NSF CPS PI Meeting, June 2021

Hardware-Supported Timing-Critical Software in Lingua Franca

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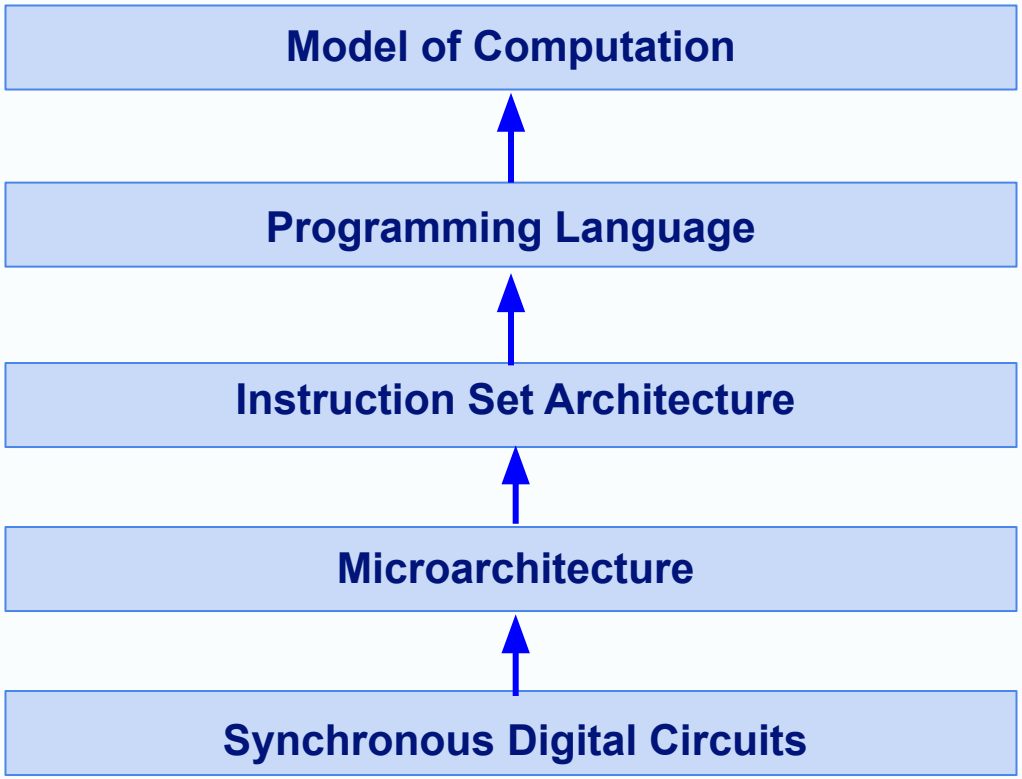
Timing Is Not in the Model!

Today, timing is considered a performance criterion. The notion of correctness doesn't include timing!



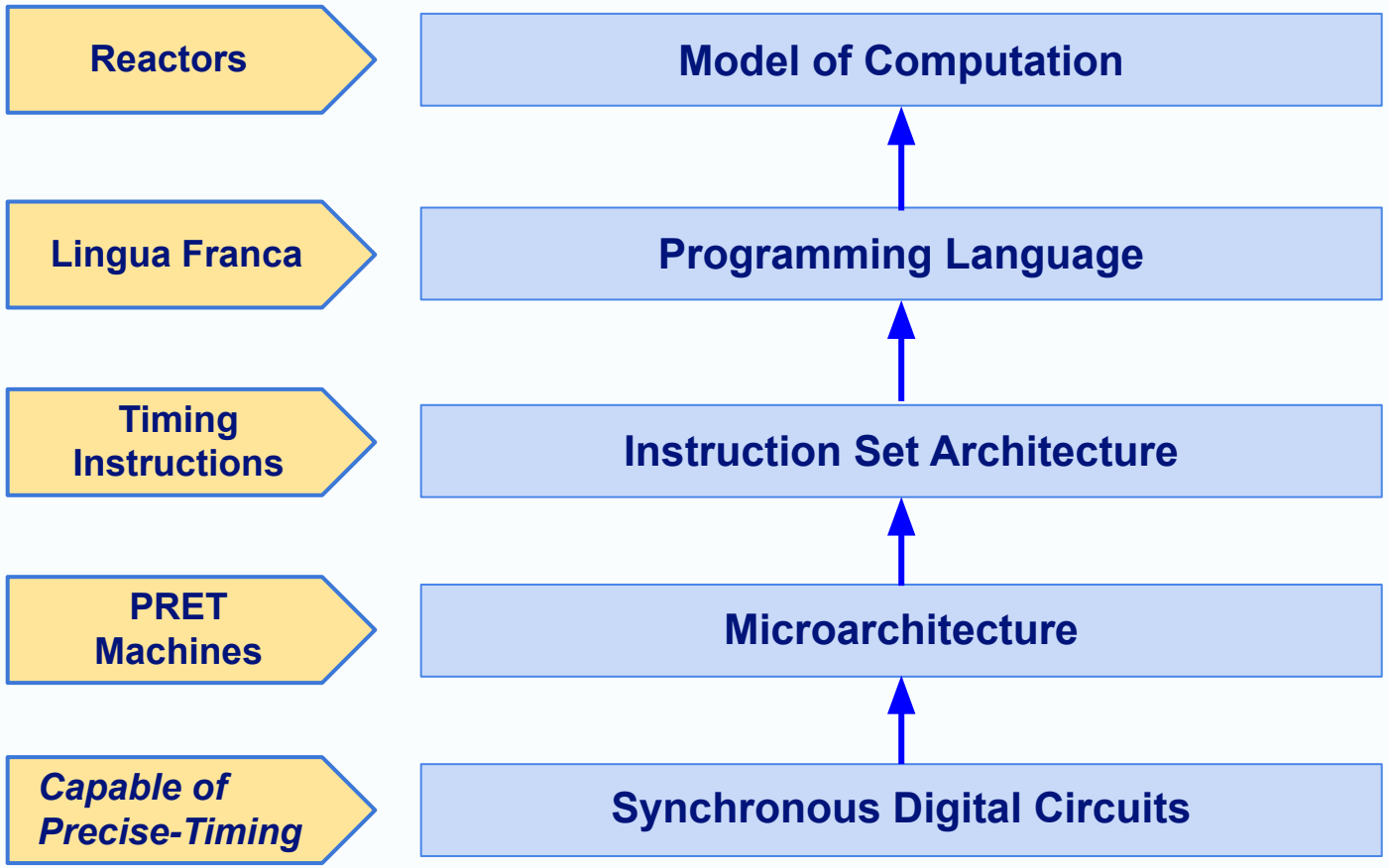
Without Precise Timing

Small changes in the hardware, software, or environment can cause big, unexpected changes in timing. As a result:

- Undetected timing-related hazards that threaten the reliability and safety of the system
- Need to pick the hardware at the first stage of design
  - Over-provisioned designs
  - Cannot take advantage of improvements in the hardware because the cost of re-testing and re-certification is too high
  - Stockpile parts to suffice for the complete production run

Slides from Edward Lee HVC'12

Adding Timing to the Layers of Abstraction



Precision-Timed Microarchitecture

MoC

PL

ISA

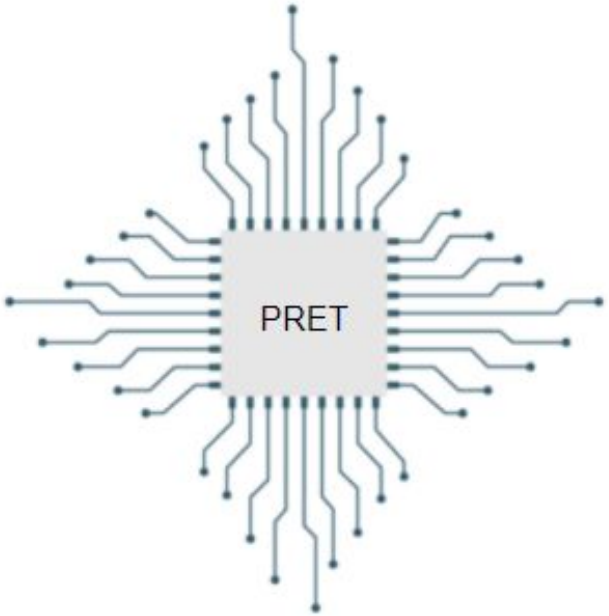
µarch

SDC

PRET: PREcision-**T**imed Processors

FlexPRET is the latest generation of PRET machines:

- ➔ 5-staged
- ➔ Fine-grained multi-threaded
- ➔ Designed specifically for mixed-criticality systems



Our goal in this project was to demonstrate that you can get excellent performance and still have control over timing.

https://github.com/pretis/flexpret

Michael Zimmer, David Broman, Chris Shaver, Edward A. Lee. "FlexPRET: A Processor Platform for Mixed-Criticality Systems. Proceedings of the 20th IEEE Real-Time and Embedded Technology and Application Symposium (RTAS), April, 2014.

Timing-Aware ISA

MoC

PL

ISA

µarch

SDC

- ➔ *get time high:* `GTH r1`
- ➔ *get time low:* `GTL r2`
- ➔ *delay until:* `DU r1,r2`
- ➔ *exception on expire:* `EE r1,r2`
- ➔ *deactivate exception on expire:* `DE`
- ➔ thread sleep: `TS`

Michael Zimmer, David Broman, Chris Shaver, Edward A. Lee. "FlexPRET: A Processor Platform for Mixed-Criticality Systems. Proceedings of the 20th IEEE Real-Time and Embedded Technology and Application Symposium (RTAS), April, 2014.

Lingua Franca: It's About Time

MoC
PL
ISA
µarch
SDC

Reactors
Model of Computation

- ➔ Timed
- ➔ Synchronous
- ➔ Deterministic
- ➔ Concurrent
- ➔ Event-driven

Establishes an unambiguous relationship between physical and logical time.

Lingua Franca
Coordination Language

- ➔ Polyglot
- ➔ Multi-core
- ➔ High-performance
- ➔ Low overhead
- ➔ Compiler + IDE

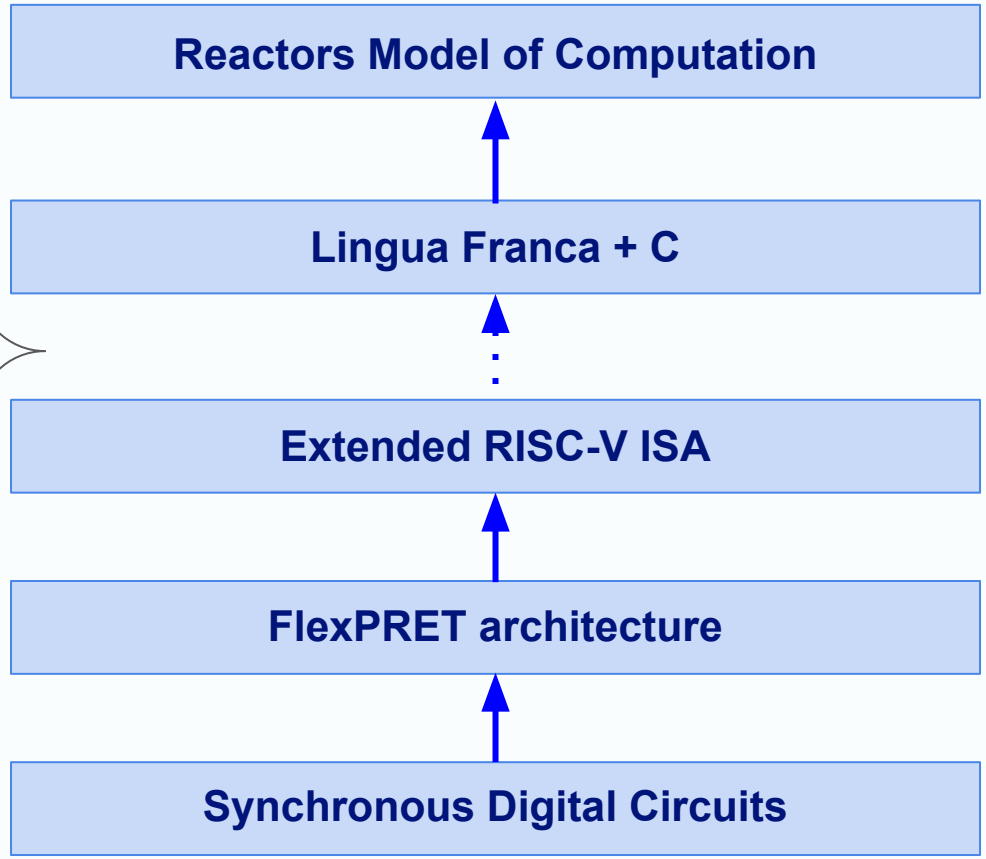
For specifying deterministic behaviors and imposing timing constraints.

https://repo.lf-lang.org

The FlexPRET Target for LF

- Run Bare-metal Lingua Franca on the FlexPRET architecture
- Provide a C* library with functions that contain inline assembly that use these special timing instructions
- Compile LF to C using these library functions

* We are starting with C, but will include other targets in the future.



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Acknowledgement

The core Lingua Franca software development team currently consists of: Soroush Bateni, Edward A. Lee, Shaokai Lin, Marten Lohstroh, Christian Menard, Alexander Schulz-Rosengarten, and Efsane Soyer.

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