Homework 3

This homework is due on Friday, February 10, 2023 at 11:59PM. Self-grades and HW Resubmissions are due the following Friday, February 17, 2023 at 11:59PM.

1. **NAND Circuit**

Let us consider a NAND logic gate. This circuit implements the boolean function $\overline{(A \cdot B)}$. The $\cdot$ stands for the AND operation, and the $\overline{}$ stands for NOT; combining them, we get NAND!

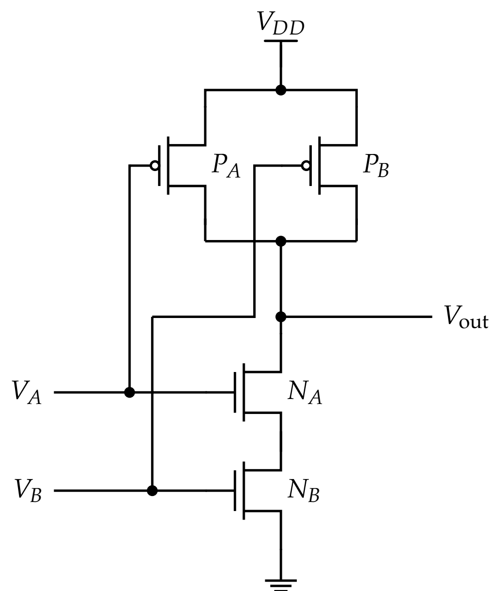


Figure 1: NAND gate transistor-level implementation.

V_{tn} and V_{tp} are the threshold voltages for the NMOS and PMOS transistors, respectively. Assume that $V_{DD} > V_{tn}, |V_{tp}| > 0$.

(a) **Label the gate, source, and drain nodes for the NMOS and PMOS transistors (please redraw the circuit).**

(b) If $V_A = V_{DD}$ and $V_B = V_{DD}$, **which transistors act like open switches? Which transistors act like closed switches? What is V_{out}?**

(c) **If $V_A = 0V$ and $V_B = V_{DD}$, what is V_{out}?**

(d) **If $V_A = V_{DD}$ and $V_B = 0V$, what is V_{out}?**

(e) **If $V_A = 0V$ and $V_B = 0V$, what is V_{out}?**

(f) **Write out the truth table for this circuit.**

V_A	V_B	V_{out}
0	0	
0	V_{DD}	
V_{DD}	0	
V_{DD}	V_{DD}	

2. Hambley P4.61

A DC source is connected to a series RLC circuit by a switch that closes at $t = 0$, as shown in Figure 2. The initial conditions are $i(0+) = 0$ and $v_C(0+) = 25$. Write the differential equation for $v_C(t)$. Solve for $v_C(t)$ given that $R = 80\,\Omega$.

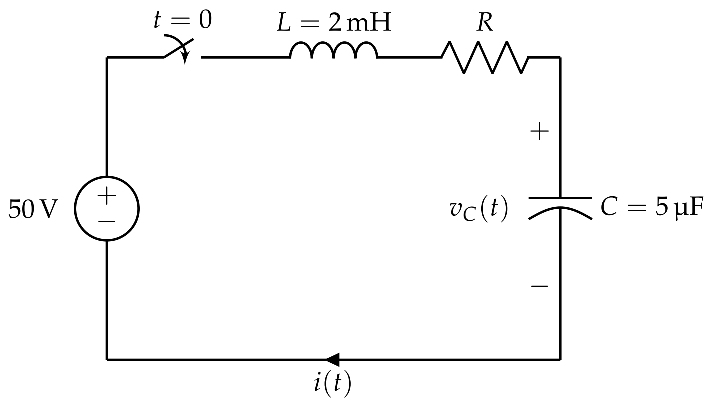


Figure 2: P4.61

3. Hambley P4.64

Consider the circuit shown in Figure 3, with $R = 25\,\Omega$.

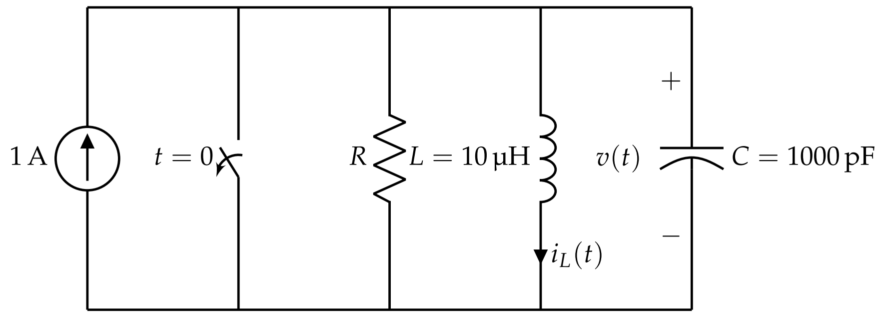


Figure 3: P4.64

(a) Compute the undamped resonant frequency, ω_0, and α.

(b) The initial conditions are $v(0+) = 0$ and $i_L(0+) = 0$. Show that this requires $v'(0+) = 10^9\,\frac{\text{V}}{\text{s}}$.

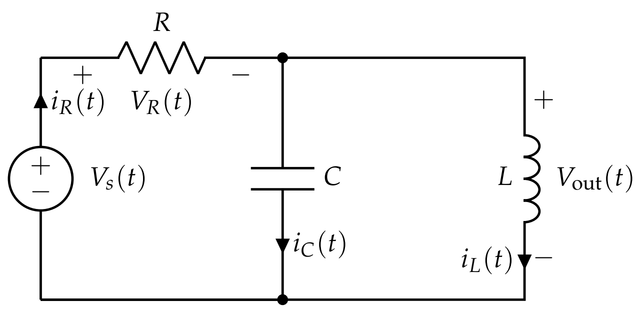
(c) Find the particular solution for $v(t)$.

(d) Find the general solution for $v(t)$, including the numerical values of all parameters.

4. Phasor-Domain Circuit Analysis

The analysis techniques you learned previously in 16A for resistive circuits are equally applicable for analyzing circuits driven by sinusoidal inputs in the phasor domain. In this problem, we will walk you through the steps with a concrete example.

Consider the following circuit where the input voltage is sinusoidal. The end goal of our analysis is to find an equation for $V_{\text{out}}(t)$.



The components in this circuit are given by:

$$V_s(t) = 10\sqrt{2}\cos\left(100t - \frac{\pi}{4}\right) \tag{1}$$

$$R = 5\,\Omega \tag{2}$$

$$L = 50\,\text{mH} \tag{3}$$

$$C = 2\,\text{mF} \tag{4}$$

(a) **Give the amplitude V_0, input frequency ω, and phase ϕ of the input voltage V_s.**

(b) Transform the circuit into the phasor domain. **What are the impedances of the resistor, capacitor, and inductor? What is the phasor $\widetilde{V}_S$ of the input voltage $V_s(t)$?**

(c) Use the circuit equations to **solve for $\widetilde{V}_{\text{out}}$**, the phasor representing the output voltage.

5. Hambley P6.55

Consider the circuit shown in Figure 4. The input signal is given by

$$v_{\text{in}}(t) = 5 + 5\cos(2000\pi t) \tag{5}$$

Find an expression for the output $v_{\text{out}}(t)$ in steady-state conditions.

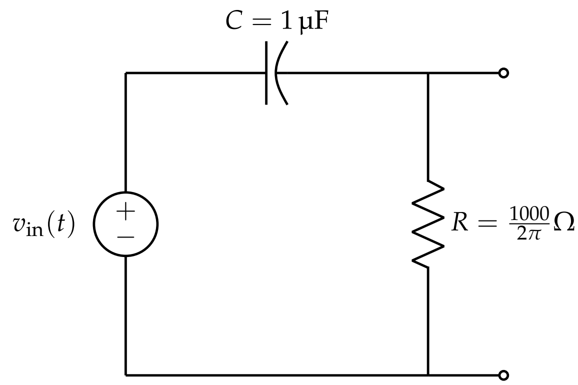


Figure 4: P6.55

(HINT: Use superposition. That is, find $v_{\text{out},1}(t)$ which is the output voltage if the input is $v_{\text{in},1}(t) = 5$, and then find $v_{\text{out},2}(t)$ which is the output voltage if the input is $v_{\text{in},2}(t) = 5\cos(2000\pi t)$. What is $v_{\text{out}}(t)$ in terms of $v_{\text{out},1}(t)$ and $v_{\text{out},2}(t)$?)

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