Battery Monitoring System: Program Logic

This program is designed to monitor the voltage of four battery cells connected to an Arduino board, display the information on an I2C LCD screen, and trigger alerts if any cell voltage falls below a specified threshold. Additionally, it includes a button to toggle between different display modes and a button to permanently reset an alarm triggered by low battery levels.

The system also allows for brightness control of the LCD display based on an analog input and provides an alarm to signal when the battery voltage is low.

Libraries Used:

- **Wire.h**: Standard I2C library for communication between the Arduino and the LCD display.
- **hd44780.h**: Library for controlling the HD44780-based LCD displays.
- **hd44780_I2Cexp.h**: Provides an I2C interface for the HD44780 library.

Constants and Variables:

- **Resolution (1023)**: The maximum value for a 10-bit ADC (Analog-to-Digital Converter), which is used to convert the analog input voltage to a digital value.
- **R1, R2**: The resistance values used in the voltage divider circuit for measuring battery voltages.
- **Calibration Factors**: Fine-tune the measurements of individual cell voltages (`calibrationFactor`) and total voltage (`totalCalibrationFactor`).
- **Voltage Range**: Defines the minimum and maximum voltages for the cells (2.7V to 4.2V) to calculate the battery charge percentage.
- **Display Modes**: The program supports three display modes:
    - Mode 0: Show the individual cell voltages.
    - Mode 1: Show the battery charge percentages.
    - Mode 2: Show the total battery voltage and overall percentage.
- **Analog Pins**: The program reads the voltages of the four battery cells from analog pins A0, A1, A2, and A3. Additionally, the potentiometer used for controlling LCD brightness is connected to pin A4.
- **Buttons**: A button (pin 13) toggles between the three display modes, and another button (pin 12) resets the alarm when pressed for 0.5 seconds.
- **Alert Pins**: The system uses multiple pins (10, 9, 8, 7) to alert the user if the individual cell voltages fall below a defined threshold. An additional pin (pin 2) is used for a total voltage alert.

Setup:

- **LCD Initialization**: The program initializes the I2C LCD with 16 columns and 4 rows. It also ensures that the LCD backlight is on.
- **Button and Alert Pin Setup**: The push button pins are initialized to `INPUT_PULLUP` to use internal pull-up resistors. The alert pins for each cell and the total voltage are configured as `OUTPUT`.
- **Alarm Pin**: The alarm pin is set to `OUTPUT` to trigger an external alert when the battery voltage is too low.

Functions:

`calculateVin(float vout)`

This function calculates the actual voltage from the output of the voltage divider using the formula:

$$Vin = Vout \times \left(\frac{R1 + R2}{R2}\right)$$

This formula assumes that the resistors R1 and R2 are connected in a voltage divider configuration and the ADC reading is taken after this divider.

`calculatePercentage(float voltage)`

This function calculates the charge percentage of a battery cell based on its voltage. The calculation is done using the following formula:

$$\text{Percentage} = \frac{(\text{Voltage} - \text{minVoltage})}{(\text{maxVoltage} - \text{minVoltage})} \times 100$$

The voltage is clamped between 0% (for 2.7V) and 100% (for 4.2V).

`averageADC(int pin)`

This function averages multiple analog readings (50 by default) from a given analog pin to reduce noise. The average value is returned as a more stable result.

Main Loop (`loop()`):

1. **Voltage and Percentage Calculation**:
    - Every second (`updateInterval` set to 1000 milliseconds), the program reads the voltages of the four battery cells.

    - The analog values are converted to voltages using the `calculateVin()` function. The voltage for each cell is calculated after adjusting for the previous cell's voltage (since the voltages are measured in a series configuration).
    - The `calculatePercentage()` function is used to determine the charge percentage of each cell.
    - The total voltage is calculated as the sum of all cell voltages and is also adjusted using the `totalCalibrationFactor`.
2. **LCD Display Update**:
    - Based on the selected `displayMode`, the LCD displays one of the following:
        - **Mode 0**: Shows individual cell voltages (in volts).
        - **Mode 1**: Shows the charge percentage for each cell.
        - **Mode 2**: Displays the total voltage and the total battery percentage.
    - The display is updated every second to reflect the most recent data.
3. **LCD Brightness Control**:
    - The program reads the value from an analog input (connected to pin A4) to adjust the brightness of the LCD. The potentiometer reading is mapped to a PWM value, which is then used to control the brightness on pin 6 via `analogWrite()`.
4. **Button for Display Mode Cycling**:
    - The button (pin 13) allows the user to cycle through the display modes (0 → 1 → 2 → 0). The button press is checked using inverted logic (`INPUT_PULLUP`), meaning a press results in a LOW state, which is used to change the mode.
    - A small debounce delay (50 ms) is used to avoid registering multiple presses from a single button press.
5. **Alarm Button Handling**:
    - The alarm button (pin 12) is used to permanently reset the alarm if it is pressed for at least 0.5 seconds. When the button is held for 0.5 seconds, the alarm pin is set to LOW, and the `alarmTriggered` state is cleared.
6. **Low Voltage Detection and Alerts**:
    - The program checks if any individual cell voltage falls below 2.7V or if the total voltage falls below 10V. If either condition is met, the alarm is triggered by setting the `alarmPin` to HIGH.
    - If any cell's voltage falls below the defined threshold (2.9V for most cells and 3.9V for others), the respective alert pins for the cells are triggered to HIGH.
    - The total voltage alert pin is triggered if the total voltage is less than 10.0V.
7. **Alarm Logic**:

- The alarm pin remains active (HIGH) as long as any cell's voltage is below the threshold (2.7V) or if the total voltage drops below the threshold (10V). If the alarm button is pressed and held for 0.5 seconds, the alarm can be turned off permanently.