

## National Exams May 2014

07-Elec-B5, Advanced Electronics

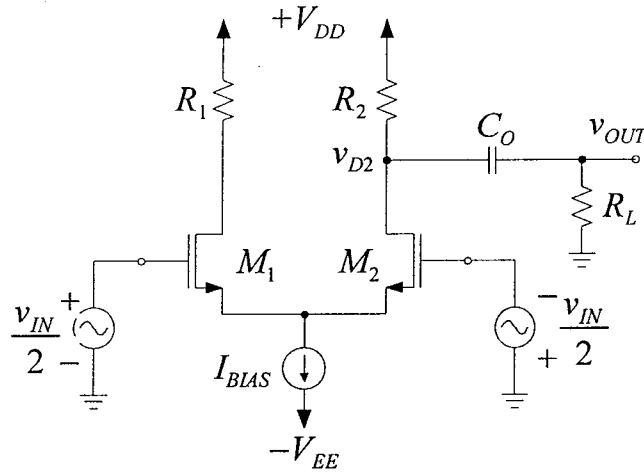
3 hours duration

### Notes:

1. If any doubt exists as to the interpretation of any question, the candidate is urged to submit, within their answer, a clear statement of any assumptions made.
2. This is a **CLOSED BOOK EXAM**.  
Any non-communicating calculator is permitted.
3. Answer all **FIVE** (5) questions.
4. All questions are worth 20 marks each.
5. Please start each question on a new page and clearly identify the question number and part number, e.g. Q4(a).
6. In schematics, ground and chassis may be assumed to be common, unless specifically stated otherwise.
7. Unless otherwise specified, assume that Op-Amps are ideal and that supply voltages are  $\pm 15V$ .
8. If questions require an answer in essay format, clarity and organization of the answer are important. Provide block diagrams and circuit schematics whenever necessary.

**QUESTION (1)**

In the following circuits, assume all transistors have the following parameters:



$K = 1.0 \text{ mA/V}^2$ ,  $V_{TH} = 1 \text{ V}$  and  $\lambda = 0.02$ .

Given:

$I_{BIAS} = 1 \text{ mA}$

$V_{DD} = 10 \text{ V}$

$V_{EE} = 10 \text{ V}$

$C_O = \infty$

- a) Design this circuit such that the open-circuit gain (i.e. without  $R_L$ )  $v_{OUT}/v_{IN}$  is  $5\text{V/V}$ . Provide the values for  $R_1$  and  $R_2$ . (6 points)
- b) Find the common mode input resistance  $R_{icm}$ . (4 points)
- c) Find the common mode input range. (4 points)
- d) If  $v_{IN}$  is a  $0.5\text{V}$  peak to peak sine wave at  $1 \text{ kHz}$ , sketch accurately the voltage waveforms for  $v_{D2}$  and  $v_{out}$  if  $R_L = 5\text{k}\Omega$  is attached to the output node. (6 points)

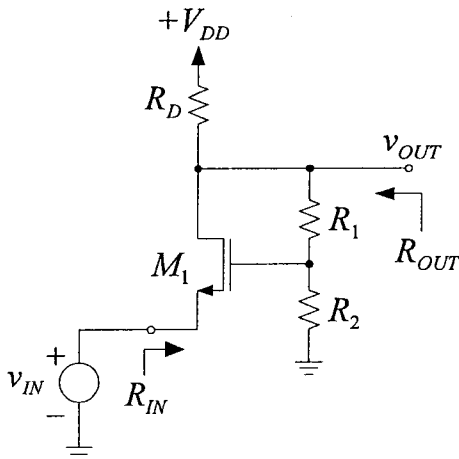
Useful formulae: for n-channel MOSFET

$i_{DS} = K \left[ (v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2 \right]$  triode region

$i_{DS} = \frac{1}{2}K(v_{GS} - V_{TH})^2(1 + \lambda v_{DS})$  saturation region

**QUESTION (2)**

In the following amplifier can be considered as a feedback circuit.



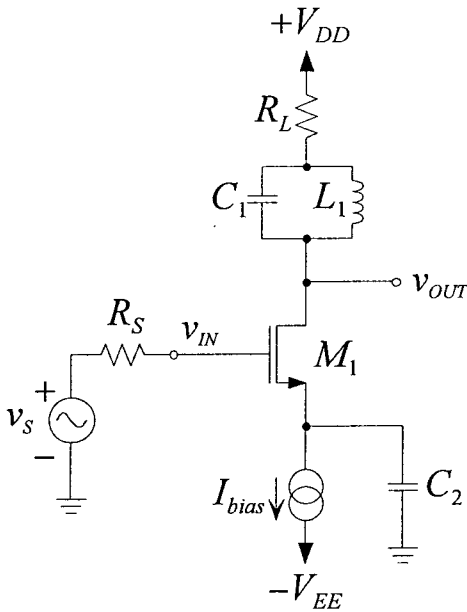
- a) Determine the input and output resistance ( $R_{IN}$  and  $R_{OUT}$ ) if there is no feedback network (i.e.  $R_1 = \infty$ , and  $R_2 = 0 \Omega$ ). (8 points)
- b) Derive the input and output resistance ( $R_{IN}$  and  $R_{OUT}$ ) if the feedback network has finite values for  $R_1$  and  $R_2$ . (12 points)

Express your answers in terms of  $g_m$ ,  $R_D$ ,  $R_1$  and  $R_2$ .

**QUESTION (3)**

In the following tuned amplifier circuit, the transistor  $M_1$  is biased by  $I_{bias} = 2$  mA. The supply voltages are  $V_{DD} = 10$  V,  $-V_{EE} = -10$  V.

The transistor parameters are given as  $K = 1$  mA/V<sup>2</sup>,  $V_{TH} = 1$  V,  $C_{gs} = 10$  pF,  $C_{gd} = 1$  pF, and  $\lambda = 0$ .



For:  $L_1 = 1$   $\mu$ H  
 $C_1 = 200$  pF,  $C_2 = \infty$   
 $R_s = 1$  k $\Omega$ ,  $R_L = 2$  k $\Omega$

- What is the center frequency,  $\omega_o$  of this amplifier? (4 points)
- What is the gain  $v_{OUT}/v_s$  at  $\omega = \omega_o$ ? (8 points)
- What is the 3dB bandwidth of this tuned amplifier? (8 points)

Useful formulae: for n-channel MOSFET

$$i_{DS} = K \left[ (v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2 \right] \quad \text{triode region}$$

$$i_{DS} = \frac{1}{2}K(v_{GS} - V_{TH})^2 (1 + \lambda v_{DS}) \quad \text{saturation region}$$

**QUESTION (4)**

This bipolar circuit is biased with a current of  $I_1 = 1$  mA and  $V_{bias} = 4$  V. Determine the voltage gain  $v_{OUT}/v_{IN}$ . (20 points)

Given:

$$\beta = 100$$

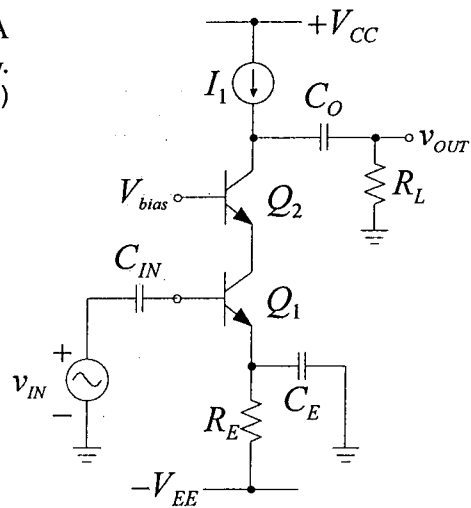
$$V_A = 5$$
 V

$$+V_{DD} = 10$$
 V

$$-V_{EE} = -10$$
 V

$$R_E = R_L = 1$$
 k $\Omega$

$$C_{IN} = C_E = C_O = \infty$$



**QUESTION (5)**

In the following push-pull output stage, assume that each transistors conducts a negligible amount of current around  $v_{IN} = 0V$ .  $Q_1$  conducts for the positive half of the input voltage and  $Q_2$  conducts for the negative half. Assuming that  $V_{CC} = |V_{EE}| = 10V$ ,  $R_L = 8\Omega$ , and the input voltage is sinusoidal, determine the followings:

- a) The maximum rms power that can be delivered to the load,  $R_L$ . (5 points)
- b) The maximum rms power dissipated by transistor  $Q_1$ . Assume that the base current is negligible. (10 points)
- c) The maximum power efficiency of this push-pull stage? Neglect the power drawn by the bias current sources  $I_1$  and  $I_2$ . (5 points)

