

Fundamentals of Computer Systems

Transistors, Gates, and ICs

Stephen A. Edwards

Columbia University

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Semiconductor

sem·i·con·duc·tor

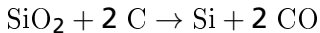
noun

1. a substance, such as silicon or germanium, with electrical conductivity intermediate between that of an insulator and a conductor
2. a semiconductor device

Sand into Silicon



Silica a.k.a. SiO_2 a.k.a. Quartz

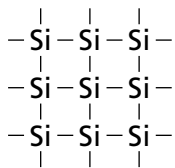


Elemental, amorphous silicon



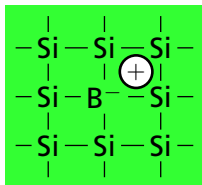
Monocrystalline Silicon
Ingot

Doping Silicon Makes It a Better Conductor



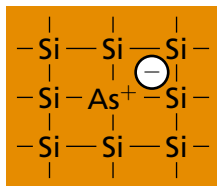
Undoped (pure)
silicon crystal

Not a good
conductor



p-type (doped)
silicon

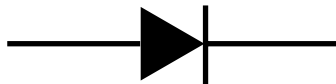
boron atom steals
a nearby electron



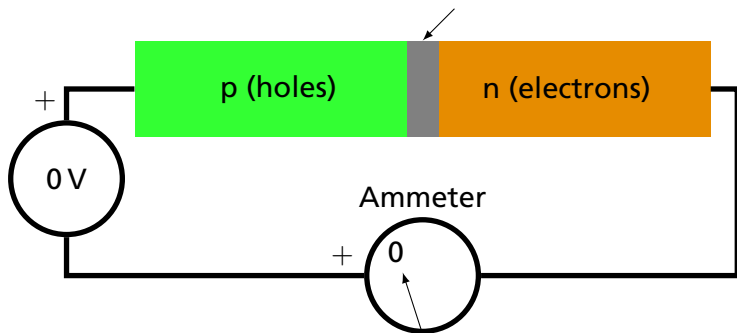
n-type (doped)
silicon:

extra electron on
arsenic atom jump
loose

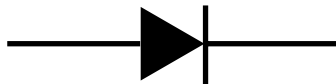
A PN Junction aka A Diode



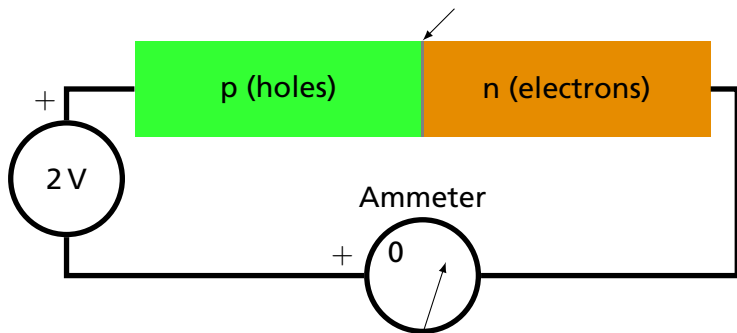
Depletion region



A PN Junction aka A Diode

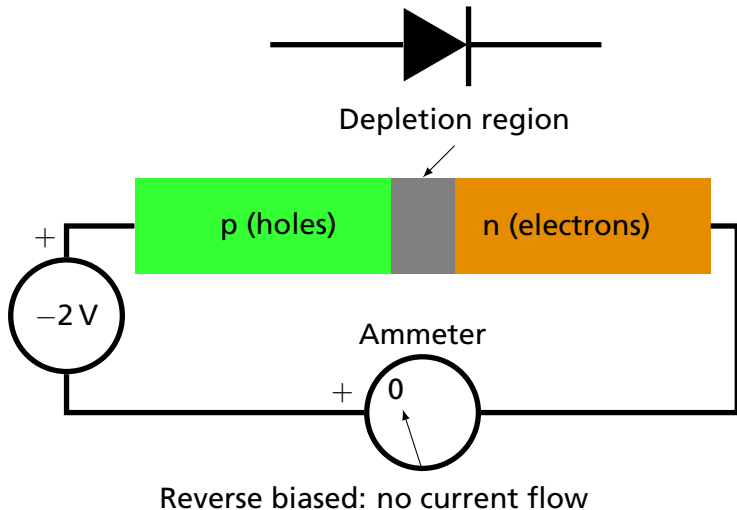


Depletion region

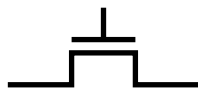


Forward biased: current flows

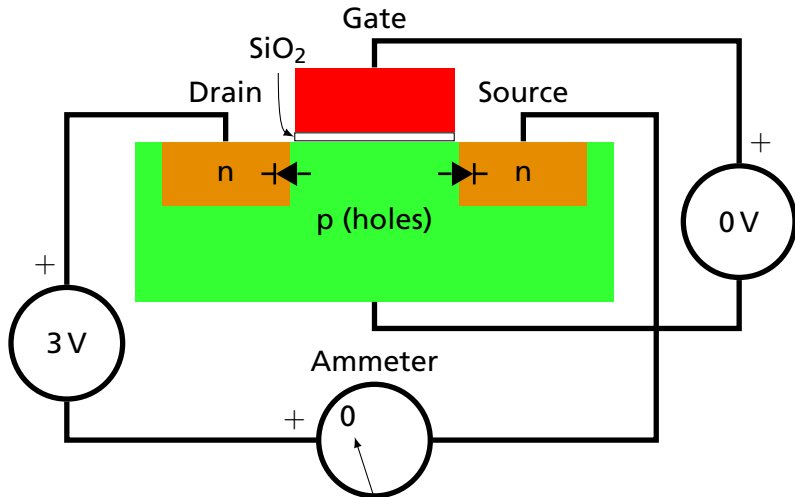
A PN Junction aka A Diode



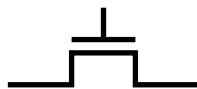
An N-Channel MOS Transistor



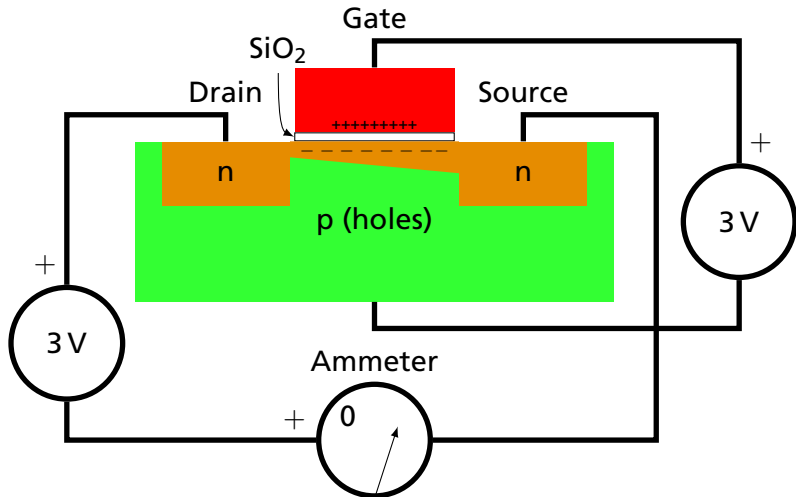
Gate at 0V: Off



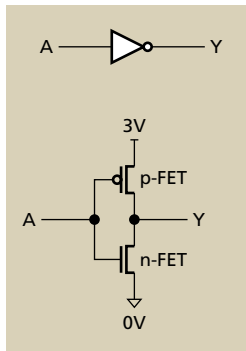
An N-Channel MOS Transistor



Gate positive: On



The CMOS Inverter

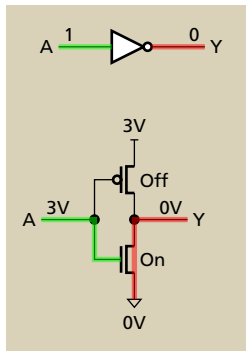


An inverter is built from two MOSFETs:

An n-FET connected to ground

A p-FET connected to the power supply

The CMOS Inverter



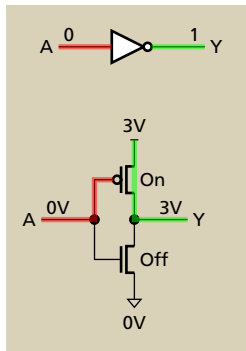
When the input is near the power supply voltage ("1"),

the p-FET is turned off;

the n-FET is turned on, connecting the output to ground ("0").

n-FETs are only good at passing 0's

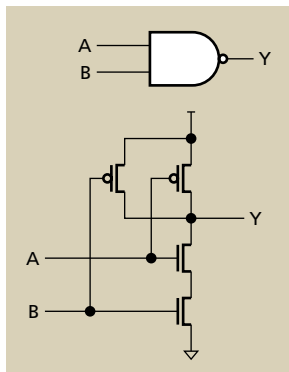
The CMOS Inverter



When the input is near ground ("0"), the p-FET is turned on, connecting the output to the power supply ("1"); the n-FET is turned off.

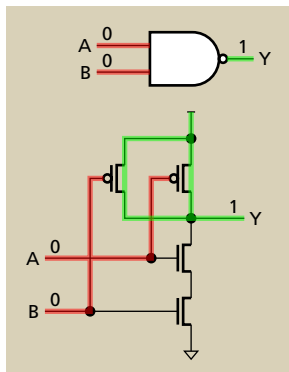
p-FETs are only good at passing 1's

The CMOS NAND Gate



Two-input NAND gate:
two n-FETs in series;
two p-FETs in parallel

The CMOS NAND Gate

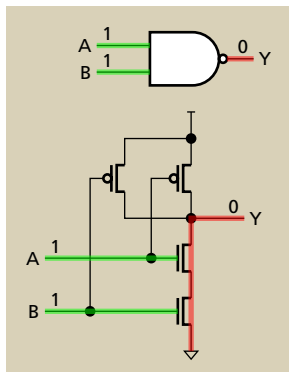


Both inputs 0:

Both p-FETs turned on

Output pulled high

The CMOS NAND Gate



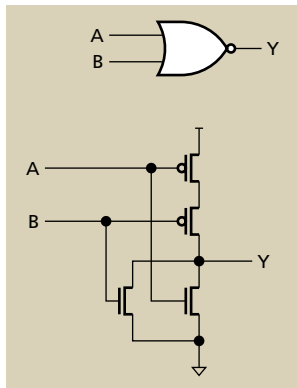
Both inputs 1:

Both n-FETs turned on

Output pulled low

Both p-FETs turned off

The CMOS NOR Gate



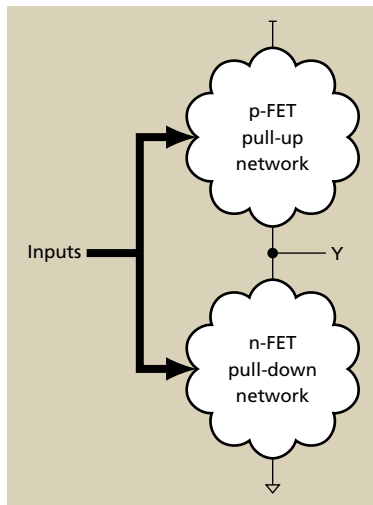
Two-input NOR gate:

two n-FETs in parallel;

two p-FETs in series.

Not as fast as the NAND gate
because n-FETs are faster than
p-FETs

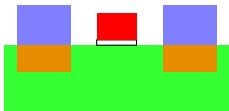
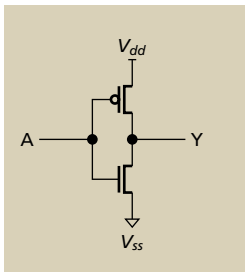
Static CMOS Gate Structure



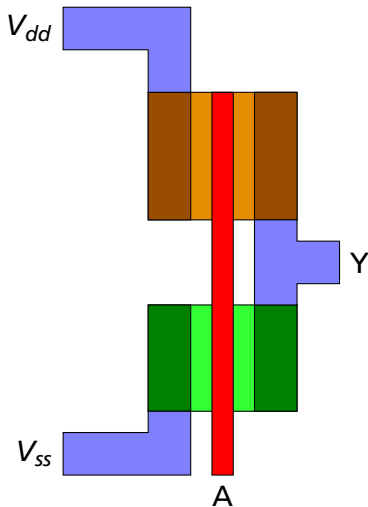
Pull-up and Pull-down networks must be complementary; exactly one should be connected for each input combination.

Series connection in one should be parallel in the other

CMOS Inverter Layout



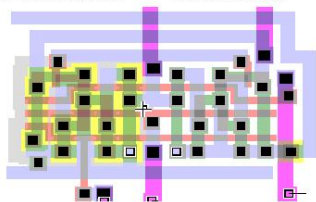
Cross Section Through
N-channel FET



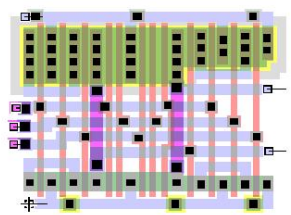
Top View

Full Adder Layouts

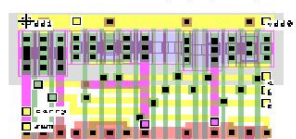
fa_ly_mini_jk size: 60 · 40 μ m (1.2 μ mCMOS)



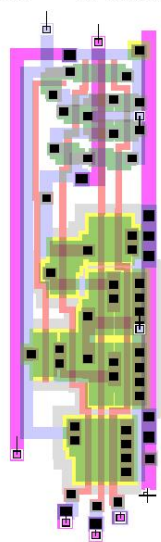
fa_ly_opt1 size: 63 · 50 μ m (1.2 μ mCMOS)



Fulladd.L size: 37 · 26 μ m (0.5 μ mCMOS)



fa_ly_itt size: 117 · 31 μ m (1.2 μ mCMOS)



From <http://book.huihoo.com/design-of-vlsi-systems/>

Intel 4004: The First Single-Chip Microprocessor

**Announcing
a new era
of integrated
electronics**



**A micro-
programmable
computer
on a chip!**

Intel introduces an integrated CMOS complete with a ROM for program memory, address and data registers, an accumulator and a single-chip random access memory. It's one of a family of four chips that comprise the MCS-4 micro-computer system - the first solution to bring you the power and flexibility of a dedicated general-purpose computer on one chip in as little as one drop of ink.

MCS-4 is a general-purpose computing and control solution for low-cost, high-reliability, utility, scientific, measuring systems, remote control systems and portable control systems.

The heart of any MCS-4 system is a Type 4004 CPU, which contains a complete set of 45 instructions, floating-point and stack Type 4001 ROM, an on-chip program and data memory plus a fully functioning program-programmed computer. To take you step with Type 4004, Intel has developed a ready-to-use Type 4000 system to expand the micro-chip.

Using its complete other Type 4000 chip, the variety of your micro-computer is greatly expanded. With Intel ROM storage and on-chip program and data memory, you can now use a fully functioning program-programmed computer. To take you step with Type 4004, Intel has developed a ready-to-use Type 4000 system to expand the micro-chip.

MCS-4 systems interface easily with switches, keyboards, displays, teleprinters, printers, modems, A/D converters and other popular peripherals.

The MCS-4 family is now in stock at Intel's Santa Clara headquarters and at our regional headquarters in Europe and Japan. In the U.S., call your nearest Intel representative for technical information and literature. In Europe, contact Intel at Avenue Louise 214, B-1050 Brussels, Belgium. Phone 32(2)22 455 4131. In Japan, contact Intel Japan, Ltd., Parkside Plaza Bldg., 8th F., 2-2-1, Shinjuku-ku, Shinjuku-Ku, Tokyo 102. Phone 81(3) 433-4131.

Intel Corporation now produces micro-computers, microprocessors and microperipherals at 3065 Avenida Arroyo, San Jose, Costa Rica. Phone 506(2) 226-1000.

**intel
delivers.**

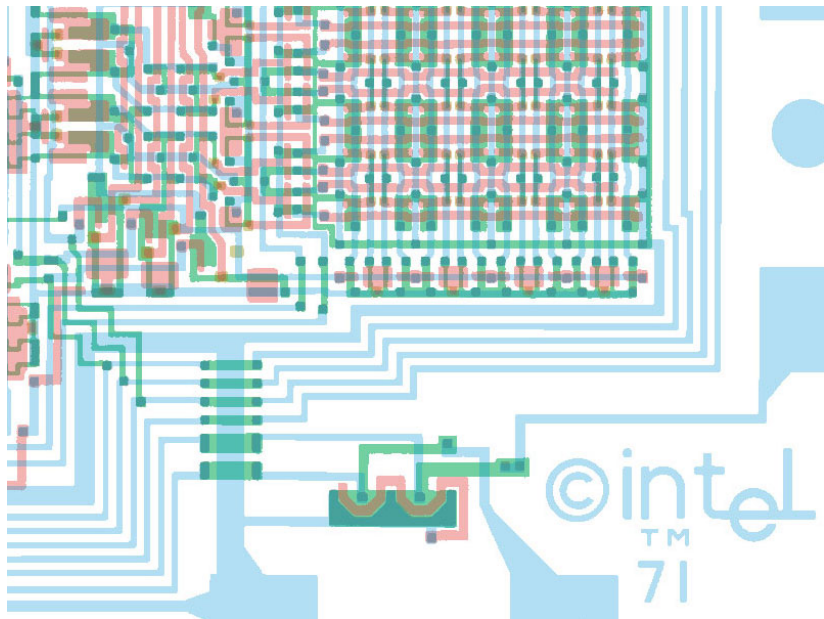
4001: 256-byte ROM + 4-bit IO port

4002: 40-byte RAM

4003: 10-bit shift register

4004: 740 kHz 4-bit CPU w/ 45 instructions (2300 transistors)

Intel 4004 Masks



Intel 4004 Die Photograph

