Feedback Cover Sheet

Complete at least one item and up to three items in each section

Section One

Reflecting on the feedback that I have received on previous lab reports, the following issues/topics have been identified as areas for improvement:

1. More in-depth analysis of results

Section Two

In this assignment, I have attempted to act on previous feedback in the following ways:

1. Better analyse the data
2. Convey my ideas more effectively

Section Three

Feedback on the following aspects of this assignment (i.e. content/style/approach) would be particularly helpful to me:

1. If I have displayed my data well
2. If I have analysed to a high level
3. If my approach was correct

ECDE Lab Report

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You must complete this checklist. Otherwise, your report will not be marked.

- If applicable, all members of the group have made contribution to the laboratory work and this report. Yes
- The report is written in my own words with data taken and graphs drawn by myself. No material has been copied from the lab sheet or elsewhere without proper reference. Yes
- The report is produced using Word processors without any handwritten content. Yes

Abstract

Electronic circuits, devices and electromagnetics play an important role in electrical engineering, this report goes into details of operational amplifiers, transistors capacitors and how they dissipate charge. During labs data was recorded from simulations and circuits in which it was then analysed to produce the conclusions within the report. Some of the most significant results in this report include task 4, where the voltage gain was found to be 163.5 V with a voltage offset of 180 mV and in lab 1 where the calculated switching rate of 12 μs was similar to the theoretical value of 11 μs.

Introduction

This lab report will begin by stating analysis the outputs and switch rates of a half wave precision rectifier providing graphs and circuit images, it will then provide data and graphs to validate the Q=CV equation. In task 3 it shall then analyse display the theoretical and measured data for quiescent and small signal analysis of a differential amplifier stating reasons for differences, and finally in task 4 it will analyse a multistage amplifier circuit including the working out and show results from DC, transient and AC analysis from a two-stage amplifier, discussing differences in theoretical and measured values.

1. Lab 1 – Task 4

1.1. Circuit diagram and pre-lab

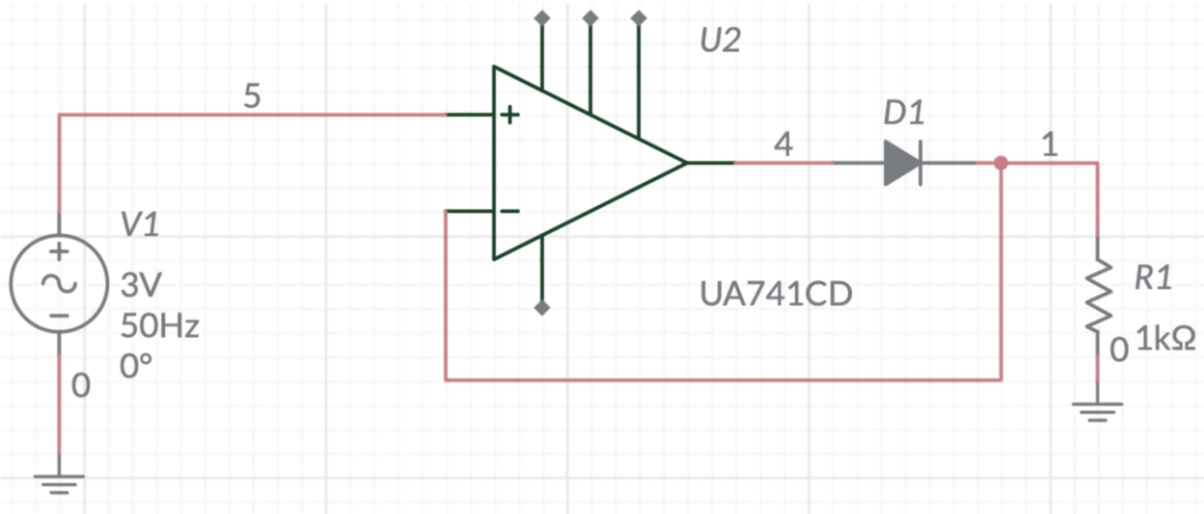

Figure 1 half wave precision rectifier with 1KΩ load

Using the data sheet of the operational amplifier 741 as seen in figure 1, the slew rate is equal to 0.5 V/μs and the with the negative saturation voltage assumed to be -2.5 V the switching time can be calculated to be 11 μs.

1.2 Results and discussion

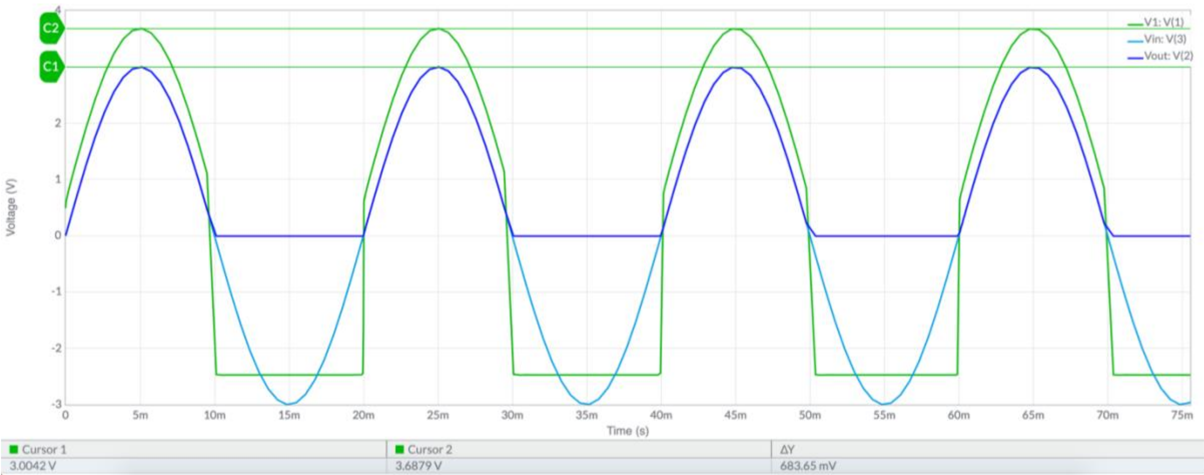

Figure 1.2 graph displaying Vin, Vout and V1 including measurements for voltage difference between V1 and Vout.

In figure 1.2, the output voltage follows the input 50Hz sine wave input whenever it is greater than 0 and remains at 0 whenever the input is less than 0 this is caused by the diode which acts as a closed switch when the input is greater than 0 and becomes reversed biased when the input is less than 0. V1 goes into negative saturation when the input signal is negative as the diode will be reversed biased and when the input signal is greater than 0 the signal will be 0.683V greater than the output measured with the cursors, due to the voltage drop in the diode.

For a 5kHz input signal, using the cursors the switching time was calculated to be 12.2 μs this is slightly larger than the theoretical value of 11 μs and this can be due to the fact the op amp is not ideal, and that the actual negative saturation value could be different causing a longer switching time. The difference in switching time could also be linked to the slew rate on the data sheet having error margins.

2. Lab 2 – Task 3

The purpose of this task is to test for equation [1] by validation of equation [2], this is done by measuring V_{int} from C_{ext} varying from 220 pF to 0.1μF with an V_{ext} of 5 V. to validate equation [2] as it can be derived from equation [1], testing for these values and plotting it will allow it to be validated.

$$Q = CV \qquad 1.$$

$$V_{int} = \frac{C_{ext}}{C_{ext} + C_{int}} \qquad 2.$$

C_{ext} (pF)	V_{int} (V)
220	0.025
470	0.034
1000	0.063
2200	0.098
4700	0.232
10000	0.448
22000	0.860
47000	1.564
100000	2.410

Figure 2.1 table showing data from capacitors

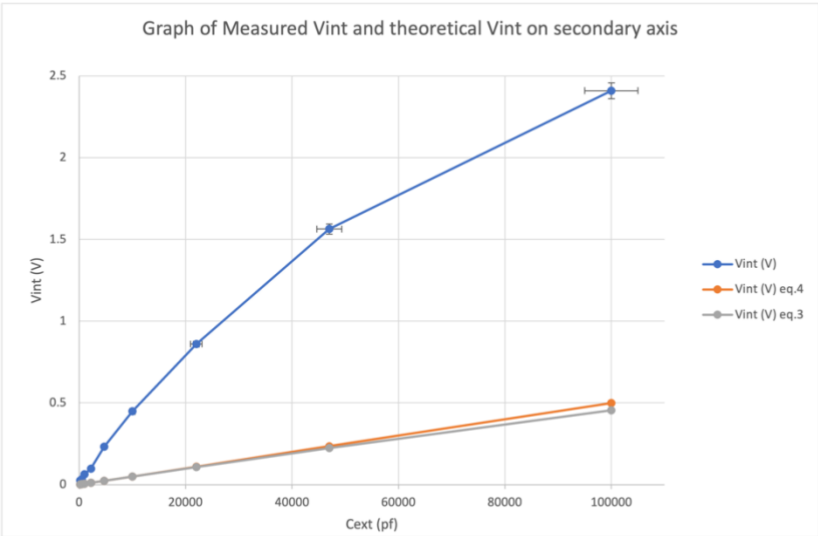

Figure 2.2 graph showing the measured Vint and the theoretical values.

3. Lab 3 – Task 2

	Theoretical calculation (pre-lab)	***Measurement***	***Calculation using measurements***
V_E (V)	*-0.5*	*-610mV*	--
I_E (mA)	0.483	--	0.520
I_C (mA)	0.483	--	0.520
V_{OUT1} (V)	-640mV	-594mV	--
V_{OUT2} (V)	10.91V	10.61V	--
g_m (S)	0.01932	--	0.0208
$v_{OUT1}/(v_{IN1}-v_{IN2})$		--	
$v_{OUT2}/(v_{IN1}-v_{IN2})$		--	

Table 1 table including theoretical and measured values for the differential amplifier

In table 1, there are differences between the theoretical and measured values, and this can be due to the transistors being idealised during calculations, the transistors being damaged, or human error whilst reading off the values due to it changing frequently.

4. Lab 4

4.1. Pre-lab workout

To calculate the overall gain of the two-stage amplifier, it is best to start of calculating the collector currents of the two NPN transistors which can be assumed to be 50µA due to the common emitter being supplied by the constant 100 µA current and Kirchhoff's law states that the two collector currents must add up to 100 µA and using equation [2] they must be equal.

$$I_{c1} = I_{c2} \qquad 3.$$

Next the transconductance can be calculated using equation [3] which is equal to 0.002 S.

$$g_{m1} = \frac{I_c}{V_T} \qquad 4.$$

Transistor 3's base current can be found using equation [4] which is equal to 40 µA after calculating the current over resistor 1.

$$I_{b3} = I_{c1} - I_{Rc1} \qquad 5.$$

This current value can then be multiplied by the assumed current gain of 300 to calculate the collector current on transistor 3 which is equal to 0.012 A. Equation [3] can be utilised again to calculate the transconductance for transistor 3 which is equal to 0.48 S. Using the voltage gain equation, it can be rearranged to find the final equation needed.

$$A_V = \frac{V_{out}}{V_{in}} = -R_c g_m \Rightarrow \qquad 6.$$

$$V_{out} = -R_{c1} g_{m1} V_{in} \Rightarrow \quad 7.$$

$$V_{be3} = \frac{R_{c1}\, g_{m1}}{2} V_{in} \Rightarrow \quad 8.$$

$$V_{in} = \frac{2V_{be3}}{R_{c1}\, g_{m1}} \quad 9.$$

$$V_{out} = i_{c3}\, R_{c3} \quad 10.$$

$$\frac{V_{out}}{V_{in}} = \frac{i_{c3}\, R_{c3}}{\frac{2V_{be3}}{R_{c1}\, g_{m1}}} \quad 11.$$

$$\frac{V_{out}}{V_{in}} = \frac{g_{m3}\, R_{c3}}{2R_{c1}\, g_{m1}} \quad 12.$$

Finally, the final equation to calculate the overall voltage gain of the circuit equation [11] after simplifying. In which the overall voltage gain of the circuit is equal to 2.4.

To calculate the collector current in the current mirror circuit, the I_{ref} is calculated which is equal to 9.76e-5 A and this is approximately equal to I_{c1} and therefor the collector current of transistor 1 is equal to 9.76e-5.

4.2. Results and Discussion

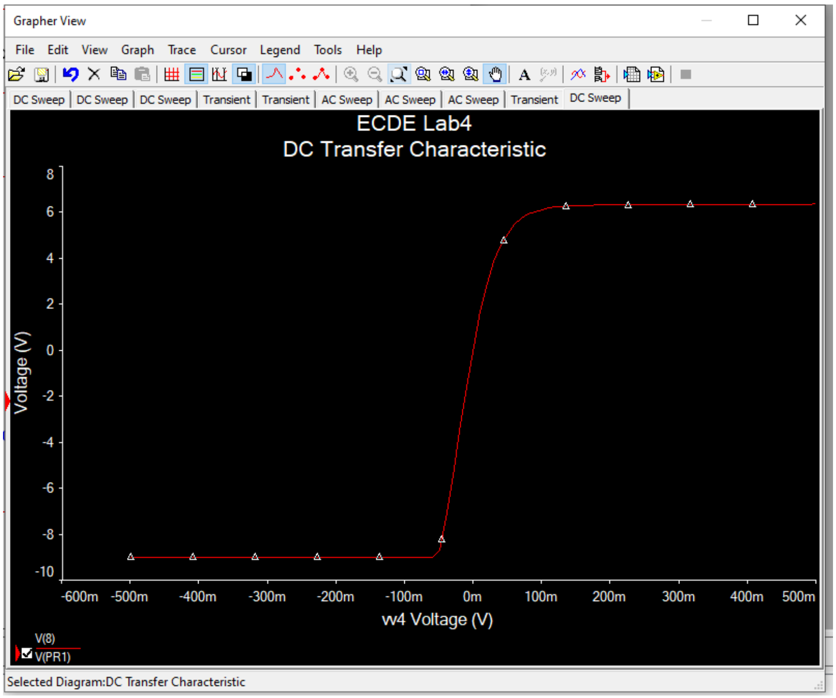

Figure 4 graph of two stage amplifier DC Analysis

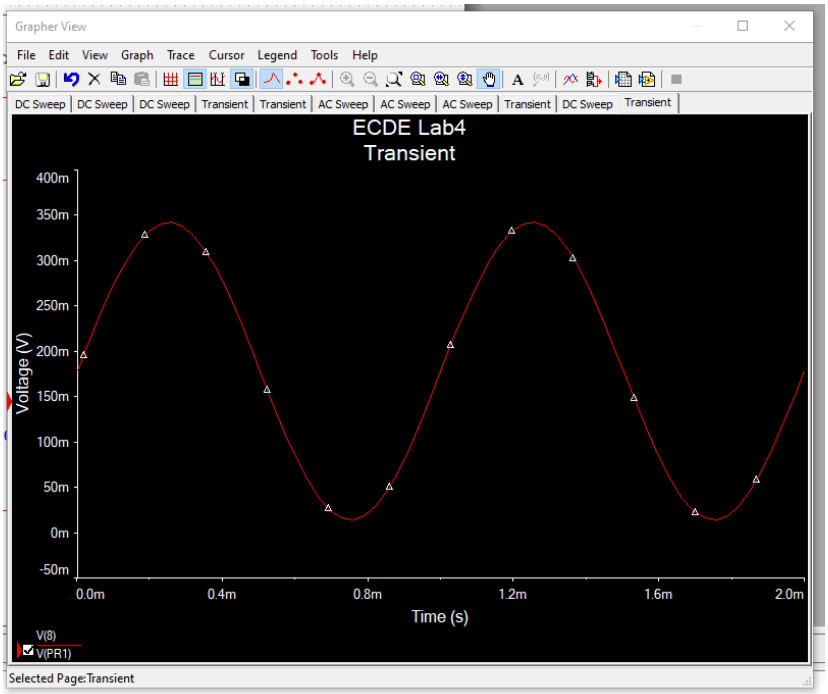

Figure 3.1 graph of two stage amplifier transient analysis

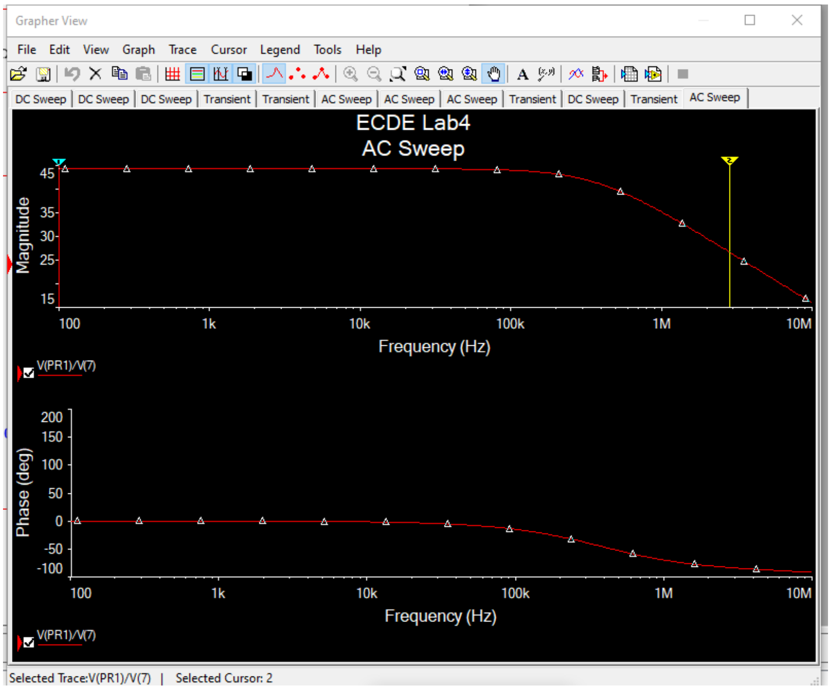

Figure 4.2 graph of two stage amplifier AC analysis

In figure 4.1 the gain was calculated to be 163.5 with a voltage offset of 180 mV, in figure 4.2 the peak gain was found to be 44.3 dB and the -3 dB point at 373.6 kHz with a gain-bandwidth product of 5.988e7.

Reflection and conclusions

The original aim of this lab report was to further the understanding of electrical circuits and compare the theoretical values to the calculated values. In task 1 the values calculated where similar to the expected ones, however in lab 2 this was not the case, this could be due to errors in the calculations in the theory side, or errors making sure to ground the capacitor before charging and discharging. Next time it would be recommended to ensure the calculations and theory knowledge is correct to not repeat any errors or miss data.

In conclusion the lab 2 equation can be verified from the experiment, transistors and opamps can be used to provide voltage or current gain depending on their parameters and configuration in the circuit.