MEMS Oscillators Improve SSD Design

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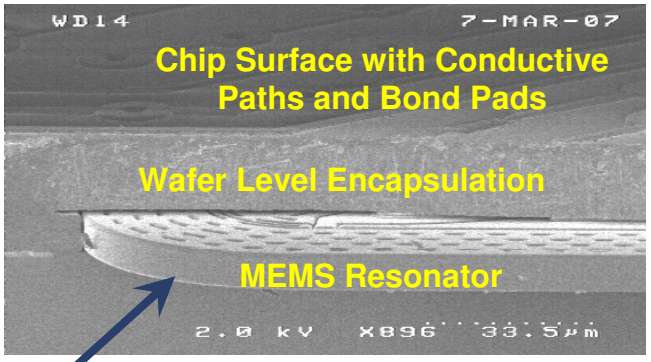
Outline

- MEMS-Based Oscillators
  - What, Why
- Clocking for SAS/SATA
- Conclusions: MEMS-Based oscillators for SSDs

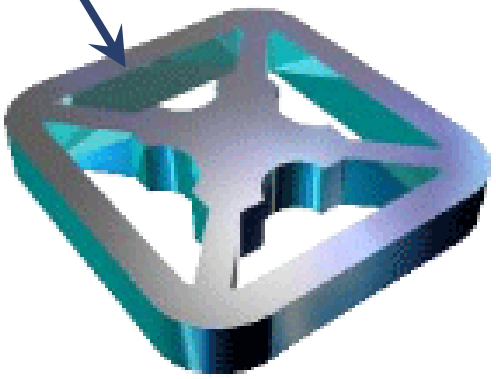
MEMS-Based Oscillators

Principles of Operation

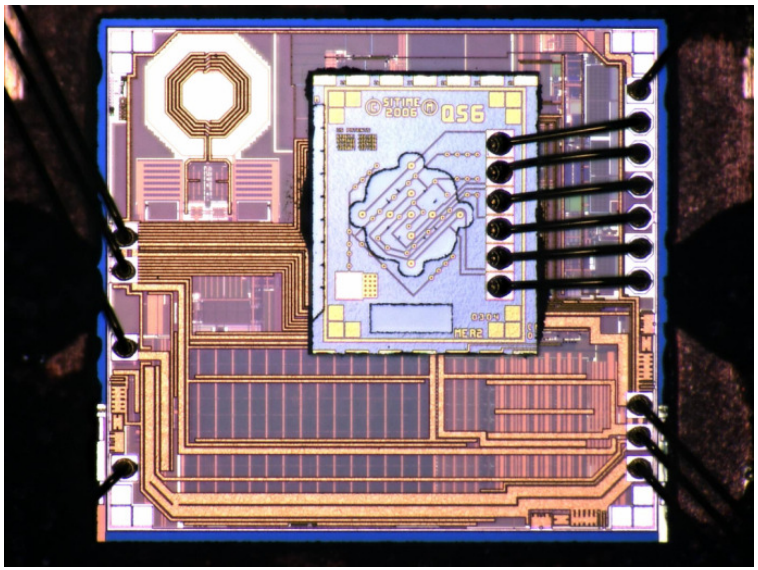


Q: 50k to 300k

Resonator Beam



MEMS Resonator



Dies Stack

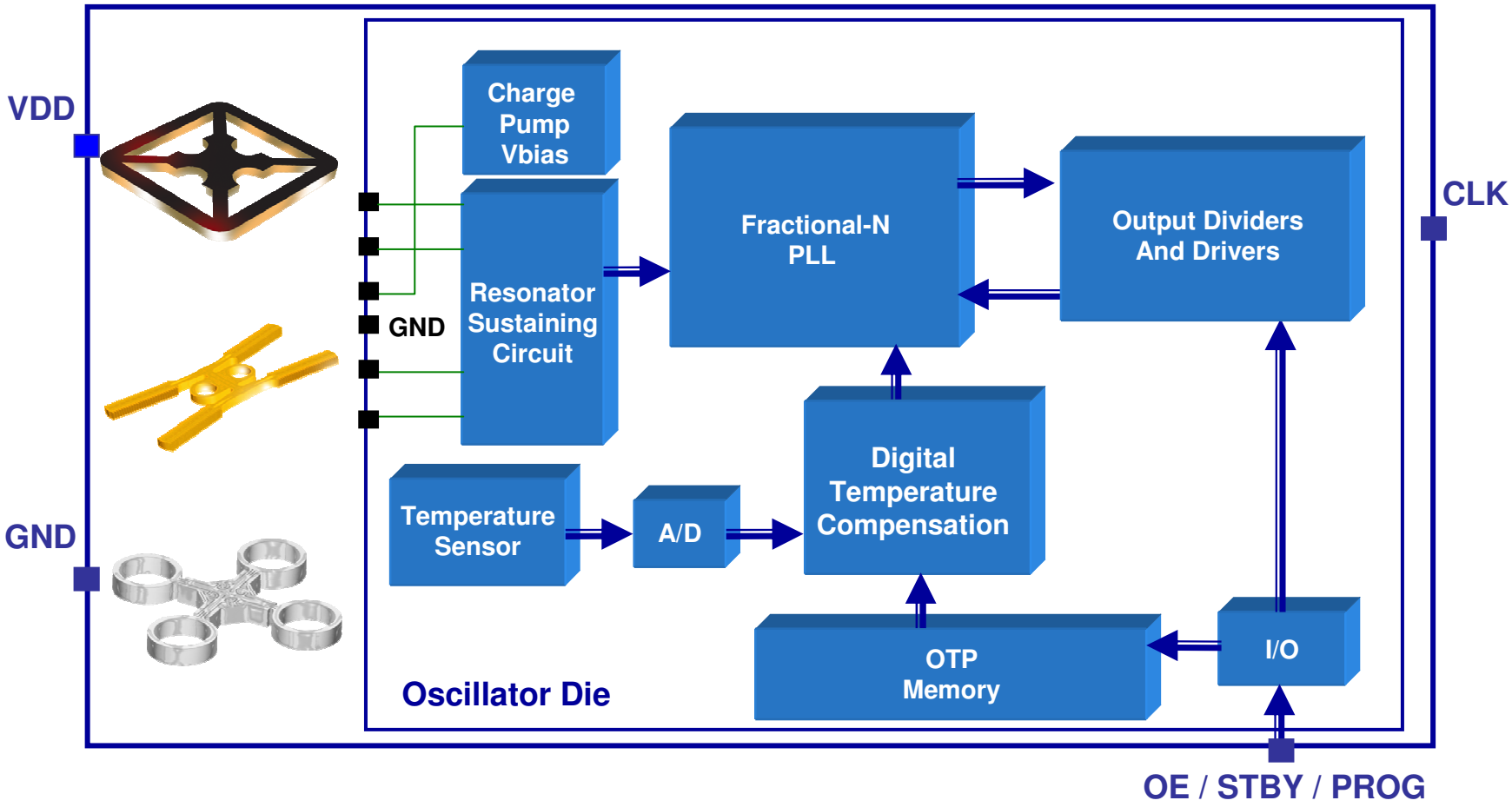
Plastic Packages

Why MEMS-Based Oscillator for SSDs

- High reliability
- Small size (as small as 2mm x 1.6mm)
- Robustness against shock/vibe
- Fast sampling and short lead time for any frequency

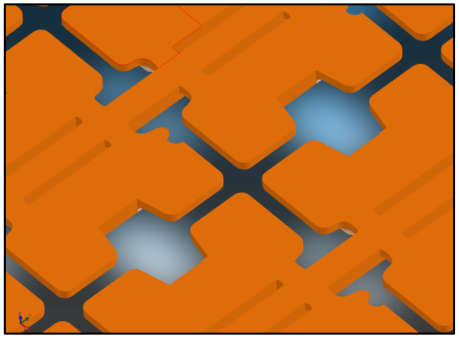
MEMS-Based Oscillators

Functional Blocks

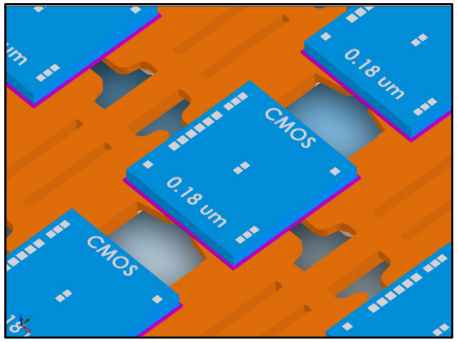


MEMS-Based Oscillators
Packaging

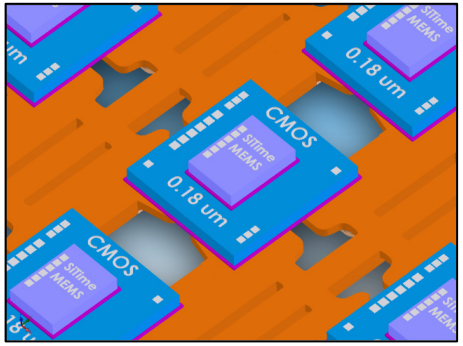
- **MEMS resonator die is packaged in standard semiconductor packaging process**
- **QFN process to achieve pin compatibility with quartz**
- **MEMS die suitable for common processes: flip chip, chip stack, BGA, bumping, wire bond…**



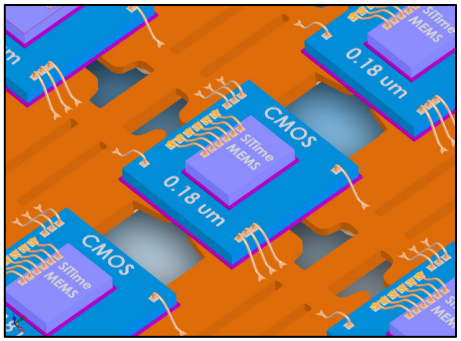
1. Copper lead frame



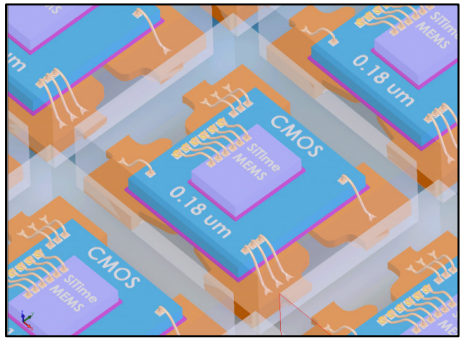
2. Mount CMOS chip



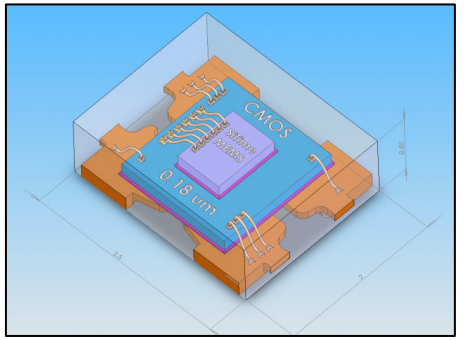
3. Mount MEMS resonator



4. Attach wire bonds



5. Mold plastic and singulate

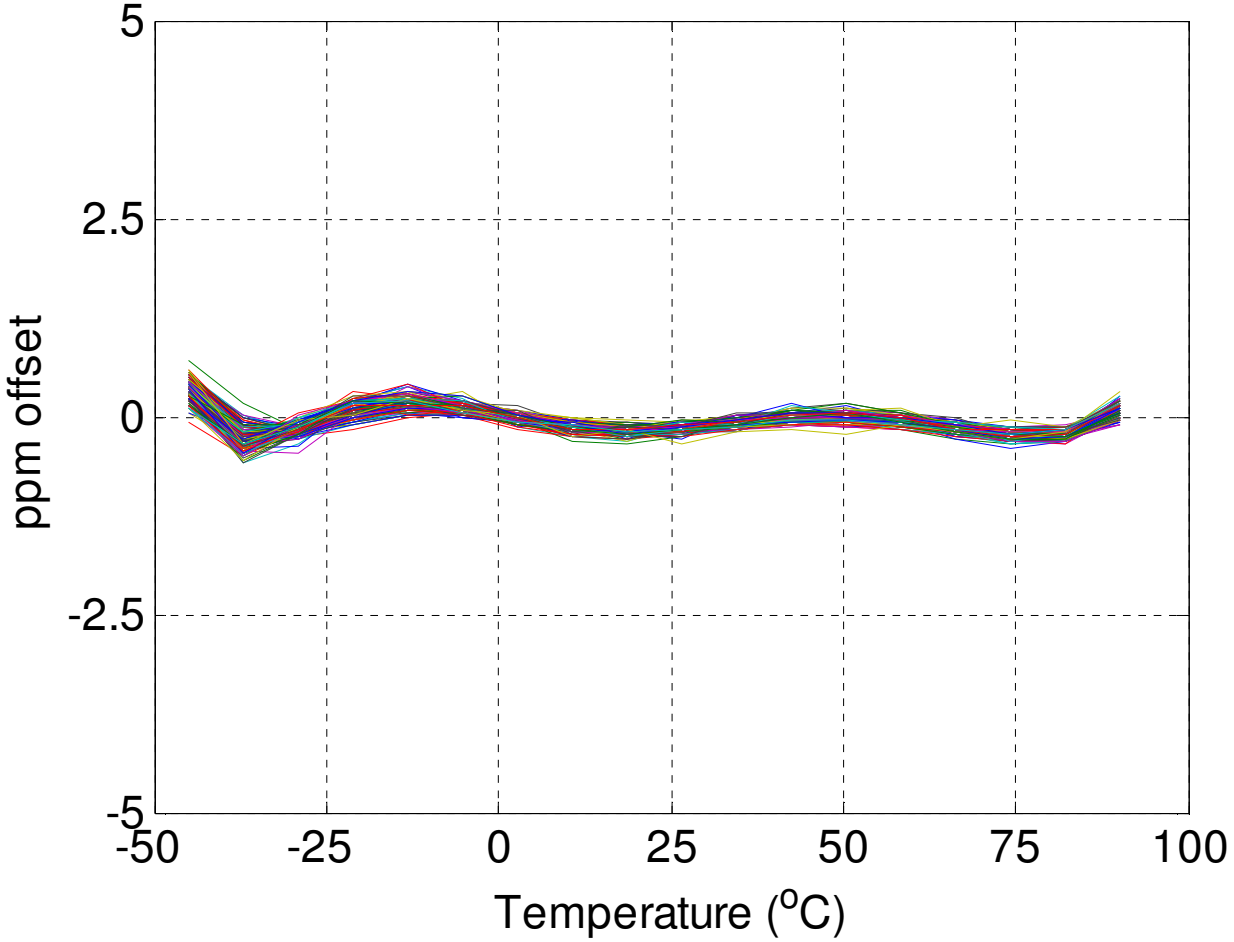


6. Test and calibrate

MEMS-Based Oscillators

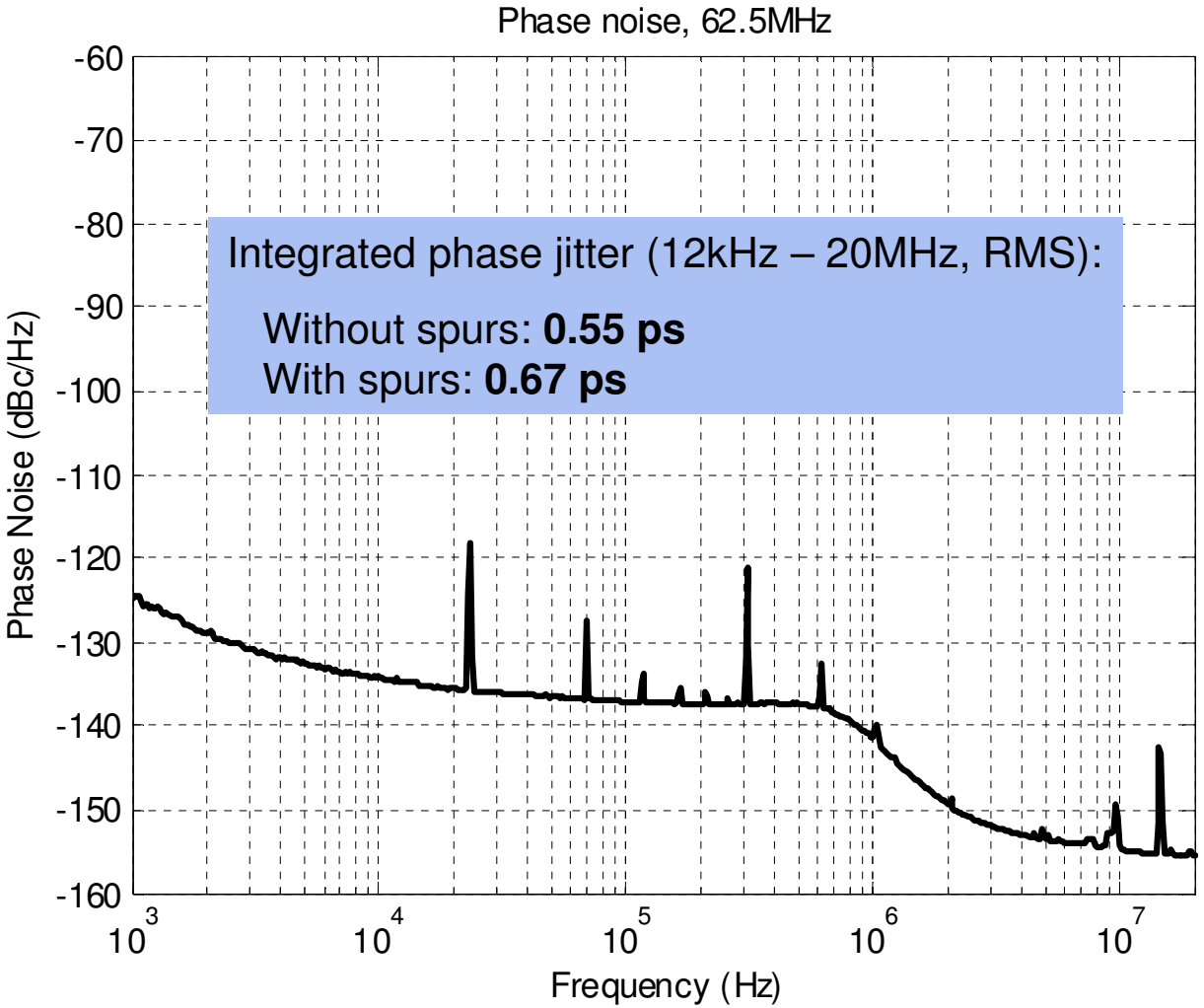
Performance – Frequency stability

Frequency stability after multi temperature calibration better than ±2.5 PPM



MEMS-Based Oscillators

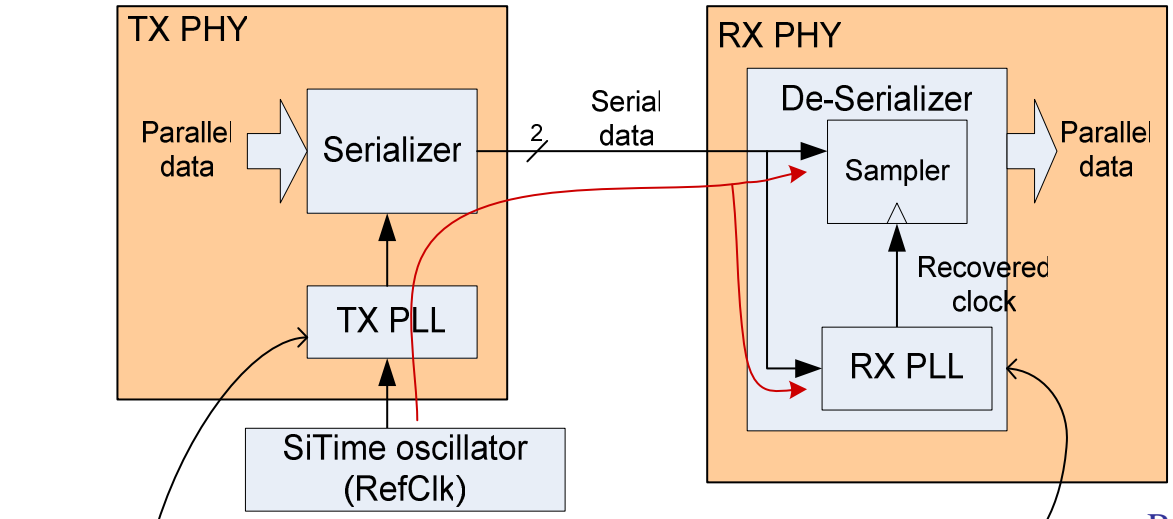
Performance – Phase Noise

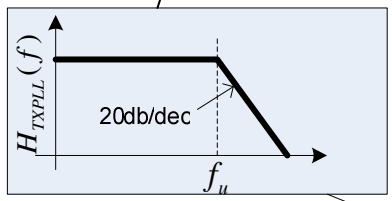


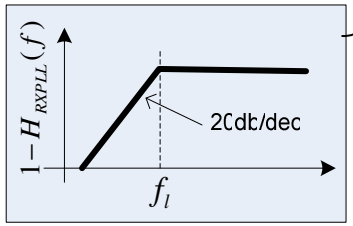
Clocking for SSD

- SAS / SATA
  - 1.5Gbs, 3Gbps, 6Gbps, 12Gbps
  - ±100ppm frequency stability
- Flash Controller
- Other interfaces
  - PCIe, Ethernet, Fibre Channel

Embedded Clocking for 1GbE and 10GbE





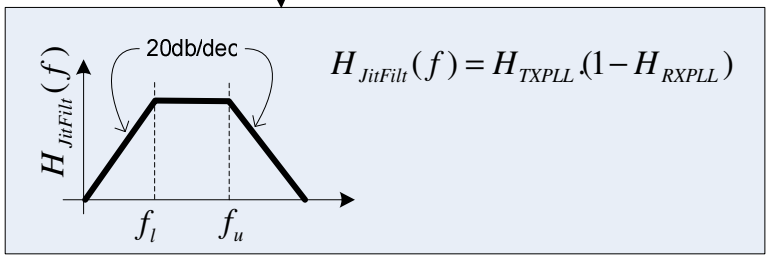


Response specified by relevant standards

For most applications (8b/10b encoded data streams) $f_l = \frac{f_{baud}}{1667}$

For most applications (64b/66b encoded data streams) $f_l = \frac{f_{baud}}{2500}$

$f_u = \frac{f_{ref}}{10}$



Clock jitter filter response determining the clock jitter impact on the interface.

Jitter Budget Estimation

- Jitter budget used by RefClk computed for transmitter
  - Transmitter has tighter jitter limits → Worst case for jitter
- Transmitter output (TXout) jitter affected by TX PHY and RefClk

Specified by the relevant standard document

TX output random jitter (RJ) budget →
$$RJ_{RMS\_TXout} = (TJ_{PP\_TXout} - DJ_{PP\_TXout})/14.1$$

TX PHY random jitter budget (excludes RefClk) →
$$RJ_{RMS\_TXphy} = \sqrt{RJ_{RMS\_TXout}^{2} - RJ_{RMS\_RefClk}^{2}}$$

TX PHY deterministic jitter (DJ) (excludes RefClk) →
$$DJ_{PP\_TXphy} = DJ_{PP\_TXout} - DJ_{PP\_RefClk}$$

Measured from RefClk

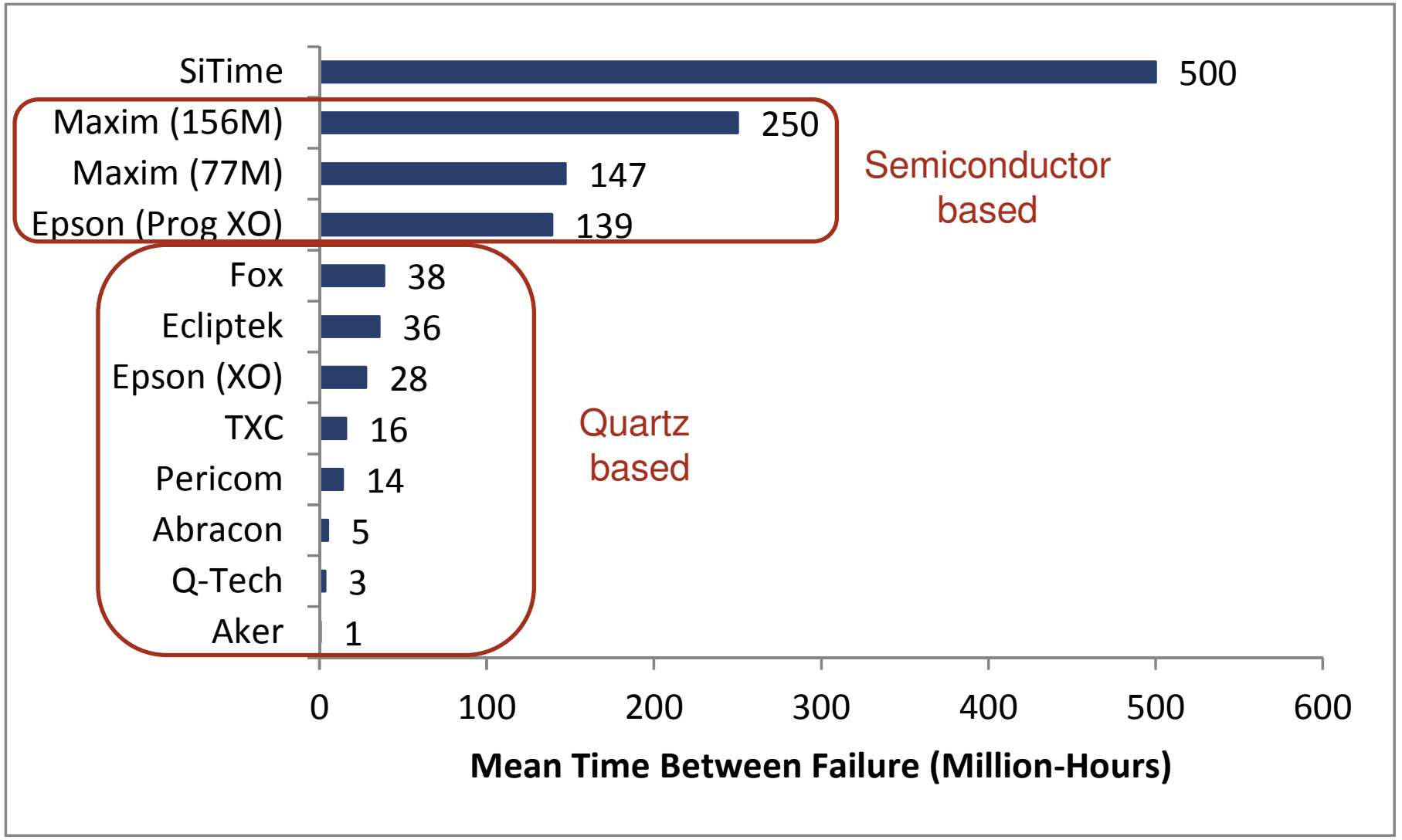
TX PHY total jitter (TJ) budget (excludes RefClk) →
$$TJ_{PP\_TXphy} = (14.1)RJ_{RMS\_TXphy} + DJ_{PP\_TXphy}$$

Percentage of total jitter budget consumed by the RefClk →
$$TJ_{PP\_RefClk\_budget} = (TJ_{PP\_TXout} - TJ_{PP\_TXphy})/TJ_{PP\_TXout}$$

SAS/SATA Jitter Margins with MEMS oscillator

SATA / SAS baud rate (Gbps)	Phase jitter (ps, max)	Jitter margin (%)
1.5	0.45	> 99%
3	0.4	> 99%
6	0.3	> 98%
12	< 0.3	> 98%

MEMS Oscillator Reliability



Conclusions: MEMS-Based Oscillator for SSDs

- High reliability
  - Critical for Enterprise systems
- Low phase jitter for optimal bit-error-rate performance
- Cost-efficient for small size (as small as 2mm x 1.6mm)
- Standard and custom frequencies
  - 31.25MHz, 62.5MHz, 37.5MHz, 75MHz, 120MHz, 150MHz
- Wide temperature operation
  - As low as ±25ppm stability over -40C to 125C
- Robustness against shock/vibe
- Fast sampling and short lead time for production
- Spread Spectrum Clocking (SSC)
- Low power