Machine Called Computer

Part 3

- More on "Abstraction"

References:

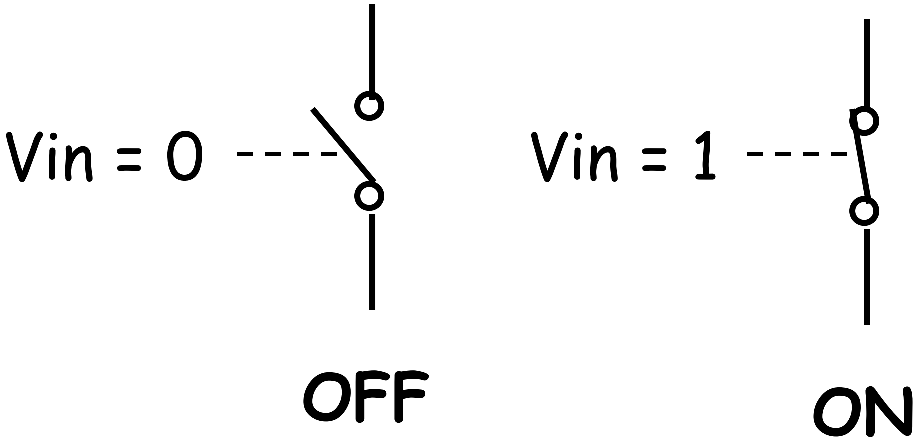
1. Computer Organization and Design & Computer Architecture, Hennessy and Patterson (slides are adapted from those by the authors)

Design processor using 10^9 transistors

(How do we handle complexity?)

3-Terminal Digital Switches (반복)

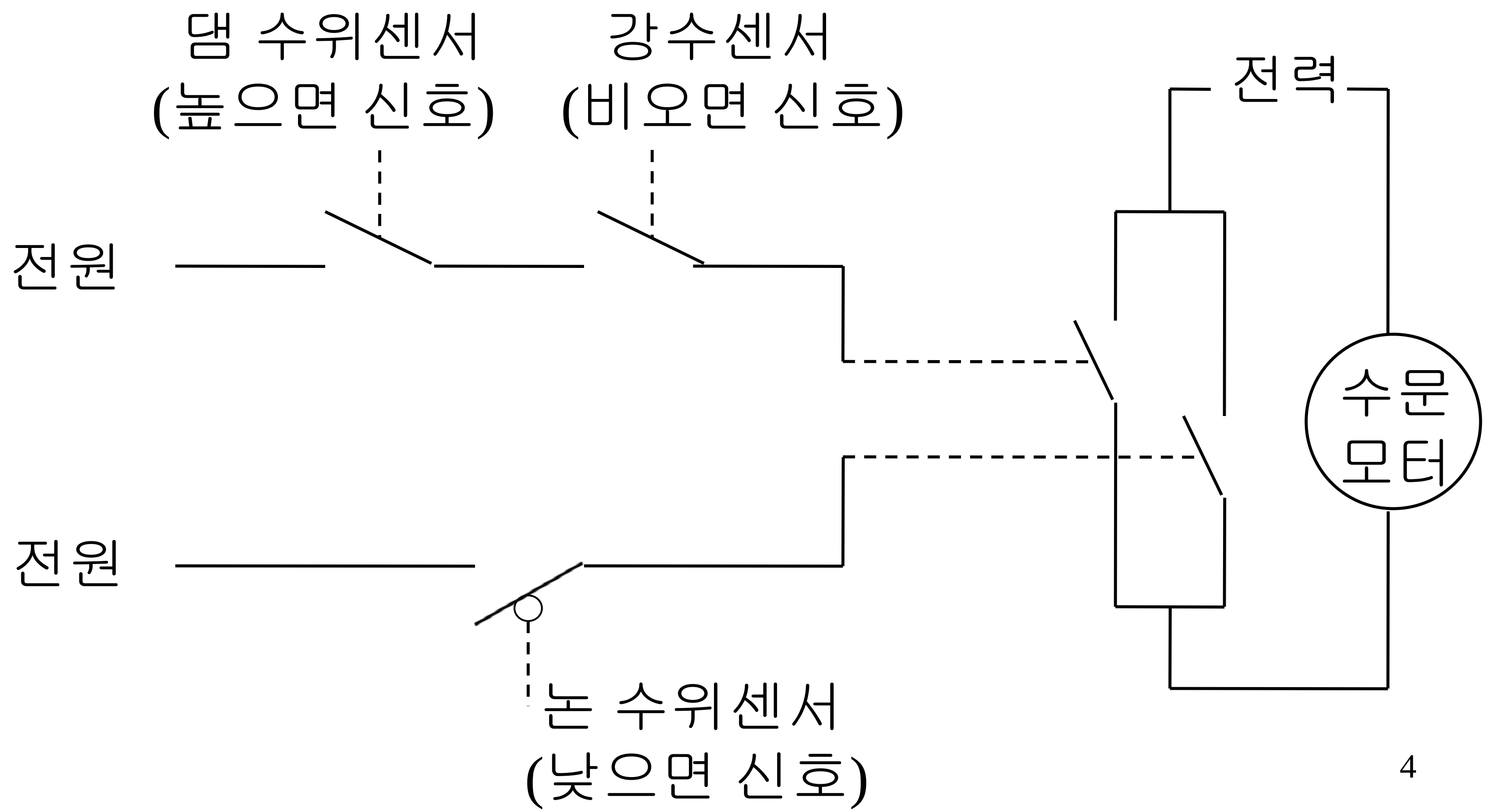
- Need for three-terminal switching device
  - Control signal, flow between the remaining two
    - Digital switch (ON, OFF)



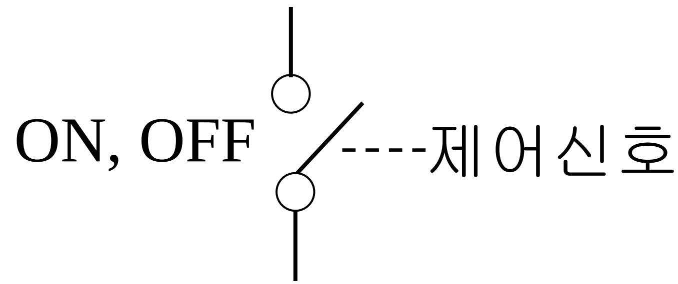
- High = 2^V = "1" = True, Low = 0^V = "0" = False

Automaton (반복)

- Self-operating machine ("sensors" and digital "switches")



3-Terminal Digital Switches
(구현 기술)



- ❑ None in mechanical era
- ❑ Electromagnetic relay (릴레이)
  - Invented in 1835 (speed: 10^{-3} second)
- ❑ Vacuum tube (진공관; speed: 10^{-6} second)
  - Invented in 1906; first commercial use in 1920
  - 라디오, TV, 오디오, 전화설비, ENIAC, ...
- ❑ Transistor – dream device (speed: 10^{-11} second)
  - Invented in 1947; 실용화에 10년 걸림
  - Small, fast, reliable, energy-efficient, inexpensive
  - Integrated Circuits 형태로 제작 가능

Electro-Mechanical Relay (반복)

- Invented in 1835, switching speed: order of milliseconds

Image of electromagnetic relays:
http://en.wikipedia.org/wiki/File:Relay.jpg
Image of electromagnetic relays:
http://en.wikipedia.org/wiki/File:Relay_symbols.svg

Electron or Vacuum Tube (반복)

- Invented in 1906 (speed: order of microseconds)
- First commercial electron tube by RCA in 1920
  - Radio, TV, Audio, telephone networks, ENIAC

Image of electronic vacuum tubes:
http://en.wikipedia.org/wiki/File:SE-300B-70W.jpg
Image of electronic vacuum tubes:
http://en.wikipedia.org/wiki/File:Triode_tube_schematic.svg

Electronic Switch - Transistor

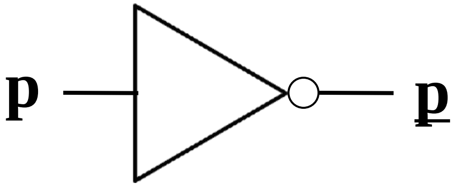
- Solid-state semiconductor device
  - “Transistor” by Bell Labs. in 1947 (c.f., ENIAC in 1946)
  - Integrated circuits in 1958

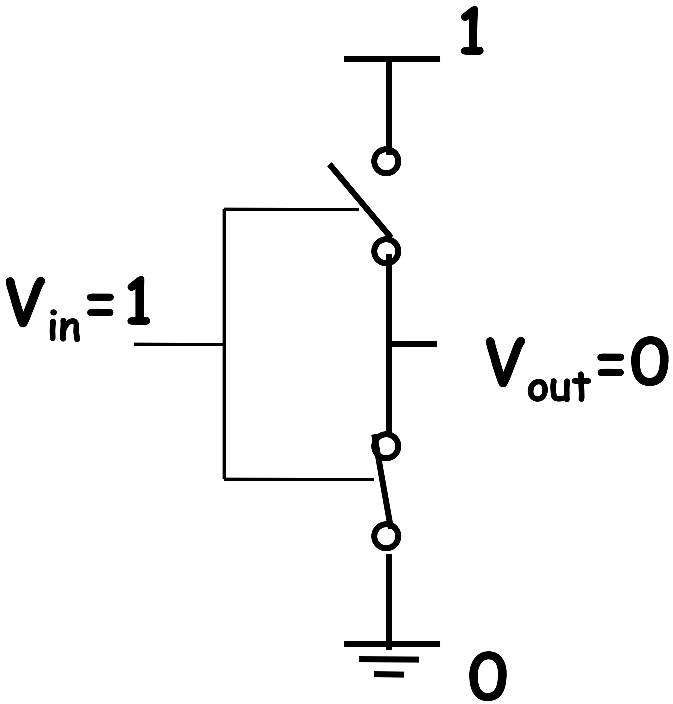
Image of transistors:
http://en.wikipedia.org/wiki/File:Transistorer_(croped).jpg
Image of ICs (Integrated Circuits):
http://en.wikipedia.org/wiki/File:Microchips.jpg

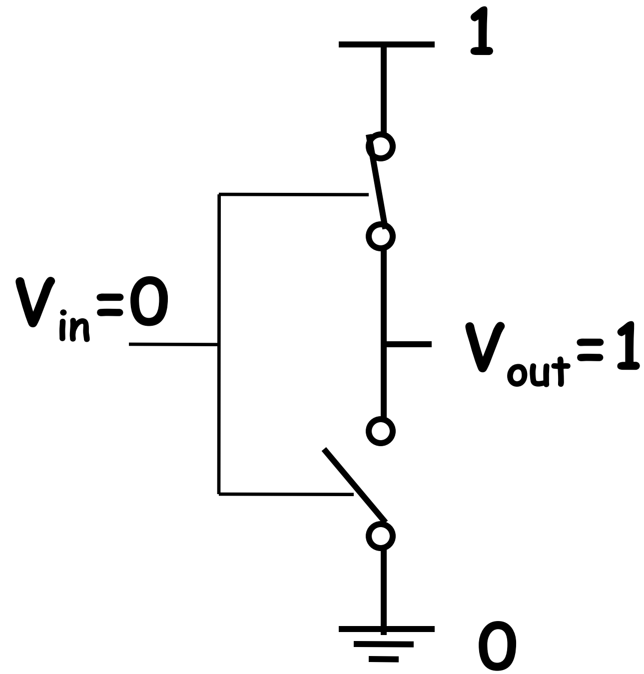
How to implement AND, OR, NOT

(move to gate-level of abstraction)
(from transistor-level of abstraction)

NOT Gate (Inverter)



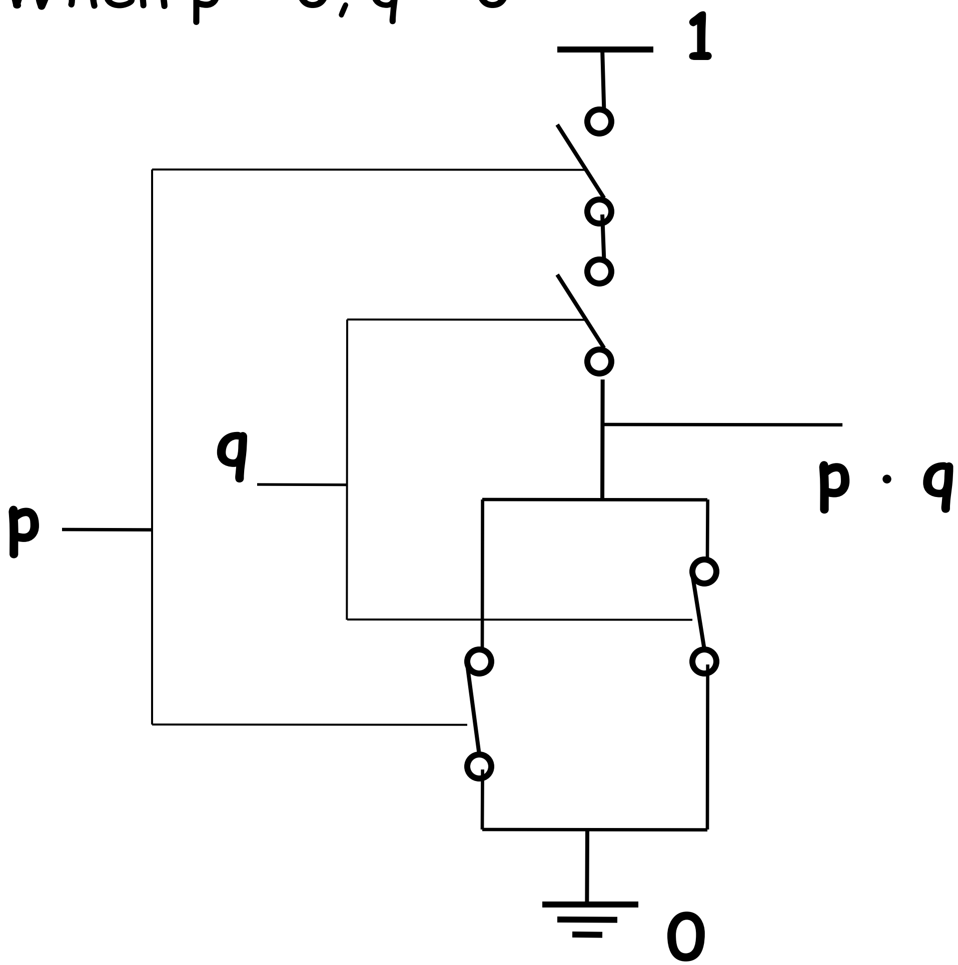


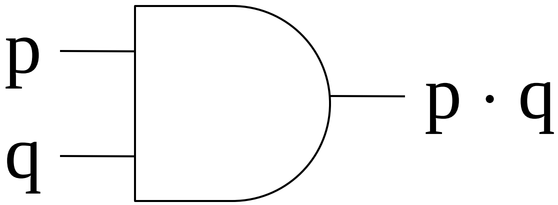


- High = 2^V = "1" = True, Low = 0^V = "0" = False

AND Gate

- High = 2^V = "1" = True, Low = 0^V = "0" = False
- When p = 0, q = 0

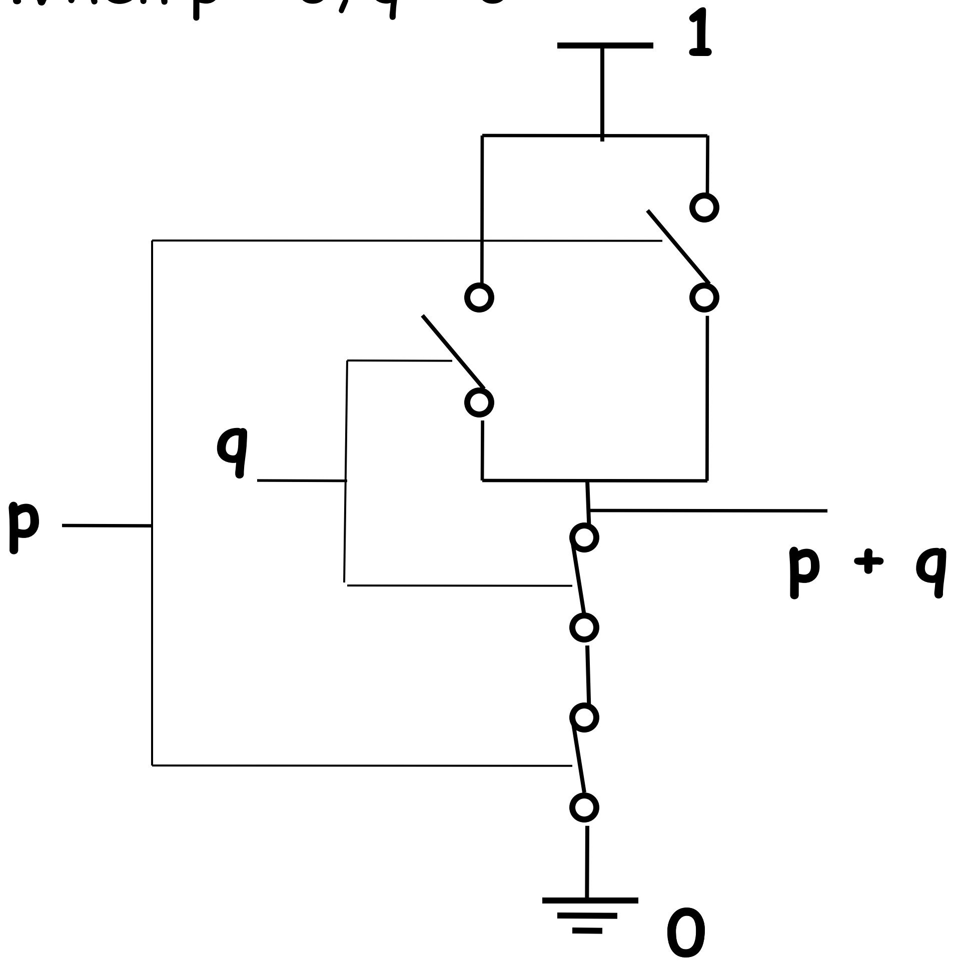


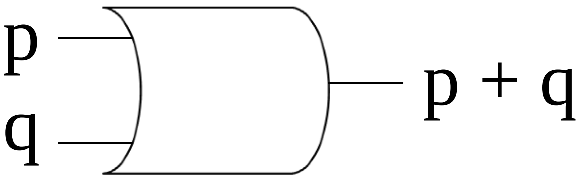


p	q	p · q
1	1	1
1	0	0
0	1	0
0	0	0

OR Gate

- High = = 2^V = "1" = True, Low = 0^V = "0" = False
- When p = 0, q = 0





p	q	p + q
1	1	1
1	0	1
0	1	1
0	0	0

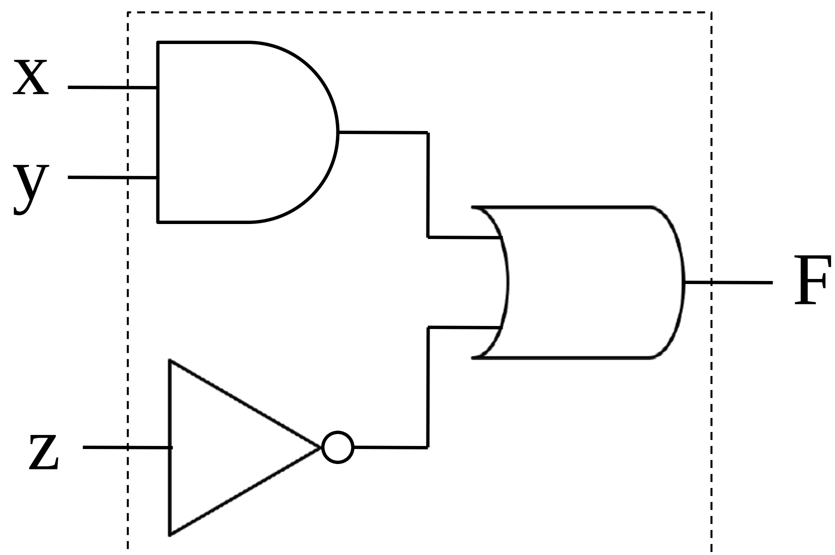
Gate-Level of Abstraction (반복)

- Real world example
  - x: 댐의수위가 높다, y: 비가 온다, z: 논에 물이 충분하다
  - F: 댐의 수문을 연다

x	y	z	F
1	1	1	1
1	1	0	1
1	0	1	0
1	0	0	1
0	1	1	0
0	1	0	1
0	0	1	0
0	0	0	1

Truth Table

- $F = x \cdot y + \underline{z}$
  - Simplest form?



Logic Diagram

Hardware Abstraction (반복)

- ❑ You have AND, OR, NOT
- ❑ What did you learn from "디지털논리설계" 교과목?
  - Designing useful functional units
    - Combinational circuits: decoder, adder, (ALU)
    - Sequential circuits: register, counter, memory, (CPU)
  - What is more important: notion of abstraction
    - Use AND, OR, NOT, to design simple functional unit (e.g., decoder)
      - You know only its interface (i.e., how to use it)
    - Then use it to build more complex functional unit
    - † This cycle is repeated indefinitely

Is transistor a simple thing?

(abstraction of a complex thing)

CMOS NAND Gate

Image of CMOS NAND gate:

http://en.wikipedia.org/wiki/File:CMOS_NAND.svg

Image of CMOS NAND layout:

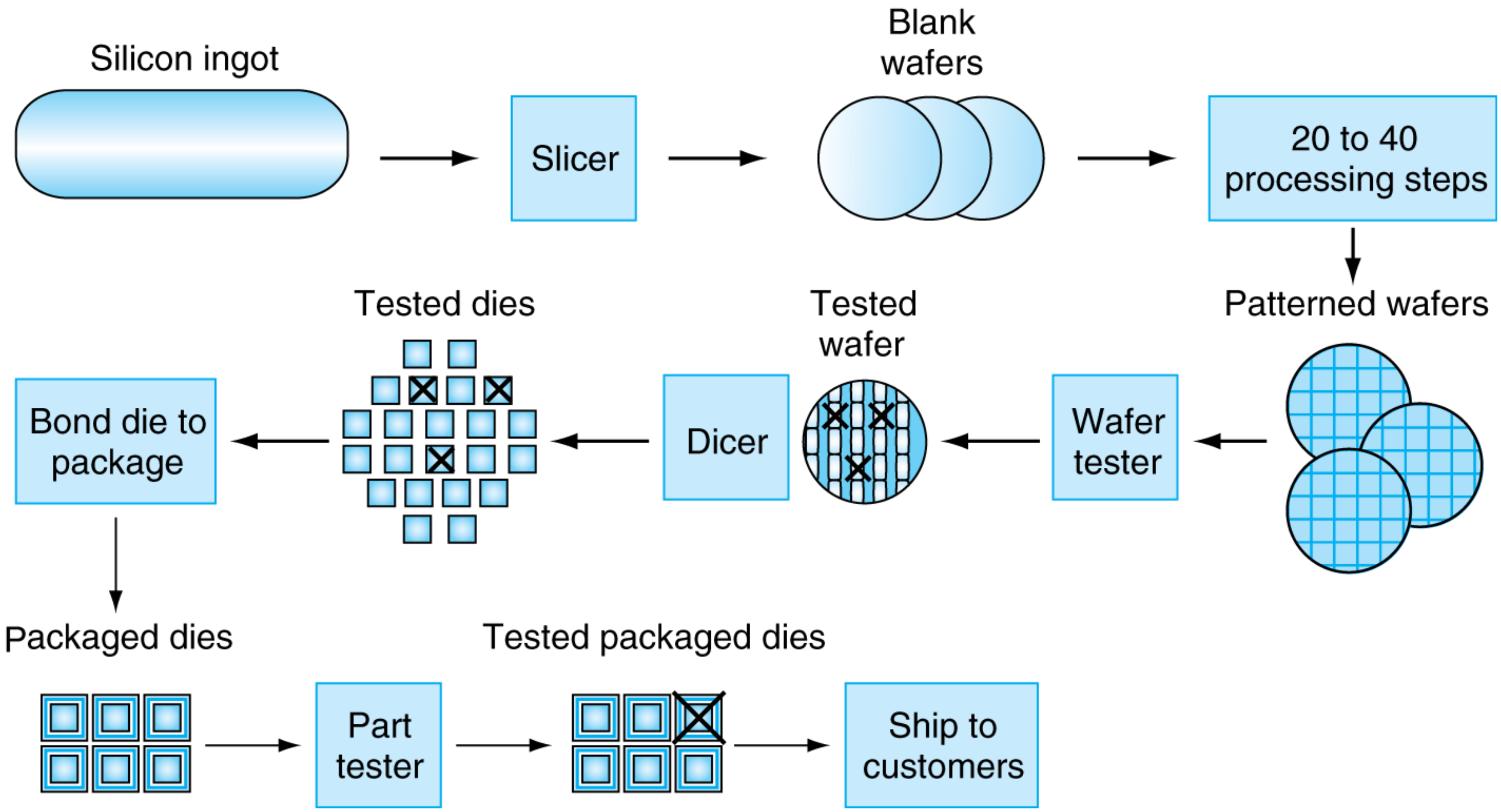
http://en.wikipedia.org/wiki/File:CMOS_NAND_Layout.svg

Image of CMOS transistor pair:

http://en.wikipedia.org/wiki/File:Cmos_impurity_profile.PNG

Manufacturing ICs

(Hennessy and Patterson slide, Computer Organization and Design, Morgan Kaufmann)



- Yield: proportion of working dies per wafer

Science and Engineering

(GEB by Hofstadter, AI by Winston)

- Levels of abstraction

Java Language

Machine Instruction

System Biology

Functional

Cell Biology

Gate

Molecular Biology

Transistor

Chemist

Semiconductor Physics

(Electron, orbit)

Atomic Physics

(Atomic nucleus)

Nuclear Physics

(Proton, neutron)

Abstraction in Software

C (or High-Level) Programming

- Basic building block
  - Statement (like sentence in human writing)
    - "atoms" (that have meanings)
- Compiler translate statements into CPU instructions

Statements

- Compiler support variety of statements for programmers
  - Variable declaration statement

```
int  a, b, c, d, i, j=0;      // colored: special symbols
float  x, y, z=3.5;           // statement end with ;
```

  - Assignment statement

```
a = 3;
```

  - Arithmetic and assignment statement

```
a = (b*3) – (c/d);
```

  - Conditional statement

```
if (i > 0)  x = x*1.1;          // if statement
if (i > 0)  x = x*1.1;          // if-else statement
    else  x = x*0.9;              (indentation)
```

Statements

- Loop statement

```
a = 0;                              // summation
for (i = 1; i < 5; i = i + 1)
    a = a + i;
```

- Compound statement

```
{ multiple statements }       // treat as single
```

- Function call statement

```
printf("hello, world!\n");    // call OS service
```

-
-
-

C Programming

- We have statements
  - Can write algebraic equation
  - Have English-like control structure
    - Can forget about hardware-level details
- Are we ready to handle million lines of source code?
  - Need design paradigm to reduce complexity
    - We need function

Small C Program - Function

(from The C Programming Language by Kernighan and Ritchie)

```
#include <stdio.h>
int power(int, int);                /* function declaration */
main()                              /* test power function */
{   int i;
    for (i = 0; i < 10; i++)
        printf("%d %d \n", i, power (2,i));  // function call statement
    return 0;
}
int power (int base, int n)   /* power: raise base to n-th power */
{   int i, p;
    p = 1;
    for (i = 1; i <= n; ++i)
        p = p * base;
    return p;
}
```

Function: Key Abstraction

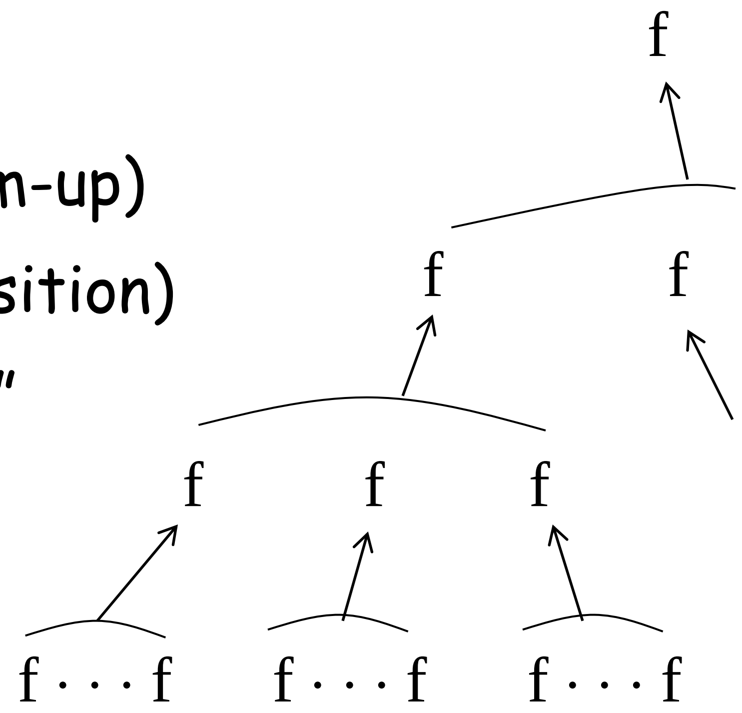
- Why define functions?
  - Write once, call many times (from different locations)
- Once we define function, all users need to know is
  - Function interface: "int power (int, int)"

    a = power (2, 3);

  - Don't have to know about implementation
- Function "int power (int, int)": single abstract operation
  - Function become like statement
    - Function has name, naming is abstracting
- Function abstraction
  - Critical to deal with program largeness and complexity

Hierarchical Function Abstraction

- Hierarchical bottom-up function abstraction
  - Critical to deal with complexity
- Notion of program structure
- Design perspective
  - Top-down (rather than bottom-up)
  - Modular design (i.e., decomposition)
  - Keep "dividing and conquering"



Primitive-Composition-Abstraction

- Fundamental paradigm in high-level programming
  - Primitives: statements
  - Composition: build function using statements
  - Abstraction
    - Given its interface, can use function
    - Function (an abstract statement) become primitive
- Function: abstraction building mechanism
- What is high-level programming?
  - Hierarchically build abstraction
    - † True in all engineering

Million Lines of Source Code

Developers

Many design steps
(manual)
to fill semantic gap

High-level language

C, C++, Java

Compiler

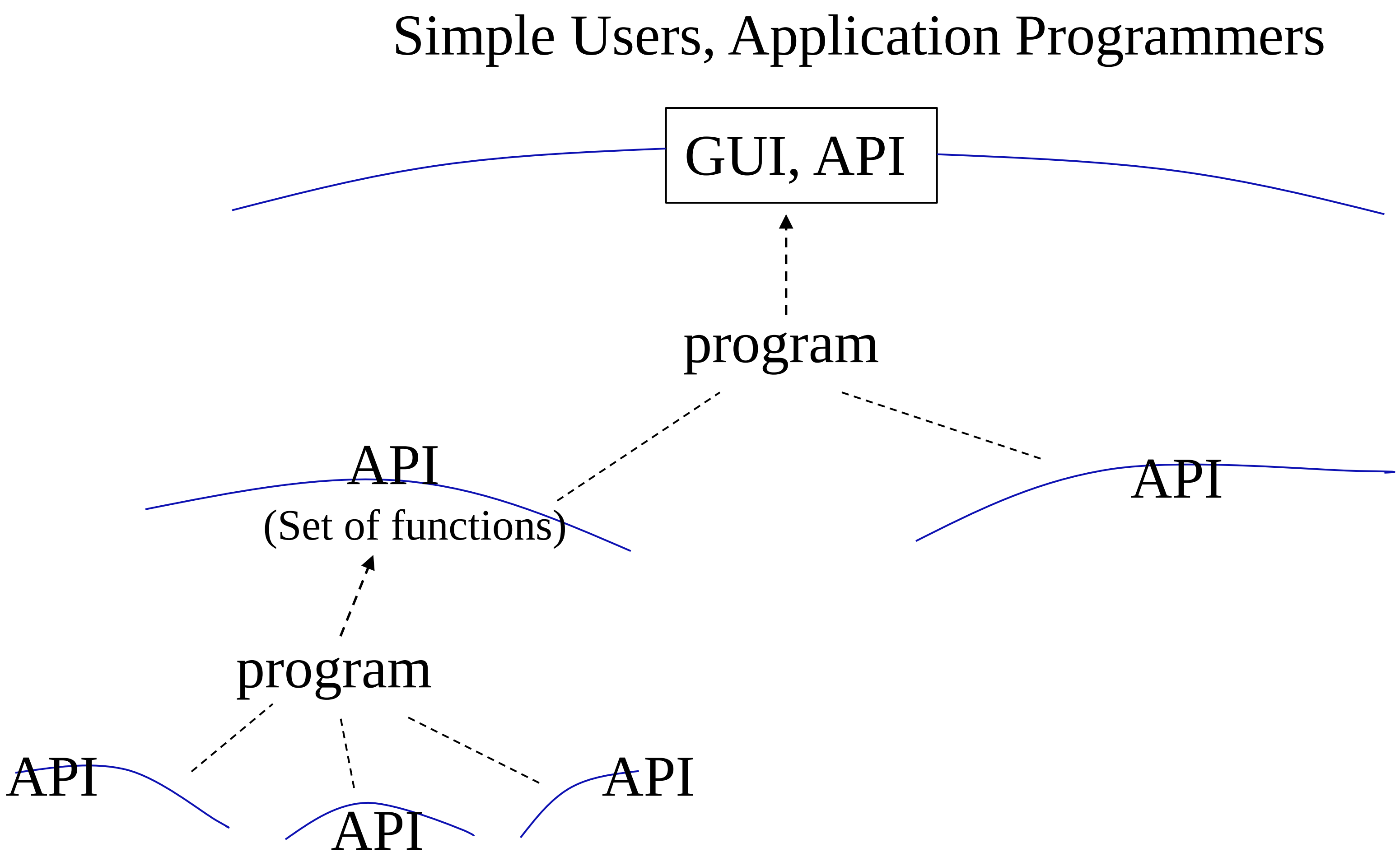
(executable) Machine-level language

ISA (Pentium, PowerPC)

Machine (CPU)

Software Design (e.g., OS)

- Hierarchy: buy library (or API), build on top of it



What is library?

- Collection of related functions (e.g., math library)
  - API (Application Programming Interface):

    int power(int, int);, double sin(double);, ….

  - Compiled code: power.o + sin.o + …

Programmer:

- Build more complex function using library functions
- Don't have to know how library functions are implemented

Library API

function1( )   function2( )   function3( )   ---------

Software Architecture

- Software architecture (or program structure)
- What is it?
  - Set of key boundaries
    - Identification of modules
    - Their interface
  - Hierarchical: all the way down to lowest library
- To think about
  - Architect vs. programmer
    - “대한민국에는 소프트웨어 아키텍트가 없다”?

† The same applies to hardware or any engineering area

Science and Engineering
(GEB by Hofstadter, AI by Winston)

- Levels of abstraction

Software Abstraction Layers

	C Language
	Machine Instruction
System Biology	Functional
Cell Biology	Gate
Molecular Biology	Transistor
Chemist	Semiconductor Physics

Atomic Physics	(Electron, orbit)
Nuclear Physics	(Atomic nucleus)
	(Proton, neutron)

Abstractions Provided by Languages

- C language
  - Statements
  - Abstraction builder
    - Function for processing
    - Array/structure for data
- Limitation of C
  - Separate abstraction of data and processing
- OOP
  - Object-based abstraction
  - Object contain both processing and data

CSE Major: Abstraction Builder

- Problem solving create new abstraction (or service)
  - Web, search engine, SNS, Kakao talk
  - RISC-style ISA in 1980s

OS Abstraction

(이 부분은 참고자료임)
- 어떤 구체적인 문제들을 풀었나?
- 어떤 solution 들을 만들어 내었나?

What is OS?

Users

GUI -

Utilities Applications

API Library functions

Process (execution)	File (storage)	TCP/IP, peripherals (connect)	Kernel
CPU	Memory	I/O	Hardware

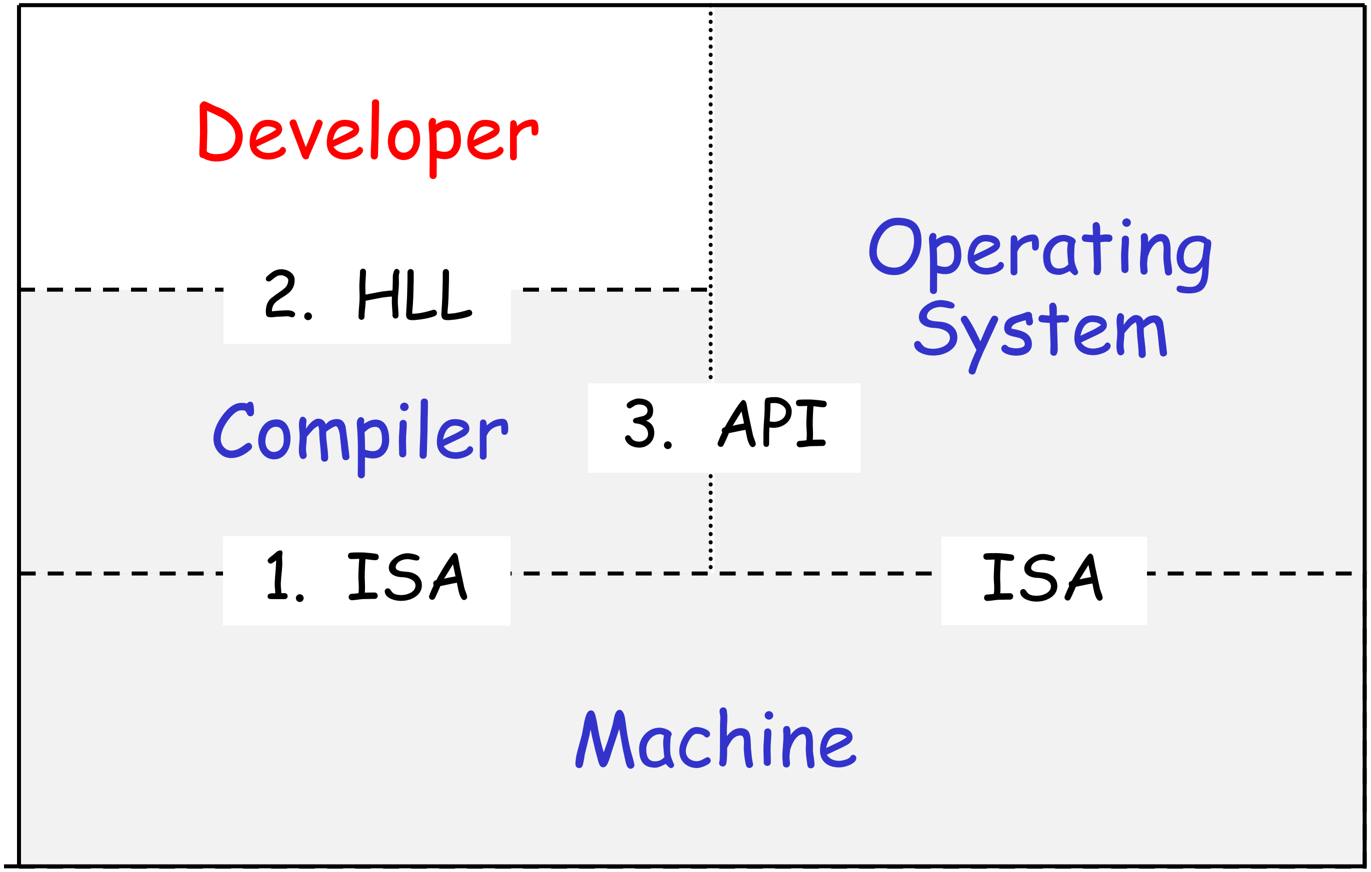
What is OS?

- Make hardware easy to use by providing library
  - CPU (program execution)
    - process_create(), process_kill(), ...
  - Memory (storage)
    - file_copy(), delete_folder(), file_rename(), ...
  - I/O (connectivity)
    - Socket("naver.com", 80), monitor_write(), ...
- GUI, utilities (common functions for all users)
- 공유자원의 사용관리 및 보호 (응용 프로그램간의 조정)

† Programmer: OS API 이용하여 Applications 개발

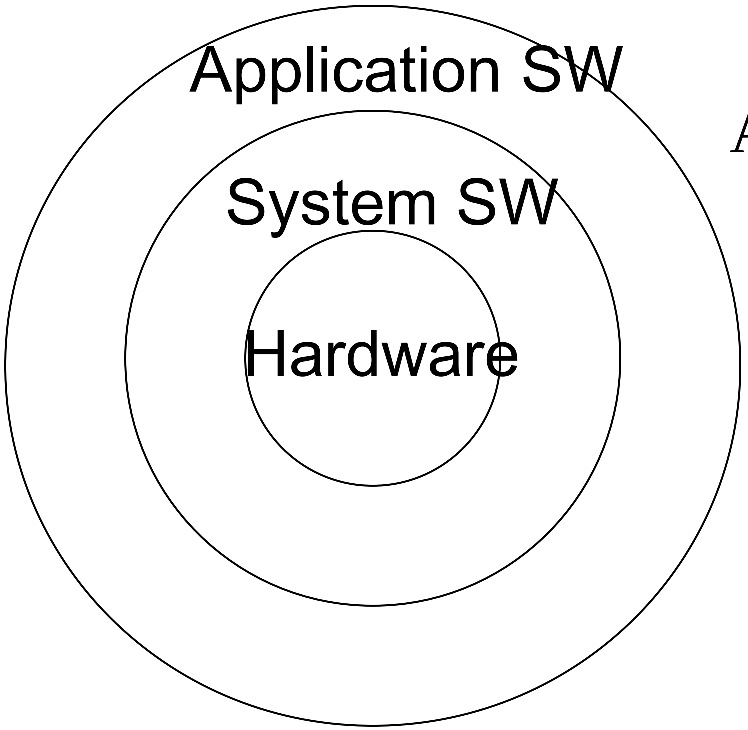
Using OS API: Third Major I/F

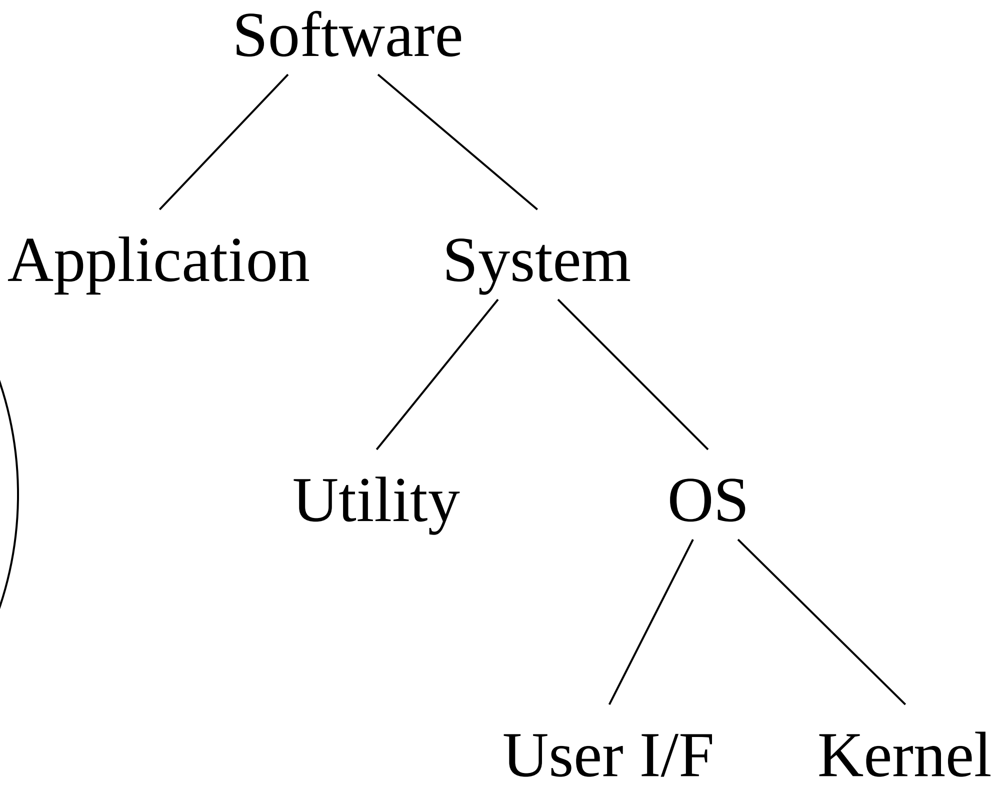
- Three interfaces, three key products and their services



What is OS?

- Map to previous figure





Summary

- How do we build complex processor?
  - Abstractions in hardware design
- Abstractions in software design
- OS abstractions