Midterm Exam 2

Instructor: Professor George Anwar

11/18/2024

5 Questions, 25 Hours

Version A

Name: ___________________________

Student ID: ___________________________

Please include units in final answers and box them unless otherwise specified.
No credit is given if no work is shown.

Instructions

- Download the PDF. Show your work either on an electronic device or paper. Submit your work as a PDF on Gradescope.
- Read and sign the statement of academic integrity in Section I.
- **Box your final answer.** If graders cannot identify the final answer, it could be marked incorrect.
- Ensure that you assign problems correctly to the page containing the work and answer on Gradescope.
- Showing correct work is crucial. Even if your final answer is accurate, failure to display correct work will result in a point deduction. Emphasis will be placed more on the process rather than the final answer.
- For series questions getting the previous answer wrong will affect the next problem so take time to double check your answer. Having wrong answer will lead to point loss.
- **Violation of the honor code will result in the following consequences:**
  - You will receive a zero for the exam.
  - Potential reporting to school authorities.

1 Code of Conduct

0 points

Statement of Academic Integrity

- I will adhere to the Berkeley Honor Code: specifically, as a member of the UC Berkeley community, I act with honesty, integrity, and respect for others.
- If I have a question of clarification about what is being asked in any question below,
I will e-mail **ganwar@berkeley.edu** or upload private post on Ed with my question.
- I will complete this assignment entirely on my own, and will not discuss its contents or any related concepts with any fellow ME100 student or other person between 4pm PDT on 11/18/2024 and 5pm PDT on 11/19/2024, other than to ask clarification questions directly of the course staff.
- While I am working on the assignment, I may access materials on the Fall 2024 ME100 bCourses site. I will not post questions from this assignment on forums, including Chegg.
- I understand that my final answers to this assignment must be uploaded to Gradescope and saved by 5pm PDT on 11/18/2024. Late submission would lead to point deduction for any reason.
- **I will check my email, announcement, and ed post during the exam for any update on the exam.**
- Calculators, including those on computers, are allowed. However, using circuit simulations or other online platforms will be deemed as showing no work. Even when utilizing a calculator, you must detail every step leading to its use. Inefficient or skipped steps can lead to point deductions. Ensure you attempt all questions.
- **I hereby acknowledge that I have read and understood the above instructions. I agree that any failure on my part to adhere to these instructions, which may result in a penalty, is solely my responsibility and fault.**

Signature: ______________________________ Date: ____________________

2 Conceptual Questions

20 points

For each of the following statements, mark whether it is True or False. Provide a brief explanation for your answer. Each correct True/False answer will earn two point, while a right explanation will earn two points.

1. **5 Points**

An operational amplifier (op-amp) in its ideal configuration always provides infinite gain with zero input offset.

True / False Explanation: ____

2. **5 Points**

Combinatorial logic circuits respond instantaneously to input changes without any propagation delay.

True / False Explanation: ____

3. **5 Points**

In Boolean algebra, the expression $\left(\overline{A}B+C\right)\left(A+\overline{BC}\right)+ABC$ is equivalent to $AB+C$.

True / False Explanation: ____

4. **5 Points**

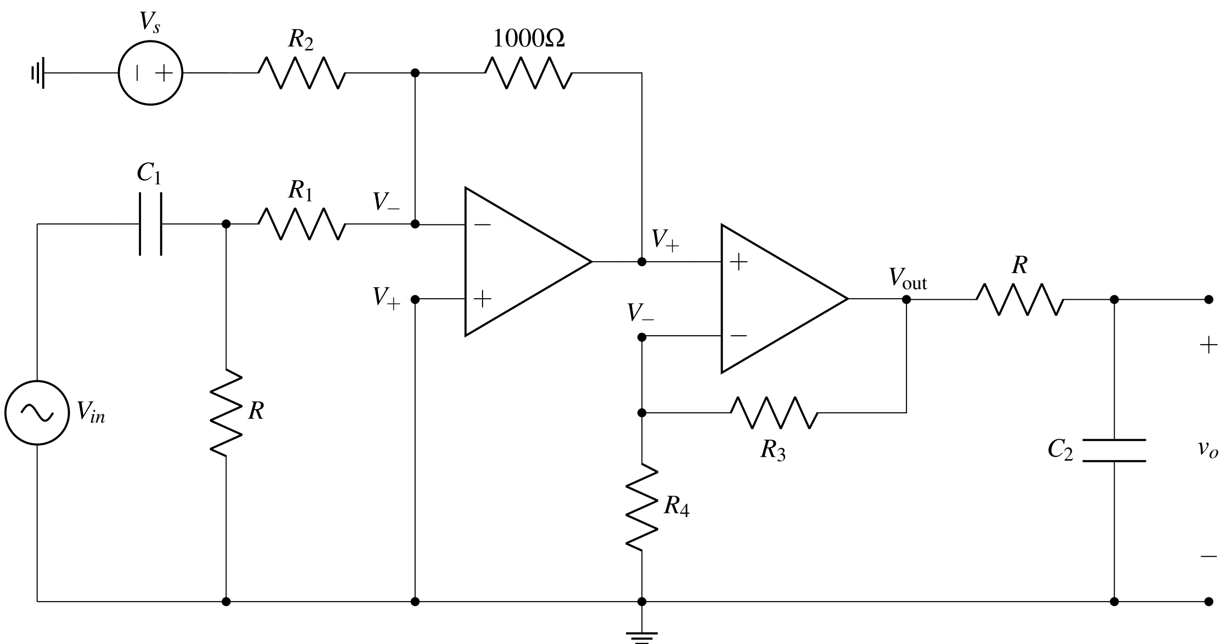
In a non-inverting op-amp configuration, the closed-loop gain is always greater than or equal to 1.

True / False Explanation: ____

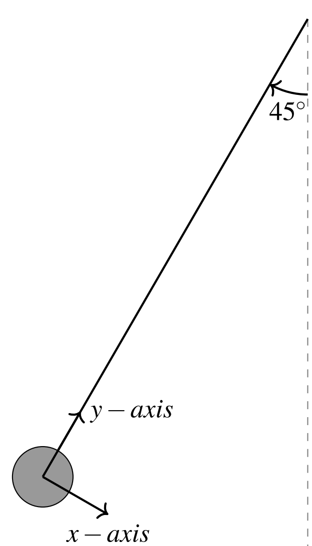
3 Filters and Op-Amp

30 points

Elliot is trying to make an ideal simple pendulum (with a mass M attached to a mass rod with length L). There is an accelerometer attached to the mass of the simple pendulum. To maximize the signal output, he developed the following circuit, assuming the op-amp operates as an ideal op-amp.



The voltage source in the circuit above V_{in} is a representation of the reading of the accelerometer due to the pendulum's motion. The pendulum shown in the figure below starts at an initial angle of 45° from the vertical. It is an ideal pendulum, meaning no energy is lost due to friction or air resistance. An accelerometer is attached to the gray ball at the end of the pendulum, and measures the (x-axis) acceleration of the ball during its motion. The natural frequency of the pendulum is given to be 1 Hz. Assuming the pendulum moves in simple harmonic motion. The accelerometer outputs $0V$ for a reading of $-1G$, and outputs $+2V$ at $+1G$. It is connected to an ESP32 GPIO pin, which has a maximum operating voltage of $3V$. X and Y axis is relative to the accelerometer. Meaning as the accelerometer moves the coordinate system move along with it. Accelerometer is measuring the center of mass of the bob.



3.1

15 points

The natural frequency of the pendulum is given to be 1 Hz. Explain the values you chose for the variables C_1, C_2, R. Follow the rule of thumb discussed in class in regard of high-pass and low-pass filter.

C_1: ____________ C_2: ____________ R: ____________

3.2

15 points

Now choose the values for V_s, R_1, R_2, R_3, R_4 that will allow maximum output signal V_o to the ESP32 based on the accelerometer reading V_{in}. Explain why you chose those values. (Hint: simple harmonic motion can be represented as either a sine wave or a cosine wave)

R_1: ____________ R_2: ____________ R_3: ____________ R_4: ____________

V_s: ____________

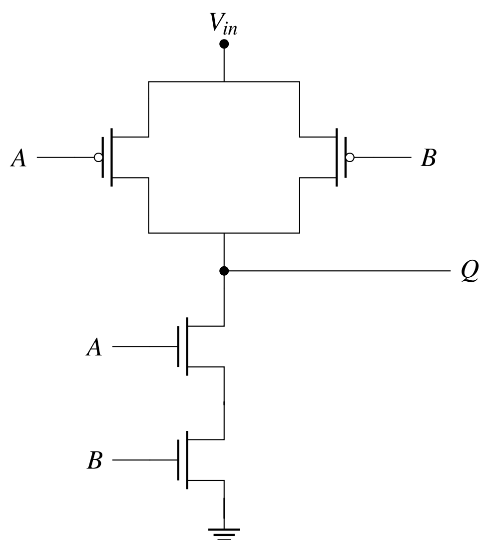
4 Transistor Circuits and Boolean Algebra

30 points

4.1 Identifying a Logic Gate

10 points

Consider the transistor circuit shown below containing NMOS and PMOS transistors. There are two binary signals *A* and *B* that control the various transistors, producing the output *Q*.



Complete the following truth table for the transistor circuit.

A	*B*	*Q*
0	0	
0	1	
1	0	
1	1	

What logic gate does the transistor circuit produce?

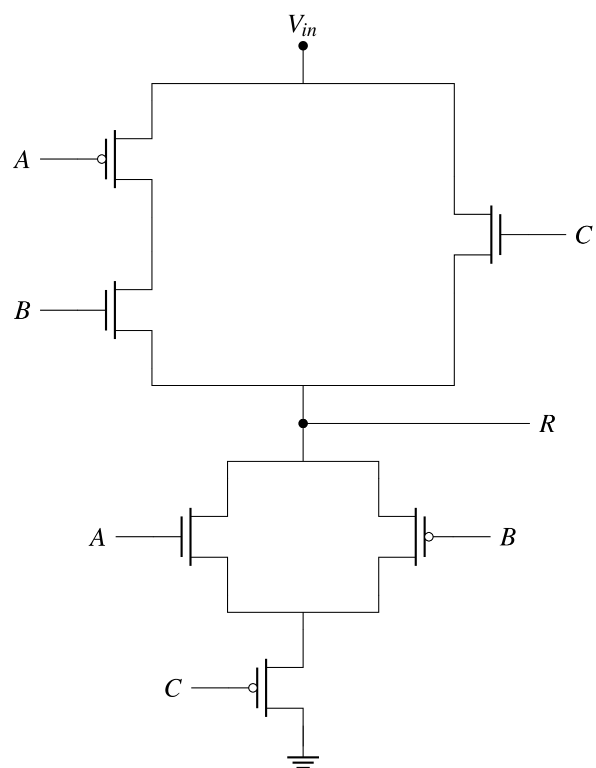
Logic Gate: ____________

4.2 Forming a Boolean Expression

10 points

Now consider a more complex transistor circuit that's controlled by three binary signals *A*, *B*, and *C* to produce the output *R*.

What is the Boolean expression that this complex transistor circuit realizes?



Boolean Expression: R = ____

Complete the following truth table for the complex transistor circuit.

A	*B*	*C*	R
0	0	0	
0	0	1	
0	1	0	
0	1	1	
1	0	0	
1	0	1	
1	1	0	
1	1	1	

4.3 Validating NAND Gate Construction

10 points

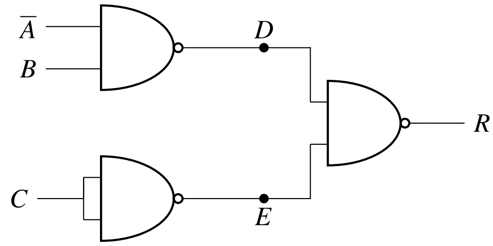
The basic gates in logic circuits are the AND, OR, and NOT gates. These are considered the fundamental building blocks for constructing more complex logic circuits as the other logic gate (like NAND, NOR, XOR, and XNOR) are derived from the basic gates. Chip manufacturers primarily use NAND gates because other logic gates (AND, OR, NOT, XOR, etc.) can be constructed using only NAND gates. As a result they are extremely versatile for chip manufacturers.

Two Berkeley students constructed different NAND gate circuits to fit the Boolean expression that the complex transistor circuit realized in question 4.2.

Which construction matches the Boolean expression from Question 4.2? Construction A / Construction B

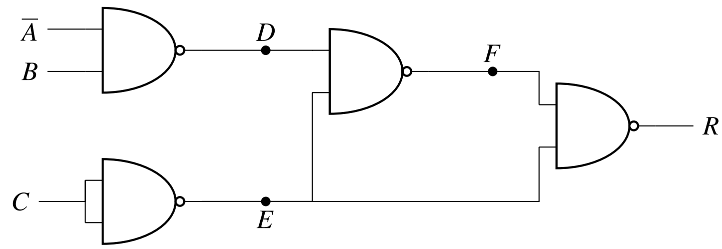
Each construction has an associated truth table for showing work.

Construction A



A	B	C	D	E	R
0	0	0			
0	0	1			
0	1	0			
0	1	1			
1	0	0			
1	0	1			
1	1	0			
1	1	1			

Construction B



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

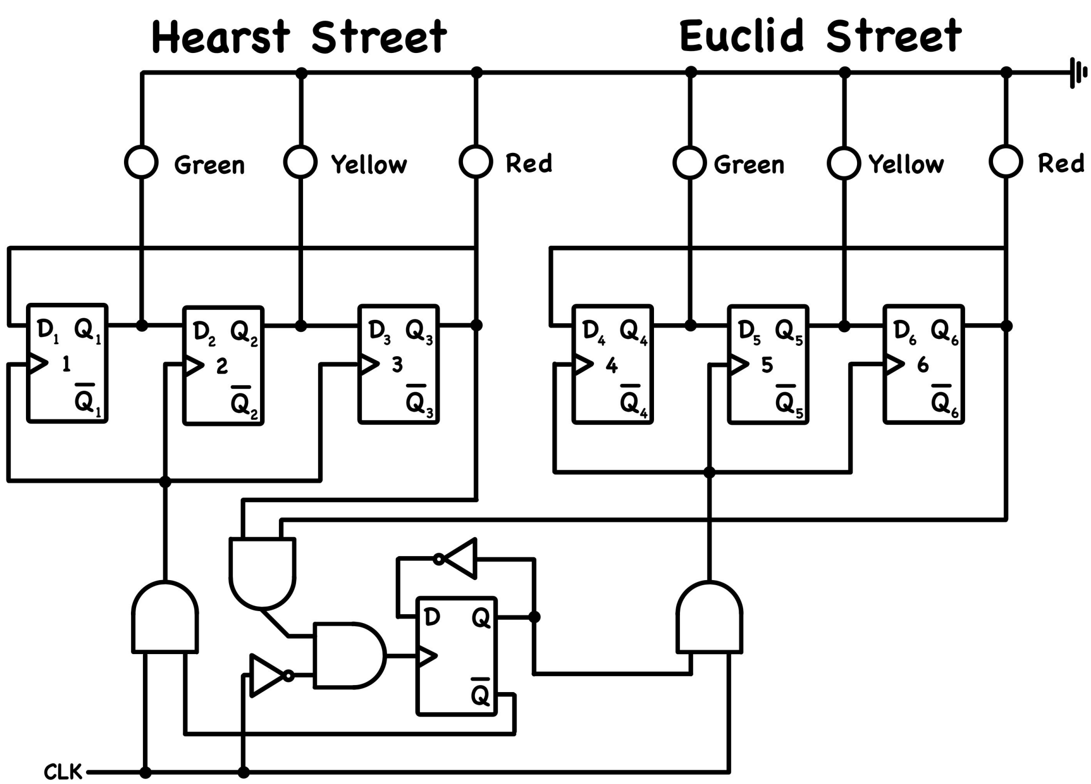
5 Digital Circuits and Sequential Logic

20 points

5.1 SAFE Traffic Light

8 points

After finishing the ME100 course Elliot got hired by the school to build a SAFE traffic light on the intersection of Hearst street and Euclid street. Make a state diagram for (Q_1, Q_2, Q_3, Q_4, Q_5, Q_6). Q_1 is the Q output of the D flip flop labeled 1 located on the most left. Start from the state (0, 0, 1, 0, 0, 1).



5.2

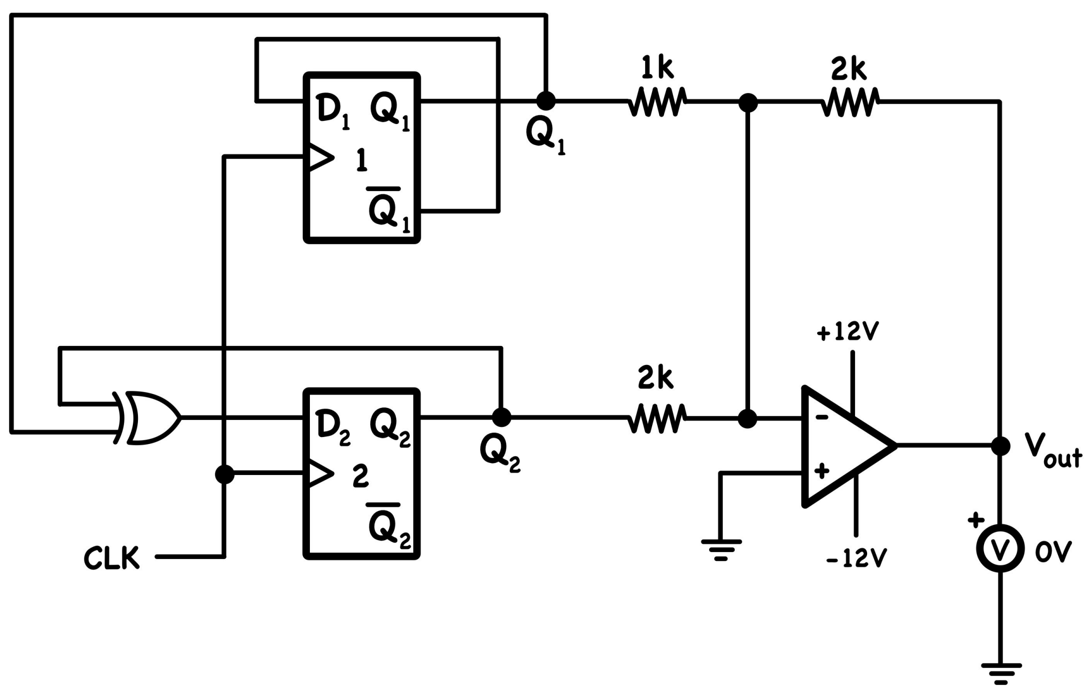
2 points

Do you think Elliot did a good jobs on making a SAFE traffic light? Briefly explain your reasoning.

5.3 Digital to Analog

10 points

After learning how Digital circuit works Elliot is now working on a project of converting a digital signal to an analog signal. Draw a state diagram as well in a format of (Q_1, Q_2, V_{out}). Your state diagram should look like (1, 0, 5V). Our digital high is +5V.



Additional Work for Question #

Additional Work for Question #