Introduction to Computer Engineering

ECE/CS 252, Fall 2007
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Economics of the Chip Business

Key Principles

- Time value of money (ROI)
- Cost vs. price
- Product cost vs. design cost (NRE)
- Business models

Acknowledgments

- Peter Hsu, *"Understanding Costs of Chip Design and Manufacture,"* Computer Architecture Colloquium, University of Wisconsin at Madison, 2001.

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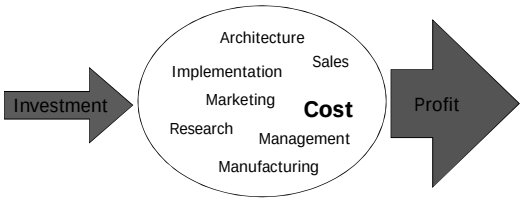
The Business of Making Chips



Time Value of Money

Money is a commodity, just like anything else

- Investors buy/sell it
- Investors have many choices

Risk vs. Reward

- Bank CD: low risk, low reward
- S&P 500: moderate risk, moderate reward
- Venture capital: high risk, high reward

Return on investment (ROI)

- Profit ÷ (amount invested) ÷ time period, e.g.

(40M$ ÷ 200M$ ÷ 4 yrs) = 5.0%

(there are more precise ways for compounding interest, e.g. daily)

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Cost vs. Price

Price – what you can charge for an item

- Set based on law of supply and demand
- Not an exact science

Cost – what you spend to design & manufacture

- Design: non-recurring engineering (NRE) Cost
  - Personnel: salary, benefits, equipment (~3x salary)
  - Prototyping
  - Main driver: design complexity
- Product cost
  - Manufacture, test, assemble, distribute
  - Main driver: chip area

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Total Product Cost

$$Cost_{unit} = \frac{NRE}{volume} + Cost_{manufacture}$$

Expected volume determines design philosophy

- Low volume (e.g. IBM): minimize ***NRE***
- High volume (e.g. Intel): minimize $Cost_{manufacture}$

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Manufacturing Cost

Functional Silicon Die

- **Die Size**
- **Process Maturity**

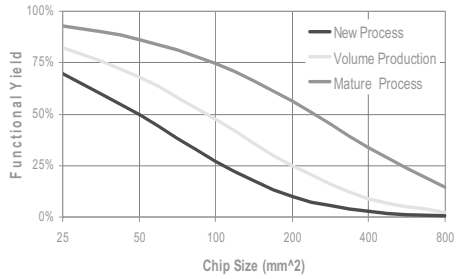
Package & Assembly

- **Substrate vs. Lead Frame**

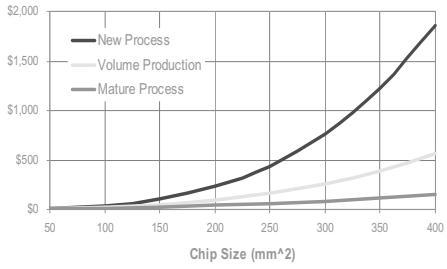
Yield

- **Functional**
- **Frequency**

Yield as Function of Die Size

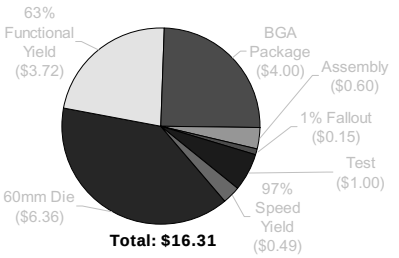


Functional Die Cost



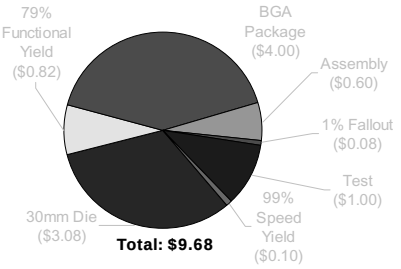
§Assumption: 200mm (8 inch) wafers at $3,000 each

Example #1: Graphics Chip



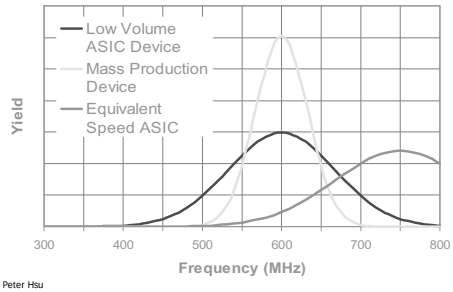
§Assumption: 200mm (8 inch) wafers at $3,000 each, defect density 0.8

Example #2: After Shrink

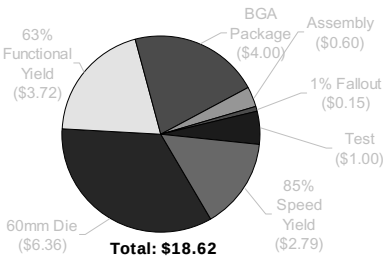


§Assumption: 200mm (8 inch) wafers at $3,000 each, defect density 0.8

Process Variation



Example #3: Speed Sorted



[§]Assumption: 200mm (8 inch) wafers at $3,000 each, defect density 0.8

Design Cost

Time

- **How Long Until Revenue**

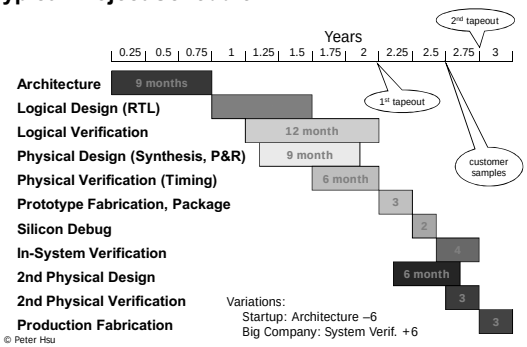
Resources

- **No. People, Expertise, CAD Tools, …**

Risk

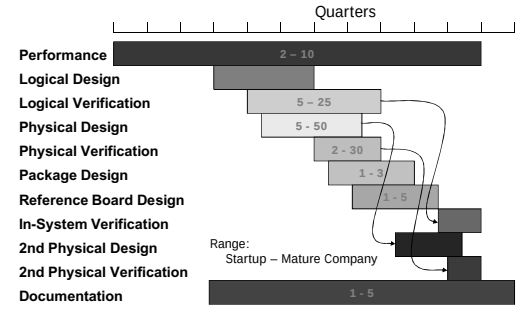
- **Schedule Slip**
- **Performance Irregularities**
- **Reliability Problems**

Typical Project Schedule



Variations:
Startup: Architecture –6
Big Company: System Verif. +6

Typical Manpower Requirements



Design Cost Summary

$333K[§] per Person Year

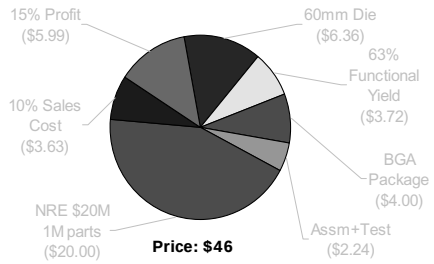
- **Low: 20p x 3y = $20M**
- **High: 150p x 3.5y = $175M**

Amortize

- **High Volume**
  - **Demand Generation**
  - **Derivative Products**
- **High-Value System Product**

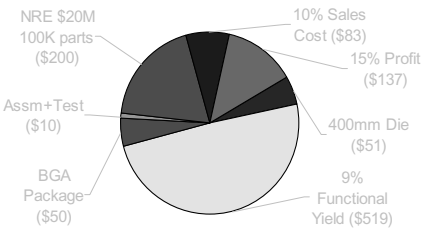
[§]Compensation $150K + 50% Benefits + 50% Equipment + 20% Facilities

Example #1: PC Graphics Chip



[§]Highest volume PC OEM product line shipped several million in year 2000

Example #2: High-End Router



Price: $1,050

[5]Chip revenue stream $100M. System revenue stream $1B?

Return On Investment (ROI)

#1: PC Graphics Chip

- **$4M Profit ÷ $20M ÷ 4yr = 5%**
  - **Do better by investing in S&P 500**

#2: High-End Router

- **$14M Profit ÷ $20M ÷ 4yr = 18%**
  - **Can afford R&D for future**

Derivative designs help

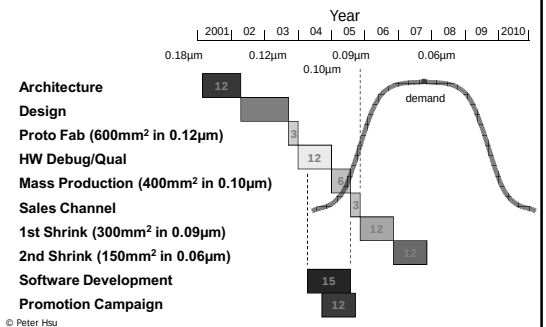
- **$16M Profit ÷ $25M ÷ 7yr = 9%**

Big Picture

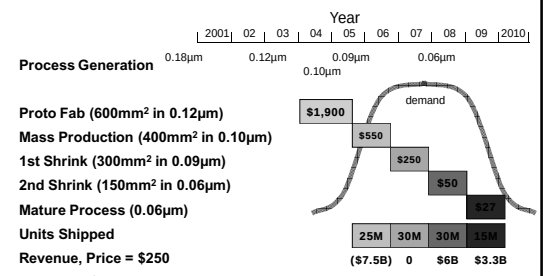
Business Models

- **Deep Pocket**
  - **Demand Generation + Forward Pricing**
  - **e.g. Nintendo, Sony Video Game Consoles**
- **System Subsidy**
  - **System Sales + Support Cost**
  - **e.g. Sun Microsystem, Hewlett-Packard Microprocessors**

Model #1: Deep Pocket



Forward Pricing



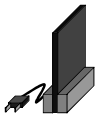
Net Gain: $1.8B

ROI: ($1.8B – $175M) ÷ $175M ÷ 9yr = 100% (– cost of $7.5B x 2yr, ...)

Model #2: System Subsidy

Example:

- **16-Processor Server**
- **Price: $7,000**
- **Cost: $6,000**
- **Volume: 50,000 units x 2 years**
- **NRE: Chip $20M + System $20M**
- **Recovery: $400 per system**
- **"Profit": $600 per system**
- **ROI: $60M ÷ $40M ÷ 5yr = 30%**



"A Better Server"

Note

System Sales + Support Cost » Chip Sales Cost

Summary

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