Who's in Charge - Solutions for HEV/EV Battery Cell Management

Keith Larson
Marketing Manager, Analog and Power Devices
Keith Larson...

- **Marketing Manager for Analog and Power Products**
  - Support advanced marketing of a full line of analog and power products used in a wide variety of automotive applications, including mixed-signal ICs, power MOSFETs, IGBTs, MOSFET gate drives and intelligent power devices (IPDs).

- **Senior Project Engineer at Delphi Corporation from 1991**
  - Held various assignments spanning many electrical engineering disciplines including manufacturing test, advanced test development, circuit development and analysis and IC architecture and development.
  - Developed breadth of knowledge in various automotive systems including passive crash sensing, body computers, braking, engine and powertrain controllers.
Renesas Technology & Solution Portfolio
Analog and Power Automotive Products

**40V-200V in Application Optimized Processes**
- Low voltage family optimized for Qgd x Rds(on)
- Separate family optimized for pure Rds(on) performance
- Low RTH packaging technology

**650V Discrete Devices**
- Class-leading turn-off loss
- High-speed, short-circuit rated, and low Vce(on) optimized
- 200A, 300A & 400A bare die

**6-200 mΩ Protected High-side Drivers**
- Scalable solutions for exterior lighting, relays, solenoids...
- Ultra-low key-off leakage current performance
- Robust protection against short-circuit conditions

**Products Addressing All Major Vehicle Systems**
- Crash-sensing chipset for airbag applications
- Powertrain output load drivers, direct gas injection...
- Battery management ICs, MOSFET gate drivers
- Micro-isolator IGBT drivers for high-voltage isolation
- Multi-chip Package devices for switch input and load control
‘Enabling The Smart Society’

■ Challenge:
“The electrification of the automobile brings substantial challenges in it’s goal to contribute to the establishment of the Smart Society as a robust, efficient yet economical alternative to fossil-fuel-derived energy. Among the greatest challenges lies within the management of the single most expensive component of the electrified vehicle, the battery.”

■ Solution:
“Renesas battery management solutions couple high-accuracy performance with exhaustive protection and flexible architectures for optimal battery management systems.”
Agenda

- Introduction to Battery Cell Management
  - The Big Deal about Lithium Ion Battery Packs
  - State of Charge (SOC) vs. State of Health (SOH)
  - Methods for Determining State of Charge (SOC)
  - Balancing Individual Cells to Optimize SOC
  - A Typical Cell Balancing Algorithm*
  - Example of Battery Management System
  - Battery Management System Architectures

- Battery Cell Management: Features of Merit
  - ADC Cell Voltage Measurement Error
  - Battery Stack Cell Voltage Acquisition Time
  - “Hot Plug” Reliability
  - Cell Balancing Methods
  - Diagnostics and Safety
  - Ultra-low Quiescent Current

- Renesas Battery Cell Management Solutions
  - Battery Monitoring IC Market Prediction
  - Major Requirements
  - Roadmap of Battery Monitor IC for HEV/EV
  - The Renesas Advantage in BMS Applications
Introduction to Battery Cell Management
The Big Deal about Lithium Ion Battery Packs

- Charge balance is the crucial performance characteristic of the battery pack
  - Charge imbalance limits the total usable capacity of the battery pack
    - Pack performs to the “lowest common denominator”
  - Charge imbalance can be caused by many factors
    - Variations in manufacturing process
    - Operating conditions, i.e. temperature, etc.
    - Age

- Battery manufacturers take great care to provide a well-balanced battery
  - Cells sorted by manufacturer to reduce variability amongst the cells
    - capacity and internal resistance
    - adds cost to the manufacturing of the battery pack
  - Battery packs still require careful monitoring and balancing to optimize performance due to mismatch reasons noted above
    - Improper balance can lead to over-charging or under-charging, eventually damaging the battery cells
State of Charge (SOC) vs. State of Health (SOH)

State of Charge

- Measure of the capacity of each cell or entire pack
  - Measured in %
  - Equivalent to a fuel gauge
- Cannot be determined by direct measurement
- Absolute Measure
  - Reflects an objective measure of charge remaining in the cell
  - Many methods generally accepted across the industry

State of Health

- Measure of the capability of the pack compared to original specifications
  - Measured in %
  - Figure of merit
- Cannot be determined by direct measurement
- Relative Measure
  - Subjective measure comparing present state to original state
  - No market agreement for determination
Methods for Determining State of Charge (SOC)

- **Direct**
  - Discharge battery at a constant rate
  - Not practical due to changing load current, discharging load current decrease versus age and others

- **Internal Impedance Measurement**
  - Not widely used due to complex measurement and data interpretation

- **Specific Gravity**
  - Measuring the weight of the active chemicals (as in lead-acid)
  - Not suitable to other chemical compositions such as lithium-ion
Methods for Determining State of Charge (SOC)

- **Coulomb Counting**
  - Measures current into or from a cell integrated over time
  - Most accurate method for determining SOC, but cannot predict voltage degradation

- **Voltage-based**
  - Simple and widely used, but varies with temperature, discharge rate, etc.
    - Lead-acid voltage is linear with charge whereas lithium ion is very nonlinear

![Graphs showing open circuit voltage vs. residual capacity and discharge characteristics of 100Ah Li-ion cell. Lead-acid and Lithium ion are labeled.]
Balancing Individual Cells to Optimize SOC

- Passive balancing is used to adjust the state of charge (SOC) to optimize the ability for the battery to provide maximum energy
  - Each cell of the pack (even the lowest) must be allowed to fully charge and discharge to maximum the battery capacity

- Passive balance bleeds charge from higher charged cells
  - Cells are discharged to the lowest common denominator
    - Cell with the lowest capacity sets the bar
  - Power dissipated in heat via an external resistor
  - Lowers the overall efficiency of the battery pack

- Balancing current depends upon many factors
  - Capacity of the cell
  - Time allowed for balancing
  - Expected amount on imbalance
A Typical Cell Balancing Algorithm

- Balancing a group of 6-12 cells begins with a charging cycle
  - Voltage on each cell is measured and stored
  - Lowest cell is identified
  - Charging begins

- Charging cycle ends when one cell reaches the maximum target voltage (or an internal timer expires)
  - Voltage on each cell is again measured and stored

- If the cell with the highest voltage is not the cell that started with the lowest voltage, the cells must be balanced
  - Cell with the lowest voltage becomes the balanced-voltage target value
  - Remaining cells are discharged until they reach the balanced-voltage target value

- The cycle is then repeated as necessary
Example of Battery Management System

- Single battery monitor IC can monitor 6 to 12 cells in series
- Multiple battery monitor ICs are cascaded in series
  - Single MCU can manage the entire string with high-speed serial communications interface
  - Battery Management Unit manages the oversight of the system
Battery Management System Architectures

- Centralized vs Distributed Cell Management Unit (CMU)

Centralized CMU

Pass-through Daisy-Chain Return

Distributed CMU

Fully-buffered Daisy-Chain Return
Battery Cell Management: Features of Merit
ADC Cell Voltage Measurement Error

- Voltage changes are relatively small over the discharge curve and vary with load and temperature

- Voltage measurements are made in a harsh automotive environment
  - Load current transients
  - Electromagnetic interference
  - Voltage transients
  - High common-mode voltages

High accuracy allows for accurate SOC calculations, allowing the battery management system to make full use of the available battery capacity.
Battery Stack Cell Voltage Acquisition Time

- SOC algorithms require a periodic, synchronous sample of all the cells in the battery pack.

- The total acquisition time depends on a number of factors:
  - BMS communications architecture: Distributed vs. Centralized
  - ADC conversion time: Delta-sigma vs. Successive Approximation
  - Number of cells

- Cells must be simultaneously sampled for the most accurate calculation.

- Customers generally require a total acquisition time between 5-10 milliseconds.
“Hot Plug” Reliability

- During vehicle assembly, cell connections from the battery pack to the CMU are made at random, known as “hot plug”
  - Not only between different BMICs in a string, but among any 12 cells of any single BMIC within the string!
- The BMIC must meet stringent voltage and transient requirements in worst case connection scenarios due to sneak paths from external components

**Sample of actual OEM test scenarios**

- Highest cell on highest IC (e.g. cell 96) is connected first followed by ½ the stack voltage (e.g. cell 48 to system ground), creating a high voltage stress through input filter components and inter-device protection discrete components
- Lowest cell on highest IC (e.g. cell 85) is connected first followed by ½ the stack voltage (cell 48 to system ground), creating a high voltage stress through cell balancing components and inter-device protection discrete components
- Next-to-highest cell on highest IC (e.g. cell 95) is connected first followed by ½ the stack voltage (cell 48 to system ground), creating a high voltage stress through input filter components and inter-device protection discrete components
Cell Balancing Methods

Passive

Active

Flyback

Buck

Buck-boost

Efficiency

Cost
Diagnostics and Safety

- Cell over-voltage and under-voltage
  - Provides fault monitoring to detect ADC fault on voltage measurement
  - Can be combined within the BMIC or in other cases is a stand-alone parallel monitor device (without cell balancing)
  - Assists with diagnosis of open cell input

- Loss of cell input voltage (open-circuit)
  - Open cell voltage input could provide valid A/D result
  - IC must successfully distinguish open-circuit from a dead cell
    - Can’t simply pull up or down on the input

- Cell balance switch status
  - Must verify the on/off capability of the switch

- Loss of VCC or ground
  - Operation is still possible based upon the presence of other cell inputs
Ultra-low Quiescent Current

- Quiescent current
  - Battery monitor IC draws current from battery cells
  - Vehicle is off most of its life, resulting in a constant discharge load
  - Minimizing leakage is paramount!

- Quiescent current variability among BMICs in a string
  - Each BMIC draws current from the cells it monitors
  - Lithium-Ion battery packs are most reliable if the charge and discharge cycles are identical
  - Customers require a balanced load drawn by all the BMICs in the stack
    - Results in a very tight distribution requirement!
Renesas Battery Cell Management Solutions
**Roadmap of Battery Monitor IC for HEV/EV**

**High Speed**

- **R2A20027FP**
  - 6 to 12 cell
  - 12-bit SAR ADC
  - +/- 4 mV total error
  - 100 us/96-cell conversion
  - Passive balancing
  - Differential SPI I/F

**Higher Accuracy**

- **R2A20028FP**
  - 6 to 12 cell
  - 12-bit Delta-sigma ADC
  - +/- 2.5 mV total error
  - 5 ms/96-cell conversion
  - Passive balancing
  - Differential SPI I/F

**Under Development**

- **R2A200yy**
  - 6 to 12 cell
  - Next Generation ADC
  - < +/- 2 mV total error
  - < 100 us/96-cell conversion
  - Active/Passive balancing
  - High speed communications
  - Integrated digital isolation
  - Next Generation, Under Consideration

**Differentiating product features**

**Merging extensive consumer experience with automotive robustness**

**2012**

**2013~**

© 2012 Renesas Electronics America Inc. All rights reserved.
Products In Development: R2A20027(28)

- Support for 6 to 12 Cells, up to 80 V
- Low A/D Measurement Error
  - R2A20027: +/- 4 mV\(^1\)
  - R2A20028: +/- 2.5 mV\(^1\)
- High-speed Conversion
  - R2A20027: 100 us\(^2\)
  - R2A20028: 5 ms\(^2\)
- Built-in Cell Balancing MOSFETs for reduced part count and smallest PCB footprint
  - 100 mA max
- Built-in Over/Under voltage detection function
- Differential SPI for Robust Communications
  - CRC>10
- Extensive diagnosis & detection functions to help enable ISO26262 compliance

\(^1\) Ta = 25 C  \(^2\) 12 cells
Cell Balancing Methods for R2A20027(28)

**Type-A**
Separated Balance & Measurement paths

**Type-B**
Common Balance & Measurement paths

**Type-C**
Isolated Balancing MOSFET

Voltage Measurement Path
Balancing Current Path
# Product Lineup for an Optimal Solution

<table>
<thead>
<tr>
<th>Cell Balancing Option</th>
<th>Packaging</th>
<th>ADC Option</th>
<th>Part Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type-A</strong></td>
<td><img src="#" alt="64-pin LQFP" /></td>
<td>12-bit SAR ADC</td>
<td>R2A20027AFP, R2A20027BFP</td>
</tr>
<tr>
<td></td>
<td><img src="#" alt="64-pin LQFP" /></td>
<td>12-bit DS ADC</td>
<td>R2A20028AFP, R2A20028BFP</td>
</tr>
<tr>
<td><strong>Type-B</strong></td>
<td><img src="#" alt="64-pin LQFP" /></td>
<td>12-bit SAR ADC</td>
<td>R2A20027CFP, R2A20027DFP</td>
</tr>
<tr>
<td></td>
<td><img src="#" alt="64-pin LQFP" /></td>
<td>12-bit DS ADC</td>
<td>R2A20028CFP, R2A20028DFP</td>
</tr>
<tr>
<td><strong>Type-C</strong></td>
<td><img src="#" alt="80-pin LQFP" /></td>
<td>12-bit SAR ADC</td>
<td>R2A20027EFP, R2A20027FFP</td>
</tr>
<tr>
<td></td>
<td><img src="#" alt="80-pin LQFP" /></td>
<td>12-bit DS ADC</td>
<td>R2A20028EFP, R2A20028FFP</td>
</tr>
</tbody>
</table>
Reference Platform

- **Cell Monitor Unit (CMU) Board**
  - R2A20027/28 BMIC\(^1\) and 78K0R/Fx3
  - Isolated connection to 78K0R/Fx3 board
  - SPI connector for daisy-chain connection to a second R2A20027/28 board

- **Load/Battery Module**
  - Design under consideration

- **Battery Management Unit (BMU) Board**
  - V850E2/Fx4 MCU
  - CAN connector for connection to the CMU
  - Cell voltage display
  - Battery charge switch

- **Battery Charger Unit**
  - Control signals available from BMU board for battery charger control

\(^1\) Battery Management IC
The Renesas Advantage in BMS Applications

- Delivering automotive robustness and consumer market leadership in lithium-ion battery cell management applications
- Offering voltage measurement options to meet evolving system architecture requirements
  - SAR for faster stack sampling and low A/D error
  - Delta-sigma for even more accurate A/D performance in less time-critical implementations
- Providing various cell-balancing options to provide greatest flexibility in passive cell balancing systems available on the market
- Integrating passive balancing switches to eliminate dozens of external components and reduce PCB footprint for the lowest system cost
- Utilizing differential SPI to enable a robust, noise-immune communication channel throughout the stack
- Supporting a full suite of built-in diagnostic functions to enable ISO26262 compliance
Questions?
‘Enabling The Smart Society’

Challenge:
“The electrification of the automobile brings substantial challenges in it’s goal to contribute to the establishment of the Smart Society as a robust, efficient yet economical alternative to fossil-fuel-derived energy. Among the greatest challenges lies within the management of the single most expensive component of the electrified vehicle, the battery.”

Solution:
“Renesas battery management solutions couple high-accuracy performance with exhaustive protection and flexible architectures for optimal battery management systems.”

Do you agree that we accomplished the above statement?
Please Provide Your Feedback...

- Please utilize the ‘Guidebook’ application to leave feedback

  or

- Ask me for the paper feedback form for you to use...
Automotive Analog and Mixed-Signal Product Experience

Dashboard
- Gauge Driver
- HVAC Control

Engine Control
- CNG Direct Injection
- MAP Sensor
- Crank Sensor
- Coolant Temp Sensor

Body
- Seat Position Control
- Keyless Entry
- HID Control
- Rain/Light Sensor
- MM-wave Radar
- Sunroof
- Window Lifter
- Steering Switch
- Power Management

Battery Management
- Li-Ion Battery Monitor
- Battery Sensor

Navigation
- Angular Sensor
- Velocity Sensor
- Audio Amp

Safety
- Occupant Sensor
- Rollover Sensor
- Squib Driver
- Satellite Sensor

Brake
- Wheel Speed Sensor
- Pre-driver
- Steering Angle Sensor
- Steering Torque Sensor

Black-ASCPs (Application Specific Custom Product)
Blue-ASSPs (Application Specific Standard Product)
**R2A20028FP (Delta-sigma ADC)**

- **High voltage:** 80Vmax (available for 12cells)
- **Low measurement error:** +/-2.5mV @25degC
- **High speed measurement:** 10ms max/12degC
- **Reduction external parts:**
  - Built-in cell balancing MOSFET(100mA max.)
  - Built-in Over/Under voltage detection function
- **High reliability I/F:** Differential SPI, CRC>10
- **Various diagnosis/detection functions** to be compliant with ISO26262

### Table: Parameters and Target Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Target Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitoring cell number</td>
<td>6 to 12cells (VCC&gt;10V)</td>
</tr>
<tr>
<td>IC addressing</td>
<td>External pin or Command</td>
</tr>
<tr>
<td>Maximum stackable number</td>
<td>External pin: 8ICs, Command: 16ICs (TBD)</td>
</tr>
<tr>
<td>Power supply voltage</td>
<td>10 to 60V (Max. rating voltage: 80V)</td>
</tr>
<tr>
<td>Cell voltage range</td>
<td>0 to 5.0V (VCC&gt;10V)</td>
</tr>
<tr>
<td>Operating temperature range</td>
<td>-40 to 105degC</td>
</tr>
<tr>
<td>ADC</td>
<td>12bit resolution Delta-sigma ADC</td>
</tr>
<tr>
<td>Sampling clock frequency</td>
<td>1MHz</td>
</tr>
<tr>
<td>Series regulator</td>
<td>VREG1: 5.0V typ. (for internal communication circuit)</td>
</tr>
<tr>
<td></td>
<td>VREG2: 3.3V typ. (for internal logic circuit)</td>
</tr>
<tr>
<td>Cell voltage measurement error</td>
<td>+/-2.5mV (25degC), +/-5mV (-40 to 105degC)</td>
</tr>
<tr>
<td>ADC conversion time</td>
<td>5ms max./12 cells</td>
</tr>
<tr>
<td>Cell voltage measurement speed</td>
<td>10ms max./12cells (ADC+Communication)</td>
</tr>
<tr>
<td>Power consumption</td>
<td>1.8mA max. (ADC operating) * excluding communication current</td>
</tr>
<tr>
<td></td>
<td>225uA max. (Standby mode)</td>
</tr>
<tr>
<td></td>
<td>10uA max. (Deep sleep mode) (TBD)</td>
</tr>
<tr>
<td>Cell balancing</td>
<td>Method</td>
</tr>
<tr>
<td></td>
<td>Type-A: Not adjacent 6 cells can discharge@100mA max</td>
</tr>
<tr>
<td></td>
<td>Type-B: All adjacent 12cells can discharge@70mA max</td>
</tr>
<tr>
<td></td>
<td>Type-C: All adjacent 12cells can discharge@70mA max</td>
</tr>
<tr>
<td>Timer</td>
<td>Built-in OFF timer (TBD)</td>
</tr>
<tr>
<td>Serial interface</td>
<td>Clock frequency</td>
</tr>
<tr>
<td></td>
<td>1MHz max.</td>
</tr>
<tr>
<td>Interrupt output</td>
<td>2ch (CRC error, ADC completion, Initialization completion)</td>
</tr>
<tr>
<td>Ext. temp. sensor (For thermistor)</td>
<td>2ch (IC addressing: External Pin)</td>
</tr>
<tr>
<td></td>
<td>4ch (IC addressing: Command)</td>
</tr>
<tr>
<td>Chip temp. sensor</td>
<td>1ch</td>
</tr>
<tr>
<td>Self diagnosis function</td>
<td>ADC data register diagnosis and write data verify</td>
</tr>
<tr>
<td></td>
<td>Communication diagnosis (CRC, frame error)</td>
</tr>
<tr>
<td>Detection function for diagnosis</td>
<td>Initialization diagnosis</td>
</tr>
<tr>
<td></td>
<td>ADC diagnosis</td>
</tr>
<tr>
<td></td>
<td>Cell balance diagnosis (Cell balance SW monitor)</td>
</tr>
<tr>
<td></td>
<td>Data register diagnosis (User test mode)</td>
</tr>
<tr>
<td></td>
<td>Open-wire diagnosis</td>
</tr>
<tr>
<td></td>
<td>OCO diagnosis (OCO CLK counter)</td>
</tr>
<tr>
<td></td>
<td>Battery over-voltage/Under-voltage detection</td>
</tr>
<tr>
<td></td>
<td>IC address diagnosis</td>
</tr>
<tr>
<td>Package</td>
<td>Cell balancing Type-A, B: 64pin LQFP</td>
</tr>
<tr>
<td></td>
<td>Cell balancing Type-C: 80pin LQFP</td>
</tr>
</tbody>
</table>

**Diagram:**

- **Supported 3 types for cell balancing:**
  - VMODE1, 2 (IC addressing: Command)
  - A0-4 (IC addressing: Ext. Pin)
- **Mixed cell balance**
  - 12-bit Δ-σ ADC
- **Control register**
  - SPI
  - CRC
- **Series regulator**
  - VREG1: 5.0V typ. (for internal communication circuit)
  - VREG2: 3.3V typ. (for internal logic circuit)
- **Cell balancing**
  - Type-A: Not adjacent 6 cells can discharge at 100mA max
  - Type-B: All adjacent 12 cells can discharge at 70mA max
  - Type-C: All adjacent 12 cells can discharge at 70mA max
- **Timer**
  - Built-in OFF timer (TBD)
- **Clock frequency**
  - 1MHz max.
- **Interrupt output**
  - 2ch (CRC error, ADC completion, Initialization completion)
- **External temp. sensor (For thermistor)**
  - 2ch (IC addressing: External Pin)
  - 4ch (IC addressing: Command)
- **Chip temp. sensor**
  - 1ch
- **Self diagnosis function**
  - ADC data register diagnosis and write data verify
  - Communication diagnosis (CRC, frame error)
- **Detection function for diagnosis**
  - Initialization diagnosis
  - ADC diagnosis
  - Cell balance diagnosis (Cell balance SW monitor)
  - Data register diagnosis (User test mode)
  - Open-wire diagnosis
  - OCO diagnosis (OCO CLK counter)
  - Battery over-voltage/Under-voltage detection
  - IC address diagnosis

**Supported 3 types for cell balancing:**

- **VMODE1, 2 (IC addressing: Command)**
- **A0-4 (IC addressing: Ext. Pin)**
- **VMODE1, 2 (IC addressing: Command)**
R2A20027FP (SAR ADC)

- High voltage: 80V max (available for 12 cells)
- Low measurement error: +/- 4mV @ 25 degC
- High speed conversion: 100us max/12 cell
- Reduced external parts:
  - Built-in cell balancing MOSFET (100mA max.)
  - Built-in Over/Under voltage detection function
- High reliability I/F: Differential SPI, CRC >= 10
- Various diagnosis/detection functions to be compliant with ISO26262

Parameter | Target Spec.
--- | ---
Monitoring cell number | 6 to 12 cells (VCC > 10V)
IC addressing | External pin or Command
Maximum stackable number | External pin: 8ICs, Command: 16ICs (TBD)
Power supply voltage | 10 to 60V (Max. rating voltage: 80V)
Cell voltage range | 0 to 5.0V (VCC > 10V)
Operating temperature range | -40 to 105 degC
ADC | 12 to 14bit resolution SAR ADC
Series regulator | VREG1: 5.0V typ. (for internal communication circuit)
 | VREG2: 3.3V typ. (for internal logic circuit)
Cell voltage measurement error | +/- 4mV (25 degC), +/- 8mV (-40 to 105 degC)
ADC conversion time | 100us max./12 cells
Cell voltage measurement speed | 5ms max./12 cells (ADC + Communication)
Power consumption | 1.8mA max. (ADC operating) * excluding communication current
 | 225uA max. (Standby mode)
 | 10uA max. (Deep sleep mode) (TBD)
Cell balancing Method | Type-A: Not adjacent 6 cells can discharge @ 100mA max
 | Type-B: All adjacent 12 cells can discharge @ 70mA max
 | Type-C: All adjacent 12 cells can discharge @ 70mA max
Timer | Built-in OFF timer (TBD)
Serial interface | Differential SPI (IC-IC: Current mode, MCU-IC: Voltage mode)
 | * MCU to IC: Differential or Single-end selectable
Clock frequency | 1MHz max.
Interrupt output | 2ch (CRC error, ADC completion, Initialization completion)
Ext. temp. sensor (For thermistor) | 2ch (IC addressing: External Pin)
 | 4ch (IC addressing: Command)
Chip temp. sensor | 1ch
Self diagnosis function | ADC data register diagnosis and write data verify
 | Communication diagnosis (CRC, frame error)
Detection function for diagnosis | Initialization diagnosis
 | ADC diagnosis
 | Cell balance diagnosis (Cell balance SW monitor)
 | Data register diagnosis (User test mode)
 | Open-wire diagnosis
 | OCO diagnosis (OCO CLK counter)
 | Battery over-voltage/Under-voltage detection
 | IC address diagnosis
Package | Cell balancing Type-A, B: 64pin LQFP
 | Cell balancing Type-C: 80pin LQFP
# Cell Balancing Methods

<table>
<thead>
<tr>
<th>Type-A</th>
<th>Type-B</th>
<th>Type-C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discharge path/Measurement path</strong></td>
<td><strong>Discharge path/Measurement path</strong></td>
<td><strong>MOSFET Drain/Source</strong></td>
</tr>
<tr>
<td>Separate type</td>
<td>Common type</td>
<td>Separated type</td>
</tr>
<tr>
<td><img src="image1" alt="Circuit diagram" /></td>
<td><img src="image2" alt="Circuit diagram" /></td>
<td><img src="image3" alt="Circuit diagram" /></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum discharge cell (current)</th>
<th>Non-adjacent 6 cells can discharge simultaneously. (100 mA max)</th>
<th>All adjacent 12 cells can discharge simultaneously. (70 mA max)</th>
<th>All adjacent 12 cells can discharge simultaneously. (70 mA max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement During cell balancing</td>
<td>Possible</td>
<td>Impossible to obtain high-accuracy measurement</td>
<td>Possible</td>
</tr>
<tr>
<td>Filtering circuit design</td>
<td>Easy</td>
<td>Complicated (Difficult to consist with discharge current setting)</td>
<td>Easy</td>
</tr>
<tr>
<td>External MOSFET</td>
<td>Drive voltage will be about BCx/2 (Need low voltage drive MOSFET)</td>
<td>Drive voltage will be about BCx</td>
<td>Drive voltage will be about BCx</td>
</tr>
<tr>
<td>Package</td>
<td>64 pin-LQFP</td>
<td>64 pin-LQFP</td>
<td>80 pin-LQFP</td>
</tr>
</tbody>
</table>
Product Lineup for Solution Optimization

- Design options based on a common set of core design features results in a broad product offering
- Choices provided for choosing ADC type, cell-balancing, thermistor inputs and address methods

<table>
<thead>
<tr>
<th>Parts No.</th>
<th>ADC Type</th>
<th>Cell balancing method</th>
<th>Thermistor I/F</th>
<th>Addressing Method</th>
<th>Assigned pin count</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>R2A20027AFP</td>
<td>SAR</td>
<td>A</td>
<td>2ch</td>
<td>I/O Pin</td>
<td>64</td>
<td>64pin LQFP</td>
</tr>
<tr>
<td>R2A20027BFP</td>
<td></td>
<td></td>
<td>4ch</td>
<td>Software</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>R2A20027CFP</td>
<td></td>
<td>B</td>
<td>2ch</td>
<td>I/O Pin</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>R2A20027DFP</td>
<td></td>
<td></td>
<td>4ch</td>
<td>Software</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>R2A20027EFP</td>
<td></td>
<td>C</td>
<td>4ch</td>
<td>I/O Pin</td>
<td>77</td>
<td>80pin LQFP</td>
</tr>
<tr>
<td>R2A20027FFP</td>
<td></td>
<td></td>
<td>4ch</td>
<td>Software</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>R2A20028AFP</td>
<td>Delta-sigma</td>
<td>A</td>
<td>2ch</td>
<td>I/O Pin</td>
<td>64</td>
<td>64pin LQFP</td>
</tr>
<tr>
<td>R2A20028BFP</td>
<td></td>
<td></td>
<td>4ch</td>
<td>Software</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>R2A20028CFP</td>
<td></td>
<td>B</td>
<td>2ch</td>
<td>I/O Pin</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>R2A20028DFP</td>
<td></td>
<td></td>
<td>4ch</td>
<td>Software</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>R2A20028EFP</td>
<td></td>
<td>C</td>
<td>4ch</td>
<td>I/O Pin</td>
<td>77</td>
<td>80pin LQFP</td>
</tr>
<tr>
<td>R2A20028FFP</td>
<td></td>
<td></td>
<td>4ch</td>
<td>Software</td>
<td>74</td>
<td></td>
</tr>
</tbody>
</table>