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Ultra-Low Power 32kHz Crystal Oscillator: Fundamentals and Design Techniques

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ABSTRACT

One of the challenges to the proliferation of the Internet of Things is ultra-low power circuit design. Wireless nodes in IoT applications use sleep timers to synchronize with each other and enable duty cycling of power-hungry communication blocks to reduce average power. 32kHz crystal oscillators remain the most popular choice for sleep timers thanks to their frequency stability, simplicity, and low cost. Because sleep timers must always be on, their power consumption must be low compared to the average power of wireless nodes. Meanwhile, 32kHz crystal oscillators must operate reliably under process, voltage, and temperature variations and exhibit good long-term stability, making design challenging considering their ultra-low power operation. This talk reviews the state-of-the-art in ultra-low power 32kHz crystal oscillators. Fundamentals of crystal oscillators are introduced and analyzed from the perspective of power and frequency stability. Based on these fundamentals and analyses, we discuss existing design techniques of 32kHz crystal oscillators, highlighting the evolution of architectures in ultra-low power 32kHz oscillators. Finally, research directions related to 32kHz crystal oscillators are introduced.

Dennis Sylvester

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BIO

Dennis Sylvester is the Edward S. Davidson Collegiate Professor of Electrical and Computer Engineering at the University of Michigan, Ann Arbor. His main research interests are in the design of miniaturized ultra-low power microsystems, touching on analog, mixed-signal, and digital circuits. He has published over 500 articles and holds more than 50 US patents in these areas. His research has been commercialized via three major venture capital funded startup companies; Ambiq, Cubeworks, and Mythic. He has received fourteen best paper awards and nominations and was named a Top Contributing Author at ISSCC and most prolific author at IEEE Symposium on VLSI Circuits. He is currently a member of the Administrative Committee for IEEE Solid-State Circuits Society, an Associate Editor for IEEE Journal of Solid-State Circuits, and was previously an IEEE Solid-State Circuits Society Distinguished Lecturer. He received his PhD in Electrical Engineering from UC-Berkeley, and held research staff positions at Synopsys and Hewlett-Packard Laboratories as well as visiting professorships at the National University of Singapore and Nanyang Technological University. He is an IEEE Fellow for "contributions to energy efficient integrated circuit design."

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BIO

Li Xu received the B.Eng. degree in automation from Tongji University, Shanghai, China, in 2009, and the M.S. degree in electrical and computer engineering from Northeastern University, Boston, MA, USA, in 2016. He is currently pursuing the Ph.D. degree with the University of Michigan, Ann Arbor, MI, USA.

From 2009 to 2011, he was an IC Design Engineer with Ricoh Electronic Devices Shanghai Co., Ltd., Shanghai, where he worked on LDO and DC/DC converter projects. During the summer of 2015, he was a Design Intern with Linear Technology Corporation, Colorado Springs, CO, USA. During the summer of 2020, he was a Research Intern with NVIDIA Corporation, Santa Clara, CA, USA. His current research interest is energy-efficient mixed-signal circuit design.

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