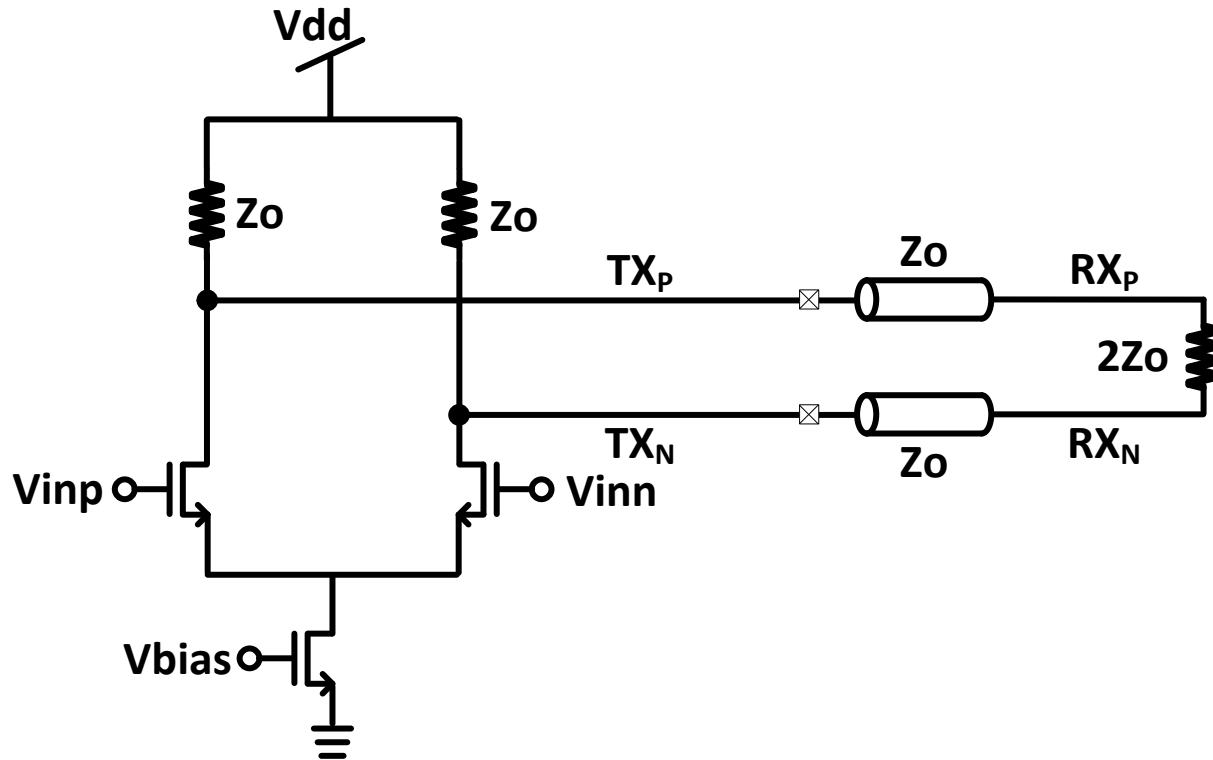


High-Speed Serial Interface Circuits and Systems

Design Exercise 7 – TX Drivers

Current-Mode Logic (CML) Driver

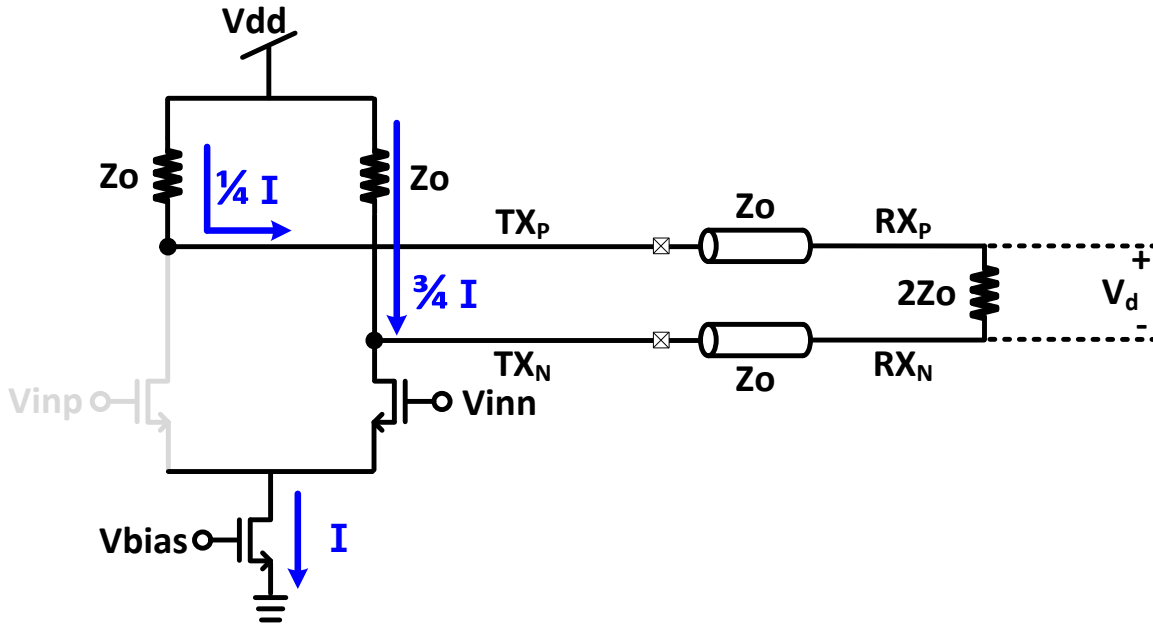


- Based on current steering
- Both sides are terminated by 50Ω
- Basic structure in high-performance serial link

CML Driver Current

- Differential termination

- Impedance matching with differential termination : $2Z_0$



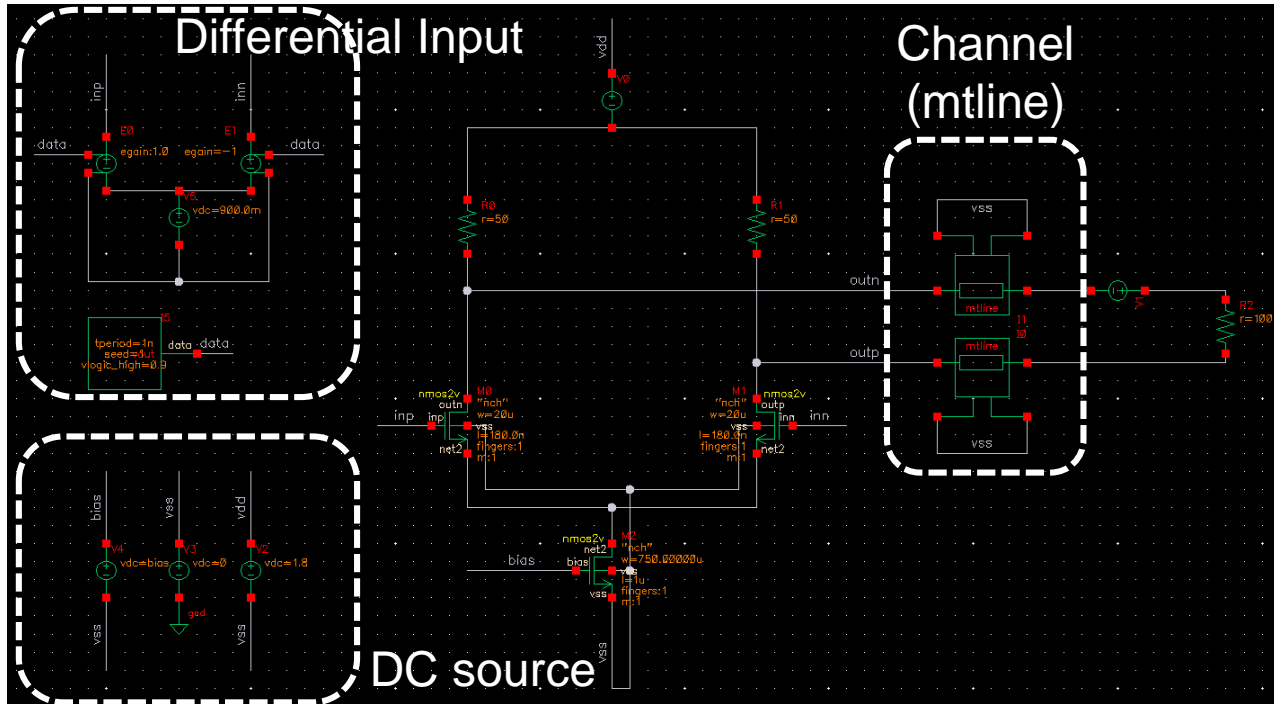
$$V_{d_1} = (I/4)(2R)$$

$$V_{d_0} = -(I/4)(2R)$$

$$V_{d_pp} = IR$$

$$I = \frac{V_{d_pp}}{R}$$

CML Driver

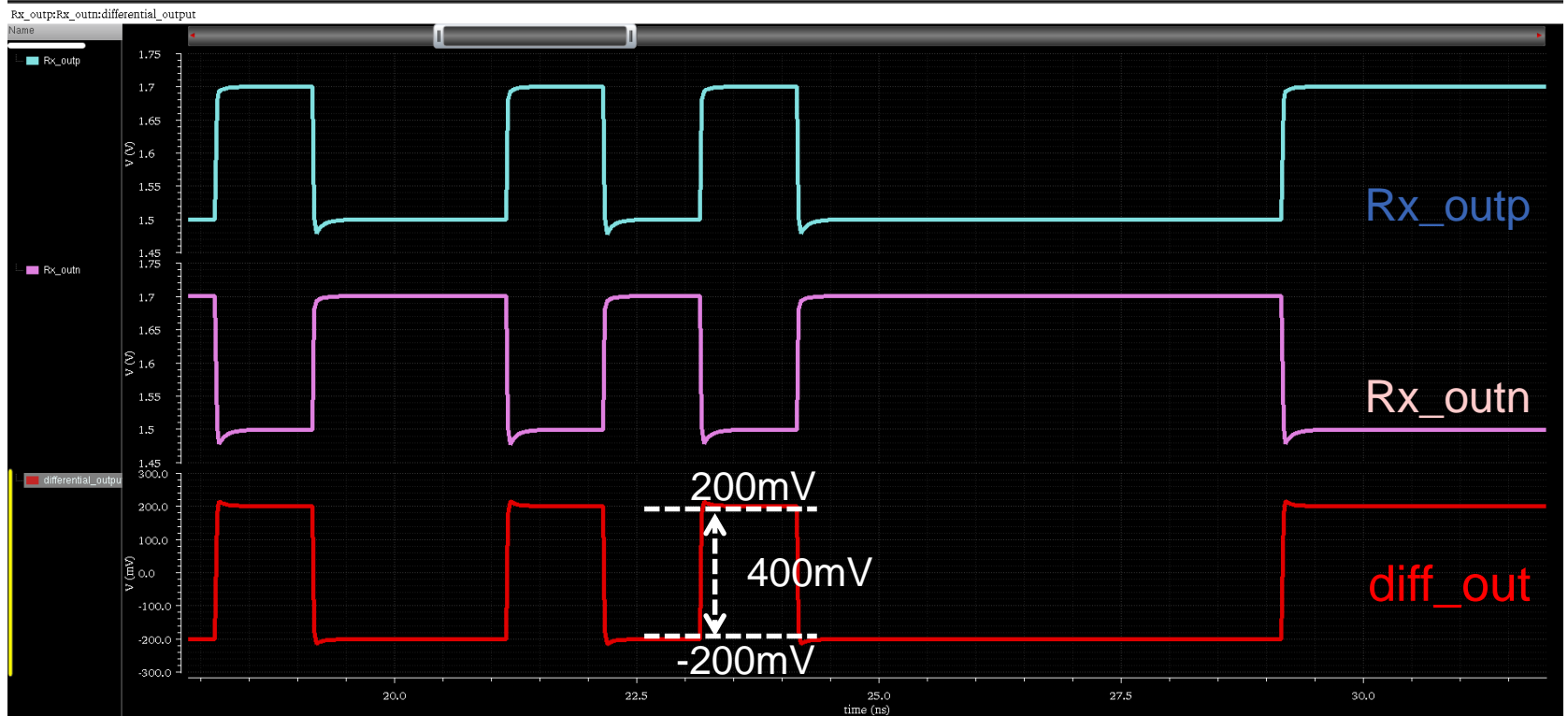


- Input MOSFET
 - Length : 180n
 - Width : 20u
- Source MOSFET
 - Length : 1u
 - Width : 750u
- Vbias
 - Voltage : 0.7
- Input_source (1-Gb/s data)
 - rand_bit_stream
 - Tperiod : 1n
 - Seed : 1
 - Vlogic_high : 1.8
 - Vlogic_low : 0
 - Vrise : 20p
 - Vfall : 20p
- Mtlne
 - Type of Input : Tline
 - Impedance : 50ohm
 - Delay Time : 150p

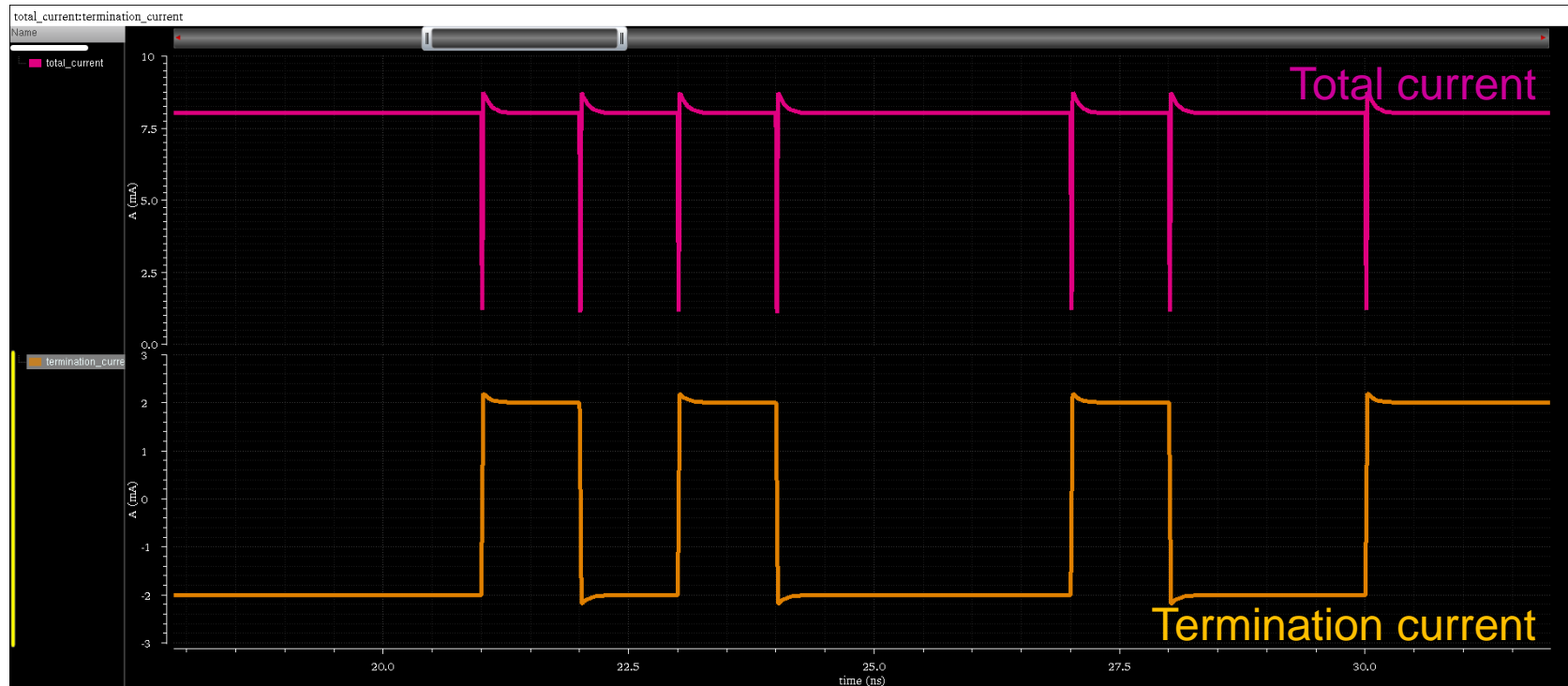
Output driver Specification

- 50Ω
- $V_{outp} = V_{outn} = 200mV$
- $V_{diff_pk_pk} = 400mV$

CML Driver Simulation Results

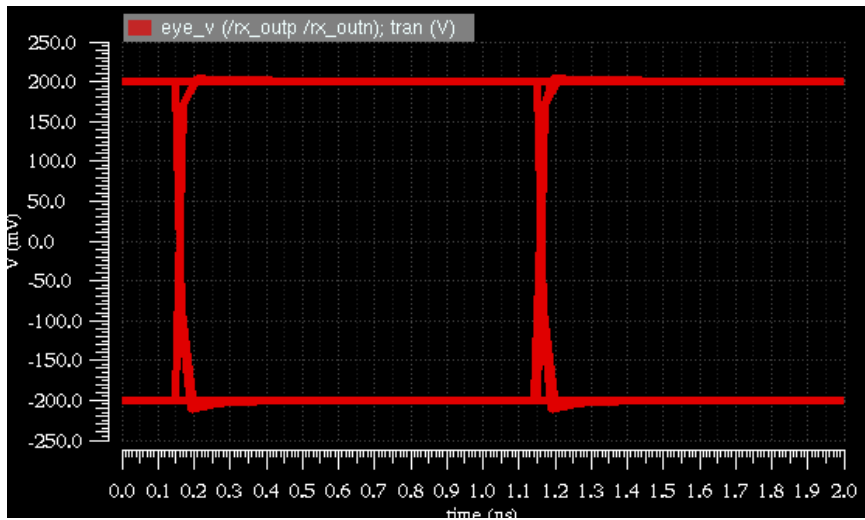


Simulation Results (Current)

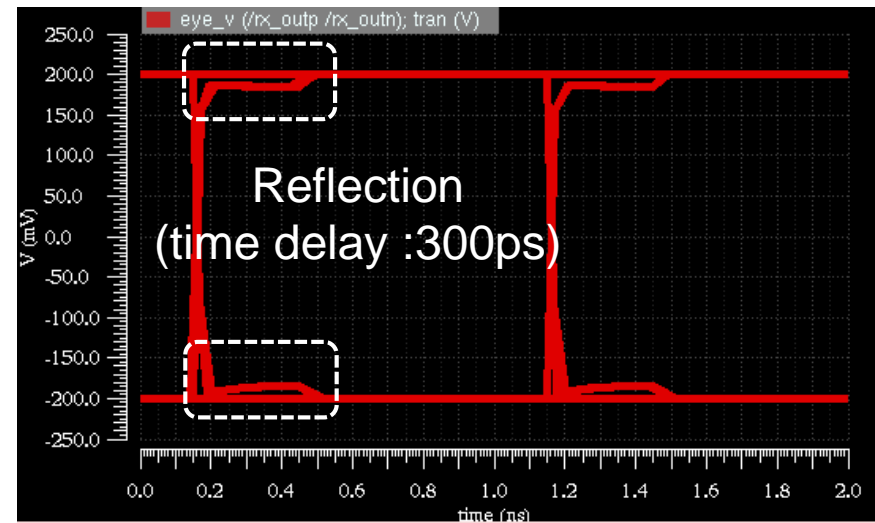


- Total current : 8.0 mA ($V_{\text{diff_pp}}$ 400mV condition)
- Termination max. current : 2.0 mA ($V_{\text{diff_pp}}$ 400mV condition)

Simulation Results (Different Z_0)



Transmission Line : 50ohm

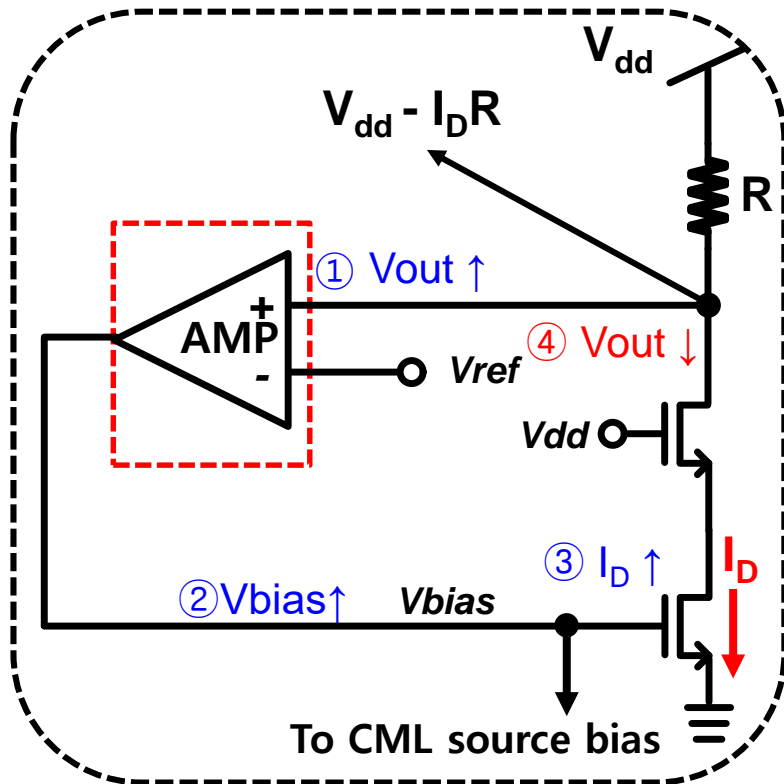


Transmission Line : 75ohm

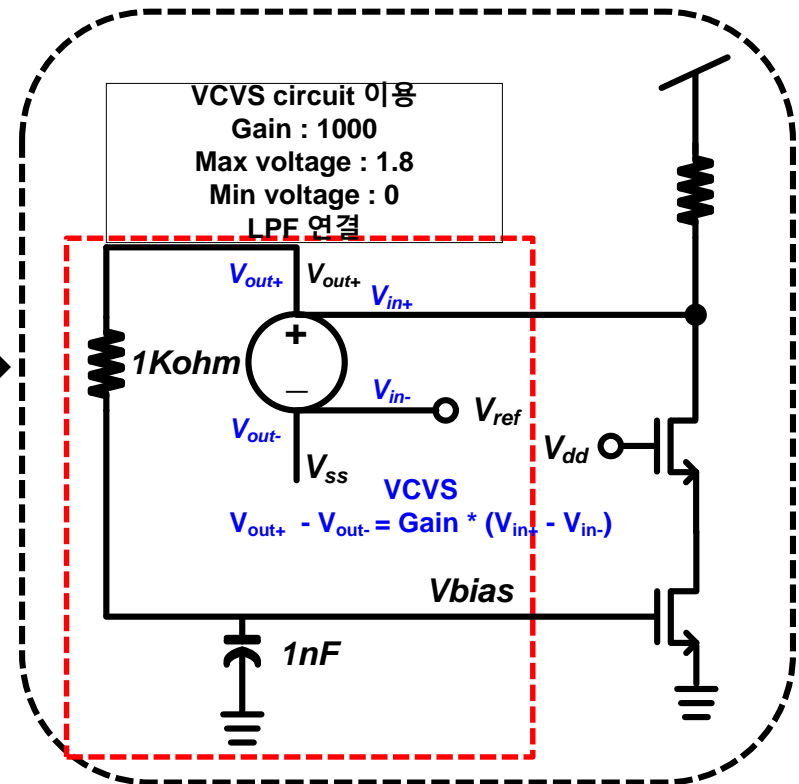
Replica Circuit for Output Swing

- Output swing voltage control
- Negative feedback

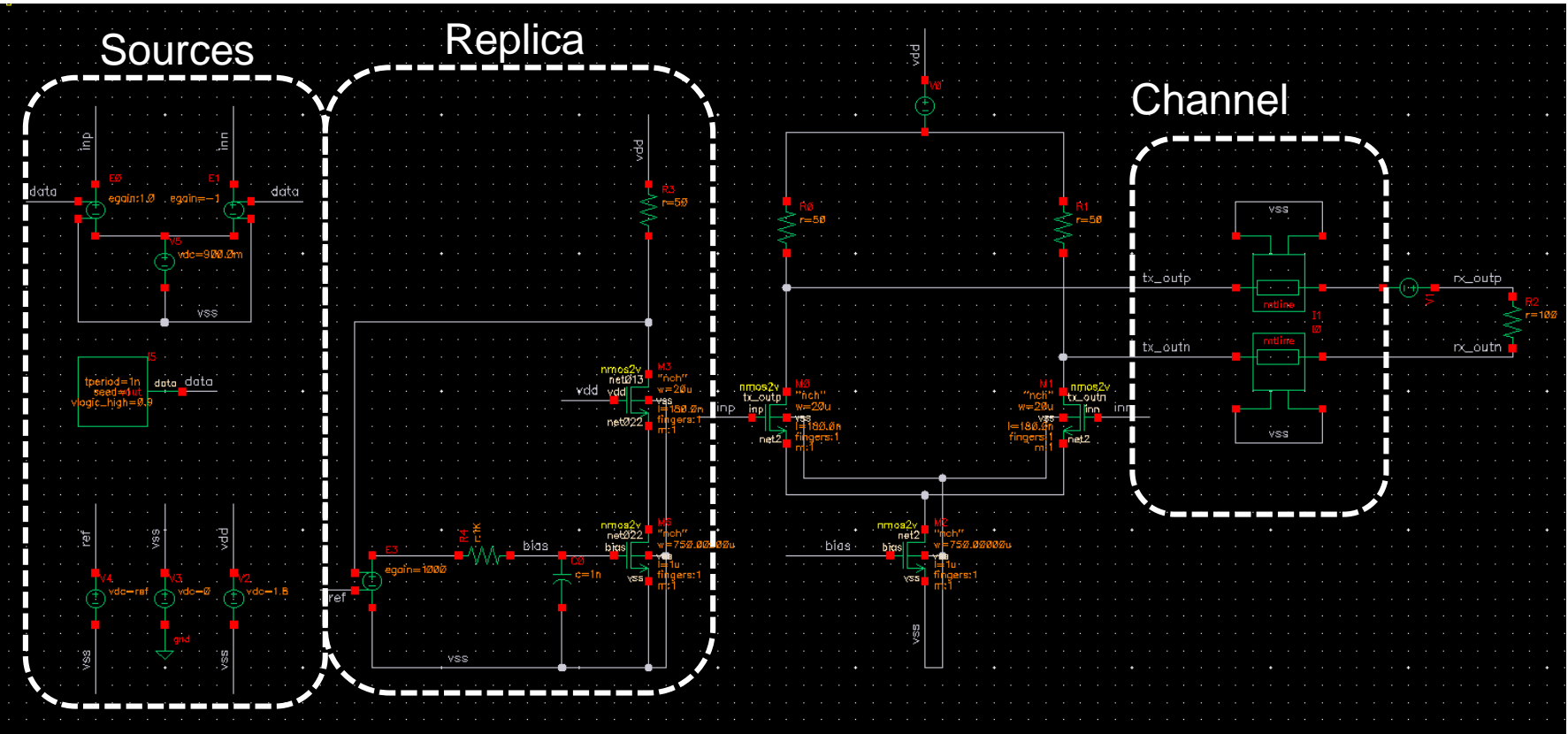
Circuit Structure



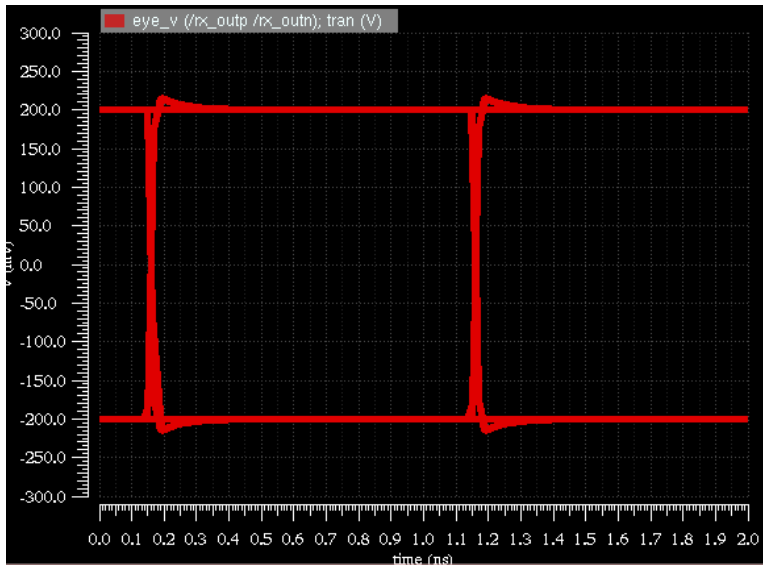
Alternative Circuit Structure



CML Driver w/ Replica

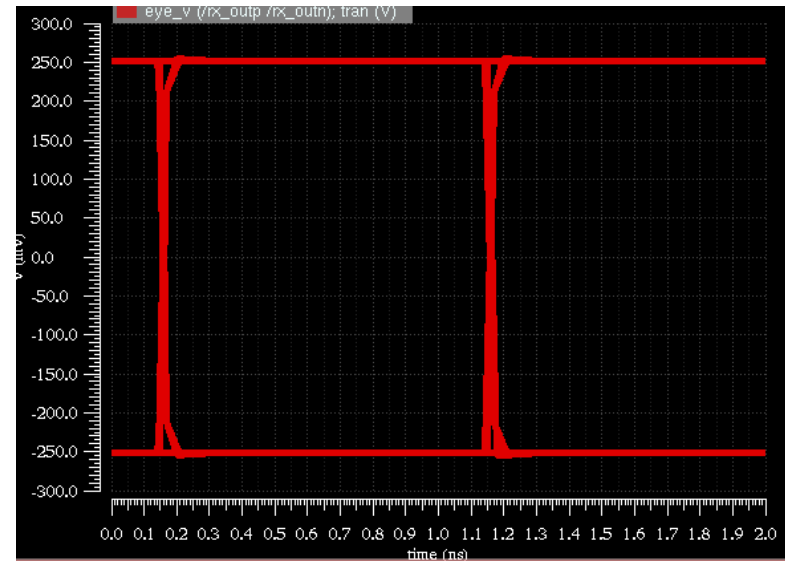


Simulation Results for Different Swing



$V_{\text{diff_pp}} : 400\text{mV}$
($V_{\text{ref}} = 1.8 - 0.4 \text{ V}$)

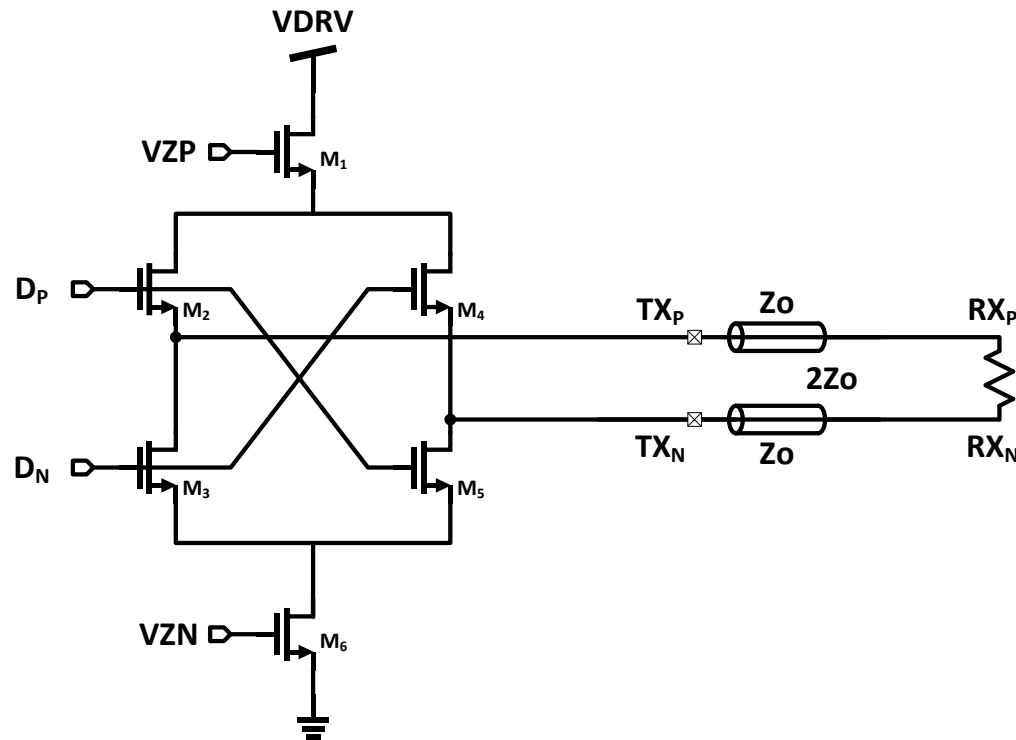
Total current : 16.0 mA (w/ replica)



$V_{\text{diff_pp}} : 500\text{mV}$
($V_{\text{ref}} = 1.8 - 0.5 \text{ V}$)

Total current : 20.0 mA (w/ replica)

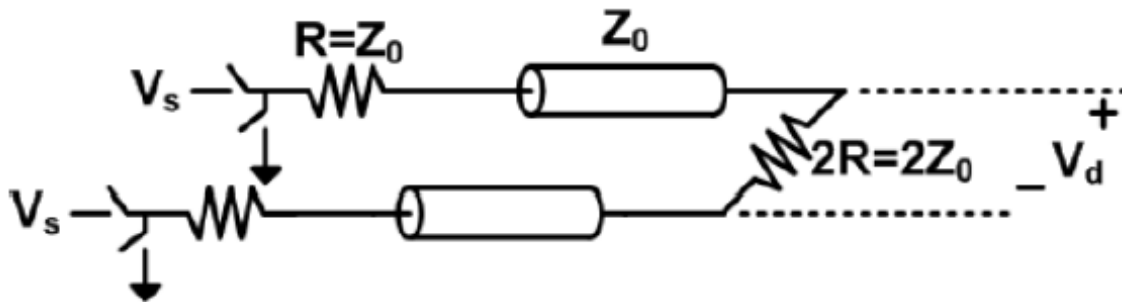
Voltage-Mode (VM) Driver



- Use $\frac{1}{4}$ current for given output swing compared to CML driver
= Low power operation!
- Driver output impedance matching issue.

VM Driver Current

- Differential termination
 - Impedance matching with differential termination : $2Z_0$



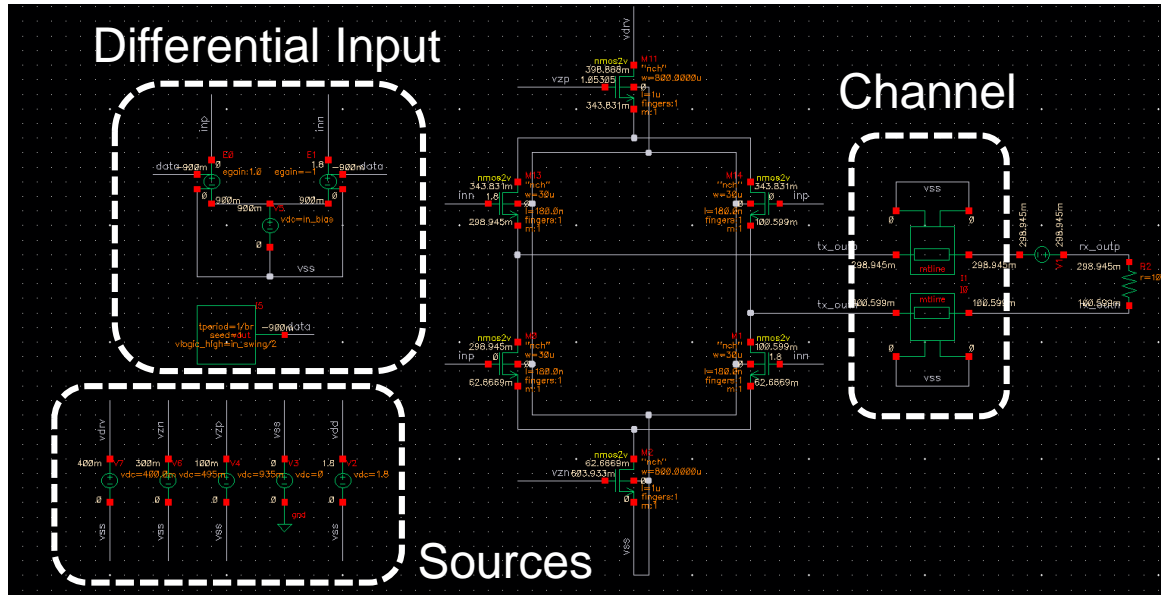
$$V_{d_1} = (V_s / 2)$$

$$V_{d_0} = -(V_s / 2)$$

$$V_{d_pp} = V_s$$

$$I = \frac{V_{d_pp}}{4R}$$

VM Driver Schematic

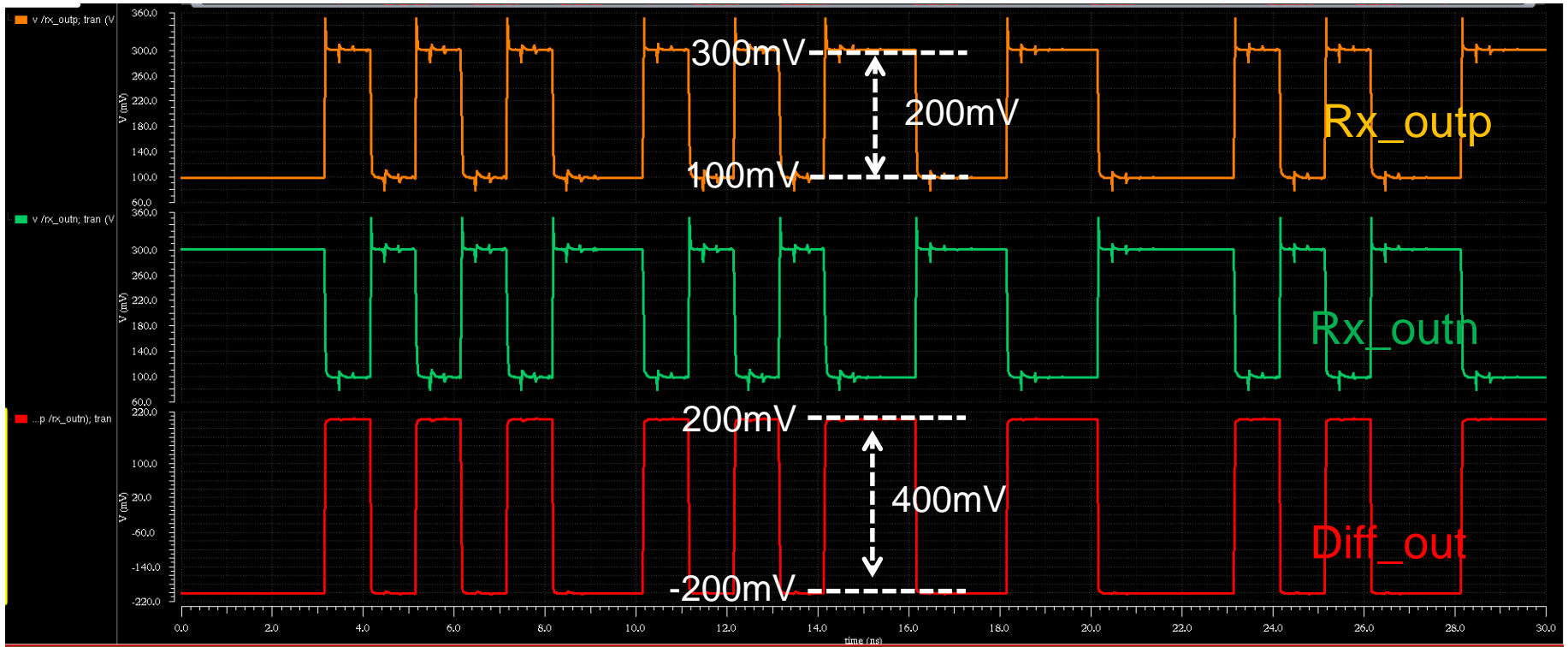


- Input MOSFET
 - Length : 180n
 - Width : 30u
- Current source MOSFET
 - Length : 180n
 - Width : 800u
- VZP bias
 - Voltage : 935mV
- VZN bias
 - Voltage : 495mV
- VDRV
 - Voltage : 400mV

Output driver Specification

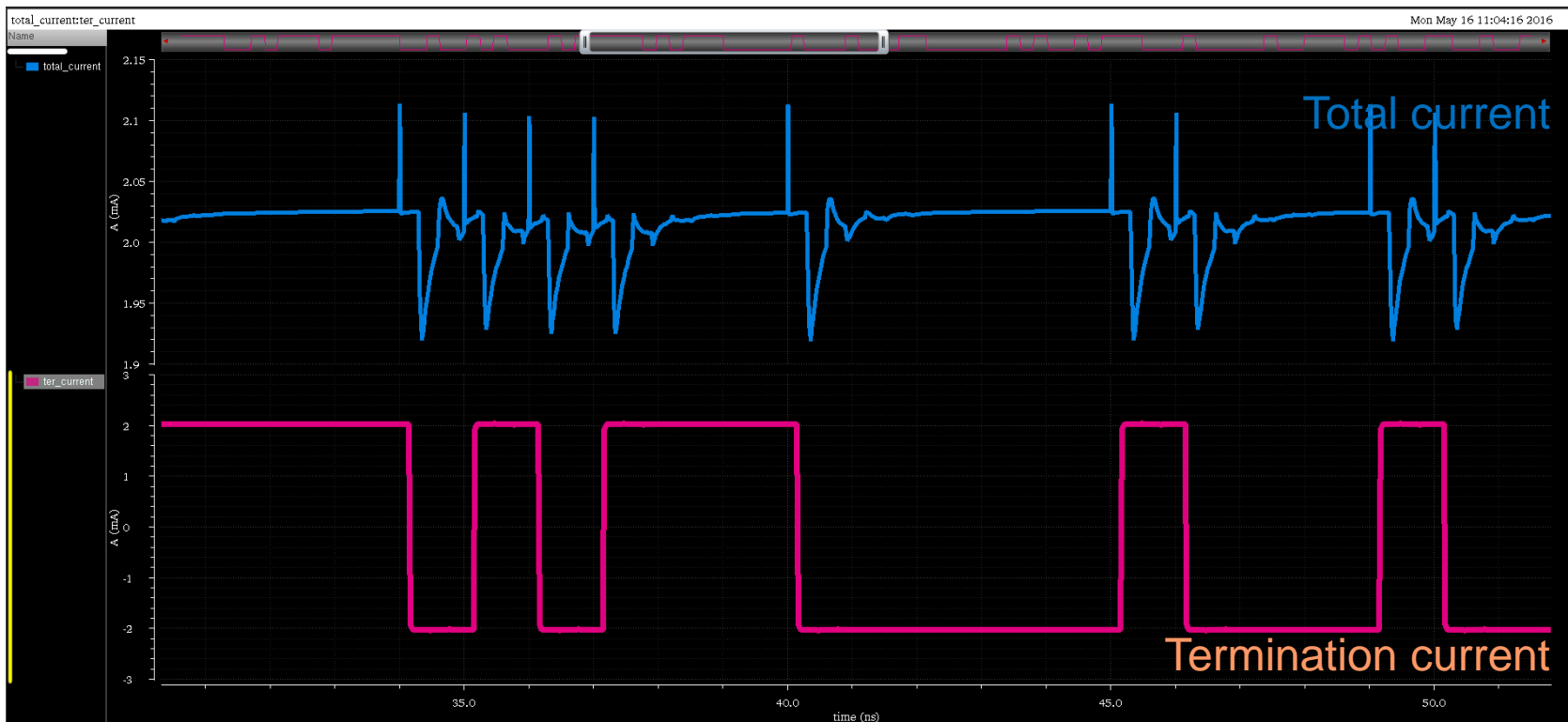
- 50Ω
- $V_{diff_outp} = 200mV$
- $V_{diff_pk_pk} = 400mV$

Simulation Results



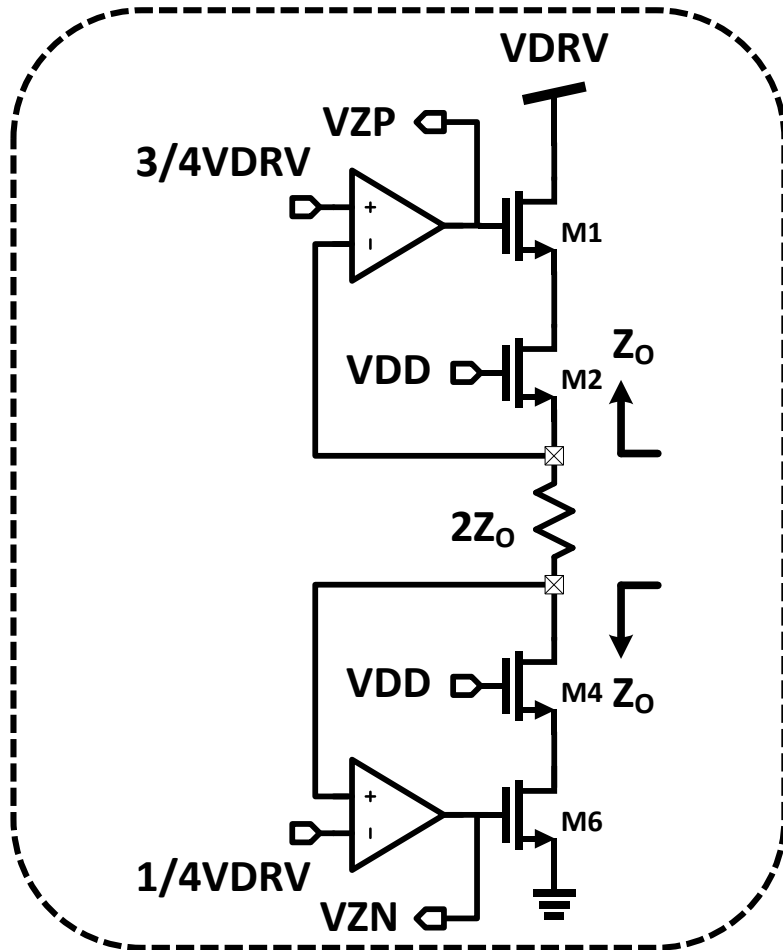
Simulation Results (Current)

- Total current : 2.0 mA ($V_{\text{diff_pp}}$ 400mV condition)
- Termination max. current : 2.0 mA ($V_{\text{diff_pp}}$ 400mV condition)

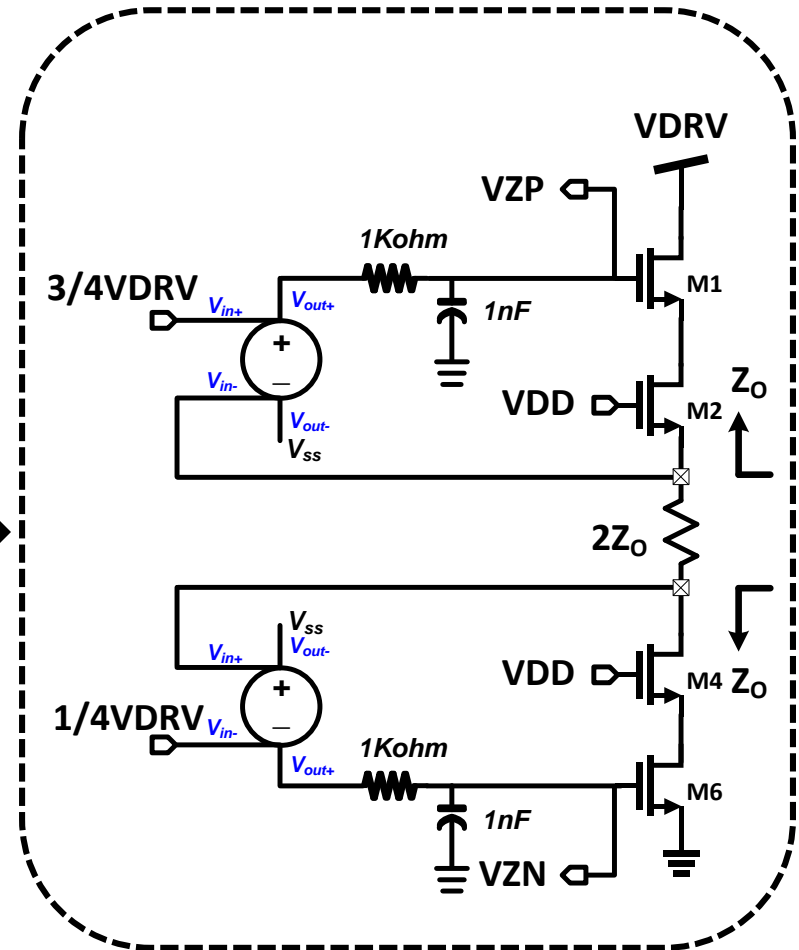


Replica Circuit for VM Driver

Circuit Structure

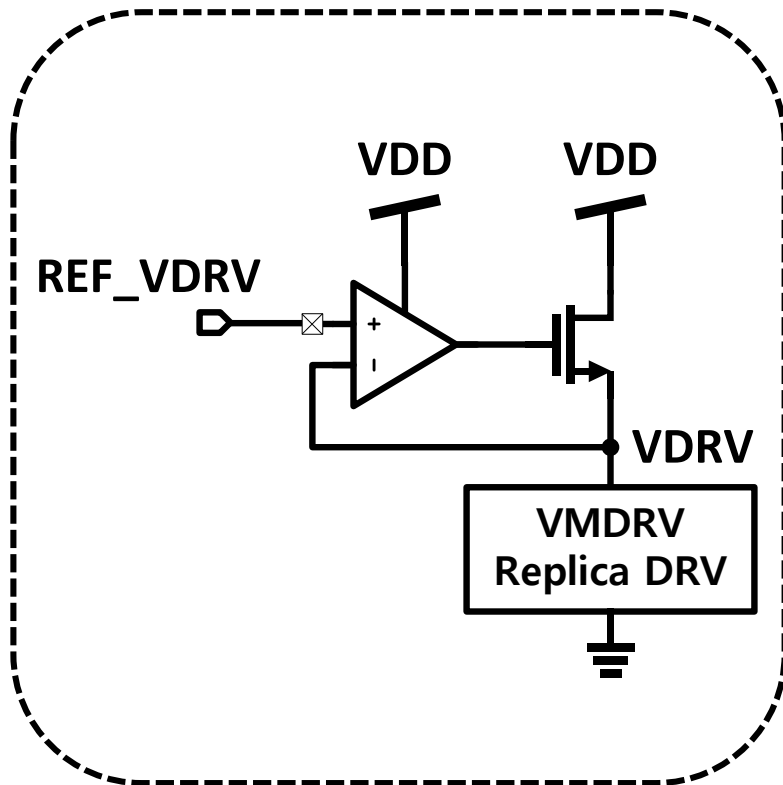


Alternative Circuit Structure

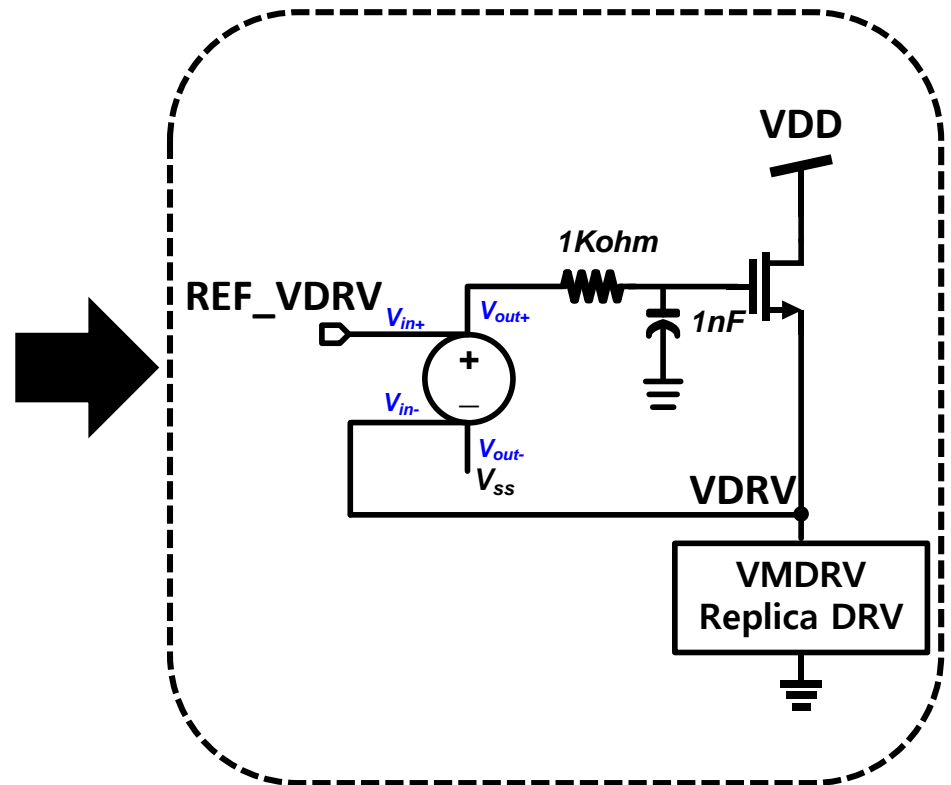


Regulator Circuit for VM Driver

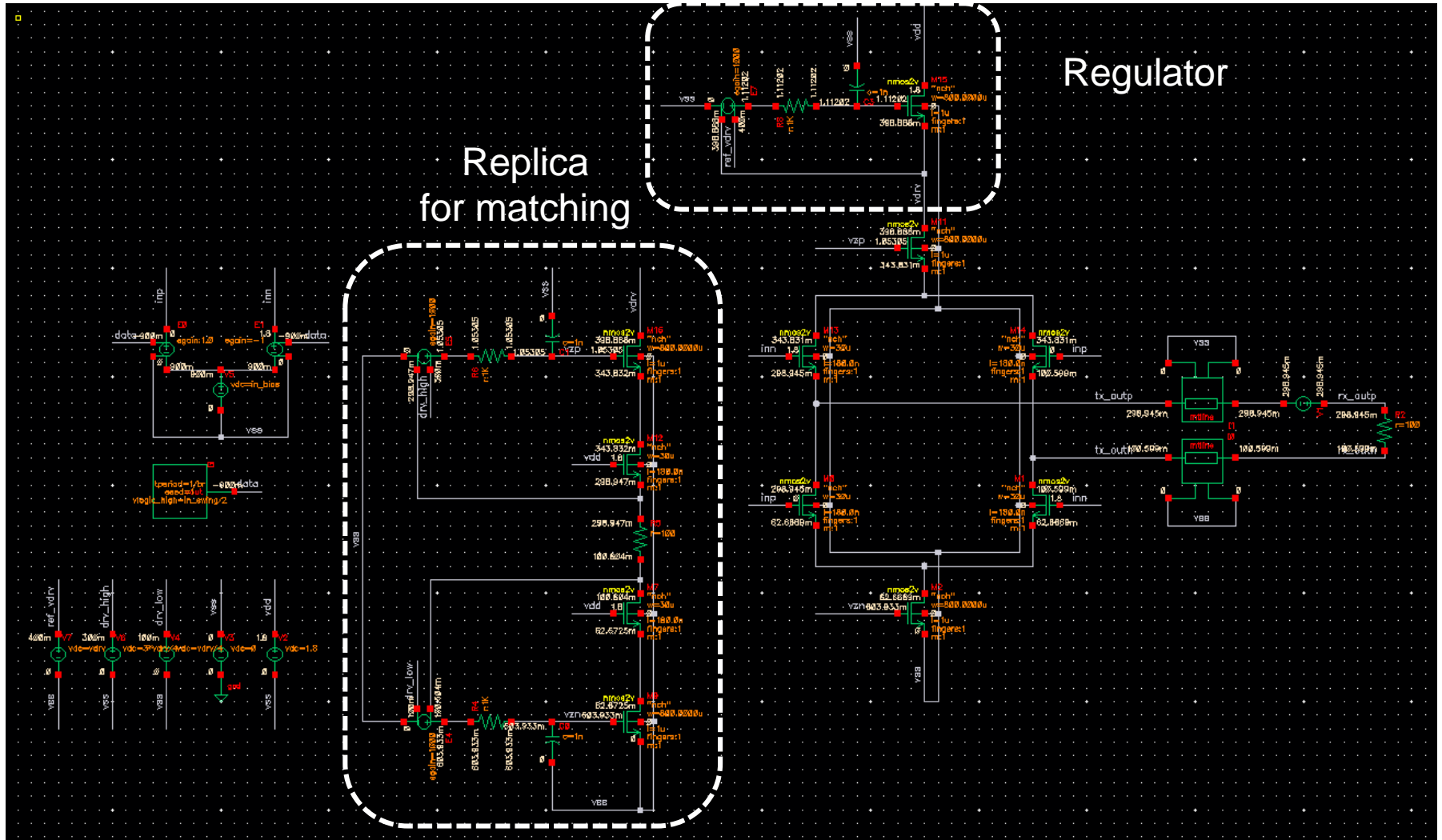
Circuit Structure



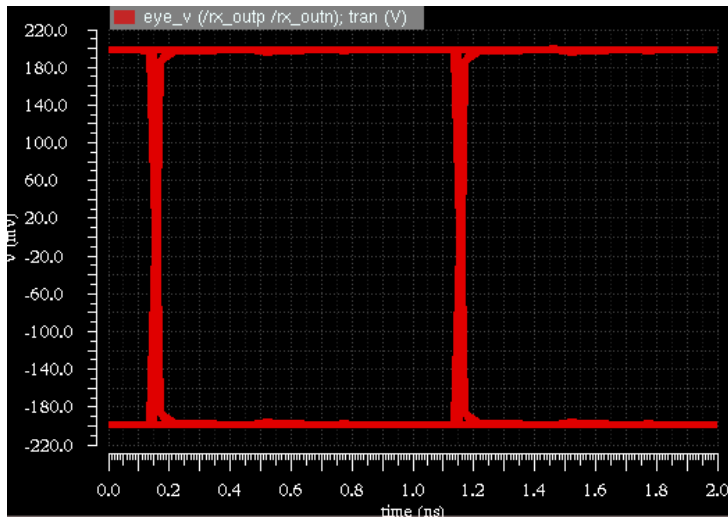
Alternative Circuit Structure



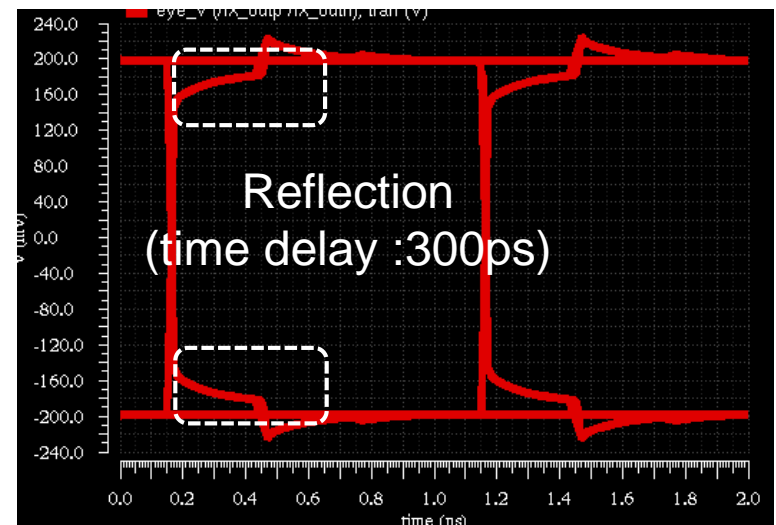
VM Driver w/ Replica



Simulation Results (Different Z_0)

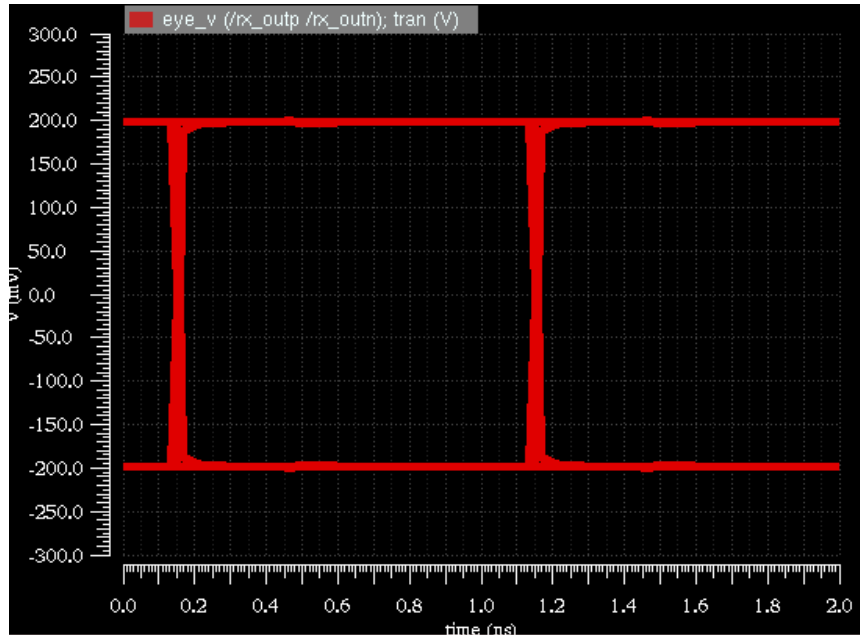


Transmission Line : 50ohm

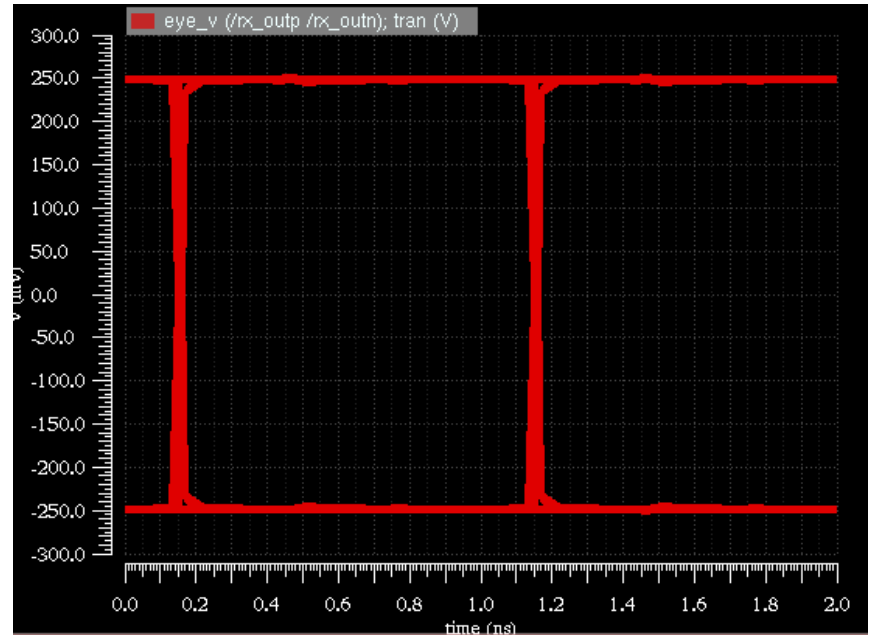


Transmission Line : 75ohm

Simulation Results for Different Swing



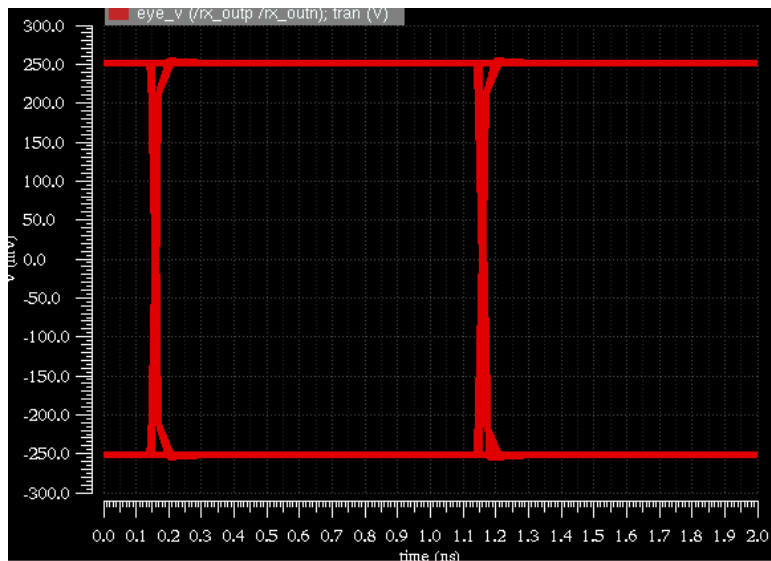
$V_{diff_pp} : 400\text{mV}$
Total current : 4.0 mA (w/ replica)



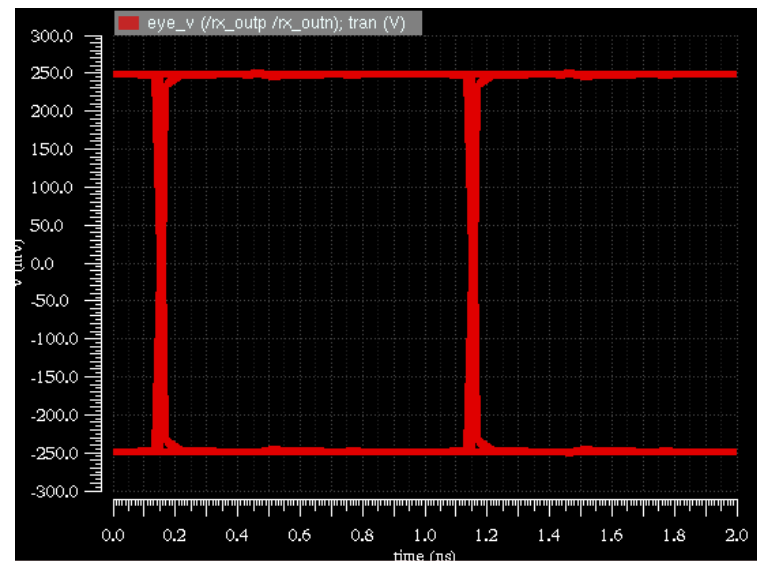
$V_{diff_pp} : 500\text{mV}$
Total current : 5.0 mA (w/ replica)

Power Consumption Comparison

- Current mode output driver
 - Total current : 16.0 mA (w/ replica, $V_{\text{diff_pp}}$ 400mV condition)
- Voltage mode output driver
 - Total current : 4.0 mA (w/ replica, $V_{\text{diff_pp}}$ 400mV condition)



Current mode output driver



Voltage mode output driver

Homework

- Current mode and voltage mode output driver
 - Design $V_{\text{diff,p2p}}$ 600mV Current and voltage mode driver with 50ohm impedance.
 - Derive mosfet size.
 - Plot the output waveform and current waveform.
 - Compare and analyze between current mode and voltage mode output driver.
 - Plot the eye diagram in case of transmission line impedance 75ohm and 50ohm. (Differential Rx termination 50ohm condition)
 - Plot the eye diagram in case of differential Rx termination 75ohm and 50ohm. (Transmission line impedance 50ohm condition)