Introduction

CSE 132

Instructional Staff

- Instructor – Roger Chamberlain
  - Office: Bryan 405C
  - Email: roger@wustl.edu
- Head TA – Josh Gelbard
  - Email: gelbard@wustl.edu
- Office hours: TBD (see web page)
- Appointments for Roger: send an email

Course Web Page

- http://classes.cec.wustl.edu/~cse132
- It is a work in progress …
  - Will contain calendar
  - Will contain studio and lab assignments
- Documents grading, collaboration, and late policies
- Contains documentation on languages (Java, C) and tools (Eclipse, Subversion, Arduino)

What is this class about?

- Organization will be like CSE 131
  - 1.5 hrs/wk lecture
  - 1.5 hrs/wk studio
  - 1.5 hrs/wk lab
- The material includes
  - Basic computer capabilities (I/O, esp. custom I/O)
  - Demystifying how computer systems operate
  - More than one machine, more than one type of machine
  - Design decisions that include both software and hardware

Some High-level Goals for CSE 132

- Introduce CoE concepts (so those who should be CoE students know what that is)
  - Do this while ensuring relevance to CS students
- Introduce the concept that not all computers are desktop/laptop class machines
  - Computing happens in many different form factors
  - Vehicle for 132 will be an 8-bit microcontroller + standard desktop environment (Java/Eclipse from CSE 131)
- Introduce distributed concurrency (more than one thing going on at a time)
- Recurring theme throughout semester will be the representation of information

Typical Module Sequence

- Lecture
  - Here in Simon
- Studio
  - In Urbauer labs (attendance is required!)
- Lab
  - Lab demos in Urbauer labs
- Help
  - A number of help sessions will get scheduled and be staffed by TAs
  - Piazza (all the TAs have instructor access)

Two Compute Platforms

- Java on laptop or lab machines, using Eclipse as the development environment (just like 131)
- ``C'' on Arduino machine
  - Actually a subset of C, and subset is *very* close to the Java you are familiar with
  - Physical computer is 8-bit machine running at only 16 MHz (over 100 times slower than desktop PC)
    - 16 Kbytes of program memory
    - 2 Kbytes of data memory
    - No keyboard or display
  - Wonderful community of users, doing lots and lots!

Let's get started

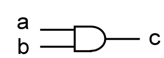
- Information Representation
- In the digital world, this means binary

What is Binary?

- Underlying base signals are two-valued:
  - 0 or 1
  - true or false (T or F)
  - high or low (H or L)
- One "bit" is the smallest unambiguous unit of information
- Propositional calculus helps us manipulate (operate on) these base signals

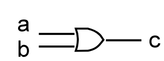
Operations in Propositional Calculus

AND $a \cdot b = c$



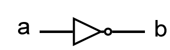
c is true if a is true <u>and</u> b is true

OR $a + b = c$



c is true if a is true <u>or</u> b is true

NOT $a' = b$

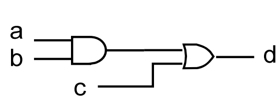


b is true if a is false

An Example

a passed microeconomics course
b passed macroeconomics course
c passed economics survey course
d met economics requirement

$d = a \cdot b + c$



Boolean Algebra

- Boolean algebra (named after 19th century mathematician George Boole) lets us manipulate and reason about expressions of propositional calculus
- Systems based on this algebraic theory are called "digital logic systems"
- All modern computer systems fall in this category

Physical Representation

- Positive logic convention
  - Binary value (1 or 0) is represented by the voltage on a wire (H or L)

  - true, 1 — voltage greater than threshold V_H
  - false, 0 — voltage less than threshold V_L

  - Voltage gap between V_H and V_L provides safety margin to limit errors

That's Not Enough!

- We are interested in representing signals that have more than just two values
  - numbers
  - text
  - images
  - audio
  - video
  - and much more

How do we represent numbers?

- A positional number system lets us represent integers. E.g., in base 10:

$$xyz_{10} = x \cdot 10^2 + y \cdot 10^1 + z \cdot 10^0$$
$$= x \cdot 100 + y \cdot 10 + z$$

x, y, z can each have 10 possible values: 0 to 9

Base 2 (binary) works the same way

$$xyz_2 = x \cdot 2^2 + y \cdot 2^1 + z \cdot 2^0$$
$$= x \cdot 4 + y \cdot 2 + z$$

x, y, z can each have 2 possible values: 0 or 1
each digit is called a "bit"

e.g.,		
	000	0
	001	1
	010	2
	011	3
	100	4
	101	5
	110	6
	111	7

Negative numbers

- With a fixed number of bits, one can represent negative numbers in a variety of ways.
  E.g., 4-bit binary number system:

- **unsigned** range 0 to 15 (0000 to 1111)
  unsigned integers with n bits range 0 to $2^n - 1$

- **offset** or **bias** (e.g., -7) range -7 to 8
  subtract fixed amount (such as midpoint value)
  generally bad for computation

4-bit Sign-Magnitude

1st bit encodes sign (0 = positive, 1 = negative)
bits 2, 3, 4 magnitude $\Rightarrow$ range 0 to 7 (000 to 111)

overall range -7 to +7
what about 1000? -0!

with n bits, use n-1 bits for magnitude
range $-(2^{n-1} - 1)$ to $+(2^{n-1} - 1)$

issues:
- two representations for "0", +0 and -0
- need significant hardware to support add, subtract

2's (radix) complement

- Use negative weight for 1st bit:
  $wxyz = w \cdot -(2)^3 + x \cdot 2^2 + y \cdot 2^1 + z \cdot 2^0$
  $= w \cdot -(8) + x \cdot 4 + y \cdot 2 + z$
- overall range -8 to +7
- 1st bit is still sign bit,
  with 0 = positive and 1 = negative
- only one zero: 0000

Properties of 2's complement

- least significant n-1 bits have unaltered meaning (i.e., standard positional notation and weights apply)
- most significant bit has weight negated (instead of weight 2^{n-1}, it is weight -2^{n-1})
- range $-(2^{n-1})$ to $+(2^{n-1}-1)$
- negation operation: flip all bits, add 1, throw away carry

Make binary more human friendly

- Hexadecimal representation – base 16
- Commonly called "hex" but don't be confused, it is not base 6, it is base 16
- Character set 0-9, a-f (alternately A-F)
  - a=10, b=11, c=12, d=13, e=14, and f=15
- C notation is to prefix hex with symbol `0x` (e.g., `0x12`, `0xa3`)

Positional notation applies

$xyz_{16} = x \cdot 16^2 + y \cdot 16^1 + z \cdot 16^0$
$= x \cdot 256 + y \cdot 16 + z$

So $02c_{16} = 0 \cdot (256) + 2 \cdot (16) + 12 = 44_{10}$

or 0x02c, which is the shorthand I will typically use in class

Benefits of Hex

- Real beauty of hex notation is ease with which one can move back and forth between hex and binary, since $16 = 2^4$
- To transform hex number (e.g., 0x3d50) to binary we expand each hex digit to 4 bits of binary:

3	d	5	0
0011	1101	0101	0000

Binary to Hex Transformation

- To transform binary number (e.g., 1001000) to hex we group into 4-bit groups (starting from right) and rewrite each group in hex

100	1000	
4	8	= 0x48

- Or, e.g., 110101110

1	1010	1110	
1	a	e	= 0x1ae

Text – Characters and Strings

- ASCII – American Standard Code for Information Interchange
  - 7-bit codes representing basic Latin characters and numbers [A-Z, a-z, 0-9], some common punctuation, and control characters
  - There are a number of extensions to 8 bits, but only the 7-bit codes really standard.
- Unicode – 8- or 16-bit codes extending to a much wider set of languages
  - The first 128 codes are equivalent to the 7-bit ASCII standard

C Strings

- Strings are sequences of ASCII characters, stored one byte per character (8 bits), terminated by a NULL (zero) character
- E.g., "Hello!"

01001000	'H'	0x48
01100101	'e'	0x65
01101100	'l'	0x6c
01101100	'l'	0x6c
01101111	'o'	0x6f
00100001	'!'	0x21
00000000	NULL	0x00

ASCII Facts

- Numerical digits are assigned in order of increasing value

  i.e., '0' = 0x30
  '1' = 0x31
  '2' = 0x32

  '9' = 0x39

- For single character, value conversion is simply a difference of 0x30

More ASCII Facts

- Letters are also assigned in lexicographical order:

  'A' = 0x41
  'B' = 0x42

  'Z' = 0x5a

  'a' = 0x61
  'b' = 0x62

  'z' = 0x7a

- Upper/lower case conversion is simply a difference of 0x20

Still More ASCII Facts

- First 32 characters (0-0x1f) are control codes:

0x00	^@	null (C string terminator)
0x07	^G	bell
0x0a	^J	line feed
0x0c	^L	form feed
0x0d	^M	carriage return

Line breaks are not standardized

- End of line conventions differ by operating system:
  - In MS Windows: 0x0a, 0x0d is end of line
  - In Unix/Linux: 0x0a is end of line
  - 0x0a, linefeed, is sometimes called 'newline'
- In C, '\n' is mapped to OS end of line termination convention

Java Strings

- Strings are represented via the class “String”
- String objects are immutable
- The character encoding is system specific, e.g., either UTF-8 or UTF-16 (typical).
- The length is an instance variable in the object (in most implementations)
- The characters are stored in a char[] array (again, in most implementations)

Unicode

- Standard for character representation
  – Supports wide variety of languages, symbols
- UTF-8
  – Variable length code with 8-bit code units
  – U+0000 to U+007F are the same as ASCII
- UTF-16
  – Uses 16-bit code units, also variable length
  – Latin + Greek + Cyrillic + Coptic + Armenian + Hebrew + Arabic + Syrian + Tāna + N’Ko fit in 16 bits
- UTF-32
  – Uses 32-bit code units, fixed length

Studio Today

- Come to Urbauer labs (load balance as on Wed)
- Form groups of 2 to 4
- Do the exercises
  – Some on whiteboard (no computer required)
  – Authoring simple C programs on the PC
- Get signed out by a TA
- Assignment 1 will start on Wed and be due Wed of next week (Feb 3) in lab
  – Don’t assume lab time next week to complete it!!!!