



Integrated Electronics for Remote Sensing of a Knee Prosthesis

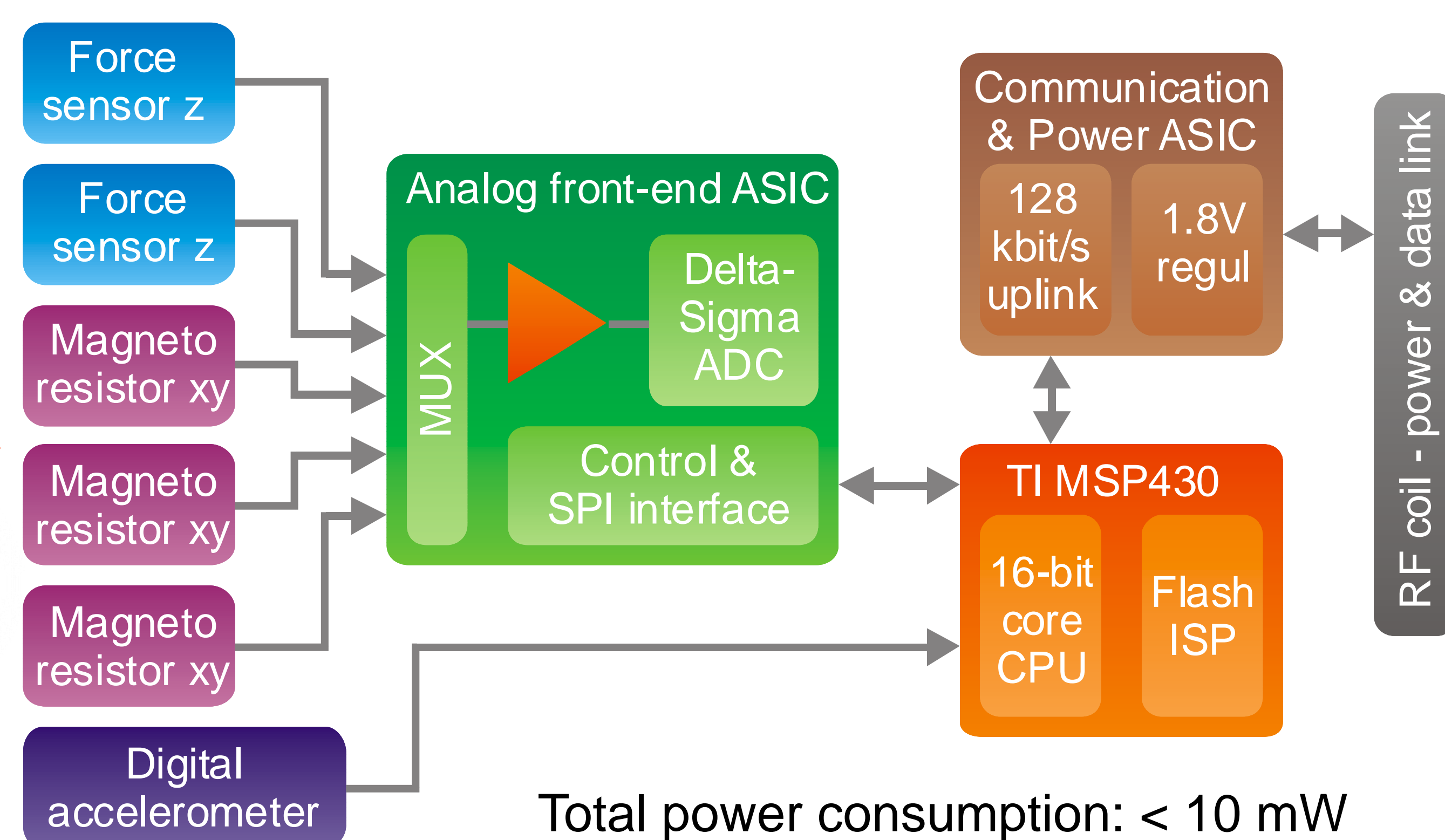
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Abstract – the SIMOS project develops tools for remote monitoring of medical implants. The first targeted application is the monitoring of a knee prosthesis developed by Symbios. The prosthesis includes sensors that measure the forces and vibrations applied to the joint, and the orientation and movements of the articulation. An integrated electronics acquires the sensor signals and transmits the information to the outside. It transforms also the incoming RF-modulated magnetic field into a stable supply voltage. Based on two ASICs and a commercial microprocessor, it consumes less than 10 mW with sensors.

Integrated Electronics Architecture



Total power consumption: < 10 mW

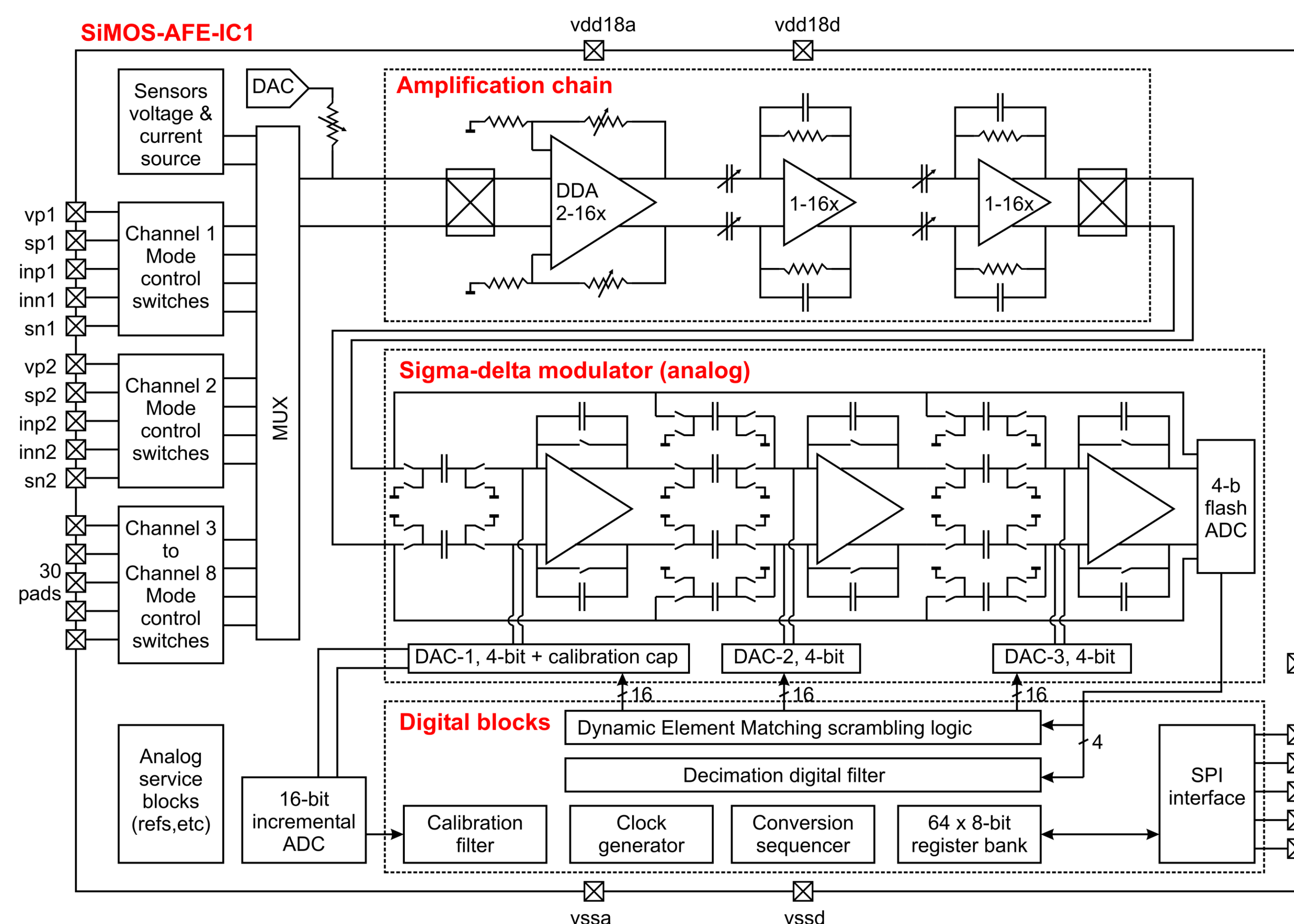
Analog Front-end ASIC

- Up to 6 magneto-resistors or Hall sensors
- Up to 4 gauge sensors
- 14-bit ADC
- Low-noise, >1000 x gain
- Power consumption: 1.5 mW

Communic. & Power ASIC

- up to 20 mW from inductor coil
- High efficiency: 80%
- Data rate: 200 kbit/s uplink
- Data rate: 500 kbit/s downlink

Analog Front-end ASIC

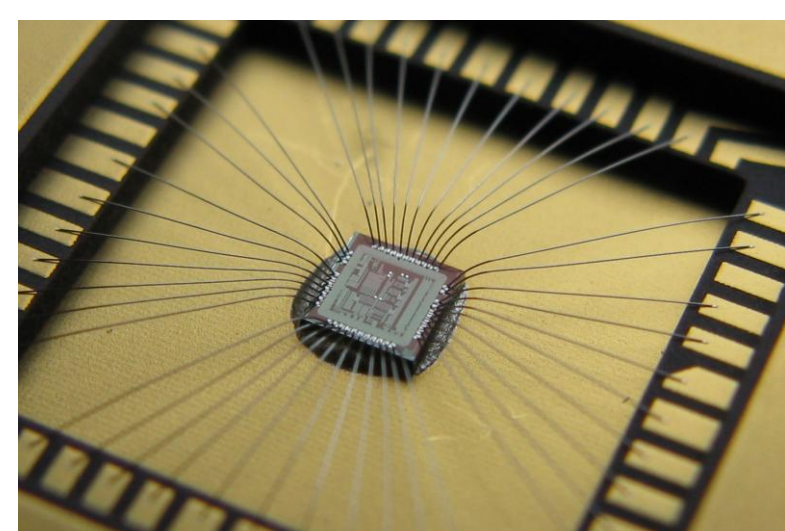


Amplifier chain specifications

- Gain from 2 to >1000
- Chopper mod/demod
- Offset correction with 12-b DAC
- Power consumption: 800 uW

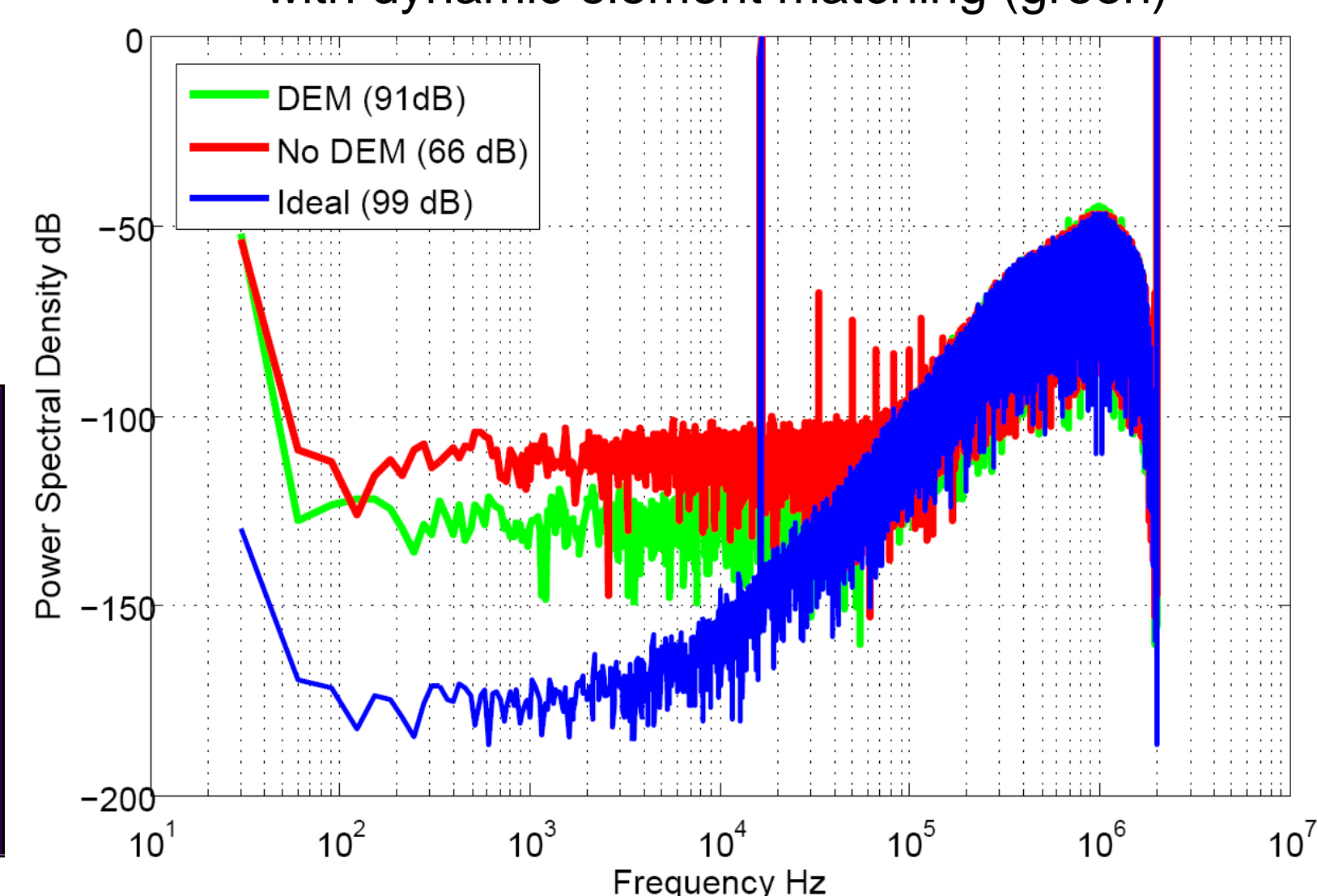
ADC specifications

- Multibit 3rd order Delta-Sigma ADC
- 100 kHz bandwidth, 6 MHz clock
- SNDR: 87 dB (14-bit)
- Power consumption: 200 uW @ 1.8V

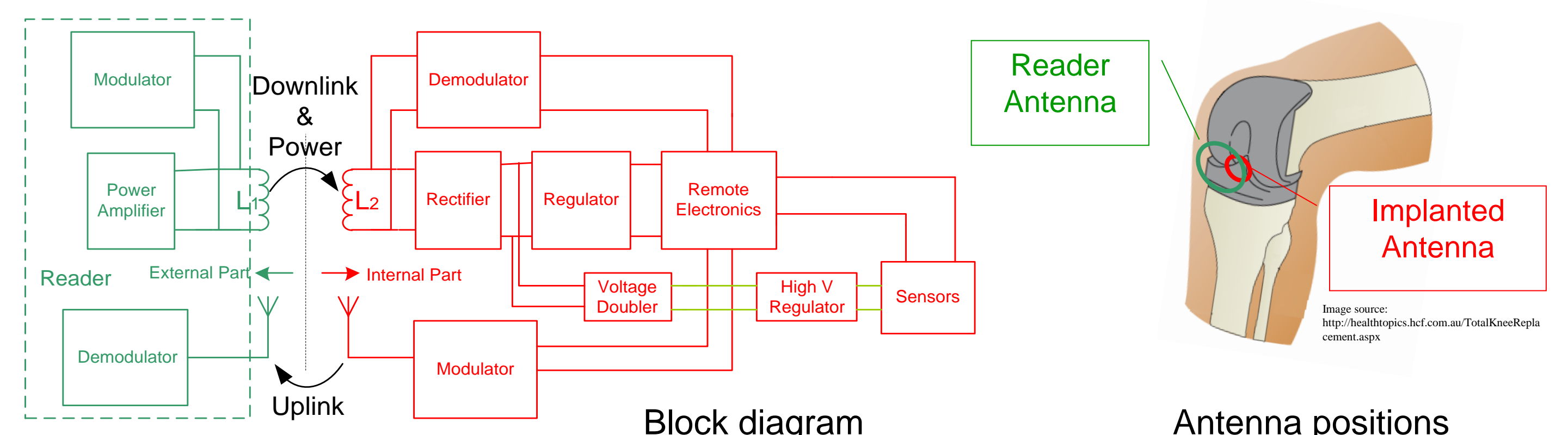


First and second ADC test chips

Spectrum of Delta-Sigma modulator linearized with dynamic element matching (green)



Remote Powering & Communication ASIC



Power Amplifier:

- Class-E type
- Suitable for inductive loads
- Adjustable output power

Full wave rectifier:

- For output power of 20 mW
- %80 power efficiency
- Works @ 13.56 MHz

Crystal Oscillator:

- 48 MHz
- 6 kHz frequency pulling with FSK data
- Reference for transmitter

FSK transmitter:

- $F_c \rightarrow 402-433$ MHz depends on the reference
- Up to 200 kbit/s
- 150 uW
- $f \rightarrow 40$ kHz

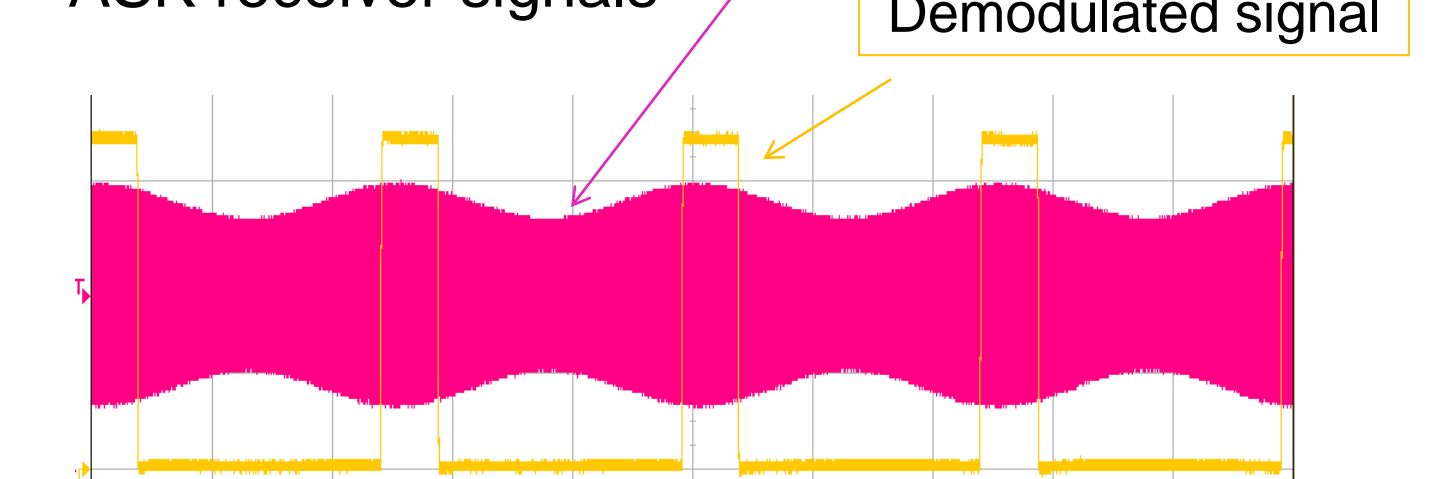
Voltage doubler:

- Enhanced Favrat cell
- For output power of 16 mW
- %90 power efficiency

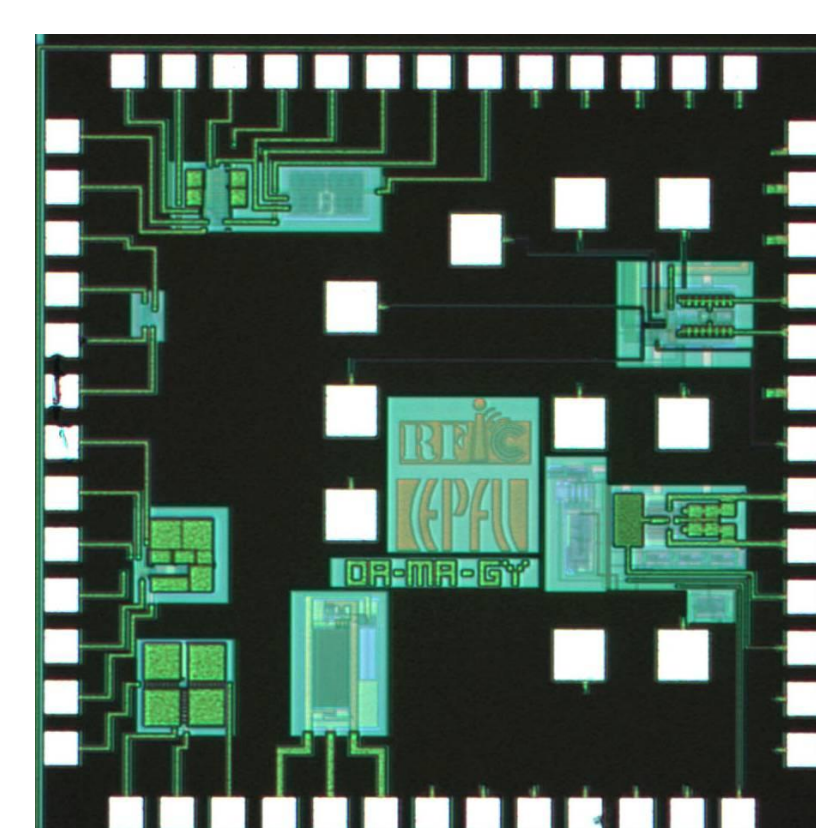
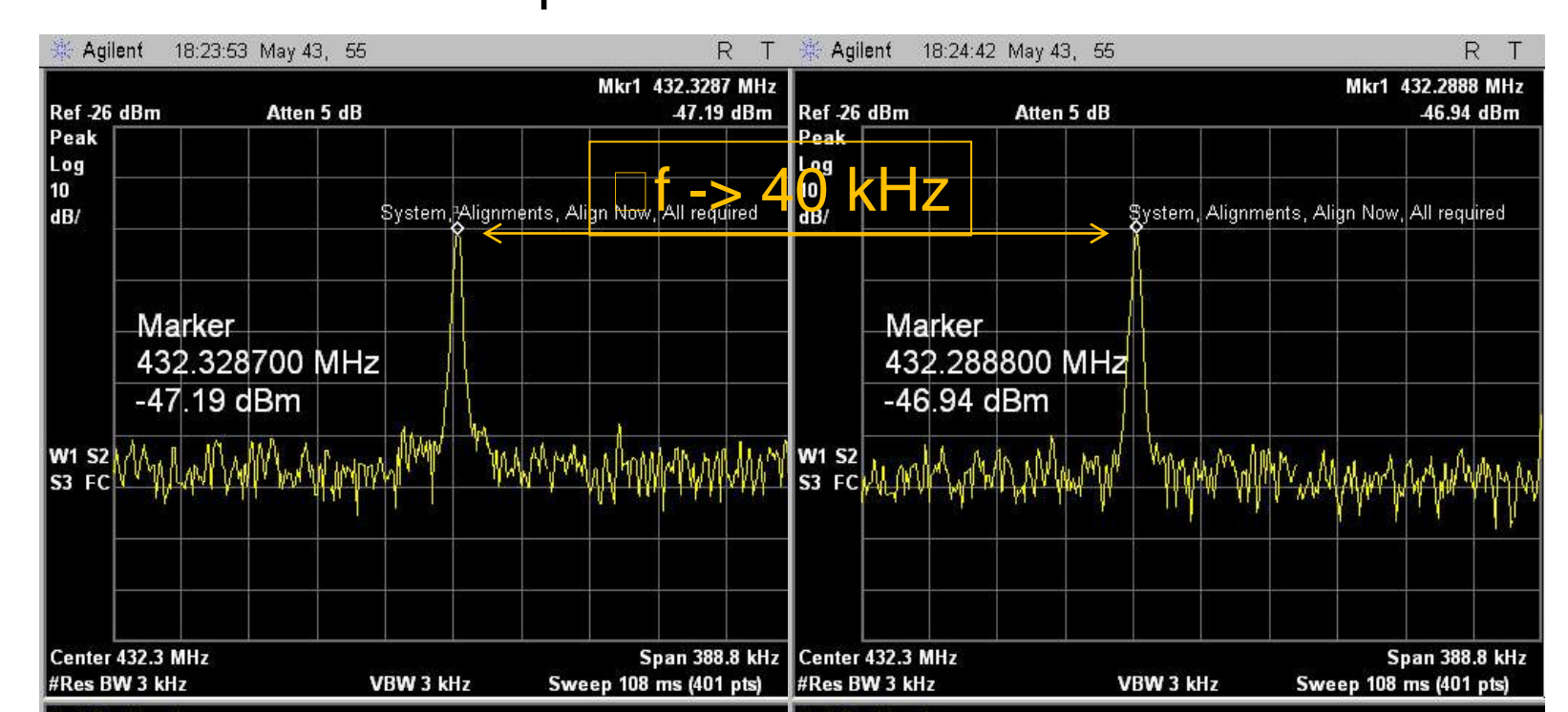
ASK demodulator:

- 20% modulation index
- Up to 500 kbit/s
- $F_c \rightarrow 13.56$ MHz

ASK receiver signals



FSK transmitter spectrum



Micrograph of the die fabricated in UMC018 CMOS tech. with rectifier, voltage doubler, ASK demodulator, FSK transmitter, crystal oscillator