RF Integrated Circuits for Medical Applications:

Meeting the Challenge of Ultra Low Power Communication

Didier Sagan

Product Line Manager,

Ultra-Low-Power Communications Division,

Zarlink Semiconductor,
(Email: didier.sagan@zarlink.com)

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Outline

- **Implanted medical devices**
  - The MICS Band
  - Applications for Medical Devices
  - Ultra-Low-Power (ULP) Design Challenges
  - Design Solutions

    ZL70101: The Implantable Transceiver
- **In-vitro medical devices**

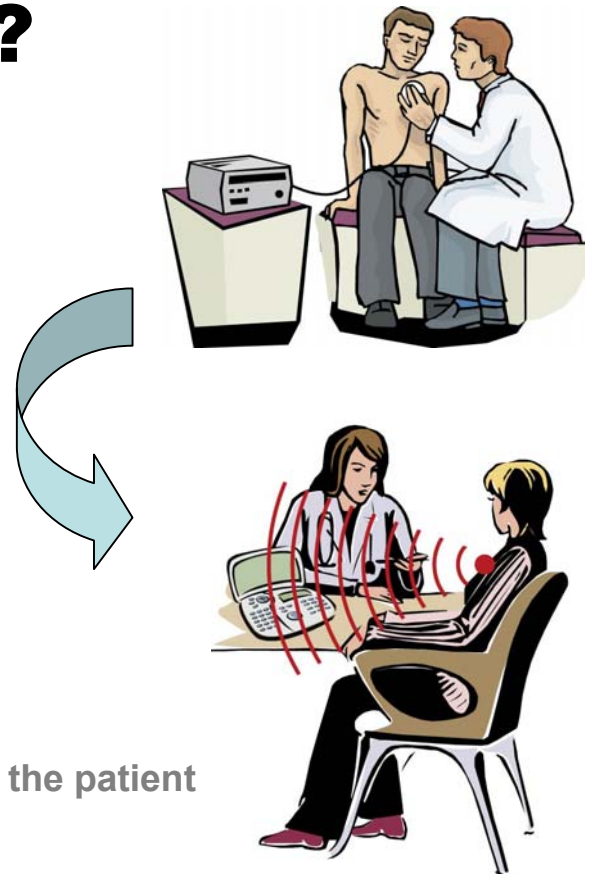
  ZL70081: The Swallowable Camera Pill Transmitter
- **Body worn medical devices**

  ZL70250: ULP Transceiver for Hearing Aids
- **Conclusion**

What is MICS ?

- **Medical Implant Communication Service (MICS)**
  - **402–405 MHz frequency allocation**
    - FCC was petitioned in 1988, 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 402-405 MHz?**
    - Reasonable signal propagation characteristics in the human body
  - **General world-wide acceptance**
    - Approved in United States, Europe, Canada, Australia and Japan

Why was MICS Introduced?



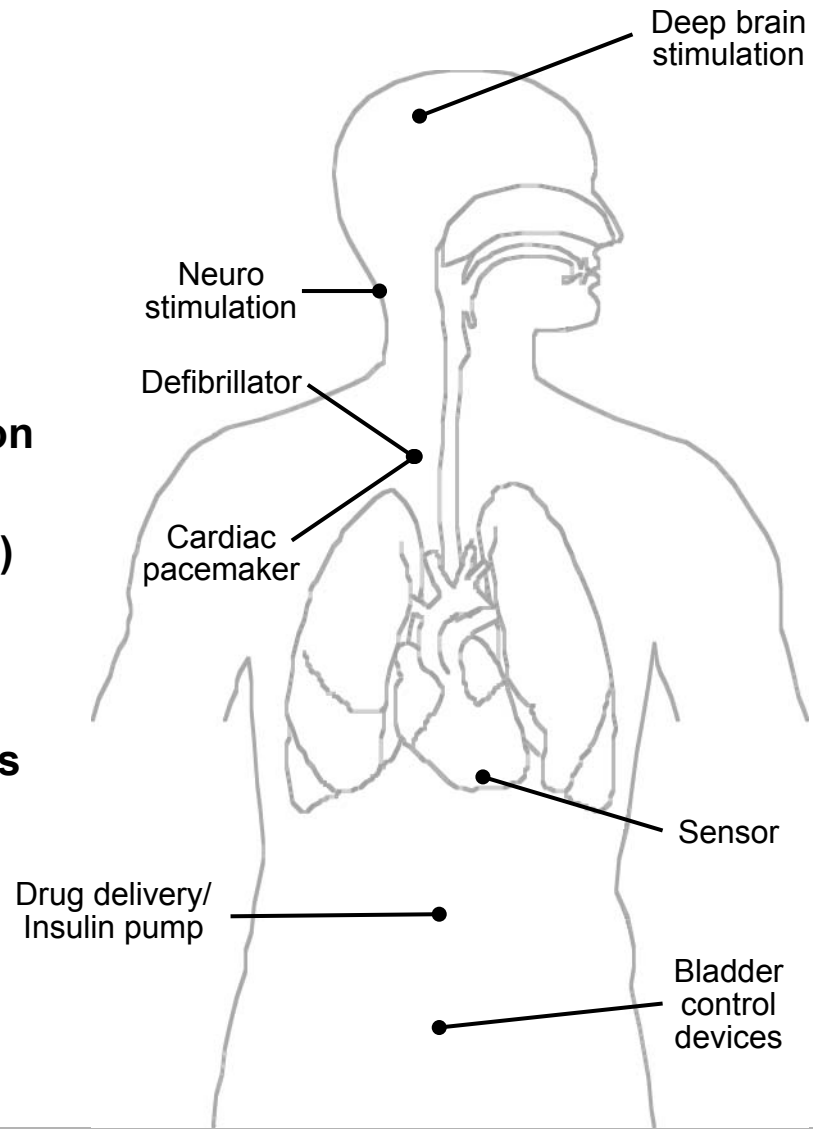
- **Traditional implants**
  - **Use inductive links**
  - **Limited range**
    - In contact with patient
  - **Low frequency**
    - Data rates similar to a dial-up computer modem
  - **Not user friendly for home monitoring**
    - Requires a wand to be positioned above the IMD by the patient
- **Need 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**

Why was MICS Introduced?

- 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 pressures of the 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**
  - **FES (Functional Electrical Stimulation)**
- **Measurement/Control/Other Devices**
  - **Drug infusion and dispensing**
  - **Artificial heart and heart assist devices**
  - **Implanted sensors**
  - **Control of other artificial organs and implanted devices**



Challenges

- **Low Power Consumption**

  - **Facts about implanted pacemakers**

    Lifetime > 7 years; up to 10 years

    Maximum current drain of the order of 10 – 20 uA

    Telemetry budgeted as no more than 15%, i.e. 2 – 3 uA

    Telemetry is off most of the time but still need to sniff every 1 – 10 s

    Consumption during Sleep/Sniff modes is therefore the most critical

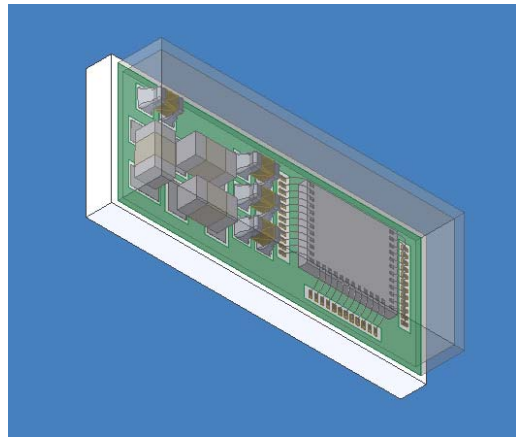
  - **Requirements**

    - Low TX/RX current <6mA, battery considerations

    - Low sleep/listen current, ideally <100s of nA

Challenges

- **Minimum External Components**
  - RF module <3x5x10 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, fading and body loss typically 40-45 dB
- **Reliability**
  - Data and link integrity, selectivity and interference rejection



Module size 3 x 5 x 10 mm

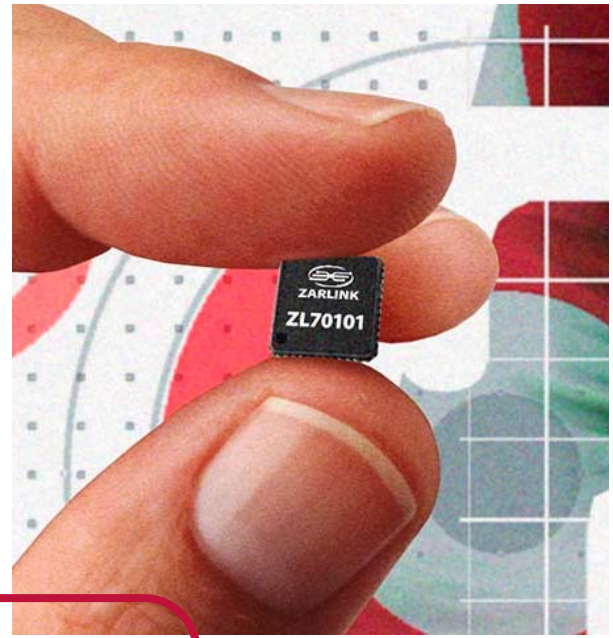
Design Solutions

- **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
  - Integrated filters

ULP Implantable Transceiver (ZL70101)

MICS and ISM Band Transceiver:

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

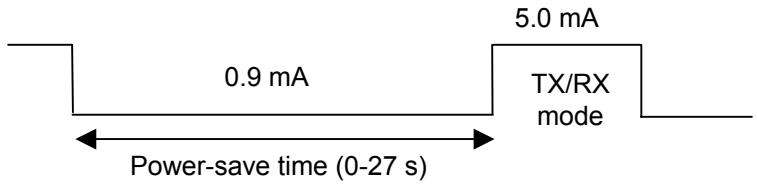


QFN package shown, also available as wire bondable bare die

Technology:	**0.18 um RF CMOS**
Supply Voltage:	**2.1 - 3.5 V Battery**
Radio Frequency:	**402-405 MHz / 433 MHz**
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:	**< 250 nA**
Ext. comps:	**3 (2 caps, Xtal) + antenna matching)**
BER:	**< 1.5 x 10^{-10}**
Range:	**~2 m**
Interface:	**SPI**

ZL70101 MICS System

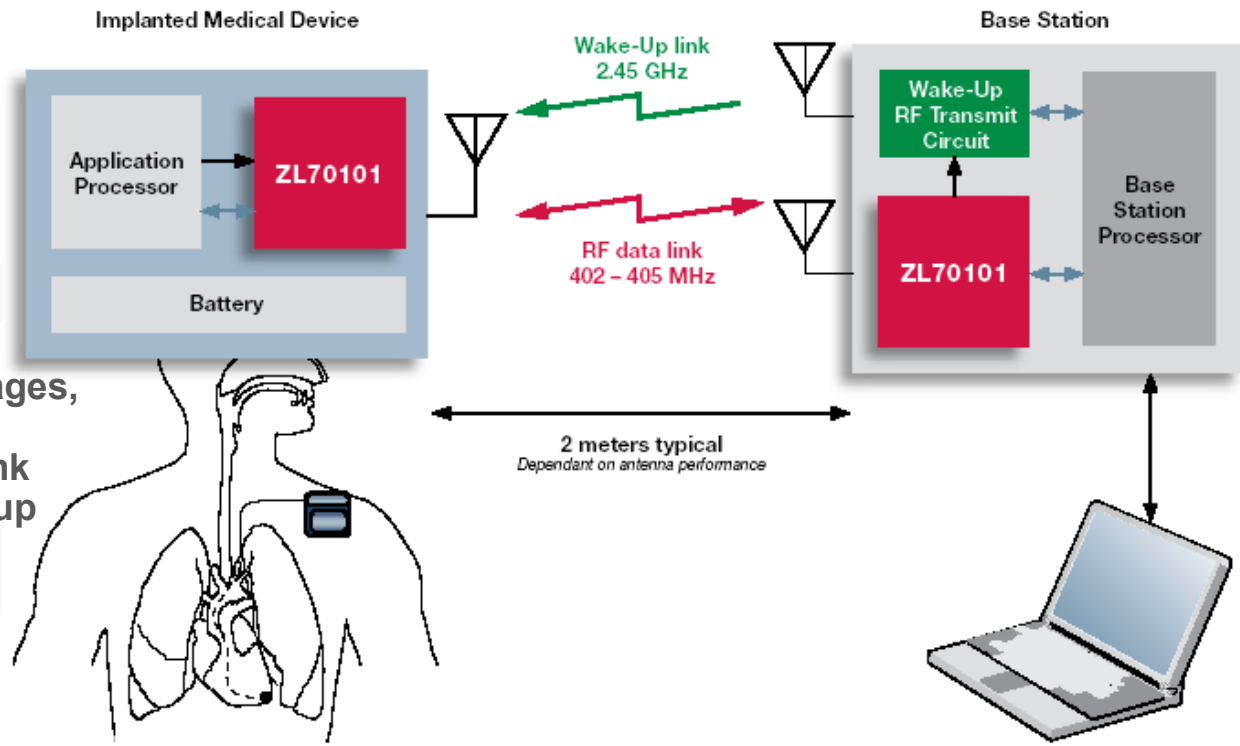
- **Extremely Low Power**
  - **5 mA continuous TX/RX**
  - **<1mA low power mode**



- **Ultra Low Power Wake-up Circuit**
  - **<250 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)



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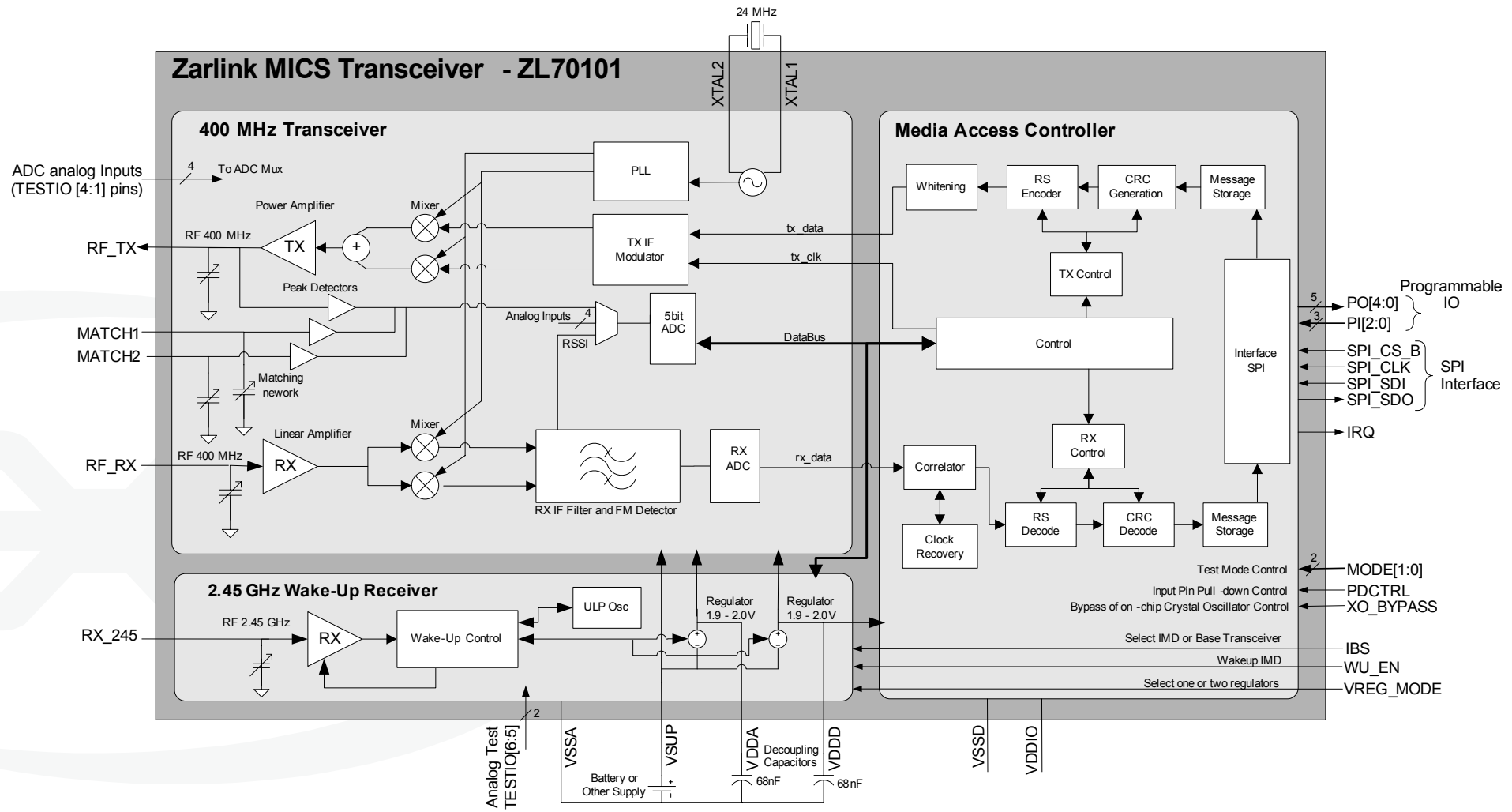
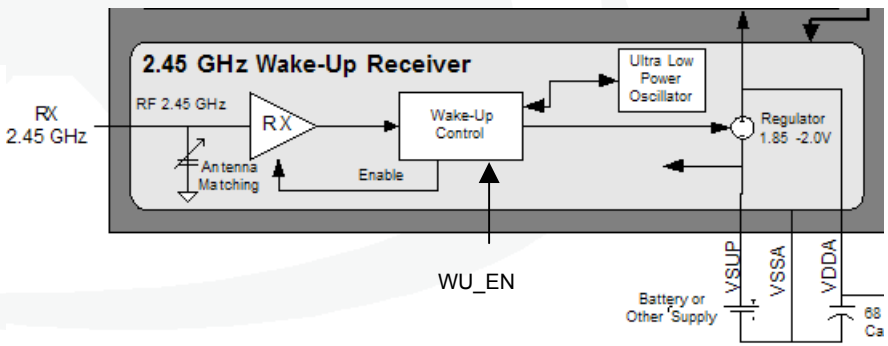
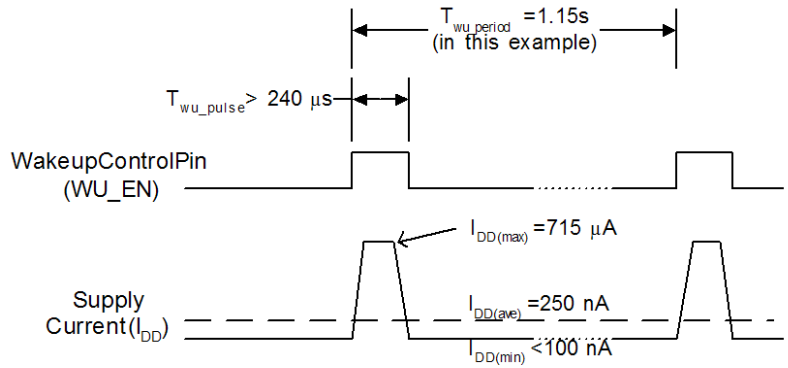
ZL70101 Block Diagram



Wakeup Receiver

- **Problem: MICS band limited to 25 uW (-16 dBm)**
- **Solution: Use band with more power 2.45 GHz (up to 20 dBm) and design synthesizer-less receiver**
  - **High Gain LNA and OOK detector**
  - **Manchester coding of pulses**
  - **250 nA average current for 1.15 second latency**
- **Possible to use for other sniffing/wakeup applications**





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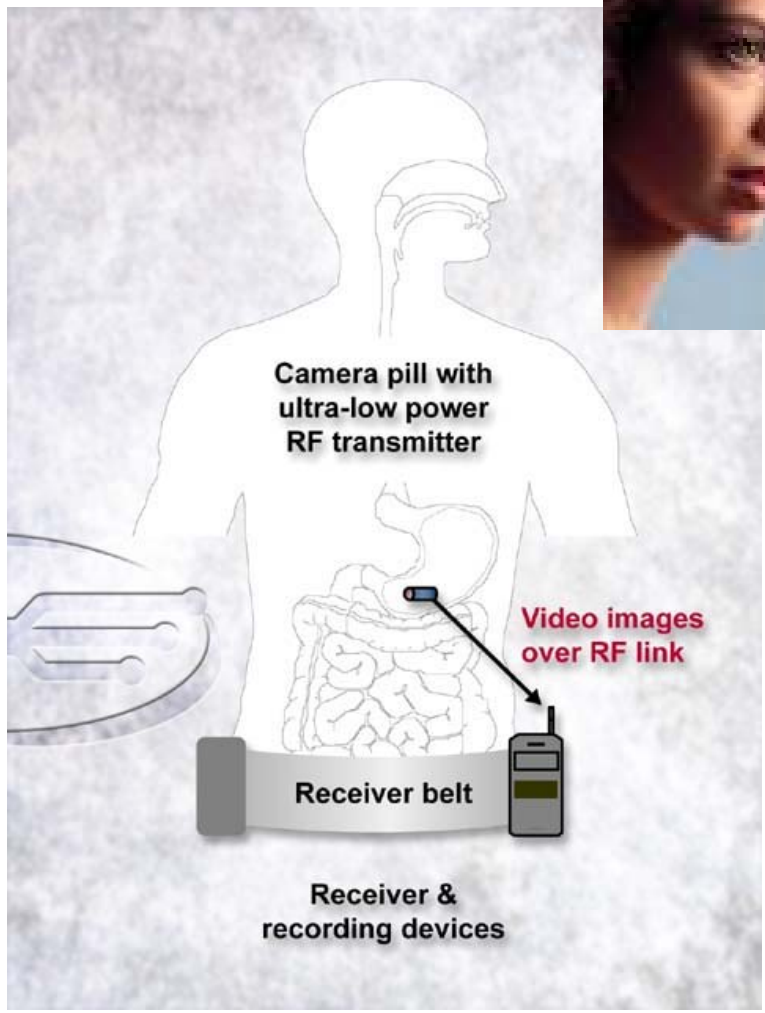
The Camera Pill
(Company: Given Imaging)

- New digestive track diagnostic tool
- Replace endoscopy
- Better diagnostic

Healthy Small Bowel



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The Camera Pill - Facts

Size: 11 x 26 mm

Weight: < 4 gram

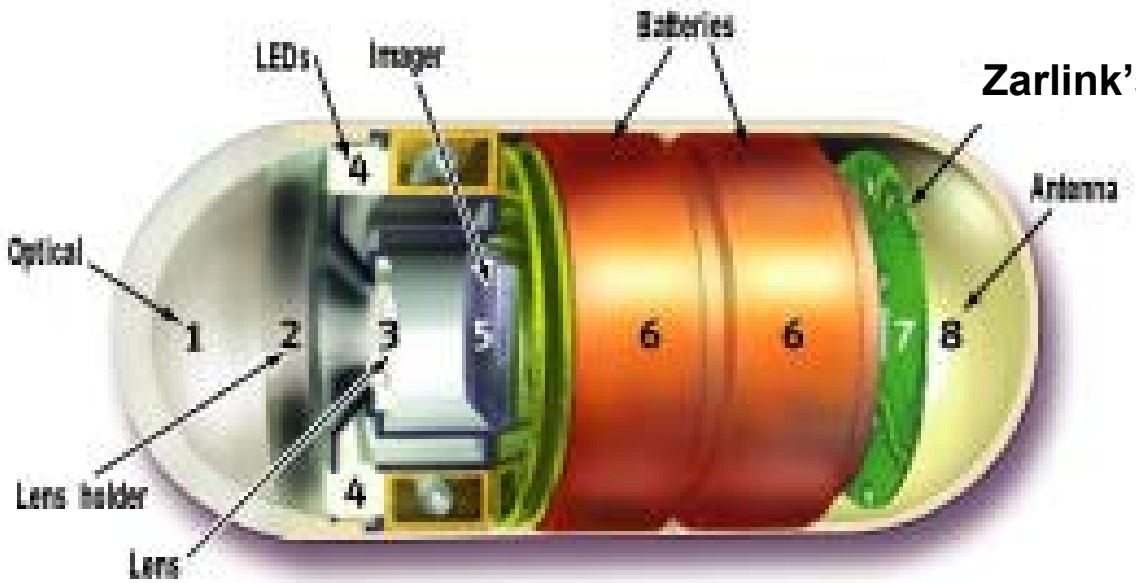
View: 140 deg

Approximately 57,000 pictures

During 8 hours

The Camera Pill – The Inside

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



A real "Fantastic Voyager," Given's tiny camera capsule is swallowed.

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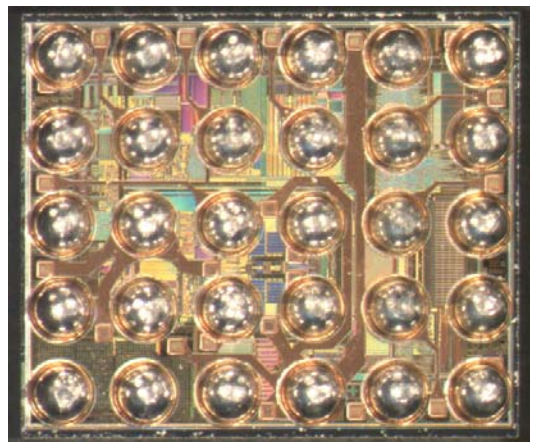
ULP Medical Transmitter (ZL70081)

Very high data rate transmitter

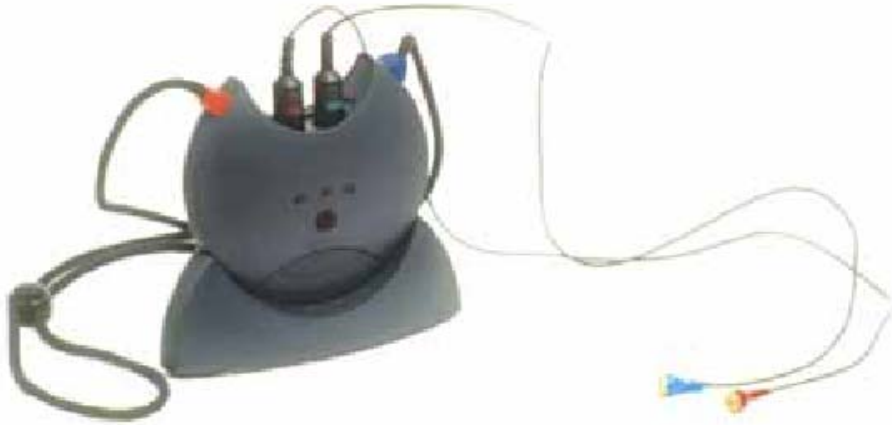
- low power
- small footprint
- designed for imaging applications

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



Hearing Aids are becoming Communication Devices

- Programming would be easier, more reliable and cheaper without cable.
- Ear-to-ear communication can improve hearing by coming closer to a real stereo image.
- Streaming audio allow connection to cell phone and MP3 player.



- But power consumption is limited
  - HA need to last 1 – 2 weeks, 16h/day
  - Battery size is limited (typ ~250 mA.h)
  - HA functionality is ~1mA
  - RF budget should be < 20%

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ULP Transceiver (ZL70250)

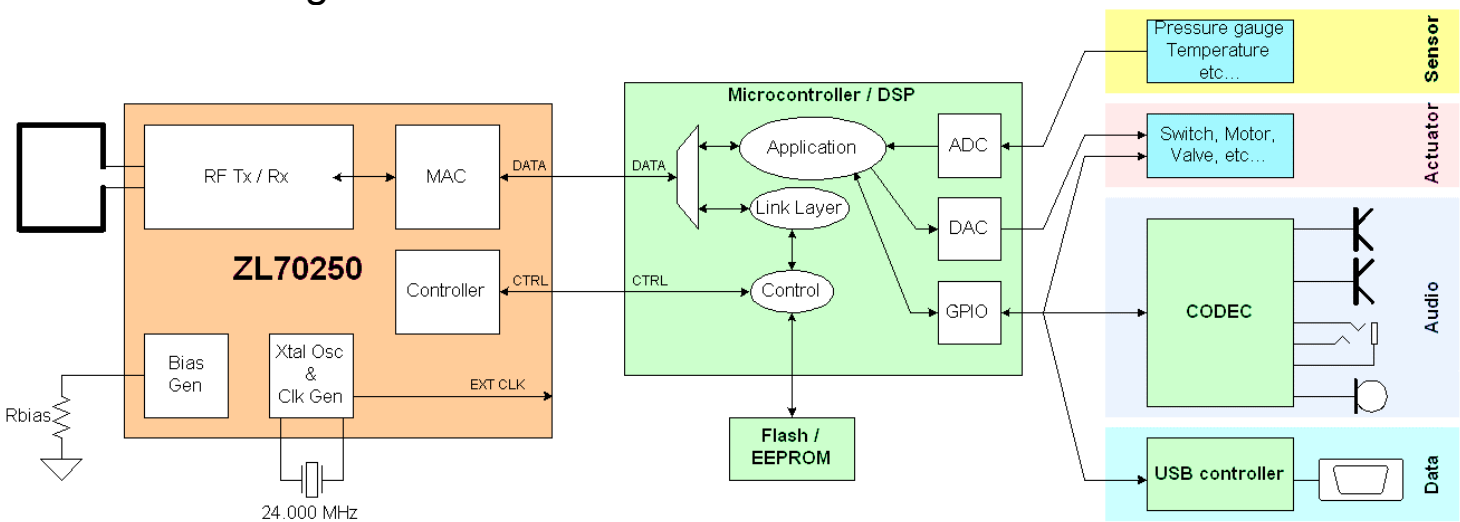
Hearing Aid wireless link:

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

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**
Range:	**3 meters (limited by antenna size)**
Externals:	**2 (Xtal,Res)**
Interface:	**SPI + 2-wire**

ULP Transceiver (ZL70250)

- **Could be used in a lot more applications:**
  - Battery powered Applications in Body Area Networks
  - Applications relying on energy scavenging
  - Short range communications with very long battery life
  - Wireless sensors
  - Remote controls
  - Voice Streaming



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Conclusion

- 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.
- Integrated circuits, modules are available now and are being used in the latest medical devices development.
- Other applications could benefits from this Ultra Low Power RF technology

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