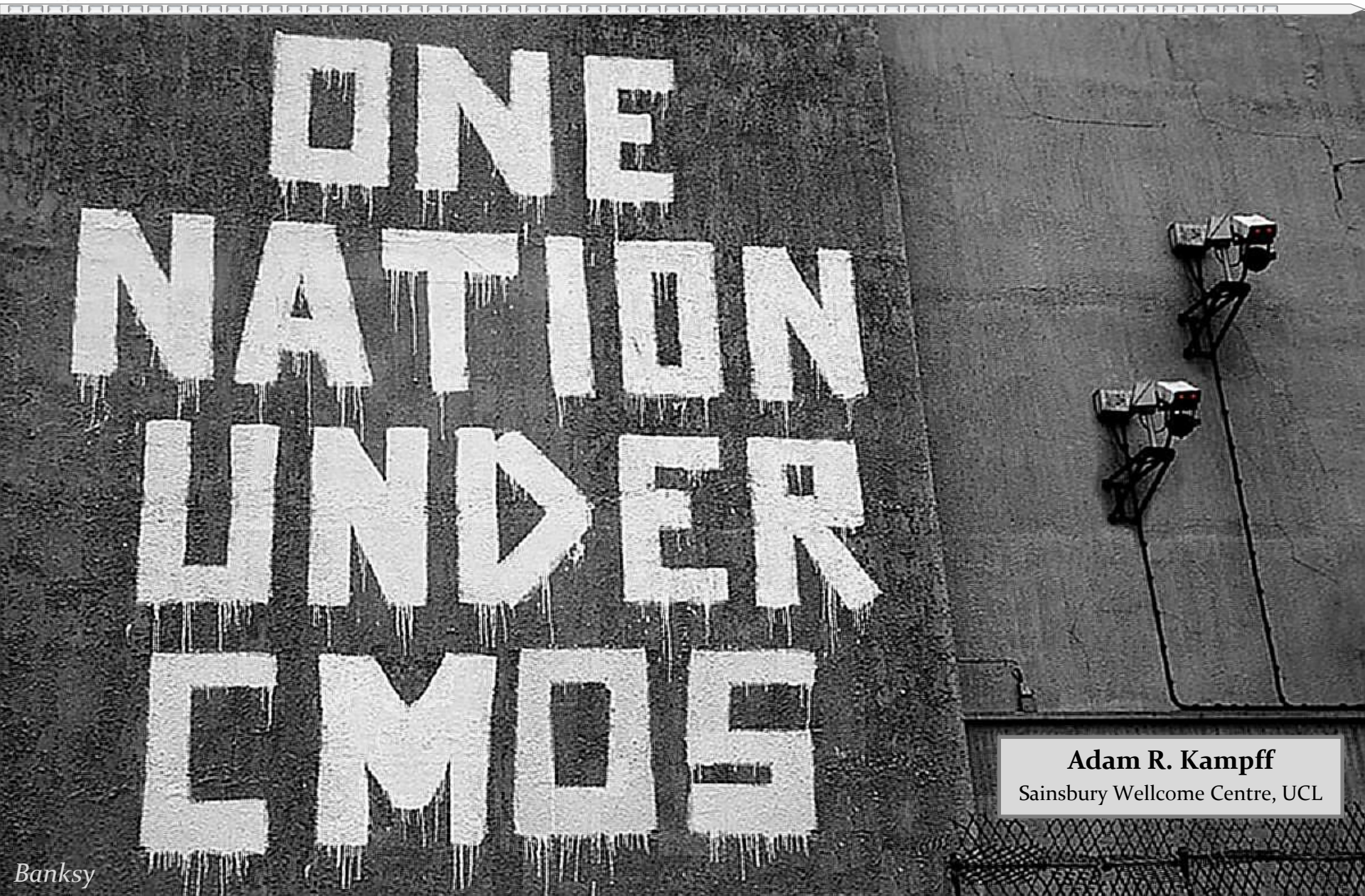




Transistors



Adam R. Kampff
Sainsbury Wellcome Centre, UCL



Linear Electronics

$$V = IR$$

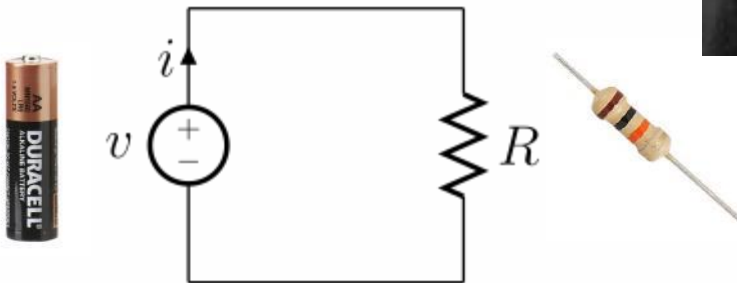
V - Voltage: Force pushing electrons
(Volts)

I - Current: Number of electrons/second
(Amps)

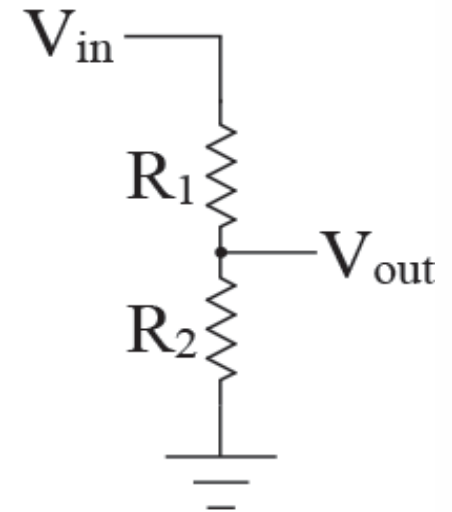
R - Resistance: Ease to electron flow
(Ohms)



Ohm



Voltage Divider



$$V_{out} = V_{in} * \frac{R2}{(R1 + R2)}$$



Semiconductor Devices

Periodic Table of the Elements																		
													18					
1 H Hydrogen 1.01																	2 He Helium 4.00	
3 Li Lithium 6.94	4 Be Beryllium 9.01												5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31												13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.63	33 As Arsenic 74.92	34 Se Selenium 78.97	35 Br Bromine 79.90	36 Kr Krypton 84.80	
37 Rb Rubidium 84.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.25	
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.84	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.09	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.2	83 Bi Bismuth 208.98	84 Po Polonium [208.98]	85 At Astatine 209.99	86 Rn Radon 222.02	
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [296]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown	

Whiteboard (P-type, N-type, PN Junction, Diode, Transistor)



MOSFETs

Devices

Metal-Oxide-Semiconductor

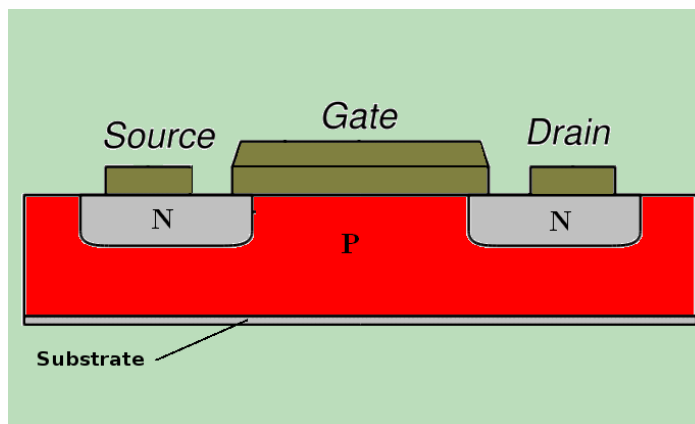
- *semiconductor device*
- *manufacturing process*

MOSFET (metal-oxide-semiconductor field effect transistor)

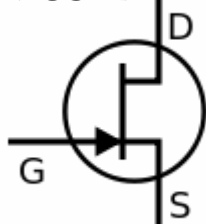


G D S

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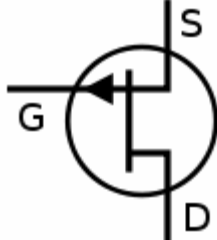


N-MOSFET



pos (+) Gate

P-MOSFET



neg (-) Gate

“NPN” MOSFET (*n*MOS)

- *Opens by creating a “N” channel through the “P” substrate, which requires a positive (+) gate voltage.*

- *The opposite is required for pMOS*



NMOS Logic

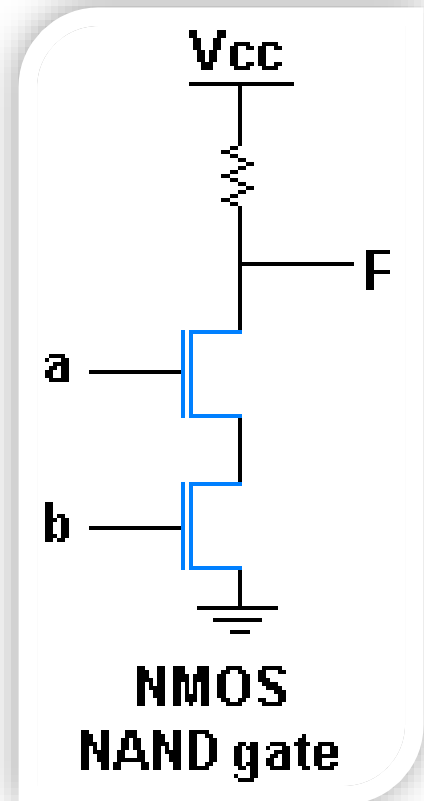
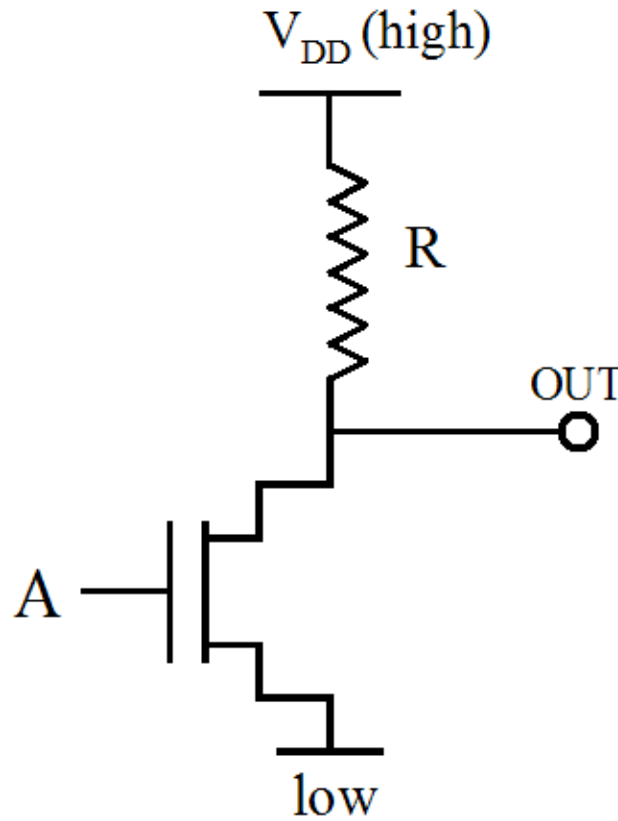
Devices

Metal-Oxide-Semiconductor

- semiconductor device
- manufacturing process

LOGIC

NMOS “NOT” Gate
(Inverter)





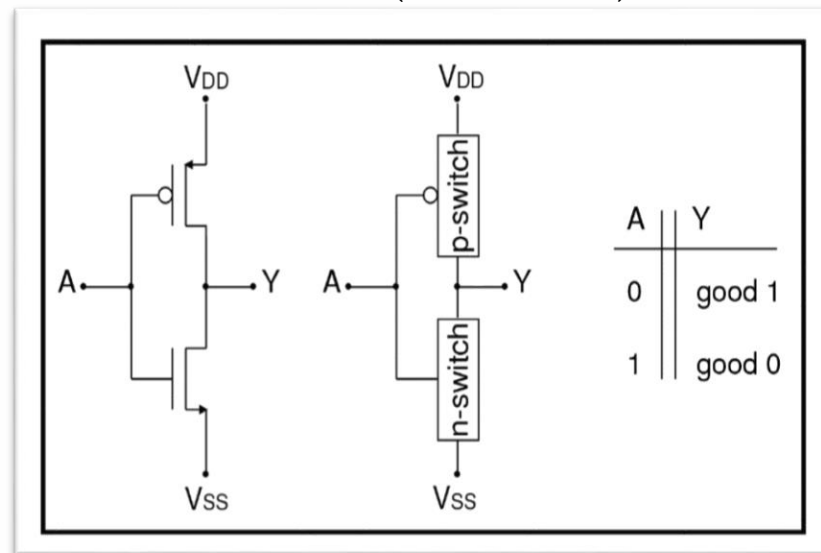
CMOS

Inverter

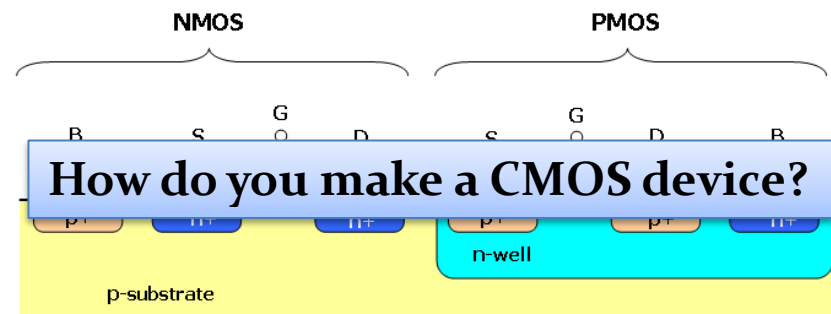
CMOS = **Complimentary** Metal-Oxide-Semiconductor

- *semiconductor device*
- *manufacturing process*

CMOS Inverter (NOT Gate)



**CMOS enabled
ultra Low Power
Electronics**





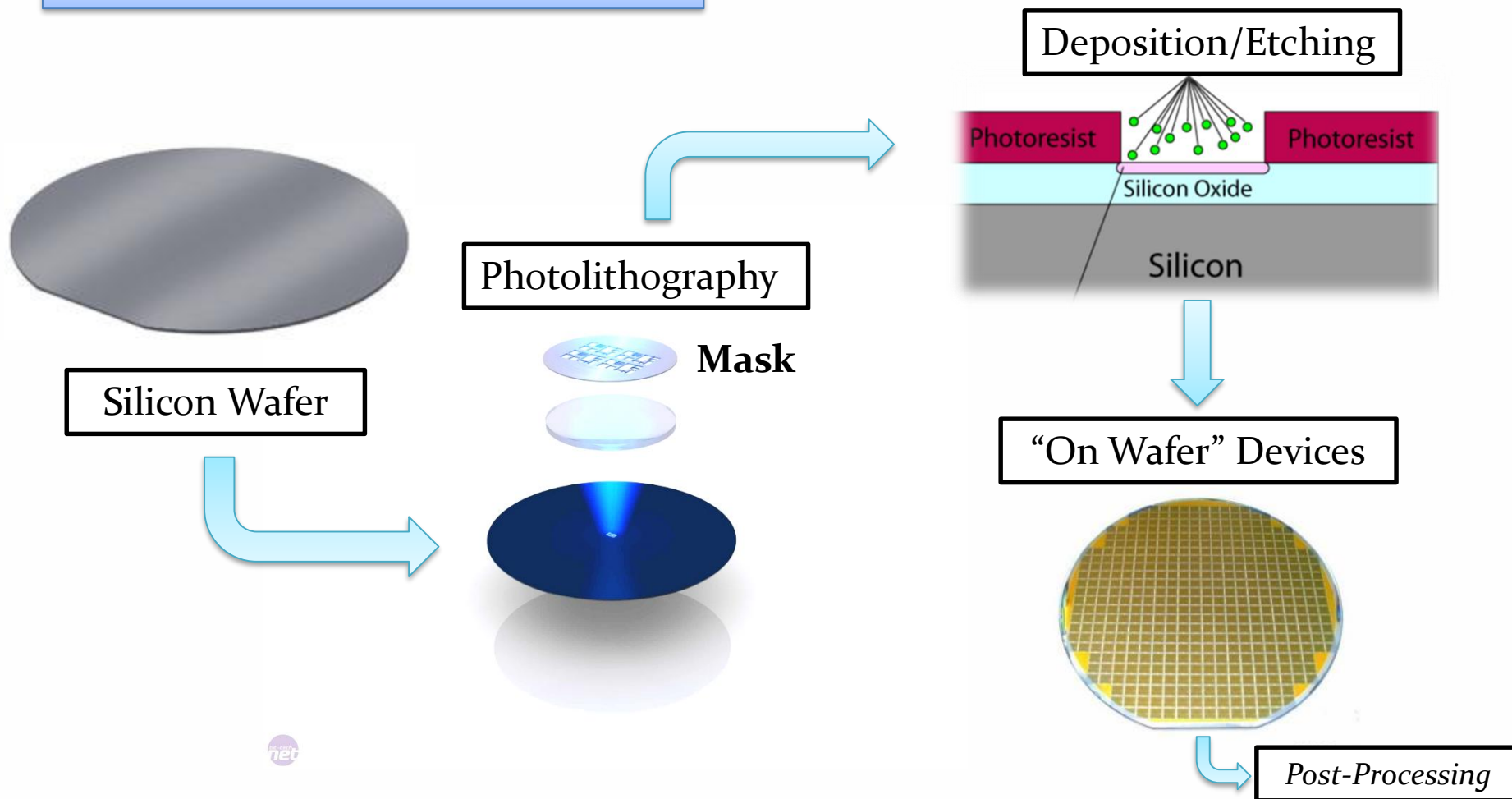
CMOS

Fabrication

CMOS = Complimentary Metal-Oxide-Semiconductor

- semiconductor device
- *manufacturing process*

How do you make a CMOS device?





CMOS

Fabrication

CMOS = Complimentary Metal-Oxide-Semiconductor

- semiconductor device
- *manufacturing process*

How do you make a CMOS device?



CMOS Fab (cleanroom)



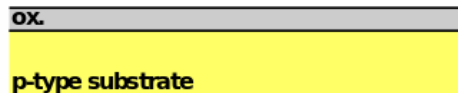
CMOS

Fabrication

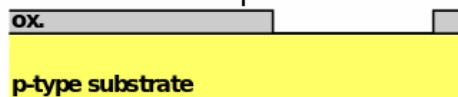
CMOS = Complimentary Metal-Oxide-Semiconductor

- semiconductor device
- *manufacturing process*

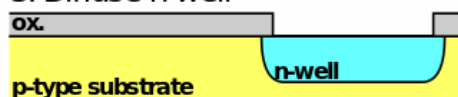
1. Grow field oxide



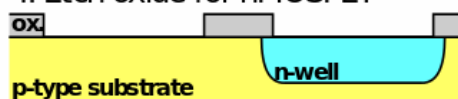
2. Etch oxide for pMOSFET



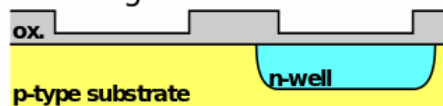
3. Diffuse n-well



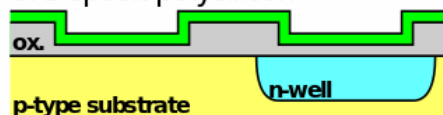
4. Etch oxide for nMOSFET



5. Grow gate oxide



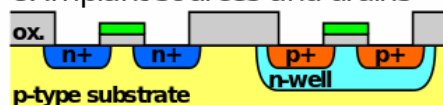
6. Deposit polysilicon



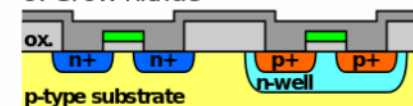
7. Etch polysilicon and oxide



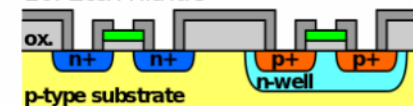
8. Implant sources and drains



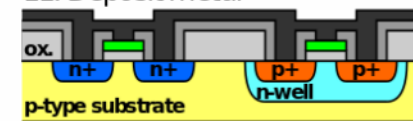
9. Grow nitride



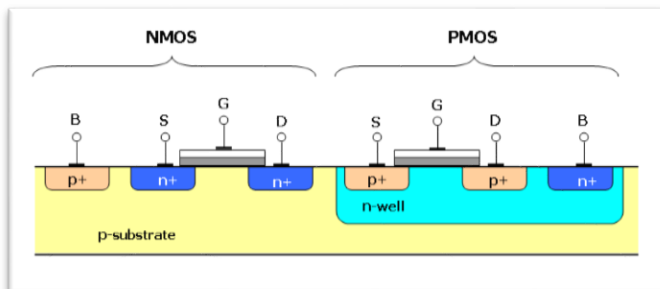
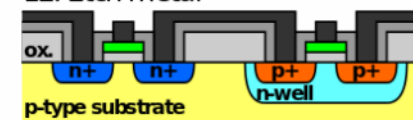
10. Etch nitride



11. Deposit metal



12. Etch metal



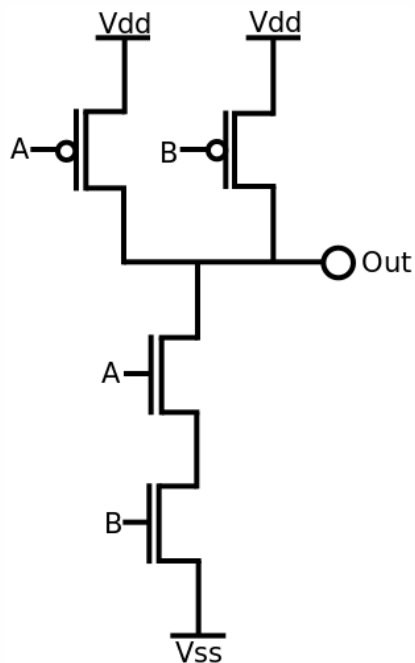


CMOS

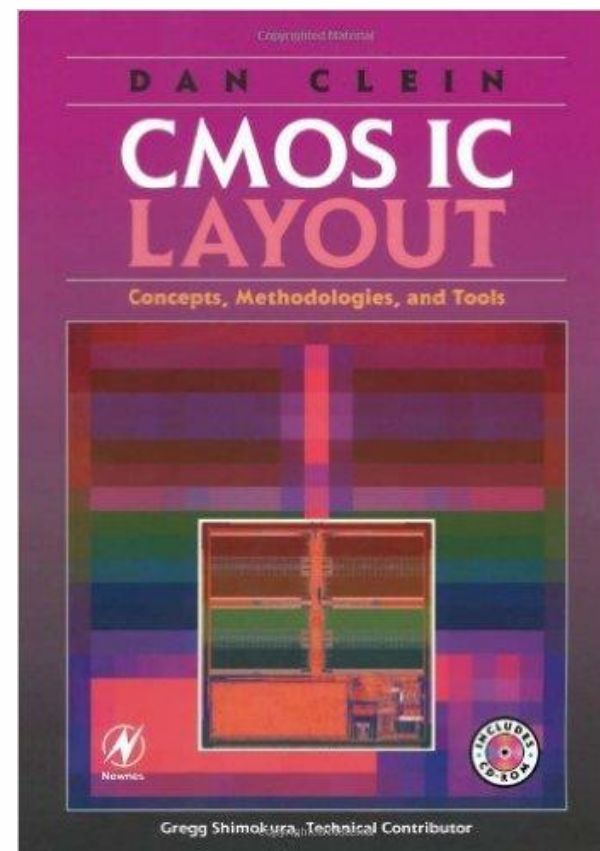
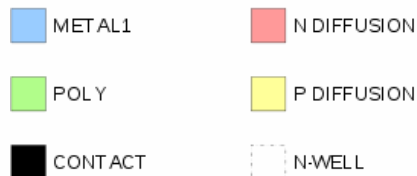
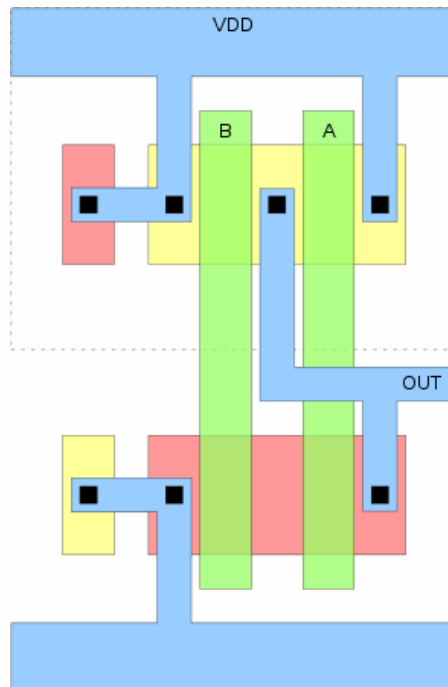
Layout

CMOS = Complimentary Metal-Oxide-Semiconductor

- semiconductor device
- *manufacturing process*

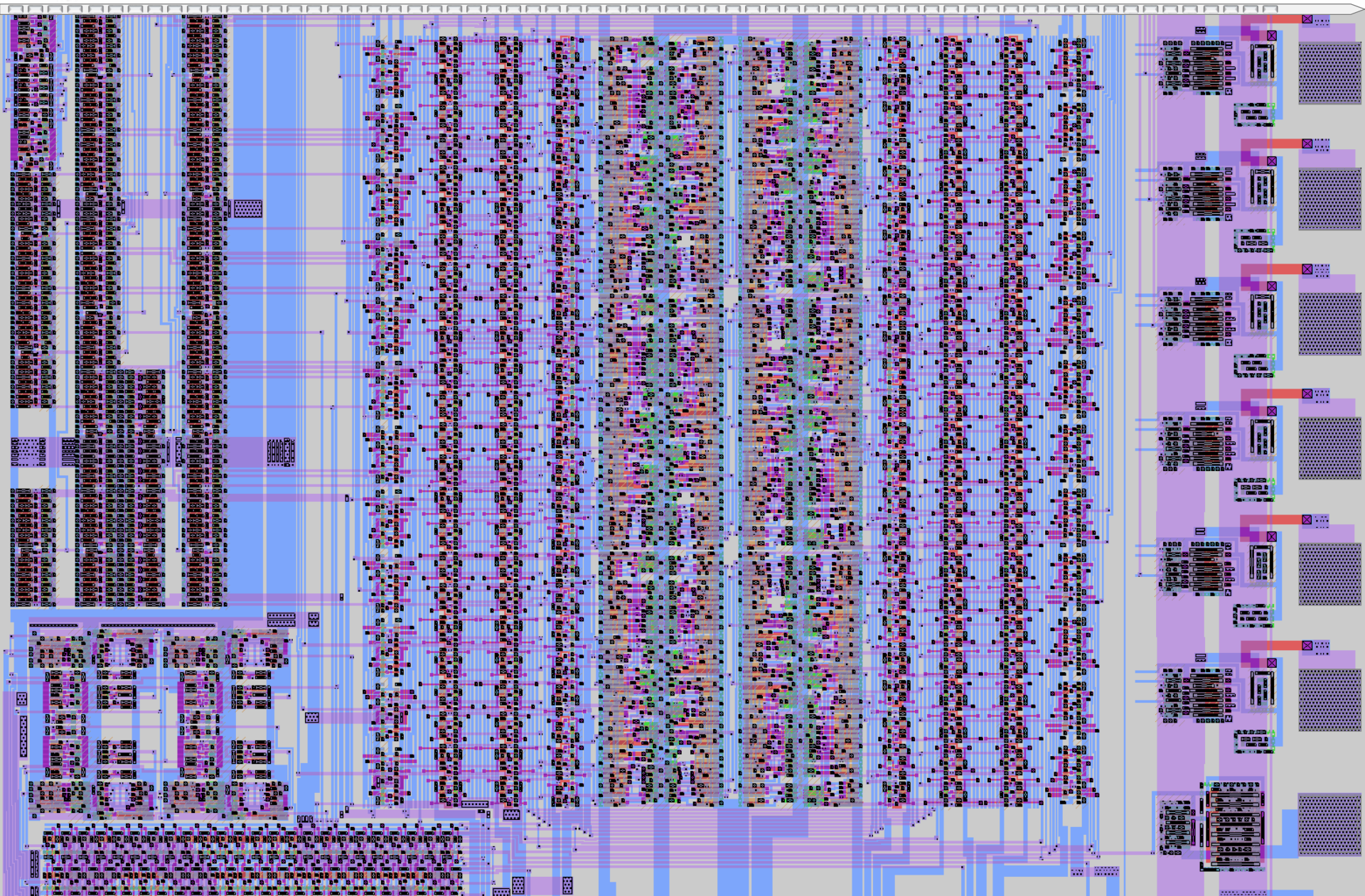


CMOS NAND Gate



CMOS

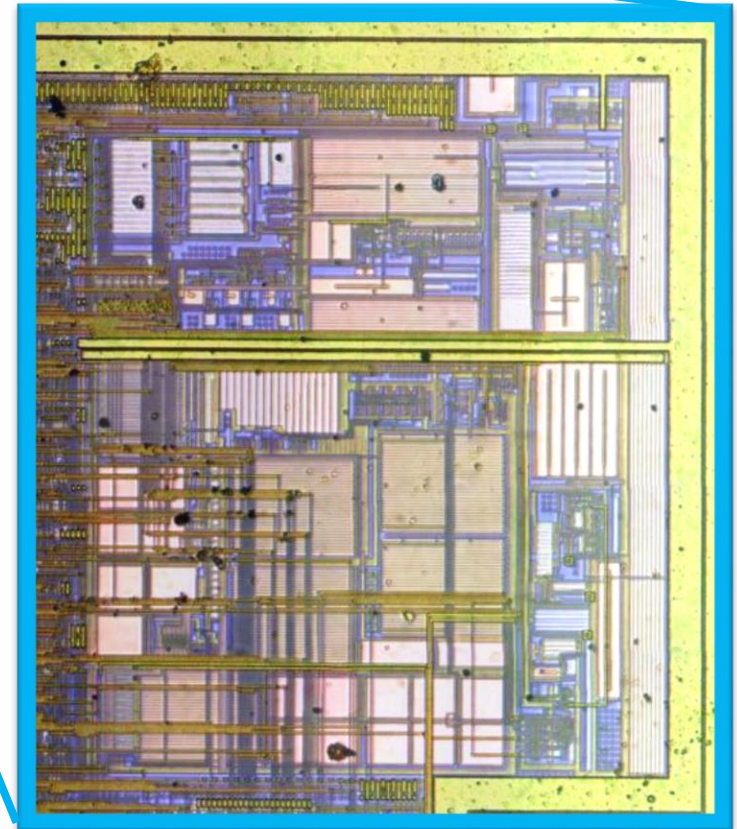
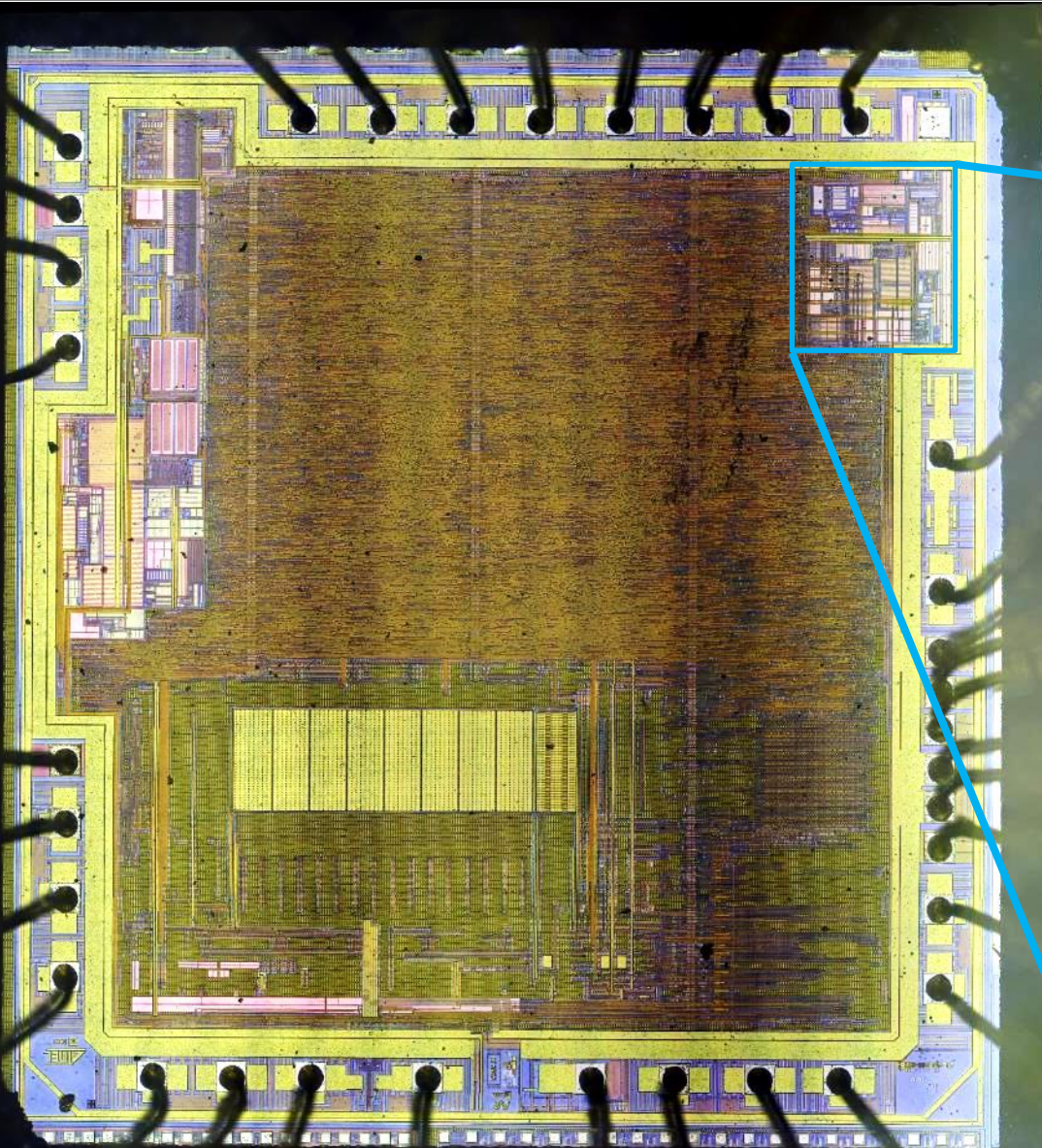
Gone wild!



CMOS

Gone wild!

Atmel Mega 328P



ALU (arithmetic/logic unit)