RISC Architecture
Ch 12

Some History

Instruction Usage
Characteristics

Large Register Files

Register Allocation
Optimization

RISC vs. CISC

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Major Inventions in Computer Architecture

- Stored Program Computer
  - store both program and data in memory
  - John von Neumann, 1945
    - Electronic Discrete Variable Automatic Computer (EDVAC) prototype
  - Maurice Wilkes, 1949
    - Electronic Delay Storage Automatic Calculator (EDSAC)
    - first fully operational stored program computer
  - software was born

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Major Inventions in Computer Architecture

- General purpose computer
  - Howard Aiken, Mark I, 1944
    - relays, 17m long, 2.4m tall
    - 500 miles of wire, 5 tons
    - 3 million connections
    - 6 sec mult, 12 sec div

    Copyright (c) 1997.
    Maxfield & Montrose Interactive Inc

    - IBM ASCC (automatic sequence controlled calculator)
    - turned off last time 1959

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Major Inventions in Computer Architecture

Floating Point hardware
- Gene Amdahl, 1953
- IBM 704
  - OS allowed for batch processing
    - combine existing commands into new commands
  - 5 kFLOPS
  - 19 units produced

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Major Inventions in Computer Architecture

- J. P. Eckert and John Mauchly, Eniac, 1946
  - 1500 relays
  - 18000 vacuum tubes
  - 70,000 resistors
  - 20 accumulators
  - 10 digits
  - modify program by rewiring

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Major Inventions in Computer Architecture

- Family of computers with different implementations of the same architecture
  - Computer system can grow within the family and all SW will still run
  - Need faster/bigger ⇒ buy a faster/bigger system in the family
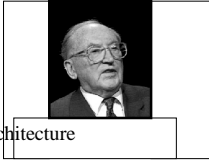 - Gene Amdahl
  - IBM S/360
  - DEC PDP-8   1964

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Major Inventions in Computer Architecture

- Microprogrammed control unit
  - can modify implementation easily
  - makes it easier to implement families of systems
  - can have different instruction set architecture (ISA) on top of the same HW
  - Maurice Wilkes, 1951
  - IBM System/360, 1964

Major Inventions in Computer Architecture

- Pipelining
  - Tom Kilburn (?)
  - Atlas, 1962
    - 2 ALU's
    - overlap execution of 3 instructions

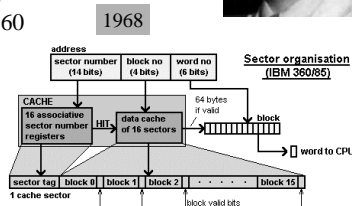Atlas Main and B-Arithmetic Units

Major Inventions in Computer Architecture

- Cache memory
  - Maurice Wilkes, 1965
  - major speed up
  - IBM System/360 Model 85

1968

address | sector number (14 bits) | block no (4 bits) | word no (6 bits)

Sector organisation (IBM 360/85)

CACHE
16 associative sector number registers   HIT   data cache of 16 sectors

64 bytes if valid   block

word to CPU

sector tag | block 0 | block 1 | block 2 | · · · · · | block 15
1 cache sector
block valid bits

Major Inventions in Computer Architecture

- Multiple processors
  - J. P. Eckert and John Mauchly
  - Sperry Rand Univac 1108II (1108A), 1964
    - 3 CPU's
    - 2 I/O controllers
      - DMA
    - 36 bit words
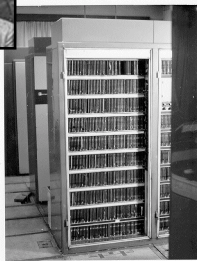   - test-and-set instruction was added for synchronization between processors

Mauchly & Univac console

Major Inventions in Computer Architecture

- Virtual memory
  - Tom Kilburn, 1962
  - Atlas, 1962
    - 20 bits for virtual address space
    - 512 word (each 48 bits) page
    - 16 KB main mem
    - 2 units sold

Atlas accumulator cabinet

Major Inventions in Computer Architecture

- Static RAM
  - Fairchild 4100, 1970
    - 256 bits
- Dynamic Random Access Memory
  - Robert Dennard, IBM, 1966
  - Intel 1103, 1970
    - John Reed
    - 1024 bits
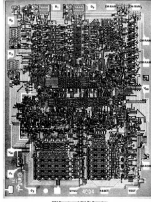   - replaces magnetic core memory by 1972

Dennard

Reed

Major Inventions in Computer Architecture

- Single chip microprocessor
  - Marcian E. (Ted) Hoff, (+ Federico Faggin & Stan Mazor ?)
  - Intel 4004, 1971   Hoff Faggin   Mazor
    - 2250 transistors, 60K OPS
    - "single chip which implements and interprets all microinstructions"
    - 4 bit words, 16 GPRs, 4-bit accumulator, operation register, instruction decoder
    - good for BCD operations (BCD = Binary Coded Decimal)
    - Japanese investors (Busicom) abandoned failed (!) project

Major Inventions in Computer Architecture (2)

- Reduced Instruction Set Computer (RISC)
  - John Cocke, 1974
  - IBM 801 (prototype), 1979
  - project cancelled because instruction set not compatible with OS/360
- Try again … and succeed
  - Hennessy (1981) & Patterson (1980)
  - Proved, that even CISC machines may work faster if only simple instructions and addressing modes are used

Major Inventions in Computer Architecture

- Vector processors
  - operate on entire vectors with one instruction
  - Texas Instrument Advanced Scientific Computer (ASC), 1971
    - W. Joe Watson
    - 4 pipelines
    - vectors stored in memory
    - 7 machines built
    - vectorizing Fortran compiler
    - theoretical max speed 50 MFLOPS
    - slow scalar unit

Major Inventions in Computer Architecture -- ??

- Make cache visible to application and (partly) under application control
  - Edmund J. Kelly, Malcolm John Wing & Robert Cmelik, Transmeta Corp., 1996
  - Certain applications can optimize and dynamically rebuild (translate & optimize) their (instruction) cache
    - lots of work, possibly big speedups
    - E.g., emulators for other architectures
  - Crusoe processor, 2000

Major Inventions in Computer Architecture

- … ??? …