

# Helping *Pythonistas* Become Microarchitects

Using Jupyter Notebooks and CIRCT/MLIR/LLVM

Zhiyang Ong

Department of Electrical and Computer Engineering  
College of Engineering,  
Texas A&M University  
College Station, TX

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- 1 Problems in Computer Architecture
- 2 New Golden Era of Computer Architecture, EDA, and Compiler Design
- 3 Python-based IC Design
- 4 Section 3

# Table of Contents

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- 2 New Golden Era of Computer Architecture, EDA, and Compiler Design
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# Problems in Computer Architecture

## Specifically with General-Purpose Processor Architectures

Golden Era of Computer Architecture (1980s till early 2000s):

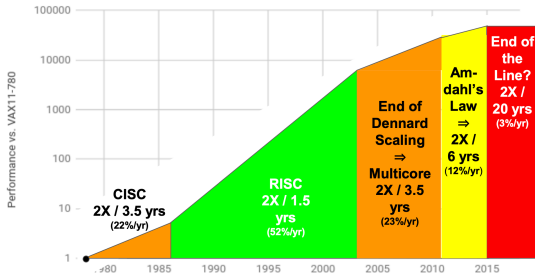
- **Memory Wall** [Wulf1995] [Hennessy1990] [Horowitz2023] [Solihin2002]
- **End of Dennard's scaling** [Dennard1974] [Haensch2006] [Chen2006] [Dennard2007] [Calhoun2008] [Iwai2009] and **Power Wall** [Keshavarzi2007]
- **Dark Silicon** [Esmaeilzadeh2011] [Esmaeilzadeh2012] [Rahmani2017] [Hurson2018]
- **ILP Wall** → **limitations of** [Hennessy2019, §1.11, pp. 39]
- **impending doom of Moore's law** [Duranton2019] [Kelleher2022]
- **decline of general-purpose processors** [Thompson2018]
- **Hardware Accelerator Wall** [Fuchs2019]

# Problems in Computer Architecture

## Specifically with General-Purpose Processor Architectures

### End of Growth of Single Program Speed?

40 years of Processor Performance



Based on SPECintCPU. Source: John Hennessy and David Patterson, Computer Architecture: A Quantitative Approach, 6/e. 2018

**Figure:** Plot of the performance of general-purpose processors over time, from 1980 till the late 2010s [Hennessy2018]



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# New Golden Era of Computer Architecture (1)

And, also for EDA and Compiler Design

Problems → Opportunities [Hennessy2019a]

**Domain-Specific Computing** [Hennessy2019] → **Heterogeneous System Architectures** [HSAFoundationAdministration2016] [Hwu2016] [Duranton2019]

**Hardware Security** [Gruss2017] [Szefer2018] [Duranton2021]

**Open-Source ISA** [Patterson2018b], and support ecosystem across the hardware/software stack

# New Golden Era of Computer Architecture (2)

And, also for EDA and Compiler Design

**Agile IC Design Methodologies** [Gerstlauer2001] [Hennesy2018]  
[Johnson2018a] + **Python-based IC Design**

**Domain-Specific Compilers** [Lattner2021a] + **Compilers for  
Heterogeneous Systems**

System-Technology Co-Optimization [Wu2021]:

- **system** → computer systems → hardware/software co-design
- **semiconductor manufacturing technology** (including semiconductor device engineering)





# New Golden Era of Computer Architecture (3)

And, also for EDA and Compiler Design

## Recent **Non- von Neumann Computing Paradigms and Technology Trends:**

- **in-memory computing** [Zhu2013] [Paul2014] [Williams2017a] [Theis2017] [Imani2020] [Wu2021]
- **hyperdimensional computing** [Imani2020] [Wu2021]
- **photonic ICs** [Topaloglu2015]
- **wafer-scale computing**
- **3-D ICs and high-bandwidth memory interconnects**
- **chiplet-based System-in-Package design**

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# Python-based IC Design: Options

Possible options:

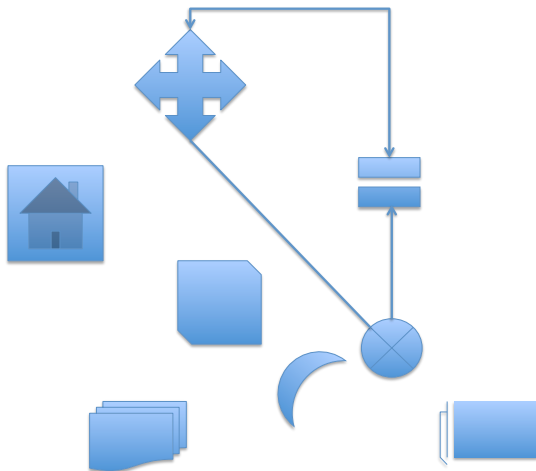
- **MyHDL** (old)
- **PyMTL** (Cornell University)
- **PyRTL** (University of California, Santa Barbara)
- **Jupyter Notebook + Python** -based IC design flow (supported by Google Colab)
- **CIRCT: Circuit IR Compilers and Tools** [Lattner2021]
  - LLVM (initially, Low Level Virtual Machine) [Lopes2014] [Pandey2015] [Sarda2015]
  - Multi-Level Intermediate Representation, MLIR (extension of LLVM ecosystem for domain-specific computing)

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# Slide Title 5

Slide Subtitle 5.



# New Golden Era of Computer Architecture, EDA, and Compiler Design

## Slide Subtitle 3

Problems → Opportunities

Domain-Specific Computing  
→ Heterogeneous System  
Architectures.

Statement 3.

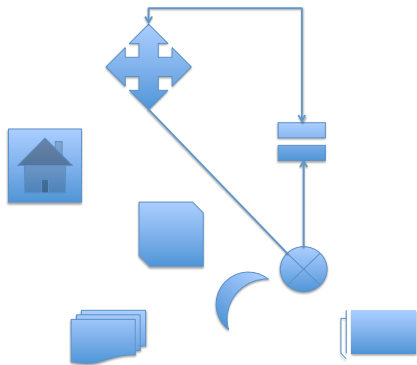


Figure: My caption [?, ?]



# References