Computer Organization and Architecture

Chapter 8

Instruction Sets:

Addressing Modes and Formats

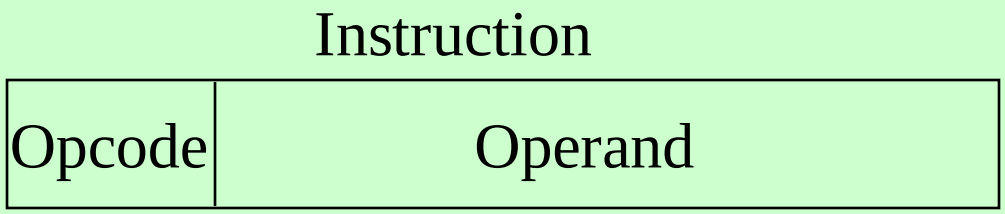
Addressing Modes

- 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
  - —5 is operand
- No memory reference to fetch data
- Fast
- Limited range

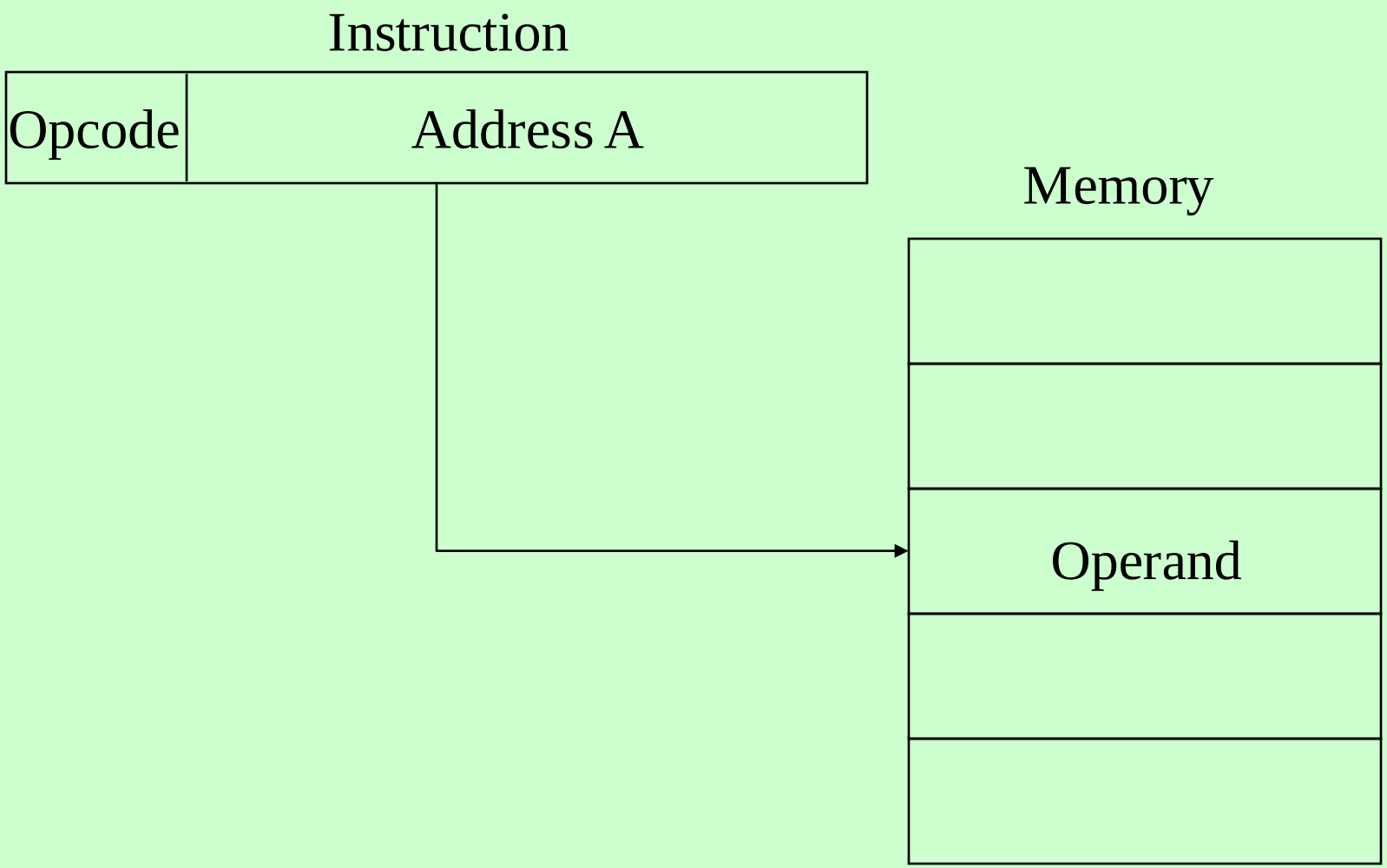
Immediate Addressing Diagram



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



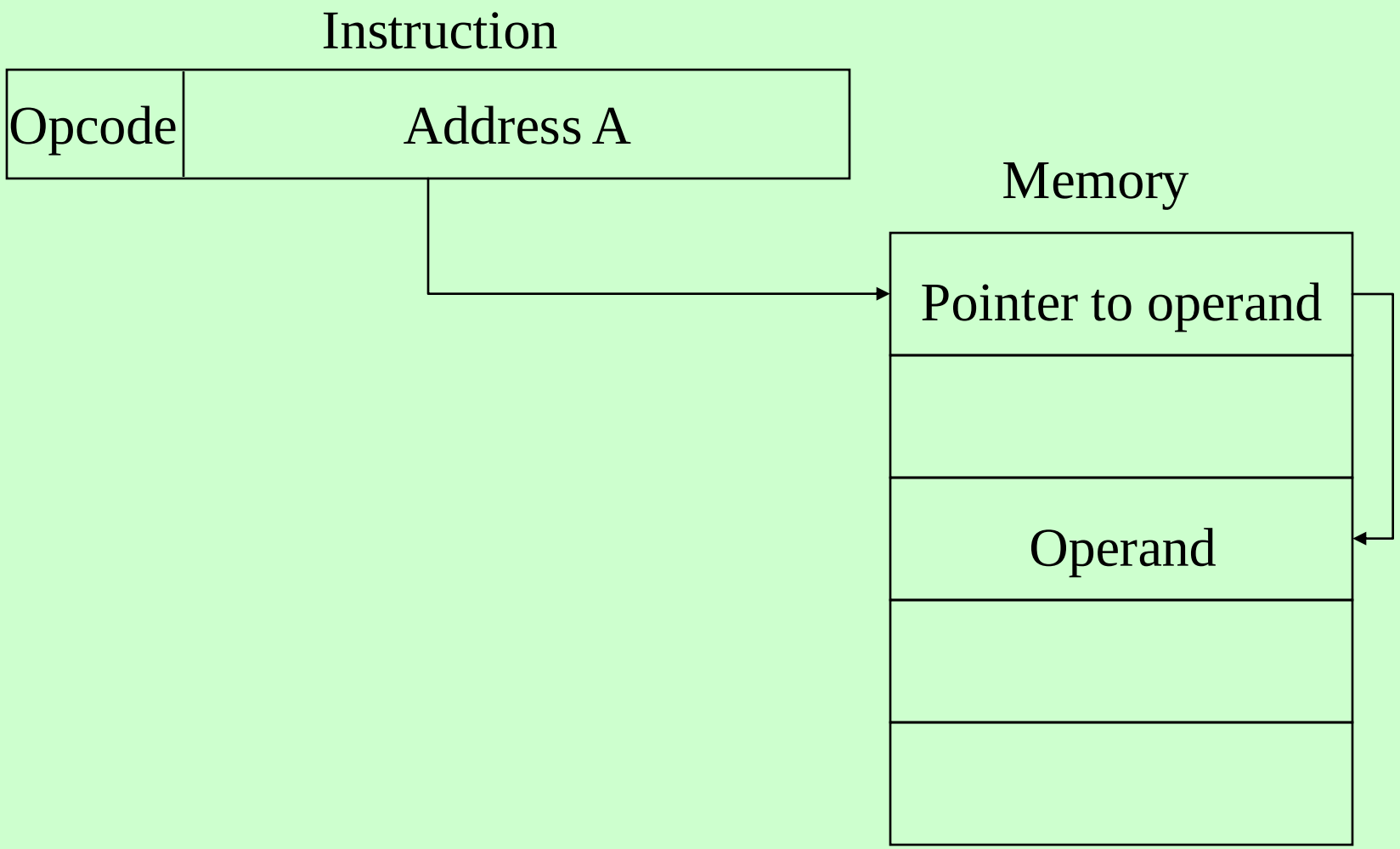
Indirect Addressing (1)

- Memory cell pointed to by address field contains the address of (pointer to) the operand
- EA = (A)
  - Look in A, find address (A) and look there for operand
- e.g. ADD (A)
  - Add contents of cell pointed to by contents of A to accumulator

Indirect Addressing (2)

- Large address space
- 2^n where n = word length
- May be nested, multilevel, cascaded
  - e.g. EA = (((A)))
    - Draw the diagram yourself
- Multiple memory accesses to find operand
- Hence slower

Indirect Addressing Diagram



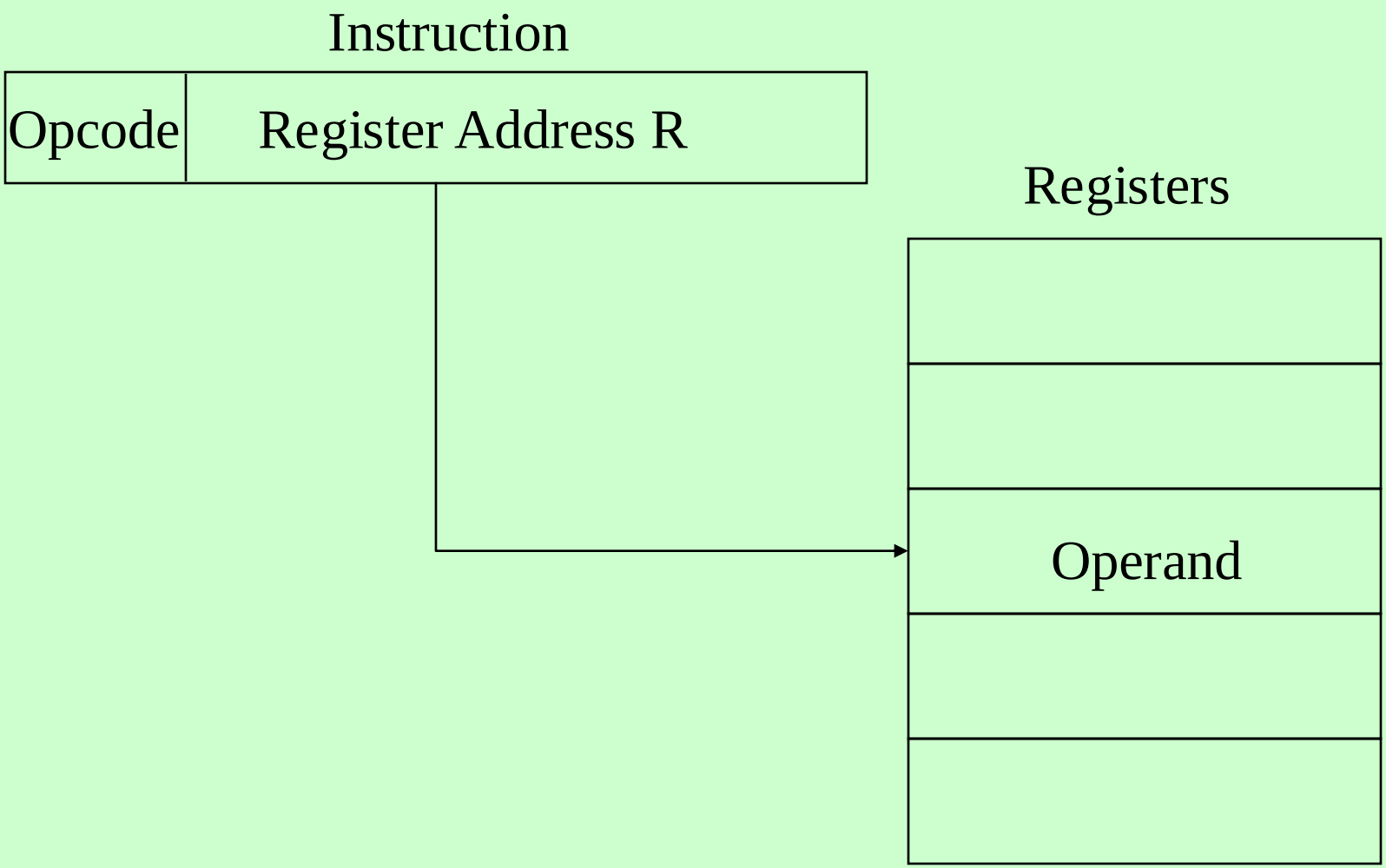
Register Addressing (1)

- Operand is held in register named in address filed
- EA = R
- Limited number of registers
- Very small address field needed
  - —Shorter instructions
  - —Faster instruction fetch

Register Addressing (2)

- No memory access
- Very fast execution
- Very limited address space
- Multiple registers helps performance
  - Requires good assembly programming or compiler writing
  - N.B. C programming
    - register int a;
- c.f. Direct addressing

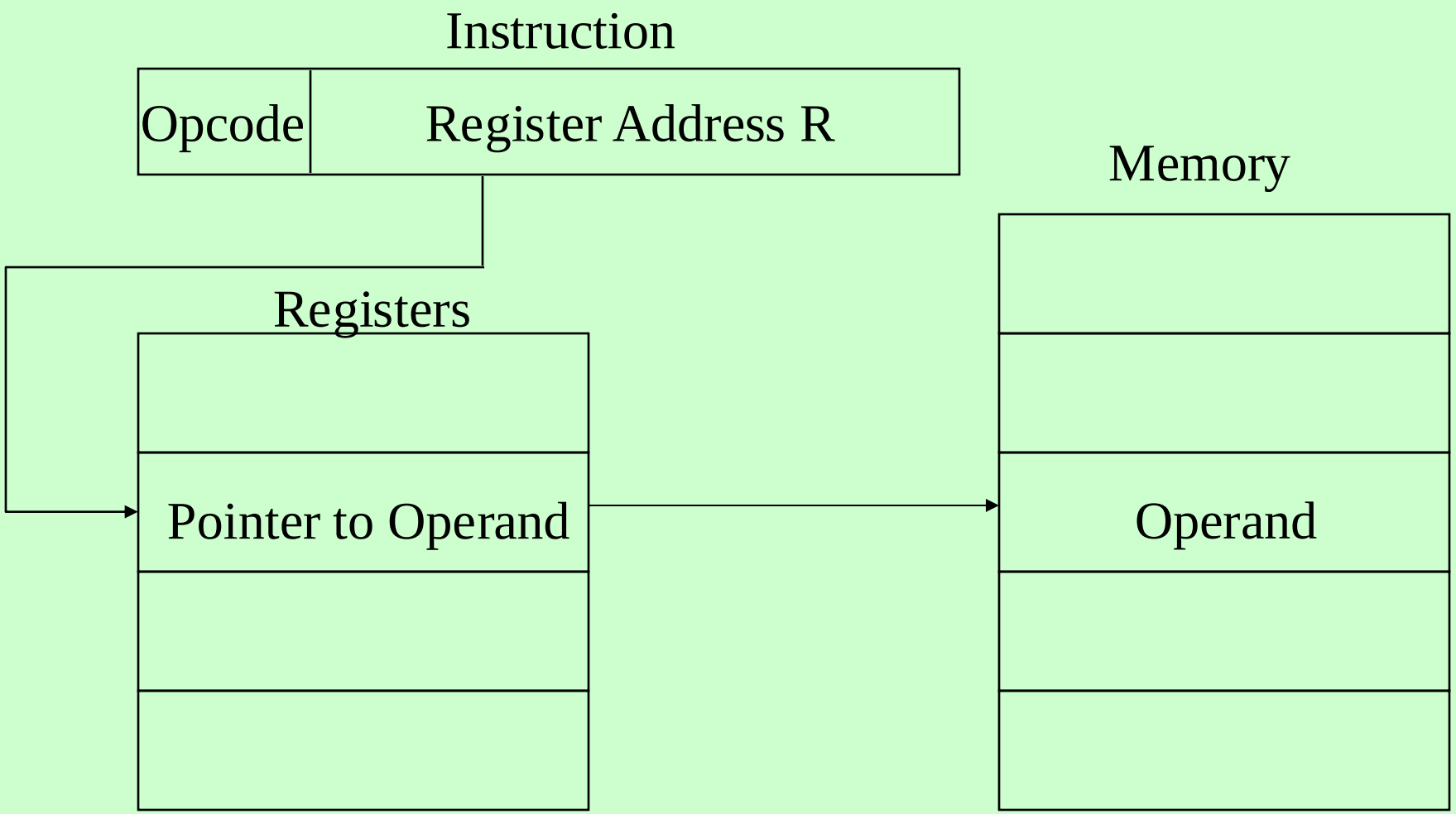
Register Addressing Diagram



Register Indirect Addressing

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

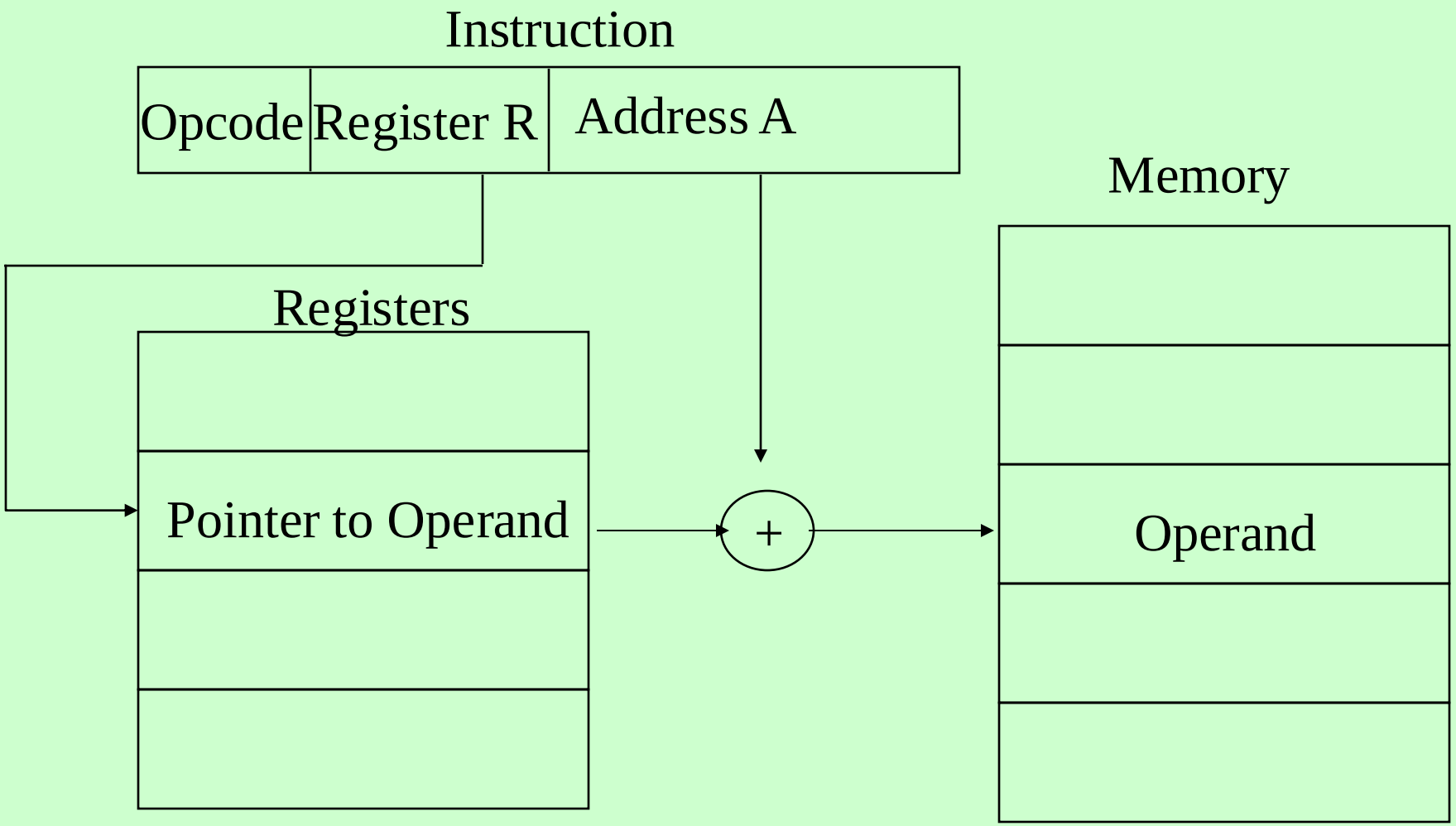
Register Indirect Addressing Diagram



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
- c.f locality of reference & cache usage

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))

- (Draw the diagrams)

Stack Addressing

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

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

Assembler

- Machines store and understand binary instructions
- E.g. N= I + J + K initialize I=2, J=3, K=4
- Program starts in location 101
- Data starting 201
- Code:
- Load contents of 201 into AC
- Add contents of 202 to AC
- Add contents of 203 to AC
- Store contents of AC to 204
- Tedious and error prone

Improvements

- Use hexadecimal rather than binary
  - —Code as series of lines
    - Hex address and memory address
  - —Need to translate automatically using program
- Add symbolic names or mnemonics for instructions
- Three fields per line
  - —Location address
  - —Three letter opcode
  - —If memory reference: address
- Need more complex translation program

Program in: Binary

Address	Contents			
101	0010	0010	101	2201
102	0001	0010	102	1202
103	0001	0010	103	1203
104	0011	0010	104	3204
201	0000	0000	201	0002
202	0000	0000	202	0003
203	0000	0000	203	0004
204	0000	0000	204	0000

Hexadecimal

Address	Contents
101	2201
102	1202
103	1203
104	3204
201	0002
202	0003
203	0004
204	0000

Symbolic Addresses

- First field (address) now symbolic
- Memory references in third field now symbolic
- Now have assembly language and need an assembler to translate
- Assembler used for some systems programming
  - —Compliers
  - —I/O routines

Symbolic Program

Address	Instruction	
101	LDA	201
102	ADD	202
103	ADD	203
104	STA	204
201	DAT	2
202	DAT	3
203	DAT	4
204	DAT	0

Assembler Program

Label	Operation	Operand
FORMUL	LDA	I
	ADD	J
	ADD	K
	STA	N
I	DATA	2
J	DATA	3
K	DATA	4
N	DATA	0