Analog IC Design (Xschem,Ngspice,ADT0

Lab 03

Cascode Amplifier

Part 1: Device Sizing Using SA

Parameter	Value
$Av = gmro$	50
g_m/I_D	$10\ S/A$
Supply (V_{DD})	$1.8\ V$
Quiescent (DC) output voltage	$V_{DD}/2 = 0.9\ V$
Bias Current	$20\ \mu A$

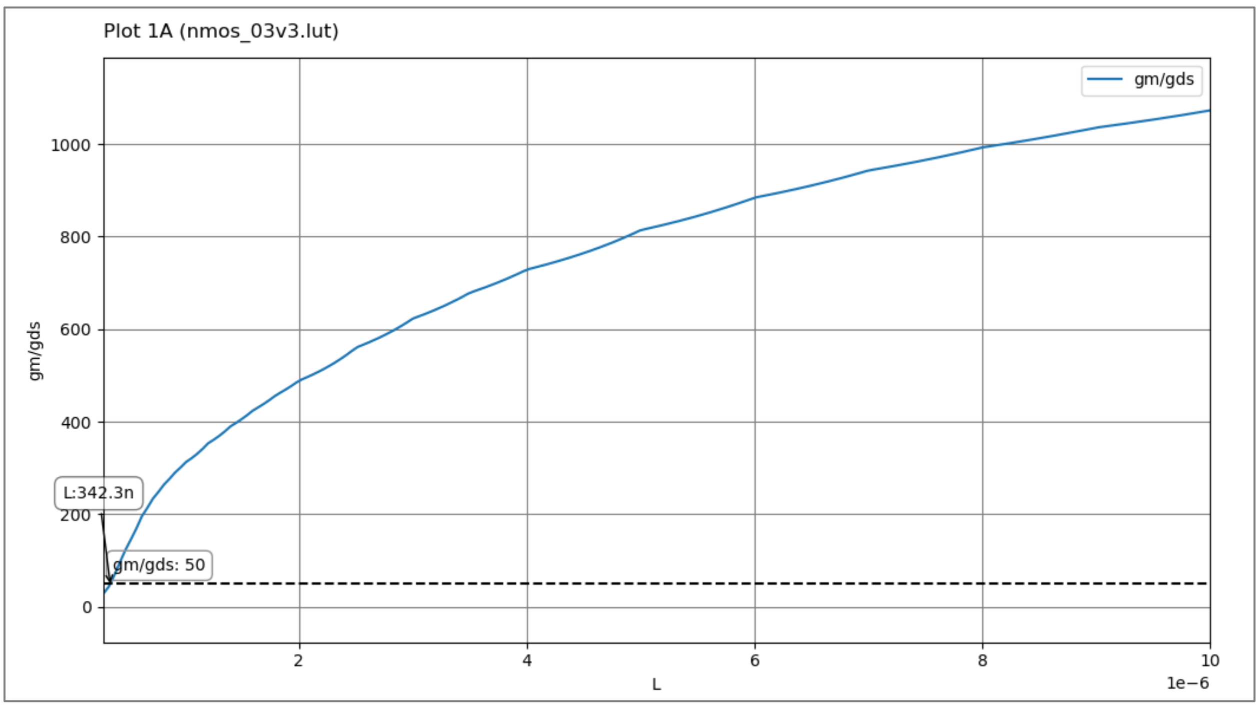
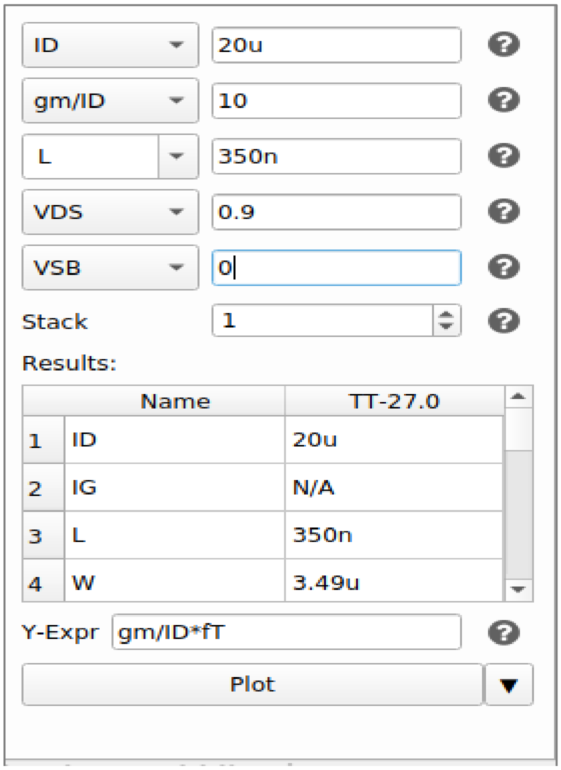


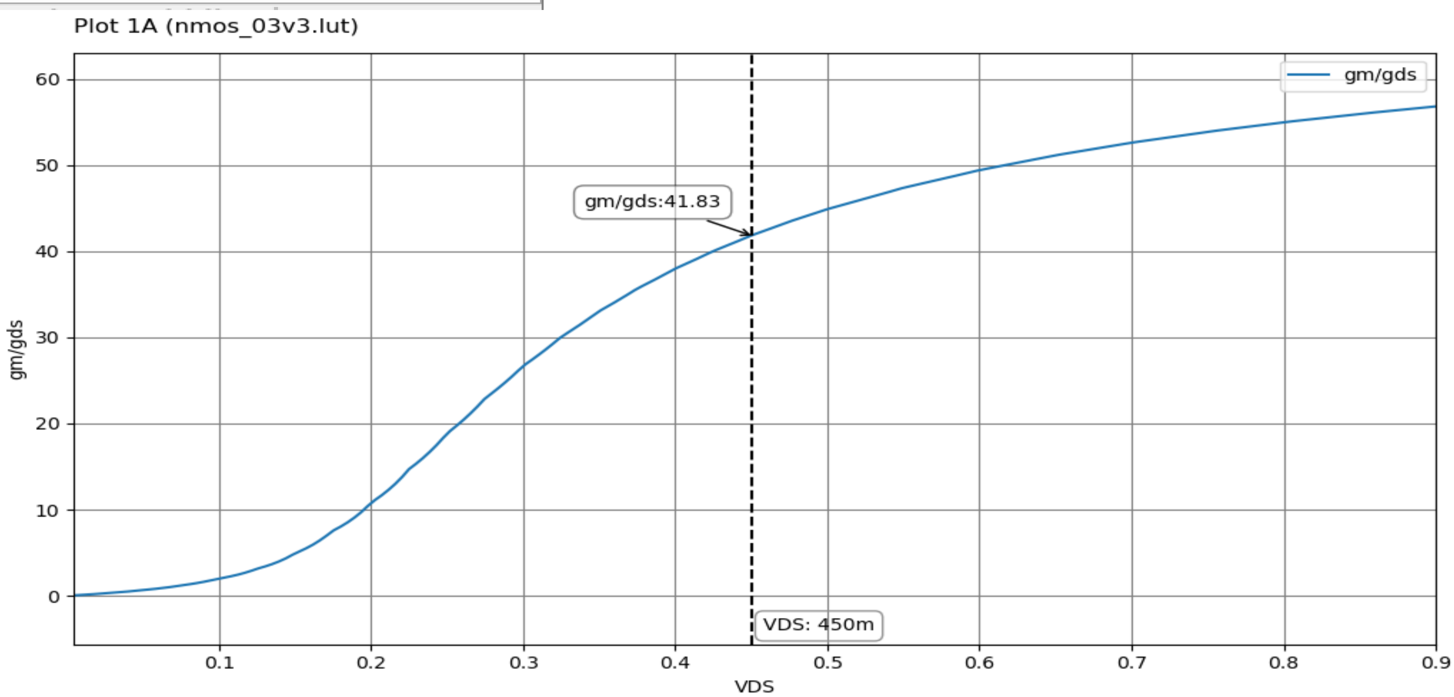
*Figure 1: gm*ro VS L*

I chose L = 350 nm instead of L=342.3 nm to add a margin for process variations and to ensure that $(\frac{g_m}{g_{ds}})$ remains above 50.



From ADT:

after adjusting values for L & VDS & ID & gm/ID
we got W=3.49u



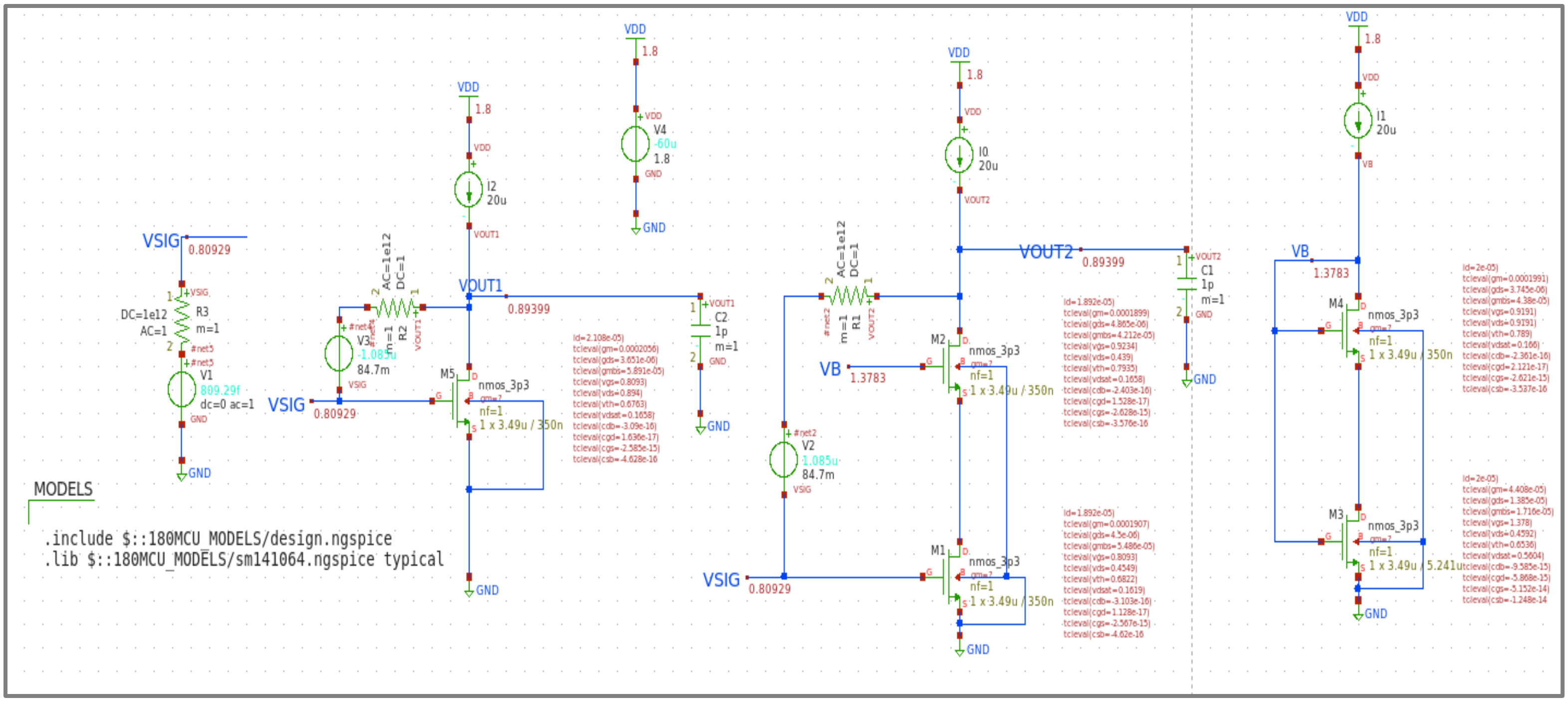
*gm*ro VS vds*

Comment:

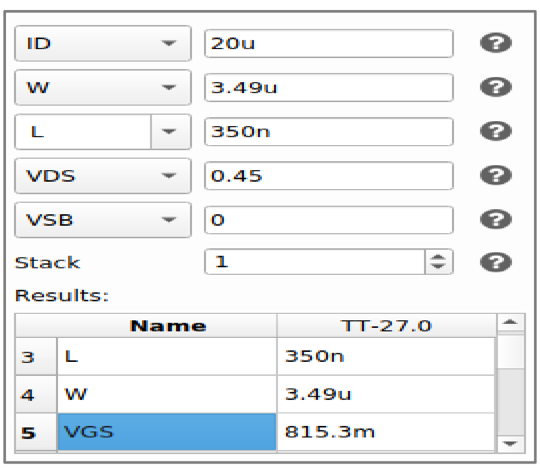
AS shown ($\frac{g_m}{g_{ds}}$) depends on VDS , where at vds=0.45 $\rightarrow$ ($\frac{g_m}{g_{ds}}$) = 41.83

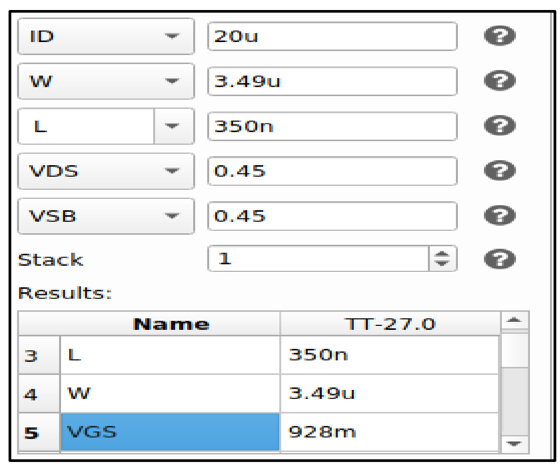
PART 2: Cascode for Gain :

1. OP Analysis :



schematic





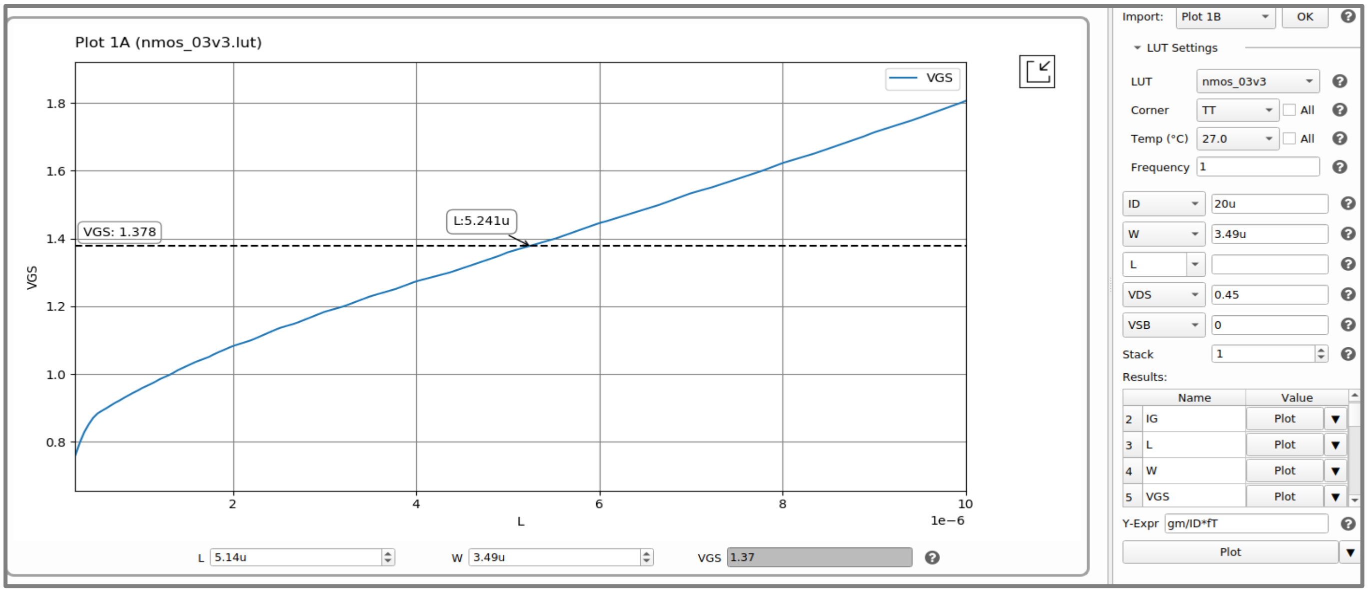
To calc value of dc source we will clac value of VGS5

As shown and the source value will=0.9-VGS5=84.7mV

To clac value of VB we will clac value of VGS2

and VB will = 0.45+VGS2=1.378V

After that We will use it to calc value of L3



As shown L3=5.241u

10)Check that all transistors operate in saturation. Does any transistor operate in triode? Why?

All transistors operate in saturation except M3, because Vdsat3>Vds3

11)Do all transistors have the same vth? Why?

Transistors have not the same Vth due to

Body Effect (Substrate Bias)

The threshold voltage depends on the voltage between the source and the substrate (VSB). If the substrate bias varies, Vth will also change

Drain-Induced Barrier Lowering (DIBL)

At higher drain-to-source voltages (VDS), the electric field from the drain can lower the potential barrier in the channel, effectively reducing Vth

12)What is the relation (≪, <, =,>, ≫) between gm and gds?

gm>>gds [M0, M1, M2, M4]

gm>gds [only M3 (TRIODE)]

What is the relation (≪, <, =,>, ≫) between gm and gmb?

gm>gmb[M0, M1, M2, M4]

gm>gmb [only M3 (TRIODE)]

What is the relation (≪, <, =,>, ≫) between cgs and cgd?

Cgs>>cgd[M0, M1, M2, M4]

Cgs>cgd [only M3 (TRIODE)]

What is the relation (≪, <, =,>, ≫) between csb and cdb?

Csb>cdb[M0, M1, M2, M4]

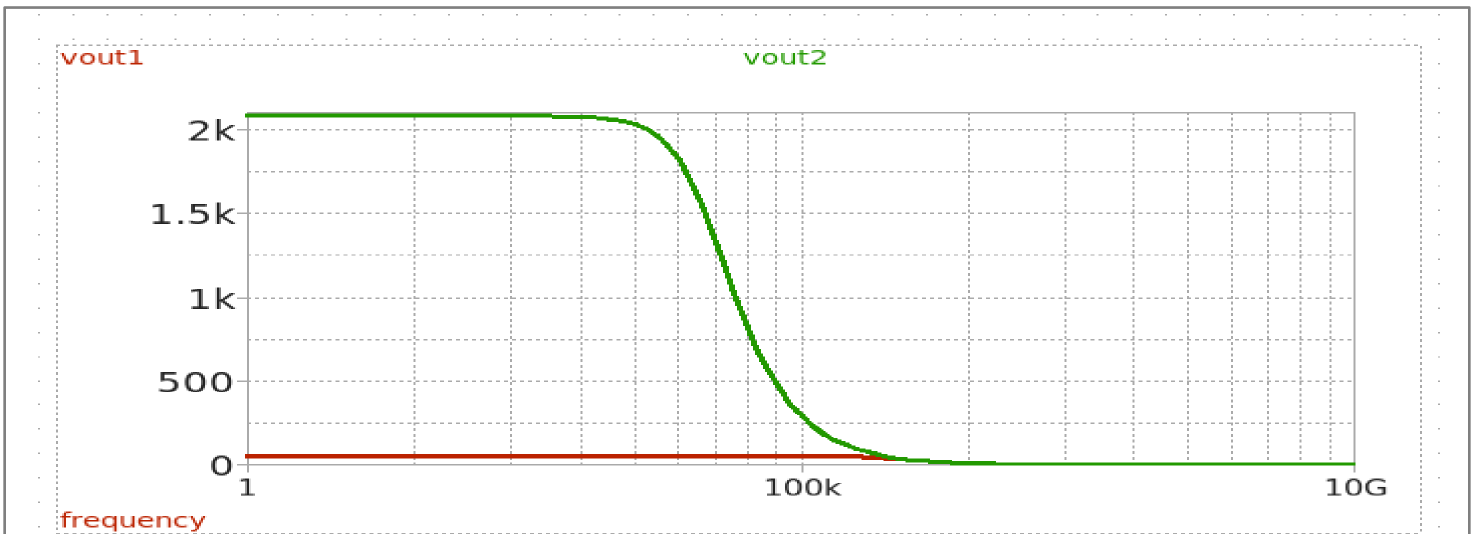
Csb>cdb [only M3 (TRIODE)]

2. AC Analysis

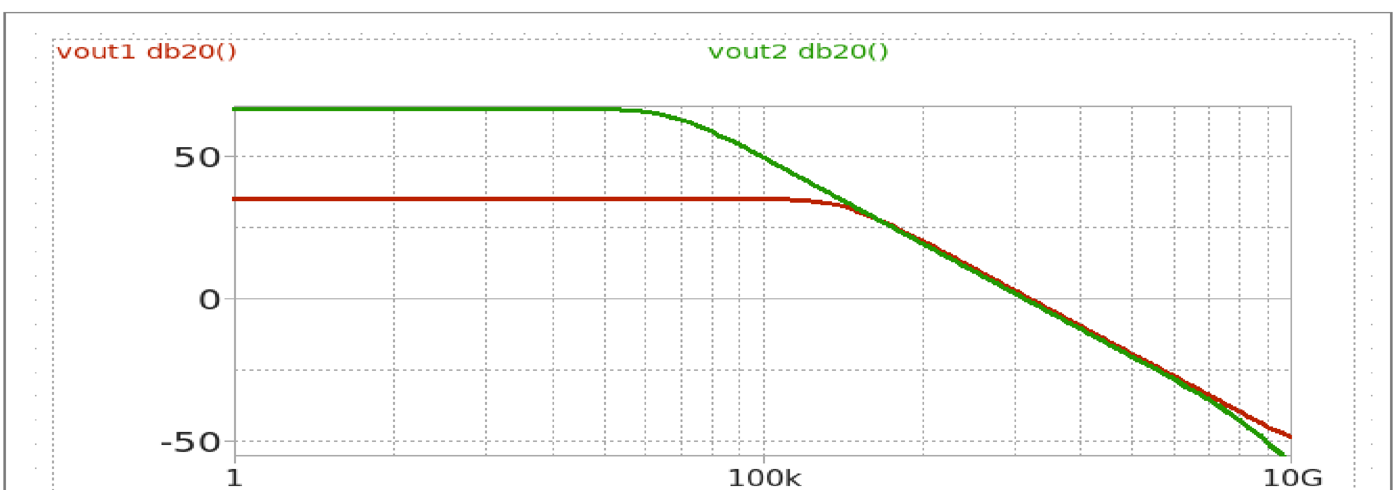
2) Use measure expressions to calculate parameters (DC gain, BW, GBW, and UGF) and export them to a text file.

```
1 max_gain_cs = 5.604095e+01
2 bw_cs = 6.017334e+05
3 gbw_cs = 3.372171e+07
4 ugf_cs = 3.401296e+07
5 max_gain_casc = 2.138377e+03
6 bw_casc = 1.340691e+04
7 gbw_casc = 2.866903e+07
8 ugf_casc = 2.894499e+07
```

3) Report the Bode plot (magnitude) of CS and cascode **appended on the same plot**



VOUT1_VOUT2 VS freq :(linear scale)



VOUT1_VOUT2 VS freq :(db scale)

Hand analysis:

In a common source amplifier , dc gain (mag) given by :

$$A_V = gm \times r_o = gm \times \frac{1}{gds} = 56.31$$

But In a cascode amplifier , dc gain (mag) given by:

$$A_V = gm \times Rout = gm1 \times ro2(gm2 + gmb2)ro1 \approx 2.066\ K$$

.

In a common source amplifier , (BW)given by :

$$\frac{1}{2\pi \times r_{o5} \times C_L} = 593.1\ KHZ$$

But In a cascode amplifier , (BW) given by:

$$\frac{1}{2\pi \times R_{out} \times C_L} = 14.21\ KHZ$$

Cs : GBW nearly = UGF = BW × Av= 33.4 MHZ

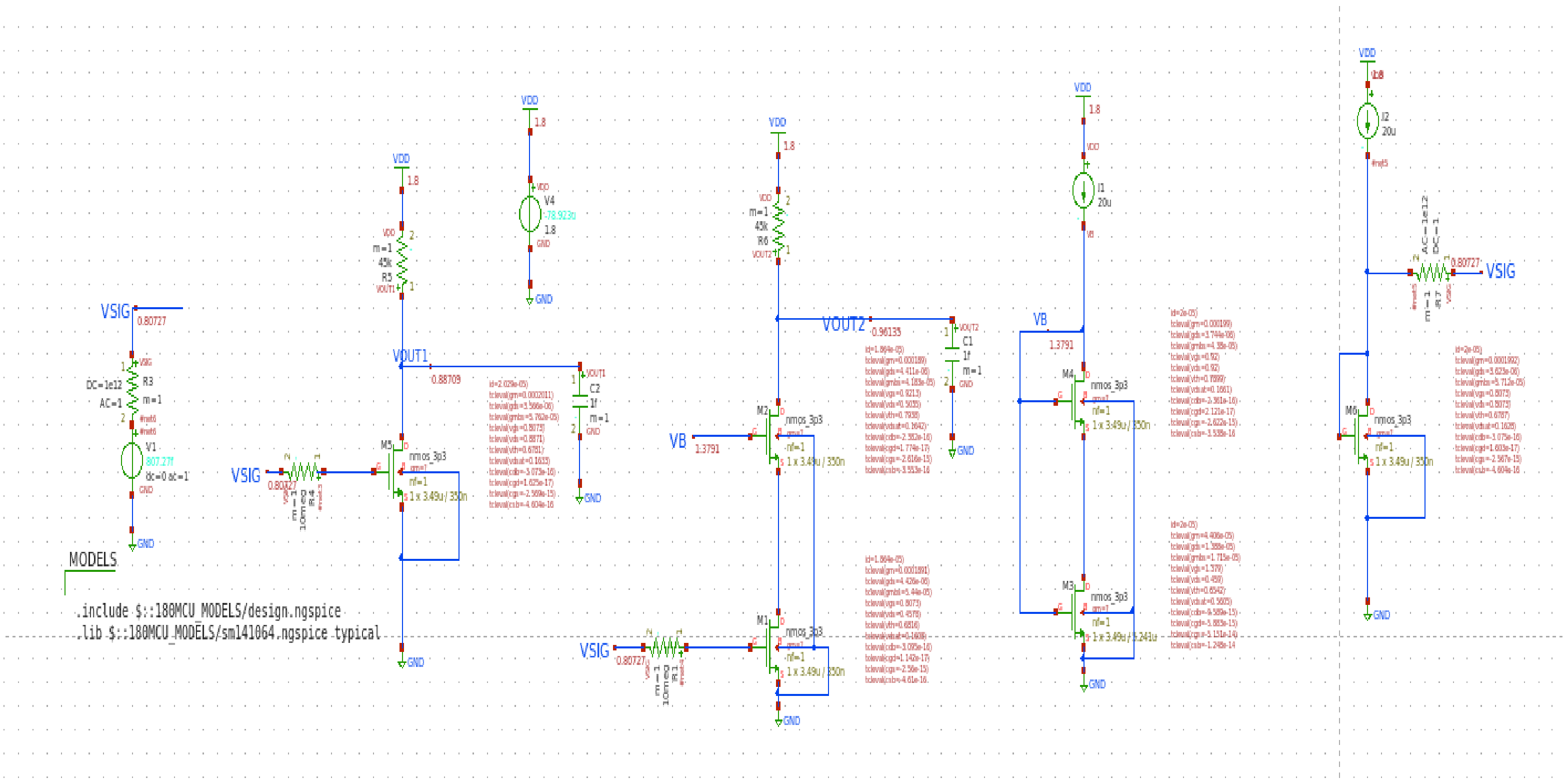
Cascode : GBW nearly = UGF = BW × Av= 29.4 MHZ

	CS	Cascode
DC gain hand analysis	56.31	2.066 K
DC gain from simulation	56.04	2.138 K
BW hand analysis	593.1 KHZ	14.21 KHZ
BW from simualtion	601.7 KHZ	13.41 KHZ
GBW hand analysis	33.4 MHZ	29.4 MHZ
GBW from simulation	33.7 MHZ	28.7 MHZ
UGF hand analysis	33.4 MHZ	29.4 MHZ
UGF from simualtion	34.01 MHZ	28.94 MHZ

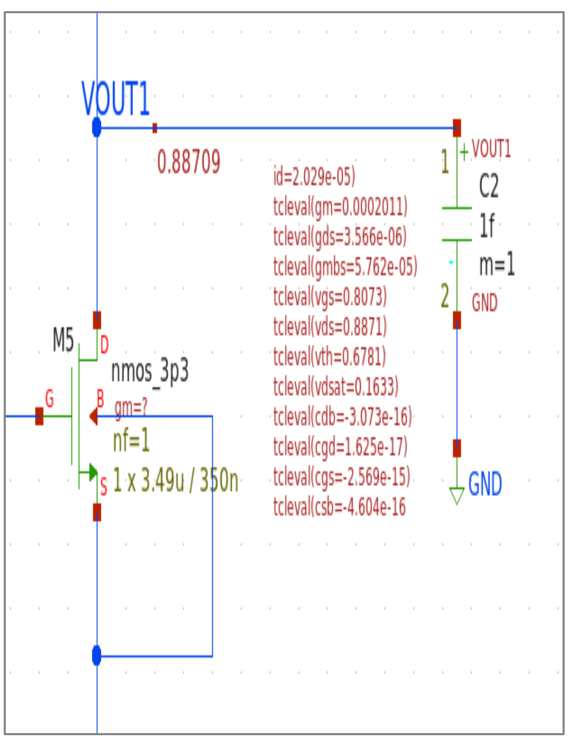
COMMENT

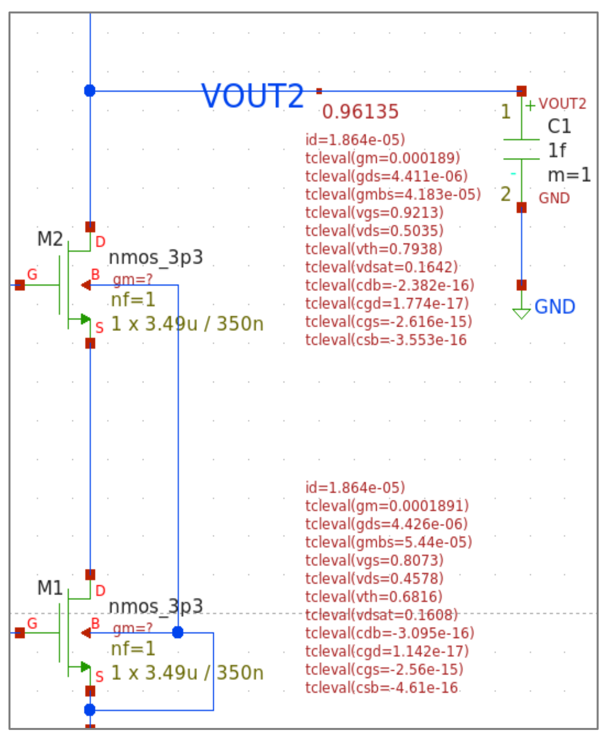
The cascode is preferred when high DC gain is critical, while the CS stage is better for wider bandwidth applications. Their GBW remains similar, demonstrating a fundamental trade-off between gain and speed.

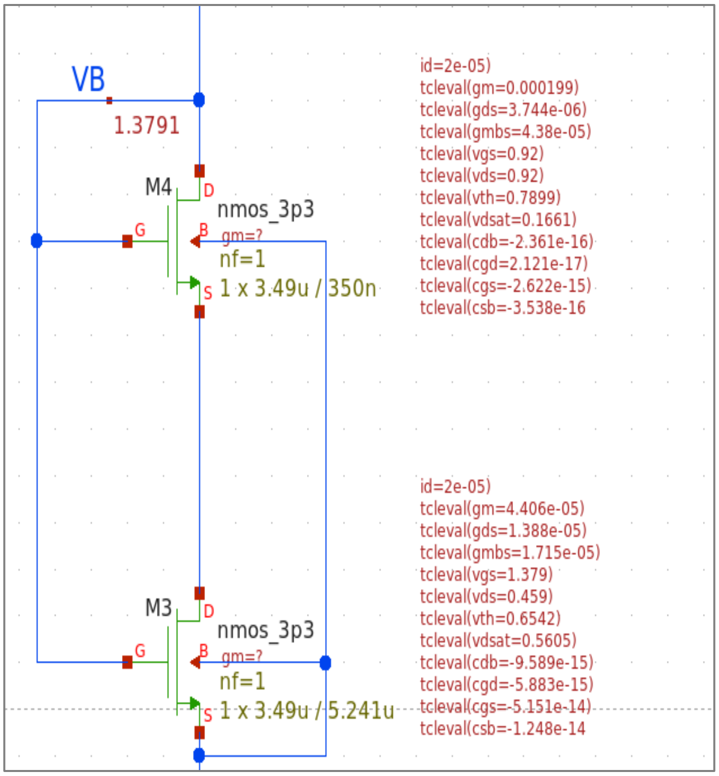
Part 3: Cascode for BW

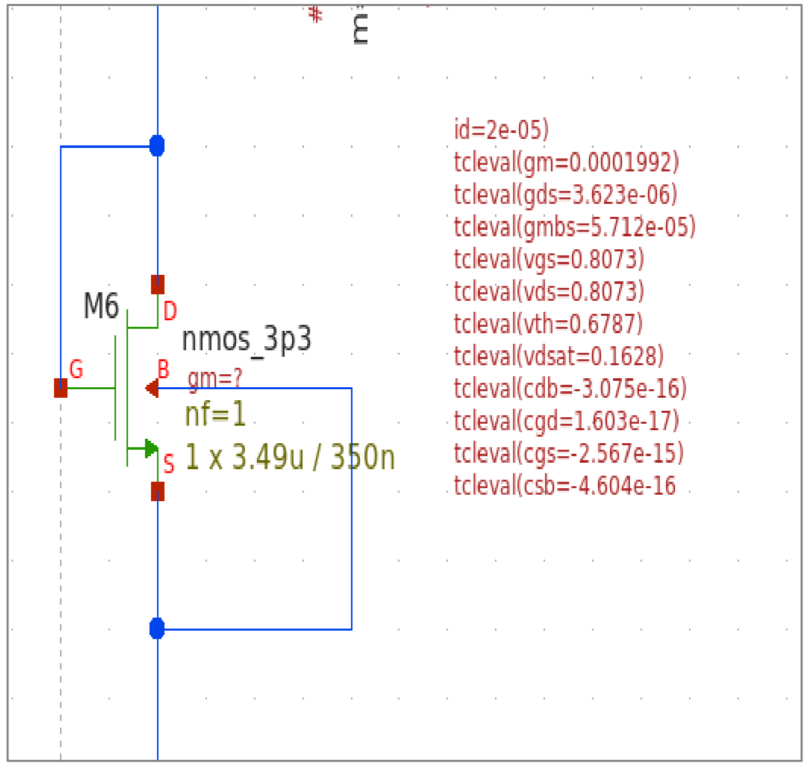


schematic









R_D the voltage drop on it is $\approx V_{DD}/2$ → $R_D = \frac{V_{DD}}{2 * I_D} = 45\ K\Omega$

4)Check that all transistors operate in saturation. Does any transistor operate in triode? Why?

→ All transistors operate in saturation except M3, because Vdsat3>Vds3

caps values:

Info: [Sizing Assistant] The resultant point 'CGS = 3.269f'
Info: [Sizing Assistant] The resultant point 'CGD = 614.2a'
Info: [Sizing Assistant] The resultant point 'CDB = 2.194f'
Info: [Sizing Assistant] The resultant point 'CSB = 3.06f'

Caps values for M5

Info: [Sizing Assistant] The resultant point 'CGS = 3.261f'
Info: [Sizing Assistant] The resultant point 'CGD = 682.2a'
Info: [Sizing Assistant] The resultant point 'CDB = 2.389f'
Info: [Sizing Assistant] The resultant point 'CSB = 3.061f'

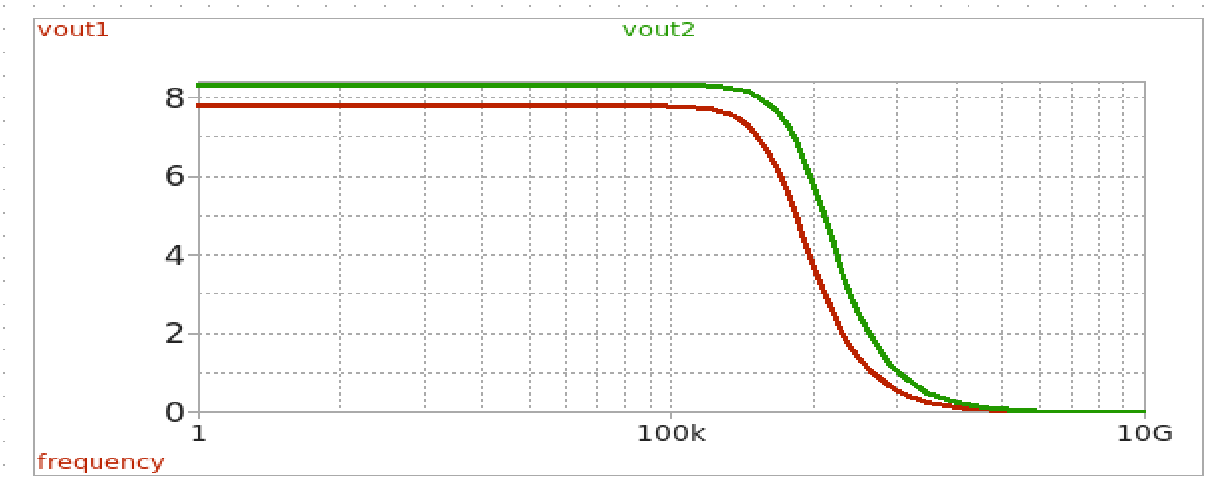
Caps values for M2

AC Analysis

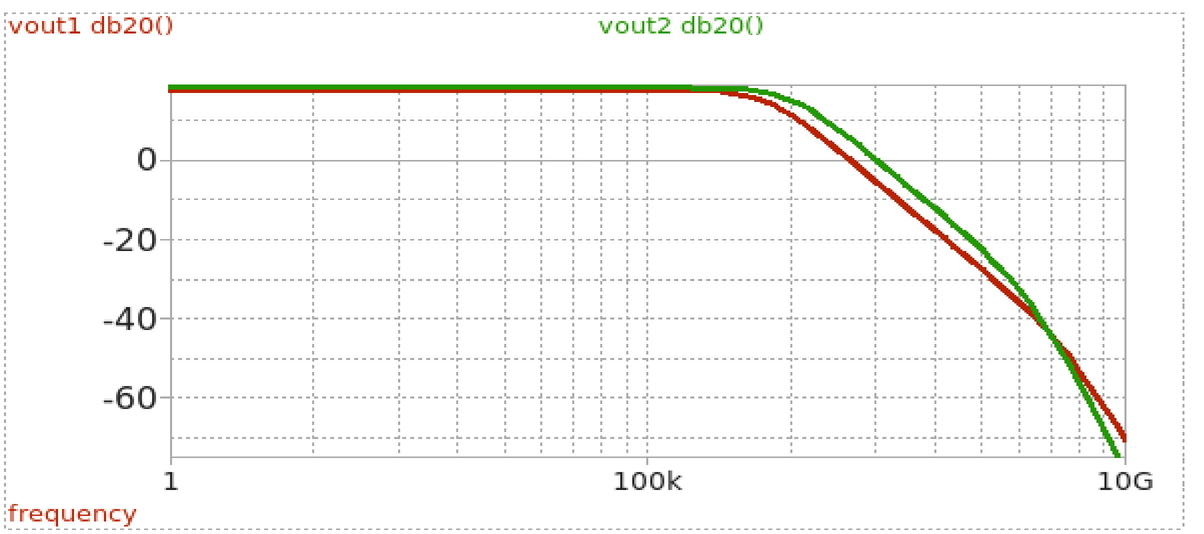
Use measure expressions to calculate parameters (DC gain, BW, GBW, and UGF) and export them to a text file.

```
max_gain_cs = 7.798065e+00
bw_cs = 1.700767e+06
gbw_cs = 1.326269e+07
ugf_cs = 1.321444e+07
max_gain_casc = 8.321841e+00
bw_casc = 3.016187e+06
gbw_casc = 2.510023e+07
ugf_casc = 2.489442e+07
```

Report the Bode plot (magnitude) of CS and cascode **appended on the same plot**



VOUT1_VOUT2 VS freq :(linear scale)



VOUT1_VOUT2 VS freq :(db scale)

Hand analysis:

In a common source amplifier , dc gain (mag) given by :

$$A_V = gm \times \ r_o//Rd = 7.798$$

But In a cascode amplifier , dc gain (mag) given by:

$$A_V = gm \ \times \ Rout \ = gm1 \times ro2(gm2 + gmb2)ro1 \ \approx 8.48$$

.

In a common source amplifier , (BW)given by :

$$\frac{1}{2\pi \times R_{in} \times C_{in}} = \frac{1}{2\pi \times R_{sig} \times (C_{gs} + C_{gd}(1+A_V))} = 1835 \text{ KHZ}$$

But In a cascode amplifier , (BW) given by:

$$\frac{1}{2\pi \times R_{in} \times C_{in}} = \frac{1}{2\pi \times R_{sig} \times (C_{gs} + 2C_{gd}(1+A_V))} = 3441 \text{ KHZ}$$

Cs : GBW nearly = UGF = BW × Av= 14.31 MHZ

Cascode : GBW nearly = UGF = BW × Av= 29.18 MHZ

	CS	Cascode
DC gain hand analysis	7.798	8.48
DC gain from simulation	7.798	8.322
BW hand analysis	1835 KHZ	3441 KHZ
BW from simualtion	1700 KHZ	3016 KHZ
GBW hand analysis	14.31 MHZ	29.18 MHZ
GBW from simulation	13.26MHZ	25.1 MHZ
UGF hand analysis	14.31 MHZ	29.18 MHZ
UGF from simualtion	13.21MHZ	24.89 MHZ

COMMENT

The cascode amplifier offers higher bandwidth, slightly higher gain, and nearly double GBW compared to the common source amplifier. This makes it a better choice for high-frequency applications.