The Role of Test Data Analysis in Taking MEMS from Initial Characterization to Volume Production

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Agenda

- Introduction
- Case studies for test data analysis in the MEMS lifecycle
  - Characterization: Mcube
  - Production yield management: SiTime
  - DPM reduction: Analog Devices
MEMS Challenges

High volume

Motion sensors for mobile devices

Air bag sensors

Blood pressure sensors

Rapid volume ramp with high quality

High reliability
Test Data Analysis is Key to Successful Ramp

- Device characterization
- Test program qualification
- Subcon acceptance testing
- Yield/volume ramp acceleration
- Production yield management
- DPM reduction/outlier removal
Case Study #1: mCube

- Company/product status:
  - Transitioning into production

- Products:
  - MEMS-based single-chip motion sensors

- Target applications:
  - Mobile gaming, image stabilization, navigation

- Data analysis challenge:
  - Device characterization and test limit setting
  - Create infrastructure for fast volume ramp
mCube Data Analysis Strategy

- Conventional strategy (rejected by mCube):
  - Use Excel for ad-hoc device characterization
  - Once production ramps - move to database oriented yield management system
    - Must bring up system under escalating production pressure
  - Bang on subcons to give you the data/formats you need

- mCube strategy:
  - Install a yield management system well in advance of production
  - Add part IDs for full traceability
  - Bang on subcons early to give you the right data in the right format
  - Use system initially as a central test data repository for all characterization activities
  - Then use same system to manage all production test data and support yield optimization
Yield Management System Architecture

Test House#1  
Test House#2  
Test House#N

Automated FTP Transfer

Automated Data Insertion

Automated Yield & SPC Alarms

Management reports

Detailed reports

Interactive analysis

RDB Query Interface

Test Data Repository (RDB)

MySQL

Automated Report Generation

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Impact at mCube

- Enabled early analysis of sample wafer and lot data
  - Compared trends across wafers over time
  - Analyzed impact of product revisions
  - Identified key parameters that were critical to performance and yield
    - e.g. calculation of spring constants based on multiple parametric tests

- Helped coordinate and correlate data from multiple subcons

- Enabled seamless transition from characterization to volume production
Case Study #2: SiTime

- **Company/product status:**
  - Volume production

- **Products:**
  - MEMS-based resonators, oscillators, clock generators (efficient alternative to quartz)

- **Target applications:**
  - Networking, computing, consumer, industrial

- **Data analysis challenge:**
  - Automate yield management, accounting correctly for test and re-test data
How SiTime Uses Automated Test Data Management for Yield Monitoring

- Data is automatically inserted for all SiTime products:
  - Currently 14 product families, with over 25,000 programmable part numbers.
  - Data is from in-house production and from global subcons.
  - Includes Final Test, WAT, PCM, and Wafersort data
- Automated yield reports generated on a weekly basis
- Major hurdle was calculation of consolidated yield data with multiple retests
Calculating Consolidated Final Test Yields

CASE 1: Basic test flow with no retest

- 1 File = Easy!

1st pass file, “P1”
(single file per test lot)
Calculating Consolidated Final Test Yields

CASE 2: Add MULTIPLE files & MULTIPLE retests to a basic test flow

- Many files (Multiple first pass, multiple retest)
- Consolidated Yield = \( \frac{P_1 - P_n \text{ good} + R_1 - R_n \text{ good} + RR_1 - RR_n \text{ good}}{\text{Total Parts}} \)
Challenges for Accurate Calculation of Consolidated Final Test Yields

- Each lot is different
  - Multiple files possible for each step (1st pass, retests)
  - Number of retests vary from lot-to-lot

- Lot quantity inconsistencies:
  - Lost parts (Less parts retested than originally failed)
  - “Created” parts (More parts retested than originally failed)

- Manual calculation is possible but not efficient:
  - Many places for calculation errors
  - Templates can make it a little easier but too many variables
  - Extremely time consuming
The Solution

- Establish consistent naming convention for final test and retest lots
  - $P_1 - P_n = 1^{st}$ pass files
  - $R_1 - R_n = 1^{st}$ retest files
  - $RR_1 - RR_n = 2^{nd}$ retest files

- Set up software to automatically recognize which retest scenario is present

- Automate the computation of consolidated yield based on the appropriate formula
  - e.g. $(P_1-P_n \text{ good} + R_1-R_n \text{ good} + RR_1-RR_n \text{ good}) / \text{Total Parts}$
Example Consolidated Yield Graph – Weekly report
Example of Consolidated Parametric Test Graphs & Statistics
Impact of Automated Yield Management at SiTime

- Allows their engineers to spend time solving problems instead of...
  - Manually collecting and storing data
  - Filling out spreadsheets for yield graphs
  - Manually creating consolidated reports for each lot
  - Manually importing and filtering files for consolidated stats, histos, and paretos

- Accurate data analysis capabilities has been key to
  - Improving process & throughput
  - Reducing production costs!
Case Study #3: Analog Devices

- Company/product status:
  - High volume production

- Products:
  - MEMS-based collision sensors

- Target applications:
  - Automotive air bags

- Data analysis challenge:
  - Implement DPM reduction techniques dictated by automotive customers without sacrificing too much yield

- Test strategy:
  - Implement Part Average Testing (PAT) and Geographical outlier removal at wafer sort
PAT Concepts

- Shifts test limits on certain parametric tests based on lot and/or historical distribution
- Removes outliers which are more likely to experience premature failures
- Recommended by AEC
  - Static PAT (SPAT)
  - Dynamic PAT (DPAT)
- Also defined by JEDEC
  - JESD50B: Static\Dynamic OIMS
Example of Geographic Outliers

- Good die in a bad neighborhood
PAT for Wafer Sort

**PAT server**
- Standard test file readers
- Rules engine
- PAT binning assignments
- Report generator
- PAT alarm notification

Raw test datalogs
(STDF, ATDF, GDF,...)

To MES
Triggers

To Assembly

Datalogs with PAT binning

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PAT Background at ADI

- Automated Part Average Test solutions were released into Analog Devices wafer sort areas (Probe) in 2005
- Initially implemented to satisfy Automotive Market sector requirements
- Have extended use of PAT into specific Consumer products
- Discovered hidden value of PAT to aid continuous improvement activities in Probe
ADI PAT Process: Production Operation

- **Wafer Sort (Probe)**
- **Automated PAT Post-processing**
- **PAT Yield Analysis**

**Sort**

DataLogs and Wafermaps are Generated

**Production is Run**

- DataLogs
- Wafermaps

**Post-Sort, the Datalogs are Processed in PAT engine, and Wafermaps and Reports are Generated**

**PAT Yield Analysis**

Yield Engineering Review PAT yield losses and categorize loss. Data is fed back to the relevant groups for analysis

Fab Eng
Sort Eng
Product Eng

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PAT Yield Loss is Characterized and Used to Improve Process

- Systematic defects occur as a result of variation or instability in the Wafer/Probe process
- Addressing these variations helps improve yield
Lessons Learned at ADI

- PAT can lead to both lower DPM and improved yield
- PAT loss review is integral to the Continuous Improvement and Quality process
- Minimizing variation decreases PAT loss and improves processes for all material
Summary of Key Lessons Learned

- **mCube:**
  - Early deployment of automated test data management is key to rapid production ramp

- **SiTime:**
  - Automated yield management with retest consolidation saves a huge amount of time and lets engineers focus on real problem-solving

- **ADI:**
  - PAT outlier removal and analysis reduces DPM and actually helps improve yield

- **Galaxy:**
  - We are excited to be part of the MEMS community and are here to answer your questions about data analysis