

The new equations for policy 2,

Access time when we can hide precharge delay = $T_{rcd} + T_{cas} + T_{ddr}$

Access time when precharge delay is in the critical path = $T_{rcd} + T_{cas} + T_{rp} + T_{ddr}$

Equation 1 will now become,

$$\begin{aligned} & \frac{r}{100}(T_{cas} + T_{ddr})A + \frac{100-r}{100}(T_{rp} + T_{rcd} + T_{cas} + T_{ddr})A \\ & = 0.9 \times (T_{rcd} + T_{cas} + T_{ddr})A + 0.1 \times (T_{rcd} + T_{cas} + T_{rp} + T_{ddr})A \\ & \Rightarrow r = 90 \times \left(\frac{T_{rp}}{T_{rp} + T_{rcd}} \right) \\ & r = 90 \times 15/30 = 45\% \end{aligned}$$

- c. For any row buffer hit rate, policy 2 requires additional $r \times (2 + 4)$ nJ per access. If $r = 50\%$, then policy 2 requires 3nJ of additional energy.
- 2.19 Hibernating will be useful when the static energy saved in DRAM is at least equal to the energy required to copy from DRAM to Flash and then back to DRAM. DRAM dynamic energy to read/write is negligible compared to Flash and can be ignored.

$$\begin{aligned} \text{Time} &= \frac{8 \times 10^9 \times 2 \times 2.56 \times 10^{-6}}{64 \times 1.6} \\ &= 400 \text{ seconds} \end{aligned}$$

The factor 2 in the above equation is because to hibernate and wakeup, both Flash and DRAM have to be read and written once.

- 2.20
- Yes. The application and production environment can be run on a VM hosted on a development machine.
 - Yes. Applications can be redeployed on the same environment on top of VMs running on different hardware. This is commonly called business continuity.
 - No. Depending on support in the architecture, virtualizing I/O may add significant or very significant performance overheads.
 - Yes. Applications running on different virtual machines are isolated from each other.
 - Yes. See "Devirtualizable virtual machines enabling general, single-node, online maintenance," David Lowell, Yasushi Saito, and Eileen Samberg, in the Proceedings of the 11th ASPLOS, 2004, pages 211–223.
- 2.21
- Programs that do a lot of computation but have small memory working sets and do little I/O or other system calls.
 - The slowdown above was 60% for 10%, so 20% system time would run 120% slower.
 - The median slowdown using pure virtualization is 10.3, while for para virtualization the median slowdown is 3.76.

Computer Architecture A Quantitative Approach

Solution 5

John L. Hennessy, David A. Patterson



Computer Architecture A Quantitative Approach Solution 5

Computer Architecture John L. Hennessy, David A. Patterson, Krste Asanović, 2012 The computing world is in the middle of a revolution mobile clients and cloud computing have emerged as the dominant paradigms driving programming and hardware innovation This book focuses on the shift exploring the ways in which software and technology in the cloud are accessed by cell phones tablets laptops and more *Computer Architecture* John L. Hennessy, David A. Patterson, 2017-11-23 *Computer Architecture A Quantitative Approach* Sixth Edition has been considered essential reading by instructors students and practitioners of computer design for over 20 years The sixth edition of this classic textbook from Hennessy and Patterson winners of the 2017 ACM A M Turing Award recognizing contributions of lasting and major technical importance to the computing field is fully revised with the latest developments in processor and system architecture The text now features examples from the RISC V RISC Five instruction set architecture a modern RISC instruction set developed and designed to be a free and openly adoptable standard It also includes a new chapter on domain specific architectures and an updated chapter on warehouse scale computing that features the first public information on Google s newest WSC True to its original mission of demystifying computer architecture this edition continues the longstanding tradition of focusing on areas where the most exciting computing innovation is happening while always keeping an emphasis on good engineering design Winner of a 2019 Textbook Excellence Award Texty from the Textbook and Academic Authors Association Includes a new chapter on domain specific architectures explaining how they are the only path forward for improved performance and energy efficiency given the end of Moore s Law and Dennard scaling Features the first publication of several DSAs from industry Features extensive updates to the chapter on warehouse scale computing with the first public information on the newest Google WSC Offers updates to other chapters including new material dealing with the use of stacked DRAM data on the performance of new NVIDIA Pascal GPU vs new AVX 512 Intel Skylake CPU and extensive additions to content covering multicore architecture and organization Includes Putting It All Together sections near the end of every chapter providing real world technology examples that demonstrate the principles covered in each chapter Includes review appendices in the printed text and additional reference appendices available online Includes updated and improved case studies and exercises ACM named John L Hennessy and David A Patterson recipients of the 2017 ACM A M Turing Award for pioneering a systematic quantitative approach to the design and evaluation of computer architectures with enduring impact on the microprocessor industry **Solutions to Selected Exercises in Computer Architecture** Thomas E. Willis, Allan D. Knies, 1996 This solution manual for the second edition of *Computer Architecture A Quantitative Approach* provides example solutions for many of the problems in the text The manual covers all eight chapters of CA AQA in addition to the two appendices that include exercises **Computer Organization and Design RISC-V Edition** David A.

Patterson, John L. Hennessy, 2017-05-12 The new RISC V Edition of Computer Organization and Design features the RISC V open source instruction set architecture the first open source architecture designed to be used in modern computing environments such as cloud computing mobile devices and other embedded systems With the post PC era now upon us Computer Organization and Design moves forward to explore this generational change with examples exercises and material highlighting the emergence of mobile computing and the Cloud Updated content featuring tablet computers Cloud infrastructure and the x86 cloud computing and ARM mobile computing devices architectures is included An online companion Web site provides advanced content for further study appendices glossary references and recommended reading Features RISC V the first such architecture designed to be used in modern computing environments such as cloud computing mobile devices and other embedded systems Includes relevant examples exercises and material highlighting the emergence of mobile computing and the cloud

Computer Architecture John L. Hennessy, David A. Patterson, 2002-05-29 This best selling title considered for over a decade to be essential reading for every serious student and practitioner of computer design has been updated throughout to address the most important trends facing computer designers today In this edition the authors bring their trademark method of quantitative analysis not only to high performance desktop machine design but also to the design of embedded and server systems They have illustrated their principles with designs from all three of these domains including examples from consumer electronics multimedia and web technologies and high performance computing The book retains its highly rated features Fallacies and Pitfalls which share the hard won lessons of real designers Historical Perspectives which provide a deeper look at computer design history Putting it all Together which present a design example that illustrates the principles of the chapter Worked Examples which challenge the reader to apply the concepts theories and methods in smaller scale problems and Cross Cutting Issues which show how the ideas covered in one chapter interact with those presented in others In addition a new feature Another View presents brief design examples in one of the three domains other than the one chosen for Putting It All Together The authors present a new organization of the material as well reducing the overlap with their other text Computer Organization and Design A Hardware Software Approach 2 e and offering more in depth treatment of advanced topics in multithreading instruction level parallelism VLIW architectures memory hierarchies storage devices and network technologies Also new to this edition is the adoption of the MIPS 64 as the instruction set architecture In addition to several online appendixes two new appendixes will be printed in the book one contains a complete review of the basic concepts of pipelining the other provides solutions a selection of the exercises Both will be invaluable to the student or professional learning on her own or in the classroom Hennessy and Patterson continue to focus on fundamental techniques for designing real machines and for maximizing their cost performance Presents state of the art design examples including IA 64 architecture and its first implementation the Itanium Pipeline designs for Pentium III and Pentium IV The cluster that runs the Google search engine EMC storage systems and their performance Sony Playstation 2

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Computer Organization and Design David A. Patterson, John L. Hennessy, 2012 Rev ed of Computer organization and design John L Hennessy David A Patterson 1998

Computer Organization V. Carl Hamacher, Zvonko G. Vranesic, Safwat G. Zaky, 1990

ARM System Developer's Guide Andrew Sloss, Dominic Symes, Chris Wright, 2004-05-10 Over the last ten years the ARM architecture has become one of the most pervasive architectures in the world with more than 2 billion ARM based processors embedded in products ranging from cell phones to automotive braking systems A world wide community of ARM developers in semiconductor and product design companies includes software developers system designers and hardware engineers To date no book has directly addressed their need to develop the system and software for an ARM based system This text fills that gap This book provides a comprehensive description of the operation of the ARM core from a developer s perspective with a clear emphasis on software It demonstrates not only how to write efficient ARM software in C and assembly but also how to optimize code Example code throughout the book can be integrated into commercial products or used as templates to enable quick creation of productive software The book covers both the ARM and Thumb instruction sets covers Intel s XScale Processors outlines distinctions among the versions of the ARM architecture demonstrates how to implement DSP algorithms explains exception and interrupt handling describes the cache technologies that surround the ARM cores as well as the most efficient memory management techniques A final chapter looks forward to the future of the ARM architecture considering ARMv6 the latest change to the instruction set which has been designed to improve the DSP and media processing capabilities of the architecture No other book describes the ARM core from a system and software perspective Author team combines extensive ARM software engineering experience with an in depth knowledge of ARM developer needs Practical executable code is fully explained in the book and available on the publisher s Website Includes a simple embedded operating system

Modern Processor Design John Paul Shen, Mikko H. Lipasti, 2013-07-30 Conceptual and precise Modern Processor Design brings together numerous microarchitectural techniques in a clear understandable framework that is easily accessible to both graduate and undergraduate students Complex practices are distilled into foundational principles to reveal the authors

insights and hands on experience in the effective design of contemporary high performance micro processors for mobile desktop and server markets Key theoretical and foundational principles are presented in a systematic way to ensure comprehension of important implementation issues The text presents fundamental concepts and foundational techniques such as processor design pipelined processors memory and I O systems and especially superscalar organization and implementations Two case studies and an extensive survey of actual commercial superscalar processors reveal real world developments in processor design and performance A thorough overview of advanced instruction flow techniques including developments in advanced branch predictors is incorporated Each chapter concludes with homework problems that will institute the groundwork for emerging techniques in the field and an introduction to multiprocessor systems

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Computer Organization and Design John L. Hennessy, David A. Patterson, 2000

Essentials of Computer Organization and Architecture Linda Null, Julia Lobur, 2014-02-12 Updated and revised The Essentials of Computer Organization and Architecture Third Edition is a comprehensive resource that addresses all of the necessary organization and architecture topics yet is appropriate for the one term course

Principles of Computer System Design Jerome H. Saltzer, M. Frans Kaashoek, 2009-05-21 Principles of Computer System Design is the first textbook to take a principles based approach to the computer system design It identifies examines and illustrates fundamental concepts in computer system design that are common across operating systems networks database systems distributed systems programming languages software engineering security fault tolerance and architecture Through carefully analyzed case studies from each of these disciplines it demonstrates how to apply these concepts to tackle practical system design problems To support the focus on design the text identifies and explains abstractions that have proven successful in practice such as remote procedure call client service organization file systems data integrity consistency and authenticated messages Most computer systems are built using a handful of such abstractions The text describes how these abstractions are implemented demonstrates how they are used in different systems and prepares the reader to apply them in future designs The book is recommended for junior and senior undergraduate students in Operating Systems Distributed Systems Distributed Operating Systems and or Computer Systems Design courses and professional computer systems designers Concepts of computer system design guided by fundamental principles Cross cutting approach that identifies abstractions common to networking operating systems transaction systems distributed systems architecture and software engineering Case studies that make the abstractions real naming DNS and the URL file systems the UNIX file system clients

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A Practical Introduction to Computer Architecture Daniel Page,2009-04-21 It is a great pleasure to write a preface to this book In my view the content is unique in that it blends traditional teaching approaches with the use of mathematics and a mainstream Hardware Design Language HDL as formalisms to describe key concepts The book keeps the machine separate from the application by strictly following a bottom up approach it starts with transistors and logic gates and only introduces assembly language programs once their execution by a processor is clearly defined Using a HDL Verilog in this case rather than static circuit diagrams is a big deviation from traditional books on computer architecture Static circuit diagrams cannot be explored in a hands on way like the corresponding Verilog model can In order to understand why I consider this shift so important one must consider how computer architecture a subject that has been studied for more than 50 years has evolved In the pioneering days computers were constructed by hand An entire computer could just about be described by drawing a circuit diagram Initially such diagrams consisted mostly of analogue components before later moving toward digital logic gates The advent of digital electronics led to more complex cells such as half adders ip ops and decoders being recognised as useful building blocks

Computer Architecture John L. Hennessy,David A. Patterson,2006-11-03 The era of seemingly unlimited growth in processor performance is over single chip architectures can no longer overcome the performance limitations imposed by the power they consume and the heat they generate Today Intel and other semiconductor firms are abandoning the single fast processor model in favor of multi core microprocessors chips that combine two or more processors in a single package In the fourth edition of Computer Architecture the authors focus on this historic shift increasing their coverage of multiprocessors and exploring the most effective ways of achieving parallelism as the key to unlocking the power of multiple processor architectures Additionally the new edition has expanded and updated coverage of design topics beyond processor performance including power reliability availability and dependability CD System Requirements PDF Viewer The CD material includes PDF documents that you can read with a PDF viewer such as Adobe Acrobat or Adobe Reader Recent versions of Adobe Reader for some platforms are included on the CD HTML Browser The navigation framework on this CD is delivered in HTML and JavaScript It is recommended that you install the latest version of your favorite HTML browser to view this CD The content has been verified under Windows XP with the following browsers Internet Explorer 6 0 Firefox 1 5 under Mac OS X Panther with the following browsers Internet Explorer 5 2 Firefox 1 0 6 Safari 1 3 and under Mandriva Linux 2006 with the following browsers Firefox 1 0 6 Konqueror 3 4 2 Mozilla 1 7 11 The content is designed to be viewed in a browser window that is at least 720 pixels wide You may find the content does not display well if your display is not set to at least 1024x768

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information systems and provides an overview of its components Subsequent sections discuss the representation of data in the computer hardware architecture and operational concepts the basics of computer networking system software and operating systems and various interconnected systems and components Students are introduced to the material using ideas already familiar to them allowing them to gradually build upon what they have learned without being overwhelmed and develop a deeper knowledge of computer architecture

STRUCTURED COMPUTER ORGANIZATION, 1996 *Modern Computer Architecture and Organization* Jim Ledin, 2020-04-30 A no nonsense practical guide to current and future processor and computer architectures enabling you to design computer systems and develop better software applications across a variety of domains Key Features Understand digital circuitry with the help of transistors logic gates and sequential logic Examine the architecture and instruction sets of x86 x64 ARM and RISC V processors Explore the architecture of modern devices such as the iPhone X and high performance gaming PCs Book Description Are you a software developer systems designer or computer architecture student looking for a methodical introduction to digital device architectures but overwhelmed by their complexity This book will help you to learn how modern computer systems work from the lowest level of transistor switching to the macro view of collaborating multiprocessor servers You ll gain unique insights into the internal behavior of processors that execute the code developed in high level languages and enable you to design more efficient and scalable software systems The book will teach you the fundamentals of computer systems including transistors logic gates sequential logic and instruction operations You will learn details of modern processor architectures and instruction sets including x86 x64 ARM and RISC V You will see how to implement a RISC V processor in a low cost FPGA board and how to write a quantum computing program and run it on an actual quantum computer By the end of this book you will have a thorough understanding of modern processor and computer architectures and the future directions these architectures are likely to take What you will learn Get to grips with transistor technology and digital circuit principles Discover the functional elements of computer processors Understand pipelining and superscalar execution Work with floating point data formats Understand the purpose and operation of the supervisor mode Implement a complete RISC V processor in a low cost FPGA Explore the techniques used in virtual machine implementation Write a quantum computing program and run it on a quantum computer Who this book is for This book is for software developers computer engineering students system designers reverse engineers and anyone looking to understand the architecture and design principles underlying modern computer systems from tiny embedded devices to warehouse size cloud server farms A general understanding of computer processors is helpful but not required

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