Data Mining and Optimization
Dec 3rd 2013

Michael Campbell – QUALCOMM INC Technologies, Inc,
Agenda:

QUALCOMM INC – Manufacturing Solutions
Data Mining
Quality
## QUALCOMM INC: An Overview

2013 Top 20 Semiconductor Revenue Ranking – 30% increase YoY

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>Headquarters</th>
<th>2012 Tot Semi</th>
<th>1Q13 Tot Semi</th>
<th>2Q13 Tot Semi</th>
<th>3Q13 Tot Semi</th>
<th>4Q13F Tot Semi</th>
<th>2013F Tot Semi</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intel</td>
<td>U.S.</td>
<td>49,114</td>
<td>11,555</td>
<td>11,785</td>
<td>12,366</td>
<td>12,615</td>
<td>48,321</td>
<td>-2%</td>
</tr>
<tr>
<td>2</td>
<td>Samsung</td>
<td>South Korea</td>
<td>32,251</td>
<td>7,946</td>
<td>7,769</td>
<td>8,805</td>
<td>9,070</td>
<td>33,590</td>
<td>4%</td>
</tr>
<tr>
<td>3</td>
<td>TSMC*</td>
<td>Taiwan</td>
<td>16,951</td>
<td>4,460</td>
<td>5,152</td>
<td>5,377</td>
<td>4,815</td>
<td>19,804</td>
<td>17%</td>
</tr>
<tr>
<td>4</td>
<td>Qualcomm**</td>
<td>U.S.</td>
<td>13,177</td>
<td>3,916</td>
<td>4,222</td>
<td>4,457</td>
<td>4,550</td>
<td>17,145</td>
<td>30%</td>
</tr>
<tr>
<td>5</td>
<td>SK Hynix</td>
<td>South Korea</td>
<td>9,057</td>
<td>2,577</td>
<td>3,521</td>
<td>3,692</td>
<td>3,250</td>
<td>13,040</td>
<td>44%</td>
</tr>
<tr>
<td>6</td>
<td>Toshiba</td>
<td>Japan</td>
<td>11,217</td>
<td>2,938</td>
<td>2,868</td>
<td>3,356</td>
<td>3,035</td>
<td>12,197</td>
<td>9%</td>
</tr>
<tr>
<td>7</td>
<td>TI</td>
<td>U.S.</td>
<td>12,081</td>
<td>2,718</td>
<td>2,872</td>
<td>3,064</td>
<td>2,820</td>
<td>11,474</td>
<td>-5%</td>
</tr>
<tr>
<td>8</td>
<td>Micron</td>
<td>U.S.</td>
<td>8,002</td>
<td>2,158</td>
<td>2,493</td>
<td>2,900</td>
<td>3,000</td>
<td>10,551</td>
<td>32%</td>
</tr>
<tr>
<td>9</td>
<td>ST</td>
<td>Europe</td>
<td>8,364</td>
<td>1,994</td>
<td>2,033</td>
<td>2,077</td>
<td>2,080</td>
<td>8,184</td>
<td>-2%</td>
</tr>
<tr>
<td>10</td>
<td>Broadcom**</td>
<td>U.S.</td>
<td>7,793</td>
<td>1,954</td>
<td>2,035</td>
<td>2,146</td>
<td>1,975</td>
<td>8,110</td>
<td>4%</td>
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<tr>
<td>11</td>
<td>Renesas</td>
<td>Japan</td>
<td>9,314</td>
<td>1,886</td>
<td>1,920</td>
<td>2,101</td>
<td>1,920</td>
<td>7,827</td>
<td>-16%</td>
</tr>
<tr>
<td>12</td>
<td>Infineon</td>
<td>Europe</td>
<td>4,928</td>
<td>1,208</td>
<td>1,327</td>
<td>1,390</td>
<td>1,340</td>
<td>5,265</td>
<td>7%</td>
</tr>
<tr>
<td>13</td>
<td>AMD**</td>
<td>U.S.</td>
<td>5,422</td>
<td>1,088</td>
<td>1,161</td>
<td>1,461</td>
<td>1,534</td>
<td>5,244</td>
<td>-3%</td>
</tr>
<tr>
<td>14</td>
<td>Sony</td>
<td>Japan</td>
<td>5,709</td>
<td>1,247</td>
<td>1,144</td>
<td>1,203</td>
<td>1,295</td>
<td>4,889</td>
<td>-14%</td>
</tr>
<tr>
<td>15</td>
<td>NXP</td>
<td>Europe</td>
<td>4,325</td>
<td>1,085</td>
<td>1,188</td>
<td>1,249</td>
<td>1,265</td>
<td>4,787</td>
<td>11%</td>
</tr>
<tr>
<td>16</td>
<td>MediaTek**</td>
<td>Taiwan</td>
<td>3,366</td>
<td>817</td>
<td>1,115</td>
<td>1,308</td>
<td>1,275</td>
<td>4,515</td>
<td>34%</td>
</tr>
<tr>
<td>17</td>
<td>GlobalFoundries*</td>
<td>U.S.</td>
<td>4,013</td>
<td>946</td>
<td>1,020</td>
<td>1,125</td>
<td>1,170</td>
<td>4,261</td>
<td>6%</td>
</tr>
<tr>
<td>18</td>
<td>Freescale</td>
<td>U.S.</td>
<td>3,803</td>
<td>925</td>
<td>987</td>
<td>1,030</td>
<td>1,000</td>
<td>3,942</td>
<td>4%</td>
</tr>
<tr>
<td>19</td>
<td>UMC*</td>
<td>Taiwan</td>
<td>3,730</td>
<td>898</td>
<td>1,016</td>
<td>1,060</td>
<td>945</td>
<td>3,919</td>
<td>5%</td>
</tr>
<tr>
<td>20</td>
<td>Nvidia**</td>
<td>U.S.</td>
<td>3,965</td>
<td>939</td>
<td>903</td>
<td>1,005</td>
<td>905</td>
<td>3,752</td>
<td>-5%</td>
</tr>
</tbody>
</table>

**Foundry**

**Fabless**

Source: IC Insights’ Strategic Reviews Database

Nov 6, 2013

Note: QUALCOMM INC 2012 Ranking was: #4 with % revenue change of 27%
### IC Insight, 2012 MPU Ranking: Combined: Server + Desktop + Mobile Aps Processors

#### Leading MPU Suppliers ($M)

<table>
<thead>
<tr>
<th>Rank</th>
<th>Company</th>
<th>2011</th>
<th>2012</th>
<th>Percent Change</th>
<th>Percent Marketshare</th>
<th>Main Product Lines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intel</td>
<td>37,435</td>
<td>36,892</td>
<td>-1%</td>
<td>65.3%</td>
<td>x86 PC, server MPUs</td>
</tr>
<tr>
<td>2</td>
<td>Qualcomm</td>
<td>4,152</td>
<td>5,322</td>
<td>28%</td>
<td>9.4%</td>
<td>ARM mobile app processors</td>
</tr>
<tr>
<td>3</td>
<td>Samsung (+Apple)*</td>
<td>2,614</td>
<td>4,664</td>
<td>78%</td>
<td>8.2%</td>
<td>ARM mobile app processors</td>
</tr>
<tr>
<td>4</td>
<td>AMD</td>
<td>4,552</td>
<td>3,605</td>
<td>-21%</td>
<td>6.4%</td>
<td>x86 PC, server MPUs</td>
</tr>
<tr>
<td>5</td>
<td>Freescale</td>
<td>1,210</td>
<td>1,070</td>
<td>-12%</td>
<td>1.9%</td>
<td>ARM and embedded MPUs</td>
</tr>
<tr>
<td>6</td>
<td>Nvidia</td>
<td>591</td>
<td>764</td>
<td>29%</td>
<td>1.4%</td>
<td>ARM mobile app processors</td>
</tr>
<tr>
<td>7</td>
<td>TI</td>
<td>510</td>
<td>565</td>
<td>11%</td>
<td>1.0%</td>
<td>ARM mobile app processors</td>
</tr>
<tr>
<td>8</td>
<td>ST-Ericsson**</td>
<td>660</td>
<td>540</td>
<td>-18%</td>
<td>1.0%</td>
<td>ARM mobile app processors</td>
</tr>
<tr>
<td>9</td>
<td>Broadcom</td>
<td>295</td>
<td>345</td>
<td>17%</td>
<td>0.6%</td>
<td>ARM mobile app processors</td>
</tr>
<tr>
<td>10</td>
<td>MediaTek</td>
<td>280</td>
<td>325</td>
<td>16%</td>
<td>0.6%</td>
<td>ARM mobile app processors</td>
</tr>
</tbody>
</table>

*Includes Apple’s custom processors made by Samsung’s foundry business.

**Cellphone IC joint venture to be dissolved by STMicroelectronics and Ericsson by 3Q13.

Source: IC Insights
QUALCOMM INC: Overview

ASIC Market Penetration

QUALCOMM INC IN CT's ASIC Product Offerings:

- QFE: RF360 Products
- WTR/WGR/WFR: RF Products
- PM/SMB: PMIC. SMB products from Summit acquisition
- WCD: CODEC
- WCN: Connectivity( Now part of QUALCOMM INC INCA product line)
- APQ: Application Processors
- MSM: Integrated Application Processor + Modem
- MPQ: Multi-Media. Smart TV. New Market.
### Snapdragon Processors + Modem Leadership

#### Segmentated Product Offering

<table>
<thead>
<tr>
<th>Processor Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snapdragon 800 Processors</td>
<td>Snapdragon 800 Processors are designed to deliver blazing fast apps and web browsing, visually stunning graphics, breakthrough multimedia capabilities, seamless communications virtually anytime, anywhere and outstanding battery life for premium smartphones, Smart TVs, digital media adapters and tablets.</td>
</tr>
<tr>
<td>Snapdragon 600 Processors</td>
<td>Snapdragon 600 Processors are designed to deliver outstanding performance for today’s complex apps, fast web browsing, seamless connectivity and great battery life for mid-range tier smartphones and tablets.</td>
</tr>
<tr>
<td>Snapdragon 400 Processors</td>
<td>Snapdragon 400 Processors are designed to deliver the performance, features, connectivity and battery life that consumers expect in high-volume smartphones and tablets.</td>
</tr>
<tr>
<td>Snapdragon 200 Processors</td>
<td>Snapdragon 200 Processors are designed to deliver a valued balance of performance, robust connectivity and better battery life for entry-level smartphones.</td>
</tr>
</tbody>
</table>

#### MSM Shipments*

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>Linley Group – ‘Snapdragon: Best Mobile Processor of 2012’ (MSM8960)</td>
</tr>
<tr>
<td>Nov 20, 2013</td>
<td>QUALCOMM INC announces next generation processor in the S800 Family. Snapdragon 805 offering 4k video, imaging, and graphics for mobile.</td>
</tr>
<tr>
<td>Nov 20, 2013</td>
<td>QUALCOMM INC announces 4th Generation LTE Solution Gobi 9x35 (20nm/ FDD Cat 6 ~ 300 Mbps download ) and RF transceiver WTR3925 (28nm).</td>
</tr>
</tbody>
</table>
Grew our #1 position in smartphones

Smartphone application processor unit shipments

Source: Strategy Analytics. Oct, 2013. *P* means provisional (aka 'preliminary') and will likely be updated; Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc.
QUALCOMM INC: ‘1000X Bandwidth’ – Enabling the Internet of Everything

July 2013 QUALCOMM INC announced plans to partner with Alcatel-Lucent to develop Alcatel-Lucent lightRadio™ small cell products featuring QUALCOMM INC Technologies FSM9000 family of Smart Cell chipsets.
QUALCOMM INC:
The ‘Internet of Everything’

Extending technology into adjacent device opportunities

Key Examples

Connected home
Transforming the home experience

Game consoles
Smartphones
Tablets
TVs

Home Gateway
Connectivity (802.11ac and low power Wi-Fi)
Internet processor
Small cells

Expanding into automotive and energy
3G/4G connectivity

Security
Appliances
Temperature
Lighting

35+
Programs from 13 OEMs in production

41%
CAGR estimated smart meter shipments between 2011-2016
Control loops and Data tracking for: Yield, Cost, and Quality

Control and Feedback Loops

Returned Material - Corrective Actions and Analysis

Test Data into Tracking Database

Design / Publication / Enforcement of Test Rules to Identify/Kill Die with Quality issues.

Test History/Device Genealogy

Outgoing device
**Data Mining for Knowledge and Value**

**Data Mining is critical to high volume manufacturing solutions.**

- We have all done it for years. Spread sheets, visual comparison of data and gut feelings:
- QUALCOMM INC has been an early adopter of OT technology and other solutions designed to drive data mining.
- QUALCOMM INC has taken advantage of engineering & operational benefits of OT SW.

![A “Big Picture” View with Real-time Status of your Operations and Better Collaboration](image)

- Improved operations across factories
- Real-time status of your testing fleet
- Get the “bigger picture”
- Improved operational efficiency and management

- Driving improved data analysis for yield, quality and process optimization
- We continue to closely collaborate / drive next generation solutions with OT
Customers are demanding more and so do we:

- Faster Development Times
- Fast Product Ramps
- High Volumes with Assurance of Supply
- High Quality HWA & SW
- A Continuous Improvement Quality Program
- Cost Competitive - Chipset with cutting edge IP, Advanced Si & Packaging Technology,
Who is using OT today?

- Product and Test Engineers
- Yield Engineers
- Operations (worldwide)
- Planning
- Management
Why use data mining tools?

ISSUES:

- Product ramp rate accelerating
- Product cost in ramp
- Product Quality in ramp/production
- Product complexity
- Process complexity
- Multiple SATs
- Multiple Fibs per product
- Multiple Foundries per product

Use cases / improvement opportunities:

- Improve quality and efficiency of engineering decision making.
- Facilitate control on cost and quality
Data Mining

Key OT Features Important to Advanced Process Nodes and Increasing Product Complexity

I. Data Enablement.
   o Enabling OT’s PCM data stream – reduces analysis cycle time
   o Enables Engineering improves process control loops
     ▪ Feed forward data analysis
     ▪ On the fly test modification
     ▪ Statistical bin limits
     ▪ Cross data type quality analysis of data

II. Optimal Test Outlier Detection
   ▪ Key Element to Continuous Quality Improvement.

a) SW features: ‘passing’ devices can discarded because of Quality Risk.
   o DAT – Dynamic Part Average Testing
   o GOAT – Geographic Part Average Testing & Good Die in Bad Neighborhood
   o NIR – Nearest neighbor analysis (per test)
Data Mining

Key OT Features Important to Process Control and Increasing Product Complexity

III. Optimal Test’s Escape Prevention Solution
   - **Feed forward / Feed back** links to multiple sources of data to optimize and enable semi-automated manufacturing controls.
   - **Dozens of unique algorithms** which were developed by analyzing many escapes and thorough RMA analysis. Many benefits to ALP products.
   - **RMA database**: tracking/managing material with potential quality risk.
   - **Cross Operational Bin Swapping @ WES.**
     
     PCM data is used as another factor to determine if a passing die should passes die should be discarded because it is a quality or manufacturing risk.
   - **OT-Detect**: an excursion prevention system that automatically tracks after ALL your products for ANY changes in BASELINE production (HOB, SB, Paramus)

IV. Optimal Test link to JUMP Data Analysis Package – Data Mining / Presentation Enablement
Data Mining

Simple Case Study

- Observation: 10 RMA from 10 different wafer lots.
- 1st Order Results: 4 out of 10 RMA were detected first try using Nearest Neighbor Algorithm

Observations/ Conclusions: Nearest neighbor algorithm provides value add analysis out of the box and with cleaner data, additional signals and can Address ‘overkill’/ under kill issue.

= OT detected die with potential quality problem

RMA
Key Take-Away: Decision Impacting Data Is Important for Success
Driving Quality of results

- Cost
- Product Quality
- Customer satisfaction
Constant Improvement and Quality

Constant improvement and Quality Starts with design and encompasses all in line processing data and Test data where separation between good, bad and marginal devices can be defined

- One goal is to identify Die with Potential issues and route them to different test ‘routes’
Quality

OT has a Tool that Aggregates Data and Enables Engineering Rules to Identify Die that Pose a potential Quality Risk.

Indicates: INPUT - OT Rules provided for Test Session
OUTPUT – Yield, Parametric, and Meta-Data of Test Session into DB
**Quality Vision**

**Complete System - Key Features:**
- Information from previous process steps used to identify die with potential quality risk.
- Potential Special flow to process die with quality risk.
- Rules developed in OT allow separation of die that may poses a Quality Risk.
- GOAL: A database including all Triage data from systems failures, WES, FT, & SLT/RMA database for engineering to refine OT Test Rules.

Triage Data for CA and Continuous improvement.
Next Steps

- **BIG DATA Challenges** – dealing with large, complex data sets.
  
  Accessing and Manipulating/Analyzing data.
  
  - Traditional Data sources (PCM, WES, FT, SLT)
  - New Data Sources: (Assembly Data, RMA data, Chip Meta Data..>)
  - Multi-Chip Products – Device genealogy adding to analysis complexity.

Translating Analysis into Action

- **Timely Data Distribution to support ‘Real Time Feed Forward’ Process Loops.**

- **A Software Solution** that enables
  
  - Data Mining & the Development of Complex Algorithms by Focused Development team.
  - Publication of generic algorithms for consumption & customization by product teams.
Key Take-Away:
Data mining for Knowledge is Important for success

BECAUSE ..... 

• Process and product complexity are exploding fueled by the desire for advanced mobile solutions
• Advanced products use cutting edge processes (Egg: 20nm ,16nm or 14nm) drives:
  • Early yield learning with rapidly increasing volumes
  • Rapid time to market drives the need for
    • Rapid, comprehensive data analysis of product capabilities
  • Continuously New/ Improved IP (driving product complexity and yield learning challenges)
• 2\textsuperscript{nd} Source: New Foundries
• Product Tiering or Customer special requirements.
• New Packaging Technology
• And Quality Requirements don’t get easier
Quality Vision
Quality Vision Statement

**Optimal Test System**

**Input:** Test Data  
**Output:** Test Rules  
*(TTR & Quality)*

**COMPLETE SYSTEM - Key Features:**

- Information from previous process steps used to identify die with potential quality risk.
- Special flow to process die with quality risk.
- Rules based decision making for yield / test time and OT rules segregate die that poses a Quality Risk

Failure Triage

- Drives Test program updates
- Highlights potential process sensitivities
- Positional dependencies
QUESTIONS?

Thank you

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