

swiss scientific initiative in health / security / environment systems



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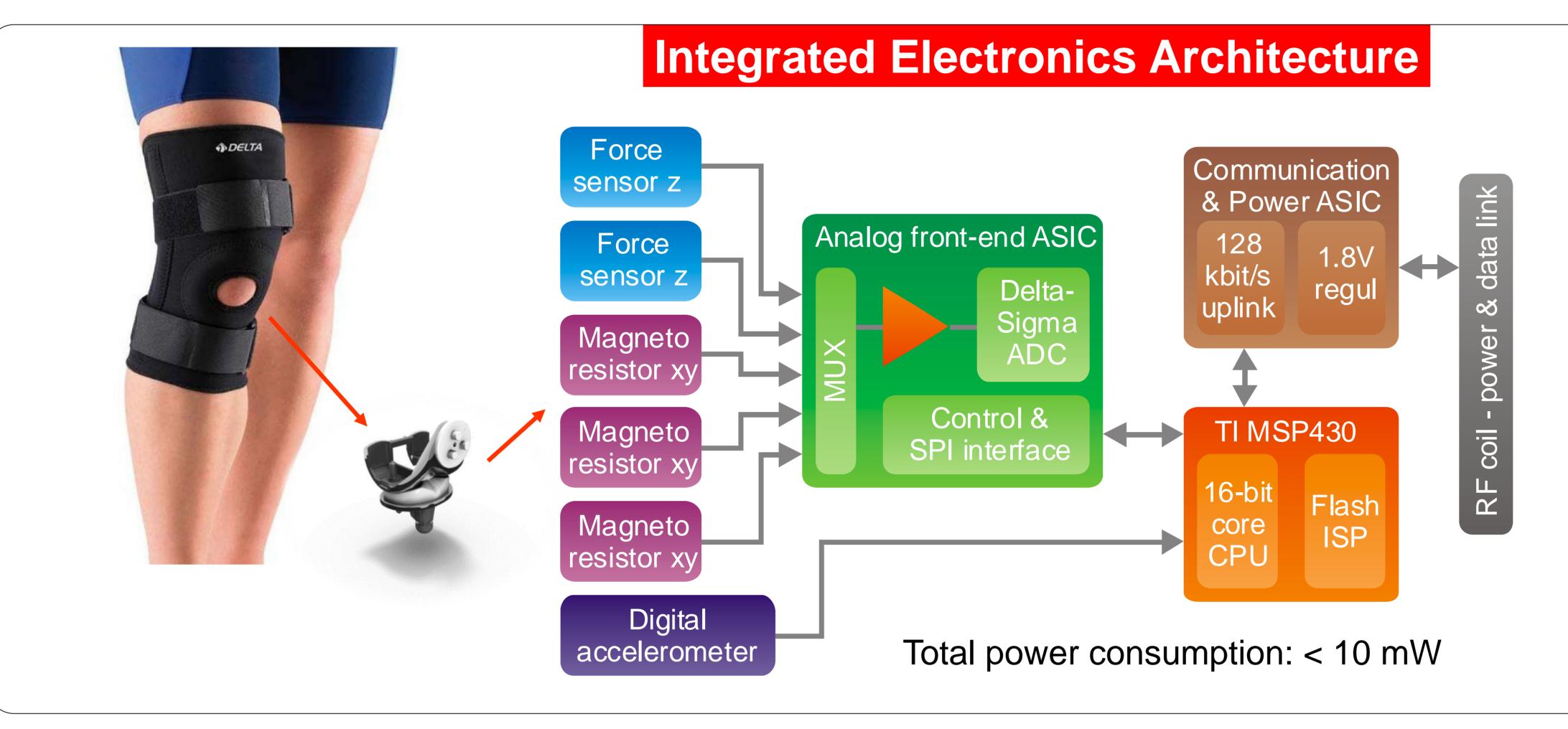
# Integrated Electronics for Remote Sensing of a Knee Prosthesis

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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 RFmodulated magnetic field into a stable supply voltage. Based on two ASICs and a commercial microprocessor, it consumes less than 10 mW with sensors.



# **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** vdd18d vdd18a SiMOS-AFE-IC1 $\square$ -🖂-**Amplification chain** DAC Sensors voltage & ->>/////\_\_\_ current -~~~--////source DDA 1-16x 1-16x 2-16x vp1 🖾 Channel Ø sp1 Mode Øinp1 contro inn1 🖾 switches sn1 vp2 🖾 Sigma-delta modulator (analog) Channel 2 sp2 🖾 MUX Mode inp2 🖾 control inn2 🖾switches sn2 🖾 4-b flash ADC Channel 3 to 30 pads Channel **L**/1 Mode contro switches DAC-1, 4-bit + calibration cap DAC-2, 4-bit DAC-3, 4-bit 🖄 ck Ł16. -16 Digital blocks Dynamic Element Matching scrambling logic ⊠ CS Analog 🖄 sck Decimation digital filter SPI service -対 sdi 16-bit interface blocks -対 sdo 64 x 8-bit Calibration Clock (refs,etc) incrementa Conversion ADC generator register bank sequencer $\boxtimes$ vssa vssd

# **Remote Powering & Communication ASIC**

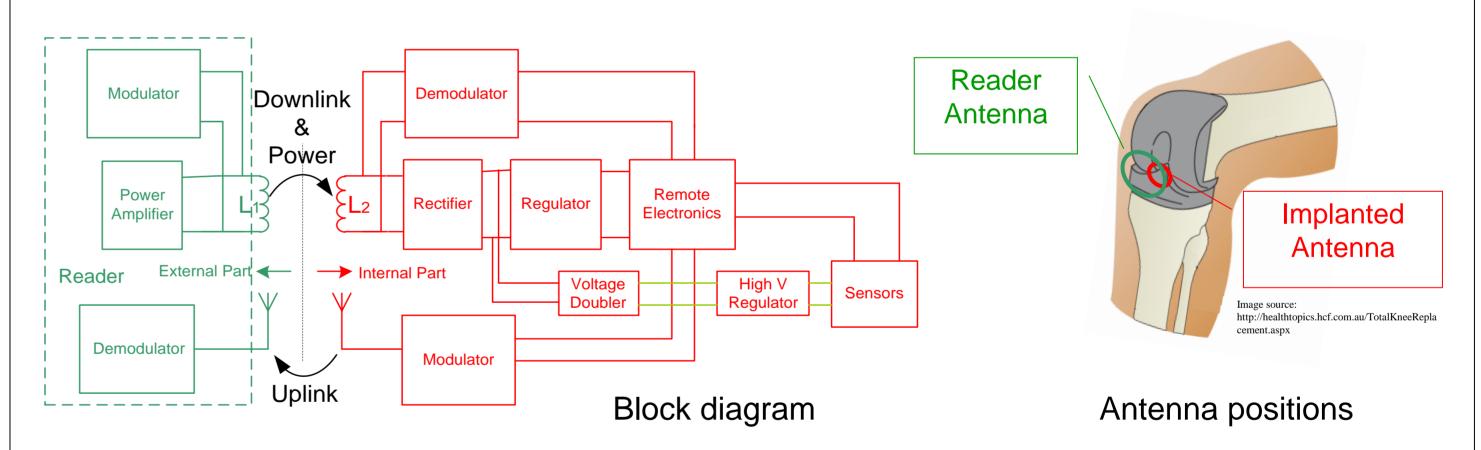
# Amplifier chain specifications

- Gain from 2 to >1000
- Chopper mod/demod

# **ADC** specifications

**DEM (91dB)** 

• Multibit 3<sup>rd</sup> order Delta-Sigma ADC •100 kHz bandwidth, 6 MHz clock



Power Amplifier: □Class-E type □Suitable for inductive loads □Adjustable output power

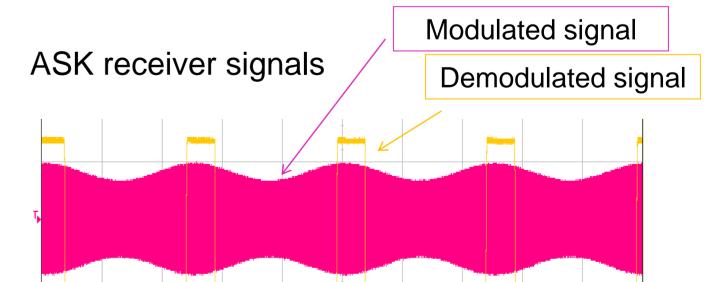
Full wave rectifier: □For output power of 20 mW □%80 power efficiency **Works** @ 13.56 MHz

# Crystal Oscillator: □48 MHz

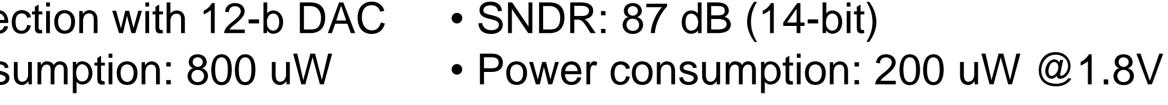
□6 kHz frequency pulling with FSK data Reference for transmitter

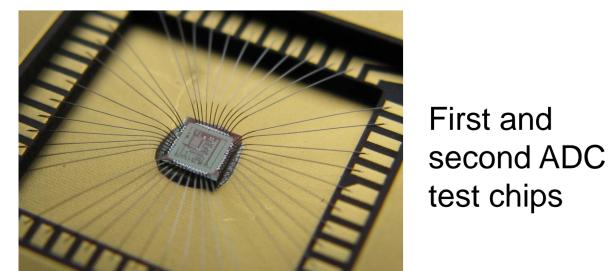
Voltage doubler: Enhanced Favrat cell □For output power of 16 mW □%90 power efficiency

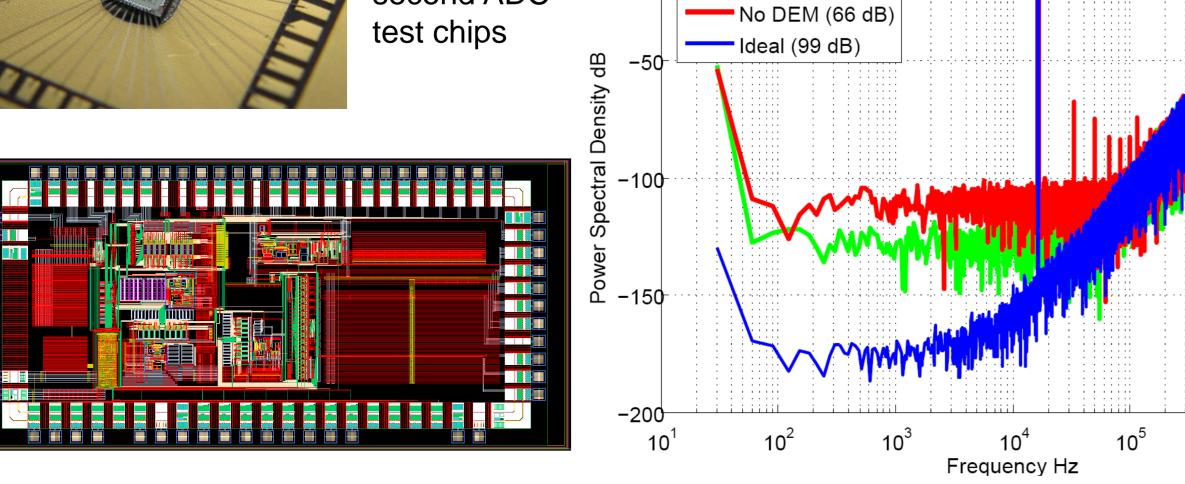
ASK demodulator: □20% modulation index □Up to 500kbit/s **G F**<sub>c</sub> ->13.56 MHz



 Offset correction with 12-b DAC Power consumption: 800 uW







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

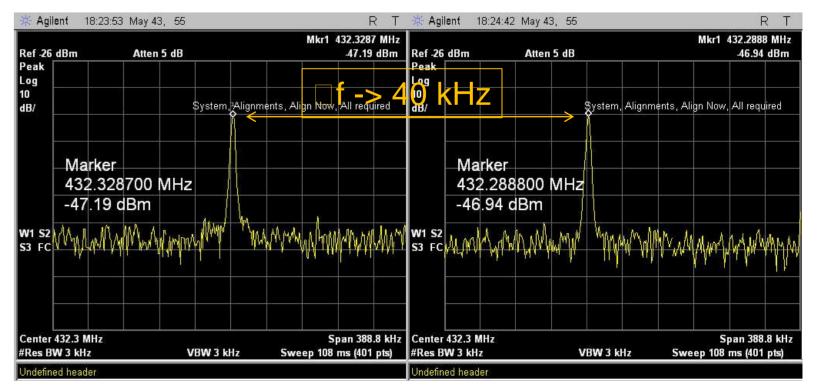
### FSK transmitter: □F<sub>c</sub> -> 402-433 MHz depends on the reference □Up to 200kbit/s □150 uW

□ \_ f -> 40 kHz

TTTTTTT



FSK transmitter spectrum



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