ASCII and BCD Arithmetic

Chapter 11

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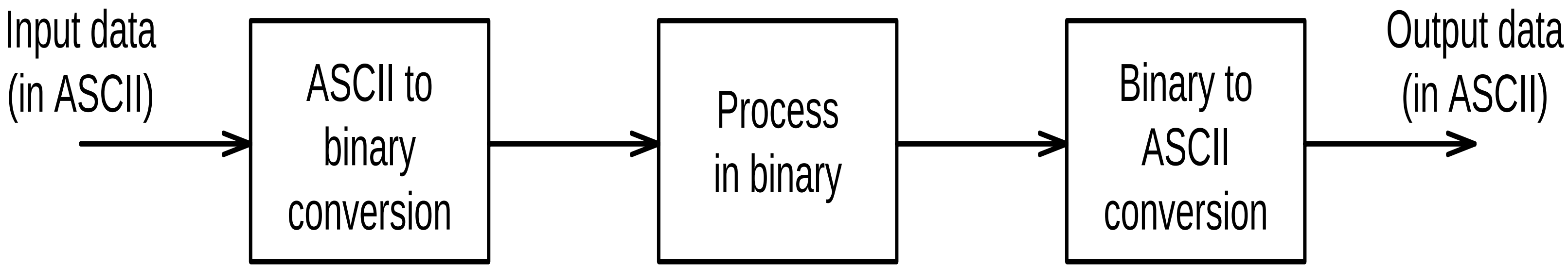
Outline

- Representation of Numbers
  - ASCII representation
  - BCD representation
    - Unpacked BCD
    - Packed BCD
- Processing ASCII numbers
    - ASCII addition
    - ASCII subtraction
    - ASCII multiplication
    - ASCII division
  - Example: Multidigit ASCII addition
- Processing packed BCD numbers
  - Packed BCD addition
  - Packed BCD subtraction
  - Example: Multibyte packed BCD addition
- Performance: Decimal versus binary arithmetic

Representation of Numbers

- Numbers are in ASCII form
  - ∗ when received from keyboard
  - ∗ when sending to the display
- Binary form is efficient to process numbers internally



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

Representation of Numbers (cont'd)

- Requires conversion between these two number representations
  - » We have used **`GetInt`**/**`GetLint`** and **`PutInt`**/**`PutLint`** to perform these two conversions
- In some applications, processing of numbers is simple (e.g. a simple addition)
  - » Does not justify the input and output conversion overheads
  - » In this case, it is better to process numbers in the decimal form
- Decimal numbers can be represented in
  - » ASCII
  - » BCD

Representation of Numbers (cont'd)

- ASCII representation
  - ∗ Numbers are stored as a string of ASCII characters
    - » Example: 1234 is stored as 31 32 33 34H
      - ✈ASCII for 1 is 31H, for 2 is 32H, etc.
- BCD representation
  - ∗ Unpacked BCD
    - » Example: 1234 is stored as 01 02 03 04H
      - – Additional byte is used for sign
        - ✈Sign byte: 00H for + and 80H for –
  - ∗ Packed BCD
    - » Saves space by packing two digits into a byte
      - – Example: 1234 is stored as 12 34H

Processing ASCII Numbers

- Pentium provides four instructions

  `aaa` – ASCII adjust after addition

  `aas` – ASCII adjust after subtraction

  `aam` – ASCII adjust after multiplication

  `aad` – ASCII adjust before division

  * These instructions do not take any operands
    » Operand is assumed to be in AL

Processing ASCII Numbers (cont'd)

ASCII addition

Example 1

```
 34H = 00110100B
 35H = 00110101B
 ---------------
 69H = 01101001B
```

Should be 09H

Ignore 6

Example 2

```
 36H = 00110110B
 37H = 00110111B
 ---------------
 6DH = 01101101B
```

Should be 13H

Ignore 6 and add 9 to D

- The **`aaa`** instruction performs these adjustments to the byte in AL register

Processing ASCII Numbers (cont'd)

- The **`aaa`** instruction works as follows:
  - ∗ If the least significant four bits in AL are > 9 or if AF =1, it adds 6 to AL and 1 to AH.
    - – Both CF and AF are set
  - ∗ In all cases, the most significant four bits in AL are cleared
  - ∗ Example:

```
sub    AH,AH     ; clear AH
mov    AL,'6'    ; AL := 36H
add    AL,'7'    ; AL := 36H+37H = 6DH
aaa              ; AX := 0103H
or     AL,30H    ; AL := 33H
```

Processing ASCII Numbers (cont'd)

ASCII subtraction

- The **`aas`** instruction works as follows:
  * If the least significant four bits in AL are > 9 or if AF =1, it subtracts 6 from AL and 1 from AH.
    - Both CF and AF are set
  * In all cases, the most significant four bits in AL are cleared
- This adjustment is needed only if the result is negative

Processing ASCII Numbers (cont'd)

- Example 1: Positive result

```
sub    AH,AH    ; clear AH
mov    AL,'9'   ; AL := 39H
sub    AL,'3'   ; AL := 39H-33H = 6H
aas             ; AX := 0006H
or     AL,30H   ; AL := 36H
```

- Example 2: Negative result

```
sub    AH,AH    ; clear AH
mov    AL,'3'   ; AL := 33H
sub    AL,'9'   ; AL := 33H-39H = FAH
aas             ; AX := FF04H
or     AL,30H   ; AL := 34H
```

Processing ASCII Numbers (cont'd)

ASCII multiplication

- The **`aam`** instruction adjusts the result of a **`mul`** instruction
  - ∗ Multiplication should not be performed on ASCII
    - » Can be done on unpacked BCD
- The **`aam`** instruction works as follows
  - ∗ AL is divided by 10
  - ∗ Quotient is stored in AH
  - ∗ Remainder in AL
- **`aam`** does not work with **`imul`** instruction

Processing ASCII Numbers (cont'd)

- Example 1

```
mov    AL,3      ; multiplier in unpacked BCD form
mov    BL,9      ; multiplicand in unpacked BCD form
mul    BL        ; result 001BH is in AX
aam              ; AX := 0207H
or     AX,3030H  ; AX := 3237H
```

- Example 2

```
mov    AL,'3'    ; multiplier in ASCII
mov    BL,'9'    ; multiplicand in ASCII
and    AL,0FH    ; multiplier in unpacked BCD form
and    BL,0FH    ; multiplicand in unpacked BCD form
mul    BL        ; result 001BH is in AX
aam              ; AX := 0207H
or     AL,30H    ; AL := 37H
```

Processing ASCII Numbers (cont'd)

ASCII division

- The **aad** instruction adjusts the numerator in AX *before* dividing two unpacked decimal numbers
  - The denominator is a single unpacked byte
- The **aad** instruction works as follows
  - Multiplies AH by 10 and adds it to AL and sets AH to 0
  - Example:
    - If AX is 0207H before **aad**
    - AX is changed to 001BH after **aad**
- **aad** instruction reverses the changes done by **aam**

Processing ASCII Numbers (cont'd)

- Example: Divide 27 by 5

```
mov    AX,0207H ; dividend in unpacked BCD form
mov    BL,05H   ; divisor in unpacked BCD form
aad             ; AX := 001BH
div    BL       ; AX := 0205H
```

- **`aad`** converts the unpacked BCD number in AX to binary form so that **`div`** can be used

Example: Multidigit ASCII addition

* ASCIIADD.ASM
* Adds two 10-digit numbers
  - » Adds one digit at a time starting with the rightmost digit

Processing Packed BCD Numbers

- Two instructions to process packed BCD numbers

  daa – Decimal adjust after addition

  ✈Used after **add** or **adc** instruction

  das – Decimal adjust after subtraction

  ✈Used after **sub** or **sbb** instruction

  * No support for multiplication or division
    - » For these operations
      - – Unpack the numbers
      - – Perform the operation
      - – Repack them

Processing Packed BCD Numbers (cont'd)

Packed BCD addition

Example 1

```
 29H = 00101001B
 69H = 01101001B
 92H = 10010010B
```

Should be 98H (add 6)

Example 2

```
 27H = 00100111B
 34H = 00110100B
 5BH = 01011101B
```

Should be 61H (add 6)

Example 3

```
 52H = 01010010B
 61H = 01100001B
 B3H = 10110010B
```

Should be 13H (add 60H)

Processing Packed BCD Numbers (cont'd)

- The **daa** instruction works as follows:
  - ∗ If the least significant four bits in AL are > 9 or if AF =1, it adds 6 to AL and sets AF
  - ∗ If the most significant four bits in AL are > 9 or if CF =1, it adds 60H to AL and sets CF

Example:

```
mov     AL,71H
add     AL,43H      ; AL := B4H
daa                 ; AL := 14H and CF := 1
```

- ∗ The result including the carry (i.e., 114H) is the correct answer

Processing Packed BCD Numbers (cont'd)

Packed BCD subtraction

- The **`das`** instruction works as follows:
  - ∗ If the least significant four bits in AL are > 9 or if AF =1, it subtracts 6 from AL and sets AF
  - ∗ If the most significant four bits in AL are > 9 or if CF =1, it subtracts 60H from AL and sets CF

Example:

```
mov    AL,71H
sub    AL,43H       ; AL := 2EH
das                 ; AL := 28H
```

Processing Packed BCD Numbers (cont'd)

Example: Multibyte packed BCD addition

- Adds two 10-digit numbers
  - » Adds two digits at a time starting from the rightmost pair
- For storage of the two input numbers and the result, we can use DT (Define Ten-byte) directive
  - ∗ DT stores in packed BCD form
  - ∗ Example:

```
DT    1234567890
```

    is stored as

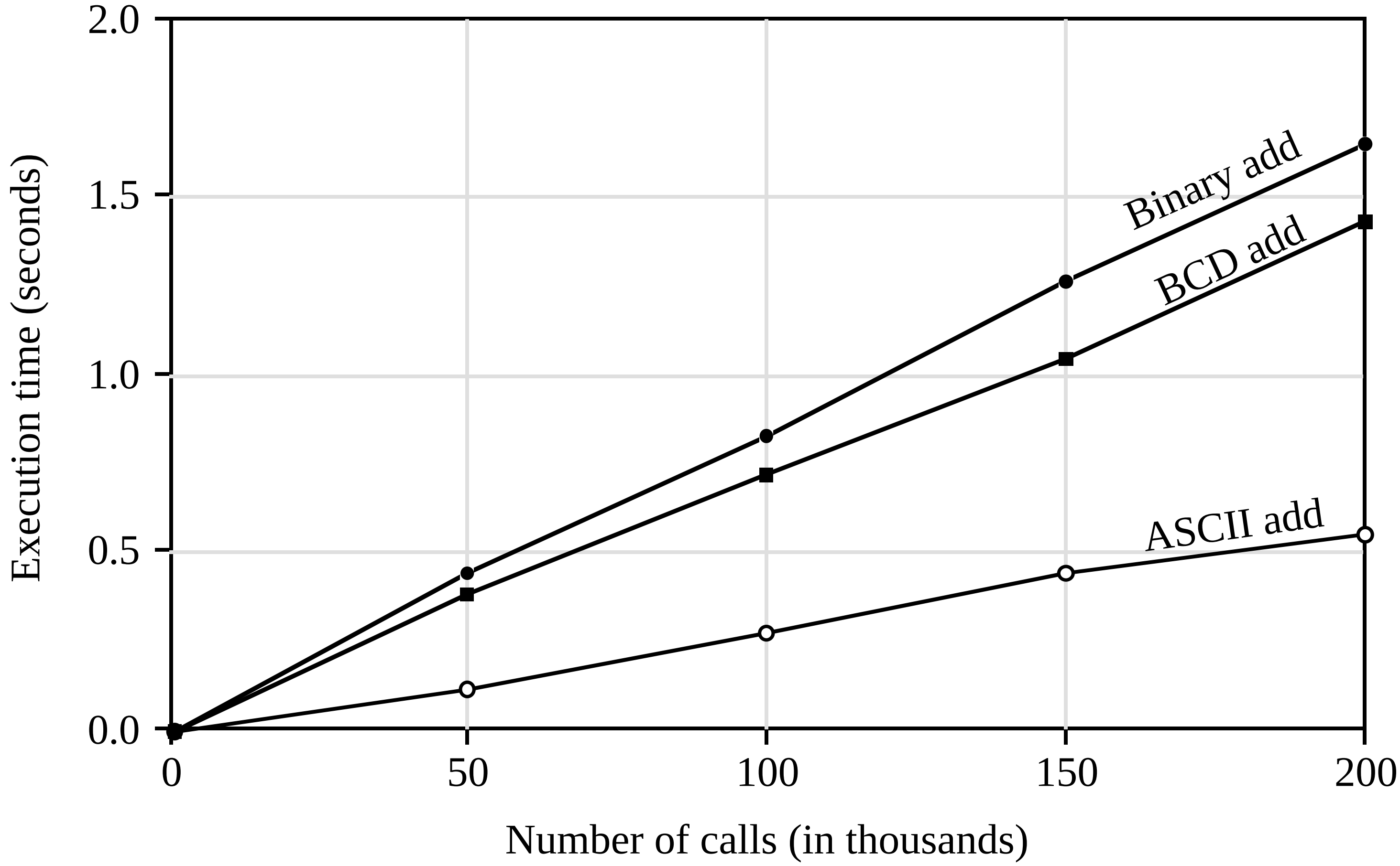
```
90 78 56 34 12H
```

Performance: Decimal vs Binary Arithmetic

- Tradeoffs associated with the three representations

Representation	Storage overhead	Conversion overhead	Processing overhead
Binary	Nil	High	Nil
Packed BCD	Medium	Medium	Medium
ASCII	High	Nil	High

Performance: Decimal vs Binary Arithmetic



Performance: Decimal vs Binary Arithmetic