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Computer Organization
and Architecture
6th Edition

Chapter 10
Instruction Sets:
Characteristics
and Functions

What is an instruction set?

- The complete collection of instructions that are understood by a CPU
- Machine Code
- Binary
- Usually represented by assembly codes

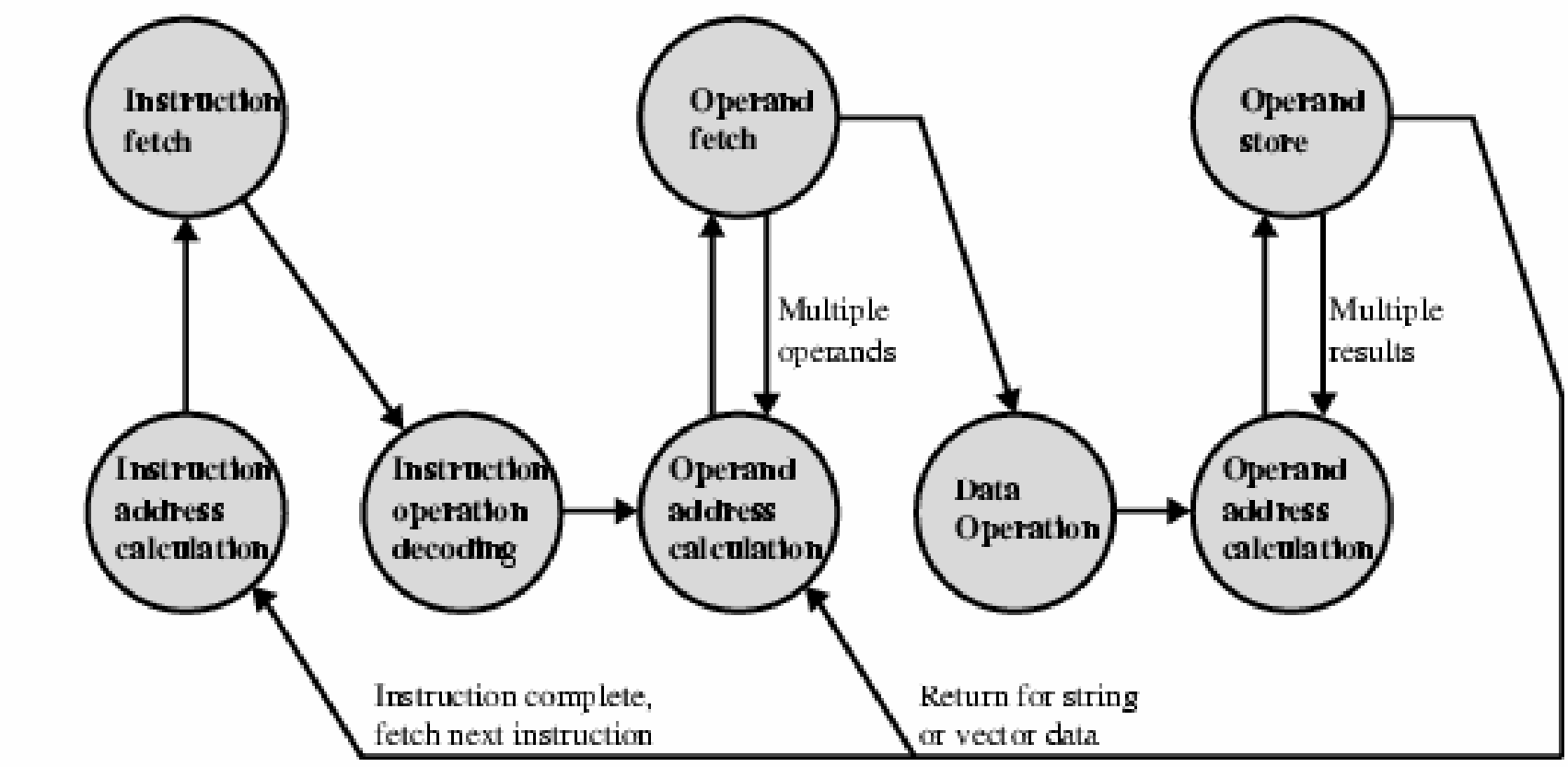
Elements of an Instruction

- Operation code (Op code)
  - —Do this
- Source Operand reference
  - —To this
- Result Operand reference
  - —Put the answer here
- Next Instruction Reference
  - —When you have done that, do this...

Where have all the Operands gone?

- Long time passing....
- (If you don’t understand, you’re too young!)
- Main memory (or virtual memory or cache)
- CPU register
- I/O device

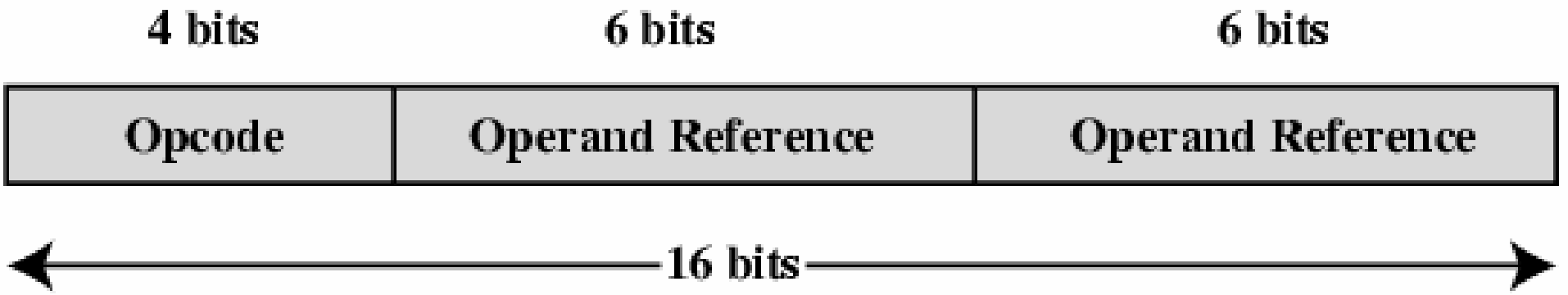
Instruction Cycle State Diagram



Instruction Representation

- In machine code each instruction has a unique bit pattern
- For human consumption (well, programmers anyway) a symbolic representation is used
  - —e.g. ADD, SUB, LOAD
- Operands can also be represented in this way
  - —ADD A,B

Simple Instruction Format



Instruction Types

- Data processing
- Data storage (main memory)
- Data movement (I/O)
- Program flow control

Number of Addresses (a)

- 3 addresses
  - —Operand 1, Operand 2, Result
  - —a = b + c;
  - —May be a forth - next instruction (usually implicit)
  - —Not common
  - —Needs very long words to hold everything

Number of Addresses (b)

- 2 addresses
  - —One address doubles as operand and result
  - —a = a + b
  - —Reduces length of instruction
  - —Requires some extra work
    - – Temporary storage to hold some results

Number of Addresses (c)

- 1 address
  - Implicit second address
  - Usually a register (accumulator)
  - Common on early machines

Number of Addresses (d)

- 0 (zero) addresses
  - —All addresses implicit
  - —Uses a stack
  - —e.g. push a
  - — push b
  - — add
  - — pop c

  - —c = a + b

How Many Addresses

- More addresses
  - —More complex (powerful?) instructions
  - —More registers
    - – Inter-register operations are quicker
  - —Fewer instructions per program
- Fewer addresses
  - —Less complex (powerful?) instructions
  - —More instructions per program
  - —Faster fetch/execution of instructions

Design Decisions (1)

- Operation repertoire
  - How many ops?
  - What can they do?
  - How complex are they?
- Data types
- Instruction formats
  - Length of op code field
  - Number of addresses

Design Decisions (2)

- Registers
  - Number of CPU registers available
  - Which operations can be performed on which registers?
- Addressing modes (later...)
- RISC v CISC

Types of Operand

- Addresses
- Numbers
  - —Integer/floating point
- Characters
  - —ASCII etc.
- Logical Data
  - —Bits or flags
- (Aside: Is there any difference between numbers and characters? Ask a C programmer!)

Specific Data Types

- General - arbitrary binary contents
- Integer - single binary value
- Ordinal - unsigned integer
- Unpacked BCD - One digit per byte
- Packed BCD - 2 BCD digits per byte
- Near Pointer - 32 bit offset within segment
- Bit field
- Byte String
- Floating Point

Types of Operation

- Data Transfer
- Arithmetic
- Logical
- Conversion
- I/O
- System Control
- Transfer of Control

Data Transfer

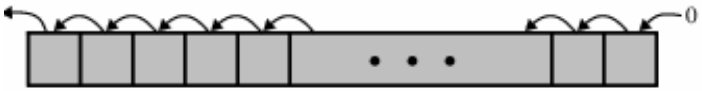
- Specify
  - —Source
  - —Destination
  - —Amount of data
- May be different instructions for different movements
  - —e.g. IBM 370
- Or one instruction and different addresses
  - —e.g. VAX

Arithmetic

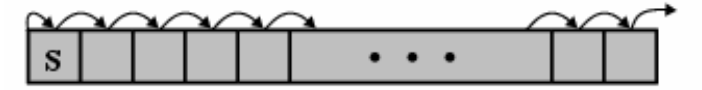
- Add, Subtract, Multiply, Divide
- Signed Integer
- Floating point ?
- May include
  - Increment (a++)
  - Decrement (a--)
  - Negate (-a)

Shift and Rotate Operations

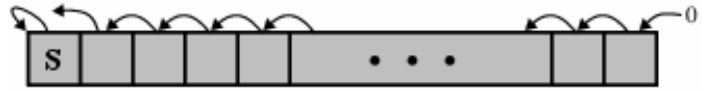
(a) Logical right shift



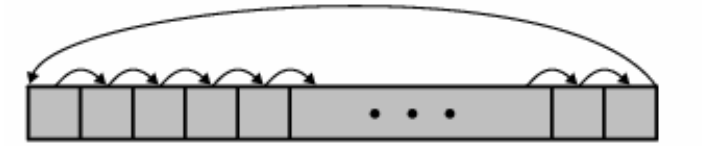
(b) Logical left shift



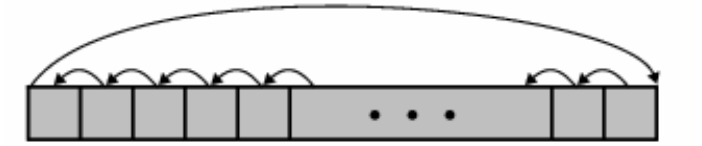
(c) Arithmetic right shift



(d) Arithmetic left shift



(e) Right rotate



(f) Left rotate

Logical

- Bitwise operations
- AND, OR, NOT

Conversion

- E.g. Binary to Decimal

Input/Output

- May be specific instructions
- May be done using data movement instructions (memory mapped)
- May be done by a separate controller (DMA)

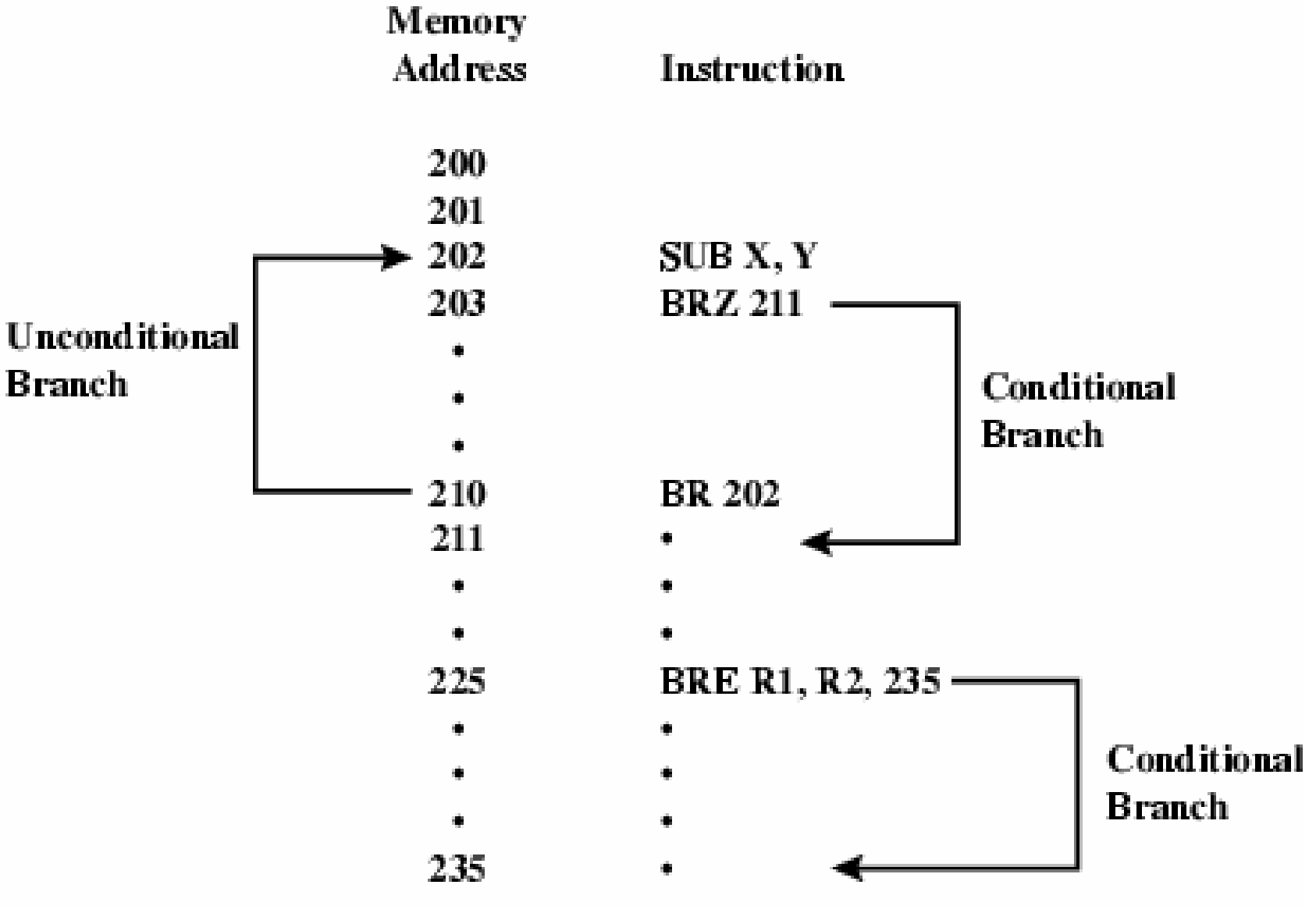
Systems Control

- Privileged instructions
- CPU needs to be in specific state
  - Ring 0 on 80386+
  - Kernel mode
- For operating systems use

Transfer of Control

- Branch
  - e.g. branch to x if result is zero
- Skip
  - e.g. increment and skip if zero
  - ISZ Register1
  - Branch xxxx
  - ADD A
- Subroutine call
  - c.f. interrupt call

Branch Instruction



Nested Procedure Calls