UNIVERSITY OF MIAMI
Department of Electrical and Computer Engineering
EEN 311

Name: ______________________
Section: ______________________
Date: ______________________

OPERATIONAL AMPLIFIERS / PART III

SINGLE SUPPLY OP-AMP CIRCUITS

PURPOSE: The purpose of this experiment is to demonstrate the operation and characteristics of an Op-Amp connected to a single power supply.

BACKGROUND: All of the Op-Amp circuits used till now were biased by a dual (or split) power-supply as shown Figure 1:

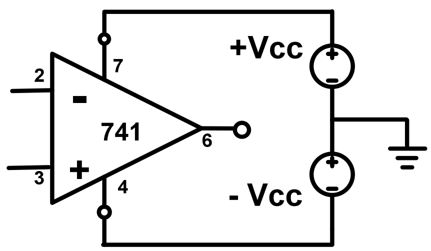


Figure 1: Typical Dual Supply Biasing of an Op-Amp

In modern circuits (i.e.: portable devices, automobile circuits etc), this may cause a problem since only one battery is available. However it is possible, with some basic modification to the biasing of an Op-Amp, to operate a general purpose Op-Amp with only one supply which is the goal of this lab.
In the moment that an Op-Amp, which was designed to operate from a dual supply, is enclosed in a negative feedback loop, the output voltage is forced to a potential very close to zero volts. As shown in Figure 2, if the output voltage will be different from zero volts, V_d will not be zero, which will drive the output either to the positive or negative saturation voltage.
At the moment that a signal is applied to the amplifier, the output can swing up to the positive or negative saturation voltages (Class A operation) as shown in Fig.3.

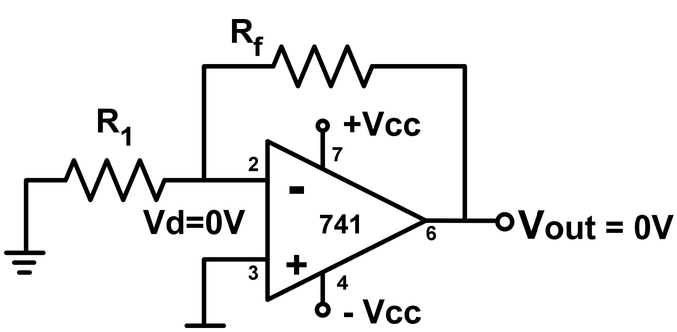


Figure 2: An Op-Amp enclosed in a Negative Feedback Loop

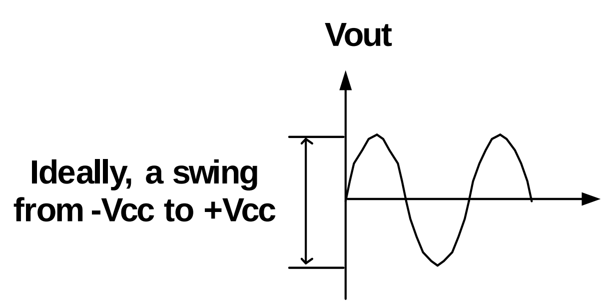


Figure 3: Output is centered around 0 Volts

In order to permit Class A operation for an Op-Amp (that is biased with only one supply), the user must place the output voltage at about half the supply voltage to achieve a maximum swing at the output which requires some modifications to the way that we bias the Op-Amp.

In the circuit of Fig. 4, a voltage divider is connected to the Noninverting input of the Op-Amp setting this voltage to half Vcc. An additional feedback resistor is connected from the output to the inverting input and since no current flows into the Op-Amp, the voltage drop on Rf is zero. The only stable operating point that this Op-Amp can operate is at half Vcc at the two inputs (Vd = 0) as well at the output.

Notes: 1. R_f could be any value.

2. The voltage divider will set the operating point to ANY desired biasing point.

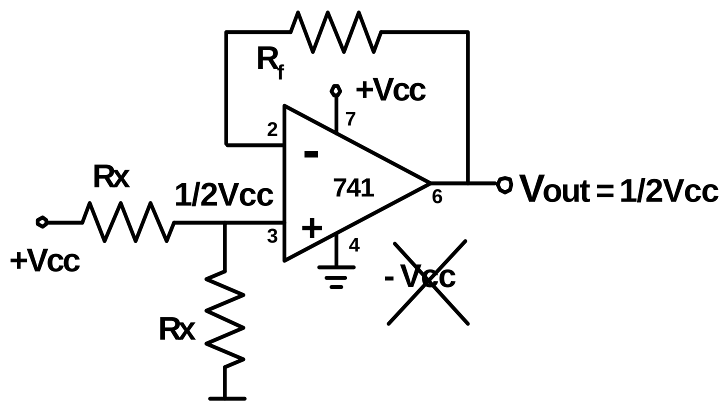


Figure 4: The Concept of biasing an Op-Amp with a single supply

The circuit in Fig. 4 must be modified to be used as an amplifier. Fig. 5 shows an inverting amplifier while fig. 6 shows a Noninverting amplifier, both using a single supply.

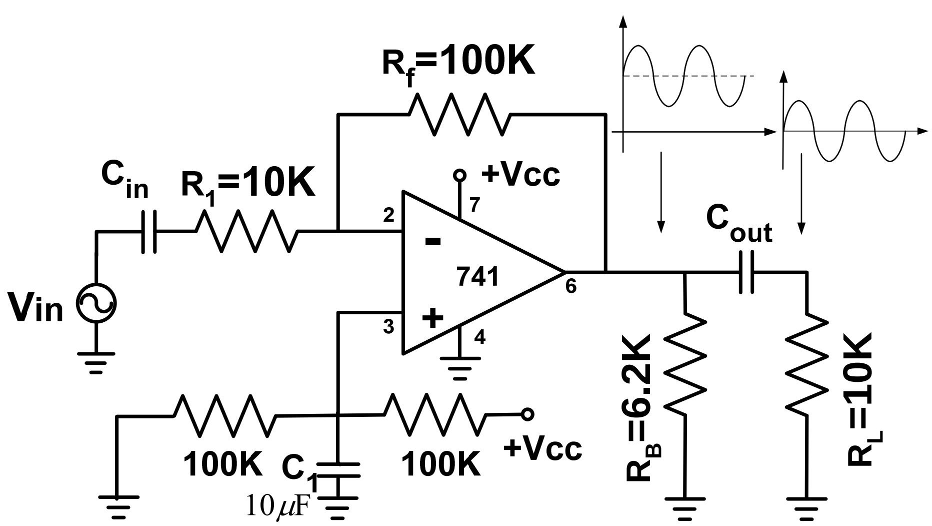


Figure 6: AC Coupled Inverting Amplifier (Gain = -10)

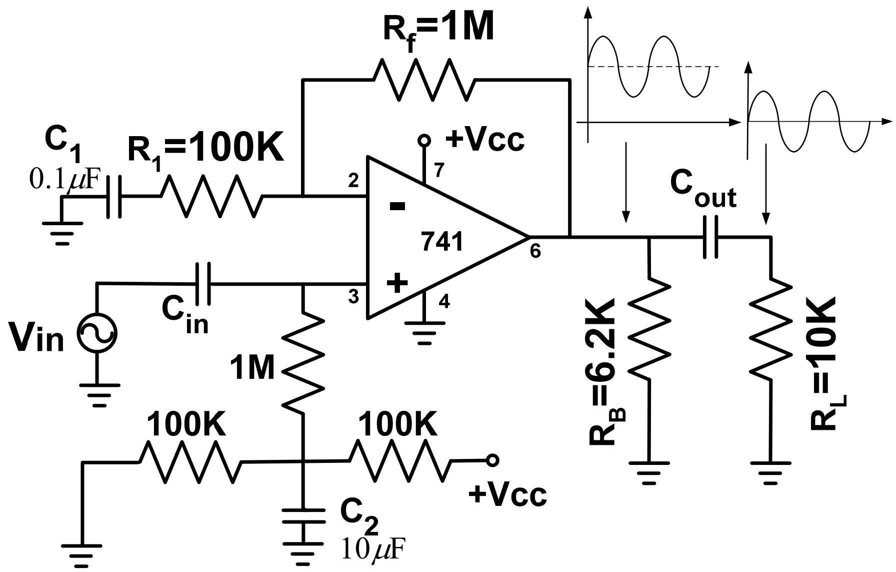


Figure 7: AC Coupled Non-Inverting Amplifier (Gain = +11)

In general, all Op-Amps can be used with a single supply however some Op-Amps were optimized for single supply operation. For example, the LM324 is designed to operate from +3 to 32 Volts or with dual supplies up to ±16 Volts. When the LM324 is operated from a single supply, its output can swing down to about 0 Volts compared to 1.5 Volts with the 741.

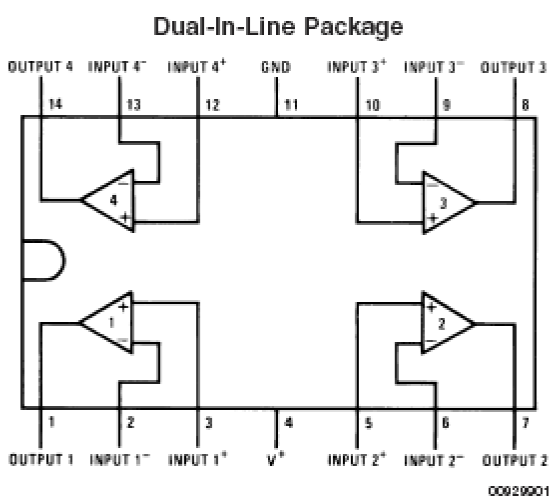


Figure 8: The LM324 Quad Op-Amp (From www.national.com)

Preliminary Work

The last two circuits are called AC coupled amplifiers since one must use the coupling capacitors (Cin and Cout) to block the DC voltages.
Shown again below is the AC coupled inverting amplifier from Fig. 6.

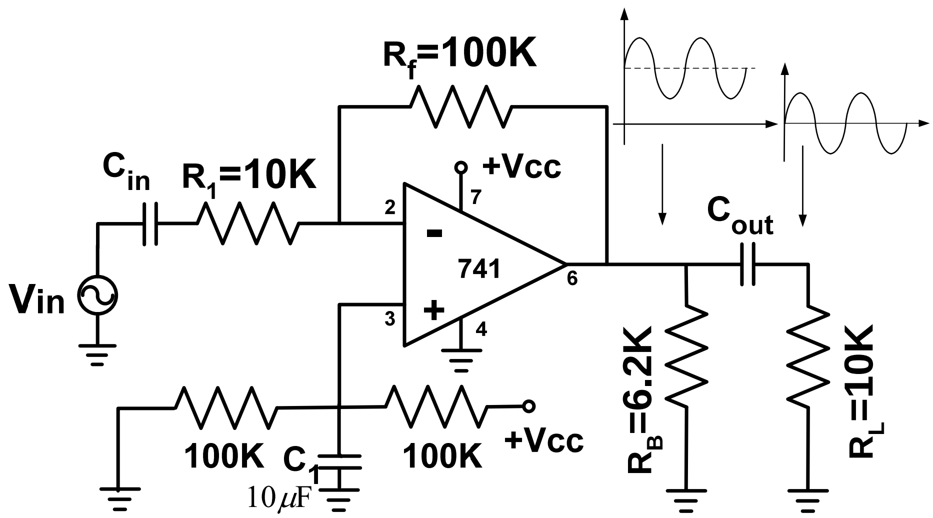


Figure 6 (repeated): AC Coupled Inverting Amplifier (Gain = -10)

a. There are two low break frequencies associated with this circuit. One break frequency is due to Cin and one is due to Cout. The frequency due Cin is given by:

$$f_{L_1} = \frac{1}{2\pi C_{in} R_1}$$

Cin=1/(2*pi*f_L1*R1) =159nF

and the break frequency given by Cout is:

$$f_{L_2} = \frac{1}{2\pi C_{out}(R_B + R_L)}$$

Assume f_L1=159HZ, Cin=100nF

If Cout = 220μF, design Cin to give a low break frequency of 100Hz.

Cin = 159nF

You are asked at the end of the laboratory to simulate this circuit. In your simulation perform an AC sweep from 1Hz to 100KHz and show clearly the low break frequency of the amplifier.

Shown below is the AC coupled inverting amplifier from Fig. 7.

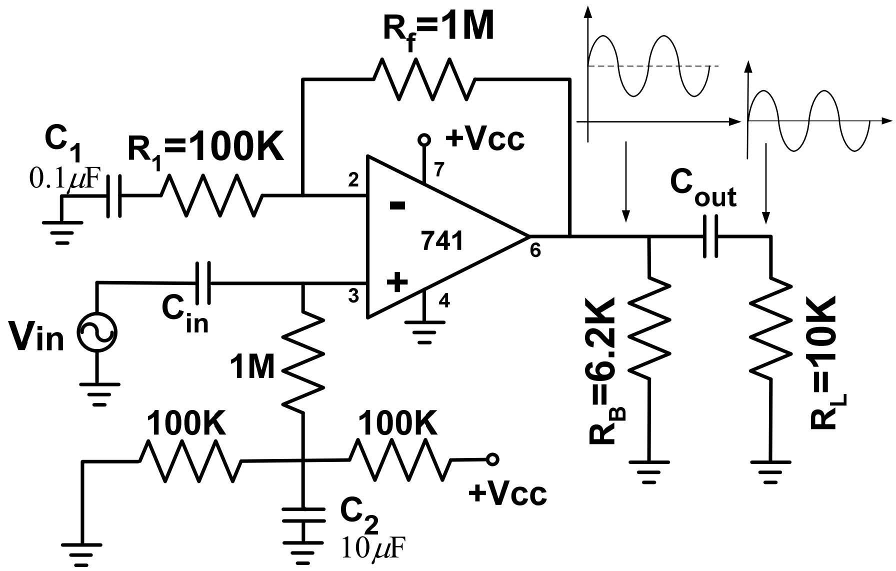


Figure 7 (repeated): AC Coupled Non-Inverting Amplifier (Gain = +11)

This amplifier has three low break frequencies.

Due to C_1:

$$f_{L_1} = \frac{1}{2\pi C_1 R_1}$$

Due to C_{out}:

$$f_{L_2} = \frac{1}{2\pi C_{out}(R_B + R_L)}$$

and due to Cin, a very low break frequency attributed to the 1MΩ resistor at the input.
As before, if Cout = 220µF and C1 = 0.1µF, calculate the two break frequencies associated with these capacitors.

Calculated f_{L1} = _______

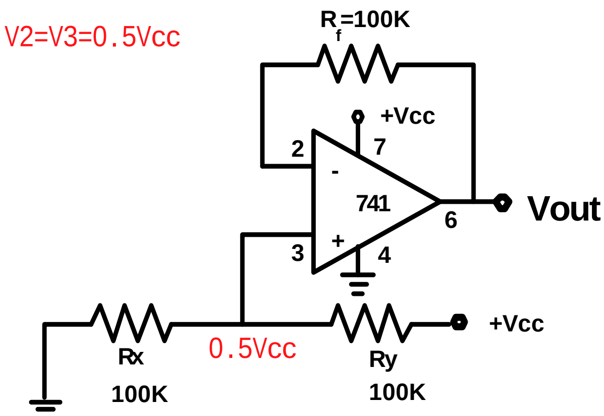
Calculated f_{L2} = _______

You are asked at the end of the laboratory to simulate this circuit. In your simulation perform an AC sweep from 1Hz to 100KHz and show clearly the low break frequency of the amplifier.

Experimental Procedure

I. Inverting Amplifier:

a. Build the circuit of Fig. 8 using 10 Volts for Vcc.



Measured Values:

Rf = 100K Rx = 100K

Ry = 100K Vcc = 10V

V_+ = +5 V_- = -5

Vout = 5V

Figure 8: Biasing an Op-Amp for Single Supply Operation

DO NOT TAKE APART!

b. Complete to assemble the amplifier in Fig 8 as shown in Fig 9. Use Cin as calculated in the preliminary work and Cout = 220µF.

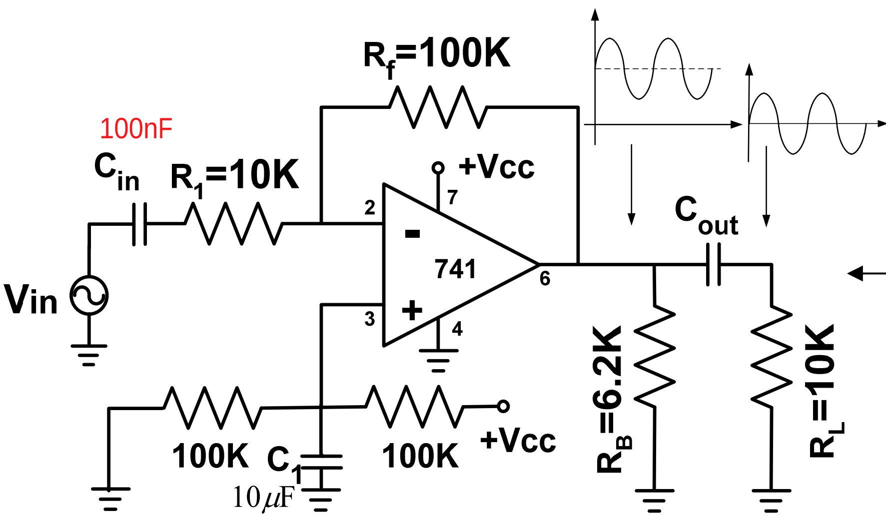


Figure 9: AC Coupled Inverting Amplifier

Vin,pp=0.5V

1dB=20log10(abs(Vout/Vin))

Vout:

Max. Pos swing: ____

Max. Neg swing: ____

Cin = 100nF

Cout= 220uF

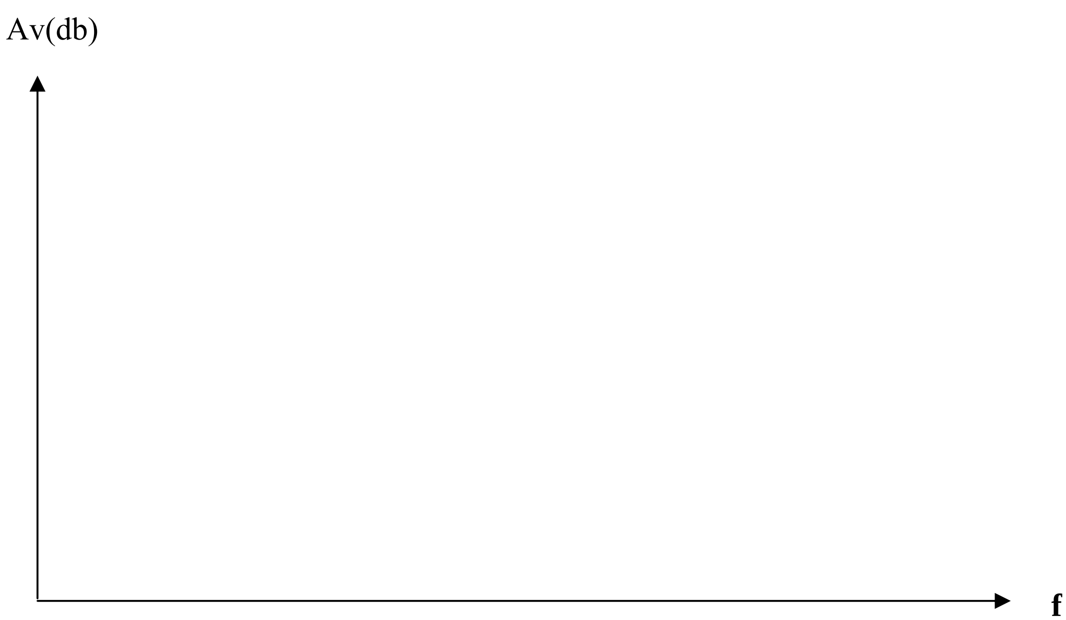
c. Set the input frequency to 1KHz. Using a dual trace oscilloscope:
   a. Observe and record the output voltage at pin 6 of the Op-Amp and at Vout.
   b. Record carefully the maximum swing at the output of the Op-Amp in Fig 9

Pin 6

Vout

d. Obtain the frequency response of the amplifier and draw the Bode plot of this amplifier (we are interested mainly with the low range):

f (Hz)	Vin	Vout	Av	Av (db)
10				
50				
100				
250				
500				
750				
1K				
1500				
2500				
7500				
10K				



DO NOT TAKE APART THE CIRCUIT!

II. **Inverting Amplifier using the LM324:**

a. Replace the 741 with the LM324 in the last circuit**. Note that the 741 and the 324 are not pin comparable**. The modified circuit is shown below in fig.10

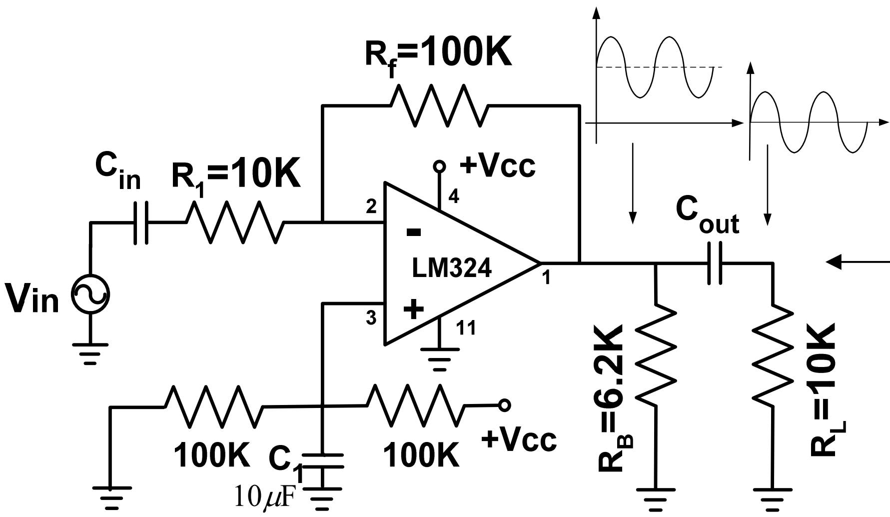


Figure 10: The LM 324 as an Inverting Amplifier using a single supply

Vout:

Max. Pos swing: +5

Max. Neg swing: -5

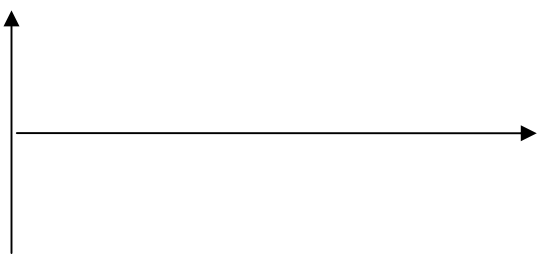
Cin = 0.1uF=100nF

Cout= 220uF

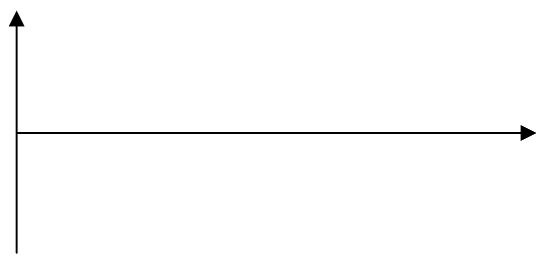
b. Set the input frequency to 1KHz. Using a dual trace oscilloscope:

  a. Observe and record the output voltage at pin 6 of the Op-Amp and at Vout.
  b. Record carefully the maximum swing at the output of the Op-Amp in Fig 9

Pin 6



Vout



III. **<u>Non-Inverting Amplifier:</u>**

a. Modify the inverting amplifier from part I to the circuit shown in Fig. 11. Use Vcc=10V, Cin = 0.1µF and Cout = 220µF

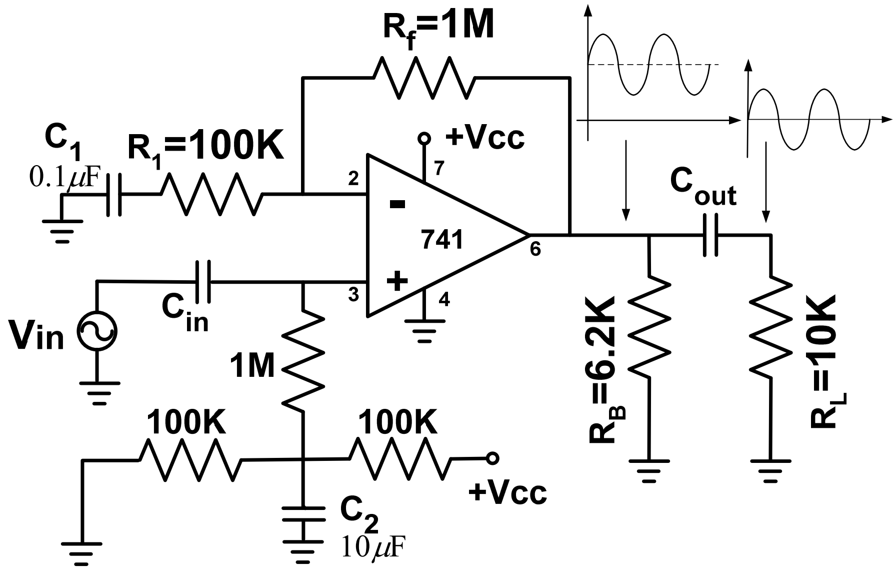
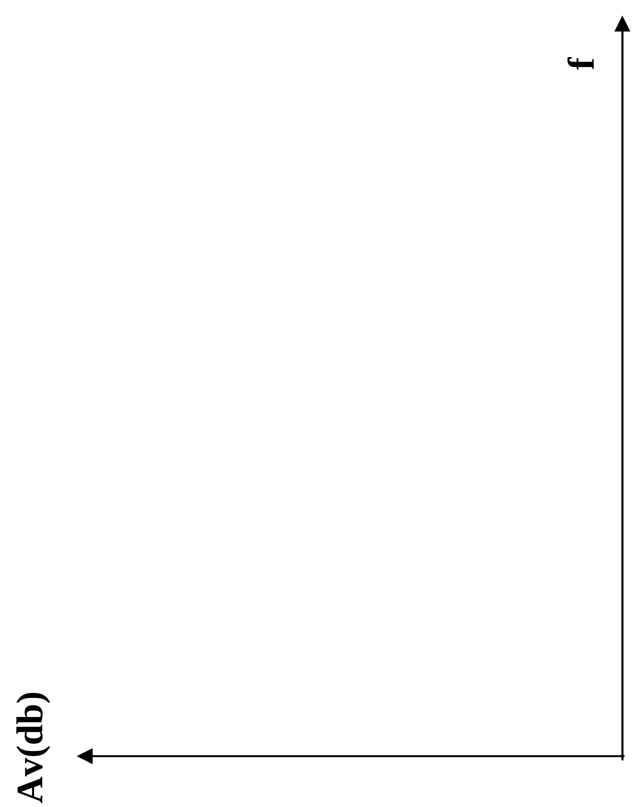


Figure 11: AC Coupled Non-Inverting Amplifier (Gain = +11)

b. Obtain the frequency response of the amplifier and draw the Bode plot of this amplifier (we are interested mainly with the low range):

f (Hz)	Vin	Vout	Av	Av (db)
10				
50				
100				
1K				
10K				



SPICE

1. Simulate the inverting amplifier of Figure 6 using the same component values you used to build the circuit in the lab. In your simulation perform an AC sweep from 1Hz to 100 KHz and show clearly the low break frequency of the amplifier.

2. Modify the inverting amplifier in Figure 6 into an integrator, with a break frequency of 1KHz and simulate the circuit.

3. Simulate the Non-inverting amplifier of Figure 7 using the same component values you used to build the circuit in the lab. In your simulation perform an AC sweep from 1Hz to 100 KHz and show clearly the low break frequency of the amplifier.

Discussion of the Results

1. Compare the maximum swings at the outputs of the 741 and the 324

2. Write a conclusion.