CIED Hardware Overview

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Agenda

- Electronics Fundamentals & Common Terminology
- Ohm's Law
- Wave Forms
- Sensors
- CIED Basic Anatomy
  - generators
  - leads & electrode martials
- CIED Battery Technology

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Electronics Fundamentals

- **Sensing**: detecting changes in electrical signals within a system (Types: biopotential, temperature, pressure, optical, capacitive/resistance)
- **Stimulation**: provoking a biological response using electrical current (pacing, neuromodulation, TENS)
- **Defibrillation**: medical procedure that aims to restore normal heart rhythm (myocardial functionality) by delivering an electrical shock.
- **Ampere**: (amp) a unit of electric current
- **Charge**: fundamental property of matter responsible for electrical interactions
- **Ohm**: unit of electrical resistance (R), named after Georg Simon Ohm
- **Volt**: unit of electrical potential or electromotive force (V)
- **Hertz**: measure of frequency or cycles per second. Named after Heinrich Hertz
- **Power**: the rate at which energy (electrical or electrochemical) is transferred or converted or otherwise consumed/used
- **Energy**: total amount of work done, or total power used over a finite time period.

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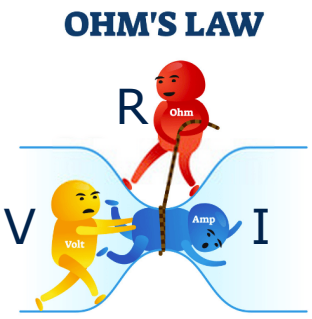
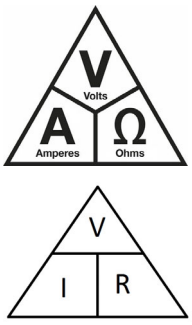
Electronics Fundamentals

Ohm's law: electric current through a conductor between two points is directly proportional to the voltage across the two points.

Per Ohm's law:

- Power (P)=VxI (voltage times current)
- Energy (E)=Pxt (power multiplied by time)





$$V = I \times R$$
$$I = V / R$$
$$R = V / I$$

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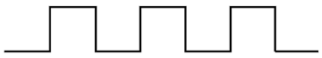
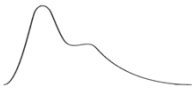
Wave Forms

Sine wave		Smooth and continuous waveform that oscillates periodically
Square wave		Sharp transitions between high and low states
Triangle wave		Linear rise and fall, resembling a triangle shape
Sawtooth wave		Linear rise followed by a sudden drop
Pulse wave		Similar to square wave but with variable duty cycle

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Software

Software in the generator

Programmer software

Remote monitoring software

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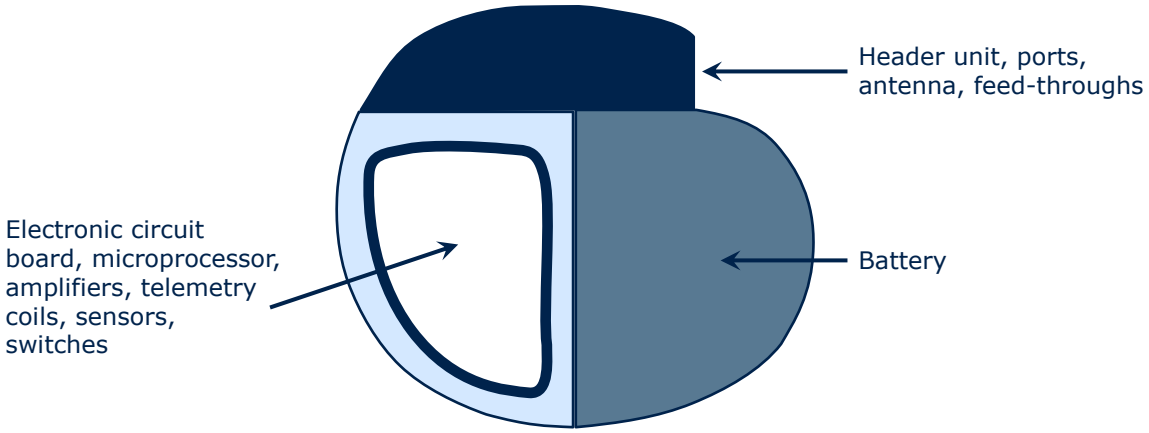
CIED Anatomy



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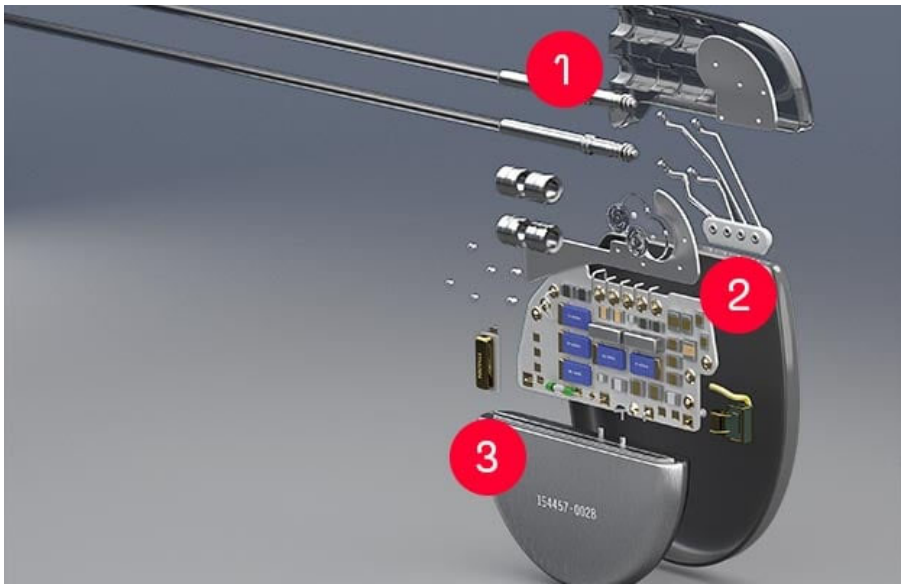
CIED Anatomy

1. Leads
2. Generator Housing
3. Battery



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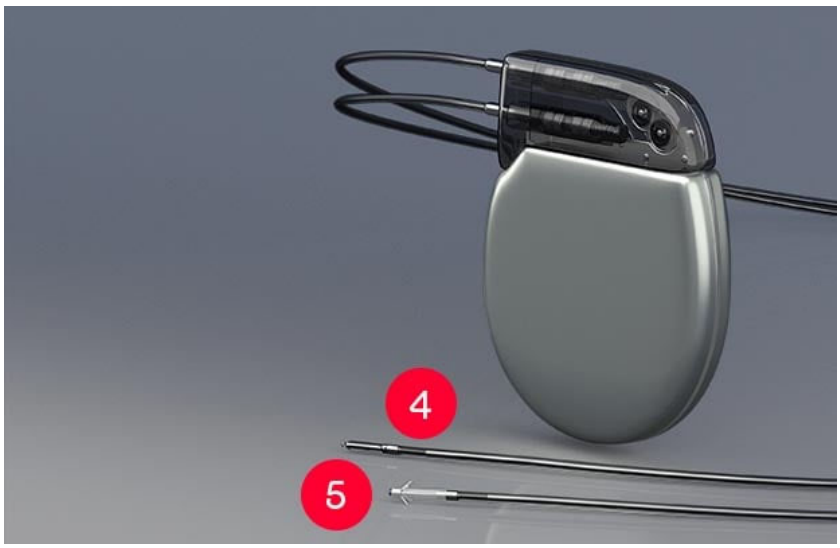
CIED Anatomy

4. Active fixation lead
5. Passive fixation lead



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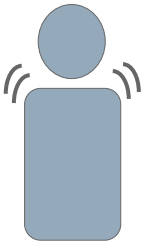
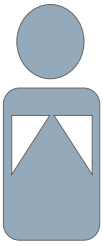
Rate Adaptation Sensors

Accelerometer



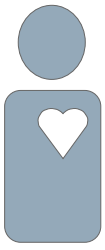
Rate changes based On motion/physical activity

Minute Ventilation



Rate changes based On changes in breathing

CLS



Rate change based On myocardial contractility

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Lead Materials

Lead Conductor Materials

- Silver
- MP-35N (alloy of nickel, cobalt, chromium, and molybdenum)
- Platinum
- Iridium

Lead Insulator Materials

- Silicone
- Polyurethane
- Hybrid insulators
- Combined layered insulators

Other Materials

- ETFE
- PTFE

Desirable properties in conductive materials

- High conductivity at all temperatures
- Very high melting point
- Hydrophobic
- Chemically inert
- Low coefficient of friction
- High tensile and flexural strength

Desirable properties in insulator materials

- Non-conductive at all temperatures
- Bio-compatible and innert
- Hydrophobic
- Chemically inert
- Low coefficient of friction
- High tensile and flexural strength:

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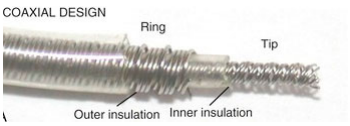
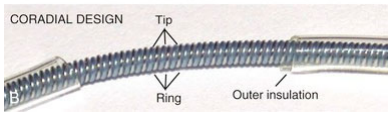
Lead Materials

Lead Construction Techniques

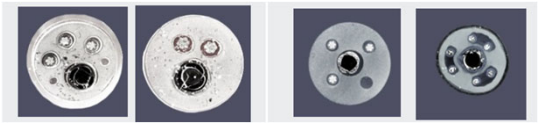
Coaxial



Coradial



Symmetrical vs Asymmetric



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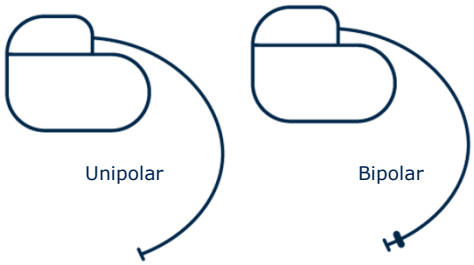
Leads/Electrodes (pacing)

What is a lead?

A lead is an insulated wire that connects an electrode to the pulse generator.

Lead types and variations



Active Fixation (helix/screw)

Passive Fixation (tines)

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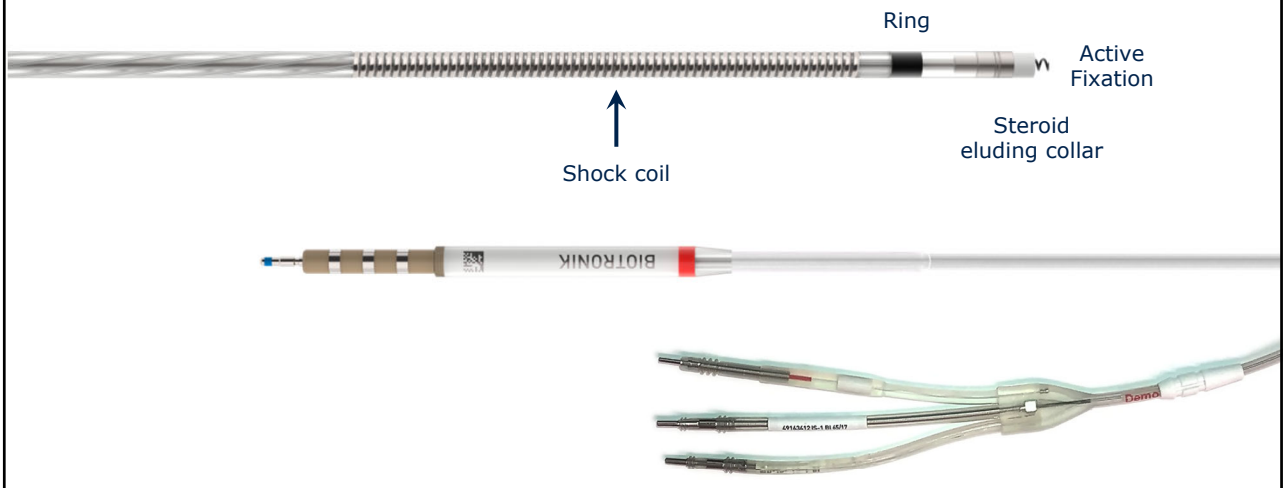
Leads/Electrodes (Defibrillator)



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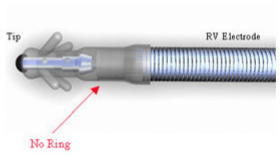
Leads/Electrodes (Defibrillator)

Dedicated Vs Integrated Bipolar

True Bipolar

- Senses between sense-pace lead tip and ring electrode
- Creates a smaller antenna than integrated bipolar
- May reduce oversensing compared to integrated bipolar
- Higher specificity, more sensitive to lead position

Integrated Bipolar



- Senses between RV coil and lead tip
- Creates a larger antenna
- May cause potential oversensing compared of far-field signals and EMI
- Simplifies lead design

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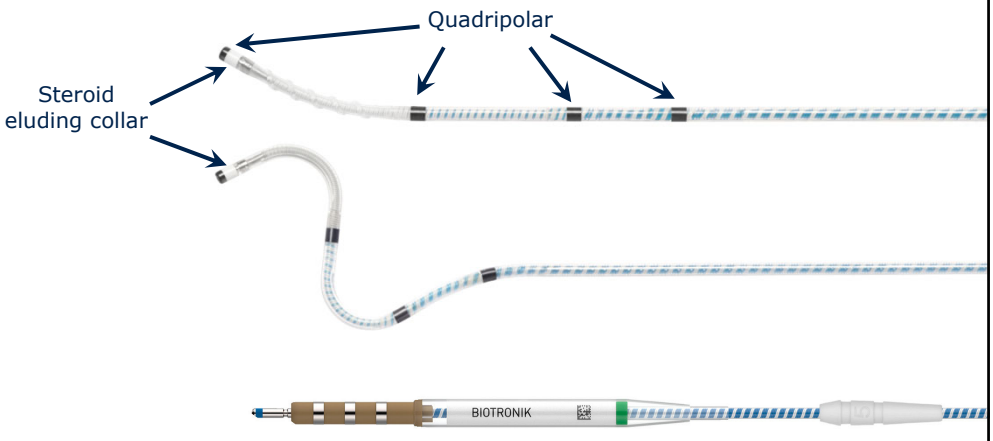
Leads/Electrodes (CRT or LV or CS)



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Battery Technology

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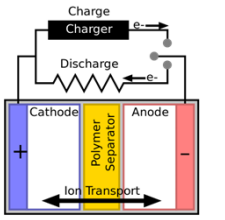
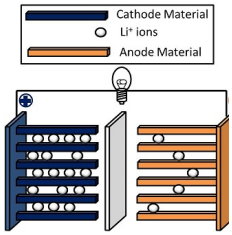
CIED Battery History

- **1950's: rechargeable nickel-cadmium**
  - at the cadmium electrode during discharge are:
    $Cd + 2OH^- \longrightarrow Cd(OH)_2 + 2e^-$
  - at the nickel oxide electrode are
    $2NiO(OH) + 2H_2O + 2e^- \longrightarrow 2Ni(OH)_2 + 2OH^-$
  - net reaction during discharge is
    $2NiO(OH) + Cd + 2H_2O \longrightarrow 2Ni(OH)2 + Cd(OH)_2$.
- **1960's: zinc-mercury**
  - 2 years of service time
- **1970's: Radioisotope Thermoelectric Generator Pacemaker**
  - Poor longevity, large device form factor, high cost
- **1970's: Lithium-iodine battery**
  - Better longevity (around 8 years), smaller form factor, favorable economics





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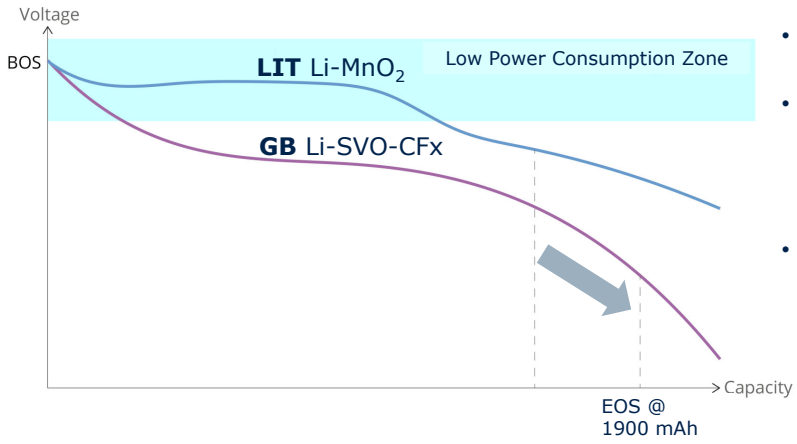
Battery Chemistry Comparison



- **Greatbatch** provides extensive longevity via a large capacity.
- **LITRONIK's** battery voltage stays longer in the low power consumption zone (>2.95 V) and thereby the circuit saves power.
- **Both LITRONIK and Greatbatch batteries have the same longevities under the same operating conditions**

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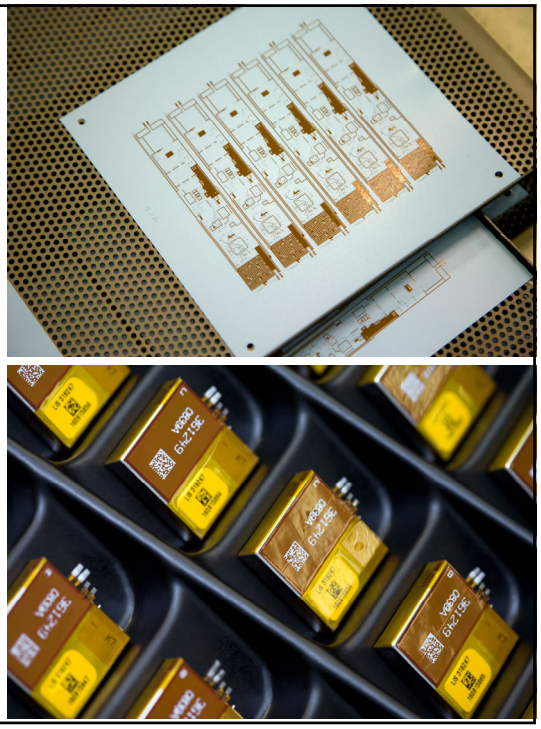
Battery Consumption

- Pacing therapies
- Tachy therapies
- Communications
- Data processing/computation
- Storage/memory
- Housekeeping current
- IC* tech consolidation vs separation



* a semiconductor wafer on which thousands or millions of tiny resistors, capacitors, diodes and transistors are fabricated.

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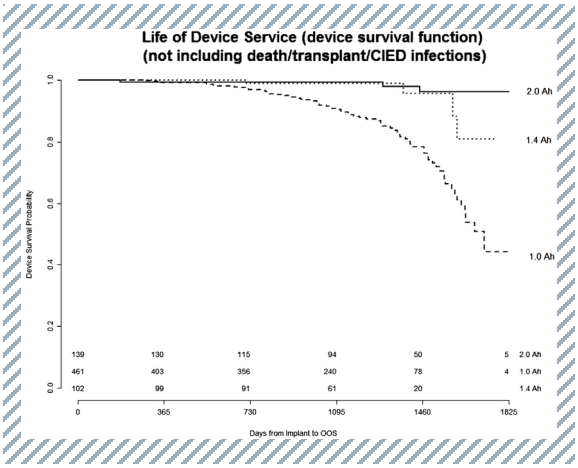
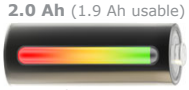
Battery Capacity A Strong Predictor of Battery Longevity



BIOTRONIK excellence for life — **2.0 Ah** (1.9 Ah usable)

Li-SVO-CFx battery

Boston Scientific — **2.0 Ah** (1.9 Ah usable)



Li-MnO_2 battery

Abbott — **1.4 Ah**

Li-SVO-CFx battery

Medtronic — **1.0 Ah**

Li-SVO-CFx battery

1 Ampere Hour (Ah) as a Predictor of CRT ICD Pulse Generator Battery Longevity. A Multi-Center Study. Christopher R. Ellis, Tiffanie Markus, Deanna Dickerman, Jodi M. Orton, Sohail Hassan, Eric D. Good, Toshimasa Okabe, Arnold Greenspon. Journal of Cardiac Failure. Volume 20, Issue 8, (August 2014) DOI: 10.1016/j.cardfail.2014.06.106. MDT, ABT and BSX Ah values based on Ellis publication.

Information on devices manufactured at companies other than BIOTRONIK was gathered from multiple sources. However it has not been verified by the vendors and we cannot guarantee its accuracy.

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Clear as mud?

Q&A

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Thank You

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