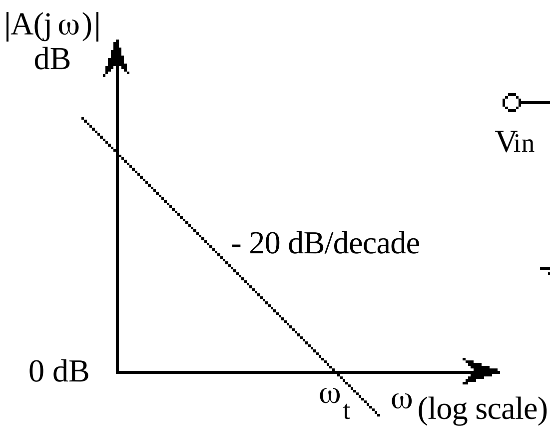
Note: in this question, certain symbols do not render properly is some PDF readers. I have annotated those.

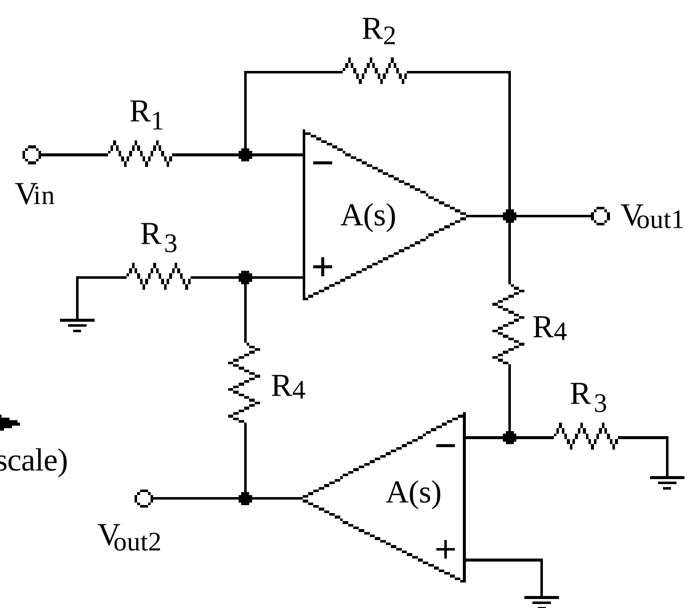
Q.1 The circuit shown below is a second-order filter containing no capacitor external to the op amps (it is called an active-R biquad). Assume that the two op amps are identical with infinite input resistance, zero output resistance and open-loop gain A(s) as given by the Bode plot shown below.

(a) Obtain the transfer functions $\frac{V_{out1}}{V_{in}}(s)$ in terms of R's and ω_t. (omega_t)

(b) Obtain expressions for ω_o and Q and their sensitivities with respect to R's and ω_t. (omega_t)

(c) Use this circuit to realize a second-order bandpass filter with unity center-frequency gain, center frequency of 10 krad/sec and a BW of 1 krad/sec. Assume that the op amps have unity-gain-bandwidth (ω_t) of 10 Mrad/sec. Obtain all the resistors values.





Q.2 (a) Using Mesh analysis write by <u>inspection</u> a set of mesh matrix equations (size 2 x 2) in the form [**A**][**I**] = **V** for the circuit shown in Figure 2. Your final answer should contains numbers only in the **A** matrix and the **V** column vector.

(b) Using the result in part (a) solve the voltage *v* across the 4 Ω resistor.

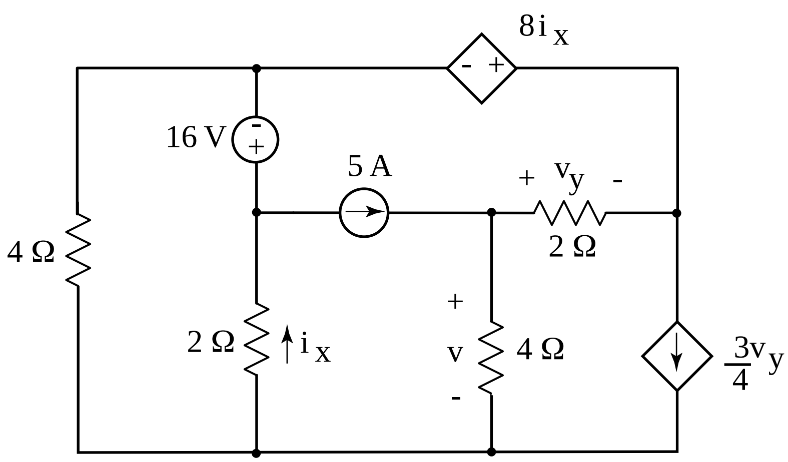


Figure 2

Q.3 (a) Using any method of your choice determine the steady state current $i_{out}(t)$ in the circuit shown in Figure 3 if $v_s(t) = 12\cos(2t + 45^\circ)$ V. v_s(t) = 12cos(2t+45 deg)

(b) Determine the natural response of this circuit assuming the capacitor held an

v_c(0-) = V_0 initial voltage of $v_c(0^-) = V_0$ and the initial current through the inductor $i_L(0^-) = I_0$, respectively. i_L(0-) = I_0

(c) If $I_o = -1A$ and $V_o = 2V$, plot $i_{out}(t)$ versus time. I_0 = -1 A and V_0 = 2 V

(d) Plot the asymptotic frequency response of this circuit if i_{out} is considered the output of the circuit and the independent source as the input.

(e) If i_{out} is considered the output of the circuit and the independent source as the input, is this circuit reciprocal? Give a brief explanation for your reasoning.

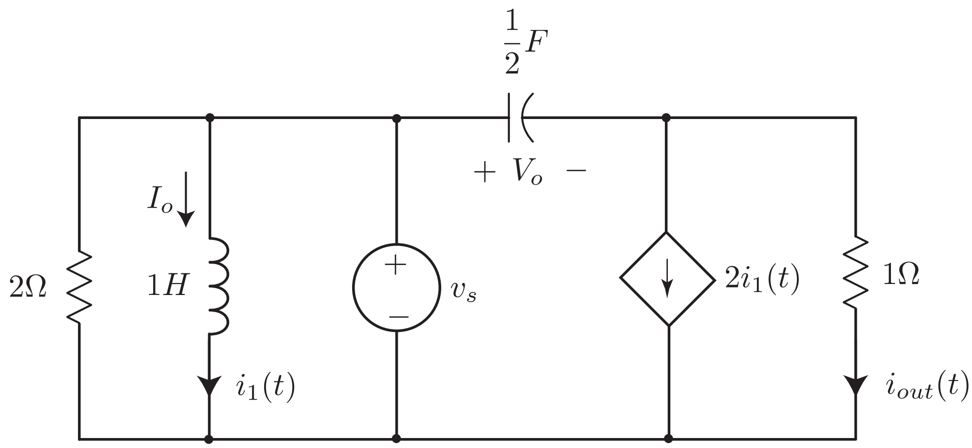


Figure 3

Q4. This question has 7 parts (a)-(g).

(a) Draw a circuit diagram of a CMOS inverter.

(b) Assume that $\mu_n = 3\mu_p$, $V_{dd} = 1.8\ V$, $V_{tn} = |V_{tp}| = 0.5\ V$, $\lambda = 0.1$, and the width of NMOS is 1 μm. Explain how you would select the size of the PMOS transistors such the threshold voltage of the inverter was 1 V?

(c) What are the V_{OH} and V_{OL} of the inverter designed in (b)

(d) What capacitance does this inverter present to a preceding logical gate? Show your answer in terms of the small signal transistor capacitances.

(e) What is the output capacitance of this inverter? Show your answer in terms of the small signal transistor capacitances.

(f) What transistor width ratios would you select to make t_{pHL} equal to t_{pLH}?

(g) What transistor width ratios would you select to minimize the average time delay (t_p)?

Q5. Design a BJT differential amplifier that provides two single-ended outputs (at the collectors). The amplifier is to have a differential gain (to each of the two outputs) of at least 100 V/V, a differential input resistance $\geq$10 kΩ, and a common-mode gain (to each of the two outputs) no greater than 0.1 V/V. Use a 2-mA current source for biasing. Give the complete circuit with component values and suitable power supplies that allow for $\pm$2 V swing at each collector. Specify the minimum value that the output resistance of the bias current source must have. The BJTs available have $\beta \geq$100. What is the value of the input common-mode resistance when the bias source has the lowest acceptable resistance?

Q6. An npn BJT with grounded emitter is operated with $V_{BE} = 0.700$ V, at which the collector current is 1 mA. A 10-kΩ resistor connects the collector to a +15 V supply. What is the resulting collector voltage V_C? Now, if a signal applied to the base raises v_{BE} to 705 mV, find the resulting total collector current i_C and total collector voltage v_C using the exponential $i_C - v_{BE}$ relationship. For this situation, what are v_{be} and v_c? Calculate the voltage gain v_c/v_{be}. Compare with the value obtained using the small-signal approximation, that is, $-g_m R_C$.

Q7. This question has 2 parts (a)-(b). Part (a) has 2 subparts (i)-(ii) and part (b) has 3 subparts (i)-(iii).

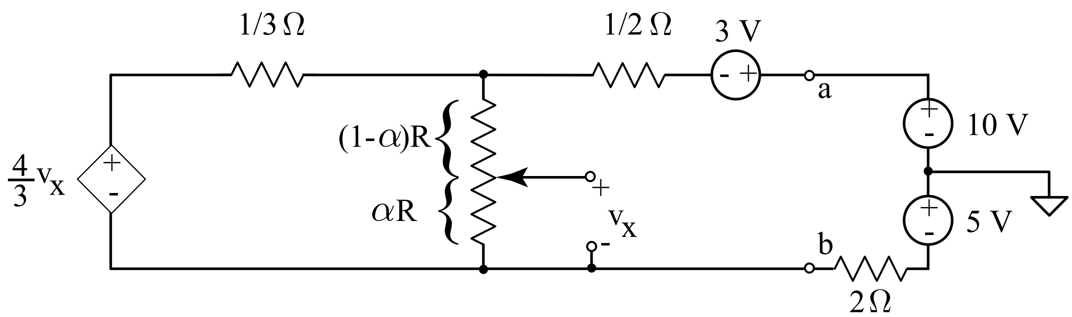
(a) Consider the circuit shown below. It contains a potentiometer modeled by two variable resistors of value αR and $(1-\alpha)R$ where α is a variable $0 \leq \alpha \leq 1$ and $R = 3\ \Omega$. For the circuit, do the following:

i. Find the Thevenin equivalent of the circuit to the left of the nodes a-b.

ii. Determine the value of α for

A. $R_{TH} = -1\ \Omega$

B. $R_{TH} = 1\ \Omega$



(b) The network shown in the figure below has been in that state for a long time with the switches closed. At $t = 0$, the switches are simultaneously opened as indicated by the arrows. For this circuit using Laplace Transform techniques do the following;

i. Determine the poles of this circuit for $t \geq 0$.

ii. Determine the current $i_c(t)$ through the capacitor for $t \geq 0$.

iii. Using the final value theorem determine $v_{4\Omega}(\infty)$.

Tables of Laplace Transforms are given on the page following.

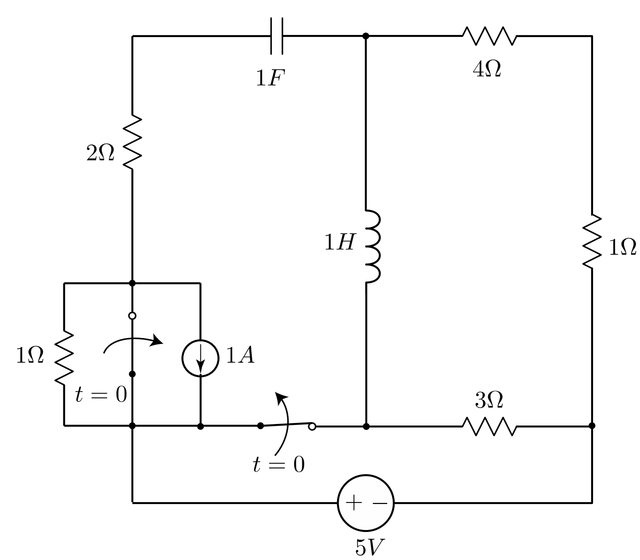


Table of Laplace Transforms

$f(t)$ for $t \geq 0$	$\mathcal{L}(s)$
$u(t)$	$\frac{1}{s}$
$e^{-at}u(t)$	$\frac{1}{s+a}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$ $(n = 0, 1, ..)$
$\sin(\omega t)u(t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)u(t)$	$\frac{s}{s^2+\omega^2}$
$e^{-at}\sin(\omega t)u(t)$	$\frac{\omega}{(s+a)^2+\omega^2}$
$e^{-at}\cos(\omega t)u(t)$	$\frac{s+a}{(s+a)^2+\omega^2}$
$e^{-at}\left[C\cos(\omega t) + \frac{D-aC}{\omega}\sin(\omega t)\right]u(t)$	$\frac{Cs+D}{(s+a)^2+\omega^2}$