IC for cMUT Micromodem

Application

PREMA developed an IC to study the communication between devices by ultrasound. The target application is the exchange of data between various implants.
The IC is part of a micromodem, using a cMUT ultrasound transducer, which together with other electronics and energy supply is encapsulated in a biocompatible case that can be implanted in the human body.

The development was part of a collaboration with Fraunhofer IBMT (St. Ingbert) and other partners as part of project "I-Call", funded by the German Ministry of Education and Research (BMBF) within the research programme „Smart Health" under funding reference 16ES0753.

Bundesministerium für Bildung und Forschung

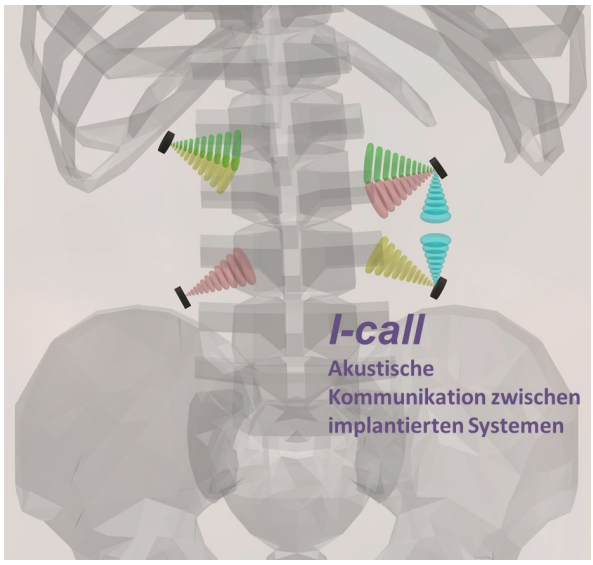
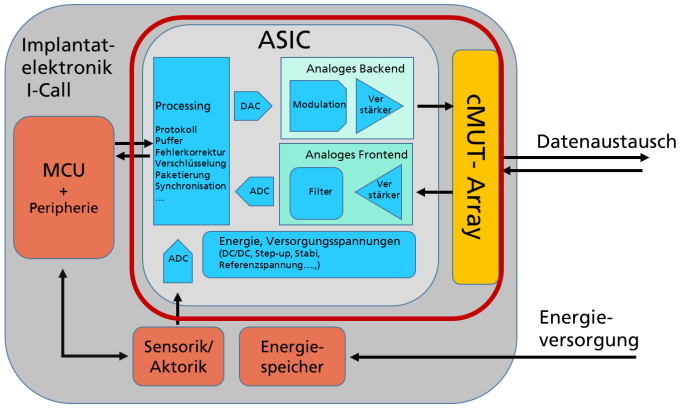


Image: FhG IBMT

SYSTEM BLOCK DIAGRAM



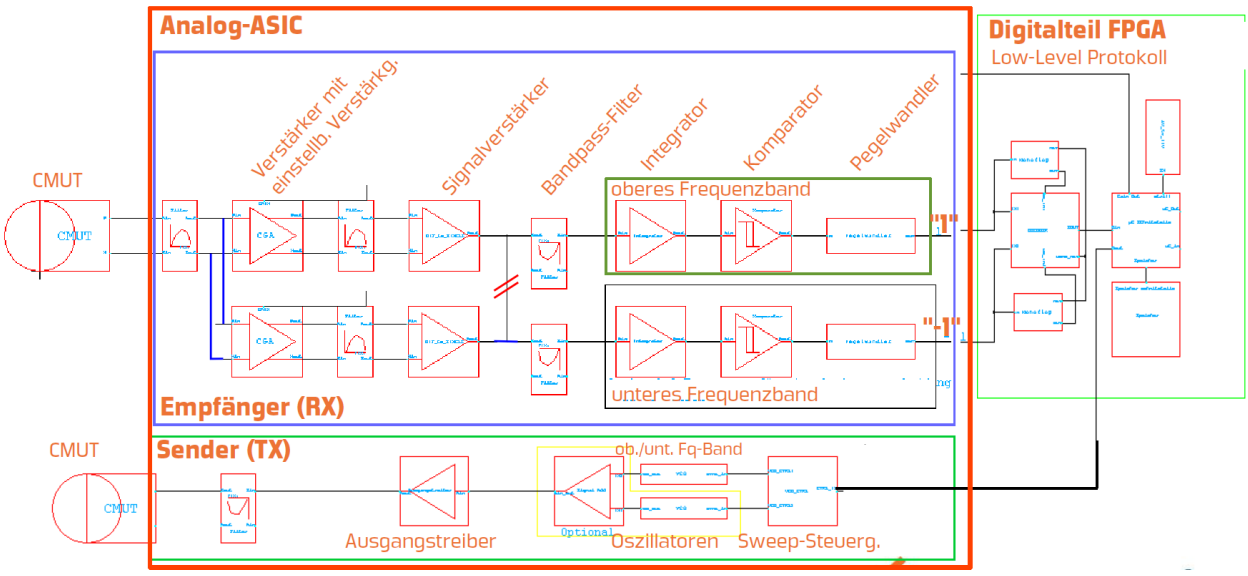
Preliminary concept, with ASIC as the central part of the micromodem. Image: FhG IBMT

cMUTs are capacitive micromachined ultrasonic transducers that have various advantages over piezo transducers.
Together with the cMUT transducer and a microcontroller, the PREMA IC forms a micromodem for the communicating implant.
The IC can amplifiy, filter and demodulate the signals received by the cMUT. It also contains a modulator and a high-voltage driver to excite the cMUT.
The system is designed that a certain number of implants can exchange data within the body via ultrasound communication at a rate of 20 kBit/s.

KEY CHARACTERISTICS

Parameter	MIN	TYP	MAX	Units
Supply voltage, V_{CC}	3.0	3.3	6.0	V
Output volt for cMUT			40	V
Frequency range	100		3000	kHz
Receive Input signal	1		100	mV
Gain variation		1::10		

IC BLOCK DIAGRAM



The **receiving part (RX)** consists of two amplifier/demodulator paths for different frequencies, each consisting of

- pre-amplifier with adjustable gain
- voltage amplifier
- bandpass filter
- demodulator with integrator
- comparator
- level shifter

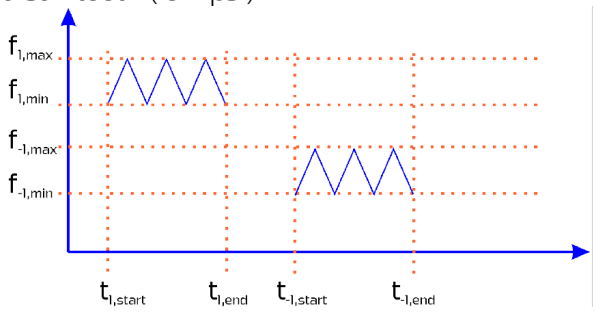
The **transmitting part (TX)** consists of

- a voltage controlled oscillator
- a sawtooth generator
- a high-voltage output driver

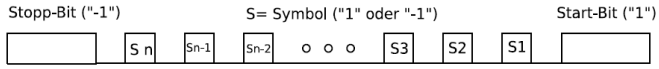
The **digital block** is realized as an FPGA that handles the low-level digital data processing (converting the analog signals to regular data words, including error detection)

TRANSMISSION PROTOCOLL

Data are transmitted with a protocoll with high immunity against noise. Two frequency bands are used, with logic "1" transmitted in the upper, and logic "-1" in the lower frequency band.
In addition, each frequency band spreaded with a sawtooth ("chirps").

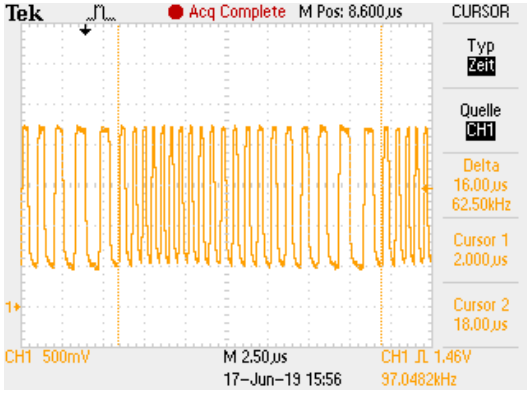


DATA WORD



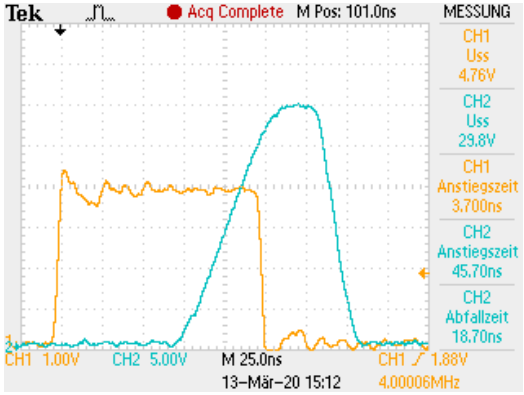
A data word consists of a start bit, defined by a longer "1" signal, a defined number of content symbols, and a stop bit, defined by a longer "-1" signal.

MODULATOR



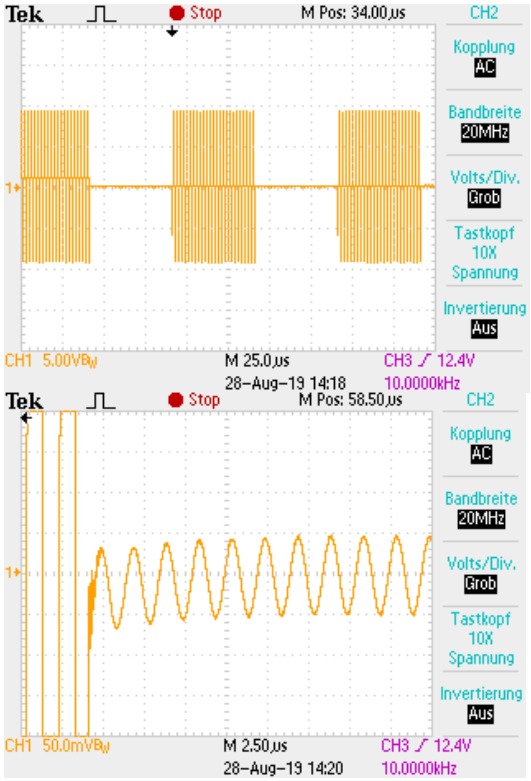
Chirp generated by the voltage-controlled oscillator (VCO)

OUTPUT STAGE



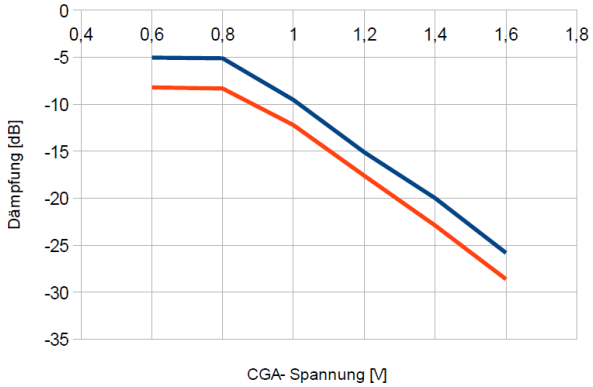
Output voltage of the driver stage (blue) for a 4 MHz control signal (orange). The load capacitance is 30 pF, the amplitude is 30V, which is typical for the conditions with cMUT.

CONTROLLED GAIN AMPLIFIER (CGA)



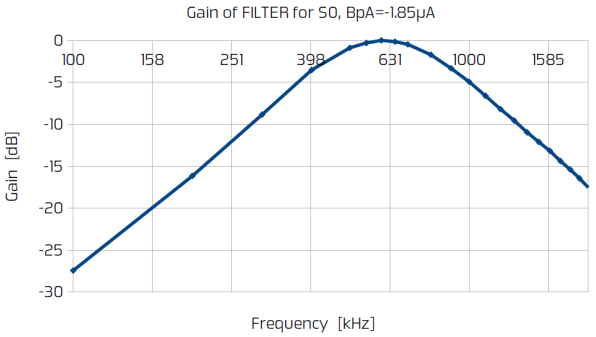
Measurement of the recovery time after burst pulses with ±10 V amplitude

To avoid the need for a fast switch at the input of the amplifier, the amplifier must be robust to withstand the transmission pulses to the cMUT that can be as high as 40 V to ground, or ±20 V amplitude. The input must recover fast enough to be able to receive immediately after a transmitted pulse.



Attenuation of the CGA output signal, depending on the control voltage

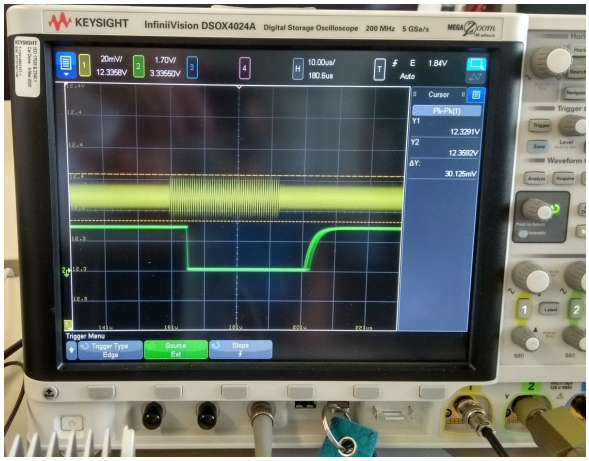
BANDPASS



Bandpass characteristics for a centre frequency of 630 kHz.

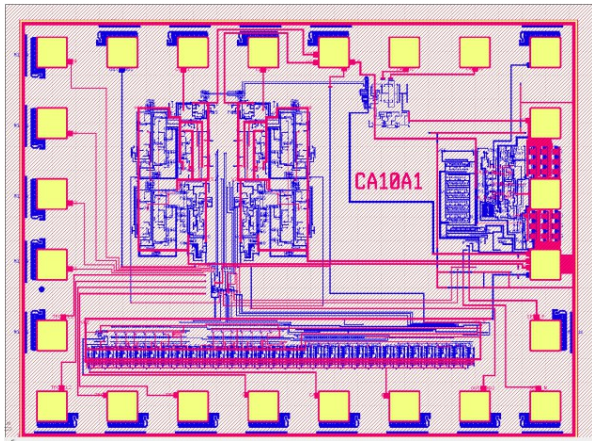
The bandpass characteristics is programmable via a configuration register and a D/A converter for centre frequencies between approx. 400 and 2000 kHz

DEMODULATOR / INTEGRATOR

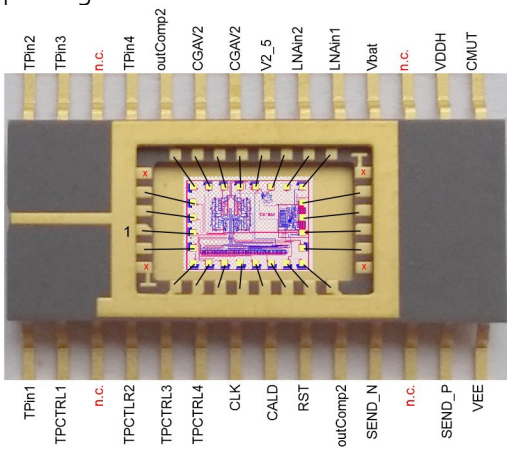


Measurement of received signal (yellow) and signal at the comparator output (green) in an experimental setup with two cMUTs

INTEGRATION



All analog functions of the IC are integrated in one chip, to achieve the necessary package density to fit into the implant.
The IC was bonded into a ceramic SOIC-28 package.



SYSTEM TEST

The system was tested with two micromodems, transmitting data via water in a tank.
In practice, all components worked as intended. However, the fact that the cMUT transient characteristics is not suitable for the transmission protocoll, requiring fast frequency changes, prevented a successful data transmission in this configuration.
Transmission with a fixed frequency worked, but would require other methods to suppress spurious signals.

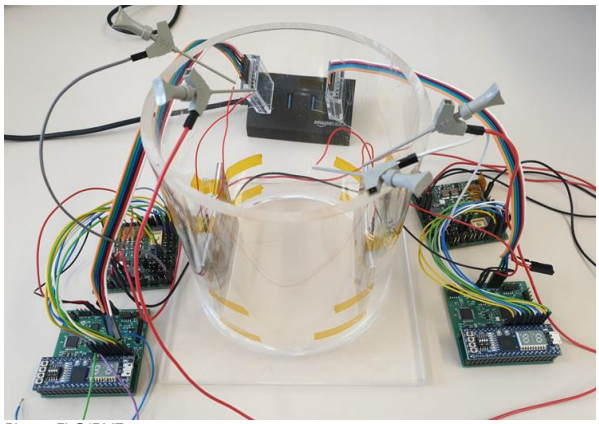


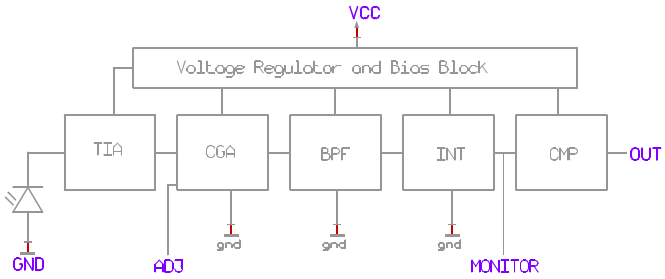
Photo: FhG IBMT

REUSABILITY

The circuit blocks developed in this project are perfect demonstrators for circuit blocks that can be re-used in other ICs.
The most important features are

- CGA with input robust against voltages up to 40 V and with very fast recovery time after high input signals
- output driver with output voltage of up to 40 V and up to 4 MHz at full swing
- VCO controllable via D/A converter and shift register

Several circuit blocks have been reused in a opto-receiver used in a light-curtain safety appiication:



The circuit uses the CGA, the bandpass and the demodulator circuits from the I-Call project.

Disclaimer

This paper is for general information only and describes a demonstrator developed as part of the research project "I-Call". There is no fully qualified product available with the functions described above.
The purpose of this document is to demonstrate the capability and versatility of the process as part of an application example, describe the status of the demonstrator IC as-is and to suggest adaptations re-using the circuit blocks in subsequent developments for similar or other applications.
The IC has been developed, produced and tested by PREMA Semiconductor. Other components of the system, including the cMUT, have been developed and produced by other participants of the research project and cannot be provided by PREMA.
No claim that the circuit can be used for a specific purpose is made.
PREMA Semiconductor products are not authorized for use as critical components in life support devices or systems without the express written approval of PREMA Semiconductor.

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