

A nighttime photograph of a city skyline, likely New York City, with numerous skyscrapers illuminated against a dark blue sky. The lights from the buildings reflect on the water in the foreground. The text is overlaid on the left side of the image.

# Battery Management System (BMS)

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Powering Business Worldwide

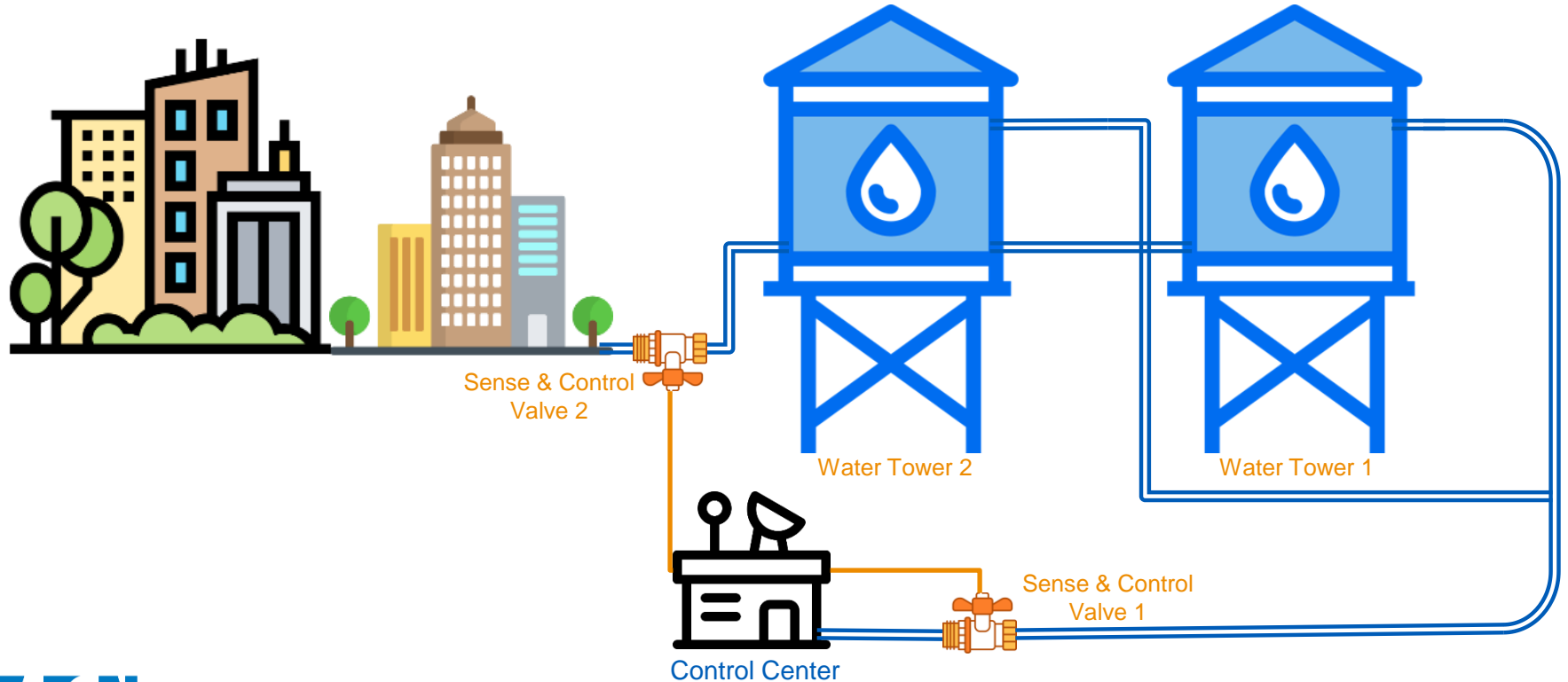
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# Agenda

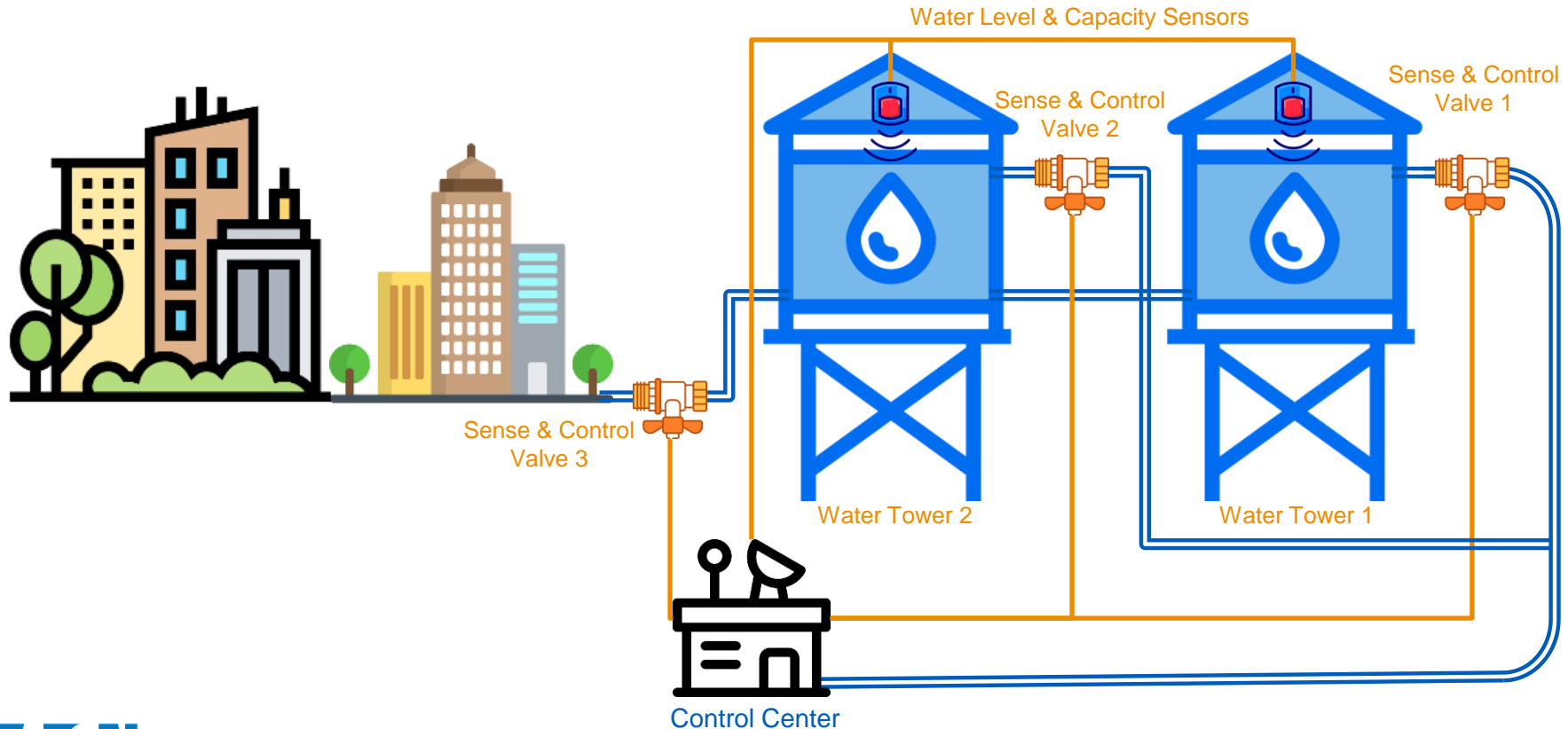
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- What is BMS
- Why use BMS
- Building Blocks of BMS
- Battery States
- BMS Monitoring
- BMS Topologies
- Eaton Resources

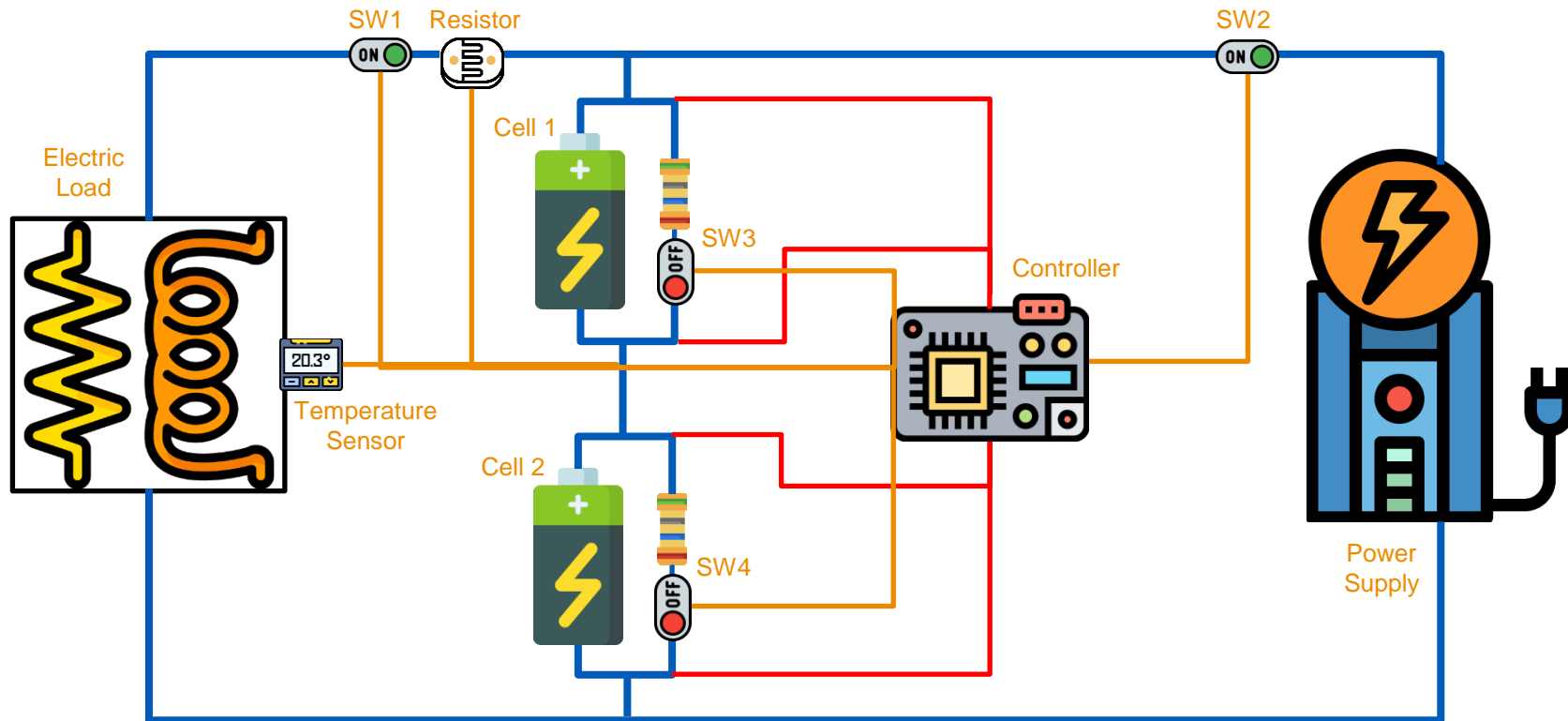
# Waterflow & Control Analogues to BMS



# Waterflow & Control Analogues to BMS



# What is BMS

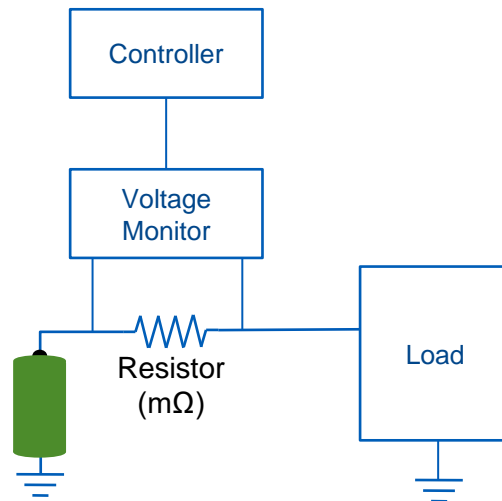


# What is BMS Cont'd

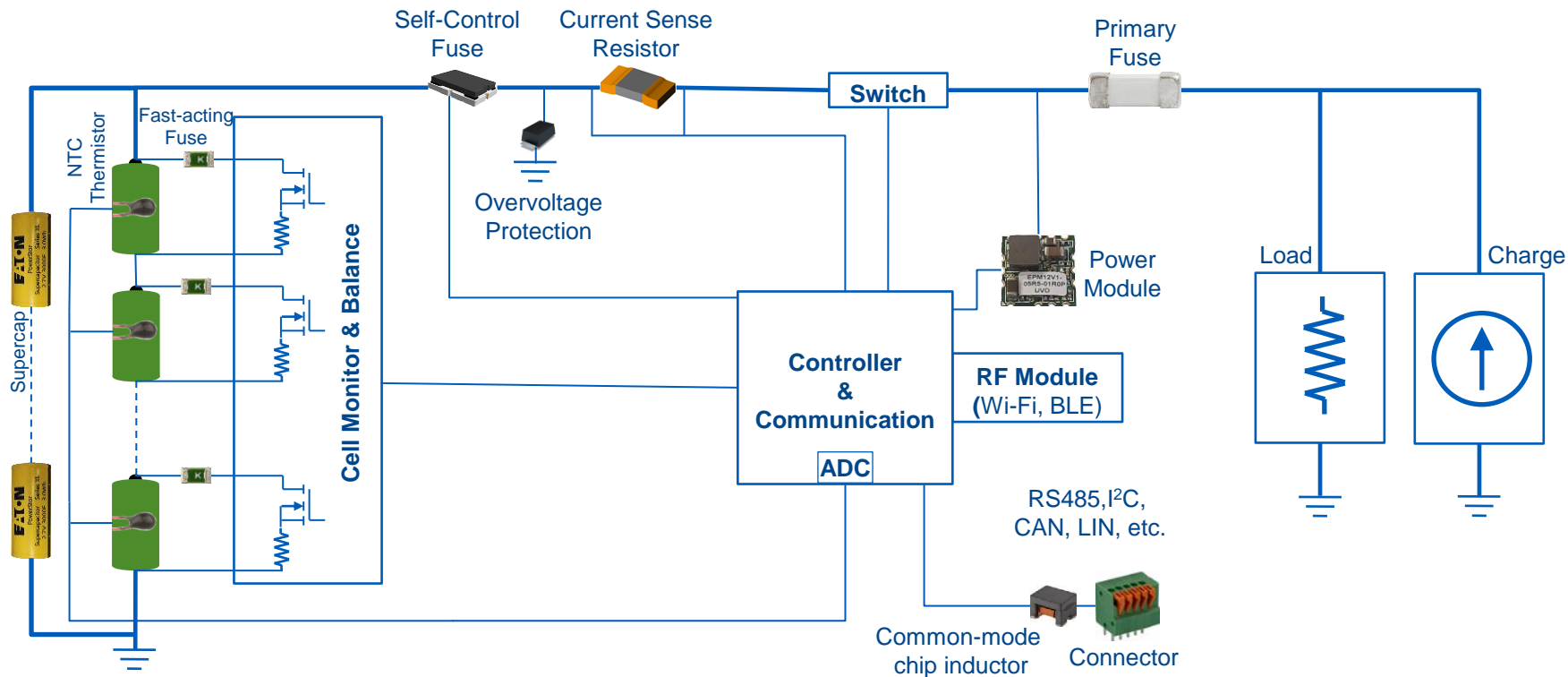
- Monitors individual cells and reacts.
  - Balances voltage and regulates the current flow.
- Monitors system voltage, current, temperature (other environmental conditions) and reacts
  - If thermal runaway is detected, positive-disconnect the battery from load and source.
  - If upper or lower voltage, current, or temperature limit is exceeded, temporarily disconnects the load or source.
- Estimates State of Health (SoH), State of charge (SoC), State of Energy (SoE), and State of Power (SoP)
  - Will explore these topics later.

# What is BMS Cont'd – A Primitive BMS

- A precision resistor is placed in series with the load.
- The resistor is sized to handle the load current.
- Any given time, Controller knows the current flow rate
$$I = V_{(across\ R)} \div R$$
- *Power consumption of the system is*
$$P = V_{(Battery)} \times I_{(Calculated)}$$
- Disadvantage: Temperature change and drift in component value will sway the result.



# Building Blocks of BMS



# Battery States

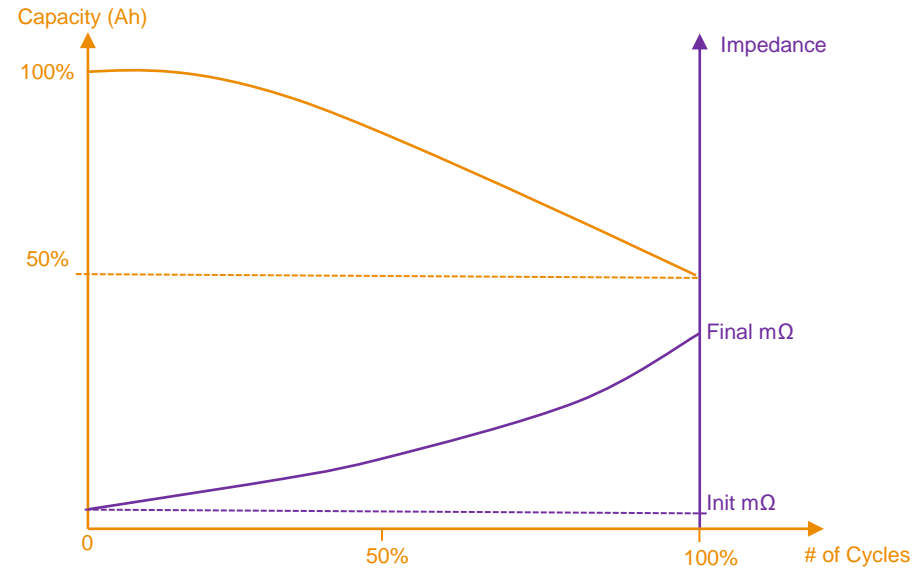
- **State of Health (SoH)**  
The capacity (%Ah) of the battery due to aging – number of cycles, temperature changes, and time.
- **State of Charge (SoC)** is the existing capacity (%Ah) due to use.
  - A method to estimate charge is Coulomb Counting  

$$\text{SoC}_{\text{Prsnt}} = \text{SoC}_{\text{Init}} - \text{Capcty}_{\text{Utilzd}} \text{ where } \text{Capcty}_{\text{Utilzd}} = \frac{I \times \Delta t}{\text{Init Ah}} \times 100$$
- **State of Energy (SoE)**  
The energy remains in the battery vs the maximum energy a battery can store  

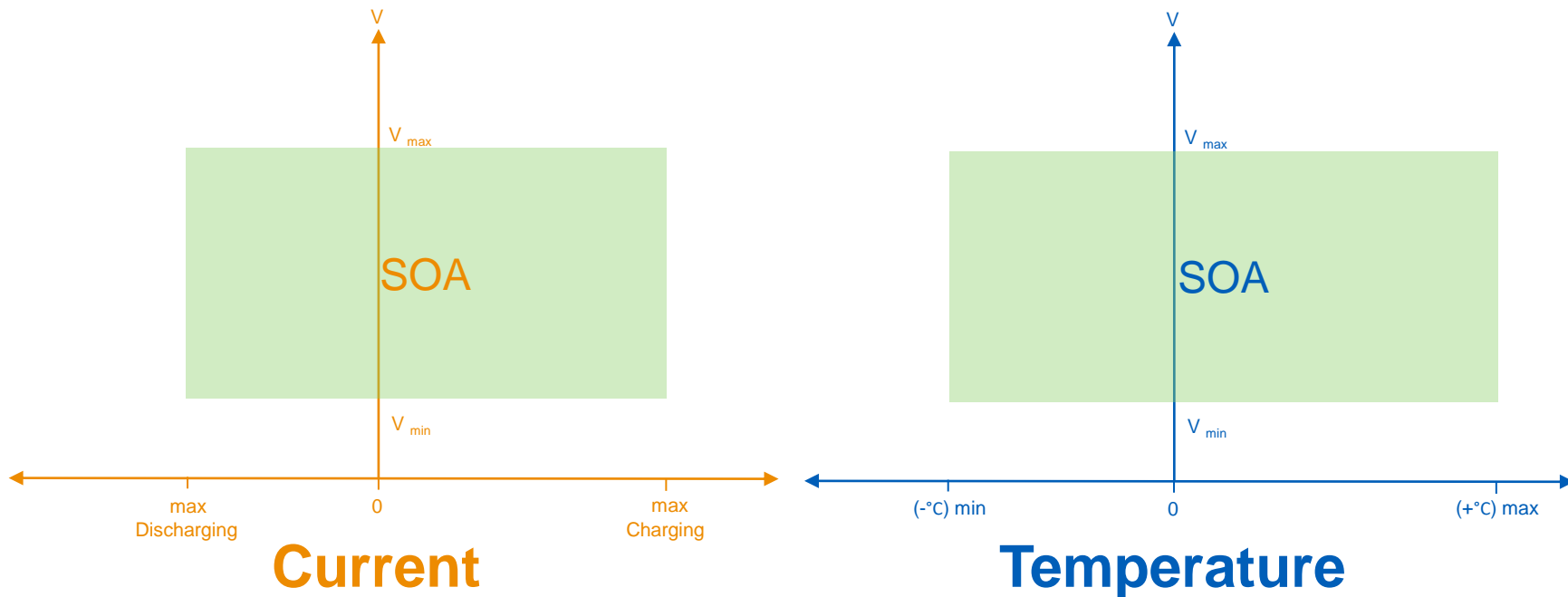
$$\Delta E = P \times t \text{ while } P = V \times I \text{ therefore } \Delta E = V \times I \times \Delta t$$

$$E_{\text{Present}} = E_{\text{Max}} - \Delta E \text{ OR } \text{SoE} = \frac{\Delta E}{E_{\text{max}}} \times 100$$
- **State of Power (SoP)**  

$$P = V \times I \text{ where } V \text{ is present voltage, and } I \text{ is the current}$$
 stated in the datasheet OR 
$$\text{SoP} = \frac{P_{\text{max now}}}{P_{\text{nominal}}} \times 100$$
- A cycle of a battery is one full charge (max V) and full discharge (min V).
- As number of cycles increase, the capacity decreases, and the internal impedance of the battery (ESR , equivalent series resistance) increases.



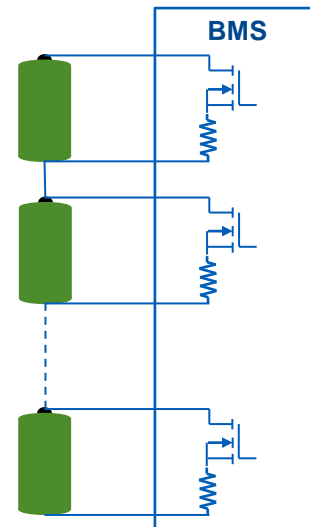
# BMS Monitoring



SOA = Safe Operating Area

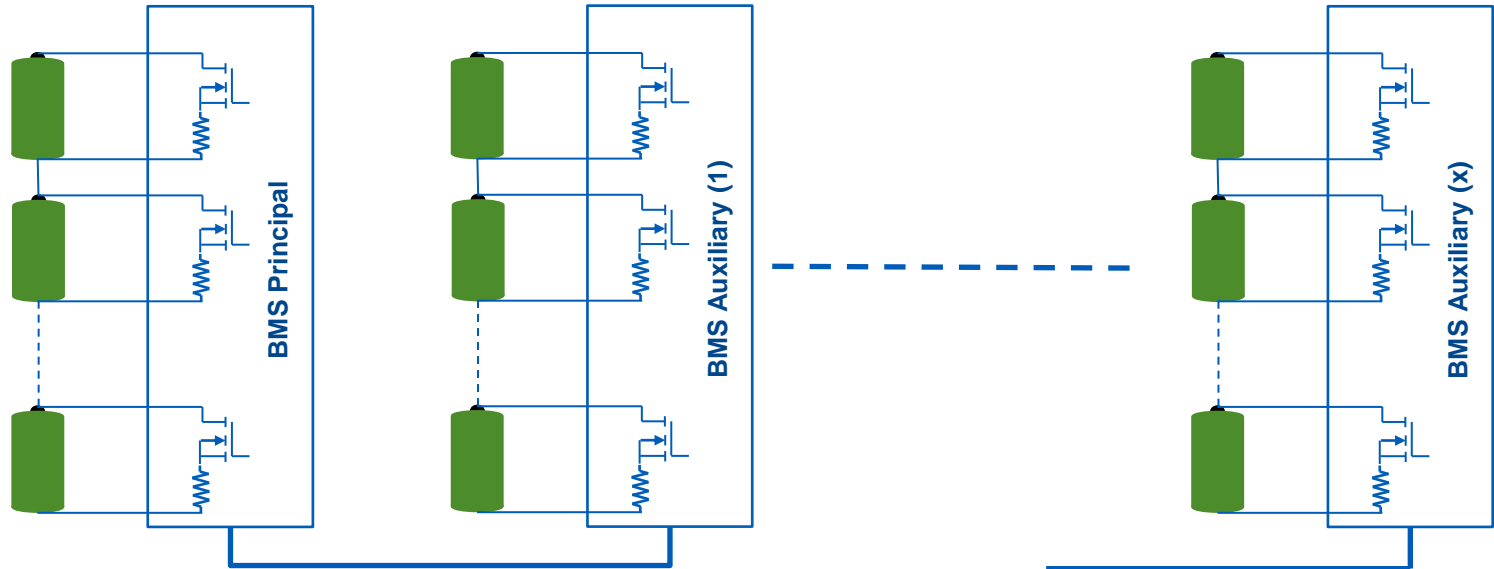
# BMS Topologies – Single BMS

- Limited number of batteries
- Controls all batteries directly
- Balances and controls each battery and optimize performance
- When number of cells are matched with available ports of the design
- Suitable for power tools, small UPS, laptops.



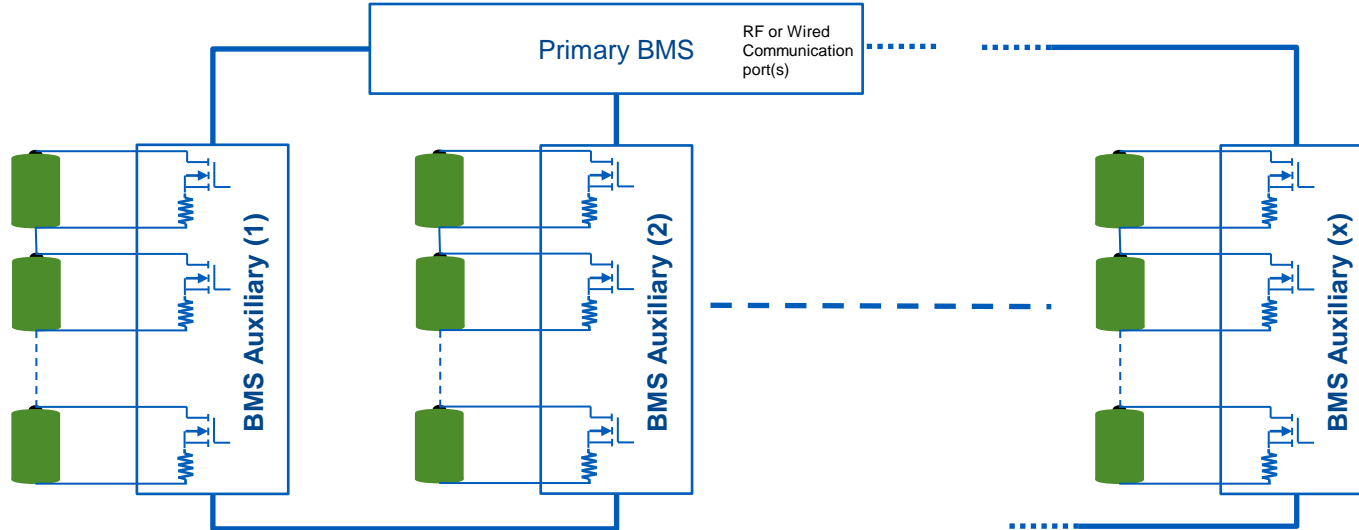
# BMS Topologies – Multiple BMS

- More than one BMS.
- Each BMS controls multiple batteries – suitable for larger number of batteries.
- Each BMS communicates its status to principal BMS.
- Principal relays the information to the central computer.
- Suitable for large UPS, e-bike, portable power station



# BMS Topologies – Multiple BMS with Dedicated Principal

- Multiple BMS with one dedicated BMS
- Each BMS controls multiple batteries
- All BMS communicate to Principal which in turn relays the information to Central Computer
- Suitable for EV, solar energy backup, data center



## Selecting Terminal Blocks



# Tools & Resources



## **Parametric Search**

Drill down into the Eaton Electronics product database to find the right part for your application



## **IC Matching**

Find the Eaton Electronics parts called out on IC manufacturers' demo and evaluation boards.



## **Cross Reference**

Find a cross to a competitor's product or to an alternate Eaton Electronics part number.



## **Supercapacitor Calculator**

Determine your calculated requirements and design capability.



## **Terminal Block Selector**

Find the right terminal block for any application.



## **Automotive Electronics Solutions**

Find electronics components for automotive solutions.

[www.eaton.com/electronics](http://www.eaton.com/electronics)

[ELXTechSupport@Eaton.com](mailto:ELXTechSupport@Eaton.com)



*Powering Business Worldwide*

# Eaton NTC Products

## NRGB



### Features:

- Operating temperature: -40~300°C
- Single ended, glass sealed construction
- Highly heat resistant with high sensitivity
- Mainly used in above 200°C applications

## NDBG



### Features:

- Operating temperature: -40~250°C
- Glass sealed construction
- Axial leaded, "diode" footprint
- Mainly used in 100~200°C applications

## NRBE



### Features:

- Operating temperature: -40~125°C
- Epoxy coated/resin sealed construction
- Broad application range
- Mainly used in below 100°C applications

## NRLx



### Features:

- Working temperature: -40~125°C
- Single ended, epoxy coated construction
- Insulated wire offered in 3 gages
- Mainly used in below 100°C applications

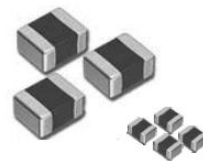
## NRMx



### Features:

- Working temperature: -40~125°C
- Single ended, epoxy coated construction
- Enameled wire insulation with color option
- Mainly used in below 100°C applications

## NTxx



### Features:

- Working temperature: -40~125°C
- 0402, 0603, 0805 sizes
- Mainly used in below 100°C applications



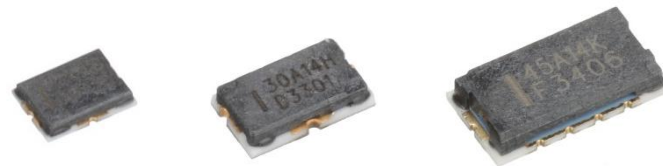
# Self-control Fuse

## Product Description

Triggerable fuse that provides overcurrent and overcharge (overvoltage) protection

## Features & Benefits

- Three terminal surface mount circuit protection device in compact and low height footprint
- 12 to 45 amp nominal current ratings
- Different variations and footprints to match with multiple cells in battery packs



## Applications

- Industrial & Consumer: Power Tools, Cordless Tools, Vacuum Cleaners
- Computing & Consumer: Notebooks, Smart phones, Tablets, PCs
- Energy: High power battery systems,
- Transportation: e-bikes, battery powered AGVs

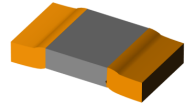


# Current Sense Resistor Technologies



# Technology Comparison

Characteristics	Film	Metal Foil	Metal Plate	Shunt
Resistor Range (mΩ)	$10 < R \leq 910$	$1 \leq R \leq 40$	$0.5 \leq R \leq 20$	$0.1 \leq R \leq 5$
Temperate Coefficient (PPM)	$\pm 100$	$\pm 50$	$\pm 50$	$\pm 50$
Power (W)	Low	Mid	High	Highest
Inductance (nH)	Low	Low	Low	Low
Conductor Content	Low	Mid	High	High



# Overcurrent Products

Trusted Bussmann name in circuit protection for over 100 years with superior reliability that meets modern safety standards throughout the world

## Overcurrent Protection

### Ferrule/Cartridge & Axial Leaded Fuses



### Fuse Clips & Holders



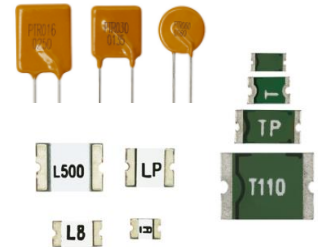
### Radial Fuses



### Surface Mount Fuses



### PPTC Resettable Fuses



# Overvoltage Products

Low capacitance ESD protection to protect against fast voltage transients

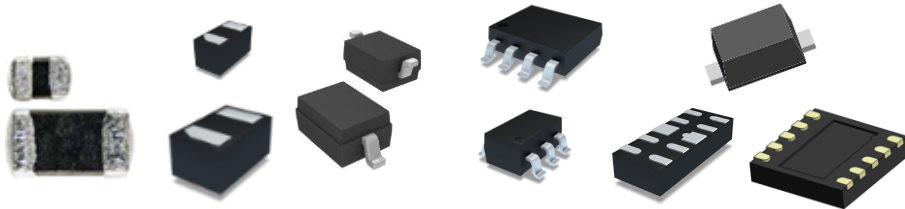
## Circuit Protection

### ESD Suppressors

#### Ultra-Low Capacitance PolySurg



#### TVS Diodes – Discrete & Arrays



#### Multilayer Varistors



# Terminal Block Products

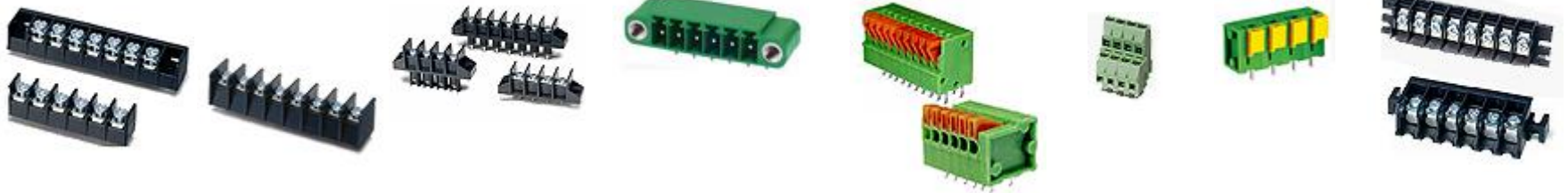
North American & European-style terminal blocks and edge connectors in a wide variety of configurations

## Terminal Blocks

Single Row Terminal Blocks  
Barrier Strips

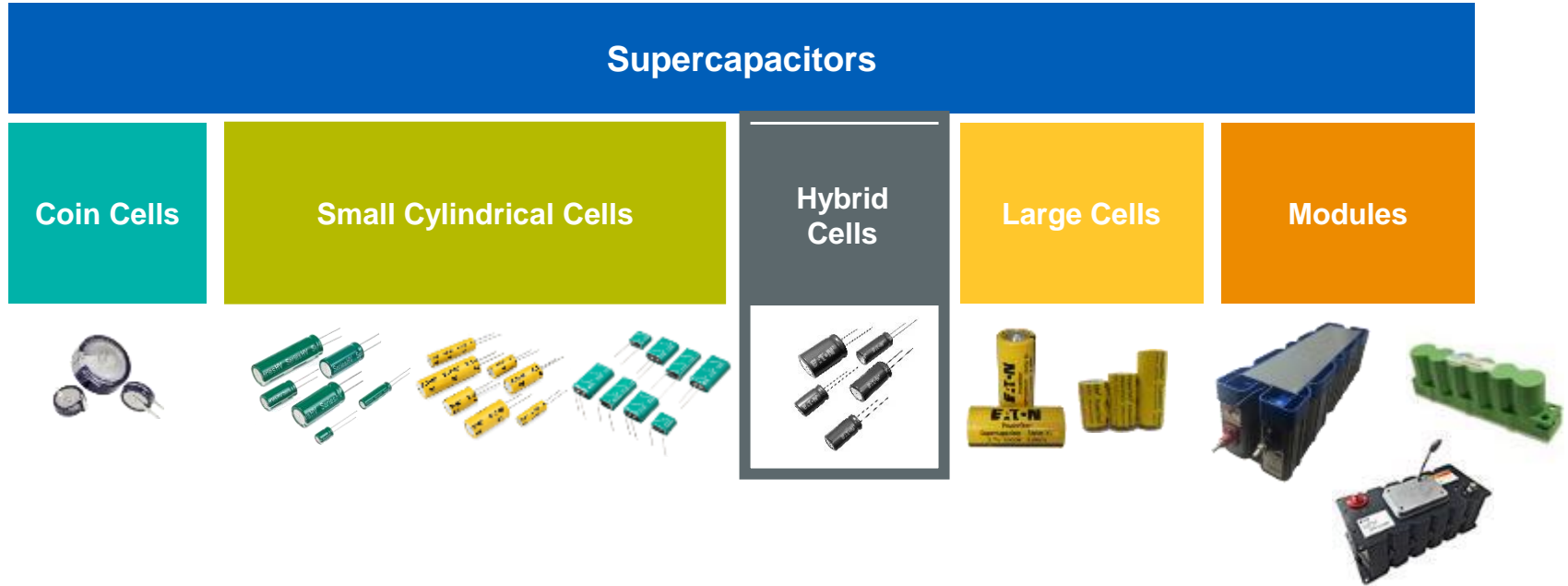
EuroMag Blocks and Plugs  
IEC style

Edge  
Connector



# Supercapacitor Products

Broad product offering – 0.1 F to 3400 F cells – for long life, reliable energy storage with leading power and efficiency



# Eaton Magnetics for Power & RF Applications

Trusted brand in power magnetics and filtering products for DC-DC conversion and EMC filtering in high frequency RF circuits.

## Magnetics Portfolio

### Power Inductors

### High Current

### Transformers

### RF/EMC Filtering

### Power Modules

Toroid

Unshielded

Semi-Shielded

Shielded

Pressed

Ferrite

Coupled

Custom

Standard

Common Mode

Chip  
Bead

DC/DC Converter



# Eaton Power Module (EPM)



**EPM78Vx**  
6 SKU

## Product Description

Non-Isolated DC-DC Converter, 1A

## Features & Benefits

- Switching vs Linear Regulator
- LM78 Compatible 3-SIP Package
- Input voltages: 4.75 V to 32 Vdc
- 6 SKU's representing 6 output voltages
- Efficiency up to 96%
- -40°C to +90 °C Operating Temperature
- Continuous short circuit protection
- Meets EN62368 safety standard



**EPM12V1**  
1 SKU

## Product Description

Non-Isolated DC-DC Converter, 1A

## Features & Benefits

- Non-isolated DC-DC converter
- 3-14 Vdc input voltage range
- Efficiency up to 89.5%
- Operating temperature from -40 to +82 °C
- Short circuit protection
- Remote ON/OFF function
- Programmable output voltage (0.9-5.5 Vdc)
- EN62368 safety standard



**EPM12V2**  
2 SKU

## Product Description

Non-Isolated DC-DC Converter, 12A

## Features & Benefits

- Non-isolated DC-DC converter
- 3-14.4 Vdc input voltage range
- Efficiency up to 91%
- Operating temperature -40 to +90 °C
- Short circuit protection
- Remote ON/OFF
- Programmable output voltage (0.6 -5.5 Vdc)
- EN62368 safety standard



# Isolated DC-DC Converter

Eaton Isolated EPM series are specially designed in SIP package which are for applications where an isolated voltage conversion is required in a Power and Distributed power supply system.



## Distributed Power

EPM06xx1V –1W- SIP4-1kVDC  
EPM06xx2V –1W- SIP7-3kVDC  
EPM07xx1V –1W- SIP7-4kVDC



## High Power Density

EPM25361V –15W- 2kVDC  
EPM25751V –30W- 2kVDC



## High Power

EPM25362V–40W- 2kVDC  
EPM25752V–60W- 2kVDC

