Battery Management System

BMS Project Report

Submitted By :-
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Project Title :- "**Dynamic Cell Balancing System Using Arduino and PCA9685**"

Dynamic Cell Balancing refers to a method of actively managing the charge and discharge cycles of individual cells in a battery pack or system.

In this project, **Active Control Cell Balancing Mechanism** is demonstrated during the cell discharge process. The system alternates between two cells to manage the discharge efficiently, ensuring uniform utilization and balancing. The approach uses an Arduino Nano to actively control the switching mechanism, powered by two PCA9685 modules. By monitoring the voltage of the cells (simulated using potentiometers), the system dynamically alternates the load (a servo motor) between the cells every 30 seconds, ensuring equal discharge cycles over 30 iterations.

Components Used :-

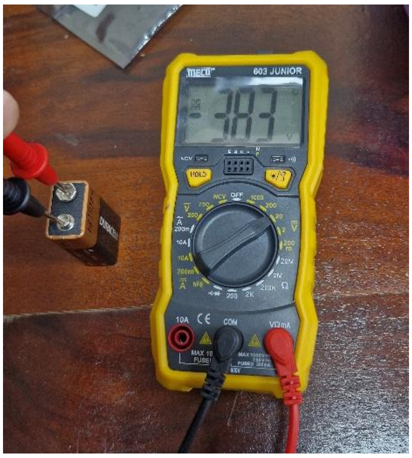
Equipment	**Quantity**	**Purpose/Use**
Arduino Nano	1	To control the switching logic and communicate with PCA9685 modules.
PCA9685 PWM Module	2	To generate PWM signals to control the servo motor.
Futaba S3003 Servo Motor	1	To demonstrate the operation controlled alternately by the cells.
Resistors	2	Used in the circuit to limit current or pull-up logic for input signals.
Jumper Wires	As required	To establish connections between components on the breadboard.
Breadboard	1	To prototype and connect components without soldering.
Multi-meter	1	To measure cell voltages
USB Cable	1	To upload the code to the Arduino Nano and power the microcontroller.

Experiment 1 :- Time-Based Switching for Cell Balancing (In this approach I used 2 ultra Alkaline cell used)

In this approach, the Active Control Cell Balancing Mechanism is implemented purely based on time intervals, without considering the voltage levels or state of the cells. The system alternates the load (a servo motor) between two cells every 30 seconds for a total of 30 cycles, ensuring equal discharge over time.

Initial Condition of cell :- Potential of cell

Cell 1



V1 = 3.83 volt

Cell 2

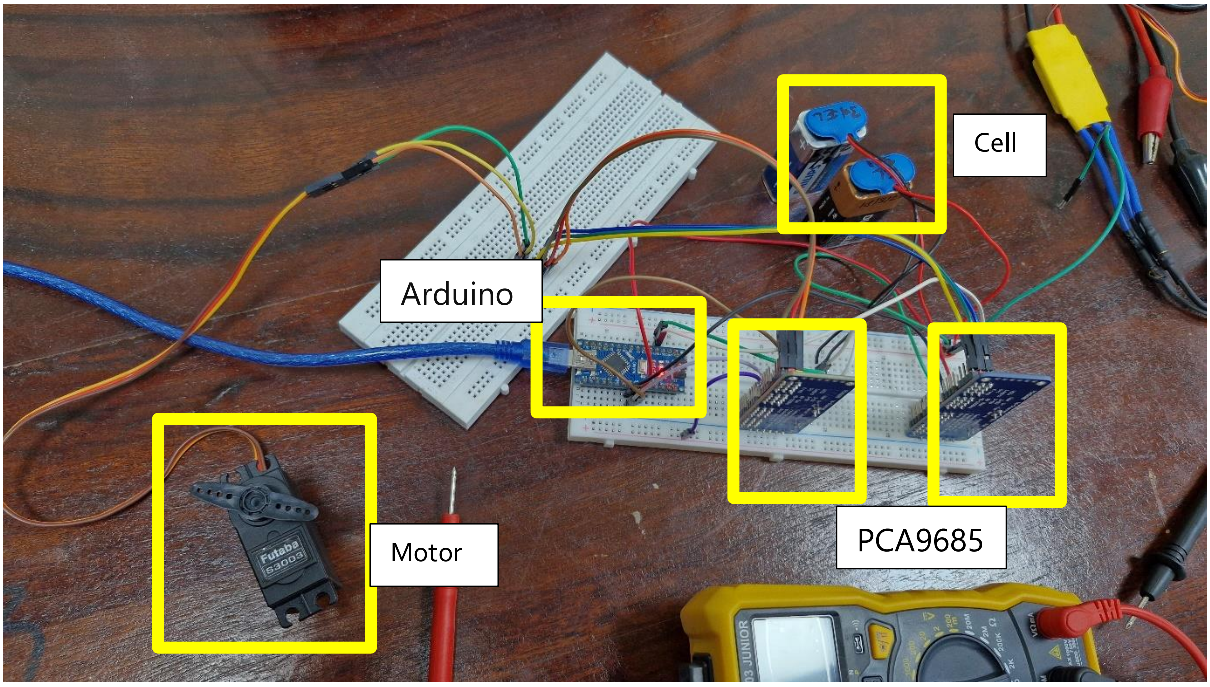
V2 = 3.82 volt

After knowing the initial potential of cell. Experiment Starts ,

- **System Initialization**:
  - Two cells (or sets of cells) power the servo motor alternately.
  - The Arduino Nano is programmed to control the switching mechanism.
  - Two PCA9685 modules generate PWM signals to control the servo motor.
- **Time-Based Alternation:**
  - The Arduino tracks time using an internal timer.
  - Every 30 seconds, the system switches from one cell to the other to power the servo.
  - This alternation is repeated for 30 cycles.

- **Equal Usage of Cells**:
  - Since the switching happens strictly based on time, each cell discharges for an equal duration regardless of its voltage or current capacity.

Experiment Setup : -



Here each cells are connected PCA9685 which gives power to motor alternately.

After Condition of cell :- Potential of cell

V"1 = 1.68 volt

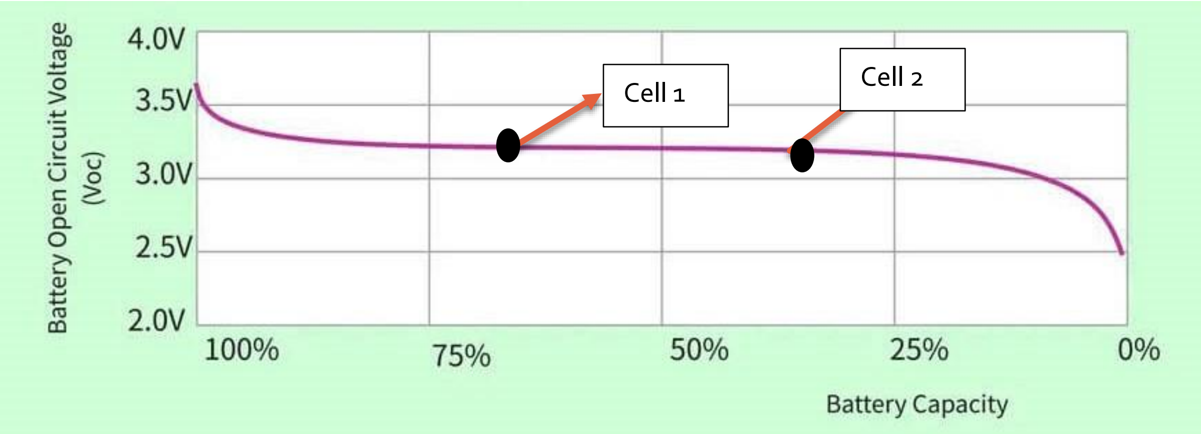
V"2 = 2.81 volt

Here we observe that cell balancing does not work properly.

Conclusion

- ➢ State of Charge (SOC) of the cells is unknown at the start, relying solely on their potential (voltage) does not guarantee that both cells are in the same SOC state.

Like here initial level of cell 1 and cell 2 both have huge different in SOC level .



Limitations of Experiment-1 is

- **No SOC Tracking**: Without knowing the SOC of each cell, the system cannot adapt or compensate for initial imbalances.
- **Risk of Over-Discharge**: A cell with a lower SOC could drop to a critically low level during discharge, reducing its lifespan or causing failure.
- **Reduced Efficiency**: The energy output from the cells might not be optimal since one cell could be under-utilized.

<u>Experiment 2</u> :- <u>Time-Based Switching for Cell Balancing (In this approach I used 2 Lithium Ion cell used)</u>

The experiment process is the same as experiment 1, but the cell is changed to a lithium-ion cell, which is fully charged and has the same SOC levels (100 %). So, in this experiment, both cells have the same potential and SOC level.

Initial Condition of cell :- Selecting two fully charge cell .
Here both cell 1 and cell 2 have same potential (3.99 volt).

V1 = 3.99 volt

V2 = 3.99 volt

After knowing the initial potential of cell. Experiment Starts ,

Repeat the experiment 1 setup and process .

After Condition of cell :-

V"1 = 3.93 volt

V"2 = 3.91 volt

Observation

1) After performing experiment several time still there is small potential difference .
This may be due to the following reasons :-----

- State of Charge (SOC) Variation :- The initial State of Charge (SOC) of the cells might not have been perfectly equal.
- Inaccurate Load Sharing :- The servo motor might not draw exactly equal current from both cells during switching.
- Aging or past history use and Capacity Differences :- If the cells are not identical in ag e or capacity, their ability to hold and deliver charge will differ.

Conclusion

Experiment 2 showcases how time-based cell balancing works by switching the servo motor alternately between the cells. While this approach achieves basic balancing, it highlights the need for more advanced mechanisms (such as voltage-based balancing) to ensure optimal cell performance and longevity.

This experiment was not performed; only a theoretical approach is provided.

<u>##Experiment 3</u> :- <u>Combining Voltage and Time-Based Approaches for Cell Balancing</u>

It requires a **precision potentiometer**, which is currently unavailable in the lab. Therefore, a **theoretical approach** has been proposed here.

This experiment implements a hybrid cell balancing technique by combining <u>voltage-based switching</u> and <u>time-based switching</u> to achieve optimal performance. The cells are connected in parallel with a precision potentiometer, which provides regular voltage updates. These voltage readings are utilized for making informed decisions about switching between cells.

- **Voltage-Based Switching:** Ensures the balancing process prioritizes cells with significantly different voltage levels, maintaining their health and preventing overuse or underuse.
- **Time-Based Alternation:** Alternates the control of the servo motor between cells every 30 seconds, ensuring fairness in usage and uniform wear across the cells.

By integrating these two methods, the hybrid approach overcomes the limitations of using either approach individually. It offers adaptability, fairness, and enhanced balancing efficiency for long-term cell performance.

Experimental Steps are

➢ **Initialization :**

- The system monitors the voltage of both cells in real-time using potentiometers (or actual voltage sensors).
- The Arduino determines which cell to use for powering the load initially based on their voltage levels.

➢ **Voltage-Based Switching Logic :**

- If the voltage of one cell is significantly higher than the other, the system prioritizes using the higher-voltage cell to prevent over-discharge of the weaker cell.
- A voltage threshold (e.g., a difference of 0.1 V) can be set to determine when to switch.

➢ **Time-Based Alternation:**

- Once the voltage difference is below the set threshold or balanced, the system alternates the load between the two cells every 30 seconds, ensuring equal usage over time.
- If a voltage imbalance reoccurs, the system reverts to voltage-based switching.

➢ **Repetition:**

- This process repeats for a predefined number of cycles (e.g., 30 cycles) or until a termination condition is met (e.g., minimum safe voltage level for both cells).

Advantages of the Hybrid Approach

- **Protection Against Imbalance**: Prevents over-discharge of weaker cells while ensuring equal time usage when the cells are balanced.
- **Improved Efficiency**: Maximizes energy utilization by actively balancing based on voltage and time.
- **Real-Time Monitoring**: Allows dynamic adjustments based on the actual state of the cells.

Arduino IDE code :-
https://drive.google.com/drive/folders/1VzBejXmJDqrnN4v9cj8lPg3IIUGGDNJE?usp=sharing