資訊工程概論

# 硬體產業透視與趨勢簡介

馬詠程

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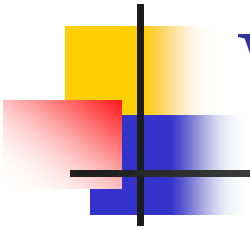


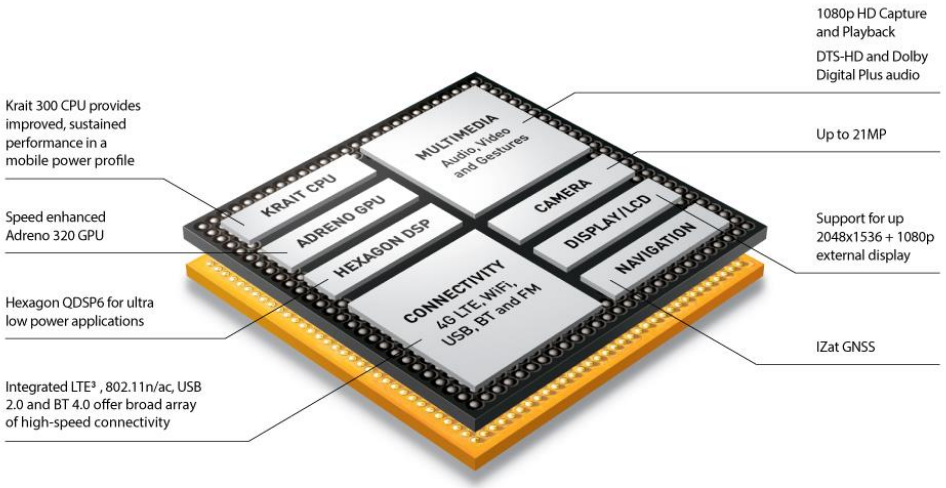
# What I want to tell you

(1) There is no pure hardware industry at all!

(2) The IC industry needs lots of programmers

(3) CS-guys are more suitable for IC industry than EE-guys

# Products Contributed by Computer Science Guys



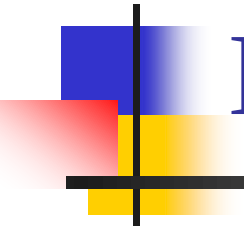
# Players in the IC Industry

- Semiconductor Manufacturing
  - TSMC (台積電), UMC (聯電)
  - Global Foundry, Samsung
- IC Design
  - Fabless IC Vendor: MediaTek (聯發科), Qualcomm, Marvell, etc.
  - IP (Intellectual Property): ARM
  - IC Vender: Intel, AMD, Apple, Samsung
- IC Design Service: Artisan, Faraday
- EDA tools: Synopsys, Cadence, Menter Graphics
- System Products
  - Apple, Samsung, hTC (宏達電), 廣達, 仁寶, 華碩, 研華, …

# IC industry at 21th century

- the system-on-chip industry

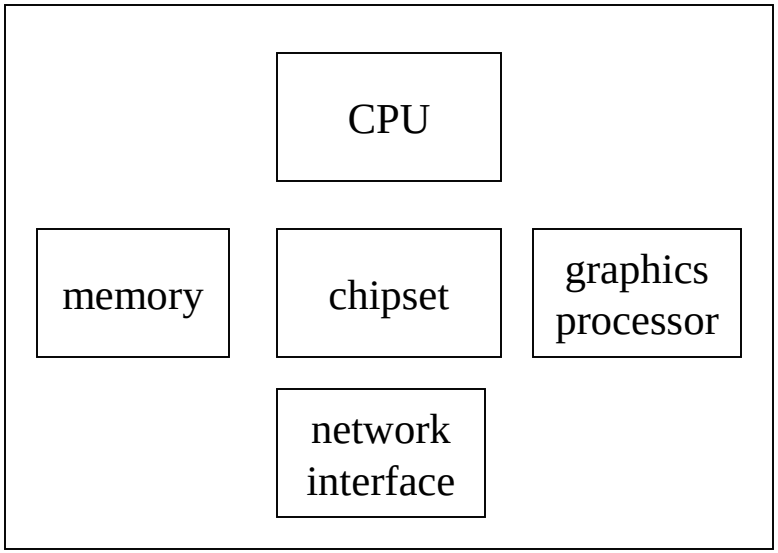
- who involved?
  - application programmer (e.g. video codec, voice recognition, etc.)
  - system software programmer (compiler, OS)
  - EDA (Electronic Design Automation) tool programmer
  - processor architect and designer
  - system simulation programmer
  - circuit layout engineer
  - semiconductor process engineer
  - printed board layout engineer
  - IC test engineer
  - … and a lot more …



# Inside the desktop computer

the traditional view of hardware industry

# Hardware components of a PC



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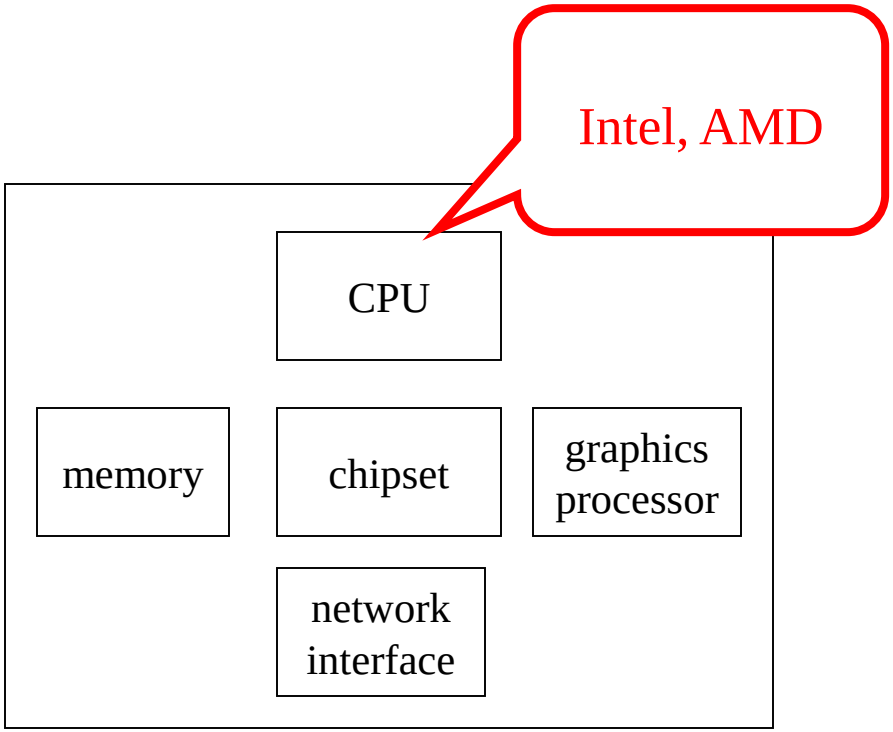
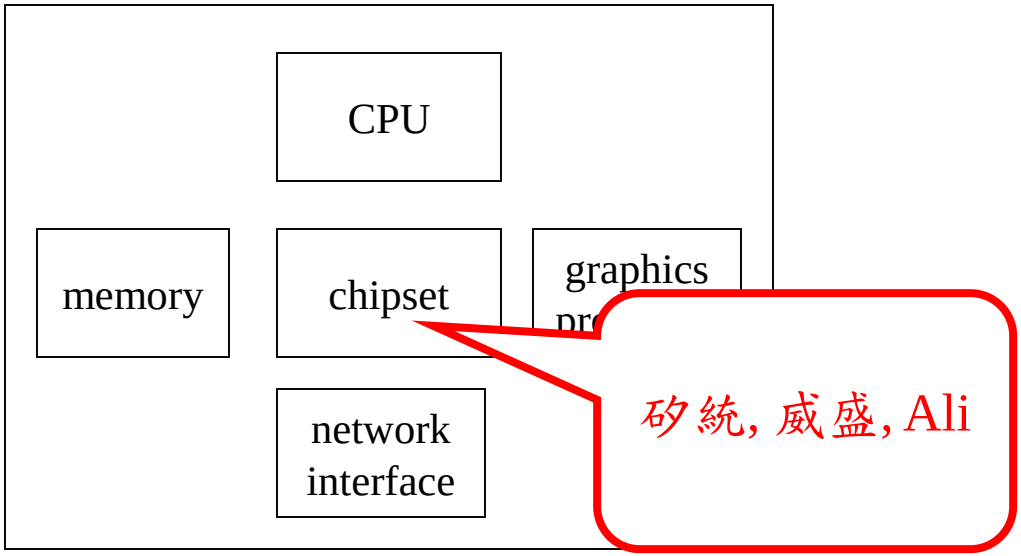
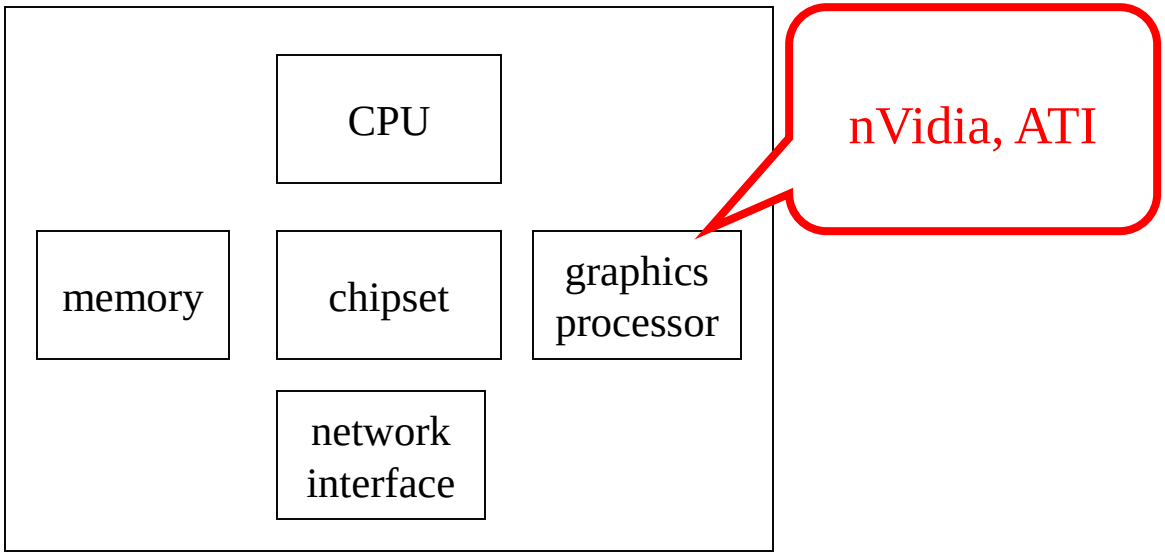


# Hardware components of a PC



# Hardware components of a PC



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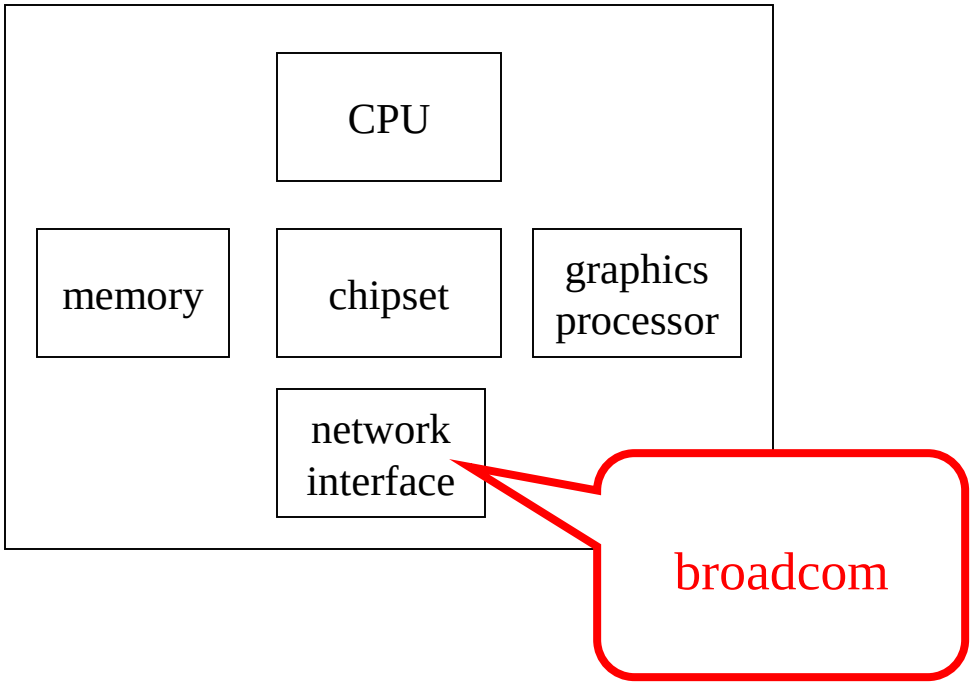
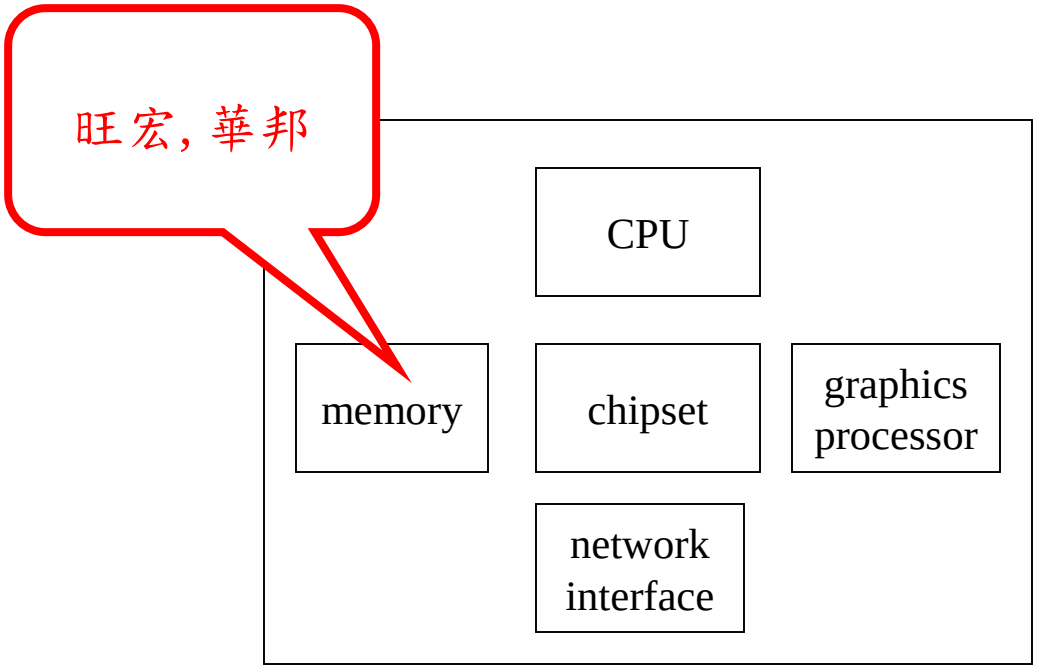
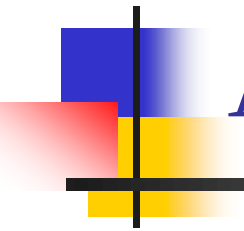


# Hardware components of a PC



- Don’t restrict yourself to PCs!



# A new world – embedded system

# What is embedded system

- a computer that works in somewhere you do not see a computer in it
  - motor control in a car
  - printer
  - DVD player
  - cell-phone
  - PDA
  - keyboard
  - …a lot more…

# Players about a Smart-Phone

- Application processors supplier
  - Qualcomm, MediaTek, Apple, Samsung, …
- System designer
  - Apple, Samsung, hTC, …
- Software and service provider
  - Apple, Google, various App developers, …

# Top Players

**1H13 Top 20 Semiconductor Sales Leaders**
**($M, Including Foundries)**

| 1H13 Rank | 2012 Rank | Company | Headquarters | 2012 Tot Semi | 1H12 Tot Semi | 1Q13 Tot Semi | 2Q13 Tot Semi | 1H13 Tot Semi | 1H13/1H12 % Change |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Intel | U.S. | 49,114 | 24,296 | 11,555 | 11,785 | 23,340 | -4% |
| 2 | 2 | Samsung | South Korea | 32,251 | 15,101 | 7,952 | 7,771 | 15,723 | 4% |
| 3 | 3 | TSMC* | Taiwan | 16,951 | 7,810 | 4,460 | 5,152 | 9,612 | 23% |
| 4 | 4 | Qualcomm** | U.S. | 13,177 | 5,928 | 3,916 | 4,222 | 8,138 | 37% |
| 5 | 8 | SK Hynix | South Korea | 9,057 | 4,406 | 2,577 | 3,521 | 6,098 | 38% |
| 6 | 6 | Toshiba | Japan | 11,217 | 5,659 | 2,938 | 2,868 | 5,806 | 3% |
| 7 | 5 | TI | U.S. | 12,081 | 6,077 | 2,718 | 2,922 | 5,640 | -7% |
| 8 | 10 | Micron | U.S. | 8,002 | 4,204 | 2,144 | 2,450 | 4,594 | 9% |
| 9 | 9 | ST | Europe | 8,364 | 4,126 | 1,994 | 2,033 | 4,027 | -2% |
| 10 | 11 | Broadcom** | U.S. | 7,793 | 3,687 | 1,954 | 2,035 | 3,989 | 8% |
| 11 | 7 | Renesas | Japan | 9,314 | 4,480 | 1,886 | 1,920 | 3,806 | -15% |
| 12 | 15 | GlobalFoundries* | U.S. | 4,560 | 2,340 | 1,240 | 1,325 | 2,565 | 10% |
| 13 | 14 | Infineon | Europe | 4,928 | 2,564 | 1,208 | 1,327 | 2,535 | -1% |
| 14 | 16 | NXP | Europe | 4,325 | 2,053 | 1,085 | 1,188 | 2,273 | 11% |
| 15 | 13 | AMD** | U.S. | 5,422 | 2,998 | 1,088 | 1,161 | 2,249 | -25% |
| 16 | 12 | Sony | Japan | 5,709 | 2,986 | 1,049 | 1,148 | 2,197 | -26% |
| 17 | 24 | Elpida*** | Japan | 3,075 | 1,997 | 945 | 1,160 | 2,105 | 5% |
| 18 | 22 | MediaTek** | Taiwan | 3,366 | 1,457 | 817 | 1,115 | 1,932 | 33% |
| 19 | 20 | UMC* | Taiwan | 3,730 | 1,804 | 898 | 1,015 | 1,913 | 6% |
| 20 | 19 | Freescale | U.S. | 3,803 | 1,892 | 917 | 988 | 1,905 | 1% |
| Top 10 Total | | | | 168,007 | 81,294 | 42,208 | 44,759 | 86,967 | 7% |
| Top 20 Total | | | | 216,239 | 105,865 | 53,341 | 57,106 | 110,447 | 4% |

*Foundry **Fabless ***Purchased by Micron on July 31, 2013

Source: IC Insights' Strategic Reviews Database

- http://www.icinsights.com/news/bulletins/IC-Insights-Reveals-Big-Changes-To-1H13-Top-20-Semiconductor-Supplier-Ranking/

# Top Players --- Fabless IC Suppliers

**2011 Top 25 Fabless IC Suppliers ($M)**

| 2011 Rank | 2010 Rank | 2009 Rank | Company | Headquarters | 2009 ($M) | 2010 ($M) | % Change | 2011 ($M) | % Change |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | Qualcomm | U.S. | 6,409 | 7,204 | 12% | 9,910 | 38% |
| 2 | 2 | 3 | Broadcom | U.S. | 4,271 | 6,589 | 54% | 7,160 | 9% |
| 3 | 3 | 2 | AMD | U.S. | 5,403 | 6,494 | 20% | 6,568 | 1% |
| 4 | 6 | 5 | Nvidia | U.S. | 3,151 | 3,575 | 13% | 3,939 | 10% |
| 5 | 4 | 6 | Marvell | U.S. | 2,690 | 3,592 | 34% | 3,445 | -4% |
| 6 | 5 | 4 | MediaTek | Taiwan | 3,500 | 3,590 | 3% | 2,969 | -17% |
| 7 | 7 | 7 | Xilinx | U.S. | 1,699 | 2,311 | 36% | 2,269 | -2% |
| 8 | 8 | 10 | Altera | U.S. | 1,196 | 1,954 | 63% | 2,064 | 6% |
| 9 | 9 | 8 | LSI Corp. | U.S. | 1,422 | 1,616 | 14% | 2,042 | 26% |
| 10 | 10 | 11 | Avago | Singapore | 858 | 1,187 | 38% | 1,341 | 13% |
| 11 | 13 | 12 | MStar | Taiwan | 838 | 1,065 | 27% | 1,220 | 15% |
| 12 | 11 | 13 | Novatek | Taiwan | 819 | 1,149 | 40% | 1,198 | 4% |
| 13 | 15 | 16 | CSR | Europe | 601 | 801 | 33% | 845 | 5% |
| 14 | 12 | 9 | ST-Ericsson* | Europe | 1,263 | 1,146 | -9% | 825 | -28% |
| 15 | 16 | 15 | Realtek | Taiwan | 615 | 706 | 15% | 742 | 5% |
| 16 | 17 | 17 | HiSilicon | China | 572 | 652 | 14% | 710 | 9% |
| 17 | 27 | 67 | Spreadtrum | China | 105 | 346 | 230% | 674 | 95% |
| 18 | 19 | 19 | PMC-Sierra | U.S. | 496 | 635 | 28% | 654 | 3% |
| 19 | 18 | 14 | Himax | Taiwan | 693 | 643 | -7% | 633 | -2% |
| 20 | 21 | — | Lantiq | Europe | 0 | 550 | N/A | 540 | -2% |
| 21 | 33 | 30 | Dialog | Europe | 218 | 297 | 36% | 527 | 77% |
| 22 | 22 | 21 | Silicon Labs | U.S. | 441 | 494 | 12% | 492 | 0% |
| 23 | 29 | 20 | MegaChips | Japan | 445 | 337 | -24% | 456 | 35% |
| 24 | 23 | 24 | Semtech | U.S. | 254 | 403 | 59% | 438 | 9% |
| 25 | 24 | 23 | SMSC | U.S. | 283 | 397 | 40% | 415 | 5% |
| Top 25 Total | | | — | — | 38,242 | 47,733 | 25% | 52,076 | 9% |
| Non-Top 25 Fabless | | | — | — | 11,091 | 14,781 | 33% | 12,811 | -13% |
| Total Fabless | | | — | — | 49,333 | 62,514 | 27% | 64,887 | 4% |

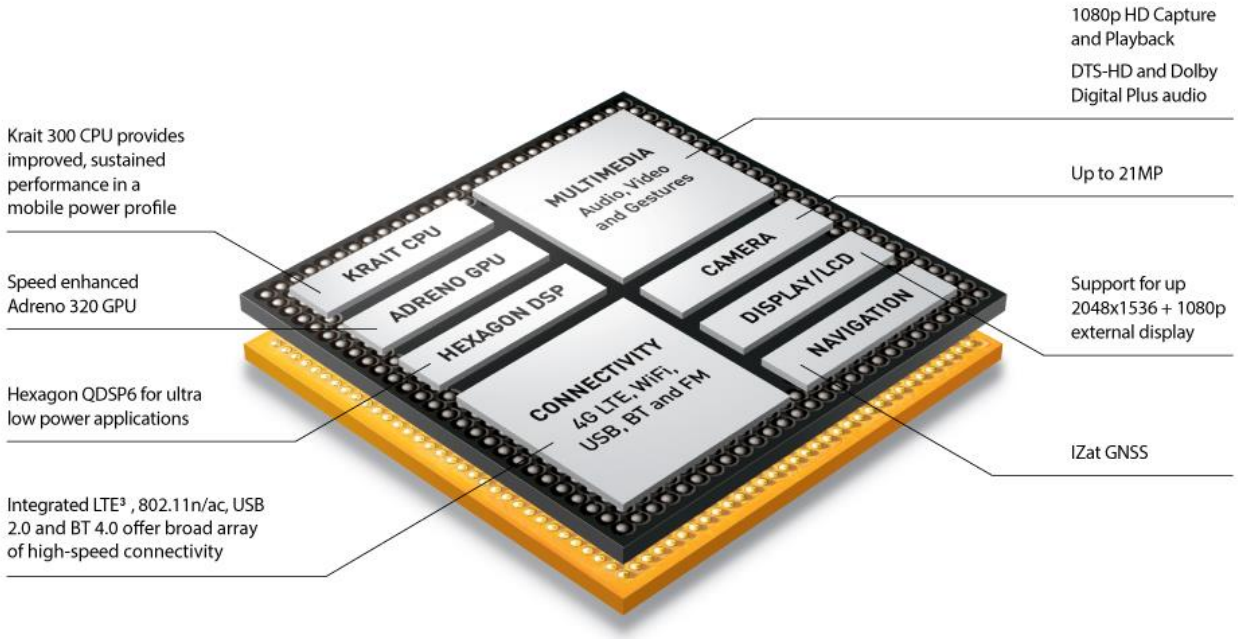
*Represents the 50% share not accounted for by ST.

Source: Company reports, IC Insights' *Strategic Reviews Database*

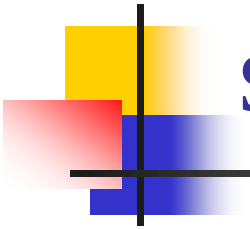
- http://www.eetimes.com/document.asp?doc_id=1261538

# Inside a Smart-Phone: the System-on-Chip (SoC)

- Snapdragon application processor by Qualcomm
- http://www.qualcomm.com/snapdragon/processors/600

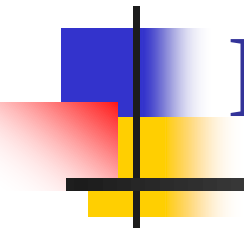


# What Qualcomm provides for a smart-phone



- Application processor
- Sample experiment board
- Software
  - Assembler, linker, optimizing compiler, OS kernels, peripheral drivers, …

- Check these websites:
  - https://developer.qualcomm.com/
  - https://developer.qualcomm.com/mobile-development/mobile-technologies/multimedia-optimization-hexagon-dsp-sdk

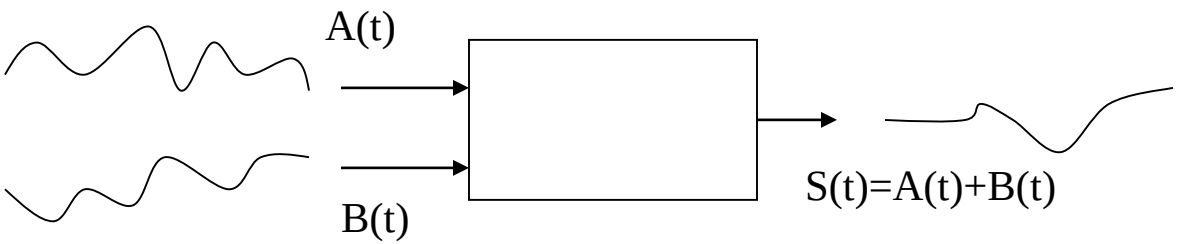


# How to make a (digital) chip

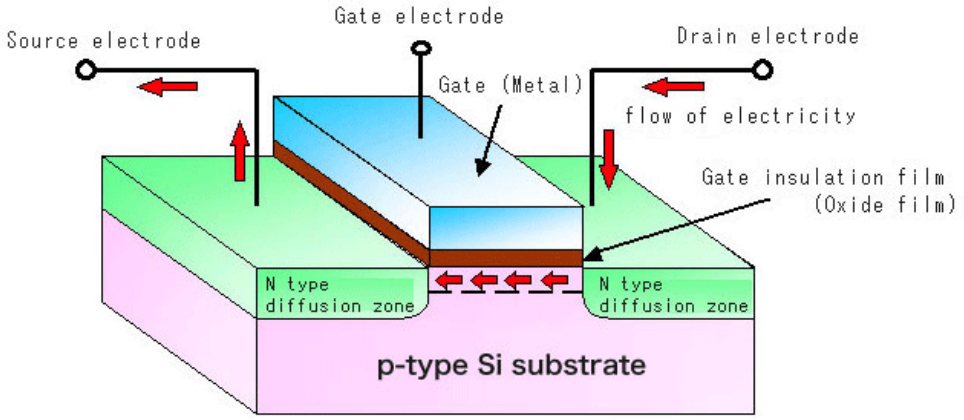
the standard flow

# Why digital?

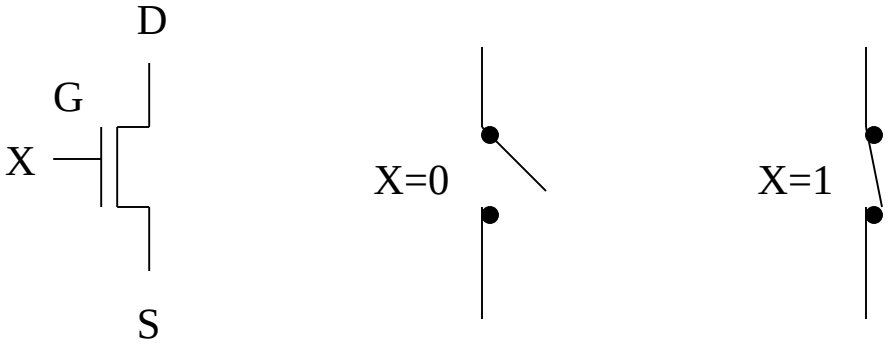
- why not analog?
- answer this question after you finish the electronics course!



# The basic device to build a chip: MOS transistor

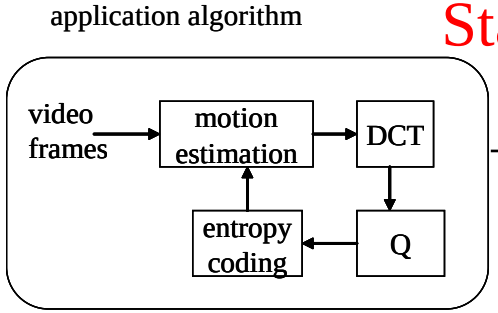



Construction of MOSFET

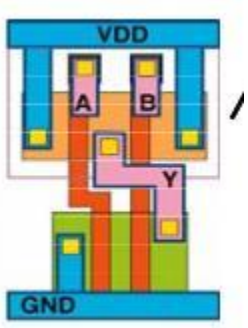


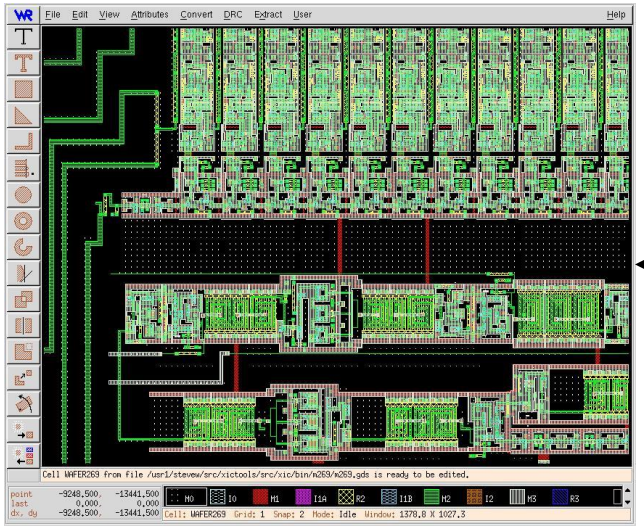
# VLSI Design Flow in SoC Era

Starting from software-like algorithms!




- ESL design (Electronic System Level)
- RTL design (Register Transfer Level)
- gate-level design
- circuit-level design (transistor-level)
- physical layout

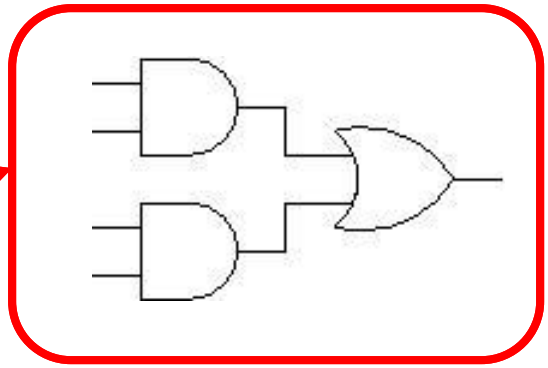


# Gate-Level Design

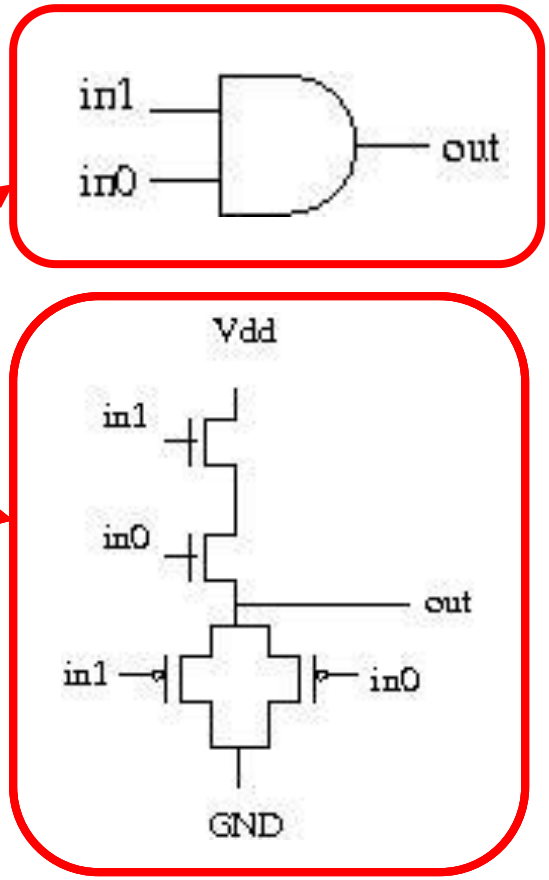
deal with signals in 0 or 1

| |
|---|
| ESL design<br>(Electronic System Level) |
| RTL design<br>(Register Transfer Level) |
| gate-level design |
| circuit-level design<br>(transistor-level) |
| physical layout |



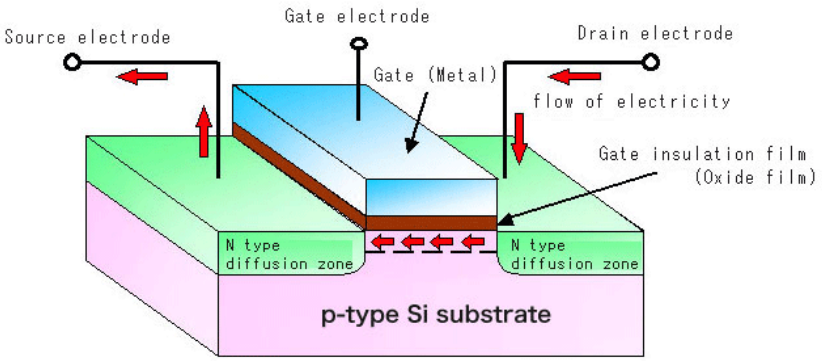
# Circuit-Level Design

| |
|---|
| ESL design<br>(Electronic System Level) |
| RTL design<br>(Register Transfer Level) |
| gate-level design |
| circuit-level design<br>(transistor-level) |
| physical layout |

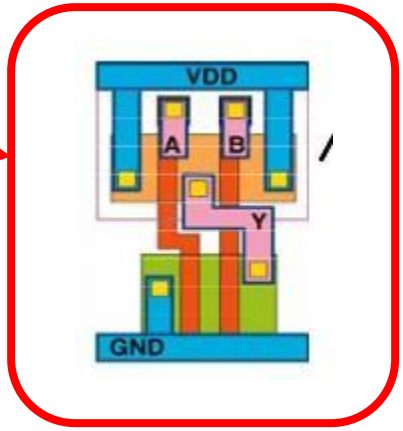


# Physical Layout

| |
|---|
| ESL design<br>(Electronic System Level) |
| RTL design<br>(Register Transfer Level) |
| gate-level design |
| circuit-level design<br>(transistor-level) |
| physical layout |




Construction of MOSFET



# RTL Design

- RTL: Register Transfer Level

| |
|---|
| ESL design<br>(Electronic System Level) |
| RTL design<br>(Register Transfer Level) |
| gate-level design |
| circuit-level design<br>(transistor-level) |
| physical layout |

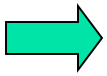
```
input   A [3:0];
input   B [3:0];
input   clock;
reg     S [3:0];

always @(posedge clock)
   S <= #1 A+B;
```

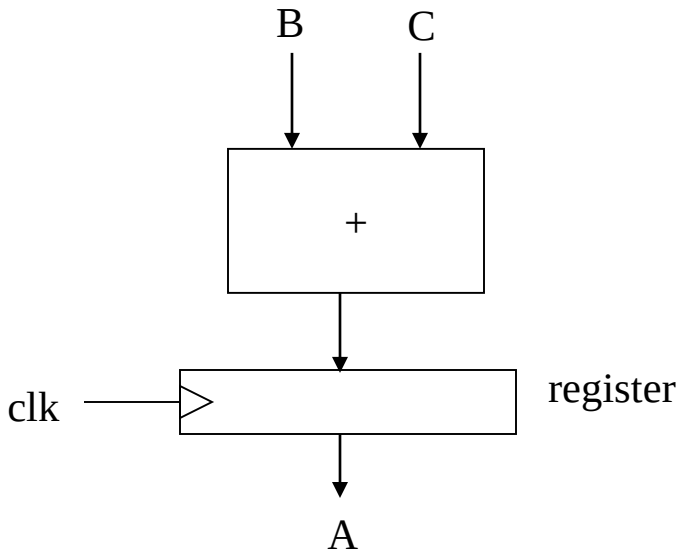
# What is RTL design

- RTL: Register Transfer Level (Language)
- a standard method to design any digital IC
- Feature:
  - designer specify rules to transfer data from one register to another register
  - EDA (electronic design automation) tool synthesis RTL code to real hardware

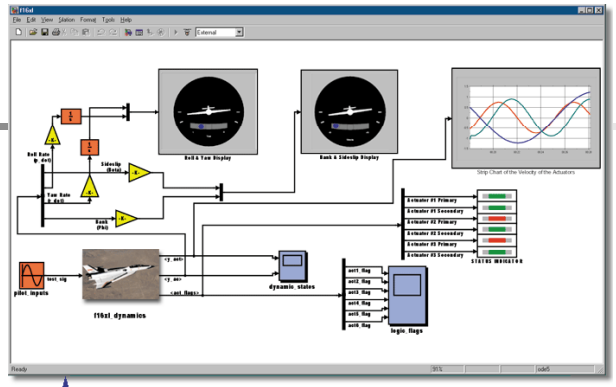
Verilog code

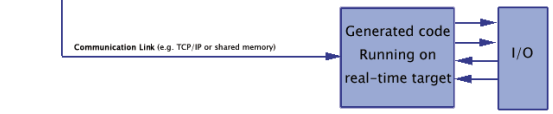
```
reg    [3:0]   A, B, C;

always @(posedge clk) begin
   A <= B+C;
end
```





# ESL Design




Communication Link (e.g. TCP/IP or shared memory)
Generated code
Running on
real-time target
I/O


DSP
RISC
DCT
FFT
IP Library
Design Tools
RISC
DSP1
DSP2

# How CGU/CSIE helps to establish yourself as IC designer

| |
|---|
| ESL design<br>(Electronic System Level) |
| RTL design<br>(Register Transfer Level) |
| gate-level design |
| circuit-level design<br>(transistor-level) |
| physical layout |

hardware/software codesign

advanced computer architecture

computer architecture

computer organization

digital circuit

electronics

# The IC industry in Taiwan

| |
|---|
| ESL design<br>(Electronic System Level) |
| RTL design<br>(Register Transfer Level) |
| gate-level design |
| circuit-level design<br>(transistor-level) |
| physical layout |

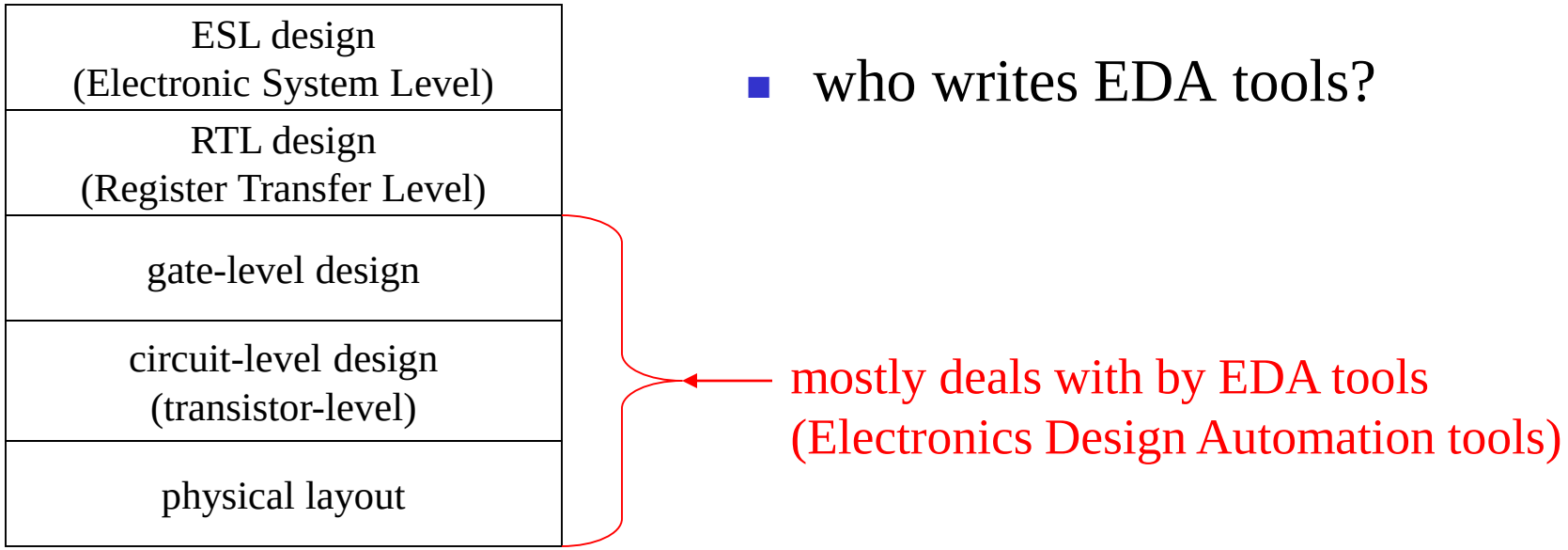
design house: 矽統, 威盛, 聯發科,...

design service: 創鈺, 智源

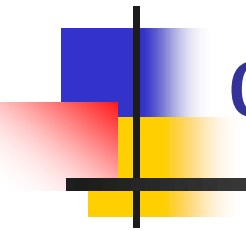
manufacture: 台積電, 聯電

# Who involves in this flow?

- software guys?
- hardware guys?
- who writes EDA tools?

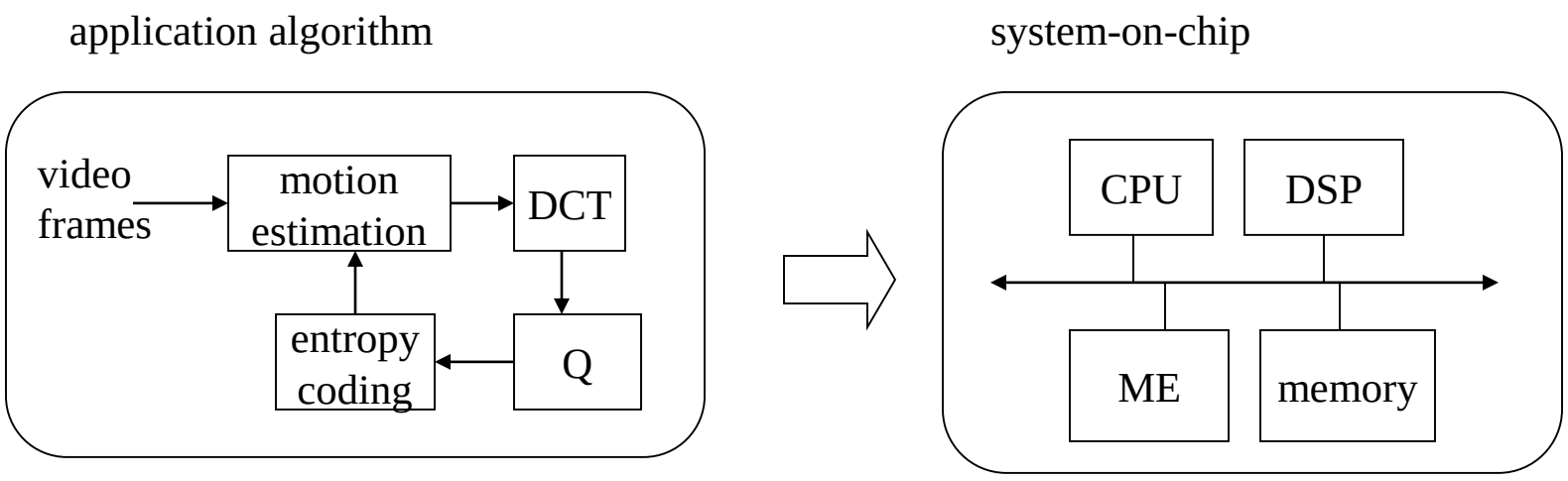


# What a CS-guy will do in IC design industry



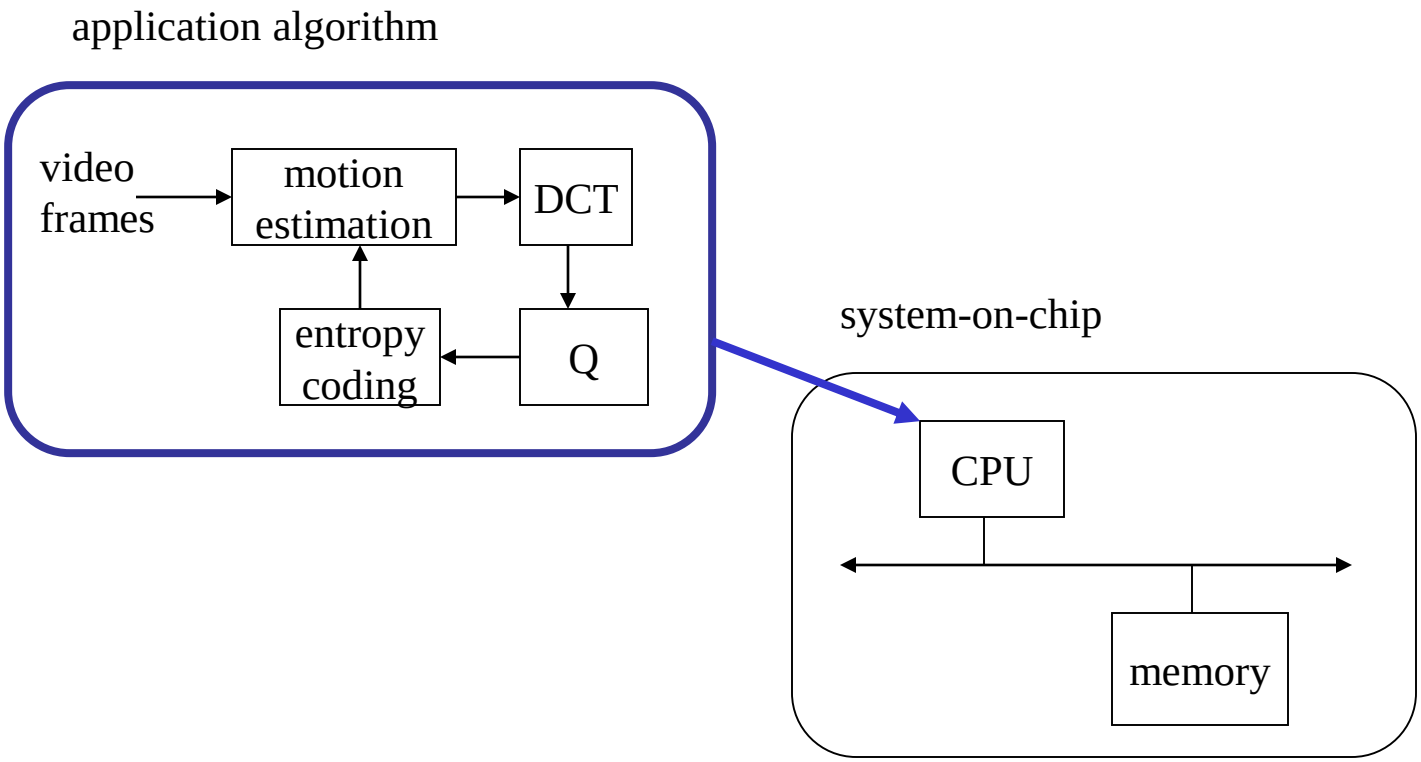
# Transform application algorithm to Silicon SoC (System-on-Chip)

- in the SoC era, you have to design both hardware and software!
- lots of SW works needs solid HW background
  - e.g. optimizing compiler design



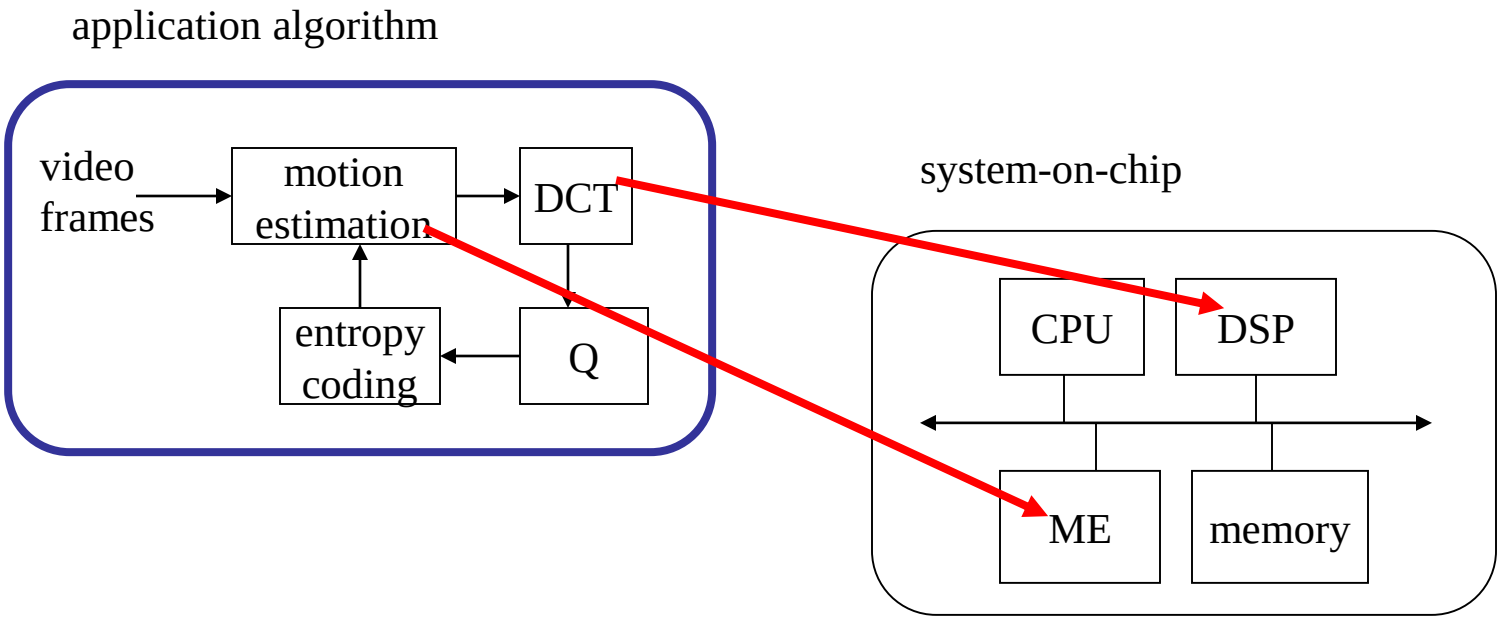
# How to make a cell-phone play video?

- Step 1: put everything on the CPU as a software program

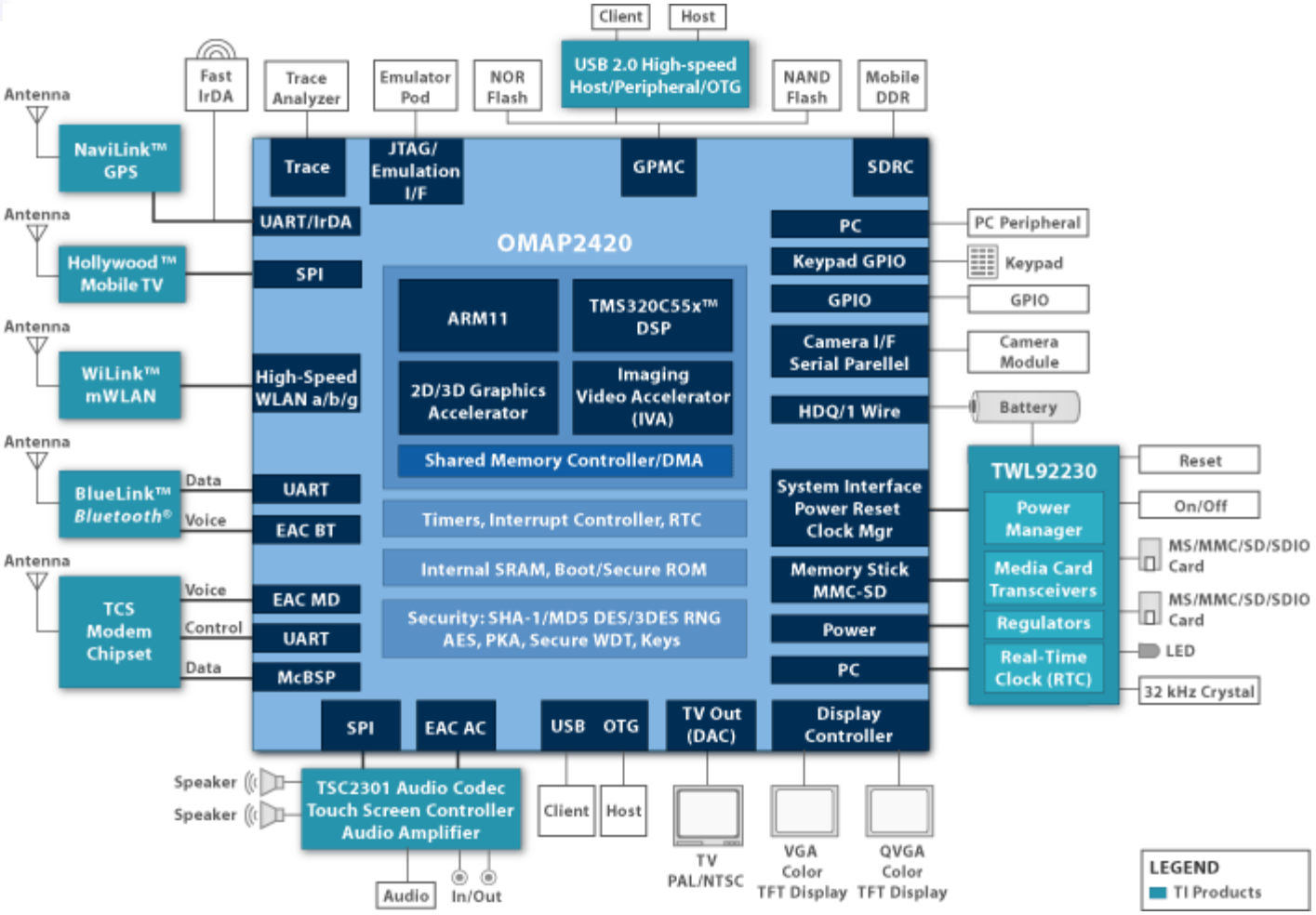


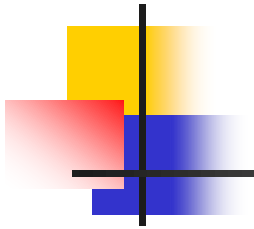
# How to make a cell-phone play video?

- Step 2: put some specific hardware and move some tasks onto these hardware
- do hardware specific program optimization



# A typical SoC for cell-phone: TI OMAP processor

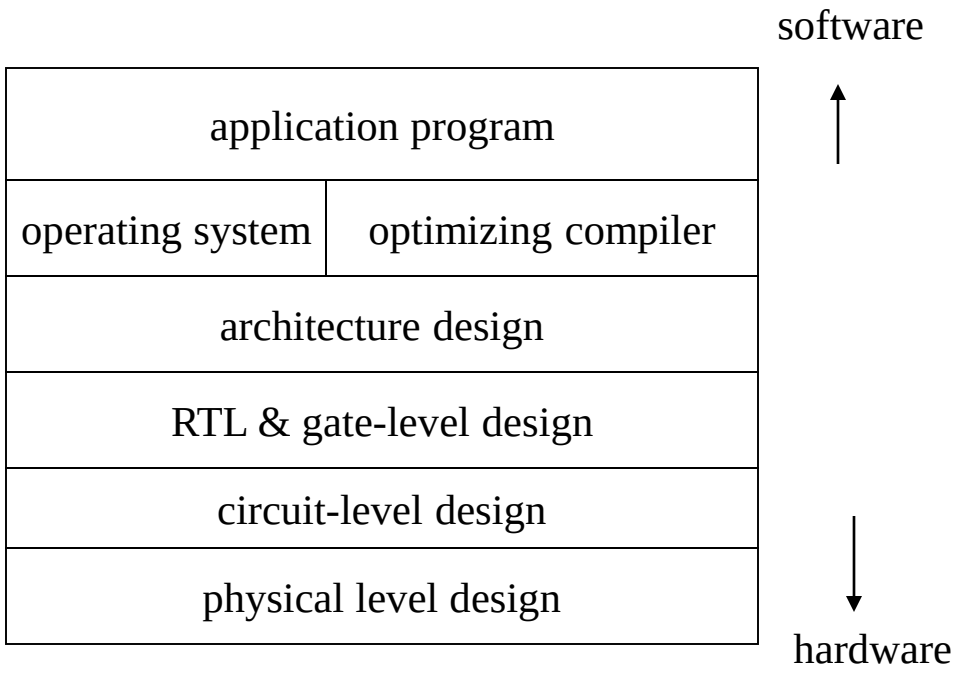




- In the SoC era, making a chip is not just hardware guys' business
- HW+SW integrated design is a must!

# What a computer architect do

- vertical integration of a computer system
- from semiconductor to application program

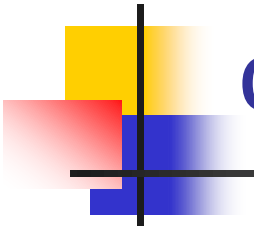


# Frequently studied problems in computer architecture

- Which part should be in hardware and which part should be in software
- How the system software optimizes the use of hardware architecture
  - optimizing compiler, operating systems

All about how to mapping application algorithms onto silicon in an efficient way

# Why you need to major in computer science



- to be with complete knowledge on both hardware and software

- to lead EE guys to build a chip!