

Physics 262  
Practice Midterm Exam

Remember to show your work.

The real exam will be similar in form, but somewhat shorter.  
You may bring a 4"  $\times$  6" notecard. You may use a calculator  
for arithmetic computations.

Name:

# Reference Material

## Ph262

Multi-stage filter parameters, based on H&H 2ed. (with 1 tiny correction), and Q values calculated to provide a more general prescription. For implementation with Sallen-Key or other 2-pole stages. The transfer function for each stage is:

$$G = \frac{k}{1 + \frac{j\omega}{\omega_0} - \left(\frac{\omega}{\omega_0}\right)^2} = \frac{k}{1 + \frac{j}{Q} \frac{f}{f_0} - \left(\frac{f}{f_0}\right)^2}$$

The above is for low pass. For high pass, multiply by  $-(f/f_0)^2$ .

legend: K Gain for a Sallen-Key stage, with equal component values, to attain the desired Q for the stage.

Q Quality factor, for the denominator of the response function. Inferred from H&H K values.

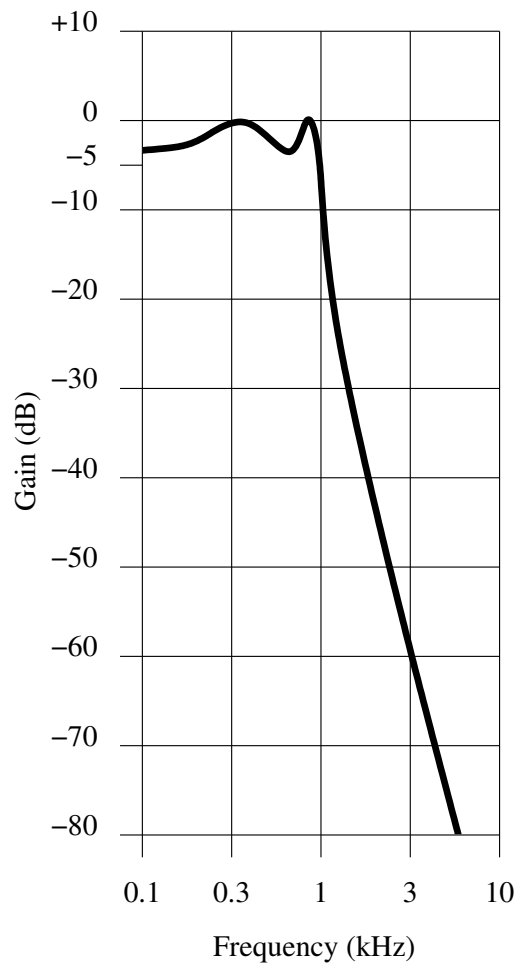
f<sub>n</sub> Low pass frequency conversion factor:  $\omega = f \cdot \omega_c$  where  $\omega_c = f_c \cdot 2\pi$ , where  $f_c$  or  $\omega_c$  is the desired critical frequency.

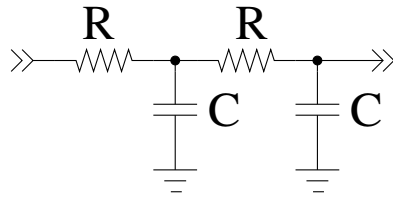
These values are for low pass filters. Use  $1/f_n$  for high pass!

Note that critical frequency for Butterworth and Bessel are at -3dB compared to DC, whereas for Chebyshev it's when the response leaves the specified passband ripple.

#poles	Butterworth (flat response in passband)			Bessel (flat time delay in passband)			Chebyshev, 0.5dB ripple (sharp roll-off)			Chebyshev, 2dB ripple (sharp roll-off)		
	K	Q	f <sub>n</sub>	K	Q	f <sub>n</sub>	K	Q	f <sub>n</sub>	K	Q	f <sub>n</sub>
2	1.586	0.707	1.000	1.268	0.577	1.273	1.842	0.864	1.231	2.114	1.129	0.907
4	1.152	0.541	1.000	1.084	0.522	1.432	1.582	0.705	0.597	1.924	0.929	0.471
	2.235	1.307	1.000	1.759	0.806	1.606	2.660	2.941	1.031	2.782	4.587	0.964
6	1.068	0.518	1.000	1.040	0.510	1.607	1.537	0.684	0.396	1.891	0.902	0.316
	1.586	0.707	1.000	1.364	0.611	1.692	2.448	1.812	0.768	2.648	2.841	0.730
	2.483	1.934	1.000	2.023	1.024	1.908	2.846	6.494	1.011	2.904	10.417	0.983
8	1.038	0.510	1.000	1.024	0.506	1.781	1.522	0.677	0.297	1.879	0.892	0.238
	1.337	0.601	1.000	1.213	0.580	1.835	2.379	1.610	0.599	2.605	2.532	0.572
	1.889	0.900	1.000	1.593	0.711	1.956	2.711	3.460	0.861	2.821	5.587	0.842
	2.610	2.564	1.000	2.184	1.225	2.192	2.913	11.494	1.006	2.946	18.519	0.990

1. (?? points) Based on the gain plotted below,
- (a) Is this filter high pass or low pass?
  - (b) What is the gain at DC?
  - (c) What is the critical frequency,  $f_c$ ?
  - (d) What is the roll-off (dB per decade) at high frequency?
  - (e) What is the passband ripple (dB)?
  - (f) What is the order (number of poles)?
  - (g) Butterworth, Bessel, or Chebyshev? How can you tell?

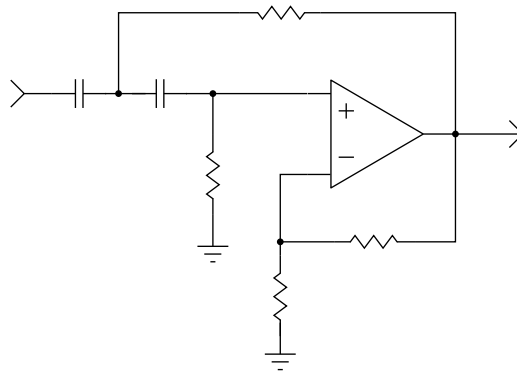




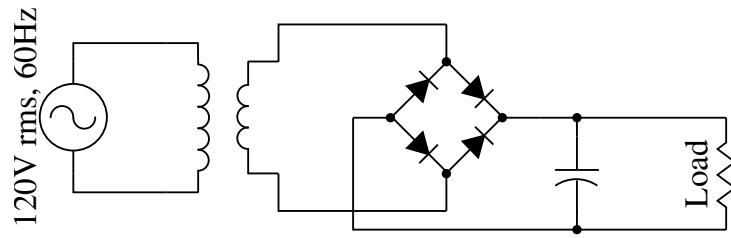
2. (?? points) Consider this simple 2-pole RC filter.

- (a) Calculate the complex response,  $\frac{\mathbf{v}_{\text{out}}}{\mathbf{v}_{\text{in}}}$ .
- (b) What are  $Q$  and  $\omega_0$ ?
- (c) What is the roll-off (how many dB per decade of frequency)? Sketch gain (dB) vs.  $\log \frac{\omega}{\omega_0}$ .
- (d) *Qualitatively*, how would this filter differ from a 2-pole Butterworth in terms of (i) sharpness of the knee; (ii) time delay vs. frequency?

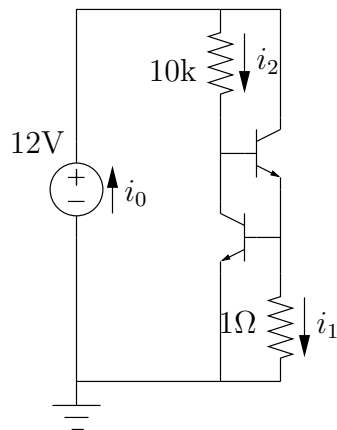
3. (*?? points*) For a generic 2-pole filter (high pass or low pass, your choice), work out the time delay in terms of  $\omega$ ,  $\omega_0$ ,  $Q$ , and  $k$ .



4. (?? points) Choose resistor and capacitor values for the above circuit to make it a high-pass Butterworth filter. Specify values in terms of a desired critical frequency  $f_c$ .



5. (?? points) Choose a turn ratio for the transformer that gives 6 V peak output voltage (that is, 6 V amplitude). Assume 0.6 V per diode.
6. (?? points) Choose the capacitor value so that the output ripple is 1 mV across a  $10\ \Omega$  load.



7. (?? points) Assume 0.7V drop from base to emitter on both transistors.
- Find the currents  $i_1$  and  $i_2$ .
  - Explain why  $i_0 \leq i_1 + i_2$ .
  - As an approximation, assume  $i_0 = i_1 + i_2$ . How much will  $i_0$  change if the power supply voltage is doubled?



8. (?? points) The AC voltage

$$V(t) = V_0 \cos(2\pi t/T)$$

is attached to a resistor  $R$ .  $V_0$  is called the amplitude.

- (a) What is the peak-to-peak voltage,  $V_{pp}$ ?
- (b) What is the root mean square voltage,  $V_{RMS}$ ?
- (c) How much power is dissipated in the resistor?
- (d) Inexpensive meters do not really measure  $V_{RMS}$ . It is easier to measure the *average absolute value*,

$$V_{AV} = \overline{|V(t)|} = \frac{1}{T} \int_0^T |V(t)| dt.$$

Calculate  $V_{AV}$  in terms of  $V_0$ .

- (e) Given a circuit that measures  $V_{AV}$ , how would you scale that result to estimate  $V_{RMS}$ ?