Energy-Efficient Circuits and Systems

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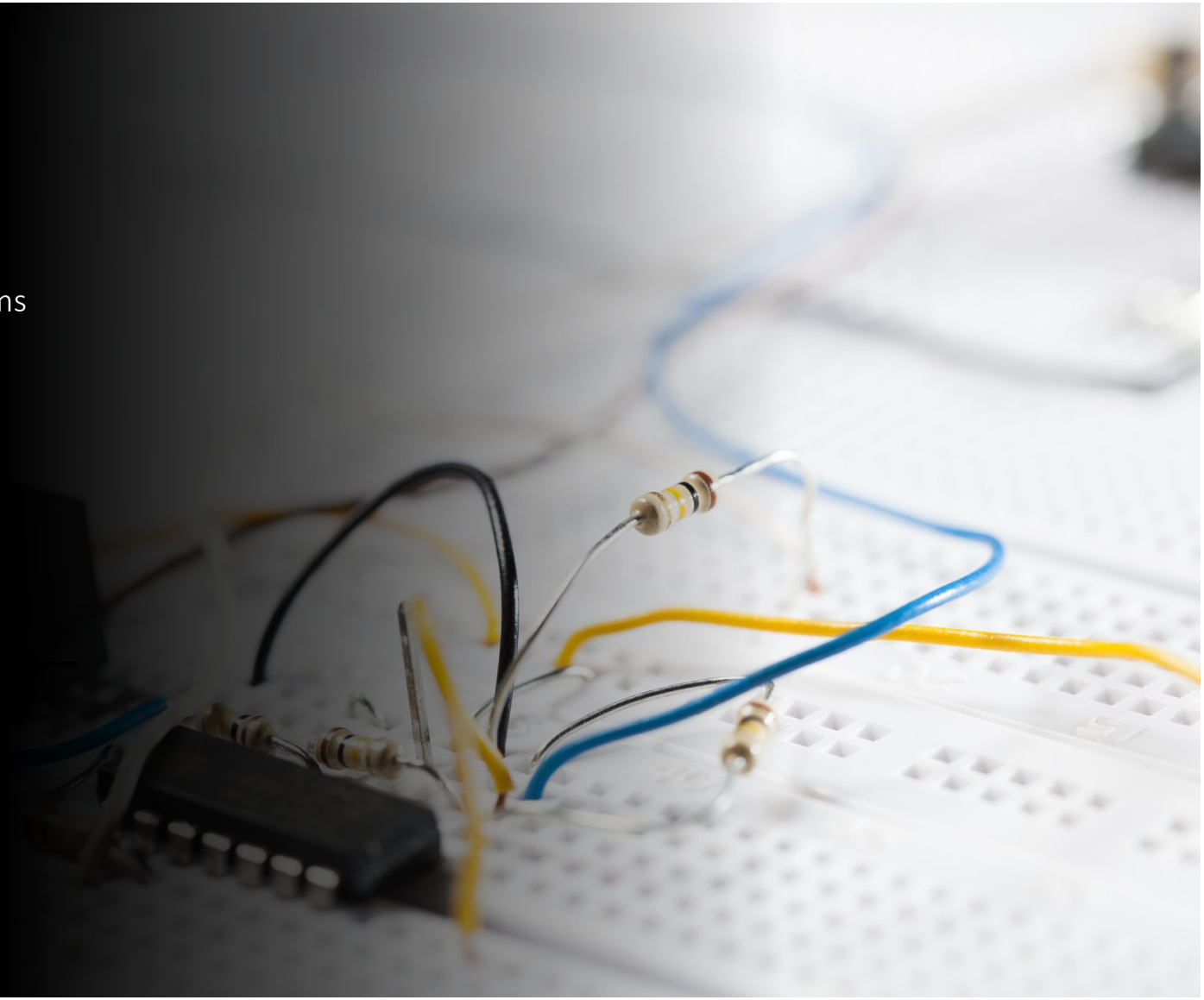


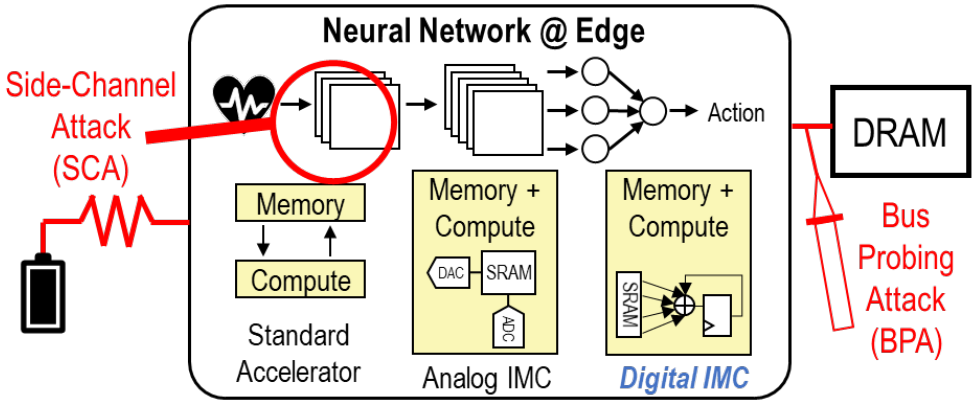
Research Directions

- Hardware Security : Materials, circuit, protocols and system
  - Secure machine learning
  - Power and EM side-channel resilient circuits

- Embedded machine learning processors
  - Robust machine learning
  - NLP
  - Generative AI
  - In-memory /near-memory machine learning

- Low-Power IoT
  - Bio-medical ICs (wearable and ingestible)
  - Energy Harvesting
  - Energy-efficient ADC
  - Authenticated Wake-up receivers

A Secure Digital In-Memory Compute Macro with Protections Against Side-Channel and Bus Probing Attacks

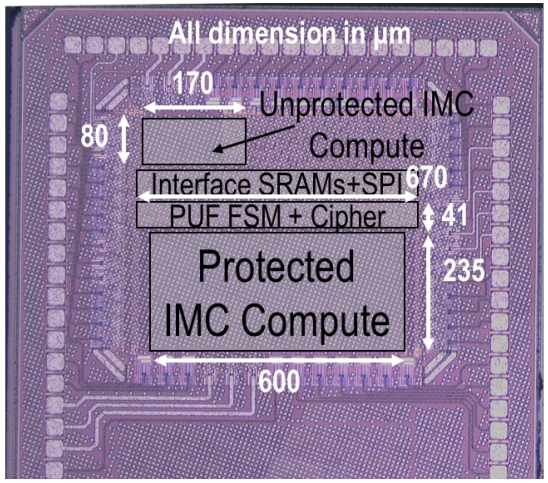


Challenge ①: SCA Security
Solution: Threshold Implementation (TI)-inspired digital in-memory compute

→ Eliminate Constant Random Bits By:
a) Using TI-shared gates and sub-blocks with natively secure statistical properties
b) Re-using previous unrelated computes as independent bits to refresh security

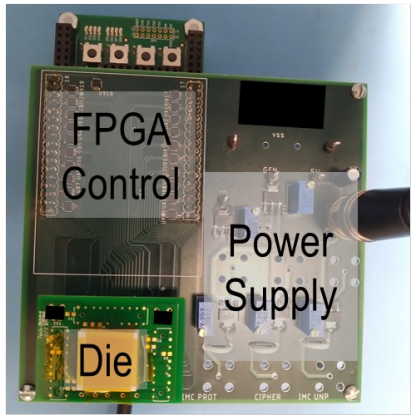
Challenge ②: BPA Security
Solution: Lightweight model decryption on-chip

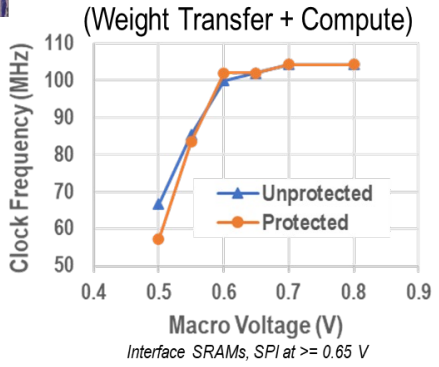
Challenge ③: Generate Secure Key
Solution: Reuse IMC SRAM for Physically Unclonable Function (PUF)



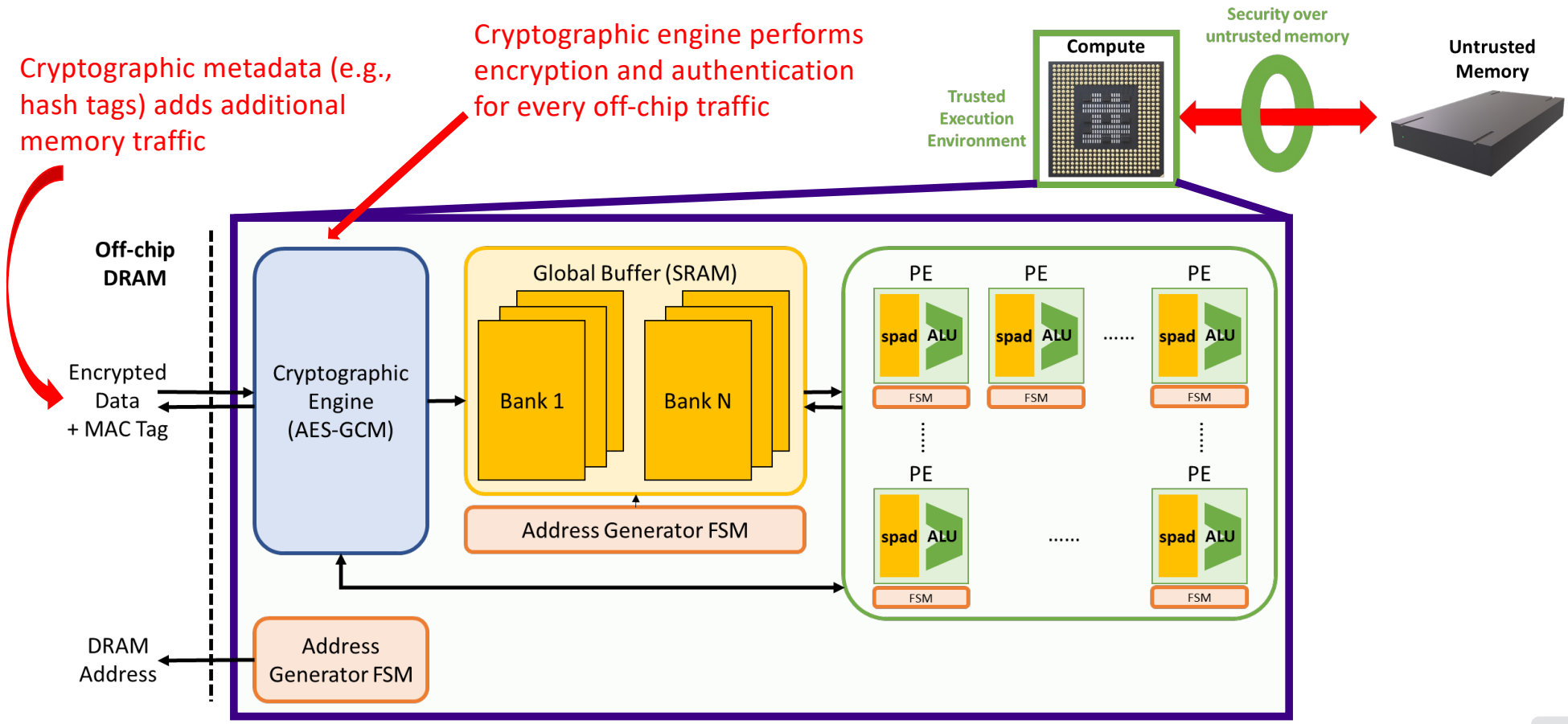
4b wgt, 1 / 8b act 0.55 V, 80 MHz	Unprotected	Protected
Throughput* (GOPS)	41.0 / 9.10	81.9 / 10.2
Energy Efficiency* (TOPS/W)	90.2 / 14.4	6.94 / 0.89
Area Efficiency* (TOPS/mm2)	3.01 / 0.67	0.49 / 0.061

*at peak utilization, weight update is 5% of time



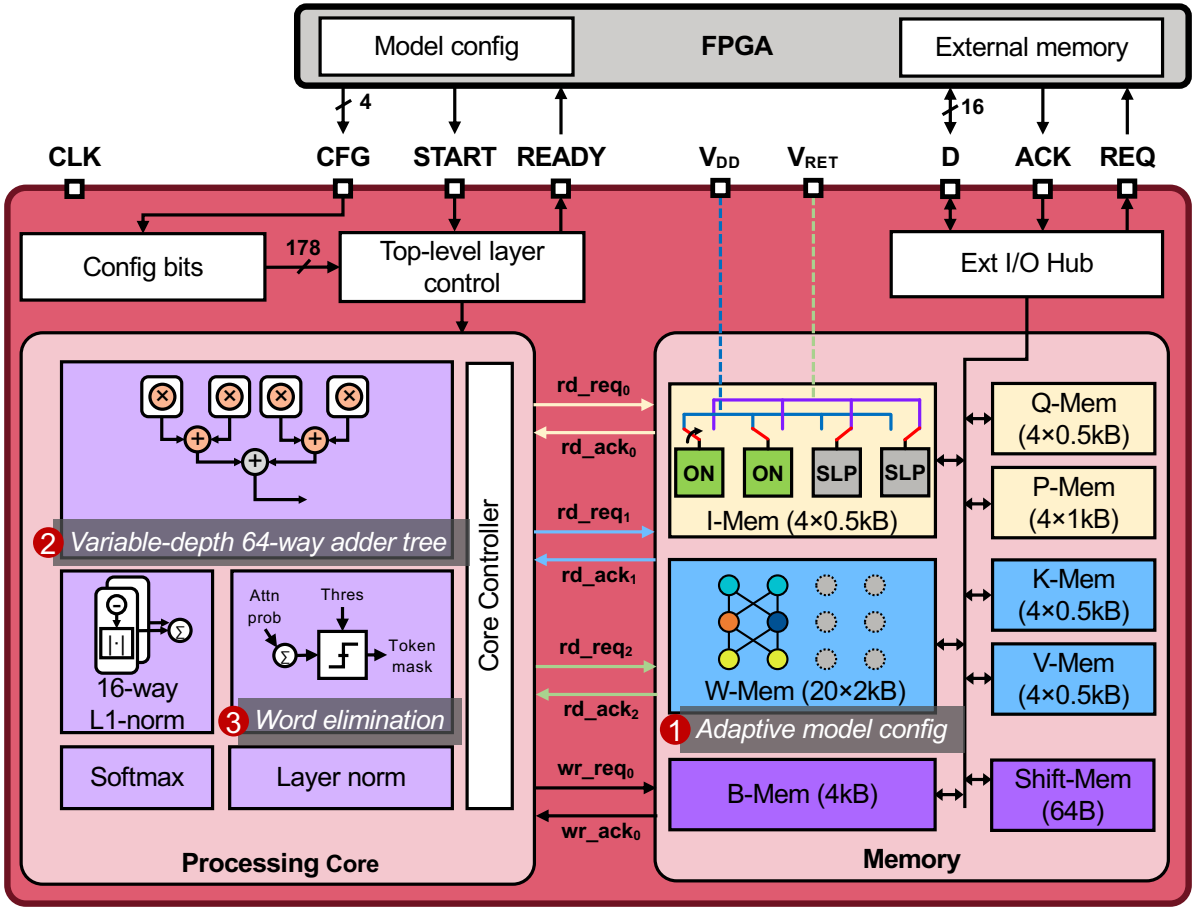


Trusted Execution Environment for DNNs



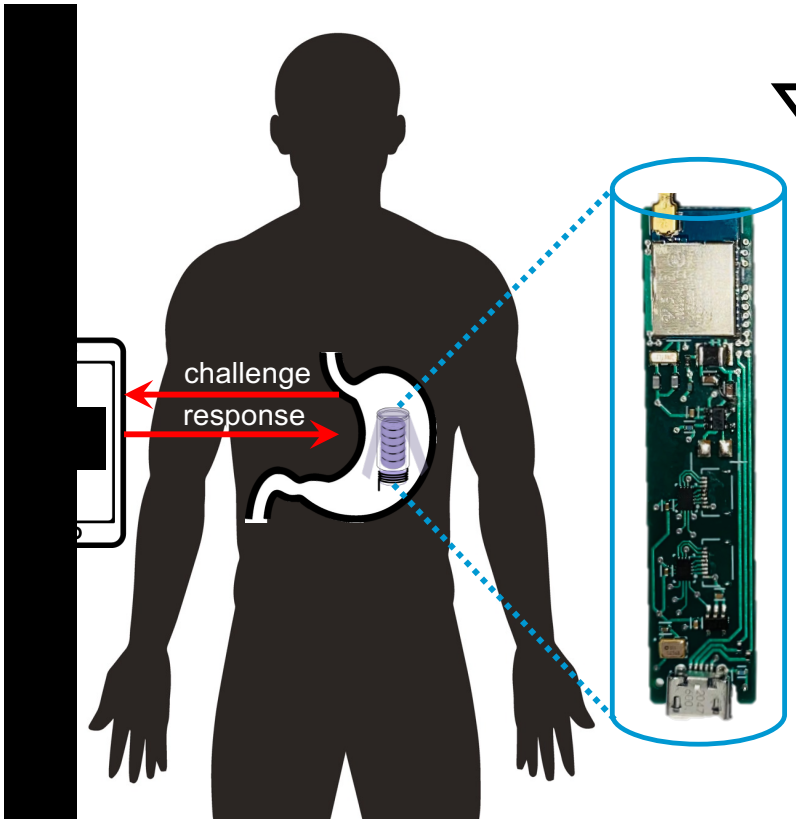
Kyungmi Lee, Joel Emer, Mengjia Yan, A. Chandrakasan, [MICRO 2024]

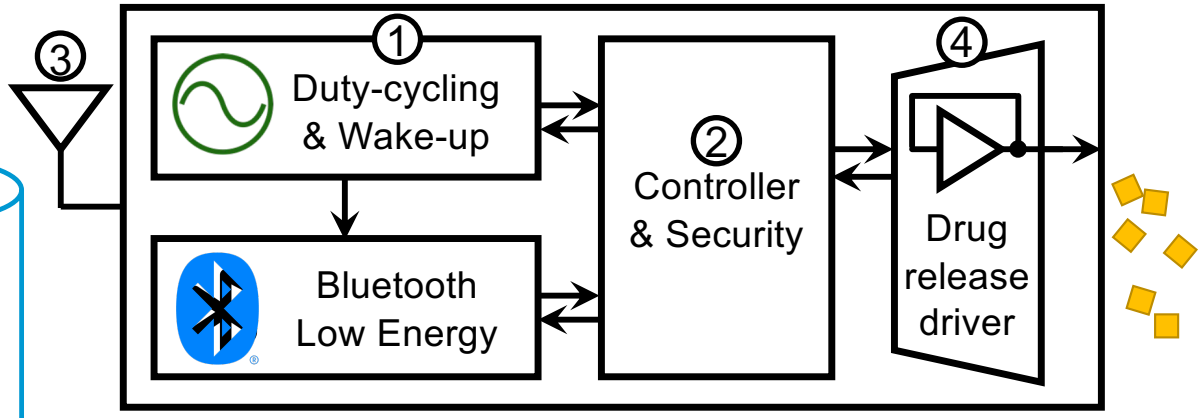
Low Power NLP



Z. Ji, H. Wang, M. Wang, W.-S. Khwa, M.-F. Chang, S. Han, A. P. Chandrakasan, "A Fully-Integrated Energy-Scalable Transformer Accelerator Supporting Adaptive Model Configuration and Word Elimination for Language Understanding on Edge Devices," *ACM/IEEE International Symposium on Low Power Electronics and Design (ISLPED)*, Aug. 2023.

Low-Power and Secure Communication System for Ingestible Devices





① Low-power RF system based on duty-cycling & wake-up

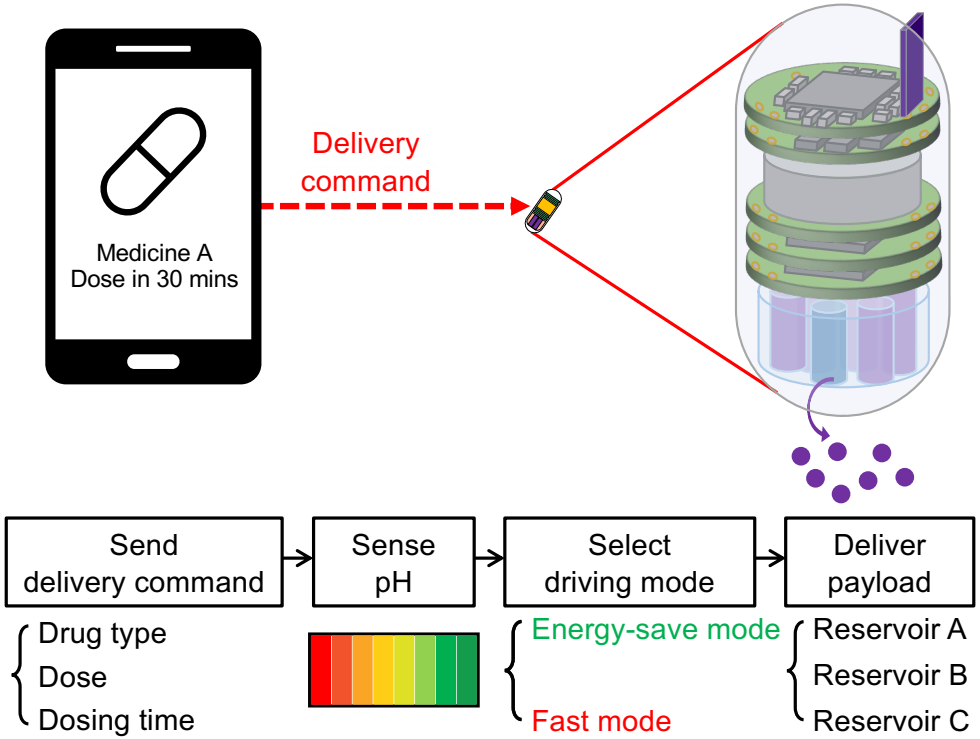
② Energy-efficient authentication protocol

③ Antenna design for ingestible device

④ Self-adaptable driver for drug release

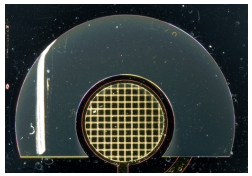
Jeon Y., S. Maji, S-Y. Yang, M. S. S. Thaniana, A. Gierlach, I. Ballinger, G. Selsing, I. Moon, J. Jenkins, A. Pettinari, N. Fabian, A. Hayward, G. Traverso, A. P. Chandrakasan, "Secure and Stable Wireless Communication for an Ingestible Device," Annual International Conference of the IEEE EMBC 2023.

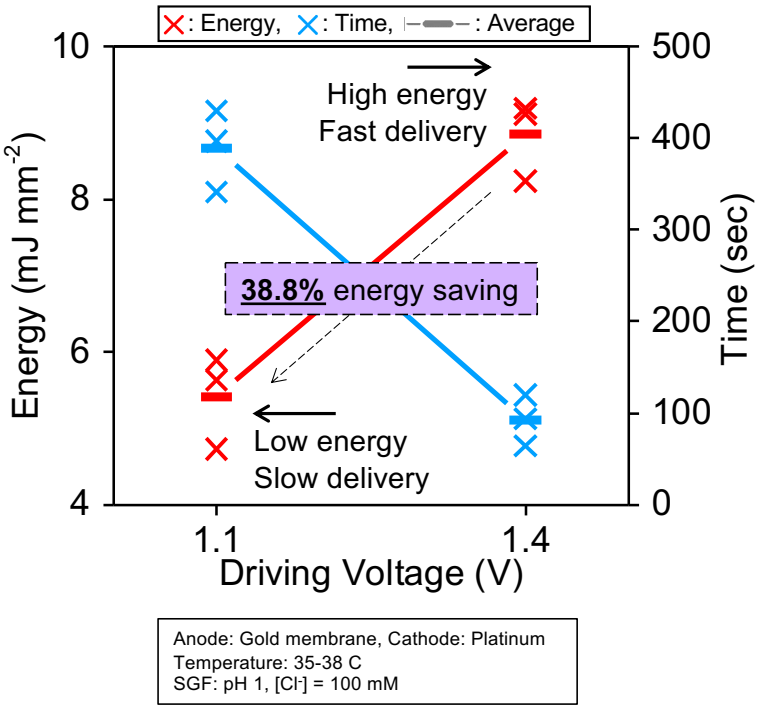
Drug Delivery



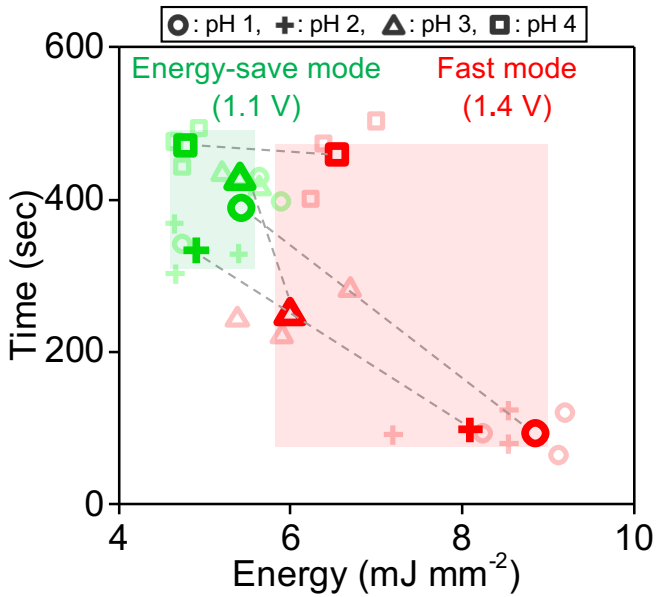
Yang S-Y., Y. Jeon, R. Mittal, K. Nan, Y. Yang, E. Kolaya, I. Moon, K-H. Kim, M. Jimenez, B. Gallant, A. P. Chandrakasan, G. Traverso, “Energy-Efficient Ingestible Drug Delivery System in the Dynamic Gastrointestinal Environment,” Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Jul. 2023.

Driving Voltage Modulation
for energy-efficient gold dissolution

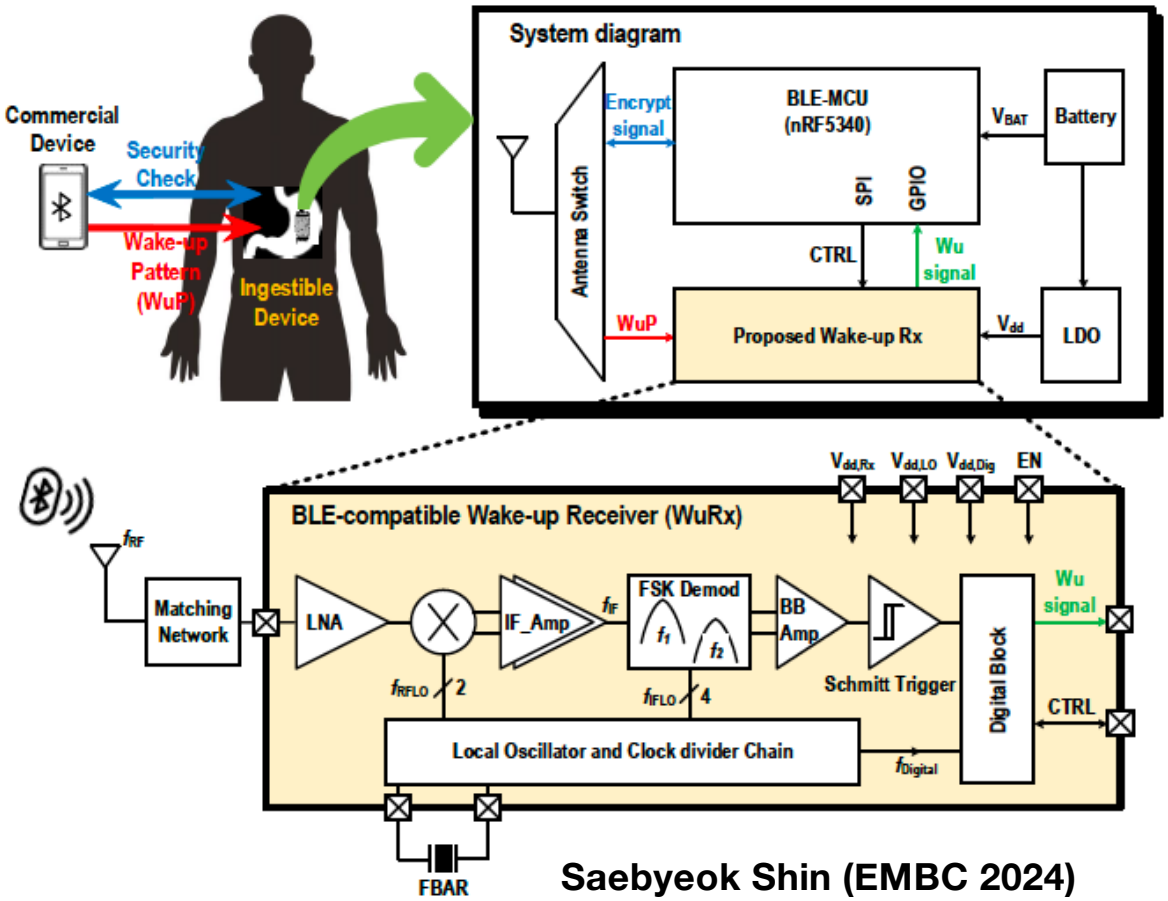




Anode: Gold membrane, Cathode: Platinum
Temperature: 35-38 C
SGF: pH 1, [Cl^-] = 100 mM

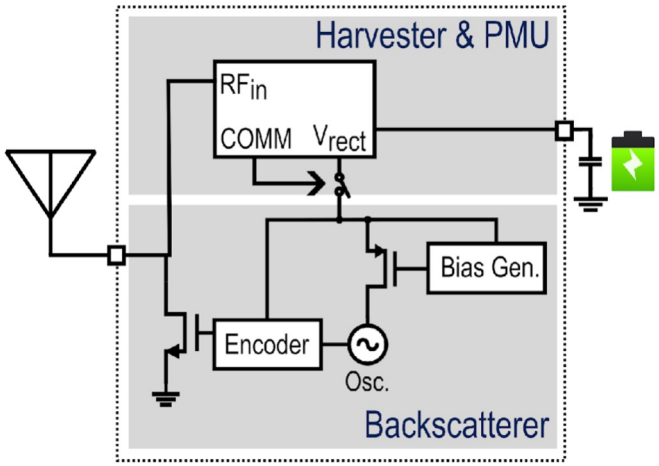


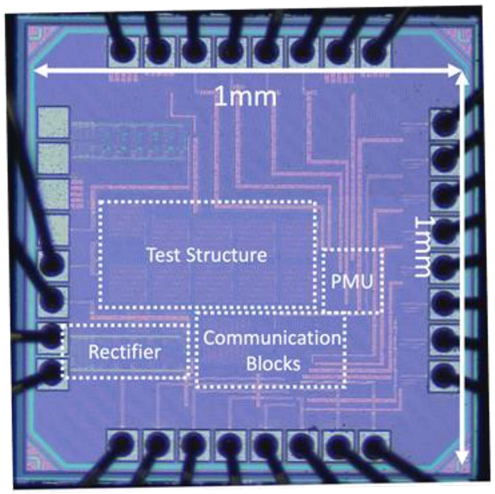
Wakeup Radio Architecture

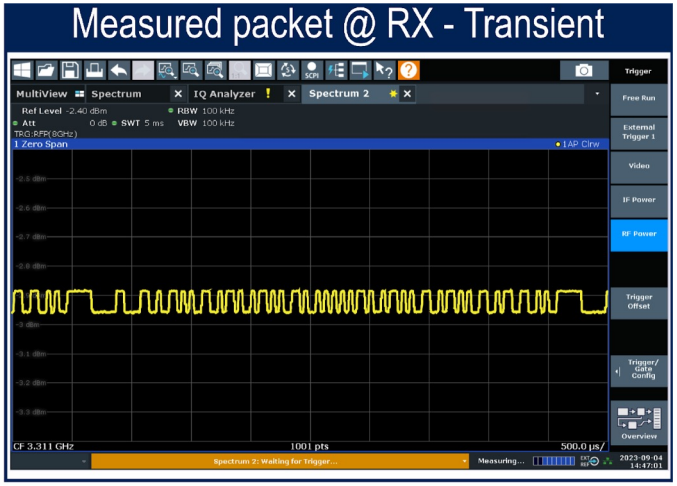


Saebyeok Shin (EMBC 2024)

Battery-free 5G energy harvester backscattering chips for asset identification in IoT - enabled warehouses

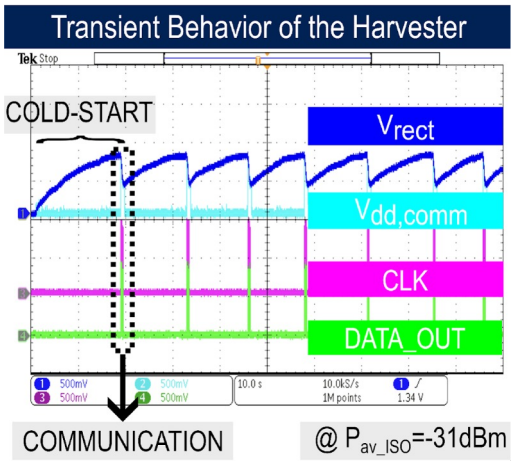






Key Features

- Harvests 5G energy for battery-free backscattering communication tags
- Ultra-low power, on-chip, PVT – resilient clock generation
- Built-in Manchester and convolutional code for enhanced backscattering resiliency



Process	65nm
Freq.	**3.5GHz**
Antenna Area (cm^2)	**0.7**
Sensitivity (dBm) or Wake-up power	-31
V_{rect} (V), R_{load}/P_{load} at sensitivity	0.9 @1nW
Cold-start charging time	18sec @ -31dBm
Communcation Scheme	OOK
Communication Bitrate	2.5kbps
Communication Power @ V_{dd}	**0.12µW @ 0.9V**

Deniz Umut Yildirim (CICC 2024)