National Exams May 2016

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.

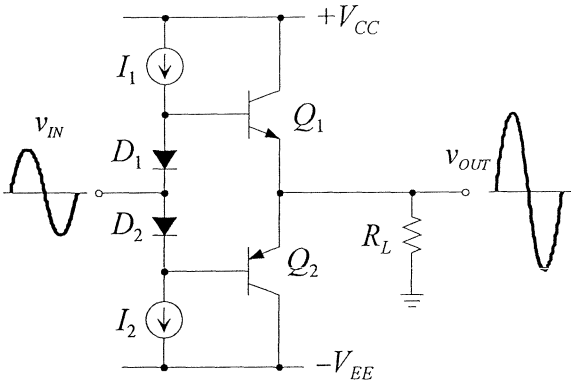
QUESTION (1)

In the following push-pull output stage, assume that each transistors conducts a negligible amount of current around $v_{IN} = 0$V. Q_1 conducts for the positive half of the input voltage and Q_2 conducts for the negative half. Assuming that $V_{CC} = |V_{EE}| = 10$V, $R_L = 8\Omega$, and the input voltage is sinusoidal, determine the followings:

a) The maximum power that can be delivered to the load, R_L. (5 points)

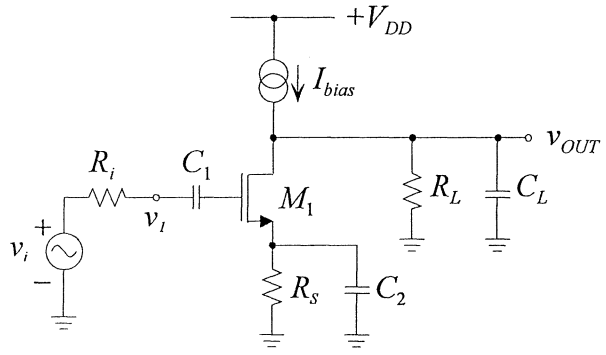
b) The maximum power dissipated by transistor Q_1. Assume that the base current is negligible. (10 points)

c) The maximum power efficiency of this push-pull stage? Neglect the power drawn by the bias current sources I_1 and I_2. (5 points)



QUESTION (2)

The following equivalent common source amplifier is already biased properly (no need to perform a DC analysis).



Given:

$V_{DD} = 10$V

$g_m = 2$ mA/V $\quad r_o = 20$ kΩ

$R_i = 20$ kΩ $\quad R_L = 20$ kΩ

$R_S = 1.5$ kΩ

$C_{gs} = 20$ fF $\quad C_{gd} = 5$ fF

$C_L = 5$ fF $\quad C_1 = \infty$

$C_2 = \infty$

a) Find the mid-band voltage gain v_{OUT}/v_i. (6 points)

b) What is the new mid-band voltage gain, v_{OUT}/v_i if capacitor C_2 is removed? (6 points)

c) What is the new 3dB frequency f_H if capacitor C_2 is removed? (8 points)

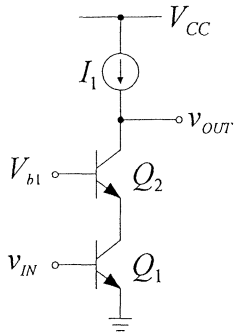
Useful formulae: for n-channel MOSFET

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

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

QUESTION (3) (Razavi, Example 9.9, pg. 405)

The bipolar circuit is biased with a current of I_1 = 1mA and V_{b1} = 5V. Determine the small signal mid-band voltage gain v_{OUT}/v_{IN}. (20 points)

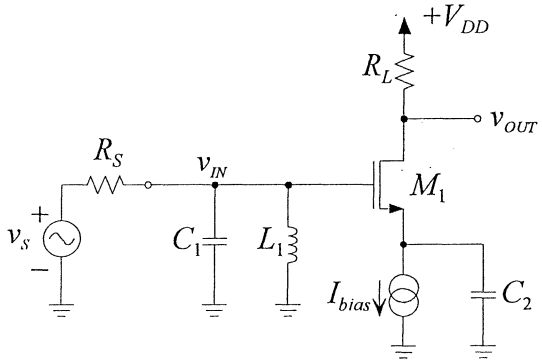


Given:

V_{DD} = 10V
β = 100
V_A = 5 V

QUESTION (4)

In the following tuned amplifier equivalent circuit, transistor M_1 is already biased properly with V_{DD} = 10 V and 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 = 1 µH
C_1 = 200 pF, C_2 = ∞
R_S = 1 kΩ, R_L = 2 kΩ

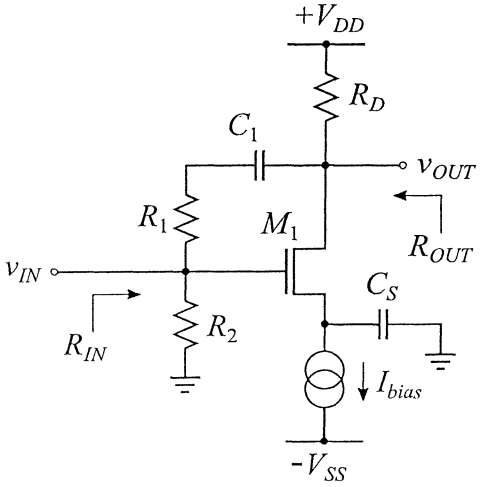
a) What is the center frequency, ω_o of this amplifier? (4 points)

b) What is the gain v_{OUT}/v_S at $\omega = \omega_o$? (8 points)

c) What is the 3dB bandwidth of this tuned amplifier? (8 points)

QUESTION (5)

Consider the following amplifier with a feedback circuit (R_1, C_1).



Given: R_D = 3k Ω, $C_S = C_1 = \infty$, R_2 = 20 kΩ
$|V_{DD}| = |V_{SS}|$ = 10 V
I_{bias} = 1 mA
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. $R_1 = \infty$). (8 points)

b) Determine the input and output resistance (R_{IN} and R_{OUT}) if R_1 = 100 kΩ. (12 points)