Midterm #1 Solutions – EECS 145L Fall 2001

1	Op Amp	Inverting op-amp circuit amplifier	Non-inverting op-amp circuit amplifier	Differential op-amp circuit amplifier	Instrumentation amplifier
High Z_{in}	YES	NO	YES	NO	YES
Differential input	YES	NO	NO	YES	YES
Defined gain over a frequency band	NO	YES	YES	YES	YES

[1 point off for each wrong answer]

2a

Op-amp equation $V_0 = -AV_3$

Kirchhoff's current law at node V_2: $\dfrac{V_1 - V_2}{100\ \text{k}\Omega} + \dfrac{V_3 - V_2}{1\ \text{k}\Omega} + \dfrac{0 - V_2}{1\ \text{k}\Omega} = 0$

$$V_1 = V_2 + 100V_2 - 100V_3 + 100V_2 = 201V_2 - 100V_3$$

Kirchhoff's current law at node V_3: $\dfrac{V_2 - V_3}{1\ \text{k}\Omega} + \dfrac{V_0 - V_3}{100\ \text{k}\Omega} = 0$

$$100V_2 = 100V_3 + V_3 - V_0 = (101 + A)V_3$$

$$V_1 = \left[\frac{201(101 + A)}{100} - 100\right]V_3 = \left[\frac{10301 + 201A}{100}\right]V_3$$

$$V_1 = \left[201 - \frac{100(100)}{101 + A}\right]V_2 = \left[\frac{10301 + 201A}{101 + A}\right]V_2$$

$$\boxed{V_2 = \frac{(101 + A)V_1}{10301 + 201A} \approx \frac{1 + A/100}{100 + 2A}V_1} \qquad \boxed{V_3 = \frac{100V_1}{10301 + 210A} \approx \frac{V_1}{100 + 2A}} \qquad \boxed{V_0 = \frac{-100AV_1}{10301 + 201A} \approx \frac{-AV_1}{100 + 2A}}$$

[7 points off for setting up the first three equations but not solving them]

[10 points off for following through with the erroneous starting equation $V_2 = V_1/101$]

2b

f = 10 Hz, A = 10^5

$V_2 \approx V_1/201 \approx 5 \times 10^{-3}\ V_1$ $\quad$ $V_3 \approx 100V_1/(201 \times 10^5) \approx 5 \times 10^{-6}\ V_1$ $\quad$ $V_0 \approx -0.5\ V_1$

f = 1 MHz, A = 1

$V_2 \approx 100V_1/10000 \approx 10^{-2}\ V_1$ $\quad$ $V_3 \approx 100V_1/10000 \approx 10^{-2}\ V_1$ $\quad$ $V_0 \approx -10^{-2}\ V_1$

[15 points off for determining As only]

[2 points off if some answers off by 2x]

To solve 2b without using 2a:

At 10 Hz, A = 10^5 is larger than the closed loop gain of 100 and the virtual short rule gives

$V_2 = V_1\ 500\ \Omega/100\ \text{k}\Omega = 5 \times 10^{-3}\ V_1$ $\quad$ $V_0 = -100\ V_2 = -0.5\ V_1$ $\quad$ $V_3 \approx -V_0/10^5 \approx 5 \times 10^{-6}\ V_1$

At 1 MHz, A = 1, negative feedback fails, and the circuit gain is limited by the op-amp gain of –1

$V_0 = -V_3$

$V_2 \approx V_3$ (voltage drop across 1 kΩ resistor is 1% of the $2V_3$ voltage drop across 100 kΩ resistor)

$V_2 = V_1\ 1\ \text{k}\Omega/100\ \text{k}\Omega \approx 10^{-2}\ V_1$ $\quad$ $V_3 \approx 10^{-2}\ V_1$ $\quad$ $V_0 = -10^{-2}\ V_1$

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3a The lower corner frequency is given by the RC time constant of the high-pass filter

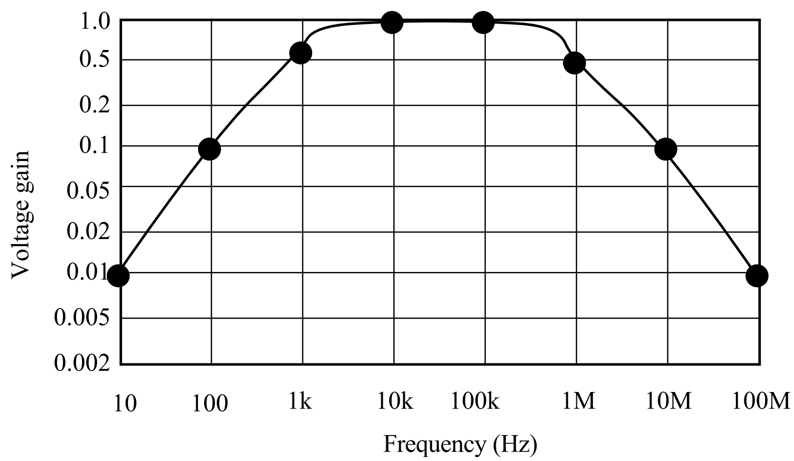
$f_c = 1/(2\ \pi\ RC) = 1/(2\ \pi\ 0.16 \times 10^{-3}) \approx 1$ kHz

[1 point off for 6.25 kHz]

3b The frequency where the gain of the buffer amplifier falls to 0.5 is the frequency where A falls to 1 which is 1 MHz. [2 MHz was also allowed].

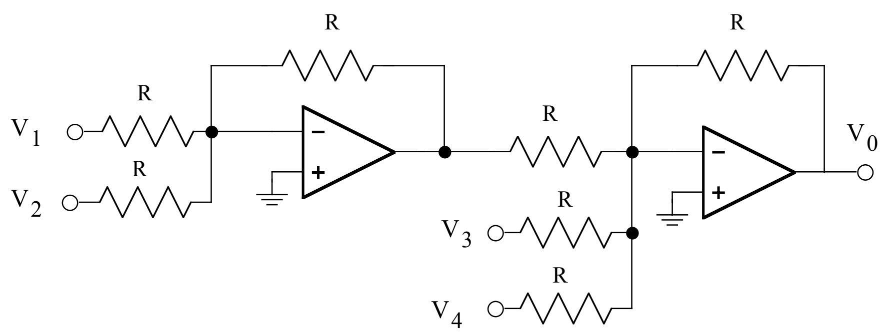
[4 points off if LPF formula used to get 500 to 2000 Hz]

3c



[5 points off if gain does not decrease as 1/f above 1 MHz]
[5 points off if gain does not increase as f below the f_c value answer in 3a]

4



[2 points off for overall sign error, e.g. $V_0 = -V_1 - V_2 + V_3 + V_4$]

[2 points off for a working circuit that uses three op amps]

[5 points off for using two differential amps to take $V_1 - V_3$ and $V_2 - V_4$ and then connecting the output directly together]

[5 points off for one summing amp plus two resistors connected to the + input of a buffer amp; this input is not a summing point]

[2 points off for the following circuit with resistor values shown because of the overall sign error, e.g. $V_0 = -V_1 - V_2 + V_3 + V_4$]

[4 points off for the following circuit with no resistor values shown]

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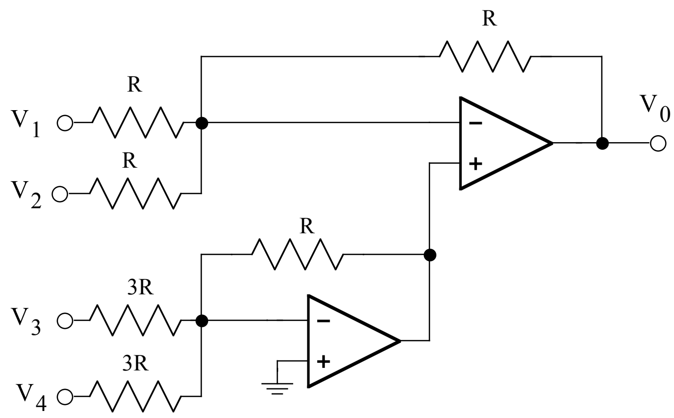

145L midterm #1 grade distribution:

Problem	
1	13.4 (15 max)
2	22.5 (40 max)
3	17.7 (25 max)
4	17.3 (20 max)

maximum score =	100	
average score =	70.9	
31-40	1	F
41-50	0	D
51-60	4	C
61-70	8	C-B
71-80	6	B
81-90	5	B-A
91-95	2	A
96-100	0	