National Exams May 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).

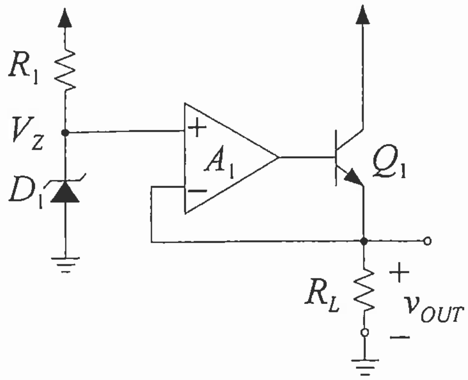
6. In schematics, ground and chassis may be assumed to be common, unless specifically stated otherwise.

7. Unless otherwise specified, assume that Op-Amps are ideal and that supply voltages are $\pm 15V$.

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)

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



Op amp, A_1 is ideal

$\beta = 20$, $V_T = 25$ mV, $V_{CE(sat)} = 0.3$ V, $V_A = 30$ V for Q_1

$V_Z = 6.7$ V at $I_Z = 1$ mA, $R_Z = 10$ kΩ for D_1.

$R_1 = 3.3$ kΩ

$R_L = 4$ Ω

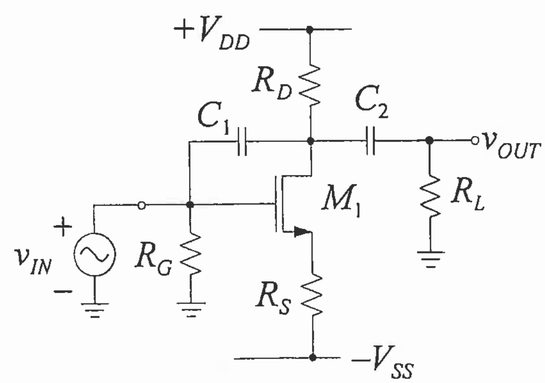
a) Given $V_{DD} = 10$V, what is the nominal output voltage, V_{OUT}? (4 points)

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 (2)

Determine the upper corner frequency for this amplifier. Assume that the transistor M_1 has unlimited bandwidth. (20 points)



Given:

$V_{DD} = |V_{SS}| = 10$ V,

$K_n = 0.5$ mA/V^2	$V_{TH} = 1$V
$R_D = 6.7$ kΩ,	$R_S = 5$ kΩ
$R_G = 50$ kΩ	$R_L = 10$ kΩ
$C_1 = 100$ pF	$C_2 = \infty$ pF

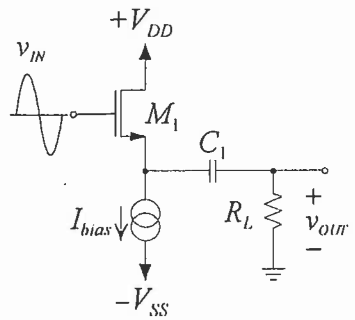
Useful formulae: for n-channel MOSFETs

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

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

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

QUESTION (3)



The following is a class A output stage.

Given: $I_{Bias} = 0.5$ A, $K = 500$ mA/V^2, $V_{TH} = 1.0$ V, $R_L = 8\ \Omega$ and $|V_{DD}| = |V_{SS}| = 10$ V.

a) The maximum undistorted RMS output power. (5 points)

b) The RMS power dissipated by the current source I_{Bias} under maximum output power. (5 points)

c) The RMS power dissipated by M_1 under maximum output power. (5 points)

d) The power efficiency, η of this output stage. (5 points)

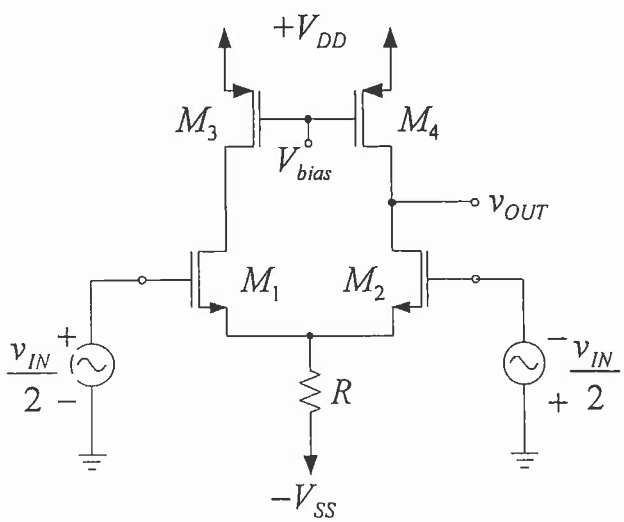
Useful formulae: for n-channel MOSFET

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

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

QUESTION (4)

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



Given:

$K_{1,2} = 5.0$ mA/V^2, for M_1 and M_2

$K_{3,4} = 0.5$ mA/V^2, for M_3 and M_4

$|V_{TH}| = 1$ V and $\lambda = 0.02$ for all MOSFETs

$V_{bias} = 8$ V

$V_{DD} = 10$ V, $V_{SS} = -10$ V

R = not specified

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

b) Find the common mode input resistance R_{icm} as a function of R. (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)

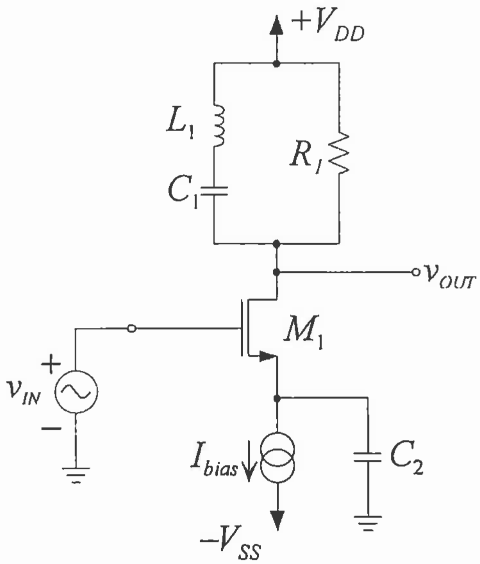
Useful formulae: for n-channel MOSFET

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

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

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: $L_l = 10$ µH
$C_1 = 1$ nF, $C_2 = \infty$
$R_l = 2$ 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? (8 points)

d) What is the gain at very low frequencies? (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 (6)

The following voltage waveforms represent the operation of a dual slope Analog to Digital Converters (ADC).

a) Provide a block level diagram for such type of ADC. Identify all the essential circuit blocks (no detail schematic is required). (8 points)

b) Provide a brief description on the working principle of dual slope ADC. (8 points)

c) What are the advantages and disadvantages of dual slope ADCs. What determines the precision? (4 points)