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ELECTRICAL & COMPUTER ENGINEERING
TEXAS A&M UNIVERSITY

S E M I N A R

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A CMOS Fractional-N PLL-Based Microwave Chemical Sensor

by

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Abstract: Detection of chemicals and biological materials is vital in an enormous number of applications, including pharmaceutical, medical, oil, gas, and food/drug safety fields. An effective material detection approach involves characterizing physical and electrical properties of materials under test (MUTs), such as electrical permittivity. The development of efficient permittivity detection techniques will benefit systems used for medical diagnosis and imaging, DNA sensing, material characterization, agricultural development, forensics, and bio-threat detection. This work proposes a highly sensitive CMOS-based sensing system for permittivity detection and mixture characterization of organic chemicals at microwave frequencies. The system determines permittivity by measuring the frequency difference between two voltage-controlled oscillators (VCOs); a sensor oscillator with an operating frequency that shifts with the change in tank capacitance due to exposure to the MUT and a reference oscillator insensitive to the MUT. This relative measurement approach improves sensor accuracy by tracking frequency drifts due to environmental variations. Embedding the sensor and reference VCOs in a fractional-N phase-locked loop (PLL) frequency synthesizer enables material characterization at a precise frequency and provides an efficient material-induced frequency shift read-out mechanism with a low-complexity bang–bang control loop that adjusts a fractional frequency divider. The majority of the PLL-based sensor system, except for an external fractional frequency divider, is implemented with a 90-nm CMOS prototype that consumes 22 mW when characterizing material near 10 GHz. Material-induced frequency shifts are detected at an accuracy level of 15 ppm and binary mixture characterization of organic chemicals yield maximum errors in permittivity of 1.5%.

Osama Elhadidy: received the B.Sc. and M.Sc. degrees in electrical engineering from Ain Shams University, Cairo, Egypt, in 2004 and 2009, respectively, and is currently working toward the Ph.D. degree in electrical and computer engineering at Texas A&M University, College Station, TX, USA.
From 2005 to 2010, he was a Development Engineer with Mentor Graphics, Cairo, Egypt. In summer 2012, he was a Design Intern with Rambus, Chapel Hill, NC, USA. In summer 2013, he was an Intern with Texas Instruments, Dallas, TX, USA. His research interests include frequency synthesizers and high-speed mixed-signal IC design.