Electronic CAD Practical work

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Week 5: Operational Amplifier circuits. Inverting Amplifier Configurations.

Primary Objectives:

- To understand the use of "real" 741 op-amp models to model and analyze inverting amplifiers.

Aims:

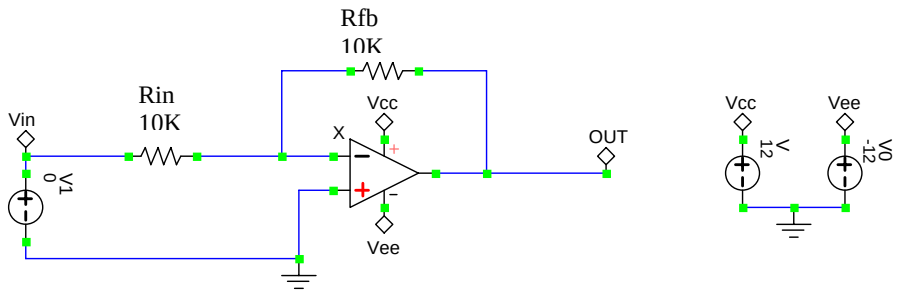
After the exercises you should be able to

- Simulate simple operational amplifier circuits.
- Include non-idealities of op amps into simulations
- Incorporate op amp parameters such as full power bandwidth, slew rate input and offset into simulations.

Exercise 1: Inverting Amplifier Configuration:

Circuit diagrams and associated equations:

Figure 1:



Operational amplifier connected in an inverting amplifier configuration.

Circuit equations

Simple voltage gain approximation for "ideal" inverting amplifier configuration the small signal voltage gain is given by: $A_v = -\frac{v_{out}}{v_{in}} = \frac{-R_{fb}}{R_{in}}$

Some Op-Amp non-idealities

Input offset voltage:

Ideally for an op-amp when:

v_{IN} = 0 (grounded); v_{OUT} should be equal to 0

However, due to finite mismatches in the input stages due to manufacturing variations, a small input offset voltage will be set up corresponding to a non zero output voltage. That is:

$$v_{OUT} = A_{OL} . V_{OS}$$

Where: A_{OL} is the op-amp DC gain and V_{OS} is the offset voltage.

This input offset is amplified by the gain stages to produce an output offset. Most operational amplifiers have an "Offset Null pin" to allow trimming of the output offset voltage to zero. **Another way to trim the offset voltage (for a non inverting amplifier) is to insert a resistor between the non-inverting terminal and ground. The resistor should have the approximate value of *R1*||*R2*.**

Slew rate limiting and full power bandwidth:

Capacitances and currents related to the internal op-amp components limit the rate at which the output voltage can change.
This limit is usually specified as **slew rate** or slewing rate (***SR***) and is specified in ***V/us***
And for a typical 741 op-amp the slew rate is 0.5*V/us*.

Full power bandwidth:

This figure of merit is usually given in op-amp data sheets. It is defined as:
The greatest frequency of a full voltage sine wave that can be output for the op-amp without incurring slew rate effects.

The equation for full power bandwidth is:

$$f_{FPBW} = \frac{1}{2\pi} \bullet \frac{SR}{V_{om}}$$

where *SR* is the slew rate which for a 741 op-amp is 0.5 x10e-6

and V_{om} is the peak voltage swing which for a 741 Op-amp is 11 volts. This assumes that the supply rails are set to *±12V* and the maximum output voltage will swing to within 1 volt of the supply rails.

Gain Bandwidth product:

The gain bandwidth product when feedback is applied is defined as:

Gain bandwidth product = $A_{mb} \bullet \omega_u$ =constant

Where A_{mb} is the midband gain of the op-amp and
$\omega_u = 2\pi f_u$: is the upper cut off frequency (3dB point) of the op-amp

Exercise 1: AC response:

Layout the schematic of figure 1.

Note: The Op-amp model is found as follows:

Toolbar -> Categories -> Opamp -> *Select 3rd device up from the bottom of the list.*

Gain bandwidth product:

Set up an AC analysis to run from 1Hz to 1MHz.
Use decade scale for the x axis.
Use 100 points per decade.
Set the input magnitude of the voltage source to 1V.
Run the simulation and view the Vout traces in magnitude and dB format.

Question 1
Run the above simulations again changing the value of R_2 to provide the following gains:

a. A gain of -10
b. A gain of -100

From the plots, estimate the gain bandwidth product for each value of R_2.
Briefly explain what is the general relationship between the gain and the 3dB point?

Offset voltage nulling:

Set R_{in} = 10 kΩ
Set up the amplifier to have a gain of -1.
Set up the voltage source to 0V DC
Run an operating point analysis.
Find V_{out} in the table.

Question 2

a) What is the value of the input offset voltage?
b) What problems could this cause when using high gains?
c) Calculate the value of the resistor that would be required to null the offset.

Insert the resistor between the non-inverting input and ground and rerun the simulation.

d) What is the new offset voltage?

Parameter sweeping to find the null resistor:

An alternative way to find the value of a suitable offset nulling resistor is as follows
Set up a simulation to sweep the value of the resistor and monitor V_{out} as follows:

Open the simulation settings dialogue -> Select Single or dual parameter sweep -> Set up the parameters in the top box.

Source name = R_1
Start Value = 1
Stop Value = 10000
Step Value = 10

Select to display both graph and table in the check boxes.

Run the simulation.

This sweeps the resistor from 1 to 10kΩ in 10Ω increments.

Question 3:

a) From the table, what resistor value gives minimum offset?

Design Exercise

Using preferred values of *R.*
Hint: try R_{in} = 10k

Design an amplifier to have a gain of approximately equal to 47.

Use simulation techniques to choose a suitable value of resistance to minimize the offset voltage.

Verify your calculations with simulations.

If you have any time left:

Try to simulate the effect of slew rate limiting for the full power bandwidth.

Answer sheet: Week 4: Student:

Question 1:

1) GBP for Av =10 :
2) GBP for Av = 100:

Comment:

Question 2:

1)
2)
3)
4)

Question 3: