# EXTRACTION OF MOSFET EFFECTIVE CHANNEL LENGTH AND WIDTH BASED ON THE TRANSCONDUCTANCE-TO-CURRENT RATIO

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## ABSTRACT

This work presents a very simple methodology for determining the MOSFET effective channel length and width, through the measurement of the $g_m/I_D$ characteristic in the linear region and moderate inversion.

## DIFFICULTIES OF MOST METHODOLOGIES

(i) Dependence upon threshold voltage determination

(ii) Influence of extrinsic resistances

(iii) Algorithm complexity

# ADVANCED COMPACT MOSFET MODEL

Simple expressions valid in all regimes of operation

$$I_D = I_S(i_f - i_r) \qquad I_S = \mu C'_{ox} n \frac{\phi_t^2}{2} \frac{W}{L}$$

$$\frac{g_m}{I_D} \cong \frac{2}{n\phi_t\left(\sqrt{1+i_f}+\sqrt{1+i_r}\right)} = \left(\frac{g_m}{I_D}\right)_{max} \frac{2}{\left(\sqrt{1+i_f}+\sqrt{1+i_r}\right)}$$

$$V_{DS} = \phi_t\left[\sqrt{1+i_f} - \sqrt{1+i_r} + \ln\left(\frac{\sqrt{1+i_f}-1}{\sqrt{1+i_r}-1}\right)\right]$$

# DETERMINATION OF SPECIFIC CURRENT

## PRINCIPLE

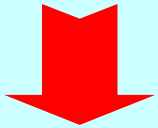
For $i_f = 3$ and $V_{DS} = \phi_t/2$:

$$\sqrt{1+i_r} + \ln\left(\sqrt{1+i_r} - 1\right) = 1.5 \quad \Rightarrow \quad i_r = 2.1196$$

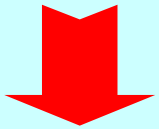
$$\frac{g_m}{I_D} \cong \frac{2\left(\frac{g_m}{I_D}\right)_{max}}{\left(\sqrt{1+i_f} + \sqrt{1+i_r}\right)} \quad \Rightarrow \quad g_m/I_D = 0.5310(g_m/I_D)_{máx}$$

$$I_D = I_S(i_f - i_r) \quad \Rightarrow \quad I_S = 1.135\ I_D$$

$V_{DS} = \phi_t/2$ (small)



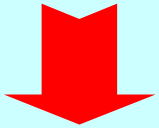
linear region



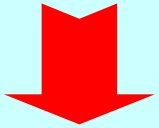
~~mobility degradation~~

~~channel length modulation~~

$i_f = 3$



moderate inversion



~~extrinsic resistances~~

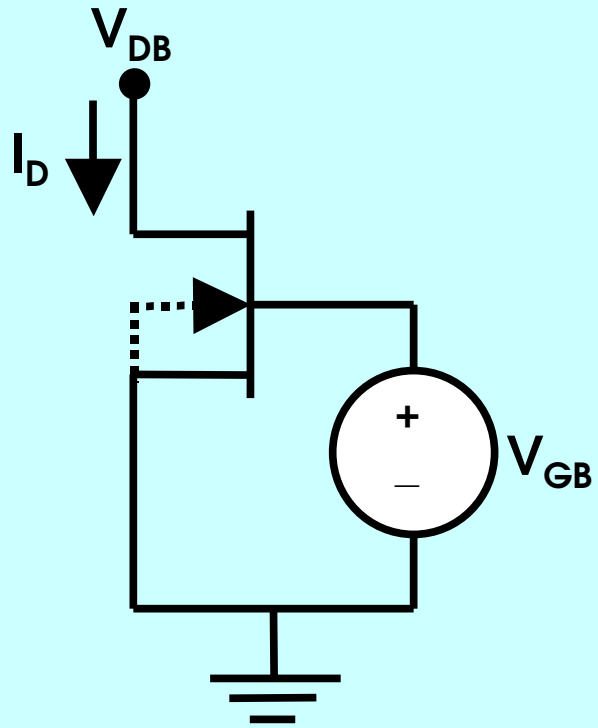
## Step 1: Test device connection

For

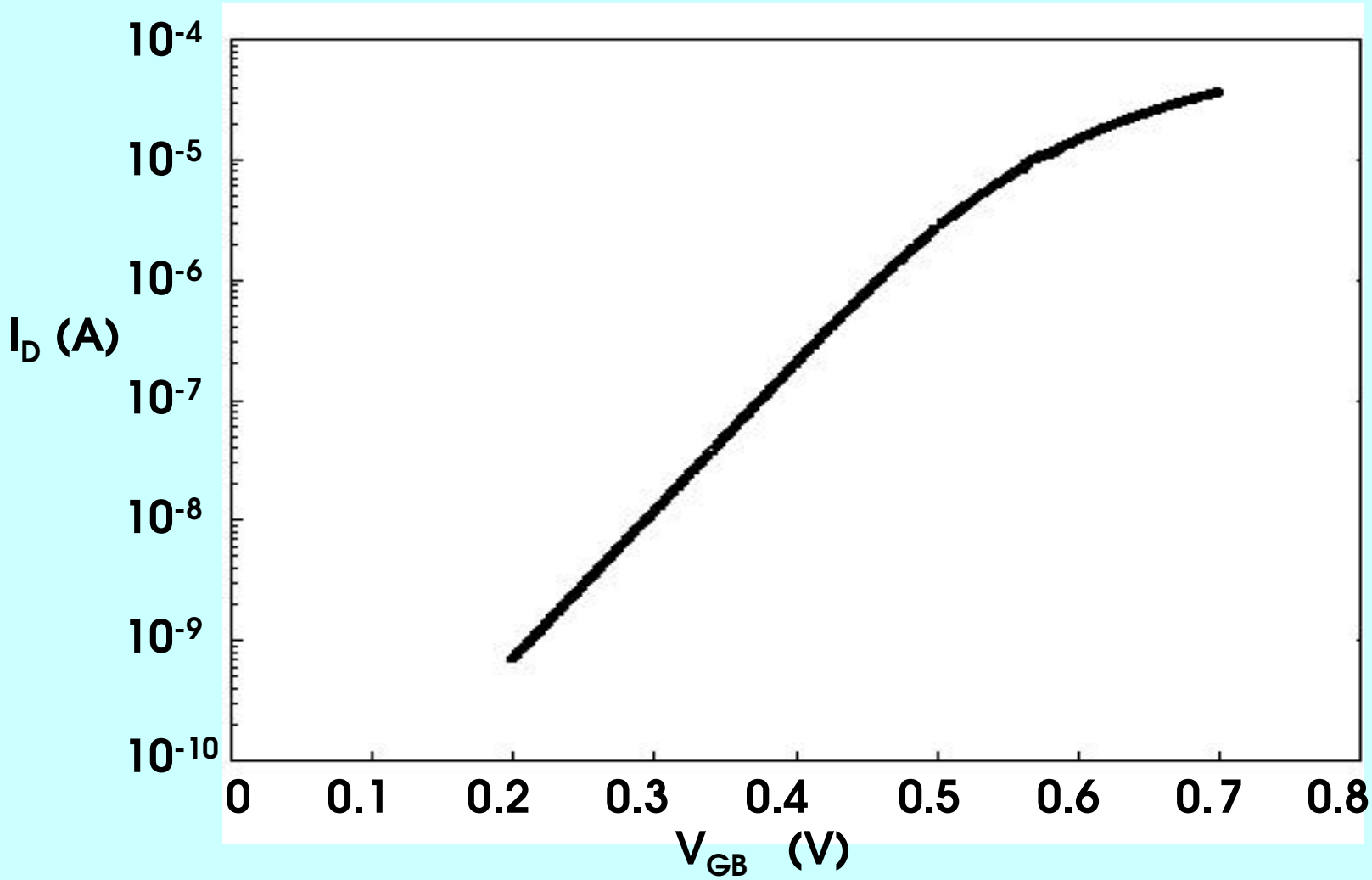
$V_{SB} = 0$ and

$V_{DS} = \phi_t/2$ (or $< 2\phi_t$)

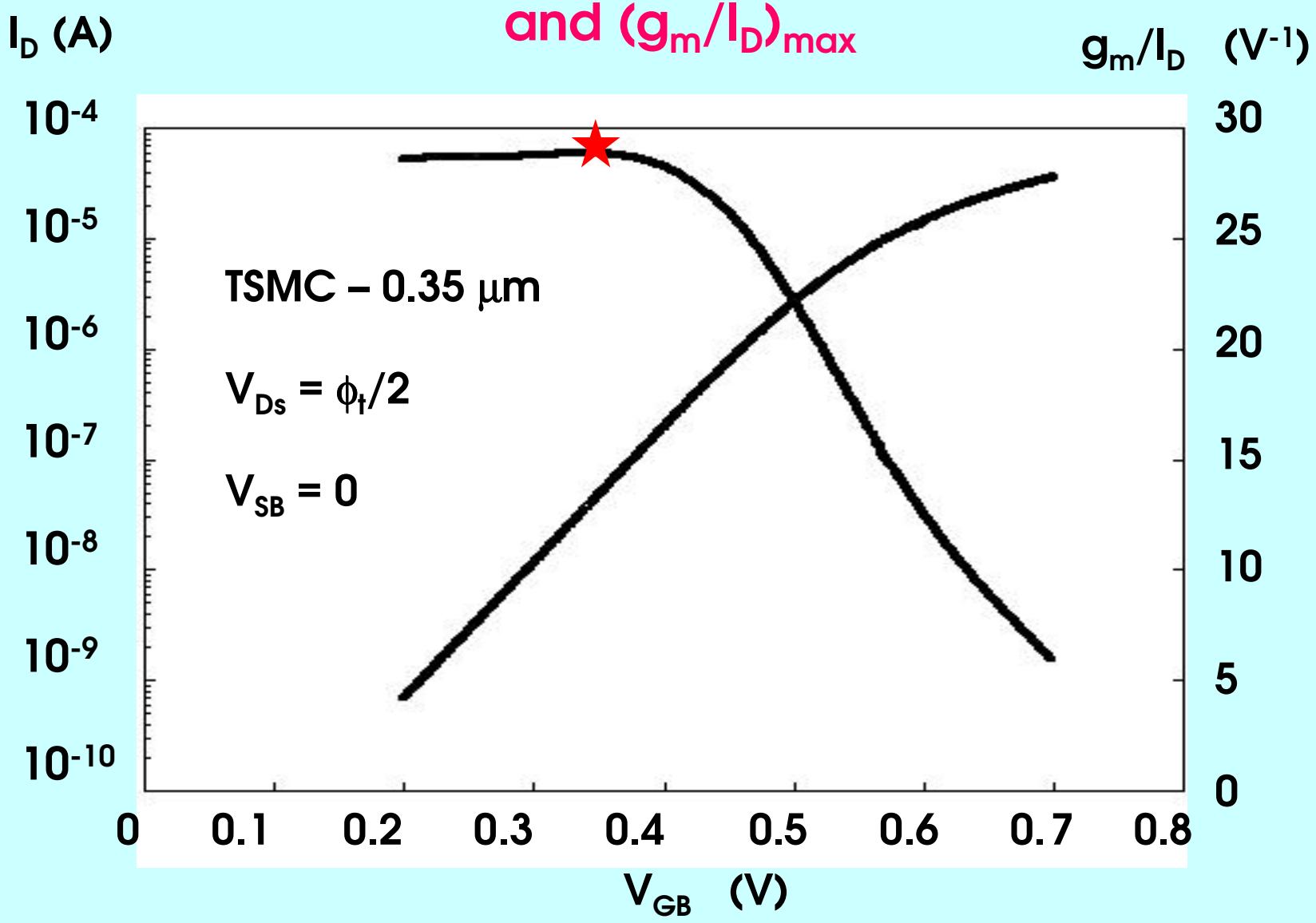
Measure $I_D$ versus $V_{GB}$



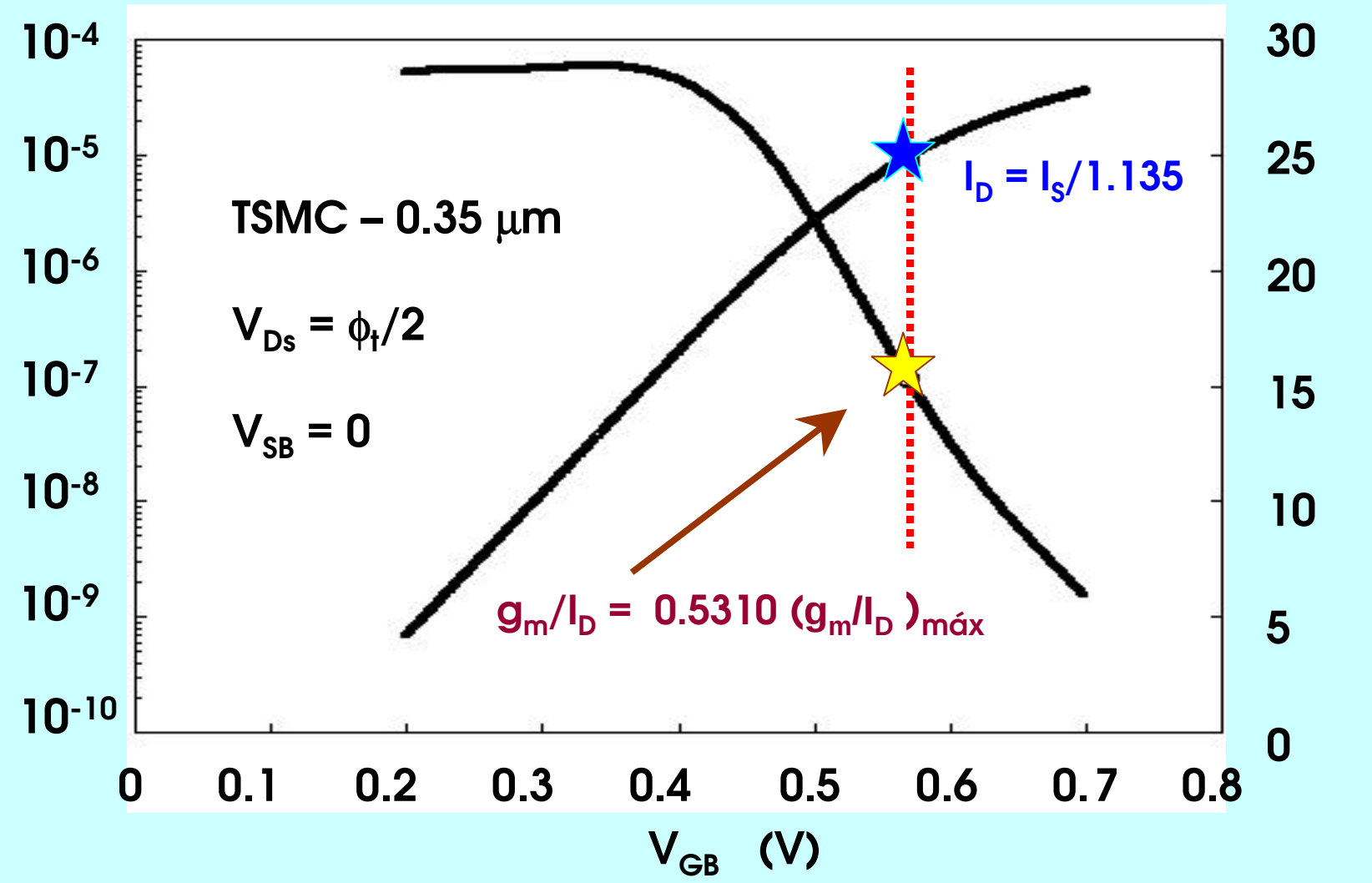
# Step 2: Measurement of common source characteristic



# Step 3: Determination of $g_m/I_D$ vs $V_{GB}$ characteristic and $(g_m/I_D)_{max}$

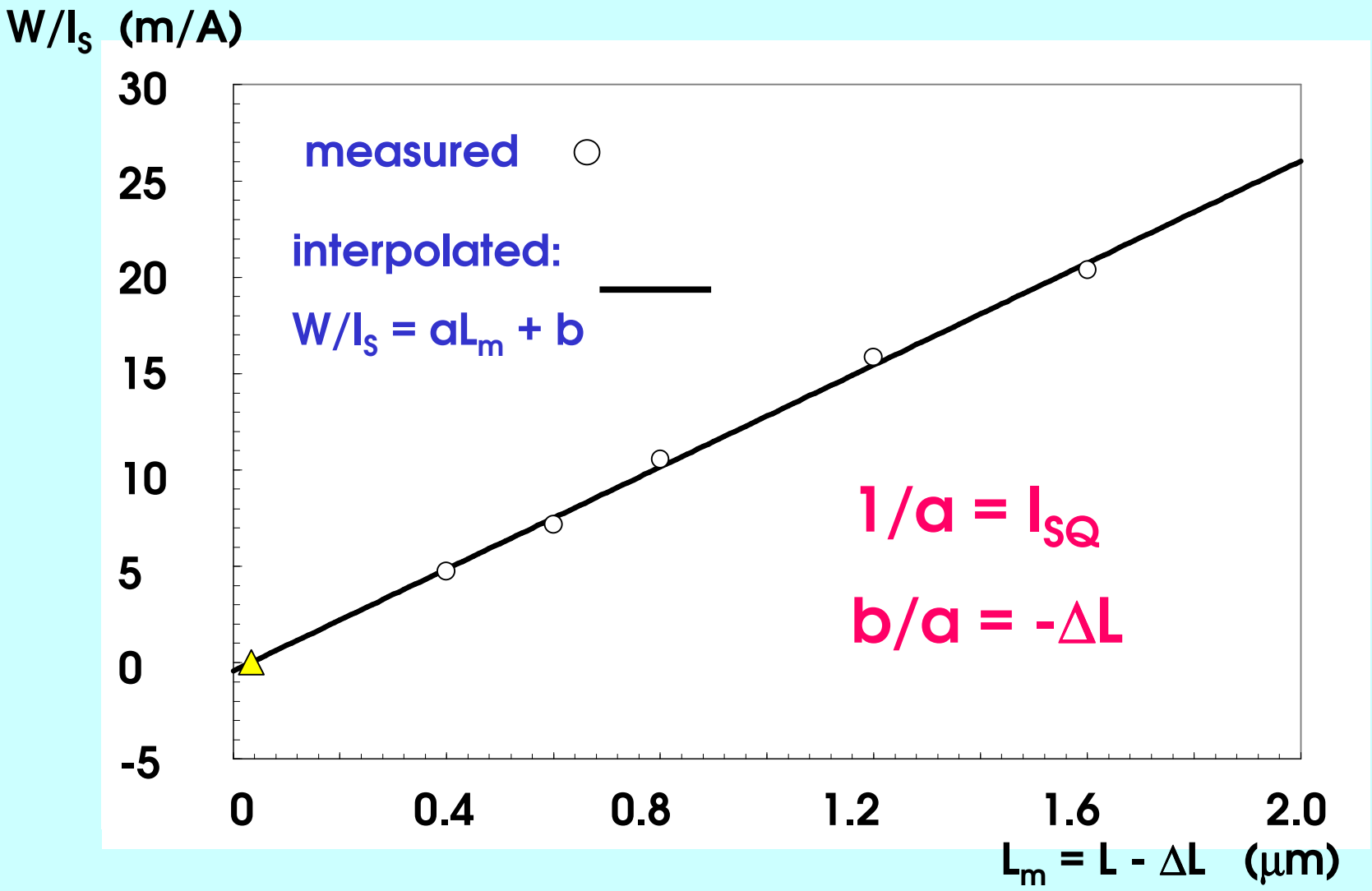


## Step 4: Determination of the value of $I_D$ for $g_m/I_D = 0.5310(g_m/I_D)_{max}$

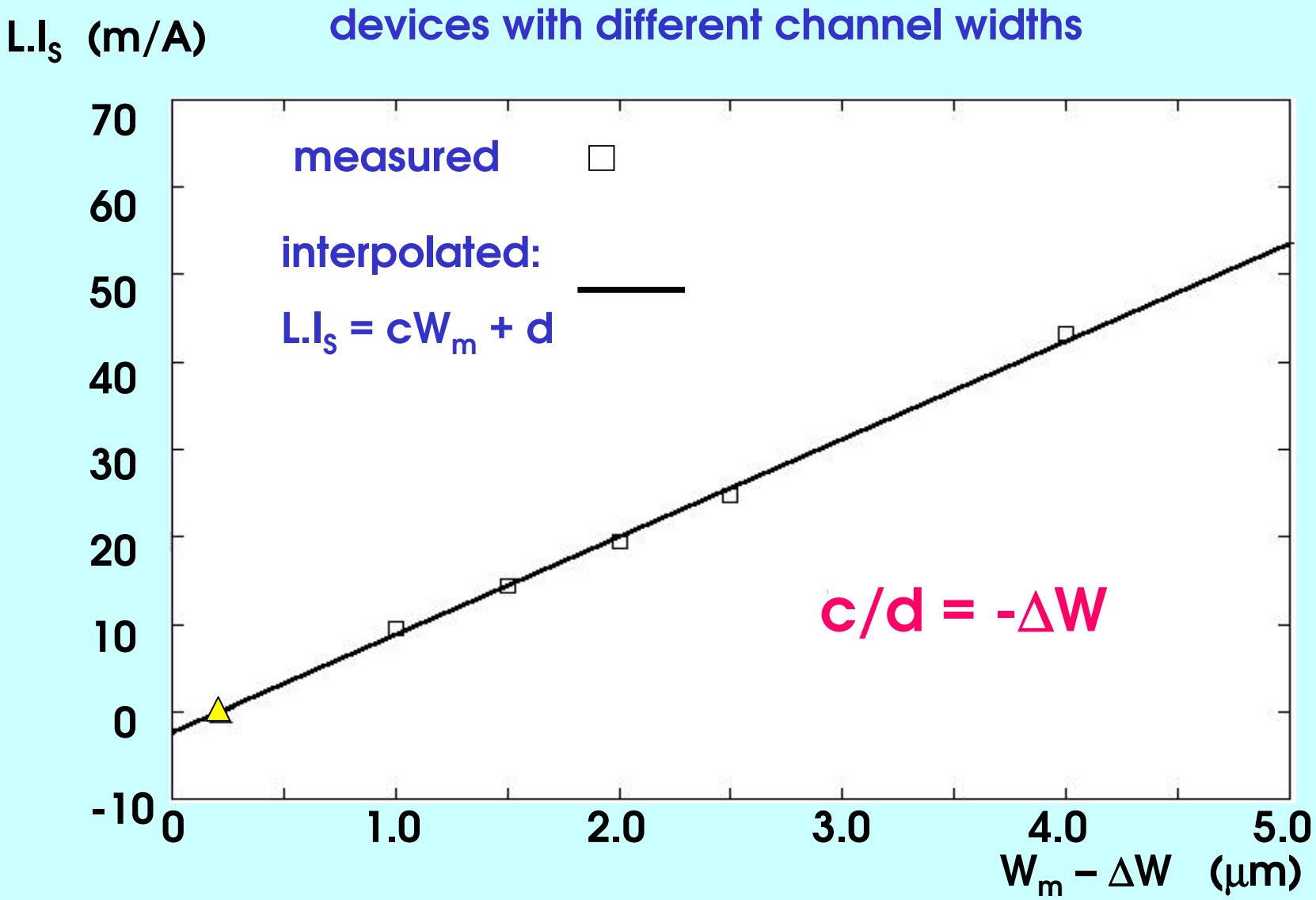


# EXTRACTION OF EFFECTIVE CHANNEL LENGTH

large-width devices with different channel lengths



# EXTRACTION OF EFFECTIVE CHANNEL WIDTH



## EXPERIMENTAL RESULTS

### Extraction of effective channel length

| $L_m$ (μm) | 0.4 | 0.6 | 0.8 | 1.2 | 1.6 | ΔL (μm) |
|---|---|---|---|---|---|---|
| $I_S$ (μA) N channel | 9.59 | 9.50 | 8.61 | 8.59 | 8.92 | 0.032 |
| $I_S$ (μA) P channel | 1.66 | 1.73 | 1.68 | 1.67 | 1.73 | 0.017 |

$W_m/L_m = 100$

## EXPERIMENTAL RESULTS

### Extraction of effective channel width

| $W_m$ (μm) | 1.0 | 1.5 | 2.0 | 2.5 | 4.0 | ΔW (μm) |
|---|---|---|---|---|---|---|
| $I_S$ (μA) N channel | 9.57 | 9.85 | 9.84 | 10.07 | 10.83 | 0.202 |
| $I_S$ (μA) P channel | 1.52 | 1.67 | 1.83 | 2.03 | 2.13 | 0.403 |

$L_m = 1.2\ \mu m$

# CONCLUSION

## Advantages of the proposed methodology:

i) Simple, fast and reliable

ii) Independent of threshold voltage determination

iii) Negligible influence of extrinsic resistances (moderate inversion)

iv) Negligible influence of mobility degradation and CLM (linear region)

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