

储能系统的BMS及电源系统设计

Dec 2021

张松刚

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- 双碳背景下能源形势变化
- 未来电网的变化及趋势
- 储能系统的作用
- 储能系统及应用

双碳背景下能源形势的变化

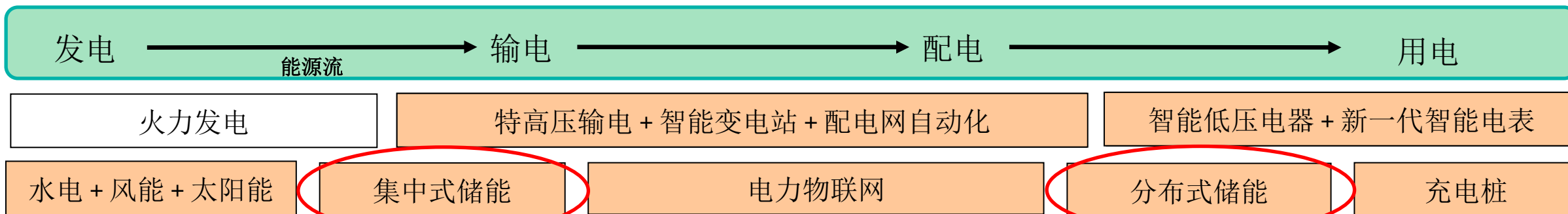
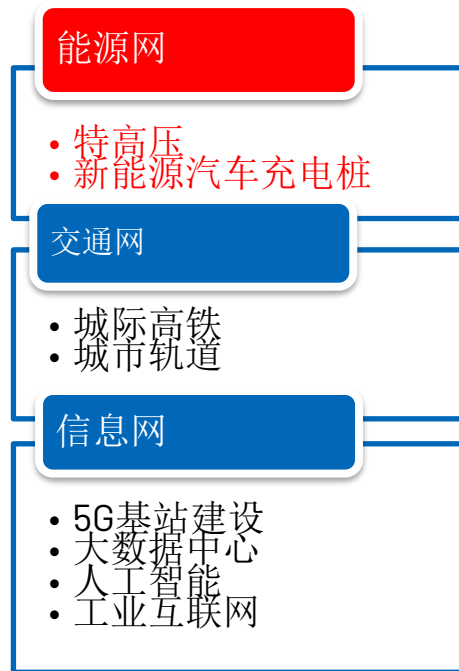


图1 “十四五”大型清洁能源基地布局示意图

清洁能源、储能、远距离能源输送和充电桩成为热点

- ▶ **2020 新基建**
 - 在能源网上包括了特高压和新能源汽车充电桩
- ▶ 在“3060 碳达峰和碳中和”的目标下，“十四五”有新布局，
- ▶ “十四五”关键指标
 - 单位GDP能源消耗降低13.5%
 - 单位GDP二氧化碳排放降低18%
 - 能源综合生产能力>46亿吨标准煤

▶ 2020年的新基建

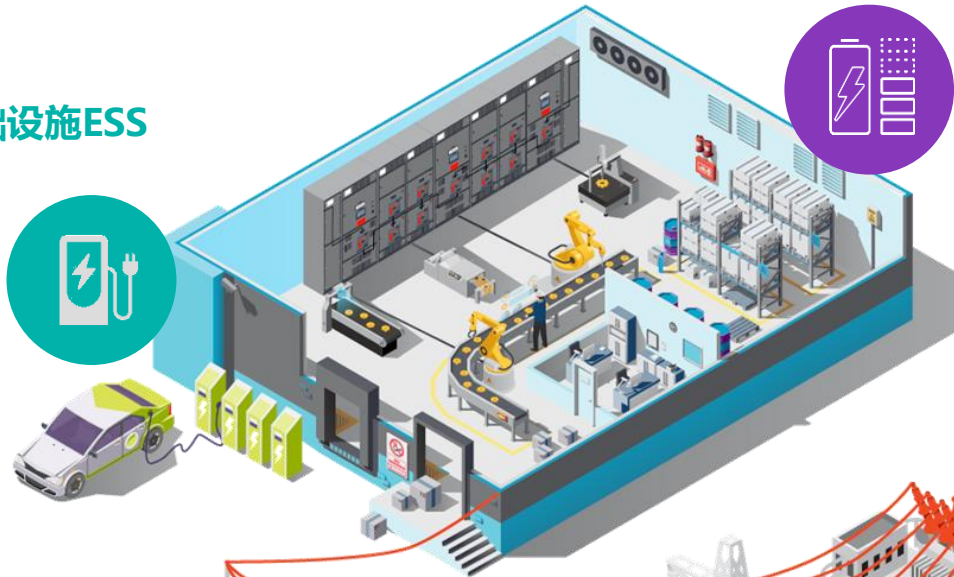


来源：“十四五”规划，ADI整理

未来电网的变化及趋势 - 越来越多的ESS

电动汽车充电基础设施ESS

增强电网稳定性
提升充电性能
V2G



工业ESS

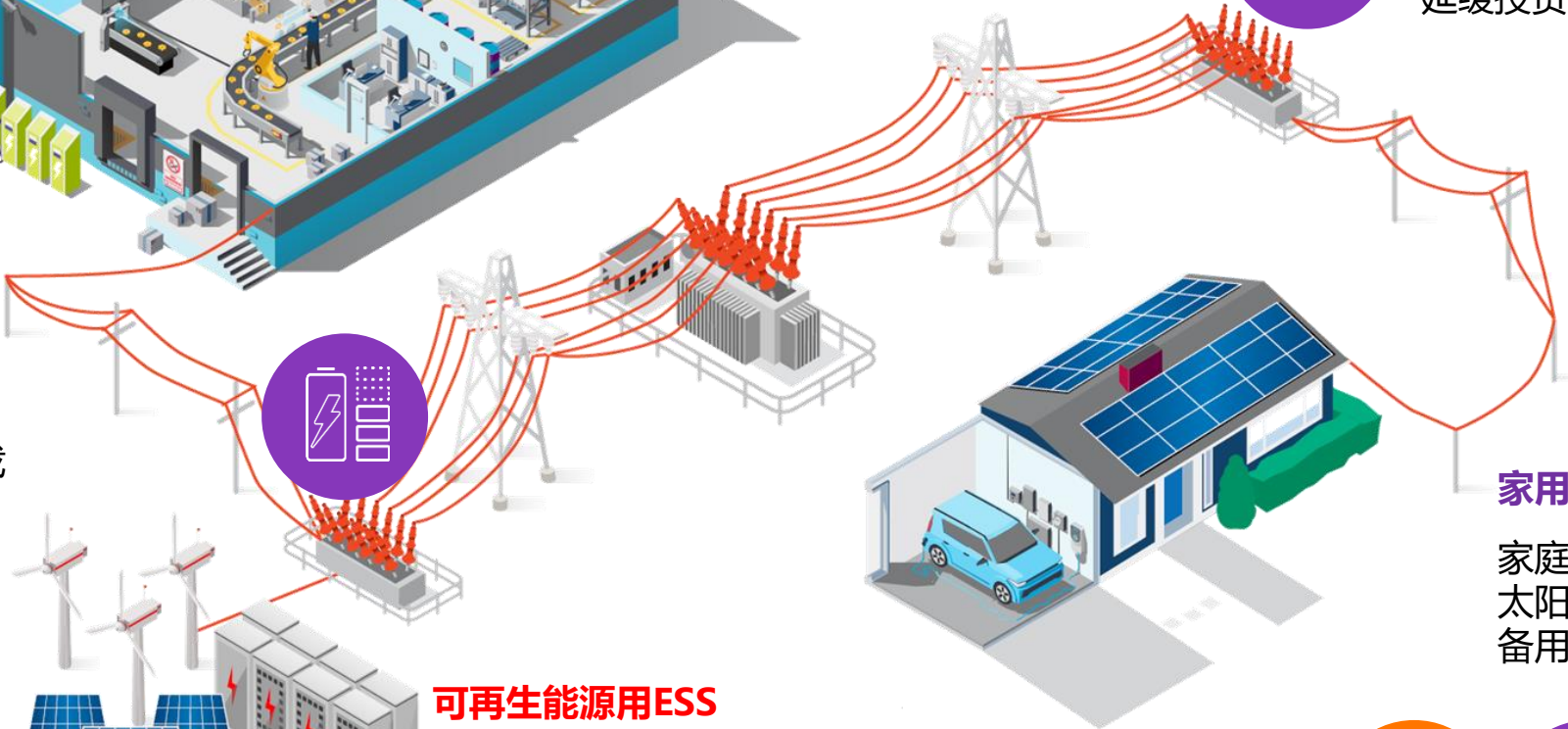
自用
调峰
电能账单优化
备用

输电领域用ESS

能源转移
延缓投资

电网和发电厂ESS

频率调节
动态适应间歇电源和负载
备用电源

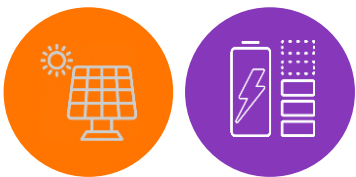


家用及住宅ESS

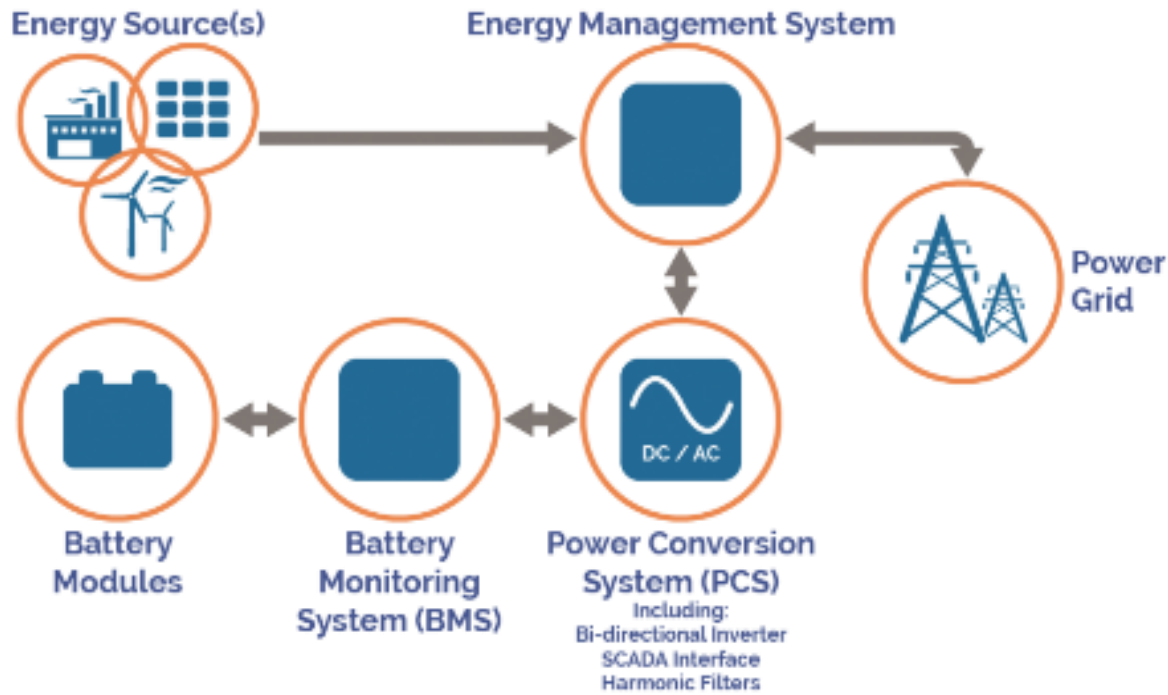
家庭自用
太阳能 + 充电桩集成
备用电源

可再生能源用ESS

可再生能源整合 = 存储和使用
降低可再生能源缩减
电网稳定性

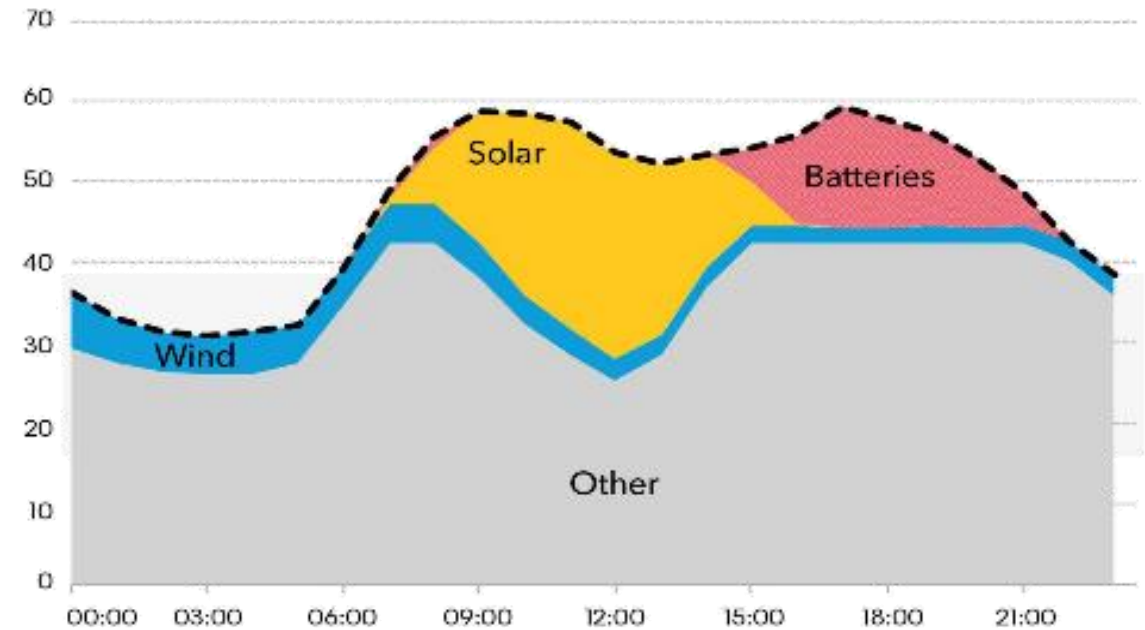


储能系统的作用

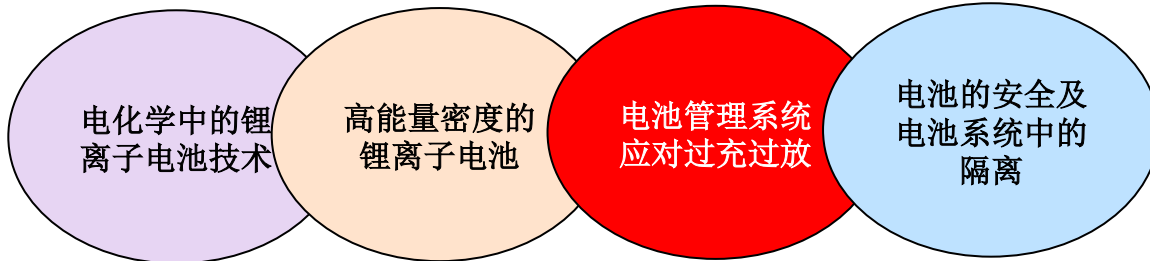


Cheap batteries can make solar and wind dispatchable

Intraday electricity generation (GW)



Source: Bloomberg NEF



▶ 储能应用的主要技术

- 电池管理
- 功率转换

电网侧储能系统



▶ 堆叠 + 集中式储能

- ▶ 电池堆叠串联可达1500V
- ▶ 总线电流/电压测量及管理
- ▶ 各模块之间需隔离
- ▶ 分级管理与控制
- ▶ 功能安全要求

▶ 单体 + 分布式储能

- ▶ 电池包独立设计(48V系统)
- ▶ 电流与电压检测同步
- ▶ 太阳能及其它电源输入
- ▶ 双向升降压DC/DC控制

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双碳背景推动储能的发展

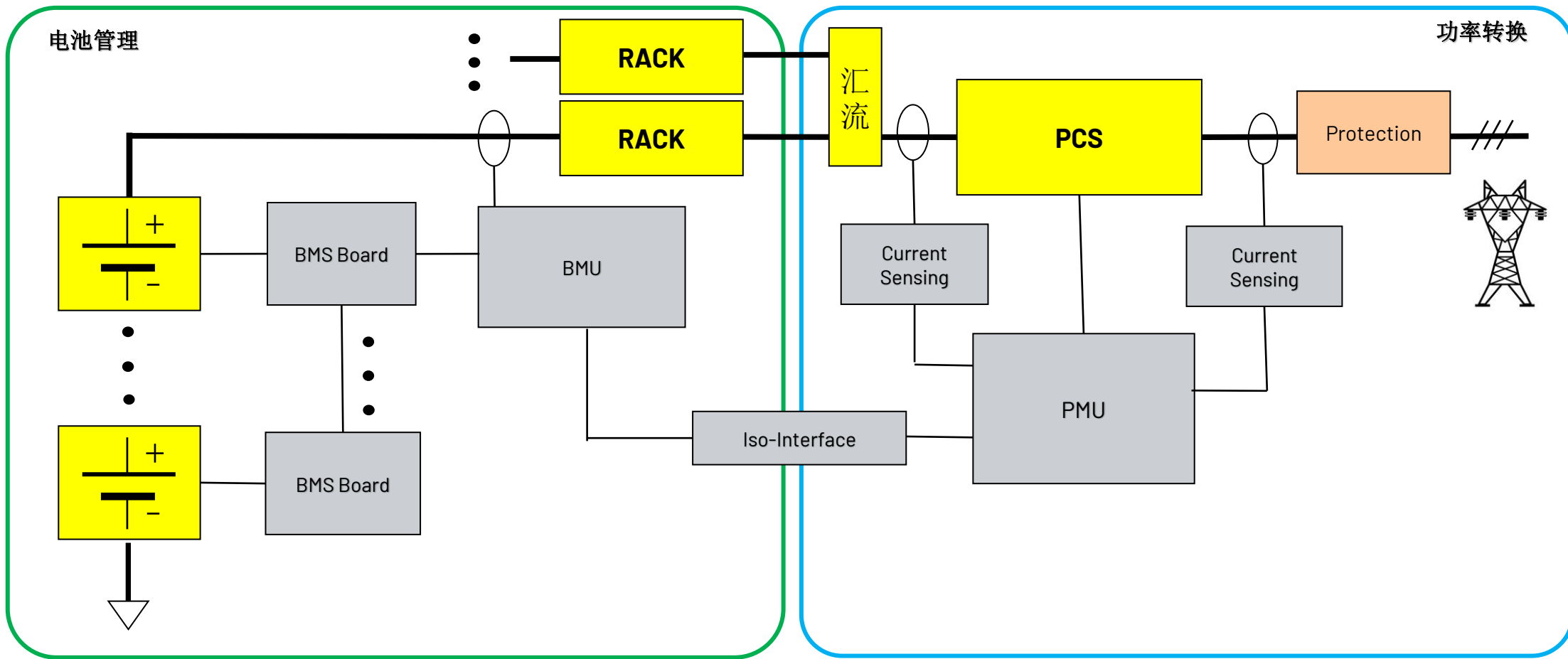
集中式储能及ADI解决方案

家用储能系统及户外电源设计

其它技术与储能系统相结合

- 集中式储能系统结构
- 储能系统中ADI 解决方案
- BMS芯片及隔离通信
- 母线监测
- 主动均衡及功能安全

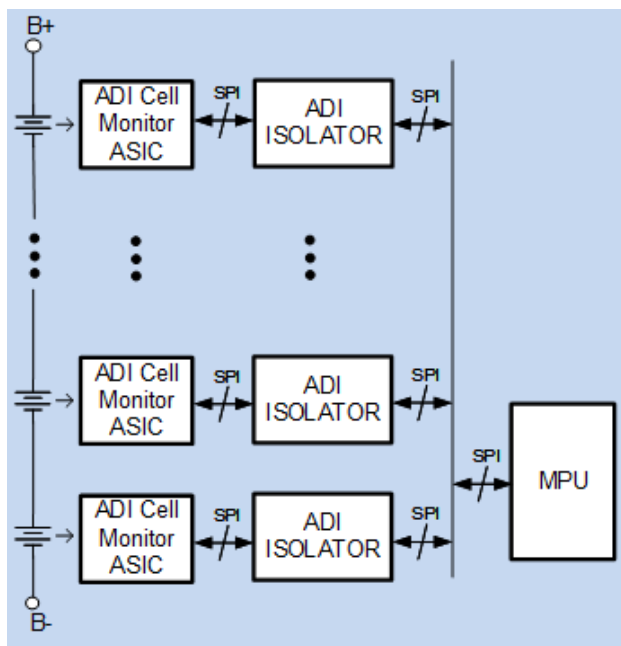
集中式储能的基本结构



一级：电池包级 (PACK)
BMS Board

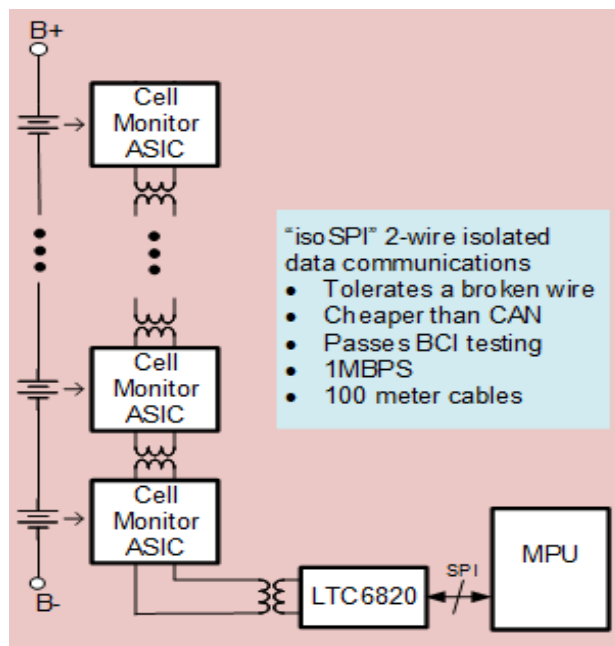
二级：电池簇级 (RACK)
BMU

▶ 三级：储能系统级
PMU



早期的电池包BMS设计

- 包内有独立的BMS板，板内含MCU
- AFE通过SPI与MCU相连，并需要隔离
- AFE主要负责测量电芯电压和温度
- MCU来控制均衡，也可以由AFE完成
- MCU输出到BMU需要隔离



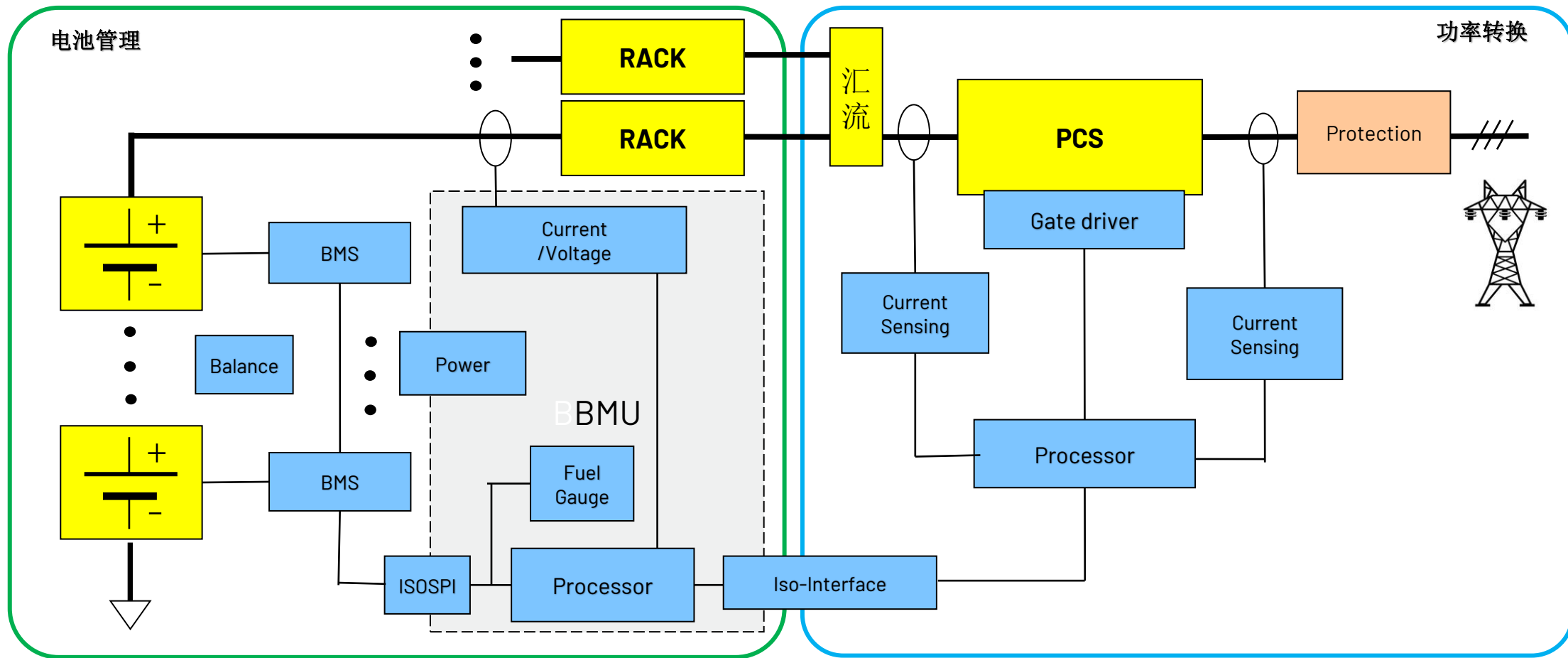
ADI的AFE带来BMS结构的改变

- AFE可以独立工作，可以直接从电池包取电
- AFE采用菊花链通信方式，可级联
- AFE自带IsoSPI接口，并兼容SPI
- AFE不仅能测量电芯电压，还能测量温度
- AFE可以完成被动均衡

▶ BMS电池管理芯片

- 电池电芯监控器
- 也称为AFE

集中式储能的基本结构 - ADI解决方案



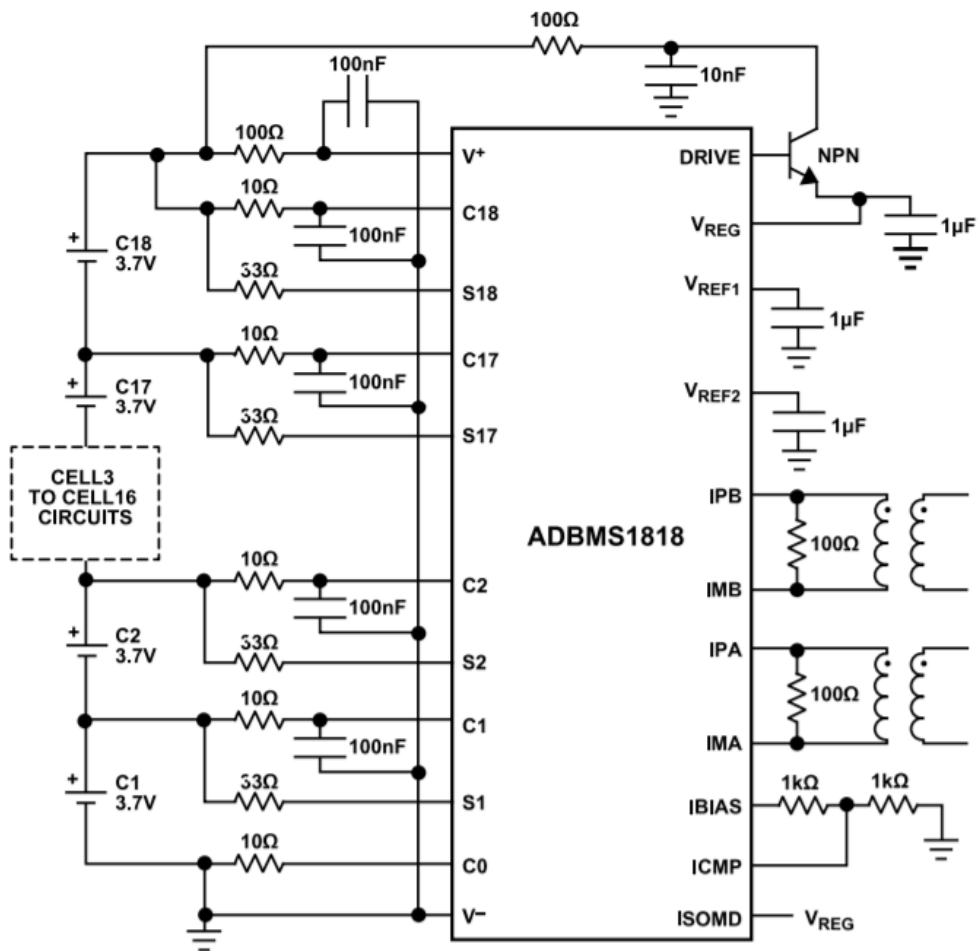
▶ ADI 的产品及方案

- BMS Monitor: ADBMS1818, ADBMS6830
- ISOSPI: LTC6820
- Bus Monitor: LTC2949/2950
- Active balancing: LT8584
- Power supply: LTC8315, LTC8302

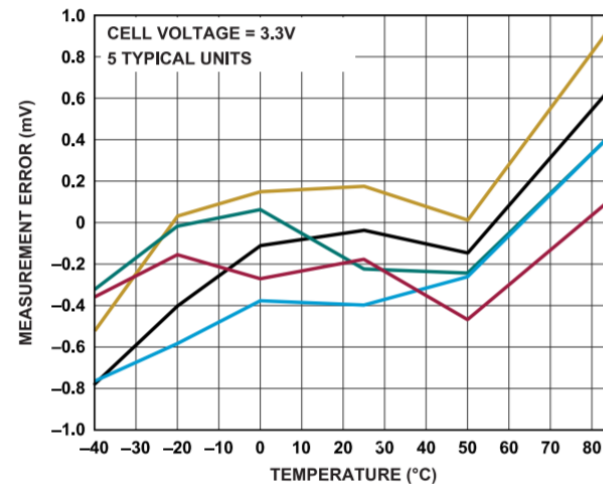
▶ ADI 的产品及方案

- Gate driver: ADuM413x, ADuM414x
- Iso-Interface: ADM3050, ADM2484, ADuM315x, ADM276xE
- Current Sense: AD8418A, ADAF1080
- Voltage detection: AD7124, AD7606, AD7616

ADBMS1818 – 18单元电池监控器

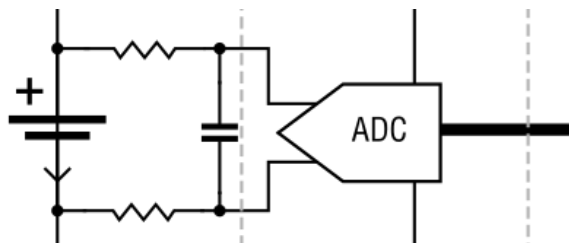


- ▶ 测量**18**个串联电池单元
- ▶ 业界较高的精度：
 - **3mV**总测量误差
- ▶ 16位Delta Sigma可编程噪声滤波器
- ▶ 高级可逆isoSPI™接口
- ▶ **200mA**被动电池平衡能力
- ▶ 9个通用数字I/O或模拟输入
- ▶ 同步电压和**GPIO**测量
- ▶ LQFP 64引脚封装

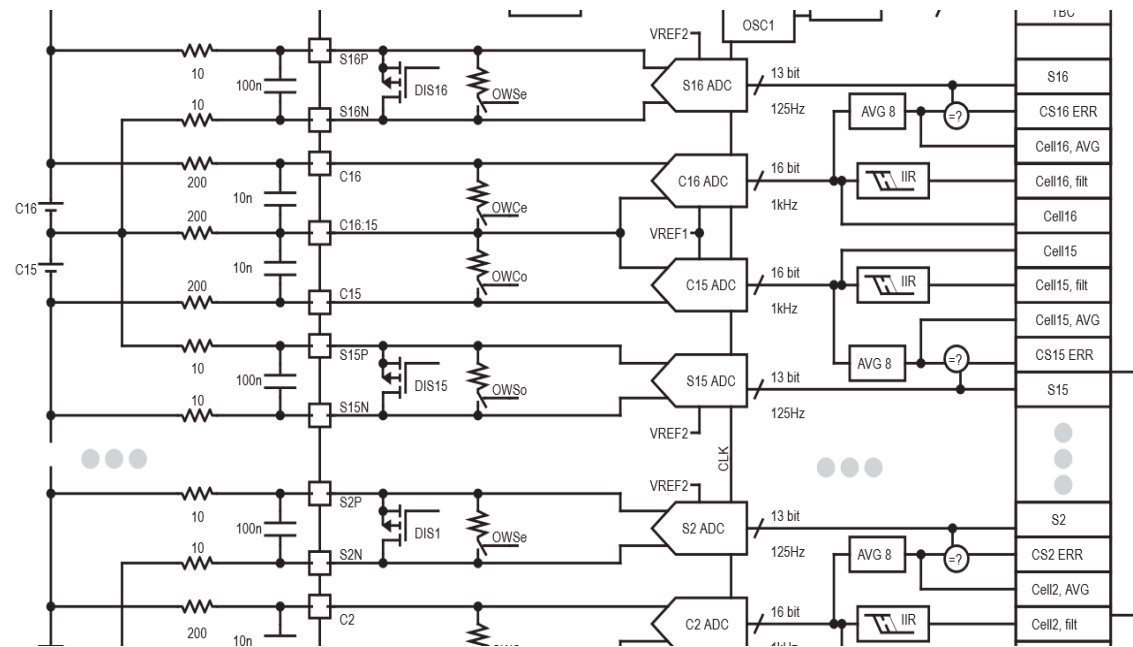


ADBMS6830 - 16单元电池监控器

- ▶ 新一代BMS芯片架构
- ▶ 16通道, 每通道一路 ADC
- ▶ 4.2MHz 输入采样
- ▶ 2 μ s 输入 AAF 滤波器
- ▶ 18-bit, 1kSPS的噪声: **27 μ V_{RMS}**
- ▶ 每通道ADC替代了输入多路开关 + RC 滤波器

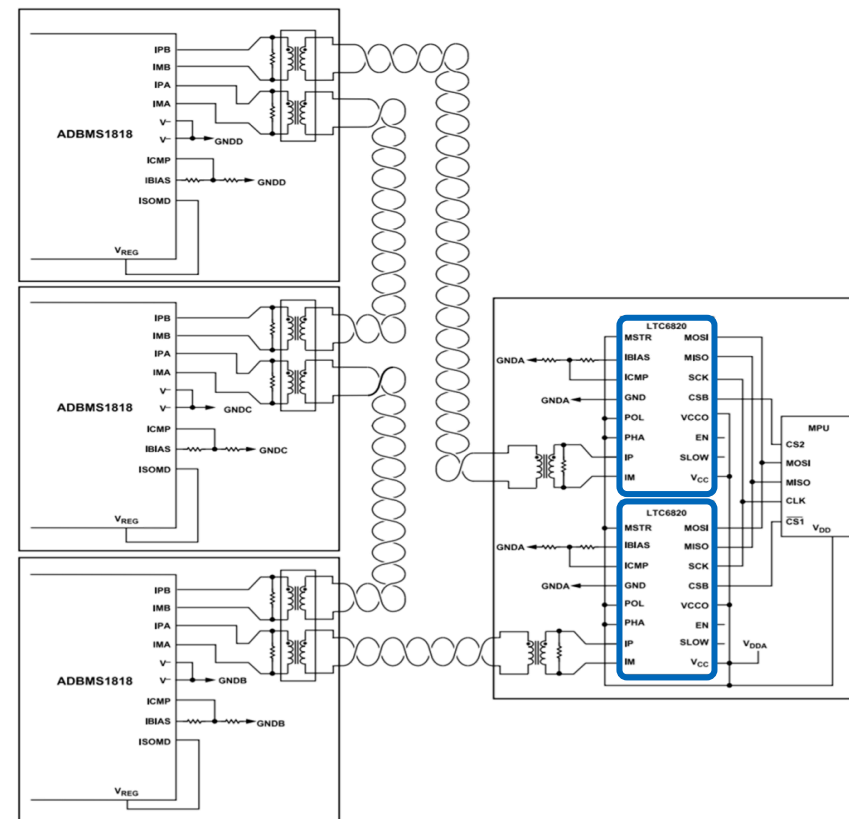
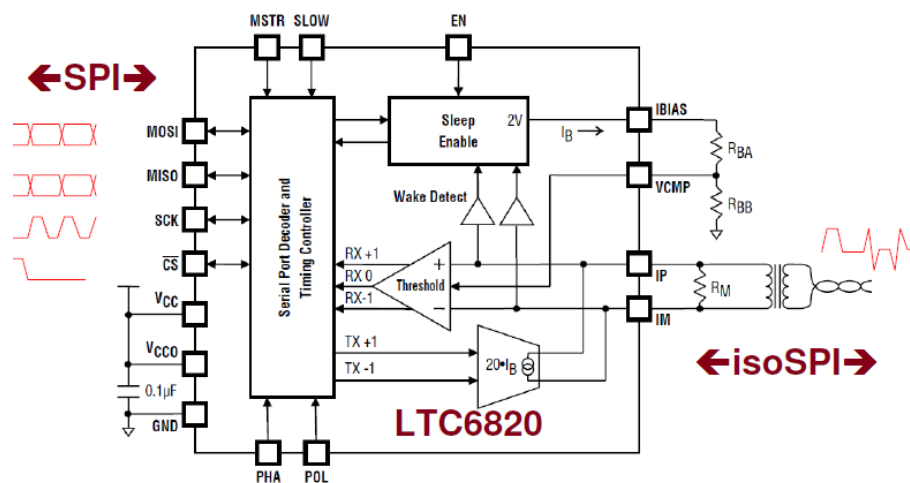


- ▶ 同样: 没有 HPF (没有最小 f_{exc})



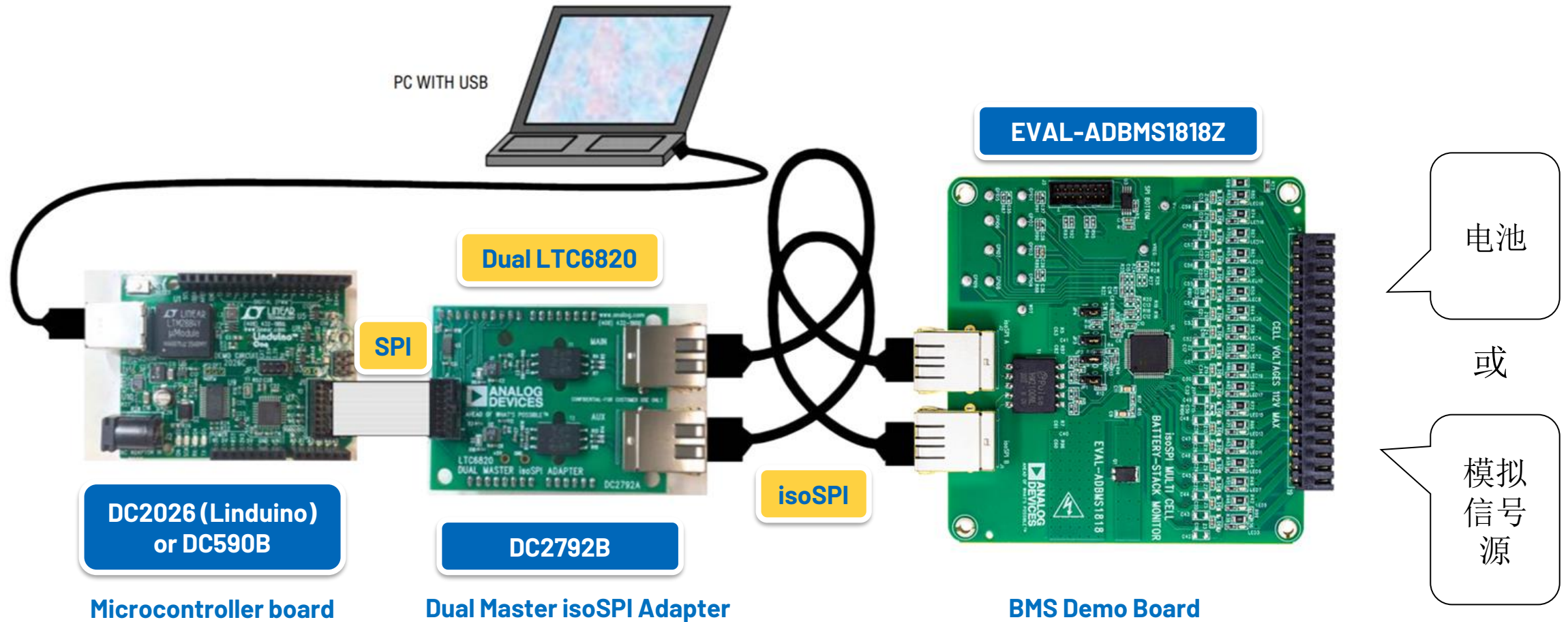
LTC6820 – isoSPI™收发器

- ▶ 支持所有ADI isoSPI™器件
- ▶ 高数据速率隔离式数据通信
 - 主机模式：2Mbps
 - 从机模式：1Mbps
- ▶ 使用标准变压器实现的电气隔离
- ▶ 低成本单条双绞线上的双向接口
 - 支持长达100米的电缆
- ▶ 极低EMI敏感性和辐射
- ▶ 超低**2μA**空闲电流
- ▶ 自动唤醒检测
- ▶ **2.7V至5.5V**电源
- ▶ 16引脚MSOP封装



ADBMS1818 评估系统

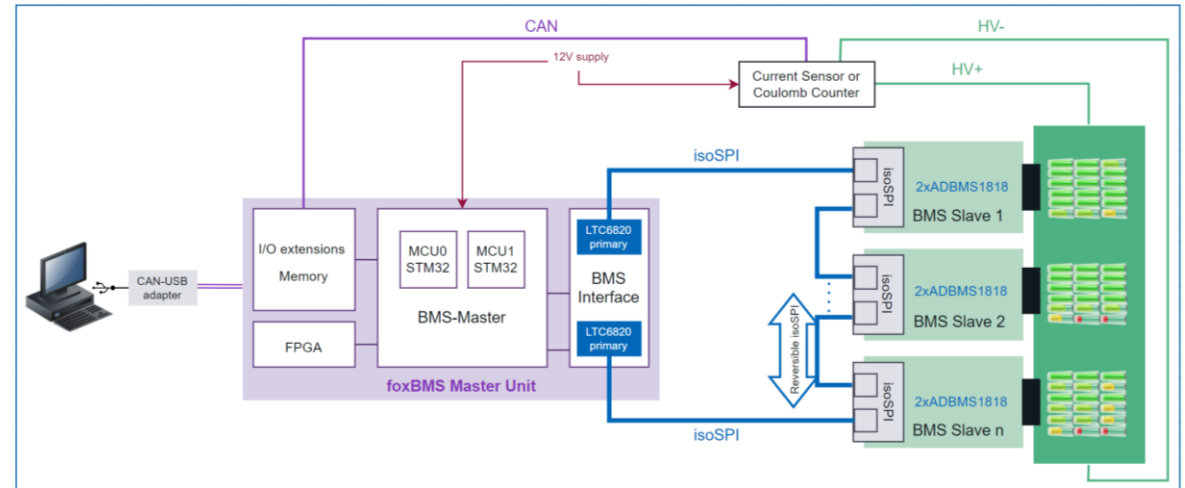
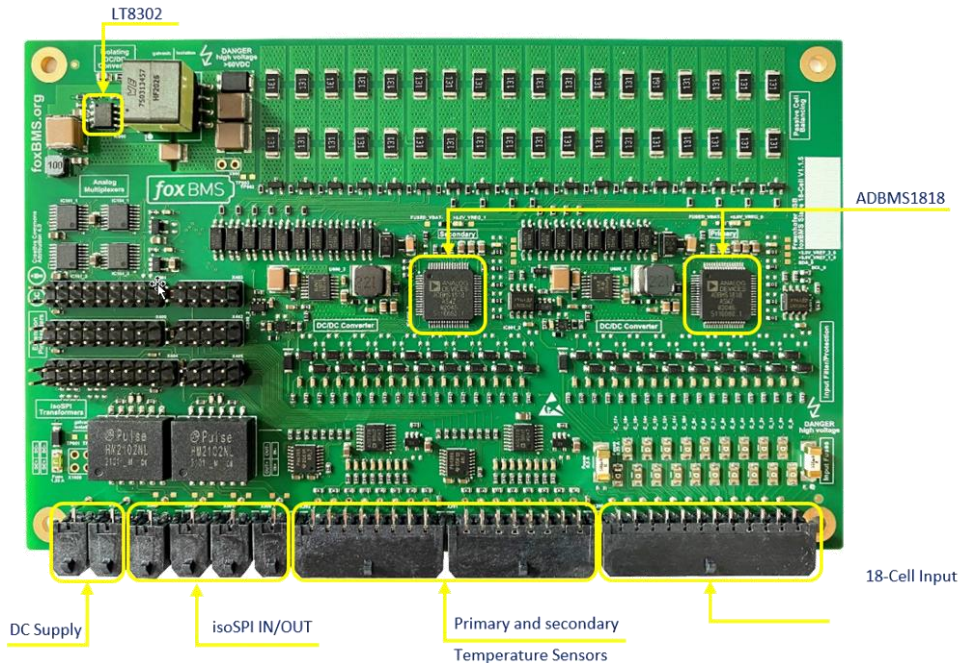
- ▶ EVAL-ADBMS1818 + DC2026 (Linduino) + DC2792A (LTC6820) + DC2472A (load interface board)



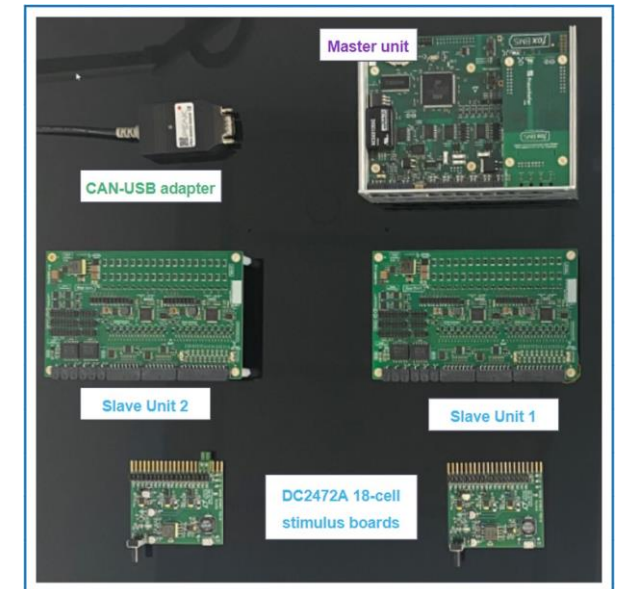
<https://www.analog.com/en/design-center/evaluation-hardware-and-software/evaluation-boards-kits/EVAL-ADBMS1818.html#eb-overview>
<https://wiki.analog.com/resources/EVAL/EVAL-ADBMS1818>

ADBMS1818 foxBMS board

- ADBMS1818 (2x – 36ch) Slave Board compatible with foxBMS Master Unit (Link [here](#))
- Each ADBMS1818 measures SOC of 18 cells in series
- Passive balancing capability
- isoSPI Daisy chain connection in forward and reverse direction
- Schematics and design files available
- Evaluation board for the ADBMS1818 available



- Cell voltage, temperature and SOC monitored
- GUI to manage all the communications and results
- Source code and GUI available from foxBMS open-source project
- Tested with the SDP-K1 MCU
- App Note released ([AN-2093](#))



LTC2949 – 整组电池总线监测

▶ 双电流测量

- Configurable for High Side or Low Side Operation
- $\pm 124\text{mV}$ Range, 237.5nV Resolution (20-Bit DS)
- $3\mu\text{V}$ Offset Max (-40°C to 125°C)
- Fast Overcurrent Detection w/ Deglitch
- Max / Min Values Stored On-board

▶ 电压测量

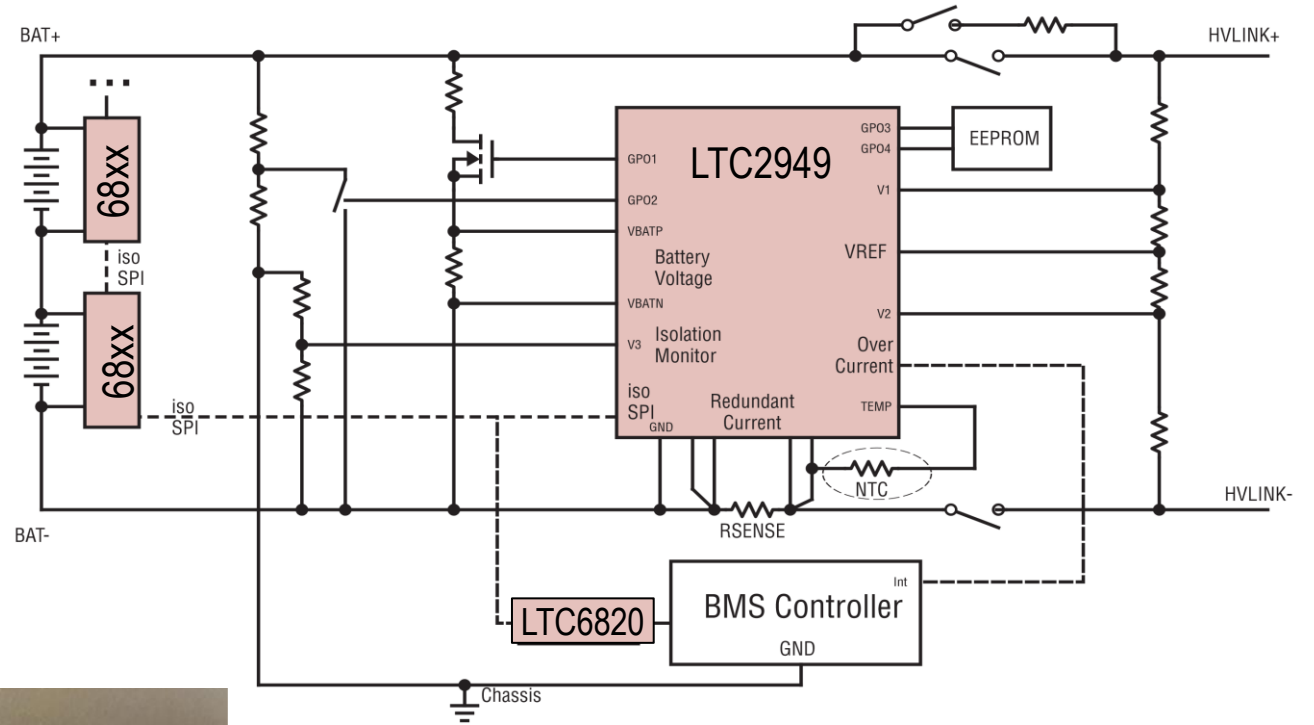
- $\pm 5.5\text{V}$ Range, $46\mu\text{V}$ Resolution (18-Bit DS)
- Dedicated Stack Measurement
- 7 Dedicated Buffered Voltage Inputs
- 5 Additional Buffered Voltage Inputs or Digital Outputs (Configurable as Heartbeat Monitors)

▶ 内置 isoSPI™ 接口

▶ BMS 芯片同步测量

▶ 4.5V ~ 14V 供电电压

▶ 温度范围: -40°C to 125°C



▶ 实时处理

- 1% 精度的功率、电能和电荷测量
- 电荷和能量的无损跟踪
- 内置 Tolerance & Tempco 校正因子

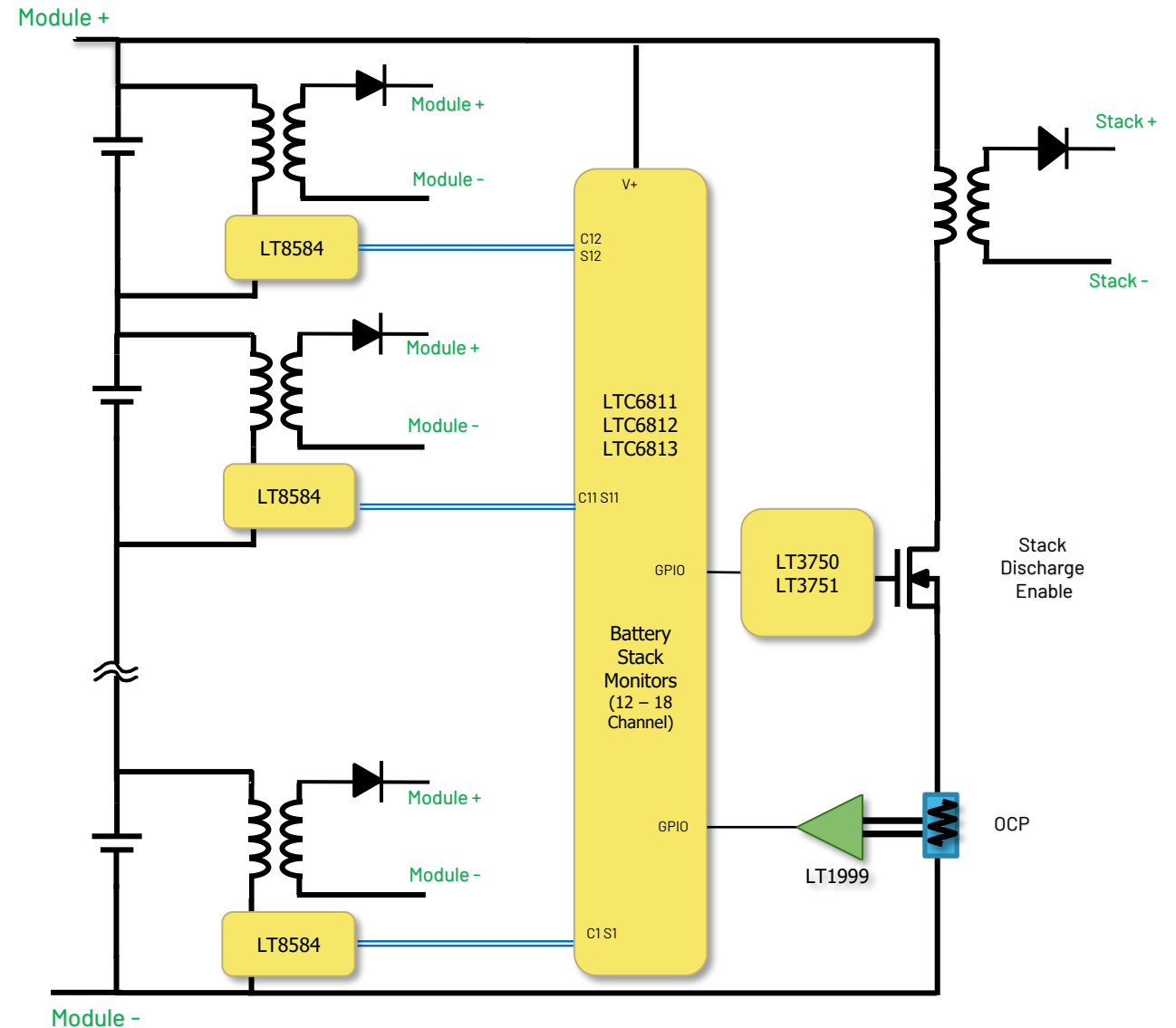
主动均衡： LT8584 – 快速均衡

▶ LT8584

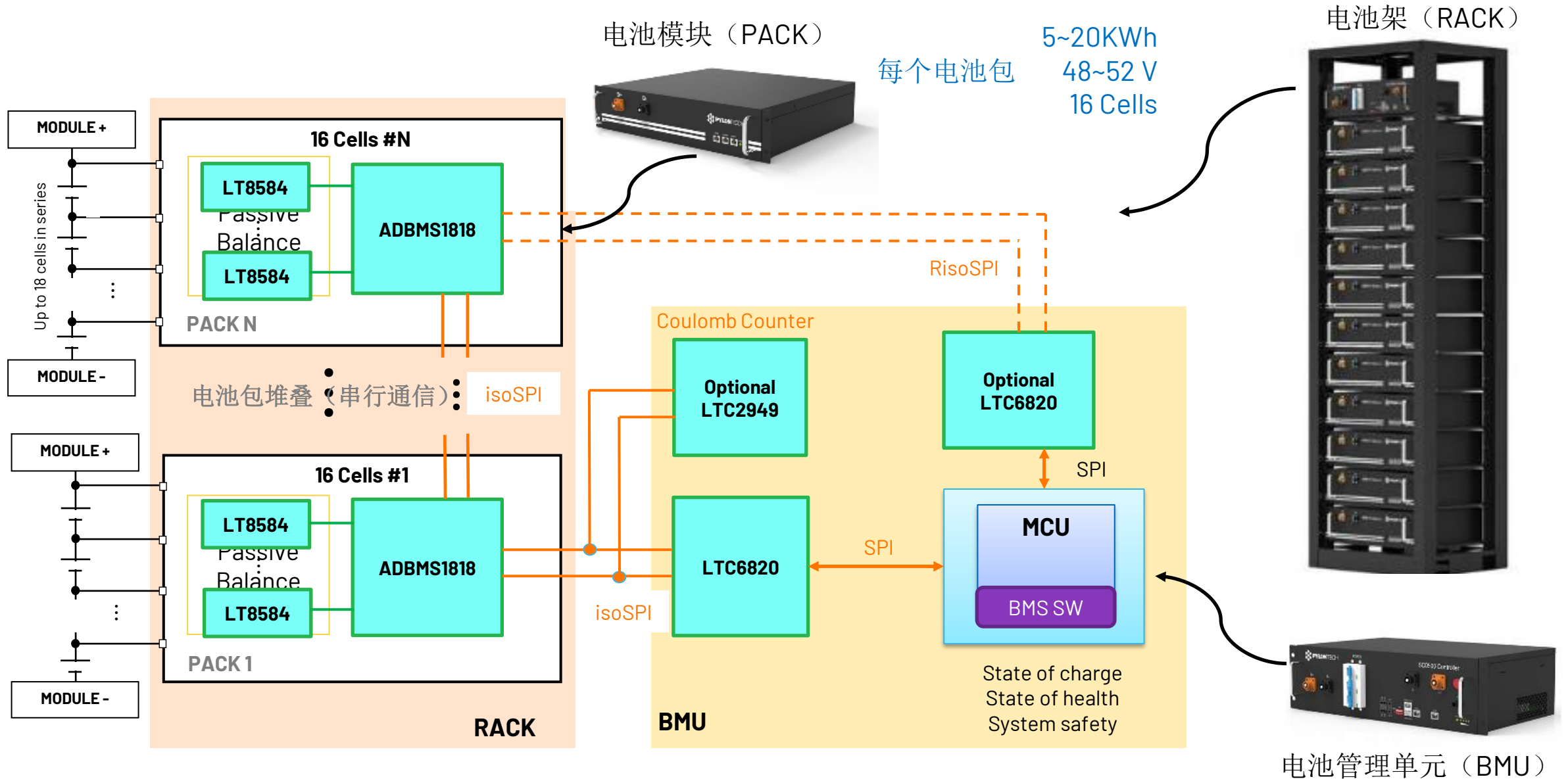
- The LT8584 operates as a boundary mode flyback converter
- Provides 2.5A average discharge current.
- Scalable by using multiple LT8584s to balance each cell.
- Each battery in the stack requires an LT8584 active cell balancer
- 10A discharge to the stack with LT3570/71 with Mosfet
- Integrated 6A switch

▶ Safety Features

- **Read Back via ADC of LTC681x:**
 - Cell Voltage
 - Cell Discharge Current
 - Die Temp
 - LT8584 Handshaking Voltage (i.e. Reference V)

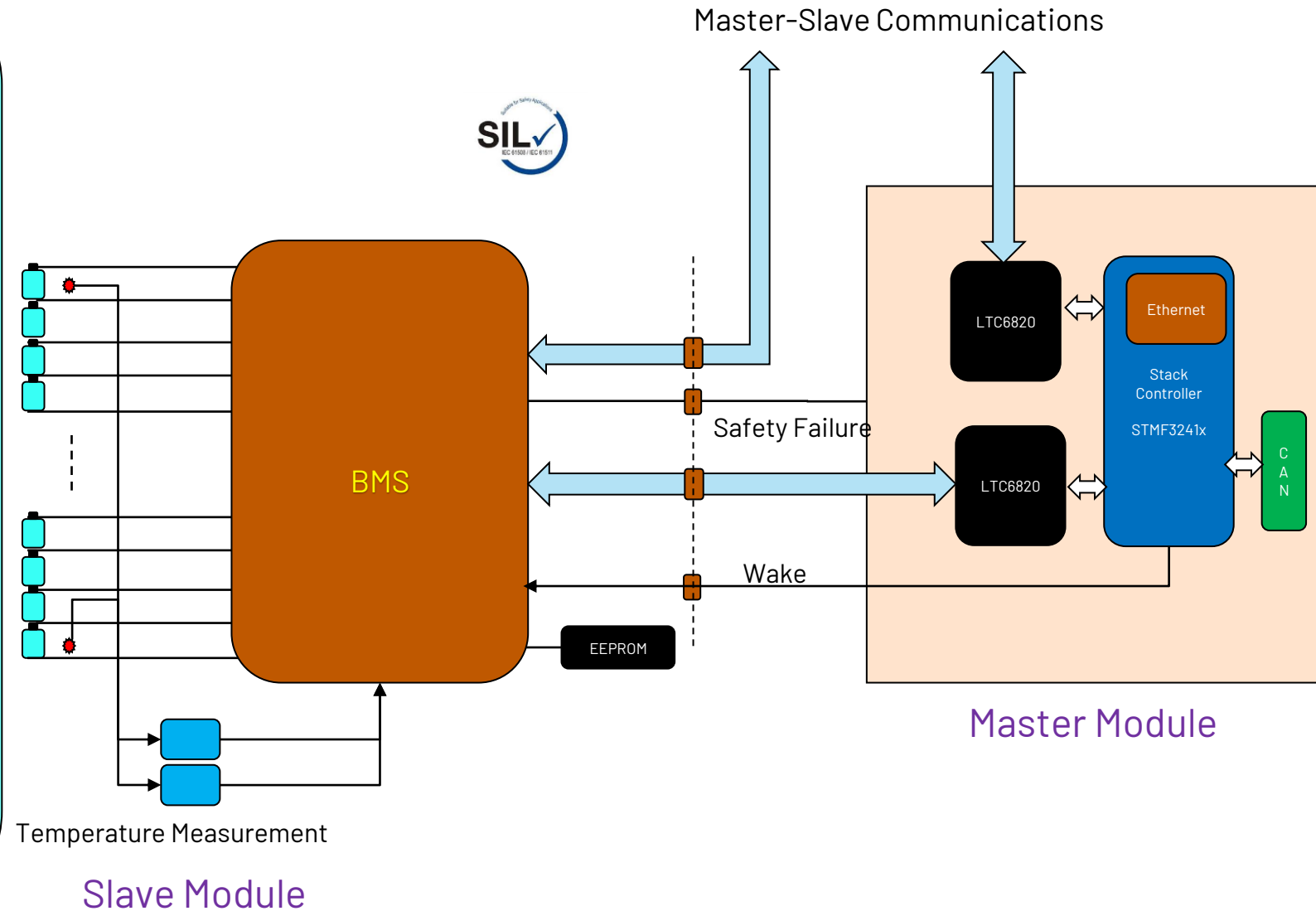


堆叠式解决方案 -- ADBMS1818 + LTC6820 + 主动均衡



功能安全设计思路

1. 48V Modules
2. Stackable to 1500V (27)
3. Functional Safety
 1. IEC61508 → SIL2
 2. OT, OV/UV, OC
4. EEPROM (Traceability & Maintenance)
5. Current Meas
 1. In the Modules or SOC
 2. BMS or Charger
6. Typically
 1. 4.2v cells e.g. Li-NMC,
 2. 3.7V cells e.g. LFP
7. Unique ID feature
 1. Order of Participants
8. Reversible IsoSPI
9. Reinforced isolation
 1. between Master & Slave
10. Devices:
 1. ADBMS181x (18/16ch)
 2. Designed to IEC61508:202x
 3. No Redundancy



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双碳背景推动储能的发展

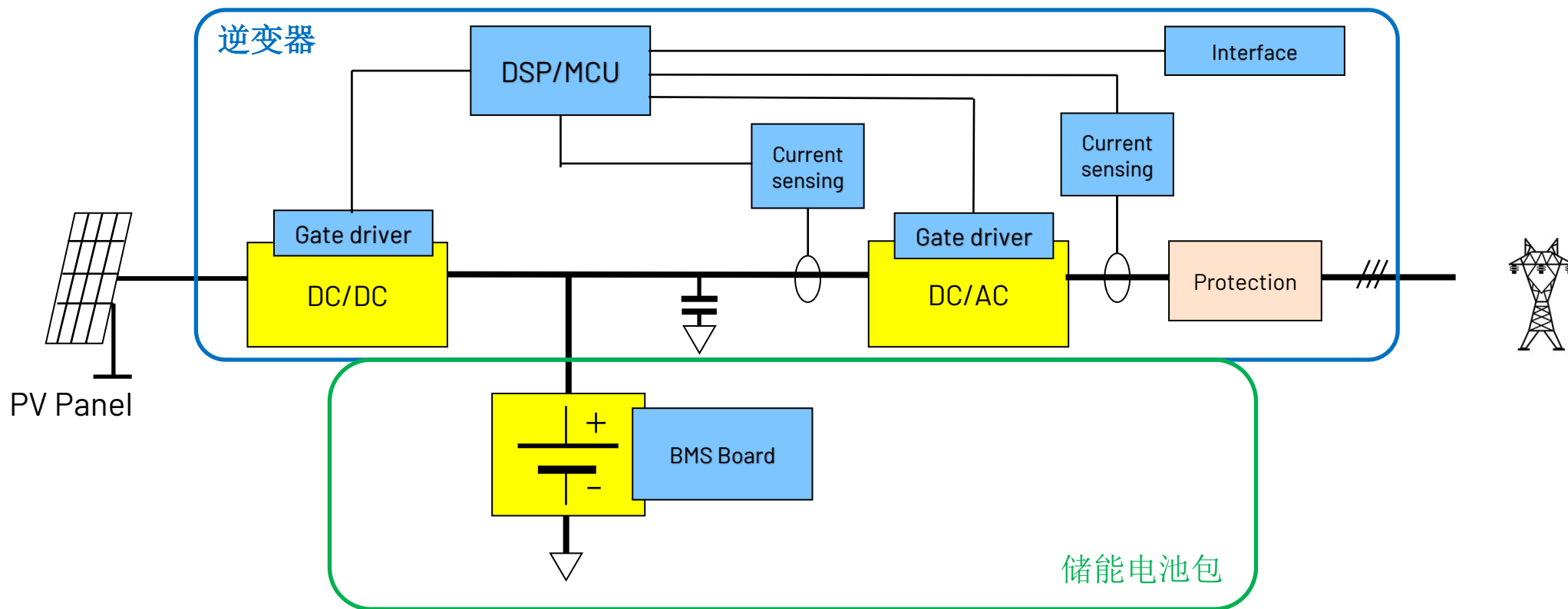
集中式储能及ADI解决方案

家用储能系统及户外电源设计

其它技术可与储能系统相结合

- 家用储能系统
- 户外及便携式电源
- 基站电源后备储能
- 双向电源设计

家用储能基本结构及ADI解决方案



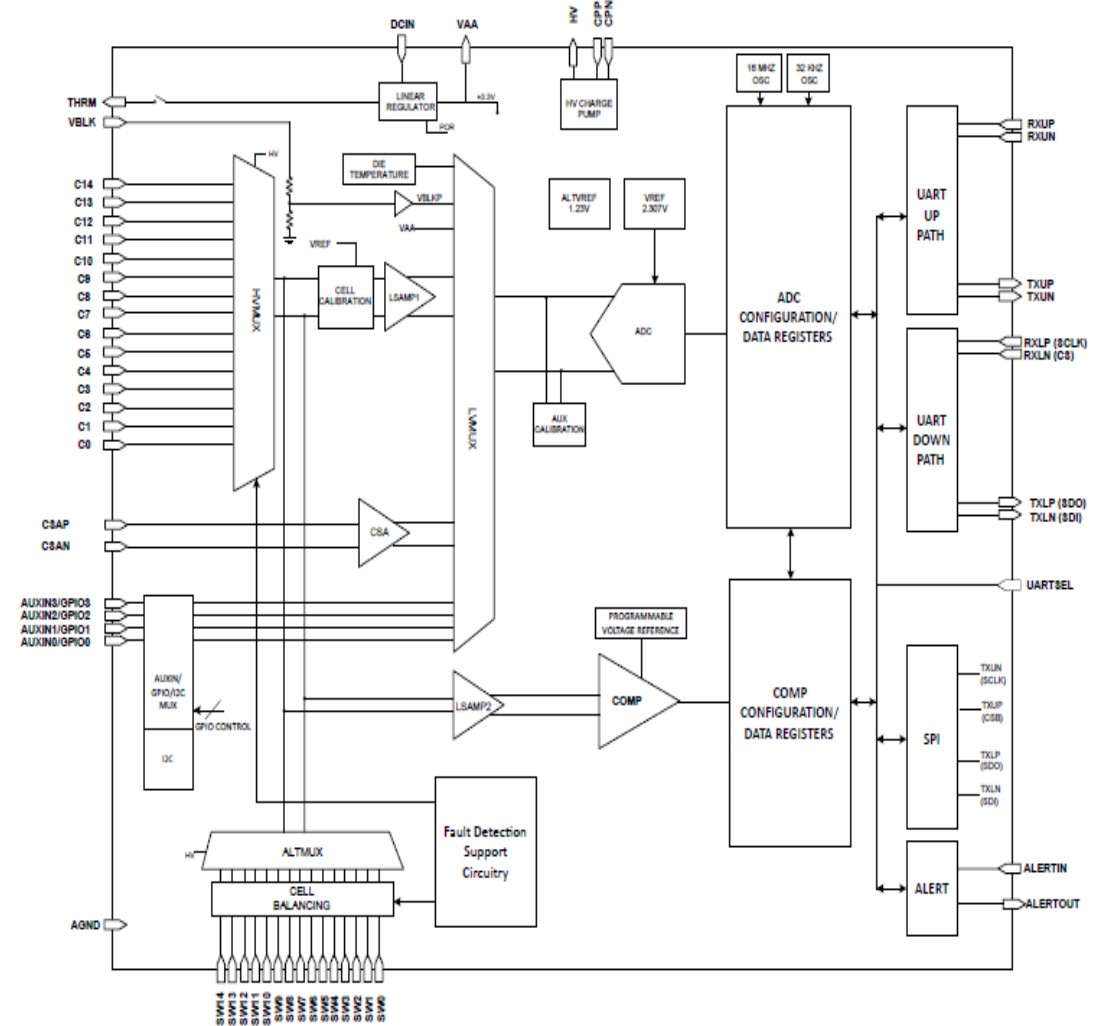
► ADI 产品及解决方案

- BMS Monitor: ADBMS181x (16-ch), ADBMS6830, MAX17852
- Gate driver: ADuM4135/36, ADuM4145/46, ADuM4177, ADuM412x, ADuM422x
- Current sensing: ADI amplifier
- Interface: ADM3050, ADM2484
- DC Meter: AD7779, ADuCM355, ADE9153A
- Processor: ADSP-21489, ADSP-CM408

MAX17852 - 带电流检测的14单元电池监控器

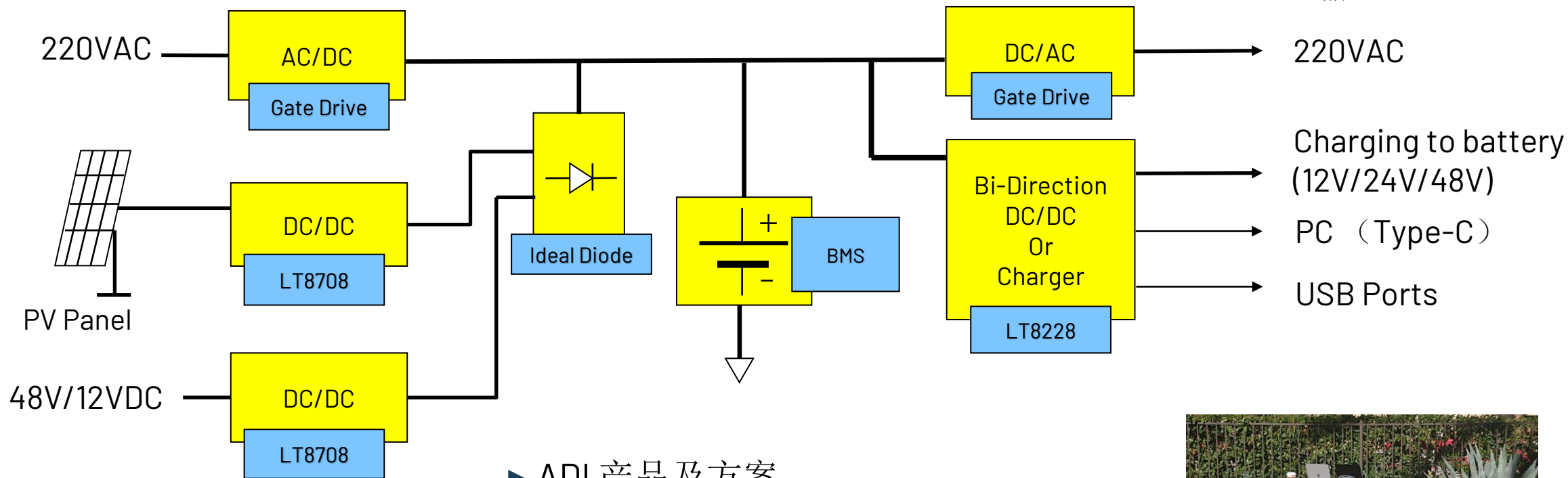
Features

- AECQ-100 Grade 1 Temperature Range
- Operating Voltage from 9V to 65V
- ASIL D - Voltage, Temperature, Current, Communication
- OBDII - Voltage/temperature measurement redundancy
- Redundant Monitor and Alert pins
- 14 Cell-Voltage Measurement Channels
 - > 2mV Accuracy (0.2V-4.8V, 5°C to 40°C)
 - > 4.5mV Accuracy (-20°C to 125°C)
- 14 Cell-Balancing Switches
 - > Up to 300mA per switch
 - > Emergency Discharge Mode
 - > Automatic cell balancing enabling micro sleep mode
- **Current sense amplifier**
 - > **7 Selectable ranges**
 - > **10mA resolution @ 256 gain**
- Improved Acquisition Time
- 4 Selectable GPIO/AUXIN pins
- **Pin Selectable SPI/UART Communication Interface**
- Dual UART, Redundant Communications, Double speed
- **I²C Master Interface**
- Ultra-Low Power Operation (Standby 2mA, Shutdown 2µA)
- Die Temperature Measurement
- **IDEAL FOR 48V APPLICATIONS**



户外及便携式电源结构及ADI解决方案

► 输入源



► 输出

► ADI 产品及方案

- 双向DC/DC: LT8708, LT8228
- Ideal Diode: LTC435x
- BMS Monitor: ADBMS181x, MAX1785x
- Buck/Boost (MPPT): LT8491
- Gate Driver: LT7000/7001

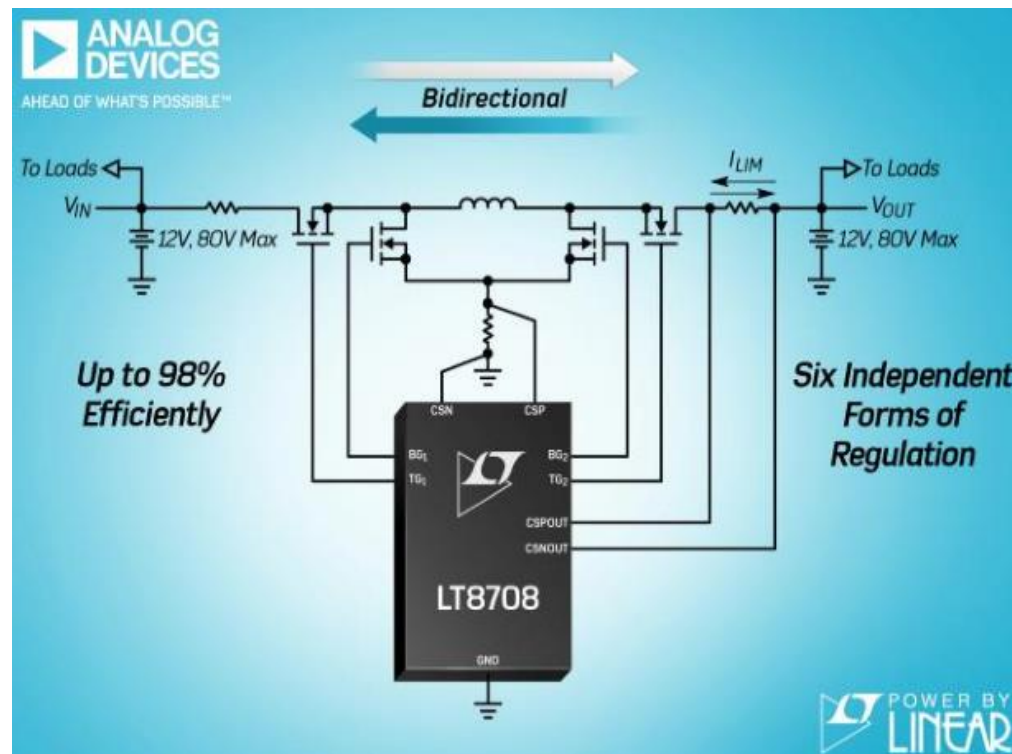


FEATURES

- Single Inductor Allows V_{IN} Above, Below, or Equal to V_{OUT}
- Six Independent Forms of Regulation
 - V_{IN} Current (Forward and Reverse)
 - V_{OUT} Current (Forward and Reverse)
 - V_{IN} and V_{OUT} Voltage
- Forward and Reverse Discontinuous Conduction Mode Supported
- Supports MODE and DIR Pin Changes While Switching
- V_{INCHIP} Range 2.8V (Need $EXTV_{CC} > 6.4V$) to 80V
- V_{OUT} Range: 1.3V to 80V
- Synchronous Rectification: Up to 98% Efficiency
- Available in 40-Lead (5mm × 8mm) QFN with High Voltage Pin Spacing

APPLICATIONS

- High Voltage Buck-Boost Converters
- Bidirectional Charging System
- Automotive 48V Systems



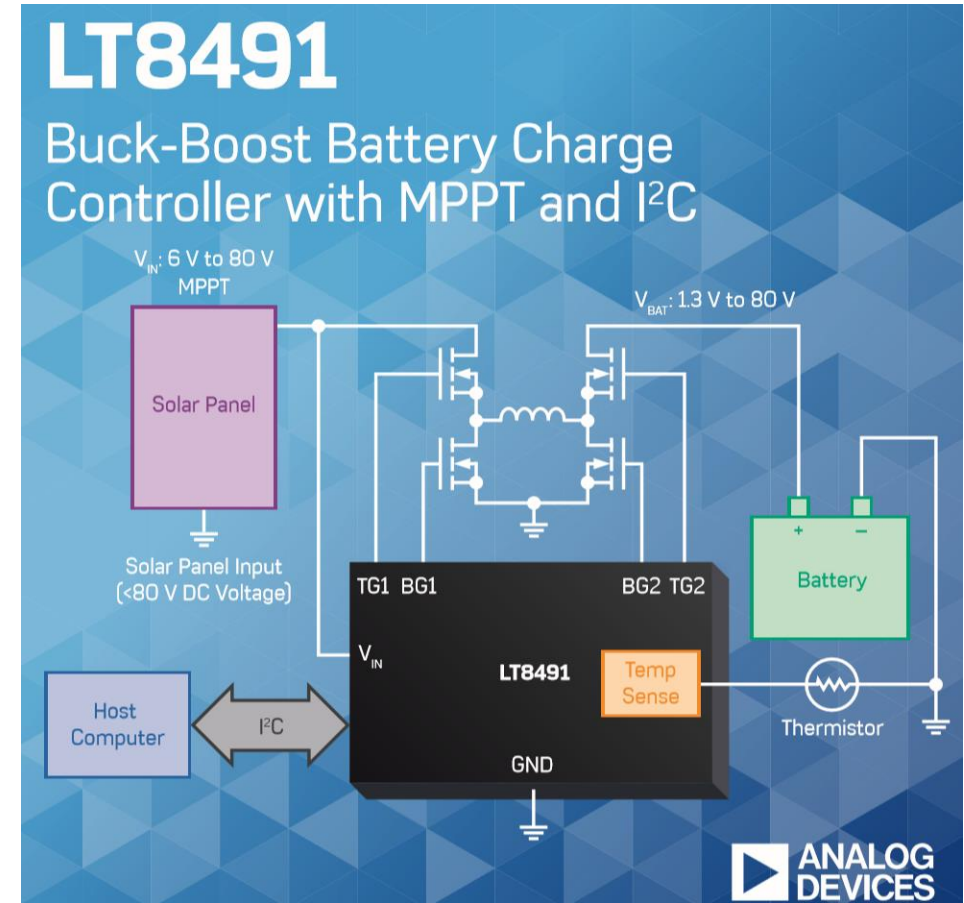
LT8491 – 帶有最大功率點追蹤 (MPPT) 的双向升降压DC/DC控制器

Value Proposition

- ▶ MPPT: Maximum Power Extracted from Panel
- ▶ Buck-Boost Topology for low V_{in} Operation
- ▶ I²C Interface Provides Valuable Information

Key Benefits

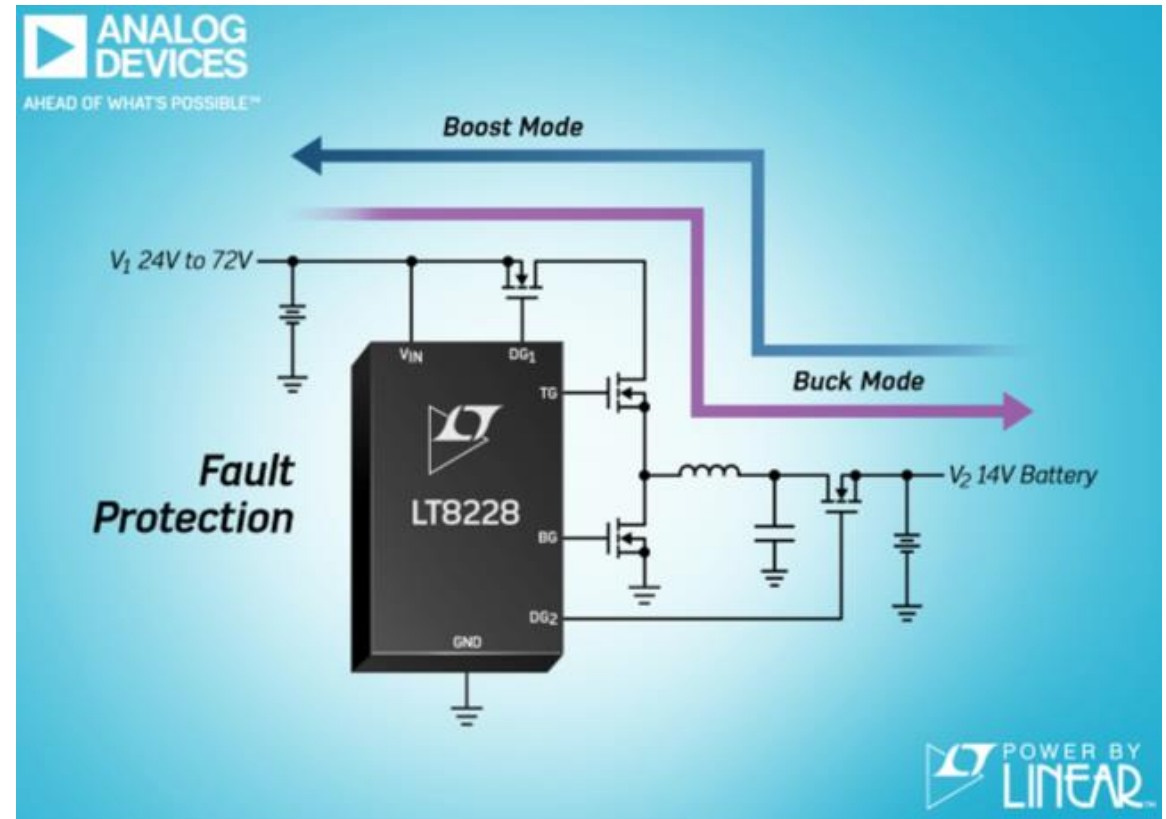
- ▶ Telemetry (V_{PANEL} , V_{BAT} , P_{IN} , P_{OUT} , etc.)
- ▶ Charging Status & Fault Reporting
- ▶ More Charger Configuration Options



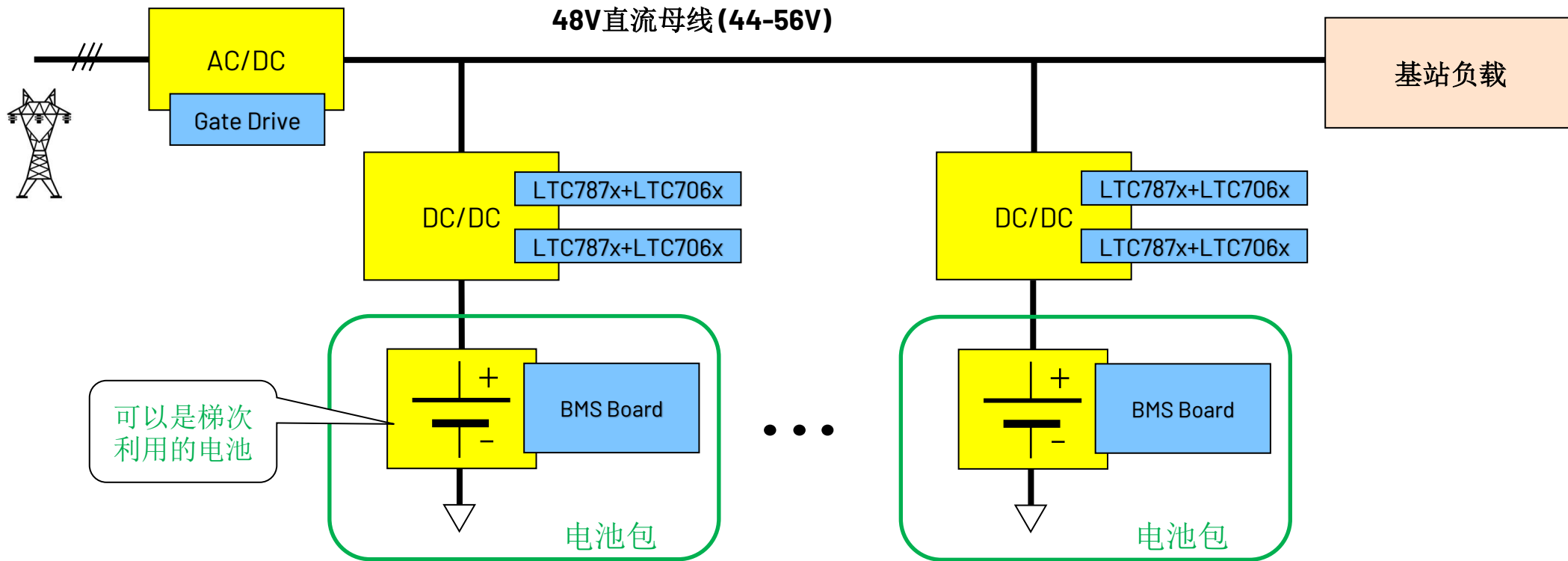
LT8228: 带保护的双向升降压DC/DC控制器

FEATURES

- Bi-directional Voltage or Current Regulation
- Bi-directional Reverse Current Protection
- Input and Output Reverse Voltage Protection to -60V
- Bi-directional In-rush Current Limit
- Switching MOSFET Short Detection and Protection
- 10V Gate Drive
- Wide Input and Output Voltage Range up to 100V
- Feedback Voltage Tolerance: $\pm 0.5\%$ Over Temperature
- Bi-directional Programmable Current Regulation and Monitoring
- Extensive Self-Test, Diagnostics and Fault Reporting



基站备用电源结构及ADI方案



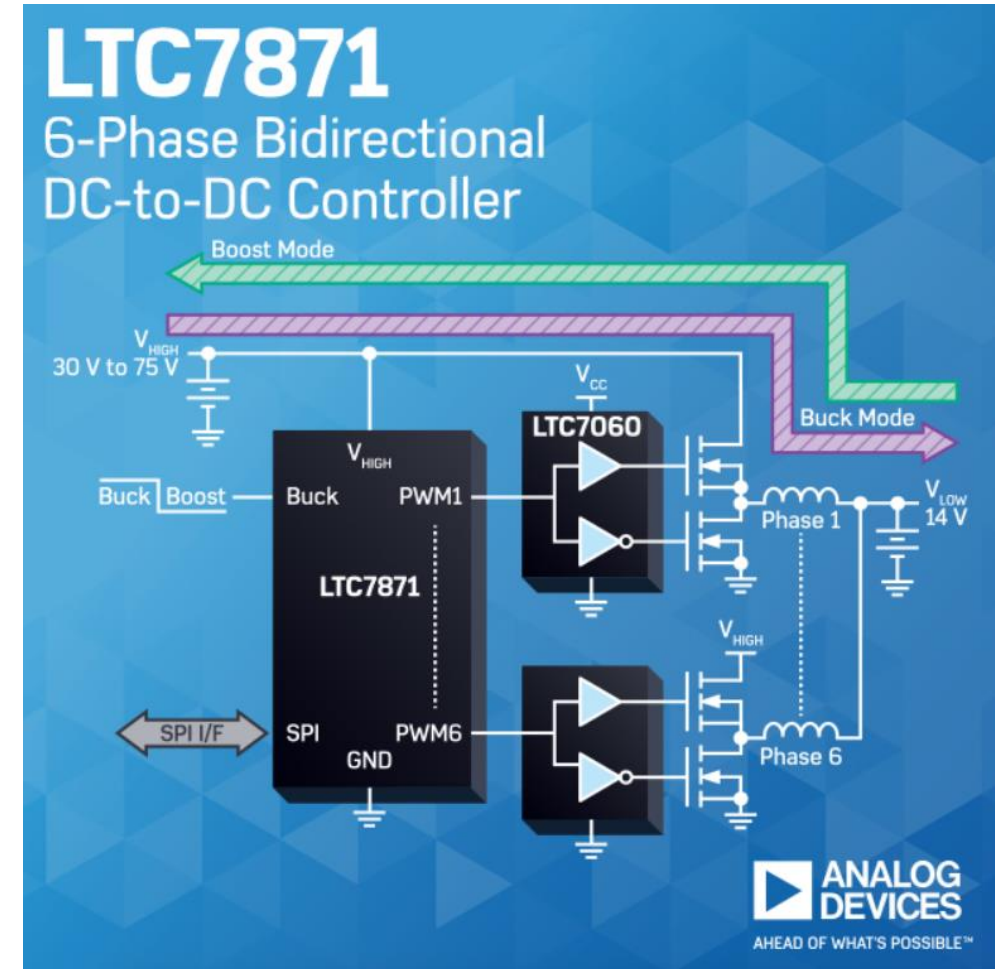
▶ ADI 产品及方案

- ▶ 双向DC/DC: LT7871, LT7872
- ▶ BMS Monitor: ADBMS181x, MAX1785x
- ▶ Gate Driver: LTC706x
- ▶ Iso-Interface: ADM3050, ADM2484, ADM276xE

LTC7871: 6相双向 DC/DC 控制器

Features and Specifications

- 6-Phase for High Power
- Dynamic Regulation of V_{IN} , V_{OUT} or Current
- Operates with External Gate Drivers and MOSFETs
- V_{HIGH} up to 100V; V_{LOW} up to 60V
- Synchronous Rectification: Up to 98% Efficiency
- Programmable Inductor Current Monitoring and Regulation
- SPI Compliant Serial Interface
- Operation Status and Fault Report
- Programmable V_{HIGH} , V_{LOW} Margining
- Phase-Lockable Frequency: 60kHz to 750kHz
- Spread Spectrum Modulation Optional
- Multiphase/Multi-ICs Operation Up to 24 Phases



LTC7872: 4相双向 DC/DC 控制器

Features and Specifications

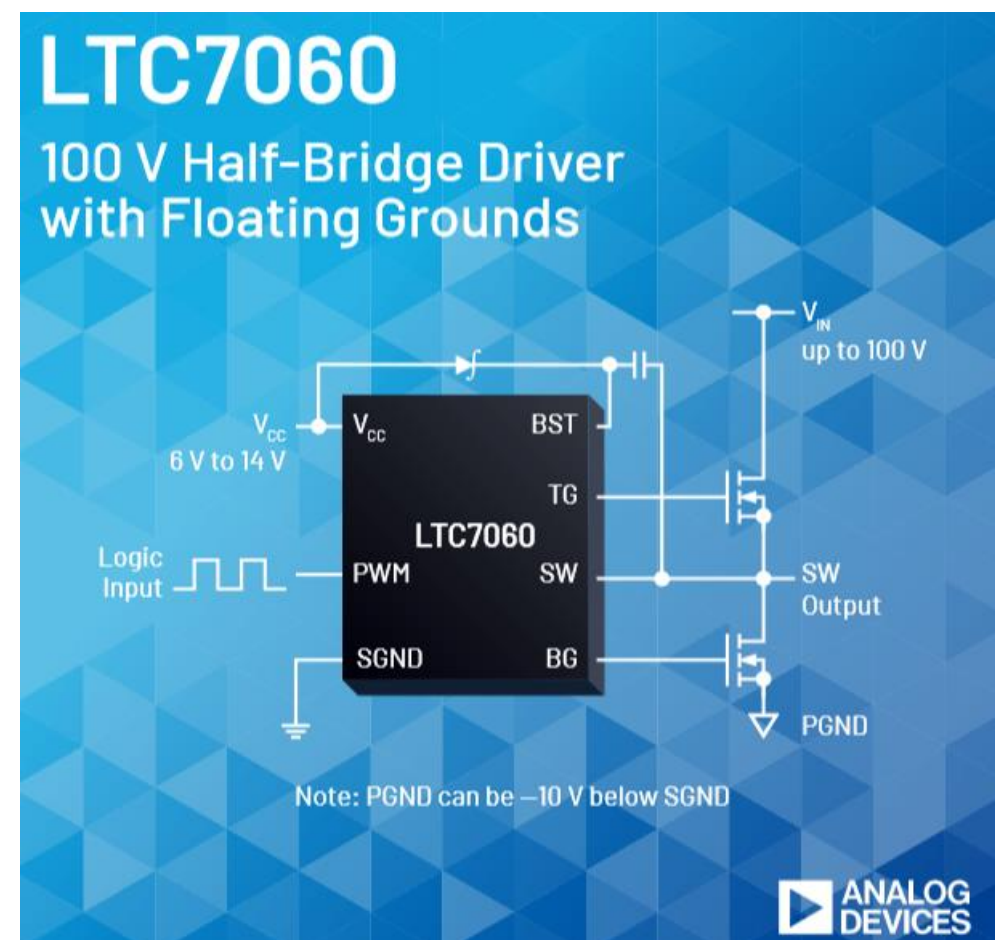
- Unique Architecture Allows Regulation of Input Voltage, Output Voltage or Current
- Operates with External Gate Drivers and MOSFETs
- V_{HIGH} up to 100V; V_{LOW} up to 60V
- Synchronous Rectification: Up to 98% Efficiency
- Programmable Inductor Current Monitoring and Regulation
- SPI Compliant Serial Interface
- Operation Status and Fault Report
- Programmable V_{HIGH} , V_{LOW} Margining
- Phase-Lockable Frequency: 60kHz to 750kHz
- Spread Spectrum Modulation Optional
- Multiphase/Multi-ICs Operation Up to 24 Phases



LTC7060: 100 V 浮地半桥驱动

Features and Specifications

- ▶ Unique symmetric floating gate driver architecture
- ▶ High noise immunity, tolerates ± 10 V ground difference
- ▶ Minimum SW voltage is -10 V
- ▶ 100 V max V_{IN} independent of IC supply voltage V_{CC}
- ▶ 6 V to 14 V V_{CC} operating voltage
- ▶ 4 V to 14 V gate driver voltage
- ▶ 0.8 Ω pull-down, 1.5 Ω pull-up for fast turn-on/off
- ▶ Shoot-through protection
- ▶ Programmable dead time
- ▶ Three-state PWM input with enable pin
- ▶ Drives dual N-channel MOSFETs
- ▶ Thermally enhanced 12-lead MSOP
- ▶ AEC-Q100 automotive qual in progress



目录

双碳背景推动储能的发展

集中式储能及ADI解决方案

家用储能系统及户外电源设计

其它技术与储能系统相结合

- 电池内阻测试技术 - EIS
- 绝缘检测技术
- 无线BMS
- 烟感技术用于储能

▶ ADI的解决方案 - CN0510

- 可充电电池不仅需要电源管理设备来确保快速、安全充电，还需要监测其健康状态和预期寿命
- 什么时候应该更换电池，现在还不得而知

▶ 该解决方案如何解决问题

- 这个参考设计提供了一个完整的健康状态和预期寿命的锂离子电池的应用，这是目前市场上最常见的可充电电池
- 电池制造商可以使用这个解决方案来测量和监控他们的电池，并制定健康电池和故障电池的外观，以改善客户的体验

▶ 特性和好处

- 为客户提供有关电池更换的健康状态和充电状态信息分析功能，减少维护时间和成本
- 真实和想象的阻抗数据集创建锂离子和其他电池化学成分的精确测量
- 提供从毫赫兹到千赫兹范围的完整频率扫描
- Arduino开发环境使该设计可用于许多处理系统

Key Parts Used/Companion Hardware

[AD5941](#) High Precision, Impedance, and Electrochemical Front End

[AD8694](#) Low Noise, Rail-to-Rail Quad Op Amp

[ADG636](#) 1 pC Charge Injection, 100 pA Leakage Dual SPDT

▶ [Web page](#)

▶ Companion hardware

- [EVAL-ADICUP3029](#)

▶ [CN-0510 design support package](#)

- Schematics
- Layout
- BOM
- Assembly

▶ Software

- [ADICUP3029 + CN-0510 Application](#)

▶ User guide

- wiki.analog.com/resources/eval/user-guides/circuits-from-the-lab/cn0510

▶ Support

- [Circuits from the Lab® EngineerZone®](#)

▶ **AD594x: 用于电化学和EIS应用的第三代内阻测量AFE**

- ADUCM350/5: 用于工业和医疗的 AFE + MCU
- AD5940: 通用市场, 发布于 2Q19
- AD5941: 汽车应用, 发布于 4Q20

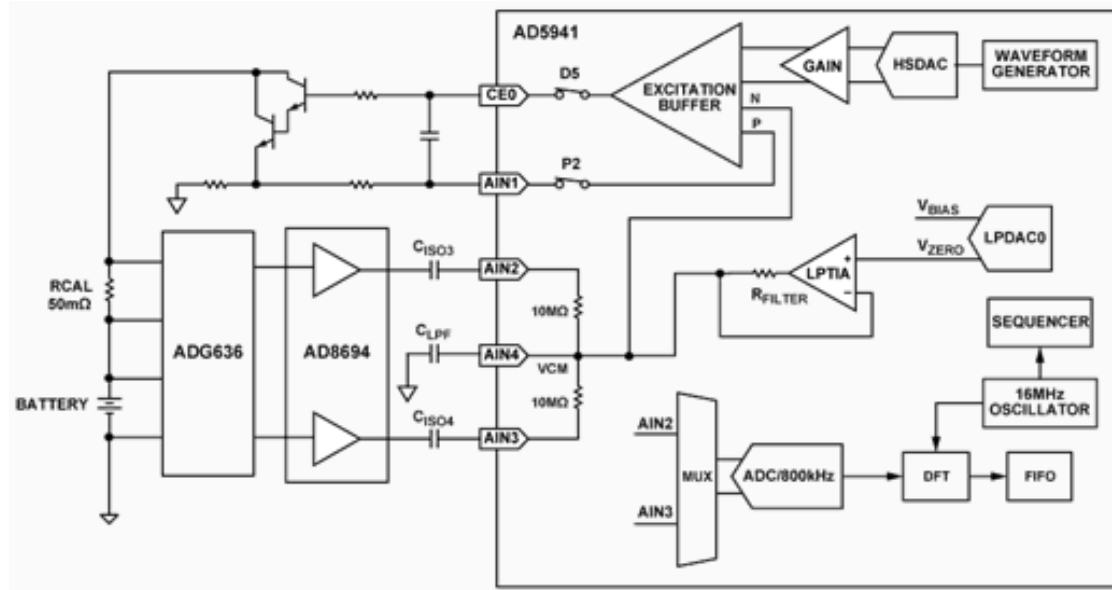
▶ **CN-0510: 已于2019年11月发布**

- 发布评估系统和CFTL
- 从1Hz到1kHz的误差小于1.5%
- 多个厂家已评估并采用

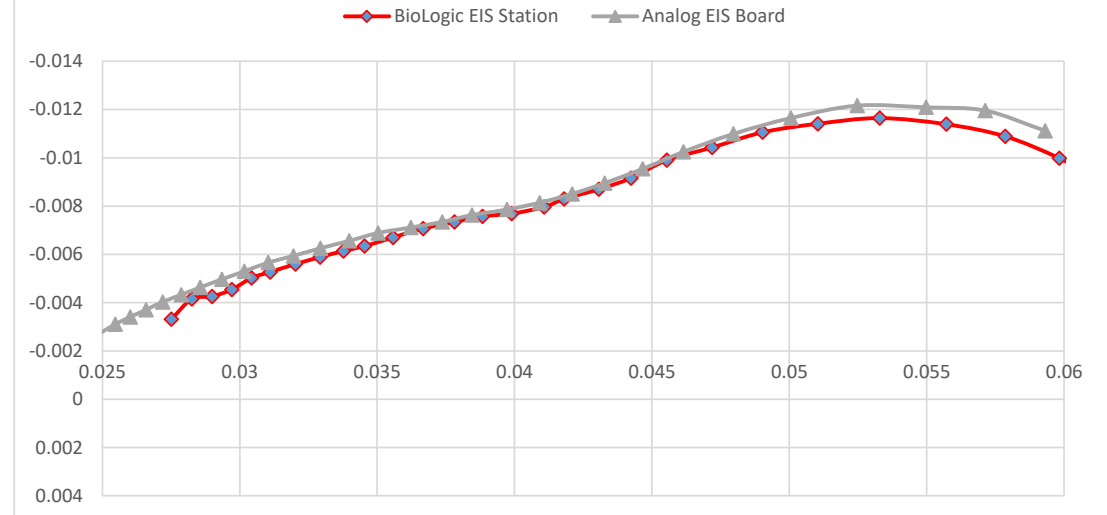
AD5941 Battery EIS System



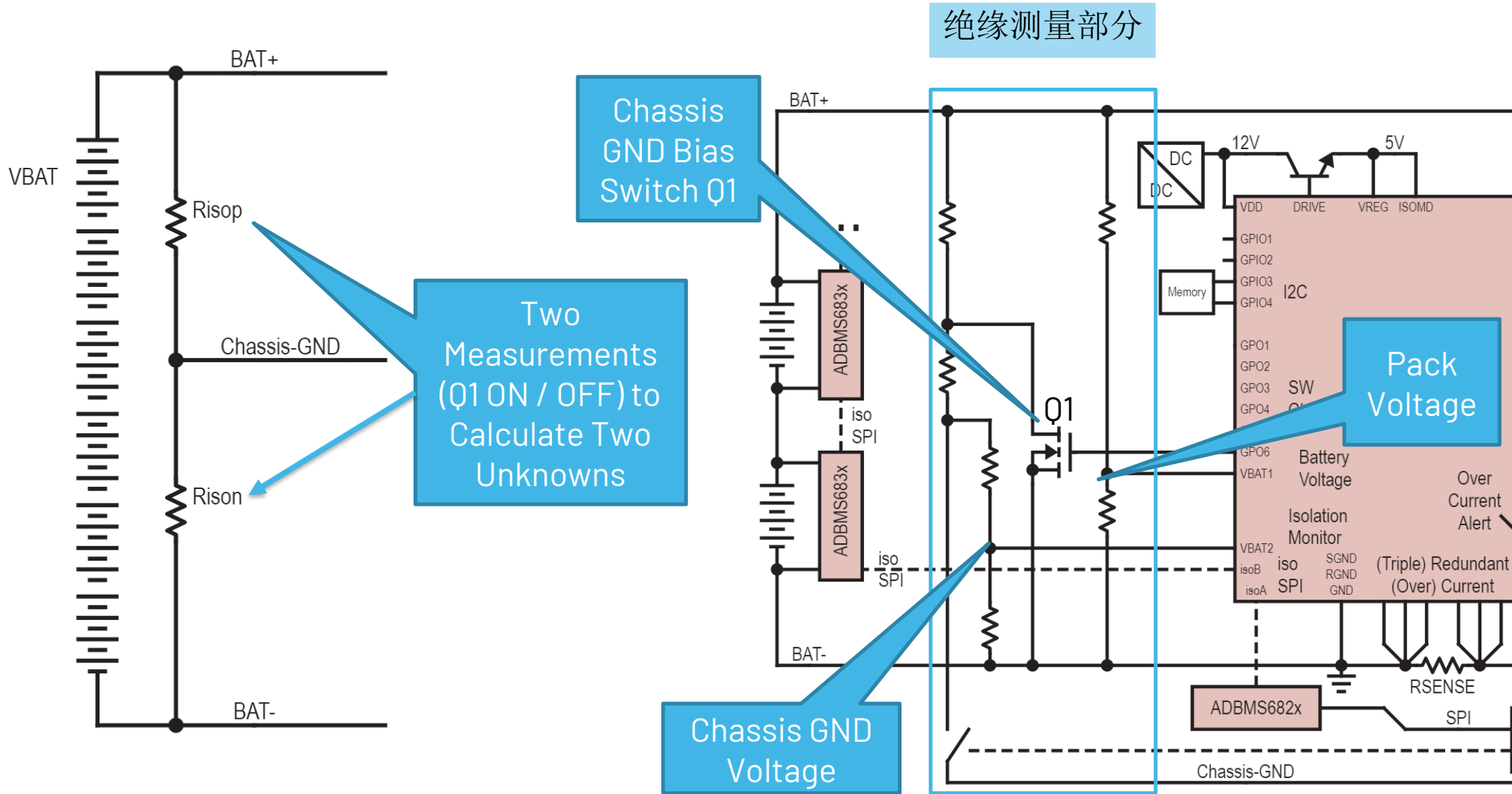
\$10K Bio-Logic EIS Benchtop



BIOLOGIC EIS VERSUS ADI EIS

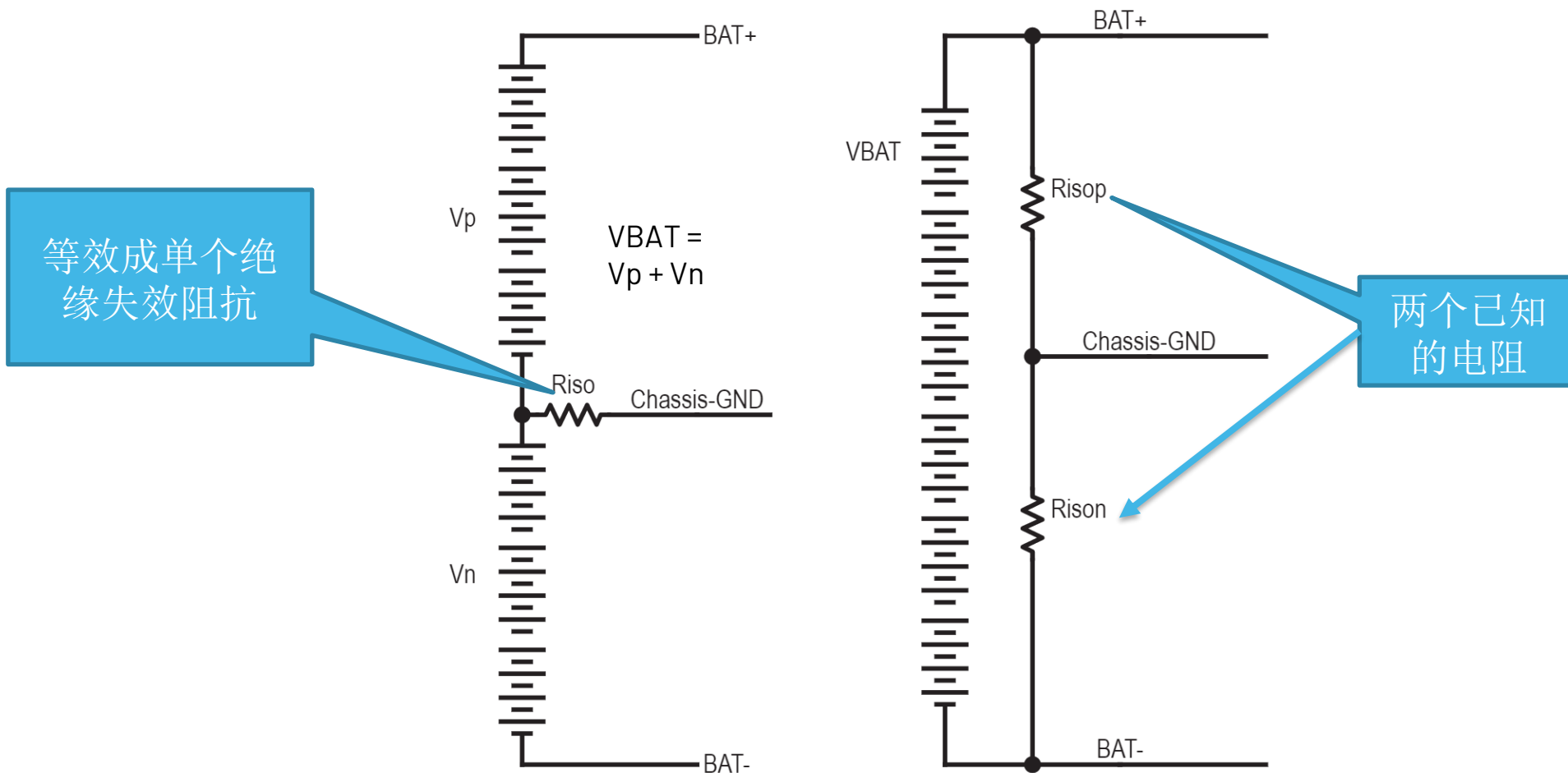


用总线管理芯片做绝缘电阻检测



对外壳的等效绝缘电阻

绝缘电阻等效电路






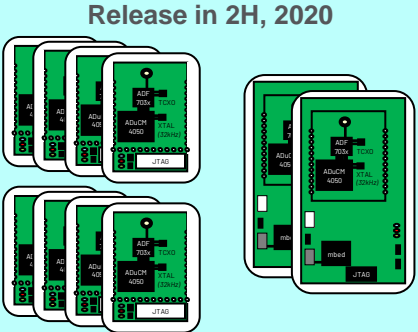
已知电阻:

▶ **Risop, Rison** or

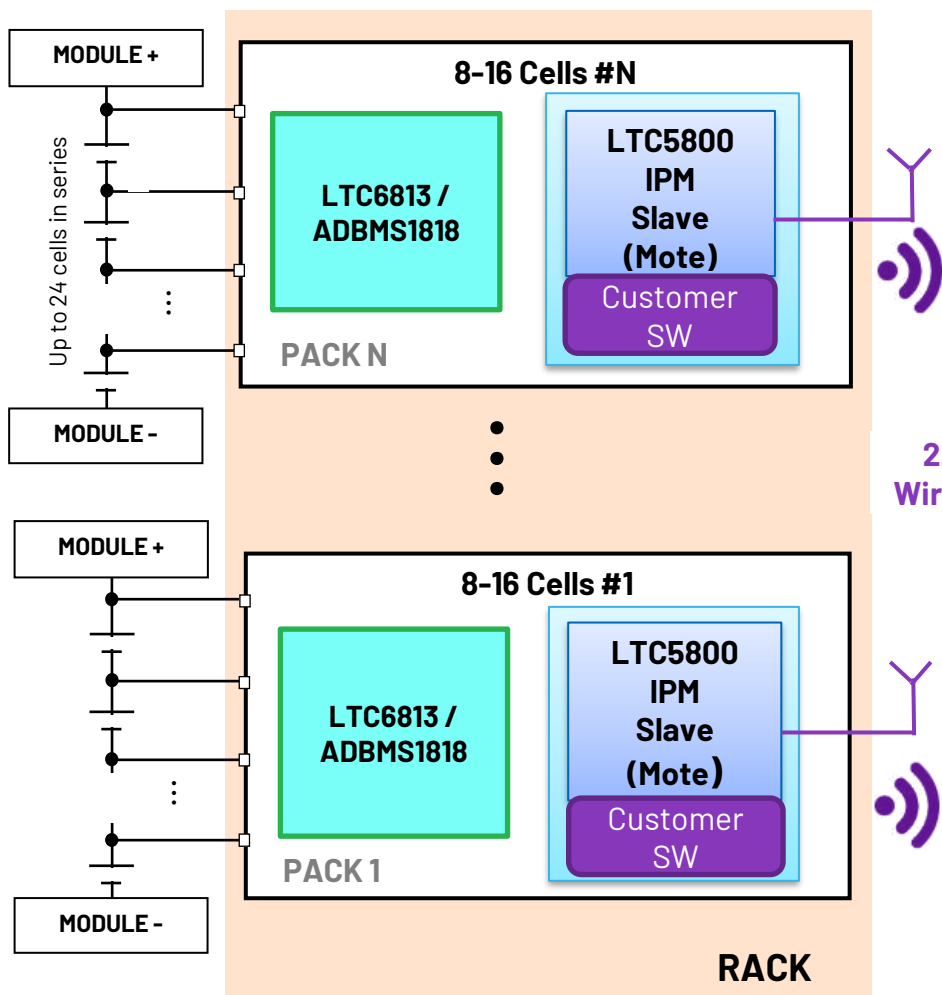
▶ **Riso** and (**Vp:Vn**)

▶ **Riso** 总是可以等效成 **Risop, Rison**

ADI 的短距离，微功耗无线组网产品系列

	ADI SmartMesh IP	WirelessHART	ADI RapidNet IP	ADI AgileNet 6T
支持芯片	LTC5800-IPMA	LTC5800-WHM	ADuCM3029 μ Controller ADF7023 Xcvr	ADuCM4050 μ Controller ADF7030-1 Xcvr
频率和波段	2.4 GHz World wide band	2.4 GHz World wide band	Sub GHz World wide regional bands	Sub GHz World wide regional bands
关键特点	IEEE802.15.4 兼容 Mesh 网 可扩展到1000个节点 250 kbps 数据带宽 长电池寿命	WirelessHART 兼容 Mesh 网 长电池寿命	6LoWPAN 兼容 P2MP 长距离网 可扩展到12000个节点 300kbps高下行链路BW 长电池寿命 长距离	6TiSCH 兼容 Mesh 网 可扩展到1000个节点 50 kbps 数据带宽 长电池寿命 长距离
用途	高密度网络在恶劣的工业环境中	高密度网络在恶劣的工业环境中	高密度的大型网络需要快速下载独特的消息。或需要低延迟警报消息的低密度网络	低密度的网络 分布在大面积或难以到达节点
开发环境	 Starter Kit DC9021B	 Starter Kit DC9022B	 EV-RAPID-ESL-900Z/EV-RAPID-ESL-900JZ and EV-RAPID-KIT-900Z EV-COG-AD3029LZ EV-GEAR-EINK1Z EV-COG-ADF7023-9Z EV-DNG-RFMD-9001Z	 Release in 2H, 2020

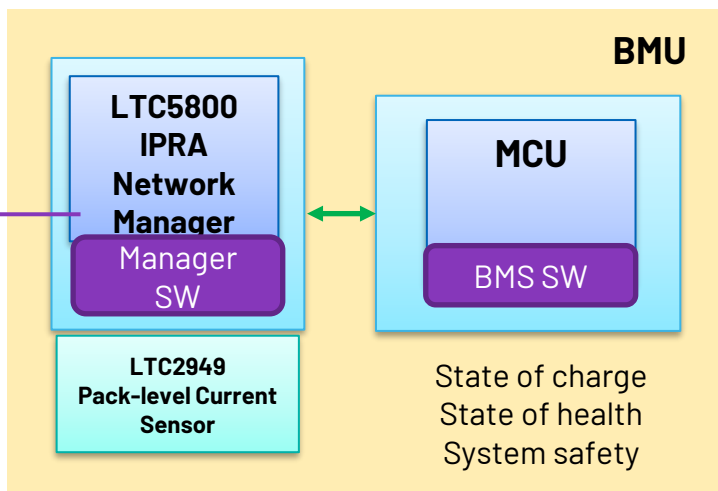
基于无线BMS的储能方案



每个电池包
2~5kWh
25~52 V
8~16 Cells

1 network
1 sec update rate/Pack
Max 32 slave/manager

2.4G
Wireless



优点	更少的复杂电缆结构 低的费用 / kWh 易于安装配置 自组网技术
缺点	成本略高于有线解决方案



60%

因火灾导致的死亡发生在未安装烟雾报警器的建筑物内



23%

因火灾导致的死亡发生在安装了烟雾报警器，但因频繁误警而被禁用的情况下



83%

与20世纪70年代相比火灾逃生的时间减少百分比，这是因为现在居住和工作环境中存在许多合成材料

各地区用于烟雾报警的法规

北美地区

- UL 268 - 用于火灾系统的烟雾报警装置
 - 第七版 - 预计于2021年 6月30日生效
- UL 217 - 烟雾报警
 - 第八版 - 预计于2021年 6月30日生效
- **主要更新了明火PU材料即汉堡烟（干扰烟）测试**

欧洲

- EN 14604 - 烟雾报警装置 (2006)
- BS EN 54 - 火灾检测及报警系统 (2015)
 - 第 29章: 多传感器火灾检测装置—提出结合热传感器和烟雾传感器结合的需求

国际标准

- ISO 7240 - 火灾检测及报警系统(2018)
 - 第7章: 规定检测器可采用散射光，透射光或电离等方式
 - 中国国标采用了2003版国际标准的内容

ADPD188BI - 用于烟雾和气溶胶探测的光学模块

▶ 采用超小模块体积的完整光学解决方案：
非常适合用于

- 住宅和商业场所的烟雾探测
- 污染监测
- 气溶胶探测

▶ 全集成不同波长光发射器，光电接收器、AFE、ADC、驱动器和时序内核

▶ 高度环境光抑制

▶ ADPD188BI: 设计资源

▶ 评估板:

- EVAL-ADPD188BIZ-SK2
- 需要采用处理器接口板:
EVAL-ADPDUCZ

▶ 烟室

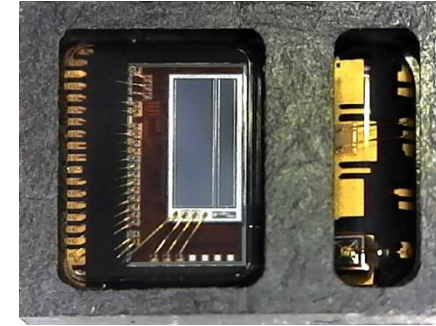
- 需要评估许可

▶ 产品主页: [ADPD188BI](#)

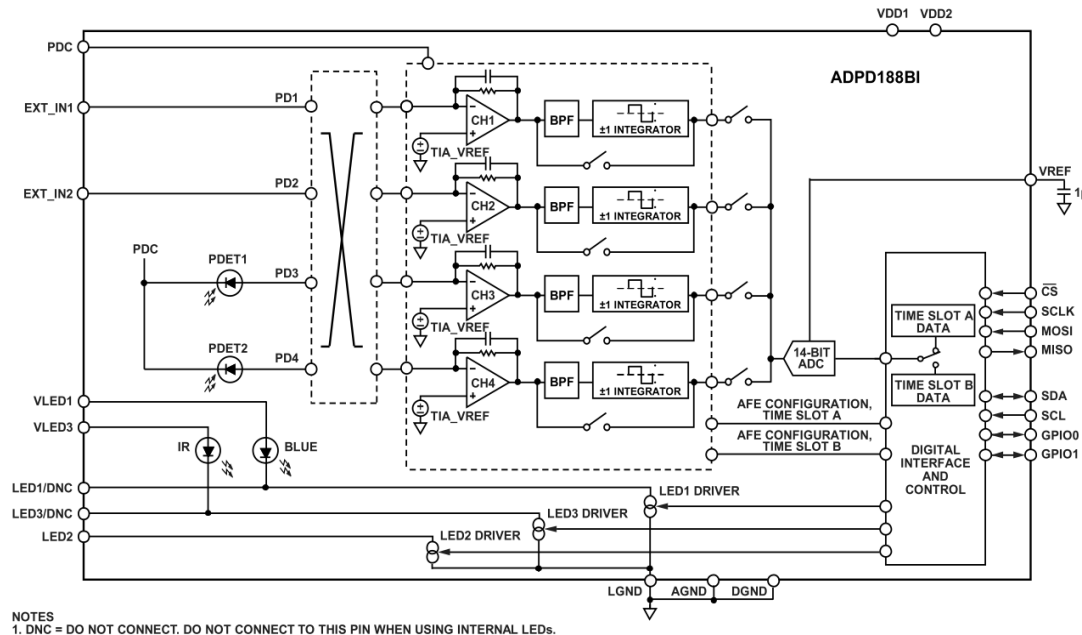


ADI获得评估许可的烟室
可以直接向ADI的合作伙伴
Accumold购买

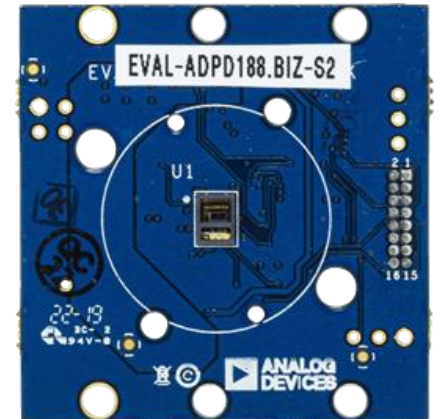
接收器和信号
调理芯片



光发射器



NOTES
1. DNC = DO NOT CONNECT. DO NOT CONNECT TO THIS PIN WHEN USING INTERNAL LEDs.



EVAL-ADPD188BIZ-S2

问题回答

在线支持：骏龙科技现场应用工程师
艾伟、梁少密、黄乐谟