EE518 Analog IC-DESIGN LAB
Experiment 4

Design and Analyze CS, CG, and CD amplifier with current-mirror load.

Submitted by,
KOTAPATI VAMSHI KRISHNA
Roll No-234102412
Mtech in VLSI and Nanoelectronics
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Contents

1 EXPERIMENTS

Design and Analyze CS, CG, and CD amplifier with current-mirror load.

2 OBJECTIVE

- Design and Analyze CS, CG, and CD amplifiers with current-mirror load.
- Compare your results of the corresponding amplifier using the Ideal Current Source as a load.
- Find the voltage gain for each configuration
- Find the output voltage and output impedance for each configuration

3 Theory

3.1 Theory for common source amplifier

In a common-source (CS) amplifier, the input signal is applied to the gate and the output signal is taken from the drain. The CS amplifiers has infinite input impedance,and a moderately high output resistance , and a high voltage gain . A common source amplifier has a very high input impedance, which means that it draws very little current from the input signal source. This makes it ideal for amplifying voltage signals from high impedance sources, such as sensors or antennas.

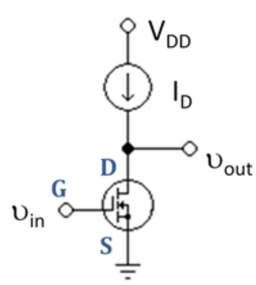

Figure 1: Cs amplifier

3.2 Theory for common gate amplifier

In this circuit, input is applied between source and gate and output is taken between drain and gate.

In CG Configuration, gate potential is at constant potential. so, increase in input voltage Vi in positive direction increase the negative gate source voltage. Due to ID reduces,the drop IDRD. Since VD= VDD-IDRD, the reduction in ID results in an increase in output voltage. typically the common gate used as a current buffer or voltage amplifier

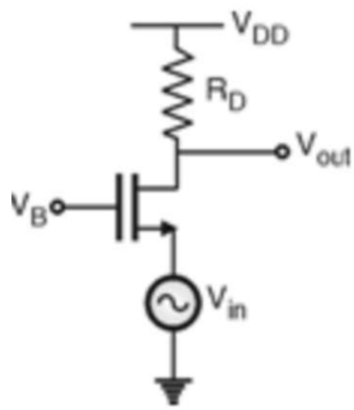

Figure 2: Cg amplifier

3.3 Theory for common drain amplifier/Source follower

A common-drain amplifier is one in which the input signal is applied to the gate and the output is taken from the source, making the drain common to both, Because it is common, there is no need for a drain resistor.

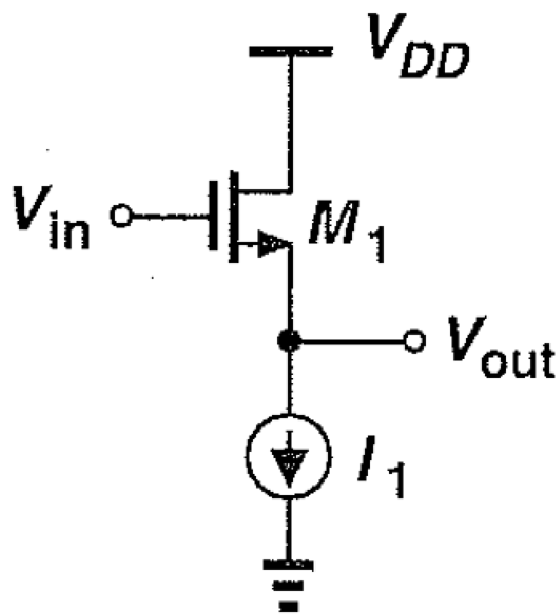

Figure 3: Cd amplifier

4 Definition of some parameters

4.1 Trans conductance ($\mathbf{g_m}$

Trans conductance indicates that how effectively a device signifies changes in input voltage to variations in output current.

$$g_m = \frac{dI_{ds}}{dV_{gs}} \tag{1}$$

4.2 Threshold Voltage($\mathbf{V_{th}}$)

The gate-source voltage at which the mosfet attains inversion or it can be said that it is the gate-source voltage above or below which nmos or pmos is turned on. The transconductance curve is differentiated or drain current is double differentiated w.r.t gate-source voltage and the gate-source voltage at which the derivative is maximum gives us the threshold voltage.

$$V_{th} = V_{gs} \ at \ which \ \frac{d^2 I_D}{dV_{GS}^2} \ is \ maximum \tag{2}$$

4.3 Early Voltage($\mathbf{V_A}$)

In a MOSFET the channel length becomes smaller as a consequence of the drain space charge widening leading to smaller channel resistance and higher drain current. This effect is known as the Early effect in MOSFET. The voltage associated with this is early voltage.

$$V_A = \frac{1}{r_o I_{D_{sat}}} \tag{3}$$

4.4 Channel length modulation parameter(λ)

As (V_{DS}) increases beyond the overdrive voltage, the pinch-off point moves away from the drain end side and thus the effective channel length is reduced. However due to this, the current is not constant in the saturation region and starts to increase, and output resistance also reduces. This is called channel length modulation and the parameter representing the effect of reduced channel length is channel length modulation parameter.

$$\lambda = \frac{1}{V_A} \tag{4}$$

5 AC analysis

Ac analysis generally we did to find out small signal response of the circuit.we generally apply the AC and DC waves as the input ,here DC voltage is used for make the transistor in proper bias ,then we analyse the how AC input will get the gain .

5.1 AC parameters

5.1.1 voltage Gain A_v:

Voltage gain is the one of the important parameter in AC analysis.It tells how much input amplifies by the circuit.generally we find out voltage gain by divide the small signal voltage output by the small signal voltage input.so maximum value of gain in the bode plot of gain treated as the voltage gain of the circuit.

$$A_v = \frac{v_{out}}{v_{in}} \tag{5}$$

5.1.2 Cut off frequency f_c:

cut off frequency is up to which we have the half power .because to get proper gain we need at least half power. It is also called the 3db frequency ,because half power means we need to have the 70 percentage of Voltage .we are going to plot the gain versus frequency graph which is the bode plot. so it will be frequency at which gain will the 3db less than the maximum value of gain.

cut off frequency= $\text{frequency}_{\text{at 3db less than maximum gain}}$

5.2 Source Drain resistance R_{ds}

r.It is used for analysis the gain of the circuit and also useful to design the current source.To find out the output resistance we can use the Channel length modulation parameter(λ) and Id at VGS-Vth.

$$Rds = \frac{V_A}{I_{ds}} \tag{6}$$

6 Design Approach for Maximum gain for CS amplifier

Here we need to design circuit which gives the bandwidth of 10Mhz.and they provided the Supply voltage of 1.8V, Available Golden current source of 10uA and Load cap of 100fF.we know that gain and Band width is constant. so we find out the gain and Bandwidth and find out the gm ,so we know how much Vgs-Vth required to get required Bandwidth

we know saturation current equation is:

$$I_D = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}(V_{GS} - V_{Th})^2 \tag{7}$$

$$R0 = \frac{V_A}{I_{ds}} = 90Kohm \tag{8}$$

$$f_c = \frac{1}{2 * pi * R0 * c} = 116.90mHz \tag{9}$$

$$gm = \frac{2Id}{Vgs - Vth} = 116.90ua/m \tag{10}$$

By doing these, we obtain Vgs = 064 v

7 Simulations and waveform

7.1 Cs amplifier with a ideal current source for DC analysis

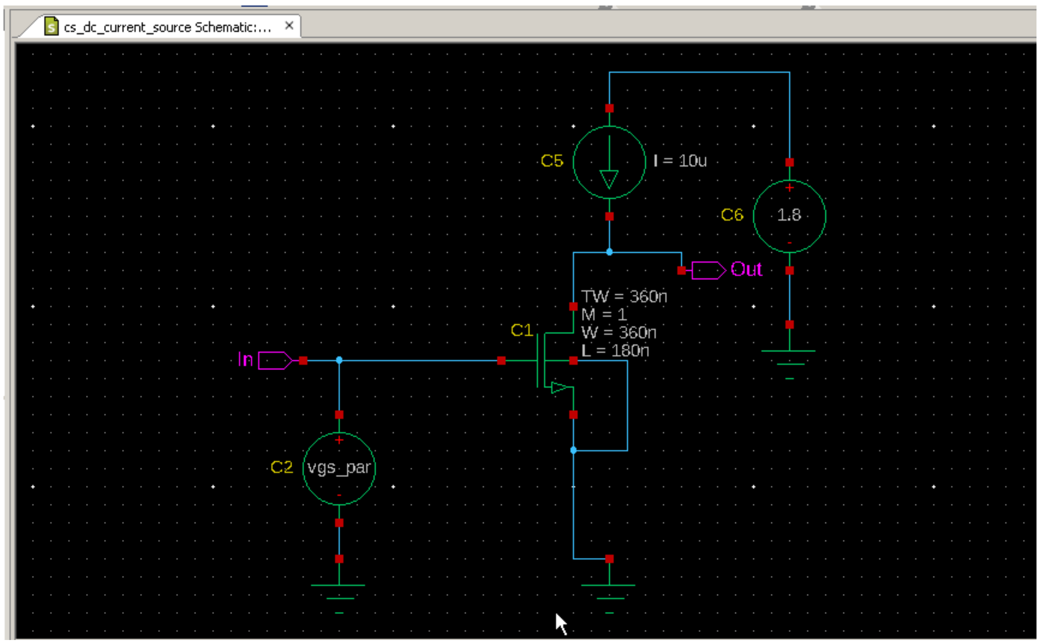

Figure 4: circuit diagram for Cs amplifier with a ideal current source for DC analysis

7.2 I_d

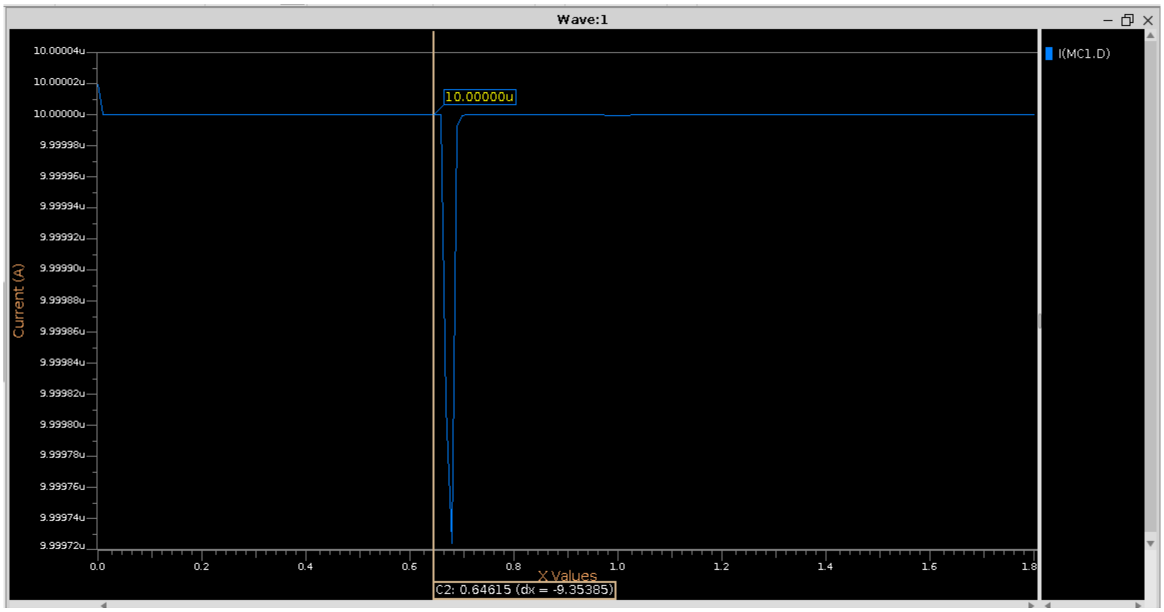

Figure 5: $I_d$for Cs amplifier with a ideal current source for DC analysis

7.3 Cs amplifier with a ideal current source for AC analysis

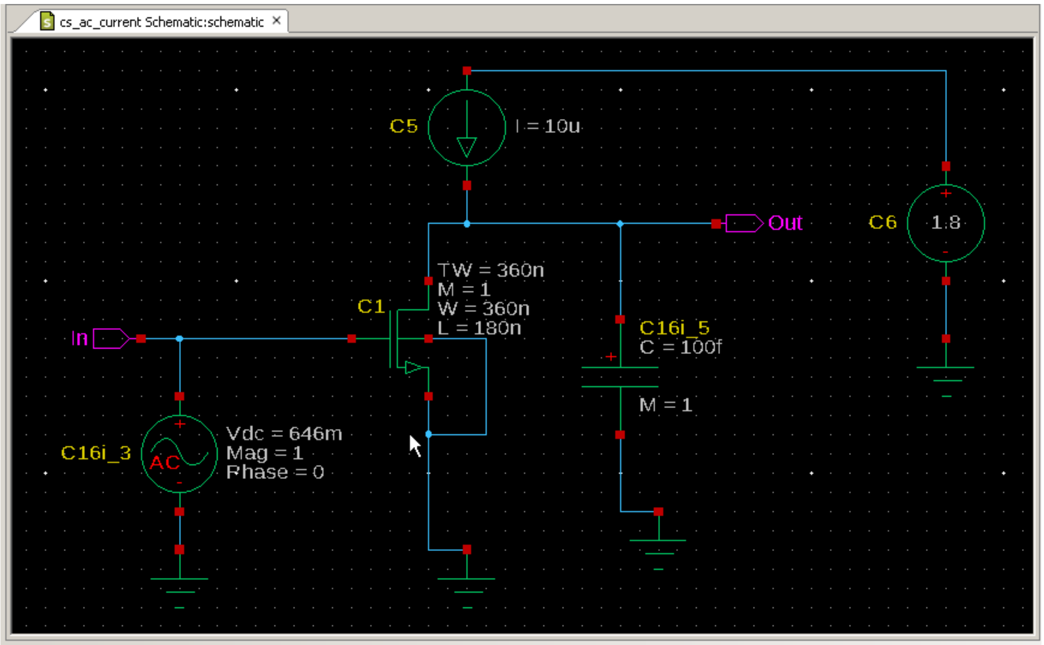

Figure 6: circuit diagram for Cs amplifier with a ideal current source for AC analysis

7.4 A_v and f_c

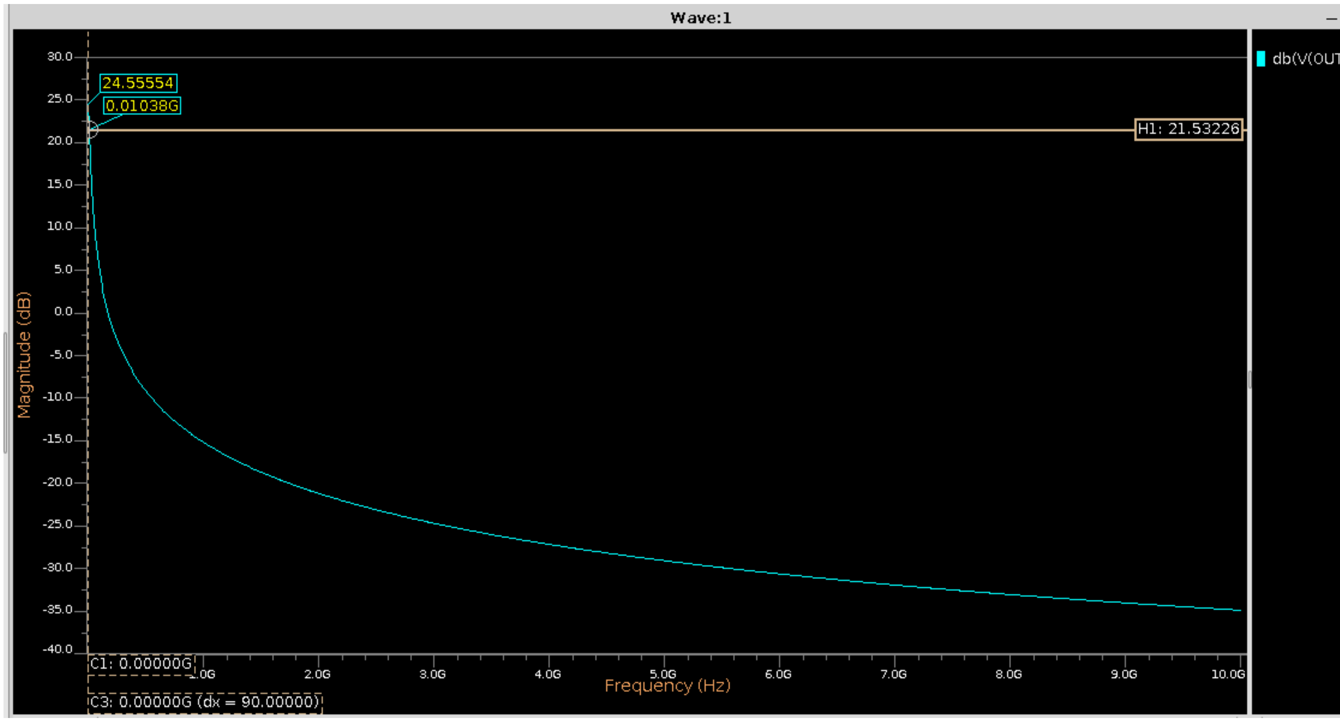

Figure 7: $A_v$for Cs amplifier with a ideal current source for AC analysis

7.5 Cs amplifier with a ideal current source to find R0

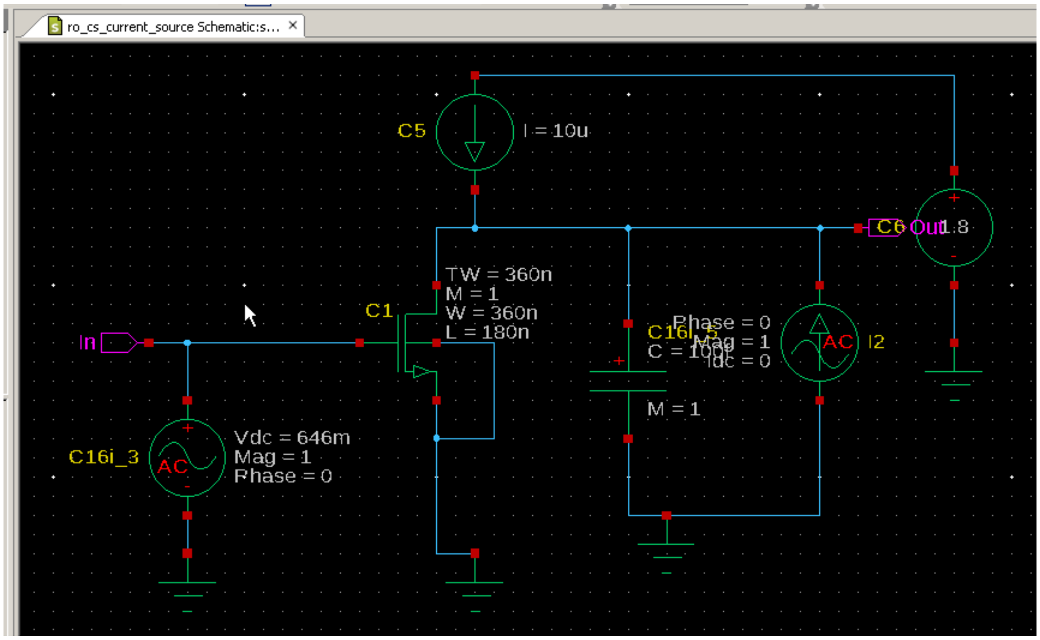

Figure 8: circuit diagram for Cs amplifier with a ideal current source for to find R0

7.6 R_0

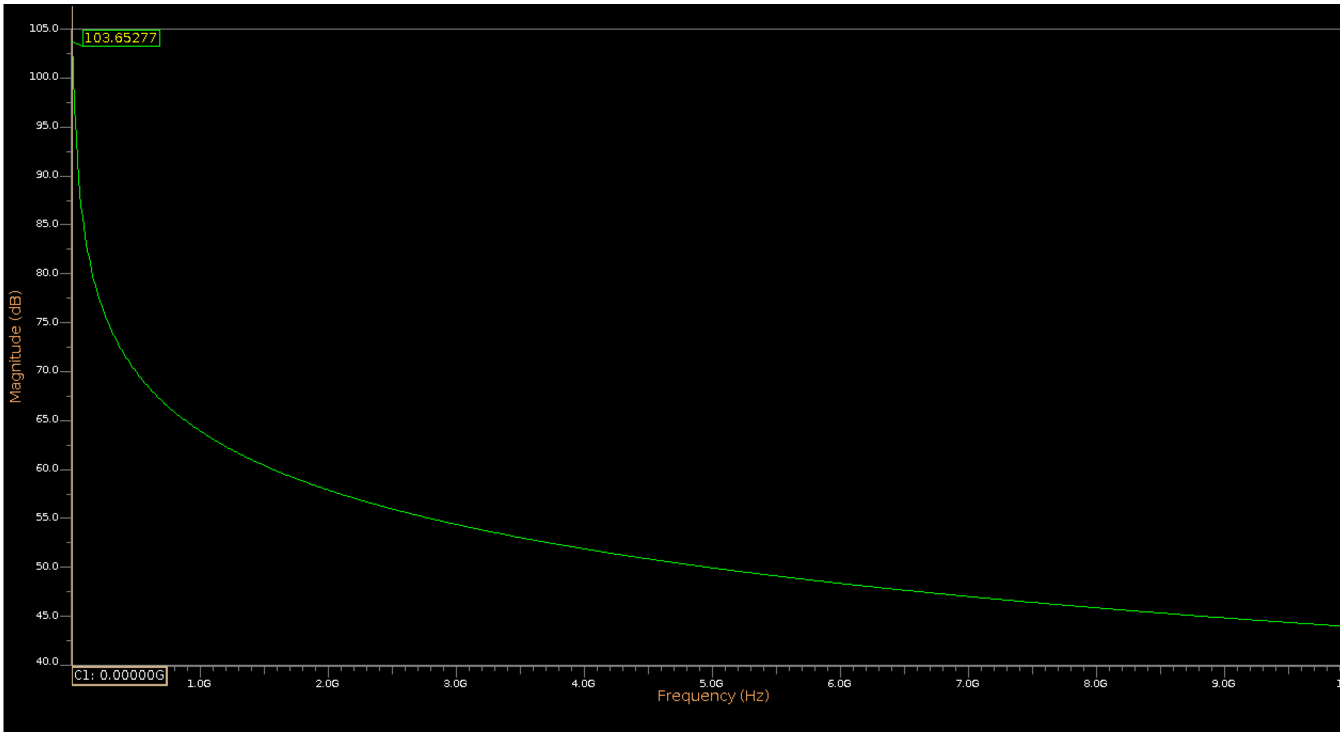

Figure 9: $R_0$for Cs amplifier with a ideal current source

7.7 Cs amplifier with a current mirror load for DC analysis

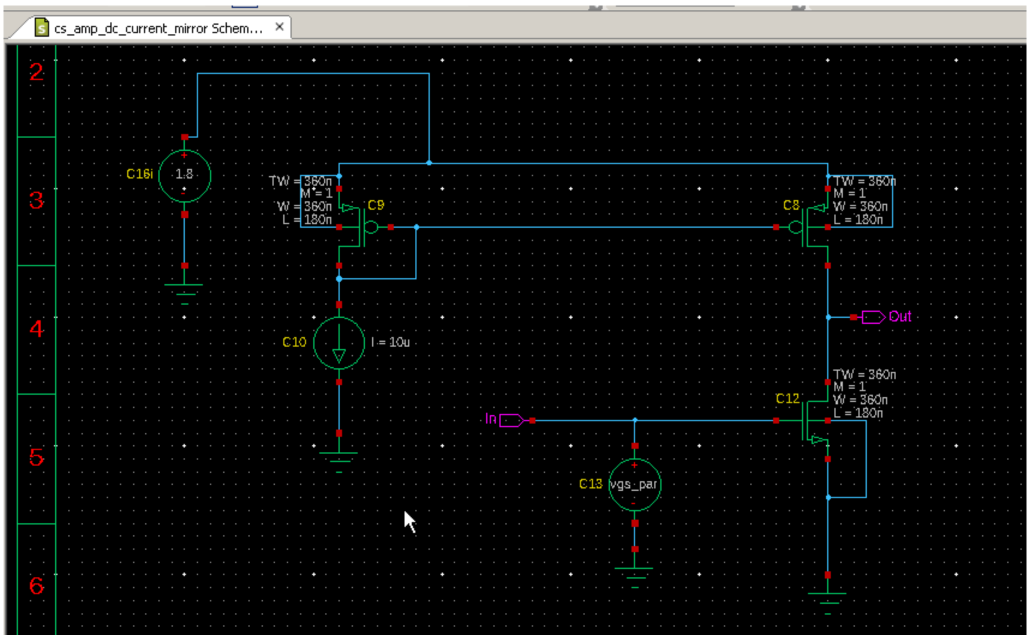

Figure 10: circuit diagram for Cs amplifier with a current mirror load for DC analysis

7.8 I_d

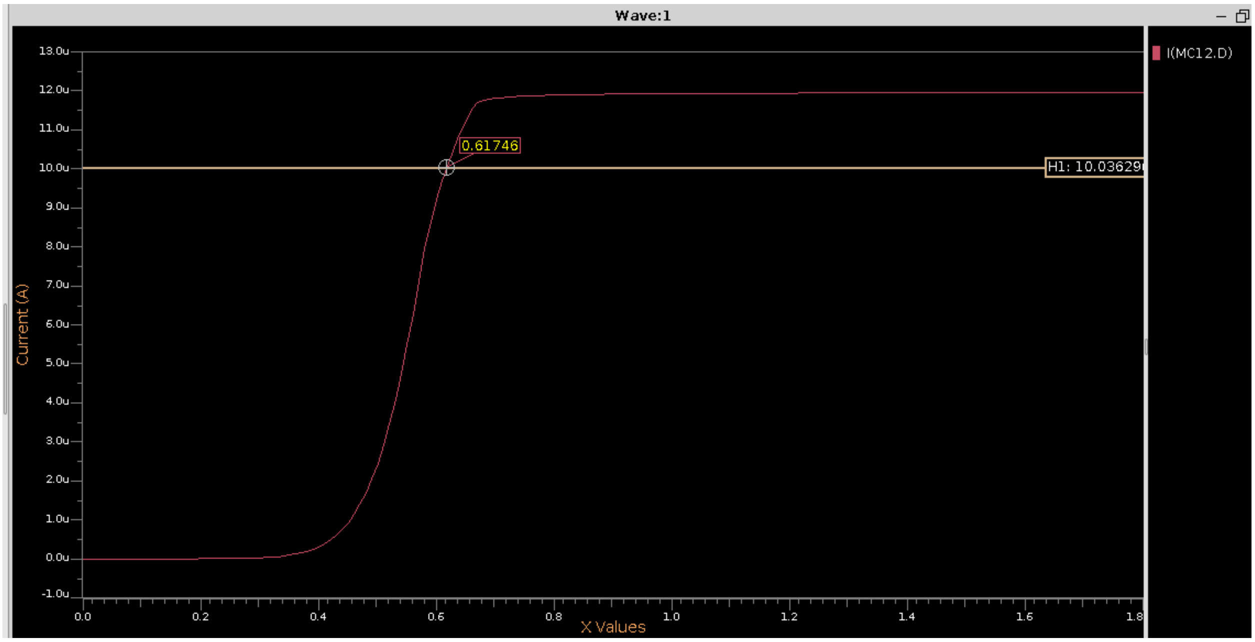

Figure 11: $I_d$for Cs amplifier with a current mirror load for DC analysis

7.9 Cs amplifier with a current mirror load for AC analysis

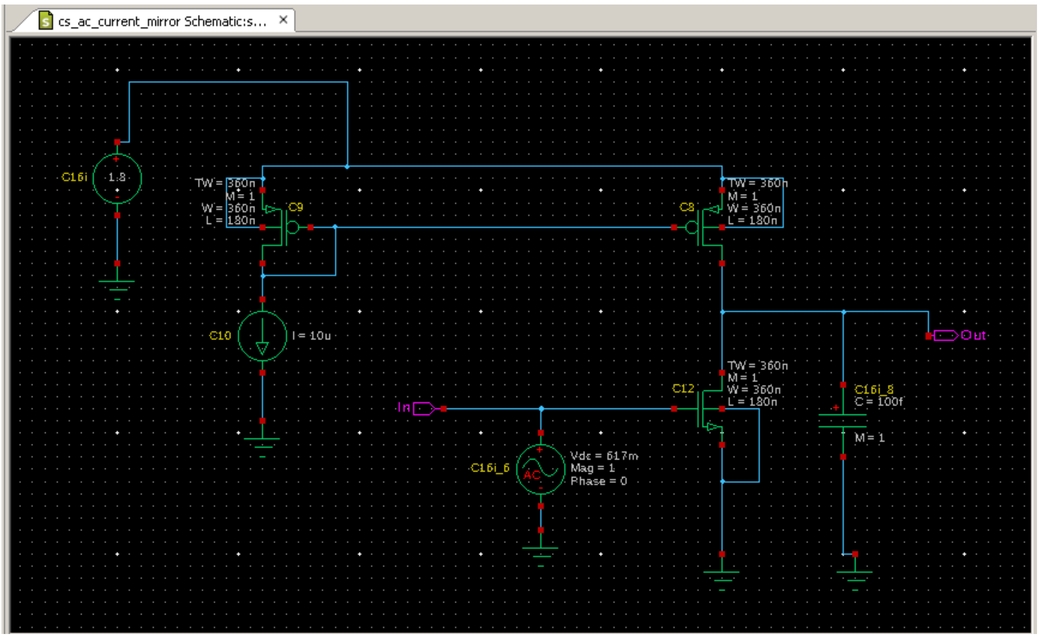

Figure 12: circuit diagram for Cs amplifier with a current mirror load for AC analysis

7.10 A_v and f_c

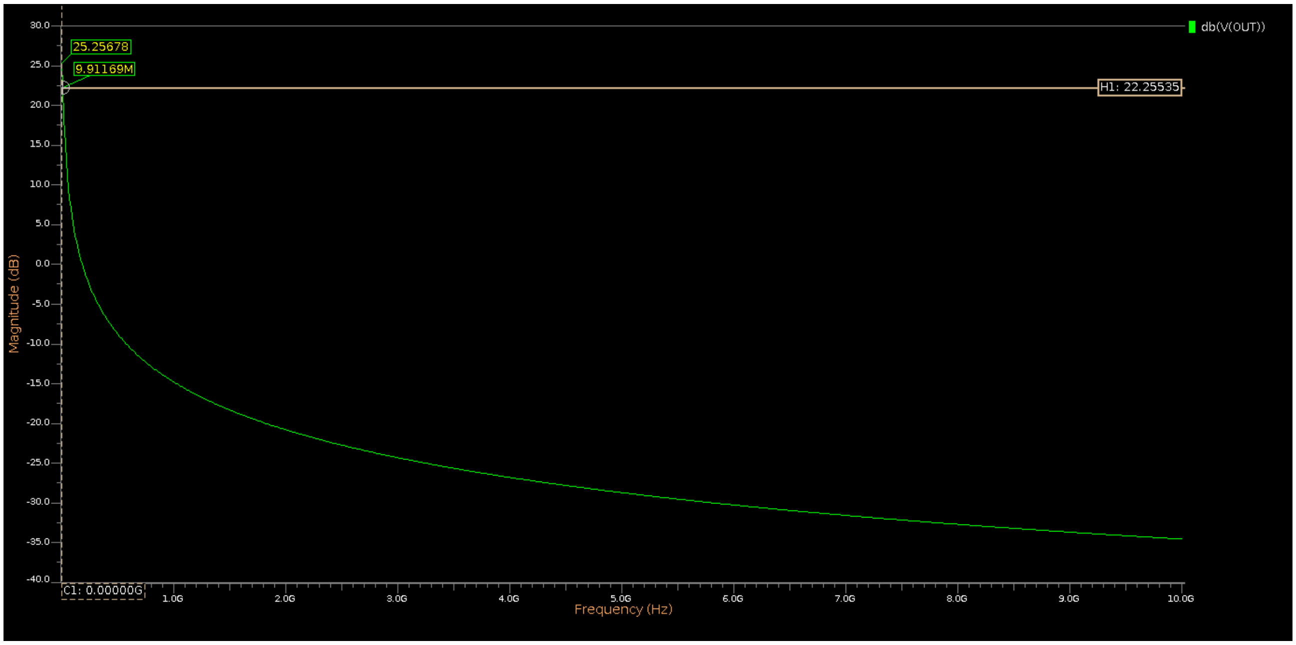

Figure 13: $A_v$for Cs amplifier with a current mirror load for AC analysis

7.11 Cs amplifier with a current mirror load to find R0

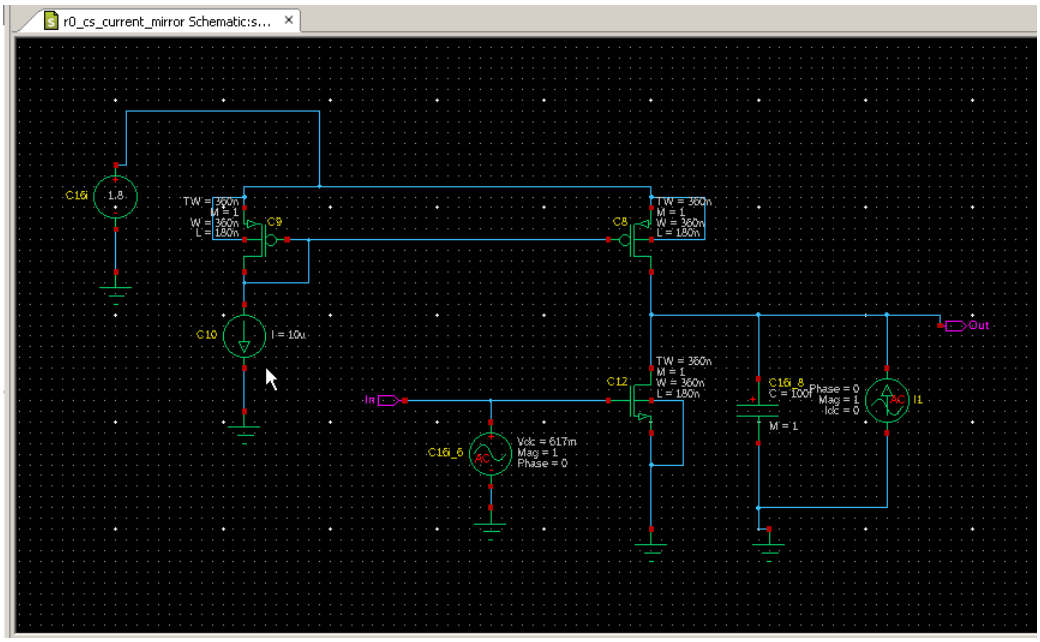

Figure 14: circuit diagram for Cs amplifier with a current mirror for to find R0

7.12 R_0

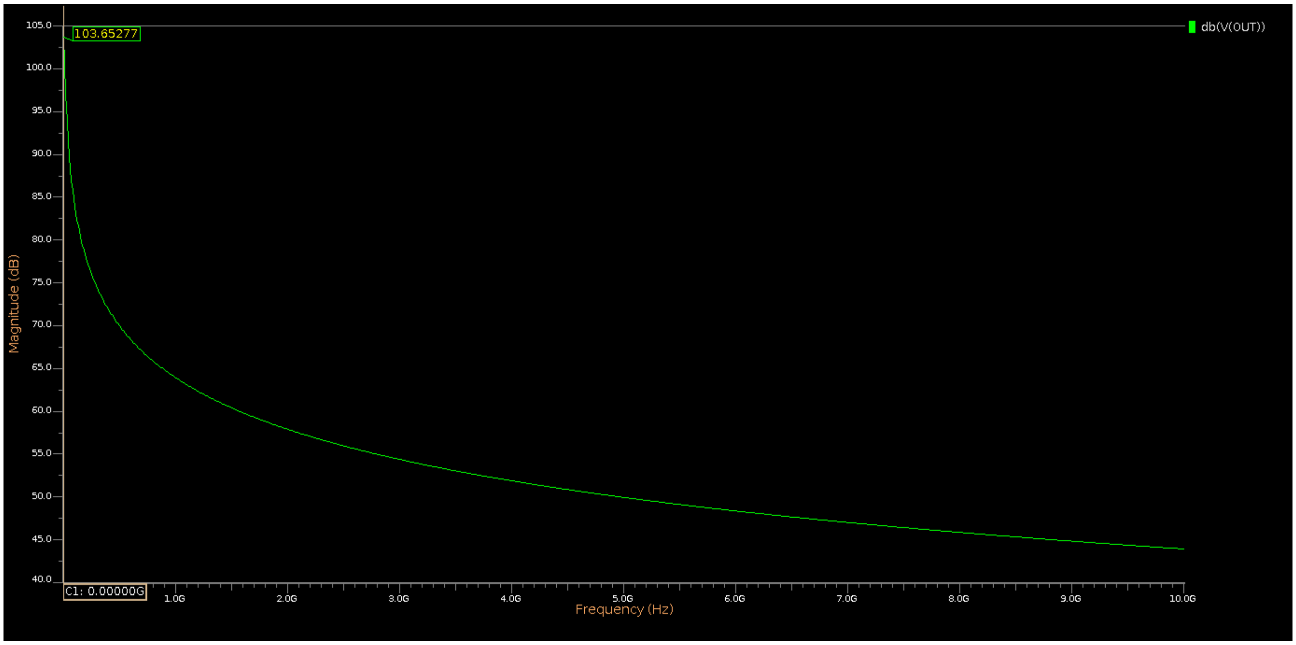

Figure 15: $R_0$for Cs amplifier with a ideal current source

7.13 Cg amplifier with a ideal current source for AC analysis

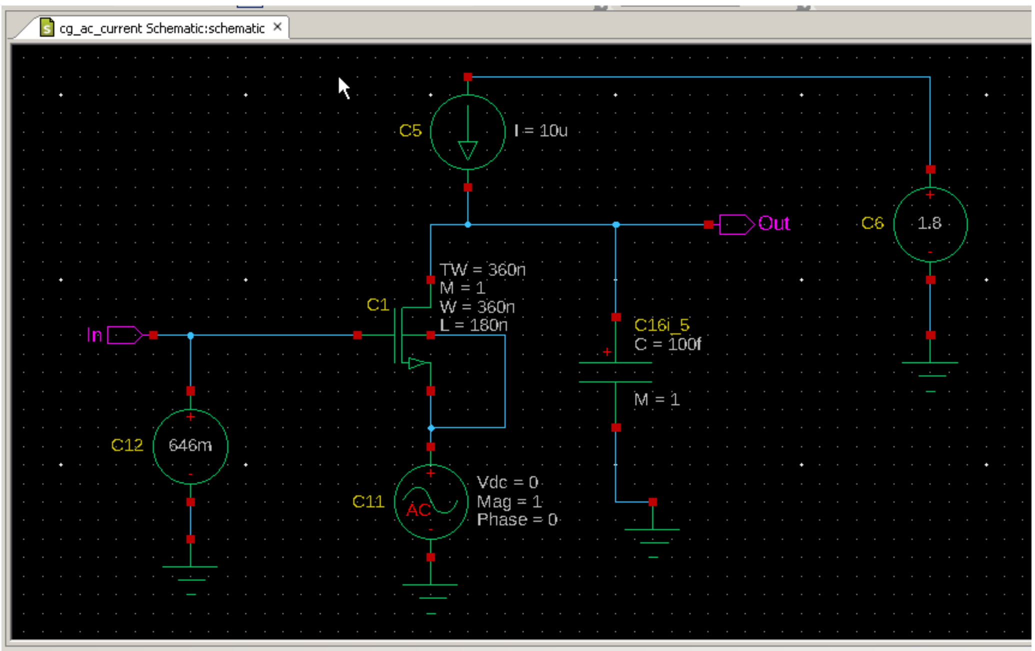

Figure 16: circuit diagram for Cg amplifier with a ideal current source for AC analysis

7.14 A_v and f_c

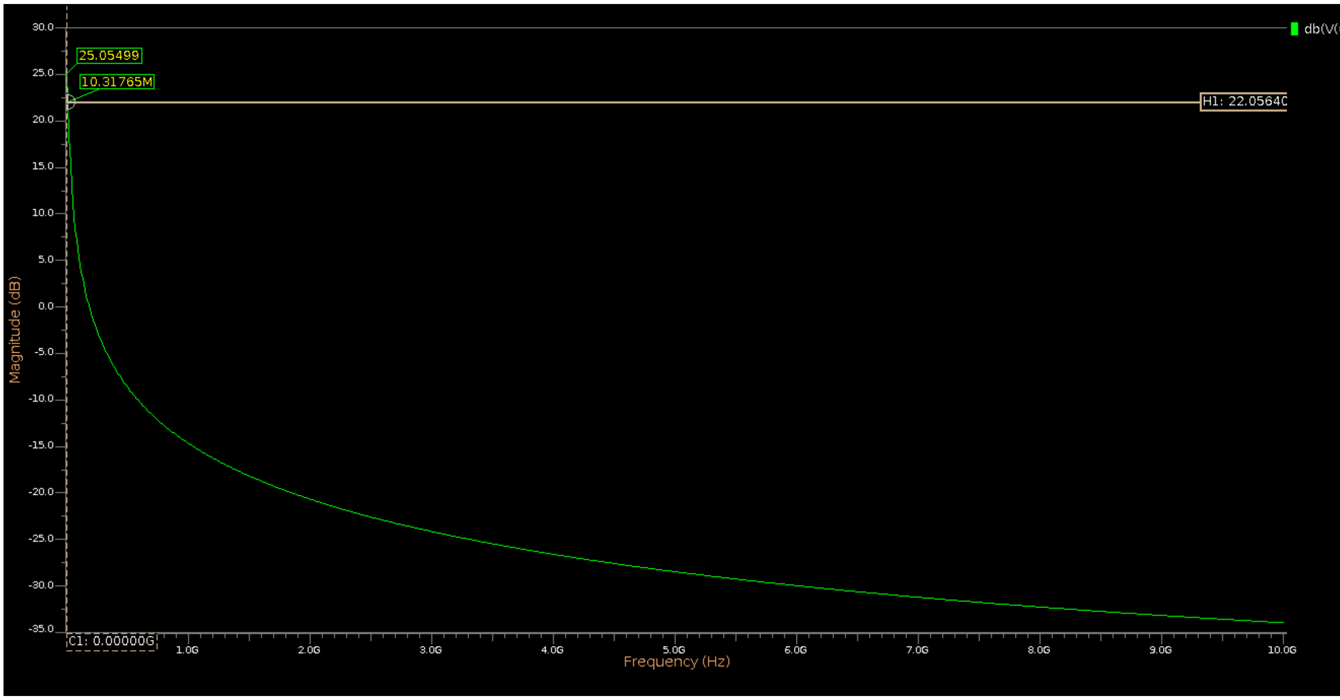

Figure 17: A_v for Cg amplifier with a ideal current source for AC analysis

7.15 Cg amplifier with a ideal current source to find R0

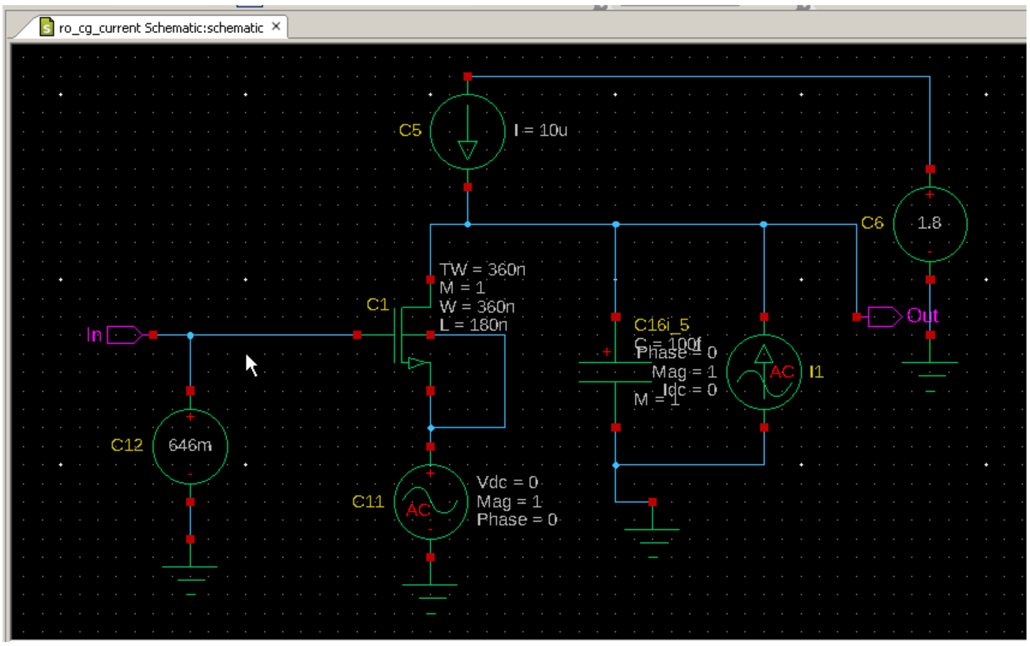

Figure 18: circuit diagram for Cg amplifier with a ideal current source for to find R0

7.16 R_0

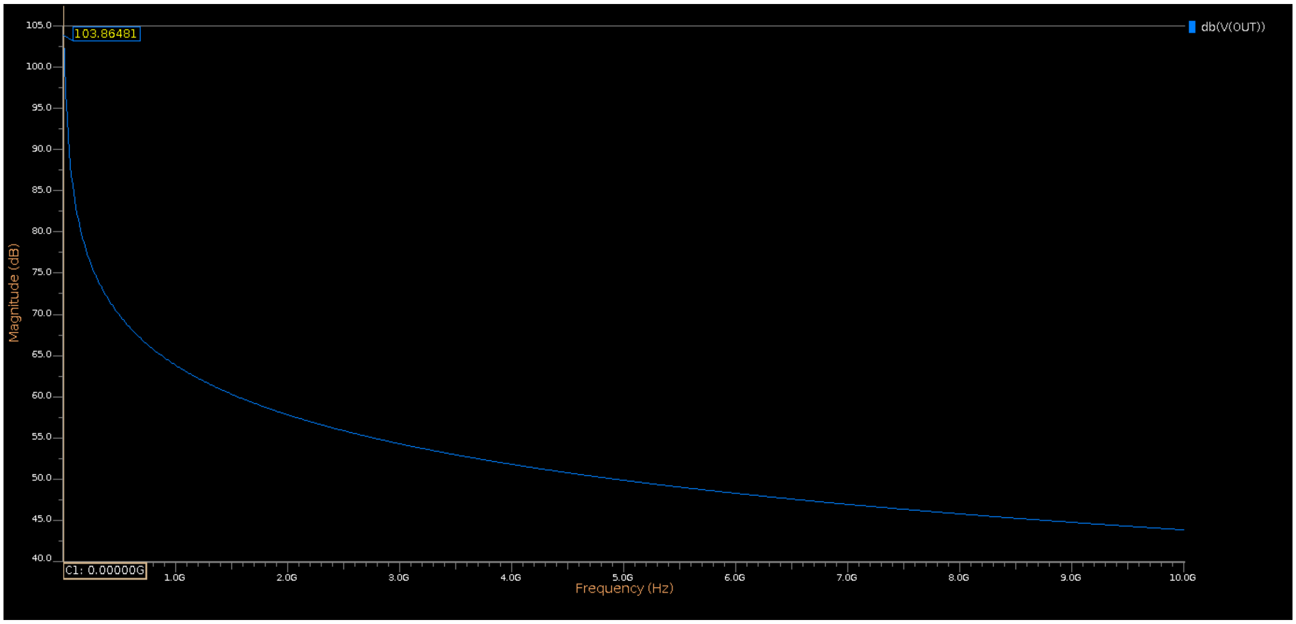

Figure 19: R_0 for Cg amplifier with a ideal current source

7.17 Cg amplifier with a current mirror load for AC analysis

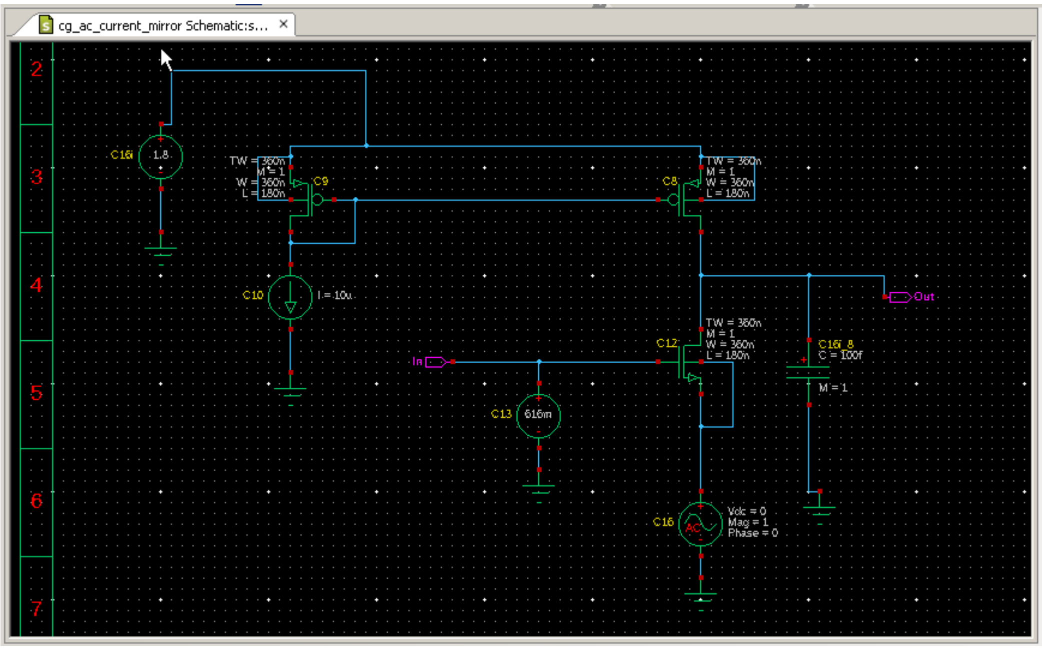

Figure 20: circuit diagram for Cg amplifier with a current mirror load for AC analysis

7.18 A_v and f_c

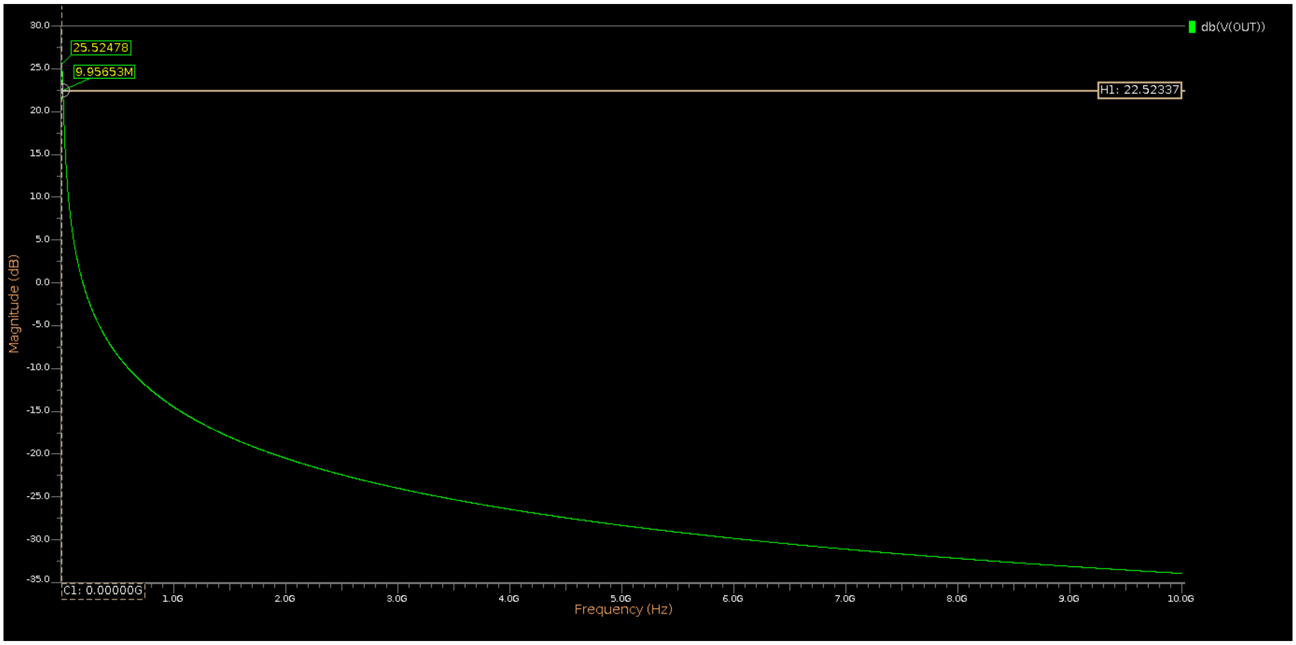

Figure 21: $A_v$for Cg amplifier with a current mirror load for AC analysis

7.19 Cg amplifier with a current mirror load to find R0

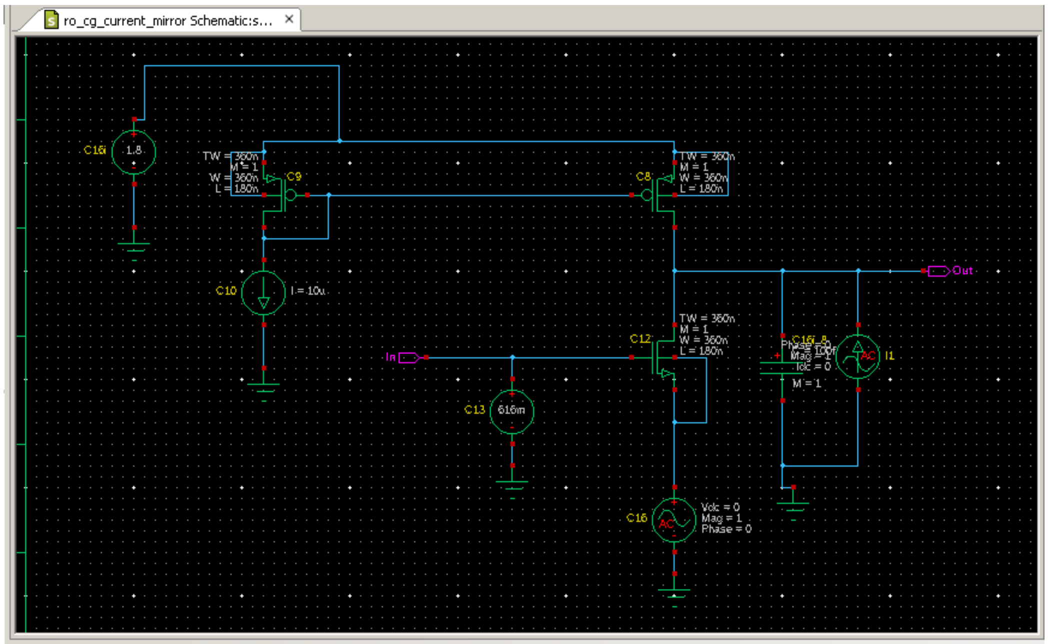

Figure 22: circuit diagram for Cg amplifier with a current mirror for to find R0

7.20 R_0

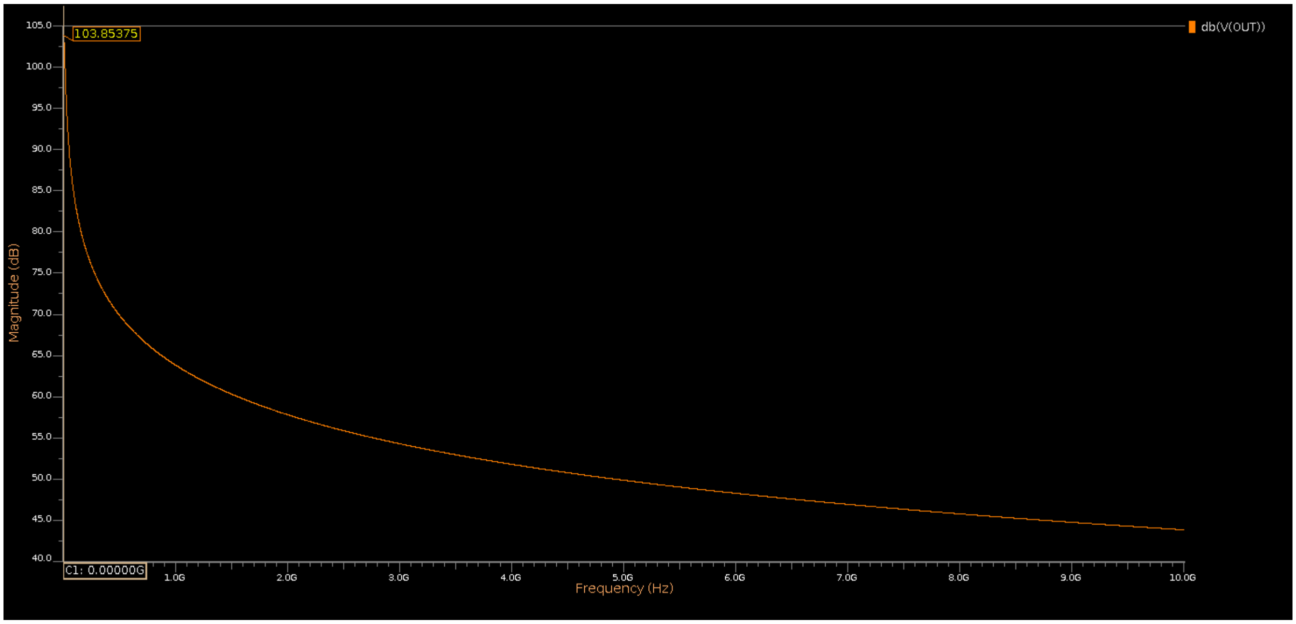

Figure 23: $R_0$for Cg amplifier with a current mirror load

7.21 Cd amplifier with a ideal current source for DC analysis

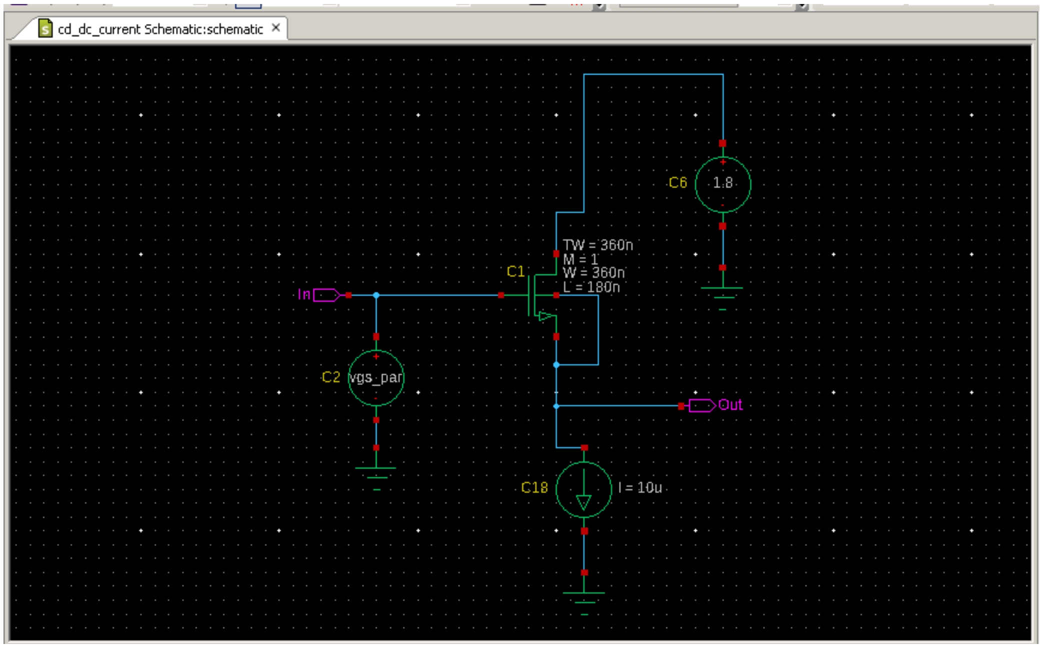

Figure 24: circuit diagram for Cd amplifier with a ideal current source for DC analysis

7.22 I_d

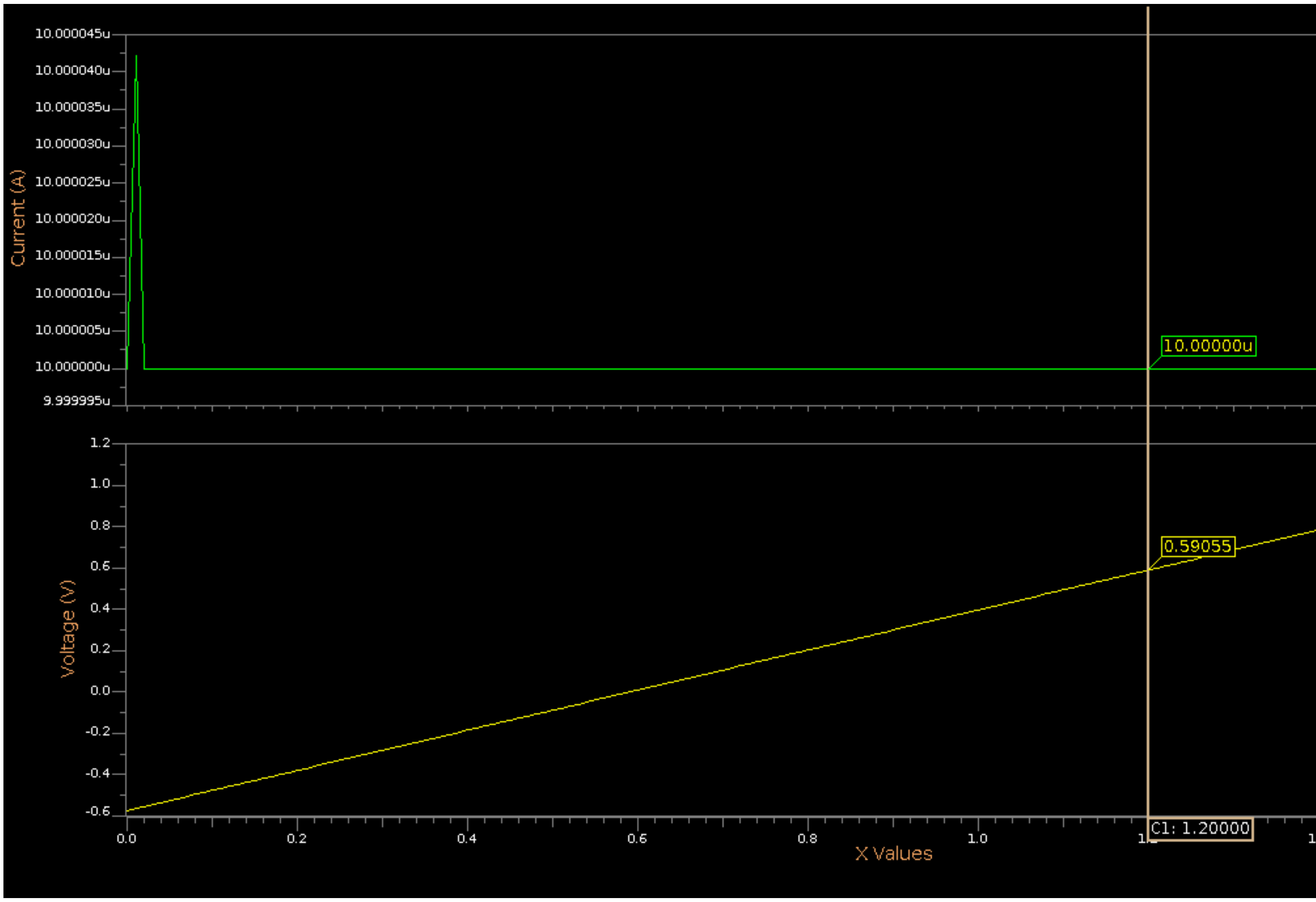

Figure 25: $I_d$for Cd amplifier with a ideal current source for DC analysis

7.23 Cd amplifier with a ideal current source for AC analysis

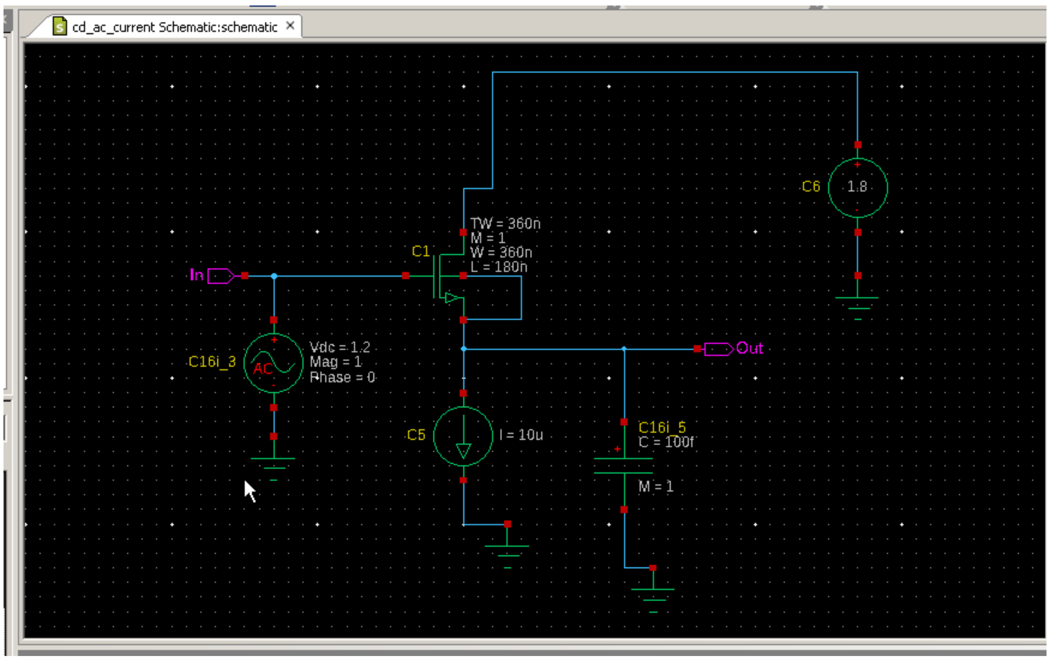

Figure 26: circuit diagram for Cd amplifier with a ideal current source for AC analysis

7.24 A_v and f_c

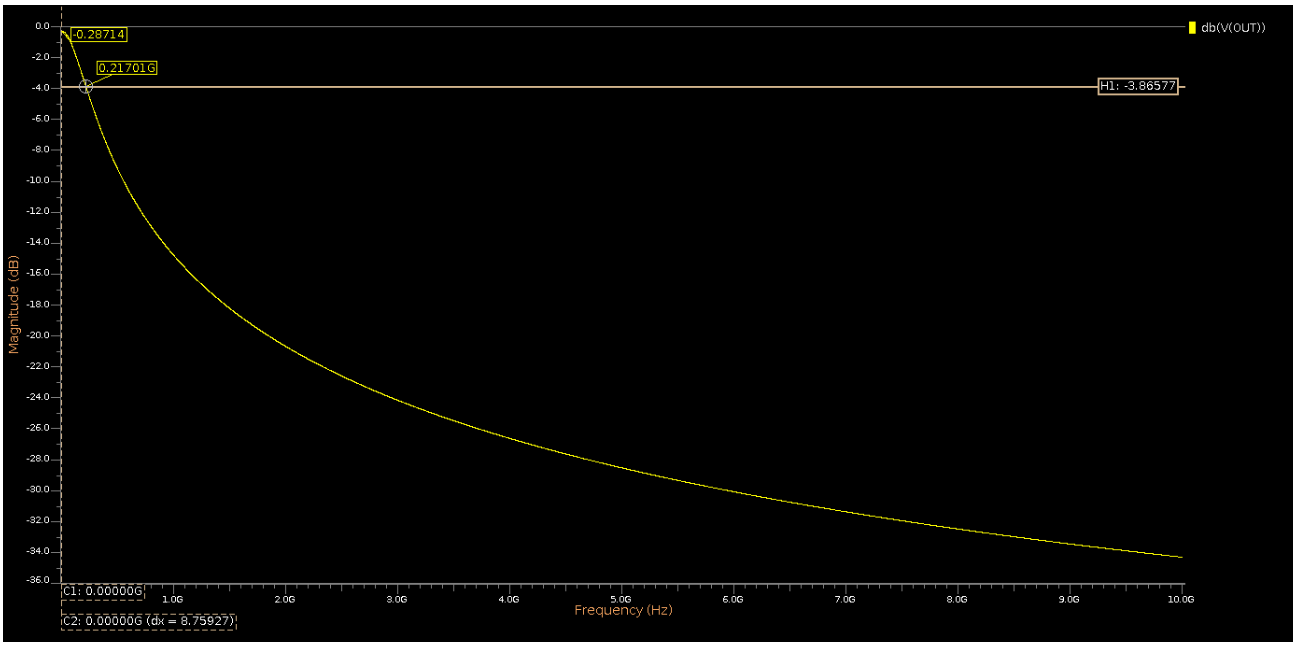

Figure 27: $A_v$for Cd amplifier with a ideal current source for AC analysis

7.25 Cd amplifier with a ideal current source to find R0

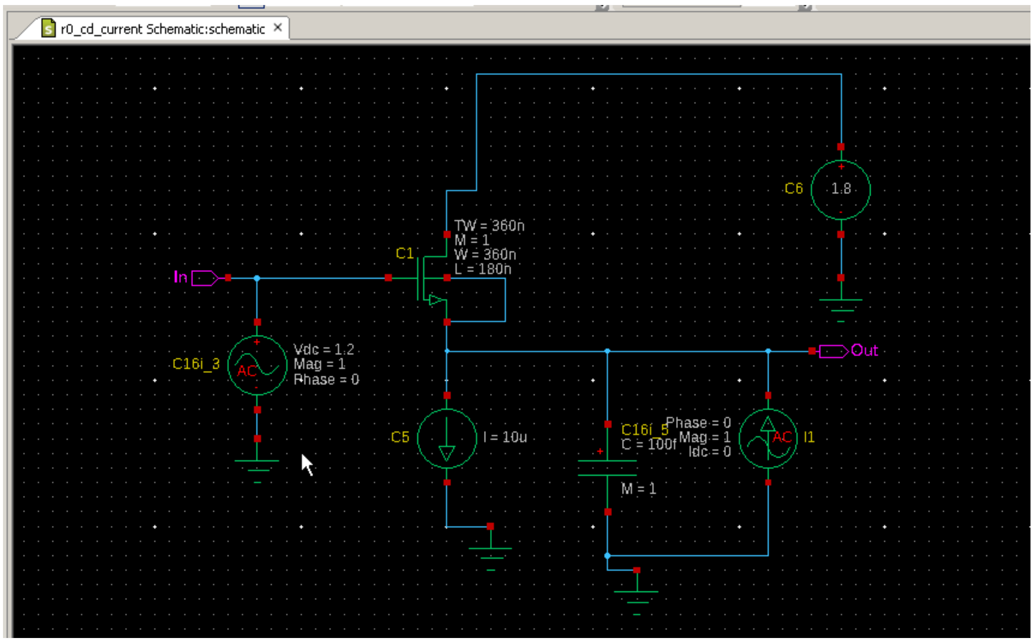

Figure 28: circuit diagram for Cd amplifier with a ideal current source for to find R0

7.26 R_0

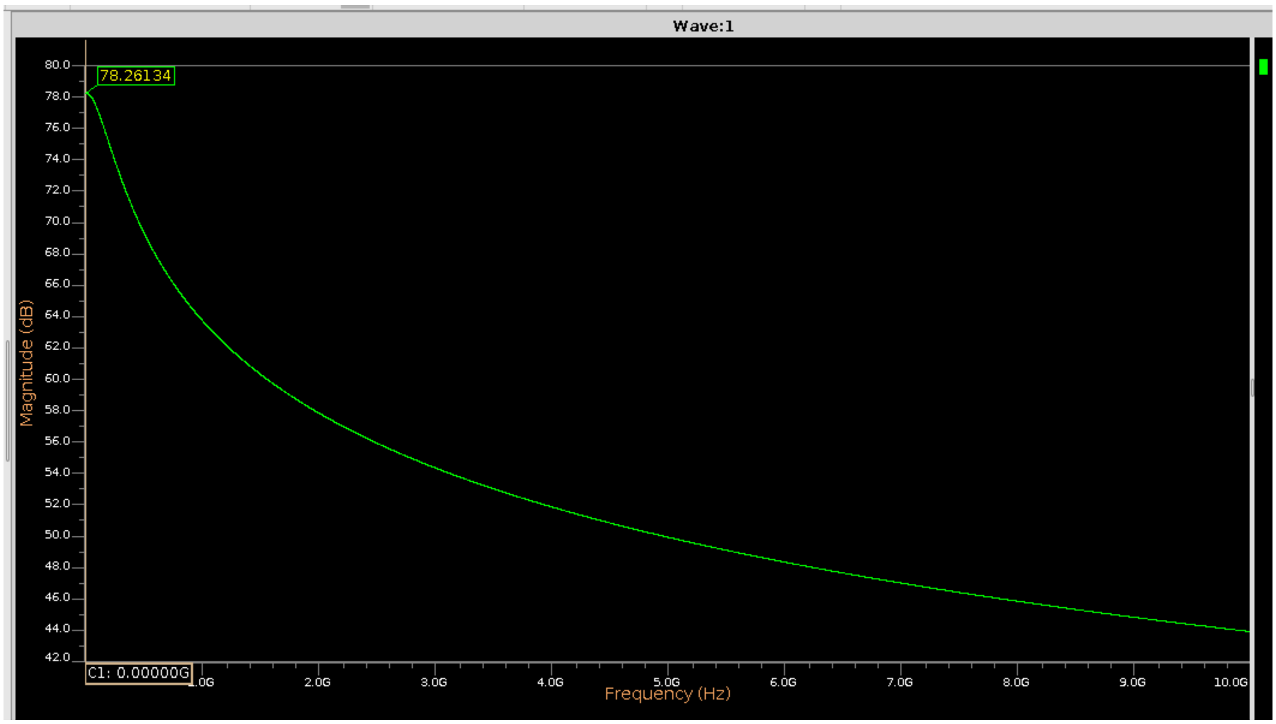

Figure 29: $R_0$for Cd amplifier with a ideal current source

7.27 Cd amplifier with a current-mirror load for DC analysis

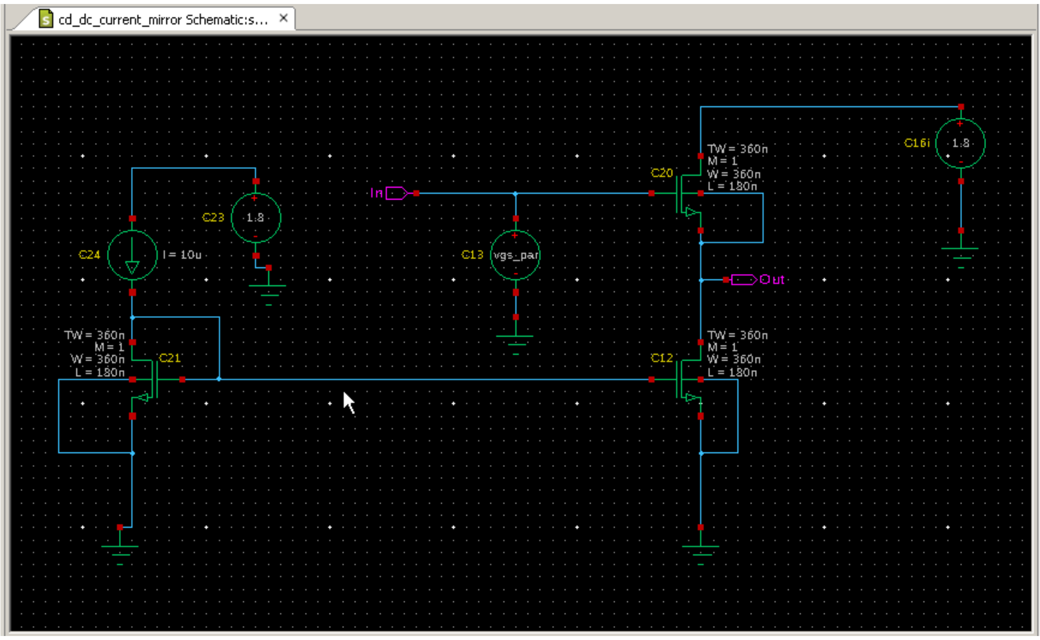

Figure 30: circuit diagram for Cd amplifier with a current mirror load for DC analysis

7.28 I_d

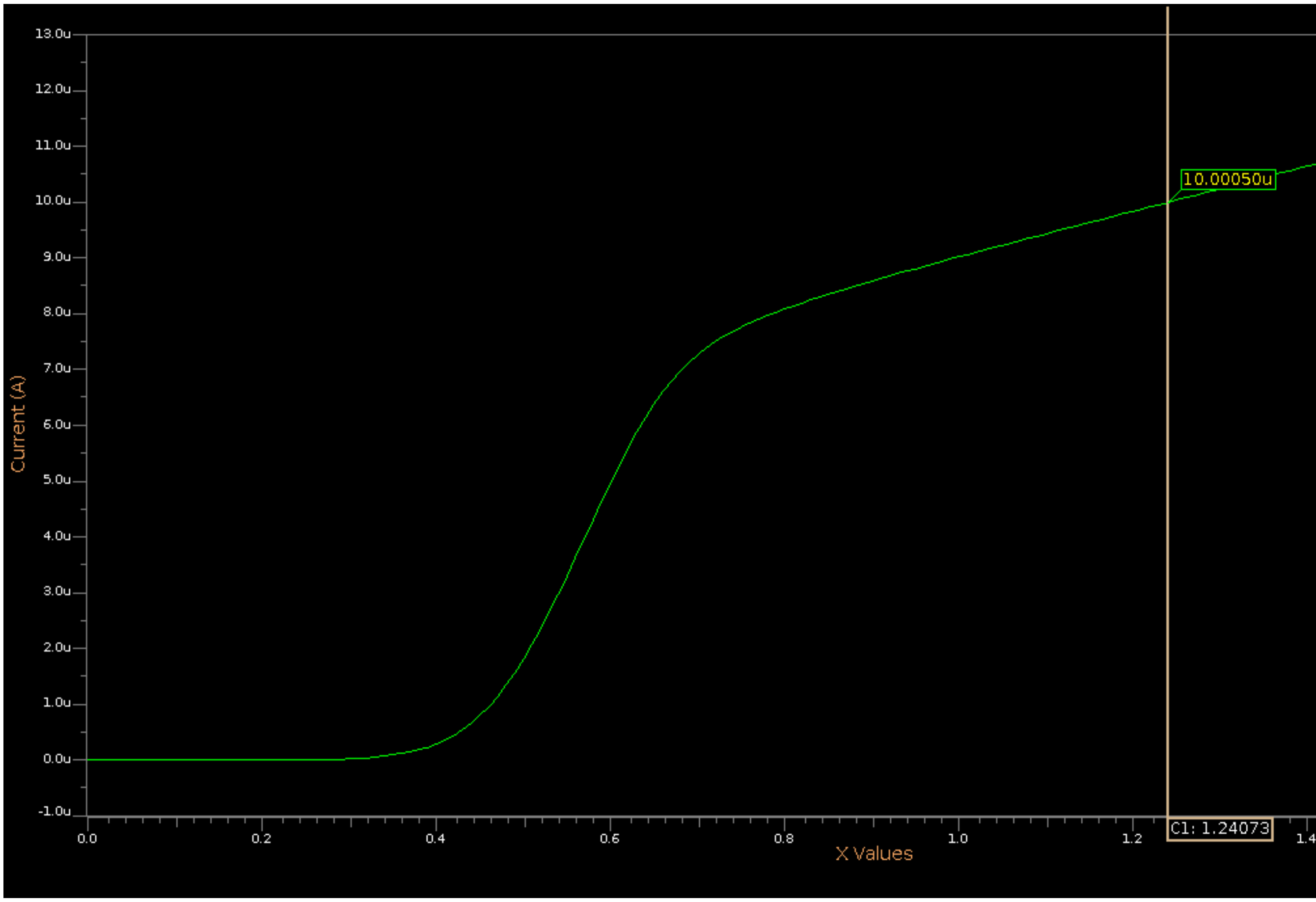

Figure 31: $I_d$for Cd amplifier with a current mirror load for DC analysis

7.29 Cd amplifier with a current mirror load for AC analysis

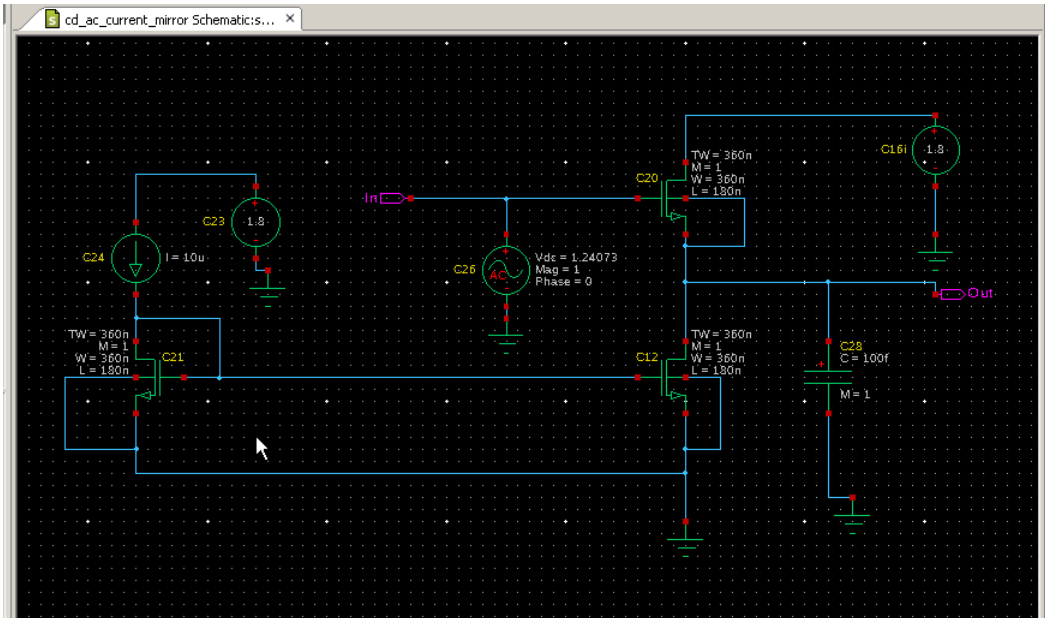

Figure 32: circuit diagram for Cd amplifier with a current mirror load for AC analysis

7.30 A_v and f_c

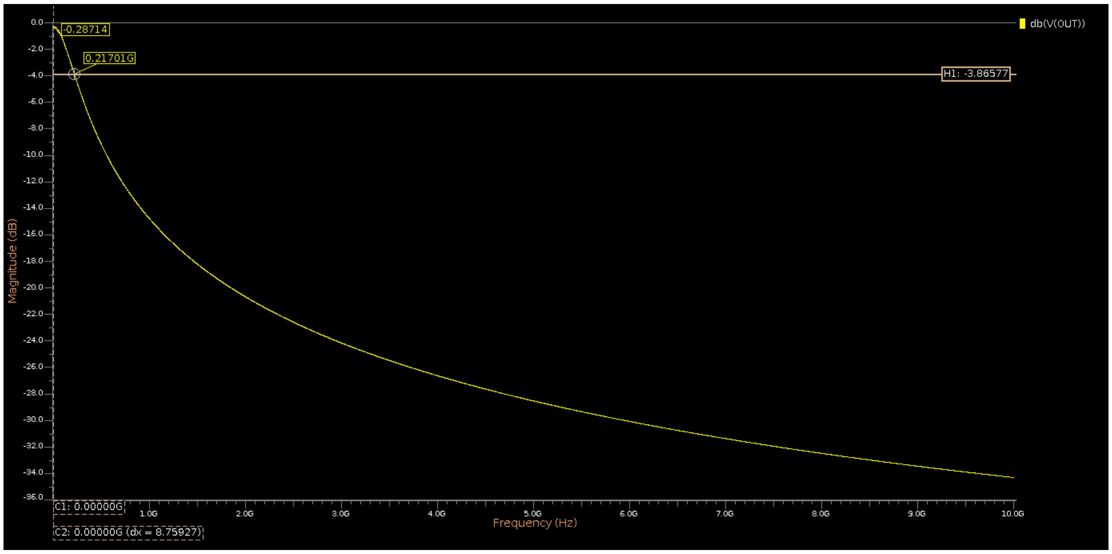

Figure 33: A_v for Cd amplifier with a current mirror load for AC analysis

7.31 Cd amplifier with a current mirror load to find R0

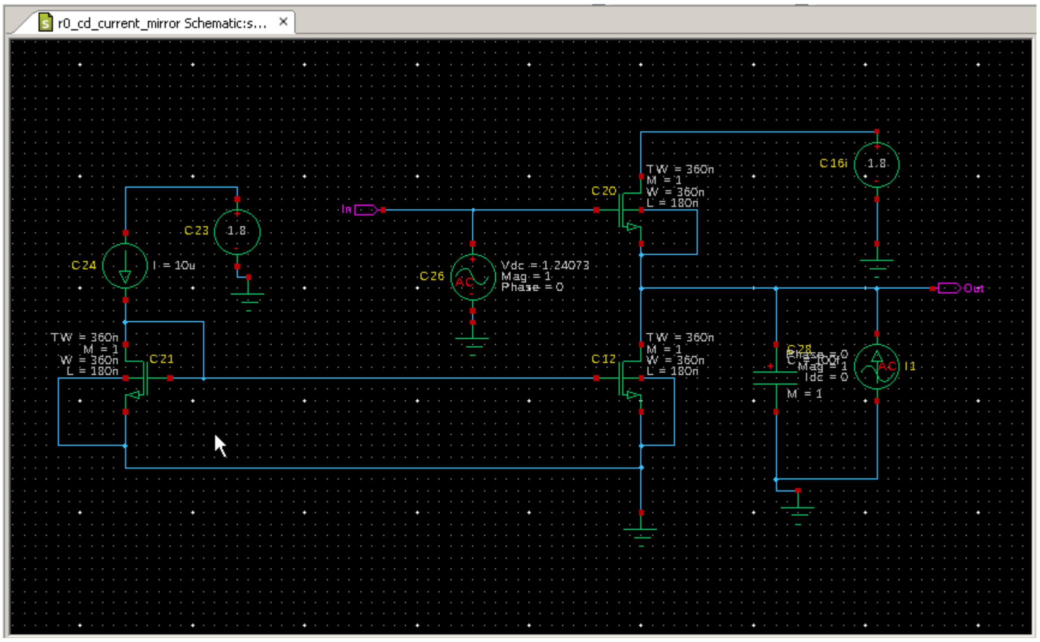

Figure 34: circuit diagram for Cd amplifier with a current mirror for to find R0

7.32 R_0

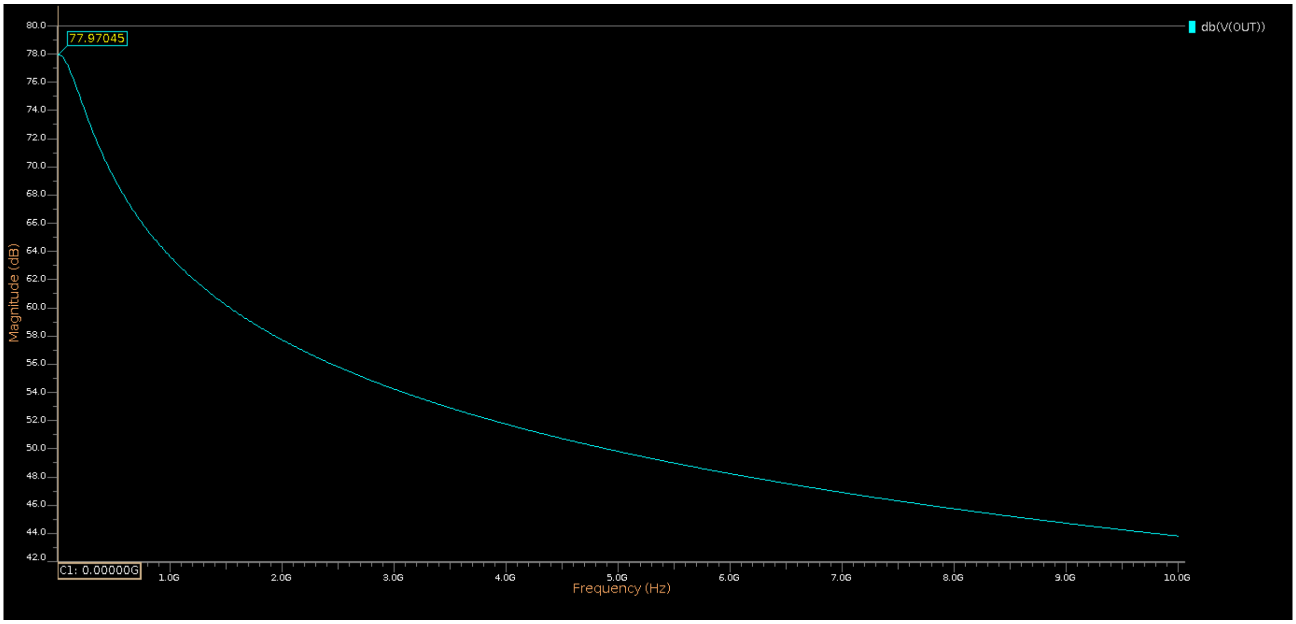

Figure 35: $R_0$for Cd amplifier with a current - mirror load

8 Theoratical calculations for Rout for all graphs

CS Amplifier: In AC analysis are all plotted as bode plot .so if we need to convert back to normal values.

$$x = \frac{dbvalue}{20} \tag{11}$$

then to get normal value we need to apply power of ten to the value

$$normalunitvalue = 10^x \tag{12}$$

9 Comparison table

9.1 Practical values

	I_d u	$v_g s(v)$	A_v	f_c (mHz)	R_0 (K ohm)
Cs current source	10	0.646	24.5554	10.3155	152.29
Cs current mirror	10	0.646	25.25678	9.911	151.63
Cg current source	10	0.646	25.05499	10.31765	155.95
Cg current mirror	10	0.646	25.5247	9.95653	155.829
Cd current source	10	1.24073	-0.28714	217.01	8.185
Cd current mirror	10	1.24073	-0.59061	195	7.915

9.2 Theoretical values

	I_d u	$v_g s(v)$	A_v db	f_c (mHz)	R_0 (K ohm)
Cs current source	10	0.596	25.39	10	90
Cs current mirror	10	0.589	25.39	10	81
Cg current source	10	0.596	25.39	10	90
Cg current mirror	10	0.596	25.39	10	81
Cd current source	10	1.3	1	182	40
Cd current mirror	10	1.3	0.992	187	40

10 Conclusions:-

- All the results have been obtained practically and matching with the theoretical justification. The theoretical calculations have been done.
- CS and CG have high resistance and CD have less resistance.
- current load have high resistance compared to the current mirror load.
- bandwidth inversely proportional to output resistance and gain
- designed and implementation of the CS,CD and CG amplifiers for 10Mhz bandwidth with different Loads are successfully implemented