

National Exams December 2013

07-Elec-B5, Advanced Electronics

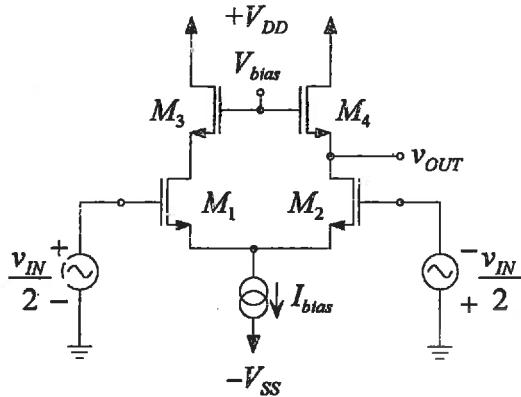
3 hours duration

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:



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

Given:

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

$V_{bias} = 6 \text{ V}$

$V_{DD} = |-V_{SS}| = 10 \text{ V}$

- 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)

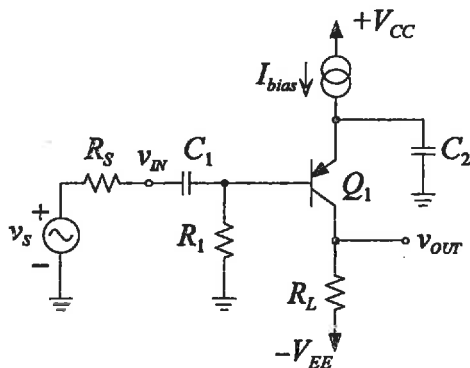
Useful formulae: for n-channel MOSFET

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

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

QUESTION (2)

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



Given: $R_S = 600 \Omega$

$R_L = 3 \text{ k}\Omega$

$R_1 = 1 \text{ k}\Omega$

$C_1 = 10 \mu\text{F}$

$C_2 = \infty$

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

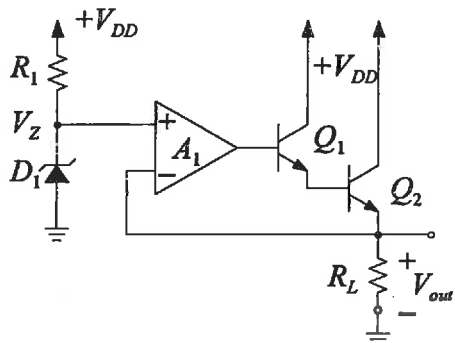
$I_{bias} = 2 \text{ mA}$

$V_T = 25 \text{ mV}$

- 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 (3)

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



Op amp, A_1 is ideal

for Q_1 and Q_2 :

$\beta = 100$, $V_{BE} = 0.7 \text{ V}$, and $V_A = 100 \text{ V}$

for D_1 :

$V_Z = 6.7 \text{ V}$ at $I_Z = 1 \text{ mA}$, $R_Z = 10 \text{ k}\Omega$

$R_1 = 3.3 \text{ k}\Omega$

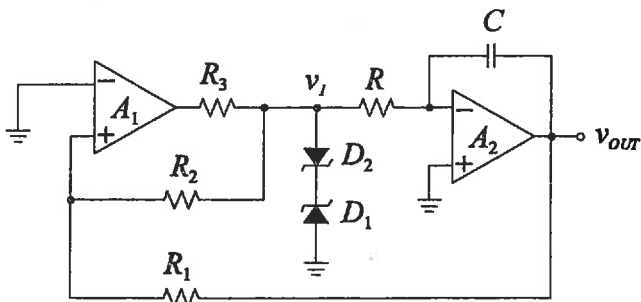
$R_L = 4 \Omega$

$V_T = 25 \text{ mV}$

- a) Given $V_{DD} = 10\text{V}$, 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 (4)

The op amps in the following circuit are ideal and are supplied by $\pm 15\text{V}$. The zener diodes, D_1 and D_2 have a zener voltage of $V_Z = 10\text{V}$ and forward voltage of 0V . Sketch accurately in your answer book the voltage waveform for v_{OUT} as a function of time. Provide accurate voltage leveling and timing information. (20 points)



Given:

$R_1 = 10 \text{ k}\Omega$

$R = 10 \text{ k}\Omega$

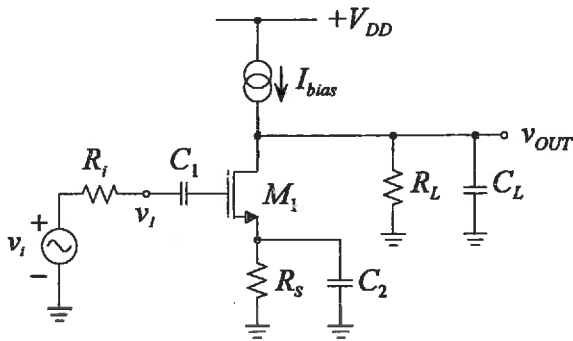
$R_2 = 10 \text{ k}\Omega$

$R_3 = 10 \text{ k}\Omega$

$C = 100 \text{ pF}$

QUESTION (5)

The following common source amplifier is already biased properly.



Given:

$$g_m = 2 \text{ mA/V}$$

$$R_i = 20 \text{ k}\Omega$$

$$R_S = 2 \text{ k}\Omega$$

$$C_{gs} = 20 \text{ fF}$$

$$C_L = 5 \text{ fF}$$

$$C_2 = \infty$$

$$r_o = 20 \text{ k}\Omega$$

$$R_L = 20 \text{ k}\Omega$$

$$C_{gd} = 5 \text{ fF}$$

$$C_1 = \infty$$

- d) Find the mid-band voltage gain v_{OUT}/v_i . (6 points)
- e) What is the new mid-band voltage gain, v_{OUT}/v_i if capacitor C_2 is removed? (6 points)
- f) What is the new 3dB frequency f_H if capacitor C_2 is removed? (8 points)