

CMOS

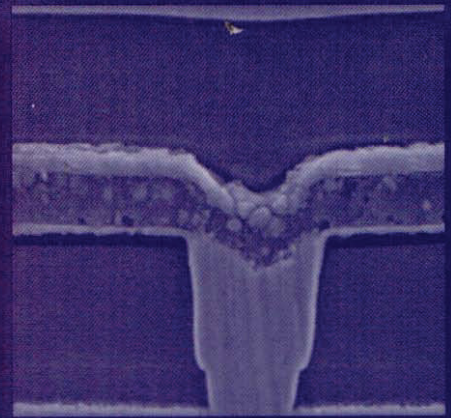
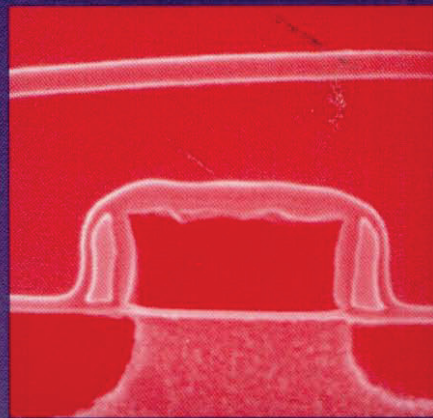
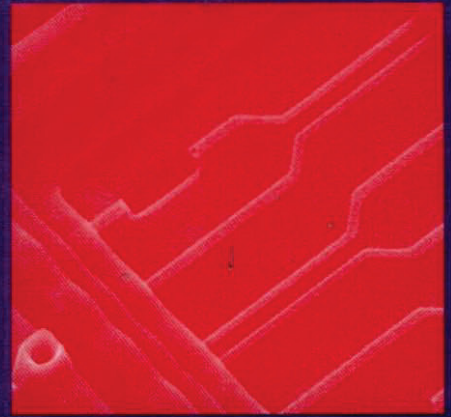
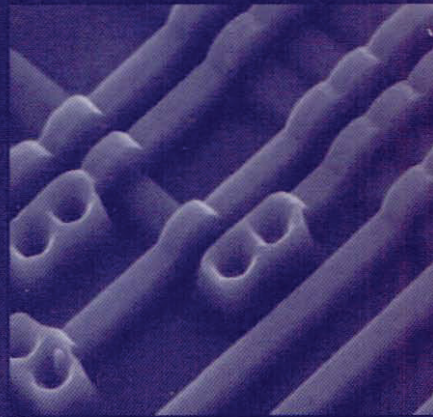
CIRCUIT DESIGN,
LAYOUT, AND
SIMULATION

Baker

TK
7871.99
.M44B335
1998
C.1

CMOS

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}

109

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	$1/(\lambda I_D)$

IEEE Press
445 Hoes Lane, P.O. Box 1331
Piscataway, NJ 08855-1331

Editorial Board

John B. Anderson, *Editor in Chief*

P. M. Anderson	R. Herrick	R. S. Muller
M. Eden	G. F. Hoffnagle	W. D. Reeve
M. E. El-Hawary	R. F. Hoyt	D. J. Wells
S. Furui	S. Kartalopoulos	
A. H. Haddad	P. Laplante	

Kenneth Moore, *Director of IEEE Press*

John Griffin, *Senior Editor*

Linda Matarazzo, *Assistant Editor*

IEEE Circuits & Systems Society, *Sponsor*
CAS-S Liaison to IEEE Press, Phillip Allen
IEEE Solid-State Circuits Society, *Sponsor*
SSC-S Liaison to IEEE Press, Stuart K. Tewksbury

Technical Reviewers

Jeff Bruce, *Micron Technology, Inc.*
Alan Buchholz, *Comlinear Corporation*
Ian Galton, *University of California, Irvine*
Bruce Johnson, *University of Nevada, Reno*
Joseph Karniewicz, *Micron Technology, Inc.*
Brent Keeth, *Micron Technology, Inc.*
William Kuhn, *Kansas State University*
Wen Li, *Micron Technology, Inc.*
Brian P. Lum Shue Chan, *Crystal Semiconductor Corporation*
Alan Mantooh, *Analogy, Inc.*
Adrian Ong, *Stanford University*
Terry Sculley, *Crystal Semiconductor Corporation*
Don Thelen, *Analog Interfaces*
Axel Thomsen, *Crystal Semiconductor Corporation*
Kwang Yoon, *Inha University, Korea*

CMOS

Circuit Design, Layout, and Simulation

R. Jacob Baker, Harry W. Li and David E. Boyce
Department of Electrical Engineering
Microelectronics Research Center
The University of Idaho

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

IEEE Circuits & Systems Society, *Sponsor*
IEEE Solid-State Circuits Society, *Sponsor*



The Institute of Electrical and Electronics Engineers, Inc., New York

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.