

Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C

Chapter 2 Data Representation Exercises ANS

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Question: Number Conversion

- ▶ Q: Convert 0x3A56E2F8 into binary
- ▶ Q: Convert binary number 111010 into hex



Answer: Number Conversion

- ▶ Q: Convert 0x3A56E2F8 into binary
- ▶ A: 0011 1010 0101 0110 1110 0010 1111 1000 (simple table lookup for each hex symbol)
- ▶ Q: Convert binary number 111010 into hex
- ▶ A: 0x3A (group 111010 into two parts 0011 1010, followed by table lookup)



Question: 2's Complement

- ▶ For each of the following binary numbers, give the corresponding binary number of the negative of its value, for 2's-complement system
- ▶ (a) $x=01010101$
- ▶ (b) $x=10101010$
- ▶ (c) $x=10000000$



Answer: 2's Complement

- ▶ For each of the following binary numbers x , give the corresponding binary number of $-x$ in 2's-complement representation?
- ▶ (a) $x=01010101$
 - ▶ $-x = 10101011$
- ▶ (b) $x=10101010$
 - ▶ $-x = 01010110$
- ▶ (c) $x=10000000$
 - ▶ $-x = 10000000$



Question: Number Conversion

- ▶ Q: What is the decimal value of binary number $x=10100111$ as either unsigned int, or signed int in 2's complement representation?
- ▶ What about $x=11100001$?
- ▶ What about $x=10000000$?



Answer: Number Conversion

- ▶ Q: What is the decimal value of binary number $x=10100111$ as either unsigned int, or signed int in 2's complement representation?
- ▶ A: if unsigned int, then $x=2^7+2^5+2^2+2^1+2^0=167$
- ▶ If signed int, then it is a negative number, since leftmost sign bit is 1. First convert it into its positive counterpart of bitwise NOT plus one to get 01011001, which is equal to decimal $2^6+2^4+2^3+2^0=89$. Hence $x=-89$
- ▶ Similarly, for $x=11100001$ (unsigned int 225), first convert it into its positive counterpart of bitwise NOT plus one to get 00011111, which is equal to decimal 31. Hence $x=-31$
- ▶ Similarly, for $x=10000000$ (unsigned int 128), first convert it into its positive counterpart of bitwise NOT plus one to get 10000000, which is equal to decimal 2^7 . Hence $x=-2^7=-128$

	uint	Int
10100111	167	-89
11100001	225	-31
10000000	128	-128



Question: Number Conversion

- ▶ Q: Which number is larger: 1001 or 0011 in binary?
- ▶ Q: Which number is larger: 0xFFFFFFFF or 0x00000001 in hex?



Answer: Number Conversion

- ▶ Q: Which number is larger: 1001 or 0011 in binary?
- ▶ A: depends on the number system.
 - ▶ If unsigned int, then 1001 is 9, and 0011 is 3 in decimal, and $9 > 3$
 - ▶ If signed int, then 1001 is -7 (negative of 0111), and 0011 is 3 in decimal, and $-7 < 3$
- ▶ Q: Which number is larger: 0xFFFFFFFF or 0x00000001 in hex?
- ▶ Q: depends on the number system.
 - ▶ If unsigned int, then 0xFFFFFFFF is $2^{32}-1$, and 0x00000001 is 1 in decimal, and $2^{32}-1 > 1$
 - ▶ If signed int, then 0xFFFFFFFF is -1 (negative of 0x00000001), and 0x00000001 is 1 in decimal, and $-1 < 1$



Question: Number Range

- ▶ Which range of decimals can be expressed with a 6-bit signed integer (assuming Two's complement representation)?

Answer	Range
A	-32 ... 32
B	-64 ... 63
C	-31 ... 32
D	-16 ... 15
E	-32 ... 31



Answer: Number Range

- ▶ Which range of decimals can be expressed with a 6-bit signed integer (assuming Two's complement representation)?

Answer	Range
A	-32 ... 32
B	-64 ... 63
C	-31 ... 32
D	-16 ... 15
E	-32 ... 31

$$[-2^{n-1}, 2^{n-1} - 1] = [-2^5, 2^5 - 1] = [-32, 31]$$

Question: Number Range

- ▶ Which range of decimals can be expressed with a 6-bit unsigned integer?

Answer	Range
A	-32 ... 32
B	-64 ... 63
C	-31 ... 32
D	-16 ... 15
E	0 ... 63



Answer: Number Range

- ▶ Which range of decimals can be expressed with a 6-bit unsigned integer?

Answer	Range
A	-32 ... 32
B	-64 ... 63
C	-31 ... 32
D	-16 ... 15
E	0 ... 63

$$[0, 2^n - 1] = [0, 2^6 - 1] = [0, 63]$$

Question: Integer arithmetic

- ▶ Q: What is the result of $1001 + 0011$?



Answer: Integer arithmetic

- ▶ Q: Consider a 4-bit system. What is the result of $1001 + 0011$?
- ▶ A: $1001 + 0011 = 1100$
- ▶ Value of 1100 depends on the number system.
 - ▶ If unsigned int, then 1100 is 12, which is equal to $9 (1001) + 3 (0011)$
 - ▶ If signed int, then 1100 is -4 (negative of 0100), which is equal to $-7 (1001) + 3 (0011)$ in decimal



Question: Addition

- ▶ Q: Consider a 4-bit system. What is the result of addition $1011+0110$, assuming either unsigned integers, or signed integers in 2's-complement representation?
- ▶ 0001

Answer: Addition

- ▶ Q: Consider a 4-bit system. What is the result of addition $1011+0110$, assuming either unsigned integers, or signed integers in 2's-complement representation?
- ▶ A: $1011+0110 = 10001$; the extra leftmost bit is discarded, so the result is 0001 (1 in decimal) for both cases.
- ▶ 1011 is 11 in decimal as unsigned int; -5 in decimal as signed int; 0110 is 6 as either unsigned or signed int. A 4-bit unsigned int has the range $[0, 2^4-1]=[0, 15]$; a 4-bit signed int has the range $[-2^3, 2^3-1]=[-8, 7]$
- ▶ For unsigned addition, true result should be $11+6=17$ in decimal. Since $17 > 15$, the result is wrong, and Carry flag is set to 1.
- ▶ For signed addition, true result should be $-5+6=1$ in decimal. So the result is correct.

Question: Subtraction

- ▶ Q: Q: Consider a 4-bit system. What is the result of subtraction $1011-0110$, assuming either unsigned integers, or signed integers in 2's-complement representation?

Answer: Subtraction

- ▶ Q: Consider a 4-bit system. What is the result of subtraction $1011-0110$, assuming either unsigned integers, or signed integers in 2's-complement representation?
- ▶ A: $1011-0110 = 0101$ (carry bit discarded), so the computed result is 0101 (5 in decimal) for both cases.
- ▶ For unsigned subtraction, true result should be $11-6=5$ in decimal. So the result is correct
- ▶ For signed subtraction, true result should be $-5-6=-11$. Since $-11 < -8$, the result of 5 is wrong, and Overflow flag is set to 1.

Question: Subtraction

- ▶ Q: Consider a 4-bit system. What is the result of subtraction $0110 - 1011$, assuming either unsigned integers, or signed integers in 2's-complement representation?

Answer: Subtraction

- ▶ Q: Consider a 4-bit system. What is the result of subtraction $0110 - 1011$, assuming either unsigned integers, or signed integers in 2's-complement representation?
- ▶ A: $0110 - 1011 = 1011$ (borrow bit discarded), so the computed result is 11 in decimal for unsigned, or -5 in decimal for signed.
- ▶ For unsigned subtraction, true result should be $6 - 11 = -5$ in decimal. Since $-5 < 0$, the result is wrong, and Carry flag is 0 (Borrow flag is 1).
- ▶ For signed subtraction, true result should be $6 - (-5) = 11$. Since $11 > 7$, the result is wrong, and Overflow flag is set to 1.

Question: True or False

- ▶ 1. Overflow is impossible when subtracting one unsigned number from another.
- ▶ 2. Overflow is impossible when subtracting two signed operands of the same sign.
- ▶ 3. There are two representations of zero in 2's complement representation.
- ▶ 4. In 2's complement, the absolute values of full-scale negative and full-scale positive are identical

Answer: True or False

- ▶ 1. Borrow=1 is impossible when subtracting one unsigned number from another. **False**
- ▶ 2. Overflow=1 is impossible when subtracting two signed operands of the same sign. **True**
- ▶ 3. There are two representations of zero in 2's complement representation. **False**
- ▶ 4. In 2's complement, the absolute values of smallest negative and largest positive numbers are identical. **False**. e.g., [-8, 7] for a 4-bit system