ElectroQuad
Problem Statement

Objective:

Design and simulate an **adaptive battery charging circuit** that efficiently charges a **12V battery** while dynamically adjusting the charging current based on load conditions. The system should:

1. **Maintain a constant charging voltage of 12V** using a **linear or switching regulator**.
2. **Dynamically adjust the charging current** based on battery state and load variations (ranging from **0.5A to 2A**).
3. Include **overvoltage, overcurrent, and thermal protection mechanisms**.
4. Provide a **stable output with minimal ripple (<100mV peak-to-peak)**.

Design Requirements & Constraints:

Input Conditions:

- **Input voltage: 15V to 30V DC** (to simulate real-world fluctuations).
- **Battery type: 12V rechargeable battery**.
- **Maximum charging current: 2A**.

Output Conditions:

- **Constant 12V output voltage** during charging.
- **Adaptive charging current: Varies between 0.5A - 2A** based on the load.
- **Load variations:** Simulate an **electronic device drawing different currents (e.g., 0.5A, 1A)**.

Circuit Features & Challenges:

1. **Voltage Regulation:**
    - Use a **linear (e.g., IC 7815 with modifications) or switching regulator (Buck-Boost, SEPIC, etc.)** to maintain **12V at output**.
    - Design a **feedback control loop** to regulate the voltage dynamically.
2. **Adaptive Current Control:**
    - Implement **a current sensing mechanism** using **shunt resistors and op-amps**.
    - Design a **PWM-based control strategy** for dynamic current adjustment.

- **Bonus challenge:** Design an **intelligent control system (e.g., using an analog comparator or microcontroller-based logic) to switch charging modes**.

3. **Protection Mechanisms:**
   - **Overvoltage Protection:** Circuit should shut down or regulate if the voltage exceeds **13.5V**.
   - **Overcurrent Protection:** Cut off charging if the current exceeds **2A**.
   - **Thermal Management:** Include **a temperature sensing mechanism** to prevent overheating of regulators.

Allowed Components:

- **Regulators: IC 7815 (modified for current control) OR Buck-Boost / SEPIC converter.**
- **Resistors, capacitors, inductors for filtering and feedback.**
- **MOSFETs / BJTs for switching control.**
- **Operational amplifiers (LM358, LM324) for current sensing & feedback.**
- **Diodes, Zener diodes for protection.**
- **NTC/PTC thermistors (if thermal protection is implemented).**

***** Strict Rule: No pre-built battery charging ICs allowed participants must design their own regulation and control system.**

Submission Requirements:

- **Circuit file (.slx for MATLAB or .asc for LTspice).**
- **Simulation results showing:**
  - **Voltage regulation across different load conditions.**
  - **Current variation (0.5A, 1A, 2A) and dynamic response.**
  - **Protection circuit response (overvoltage, overcurrent, thermal control).**
- **Short explanation (max 500 words) detailing:**
  - **Design methodology & component choices.**
  - **How adaptive current control is implemented.**
  - **Protection strategies and their working principles.**
  - **Efficiency improvements and trade-offs**