Analog IC Design – Cadence Tools

Lab 03

Cascode Amplifier

PART 2: Cascode for Gain

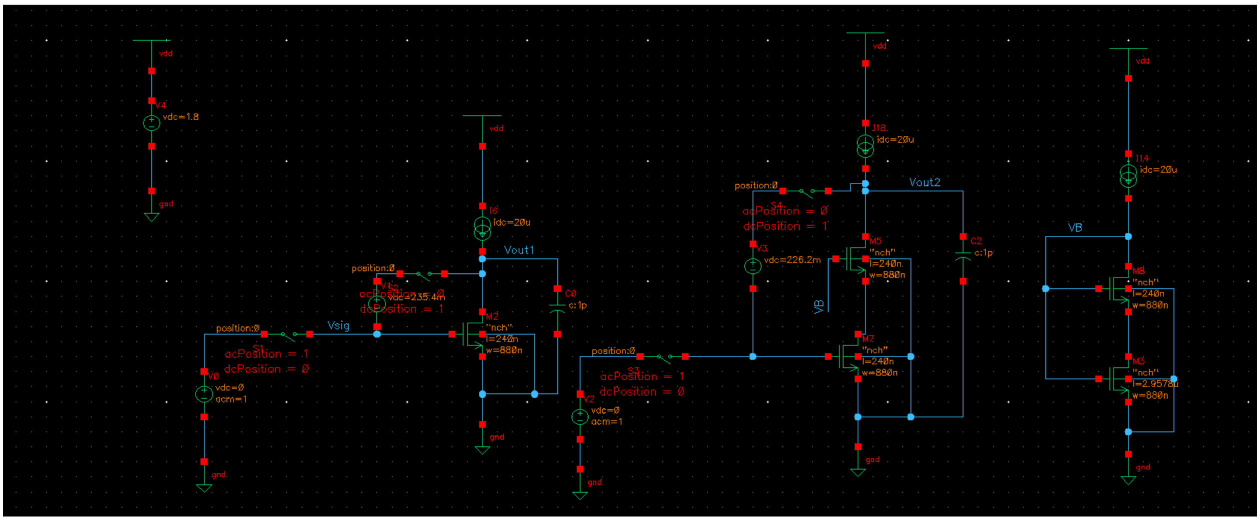

Figure 1 schematic

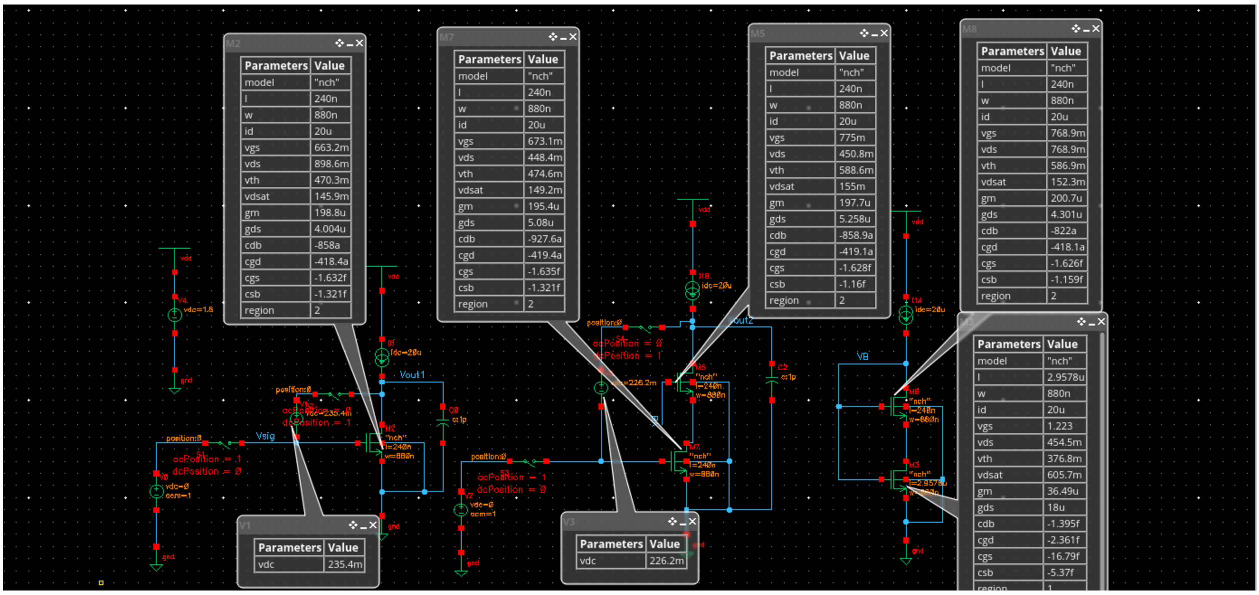

Figure 2 balloons

	M2	M3	M5	M7	M8
Gmb	48.32u	10.47u	42.14u	47.62u	42.63u

Transistors M[8,2,5,7] are in saturations (region = 2)

Transistor M3 is in triode (region 1), because its Vgs =VB, and its Vds= VB – Vds(M0)

∴ Vgs > Vds, ∴ Transistor M3 is in triode.

Vth for M2 & M7 & M5

V_{TH} for M2 & M7 are the same, but M5 is different, because of the source body effect.

$$V_{TH} = V_{THo} + \gamma\left(\sqrt{2\varphi_F + V_{SB}} - \sqrt{|2\varphi_F|}\right)$$

Transistors have the different V_{th}, because Vth depend on the value of V_{SB} and as V_B is grounded, so the value of V_{th} will depend only on V_S, so as shown $V_{th1}$and V_{th2} are equal because V_S is equal and $V_{th3}$is different from them because its value of V_s is different.

(Note that M[2,5,7] transistors are identical, but M[3] isn't, as it has different L)

7) gm >> gds

8) gm > gmb

9) cgs > cgd

10) csb > cdb

2. AC Analysis

Name	Type	Details	Value	Plot
	expr	VF("/Vout1")		✓
	expr	dB20(VF("/Vout1"))		✓
	expr	ymax(dB20(VF("/Vout1")))	33.92	✓
	expr	ymax(mag(VF("/Vout1")))	49.65	✓
	expr	bandwidth(VF("/Vout1") 3 "low")	635.2K	✓
	expr	gainBwProd(VF("/Vout1"))	31.62M	✓
	expr	VF("/Vout2")		✓
	expr	dB20(VF("/Vout2"))		✓
	expr	ymax(dB20(VF("/Vout2")))	65.07	✓
	expr	ymax(mag(VF("/Vout2")))	1.792K	✓
	expr	bandwidth(VF("/Vout2") 3 "low")	16.98K	✓
	expr	gainBwProd(VF("/Vout2"))	30.52M	✓

Figure 3 circuit parameters

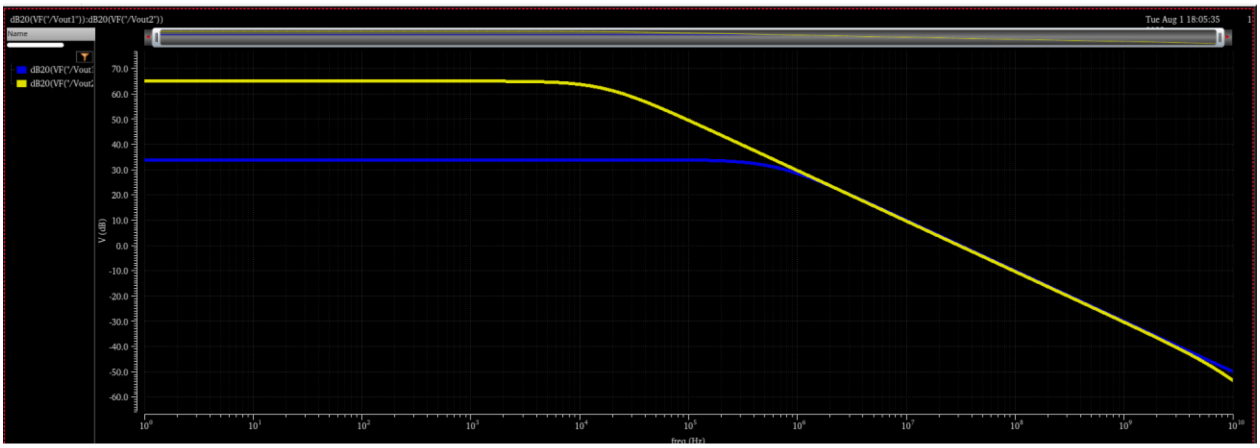

Figure 4 Bode plot (magnitude) of CS and cascode

Hand analysis:

C (out) =1P, as all parasitic capacitances << 1P , and in parallel with it.

$$r_o = \frac{1}{g_{ds}}$$

$$DC\ gain\ (CS) = -g_m * r_o = \frac{-g_{m2}}{g_{ds2}} = \frac{-198.8}{4} = -49.7$$

$$r_{o5t} = (r_{o7} + r_{o5} + (g_{m5} + g_{mb5}) * r_{o5} * r_{o7})$$

$$r_{o5t} = \left(\frac{1}{5.258\mu} + \frac{1}{5.08\mu} + (197.7\mu + 42.14\mu) * \frac{1}{5.258\mu} * \frac{1}{5.08\mu}\right) = 9.366M$$

$$DC\ gain\ (Cascode\ ) = -g_{m7} * r_{o5t} = -195.4u * 9.366M = -1830 = -1.83K$$

$$BW(CS) = \frac{1}{2*\pi*r_o*C} = \frac{4u}{2\pi*1p} = 636.62K$$

$$BW(Cascode\ ) = \frac{1}{2*\pi*r_{o2t}*C} = \frac{1}{2\pi*9.366M*1p} = 17K$$

$$GBW(CS) = BW1 * DC\ gain\ 1 = 31.64M$$

$$GBW(Cascode\ ) = BW2 * DC\ gain\ 2 = 31.11M$$

GPW analytically is UGF (unity gain frequency)

	Simulation	Hand analysis
DC Gain (CS)	49.65	49.7
$BW(CS)$	635.2K	$636.62K$
$GBW(CS)$	31.62M	$31.64M$
DC Gain ($Cascode$)	17.92K	$1.83K$
$BW(Cascode)$	16.98K	$17K$
$GBW(Cascode)$	30.52M	$31.11M$

Comments:

The Cascode amplifier Gain is higher than the common-source amplifier Gain, as The Cascode amplifier has higher Rout and $DC\,gain = -g_m * r_o$.

The Cascode amplifier Bandwidth is lower than the common-source amplifier Bandwidth, as The Cascode amplifier has higher Rout and $BW = \frac{1}{2*\pi*r_o*C}$.

I didn’t use the parasitic capacitances as 1p >> from it

PART 3 [Optional]: Cascode for BW

1. OP Analysis

RD = 0.9/20u = 45K

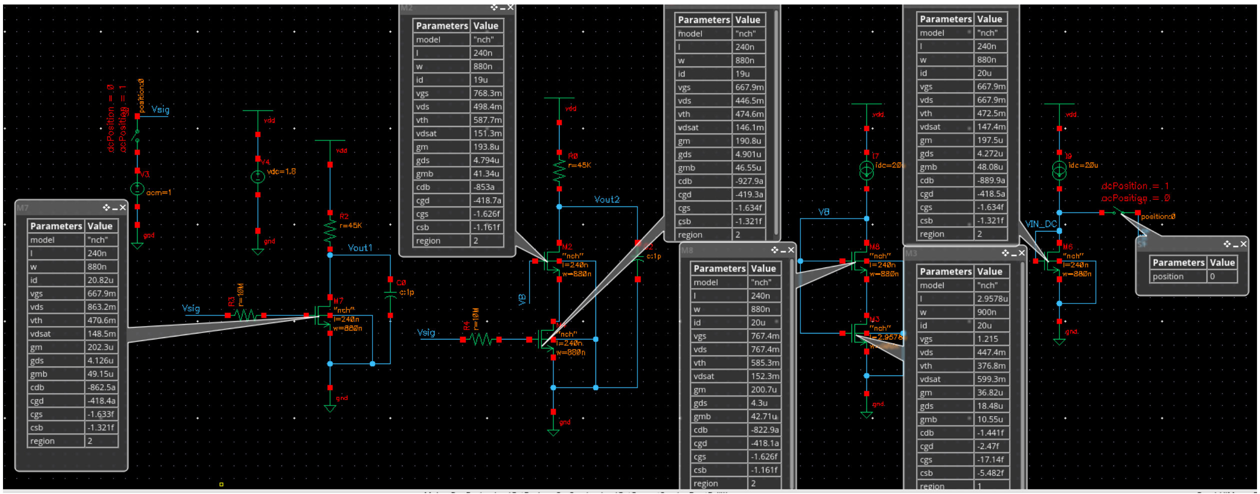

Figure 5 balloonsof CS and cascode

4) All transistor (CM & Cascode) have (region = 2), that is mean that all of them is in saturation region.

2. AC Analysis

Name	Type	Details	Value	Plot	Save	Spec
	expr	VF("/Vout1")		✔		
	expr	dB20(VF("/Vout1"))		✔		
	expr	ymax(dB20(VF("/Vout1")))	17.71	✔		
	expr	ymax(mag(VF("/Vout1")))	7.678	✔		
	expr	bandwidth(VF("/Vout1") 3 "low")	2.962M	✔		
	expr	gainBwProd(VF("/Vout1"))	22.79M	✔		
	expr	VF("/Vout2")		✔		
	expr	dB20(VF("/Vout2"))		✔		
	expr	ymax(dB20(VF("/Vout2")))	18.46	✔		
	expr	ymax(mag(VF("/Vout2")))	8.378	✔		
	expr	bandwidth(VF("/Vout2") 3 "low")	6.224M	✔		
	expr	gainBwProd(VF("/Vout2"))	52.27M	✔		

Figure 6 circuit parameters

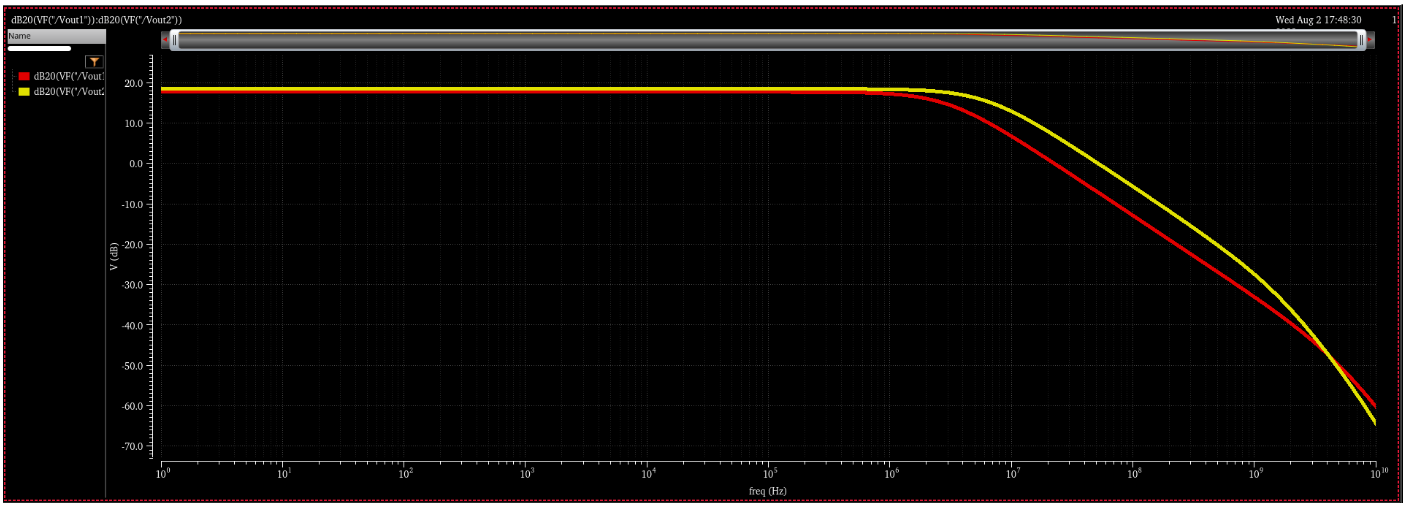

Figure 7 Bode plot (magnitude) of CS and cascode

Hand analysis:

C (out) =1P, as all parasitic capacitances << 1P , and in parallel with it.

$$r_o = \frac{1}{g_{ds}}$$

$r_{ot(CS)} = \frac{1}{g_{ds7}} \,||\, R_D = \frac{1}{4.126\mu} \,||\, 45K = 37.95K$

$DC\ gain\ (CS) = -g_m * r_o = -202.3\mu * 37.95K = -7.677$

$r_{ot(Cascode)} = (r_{o4} + r_{o5} + (g_{m5} + g_{mb5}) * r_{o5} * r_{o4}) \,||\, R_D$

$$r_{ot(Cascode)} = \left(\frac{1}{4.9\mu} + \frac{1}{4.8\mu} + (193.8\mu + 41.34\mu) * \frac{1}{4.9\mu} * \frac{1}{4.8\mu}\right) || R_D = 10.4M \,||\, 45K = 44.8K$$

$DC\ gain\ (Cascode) = -g_{m4} * r_{ot(Cascode)} = -190.8\mu * 44.8K = -8.548$

R dominant is 10M at the input

$BW(CS) = \frac{1}{2*\pi*r_o*C} = \frac{1}{2\pi*10^7*((1+7.677)*418.4a+1.633f)} = 2.6M$

$BW(Cascode) = \frac{1}{2*\pi*r_{o2t}*C} = \frac{1}{2\pi*10^7*((1+1.1935)*418.1a+1.634f)} = 6.2M$

*GBW(CS) = BW1 * DC gain 1 =20 M*

*GBW(Cascode) = BW2 * DC gain 2 = 53M*

GPW analytically is UGF (unity gain frequency)

	Simulation	Hand analysis
DC Gain (CS)	7.678	7.677
BW(CS)	2.962M	2.6M
GBW(CS)	22.79M	20M
DC Gain (*Cascode*)	8.378	8.548
BW(Cascode)	6.224M	6.2M
GBW(Cascode)	52.27M	53M

Comments:

The Cascode amplifier Gain is higher than the common-source amplifier Gain, as The Cascode amplifier has higher Rout and $DC\ gain = -g_m * r_o$.

The Cascode amplifier Bandwidth is lower than the common-source amplifier Bandwidth, as The Cascode amplifier has higher Rout and $BW = \frac{1}{2*\pi*r_o*C}$.

The Gain in this case is lower than the gain in part 2 because we used Resistance instead of the ideal current source which made the output resistance lower.