Unit 8. Intrinsic gain

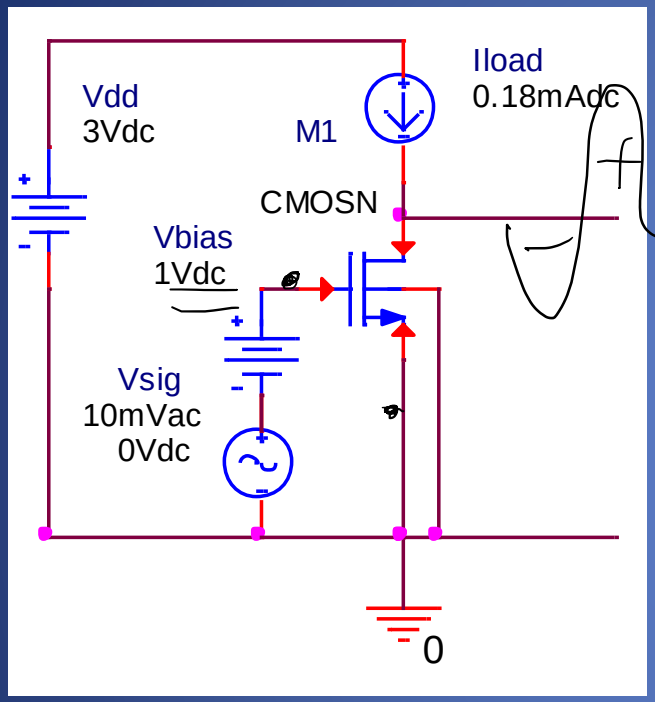
Outline

1. MOSFET intrinsic gain

* Design strategies for improving the voltage gain of a MOSFET stage
* Strong inversion vs Weak inversion limits

2. BJT intrinsic gain

Improving Intrinsic Gain $A_o = g_m r_o$



How to select the MOSFET parameters and the bias current to obtain a greater voltage gain?

Increasing product

$g_m = \frac{2I_D}{V_{OV}}$; $r_o = \frac{V_A}{I_D}$

$A_o = \frac{2I_D}{V_{OV}} \cdot \frac{V_A}{I_D} = \frac{2V_A}{V_{OV}}$

- Decreasing V_{OV}!
- Increasing L for V_A ↑
- Increasing W for V_{OV} ↓
- Decreasing I_D for V_{OV} ↓

Vov slowly increases with L so that overall improvement of Ao is modest ->

$$A_o = \frac{2V_A' L}{V_{OV}}$$

Improving voltage gain

$$A_0 = 2\frac{V_A' \cdot L}{V_{OV}}$$

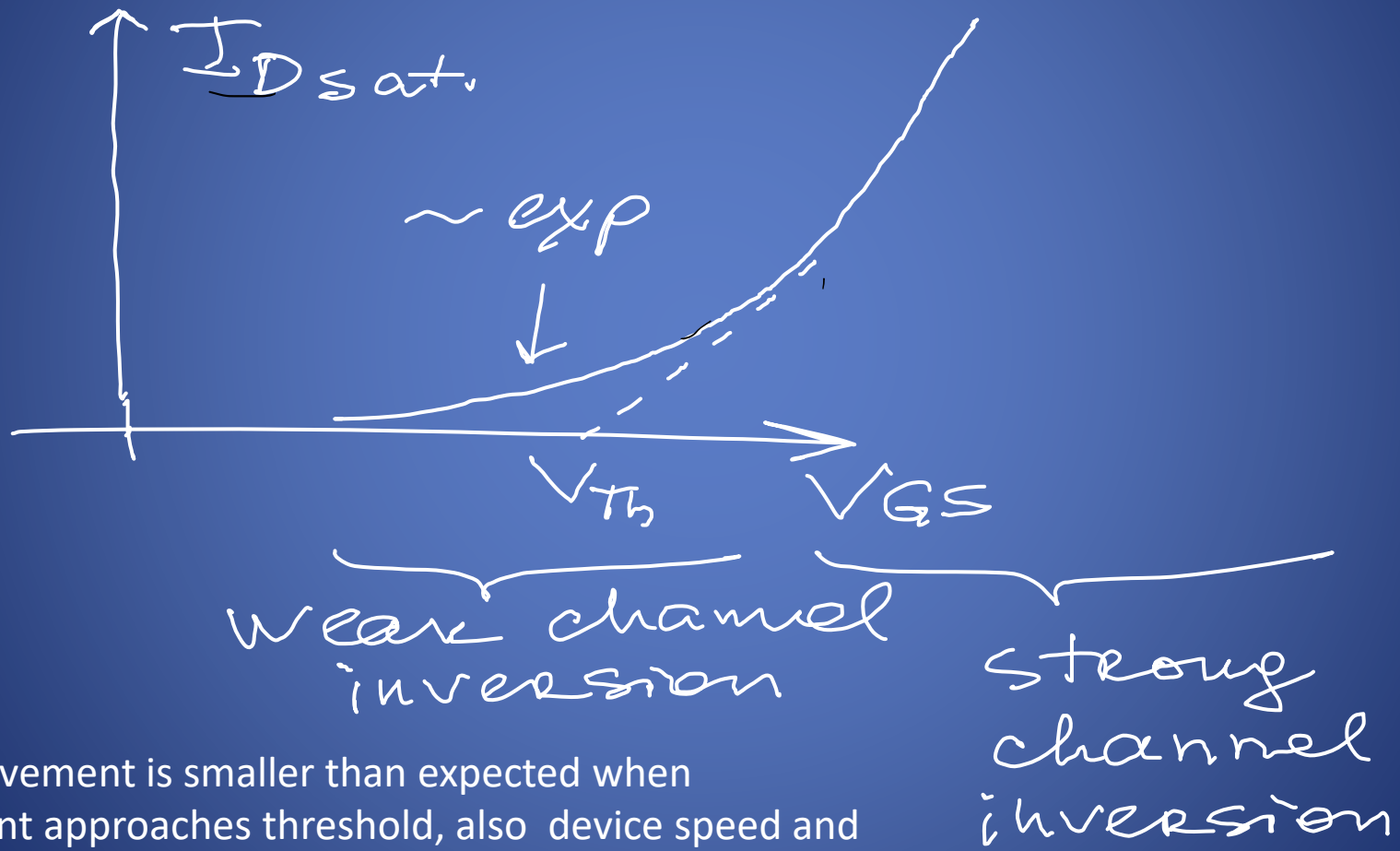
(1) $I_D = \text{const.}$: $A_0 \propto \sqrt{W}$ $\left(V_{OV} \propto \frac{1}{\sqrt{W}}\right)$

$A_0 \propto \sqrt{L}$ $\left(\begin{matrix} V_A \propto L \\ V_{OV} \propto \frac{1}{\sqrt{L}} \end{matrix}\right)$

(2) $\left.\begin{matrix} W = \text{const} \\ L = \text{const} \end{matrix}\right\}$ $A_0 \propto \frac{1}{\sqrt{I_D}}$ $\left(V_{OV} \propto \frac{1}{\sqrt{I_D}}\right)$

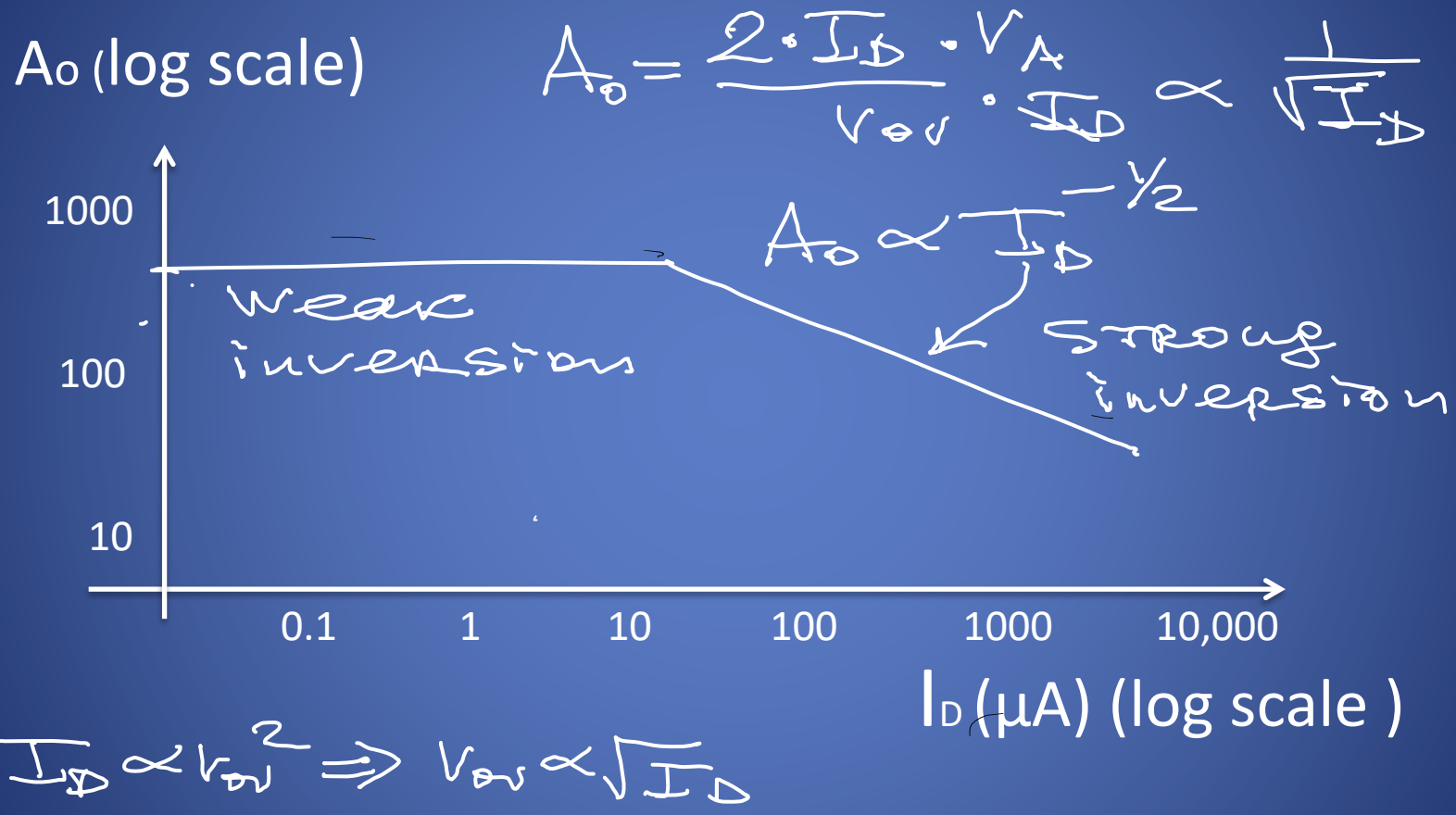
How small can V_{OV} be made?

MOSFET transfer characteristic near threshold



Improvement is smaller than expected when current approaches threshold, also device speed and range of Vsig decrease => typically Vov =0.1-0.3 V

Intrinsic gain versus bias current



Selection of small current will degrade response time (frequency range) because a greater time will be needed to charge capacitances

MOSFET intrinsic gain

1) $\frac{W}{L} = 20$; $k_n' = 200 \frac{\mu A}{V^2}$; $V_{ov} = 0.1\ V$; $V_A = 10\ V$

The intrinsic gain is expected to by a factor of 3 greater compared to the previous example with Vov = 0.3 V, indeed

$$A_0 = \frac{V_A}{V_{ov}/2} = \frac{10}{0.05} = 200$$

2) $\frac{W}{L} = 5$, $A_0 = \frac{10}{0.1} = 100$

$I_D \propto \frac{W}{L} V_{ov}^2 \rightarrow$ V_{ov} ↑ by a factor of 2

$V_{ov} = 0.2\ V$

BJT intrinsic gain

$$A_0 = g_m r_o = \frac{I_C}{V_T} \cdot \frac{V_A}{I_C} = \frac{V_A}{V_T}$$

Intrinsic gain does not depend on current , however it is much more sensitive to temperature change compared to MOSFET

$V_A = 35V$ (npn)

$$A_0 = \frac{35}{26 \cdot 10^{-3}} = 1350!$$

$$V_T = \frac{k_B T}{e} = \frac{1.38 \cdot 10^{-23} \cdot 300}{1.6 \cdot 10^{-19}} = 0.026\ V$$

$k_B = 1.38 \cdot 10^{-23}$ J/K (Boltzmann const)

$e = 1.6 \cdot 10^{-19}$ C (charge of electron)