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Temperature and On-chip Crosstalk Measurement using Ring Oscillators in FPGA

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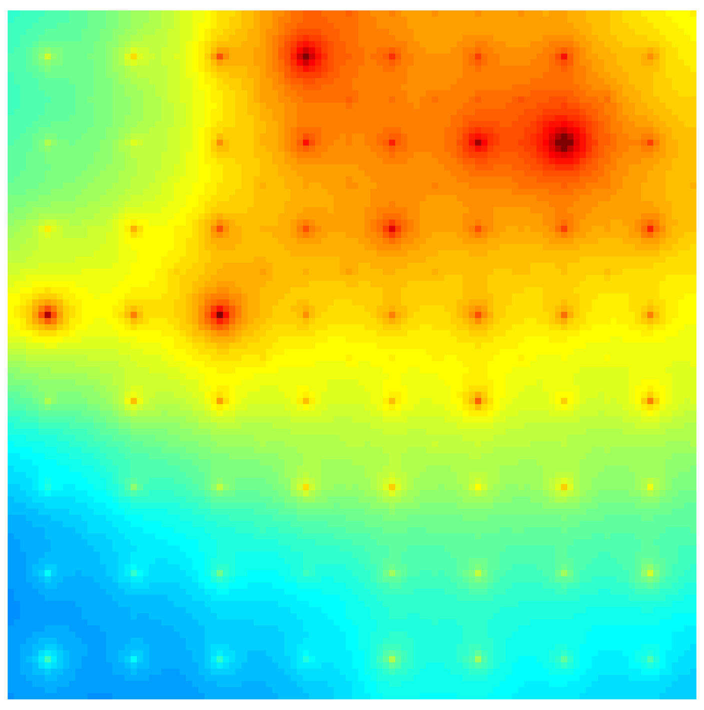
Motivation

- Power density ↑
- Process variations ↑
- Heterogeneous Systems-on-Chip

➡ **Thermal Imbalances**

- Thermal Monitoring
  - Need small distributed sensors
  - Compile temperature map
  - Enable thermal management

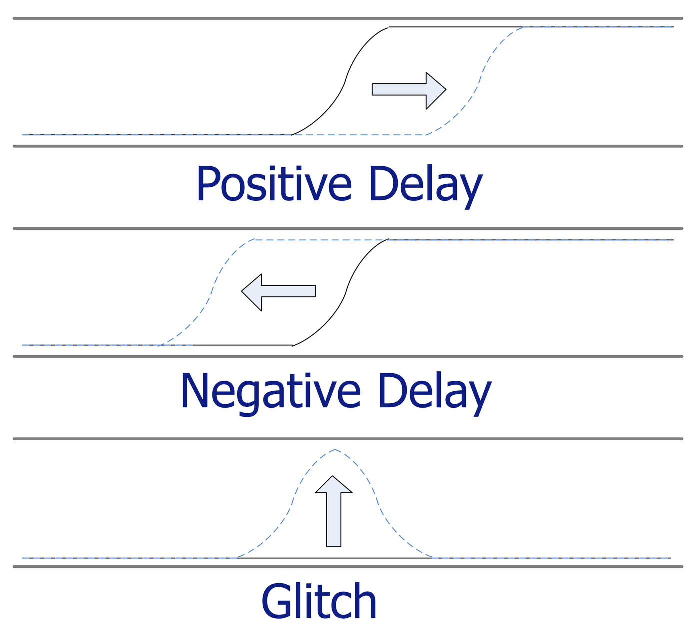


- Computational resources ↑
- Communicational resources ➚
- Capacitances ↑
- Variations ↑

➡ **Signal Integrity and Aging**

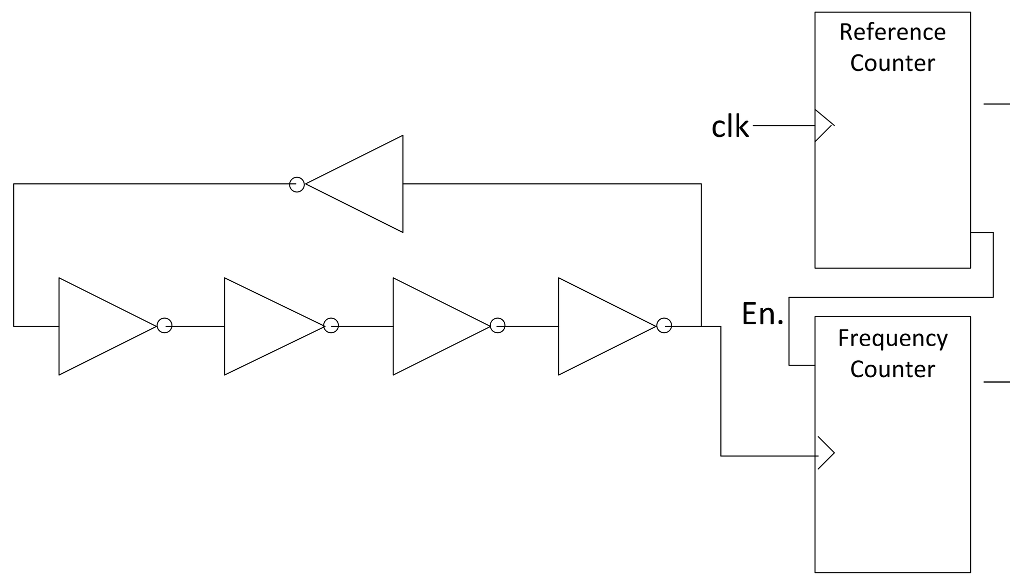
- Need to sense delay
- \+ Coupling induced delay
- Test circuit on FPGA

Crosstalk induced phenomena:



Measurement of On-chip Temperature and Crosstalk

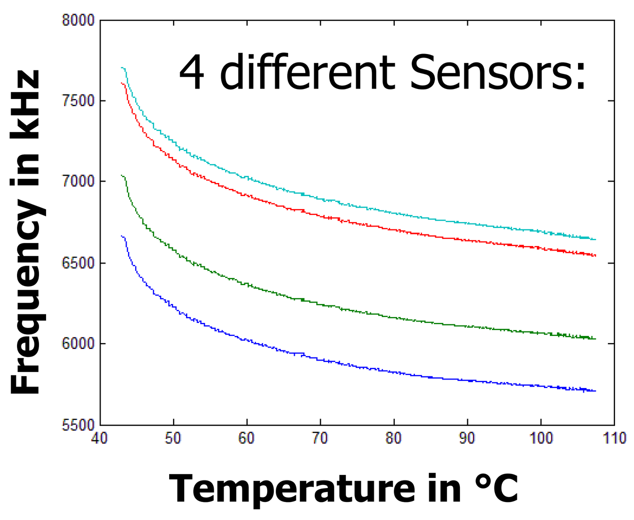
Temperature sensitive ring oscillator with frequency counter:



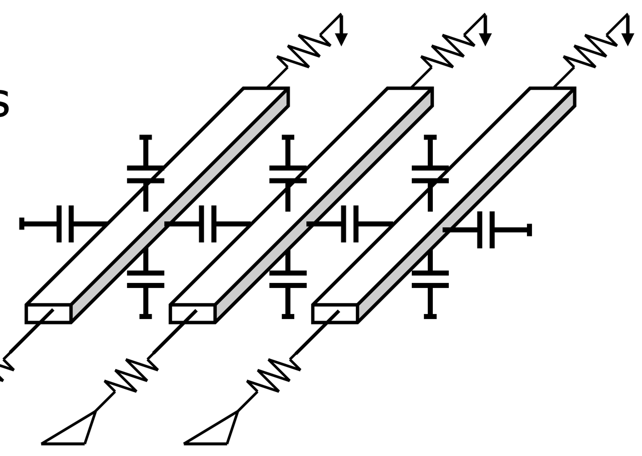
Frequency depends on supply voltage and temperature

$$Vt = Vt_0 + \alpha_{Vt} \cdot (T - T_0)$$
$$\text{for } \alpha_{Vt} = -2 \ldots -4 \left[\frac{mV}{K}\right]$$
$$\mu = \mu_0 \cdot \left(\frac{T}{T_0}\right)^{\alpha_\mu} \quad \text{for } \alpha_\mu = -1.5 \ldots -2.5$$

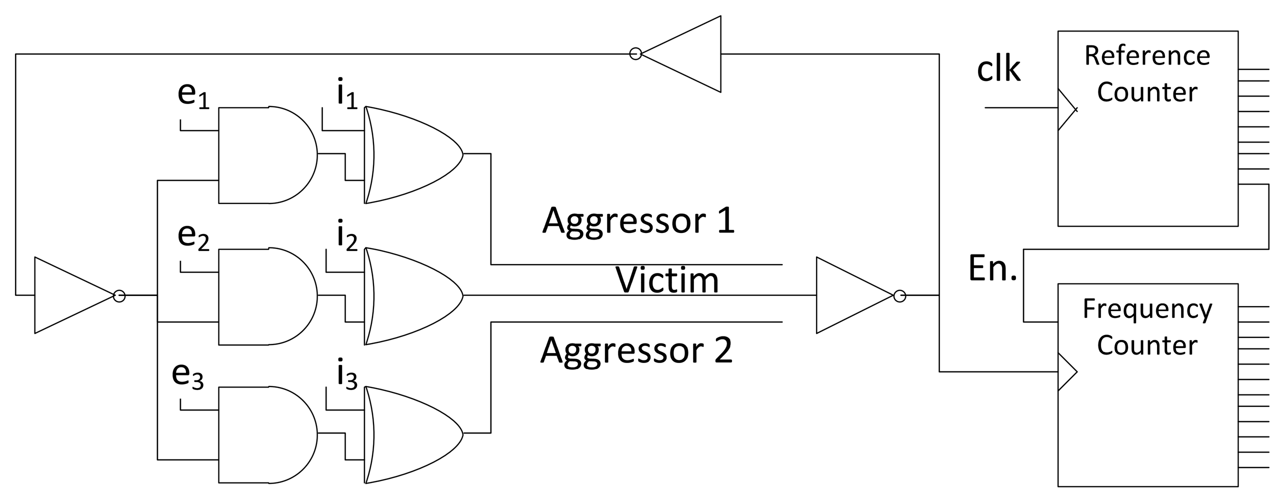
- Influence of μ is dominating
- Overall a linear relationship is assumed
- Only true for certain temperatures:



- Capacitive coupling
- Activity on neighboring wires influences voltage level
- Induced delay can be positive or negative



Ring oscillator for measuring coupling induced delay:
- Contains test line (victim) and
- Neighboring aggressors



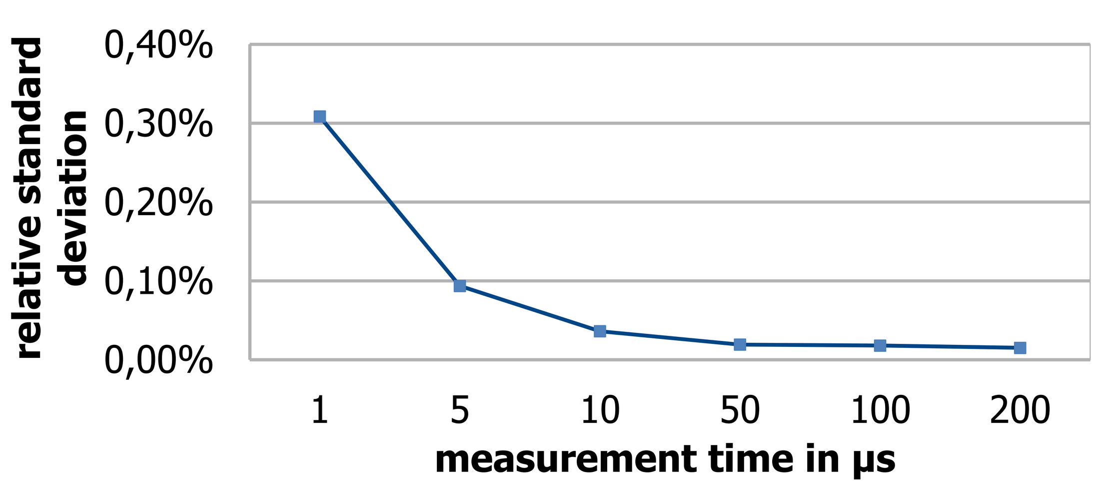
Inputs e and i allow to create all possible crosstalk patterns

➡ Change of frequency

Results of Measurements

Precision depending on parameters like:
- Ring length,
- Measurement time, …

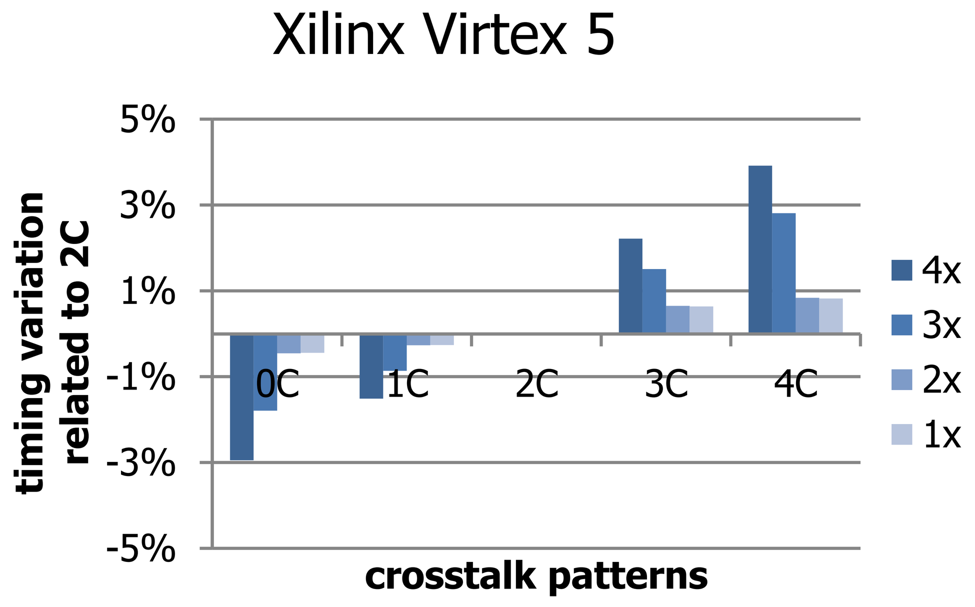
Best parameter set -> ~0.012%

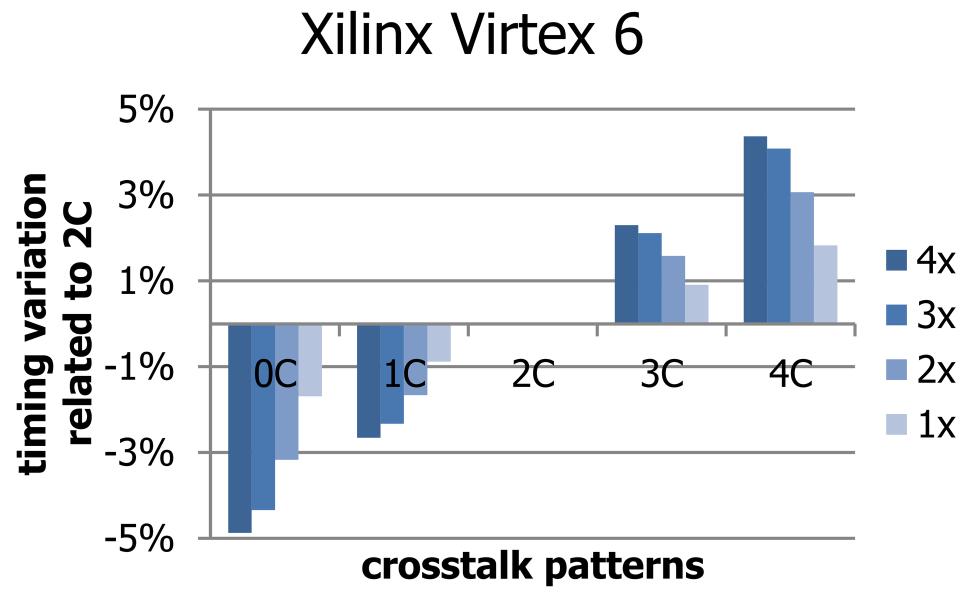


Scattering an array of sensors is possible
Calibration of multiple sensors could be tricky

➡ Runtime Thermal Management,
Temperature Aware Mapping,
…

Coupling induced delay is measured
All crosstalk patterns can be differentiated





Very small standard error: 0,0001%
Measured over different wire length: 4x = ~ 1/4 chip length -> up to 9% delay variation
2x = ~ 1/8 chip length, …

➡ Higher influence of crosstalk on Virtex 6 (40 nm) than on Virtex 5 (65 nm)

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