Data Representation: Signed Integers

Introduction

"Data" in a computer is just _____

We have assigned meaning!

_____ → _____ , _____ → _____

How do we interpret this "data?"

It depends on _____

e.g. _____

Computers encode all sorts of data:

Numbers

- → _____
  - → _____
  - → _____
    _____
- → _____
  - → _____
  - → _____

Text

- → _____
  _____
- → _____
  _____
- → _____
  _____

Integers

Unsigned

These are interpreted as _____ numbers

n = _____, Range: _____

distinct values: _____

Sign Magnitude

The MSB is the _____: 0 = _____ 1 = _____

Other bits are treated as a _____

If we have 4-bit sign magnitude notation, what are the maximum and minimum values? How many distinct values can we represent?

n = _____, Range: _____

distinct values: _____

What is the binary representation of -64 in 8-bit sign magnitude notation?	What does 0xFF represent in 8-bit signed magnitude notation?

Two's Complement (2SC)

Two's complement is how modern computers store _____ integers.

The MSB is the _____: 0 = _____ 1 = _____

Positive #s are encoded the same as _____

with _____

There are 3 steps to encode a negative # in 2SC notation:

(1) _____

(2) _____ (3) _____

n = _____, Range: _____

distinct values: _____

What is -7_10 in 4-bit two's complement? (1) (2) (3)	What is 7_10 in 4-bit two's complement? (1) (2) (3)

To find the additive inverse of a 2SC #:

(1) _____ (2) _____

What is -5_10 in 4-bit two's complement?	What is 5_10 in 4-bit two's complement?
What decimal number does 0b0100 represent? (4-bit 2SC)	What decimal number does 0b1100 represent? (4-bit 2SC)

What decimal number does 0b1111 represent? (4-bit 2SC)	What number does 0b11111111 represent? (8-bit 2SC)
What number does 0b1110 represent? (4-bit 2SC)	What number does 0b11111110 represent? (8-bit 2SC)
What number does 0b1000 represent? (4-bit 2SC)	What number does 0b10000000 represent? (8-bit 2SC)

How to convert 2SC to decimal?

Just like before except… _____

Convert the following binary number to decimal: 0b101 Assuming this number is unsigned: Assuming this number is 3-bit 2SC:
Convert the following 5-bit 2SC binary number to decimal: 0b10111
Convert the following 8-bit 2SC binary number to decimal: 0x81

4-Bit Number Line

-8	+8 (Can we represent this number?)
-7	+7
-6	+6
-5	+5
-4	+4
-3	+3
-2	+2
-1	+1
-0 (Can we represent this number?)	0

8-Bit Number Line

-8	+8 (Can we represent this number?)
-7	+7
-6	+6
-5	+5
-4	+4
-3	+3
-2	+2
-1	+1
-0 (Can we represent this number?)	0

2SC Addition

Just like unsigned, except: _____

Perform the following computation using 6-bit 2SC notation

```
 10
+ 3
----
```

Express the result in hex:

Perform the following computation using 6-bit 2SC notation

```
-10
+ 3
----
```

Express the result in hex:

Perform the following computation using 6-bit 2SC notation

```
 -1
+ 1
----
```

Express the result in hex:

Perform the following computation using 6-bit 2SC notation

```
 -10
+ -3
-----
```

Express the result in hex:

2SC Subtraction

Convert to an addition problem, e.g. _____

Perform the following computation using 5-bit 2SC notation

```
   4
-  1
-----
```

Biased / Excess Notation

Biased notation is like unsigned, where 0 is _____ on the number line.

Example

Unsigned

```
    |----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111
```

Excess 8

```
    |----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
  0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111
```

The MSB is the _____: 0 = _____ 1 = _____

n = _____, Range: _____

distinct values: _____

The bias is often _____

_____

To convert from biased notation to unbiased, _____

To convert from unbiased notation to biased, _____

Examples

Express 2_10 in 3-bit bias 4 notation.	Express -2_10 in 3-bit bias 4 notation.
Convert from 3-bit bias 4 notation to signed decimal notation: 0b001	Convert from 3-bit bias 4 notation to signed decimal notation: 0b100
What is the range for 8-bit bias 127 notation?	Convert from 8-bit bias 127 notation to signed decimal notation: 0b00001100
Express 6_10 in 8-bit bias 127 notation.	Express -12_10 in 8-bit bias 127 notation.

Sign Extension

Adder Example

In a computer, computations on two numbers must have the _____

Sign Magnitude

1 - _____

2 - _____

3 - _____

Examples

Sign extend 0101 to 8 bits	Sign extend 0x1E from 5 to 8 bits

Two's Complement

Examples

Sign extend 0xB from 4 to 8 bits	Sign extend 0x1E from 5 to 8 bits
Sign extend 0x0B from 6 to 8 bits	Sign extend 0x1E from 6 to 8 bits
Sign extend 26_8 from 5 to 8 bits	Sign extend 26_8 from 6 to 8 bits
Sign extend 0x29 from 8 to 12 bits	Sign extend 0x29 from 6 to 8 bits