Sample Midterm Exam

VE311 2020 Summer

UM-SJTU Joint Institute 2020SU VE311 Teaching Group

Some tips:

I) This sample exam paper covers the Diode, diode circuit and BJT.

II) This sample exam is not an assignment and **it will never be counted into course grades, no bonus.**

III) Mention that these problems do not cover all the contents in the courses and exams.

IV) **Some problems, such as the "discuss" part, are designed for you to understand the circuit principle better and will never appears in the exam. Besides, it's better for you to think more than those problems. i.e. generate and analysis circuits in different cases by yourself.**

V) The solution to this problem is attached in the end. For any problems, please contact the TAs.

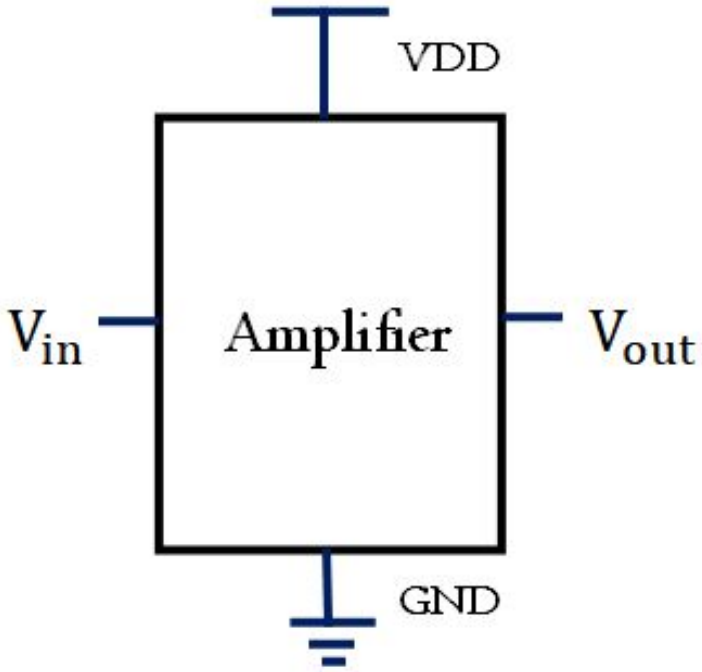
☺ Hope you ENJOY it ☺

Problem I(8marks)

The following diagram shows an amplifier model, whose DC sweep relationship between DC output voltage $\mathbf{V_{OUT}}$ and DC input voltage $\mathbf{V_{IN}}$ is $\mathbf{V_{OUT} = (V_{IN} - 2)^2}$. Please plot the output voltage $\mathbf{V_{out}}$ if the input voltage $\mathbf{V_{in}}$ is:

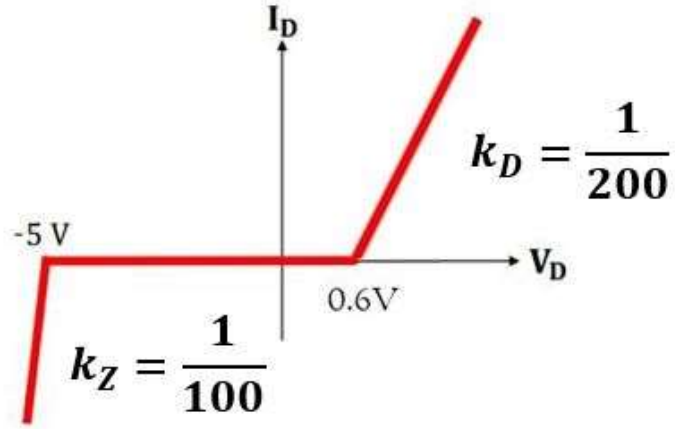
1) $\mathbf{1 + 0.01sin60\pi t}$ V

2) $\mathbf{3 + 0.01sin60\pi t}$ V

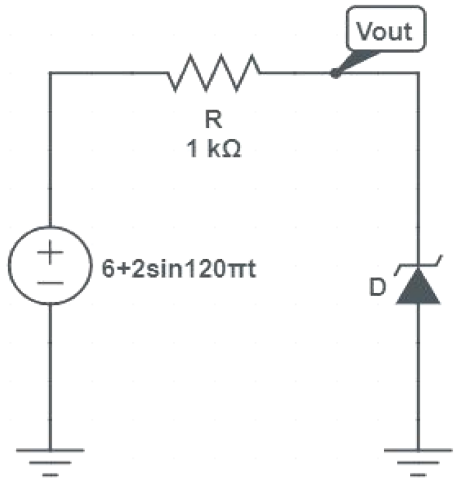


Problem 2 (16 marks)

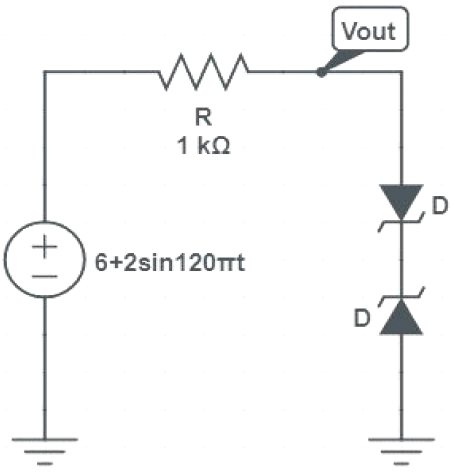
For the Zener diode D_1, the I-V relationship is showed in the following diagram:



Please plot the diagram of $\mathbf{V_{out}}$ in the following circuits, suppose the input voltage $\mathbf{V_{in} = 6 + 2sin120\pi t}$ and $\mathbf{R = 1000\Omega}$.



(circuit I)

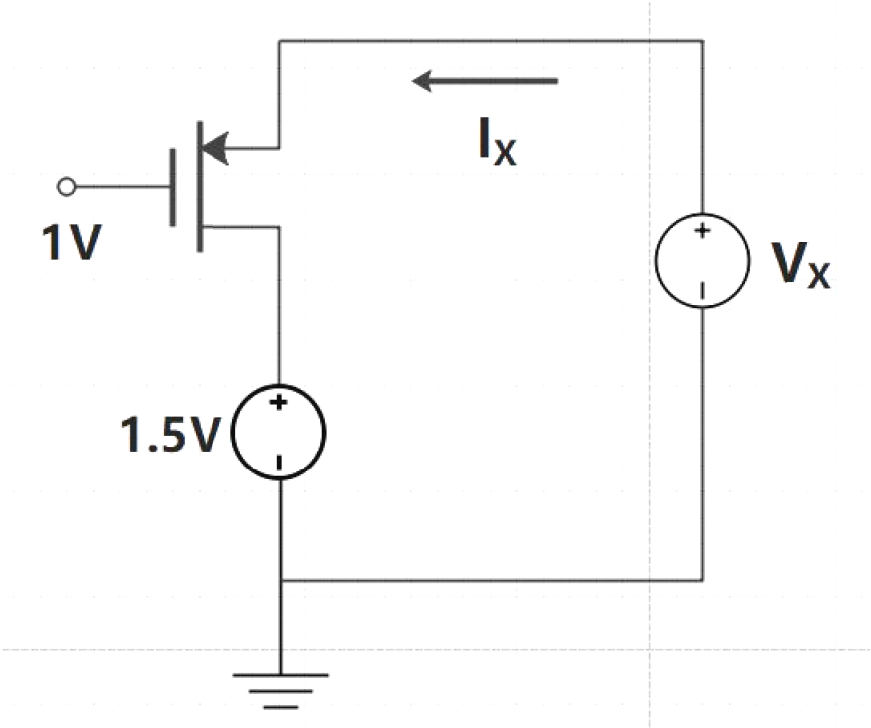


(circuit II)

Problem 3 (16 marks)

Suppose $\frac{\mathbf{W_{drawn}}}{\mathbf{L_{drawn}}} = \frac{\mathbf{2XX\mu m}}{\mathbf{2\mu m}}$ (XX is the last two digits of your student code), please plot the DC-sweep diagram of $\mathbf{I_X}$ vs $\mathbf{V_X}$ (0V to 5V) based on the following model. <u>You need to mark the values of $\mathbf{I_X}$ and $\mathbf{V_X}$ at the points when the working region of MOSFET changes.</u>

Hint: $\boldsymbol{V_X}$ should be the unique variable.



NMOS Model				
	LEVEL = 1	VTO = 0.7	GAMMA = 0.45	PHI = 0.9
	NSUB = 9e+14	LD = 0.08e−6	UO = 350	LAMBDA = 0.1
	TOX = 9e−9	PB = 0.9	CJ = 0.56e−3	CJSW = 0.35e−11
	MJ = 0.45	MJSW = 0.2	CGDO = 0.4e−9	JS = 1.0e−8
PMOS Model				
	LEVEL = 1	VTO = −0.8	GAMMA = 0.4	PHI = 0.8
	NSUB = 5e+14	LD = 0.09e−6	UO = 100	LAMBDA = 0.2
	TOX = 9e−9	PB = 0.9	CJ = 0.94e−3	CJSW = 0.32e−11
	MJ = 0.5	MJSW = 0.3	CGDO = 0.3e−9	JS = 0.5e−8

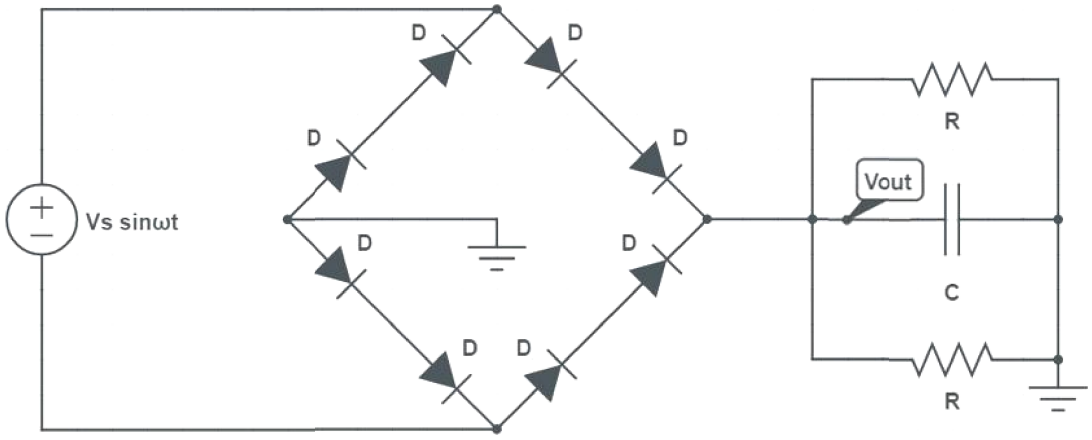
VTO: threshold voltage with zero V_{SB} (unit: V)
GAMMA: body effect coefficient (unit: $V^{1/2}$)
PHI: $2\Phi_F$ (unit: V)
TOX: gate oxide thickness (unit: m)
NSUB: substrate doping (unit: cm^{-3})
LD: source/drain side diffusion (unit: m)
UO: channel mobility (unit: $cm^2/V/s$)
LAMBDA: channel-length modulation coefficient (unit: V^{-1})
CJ: source/drain bottom-plate junction capacitance per unit area (unit: F/m^2)
CJSW: source/drain sidewall junction capacitance per unit length (unit: F/m)
PB: source/drain junction built-in potential (unit: V)
MJ: exponent in CJ equation (unitless)
MJSW: exponent in CJSW equation (unitless)
CGDO: gate-drain overlap capacitance per unit width (unit: F/m)
CGSO: gate-source overlap capacitance per unit width (unit: F/m)
JS: source/drain leakage current per unit area (unit: A/m^2)

$\boldsymbol{\varepsilon_0} = 8.85 \times 10^{-12}$ F/m, $\boldsymbol{\varepsilon_{Si}} = 11.5, \boldsymbol{\varepsilon_{SiO2}} = 3.9$

Problem 4 (12marks)

For the following full-wave bridge rectifier circuit, the input voltage $\mathbf{V_{in} = V_s sin\omega t}$ and all the diodes has the same turn-on voltage $\mathbf{V_{on}}$. Both the resistors have the resistance R and the capacitor is C. Suppose RC>>T.

1) Suppose all the diodes' inner resistance is zero, please find the DC output current $\mathbf{I_{dc}}$, the conduction interval $\mathbf{\Delta T}$ and the maximum inverse voltage PIV of the circuit.
2) Suppose all the diodes have the inner resistance R, could the circuit work? Why?



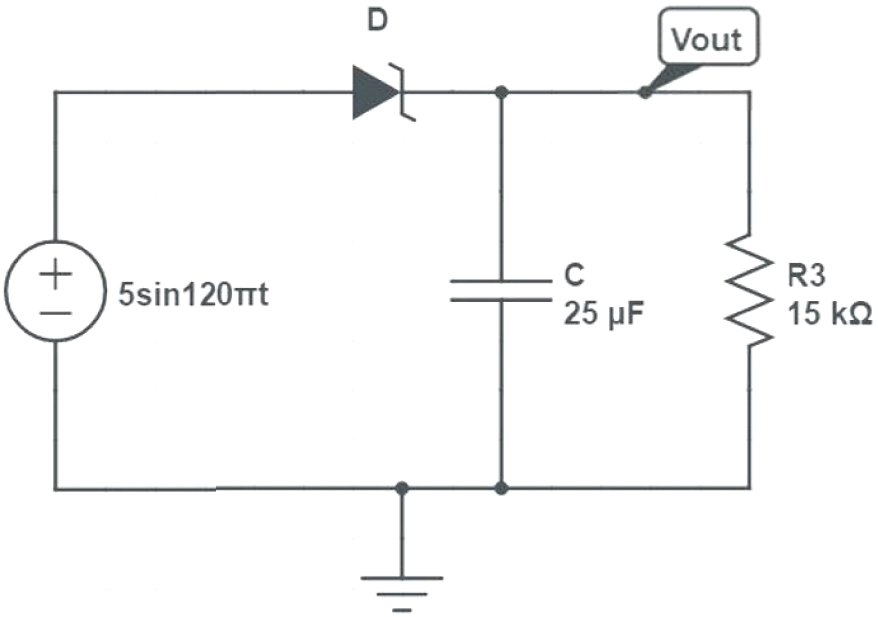
Problem 5 (18 marks)

For the following half-wave rectifier circuit, the input voltage $\mathbf{V_{in} = 5sin120\pi t}$. The zener diode has the turn-on voltage $\mathbf{V_{on}}$=0.7V. The resistor is $\mathbf{15k\Omega}$ and the capacitor is $\mathbf{25\mu F}$.

1) Please plot the diagram of output voltage $\mathbf{V_{out}}$ if the diode's Zener breakdown voltage $\mathbf{V_Z}$=5V

2) Please plot the diagram of output voltage $\mathbf{V_{out}}$ if the diode's Zener breakdown voltage $\mathbf{V_Z}$=4V

(make sure you mark the value and time of all of the critical points)



Problem 6 (30marks)

For the following BJT amplifier circuit, $\mathbf{R_c}$ is connected to the collector and $\mathbf{R_e}$ is connected to the emitter.

1) If $\mathbf{r_\pi, r_0} \neq \infty$, please find the small signal gain $\mathbf{A_v} = \frac{\mathbf{v_{out}}}{\mathbf{v_{in}}}$ using analytical expression.

2) Suppose the DC input voltage $\mathbf{V_{IN}} = \mathbf{0.7}\mathrm{V}$ and the DC power supply $\mathbf{V_{CC}} = \mathbf{3}\mathrm{V}$, the resistor $\mathbf{R_C}$ and $\mathbf{R_e}$ are both equal to $\mathbf{5000}\Omega$. Besides, the SPICE model of the BJT is listed below.

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.model Qbreakn NPN Is=1e-16 BF=10 VAF=100
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i. Please calculate the values of $\mathbf{gm}$, $\mathbf{r_\pi}$ and $\mathbf{r_0}$.

ii. Please calculate the value of $\mathbf{A_v}$.