CMOS

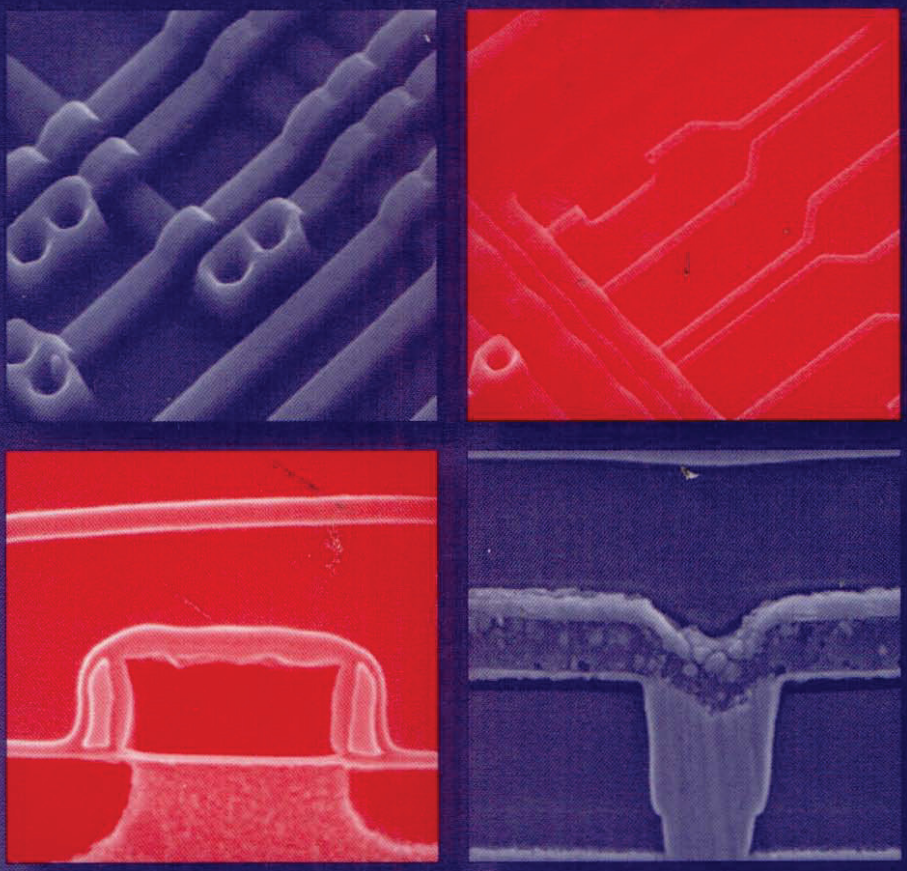
CIRCUIT DESIGN, LAYOUT, AND SIMULATION

Baker



# 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 | *CN*20 NMOS | *CN*20 PMOS | *CMOS*14 NMOS | *CMOS*14 PMOS |
|---|---|---|---|---|
| | | | | |
| Information | App. A | App. A | App. C | App. C |
| $VDD$ ($VSS = 0$) | 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, µA/V$^2$ | 50 | 17 | 170 | 50 |
| λ, V$^{-1}$ | 0.06 for $L \geq 5$ µm | 0.06 for $L \geq 5$ µm | | |
| $I_{drive}$ (µA/µm) | | | 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 kΩ · ($L$/$W$) | 36 kΩ · ($L$/$W$) | (9 kΩ · µm)/$W$ | (18 kΩ · µm)/$W$ |
| $\tau_n$ or $\tau_p$ | 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 | $\varepsilon_0$ | 8.85 aF/μm |
| Silicon dielectric constant | $\varepsilon_{si}$ | $11.7\varepsilon_0$ |
| $SiO_2$ dielectric constant | $\varepsilon_{ox}$ | $3.97\varepsilon_0$ |
| $SiN_3$ dielectric constant | $\varepsilon_{Ni}$ | $16\varepsilon_0$ |
| Boltzmann's constant | k | $1.38 \times 10^{-23}$ J/K |
| Electronic charge | q | $1.6 \times 10^{-19}$ C |
| Temperature | T | K |
| Thermal voltage | $V_T$ | kT/q<br>= 26 mV @ 300 K |

# Equations

| Parameter | NMOS equations in terms of BSIM1 parameters |
|---|---|
| | for PMOS use $V_{SD}$, $V_{SG}$, $V_{BS}$, and $V_{THP}$ |
| | |
| $V_{THN}$ | $VFB + PHI + K1 \cdot \sqrt{PHI + V_{SB}} - K2 \cdot (PHI + V_{SB})$ |
| $C'_{ox}$ | $\varepsilon_{ox}/TOX$ |
| $KP$ | $MUZ \cdot C'_{ox}$ |
| β | $KP \cdot (W/L)$ |
| $I_D$ (triode)<br>$V_{DS} \le V_{GS} - V_{THN}$ | $\beta\left((V_{GS} - V_{THN})V_{DS} - \frac{V_{DS}^2}{2}\right)$ (for Long L) |
| $I_D$ (saturation)<br>$V_{DS} \ge V_{GS} - V_{THN}$ | $\frac{\beta}{2}(V_{GS} - V_{THN})^2[1 + \lambda(V_{DS} - V_{DS,sat})]$ (for Long L) |
| $g_m$ | $\beta(V_{GS} - V_{THN}) = \sqrt{2\beta I_D}$ or $I_D/(V_T \cdot N0)$ |
| 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

# 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*

IEEE
PRESS

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

DOCKET ALARM

# 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.