

Representations in memory, pointers, strings

Computer Systems

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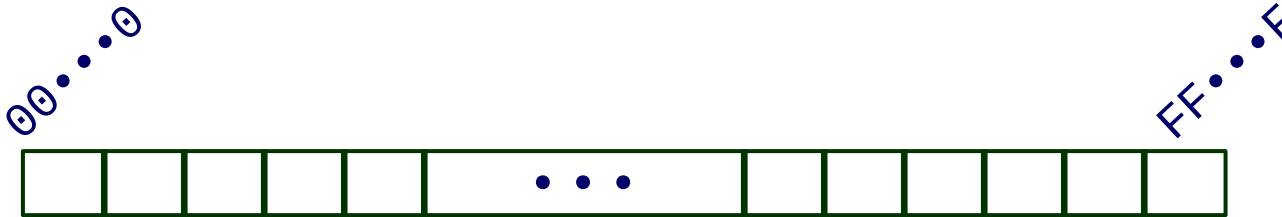
Based on slides by:

Randal E. Bryant and David R. O'Hallaron

Today: Bits, Bytes, and Integers

- 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

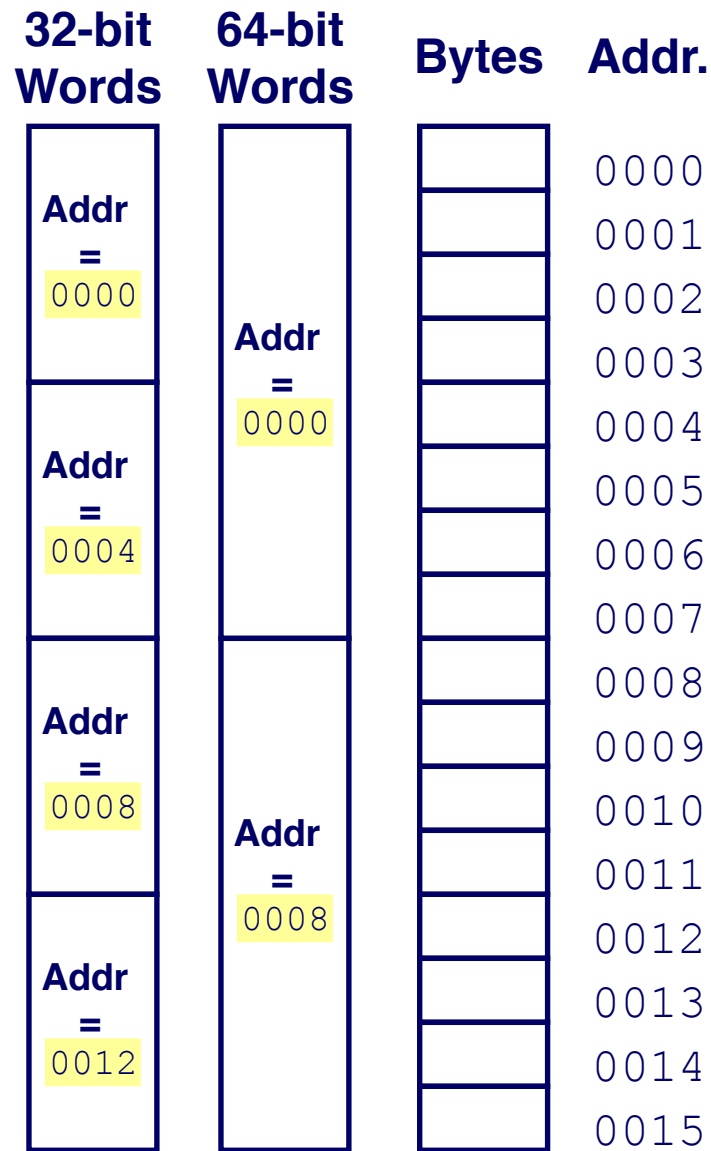
Machine Words

- **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 18.4×10^{18}
 - Current machines only use lower 48 bits.
 - 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)



Example Data Representations

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

Byte Ordering

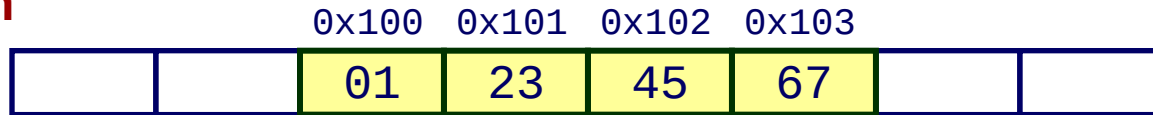
- So, how are the bytes within a multi-byte word ordered in memory?
- Conventions
 - Big Endian: Sun, PPC Mac, Internet
 - Least significant byte has highest address
 - Little Endian: x86, ARM processors running Android, iOS, and Windows
 - Least significant byte has lowest address

Byte Ordering Example

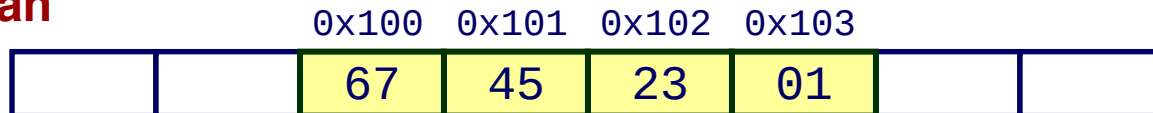
■ Example

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

Big Endian



Little Endian



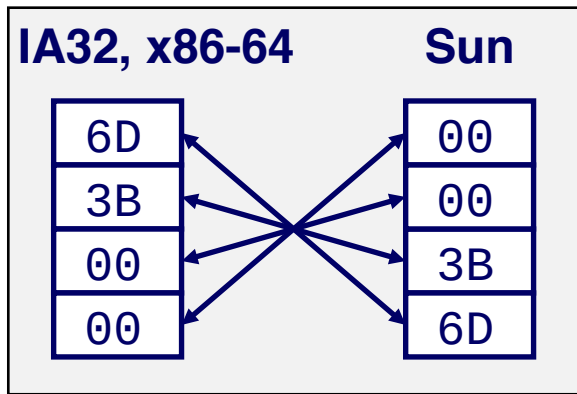
Representing Integers

Decimal: 15213

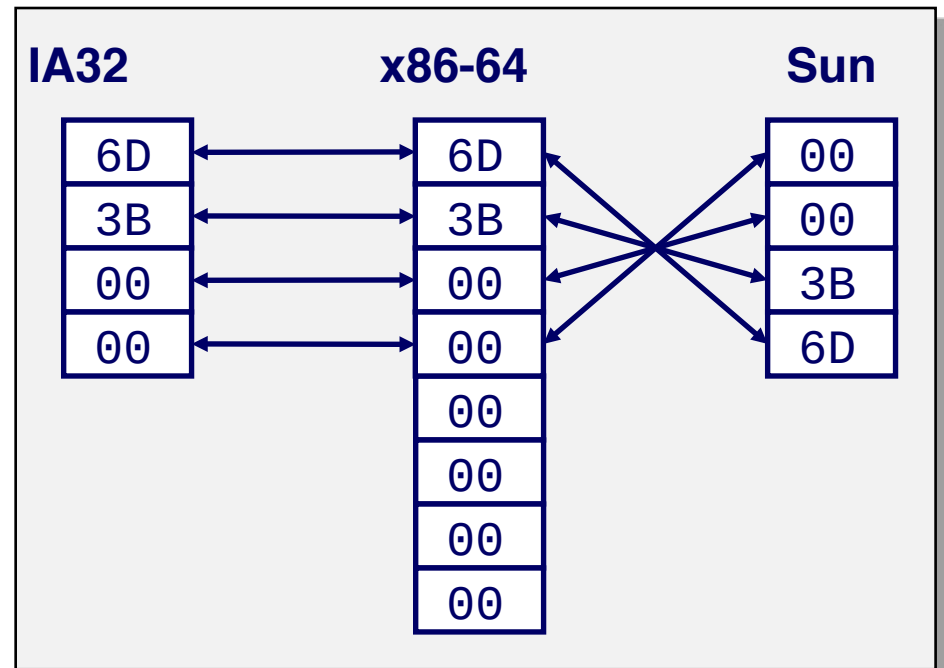
Binary: 0011 1011 0110 1101

Hex: 3 B 6 D

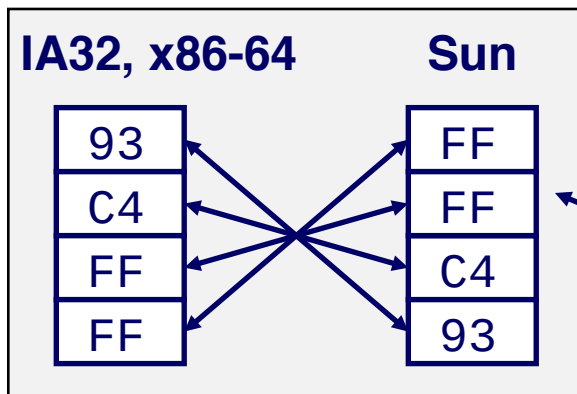
`int A = 15213;`



`long int C = 15213;`



`int B = -15213;`



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

```
void show_bytes(unsigned char* 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;  
0x7ffffb7f71dbc 6d  
0x7ffffb7f71dbd 3b  
0x7ffffb7f71dbe 00  
0x7ffffb7f71dbf 00
```

Representing Pointers

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

Sun

EF
FF
FB
2C

IA32

AC
28
F5
FF

x86-64

3C
1B
FE
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

