

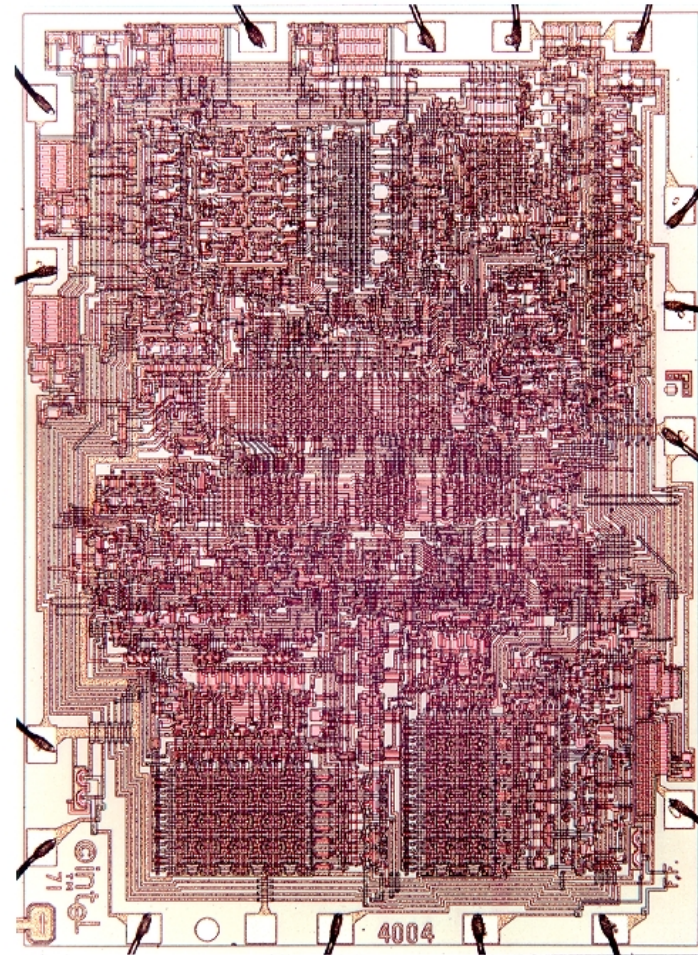
Lecture 24: Case Study: Intel Processors

Outline

- ❑ Evolution of Intel Microprocessors
 - Scaling from 4004 to Core i7
 - Courtesy of Intel Museum

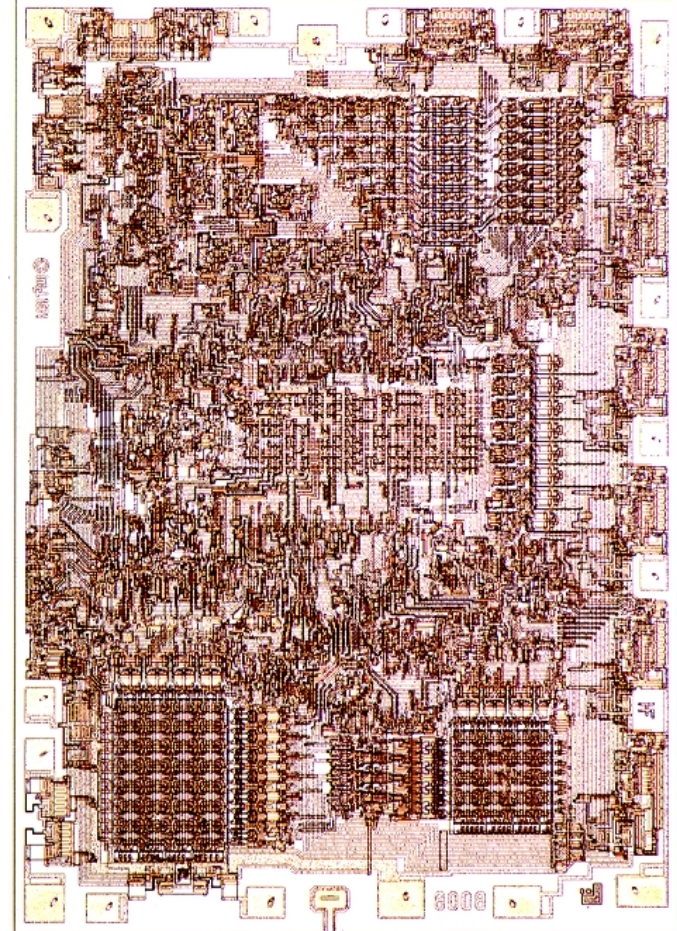
4004

- ❑ First microprocessor (1971)
 - For Busicom calculator
- ❑ Characteristics
 - 10 μm process
 - 2300 transistors
 - 400 – 800 kHz
 - 4-bit word size
 - 16-pin DIP package
- ❑ Masks hand cut from Rubylith
 - Drawn with color pencils
 - 1 metal, 1 poly (jumpers)
 - Diagonal lines (!)



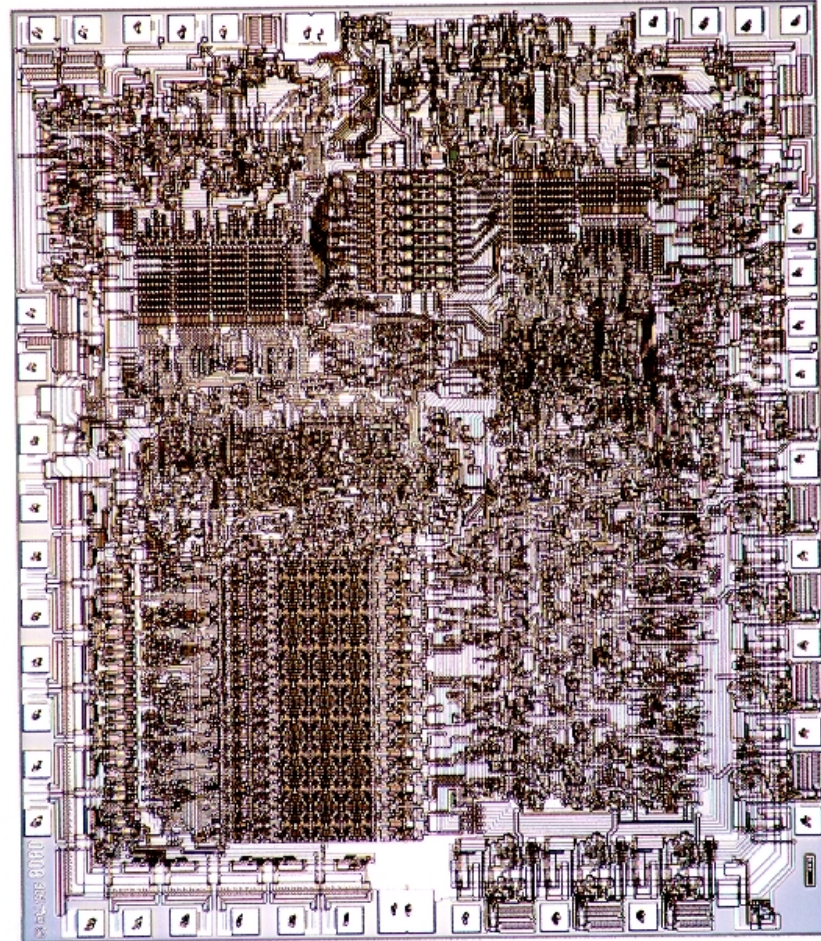
8008

- ❑ 8-bit follow-on (1972)
 - Dumb terminals
- ❑ Characteristics
 - 10 μm process
 - 3500 transistors
 - 500 – 800 kHz
 - 8-bit word size
 - 18-pin DIP package
- ❑ Note 8-bit datapaths
 - Individual transistors visible



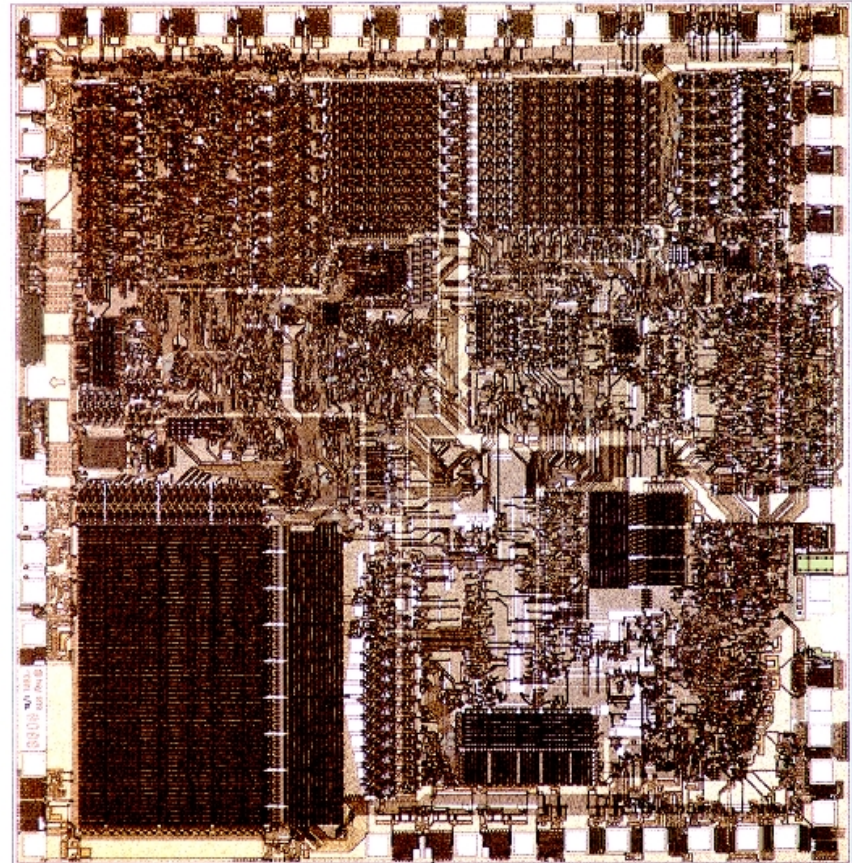
8080

- ❑ 16-bit address bus (1974)
 - Used in Altair computer
 - (early hobbyist PC)
- ❑ Characteristics
 - 6 μm process
 - 4500 transistors
 - 2 MHz
 - 8-bit word size
 - 40-pin DIP package



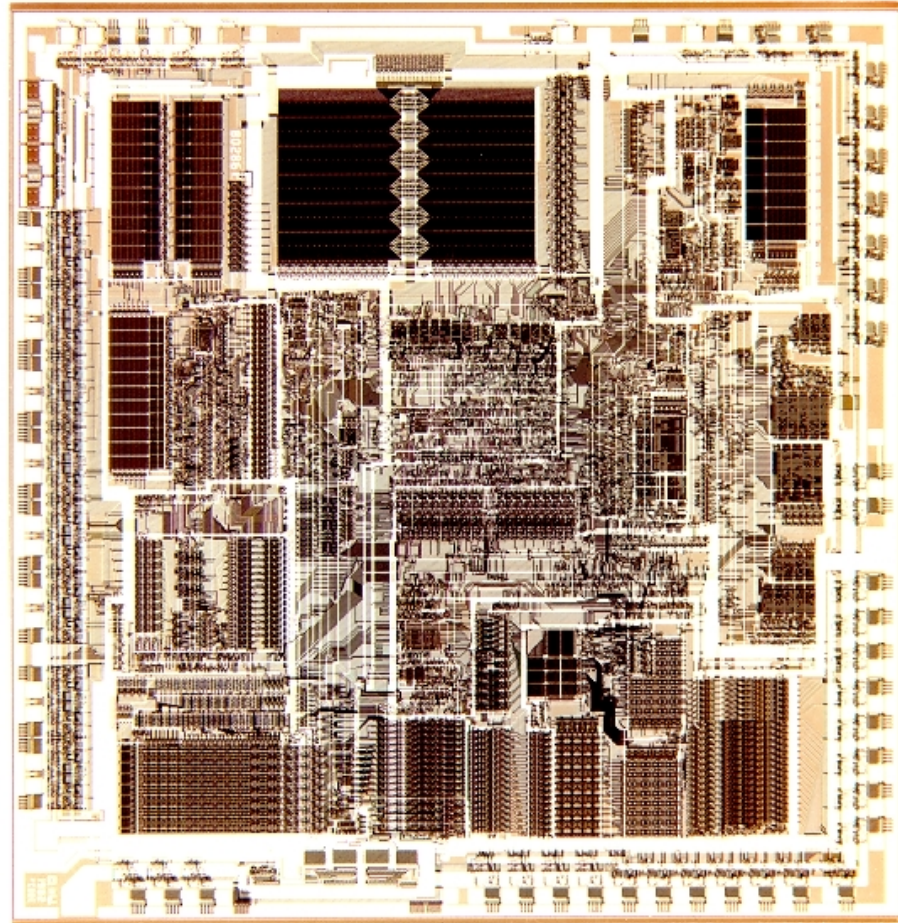
8086 / 8088

- ❑ 16-bit processor (1978-9)
 - IBM PC and PC XT
 - Revolutionary products
 - Introduced x86 ISA
- ❑ Characteristics
 - 3 μm process
 - 29k transistors
 - 5-10 MHz
 - 16-bit word size
 - 40-pin DIP package
- ❑ Microcode ROM



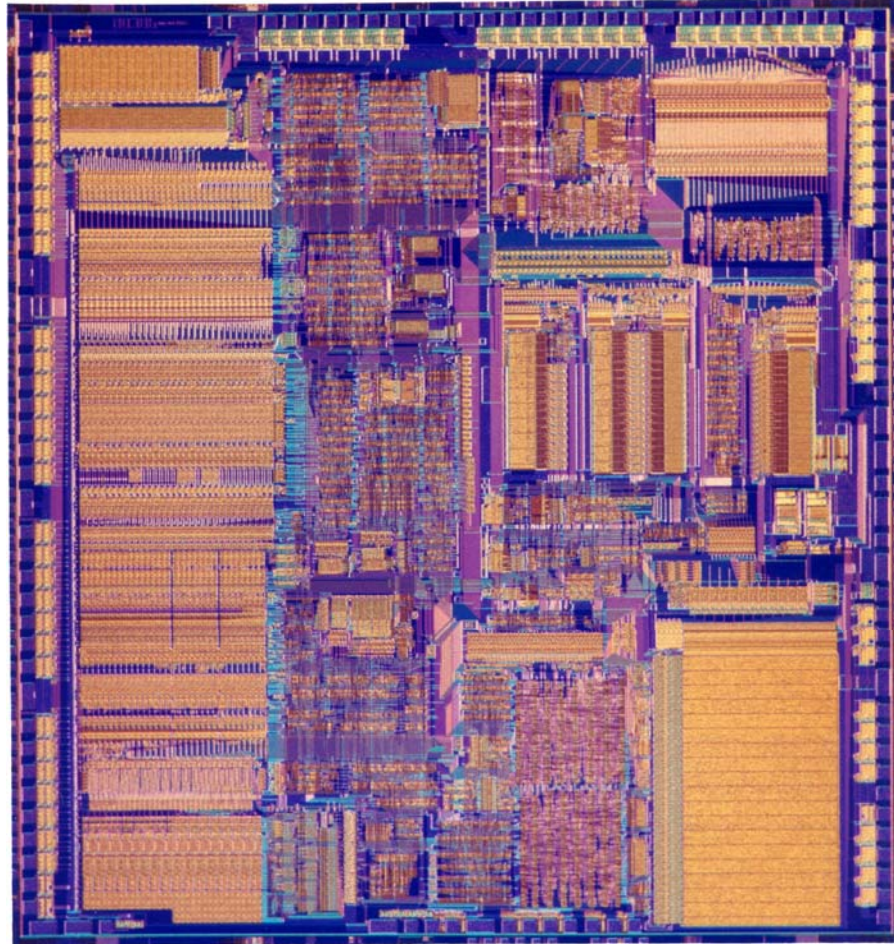
80286

- ❑ Virtual memory (1982)
 - IBM PC AT
- ❑ Characteristics
 - 1.5 μm process
 - 134k transistors
 - 6-12 MHz
 - 16-bit word size
 - 68-pin PGA
- ❑ Regular datapaths and ROMs
Bitslices clearly visible



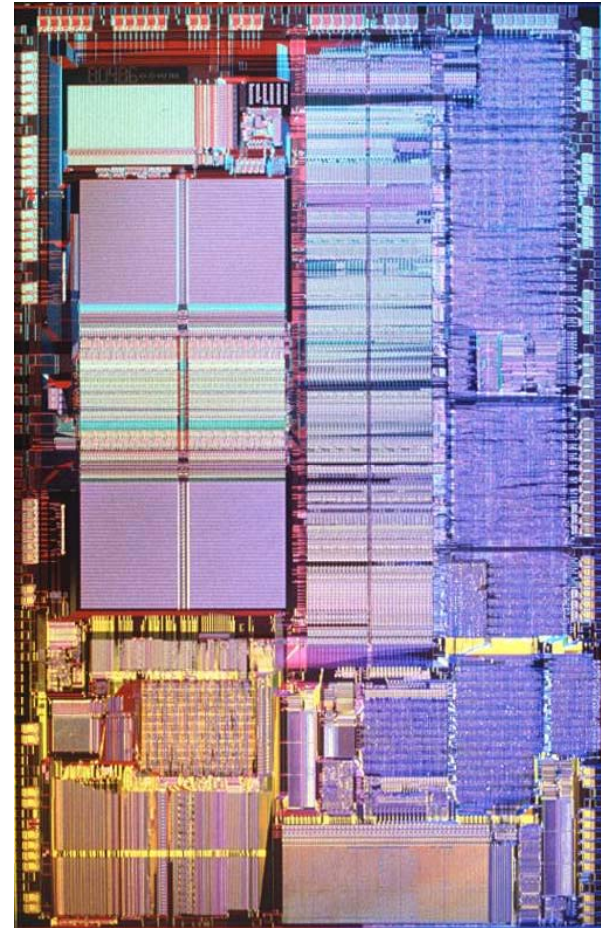
80386

- ❑ 32-bit processor (1985)
 - Modern x86 ISA
- ❑ Characteristics
 - 1.5-1 μm process
 - 275k transistors
 - 16-33 MHz
 - 32-bit word size
 - 100-pin PGA
- ❑ 32-bit datapath,
microcode ROM,
synthesized control



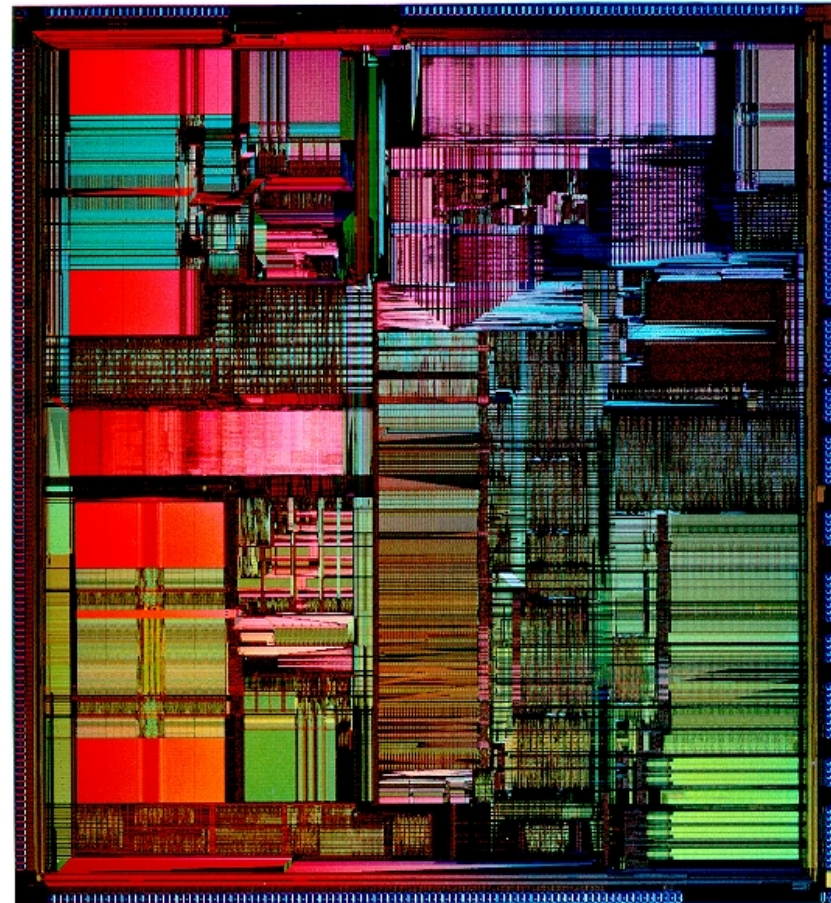
80486

- ❑ Pipelining (1989)
 - Floating point unit
 - 8 KB cache
- ❑ Characteristics
 - 1-0.6 μm process
 - 1.2M transistors
 - 25-100 MHz
 - 32-bit word size
 - 168-pin PGA
- ❑ Cache, Integer datapath, FPU, microcode, synthesized control



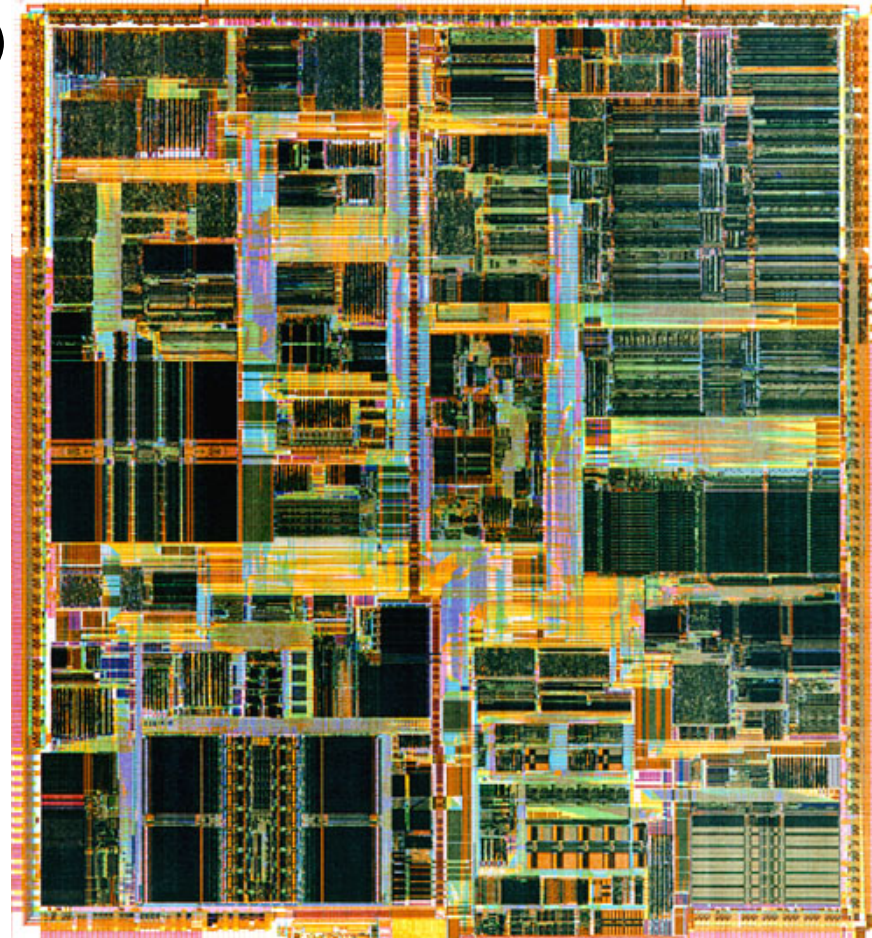
Pentium

- ❑ Superscalar (1993)
 - 2 instructions per cycle
 - Separate 8KB I\$ & D\$
- ❑ Characteristics
 - 0.8-0.35 μm process
 - 3.2M transistors
 - 60-300 MHz
 - 32-bit word size
 - 296-pin PGA
- ❑ Caches, datapath, FPU, control



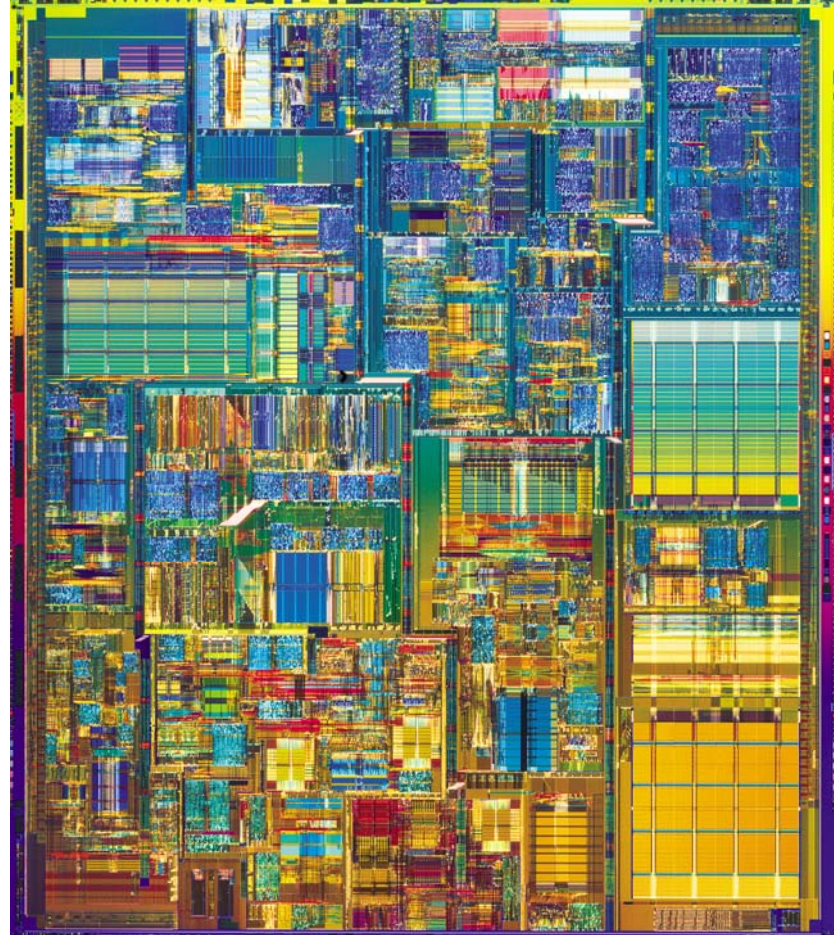
Pentium Pro / II / III

- ❑ Dynamic execution (1995-9)
 - 3 micro-ops / cycle
 - Out of order execution
 - 16-32 KB I\$ & D\$
 - Multimedia instructions
 - PIII adds 256+ KB L2\$
- ❑ Characteristics
 - 0.6-0.18 μm process
 - 5.5M-28M transistors
 - 166-1000 MHz
 - 32-bit word size
 - MCM / SECC



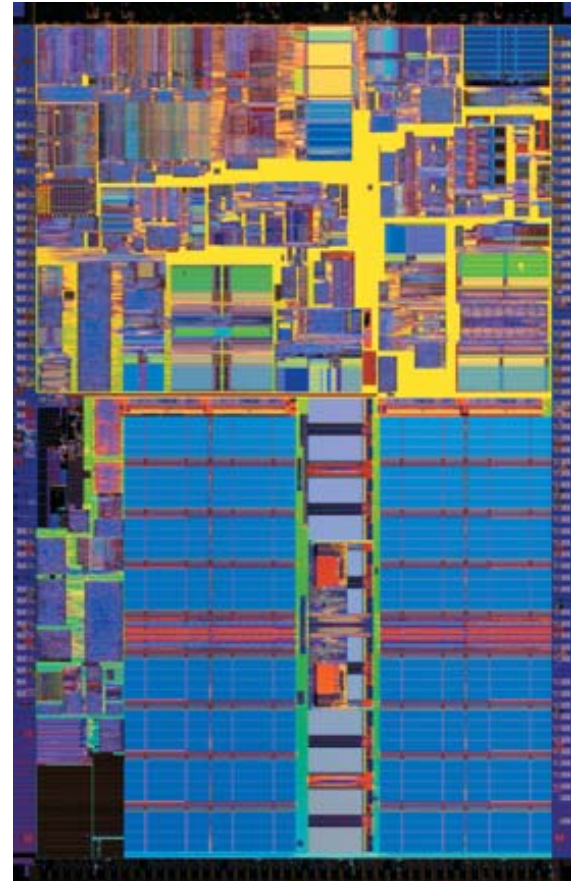
Pentium 4

- ❑ Deep pipeline (2001)
 - Very fast clock
 - 256-1024 KB L2\$
- ❑ Characteristics
 - 180 – 65 nm process
 - 42-125M transistors
 - 1.4-3.4 GHz
 - Up to 160 W
 - 32/64-bit word size
 - 478-pin PGA
- ❑ Units start to become invisible on this scale



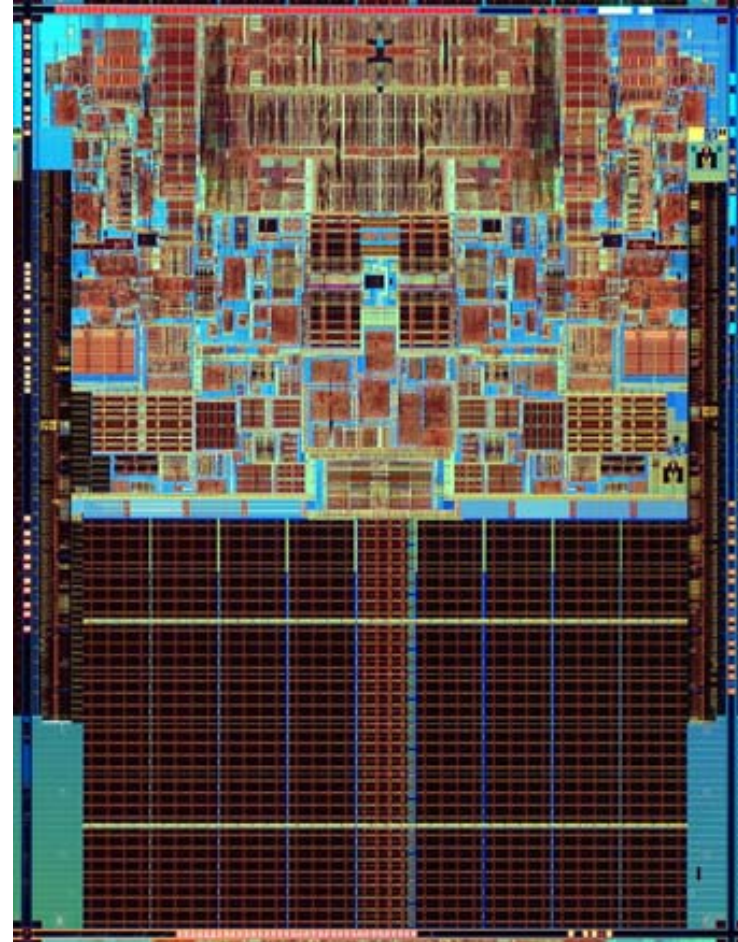
Pentium M

- ❑ Pentium III derivative
 - Better power efficiency
 - 1-2 MB L2\$
- ❑ Characteristics
 - 130 – 90 nm process
 - 140M transistors
 - 0.9-2.3 GHz
 - 6-25 W
 - 32-bit word size
 - 478-pin PGA
- ❑ Cache dominates chip area



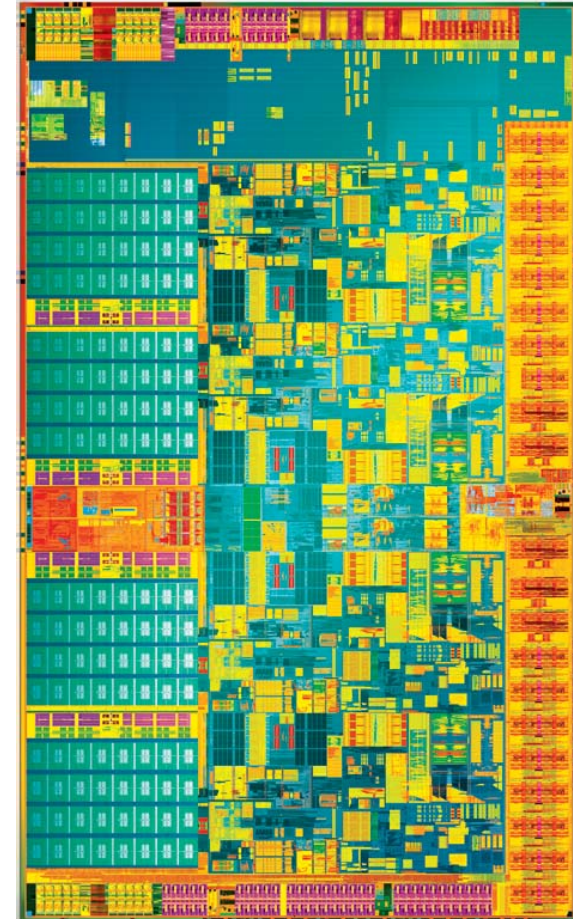
Core2 Duo

- ❑ Dual core (2006)
 - 1-2 MB L2\$ / core
- ❑ Characteristics
 - 65-45 nm process
 - 291M transistors
 - 1.6-3+ GHz
 - 65 W
 - 32/64 bit word size
 - 775 pin LGA
- ❑ Much better performance/power efficiency



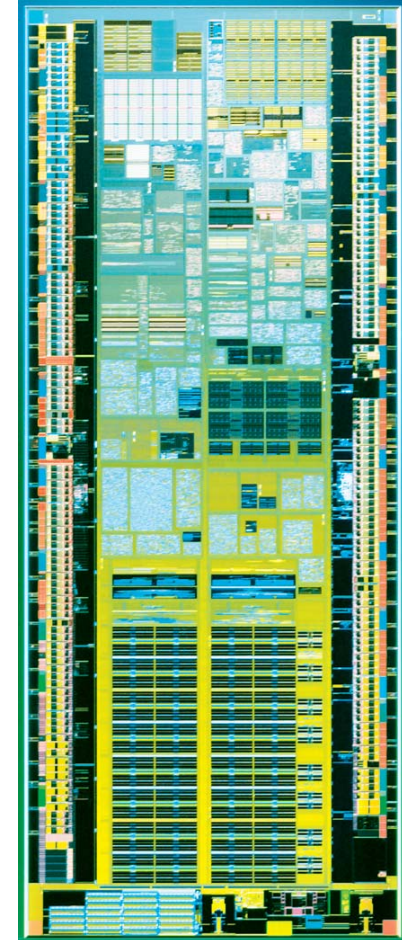
Core i7

- ❑ Quad core (& more)
 - Pentium-style architecture
 - 2 MB L3\$ / core
- ❑ Characteristics
 - 45-32 nm process
 - 731M transistors
 - 2.66-3.33+ GHz
 - Up to 130 W
 - 32/64 bit word size
 - 1366-pin LGA
 - Multithreading
- ❑ On-die memory controller



Atom

- ❑ Low power CPU for netbooks
 - Pentium-style architecture
 - 512KB+ L2\$
- ❑ Characteristics
 - 45-32 nm process
 - 47M transistors
 - 0.8-1.8+ GHz
 - 1.4-13 W
 - 32/64-bit word size
 - 441-pin FCBGA
- ❑ Low voltage (0.7 – 1.1 V) operation
 - Excellent performance/power



Summary

- 10^4 increase in transistor count, clock frequency over 3 decades!

Processor	Year	Feature Size (μm)	Transistors	Frequency (MHz)	Word Size	Power (W)	Cache (L1 / L2 / L3)	Package
4004	1971	10	2.3k	0.75	4	0.5	none	16-pin DIP
8008	1972	10	3.5k	0.5–0.8	8	0.5	none	18-pin DIP
8080	1974	6	6k	2	8	0.5	none	40-pin DIP
8086	1978	3	29k	5–10	16	2	none	40-pin DIP
80286	1982	1.5	134k	6–12	16	3	none	68-pin PGA
Intel386	1985	1.5–1.0	275k	16–25	32	1–1.5	none	100-pin PGA
Intel486	1989	1–0.6	1.2M	25–100	32	0.3–2.5	8K	168-pin PGA
Pentium	1993	0.8–0.35	3.2–4.5M	60–300	32	8–17	16K	296-pin PGA
Pentium Pro	1995	0.6–0.35	5.5M	166–200	32	29–47	16K / 256K+	387-pin MCM PGA
Pentium II	1997	0.35–0.25	7.5M	233–450	32	17–43	32K / 256K+	242-pin SECC
Pentium III	1999	0.25–0.18	9.5–28M	450–1000	32	14–44	32K / 512K	330-pin SECC2
Pentium 4	2000	180–65 nm	42–178M	1400–3800	32/64	21–115	20K+ / 256K+	478-pin PGA
Pentium M	2003	130–90 nm	77–140M	1300–2130	32	5–27	64K / 1M	479-pin FCBGA
Core	2006	65 nm	152M	1000–1860	32	6–31	64K / 2M	479-pin FCBGA
Core 2 Duo	2006	65–45 nm	167–410M	1060–3160	32/64	10–65	64K / 4M+	775-pin LGA
Core i7	2008	45 nm	731M	2660–3330	32/64	45–130	64K / 256K / 8M	1366-pin LGA
Atom	2008	45 nm	47M	800–1860	32/64	1.4–13	56K / 512K+	441-pin FCBGA