Representation of Numbers and Characters

Number Systems

- A.   Decimal
- B.   Binary
- C.   Hexadecimal
  - Is a short-hand notation for binary
  - Consists of 16 digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
- *Note:* Yu's book use:
  - 101d to represent decimal
  - 101b to represent binary
  - 101h to represent hexadecimal

Conversion between number systems

- A.   Binary to Decimal
- B.   Decimal to Binary
- C.   Hexadecimal to   Decimal
- D.   Decimal to Hexadecimal
- E.   Binary to Hex
- F.   Hex to Binary
- *Note: we will learn addition and subtraction in hexadecimal only*

Terminology

- MSB - most significant bit is bit 15 in a word or bit 7 in a byte

- LSB - least significant bit is bit 0 in both a word and a byte (If the LSB of an integer is 0, the integer is even. If its LSB is a 1, the integer is odd)

Representing Integers

- Unsigned Integers
  - Integers that are never negative
  - Memory addresses, counters, and ASCII character codes are stored as unsigned numbers
  - No bit is needed to represent the sign bit
  - Largest unsigned integer in a byte is 11111111b or 255 or $2^8 - 1$; in a word it is 1111111111111111b or 65,535 or $2^{16} - 1$

- Signed Integers
  - In a signed number the MSB is the sign. The number is positive if the MSB is a 0 and the number is negative if the MSB is a One's complement in binary
    - flip all the bits from 0 to 1 or from 1 to 0
  - Two's complement in binary -
    - get one's complement and then add 1 (that is, flip all the bits and then add 1)

Representing Positive and Negative Numbers in Hex

- Positive numbers - straight conversion to hex

- Negative numbers are stored in two's complement form

- To get the two's complement form of a number in hex:
    - First: Represent the number as if it were positive
    - Second: Subtract it from FF(byte) or FFFF(word)
    - Third: Add 1

- Examples:

  -97 as a word is FFFF

                 -0061

                  FF9E

                  + 1

                  FF9F = -97

  -97 as a byte is FF

                 -61

                  9E

                 + 1

                  9F = - 97

Advantage of Storing Numbers in 2's Complement Form

- Advantage of storing numbers in 2's complement form is that subtraction can be accomplished by bit complementation and addition

- Circuits for complementation and addition are easy to design

- Also the same addition circuit can be used for subtraction as well. Hence, no separate circuit is needed for subtration

Interpreting Signed and Unsigned Bytes and Words in Memory as Decimal Numbers

- **Unsigned**
  - Straight translation from binary or hex to decimal

- **Signed numbers**
  - First determine the sign of the number by looking at its MSB. If its 0, its positive and you can do a straight translation from binary or hex to decimal
  - If its MSB is a 1, its negative and you must <u>Re-complement</u> it!
  - Since everything you see in memory will be expressed in hexadecimal, you won't "see" the MSB. Instead, you will see a hex digit. Therefore, if the first hex digit of a signed word or a byte is 0 to 7, the number is positive. If the first hex digit of a signed word or a byte is 8 to F, the number is negative. Why?

Identifying Positive Integers in Hex

First Hex Digit	Expressed in Binary
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111

- *In all of the above cases, the MSB is 0!*

- Therefore, if the first hex digit of a signed word or a byte is 0 to 7, the number is positive.

Identifying Negative Integers in Hex

First Hex Digit	Expressed in Binary
8	1000
9	1001
A	1010
B	1011
C	1100
D	1101
E	1110
F	1111

- *In all of the above cases, the MSB is 1 !*
- Therefore, if the first hex digit of a signed word or a byte is 8 to F, the number is positive

How to Interpret a Negative Integer Given in Hex

- Re-complement the number in hex. To do that,
  - First: Subtract the byte or word from FF or FFFF respectively
  - Second: Add 1

- Interpret your hex answer as a decimal answer and place a minus sign in front of your answer!

- Example: What signed number does the byte AAh represent?

```
 FF
-AA   Subtract from all F's
 55
+ 1   Add 1
 56h  Interpret your HEX answer as
       a decimal number
 So the answer is:  -86
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How to Interpret a Negative Integer Given in Binary

- Re-complement the number in binary. To do that,
  - First: Flip all the bits
  - Second: Add 1

- Interpret your binary answer as a decimal answer and place a minus sign in front of your answer!

- Example: What signed number does the byte 11111000b represent?

    Flip all bits ➜ 00000111b

    Add 1 ⟶ 00001000b

    So the answer is: -8

Range of Integers

- The range of signed values that can be stored in a byte is from -128 to 127

- The range of signed values that can be stored in a word is from -32,768 to 32,767

Character Representation

- Code chosen for IBM PC is the ASCII code
  - 7 bit code
  - 2^7 or 128 possible values
  - stored in a byte
- 95 ASCII codes are printable (32 to 126)
- 0 to 31 and 127 are used for control purposes
- IBM PC uses an extended character set using an 8 bit code thus in can represent 2^8 or 256 possible values
- ASCII keyboard
  - Each key pressed is stored in ASCII code
  - Today on IBM PC, each key is assigned a unique number called a <u>scan code</u> to handle the many control and function keys in addition to the ASCII character keys

ASCII Codes for Capital Letters

- Capital Letters of the Alphabet (41 - 5A)

A - 41	J - 4A	Q - 51	Z - 5A
B - 42	K - 4B	R - 52	
C - 43	L - 4C	S - 53	
D - 44	M - 4D	T - 54	
E - 45	N - 4E	U - 55	
F - 46	0 - 4F	V - 56	
G - 47	P - 50	W - 57	
H - 48		X - 58	
I - 49		Y - 59	

ASCII Codes for Lower Case Letters

- Lower case letters of the alphabet (61-7A)

a - 61	j - 6A	q - 71	z - 7A
b - 62	k - 6B	r - 72	
c - 63	l - 6C	s - 73	
d - 64	m - 6D	t - 74	
e - 65	n - 6E	u - 75	
f - 66	o - 6F	v - 76	
g - 67	p - 70	w - 77	
h - 68		x - 78	
i - 69		y - 79	

ASCII Codes for Digits and Special Characters

- Digits (30-39)

    0 - 30 3 - 33 6 - 36 9 - 39

    1 - 31 4 - 34 7 - 37

    2 - 32 5 - 35 8 - 38

- Special Characters

    space - 20

    ! - 21

    + - 2B

    - - 2D

- *See pages 442-443 in Yu's book for the complete ASCII CODE chart*

Practice Problems on ASCII Code

- Interpret this: 31 32 33 20 4F 41 4B 20 53 54 52 45 45 54

- Interpret this: 49 53 4E 27 54 20 54 48 49 53 20 46 55 4E 21

Homework - Number System Review

Conversion:

1. Convert from decimal to binary

    a. 43   b. 167

2. Convert from binary to decimal

    a. 1101100b   b. 1100011b

3. Convert from decimal to hexadecimal

    a. 6242   b. 12321

4. Convert from hexadecimal to decimal

    a. 4BFh   b. A2F7h

5. Convert from binary to hexadecimal

    a. 110010011110b   b. 100001011b

6. Convert from hexadecimal to binary

    a. FADh   b. 265Ch   c. BE98h

Homework: Data Representations Set 1

Problems

Note: Express all answers to problems 1-9 in HEXADECIMAL

1. How do you represent 231 as an unsigned byte? _____
2. How do you represent 110 as a signed byte? _____
3. How do you represent -103 as a signed byte? _____
4. How do you represent 64785 as an unsigned word? _____
5. How do you represent 1600 as a signed word? _____
6. How do you represent -160 as a signed word? _____
7. How do you represent +7623 as a character string?_____
8. How do you represent -632 as a character string? _____
9. How do you represent WOW! as a character string? _____

Homework: Hex to Decimal or Character - Set 1

You are looking at a dump. Therefore, the values in problems 10-16 are expressed in HEXADECIMAL. Express your answers to problems 10-16 in decimal or character form:

10. You know 8E is an unsigned byte. What number does it represent? _____

11. You know 8E is a signed byte. What number does it represent? _____

12. You know 7E is a signed byte. What number does it represent? _____

13. You know 34A2 is an unsigned word (PV). What number does it represent? _____

14. You know 34A2 is a signed word (PV). What number does it represent? _____

15. You know 3452 is a signed word (PV). What number does it represent? _____

16. You know 5745 is a character string. What value does it represent? _____

Homework: Hex to Decimal or Character - Set 1 (cont'd)

You are looking at a dump. Therefore, the values in problems 10-16 are expressed in HEXADECIMAL. Express your anwers to problems 10-16 in decimal or character form:

Answers

10. You know 8E is an unsigned byte. What number does it represent?   142

11. You know 8E is a signed byte. What number does it represent?   -114

12. You know 7E is a signed byte. What number does it represent?   126

13. You know 34A2 is an unsigned word (PV). What number does it represent?   41524

14. You know 34A2 is a signed word (PV). What number does it represent?   -24012

15. You know 3452 is a signed word (PV). What number does it represent?   21044

16. You know 5745 is a character string. What value does it represent?   WE

HOMEWORK: Data Representations - Set 2

LV: Logical View   PV: Physical View

Express all answers to problems 1-9 in HEXADECIMAL

1. How do you represent 195 as an unsigned byte? _____

2. How do you represent 101 as a signed byte? _____

3. How do you represent -119 as a signed byte? _____

4. How do you represent 42623 as an unsigned word? (LV)_____

5. How do you represent 32001 as a signed word? (LV)_____

6. How do you represent -1675 as a signed word? (LV) _____

7. How do you represent +25 as a character string?_____

8. How do you represent -413 as a character string? _____

9. How do you represent (TEST) as a character string? _____

Hex to Decimal or Character: Set 2

You are looking at a dump. Therefore, the values in problems 10-16 are expressed in HEXADECIMAL. Express your answers to problems 10-16 in decimal or character form:

10. You know 95 is an unsigned byte. What number does it represent? _____

11. You know 95 is a signed byte. What number does it represent? _____

12. You know 7F is a signed byte. What number does it represent? _____

13. You know 1DB1 is an unsigned word (PV). What number does it represent? _____

14. You know 1DB1 is a signed word (PV). What number does it represent? _____

15. You know 6C73 is a signed word (PV). What number does it represent? _____

16. You know 4D41 is a character string. What value does it represent? _____