DIEHL & EAGLE PICHER
Batterie-Systeme

Alternative Power Supply for Medium Caliber Fuzes

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Overview

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- Background
- Conceptual idea
- Design considerations
- Thermal model and optimization
- Experimental set-up
- System concept
- Conclusion and future work

Background

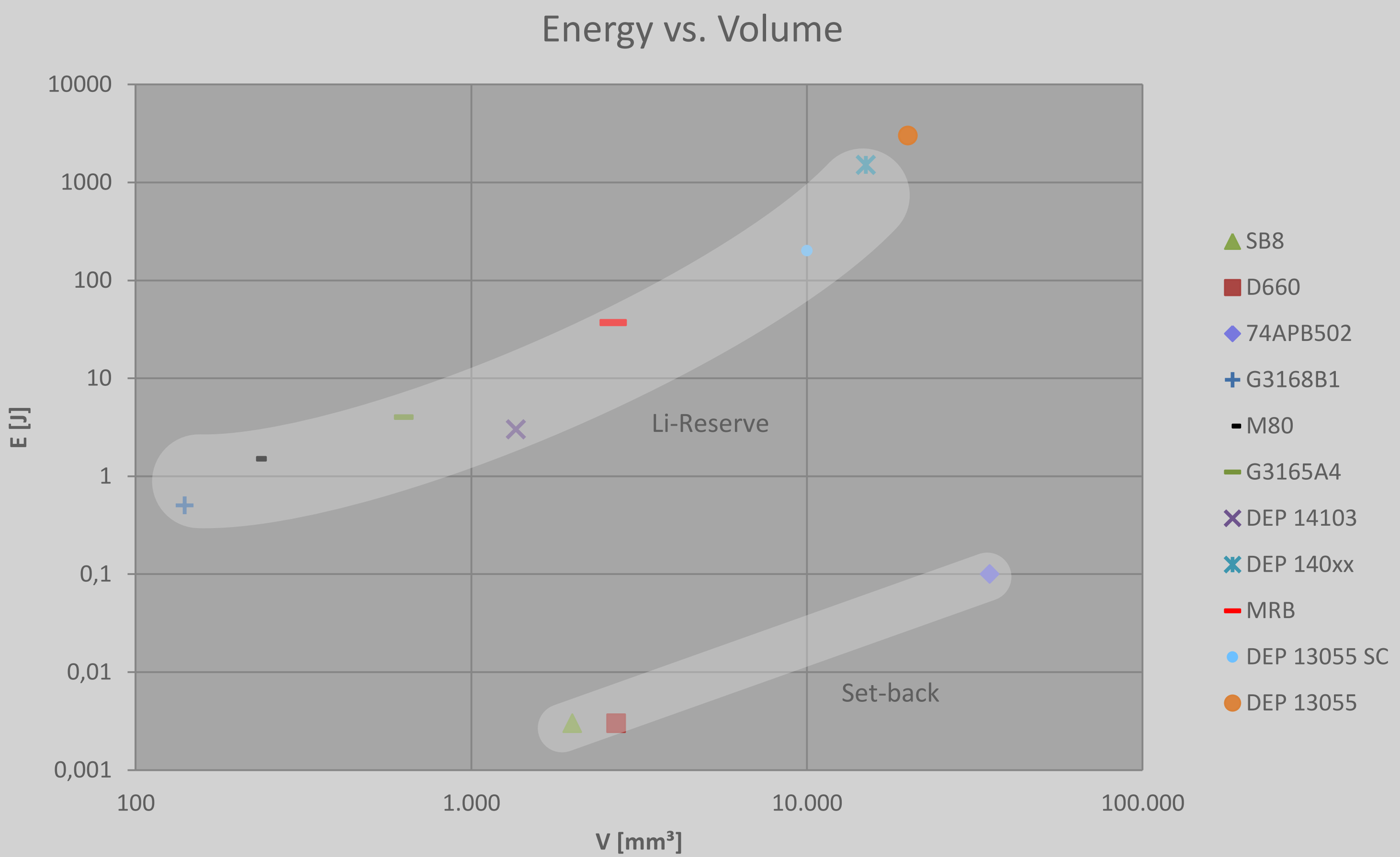
- Power requirement for Medium Caliber Fuze
  - Used to be "generation→impact→function" in the past 40 years
    - Very simple function
    - Very sensitive igniters/detonators
    - Very low energy generated; single-digit mJ's
  - Started to incorporate lots of functions few years ago
    - Full digital control, timing, proximity, detection, correction
    - Less sensitive pyrotechnic due to EMC requirements
    - Need for more mJ; some ten to hundred mJ's
    - Can be lower voltage

Background

- Power Sources for Medium Caliber Fuze
  - Used to be set-back Generator Designs
    - Piezoelectric charge generated during firing acceleration
    - Electromagnetic field change generated due to firing acceleration
    - mJ’s to <10 mJ are generated during ms or sub ms
    - Storage capacitor for flight time
  - Liquid Reserve Batteries
    - Lithium Oxihalid Systems
    - Commonly used in large caliber (artillery, mortar)
    - Long lifetime
    - High power
    - High energy

Background

- Power Sources for Medium Caliber Fuze



Conceptual idea

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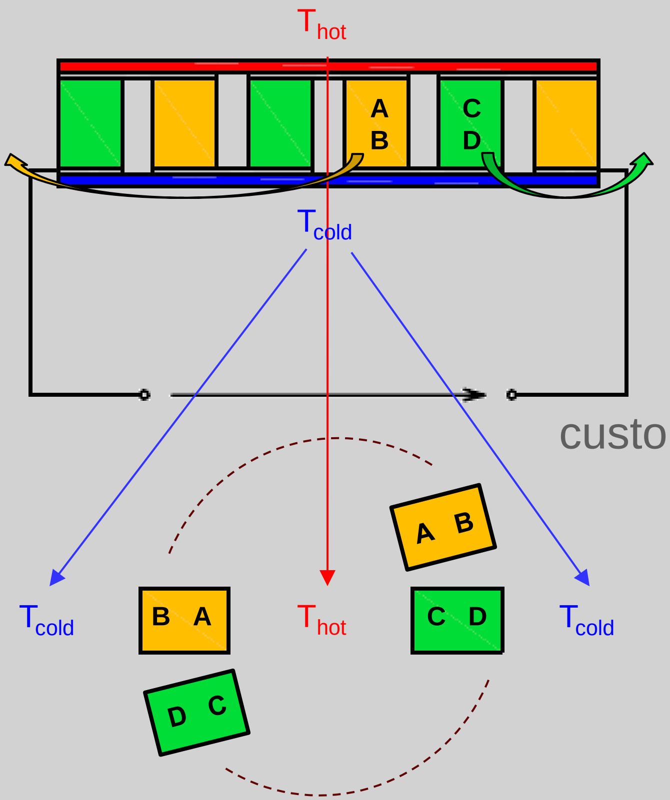
- Power Source in the 50 - 500 mJ range
  - >10 fold energy density of set-back
  - Independent of spin
  - Easy to scale

Converter	≙	Power, voltage
	+	
“fuel”	≙	Energy

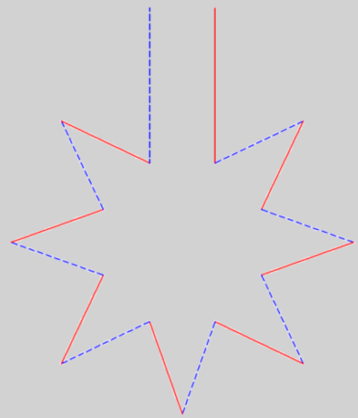
Converter ⇢ Thermoelectric Generator
Fuel ⇢ Pyrolant (pyrotechnic heat source)

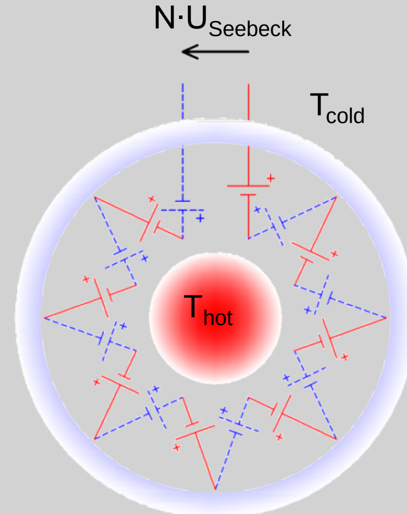
Conceptual idea

- Thermoelectric Generator



customary





our concept

Design Consideration

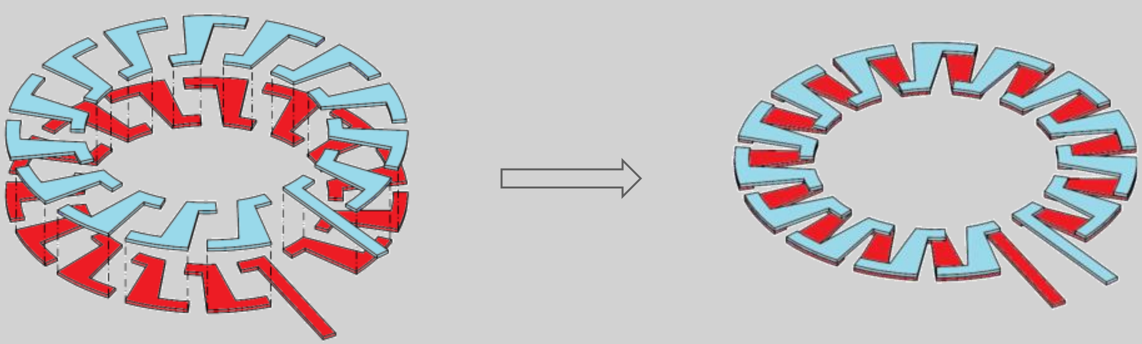
- Thermoelectric Conversion

$$\eta_{Max} = \frac{T_{hot} - T_{cold}}{T_{hot}} \cdot \frac{\sqrt{1 + Z_M \cdot \overline{\overline{T}}} - 1}{\sqrt{1 + Z_M \cdot \overline{\overline{T}}} + \frac{T_{cold}}{T_{hot}}} \quad \Longrightarrow \quad T_{hot} \uparrow , \; T_{cold} \downarrow$$

↳ Thermoelectric Alloys

Material	Seebeck coefficient a (mV/K) 0-1000°C/mV	Melting point (°C)
Constantan (45Ni-55Cu)	-35.1	1270
Nickel	-14.8	1453
Platinum	0	1769
Copper	+7.5	1084
Nickel-chrome (80Ni-20Cr)	+11.4	1400
Iron	+19.8	1534
Chromel (90Ni-9Cr)	+28.1	1350

TEG-Design



Thermal model and optimization

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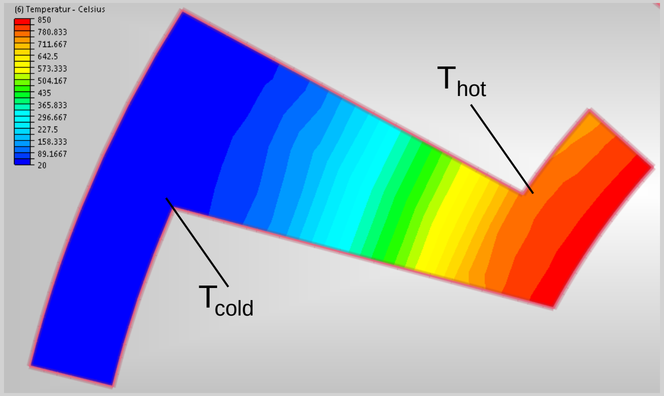
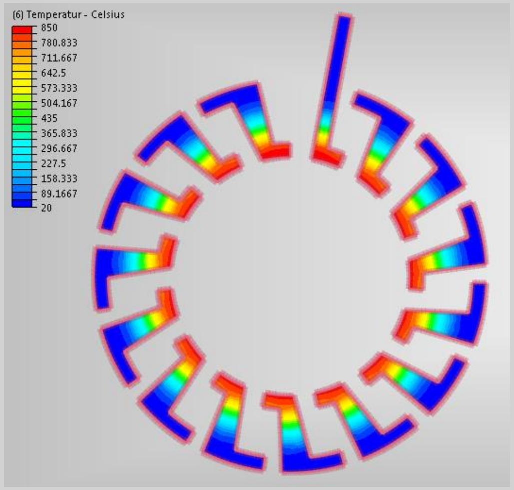
- Software based on finite elements method





  - Material selection
  - Geometrical optimization of TEG-legs
  - Optimization of support structure and electrical isolation

Thermal model and optimization

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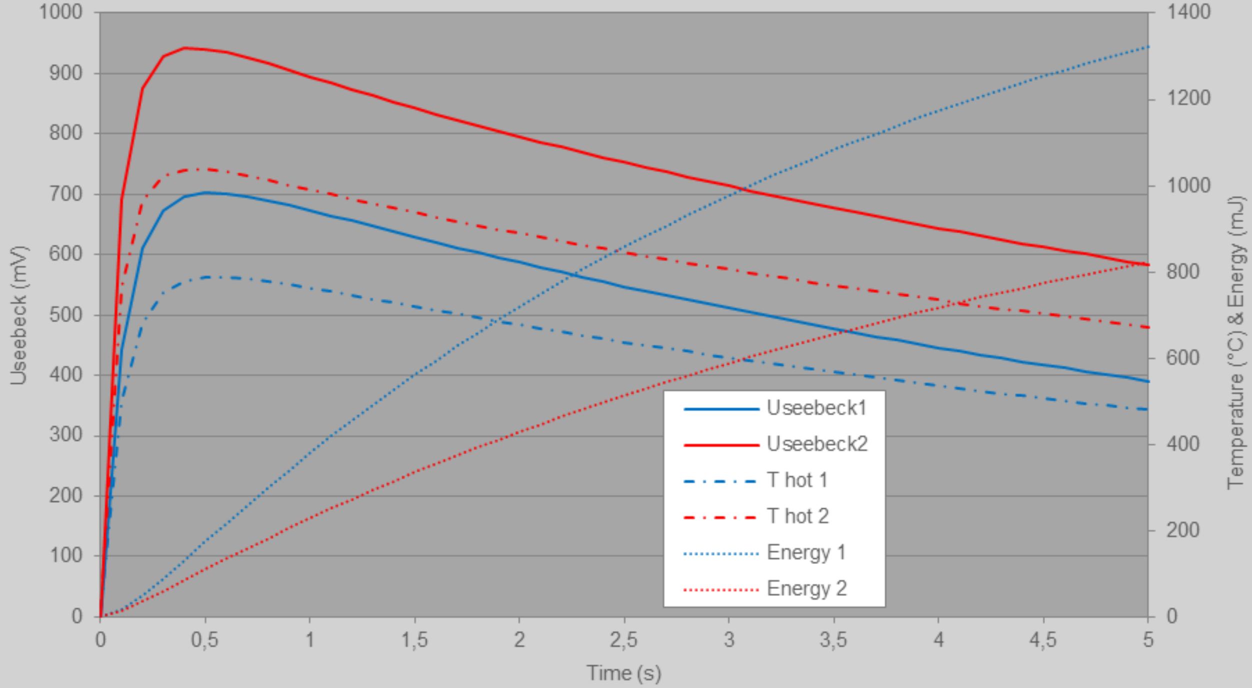
- Leg-thickness
  - **Thin leg** improves voltage level and time response
  - **Thick leg** improves max power and energy



Thermal model and optimization

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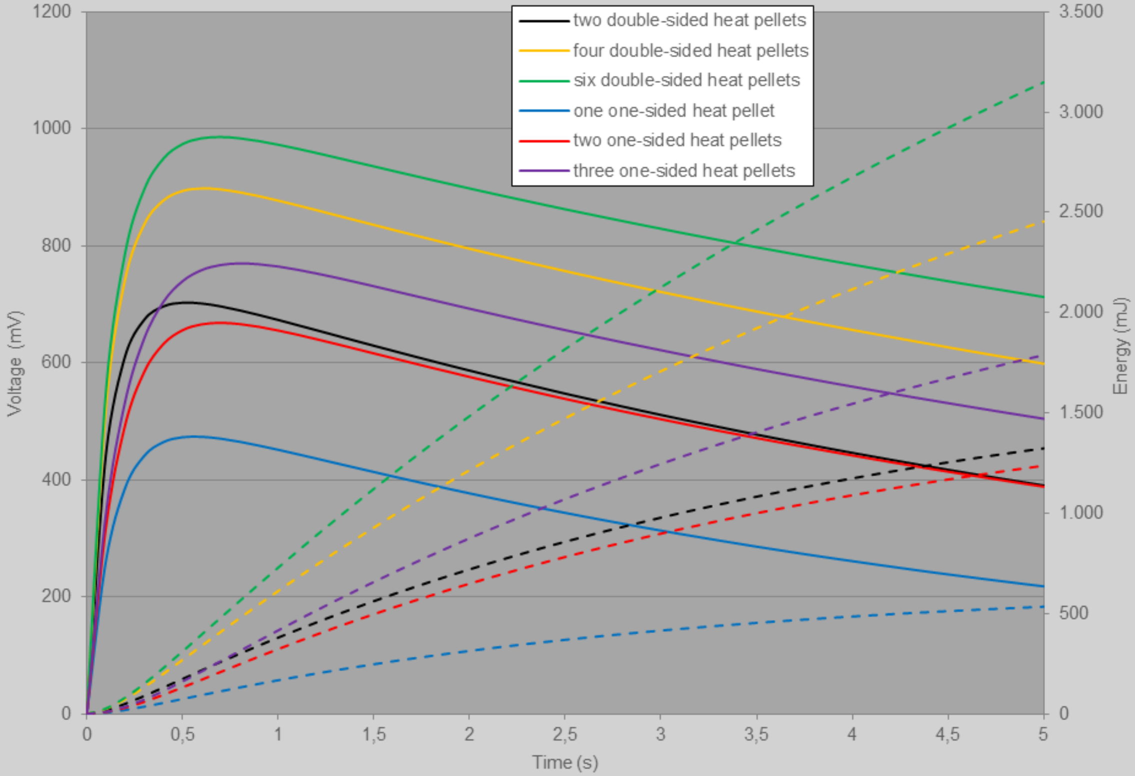
- “Fuel”-Energy
  - More fuel
    - Small increase in voltage ⇢ power
    - Significant increase in energy and lifetime



Experimental set-up

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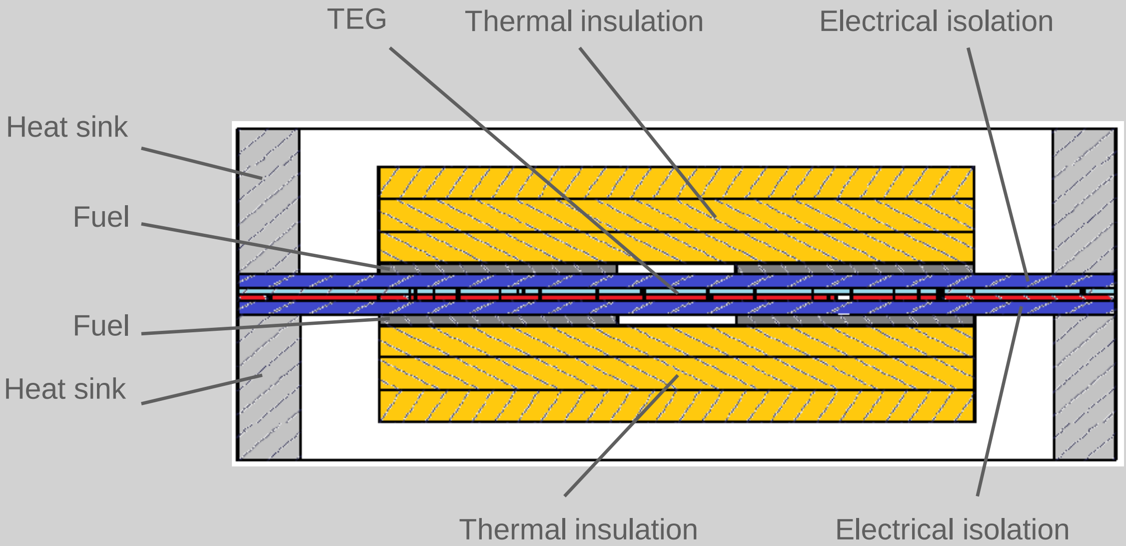
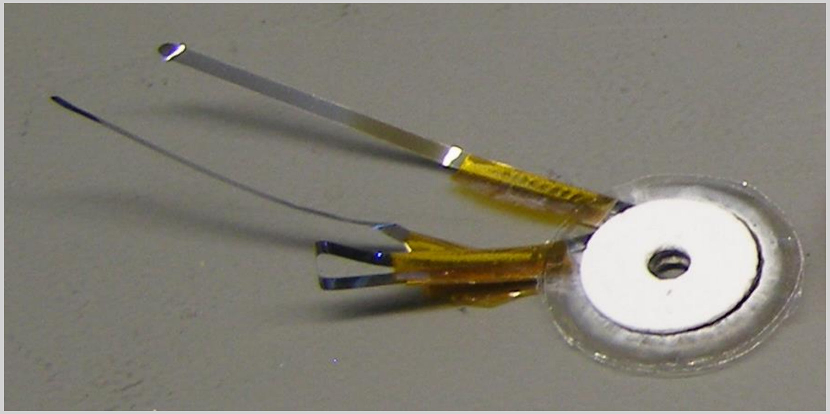
- Principal system components only

Test set-up layout





Generator with „fuel-pellet“, connecting leads and thermal insulation

Experimental set-up

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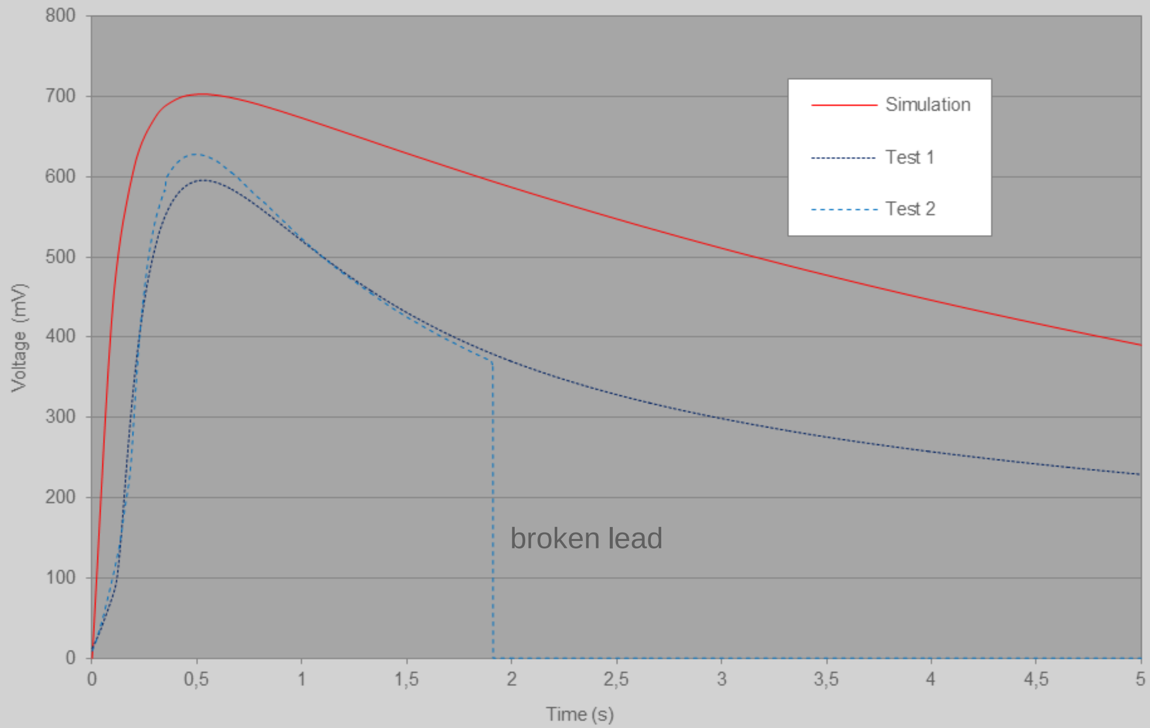
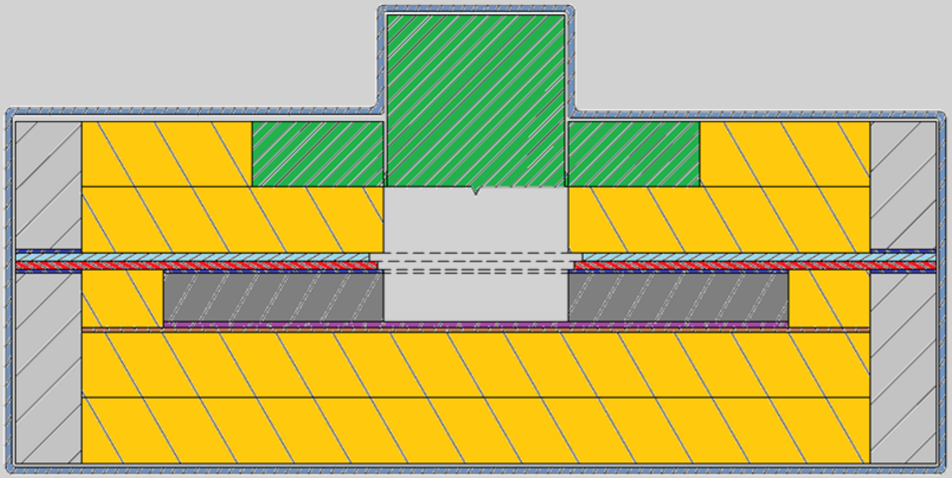
- Test results
  - Good match between simulation and test-results
  - Deviations due to simplifications in simulation and test-set-up

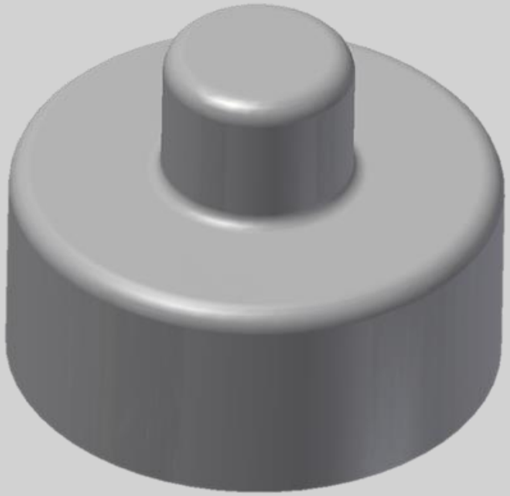


System concept

- Design

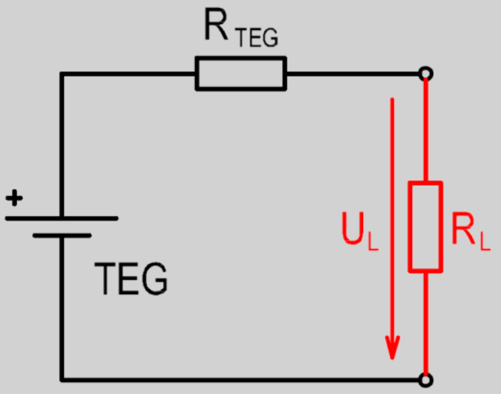


Not all details shown

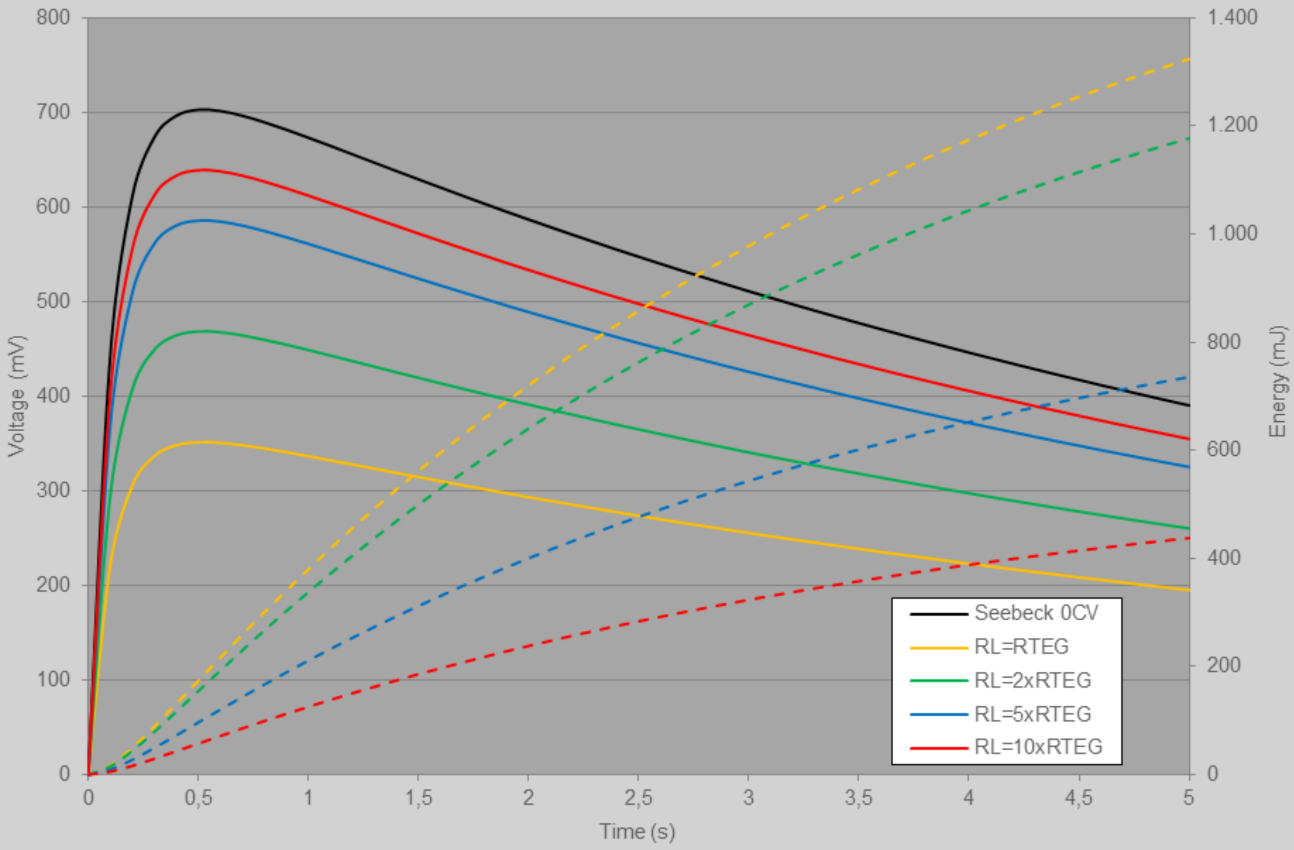


System concept

- Electrical

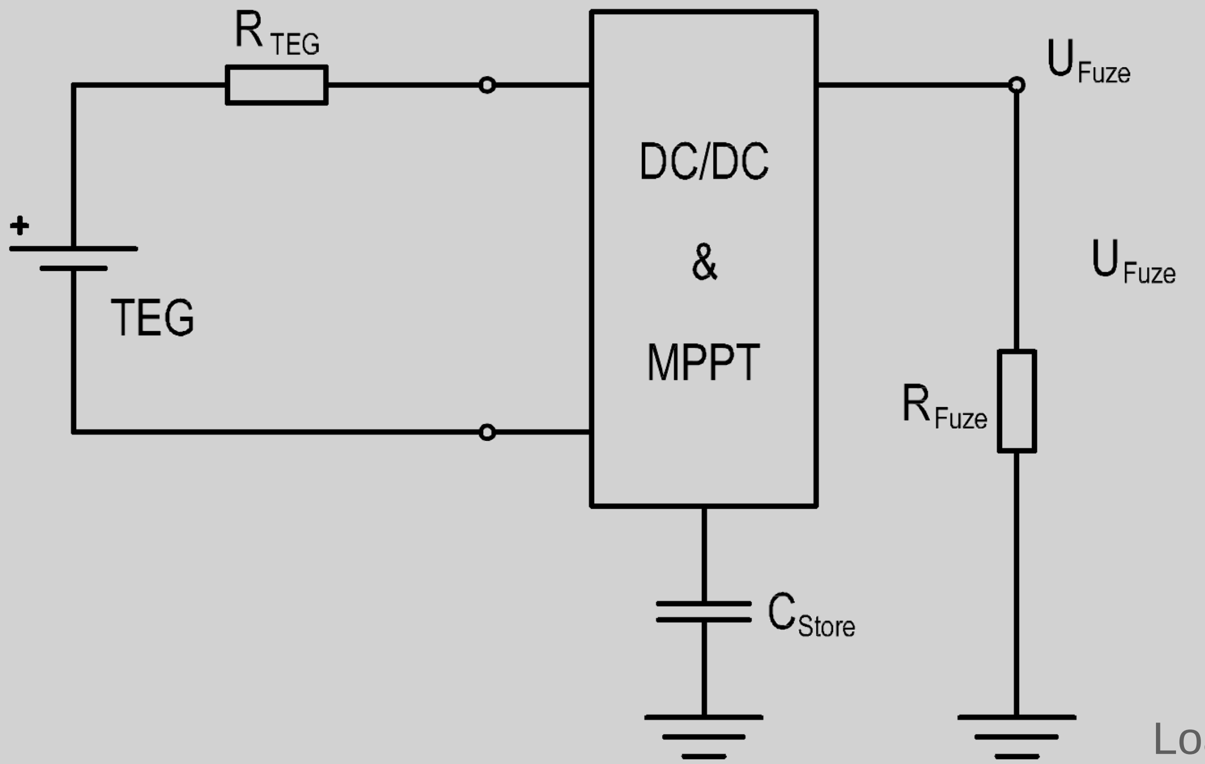


Equivalent Circuit Diagram



System concept

- Electrical



Load circuit and storage

Conclusion and future work

- Concept idea of separating
  - Generator and
  - Fuel is feasible
- FEM simulation of “Thermal behavior” very important
- Easy to scale
- Design goal of 50 to 500 mJ achieved within volume
- Future work
  - Finalize design
  - Build and test full-up prototypes

- This work was fully funded by D&EP R&D-Money
- Components and system concept patent pending

Thank you for your attention!

Questions?