National Exams December 2014

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)

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

![Circuit Diagram]

Op amp, $A_1$ is ideal
for $Q_1$ and $Q_2$:

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

for $D_1$:

$V_Z = 6.7$ V at $I_Z = 1$ mA, $R_Z = 10$ $\Omega$

$R_1 = 3.3$ k$\Omega$

$R_L = 4$ $\Omega$

$V_T = 25$ mV

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, $\eta$ of this voltage regulator. (8 points)

QUESTION (2)

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 $\lambda = 0$.

![Circuit Diagram]

For:

$L_1 = 1$ $\mu$H

$C_1 = 200$ pF, $C_2 = \infty$

$R_I = 2$ k$\Omega$

a) What is the center frequency, $\omega_0$ of this amplifier? (4 points)
b) What is the gain $v_{OUT}/v_S$ at $\omega = \omega_0$? (8 points)
c) What is the 3dB bandwidth of this tuned amplifier? (8 points)

Useful formulae: for n-channel MOSFET

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

\[ i_{DS} = \frac{1}{2} K (v_{GS} - V_{TH})^2 (1 + \lambda v_{DS}) \] \hspace{1cm} \text{saturation region}
QUESTION (3)
The following common source amplifier is already biased properly.

\[ +V_{DD} \]
\[ \begin{array}{c}
\text{\( R_i \)} \\
\text{\( C_1 \)}
\end{array} \]
\[ \begin{array}{c}
\text{\( M_1 \)} \\
\text{\( R_L \)} \\
\text{\( C_L \)}
\end{array} \]
\[ v_{OUT} \]
\[ \begin{array}{c}
\text{\( R_s \)} \\
\text{\( C_2 \)}
\end{array} \]
\[ v_i \]

Given:
- \( g_m = 2 \text{ mA/V} \)
- \( r_o = 20 \text{ k}\Omega \)
- \( R_i = 20 \text{ k}\Omega \)
- \( R_L = 20 \text{ k}\Omega \)
- \( R_s = 100 \text{ \Omega} \)
- \( C_{gs} = 20 \text{ fF} \)
- \( C_{gd} = 5 \text{ fF} \)
- \( C_L = 5 \text{ fF} \)
- \( C_2 = \infty \)
- \( C_1 = \infty \)

(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 \( f_{TH} \) if capacitor \( C_2 \) is removed? (8 points)

QUESTION (4) (Razavi, Example 9.9, pg. 405)
The bipolar circuit is biased with a current of \( I_I = 1\text{ mA} \). Determine the voltage gain \( v_{OUT}/v_{IN} \). (20 points)

Given:
- \( \beta = 100 \)
- \( V_A = 5 \text{ V} \)

QUESTION (5)
In the following amplifier can be considered as a feedback circuit. You can assume that the transistor is operating in saturation mode.

- a) Determine the input and output resistance (\( R_{IN} \) and \( R_{OUT} \)) if there is no feedback network (i.e. \( R_1 = \infty \), and \( R_2 = 0 \text{ \Omega} \)). (8 points)
- b) Derive the input and output resistance (\( R_{IN} \) and \( R_{OUT} \)) if the feedback network has finite values for \( R_1 \) and \( R_2 \). (12 points)

Express your answer in terms of \( g_m, R_D, R_1 \) and \( R_2 \).