EnerHarv 2024

PSMA International Workshop | 26-28 June, 2024 | Perugia, Italy

COMMERCIAL SPONSORS

# EnerHarv 2024 Workshop:

*Optimizing Energy harvesting micro power design*
*& ecosystem elements choice*
*for better system performance*

**Presented By –**


**Bruno DAMIEN**
**Ecosystem and Partner Marketing Director**
e-peas
bruno.damien@e-peas.com


ORGANIZER

HOST

MEDIA SPONSORS

TECHNICAL SPONSORS

Wednesday, June 28, 2024

# Content of this presentation

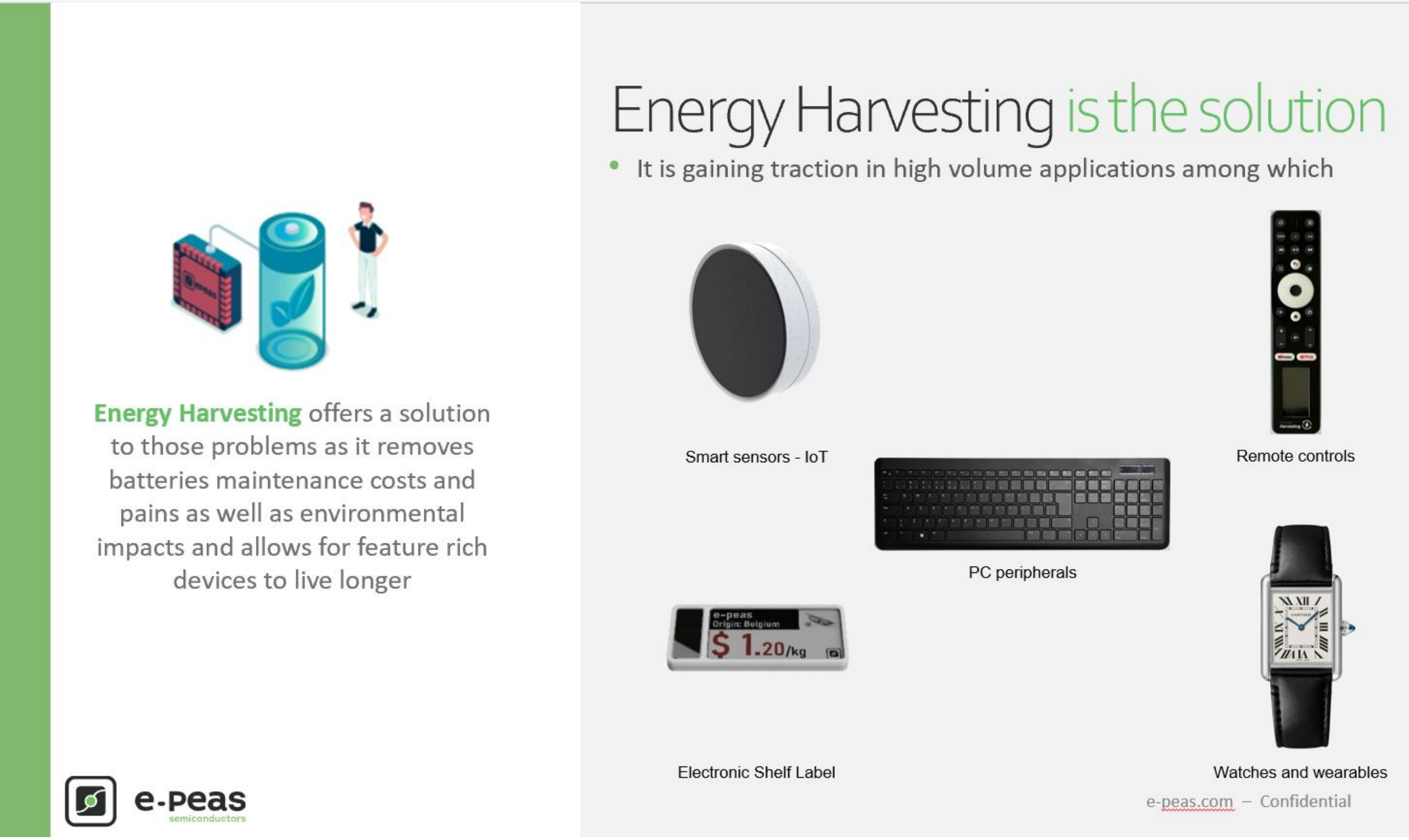
- **Context**
- **Introducing e-peas : an Energy Harvesting PMIC Company**
- **Energy Harvesting power supply – system considerations**
- **Architecture choice for power conversion efficiency in Energy Harvesting**
- **Reaching 95% energy conversion efficiency with good practices**
- **4 corners validation**
- **e-peas PMIC portfolio outlook**
- **Invitation to demo**
- **Conclusions**

# Introducing

e-peas semiconductors

# an Energy Harvesting PMIC company

# Key focus application

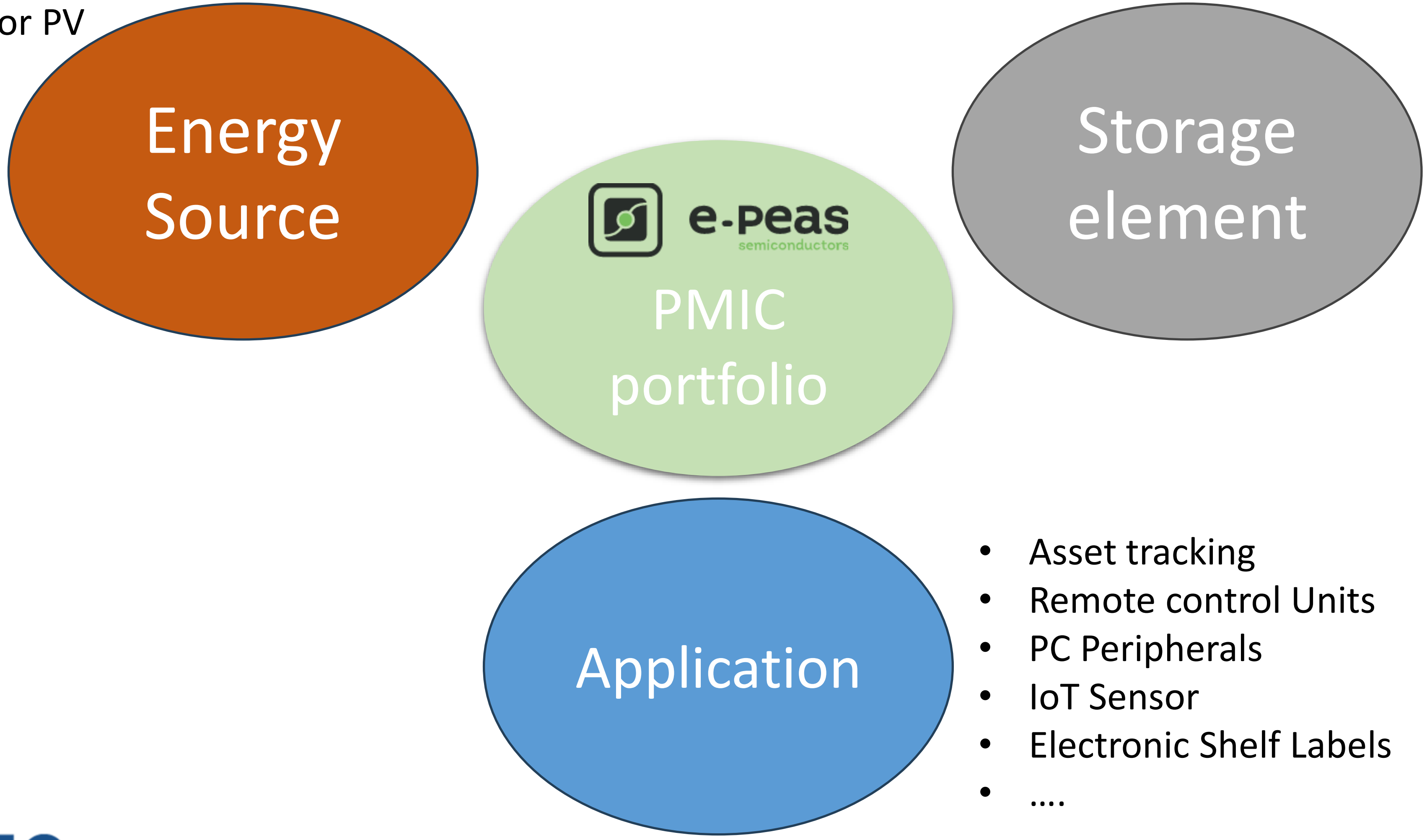



- **e-peas is specialized in ultra-low power electronics for Energy Harvesting.**
- **E-peas PMICs give energy to IoT products.**
- **We focus on :**
  - SMART SENSOR,
  - REMOTE CONTROL UNITS,
  - PC PERIPHERALS,
  - ELECTRONIC SHELF LABELS,
  - WATCHES and WEARABLE DEVICEs
- **There is clear market traction for using energy harvesting in those applications.**

# Ecosystem and Partners

## Energy Harvesting System Landscape

- Indoor/Outdoor PV
- TEG
- Vibrations
- Magnetic
- Kinetic
- …




- LiPO
- LFP
- LTO
- LiC
- NiMH
- Supercap
- Ceramic Cap
- ….

- Asset tracking
- Remote control Units
- PC Peripherals
- IoT Sensor
- Electronic Shelf Labels
- ….

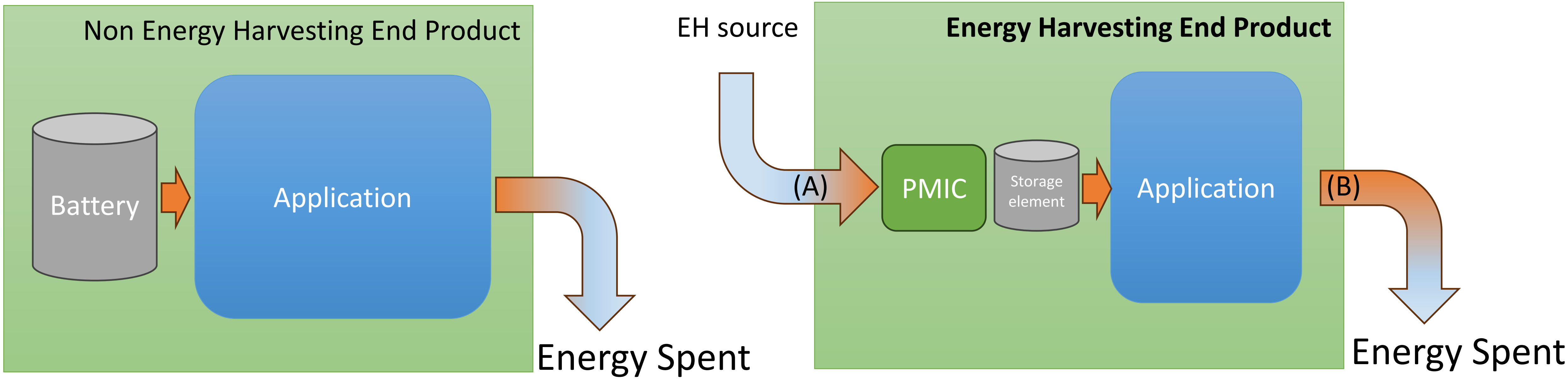


*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

# Energy Harvesting System - Design considerations

**Towards a fully balanced system**

# From closed to open Energy Source




CLOSED

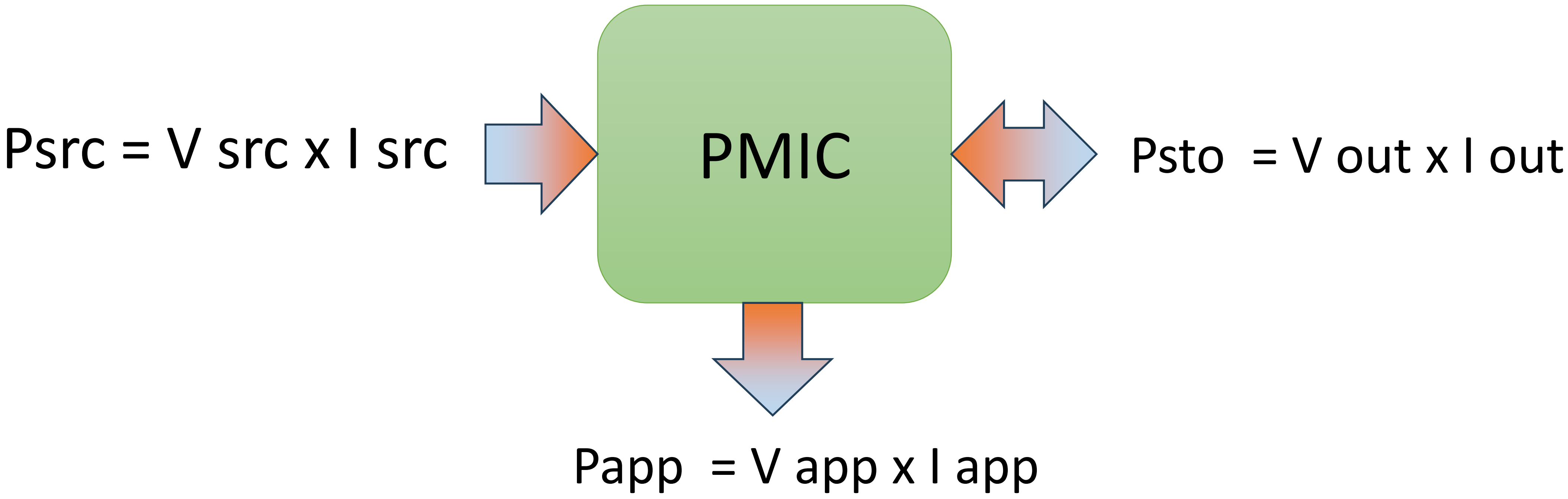
OPEN

- Rechargeable Storage element
- **Average(A) = Average(B) to make a well-balanced system**
- **Benefits :**
  - Downsized storage element
  - Improved QoS
  - Reduced TCO
  - Reduced weight



*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

# PMIC : a continuous-power converter




An e-peas PMIC “isolates” all 3 domains :
It provides continuous, constant power transfer efficiency from left to right,
regardless of STORAGE conditions, until Storage is fully charged.

EnerHarv 2024 PSMA

ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.

e-peas semiconductors

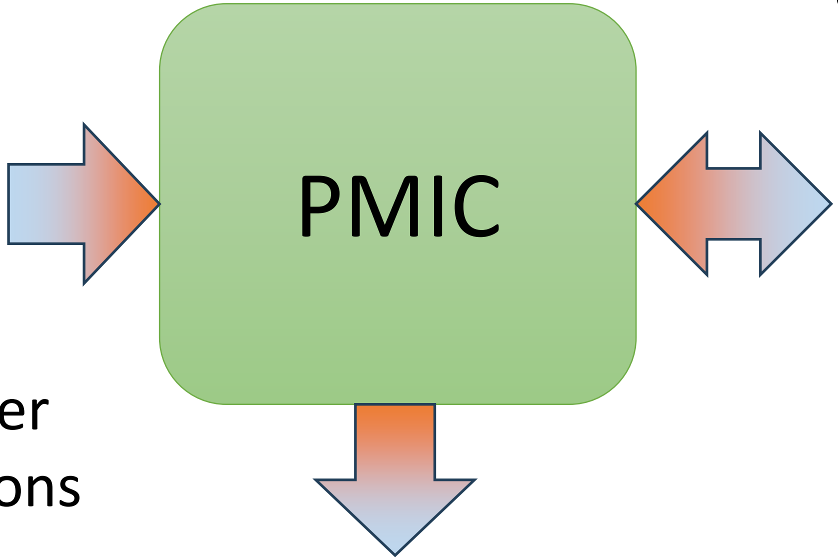
# PMIC : a continuous power converter

Imposed by storage element
*Usually slow moving

$P_{sto} = V_{out} \times I_{out}$

Psrc = V src x I src

Imposed by Harvester
and Ambient conditions
*Fast real time




Papp = V app x I app

Imposed by Chipset
*Usually steady

Psto = V out x I out

*Energy harvesting PMIC adapts in real time to the Ambient source conditions .

⇒ Under a given source ambient condition, a PMIC extracts Continuous power from source independent of Storage element bias :

Psto = Eff% x Psrc

EnerHarv 2024 PSMA

ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.

e-peas semiconductors

# Energy Harveting PMIC role

- **ISOLATE SOURCE from STORAGE dependencies.**

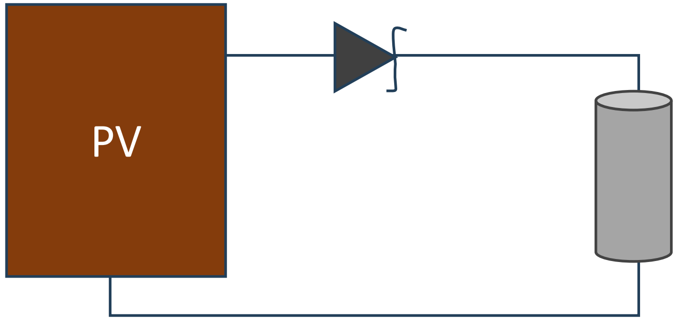
- **ISOLATE APPLICATION supply from the rest.**

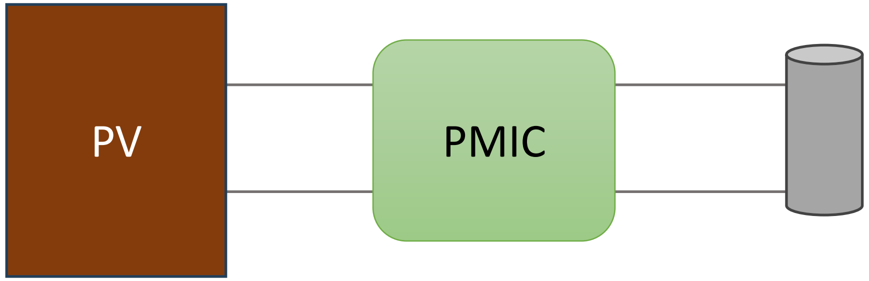

*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

# Power extraction conversion efficiency

# Comparing 2 popular architectures

## Energy extraction concepts



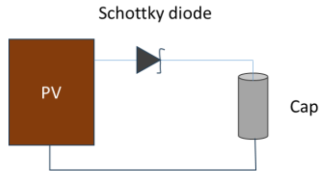

Time dependent power transfer

Low performance

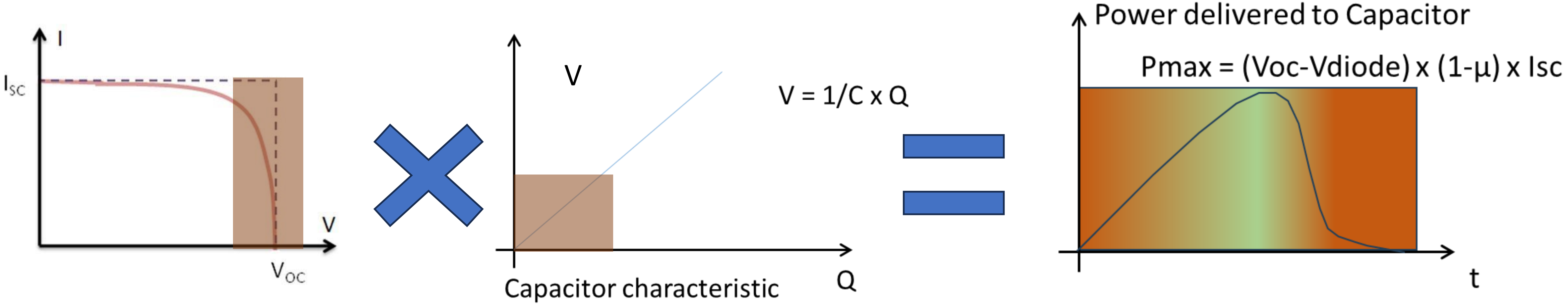
Continuous power transfer

Good practice

# Variable power transfer architecture




## PV + Diode + Super cap power transfer is time dependent:



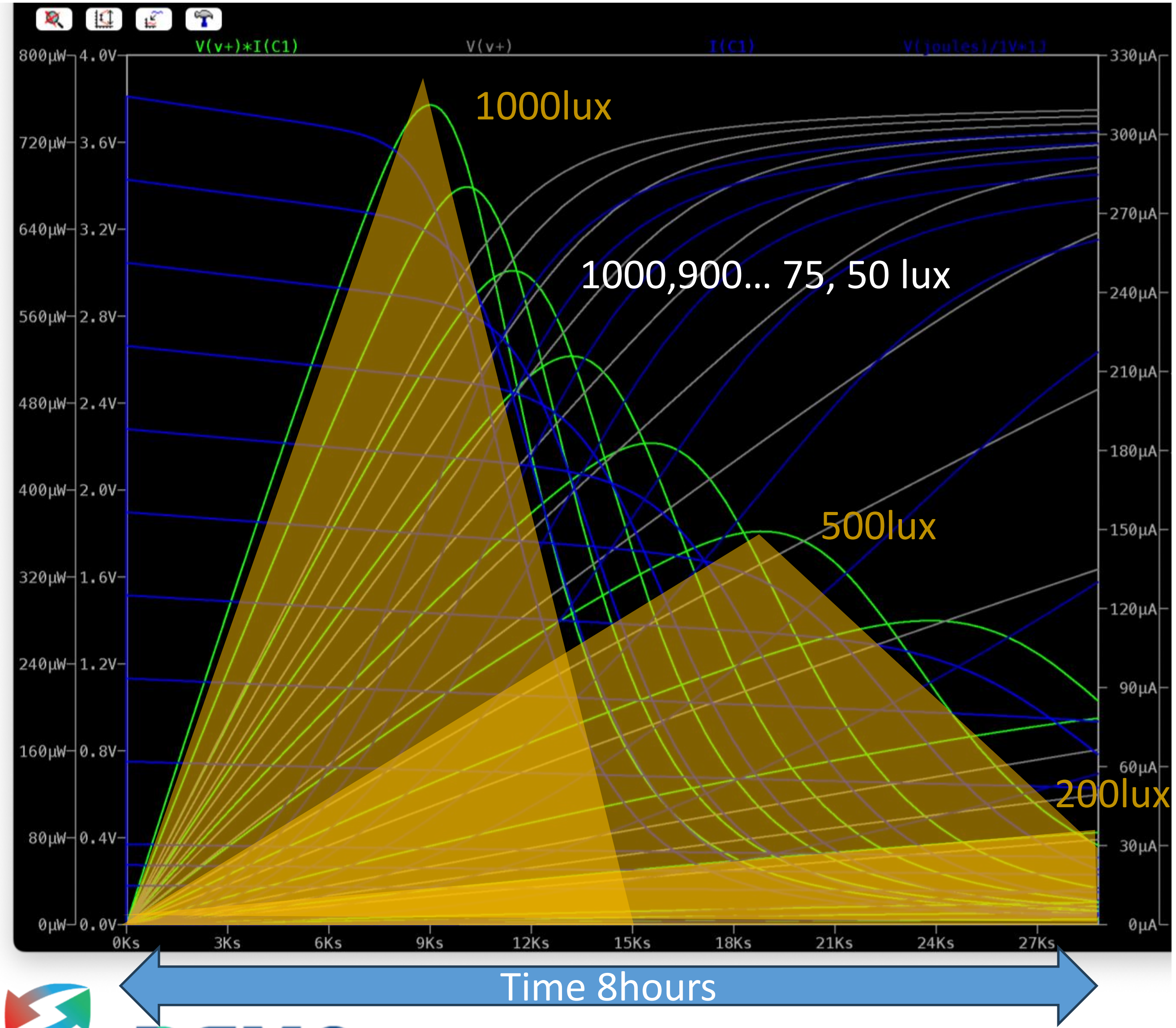

PV cell characteristic

- Vmax is clamped to Voc –Vdiode
  - => need to Oversize PV
  - Low drop Diode
- If Vsto is high, efficiency collapse due to PV current drop
- If Vsto is low, efficiency collapse due to low Sto voltage
- Overall is Low efficiency
- Plus there is no energy extraction at low lux

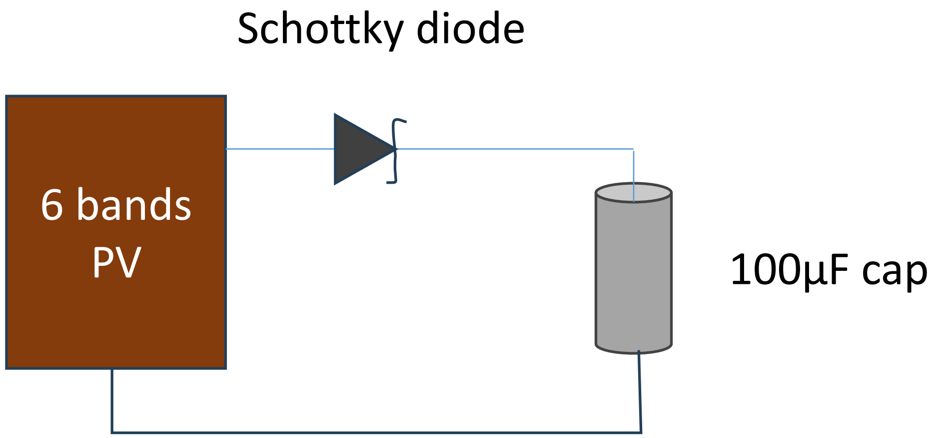



*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

# Spice model of diode-based power transfer over time




- **Power transfer from PV to a capacitor has a "bell-shape" over time ▲**




**Green** : Power delivered to storage
*Blue left : Current from PV*
*Blue right : Joule in storage*
*Grey : PV Voltage*

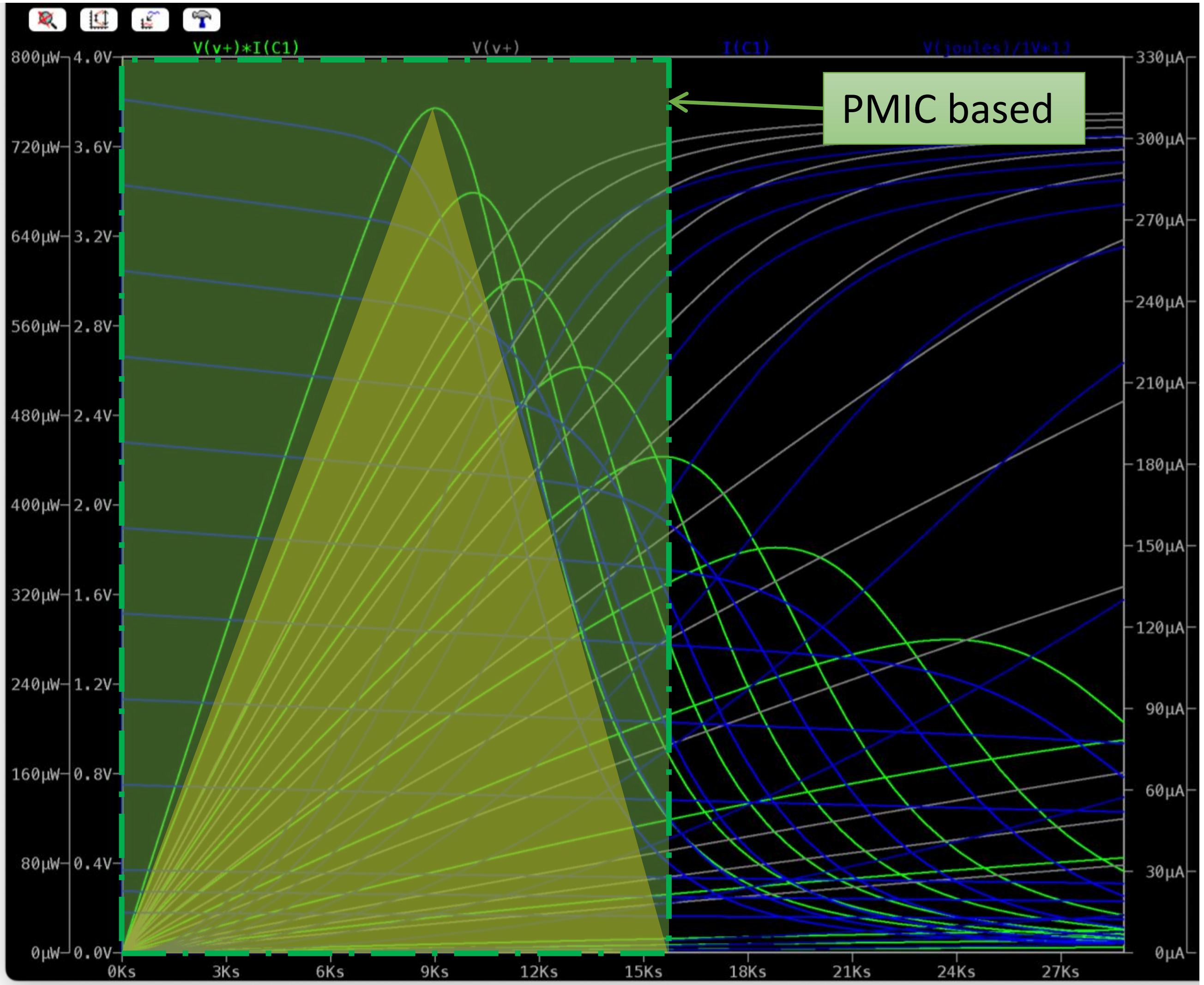
EnerHarv 2024 PSMA

e-peas semiconductors



*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

# Comparison with PMIC Power transfer over time



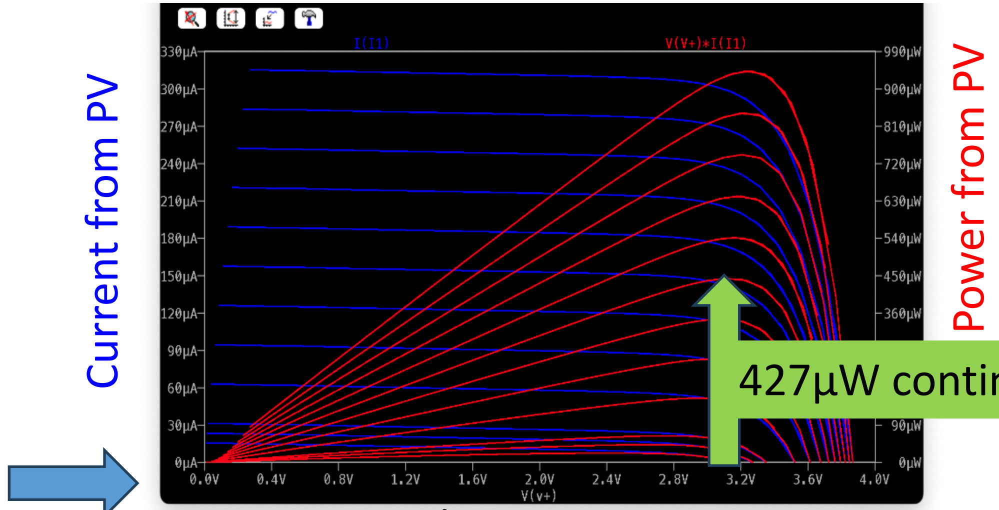

- Constant power transfer with EH PMIC <u>is ~2 x more efficient</u>

⇒ For best practice, go for PMIC ☺

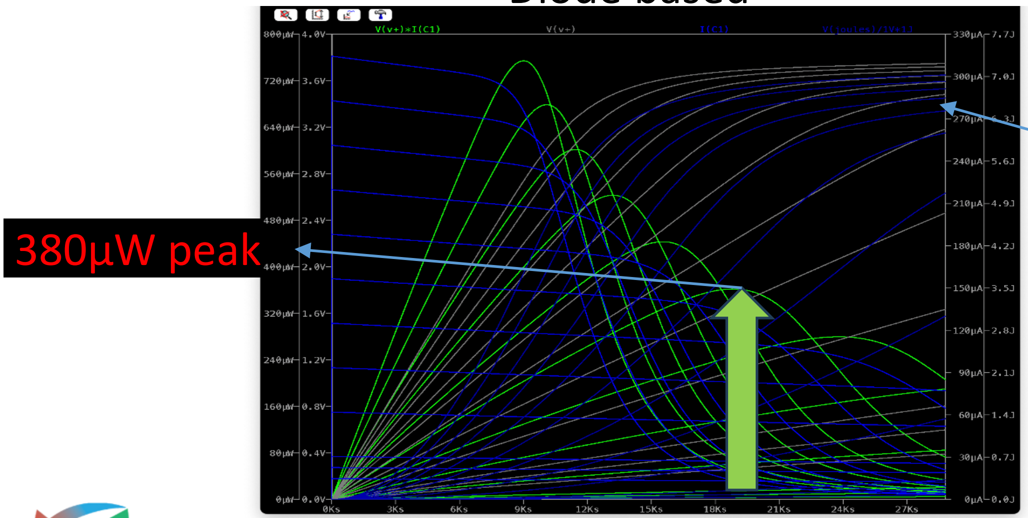
**Green** : Power to storage
*Blue left : Current from PV*
*Blue right : Joule in storage*
*Grey : PV Voltage*

# Energy-wise

PMIC MPPT tracker




Diode based




## For 8 hours of illumination at 500 lux :

- An **e-peas** based **PMIC** architecture will collect continuously :

  E =8 x 3600 x (450E-6 x 95%)

  E= 12.3J

- A diode-based architecture will collect a total of :

  E= 6.5 Joules

How to get this 95% efficiency then ?



ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.

# PMIC with 95% energy conversion efficiency

**Guaranteeing performance by design**

# Good Energy Harvesting PMIC challenges

## Bias Energy source at Maximum power capability

- Maximum Power Point Tracking

## Be very efficient in Power conversion from Source to Storage

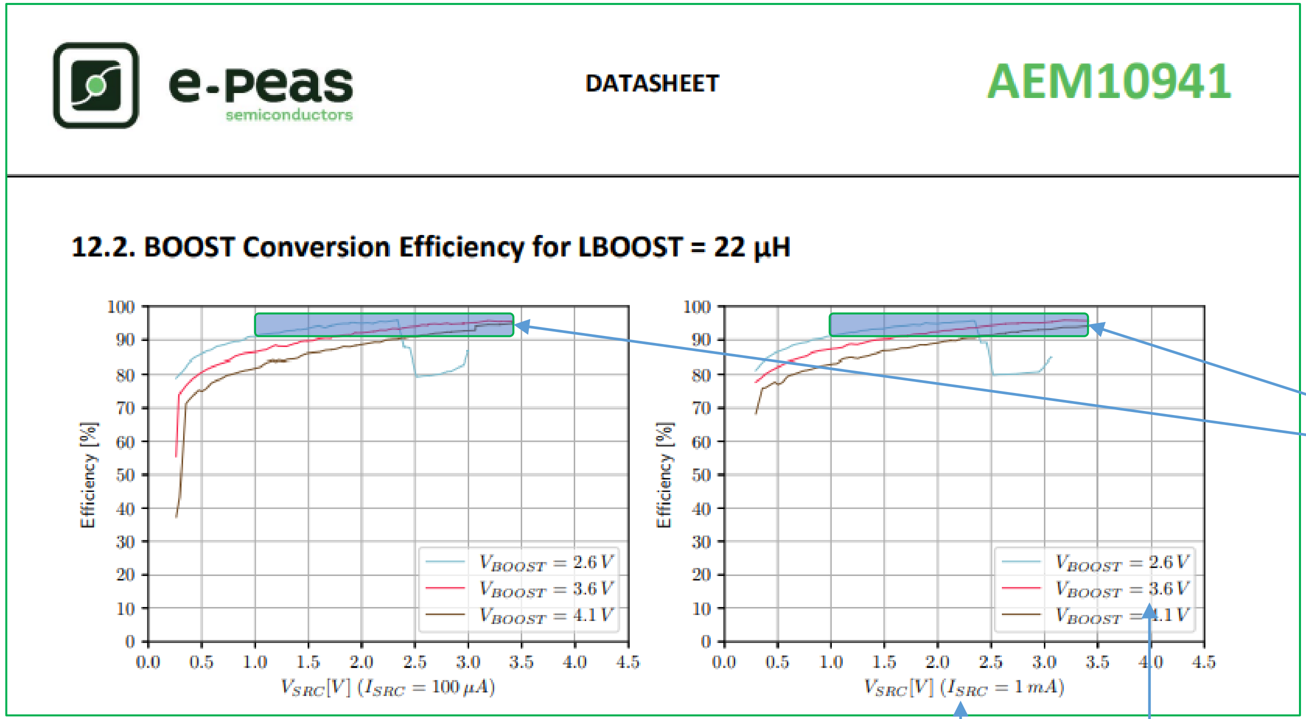
- 90-98%

## Maintain performance over variable conditions

- Isolate Source bias point from Storage and application bias points
- Make Tracking over time
- Design the system accordingly

## Supply the application

# Draw highest Energy efficiency domain in PMIC Data sheet




[DS-AEM10941_QFN28-v2.1==REVc.pdf (e-peas.com)](DS-AEM10941_QFN28-v2.1==REVc.pdf (e-peas.com))

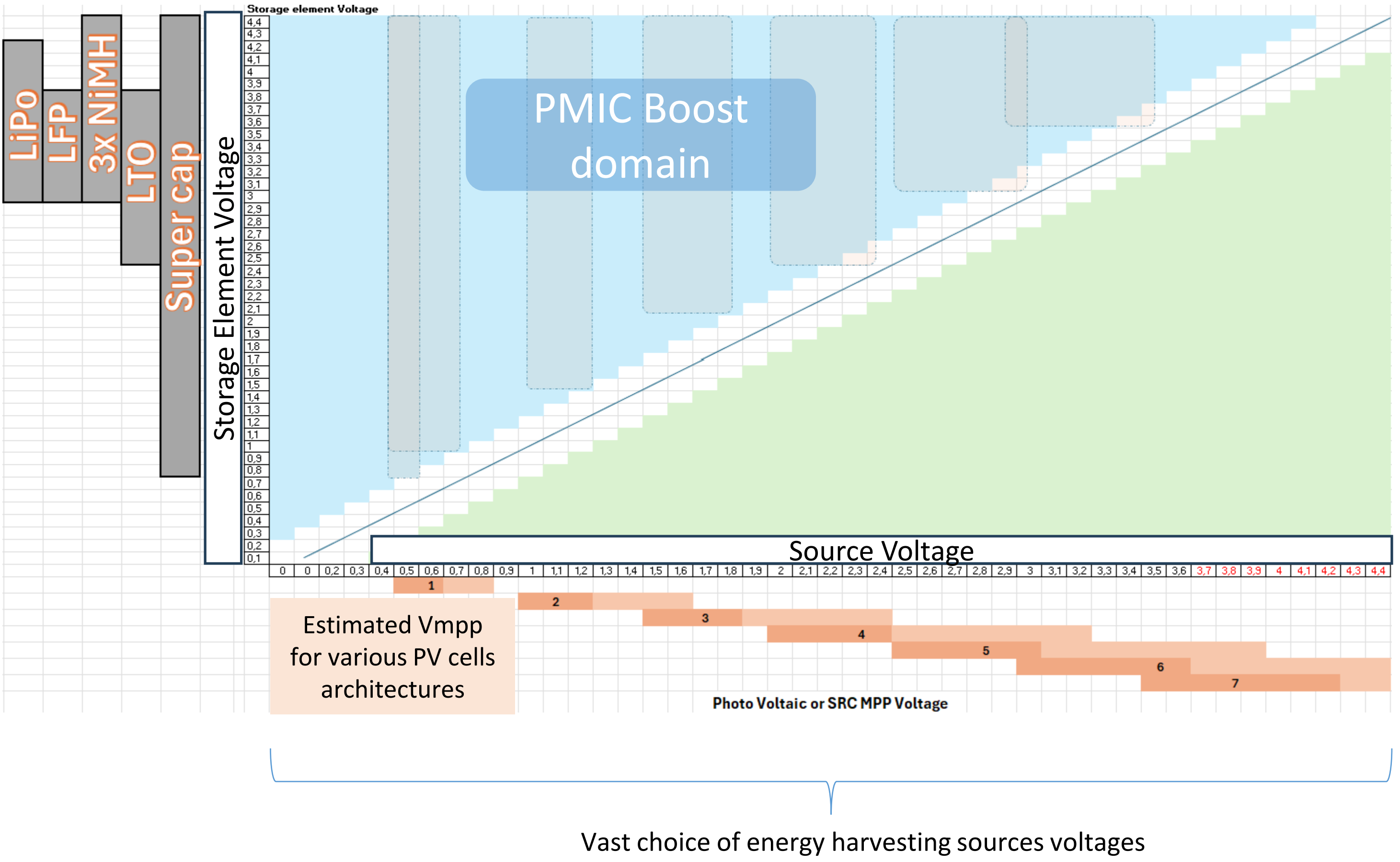
Storage selection

SOURCE selection

- **AEM10941 as an example**
- **A BOOST PMIC optimized for :**
  - Maximum power point tracking from source
  - AND
  - Highest efficiency
  - 95% conversion efficiency from Energy harvester Source to Storage element
  - Conditional to :
    - Selecting ideal combination of Source + Storage combination
    - Work in Boost conversion domain
- **BUCK PMICs work opposite**

e-peas semiconductors

# Fitting the ideal ecosystem with PMIC



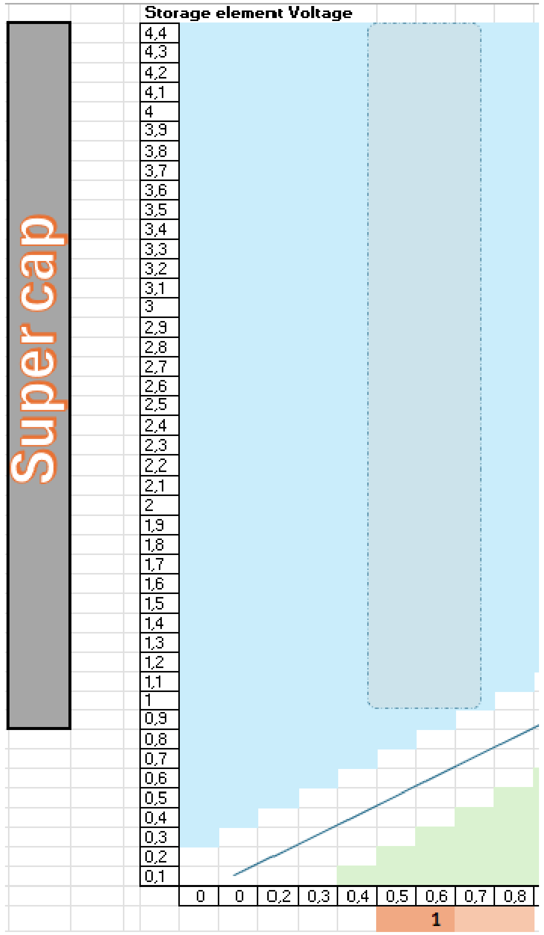

- **Let's consider AEM10941 architecture**
- **Be sure to operate in BOOST mode**
  - => Vin of boost < Vout of boost
  - => Select appropriate PV architecture vs Storage
- **Nothing is forcing designer to use high voltage source :**
  - Low Voltage PVs' are also a good strategic fit

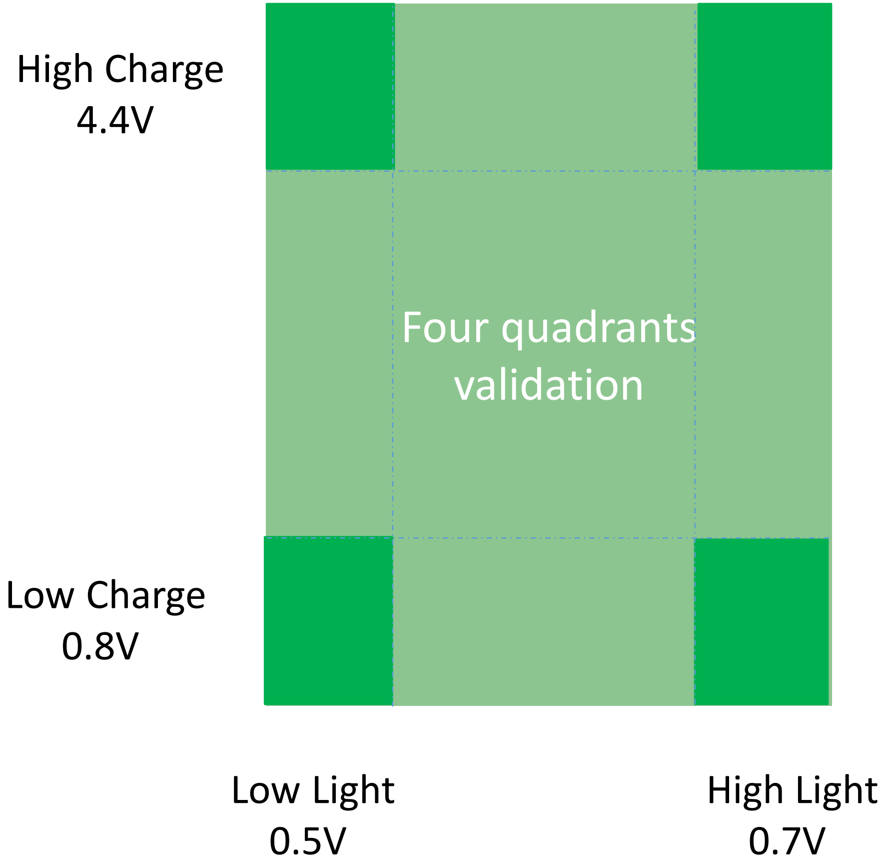
# Example of 4 quadrants validation of EH source vs Storage element

- **Super cap voltage range:**
  - 0.8V (Full discharge)
  - 4.4V (Full charge)

- **Single element PV Mpp range**
  - 0.5v (Low light)
  - 0.7v (High light)

- **Guaranty of Highest efficiency**




Whatever the situation

Vsource << V storage element : we are safe

# e-peas PMIC Portfolio overview

**Allowing flexibility over**

**Energy Harvesting sources**

**and Storage Elements choices**

# Step-by-step PMIC selection process

| e-peas | | AEM10941 | AEM10330 | AEM10920 | AEM10300 | AEM10900 | AEM00920 | AEM00940 AEM00941 | AEM00330 | AEM00300 | AEM00900 AEM00901 | AEM30940 | AEM30330 | AEM30300 | AEM20940 | AEM13920 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENERGY HARVESTER SOURCE | Indoor / Outdoor PV Cell | | | | | 1 | | | | | | | | | | |
| | Thermo Electric Generator | | | | | | | | | | | | | | | |
| | RF Antenna | | | | | | | | | | | | | | | |
| | Vibration Transducer | | | | | | | | | | | | | | | |
| | Pulse Generator | | | | | | | | | | | | | | | |
| SPECIAL PURPOSE INPUTS | Harvester inputs | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | DUAL |
| | Primary Battery input | | | | | | | | | | | | | | | |
| | 5Volt input for Quick charge | | | | | | | | | | | | | | | |
| STORAGE ELEMENT PROTECTIONS | GPIO Configurations | 7 presets | 15 presets | 4 presets | 15 presets | 8 presets + 64 with I2C | 4 presets | 7 presets | 15 presets | 15 presets | 8 presets + 64 with I2C | 7 presets | 15 presets | 15 presets | 7 presets | 8 presets |
| | Storage voltage range | 0V to 4.5V | 0V to 4.65V | 2.5V-4.35V | 0V to 4.65V | 2.8V to 4.8V 4 | 2.5V-4.35V | 0V to 4.5V | 0V to 4.65V | 0V to 4.65V | 2.8V to 4.8V | 0V to 4.5V | 0V to 4.65V | 0V to 4.65V | 0V to 4.5V | 2.5V-4.12V |
| | Custom mode with GPIO | | | | | | | | | | | | | | | |
| | Temperature Protection | | | | | | | | | | | | | | | |
| LOAD SUPPLY REGULATION TYPE | Storage charger | | | | | | | | | | | | | | | |
| | Regulation type | 2 LDOs | 1 Buck/Boost | 1Buck | | | 1Buck | 2 LDOs | 1 Buck/Boost | | | 2 LDOs | 1 Buck/Boost | | 2 LDOs | 1Buck |
| LOAD SUPPLY Voltage | Voltage value | 7 presets | 6 presets | 3 presets | | | 3 presets | 7 presets | 6 presets | | | 7 presets | 6 presets | | 7 presets | 8 presets |
| | | 1.2V - 4.1V | 3 1.2V - 3.3V | 2.2V-2.8V | | | 2.2V-2.8V | 1.2V - 4.1V | 1.2V - 3.3V | | | 1.2V - 4.1V | 1.2V - 3.3V | | 1.2V - 4.1V | 0.6-2.5V |
| MPPT MODE | Adaptive MPPT | | | 2 | | | | | | | | | | | | |
| | Fixed voltage | | | | | | | | | | | | | | | |
| CONFIGURATION | I2C interface | | | | | | | | | | | | | | | |
| | GPIO | | | | | | | | | | | | | | | |
| ADVANCED FEATURES | Average Power Monitor | | | | | APM on Sto | | | | | APM on Sto | | | | | APM on Source and Sto |
| | Shipping mode | | | | | | | | | | | | | | | |
| TEMPERATURE RANGE | Industrial (-40 +85 C) | | | | | | | | | | | | | | | |
| PACKAGING | Type / Body size | QFN 28 5x5mm | QFN 40 5x5mm | QFN 24 4x4mm | QFN 28 4x4mm | QFN 28 4x4mm | QFN 24 4x4mm | QFN 28 5x5mm | QFN 40 5x5mm | QFN 28 4x4mm | QFN 28 4x4mm | QFN 28 5x5mm | QFN 40 5x5mm | QFN 28 4x4mm | QFN 28 5x5mm | QFN 40 5x5mm |
| | | | | | | WLCSP 16 2x2mm | | | | | WLCSP 16 2x2mm | | | | | |

## BOOST

- AEM10941 00940
- AEM10900 00900
- AEM10920 00920
- AEM20940 30940
- AEM13920

## BUCK

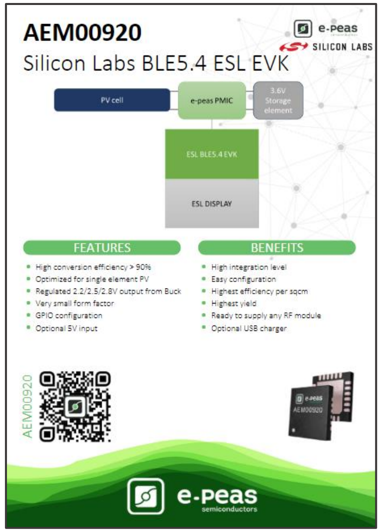
- AEM10300 10330
- AEM30300 30330
- AEM 00300 00330

# DEMO

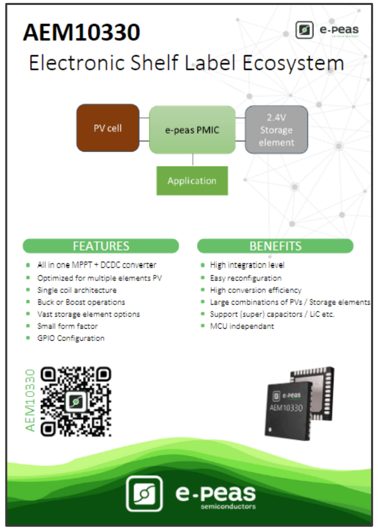
- **A fully autonomous <u>E</u>lectronic <u>S</u>helf <u>L</u>abel with VGA screen and Bluetooth 5.4 PAwR**



DSSC PV




Organic PV




Perovskite PV

EnerHarv 2024 PSMA

*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

e-peas semiconductors

# Product integration examples


DSSC PV


Organic PV


Perovskite PV



ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.

# Conclusions

- **Fully autonomous Energy Harvesting OEM Products are real.**
- **PMIC based architectures demonstrate best Energy efficiency ( 95% )**
- **Adequate combination of Ecosystem elements with PMIC is key for successful implementation ( secure 95% with 4 corners operations )**
- **Boost or Buck : both options are available.**
- **EH PMIC-based architecture are best in many respects :**
  - Size , Weight
  - QoS
  - Cost
- **E-peas EH PMIC portfolio enable designers' high degree of freedom.**

# References

- **Datasheets**
  - DS-AEM10941_QFN28-v2.1==REVc.pdf (e-peas.com)
  - AEM13920 Dual Source Energy Harvesting | e-peas
  - AEM10920 PMIC for RCUs & Keyboards | Energy Harvesting | e-peas
  - AEM00920 PMIC for remote control and keyboard | Energy Harvesting | e-peas
- **Where to buy ?**
  - e-peas Distributor | Mouser Belgique
- **Selector guide**
  - AEM Selector Guide - E-peas
- **Social Network**
  - e-peas | LinkedIn



ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.

# Q & A

EnerHarv 2024
PSMA International Workshop | 26-28 June, 2024 | Perugia, Italy

## Thanks very much for your time and attention!

## Questions/comments???

TECHNICAL SPONSORS

ORGANIZER

HOST

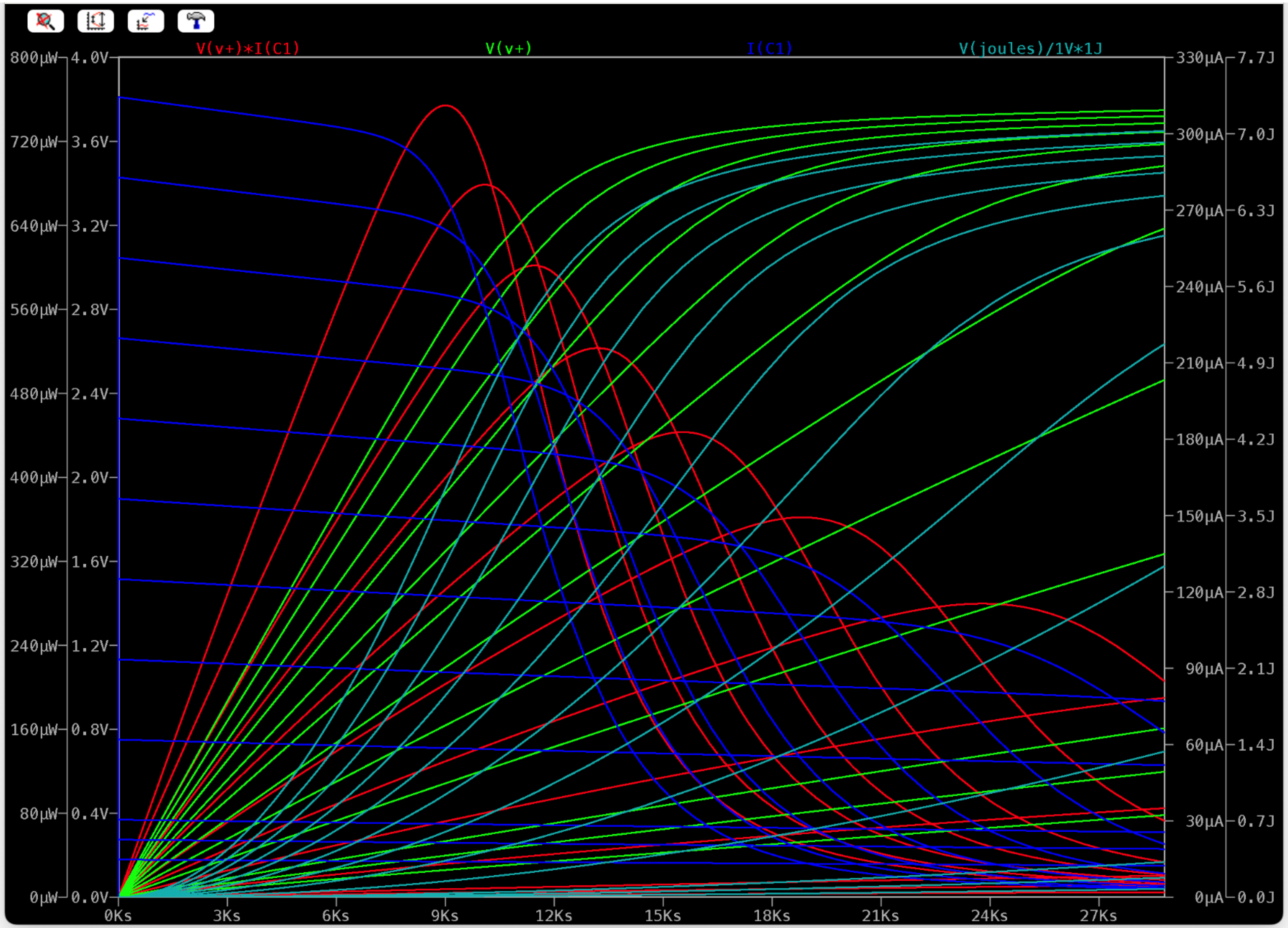
COMMERCIAL SPONSORS

MEDIA SPONSORS



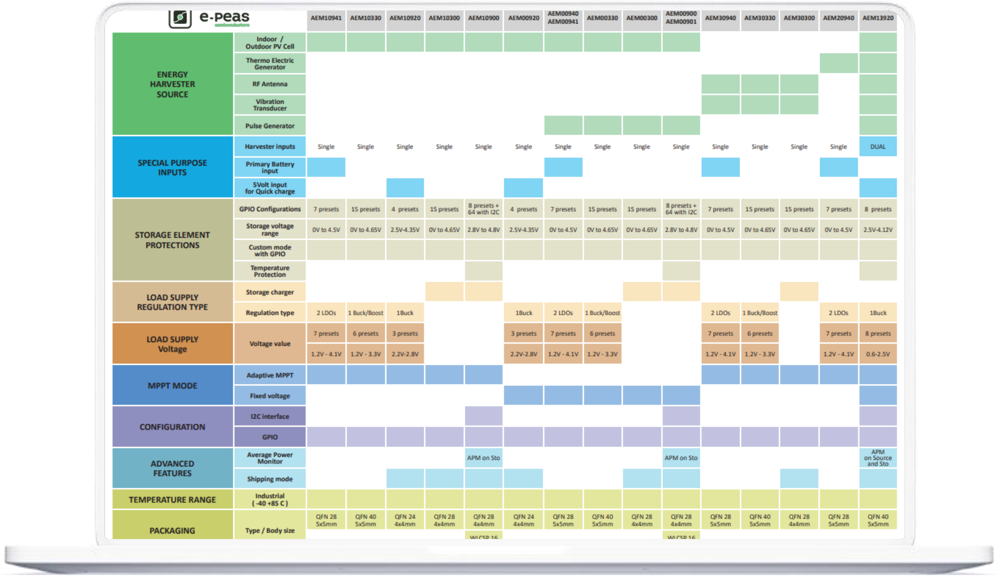
*ALL INFORMATION SHALL BE CONSIDERED SPEAKER PROPERTY UNLESS OTHERWISE SUPERSEDED BY ANOTHER DOCUMENT.*

# Back-up



V(v+)*I(C1)
V(v+)
I(C1)
V(joules)/1V*1J
800µW–4.0V
720µW–3.6V
640µW–3.2V
560µW–2.8V
480µW–2.4V
400µW–2.0V
320µW–1.6V
240µW–1.2V
160µW–0.8V
80µW–0.4V
0µW–0.0V
330µA–7.7J
300µA–7.0J
270µA–6.3J
240µA–5.6J
210µA–4.9J
180µA–4.2J
150µA–3.5J
120µA–2.8J
90µA–2.1J
60µA–1.4J
30µA–0.7J
0µA–0.0J
0Ks
3Ks
6Ks
9Ks
12Ks
15Ks
18Ks
21Ks
24Ks
27Ks

# PMIC selection resources



| e-peas semiconductors | | AEM10941 | AEM10330 | AEM10920 | AEM10300 | AEM10900 | AEM00920 | AEM00940 AEM00941 | AEM00330 | AEM00300 | AEM00900 AEM00901 | AEM30940 | AEM30330 | AEM30300 | AEM20940 | AEM13920 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ENERGY HARVESTER SOURCE | Indoor / Outdoor PV Cell | | | | | | | | | | | | | | | |
| | Thermo Electric Generator | | | | | | | | | | | | | | | |
| | RF Antenna | | | | | | | | | | | | | | | |
| | Vibration Transducer | | | | | | | | | | | | | | | |
| | Pulse Generator | | | | | | | | | | | | | | | |
| SPECIAL PURPOSE INPUTS | Harvester inputs | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | Single | DUAL |
| | Primary Battery input | | | | | | | | | | | | | | | |
| | 5Volt input for Quick charge | | | | | | | | | | | | | | | |
| STORAGE ELEMENT PROTECTIONS | GPIO Configurations | 7 presets | 15 presets | 4 presets | 15 presets | 8 presets + 64 with I2C | 4 presets | 7 presets | 15 presets | 15 presets | 8 presets + 64 with I2C | 7 presets | 15 presets | 15 presets | 7 presets | 8 presets |
| | Storage voltage range | 0V to 4.5V | 0V to 4.65V | 2.5V-4.35V | 0V to 4.65V | 2.8V to 4.8V | 2.5V-4.35V | 0V to 4.5V | 0V to 4.65V | 0V to 4.65V | 2.8V to 4.8V | 0V to 4.5V | 0V to 4.65V | 0V to 4.65V | 0V to 4.5V | 2.5V-4.12V |
| | Custom mode with GPIO | | | | | | | | | | | | | | | |
| | Temperature Protection | | | | | | | | | | | | | | | |
| LOAD SUPPLY REGULATION TYPE | Storage charger | | | | | | | | | | | | | | | |
| | Regulation type | 2 LDOs | 1 Buck/Boost | 1Buck | | | 1Buck | 2 LDOs | 1 Buck/Boost | | | 2 LDOs | 1 Buck/Boost | | 2 LDOs | 1Buck |
| LOAD SUPPLY Voltage | Voltage value | 7 presets | 6 presets | 3 presets | | | 3 presets | 7 presets | 6 presets | | | 7 presets | 6 presets | | 7 presets | 8 presets |
| | | 1.2V - 4.1V | 1.2V - 3.3V | 2.2V-2.8V | | | 2.2V-2.8V | 1.2V - 4.1V | 1.2V - 3.3V | | | 1.2V - 4.1V | 1.2V - 3.3V | | 1.2V - 4.1V | 0.6-2.5V |
| MPPT MODE | Adaptive MPPT | | | | | | | | | | | | | | | |
| | Fixed voltage | | | | | | | | | | | | | | | |
| CONFIGURATION | I2C interface | | | | | | | | | | | | | | | |
| | GPIO | | | | | | | | | | | | | | | |
| ADVANCED FEATURES | Average Power Monitor | | | | | APM on Sto | | | | | APM on Sto | | | | | APM on Source and Sto |
| | Shipping mode | | | | | | | | | | | | | | | |
| TEMPERATURE RANGE | Industrial ( -40 +85 C ) | | | | | | | | | | | | | | | |
| PACKAGING | Type / Body size | QFN 28 5x5mm | QFN 40 5x5mm | QFN 24 4x4mm | QFN 28 4x4mm | QFN 28 4x4mm WLCSP 16 | QFN 24 4x4mm | QFN 28 5x5mm | QFN 40 5x5mm | QFN 28 4x4mm | QFN 28 4x4mm WLCSP 16 | QFN 28 5x5mm | QFN 40 5x5mm | QFN 28 4x4mm | QFN 28 5x5mm | QFN 40 5x5mm |

- AEM Selector Guide - E-peas
- Interactive tool
- Brochure