A Multi-Step Multi-Sample μNMR Relaxometer Using Inside-Magnet Digital Microfluidics and a Butterfly-Coil-Input CMOS Transceiver

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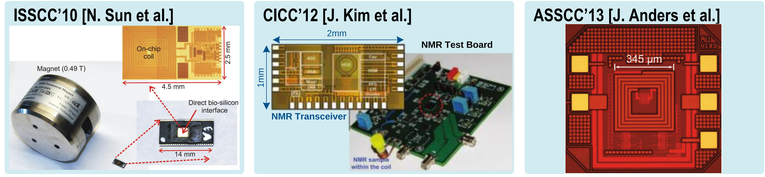
Research Background

Nuclear magnetic resonance (NMR):

- A novel and tantalizing tool
- Non-invasive and target-specific
- Several CMOS NMR systems have been reported
- Sample management poses a great challenge



Challenges on Multi-Sample Multi-Step Experiments

System Highlights:

- Co-integration of **microelectronics** and **digital microfluidics** technologies
- Sample manipulation (and sensing) **inside portable magnet** (1.2 kg, 0.5 Tesla)
- Cross-domain optimized **Butterfly-coil** to expand the effective electrodes

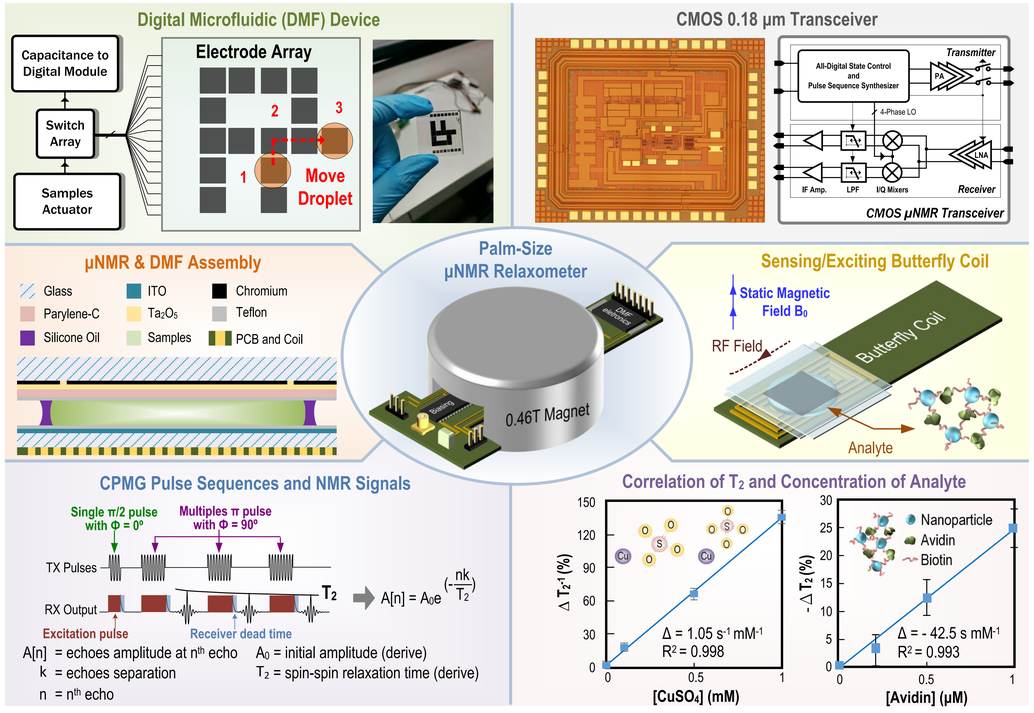
Result Highlights:

- **World-first electronic-automated μNMR relaxometer**
- **Multi-step multi-sample chemical/biological assays**
- **Unprocessed targets can be quantified by spin-spin relaxation time (T_2)**
- **Auto-handling and recognition of 2 biological samples with pre-designed probe**
- **Flexible route projection and optimization at software level**

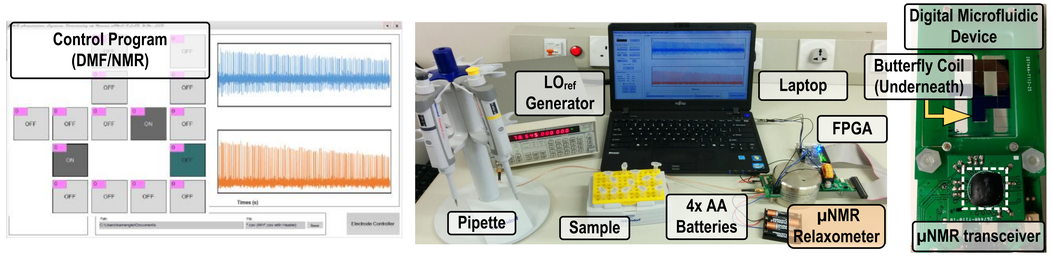
Comparison with the State-of-the-Art

	ISSCC '10	CICC '12	ASSCC '13	This Work
System Perspective				
Functionality	Relaxometry	Spectroscopy	Imaging	Relaxometry
Coil Style	On-chip spiral	Off-chip solenoid	On-chip spiral	**Off-chip PCB Butterfly**
Magnet	Portable (1.2 kg, 0.5 T)	N/A (5 T)	Large-scale (Bruker 7 T)	Portable (1.2 kg, 0.5 T)
Sample Handling per Experiment	One	One	One	**Multiple**
Pre-/Post-Sample Reaction Supportability	No (Only μNMR)	No (Only μNMR)	No (Only μNMR)	Yes (Mixing, Splitting + μNMR)
Circuit perspective				
Process (Voltage)	0.18 μm (1.8 V)	0.13 μm (1.5 V)	0.13 μm (1.5 V)	0.18 μm (1.8 V)
Freq.	21 MHz	5-300 MHz	300 MHz	20 MHz
Architecture	TRx	Rx	Rx	TRx
IRN (with/without coil)	0.93/1.26 nV/√Hz	--/3.5 nV/√Hz	0.26/-- nV/√Hz	**0.16/0.92 nV/√Hz**
Power	N/A	18 mW	18 mW	26.6 mW

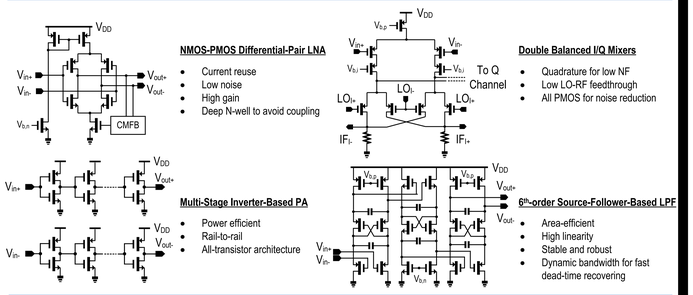
Multidisciplinary Lab-on-a-Chip Solution



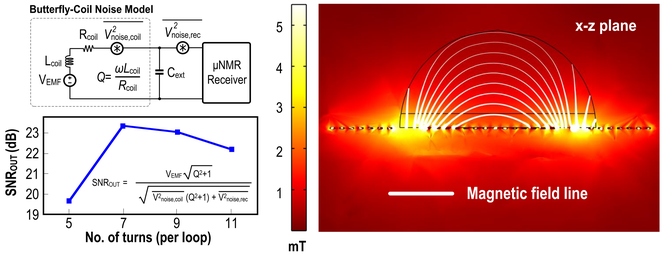
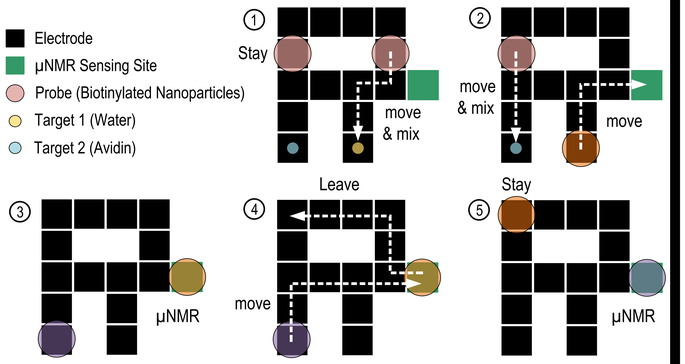
Hardware Setup & Software Control



Transceiver Schematics



Cross-Domain Butterfly-Coil Optimization



Multi-Sample Management