

A microscopic view of a silicon chip, showing a complex network of circuitry. The chip is primarily grey with intricate patterns of gold and purple lines. On the left side, there are several gold pads with purple wires attached. The text "Looking at silicon" is overlaid in the center. At the bottom, the text "Ken Shirriff" and "righto.com" are visible. In the bottom left corner, the text "MK6010" is printed on the chip. On the right side, there are labels "3a", "4", "6", "7", and "Vb".

Looking at silicon

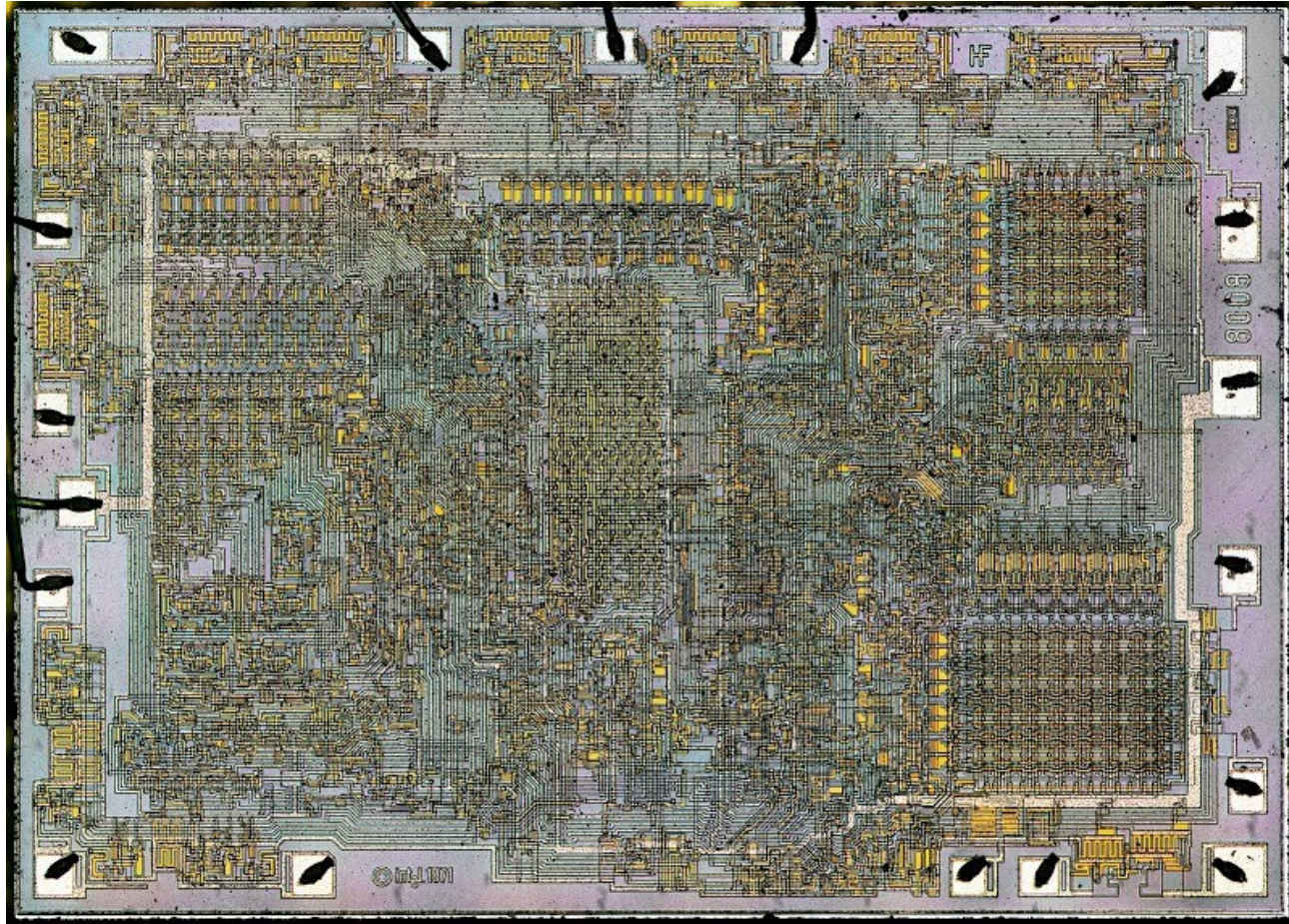
Ken Shirriff

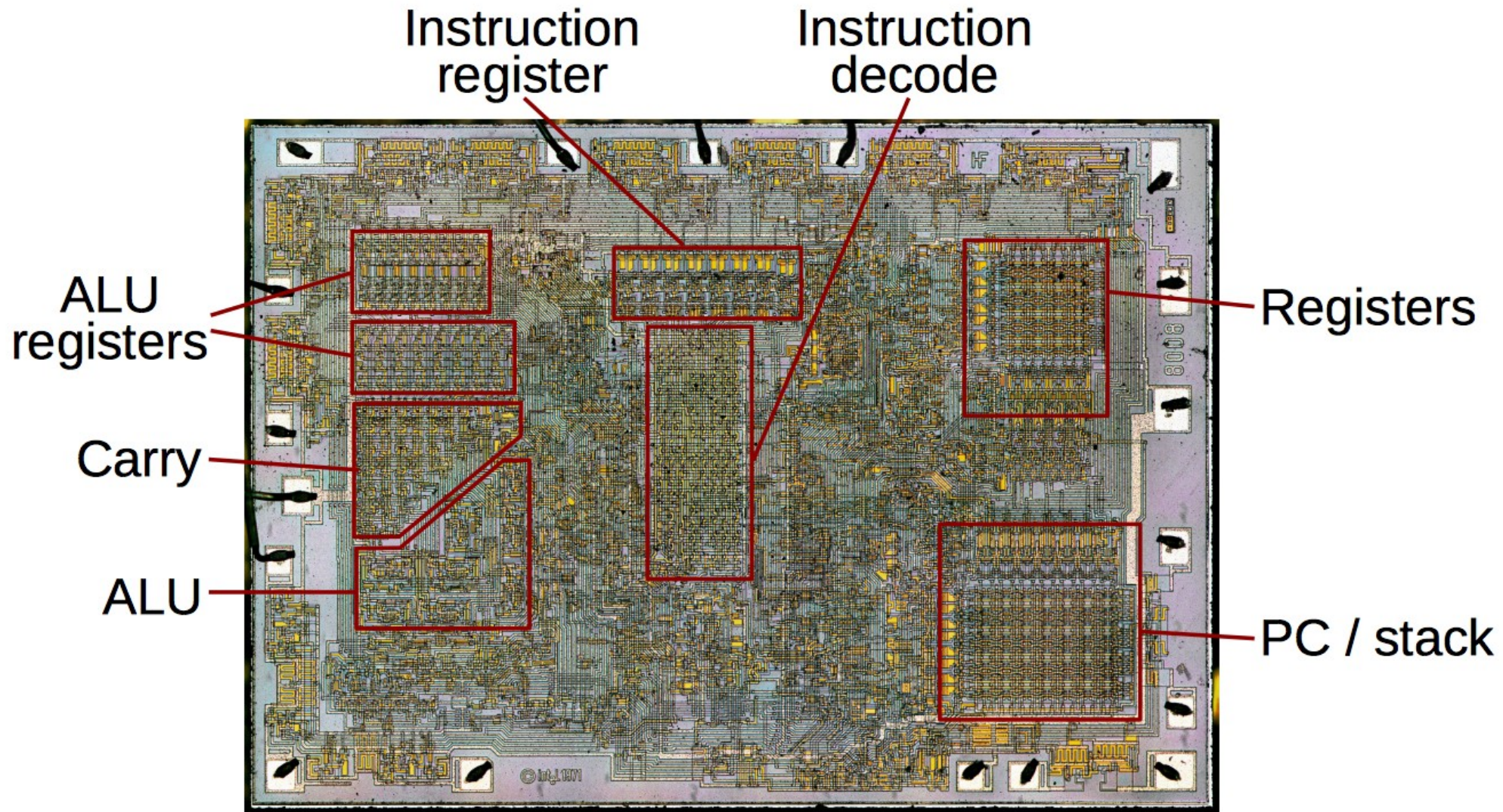
righto.com

MK6010

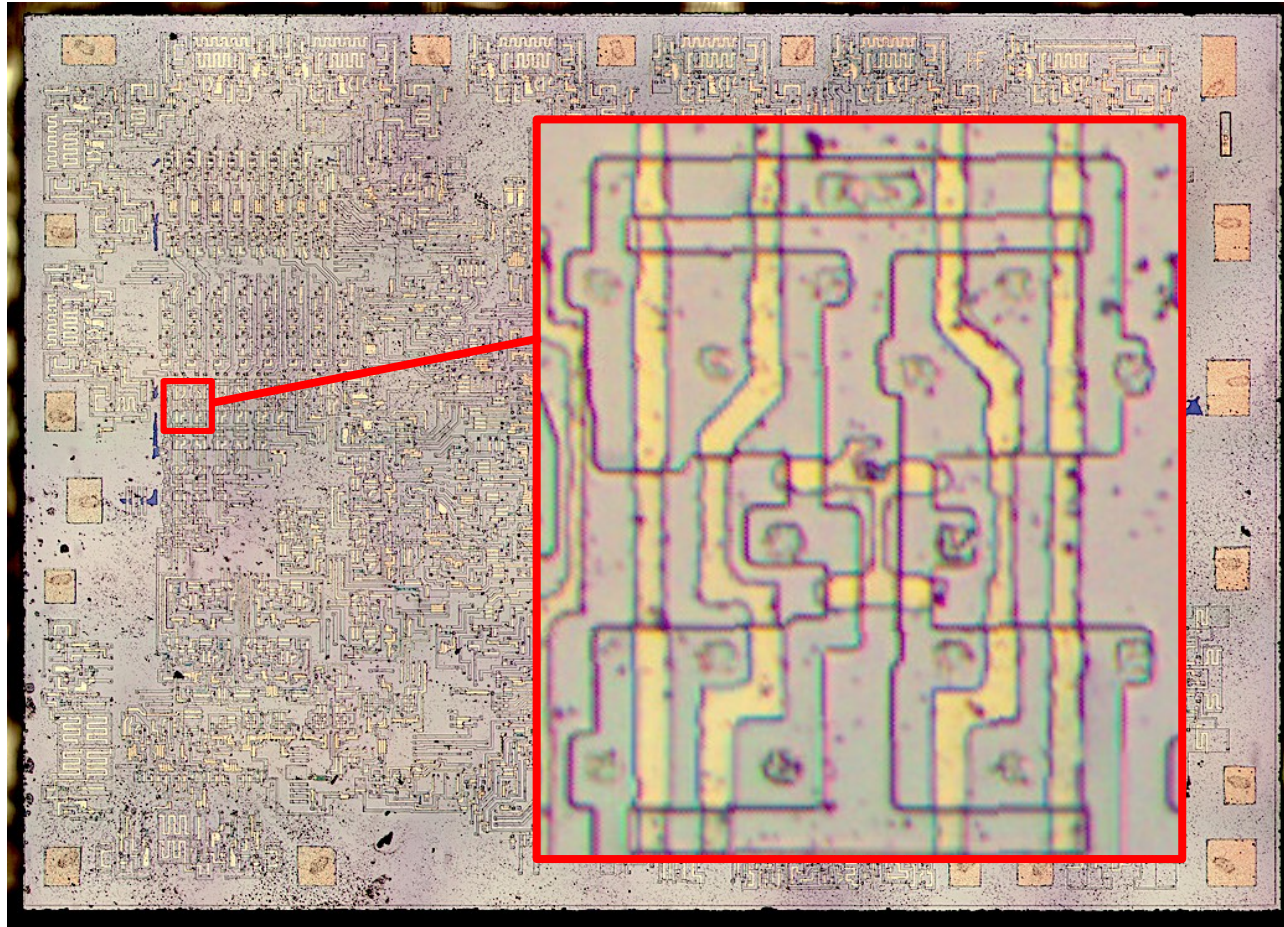
3a
4
6
7
Vb

Intel 8008 (1971)

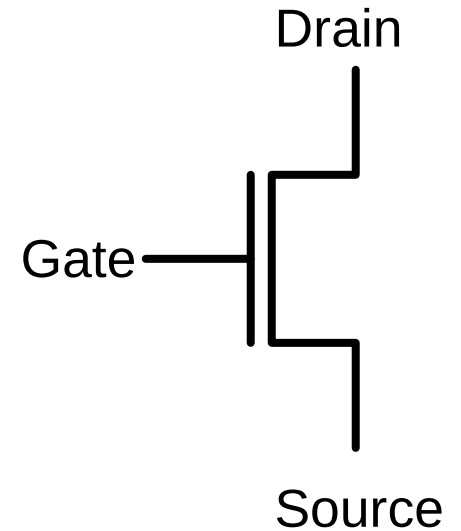
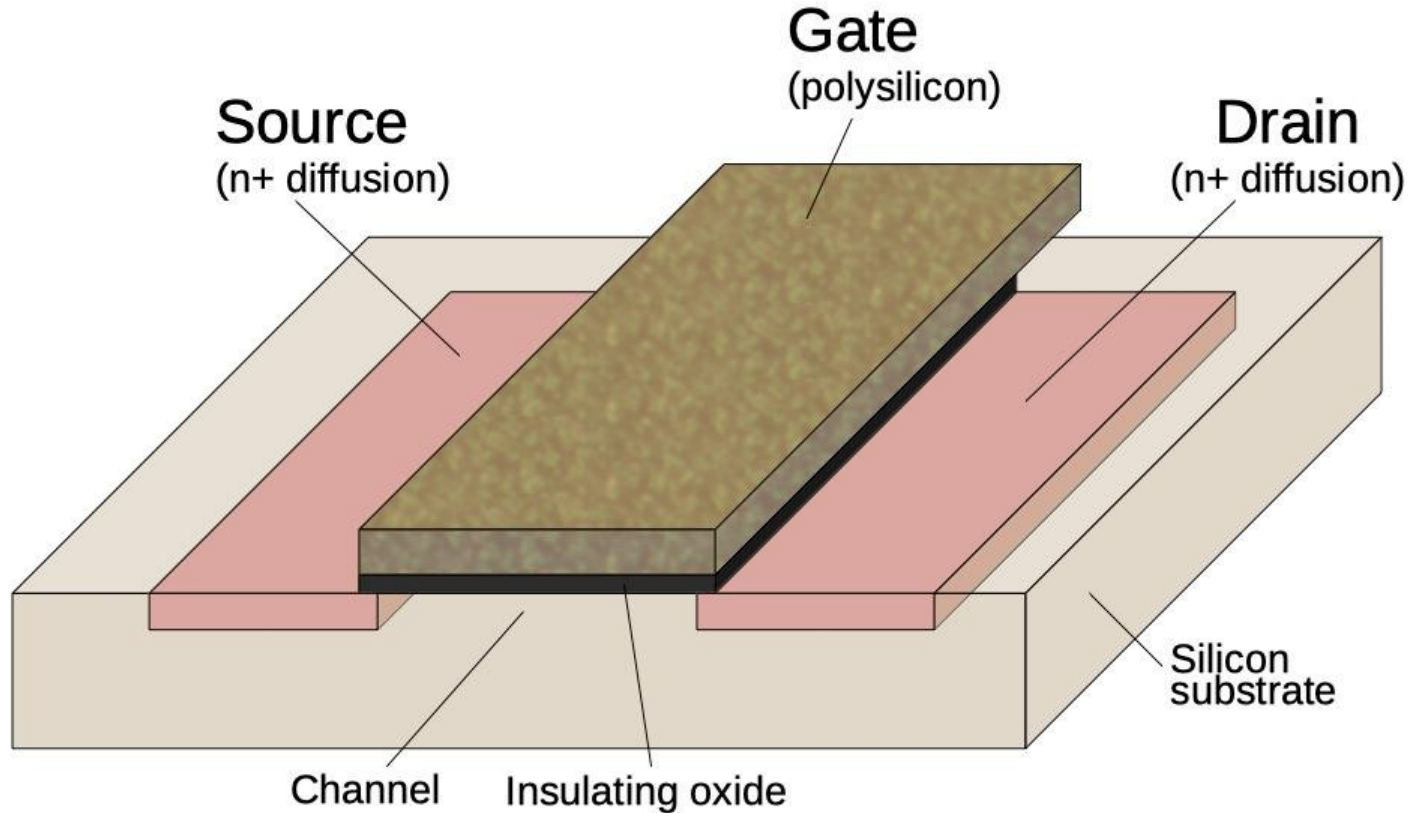




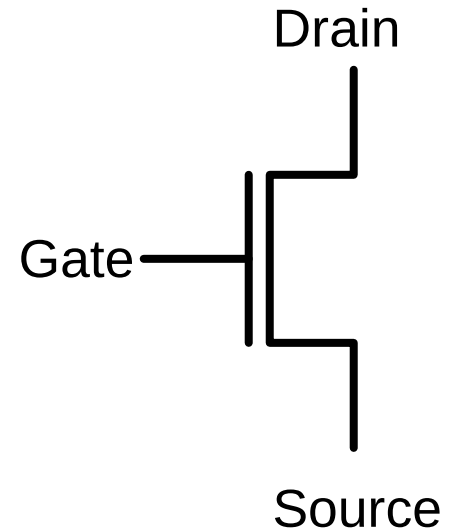
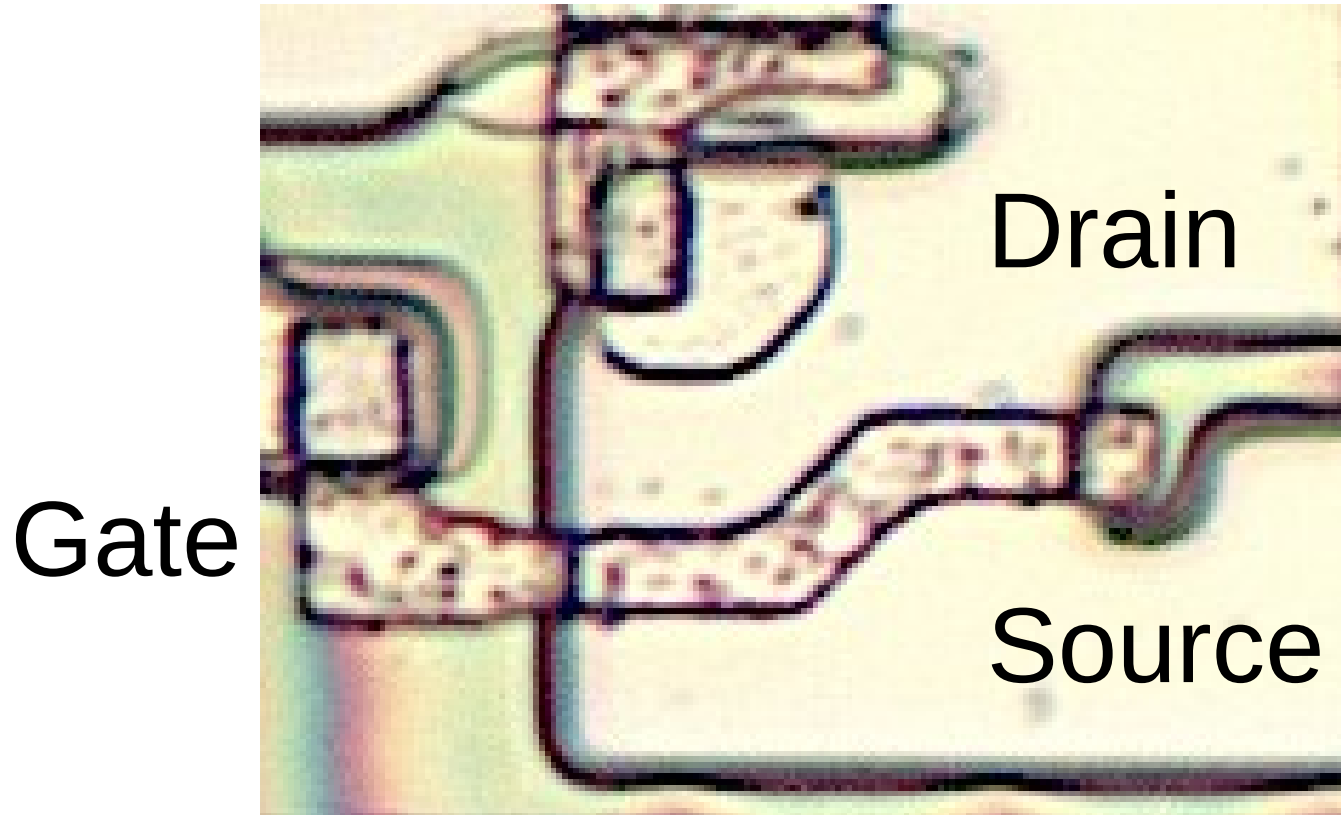
Silicon and polysilicon



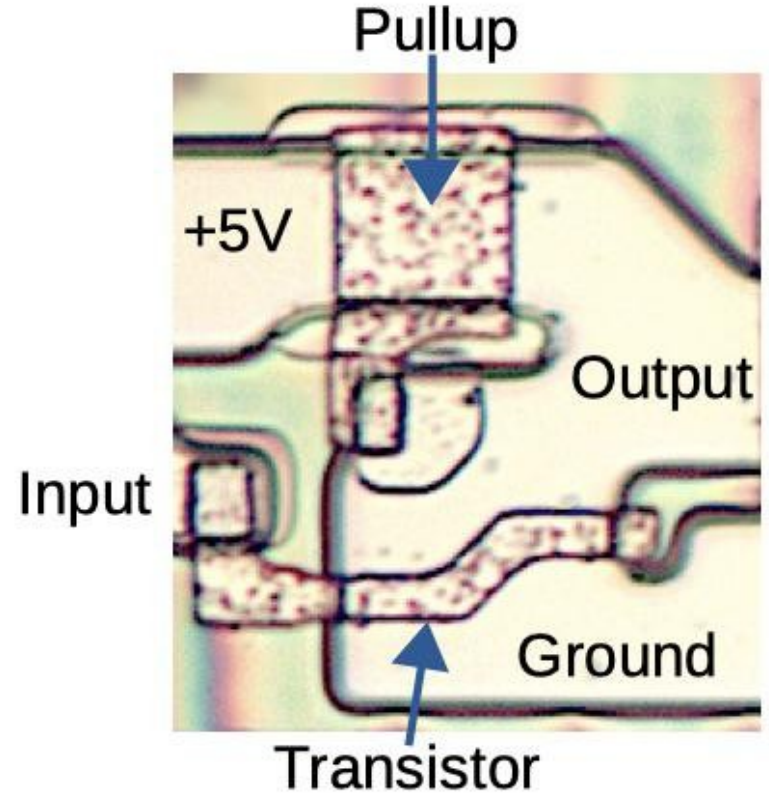
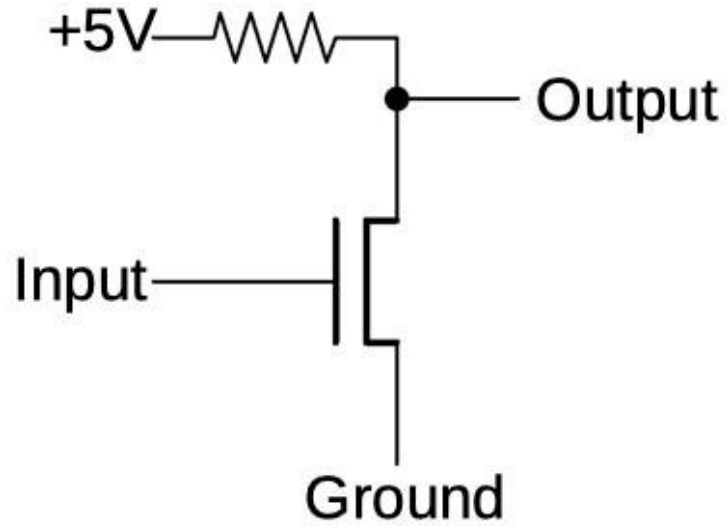
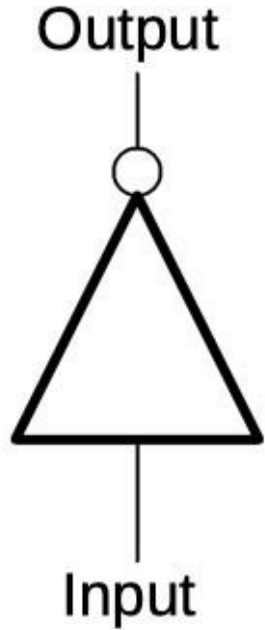
MOS transistor

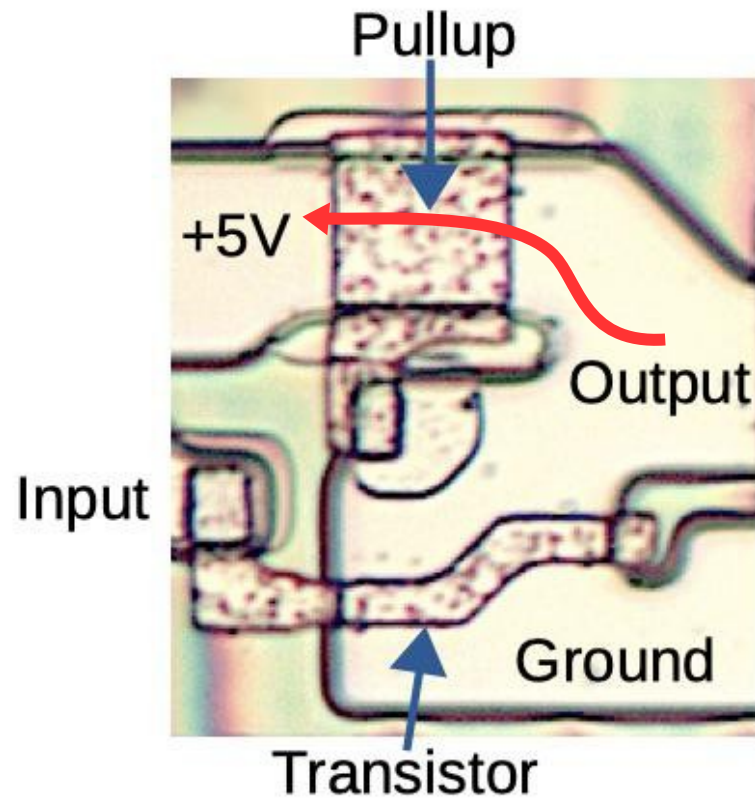
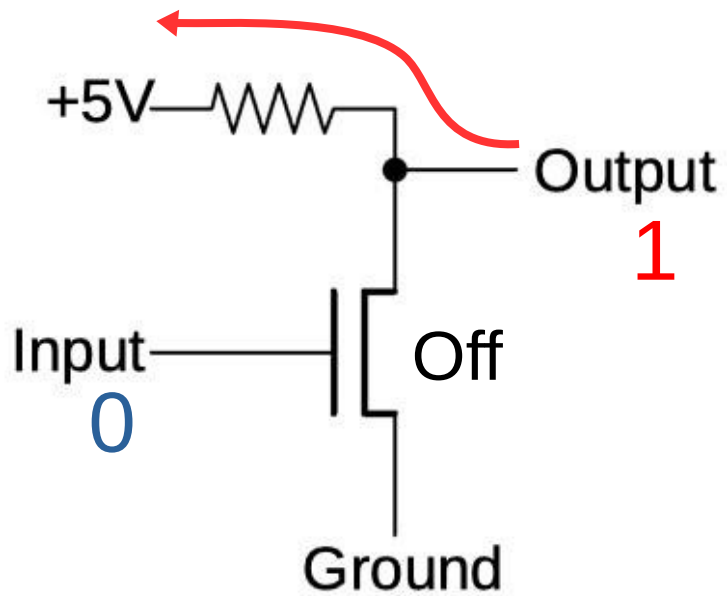
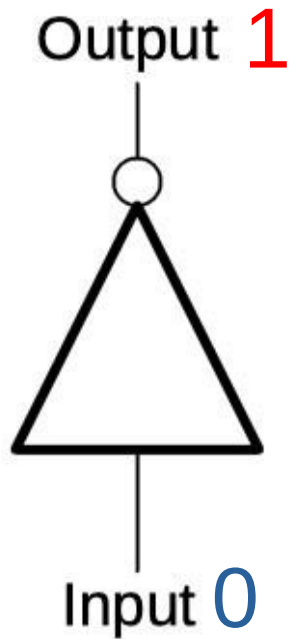


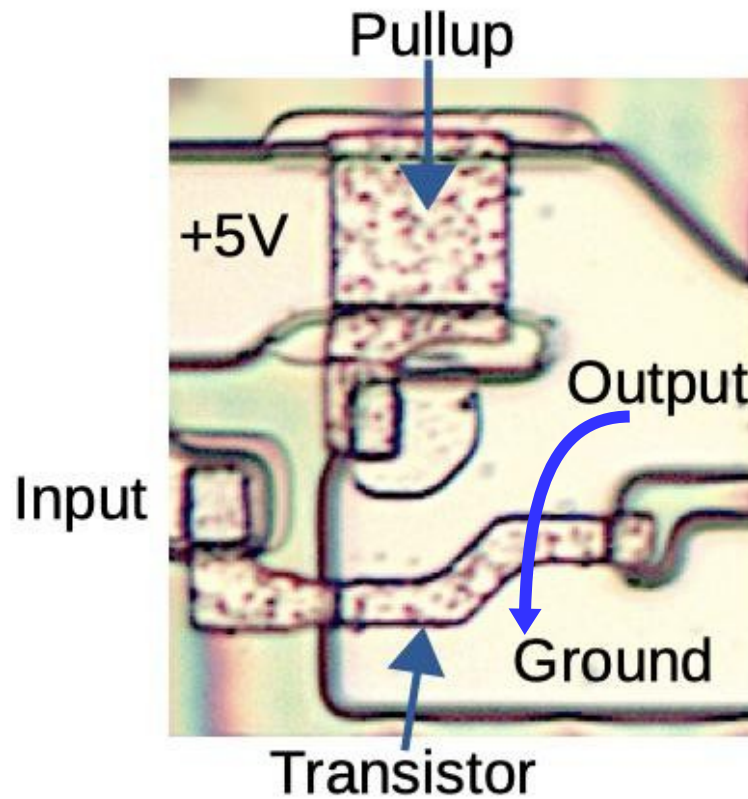
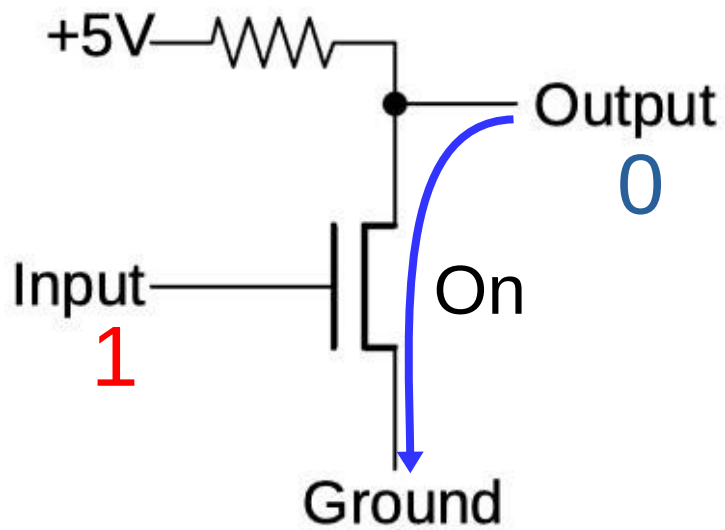
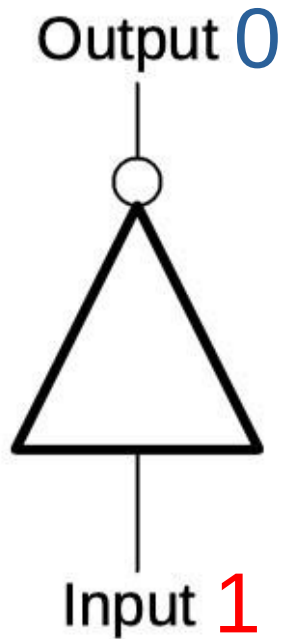
MOS transistor



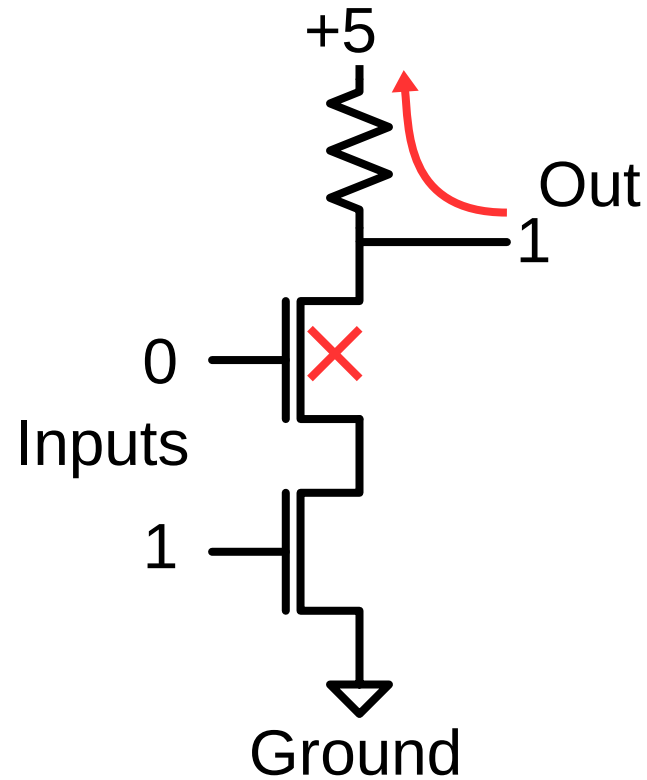
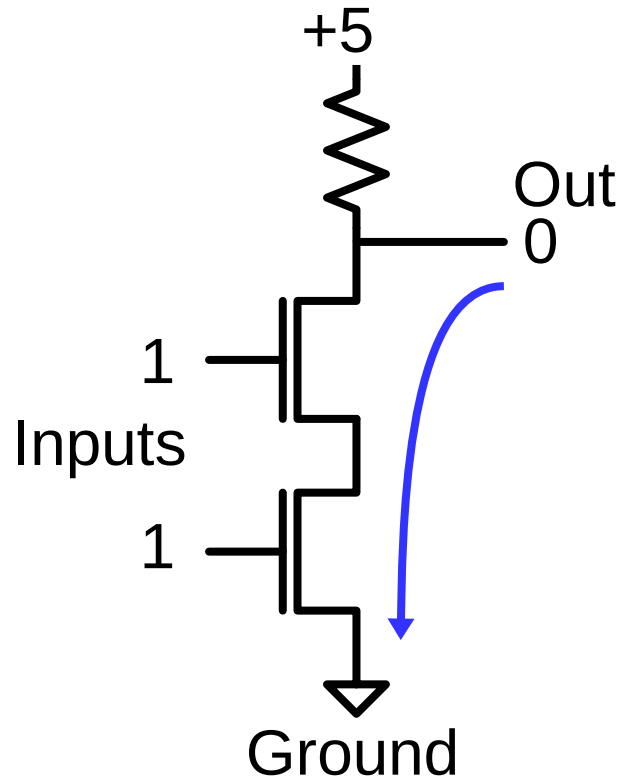
Inverter



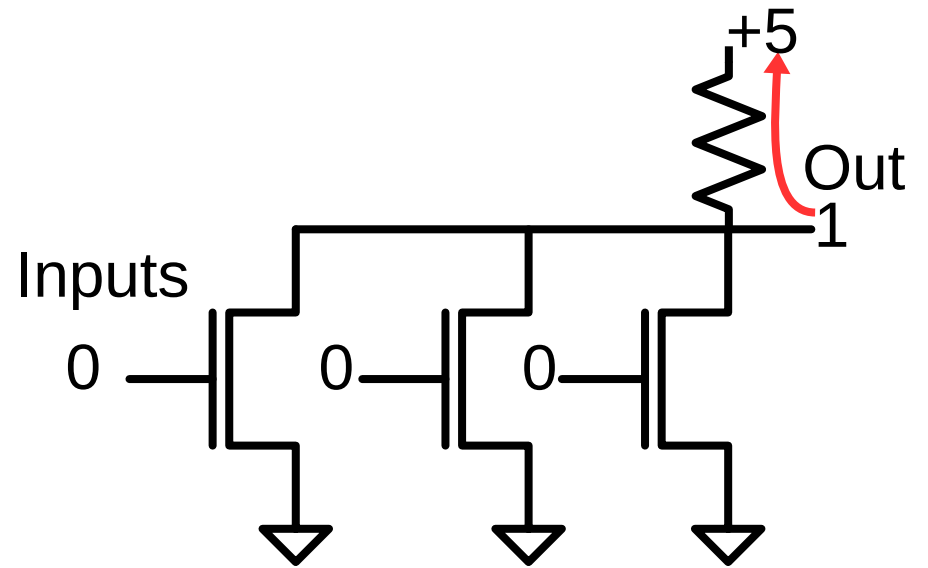
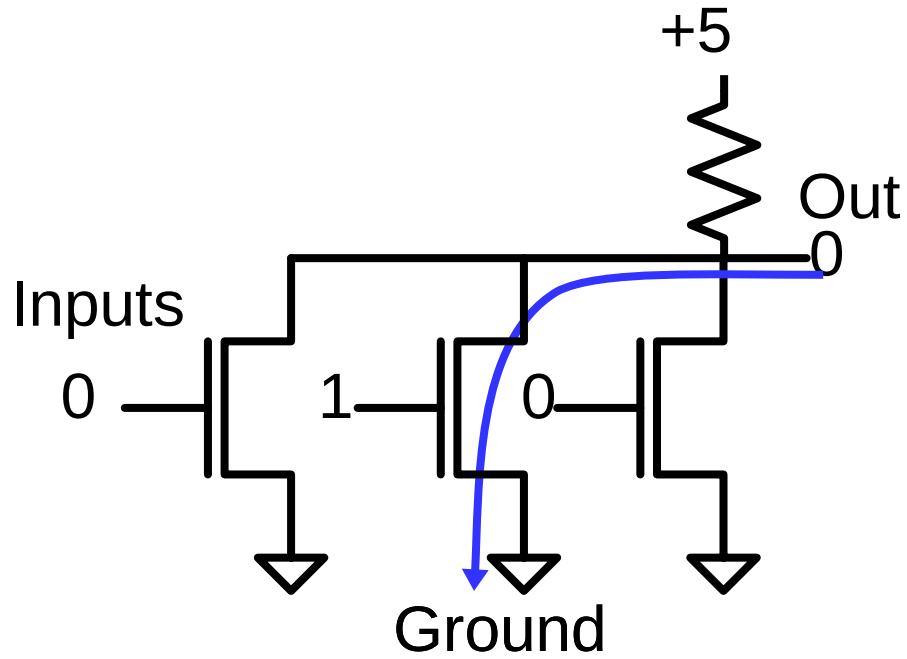




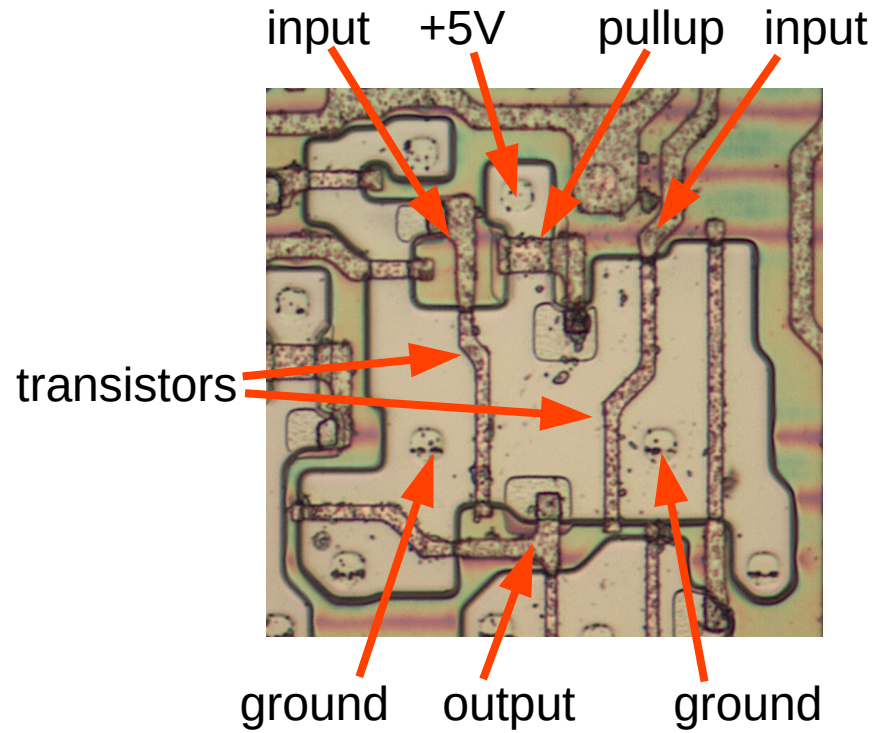
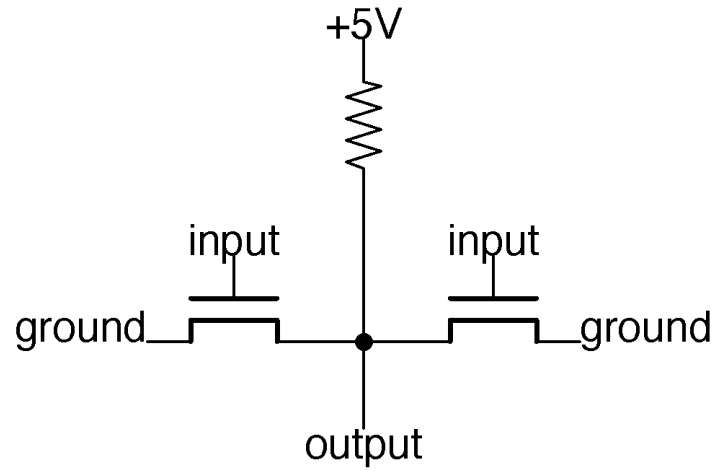
NAND gate

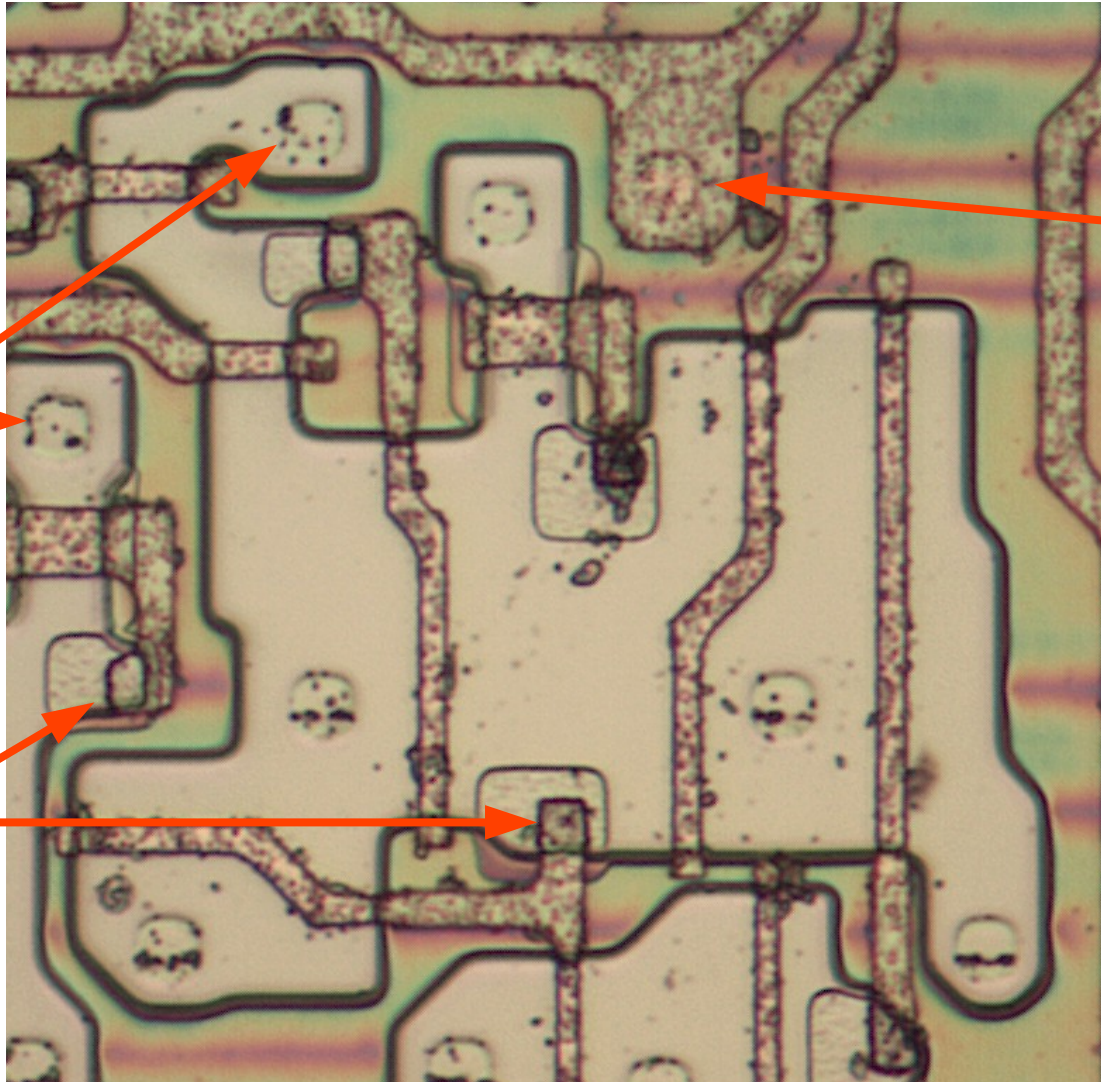


NOR gate



NOR gate

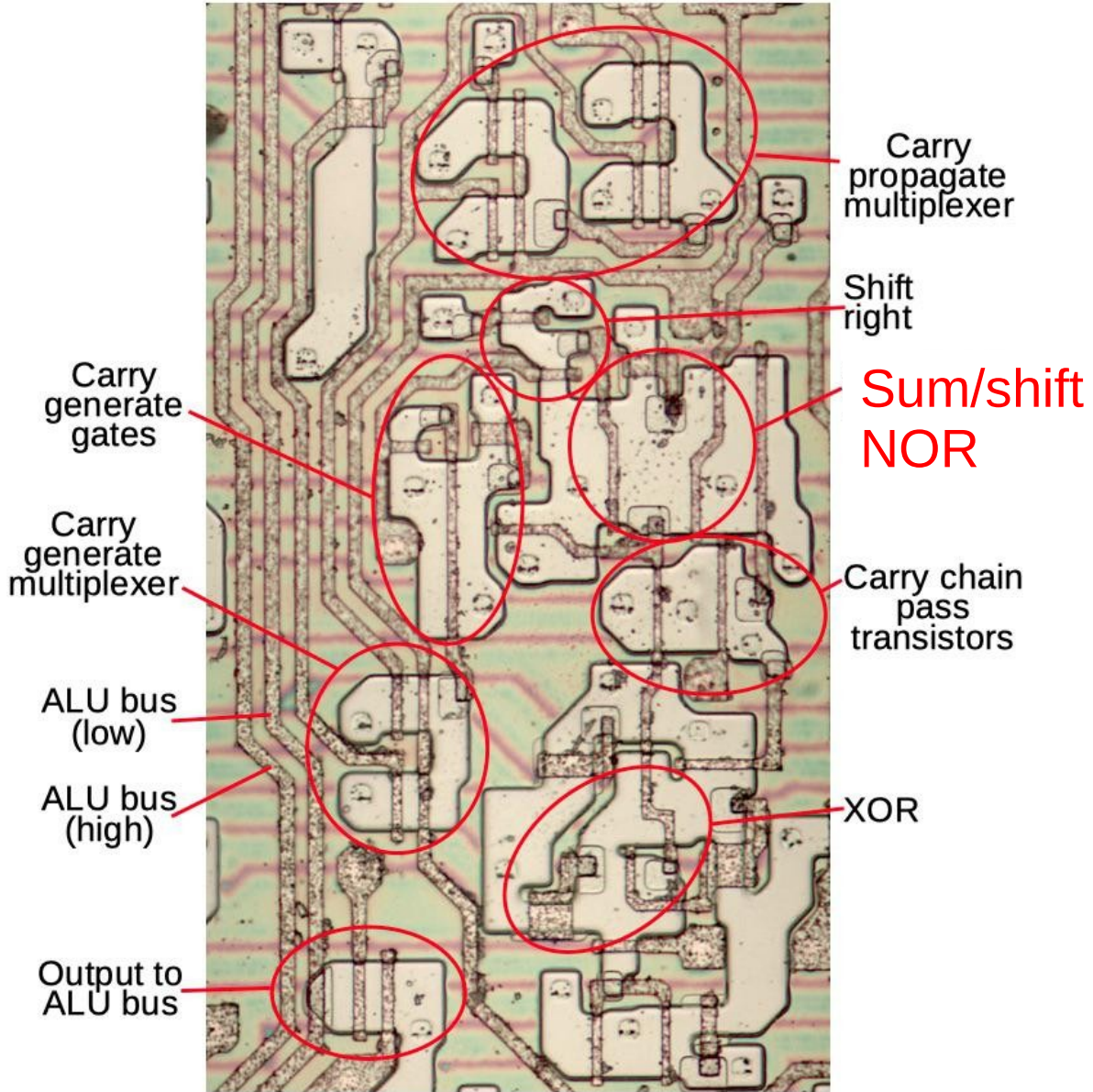




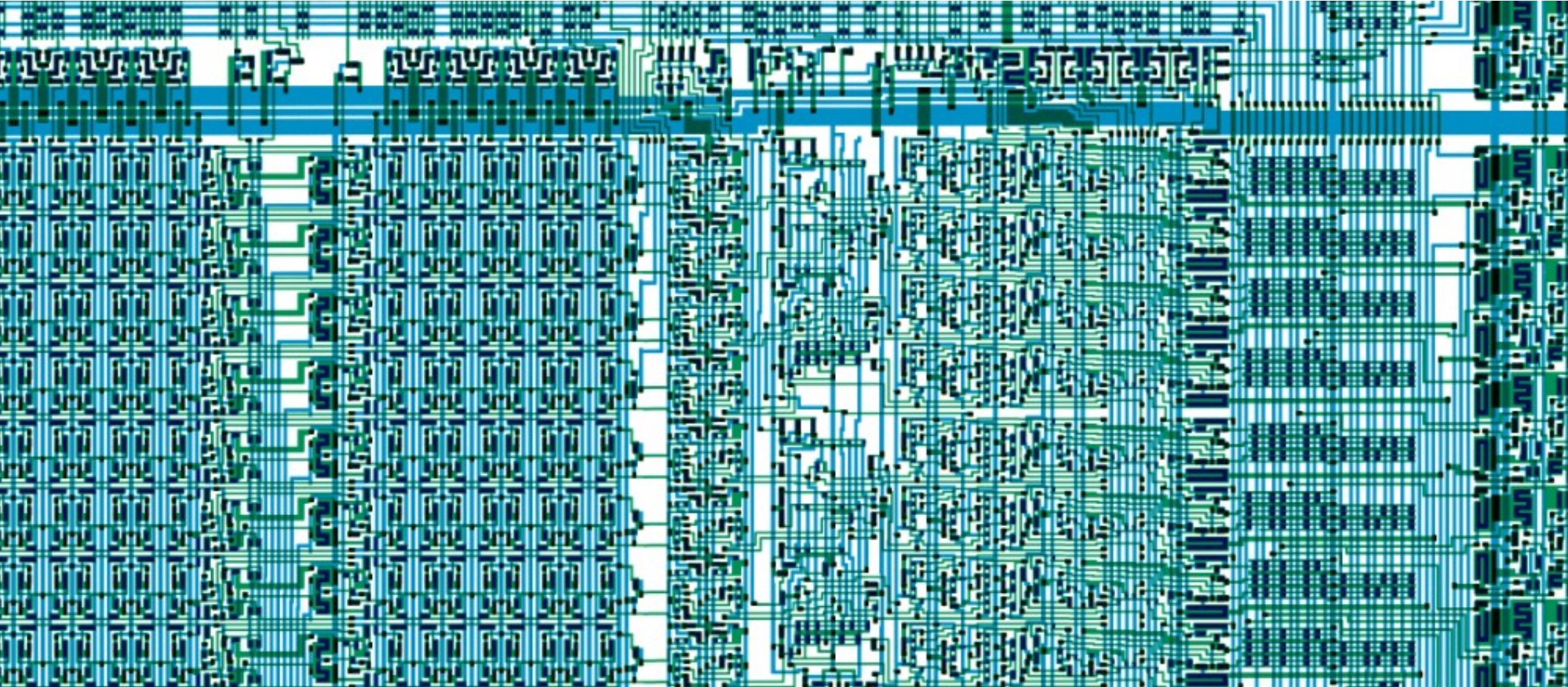
Via between
silicon and
metal

Via between
polysilicon
and metal

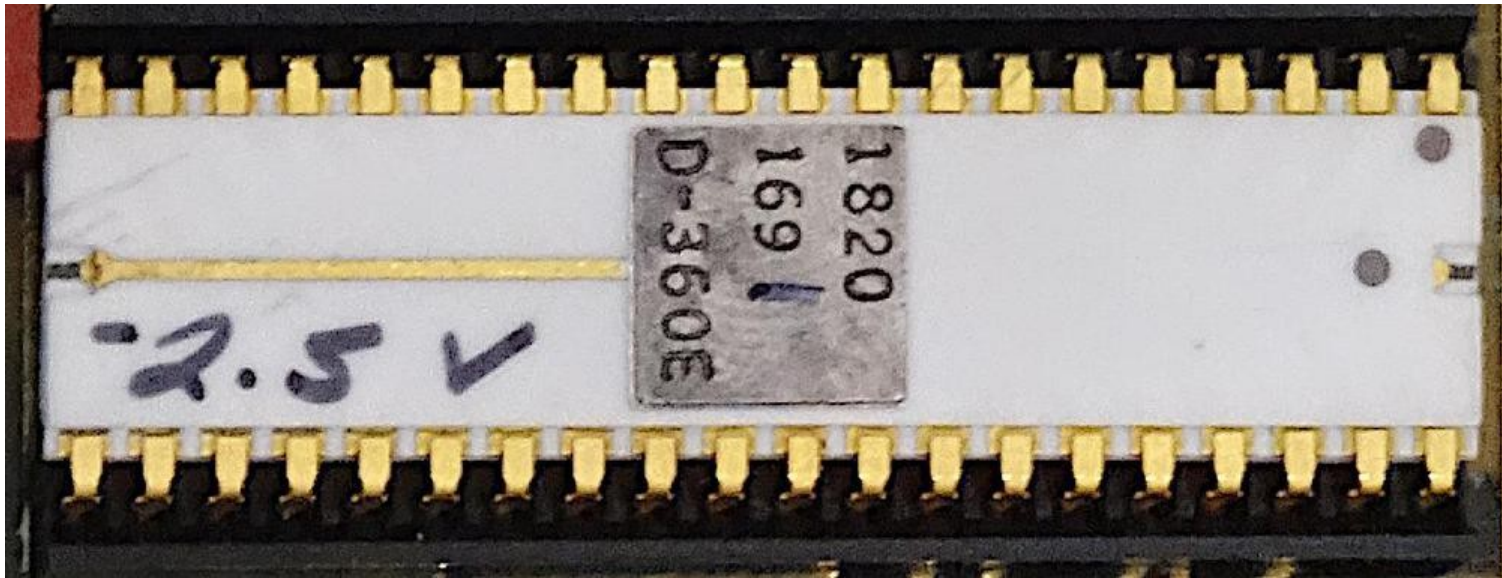
Contact between
silicon and
polysilicon



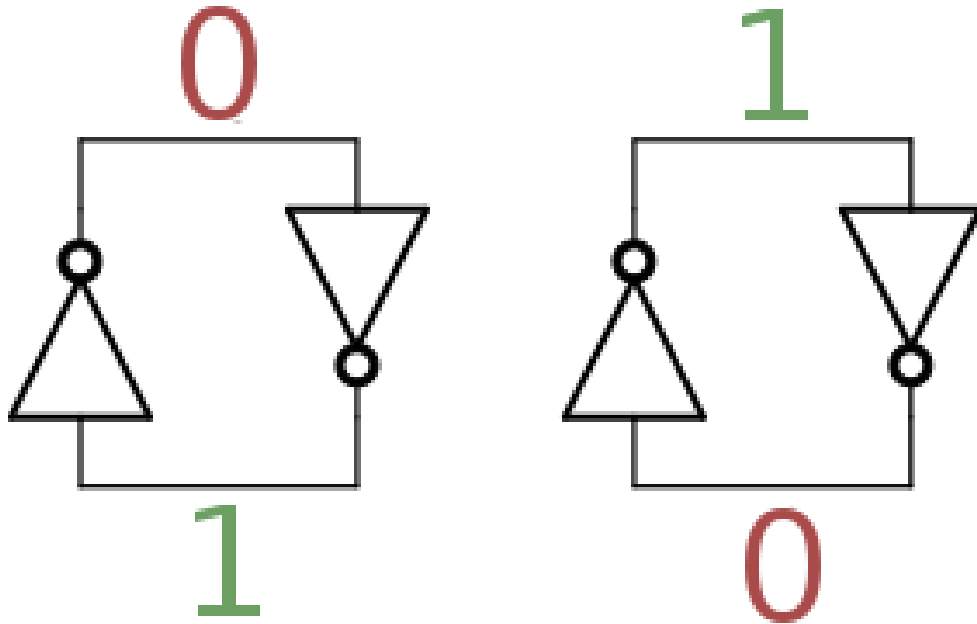
Some interesting chips

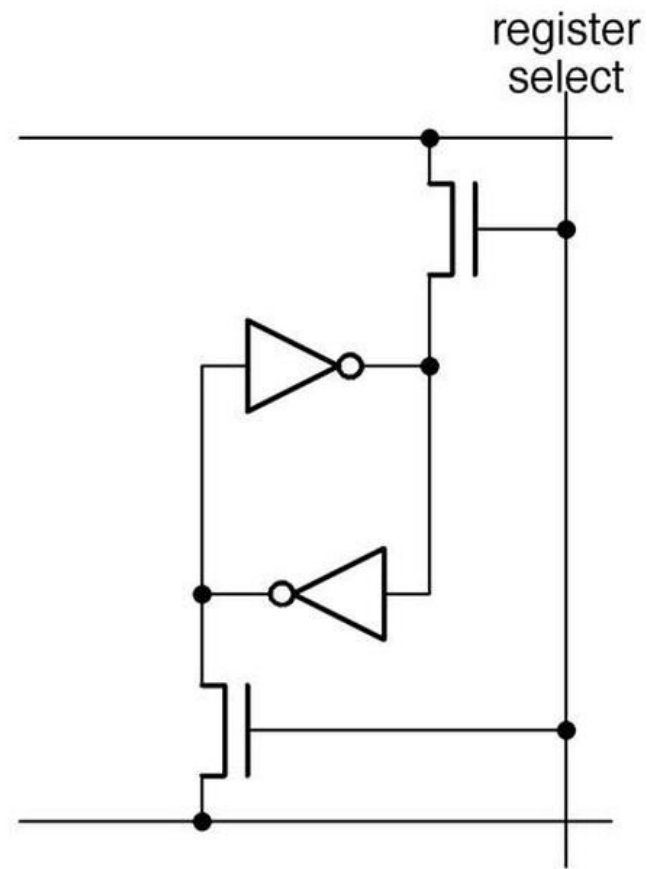
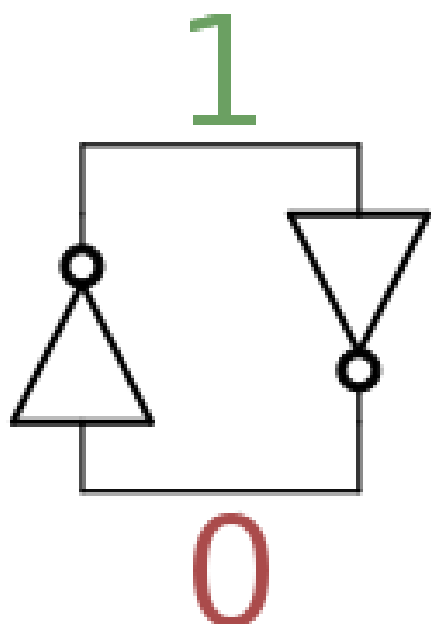
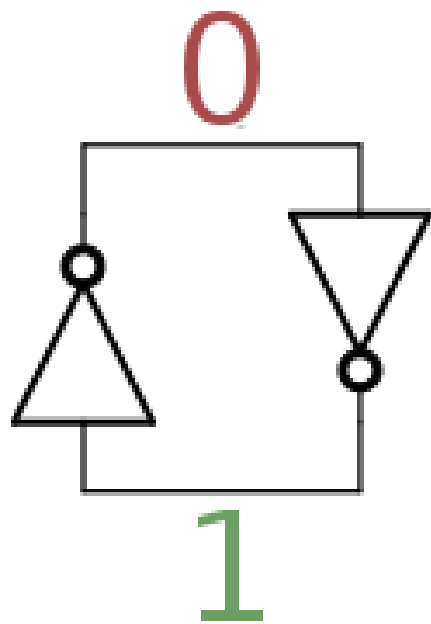


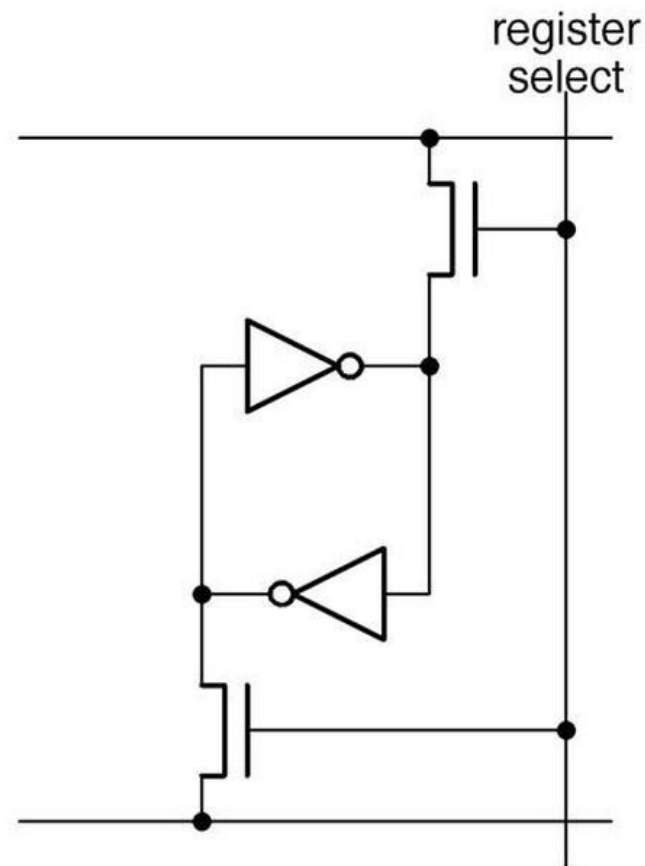
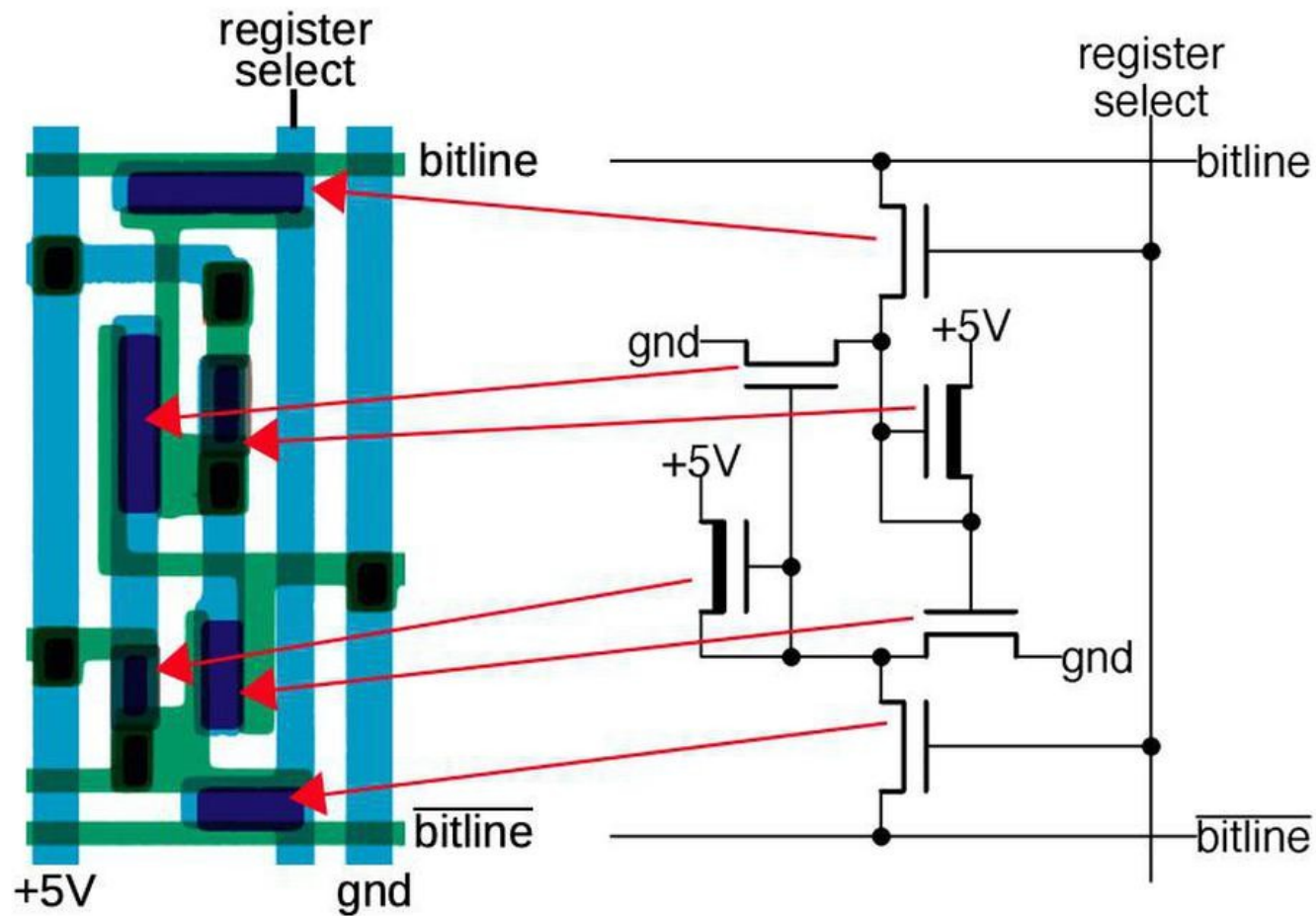
HP Nanoprocessor (1974)



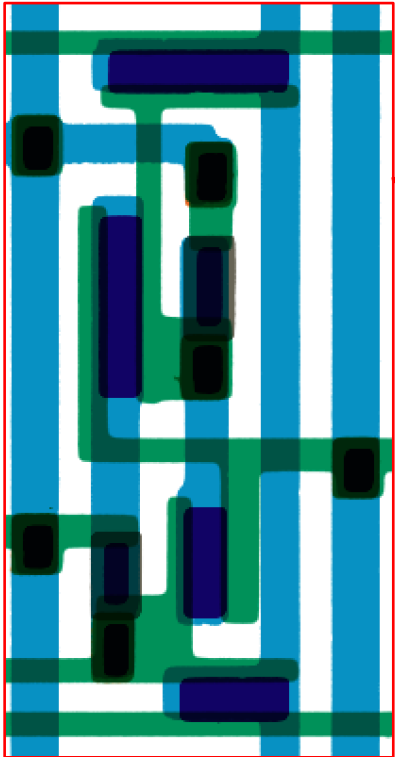
Register storage: one bit



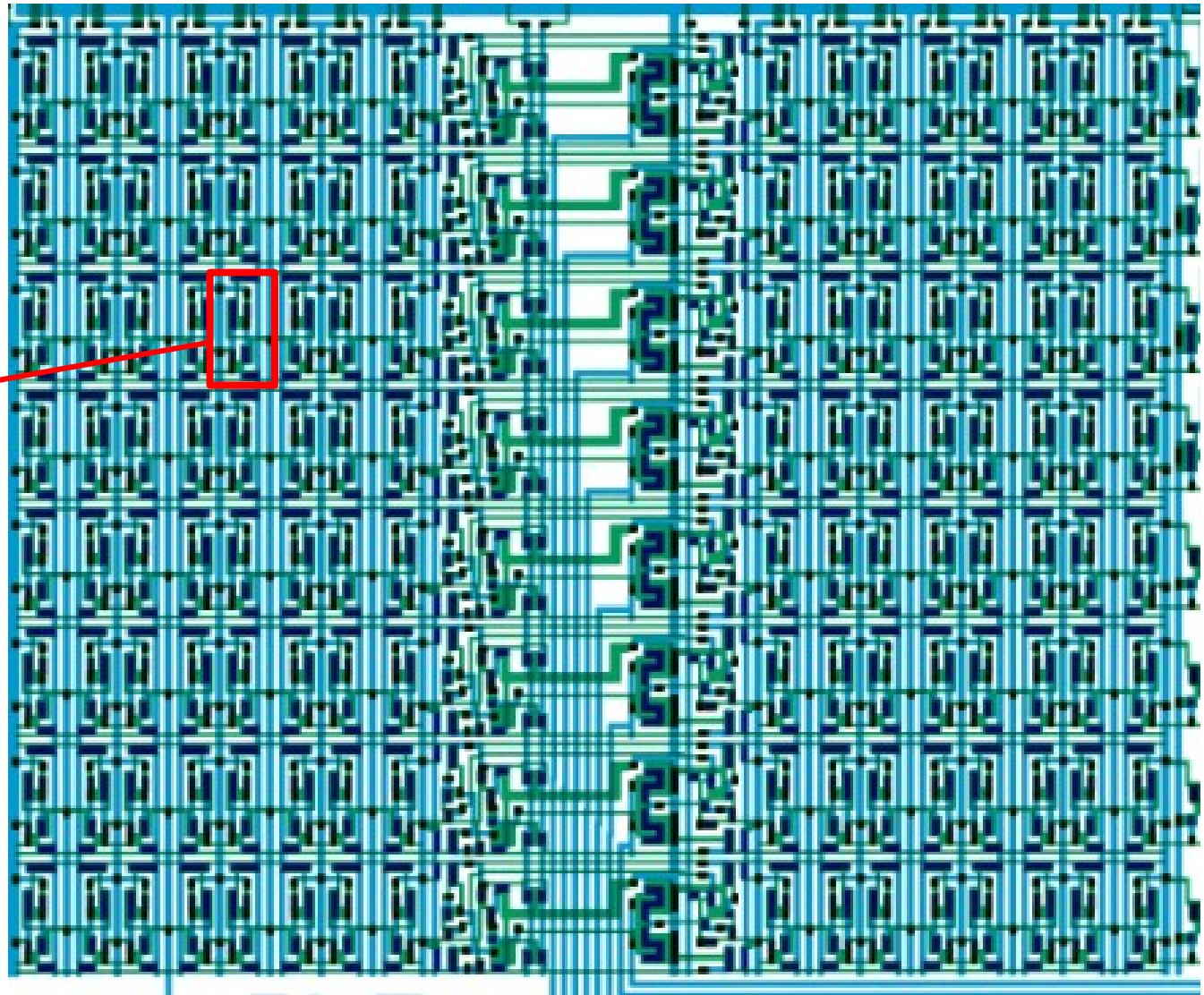
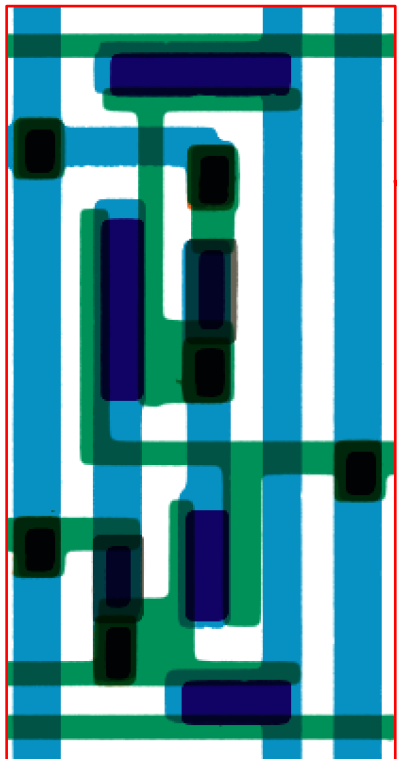


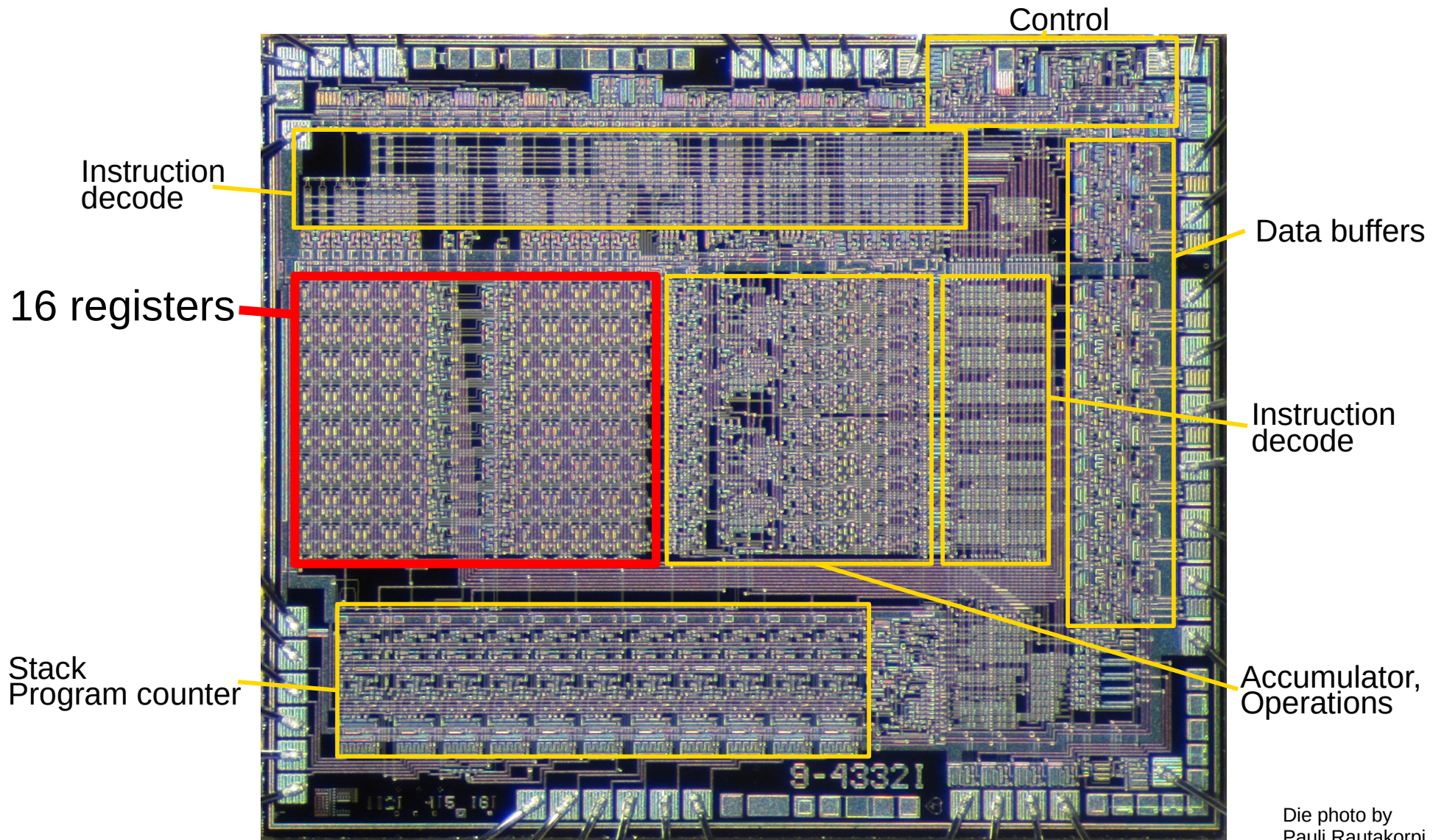


8-bit register



16 registers





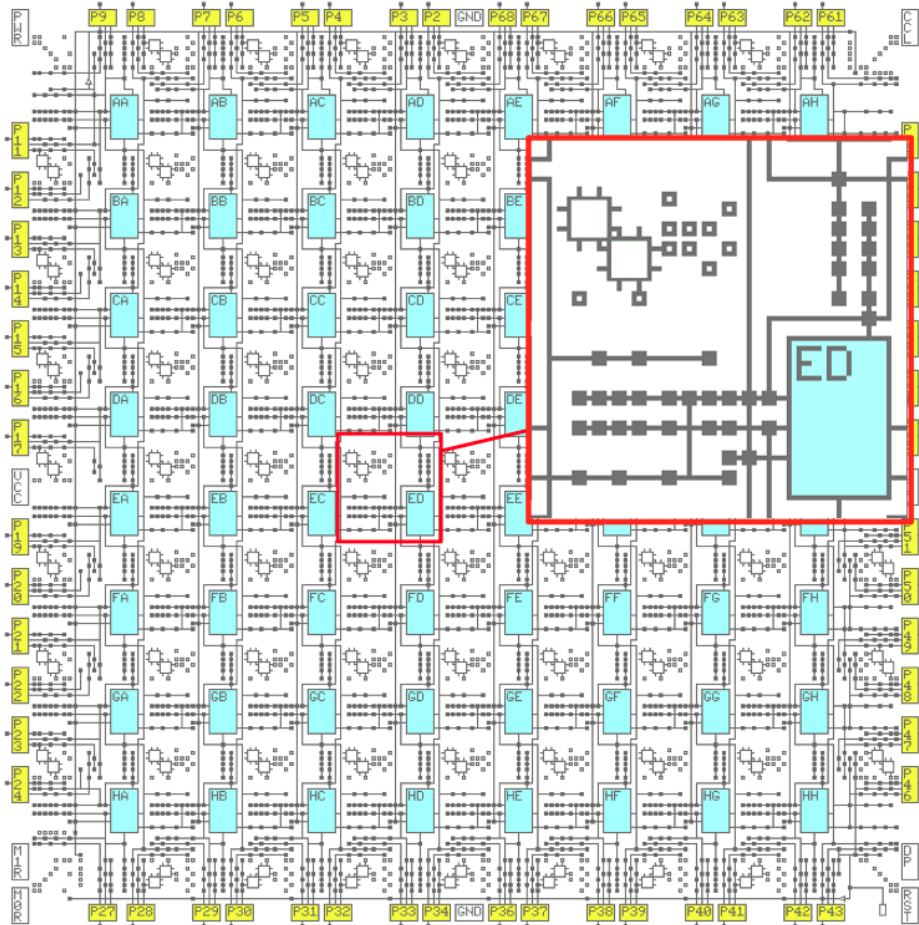
Die photo by Pauli Rautakorpi,

First FPGA: XC2064 (1984)

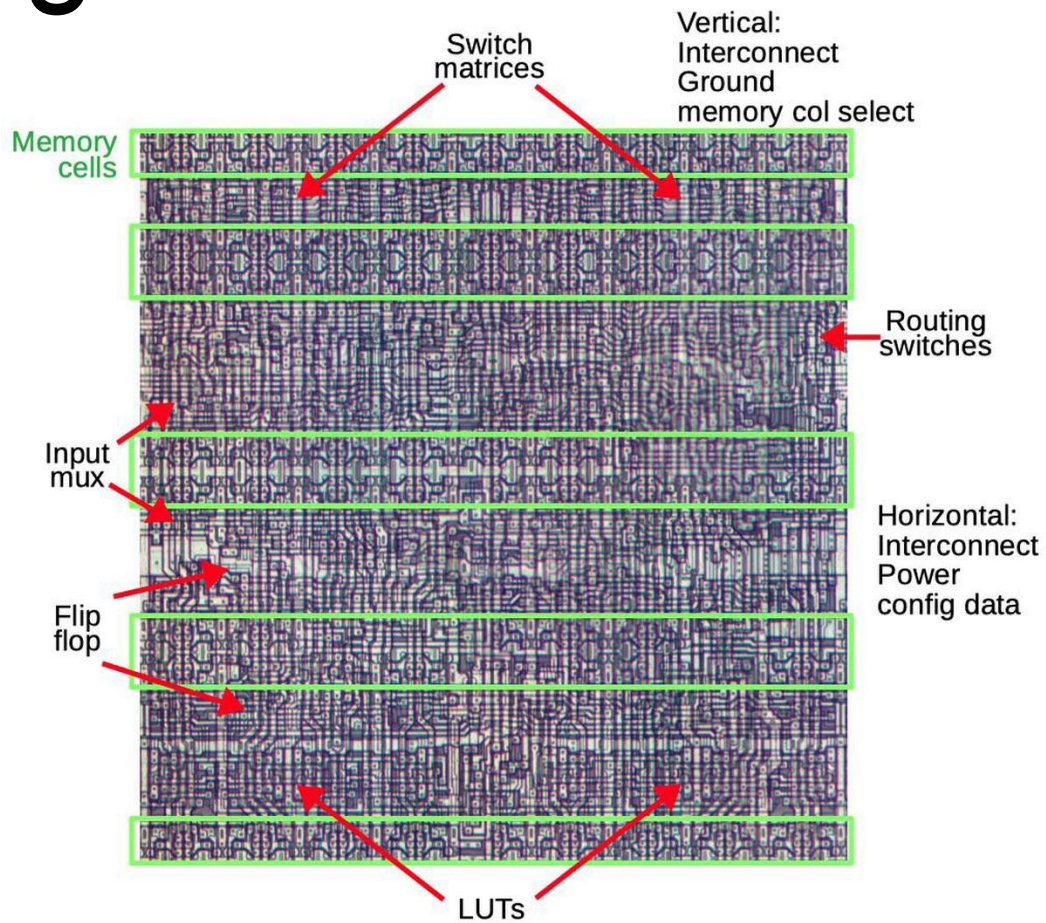
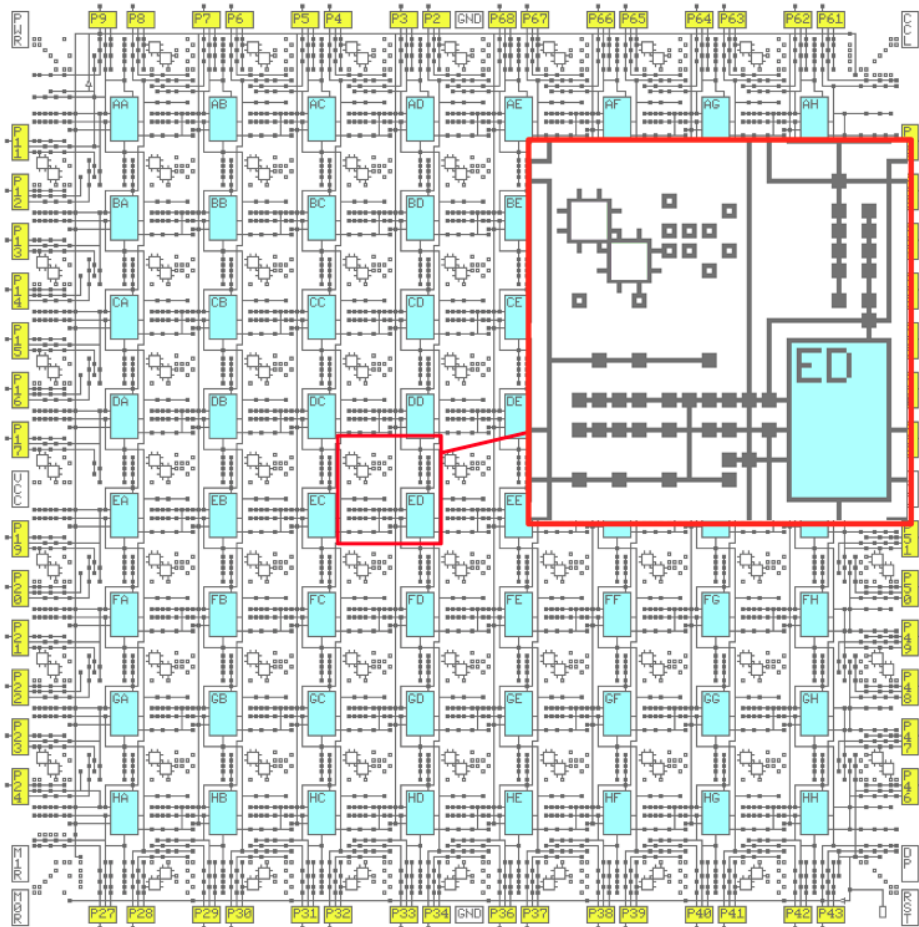
Programmed via proprietary
bitstream



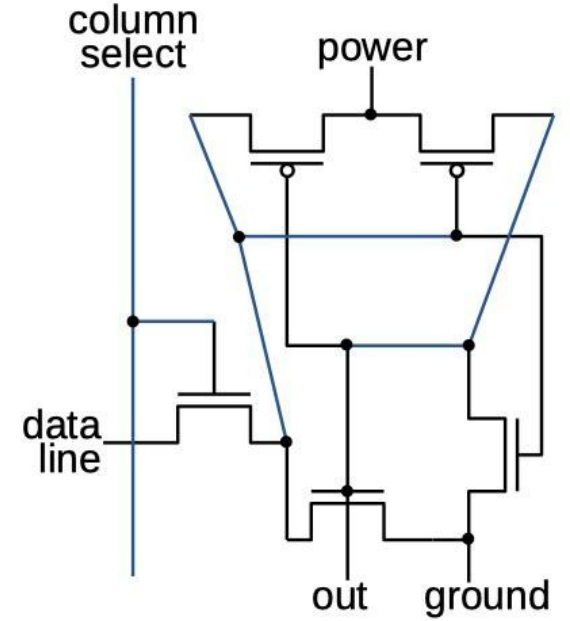
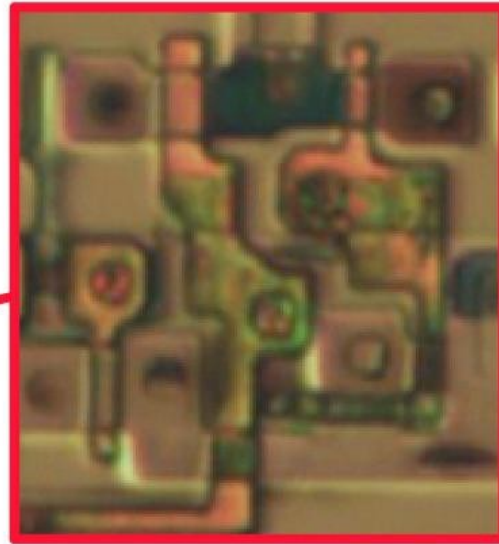
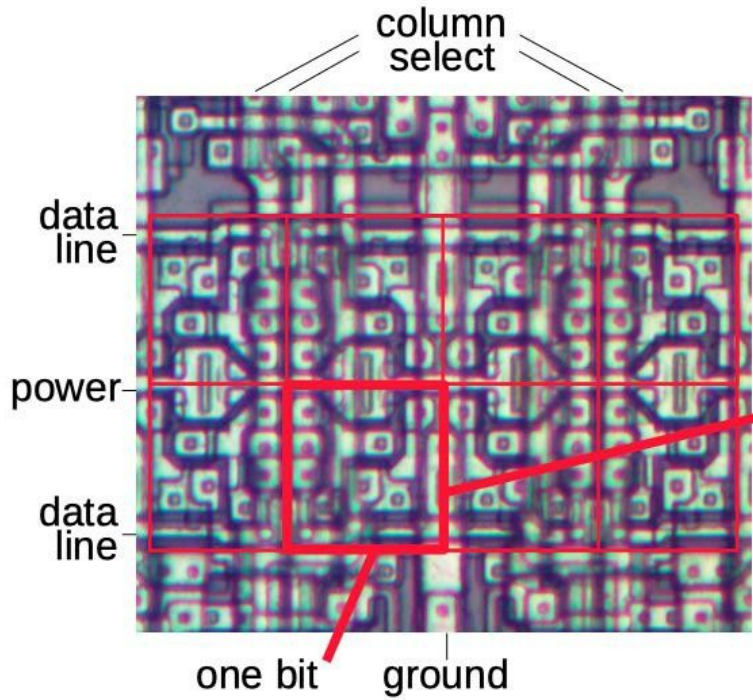
CLBs and routing vs tiles



CLBs and routing vs tiles



Configuration memory

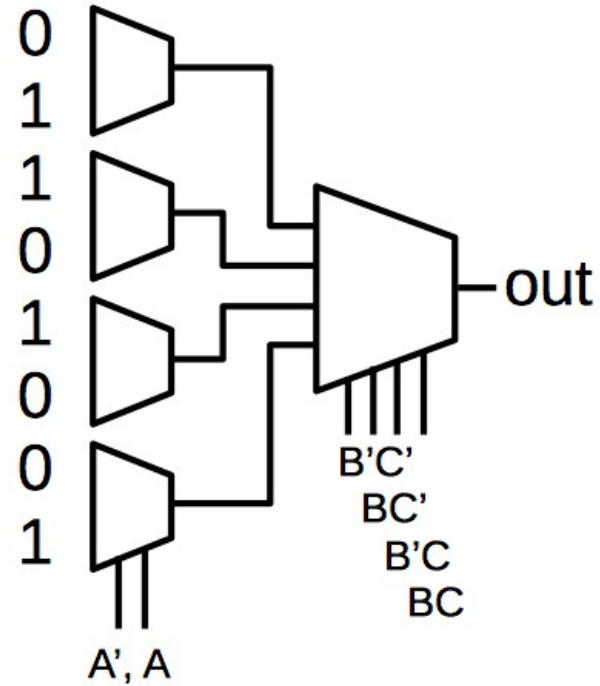


Lookup Table (LUT)

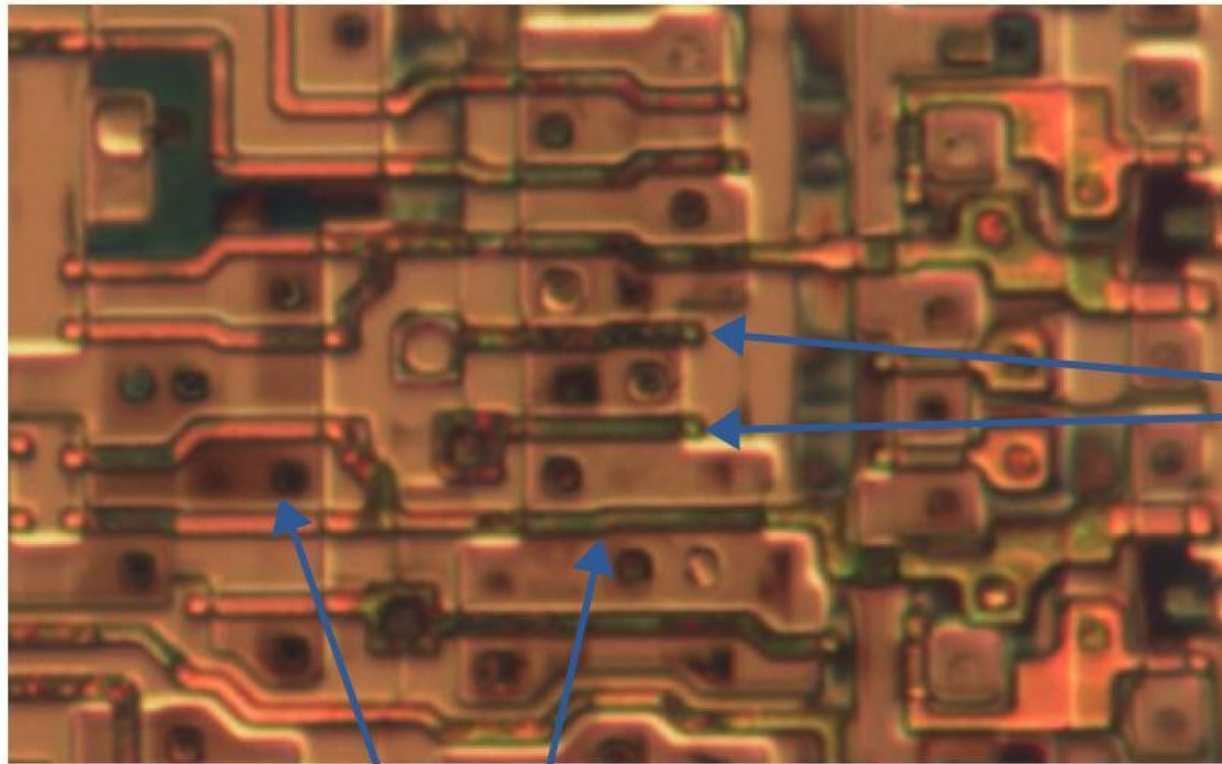
A	B	C	out
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1

Lookup Table (LUT)

A	B	C	out
0	0	0	0
0	0	1	1
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	0
1	1	1	1



Lookup Table (LUT)



memory
cell

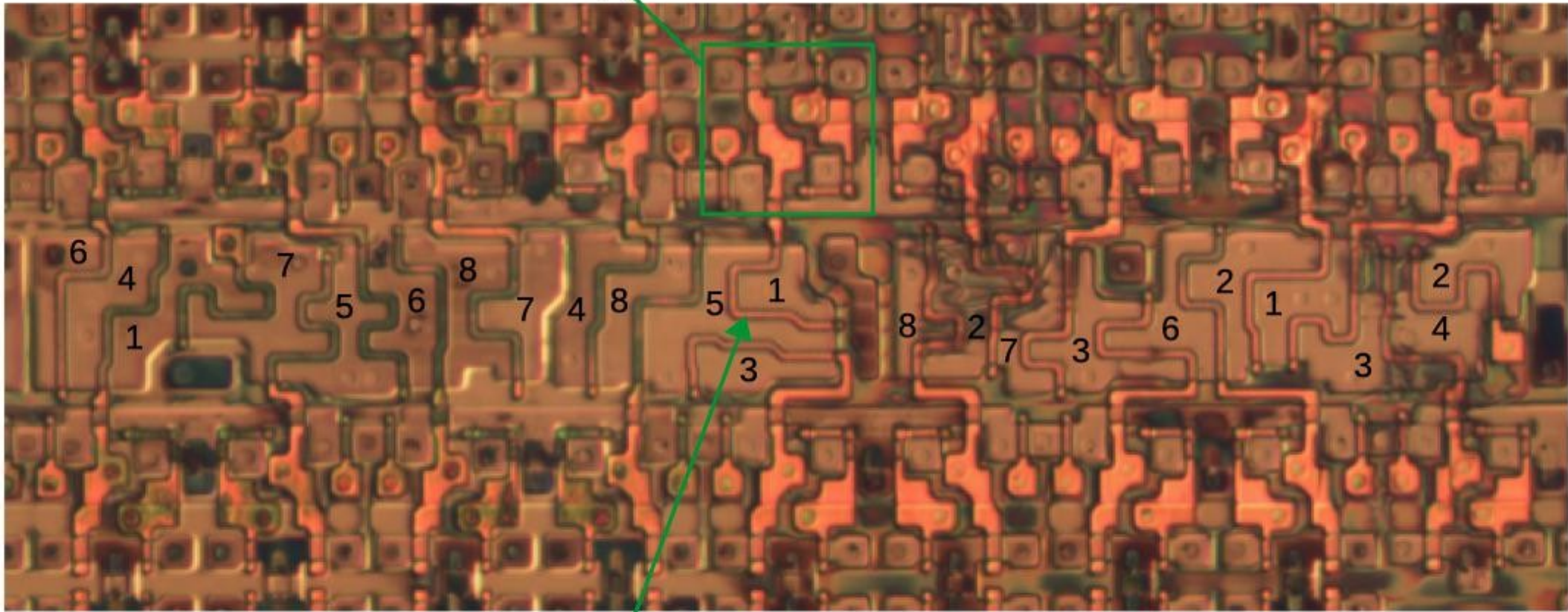
mux

memory
cell

Inverter (buffer)

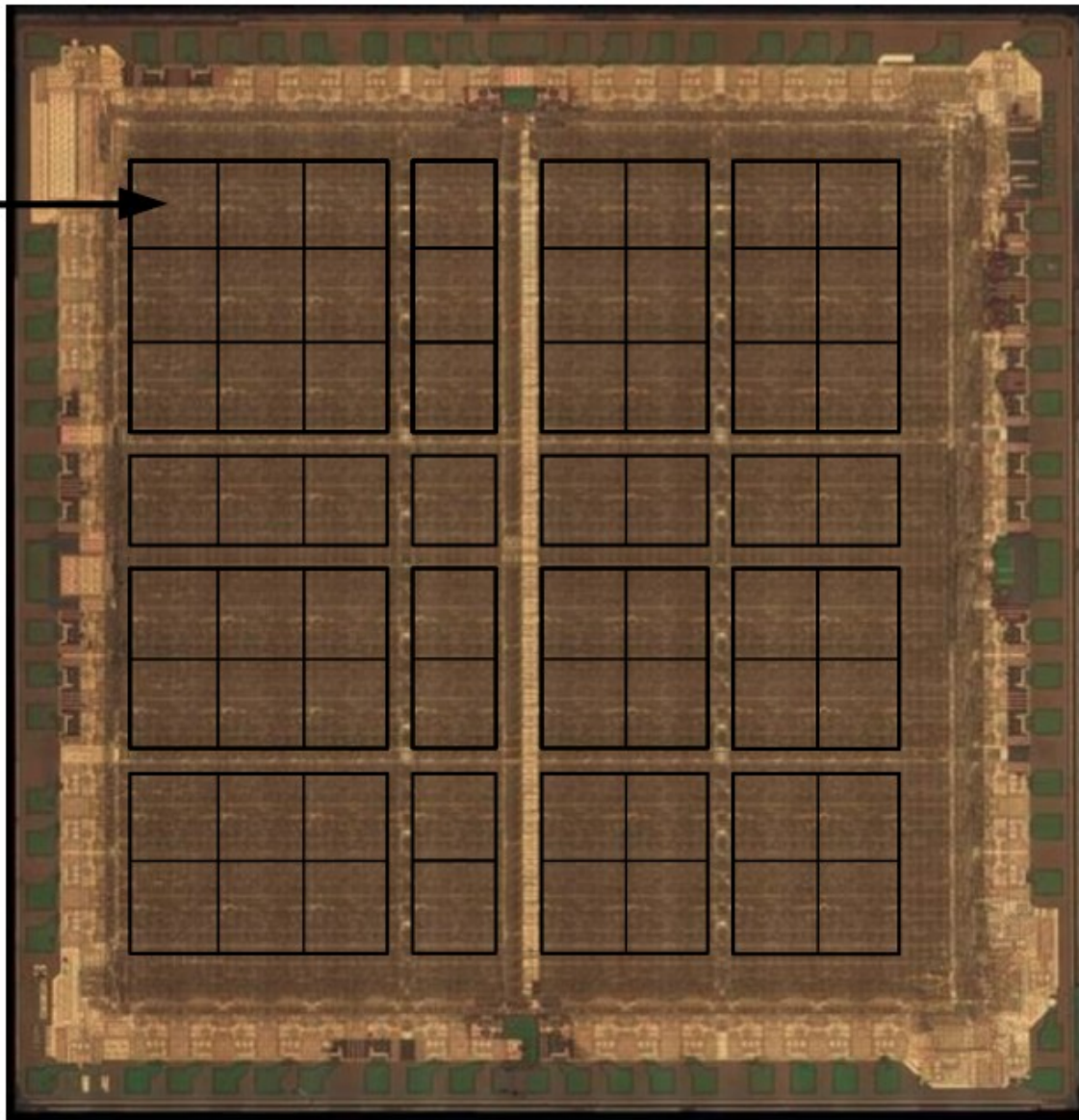
Routing: switch matrix

memory cell

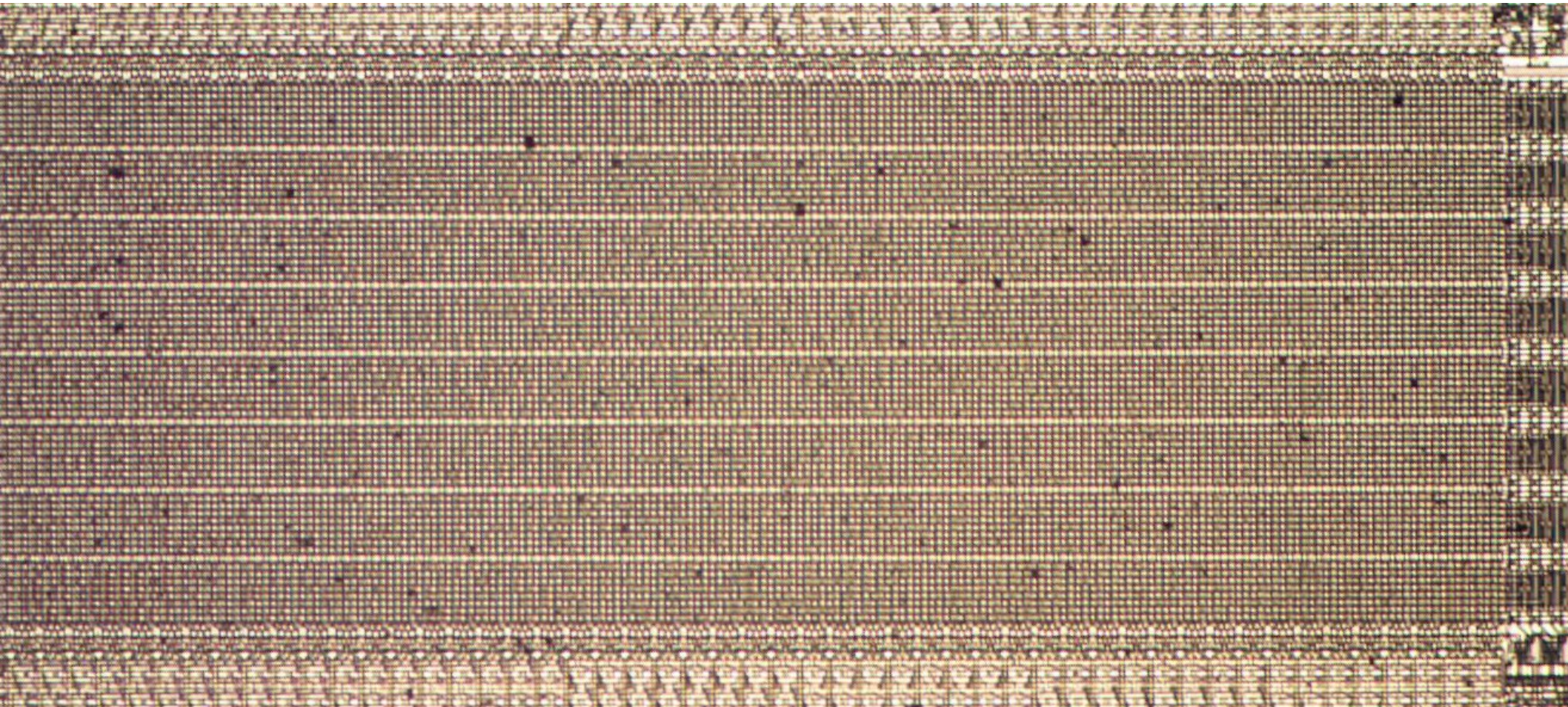


pass transistor

Tile



Looking at ROMs

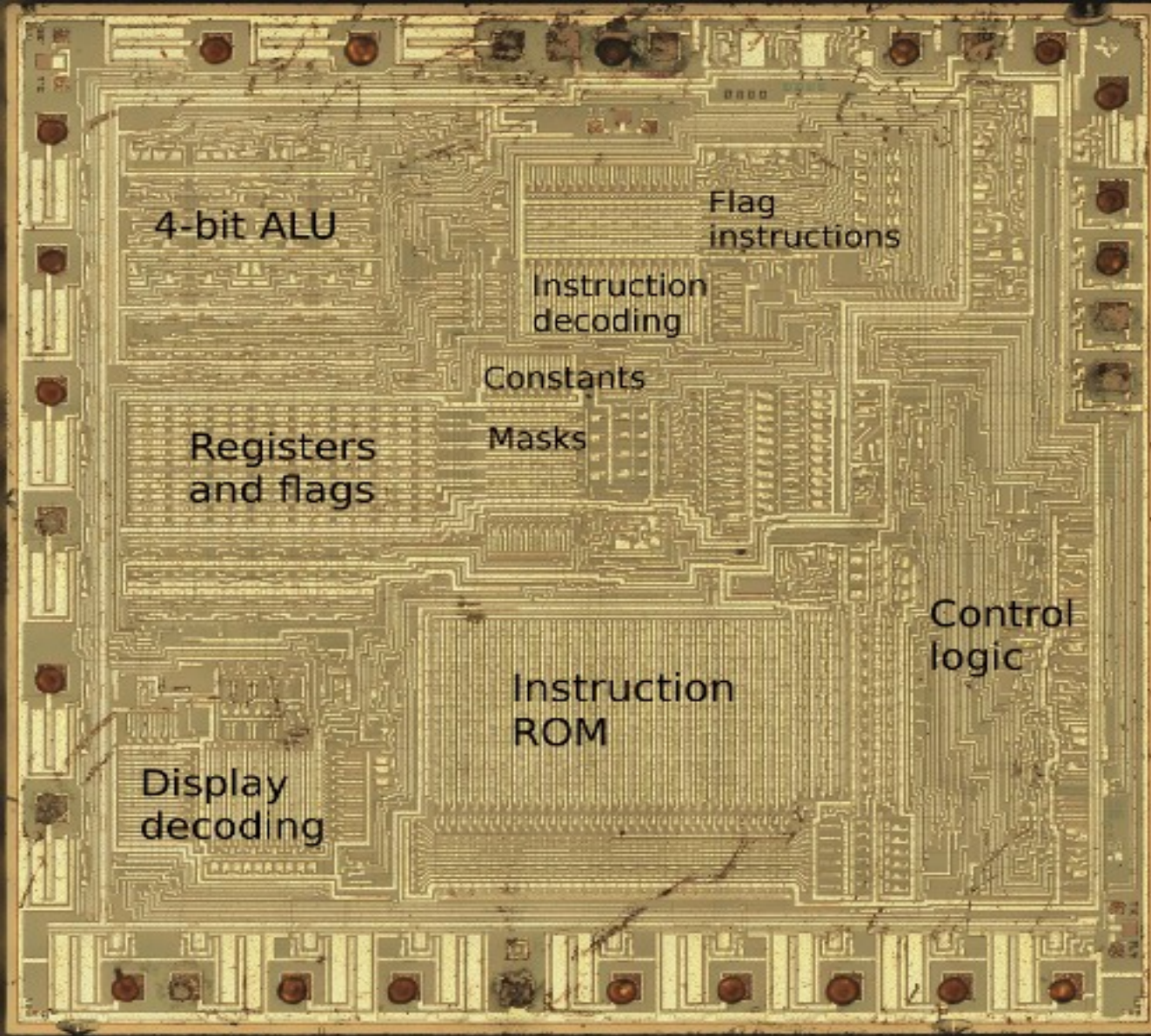


Sinclair Scientific Calculator (1974)

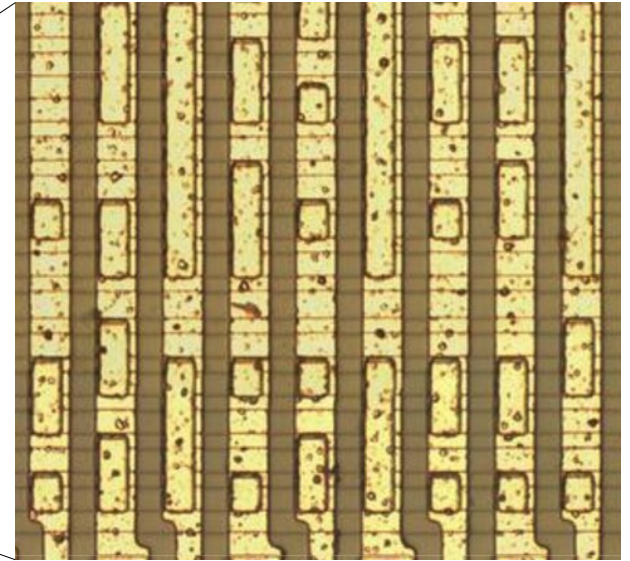
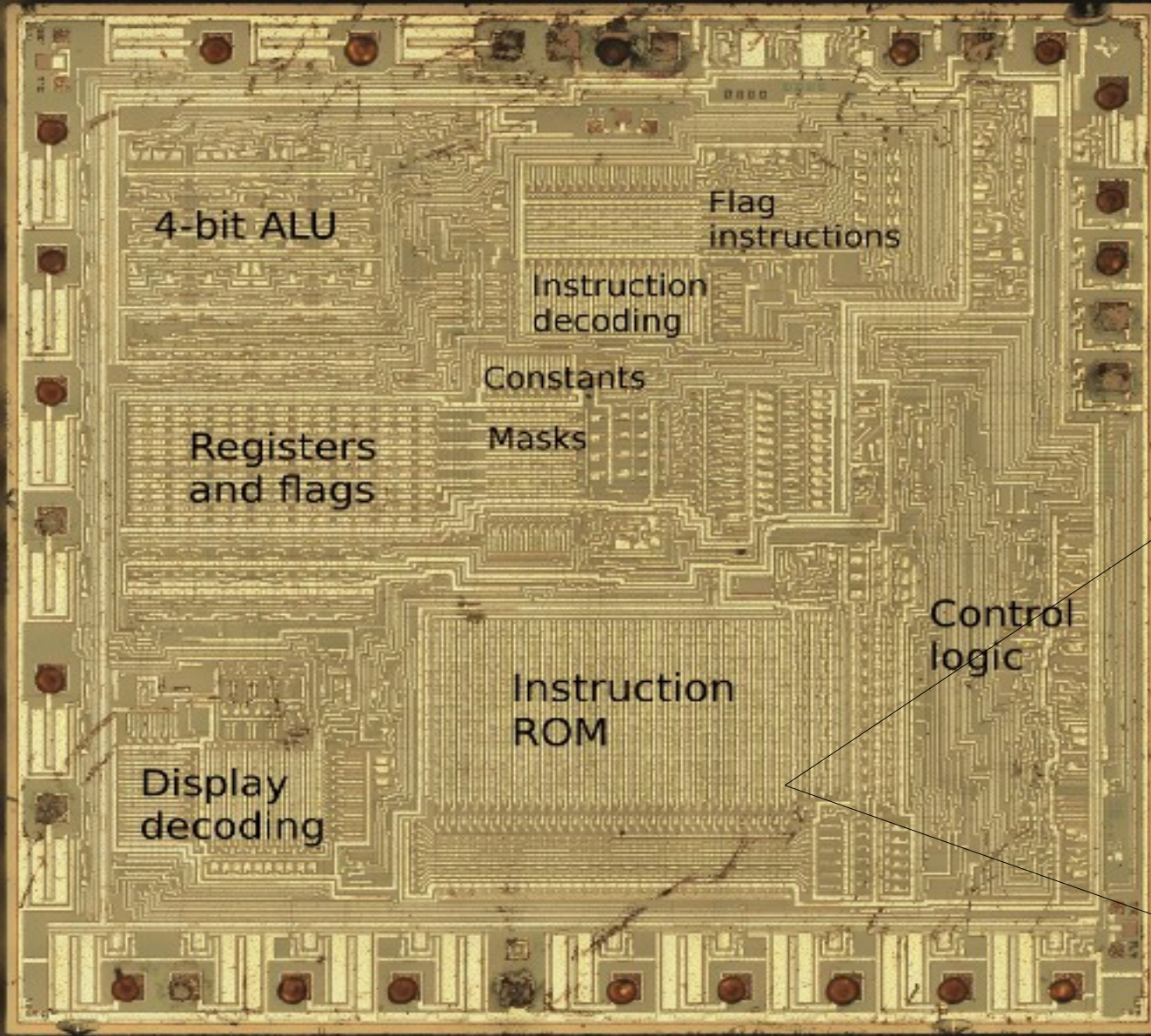
Reprogrammed
TI 0800 4-function
calculator chip to
support trig, log.
How?



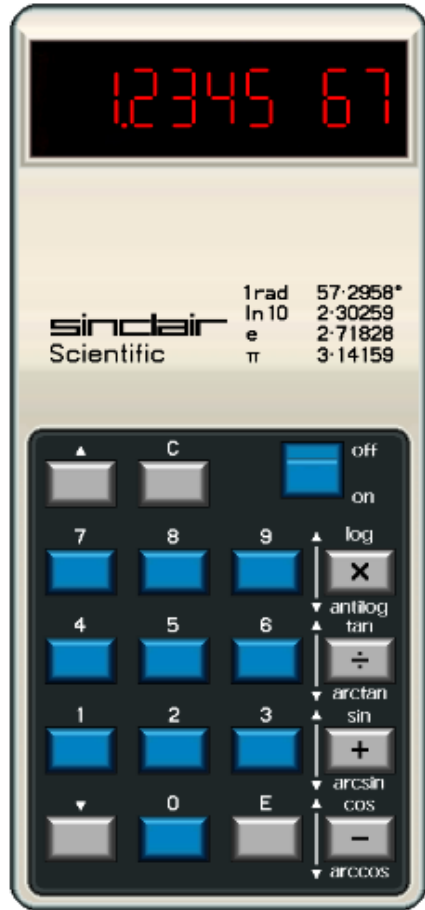
TMS 0805 calculator chip



Can see bits in
the 320-word
instruction ROM



Built instruction-level simulator



```
AKC ALL
For display, A's MANT starts in digit 5. For computation
C holds the previous value, with MANT starting in digit 1
MAINLOOP SLLA MANT Shift mantissa for display
AKB ALL clear B
WAITSCAN SYNC loop until no key pressed
SCAN
BINE WAITSCAN
WAITKEY WAITNO WAITED wait for key
WAITED2 SYNC debounce: still pressed?
SCAN
BIE WAITKEY loop if no key
SYNC
SRLA MANT MANT is shifted right during ca
BKO LOWERKEY sequentially scan key columns
BKO PLUSKEY
BKO MINUSKEY
BKO DIVKEY
BKO MULTKEY
BKO UPPERKEY
BKO EKEY
BKO ZEROKEY
EXAB ALL save A in B, A=0
AKCN DIGIT1 get digit by incrementing until
EXAB ALL restore A, B holds count
BINE MAINLOOP start over if nothing pressed
ZEROKEY TFB EMODE B holds key 0-9
BINE EDIGIT
If OPDONE, a digit starts a new number in A, leaving the
TFB OPDONE if OPDONE...
BIE LABEL33
AKA ALL then clear A and OPDONE
ZFB OPDONE
LABEL33 ACKA DIGIT C holds digit position
BSHIFT SRLB ALL shift B right C times.
SAKA DIGIT1 decrement A
BIE BSHIFT (no borrow)
AKCN DIGIT1 increment digit count in C
```

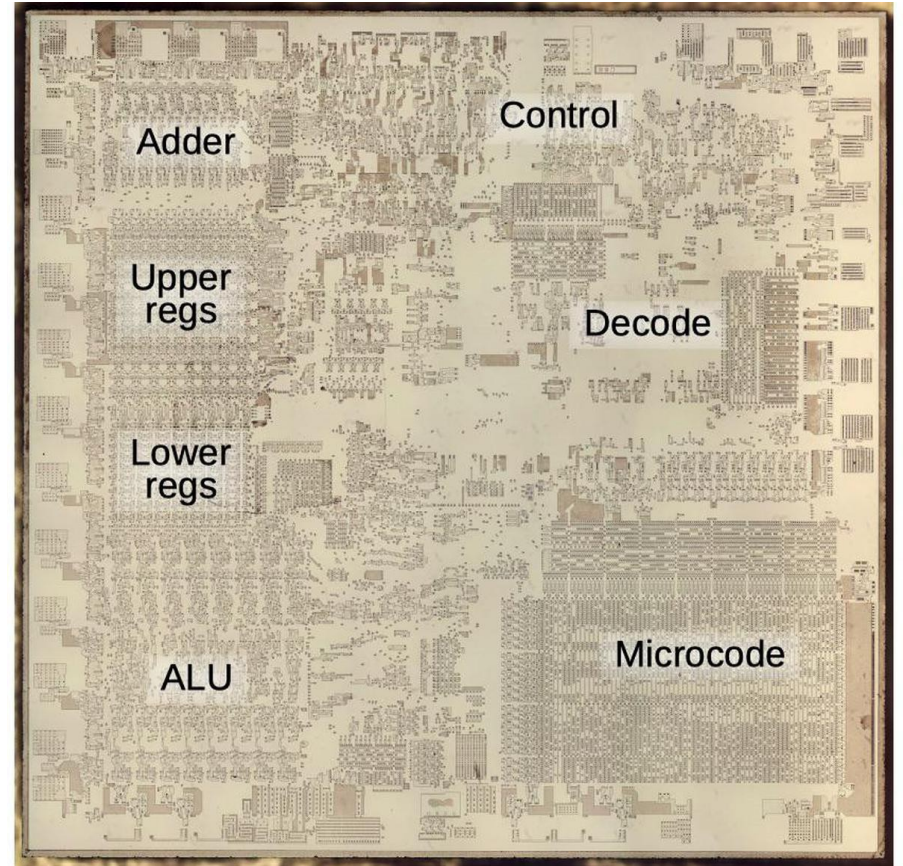
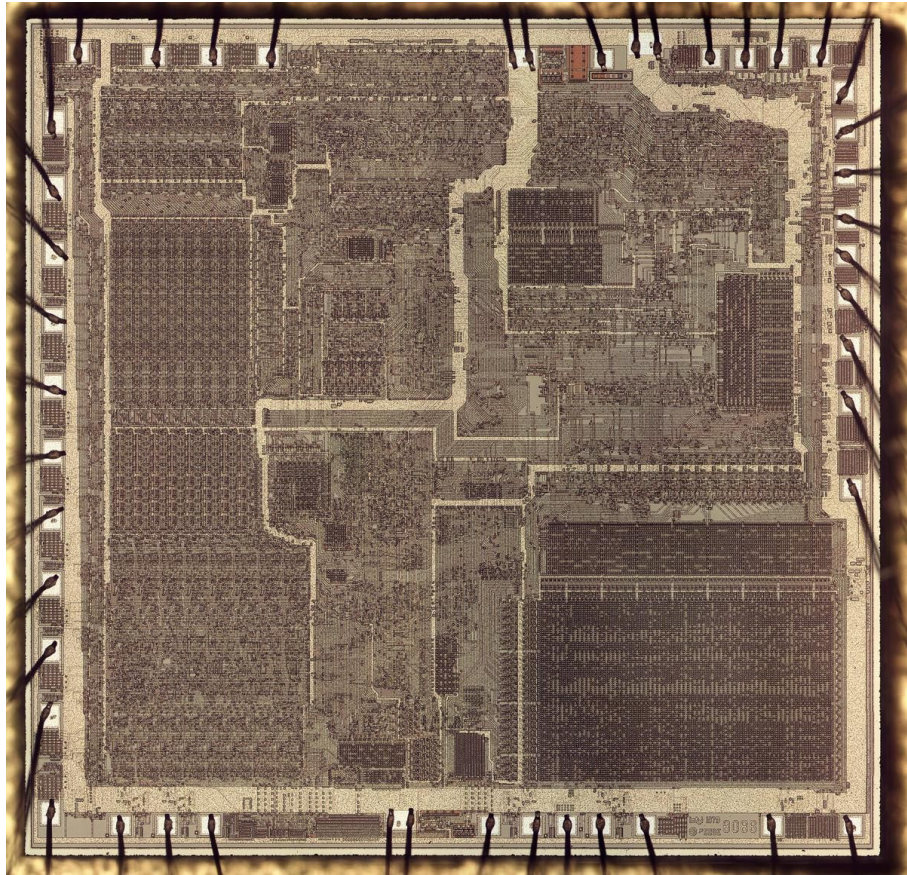


Decimal algorithms

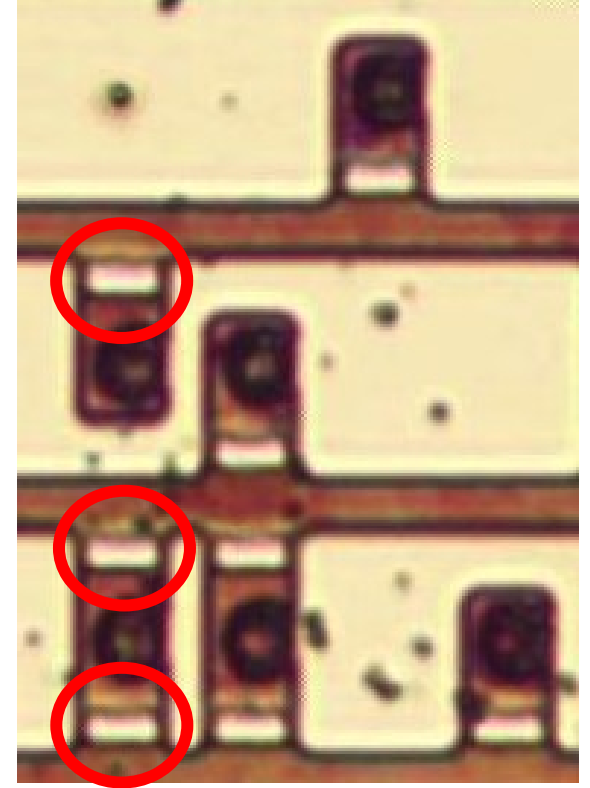
Trig: repeated rotates by .001 rad

Log: powers of 0.99

Intel 8086 (1978)



Intel 8086 microcode

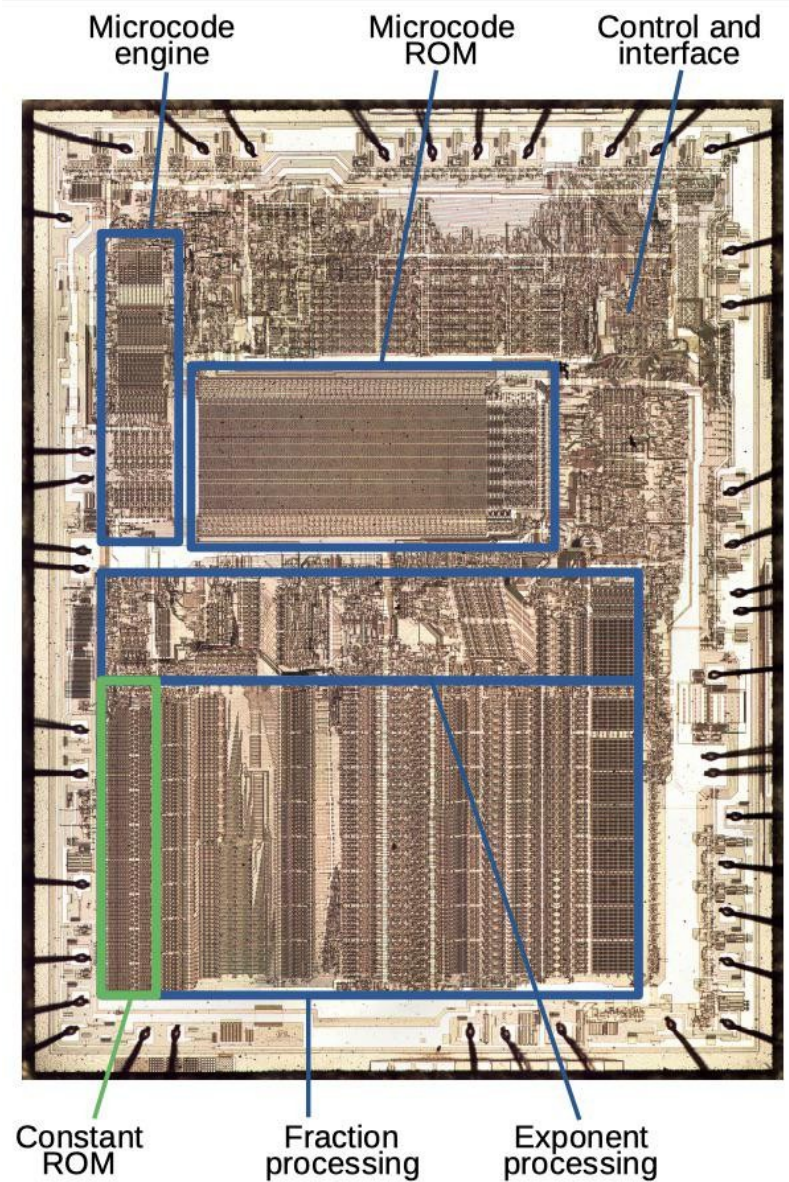


Intel 8086 microcode

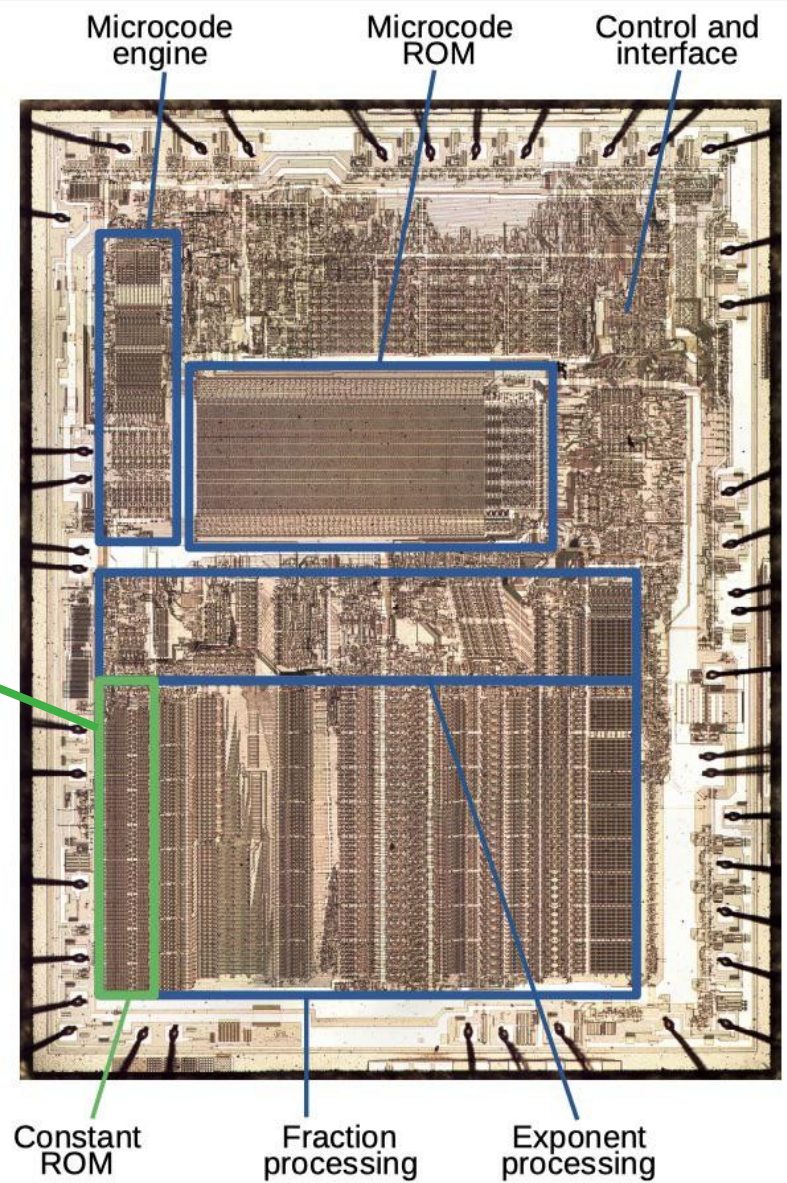
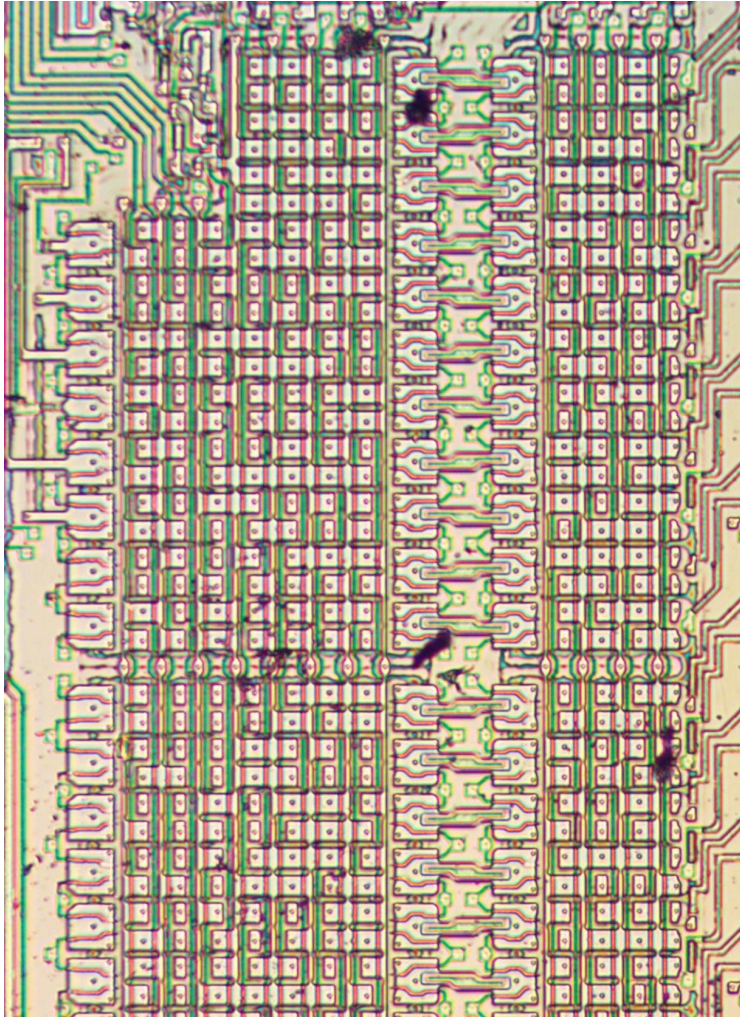
000	R	-> tmpb	4	none	WB, NX	0100010???.00	MOV rm<->r
001	tmpb	-> M	4	none	RNI		
002			6	W	DD, P0		
003	IJ	-> tmpa	5	UNC	EAOFFSET		[SI]
004	IND	-> R	4	none	RNI	010001101.00	LEA
005							
006							
007							
008	M	-> tmpa	1	XI	tmpa	000???0???.00	alu rm<->r
009	R	-> tmpb	4	none	WB, NX		
00a	SIGMA	-> M	4	none	RNI		F
00b			6	W	DD, P0		
00c	Q	-> tmpbL	0	L8	2	01000000???.00	alu rm, i
00d	Q	-> tmpbH					
00e	M	-> tmpa	1	XI	tmpa, NX		

Intel 8087

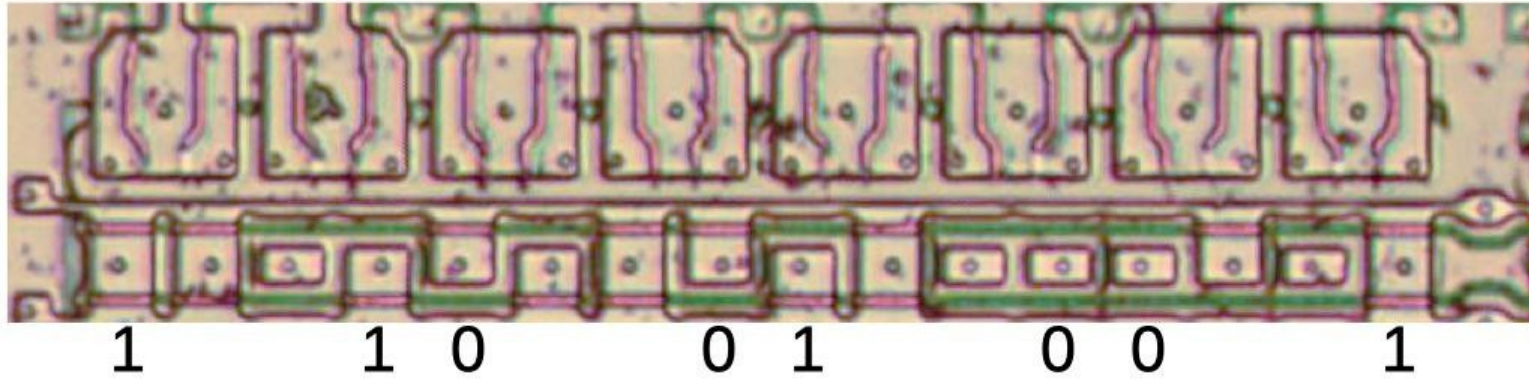
Floating point coprocessor



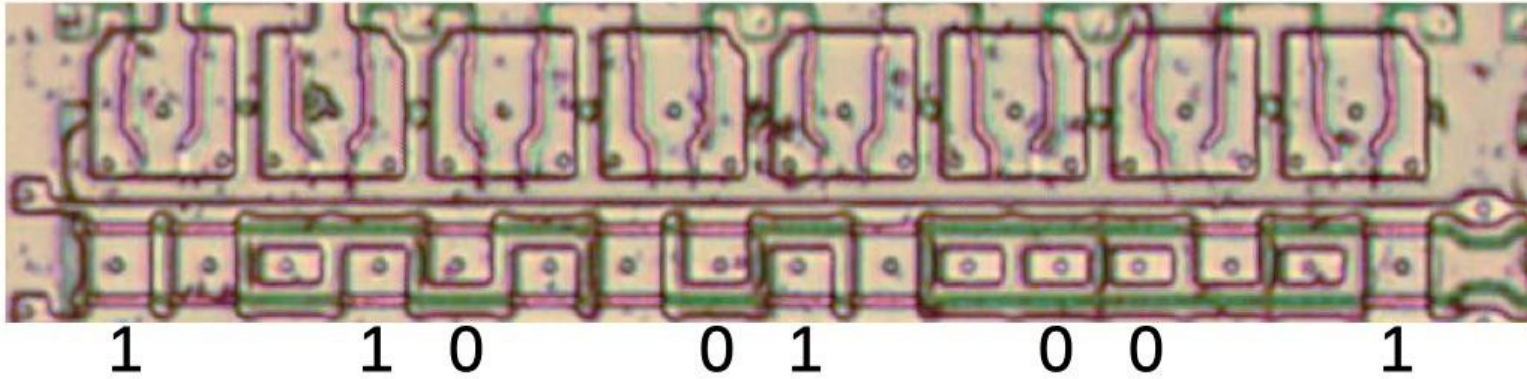
Constant ROM



Constant ROM

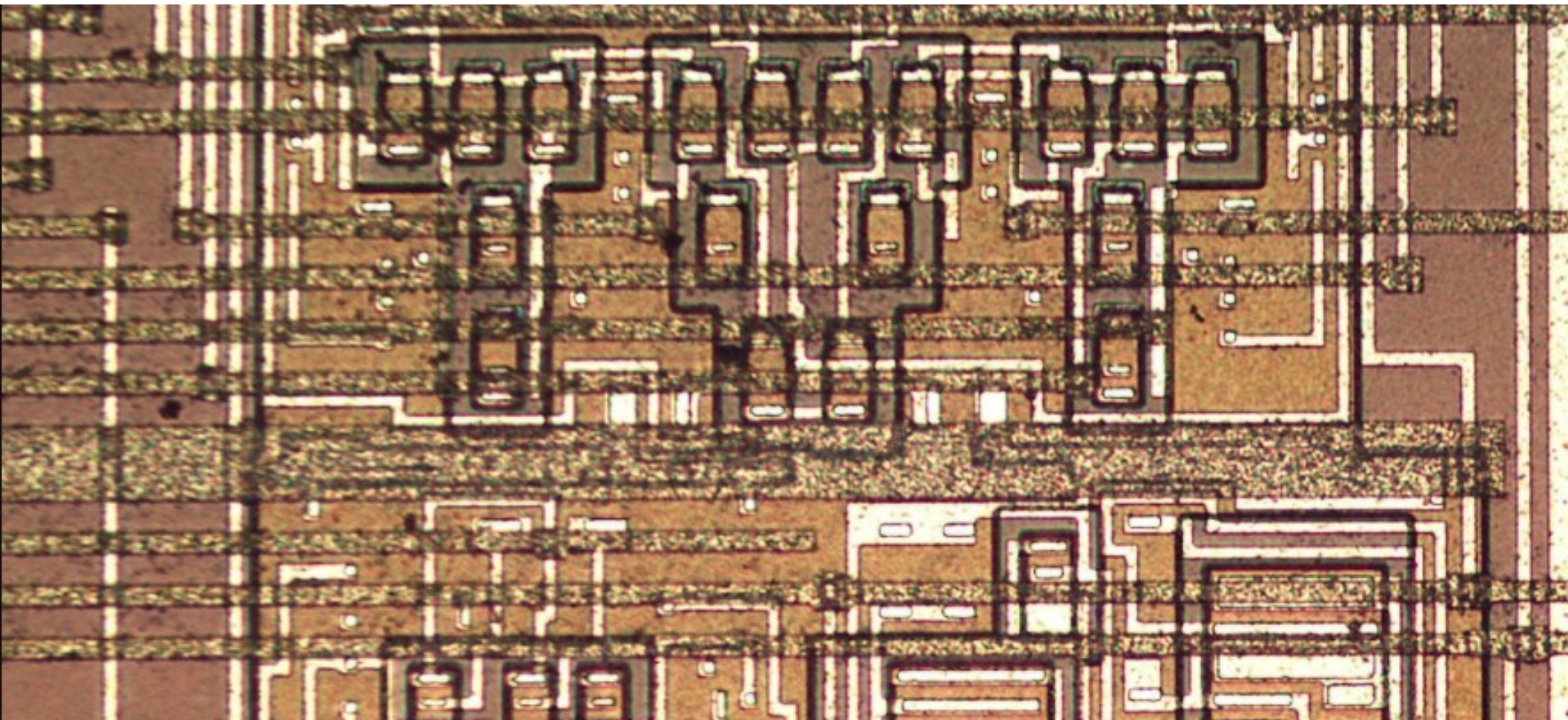


Constant ROM

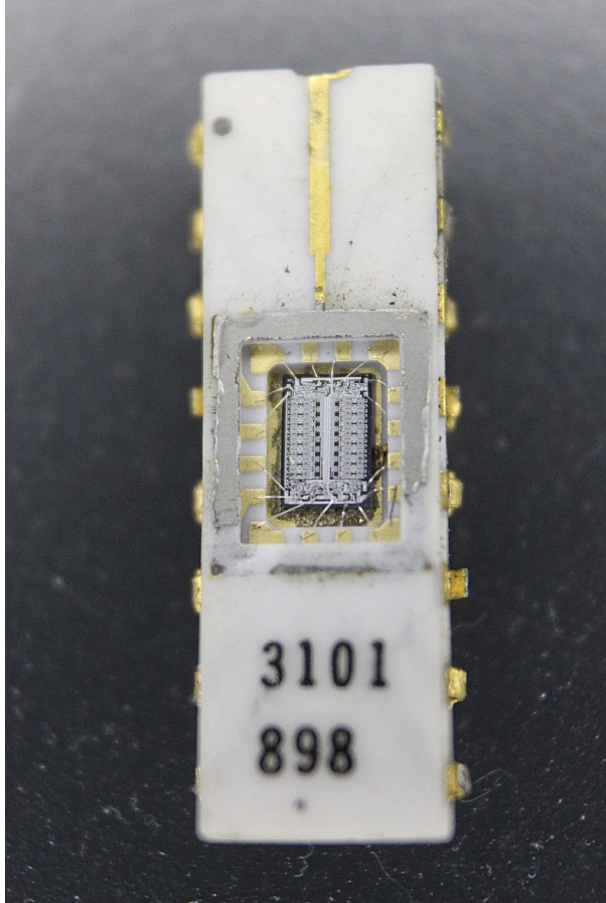


Pi in binary: 11.001001...

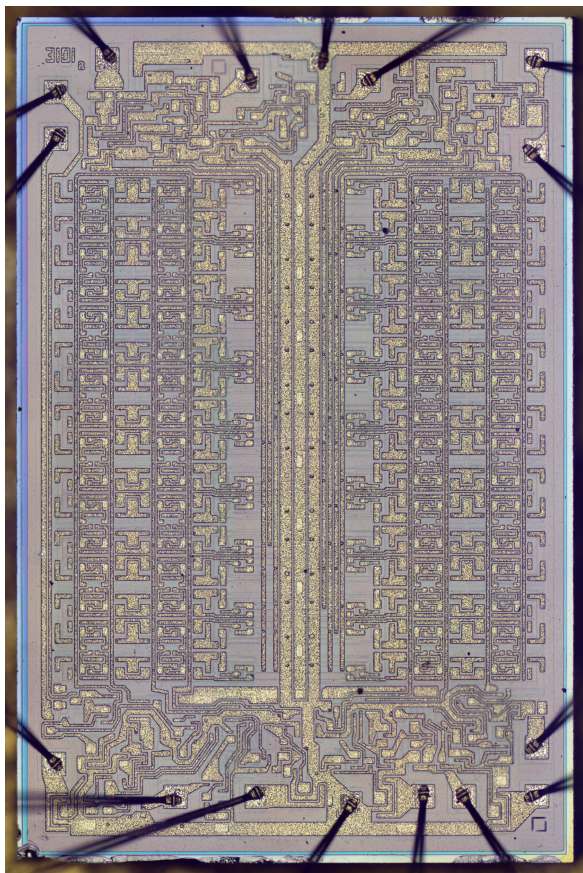
Counterfeits



64-bit bipolar RAM



Original



Suspect

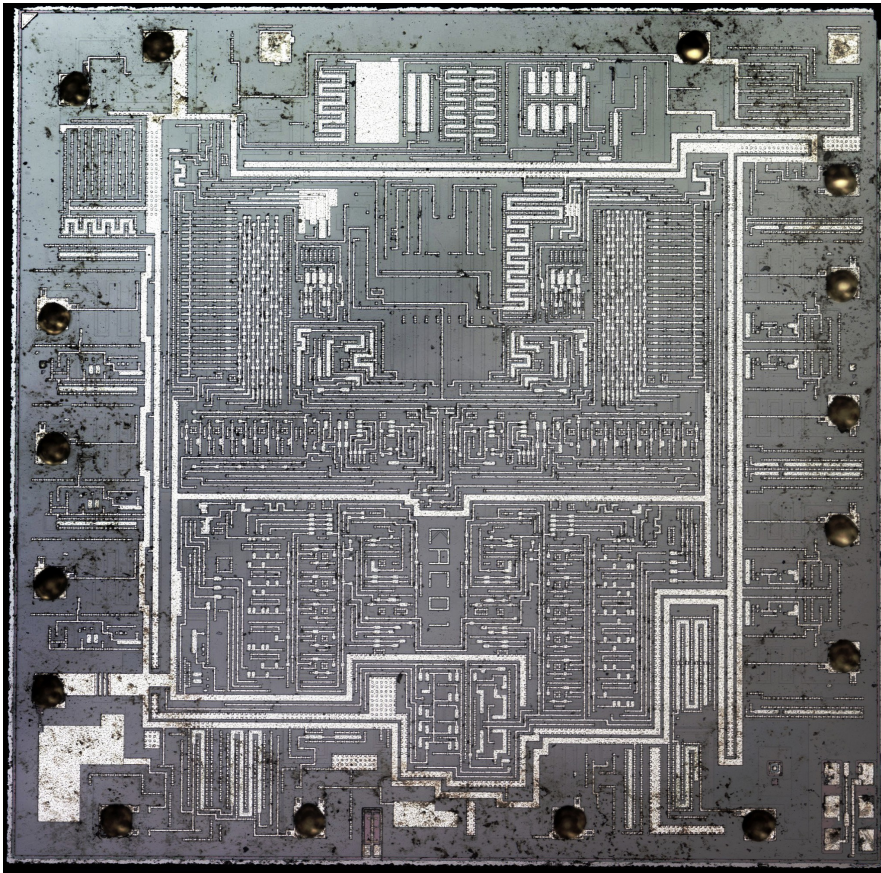
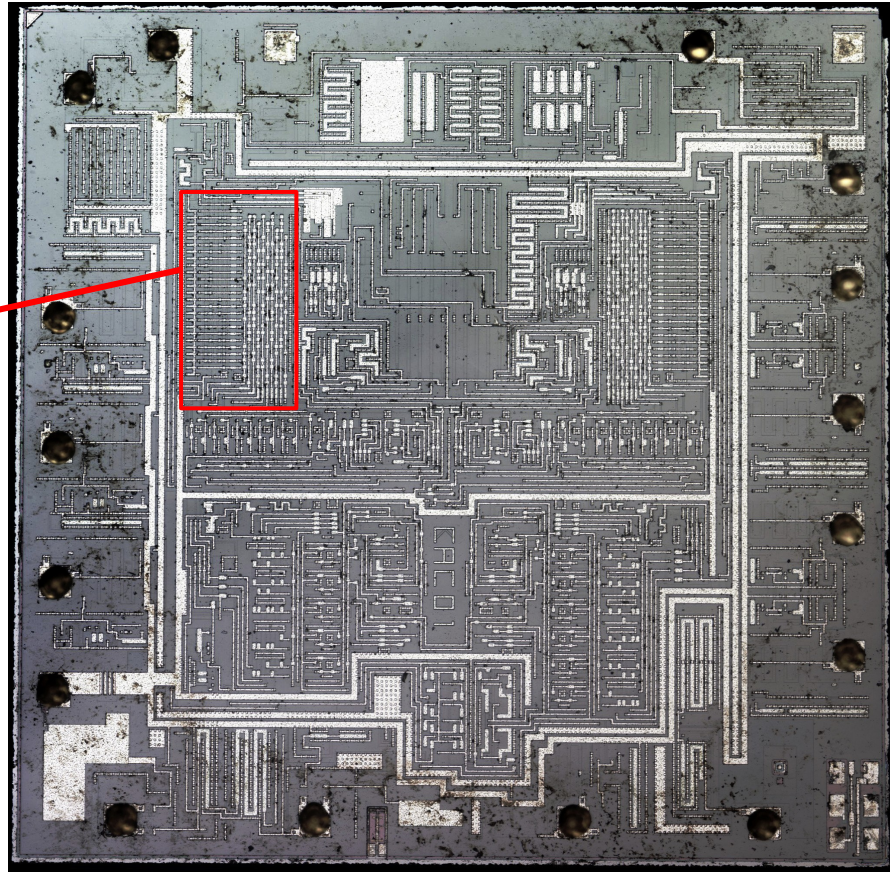
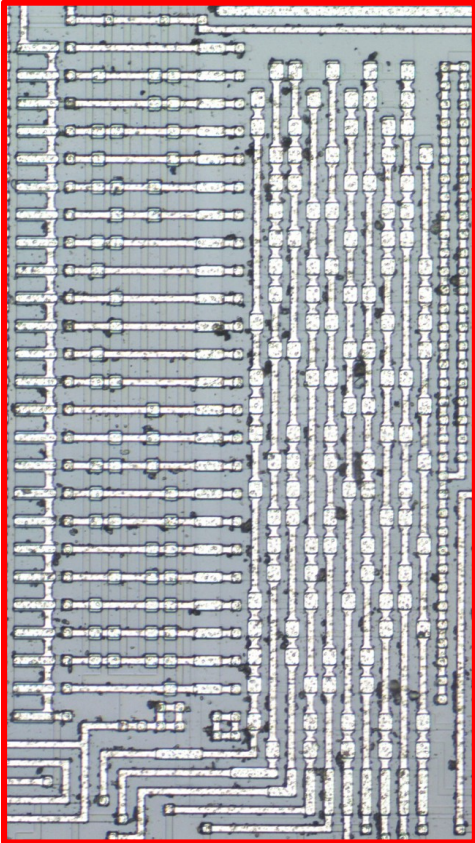


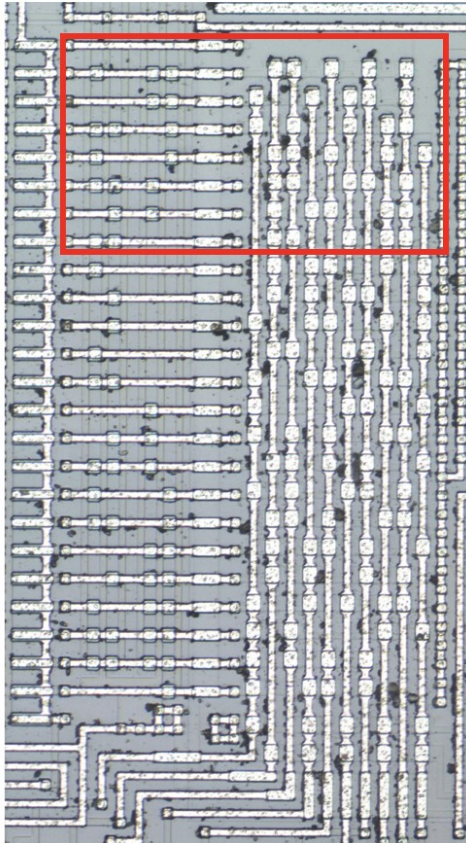
Photo: Robert Baruch
project5474.org

ROM



Touch-Tone phone chip

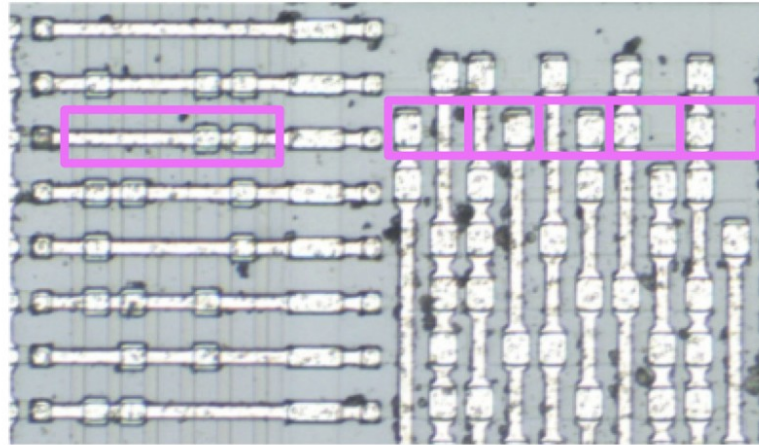
ROM



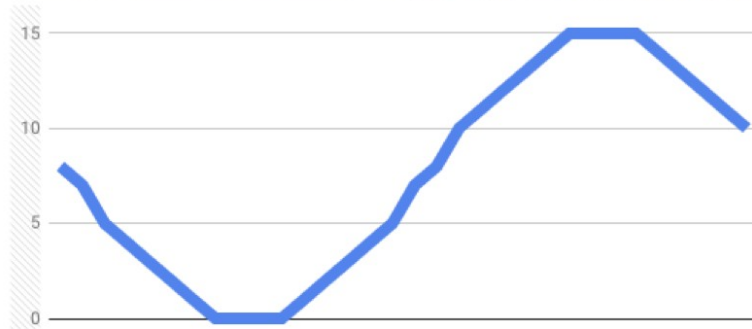
Data

Address
decode

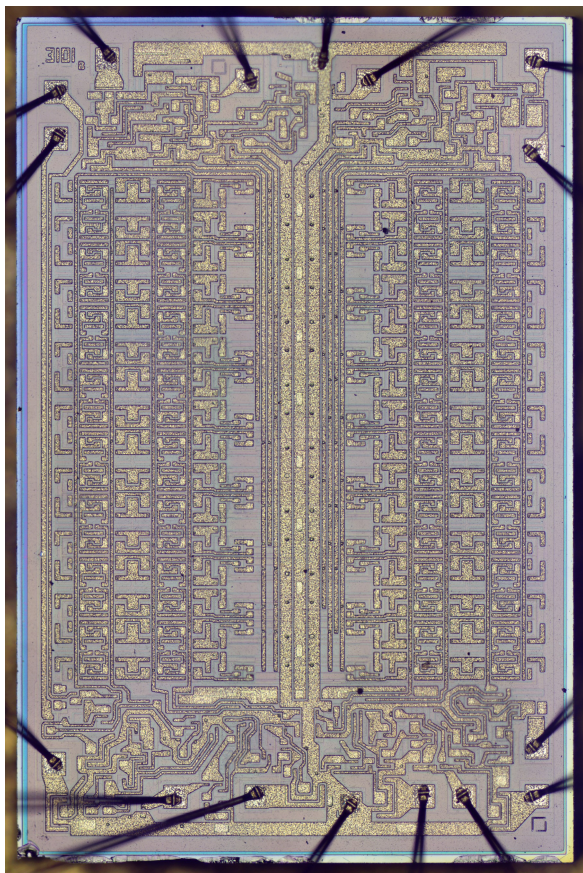
00 11



10011



Original



Suspect

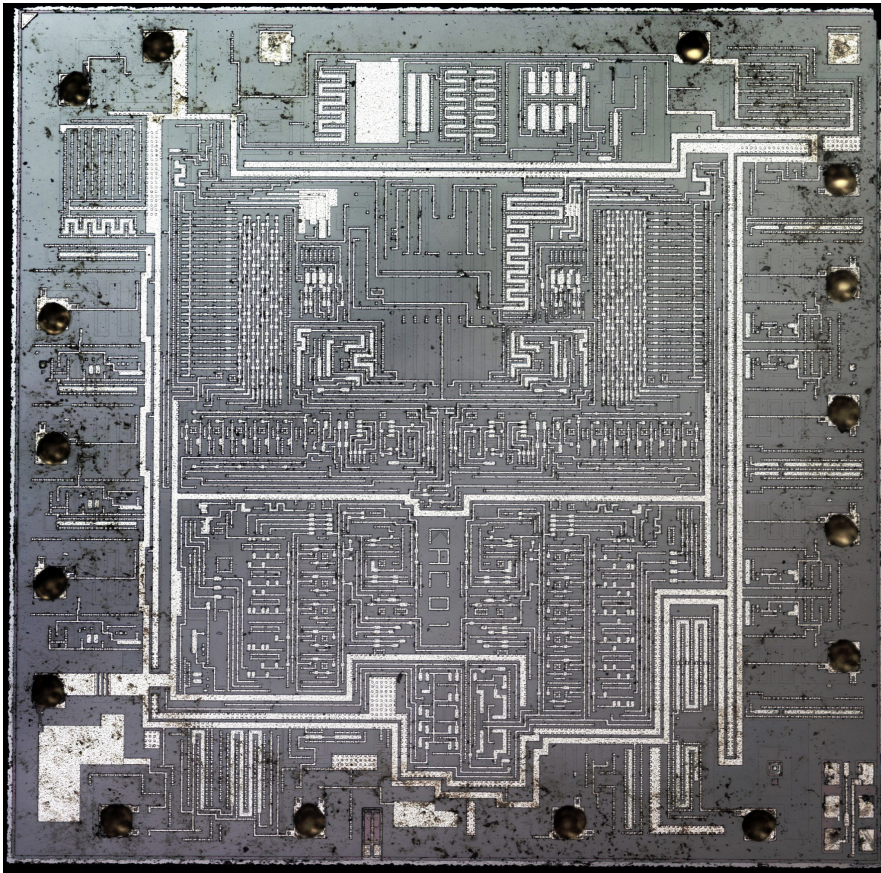
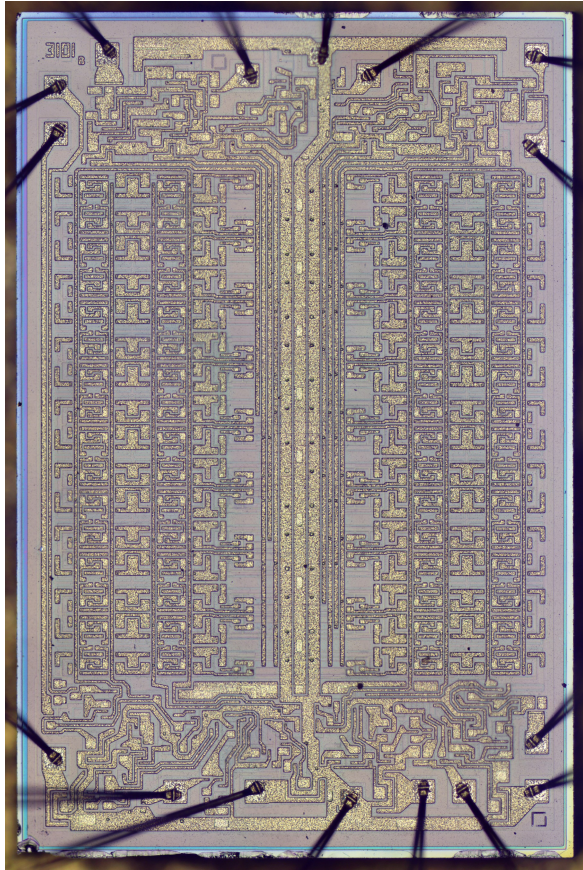


Photo: Robert Baruch
project5474.org

Original



Suspect

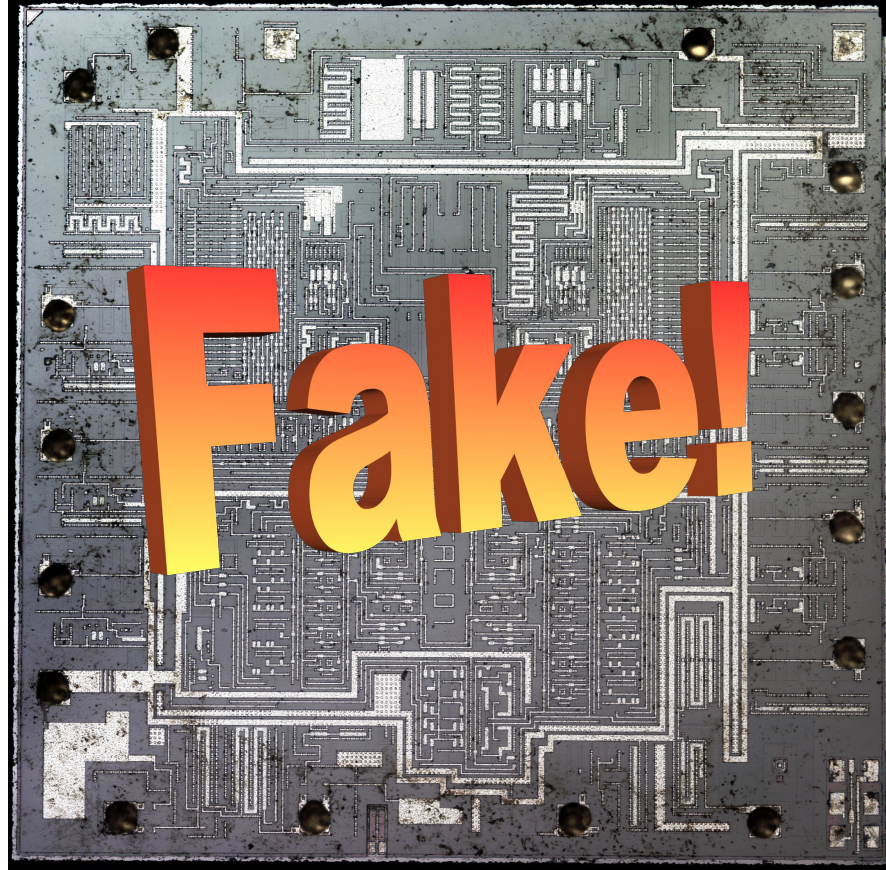
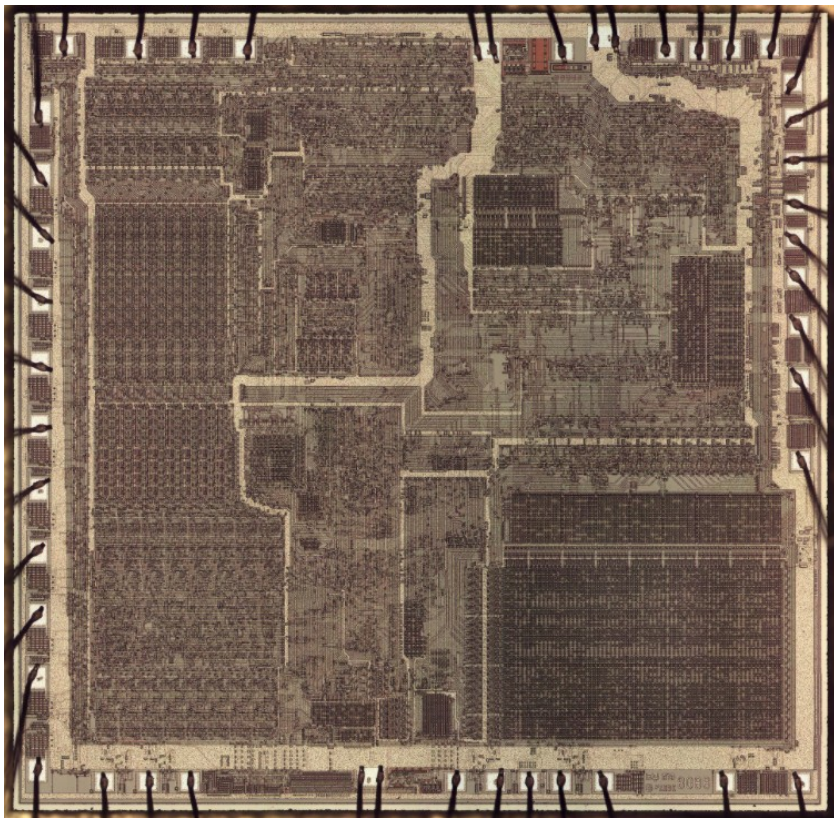


Photo: Robert Baruch
project5474.org

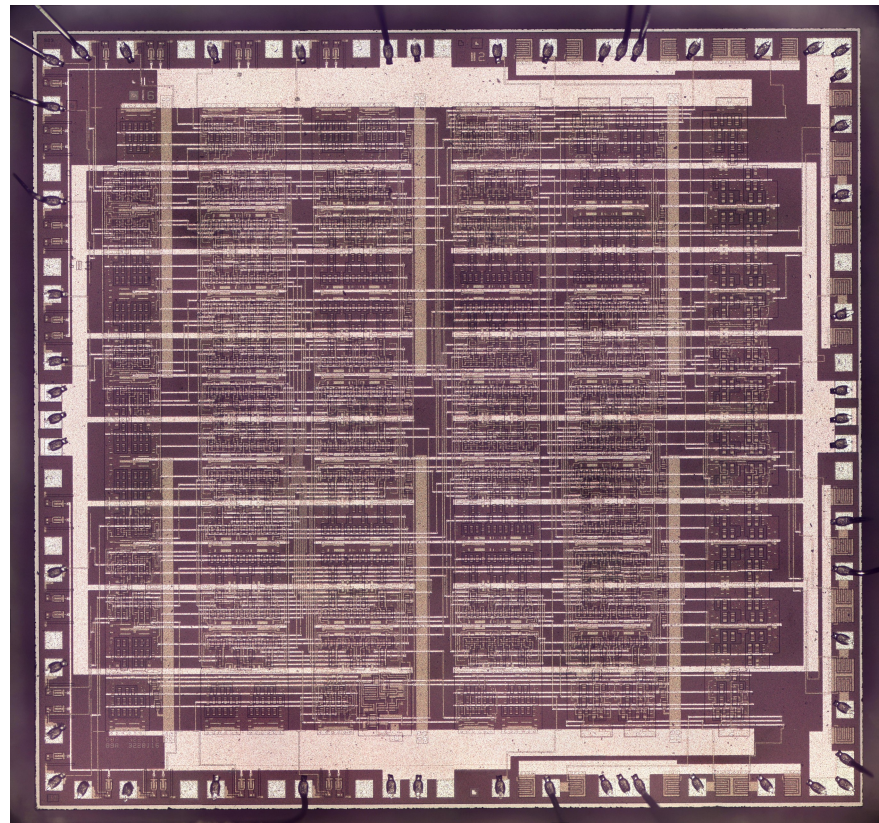
8086 processor



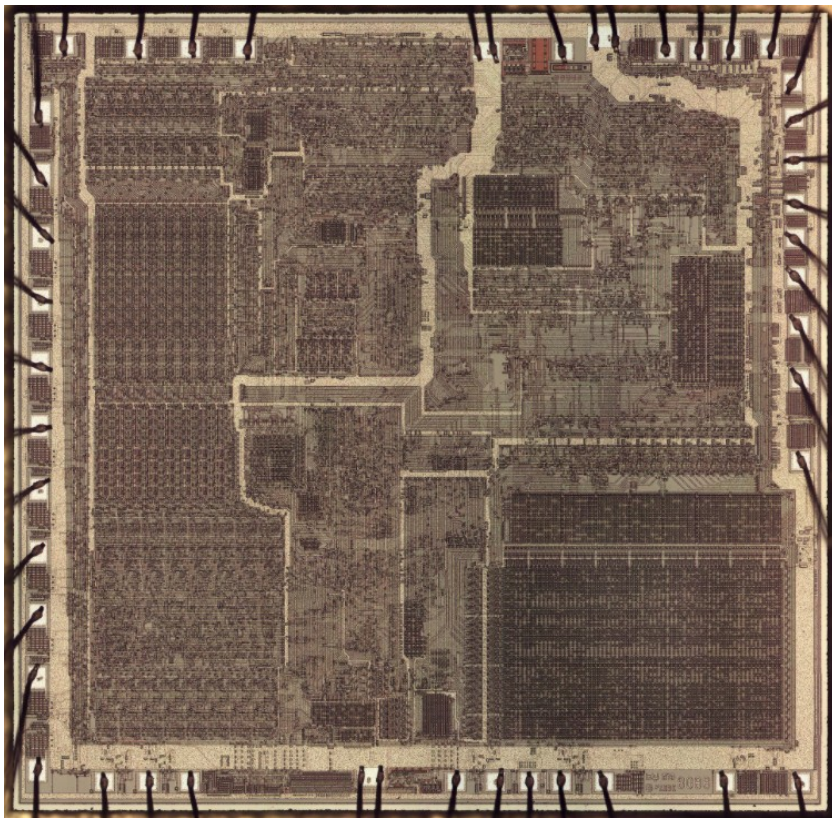
Original



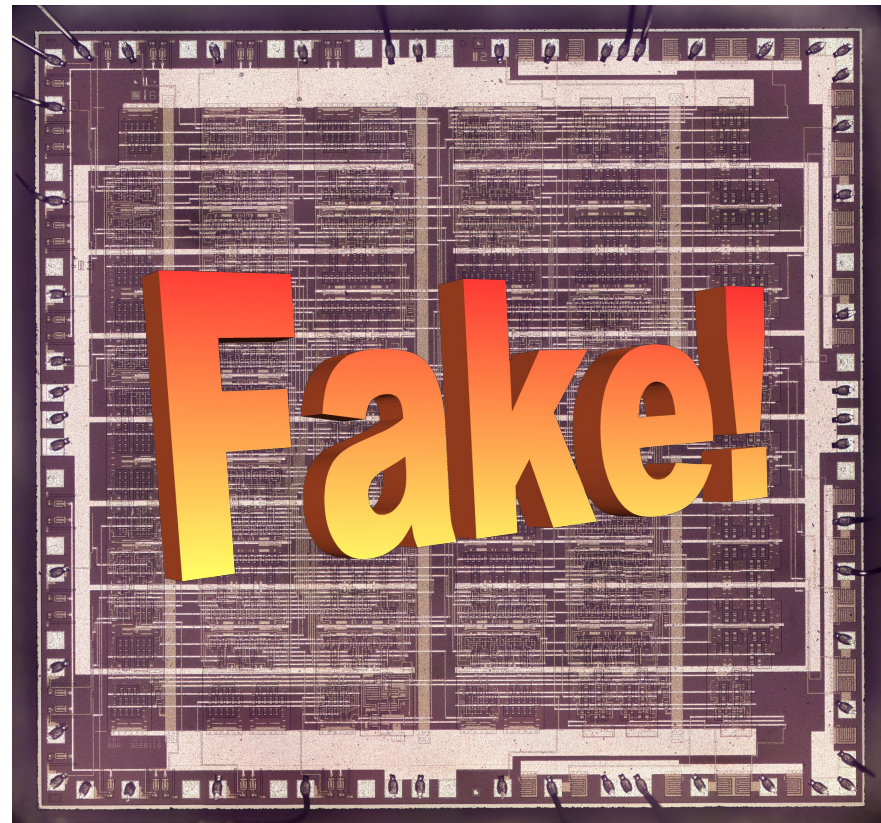
Suspect



Original

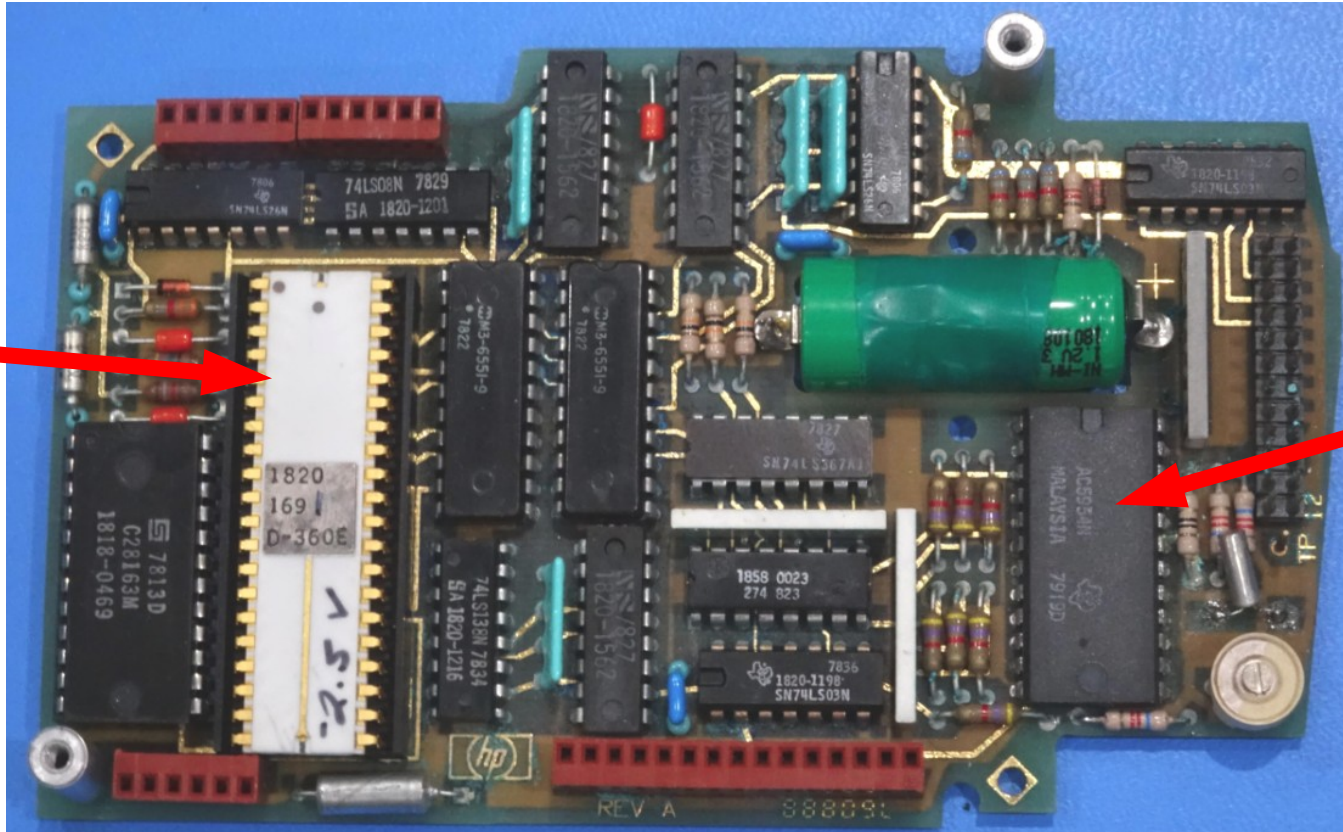
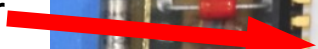


Suspect



HP real-time clock module

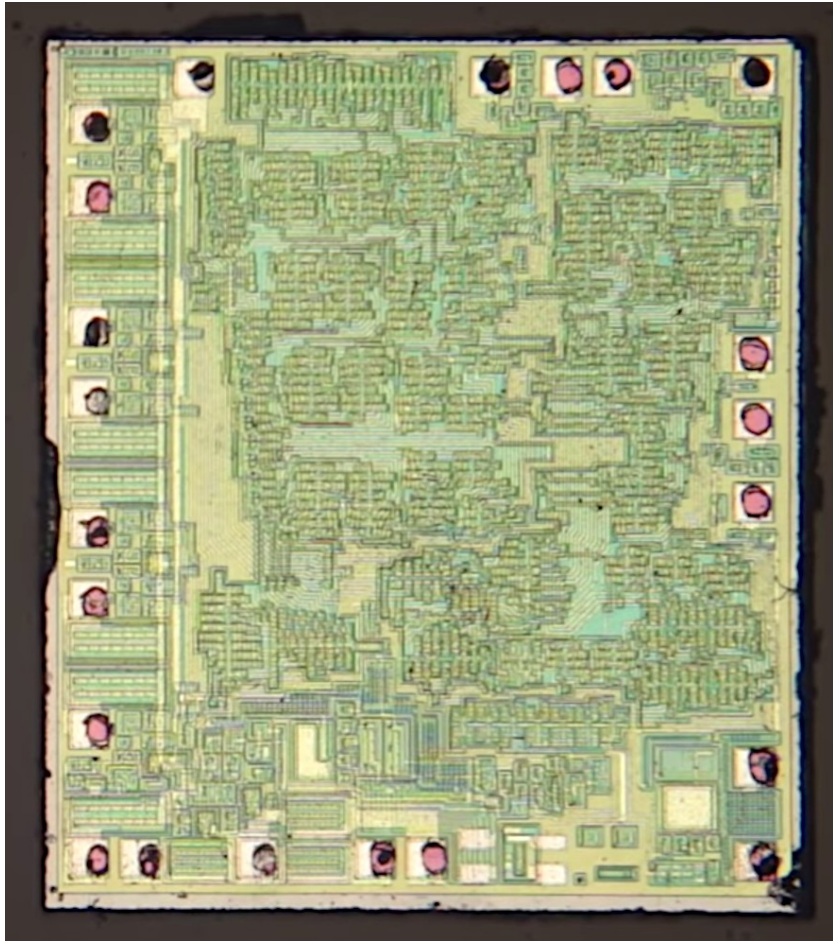
Nanoprocessor



TI watch chip



Original



Suspect

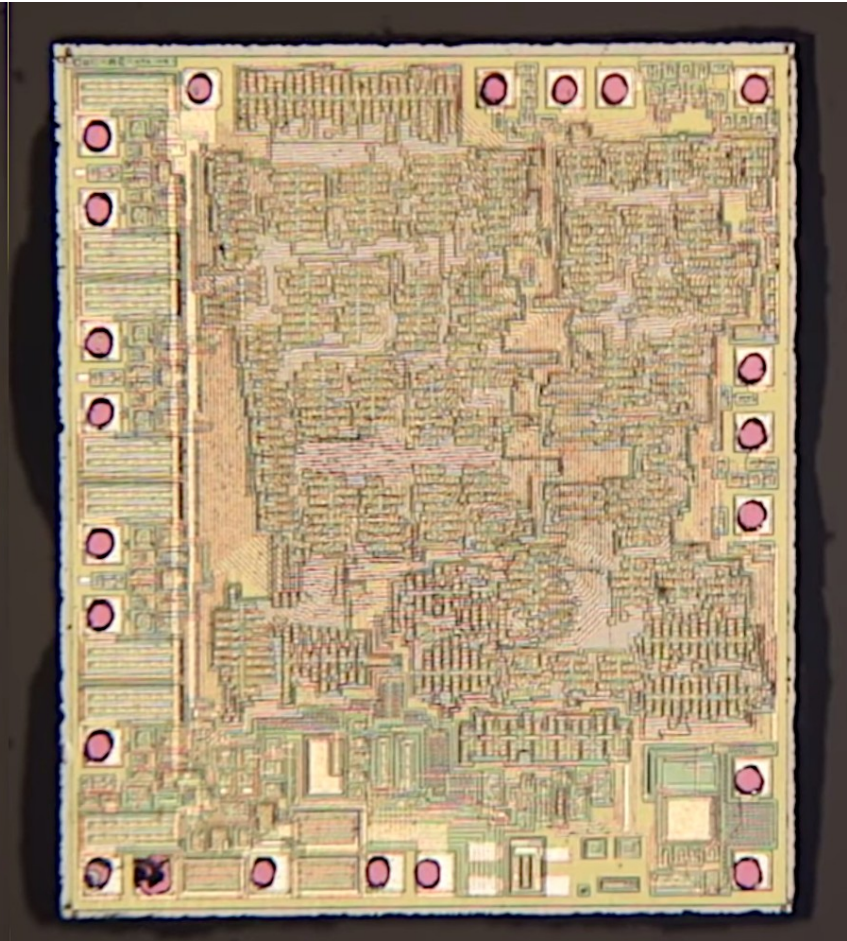
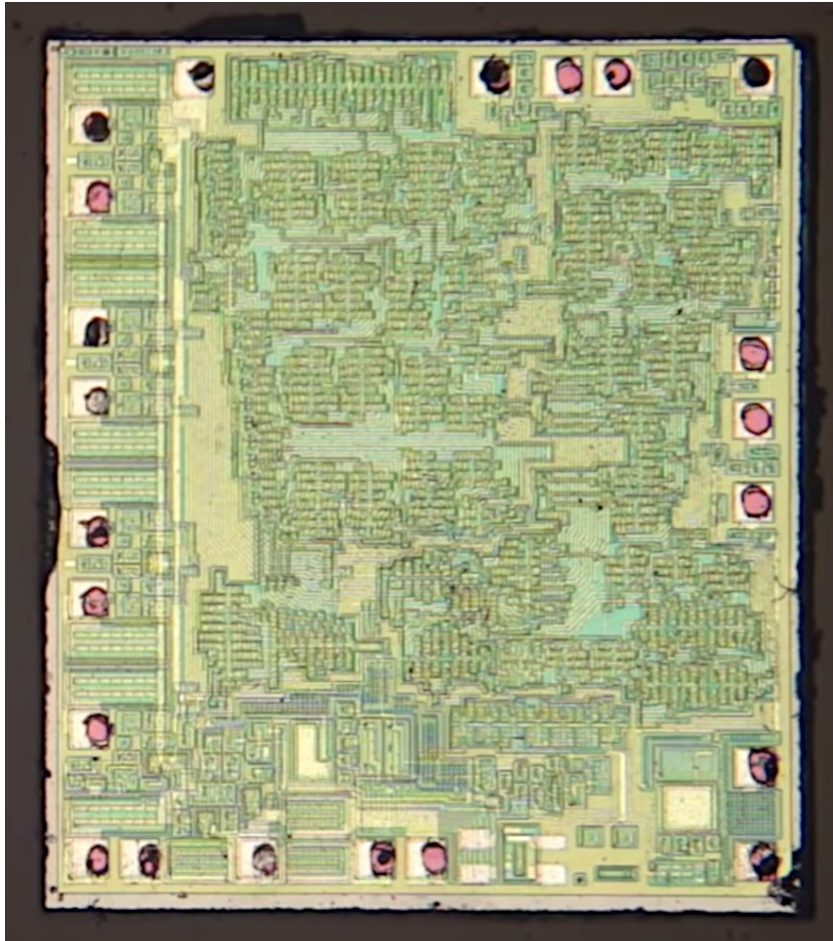


Photo:
@CuriousMarc

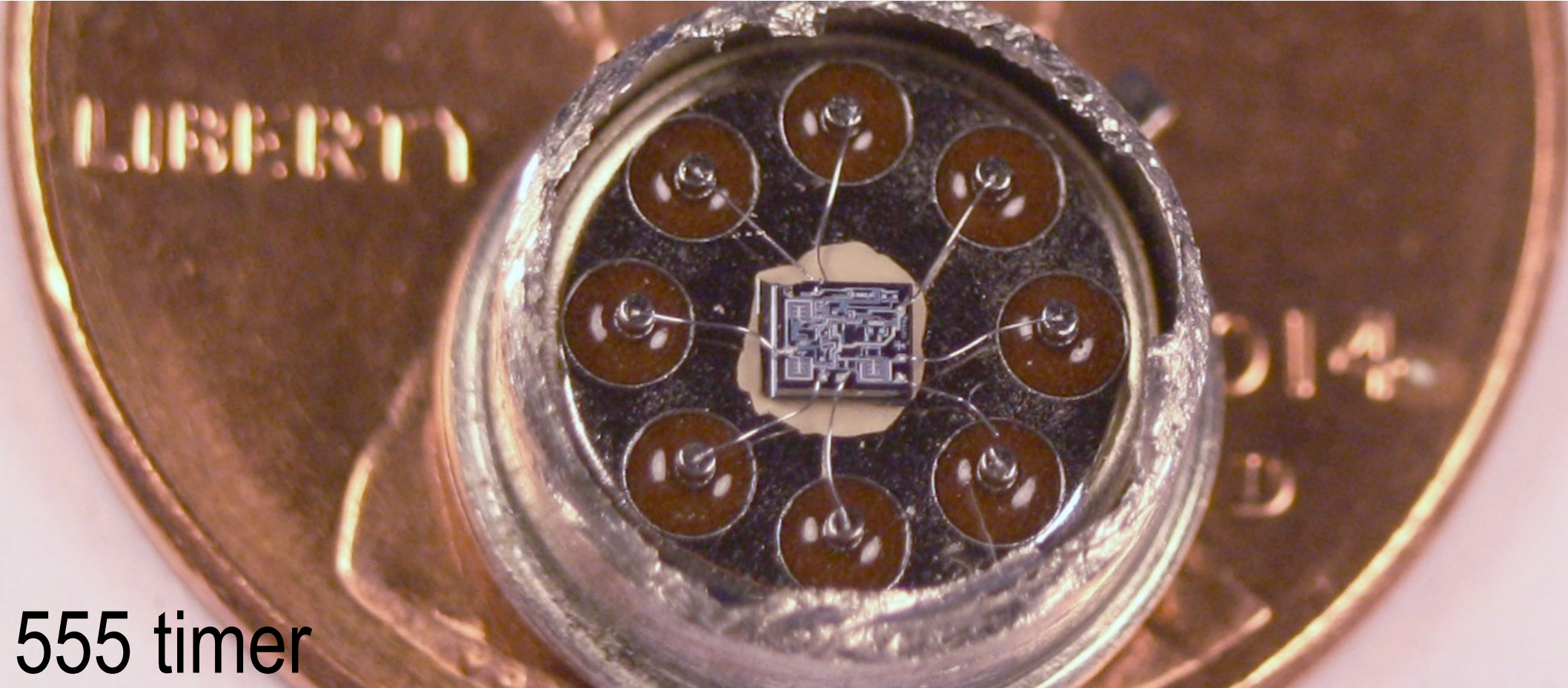
Original



Suspect



Looking at chips yourself



555 timer

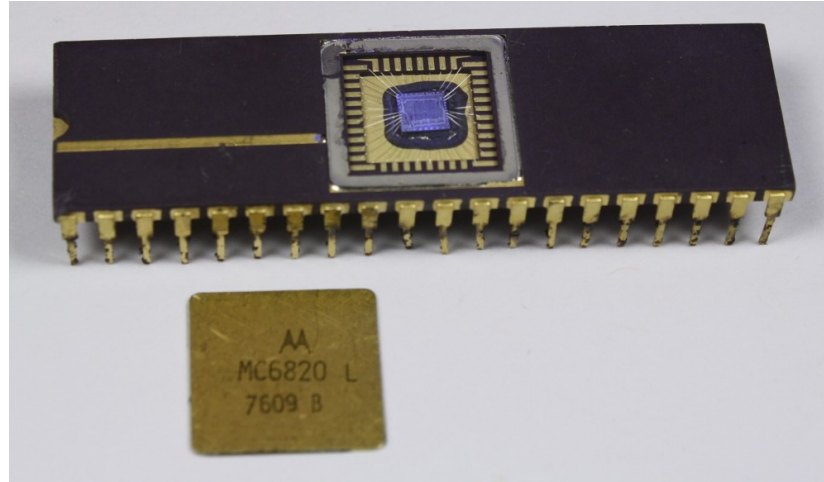
How to get to the die?



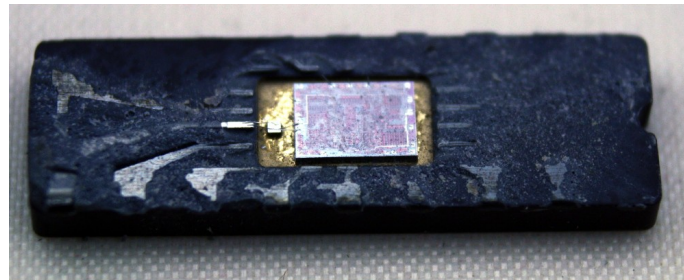
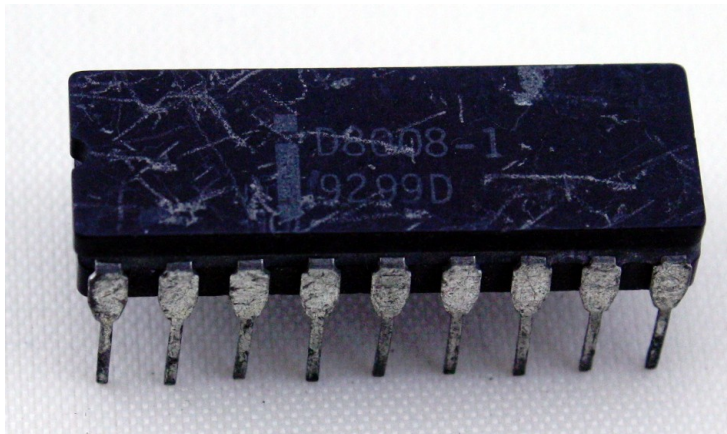
Photo: zeptobars

Hard way: boil chips in sulfuric / nitric acid

Acid-free way: chips without epoxy



Hacksaw
(jeweler's saw)
or chisel

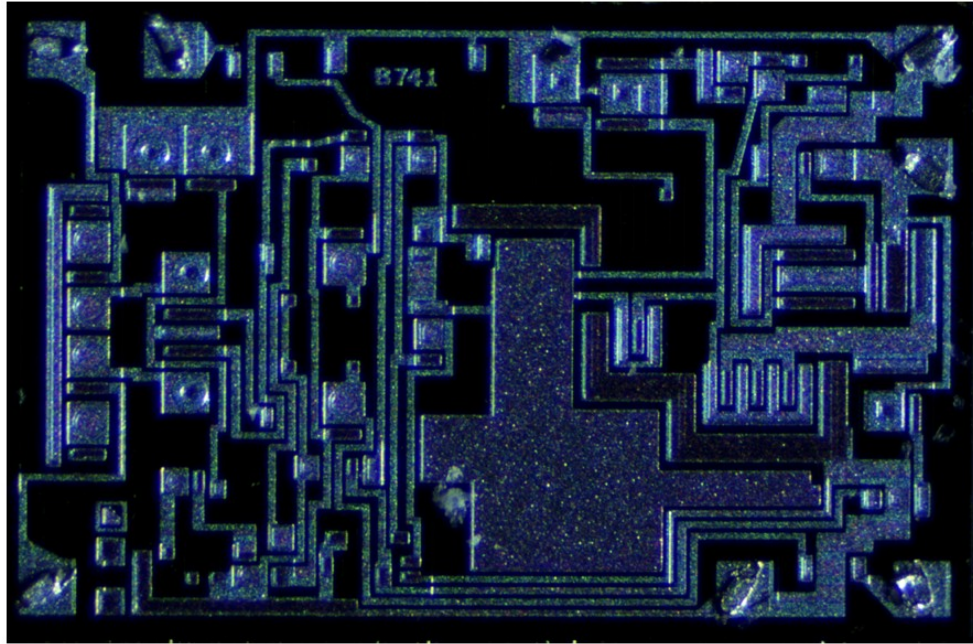


Die photos: Metallurgical microscope

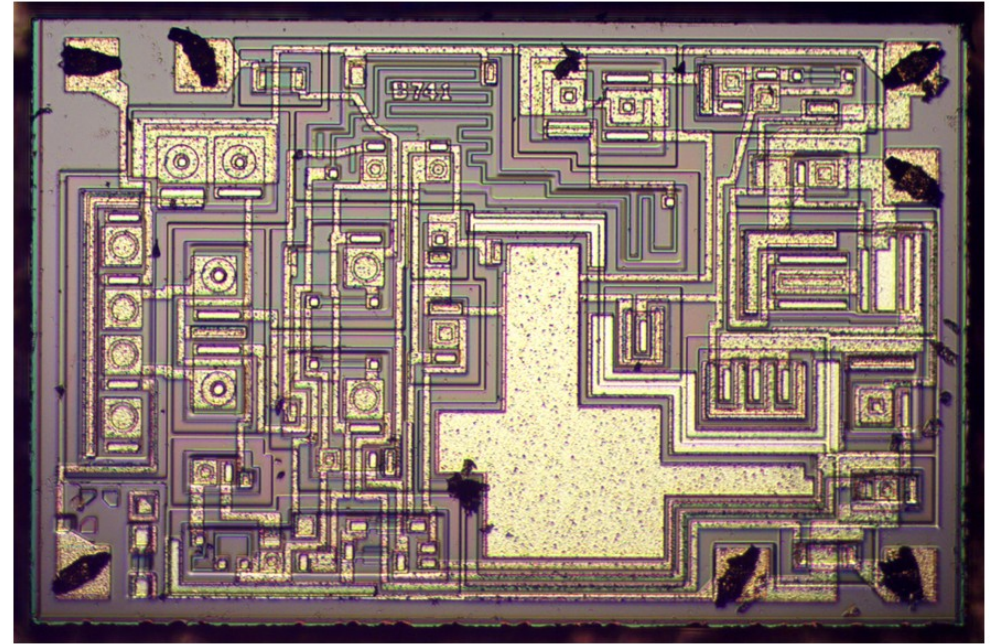


Shines light from above through lens

741 op amp (1968)

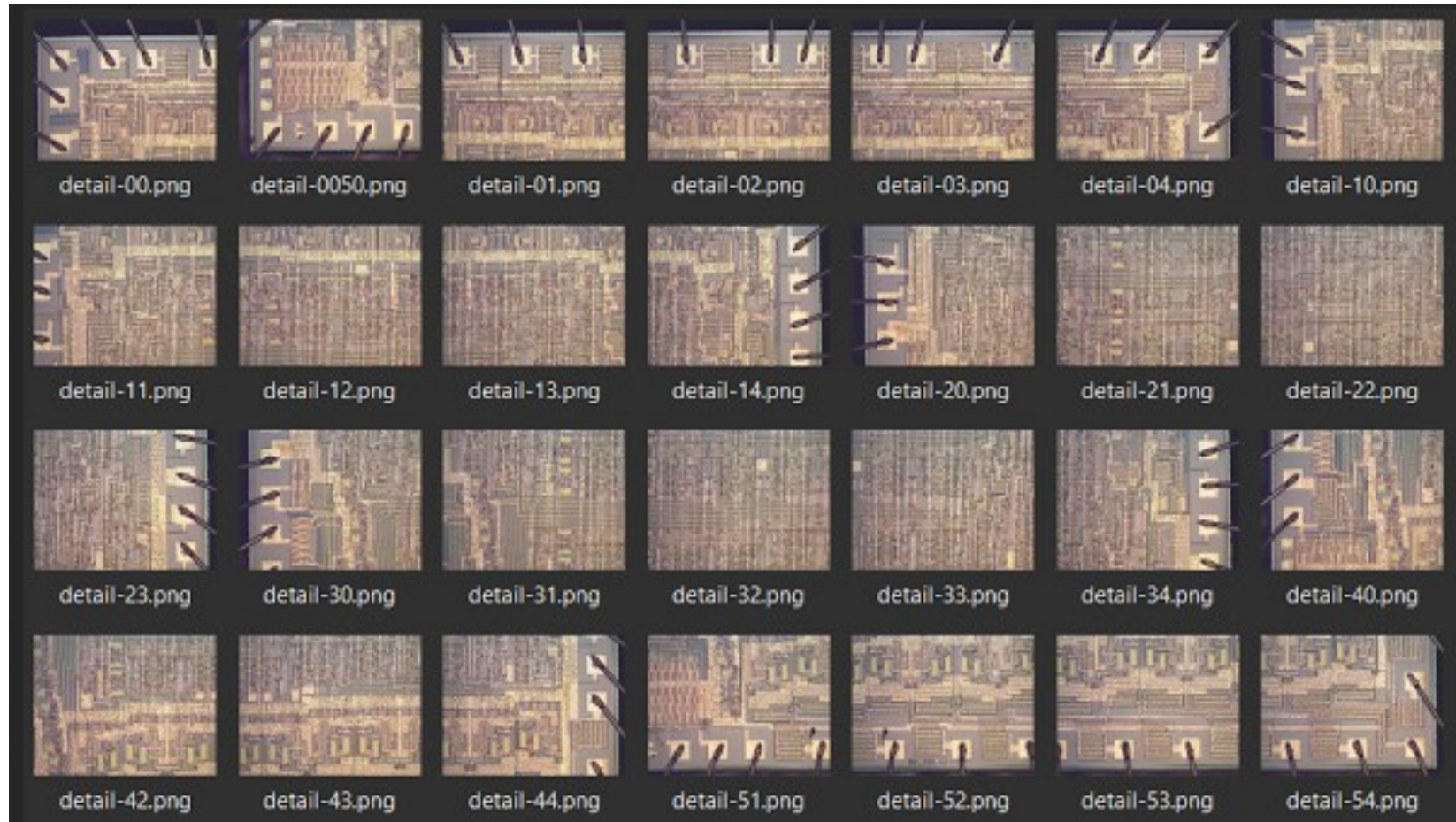


**Regular
microscope**



**Metallurgical
microscope**

Stitch photos together for high-resolution

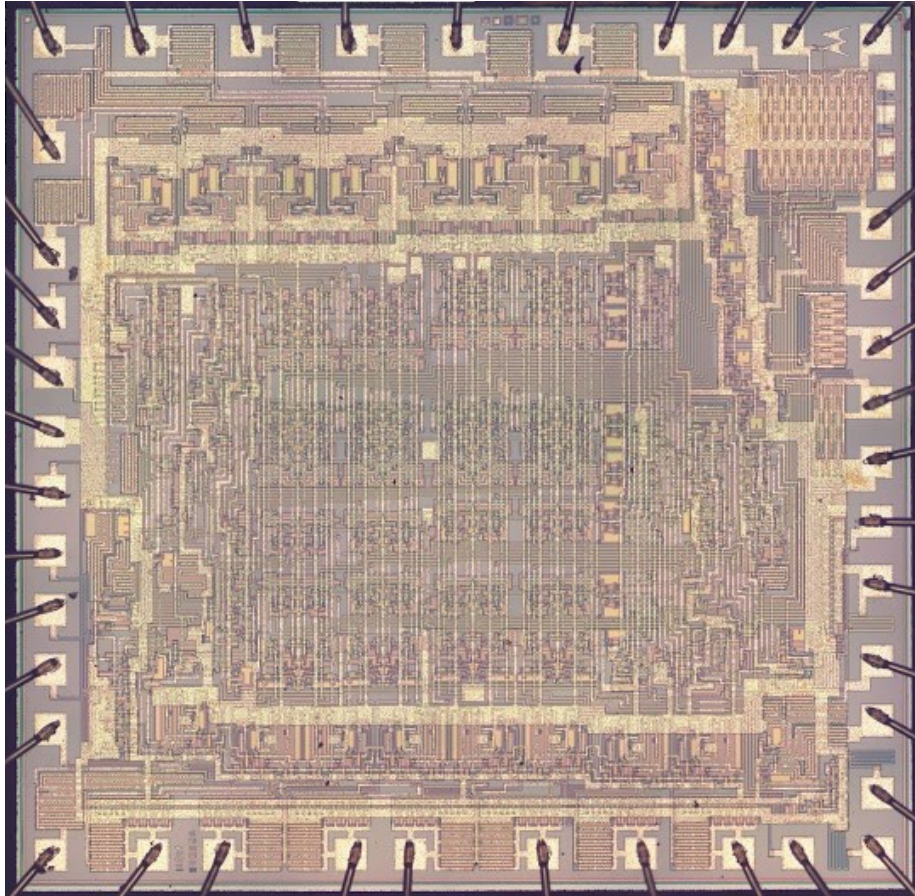


Hugin takes some practice



Tip: have lots
of overlap between
images

More info: righto.com/hugin



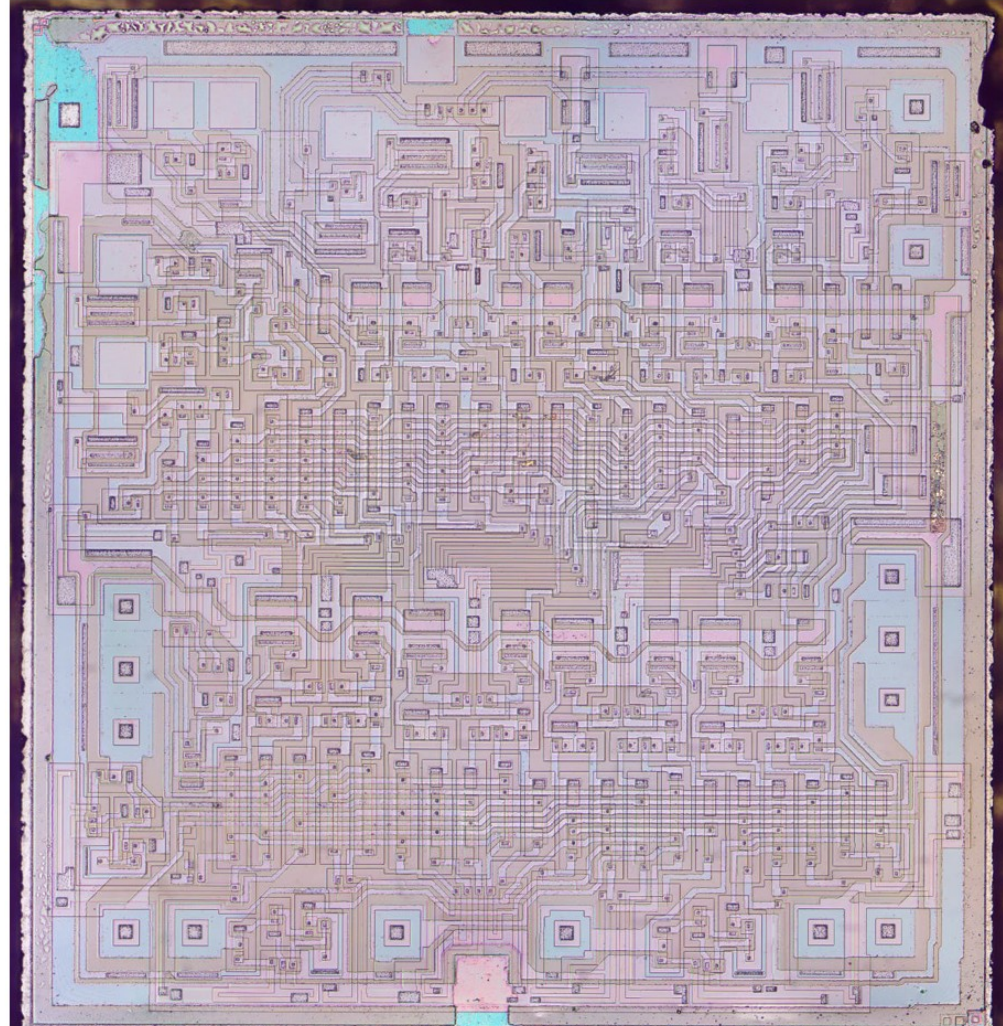
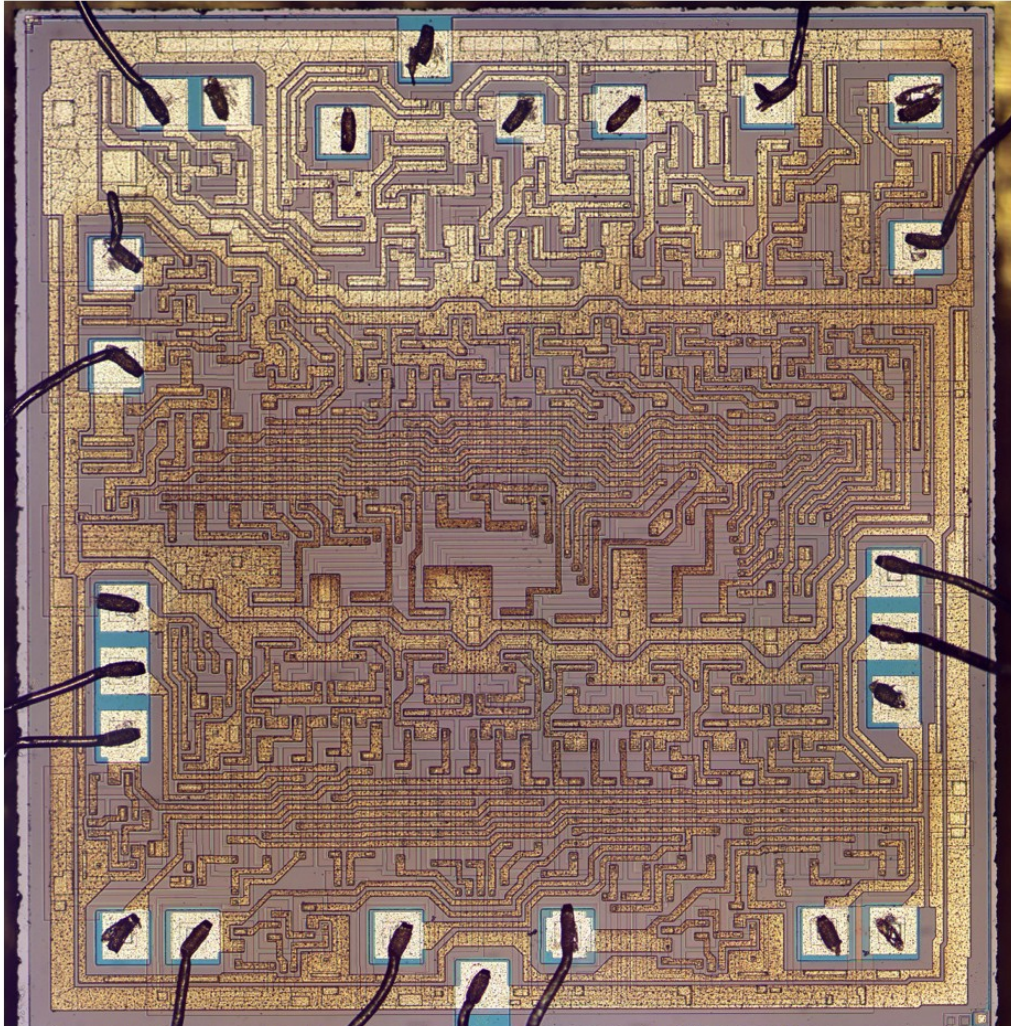
Motorola 6820 PIA chip

Removing the metal layer

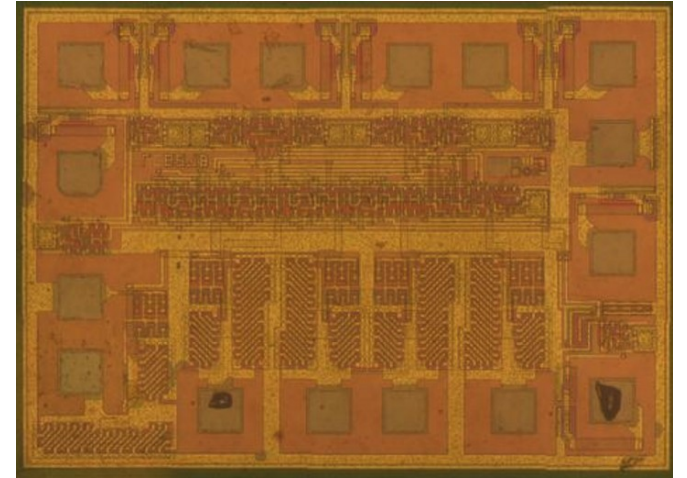
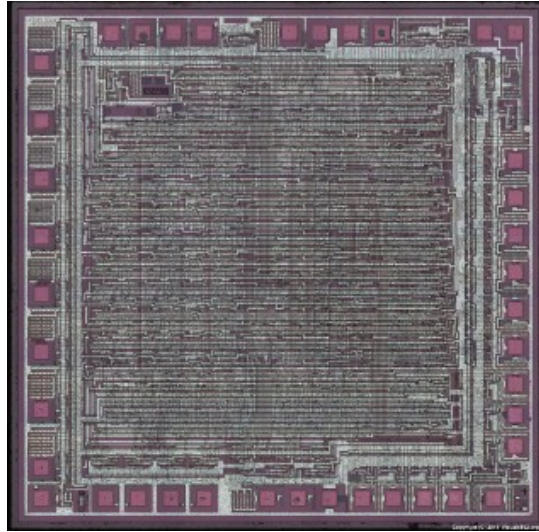
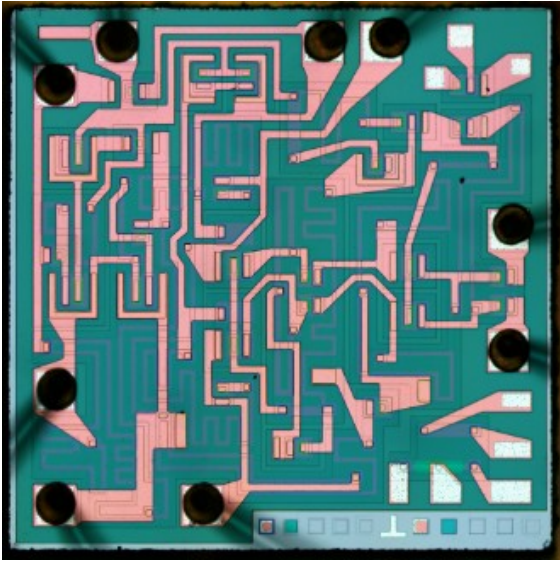
- Armour Etch glass etching cream removes the silicon dioxide layer
- Then hydrochloric acid dissolves the metal



74181 ALU



Getting started: download die photos



zeptobars.com, visual6502.org, siliconpr0n.org



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