CAPÍTULO 3
INVERSOR CMOS

Baseado nos slides de Peter Cheung
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OBJETIVOS

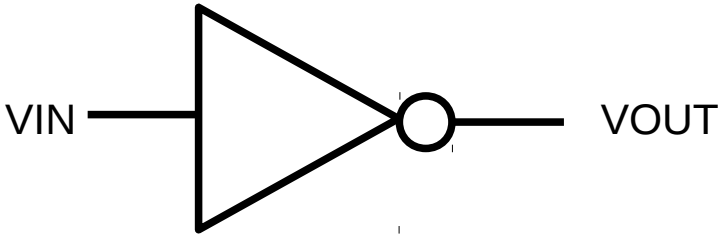
1. Compreender o funcionamento do inversor CMOS

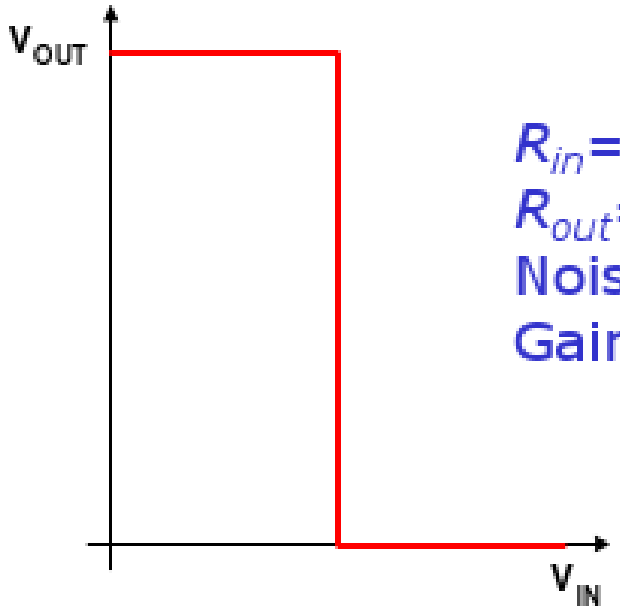
2. Identificar os parâmetros fundamentais do inversor CMOS

3. Analisar e dimensionar inversores CMOS

4. Simulação elétrica e caracterização de inversores

INVERSOR IDEAL





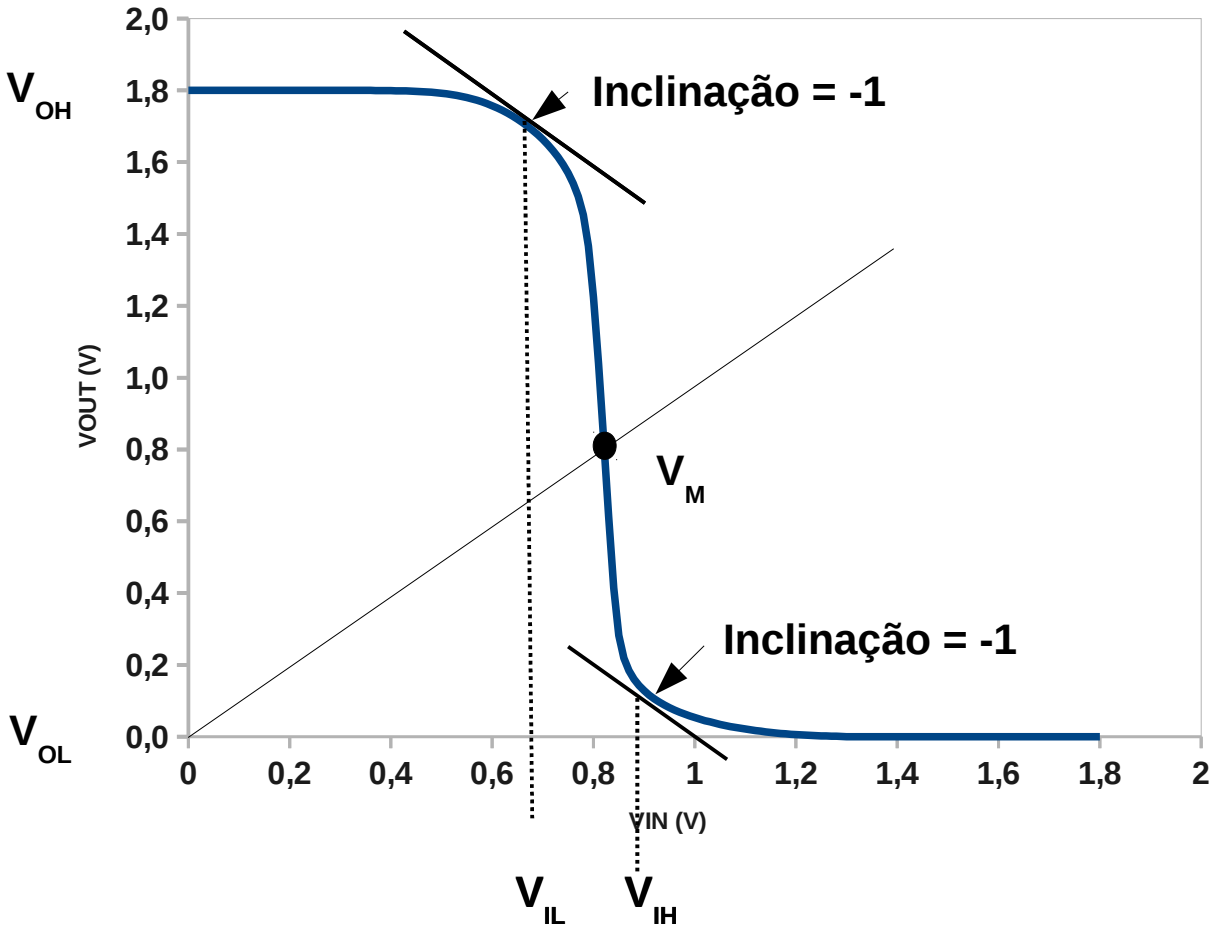
$R_{in} = \infty$

$R_{out} = 0$

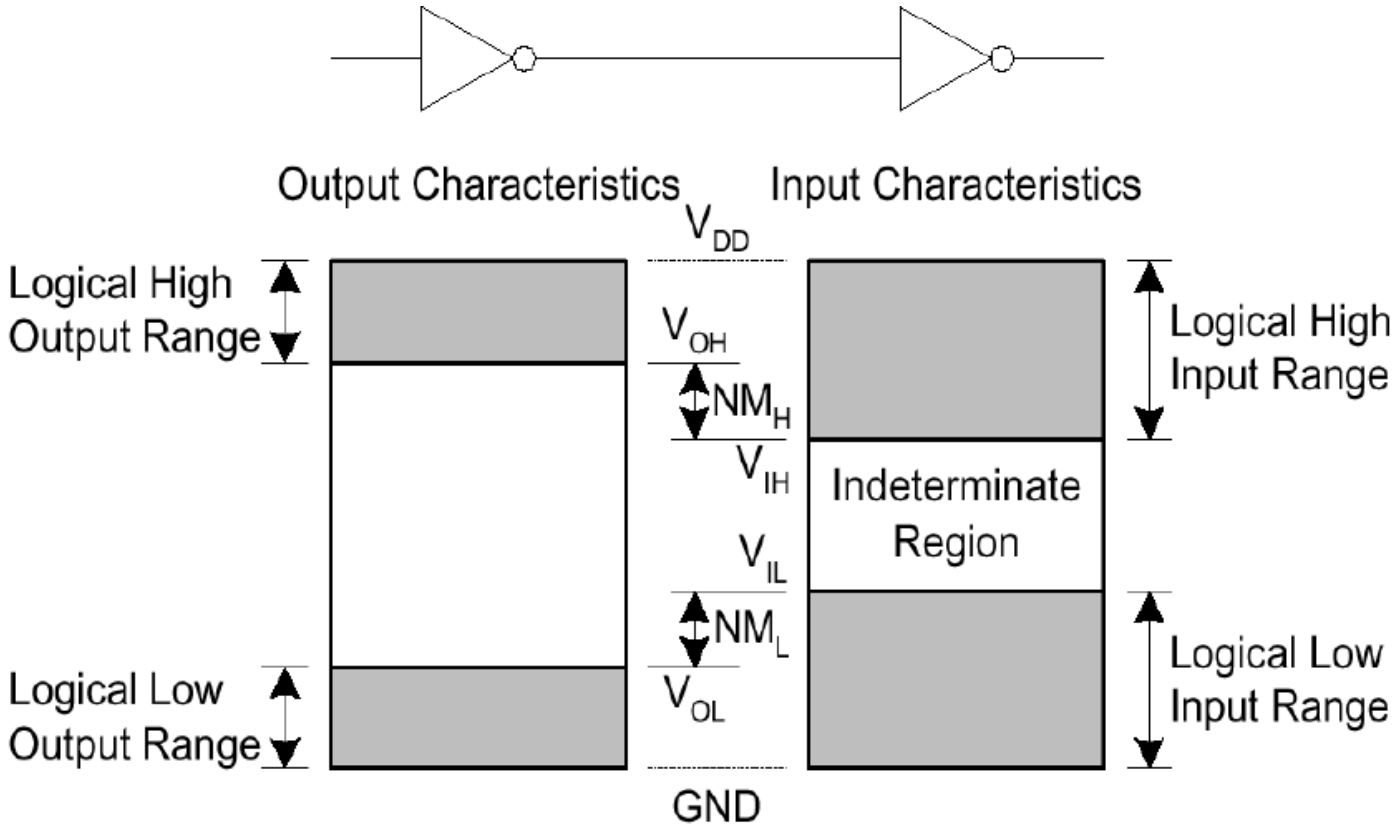
Noise Margin $= V_{DD}/2$

Gain $= \infty$

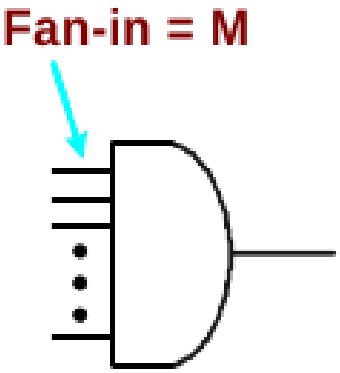
NÍVEIS LÓGICOS



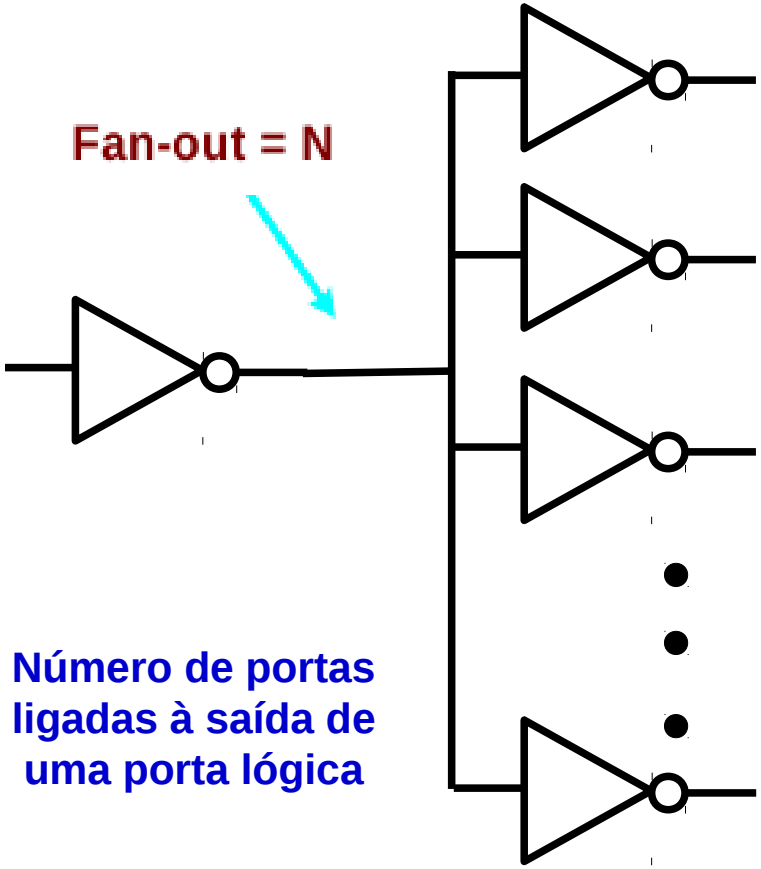
MARGENS DE RUÍDO



Fan-In e *Fan-Out*

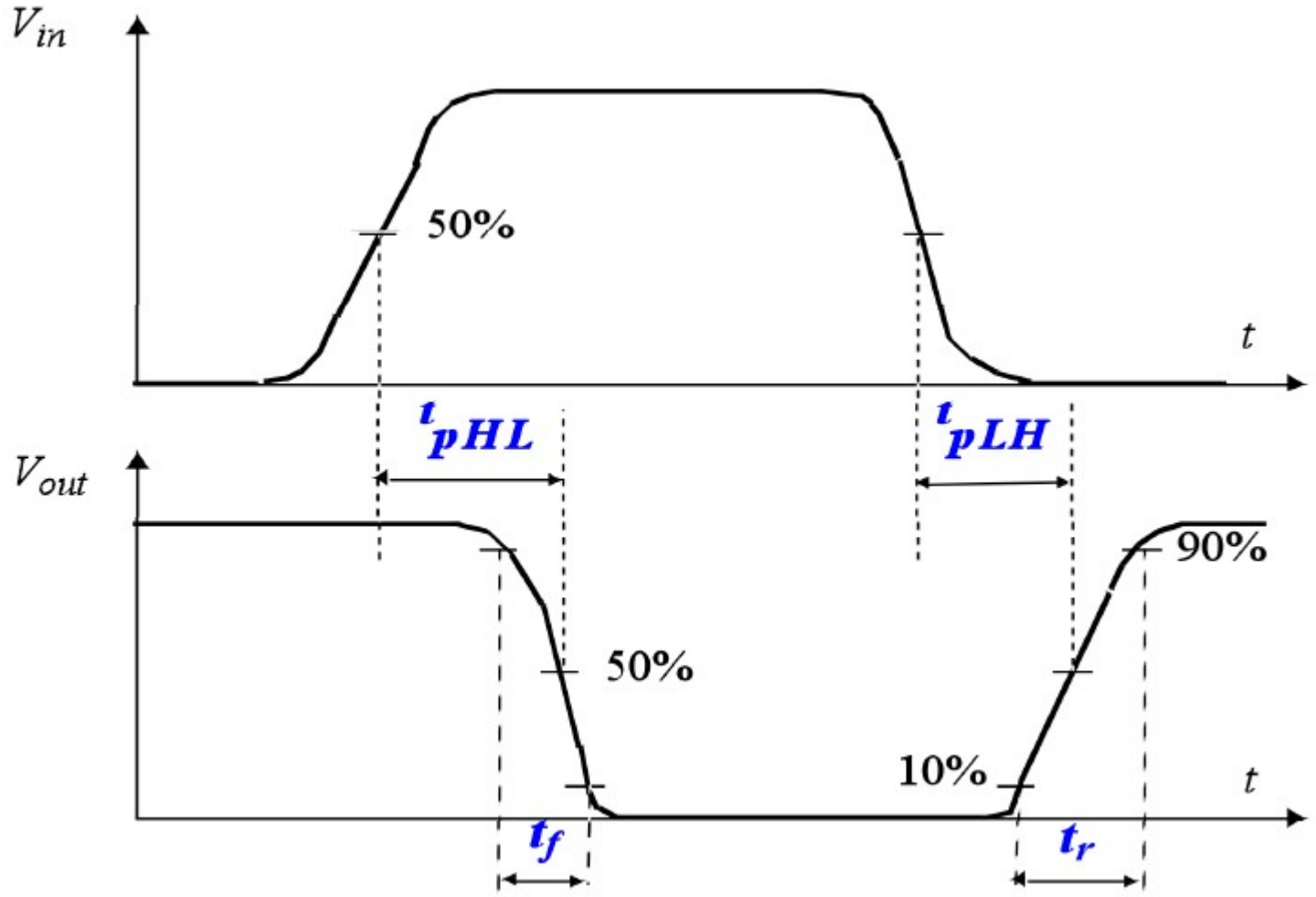


Número de entradas ligadas a uma porta lógica

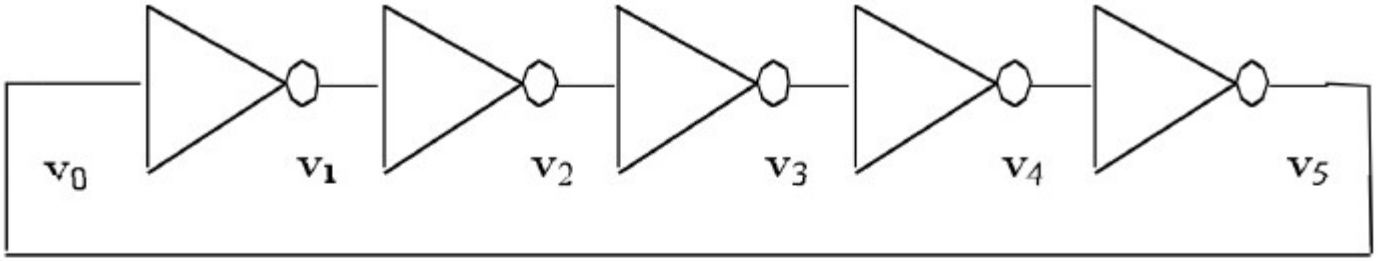


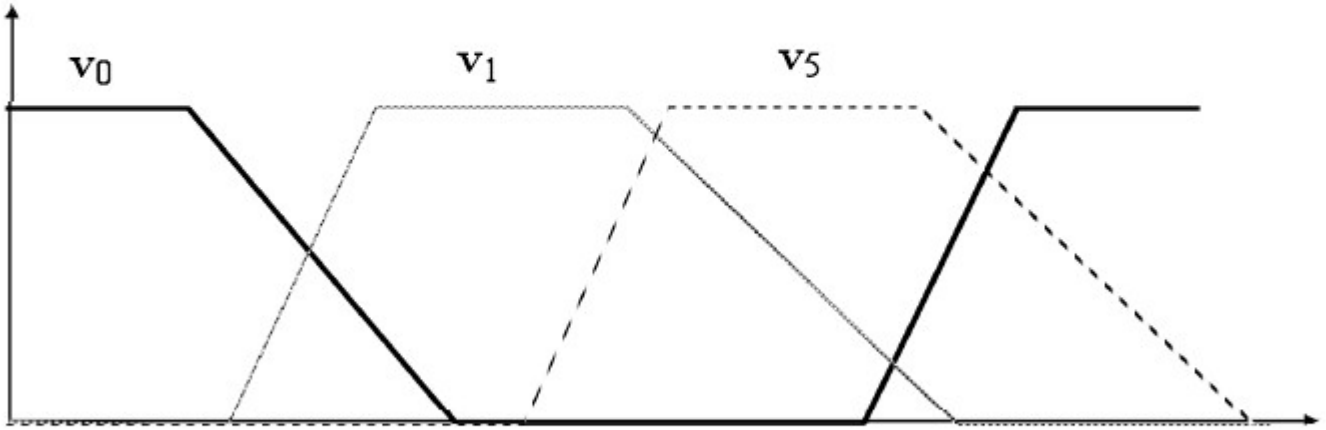
Número de portas ligadas à saída de uma porta lógica

COMPORTAMENTO DINÂMICO



OSCILADOR EM ANEL





$$T = 2 \times t_p \times N$$

DISSIPAÇÃO DE POTÊNCIA

Potência máxima $P_{max} = V_{DD} * I_{DD}$

Potência média $P_{med} = \frac{1}{T}\int_0^T p(t)\,dt = \frac{V_{DD}}{T}\int_0^T i_{DD}(t)\,dt$

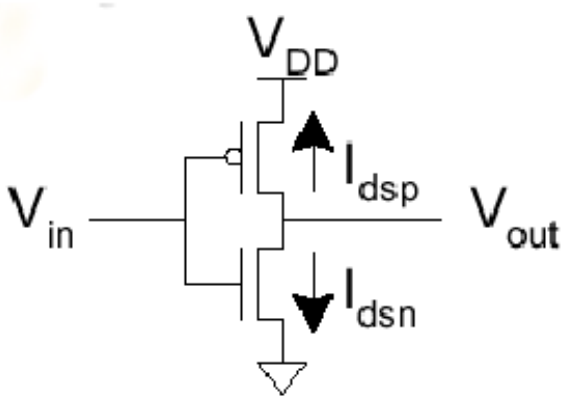
Produto Potência-Atraso (Power-Delay Product)

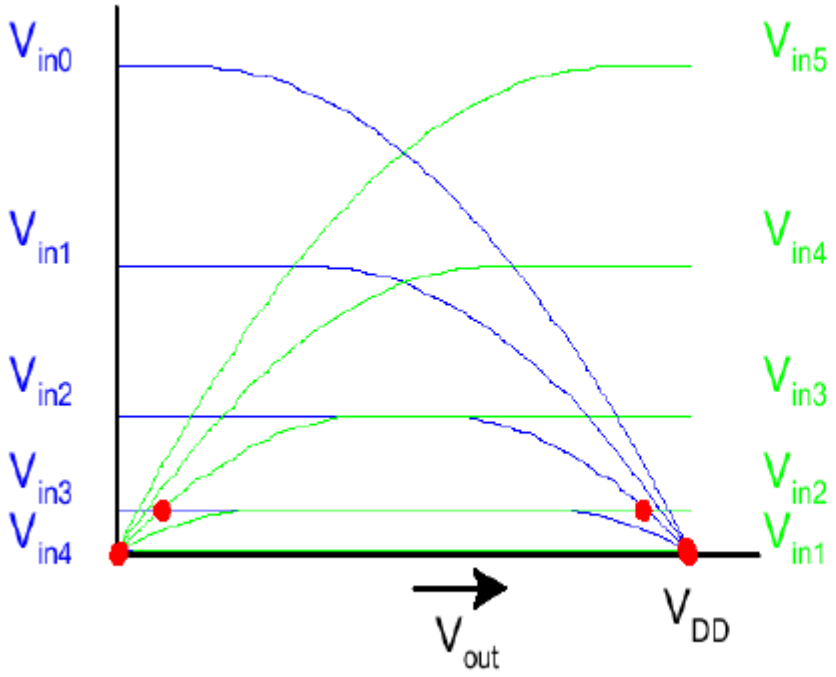
- **energia por operação de chaveamento**

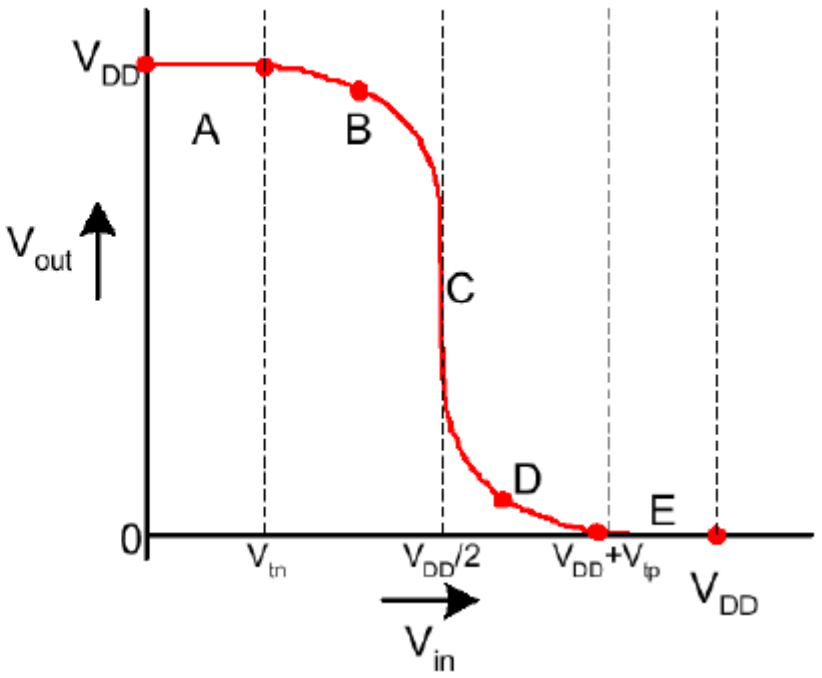
$$PDP = P_{med} * t_p$$

ANÁLISE DO INVERSOR CMOS

CARACTERÍSTICA DE TRANSFERÊNCIA DC

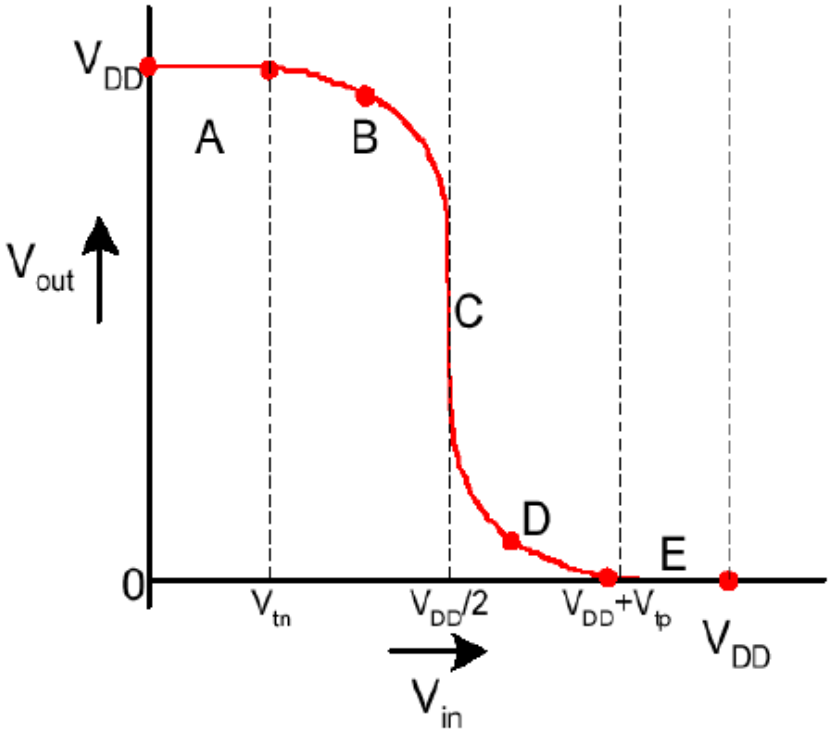




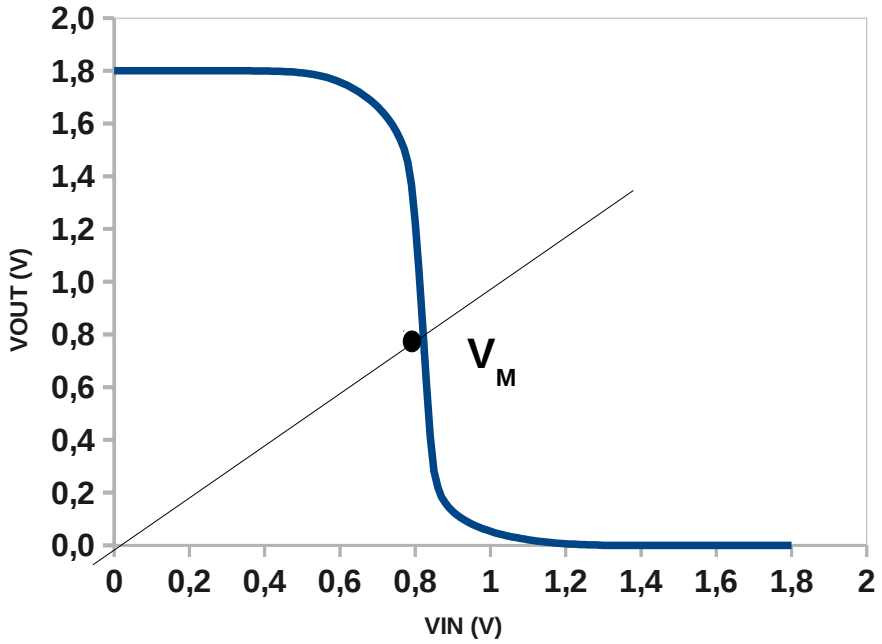


REGIÕES DE OPERAÇÃO

Region	nMOS	pMOS
A	Cutoff	Linear
B	Saturation	Linear
C	Saturation	Saturation
D	Linear	Saturation
E	Linear	Cutoff



Determinação de V_M



Ambos transistores saturados

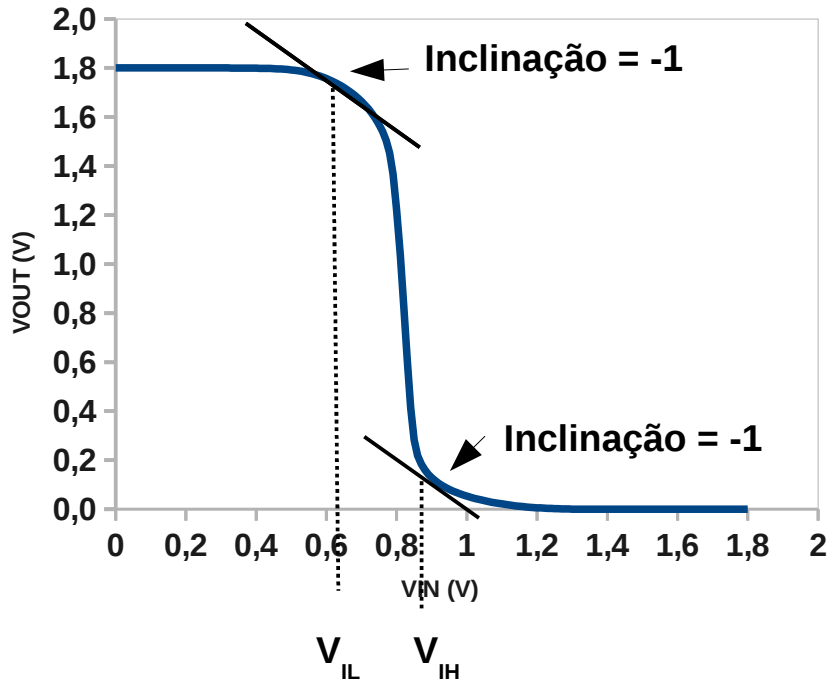
$$\frac{k_n}{2}(V_M - V_{tn})^2 = \frac{k_p}{2}(V_{DD} - V_M - |V_{tp}|)^2$$

$$V_M = \frac{r(V_{DD} - |V_{tp}|) + V_t}{1 + r}$$

onde $$r = \sqrt{\frac{k_p}{k_n}}$$

$$k_{n(p)} = k'_{n(p)} \left(\frac{W}{L}\right)_{n(p)}$$

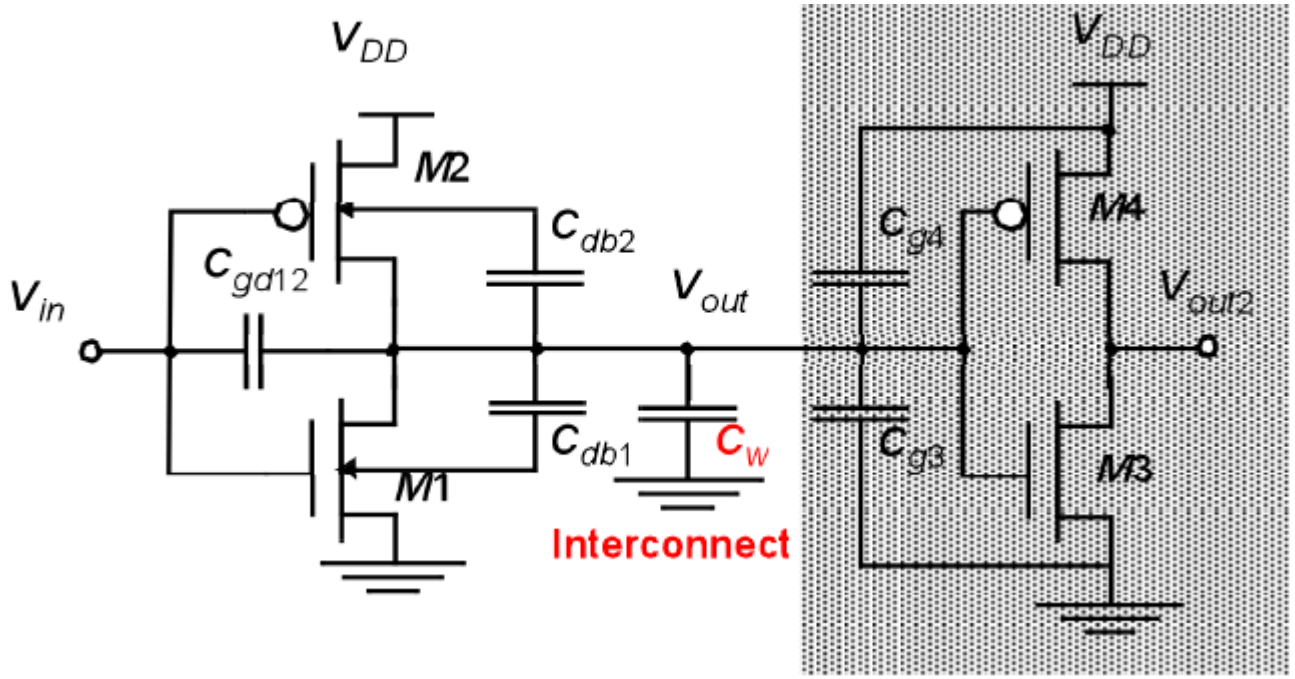
Determinação de V_{IL} e V_{IH}



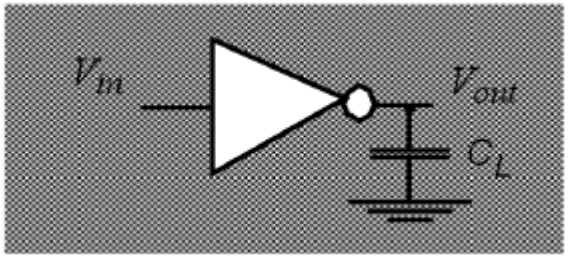
Calcular o ganho do inversor e igaualar à unidade. Observar as regiões de operação dos transistores.

$$\frac{dV_{OUT}}{dV_I} = -1$$

ANÁLISE DINÂMICA



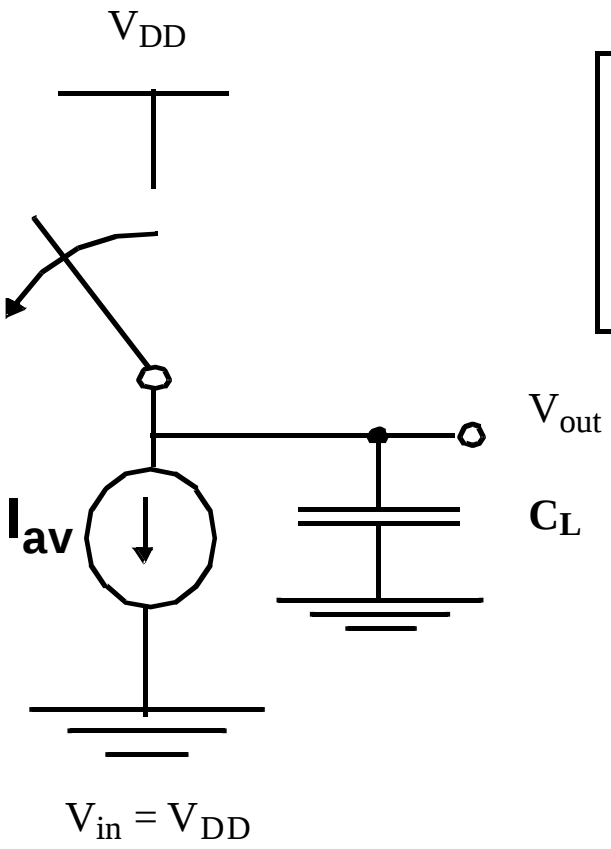
Modelo simplificado



CÁLCULO DAS CAPACITÂNCIAS

Capacitor	Expression
C_{gd1}	2 CGD0 W_n
C_{gd2}	2 CGD0 W_p
C_{db1}	K_{eqn} (AD_n CJ + PD_n CJSW)
C_{db2}	K_{eqp} (AD_p CJ + PD_p CJSW)
C_{g3}	C_{ox} W_n L_n
C_{g4}	C_{ox} W_p L_p
C_w	From Extraction
C_L	Σ

ATRASO DE PROPAGAÇÃO



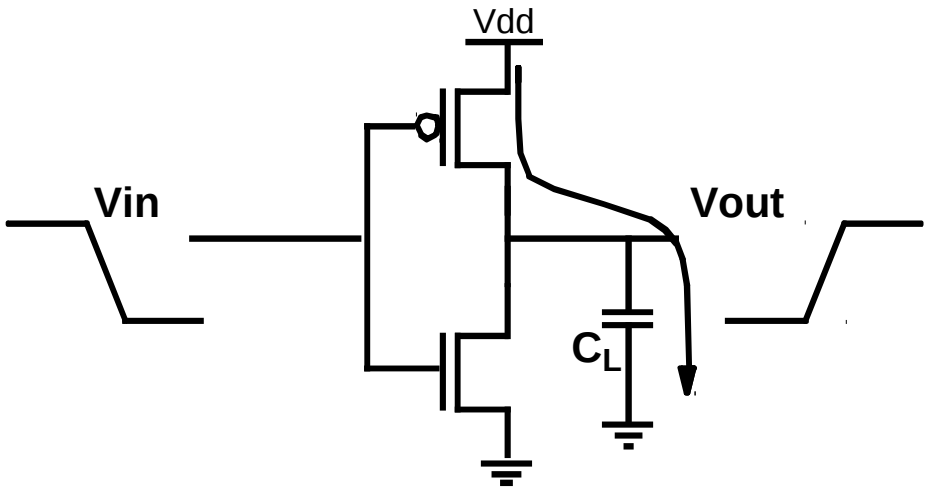
$$t_{pHL} = \frac{C_L \, V_{swing}/2}{I_{av}}$$

$$\sim \frac{C_L}{k_n \, V_{DD}}$$

Do mesmo modo para t_{pLH}

$$t_{pLH} = \frac{C_L}{K_p V_{DD}}$$

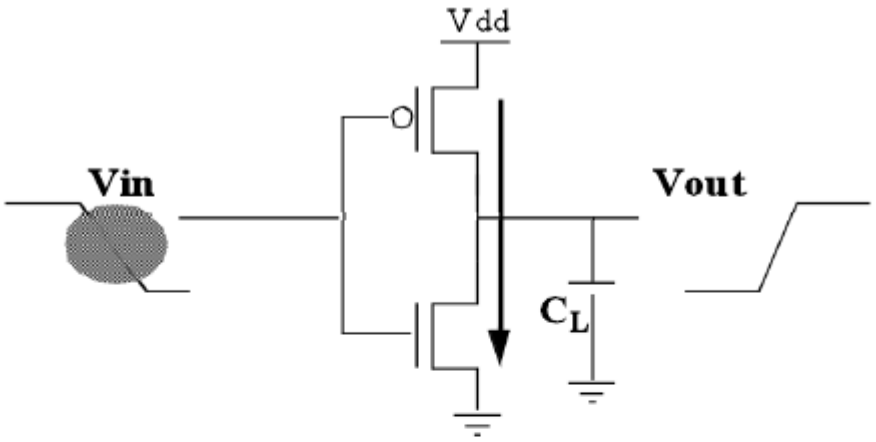
DISSIPAÇÃO DE POTÊNCIA

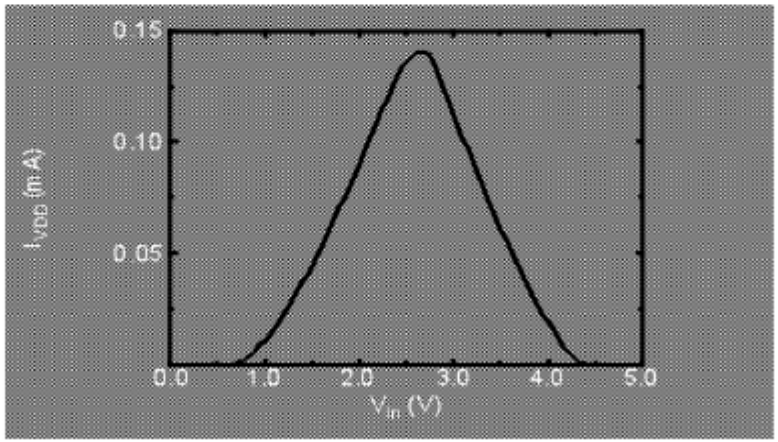


$$\text{Energy/transition} = C_L * V_{dd}^2$$

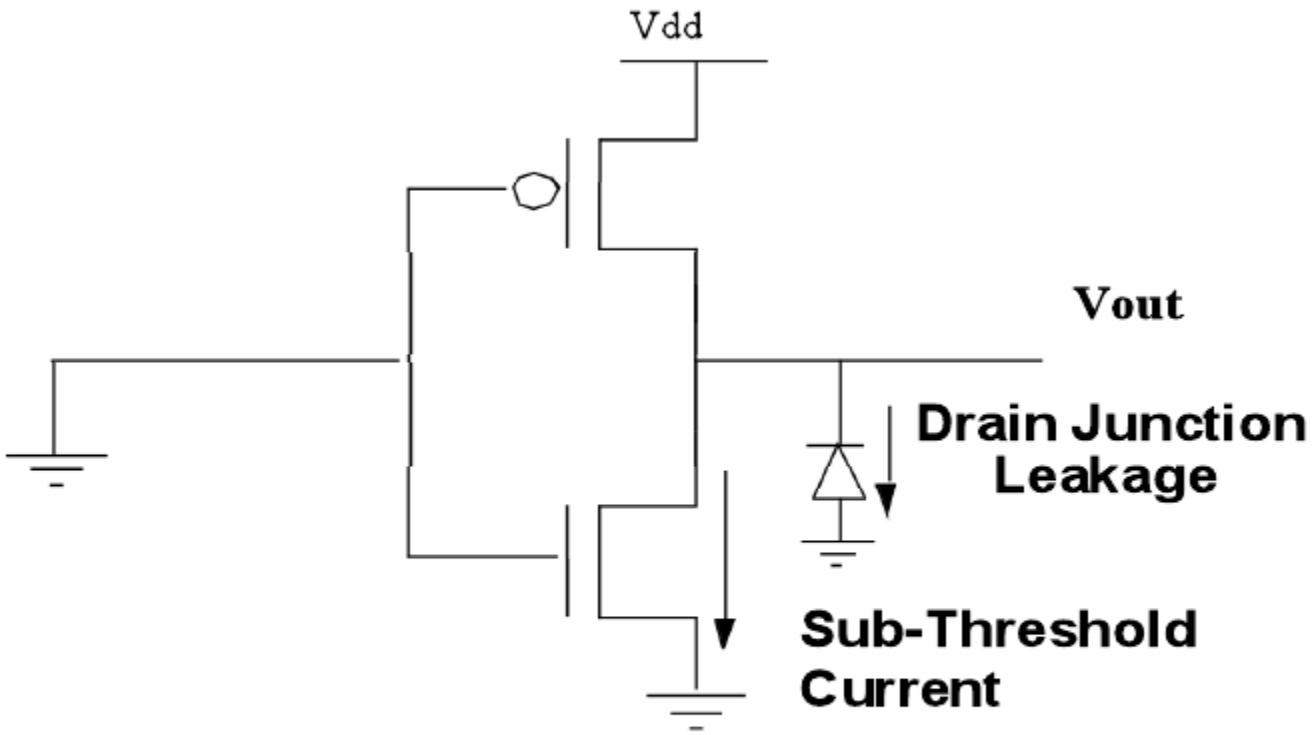
$$\text{Power} = \text{Energy/transition} * f = C_L * V_{dd}^2 * f$$

CORRENTE DE CURTO-CIRCUITO





CORRENTE DE FUGA



Sub-Threshold Current Dominant Factor