Cross-layer Accelerated Self-Healing (CLASH) - Aging Effect in FPGA chips and systems

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BACKGROUND

Circuit reliability

- Defined in term of mean time between failures (MTBF)
- Process, voltage, temperature and aging variations (PVTA) have a substantial effect
- Relatively hard to capture and deal with

Aging Effect

- Deterioration of circuit performance over time
- More significant with extremely scaling technology
- Including bias temperature instability (BTI), Hot carrier injection (HCI), time-dependent dielectric breakdown (TDDB), Elctromigation(EM), etc.

Purposes

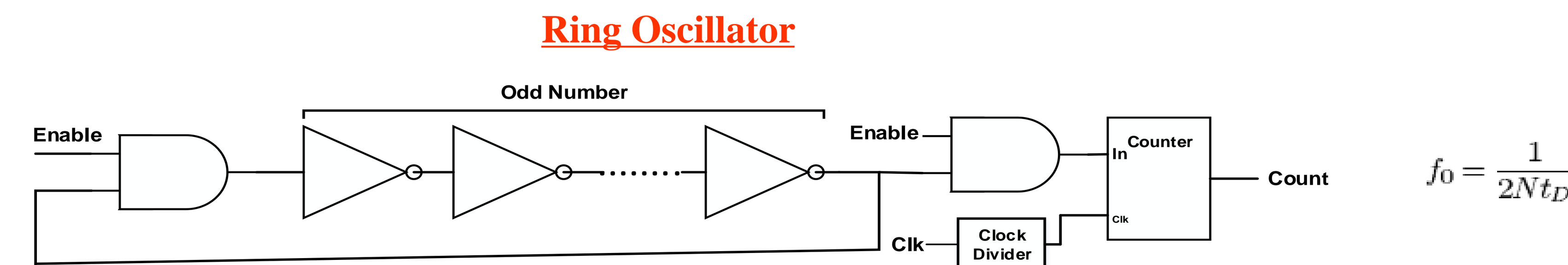
- Capture aging/wearout effect in FPGA based systems
- Develop accelerated recovery mechanism to rejuvenate electronic system
- Develop and optimize aging mechanism models
- Develop aging/wearout sensors for electronic systems

RESEARCH FLOW

Step	Details
Measure FPGA Performance, Power and Variations	Based on evaluation Board (Done)
Design Measurement System	Design connector Board (Done)
Stress FPGA chip	Based on Atmel Board (Ongoing)
Develop recovery strategy	Accelerated and self-heating Thermal recovery (In the future)
Develop aging mechanism models	BTI, HCI and EM models (In the future)
Aging Sensors	Sensing aging effect (In the future)
Validation	Based on test chip (In the future)

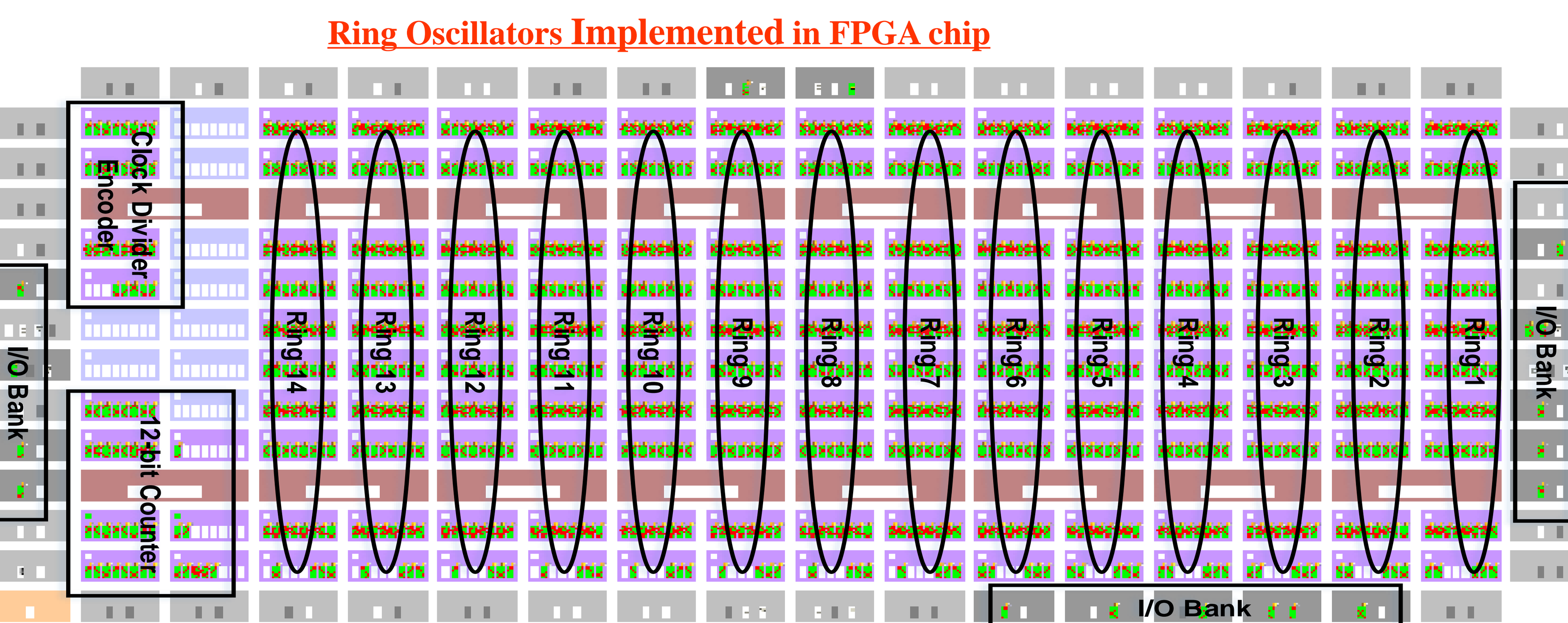
PLATFORM

Ring Oscillator



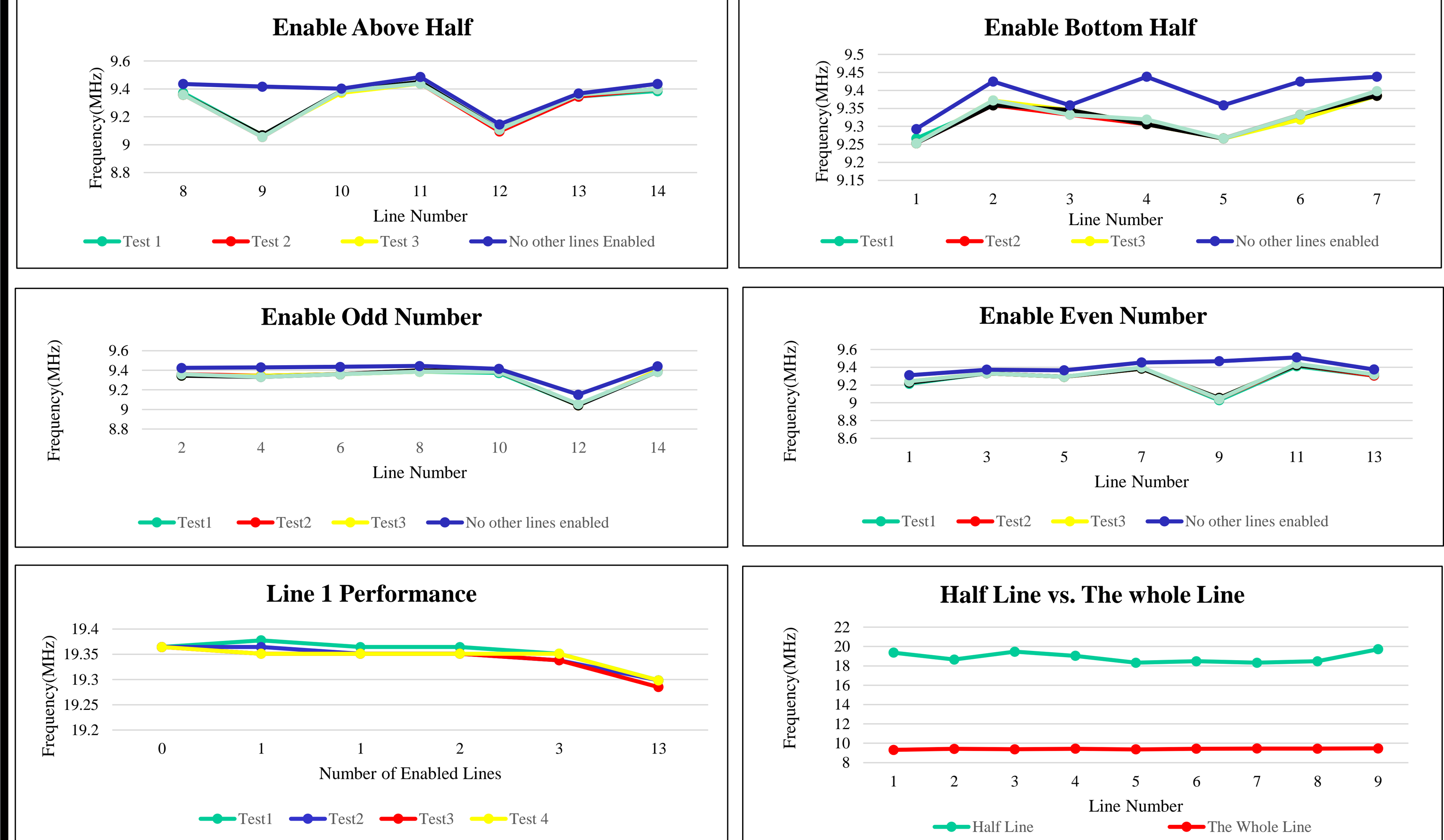
$$f_0 = \frac{1}{2Nt_D}$$

Ring Oscillators Implemented in FPGA chip



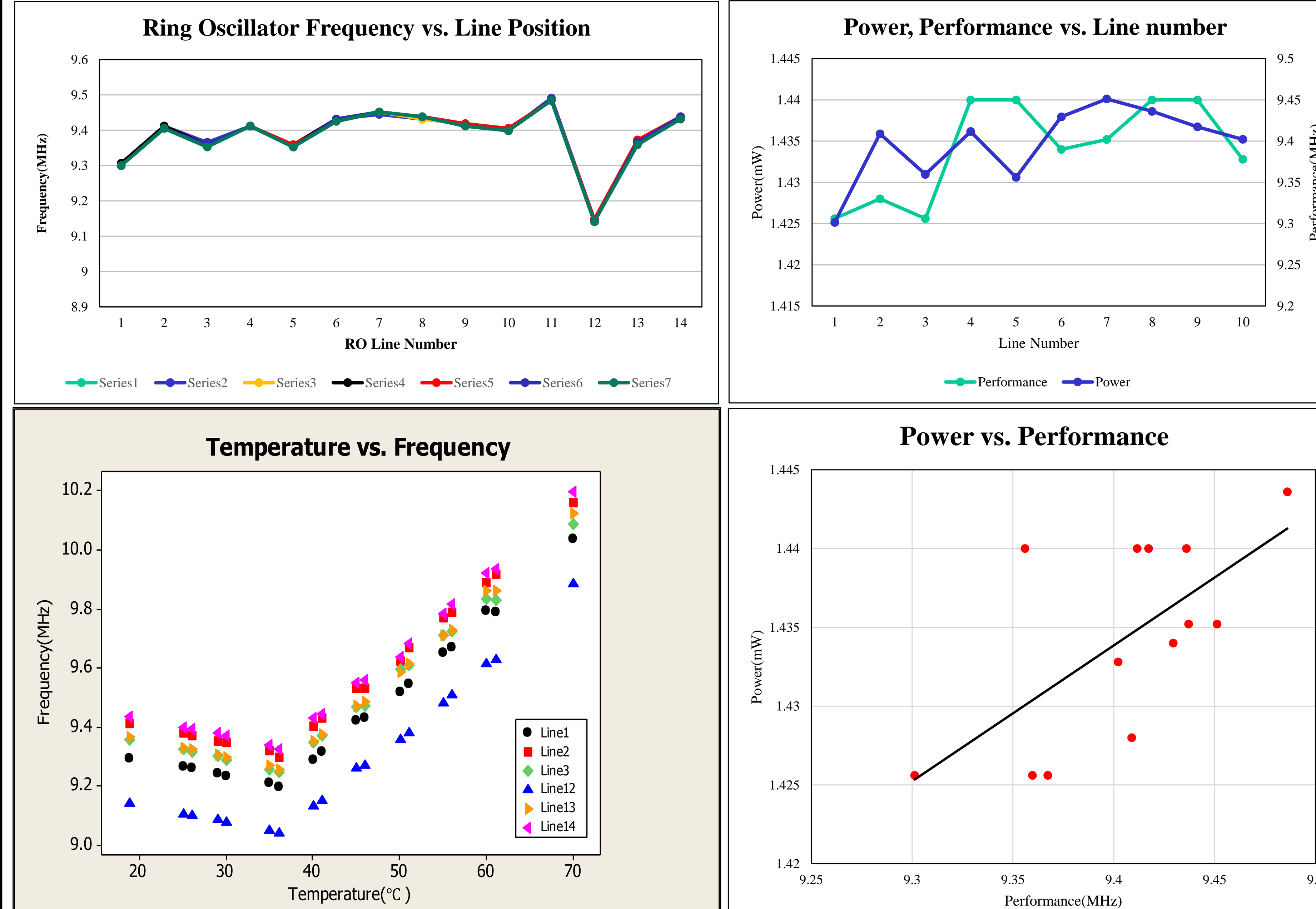
- Each ring oscillator can be enabled separately
- Clock divider is used to achieve fine granularity
- Encoder is used to choose enabled lines
- I/Os are assigned based on availability

MUTUAL EFFECT MEASURMENTS

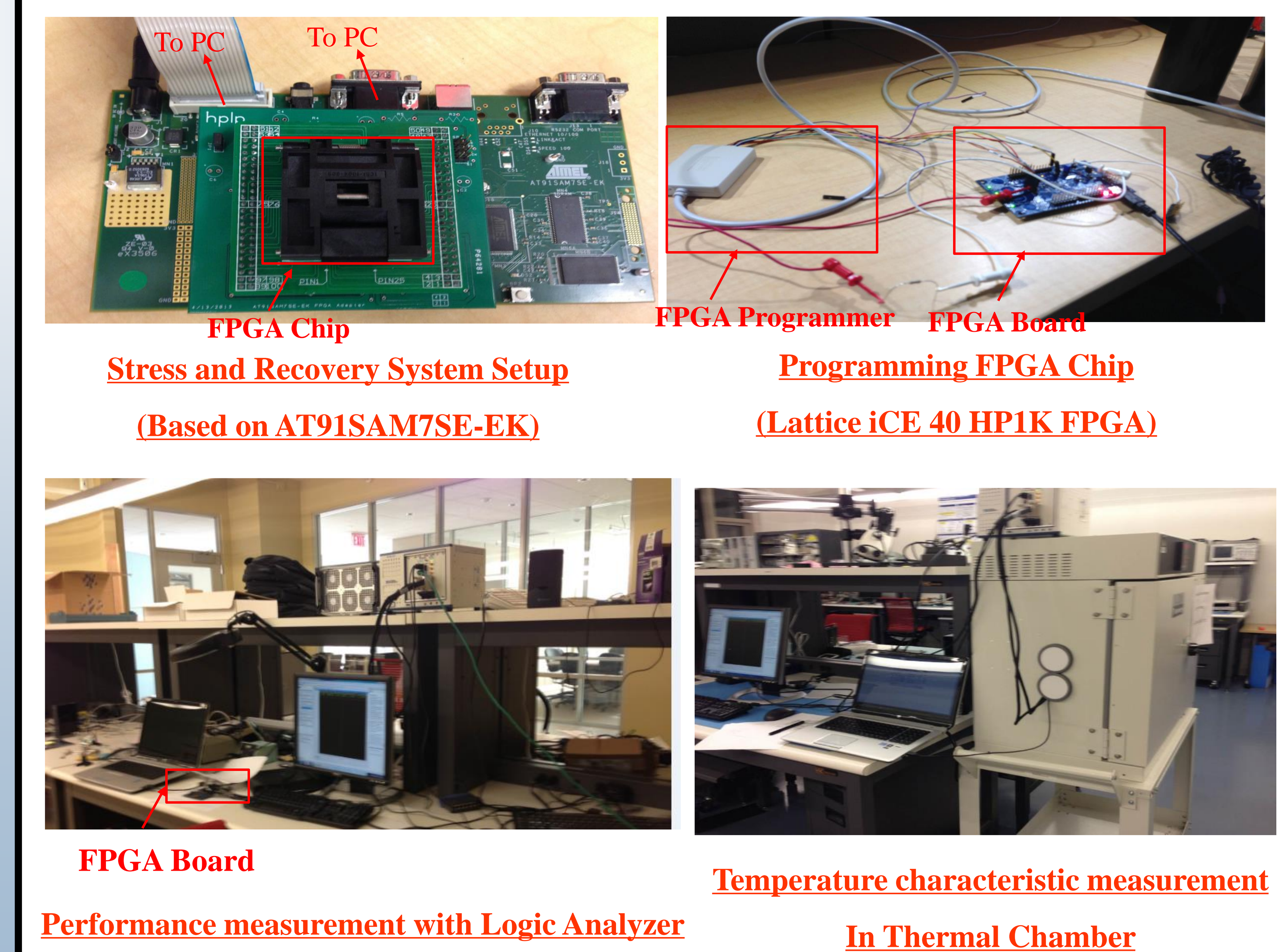


- Mutual effect will affect the performance of ring oscillator
- Self-heating can also influence performance and power

MEASUREMENT RESULTS



EXPERIMENT SETUP



Stress and Recovery System Setup (Based on AT91SAM7SE-EK)

Programming FPGA Chip (Lattice iCE 40 HP1K FPGA)

Performance measurement with Logic Analyzer

Temperature characteristic measurement In Thermal Chamber