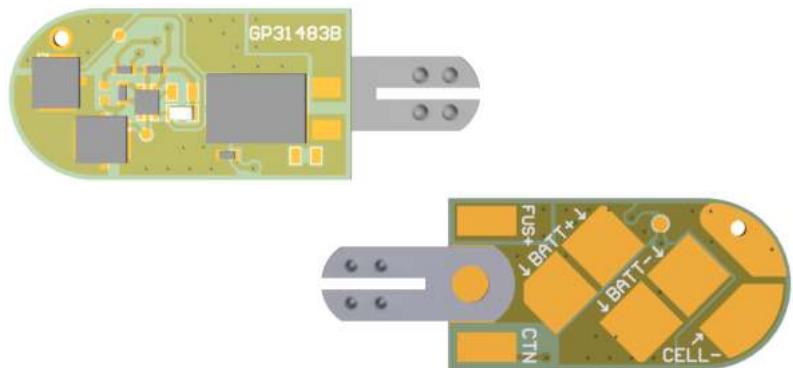


# Battery safety

## Single cell protection circuits

## Electronic protection circuits for Li-ion 3.65 V MP xlr cells

The *S. H.* "is not likely to be  
a well-co-ordinated body of work  
of high quality, and I hardly believe  
it could have been produced without  
one or two hitches & with many more.  
I suggest that no decision should be  
delayed until the Committee has had time  
to get to know it & to see if it can be  
made to do better by other  
means.



הנתקן

- *factory method*: *method to create objects*
  - *copy constructor*: *constructor that takes another object as argument*
  - *operator =*: *assignment operator*
  - *operator <<*: *operator to print objects*
  - *operator >>*: *operator to read objects*
  - *operator ==*: *operator to compare objects*
  - *operator !=*: *operator to compare objects*
  - *operator <*: *operator to compare objects*
  - *operator >*: *operator to compare objects*
  - *operator <=*: *operator to compare objects*
  - *operator >=*: *operator to compare objects*

ANSWER



- **Quadratic** – more difficult to solve;
- **Polynomial** – can have many solutions;
- **Quadratic Equations** – can have 0, 1 or 2 real solutions;
- **Parabola** – U-shaped curve;
- **Vertex** – point where parabola turns;
- **Roots** – points where parabola crosses x-axis.

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- **Geography** (land, symbols, numbers)
  - **Environment**
  - **Population** (size, density)
  - **Economy** (output, imports, exports)
  - **Government** (size, functions)
  - **Geography** (physical, political)
  - **Climate**

| Experiments                            | Results                          | Conclusion                       |
|--|----------------------------------|----------------------------------|
| Yellow-green light (550 nm) vs. 300 nm | 2.2% $\pm$ 0.3%                  |                                  |
| Yellow-red light (550 nm) vs. 450 nm   | 2.0% $\pm$ 0.2%                  |                                  |
| Red-orange light (610 nm) vs. 450 nm   | 1.0% $\pm$ 0.2%                  |                                  |
| Yellow-green light (550 nm) vs. 300 nm | 1.3% $\pm$ 0.3%                  |                                  |
| Yellow-red light (550 nm) vs. 450 nm   | 0.5% $\pm$ 0.1%                  |                                  |
| Red-orange light (610 nm) vs. 450 nm   | 0.1% $\pm$ 0.1%                  |                                  |
| Experiments                            | Results                          | Conclusion                       |
| Control                                | 90%<br>95%<br>90%<br>95%         | 90%<br>95%<br>90%<br>95%         |
| Orange light (550 nm) vs. 300 nm       | 91%<br>94%<br>92%<br>96%         | 91%<br>94%<br>92%<br>96%         |
| Orange light (550 nm) vs. 450 nm       | 93%<br>96%<br>94%<br>97%         | 93%<br>96%<br>94%<br>97%         |
| Orange light (550 nm) vs. 610 nm       | 94%<br>97%<br>95%<br>98%         | 94%<br>97%<br>95%<br>98%         |
| Yellow light (550 nm) vs. 300 nm       | 95%<br>98%<br>96%<br>99%         | 95%<br>98%<br>96%<br>99%         |
| Yellow light (550 nm) vs. 450 nm       | 96%<br>99%<br>97%<br>100%        | 96%<br>99%<br>97%<br>100%        |
| Yellow light (550 nm) vs. 610 nm       | 97%<br>100%<br>98%<br>100%       | 97%<br>100%<br>98%<br>100%       |
| Experiments                            | Results                          | Conclusion                       |
| Orange light (550 nm) vs. 300 nm       | 9.5%<br>10.0%<br>9.8%<br>10.2%   | 9.5%<br>10.0%<br>9.8%<br>10.2%   |
| Orange light (550 nm) vs. 450 nm       | 9.8%<br>10.5%<br>9.6%<br>10.8%   | 9.8%<br>10.5%<br>9.6%<br>10.8%   |
| Orange light (550 nm) vs. 610 nm       | 10.0%<br>10.8%<br>9.8%<br>11.2%  | 10.0%<br>10.8%<br>9.8%<br>11.2%  |
| Yellow light (550 nm) vs. 300 nm       | 10.2%<br>11.0%<br>10.0%<br>11.5% | 10.2%<br>11.0%<br>10.0%<br>11.5% |
| Yellow light (550 nm) vs. 450 nm       | 10.5%<br>11.5%<br>10.3%<br>12.0% | 10.5%<br>11.5%<br>10.3%<br>12.0% |
| Yellow light (550 nm) vs. 610 nm       | 10.8%<br>11.8%<br>10.6%<br>12.5% | 10.8%<br>11.8%<br>10.6%<br>12.5% |
| Experiments                            | Results                          | Conclusion                       |
| Orange light (550 nm) vs. 300 nm       | 10.0%<br>10.5%<br>10.2%<br>11.0% | 10.0%<br>10.5%<br>10.2%<br>11.0% |
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| Yellow light (550 nm) vs. 300 nm       | 11.0%<br>11.5%<br>10.8%<br>12.0% | 11.0%<br>11.5%<br>10.8%<br>12.0% |
| Yellow light (550 nm) vs. 450 nm       | 11.5%<br>12.0%<br>11.3%<br>13.0% | 11.5%<br>12.0%<br>11.3%<br>13.0% |
| Yellow light (550 nm) vs. 610 nm       | 11.8%<br>12.5%<br>11.6%<br>13.5% | 11.8%<br>12.5%<br>11.6%<br>13.5% |

## • Protection and topology

### ■ Cell Balancing protection

- If one cell is overcharged, the voltage will be higher than the others, and the current will flow from the other cells to the overcharged cell.

### ■ Current under protection

- Cells connected in series will have different currents flowing through them. If the current is too high, it can damage the cell.
- Cells connected in parallel will have the same current flowing through them, but the voltage will be lower than the individual cell voltages.

### ■ Current limit protection

- The goal is to prevent the battery from overheating and causing damage to the cells.
- This is achieved by monitoring the current and turning off the power source if it reaches a certain threshold.

### ■ Cell balancing

- Cells connected in series will have different currents flowing through them. If the current is too high, it can damage the cell.
- Cells connected in parallel will have the same current flowing through them, but the voltage will be lower than the individual cell voltages.

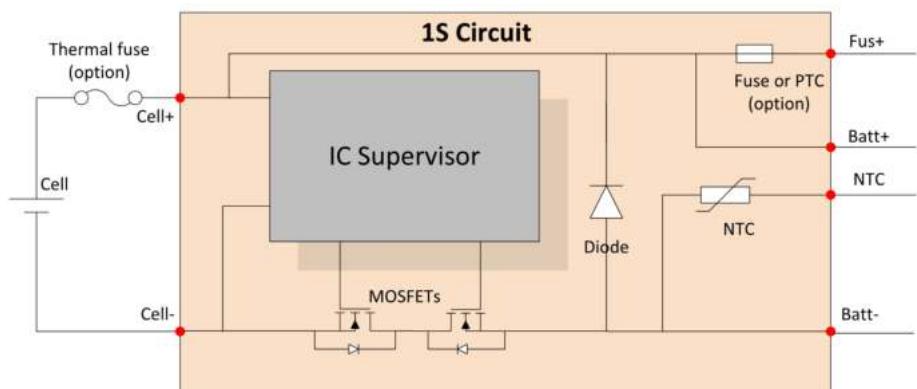
### ■ Charge

- Cells connected in series will have different currents flowing through them. If the current is too high, it can damage the cell.
- Cells connected in parallel will have the same current flowing through them, but the voltage will be lower than the individual cell voltages.

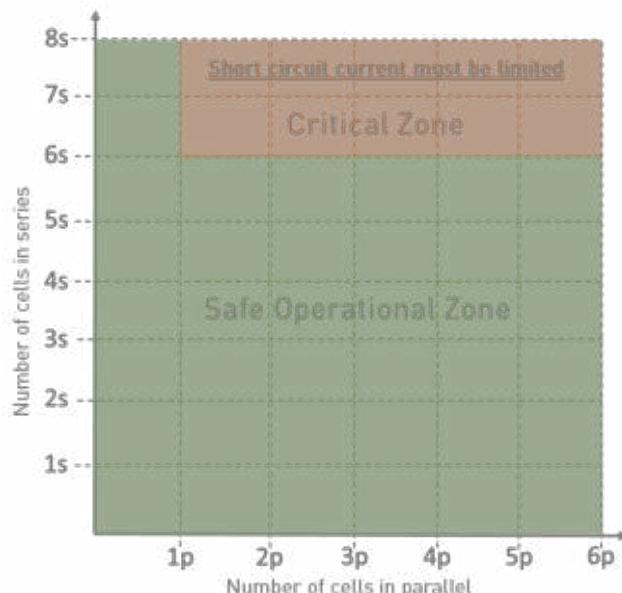
| Circuit by number of cells (parallel) | 41V           | over-voltage            | over-current            |
|---------------------------------------|---------------|-------------------------|-------------------------|
| Cell 1s                               | V+ =<br>Vcell | Vcell < V+ < Vcell + ΔV | Icell < I+ < Icell + ΔI |

| Circuit by number of cells (parallel) | 41V           | over-voltage            | over-current            |
|---------------------------------------|---------------|-------------------------|-------------------------|
| Cell 1s                               | V+ =<br>Vcell | Vcell < V+ < Vcell + ΔV | Icell < I+ < Icell + ΔI |

• Design of the system: need to take into account the following requirements:  
 - Protection against short circuit and overvoltage.  
 - Protection against overcurrent and overtemperature.  
 - Protection against overcharge and overdischarge.  
 - Protection against overvoltage and overcurrent.  
 - Protection against overtemperature and overvoltage.



• Short circuit protection: during the short circuit, the current is very high. The thermal fuse (HTF) or the PTC must be able to protect the system.



• Overvoltage protection: the maximum voltage is reached when all cells are fully charged. The overvoltage must be limited to avoid damage to the cells.



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