Name: Swagat Panda
ID: 2017B5A30983P

Lab V

Study of Instrumentation Amplifier using LM741

Objectives

To study the Instrumentation Amplifier using op-amp LM741 and find out

1. Value of resistance (R_f) for DC null point,
2. Common mode gain (A_{cm}) for the instrumentation amplifier,
3. Differential mode gain(A_{dm})for the instrumentation amplifier

and find

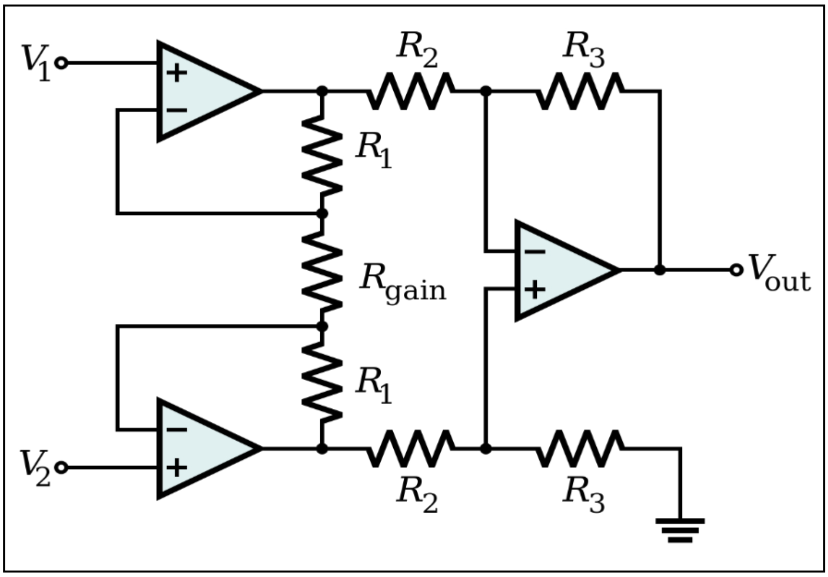
a) the common mode rejection ratio (CMRR) for the instrumentation amplifier,
b) compare the results from simulation with the theoretical values of the quantities.

Also, draw schematic for each case.

Instrumentation Amplifier

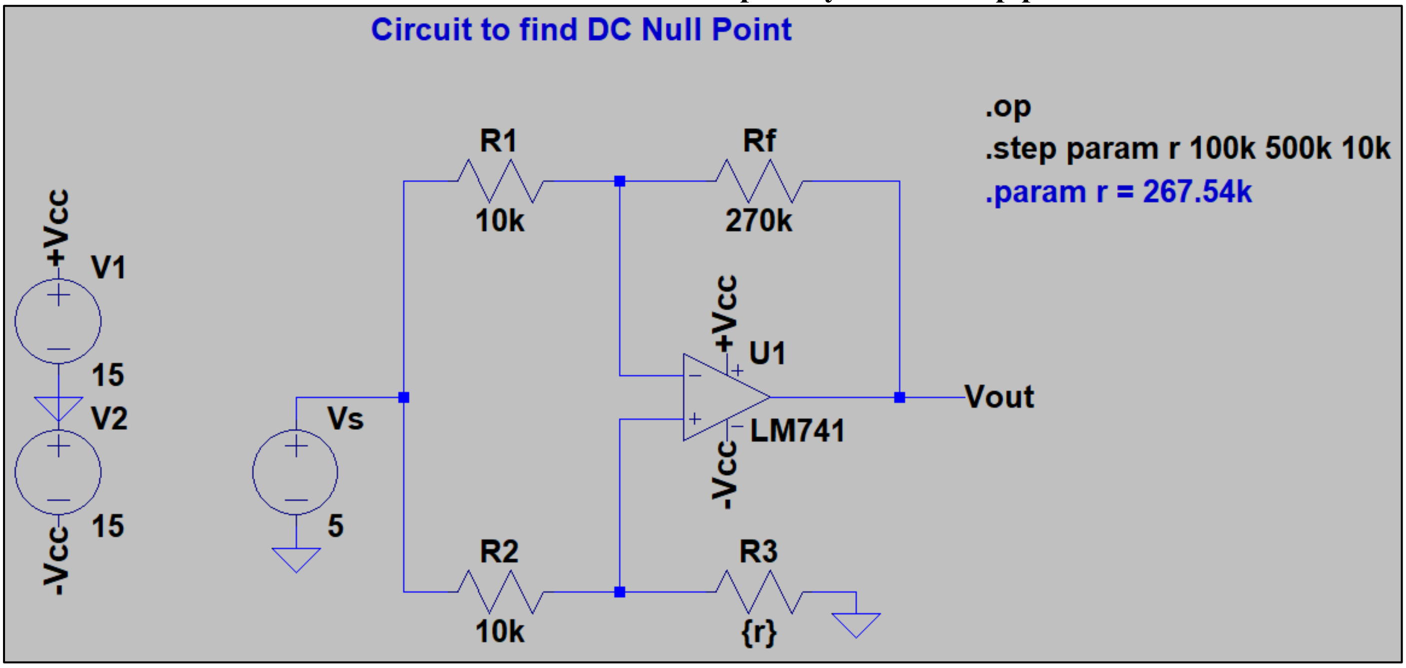
An **instrumentation amplifier** is a type of differential amplifier that has been outfitted with input buffer amplifiers, which eliminate the need for input impedance matching and thus make the amplifier particularly suitable for use in measurement and test equipment.

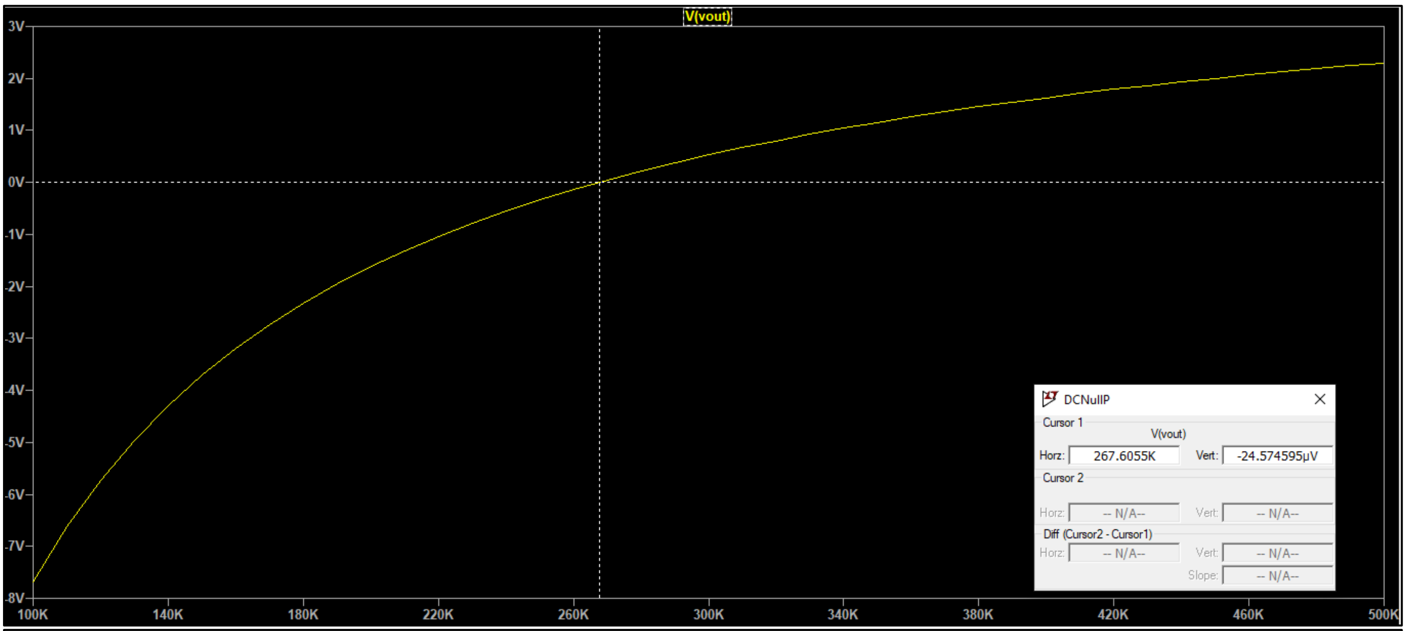
Additional characteristics include **very low DC offset, low drift, low noise, very high open-loop gain, very high common-mode rejection ratio**, and **very high input impedances**. Instrumentation amplifiers are used where great accuracy and stability of the circuit both short and long-term are required.

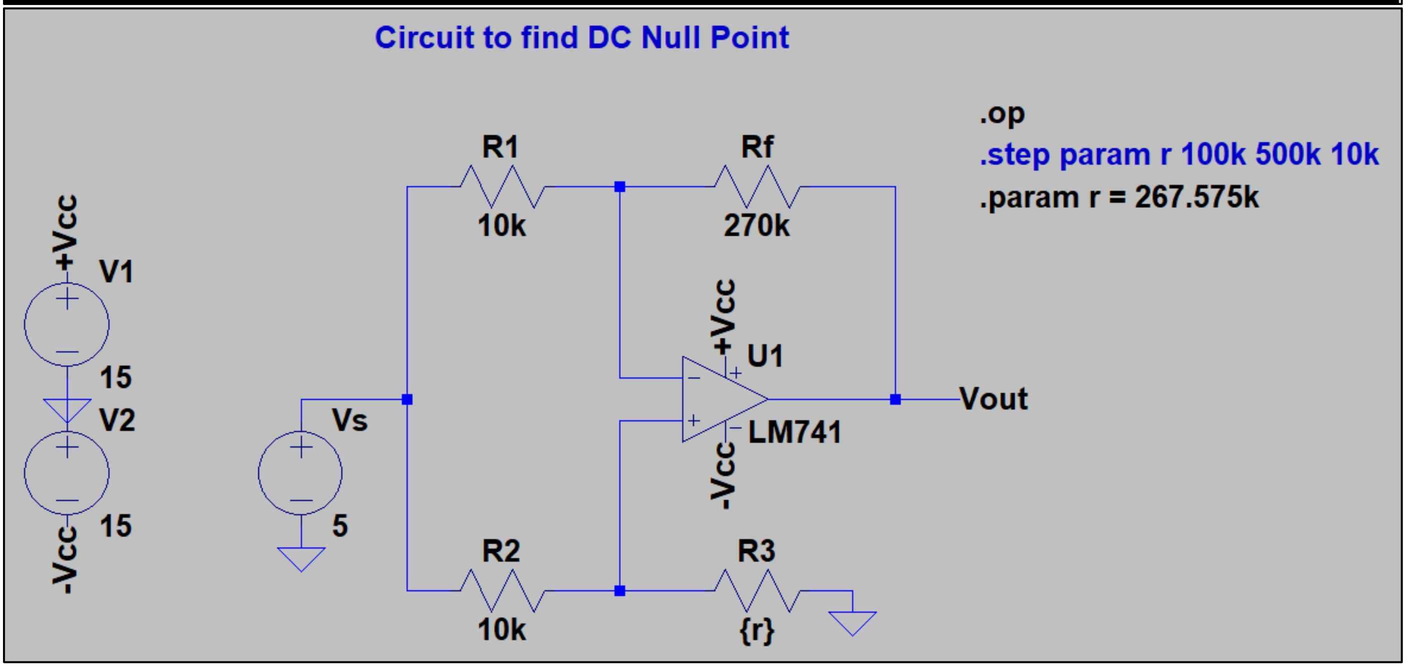


1. DC Null Point

Schematic and results from .op analysis with .step param







* H:\Academics\BITS\Year 4\4 - Semester 2\Analog Electronics\Labs\Lab 5\ASC Files\DCNullP.asc

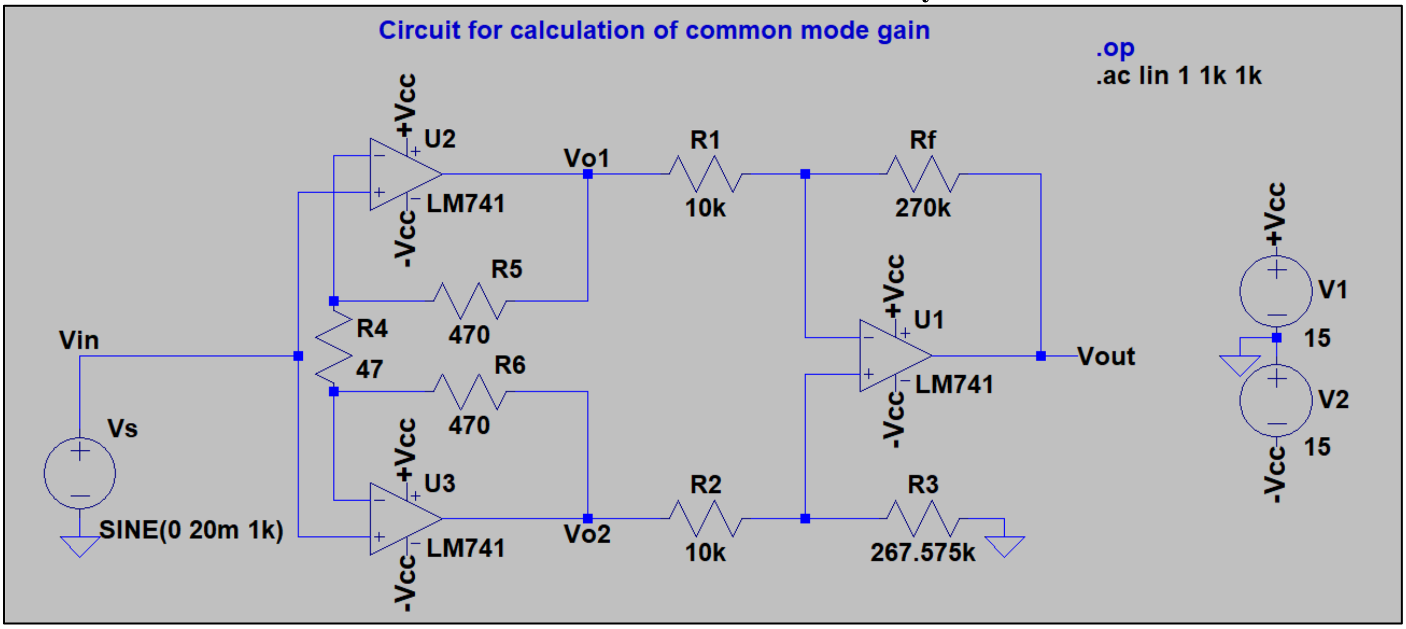
```
       --- Operating Point ---

V(-vcc):        -15            voltage
V(+vcc):        15             voltage
V(n002):        4.82047        voltage
V(n003):        4.81931        voltage
V(vout):        0.000635892    voltage
V(n001):        5              voltage
I(Rf):          -1.78512e-005  device_current
I(R3):          -1.80111e-005  device_current
I(R2):          -1.80686e-005  device_current
I(R1):          -1.79534e-005  device_current
I(Vs):          -3.6022e-005   device_current
I(V1):          -0.00169262    device_current
I(V2):          -0.00171063    device_current
Ix(u1:1):       5.75579e-008   subckt_current
Ix(u1:2):       1.02168e-007   subckt_current
Ix(u1:99):      0.00169262     subckt_current
Ix(u1:50):      -0.00171063    subckt_current
Ix(u1:28):      1.78512e-005   subckt_current
```

Results

The value of resistance Rf at DC null point (Vout = -9 nV ≈ 0V) comes out to be approximately 267.575 kΩ.

2. Common Mode Gain (A_{cm})

Schematic and results from AC analysis




```
* H:\Academics\BITS\Year 4\4 - Semester 2\Analog Electronics\Labs\Lab 5\ASC Files\CMgain.asc

       --- AC Analysis ---

frequency:     1000          Hz
V(+vcc):       mag:          0 phase:           0°        voltage
V(-vcc):       mag:          0 phase:           0°        voltage
V(n002):       mag:  0.0192807 phase: -0.0446846°        voltage
V(n003):       mag:    0.01928 phase: -0.0512225°        voltage
V(vout):       mag: 0.000167774 phase:    157.483°        voltage
V(vo1):        mag:  0.0200005 phase: -0.0513552°        voltage
V(vo2):        mag:  0.0200005 phase:  -0.051356°        voltage
V(n001):       mag:  0.0200005 phase: -0.0512658°        voltage
V(vin):        mag:       0.02 phase:           0°        voltage
V(n004):       mag:  0.0200005 phase: -0.0512658°        voltage
I(R4):         mag: 8.91015e-013 phase:    160.983°      device_current
I(R6):         mag: 6.69901e-011 phase:   -88.5106°      device_current
I(R5):         mag: 6.63868e-011 phase:   -89.9514°      device_current
I(Rf):         mag: 7.19845e-008 phase:    179.766°      device_current
I(R3):         mag: 7.20546e-008 phase:    179.949°      device_current
I(R2):         mag: 7.20531e-008 phase:    179.945°      device_current
I(R1):         mag: 7.1986e-008 phase:     179.77°       device_current
I(Vs):         mag: 1.33365e-010 phase:   -89.2621°      device_current
I(V2):         mag: 3.60105e-008 phase:  -0.157326°      device_current
I(V1):         mag: 3.6046e-008 phase:    179.843°       device_current
Ix(u1:1):      mag: 4.8737e-012 phase:   -107.112°       subckt_current
Ix(u1:2):      mag: 4.88516e-012 phase:   72.4558°       subckt_current
Ix(u1:99):     mag: 3.60236e-008 phase:   179.766°       subckt_current
Ix(u1:50):     mag: 3.5961e-008 phase:    179.766°       subckt_current
Ix(u1:28):     mag: 7.19845e-008 phase:  -0.233732°      subckt_current
Ix(u2:1):      mag: 6.66826e-011 phase:   90.7379°       subckt_current
Ix(u2:2):      mag: 6.66832e-011 phase:  -89.2278°       subckt_current
Ix(u2:99):     mag: 3.60066e-008 phase:  -0.282859°      subckt_current
Ix(u2:50):     mag: 3.59796e-008 phase:  -0.282859°      subckt_current
Ix(u2:28):     mag: 7.19863e-008 phase:   179.717°       subckt_current
Ix(u3:1):      mag: 6.66827e-011 phase:    90.738°       subckt_current
Ix(u3:2):      mag: 6.66832e-011 phase:  -89.2277°       subckt_current
Ix(u3:99):     mag: 3.6063e-008 phase:  -0.108177°       subckt_current
Ix(u3:50):     mag: 3.59919e-008 phase:  -0.108177°      subckt_current
Ix(u3:28):     mag: 7.2055e-008 phase:    179.892°       subckt_current
```

Results

- The value of common mode gain from simulation comes out to be

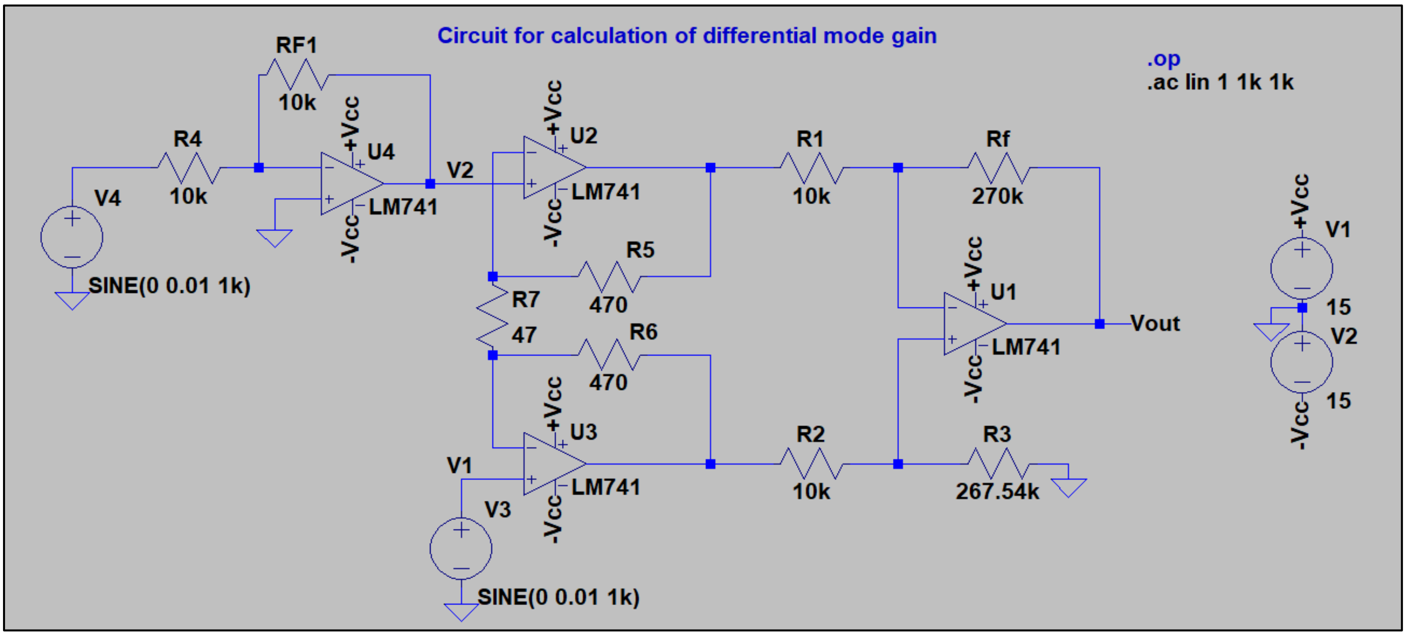
$$A_{cm} = {}^{V_{out}}/_{V_{in}} = 8.387 \times 10^{-3} = -41.527 \text{ dB}$$

- The theoretical value of common mode gain should be

$$A_{cm} = 0$$

3. Differential Mode Gain A_{dm}

Schematic and results from AC analysis



* H:\Academics\BITS\Year 4\4 - Semester 2\Analog Electronics\Labs\Lab 5\ASC Files\DMgain.asc

```
       --- AC Analysis ---

frequency:     1000           Hz
V(+vcc):       mag:          0 phase:         0°         voltage
V(-vcc):       mag:          0 phase:         0°         voltage
V(n005):       mag:   0.202269 phase:  -4.99967°         voltage
V(n006):       mag:   0.202315 phase:  -1.79694°         voltage
V(vout):       mag:    11.3258 phase:  -3.40151°         voltage
V(n004):       mag:    0.20989 phase:   178.305°         voltage
V(n008):       mag:    0.20989 phase:  -1.68752°         voltage
V(n001):       mag:  0.0099949 phase:   178.232°         voltage
V(v2):         mag: 0.00999989 phase:   179.881°         voltage
V(n007):       mag: 0.00999468 phase:  -1.61445°         voltage
V(v1):         mag:       0.01 phase:         0°         voltage
V(n002):       mag:       0.01 phase:         0°         voltage
V(n003):       mag: 1.01772e-005 phase:   89.6243°       voltage
I(R4):         mag: 9.99994e-007 phase:   179.942°       device_current
I(Rf1):        mag: 9.99994e-007 phase:    179.94°       device_current
I(R7):         mag: 0.00042531 phase:   178.309°         device_current
I(R6):         mag: 0.00042531 phase:  -1.69117°         device_current
I(R5):         mag: 0.00042531 phase:   178.309°         device_current
I(Rf):         mag: 4.11986e-005 phase:  -3.37245°       device_current
I(R3):         mag: 7.56204e-007 phase:   178.203°       device_current
I(R2):         mag: 7.58558e-007 phase:  -178.768°       device_current
I(R1):         mag: 4.11988e-005 phase:  -3.31668°       device_current
I(V4):         mag: 9.99994e-007 phase:   179.942°       device_current
I(V3):         mag: 1.00013e-009 phase:   -91.916°       device_current
I(V2):         mag: 0.00017082 phase:  -1.77912°         device_current
I(V1):         mag: 0.000171064 phase:  -1.76866°        device_current
Ix(u1:1):      mag: 4.0103e-008 phase:   86.3541°        subckt_current
Ix(u1:2):      mag: 4.0103e-008 phase:  -93.6454°        subckt_current
Ix(u1:99):     mag: 1.98338e-005 phase:  -3.37245°       subckt_current
Ix(u1:50):     mag: 2.13648e-005 phase:  -3.37245°       subckt_current
Ix(u1:28):     mag: 4.11986e-005 phase:   176.628°       subckt_current
Ix(u2:1):      mag: 1.02144e-009 phase:  -91.9625°       subckt_current
Ix(u2:2):      mag: 1.02144e-009 phase:   88.0386°       subckt_current
Ix(u2:99):     mag: 0.000325609 phase:   178.165°        subckt_current
Ix(u2:50):     mag: 0.000140884 phase:   178.165°        subckt_current
Ix(u2:28):     mag: 0.000466493 phase:  -1.83472°        subckt_current
Ix(u3:1):      mag: 1.00013e-009 phase:    88.084°       subckt_current
Ix(u3:2):      mag: 1.00013e-009 phase:  -91.9149°       subckt_current
Ix(u3:99):     mag: 0.00013522 phase:  -1.68597°         subckt_current
Ix(u3:50):     mag: 0.000290847 phase:  -1.68597°        subckt_current
```

Results

- The value of differential mode gain from simulation comes out to be

$$A_{dm} = {}^{V_{out}}/_{(V_1 - V_2)} = 566.29 = 55.06 \text{ dB}$$

- The theoretical value of differential mode gain should be

$$A_{dm} = \left(1 + \frac{2R_5}{R_7}\right)\frac{R_F}{R_1} = 567 = 55.07 \text{ dB}$$

Calculation of CMRR

The simulated value of common mode rejection ratio (CMRR) is:

$$\frac{A_{dm}}{A_{cm}} = \frac{566.29}{8.387 \times 10^{-3}} = 67519.97 = 96.58 \text{ dB}$$

The theoretical value of CMRR is: infinity.

Conclusions

Hence, practical circuits like the instrumentation amplifier using LM 741 do not have ideal infinite CMRR but are limited to some finite large value due to mismatch. The theoretical value of CMRR is much higher than simulated value as per calculations.