Introduction to Electronics Laboratory

EXPERIMENT-11

Differential Amplifiers using MOSFETS

Shorya Sharma
19EE01017

OBJECTIVES

- DC Analysis of the differential amplifier.
- AC Analysis with same R1 and R2.
- AC Analysis without same R1 and R2.

THEORY

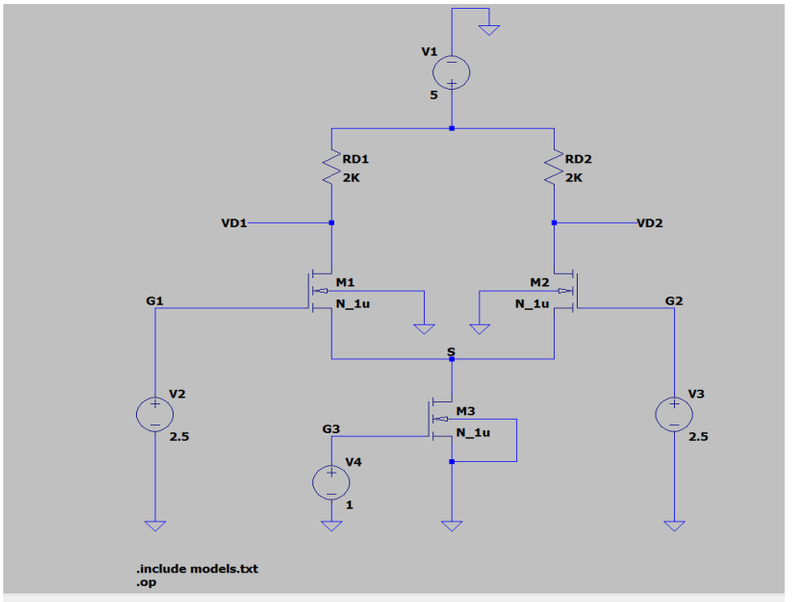
The differential amplifier is a circuit which amplifies the difference between signals applied to the inputs. The input signals to a differential amplifier in general contains two components named as common mode and difference mode signals. The common mode is average of two input signals and the difference mode is the difference between the two inputs. In ideal case the differential amplifier should affect the difference mode signal only. However, the common mode signal is also amplified to some extent. The Common mode rejection ratio(CMRR) is defined as the ratio of the difference signal voltage gain to the common mode signal voltage gain. For a good quality differential amplifier the CMRR should be very large.

In DC-Analysis we will check the three mosfets to be in saturation. The condition for saturation is voltage between gate and drain must be less than the threshold voltage. As per the mosfet it is given that it has the threshold voltage of 0.8V and VDD of 5V.

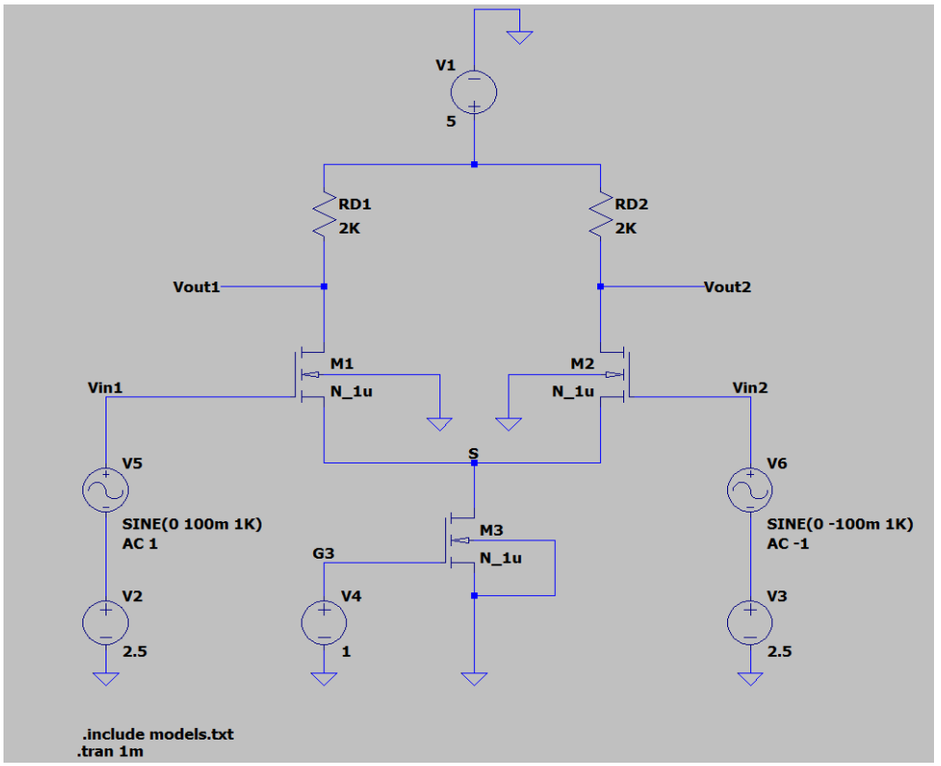
In AC-Analysis the difference mode gain(Ad) is **(Vout1- Vout2) /(Vin1-Vin2)** which is the ratio of difference in output voltage to the difference in input voltage which will be a large value and common mode gain(Ac) is **(Vout1- Vout2) /((Vin1+Vin2)/2)** the ratio of difference between output voltages to the average of input voltages. Using these we will find out the CMRR. The ratio of Ad and Ac.

CIRCUIT DIAGRAMS

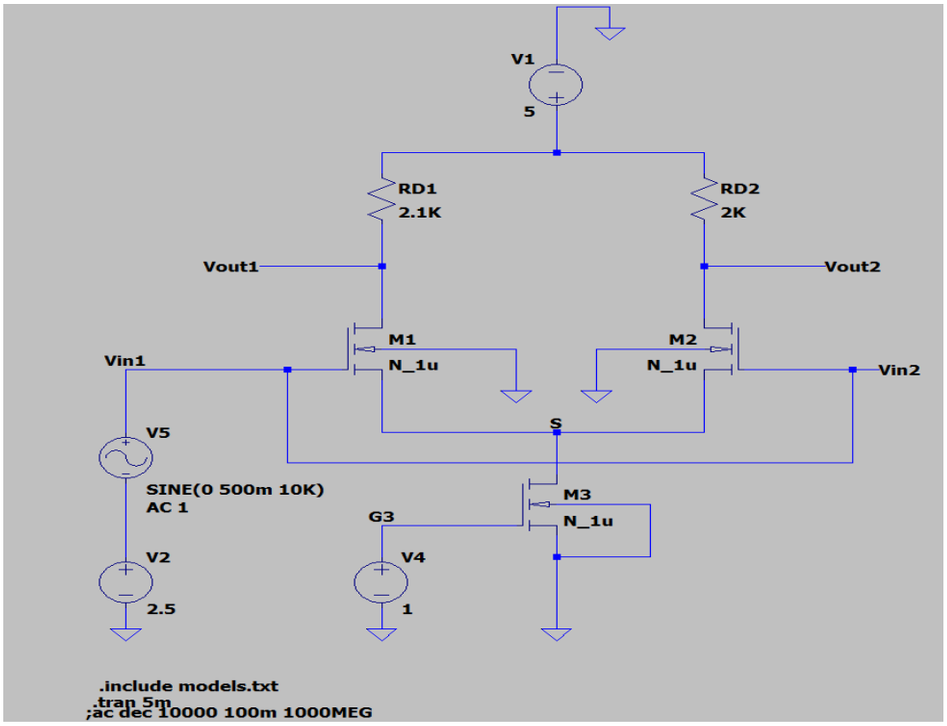
CASE-1: DC-ANALYSIS



CASE-2: AC-ANALYSIS



CASE-3: R1 and R2 are changed



GRAPHS AND CALCULATIONS

DC-ANALYSIS

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       --- Operating Point ---

V(vd1):         4.0095          voltage
V(vin1):        2.5             voltage
V(n001):        1.08999         voltage
V(vd2):         4.0095          voltage
V(vin2):        2.5             voltage
V(vgs3):        1.5             voltage
V(vdd):         5               voltage
Id(M3):         0.000990462     device_current
Ig(M3):         0               device_current
Ib(M3):         -1.09999e-012   device_current
Is(M3):         -0.000990462    device_current
Id(M2):         0.000495177     device_current
Ig(M2):         0               device_current
Ib(M2):         -5.11949e-012   device_current
Is(M2):         -0.000495177    device_current
Id(M1):         0.000495177     device_current
Ig(M1):         0               device_current
Ib(M1):         -5.11949e-012   device_current
Is(M1):         -0.000495177    device_current
I(R2):          0.000495248     device_current
I(R1):          0.000495248     device_current
I(V4):          0               device_current
I(V3):          0               device_current
I(V2):          0               device_current
I(V1):          -0.000990496    device_current
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For M1; Vgd = Vg-Vd = 2.5-4.0095 = -1.5095V

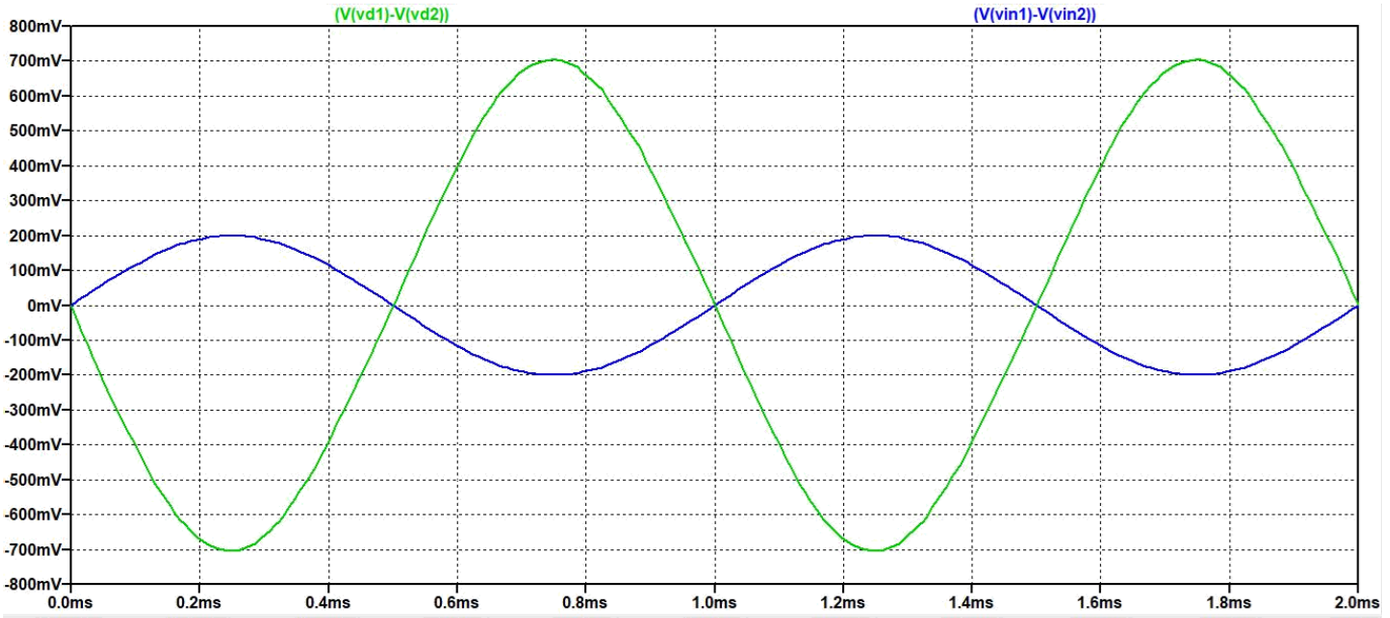
For M2; Vgd = Vg-Vd = 2.5-4.0095 = -1.5095V

For M3; Vgd = Vg-Vd = 1.5-1.0899 = 0.41001V

AC-ANALYSIS

CASE-1

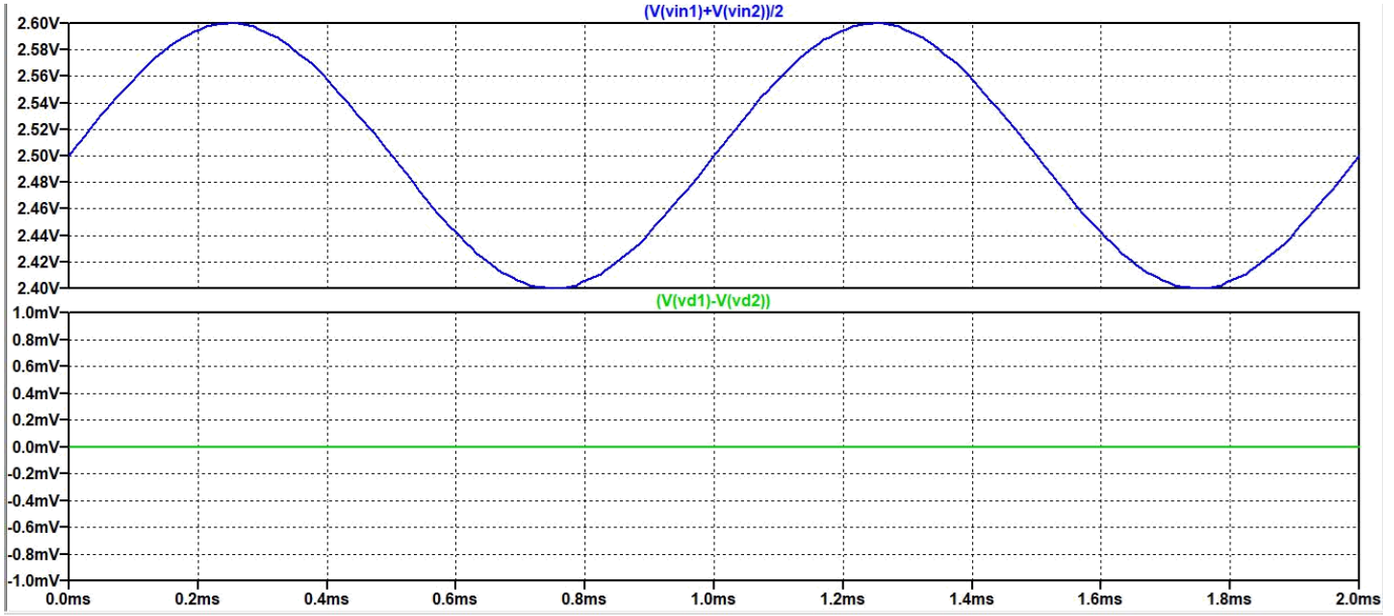
Ad



Ad = (Vout1-Vout2)/ (Vin1-Vin2) = -700mV/200mV = -3.5 V/V

(as they are in out of phase negative sign occurs)

Ac



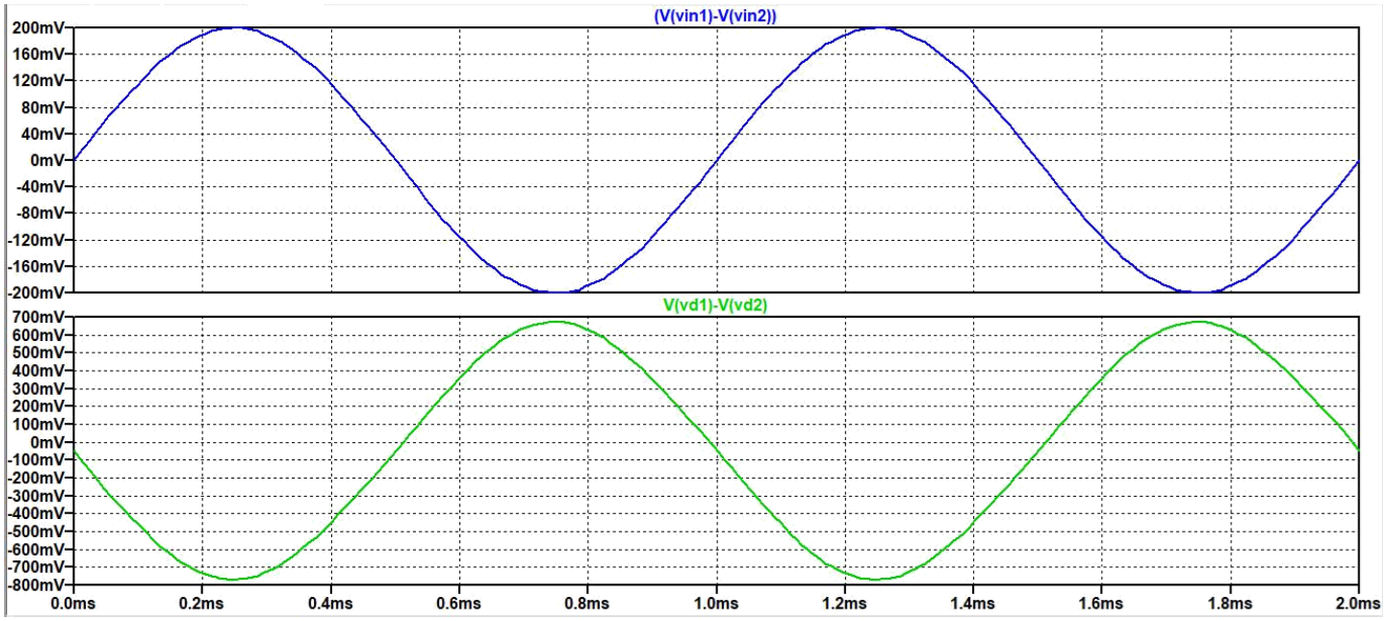
Ac = (Vout1-Vout2)/(0.5*(Vin1+Vin2)) = 0mV/500mV = 0V/V.

(negative shows they are in out of phase)

CMRR = Ad/Ac = -3.5/0 = -infinite.

CASE-2

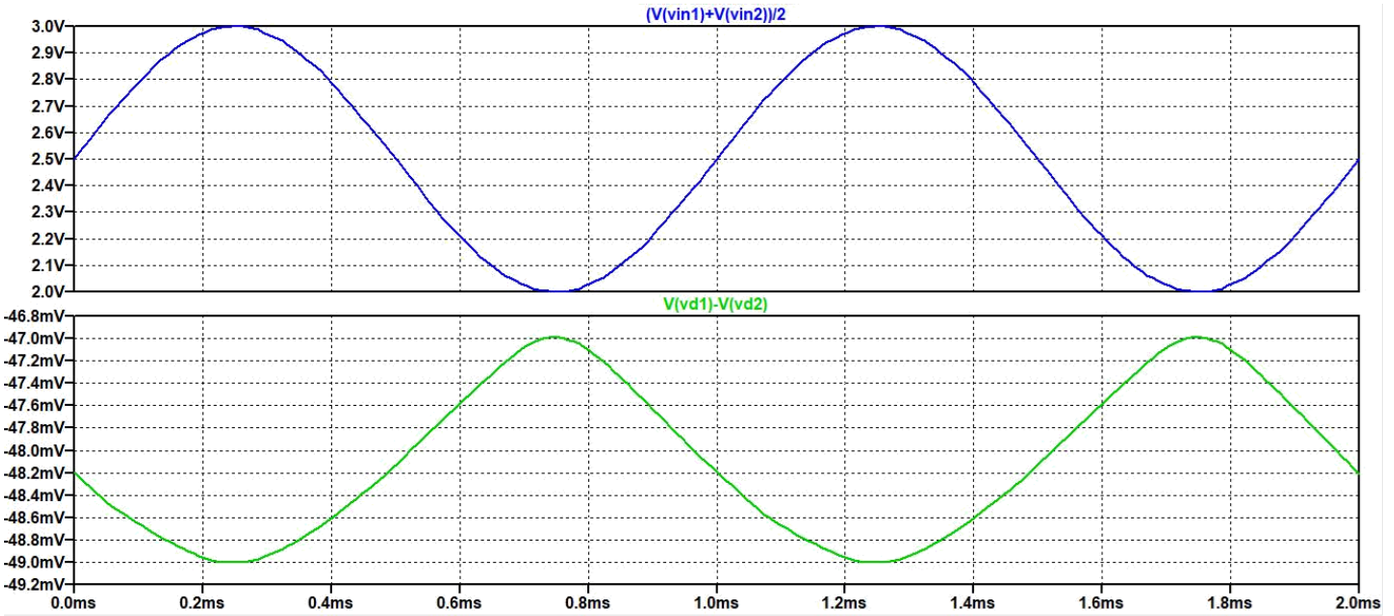
Ad



Ad = (Vout1-Vout2)/ (Vin1-Vin2) = -721mV/200mV = -3.605 V/V

(as they are in out of phase negative sign occurs)

Ac



Ac = (Vout1-Vout2)/(0.5*(Vin1+Vin2)) = -1mV/100mV = -0.01

V/V. (negative shows they are in out of phase) CMRR = Ad/Ac = -

3.605/-0.01 = 360.5.

CMRR(dB) = 20log(|CMRR|) = 51.138dB.

RESULTS

DC-ANALYSIS

For M1; Vgd = -1.5095V < 0.8 = Vt

For M2; Vgd = -1.5095V < 0.8 = Vt

For M3; Vgd = 0.41001V < 0.8 = Vt

It shows that all mosfets are in saturation.

AC-ANALYSIS

Case-1

Ad = -3.5V/V

Ac = infinite.

Case-2

Ad = -3.605V/V

Ac = -0.01 V/V.

We can observe that the Ad is larger value than Ac.

CMRR = 360.5.

CMRR(in dB) = 51.138dB.

DISCUSSION

In DC-Analysis we first simulated DC operating points to get the voltages at every node and found the values of Vgd for each mosfet. From this we got to know that for R1 and R2 as 2Kohms the three mosfets are in saturation that is Vgd < Vt. Vt is threshold voltage of the mosfet.

Then done the AC-Analysis to find the Ad-difference mode gain for this we gave inputs as out of phase to each other, then to find the Ac-common mode gain we gave same inputs otherwise also can be said as we shorted both inputs. Then found Ad and Ac further CMRR got as infinite as Ac is zero in that case. This shows it has no common mode.

So now increased the R1 by small increment made it 2.1kohms to get some value of the Ac, it is a very small value and now the CMRR is a large value that can be compared to the Ad.this is the second case.

CONCLUSION

We understood the working of differential amplifier, also it is the basic part of op-amp and many components. Without the differential amplifier the world of electrical components used for amplifying would be nothing. This amplifies the input signals difference and mainly useful for getting rid of the noise produced. The Ac should be as small as possible for having less noise.