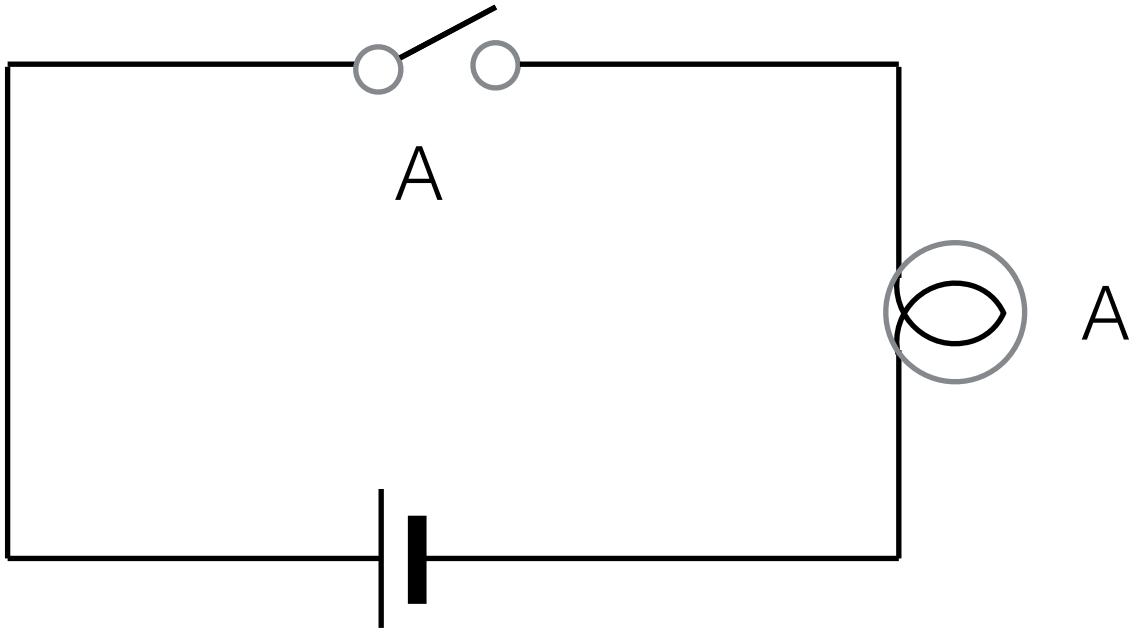
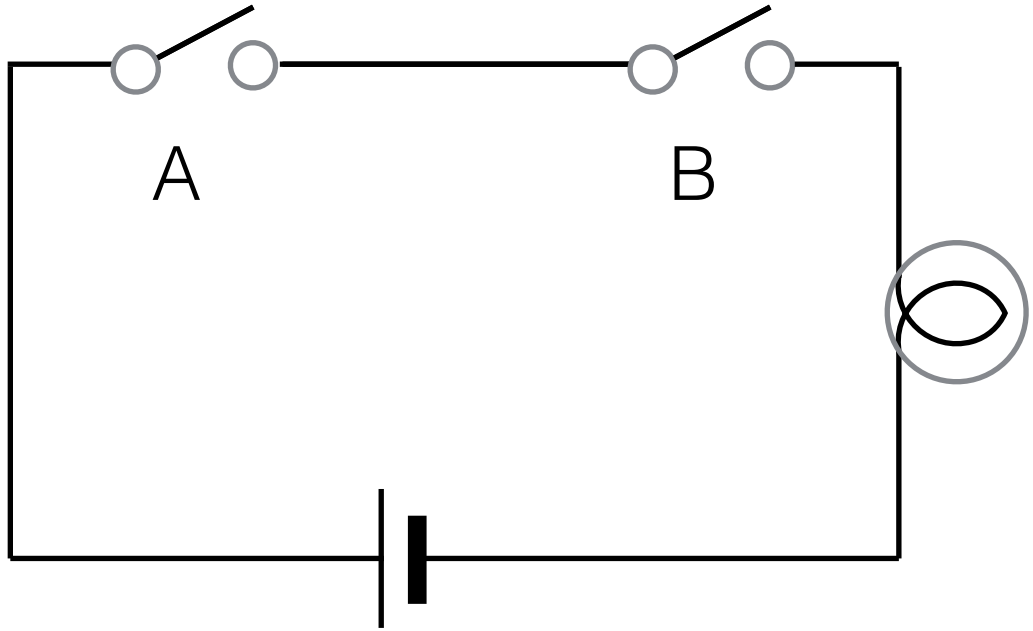
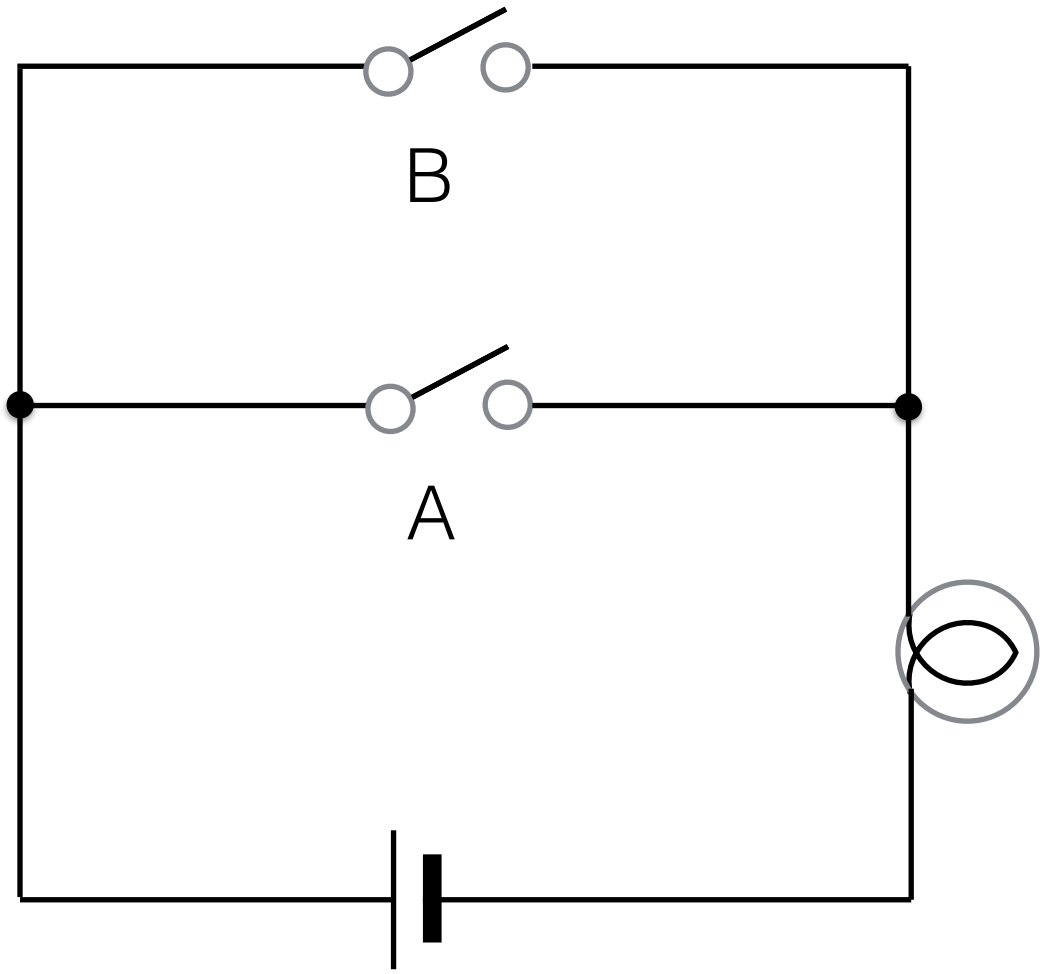
Informatics 1

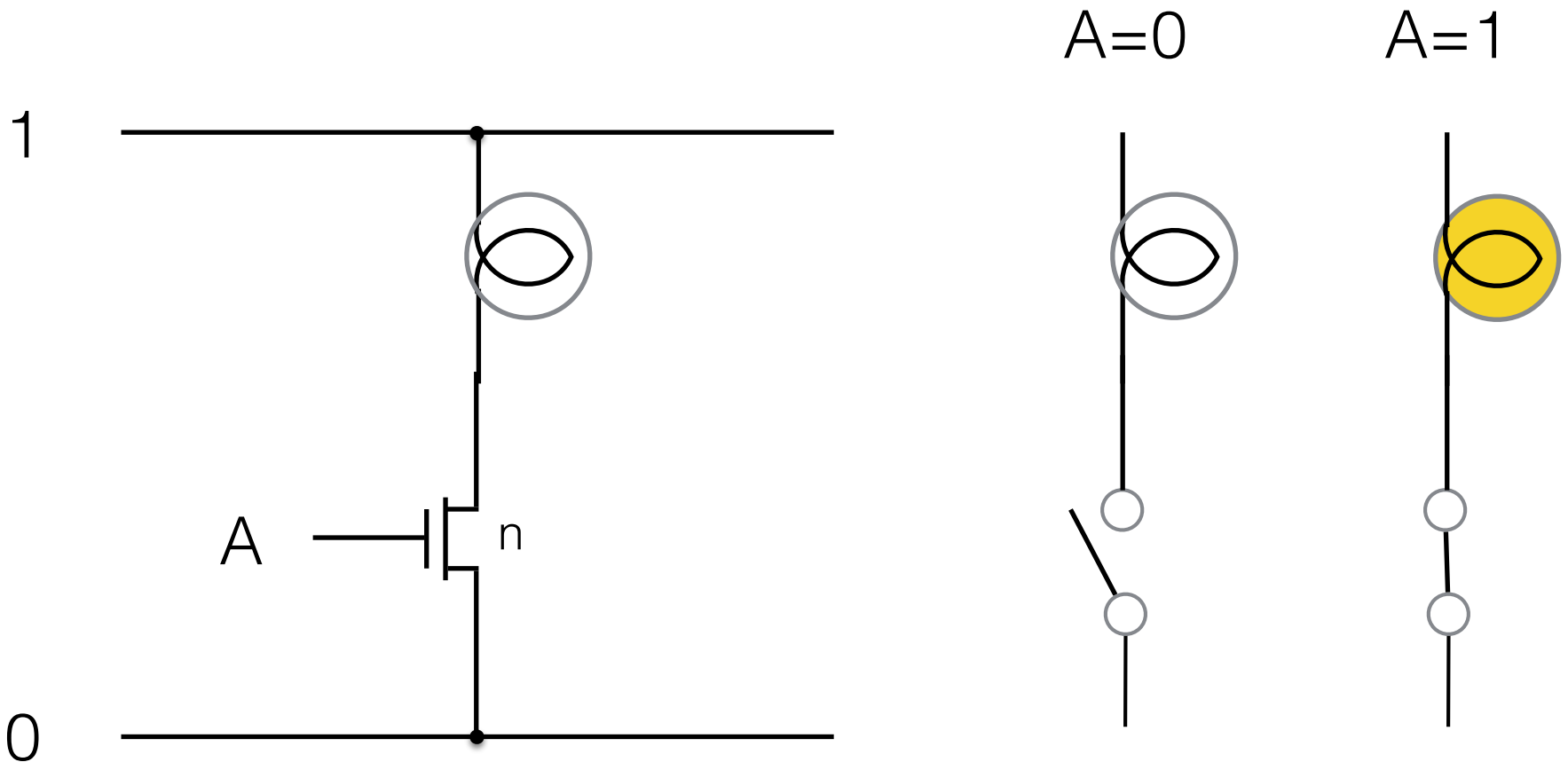
Lecture 5 Switches and Circuits

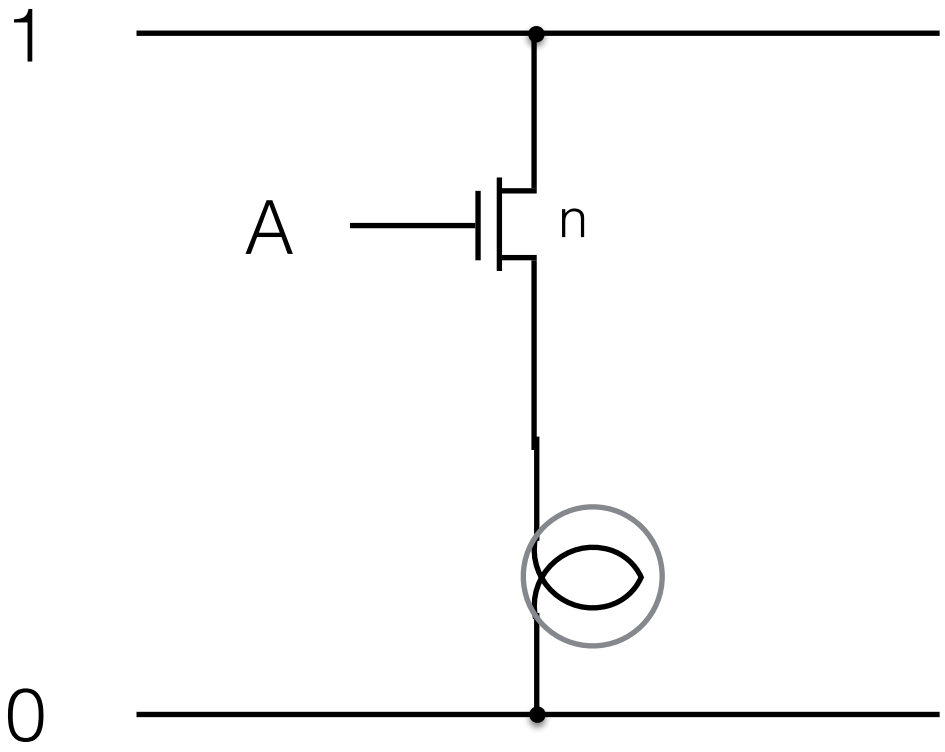
Michael Fourman

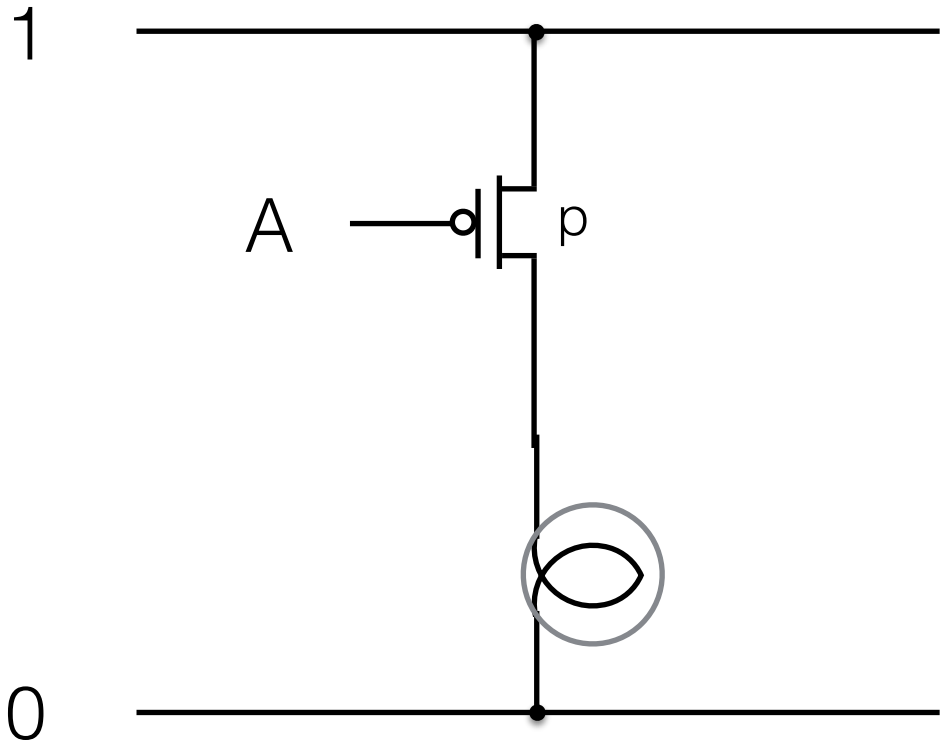

A
A

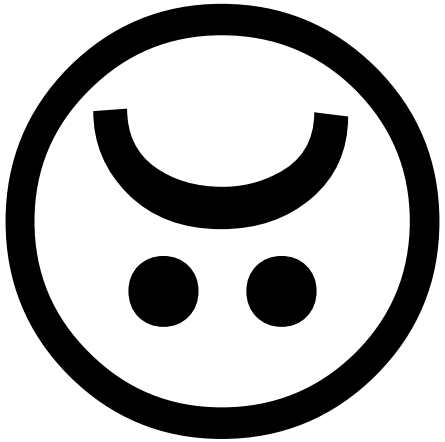

A
B

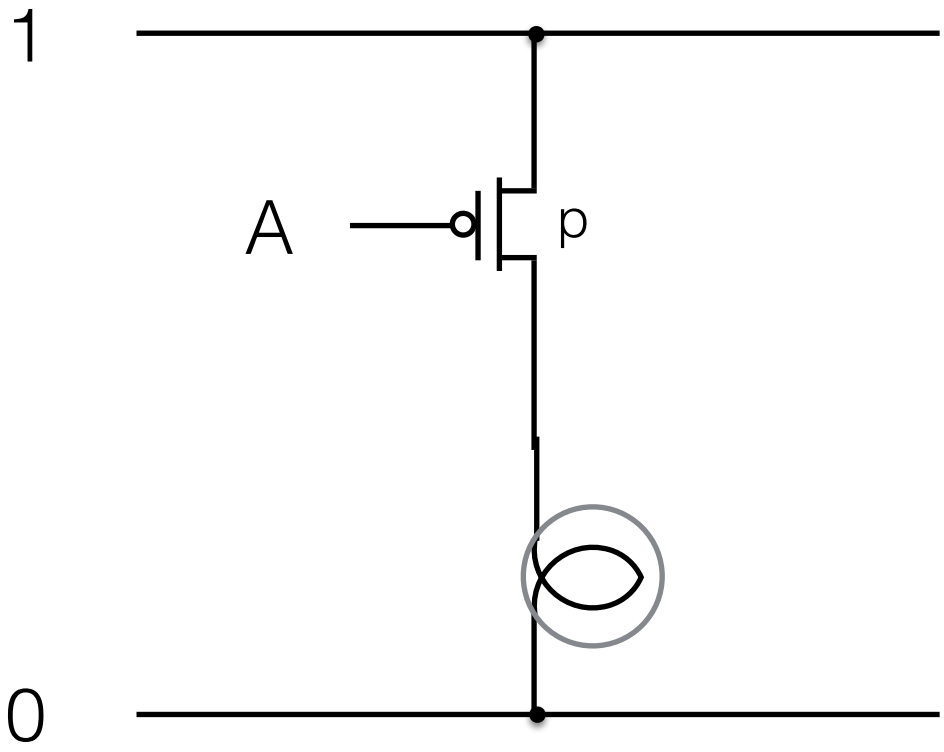

B
A

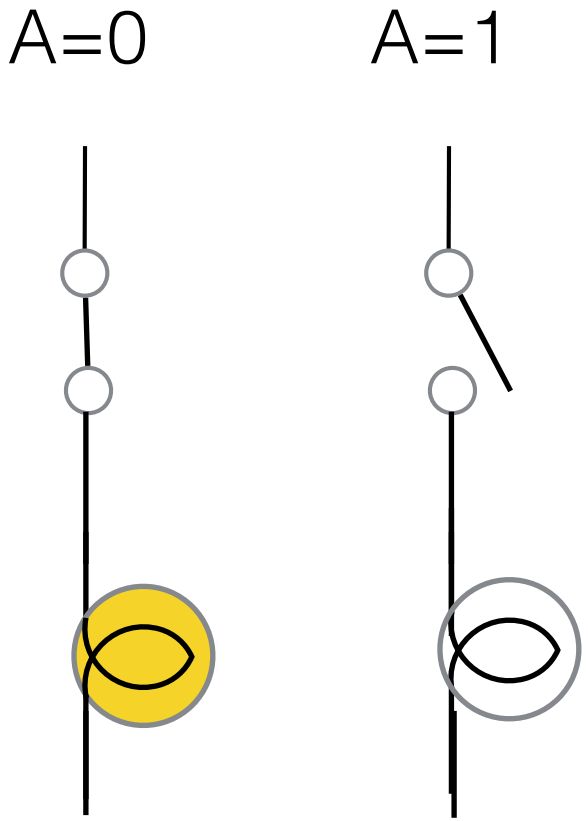

1
A
n
0
A=0
A=1

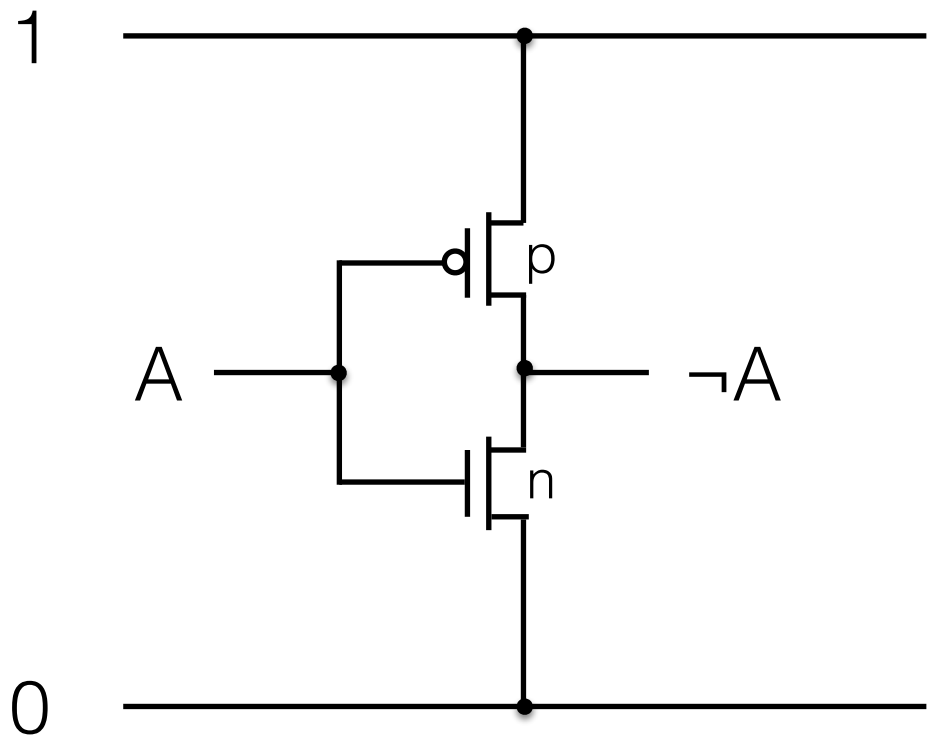

1
A
n
0

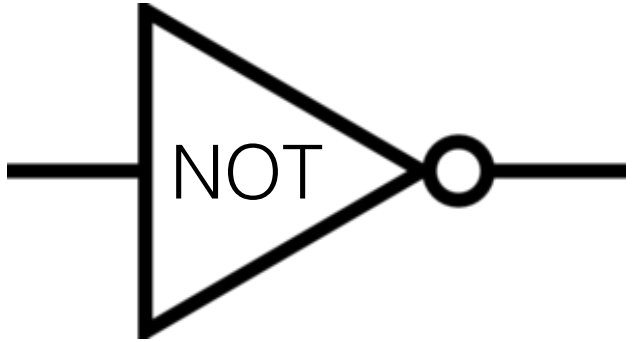

1
A
p
0

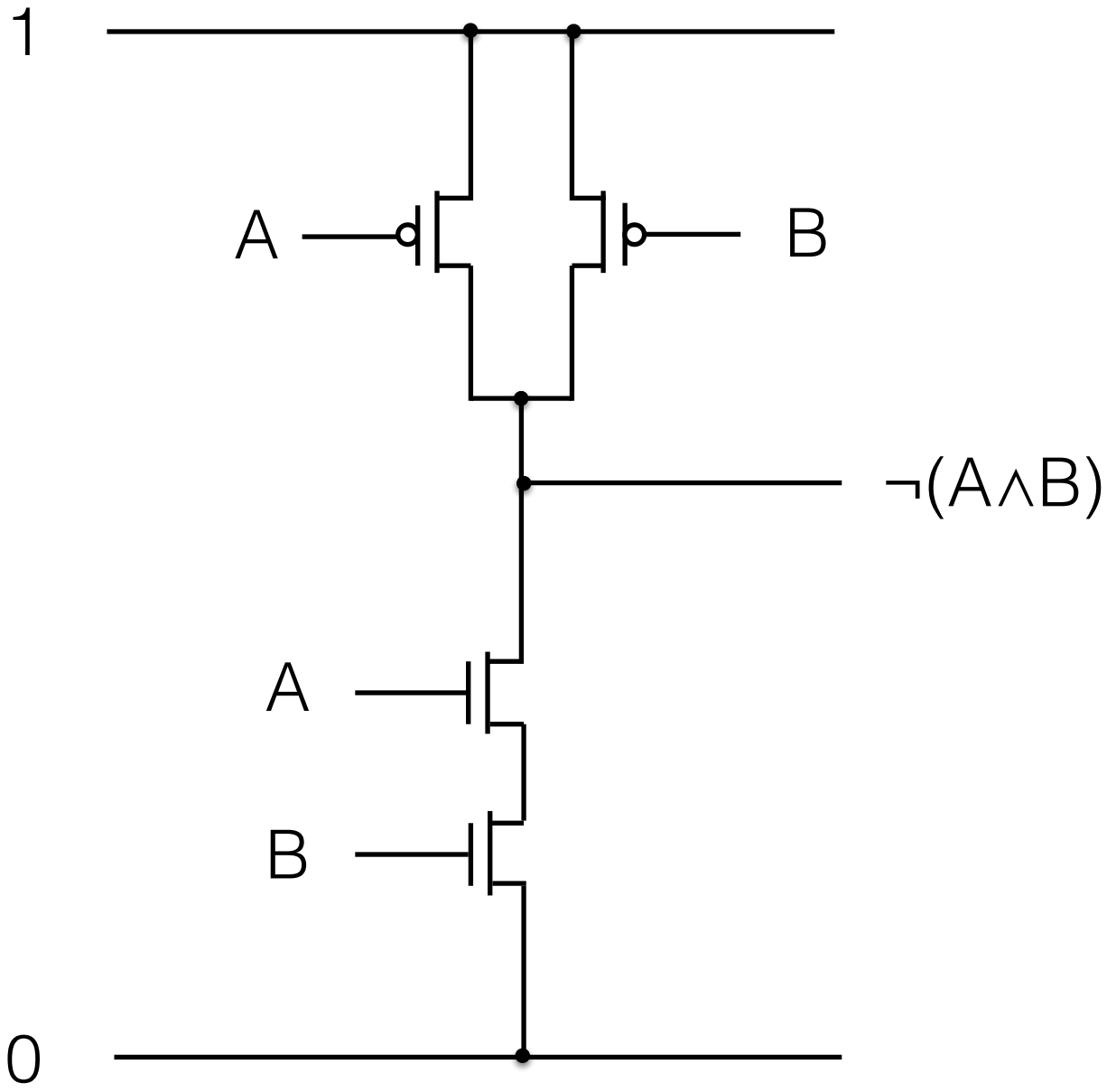


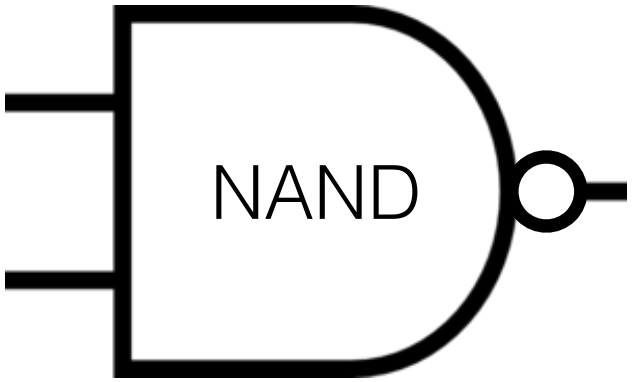

1
A
p
0

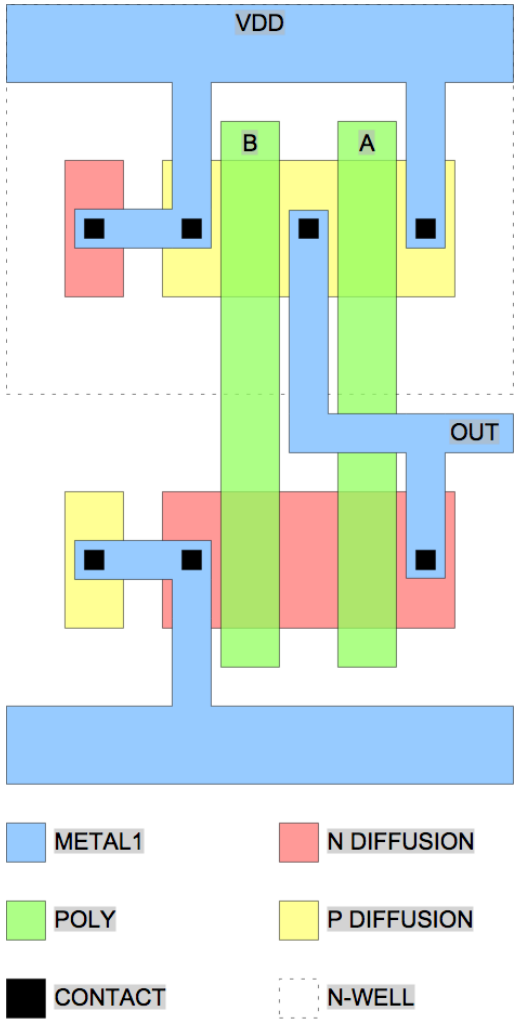

A=0
A=1

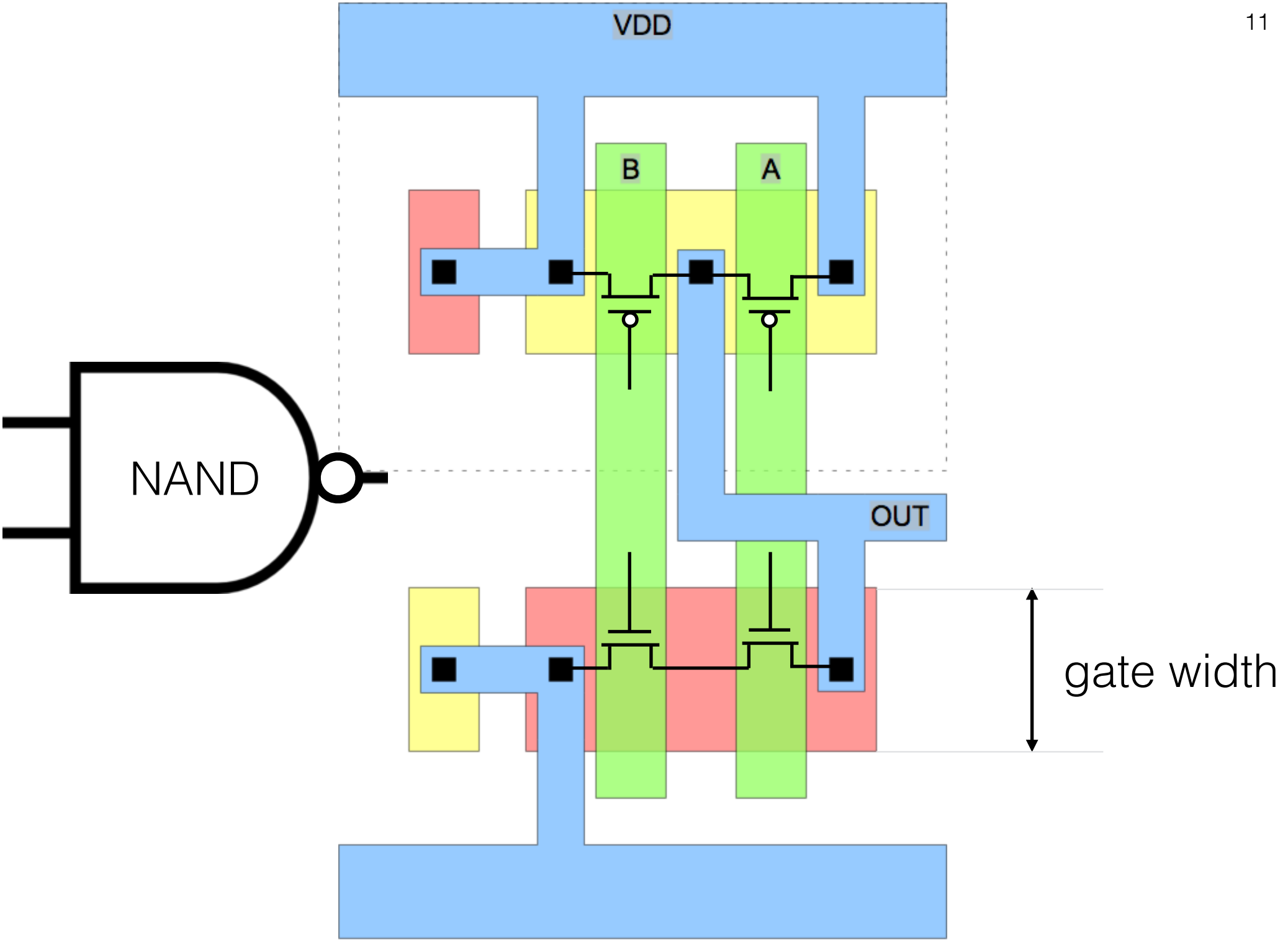

1
p
A
¬A
n
0


NOT


1
A
B
¬(A∧B)
A
B
0

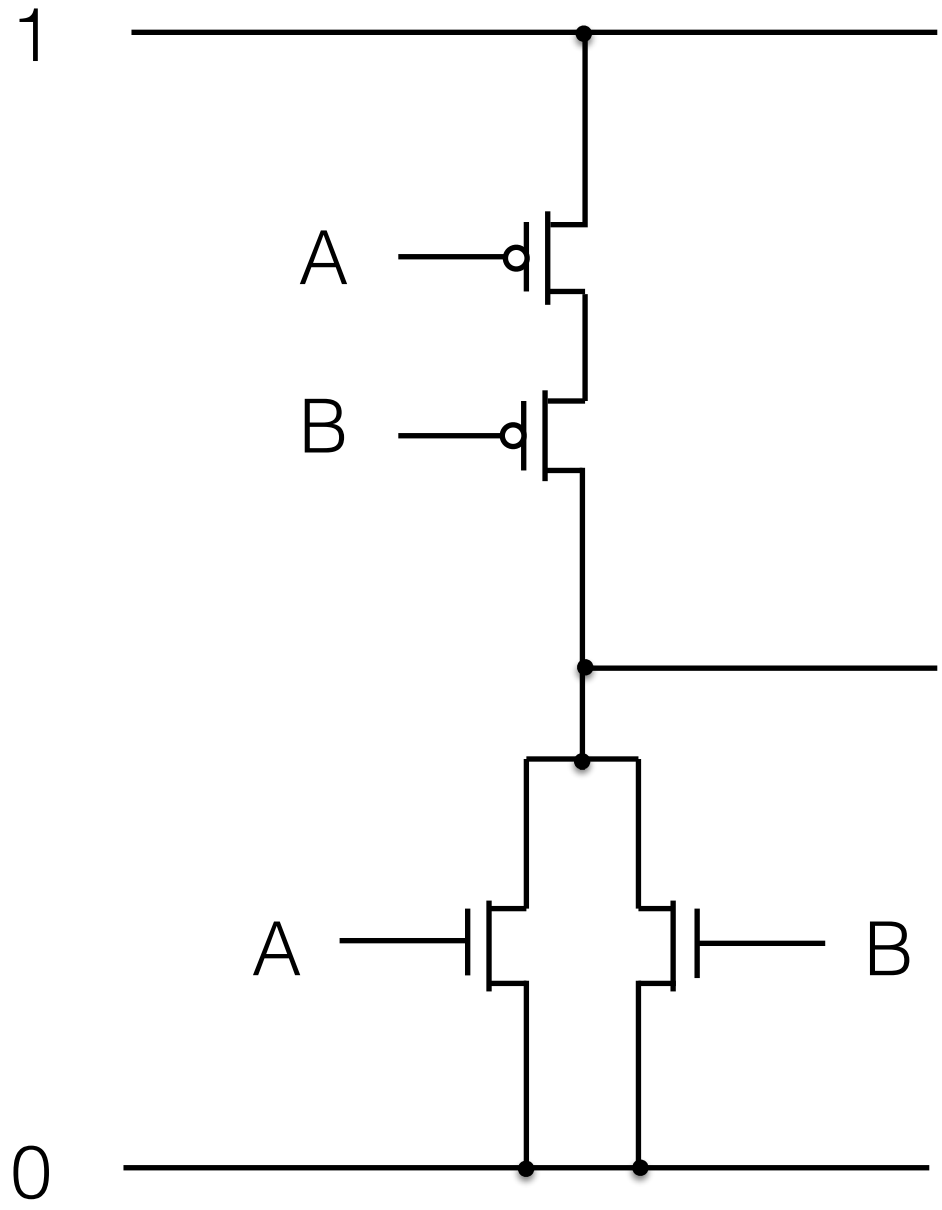

NAND

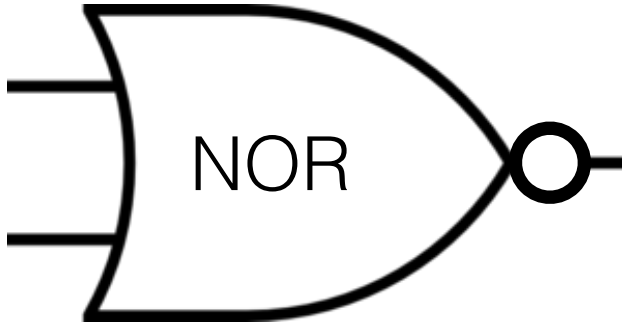

VDD
B
A
OUT
METAL1
N DIFFUSION
POLY
P DIFFUSION
CONTACT
N-WELL

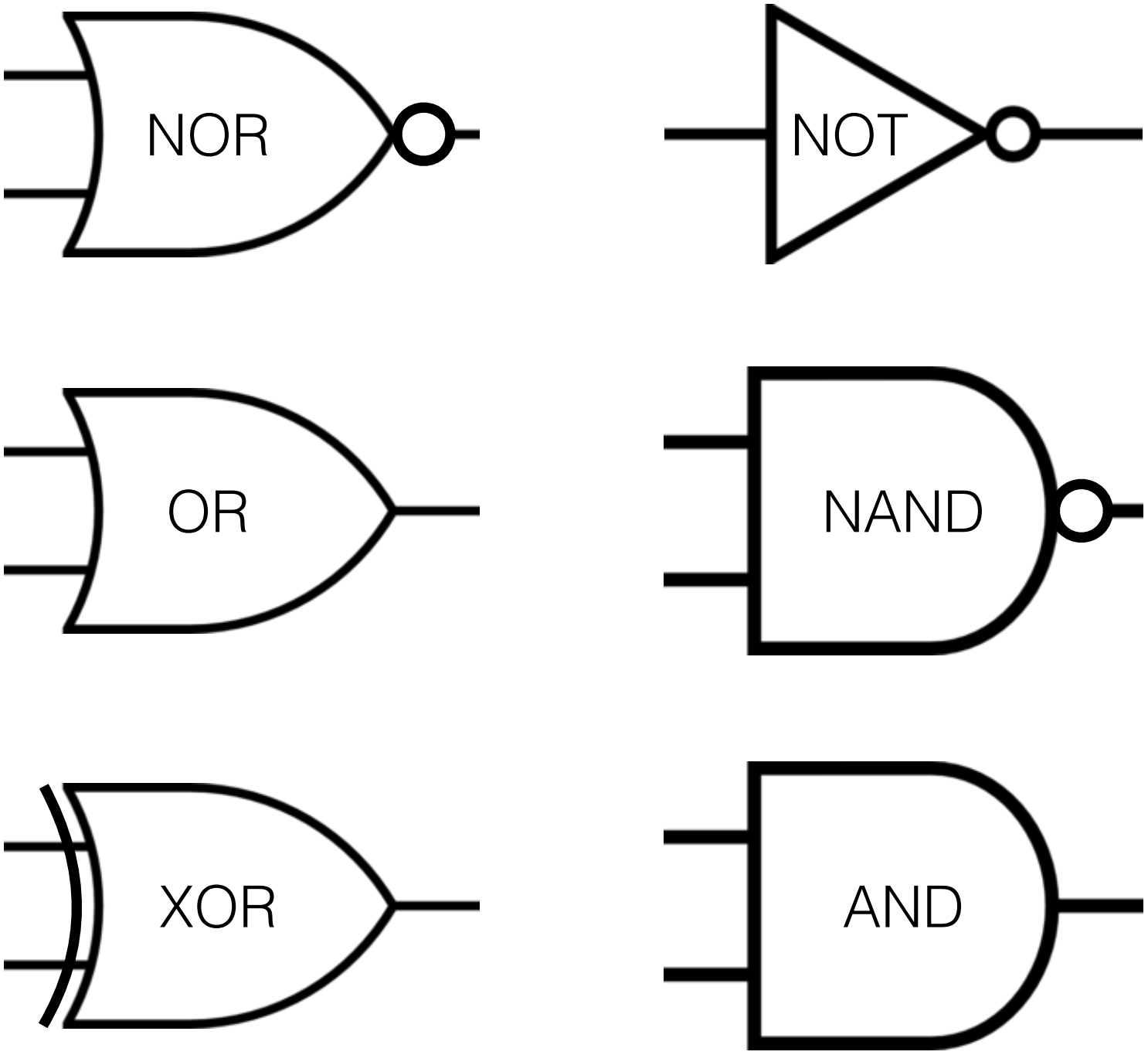

VDD
B
A
OUT
NAND
gate width

SCALING TRENDS OF HIGH PEFORMANCE MICROPROCESSORS FROM INTEL

Name	Year	Process Type	Feature Size (μm)	Transistor Count (millions)	Die Area (mm^2)	Frequency (MHz)
4004	1971	PMOS	10	0.0023	13.5	0.108
8080	1974	NMOS	6	0.006	20	2
8086	1978	NMOS	3	0.029	28.6	5-10
80286	1982	CMOS	1.5	0.134	68.7	6-12
80386	1985	CMOS	1.5	0.275	104	16-33
80486	1989	CMOS	1	1.2	163	25-50
Pentium	1993	BiCMOS	0.8	3.1	264	60-66
Pentium II	1997	CMOS	0.35	7.5	209	233-300
Celeron	1998	CMOS	0.25	19	154	300-333
Pentium III	1999	CMOS	0.18	28	140	500-733
Pentium 4	2001	CMOS	0.13	55	146	2000-2200
Itanium II	2003	CMOS	0.13	220	421	1300-1500
Montecito (dual-core)	2006	CMOS	0.09	1720	596	1600
Core 2 Duo	2006	CMOS	0.065	291	143	1800-2900
Penryn	2007	CMOS	0.045	410	107	>1800


1
A
B
¬(A∨B)
A
B
0


NOR


NOR
NOT
OR
NAND
XOR
AND

$$\big(\neg R(x) \vee A(x) \vee \neg G(x)\big)$$

$$\wedge$$

$$\big(R(x) \vee \neg A(x) \vee \neg G(x)\big)$$

$$\wedge$$

$$\big(R(x) \vee A(x) \vee G(x)\big)$$

$$\wedge$$

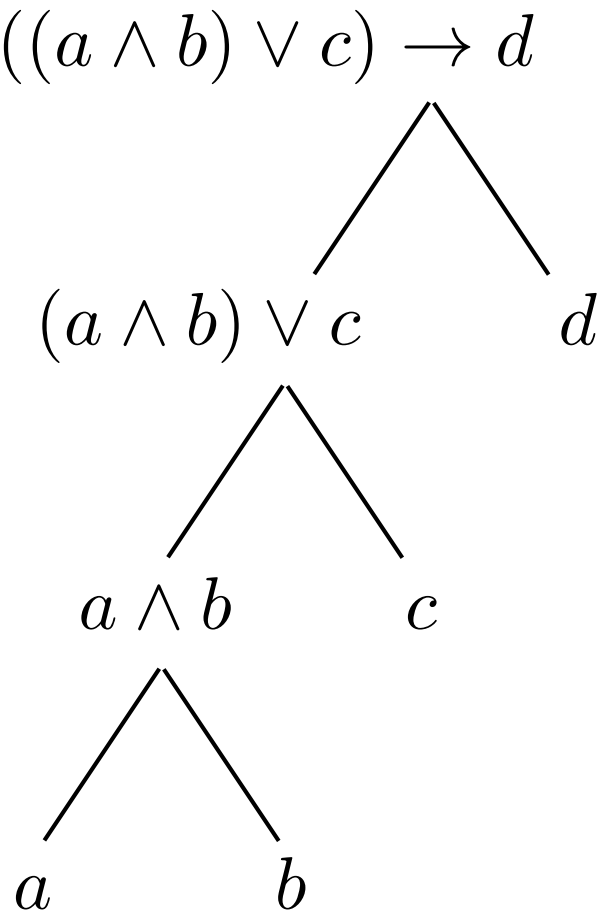
$$\big(\neg R(x) \vee \neg A(x) \vee G(x)\big)$$

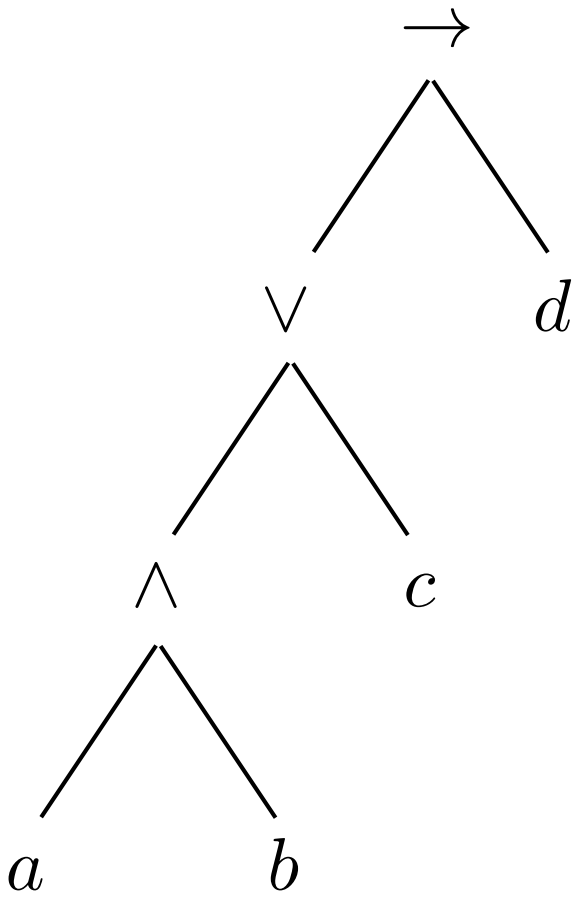
$$
\begin{aligned}
&\big(\neg R(x) \vee A(x) \vee \neg G(x)\big) \\
&\quad \wedge \\
&\big(R(x) \vee \neg A(x) \vee \neg G(x)\big) \\
&\quad \wedge \\
&\big(R(x) \vee A(x) \vee G(x)\big) \\
&\quad \wedge \\
&\big(\neg R(x) \vee \neg A(x) \vee G(x)\big)
\end{aligned}
\quad \equiv \quad
\begin{aligned}
&\neg\neg\Big(\big(\neg R(x) \vee A(x) \vee \neg G(x)\big) \\
&\qquad \wedge \\
&\big(R(x) \vee \neg A(x) \vee \neg G(x)\big) \\
&\qquad \wedge \\
&\big(R(x) \vee A(x) \vee G(x)\big) \\
&\qquad \wedge \\
&\big(\neg R(x) \vee \neg A(x) \vee G(x)\big)\Big)
\end{aligned}
$$

$$\neg\neg\Big(\big(\neg R(x) \vee A(x) \vee \neg G(x)\big) \wedge \big(R(x) \vee \neg A(x) \vee \neg G(x)\big) \wedge \big(R(x) \vee A(x) \vee G(x)\big) \wedge \big(\neg R(x) \vee \neg A(x) \vee G(x)\big)\Big)$$

$$\equiv$$

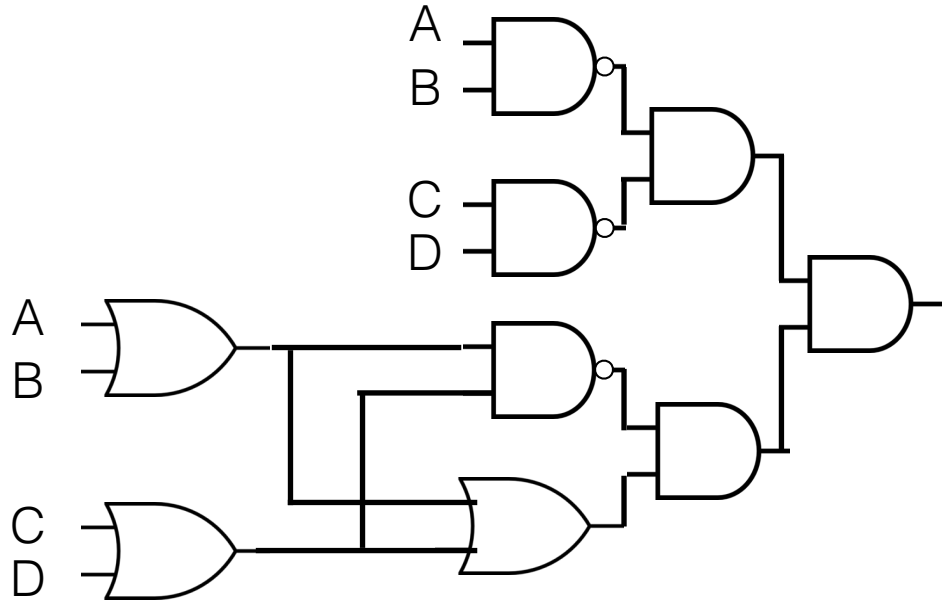
$$\neg\Big(\neg\big(\neg R(x) \vee A(x) \vee \neg G(x)\big) \vee \neg\big(R(x) \vee \neg A(x) \vee \neg G(x)\big) \vee \neg\big(R(x) \vee A(x) \vee G(x)\big) \vee \neg\big(\neg R(x) \vee \neg A(x) \vee G(x)\big)\Big)$$

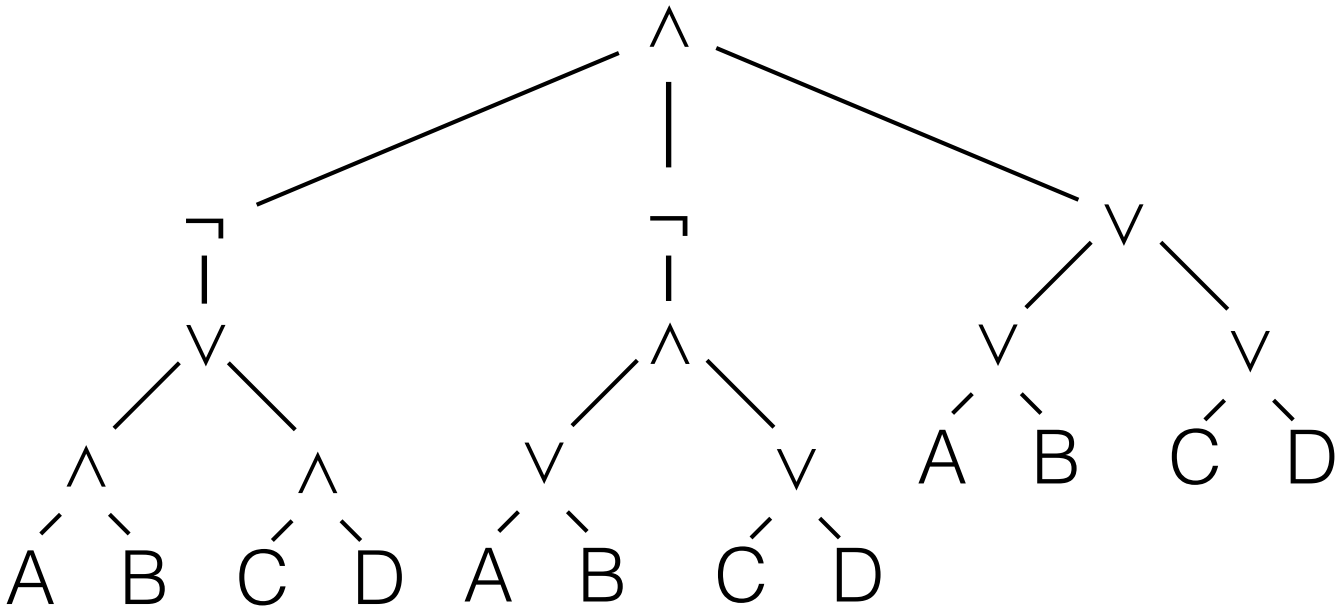

$((a \wedge b) \vee c) \to d$
$(a \wedge b) \vee c$
d
$a \wedge b$
c
a
b


$\rightarrow$
$\vee$
d
$\wedge$
c
a
b

Exactly one of A, B, C, D

$$(A \vee B \vee C \vee D)$$
$$\wedge$$
$$\neg((A \vee B) \wedge (C \vee D))$$
$$\wedge$$
$$\neg((A \wedge B) \vee (C \wedge D))$$





Tautology

Satisfied for all valuations of the atoms

Contingent

Satisfied for some valuations of the atoms

Contradiction

Satisfied for no valuations of the atoms