Logical and Bit Operations

Chapter 8

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Outline

- Logical instructions
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  - OR
  - XOR
  - NOT
  - TEST
- Shift instructions
  - Logical shift instructions
  - Arithmetic shift instructions
- Rotate instructions
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  - Rotate through carry
- Logical expressions in high-level languages
  - Representation of Boolean data
  - Logical expressions
- Bit instructions
  - Bit test and modify instructions
  - Bit scan instructions
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Logical Instructions

- Logical instructions operate on bit-by-bit basis
- Five logical instructions:
  - AND
  - OR
  - XOR
  - NOT
  - TEST
- All logical instructions affect the status flags

Logical Instructions (cont’d)

- Since logical instructions operate on a bit-by-bit basis, no carry or overflow is generated
- Logical instructions
  - ∗ Clear carry flag (CF) and overflow flag (OF)
  - ∗ AF is undefined
- Remaining three flags record useful information
  - ∗ Zero flag
  - ∗ Sign flag
  - ∗ Parity flag

Logical Instructions (cont'd)

AND instruction

- Format

```
and    destination,source
```

- Usage
  - ∗ To support compound logical expressions and bitwise AND operation of HLLs
  - ∗ To clear one or more bits of a byte, word, or doubleword
  - ∗ To isolate one or more bits of a byte, word, or doubleword

Logical Instructions (cont'd)

OR instruction

- Format

```
or    destination,source
```

- Usage
  - ∗ To support compound logical expressions and bitwise OR operation of HLLs
  - ∗ To set one or more bits of a byte, word, or doubleword
  - ∗ To paste one or more bits of a byte, word, or doubleword

Logical Instructions (cont’d)

XOR instruction

- Format

```
xor    destination,source
```

- Usage
  - ∗ To support compound logical expressions of HLLs
  - ∗ To toggle one or more bits of a byte, word, or doubleword
  - ∗ To initialize registers to zero
    - » Example: `xor    AX,AX`

Logical Instructions (cont’d)

NOT instruction

- Format

```
not    destination
```

- Usage
  - ∗ To support logical expressions of HLLs
  - ∗ To complement bits
    - » Example: 2’s complement of an 8-bit number

```
not    AL
inc    AL
```

Logical Instructions (cont'd)

TEST instruction

- Format

```
test    destination,source
```

  - ∗ TEST is a non-destructive AND operation
    - » Result is not written in **destination**
    - » Similar in spirit to **cmp** instruction
- Usage
  - ∗ To test bits
    - » Example:

```
test    AL,1
jz      even_number   ; else odd number
```

Shift Instructions

- Two types of shift instructions
  - ∗ Logical shift instructions
    - » **`shl (SHift Left)`**
    - » **`shr (SHift Right)`**
    - » Another interpretation:
      - – Logical shift instructions work on unsigned binary numbers
  - ∗ Arithmetic shift instructions
    - » **`sal (Shift Arithmetic Left)`**
    - » **`sar (Shift Arithmetic Right)`**
    - » Another interpretation:
      - – Arithmetic shift instructions work on signed binary numbers

Shift Instructions (cont'd)

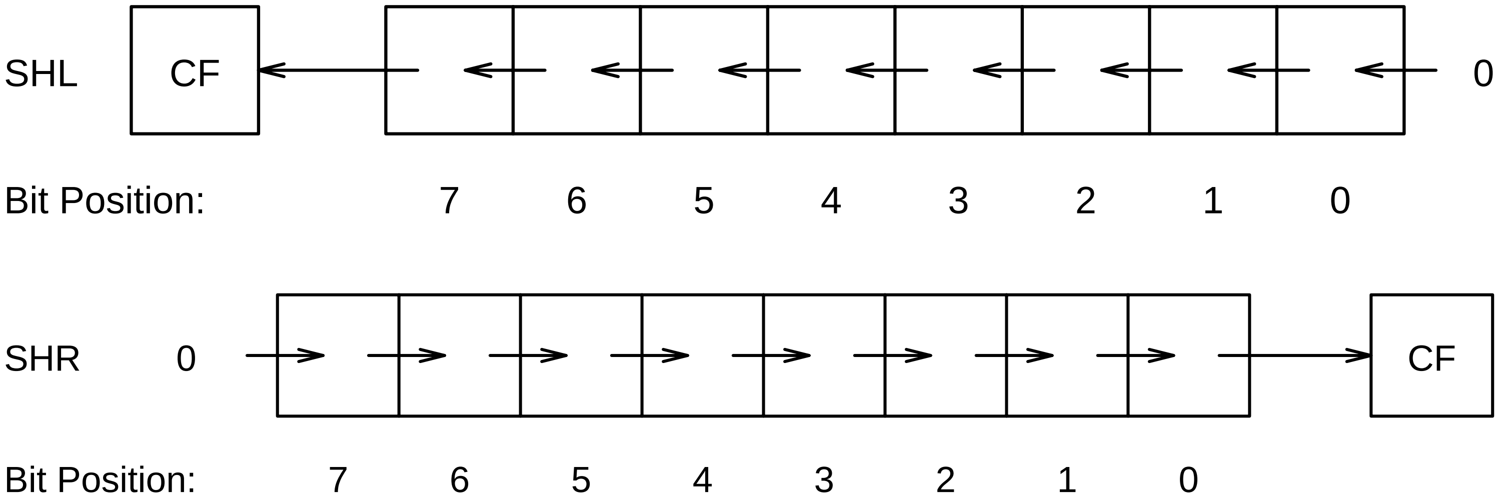
- Effect on flags
  - ∗ Auxiliary flag (AF): undefined
  - ∗ Zero flag (ZF) and parity flag (PF) are updated to reflect the result
  - ∗ Carry flag
    - » Contains the last bit shifted out
  - ∗ Overflow flag
    - » For multibit shifts
      - – Undefined
    - » For single bit shifts
      - – OF is set if the sign bit has changed as a result of the shift
      - – Cleared otherwise

Logical Shift Instructions

- General format

```
shl    destination,count
shr    destination,count
```

`destination` can be an 8-, 16-, or 32-bit operand located either in a register or memory



Logical Shift Instructions (cont'd)

- Two versions

```
shl/shr    destination,count
shl/shr    destination,CL
```

  - First format directly specifies the count value
    - Count value should be between 0 and 31
    - If a greater value is specified, Pentium takes only the least significant 5 bits as the count value
  - Second format specifies count indirectly through CL
    - CL contents are not changed
    - Useful if count value is known only at the run time as opposed at assembly time
      - Ex: Count is received as an argument in a procedure call

Logical Shift Instructions (cont’d)

- Usage
  - ∗ Bit manipulation

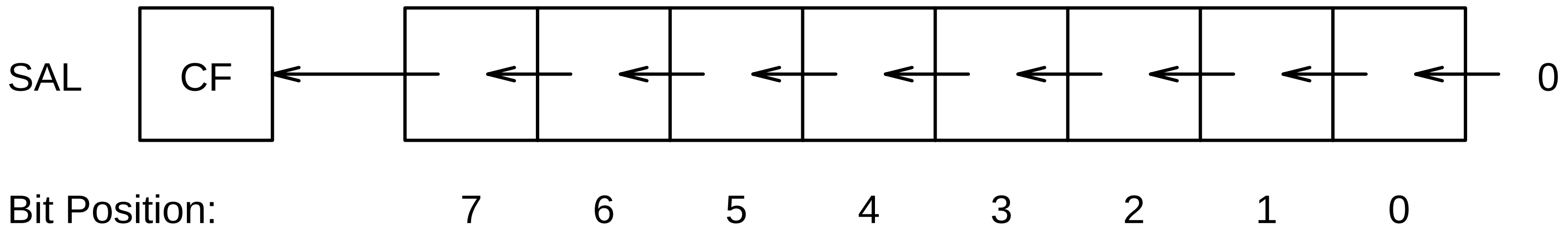
```
; AL contains the byte to be encrypted
mov    AH,AL
shl    AL,4     ; move lower nibble to upper
shr    AH,4     ; move upper nibble to lower
or     AL,AH    ; paste them together
; AL has the encrypted byte
```

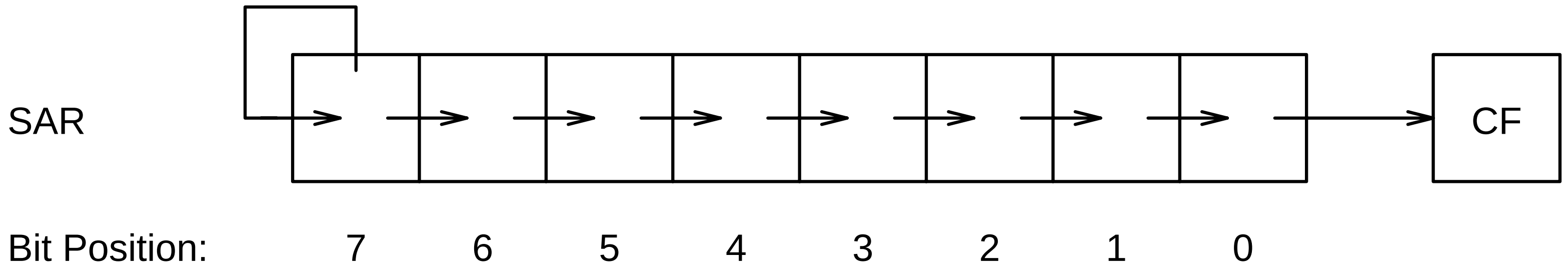
  - ∗ Multiplication and division
    - » Useful to multiply (left shift) or divide (right shift) by a power of 2
    - » More efficient than using multiply/divide instructions

Arithmetic Shift Instructions

- Two versions as in logical shift

```
sal/sar    destination,count
sal/sar    destination,CL
```





Double Shift Instructions

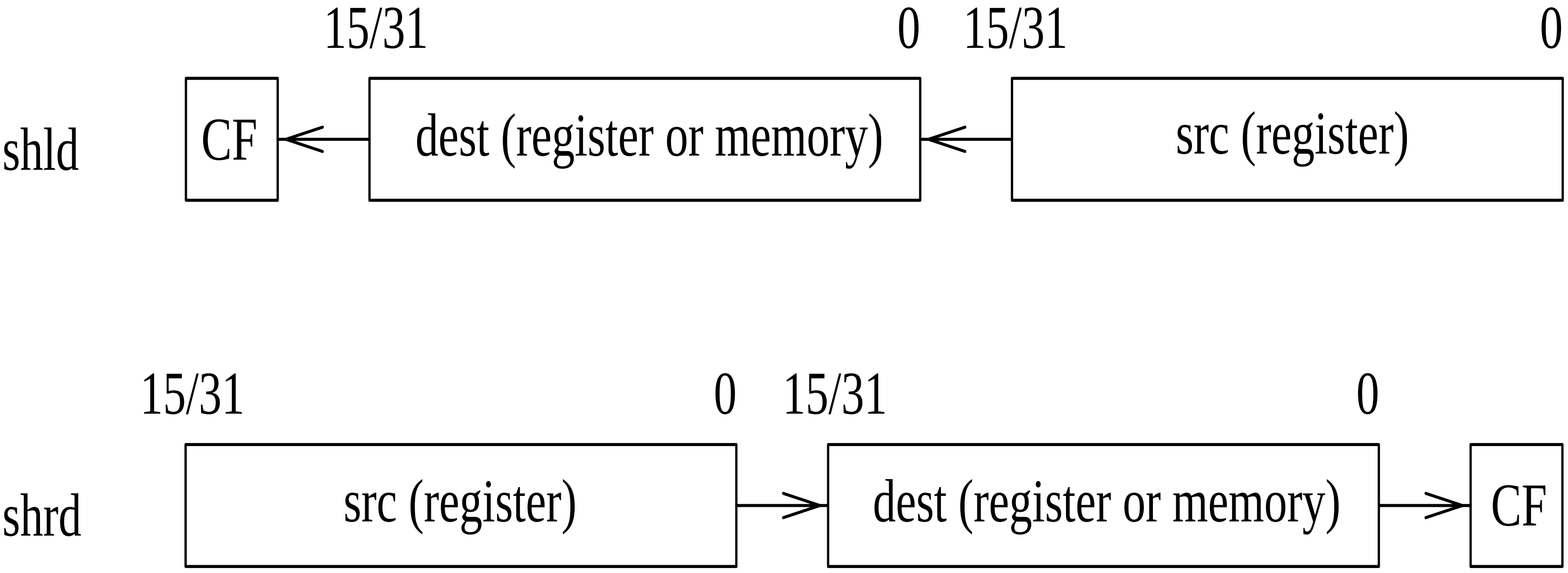
- Double shift instructions work on either 32- or 64-bit operands
- Format
  - ∗ Takes three operands

```
shld    dest,src,count  ; left shift
shrd    dest,src,count  ; right shift
```

  - ∗ **`dest`** can be in memory or register
  - ∗ **`src`** must be a register
  - ∗ **`count`** can be an immediate value or in CL as in other shift instructions

Double Shift Instructions (cont’d)

- **`src`** is not modified by doubleshift instruction
- Only **`dest`** is modified
- Shifted out bit goes into the carry flag



Rotate Instructions

- A problem with the shift instructions
  - ∗ Shifted out bits are lost
  - ∗ Rotate instructions feed them back

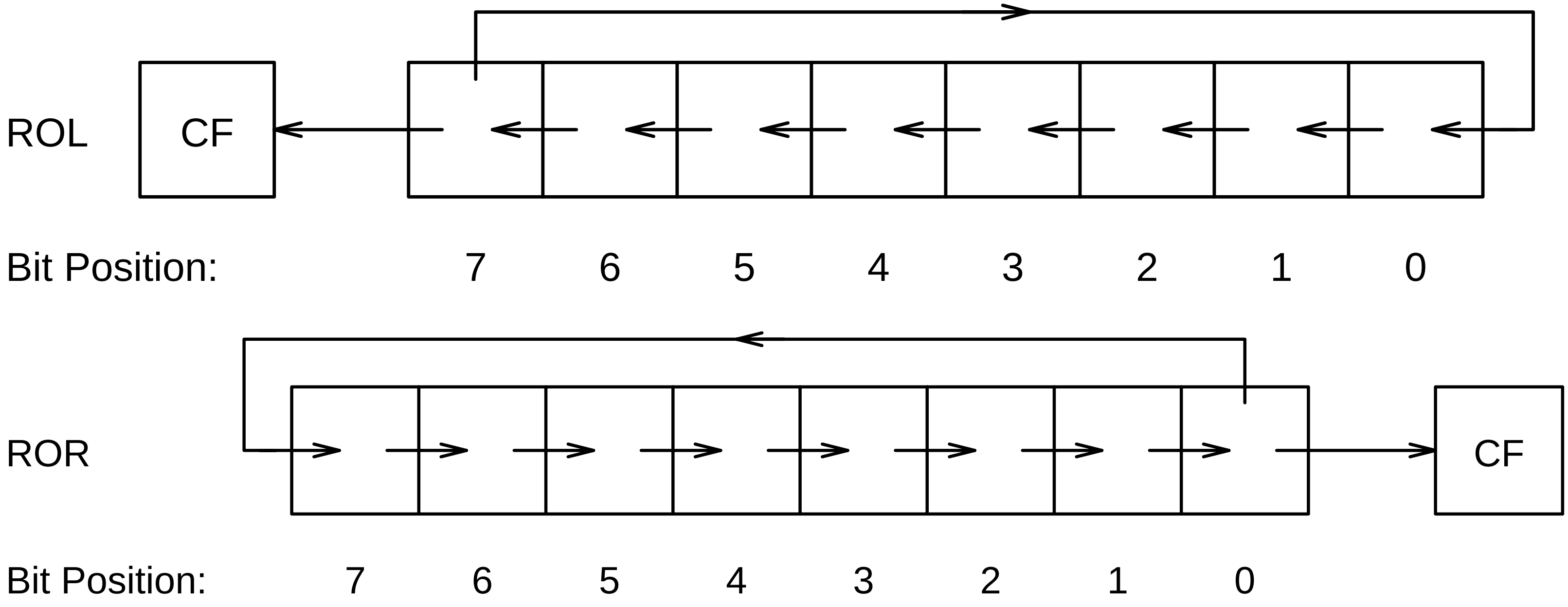
- Two types of rotate instructions
  - ∗ Rotate without carry
    - » Carry flag is not involved in the rotate process
  - ∗ Rotate through carry
    - » Rotation involves the carry flag

Rotate Without Carry

- General format

```
rol    destination,count
ror    destination,count
```

`count` can be an immediate value or in CL (as in shift)

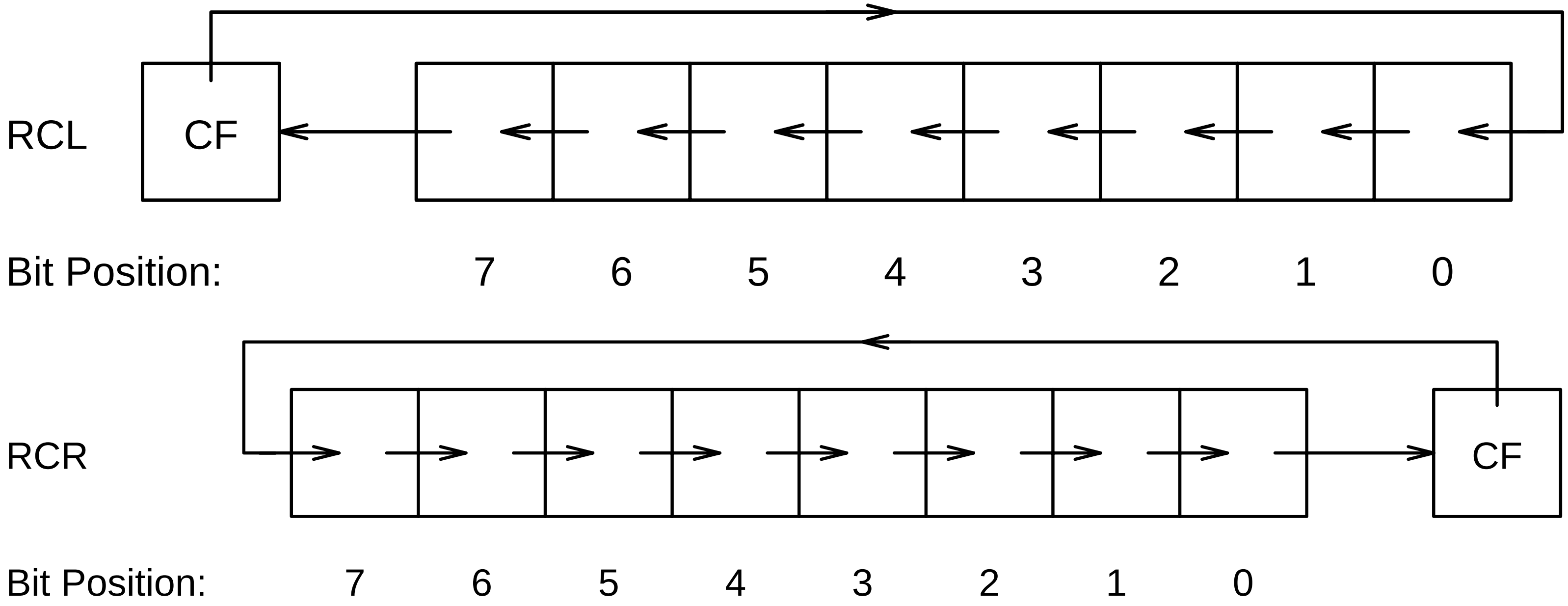


Rotate Through Carry

- General format

```
rcl    destination,count
rcr    destination,count
```

`count` can be an immediate value or in CL (as in shift)



To be used with S. Dandamudi, “Introduction to Assembly Language Programming,” Springer-Verlag, 1998.

Rotate Through Carry (cont’d)

- Only two instructions that take CF into account
    - » This feature is useful in multiword shifts
- Example: Shifting 64-bit number in EDX:EAX
    - ∗ Rotate version

```
     mov     CX,4       ; 4 bit shift
shift_left:
    shl     EAX,1     ; moves leftmost bit of EAX to CF
    rcl     EDX,1     ; CF goes to rightmost bit of EDX
    loop    shift_left
```

- ∗ Double shift version:

```
    shld    EDX,EAX,4 ; EAX is unaffected by shld
    shl     EAX,4
```

Logical Expressions in HLLs

- Representation of Boolean data
  - ∗ Only a single bit is needed to represent Boolean data
  - ∗ Usually a single byte is used
    - » For example, in C
      - – All zero bits represents *false*
      - – A non-zero value represents *true*
- Logical expressions
  - ∗ Logical instructions AND, OR, etc. are used
- Bit manipulation
  - ∗ Logical, shift, and rotate instructions are used

Bit Instructions

- Bit Test and Modify Instructions
  - ∗ Four bit test instructions
  - ∗ Each takes the position of the bit to be tested

Instruction	Effect on the selected bit
bt (Bit Test)	No effect
bts (Bit Test and Set)	selected bit ← 1
btr (Bit Test and Reset)	selected bit ← 0
btc (Bit Test and Complement)	selected bit ← NOT(selected bit)

Bit Instructions (cont'd)

- All four instructions have the same format
- We use **`bt`** to illustrate the format

```
bt      operand,bit_pos
```

  - **`operand`** is word or doubleword
    - Can be in memory or a register
  - **`bit_pos`** indicates the position of the bit to be tested
    - Can be an immediate value or in a 16- or 32-bit register

- Instructions in this group affect only the carry flag
    - Other five flags are undefined following a bit test instruction

Bit Scan Instructions

- These instructions scan the operand for a 1 bit and return the bit position in a register
- Two instructions

```
bsf    dest_reg,operand     ;bit scan forward
bsr    dest_reg,operand     ;bit scan reverse
```

» **`operand`** can be a word or doubleword in a register or memory

» **`dest_reg`** receives the bit position

– Must be a 16- or 32-bit register

∗ Only ZF is updated (other five flags undefined)

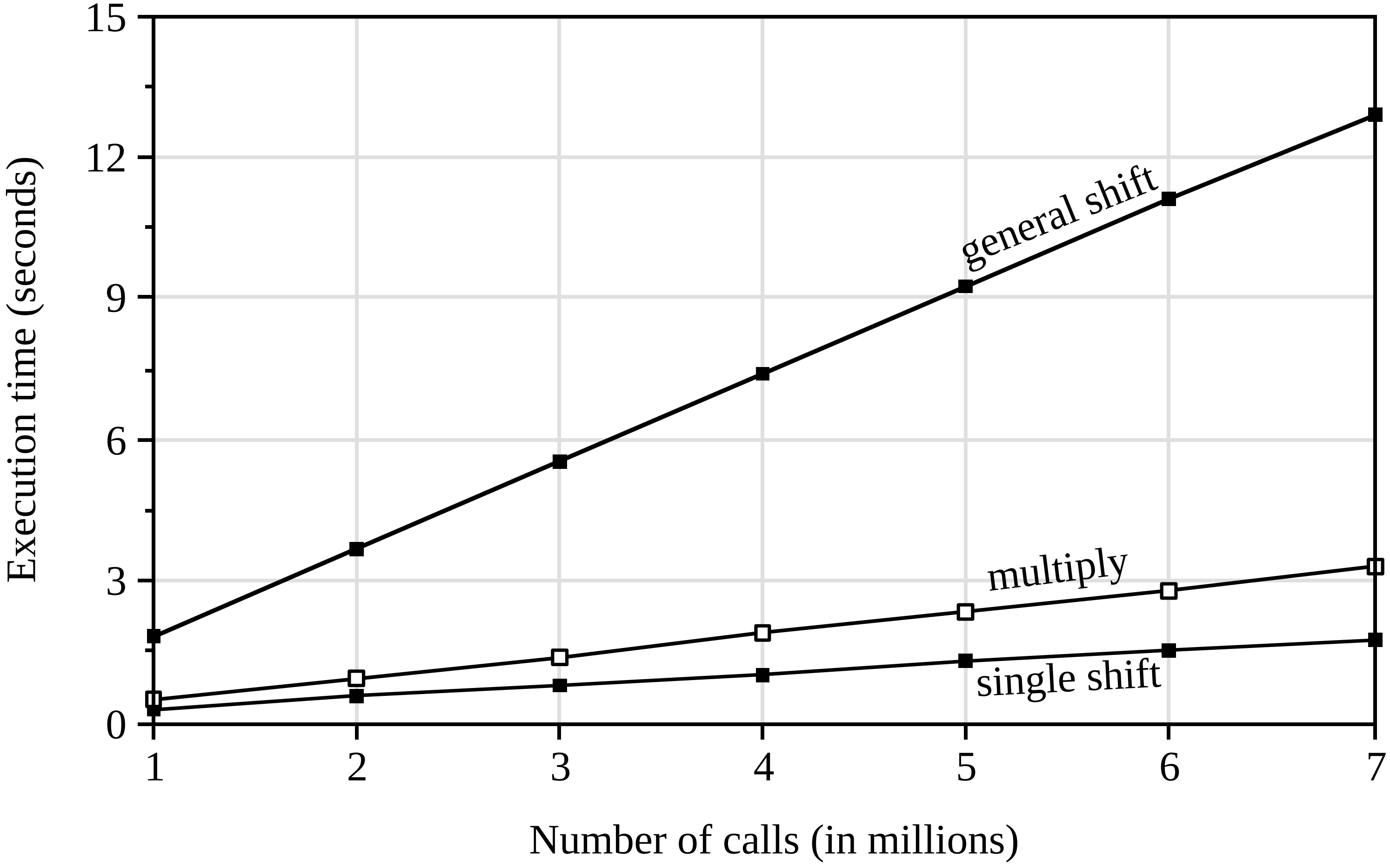
– ZF = 1 if all bits of operand are 0

– ZF = 0 otherwise (position of first 1 bit in **`dest_reg`**)

Illustrative Examples

- Example 1
  - ∗ Multiplication using shift and add operations
    - » Multiplies two unsigned 8-bit numbers
      - – Uses a loop that iterates 8 times
- Example 2
  - ∗ Same as Example 1 (efficient version)
    - » We loop only for the number of 1 bits
      - – Uses bit test instructions
- Example 3
  - ∗ Conversion of octal to binary

Performance: Shift vs. Multiplication



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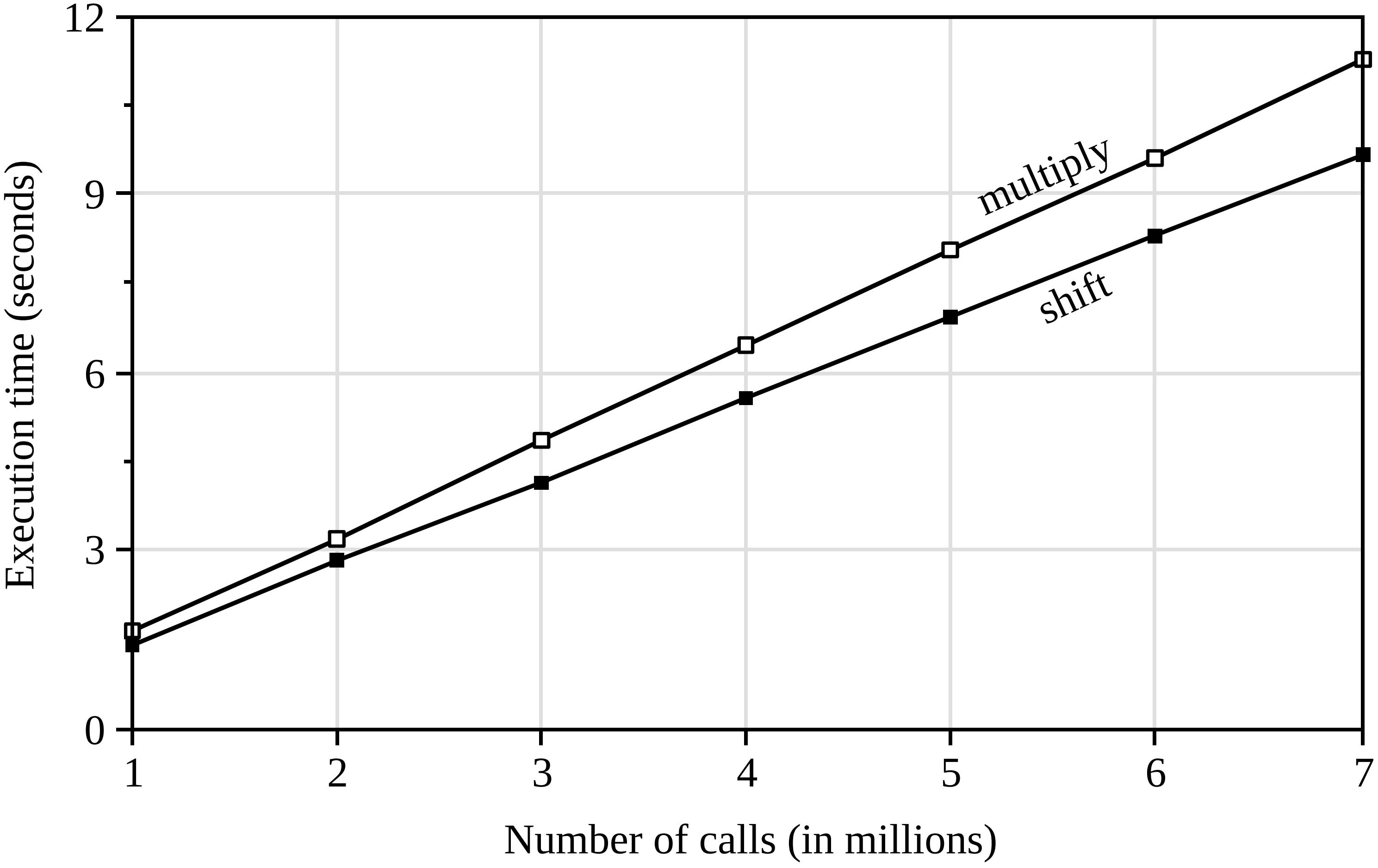
Performance: Shift vs. Multiplication (cont’d)


Execution time (seconds)
Number of calls (in millions)
multiply
shift