

Physics 262
Practice Final Exam

(Please also review the Midterm and Practice Midterm!)
Remember to show your work.

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

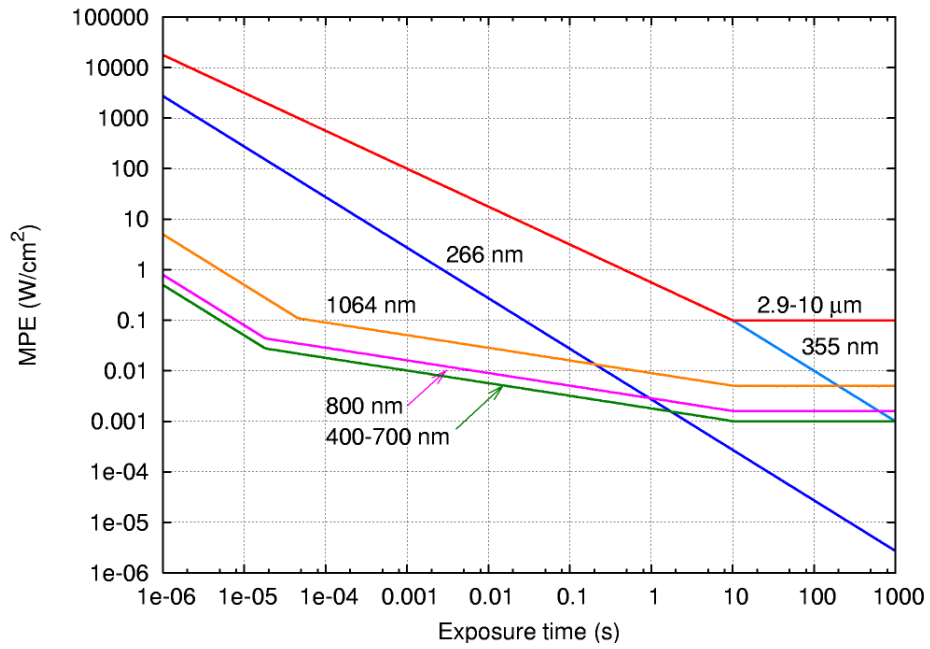
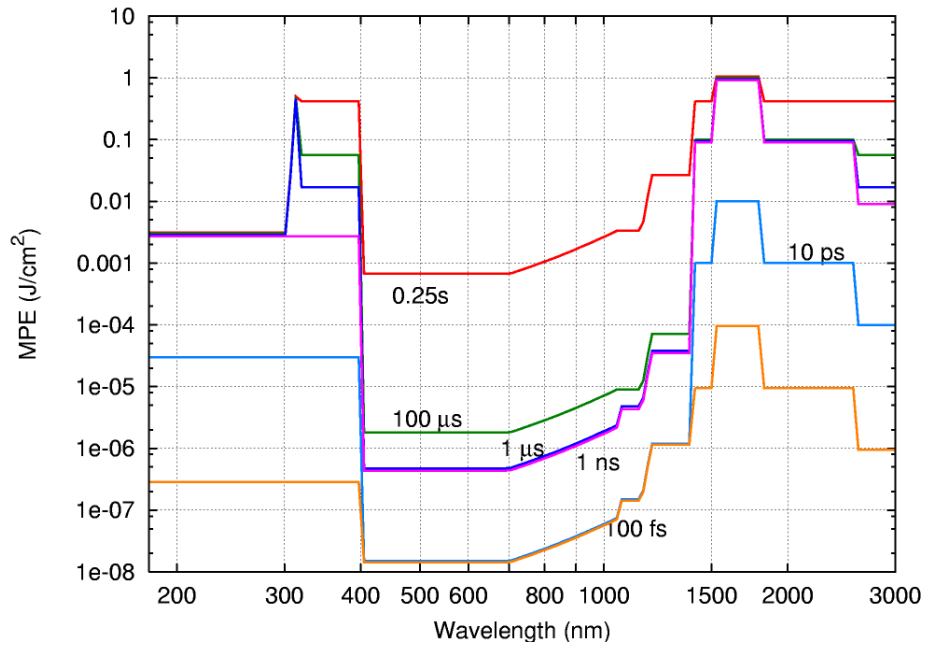
Quality factor, for the denominator of the response function. Inferred from H&H K values.

Low pass frequency conversion factor: $\omega_0 = f_n \cdot \omega_{c_c} = f_n \cdot f_c \cdot 2\pi$, where f_c or ω_{c_c} is the desired critical frequency.

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

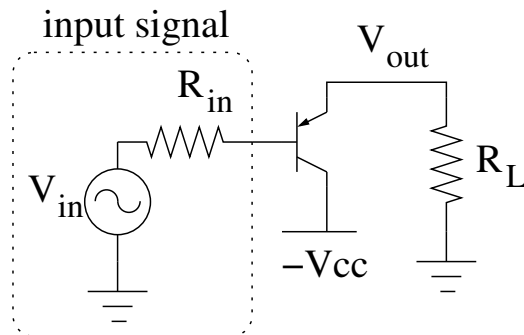
Note that critical frequency for Butterworth and Bessel are at -3dB compared to DC, whereas for Chebyshev it's when the response leaves the specified passband ripple.

#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	fn	K	Q	fn	K	Q	fn	K	Q	fn
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



Practice Problems (Please also review the Midterm!)

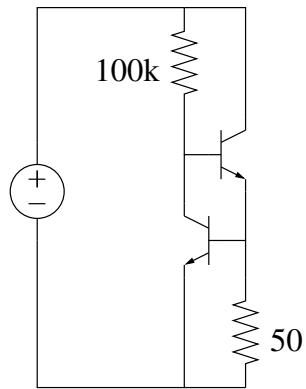
1. (25 points) A signal V_{in} with impedance R_{in} is boosted through the BJT follower to power a load R_L .



- For what values of V_{in} is the transistor in active mode?
- In active mode, what is V_{out} ?
- Draw an improved version of this circuit with an op amp and feedback to control the output of the transistor, with unity gain for $V_{in} < 0$.

2. (*20 points*) A 2 GHz sinewave is measured on an oscilloscope with a sample frequency of 3 GHz.
- (a) What is the Nyquist frequency?
 - (b) Sketch a few periods of the sinewave and mark the measured points.
 - (c) Given only the oscilloscope data, what frequency would you infer?¹

¹Hint: a sinusoid of frequency f sampled at frequency f_S is indistinguishable from a sinusoid of frequency $|f - Nf_S|$, for any integer N .



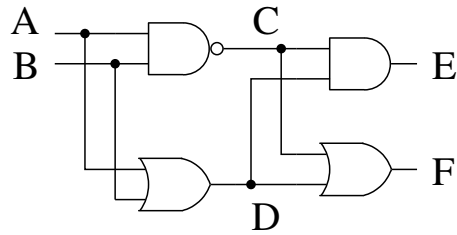
3. (15 points) A pair of transistors can be used in the above manner to limit the current in a circuit.
- Nearly all of the current in the above circuit goes through the $50\ \Omega$ resistor. Why?
 - Assuming the lower transistor is turned on (not in cutoff mode), find the approximate current in the circuit.
 - Explain in words how the transistors work together to limit the current.

4. (12 points) An infrared ($\lambda = 1.57 \mu\text{m}$) laser rangefinder has a 2 mm diameter beam and 1 ns pulse.
- (a) What is the maximum safe pulse energy (J)?
 - (b) Why is this wavelength a good choice from a safety perspective?
 - (c) How far does the light travel in the duration of one pulse?

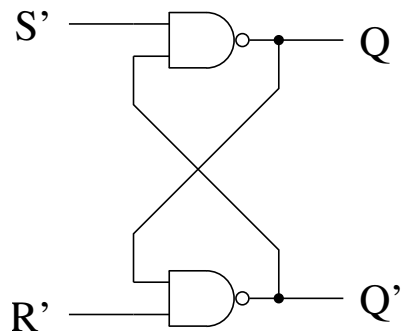
5. (*?? points*) Make a table showing the binary equivalents of each of the 16 hexadecimal digits from 0 to F.
6. (*?? points*) Convert the following binary fraction to hexadecimal. Don't bother to simplify!

$$\frac{0010\ 0000\ 1101\ 1011}{1101\ 1110\ 1100\ 1010\ 1101\ 1110}$$

7. (?? points) Complete the truth table.



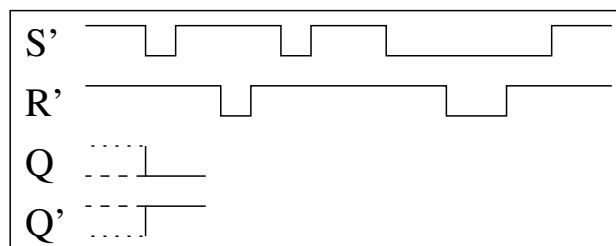
A	B	C	D	E	F
0	0				
0	1				
1	0				
1	1				



8. (?? points) Complete the truth table for the above circuit. 0 means logic low (false); 1 means logic high (true); Q_0 means the previous value of Q ; and Q'_0 means the previous value of Q' .

S'	R'	Q	Q'
0	0		
0	1		
1	0		
1	1		

9. (?? points) Complete the timing diagram for the circuit at the top of the page.



10. A digital output line from a computer is used for pulse width modulation (PWM) of an audio signal. The computer clock frequency is $f_c = 2.0$ GHz.
- (a) Assume that the clock period Δt_c is the shortest interval in which the output line can be turned on and off again. Calculate Δt_c .
 - (b) How many clock cycles does it take to represent the full range of a 16-bit number using PWM?
 - (c) What is the resulting PWM frequency, f_{PWM} ?
 - (d) What is the Nyquist frequency, f_N , for sound sampled at f_{PWM} ?
 - (e) Suppose a 20 kHz tone is sampled at f_{PWM} . When it is played back, what will its frequency be (circle the correct answer):
 - i. 20 kHz.
 - ii. $|20 \text{ kHz} - f_{PWM}|$, due to aliasing.
 - iii. $f_N - 20 \text{ kHz}$, due to aliasing.