Analog Electronic Circuits Lab (EC2.103, Spring 2023)

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Instructions:

1. Systematically record all your observations in the lab book (mandatory)
2. Save results in USB or take pictures
3. Make meaningful tables to summarize your findings and show it to the instructor(s) during the lab session only
4. Bring your calculators and DMM (if available)
5. Handle equipment carefully and report in case of any incidence
6. Enjoy your time in lab and strengthen your understanding about circuits

Experiment-8
Operational Amplifiers

1. **CMOS inverter with feedback**

   (a) Consider the circuits shown in Fig. 1, where coupling capacitor C_C =10 μF, $R_{BIAS} \approx 1$ MΩ (very high value) and $V_{DD} = 5$ V. Use Fig. 1(a) to plot the voltage transfer characteristics (V_{OUT} vs V_{IN}) and identify the valid input output region for the circuit to act as an amplifier. *(Hint: use acquire function in DSO by giving a sinusoidal signal of amplitude 5 V at input; slope* $|\frac{dv_{out}}{dv_{in}}| > 1$*)*

   (b) Connect the circuit as shown in Fig. 1(b). Find DC values at drain and gate terminals. Apply a sinusoidal signal (v_{in}) with amplitude 100 mV v_{p-p} and frequency 1 KHz. Measure the gain by plotting v_{in} and v_{out} on DSO. Tabulate the value of gain for different input amplitudes (V_{gs}) - 200 mV, 300 mV, 400 mV, 500 mV and 600 mV V_{p-p}. Do you observe any clipping of the output signal as the input is increased? State and explain the reason for the same.

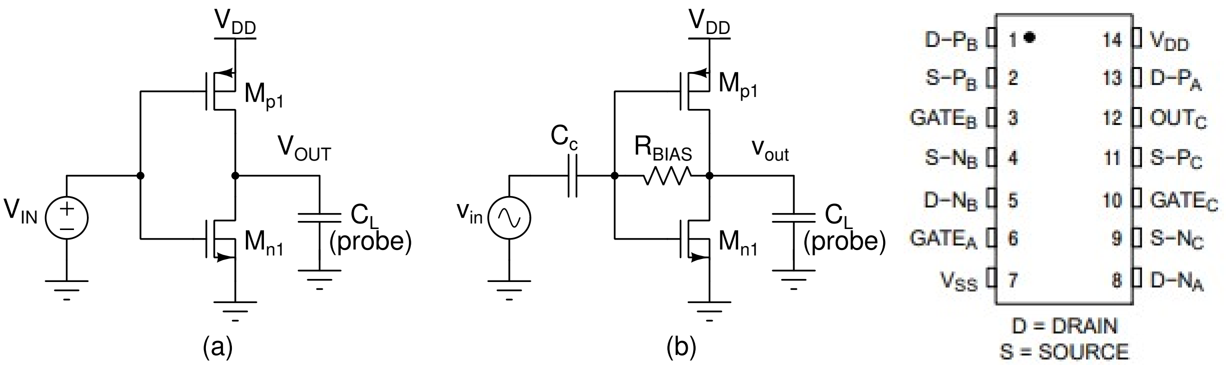
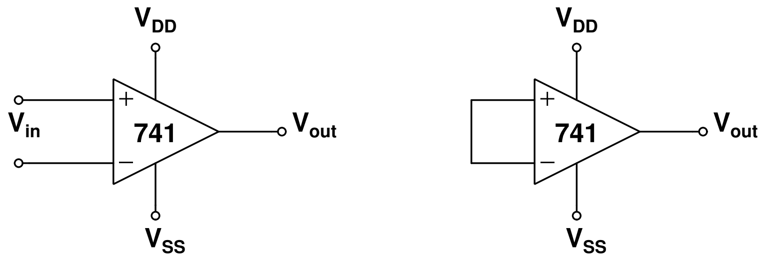


Figure 1: (a) VTC (b) voltage amplifier

2. **Characterization of an operational amplifier**
As depicted in Figure 2(a), an opamp is a differential amplifier, which has two input terminals - non-inverting ($IN+$) and inverting ($IN-$). Opamp can amplify the difference between the two inputs. An ideal opamp has very high (∞) open loop gain, very large (∞) input impedance and small (0) output impedance.

   (a) Realise the circuit given in Figure 2(a), with $V_{in} = 12$ V peak-to-peak, frequency = 100 Hz, offset 0 V from the function generator, $V_{DD} = 10$ V, $V_{SS} = -10$ V (refer to opamp pin diagram in figure 3(b) for making connections). Probe the input and output nodes and observe the voltage transfer characteristic (VTC) using acquire function in DSO.

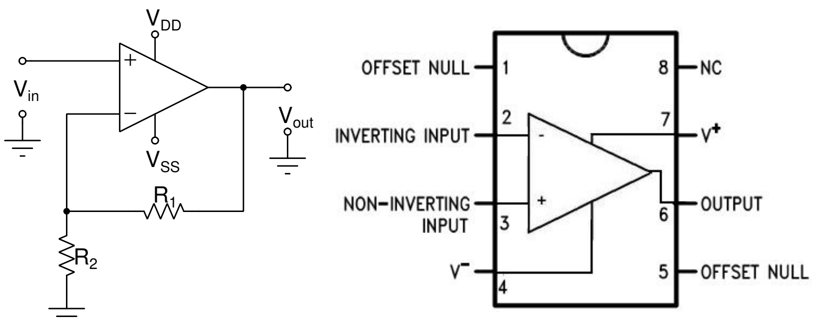
   (b) Connect the inverting and non-inverting terminals as shown in 2(b). Probe the output node using DSO and observe the output. Ideally, you should see 0 V at the output because input difference is 0 V. However, due to opamp imperfection (DC offset), you might observe some voltage at the output. Can you adjust input voltages such that V_{OUT} becomes zero. Show the setup and results.



(a) (b)

Figure 2: Opamp open loop characteristics (b) offset measurement

3. **Non-inverting amplifier**



((a)) ((b))

Figure 3: a) Schematic of non-inverting amplifier and b) UA741 pin diagram

Consider the circuit shown in Fig. 3(a). Output is fed back to inverting terminal (IN-) at input through a resistor divider. This is called negative feedback. Due to the very high gain of the opamp, **in negative feedback**, voltages at inverting and non-inverting terminal become equal and hence they are considered as virtually shorted (no current flows between $IN+$ and $IN-$ but voltages are same)

   (a) Derive the gain of the non-inverting amplifier shown in Figure 3 (a).

(b) Realise the circuit given in Figure 3 (a), with $V_{in} = 250$ mV peak-to-peak, frequency = 5 kHz from the function generator, $V_{DD} = 12$ V, $V_{SS} = -12$ V (refer to the pin diagram for making connections). Connect the resistors R_1 and R_2 according to Table 1 and note the gain obtained in each case. Compare the values with the calculated gain.

Table 1

R_1	R_2	V_{out}	Calculated Gain	Obtained Gain=$\frac{V_{out}}{V_{in}}$
10 kΩ	10 kΩ			
10 kΩ	4.7 kΩ			

(c) Calculate R_1 and R_2 values to obtain gain of 4 and 5. Fill in Table 2 with v_{out} and gain obtained from circuit. Verify through measurements and report plots.

Table 2

Expected Gain	R_1	R_2	V_{out}	Obtained Gain=$\frac{V_{out}}{V_{in}}$
4				
5				

(d) Now, remove R_1 and R_2 and connect V_{out} to the inverting input terminal directly. Report the gain and comment on possible uses of this circuit?

4. **Inverting amplifier**

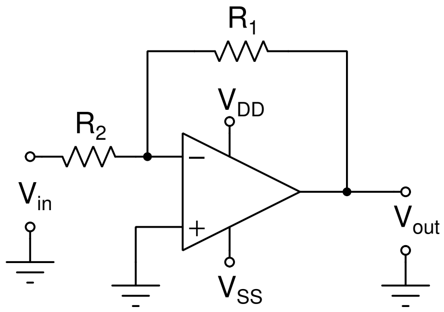


Figure 4: Inverting amplifier

(a) Derive the gain of the inverting amplifier shown in Figure 4.

(b) Realise the circuit given in Figure 4, with $V_{in} = 250$ mV peak-to-peak from the function generator, $V_{DD} = 12$ V, $V_{SS} = -12$ V (refer to the pin diagram for making connections). Connect the resistors R_1 and R_2 according to Table 3 and note the gain obtained in each case. Compare the values with the calculated gain.

Table 3

R_1	R_2	V_{out}	Calculated Gain	Obtained Gain=$-\frac{V_{out}}{V_{in}}$
10 kΩ	10 kΩ			
10 kΩ	4.7 kΩ			

(c) Find R_1 and R_2 values to obtain gain of 4 and 5 using the expression derived and fill in Table 4 with V_{out} and gain obtained from circuit.

Table 4

Expected Gain	R_1	R_2	V_{out}	Obtained Gain=-$\frac{V_{out}}{V_{in}}$
4				
5				