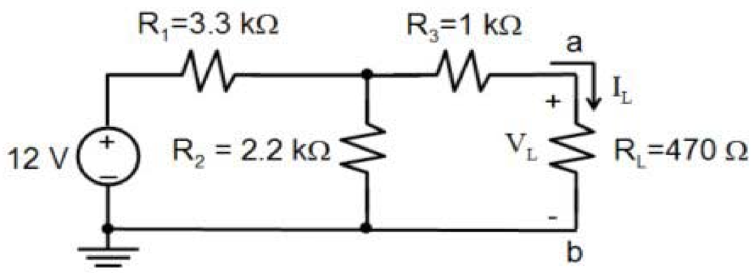
EE 2240 Basic Circuit Laboratory

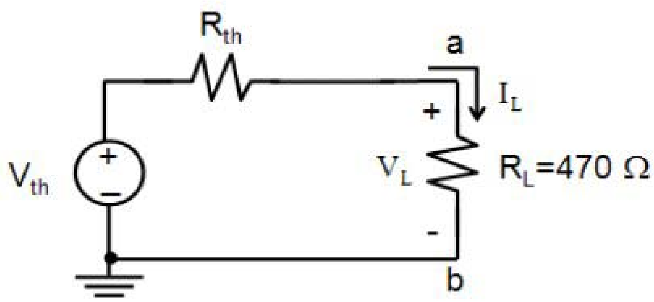
Final Examination, 6/12/2007

1. (20%)

(1) (8%) Please calculate the Thévenin voltage V_{th} and resistance R_{th} of the circuit.

Ans: V_{th} = 12 * 2.2k/(2.2k + 3.3k) = 4.8. R_{th} = 1k + (2.2k || 3.3k) = 2.32kΩ.





(2) (12%) For the circuit below:

(2-1) (3%) Can we measure the voltage V_R of the resistance directly using the oscilloscope? Please explain.

Ans: No. Vc would be shorted by doing so.

(2-2) (4%) Will the peak-to-peak voltage values satisfy the equation $V_{C(p\text{-}p)} + V_{R(p\text{-}p)} = E_{(p\text{-}p)}$? Please give your reasoning to the answer.

Ans: No. It should be: $V_{c(p-p)}^2 + V_{R(p-p)}^2 = E_{p-p}{}^2$.

(2-3) (5%) How would you obtain/judge the phase difference, including the sign (+ or -) and value, between the sinusoidal signals V_c and E_s of the period T on the oscilloscope?

Ans: (1) Find the time difference ΔT of the input and output signals.

(2) For Vc is lagging behind the input signal of period T, Vc will appear on the right of the input. Then

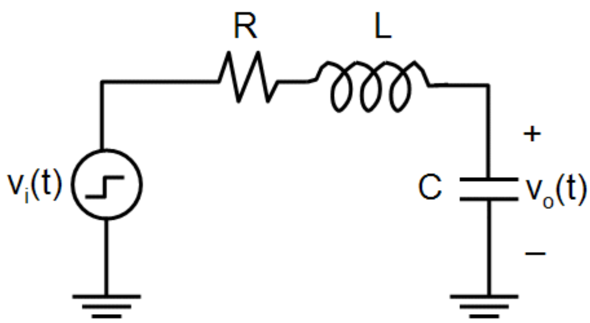
$$\theta = -\frac{\Delta T}{T} \times 360°$$

2. (25%)

(1) (15%) For the R-L-C circuit as shown, $v_i(t)$ is a unit-step input, and the value of *R*, *L*, and *C* are 50 Ω, 10 mH, and 1 μF, respectively. Please calculate the damping ratio, the quality factor, and the natural frequency of the circuit. Also, please compute the rise time and overshoot in the output.

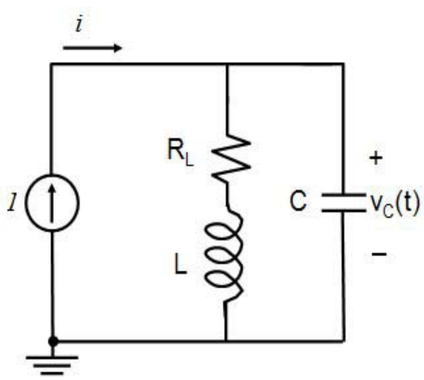
Ans: $\frac{v_o(s)}{v_i(s)} = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$. Damping ratio = 0.25, Q = 2, ωn = 10000 rad/s,

rise time = $tan^{-1}\left(-\sqrt{1-\xi^2}/\xi\right)/\left(\omega_n\sqrt{1-\xi^2}\right) = 1.883 \times 10^{-4}$, overshoot = $exp\left(-\xi\pi/\sqrt{1-\xi^2}\right) = 0.4443 = 44.43\%$

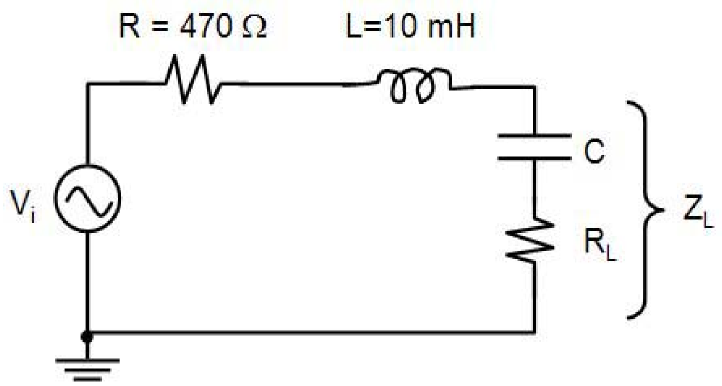


(2) (5%) For the circuit as shown below, determine whether the resistance R_L should be large or small to produce a high quality factor. Give your reasoning.

Ans: $Q = \omega_r L/R_L$. So a small R_L is desired for a large Q.



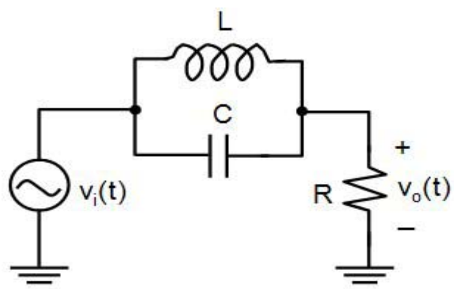
(3) (5%) For the circuit as shown, determine the values of C and R_L for maximum power transfer to the load Z_L at 40 kHz.



Ans: R_L = 470 Ω. ωL = 1/(ωC), $2\pi(40\cdot10^3)\cdot(10\cdot10^{-3}) = \frac{1}{2\pi(40\cdot10^3)C}, C = 1.583\ nF$

3. (25%)

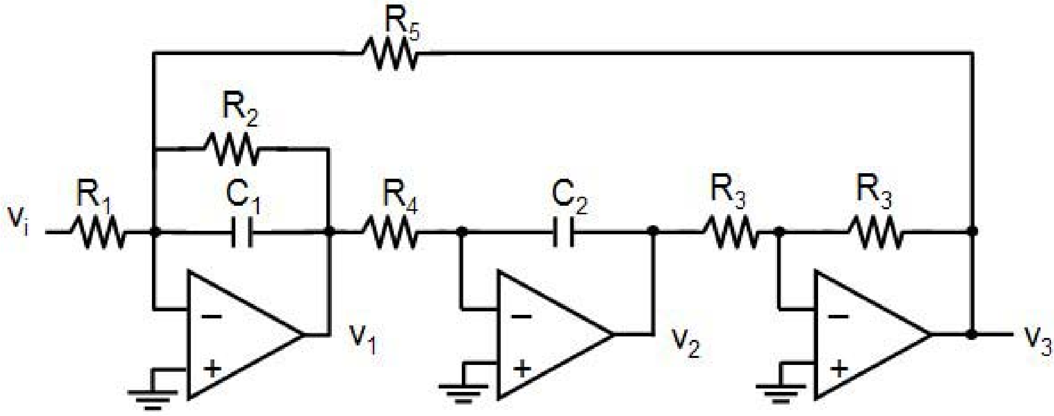
(1) (7%) Find the transfer function $v_o(s)/v_i(s)$ of the filter as shown, and explain what type of filter it is with your reasoning.



Ans: $\frac{v_o(s)}{v_i(s)} = \frac{s^2 + \frac{1}{LC}}{s^2 + \frac{1}{RC}s + \frac{1}{LC}}$.

At ω = 0, $\left|\frac{v_o(j\omega)}{v_i(j\omega)}\right| = 1$. At ω = ∝, $\left|\frac{v_o(j\omega)}{v_i(j\omega)}\right| = 1$. At $\omega = 1/\sqrt{LC}$, $\left|\frac{v_o(j\omega)}{v_i(j\omega)}\right| = 0$. A band-reject filter.

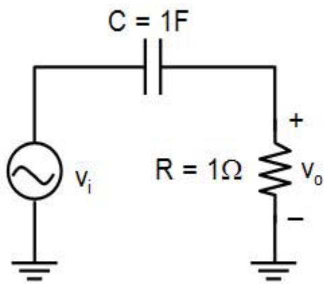
(2) (10%) Find the transfer function $v_2(s)/v_i(s)$ of the filter as shown.



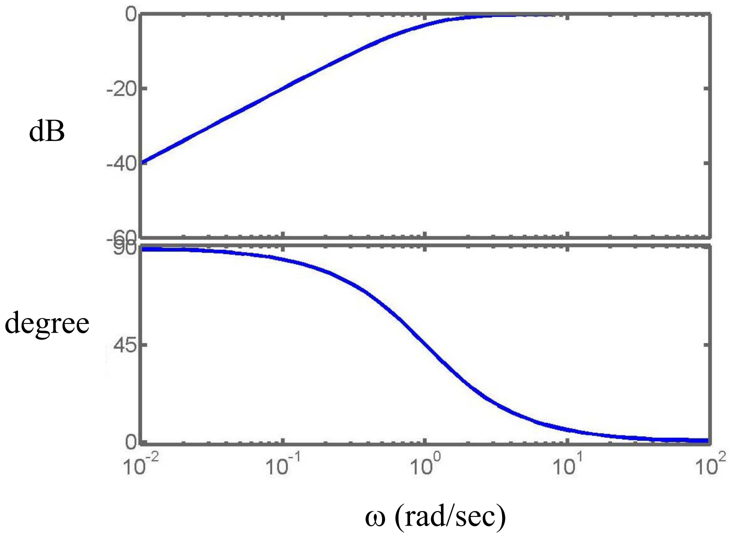
Ans: $\dfrac{v_i}{R_1}+\dfrac{v_3}{R_5}+\dfrac{v_1}{R_2}+\dfrac{v_1}{\dfrac{1}{sC_1}}=0,\quad v_2=-\dfrac{1}{sR_4C_2}v_1,\quad v_3=-v_2$

so, $\dfrac{v_2(s)}{v_i(s)}=\dfrac{1}{C_1C_2R_1R_4}\dfrac{1}{s^2+\dfrac{1}{R_2C_1}s+\dfrac{1}{C_1C_2R_4R_5}}$

(3) (8%) Please draw the frequency response (magnitude and phase) of the R-C circuit as shown. Especially you should provide the values at ω = 0, ∝, and the 3dB frequency.



Ans:

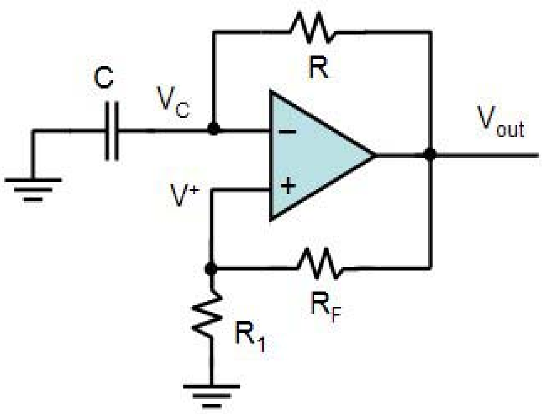


4. (10%) Determine the order of a low-pass Butterworth filter that has a dc gain of 1, a cut-off frequency of 10 kHz, and a gain of no more than -60 dB at 50 kHz.

Ans: $n = log_{10} \frac{\sqrt{10^{-0.1\cdot(-60)} - 1}}{\sqrt{10^{-0.1\cdot(-3)} - 1}} / log_{10}\left(\frac{50kHz}{10kHz}\right) = 4.2935$. So n = 5.

5. (20%)

(1) (10%) Derive the oscillation frequency of the circuit below.



Ans:

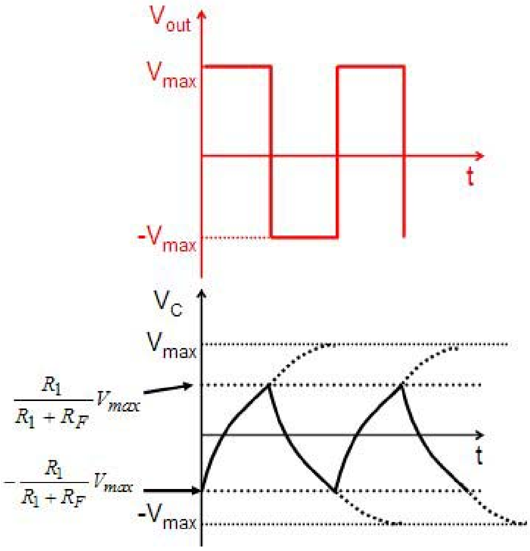
When charging the capacitor:

$$V_{max} = -\frac{R_1}{R_1 + R_F} V_{max} + \left(V_{max} - \left(-\frac{R_1}{R_1 + R_F} V_{max}\right)\right) \cdot \left(1 - e^{-\frac{t}{RC}}\right)$$

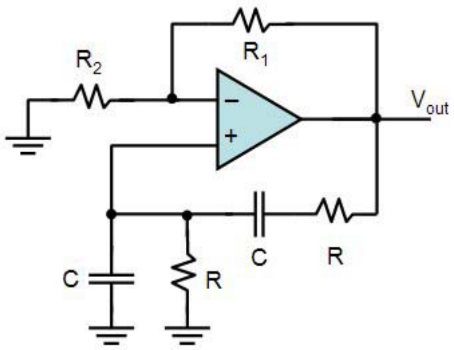
At t = T/2:

$$\frac{R_1}{R_1+R_F}V_{max} = -\frac{R_1}{R_1+R_F}V_{max} + \left(V_{max} - \left(-\frac{R_1}{R_1+R_F}V_{max}\right)\right)\cdot\left(1-e^{-\frac{T/2}{RC}}\right)$$

Then $T = 2RC\,ln\frac{R_F+2R_1}{R_F}$, f= 1/T.



(2) (10%) Derive the oscillation frequency of the circuit below, and determine the value of R_1/R_2 to start the oscillation.



Ans: $\frac{v^+(s)}{v_{out}(s)} = \frac{sRC}{R^2C^2s^2+3RCs+1}$

$\frac{v^+(j\omega)}{v_{out}(j\omega)} = \frac{j\omega RC}{\left(1-\omega^2R^2C^2\right)+j\omega 3RC}$. when at resonant frequency = 1/(RC)

$\left|\frac{v^+(j\omega)}{v_{out}(j\omega)}\right| = \frac{1}{3}$, Then (1+ R_1/R_2) = 3 to start the oscillation. R_1/R_2 = 2.