IDEC Chip Design Contest

Precision Monitoring and Balancing for EV batteries

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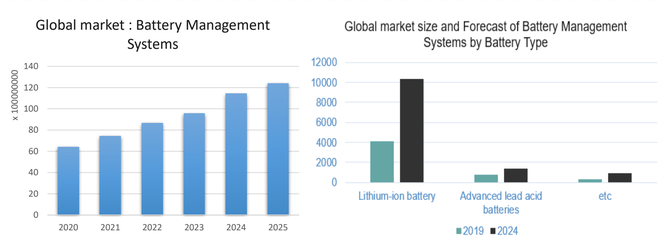
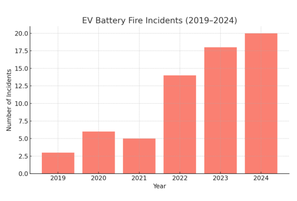
Market growth



Market growth due to increasing demand for batteries.

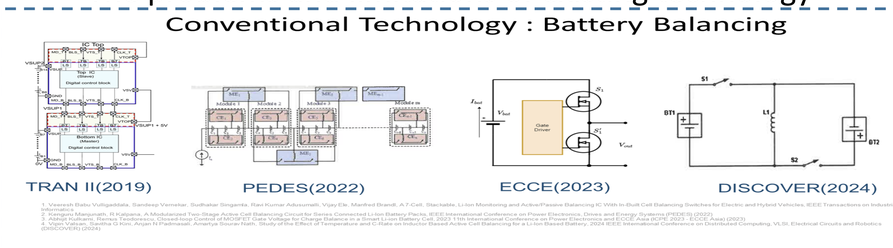
Electric vehicle fire

https://automobilekorea.com/archives/33330 https://theicct.org/clearing-the-air-evs-could-bring-lower-fire-risk-oct24/ https://www.nyc.gov/site/fdny/news/03-25/fdny-commissioner-robert-s-tucker-significant-progress-the-battle-against-lithium-ion https://www.lion.com/lion-news/may-2025/lithium-battery-air-incidents-up-16-in-2024



Increase in fire incidents due to battery thermal runaway.

The problems and limitations of existing technology



1. Veeresh Babu Vulligaddala, Sandeep Vernekar, Sudhakar Singamla, Ravi Kumar Adusumalli, Vijay Ele, Manfred Brandl, A 7-Cell, Stackable, Li-Ion Monitoring and Active/Passive Balancing IC With In-Built Cell Balancing Switches for Electric and Hybrid Vehicles, IEEE Transactions on Industrial Informatics
2. Kenguru Manjunath, R Kalpana, A Modularized Two-Stage Active Cell Balancing Circuit for Series Connected Li-Ion Battery Packs, IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES) (2022)
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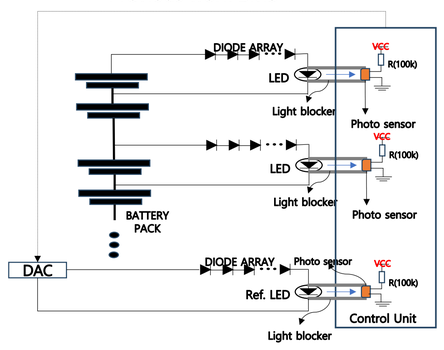
4. Vipin Valsan, Savitha G Kini, Anjan N Padmasali, Amartya Sourav Nath, Study of the Effect of Temperature and C-Rate on Inductor Based Active Cell Balancing for a Li-Ion Based Battery, 2024 IEEE International Conference on Distributed Computing, VLSI, Electrical Circuits and Robotics (DISCOVER) (2024)

- Existing technologies have low-voltage control circuits that are directly connected to high-voltage batteries and can be affected by high voltage.

I. Proposed Technology

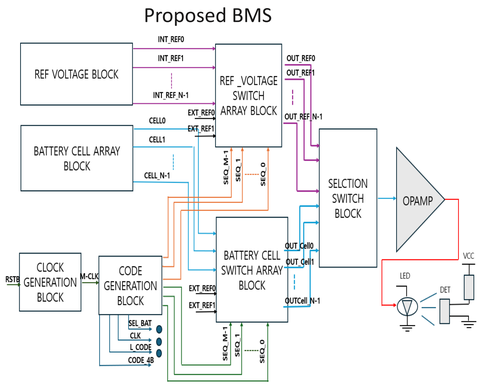
< Proposed Monitoring Method >

Previous work BMS



Jin Uk Yeon, Ji Whan Noh, Innyeal Oh, "Temperature-Compensated Overcharge Protection Measurement Technology," Advances in Science, Technology and Engineering Systems Journal Vol. 8, No. 2, 24-29 (2023)

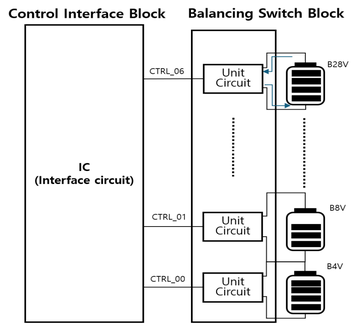
Proposed BMS



- Limits to accurate cell voltage monitoring.
- Suggestion of accurate cell voltage monitoring method.

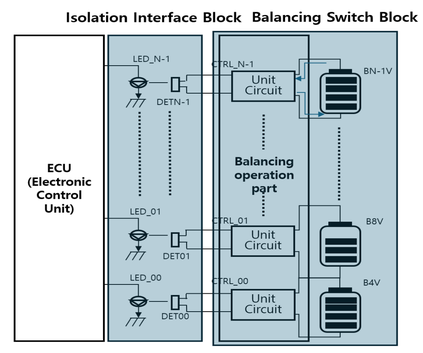
< Proposed Cell Balancing >

Previous Technology



Veeresh Babu Vulligaddala, Sandeep Vernekar, Sudhakar Singamla, Ravi Kumar Adusumalli, Vijay Ele, Manfre Brandl, A 7-Cell, Stackable, Li-Ion Monitoring and Active/Passive Balancing IC With In-Built Cell Balancing Switches for Electric and Hybrid Vehicles, IEEE Transactions on Industrial Informatics, (2019)

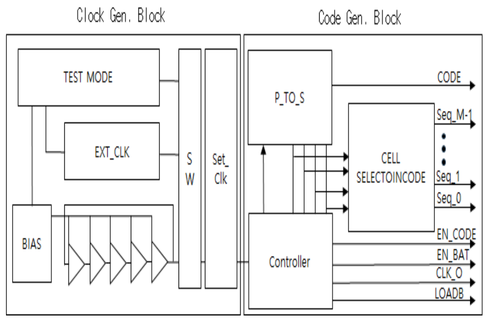
Proposed Technology



- High voltage limitations due to direct connection
- Propose an isolation structure that is safe for high voltage

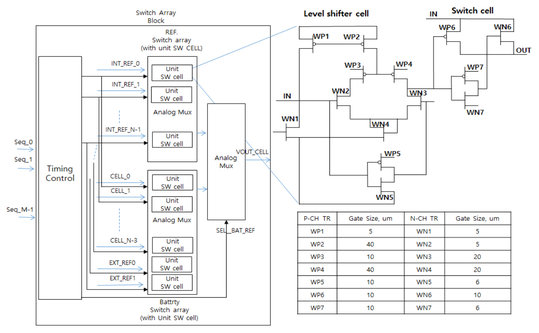
II. Detailed Design

< CODE/CLK Generating Circuit >



1. In the clock generation circuit, one of an external clock and an internal clock is selected and outputted.
2. Signals that can receive the selected clock and recognize each battery cell voltage (seq_0 to M-1, EN_CODE, … ,LOADB) is generated.
3. Single path monitoring is implemented by supporting cell voltage recognition along with the generation of code values of each battery cell.

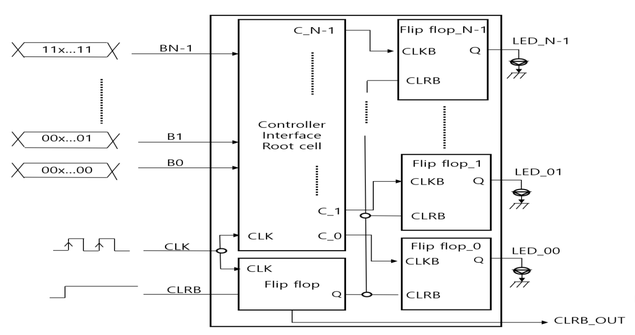
< Monitoring Switch ARY Circuit >



P-CH TR	Gate Size, um	N-CH TR	Gate Size, um
WP1	5	WN1	5
WP2	40	WN2	5
WP3	10	WN3	20
WP4	40	WN4	20
WP5	10	WN5	6
WP6	10	WN6	10
WP7	10	WN7	6

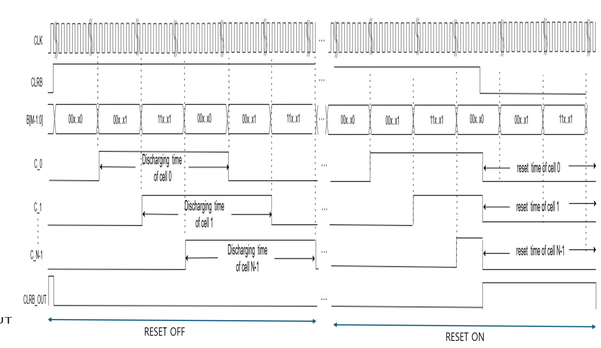
1. The code value of each battery cell is generated and the battery cells are recognized separately through the selected switch and outputted as a single path.
2. Supports temperature compensation with EXT_REF, INT_REF signal processing with monitoring behavior.

< Balancing Controller IF Circuit >



1. Isolation operation part is a part that receives M bits from the ECU and creates a signal that controls the balancing.
2. Designed to operate the control signal in a flip-flop structure with the CLK signal.
3. It minimizes noise and synchronize operations, ensuring safe balancing.
4. Memory-based, simultaneous balancing of multiple cells.

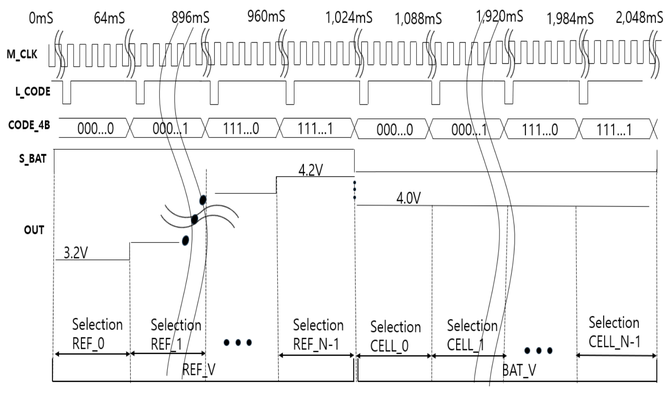
< Controller Interface Root Cell Timing Chart >



This Chart illustrates the synchronization of discharge, balancing, and reset operations of battery cells with the CLK signal, based on ECU commands. In the RESET OFF state, balancing proceeds normally, while in the RESET ON state, all cells are reset.

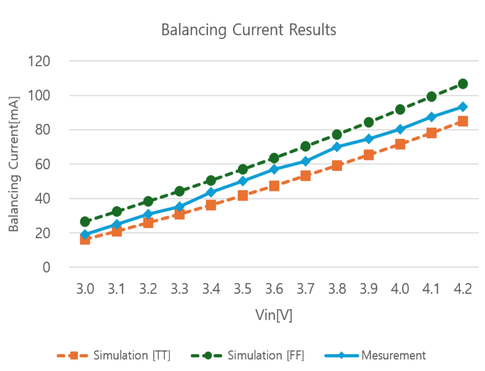
III. Result

< Monitoring Single Path Multicell Result >



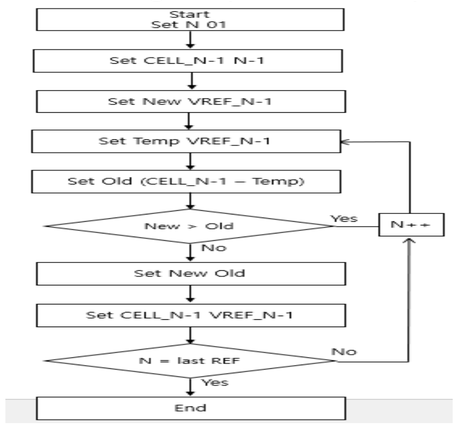
1. All battery cell voltages are recognized in 2 sec and temperature compensation is possible.
2. This operation consumes 1/3 less power than the existing BMS. (Existing 16 x 300uW= 4.8mW, Improved 1.6 mW(=0.3mW+1.3mW))

< Isolated Balancing Circuit Result >



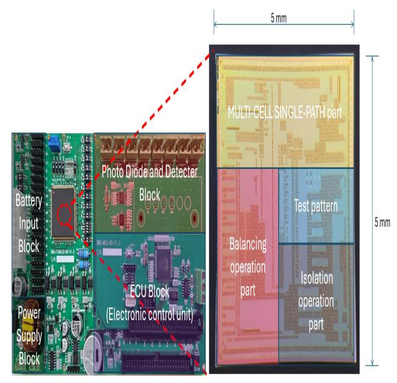
1. The balancing current results based on battery input voltage (Vin) show that the measured values lie between the TT and FF simulation values, with over 20mA at Vin 3V and over 87mA at Vin 4.2V.
2. TT means typical performance, while FF indicates faster speed and higher current drive, but with potentially increased power consumption.

< Perform monitoring temperature compensation >



1. Battery cell voltage regulation based on reference voltage by selecting the closest REF with minimum error for temperature compensation
2. V_REF is selectable internal/external.

< Build Package >



Conclusion

< Multicell Single-Path Monitoring >

1. Secure voltage monitoring using an isolated single-path architecture for multi-cell battery systems.
2. Simultaneous acquisition of 16 battery cell voltages and 16 REF signals through a single path.
3. Accurate temperature-compensated voltage monitoring with ±5 mV resolution from –20°C to 80°C.
4. Low-power operation at 1.6 mW, achieving 1/3 the power consumption of conventional BMS designs.

< Isolated Stable Balancing >

1. The proposed isolated balancing circuit completely separates high and low voltage regions, ensuring stable balancing control.
2. Operates on a power consumption as low as 180 uW.

< Comparison of Battery Balancing Circuit Technologies >

	TRAN II (2019)	PEDES (2022)	ECCE (2023)	DISCOVER (2024)	This Work
Circuit connection	Direct	Direct	Direct	Direct	Indirect
High voltage effect	Yes	Yes	Yes	Yes	No
Cell Balancing	Passive	Active	Active	Passive	Passive
Fab.(um)	0.35	0.18	0.25	0.5	0.18
Consumption(W)	0.16	-	5	-	0.18

1. Veeresh Babu Vulligaddala, Sandeep Vernekar, Sudhakar Singamla, Ravi Kumar Adusumalli, Vijay Ele, Manfred Brandl, A 7-Cell, Stackable, Li-Ion Monitoring and Active/Passive Balancing IC With In-Built Cell Balancing Switches for Electric and Hybrid Vehicles, IEEE Transactions on Industrial Informatics
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- Unlike conventional technologies directly connected to high voltage, this isolation-based technology ensures stable cell balancing control under high voltage without affecting the low-voltage controller circuit. It operates at a low power of 180μW and is fabricated with a compact size of 180nm.

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