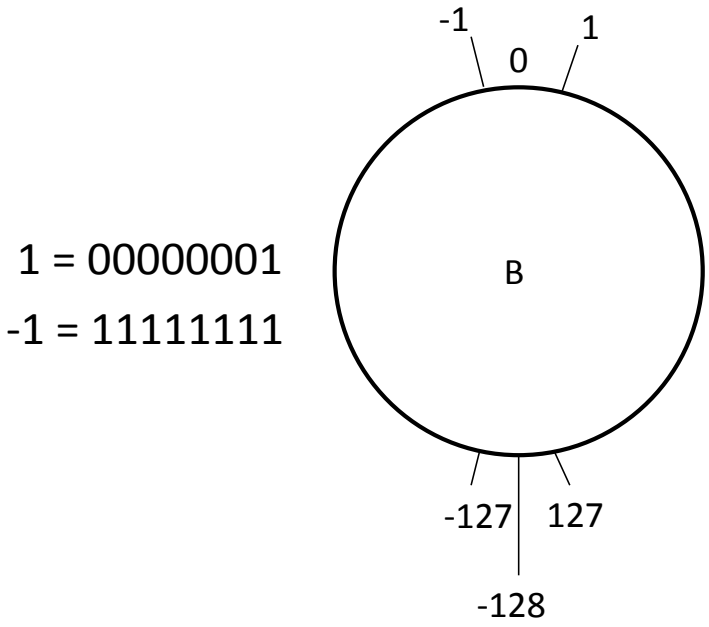
# Two's Complement






# Representation Exercises

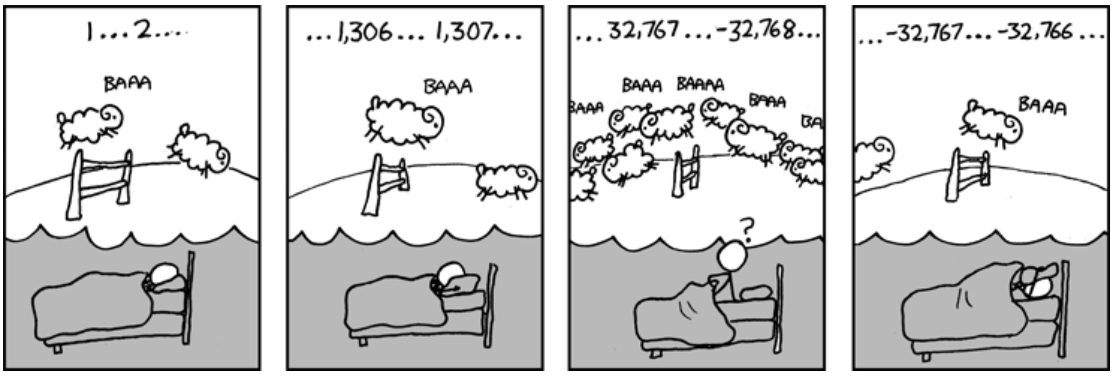
| | Smallest (binary) | Smallest (decimal) | Largest (binary) | Largest (decimal) |
|---|---|---|---|---|
| **Unsigned (4 bits)** | 0000 | 0 | 1111 | 15 |
| **Unsigned (n bits)** | N/A | 0 | N/A | 2^n - 1 |
| **Sign Magnitude (4 bits)** | 1111 | -7 | 0111 | 7 |
| **Sign Magnitude (n bits)** | N/A | -2^(n - 1) + 1 | N/A | 2^(n - 1) - 1 |
| **1's Complement (4 bits)** | 1000 | -7 | 0111 | 7 |
| **1's Complement (n bits)** | N/A | -2^(n - 1) + 1 | N/A | 2^(n - 1) - 1 |
| **2's Complement (4 bits)** | 1000 | -8 | 0111 | 7 |
| **2's Complement (n bits)** | N/A | -2^(n - 1) | N/A | 2^(n - 1) - 1 |

# Signed vs Unsigned

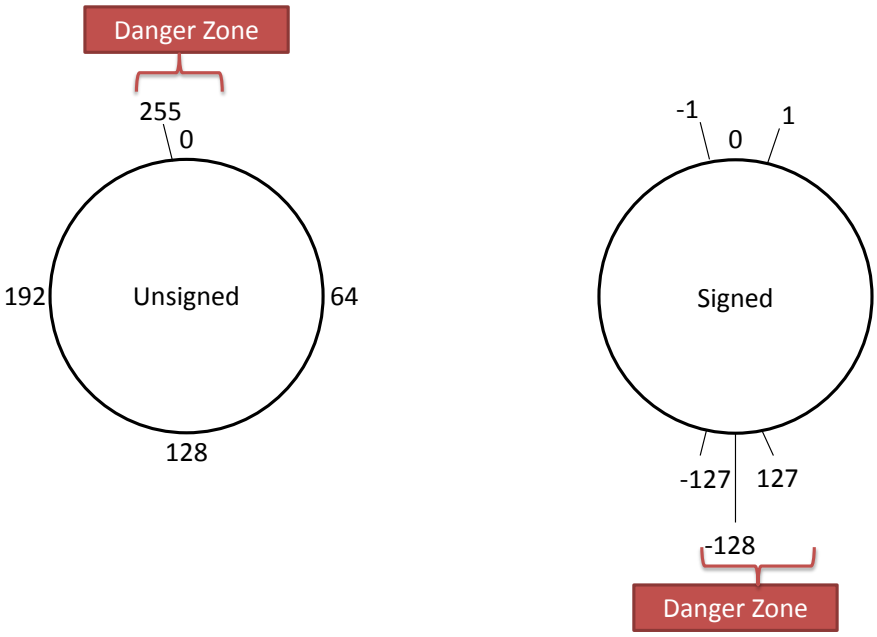
| Bits | Signed | | Unsigned |
|---|---|---|---|
| 0000 | 0 | | 0 |
| 0001 | 1 | | 1 |
| 0010 | 2 | | 2 |
| 0011 | 3 | = | 3 |
| 0100 | 4 | | 4 |
| 0101 | 5 | | 5 |
| 0110 | 6 | | 6 |
| 0111 | 7 | | 7 |
| 1000 | -8 | | 8 |
| 1001 | -7 | | 9 |
| 1010 | -6 | | 10 |
| 1011 | -5 | +/- 16 | 11 |
| 1100 | -4 | | 12 |
| 1101 | -3 | | 13 |
| 1110 | -2 | | 14 |
| 1111 | -1 | | 15 |



# Overflow



# Overflow






# Sign Extension

(5) 0101 → 00000101

(-4) 1100 → 11111100

# Project 1 Preview

- Given a signed 32-bit int X, return 1 if X is positive, 0 if X is zero, and -1 if X is negative.
- No loops or conditionals!
- Allowed operators: ! ~ & ^ | + << >>