National Exams May 2010

07-Elec-B5, Advanced Electronics

3 hours duration

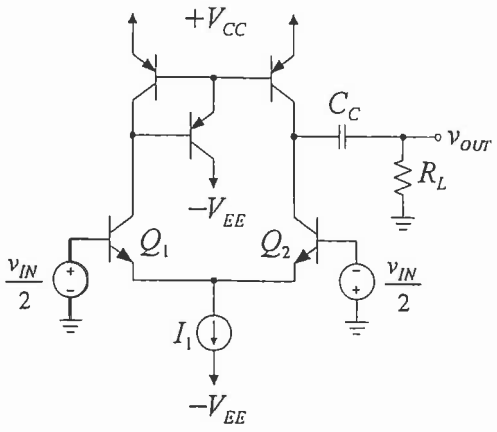
Notes:

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.
   One of two calculators is permitted; a Casio or Sharp approved models
3. Any 5 (FIVE) questions constitute a complete paper. The first five questions as they appear in the answer book will be marked.
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 ±15V.
8. Some 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)

Consider the diff amp circuit.

Given: $I_1 = 0.2\text{mA}$
$V_A = 100\text{V}$ for all transistors

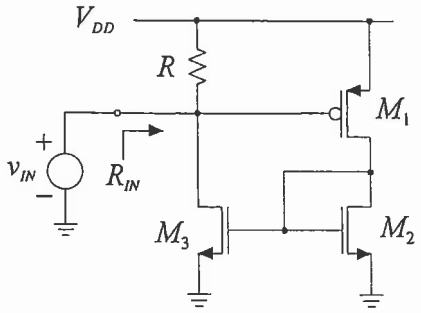


a) Determine the open-circuit ($R_L = \infty$) differential gain v_{OUT}/v_{IN}. (15 points)

b) What will be the differential gain if $R_L = 100\text{k}\Omega$? (5 points)

QUESTION (2)

Assuming all the transistors in this circuit is properly biased to operate in the saturation mode. Transistors $M2$ and $M3$ are matched. Derive an expression for the equivalent input resistance R_{IN}. (20 points)



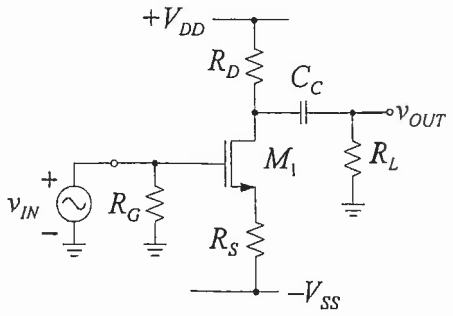
Useful formulae: for n-channel MOSFETs

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

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

$$g_m = K(V_{GS} - V_{TH})$$

QUESTION (3)



This circuit is intended for audio application. Determine the maximum value for CC such that the lower corner frequency for this amplifier is $f_L = 20$ Hz. (20 points)

Given:

$V_{DD} = |V_{SS}| = 5\text{V}$,
$K_n = 0.5\ \text{mA/V}^2$ $V_{TH} = 1\text{V}$
$R_D = 6.7\ \text{k}\Omega$, $R_S = 5\ \text{k}\Omega$
$R_G = 50\ \text{k}\Omega$ $R_L = 10\ \text{k}\Omega$

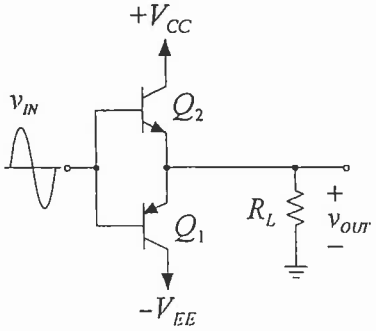
Useful formulae: for n-channel MOSFETs

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

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

$$g_m = K(V_{GS} - V_{TH})$$

QUESTION (4)



For this class B output stage, determine

a) The maximum RMS output power. (4 points)

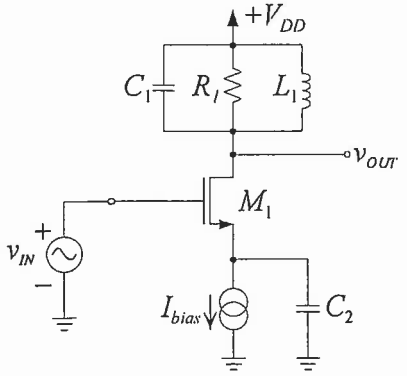
b) The RMS power dissipated by M1 under maximum output power. (8 points)

c) The power efficiency, η of this output stage. (8 points)

Given: $\beta = 50$,
$V_{BE,on} = 0.7$ V,
$R_L = 8\ \Omega$
$|V_{CC}| = |V_{EE}| = 20$ V.

QUESTION (5)

In the following tuned amplifier circuit, V_{DD} = 10 V, I_{bias} = 2 mA. The transistor parameters are given as K = 1 mA/V^2, 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, $C_2 = \infty$
$R_1 = 2\ k\Omega$

a) What is the center frequency, ω_o of this amplifier? (4 points)

b) What is the gain v_{OUT}/v_S at $\omega = \omega_o$? (8 points)

c) What is the 3dB bandwidth of this tuned amplifier? (8 points)

Useful formulae: for n-channel MOSFET

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

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

QUESTION (6)

Assuming that the op amp is ideal, derive the relationship between v_{OUT} and v_{IN}. Please note that this circuit behaves differently for positive and negative input voltages. (20 points)