NANYANG TECHNOLOGICAL UNIVERSITY

SEMESTER 1 EXAMINATION 2022-2023

EE4341 – ADVANCED ANALOG CIRCUITS

November / December 2022 Time Allowed: 2 hours

INSTRUCTIONS

1. This paper contains 4 questions and comprises 5 pages.
2. Answer all 4 questions.
3. All questions carry equal marks.
4. This is a closed book examination.
5. Unless specifically stated, all symbols have their usual meanings.

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1. A common emitter amplifier (biasing circuit not shown) is shown in Figure 1 on page 2. Assume Boltzmann's constant $k = 1.38 \times 10^{-23}$ J/K, $q = 1.6 \times 10^{-19}$ C, $T = 300$ K, $V_T = 26$ mV, the equivalent noise bandwidth is 50 kHz, $I_c = 0.25$mA, $\beta = 100$, $r_{bb'} = 100\ \Omega$, $r_\pi \gg r_b$, $R_E = 100\text{k}\Omega$, $R_B = 1\text{M}\Omega$, $R_S = 100\Omega$, and $R_L = 200\ \text{k}\Omega$. Neglect flicker noise and capacitive effect.

   Note: For the BJT biased on forwards active region: $r_\pi = \frac{V_T}{I_B}$, $g_m = \frac{I_C}{V_T}$.

   (a) Draw the noise equivalent circuit.

   (5 Marks)

   (b) Calculate the equivalent input rms noise voltage and noise current sources of the circuit looking from point "***a***" to the output.

   (15 Marks)

   (c) Between R_S and R_B (i. e. at point "***a***"), a transformer can be inserted for noise matching. Determine the optimum transformer turns ratio 1: N, so that the total input SNR can be maximized.

   (5 Marks)

Note: Question No. 1 continues on page 2.

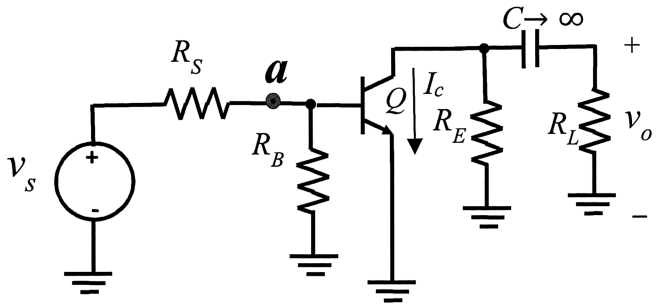

Figure 1

2. For the MOSFET feedback amplifier shown in Figure 2 on page 3, assume that $V_{DD} = 10$ V, $V_{TN} = 1$ V, $K_n = 1.5$ mA/V^2, $r_o = \infty$, $R_S = 1$ MΩ, $R_1 = 6.285$ MΩ, $R_2 = 2$ MΩ, $R_D = 5.07$ kΩ, $R_L = 3$ kΩ, $C_{GD} = 0.5$ pF, $C_{GS} = 1$ pF, and $C_L = 1$ pF.
Note: For the MOSFET biased in saturation region: $I_D = \frac{K_n}{2}(V_{GS} - V_{TN})^2$, $g_m = \sqrt{2K_n I_D}$.

(a) Determine the Q-point for the transistor.

(8 Marks)

(b) Determine the middle-band gain A_v, and the break frequencies f_1 and f_2.

(12 Marks)

(c) Draw the frequency response based on the calculations in part (b).

(5 Marks)

Note: Question No. 2 continues on page 3.

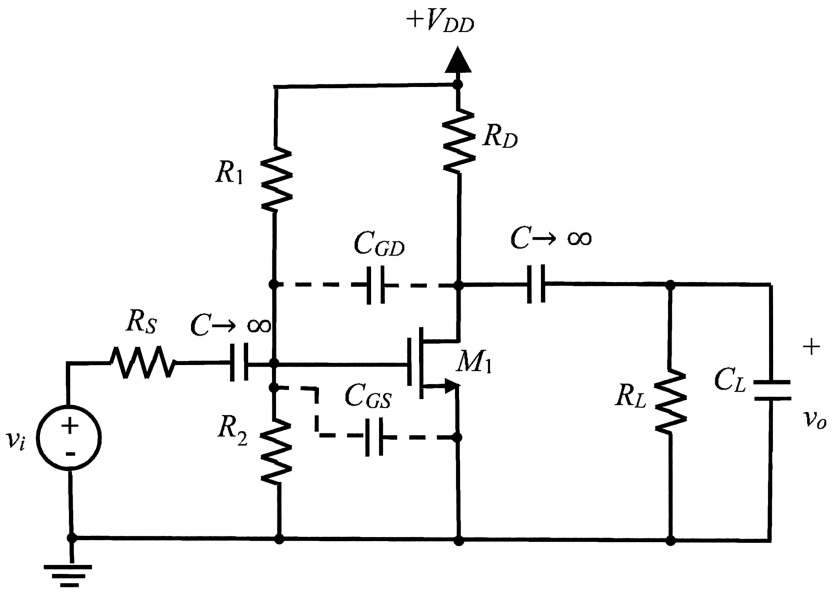

Figure 2

3. Figure 3 on page 4 shows a BiCMOS power amplifier output stage that consists of a BJT Q_1 and a depletion NMOS M_1. Q_1 has the following parameters: V_{BE} = 0.7 V and $V_{CE(sat)}$ = 0.2 V. M_1 has the following parameters: V_{TN} = –1.5 V and $K_n = \frac{1}{2}k_n'\left(\frac{W}{L}\right)$ = 10 mA/V^2. The amplifier is powered by ± 9 V and the load resistor R_L = 500 Ω.

   (a) Plot the v_o versus v_i transfer function of the amplifier. Clearly indicate the maximum and minimum output voltages and their corresponding input voltages.

   (12 Marks)

   (b) From the transfer function in part (a), what is the peak voltage of the sinusoidal waveform at the output without clipping?

   (3 Marks)

   (c) To achieve an output sinusoidal waveform of 5 V peak, what is the smallest possible value of R_L that can be connected to the output? What is the corresponding conversion efficiency for the calculated R_L?

   (10 Marks)

Note: Question No. 3 continues on page 4.

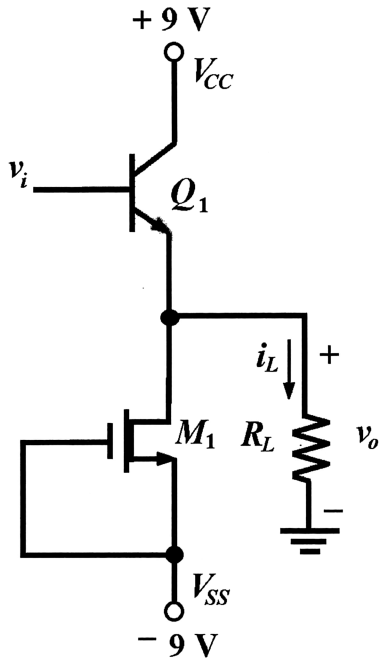

Figure 3

4.

(a) Figure 4 shows a biquadratic active filter with V_i as the input. It has three outputs, s^2V_{LP}, $-sV_{LP}$ and V_{LP}, where V_{LP} denotes output that provides the low-pass filter function. Given the biquadratic active filter, design a second order band-pass filter with –3 dB bandwidth from 2.75 kHz to 3.25 kHz and a unity gain at the centre frequency. Additional op-amp and resistors can be added, if necessary. In your design, use as many 10 kΩ standard resistors as possible. Draw the final active band-pass filter circuit and clearly indicate the values of all the resistors and capacitors.

(13 Marks)

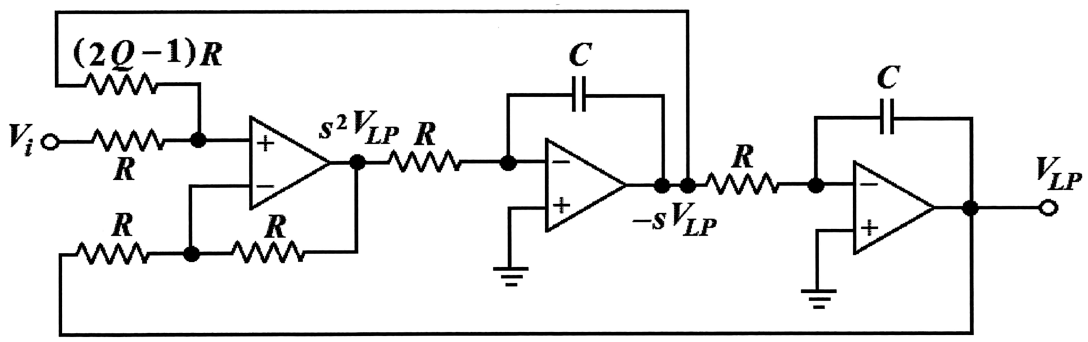

Figure 4

Note: Question No. 4 continues on page 5.

(b) Figure 5 shows a DC-DC Buck converter that converts 15 V to 9 V. The load resistor R_L = 10 Ω and the ripple voltage across the load must be kept within 1 %. The switching frequency f_s of the power MOSFET has been selected to be 100 kHz. Assume that all the components in the converter circuit are ideal and lossless. The inductor should be sized 20% higher than the minimum value to ensure continuous current operation. Determine the values of L and C, and their respective voltage and current ratings.

(12 Marks)

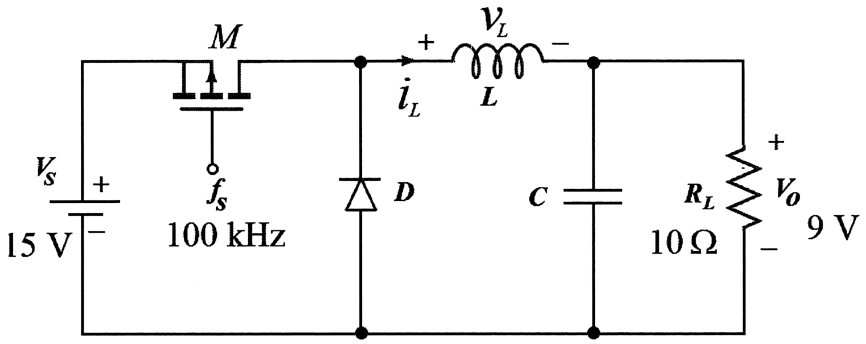

Figure 5

END OF PAPER

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Please read the following instructions carefully:

1. **Please do not turn over the question paper until you are told to do so. Disciplinary action may be taken against you if you do so.**

2. You are not allowed to leave the examination hall unless accompanied by an invigilator. You may raise your hand if you need to communicate with the invigilator.

3. Please write your Matriculation Number on the front of the answer book.

4. Please indicate clearly in the answer book (at the appropriate place) if you are continuing the answer to a question elsewhere in the book.