DC Voltmeter Using ATmega328P and ADS1115 ADC

Project Description

This project is a DC voltmeter designed using an ATmega328P microcontroller and an ADS1115 16-bit ADC. The device is capable of measuring four voltage ranges simultaneously and displaying the readings on a 16x2 I2C-based LCD. It also features an inbuilt rechargeable Li-ion battery for portable operation.

Features

- **Four Voltage Ranges:**
  - Voltage 1: 1V to 25V DC (high precision)
  - Voltage 2: 1V to 250V DC
  - Voltage 3: 1mV to 5V DC
  - Voltage 4: 1mV to 5V DC

- **16-bit Precision:** Achieved using the ADS1115 ADC for accurate voltage measurement.
- **Display:** Results are displayed on a 16x2 I2C-based LCD in real-time.
- **Exponential Moving Average (EMA):** Method used to smooth voltage readings for enhanced stability.
- **Power Source:** Powered by an inbuilt rechargeable Li-ion 18650 battery (1200mAh), charged via a TP4056 charging module.

System Components

1. ATmega328P Microcontroller

- **Purpose:**
  - Serves as the central processing unit.
  - Reads ADC values from the ADS1115, processes them, and calculates the actual voltage.
  - Displays processed data on the I2C LCD.
- **Key Features:**
  - 8-bit microcontroller.
  - Low power consumption.
  - I2C communication support.

2. ADS1115 16-bit ADC

- **Purpose:**
  - Converts analog signals from the voltage divider circuits into precise digital values.
- **Key Features:**
  - 16-bit resolution.
  - Four input channels (A0, A1, A2, A3).
  - Configurable gain to handle different voltage ranges.

3. Voltage Divider Circuits

- **Purpose:**
  - Scales down input voltages to a range suitable for the ADS1115 ADC.
- **Details:**
  - **Voltage 1 (1V to 25V):** Resistor network designed to scale down to <4.096V.
  - **Voltage 2 (1V to 250V):** High-resistance network for safe scaling.
  - **Voltage 3 & 4 (1mV to 5V):** Designed for high precision.

4. 16x2 I2C LCD Display

- **Purpose:**
  - Displays voltage readings in real-time.
  - Reduces pin usage via I2C communication.
- **Features:**
  - Backlight for better visibility.
  - Compact and efficient.

5. Power System

a. 18650 Li-ion Battery

- **Purpose:**
  - Provides portable power to the device.
  - Capacity of 1200mAh ensures long operational life.

b. TP4056 Charging Module

- **Purpose:**
  - Manages safe charging of the Li-ion battery.
- **Features:**
  - Overcharge protection.
  - Type -C input for charging.

6. Additional Components

- **Pull-up Resistors:** Ensure stable I2C communication.
- **Decoupling Capacitors:** Minimize noise in power lines.
- **On/Off Switch:** Controls the device's power state.
- **Enclosure:** Protects internal circuitry and enhances portability.

Working Principle

1. **Voltage Measurement:**

   - Input voltages are passed through their respective voltage divider circuits.
   - The scaled-down voltage signals are fed into the ADS1115 ADC channels.

2. **Analog-to-Digital Conversion:**

   - ADS1115 converts the analog signals to 16-bit digital values.
   - Gain settings are configured to optimize the resolution for each range.

3. **Data Processing:**

   - ATmega328P reads the digital values over I2C.
   - Applies the voltage divider formula to calculate the actual input voltage.
   - Smooths readings using the EMA method for stability.

4. **Display:**

   - The processed voltages are displayed on the 16x2 I2C LCD.
   - Each voltage range is shown on a dedicated line.

5. **Power Management:**

   - The Li-ion battery powers the device.
   - The TP4056 ensures safe and efficient charging when connected to a power source.

Software Implementation

- **Programming Language:** C++
- **Development Environment:** Arduino IDE
- **Libraries Used:**
  - `Wire.h` for I2C communication.

- `Adafruit_ADS1X15.h` for ADS1115 functionality.
- `hd44780.h` for LCD operation.

Exponential Moving Average (EMA) Method:

- Smoothing factor (α) set to 0.9.

Formula:

EMA = α * NewValue + (1 - α) * PreviousEMA

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Usage Instructions

1. **Powering On:**

- Toggle the on/off switch.
- The LCD will initialize and display "Voltage Meter" before showing readings.

2. **Input Voltage:**

- Connect input voltages to their respective terminals.
- Ensure inputs do not exceed the specified ranges.

3. **Charging:**

- Use a Micro-USB cable to connect the TP4056 module to a power source.
- The module will handle charging and cut off when the battery is full.

4. **Reading Display:**

- Voltage readings for all four channels are displayed on the LCD.

Advantages

- High precision with 16-bit ADC.
- Portable and battery-powered.
- User-friendly display.
- Supports multiple voltage ranges.

Future Enhancements

- Integration of data logging to an SD card.
- Adding Bluetooth connectivity for remote monitoring.
- Expansion to measure AC voltages with rectification.
