Name: Solution MT1 - Fall 2016

EE303 - Midterm Exam #1

Closed Book:

One 8.5"x11" sheet of handwritten notes permitted

Calculator permitted

Important Notes:

- Read each problem completely and thoroughly
- Summarize all your answers in the boxes provided on these exam sheets
- Make sure to mark the units on your answers !
- Do all your work on the exams sheets provided. If you use any additional sheets, please turn them in, so we can consider all work for partial credit
- Do not forget to put your name in the space above

Problem #	Points	Score
1	30	
2	5	
3	5	
4	15	
5	5	
6	20	
TOTAL	**80**	

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Problem 1 [30 pts]

Given the circuit in Fig.1 find an expression for R_{in}, R_{out}, and $A_V = v_{out}/v_{in}$

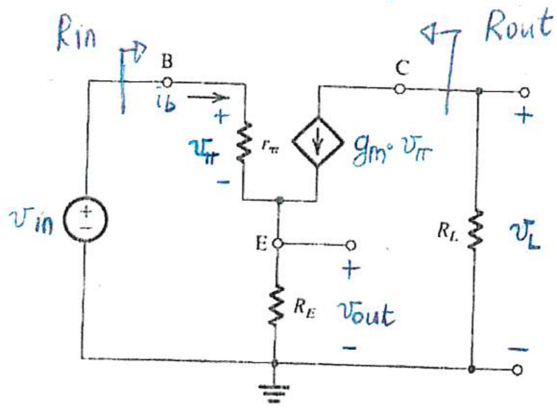


Figure 1

$$v_{out} = R_E\left(\frac{v_\pi}{r_\pi} + g_m v_\pi\right)$$

$$v_{in} = v_\pi + v_{out} \rightarrow$$

$$v_\pi = v_{in} - v_{out}$$

R_{in}	$\approx r_\pi (1 + g_m R_E)$
R_{out}	$= \infty$
A_V	≈ 1

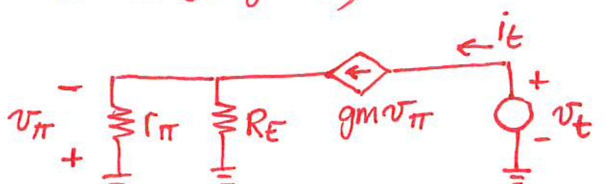
$$v_{out} = v_\pi\left(\frac{R_E}{r_\pi} + g_m R_E\right) = v_{in}\left(\frac{R_E + g_m R_E r_\pi}{r_\pi}\right) - v_{out}\left(\frac{R_E + g_m R_E r_\pi}{r_\pi}\right)$$

$$v_{out}\left(1 + \frac{R_E + g_m R_E r_\pi}{r_\pi}\right) = v_{in}\,\frac{R_E + g_m R_E r_\pi}{r_\pi}$$

$$\frac{v_{out}}{v_{in}} = \frac{R_E + g_m R_E r_\pi}{r_\pi + R_E + g_m R_E r_\pi} = \frac{R_E(1 + g_m r_\pi)}{r_\pi + R_E(1 + g_m r_\pi)} \approx 1$$

$$R_{in} = \frac{v_{in}}{i_b} = \frac{v_\pi + R_E g_m v_\pi + (v_\pi / r_\pi)\cdot R_E}{v_\pi / r_\pi} = r_\pi\left(1 + R_E g_m + R_E / r_\pi\right) \approx$$

$$\approx r_\pi (1 + g_m R_E)$$



$R_{out} = v_t / i_t = \infty$

$$i_t = g_m \cdot v_\pi$$

$$v_\pi = -i_t (r_\pi \| R_E) = -i_t \cdot R$$ (R: positive quantity)

$$i_t = -i_t g_m R \rightarrow i_t (1 + g_m R) = 0 \rightarrow$$

$$\rightarrow i_t = 0$$

Name: ____________________

Problem 2 [5 pts]

A silicon wafer is doped with donors at a concentration of $N_D=10^{15}$ cm^{-3}. Assuming n_i at room temperature is 10^{10} cm^{-3}

(a) What is the electron concentration n_o (cm^{-3}) at room temperature?

(b) What is the holes concentration p_o (cm^{-3}) at room temperature?

(a) n_o =	10^{15} cm^{-3}
(b) p_o =	10^{5} cm^{-3}

$$p_o \cong \frac{n_i^2}{n_o} = \frac{10^{20}}{10^{15}}$$

Problem 3 [5 pts]

Using the fact that a silicon diode has $I_S = 10^{-14}$ A at 25°C and that I_S increases by 15% per °C rise in temperature, find the value of I_S at 125°C.

I_S at 125°C =	117×10^{-10} A

$$I_S(125°C) = I_S(25°C) \times 1.15^{\Delta T} =$$

$$= 10^{-14} \times 1.15^{100} \simeq 117 \times 10^{-10} \text{ A}$$

$$\Delta T = T - T_0$$

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Problem 4 [15 pts]

Consider the circuit shown in Fig. 2. A string of three diodes is used to provide a constant voltage of about 2.1 V. We want to calculate the percentage change in this regulated voltage caused by
(a) a ±10% change in the power-supply voltage without the load
(b) a ±10% change in the power-supply voltage with a load of 1-kΩ connected

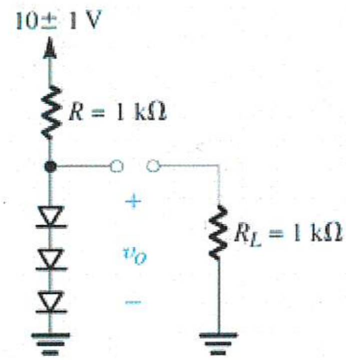

Figure 2

(a) $\Delta V_o/\Delta V_{supply} =$	9.51 mV/V
(b) $\Delta V_o/\Delta V_{supply} =$	12.5 mV/V

without load :

$$I_D = \frac{10-2.1V}{1K\Omega} = 7.9mA$$

$$r_d = \frac{V_T}{I_D} = \frac{25mV}{7.9mA} \simeq 3.2\Omega$$

$$\frac{\Delta V_o}{\Delta V_{supply}} = \frac{3\times r_d}{R+3r_d} = \frac{9.6}{9.6+1000} \simeq 9.51\frac{mV}{V}$$

with load

the operating point changes : $I_{R_L} = \frac{2.1V}{1K\Omega} = 2.1\,mA$

$$I_R = \frac{10-2.1}{1K\Omega} = 7.9\,mA$$

$$I_D = I_R - I_{R_L} = 5.8mA \rightarrow r_d = \frac{V_T}{I_D} \simeq 4.3\Omega$$

$$\frac{\Delta V_o}{\Delta V_{supply}} = \frac{3r_d // R_L}{3r_d // R_L + R} \simeq 12.5\,mV/V$$

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Problem 5 [5 pts]

For the circuit in Figure 3, utilizing an ideal diode, sketch the steady state output for the input shown. Label the most positive and most negative output levels.

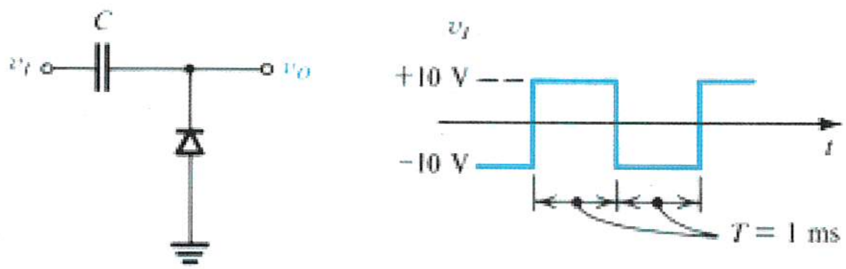
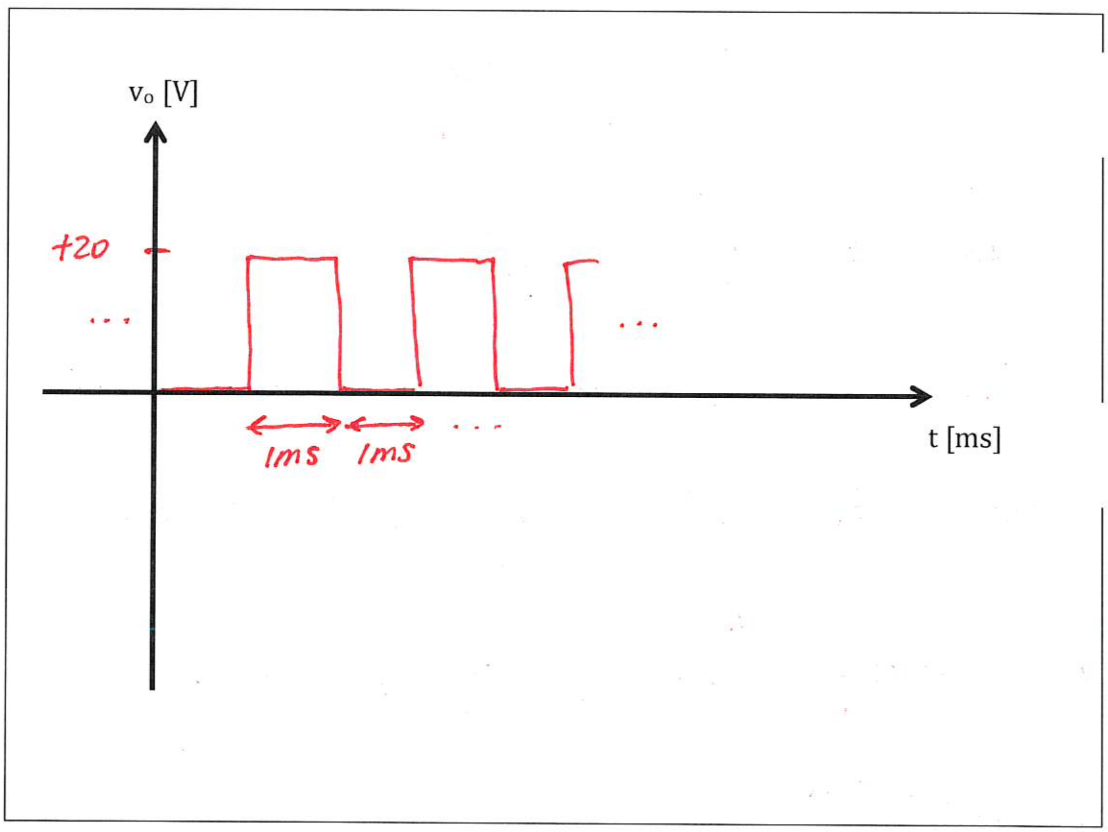


Figure 3.



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Problem 6 [20 pts]

In the following circuit assuming $\mu_n C_{ox} = 100\ \mu A/V^2$ and $V_{TH} = 0.4$ V and $\lambda \approx 0\ V^{-1}$, determine the maximum allowable value of W/L if M_1 must remain in saturation.

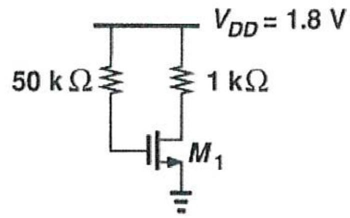

Figure 4.

Assume the current flowing into the gate of the transistor is negligible ($I_G = 0$).

V_{GS} =	$V_{DD} = 1.8V$
$W/L \leq$	4

$$I_D = \frac{\mu C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$$

$V_{DS} \geq V_{GS} - V_{TH}$ for M1 to remain in sat.

$$V_{DS} = V_{DD} - R_D I_D = V_{DD} - R_D \frac{\mu C_{ox}}{2} (V_{GS} - V_{TH})^2 \frac{W}{L}$$

$$1.8 - 1K \cdot \frac{100\mu}{2} (1.8 - 0.4)^2 \frac{W}{L} \geq 1.8 - 0.4$$

$$-50 \times 10^{-3} \times 1.4^2 \cdot \frac{W}{L} \geq -0.4$$

$$\frac{W}{L} \leq \frac{0.4}{50 \times 10^{-3} \times 1.4^2} = \frac{0.4}{98 \times 10^{-3}} \cong 4$$