Battery Level Indicator Using Op-Amp

[GROUP – 10]

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Abstract:

Batteries are essential in all electronic devices like smart phone, smart watches, laptops and even in electric vehicles. As it is used in day to day life, monitoring the battery charge level in the electronic devices is crucial. Batteries come in various types, such as Lead-Acid, Ni-Cd, and Lithium-Ion, each serving different applications.

This project is based on designing and implementation of a battery level indicator using four LM741 operational amplifier integrated circuit which helps in estimating battery levels through voltage comparison. The Op-Amp acts as a comparator, compares one analogue voltage level with another analogue voltage level. Here, each Op-Amp compares the battery voltage with reference voltages. The reference voltages are created by using a Zener diode-based voltage divider circuit which consists of a Zener diode and four 1kΩ resistors. These reference voltages are connected to non-inverting terminal of each Op-Amp. These reference voltages are compared with changing battery voltages which are connected to inverting terminal of each Op-Amp.

LEDs are connected to the outputs of each Op-Amp. As the battery voltage changes, the Op-Amps compare it with the reference voltages, lighting up the LEDs accordingly which show the battery charge levels.

CONTENT

1.Introduction:

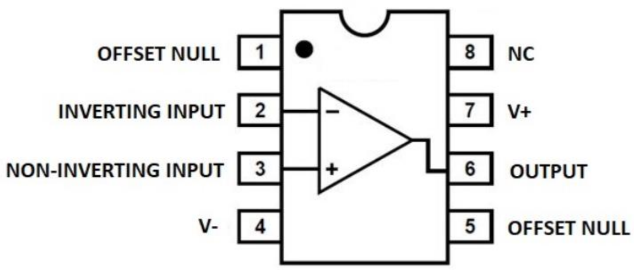
In today's technology-driven world, batteries are integral to nearly every electronic device, from mobile phones and smartwatches to electric vehicles, aircraft, satellites, and even robotic rovers like those used on Mars. Batteries are electrochemical storage devices, without the invention of these electrochemical storage devices, modern life as we know it would be very different. Monitoring battery charge levels is essential to ensure optimal device performance. For 12V batteries, such as Lead-Acid types commonly found in automotive and industrial settings, monitoring can be achieved using simple methods that assess voltage characteristics.

This project focuses on designing a practical 12V battery level indicator using the four LM741 operational amplifier. By measuring battery voltage and comparing it against preset thresholds, this circuit will activate LEDs to visually display the battery's charge levels. This project shows how basic electronic components, like the LM741 op-amp, can be applied to develop a reliable battery monitoring system essential for maintaining efficiency across diverse electronic applications.

2.Components Required:

- 4×LM741 IC OPAMP
- 4×LED Lights
- 1×2.5kΩ Resistor
- 5×1kΩ Resistor
- 1×1.6kΩ Resistor
- 4×0.5kΩ Resistor
- 1×10kΩ Resistor
- Bread broad
- Zener Diode
- Battery

a) LM741 OP-AMP:



Op-Amp IC 741 or LM741 is one of the most used operational amplifier integrated circuits that perform both mathematical operations and amplification functions. The IC 741 operational amplifier looks like a small chip. This small chip mainly performs mathematical operations like addition, subtraction, multiplication, division, differentiation, integration, etc. in various circuits.

Features of Op-Amp IC 741 –

i. **High Gain:**
Ratio of output voltage to input voltage. The IC 741 has a high voltage amplification capability, around 200,000. This allows for effective signal amplification.

ii. **Bandwidth:**
The IC741 works for low-frequency applications, with a bandwidth of 1 to 1.5MHz.

iii. **Impedance:**
Equivalent resistance that can be measured at either inverting terminal or non-inverting terminal connected to ground is the differential input resistance. IC 741 has high input impedance (around 2MΩ)
Equivalent resistance between output and ground is the output impedance. IC 741 has low output impedance (around 75Ω).

iv. **Slew Rate**:
It is defined as maximum rate of change of output voltage per unit of time. It is measured in V/μ sec or V/m sec. one of the drawback of IC 741 is its low slew rate typically 0.5 V/μ sec.

v. **Power Supply:**
The IC 741 needs dual power supplies, typically between ±5V and ±18V, for proper operation.

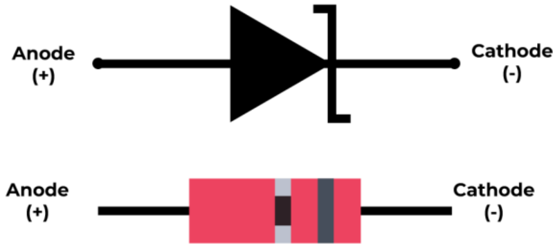
vi. **Input Offset Voltage**:
To nullify the output, we have to apply a small amount of voltage in the input side that is input offset voltage. For IC 741, the input offset is typically 2mV to <6mV.

vii. **Common-Mode Rejection Ratio (CMRR):**
It is defined as ratio of closed loop differential gain, and common mode gain. CMRR is typically 90dB for IC 741.

viii. **Operating Temperature Range:**
The IC 741 can operate between -55°C and +125°C.

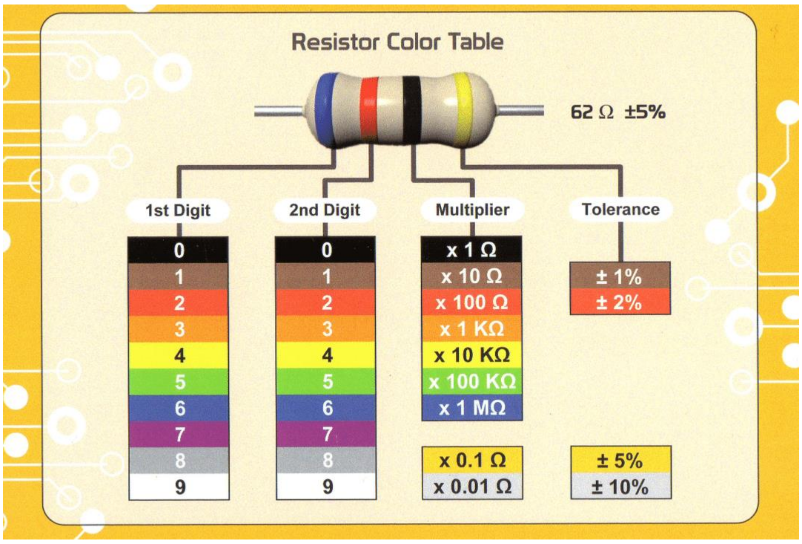
b) ZENER DIODE:

Zener diodes are semiconductor devices that allow current to flow in both directions but specialize in current flowing in reverse. Also known as breakdown diodes, Zener diodes are the most common electronic components used as stable voltage references for electronic circuits.



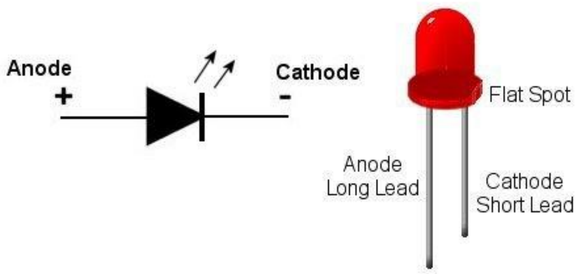
c) RESISTOR:

A resistor that implements electrical resistance as a circuit element. It is a passive two-terminal electrical component. Resistor limits or regulates the flow of electrical current in a circuit. In electronic circuits, resistors are used to adjust signal levels, to divide voltages, bias active elements, and terminate transmission lines, among other uses. They are important in setting the operating conditions of various components within a circuit, such as LEDs.



d) LED:

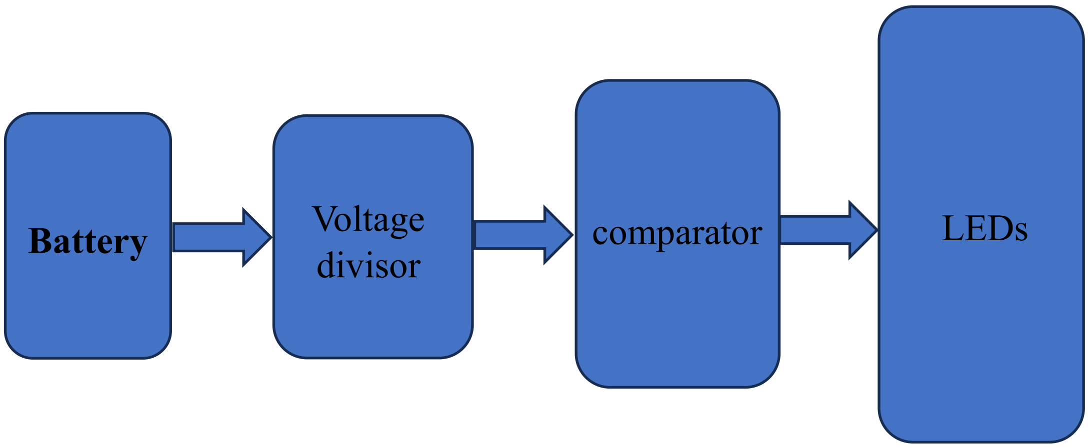
A light-emitting diode (LED) is a semiconductor device that emits light when an electric current flows through it. It is more used due to its compact size, low consumption of energy. It is commonly used for indicators and digital displays in many consumer appliances.



e) BATTERY:

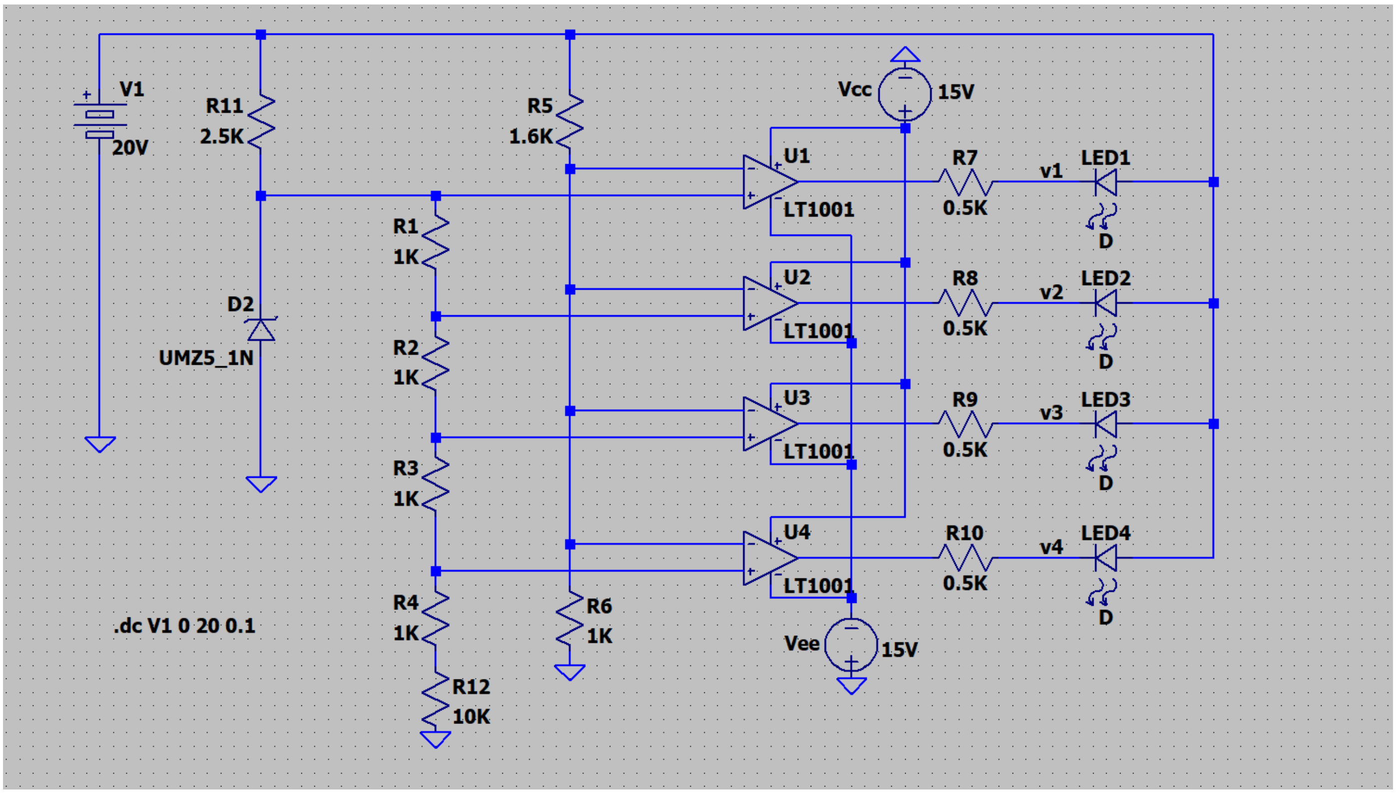
It is an electrochemical device which can be charged with an electric current and whenever required it will discharge.

3.Block Diagram:



4. Working:

a) CIRCUIT DIAGRAM:



b) WORKING OF CIRCUIT:

This circuit can be divided into two different parts –

- Reference voltages section
- Comparator and LED section

- **Reference voltages section:**

In this circuit, D2 is a reference Zener diode which regulate the output to 5.1V across it. There are four 1kΩ resistors which are connected in series to the ground.
The accuracy will improve by adding an additional resistor (10kΩ) in series with potential divider across the Zener diode. Due to which it will allow finer voltage level detection in smaller ranges.
By voltage division rule, the reference voltages approximately 5.1V, 4.74V, 4.37V, 4V. i.e., there will be 0.37V drop across every resistor. These voltages are connected to the non-inverting terminal of each Op-Amp and these are used for comparisons with the battery voltage.

There will be voltage divider circuit. In this circuit, we use one 1.6kΩ and one 1kΩin series. This will provide a dividing factor of 2.6. These voltages are connected to inverting terminal of the Op-Amp. The dividing factor is 2.6 because the battery voltage is V1 and the voltages which are connected to the inverting terminal will be equal to V1×1k / (1k + 1.6 k) = V1 / 2.6 (by voltage division rule).

- **Comparator and LED section**:

  Op-Amp in open loop configuration acts as comparator. The two basic types of voltage comparator are inverting and non-inverting comparators.
  Inverting Comparator : Input voltage is applied to the inverting terminal and reference voltage is applied to the non-inverting terminal.
  Non-inverting Comparator : Input voltage is applied to the non-inverting terminal and reference voltage is applied to the inverting terminal.

  In this circuit, the reference voltages are connected to each Op-Amp non-inverting terminal and input voltages are connected to each Op-Amp inverting terminal. So, the Op-Amp acts as inverting comparator in this circuit.

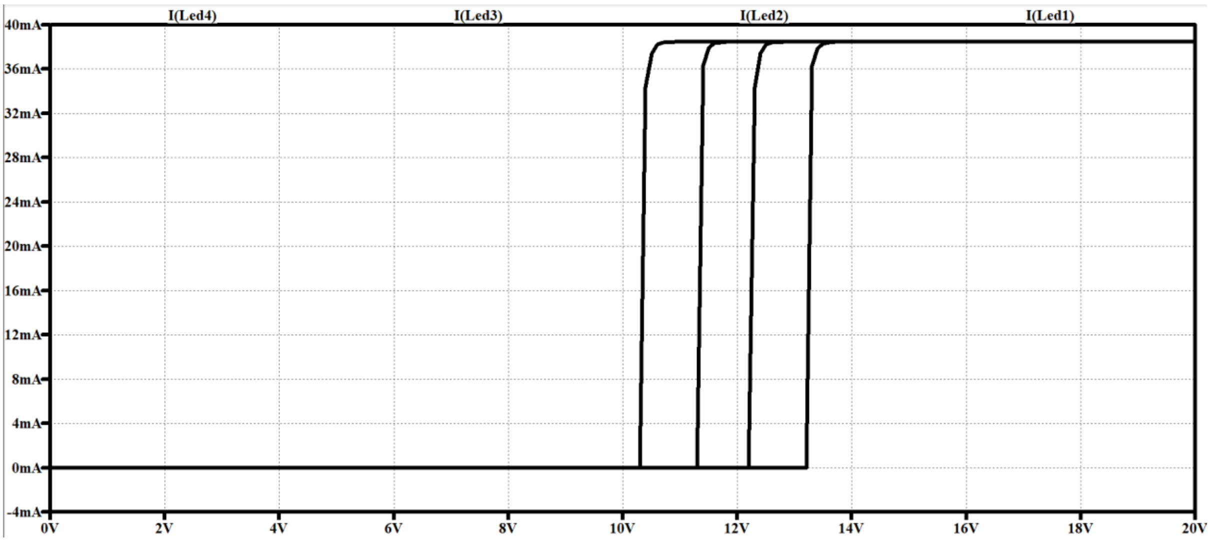
  Whenever the voltage at non-inverting terminal of a particular Op-Amp is higher than the inverting terminal, the Op-Amp output will be high, approximately battery voltage level. Here the LED won't light because the voltages at both anode and cathode are equal so no current will flow.
  If the inverting terminal's voltage is higher than the non-inverting terminal's voltage, then the output of Op-Amp will be low, ground level. Here the LED will light up because it has a potential difference across its terminal.

Example:
For 12V battery voltage,
Inverting terminal voltage of each Op-Amp is 12 / 2.6 = 4.61V
Non-inverting terminal voltage (reference volage) of,

Op-Amp U1, 5.1 > 4.61, LED1 won't glow
Op-Amp U2, 4.74 > 4.61, LED2 won't glow
Op-Amp U3, 4.37 > 4.61, LED3 will glow
Op-Amp U4, 4 > 4.61, LED4 will glow

5.Output:

The current flow in each LED at different voltage levels.



6. Applications:

- **Battery Monitoring**:
  Indicates the health and charge status of a 12V battery.

- **Car Batteries:**
  To check the charge status of car batteries, ensuring they are functioning properly and to prevent being stranded due to a dead battery.

- **Solar Energy Storage:**
  To monitor the charge level of batteries in solar power systems, ensuring optimal energy storage and usage.

- **UPS (Uninterruptible Power Supplies):**
  To monitor the battery status in UPS systems, ensuring they are ready to provide backup power during outages.

- **Emergency Lighting:**
  To check battery levels in emergency lighting systems, ensuring they are operational when needed.

- **Portable Battery Packs:**
  To monitor the charge status of portable battery packs used for charging electronic devices on the go.

7. Conclusion:

In conclusion, the 12V battery level indicator utilizing the LM741 IC is a valuable and efficient project for monitoring battery health status. Its simple yet effective design illustrates how fundamental electronic components can be employed to develop a dependable battery monitoring system. This project meets the crucial need for battery level indication, ensuring power sources are reliable and efficient. Additionally, it provides a foundation for further innovations and enhancements, contributing to the longevity and safety of various battery-powered devices and systems.