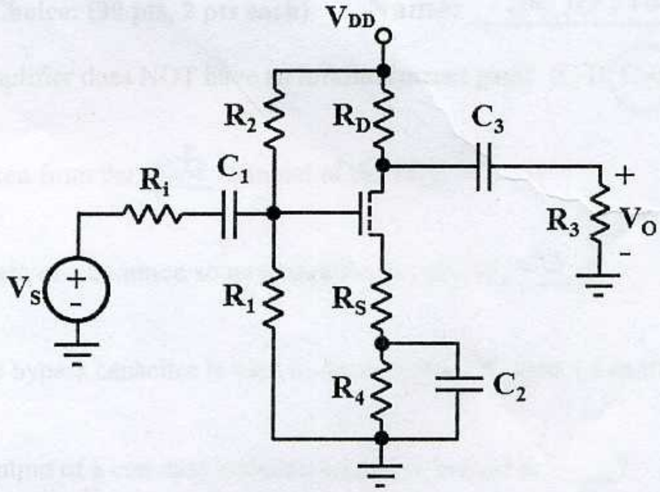
2012 01 - EE4313 Electronic Circuits II Exam #2
Part 1 (70 pts – includes take-home discussion)

Short Answer/Multiple Choice: (30 pts, 2 pts each) **Name:** Solutions

1. Which type of FET amplifier does NOT have an infinite current gain? (C-D, C-G, C-S)
2. The output is never taken from the gate terminal of the FET.
3. The terminal current gain of a common source amplifier is typically ∞ ?
4. For a CE amplifier, the bypass capacitor is used to decrease the DC gain. (true, false)
5. The capacitor on the output of a common collector amplifier is used to _____? block DC from the load
6. When the gain of an amplifier is lowered, the input signal range (decreases, increases).
7. For calculating capacitor values for a specific frequency range, you should always use the (lower, upper) end of the range.
8. Conceptually, in order to act as a good coupling or bypass capacitor, the impedance of the capacitor must be much, much less than _____. resistance seen at its terminals
9. What is the advantage/disadvantage of only bypassing a part of the emitter resistance?
   control gain vs. input signal range
10. What is the advantage of cascading multiple transistor amplifiers together?
    obtain characteristics not possible with a single transistor
11. Why can r_o typically be neglected in our impedance calculations?
    relatively large
12. $r_o = \beta (V_T / I_C)$ With all other parameters staying the same, how will removing R_E affect r_o?
    I_c increases, ∴ r_o decreases
13. How will bypassing R_E affect r_o?
    does not affect it
14. Is r_o affected at all by temperature? (Yes, No)
15. List two typical uses for the common collector amplifier.
    impedance transformation
    driver

Conceptual Amplifier Questions: (20 pts)

Given the diagram below, answer the following questions. You can express some answers in simple equation form such as R_i // R_1 or $R_1 + R_2$, etcetera.



16. What type of amplifier is shown above?

C-S

17. For DC, what is the total resistance providing negative feedback.

$R_S + R_4$

18. How would you calculate the "rule-of-thumb" maximum value of I_{DS}?

$\frac{V_{DD}}{R_D + R_S + R_4}$

19. If C_1 were removed, how would that complicate the design of this circuit?

the DC of the source would affect the bias point

20. If R_1 and R_2 were both reduced by a factor of 10 (ratio is unchanged), what would this affect?

power dissipation

21. How would removing R_D affect AC operation?

R_L & R_{out} → circuit would not work!

22. (4 pts) For AC operation, increasing R_S would accomplish two things, what are they?

reduce gain, increase input signal range

23. (4 pts) Write the equation(s) for DC power consumption.

$P = \frac{V_{DD}^2}{R_1 + R_2} + (V_{DD})(I_{DS})$

24. BONUS: (5 pts) Suppose you determine a specific value of C_2 for a particular frequency range and the part is too expensive. You need to lower the required value of C_2. What can you change in the circuit?

R_S & R_4

increase

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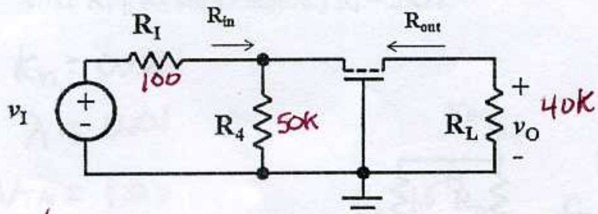
Part 2 (65 pts)

Name: Solutions

1. **(25 pts) What are the values for A_v, R_{in}, R_{out}, and A_i (i_o/i_i) for the amplifier shown below. R_4= 50kΩ, R_I= 100Ω, and R_L= 40kΩ. V_{TN}=0.8V, V_{GS}=3V, V_{DS}=5V, I_{DS}=1mA, and λ=0.005.**



$$g_m = \frac{2 I_{DS}}{V_{GS} - V_{TN}} = \frac{2\times 10^{-3}}{3-0.8} = 909\,\mu S$$

$$r_o = \frac{1+\lambda V_{DS}}{\lambda I_{DS}} = \frac{1.025}{5\times 10^{-6}} = 205{,}000\,\Omega$$

$$A_V = \left(\frac{g_m R_L}{1+g_m R_{th}}\right)\cdot\left(\frac{50K}{50K+100}\right) \quad R_{th} = R_4 \| R_I = 99.8\,\Omega$$

$$= \frac{(909\times 10^{-6})(40000)}{1+(909\times 10^{-6})(99.8)}\cdot(.998) = 33.27$$

$$i_o = \frac{V_o}{R_L} \quad i_i = \frac{V_i}{R_I + R_4\|R_{is}}$$

$$R_{in} = R_4 \| R_{is} \quad R_{is} = \frac{1}{g_m} = 1100\,\Omega$$

$$50000 \| 1100 = \frac{55\times 10^6}{51{,}100} = 1076\,\Omega$$

$$A_i = \frac{V_o/R_L}{V_i/(R_I+R_{in})} = \frac{V_o}{V_i}\frac{(R_I+R_{in})}{R_L}$$

$$= 33.27\,\frac{(100+1076)}{40000}$$

$$= 0.978$$

$$R_{OUT} = 205k\left[1+(909\times 10^{-6})(99.8)\right]$$

$$= 223.6k\,\Omega$$

$$A_i \cong +1$$ from formula sheet

2. **(40 Total Points) Given the circuit and parameters below. *<u>BEFORE CALCULATING, MAKE SURE IT'S NOT ALREADY GIVEN!!!</u>***

For the common source amplifier: $V_{DD} = 10V$, R_1=1 MΩ, R_2 =1.5 MΩ, R_D=5 KΩ, R_S = 2KΩ. Kn = 0.01A/V^2. λ = 0.01 V_{TN} = 1.0V.

For the common collector amplifier: R_4=60 KΩ, R_3=40 KΩ, R_C=4 KΩ, R_E=300 Ω, gm = 0.4S, and βo = 100. R_5 = 1500Ω.

(6 pts) Draw the AC equivalent circuit below this diagram. Calculate and show all equivalent resistances (like $R_1 \parallel R_2$ for example.) R_i = 5KΩ.

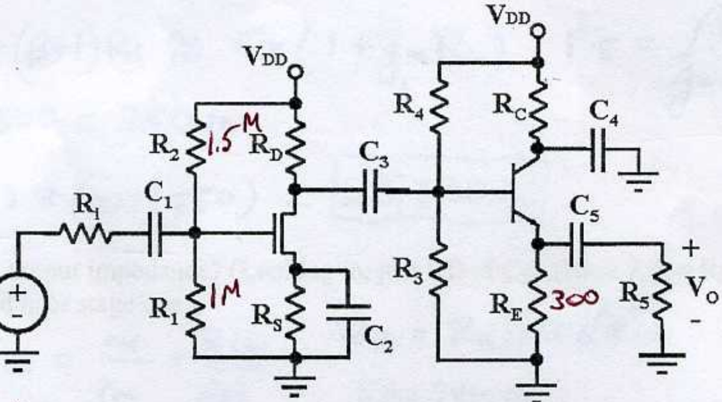
$K_n = 0.01$

$\lambda = 0.01$

$V_{TN} = 1.0V$

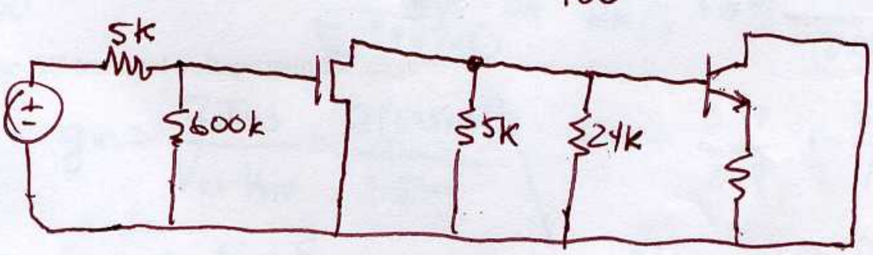
$g_m = 0.4$

$\beta = 100$

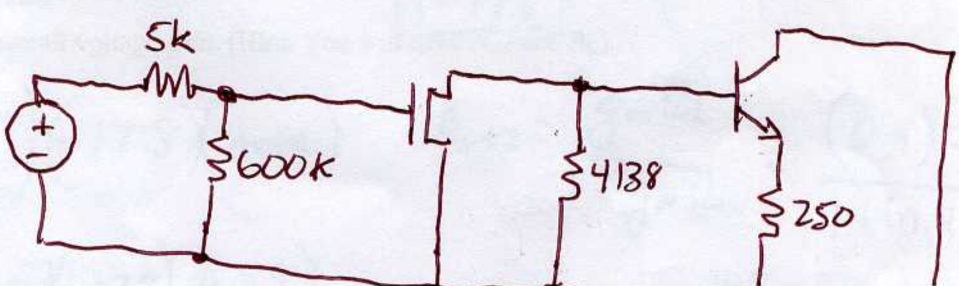


$R_E \| R_5 = \frac{(300)(1500)}{1800} = \underline{250\Omega}$

$R_1 \| R_2 = \frac{(1.5M)(1M)}{2.5M} = \underline{600k\Omega}$ $\quad R_4 \| R_3 = \frac{(60K)(40K)}{100} = \underline{24k\Omega}$



$5k \| 24k = 4138$



a. (9 pts) For the DC operating point, **write** the 3 equations relating V_{GS}, V_{DS}, and I_{DS}. State any assumptions. **Find** V_{DS} and I_{DS} given V_{GS} = 1.5V. Neglect channel length modulation.

① $10 = 7000 I_{DS} + V_{DS}$

② $4 = V_{GS} + 2000 I_{DS}$

③ $I_{DS} = \frac{K_n}{2}(V_{GS} - V_{TN})^2$

$V_{EQ} = \left(\frac{1}{2.5}\right)10 = 4V$

$I_{DS} = 1.25mA$

$10 = 7000 I_{DS} + V_{DS}$

$V_{DS} = 1.25V$

b. (5 pts) Find the terminal input impedance of stage 2 [R_{iB}]. (Looking in, just after R_3 and R_4).

$R_{iB} = r_\pi + (\beta+1)R_L \approx r_\pi(1 + g_m R_L)$ $\quad r_\pi = \frac{\beta}{g_m} = \frac{100}{0.4} = 250\Omega$

$R_L = 300 \| 1500 = 250\Omega$

$R_{iB} = 250 + (101)(250) = 25{,}500\Omega$

c. (5 pts) Find the output impedance? (Looking in, just left of C_5). (Hint: Rth = $R_D \| R_B \| R_{OUT}$ of stage 1 - you will need to find r_o of stage one.)

$R_{OUT} = R_E \| R_{iE}$ $\quad R_{iE} = \frac{\alpha}{g_m} + \frac{R_{th}}{\beta+1}$

$R_E = 300\Omega$

$\alpha = \frac{100}{101} = 0.990$

$g_m = 0.4S$ $\quad \beta = 100$

$R_{th} = R_B \| 5k \| R_{iD}$ $\quad R_{iD} = r_o(1 + g_m R_S)$ $\quad R_S = 0$ bypassed

$R_B = 24k\Omega$

$R_{th} = 24k \| 5k \| 81k = \frac{1}{\frac{1}{24k} + \frac{1}{5k} + \frac{1}{81k}} = 3937\Omega$

$r_o = \frac{1 + \lambda V_{DS}}{\lambda I_{DS}}$

$r_o = \frac{1 + (0.01)(1.25)}{(0.01)(1.25\times10^{-3})} = 81k\Omega$

d. (10 pts) Calculate the AC terminal voltage gain for stage 1.

$A_{vt1} = \frac{-g_m R_L}{1 + g_m R_S}$

$g_m = \frac{2I_{DS}}{V_{GS} - V_{TN}} = \frac{2(1.25\times10^{-3})}{1.5 - 1} = 5mS$

$R_{iE} = \frac{0.99}{0.4} + \frac{3937}{101} = 41.46\Omega$

$R_{OUT} = 300 \| 41.46 = 36.4\Omega$

$R_L = 5k \| 24k \| R_{iB} = \frac{1}{\frac{1}{5k} + \frac{1}{24k} + \frac{1}{25500}} = 3560\Omega$

$A_{vt1} = (-5\times10^{-3})R_L = -17.8$

e. (5 pts) Find the overall voltage gain. (Hint: You will need A_{vt2} and R_L)

$A_v = \left(\frac{600k}{605k}\right)(-17.8)(A_{vt2})$

$A_{vt2} = \frac{g_m R_L}{1 + g_m R_L} = \frac{(0.4)(250)}{1 + (0.4)(250)} = $

$A_{vt2} = \frac{100}{101} = 0.99$

$A_v = (0.9917)(-17.8)(0.99) = -17.48$

↖ can approximate to one.