

Analog IC Design – Cadence Tools & SA

Lab 06

Differential Amplifier

Part 1: Differential Amplifier Design

$$R_D = 30\text{ K}\Omega$$

$$V^* = 0.1356$$

The screenshot shows the ADT Sizing Assistant window. It has a title bar with 'ADT Sizing Assistant' and standard window controls. Below the title bar are 'Settings' and 'Help' buttons. A 'LUT Settings' section is expanded, showing a 'State1' dropdown and a 'Save State' button. Below this are several input fields with dropdown menus: 'ID' (20u), 'Vstar' (1.82*0.6/8), 'ro' ((0.6/ID)*10), 'VDS' (0.9), 'VSB' (0.3), and 'Stack' (1). There are 'Get' and 'Apply' buttons below these fields. A 'Y-Expr' dropdown is set to 'ID/CGG'. Below this are 'Plot', 'Replace', and 'Append' buttons. At the bottom is a 'Device Parameters' table with 23 rows and 3 columns: '#', 'Parameter', and 'Value'.

#	Parameter	Value
1	ID	20u
2	L	420n
3	W	15.88u
4	VGS	643.3m
5	VDS	900m
6	VSB	300m
7	gm/ID	14.42
8	Vstar	138.7m
9	rt	797.4M
10	gm/gds	86.81
11	VA	6.021
12	ID/W	1.259
13	gm/W	18.16
14	AREA	6.67p
15	gm	288.4u
16	gmb	78.47u
17	gds	3.322u
18	ro	301k
19	VTH	527.4m
20	VDSAT	111.7m
21	cgg	57.56f
22	cgs	45.3f
23	cgd	10.05f

Figure 1 the input pair sizing using SA

$$L=420\text{n} , W=15.88\text{u}$$

8) Give the above assumption, calculate the CM input level. Calculate the min and max CM input levels. Is the selected CM input level in the valid range?

$$V_{iCM} = V_{DD} - V_{SGdiff} - V_{SDCS} = 1.8 - 643.3\text{m} - 300\text{m} = 856.7\text{ mV}$$

Yes, the selected CM input level is in the valid range as $ViCMmin < ViCM < ViCMmax$



Figure 3 the schematic of a differential amplifier

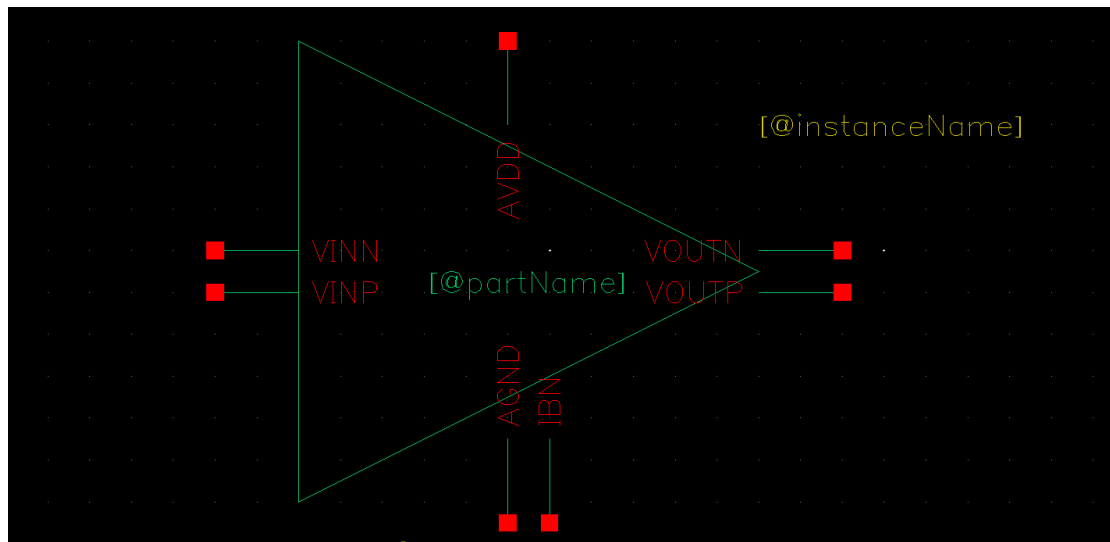


Figure 4 symbol for the diff pair

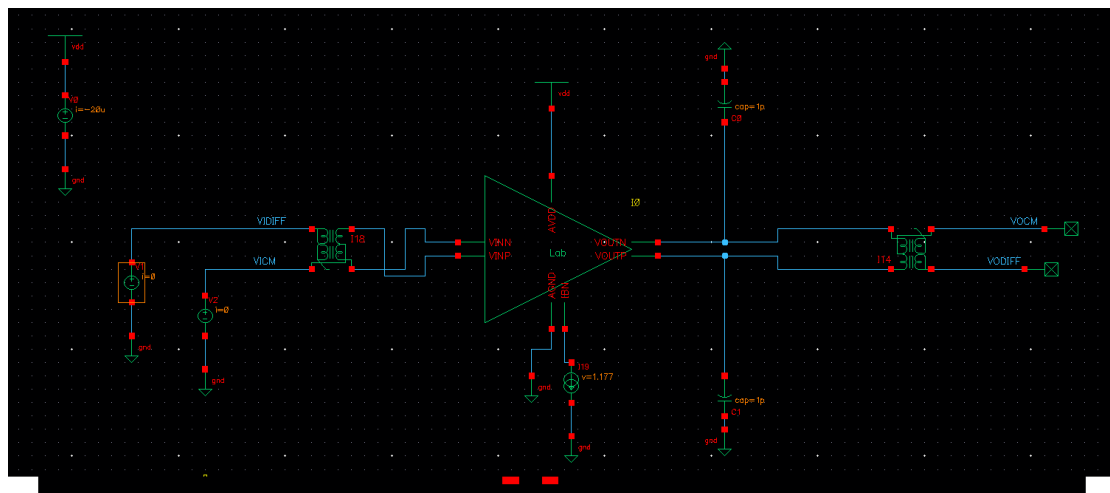


Figure 5 the testbench schematic

1) OP simulation

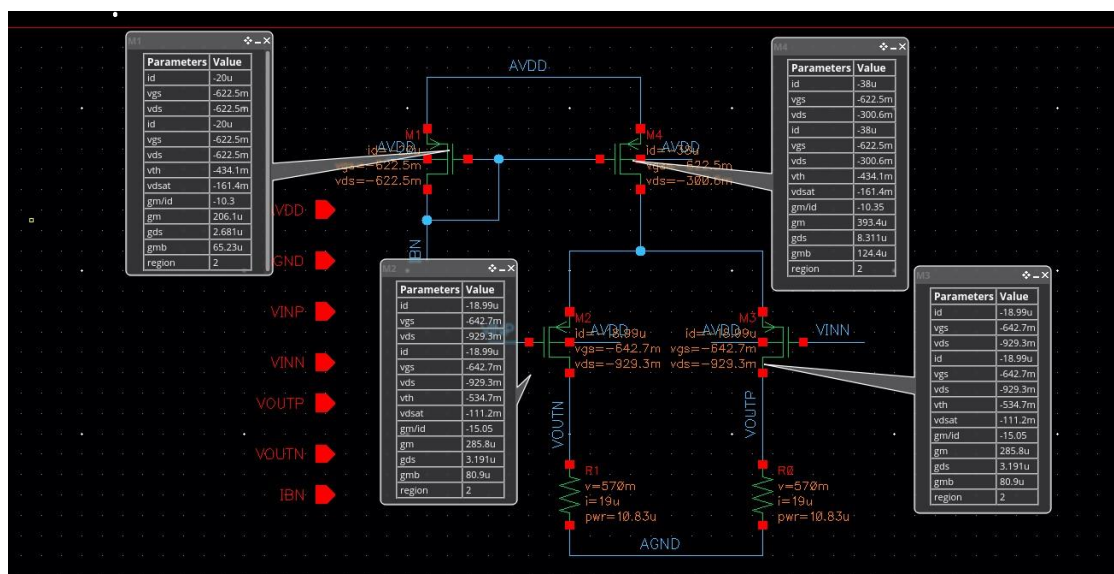


Figure 6 DC OP point

all transistors operate in saturation, as Region = 2

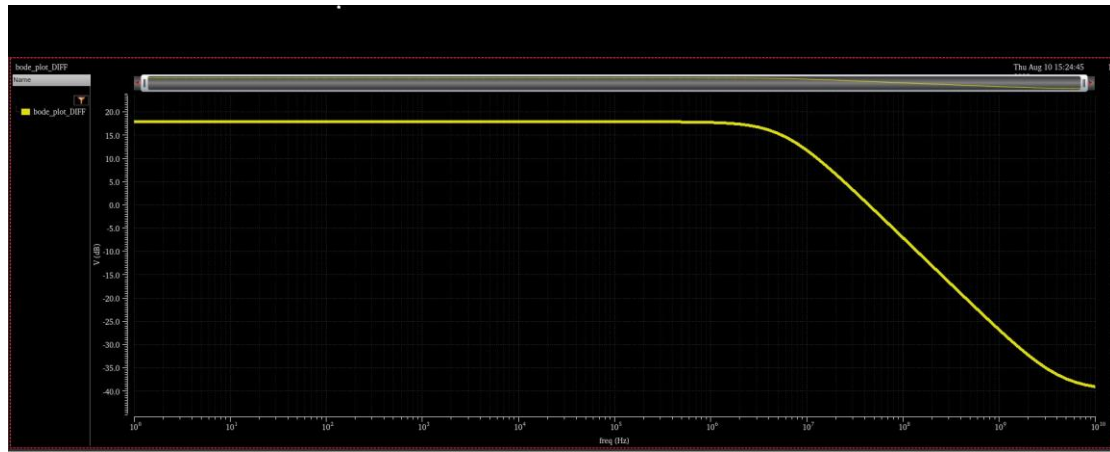


Figure 7 the Bode plot of small signal diff gain

$$\text{Simulation gain} = 10^{\frac{17.86}{20}} = 7.82$$

Name	Type	Details	Value	Plot	Save	Spec
	expr	VF("VODIFF")		<input checked="" type="checkbox"/>	<input type="checkbox"/>	
	expr	bandwidth(VF("VODIFF") 3 "low")	5.697M	<input checked="" type="checkbox"/>	<input type="checkbox"/>	

Figure 8 BW_DIFF

$$\text{BW (If we ignored the parasitic capacitance)} = \frac{1}{2\pi \cdot 30K \cdot 1p} = 5.305M$$

$$\text{The DC CM gain} \approx g_m \cdot (R_D || r_o) = 7.8$$

	Simulation	Hand Analysis
BW	5.7M	5.305M
The DC diff gain	7.8	7.8

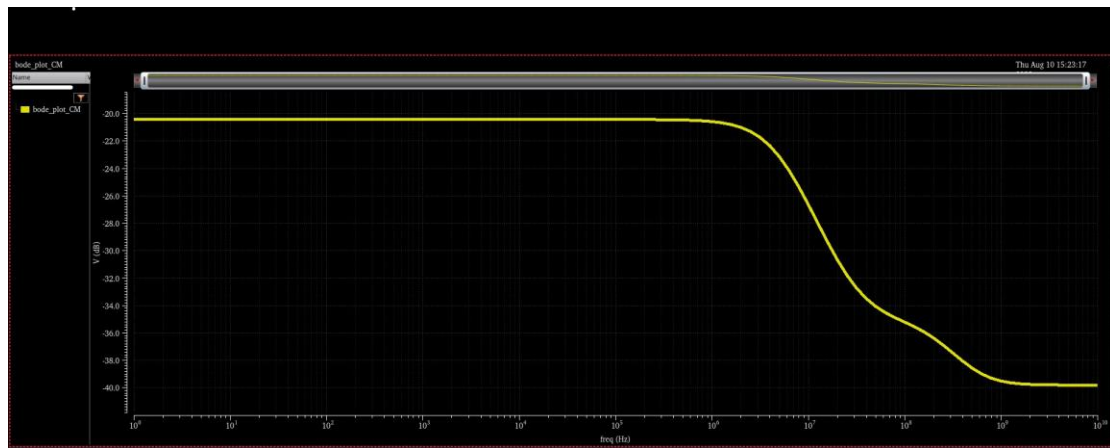


Figure 9 the Bode plot of small signal CM gain

CM_BW	expr	bandwidth(VF("VOCM") 3 "low")	5.388M
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Figure 10 BW_CM

$$\text{BW} = \frac{1}{2\pi \cdot 30K \cdot 1p} = 5.305M$$

$$\text{The DC CM gain (AvCM)} = -\frac{g_m(R_D || (r_o(1 + (g_m + g_{mb})(2R_{SS}))))}{(1 + (g_m + g_{mb})(2R_{SS}))} = -0.072 \text{ m}$$

$$R_{SS} = \frac{1}{g_{ds1,4}} = 120.3 \text{ K}\Omega$$

$$r_o = \frac{1}{g_{ds2,3}} = 313.4 \text{ K}\Omega$$

	Simulation	Hand Analysis
BW	5.388M	5.305M
The DC diff gain	0.08	0.072

- Is it smaller than “1”? Why?

Yes, due to the degeneration of the output resistance of the current source.

- Justify the variation of A_{vcm} vs frequency.

A_{vcm} has a small value, as R_{ss} has high value, and it attenuates, due to the poles ($c=1p$, parasitics).

- Plot A_{vd}/A_{vcm} in dB. Compare A_{vd}/A_{vcm} @ DC with hand analysis in a table.

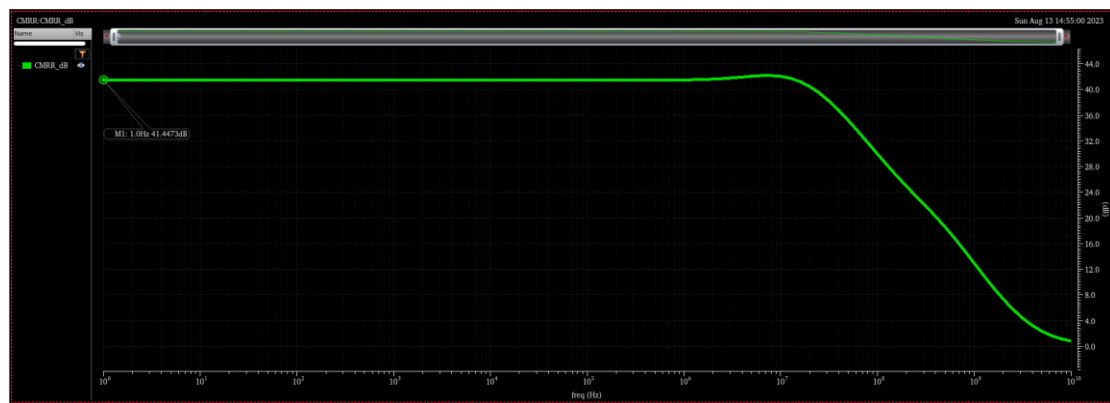


Figure 11 CMRR dB

Analytically $A_{vd}/A_{vCM} = 108.33 = 40.7 \text{ dB}$

- Justify the variation of A_{vd}/A_{vcm} with frequency

CMRR follow A_{vd} as it has large variation from 20dB to -40dB but A_{vcm} has little variation from -20dB to -40dB so the variation of A_{vd}/A_{vcm} with frequency will be like the variation of A_{vd} with frequency.

4) Diff large signal ccs:

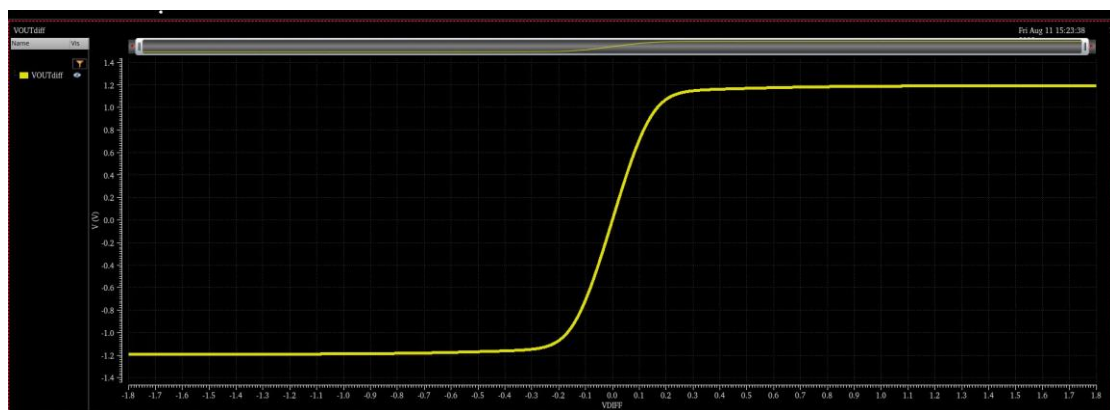


Figure 12 VODIFF vs VIDIFF

Analytically

The extreme values = $\pm I_{ss} R_D = \pm (40 \mu A)(30 \text{ k}\Omega) = \pm 1.2 \text{ V}$

	Simulation	Hand Analysis
Extreme Values	$\pm 1.194\text{ V}$	$\pm 1.2\text{ V}$

5) CM large signal ccs (region vs VICM):

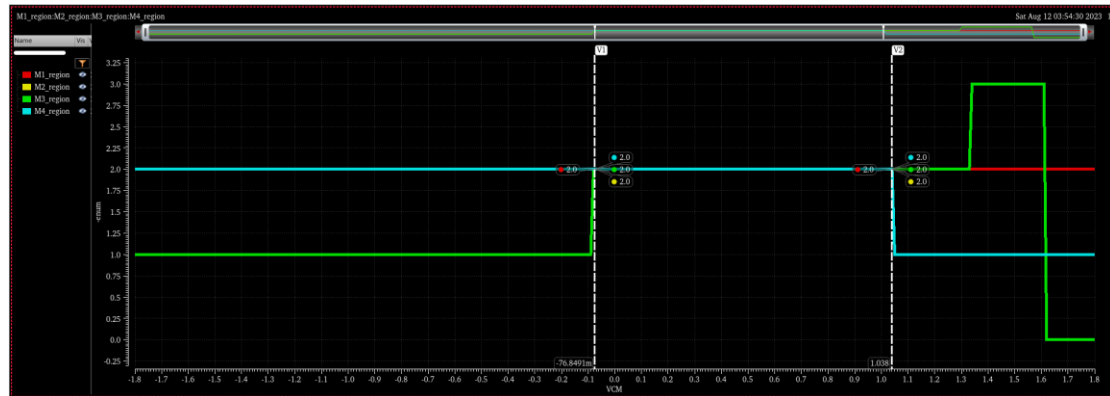


Figure 13 Region vs Vicm

- The CM input range (CMIR) is from -76.85 mV to 1.04 V

Hand Analysis

$$ViCm_{max} = VDD - VSG_{diff} - V_* = 1.0202\text{ V}$$

$$ViCm_{min} = VRD - VTH = 72.6\text{ mV}$$

	simulation	Hand Analysis
$ViCm_{max}$	1.04 V	1.0202 V
$ViCm_{min}$	-76.85 mV	72.6 mV

6) CM large signal ccs (GBW vs Vicm):

MAX GAIN DIFF = 7.864 V

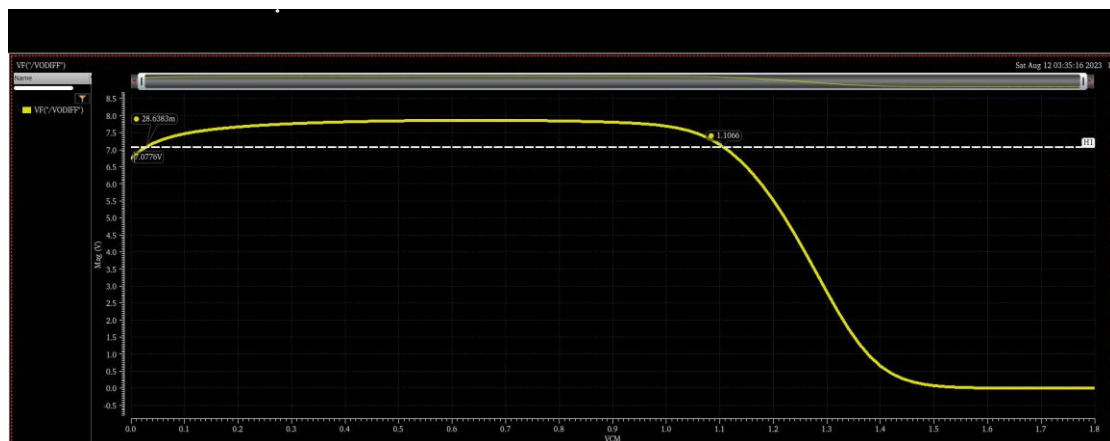


Figure 14 Avd vs Vicm

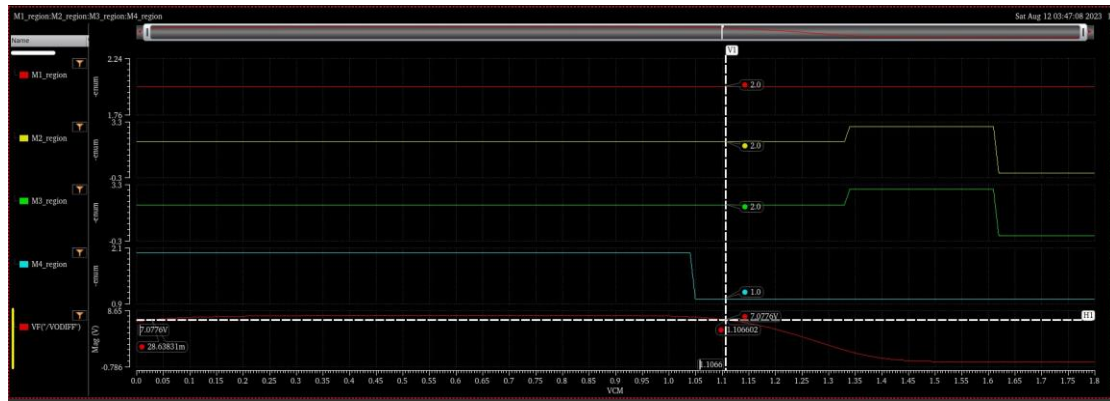


Figure 15 Region parameter & Avd vs Vicm

The CM input range = 28.6m : 1.1 V

	From	TO
Avd 90%	28.6m	1.1
Region	-76.85m	1.04