Analog IC Design

Lab 04

Common Drain Frequency Response

Part 1: Sizing Chart

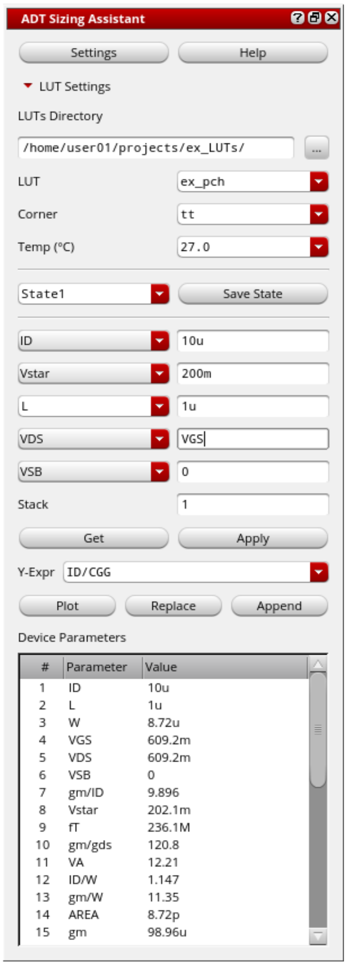


Figure 1 Sizing

W = 8.72u

PART 2: CD Amplifier

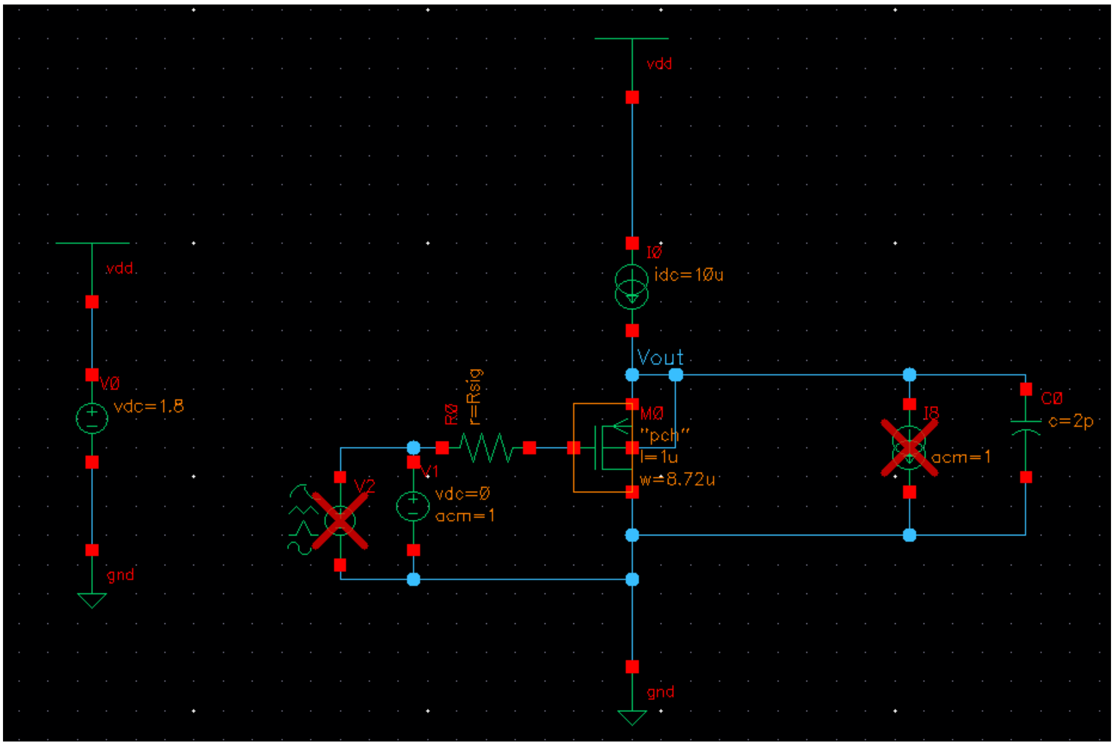
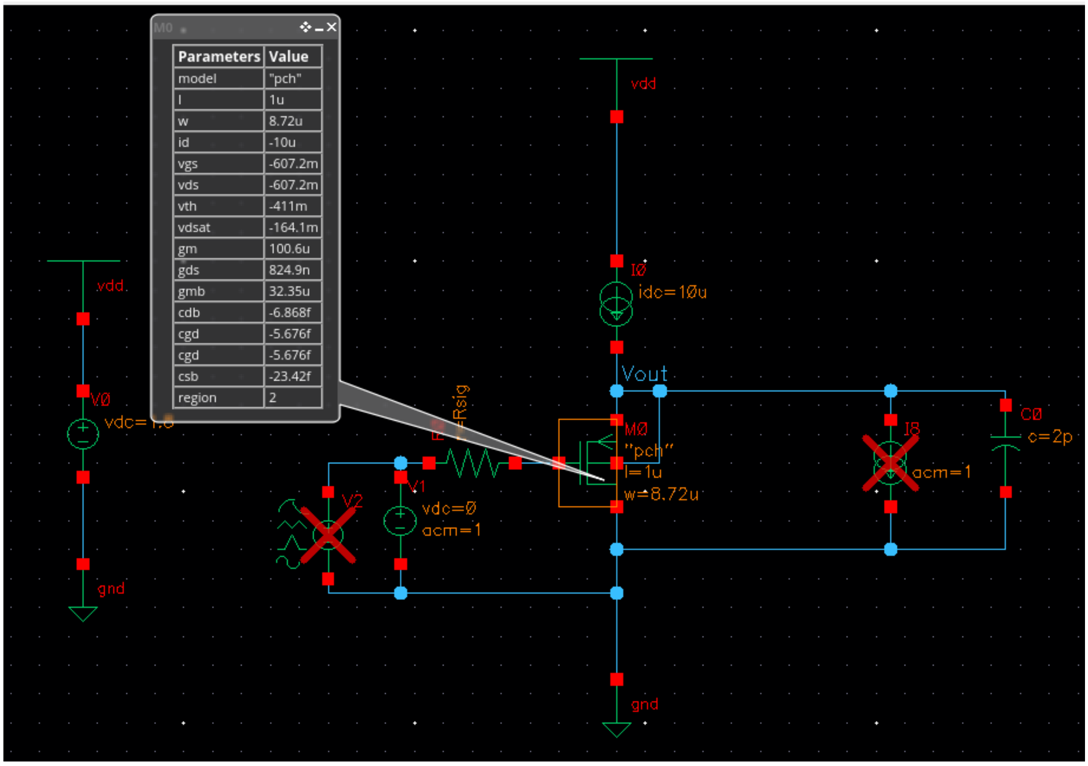


Figure 2 Schematic



Parameters	Value
model	"pch"
l	1u
w	8.72u
id	-10u
vgs	-607.2m
vds	-607.2m
vth	-411m
vdsat	-164.1m
gm	100.6u
gds	824.9n
gmb	32.35u
cdb	-6.868f
cgd	-5.676f
cgd	-5.676f
csb	-23.42f
region	2

Figure 3 Schematic with Ballon

C_{gs}=58.97f

Transistor is in saturation as Region = 2 ,(Vsd >|| Vdsat||)

2. AC Analysis

2)

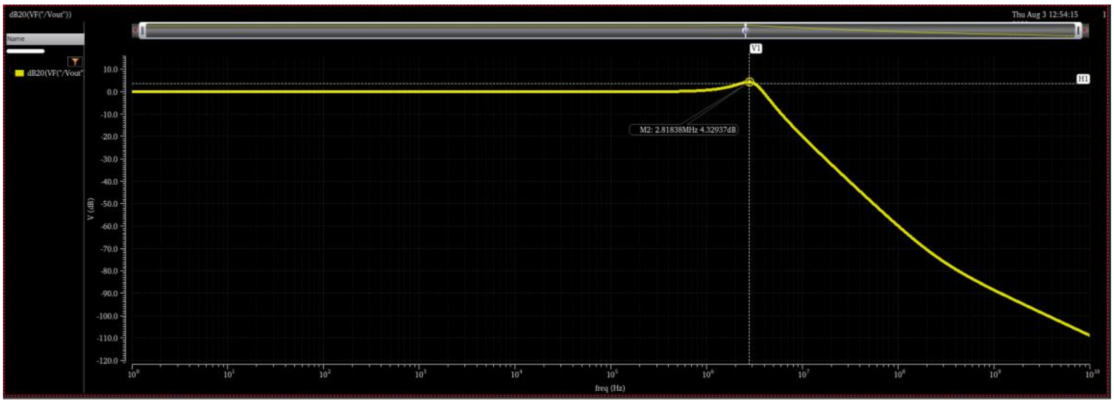


Figure 4 Bode plot (magnitude)

3)Yes, at 2.8 MHz and its value is 4.329

4) Analytically calculate quality factor (use approximate expressions). Is the system underdamped or overdamped?

∵ (RS ↑↑ (IDC) + CLM and body effect neglected + $\boldsymbol{CL}$ ↑↑)

$$\therefore \mathrm{Q} = \sqrt{\frac{\mathrm{g_m}(\mathrm{C_{gd}} + \mathrm{C_{gs}}) * \mathrm{R_{sig}}}{\mathrm{C_l}}}$$

$$\therefore \mathrm{Q} = \sqrt{\frac{100.6\mu * (5.676\mathrm{f} + 58.97\mathrm{f}) * 2\mathrm{M}}{2\mathrm{p}}} = 2.55$$

The system is Underdamped (Q > 0.5).

5) (Optional) Perform parametric sweep: CL = 2p, 4p, 8p.

• Report Bode plot magnitude overlaid on same plot.

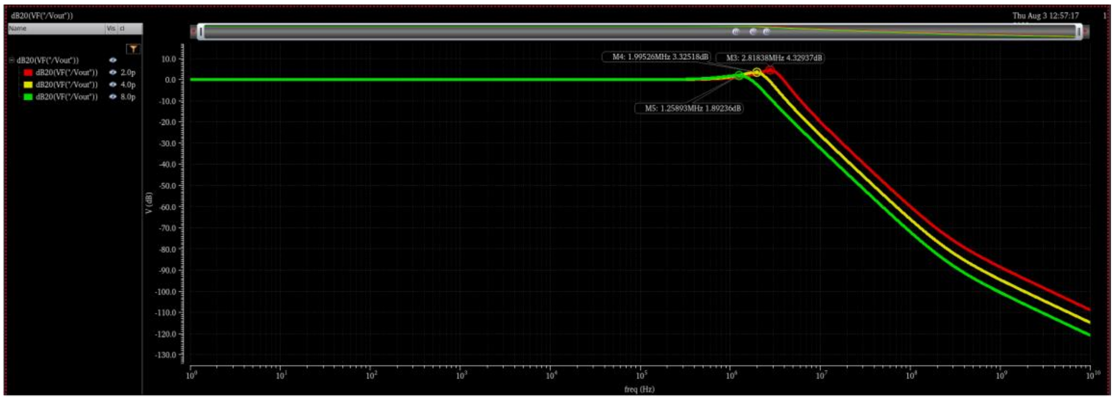


Figure 5 Bode plot at c = [2p , 4p , 8p]

• Report the peaking vs CL.

Parameters: cl=2p			
1	lab4_lab4_1	dB20(VF("/Vout"))	
1	lab4_lab4_1	ymax(dB20(VF("...	4.329
1	lab4_lab4_1	VF("/Vout")	
1	lab4_lab4_1	phase(VF("/Vout"))	
Parameters: cl=4p			
2	lab4_lab4_1	dB20(VF("/Vout"))	
2	lab4_lab4_1	ymax(dB20(VF("...	3.354
2	lab4_lab4_1	VF("/Vout")	
2	lab4_lab4_1	phase(VF("/Vout"))	
Parameters: cl=8p			
3	lab4_lab4_1	dB20(VF("/Vout"))	
3	lab4_lab4_1	ymax(dB20(VF("...	1.892
3	lab4_lab4_1	VF("/Vout")	
3	lab4_lab4_1	phase(VF("/Vout"))	

Figure 6 The Peaking vs CL

• Comment.

The peaking is inversely proportional to the capacitance value, as when CL increase, peaking decrease (Approximately linear as ω_{out} is the dominant).

$$\zeta = \frac{\omega * R * Cl}{2}$$

And the Peaking in frequency response is inversely proportional to ζ.

Because ω_{out} is the dominant as (RS ↑↑ (IDC) + CLM and body effect neglected + $\boldsymbol{CL}$ ↑↑)

Then $Q = \sqrt{\frac{g_m(C_{gd}+C_{gs})*R_{sig}}{C_l}}$

∵ Q is proportional to The peaking value, C_l is inversely proportional to Q.

∴ C_l is inversely proportional to the peaking.

6) (Optional) Perform parametric sweep: Rsig = 20k, 200k, 2M.

- Report Bode plot magnitude overlaid on same plot.

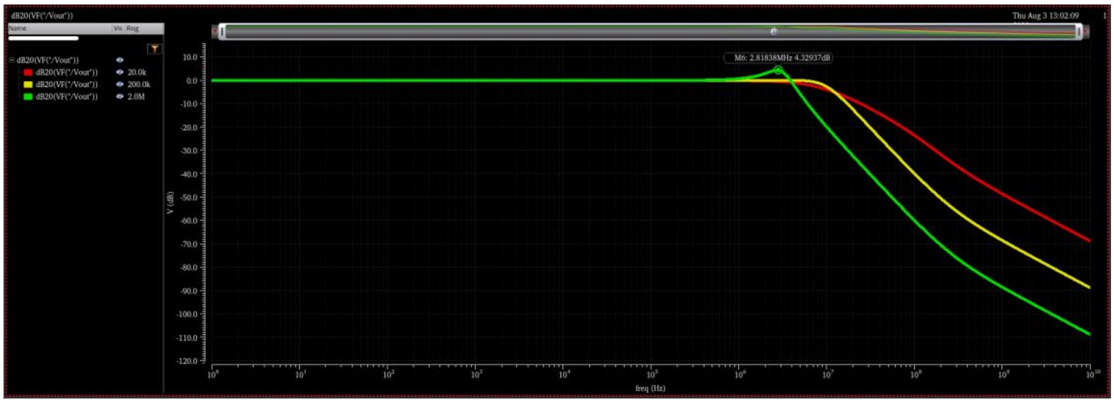


Figure 7 Bode plot at Rsig = [20K , 200K , 2M]

- Report the peaking vs Rsig

.

Parameters: Rsig=20K			
1	lab4_lab4_1	dB20(VF("/Vout"))	
1	lab4_lab4_1	ymax(dB20(VF("...	-70.73m
1	lab4_lab4_1	VF("/Vout")	
1	lab4_lab4_1	phase(VF("/Vout"))	
Parameters: Rsig=200K			
2	lab4_lab4_1	dB20(VF("/Vout"))	
2	lab4_lab4_1	ymax(dB20(VF("...	7.88m
2	lab4_lab4_1	VF("/Vout")	
2	lab4_lab4_1	phase(VF("/Vout"))	
Parameters: Rsig=2M			
3	lab4_lab4_1	dB20(VF("/Vout"))	
3	lab4_lab4_1	ymax(dB20(VF("...	4.329
3	lab4_lab4_1	VF("/Vout")	
3	lab4_lab4_1	phase(VF("/Vout"))	

Figure 8 The Peaking vs Rsig

- Comment.

The peaking is proportional to the Resistance value, as when Rsig increase, peaking increase.

Because ω_{out} is the dominant as (RS ↑↑ (IDC) + CLM and body effect neglected + $\boldsymbol{CL}$ ↑↑)

Then $Q = \sqrt{\frac{g_m(C_{gd}+C_{gs})*R_{sig}}{C_l}}$

∵ Q is proportional to The peaking value, R_{sig} is proportional to Q.

∴ R_{sig} is proportional to the peaking.

3. Transient Analysis

1) Use a pulse source (pulse_v_source) as your transient stimulus and set it as follows (delay = 2us,

initial = 0V, period = 8us, pulse_value = 100mV, t_fall = 1ns, t_rise = 1ns, width = 4us). Run transient

analysis (max step = 10n) for 10us to investigate the time domain ringing.

2) Report Vin and Vout overlaid vs time.

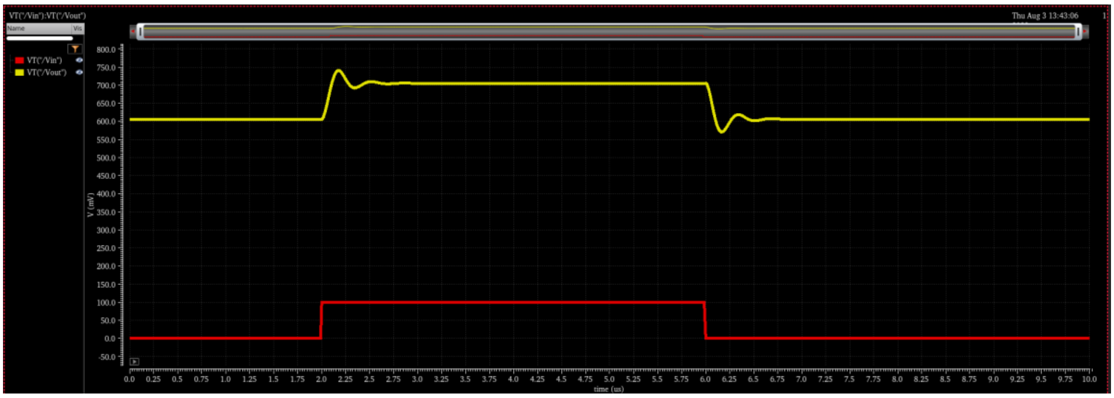


Figure 9 Vin and Vout overlaid vs time

3) Calculate the DC voltage difference (DC shift) between Vin and Vout.

• What is the relation between the DC shift and VGS?

the DC voltage difference (DC shift) between Vin and Vout is the value of VGS, as the common drain is a voltage buffer which shift DC level for input signal without any gain effect on it.

• How to shift the signal down instead of shifting it up?

To shift the signal down instead of shifting it up, we can use NMOS Common Drain instead of PMOS one.

4) Do you notice time domain ringing?

Parameters: cl=2p			
1	lab4_lab4_1	overshoot(VT("/...	35.33

Yes, and it is equal 35.33%

5) (Optional) Perform parametric sweep: CL = 2p, 4p, 8p.

• Report Vout vs time overlaid on same plot.

Figure 10 Vout vs time

• Report the overshoot vs CL.

Parameters: cl=2p			
1	lab4_lab4_1	overshoot(VT("/...	35.33
Parameters: cl=4p			
2	lab4_lab4_1	overshoot(VT("/...	29.72
Parameters: cl=8p			
3	lab4_lab4_1	overshoot(VT("/...	20.34

Figure 11 overshoot vs CL

• Comment.

C_L is inverse proportional to the overshoot, as it is the percentage of the peaking, and as ac analysis, C_L is inverse proportional to the peaking.

6) (Optional) Perform parametric sweep: Rsig = 20k, 200k, 2M.

• Report Vout vs time overlaid on same plot.

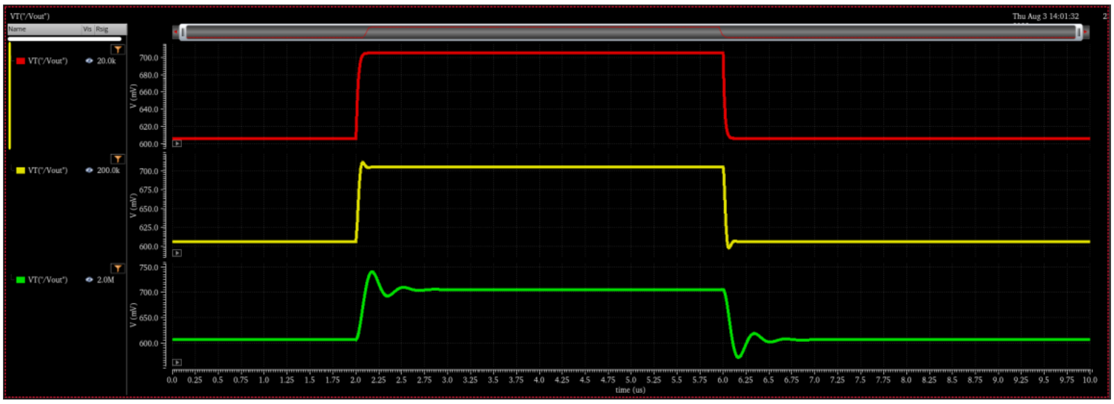


Figure 12 Vout vs time (Trace)

Figure 13 Vout vs time (overlaid)

• **Report the overshoot vs Rsig.**

Parameters: Rsig=20K			
1	lab4_lab4_1	overshoot(VT("/...	15.56n
Parameters: Rsig=200K			
2	lab4_lab4_1	overshoot(VT("/...	6.162
Parameters: Rsig=2M			
3	lab4_lab4_1	overshoot(VT("/...	35.33

Figure 14 overshoot vs Rsig

• **Comment.**

R_{sig} is direct proportional to the overshoot, as it is the percentage of the peaking, and as ac analysis, R_{sig} is proportional to the peaking.

4. Zout (Inductive Rise) (optional)

3) Plot the output impedance (magnitude and phase) vs frequency.

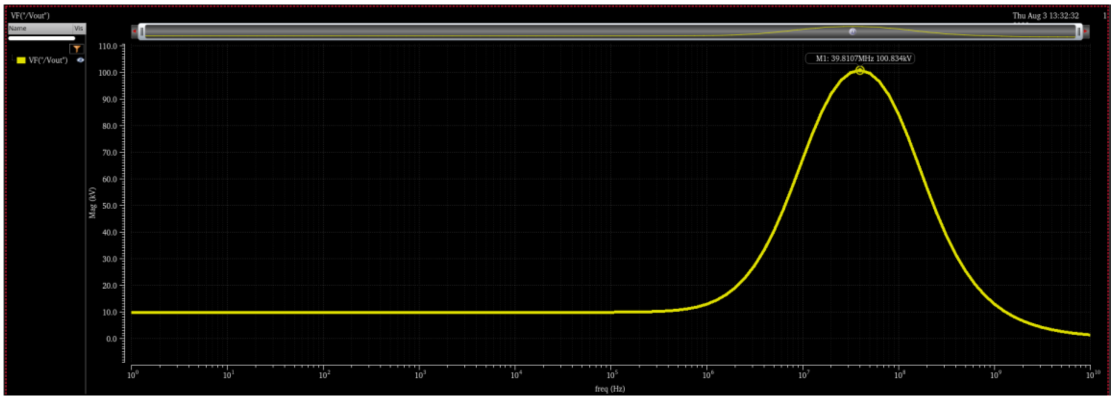


Figure 15 Rout (Magnitude)

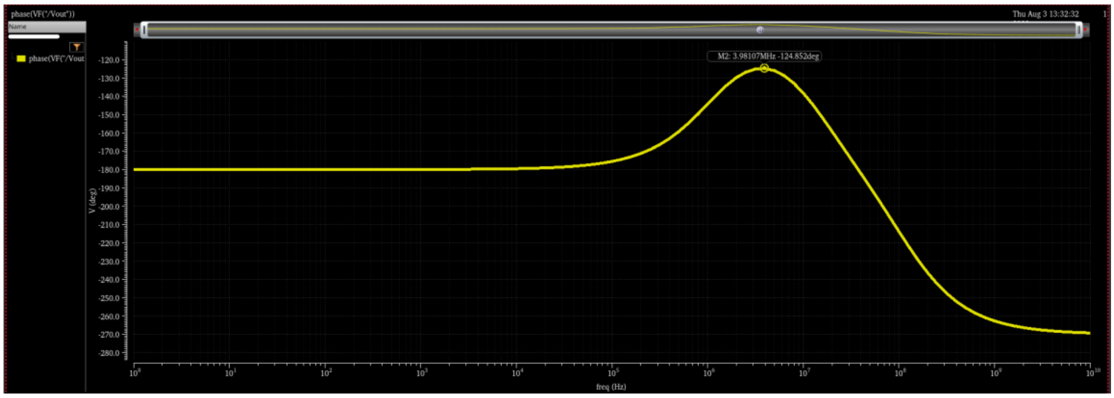


Figure 16 Rout (Phase)

Do you notice an inductive rise? Why?

To simplify: we will consider only the existence of C_{gs}

Yes, as $Z_{OUT} = \frac{v_X}{i_X} = \frac{1}{gm}\left(\frac{1+sR_{SIG}C_{gs}}{1+s\frac{C_{gs}}{gm}}\right)||r_o$

For Low ω : $Zout \approx 1/g_m$ || ro
For High ω : $Zout \approx R_{SIG}$ || ro
In our case $Rsig > 1/g_m$, $\therefore$ *the Zero comes first* (inductive rise)

4) Does Zout fall at high frequency? Why?

Yes, as $Z_{in} = R_{sig}||C_{gd} = \frac{R_{sig}}{1+sC_{gd}R_{sig}}$

$$Z_{OUT} = \frac{v_X}{i_X} = \frac{1}{gm}\left(\frac{1+sZ_{in}C_{gs}}{1+s\frac{C_{gs}}{g_m}}\right)||r_o = \frac{1}{gm}\left(\frac{(1+sR_{sig}(C_{gd}+C_{gs}))}{(1+sC_{gd}R_{sig})(1+s\frac{C_{gs}}{g_m})}\right)||r_o$$

For Low ω : $Zout \approx 1/g_m$ || ro
For High ω : $Zout \approx \frac{1}{sC_{gd}}$|| ro

$\therefore$Zout falls at high frequency.

5) Analytically calculate the zeros, poles, and magnitude at low/high frequency for Zout. Compare with simulation results in a table.

$$R_{in} = \frac{R_{sig}}{1 + sC_{gd}R_{sig}}$$

$$Z_{OUT} = \frac{v_X}{i_X} = \left(\frac{(1 + sR_{in}(C_{gs}))}{(g_m + sC_{gs})}\right)||r_o$$

$$Z_{OUT} = \frac{v_X}{i_X} = \left(\frac{(1 + sR_{sig}(C_{gs}))}{(1 + sC_{gd}R_{sig})(g_m + sC_{gs})}\right)||r_o$$

$$Y_{OUT} = \frac{i_X}{v_X} = \left(\frac{(1 + sC_{gd}R_{sig})(g_m + sC_{gs})}{(1 + sR_{sig}(C_{gs}))}\right) + \frac{1}{r_o}$$

$$Y_{OUT} = \frac{i_X}{v_X} = \left(\frac{(1 + sC_{gd}R_{sig})\big(g_m + sC_{gs}\big)r_o + (1 + sR_{sig}(C_{gs}))}{(1 + sR_{sig}(C_{gs}))r_o}\right)$$

$$Z_{OUT} = \frac{v_X}{i_X} = \left(\frac{(1 + sR_{sig}(C_{gs}))r_o}{(1 + sC_{gd}R_{sig})\big(g_m + sC_{gs}\big)r_o + (1 + sR_{sig}(C_{gs}))}\right)$$

$$Z_{OUT} = \frac{v_X}{i_X} = \left(\frac{(1 + sR_{sig}(C_{gs}))r_o}{((g_m r_o + 1) + s\big((g_m C_{gd}R_{sig} + C_{gs})r_o + R_{sig}(C_{gs})\big) + s^2 C_{gs}C_{gd}R_{sig}r_o)}\right)$$

$$f_{Zero} = \frac{1}{2\pi * R_{sig}C_{gs}} = 1.3\ MHz$$

$$Z_m \approx \left(\frac{r_o(1 + sR_{sig}C_{gs})}{\big(1 + sC_{gd}R_{sig}\big) + r_o(g_m + sC_{ds})}\right)$$

$$f_{poleo} = \frac{1}{2\pi * \dfrac{C_{gs} + (R_{sig}g_{ds}C_{gs})}{\big(g_m + g_{ds}\big)}} = 103.2M$$

$$f_{pole2(domenant)} = \frac{1}{2\pi * C_{gd}R_{sig}} = 14.02\ MHz$$

Figure 17 zeros, poles

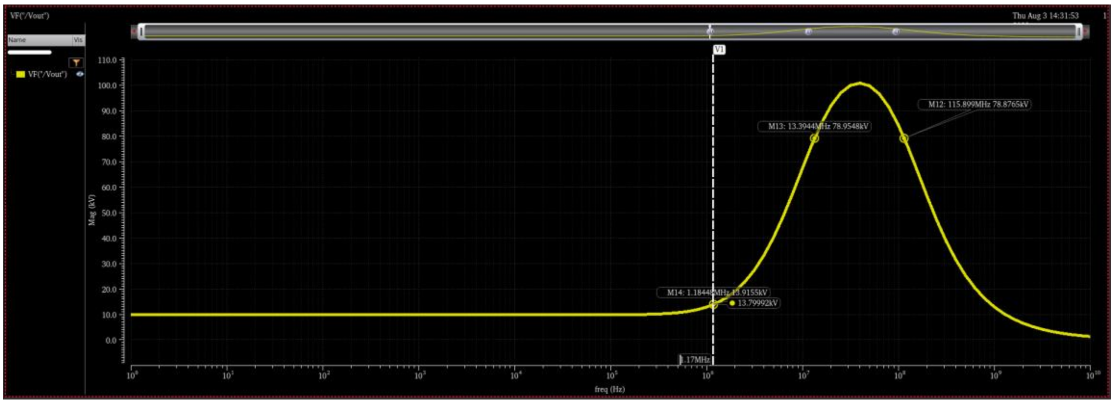


Figure 18 Rout vs frequency

	Analytically	simulation	Magnitude
Zeros	1.3M Hz	1.2M Hz	13.9 KV
Poles 1	103.2M Hz	115.9M Hz	78.9 KV
Poles 2	14.02M Hz	13.4M Hz	78.9 KV