LAB REPORT -4

NMOS Common Source Amplifier

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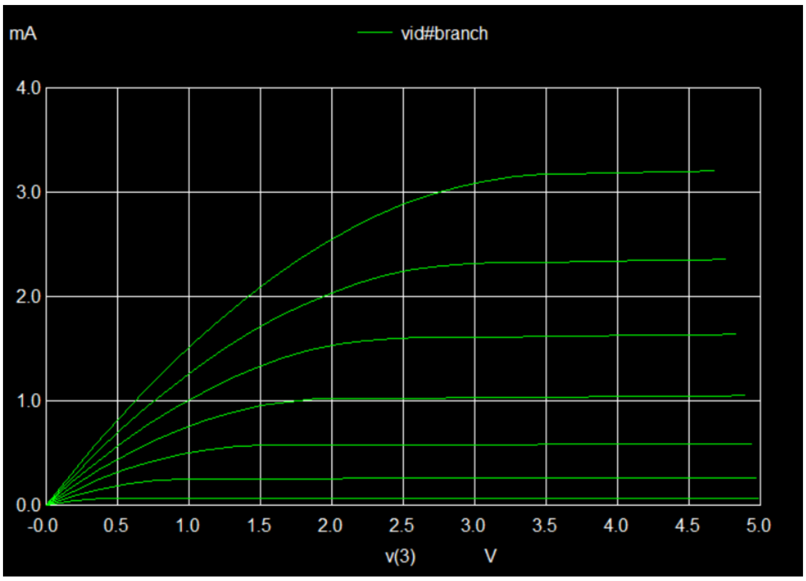
Q2. Plot ID vs V_{DS} characteristics:

I-V Characteristics of CD4007

```
*CD4007 MOS Array
* N4007 (NMOS on CD4007 CMOS integrated circuit)
.model MN4007 NMOS (Kp=500u Vto=1.5 Lambda=0.01 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6 Rs=0
Rd=0 Cbd=2.0p Cbs=2.0p Pb=.8 Cgso=0.1p Cgdo=0.1p Is=16.64p N=1)
* P4007 (PMOS on CD4007 CMOS integrated circuit)
.model MP4007 PMOS (Kp=500u Vto=-1.5 Lambda=0.04 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6 Rs=0
Rd=0 Cbd=4.0p Cbs=4.0p Pb=.8 Cgso=0.2p Cgdo=0.2p Is=16.64p N=1)
*Fixing gate bias at 3.5V
vgg 1 0 dc 2v
rg 1 2 680
M1 3 2 0 0 MN4007
Rd 3 4 100
*DC source of 0v to measure current
vid 5 4 dc 0v
vdd 5 0 dc 0v
*DC analysis to sweep vds from 0 to 5V
.dc vdd 0 5 0.2 vgg 2 5 0.5

.control
run
plot vid#branch vs v(3)
.endc
.end
```

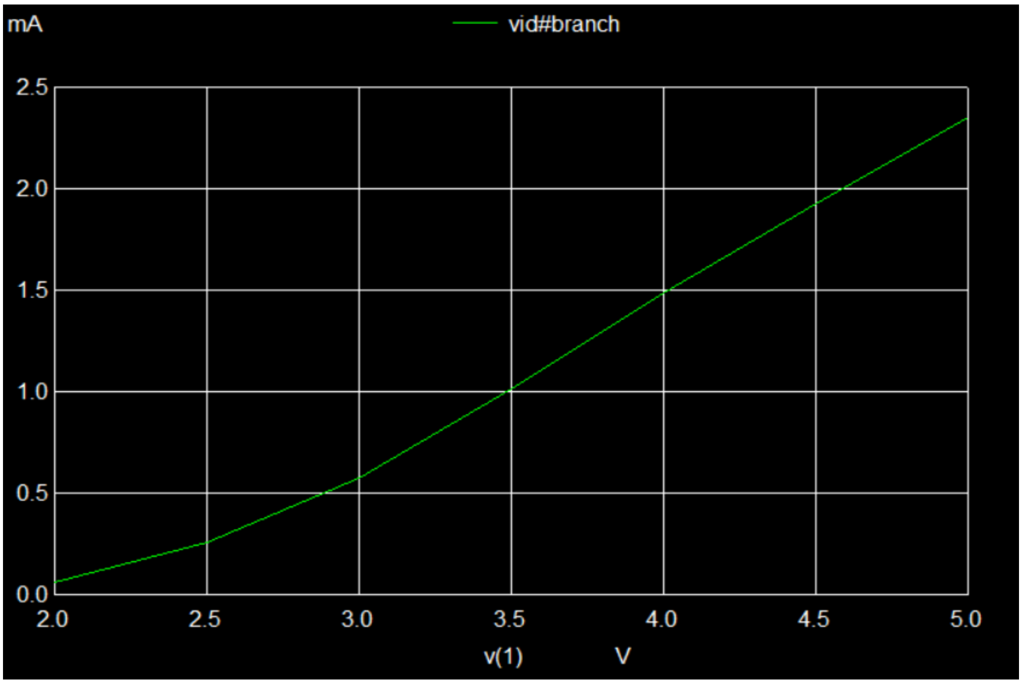


Q5. Ngspice netlist to plot ID vs VGS by varying VGS from 0 to 5 V.

I-V Characteristics of CD4007

```
*CD4007 MOS Array
* N4007 (NMOS on CD4007 CMOS integrated circuit)
.model MN4007 NMOS (Kp=500u Vto=1.5 Lambda=0.01 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6 Rs=0
Rd=0 Cbd=2.0p Cbs=2.0p Pb=.8 Cgso=0.1p Cgdo=0.1p Is=16.64p N=1)
* P4007 (PMOS on CD4007 CMOS integrated circuit)
.model MP4007 PMOS (Kp=500u Vto=-1.5 Lambda=0.04 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6 Rs=0
Rd=0 Cbd=4.0p Cbs=4.0p Pb=.8 Cgso=0.2p Cgdo=0.2p Is=16.64p N=1)
*Fixing gate bias at 3.5V
vgg 1 0 dc 2v
rg 1 2 5k
M1 3 2 0 0 MN4007
Rd 3 4 100
*DC source of 0v to measure current
vid 5 4 dc 0v
vdd 5 0 dc 2v
*DC analysis to sweep vds from 0 to 5V
.dc vgg 2 5 0.5

.control
run
plot vid#branch vs v(1) title 'I-V Characteristics of CD4007'
.endc
.end
```



It can be clearly seen that the ID is zero for VGS less than 2V and starts increasing when VGS is above 1.6V, thus, the T**hreshold Voltage (V_{TH}) for the MOSFET is approximately 2V**.

Q6.The values of R_2 and R_D for $I_D = 1.5$ mA, $V_{DS} = 4$ V, $V_{GS} = 3$ V, $V_{DD} = 10$ V, $R_1 = 7.5$ kΩ

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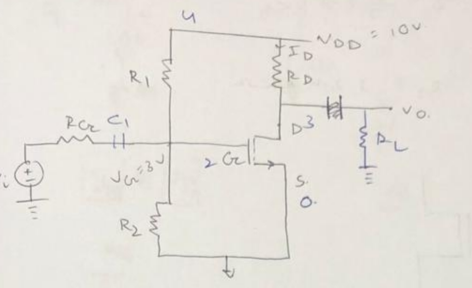


$$\Rightarrow V_{DD} - I_D \times R_D - V_{DS} = 0$$

$$\Rightarrow 10 - 1.5\times10^{-3} \times R_D - 4 = 0$$

$$\frac{6}{1.5\times10^{-3}} = R_D$$

$$\Rightarrow \boxed{4K\Omega = R_D}$$

$$V_{GS} = 3V \Rightarrow V_G = 3V$$

$$\frac{10}{R_1+R_2} = \frac{7}{R_1} \qquad V_G = \frac{10}{R_1+R_2} \times R_2$$

$$\Rightarrow 3(R_1+R_2) = 10R_2$$

$$3R_1 = 7R_2 \Rightarrow R_2 = \frac{3}{7} R_1$$

$$\Rightarrow R_2 = \frac{3}{7} \times 7.5K$$

$$R_2 = 3.214\ K\Omega$$

Q8.Simulation and verify the results with your calculated values:

output voltage waveform and input voltage waveform for Vin = 200 mVp−p at 1kHz

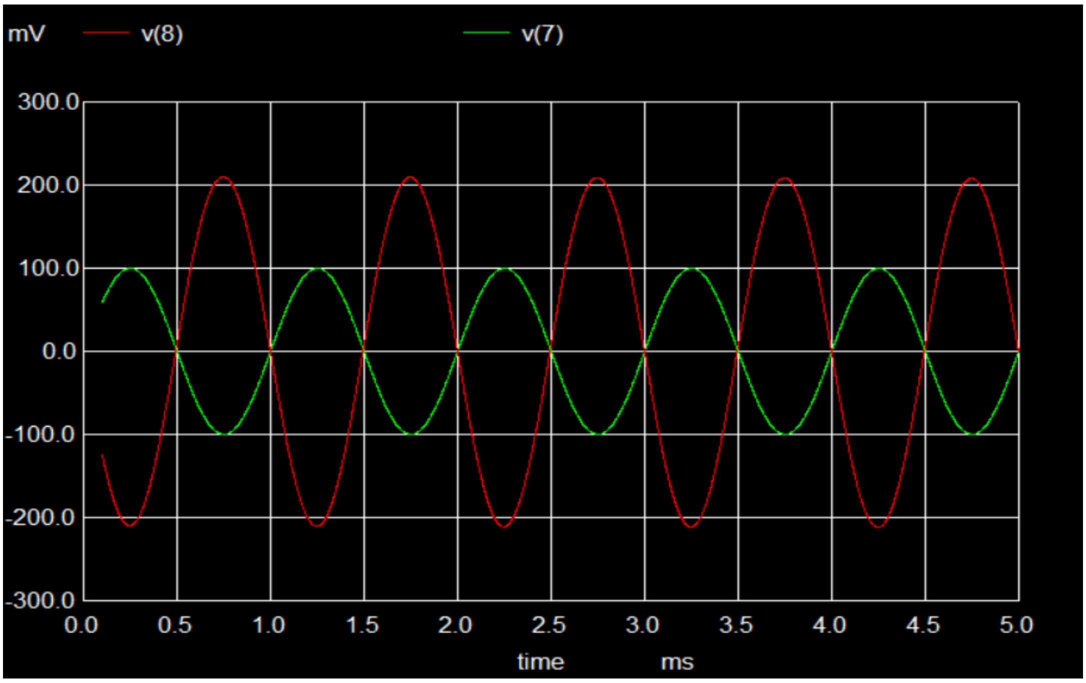
```
.model MN4007 NMOS (Kp=500u Vto=1.5 Lambda=0.01 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6
Rs=0 Rd=0 Cbd=2.0p Cbs=2.0p Pb=.8 Cgso=0.1p Cgdo=0.1p Is=16.64p N=1)

M1 3 4 0 0 MN4007

Vdd 1 0 10v
Vd 1 2 0
Vd1 1 5 0
Vin 7 0 3V

Rd 2 3 4k
R1 5 4 7.5k
R2 4 0 3.214k
Rl 8 0 100k
Rg 6 7 1k

C1 4 6 2.2u
C2 3 8 2.2u

.dc 0 3 3
.control
op
run
print v(3) v(4) i(vd1)
.endc
.end
```

```
v(3) = 7.580051e+00
v(4) = 2.999813e+00
i(vd1) = 9.333582e-04
```

Q9.The output voltage waveform and input voltage waveform for V_{in} = 200 mV_{p-p} at 1kHz.

output voltage waveform and input voltage waveform for Vin = 200 mVp−p at 1kHz

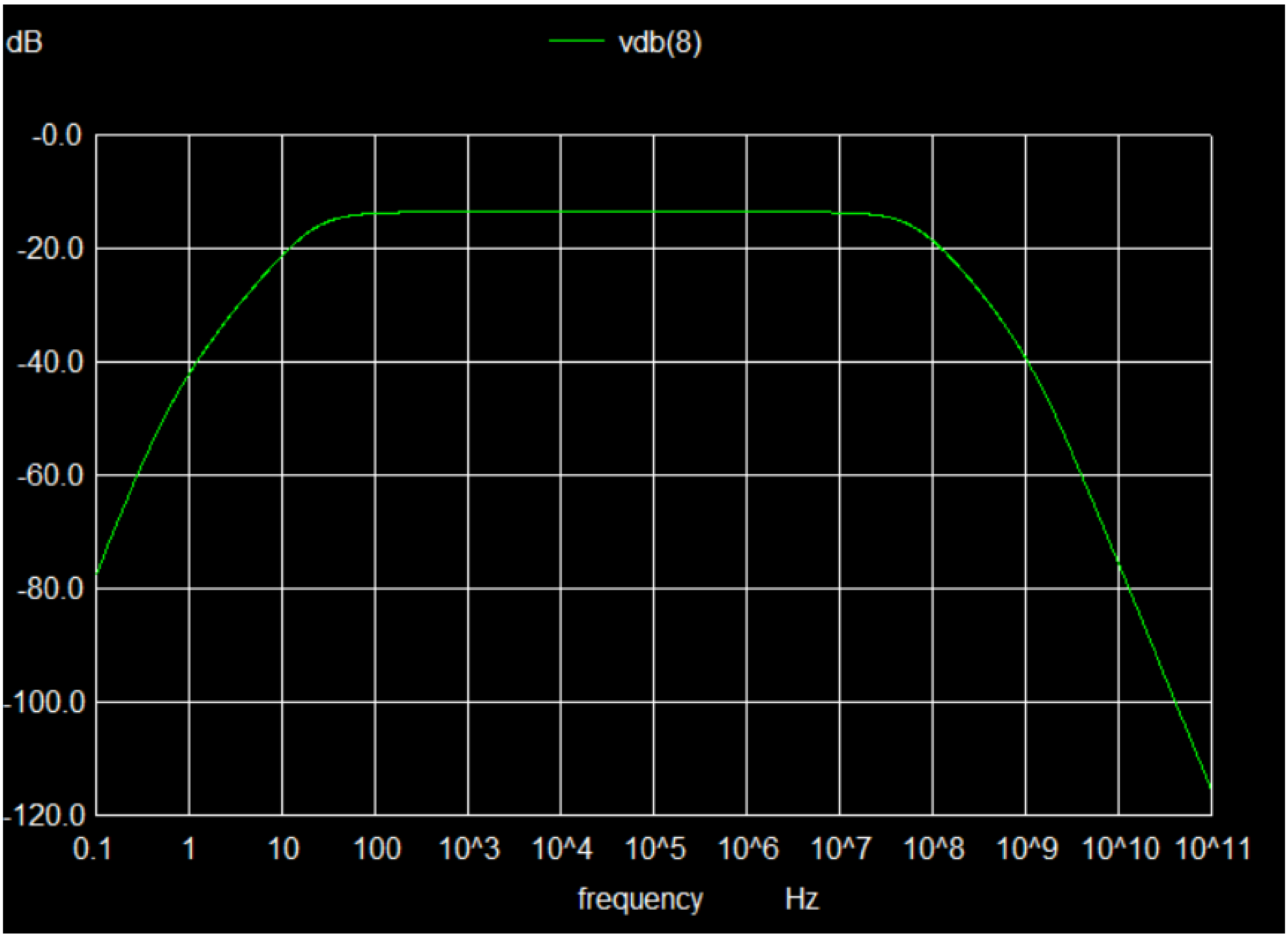
```
.model MN4007 NMOS (Kp=500u Vto=1.5 Lambda=0.01 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6 Rs=0
Rd=0 Cbd=2.0p Cbs=2.0p Pb=.8 Cgso=0.1p Cgdo=0.1p Is=16.64p N=1)

M1 3 4 0 0 MN4007

Vdd 1 0 10v
Vd 1 2 0
Vd1 1 5 0
Vin 7 0 sin (0 100m 1k 0 0 0)

Rd 2 3 4k
R1 5 4 7.5k
R2 4 0 3.214k
Rl 8 0 100k
Rg 6 7 1k

C1 4 6 2.2u
C2 3 8 2.2u

.tran 0.001ms 5ms 0.1ms
.control
op
run
plot v(7) v(8)
.endc
.end
```



Q10.The frequency response of the amplifier by varying the frequency from 100 Hz to 1 MHz.

output voltage waveform and input voltage waveform for Vin = 200 mVp−p at 1kHz

```
.model MN4007 NMOS (Kp=500u Vto=1.5 Lambda=0.01 Gamma=0.6+ Xj=0 Tox=1200n Phi=.6 Rs=0 Rd=0 Cbd=2.0p Cbs=2.0p Pb=.8 Cgso=0.1p Cgdo=0.1p Is=16.64p N=1)

M1 3 4 0 0 MN4007
Vdd 1 0 10v
Vd 1 2 0
Vd1 1 5 0
Vin 7 0 dc 0 ac=100m
Rd 2 3 4k
R1 5 4 7.5k
R2 4 0 3.214k
Rl 8 0 100k
Rg 6 7 1k
C1 4 6 2.2u
C2 3 8 2.2u

.ac dec 100 0.1 100G
.control
op
run
plot vdb(8) xlog
.endc
.end
```

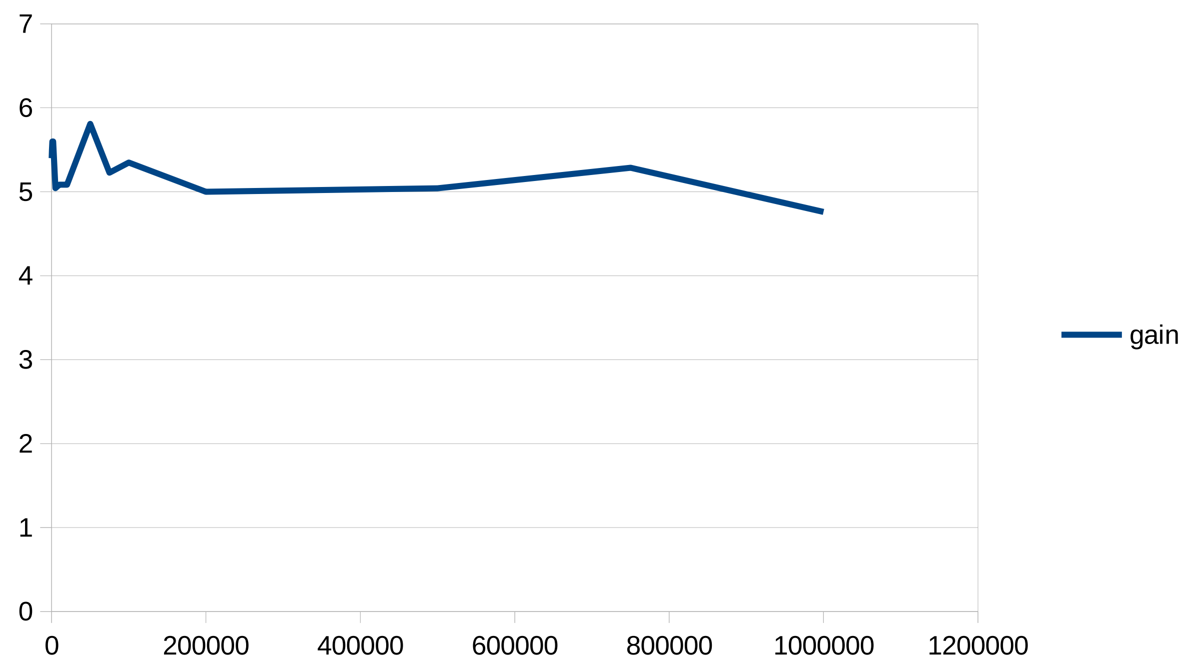


Hardware Implementation:

Q3.Amplitude of the sinusoidal input to 200 mVp-p and vary the frequency from 100 Hz to 1.5 MHz

			200mV P-P	
Vin (in mV)	**Vout (in V)**	**Vin (in V)**	**Frequency**	**Gain**
200	1.07	0.2	100	5.35
200	1.11	0.2	500	5.55
200	1.12	0.2	1000	5.6
200	1.12	0.2	2000	5.6
230	1.16	0.23	5000	5.04347826086956
240	1.22	0.24	10000	5.08333333333333
210	1.1	0.21	20000	5.23809523809524
240	1.22	0.24	50000	5.08333333333333
220	1.15	0.22	75000	5.22727272727273
260	1.23	0.26	100000	4.73076923076923
230	1.15	0.23	200000	5
240	1.21	0.24	500000	5.04166666666667
230	1.11	0.23	750000	4.82608695652174
250	1.19	0.25	1000000	4.76

Q6.Frequency responses of the amplifier (log-log plot)



The gain is constant over a range of frequencies and increases and decreases before and after the range of frequencies.

Q5.After increasing the input amplitude to 200 mVp-p to 2Vp-p in steps of 500 mV, we get gain value approximately as

Gain	Input $signal_{P-P}$
5.4	200 mV
5.08333	700 mV
4.91667	1.2 V
4.45	2 V

With Increase in Amplitude, We have Clearly seen Distortion in Output Waveform and this acts like a **Band pass filter**.

Discussion:

1. I understood how to implement a NMOS Common Source Amplifier and found out the required resistances R_2 and R_D that need to be implemented in the circuit for the CMOS to work in amplifier mode.
2. Understood the frequency dependent amplification nature of the NMOS Common Source Amplifier.
3. Operation of Arbitrary Function Generator (AFG) and Digital Oscilloscope for generation and analysis of Periodic signals at different frequencies and finding out the gain of the signal for various frequencies and various input voltages.
4. As the frequency of the input sinusoid increases from 30 Hz to 100 MHz, initially, the gain increases becomes almost constant in the mid-band frequency range and after that starts decreasing.
5. Since The active region in I_{ds} vs V_{gs} curve of MOSFET resemble a line for small values of V_{gs}, It will not Be linear but approximately parabolic for large values of V_{gs} and that is why we are having distortions for large amplitude input waves while increasing amplitude of Input sine wave.
6. All our Simulation and Hardware Results are Similar, so we have successfully understood how to use MOS based amplifiers.