National Exams December 2011

07-Elec-B5, Advanced Electronics

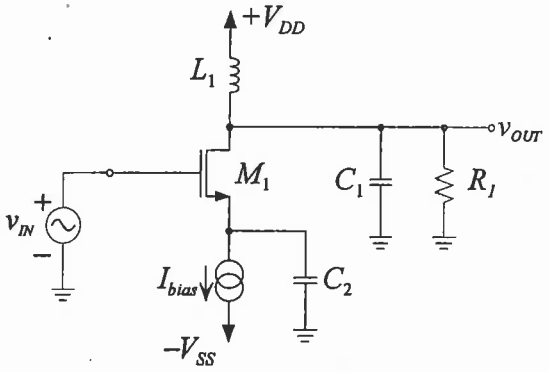
3 hours duration

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 tuned amplifier circuit, $V_{DD} = 10$ V, $-V_{SS} = -10$ 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: $L_1 = 10$ µH
$C_1 = 1$ nF, $C_2 = \infty$
$R_1 = 2$ kΩ

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 gain at very high frequencies? (4 points)

d) What is the gain at very low frequencies? (4 points)

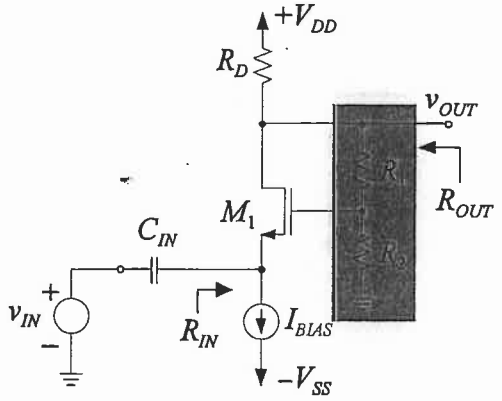
Useful formulae: for n-channel MOSFET

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

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

QUESTION (2)

In the following is a common gate (CG) amplifier with a feedback network consisting of R_1 and R_2. Given $R_D = 2$ kΩ, $V_{DD} = 10$ V, $-V_{SS} = -10$ V, $I_{bias} = 2$ mA, and the transistor parameters as $K = 1$ mA/V^2, $V_{TH} = 1$ V, and $\lambda = 0$,



a) Determine the input and output resistance (R_{IN} and R_{OUT}) if there is no feedback network (i.e. $R_1 = \infty$, and $R_2 = 0$ Ω). (8 points)

b) Derive the input and output resistance (R_{IN} and R_{OUT}) if for $R_1 = 200$ kΩ and $R_2 = 100$ kΩ. (12 points)

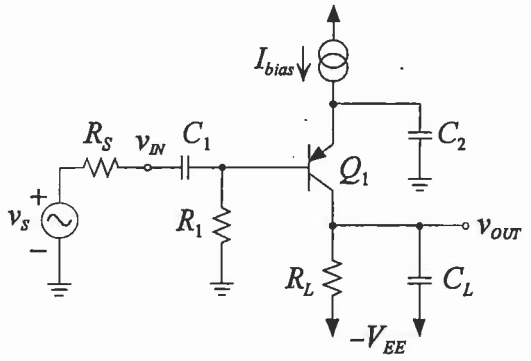
Useful formulae: for n-channel MOSFET

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

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

QUESTION (3)

In the following circuit is a common emitter (CE) amplifier with a pnn transistor. Assume that $\beta = 100$, $V_{EB} = 0.7$ V, $V_{EC(sat)} = 0.3$ V, $V_A = \infty$, $C_\mu = 2$ pF. Neglect r_x and r_o in the hybrid-π model.



Given: $R_S = 600\ \Omega$
$R_L = 5\text{k}\ \Omega$
$C_L = 1\ \mu\text{F}$
$R_1 = 1\text{k}\ \Omega$
$C_1 = 10\ \mu\text{F}$
$C_2 = \infty$
$|V_{CC}| = |V_{EE}| = 10$ V
$I_{bias} = 1$ mA
$V_T = 25$ mV

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

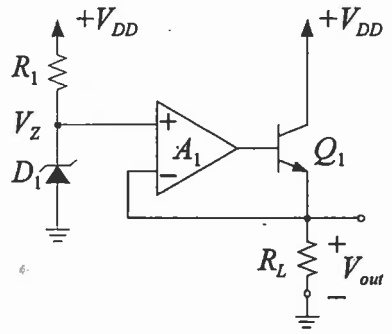
b) Find the lower 3dB frequency f_L in (Hz). (4 points)

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 (4)

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, $R_Z = 3.3\ \text{k}\Omega$ for D_1.
$R_1 = 3.3\ \text{k}\Omega$
$R_L = 4\ \Omega$

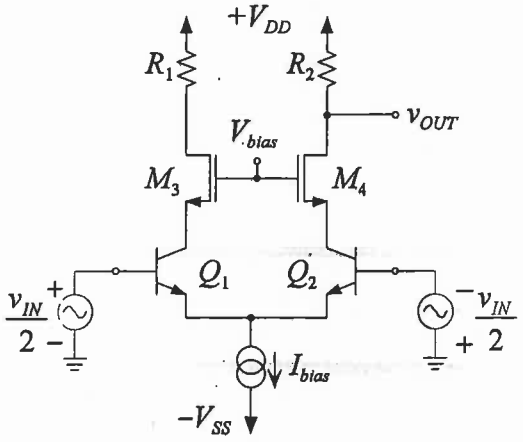
a) Given $V_{DD} = 10$ V, what is the nominal output voltage, V_{OUT}? (4 points)

b) If V_{DD} experience a transient by dropping from 10 V to 8 V momentary and then return to 10V, what will be the maximum voltage droop at the output? (8 points)

c) If V_{DD} experience a transient by dropping from 10 V to 5 V momentary and then return to 10V, what will be the maximum voltage droop at the output? (8 points)

QUESTION (5)

In the following circuit, assume the transistors have the following parameters:



For BJTs:
$\beta = 100$, $V_{BE} = 0.7$ V, $V_T = 25$ mV, $V_A = 100$ V,

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

Given:

$V_{DD} = 10$ V, $V_{SS} = -10$ V
$I_{bias} = 1$ mA
$V_{bias} = 5$ V
$V_{DD} = 10$ V
$R_1 = R_2 = 1$ 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)

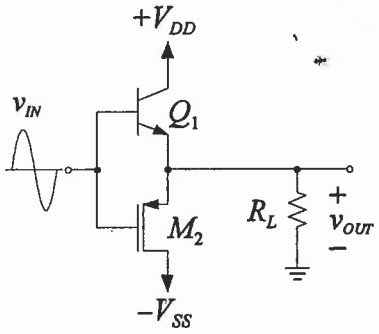
Useful formulae: for n-channel MOSFET

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

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

QUESTION (6)

The following is a class B output stage with a combination of BJT and MOSFET output transistors to handle the positive and negative input.



Given: $\beta = 100$, $V_{BE} = 0.7$ V, $V_{CE(sat)} = 0.3$ V, $V_T = 25$ mV,
$V_A = 100$ V,
$K = 500$ mA/V^2, $V_{TH} = 1.5$ V,
$|V_{DD}| = |V_{SS}| = 10$ V
$R_L = 8\ \Omega$

a) Sketch accurately the output voltage waveform at v_{out} for a 1 kHz, 10 V peak to peak triangular-wave input. (8 points)

b) The RMS power dissipated by M1 under maximum output power. (4 points)

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