

EE-320 – Exercise 5 Solutions - Fall 2024

1) CS stage with current source load: $A_V = -g_{m1}(r_{o1}||r_{o2})$

$$g_{m1} = \sqrt{2\mu_n C_{ox} \left(\frac{W}{L}\right)_1 I_{D1}} \quad r_{o1} = \frac{1}{\lambda_n I_{D1}} \quad r_{o2} = \frac{1}{\lambda_p \cdot I_{D2}}$$

$$g_{m1} = \sqrt{2 \times 0.134 \times 10^{-3} \times 100 \times 0.5 \times 10^{-3}} = 3.66 \text{ mS}$$

$$r_{o1} = \frac{1}{0.1 \times 0.5 \times 10^{-3}} = 20 \text{ k}\Omega$$

$$r_{o2} = \frac{1}{0.2 \times 0.5 \times 10^{-3}} = 10 \text{ k}\Omega$$

$$A_V = -3.66 \times 10^{-3} \times (20 \text{ k} || 10 \text{ k}) = -24.4$$

2) M_1 at the edge of triode $\Rightarrow V_{out} = V_{in} - V_{TH1}$

$$V_{out} = V_{DD} - V_{GS2}, \quad I_{D1} = I_{D2}$$

$$I_{D1} = \frac{1}{2} \mu_n C_{ox} \left(\frac{W}{L}\right)_1 (V_{in} - V_{TH1})^2 = I_{D2} = \frac{1}{2} C_{ox} \left(\frac{W}{L}\right)_2 (V_{GS2} - V_{TH2})^2 \quad (1)$$

$$V_{GS2} = V_{DD} - V_{out} = V_{DD} - (V_{in} - V_{TH1})$$

$$V_{GS2} - V_{TH2} = V_{DD} - V_{in} + (V_{TH1} - V_{TH2}) = V_{DD} - V_{in} \quad (\gamma = 0)$$

$$(1) \Rightarrow (V_{in} - V_{TH1}) = \sqrt{\frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1}} (V_{DD} - V_{in})$$

$$V_{in} \left(1 + \sqrt{\frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1}}\right) = \underbrace{V_{TH1}}_{V_{TH0}} + V_{DD} \sqrt{\frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1}}$$

$$V_{in} \left(1 + \sqrt{\frac{20}{100}}\right) = 0.7 + 3 \sqrt{\frac{20}{100}} \Rightarrow V_{in} = 1.413 \text{ V}$$

$$A_V = -\frac{g_{m1}}{g_{m2}} = -\sqrt{\frac{\left(\frac{W}{L}\right)_1}{\left(\frac{W}{L}\right)_2}} = -2.236$$