Economics of SOC Development
How can we make this a profitable endeavor?

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Summary

• ROI has to drive technical decisions
• Sound technology choices are major drivers for sound business endeavors
  – Program schedule – Market Window
  – Program cost
  – Platform choice
  – S/W - H/W partitioning
  – IP reuse
  – Labor partitioning
  – Wafer and Package technologies
• Technical leads are no longer just responsible for device performance
  – They have to actively collaborate in determining the optimum solution in the 4 dimensional space of Cost, Revenue, Time, and Risk.
Outline

• Why should we care?
• Analysis framework
• Risk
• Revenue & Time
• Cost
• ROI – a unifying analysis
• Examples of technology choices
• Closing remarks
Why Should We Care?

- This stuff is for the CFO and the other bean counters to worry about!

- The industry is not blindingly after performance any longer
  - The concept of “you make it, they will come” has passed its time
  - Do we really need a faster PC now?
  - Where are the OC-192 (40G) and Network Processor markets now?

- Why should we care?
  - Sound technical decisions can significantly influence the prospect of good business health for a product development endeavor.
  - We are now in a much more business rational environment
  - There are significant opportunities in the intersection of technical and business requirements

Business prosperity is a necessity for growth, innovation, creativity, personal reward, and job security.
Analysis framework

• **Product development business parameters:**
  - Cost
  - Revenue
  - Time
  - Risk

• **The above 4 factors are seemingly in different dimensions**
  - Potentially hard to trade off and seemingly difficult consider them all in one analysis

We postulate that the $ is a global and unifying parameter and the above factors can be transformed into $.

Return On Investment (ROI) analysis correlates the above 4 parameters and explores their interdependencies.
Finance 101

**Revenue (R):** Dollar amount of sales  
**Gross Margin (GM):** % of revenue not spent for cost of goods sold (COGS)  
**Operating Expenses:** R&D + SG&A expenses  
**Net Present Value (NPV):** Present value of future money  
**Discount Rate (DR):** The rate by which the future money is discounted

\[
R = (1 - GM) \times R + (\text{Operating Expenses}) + Income
\]

\[
NPV = \sum_{y=0}^{n} \frac{R_y}{(1+DR)^y}
\]

**Example #1:**  
Revenue = 100M, Operating Expenses = 60M, GM = 70%  
\[100 = (1-0.7)x(100) + 60 + Income\]  
\[\Rightarrow \text{Income} = \$10M\text{ Profit}\]

**Example #2:**  
R1 = 0, R2= $3M, R3= $5M R4 = $5M, R5 = $5M, R6 = $3M, R7 = 0  
Discount Rate = 20%  
Total Revenue = $21M, NPV = $10.4M
The cost of borrowing money for a business is directly proportional to the risk.
Revenue window and time

<table>
<thead>
<tr>
<th>NPV</th>
<th>Year 0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<tr>
<td>$10.40</td>
<td>Revenue Model #1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>0</td>
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<tr>
<td>$8.67</td>
<td>Revenue Model #2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Development R&amp;D</td>
<td>-7</td>
<td>-2</td>
<td>-1</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.1</td>
<td>-0.1</td>
</tr>
</tbody>
</table>
Revenue & Time

- **Too late to market:**
  - A smaller portion of the revenue curve is covered
  - Market assumptions are violated
    - Type of competitors change (e.g. large versus small)
    - Gross margin assumptions are violated
- **Too early to market (the market window is farther out than predicted):**
  - Revenue forecast is pushed out, hence reduction in NPV
  - Risk increases, as the level of uncertainty in market acceptance increases
  - Risk increases, as the assumptions for competitive landscape are violated
    - Competitors catch up
    - New competitors come into play
- **Added risk in supply chain**
  - Change in the forecast to the suppliers always entails added risk
- **Sensitivity Analysis**
  \[
  \frac{d(\$)}{dt} = \frac{\Delta(\$)}{\Delta t}
  \]

- Early bird may go bankrupt!
Outline

- Why should we care?
- Analysis framework
- Risk
- Revenue & Time
- Cost
  - Example: a VOP
  - Cost Breakdown
- ROI – a unifying analysis
- Examples of technology choices
- Closing remarks
Economics of large SOC Development

- **Mask Cost**
  - > $500K for 0.15um, > $750K for 0.13um, and > $1M for 0.1um
- **Long development time**
  - 9-18 months from feasibility to first sample
  - Typically, successful projects require 3 tape outs
    - 1st tape out to sample (TTM driven)
    - 2nd tape out – metal rev, minor changes
    - 3rd tape out – production
- **Design team: 50 -> 100**
  - IC design: ~20
  - System, software, architecture: ~30
  - Physical design, CAD support: ~10
  - Board, test, validation: ~10
- **Total development cost: ~$10M -> $20M**
Cost Breakdown

- IC Product Development Cost Breakdown:

  - Architectures and Partitioning
  - Software Design
  - Front End IC Design
  - Physical Design and Integration
  - Characterization and System Eval
  - EDA Licenses
  - Test Chips, Libraries, and IP
  - Engineering Computing
  - Other Infrastructure

- ~15% of total R&D Cost

- Development R&D
- Manufacturing
- Maintenance and Life Cycle Support
- Marketing, Sales, General & Admin
Cost Sharing in Development R&D - 1

- Unlike the infrastructure, cost sharing has to be by design

<table>
<thead>
<tr>
<th>% of cost</th>
<th>Opportunities</th>
<th>Example – a VOP device</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture and Partitioning</td>
<td>low</td>
<td>Mid</td>
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<tr>
<td>Front End IC Design</td>
<td>High</td>
<td>Mid</td>
</tr>
<tr>
<td>Software Design</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Physical Design and Integration</td>
<td>Mid</td>
<td>Low</td>
</tr>
<tr>
<td>Characterization and System Eval</td>
<td>Mid</td>
<td>Low</td>
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</table>

Platform, architecture, and software reuse are key to reducing the total product development cost
Cost Sharing in Development R&D - 2

- **Unification and focused investment are key factors for common infrastructure**
  
  | EDA Licenses               | Consistent and unified tools and flow |
  | Test Chips, Libraries, and IP | Limited and consistent technology nodes |
  | Engineering Computing       | High return on investment opportunity |
  | Other Infrastructure        | Systematic and predictable process |

**Investment in R&D infrastructure will significantly reduce the total development cost, if the same infrastructure is shared across many products.**
COGS & life cycle maintenance

- Cost to production and life cycle maintenance
  - Product qualification
  - S/W debug and maintenance
  - Feature add for H/W
  - Future cost reduction efforts

- Manufacturing cost (COGS) - Influencing factors:
  - Wafer Technology
  - Package Technology
  - Test
  - Logistics
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## ROI Analysis for SOC Development

<table>
<thead>
<tr>
<th></th>
<th>Year 0</th>
<th>Year 1</th>
<th>Year 2</th>
<th>Year 3</th>
<th>Year 4</th>
<th>Year 5</th>
<th>Total</th>
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<tbody>
<tr>
<td>Revenue Curve</td>
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<td>0.75</td>
<td>1</td>
<td>0.75</td>
<td>0.25</td>
<td>60</td>
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<tr>
<td>Revenue $$</td>
<td>0</td>
<td>5</td>
<td>15</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>60</td>
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<td>R&amp;D</td>
<td>8.00</td>
<td>2.00</td>
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<td>0.10</td>
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<td>COGS</td>
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<td>6.00</td>
<td>8.00</td>
<td>6.00</td>
<td>2.00</td>
<td></td>
<td>18</td>
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<tr>
<td>Cost of Sales</td>
<td>0.25</td>
<td>0.75</td>
<td>1.00</td>
<td>0.75</td>
<td>0.25</td>
<td></td>
<td>3.00</td>
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<tr>
<td>Total Cost</td>
<td>4.25</td>
<td>6.85</td>
<td>9.10</td>
<td>6.85</td>
<td>2.35</td>
<td></td>
<td>35.50</td>
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<tr>
<td>Gross Income</td>
<td>0.75</td>
<td>8.15</td>
<td>10.90</td>
<td>8.15</td>
<td>2.65</td>
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<td>18.85</td>
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<tr>
<td>Net Income</td>
<td>0.53</td>
<td>5.71</td>
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<td>1.86</td>
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<td>Present Value</td>
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<td>3.96</td>
<td>4.42</td>
<td>2.75</td>
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<td>ROI</td>
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</tr>
</tbody>
</table>
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  – Time, Cost, Risk, Revenue
• Closing remarks
Technology Decisions – Example 1

- Die cost as a function of time:
Technology Decisions – Example 2

Yield and die cost as a function of die size - 0.13um

- Yield:
  - 97%
  - 19%

- Die cost:
  - $0.47
  - $0.76/mm²
  - $195.84

- Die size (mm):
  - 2
  - 4
  - 6
  - 8
  - 10
  - 12
  - 14
  - 16

- Die Cost per unit area:
  - $0.13/mm²

- Expected Yield:
  - $0.47
  - $0.13/mm²
  - $195.84

Legend:
- Pink line: Die cost
- Green line: Die Cost per unit area
- Blue line: Expected Yield
Technology Decisions – Example 3

A 0.18um die shrink to 0.15um and 0.13um

- 0.18um => 14x14
- 0.15um = 11.7x11.7
- 0.13um = 10x10

Graph showing costs from Q1/03 to Q4/04 for different technologies.
Top 10 Engineering Control Parameters

6- Design efficiency
   – Reusable flow

7- Off-shore outsourcing
   – Foster and develop an efficient non-homogeneous environment

8- Schedule and cost predictability
   – Realistic “time to sample”, and “time to production”
   – Comprehensive product development cost analysis
     • Under estimation may win the battle, but lose the war

9- Thorough analysis for wafer and package technology selection

10- Upfront consideration of device yield and technology qualification
   – The impact of choosing non qualified technologies is much more than the cost of qualification. They can potentially impact time to revenue.
   – DFM aware cell libraries and routing
   – Yield loss is no longer only defect based, but also geometry based
Top 10 Engineering Control Parameters

2- Software reuse
   – Structural documentation, flow diagram, and dependency management
   – S/W profiling, verification, and test benches
   – Tools for generating customer collaterals

3- Platform reuse
   – In most cases, ROI requirements can only be satisfied through a family of products, with significant development cost sharing

4- IP Reuse
   – Build strong relationship with select IP providers to augment the core competency

5- Interlinked technology and business decision process
   – e.g. reduced power in the IC core can lead to cheaper package cost
Top 10 Engineering Control Parameters

1- If you are a California resident, vote for Arnold!

“We will be safe from aliens while he is in office” – Michael Chian
Final Remarks

- The foundation of innovation, creativity, and personal reward is business prosperity.

- We can significantly impact the business prosperity of our institution
  - Not just by advancing the state of the art
  - .... And pushing the performance limits
  - .... But also by finding more economical solutions

- Performance sells to early adopters. Economical solutions sell to the mass.

Business consideration in all technical decisions