

# **Low-Power CMOS Circuits**

Technology, Logic Design  
and CAD Tools

**Christian Piguet**



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# Low Power Cmos Circuits Technology Logic

**Kung Yao**



## **Low Power Cmos Circuits Technology Logic:**

**Low-Power CMOS Circuits** Christian Piguet, 2018-10-03 The power consumption of microprocessors is one of the most important challenges of high performance chips and portable devices In chapters drawn from Piguet s recently published *Low Power Electronics Design Low Power CMOS Circuits Technology Logic Design and CAD Tools* addresses the design of low power circuitry in deep submicron technologies It provides a focused reference for specialists involved in designing low power circuitry from transistors to logic gates The book is organized into three broad sections for convenient access The first examines the history of low power electronics along with a look at emerging and possible future technologies It also considers other technologies such as nanotechnologies and optical chips that may be useful in designing integrated circuits The second part explains the techniques used to reduce power consumption at low levels These include clock gating leakage reduction interconnecting and communication on chips and adiabatic circuits The final section discusses various CAD tools for designing low power circuits This section includes three chapters that demonstrate the tools and low power design issues at three major companies that produce logic synthesizers Providing detailed examinations contributed by leading experts *Low Power CMOS Circuits Technology Logic Design and CAD Tools* supplies authoritative information on how to design and model for high performance with low power consumption in modern integrated circuits It is a must read for anyone designing modern computers or embedded systems *Low Power Vlsi Design And Technology* Farid N Najm, Garey K-h

Yeap, 1996-08-30 Low power and low energy VLSI has become an important issue in today s consumer electronics This book is a collection of pioneering applied research papers in low power VLSI design and technology A comprehensive introductory chapter presents the current status of the industry and academic research in the area of low power VLSI design and technology Other topics cover logic synthesis floorplanning circuit design and analysis from the perspective of low power requirements The readers will have a sampling of some key problems in this area as the low power solutions span the entire spectrum of the design process The book also provides excellent references on up to date research and development issues with practical solution techniques *Low Power Digital CMOS Design* Anantha P. Chandrakasan, Robert W.

Brodersen, 2012-12-06 Power consumption has become a major design consideration for battery operated portable systems as well as high performance desktop systems Strict limitations on power dissipation must be met by the designer while still meeting ever higher computational requirements A comprehensive approach is thus required at all levels of system design ranging from algorithms and architectures to the logic styles and the underlying technology Potentially one of the most important techniques involves combining architecture optimization with voltage scaling allowing a trade off between silicon area and low power operation Architectural optimization enables supply voltages of the order of 1 V using standard CMOS technology Several techniques can also be used to minimize the switched capacitance including representation optimizing signal correlations minimizing spurious transitions optimizing sequencing of operations activity driven power down etc The

high efficiency of DC DC converter circuitry required for efficient low voltage and low current level operation is described by Stratakis Sullivan and Sanders The application of various low power techniques to a chip set for multimedia applications shows that orders of magnitude reduction in power consumption is possible The book also features an analysis by Professor Meindl of the fundamental limits of power consumption achievable at all levels of the design hierarchy Svensson of ISI describes emerging adiabatic switching techniques that can break the CV<sup>2</sup>f barrier and reduce the energy per computation at a fixed voltage Srivastava of AT T presents the application of aggressive shut down techniques to microprocessor applications

*Low-Power Digital VLSI Design* Abdellatif Bellaouar, Mohamed Elmasry, 2012-12-06 Low Power Digital VLSI Design Circuits and Systems addresses both process technologies and device modeling Power dissipation in CMOS circuits several practical circuit examples and low power techniques are discussed Low voltage issues for digital CMOS and BiCMOS circuits are emphasized The book also provides an extensive study of advanced CMOS subsystem design A low power design methodology is presented with various power minimization techniques at the circuit logic architecture and algorithm levels Features Low voltage CMOS device modeling technology files design rules Switching activity concept low power guidelines to engineering practice Pass transistor logic families Power dissipation of I/O circuits Multi and low VT CMOS logic static power reduction circuit techniques State of the art design of low voltage BiCMOS and CMOS circuits Low power techniques in CMOS SRAMS and DRAMS Low power on chip voltage down converter design Numerous advanced CMOS subsystems e.g. adders multipliers data path memories regular structures phase locked loops with several design options trading power delay and area Low power design methodology power estimation techniques Power reduction techniques at the logic architecture and algorithm levels More than 190 circuits explained at the transistor level

Practical Low Power Digital VLSI Design Gary K. Yeap, 2012-12-06 Practical Low Power Digital VLSI Design emphasizes the optimization and trade off techniques that involve power dissipation in the hope that the readers are better prepared the next time they are presented with a low power design problem The book highlights the basic principles methodologies and techniques that are common to most CMOS digital designs The advantages and disadvantages of a particular low power technique are discussed Besides the classical area performance trade off the impact to design cycle time complexity risk testability and reusability are discussed The wide impacts to all aspects of design are what make low power problems challenging and interesting Heavy emphasis is given to top down structured design style with occasional coverage in the semicustom design methodology The examples and design techniques cited have been known to be applied to production scale designs or laboratory settings The goal of Practical Low Power Digital VLSI Design is to permit the readers to practice the low power techniques using current generation design style and process technology Practical Low Power Digital VLSI Design considers a wide range of design abstraction levels spanning circuit logic architecture and system Substantial basic knowledge is provided for qualitative and quantitative analysis at the different design abstraction levels Low power techniques are presented at the circuit logic architecture and

system levels Special techniques that are specific to some key areas of digital chip design are discussed as well as some of the low power techniques that are just appearing on the horizon Practical Low Power Digital VLSI Design will be of benefit to VLSI design engineers and students who have a fundamental knowledge of CMOS digital design *Integrated Circuit and System Design. Power and Timing Modeling, Optimization and Simulation* José L. Ayala, Delong Shang, Alex

Yakovlev, 2013-01-03 This book constitutes the refereed proceedings of the 22nd International Conference on Integrated Circuit and System Design PATMOS 2012 held in Newcastle UK Spain in September 2012 The 25 revised full papers presented were carefully reviewed and selected from numerous submissions The paper feature emerging challenges in methodologies and tools for the design of upcoming generations of integrated circuits and systems including reconfigurable hardware such as FPGAs The technical program focus on timing performance and power consumption as well as architectural aspects with particular emphasis on modeling design characterization analysis and optimization **Designing**

**CMOS Circuits for Low Power** Dimitrios Soudris, Christian Piguet, Costas Goutis, 2010-10-29 This book is the fourth in a series on novel low power design architectures methods and design practices It results from of a large European project started in 1997 whose goal is to promote the further development and the faster and wider industrial use of advanced design methods for reducing the power consumption of electronic systems Low power design became crucial with the wide spread of portable information and communication terminals where a small battery has to last for a long period High performance electronics in addition suffers from a permanent increase of the dissipated power per square millimeter of silicon due to the increasing clock rates which causes cooling and reliability problems or otherwise limits the performance The European Union's Information Technologies Programme Esprit did therefore launch a Pilot action for Low Power Design which eventually grew to 19 R D projects and one coordination project with an overall budget of 14 million EURO It is meanwhile known as European Low Power Initiative for Electronic System Design ESD LPD and will be completed in the year 2002 It involves to develop or demonstrate new design methods for power reduction while the coordination project takes care that the methods experiences and results are properly documented and publicised **Green Mobile Devices and Networks**

Hrishikesh Venkataraman, Gabriel-Miro Muntean, 2016-04-19 While battery capacity is often insufficient to keep up with the power demanding features of the latest mobile devices powering the functional advancement of wireless devices requires a revolution in the concept of battery life and recharge capability Future handheld devices and wireless networks should be able to recharge themselves automatically Low-Power CMOS Design Anantha Chandrakasan, Robert W.

Brodersen, 1998-02-11 This collection of important papers provides a comprehensive overview of low power system design from component technologies and circuits to architecture system design and CAD techniques LOW POWER CMOS DESIGN summarizes the key low power contributions through papers written by experts in this evolving field *Low-Power Deep Sub-Micron CMOS Logic* P. van der Meer, A. van Staveren, Arthur H.M. van Roermund, 2004 The strong interaction between

the demand for increasing chip functionality and data processing speeds and technological trends in the integrated circuit industry like e.g. shrinking device geometry, growing chip area and increased transistor switching speeds cause a huge increase in power dissipation for deep sub micron digital CMOS circuits. Low Power Deep Sub micron CMOS Logic Sub threshold Current Reduction classifies all power dissipation sources in digital CMOS circuits and provides for a systematic approach of power reduction techniques. A clear distinction has been made between power dissipated to perform a calculation in a certain time frame i.e. functional power dissipation and power dissipated even when a circuit is idle i.e. parasitical power dissipation. The threshold voltage level forms an important link between the functional and the parasitical power dissipation. Since for high data processing speeds the threshold voltage needs to be low whereas for low sub threshold leakage currents it needs to be high. The latter is extremely important for battery operated circuits in standby modes. Therefore a separate classification of sub threshold current reduction techniques is presented showing existing and new circuit topologies. Low Power Deep Sub micron CMOS Logic Sub threshold Current Reduction is a valuable book for researchers, designers as well as students in the field of low power digital design. Power dissipation is discussed from a fundamental, quantum mechanical and a practical point of view. Theory is accompanied with practical circuit implementations and measurement results.

**The Electrical Engineering Handbook** Wai Kai Chen, 2004-11-16. The Electrical Engineer's Handbook is an invaluable reference source for all practicing electrical engineers and students. Encompassing 79 chapters, this book is intended to enlighten and refresh knowledge of the practicing engineer or to help educate engineering students. This text will most likely be the engineer's first choice in looking for a solution. Extensive complete references to other sources are provided throughout. No other book has the breadth and depth of coverage available here. This is a must have for all practitioners and students. The Electrical Engineer's Handbook provides the most up to date information in Circuits and Networks, Electric Power Systems, Electronics, Computer Aided Design and Optimization, VLSI Systems, Signal Processing, Digital Systems and Computer Engineering, Digital Communication and Communication Networks, Electromagnetics and Control and Systems. About the Editor in Chief: Wai Kai Chen is Professor and Head Emeritus of the Department of Electrical Engineering and Computer Science at the University of Illinois at Chicago. He has extensive experience in education and industry and is very active professionally in the fields of circuits and systems. He was Editor in Chief of the IEEE Transactions on Circuits and Systems Series I and II, President of the IEEE Circuits and Systems Society and is the Founding Editor and Editor in Chief of the Journal of Circuits, Systems and Computers. He is the recipient of the Golden Jubilee Medal, the Education Award and the Meritorious Service Award from the IEEE Circuits and Systems Society and the Third Millennium Medal from the IEEE. Professor Chen is a fellow of the IEEE and the American Association for the Advancement of Science. 77 chapters encompass the entire field of electrical engineering. THOUSANDS of valuable figures, tables, formulas and definitions. Extensive bibliographic references.

*The Electrical Engineering Handbook - Six Volume Set* Richard C. Dorf, 2018-12-14. In

two editions spanning more than a decade The Electrical Engineering Handbook stands as the definitive reference to the multidisciplinary field of electrical engineering Our knowledge continues to grow and so does the Handbook For the third edition it has grown into a set of six books carefully focused on specialized areas or fields of study Each one represents a concise yet definitive collection of key concepts models and equations in its respective domain thoughtfully gathered for convenient access Combined they constitute the most comprehensive authoritative resource available Circuits Signals and Speech and Image Processing presents all of the basic information related to electric circuits and components analysis of circuits the use of the Laplace transform as well as signal speech and image processing using filters and algorithms It also examines emerging areas such as text to speech synthesis real time processing and embedded signal processing Electronics Power Electronics Optoelectronics Microwaves Electromagnetics and Radar delves into the fields of electronics integrated circuits power electronics optoelectronics electromagnetics light waves and radar supplying all of the basic information required for a deep understanding of each area It also devotes a section to electrical effects and devices and explores the emerging fields of microlithography and power electronics Sensors Nanoscience Biomedical Engineering and Instruments provides thorough coverage of sensors materials and nanoscience instruments and measurements and biomedical systems and devices including all of the basic information required to thoroughly understand each area It explores the emerging fields of sensors nanotechnologies and biological effects Broadcasting and Optical Communication Technology explores communications information theory and devices covering all of the basic information needed for a thorough understanding of these areas It also examines the emerging areas of adaptive estimation and optical communication Computers Software Engineering and Digital Devices examines digital and logical devices displays testing software and computers presenting the fundamental concepts needed to ensure a thorough understanding of each field It treats the emerging fields of programmable logic hardware description languages and parallel computing in detail Systems Controls Embedded Systems Energy and Machines explores in detail the fields of energy devices machines and systems as well as control systems It provides all of the fundamental concepts needed for thorough in depth understanding of each area and devotes special attention to the emerging area of embedded systems Encompassing the work of the world s foremost experts in their respective specialties The Electrical Engineering Handbook Third Edition remains the most convenient reliable source of information available This edition features the latest developments the broadest scope of coverage and new material on nanotechnologies fuel cells embedded systems and biometrics The engineering community has relied on the Handbook for more than twelve years and it will continue to be a platform to launch the next wave of advancements The Handbook s latest incarnation features a protective slipcase which helps you stay organized without overwhelming your bookshelf It is an attractive addition to any collection and will help keep each volume of the Handbook as fresh as your latest research

*Electronic Materials Handbook* ,1989-11-01 Volume 1 Packaging is an authoritative reference source of practical

information for the design or process engineer who must make informed day to day decisions about the materials and processes of microelectronic packaging Its 117 articles offer the collective knowledge wisdom and judgement of 407 microelectronics packaging experts authors co authors and reviewers representing 192 companies universities laboratories and other organizations This is the inaugural volume of ASMAs all new Electronic Materials Handbook series designed to be the Metals Handbook of electronics technology In over 65 years of publishing the Metals Handbook ASM has developed a unique editorial method of compiling large technical reference books ASMAs access to leading materials technology experts enables to organize these books on an industry consensus basis Behind every article Is an author who is a top expert in its specific subject area This multi author approach ensures the best most timely information throughout Individually selected panels of 5 and 6 peers review each article for technical accuracy generic point of view and completeness Volumes in the Electronic Materials Handbook series are multidisciplinary to reflect industry practice applied in integrating multiple technology disciplines necessary to any program in advanced electronics Volume 1 Packaging focusing on the middle level of the electronics technology size spectrum offers the greatest practical value to the largest and broadest group of users Future volumes in the series will address topics on larger integrated electronic assemblies and smaller semiconductor materials and devices size levels

Nanotechnology and Computer Engineering Donald C. Wunsch II, Hong Hua Tan, Dehuai Zeng, Qi Luo, 2010-06-30 Selected peer reviewed papers from the 2010 IITA International Conference on Nanotechnology and Computer Engineering CNCE 2010 held in Qingdao China July 20 21 2010

**Green Photonics and Electronics** Gadi Eisenstein, Dieter Bimberg, 2017-11-18 This books focuses on recent break throughs in the development of a variety of photonic devices serving distances ranging from mm to many km together with their electronic counter parts e g the drivers for lasers the amplifiers following the detectors and most important the relevant advanced VLSI circuits It explains that as a consequence of the increasing dominance of optical interconnects for high performance workstation clusters and supercomputers their complete design has to be revised This book thus covers for the first time the whole variety of interdependent subjects contributing to green photonics and electronics serving communication and energy harvesting Alternative approaches to generate electric power using organic photovoltaic solar cells inexpensive and again energy efficient in production are summarized In 2015 the use of the internet consumed 5 6% of the raw electricity production in developed countries Power consumption increases rapidly and without some transformational change will use by the middle of the next decade at the latest the entire electricity production This apocalyptic outlook led to a redirection of the focus of data center and HPC developers from just increasing bit rates and capacities to energy efficiency The high speed interconnects are all based on photonic devices These must and can be energy efficient but they operate in an electronic environment and therefore have to be considered in a wide scope that also requires low energy electronic devices sophisticated circuit designs and clever architectures The development of the next generation of high performance exaFLOP



computers suffers from the same problem Their energy consumption based on present device generations is essentially prohibitive

Logic Synthesis for Low Power VLSI Designs Sasan Iman, Massoud Pedram, 2012-12-06 Logic Synthesis for Low Power VLSI Designs presents a systematic and comprehensive treatment of power modeling and optimization at the logic level More precisely this book provides a detailed presentation of methodologies algorithms and CAD tools for power modeling estimation and analysis synthesis and optimization at the logic level Logic Synthesis for Low Power VLSI Designs contains detailed descriptions of technology dependent logic transformations and optimizations technology decomposition and mapping and post mapping structural optimization techniques for low power It also emphasizes the trade off techniques for two level and multi level logic circuits that involve power dissipation and circuit speed in the hope that the readers can better understand the issues and ways of achieving their power dissipation goal while meeting the timing constraints Logic Synthesis for Low Power VLSI Designs is written for VLSI design engineers CAD professionals and students who have had a basic knowledge of CMOS digital design and logic synthesis

**Low-Power Cmos Vlsi Circuit Design** Kaushik Roy, Sharat C. Prasad, 2009-02-02 This is the first book devoted to low power circuit design and its authors have been among the first to publish papers in this area Low Power CMOS VLSI Design Physics of Power Dissipation in CMOS FET Devices Power Estimation Synthesis for Low Power Design and Test of Low Voltage CMOS Circuits Low Power Static Ram Architectures Low Energy Computing Using Energy Recovery Techniques Software Design for Low Power

*Low-Power VLSI Circuits and Systems* Ajit Pal, 2014-11-17 The book provides a comprehensive coverage of different aspects of low power circuit synthesis at various levels of design hierarchy starting from the layout level to the system level For a seamless understanding of the subject basics of MOS circuits has been introduced at transistor gate and circuit level followed by various low power design methodologies such as supply voltage scaling switched capacitance minimization techniques and leakage power minimization approaches The content of this book will prove useful to students researchers as well as practicing engineers

**IEICE Transactions on Electronics**, 2007

VLSI Signal Processing, V Kung Yao, 1992

## The Enigmatic Realm of **Low Power Cmos Circuits Technology Logic**: Unleashing the Language is Inner Magic

In a fast-paced digital era where connections and knowledge intertwine, the enigmatic realm of language reveals its inherent magic. Its capacity to stir emotions, ignite contemplation, and catalyze profound transformations is nothing lacking extraordinary. Within the captivating pages of **Low Power Cmos Circuits Technology Logic** a literary masterpiece penned with a renowned author, readers embark on a transformative journey, unlocking the secrets and untapped potential embedded within each word. In this evaluation, we shall explore the book's core themes, assess its distinct writing style, and delve into its lasting affect the hearts and minds of those that partake in its reading experience.

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web dr michael heggerty alisa vanhekken in the years leading up to 1996 my colleagues and i were noticing in our school developed a phonemic awareness curriculum approach which became a cornerstone in our literacy program it truly was the missing component in the years that followed i personally began to develop and test these written

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web the phonemic awareness program written by dr michael heggerty is a tier 1 supplemental program for phonemic awareness for pre k kindergarten 1st and 2nd grade classrooms however it can also be used to provide tier 2 and tier 3 support through small group or individual instruction for students in grades k 8

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web the revised 2022 edition of the english kindergarten curriculum includes lessons that are quick and fast paced using a reduced number of words for each skill in order to provide students with exposure to hearing sounds and build an awareness of the sounds we hear in spoken words

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web heggerty phonemic awareness is a well organized 35 week curriculum of daily phonemic awareness lesson plans developed on a systematic scope and sequence of skills each level focuses on

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web true progress in just 8 12 minutes a day each level of the heggerty phonemic awareness curriculum provides up to 35 weeks of daily lessons focusing on eight phonemic awareness skills along with two additional activities to develop letter and sound recognition and language awareness

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web developed in 2003 by dr michael heggerty the heggerty phonemic awareness curriculum is a systematic program of daily lesson plans that provide a high level of explicit modelling and student engagement

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web the heggerty phonemic awareness curricula align to the phonological awareness standards for kindergarten and 1st grade under the foundational skills standards for both grade levels many states have their own state standards and many states use the common core state standards for phonological awareness when planning classroom

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web 35 weeks of teacher friendly phonological and phonemic awareness lessons for your preschool students designed to supplement your existing literacy curriculum the heggerty phonemic awareness pre kindergarten lessons easily integrate into half day or full day preschool programs

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web answer the digital access included in myheggerty for the phonemic awareness curriculum provides standards aligned instruction to develop phonemic awareness in all learners working systematically from phonological to phonemic awareness

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web michael heggerty literacy resources incorporated 2020 early childhood education 210 pages the 2020 edition of the curriculum presents the eight phonemic awareness skills in a

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web answer we suggest that phonemic awareness is 8 12 minutes no more than 15 minutes of your literacy instruction within the school day phonemic awareness can be a warm up to your phonics instruction teaching pa right before phonics it can be used to complement any reading series or phonics curriculum

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web the 2020 edition of the curriculum presents the eight phonemic awareness skills in a revised order to reflect the progression of these important literacy skills lessons progress from early phonological awareness skills to basic phonemic awareness skills and end with the advanced phonemic awareness skills letter name and language

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web initial phoneme isolation 4 total purpose the following set of four assessments can be used with any grade level to monitor student progress with the phonemic awareness skill of isolating the initial sound in spoken words after administering forms a b or c of the heggerty phonemic awareness assessments teachers may want to

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web jun 9 2021 district announces summer meals schedule the district will begin its free summer meals program on monday june 14 with the current meal program ending friday june 11 the hours for summer meal pickup will change as will some locations from the district s current free meals program

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web summer camps summer camp bus hubs are located at each of our 7 regional high schools click the links below to see maps of the bus hub locations bullard edison fresno hoover mclane roosevelt sunnyside click on the links below to view each summer camp s bus schedule session 3 july 24 july 28

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web summer school will start on monday june 12 2023 and end on july 14 2023 the first session will be from june 12 june 27 the second session will be from june 28 july 14 see schedule below remember that transportation will not be

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web independence day july 4 labor day sept 5 veterans day nov 11 thanksgiving nov 21 25 winter break dec 19 jan 6 m l king jr day jan 16 lincoln s birthday feb 13 presidents day feb 20 spring break april 3 10 memorial day may 29 independence day july 4 2023 holidays for classified personnel

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web purpose to provide a wide range of courses to match learning and credit recovery needs for students to get on track with graduation and or a g requirements summer credit recovery schedule dates summer high school credit recovery 2024 dates are to be determined high school schedule start and end times may vary from school site to school site

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web aug 14 2023 school holidays starts finishes first day of school 14 aug 2023 mon thanksgiving break 20 nov 2023 mon 24 nov 2023 fri christmas break 18 dec 2023 mon 5 jan 2024 fri spring break 25 mar 2024 mon 1 apr 2024 mon last day of school 6 jun 2024 thu summer break 7 jun 2024 fri

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web jan 11 2021 general what are the summer school program dates for 2021 the elementary middle comprehensive high school and special education summer programs include 2 sessions the dates are session 1 is june 14 2021 june 28 2021 session 2 is june 29 2021 july 14 2021 the alternative ed high school summer program

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web there are three distinctive extended learning summer programs offered within fresno unified summer academy grades k 8 summer enrichment camps credit recovery grades 9 12

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web fresno unified school district academic calendar for the 2022 2023 school year board adopted on february 2 2022 april 10 2023 spring break school not in session may 2023 monday may 29 2023 memorial day holiday june 2023 thursday june 8 2023 last day of school july 2023 tuesday july 4 2023 independence day

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web elementary sports schedule illuminate student login paper 24 7 tutoring service central unified school district fresno ca 93722 4605 n polk ave fresno ca 93722 559 274 4700 559 271 8200 email protected normal business hours 8 00 am to 4 30 pm district office 559 274 4700 transportation 559 275 9734 operations 559

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web for regular summer school starting with the 2014 2015 school year and subsequent years teacher summer school salaries are based on an hourly rate of 31 88 for the number of student days plus two 2 days to be used for faculty meetings preparation time and student registration 1 2 supplemental compensation for district assigned