SARKAR, Mohul

Experiment Number 7

Op Amp Circuits

TUESDAY

April 9

ECE 1101L

Spring 2024

Partner Name(s): MARIN, Gregorio

Lab:

ECE 1101L Experiment 7

OP AMP CIRCUITS

OBJECTIVES

MATERIALS REQUIRED BY STUDENT

-11 clip leads

-A breadboard plus jumper wires

-Required Resistors

MATERIALS TO BE SUPPLIED

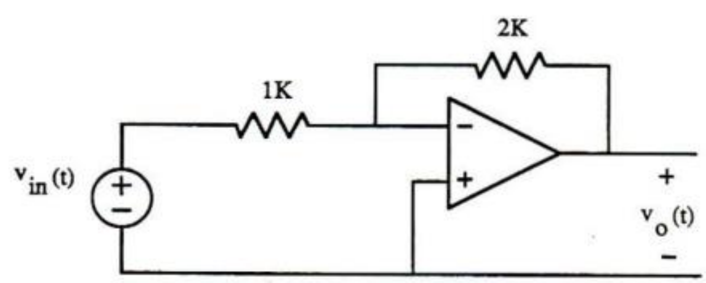
-Multimeter S/N: MY50210029

-Oscilloscope S/N: MY50512828

-Waveform Generator S/N: MY48008120

-Power Supply S/N: MY51110030

Pre-lab:



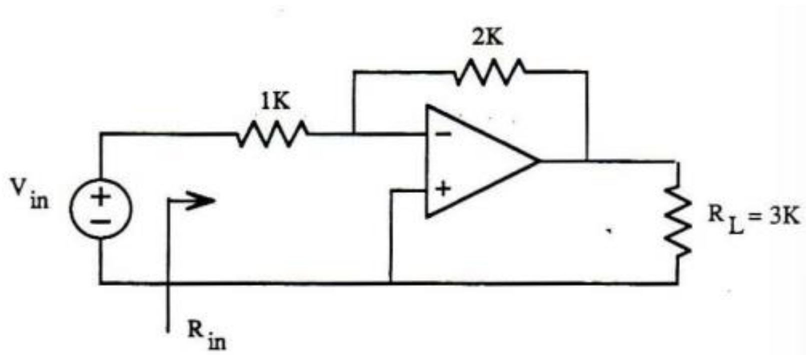
Calculate – assuming the op amp is **ideal**

a. The gain $G = v_o/v_{in}$
b. The input resistance R_{in} as seen from the source

To calculate gain I use the equation and plug in my values and since it's an inverting op amp. From this I get, $V_0 / V_{in} = -2k\Omega / 1k\Omega = -2 = A_v$.

$R_{in} = V_{in} / I_{in} = 1k$

B)

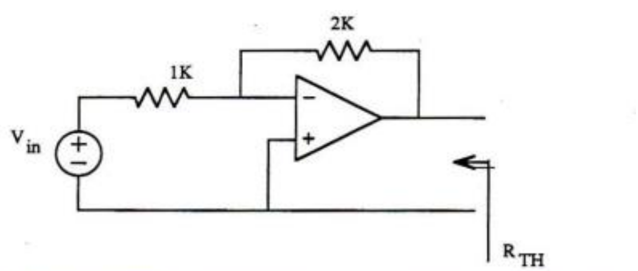


$V_x = V_T / 3$

$I_T = V_T / 3\ k\Omega + (V_T - 10^5 V_x)/75 + V_T(1+10^5(1/3)) / 75$

$I_T = V_T / 3\ k\Omega + V_T[1+(10^5/3)] / 75$

$V_T / I_T = 1/(1/3k) + (10^5/3)/75 = 2.25\ m\Omega$



Do not calculate R_{TH} by actually shorting V_{in} and putting a source at the output. See Section 3.3.5 of Chapter 3 to see how to calculate R_{TH} with V_{in} present and a known load R_L connected at the output. Assume $R_o = 75\ \Omega$ and $A = 10^5$

2. Design a positive gain op amp circuit with gain

$$G = \frac{V_o}{V_{in}} = (\text{Birthday})^{1/4}$$

where by Birthday is meant the date of your birth (from 1 to 31). Assuming the op amp in your circuit is ideal calculate the

a. Input resistance R_{in} of your circuit as seen by the source

b. Thevenin Equivalent output resistance R_o of your circuit as seen by the load

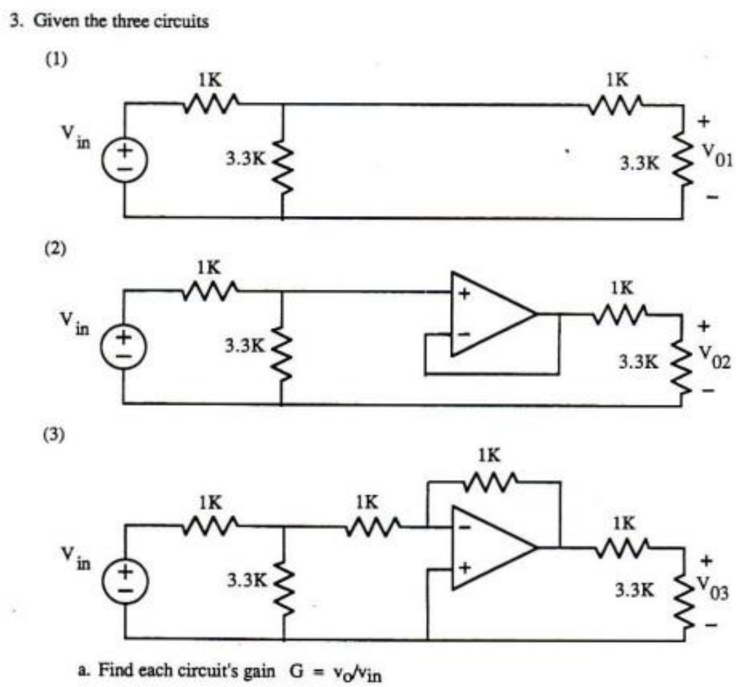
2a)

My birthday is August 16th

$G = (V_o/V_{in}) = (16)^{1/4} = 2$

$R_f = 10\ k\Omega$

Current entering the op-amp is 0, so resistance seen by source is infinite.



3a)

Node V: Use nodal analysis to get both values then divide to get gain

$V-V_{in}/1\ k\Omega + V/3.3k + V/(1\ k\Omega + 3.3\ k\Omega) = 0$

$V(1.5365) = Vin$

$V = 0.651V_{in}$

$V_{01} = V * 3.3\ k\Omega / 3.3\ k\Omega + 1\ k\Omega = 0.499$

3b)

Node V: Use voltage divider to simplify circuit then use again to find both voltages then divide to get gain

$V_p = (3.3\ k\Omega/ 1\ k\Omega + 3.3\ k\Omega)V_{in}$

$V_p = 0.767V_{in}$

$V_0 = V_p$

$V_{02} = (3.3\ k\Omega /1\ k\Omega +3.3\ k\Omega)0.767V_{in}$

$V_{02}/V_{in} = 0.589$

3c)

Node V1: use nodal analysis to get voltages then use voltage divider to solve for V_{03}. Then divide that value by V_{in} to get gain.

$V_1\text{-}V_{in} / 1\ k\Omega + V_1 / 1\ k\Omega + V_1 / k\Omega = 0$

$V_1(1 + 1/3.3 + 1) – V_{in} = 0$

$V_1 = 0.434V_{in}$

$V_p = V_n = 0$

$V_p – V_1 / 1\ k\Omega + -V_0 / 1\ k\Omega = 0$

$V_0 = -V_1$

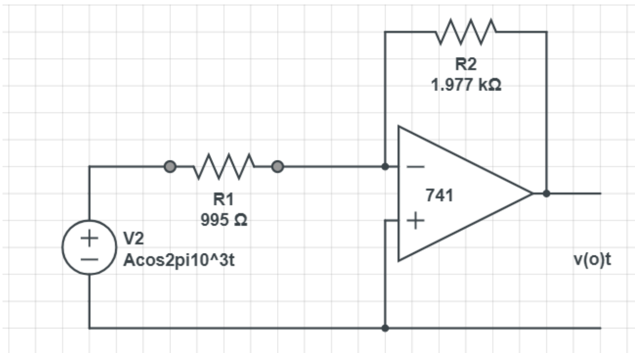
$V_0 = -0.434\ V$

$V_{03} = (3.3\ k\Omega / 1\ k\Omega + 3.3\ k\Omega)V_0$

$V_{03} = 3.3\ k\Omega/ 4.3\ k\Omega * (-0.434V_{in})$

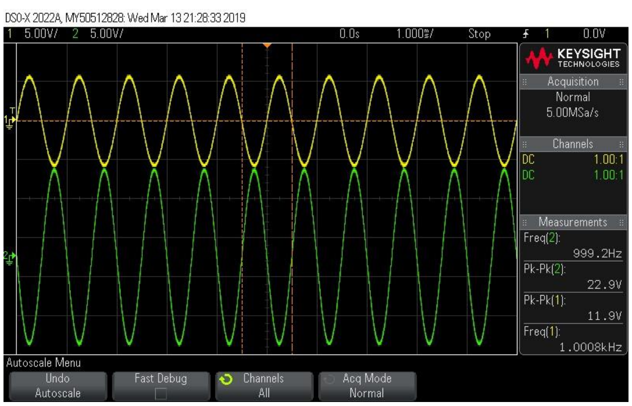
$V_{03}/V_{in} = -0.333$

Given CKT2:

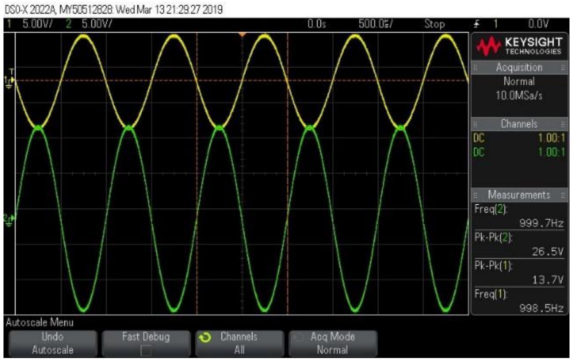


A)

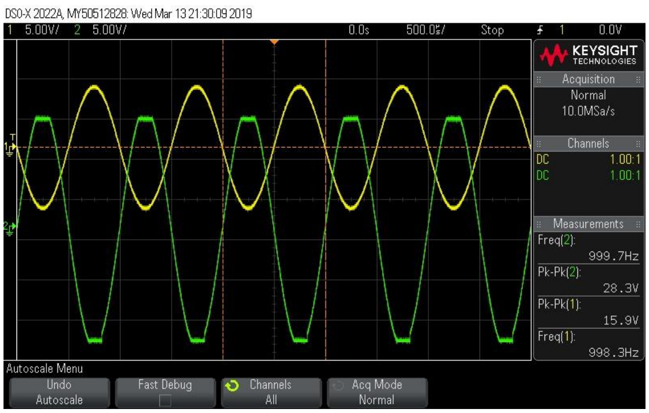
Per sign convention shown on CKT1		
Voltages [V]	A V_{in} [V]	A V_{out} [V]
5	10.1	19.5
6	11.9	22.9
7	13.7	26.5
8	15.7	28.3
9	17.5	28.3



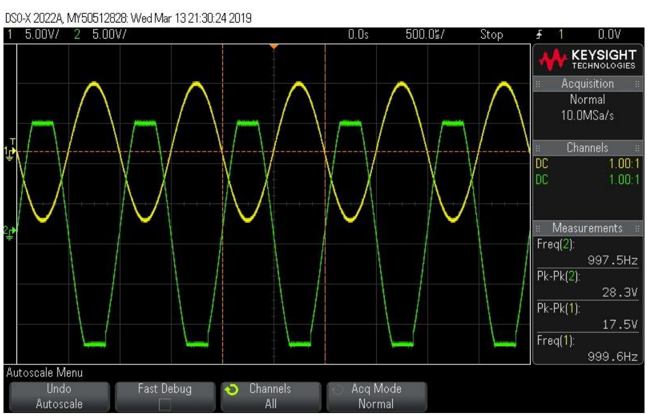
Pk-pk(1) = 11.9 V, Pk-pk(2) = 22.9 V



Pk-Pk(1) = 13.7 V, Pk-Pk(2) = 26.5 V



Pk-Pk(1) = 15.9 V, Pk-Pk(2) = 28.3 V



Pk-Pk(1) = 17.5 V, Pk-Pk(2) = 28.3 V

B)

1 V / 1 mA = 1 kΩ

The input resistance as seen by the source while A_{Vin} = 1 V is R_{in} = 1kΩ

C)

Short circuit

Add 2.2k resisor (2.17kΩ real value)

$V_o = V_{th} = 19.1$ V

$V_L = V_{RL} = 19.3$ V

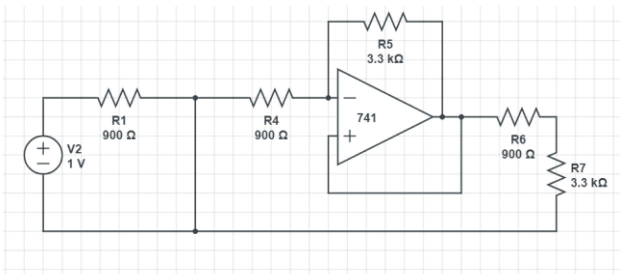
$R_{th} = (V_{th} - V_{2.17k\Omega}) / I_{2.17k\Omega}$

D)

With $A_{v(in)} = 5$ V these are the measurements to verify the op amp input is a virtual short:

$V_p = 74$ mV, $V_n = 78$ mV = ~0

Given CKT4:



Measured resistor values: $R_{3.3k}$ = 3.3k, $R_{3.3k}$ = 3.3k, $R_{0.9k}$ = 0.9k, $R_{0.9k}$ = 0.9k

Gain for number 3a) 518 mV

Gain for number 3b) 560 mV

Gain for number 3c) 400 mV

Discussion of Results:

My results from the lab have shown that I have properly learned to find the gain of an op-amp. I have also learned how the specific pins of an op-amp work to make mathematical calculations and to amplify the voltage it receives. Another thing I learned was that not only do you need to put power into the part which converts the value, but you must also put power into the op-amp itself. I am confident now in being able to utilize op-amps in my future circuits and understand how they can create a virtual short.

Post Lab:

3.19)

We know in finding Thevenin equivalent we need to find Thevenin voltage and Thevenin resistance.

Thevenin Voltage:

Using KCL:

$(V_{th} - V_{in}) / 1k\Omega + V_{th} / 1k\Omega + V_{th} / 1k\Omega + 10I_1 = 0$

$I_1 = V_{th} / 1k\Omega = V_{th}$

$(V_{th} - V_{in}) / 1k\Omega + V_{th} / 1k\Omega + V_{th} / 1k\Omega + 10V_{th} = 0$

$V_{th} = V_{in} / 13$

To find the Thevenin equivalent resistance you must remove the dependent source then apply a test voltage and current.

Using KCL:

$V / 1k\Omega + V / 1k\Omega + V - V_x / 1k\Omega = 0$

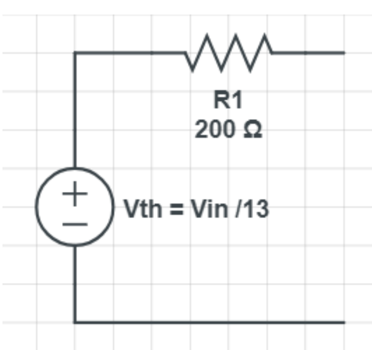
$V = V_x / 3$

$V_x - V / 1k\Omega + 10I_1 + V_x / 1k\Omega = I_x$

$2V_x + 3V_x = I_x$

$V_x = I_x / 5$

$R_{th} = 1/5 = 0.2k\Omega$



3.20)

Thevenin Voltage:

Using KCL:

$(V - \cos t) / 1k\Omega + V / 1k\Omega + (V - V_{th}) / 1k\Omega + 2I_2 = 0$

$I_1 = \cos t - V$

$2 V = V_{th} - I_1$

$2 V = V_{th} - \cos t + V$

$V = V_{th} - \cos t$

$V_{th} = V + 2I_1$

$V_{th} = V + 2(\cos t - V)$

$V_{th} = (3/2)\cos t$

Thevenin Resistance:

Using KCL:

$V / 1k\Omega + V / 1k\Omega + V - V_x / 1k\Omega + 2I_1 = 0$

$I_1 = -V$

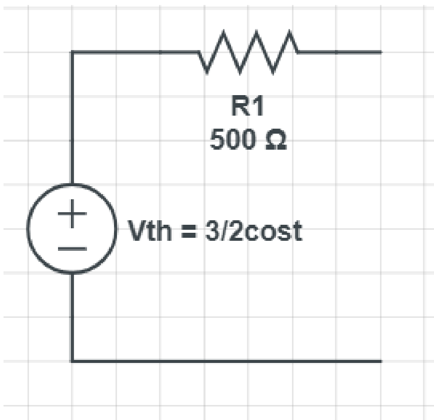
$3 V = V_x - 2(-V)$

$I_x = (V_x - V) / 1k\Omega - 2I_2$

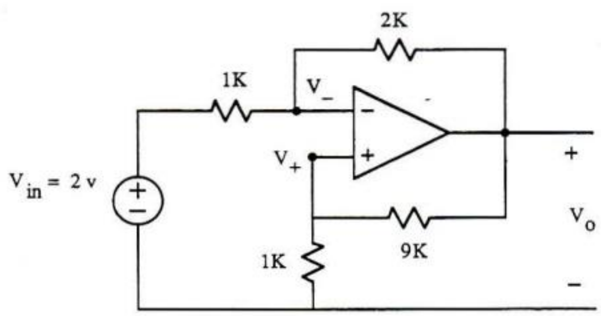
$I_x = V_x - V - 2I_2$

$I_x = 2V_x$

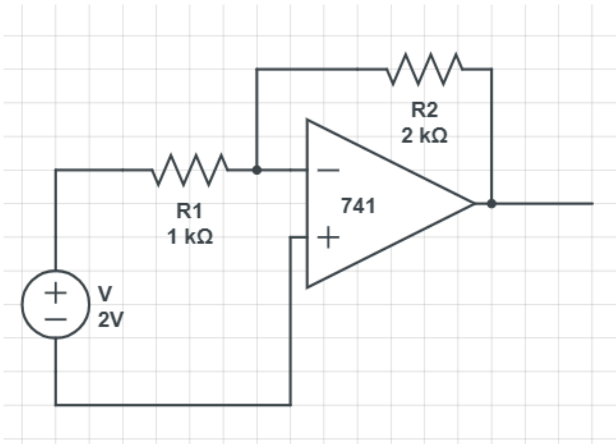
$R_{th} = V_x / I_x = 1/2 = 0.5k\Omega$



3.31)



a) No input terminal is directly grounded so +V = -V. feedback is also taken to non-inverting terminal.
b) $(V_2 - 2) / 1\ k\Omega + (V - V_o) / 2\ k\Omega = 0$
   $V[1.5 * 10^{-3}] - 2 * 10^{-3} = V_o / k\Omega$
   $V_o / 9k\Omega + V / 1k\Omega = 0$
   $V_o / 9k\Omega = V[1/9000 + 1/1000]$
   $10\ V = 3\ V - 4$
   $V = -0.5714\ V$
c) Remove $9k\Omega$ resistor



3)

$R_{in1} = R_{in2} = R_{in3} = R_{out}$

$V_{in1} = V_n * R_{in} / R_{in} + R_{in} = A_{v(in)} [R_{in} / R_{in} + R_{out}]V_{in}$

$V_{in3} = A_{v(in)2} * R_{in} / R_{in} + R_{out} = A^3/2[(R_{in}*R_2) / (R_{in} + R_{out})^2(R_2+R_{out})]V_{in}$

$V_{out} / V_{in} = A^3/2[R_{in} / R_{in} + R_{out}]^2R_{in} / R_{in} + R_{out}$

4)

Node 1:

$V_{in} / 1k\Omega$

$V = -10V_{in}$

Node 2:

$-[V/10\ k\Omega + V/100 + V / 10\ k\Omega] = -V_0 / 10\ k\Omega$

$V_0 = 102\ V_{in}$

$V_0 / -10V_{in} = -102$

$V_0 / V_{in} = -1020 = \text{Gain}$