National Exams December 2010

07-Elec-B5, Advanced Electronics

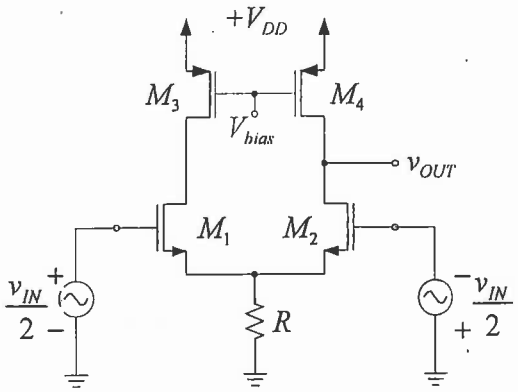
3 hours duration

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.
   A Casio or Sharp approved calculator is permitted.
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)

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



$K = 0.5$ mA/V^2, $|V_{TH}| = 1$ V and $\lambda = 0.02$.

Given:

$V_{bias} = 8$ V

$V_{DD} = 10$ V

$R = 2$ kΩ

a) Estimate the differential gain v_{OUT}/v_{IN} in (V/V). (6 points)

b) Find the common mode input resistance R_{icm}. (4 points)

c) Find the common mode input range. (4 points)

d) Estimate the common mode rejection ratio, CMRR. Express your result in dB. (6 points)

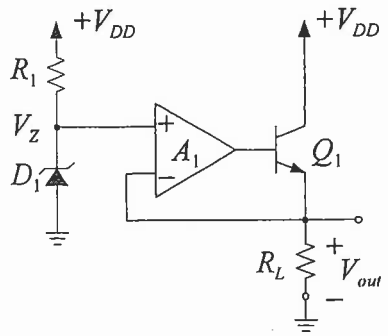
Useful formulae: for n-channel MOSFET

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

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

QUESTION (2)

This series voltage regulator has the following components values and device characteristics:



Op amp, A_1 is ideal

$\beta = 10$, $V_{BE} = 0.7$ V, $V_{CE(sat)} = 0.3$ V, $V_A = 30$ V for Q_1

$V_Z = 6.7$ V at $I_Z = 1$ mA, $R_Z = 3.3$ kΩ for D_1.

$R_1 = 3.3$ kΩ

$R_L = 4$ Ω

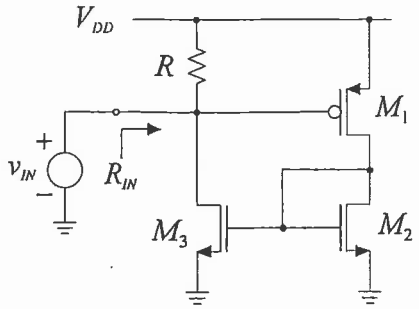
a) Given $V_{DD} = 10$V, what is the nominal output voltage, V_{OUT}? (4 points)

b) If V_{DD} has a 1V p-p ripple, what will be the ripple voltage at the output? (8 points)

c) Find the power efficiency, η of this voltage regulator. (8 points)

QUESTION (3)

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

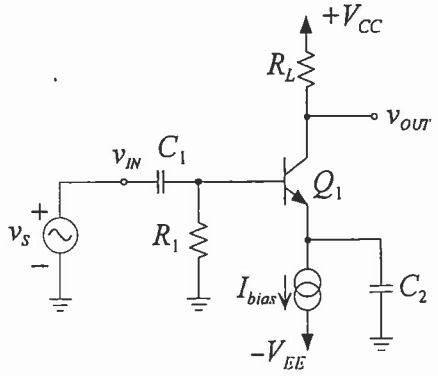
$$i_{DS} = K\left[(v_{GS} - V_{TH})v_{DS} - \frac{1}{2}v_{DS}^2\right] \qquad \text{triode region}$$

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

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

QUESTION (4)

In the following circuit, assume that $\beta = 100$, $V_{BE} = 0.7$ V, $V_{CE(sat)} = 0.3$ V, $V_A = 100$ V, $C_\mu = 2$ pF for all transistors. Neglect r_x and r_o in the hybrid-π model.



Given: $R_L = 5\text{k}\,\Omega$
$R_1 = 1\text{k}\,\Omega$
$C_1 = 10\ \mu\text{F}$
$C_2 = \infty$
$|V_{CC}| = |V_{EE}| = 10$ V
$I_{bias} = 1$ mA
$V_T = 25$ mV

a) Estimate the mid-band gain v_{OUT}/v_S in (V/V). (4 points)

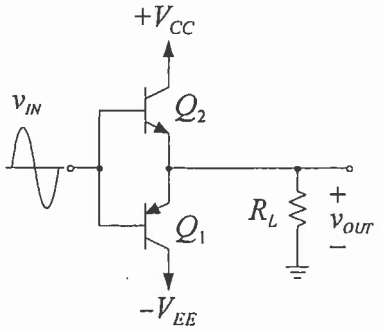
b) Find the lower 3dB frequency f_L in (Hz). (4 points)

c) Find the upper 3dB frequency f_H in (Hz). (6 points)

d) Find the 2nd high frequency dominant pole in (Hz). (6 points)

QUESTION (5)

For this class B output stage, determine



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

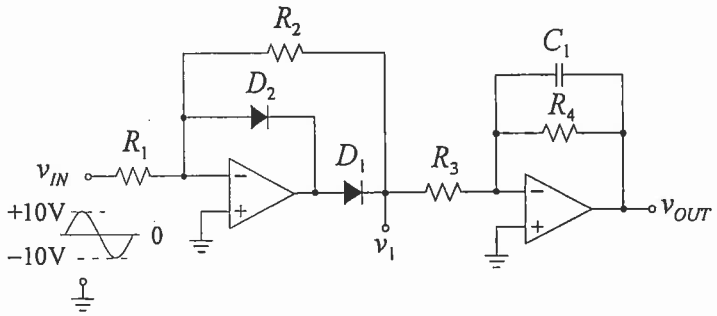
b) The RMS power dissipated by Q_1 under maximum output power. (8 points)

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 (6)

In this op amp circuit, the diodes are ideal and have a forward voltage drop of 0.7V.



a) Derive an expression for v_{OUT}/v_{IN} as a function of R_1, R_2, R_3, R_4, and C_1. (10 points)

b) Can this expression be further simplified if $\omega_{\min} >> \dfrac{1}{R_4 C_1}$,

where $\omega_{\min}$ is the lowest frequency of interest? (6 points)

c) What would be a potential function for this circuit? (4 points)