Course: **Electronic Circuits, VE 311, Summer 2023** **Midterm**

上 海 交 通 大 学 试 卷

2022 – 2023 Academic Year (Summer Term)

Name (Hanzi) _____ Name (Pinyin) _____

Student No. _____ Class No. _____

You have **100 minutes** to complete this midterm. Please write your answers in this booklet. Remember to write neatly and clearly, so your answers can be fully understood. Make sure that you explain your reasoning in as detailed a manner as possible.

- You **may not** use your electronic devices other than your calculator.
- **One double-sided** cheating-sheet can be used.
- Time is tight. If you don't know how to answer, come back to the question later.

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The University of Michigan – Shanghai Jiao Tong University Joint Institute trusts its students to participate in examinations in an honorable and respectful manner, following a spirit of fairness and equality. Cheating, seeking unfair advantage, and disturbing the safe and harmonious environment of examinations are contrary to the ethical principles of students of the Joint Institute. The letter and spirit of the Honor Code shall guide the behavior of students, faculty and all members of the Joint Institute. Therefore, I hereby declare that

(i) I will neither give nor receive unauthorized aid during the present examination, nor will I conceal any violations of the Honor Code by others or myself.

(ii) I confirm that I have read and understood the rules and procedures for the examination set out by SJTU. I will follow them to the best of my ability.

(iii) I understand that violating the rules and procedures for examinations or the Honor Code will lead to administrative and/or academic sanctions.

Date: _____

Signature: _____

Exercise	Points	Grader's Signature
1		
2		
3		
4		
Total		

1 [Easy] Job Interview (30 minutes)

Blue Tiger Analog is now hiring. Here are the job interview questions. Those are also the types of questions you would expect every year during the graduate program interviews. Keep your answers concise and right to the point.

1. Your boss says the output voltage readings dropped by 4 dB. how much is the voltage now if it was 1 volt V_{pp}?

2. What parameters do you need to know to calculate the velocity of a carrier in a P-type MOSFET?

3. What shall be the input and output impedance if I would like to amplify a current into a larger current. Draw the equivalent model.

4. Draw a PN junction. Draw the source, the direction of the current, the direction of the electric field in the depletion region, and the built-in potential when a tiny forward bias voltage is just applied to it.

5. What material would you dope to silicon to make it P type. How much would you dope it till you have a minority carrier density of 10^5 cm^{-3}.

6. The differential amplifier is applied two sets of input signals. One set of signal is $V_1 = 50mV$ and $V_2 = -50mV$. While the second set of signal is $V_1 = 1050\mu V$ and $V_2 = 950\mu V$. Watch out for the unit! If the CMRR of the amplifier is 100, find the percentage difference in the output voltage obtained for two sets of input signal.

7. (Medium) For a capacitor C, how will the equivalent capacitance change (for example, increase/ decrease/ unchanged/ first increase then decrease/ first decrease then increase) if there is an inductor L connected in series with it whose inductance increases from 0 to a small value? The frequency is lower than self-resonance frequency. Explain Why.

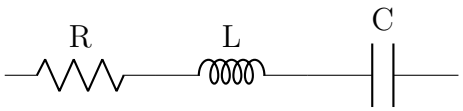


Figure 1: Simple RLC circuit

8. (No Points) Your boss is interested in the statistical relationship between attendance and academic performance and has asked you how many lectures you have attended in person. This question is purely for informational purposes and will not be assessed in any way.

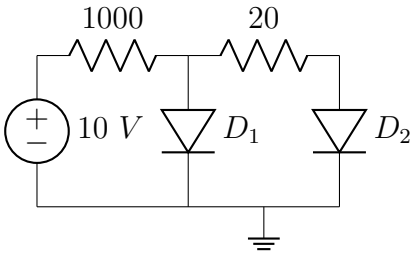
Question 1 Answer Sheet

2 [Easy] Diode Circuit (10 minutes)

There are two LED diodes that looks similar to each other. If it turns on, they both emit red light. Your boss only stocks two kinds of resistors (1 $K\Omega$ and 20 Ω). First, If we assume the Forward voltage turn-on voltage across diode D_1 and D_2 are 0.7 V and 0.4 V, respectively.

1. First, assume the diode(s) has no internal resistance. Determine which diode(s) is turned on (or both are off), and how much current approximate goes through the diode(s).

2. Now, the internal resistances of both Diodes are 10 Ω. Determine which diode(s) is turned on (or both are off), and how much current approximate goes through the diode(s).



Question 2 Answer Sheet

3 [Medium] BJT Circuit (30 minutes)

Blue Tiger Analog sells common-emitter amplifiers. Your boss is not happy with the gain of it. To deal with that, you invented a new type of amplifier by connecting two BJTs together (It is official name is the darlington pair) as follows. Assume the $\beta \gg 1$ for both BJTs, and we ignore early effect for simplicity. Assume both transistors are in Forward Active Region. Resistors used are large enough ($\gg 1\ K\Omega$), two marked resistors (R) have the same value.

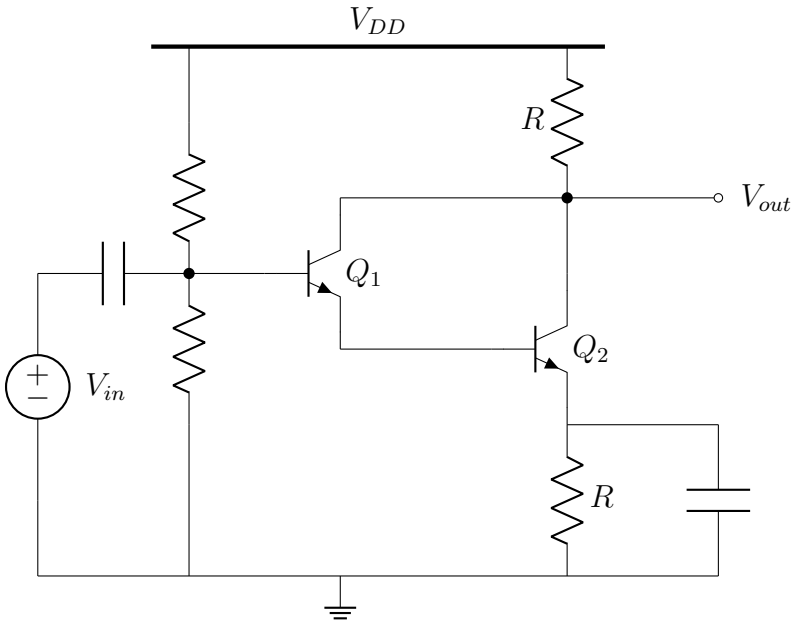


Figure 2: A Blue Tiger Pair

1. what is the relationship between g_{m1} and g_{m2}?
2. what is the relationship between $r_{\pi 1}$ and $r_{\pi 2}$?
3. Draw the small signal model for a high-frequency AC signal, assuming that the caps can be ignored.
4. Write the KCL for nodes (1) Emitter of Q_1. (2) Collector of Q_1.
5. (Hard) Write the expressions for the small signal gain. Assume $g_m r_{\pi 2} \gg 1$. How is the gain compared with a common emitter amplifier?

Question 3 Answer Sheet

4 [Easy] MOSFET Circuit (20 minutes)

Since resistors has too much of a process variation, you have proposed that Blue Tiger Analog should to use MOSFET circuits to generate the DC voltages the opamps require because a stacked NMOS pair is a good way of mitigating process variation. The circuit you use looks like to following. $\mu_n C_{ox} = 50\ \mu A/V^2$, and the width/length ratio of the transistors are indicated in the figure. The V_{TH0} for both transistors are of 1 V. $\lambda = 0$, $\gamma = 0.8V^{1/2}$, and $2\phi_F = 0.7V$.

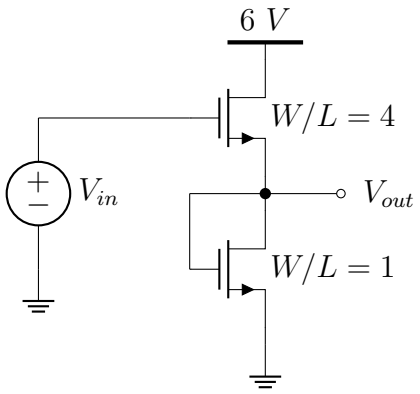


Figure 3: MOSFET

- To begin with, $V_{in} = 5\ V$. Assume the bulk of the top transistor is connected to its source, find the output voltage.
- Keep the bulk connection as it is, the input voltage is now increased to 9 V. Plot how the output changes with respect to the input voltage, What value does it asymptotically approach?
- Now, keep V_{in} and change the bulk connection of the top transistor. Assume the transistor can take a very negative bulk voltage without breakdown. What shall be the bulk voltage be to ensure top transistor is operating in saturation? If not possible, state why.

Question 4 Answer Sheet