Study of Instrumentation amplifier using OPAMP (IC-741)

Analog Electronics Lab Experiment -5

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1. Objective

To study the characteristics of an instrumentation feedback amplifier made using Operational Amplifier and verify the same using LTSpice simulation of IC 741:

Report the following:

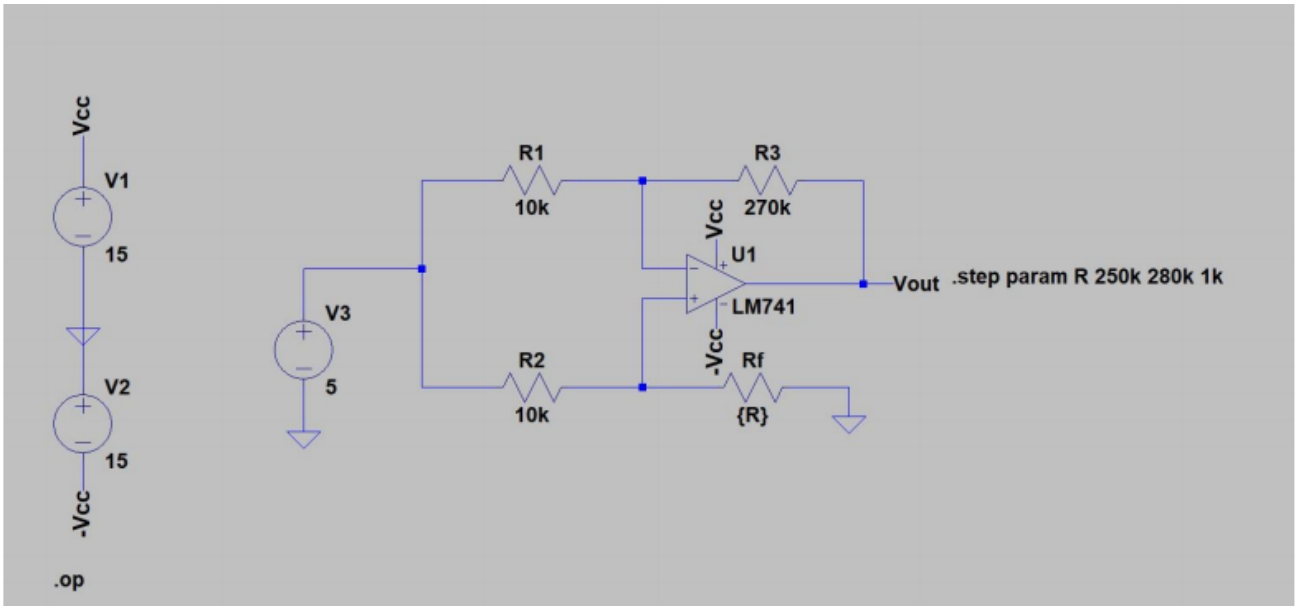
1) Circuit diagrams after finding the DC null point.
2) Calculate the Voltage gain (A_v) for :
    a) Common mode
    b) Differential mode
3) Theoretical Voltage and simulated value of CMRR.

Assumptions:

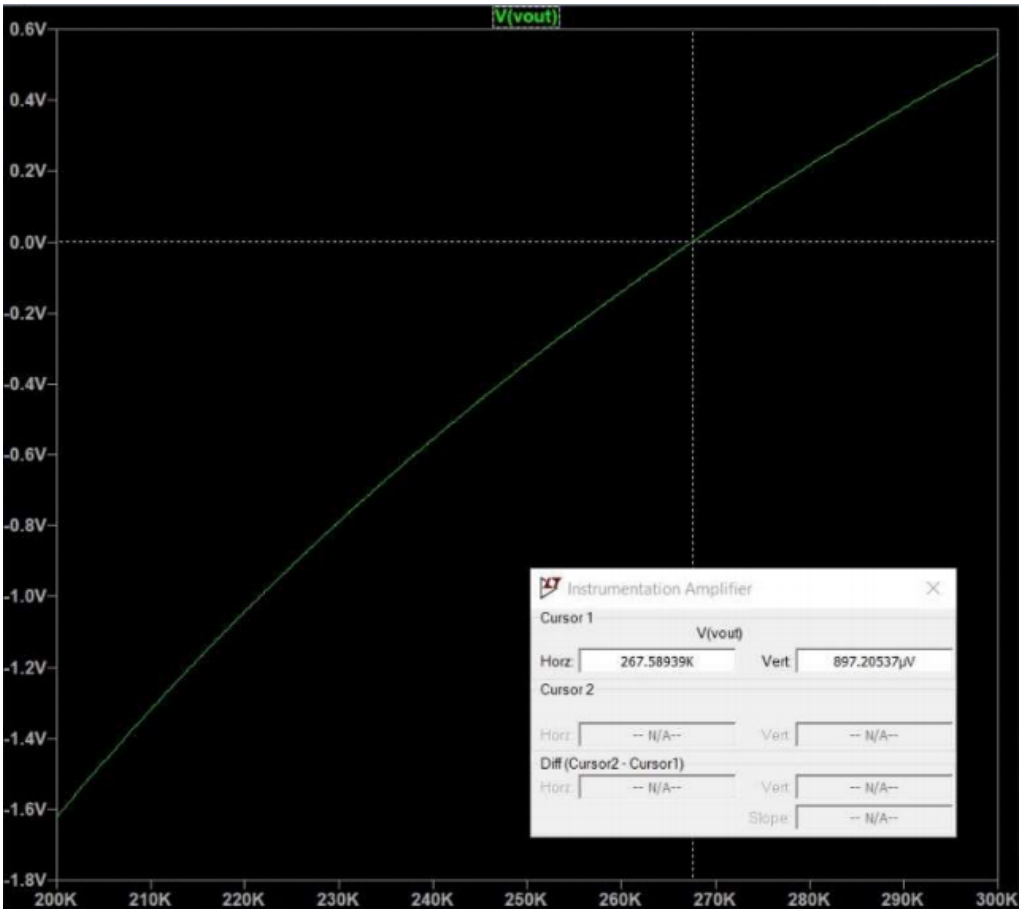
1) Ideal behaviour of the OPAMP.
2) All the calculations to be done at 1kHz frequency.

2. DC Null Point

1. **Circuit Diagram**:



2. **Resultant Curve and simulation result**



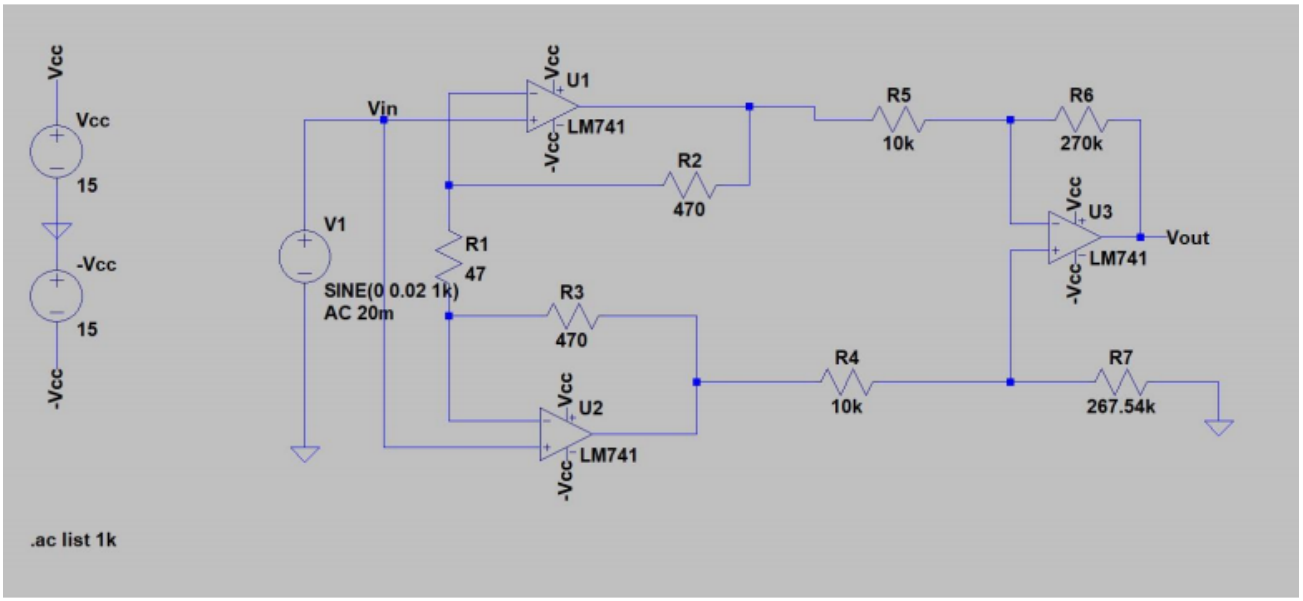
Simulated Value of Rf obtained = 267.58k ohm (approx.)

3. **Hand Calculations**

R1/R2 = Rf/R3 (for ideal Op-Amp) => Rf = 270k ohm

3. Common Mode Gain

1. **Circuit Diagram**:



2. **Resultant analysis and simulated result**

```
      --- AC Analysis ---

frequency:     1000          Hz
V(n001):       mag:  0.0192807 phase: -0.0446857°        voltage
V(n003):       mag:    0.01928 phase: -0.0512225°        voltage
V(vcc-):       mag:          0 phase:          0°        voltage
V(vcc+):       mag:          0 phase:          0°        voltage
V(vout):       mag: 0.000167435 phase:    157.439°       voltage
V(b):          mag:  0.0200005 phase:  -0.051356°        voltage
V(a):          mag:  0.0200005 phase: -0.0513552°        voltage
V(n002):       mag:  0.0200005 phase: -0.0512658°        voltage
V(v1):         mag:       0.02 phase:          0°        voltage
V(n004):       mag:  0.0200005 phase: -0.0512658°        voltage
I(R7):         mag: 8.9088e-13 phase:   -19.0189°        device_current
I(R6):         mag: 6.69901e-11 phase:   -88.5107°       device_current
I(R5):         mag: 6.63868e-11 phase:   -89.9513°       device_current
I(R2):         mag: 7.19847e-08 phase:     179.77°       device_current
I(R3):         mag: 7.20518e-08 phase:    179.945°       device_current
I(R4):         mag: 7.20533e-08 phase:    179.949°       device_current
I(R1):         mag: 7.19832e-08 phase:    179.766°       device_current
I(V3):         mag: 1.33365e-10 phase:   -89.2621°       device_current
I(V1):         mag: 3.60453e-08 phase:    179.843°       device_current
I(V2):         mag: 3.60099e-08 phase:  -0.157328°       device_current
Ix(u1:1):      mag: 4.87246e-12 phase:   -107.116°       subckt_current
Ix(u1:2):      mag: 4.88392e-12 phase:    72.4518°       subckt_current
Ix(u1:99):     mag: 3.60229e-08 phase:    179.766°       subckt_current
Ix(u1:50):     mag: 3.59603e-08 phase:    179.766°       subckt_current
Ix(u1:28):     mag: 7.19832e-08 phase:  -0.233705°       subckt_current
Ix(u2:1):      mag: 6.66826e-11 phase:    90.7379°       subckt_current
Ix(u2:2):      mag: 6.66832e-11 phase:   -89.2278°       subckt_current
Ix(u2:99):     mag: 3.6006e-08 phase:  -0.282833°        subckt_current
Ix(u2:50):     mag: 3.5979e-08 phase:  -0.282833°        subckt_current
Ix(u2:28):     mag: 7.1985e-08 phase:    179.717°       subckt_current
Ix(u3:1):      mag: 6.66827e-11 phase:     90.738°       subckt_current
Ix(u3:2):      mag: 6.66832e-11 phase:   -89.2277°       subckt_current
Ix(u3:99):     mag: 3.60623e-08 phase:  -0.108177°       subckt_current
Ix(u3:50):     mag: 3.59913e-08 phase:  -0.108177°       subckt_current
Ix(u3:28):     mag: 7.20537e-08 phase:    179.892°       subckt_current
```

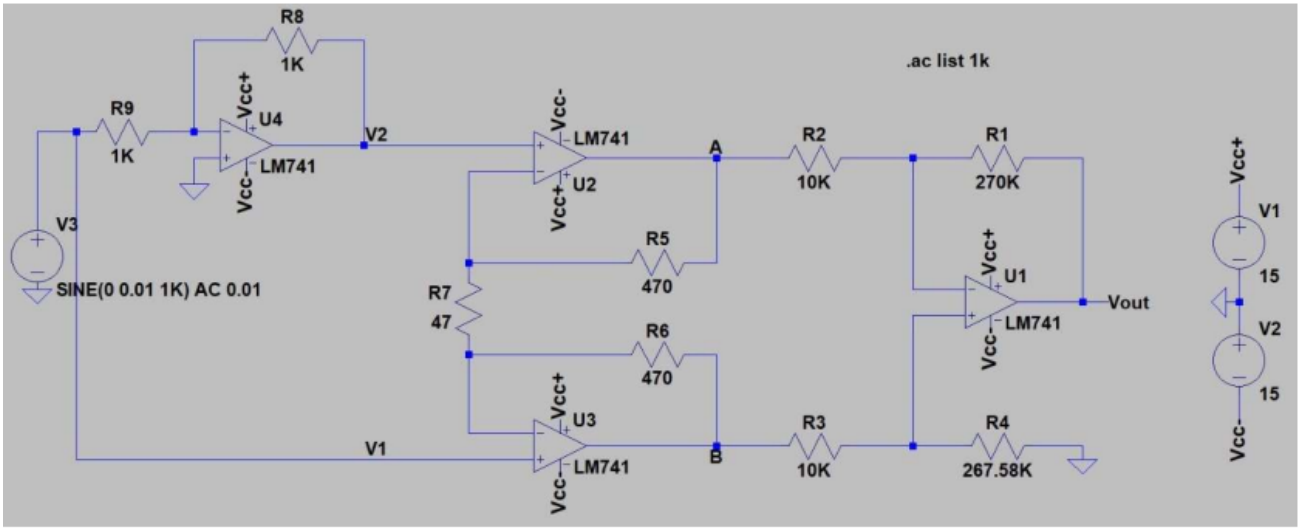
Simulated Value of Acm obtained = Vo/Vin = = 0.00837 (-41.54dB)

3. **Hand Calculations**

Acm = 0

4. Differential mode gain

1. **Circuit Diagram**:



2. **Resultant analysis and simulation results**

```
      --- AC Analysis ---

frequency:     1000          Hz
V(n002):       mag:    0.202268 phase:   -5.02225°        voltage
V(n004):       mag:    0.202314 phase:   -1.81952°        voltage
V(vcc-):       mag:           0 phase:          0°        voltage
V(vcc+):       mag:           0 phase:          0°        voltage
V(vout):       mag:     11.3257 phase:   -3.42458°        voltage
V(b):          mag:    0.209888 phase:    -1.7101°        voltage
V(a):          mag:    0.209888 phase:    178.282°        voltage
V(n003):       mag: 0.00999483 phase:    178.199°        voltage
V(v2):         mag: 0.00999987 phase:    179.864°        voltage
V(n005):       mag: 0.00999455 phase:   -1.62725°        voltage
V(v1):         mag:       0.01 phase:          0°        voltage
V(n001):       mag: 1.1816e-05 phase:    89.6166°        voltage
I(R9):         mag: 9.99993e-06 phase:    179.932°        device_current
I(R8):         mag: 9.99993e-06 phase:    179.932°        device_current
I(R7):         mag: 0.000425306 phase:   -1.71411°        device_current
I(R6):         mag: 0.000425306 phase:   -1.71425°        device_current
I(R5):         mag: 0.000425306 phase:    178.286°        device_current
I(R2):         mag: 4.11985e-05 phase:   -3.33976°        device_current
I(R3):         mag: 7.58442e-07 phase:    -178.79°        device_current
I(R4):         mag: 7.56088e-07 phase:     178.18°        device_current
I(R1):         mag: 4.11983e-05 phase:   -3.39553°        device_current
I(V3):         mag: 9.99996e-06 phase:    179.938°        device_current
I(V1):         mag: 0.000128319 phase:   -1.72878°        device_current
I(V2):         mag: 0.00011908 phase:    -1.8693°        device_current
Ix(u1:1):      mag: 4.01028e-08 phase:     86.331°        subckt_current
Ix(u1:2):      mag: 4.01028e-08 phase:   -93.6684°        subckt_current
Ix(u1:99):     mag: 2.00714e-05 phase:   -3.39553°        subckt_current
Ix(u1:50):     mag: 2.11269e-05 phase:   -3.39553°        subckt_current
Ix(u1:28):     mag: 4.11983e-05 phase:    176.604°        subckt_current
Ix(u2:1):      mag: 1.03156e-09 phase:   -91.9873°        subckt_current
Ix(u2:2):      mag: 1.03156e-09 phase:    88.0138°        subckt_current
Ix(u2:99):     mag: 0.000300315 phase:    178.142°        subckt_current
Ix(u2:50):     mag: 0.000166174 phase:    178.142°        subckt_current
Ix(u2:28):     mag: 0.000466489 phase:   -1.85779°        subckt_current
Ix(u3:1):      mag: 1.00805e-09 phase:     88.061°        subckt_current
Ix(u3:2):      mag: 1.00805e-09 phase:   -91.9379°        subckt_current
Ix(u3:99):     mag: 0.000156966 phase:   -1.70904°        subckt_current
Ix(u3:50):     mag: 0.000269098 phase:   -1.70904°        subckt_current
```

V1 = 10 mV, V2 = -10mV, Vi = 20mV

Vout = 11.3257

Adm = Vo/Vi =566.285 (55.06 dB)

3. **Hand Calculations**

Adm = (R1/R2) x (1+2*R5/R7) = 567 (55.07 dB)

5. CMRR

The Common Mode Rejection Ratio is defined as the ratio of differential-mode gain to the common-mode gain.

1. **Simulated value**

CMRR = Adm / Acm = 67616.12 (96.6 dB)

2. **Hand Calculations**

Adm = 567 and Acm = 0

=> **CMRR = Infinite**