

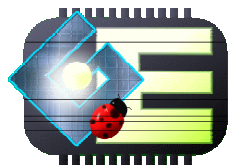
綠能電子聯盟

車用電源管理產學論壇

演講題目：電動車電池管理系統

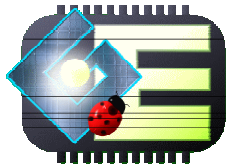
演講者：工研院機械所-柯嘉城

101年03月06日

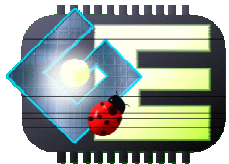


課程內容

-  電動車輛.....
-  電池系統組成.....
-  電池管理系統.....
-  電池系統測試驗證.....

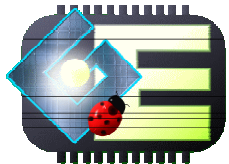
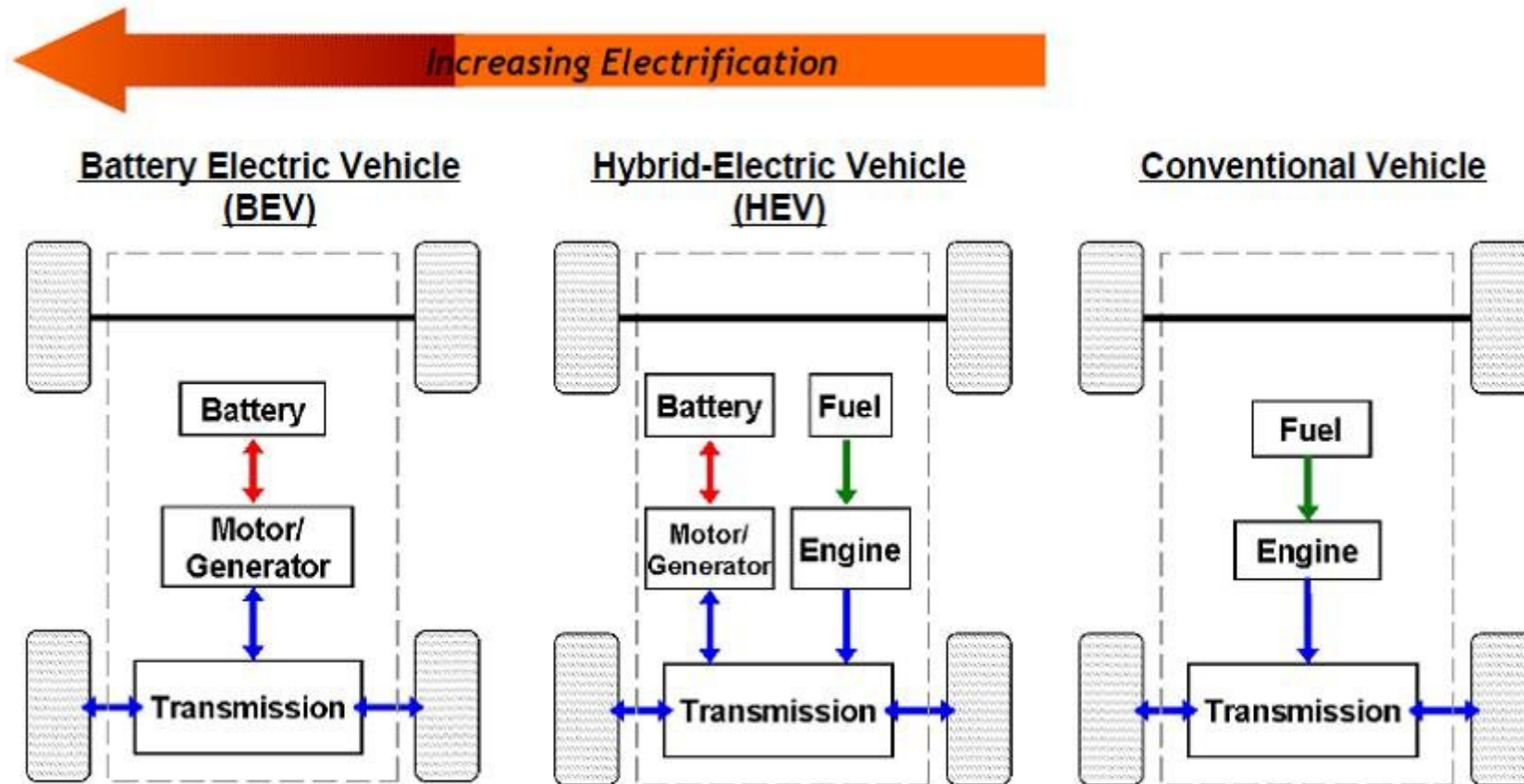


1. 電動車輛



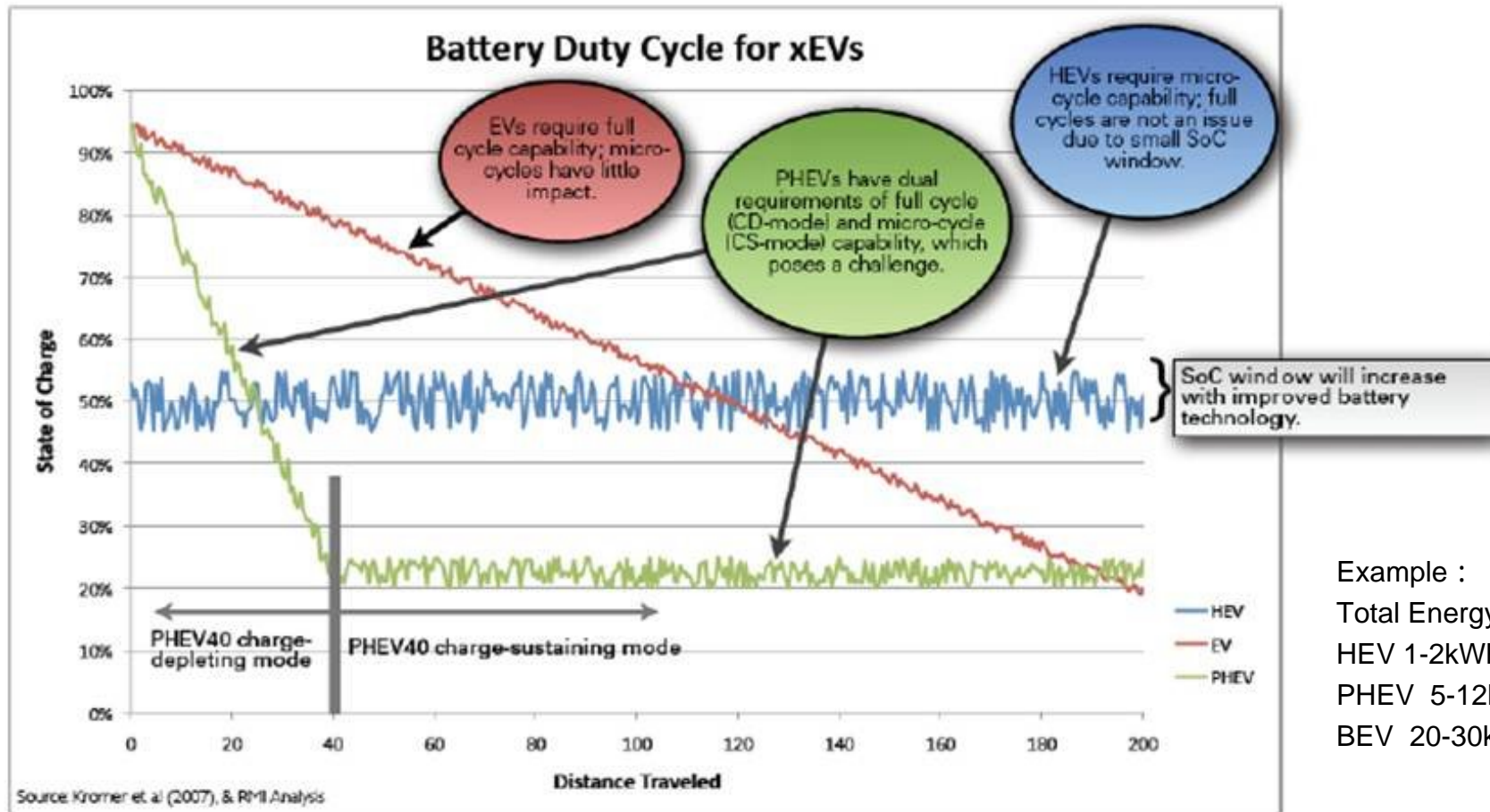
車輛動力電動化

電動車輛包括混合動力、插電式混合動力、純電動車

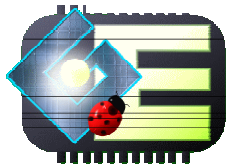


xEV 電池運作週期

電動車輛電池放電循環



Example :
Total Energy
HEV 1-2kWh
PHEV 5-12kWh
BEV 20-30kWh



電動車電動動力組件

充電&電力系統

交流充電柱



AC

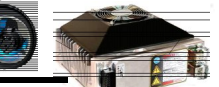


DC

快速充電機

電能儲存系統

車載充電機



AC

DC

電池組



DC

DC

電動動力系統

整車控制器



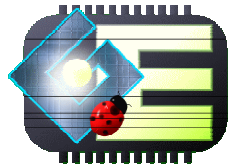
驅控器



馬達



AC



電動車與快充設備

快充機



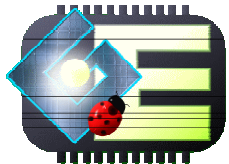
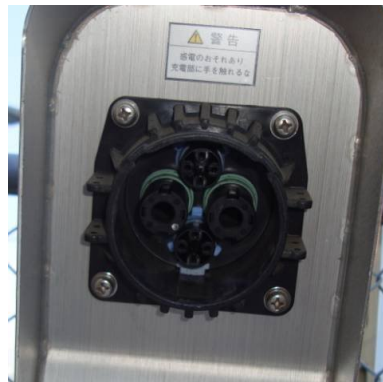
iMiEV



充電機插頭



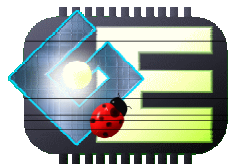
充電機插座



EV儲能-鋰電池

鋰電池是全球電動車輛儲能系統主流

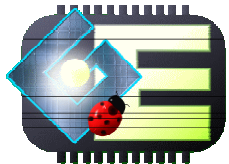
| | | | | | | | | | | |
|------|---|---|---|--|---|---|---|---|---|---|
| 車廠 | TOYOTA | LEXUS | VW Porsche | GM Chevrolet | GM SATURN | HONDA | FORD | M-Benz | Nissan | Mitsubishi |
| 車型名稱 | Prius III | RX400h II | Cayenne Hybrid | Volt | Vue Green Line 2 | CR-Z | EDGE | Smart EV | Leaf | i-MiEV |
| 車輛型式 |  |  |  |  |  |  |  |  |  |  |
| 量產年份 | 2009年 | 2009年 | 2010年 | 2009年 | 2009年 | 2009年 | 2010年 | 2010年 | 2010年 | 2009年 |
| 動力配置 | HEV | HEV | HEV | PHEV | PHEV | HEV | HEV | EV | EV | EV |
| 電池系統 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 | 鋰電池 |



大車廠電池供應鏈

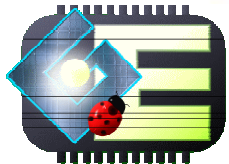
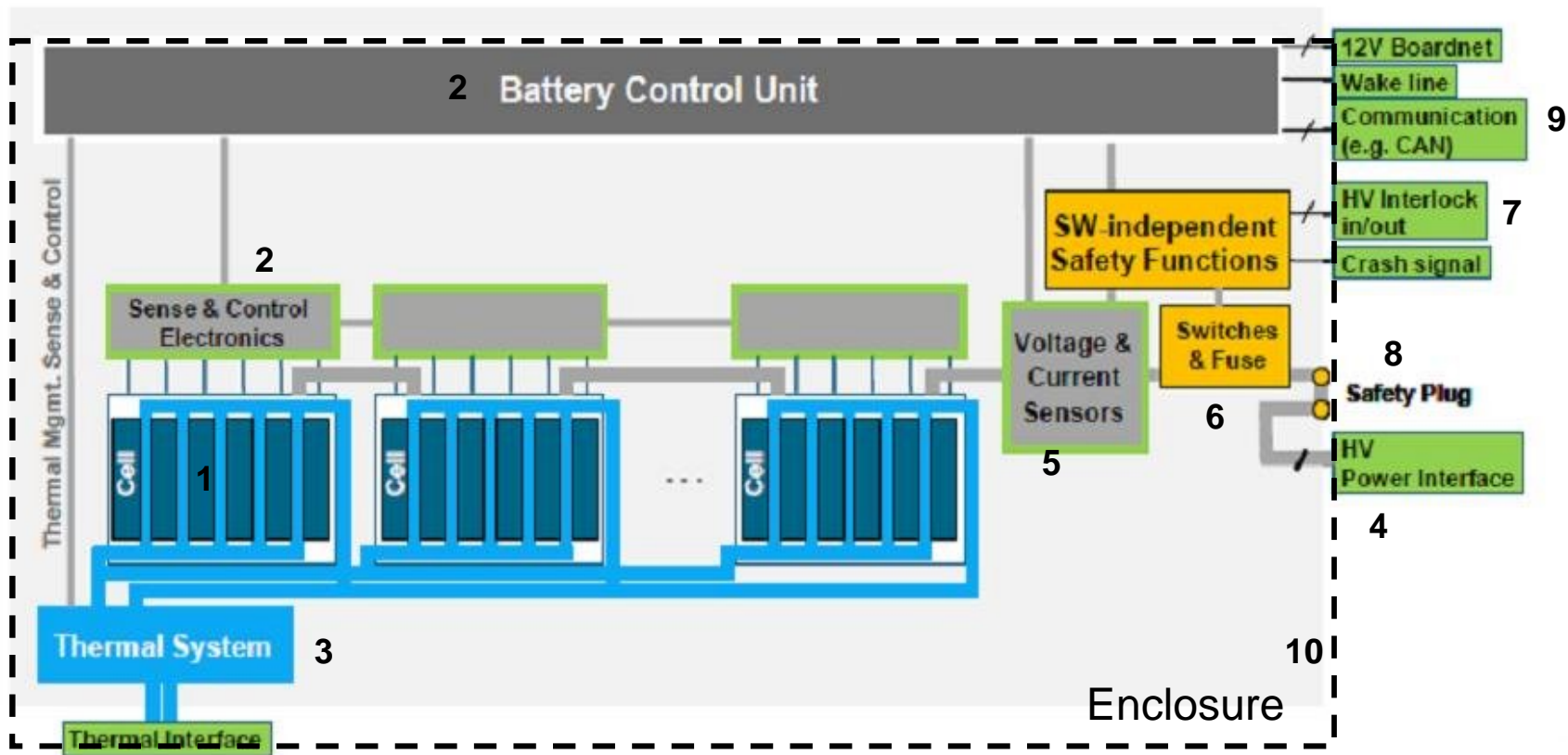
大車廠、電池廠、Tier 1電裝廠整合電動車電池供應鏈

| Vehicle Manufacturer | Battery Cell Supplier | Battery Supplier | Battery Electronics Supplier | Year of Introduction |
|----------------------|-----------------------|-------------------------|------------------------------|----------------------|
| General Motors | LG Chem | Compact Power | Compact Power | 2010 |
| Ford | Saft | Johnson Controls, Magna | JCI, Delphi | 2010 |
| Chrysler | A123Systems | A123Systems | Continental | 2011 |
| Toyota | Panasonic EV Energy | Panasonic EV Energy | Denso | 2010 |
| Renault Nissan | NEC | NEC | NEC, Hitachi | 2010 |
| Hyundai | LG Chem | Compact Power | Compact Power, Denso | 2013 |
| BMW | Saft | Johnson Controls | JCI, AC Propulsion | 2012 |
| Daimler | Li-Tec, Saft | Continental, Tesla | Continental | 2010 |
| Mitsubishi | GS Yuasa | GS Yuasa | Mitsubishi Electric | 2010 |
| Volkswagen | Toshiba | Toshiba | Continental, ZF | 2010 |



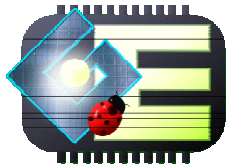
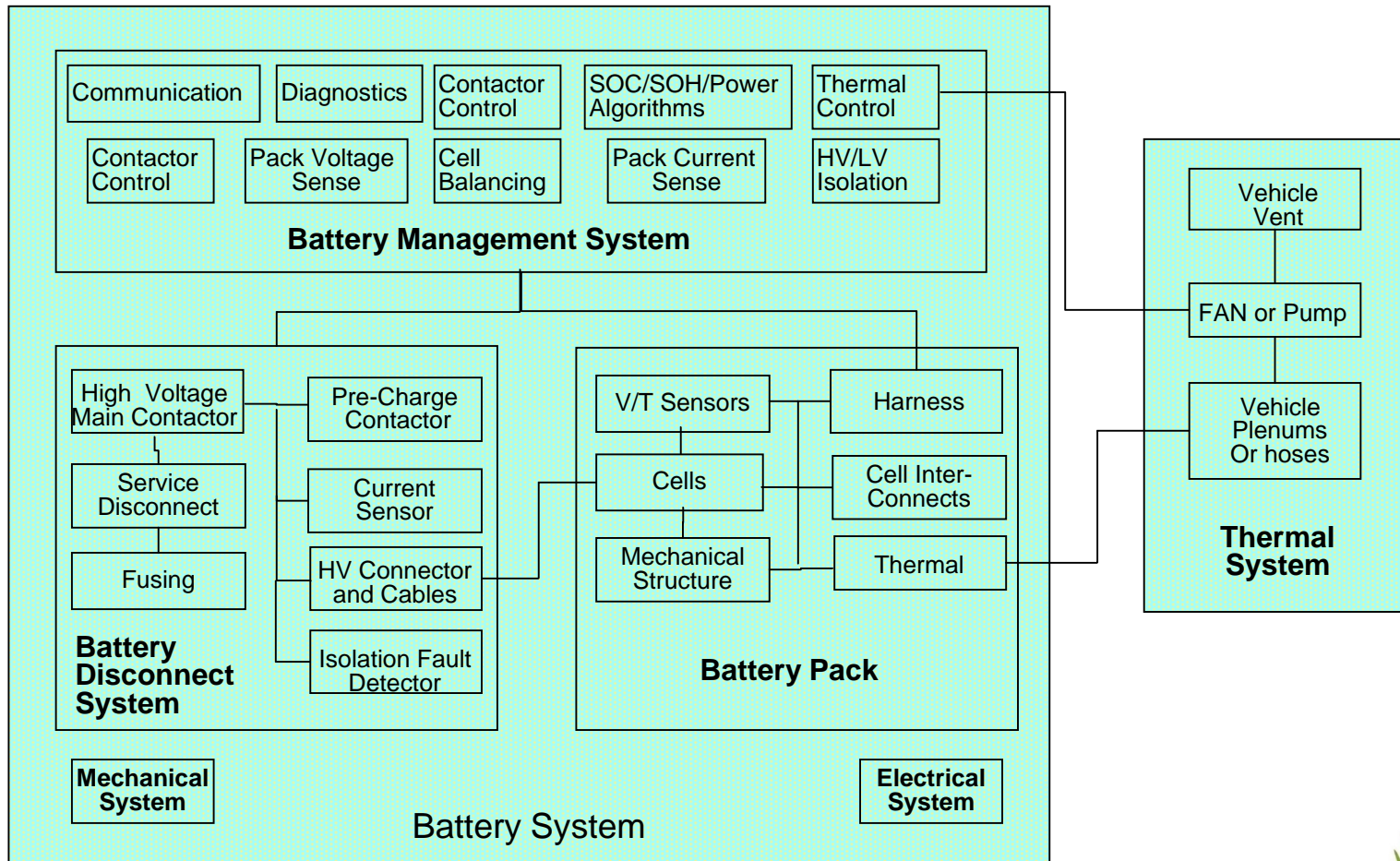
2. 電池系統組成

- 1.Cell/Module
- 2.Sense & Control, Battery Control Unit (BMS)
- 3.Thermal System
- 4.HV Power IF
- 5.V & A Sensors
- 6.Switches & Fuse
- 7.HVIL
- 8.Safety Plug
- 9.Communication
- 10.Enclosure



電池系統功能方塊圖

BMS + Battery Disconnect System + Battery Pack + Thermal System

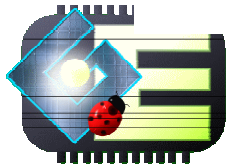
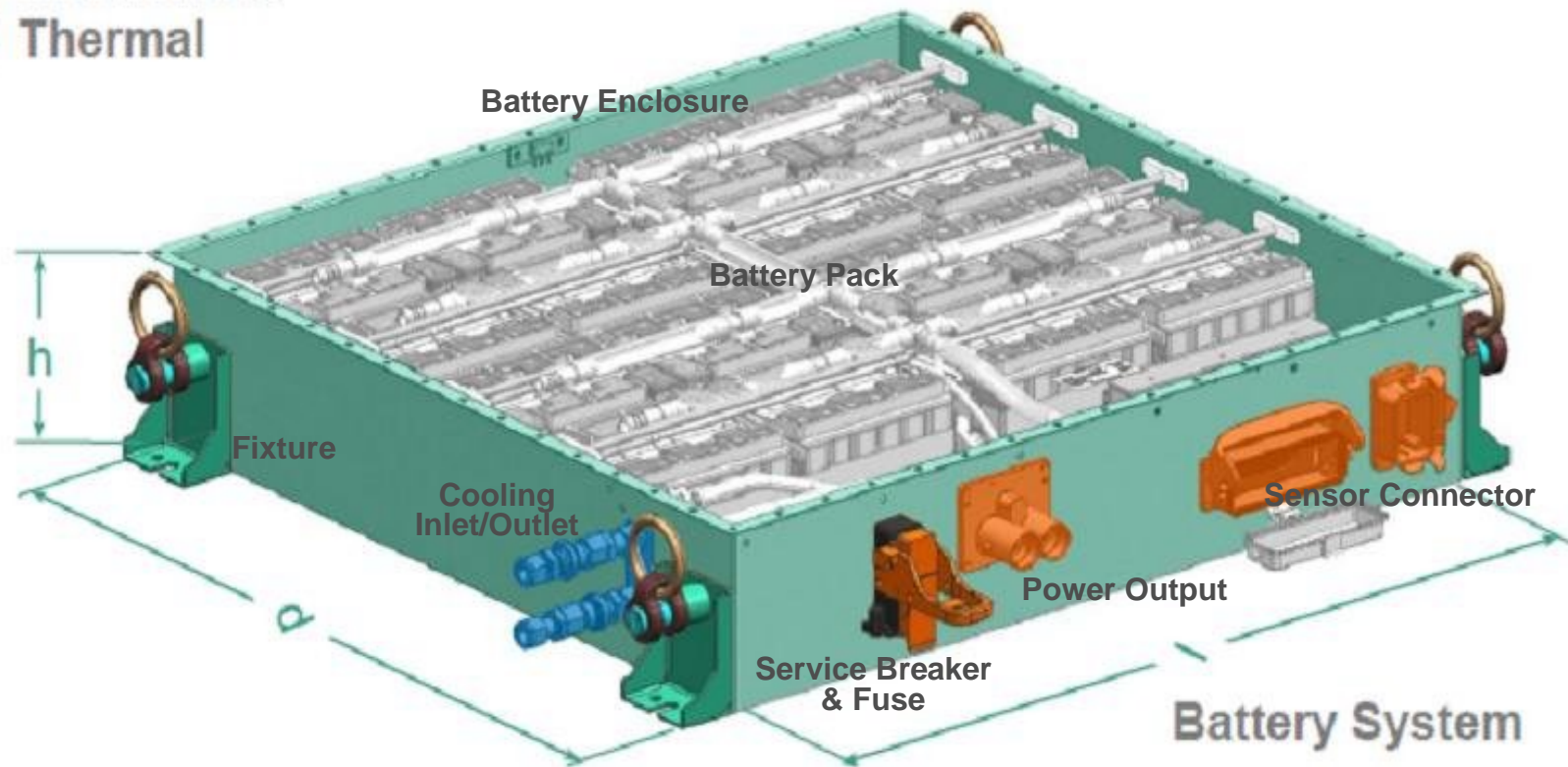


電池系統界面

電力輸出/充電連接器、手動服務開關及保險絲；電池組機箱及散熱用進出水口等

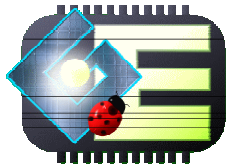
Interfaces

- Electrical
- Mechanical
- Thermal



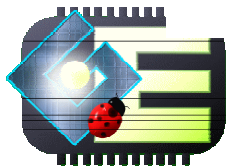
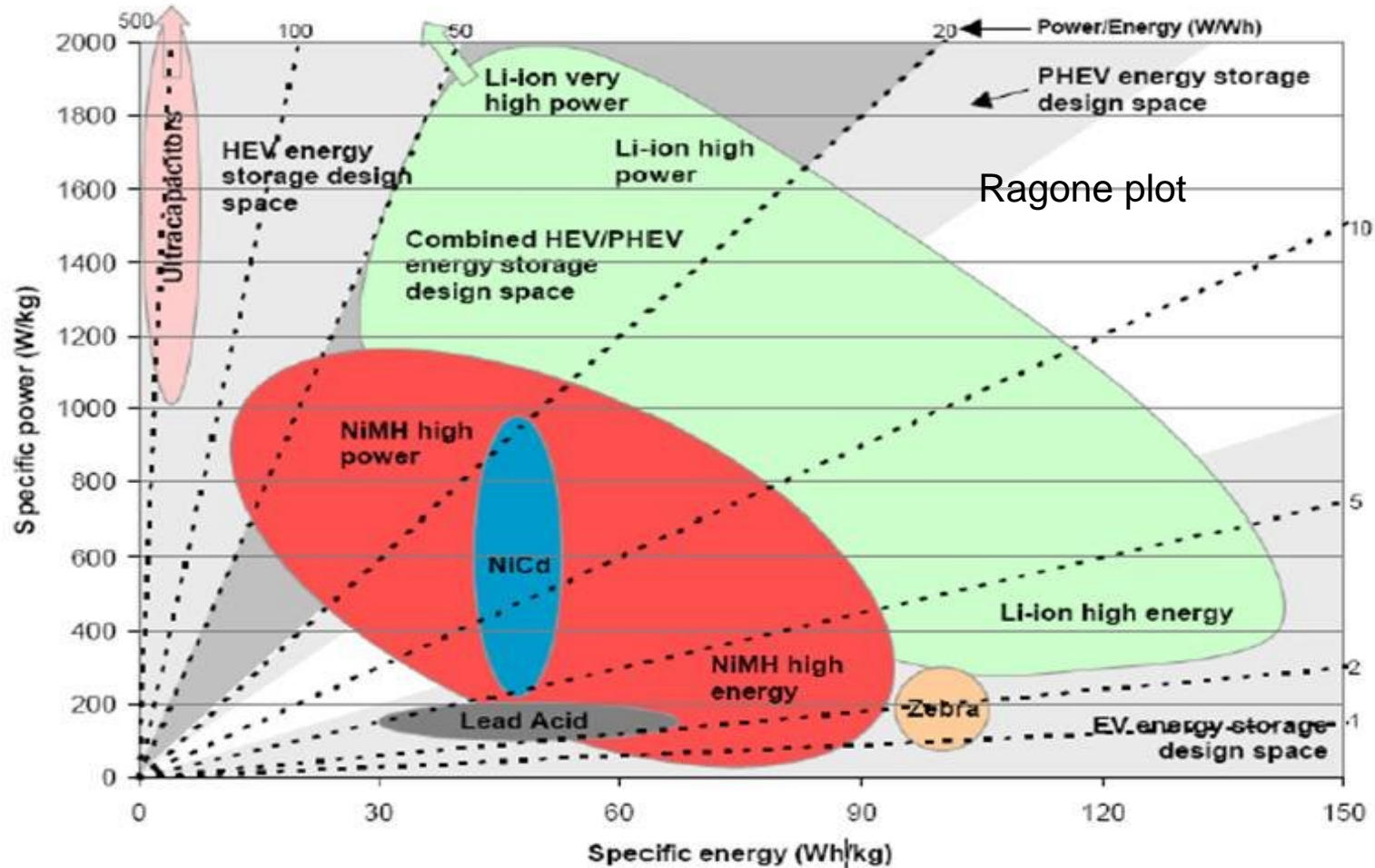
電動車電池指標特性

| | |
|---|--|
| Safety | No Fire / No Explosion / Thermal Runaway |
| Life | Cycle Life / Calendar Life |
| Cost | \$ / kWh/Cycle ; \$ / kWh/Total |
| Discharge Performance Energy Density | Wh/kg ; Wh/liter Internal Resistance & Temperature Effect |
| Discharge Performance Power Density | W/kg ; W/liter Internal Resistance & Temperature Effect |
| Charge Performance | Fast Charging / Charge Control |
| Self-Discharge | Rate vs SOC Rate vs Temperature |
| Reliability | Abuse Loading Quality Control |
| Storage & Transportation | Shipping Limitation / Maintenance |
| Memory Effect | Charge / Discharge @ any SOC |
| Environmentally friendly | Toxic Material / Recycling |



電池 Ragone Plot

HEV-High Power, PHEV-Power/Energy, BEV- High Energy



電動車輛電池系統

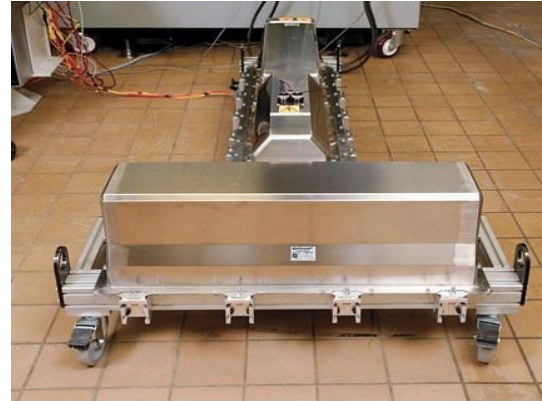
電池系統電能容量依據電動車輛動力需求及空間限制而設計



LG Chem/CPI Battery Pack

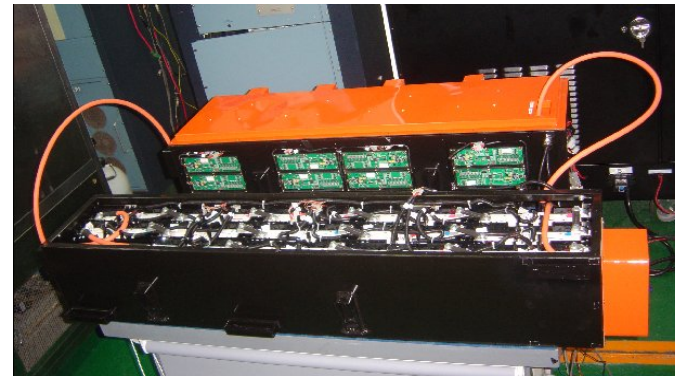


NISSAN Leaf Battery Pack

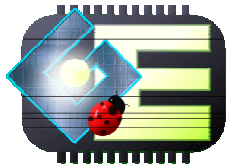


A123 cells in Volt's T-shaped pack. [Photo courtesy GM]

A123 Cells in Volt's T-Shaped Pack



ITRI CP e-Van Battery Pack

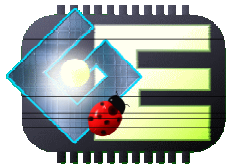
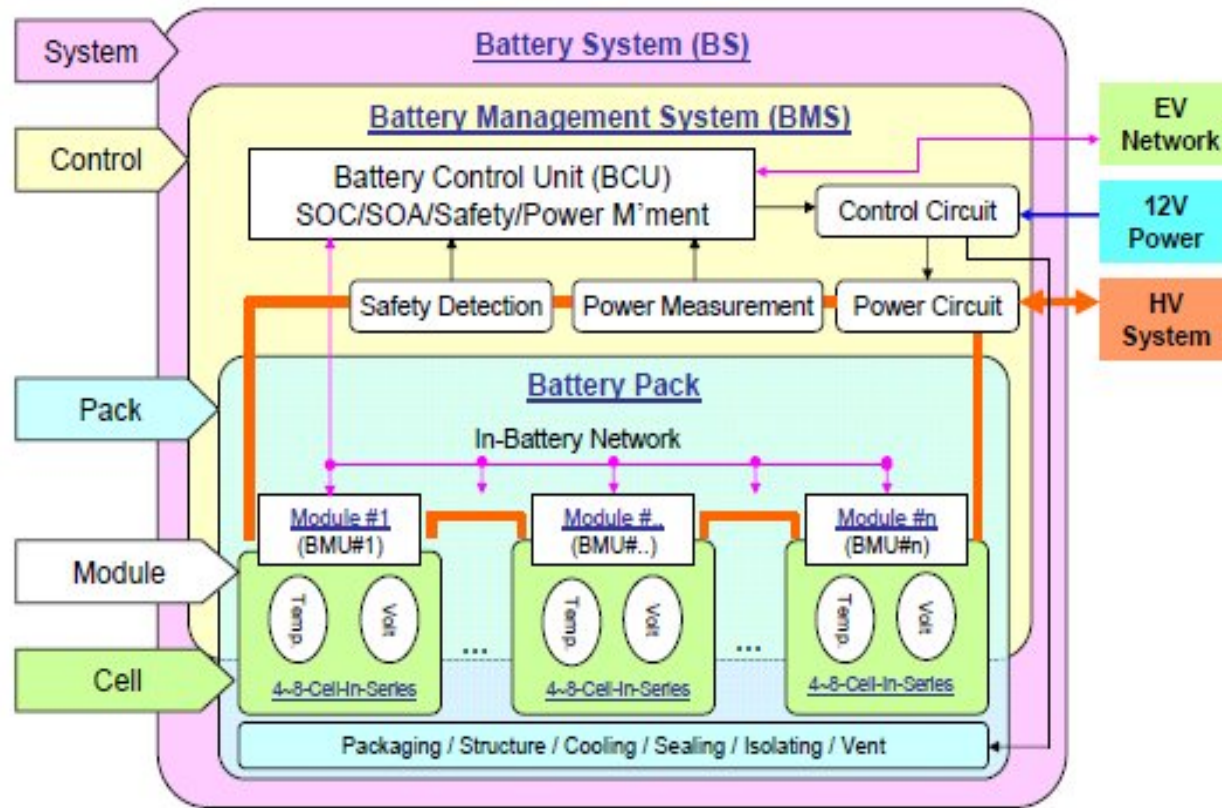


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Green Electronics



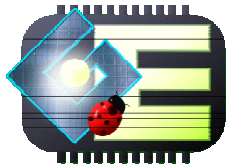
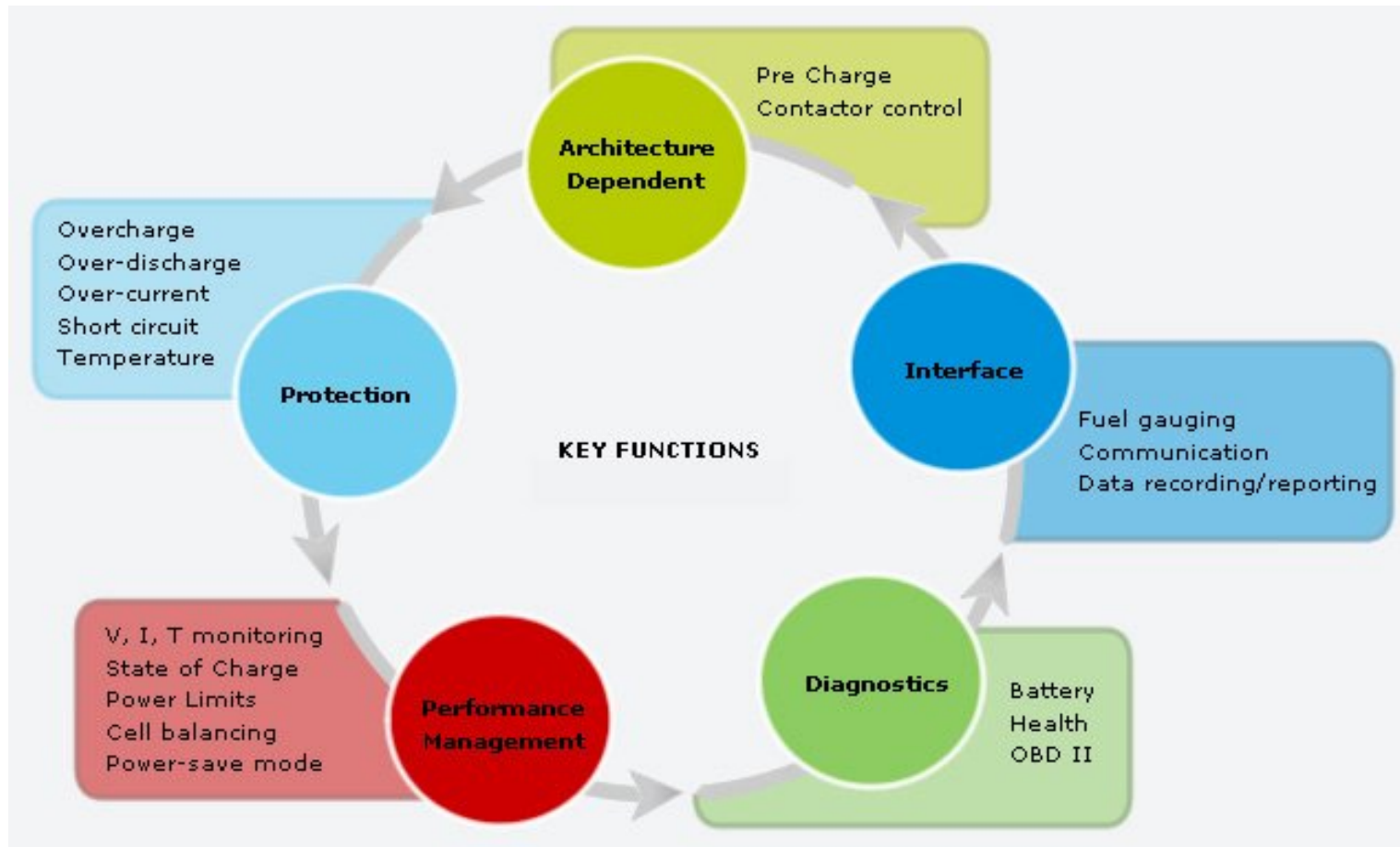
3. 電池管理系統

Battery Management System (BMS) 監控電池電壓、溫度、電流，用於電池保護、充放電控制、SOC/ SOH估測及平衡等化，提高電池組效能、安全性及壽命。



電池管理設計要點

電池性能管理+安全可靠度+偵錯維護性+系統介面



電池管理項目

❑ Battery Safety Protection

Temperature / Voltage / Short / Pressure / Leakage / Impact /

❑ Battery Life Cycle Protection

Temperature / Voltage / Idchg & Depth of DCHG / Ichg & End of CHG / Cooling

❑ Battery Energy Calculation

SOC / SOA(IR) / OCV

❑ Battery Power Calculation

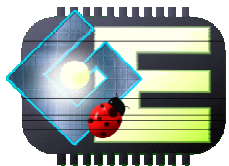
Voltage / IR / Idchg / Ichg / Temperature /

❑ System Reliability

Power Setup & Down / Power Devices Protection / Maintenance - Unbalance & Self-Diagnosis / Communication

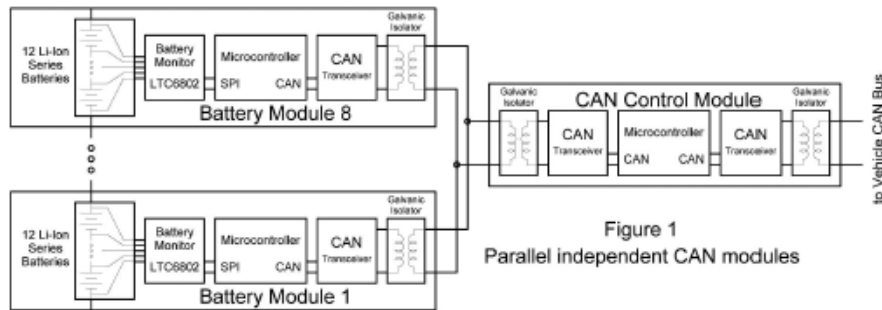
❑ Cost Effective

Battery Optimum Matching / Modular Design /

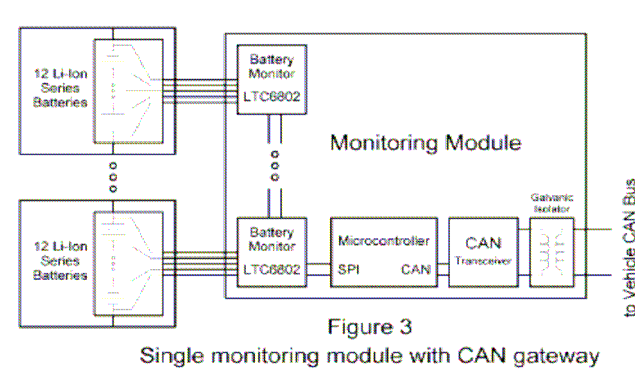


BMS架構

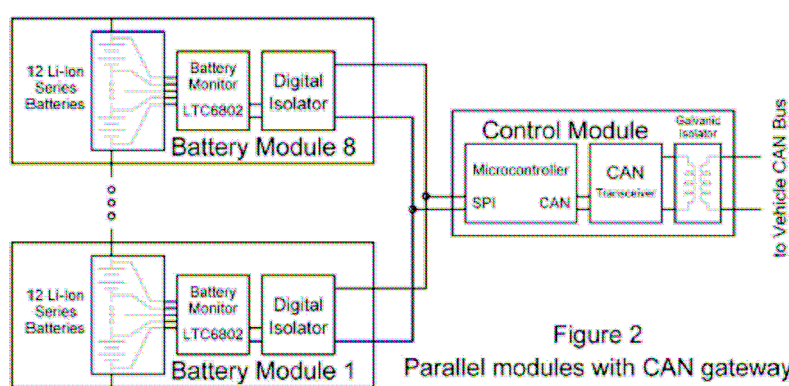
LTC 6802 Base



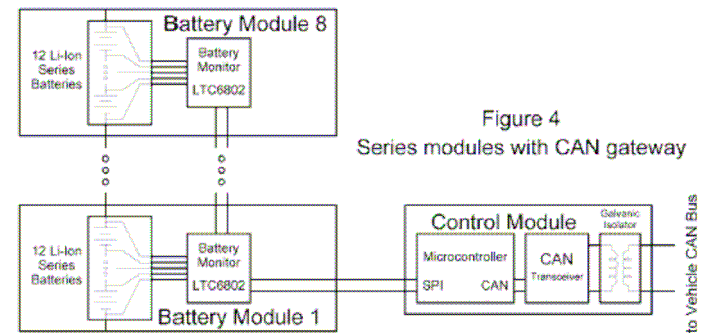
並聯式獨立CAN模組



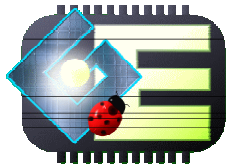
單一監控模組具CAN Gateway



並聯式模組具CAN Gateway



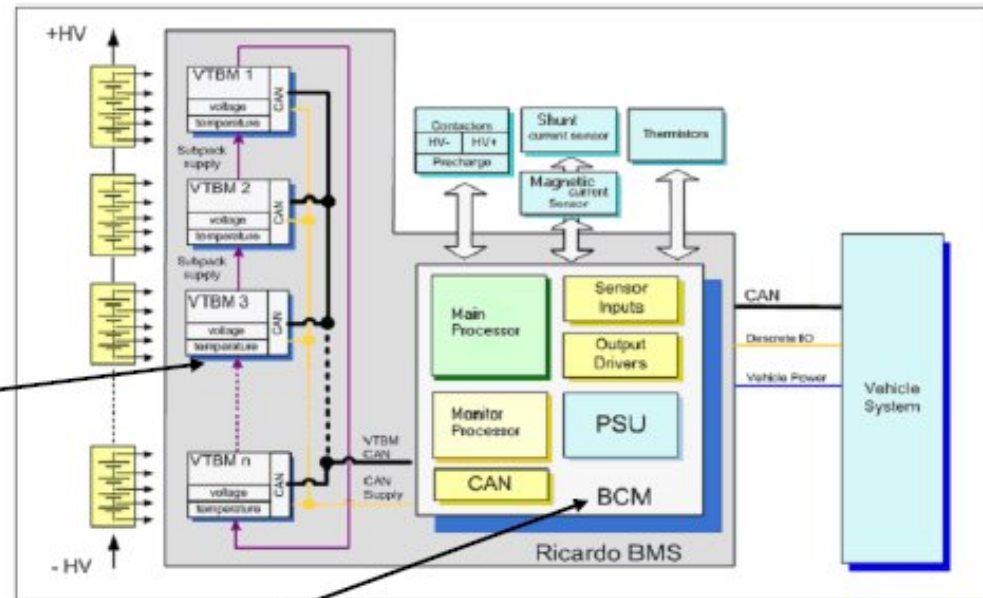
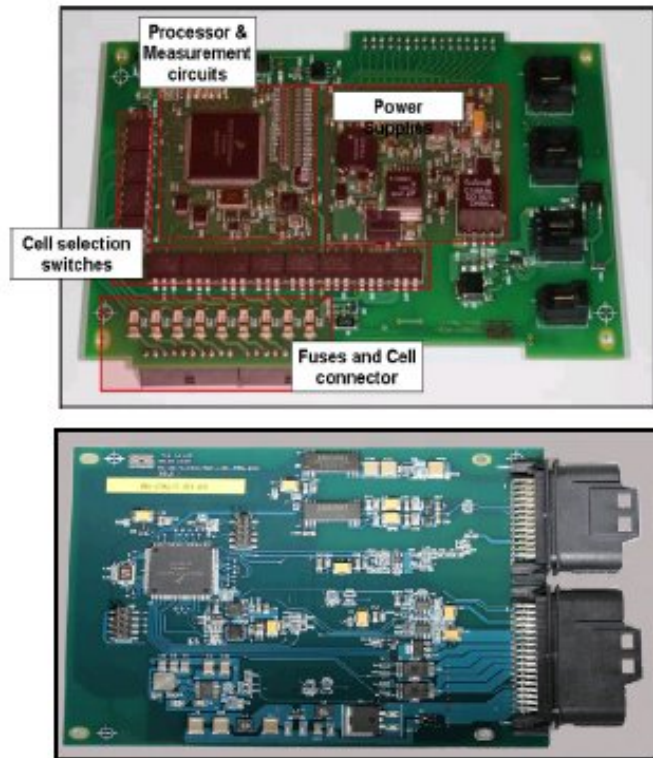
串聯式模組具CAN Gateway



Ricardo BMS 硬體

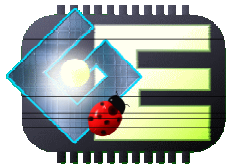
包括多片VTBM用於電池電壓、溫度量測，經由CAN與BCM 連結

VTBM



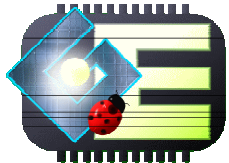
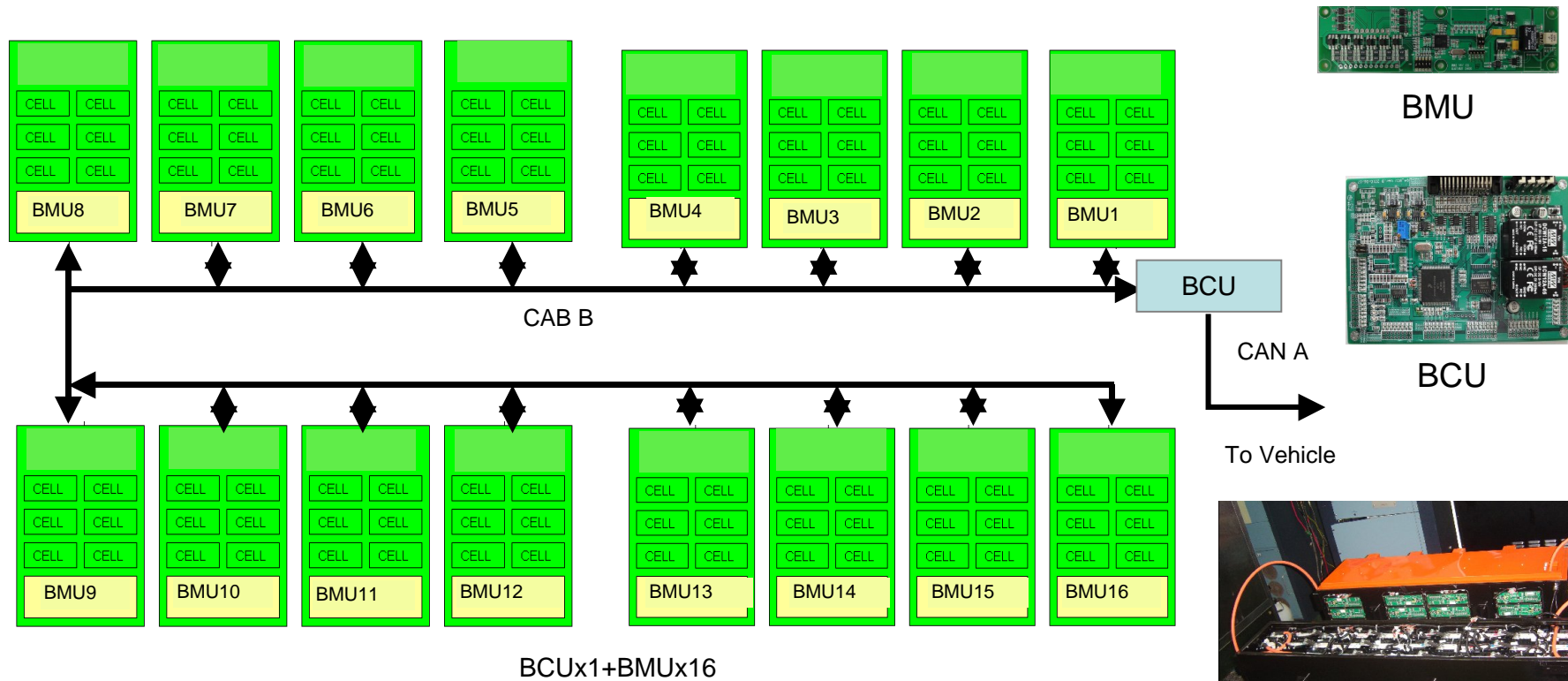
BCM

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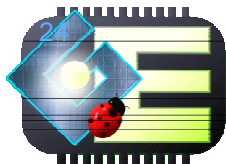
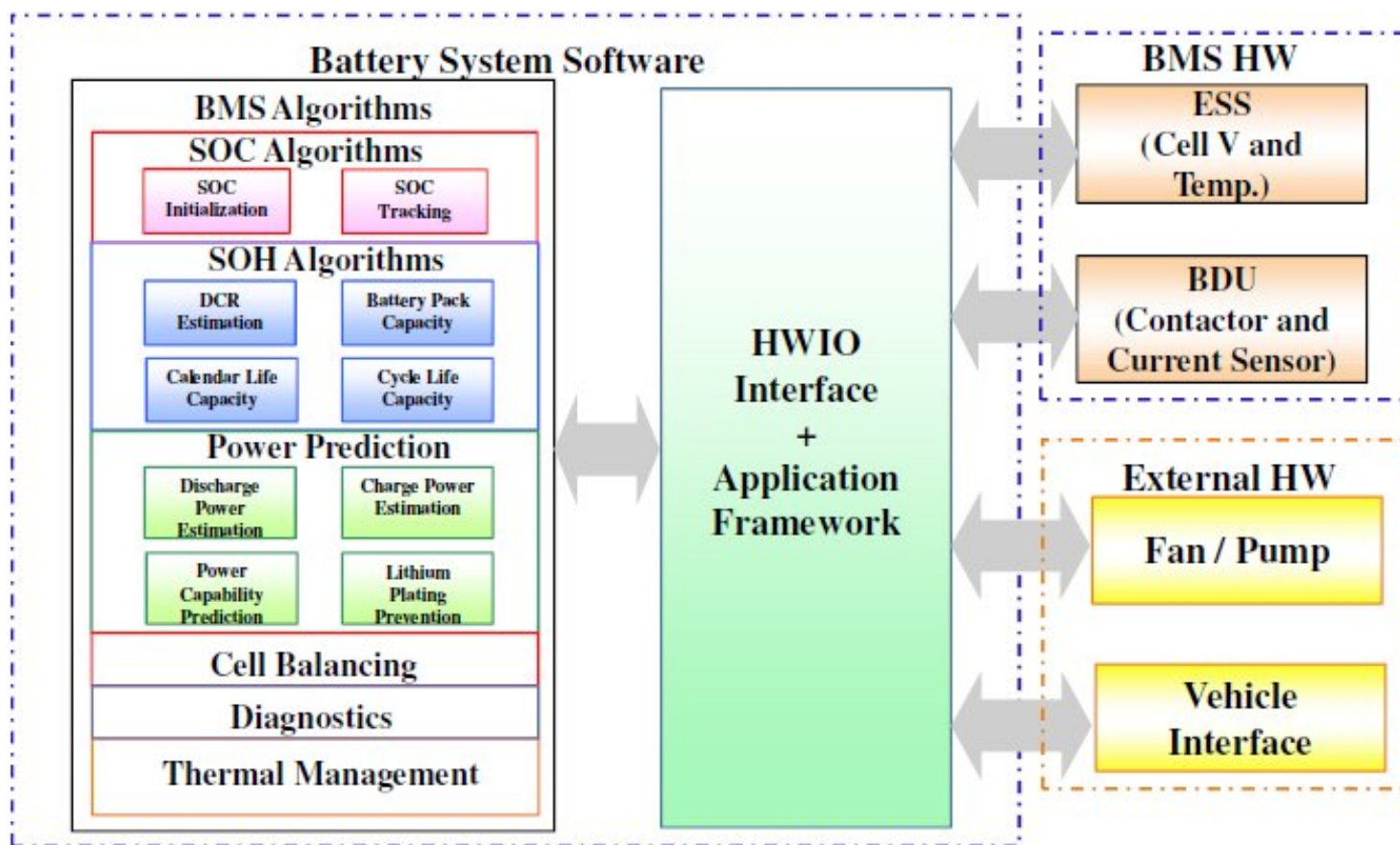
ITRI BMS 硬體

包括多片BMU用於電池電壓、溫度量測，經由CAN與BCU 連結



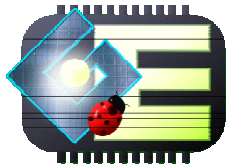
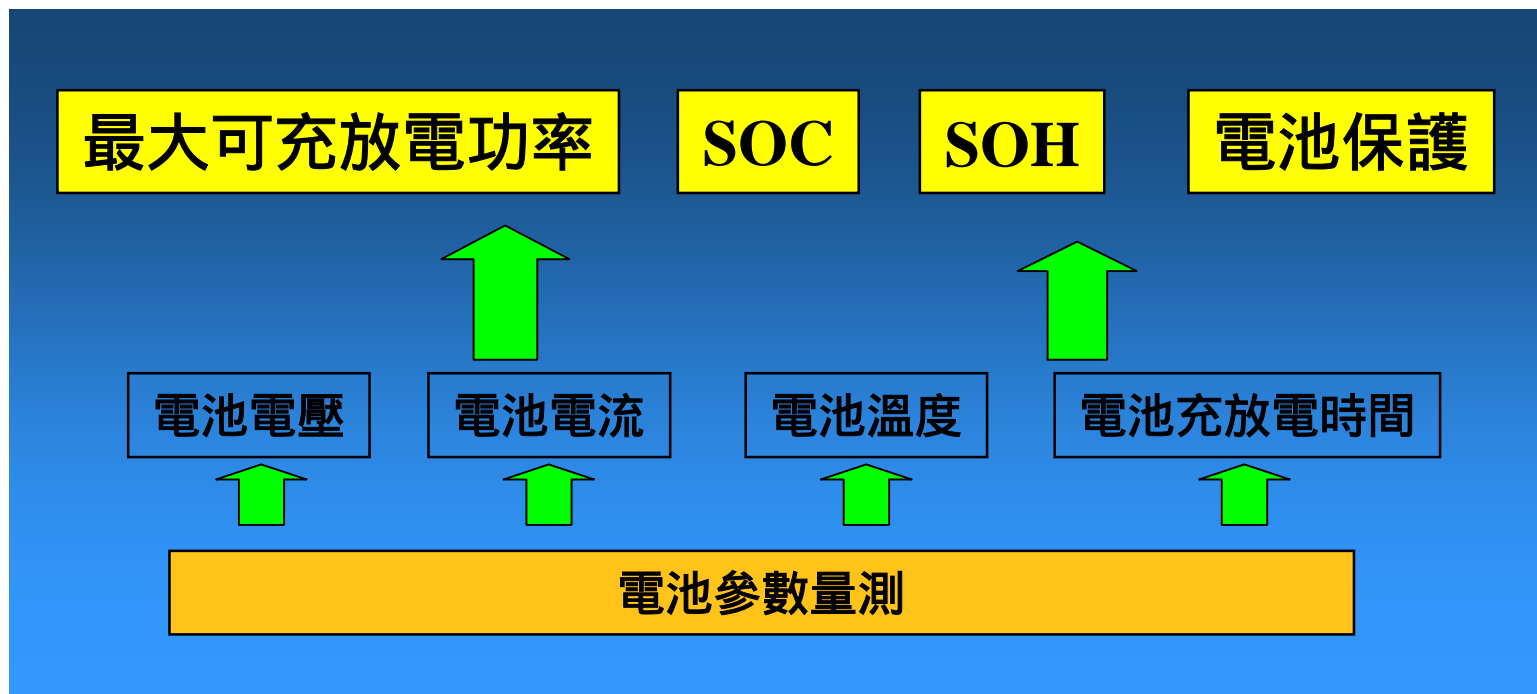
電池管理軟體功能

SOC/SOH/Power Prediction/Cell Balancing/Diagnostics/
Thermal Management等主要軟體功能



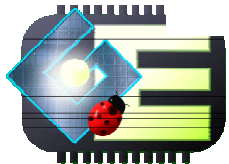
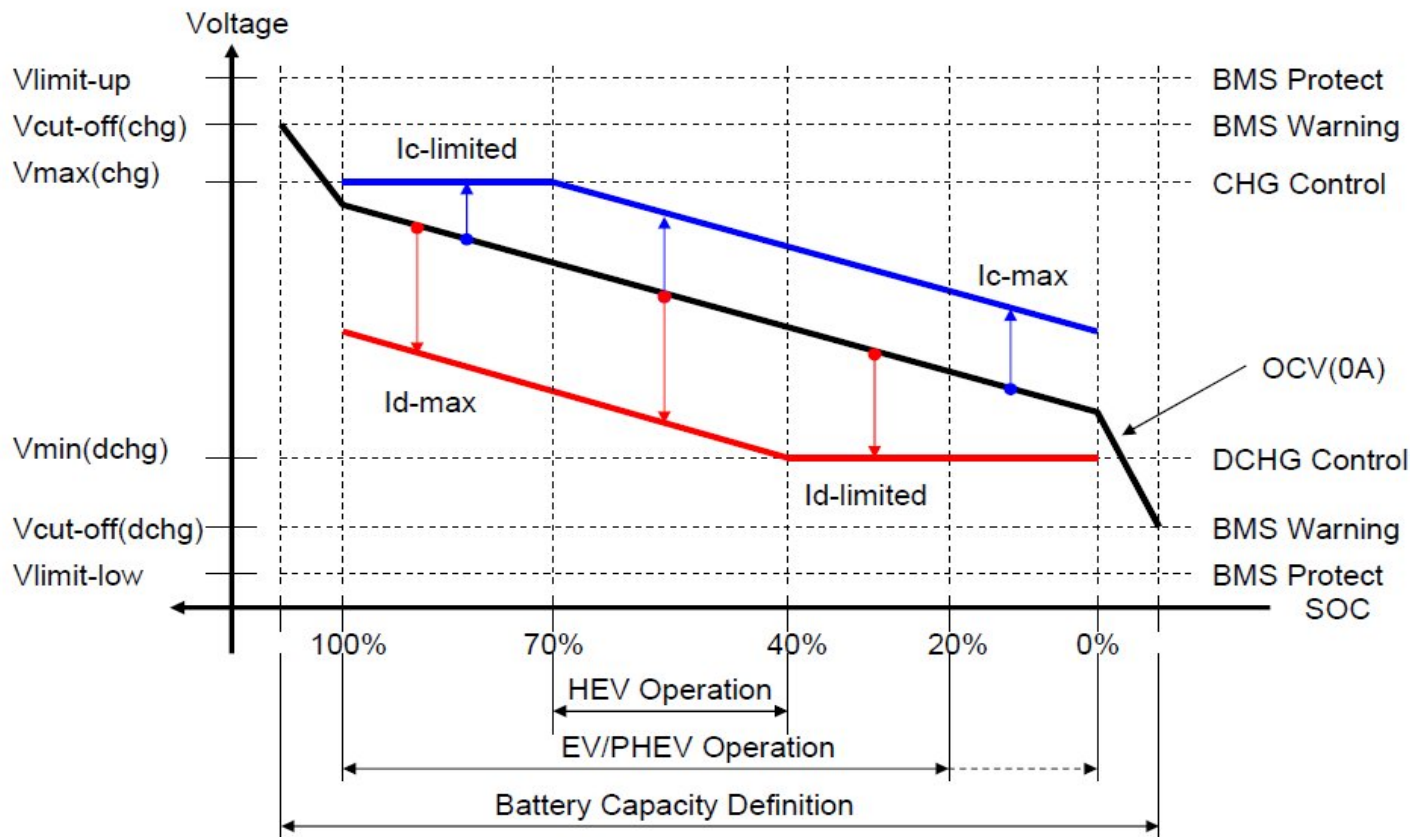
電能管理

- 依據SOC值實現深度放電、滿載負荷功率及安全放電而不影響電池壽命；並依SOC、現行路況及附件耗能估算可持續行駛里程。(放電能力)
- 依SOC、溫度、最大充電電流、電池充電特性等參數及充電設備的充電形式(慢充或快充，AC或DC)，進行充電控制，保護電池組獲得最佳電池壽命。(充電能力)



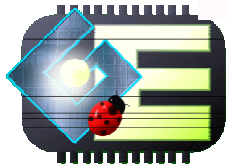
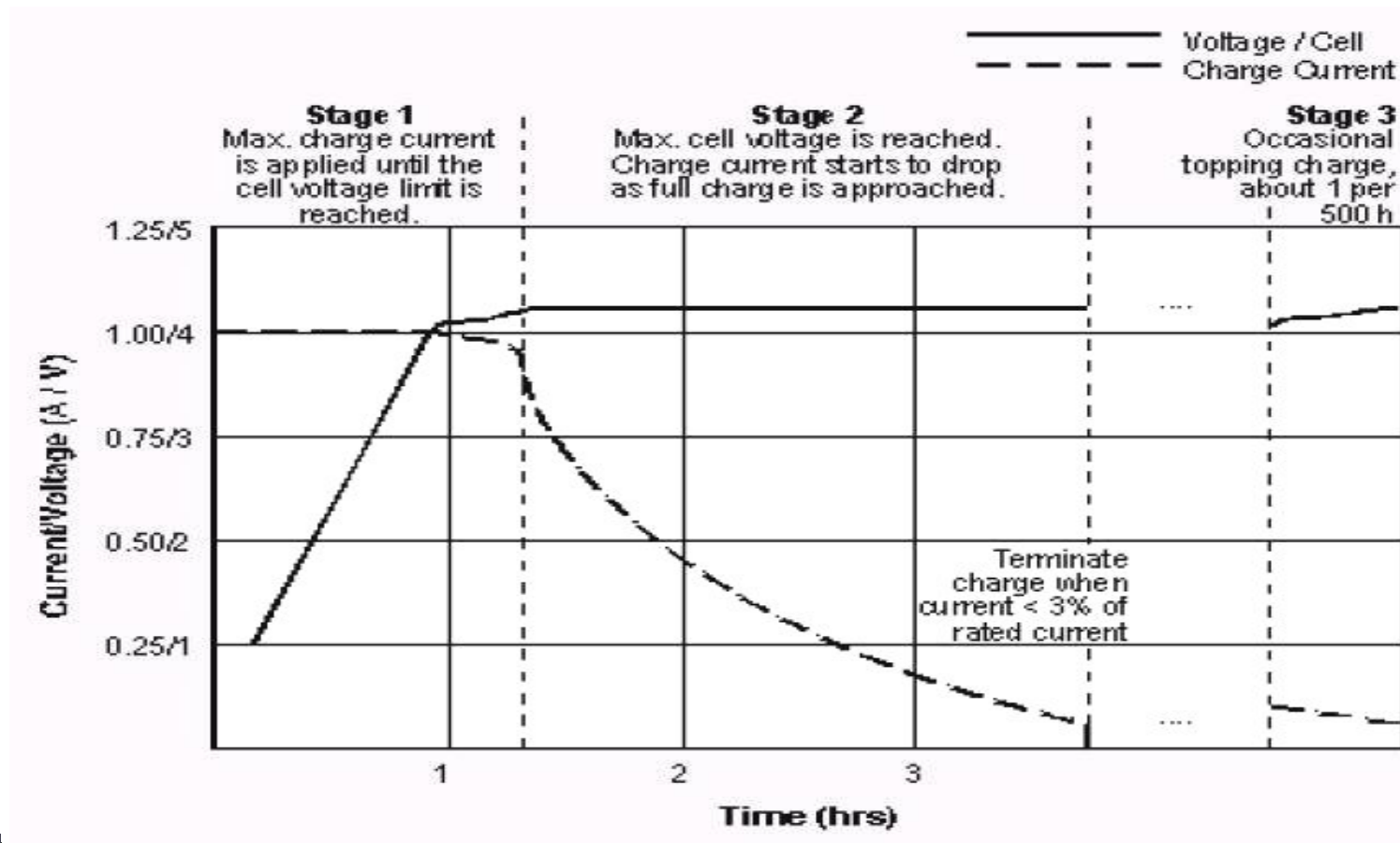
電池充放電控制

- 依SOC值設定最大充放電流及限制值
- 監控各串接電池充放電壓，BMS設定Warning及Protect限制值



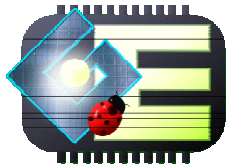
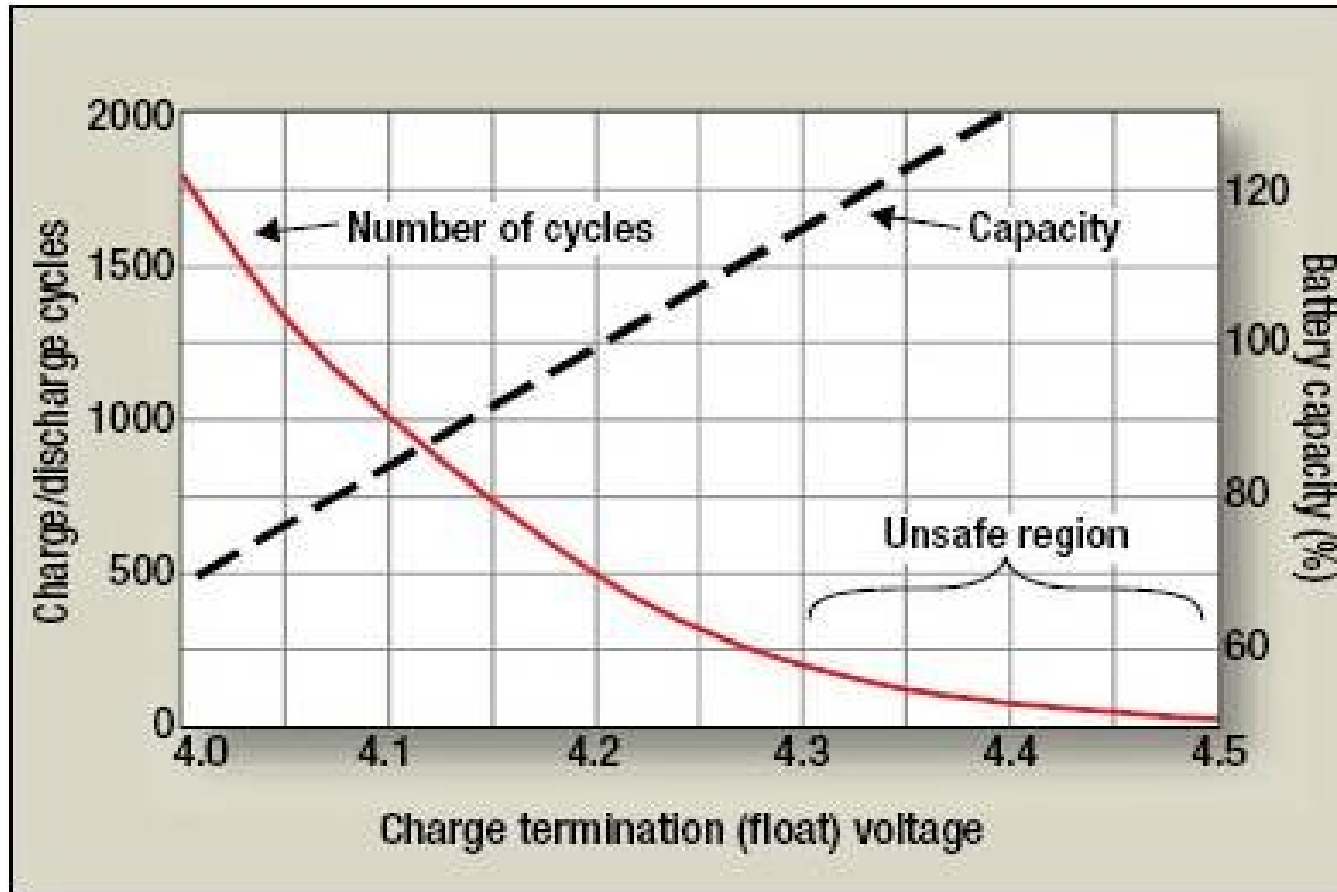
電池充電模式

車載充電為CC(固定電流)充電到設定充電壓值後，轉換成CV(固定電壓)充電到電流小於3%額定電流後截止充電。



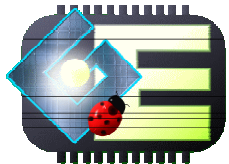
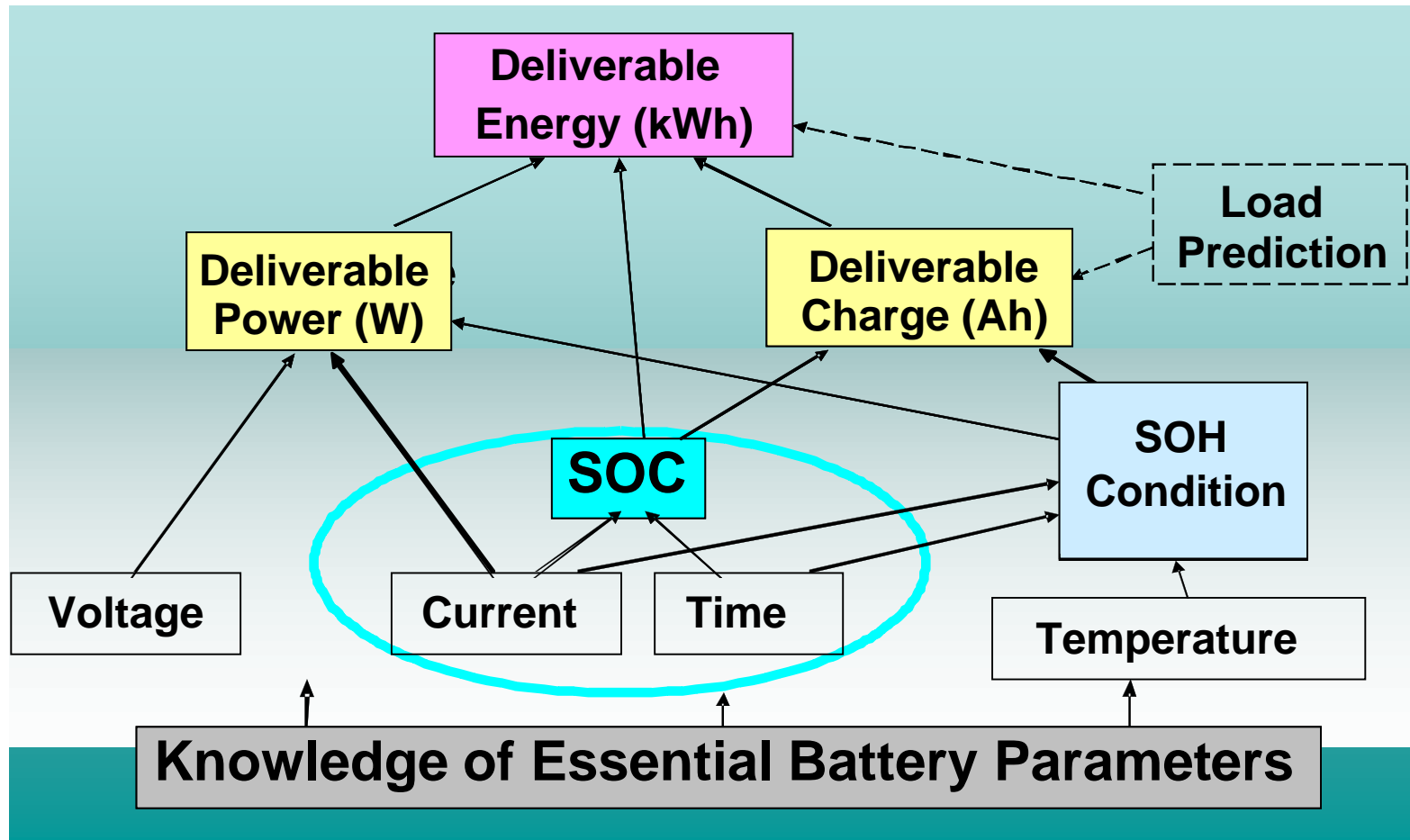
充電電壓影響電池壽命

鋰電池充電電壓4.20V (NCM) or 3.60V (LFP) ，降低充電電壓可延長電池使用壽命



SOC/SOH與電池估算

SOC及SOH計算，用於估測電池放電及充電能力



SOC 估算

- SOC由電池管理系統依電流、電壓、溫度等演算得出。
- SOC精度受動態負載變化、電池種類、電池電化特性、運算能力、演算法等因素影響。
- SOC演算法：開路電壓法、Ah積分法、直流內阻法、負載電壓法、卡爾曼濾波器法...等。

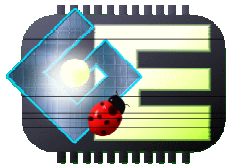
1. OCV法

- ˘ OCV Curve
- ˘ BCU完成開機程序後、主繼電器ON 之前
- ˘ 主繼電器ON 時電池充放電電流小於額定值3%持續超過30秒

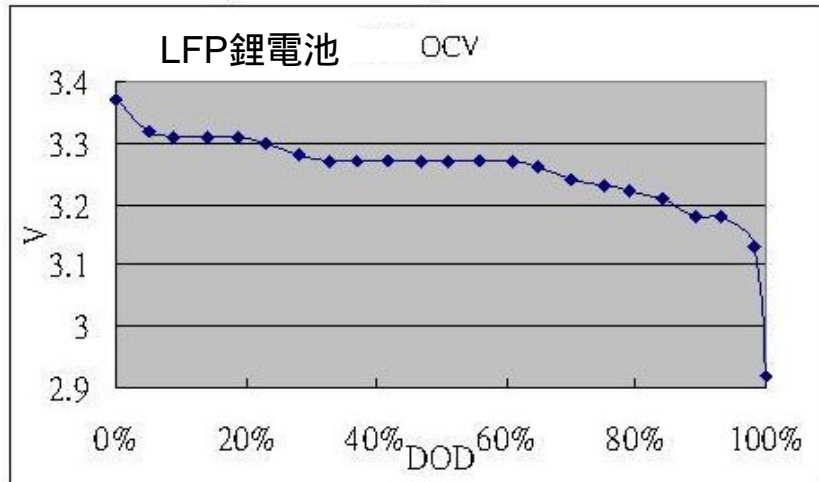
2. Ah積分法

- ˘ $Ah = \int I dt = I^* t$
I：充電時為正；放電時為負， t內之量測電流平均值
- ˘ Kalman filter for SOC Estimation

3. 溫度及老化係數修正



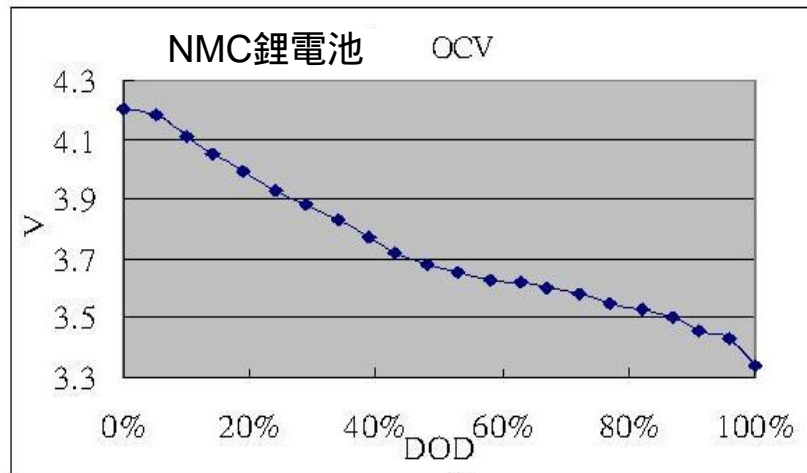
電池SOC與OCV



LFP 鋰鐵電池

左圖放電深度(DOD)5%~95% ,
Vcell 3.32V-3.18V

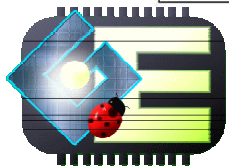
OCV 在SOC值變化90 %的電壓差
值140mv , 有多段電壓平整幾無變
化 , SOC很難由OCV精準估算



NMC三元鋰電池

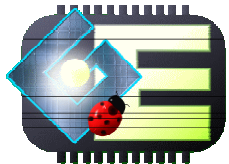
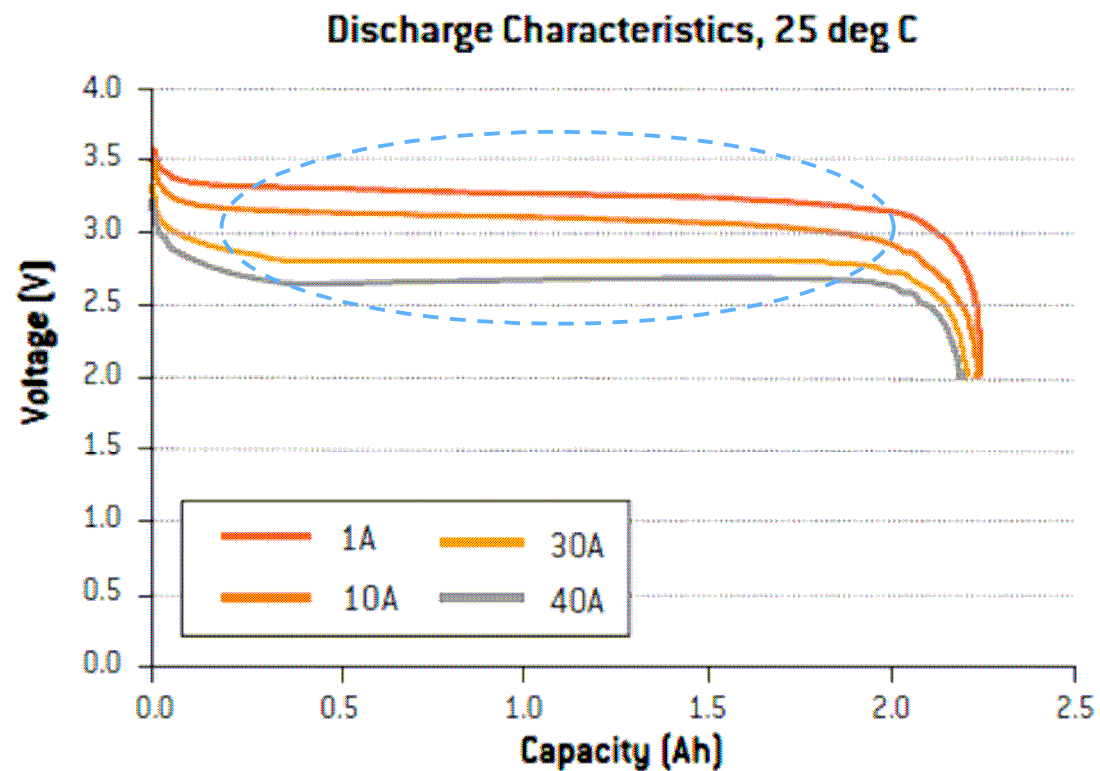
左圖放電深度(DOD)0%~100% ,
Vcell 4.2V-3.32V

OCV 在SOC值變化100 %的電壓差
值880mv , 幾成直線斜率變化 ,
SOC可由OCV精準估算



鋰鐵電池SOC估測

- 鋰鐵電池放電曲線平整，依OCV估測SOC是一挑戰
- Ah積分法在放電過程中估算，常受限於Embedded System運算能力，較大誤差



電池 SOH

偵測出明顯偏移誤差（如，電池短路或失效）

以電池功能特性的能力判別

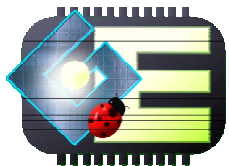
對純電動車而言，能量儲存是比較重要

$SOH = \text{Detected Capacity} / \text{Original Capacity}$

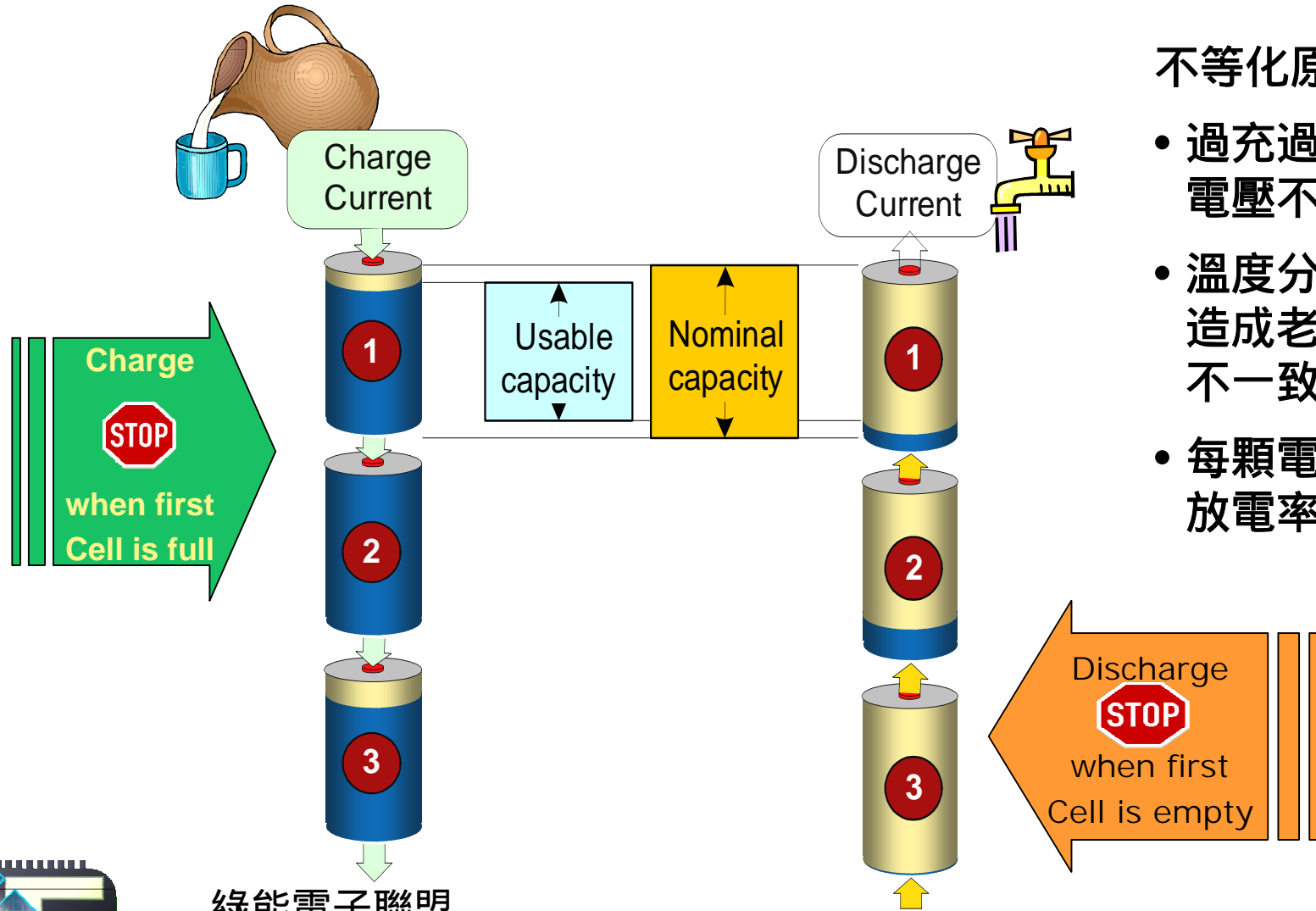
對混合電動車而言，輸出功率是比較重要

$SOH = \text{Detected Conductance} / \text{Original Conductance}$

對插電式混合電動車而言，兩者皆是

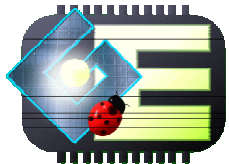


電池不等化影響充放電效能



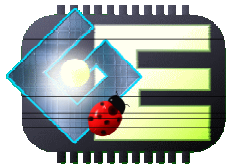
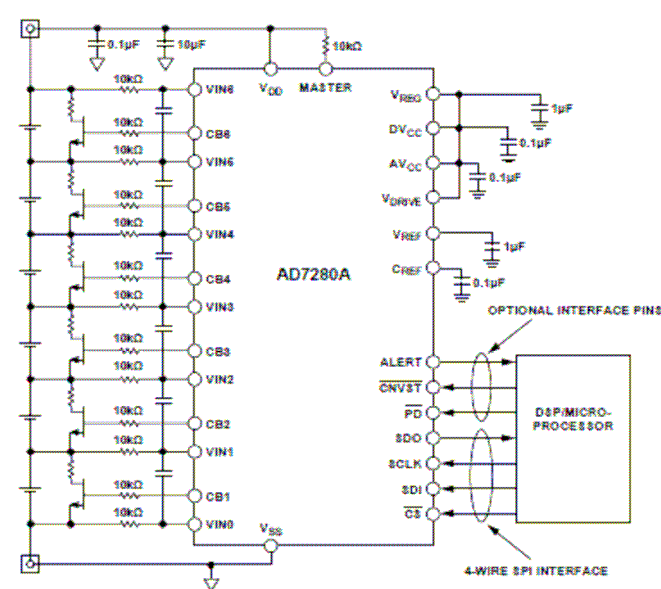
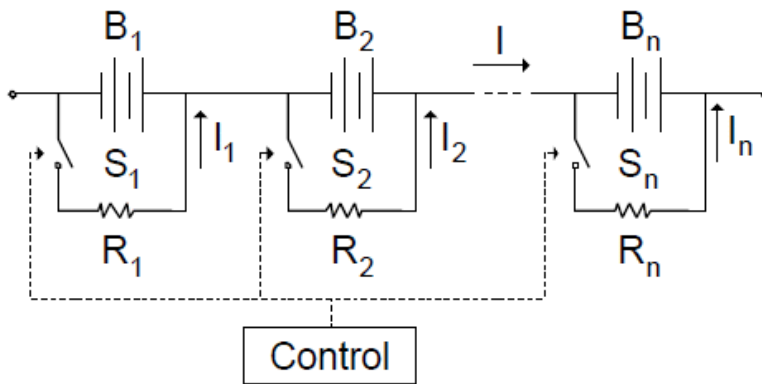
不等化原因

- 過充過放造成電壓不一致
- 溫度分佈不均造成老化速度不一致
- 每顆電池芯自放電率不一樣



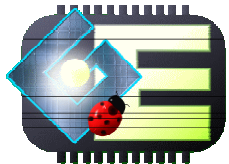
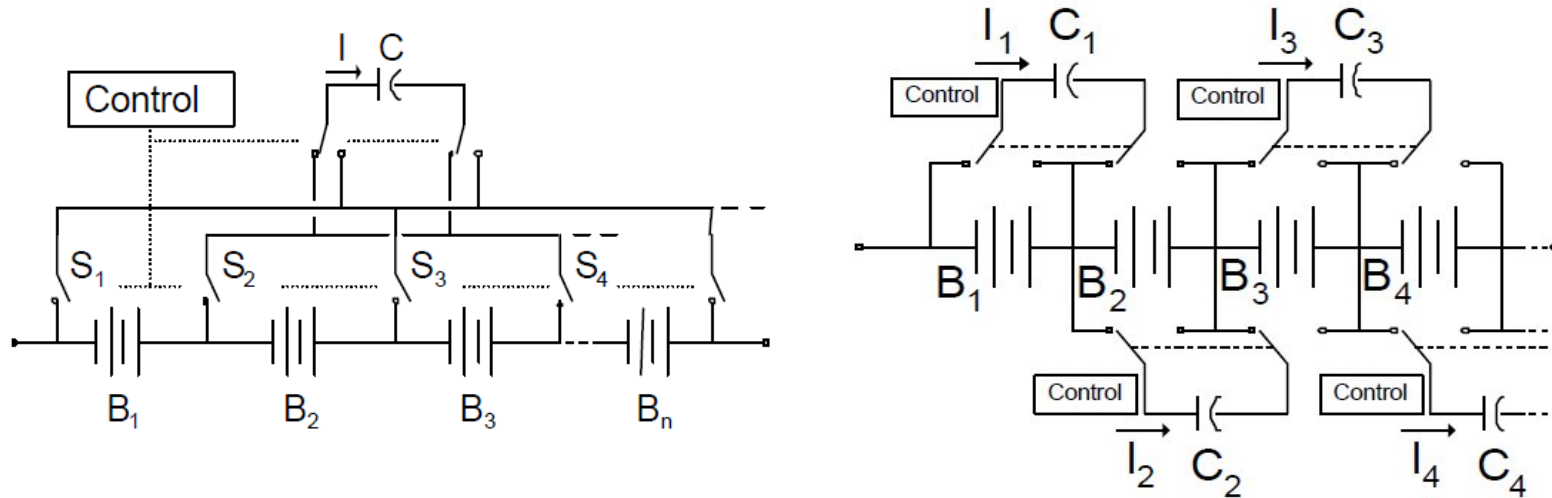
電阻被動式等化平衡

- 電池電阻並聯分流，分散消耗電能
- 高於最低電壓的電池進行分流電阻並聯控制，直到相符合為止
- 簡單便宜，但效率不佳
- 如連續操作，考量電阻散熱及符合電池等化平衡時間需求的分流大小



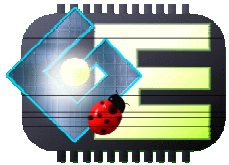
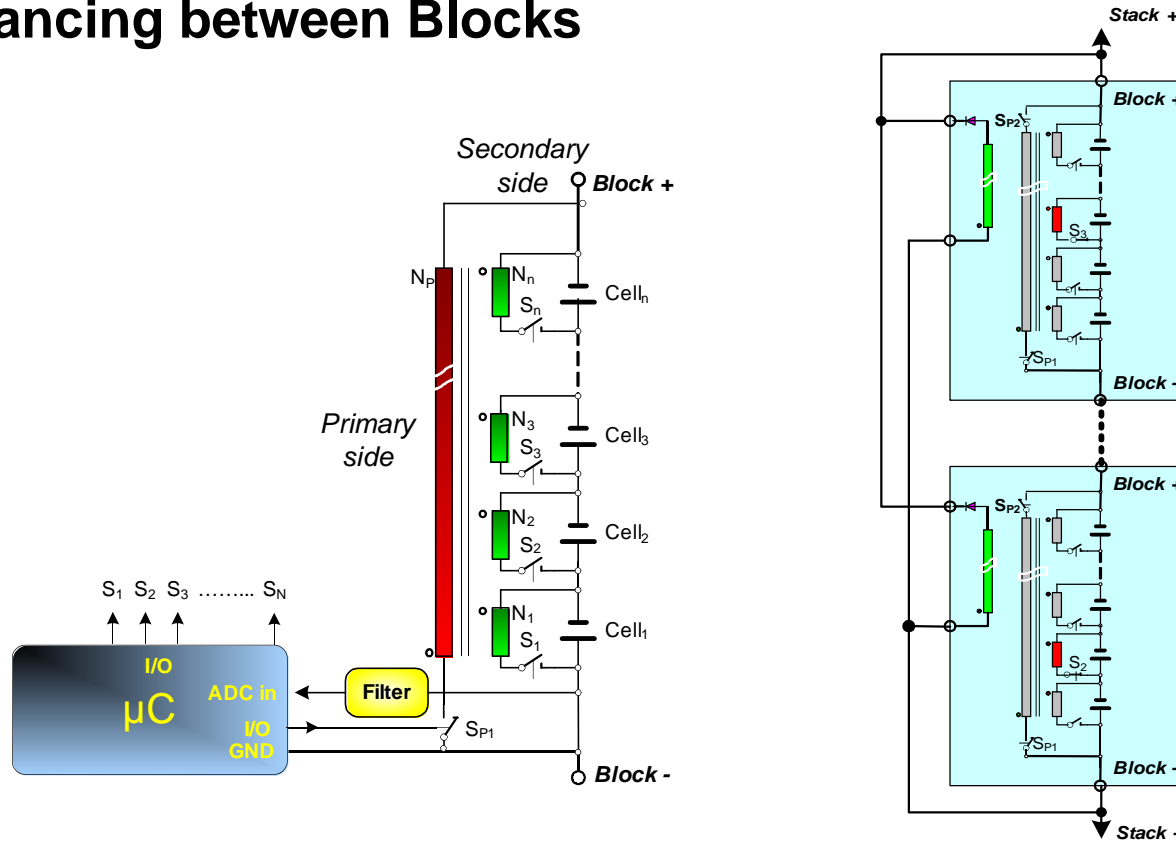
電容主動式等化平衡

使用電容並接較高電壓電池進行充電並抽取電能後，將之轉移儲存到較低電壓的電池

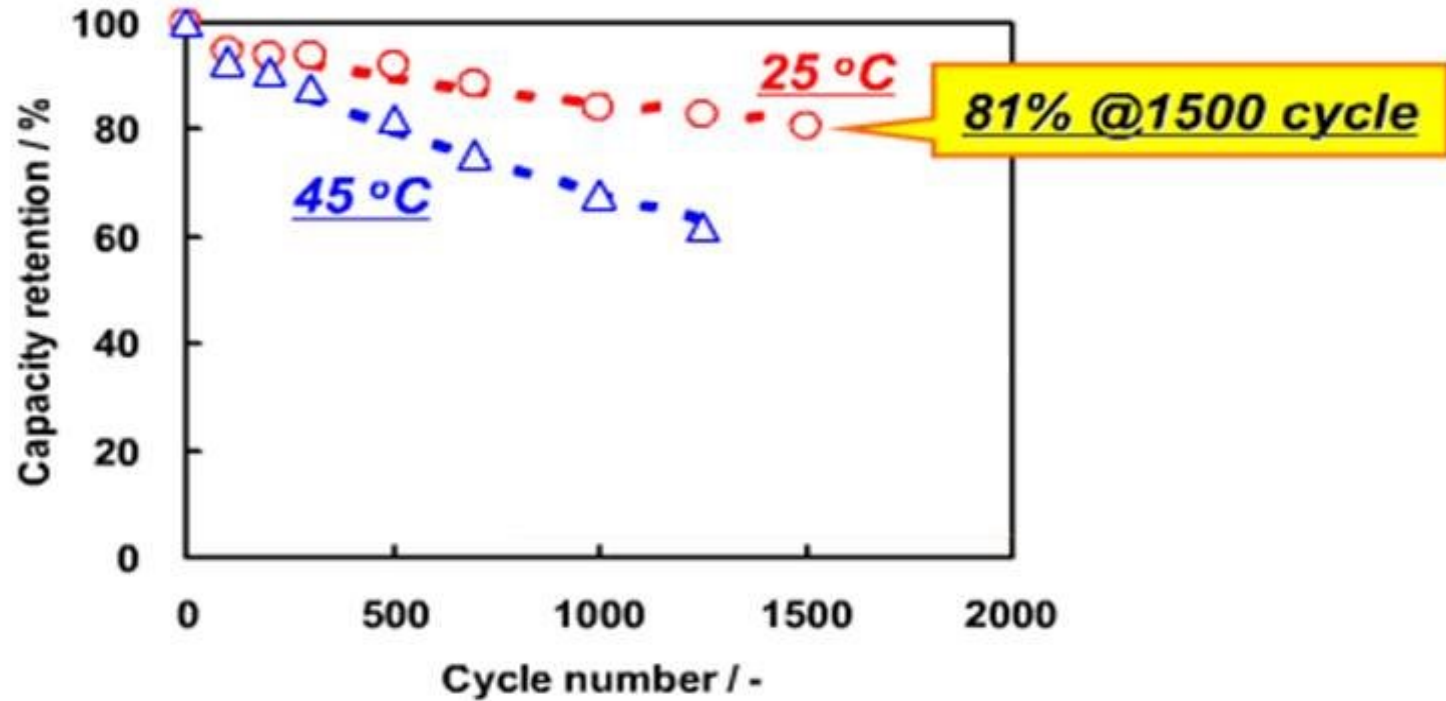


電感式主動等化平衡

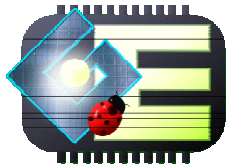
- Top-Balancing：較高電壓電池經由切換變壓器對整個電池組充電
- Bottom-Balancing：經由切換變壓器對較低電壓電池充電轉移
- Balancing between Blocks



工作溫度影響電池壽命



Cycle condition
Charge: CCCV 50 A to 4.1 V for 3 hrs at 25 and 45 °C.
Discharge: CC various current to 2.75 V at 25 and 45 °C.



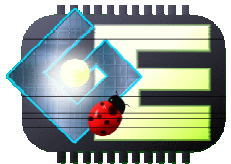
熱管理系統

功能

- ✓ 電池溫度的準確量測和監控
- ✓ 電池組溫度過高時的有效散熱
- ✓ 低溫條件下的快速加熱,使電池組能夠正常工作
- ✓ 有害氣體產生時的有效通風
- ✓ 保證電池組溫度場的均勻分布

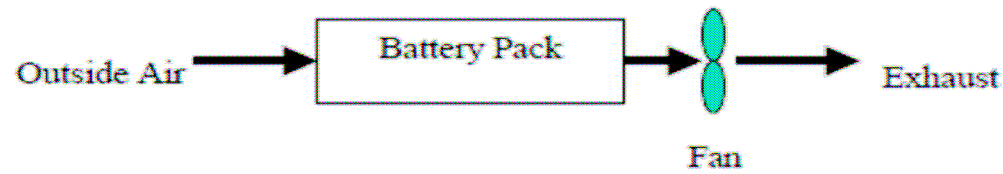
目的

- ✓ 保持電池最佳工作環境(25-40)
- ✓ 延長電池使用壽命
- ✓ 確保安全

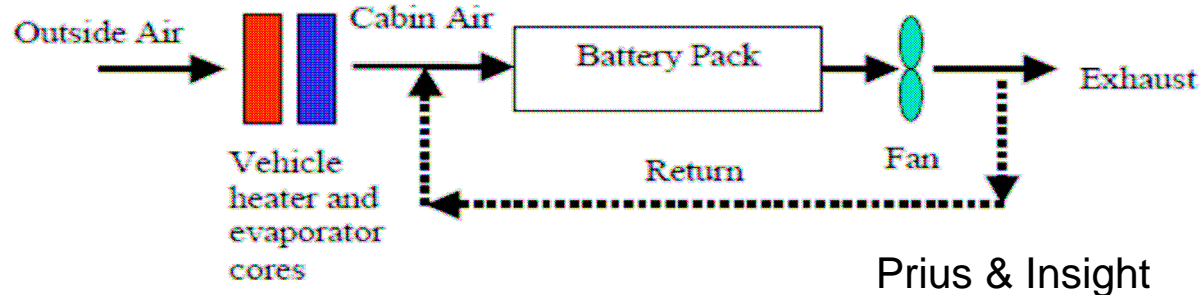


氣冷式熱處理

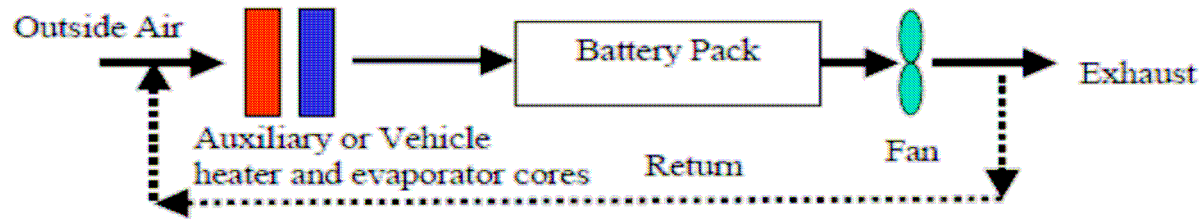
以空氣為散/傳熱媒介，流經電池將熱交換帶出或電池加熱



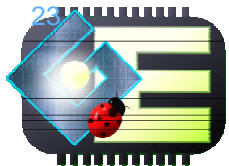
A. *Passive Cooling – Outside Air Ventilation*



B. *Passive Heating and Cooling – Cabin Air Ventilation*

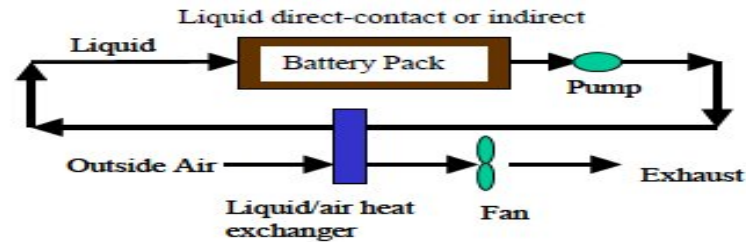


C. *Active Heating and Cooling – Outside or Cabin Air*

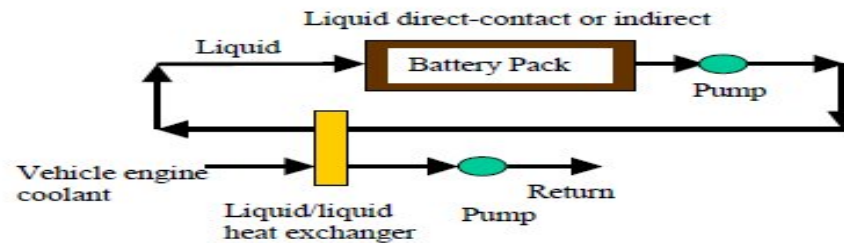


液冷式熱處理

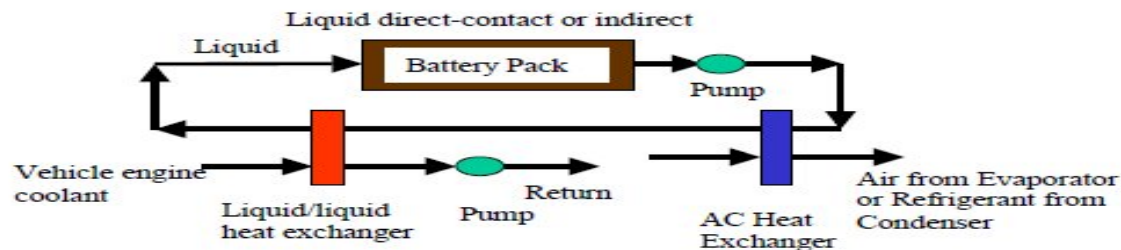
以液體為散/傳熱熱媒介，流經電池將熱交換帶出或電池加熱



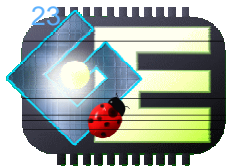
D. Passive Cooling - Liquid Circulation



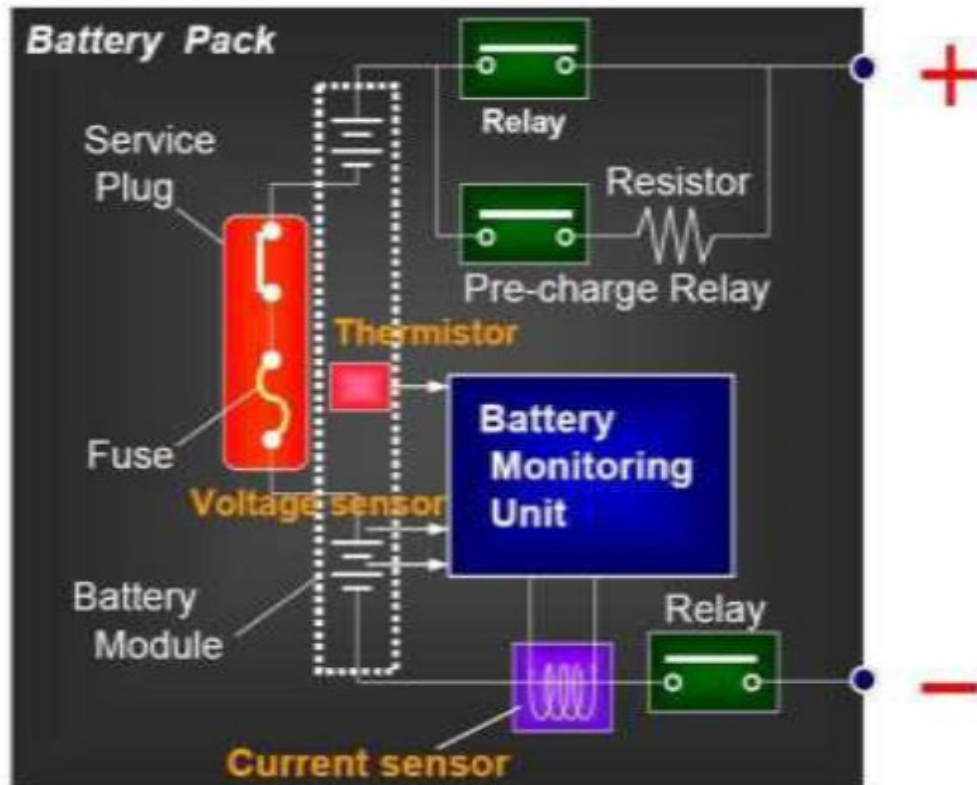
E. Active Moderate Cooling/Heating - Liquid Circulation



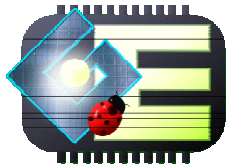
F. Active Cooling and Heating - Liquid Circulation



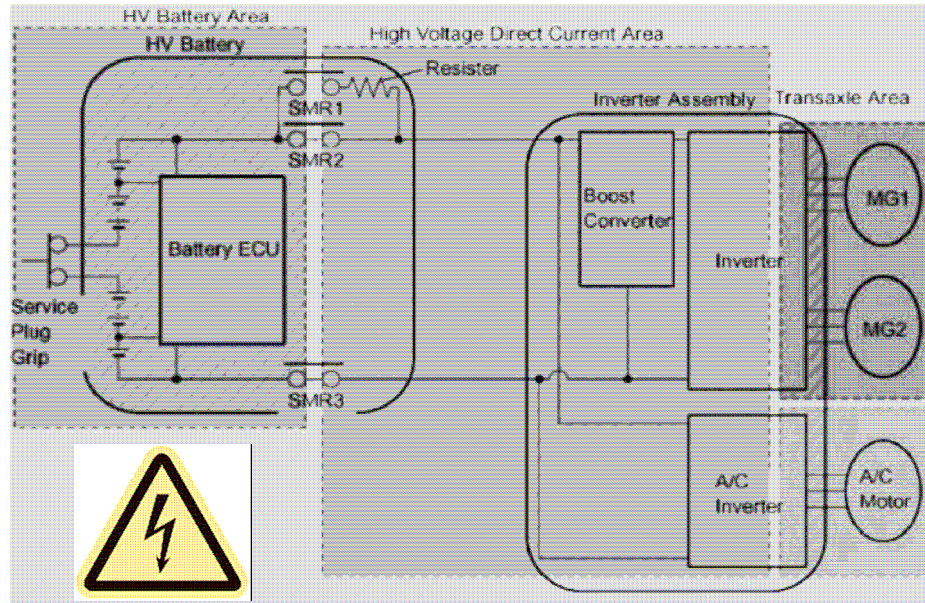
電池系統電力迴路



高壓大電流組件
包含連接器、繼電器、預
充電阻、保險絲、手動服
務開關、電流感知器等
連接器作為電能輸出或多
個電池組連接用
繼電器用於電能輸出控制
Pre-Charge用於預充負載
電壓用，防止開機瞬間大
脈衝電流產生
手動服務開關用於手動斷
開電池組高壓迴路，維護
維修工作人員安全

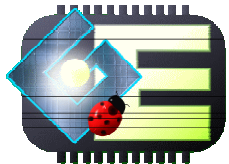


電池系統高壓安全防護



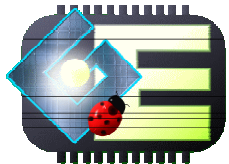
- FMVSS 305 規定電動車高壓迴路與車體之間的阻抗不得小於500 Ω 。
- 當高壓迴路因老化、劣化、鹽化、涉水結露或意外撞擊鬆脫等造成與車體之間的絕緣破壞，電動車具備絕緣故障偵測器，達到警報位準時，發出警報。

1. 以橙色表示電動車高壓組件及電纜線並標示高壓危險標誌
2. 電動車高壓電池組與控制12V電壓高絕緣組抗隔離，以防護人員安全
3. 高壓迴路互鎖安全防護
4. 高壓隔離漏電偵測
5. 電池短路保護
6. 電池組電壓/電流/溫度/充放電/迴路元件偵錯診斷



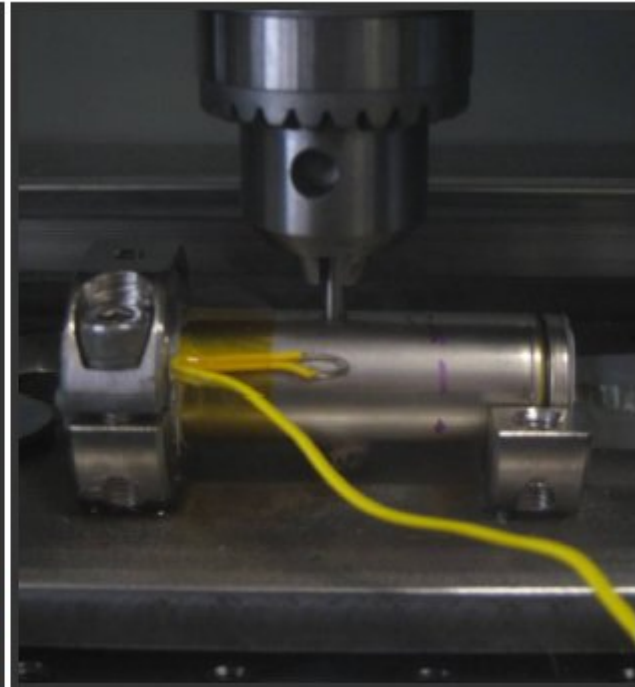
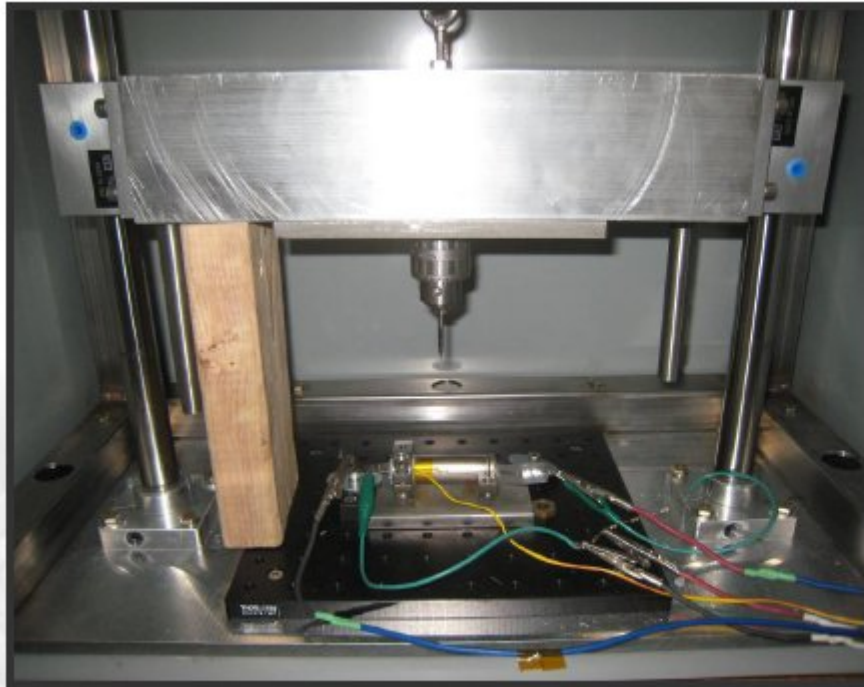
4. 電池系統測試驗證

電池芯、電池模組、電池組、整車性能及安全測試驗證

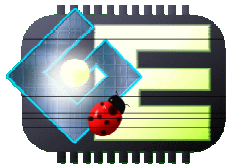


電池芯穿刺測試

18650 Cell Nail Penetration Test

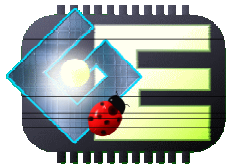


3 mm diameter steel nail



電池芯撞擊測試

18650 Cell Impact Test



電池芯振動測試

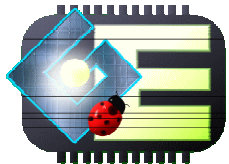
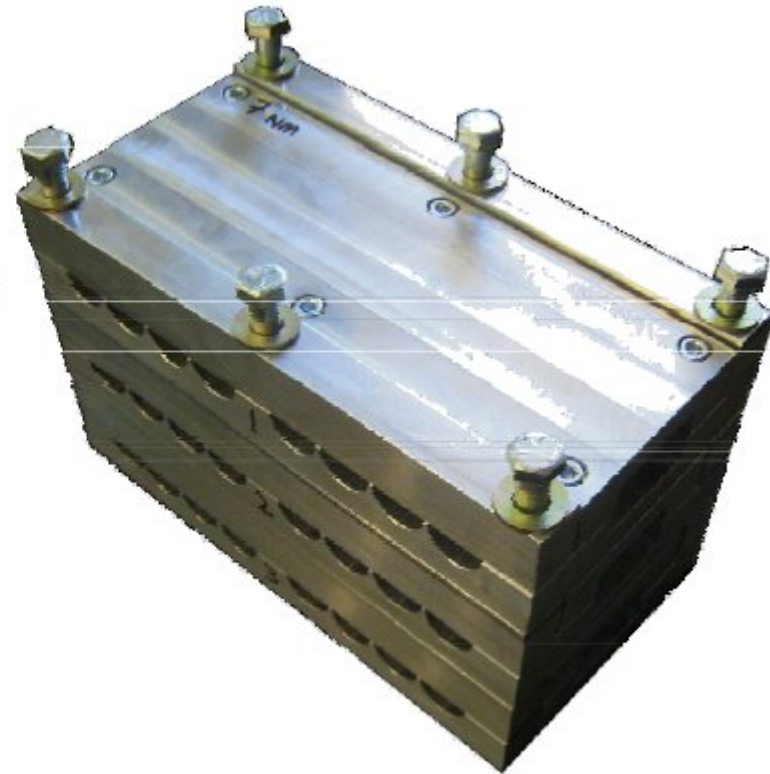
Cells Vibration Testing

Characterize cells

Perform Vibration Test

- ▼ USABC Battery Test Procedures Manual, Procedure #10 - Battery Vibration Test / SAEJ2380
- ▼ The vibration envelopes of this procedure correspond to approximately 100 000 miles of usage at the 90th percentile.

Re-characterize cells

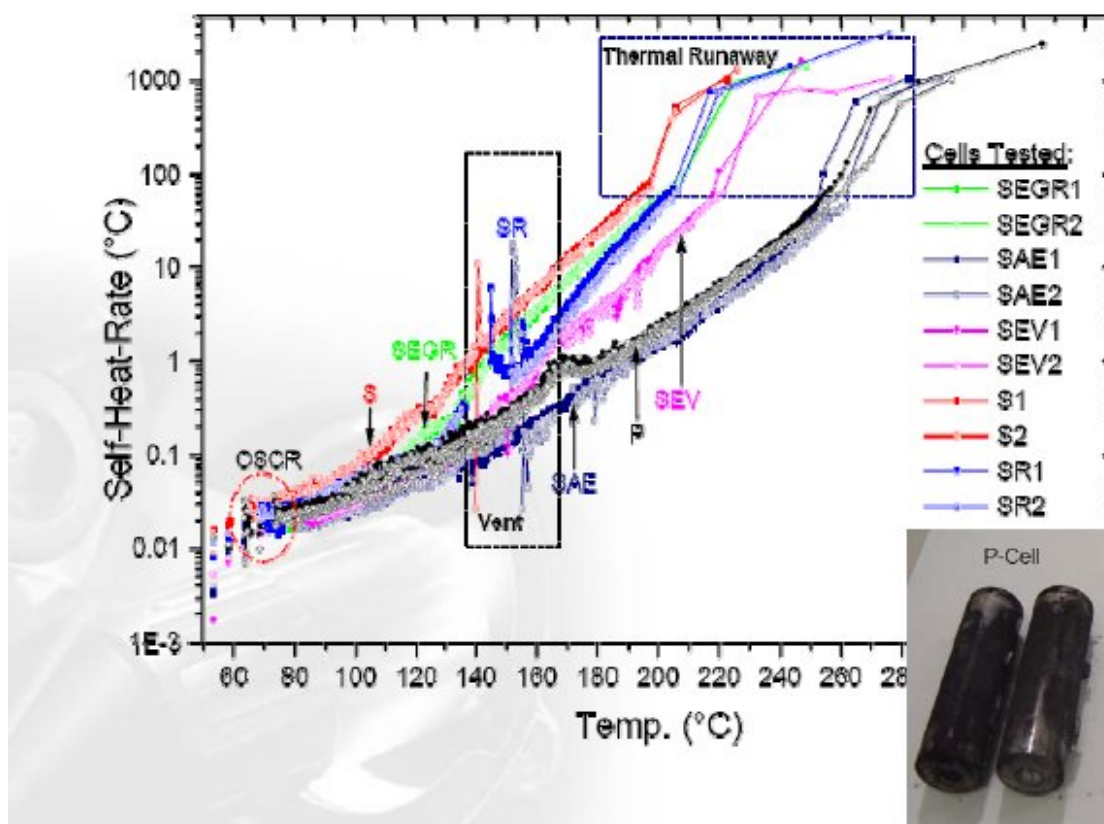


單元電池ARC測試

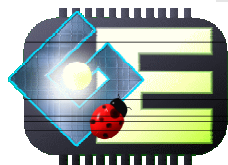
Accelerating Rate Calorimeter (ARC) Test Results

Comparison of Self-Heat-Rate Vs. Temperature

(1 of each cell type)

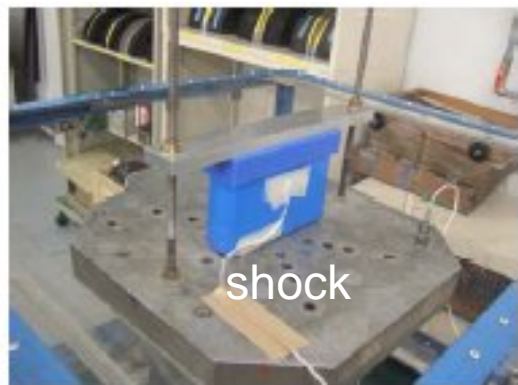


ARC measures cell internal heat release at high temperatures, giving an indication of thermal stability under failure



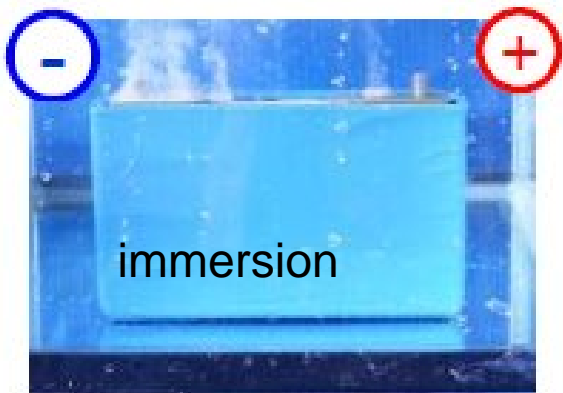
電池模組機械測試

LEV50 Tests based on the FreedomCAR test manual



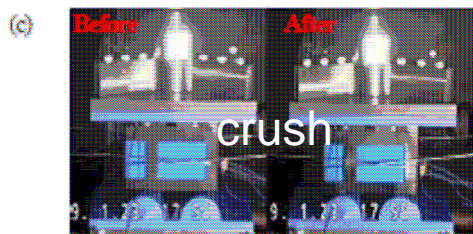
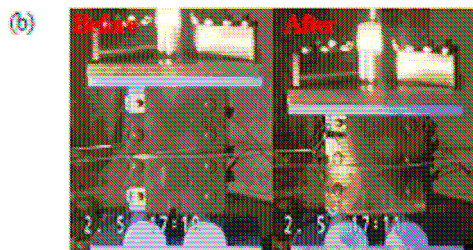
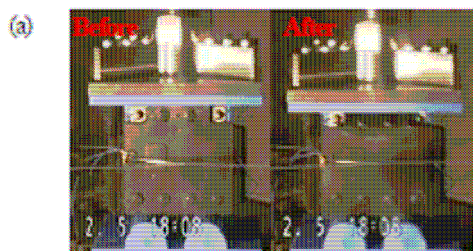
shock

Shock Test



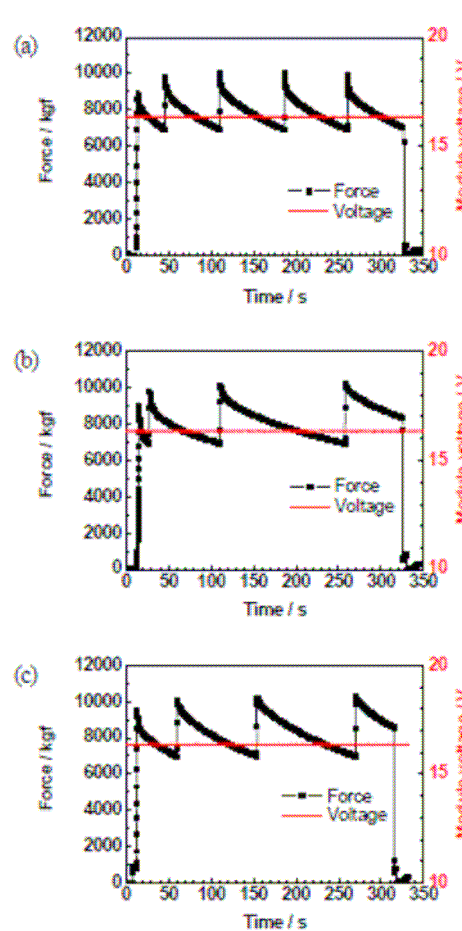
immersion

Immerseion Test

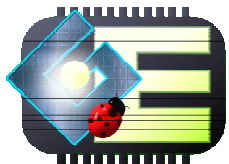


crush

Modules Controlled
Crush Test



Variations Test



電池模組穿刺測試

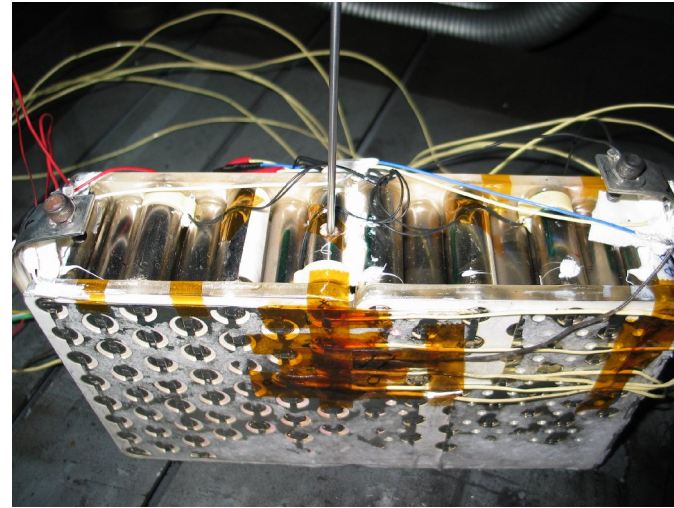
穿刺燃燒後持續自燃嚴重燒毀



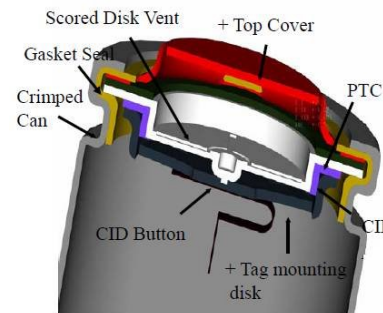
Without PTC



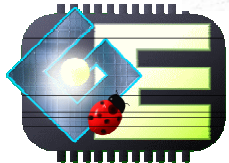
穿刺後不燃燒不爆炸



With PTC



18650 Cell
with PTC/CID




電池系統防水驗證

Nissan Leaf Battery System

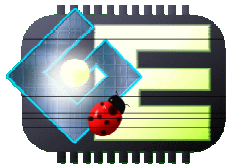
On going Battery testing

Water-tightness evaluation

- Internal pressure effect by rapid cooling in ice
- Water-tightness to high pressure car washer
- Water-tightness in full submersion



Zero Emission



綠能電子聯盟
Green Electronics



電池系統環境驗證

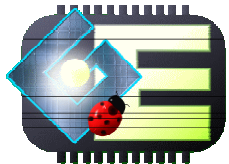
Mitsubishi iMiEV Battery System Environment Tests

PLUG-IN 2008 
A Short Drive to Tomorrow

Successful Development

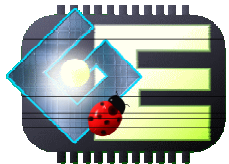
| | | |
|---|---|---|
|  <p>Low-temperature testing</p> |  <p>Grade testing on intermountain road</p> |  <p>Test car for Kyushu Electric Power Co., Inc.</p> |
|  <p>20-30cm water crossing test</p> |  <p>Pace car for local marathon</p> |  <p>Highway driving in Yokohama, Japan</p> |


MITSUBISHI MOTORS

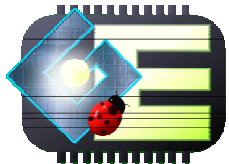


電池系統整車惡路測試

ARTC 耐久行駛各式不良路面



敬請指教



綠能電子聯盟
Green Electronics

