Low Power Crystal And Mems Oscillators The Experience Of Watch Developments Integrated Circuits And Systems

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EMMALEE WILLIAMSON

Low-Power Crystal and MEMS Oscillators
Springer Science & Business Media
This groundbreaking book provides you with a comprehensive understanding of FBAR (thin-film bulk acoustic wave resonator), MEMS (microelectomechanical system), and NEMS (nanoelectromechanical system) resonators. For the first time anywhere, you find extensive coverage of these devices at both the technology and application levels. This practical reference offers you guidance in design, fabrication, and characterization of FBARs, MEMS and NEBS. It discusses the integration of these devices with standard CMOS (complementary-metal-oxide-semiconductor) technologies, and their application to sensing and RF systems. Moreover, this one-stop resource looks at the main characteristics, differences, and limitations of FBAR, MEMS, and NEMS devices, helping you to choose the right approaches for your projects. Over 280 illustrations and more than 130 equations support key topics throughout the book.
An Illustrative Guide to Learn Fundamentals of Robotics, Including Kinematics, Motion Control, and Trajectory Planning (English Edition)
Artech House
There is little question that the commercial success of smartphones has substantially increased the volume of products utilizing Micro Electro Mechanical Systems (MEMS) technology, especially accelerometers, gyroscopes, bandpass filters, and microphones. The Internet of Things (IoT), a more recent driver for small, low power

microsystems, seems poised to provide an even bigger market for these and other potential products based on MEMS. Given that the IoT will likely depend heavily on massive sensor networks using nodes for which battery replacement might not be practical, cost and power consumption become even more important. As already known for existing sensor networks, sleep/wake cycles will likely be instrumental to maintaining low sensor node power consumption in the IoT, and if so, then the clocks that must continuously run to synchronize sleep/wake events often become the bottlenecks to ultimate power consumption. On the communications side, narrowband RF channel-selecting front-end filters stand to greatly reduce receive power consumption by relaxing transistor circuit dynamic ranges. Both the accuracy of the clocks and ability of filters to achieve bandwidths small enough to select individual channels depend heavily on the accuracy and precision to which the frequency-setting devices they rely on are constructed. Inevitably, fabrication tolerances are finite, which means the ability to attain the highest performance relies on trimming or tuning. This dissertation focuses on methods by which voltage-controlled frequency tuning of capacitively-transduced micromechanical resonators make possible 1) an ultra-compact, low-power 32.768-kHz micromechanical clock oscillator; and 2) a high-order, small percent bandwidth coupled-resonator filter with minimal passband distortion. Currently, quartz crystal-based oscillators at 32.768 kHz dominate the market because they offer the best combination of cost and performance. However, the physical dimensions of these oscillators are presently too large for future small form-factor electronic applications, such as ones that fit within credit cards. While there have been attempts to shrink quartz resonating elements, the increasingly difficult fabrication steps required to produce such devices raises manufacturing costs, thereby preventing widespread adoption (so far). In addition, quartz crystal motional resistance values typically increase as resonator dimensions shrink, which in many oscillator configurations raises power consumption. Unlike common quartz resonators, properly designed MEMS resonators benefit greatly from scaling in that reductions in lateral dimensions lead to a rapid decrease in motional resistance by a square law. The work described herein harnesses these scaling advantages to realize an oscillator much smaller than quartz-based oscillators with potential for much less power consumption. Specifically, this work uses aggressive lithography to achieve a capacitive-comb transduced micromechanical resonator occupying only 0.0154 mm2 of die area. Wire bonding this resonator to a custom sustaining amplifier and a supply voltage of only 1.65V then realizes a 32.768-kHz real-time clock oscillator more than 100× smaller by area than miniaturized quartz crystal implementations and at least 4× smaller than other MEMS-based approaches. The use of voltage-controlled tuning Oscillations sustains with only 2.1 [mu]W of power consumption. On the filter front, whether realized using quartz, FBAR, or capacitive-gap transduced MEMS resonator, mechanical filter responses are only as flat as the accuracy of their constituent resonator center frequencies. While narrowband micromechanical filters comprised of up

to three mechanically coupled resonators have been demonstrated in the past, there exists a demand for bandpass filters with even sharper roll-offs and larger stopband rejections, and this requires higher order filters utilizing more than three coupled resonators. The work herein demonstrates filters comprised of four coupled resonators with bandwidths narrow enough to select individual channels. Before correction, filter passbands fresh out of the fab look nothing like their intended responses. Application of the automated passband correction protocol of this work, based on voltage-controlled frequency tuning, permits measurement of a 4-resonator micromechanical filter with a 0.1% bandwidth commensurate with the needs of channel-selection (albeit at a low frequency) and an impressive 20-dB shape factor of 1.59, all with less than 3dB of additional passband ripple (beyond the design ripple).

Integrated Satellite Navigation, Sensor Systems, and Civil Applications, Set CRC Press

This book is based on the 18 invited tutorials presented during the 27th workshop on Advances in Analog Circuit Design. Expert designers from both industry and academia present readers with information about a variety of topics at the frontiers of analog circuit design, including the design of analog circuits in power-constrained applications, CMOS-compatible sensors for mobile devices and energy-efficient amplifiers and drivers. For anyone involved in the design of analog circuits, this book will serve as a valuable guide to the current state-of-the-art. Provides a state-of-the-art reference in analog circuit design, written by experts from industry and academia; Presents material in a tutorial-based format; Covers the design of analog circuits in power-constrained applications, CMOS-compatible sensors for mobile devices and energy-efficient amplifiers and drivers.

Low-Power Processors and Systems on Chips Academic Press

The field of low-dimensional structures has been experiencing rapid development in both theoretical and experimental research. Phonons in Low Dimensional Structures is a collection of chapters related to the properties of solid-state structures dependent on lattice vibrations. The book is divided into two parts. In the first part, research topics such as interface phonons and polaron states, carrier-phonon non-equilibrium dynamics, directional projection of elastic waves in parallel array of N elastically coupled waveguides, collective dynamics for longitudinal and transverse phonon modes, and elastic properties for bulk metallic glasses are related to semiconductor devices and metallic glasses devices. The second part of the book contains, among others, topics related to superconductor, phononic crystal carbon nanotube devices such as phonon dispersion calculations using density functional theory for a range of superconducting materials, phononic crystal-based MEMS resonators, absorption of acoustic phonons in the hyper-sound regime in fluorine-modified carbon nanotubes and single-walled nanotubes, phonon transport in carbon nanotubes, quantization of phonon thermal conductance, and phonon Anderson localization.

Design and Development of MEMS based Guided Beam Type Piezoelectric Energy Harvester Butterworth-Heinemann

Many argue that telecommunications network infrastructure is the most impressive and important technology

ever developed. Analyzing the telecom market's constantly evolving trends, research directions, infrastructure, and vital needs, Telecommunication Networks responds with revolutionized engineering strategies to optimize network construction. Omnipresent in society, telecom networks integrate a wide range of technologies. These include quantum field theory for the study of optical amplifiers, software architectures for network control, abstract algebra required to design error correction codes, and network, thermal, and mechanical modeling for equipment platform design. Illustrating how and why network developers make technical decisions, this book takes a practical engineering approach to systematically assess the network as a whole—from transmission to switching. Emphasizing a uniform bibliography and description of standards, it explores existing technical developments and the potential for projected alternative architectural paths, based on current market indicators. The author characterizes new device and equipment advances not just as quality improvements, but as specific responses to particular technical market necessities. Analyzing design problems to identify potential links and commonalities between different parts of the system, the book addresses interdependence of these elements and their individual influence on network evolution. It also considers power consumption and real estate, which sometimes outweigh engineering performance data in determining a product's success. To clarify the potential and limitations of each presented technology and system analysis, the book includes quantitative data inspired by real products and prototypes. Whenever possible, it applies mathematical modeling to present measured data, enabling the reader to apply demonstrated concepts in real-world situations. Covering everything from high-level architectural elements to more basic component physics, its focus is to solve a problem from different perspectives, and bridge descriptions of well-consolidated solutions with newer research trends.

RF and Microwave Passive and Active Technologies CRC Press

Wireless technology, which already plays a major part in our daily lives, is expected to further expand to networks of billions of autonomous sensors in coming years: the so-called Internet of Things. In one vision, sensors employing low-cost, low-power wireless motes collect and transmit data through a mesh network while operating only on scavenged or battery power. RF MEMS provides one approach to the stringent power and performance required by sensor networks. This dissertation presents improvement to these MEMS technologies and introduces new approaches for wireless communication in low power wireless networks. First, this work presents oscillators based on the capacitive-gap transduced MEMS resonator. As wireless radio needs at least one such oscillator, the space and power savings offered by these MEMS oscillators make them compelling alternatives over bulky quartz-based devices. The high quality factors (Q) > 100,000 possible in these on-chip resonators allow for phase noise performance of the oscillator exceeding even the challenging GSM specifications using less than 100 uW of power consumption. Despite their small size and tiny capacitive gaps, MEMS-based oscillators are found to be insensitive to vibration and achieve only a few ppm

shift in frequency over 10 months of measurement: the performance shown is on par or better than the off-the-shelf crystal oscillators. Interestingly, exploiting nonlinearities in the MEMS resonators also allows multiple simultaneous oscillation frequencies using one amplifier. Combined with electrical stiffness-based frequency tuning, this enables Frequency-Shift Keyed modulation of the output waveform, offering a space and power-efficient multichannel transmitter, as desired for mobile applications requiring long battery life. Intrinsically, oscillator systems involve positive feedback loops, which regeneratively amplify signals in the loop. Taking advantage of this property, MEMS oscillator systems may be used for other wireless signal processing applications. This dissertation explores such systems applied to: 1) a narrow channel-select filter with low insertion loss unachievable using passive resonators only and 2) a super-regenerative amplification-based channel-selecting radio transceiver. Finally, this dissertation presents two capacitive-gap transduced micromechanical resonator designs which can achieve the high Q at GHz frequencies needed for many wireless communication standards. The methods and solutions provided here pave a path towards realization of future low-power wireless technologies.

Acoustic Wave and Electromechanical Resonators Springer Science & Business Media

The power consumption of integrated circuits is one of the most problematic considerations affecting the design of high-performance chips and portable devices. The study of power-saving design methodologies now must also include subjects such as systems on chips, embedded software, and the future of microelectronics. Low-Power Electronics Design covers all major aspects of low-power design of ICs in deep submicron technologies and addresses emerging topics related to future design. This volume explores, in individual chapters written by expert authors, the many low-power techniques born during the past decade. It also discusses the many different domains and disciplines that impact power consumption, including processors, complex circuits, software, CAD tools, and energy sources and management. The authors delve into what many specialists predict about the future by presenting techniques that are promising but are not yet reality. They investigate nanotechnologies, optical circuits, ad hoc networks, e-textiles, as well as human powered sources of energy. Low-Power Electronics Design delivers a complete picture of today's methods for reducing power, and also illustrates the advances in chip design that may be commonplace 10 or 15 years from now.

The Experience of Watch Developments Springer Science & Business Media

The 4th edition of this popular Handbook continues to provide an easy-to-use guide to the many exciting new developments in the field of optical fiber data communications. With 90% new content, this edition contains all new material describing the transformation of the modern data communications network, both within the data center and over extended distances between data centers, along with best practices for the design of highly virtualized, converged, energy efficient, secure, and flattened network infrastructures. Key topics include networks for cloud computing, software defined networking, integrated

and embedded networking appliances, and low latency networks for financial trading or other time-sensitive applications. Network architectures from the leading vendors are outlined (including Smart Analytic Solutions, Qfabric, FabricPath, and Exadata) as well as the latest revisions to industry standards for interoperable networks, including lossless Ethernet, 16G Fiber Channel, RoCE, FCoE, TRILL, IEEE 802.1Qbg, and more. Written by experts from IBM, HP, Dell, Cisco, Ciena, and Sun/ Oracle Case studies and 'How to...' demonstrations on a wide range of topics, including Optical Ethernet, next generation Internet, RDMA and Fiber Channel over Ethernet Quick reference tables of all the key optical network parameters for protocols like ESCON, FICON, and SONET/ATM and a glossary of technical terms and acronyms

Temperature- and Supply Voltage-Independent Time References for Wireless Sensor Networks Academic Press

This book describes an alternative method of realizing accurate on-chip frequency references in standard CMOS processes. This method exploits the thermal-diffusivity of silicon, i.e. the rate at which heat diffuses through a silicon substrate. This is the first book describing the design of such electrothermal frequency references. It includes the necessary theory, supported by practical realizations that achieve inaccuracies as low as 0.1% and thus demonstrate the feasibility of this approach. The book also includes several circuit and system-level solutions to the precision circuit design challenges encountered during the design of such frequency references.

A Practical Guide to Optical Networking Springer

Low power and low phase noise RF frequency references are essential for applications such as high performance ADCs, high speed serial data links, and low power radios. They constitute a multi-billion dollar market in today's electronic industry. Quartz crystal is the most commonly used mineral for generating a reference clock. However, it needs a complicated manufacturing process, which increases cost, and it cannot be integrated with CMOS circuits. This is reason why wafer scale high-Q MEMS resonators are becoming attractive alternatives to quartz owing to their small size, low cost and integration potential. However, oscillators using MEMS resonator perform poorly compared to quartz based oscillators in terms of close-in phase noise. Close-in phase noise is an important performance metric for a reference oscillator as it dominates the in-band phase noise of a frequency synthesizer in a radio. In addition, highly miniaturized MEMS resonator based oscillators have exhibited poor frequency stability over temperature. This characteristic is an issue, which limits the choice of the oscillator type in wireless application such as Bluetooth, Wi-Fi and GPS. The first part of this thesis addresses the close-in phase noise issue and proposes circuits with MEMS resonator such as AlN contour mode resonator and FBAR (thin-Film Bulk-Acoustic Resonator) to demonstrate solutions for improving the phase noise and lowering the power consumption. The proposed oscillator with FBAR culminates in achieving more than 10dB lower phase noise than that of conventional oscillator with 350uW power consumption. The following part of this thesis addresses the frequency drift of the reference clock when the temperature changes. The wireless

application requires stringent and challenging spec. for the oscillator to generate a stable clock signal. For example, GPS needs to have less than 2ppm frequency drift over temperature. The first prototype of fully integrated oven-controlled temperature compensation system is thus introduced. This effort aims to have a ±1.6ppm stability reference clock with 150uK temperature resolution.

Chemical Solution Deposition of Functional Oxide Thin Films Low-Power Crystal and MEMS OscillatorsThe Experience of Watch Developments Aggressively duty-cycling the operation of a system between ON and OFF states has proven to be the most effective way to reduce the average power consumption in energy-constrained applications such as Internet-of-Things (IoT). Since these devices are either battery-powered with a very small form factor or rely on energy harvesting where small amount of ambient energy is captured to power up the device, ultra-low power consumption is crucial in enabling all the advantages that applications such as IoT and biomedical implantable/wearable devices are expected to produce. However, the amount of power saving in a duty-cycled system is usually constrained by two main factors: 1) the start-up time of the system; and 2) the OFF-state power consumption. The system start-up time is usually limited by the long start-up time of its reference oscillator, typically a high-Q, MHz-range crystal oscillator that usually takes several milliseconds to turn on. The OFF-state (sleep) power consumption, on the other hand, is dominated by the sleep timer that is an always-ON 32KHz crystal oscillator. Sleep timer synchronizes the transmitting and receiving bursts which requires a very accurate oscillation frequency to minimize the guard band in order to reduce the active energy consumption. To address the mentioned challenges, we have developed circuit techniques and architectures that enable low-power clock generation. To kick-start high-Q oscillators, such as crystal and/or MEMS-based reference oscillators, pre-energization of the resonator through injecting energy for a precise duration is proposed. A universal analysis for energy injection into high-Q resonators is developed and used to calculate the optimal injection duration essential to obtain a minimum start-up time. The proposed method ameliorates the sensitivity of the start-up time to the matching between the injection and resonance frequencies. To further relax the frequency accuracy requirement of the injection oscillator, energy injection with a dynamically-adjusted injection duration is presented. Measurement results from a 65nm CMOS IC show that the proposed technique reduces the start-up time of multiple tested crystal oscillators to about 100-120 number of oscillation cycles. The measured start-up time using the proposed precisely-timed energy injection method is 15 times faster than the best case reported in the literature while consuming the lowest start-up energy of ~12nJ. In order to reduce the sleep power consumption, an ultra-low power sleep timer that is based on a DC-only sustaining amplifier is presented. New oscillator architecture is proposed that enables sub-nW power consumption in a 32KHz crystal oscillator by amplifying the oscillation signal at DC, instead of amplifying it at the oscillation frequency. Measurement results of 20 different 65nm standard CMOS dies show an average power consumption of 0.55nW drawn from a

0.5V supply at room temperature for a 32KHz crystal oscillator. The measured long-term stability of the sleep timer indicated by the Allan deviation floor is 14ppb. The proposed oscillator architecture does not require any calibration schemes or multiple supply domains, unlike most prior art.

Electromagnetics of Body Area Networks CRC Press

A comprehensive outlook on all the concepts of Robotics for beginners KEY FEATURES ● Includes key concepts of robot modeling, control, and programming. ● Numerous examples and exercises on various aspects of robotics. ● Exposure to physical computing, robotic kinematics, trajectory planning, and motion control systems. DESCRIPTION 'Robotics Simplified' is a learner's handbook that provides a thorough foundation around robotics, including all the basic concepts. The book takes you through a lot of essential topics about robotics, including robotic sensing, actuation, programming, motion control, and kinematic analysis of robotic manipulators. To begin with, the book prepares you with the basic foundational knowledge that assists you in understanding the basic concepts of robotics. It helps you to understand key elements of robotic systems, including various actuators, sensors, and different vision systems. It explains the actual physics that robotic systems work upon such as trajectory planning and motion control of manipulators. It covers the kinematics and dynamics of multi-body systems while you learn to develop a robotic model. Various programming techniques and control systems have practically been demonstrated that guide you to reverse engineer, reprogram and troubleshoot some existing simple robots. You will also get a practical demonstration of how your robots can become smart and intelligent using various image processing techniques illustrated in detail. By the end of this book, you will gain a solid foundation of robotics and get well-versed with the modern techniques that are used for robotic modeling, controlling, and programming. WHAT YOU WILL LEARN ● Understand and develop robotic vision and sensing systems. ● Integrate various robotic actuators and end-effectors. ● Design and configure manipulators with robotic kinematics. ● Prepare the trajectory and path planning of robots. ● Learn robot programming using C, Python, and VAL. WHO THIS BOOK IS FOR This book has been meticulously crafted for engineers, students, entrepreneurs, and robotics enthusiasts. This book provides a complete explanation of all major robotics principles, allowing readers of all levels to learn from scratch. TABLE OF CONTENTS 1. Introduction to Robotics 2. End-Effectors 3. Sensors 4. Robotic Drive Systems and Actuators 5. Robotic Vision Systems and Image Processing 6. Introduction to Robotic Kinematics 7. Forward and Inverse Kinematics 8. Velocity Kinematics and Trajectory Planning 9. Control Systems for Robotic Motion Control 10. Robot Programming 11. Applications of Robotics and Autonomous Systems

Concept to Key Applications BoD – Books on Demand

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, this volume addresses the design of low-power microprocessors in deep submicron technologies. It provides a

focused reference for specialists involved in systems-on-chips, from low-power microprocessors to DSP cores, reconfigurable processors, memories, ad-hoc networks, and embedded software. Low-Power Processors and Systems on Chips is organized into three broad sections for convenient access. The first section examines the design of digital signal processors for embedded applications and techniques for reducing dynamic and static power at the electrical and system levels. The second part describes several aspects of low-power systems on chips, including hardware and embedded software aspects, efficient data storage, networks-on-chips, and applications such as routing strategies in wireless RF sensing and actuating devices. The final section discusses embedded software issues, including details on compilers, retargetable compilers, and coverification tools. Providing detailed examinations contributed by leading experts, Low-Power Processors and Systems on Chips supplies authoritative information on how to maintain high performance while lowering power consumption in modern processors and SoCs. It is a must-read for anyone designing modern computers or embedded systems.

Reference Clock Design for Low Power and Low Phase Noise with Temperature Compensation Springer

This book presents device design, layout design, FEM analysis, device fabrication, and packaging and testing of MEMS-based piezoelectric vibration energy harvesters. It serves as a complete guide from design, FEM, and fabrication to characterization. Each chapter of this volume illustrates key insight technologies through images. The book showcases different technologies for energy harvesting and the importance of energy harvesting in wireless sensor networks. The design, simulation, and comparison of three types of structures – single beam cantilever structure, cantilever array structure, and guided beam structure have also been reported in one of the chapters. In this volume, an elaborate characterization of two-beam and four-beam fabricated devices has been carried out. This characterization includes structural, material, morphological, topological, dynamic, and electrical characterization of the device. The volume is very concise, easy to understand, and contains colored images to understand the details of each process.

Nano Devices and Circuit Techniques for Low-Energy Applications and Energy Harvesting Springer

Quartz, unique in its chemical, electrical, mechanical, and thermal properties, is used as a frequency control element in applications where stability of frequency is an absolute necessity. Without crystal controlled transmission, radio and television would not be possible in their present form. The quartz crystals allow the individual channels in communication systems to be spaced closer together to make better use of one of most precious resources -- wireless bandwidth. This book describes the characteristics of the art of crystal oscillator design, including how to specify and select crystal oscillators. While presenting various varieties of crystal oscillators, this resource also provides you with useful MathCad and Genesys simulations.

Ultra-Low-Power Short-Range Radios CRC Press

The book addresses the need to investigate new approaches to lower energy requirement in multiple

application areas and serves as a guide into emerging circuit technologies. It explores revolutionary device concepts, sensors, and associated circuits and architectures that will greatly extend the practical engineering limits of energy-efficient computation. The book responds to the need to develop disruptive new system architecutres, circuit microarchitectures, and attendant device and interconnect technology aimed at achieving the highest level of computational energy efficiency for general purpose computing systems. Features Discusses unique technologies and material only available in specialized journal and conferences Covers emerging applications areas, such as ultra low power communications, emerging bio-electronics, and operation in extreme environments Explores broad circuit operation, ex. analog, RF, memory, and digital circuits Contains practical applications in the engineering field, as well as graduate studies Written by international experts from both academia and industry

Handbook of Fiber Optic Data Communication John Wiley & Sons

This book investigates the possible circuit solutions to overcome the temperature and supply voltage-sensitivity of fully-integrated time references for ultra-low-power communication in wireless sensor networks. The authors provide an elaborate theoretical introduction and literature study to enable full understanding of the design challenges and shortcomings of current oscillator implementations. Furthermore, a closer look to the short-term as well as the long-term frequency stability of integrated oscillators is taken. Next, a design strategy is developed and applied to 5 different oscillator topologies and 1 sensor interface. All 6 implementations are subject to an elaborate study of frequency stability, phase noise and power consumption. In the final chapter all blocks are compared to the state of the art.

Wireless Technologies Springer Nature

Low-Power Crystal and MEMS OscillatorsThe Experience of Watch DevelopmentsSpringer Science & Business Media

Low Power Circuits for Emerging Applications in Communications, Computing, and Sensing Springer Science & Business Media

This book is based on the 18 tutorials presented during the 24th workshop on Advances in Analog Circuit Design. Expert designers present readers with information about a variety of topics at the frontier of analog circuit design, including low-power and energy-efficient analog electronics, with specific contributions focusing on the design of efficient sensor interfaces and low-power RF systems. This book serves as a valuable reference to the state-of-the-art, for anyone involved in analog circuit research and development.

Electrothermal Frequency References in Standard CMOS BPB Publications

The importance and ubiquity of wireless networks in the modern age justifies the depth and scope of the chapters included in this book, with its special focus on sensors. Topics covered include MAC protocols, with one contribution offering a literature review on them. Energy efficiency is also important, with several chapters addressing cooperative beamforming, modern spatial-diversity techniques and MEMS. Hardware issues are addressed by a batch of chapters, on extending network coverage areas,

CMOS RF transceivers, the use of an accelerometer sensor module and a fall-detection monitoring system and a couple of contributions on hierarchical paradigms in wireless sensor networks.

More mathematical approaches are also included, with chapters on data aggregation tree construction and distributed localization algorithms.