Safia Reazi

170LC

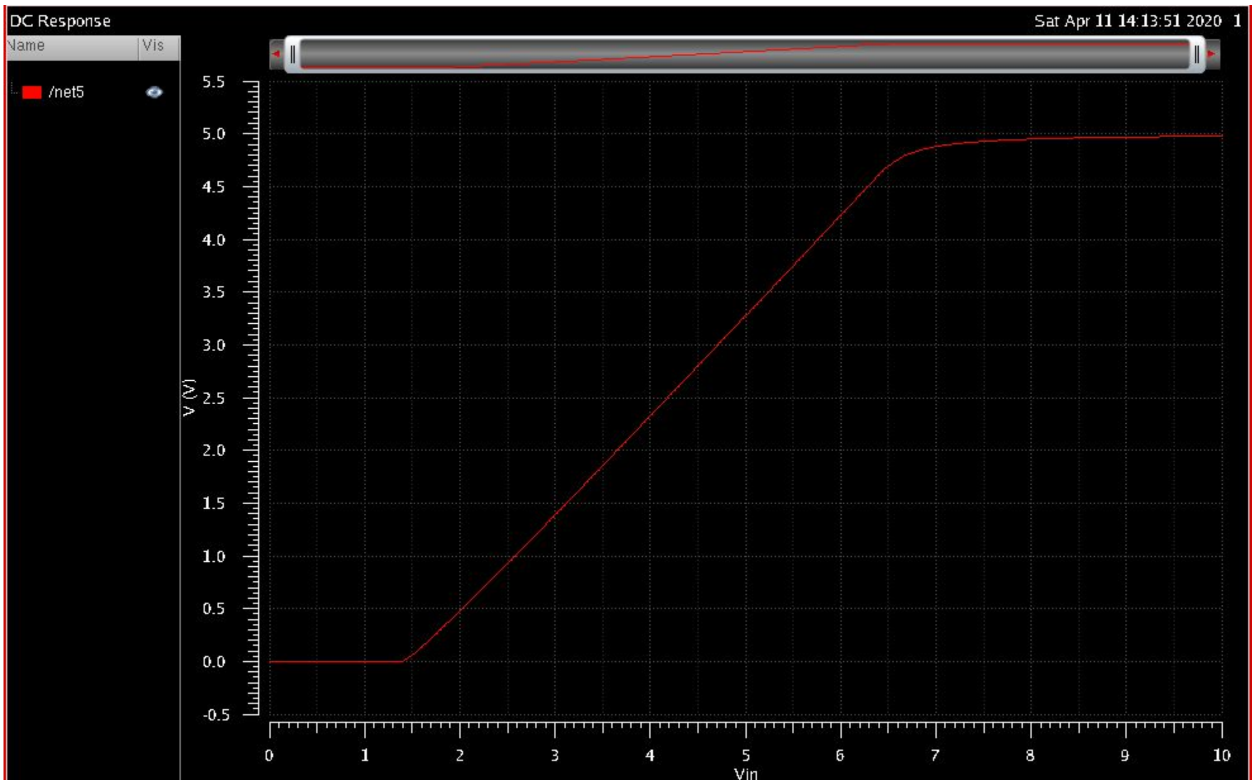
Lab 1

4/14/2020

Problem 1

A.

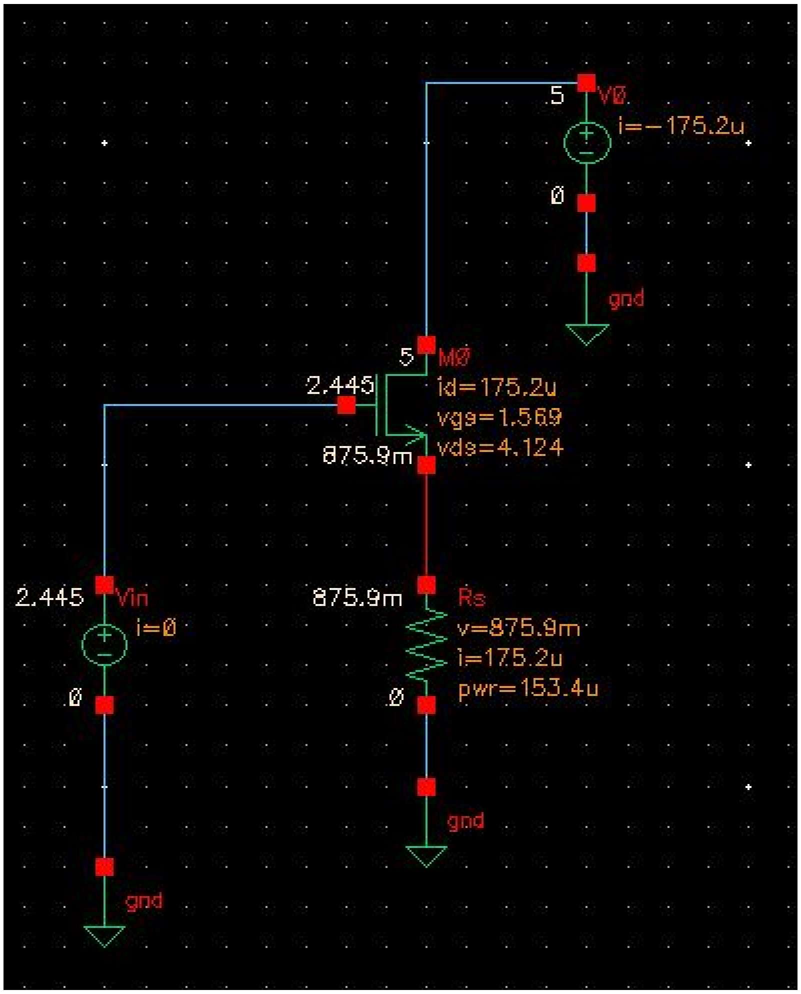
Vout vs. Vin



- $V_{in} = V_{in(eq1)}$: $\frac{6.33V - 1.44V}{2} = 2.445\text{V}$
- Region of operation (from bottom to top of graph): 1) cutoff, 2) saturation, 3) triode

B.

DC Operating Point Analysis



C.

<u>Calculations</u>

Small signal parameters from simulation:

- gm = 2.072n
- ro = 1.11 MΩ

Calculated small signal parameters

- gm = $\frac{2Ids}{Vgs-Vt}$ = 2.061n
  - Ids = k'/2(W/L)(Vgs-Vt)^2 => 175.2u = 0.6m/2(200u/10u)(Vgs-Vt)^2
  - Vgs = $\sqrt{(175.2u/6m)}$ +1.4 = 1.57V

- ro = $\frac{1}{\lambda Ids}$ = 1/(0.005)(175.2u) = 1.14 MΩ

Percent error:

- gm % error = 2.072n-2.061n/2.072n *100% = 0.53%
- ro % error = |1.11MΩ - 1.14MΩ|/1.11MΩ *100% = 2.7%

D.

Comparing AC and DC components of Vin and Vout

- DC input level: 2.445V
- DC output level: 0.876V
- Amplitude_Vin: 20mV
- Amplitude_Vout: 885 mV - 866 mV= 19mV
- Gain = Amp_Vout/Amp_Vin = 20/19 = 1.05
- DC and AC output levels decrease when adding a sine wave input and the gain is small.

E.

Increase Vin(eq1) by 10mV

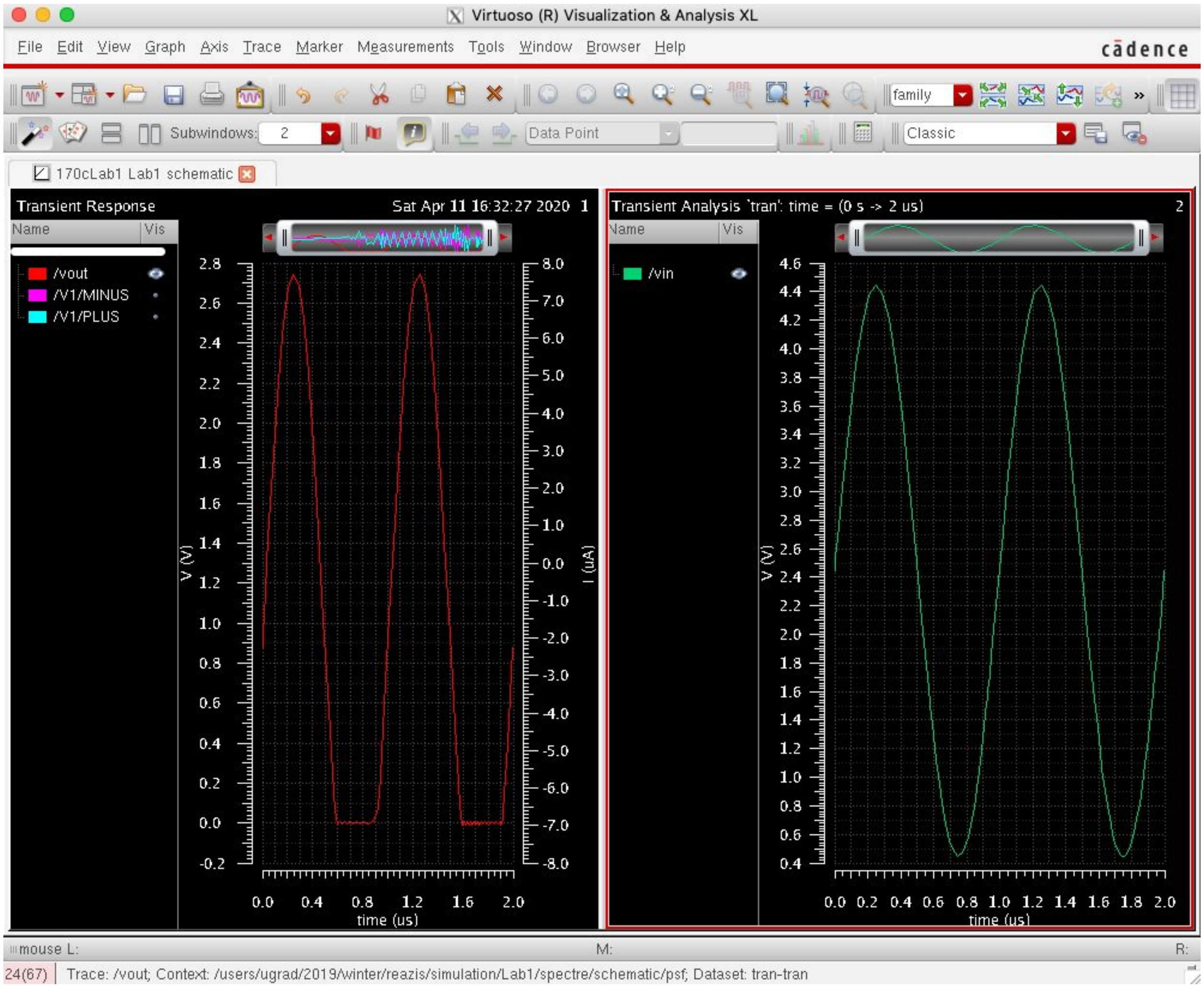
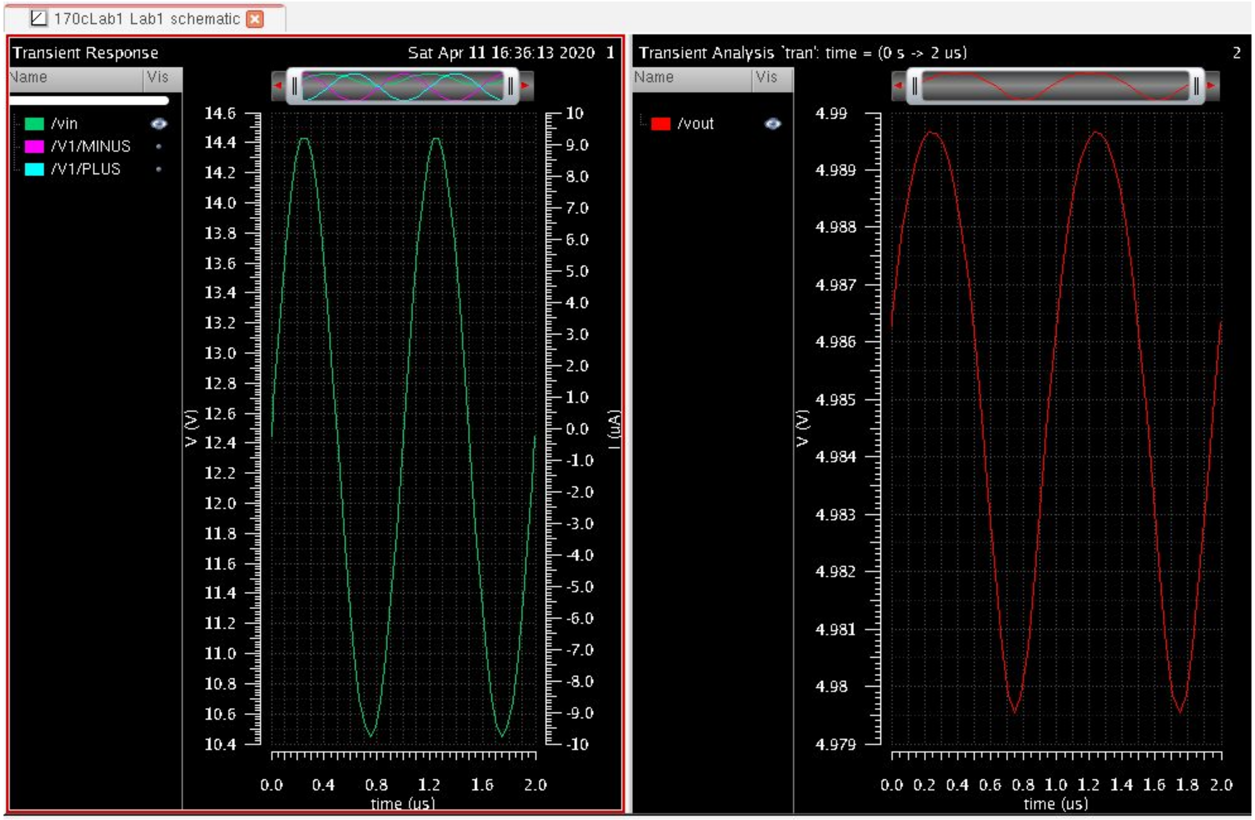


Fig. 1

- Since this is a buffer circuit, increasing Vin by 10mV will have no effect on the amplitude. However, increasing the amplitude from 10mV to 2V, which would be the maximum value, shows that Vout will start to clip (Fig.1). On the other hand, if Vin is increased significantly the output does not clip but the input does at around 14.4V (Fig. 2).



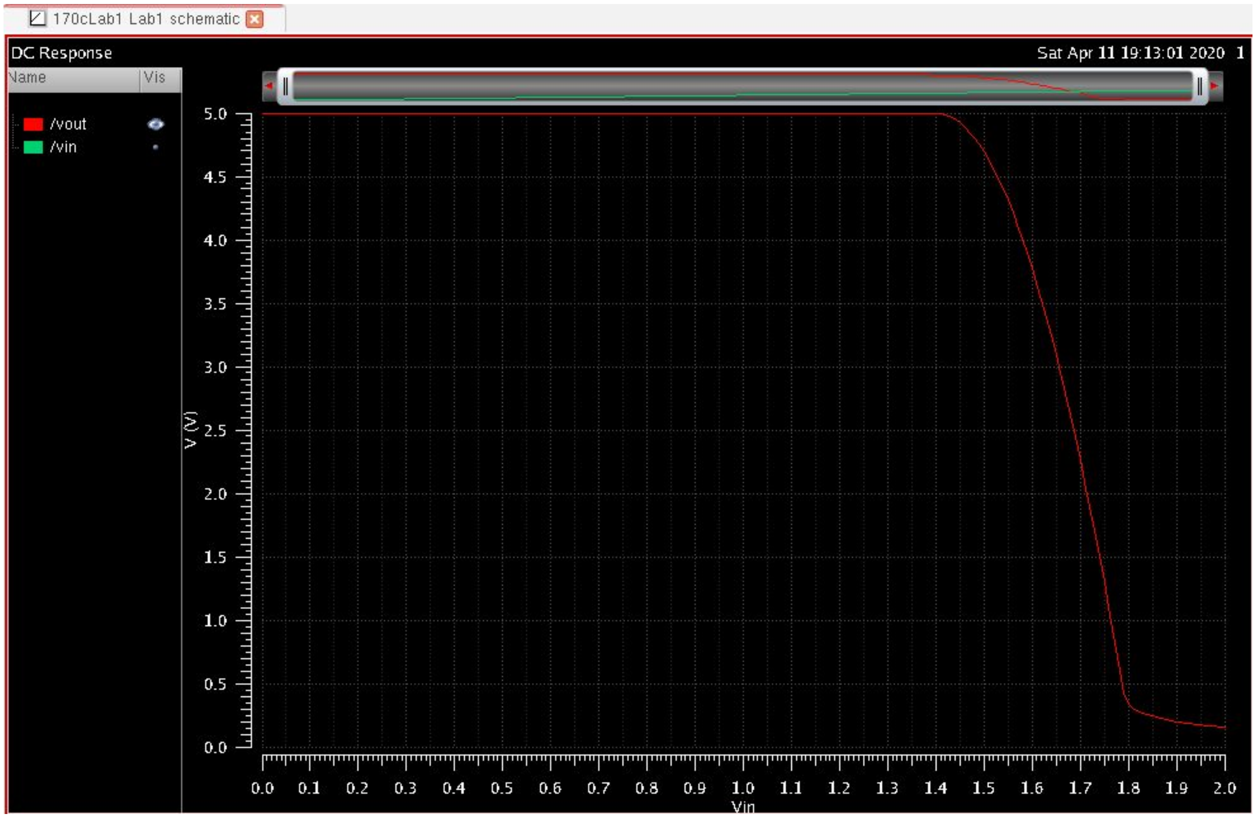
170cLab1 Lab1 schematic
Transient Response
Sat Apr 11 16:36:13 2020 1
Name
Vis
/vin
/V1/MINUS
/V1/PLUS
V (V)
I (uA)
time (us)
Transient Analysis `tran': time = (0 s -> 2 us)
2
/vout

Fig.2

Problem 2

A.

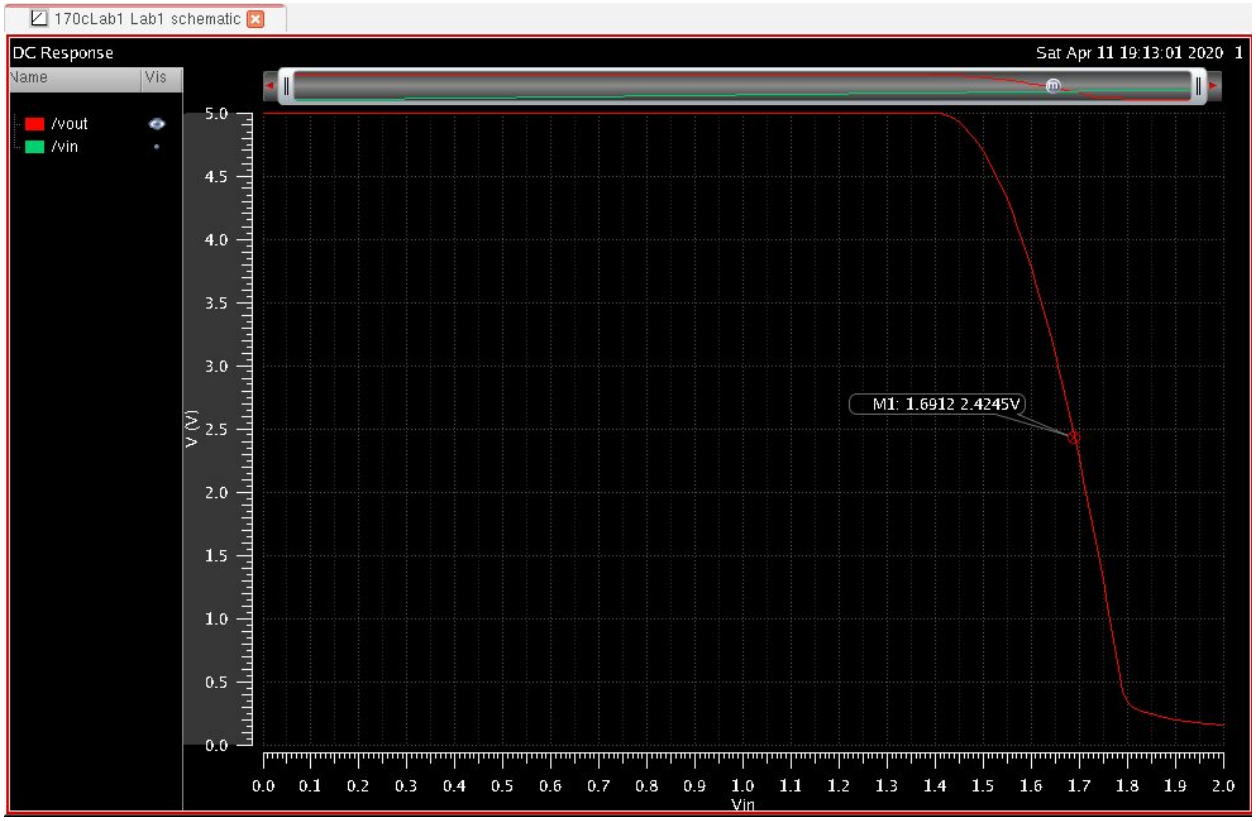
Vout vs. Vin



- Region of operation (from top to bottom of graph): 1) cutoff, 2) saturation, 3) triode

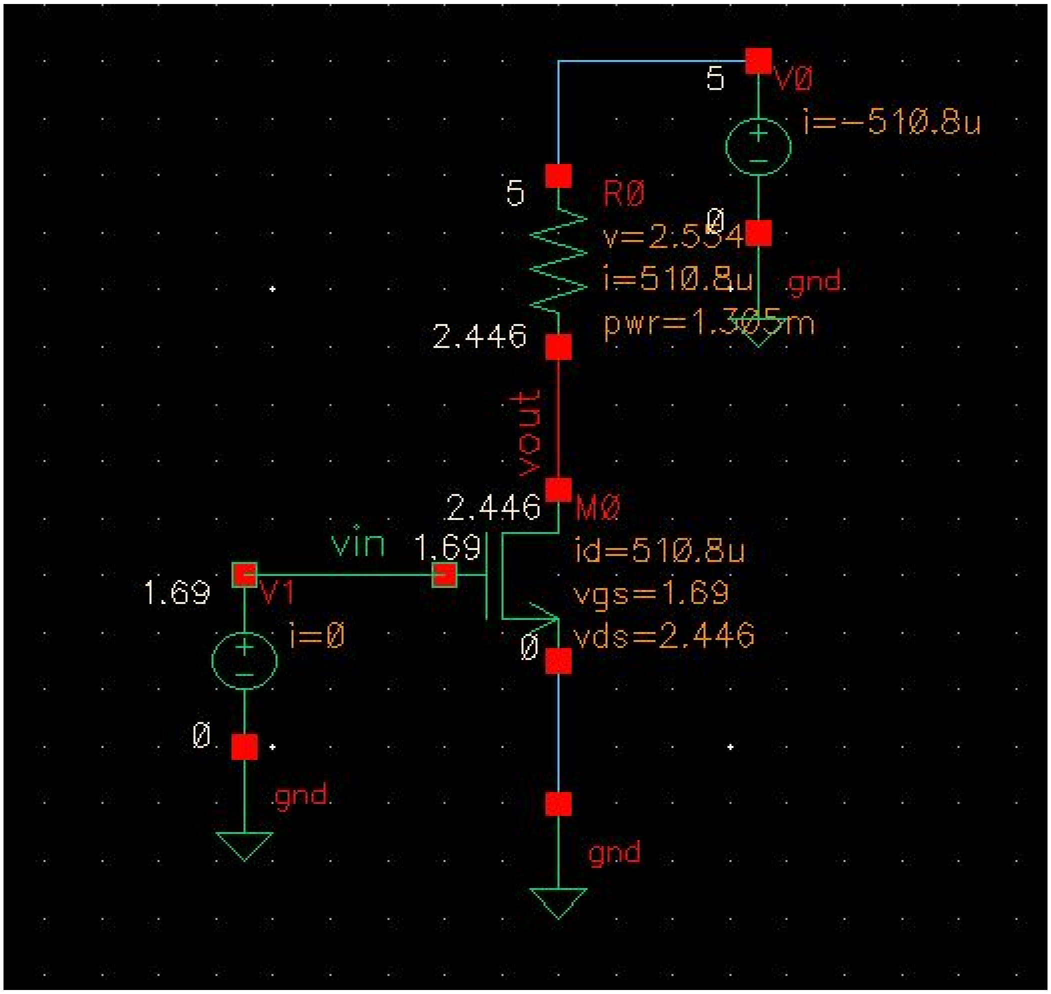
B.

Vin = Vin(eq2)



- Vout = 1.69V
- $V_{in} = V_{in(eq2)}$: $\frac{5V - 0.155V}{2} = 2.422V$

DC Operating Point Analysis



- The transistor is operating in saturation mode since Vds $\geq$ Vgs - Vt.
  - 2.446V $\geq$ 1.69V - 1.4V

C.

<u>Calculations</u>

Small signal parameters from simulation:

- gm =3.523m
- ro = 0.386 MΩ

Calculated small signal parameters

- gm = $\frac{2Ids}{Vgs-Vt}$ = <u>3.517m</u>
  - Ids = k'/2(W/L)(Vgs-Vt)^2 => 510.8u = 0.6m/2(200u/10u)(Vgs-Vt)^2
  - Vgs = $\sqrt{(510.8u/6m)}$ +1.4 = 1.69V

- ro = $\frac{1}{\lambda Ids}$ = 1/(0.005)(510.8uu) = 0.392 MΩ

Percent error:

- gm % error = 3.523n-3.517n/3.523n *100% = 0.17%
- ro % error = |0.386MΩ - 0.392MΩ|/0.386MΩ *100% = 1.5%

D.

Gain for common source circuit

- A =gm*(Rd || ro), Accepted gain: <u>17.3</u>
- Slope (5-0.311)/(1.8-1.43)=12.64
- Calculated gain: A = 3.523m * (4.9k) = <u>17.26</u>
- ro = 1/gds =1/2.586u=<u>386k</u>

Gain percent error:

17.3-17.26/17.3 *100% = <u>0.23%</u>

E.

Comparing AC and DC components of Vin and Vout

- DC input level: 1.69V
- DC output level: 2.45V
- Amplitude_Vin 1.691-1.689=2mV
- Amplitude_Vout 2.4631-2.4284=34.7mV
- Gain = Amp_Vout/Amp_Vin = 34.7/2=17.35
- DC and AC output levels increase when adding a sine wave input and the gain is high.

F.

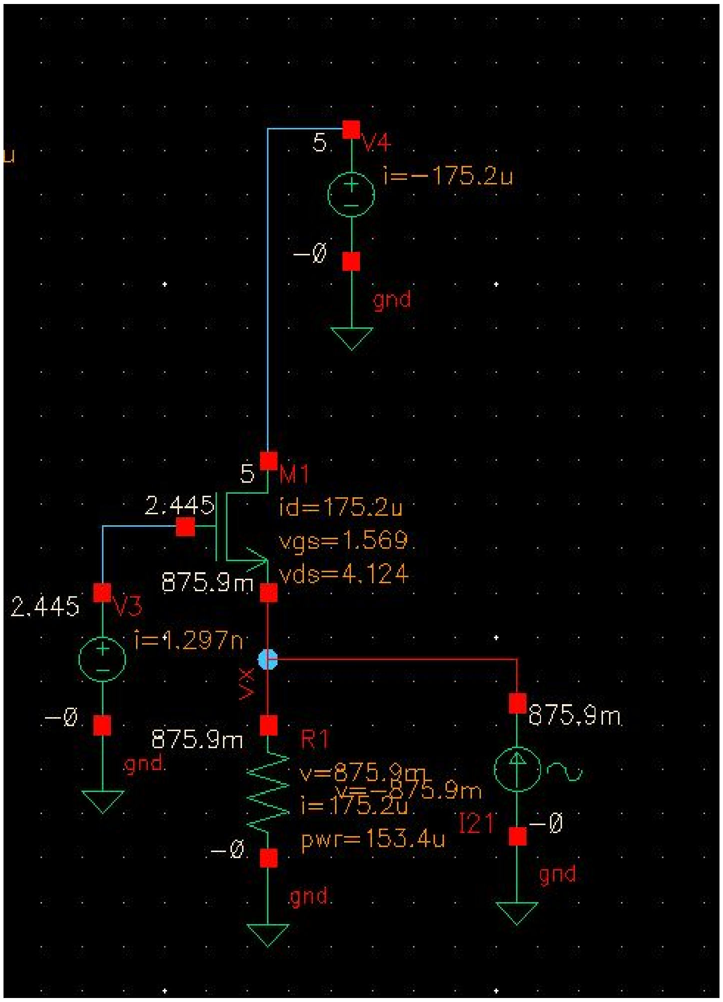
Increase Vin(eq2) by 10mV

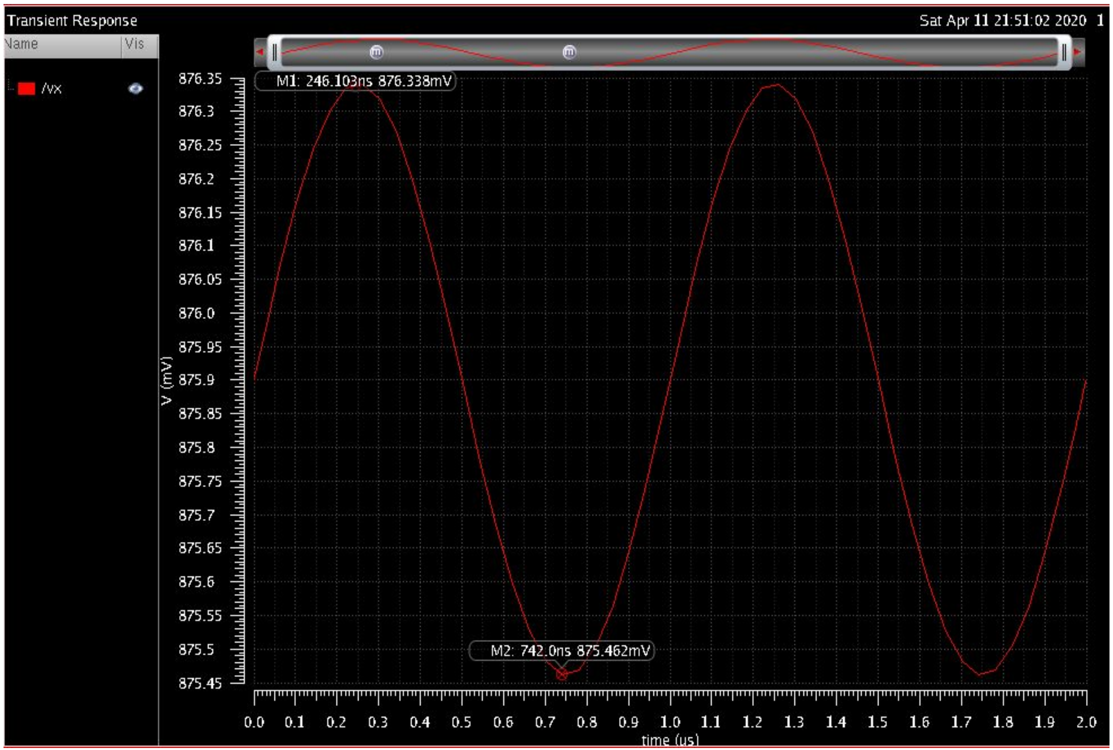
- Increasing Vin(eq2) by 10 mV increases the amplitude of the output to 347 mV.

Problem 3

A.

Calculate Rout for a common source circuit

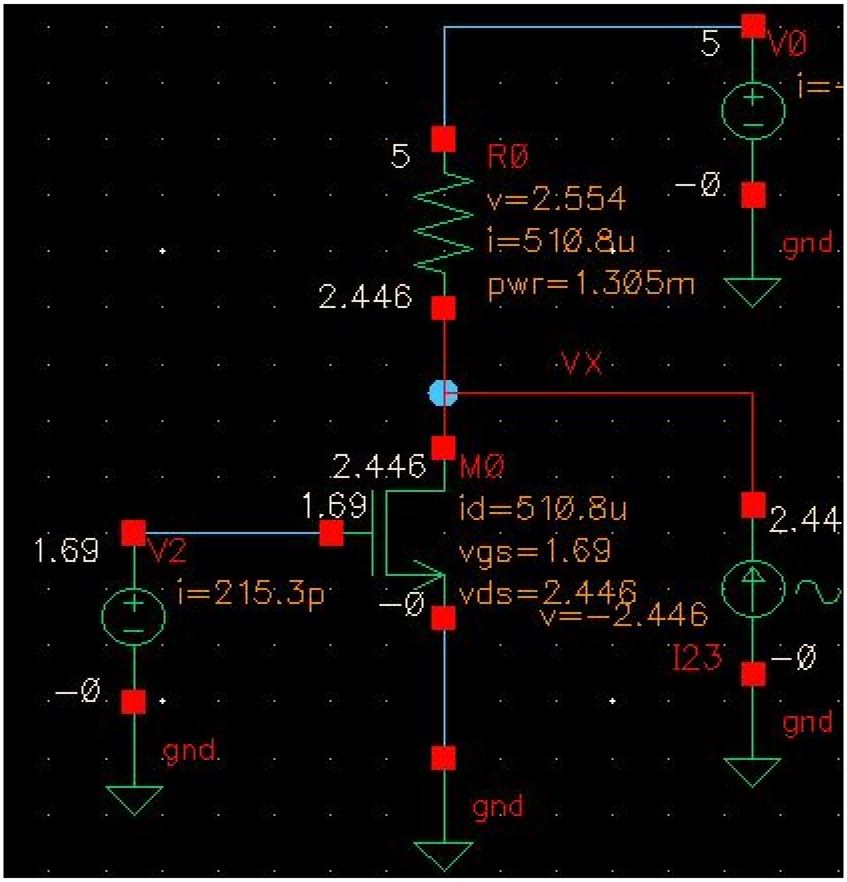


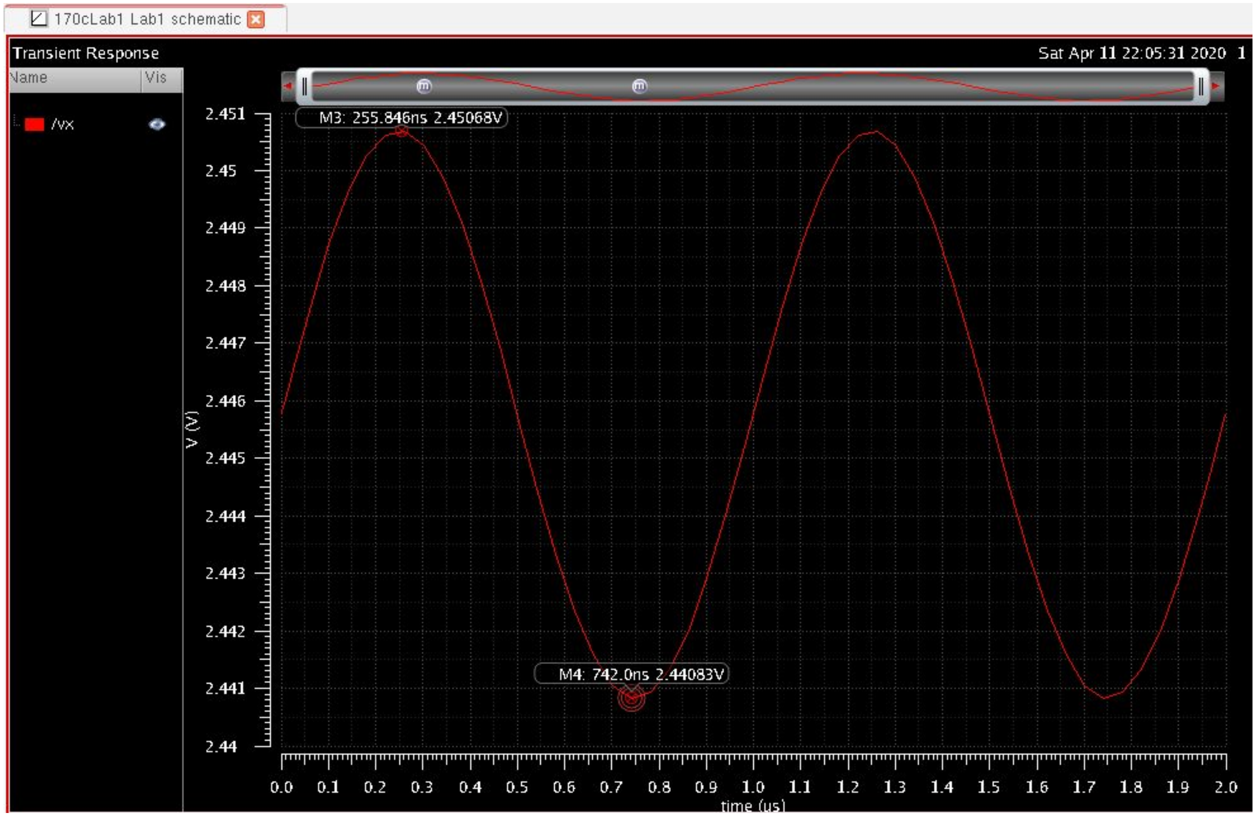


- Rout: Amp_vx/Amp_ix
- Amp_Vx = 876.3-875.4 mV = 0.9mV = 900u
- Amp_Ix = 2u
- Rout = 900uV/2uA = <u>450 ohm</u>

B.

Calculate Rout for common drain



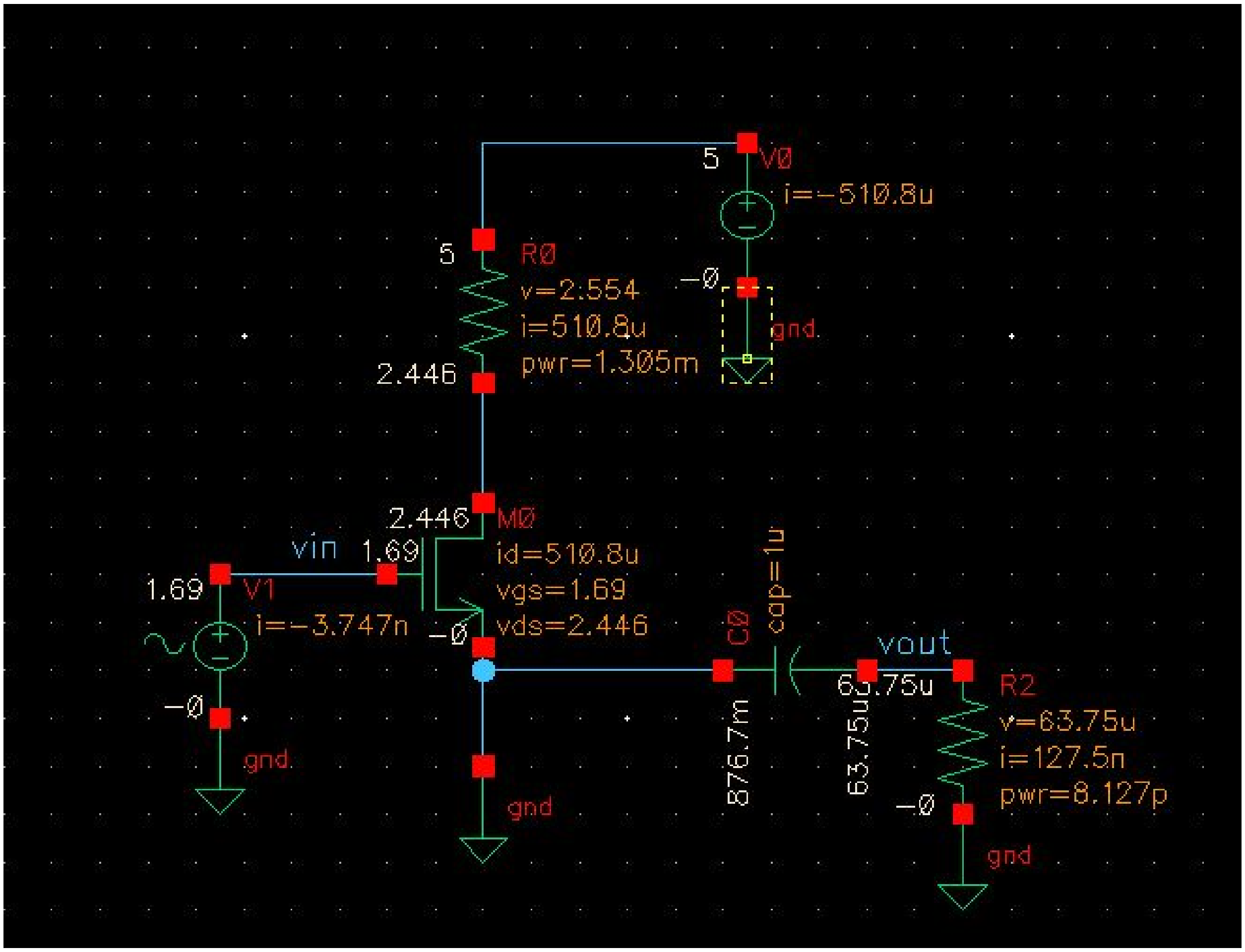


- Rout: Amp vx/Amp_ix
- Amp_Vx = 2.45V-2.44V = 0.01V = 10mV
- Amp_Ix = 2uA
- Rout = 10mV/2uA = <u>5k</u>

Problem 4

A.

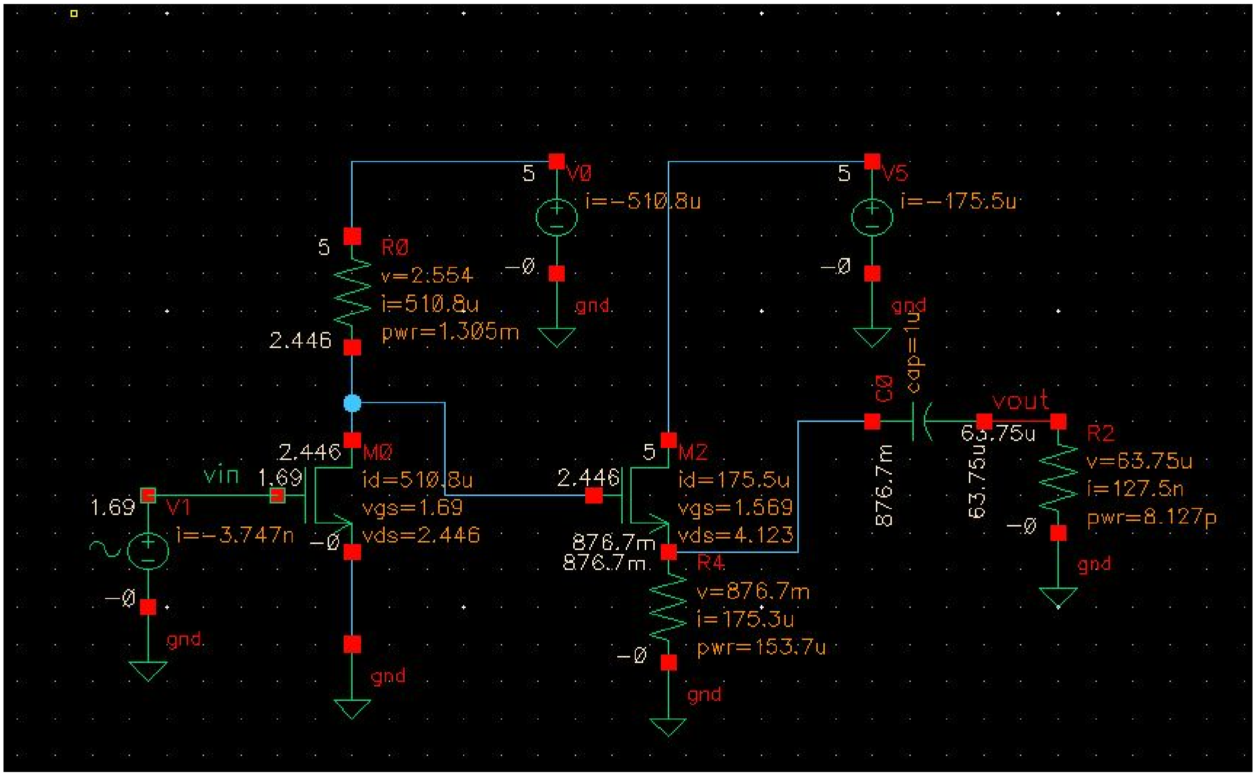
Small-signal gain Vout/Vin for one stage amplifier

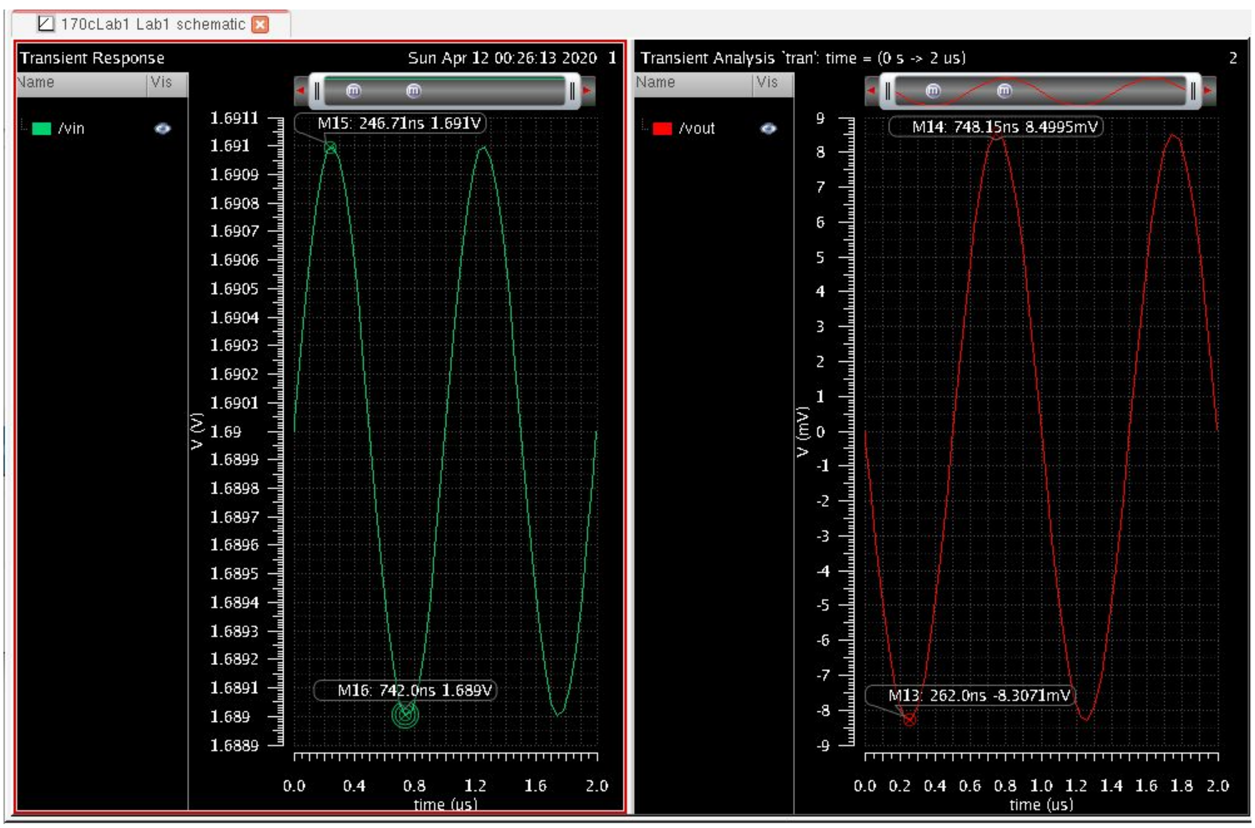


- A= gm* (Rd || ro || Rl) = gm*(Rd || Rl). Since ro is large it goes to 0.
- A = gm*(RL). Since Rd is a lot smaller than Rl, it goes to 0. This will decrease the gain.
- Amp_vout = 1.59mV
- Amp_vin = 2mV
- DC output level is 0 because we are looking at Vout after the capacitor.
- Gain = Amp_vout/Amp_vin = <u>0.795</u>. Small!

B.

Small signal gain Vout/Vin for two stage amplifier





- Gain = A1 * A2
- A1 = gm *Rd
- A2 = (Rs||Rl / (1/gm + Rs||Rl))
- Gain = gm*Rd <- expecting higher gain
- A_vout=8.4mV
- A_vin=2mV
- Gain = Amp_vout/Amp_vin = 4.2 which is a lot higher than previous the one-stage amplifier

Conclusion

The simulations given produced the results as expected. In the common drain and common source circuit, the correct plots along with the calculations for Vin(eq1) and Vin(eq2), gm, and ro were determined. The percent error between the actual and calculated values for gm and ro were small. In the circuits, Rout was calculated by putting a current source on the source and drain, respectively. To consider the effects of loading on the common source and common drain circuit, a capacitor was connected to the circuit. In the circuit with one transistor, the gain is small but when there are two transistors connected together, the gain is a lot higher thus making the circuit more robust.