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170LC

Lab 3

4/28/2020

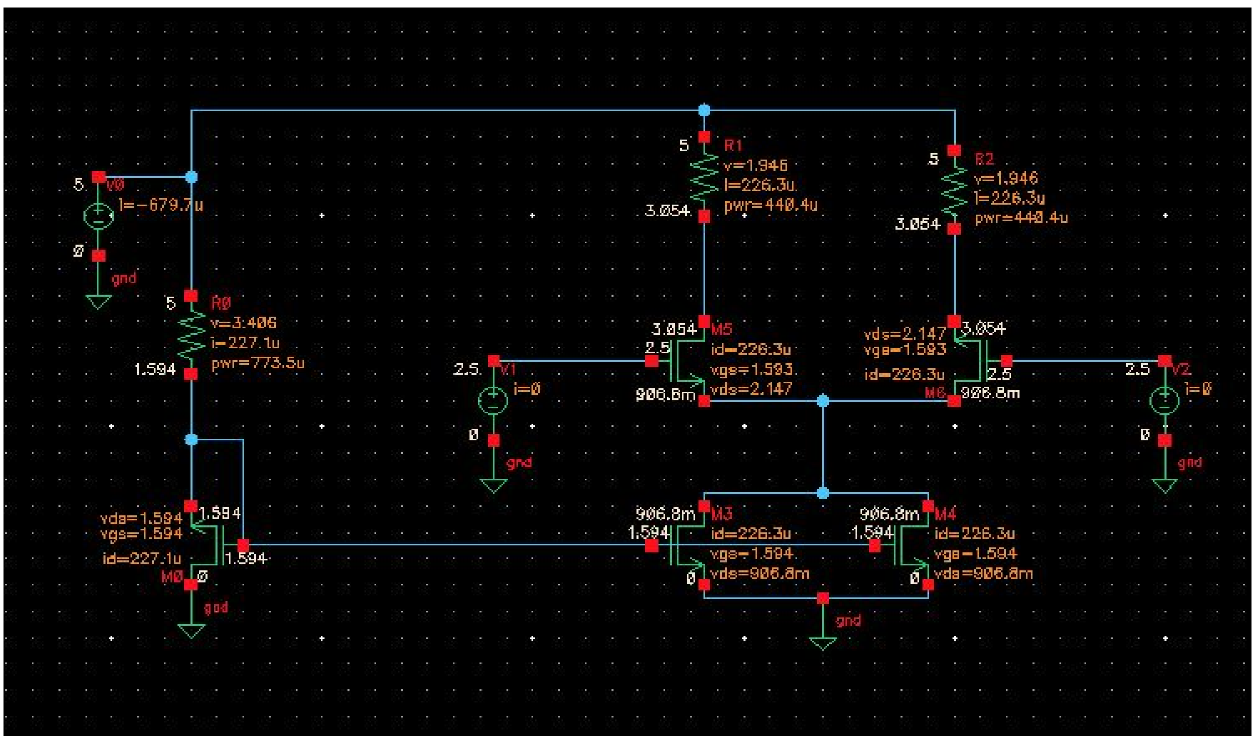
SIM 1

Rref Sweep

Calculations before simulation:

- I(Md) = ½ μCox(W/L)(Vgs-Vt)^2(1+λVds)
    - 225μA = ½ (0.6e-3)(200μm/10μm)(Vgs-1.4)^2(1+0.005Vgs)
        - **Vgs = 1.6V**
- I(Md) = Vdd-Vgs/Rref
    - Vdd = 5V
    - 5V-1.6V/Rref
        - **Rref = 15.1kΩ**

- Transistor is in saturation
  - Vds > Vgs - Vt
  - Vd - Vs > 2.5V - Vs - 1.4V
    - **Vd > 1.1V**
- DC operating point
  - Vout(dc) = [Vdd + Vd(min)]/2 → (5V + 1.1V)/2
    - **Vout(dc) = 3.05V**
- Rd value
  - (5V-3.05V)/225μA
    - **Rd = 8.66kΩ**

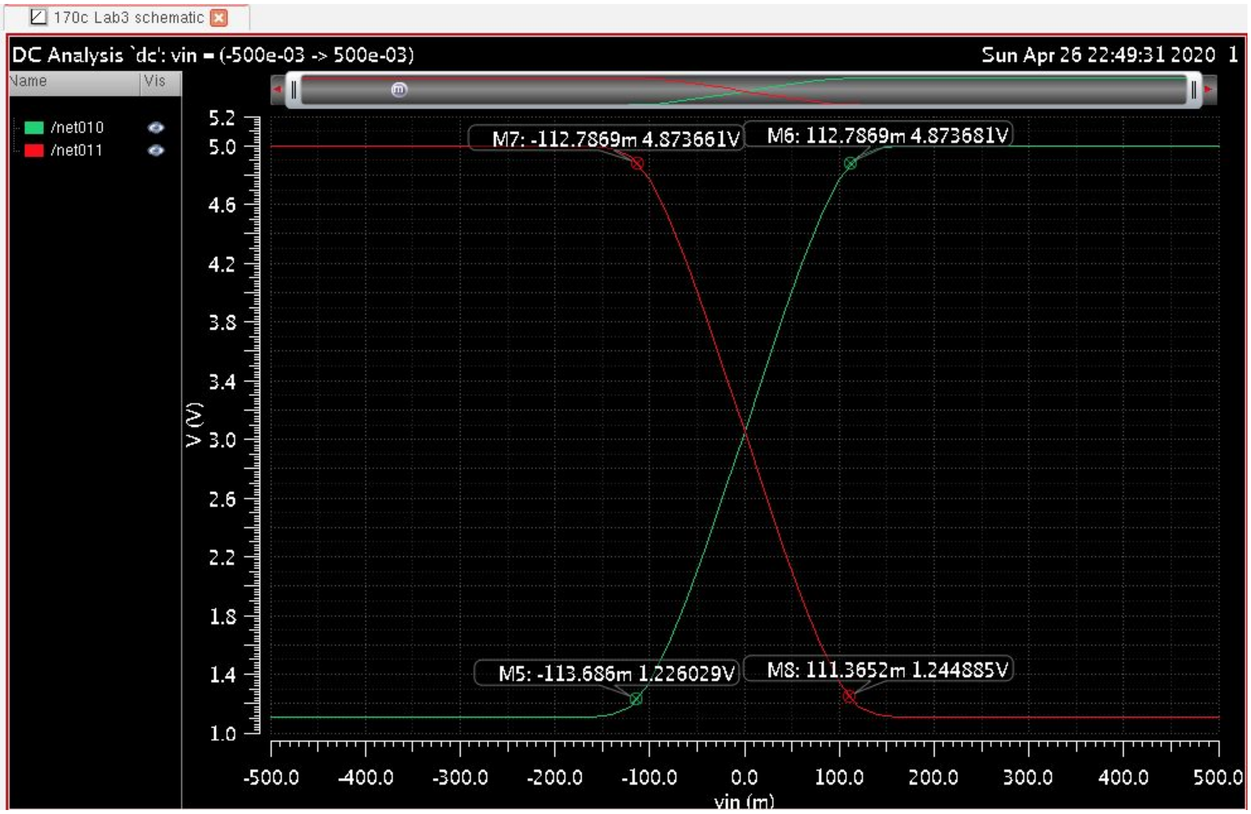


Calculations after simulation:

- Differential Mode Gain = -gmRd = - 2IdRd/Vgs-Vt
  - [-2(226.3μA)(8.66kΩ)]/(1.593-1.4)
    - **Adm = -20.16**

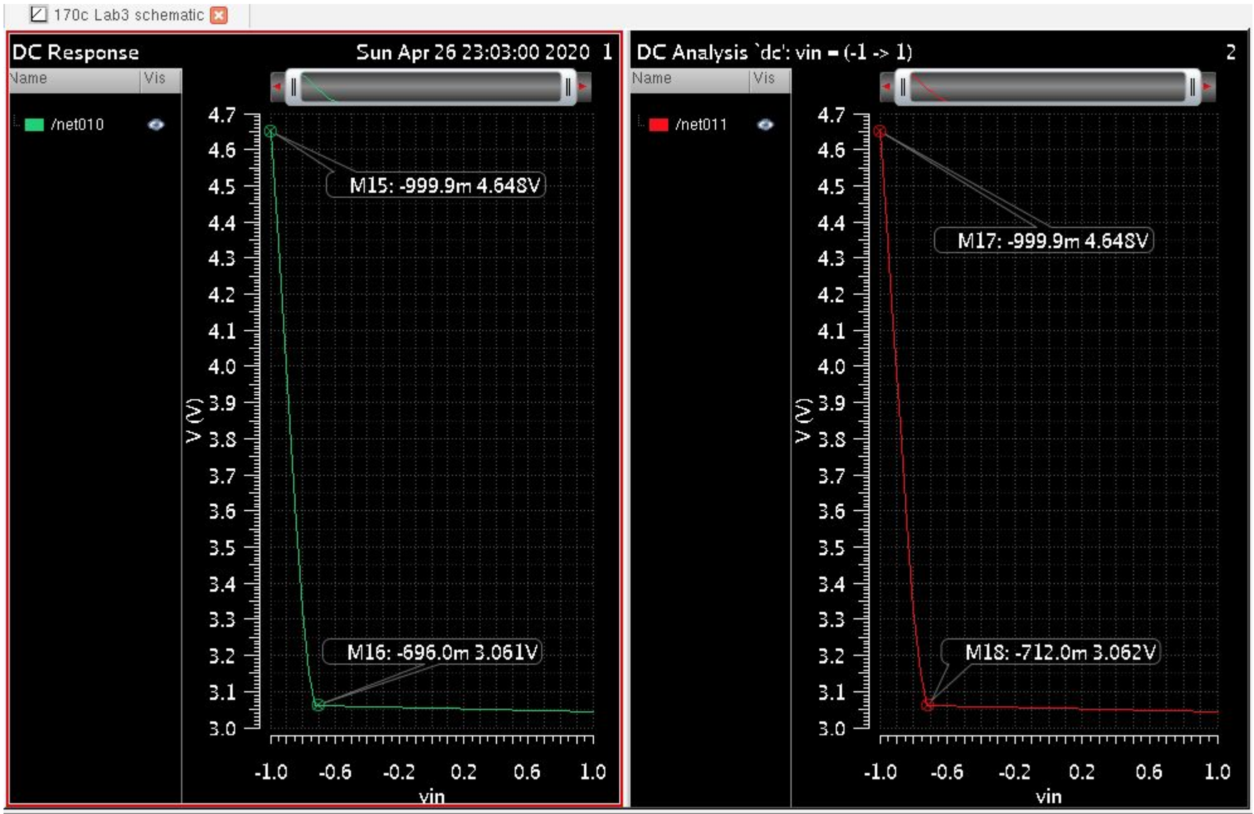
- Common Mode Gain = - gmRd/1+gmro = - (2IdRd/Vgs-Vt)/(1+(2Id/Vgs-Vt)(1/λId)) = - (2IdRd/Vgs-Vt)/(1+(2/Vgs-Vt)(1/λ))
    - - 20.30/1037
        - **Acm = -0.019**

SIM 2



- Input voltage range: -113mV to 112mV
- Output voltage range: 4.87V to 1.24V
- Slope (Green curve): y2-y1/x2-x1 = (4.87-1.22)/(0.112+0.113) = **16.22**
- Slope (Red curve): y2-y1/x2-x1 = (1.24-4.87)/(0.111+0.112) = **-16.27**
- The values for the slope were close to the calculated value for differential-mode gain.
    - Calculated Value: **-20.16**

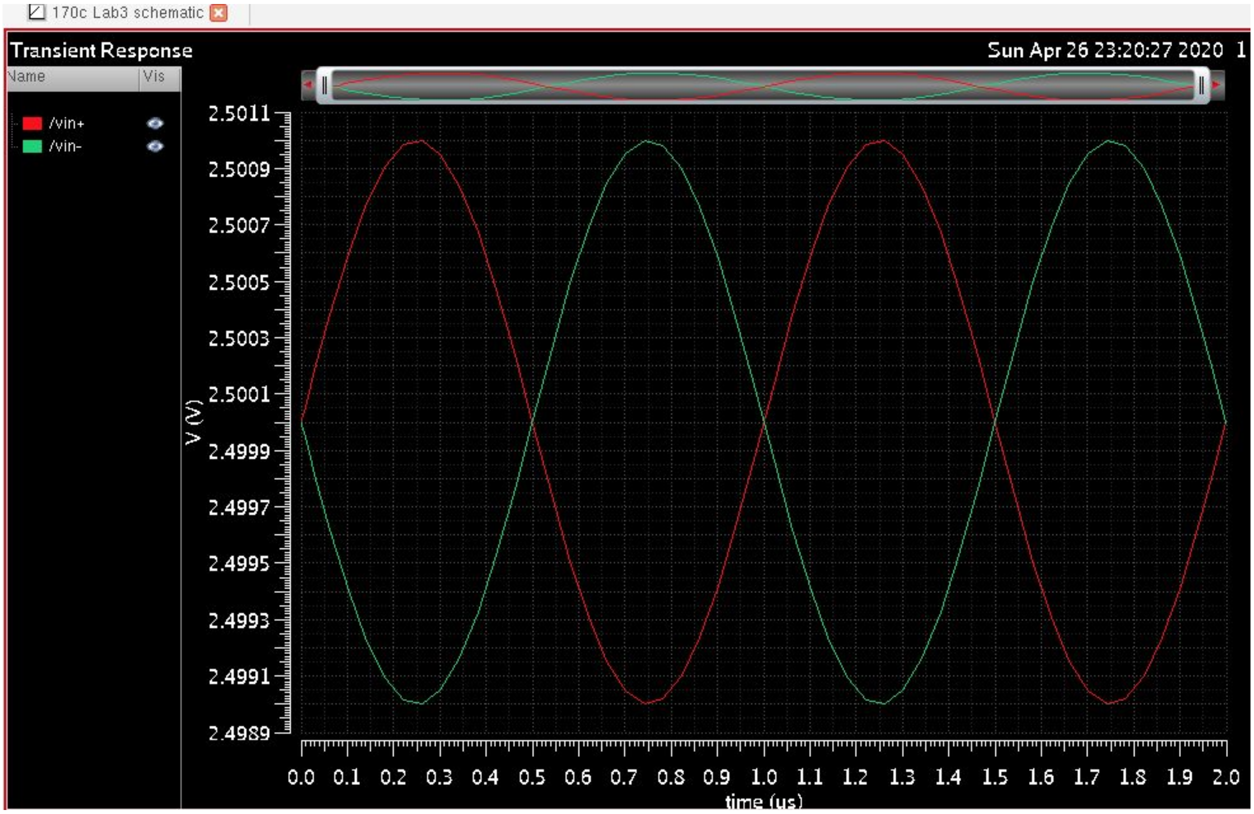
SIM 3



- Input voltage range: -999mV to -696mV
- Output voltage range: 4.64V to 3.06V
- Slope (Green curve): y2-y1/x2-x1 = (3.06-4.64)/(-0.696+0.999) = **-5.21**
- Slope (Red curve): y2-y1/x2-x1 = (3.06-4.64)/(-0.712+0.999) = **-5.50**
- The values for the slope were significantly lower than the common-mode gain that was calculated.
  - Calculated Value: **-0.019**

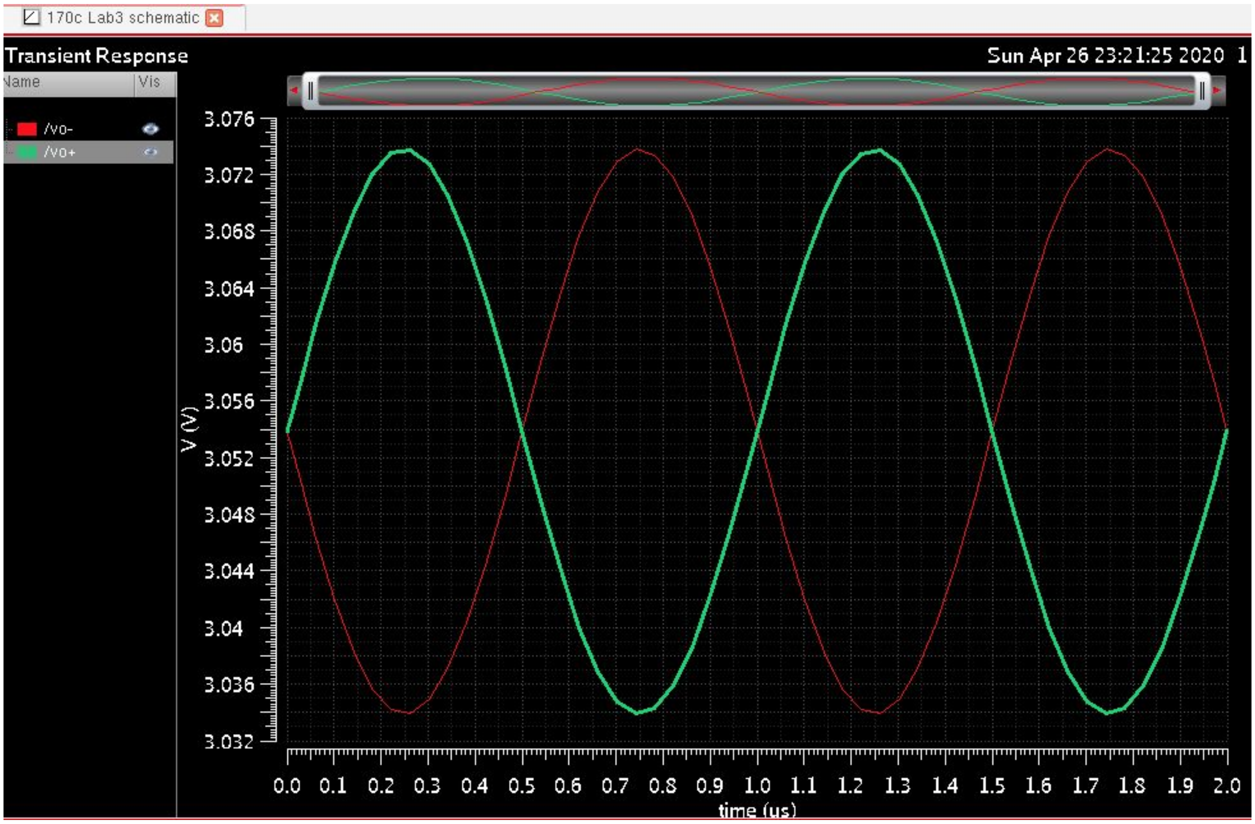
SIM 4

Differential Inputs



- DC value at 2.5 V

Differential Outputs

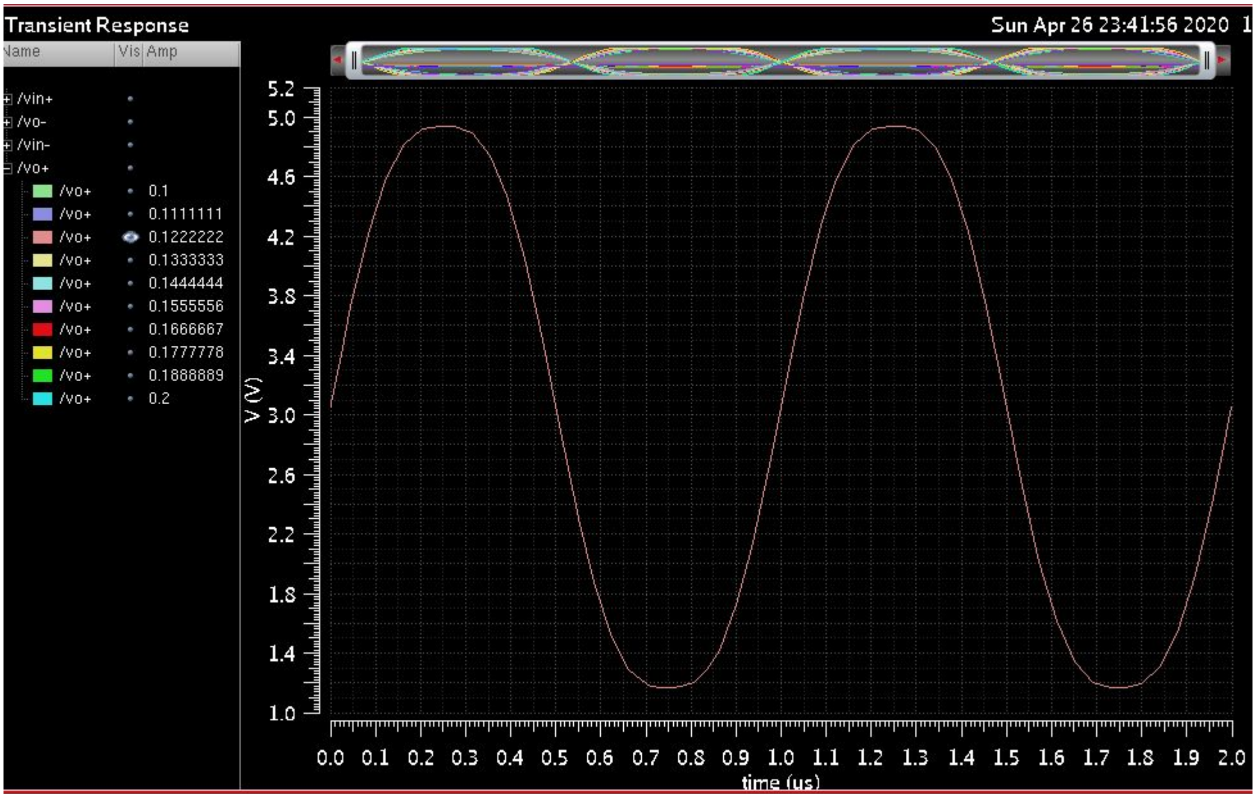


- DC value at 3.05V

Differential-mode Input and Output

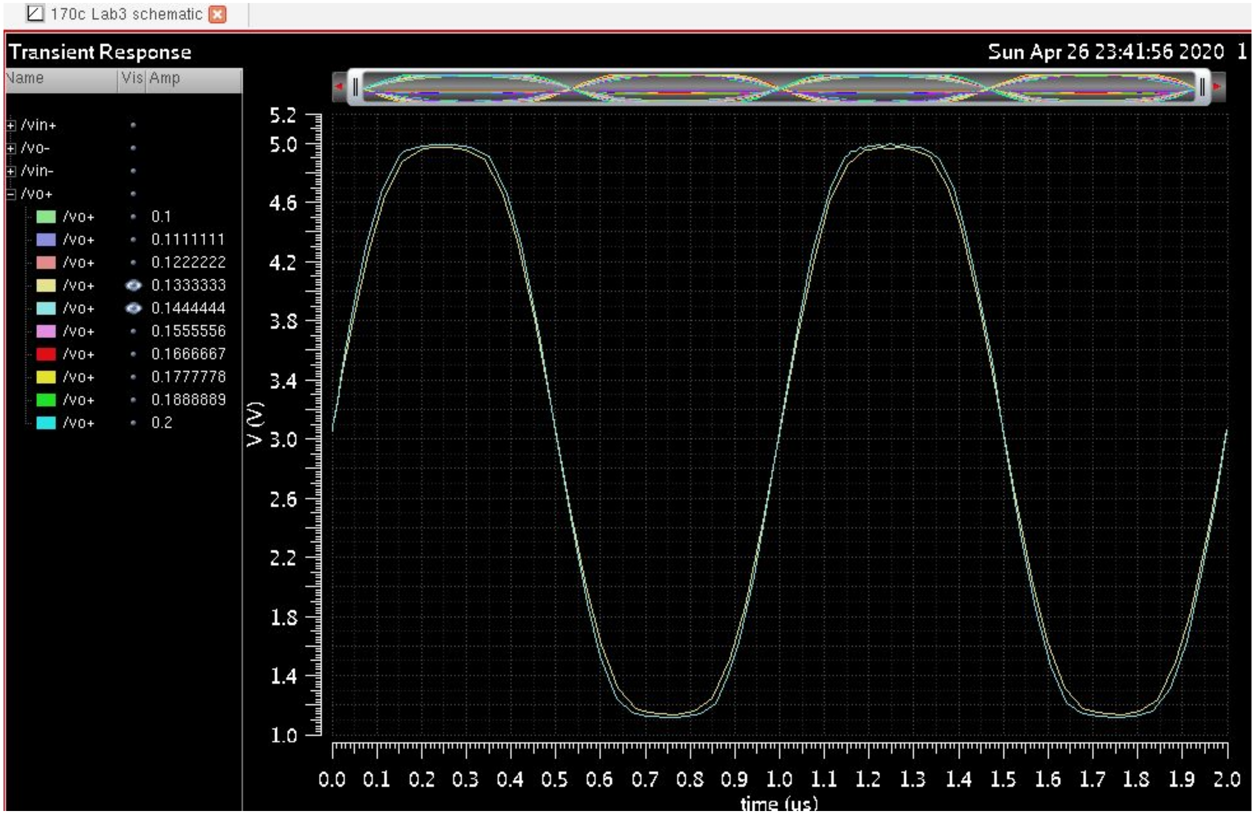
- Differential output gain is significantly higher than the input gain.

Maximum Amplitude



- The maximum amplitude for which the differential mode output looks sinusoidal is at 122mV.

Increasing Amplitude



- When the amplitude is increased higher than its maximum value, the output waveform starts to clip. This means the transistor is no longer in the saturation region.

Conclusion

In this lab, we were asked to design a CMOS differential amplifier. The reference resistor value was determined from I(Md), Vdd, and Vgs. The DC operating point was determined from the maximum and minimum values that kept the transistor in saturation. The value of Rd was calculated from the DC operating point. Differential and common mode gains were calculated and confirmed with simulation results. The slope for the differential-mode input and output was close to the calculated value however, the calculated value for the common mode gain was significantly higher than the slope. Adding a differential sine wave to the inputs produced outputs with much higher gain. The output waveform begins to clip when the amplitude is above 122mV. This implies the region of operation has changed in the transistor.