CS 704 Version 5.1 (2024–25)

Advanced Computer Architecture

Dr. Muhammad Al-Hashimi

Credits 3

Prerequisite None • See *Undergrad Background*

Homepage www.hashimi.ws/cs704

Email cs704@hashimi.ws

Office Room 139 (B31) ✆ Ext. TBA

Graduate course on designs, organizations, and methods used to build computers. It combines a historical perspective of evolving technologies with a modern take on the current state of the art. Students gain unique, original insights into modern computers by reading technical articles, including seminal works in the field. Discussions and short presentations help to develop an understanding of architectural principles. I cover some background material to get the most out of reading. An optional small programming project allows some students to explore the GPU as a modern massively parallel architecture.

Topics

- ✎ **Evolving Power** Moore's law, Flynn's taxonomy, Amdahl's law, seminal machines and architectures from CDC6600 to the Frontier.
- ✎ **Instruction Set Design** The road to modern power-efficient RISC.
- ✎ **Instruction Level Parallelism** Pipelined processors, processor performance equation, multiple issue, dynamic scheduling, speculative and out-of-order, emerging security concerns.
- ✎ **Parallel Computers** The data flow computer, multithreading, SIMD, multiprocessors, multicores, and modern fine-grained parallelism.
- ✎ **Cache Memory** Reference locality and memory hierarchies, direct-mapped, associative and multilevel strategies, performance and design tradeoffs, coherence in parallel systems.
- ✎ **High Performance Computing** Bell's eleven rules of supercomputer design, modern supercomputing and high-performance applications.
- ✎ **Looking Ahead** Exascale and quantum computers: issues, architectures and challenges.

Resources Check announcement conversations in course group for reading schedules and material.

Undergrad Background Patterson and Hennessy, *Computer Organization & Design*, revised forth edition or later.

Assessment Weekly presentations, group discussions, and short techincal essays assess reading quality and grasp of course material.

50%	Weekly class presentations
35%	Semester work portfolio
15%	Final presentation

References

1. Mark D. Hill (Editor) et al., *Readings in Computer Architecture*, Morgan Kaufmann Series in Computer Architecture and Design 2000.
2. Daniel Siewiorek and Philip Koopman, *The Architecture of Supercomputers: Titan, a Case Study*, Academic Press 1991.
3. David B. Kirk and Wen-mei W. Hwu, *Programming Massively Parallel Processors, A Hands-on Approach*, 3rd ed., Morgan Kaufmann 2016.
4. David A. Bader (Editor), *Petascale Computing: Algorithms and Applications*, Chapman & Hall/CRC 2008.
5. Jeffrey S. Vetter (Editor), *Contemporary High Performance Computing: From Petascale toward Exascale* , Chapman & Hall/CRC 2013.
6. David Patterson and Andrew Waterman, *The RISC-V Reader: An Open Architecture Atlas*, Strawberry Canyon LLC.
7. W. Wayt Gibbs, *The Law of More*, from Understanding Supercomputing (Science Made Accessible Series), Sandy Fritz (Editor) 2002.
8. Chris Mack, *The Multiple Lives of Moore's Law*, IEEE Spectrum April 2015.
9. Olin Sibert, Phillip Porras, and Robert Lindell, *Intel 80x86 Processor Architecture: Pitfalls for Secure Systems*, Proceedings 1995 IEEE Symposium on Security and Privacy.
10. W. Daniel Hillis and Lewis W. Tucker, *The CM-5 Connection Machine: A Scalable Supercomputer*, Comm. ACM, November 1993.
11. P. Kocher et al., *Spectre Attacks: ACM Speculative Execution*, Comm. ACM, July 2020.
12. Dongarra, Luszczek1, Antoine, *The LINPACK Benchmark: past, present and future*, Concurrency Computat.: Pract. Exper., 2003.
13. Oreste Villa et al., *Scaling the Power Wall: A Path to Exascale*, SC14 (New Orleans) 2014.
14. S. Atchly et al., *Frontier: Exploring Exascale: The System Architecture of the First Exascale Supercomputer*, SC23 (Denver), 2023.
15. Eleanor Hutterer, *Not Magic… Quantum*, 1663, July 2016.
16. D-Wave 2000Q Technology Overview, 2018.
17. M. Veldhorst et al., *Silicon CMOS architecture for a spin-based quantum computer*, Nature Communications, December 2017.