Computer Architecture

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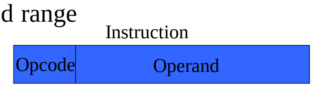
Addressing Modes and Formats

Addressing Modes

- Immediate
- Direct
- Indirect
- Register
- Register Indirect
- Displacement (Indexed)
- Stack

Immediate Addressing

- Operand is part of instruction
- Operand = address field
- e.g. ADD 5
  - Add 5 to contents of accumulator
  - Here 5 is operand
- No memory reference to fetch data
- Fast
- Limited range



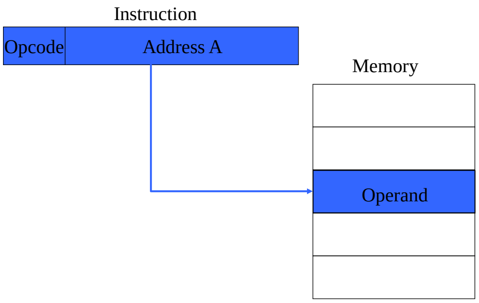
Instruction

Opcode | Operand

Direct Addressing

- Address field contains address of operand
- Effective address (EA) = address field (A)
- e.g. ADD A
  - Add contents of cell A to accumulator
  - Look in memory at address A for operand
- Single memory reference to access data
- No additional calculations to work out effective address
- Limited address space

Direct Addressing Diagram



Instruction

Opcode | Address A

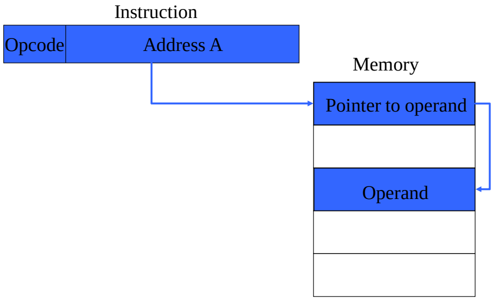
Memory

Operand

Indirect Addressing (1)

- Memory cell pointed to by address field contains the address of (pointer to) the operand
- Large address space
- 2^n where n = word length
- May be nested, multilevel, cascaded
- Multiple memory accesses to find operand
- Hence slower

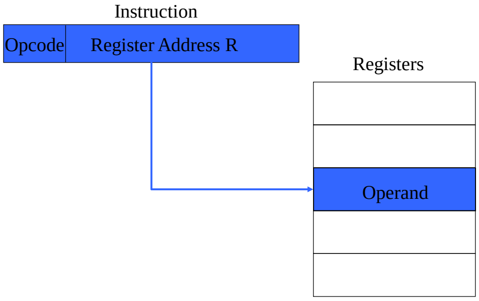
Indirect Addressing Diagram



Register Addressing (1)

- Operand is held in register named in address field
- EA = R
- Limited number of registers
- Very small address field needed
  - Shorter instructions
  - Faster instruction fetch
- No memory access
- Very fast execution
- Very limited address space
- Multiple registers helps performance
  - Requires good assembly programming or compiler writing

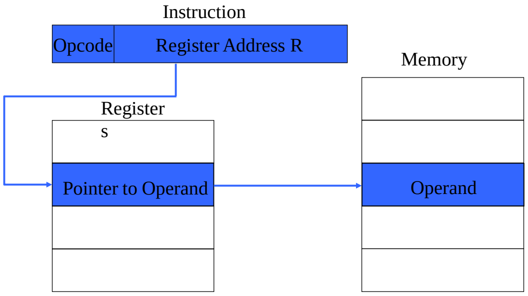
Register Addressing Diagram



Register Indirect Addressing

- Operand is held in memory cell pointed to by contents of register R named in address field
- EA = (R)
- Large address space (2^n)
- One fewer memory access than indirect addressing

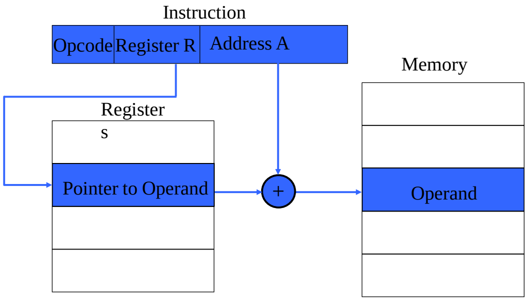
Register Indirect Addressing Diagram



Displacement Addressing

- EA = A + (R)
- Address field hold two values
  - A = base value
  - R = register that holds displacement
  - or vice versa

Displacement Addressing Diagram



Relative Addressing

- A version of displacement addressing
- R = Program counter (PC)
- EA = A + (PC)
- i.e. get operand from A cells from current location pointed to by PC

Base-Register Addressing

- A holds displacement
- R holds pointer to base address
- R may be explicit or implicit
- e.g. segment registers in 80x86

Indexed Addressing

- A = base
- R = displacement
- EA = A + R
- Good for accessing arrays
  - EA = A + R
  - R++

Combinations

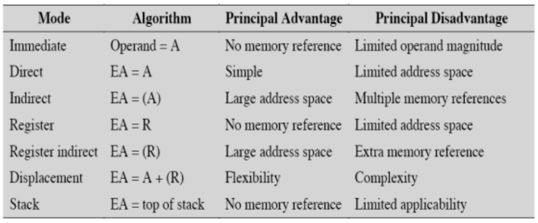
- Postindex
- EA = (A) + (R)

- Preindex
- EA = (A+(R))

Stack Addressing

- Operand is (implicitly) on top of stack
- e.g.
  - ADD Pop top two items from stack and add

Summary of basic addressing modes



Mode	Algorithm	Principal Advantage	Principal Disadvantage
Immediate	Operand = A	No memory reference	Limited operand magnitude
Direct	EA = A	Simple	Limited address space
Indirect	EA = (A)	Large address space	Multiple memory references
Register	EA = R	No memory reference	Limited address space
Register indirect	EA = (R)	Large address space	Extra memory reference
Displacement	EA = A + (R)	Flexibility	Complexity
Stack	EA = top of stack	No memory reference	Limited applicability

Instruction Formats

- Layout of bits in an instruction
- Includes opcode
- Includes (implicit or explicit) operand(s)
- Usually more than one instruction format in an instruction set

Instruction Length

- Affected by and affects:
  - Memory size
  - Memory organization
  - Bus structure
  - CPU complexity
  - CPU speed
- Trade off between powerful instruction repertoire and saving space

Allocation of Bits

- Number of addressing modes
- Number of operands
- Register versus memory
- Number of register sets
- Address range
- Address granularity