Low-Cost, Low-Noise Lithium-Ion Battery Power Supply for Enhanced Accessibility in Electronics Research

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Background

Developing low-cost, low-noise power supplies is crucial for enabling accessible, high-quality testing of sensitive integrated circuits in academic and research settings. This project aims to create a power supply that meets the following target specifications:

- Noise level: Less than 5 mV peak-to-peak.
- Cost: Under $100.
- Performance: Comparable to or better than industry-standard power supplies.
- Features: Rechargeable, portable, and safe.

By leveraging lithium-ion batteries, this device achieves low-noise characteristics while maintaining affordability.

Approach

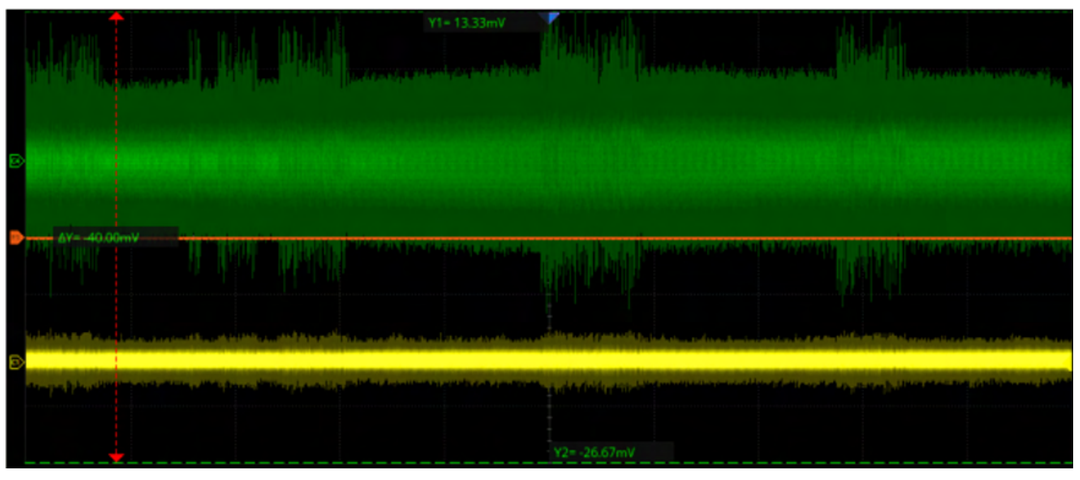

Figure 1. 5V signal Agilent E3631A (top) versus Battery Solution (bottom)

This design comprises a motherboard and a daughterboard, where the daughterboard enables user interaction with the GUI via buttons, and the motherboard contains all remaining logic.

Key Features:

- **Power Source:** Two 18650 Li-Ion (Lithium Ion) cells in series for stable, low-noise power without AC or DC switching conversion.
- **Microcontroller:** 8-bit AVR-based ATMEGA32U chip for efficient control of power management and user interface (UI) running Real-Time Operating System (RTOS) and Battery Protection System (BPS).
- **Safety Features:** Cell voltage/temperature monitoring, passive balancing, over-current protection.
- **Output Control:** Conditional logic block using PFETs and NFETs with a relay for battery recharge/discharge.
- **User Interface:** OLED display, LED indicator,and navigation buttons for interacting with the control panel GUI.

Board Layout Strategies for Noise Reduction:

- 2-layer board with thick power traces and isolated signal lines.
- Low-pass filter and ferrite beads for high/low-frequency filtering.
- Careful component selection (SMD, temperature-stable capacitors, e.g. X7R).

Performance Analysis Device: Siglent SDS2204X oscilloscope.

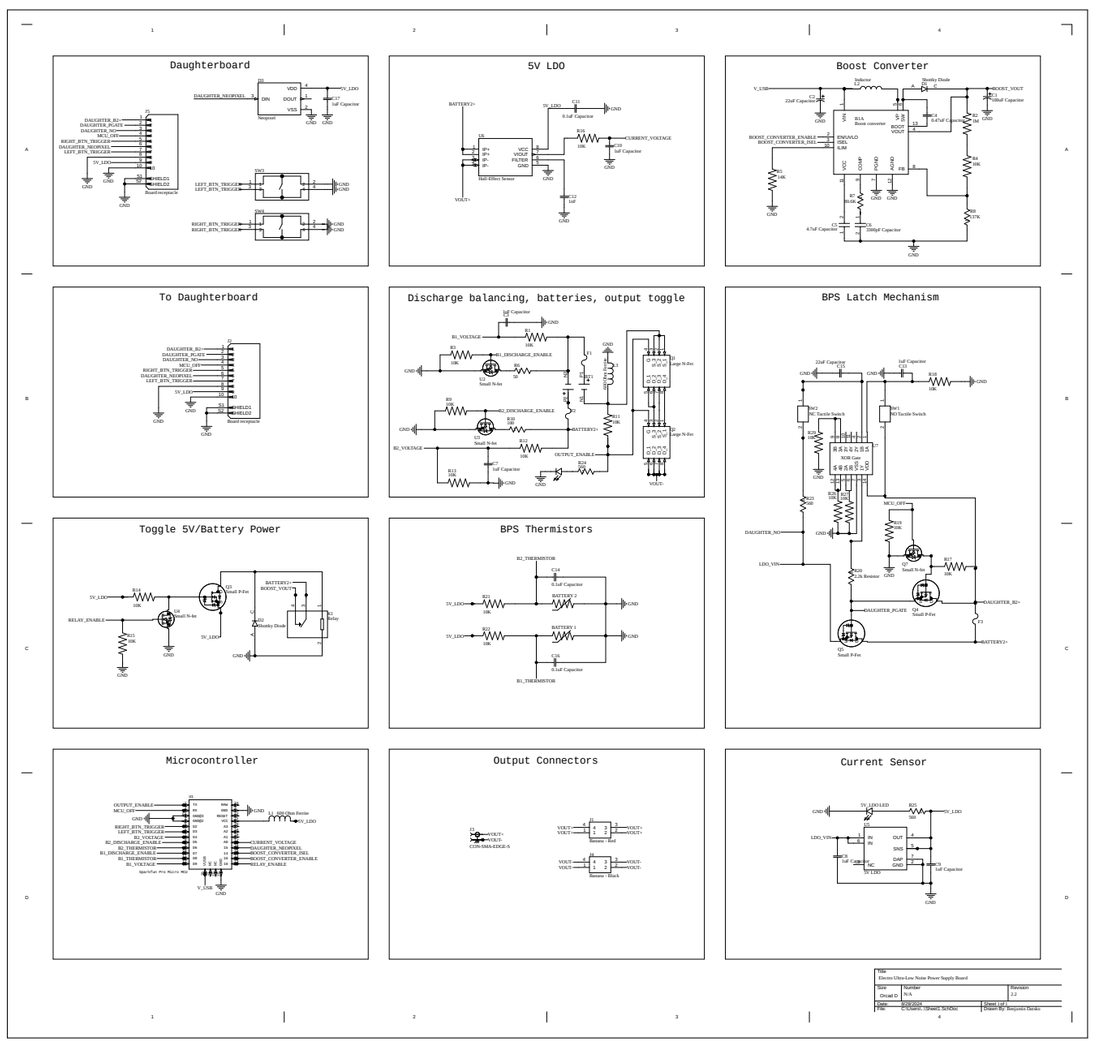

Figure 2. System schematic

Results

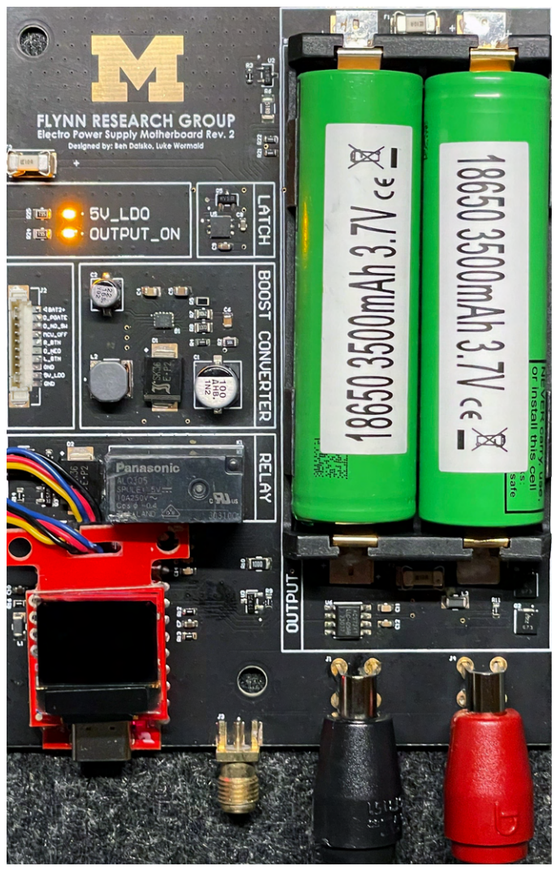

Figure 3. Motherboard (left), daughterboard (top right), and system in 3D printed case (bottom right)

When a 50 ohm load resistor is applied, the power supply exhibits a noise level of 3.89 mV peak-to-peak. Compared to the average noise of a sample of bench power supplies used in laboratory settings, the battery supply measures **40% lower** :

Power Supply	Noise (mV)	Price ($)
Agilent E3631A	6.41	1,414
Keysight E36103B	7.11	828
Siglent SPD3303X-E	6.53	469
Rigol DP832	7.02	529
Proposed Solution	**3.89**	**80**

Table 1. Power supply noise (mV Pk-Pk) and associated price (USD)

Technology Transfer and Impact

This compact, low-noise lithium-ion battery power supply is ideal for powering sensitive electronic test benches, such as those used for neuromorphic computing ICs and CMOS Ising solvers. With noise levels as low as 3.89 mV peak-to-peak and an adjustable voltage range of 5V to 8.4V, it ensures the integrity of functions like simulating artificial neuron behaviors or maintaining the stability of Ising model spin states in the solver chips on the test bench.

Moreover, the power supply's affordability and portability make advanced computing and embedded systems more accessible to a broader range of users, including academic and research institutions, hobbyists, and industry professionals.

Key Findings and Future Work

Results suggest that utilizing rechargeable lithium-ion batteries can significantly improve the signal integrity of power signals compared to switching power supplies.

This research has the potential to increase accessibility to further electronics research and education by providing a cost-effective and reliable alternative to expensive power supplies in schools, labs, and testing facilities.

To enhance the system's performance, future work could include integrating a high PSRR LDO to improve noise filtering, stabilize voltage, and increase accuracy. Additionally, configuring the batteries in parallel instead of in series may further reduce noise by increasing capacitive noise filtering and decreasing series resistance.

For references, contact details, and further documentation, please scan the QR code.