

CMOS

CIRCUIT DESIGN,
LAYOUT, AND
SIMULATION

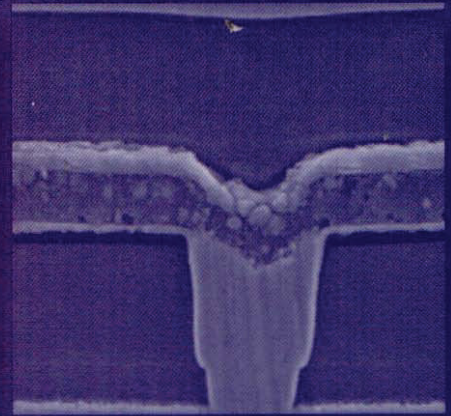
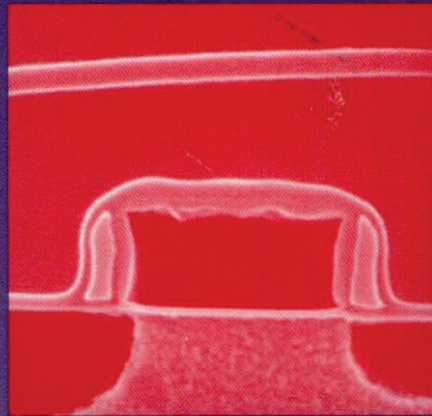
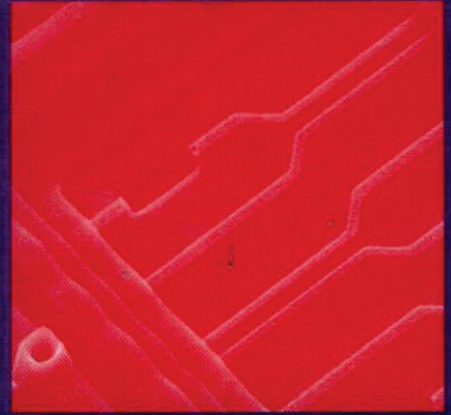
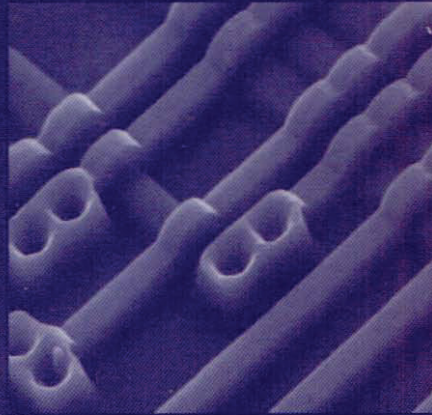
Baker



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CIRCUIT DESIGN, LAYOUT, AND SIMULATION



R. Jacob Baker ■ Harry W. Li ■ David E. Boyce

IEEE Press Series on Microelectronic Systems
Stuart K. Tewksbury, *Series Editor*

The LASI Layout Software, as well as other
layout software, can be downloaded at
http://www.mrc.uidaho.edu/vlsi/cad_free.htm

Process Information for Hand-Calculations

Process	CN20 NMOS	CN20 PMOS	CMOS14 NMOS	CMOS14 PMOS
Information	App. A	App. A	App. C	App. C
V_{DD} ($V_{SS} = 0$)	5 V	5 V	3.3 V	3.3 V
minimum L_{drawn}	2.0 μm	2.0 μm	0.6 μm	0.6 μm
$DL = L_{drawn} - L_{eff}$	0.6 μm	0.8 μm	0.06 μm	0.09 μm
minimum W_{drawn}	3.0 μm	3.0 μm	0.9 μm	0.9 μm
$DW = W_{drawn} - W_{eff}$	0.14 μm	0.16 μm	0.35 μm	0.35 μm
V_{THN} or V_{THP}	0.83 V	0.91 V	0.7 V	0.9 V
KP, $\mu\text{A}/\text{V}^2$	50	17	170	50
λ , V^{-1}	0.06 for $L \geq 5 \mu\text{m}$	0.06 for $L \geq 5 \mu\text{m}$		
I_{drive} ($\mu\text{A}/\mu\text{m}$)			380 (typ.)	190 (typ.)
C'_{ox}	800 aF/ μm^2	800 aF/ μm^2	3.7 fF/ μm^2	3.7 fF/ μm^2
R_n or R_p	12 $\text{k}\Omega \cdot (L/W)$	36 $\text{k}\Omega \cdot (L/W)$	(9 $\text{k}\Omega \cdot \mu\text{m})/W$	(18 $\text{k}\Omega \cdot \mu\text{m})/W$
τ_n or τ_p	38 ps	114 ps	20 ps	40ps

Multipliers

Name	Symbol	Value
terra	T	10^{12}
giga	G	10^9
mega	M or (MEG)	10^6
kilo	k	10^3
milli	m	10^{-3}
micro	μ (or u)	10^{-6}
nano	n	10^{-9}
pico	p	10^{-12}
femto	f	10^{-15}
atto	a	10^{-18}

Physical Constants

Name	Symbol	Value/Units
Vacuum dielectric constant	ϵ_0	8.85 aF/ μm
Silicon dielectric constant	ϵ_{si}	$11.7\epsilon_0$
SiO ₂ dielectric constant	ϵ_{ox}	$3.97\epsilon_0$
SiN ₃ dielectric constant	ϵ_{Ni}	$16\epsilon_0$
Boltzmann's constant	k	1.38×10^{-23} J/K
Electronic charge	q	1.6×10^{-19} C
Temperature	T	K
Thermal voltage	V_T	kT/q = 26 mV @ 300 K

Equations

Parameter	NMOS equations in terms of BSIM1 parameters
	for PMOS use V_{SD} , V_{SG} , V_{BS} , and V_{THP}
V_{THN}	$V_{FB} + PHI + K1 \cdot \sqrt{PHI + V_{SB}} - K2 \cdot (PHI + V_{SB})$
C'_{ox}	ϵ_{ox}/TOX
KP	$MUZ \cdot C'_{ox}$
β	$KP \cdot (W/L)$
I_D (triode) $V_{DS} \leq V_{GS} - V_{THN}$	$\beta \left((V_{GS} - V_{THN})V_{DS} - \frac{V_{DS}^2}{2} \right)$ (for Long L)
I_D (saturation) $V_{DS} \geq V_{GS} - V_{THN}$	$\frac{\beta}{2} (V_{GS} - V_{THN})^2 [1 + \lambda(V_{DS} - V_{DS,sat})]$ (for Long L)
g_m	$\beta(V_{GS} - V_{THN}) = \sqrt{2\beta I_D}$ or $I_D/(V_T \cdot NO)$
η	$K1 \cdot \left(2\sqrt{PHI + V_{SB}} \right)^{-1} - K2$ and $g_{mb} = g_m \cdot \eta$
r_o	$1/(\lambda I_D)$

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