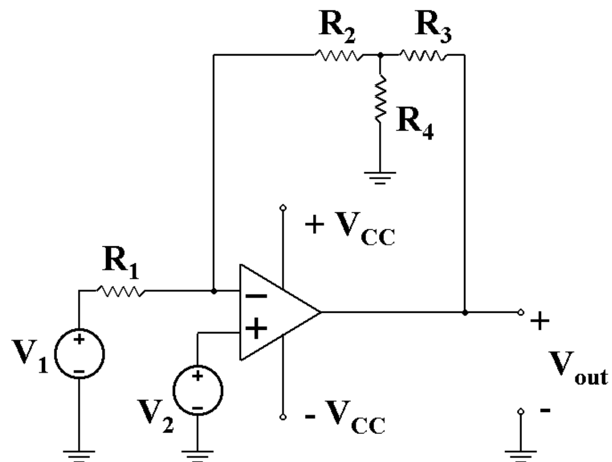
Midterm exam 2

Problem 1

Consider the amplifier circuit shown on the diagram:

Part 1 (5 points)
Assume an ideal op amp. Derive the algebraic expression for the output voltage V_{out}.



Part 2 (5 points)
Consider the following resistances:

$R_1 = 10\ k\Omega$
$R_2 = 20\ k\Omega$
$R_3 = 30\ k\Omega$
$R_4 = 40\ k\Omega.$

Calculate the output voltage V_{out}.

Part 3 (5 points)
Consider the following saturation conditions: $+V_{CC} = +12\ V$; $-V_{CC} = -12\ V$; assume that the saturation occurs if $V_{out} \geq +V_{CC}$ and/or $V_{out} \leq -V_{CC}$.
Use the resistances listed in Part 2 above. Assume $V_1 = 6\ V$ and $V_2 = 6\ V$. Determine whether the output signal is saturated.

Part 4 (5 points)
Consider the saturation conditions listed in Part 3 above and assume $V_1 = 6\ V$. Determine the range of V_2 such that the output signal is not saturated.

Write your answers in the box below:

(Part 1) Your algebraic expression for the output voltage is:

$V_{out} =$

(Part 2) The output voltage equals: ______________________________ (units!)

(Part 3) The output signal is saturated (circle one): **True** **False**

(Part 4) To avoid saturation, we need __________ $\leq V_2 \leq$ ___________ (units!)

Your solution should justify your answers.

Consider the circuit with the following elements:

$V_{S1} = 16\ V$

$V_{S2} = -12\ V$ *(notice the negative sign!)*

$R_1 = 20\ \Omega$

$R_2 = 60\ \Omega$

$R_3 = 5\ \Omega$

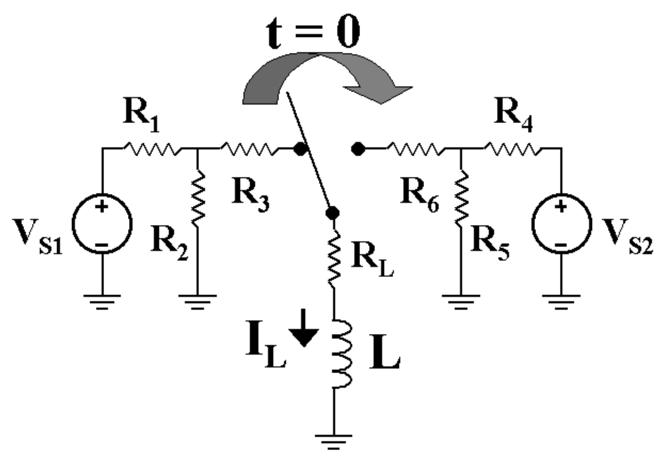
$R_4 = 6\ \Omega$

$R_5 = 6\ \Omega$

$R_6 = 7\ \Omega$

$L = 150\ mH$

$R_L = 20\ \Omega$



Assume DC steady-state conditions at $t < 0$.

Write and solve the differential equation for the inductor current i_L as a function of time at $t > 0$. Sketch the inductor current on the grid below.

Find the time t_0 when $i_L = 0$ ($\pm$ 10 mA).

Determine the range of resistances R_6 to ensure the time constant $\tau < 1$ msec.

Your differential equation for the inductor current:

The solution of your differential equation is:

Your <u>numerical</u> answers (remember the units):

The inductor current $i_{L,\,0}$ at $t = 0$ equals ____________________

The inductor current $i_{L,\infty}$ at $t \to \infty$ equals ____________________

The $i_{L,\infty}$ value will be reached within ≈ 1% at $t = 5\tau =$ ____________________

The time t_0 when $i_L = 0$ ($\pm$ 10 mA) equals ____________________

To ensure $\tau < 1$ msec, R_6 should be ____________________

Your solution should justify your answers.

Workspace for Problem 1

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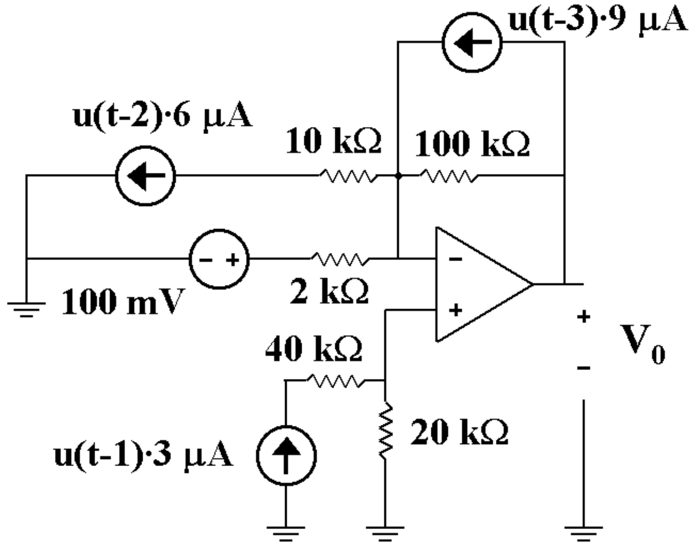
Problem 2

Consider the circuit with an ideal op amp:

The source currents are determined by step functions, where time t is in seconds.

Calculate the output voltage V_0 .



Your answers (remember the units):
The output voltage at time $t = 0.5\ sec$ equals ____________________
The output voltage at time $t = 1.5\ sec$ equals ____________________
The output voltage at time $t = 2.5\ sec$ equals ____________________
The output voltage at time $t = 3.5\ sec$ equals ____________________

Your solution should justify your answers.

Workspace for Problem 2

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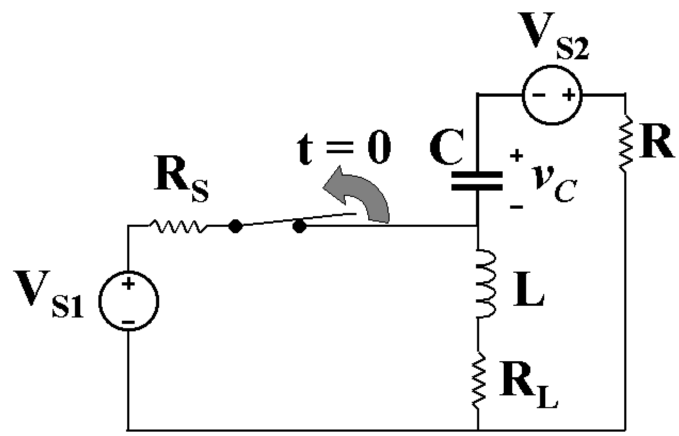
Problem 3

Consider the circuit with the following parameters:

$V_{S1} = 12\ V$
$V_{S2} = 10\ V$
$R_S = 25\ \Omega$
$R = 100\ \Omega$
$C = 32\ nF$
$L = 500\ \mu H$
$R_L = 50\ \Omega$



Assume DC steady-state conditions at $t < 0$.

Write and solve the differential equation for the capacitor voltage v_C as a function of time at $t > 0$.

Find the resistance R to ensure the critically damped response of the circuit.

Your differential equation for the capacitor voltage:

The solution of your differential equation is:

Your numerical answers (remember the units):

The capacitor voltage $v_{C,\,0}$ at $t = 0$ equals ____________________

The capacitor voltage $v_{C,\infty}$ at $t \to \infty$ equals ____________________

If you obtained the under-damped response, write K_1 _________ and K_2 __________

α ____________________ and ω ____________________

If you obtained the over-damped response, write K_1 _________ and K_2 __________

s_1 ____________________ and s_2 ____________________

The resistance R that ensures the critically damped response equals __________

Your solution should justify your answers.

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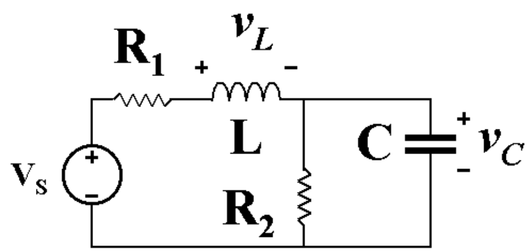
Problem 4

Derive the differential equation for the capacitor voltage v_C in this circuit.

Do NOT solve the differential equation, but determine the type of response (under-damped, over-damped) for the following parameters:



$V_S = u(t) \cdot 10\ V$

$R_1 = 30\ \Omega$

$R_2 = 10\ \Omega$

$C = 1\ \mu F$

$L = 1\ mH$

If you obtained the under-damped response, calculate α and ω.

If you obtained the over-damped response, calculate s_1 and s_2.

Calculate the power supplied by the source at $t = 0_+$ and at $t \to \infty$.

Determine the inductor voltage v_L at $t = 0_+$.

Determine the inductance L, which ensures the critically damped response.

Your differential equation (with coefficients in the algebraic form) is:

For the given circuit parameters, the solution of your differential equation has the form:

Your numerical answers (remember the units):

If you obtained the under-damped response, write

α ____________________________ and ω ______________________________

If you obtained the over-damped response, write

s_1 ____________________________ and s_2 ______________________________

The power supplied by the source at $t = 0_+$ equals ______________________________

The power supplied by the source at $t \to \infty$ equals _____________________________

The inductor voltage v_L at $t = 0_+$ equals ______________________________________

The critical damping is ensured by inductance L =________________________________

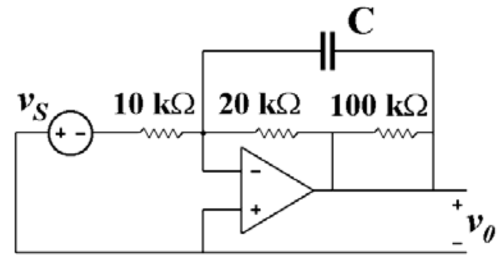
Your solution should justify your answers.

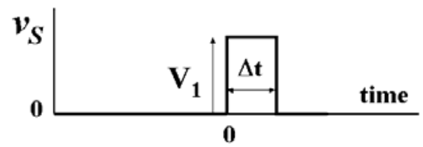
Midterm exam 2

Problem 5

The voltage source produces a rectangular pulse that begins at $t = 0$ and has the amplitude V_1 and duration Δt. *(Notice the polarity of the source.)*

Assume an ideal op amp and DC steady-state conditions at $t < 0$. Derive the differential equation for the output voltage v_0 for $t > 0$.





Solve your differential equation for the following parameters:

$V_1 = 4\ V$

$\Delta t = 1\ msec$

$C = 1\ \mu F$

Calculate the output voltage $v_{0,\ \infty}$, which would eventually be reached under DC steady-state conditions if $\Delta t \rightarrow \infty$ and $t \rightarrow \infty$.

Determine the maximal output voltage $v_{0,\ max}$, which is reached for $\Delta t = 1\ msec.$

For $\Delta t = 1\ msec,$ determine the range of capacitance C to ensure $v_{0,\ max} > 3.5\ V.$

If you think that $v_{0,\ max}$ never reaches $3.5\ V$, explain.

Your differential equation for the output voltage v_0 is:

The solution of your differential equation for v_0, for the given parameters, is:

Your numerical answers (remember the units):

At $t = 0$, the output voltage v_0 equals ______________________________________

If $\Delta t \rightarrow \infty$ and $t \rightarrow \infty$, output voltage eventually reaches $v_{0,\ \infty} =$ ____________

For the given parameters, the time constant τ equals __________________________

the ratio ($\Delta t / \tau$) equals __________________________

For Δt = 1 msec, the maximal output voltage $v_{0,\ max}$ equals ___________________

For Δt = 1 msec, $v_{0,\ max}$ exceeds 3.5 V if the ratio ($\Delta t / \tau$) is _________________ ,

the time constant τ is ______________ and the capacitance is ________________

Your solution should justify your answers.