Its All 0s and 1s
Part 1: bits, bytes, integers
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This lecture Includes materials from the textbook authors:

15-213: Introduction to Computer Systems
2nd and 3rd Lectures, Sep. 3 and Sep. 8, 2015

Randal E. Bryant and David R. O'Hallaron

It is a modified version of the original slides.

Today: Bits, Bytes, and Integers

- **Representing information as bits**
- **Bit-level manipulations**
- **Integers**
  - Representation: unsigned and signed
  - Conversion, casting
  - Expanding, truncating
  - Addition, negation, multiplication, shifting
  - Summary
- **Representations in memory, pointers, strings**

Everything is bits

- **Each bit is 0 or 1**

- **By encoding/interpreting sets of bits in various ways**
  - Computers determine what to do (instructions)
  - … and represent and manipulate numbers, sets, strings, etc…

- **Why bits? Electronic Implementation**
  - Easy to store with bistable elements
  - Reliably transmitted on noisy and inaccurate wires
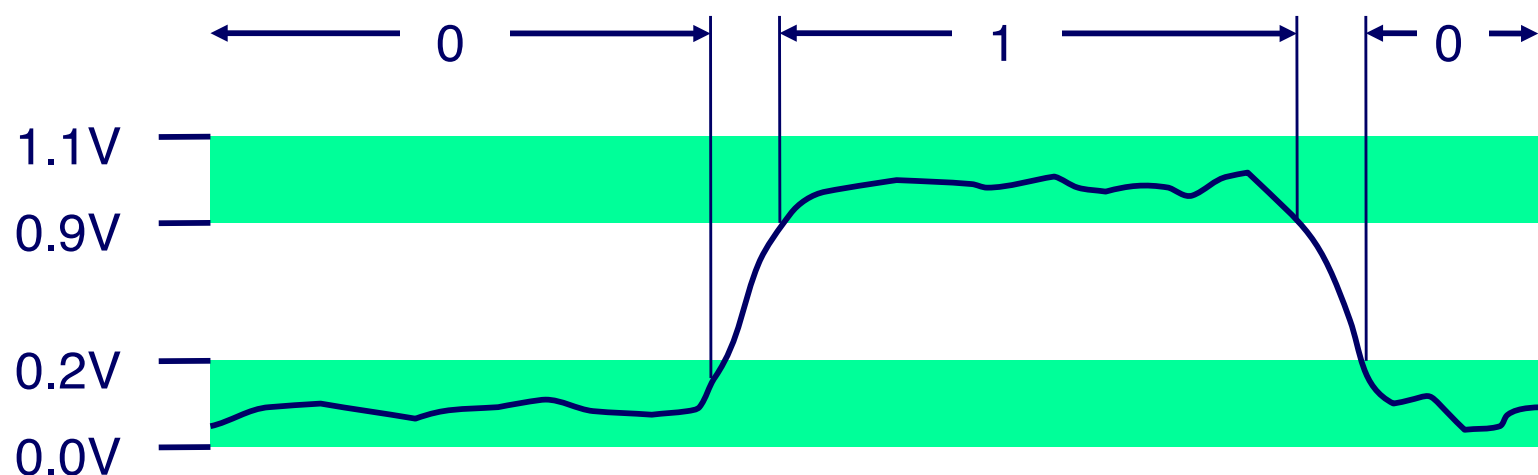
For example, can count in binary

- **Base 2 Number Representation**
  - Represent 15213_{10} as 11101101101101_2
  - Represent 1.20_{10} as $1.0011001100110011[0011]..._2$
  - Represent 1.5213×10^4 as $1.1101101101101_2 \times 2^{13}$

Encoding Byte Values

- **Byte = 8 bits**
  - Binary 00000000_2 to 11111111_2
  - Decimal: 0_{10} to 255_{10}
  - Hexadecimal 00_{16} to FF_{16}
    - Base 16 number representation
    - Use characters '0' to '9' and 'A' to 'F'
    - Write $FA1D37B_{16}$ in C as
      - 0xFA1D37B
      - 0xfa1d37b

Hex	Decimal	Binary
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111

Example Data Representations

C Data Type	Typical 32-bit	Typical 64-bit	x86-64
char	1	1	1
short	2	2	2
int	4	4	4
long	4	8	8
float	4	4	4
double	8	8	8
long double	–	–	10/16
pointer	4	8	8

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Boolean Algebra

- **Developed by George Boole in 19th Century**
    - Algebraic representation of logic
        - Encode "True" as 1 and "False" as 0

And

- **A&B = 1 when both A=1 and B=1**

&	0	1
0	0	0
1	0	1

Or

- **A|B = 1 when either A=1 or B=1**

|	0	1
0	0	1
1	1	1

Not

- **~A = 1 when A=0**

~	
0	1
1	0

Exclusive-Or (Xor)

- **A^B = 1 when either A=1 or B=1, but not both**

^	0	1
0	0	1
1	1	0

General Boolean Algebras

- **Operate on Bit Vectors**
  - Operations applied bitwise

```
  01101001      01101001      01101001
& 01010101    | 01010101    ^ 01010101    ~ 01010101
  01000001      01111101      00111100      10101010
```

- **All of the Properties of Boolean Algebra Apply**

Example: Representing & Manipulating Sets

- **Representation**
  - Width w bit vector represents subsets of {0, …, w–1}
  - a_j = 1 if j $\in$ A

    - 01101001   { 0, 3, 5, 6 }
    - *76543210*

    - 01010101   { 0, 2, 4, 6 }
    - *76543210*

- **Operations**
  - &   Intersection   01000001   { 0, 6 }
  - | Union   01111101   { 0, 2, 3, 4, 5, 6 }
  - ^   Symmetric difference   00111100   { 2, 3, 4, 5 }
  - ~   Complement   10101010   { 1, 3, 5, 7 }

Bit-Level Operations in C

- ## Operations &, |, ~, ^ Available in C
  - Apply to any "integral" data type
    - `long, int, short, char, unsigned`
  - View arguments as bit vectors
  - Arguments applied bit-wise

- ## Examples (Char data type)
  - ~0x41 ➡ 0xBE
    - ~01000001_2 ➡ 10111110_2
  - ~0x00 ➡ 0xFF
    - ~00000000_2 ➡ 11111111_2
  - 0x69 & 0x55 ➡ 0x41
    - 01101001_2 & 01010101_2 ➡ 01000001_2
  - 0x69 | 0x55 ➡ 0x7D
    - 01101001_2 | 01010101_2 ➡ 01111101_2

Contrast: Logic Operations in C

- **Contrast to Logical Operators**
  - **&&, ||, !**
    - View 0 as "False"
    - Anything nonzero as "True"
    - Always return 0 or 1
    - Early termination

- **Examples (char data type)**
  - !0x41 � 0x00
  - !0x00 ➝ 0x01
  - !!0x41 ➝ 0x01

  - 0x69 && 0x55 ➝ 0x01
  - 0x69 || 0x55 ➝ 0x01
  - p && *p   (avoids null pointer access)

Contrast: Logic Operations in C

- **Contrast to Logical Operators**
  - **&&, ||, !**
    - View 0 as "Fal...
    - Anything nonze...
    - Alway...
    - Early ...
- **Example**
  - !0x41
  - !0x00
  - !!0x41

  - 0x69 && 0x55 → 0x01
  - 0x69 || 0x55 → 0x01
  - p && *p (avoids null pointer access)

Watch out for && vs. & (and || vs. |)… one of the more common oopsies in C programming

Shift Operations

- **Left Shift: `x << y`**
  - Shift bit-vector **x** left **y** positions
    - Throw away extra bits on left
  - Fill with 0's on right

- **Right Shift: `x >> y`**
  - Shift bit-vector **x** right **y** positions
    - Throw away extra bits on right
  - Logical shift
    - Fill with 0's on left
  - Arithmetic shift
    - Replicate most significant bit on left

- **Undefined Behavior**
  - Shift amount < 0 or ≥ word size

Argument x	01100010
<< 3	00010*000*
Log. >> 2	*00*011000
Arith. >> 2	*00*011000

Argument x	10100010
<< 3	00010*000*
Log. >> 2	*00*101000
Arith. >> 2	*11*101000

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- **Summary**

Encoding Integers

Unsigned

$$B2U(X) \quad = \quad \sum_{i=0}^{w-1} x_i \cdot 2^i$$

Two's Complement

$$B2T(X) \quad = \quad -x_{w-1} \cdot 2^{w-1} + \sum_{i=0}^{w-2} x_i \cdot 2^i$$

Sign Bit

```
short int x =   15213;
short int y = -15213;
```

- **C short 2 bytes long**

	Decimal	Hex	Binary
x	15213	3B 6D	00111011 01101101
y	-15213	C4 93	11000100 10010011

- **Sign Bit**
  - For 2's complement, most significant bit indicates sign
    - 0 for nonnegative
    - 1 for negative

Two-complement Encoding Example (Cont.)

Weight	15213		-15213	
1	1	1	1	1
2	0	0	1	2
4	1	4	0	0
8	1	8	0	0
16	0	0	1	16
32	1	32	0	0
64	1	64	0	0
128	0	0	1	128
256	1	256	0	0
512	1	512	0	0
1024	0	0	1	1024
2048	1	2048	0	0
4096	1	4096	0	0
8192	1	8192	0	0
16384	0	0	1	16384
-32768	0	0	1	-32768
Sum		**15213**		**-15213**

Numeric Ranges

- **Unsigned Values**
  - *UMin* $\quad=\quad$ 0

    000...0
  - *UMax* $\quad=\quad$ $2^w - 1$

    111...1

- **Two's Complement Values**
  - *TMin* $\quad=\quad$ -2^{w-1}

    100...0
  - *TMax* $\quad=\quad$ $2^{w-1} - 1$

    011...1
- **Other Values**
  - Minus 1

    111...1

Values for *W* = 16

	Decimal	Hex	Binary
UMax	**65535**	FF FF	11111111 11111111
TMax	**32767**	7F FF	01111111 11111111
TMin	**-32768**	80 00	10000000 00000000
−1	**-1**	FF FF	11111111 11111111
0	**0**	00 00	00000000 00000000

Values for Different Word Sizes

	W			
	8	**16**	**32**	**64**
UMax	255	65,535	4,294,967,295	18,446,744,073,709,551,615
TMax	127	32,767	2,147,483,647	9,223,372,036,854,775,807
TMin	-128	-32,768	-2,147,483,648	-9,223,372,036,854,775,808

- **Observations**
  - $|TMin| = TMax + 1$
    - Asymmetric range
  - $UMax = 2 * TMax + 1$

- **C Programming**
  - #include <limits.h>
  - Declares constants, e.g.,
    - ULONG_MAX
    - LONG_MAX
    - LONG_MIN
  - Values platform specific

Unsigned & Signed Numeric Values

X	B2U(X)	B2T(X)
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	9	−7
1010	10	−6
1011	11	−5
1100	12	−4
1101	13	−3
1110	14	−2
1111	15	−1

- **Equivalence**
  - Same encodings for nonnegative values

- **Uniqueness**
  - Every bit pattern represents unique integer value
  - Each representable integer has unique bit encoding

- ⇒ **Can Invert Mappings**
  - U2B(x) = B2U^{-1}(x)
    - Bit pattern for unsigned integer
  - T2B(x) = B2T^{-1}(x)
    - Bit pattern for two's comp integer

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■ **Representing information as bits**

■ **Bit-level manipulations**

■ **Integers**

    ■ Representation: unsigned and signed

    ■ **Conversion, casting**

    ■ Expanding, truncating

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    ■ Summary

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Mapping Between Signed & Unsigned

Two's Complement

x

T2U

T2B X B2U

Unsigned

ux

Maintain Same Bit Pattern

Unsigned

ux

U2T

U2B X B2T

Two's Complement

x

Maintain Same Bit Pattern
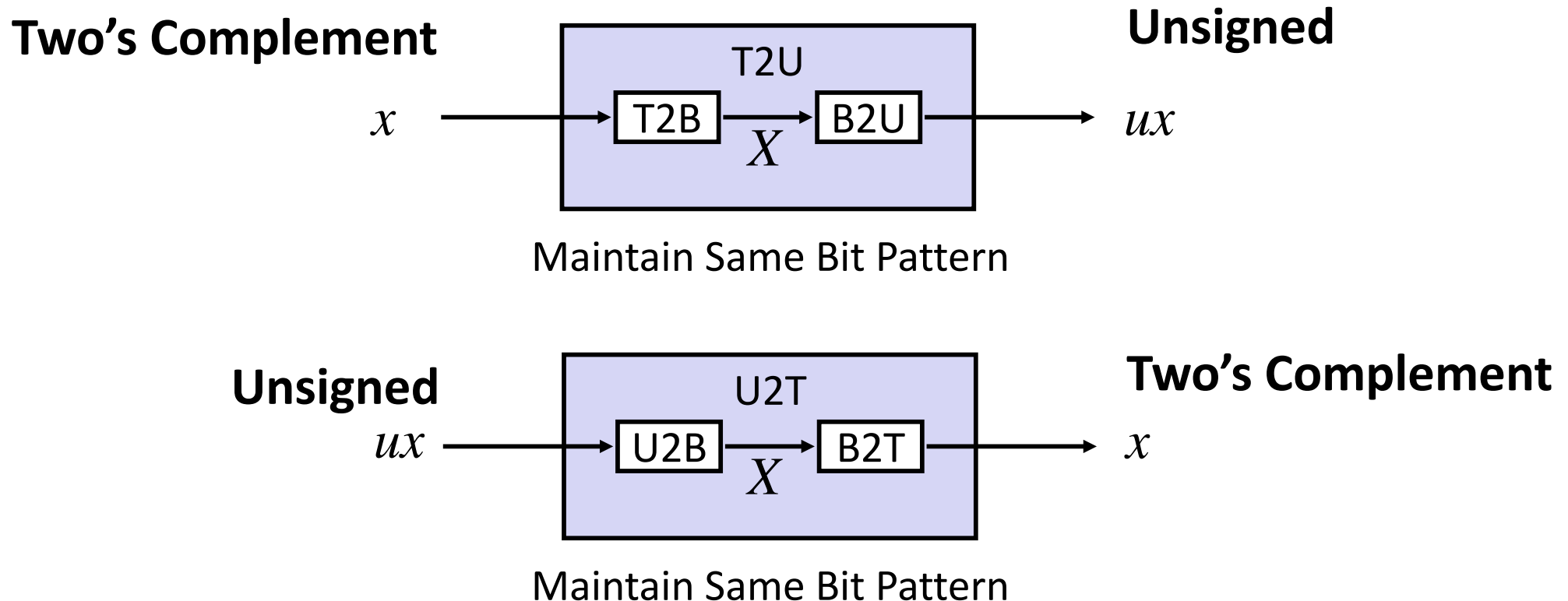
- **Mappings between unsigned and two's complement numbers:**
  Keep bit representations and reinterpret

Mapping Signed ↔ Unsigned

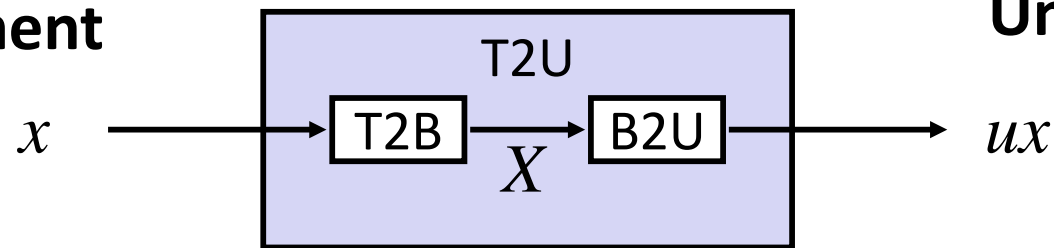| Bits |
|------|
| 0000 |
| 0001 |
| 0010 |
| 0011 |
| 0100 |
| 0101 |
| 0110 |
| 0111 |
| 1000 |
| 1001 |
| 1010 |
| 1011 |
| 1100 |
| 1101 |
| 1110 |
| 1111 |

Signed
0
1
2
3
4
5
6
7
−8
−7
−6
−5
−4
−3
−2
−1

T2U

U2T

Unsigned
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

Mapping Signed ⟷ Unsigned

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

Signed
0
1
2
3
4
5
6
7
−8
−7
−6
−5
−4
−3
−2
−1

Unsigned
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

=

+/- 16

Relation between Signed & Unsigned

Two's Complement   **Unsigned**

Maintain Same Bit Pattern

Large negative weight
becomes
Large positive weight
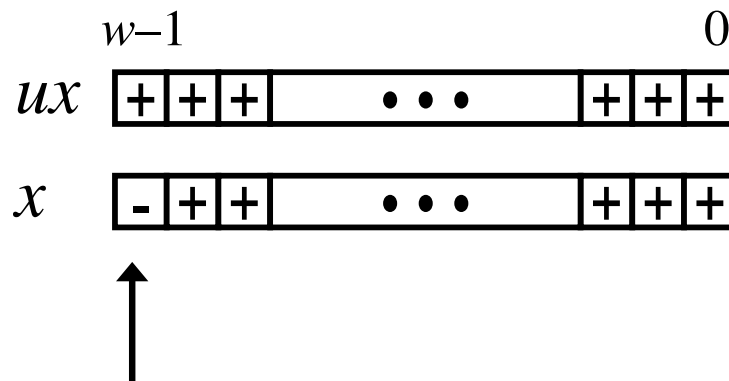
Conversion Visualized

- **2's Comp. → Unsigned**
  - Ordering Inversion
  - Negative → Big Positive
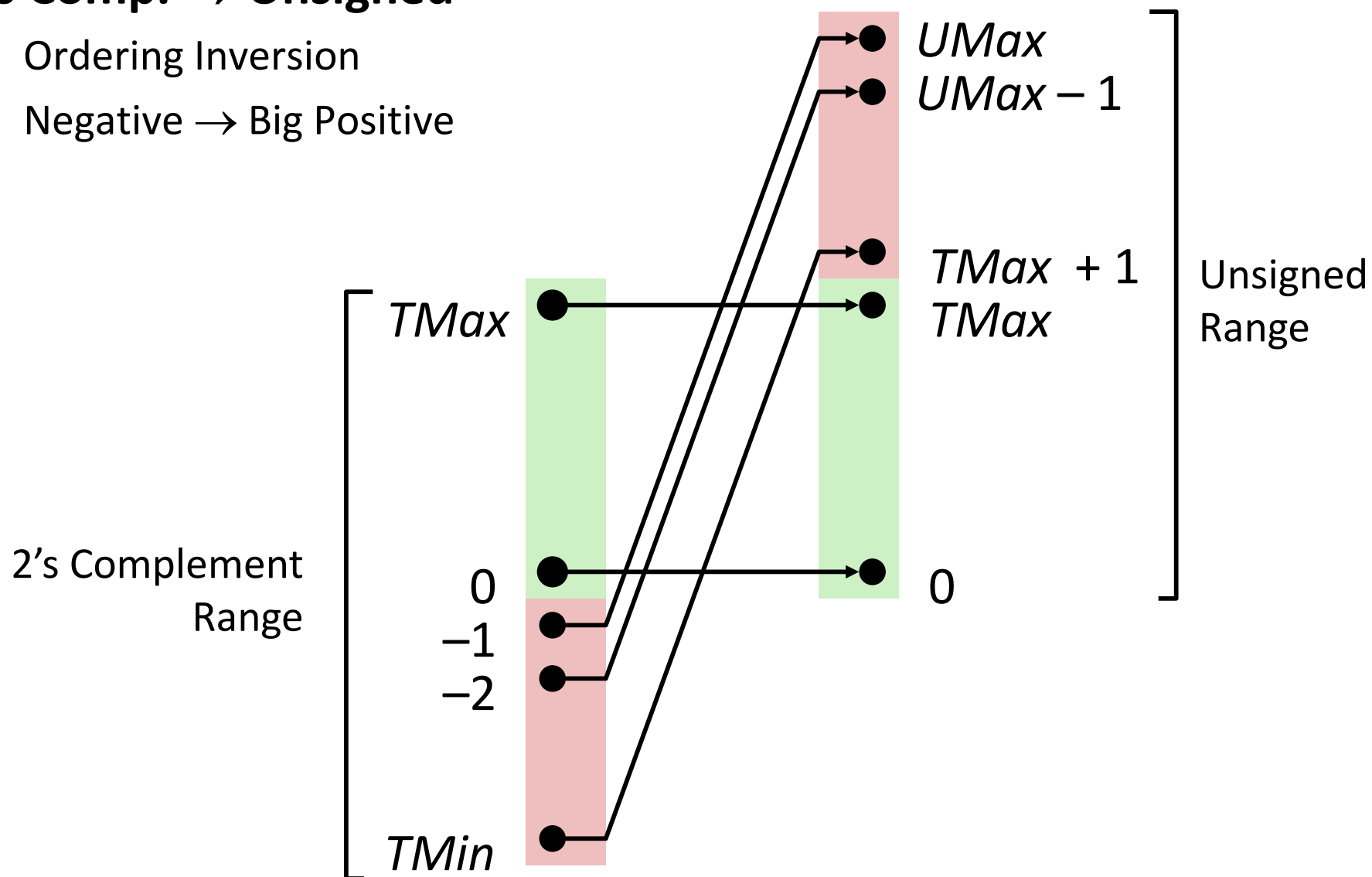
Signed vs. Unsigned in C

- **Constants**
  - By default are considered to be signed integers
  - Unsigned if have "U" as suffix

    `0U, 4294967259U`

- **Casting**
  - Explicit casting between signed & unsigned same as U2T and T2U

    ```
    int tx, ty;
    unsigned ux, uy;
    tx = (int) ux;
    uy = (unsigned) ty;
    ```

  - Implicit casting also occurs via assignments and procedure calls

    ```
    tx = ux;
    uy = ty;
    ```

Casting Surprises

- **Expression Evaluation**
    - If there is a mix of unsigned and signed in single expression, *signed values implicitly cast to unsigned*
    - Including comparison operations **<, >, ==, <=, >=**
    - Examples for $W = 32$:   **TMIN = -2,147,483,648 ,   TMAX = 2,147,483,647**

- **Constant$_1$**   **Constant$_2$**   **Relation**   **Evaluation**

Constant$_1$	Constant$_2$	Relation	Evaluation
0	0U	==	unsigned
-1	0	<	signed
-1	0U	>	unsigned
2147483647	-2147483647-1	>	signed
2147483647U	-2147483647-1	<	unsigned
-1	-2	>	signed
(unsigned)-1	-2	>	unsigned
2147483647	2147483648U	<	unsigned
2147483647	(int) 2147483648U	>	signed

Summary
Casting Signed ↔ Unsigned: Basic Rules

- **Bit pattern is maintained**

- **But reinterpreted**

- **Can have unexpected effects: adding or subtracting 2^w**

- **Expression containing signed and unsigned int**
  - `int` is cast to `unsigned`!!

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  - ▪ **Expanding, truncating**
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  - ▪ Summary
- ■ **Representations in memory, pointers, strings**

Sign Extension

- **Task:**
  - Given w-bit signed integer x
  - Convert it to $w+k$-bit integer with same value

- **Rule:**
  - Make k copies of sign bit:
  - $X' = x_{w-1}, \ldots, x_{w-1}, x_{w-1}, x_{w-2}, \ldots, x_0$

k copies of MSB
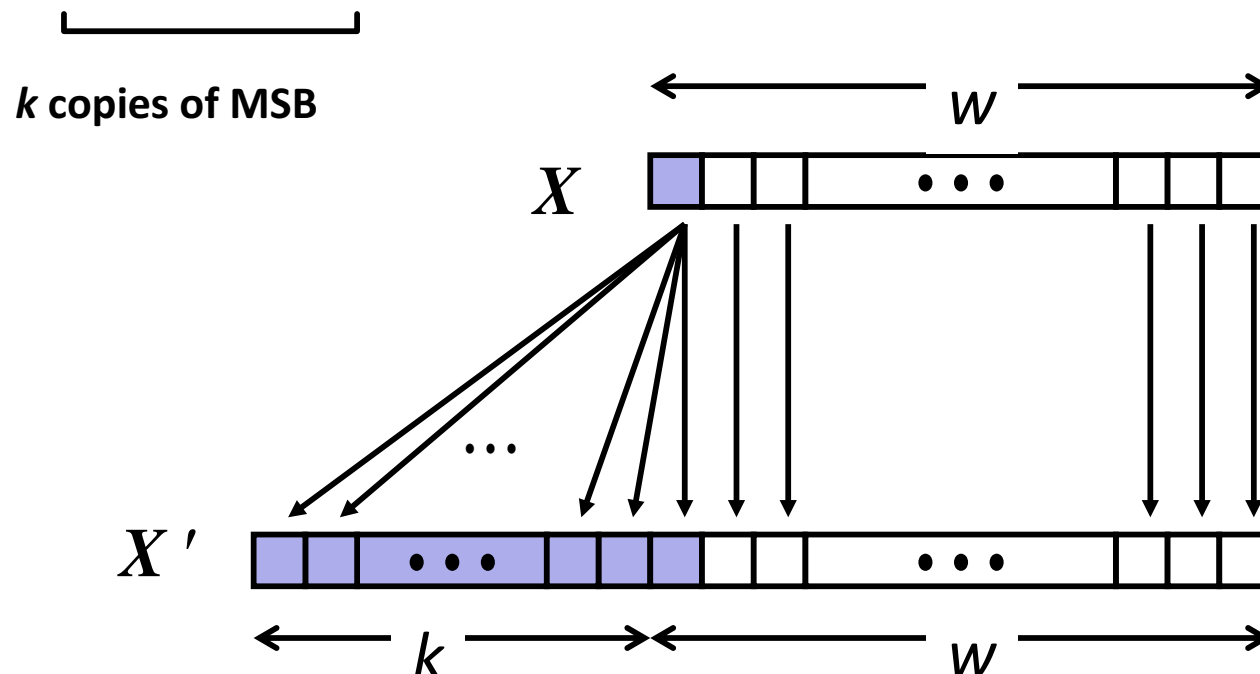
Sign Extension Example

```
short int x =  15213;
int       ix = (int) x;
short int y = -15213;
int       iy = (int) y;
```

	Decimal	Hex	Binary
x	15213	3B 6D	00111011 01101101
ix	15213	00 00 3B 6D	00000000 00000000 00111011 01101101
y	-15213	C4 93	11000100 10010011
iy	-15213	FF FF C4 93	11111111 11111111 11000100 10010011

- **Converting from smaller to larger integer data type**
- **C automatically performs sign extension**

Summary:
Expanding, Truncating: Basic Rules

- **Expanding (e.g., short int to int)**
  - Unsigned: zeros added
  - Signed: sign extension
  - Both yield expected result

- **Truncating (e.g., unsigned to unsigned short)**
  - Unsigned/signed: bits are truncated
  - Result reinterpreted
  - Unsigned: mod operation
  - Signed: similar to mod
  - For small numbers yields expected behavior

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- ■ **Summary**

Unsigned Addition

Operands: *w* bits

True Sum: *w*+1 bits

Discard Carry: *w* bits

$$u$$

$$+ v$$

$$u + v$$

$$\text{UAdd}_w(u\,,v)$$

- ■ **Standard Addition Function**
  - ▪ Ignores carry output
- ■ **Implements Modular Arithmetic**

  $s\ \ =\ \ \text{UAdd}_w(u\,,v)\ \ =\ \ u + v\ \bmod\ 2^w$

Two's Complement Addition

Operands: w bits

u

$+\ v$

True Sum: w+1 bits

$u + v$

Discard Carry: w bits

$\text{TAdd}_w(u\,,v)$

- **TAdd and UAdd have Identical Bit-Level Behavior**
  - Signed vs. unsigned addition in C:

```
int s, t, u, v;
s = (int) ((unsigned) u + (unsigned) v);
t = u + v
```

  - Will give `s == t`

TAdd Overflow

- **Functionality**
  - True sum requires $w+1$ bits
  - Drop off MSB
  - Treat remaining bits as 2's comp. integer

True Sum

TAdd Result

0 111...1 $2^w - 1$

PosOver

0 100...0 $2^{w-1} - 1$ 011...1

0 000...0   0   000...0

1 011...1 -2^{w-1} 100...0

NegOver

1 000...0 -2^w
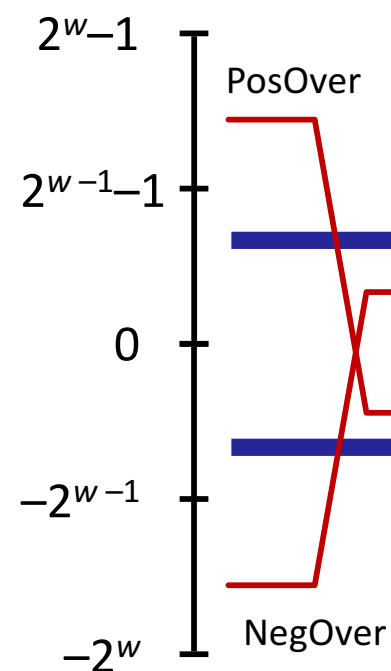
Multiplication

- **Goal: Computing Product of w-bit numbers x, y**
  - Either signed or unsigned

- **But, exact results can be bigger than w bits**
  - Unsigned: up to $2w$ bits
    - Result range: $0 \leq x * y \leq (2^w - 1)^2 = 2^{2w} - 2^{w+1} + 1$
  - Two's complement min (negative): Up to $2w$-1 bits
    - Result range: $x * y \geq (-2^{w-1})*(2^{w-1} - 1) = -2^{2w-2} + 2^{w-1}$
  - Two's complement max (positive): Up to $2w$ bits, but only for $(TMin_w)^2$
    - Result range: $x * y \leq (-2^{w-1})^2 = 2^{2w-2}$

- **So, maintaining exact results…**
  - would need to keep expanding word size with each product computed
  - is done in software, if needed
    - e.g., by "arbitrary precision" arithmetic packages

Unsigned Multiplication in C

Operands: w bits

u

$* \quad v$

True Product: $2*w$ bits $\quad u \cdot v$

$\text{UMult}_w(u , v)$

Discard w bits: w bits
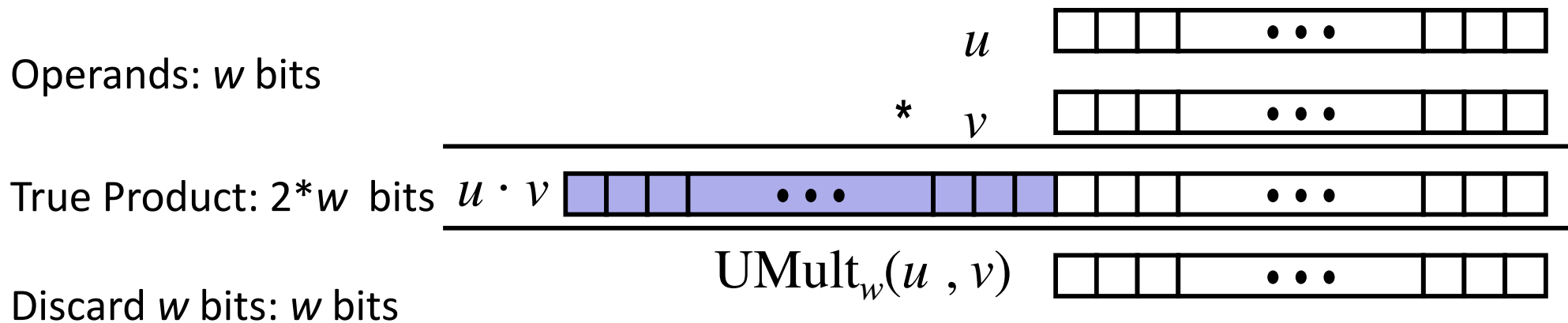
- **Standard Multiplication Function**
  - Ignores high order w bits

- **Implements Modular Arithmetic**

  $\text{UMult}_w(u , v) = u \cdot v \bmod 2^w$

Signed Multiplication in C

Operands: w bits

$$u$$
$$* \quad v$$

True Product: $2*w$ bits $\quad u \cdot v$

$$\text{TMult}_w(u, v)$$

Discard w bits: w bits

- **Standard Multiplication Function**
  - Ignores high order w bits
  - Some of which are different for signed vs. unsigned multiplication
  - Lower bits are the same

Power-of-2 Multiply with Shift

- ## Operation
 - u `<<` k gives u `*` 2^k
  - Both signed and unsigned

Operands: w bits

True Product: $w+k$ bits $\qquad u \cdot 2^k$

Discard k bits: w bits $\qquad \text{UMult}_w(u, 2^k)$
$\qquad\qquad\qquad\qquad\qquad \text{TMult}_w(u, 2^k)$
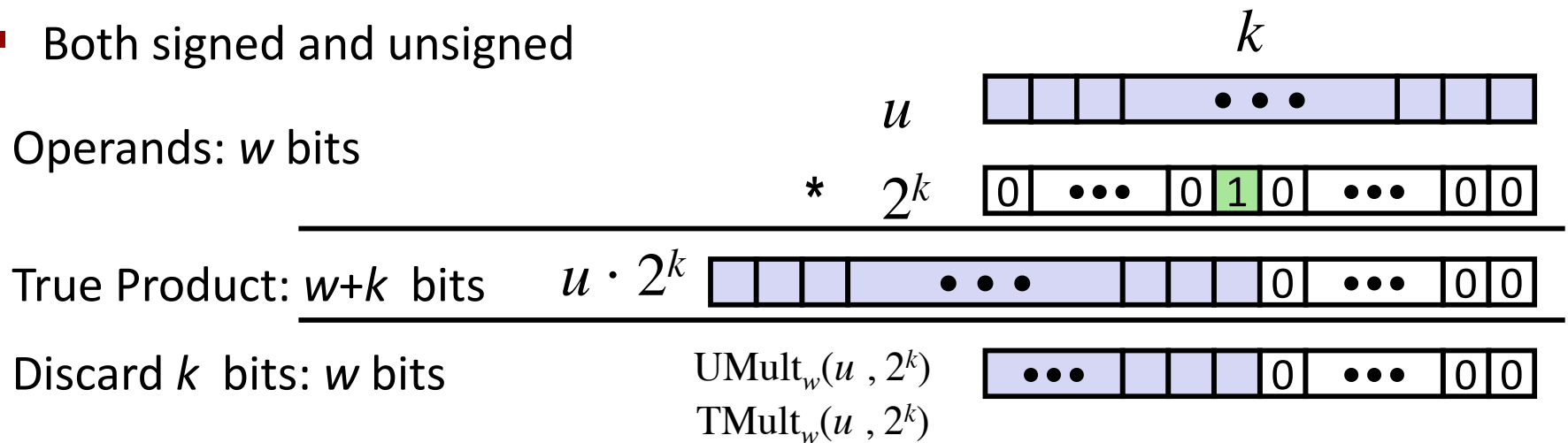
- ## Examples
  - `u << 3        ==   u * 8`
  - `(u << 5) – (u << 3) ==    u * 24`
  - Most machines shift and add faster than multiply
    - Compiler generates this code automatically

Unsigned Power-of-2 Divide with Shift

■ **Quotient of Unsigned by Power of 2**

  ▪ `u >> k` gives $\lfloor u\ /\ 2^k \rfloor$

  ▪ Uses logical shift

Operands: u

$/\ 2^k$

Division: $u\ /\ 2^k$

Result: $\lfloor u\ /\ 2^k \rfloor$

Binary Point
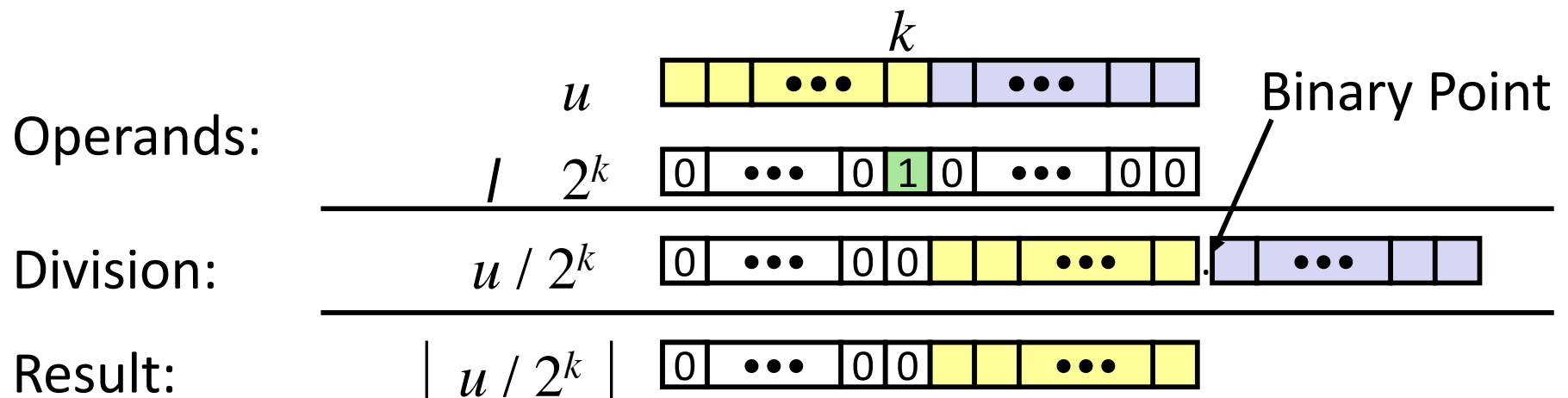
	Division	Computed	Hex	Binary
`x`	15213	15213	`3B 6D`	`00111011 01101101`
`x >> 1`	7606.5	7606	`1D B6`	`00011101 10110110`
`x >> 4`	950.8125	950	`03 B6`	`00000011 10110110`
`x >> 8`	59.4257813	59	`00 3B`	`00000000 00111011`

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Arithmetic: Basic Rules

- ■ **Addition:**
  - ▪ Unsigned/signed: Normal addition followed by truncate, same operation on bit level
  - ▪ Unsigned: addition mod 2^w
    - ▪ Mathematical addition + possible subtraction of 2^w
  - ▪ Signed: modified addition mod 2^w (result in proper range)
    - ▪ Mathematical addition + possible addition or subtraction of 2^w

- ■ **Multiplication:**
  - ▪ Unsigned/signed: Normal multiplication followed by truncate, same operation on bit level
  - ▪ Unsigned: multiplication mod 2^w
  - ▪ Signed: modified multiplication mod 2^w (result in proper range)

Why Should I Use Unsigned?

- *Don't* use without understanding implications
  - Easy to make mistakes
    ```
    unsigned i;
    for (i = cnt-2; i >= 0; i--)
       a[i] += a[i+1];
    ```

  - Can be very subtle
    ```
    #define DELTA sizeof(int)
    int i;
    for (i = CNT; i-DELTA >= 0; i-= DELTA)
       . . .
    ```

Counting Down with Unsigned

- **Proper way to use unsigned as loop index**

```
unsigned i;
for (i = cnt-2; i < cnt; i--)
    a[i] += a[i+1];
```

- **See Robert Seacord, *Secure Coding in C and C++***

  - C Standard guarantees that unsigned addition will behave like modular arithmetic
    - $0 - 1 \rightarrow UMax$

- **Even better**

```
size_t i;
for (i = cnt-2; i < cnt; i--)
    a[i] += a[i+1];
```

  - Data type `size_t` defined as unsigned value with length = word size
  - Code will work even if `cnt` = *UMax*
  - What if `cnt` is signed and < 0?

Why Should I Use Unsigned? (cont.)

- **_Do_ Use When Performing Modular Arithmetic**
  - Multiprecision arithmetic

- **_Do_ Use When Using Bits to Represent Sets**
  - Logical right shift, no sign extension

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  - Addition, negation, multiplication, shifting
  - Summary

- **Representations in memory, pointers, strings**

Byte-Oriented Memory Organization
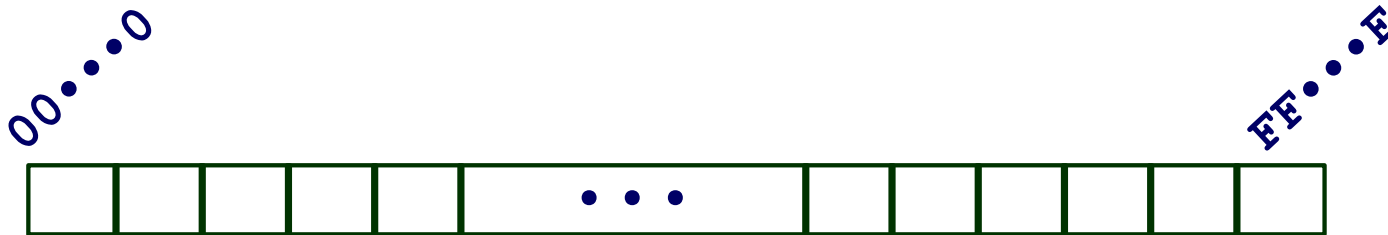
- **Programs refer to data by address**
  - Conceptually, envision it as a very large array of bytes
    - In reality, it's not, but can think of it that way
  - An address is like an index into that array
    - and, a pointer variable stores an address

- **Note: system provides private address spaces to each "process"**
  - Think of a process as a program being executed
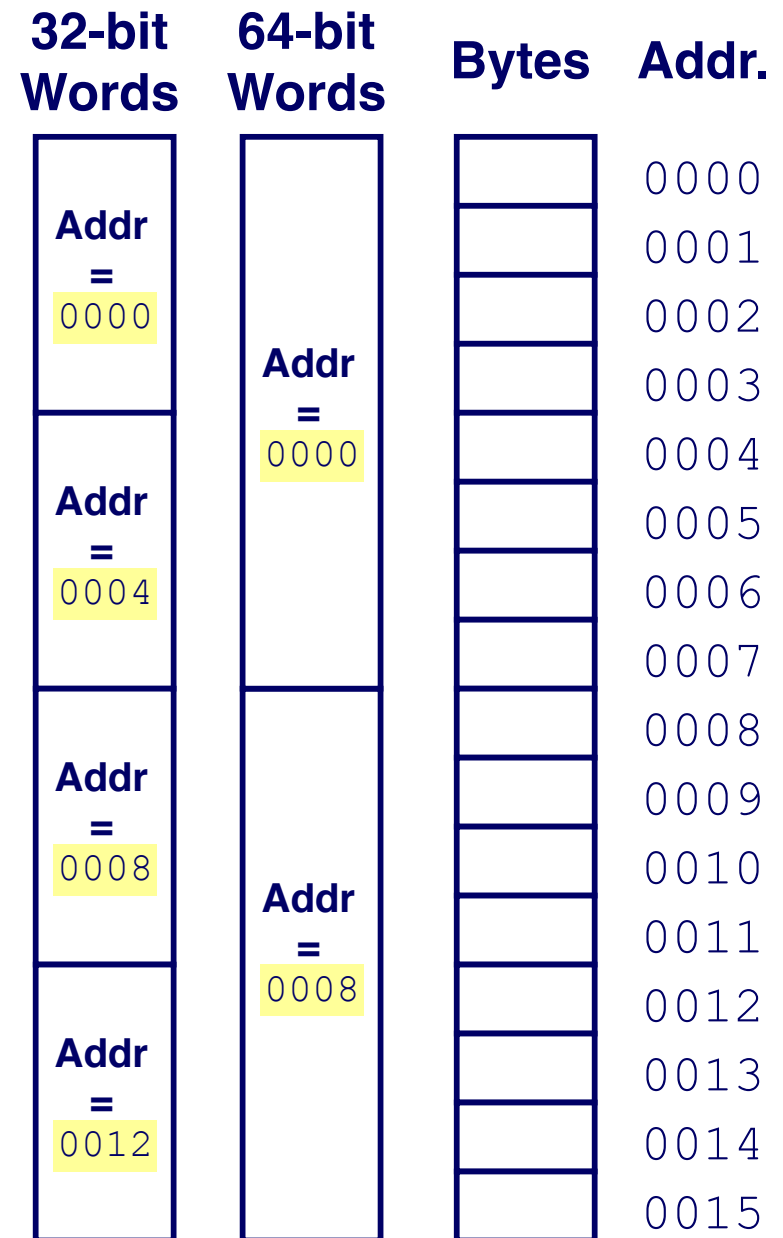 - So, a program can clobber its own data, but not that of others

Machine Words

- **Any given computer has a "Word Size"**
  - Nominal size of integer-valued data
    - and of addresses

  - Until recently, most machines used 32 bits (4 bytes) as word size
    - Limits addresses to 4GB (2^{32} bytes)

  - Increasingly, machines have 64-bit word size
    - Potentially, could have 18 EB (exabytes) of addressable memory
    - That's 18.4 X 10^{18}

  - Machines still support multiple data formats
    - Fractions or multiples of word size
    - Always integral number of bytes

Word-Oriented Memory Organization

- **Addresses Specify Byte Locations**
  - Address of first byte in word
  - Addresses of successive words differ by 4 (32-bit) or 8 (64-bit)

32-bit Words	64-bit Words	Bytes	Addr.
Addr = 0000	**Addr =** 0000		0000
			0001
			0002
			0003
Addr = 0004			0004
			0005
			0006
			0007
Addr = 0008	**Addr =** 0008		0008
			0009
			0010
			0011
Addr = 0012			0012
			0013
			0014
			0015

Example Data Representations

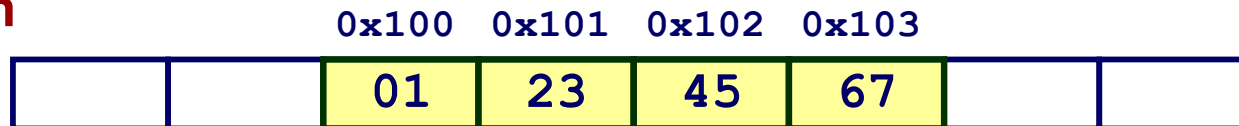| C Data Type	Typical 32-bit	Typical 64-bit	x86-64
`char`	1	1	1
`short`	2	2	2
`int`	4	4	4
`long`	4	8	8
`float`	4	4	4
`double`	8	8	8
`long double`	–	–	10/16
pointer	4	8	8

Byte Ordering

- **So, how are the bytes within a multi-byte word ordered in memory?**

- **Conventions**

  - Big Endian: Sun, PPC Mac, Internet

    - Least significant byte has highest address

  - Little Endian: x86, ARM processors running Android, iOS, and Windows

    - Least significant byte has lowest address
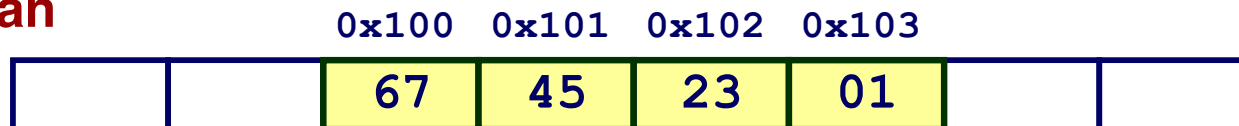
Byte Ordering Example

- **Example**
  - Variable x has 4-byte value of 0x01234567
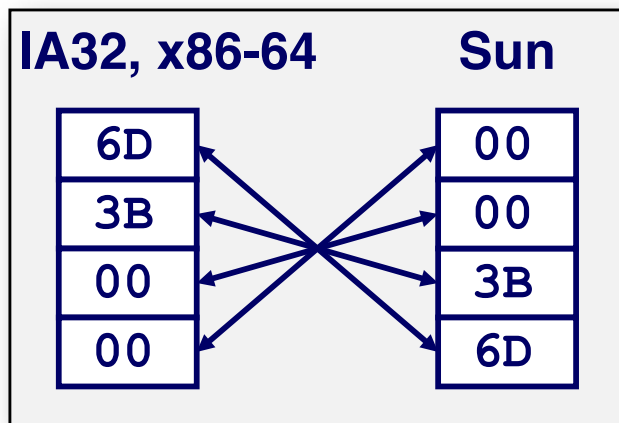 - Address given by &x is 0x100

Big Endian

0x100 0x101 0x102 0x103

| | | 01 | 23 | 45 | 67 | | |

Little Endian

0x100 0x101 0x102 0x103

| | | 67 | 45 | 23 | 01 | | |

Representing Integers

`int A = 15213;`

IA32, x86-64 | Sun

`long int C = 15213;`

IA32 | x86-64 | Sun

`int B = -15213;`

IA32, x86-64 | Sun
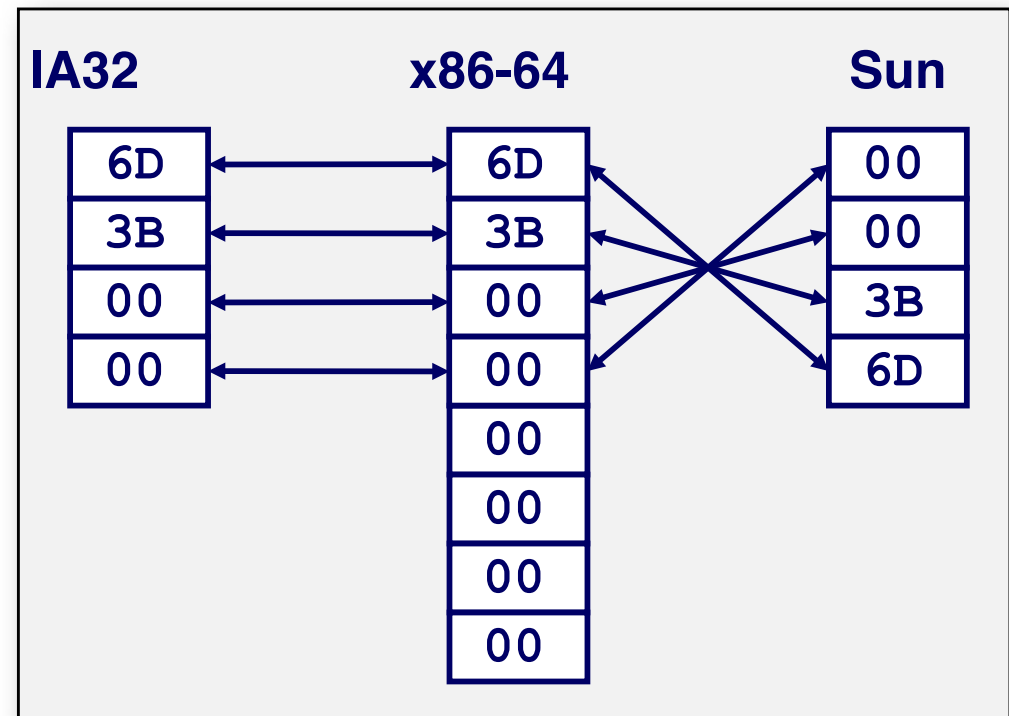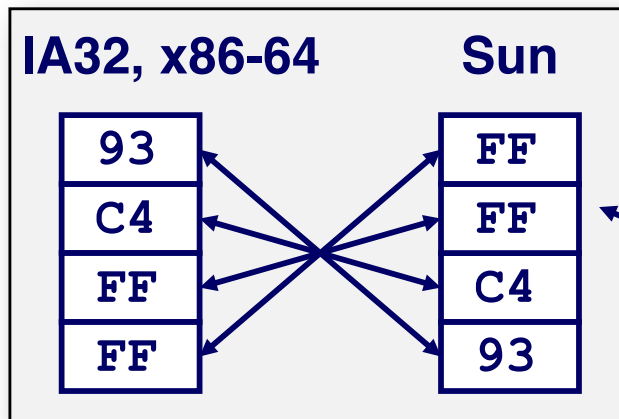
Two's complement representation

Examining Data Representations

- **Code to Print Byte Representation of Data**
  - Casting pointer to unsigned char * allows treatment as a byte array

```
typedef unsigned char *pointer;

void show_bytes(pointer start, size_t len){
   size_t i;
   for (i = 0; i < len; i++)
     printf("%p\t0x%.2x\n",start+i, start[i]);
   printf("\n");
}
```

Printf directives:
%p: Print pointer
%x: Print Hexadecimal

`show_bytes` Execution Example

```
int a = 15213;
printf("int a = 15213;\n");
show_bytes((pointer) &a, sizeof(int));
```

Result (Linux x86-64):

```
int a = 15213;
0x7fffb7f71dbc      6d
0x7fffb7f71dbd      3b
0x7fffb7f71dbe      00
0x7fffb7f71dbf      00
```

Representing Pointers

```
int B = -15213;
int *P = &B;
```

	Sun		IA32		x86-64
	EF		AC		3C
	FF		28		1B
	FB		F5		FE
	2C		FF		82
					FD
					7F
					00
					00

Different compilers & machines assign different locations to objects

Even get different results each time run program
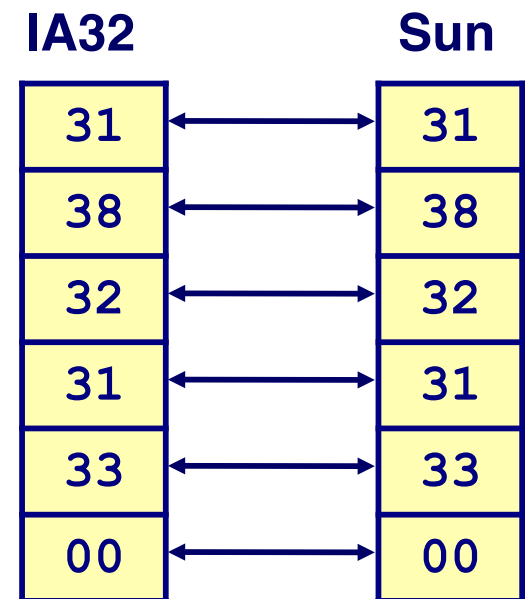
Representing Strings

```
char S[6] = "18213";
```

- **Strings in C**
  - Represented by array of characters
  - Each character encoded in ASCII format
    - Standard 7-bit encoding of character set
    - Character "0" has code 0x30
      - Digit i has code 0x30+i
  - String should be null-terminated
    - Final character = 0

- **Compatibility**
  - Byte ordering not an issue

IA32		Sun
31	⟷	31
38	⟷	38
32	⟷	32
31	⟷	31
33	⟷	33
00	⟷	00

Integer C Puzzles

- `x < 0`　　　　➡　`((x*2) < 0)`
- `ux >= 0`
- `x & 7 == 7`　➡　`(x<<30) < 0`
- `ux > -1`
- `x > y`　　　　➡　`-x < -y`
- `x * x >= 0`
- `x > 0 && y > 0`　➡　`x + y > 0`
- `x >= 0`　　　➡　`-x <= 0`
- `x <= 0`　　　➡　`-x >= 0`
- `(x|-x)>>31 == -1`
- `ux >> 3 == ux/8`
- `x >> 3 == x/8`
- `x & (x-1) != 0`

Initialization

```
int x = foo();
int y = bar();
unsigned ux = x;
unsigned uy = y;
```