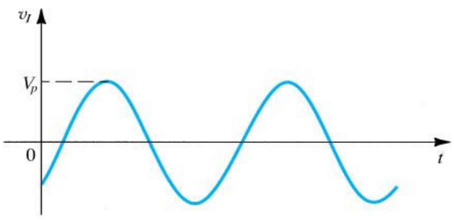
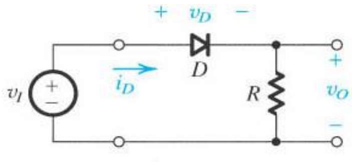
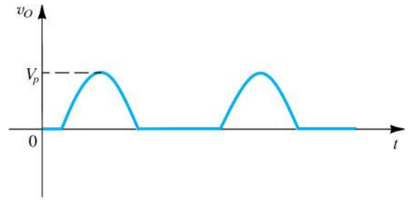
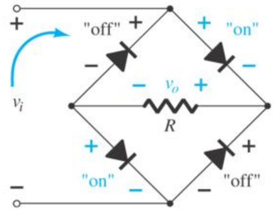
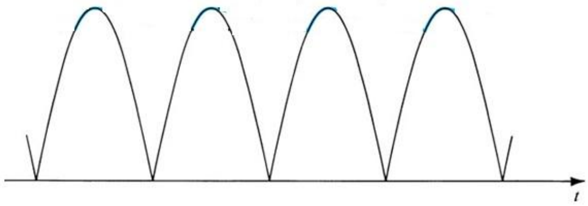
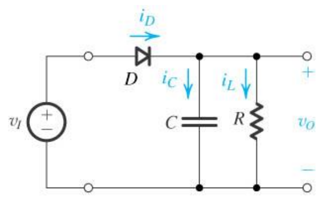
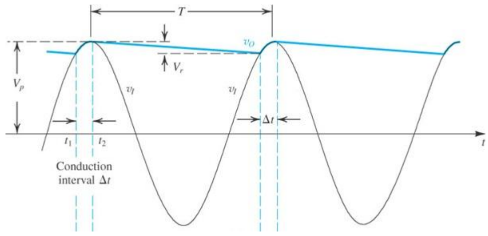
中山大学理工学院 2012 学年 1 学期期末

11 级微电子 2+2 模拟电子技术 试卷（A）

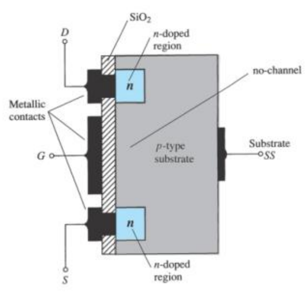
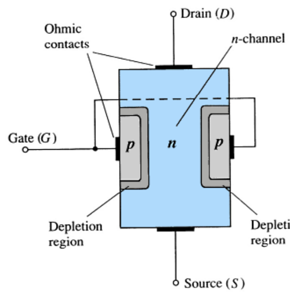
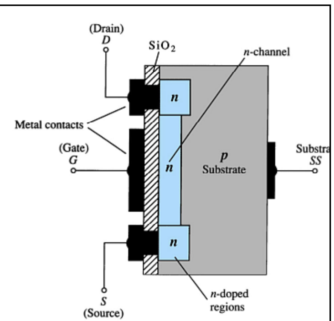
______年级 ______专业 姓名__________学号___________

老师姓名： 考试成绩 ：

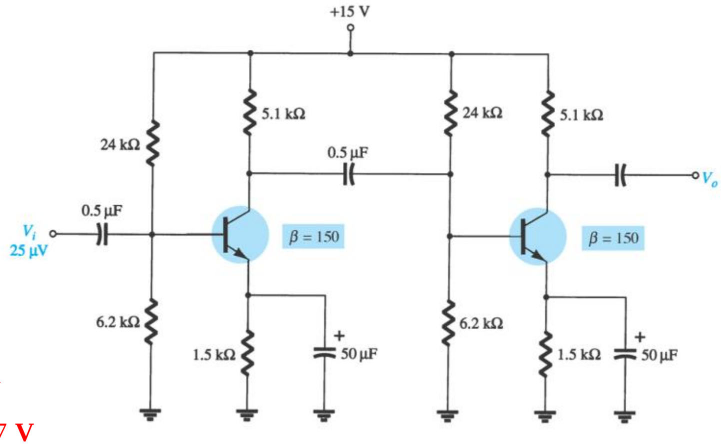
1. Assuming all diodes are ideal, draw the output waveform for each rectifier circuit. (10%)

Input waveform	Rectifier configurations	**Output Waveforms**
 (b)	 (a)	 (e)
		
	 (a)	

2. Fill in the blank areas (10%)

FET Structure			
FET Type	**Enhancement MOSFET**	**JFET**	**Depletion MOSFET**
Operation Mode (Tick your selection)	Depletion (D) (. .) Enhancement (E) (√)	Depletion (D) (√) Enhancement (E) ( )	Depletion (D) (√) Enhancement (E) ( )
Difference between D- and E- operations	**The channel exists when $V_{GS} = 0$ in D-FET, while in E-FET which exists when $V_{GS} > V_{TH}$**		

3. (15%) A BJT cascade amplifier is shown below. Assuming $V_{BE(on)}$ is 0.7 V,
   (1) Calculate the dc bias voltages, collector current and voltage gain of each stage
   (2) Calculate the overall ac voltage gain.



(1) $\because R_2 = 6.2\mathbf{k} \ll \beta R_{E1} = 150 \times 1.5\mathbf{k} = \mathbf{225k}$

$$\therefore V_{B1} \approx \frac{R_2}{R_1 + R_2} V_{DD} = \frac{6.2}{24 + 6.2} \times 15 \approx 3.08 \text{ V}$$

$$\therefore V_{E1} \approx V_{B1} - 0.7 \approx 3.08 - 0.7 = 2.38 \text{ V}$$

$$\therefore I_{E1} = \frac{V_{E1}}{R_{E1}} = \frac{2.38}{1.5\mathbf{k}} \approx 1.59 \text{ mA}$$

Assume Q_1 works in linear region, then

$$I_{C1} = \frac{\beta}{\beta + 1} I_{E1} \approx 1.58 \text{ mA}$$

$$\therefore V_{C1} = V_{DD} - I_{C1} R_{C1} \approx 15 - 1.58 \times 5.1 \approx 6.94 \text{ V}$$

$$\therefore V_{CE1} = V_{C1} - V_{E1} \approx 6.94 - 2.38 = 4.56 \text{ V} > 0.7 \text{ V}$$

Q_1 working in linear region is checked.

Since two transistors are bised identically, they have same bias voltages and currents.

$$r_{e1} = r_{e2} = \frac{V_T}{I_C} = \frac{26}{1.58} \approx 16.5\ \Omega$$

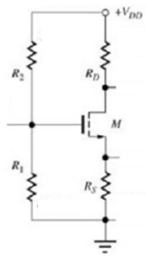
$$A_{v1} \approx -\frac{R_{L1}}{r_{e1}} \approx -\frac{R_{C1} \parallel R_1 \parallel R_2 \parallel \beta r_{e2}}{r_{e1}} \approx -\frac{1245}{16.5} \approx -75.5$$

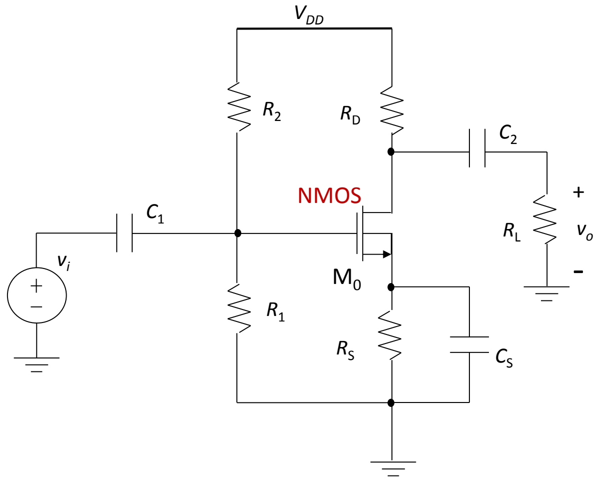
$$A_{v2} \approx -\frac{R_{L2}}{r_{e2}} \approx -\frac{R_{C2}}{r_{e1}} \approx -\frac{5.1\mathbf{k}}{16.5} \approx 309.1$$

(2) $A_v = A_{v1} A_{v2} \approx 75.5 \times 309.1 \approx 23337$

4. A single-stage amplifier with N-type enhancement MOSFET is shown below. (10%)
   (1) Draw the DC equivalent circuit.
   (2) List the equations to decide I_D and V_{DS} of NMOSFET M_0 if I-V relationship of M_0 is given as $I_{D0} = \frac{1}{2}\mu_n C_{OX} \frac{W}{L}(V_{GS} - V_{TH})^2(1 + \lambda V_{DS})$. Ignore channel length modulation effect in this step.
   (3) Draw the AC equivalent circuit based on small-signal modeling of M_0. Write the expression of overall voltage gain (v_o/v_i). Channel length modulation effect should be included in this step.

(1) DC equivalent circuit:



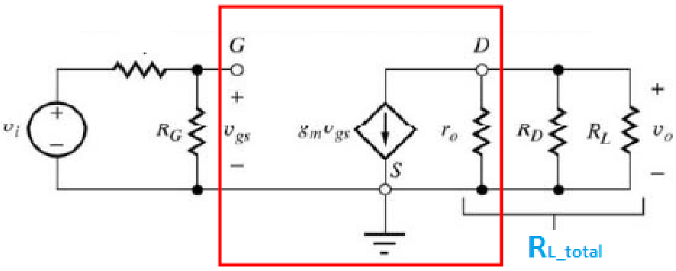


(2) Equations for DC biasing

$$
\begin{cases}
I_{D0} = \frac{1}{2}\mu_n C_{OX}\frac{W}{L}(V_{GS} - V_{TH})^2 \\
V_G = \frac{R_1}{R_1 + R_2}V_{DD} \\
V_{GS} = V_G - I_{D0}R_S \\
V_{DD} = V_{DS} + I_{D0}(R_D + R_S)
\end{cases}
$$

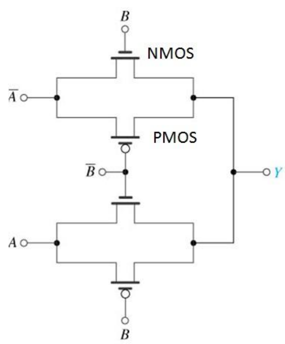
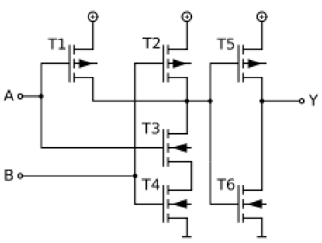
(3) AC small-signal equivalent circuit

NMOS small-signal model



$$
\begin{cases}
A_v = \frac{v_d}{v_g} = \frac{v_o}{v_{gs}} = -g_m R_{L\_total} \\
g_m = \frac{\partial i_D}{\partial v_{GS}} = \frac{2I_D}{V_{GS} - V_{TH}} \approx \mu_n C_{OX}\frac{W}{L}(V_{GS} - V_{TH}) \\
R_{L\_total} = R_L \parallel R_D \parallel r_o \\
r_o = \frac{\partial i_D}{\partial v_{DS}} \approx \frac{1}{\lambda I_D}
\end{cases}
$$

5. Fill in the blank areas (10%)

Logic circuit	Truth table	Function
	4% <table><tr><td>A</td><td>B</td><td>Y</td></tr><tr><td>0</td><td>0</td><td>**0**</td></tr><tr><td>0</td><td>1</td><td>**1**</td></tr><tr><td>1</td><td>0</td><td>**1**</td></tr><tr><td>1</td><td>1</td><td>**0**</td></tr></table>	1% **XOR** $Y = A \oplus B$
4% 	<table><tr><td>A</td><td>B</td><td>Y</td></tr><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></table>	1% **AND** $Y = A \cdot B$

6. Comparator circuits analysis (10%)

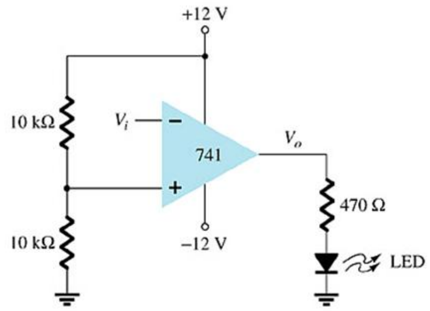
(1) Explain the function of the circuit shown below. What will be happened if V_i is very noisy?

This is a comparator with reference voltage $V_{ref} = V_{i+} = 6V$ in non-inverting input terminal.

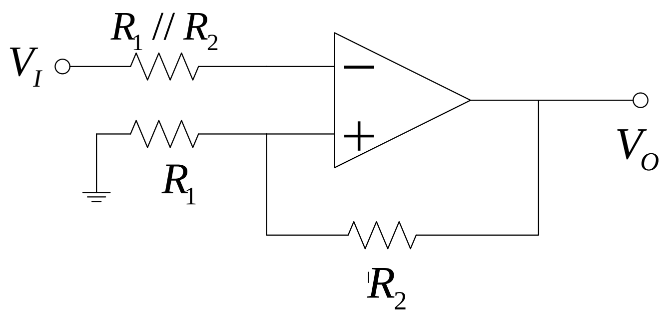
When $V_i < 6V$, $V_o = V_{sat}$, LED turn on;

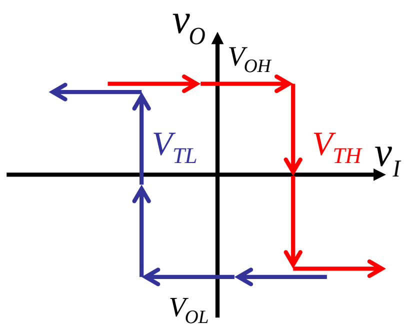
When $V_i > 6V$, $V_o = -V_{sat}$, LED turn off;

If V_i is very noisy, V_o maybe switch between high and low and the LED turns on and off when V_i is around 6 V.



(2) Explain the function of Schmitt Trigger shown below. Why the hysteresis operation is introduced in this configuration?





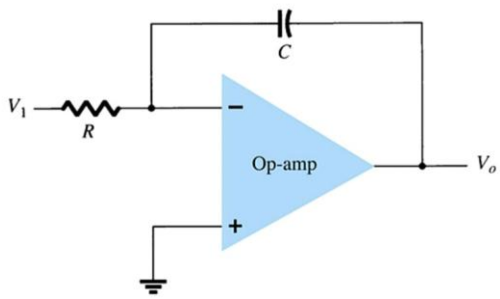
This is an inverting Schmitt Trigger. There are two thresholds in the Schmitt Trigger, whick makes the circuit can operate correctly even in the presence of noise.

(1) when $v_O = V_{OH}$**, high state,** $v_+ = \frac{R_1}{R_1 + R_2} V_{OH}$**, crossover occurs when** $v_I = v_+, V_{TH} = \frac{R_1}{R_1 + R_2} V_{OH}$

(2) when $v_O = V_{OL}$**, low state,** $v_+ = \frac{R_1}{R_1 + R_2} V_{OL}$**, crossover occurs when** $v_I = v_+, V_{TL} = \frac{R_1}{R_1 + R_2} V_{OL}$

7. Op-Amp application circuits (20%)

（1） Find the relationship between V_1 and V_o (5%)



$$\mathbf{v_o(t) = -\frac{1}{RC}\int v_1(t)dt}$$

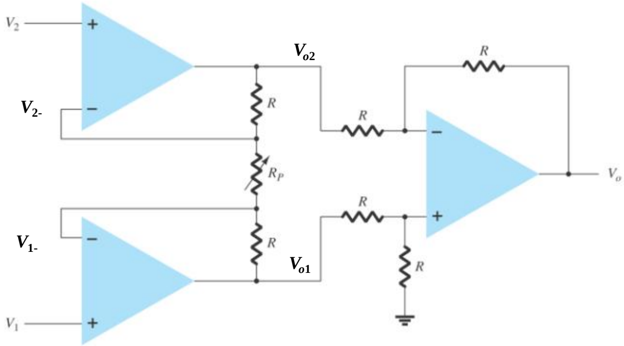
（2）For the instrumentation amplifier circuit shown below, R = 5 kΩ, R_P = 500 Ω, and all operaional amplifiers are ideal. (15%)

a. Find the relationship between V_1,V_2 and V_{o2}

b. Find the relationship between V_1,V_2 and V_{o1}

c. Find the relationship between V_{o1},V_{o2} and V_o

d. Find the value of V_o if V_2 = 10 V and V_1 = 5 V



a&b. $V_{2-} = V_2$; $V_{1-} = V_1$

$$V_{o2} = V_2 + R\frac{V_2 - V_1}{R_P} = 11V_2 - 10V_1$$

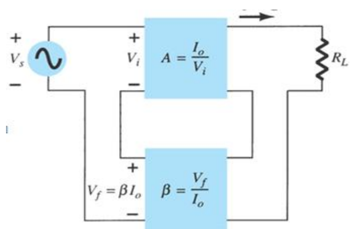
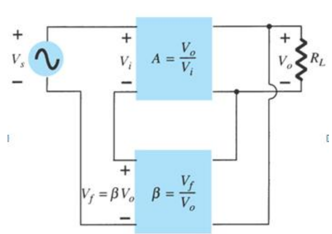
$$V_{o1} = V_1 - R\frac{V_2 - V_1}{R_P} = 11V_1 - 10V_2$$

c. $V_o = V_{o1} - V_{o2}$

d. $V_o = V_{o1} - V_{o2} = (11V_1 - 10V_2) - (11V_2 - 10V_1) = -45 - 60 = -105\ \mathbf{V}$

8. Feedback types and feedback circuit analysis (15%)

(1) Fill in the blank areas

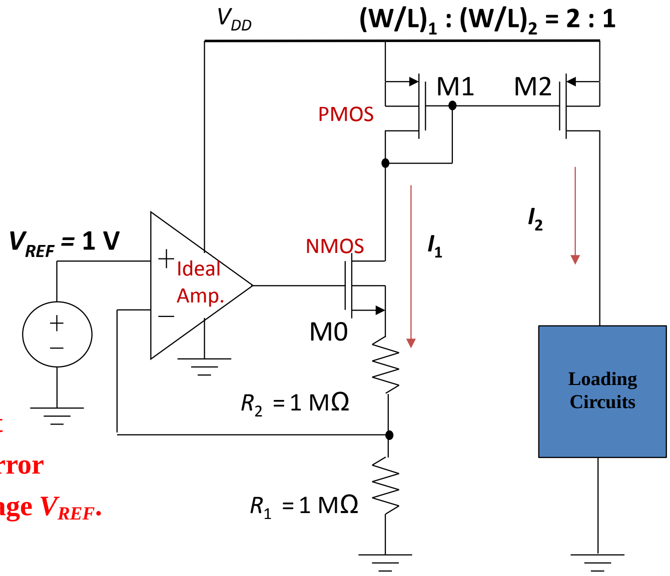
Feedback configurations		
Feedback type	**Current-series**	**Voltage-series**
Close-loop gain	$A/(1+\beta A)$	$A/(1+\beta A)$
Close-loop R_{in}	$(1+\beta A)R_i$	$(1+\beta A)R_i$
Close-loop R_{out}	$(1+\beta A)R_o$	$R_o/(1+\beta A)$

(2) A CMOS circuit with negative feedback configuration is shown below. Assuming the amplifier is ideal and all enhancement MOSFTEs are working in saturation mode.

a. Find the values of I_1 and I_2

b. Comments on the circuit function

c. What is the feedback type?



a.

$$I_1 = \frac{V_{REF}}{R_1} = 1\ \mu\text{A}$$

$$I_2 = \frac{(W/L)_2}{(W/L)_1} I_1 = 0.5\ \mu\text{A}$$

b. This is a voltage control current source. The output current I_2 is decided by the size ratio of current mirror (M1 and M2) and I_1. I_1 is decided by the input voltage V_{REF}.

c. Current-series negative feedback

The End