Controlled sources using opamps & transistors

VCVS ✓ ✓ (But 1x)

VCCS + CCVS ✓

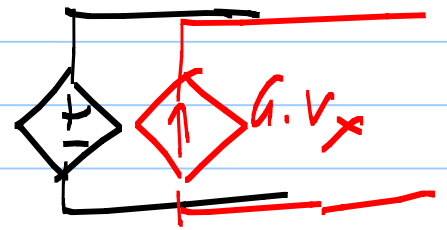
$\frac{1}{R_1}$ ↓ R_2 VCCS

CCVS ✓ ✓

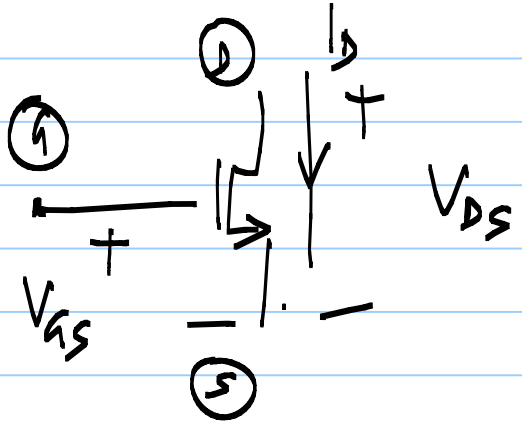
CCVS + VCCS ✓ (But 1x)

R_2 $\frac{1}{R_1}$ CCCS $A \cdot V_x$

$\pm V_x$

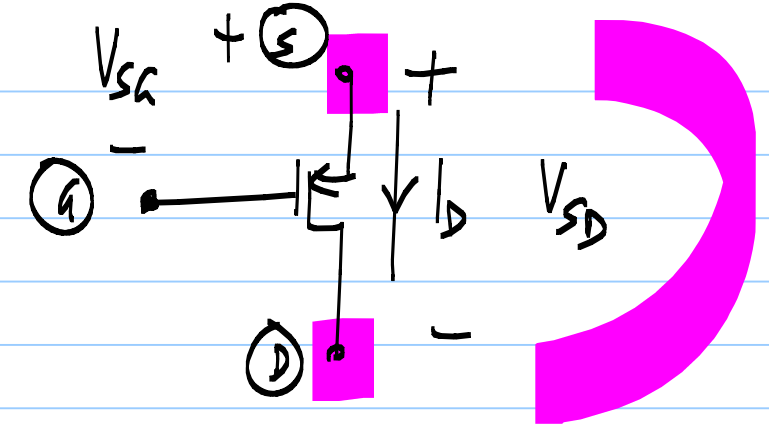


nMOS transistor



Drain voltage can be below the gate voltage but not by more than V_T

pMOS transistor



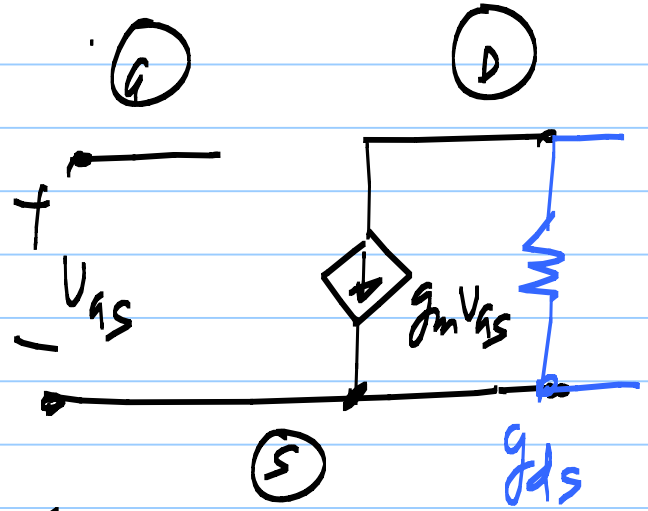
$I_D = 0$ (OFF) $\quad V_{SG} < V_T$

$\frac{\mu_p}{\mu_n} \sim \frac{1}{3}$

$\mu_p C_{ox} \cdot \frac{W}{L}\left((V_{SG} - V_{Tp})V_{SD} - \frac{V_{SD}^2}{2}\right)$ (TRIODE) $\quad V_{SG} > V_T$, $V_{SD} < V_{SG} - V_T$

$\frac{\mu_p C_{ox}}{2}\frac{W}{L}\left(V_{SG} - V_{Tp}\right)^2(1 + \lambda_p V_{SD})$ (SAT) $\quad V_{SG} > V_T$, $V_{SD} > V_{SG} - V_T$

nMOS:



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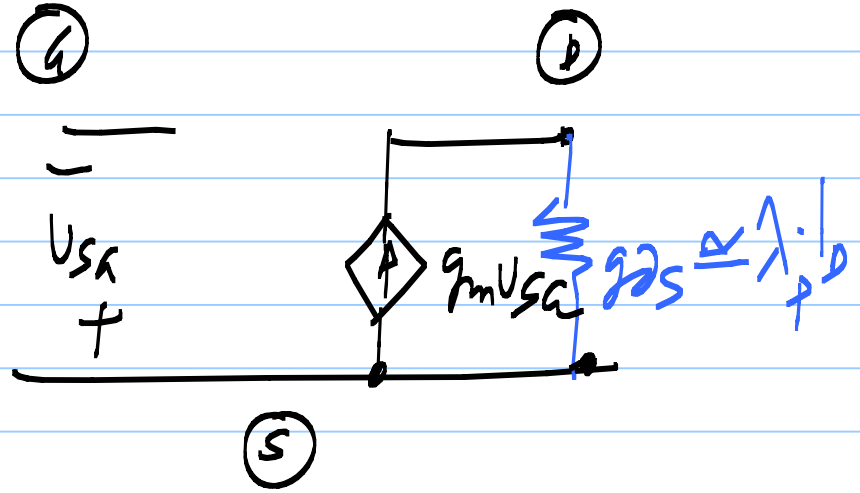
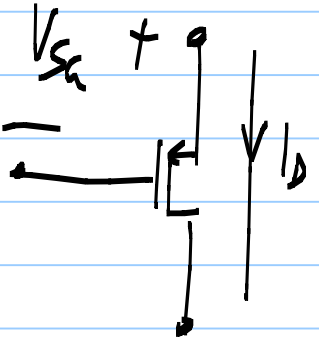
pMOS

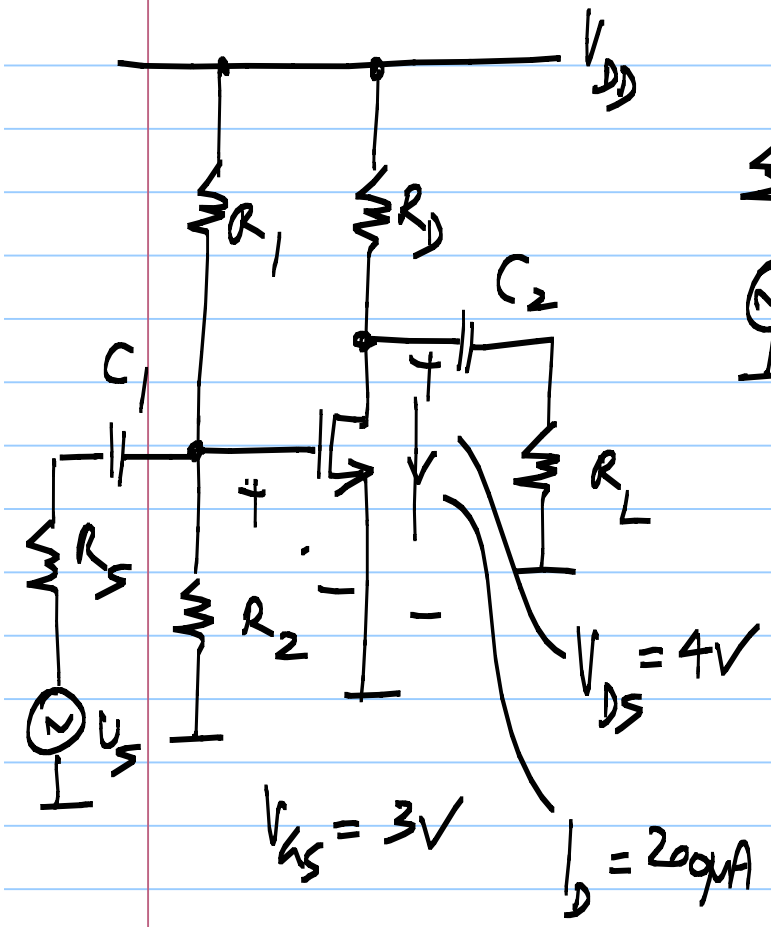


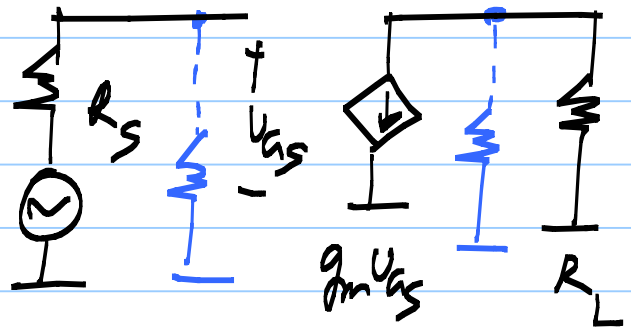


* V_{SG} increases ⇒ negative V_{GS}
* Current flowing out of the drain increases ⇒ negative increment into the drain

Common source amplifier:

$V_{SG} = 3V$; $V_{SD} = 4V$

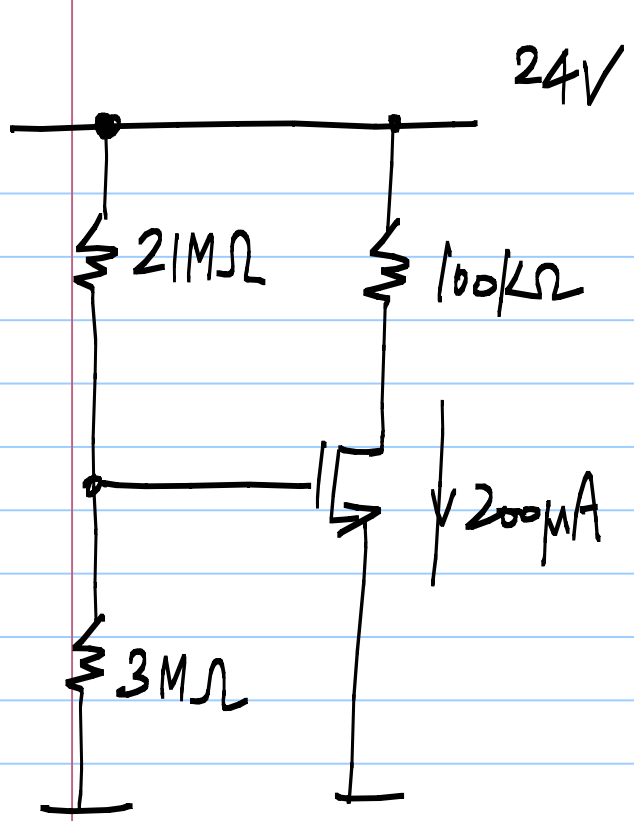


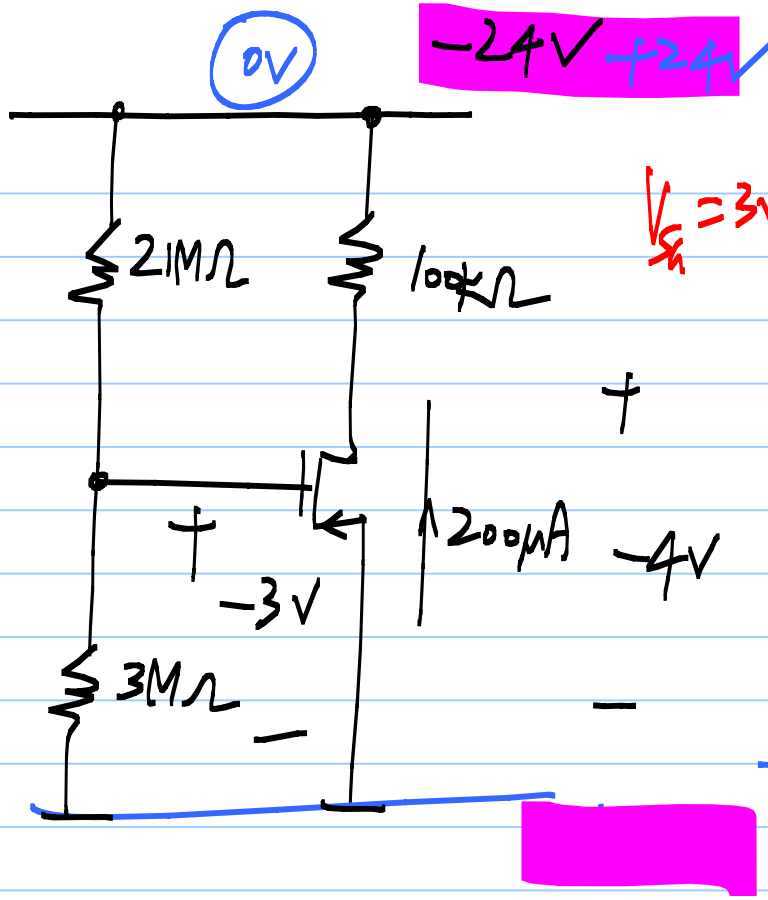


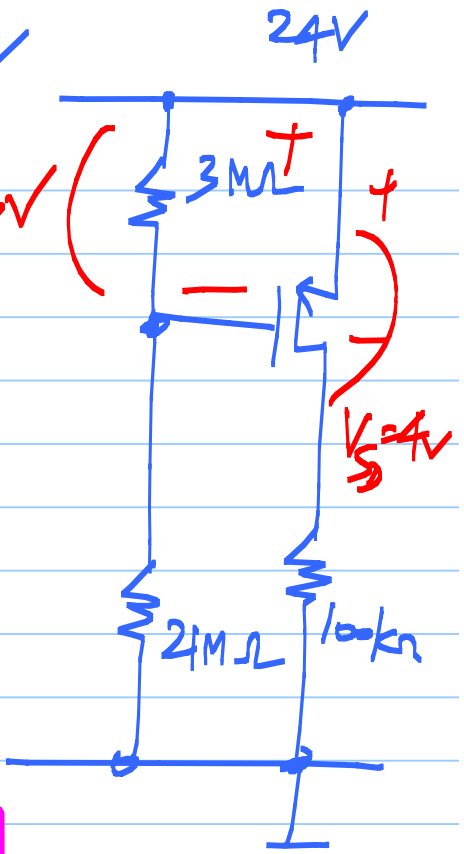
$\mu_n C_{ox} \frac{W_n}{L_n} = 100\mu A/V^2$

$\mu_p C_{ox} \frac{W_p}{L_p} = 100\mu A/V^2$

$V_{T_n} = V_{T_p} = 1V$

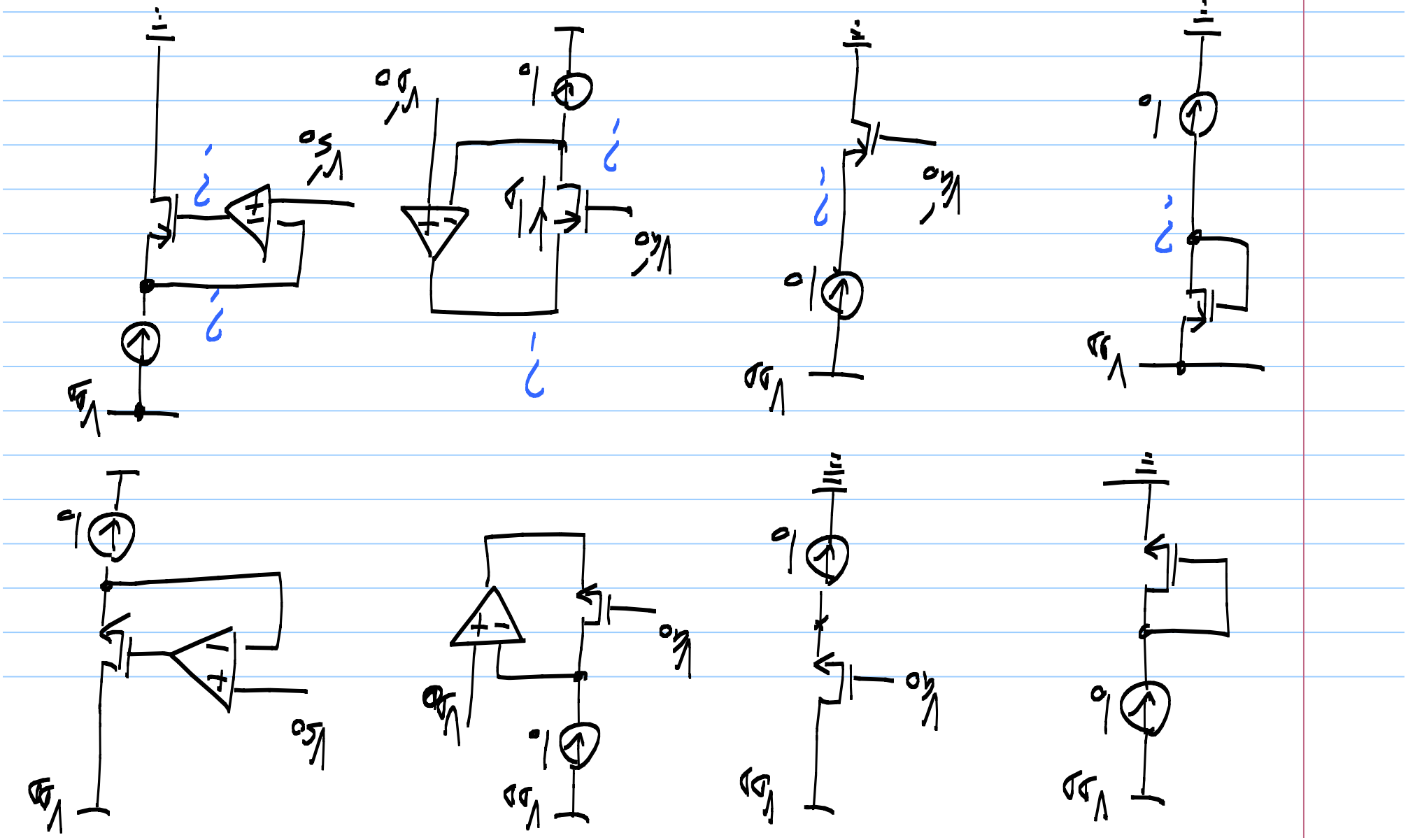

24V
21MΩ
100kΩ
200μA
3MΩ


0V
−24V
+24V
21MΩ
100kΩ
200μA
−3V
−4V
3MΩ


24V
3MΩ
21MΩ
100kΩ

$V_{GS} = +3V$

$V_{SD} = +4V$

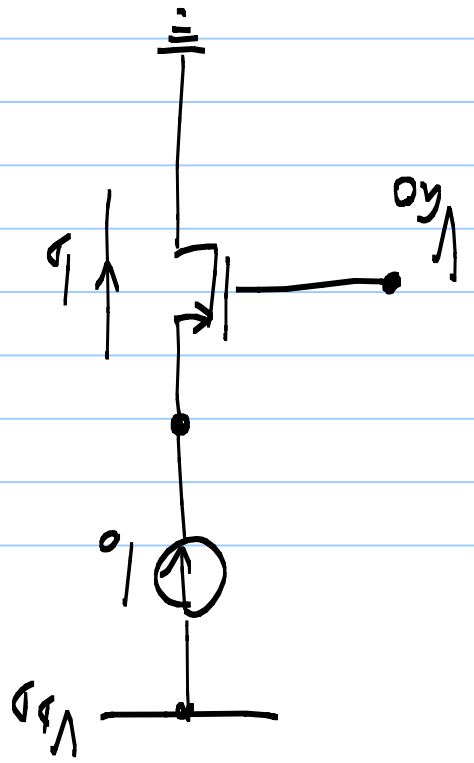


$V_{GS} = V_{GS}$

$V_{GS} > V_{GS} - V_t$

V_G increases

If $I_D > I_D$ must be increased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