RFIC-Lab @ ECE-TUT, Finland

Founded: 1995 in Dpt. Communications
Team: 15+34 BSc, MSc & PhD
CAD: 50 Cadence Licenses
Measurements: Up to 27GHz On-Wafer
Teaching: 9 courses: Com. RF-IC

Partners: Bell-Labs, IBM, Infineon, Intel, Nokia, STMicro, TI.
Funding: 9.4 Mln.USD
Patents: 46 (W-4, USA-12, UK-8 …)
Publications: 98 (25 in IEEE)

Some Key Publications:
Tchamov N.T., S.Broussev, I.Uzunov, K.Rantala,
Dual-Band LC VCO Architecture With a Fourth-Order Resonator,

Steyaert M., B.Razavi, J.Fenk, W.Decock, N.T.Tchamov, K.Lee, M.Banu,
R.Schreier, H.Tanimoto, GigaHertz-Radio Front Ends, Workshop ‘GIRaFE’

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Apr-2013
Published Main R & D Achievements

Two-Phase Self-Assisted Zero-Voltage Switching DCDC Converter,

Q-factor analysis for C-C LC oscillators using TVRL,

Design consideration in tapped-inductor 4th-order Dual-Band VCO,

A Darlington-Enhanced CMOS Oscillator Architecture

Evaluation & Comparison GHz-range LC Oscillators using TVRL,

UMTS and GSM Low Phase Noise Inductively Tuned LC VCO,

Time-Varying Root Locus of Large-Signal LC Oscillators,
IEEE Tr. CAD IC and Sys, no. 5, May 2010.

Flicker Noise Up-Conversion Suppression in Differential LC Oscillators,
IEEE Tr. on CAS-2, no.11, Nov 2007.

Wideband Low Phase-Noise LC-VCO With Programmable $K_{vco}$,

Dual-Band LC VCO Architecture With a Fourth-Order Resonator,

Novel VCO Using Series Above-IC FBAR and Parallel LC Resonator,
IEEE Journal Solid-State Circuits, no.10.

Differential Pre-Compensated GHz-range Low-voltage Track-and-Hold,
IEE EL, no.2, Jan 2003.

Monolithic RF Bandpass Track-and-Hold,
IEE EL, no.2, Jan 2003.

3.6 GHz Double Cross-Coupled Multivibrator VCO 1.6 GHz Tuning,

High-Performance Differential VCO Based on Armstrong Oscillator,

4.3 GHz VCO with 2-GHz Tuning Range and Low Phase Noise,

R & D Collaborations

TUT-ECE RFIC

Project Funding

EU

Industry(Ger)

Industry(Fin)

Academy

Industry(USA)

Academy

Tekes

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RFCC-Lab Core Expertise Areas

- Semi-Symbolic Time-Variant Analysis of Multiple Transistors Non-Linear Circuits
- RF Measurements On-Wafer versus Simulations with Extracted Parasitics
- Complete IC Specs Evaluation
- 46 Patents in Germany, USA, UK
- 98 Journal Publications (24 in IEEE)
- 81% INDUSTRY, 8% ACADEMY, 11% TEKES

Creating New Architectures of Monolithic Circuits
VCO, DCO, LNA, T&H, DCDC in the Frequency Range 10MHz ÷ 65GHz using CADENCE

Evaluation & Scaling
of the Critical Devices on Novel 32nm, 45nm, 65nm, 90nm, 130nm … RF-CMOS, SiGe/BiCMOS, Si/Sapphire

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RFIC-Lab Background, Works & Targets

Devices Modeling in CMOS, SiGe/BiCMOS

Nonlinear Electronic Circuits Theory & CAD

Novel GHz Circuits Architectures

On-Wafer RF Measurements

VCO & DCO for Mobile Terminals since 1995 ...

GHz Sampling Circuits since 1997

LNA and Filters for DVB-IC since 2003 ...

DC-DC for PA Modulation since 2006 ...

Battery & SuperCap Management ICs since 2007 ...

Low-Voltage and High-Power DC-DC since 2009 ...

Kinetic Energy Recovery Systems since 2011 ...

Wireless & PLC in High EMI since 2012 ...

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Mobile / Stationary Big Volume Applications

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Energy Storages

Battery 48V
Motor Controller 3004
DCDC
3-Phase Rectifier
KERS

Break
‘Gas’

15 kW

Mobile / Stationary Big Volume Applications

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Energy Storages

Battery 48V
Motor Controller 3004
DCDC
3-Phase Rectifier
KERS

Break
‘Gas’

15 kW
The Energy Storages and the IoET
The Slow and Fast Energy Loops

**Standard Concept**

- **M/G**
  - DC-to-AC
  - AC-to-DC

**Energy Recovery**

- 20% Energy Recovery

**ADVANCED**

- 80% Energy Recovery by 1,000 Battery Cycles VERSUS 1,000,000 SuperCap Cycles

**Energy Loops**

- **Battery** 48V
  - DC-to-DC
  - Energy taken from Battery
  - DC-to-DC
  - Energy Restored to Battery

- **SuperCap** 48V
  - DC-to-AC
  - Energy taken from SuperCap
  - AC-to-DC
  - Energy Restored to SuperCap

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The **Super-Battery** Project

**Main Applications:** **City-eBusses; Fork-Lifts, Tools, UPS**

### Standard Battery
- **Cost:** €3,000
- **I/O:** 2,000 Cycles
- **Battery:** 48V 200Ah
  - **Charge:** 35 A (8 hours)
  - **Load:** 400 A (20 minutes)
  - **Return:** 200 A (320 minutes)
- **Efficiency:**
  - Charge: $\eta = 70\%$
  - Load: $\eta = 65\%$
  - Return: $\eta = 30\%$

### Super Battery
- **Cost:** €5,500
- **I/O:** 800,000 Cycles
- **Super-Capacitor:** 48V 3000Ah
  - **Charge:** 400 A (45 seconds)
  - **Load:** 3000 A (6 seconds)
  - **Return:** 3000 A (6 seconds)
- **Efficiency:**
  - Charge: $\eta = 80\%$
  - Load: $\eta = 80\%$
  - Return: $\eta = 80\%$

**RF-DCDC Converters**
- 48V 3000A

**Cell Balancers**
- Battery 48V 50Ah
- 20 Ah
**56kW Demonstrator:**
The SuperKart of RFIC-Lab @ ECE-TUT

- **Max Speed:** 280 km/h
- **Torque:** 528 Nm
- **0 to 100km/h:** 3.1 sec

**Battery & SuperCap**
- Weight: 47.3 Kg
- Capacity: 6.2 kWh
- Max Discharge: 40C
- Max Charge: 4C (15min)
- Cell-Dynamic BMS-CPU

**Motor & Transmission**
- Development Voltage: 60 V
- Continuous Power: 60 kW
- Max Power: 90 kW
- Weight: 31.4 Kg
- Power-to-Weight Ratio: 2:1