EE230 ENDSEM

Name: **Roll No.**

Endsem Exam (22 marks) Date: April 13, 2024

Instructions:

- Write your name and roll no. on the question paper and answer sheet.
- **Make sure that you have tested all the equipments on your workstation and the components/ ICs provided to you.**
- **No help will be given in circuit debugging and handling the equipment.**
- Write your observations, input-output waveforms with proper labelling (x and y axis markings) in the answer sheet.
- **Show your waveforms, observations written on the answersheets to your TA and get signature with time stamp from the TA, wherever asked in the questions.**
- **No demo, no credit. TAs will evaluate you based on the answers written in the answer sheet and waveforms demonstrated to the TAs.**
- Submit your question paper and answer sheet to your TA.
- Use +/- 15 V as supply voltages for the OP-AMP.

1. **Motivation**
   Designing practical Current Source with the help of Negative Resistance

2. **Testing of IC 741:**

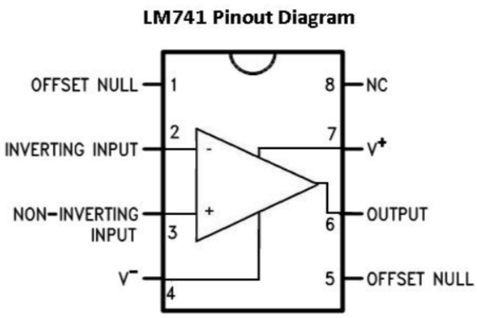

Figure 1: LM741 Pin Diagram

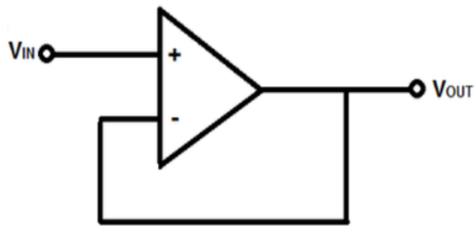

Figure 2: Buffer Circuit

You'll be using LM741 OP-AMP IC to perform this experiment. Refer pinout diagram in Fig.[1]. Test the 741 ICs in a unity feedback configuration as shown in Fig.[2]. Apply a sine wave of 1 KHz, 2V$_{pp}$ as the input signal V_{in}, power supply of $\pm 15V$ and check your output V_{out}. Once you are sure that V_{out} is as expected, show the output waveform to your TA and proceed further. **[1 Marks]**

3. **Theory**

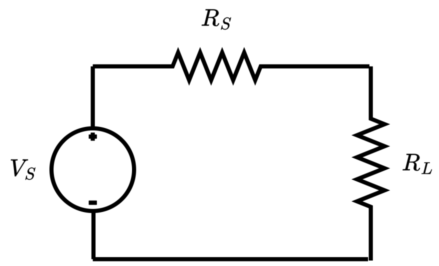

Figure 3: Practical Source Circuit

1. Refer to the circuit in Fig.3. V_s is the source voltage whose internal resistance is R_{int}. R_L is the load resistance through which we have to supply a constant current. We have also added extra series resistance R_s then total series resistance of the voltage source is $R_s + R_{int} \approx R_s(R_{int}$ is around 5-10 Ω which is very small).
2. Ideally, if we vary the load resistance R_L, the current in the circuit changes. Our objective is that even after the load resistance changes, the source should supply the same current $\frac{V_s}{R_s}$.

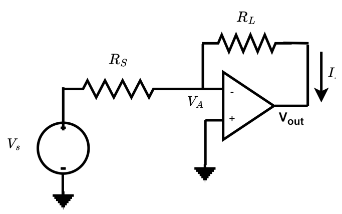

Figure 4: Constant current through load Circuit

3. Refer the circuit shown in figure [4]. Derive the current flowing through R_L in terms of V_s, R_s or R_L. Comment on the current flowing through load resistance R_L if we vary the load resistance. Consider the op-amp as ideal. **[2 Marks]**
4. The drawback of the circuit shown above in figure [4] is its one of the load terminal is floating. But generally we would like to have one of the load terminal is grounded.
5. Now, you have to design a current source that supply constant current to the load in which one of the nodes of the load is grounded.
6. Refer to the circuit in Fig.5. This is the Norton equivalent of the circuit above in Fig.3. If we wish to supply the current magnitude of $\frac{V_s}{R_s}$ to the load, we connect an extra resistance of $-R_s$ in parallel, as shown in Figure Fig.6. The parallel Combination of R_s and $-R_s$ will give you infinite impedance and the current $\frac{V_s}{R_s}$ will flow through the load R_L.

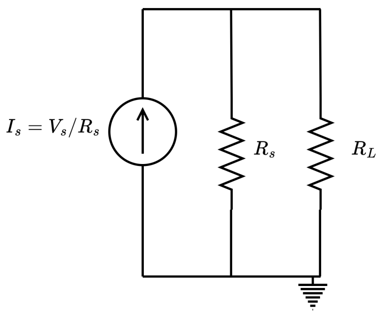

Figure 5: Norton Equivalent of figure [3]

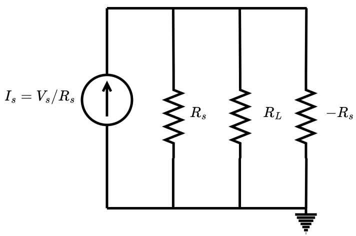

Figure 6: Adding Extra Negative Resistance in figure [5]

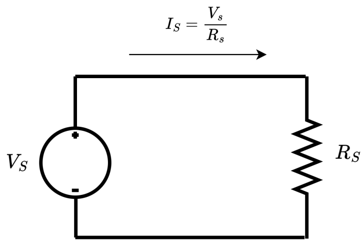

Figure 7: Positive Resistance

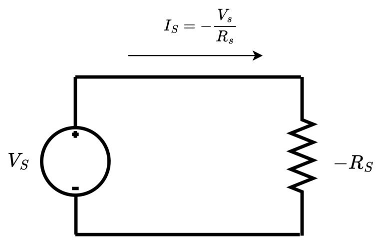

Figure 8: Negative Resistance

   (a) **Concept of the Negative Resistance:**
   If you have a passive resistance then it draws the current as shown in figure [7]. But when you have a negative resistance made by active element then it supplies the current as you can see the current flowing through the resistor is negative as shown in figure [8].

7. This negative resistance can be realized using an active element in the circuit. Refer the circuit 10, From Miller's theorem, the seen impedance seen through the input pin of the op-amp is $\frac{R_s}{1-A}$. R_s is the equivalent resistance between the input and output terminals and A is the voltage gain of the network. If we make the gain of the circuit to be 2, then the input resistance seen through the input branch of this circuit shown in figure below will be $-R_s$.

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4. **Hardware Implementation**

   1. **Design of gain block**

      (a) The gain(A=2) block as shown in figure 9, has to be designed by op-amp

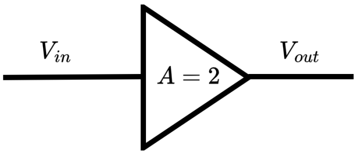

Figure 9: Gain Block

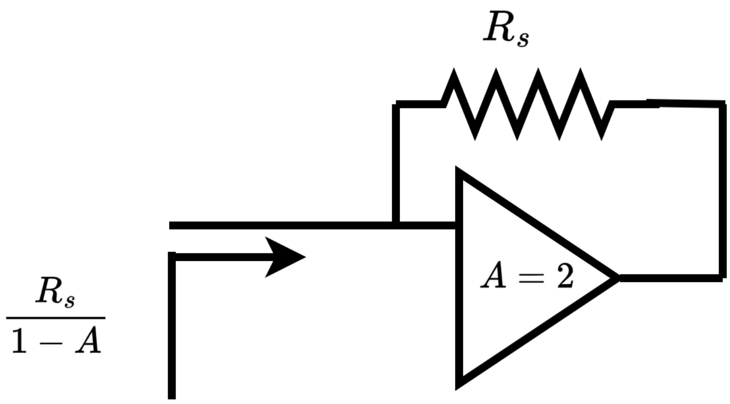

Figure 10: Negative Resistance Emulator Circuit

and resistors. Use Dc power Supply voltage as ±15 V.

(b) You have to design the gain block such that the current flowing through the opamp output should not be greater than $0.5mA$, if we apply the input voltage as 5 V. Hence you have to select the values of resistors accordingly. **[3 Marks]**

(c) Draw the circuit diagram on the answer sheet. Mention the component values that you used to the design the gain block. **[2 Marks]**

(d) Apply 5 V at the input and measure the output voltage and current flowing through the output node. Use Lab DMM for measurement and show the results to the TA. **[1 Marks]**

2. **Test circuit for negative resistance**

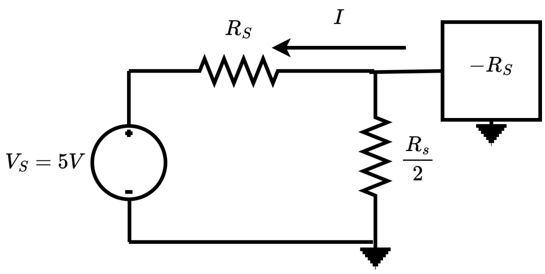

Figure 11: Test Circuit for Negative Resistance

(a) Once you designed the gain block, you connect the R_s in the feedback accordingly then you will get negative resistance R_s at the input side. Draw the complete Negative Resistance Emulator Circuit on the answer sheet. Mention all component values for designing the negative resistance of -10 KΩ. **[1 Marks]**

(b) The circuit shown in figure [11] is used for testing the negative resistance. Derive the current I shown in figure [11] in terms of V_s and R_s. Consider the op-amp to be ideal. **[2 Marks]**

(c) Construct the circuit shown in figure [11]. Take R_s=10 KΩ. Measure the current I shown in figure [11] and verify the current from your derived equation. Show the results to the TA. Do not dismantle the circuit because you may need it later. **[2 Marks]**

3. **Constructing the Current Source**

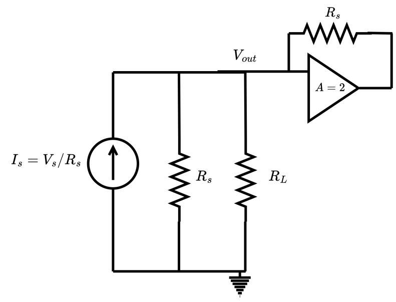

Figure 12: Circuit for Calculation of Maximum load Resistance

(a) The circuit shown in figure [12] is similar to the norton equivalent circuit shown in figure [6] where we emulated negative resistance. Now you have to define the maximum value of the load resistance R_L over which the current through the load will remain constant if R_s is 10 KΩ. (**Hint:** The output of the op-amap that you used in the gain block should not saturate. Take $V_{sat} = 15V$). **[3 Marks]**

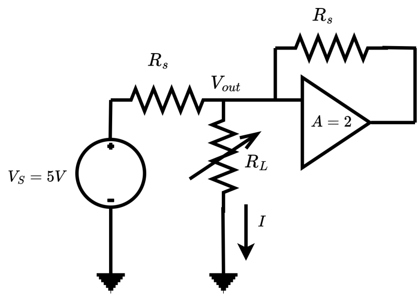

Figure 13: Complete Current Source Circuit

(b) Construct the circuit shown in figure [13]. Sweep the load resistance from $1k\Omega$ to maximum value that you obtained part 3(a). Plot I_L vs R_L. **[2 Marks]**

4. **One more application of the Negative Resistance:**

(a) You can also make an amplifier using negative resistance. The equivalent circuit for the amplifier is shown in the figure [14]. Derive the transfer function from V_{in} to V_{out} shown in figure [14]. Design an amplifier for a gain of 5 $\frac{V}{V}$. Use same negative resistance emulator circuit with resistance of -10 KΩ for designing the amplifier. **[2 Marks]**

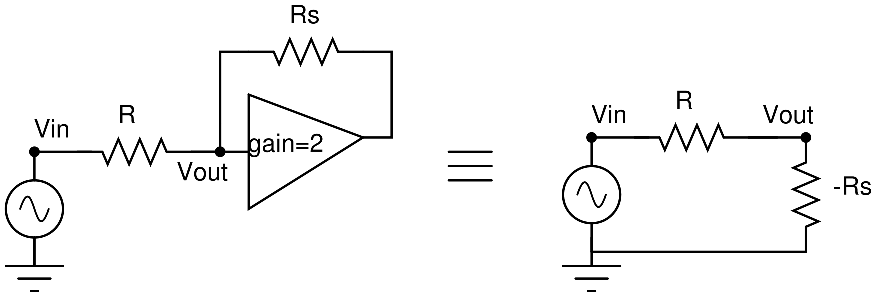

Figure 14: Amplifier using Negative Resistance

(b) Apply V_{in} as 1 V V_{pp} with 1 kHz input frequency. Plot the V_{in} V_{out} and draw the same on you answer sheet. **[1 Marks]**

(c) With the understanding of part 4.(a) now design the amplifier with a gain of 10. Use same negative resistance emulator circuit. Define the maximum value of the input signal over which the amplifier works properly. Plot the V_{in}, V_{out} and draw the same on you answer sheet. **[2 Marks]**