Moore’s Law,
the Microcomputer,
and Me©

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Outline

• Introduction and Overview
• Moore’s Law—density doubles each year \( (2^{40} = 10^{12}) \)
• 1970-- Can you define a standard LSI chip:
  – unit volume: 10-100 million units/year
  – pin count: 16-20
  – power: 1/2 Watt

• Computer Architecture-- historical examples
  – ibm 1620
  – Fairchild Symbol Computer
  – intel 4004
  – intel 8008
  – intel 8080
Mazor--Chronology

1960  San Francisco State (Student)
1964  Fairchild (Semiconductor)
1969  Intel (Semiconductor)
1983  Silicon Compilers (CAD)
1988  Synopsys (CAD)
1996  BEA Systems (Middleware)
1998  Cadabra/Numerical (CAD)
2003  Retired (Author)
IEEE Annals --Anecdotes

Mazor's--short articles:

- intel 4004: 2005
- intel 8008: 2006
- intel 8080: 2007
- intel 8086: 2010
- Symbol Computer: 2008
- Magnavox video game: 2009
Bowers Ave.      (David) Coffin Rd.
Desk Calculator

Custom LSI 'killer-app'

- High unit volume
- Ready market; distribution
- Slow speed--user keying
- Logic intensive (floating point)
- A/C power (no battery)
- I/O--keypad, display, printer
8008 Microprocessor Spec

Written in Pencil by Mazor
edits by Hoff
Uses 14-bit address
Three major issues:
die size
power dissipation
package pin count
Patented by TI
CTC never uses chip
Symbol Printed Circuit Board (PCB)

My first design:
200 chips/PCB
12 PCB's
Decimal floating point and string processing units

DIP
DIP Package and Chip
Chip (Die)
Wafer
Tested/Marked Wafer

- 300+ processing steps
- 20+ photographic steps
- ~3 months to make

Ink marks defective dice

Defects:
- wafer material defects
- processing defects
- statistical limits
Yield Estimate: 4X Larger Die

(of 81+ possible)
Yield Estimate:  25X Larger Die

Almost good (of 16 possible)
Moore's Law (Visualized)

4096 BITS OF INTEL STATIC RAM

256

1K

4K

SIXTEEN 1101

FOUR 2102

ONE 211
Semiconductor Photolithography

250 nm Laser

Light

10:1 Reduction Lens

Mask Set of 25 = $1M

Pattern image

Wafer with ‘photo resist’
Moore's Law & Photolithography

2**13.3 = 10,000x  (Moore's doubling @ 13.3 years)

(die size increase + circuit innovation)

2000 nanometer = 2.0 micron

1000nm
800nm

100 Mhz Pentium
180nm
130nm

2 Ghz Penryn
50nm

wavelength light

Layout Enhancement (180nm)

- Improve yield
- Improve device performance

Conventional (no OPC) → OPC Layout → Silicon Image with OPC

Serif's and scattering bars
Smaller and Faster (c.a. 2005)

Speed depends on gate size \((W/L)\)

L = 25nm

25-nm transistors with 248-nm lithography
SEM Courtesy MIT Lincoln Laboratories
Outline

• Moore’s Law—density doubles each year ($2^{40} = 10^{12}$)
• **Computer Architecture**—historical examples
  – ibm 1620
  – Fairchild Symbol Computer
  – intel PDP-8 emulator (study)
  – intel 4004
  – intel 8008
  – intel 8080
Fairchild Symbol Computer
DEC PDP-8 CPU-- Emulator

Feasibility Study (34 chips)
- LSI bipolar '4-bit slices'
- Proposed: 4-bit ALU chip
- ROM based microcode
- RAM chip for registers
- 12-bit data path for PDP-8

NEREM 1970
"Standard LSI for a Microprogrammed Processor"

Hoff and Mazor
Busicom Calculator
LSI 16-pin packages

CPU (4004)

4 ROM's 1k byte total

2 RAM's 8 16-digit numbers
Announcing a new era of integrated electronics

Nov 1971
Intel’s second computer on a chip!

April 1972
8008 CPU Block Diagram

Stack

Registers
8008 Chip Photo --1972

- **Registers**: 7 x 8-bits
- **PC Stack**: 8 x 14-bits
- **Instruction Decoder**
- **8-bit ALU**
- **Parallel Carry Adder**

**Hal Feeney designer**
Intel 8080 Chip--1974

40- pin DIP
16-bit address bus
5 Volts
No stack on chip
Ripple carry adder
Expanded instructions
• 16-bit operations
• Direct memory address
• Interrupts

M. Shima (island)
Patents

**Intel** awarded U.S. Patent: 3,821,715 on June 28, 1974 for 3 chip computer with single chip **4-bit** CPU. "Memory system for a multi-chip digital computer," M. E. Hoff, S. Mazor, and F. Faggin

17 Claims: Dynamic RAM with refresh using a counter; timing schemes; RAM with tie-off pin; ROM and RAM memory ports.

**TI** awarded U.S. Patent: 3,757,306 on September 4, 1973 for the single-chip **8-bit** CPU (8008)

"A simple restart program would store out the current contents of all the CPU registers and store the return address of a program which would recover them."

**Intel** awarded U.S. Patent: 4,010,449 on March 1977 for "MOS Computer" (8080) F. Faggin, M. Shima, S. Mazor. 2 Claims: coding