

Fundamentals of Computer Systems

Transistors, Gates, and ICs

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Semiconductor

sem·i·con·duc·tor

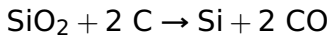
noun

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

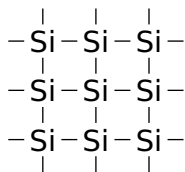


Elemental, amorphous silicon



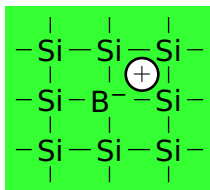
Monocrystalline
Silicon Ingot

Doping Silicon Makes It a Better Conductor

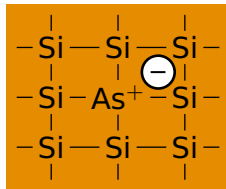


Undoped (pure)
silicon crystal

Not a good
conductor

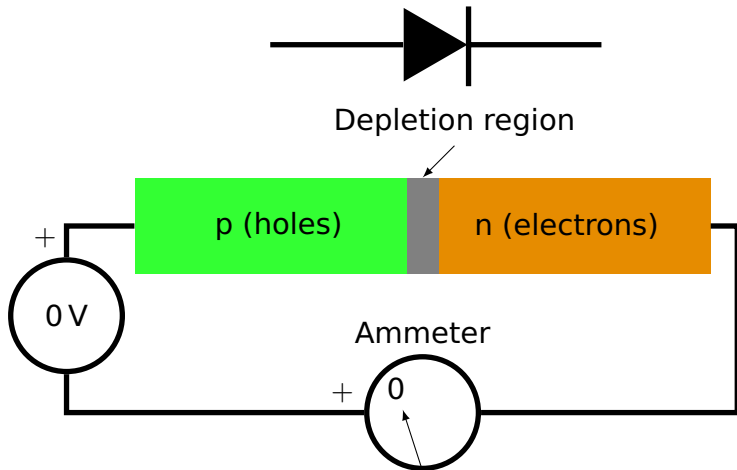


p-type (doped)
silicon
boron atom
steals a nearby
electron

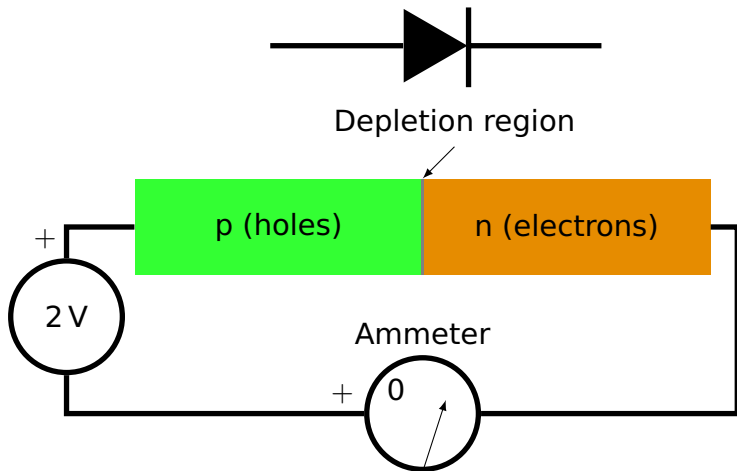


n-type (doped)
silicon:
extra electron on
arsenic atom
jump loose

A PN Junction aka A Diode

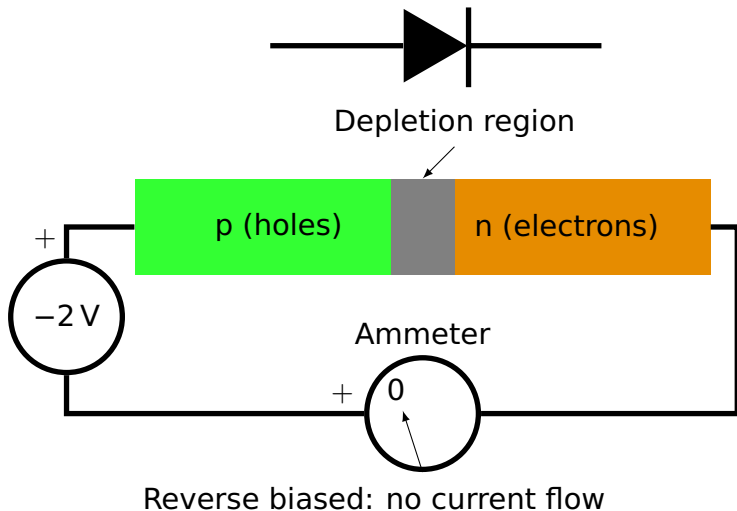


A PN Junction aka A Diode

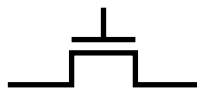


Forward biased: current flows

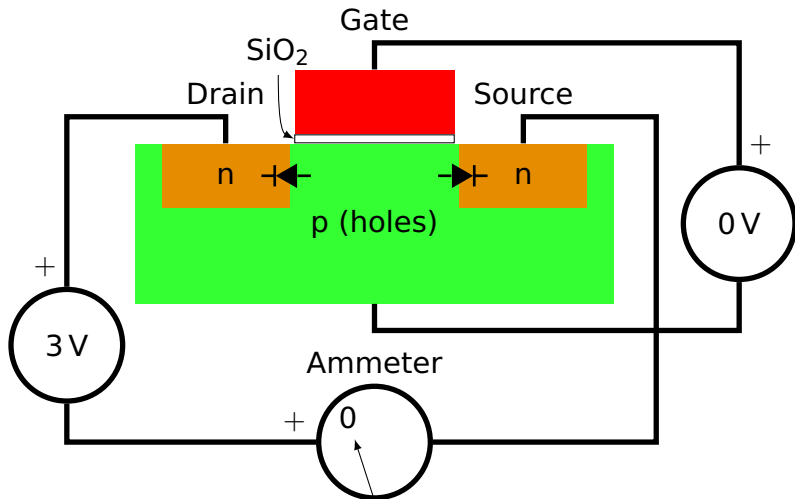
A PN Junction aka A Diode



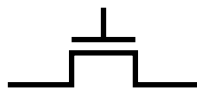
An N-Channel MOS Transistor



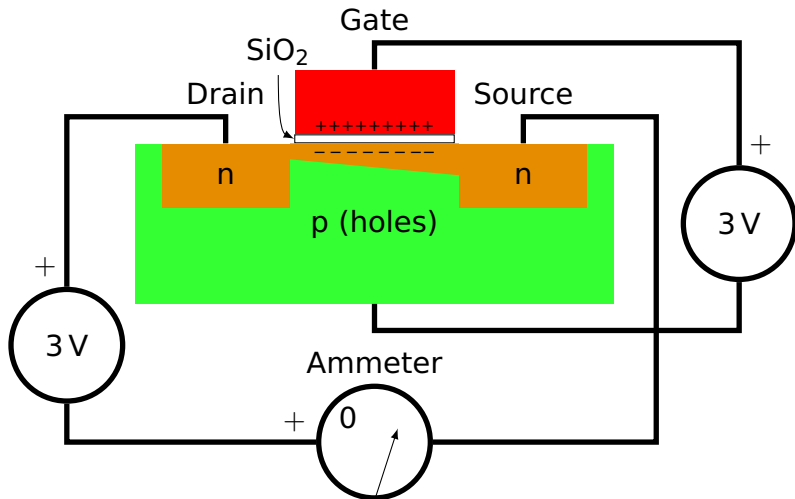
Gate at 0V: Off



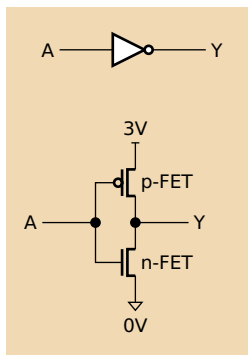
An N-Channel MOS Transistor



Gate positive: On



The CMOS Inverter

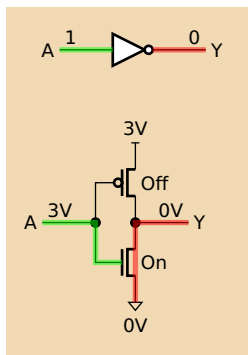


An inverter is built from two MOSFETs:

An n-FET connected to ground

A p-FET connected to the power supply

The CMOS Inverter



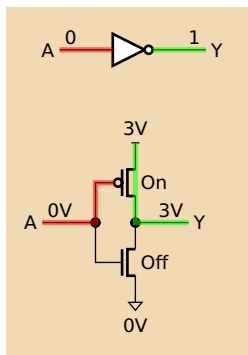
When the input is near the power supply voltage ("1"),

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

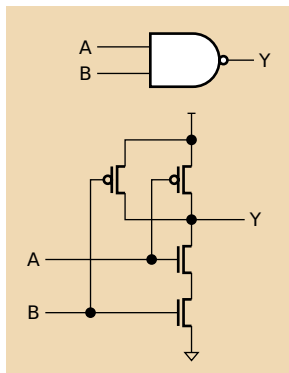
The CMOS Inverter



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.

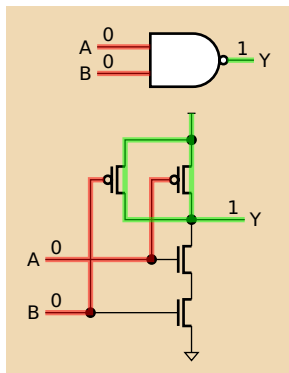
p-FETs are only good at passing 1’s

The CMOS NAND Gate



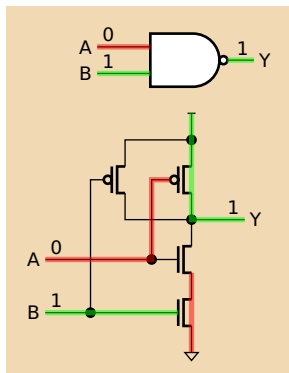
Two-input NAND gate:
two n-FETs in series;
two p-FETs in parallel

The CMOS NAND Gate



Both inputs 0:
Both p-FETs turned on
Output pulled high

The CMOS NAND Gate



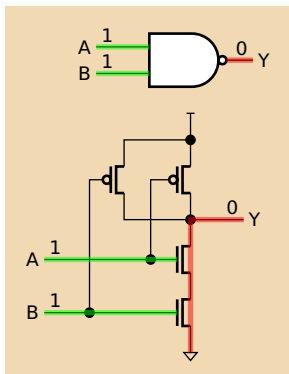
One input 1, the other 0:

One p-FET turned on

Output pulled high

One n-FET turned on, but does not control output

The CMOS NAND Gate



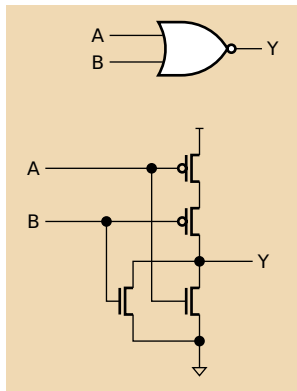
Both inputs 1:

Both n-FETs turned on

Output pulled low

Both p-FETs turned off

The CMOS NOR Gate



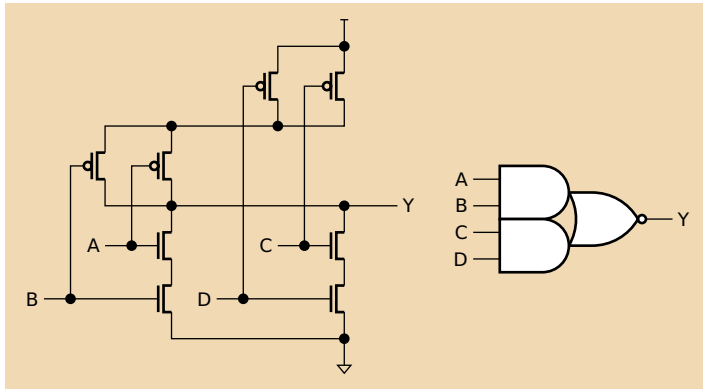
Two-input NOR gate:

two n-FETs in parallel;

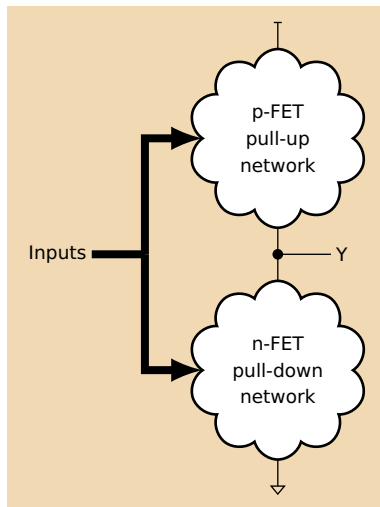
two p-FETs in series.

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

A CMOS AND-OR-INVERT Gate



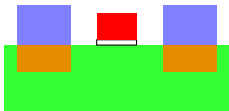
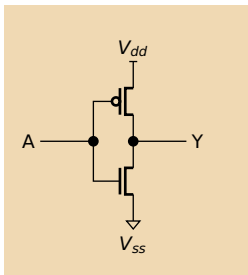
Static CMOS Gate Structure



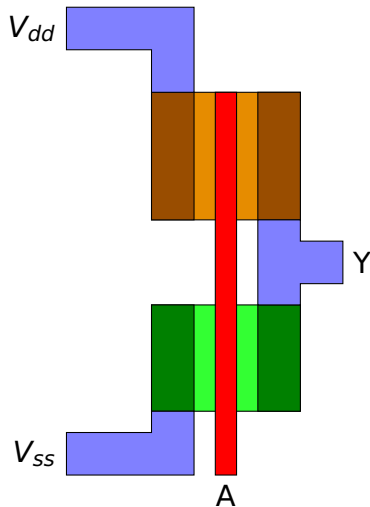
Pull-up and Pull-down networks must be complementary; exactly one should be connected for each input combination.

Series connection in one should be parallel in the other

CMOS Inverter Layout



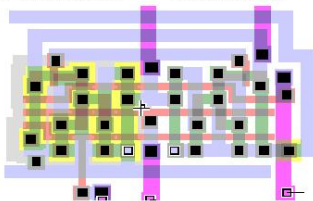
Cross Section Through
N-channel FET



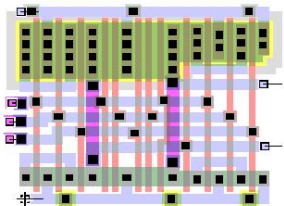
Top View

Full Adder Layouts

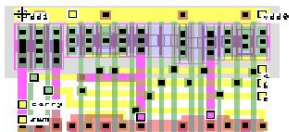
fa_ly_mini_jk size: 60 · 40 μ m (1.2 μ mCMOS)



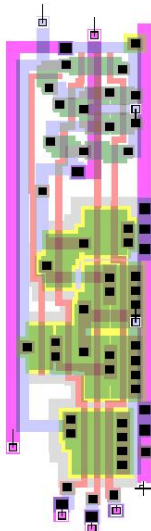
fa_ly_opt1 size: 63 · 50 μ m (1.2 μ mCMOS)



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 circuit complete with a ROM for user-written software and a 4-bit register, an accumulator and a stack pointer capable of one step. It's one of a family of four chips that comprise the MCS-4 micro-computer system - the final solution to bring you the power your facilities or your budget demand general-purpose computers can use today in an area as broad as the space in the microchip.

MCS-4 software provides complete computing and control functions for user operations, data handling, utility functions, measuring systems, control control systems and program control systems.

The heart of any MCS-4 system is a Type 4004 CPU, which contains a complete set of 45 instructions, floating point or stack Type 4001 ROM, the program storage and data buffer plus a built-in hardware program-programmer. To take you step with Type 4004, Intel has built-in memory and Type 4002 registers to expand the output code.

Using its flexible output pins, the 4004 family of chips, also can be used in systems with ROM, RAM, Type 4001 storage and/or 4002 on-chip storage. When you require rapid bit-stream or need only a few gates, Intel's versatile on-chip programmable ROM, Type 4003, may be substituted for the Type 4001 micro-programmed ROM.

MCS-4 systems interface easily with terminals, keyboards, displays, video cameras, 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 local Intel representative for technical information and literature. In Europe, contact Intel at Avenue Louise 214, B-1050 Brussels, Belgium. Phone 02/539-4151. In Japan, contact Intel Japan, Ltd., Parkside Plaza Bldg., 10-1-2, 3-chome, Shinjuku-ku, Tokyo 163. Phone 03-455-4151. Intel Corporation also produces micro-computers, microprocessors and peripheral systems at 3065 Atkinson Avenue, Santa Clara, CA 95051. Phone (408) 298-7000.

intel
delivers.

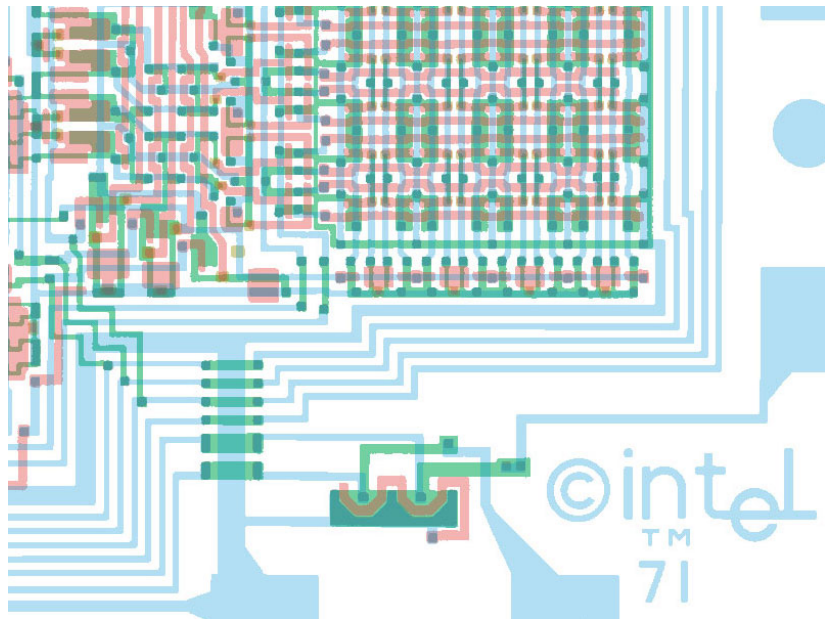
4001: 256-byte ROM + 4-bit IO port

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

