CARLETON UNIVERSITY

FINAL
EXAMINATION
April 1999

DURATION 3 **HOURS** No. Of Students 39

Department Name & Course Number: Electronics 97.477
Course Instructor(s): Prof. Calvin Plett

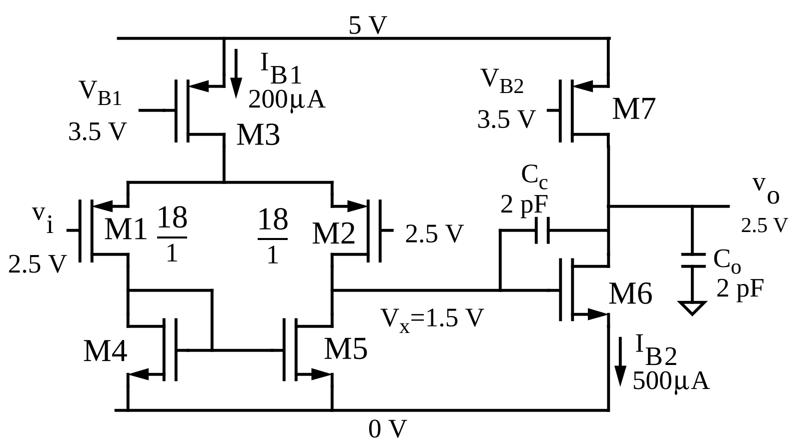
AUTHORIZED MEMORANDA: Official Course Summary and Calculators Allowed

Students MUST count the number of pages in this examination question paper before beginning to write, and report any discrepancy immediately to a proctor. This question paper has 3 pages.

This examination question paper MAY **be taken from the examination room.**

Question 1 (Total 30 Marks)

For the CMOS Opamp shown:



$K_{pp} = 25\ \mu A/V^2$

$K_{pn} = 50\ \mu A/V^2$

$V_{tn} = 0.5\ V$

$V_{tp} = -0.5\ V$

$\lambda_p = 0 \quad \lambda_n = 0.05$

$\gamma_p = 0 \quad \gamma_n = 0$

a) With an opamp having a circuit as shown, and bias currents and other parameters as specified, pick and specify any necessary transistor sizes to establish an internal bias voltage level V_x of 1.5V as shown, and an output bias of 2.5 V.

b) Determine the DC magnitude gain of the two stages (v_x/v_i, v_o/v_x) and the overall DC gain in dB.

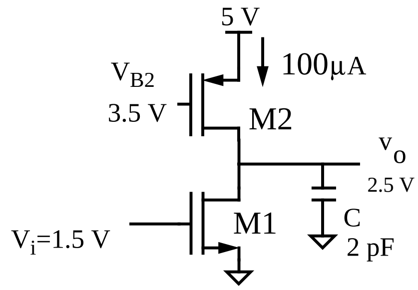
c) Calculate the pole and zero frequencies and the UGBW of the opamp in Hertz. Determine if the opamp is stable. Explain your reasoning.

d) Find the positive and negative common-mode input range. Identify which transistors will leave the saturation region.

<u>Question 2</u> (Total 10 marks)

a) A first-order filter has a passband from DC to 20 kHz, with a passband voltage gain of 5. An opamp used to realize this filter has a unity-gain frequency of 1 MHz and a DC gain of 80 dB. Calculate the maximum gain error for this filter and the frequency for which this maximum gain error occurs.

b) For the following circuit with $v_{tn} = 0.5V$, the nominal input voltage is 1.5 V at which time the nominal current is 100 μA and the output voltage is 2.5 V. Calculate the positive and negative slew rate for the input at 1.5 ± 0.5 V, that is, it is switching between 2 V and 1V.



<u>Question 3</u> (Total 15 Marks)

A circuit has the transfer function

$$\frac{v_o}{v_i} = -\frac{z^{-1}}{1 - 2z^{-1} + 2z^{-2}}$$

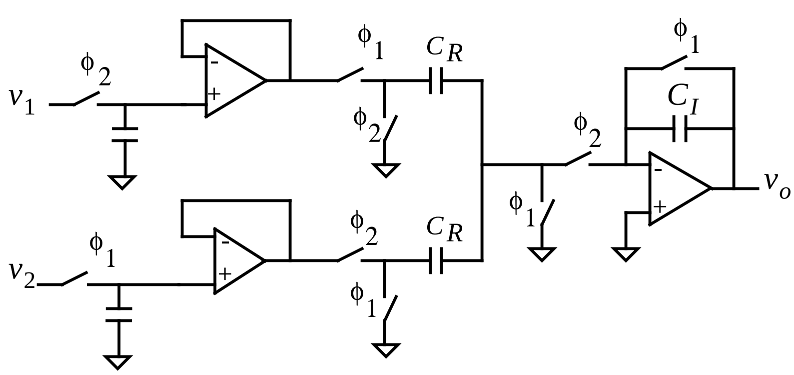
a) Determine the magnitude of the frequency response in the ideal sampled-data domain at DC, $f_{clock}/4$. $f_{clock}/2$, and f_{clock}.

b) Suppose the input frequency is fixed at 5/4 of the clock frequency and the frequency range from DC to twice the clock is looked at. Sketch the frequency spectrum seen by a spectrum analyzer, with approximate relative amplitudes. Explain your reasoning.

c) Determine the first four points (n = 0, 1, 2, 3) of the response in the time domain for a 1 V step input at $t = 0$.

<u>Question 4</u> (Total 15 Marks)

For the circuit shown below:

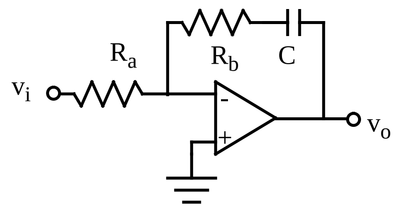


a) Do a charge balance analysis for the above circuit.

b) Determine the Z transform in the form $v_o = H_1(z)v_1 + H_2(z)v_2$.

<u>Question 5</u> (Total 15 marks)

For the circuit shown below:



$$R_a = 1\ \mathrm{M\Omega} \qquad R_b = 2\ \mathrm{M\Omega} \qquad C = 5\mathrm{pF}$$

a) Find the transfer functions relating the noise due to R_a and R_b to the output.

b) Calculate the power spectral density at the output due to R_a and R_b at 100 kHz.

c) Find the integrated output noise due to R_b up to a bandwidth of 1 MHz.

d) The opamp has input referred thermal noise voltage v_n of 20 nV/$\sqrt{\mathrm{Hz}}$. Sketch the output noise density due to v_n from 1 kHz to 1 Mhz (for the same circuit as above).

<u>Question 6</u> (Total 15 marks) (Full Marks will not be given if answer is not grammatical).

a) Define and discuss in no more than 3 pages, replication, aliasing, and sin(x)/x in sampled data systems. Describe how these effects would be seen in both the frequency domain and in the time domain.