

# LAB REPORT -4

## NMOS Common Source Amplifier

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Q2. Plot  $I_D$  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

v<sub>gg</sub> 1 0 dc 2v

r<sub>g</sub> 1 2 680

M1 3 2 0 0 MN4007

R<sub>d</sub> 3 4 100

\*DC source of 0v to measure current

v<sub>id</sub> 5 4 dc 0v

v<sub>dd</sub> 5 0 dc 0v

\*DC analysis to sweep v<sub>ds</sub> from 0 to 5V

.dc v<sub>dd</sub> 0 5 0.2 v<sub>gg</sub> 2 5 0.5

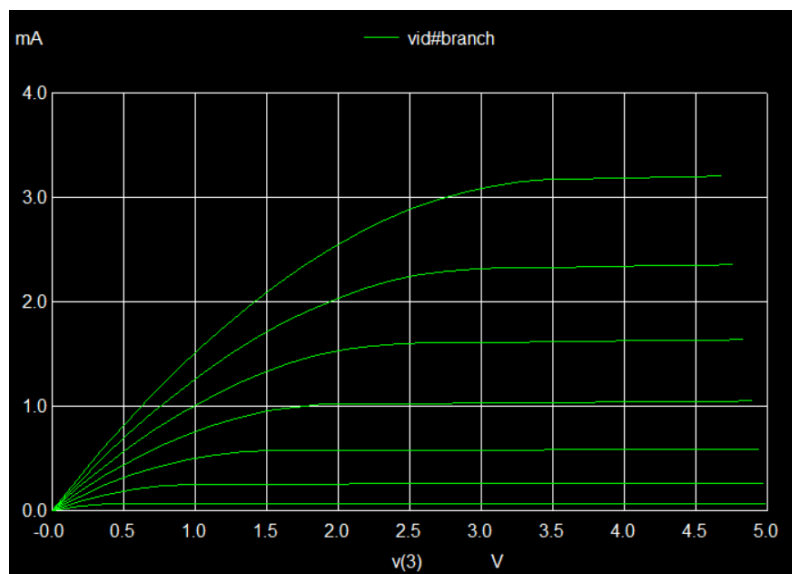
.control

run

plot v<sub>id</sub>#branch vs v(3)

.endc

.end

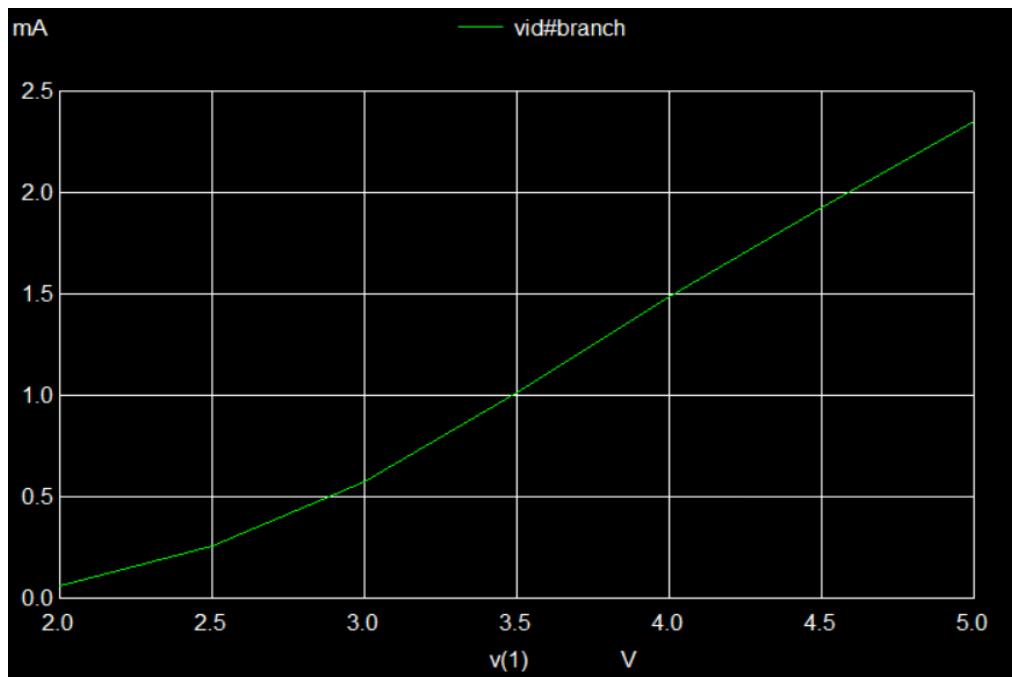


Q5. ngspice netlist to plot ID vs VGS by varying VGS from 0 to 5 V.

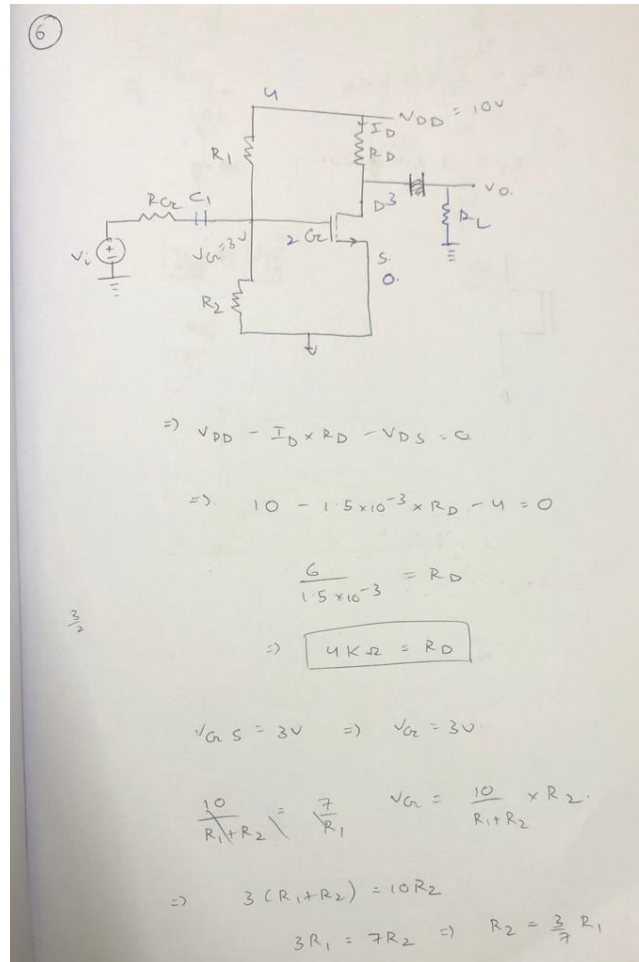
I-V Characteristics of CD4007

```
*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
```



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



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

$$R_2 = 3.214 \text{ k}\Omega$$

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

output voltage waveform and input voltage waveform for  $V_{in} = 200 \text{ mV}_{p-p}$  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  $V_{in} = 200 \text{ mV}_{p-p}$  at 1kHz.

output voltage waveform and input voltage waveform for  $V_{in} = 200 \text{ mV}_{p-p}$  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
```

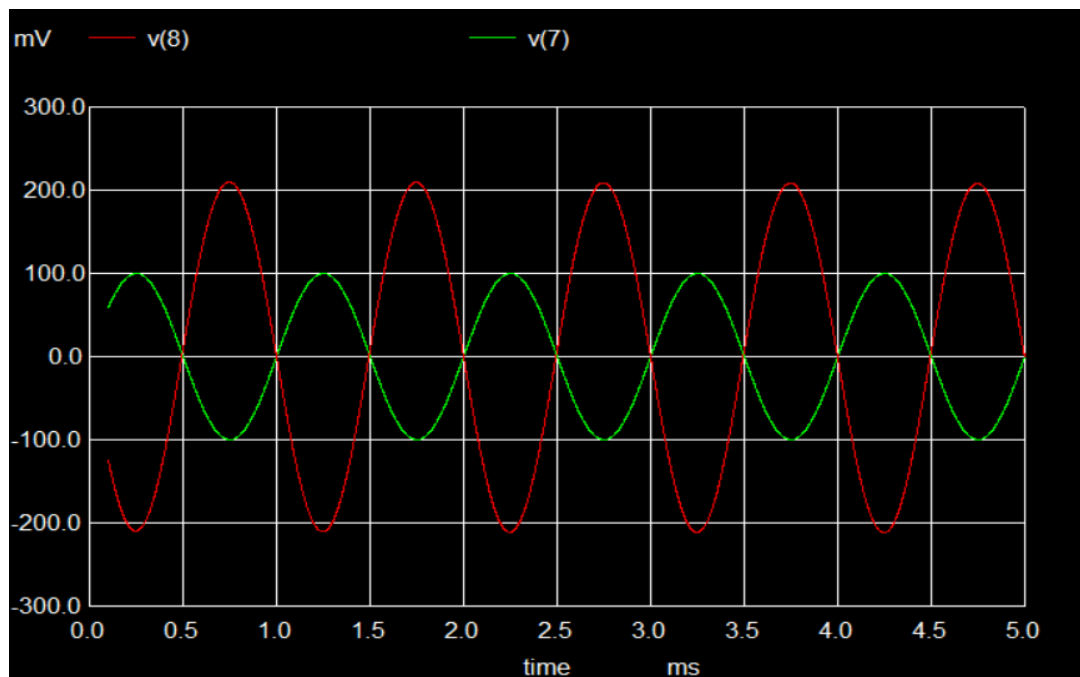
```
op
```

```
run
```

```
plot v(7) v(8)
```

```
.endc
```

```
.end
```



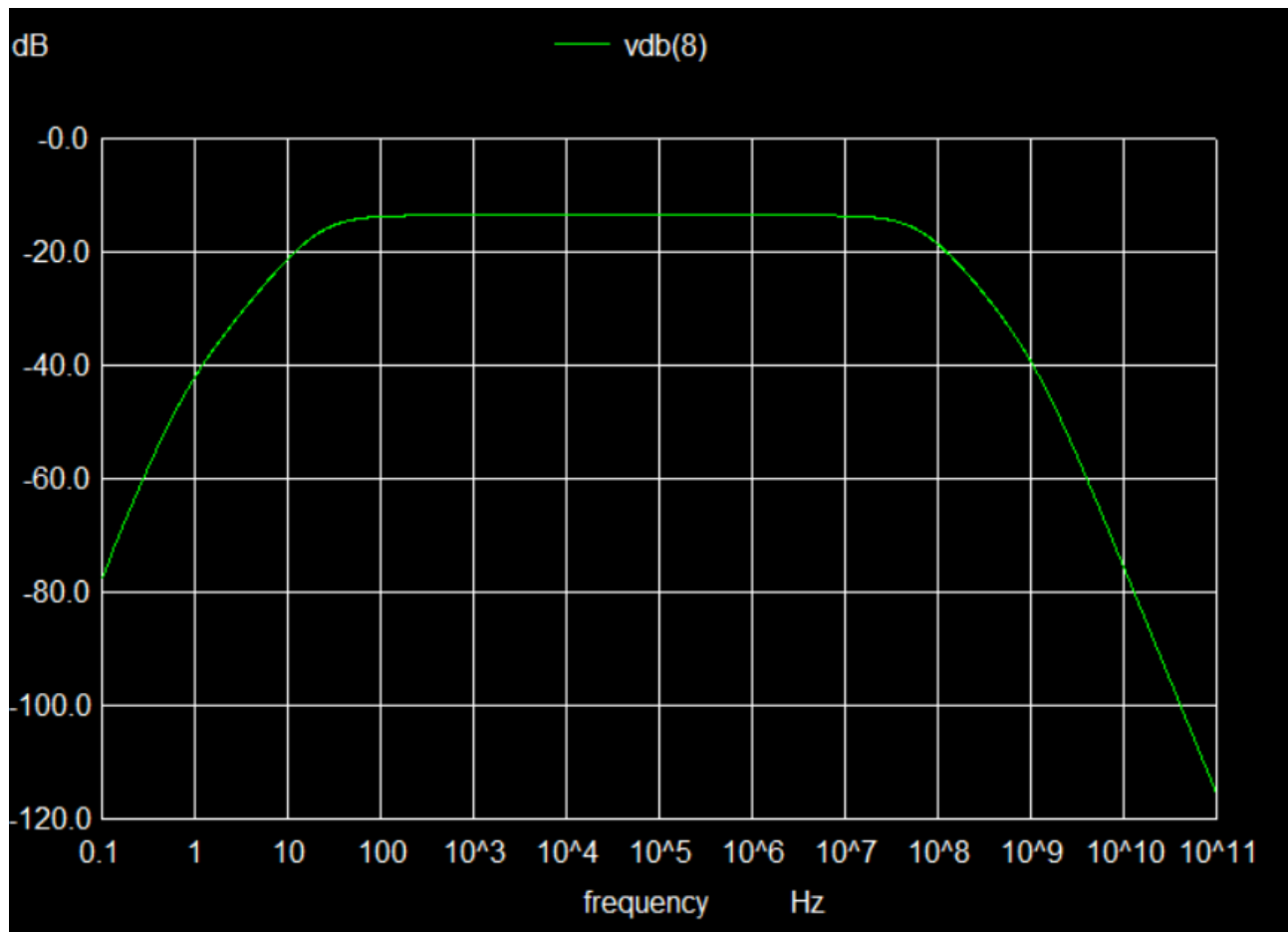
Q10.The frequency response of the amplifier by varying the frequency from 100 Hz to 1 MHz.

output voltage waveform and input voltage waveform for  $V_{in} = 200 \text{ mVp-p}$  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
```

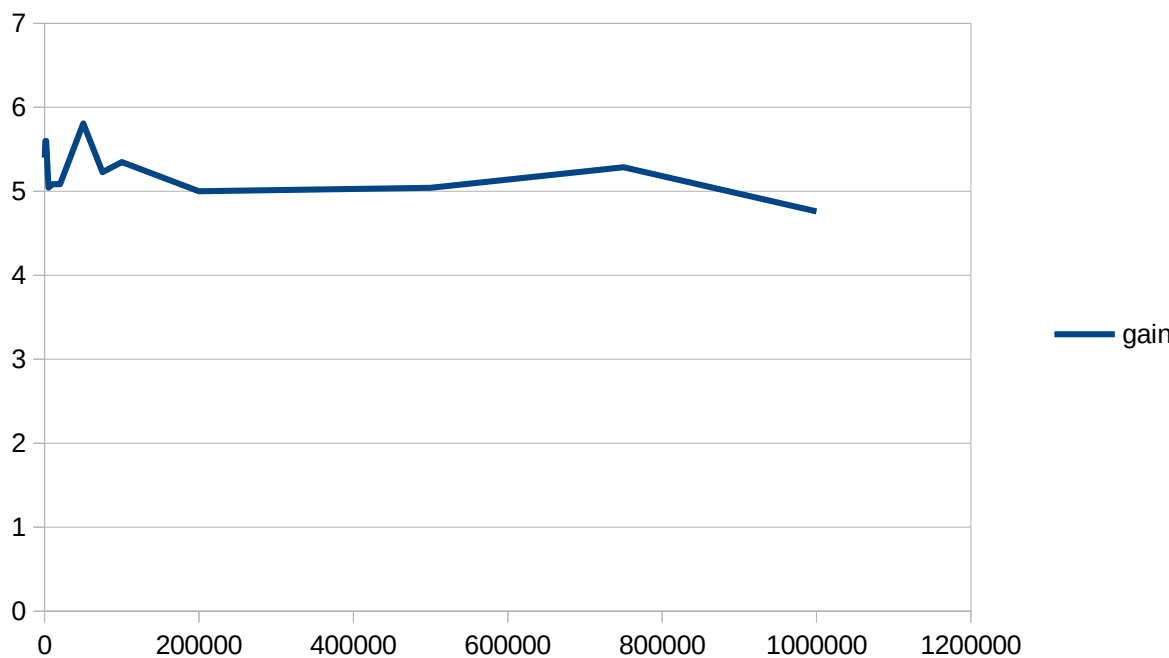


**Hardware Implementation:**

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 <sub>p-p</sub>
5.4	200 mV
5.08333	700 mV
4.91667	1.2 V
4.45	2 V

### 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.