Signed Binary

Last updated 3/16/23

These slides introduce signed binary number concepts

Signed Binary

- 3 variations of signed binary numbers
  - Sign-Magnitude
  - One's Complement
  - Two's Complement

- Two's complement is used in almost all digital systems
- We will use the names Two's Complement and Signed interchangeably

Signed Binary

- Signed Binary (2's complement)
  - Binary representation for a number that is can be positive or negative
    - Most data
  - Often just called "signed"
  - Characterized by n-bits
    - I have a 32 bit signed binary number

Signed Binary

- Bit Values
  - The most significant bit is NOT used to represent the magnitude of the value
  - The most significant bit INDICATES the sign but is NOT a sign bit

  - Positive numbers are formed in normal binary format
    - Excluding the msb – it is not used to create the binary value

  - Negative numbers are formed by
    1) creating the positive binary number
    2) flipping all bits
    3) adding 1

  - MSB = 0 → indicates a positive value
  - MSB = 1 → indicates a negative value

Signed Binary

- Bit Values

50 → 0011 0010 (32 + 16 + 2)

-50 → 1) positive value → 0011 0010

2) flip bits → 1100 1101

3) add 1 → + 0000 0001

1100 1110

The msb indicates
it is a negative number

37 → ?

-37 → ?

10010110_b signed → ?

00010110_b signed → ?

Signed Binary

- Convert Decimal to Signed Binary

convert 37 decimal to 8 bit signed binary

8 bits → positive bit values of x | 64 | 32 | 16 | 8 | 4 | 2 | 1

	Positive	→	0
37	How many 64s	→ 0	00
37	How many 32s	→ 1 r 5	001
5	How many 16s	→ 0	0010
5	How many 8s	→ 0	0010 0
5	How many 4s	→ 1 r 1	0010 01
1	How many 2s	→ 0	0010 010
1	How many 1s	→ 1 r 0	0010 0101
0			0010 0101

Signed Binary

- Convert Decimal to Signed Binary

convert −37 decimal to 8 bit signed binary

Negative:

1) positive value	→	0010 0101
2) flip bits	→	1101 1010
3) add 1	→	+ 0000 0001
		1101 1011

Signed Binary

- Convert Signed Binary to Decimal

convert 00110110 signed to decimal

MSB is 0 (positive) → nothing special to do - find value

Positive:

0011 0110 → 32 + 16 + 4 + 2 = 54

Signed Binary

- Convert Signed Binary to Decimal

convert 10010110 signed to decimal

MSB is 1 (negative) → remember this for the end
→ flip the bits and add 1 (works both directions)

Negative:

1) negative value	→	1001 0110
2) flip bits	→	0110 1001
3) add 1	→	+ 0000 0001
		0110 1010

Evaluate the number (remember the minus sign)

0110 1010 → 64 + 32 + 8 + 2 = 106 → -106

Signed Binary

- Convert Signed Binary ←→ Decimal

Is it negative (- sign in decimal or 1 in MSB for signed binary)

No – just do the conversion

Yes – flip the bits and add 1

Signed Binary

- Limits

  - Maximum values:

    - 4 bits = +7, -8 = $2^3-1, -2^3$
    - 8 bits = + 127, -128 = $2^7-1, -2^7$
    - 16 bits = + 32,767, -32,768 = $2^{15}-1, -2^{15}$

    - Not Symmetric

7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
0111	0110	0101	0100	0011	0010	0001	0000	1111	1110	1101	1100	1011	1010	1001	1000

Signed Binary

- Advantages
  - Addition is done the same way as unsigned numbers – same adder circuit
  - ONLY 1 ZERO !
  - Simple word length extension

- Disadvantages
  - Asymmetric range
  - Harder to do comparisons
  - Not intuitive

7	6	5	4	3	2	1	0	-1	-2	-3	-4	-5	-6	-7	-8
0111	0110	0101	0100	0011	0010	0001	0000	1111	1110	1101	1100	1011	1010	1001	1000

Signed Binary

- Sign Extension

  - When extending to larger word sizes, extend the MSB to the left

4 bit		8 bit		16 bit
0110	→	00000110	→	0000000000000110
1001	→	11111001	→	1111111111111001