NAME:_____ **HUID:**_____.

THE QUIZ

Engineering Sciences 50
Harvard School of Engineering and Applied Sciences

Instructors: Evelyn Hu & Marko Loncar April 17, 2013

There are 7 questions worth of total of 75 points (+ 4 bonus points) and 1 Bonus question worth of total of 15 points.

You have 75 minutes to complete the quiz. Unjustified answers receive little credit, so use the space provided to show all work.

Good luck! ☺

1	2	3	4	5	6	7	B1	Σ

Question 1: Easy Circuits (8 points)

a) **(4 points)** For the circuit shown in Figure 1.1, find the expression for the *equivalent resistance* R_{eq} seen by the voltage source V_S so that circuit can be simplified as shown in Figure 1.2.

b) (**2 points**) Using the information from part a) find the power generated by the voltage source V_S and power dissipated by resistor R_1.
You can assume that $R_1=R_2=R_3=R_4=R_5=2\Omega$, and $V_S=16V$.

c) **(2 points)** What is the total power dissipated by ALL resistors together?
(Hint: this can be done without finding all currents and voltages for all resistors ☺)

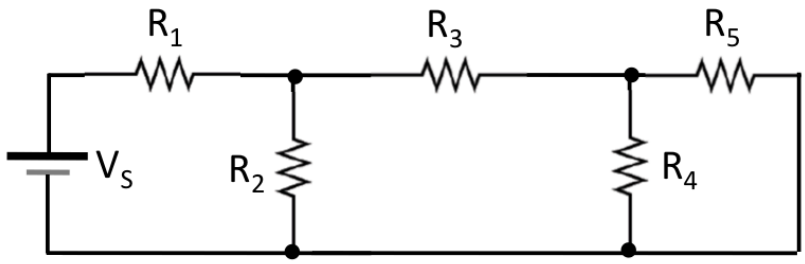


Figure 1.1

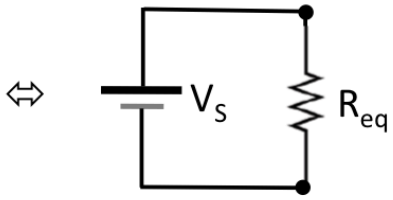
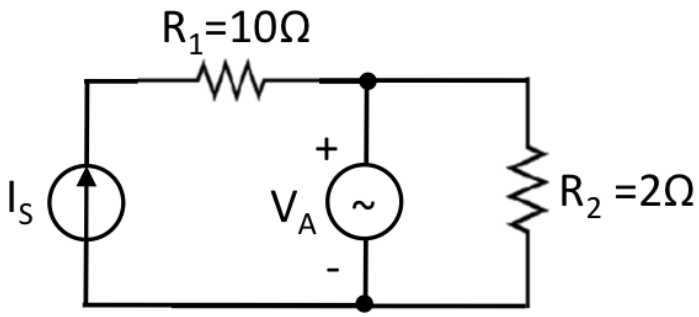


Figure 1.2

Question 2: KVL, KCL & Ohm's Law (8 points)

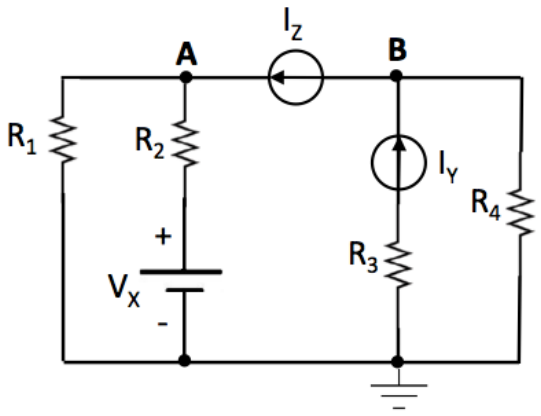
a) **(2 points)** In the circuit below, label all resistor currents and voltages consistent with the references used in the Ohm's Law. Also, label voltage-source current and current-source voltage.
b) (**4 points**) Solve the circuit, and find all resistor currents, current through the voltage source, and voltage on the current source using the reference directions you chose in a). *Note: KCL & KVL may be the most efficient way of doing this, though nodal voltages would certainly work as well.*
c) **(2 points)** What is the total power generated by both sources?

I_S=2A, V_A=10V



Question 3: Nodal Voltages (6 points)

For circuit shown below write the complete set of nodal voltages equations that can be used to find potentials (voltages) V_A and V_B with respect to ground. You do not need to solve the system of equations.



Question 4: Op Amp Analysis (8 points)

(Note: this is not hard! Do not panic! ☺).

Consider the Op Amp circuit shown below. Find V_{out} as a function of V_1 and V_2, (and resistor values) when:

a) **(4 points)** R_F=0 Ω

b) **(4 points)** R_F= ∞ Ω

(You can assume that the Op Amp is *powered* by 5V battery connected to its *positive bias* terminal and ground connected to its *negative bias* terminal, as shown in Figure 4.2)

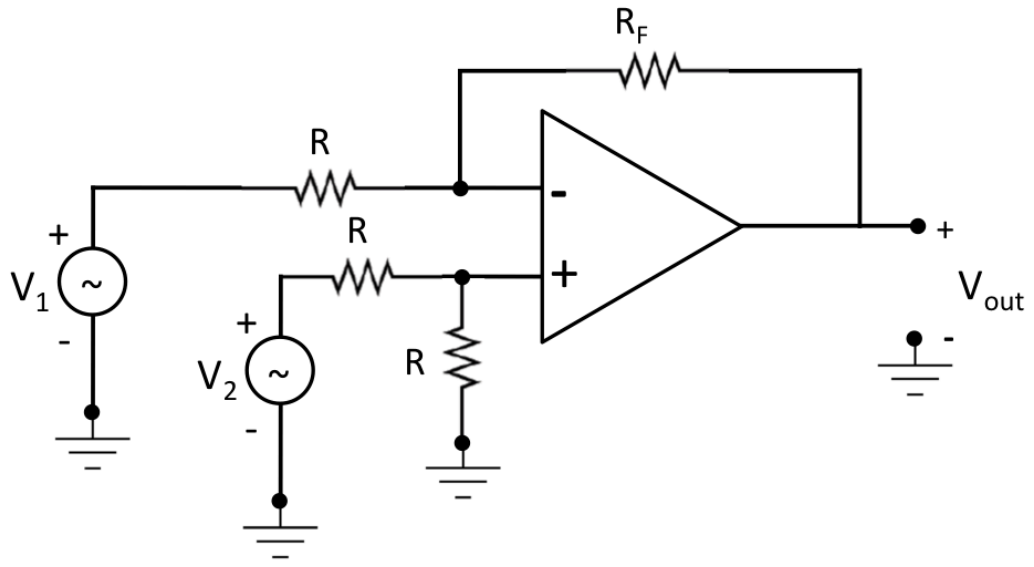


Figure 4.1

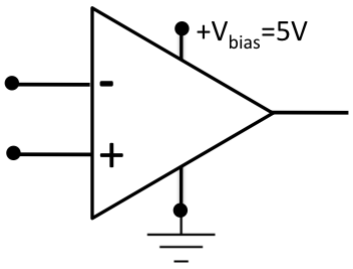


Figure 4.2

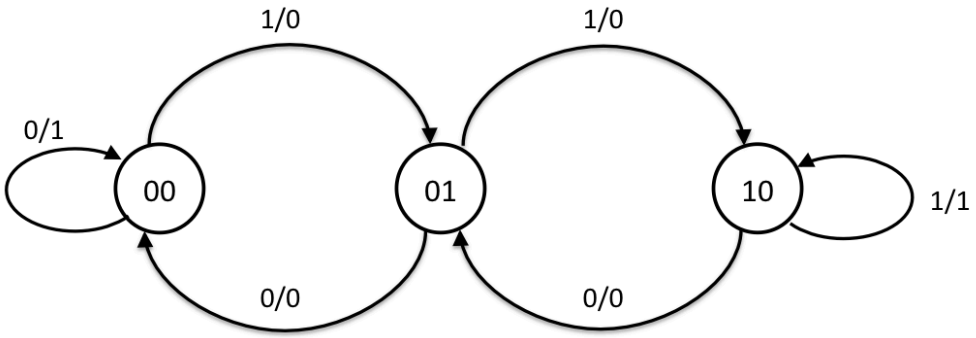
Question 5: Digital Logic Warm-Up (5 points)

a) **(2 points)** Simplify $Z = ABC + AB\overline{C} + \overline{A}BC + A\overline{B}\,\overline{C} + A\overline{B}C + \overline{A}B\overline{C}$
   Note: Fur full credit reduce to one two-input gate
b) **(3 points)** Using only 2-input NAND gate implement NOT, OR and AND gates

Question 6: Finite State Machine Implementation (20+4)

The diagram of a finite state machine is shown below:

a) **(6 points)** Using the state diagram, construct a truth table to describe the dependence of the 'next state' and outputs on the 'present state' and inputs.
b) **(3 points)** Find the logic expressions for 'next state' and outputs.
c) **(3 points)** Simplify the logic equations found in c).
d) **(8 points)** Construct the finite state machine using flip flops of your own choice, and any number of logic gates with as many inputs as you wish. You have to implement the outputs as well.
e) **(BONUS 4 points):** modify your FSM to implement the LOAD function according to following rules: when LOAD signal is high, "10" is written into the FSM. When LOAD is low, FSM does its normal stuff.
    a. Provide synchronous solution: LOAD happens only when clock is active;
    b. Provide asynchronous solution: LOAD happens regardless of the clock;



Question 7: Finite State Machine (20 points)

Two people (A and B) are playing a question and answer game. This game is controlled by a judge. Each player is assigned one button and one LED. Judge, on the other hand has three buttons at his disposal: DISPLAY QUESTION, CORRECT, and INCORRECT. Following are the rules of the game:

- The game starts in WAIT state in which players are waiting for judge to display the question on a big screen. If players press their buttons before the question is displayed, the buttons are ignored and nothing happens.
- Once the judge presses the DISPLAY QUESTION button, the question is displayed, and the game is on.
- The first player who presses the button gets her/his LED turned on and gets to answer the question. Once first player presses his/her button, additional button pressings (from either player) are ignored and no action is taken.
- If the first player's answer is correct, judge presses CORRECT button, player's score is increased by one, player's LED is turned off, and the game returns to the first state (WAIT) where players wait for the judge to display next question.
- If the player's answer is incorrect, the judge presses INCORRECT button, player's score is decreased by one, players LED is turned off, and the game returns to the first state (WAIT) where players wait for the judge to display next question.
- if judge accidentally presses either CORRECT or INCORRECT buttons before the players have a chance to answer the question, those inputs are ignored, and no action is produced.
- The judge can press DISPLAY button only once during the game – in the "WAIT" state. If DISPLAY is pressed in any other state, this action is ignored and no output is produced.
- You also need to take into account "no input" situation: that is the case when no inputs are provided.

a) **(5 points)** Please identify the states, inputs and outputs of this machine
b) **(13 points)** Draw the finite state machine diagram
c) **(2 points)** How many flip-flops do you need to implement this FSM? How many input and out wires, assuming that both inputs and outputs are encoded.

Note: if anything in this FSM is undefined, please make your own assumptions, state them clearly, and proceed with them.

BONUS 1: Flip-Flops and Sequential Logic (15 points)

Consider the sequential logic circuit shown in Figure B1 below.

a) (**8 points**) In the area provided below show the outputs of Q_1, Q_0 as a function of time.
b) (**3 points)** What does this circuit do? That is, what does the combination of output wires Q_1 Q_0 encode?
c) **(4 points)** Now assume that CLK input is provided by the circuit shown in Figure B2, that is output of the Op Amp (point A) is connected to point C. Assume that someone is clapping in front of the microphone. When is LED going to turn on?

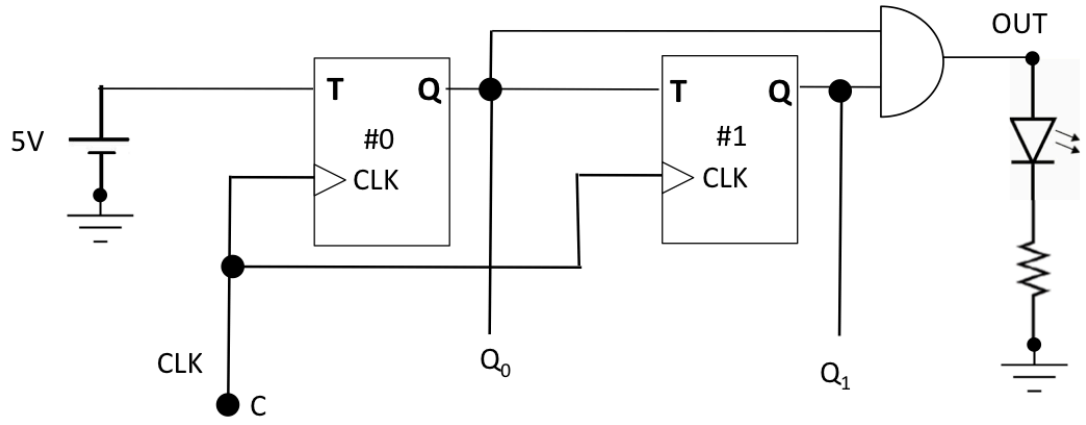
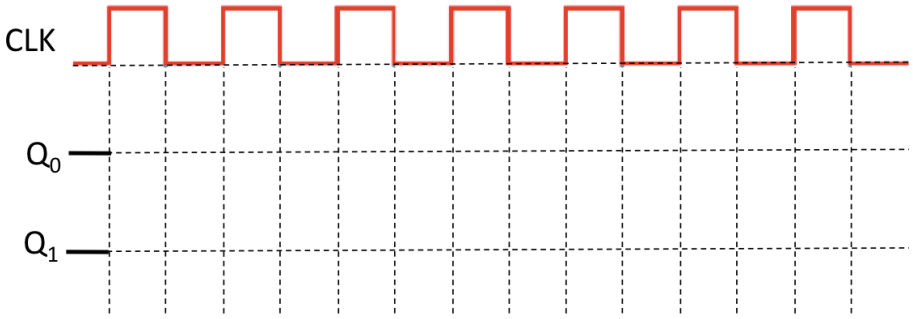


Figure B1



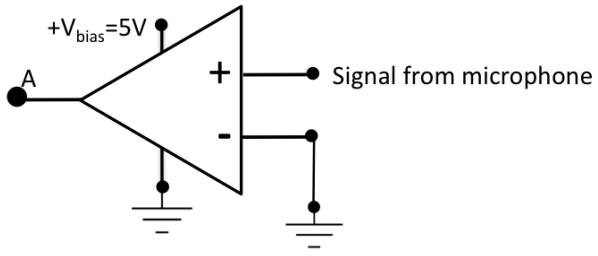


Figure B2