Simulation Report - Week 2

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1. Introduction

This week I studied about the frequency response of opamps, while working on this topic I was able to learn about compensated and decompensated opamps. I also learnt to calculate *break frequency(f_0), unity gain bandwidth (UGB) and large-signal voltage gain (A)* from the bode plots generated in LTspice. But still much of frequency analysis is yet to be covered so I shall deal with them in the coming week.

2. Simulation Details

- Environment: LTspiceXVII
- Important component(s): LM741 and OP37[1] Opamp IC
- Reference Book: Gayakwad[2]

2.1 Decompensated Opamps — OP37

A. Theory

Before understanding decompensated opamps, we first need to understand *compensating networks*, these networks are created using components like resistors and capacitors. The main purpose of such networks is to modify the performance of an op-amp circuit over the desired frequency range by controlling its gain and phase shift. Opamps such as LM741 and uA741 have internal compensating networks while opamps such as 709C[3] require external compensating networks so the latter is an example of a decompensated opamp. Nowadays, decompensated opamps are hard to find while one may find partially compensated opamps such as OP37.

Partially compensated opamps such OP37 are special in the sense that like other decompensated opamps, they have higher bandwidth and slew rate but they are unstable under a certain open loop gain (for OP37 this value is 5dB)[4]. This is because the OP37 is compensated only for values of gain higher than 5dB.

B. Open loop simulation

I prepare the circuit as shown in figure 1(i) where I feed a signal V_1 into the non-inverting terminal of the opamp and perform an AC sweep. Using the bode plot (figure 1(ii)) that is generated from the sweep, I calculated $A = 2.28 \times 10^6$, $f_0 = 29.51$ KHz and unity-gain bandwidth (UGB) = 29.13 MHz.

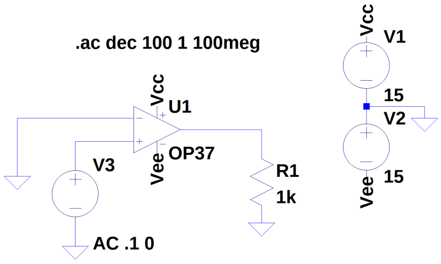
Info: With the help of the bode plot, I was also able to verify the equation, $f_0 = \frac{UGB}{A}$

It is noticeable from the bode plot that towards the gain values below 5dB, the frequency reponse of the opamps becomes unstable. We shall investigate this further in the next section.

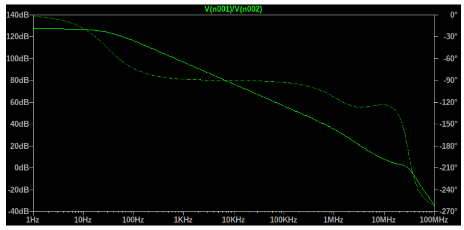
C. Closed loop simulation

For the closed loop simulation I prepared the circuit of a non-inverting amplifier, see figure 2(i) with $R2 = 3k\Omega$ which is the feedback resistor and $R1 = 1k\Omega$ such that $A = 1 + \frac{R2}{R1} = 4$. I performed an AC sweep and obtained the bode plot shown in figure 2(ii). The calculated values are $A = 3.99$, $f_0 = 12.08$ MHz and unity-gain bandwidth (UGB) = 31 MHz.

As the OP37 opamp is not compensated for gain values below 5dB, we find that the frequency response is unstable but it has a large bandwidth of $\approx$ 12MHz.

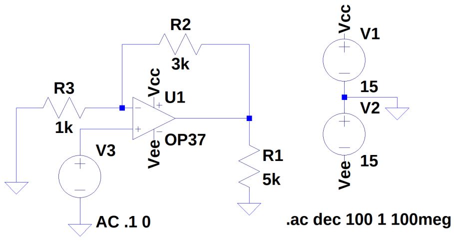


(i) OP37 in open-loop configuration

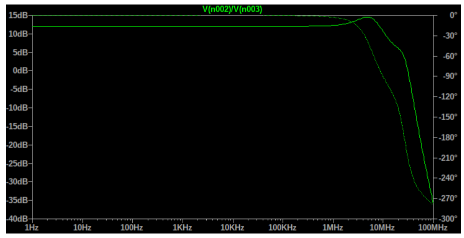


(ii) Bode plot for circuit in fig. 1(i)

Figure 1: Open loop simulation



(i) OP37 in closed-loop configuration



(ii) Bode plot for circuit in fig. 2(ii)

Figure 2: Closed-loop simulation

2.2 Problem Solving: Selecting gain for a specific frequency response

Imagine that you are working at an electronics firm and your employer asked you to design a non-inverting amplifier whose frequency response should be flat upto 300KHz. In order to solve this problem, the only parameter that you need is the closed-loop voltage gain value using which you can determine the value of the resistors R_F and R_1. We first plot the open loop voltage gain (A) against the frequency values. Then we the determine the value of voltage gain in y-axis corresponding to the value of 300KHz on the x-axis, let us assume this value is 10.27dB. We do this because we can roughly predict the closed-loop voltage gain plot by discarding the part of the plot above 10.27dB. We can then convert 10.27dB to magnitude using $A_{ratio} = 10^{\frac{A_{dB}}{20}} = 3.26$ and find a pair of resistances to achieve this value of voltage gain.

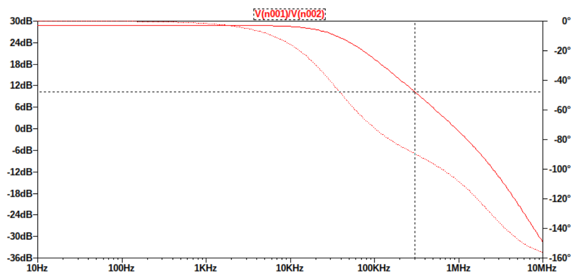


Figure 3: Determining the value of voltage gain

References

[1] Analog Devices. OP37 Datasheet. https://www.analog.com/media/en/technical-documentation/data-sheets/OP37.pdf.

[2] Ramakant A. Gayakwad. *Op-Amps and Linear Integrated Circuits.* PHI Learning Pvt. Ltd., New Delhi-110001, fourth edition, 2010.

[3] National Semiconductor. LM709 Operational Amplifier Datasheet. https://www.ee.nsysu.edu.tw/lab/F6027/LM709%20Operational%20Amplifiers.pdf.

[4] edaboard forum. Can we make OP37 as a voltage follower. https://www.edaboard.com/threads/can-op37-be-a-volatge-follwer.97645/.