EE 230 Experiment - 5

NMOS Output Characteristics, Common Source Amplifier, and Current Mirror

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1 NMOS Output Characteristics

```
Vinamra Baghel 190010070 Simulation of MOSFET Circuits
.model NXYAA5U nmos Level=1 Vto=0.7 KP=100u w=10u L=1u Gamma=0 Phi=0.65 Lambda
   =0.0
m d g 0 0 NXYAA5U
vg g 0 1.5
vd d 0 0.5
.op
.control
run
print -i(vd)
.endc
.end
```

Simulation

(a) i. $V_D = 0.5$ V, $I_D = 275\,\mu$A
ii. $V_D = 0.9$ V, $I_D = 320\,\mu$A
iii. $V_D = 3$ V, $I_D = 320\,\mu$A

```
Vinamra Baghel 190010070 NMOS Output Characteristics
.model NXYAA5U nmos Level=1 Vto=0.7 KP=100u w=10u L=1u Gamma=0 Phi=0.65 Lambda
   =0.0
rd d d2 2.2k
m d g 0 0 NXYAA5U
vg g 0 2
v2 d2 0 12
.control
dc vg 0 5 0.1 v2 0 10 0.1
run
plot -i(v2)
.endc
.end
```

Simulation

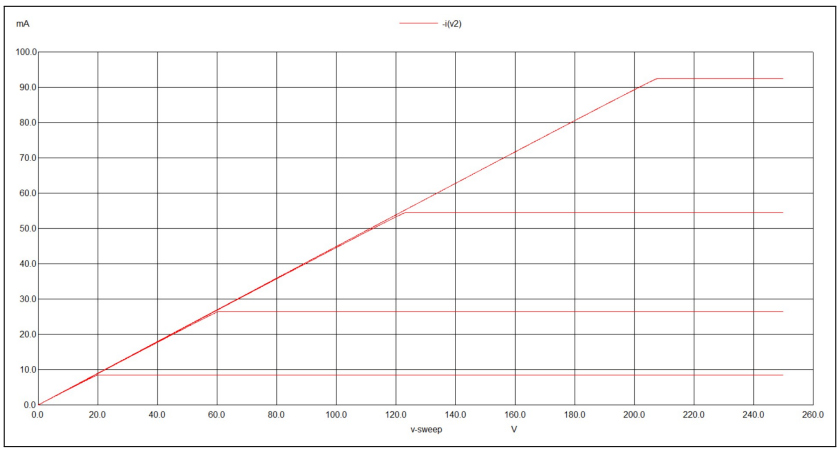

Figure 1: I_D vs V_2 for $V_{GS} \in \{2, 3, 4, 5\}$

Learnings:

At $V_{DS} = V_{GS} - V_T$, the transistor enters saturation.

2 NMOS Common-Source Amplifier

2.1 Bias Circuit

```
Vinamra Baghel 190010070 NMOS Common-Source Amplifier (Bias Circuit)
.model NXYAA5U nmos Level=1 Vto=0.7 KP=100u w=10u L=1u Gamma=0 Phi=0.65 Lambda
   =0.0
rd d d1 3.3k
rs s 0 1k
r1 dd g 8.2k
r2 g 0 3.3k
m d g s 0 NXYAA5U
vdum dd d1 0
vdd dd 0 12
.op
.control
run
print i(vdum) v(g) v(d) v(s)
.endc
.end
```

Simulation

$I_D = 1.197$ mA
$V_G = 3.443$ V
$V_D = 8.051$ V
$V_S = 1.197$ V

2.2 Small Signal Analysis

```
Vinamra Baghel 190010070 NMOS Common-Source Amplifier

.model NXYAA5U nmos Level=1 Vto=0.7 KP=100u w=10u L=1u Gamma=0 Phi=0.65 Lambda
   =0.01

rd d d1 3.3k
rs s 0 1k
r1 dd g 8.2k
r2 g 0 3.3k
cs s 0 100u
c1 in g 10u
m d g s 0 NXYAA5U
vdum dd d1 0
vdd dd 0 12
vin in 0 sin(0 50m 1k 0 0)
*vin in 0 dc 0 ac 50m

.tran 0.1u 10m
*.ac dec 10 10 10Meg

.control
run
*print v(d)*20
plot v(in)*10 v(d)
meas tran pp_out pp v(d)
meas tran pp_in pp v(in)
let gain = -1*pp_out/pp_in
print gain
.endc
.end
```

Analysis

Based on the given values of I_D and V_A,

$$g_m = \sqrt{2\mu_n C_{ox}\left(\frac{w}{l}\right) I_D} = \sqrt{2 * 10^{-4} * \left(\frac{10}{1}\right) 10^{-3}} = 1.414 \times 10^{-3}$$

$$r_o = \frac{V_A}{I_D} = \frac{100}{0.001} = 100\ k\Omega$$

Voltage Gain,

$$A_V = -g_m(R_D||r_o) = -gm * \frac{R_D * r_o}{R_D + r_o} = -(1.414 \times 10^{-3}) * \frac{3.3k * 100k}{3.3k + 100k} = -4.52$$

Simulation

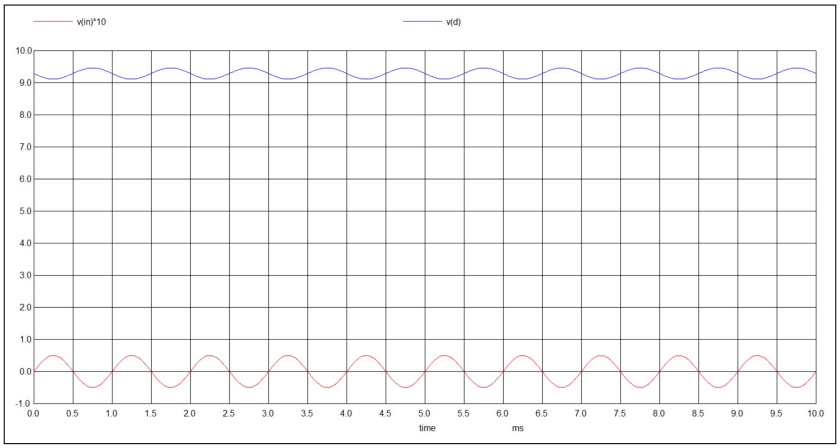

Figure 2: $V_{in} * 10$ and V_d

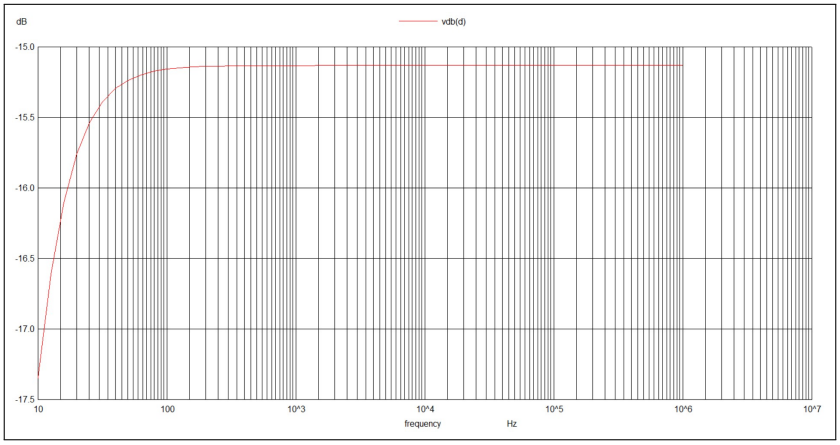

Figure 3: Plot of Vdb at D, V_d

Midband Voltage Gain = **-5.15**.

Learnings:

Finding gain of NMOS Common Source Amplifier.

3 NMOS Current Mirror based Current Source

```
Vinamra Baghel 190010070 NMOS Current Mirror based Current Source
.model NXYAA5U nmos Level=1 Vto=1 KP=100u w=10u L=1u Gamma=0 Phi=0.65 Lambda=0.01
r dd g 8.2k
m1 g g 0 0 NXYAA5U
m2 o g 0 0 NXYAA5U
vo o 0 1
vdd dd 0 12
.dc vo 1 5 0.2
.control
run
print i(vdd) i(vo)
plot i(vdd) i(vo)
.endc
.end
```

Analysis

For $I_{ref} = 1.1552$ mA,

1. For $V_o = 1$ V, $I_o = 1.137$ mA.
2. For $V_o = 2$ V, $I_o = 1.149$ mA.
3. For $V_o = 3$ V, $I_o = 1.160$ mA.
4. For $V_o = 4$ V, $I_o = 1.172$ mA.
5. For $V_o = 5$ V, $I_o = 1.183$ mA.

Simulation

For $I_{ref} = 1.158$ mA,

1. For $V_o = 1$ V, $I_o = 1.013$ mA.
2. For $V_o = 2$ V, $I_o = 1.152$ mA.
3. For $V_o = 3$ V, $I_o = 1.163$ mA.
4. For $V_o = 4$ V, $I_o = 1.175$ mA.
5. For $V_o = 5$ V, $I_o = 1.186$ mA.

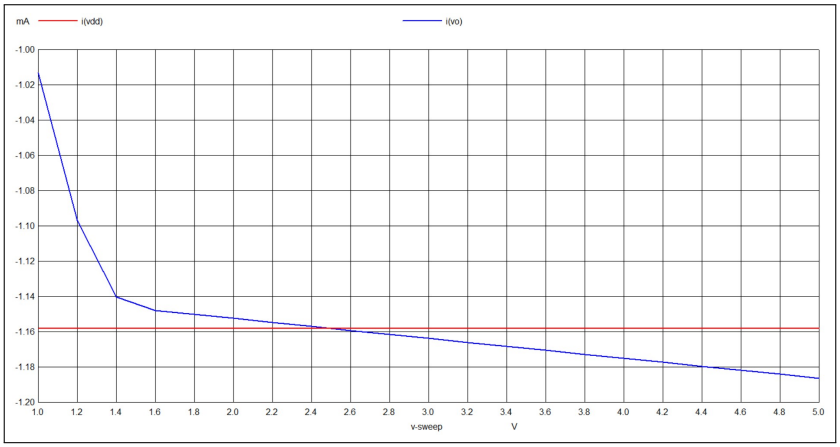

Figure 4: $-I_{dd}$ and $-I_o$

Learnings:

Current Mirror based Current Source Characteristics.

Files associated: https://github.com/VNMR-35/EE-230-Lab