EE537 Circuit Simulation Lab
Experiment 5

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Aim: Design of common drain and cascode amplifier using MOS transistors.

In this simulation experiment, we will be using GPDK 0.18 μ m technology and VDD= 1.8 V. Following are the tasks to be done and in all the questions include your hand calculations which you have used to arrive at the initial transistor sizing.

1 Design a Common-Drain (CD) amplifier stage

Design a CD amplifier with current source(MOS) load having total current consumption of 100 μA, minimum output voltage swing (Vout,pp) of 500 mV, CL = 5 pF.

1.1 With body connected to source

For common drain with no body effect the gain is given by

$$Av = \frac{gm1}{gm1 + \frac{1}{ro1} + \frac{1}{ro2}} \tag{1}$$

Now we know that

$$Vo > 250mV + Vov \tag{2}$$

Taking Vov to be around 100mV we can say that the output voltage should be greater that 350mV Considering Vgs = 547mV Put the values in the square law equation we get the value of W/L >32 the lower nmos. We can find the Vds for the upper Nmos as Vdd- Vds(Lower Nmos) Vds of lower Nmos is considered to be 400mV so Vds of upper NMos is 1.4V The value of Vg for upper nmos can be taken to be lower than 1.4V for keeping the circuit in saturation. The Value of W/L calculated from the square law model is given to be around 40. The gain observed in this case is around 0.992. To get the proper swing we need to calculate amplitude which is equal to (output amplitude swing)/Gain

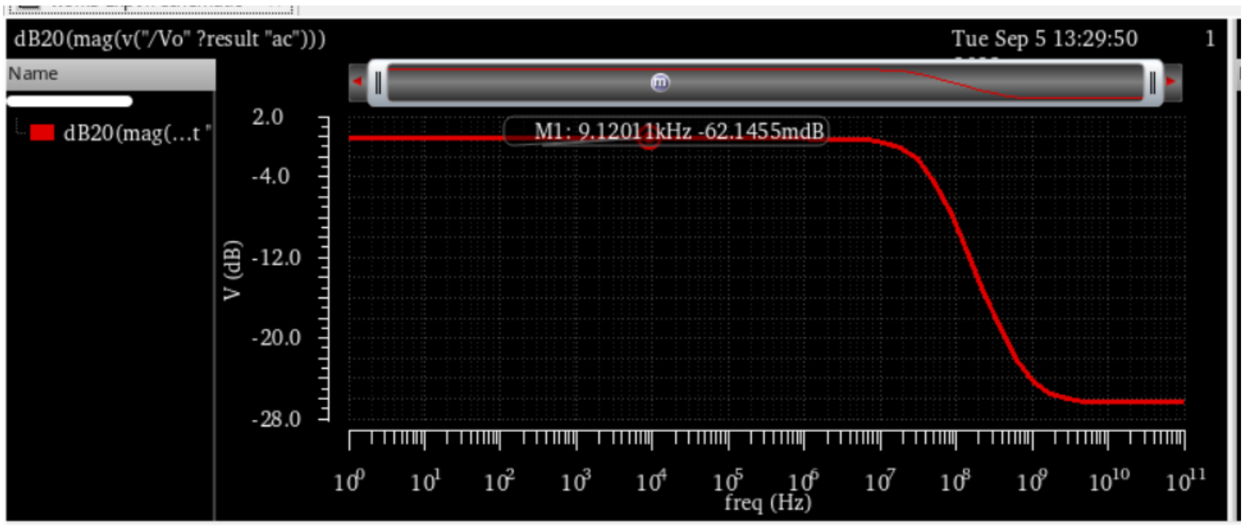

Figure 2: AC response of CD amplifier with Current source

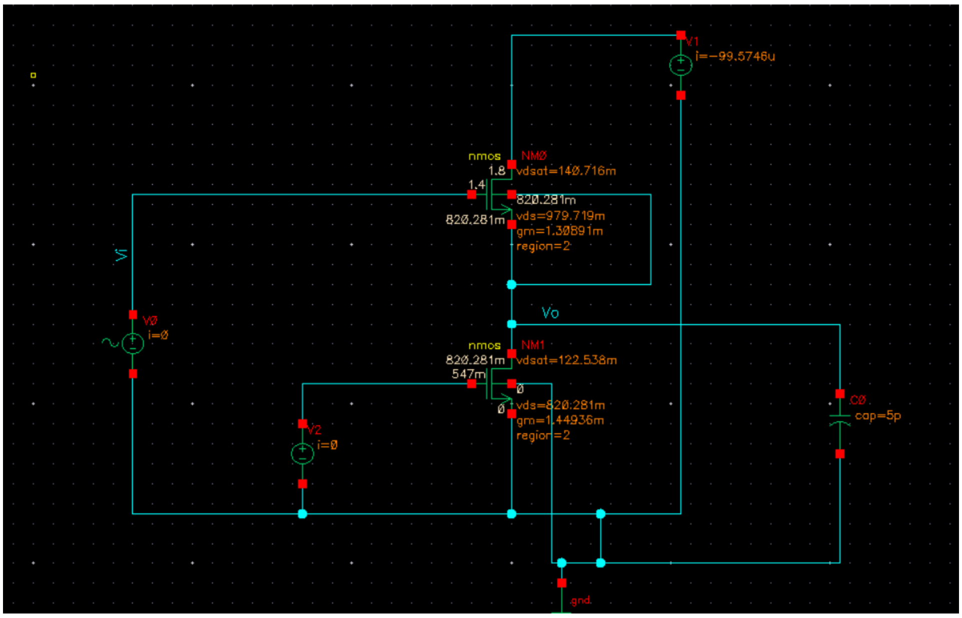

Figure 1: ckt of CD amplifier with nmos current source

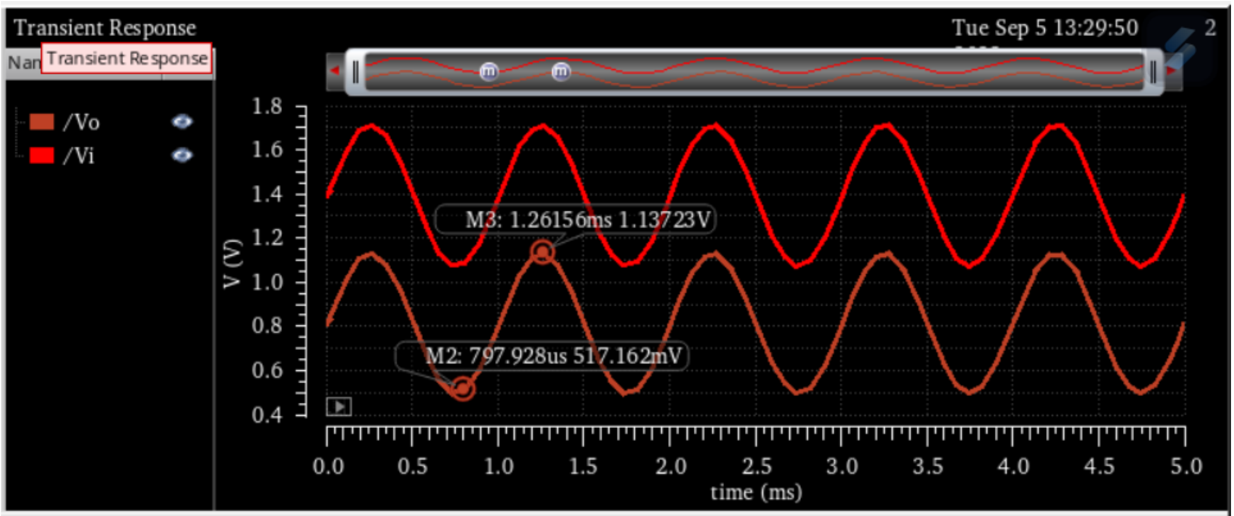

Figure 3: Transient response of CD amplifier connected to current source

1.2 With body not connected to source

In this case the gain can be given as

$$Av = \frac{gm1}{gm1 + gmb1 + \frac{1}{ro1} + \frac{1}{ro2}} \tag{3}$$

Here also we can say that the value of Vo > 250mV + Vov Again considering Vov to be around 100mV we can say that the output volage bias should be greater than 350mV to sustain the swing that is required. This time taking the Vgs as 547mV and putting the values in the square law model we get W/L > 32 for lower NMOs and again solving like we have done in the first part but this time the regions are not in the saturation and current is less than 100μA. So increasing the voltage to 600mV and keeping the upper mos voltage almost similar Taking μnCox to be 0.3m and solving the square law model we get the W/L around 60 For the upper nmos doing the similar we get W/L to be around 45. Modifying these values we can get the maximimum gain when W/L for lower mosfet is 22.22 and for upper it is around 44. The maximum gain that is observed in this case is around 0.813. To get the proper swing we need to calculate amplitude which is equal to (output amplitude swing)/Gain

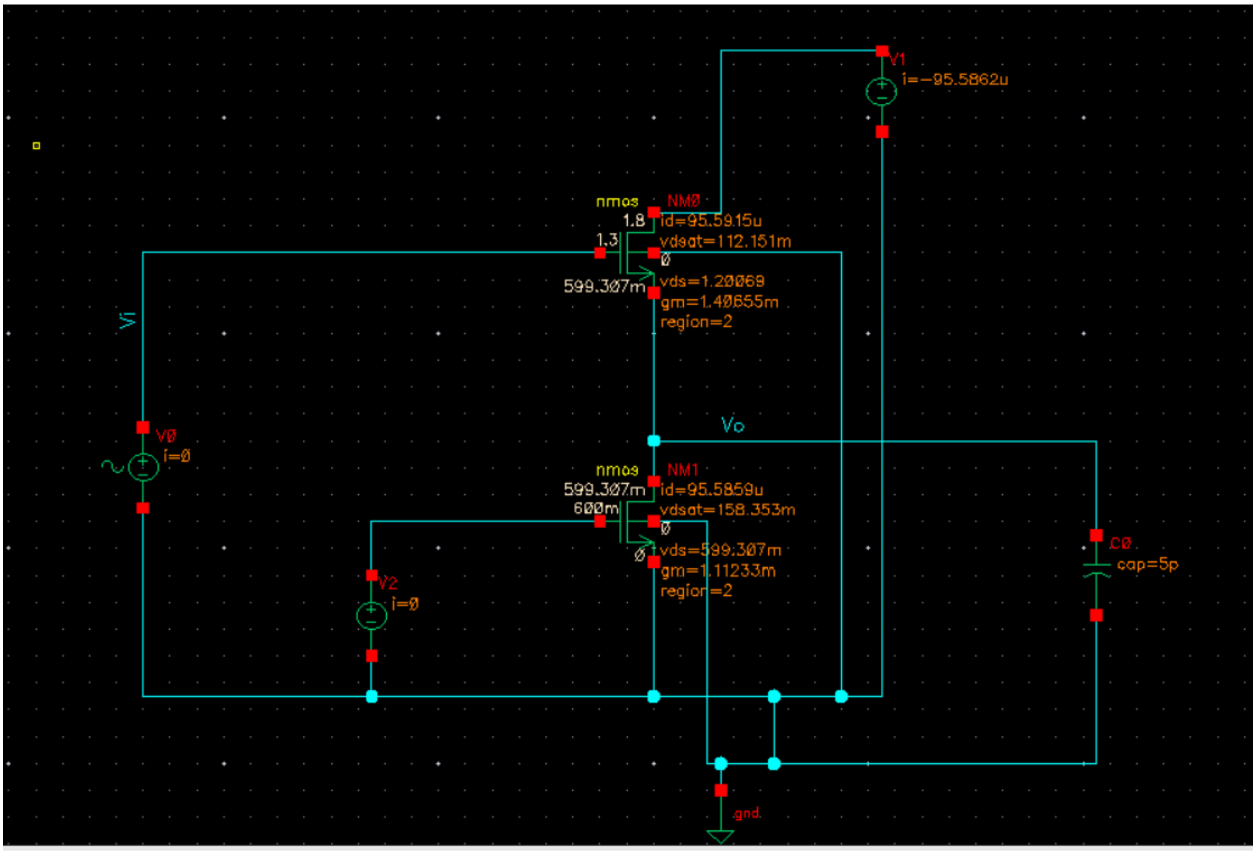

Figure 4: ckt of CD amplifier with nmos current source with body effect

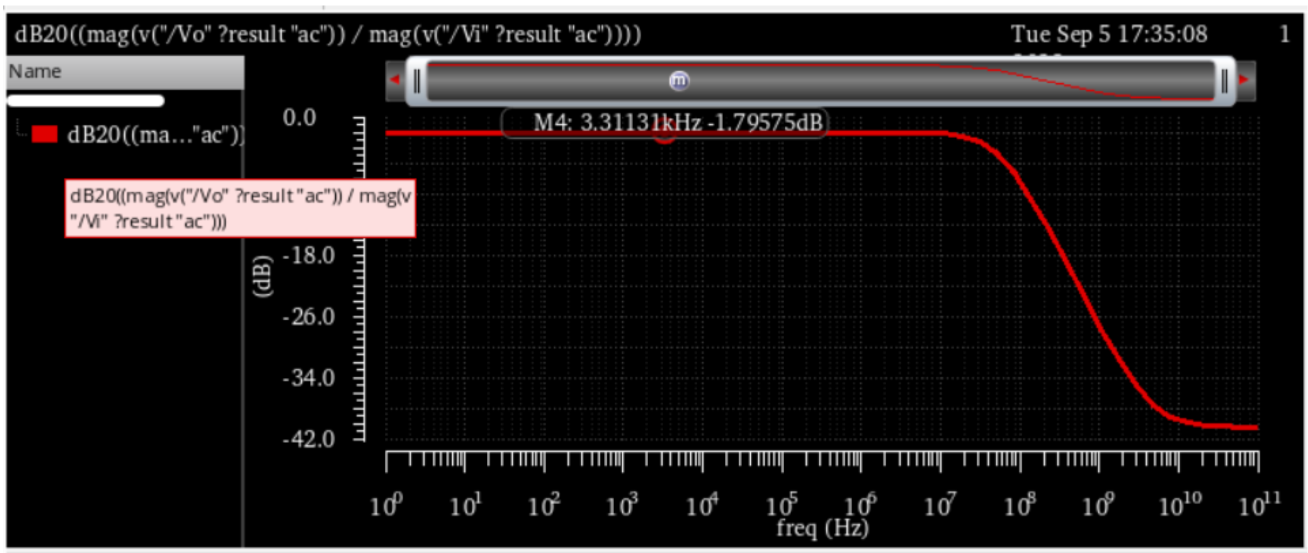

Figure 5: AC response of CD amplifier with Current source with body effect

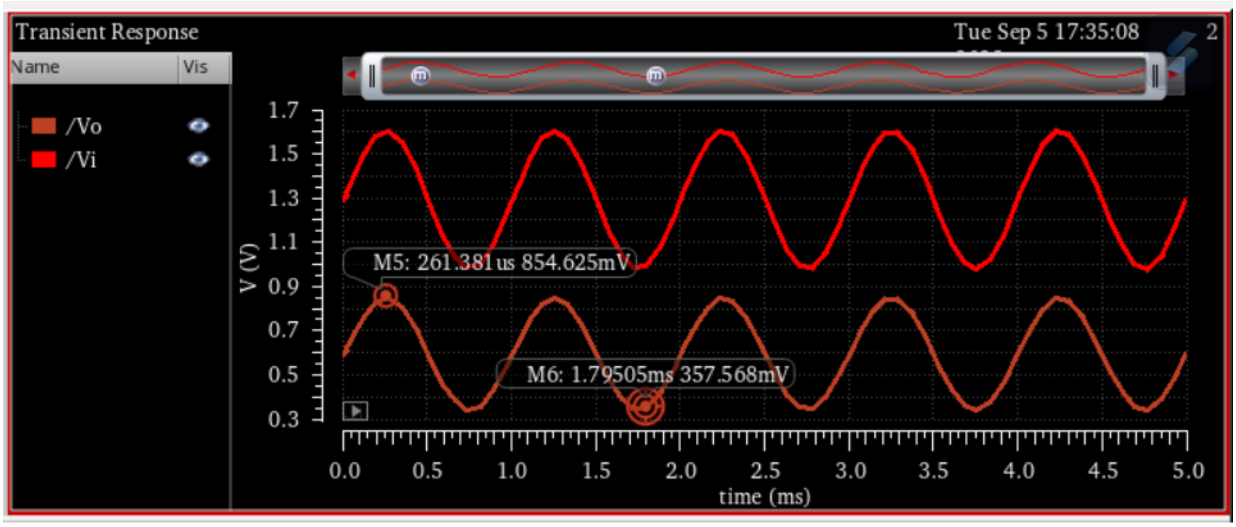

Figure 6: Transient response of CD amplifier connected to current source with body effect

1.3 Plot the frequency behaviour of the Output impedance(without CL). Use a source resistance of Rs = 100 KOhm and Rs = 0 at the input for output impedance calculation. Explain the results.

The values of output resistance is given by

$$Ro = \frac{1}{gm1} \tag{4}$$

No body effect is considered in these cases. gm1 = 1.30891mS Hence the value of Ro = 763.9 Ω

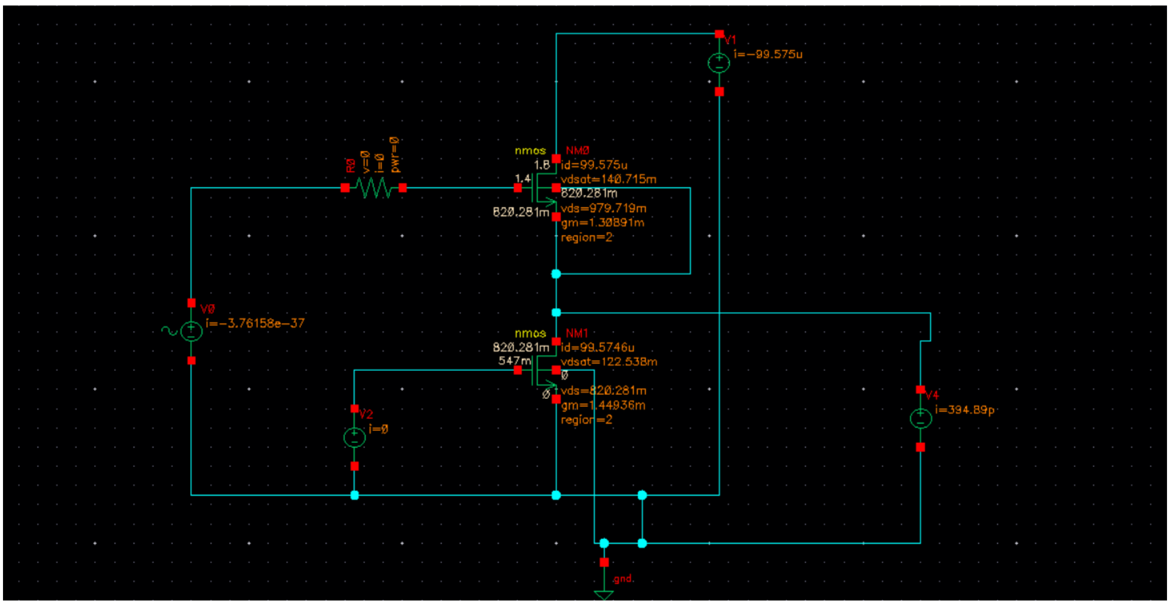

Figure 7: Ckt for calculating the output resistance Rs = 100 kohm

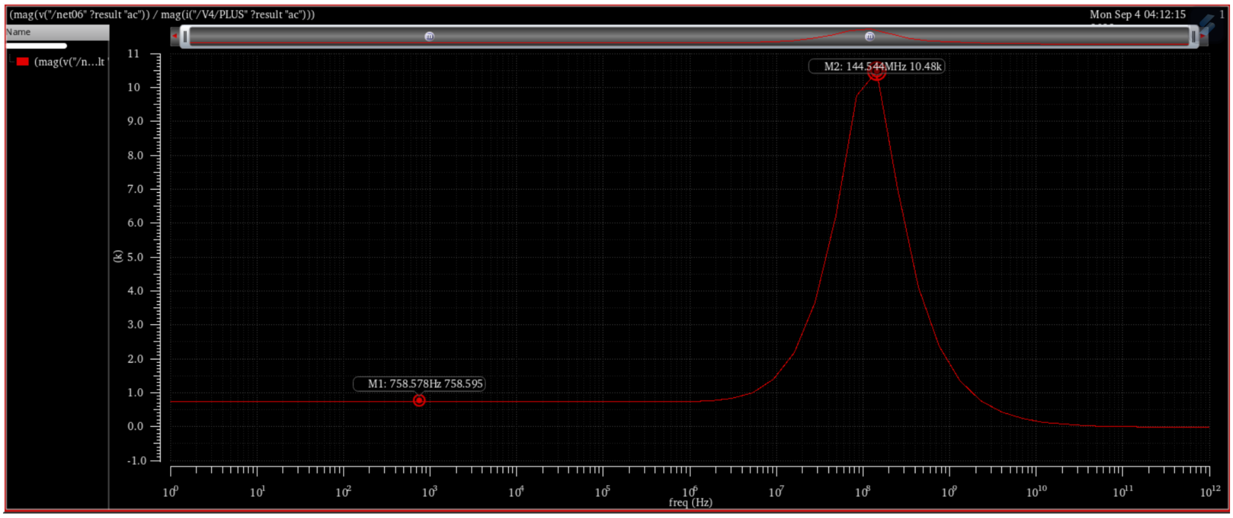

Figure 8: Output resistance vs frequency Rs=100 kohm

For the Rs = 0 and Rs=100k Ω the initial values of the output resistance remains same but as the frequency increase in case of Rs=100kohm the value of resistance tends to approach Rs but when the frequency is increased the value will again come down and approaches 0ohm as observed in 1st case.

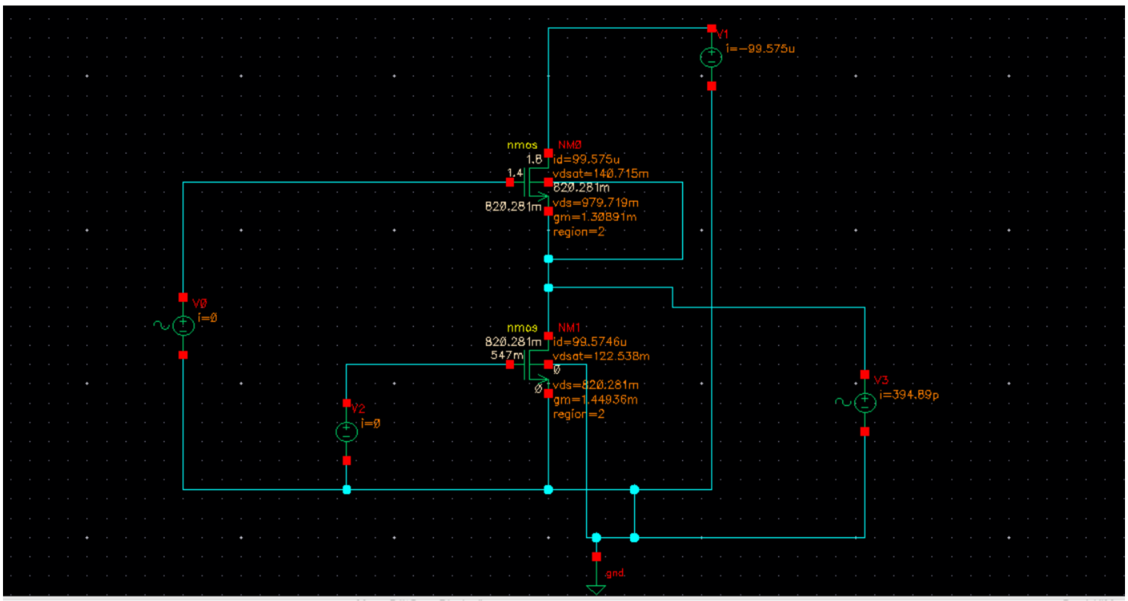

Figure 9: Ckt for calculating the output resistance Rs = 0 kohm

Figure 10: Output resistance vs frequency Rs=0 kohm

2 Design a Cascode amplifier stage

Design a Cascode amplifier with ideal current source load, total current consumption of 100 μA, minimum output voltage swing (Vout,pp) of 500 mV, CL = 5 pF, fugb > 40 MHz and maximize the voltage gain.

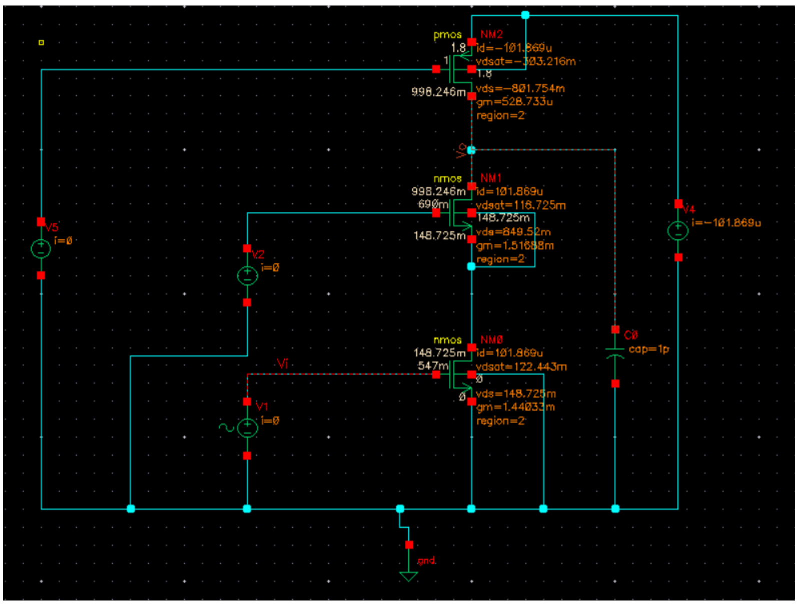

Figure 11: Circuit diagram of cascode amplifier

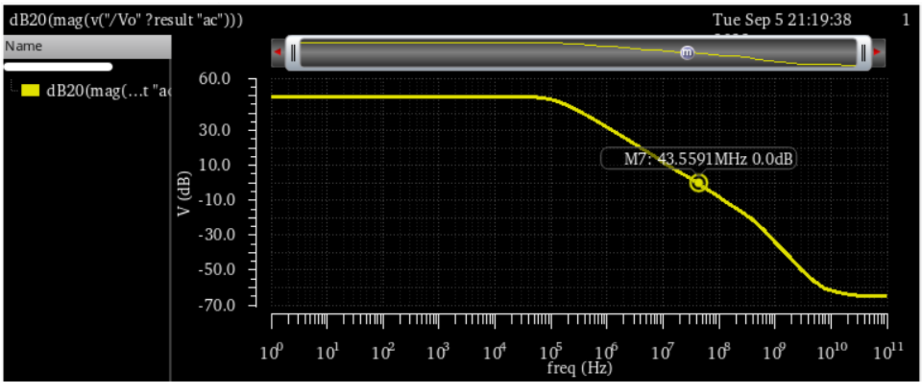

Figure 12: Ac response of cascode amplifier

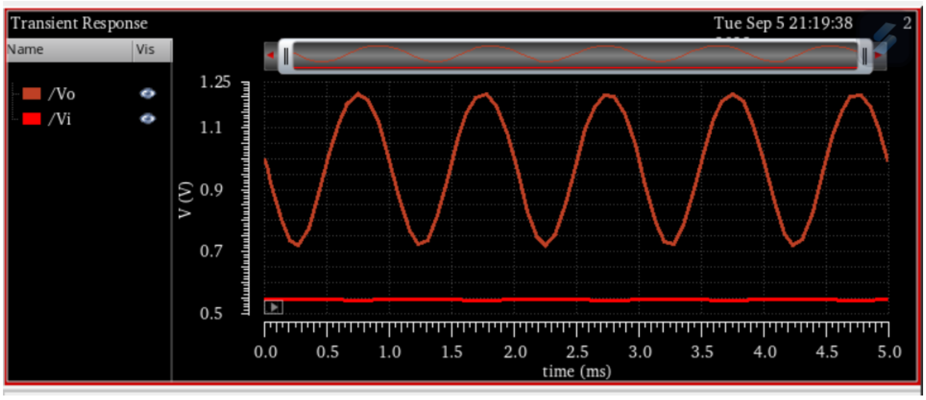

Figure 13: Transient response of cascode amplifier

Here in the cascode amplifier also we can approach this problem in a similar way fugb > 40MHz

$$\frac{gm}{2\pi Cl} > 40MHz \tag{5}$$

or gm > 1.26mS For maximum gm the mosfet should be in the subthershold region. i.e. Vgs-Vt should be small Taking Vgs to be around 550mV and finding the W/L we get W/L to be near around 42. Vo has to be atleast 400mV (250m+100m) to sustain the swing. The voltage of the gate of middle mosfet is Vs + Vt. Assuming Vds of lower mosfet to be around 200mV. The value of W/L of middle mosfet can be set similar to the one which is that of lower Mos keeping the Vgs same as before. This will result in similar currents in both circuits. The value of Vg of pmos is set to be around 1V and the W/L is calculated using the square law equation. the value of W/L comes near to 22. Gain observed in this case is around 50dB and to get the proper swing the output swing has to be divided by two times the gain. This will result in around 250mV above and below.

3 Comparison of basic gain stages

Present a comparison table, comparing all the basic amplifier stages that you have designed in experiment 4 and 5 in terms of gain, bandwidth, unity gain bandwidth, input impedance, output impedance, voltage swing, power dissipation, etc.

	GAIN	BANDWIDTH	UGB	I/P IMPEDANCE	O/P IMPEDANCE	VOLTAGE SWING	PD
CS(resistive load)	25.633dB	2.519MHz	48.545MHz	infinity	14kohm	487mV	39.49microwatts
CS(Diode connected)	18.554dB	5.928Mhz	50.062MHz	infinity	617ohm	499mV	36.889microwatts
CS(PMOS CS)	44.085dB	293.965kHz	47.7929MHz	infinity	169.314kohm	521mV	59.352microwatts
CS(Source degeneration)	18.101dB	2.4294MHz	19.716MHz	infinity	12.97kohm	496mV	30.854microwatts
CG amplifier	27.7167dB	2.49266MHz	62.6157MHz	575.831ohm	12.56kohm	493mV	39.764microwatts
CD amplifier	-62.145mdB			infinity	761ohm	515.8mV	81.679microwatts
CASCODE amplifier	50.252dB	130.62kHz	43.559MHz	infinity	2.9Mohm	486mV	0.1mW

Figure 14: Comparison table