Artificial Intelligence Technique for Structural Health Monitoring SHM

By: *Dr. Yarub Alazzawi*

Self-powered System-on-Chip for Substrate Computing and Ultrasonic Communications

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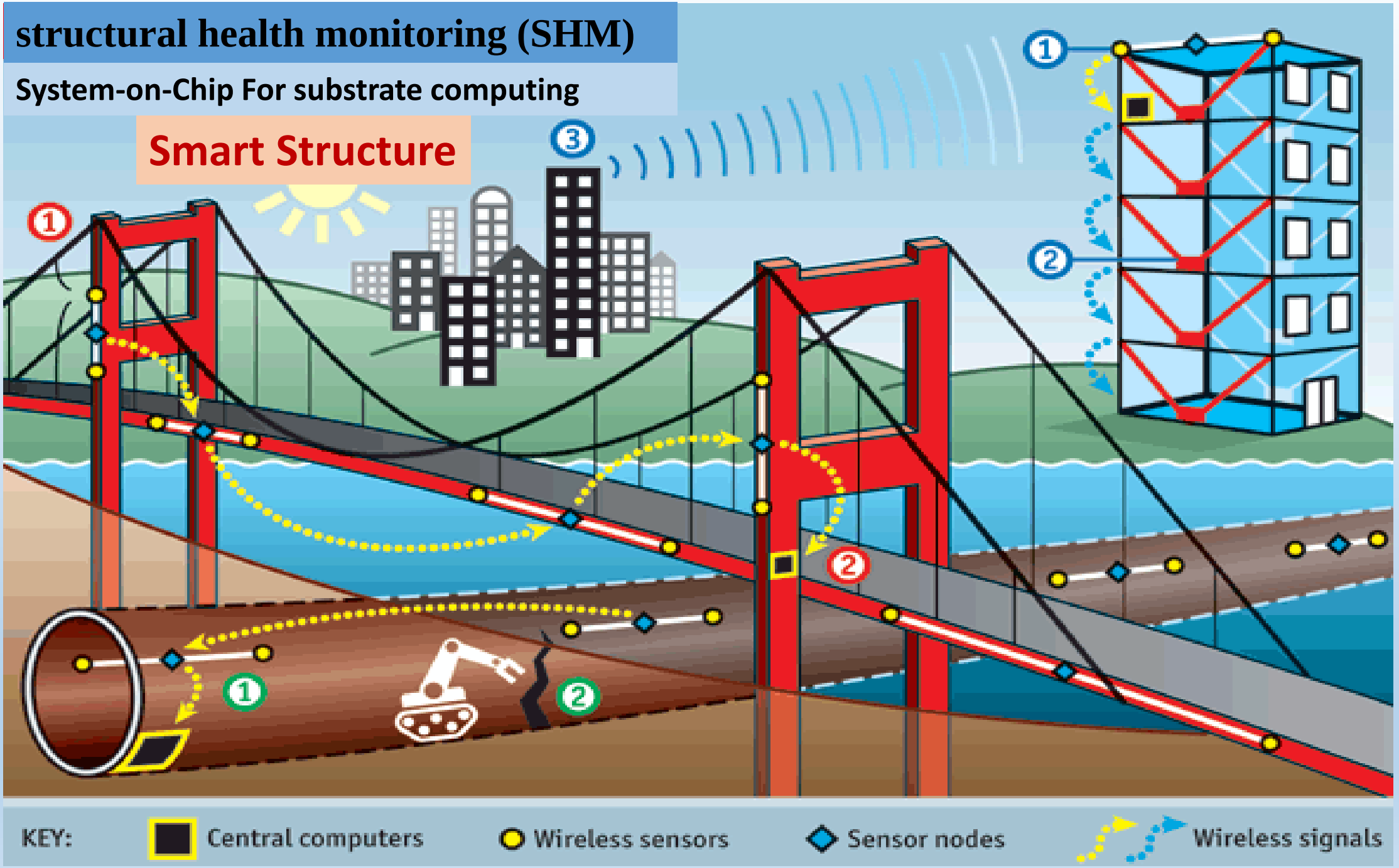
structural health monitoring (SHM)

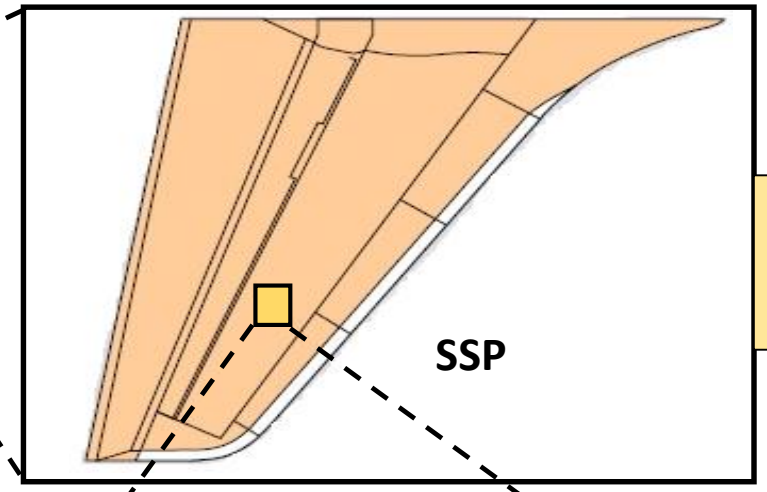
System-on-Chip For substrate computing



https://phys.org/news/2016-09-smart-infrastructure-sensors.html

smart structures

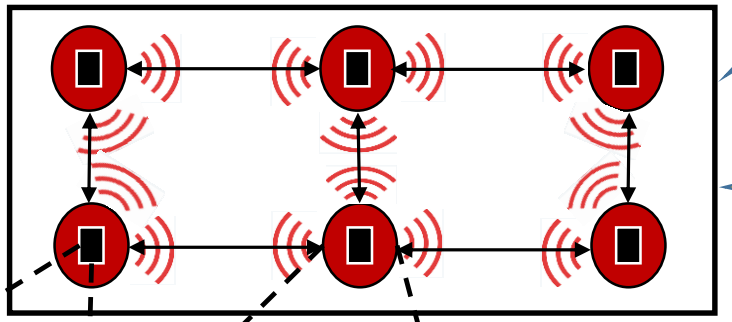
- *Structure health monitoring*
- *Self-contained energy harvester*
- *Bi-direction communication*
- *Low-power embedded hardware*



Smart Substrate Plate SSP

Central computer

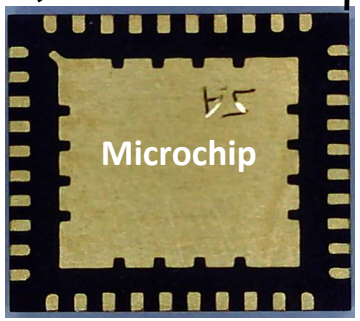
US Substrate Pulse Link

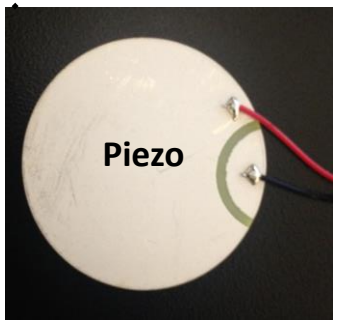


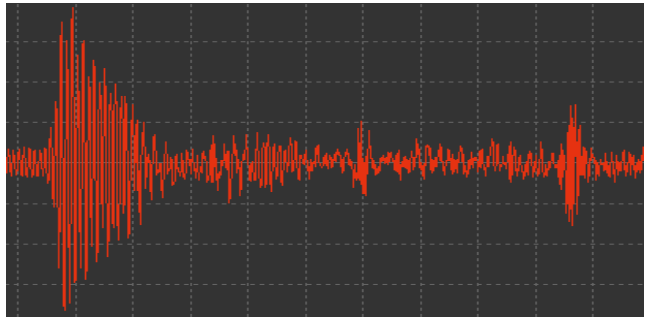
Wireless sensor

Sensor node

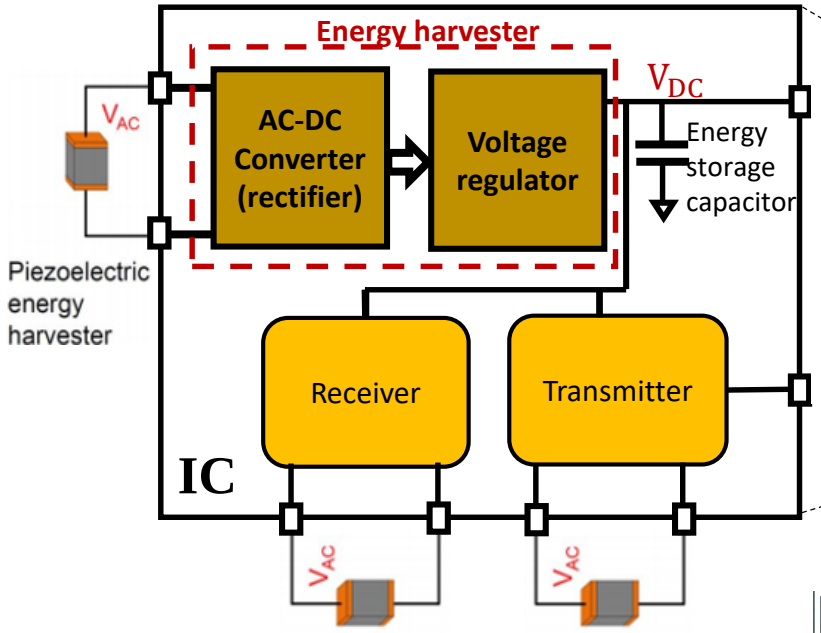
Wireless signal

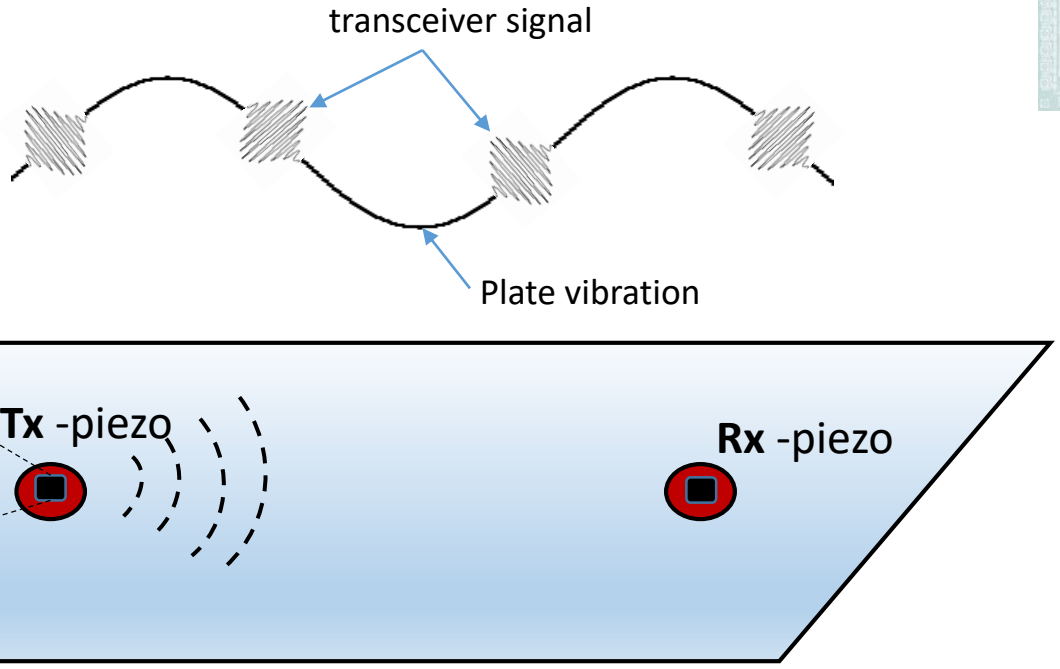




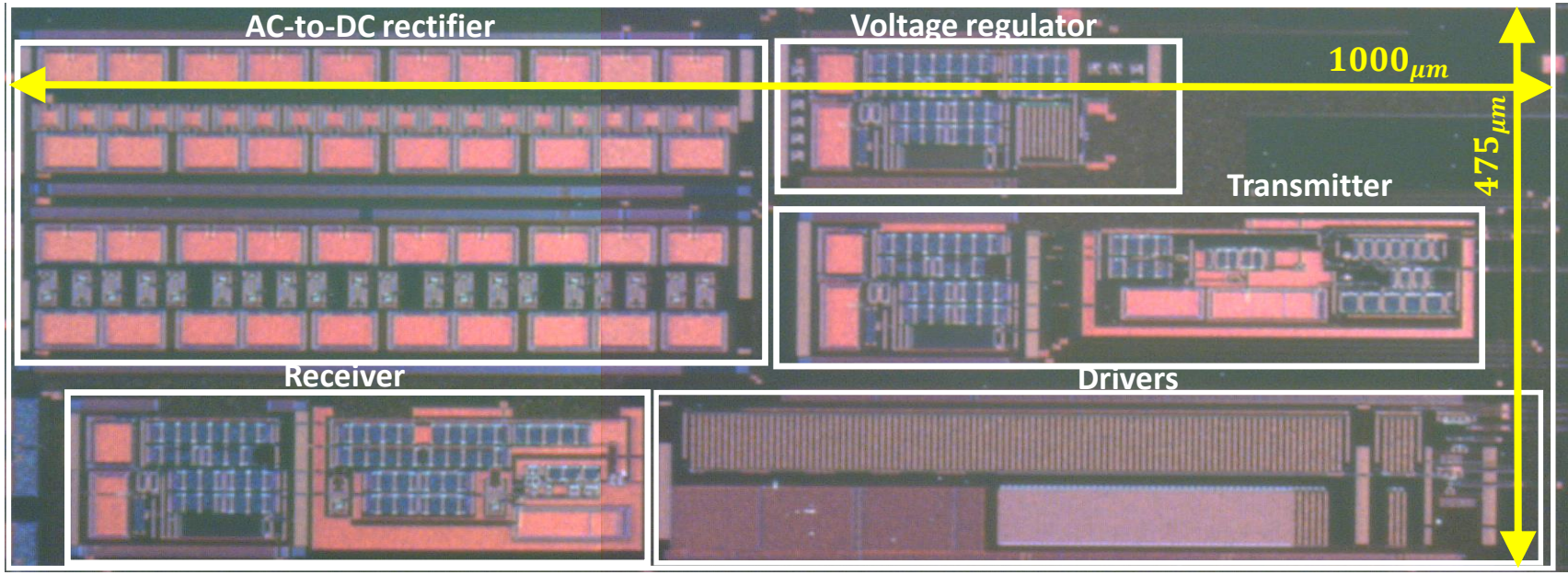


System block diagram of the wireless node





- ***Three piezoelectric interfaces:***
  - Harvesting and regulating energy
  - Transmitting ultrasonic pulses
  - Receiving ultrasonic pulses



Transceiver circuit implementation

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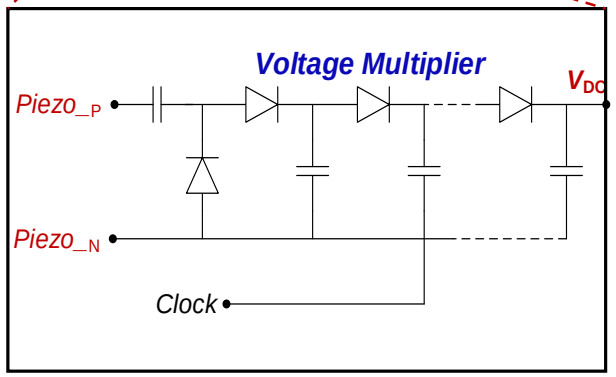
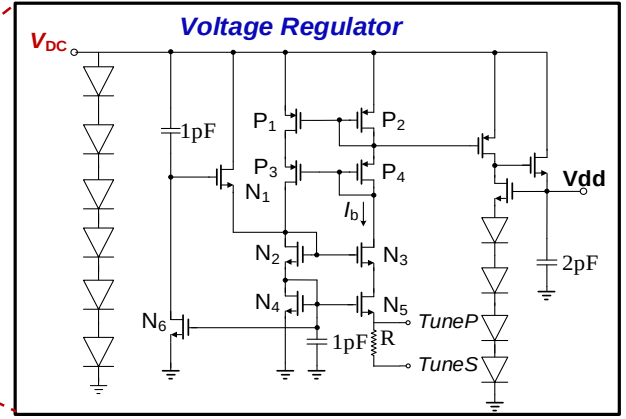
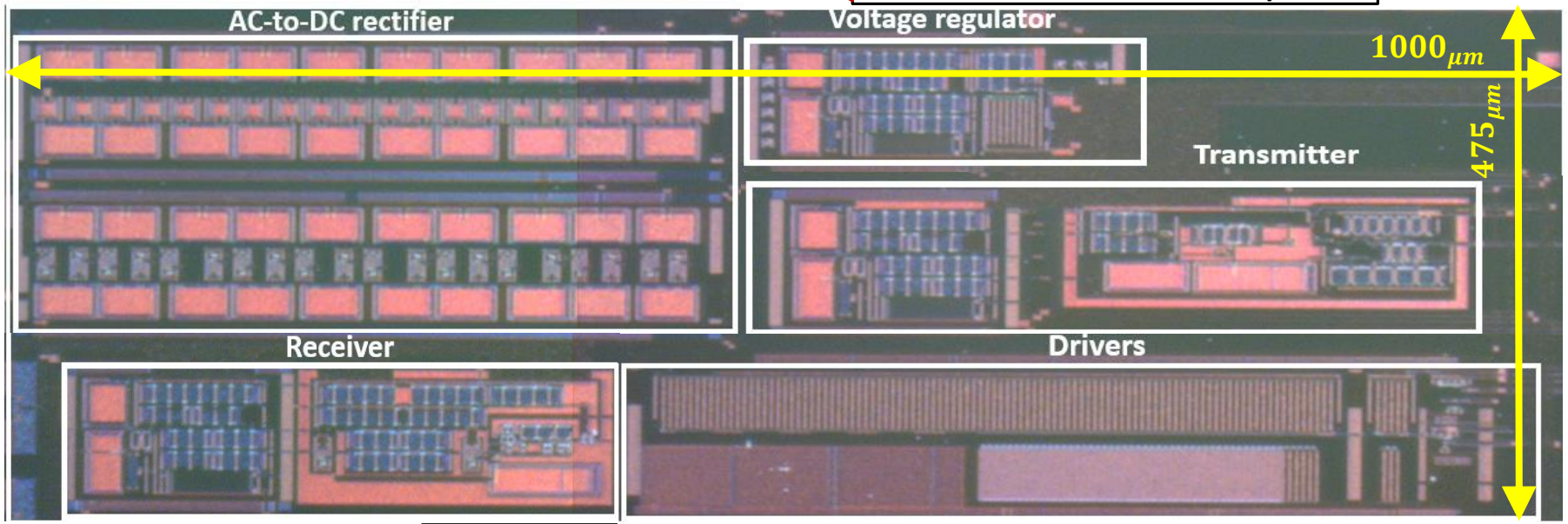
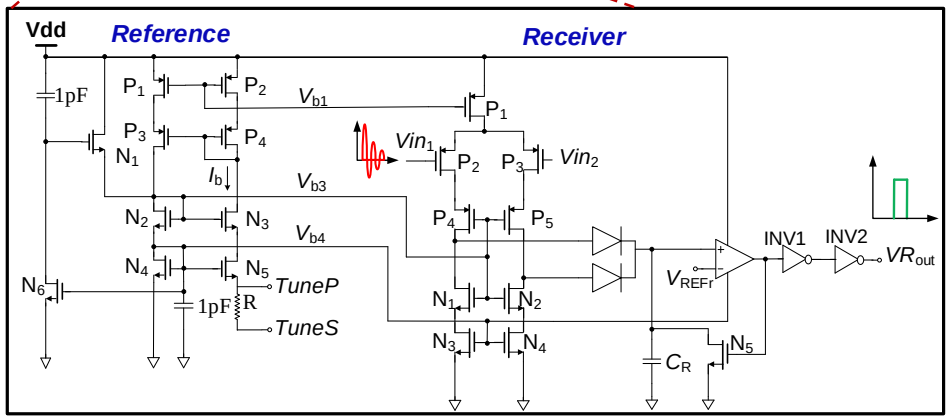
PZT → Voltage Multiplier → Voltage Regulator

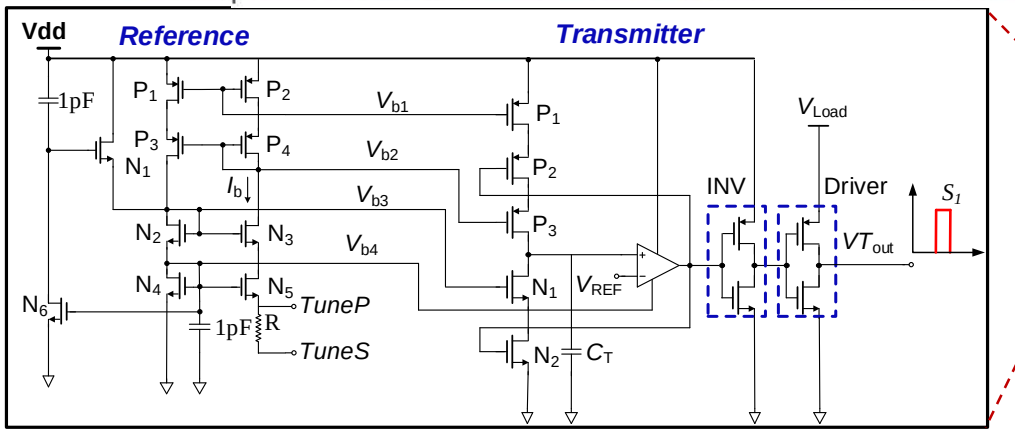






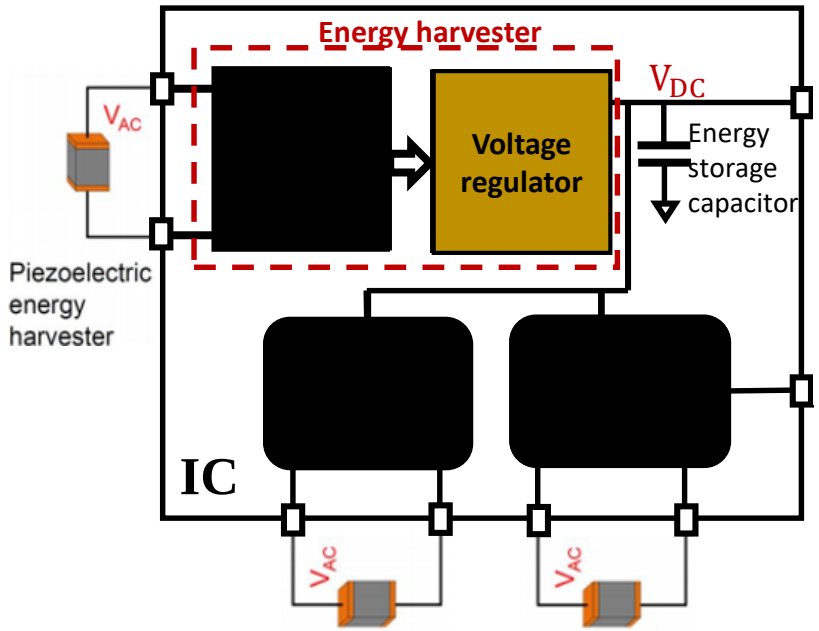
PZT → Receiver

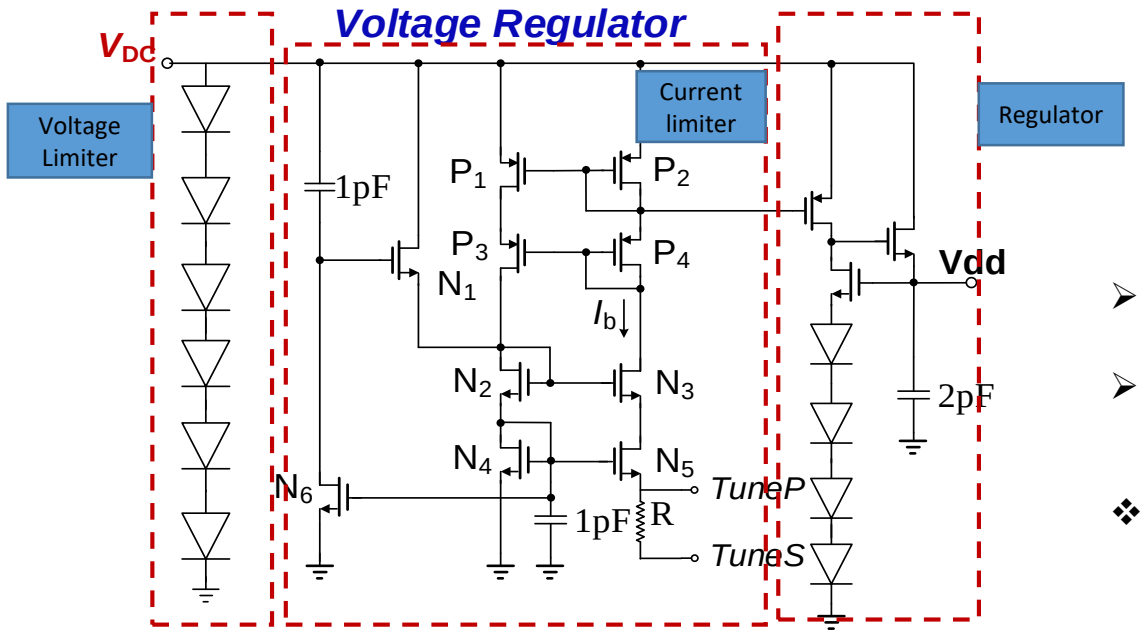


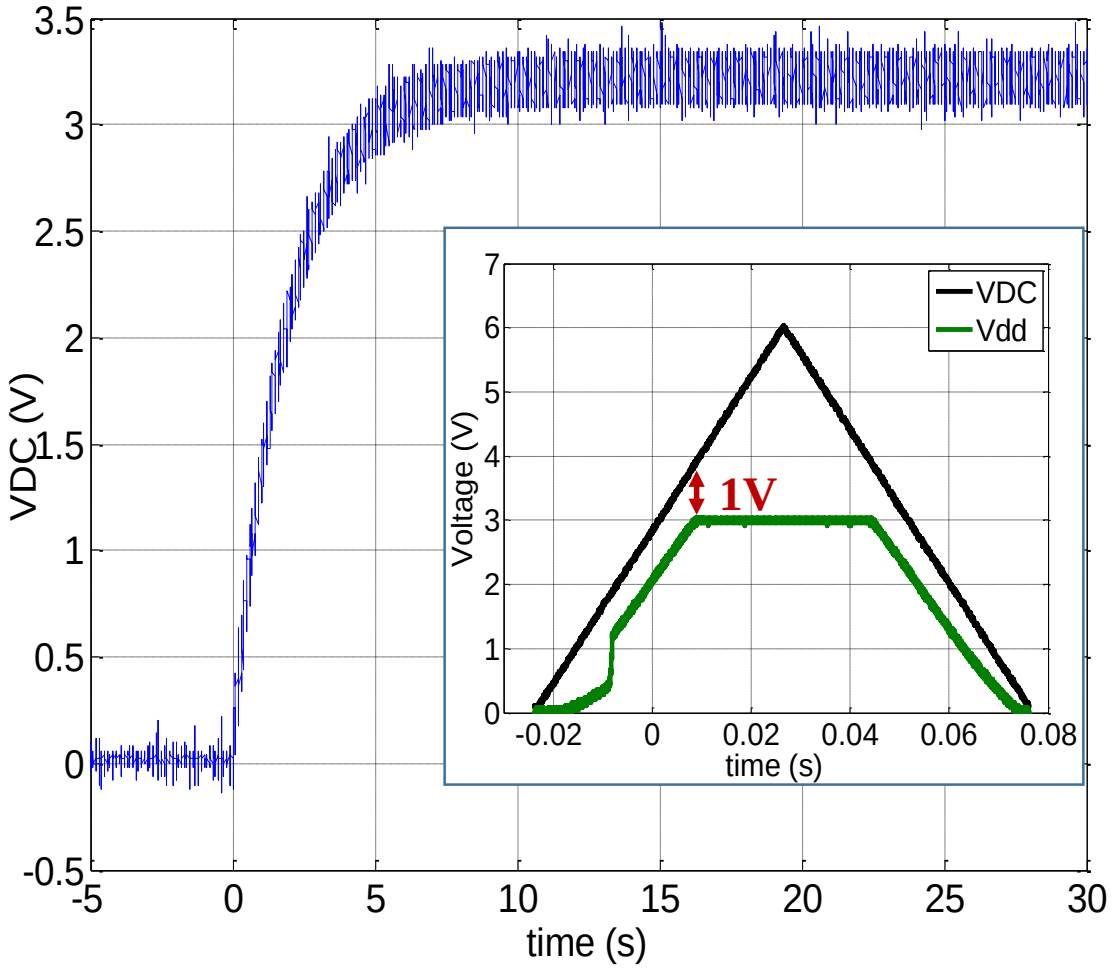


Transmitter → PZT

System block diagram of the wireless node



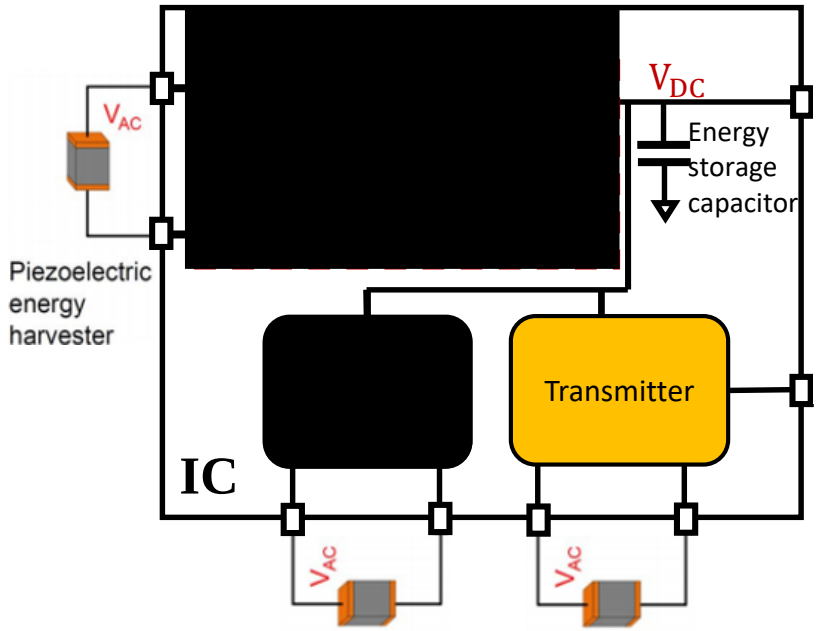


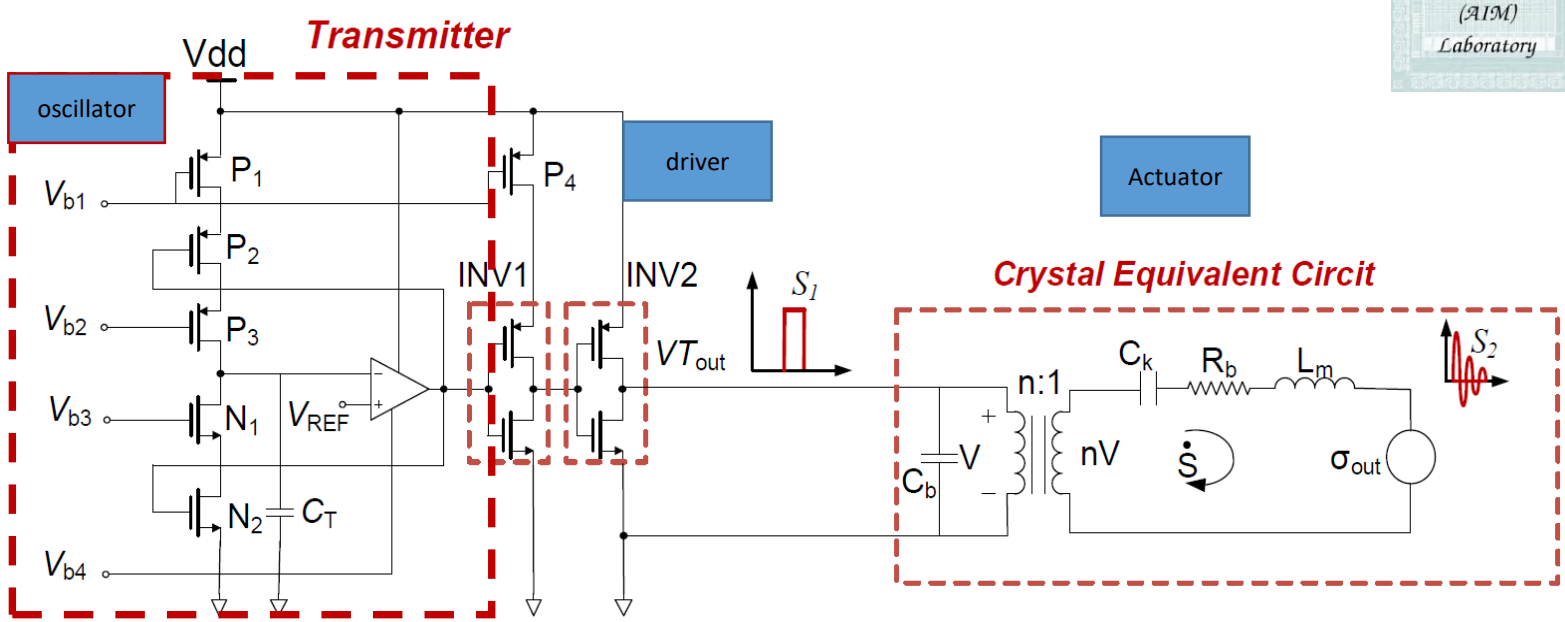


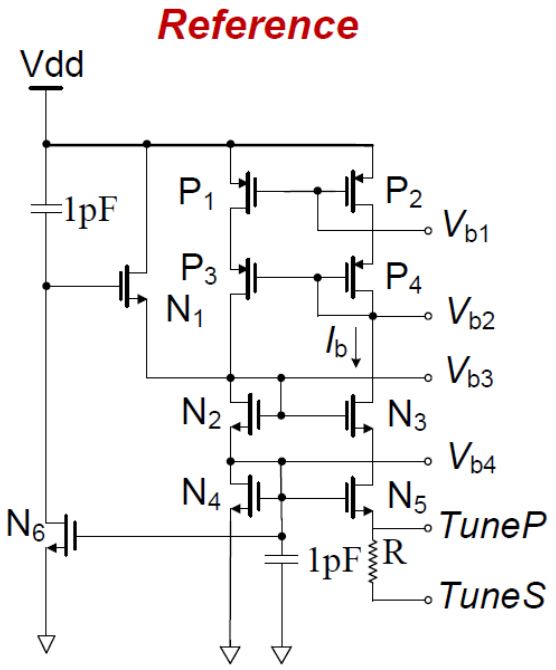
- multiplies the input voltage by number of stages.
- The built-up DC voltage has ripples.

- The generated DC-voltage is stable with drop-off voltage around 1V.

System block diagram of the wireless node

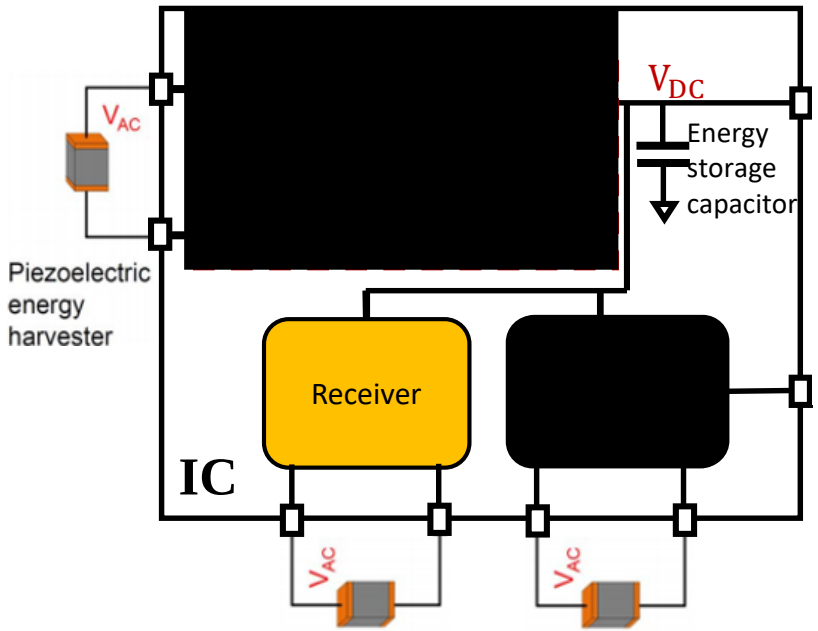


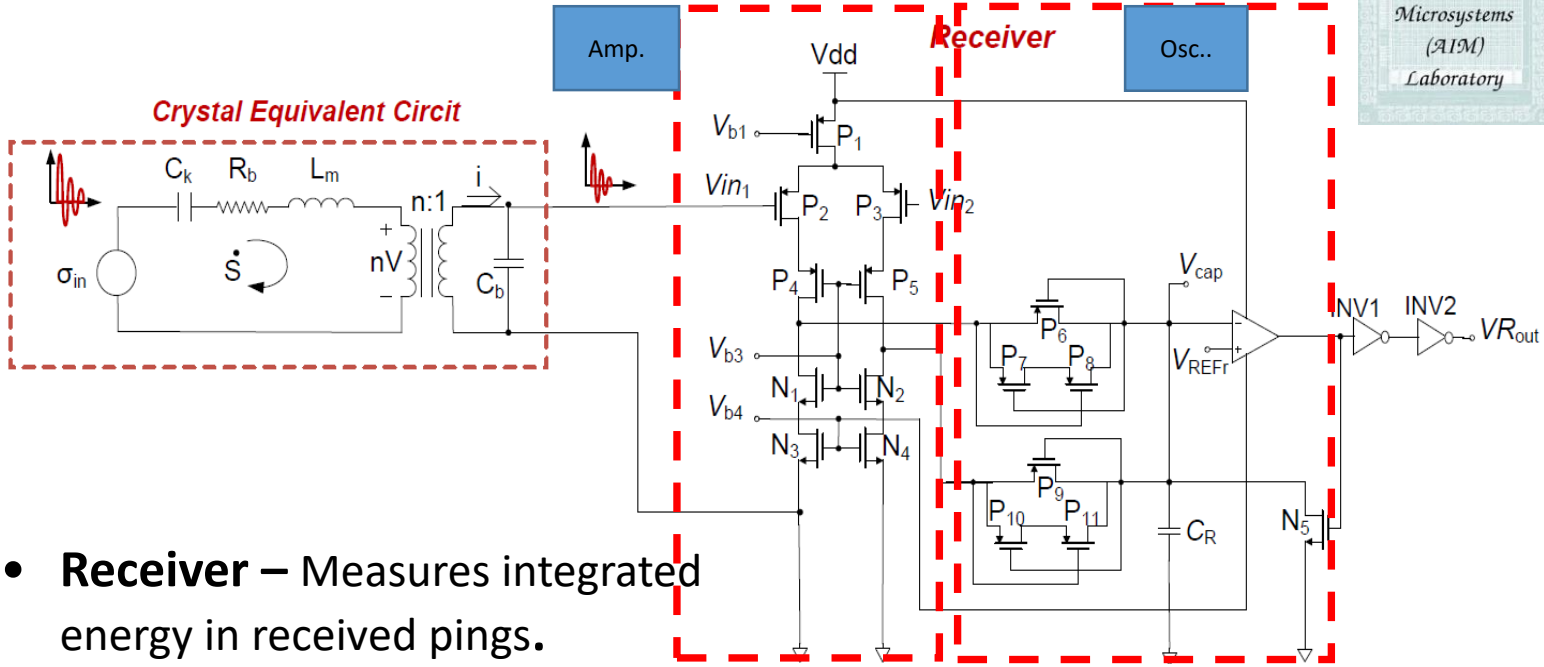




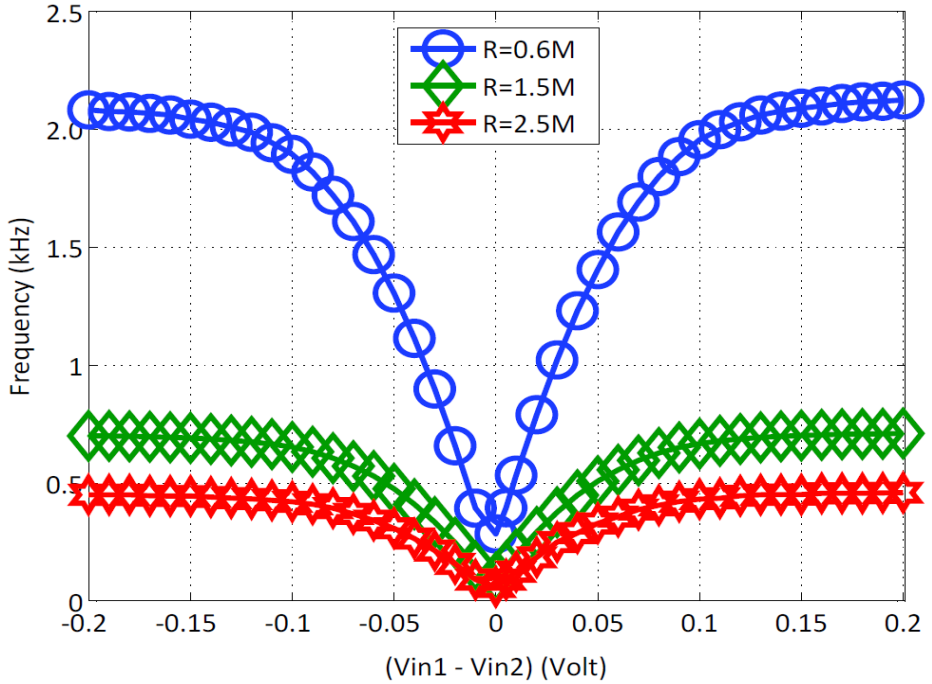
- **UWB ultrasound transmission –** Relies on the pulse-shaping property of the crystal**.**
- **Power dissipation and loss** – charging and discharging of the crystal capacitance**.**

System block diagram of the wireless node





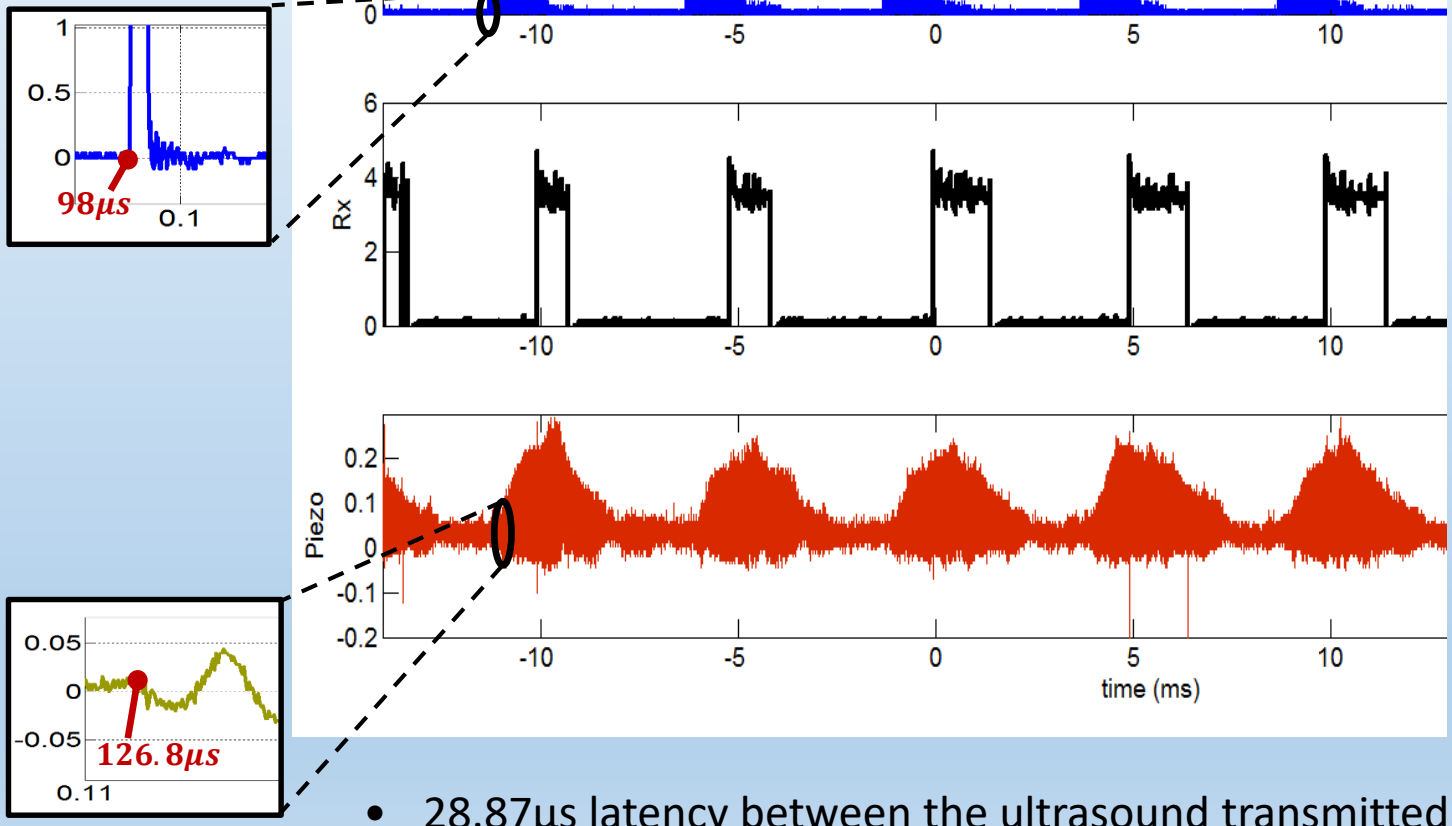
- **Receiver –** Measures integrated energy in received pings**.**



- **Gain and Sensitivity** – can be adjusted by changing the reference resistor**.**

- **Digital output –** Using a relaxation oscillator.

Complete transceiver performance



SPECIFICATIONS OF THE SELF-POWERED TRANSCEIVER.

Parameter	Specification
Circuit dimensions	$1000\mu m$ x $475\mu m$
Power dissipation	$55\ \mu W$ at $8KHz$ data rate
Generated DC voltage	$3.44V$
DC voltage settling time	$10s$
Regulator Dropout	$1V$
Transmitter pulse transition time	$2\mu s$
Received Voltage Range	$350\ mV$
Receiver sensitivity	$4Hz/mV$
Material	PZT-5H Piezo-crystal
Resonance frequency	$230kHz$
Bandwidth	$\approx 200KHz$

- 28.87μs latency between the ultrasound transmitted and received signals separated by 17cm.

On-going research work

Energy Harvesting of Mechanical Structures for Through-Substrate Communications

Yarub Alazzawi, *Member, IEEE*

***Abstract*—Substrate computing refers to a paradigm where sensing, computing, communications, energy scavenging and energy storage functions are seamlessly integrated within a substrate. The substrate could be a part of an aircraft wing or a chassis of the car and the computing, communications and energy scavenging functions could be implemented using self-powered devices embedded inside the substrate. In this paper we present the design of a CMOS transceiver that could be used for through-substrate communications using ultrasonic pulses. The transceiver comprises of two different piezoelectric interfaces, one of which is used for transmitting and the other is used for receiving ultrasonic pulses. We present measurement results using prototypes of the transceiver fabricated in a 0.5-μm CMOS process integrated with piezoelectric transducers that are attached to a segment of an aluminum wing. Bit-error-rate degradation caused by the interference signal was measured to achieve the maximum reliable communication. The results demonstrate the functionalities along with the bi-directional telemetry functions needed to implement a complete transceiver for substrate computing.**

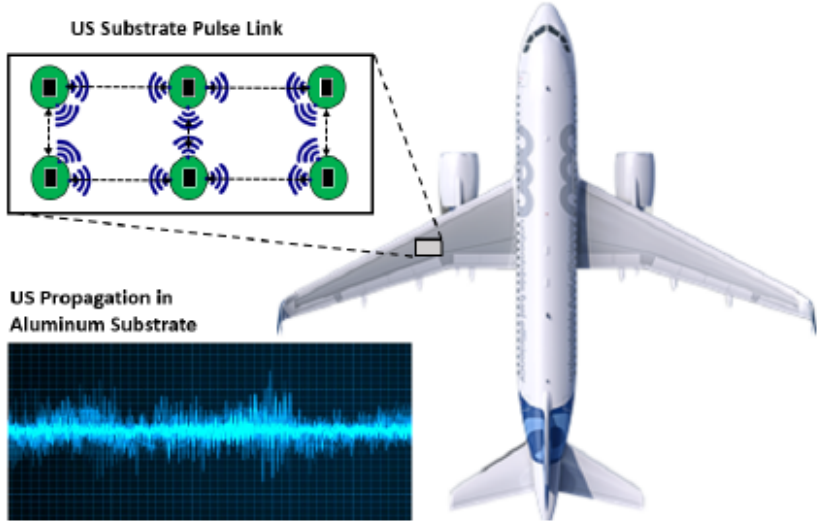


Figure 1. The concept of smart substrate plates (SSPs) with a fabric of embedded sensors. The sensors operate by harvesting energy from ambient vibrations in the substrate and communicate through the substrate using ultrasonic pulses. Large-structures like an aircraft wing can be assembled without the need to separate instrumenting the sensors. (Aircraft image source: Google image).

I. Introduction

ADVANCES in miniaturization are enabling novel sensing technologies that promise breakthroughs in all areas of science and engineering. Nowhere is the impact more evident

In this paper we present the design of a CMOS transceiver that can be used for through-substrate communications in SSPs using and ultrasonic data link (i.e., without a separate medium

CONCLUSIONS

- We have proposed a design of a self-powered CMOS transceiver that can be used for through-substrate communications using ultrasonic pulses.
- The transceiver is powered by energy that can be harvested from ambient vibrations present in the substrate and hence can operate without batteries.
- The transceiver will be integrated with a digital processor (also powered by the energy harvesting modules) which will be programmed to control the transmitter and also process the digital output produced by the receiver.
- The processor will also be programmed to implement communication protocols that can be used to form a sensor network inside the substrate such that important information related to the health of the structure can be reliably communicated.
- Characterization of the proposed telemetry system for these different structures, combined with the ability of harvest ambient energy for real-time operation will form the basis of future research in this area.

Adaptive Integrated Microsystems (AIM) Laboratory

References

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ACKNOWLEDGMENT

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Thank you