Assessment of Accelerometer versus LASER for Board Level Vibration Measurements

Varun Thukral

Senior Board Level Reliability Engineer

NXP, Nijmegen, The Netherlands

ECTC 2019
The 2019 IEEE 69th Electronic Components and Technology Conference

IEEE 69th ECTC – Las Vegas, NV, USA

May 28 – 31, 2019

NXP Overview

#1 Automotive

#1 Broad-based MCUs[1]

#1 Secure Identification

#1 Communications Processors

#1 RF Power Transistors

NXP

SECURE CONNECTIONS FOR A SMARTER WORLD

- ✓ **5TH largest** semiconductor company[2]
- ✓ **31,000** employees
- ✓ **10,300** engineers
- ✓ **9,000** patent families[3]
- ✓ **60+** year history
- ✓ **$9.3B** annual revenue[4]

Sources: HIS, ABI Research, Strategy Analytics, The Linley Group

(1) MCU market excluding Automotive

(2) Excludes memory

(3) May be adjusted if and when patents are assigned to Nexperia

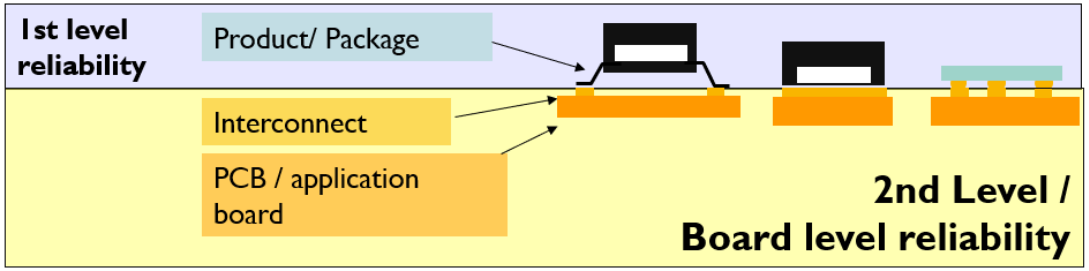
(4) NXP posted revenue of $9.5 Billion (USD) in 2017 after Nexperia divestiture

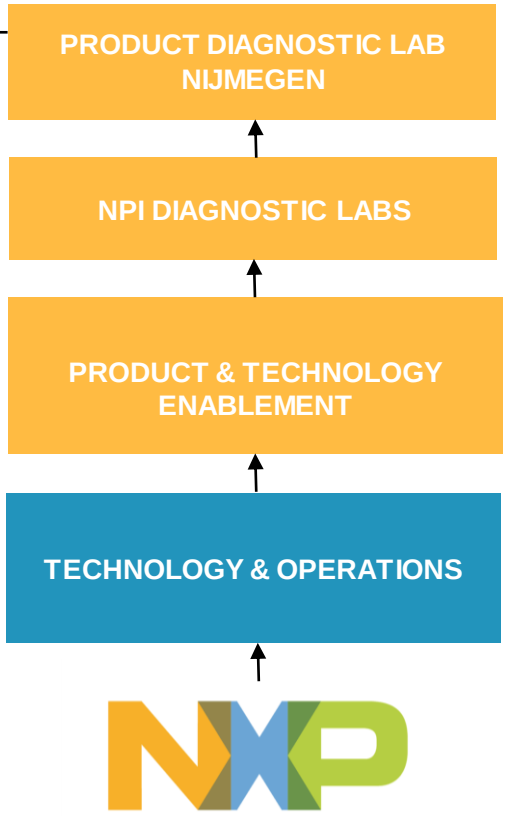
Personal Introduction

VARUN THUKRAL
Senior Reliability Engineer at NXP Semiconductors
Nijmegen, Gelderland Province, Netherlands · 500+ connections

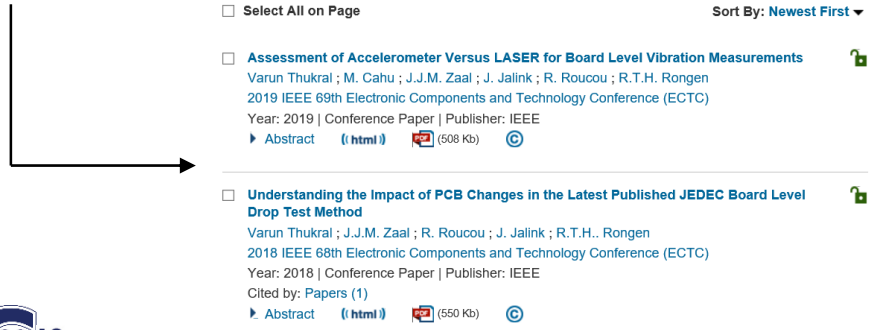
NXP Semiconductors
Technische Universität Chemnitz

- Senior Board Level Reliability Engineer
  - Joined NXP in 2015 as Reliability Engineer





- Reliability Risk Assessments
- Research interests: Highly Accelerated reliability testing such as Drop, shock, Vibration, temperature cycling, bend, etc.

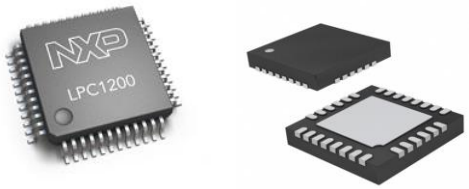


Agenda

- Industry Trend & Motivation
- Experimental and Numerical details
- Vibration measurement results and comparison
- Conclusions

Industry Trend & Motivation

- Miniaturization trend leads to smaller solder interconnections



- Risks related to vibration needs to be accessed for automotive and non-automotive (e.g. Handheld) components

- Board Level Vibration test is performed to assess solder joint lifetime under differential board strain load in an accelerated test environment

- Test board (PCB) vibration response is key in evaluating the solder joint reliability performance

- A well characterized vibration test set up is required to determine the precise reliability performance of solder joints

Industry Trend & Motivation

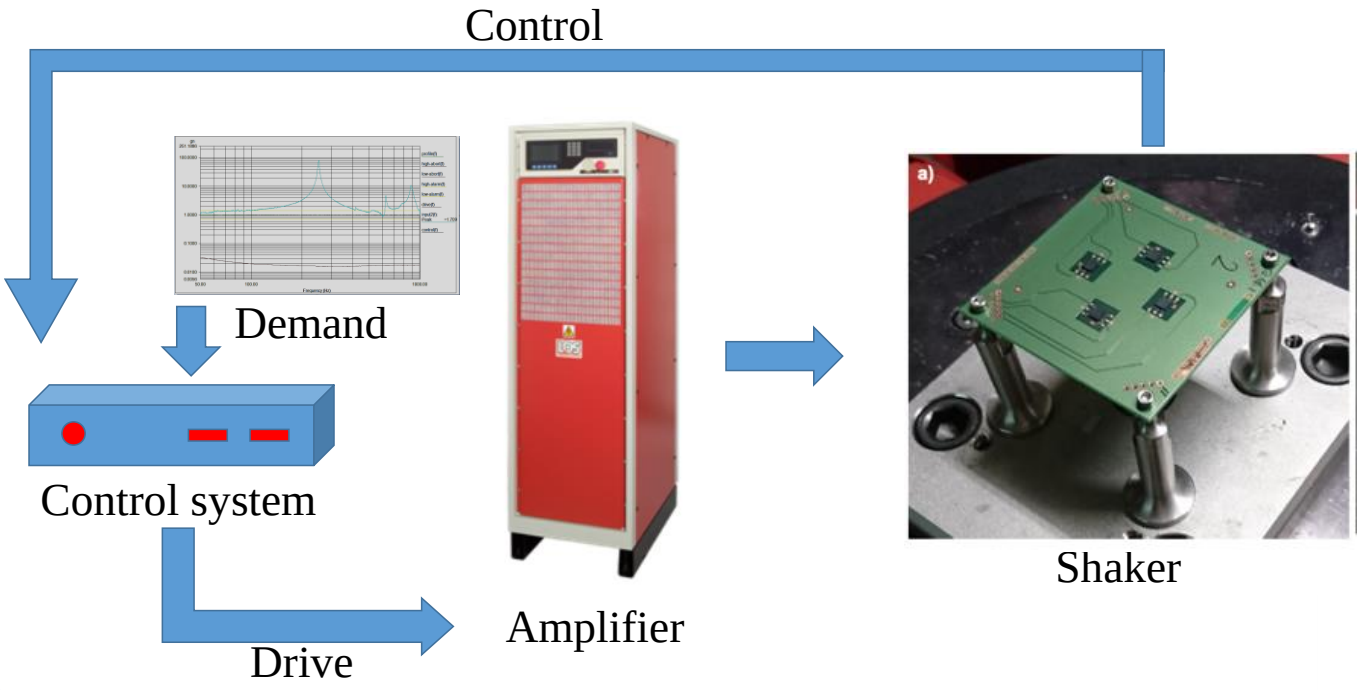
- No widely accepted vibration test method for testing components mounted on the Printed Circuit Board (PCB)
- In general, accelerometers are used to measure the vibration response of a PCB
- However, accelerometers might influence the vibration motion of some electronic systems
- Objective: Investigate the impact of vibration characterization technique on the dynamic motion of the test boards containing distinct electronic component constructions

Agenda

- Industry Trend & Motivation
- Experimental and Numerical details
  - Test Vehicles
  - PCB Vibration Spectrum
  - Finite Element Analysis
  - LDV setup verification
- Vibration measurement results and comparison
- Conclusions

Experimental Setup

- Sweep sine vibration between 100Hz and 500Hz
- PCB is mounted on 4 mounting pillars (stand-offs)
- Orientation of IC in z direction

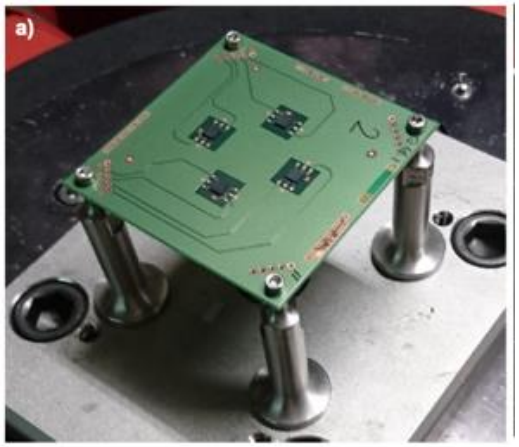


PCB Assembly Test Vehicles

- PCB layout based on JESD22B111A
  - Size: 77mm x 77mm x 1.0mm (10 Copper layers and FR4)
  - Weight: 16g

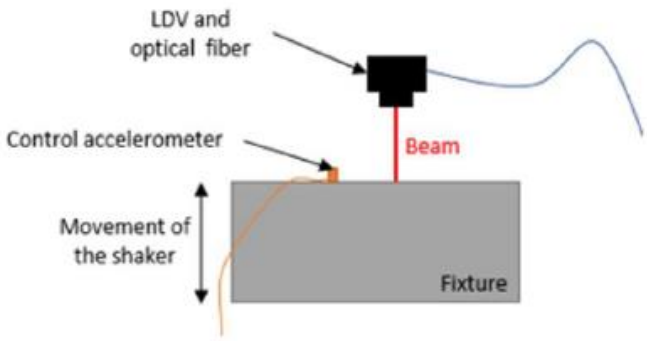
- Molding compound laminate based and wafer level chip scale packages mounted on the PCBs:
  - Size: 3mm x 3mm up to 12mm x 12mm
  - Weight: 0.02g to 0.5g

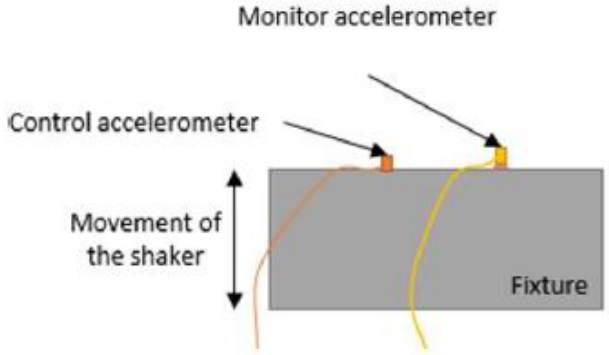
- Vibration spectrum of a PCB is measured using:
  - Accelerometer : Weight: 0.5g
  - LASER Doppler Vibrometer (LDV)

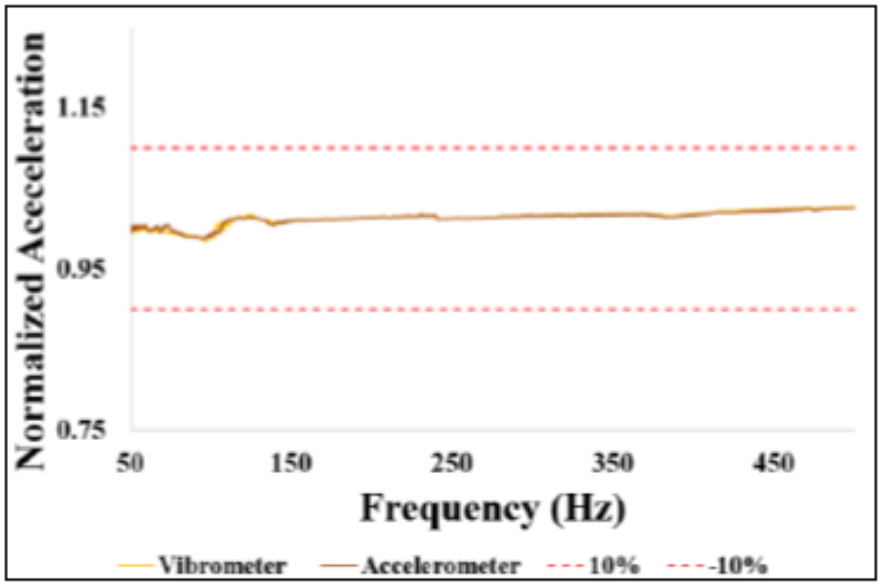


LDV Setup Verification on Shaker plate

- Verification of new test set up with LDV is performed:
  - Heavy shaker plate response from Accelerometer and LDV overlapping



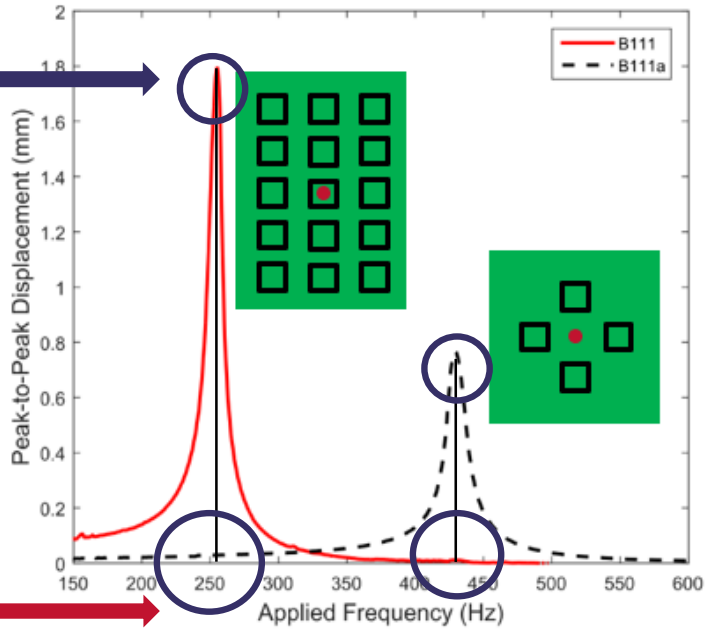




PCB Vibration Spectrum

- Typical vibration spectrum of a PCB during Board Level vibration testing:

Maximum pk-pk displacement



PCB Natural frequency

- Measurement Location (accelerometer)

- Determination of Natural frequency is the first step in vibration testing of any system

PCB Natural Frequency

- Natural frequency of the PCB from Stenberg[1]:

$$f_0 = \lambda \left(\frac{1}{a^2} + \frac{1}{b^2} \right) \sqrt{\frac{Eh^3}{12\rho(1-\nu^2)}}$$

Influencing parameters in case of fixed PCB dimension

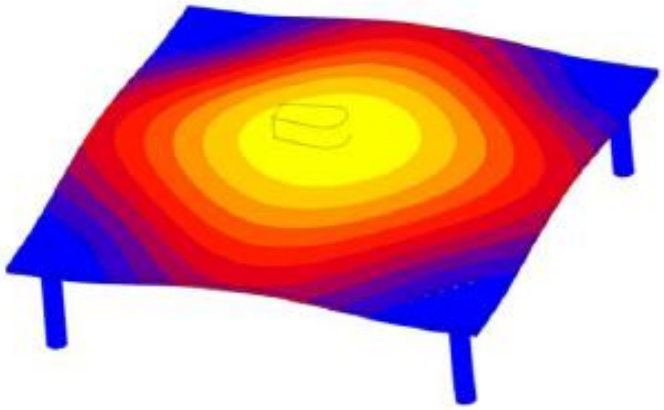
Impact of board dimension

- With: a, b the PCB board length and width, E the Young's modulus, h the board thickness and ρ the density

1. D.S. Steinberg, Vibration analysis for electronic equipment, John Wiley and Sons, 3rd edition, 2000

Finite Element Analysis (FEA)

- Model of PCB and mounting pillars, including variation of parameters (e.g. accelerometer, components) with brick and penta elements
- Homogenized properties based on DMA/TMA measurements.



Mode 1: 430Hz (with Accelerometer)

Mode 1: 448Hz (without Accelerometer)

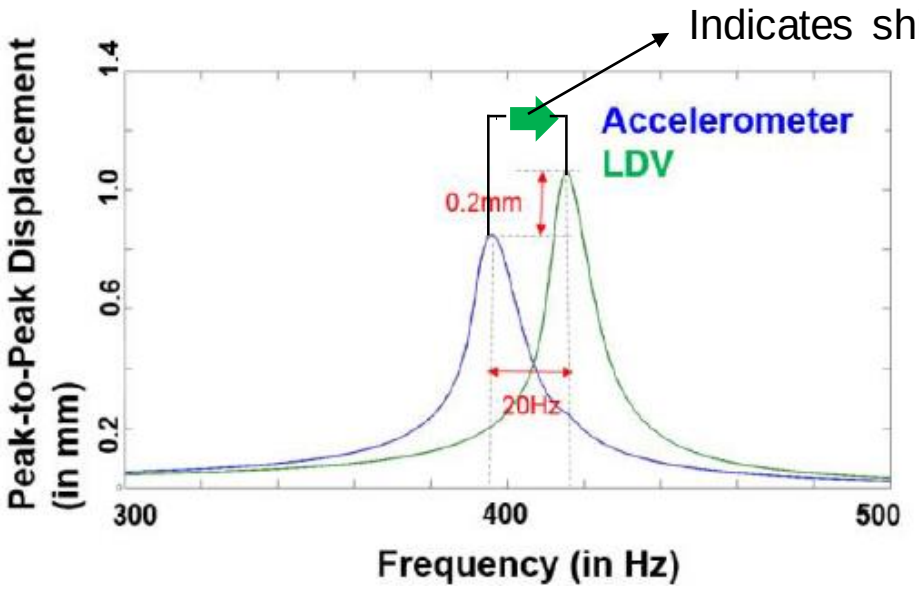
Shift: 18Hz

Agenda

- Industry Trend & Motivation
- Experimental and Numerical details
- Vibration Measurement Results and Comparison
  - Impact at Bare PCB Levels
  - Impact at Assembled PCB Levels
  - Impact at Solder Joint levels
- Conclusions

Impact at Bare PCB Levels (1/2)

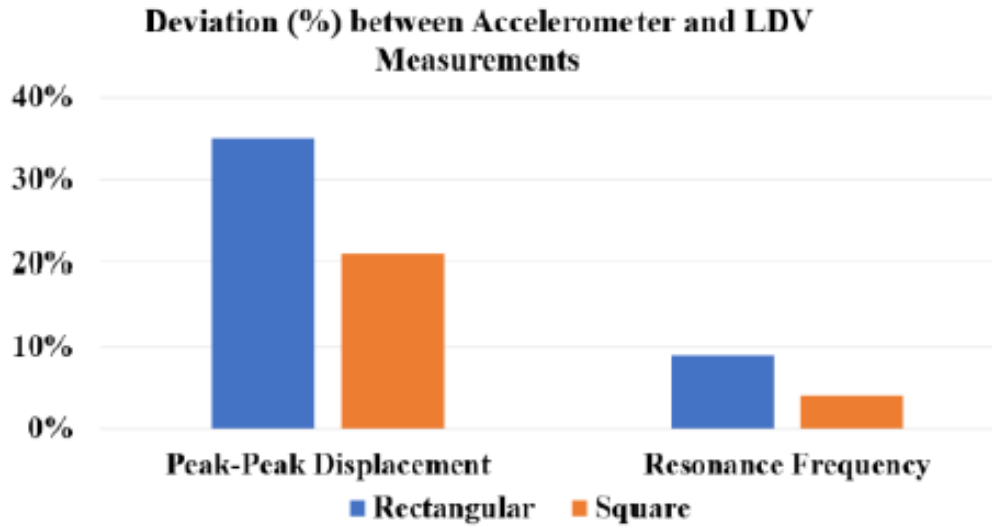
- Impact of measurement differences on PCB spectrum analysis:
  - Clear shift in natural frequency due to removal of accelerometer (mass)
  - Increment of the peak-to-peak displacement
- Good agreement between experimental data and FEM simulation



Measurement Method	f_0 (Hz)	Peak-peak Displacement (mm)	FEM f_0 (Hz)
Accelerometer	397±1	0.88±0.03	430
LDV with Accelerometer	395±2	0.90±0.01	NA
LDV	415±1	1.07±0.02	448

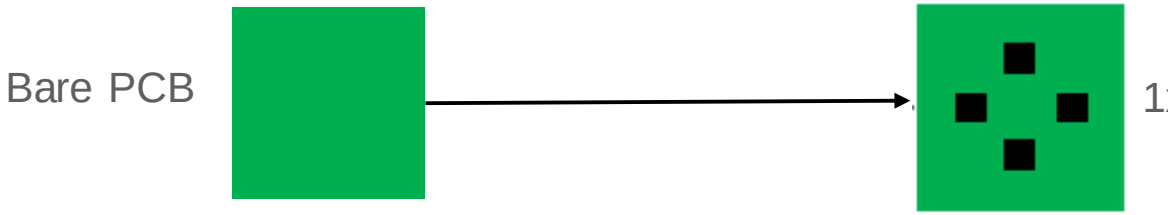
Impact at Bare PCB Levels (2/2)

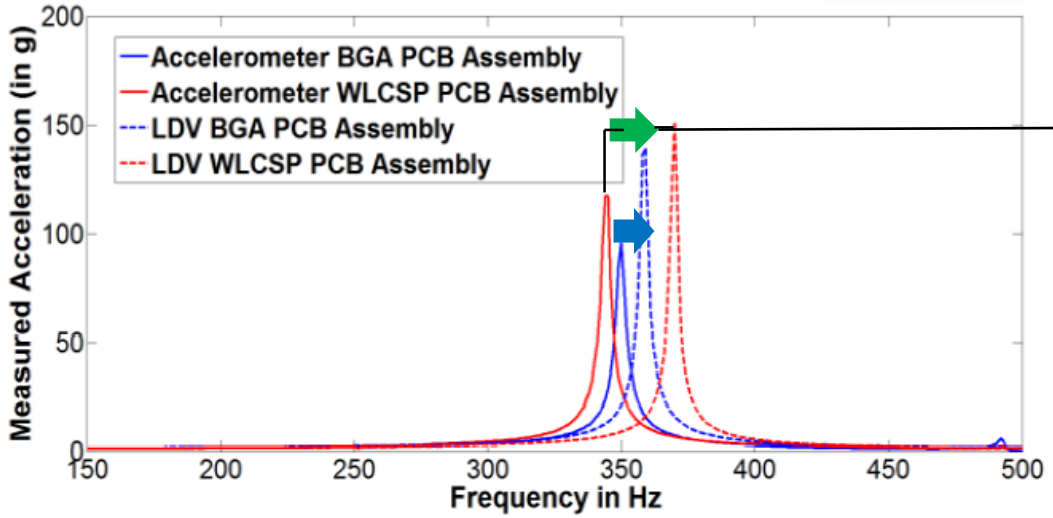
- A customized rectangular PCB is used to show the impact of PCB types on the measurement differences originating from an accelerometer weight
- Lower resonance frequency and weight when compared to that of B111A PCB type 
- A larger alteration of vibration characteristics are observed for rectangular PCB when compared to the deviation seen for B111A type PCB



Impact at Test Board Assembly Levels

- Mounting a 12mm x 12mm epoxy molded laminated based package causes a small shift in resonance frequency
- However, bigger deviation observed for light weight WLCSP components based PCB assembly
  - Mass ratio between accelerometer and component is bigger

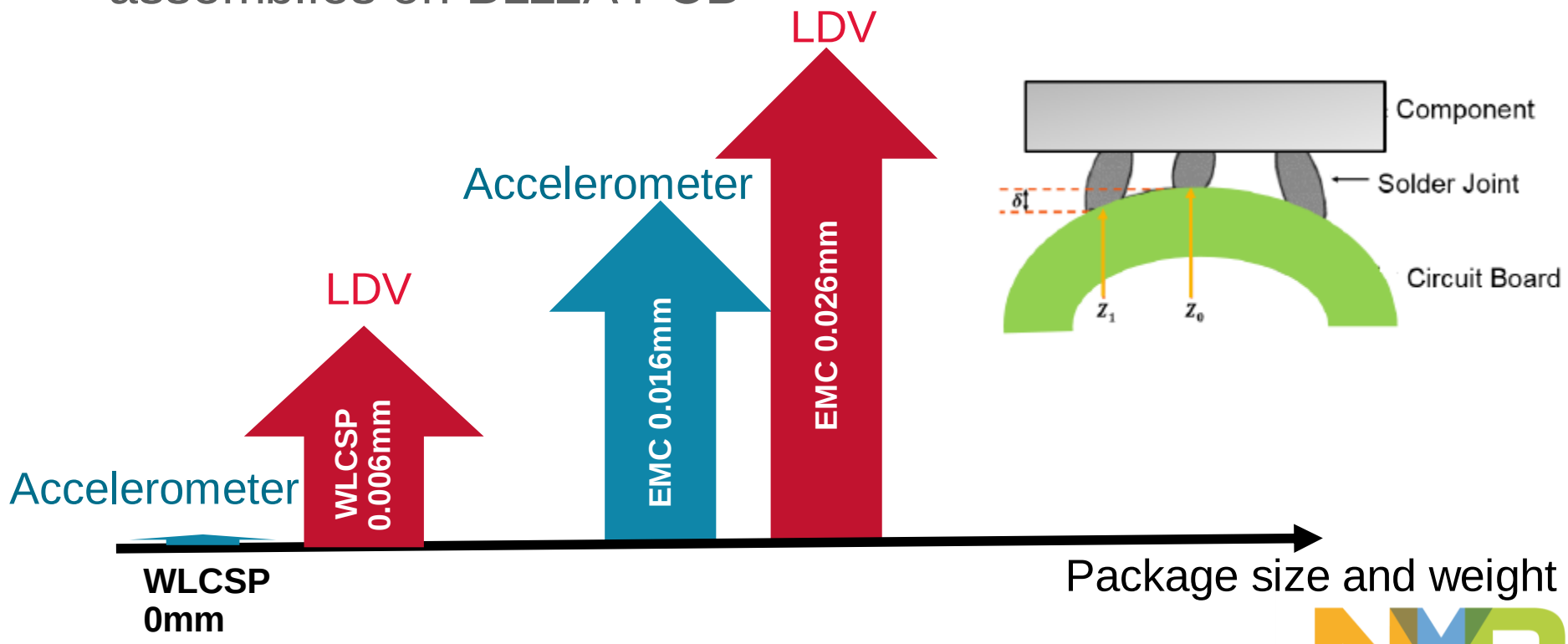




Indicates bigger shift for WLCSP based test board

Impact at Solder Joint Levels

- LDV offers better lateral resolution than the accelerometer
  - Resolution of the accelerometer is limited by the size
- This allows to measure PCB deformation of any component assemblies on B111A PCB



Agenda

- Industry Trend & Motivation
- Experimental and Numerical details
- Vibration measurement results and comparison
- Conclusions

Conclusions

- Measurement method influences the PCB vibration response
- Accelerometer is shown to perturb the vibration motion of a PCB
- PCB type has an impact on the measurement differences between the contact-less LDV and accelerometer
- Package type has an impact on the measurement differences between the contact-less LDV and accelerometer
  - Impact depends upon component stiffness, size and weight
- Precise vibration response of PCB assemblies shall be measured using contact-less techniques or very light weight accelerometers
- LDV offers better lateral resolution
- Measurement approach shall be considered in defining a reliable board level vibration test

Acknowledgment

- Rene Rongen
- Jeroen Jalink
- Jeroen Zaal
- Romuald Roucou
- Maelle Cahu
- Minh Chau
- Peter Vullings
- Kevin Hussey
- Marcel van der Straaten
- Ronald Minkhorst

Thank You

Contact Details

- NXP Semiconductors
- Gerstweg 2, 6534 AE Nijmegen – BX0.032
- +31 (0)620502753
- varun.thukral@nxp.com