Characterization of feedback operational amplifiers

1 Introduction

1.1 Goal of the experimental lab

Aim of this lab is:

- Analyze the behavior of feedback operational amplifiers
- Characterize the parameters of amplifiers realized with OA
- Verify some deviations with respect to the predictions of the ideal OA model.

As in the previous lab, students are required to carry out a comparison between the results of calculations and measurements. In this lab some of the behaviors measured experimentally highlight the limitations of the simplified models proposed in the lectures.

1.2 Modules and Instrumentation tools

The circuits to be measured are pre-assembled; during the lab they should only be connected to the instrument tools (power supply, signal generator and oscilloscope) at the measuring points. Use only the module A3 (AMPLIFIERS); see page 9 for a detailed circuit diagram.

Note

For some measurements it is needed to change the DC component of the input signal; to this aim use the command “offset” in the waveform generator.

Supply the circuits with voltages of +12 V and -12 V.

Refer to the guide of the previous lab for warning on the use of power supplies.

For each measurement only one of the pre-assembled circuit on the board is used, arranged according to the configuration shown.

This guide does not indicate the connection of instruments, use the one seen in the previous tutorial, with the appropriate changes (in some cases measures are required on internal nodes, instead of only on terminal input / output).

2 Measurements

2.1 Non-inverting amplifier

2.1.1 Configuration

Use the module A3-1, and configure it as indicated in the switch table 1. Below (Figure 1) the term "amplifier" refers to the complete circuit (part within the dashed box).

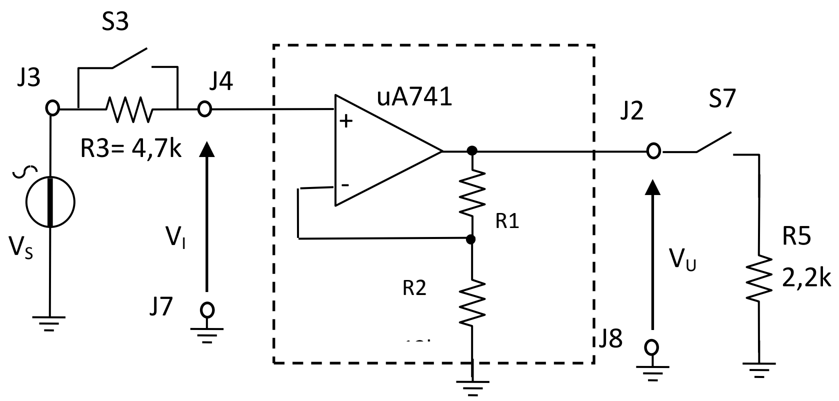


Figure 1: non-inverting amplifier diagram

switch	Board position	note
S1	1	Open
S2	2	Closed
S3	1	R3 inserted
	2	R3 short-circuited
S4	2	closed
S5	1	open
S6	1	open
S7	1	R5 not inserted
	2	R5 inserted

Table 1

2.1.2 Homework

Calculate the amplifier gain.

Evaluate the equivalent input and output resistances of the amplifier assuming the following parameters for the real OA: R_{id} = 1 MΩ, R_o = 100 Ω, A_d = 200000.

2.1.3 Measurements

Measure the voltage gain V_u/V_i. (V_s is a sinusoidal signal with peak amplitude = 0,5 V, f=2 kHz; use the oscilloscope or the multimiter ACV – **Beware:** measure V_u/V_i, not V_u/V_s).

Acting on S3 and S7 verify that the input resistance at the input terminal V_i is very high, and that the output resistance at the terminal V_u is very low (see paragraphs 2.1.2 and 2.1.3 of the previous electronic lab).

2.2 Inverting amplifier

2.2.1 Configuration

Use the module A3-2, and arrange it (Figure 2) as indicated in the switch table 2.

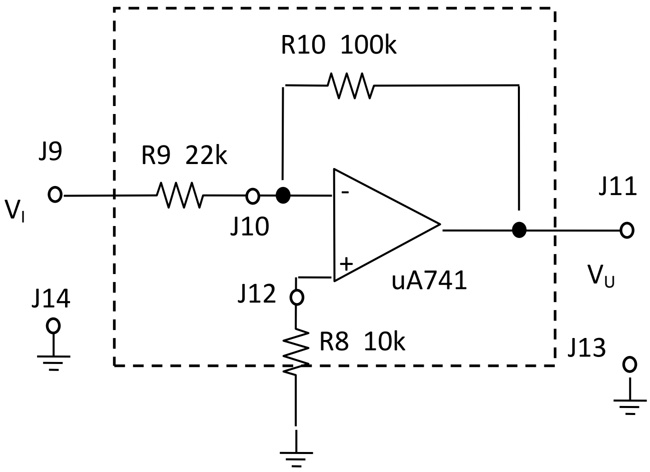


Figure 2: inverting amplifier diagram

switch	Position on board	note
S8	1	open
S9	1	open
S10	2	closed
S11	1	open
S12	1	open
S13	1	R11 not inserted
S14	1	R12 not inserted

Table 2

2.2.2 Homework

Calculate the voltage gain, input resistance and output resistance for an intrinsic output resistance R_o of the OA equal to 100 Ω. For the other parameters use the values given for the previous circuit.

2.2.3 Measures

Apply at the input a triangular waveform with peak-to-peak amplitude Vpp = 2 V and frequency 300 Hz.

a) Evaluate the gain by measuring the input and output signals.
b) Verify that the non-inverting terminal (+) of the OA is at an almost zero potential (multimeter or oscilloscope).
c) Verify that the DC voltage and the signal voltage at the inverting terminal (-) are close to zero (oscilloscope).
d) Increase the amplitude of the input signal up to obtain obvious distortion (clipping) in the output signal (Vpp = about 5 V).

2.3 Differential amplifier

2.3.1 Configuration

Use the module A3-2, and arrange it as indicated in Figure 3.

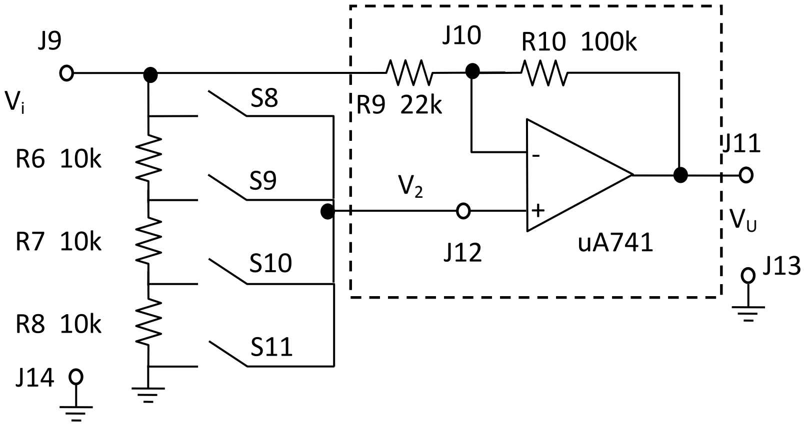


Figure 3: differential amplifier diagram

The switches allow obtaining V_2 as a voltage corresponding to fractions of V_i through the divider formed by R6, R7 and R8. We must close one switch at a time of the group S8, S9, S10 and S11, leaving the others open. The presence of V_i and V_2 allows to check the operation of the differential amplifier starting from a single signal.

switch	Position on the board	note
S8	1	open
	2	closed, V_2=V_i
S9	1	open
	2	closed, V_2=2/3 V_i
S10	1	open
	2	closed, V_2=1/3 V_i
S11	1	open
	2	closed, V_2=0
S12	2	closed
S13	1	R11 not inserted
S14	1	R12 not inserted

Table 3

2.3.2 Homework

Calculate $V_u(V_i)$ for the different configurations of the switches S8, S9, S10 e S11 (by closing only one at a time).

2.3.3 Measurements

Apply a sinusoidal signal with Vpp = 1,6 V and frequency 200 Hz.

Measure the voltage gain $A_V = V_u/V_i$ for the different configurations (close only one of the switches S8, S9, S10 and S11 at a time). For the voltage measurements use the oscilloscope or the ACV multimeter.

Compare the results of the measurements with the homework calculations.

2.4 - AC/DC amplifier

2.3.4 Configuration

Use the module A3-1, and arrange it as shown in Figure 4.

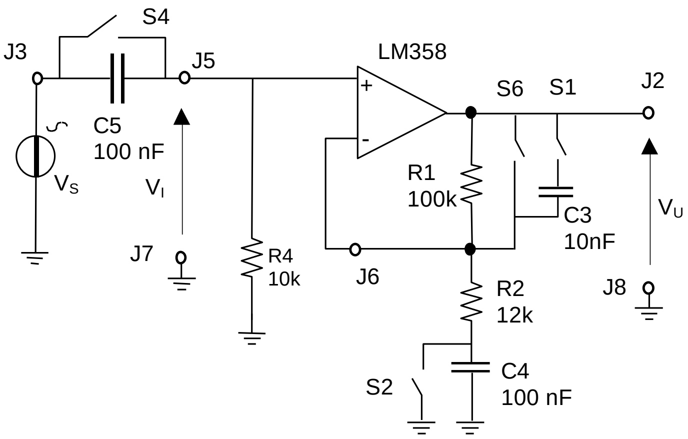


Figure 4: AC/DC amplifier diagram

The switches allow configuring the amplifier as a DC or AC stage with changes of gain and bandwidth.

switch	position on the board	note
S1	1	open, C3 not inserted
	2	closed, C3 inserted
S2	1	open, C4 not inserted
	2	closed, C4 inserted
S3	2	closed
S4	1	open, C5 inserted
	2	closed, C5 short-circuited
S5	2	Closed
S6	1	open

Table 4

2.3.5 Homework

Evaluate the effect of the steps e) and f) described in the following "Measurements" section.

2.3.6 Measurements

Arrange the circuit as a DC amplifier with S4 closed, S2 closed, S1 open,

a) Measure the gain for frequencies 100 Hz, 1 kHz, 10 kHz, 100 kHz. **Beware:** in the measurements at high frequency, beyond the OA bandwidth limitation, also the slew-rate limit (not discussed in lectures) can appear. In this case the output waveform is distorted, and changes from a sinusoidal one into a triangular one. To measure the pass band of the amplifier, check the output waveform; if it appears as a triangular one, decrease the input signal level until it turns back into a sinusoidal one.

b) Evaluate at which frequency the amplifier response decreases by 3 dB (i.e. the pole position at high frequency - maintain the output signal at low level, such that it will not cause visible distortion).

   For this measure,one should take the amplifier in the area of the pass band (maximum gain), set the signal level to a value such as to obtain a track on the oscilloscope which exploits all or almost all the vertical size of the screen, and vary the frequency until the measured amplitude output drops by 3 dB (factor 0.707).

c) Apply an offeset at the generator and verify that it is amplified at the output.

d) Insert C3 (close S1; keep S4 closed and S2 closed) and verify that C3 introduces an upper band limit, measuring again the upper frequency cutoff.

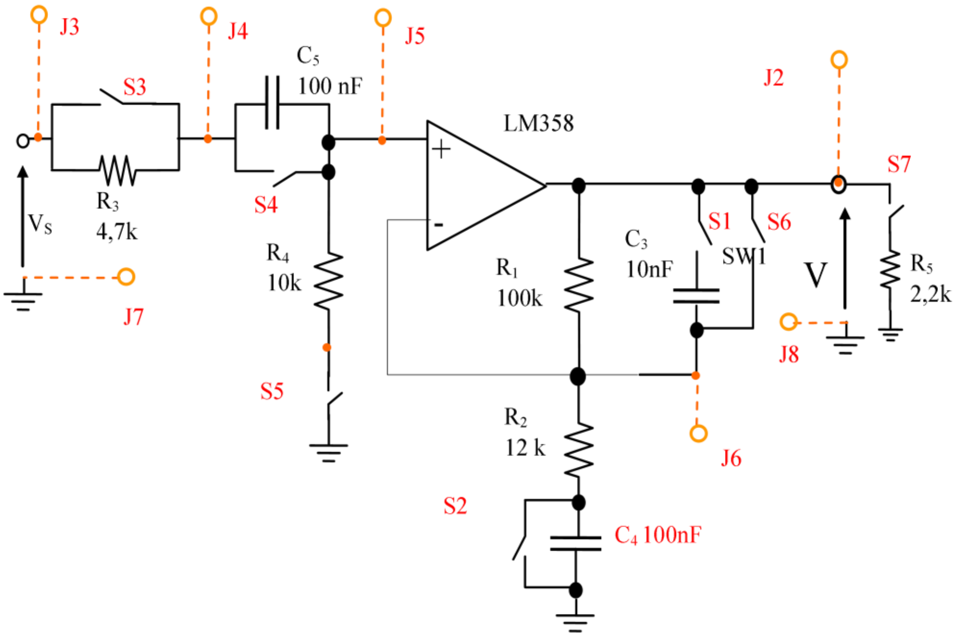
   The DC output component depends not only on the DC component at the input, but also on other factors (offset, unbalanced power supplies …). In order to measure the DC gain one should impose the DC input (using the "offset" of the generator), check the corresponding variations at the output, and calculate the ratio.

e) Insert C4 (open S2; keep S4 closed and S1 open) and verify the influence of C4 on the frequency response.

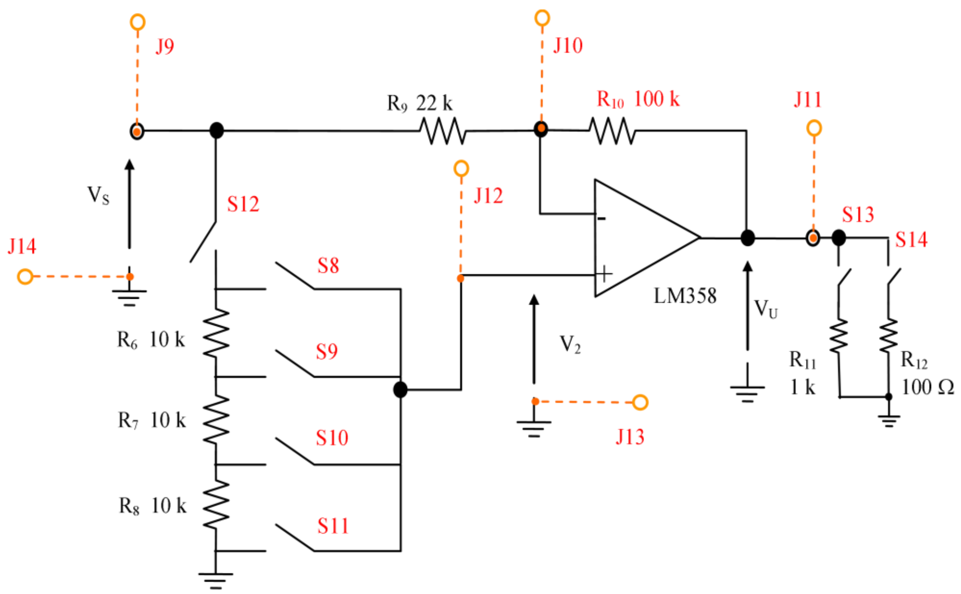
f) Insert C5 (open S4; keep S2 closed and S1 open) and verify the influence of C5 on the frequency response.

Complete diagram of the board A-3

Module A3 – 1.



Module A3 – 2.



3 Draft for the final report

Electronic lab 2: Characterization of feedback operational amplifiers

Datea:

3.1.1 Group ………; components:

First Name	Last Name	Signature

3.1.2 Used instruments

Instrument	Make and model	Characteristics
Waveform generator		
Oscilloscope		
Power supply		
Pre-assembled circuit board		

3.1.3 Synthetic description of the lab goals

3.1.4 Non inverting amplifier

Homework

Amplifier gain:

Equivalent input and output resistances (estimated values)

Measurements

Gain V_u/V_i

Equivalent resistances

	S3 close	S3 open	R_i (from R3 and measured V_i)
Measured V_i			

	S7 chiuso	S7 aperto	R_u (from R5 and measured V_u)
Measured V_u			

(comment on the measurements)

Comparison with homework calculations

	Calculated	Measured
Gain A_v		
Gain $\|A_v\|$(dB)		
R_i		
R_u		

3.1.5 Inverting Amplifier

Homework

Gain

Input resistance

Output resistance

Measurements

Gain

Voltage on the inverting terminal of the OA

Input level at which output signal distortion appears (clipping)

3.1.6 Differential amplifier

Homework

$V_u(V_i)$ for the different switch configurations

Measurements

Measured gain $A_V = V_u/V_i$ in the different configurations and comparison with the calculated values

configuration	Calculated gain		Measured gain	
	ratio	dB	ratio	dB

3.1.7 AC/DC Amplifier

Measurements

Circuit configured as DC amplifier

Gain for sinusoidal signals with frequencies 100, 1.000, 10.000, 100.000 Hz;

Upper frequency cutoff

Relationship between generator and output offset

Circuit with C3 inserted:

DC gain

Upper band limit

Circuit with C4 inserted:

Lower band limit

Circuit with C5 inserted:

DC gain