National Exams May 2015

07-Elec-B5, Advanced Electronics

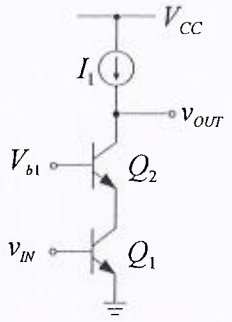
3 hours duration

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 ±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) (Razavi, Example 9.9, pg. 405)

In this circuit, the bipolar transistors are biased with a current of I_1 = 1mA. V_{b1} is a DC bias voltage. Determine the voltage gain v_{OUT}/v_{IN}. (20 points)

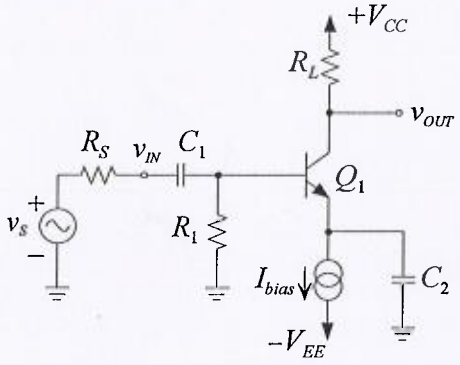


Given:

β = 100
V_A = 5 V (Early Voltage)

QUESTION (2)

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

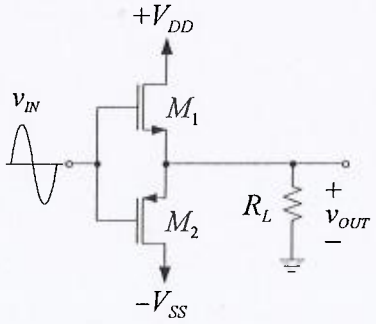


Given: R_S = 600 Ω
R_L = 5k Ω
R_1 = 1k Ω
C_1 = 10 μF
C_2 = ∞
$|V_{CC}| = |V_{EE}|$ = 10 V
I_{bias} = 1 mA
V_T = 25 mV

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 (3)

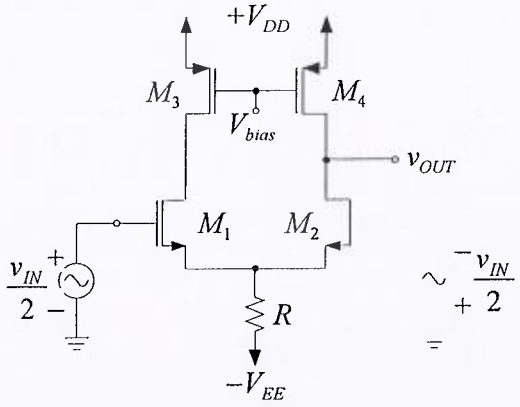
The following is a class B output stage.



Given: K = 500 mA/V^2, V_{TH} = 1.0 V,
R_L = 8 Ω and $|V_{DD}| = |V_{SS}|$ = 10 V.

a) The maximum RMS output power. (4 points)
b) The RMS power dissipated by M_1 under maximum output power. (8 points)
c) The power efficiency, η of this output stage. (8 points)

QUESTION (4)



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)

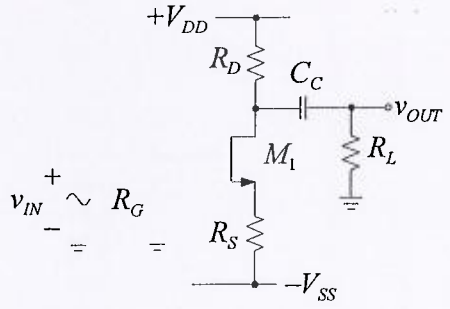
b) Find the common mode input resistance R_{icm}. (4 points)

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

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

QUESTION (5)

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



Given:

$V_{DD} = |V_{SS}| = 5$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

Useful formulae: for n-channel MOSFETs

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

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

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