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

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Motivation

Low-noise laboratory-grade power supplies are essential for testing highly-sensitive and high-performance modern integrated circuits (ICs). However, these power supplies can be prohibitively expensive in an academic setting.

To address this challenge, we have developed a cost-effective and reliable solution for low-noise power supply. Our design utilizes two 18650 L-Ion battery cells. We have also implemented basic recharging capabilities and safety features such as over/under-voltage protection.

Our power supply provides comparable signal cleanliness to many top-line industry-grade power supplies at a fraction of the cost - just under $80. This represents a significant advancement for students, instructors, and researchers in academic settings where budget constraints may limit the availability of high-end equipment.

Methods

To develop a cost-effective and reliable low-noise power supply for testing highly-sensitive and high-performance modern integrated circuits (ICs) in an academic setting. This approach minimizes unwanted frequencies (given that chemical reactions in batteries occur gradually) and overall provides a clearer signal than a switching boost/buck converter (M. Shoyama, M. Ohba and T. Ninomiya, 2002).

Our design includes basic recharging capabilities through passive balancing and safety features such as over/under-voltage protection. Despite its cost-effective nature, our design delivers comparable signal cleanliness to many high-end industry-grade power supplies at a fraction of the cost, totaling just under **$80**.

This board was designed with a ground plane and uses polygon pours for power lines instead of traces to lower resistance. Additionally, careful consideration was given to component placement (all components are surface-mount) to mitigate cross-talk and thermal noise coupling. We also installed low-pass filters on signal lines coming off the batteries and added ferrite beads to filter high-frequency noise on the ground plane.

The accompanying figures provide a visual representation of our, including the board schematic and circuitry (Figure 1), board with connected components (Figure 2), and board layout (Figure 3) wherein one can observe these practices being employed.

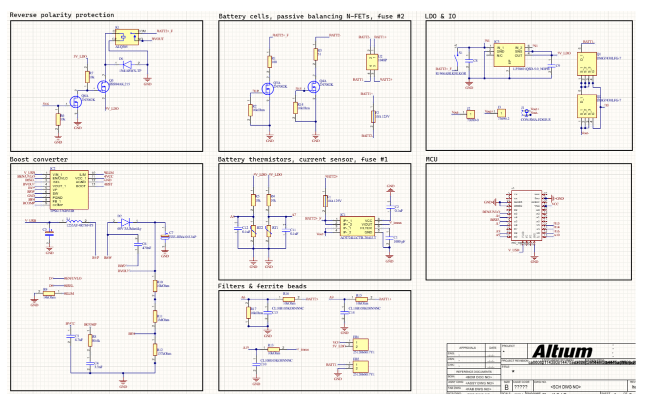


Figure 1: Board schematic

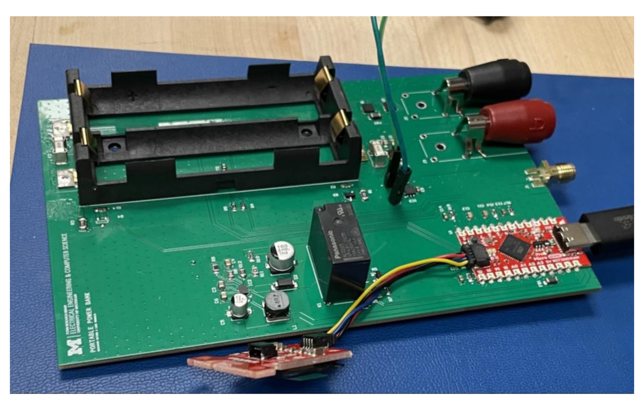


Figure 2: Assembled board

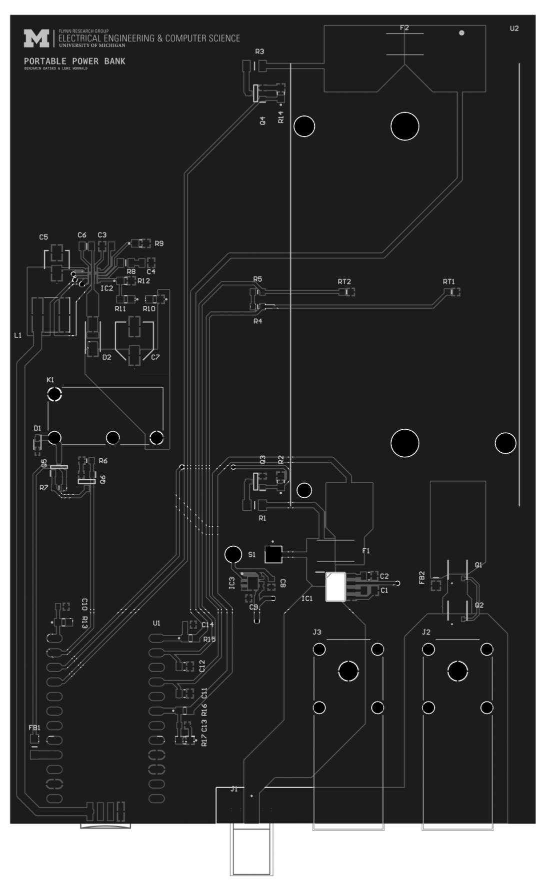


Figure 3: Board layout

Breakdown

IDEATION

ECAD Designing

Utilized Altium Designer Autodesk Eagle, and SparkFun/Mouser design libraries.

SCHEMATIC — Create recharging board circuitry → BatteryBoard.SchDoc

LAYOUT — Create PCB layout → BatteryBoard.PcbDoc

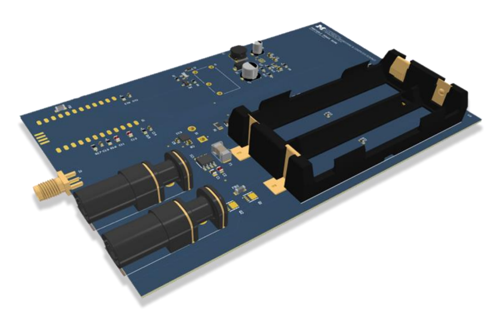
BattInit.cpp → **FIRMWARE** — State machine, sensor interface, display driver

Durability Testing

Casing durability tested via one-week longevity test wherein PSU was subject to atypical testing conditions

CASING — Develop board casing in Inventor → board.step, decal.psd, top.ipt, body.ipt, case.iam

VALIDATION — Characterize bench PSU noise & compare to battery solution



BILL OF PRIMARY COMPONENTS

- Sparkfun Qwiic Pro Micro USB-C
- ACS724LLCTR-20AU-T Current Sensor
- TPS61376RYHR Boost Converter
- SparkFun Qwiic OLED
- 2X 2N7002,215 High-power NFETs

FIRMWARE BREAKDOWN

- Control state machine for passive balancing FETs, SparkFun OLED, current sensor, and temperature sensors
- State machine manages system recharging
- Current sensor data processed for detecting overcurrent and undercurrent conditions
- Includes overvoltage protection to prevent voltage limits from exceeding limits

Results

A Siglent SDS2204X oscilloscope capable of sampling at 2 GSa/s (with a noise floor of ~650μV) was connected to the SMA port on the board to quantify the noise produced by our power supply. By averaging peak-to-peak measurements over a standardized arbitrarily-chosen period (50 seconds), we measured that our power supply solution produces roughly 3.89 mV of noise peak-to-peak.

To evaluate the viability of our solution in an industrial setting, we characterized four industry-standard power supplies. Our power bank outperforms the power supplies measured by 40% (the aforementioned power supplies are listed in Table 1, along with each power supply's price).

Siglent SDS2204X Plus Oscilliscope (Noise Floor μV)		
Power Supply	Peak-to-Peak Noise (mV)	Price (USD at MSRP)
HP Harrison 6205B	10.09	125
Agilent E3631A	23.43	495
Keithley 2400	74.68	5000
Rigol DP832	4.04	359
Battery power bank	*3.89*	*80*

Table 1: Characterized power supply noise and associated price

A comparison between the Agilent E3631A power supply (top channel) and battery-based power supply (bottom channel) is provided in Figure 3, wherein the difference in noisiness is demonstrated:

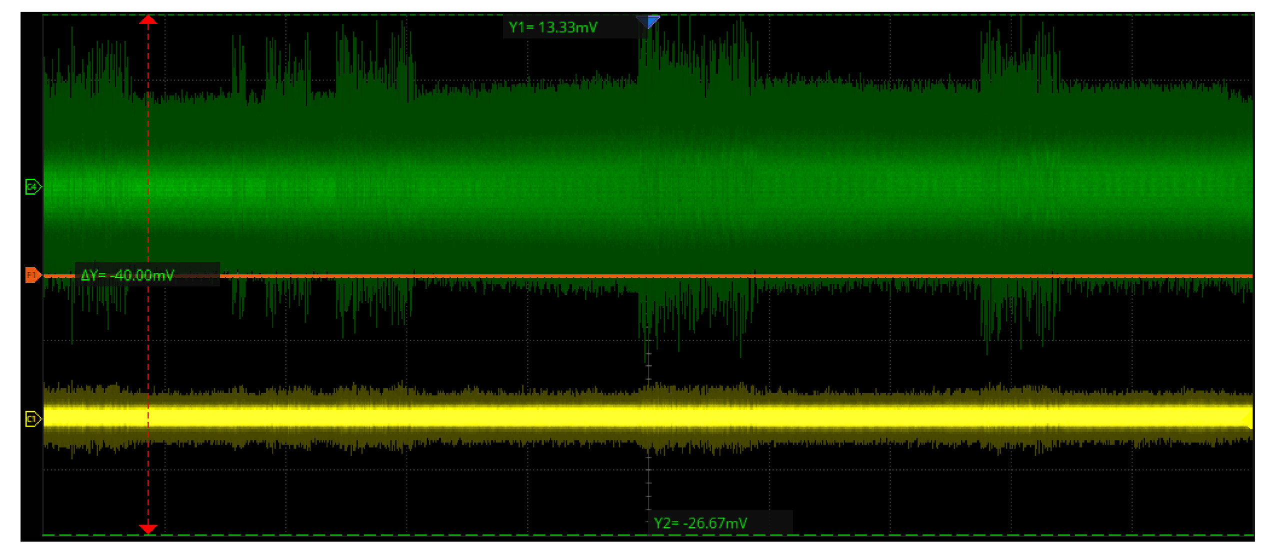


Figure 3: Noise snapshot—Agilent E3631A (top); Battery Solution (bottom)

Discussion and conclusions

With a noise peak-to-peak of approximately 3.89 mV, our low-cost, low-noise lithium-ion battery power supply outperforms industry-standard power supplies by 40%, as shown in Table 1 and Figure 3.

This research can increase accessibility to further electronics research and education by providing a cost-effective and reliable alternative to expensive industry-grade power supplies in schools, labs, and testing facilities where high quantities of such power supplies are necessary.

Literature cited

M. Shoyama, M. Ohba and T. Ninomiya, "Balanced buck-boost switching converter to reduce common-mode conducted noise," 2002 IEEE 33rd Annual IEEE Power Electronics Specialists Conference.