RF Integrated Circuits for Medical Implants:

Meeting the Challenge of Ultra Low Power Communication

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Outline

- The MICS Band
- Applications for Medical Devices
- Ultra-Low-Power (ULP) Design Challenges
- Design Solutions
- Design Examples
  - ***ZL70100: The Implantable Transceiver***
  - ***ZL70081: The Swallowable Camera Pill Transmitter***
  - ***ZL70262: ULP Audio Transmitter (Hearing Aids)***
- Conclusion

The MICS Band

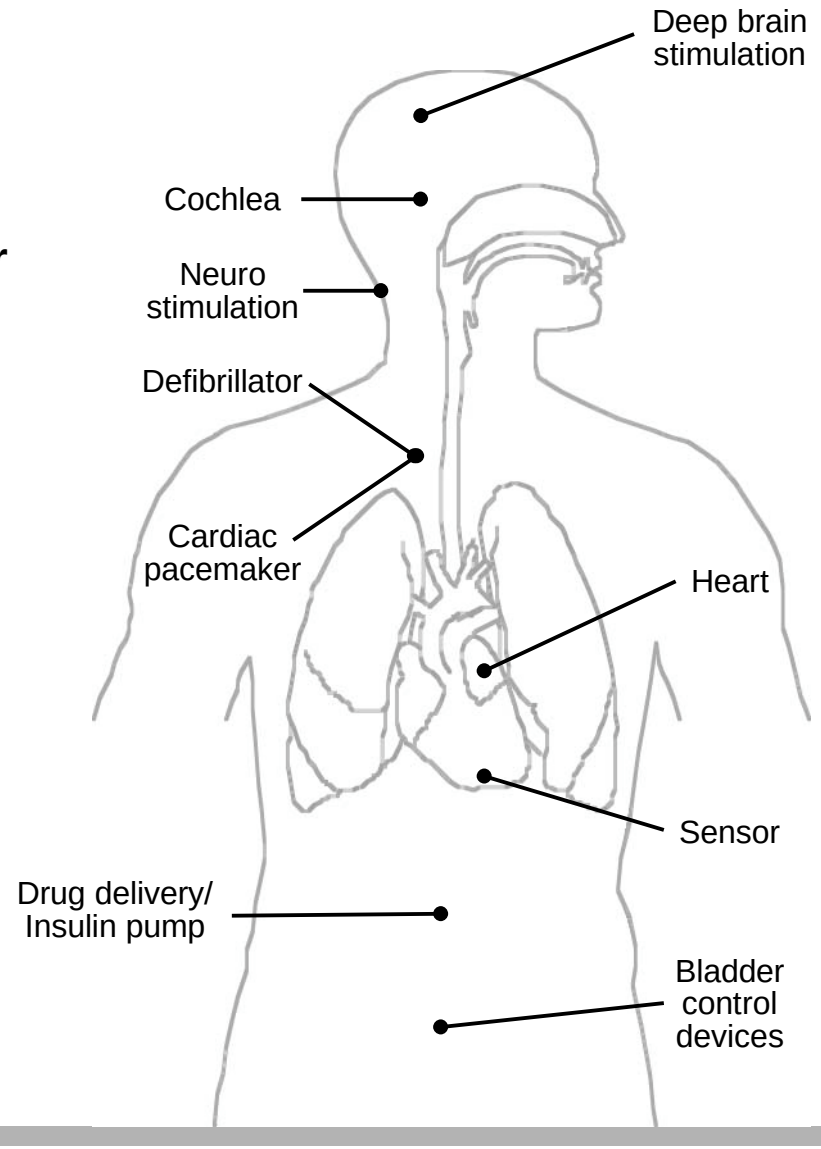
- **Medical Implant Communication Service (MICS)**
  - **402–405 MHz frequency allocation**
    FCC was petitioned in mid-1990s, allocated in 1999
  - **Short-range, wireless link to connect low-power implanted medical devices with monitoring and control equipment**
    Implanted Medical Devices (IMD) such as cardiac pacemakers, implantable cardioverter defibrillator (ICD), neurostimulators, etc.
  - **Why introduce MICS ?**
    - Removes limitations associated with existing short range inductive links (low data rate, very short range requires body contact)
    - Opportunity for improved healthcare and new applications
  - **Why 402-405 MHz?**
    - Reasonable signal propagation characteristics in the human body
    - Compatibility with incumbent users of the band (e.g. weather balloons)
    - General world-wide acceptance (US, Europe, Japan, Australia etc)

Why was MICS Introduced?

- **Need for higher data rates**
  - **To upload patient events captured in the IMD's memory to the base station for analysis**
  - **Shorten doctor/patient consultancy times**
- **Need for longer range**
  - **Simplify home-monitoring for elderly**
  - **Locate the base station (programmer) outside of the sterile field during surgery**
  - **Broaden possible applications:**
    Bedside monitor for emergency
- **Competitive pressure of medical device industry**
  - **Higher data rates enable new, value-added services**

MICS—Applications

- **Stimulatory Devices**
  - **Pacemaker**
  - **Implantable Cardioverter/Defibrillator (ICD)**
  - **Neurostimulators and pain suppression devices**
  - **Cochlea implants/hearing aids**
- **Measurement/Control/Other Devices**
  - **Drug infusion and dispensing**
  - **Artificial heart and heart assist devices**
  - **Implanted sensors**
  - **Control of other artificial organs and implanted devices**



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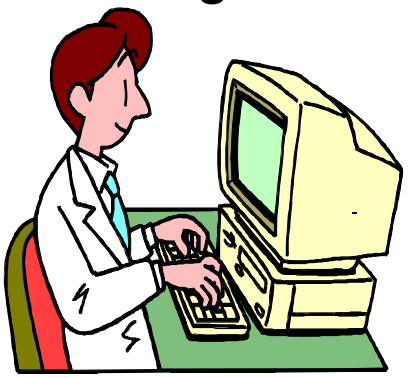
MICS - Applications

Clinical Setting - Consultations and Operating room



Cardiologist with
Programmer

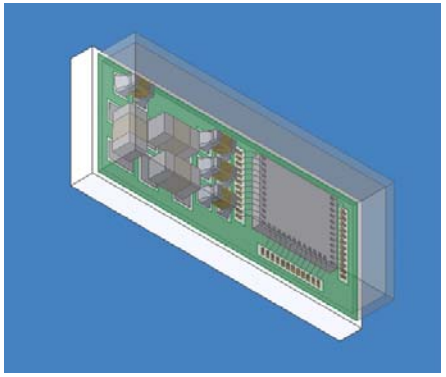
RF
Link

Patient with
Pacemaker / ICD

Home Monitoring

Transfer to
Hospital

Challenges



Module size 2 x 5 x 12 mm

- **Low Power Consumption**
  - Low TX/RX current <6mA, battery considerations
  - Low sleep/listen current, ideally <100s of nA
- **Minimum External Components**
  - Implantable RF module <5x5x12 mm
  - Fewer components => higher reliability, lower cost, smaller size
- **Reasonable data rates**
  - Pacemaker applications >20 kbps and higher projected in the future
- **Operating range**
  - Require ~2 m to improve on existing links (short range inductive)
  - Antenna matching and body loss typically 40 dB
- **Reliability**
  - Data and link integrity, selectivity and interference rejection

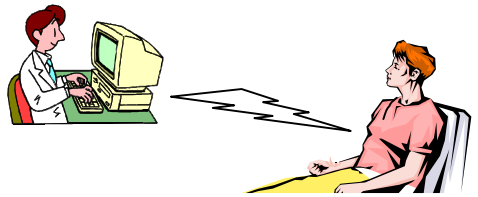
Design Solutions

- **Key Concept - Duty Cycle**
  - **- Duty cycle normal data exchange for given data rate**
  - **- Duty cycle sniffing for wakeup**
  - **- Turn off sub-systems in chip when not required.**
- **Use the highest possible data rate for required sensitivity**
  - **- Apply concept even for systems that require low data rates (low kHz range)**
  - **- Sending data in short bursts conserves power**
  - **- Reduces time window for interference and easier supply decoupling**
- **High Data Integrity**
  - **- Reed-Solomon Forward Error Correction, CRC error detection**
  - **- Capable of several years continuous operation without error**
- **High Level of Integration**
  - **- Sub-micron CMOS RF technology**

ULP Implantable Transceiver (ZL70100)

MICS and ISM Band Transceiver:

- **Negligible standby current**
- **high data and low error rates in a small footprint**



Technology:	**0.18 um RF CMOS**
Supply Voltage:	**2.1 - 3.5 V Battery**
Radio Frequency:	**402-405 MHz (MICS-Band)**
Type of RF link	**Bi-directional, half duplex**
Modulation Scheme:	**FSK**
Raw Bit Rate:	**800 / 400 / 200 kbits/s**
Operating Current:	**5mA TX/RX down to <1mA**
Sleep Current:	**< 200 nA**
Ext. comps:	**2 (excluding antenna matching)**
BER:	**<1.5 x 10^{-10}**
Range:	**~2 m**

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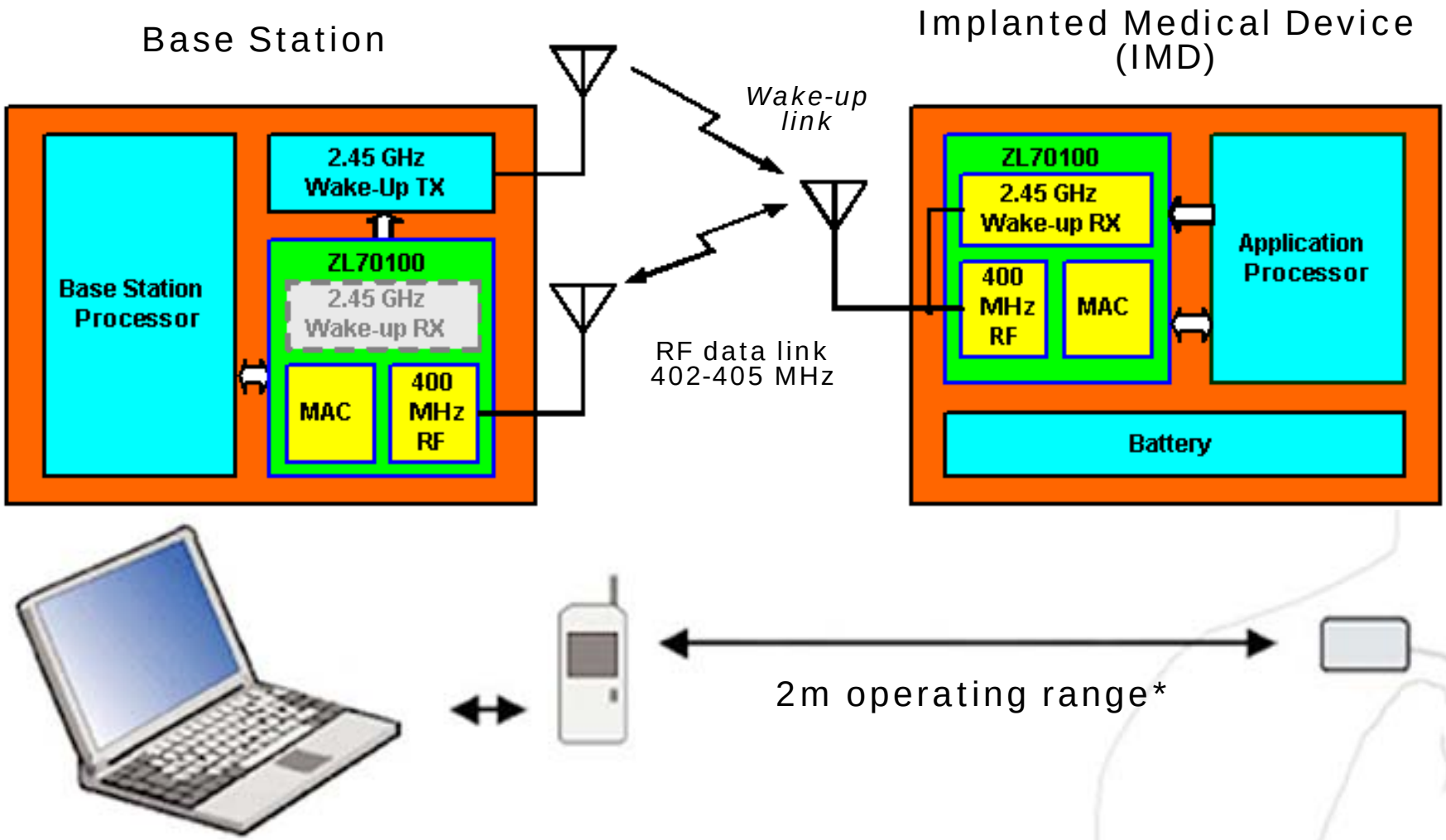
ZL70100 Features

- **12-Channels**
  - 402 –405 MHz (10 MICS)
  - 433 – 434 MHz (2 ISM)
- **Selectable Data Rate**
  - 200/400/800 kbps raw data rate
- **High Performance Media Access Controller (MAC)**
  - Auto error handling and flow control, Reed-Solomon, CRC
  - Typically <1.5 x10^{-10} BER
- **Min. External Components**
  - 2 pieces plus antenna matching
- **Extremely Low Power**
  - 5 mA continuous TX/RX
  - <1mA low power TX/RX
- **Ultra Low Power Wake-up Circuit**
  - <200 nA
- **Multiple Startup Methods**
  - 2.45 GHz signal
  - Pin Control

    (for Emergency messages, 400 MHz sniffing, low frequency inductive link sniffing or other wakeup methods)
- **Standards Compatible**
  - MICS, FCC, IEC

ZL70100 MICS System



* Dependent on antenna performance

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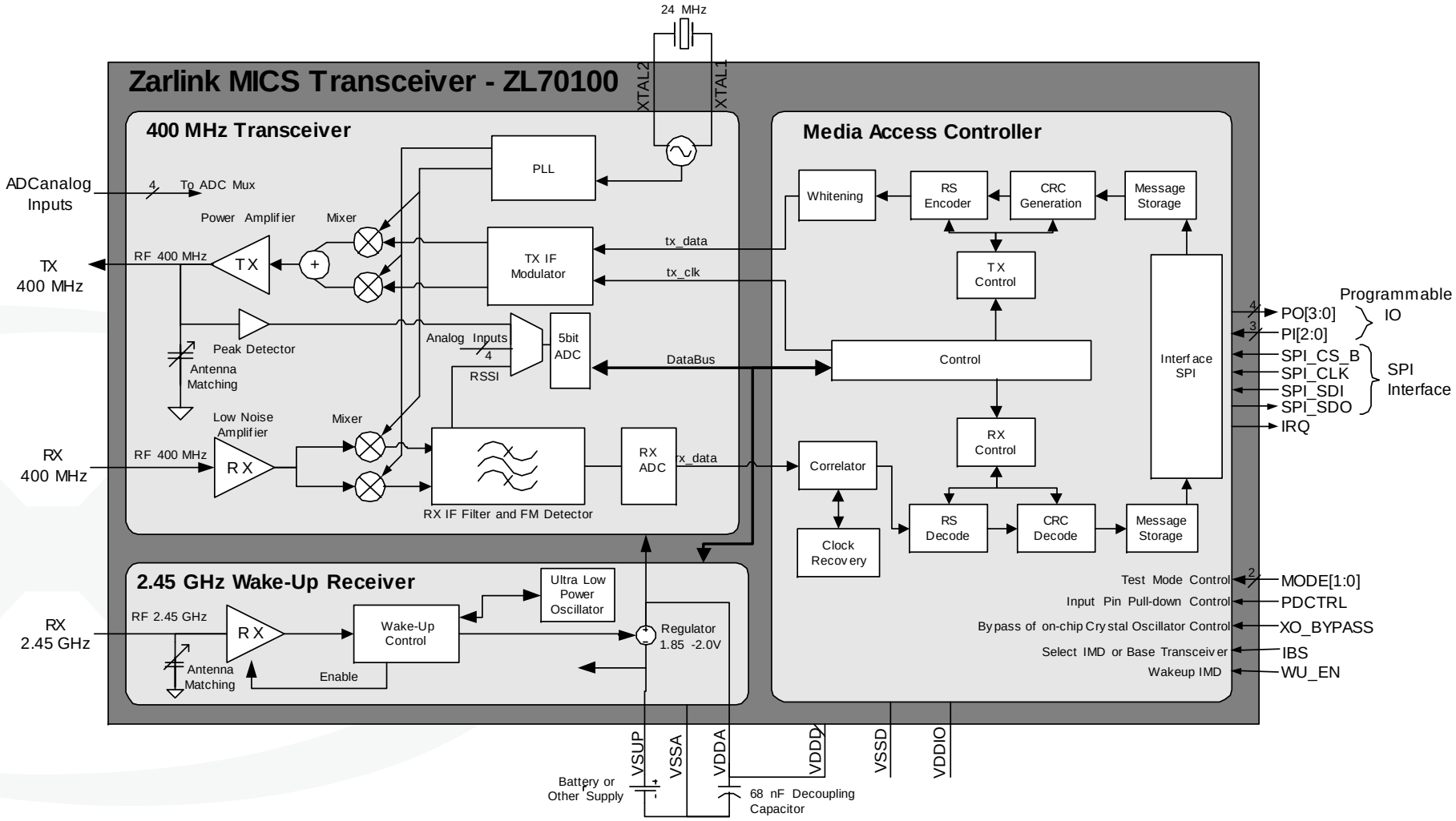
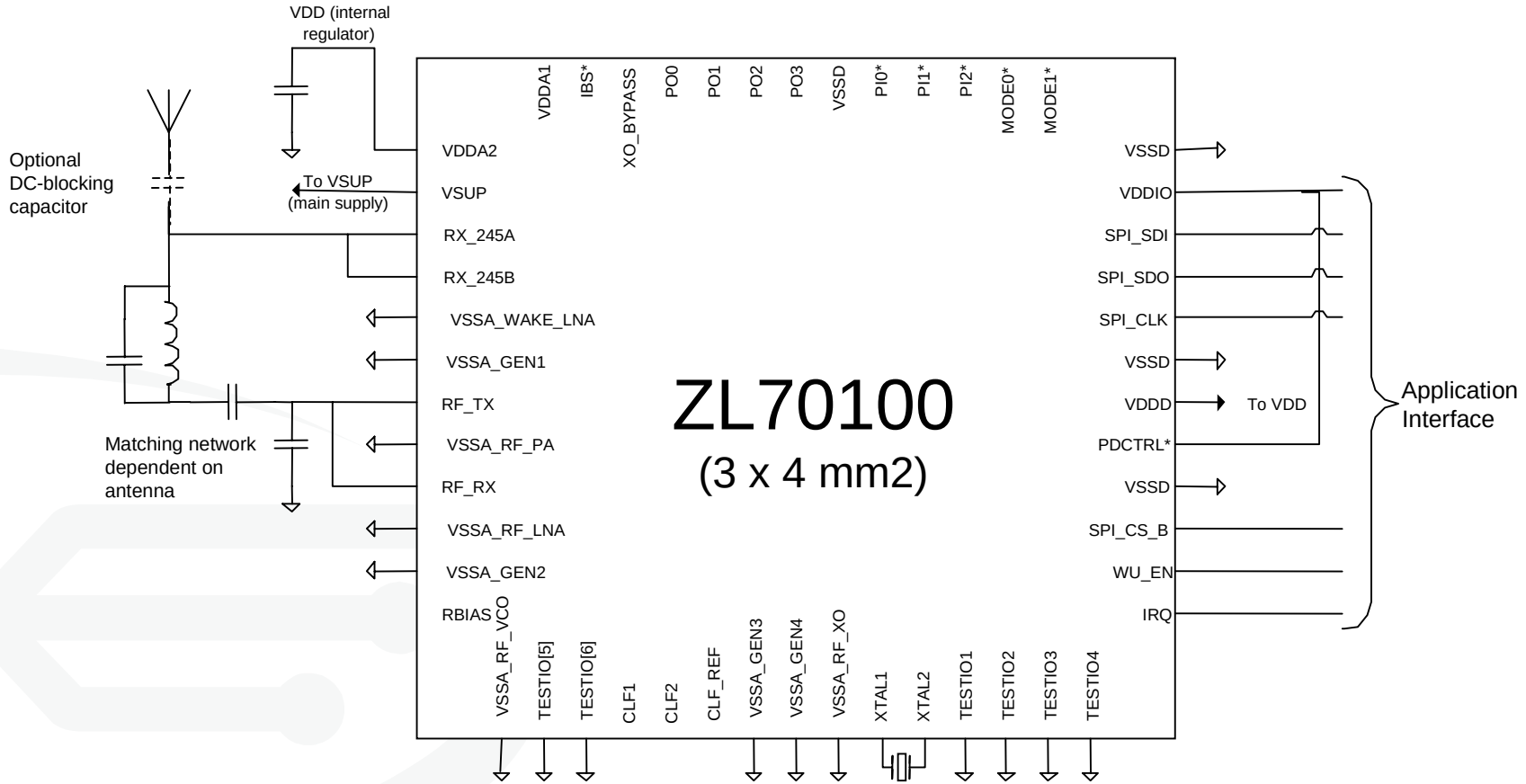
ZL70100 Block Diagram



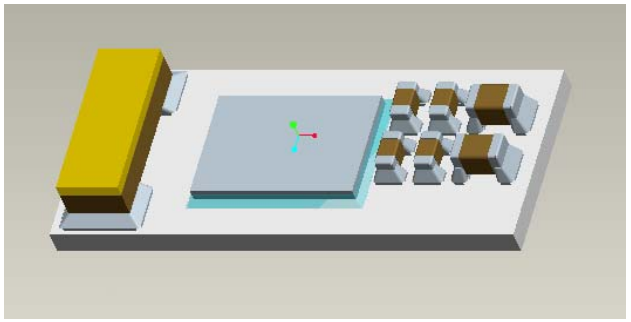
ZL70100 Typical Implant Design

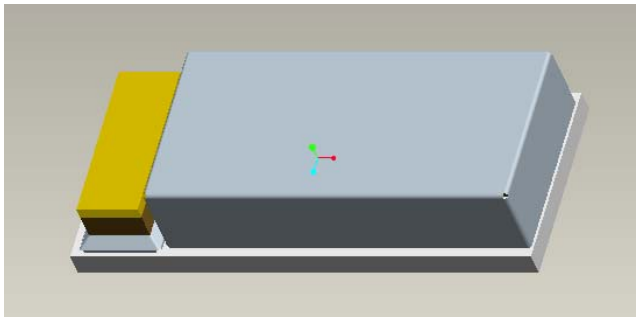


Note 1: *Inputs connected via internal pull-down to ground. Right-hand side pins do not need to be bonded out

Note 2: Two supply voltages are required VSUP (the main supply,2.1-3.6V) and VDDIO (the digital IO voltage which may be 1.5V to VSUP)
VDD is an on-chip derived regulated supply which requires a 68 nF decoupling capacitor and connection of VDDA to VDDD

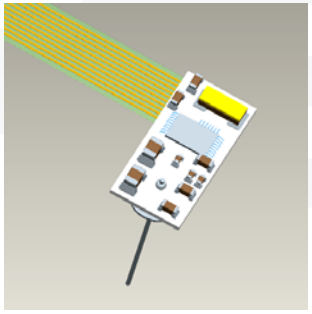
RF Module Technology for Implants



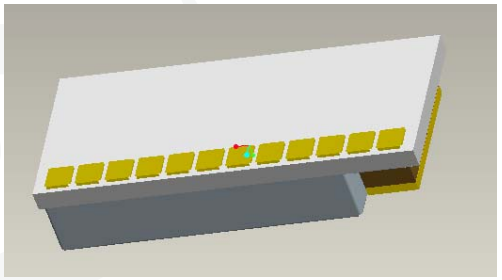


Ceramic, FR4, Rigid Flex

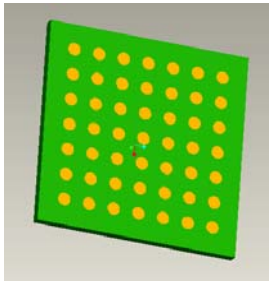
- **I/O Connectivity**

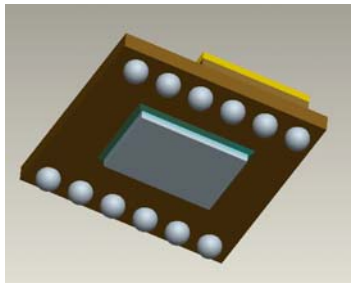


Flex



WireBond / Solder





LGA / BGA

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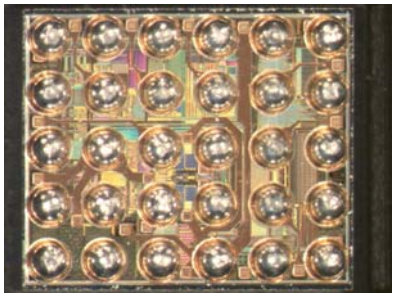
ULP Medical Transmitter (ZL70081)

Very high data rate transmitter

- **low power**
- **small footprint**
- **designed for imaging applications**

Technology:	**0.35µm CMOS**
Supply Voltage	**2.6 - 3.2 V Battery**
Radio Frequency:	**400 - 440 MHz**
Type of RF link:	**Transmit only**
Bit Rate:	**2700 kbits/s**
Operating Power:	**5.2 mW**
Ext. comps:	**10**



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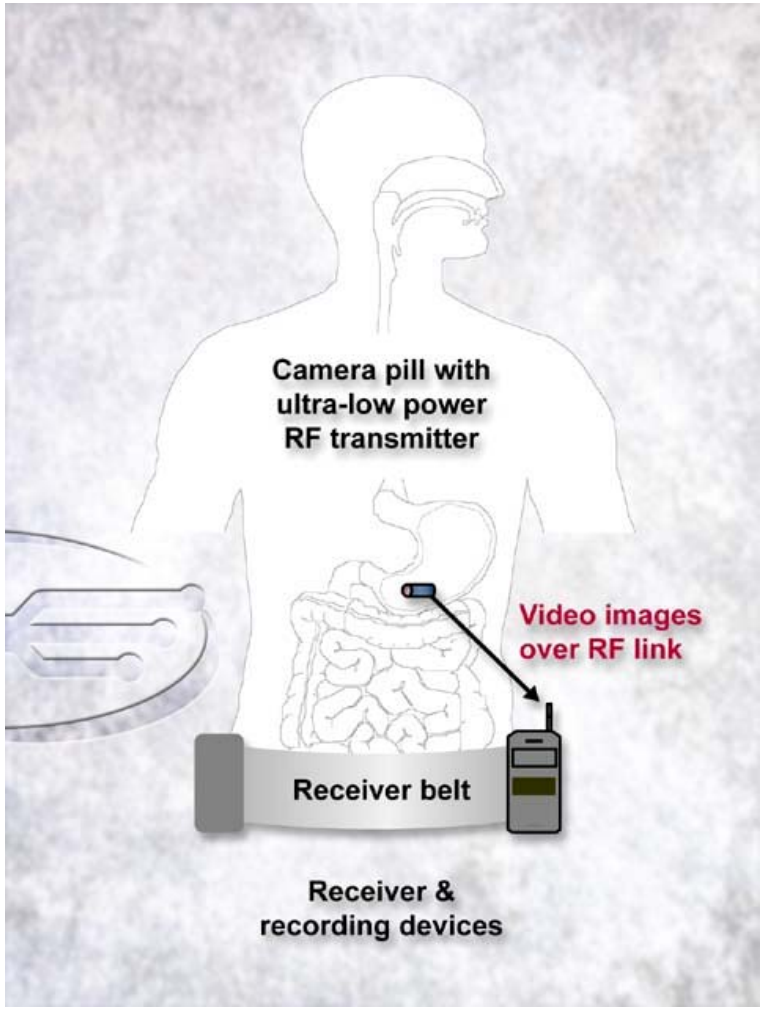
The Diagnostic Procedure
(Company: Given Imaging)

Healthy Small Bowel



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The Camera Pill

Size: 11 x 26 mm Weight: < 4 gram View: 140 deg
Approximately 57,000 pictures during 8 hours

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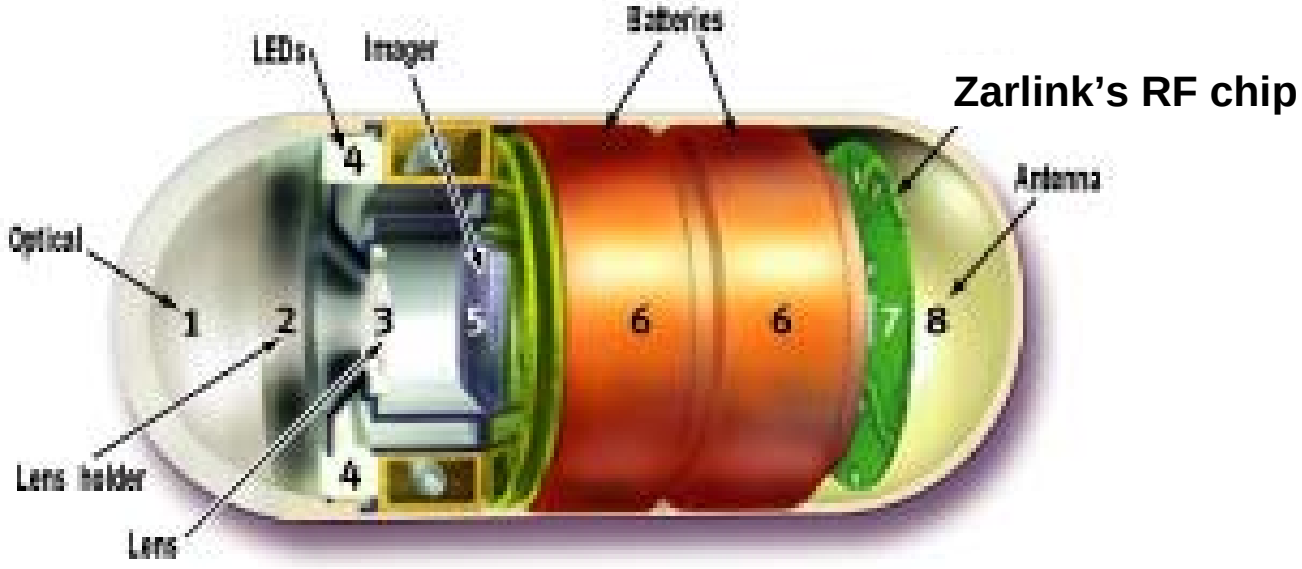
The Camera Pill

- **World's Only Swallowable Camera Capsule, from Given Imaging, including Zarlink's ULP RF Transmitter**

- **Size: 11 x 26 mm, Weight: < 4 gram, View: 140 deg**
  Approximately 57,000 pictures during 8 hours



A Real "*Fantastic Voyage*"

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ULP Audio Transceiver (ZL70262)

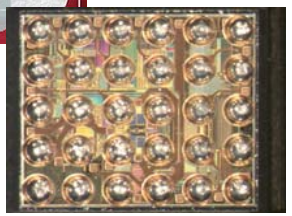
Hearing Aid wireless link:

- **Device programming**
- **Ear to ear volume control**
- **Ear to ear communication for active noise cancellation and directional hearing**

Technology:	**0.18 μm RF CMOS**
Radio Frequency:	**915 MHz (Americas) / 863-865 MHz (Europe)**
Type of RF link:	**Bi-directional, half duplex**
Bit Rate:	**186 kbits/s**
Current Consumption:	**<2 mA from 1.05 - 1.5 V Battery (cf 90 mA Bluetooth)**
Range:	**4 meters**
Externals:	**2 (Xtal,Res)**

Summary

- **RF integrated circuits for the MICS and ISM bands will open up a new range of clinical applications for the next generation medical devices.**
- **The development of such circuits requires cutting edge technology and design with specific attention to power consumption**
- **Chips for implantable medical products and complete RF modules solutions are available now !**



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SIMPLY COMMUNICATING