Exam I

ECE 342 Electronics I

Sept. 28, 2018

Name: Spencer Goulette

- Make sure you write your name on all pages.
- Detailed descriptions of how you solved the problem will get you maximum partial credit if your final answer is wrong.
- You must provide the correct unit along with your answer in the answer areas. An answer without its unit will be considered incorrect.
- You may only use FE exam approved, so called dumb calculators.
- A table of commonly used constants, parameters and equations is at the end of the exam.
- Unless noted otherwise, assume room temperature conditions, i.e. T = 300K

Question	Grade	Out of
#1	18	20
#2	20	20
#3	24	24
#4	18	20
#5	16	16
Total Grade	96	100

Rank: #2

Circle your favorite season:

Fall Summer Winter Spring

Exam I ECE 342 Electronics I Sept. 28, 2018

Name: Spencer Goulette

1. **(20 points)** Each correct answer is worth +2 points. Indicate if the following statements are True or False:

T When designing an active filter, the designer aims to set the 3 dB frequency (or frequencies) using passive components. (resistors and capacitors)

F A difference amplifier should amplify the common mode signal while rejecting the difference mode signal. Amplify the difference reject common

T The slew rate of an op-amp limits the rate of change of the output for large output voltages.

T The output voltage magnitude of a voltage follower (i.e. unity gain amplifier) implemented with a practical finite-gain op-amp will be smaller than its input voltage magnitude.

F T A gain of -46 dB means the gain magnitude is 200 V/V and the phase shift between the input and output is 180°.

F An op-amp's output voltage can exceed the supply voltages RC circuits can

F The non-inverting input of an op-amp used in an inverting amplifier circuit must always be connected to DC ground. AC ground

T An instrumentation amplifier is preferred over a difference amplifier because it has better input resistance.

T A simple op-amp circuit which uses only resistors will still have a low pass response.

T An op-amp will have a finite but large input impedance

Name: Spencer Gedelle

2. **Quick calculations (20 points).** Each of the questions below are quick calculations, usually requiring a single equation.

a) The DC open-loop voltage gain of the MCP6001 operational amplifier is approximately 200,000 V/V. The voltage difference between its two input terminals is 10 μV. What is its output voltage?

$G_v = A_v(V_{i+} - V_{i-})$

$G_v = 200{,}000 \cdot 10\,\mu V$

$G_v = 2\,V$

V_{OUT} = 2 V

b) An inverting amplifier is implemented using an op-amp with a finite gain of A_{vo} = 1,000 V/V at DC. The resistors are R_1 = 2 kΩ and R_2 = 18 kΩ. What is the closed loop voltage gain, in V/V?

$$G_v = \frac{-\frac{R_2}{R_1}}{1 + \frac{1 + R_2/R_1}{1000}}$$

$G_v = -8.91\ \frac{V}{V}$

Gv [V/V]= $-8.91\ \frac{V}{V}$

c) The MCP6021 op-amp has an open loop voltage gain of A_{vo} = 116 dB at DC, and a unity gain frequency of f_T = 10 MHz. What is the upper 3 dB frequency limit of a single stage non-inverting amplifier built using the MCP6021 with a gain of G_V = 500 V/V?

$f_{3dB,max}$ = 20k Hz

$f_T = f_{3dB_{max}} \cdot G_v$

$f_{3dB_{max}} = \frac{10\,MHz}{500} = 20\,KHz$

d) The input voltages to a difference amplifier are 0 V and +2.4V. What is the common mode voltage, V_{ICM}?

$V_{ICM} = \frac{1}{2}(V_{i1} + V_{i2})$

V_{ICM} = 1.2 V

$V_{ICM} = \frac{1}{2}(0 + 2.4v)$

$V_{ICM} = 1.2\,V$

Exam I

ECE 342 Electronics I

Sept. 28, 2018

Name: Spencer Goulette

e) A difference amplifier has a differential gain of $A_d = 20$ V/V and a common mode gain of $A_{CM} = +1$ mV/V. What is its output voltage if the differential input voltage is $v_{id} = 200$ mV and the common mode voltage is $V_{ICM} = -100$ V.

$V_{OUT} =$ 3.9 V

$V_{out} = A_d V_{id} + A_{cm} V_{icm}$

$V_{out} = 20\frac{V}{V} \cdot 200mV + 1mV/V \cdot -100V$

$V_{out} = 4V + -0.1V$

$V_{out} = 3.9V$

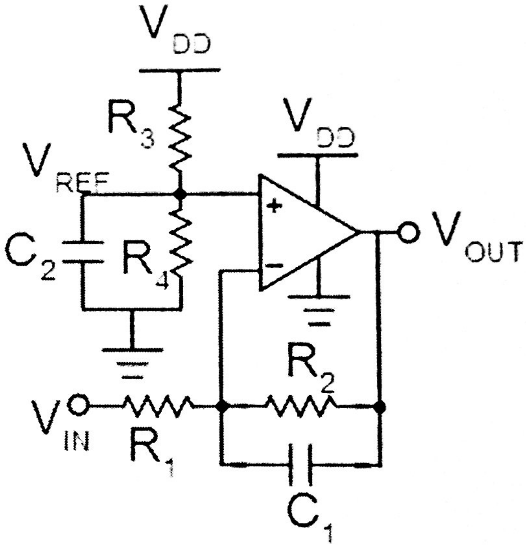
Name: Spencer Goulette

3. **(24 points)** The single-supply amplifier circuit in the figure below is constructed with the MCP6001 rail-to-rail output op-amp, which has a unity gain frequency of 1 MHz. The supply voltage is $V_{DD} = +3.3$ V. The resistor values are $R_1 = 10$ kΩ, $R_2 = 100$ kΩ, and $R_3 = R_4 = 200$ kΩ. The capacitor values are $C_1 = 100$ pF, and $C_2 = 1$ μF.

a) Derive an expression for V_{OUT} as a function of V_{IN}, V_{REF} and the resistors (note that these are DC values). Plug in the component values to obtain a numerical expression.

b) Determine the range of input voltages for which the amplifier will operate linearly, i.e. it will not saturate ($0 < V_{OUT} < +3.3$ V).

c) What is the upper 3 dB frequency of the amplifier?



a. Superposition

$V_{REF} = 0$

$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

$V_{in} = 0$

$$V_{out} = V_{REF}\left(1 + \frac{R_2}{R_1}\right)$$

$$V_{OUT} = -\frac{R_2}{R_1}(V_{in} - V_{REF}) + V_{REF}$$

$$V_{OUT} = -\frac{100k}{10k}(V_{in} - 1.65) + 1.65$$

$$V_{OUT} = -10V_{in} + 18.15$$

b.
$$3.3V = \frac{-100k}{10k}(V_{in} - 1.65V) + 1.65V$$

$$1.65V = -10(V_{in} - 1.65V)$$

$$-0.165V = V_{in} - 1.65V$$

$$V_{in} = 1.485\ V$$

$$0V = \frac{-100k}{10K}(V_{in} - 1.65V) + 1.65V$$

$$-1.65V = -10(V_{in} - 1.65V)$$

$$0.165V = V_{in} - 1.65V$$

$$V_{in} = 1.815\ V$$

c.
$$f_{3dBmax} = \frac{1\ MHz}{11} = 90.9kHz$$

$$f_{3dB} = \frac{1}{2\pi R_2 C_1}$$

$$f_{3dB} = \frac{1}{2\pi(100k)\cdot 100p}$$

$$f_{3dB} = 15.9\ kHz$$

(a) V_{OUT}= $-10V_{in} + 18.15$ Volts

(b) $V_{IN,min}$ 1.485 V

$V_{IN,max}$ 1.815 V

(c) f_{3dB} 15.9 kHz

Exam I ECE 342 Electronics I

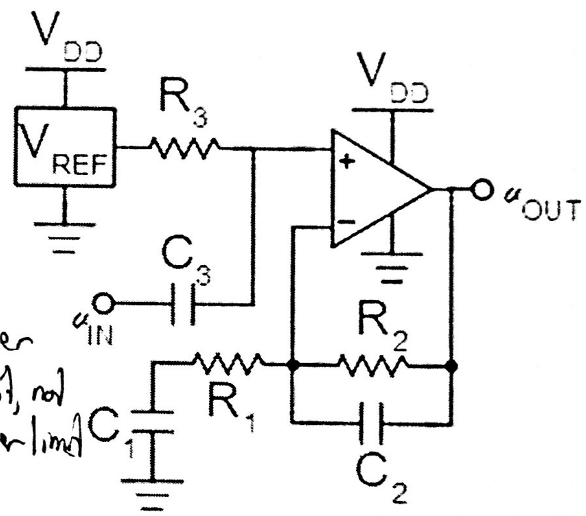
Name: Spencer Candelotte Sept. 28, 2018

4. (20 points) A non-inverting single-supply amplifier meant for use with audio frequencies is shown in the figure below. The supply voltage is $V_{DD} = +3.3V$, and the reference voltage is $V_{REF}=+1.65V$, as provided by the REF2033 voltage reference IC. The resistor values are $R_1 = 1\ k\Omega$ and $R_2 = R_3 = 100\ k\Omega$. The capacitor values are $C_1 = 10\ \mu F$, $C_2 = 82\ pF$ and $C_3 = 1\ \mu F$. The MCP6001 op-amp has a DC open loop voltage gain of 106 dB and a gain-bandwidth product of $f_T = 1$ MHz.

a) What is the nominal output voltage if the input is grounded?

b) What is the lower 3 dB cut-off frequency of the amplifier? Consider C_2 to be an open.

c) Did the circuit designer meet the upper cut-off frequency specification of $f_{HI} = 20$ kHz ± 1 kHz? Explain your reasoning.



a. since no current going through R_3 and R_2,

$V_{out} = V_{REF}$

$V_{out} = 1.65\ V$

b. $f_{3dBmax} = \dfrac{1\ MHz}{1 + \frac{100k}{1k}}$

$f_{3dBmax} = 9.9\ kHz$

upper limit, not lower limit

C_1 and R_1: $f_{3dB} = \dfrac{1}{2\pi C_1 R_1}$

$f_{3dB} = \dfrac{1}{2\pi \cdot 10\mu \cdot 1k\Omega}$ this is

$\boxed{f_{3dB} = 15.9\ Hz}$

calculated both, chose wrong answer

either 15.9 Hz or 1.59 Hz

C_3 and R_3: $f_{3dB} = \dfrac{1}{2\pi \cdot 1\mu \cdot 100K} = 1.59\ Hz$

c. The upper cut-off frequency is

$f_{3dB} = \dfrac{1}{2\pi \cdot 100k \cdot 82p} = 19.41\ kHz$,

but since the $f_{3d\,max}$ is 9.9kHz, that makes the upper f_{3dB} cutoff 9.9kHz, which is very far from meeting the spec.

(a) V_{OUT}= 1.65 V 4/4

(b) f_{3dB}= 1.59 Hz 6/8

(c) **YES** or **NO** 8/8

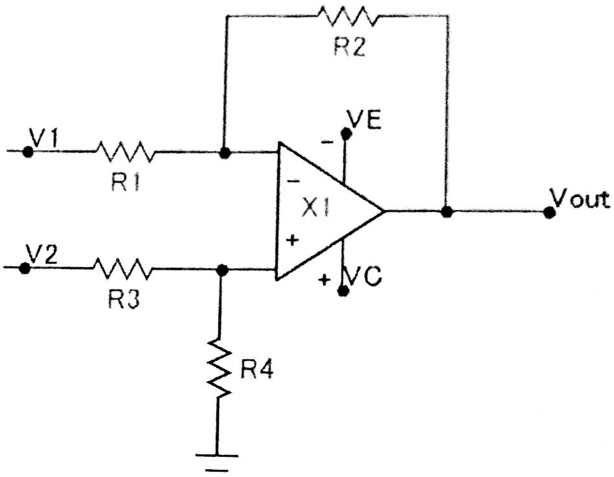
Name: Spencer Goulette Sept. 28, 2018

5. **(16 points)** A difference amplifier circuit is shown in the figure below is to have a differential gain of $A_d = 10$ V/V. The nominal resistor values for the input resistors are $R_1 = R_3 = 100\ k\Omega$. $R_2 = R_4$.

a) Calculate the input differential resistance, R_{id}.

b) Calculate the required values of R_2 and R_4.

c) What is the common mode gain if CMRR = 80 dB, in units of mV/V?



a. $R_{id} = R_1 + R_3$

$R_{id} = 100k\Omega + 100k\Omega$

$R_{id} = 200k\Omega$

b. $A_d = \frac{R_2}{R_1}$

$10 = \frac{R_2}{100k}$

$1M\Omega = R_2$

c. $CMRR = 20\log_{10}\left(\left|\frac{A_d}{A_{CM}}\right|\right)$

$10^{80/20} = \left|\frac{A_d}{A_{CM}}\right|$

$10{,}000\ \frac{V}{V} = \left|\frac{10}{A_{CM}}\right|$

$A_{CM} = \pm\frac{10}{10{,}000}\ \frac{V}{V}$

$A_{CM} = \pm 1\ mV/V$

(a) R_{id} $200k\Omega$

(b) R_2 $1M\Omega$

(c) A_{cm} [mV/V] ± 1 mV/V