别担心，好好复习，咱们尽可能地去拿下所有可以拿下的分数就好，不要急，也不要懊悔什么，按自己的节奏来读书就好！明确自己的赛道，便无怨无悔。加油吧！！！

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SEMESTER 1
2020-21

EE204FZ
Analogue Electronics 1

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Time allowed: 2 hours

Answer question ONE and any TWO other questions
Q1 is worth 34 marks. All others are worth 33 marks each.

Instructions

	Yes	No
Log Books Allowed	☐	X
Formula Tables Allowed*	X	☐
Other Allowed (*enter details)*	X	☐

General

- Formula Tables Allowed: Attached to the back of the exam paper
- Other Allowed: Non-programmable calculator

<u>QUESTION 1</u> (34-marks)

(a) Choose the correct answer. Each question carries equal 1 mark. (10-marks)

(1) When PN junction is in forward bias, by increasing the battery voltage

(A) circuit resistance increases
(B) current through PN junction increases
(C) current through PN junction decreases
(D) none of the above

(2) A PN junction is said to be forward-biased when

PP正—forward

(A) N-side is connected directly to the p-side
(B) junction is earthed
(C) the positive terminal of the battery is connected to P-side and the negative side to the N-side
(D) the positive terminal of the battery is connected to N-side and the negative side to the P-side

(3) MOSFET uses the electric field of

(A) gate capacitance to control the channel current.
(B) barrier potential of p-n junction to control the channel current.
(C) both (A) and (B)
(D) none of these

(4) The extremely high input impedance of a MOSFET is primarily due to the
(A) absence of its channel
(B) negative gate-source voltage
(C) depletion of electric current carriers
(D) extremely small leakage electric current of its gate capacitor

(5) The ratio of output current change against an input voltage change is called:
(A) Trans-conductance
(B) Siemens
(C) Resistivity
(D) Gain

(6) For which region of operation is a MOSFET represented by its small signal model?
(A) Triode
(B) Saturation
(C) Cut-off
(D) Independent of the region

(7) In a small signal equivalent model of an FET, what does $g_m V_{GS}$ stand for?

(A) A pure resistor
(B) Voltage controlled current source
(C) Current controlled current source
(D) Voltage controlled voltage source

(8) A noninverting closed-loop op-amp circuit generally has a gain factor:

(A) less than one
(B) greater than one
(C) of zero
(D) equal to one

同向大于一

(9) Op-amps used as high- and low-pass filter circuits employ which configuration?

(A) Noninverting
(B) Comparator
(C) Open-loop
(D) Inverting

(10) An ideal operational amplifier has

(A) infinite output impedance
(B) zero input impedance
(C) infinite bandwidth
(D) All of the above

(b) Describe the three regions of operation of a MOSFET. (3-marks)

(c) Define channel length modulation parameter (λ). Discuss, how the voltage-current characteristics of MOSFET are affected by λ value.

(3-marks)

(d) Differentiate between BJT and FET in terms of their structure, characteristics and applications.

unipolar bipolar

(4-marks)

Triode region: current is proportion to Vds

Active region: current will not increase dramatically and Vgs determine current

Cutoff region: there is no current in the channel

(e) For the MOSFET in figure 1(e), determine the region of operation. The threshold voltage of MOSFET is $V_{TP} = -0.4$ V. (3-marks)

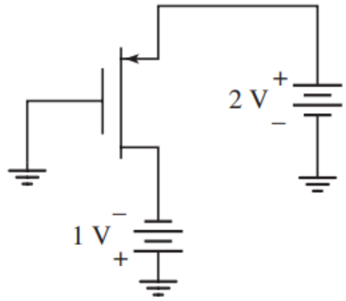

Figure 1(e)

(f) When analyzing an ideal operational amplifier, what assumptions are made? List them down.

(3-marks)

(g) With the help of a diagram, define what is the slew rate of an operational amplifier? (4-marks)

(h) The op-amp in the circuit shown in figure 1(h) is ideal except it has a finite open-loop gain. If $A_{od} = 104$ and $v_O = -2$ V, determine v_I.

(4-marks)

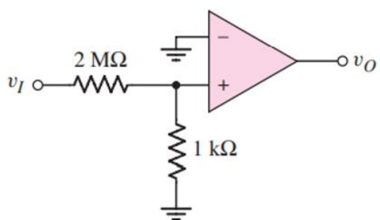

Figure 1(h)

<u>QUESTION 2</u> (33-marks)

(a) Describe what does it mean "the channel is pinched off" in MOSFET?

(3-marks)

(b) Consider the circuit in figure 2(b). Assume that V_{TN} = 1 V, K_n = 1.5 mA/V^2, and λ = 0. Sketch I_D versus V_{DS} for $0 \le V_{DS} \le$ 5V. Label and add numerical values on each the axis. Calculate and indicate V_{DS} *(Sat)* on the plot. Clearly indicate the saturation and Ohmic regions and the saturation current in the diagram.

(4-marks)

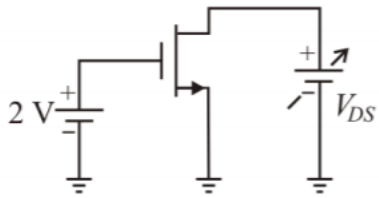

Figure 2(b)

(c) The transistor characteristics i_D versus v_{DS} for an NMOS device are shown in figure 2(c).

(i) Is this an enhancement-mode or depletion-mode device?

(1-marks)

(ii) Determine the values for K_n and V_{TN}.

(3-marks)

(iii) Determine $i_D(sat)$ for v_{GS} = 3.5 V and v_{GS} = 4.5 V.

(2-marks)

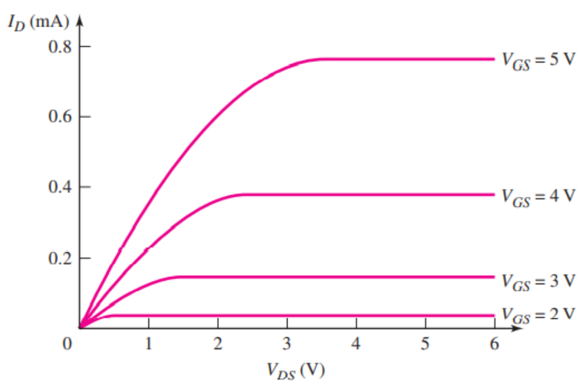

Figure 2(c)

(d) CMOS transistors are used for a logic gate as shown in figure 2(d). Identify the type of logic gate, draw the logic symbol and write truth table for the logic function.

(3-marks)

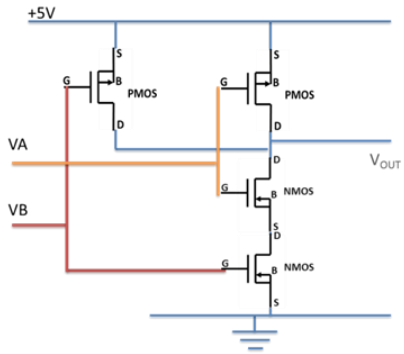

Figure 2(d)

(e) An NMOS device has parameters $V_{TN} = 0.8$ V, $L = 0.8\mu$m, and $k'_n = 120\mu A/V^2$. When the transistor is biased in the saturation region with $V_{GS} = 1.4$ V, the drain current is $I_D = 0.6$ mA.

(i) What is the channel width W? (3-marks)

(ii) Determine the drain current when $V_{DS} = 0.4$ V. (2-marks)

(iii) What value of V_{DS} puts the device at the edge of saturation?

(2-marks)

(f) Describe the operation of a transmission gate? Draw its symbol and discuss its applications.

(4-marks)

(g) The transistor in the circuit in figure 2(g) is used to turn the LED on and off. The transistor parameters are $V_{TN} = 0.6$ V, $k'_n = 80\mu A/V^2$, and $\lambda = 0$. The diode cut-in voltage is $V_\gamma = 1.6$ V. Design R_D and the transistor width-to-length ratio such that $I_D = 12$ mA for $V_I = 5$ V and $V_{DS} = 0.15$ V.

(6-marks)

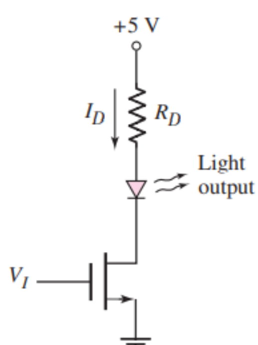

Figure 2(g)

<u>QUESTION 3</u> (33-marks)

(a) Define biasing and why is it important for a MOSFET amplifier? List down different ways of biasing.

(5-marks)

(b) Explain the impact of the Miller Effect on the importance of the gate-drain capacitance for a MOSFET amplifier?

(3-marks)

(c) What does the term “clipping” refer to and how should you select your biasing values such that you would minimise the risk of it occurring?

(3-marks)

(d) Draw the small signal equivalent circuit model for a MOSFET, label clearly model components and pin names.

(3-marks)

(e) For the NMOS common-source amplifier in figure 3(e), the transistor parameters are: V_{TN} = 0.8 V, Kn = 1 mA/V^2, and λ = 0. The circuit parameters are V_{DD} = 5 V, R_S = 1 kΩ, R_D = 4 kΩ, R_1 = 225 kΩ, and R_2 = 175 kΩ.

(i) Calculate the quiescent values I_{DQ} and V_{DSQ}.

(4-marks)

(ii) Determine the small-signal voltage gain for $R_L = \infty$.

(3-marks)

(iii) Determine the value of R_L that will reduce the small-signal voltage gain to 75 percent of the value found in part (ii).

(3-marks)

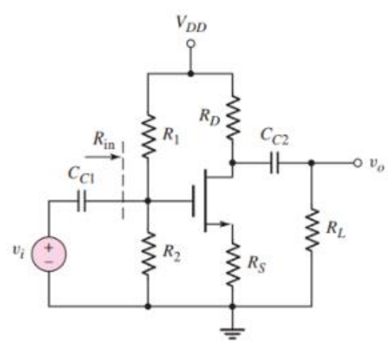

Figure 3(e)

(f) What is the function of decoupling capacitors in amplifier circuits? Discuss what size of capacitor is best for high frequency signals.

(3-marks)

(g) Consider the source-follower circuit in figure 3(g). The small-signal parameters of the transistor are g_m = 2 mA/V and r_o = 25 kΩ.

(i) Determine the open-circuit ($R_L = \infty$) voltage gain and output resistance.

(3-marks)

(ii) If R_L = 2 kΩ and the small-signal transistor parameters remain constant, determine the voltage gain.

(3-marks)

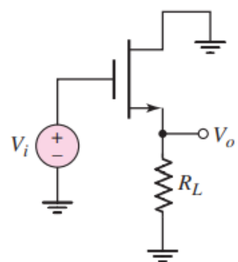

Figure 3(g)

Infinite input
Zero output
Infinite bandwidth

(b)
The gain is Big enough
The input impedance is high enough
The output impedance is low enough

QUESTION 4 (33-marks)

(a) List down the characteristics of ideal and practical operational amplifiers (Op-Amp).
(4-marks)

(b) What are the design factors must be considered when designing Op-Amp?
(3-marks)

(c) Using the op-amp circuit in figure 4(c), explain the concept of 'virtual earth'.
(3-marks)

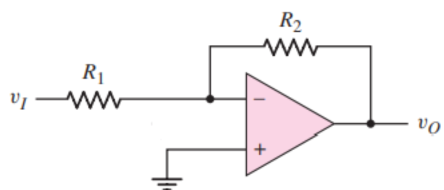

Figure 4(c)

(d) Consider the ideal noninverting Op-Amp circuit in figure 4(d).
(i) Derive the expression for v_O as a function of v_{I1} and v_{I2}.
(4-marks)

(iii) Find v_O for v_{I1} = 0.2 V and v_{I2} = 0.3 V.
(2-marks)

(iii) Find v_O for v_{I1} = +0.25 V and v_{I2} = −0.40 V.
(2-marks)

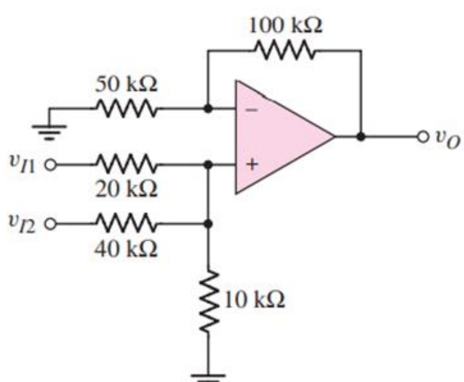

Figure 4(d)

(e) Explain why low output impedance in an Op-Amp is important?
(3-marks)

(f) The circuit in figure 4(f) is a first-order low-pass active filter.

(i) Show that the voltage transfer function is given by:

(4-marks)

$$A_v = -\frac{R_2}{R_1} \cdot \frac{1}{(1 + j\omega R_2 C_2)}$$

(ii) What is the voltage gain at dc(ω = 0)?

(2-marks)

(iii) At what frequency is the magnitude of the voltage gain a factor of $\sqrt{2}$ less that the dc value? (This is the −3 dB frequency.)

(2-marks)

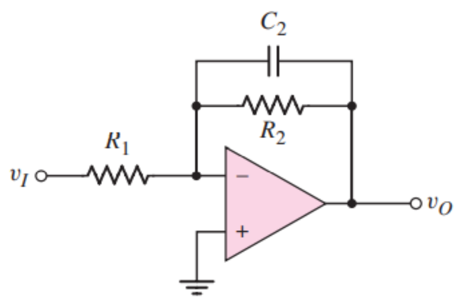

Figure 4(f)

(g) Design the low-pass active filter in figure 4(f) such that the input resistance is 20 kΩ, the low-frequency gain is −15, and the −3 dB frequency is 5 kHz.

(4-marks)

Key MOSFET Equations

$$I_{D\,(Linear)} = \frac{W}{L}\mu_n C_{ox}\left((V_{GS} - V_T)V_{DS} - \frac{1}{2}V_{DS}^2\right)$$

$$I_{D(sat)} = \frac{1}{2}\frac{W}{L}\mu_n C_{ox}\left(V_{GS} - V_T\right)^2$$

$$g_m = \frac{W}{L}\mu_n C_{ox}\left(V_{GS} - V_T\right) = \sqrt{2\frac{W}{L}\mu_n C_{ox}\left(I_{D(SAT)}\right)}$$