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

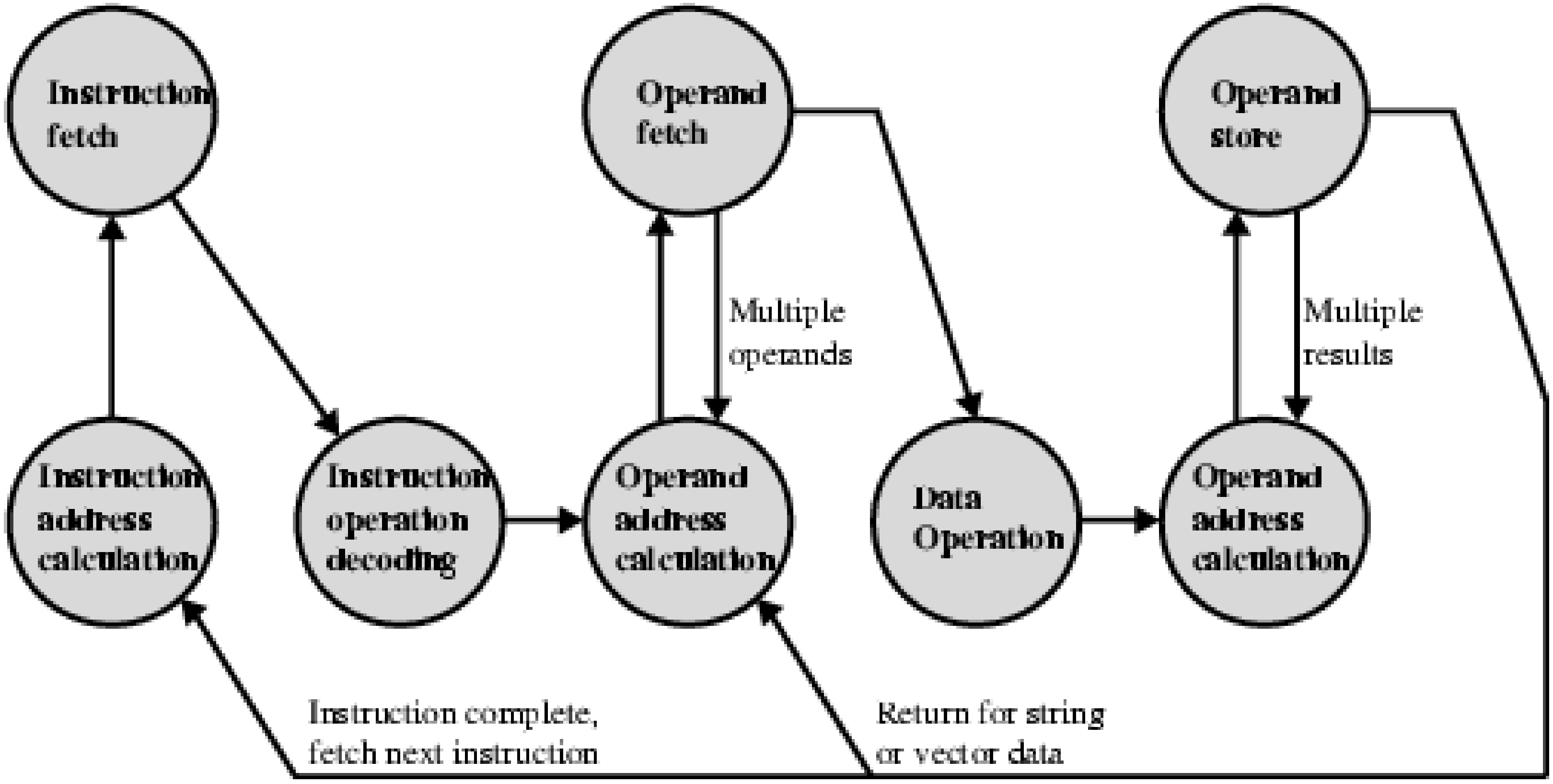
Elements of an Instruction

- 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

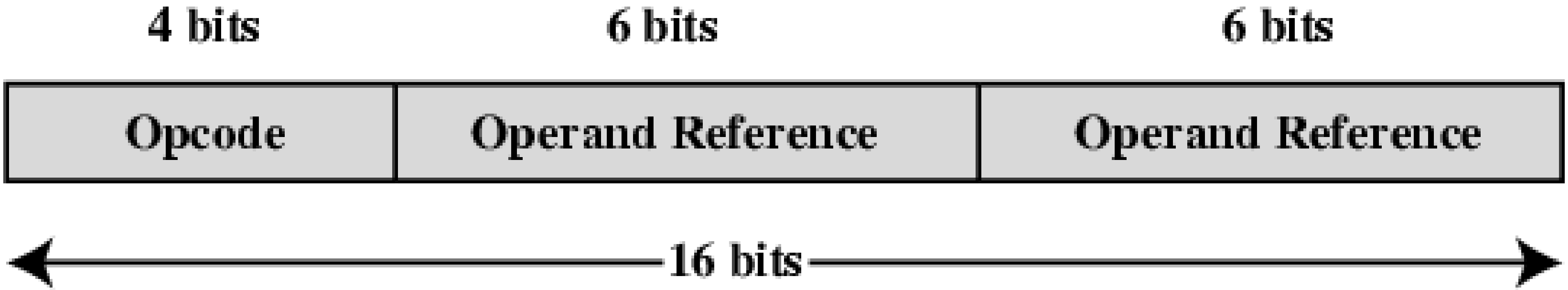
Instruction Cycle State Diagram


Instruction fetch
Operand fetch
Operand store
Multiple operands
Multiple results
Instruction address calculation
Instruction operation decoding
Operand address calculation
Data Operation
Operand address calculation
Instruction complete, fetch next instruction
Return for string or vector data

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



4 bits	6 bits	6 bits
Opcode	Operand Reference	Operand Reference

16 bits

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!)

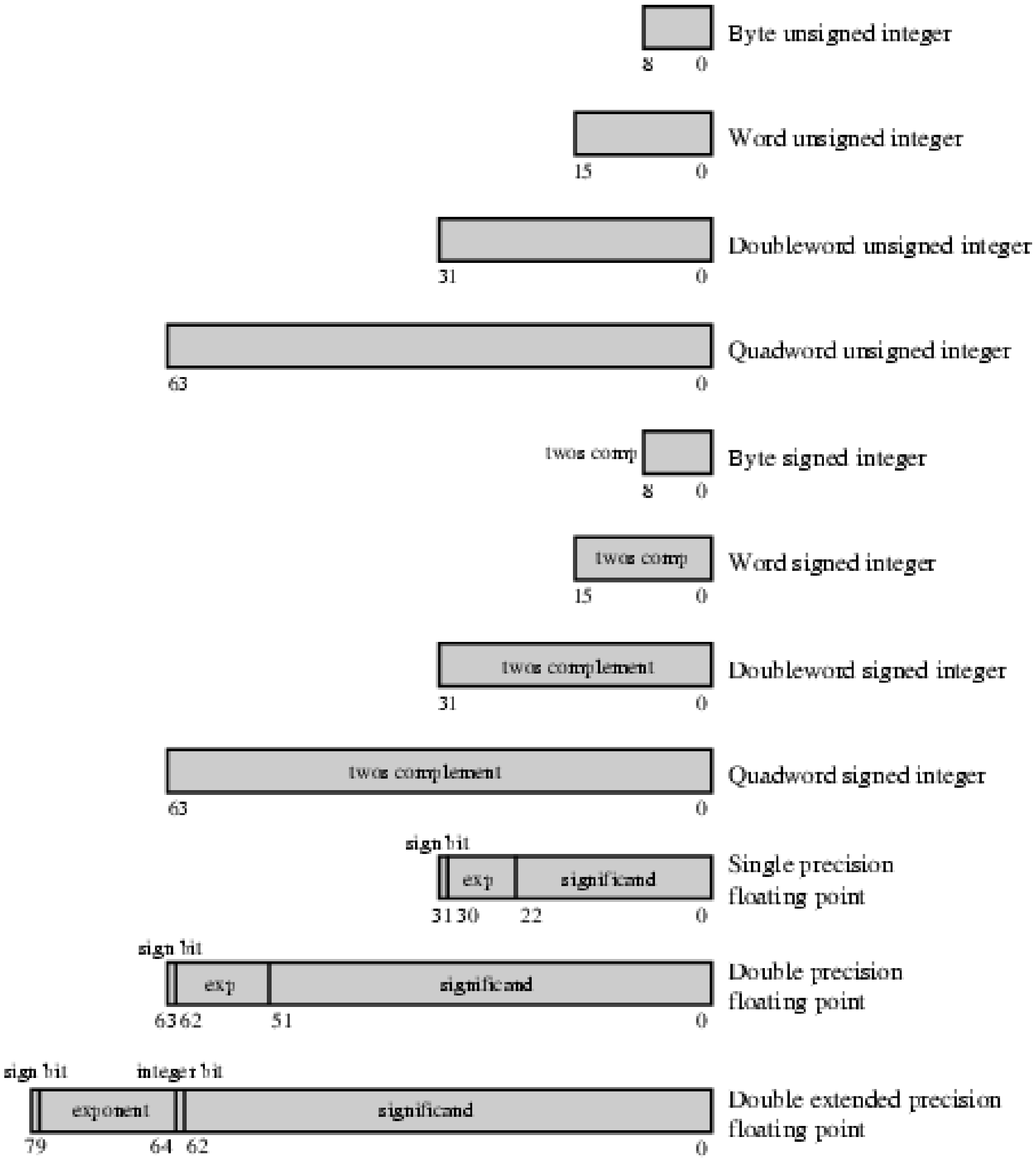
Pentium Data Types

- 8 bit Byte
- 16 bit word
- 32 bit double word
- 64 bit quad word
- Addressing is by 8 bit unit
- A 32 bit double word is read at addresses divisible by 4

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

Pentium Floating Point Data Types



Byte unsigned integer
8 0

Word unsigned integer
15 0

Doubleword unsigned integer
31 0

Quadword unsigned integer
63 0

twos comp
Byte signed integer
8 0

twos comp
Word signed integer
15 0

twos complement
Doubleword signed integer
31 0

twos complement
Quadword signed integer
63 0

sign bit
exp
significand
Single precision floating point
31 30 22 0

sign bit
exp
significand
Double precision floating point
63 62 51 0

sign bit
integer bit
exponent
significand
Double extended precision floating point
79 64 62 0

PowerPC Data Types

- 8 (byte), 16 (halfword), 32 (word) and 64 (doubleword) length data types
- Some instructions need operand aligned on 32 bit boundary
- Can be big- or little-endian
- Fixed point processor recognises:
    - Unsigned byte, unsigned halfword, signed halfword, unsigned word, signed word, unsigned doubleword, byte string (<128 bytes)
- Floating point
    - IEEE 754
    - Single or double precision

Types of Operation

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

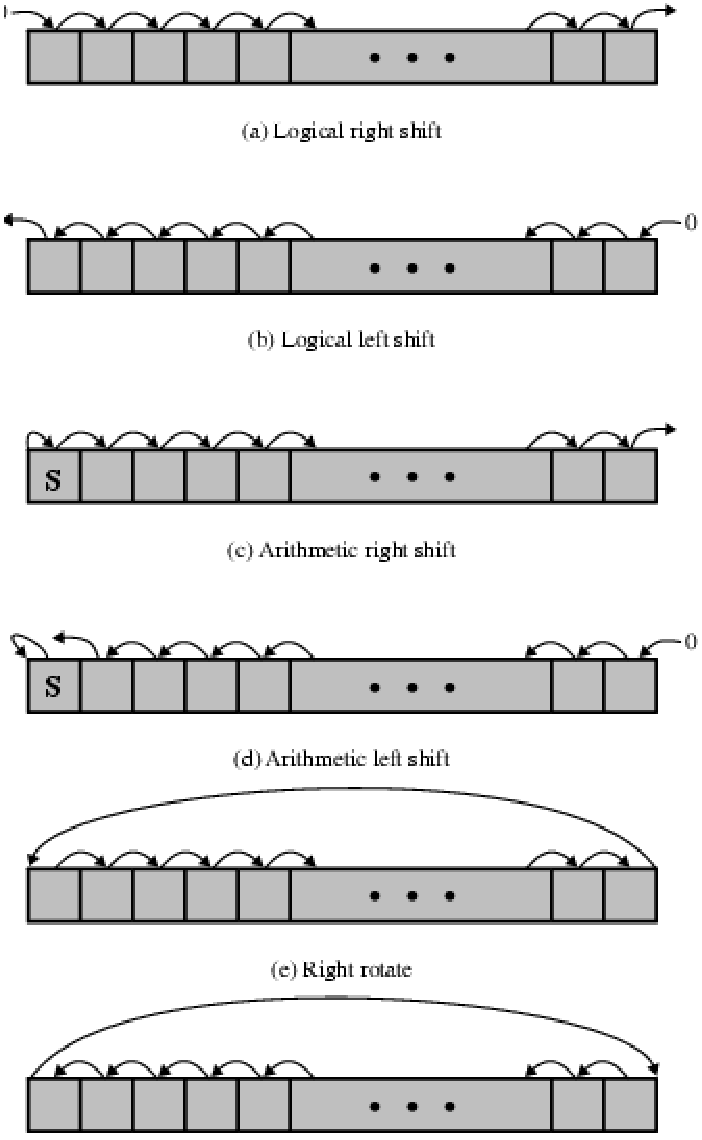
Data Transfer

- 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