the circuit below and has transfer function

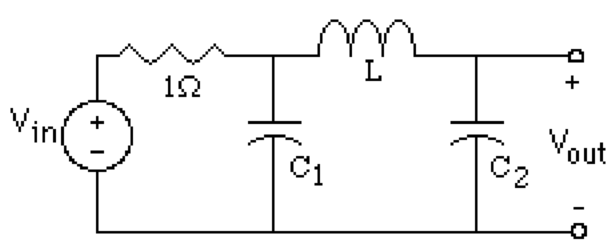
$$H_{cir}(s) = \frac{V_{out}(s)}{V_{in}(s)} = \frac{\frac{1}{LC_1C_2}}{s^3 + \frac{1}{C_1}s^2 + \frac{C_1 + C_2}{LC_1C_2}s + \frac{1}{LC_1C_2}}$$

(a) Compute $L$ in H and $C_1$ and $C_2$ in F to realize the 3 dB normalized 3rd order Butterworth prototype. **Check**: $C_2 = 1.5$ F.

(b) Using (a), construct a NHP circuit with $\Omega_{c,HP} = 1$ rad/s. This is the so-called 3 dB normalized HP filter (3dBNHP).

(c) Now construct the final HP circuit design if the source resistance is to be 16 Ω. Draw and clearly label your final circuit.

(d) Do a SPICE simulation to verify your design.




**QUOTE**: If I can make men [and women] of my people, my business will take care of itself. Everything I can do to help them ultimately benefits me. –Henry Ford