IDEC Chip Design Contest

A 20-MHz 2.3-Mw Ultrasound Receiver and a High-Voltage Transmitter for Ultrasound Capsule Endoscopy

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Abstract

This paper presents a firstly high power-efficient ultrasound (US) receiver (RX) IC and an on-chip US transmitter (TX) IC for US capsule endoscopy (USCE) systems. The proposed USCE system firstly employs ASIC with a single-element piezoelectrical transducer (PZT) and a mechanically rotating reflector together to continuously scan 360 degrees of the gastrointestinal (GI) tract throughout the trip. Since the USCE system operates using a battery, the power efficiency is of a great importance. To reduce the required ADC speed and power consumption, we propose a new RX structure with a synchronized analog envelope detection unlike other conventional systems using a power-hungry high-speed ADC to acquire the US signal at the center frequency (f_{center}) of 20 MHz. The proposed analog envelope detector, which is based on a quadrature demodulation method, uses a single path by detecting US signal phase rather than using two (I and Q) paths. Besides, a TX IC including an on-chip charge pump is designed, while generating 25-V high voltage pulses with 25-ns pulse width

Motivation

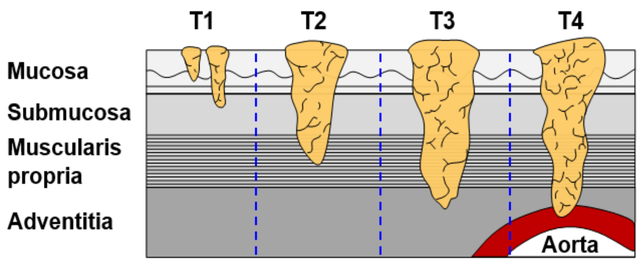
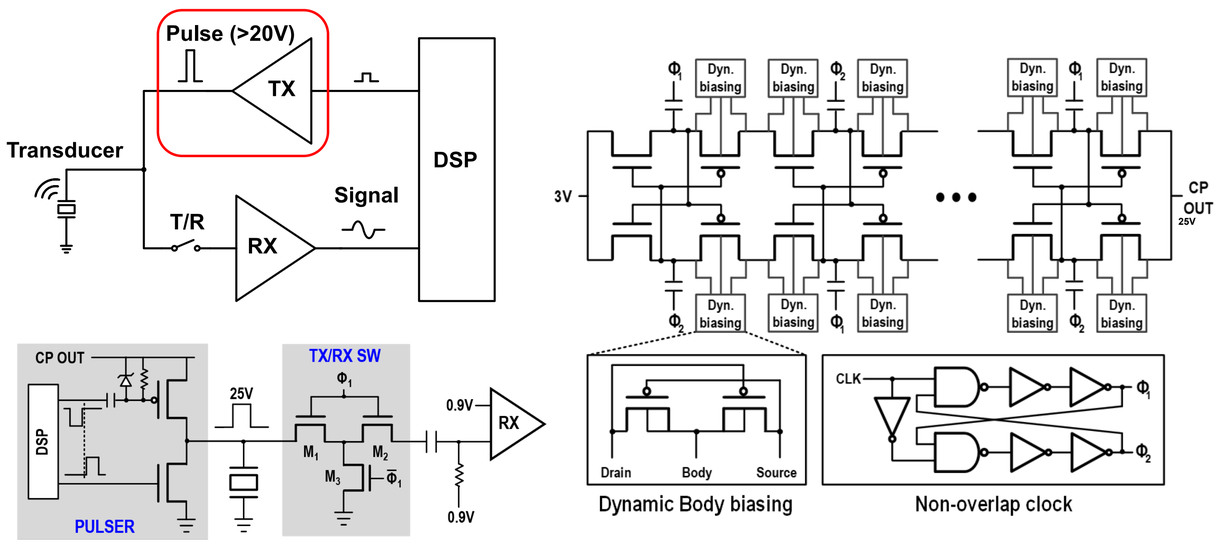


Fig. 1. Scheme of the depth of esophageal cancer invasion from T1-T4 stage.

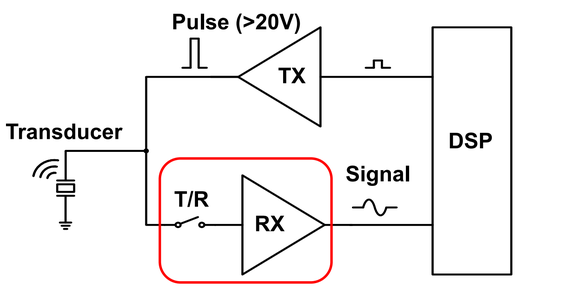
- Deeper subsurface tissues can be diagnosed through ultrasound imaging.
- Capsule endoscopy is easy for patients to swallow.
- Single-transducer with motor, transducer array researches are ongoing.
- There has been no ASIC reported for USCE.
- Conventional 7.5MHz EUS is difficult to distinguish T1 stage cancer.
- 20Mhz high-frequency ultrasound transducer is needed for early staging of esophageal cancer.

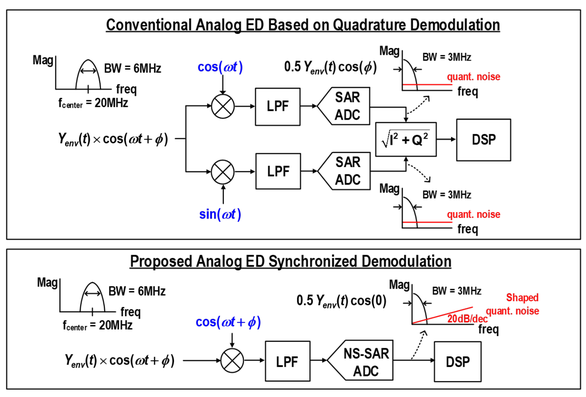
Ultrasound Transmitter

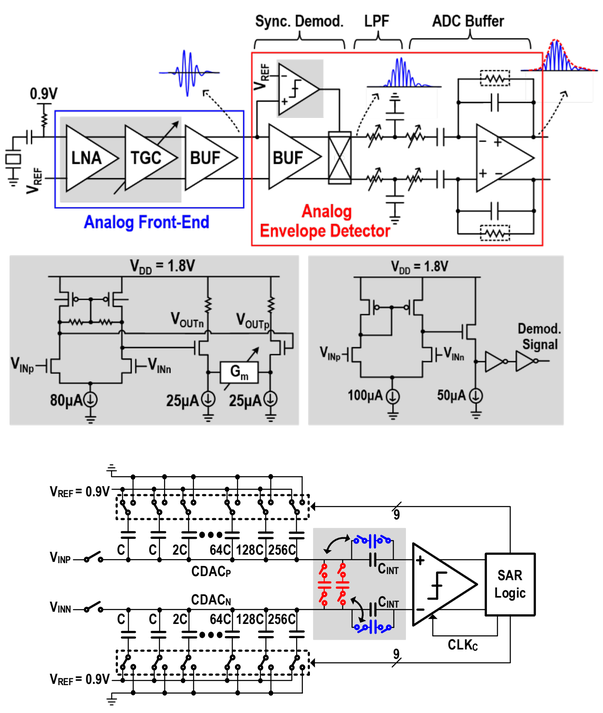


- Charge pump : Dickson type, 10 stages with dynamic body biasing.
- Pulser : Class-D amplifier.
- TX/RX switch for protect high voltage pulse signal.

Ultrasound Receiver

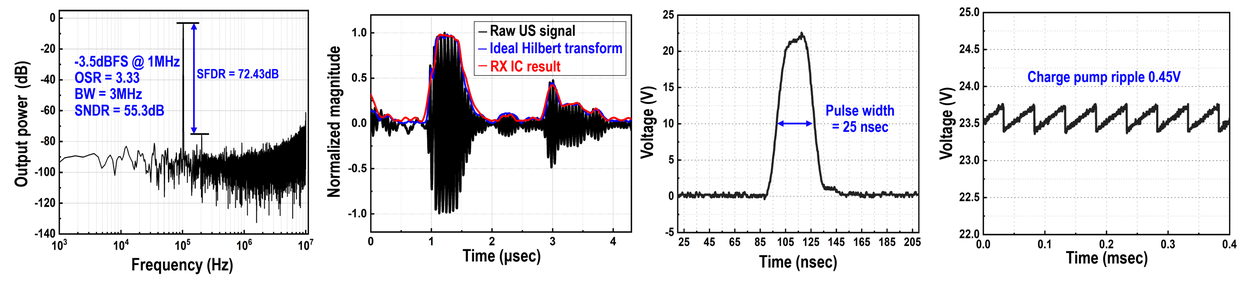


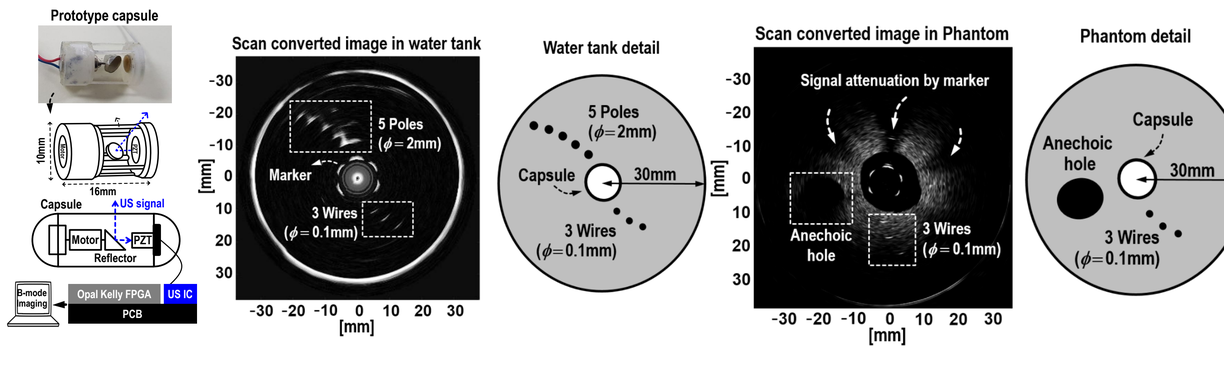




- Analog envelope detector using synchronized demodulation.
- Analog envelope detector is designed by using continuous comparator.
- Reduce ADC sampling frequency and number of RX paths.
- Decrease data communication speed in DSP.
- Ping-pong noise shaping SAR is used for high resolution with power efficiency.

Measurement results





- ADC SNDR: 55.3dB @ 1MHz signal (BW = 3MHz, OSR = 3.33) SFDR:72.43dB
- Envelop signal is well demodulated compared with ideal Hilbert transform
- Charge pump generates 23.5V with 0.45V charge pump ripple at a pulse repetition frequency 20kHz.
- 25V pulse signal with 25nsec pulse width.
- Ultrasound B-mode image is achieved well both water and phantom using prototype capsule.

Conclusion & Acknowledgement

- For early staging of esophageal cancer, an over than 20MHz ultrasound transducer is needed. We proposed a synchronized demodulator for 20Mhz ultrasound signal processing and a on-chip high voltage transmitter. Ultrasound image is achieved clearly in both water tank and phantom.
- The chip fabrication was supported by the IC Design Education Center(IDEC), Korea.

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