

# Capacitive micromachined ultrasonic transducers (CMUT)

*CMUT element, chip and a module*

## Motivation

Ultrasonic transducers are as established in medical diagnostics and therapy as they are in industrial testing – for example, in the low-interference monitoring and analysis of static and dynamic processes or in automation technology. These applications benefit from the non- or minimal invasive and non-ionizing working principle of ultrasound. Innovations and developments in these market segments show trends towards automated systems, human-machine interaction, and multi-sensor fusion, which demand miniaturized ultrasonic sensor devices with a high level of integration and performance.

Capacitive micromachined ultrasonic transducers (CMUTs) address these market requirements for the next generation ultrasound systems based on MEMS structures utilized to generate and sense acoustic signals in the ultrasonic range.

## Applications

Based on their unique properties, CMUTs pave the way for innovations in a variety of application areas (see next page).

## Advantages

CMUTs reveal favorable properties compared to state-of-the-art ultrasound devices:

- Freedom of design and miniaturization (single elements to 2D arrays)
- High acoustical bandwidth
- High receive sensitivity
- Impedance matching to fluids and air
- Highly reproducible MEMS technology
- Fully integrable in CMOS technology
- RoHS conformity (non-toxic materials)

## Services

Fraunhofer IPMS serves as a one-stop-shop for CMUT developments from concept to system solutions:

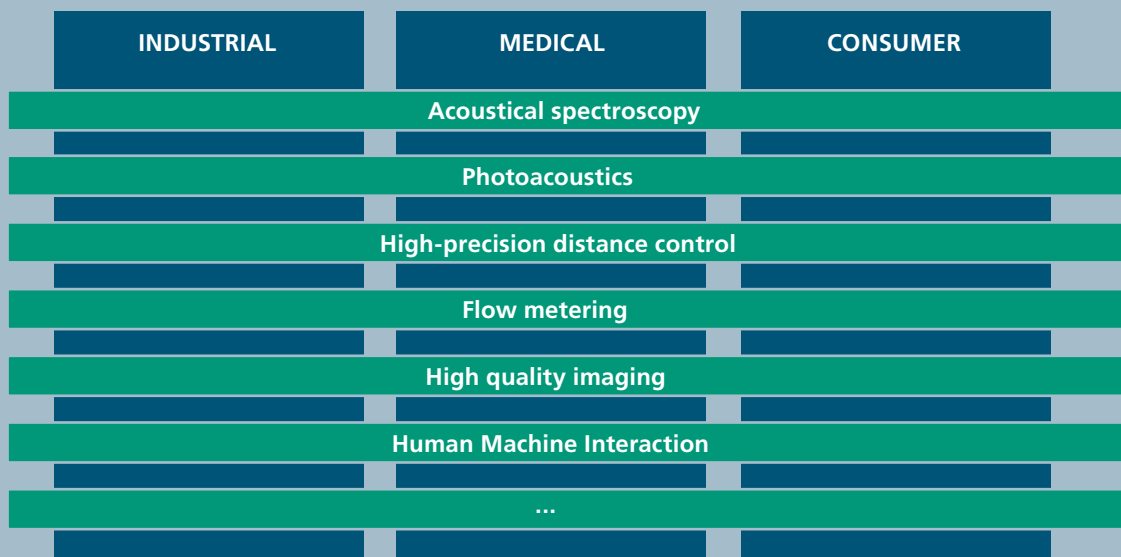
- Concept and Design
- Manufacturing and characterization
- Housing and packaging
- Electronic and software
- Prototyping and evaluation kits
- Low-volume (R&D) and higher volume (market entry and beyond) fabrication

## Contact

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## Application areas of CMUT devices and systems

### Structure and Functionality

CMUT are MEMS-based devices that represent a new class of ultrasound technology. The structure of a CMUT cell is a capacitor with two electrodes that are separated by a cavity and dielectric layers. A flexible plate comprising one of the electrodes can transmit and receive ultrasound waves. Essential properties of the transducer as the frequency and bandwidth are tuned by the design of the CMUT cell. Individual CMUT elements can be arranged in arrays and fields of arrays for multi-channel purposes

In transmit mode, the electrodes are biased with a DC voltage that deflects the membrane and an AC voltage that excites movement of the membrane. The coupling of this motion to a fluid environment generates ultrasound waves. In the sensor mode, the ultrasound waves approaching the plate cause a deflection that generates a current in the biased CMUT structure that is detected.

### Device Design

Fraunhofer IPMS has extensive experience in the manufacturing of CMUT devices of different designs. Customized CMUTs can be designed upon request.

Design	CMUT Type							Unit
	Single-Air	Single-Im	Annular-6	Annular-10	1D-64	1D-96	1D-128	
Medium	Air	Immersion	Immersion	Immersion	Immersion	Immersion	Immersion	-
Array type	Single	Single	Annular	Annular	1D linear	1D linear	1D linear	-
Number of element	1	1	6	10	64	96	128	-
Center frequency	> 1.5	2.5 ... 12.0	3.5 ... 7.8	7.0 ... 11.0	2.5 ... 3.0	3.5 ... 4.0	2.0 ... 30	MHz
Fractional bandwidth (typ.)	> 15 (in air)	> 100 (in water)	80 (in water)	80 (in water)	110 (in water)	30 ... 80 (in water)	> 100 (in water)	%
Operational voltage (typ.)	25 ... 200	15 ... 80	28 ... 156	108 ... 235	50 ... 200	130 ... 200	20 ... 200	V
Channel size	0.4, 0.7, 1.0 (circle diam.)	0.4, 0.7, 1.0 (circle diam.)	4.0 mm (inner circle), 10.0 mm (outer circle)	2.6 mm (inner circle), 10.0 mm (outer circle)	0.315 x 12.0	0.200 x 5.0	0.256 x 1.0	mm <sup>2</sup>
Pitch	-	-	Equal area each ring, except outer	Equal area each ring, except outer	315	200	256	µm
Chip size (HxW)	1.2 x 1.5	1.2 x 1.5	10.2 x 10.2	10.2 x 10.2	13.8 x 20.55	6.8 x 19.7	2.33 x 36.18	mm <sup>2</sup>
Coating	no	On request	On request	On request	On request	On request	On request	-
Notes	-	-	4 segments in outer ring	4 segments in outer ring	-	-	-	-