# Steady-State Dynamic Temperature Analysis and Reliability Optimization for Embedded Multiprocessor Systems

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June 2012

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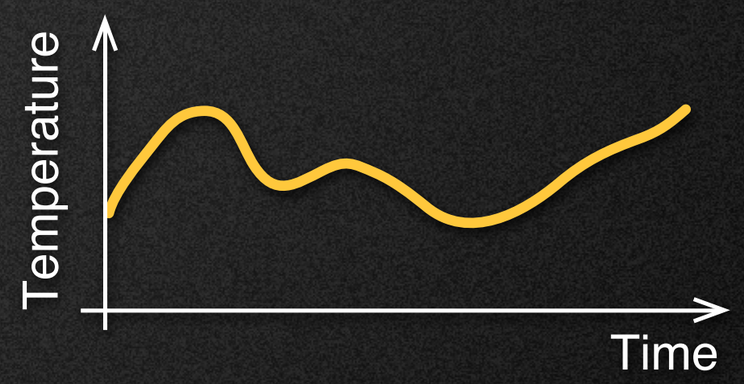

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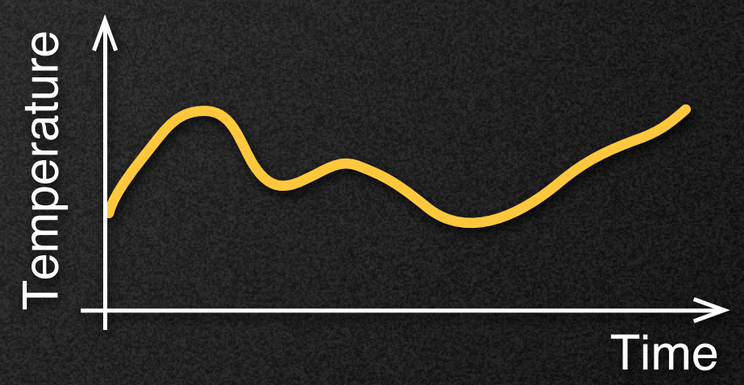
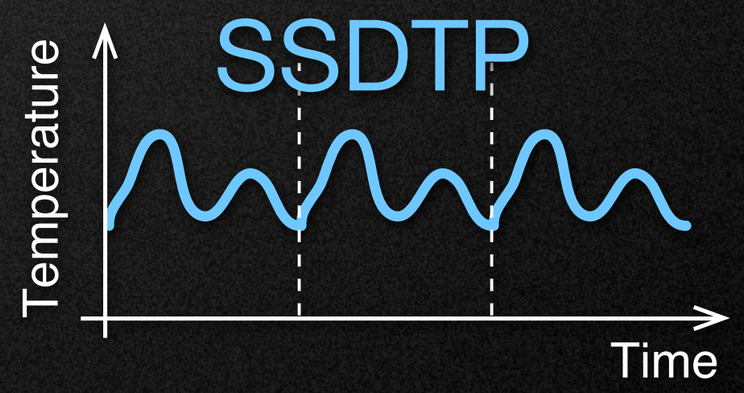



## Steady-State Dynamic TA (SSDTA):

- Periodic power profile → Periodic temperature profile.



# Overview

We have:

- Multiprocessor platform with thermal package.
- Periodic dynamic power profile.

We perform:

- Steady-State Dynamic Temperature Analysis.

We obtain:

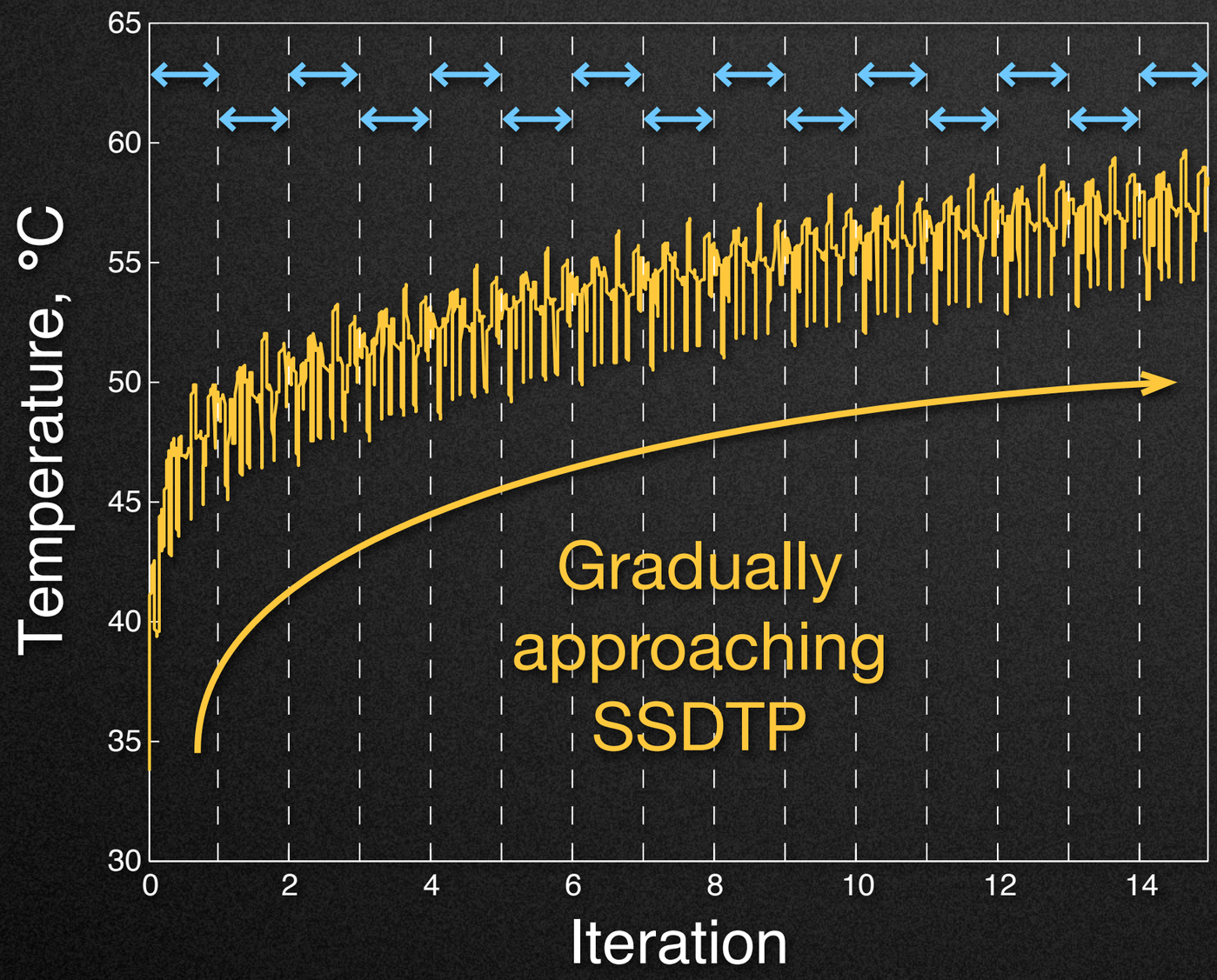
- Steady-State Dynamic Temperature Profile.

We demonstrate:

- Importance for reliability optimization.

# The State of The Art (1)

Iterative simulation using TTA…

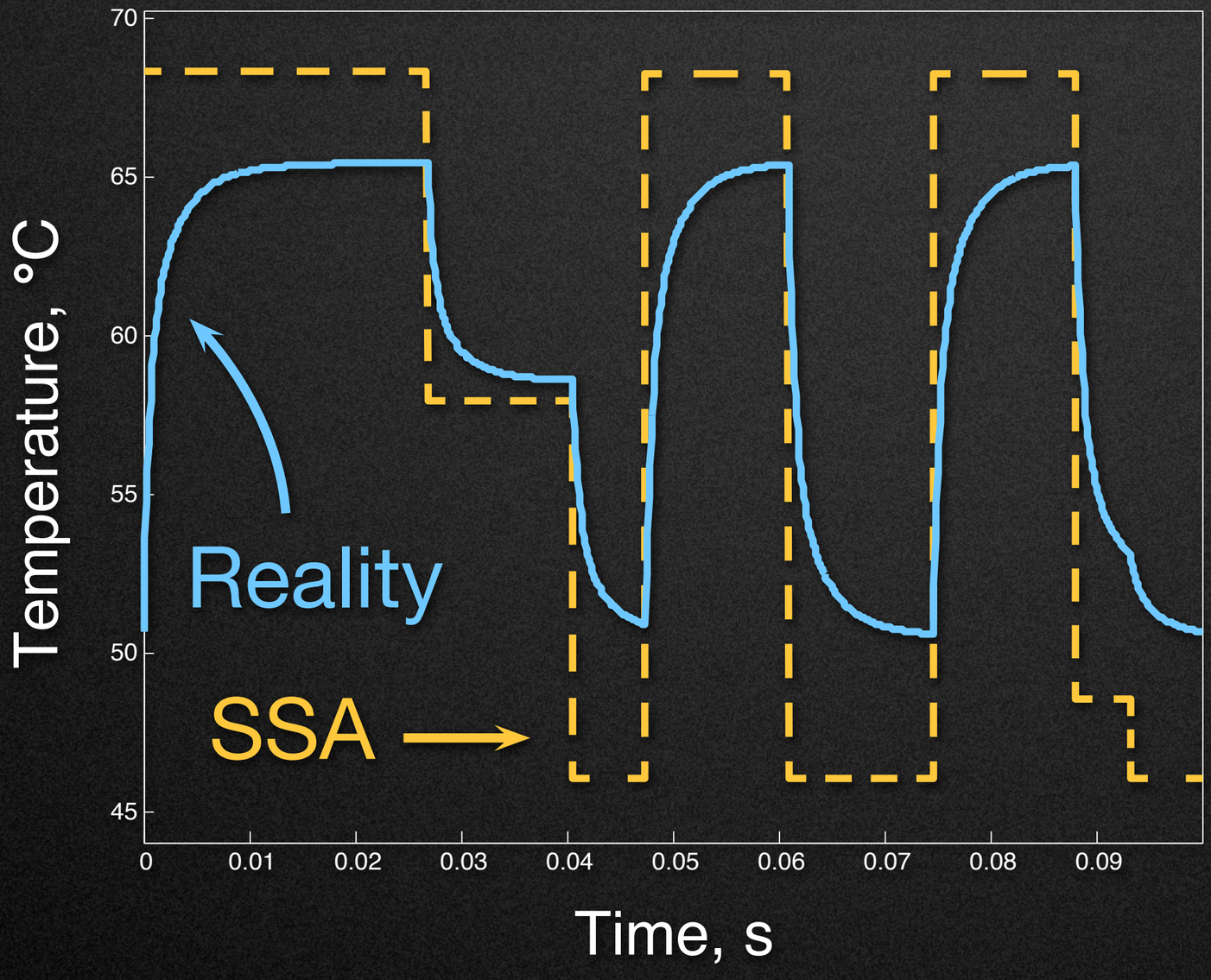



Successive simulations with the same power profile

… takes a long time to perform.

# The State of The Art (2)

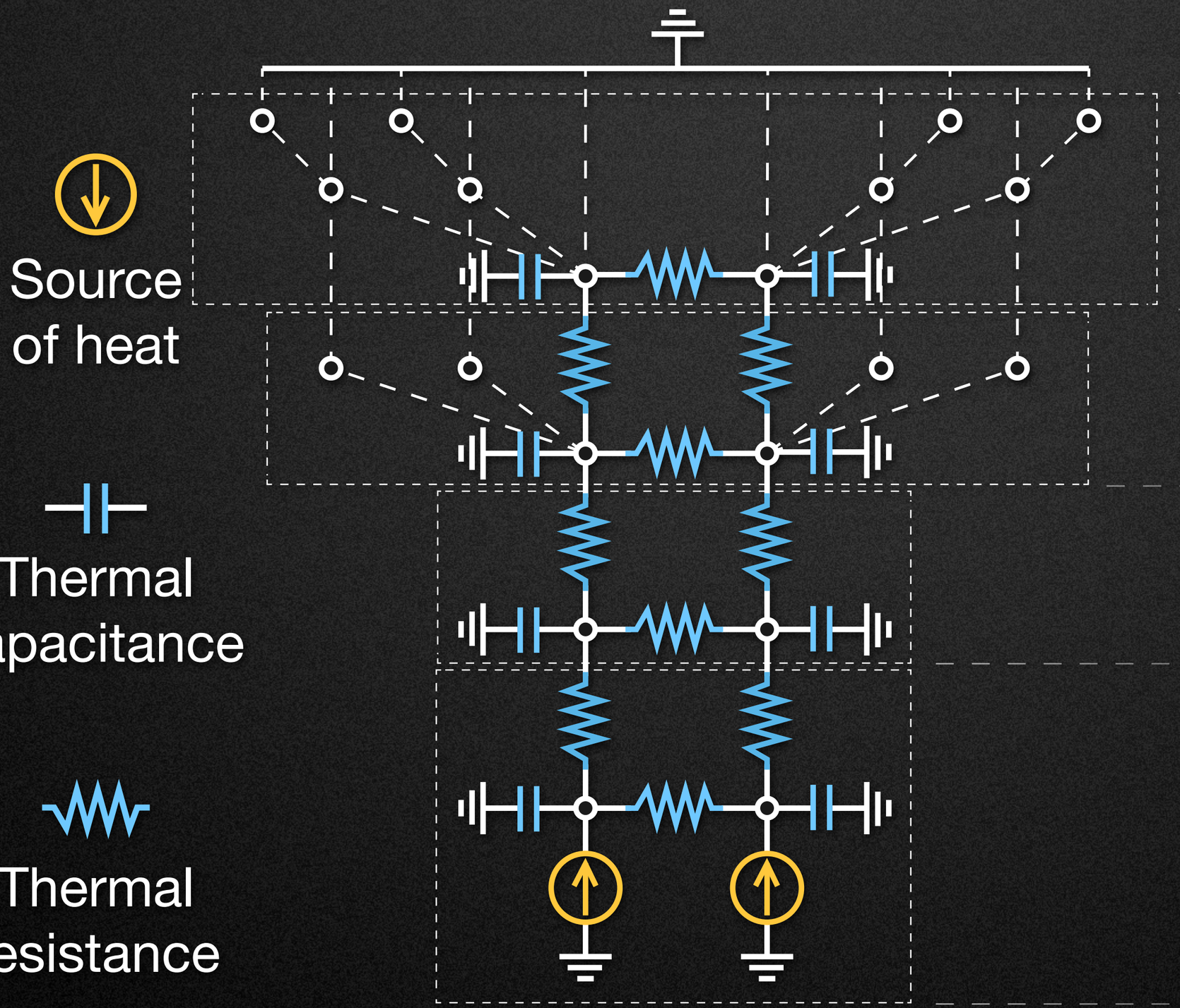
## Steady-State Approximation (SSA) using SSTA…




SSA assumes the system is always in the steady state

… gives a rough estimation.

# Thermal RC Circuit



Source of heat

Thermal capacitance

Thermal resistance

Heat sink

Heat spreader

Thermal interface material

Hot die

# Proposed Method (1)

Heat equation:

$$\mathbf{C}\frac{d\mathbf{T}(t)}{dt} + \mathbf{G}(\mathbf{T}(t) - \mathbf{T}_{\mathrm{amb}}) = \mathbf{P}(t)$$

Leakage inside

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Iterative solution:

$$\mathbf{T}_{i+1} = \mathbf{K}_i\,\mathbf{T}_i + \mathbf{B}_i\,\mathbf{P}_i$$

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TTA

SSDTA

$$\mathbf{T}_{\mathrm{start}} = \mathbf{T}_{\mathrm{end}}$$

# Proposed Method (2)

Huge system of linear equations:

$$\mathbf{A}\mathbf{X} = \mathbf{B}$$

$$N_\mathrm{s} N_\mathrm{n} \times N_\mathrm{s} N_\mathrm{n}$$

Number of steps in the power profile

Number of nodes in the thermal circuit

# Proposed Method (3)

We propose:

- Auxiliary transformation of the heat equation.
- Analytical solution via a condensed system.

We consider:

- Structure and sparseness of the system.

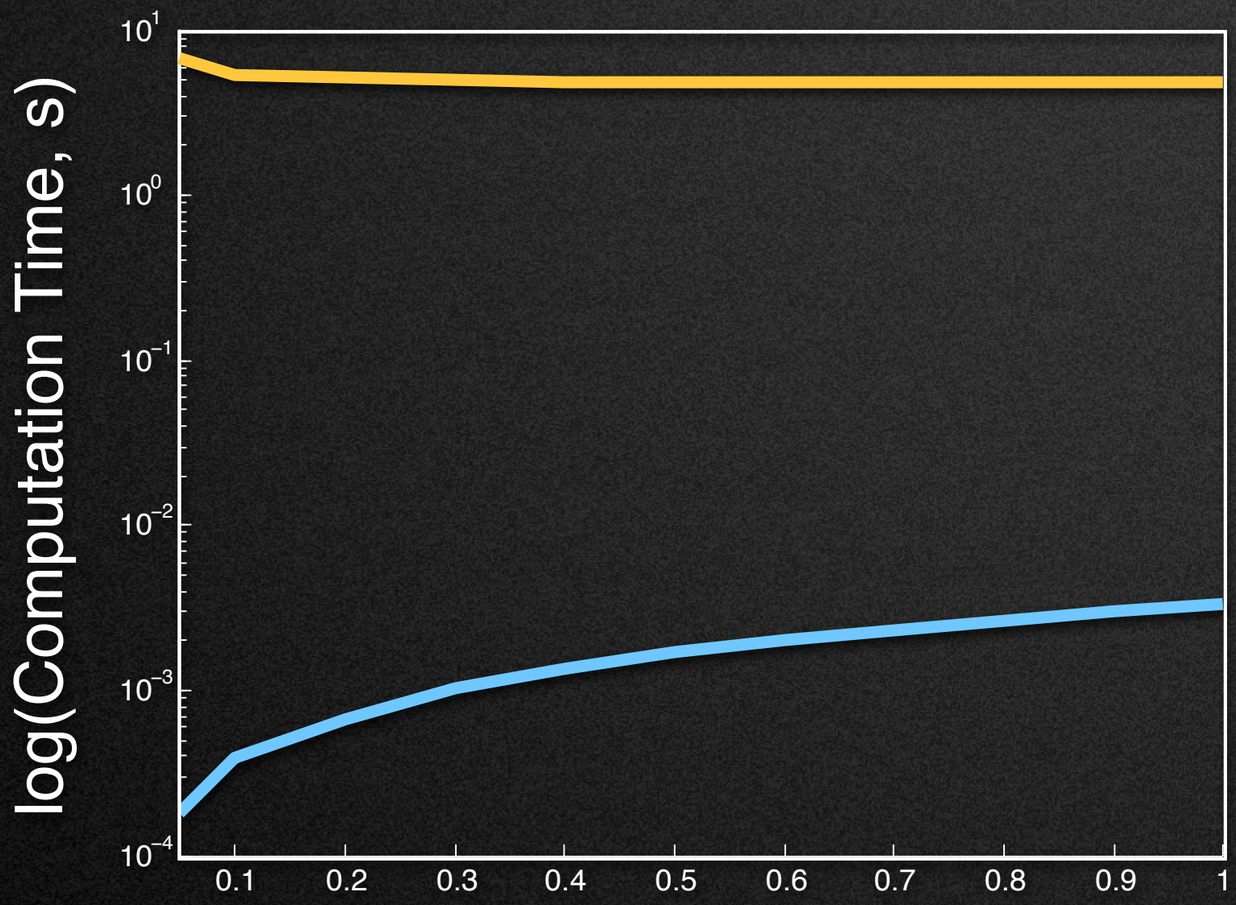
We deliver:

- Accurate and computationally cheap results.

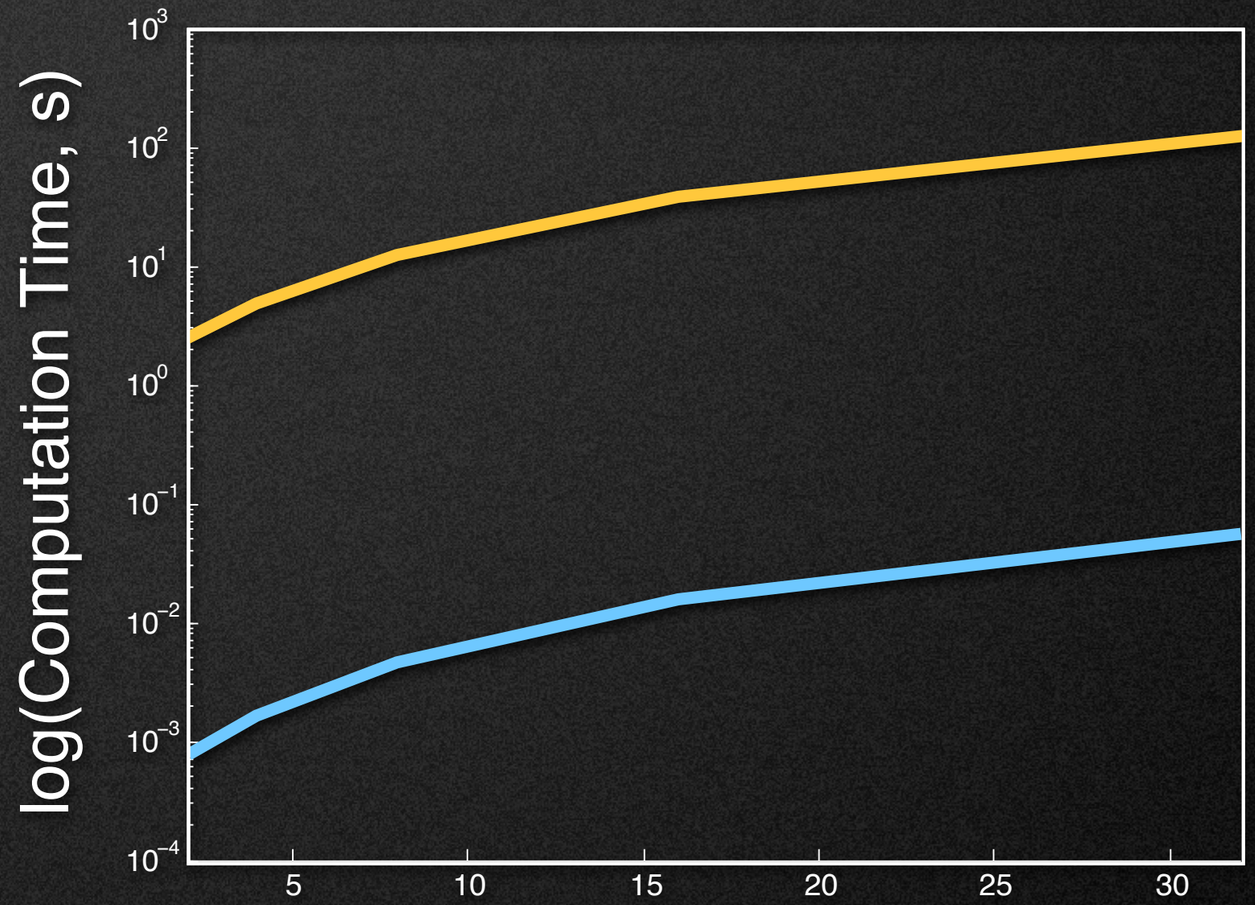
$$\propto \cancel{N_{\mathrm{s}}^{2}} N_{\mathrm{n}}^{3} \qquad N_{\mathrm{s}} \ggg N_{\mathrm{n}}$$

# Experimental Results (1)

Proposed Method outperforms TTA with HotSpot.

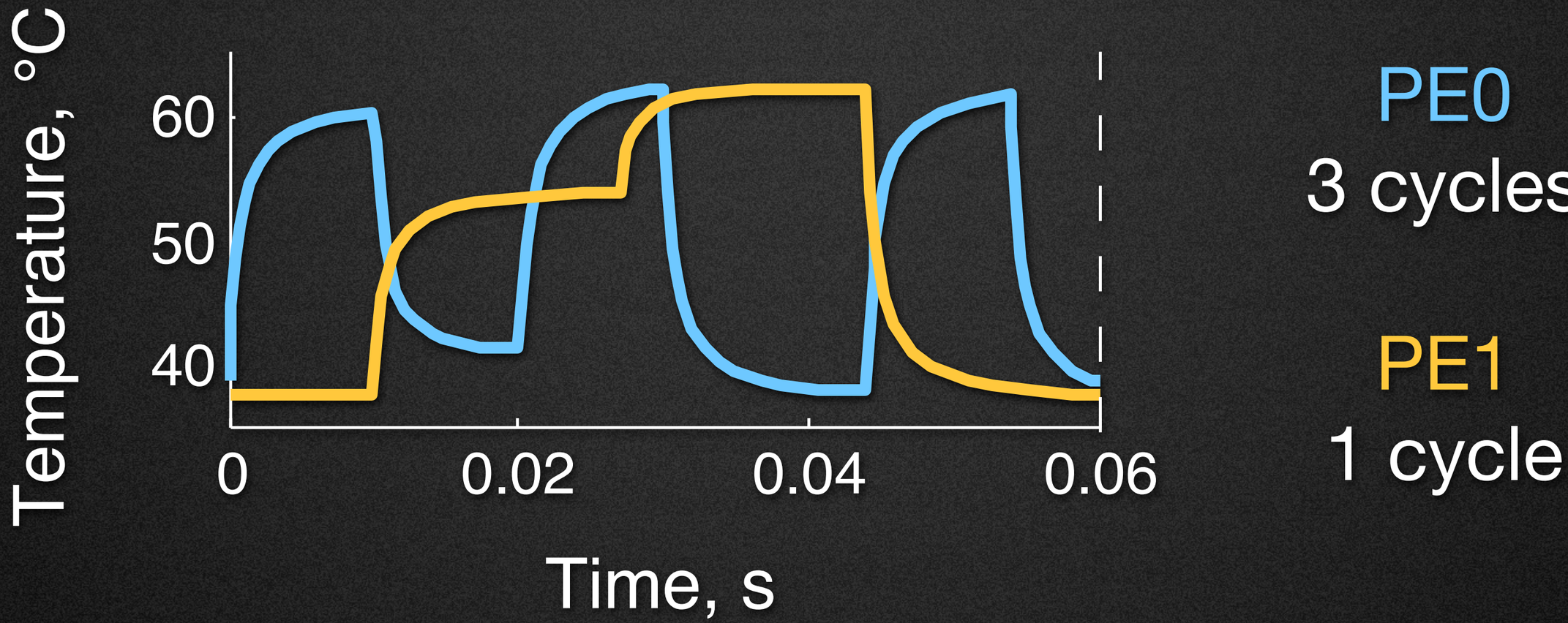



2000× faster




5000× faster

# Thermal Cycling Fatigue




Total damage depends on maximal temperature, amplitudes, and frequency of thermal cycles.

# Reliability Optimization: Motivation

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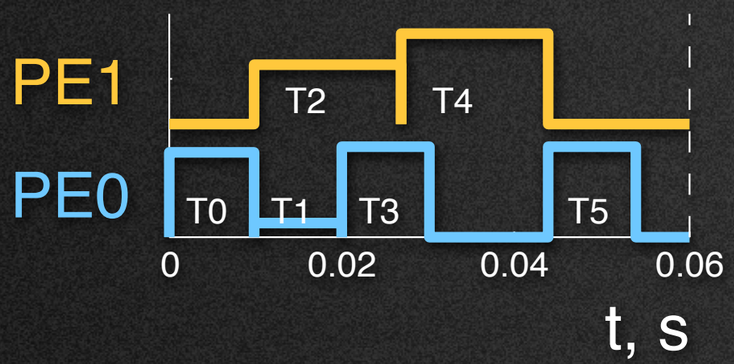
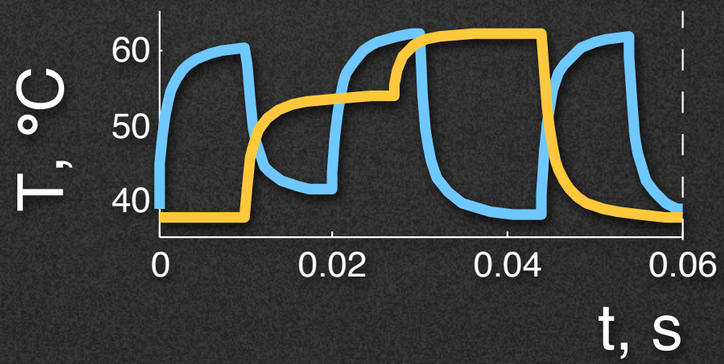
## Map & Schedule




## SSDTPs




3 cycles

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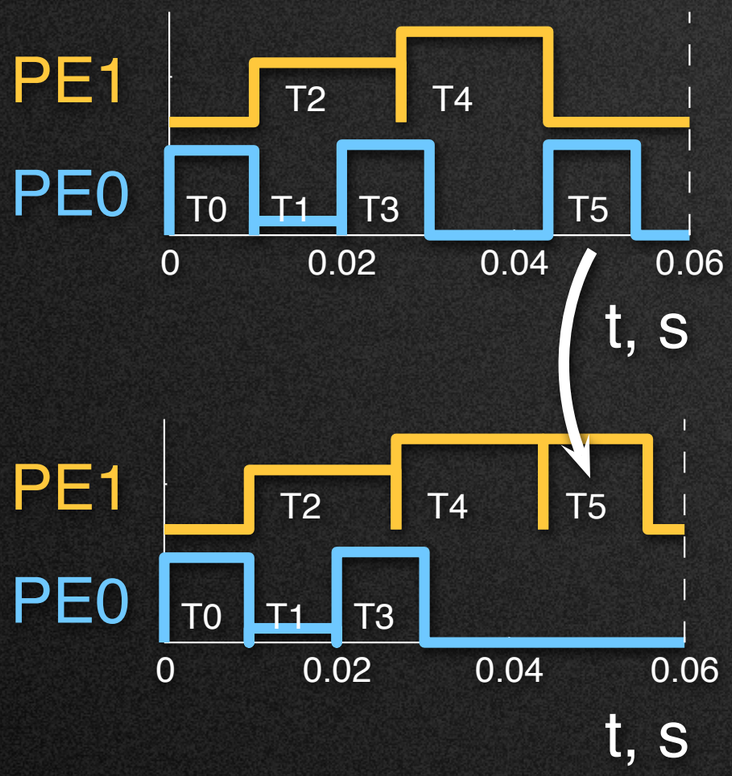


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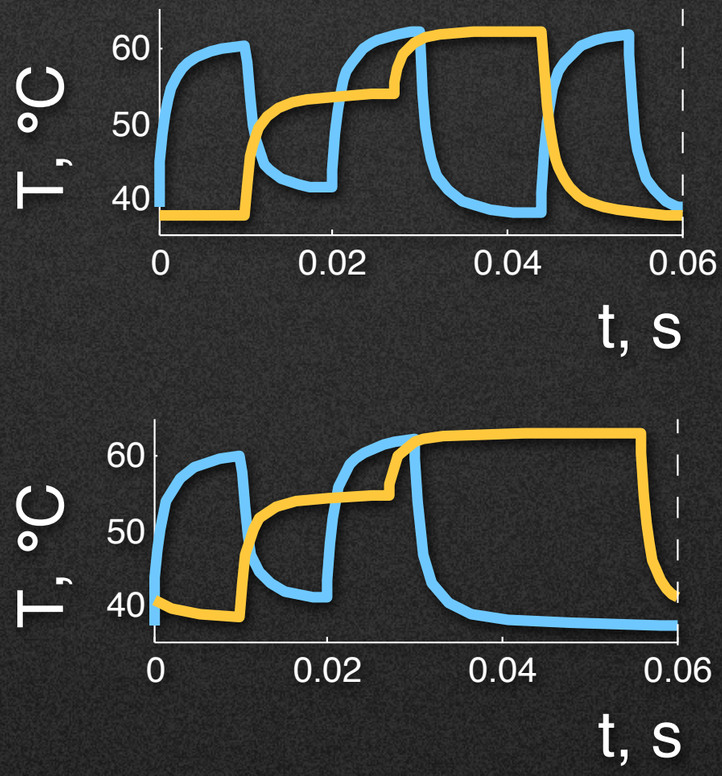


3 cycles

2 cycles

+45% lifetime

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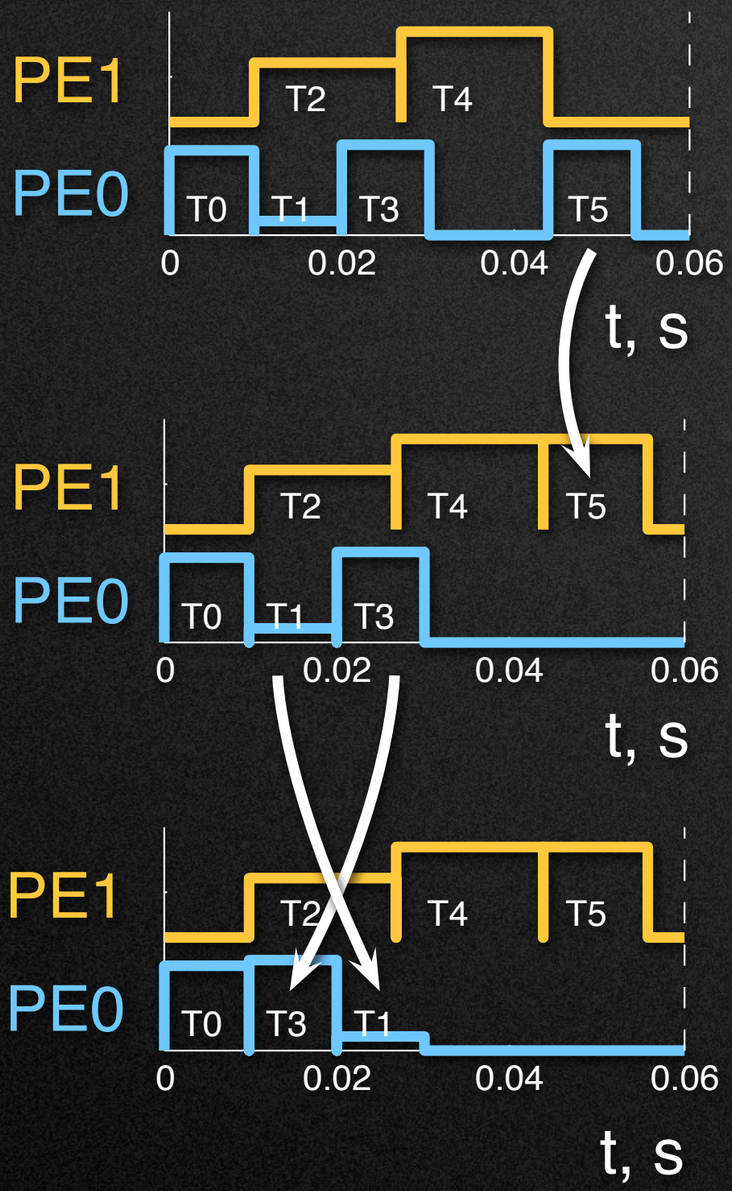
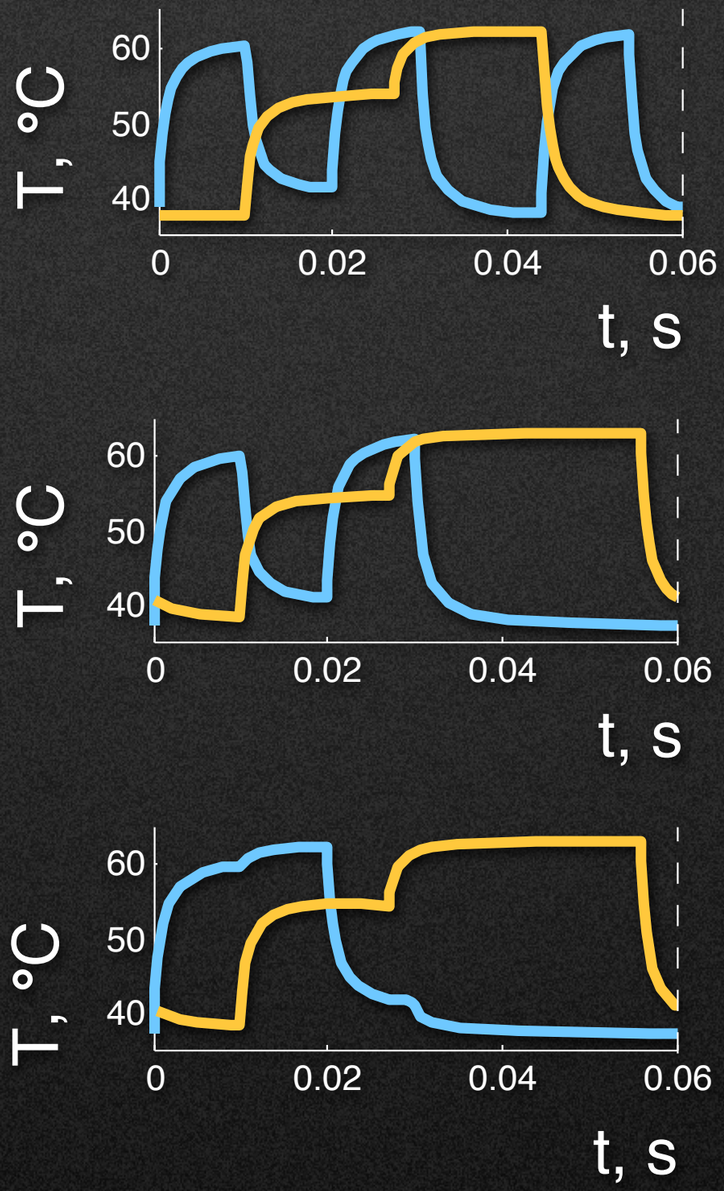



## SSDTPs




3 cycles

2 cycles

+45% lifetime

1 cycle

+55% lifetime

# Reliability Optimization: Summary

Goal:

- Decrease the thermal cycling (TC) fatigue in order to prolong the lifetime of the system.

Means:

- Employ a genetic algorithm to perform a temperature-aware mapping and scheduling.

Important:

- SSDTP is a must to address the TC fatigue.
- Do not compromise the energy efficiency.

# Experimental Results (2)

<u>Real-life example:</u>

- MPEG2 decoder.
- 34 tasks.
- 2 cores.

<u>Increase of the lifetime:</u>

- 24× using Proposed Method.
- 5× using TTA with HotSpot.
- 11× using Steady-State Approximation.

# Thank you!

Questions?