Rutronik Tech Talk

Energy and Power

Agenda:
Renewable Energy
Energy Generation (passive components for storage elements)
- Solar inverter
- Wind mill generator
Energy Harvesting reference design - IoT

Tassilo Gernandt
Field Application Engineer

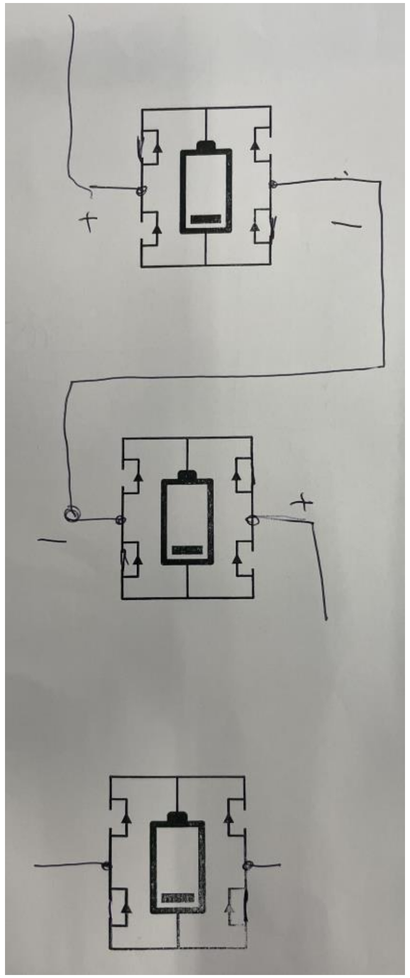
Motivation

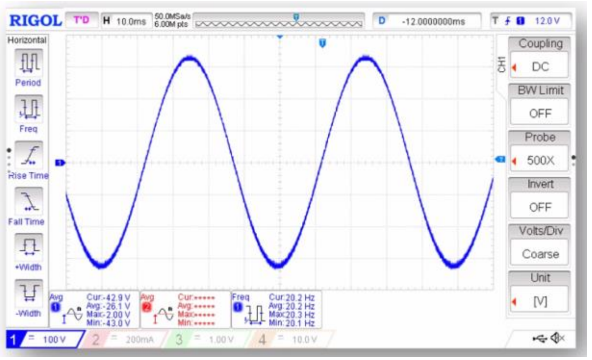
Trends to improve efficiency

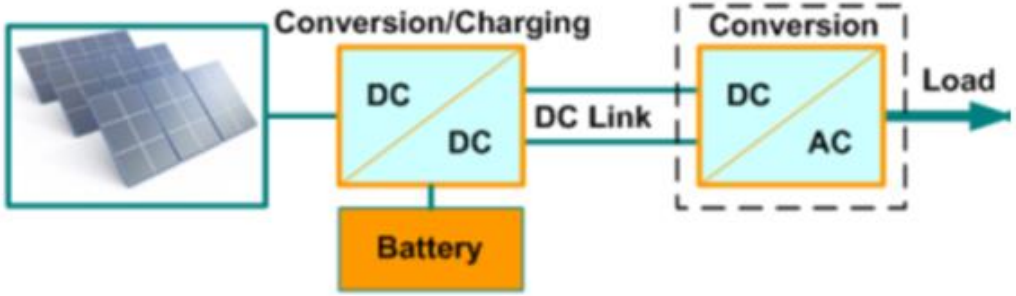
- Battery inverters (multi level design – chaining cells to generate 110V to 380V or DC)
- No inductors (efficiency only up to ~95% - if not a high freq implementation)
    - BUCK/BOOST (including inductors)
        - IHLP8787 best-in-class in soft saturation composite (special low aging composites)
- Generate AC directly from solar panels (no more storage and conversion losses)

Motivation

Battery Inverters with 99% efficiency / Multi-level approach = AC or DC or var







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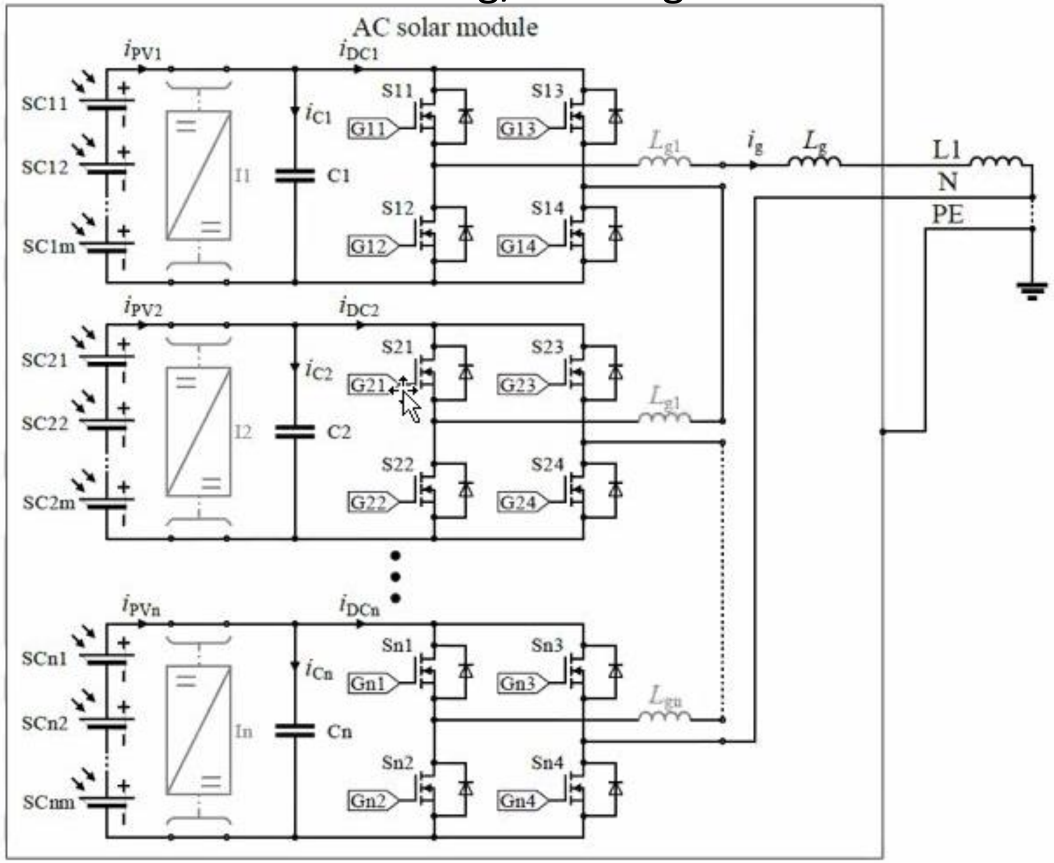
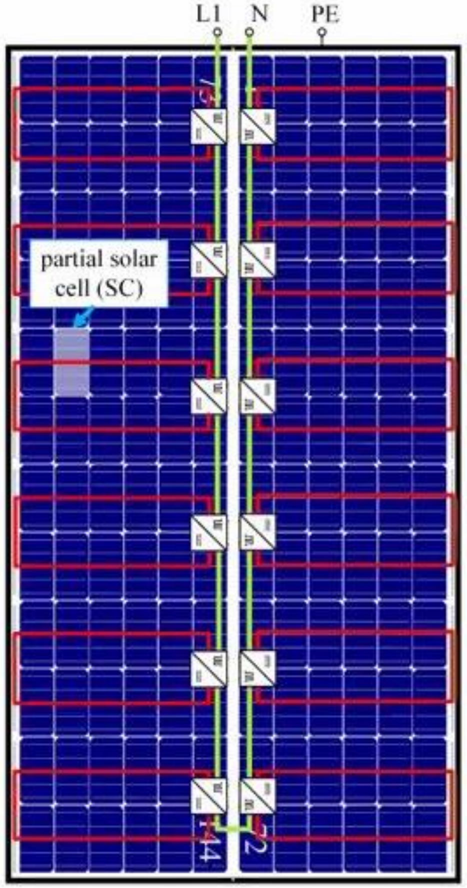
Motivation

Solar inverters with smart chaining

work around shadowing/clouding effect



(a) Functional diagram



(b) Electromechanical arrangement based on [3]

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inverter

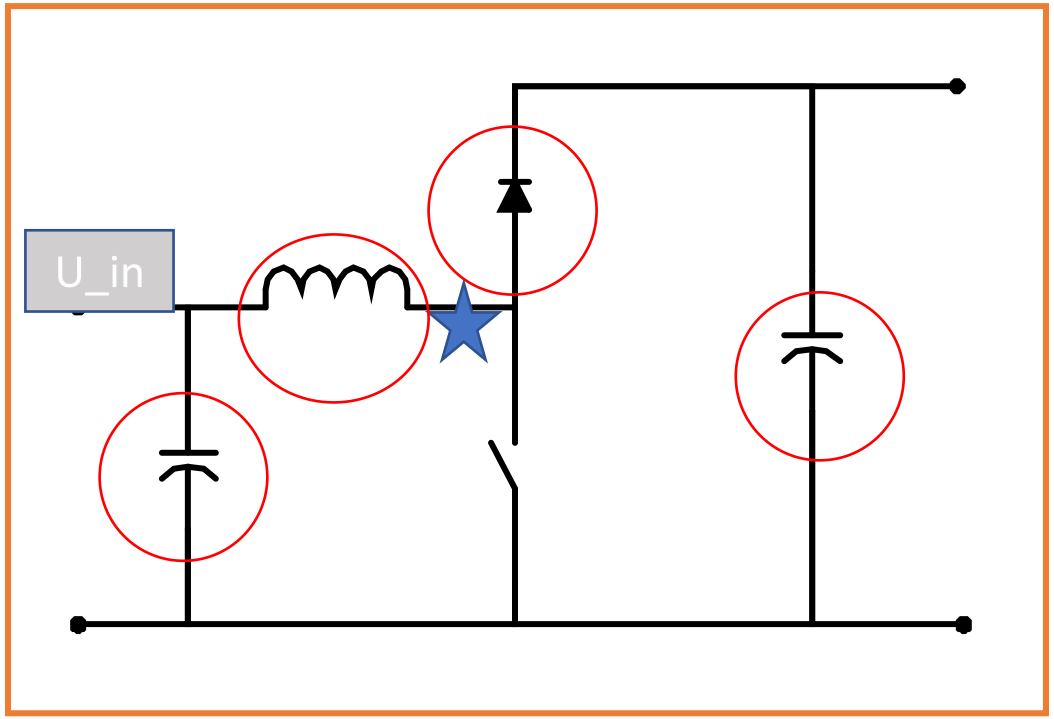
key component: MPPT Tracker

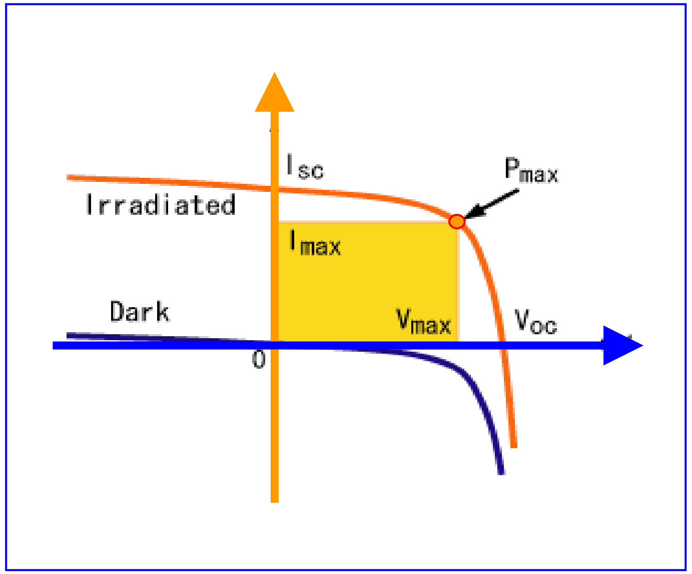
Voltage at point ★

$$U = U_{in} \pm L \cdot \frac{\Delta I}{\Delta T}$$

- Resistors: voltage measurement
  - Selb and Heide
- Resistors: current measurement
  - Mexiko, USA, Israel
- Capacitors: Buffer and Filter
  - Portugal, Israel, Austria, CZ, China and Selb
- Diodes: as rectifiers
  - Turin

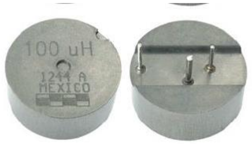
➢ Inductors: storage switching elements
  - USA





IHLP Sizes

- **9 Footprints** (1.0µH)
  - 1008: 2x2.5mm² (3.1A)
  - 1212: 3x3mm² (5A)
  - 1616: 4x4mm² (4.5A)
  - 2020: 5x5mm² (10A)
  - 2525: 6x6mm² (12.5A)
  - 3232: 8x8mm² (17A)
  - 4040: 10x10mm² (25A)
  - 5050: 13x13mm² (33A)
  - 6767: 17x17mm² (55A)
  - 8787: 22x22mm² (85A)
- **15+ Profiles** from 0.9mm to 13mm
- Sn, SnPb, Gold Termination
- Values from **0.05µH to 100µH**
- Current Rating up to **100A**
- Robust design – all IHLP series are qualified to **AEC-Q200** automotive requirements
- 3 Temperature Ranges: **-55ºC up to 125ºC | 155ºC | 180ºC**
- Radial leaded version available – IHTH series



smallest inductors - IHHP0806 / IHLP1008

- inductors → low power, small package (IHHP0806 non-automotive + IHLP1008 automotive)
  - 0.47uH 31mR in 0806 and 4A in soft saturation composite
  - 0.56uH 36mR in 1008 and 8A in soft saturation composite

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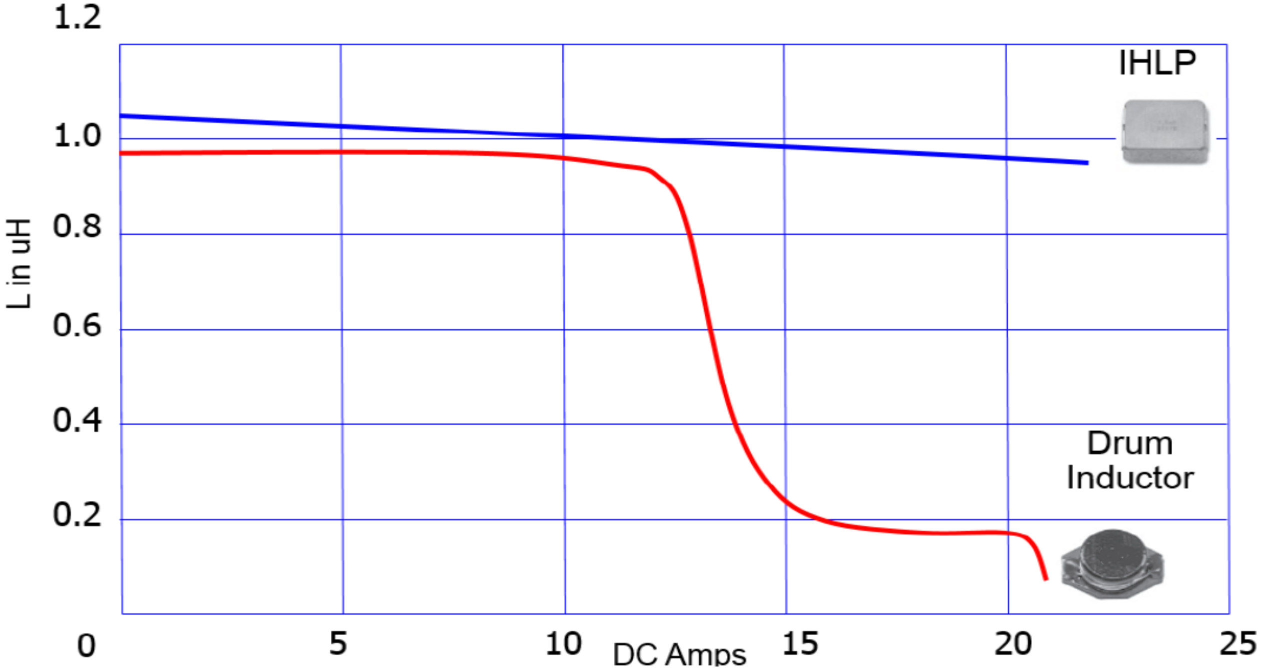
largest inductors - soft saturation powered iron composite

IHLP8787

- IHLP8787
  - →-51 up to 155°C
  - →-11 up to 125°C



- low freq: 100uH 36mR, 7A @-20%
- high freq: 0.47uH + e.g. 1MHz, 0.56mR, 100A @-20%

Inductors with soft saturation – powered iron core

„Standard“ IHLP Material –suffix 01 Best performance in 1-5MHz frequency range **(-0H** up to 10MHz AECQ 125°C)

- Operating temperature range from -55°to 125°C

▪**Low DCR IHLP Material –suffix 11**Best performance in 500KHz frequency range

- Operating temperature range from -55°to 125°C

▪**High Temp IHLP Material –suffix 51 // 81**Best performance around 1-2MHz frequency range

- 2 different operating temperature → -51 = 155°C and -81 = 180°C

▪**High Frequency IHLP Material –suffix 0H** Extended frequency range up to 10MHz

- Operating temperaturerangefrom-55°to 125°C

▪**Changed part numbers for AEC-Q200 version:** Standard IHLP Material -01 → Automotive version –A1

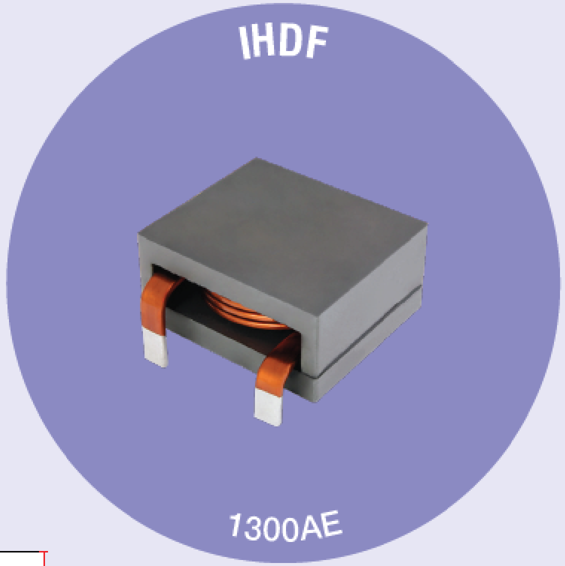
- Low DCR IHLP Material -11 → Automotive version -1A
- High Temp (155ºC) -51 → Automotive version -5A
- Ultra High Temp (180°C) –81 → Automotive version -8A
- High Frequency IHLP Material -0H → Automotive version -AH

IHDF High Current Edge wound inductors– Vishay also has ferrite cores

- The IDHF is a ferrite core design. Inductance controlled by an air gap.
  All IHDF-1300 from 2,2µH – 10µH have identical windings and wire and therefore have the same DCR und I_R.

ELECTRICAL SPECIFICATIONS

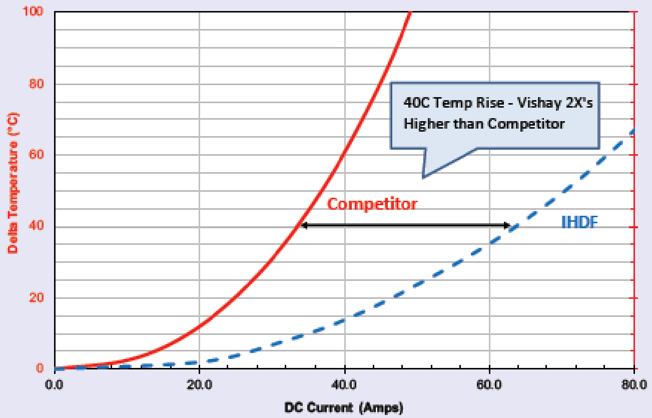
L +/- 10% @ 0Adc (uH)	Max DCR (mΩ)	I Rated (A)	1 Sat (A)
1.0	0.79	72.0	230
2.2	1.11	58.0	149
3.3	1.11	59.0	112
4.7	1.11	59.0	92
5.0	1.11	59.0	78
10.0	1.11	59.0	35



FEATURES

- Low loss ferrite core for high performance designs with minimal ac power losses
- Low DCR losses that yield higher rated currents
- Low profile package – better for mechanical shock and vibration
- High temperature performance to 155 °C continuous
- Easily customizable for mounting orientation, termination type, SMD, nominal L, voltage rating

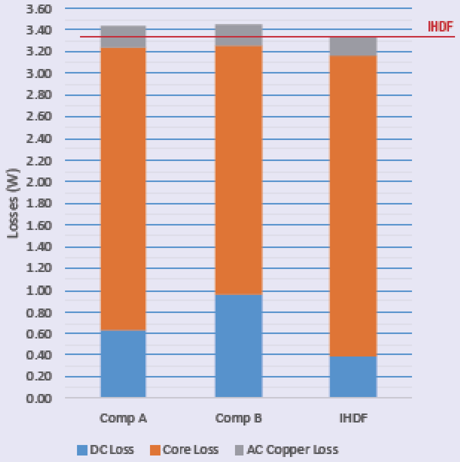
SUPERIOR VISHAY RATED CURRENT PERFORMANCE BASED ON TEMPERATURE RISE



APPLICATIONS

- High current and high temperature applications
- DC/DC converters
- Inverters
- High current filters for motor and switching noise suppression

IHDF LOSS PERFORMANCE AT 100 kHZ BETTER THAN COMPETITORS



www.vishay.com

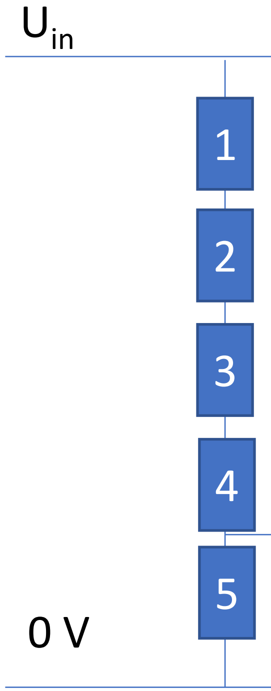
magnetics@vishay.com

IG12572336-19xx

Resistors in inverters

Voltage measurement

- voltage divider:



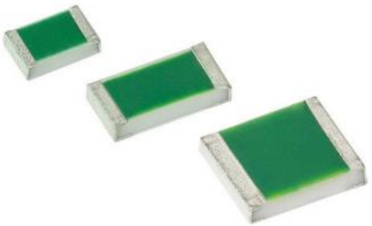
$$U_{mess} = U_{in} \cdot \frac{R_5}{\sum_1^5 R_i}$$

Thick Film Chip

CDHV 3kV

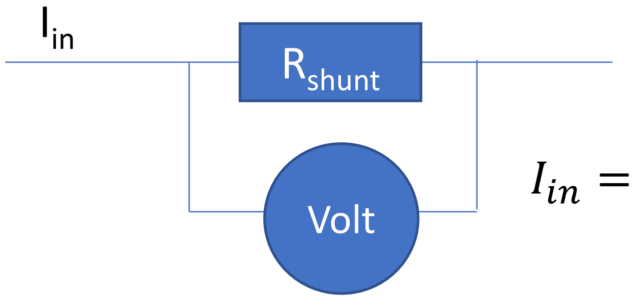
TNPV 1kV

High Voltage Thin Film

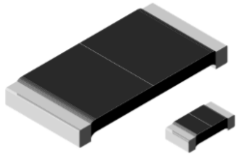


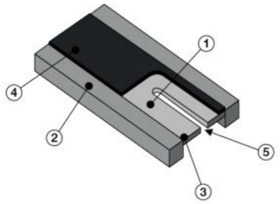
current measurement

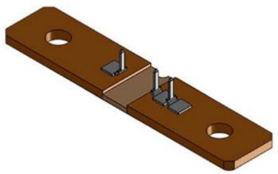
- shunt resistor



$$I_{in} = \frac{U_{Volt}}{R_{shunt}}$$







metal bars

large battery shunts

small WSL0603 with lowest parasitic inductance

Capacitors

Filter

- high freq filter to ground
  - capacitor=high pass $R \propto \frac{1}{frequenz}$

THB PORTFOLIO

- New RFI F340 Family
- New DC-LINK MKP1848H
- AC Filter MKP1847H
- Snubber MKP385e

Buffer

- unify voltages

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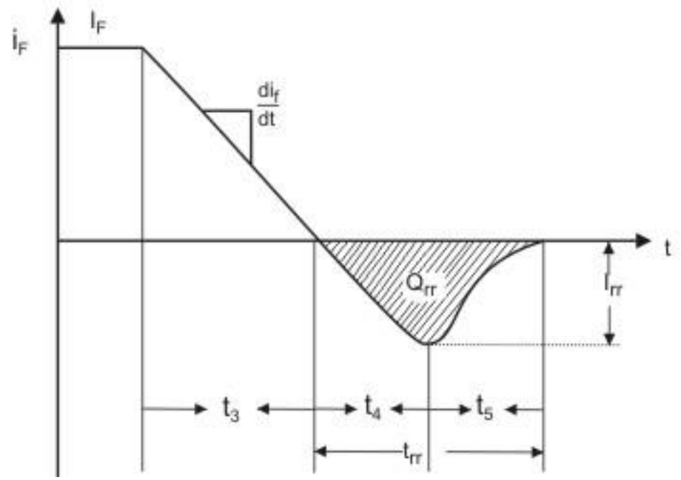
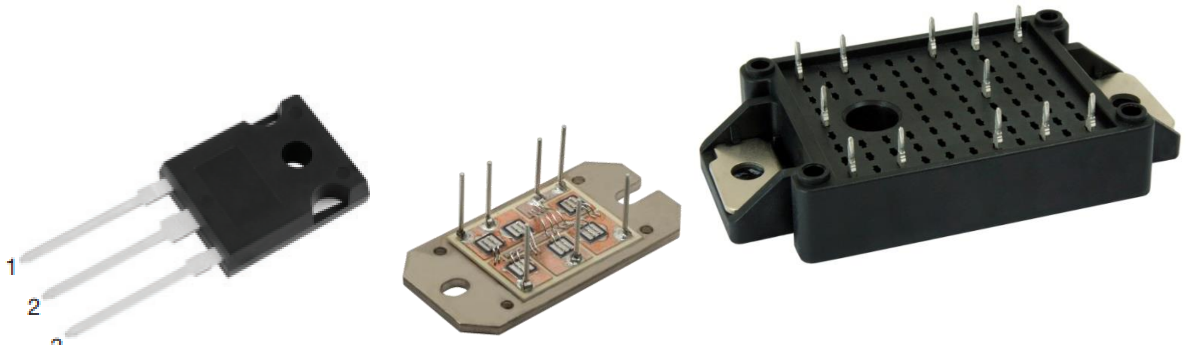
Diodes

forward conduct – isolate in back direction

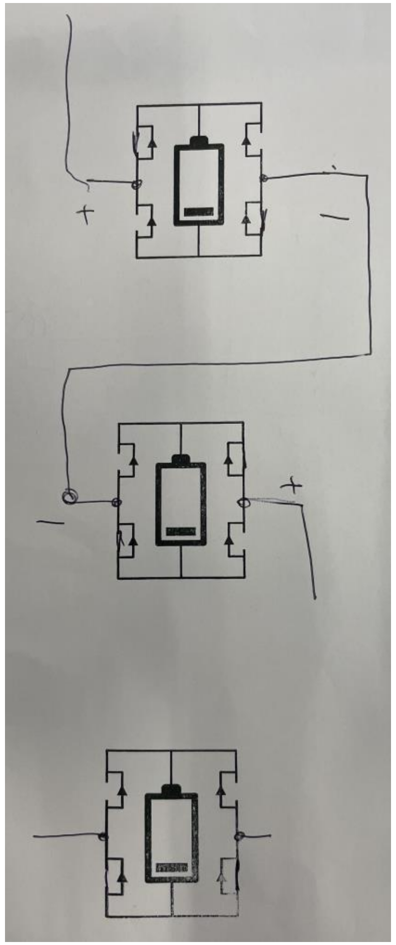
- power components up to:
  - 1200V
  - 10 – 300A
  - 26ns reverse recovery time
  - 175°C chip temperature

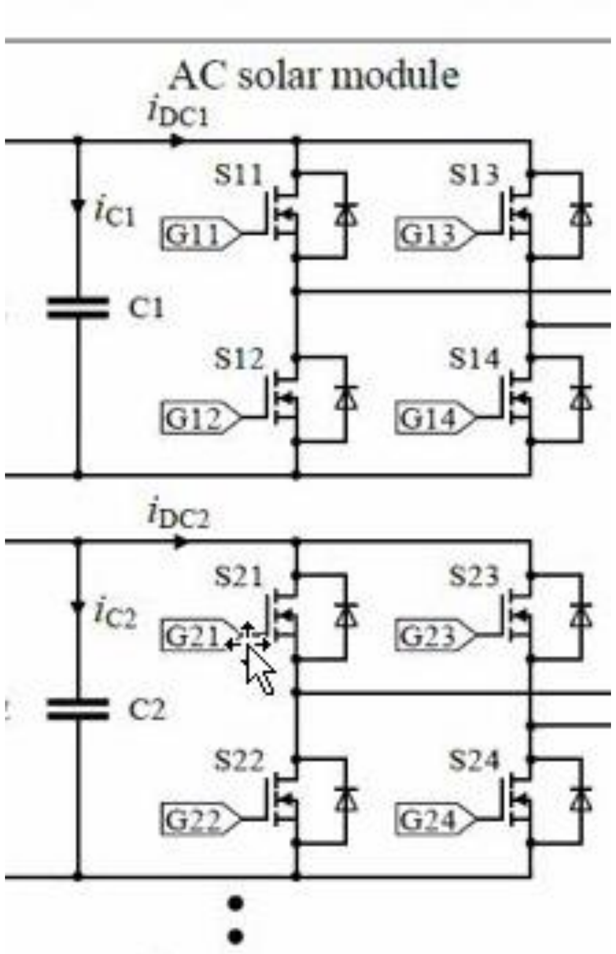




Back to Mosfets in multi level BMS and solar modules

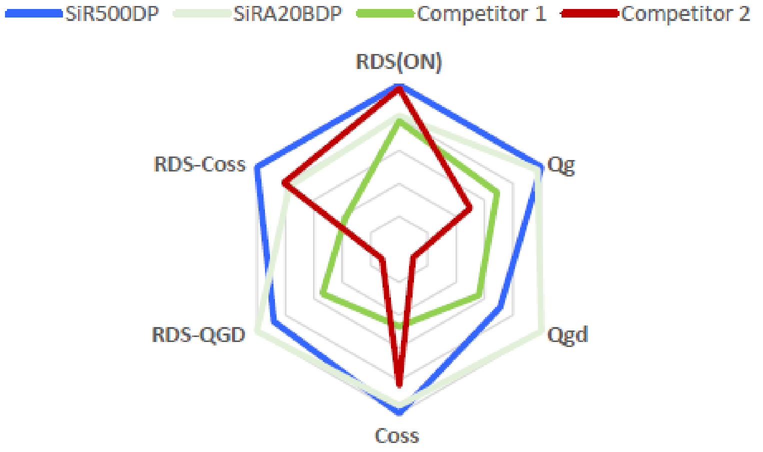
Mosfet for switching batteries

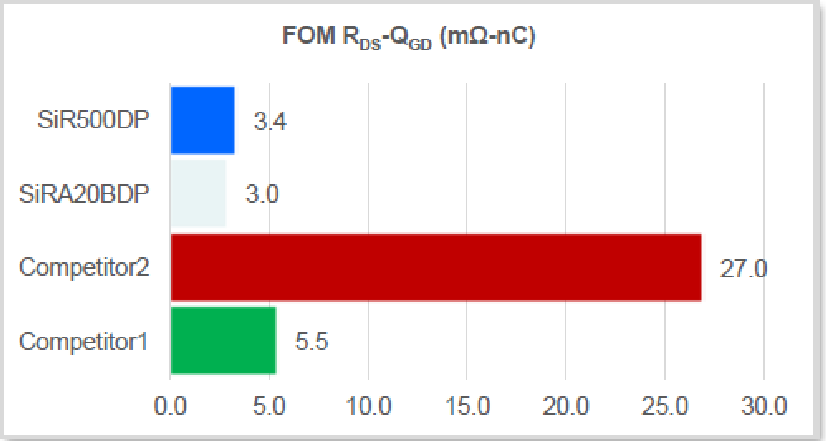




often: low commutation
all about RDSon

Notable Release - 30V Gen V SiR500DP (No1. Lowest Rdson In The World)





Part Numbers	Vendor	Package	V_{DS} (V)	V_{GS} (V)	$R_{DS(ON)}$ (mΩ) 10V		Q_g (nC) 10V	Q_{gs} (nC	Q_{gd} (nC)	C_{oss} (pF)	R_{DS}-Q_{GD} (mΩ-nC)	R_{DS}-C_{oss} (mΩ-pF)
					Typ.	Max.						
SiR500DP (Gen V)	VISHAY	PPAK SO8	30	16	0.39	0.47	120	25.6	8.7	2990	3.4	1166
SiRA20BDP (Gen IV)	VISHAY	PPAK SO8	25	16	0.48	0.58	124	30	6.2	3140	3.0	1507
Competitor 1	X	Power 56	30	20	0.5	0.58	173	39	11	6430	5.5	3215
Competitor 2	X	TSDSON-8	25	20	0.4	0.45	238	24	69	3600	27	1440

Part Number	Package	V_{DS} (V)	V_{GS} (V)	R_{DS}(on) Max. @ 10V (mΩ)	R_{DS}(on) Max. @ 4.5V (mΩ)	Qg @ 4.5 V (nC)	Qgs (nC)	Qgd (nC)	Coss (pF)	Rg (Typ)	Estimated Release Schedule
SiR500DP	PowerPAK SO-8	30	16	0.47	0.68	54.3	25.6	8.7	2990	0.9	Q4 2020
SiSS54DN	PowerPAK 1212	30	16	1.06	1.5	21	11.3	3	1220	0.75	Q4 2020
SiSS52DN	PowerPAK 1212	30	16	1.2	1.9	19.9	9.6	3.9	1035	0.73	Q4 2020
SiSH532DN	PowerPAK 1212	30	16	1.5	2.1	13.6	8.5	2.4	770	0.5	Q2 2021
SiSH536DN	PowerPAK 1212	30	16	3.25	4.6	7.6	3.4	1.4	392	0.9	Q1 2020

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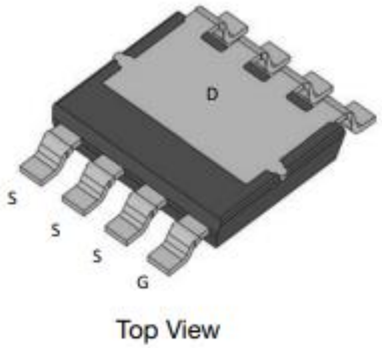
What else is inside?

Transistors

- MOSEFT and IGBTs
  - ➢ Turin, Itzehoe, Isral, China, Taiwan

➢ on off switch



filter Elements

- capacitors – as above
- inductor/CMC: low pass filter $R \propto L \cdot \omega$

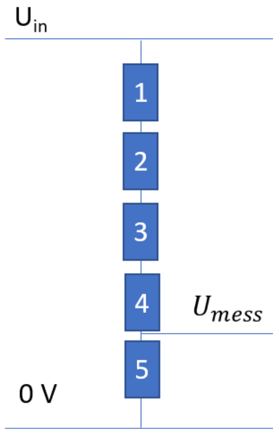
wind energy plant - generator

Function – Multi Coil

- power in mega-watts

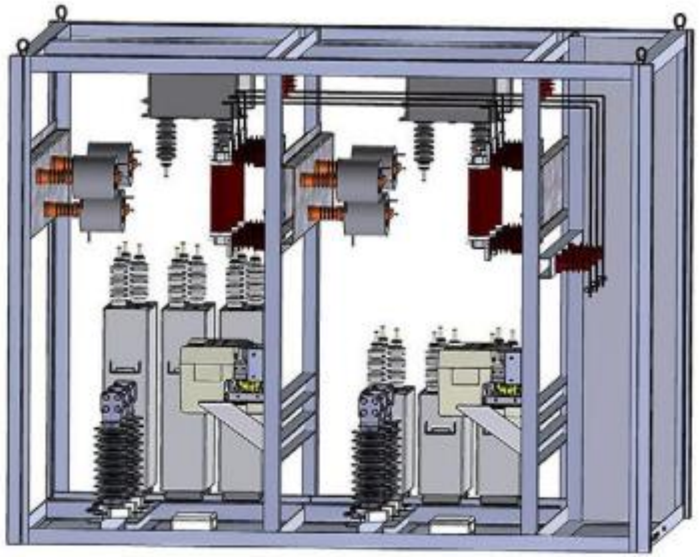
- Key components:
  - angular measurement
    - – RAMK magnetic encoder
  - Filter- and storage capacitor
  - voltage measurement
  - safety discharge

Wind mill - Components



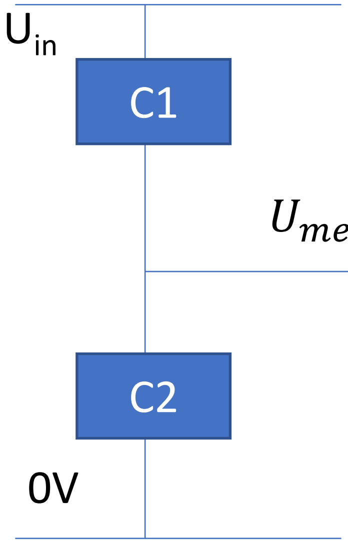
low pass-and filter-caps

- Landshut and CZ:
  - up to 36000V
  - up to 20.000kVA (~20MW)



current measurement

- with Resistors as above
- capacitive up to 50kV



$$U_{mess} = U_{in} \cdot C_{gesamt} \cdot \frac{1}{C_2}$$

- Selb
  - up to 50kV

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Wind mill - safety discharge

destruction of energy

- upon, safety/emergency case

➢ Energy $W = P \cdot t \approx 1MW \cdot 10s = 10MWs = 10MJ$

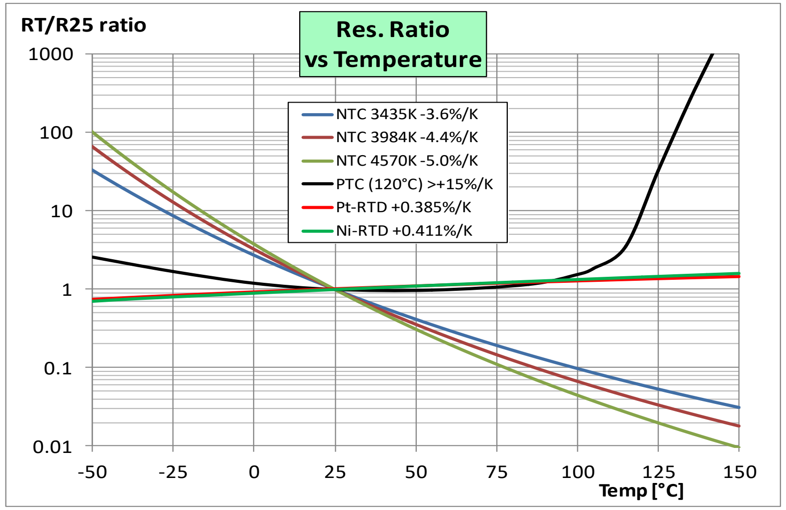
➢ heat up of metal bar:

$$\Delta Q = \Delta T \cdot m \cdot c_{spez} \Leftrightarrow m = \frac{\Delta Q}{\Delta T \cdot c_{spec}} = \frac{10MJ}{400°C \cdot 500\frac{J}{kgK}} = 50kg$$

- France and USA

Usage of thermistors in energy storage systems (ESS)

- **what are thermistors?** Thermistors are temperature dependent resistors. NTC PTC RTC.
  They change their resistance value when the temperature as well as through self-heating. This makes them particularly suitable for temperature measurement and monitoring, as well as for overload protection.
- **And why do you need thermistors in energy storage systems?** ESS includes huge batteries (see image) that temporarily store the energy. Here it is important to monitor the temperature, especially when charging and discharging, so that nothing over-heats and the battery cells are always balanced.



More Info: click here!

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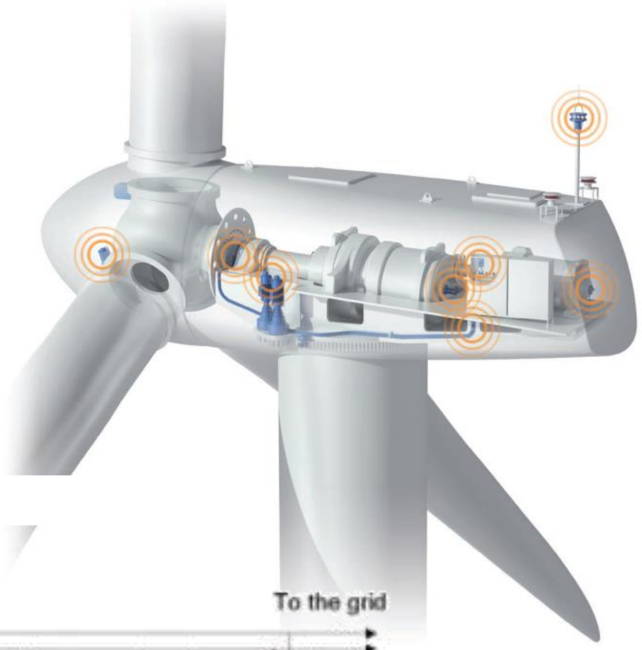
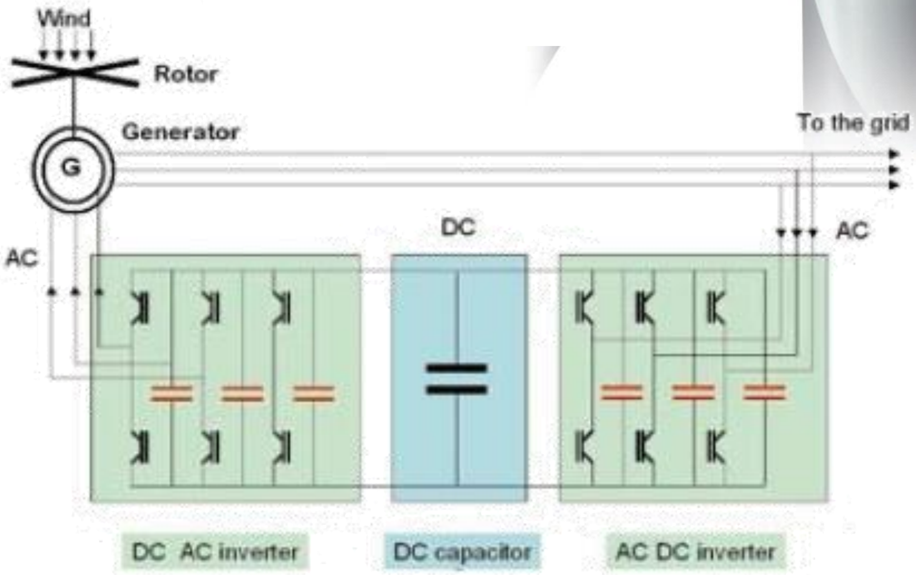
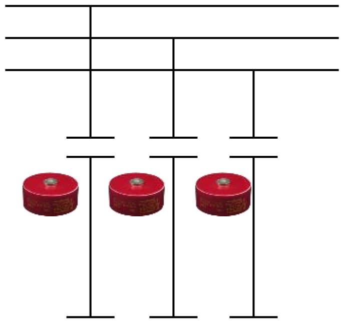
Usage of ceramic capacitors in wind mills

- **Capacitors in wind mills – why?**
  - smooth any spike/transients – filter out and protect the attached power nets







up to 50kV

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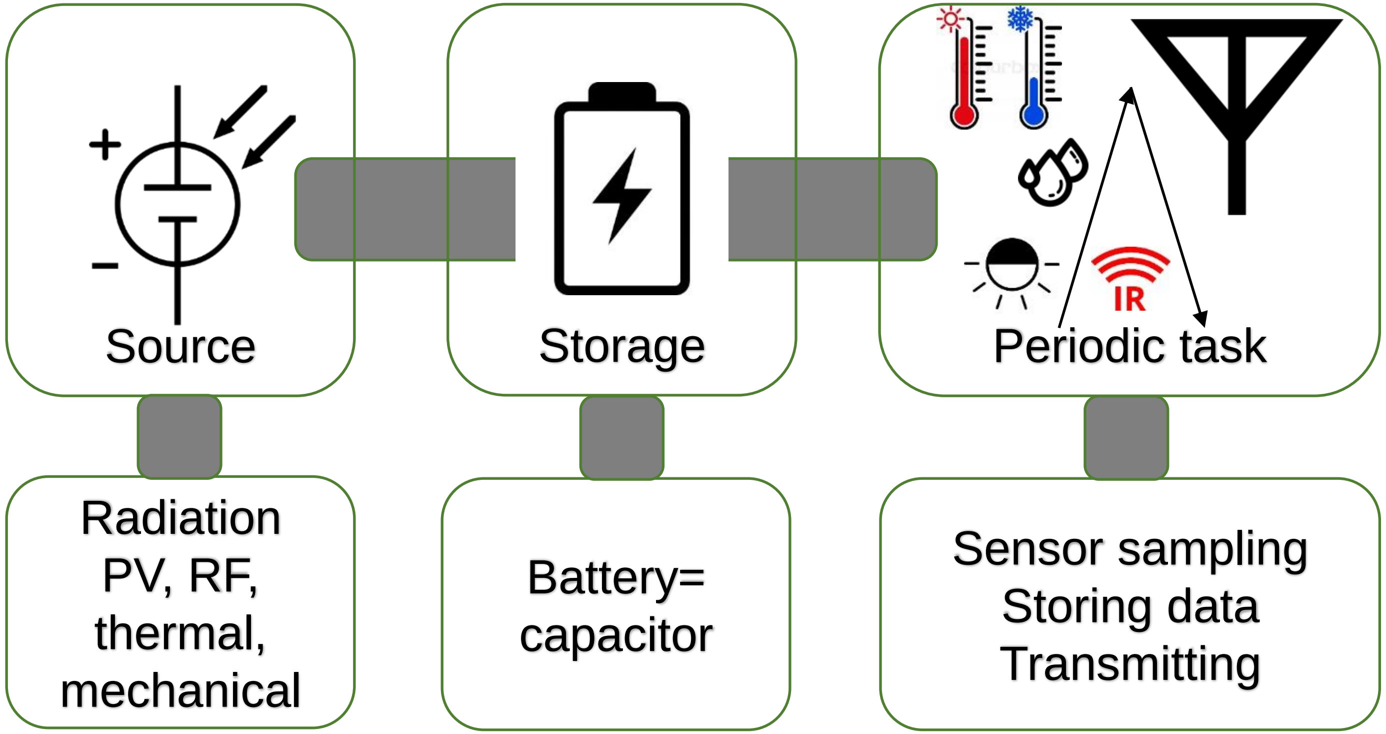
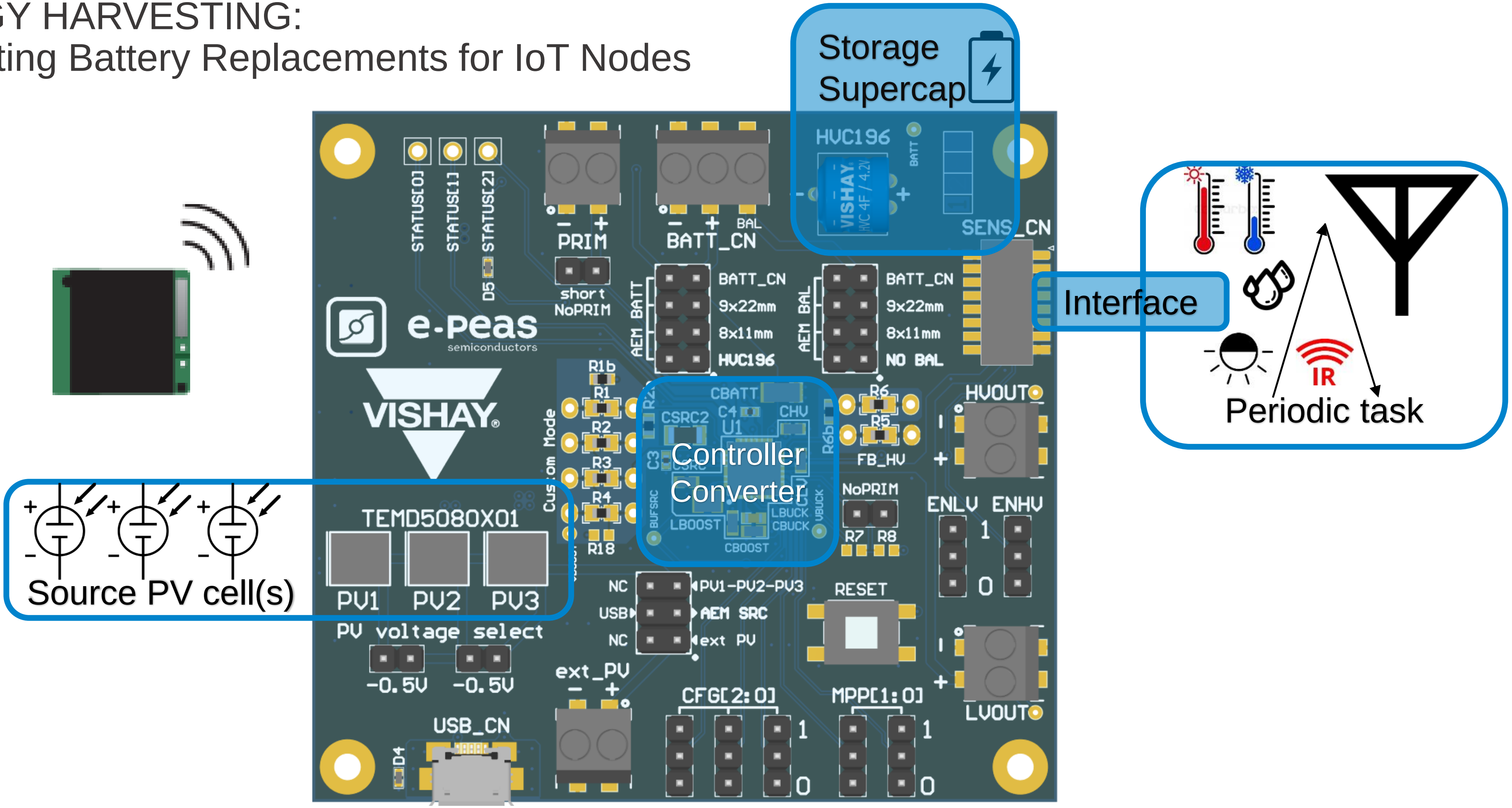
Other topic: Motivation – Energy Harvesting reference design - IoT

Autonomous / Self-Sustaining IoT Sensor



Overview

ENERGY HARVESTING:
Eliminating Battery Replacements for IoT Nodes



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Solution

Blue Enhanced PV Cell

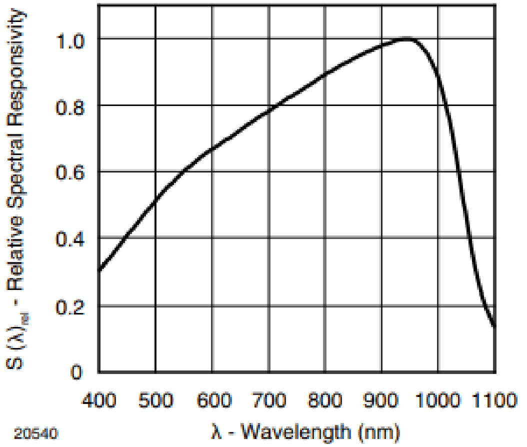
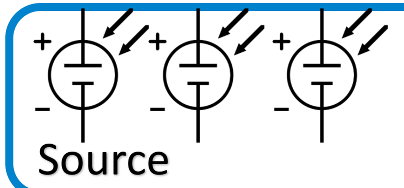
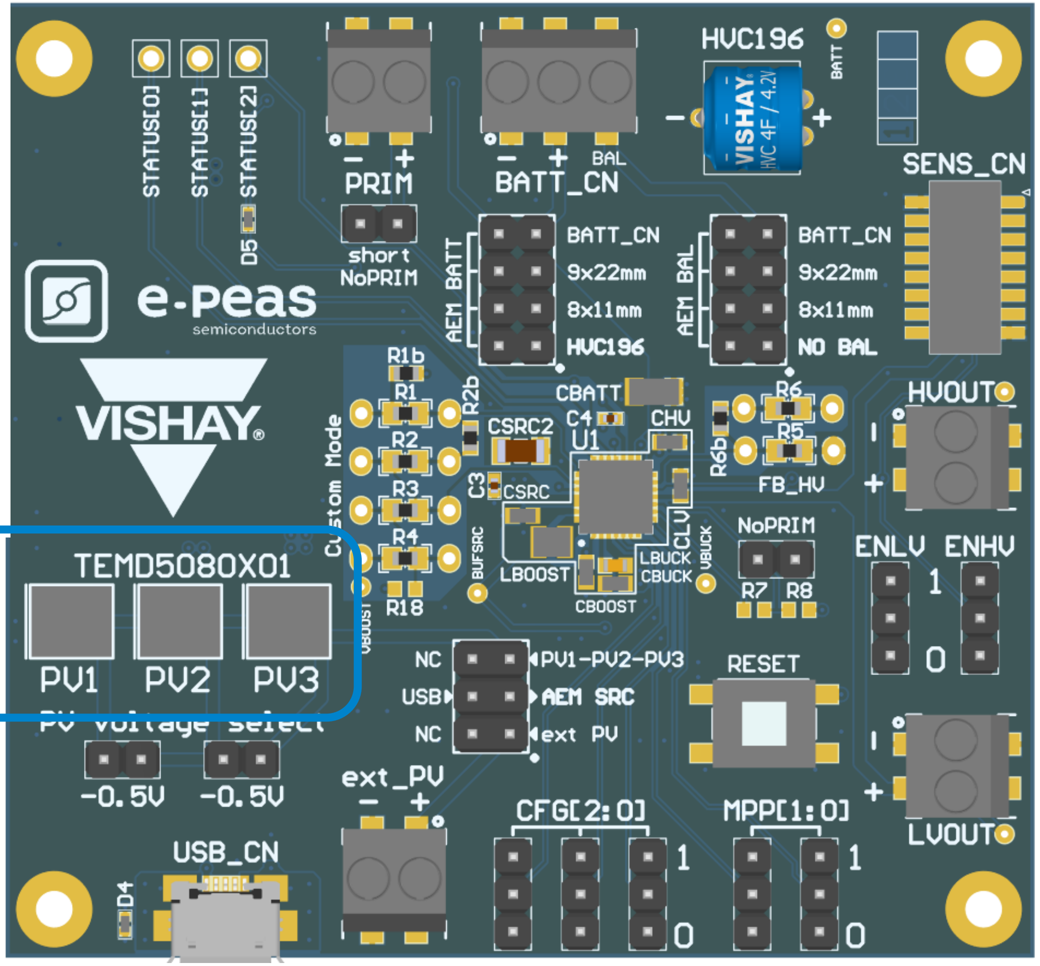


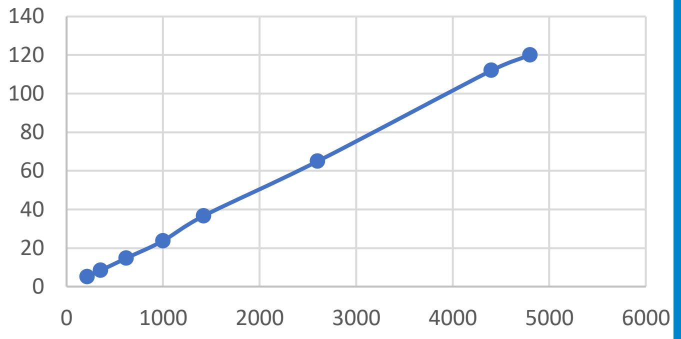
Fig. 5 - Relative Spectral Sensitivity vs. Wavelength



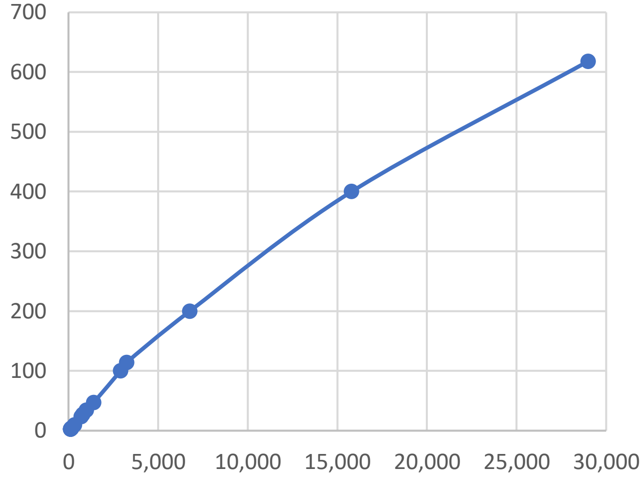
Ee = 1 mW/cm², @950 nm
Isc=50uA, Voc=350mV typical
A=5x4mm



LED - 2700K 45mA dimmable
x=lx, y=uA (max 120uA@4800lx)



sunlight x=lx, y=uA



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Office Desk – Reference measurement - Brightness vs. Current

from slide 2-3: requirement 7 to 17uA – (half a day 14-34uA)

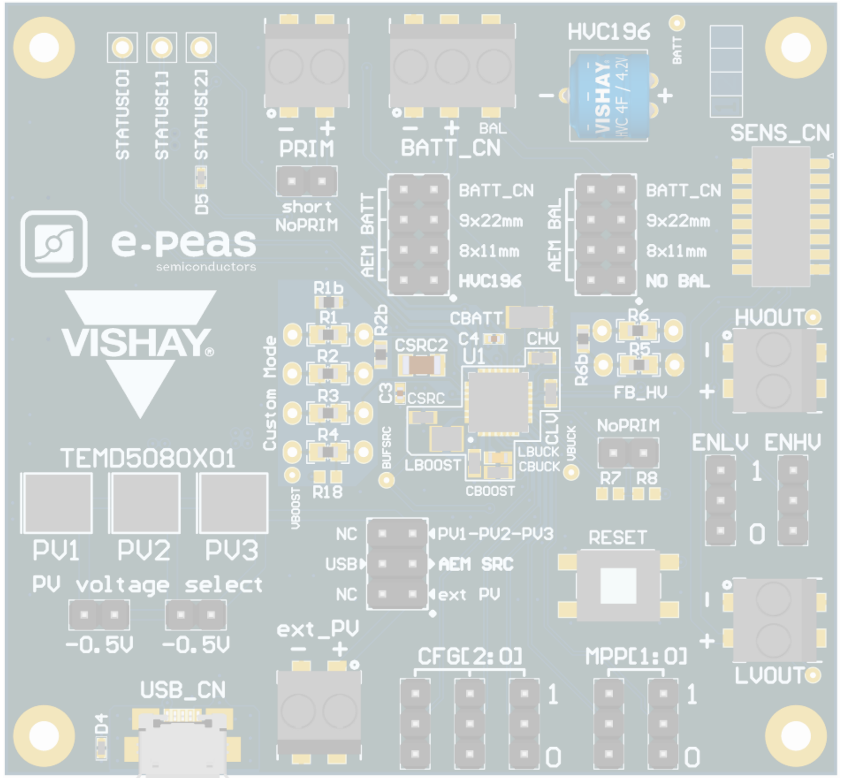
LED - 2700K 45mA dimmable	
lux	uA
215	5.15
354	8.44
617 ✓	14.76
1.000	23.79
1.420	36.72
2.600	65
4.400	112
4.800	120

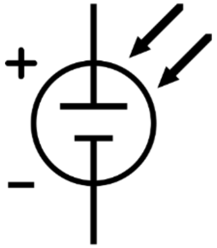
sunlight		
lux	uA	
162	4.25	
331	9.65	
703	23	
800	27	
1.000	34	✓
1.400	47	0.34V OC
2.900	100	0.366V OC
3.240	114	
6.770	200	0.39V OC
29.000	618	0.5V OC

input	output	efficiency
29.000lx=229W/m² (on 7.7mm² → 1765uW incident sun power)	618uA*0.48V=297uW	16.8%
1.000lx=7.9W/m² (on 7.7mm² → 61uW incident sun power)	34uA*0.33V=11.22uW	18.4%

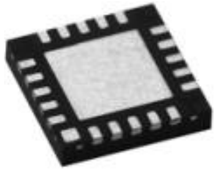
*efficiency calculation: bright sunlight 136.000 lux = 1.075 W/m2 = 126.7
active area per PV cell: 7.7mm²

Block Diagram

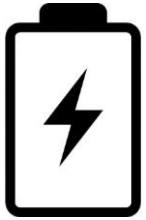




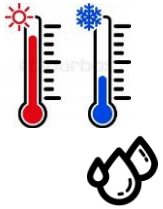
Energy harvesting



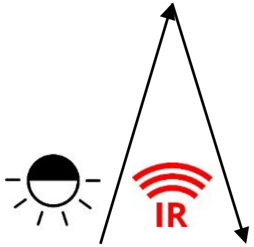
Controller+MPPT



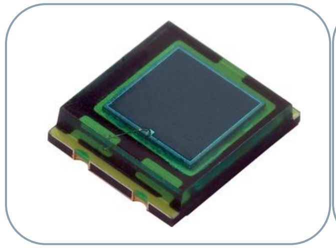
Battery/Capacitor



Temp/Humidity



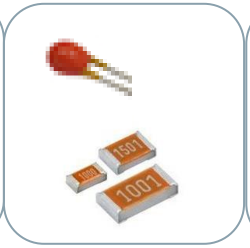
Ambient+Proximity

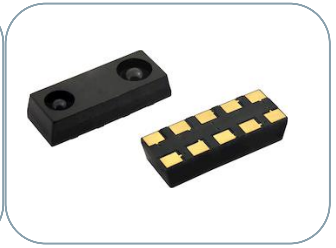


TEMD5080X01

EM10941 e-peas

HVC196 4.2V – 4F

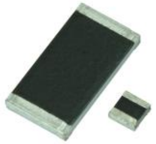




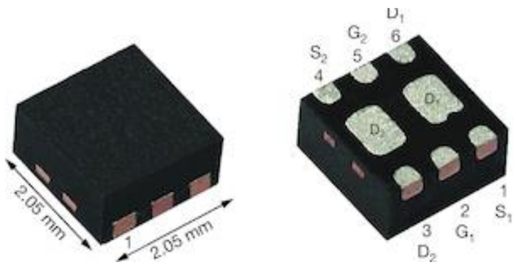
Interface connector

VISHAY Key Components

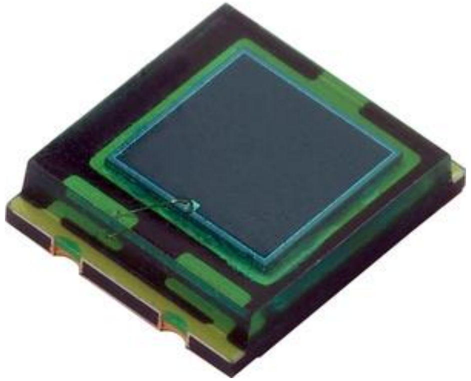
Buck storage
Inductor:
IHLP1008



High Ohmic voltage divider
Thick film 0402 1% >=20MΩ

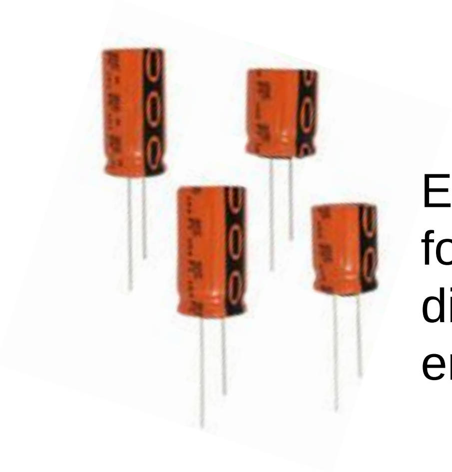


Switching dual
MOSFETS
PPAK SC70
SIA517

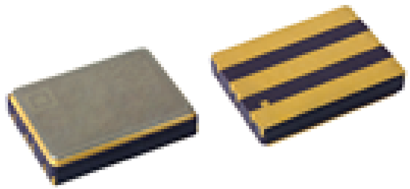


Blue enhanced PV
PIN Photodiode
5x4mm
TEMD5080X01

HVC 196
7.5mm x 2.6mm
coin cell type



EDLC 220-235
for 10mm
diameter
embodiments



EDLC 238 for
reflow soldering
and hermetically
sealed

The DNA of tech.™

Photovoltaic Energy Harvester

- NANO Power Photovoltaic Energy Harvester with ENYCAP™ supercapacitors
- 23mm^2 Photocell, Dark light optimized with spectroscopic performance, 2mA max.
- MPPT to optimize converter and converted energy
- Ultra low leakage back-to-back MOSFET switches for extreme low reverse current
- IHLP® power inductors optimized for lowest loss conversion
- >10-year Life
- Lowest leakage, efficient transformation and storage

Links:

- Batteryless IoT Sensor Telecommunications Applications | Vishay
    - https://origin-www.vishay.com/applications/telecommunications/batteryless_iotsensor/
- Vishay - Engineer's Toolbox
    - https://origin-www.vishay.com/landingpage/et4/et3te_iot1.html
- SensorXplorer™ (vishay.com)

VISHAY

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Thank you! QUESTIONS?

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