Wireless Communication & Charging Platform for Solid State Batteries in Miniature Implantable Medical Devices

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- Miniature Implantable Medical Devices
- Solid State Batteries
- Wireless Communication & Charging Platform
- Conclusions
Miniature Implantable Medical Devices

**IMDs**
- ~15 to 50cc
- Chest/Abdomen
- Long Leads/Catheters
- Invasive Surgery
- Pacemakers/Defibrillators
- Spinal Cord Stimulators
- Drug Infusion Pumps

**MIMDs**
- < 4cc
- Head/Neck/Limbs
- Small Leads/Catheters
- Minimally Invasive
- ECG/EEG Monitors
- Peripheral Nerve Stimulators
- Micro Infusion Pumps
Miniature Implantable Medical Devices

Example: Vagus Nerve Stimulator

*Device Volume < 1cc*
Small Enough to Implant at Point of Therapy

Electrodes Attached to Nerve

 Leads Routed to Neck

IMD Implanted in Chest

Vagus Nerve Stimulation
Solid State Batteries

Rechargeable Batteries
Volume vs Capacity

Battery Volume (cc) vs Battery Capacity (mA-H)

- Solid State Batteries
  - Extremely Low Volume – Required for MIMDs
  - Extremely Low Capacity

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**Solid State Batteries**

- Fabricated on Silicon Wafers
- Standard Semiconductor Processes & Equipment
- Functions like Standard Rechargeable Li-Ion Battery
Solid State Batteries

• **Advantages**
  • Low Cost
  • Small Footprint (~ 6x6mm for 50uA-H)
  • Low Profile (200u)
  • Custom Dimensions
  • Available in Standard IC Packages
  • Flip Chip & Die Stack Compatible
  • SMT/Reflow Tolerant *(Automated Assembly)*
Advantages

- Simple Constant-Voltage Recharge
  - No current control required
  - Charging continues at very low current
- Flat Voltage Profile *(4.1 to 3.8V)*
- High Cycle Life *(5000 Cycles)*
- Low Self-Discharge *(2.5% per Year)*
- Fast Recharge *(20 Minutes)*
- Safe *(Non-Toxic)*
- Eco-Friendly *(No Disposal Requirements)*
Solid State Batteries

- **Circuit Implications**
  - Low Capacity \((\mu A-H \text{ not } mA-H)\)
  - High Cell Resistance \((> 1K\Omega \text{ near EOL})\)
  - Constant-Voltage Recharge

[Unique Circuit Solution Required]
Wireless Communication & Charging Platform

- **Highlights**
  - Near-Field Magnetic Induction [NFMI]
  - Short Range (< 20cm)
  - Low Frequency (< 1MHz)
  - One Link for Charging & Communication
  - Simultaneous Charging & Communication
  - Ultra-Low Power Timekeeping (200nW)
  - No Crystal Required
  - Zero Battery Power for Communication
  - Optimized for Solid State Batteries
Wireless Communication & Charging Platform

- **Features**
  - Wireless Power Interface
  - Solid State Battery Charger
  - Bi-Directional Wireless Transceiver
  - Supply Monitors & Switches
  - Step-Down Voltage Regulators
  - Ultra-Low Power Timekeeping
  - Control/Calibration Registers
  - Serial Peripheral Interface
Wireless Communication & Charging Platform

• **Advantages**
  • Enables Solid State Batteries
  • Provides Wireless Communication
  • Supports Device Calibration
  • Reduces ASIC Development Time
  • Reduces ASIC Development Cost
  • Reduces ASIC Development Risk
Wireless Communication & Charging Platform

- Wireless Power Interface
  - One Link for Charging & Communication
  - Simultaneous Charging & Communication
  - Doubled Output Voltage
  - Minimal External Components
Wireless Communication & Charging Platform

- Wireless Power Interface
Wireless Communication & Charging Platform

• **Solid State Battery Charger**
  • Supports Supply Voltage up to 20V
  • Automatic Supply Voltage Detection
  • 4.1V Constant-Voltage Charging
  • Calibration for High-Precision Charging
  • Supports Charging Current up to 10mA
  • Built-In Charge Current Monitor
Wireless Communication & Charging Platform

- Solid State Battery Charger
Wireless Communication & Charging Platform

- Bi-Directional Wireless Transceiver
  - Simple Amplitude Modulation Scheme
  - Manchester Encoded Data
  - Integrated Demodulator & Decoder
  - Integrated Encoder & Modulator
  - Passive Transmitter (*No Battery Power*)
  - ~ 150KHz Carrier Frequency
  - Programmable Baud Rates (*600 to 9600*)
Wireless Communication & Charging Platform

- Bi-Directional Wireless Transceiver
Wireless Communication & Charging Platform

- Supply Monitors & Switches
  - Charger, Battery, Circuit Supply Monitors
  - Automatic Supply Voltage Switching
    - Charger to Battery / Battery to Circuit / Charger to Circuit
  - Low & Dead Battery Indicators
    - Programmable Thresholds
  - Calibration for High-Precision Monitoring
  - Manual Override Option
Wireless Communication & Charging Platform

• Supply Monitors & Switches
Wireless Communication & Charging Platform

- **Step Down Voltage Regulators**
  - 2.5V Linear Regulator
    - Supports MCU & ASIC Digital Functions
    - Supports Load Current up to 10mA
    - On-Demand Operation (*Normally-Off*)
  - Ultra-Low Power 1.8V Linear Regulator
    - Supports Ultra-Low Power Timekeeping Function
Wireless Communication & Charging Platform

- 2.5V Voltage Regulator
Wireless Communication & Charging Platform

- **1.8V Voltage Regulator**

![Diagram of a 1.8V Voltage Regulator](image.png)

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Wireless Communication & Charging Platform

- Ultra-Low Power Timekeeping
  - Ultra-Low Power Oscillator
    - 128Hz Clock Output
    - Calibration for Precise Timing
    - Stable Frequency as Battery Decays
    - 200nW – Including Voltage Regulator
  - 40-bit Counter/Timer
    - Supports Real-Time Clock Functions
    - Read, Write, & Pause Functions
    - Low-Frequency Output for Supply Monitor
Wireless Communication & Charging Platform

- Ultra-Low Power Oscillator
Wireless Communication & Charging Platform

- Control Registers & SPI
  - Read/Write Control of Analog Functions
  - Supports Device Calibration
  - “Non-Volatile” with Valid Battery
  - Flexible Array Size ($16 \times 8$ bits pages)
  - Standard 4-Wire Serial Interface ($10MHz$)
  - Block Read/Write Functions
Conclusions

- Extreme Miniaturization requires Solid State Batteries
- Solid State Batteries have unique characteristics
- Cactus’ Platform provides the infrastructure to build into application-specific devices with Solid State Batteries
- Platform Includes Features common to most MIMDs
- Reduces ASIC development Time, Cost, & Risk
Cactus Semiconductor Inc. is a fabless semiconductor company. We offer **full turn-key product design** and production as well as **integrated circuit design services**. Our expertise in **power management** and **analog circuits** find value in products for **medical** and **portable applications**.

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