ANALOG DEVICES
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Project Code: APM_BATTERY-TESTER-2016

ADI LI-ION BATTERY FORMATION/GRADING EQUIPMENT SOLUTION

Application Introduction

Energy consumption is a common problem faced by the world, and many industries are working to achieve safer, cleaner, efficient, low cost power solutions to overcome it. The increasing popularity of hybrid and electric vehicles, solar PV energy, and wind energy is a result of this trend. All of these solutions share one trait in common: Li-Ion batteries. Because of the rapid growth of these fields, Li-Ion batteries will play a more important role in energy conversation.

Li-Ion battery manufacturing is a complicated procedure, which includes electrode production, stack construction, and cell assembly. After this process, an electrical test is then performed to grade battery capacity and performance. After this process, an electrical test grades the performance capacity of the battery. For these electrical tests, high power, efficient, and highly accurate test equipment for Li-Ion battery manufacturing is required. This is the highlight of ADI's solution based on AD8450/AD8451 and ADP1972/ADP1974.

System Design Considerations

Efficiency

The capacity of Li-Ion batteries in laptops, cell phones, and similar portable devices is usually small—typically several ampere hours. However, Li-Ion batteries for vehicles or energy storage have much higher capacity—typically in tens or even hundreds of ampere hours. The linear test equipment for small capacity batteries will consume and dissipate a lot of power during the charge phase if it is also used for high capacity battery testing; it is inefficient and also a considerable thermal issue for equipment hardware design. The ADI AD8450/AD8451 and ADP1972/ADP1974 solution is based on PWM architecture, which can help to resolve this problem.

The ADI PWM architecture can also help boost battery energy back to the grid or other channels for charging. This is an environmentally friendly and efficient solution compared to the linear architecture, which discharges battery energy to a resistive load.

Accuracy

To achieve accurate Li-Ion battery capacity, precise measurements for current and voltage in both the charge and discharge mode are required. ADI's solution based on AD8450/AD8451 and ADP1972/ADP1974 can deliver highly accurate measurements and settings with precise ADCs, DACs, and other components in the system.

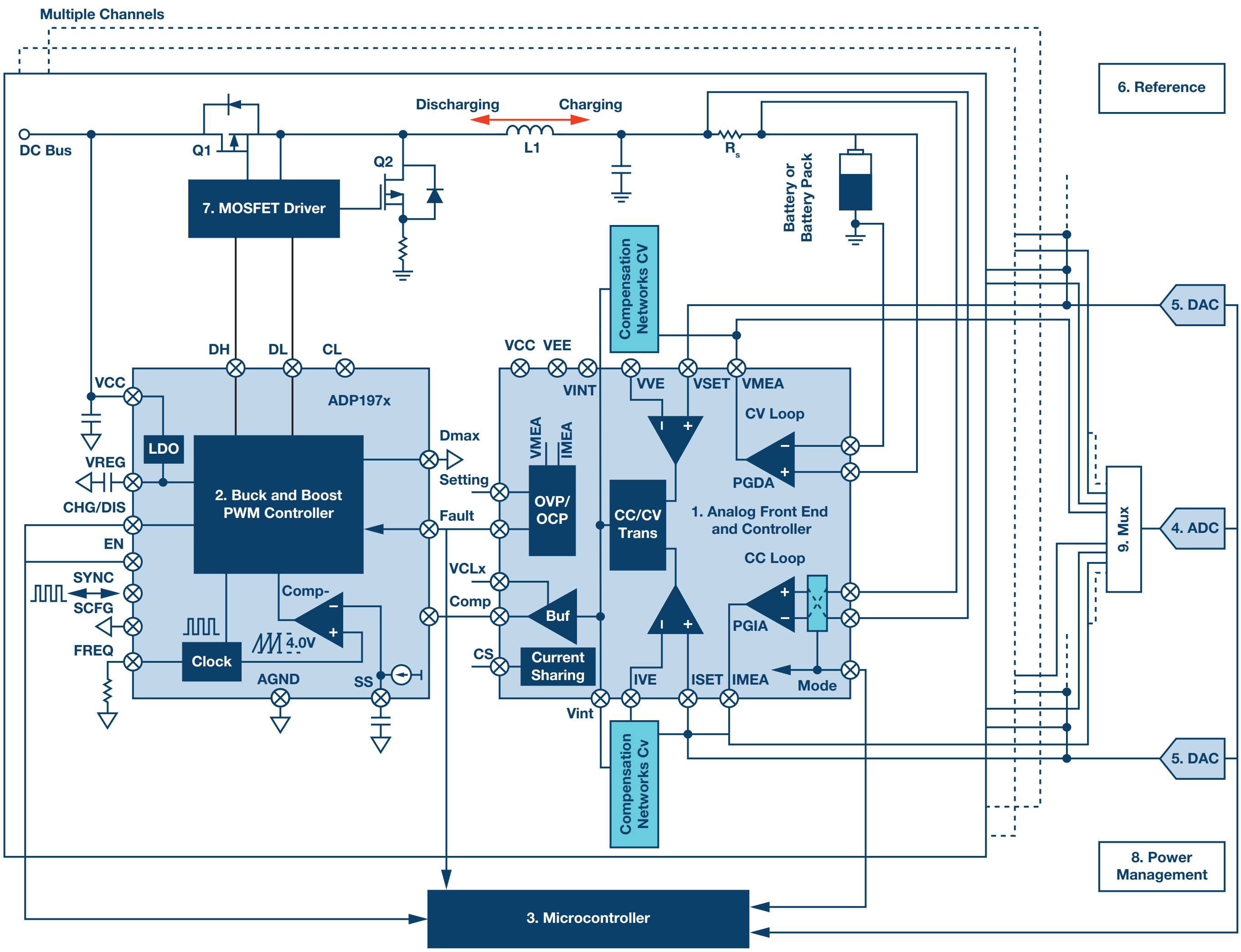
Low System Cost

- Higher switching frequency enables smaller size and cheaper power components, such as inductors and capacitors
- Energy recycling enables lower operational costs
- AD8450/AD8451's higher accuracy enables lower cost heat management and simplifies the control loop's design
- AD8450/AD8451's unique in-amp design enables half the calibration time in manufacturing and longer warranty time
- An integrated solution leads to smaller size, which enables lower cost equipment and maintenance

ADI Solution

System Block Diagram

Below is the system block for channel board from dc bus to battery, including the microcontroller, analog front end and controller, PWM controller, high voltage MOSFET driver, power stage (MOSFET, inductor, capacitor, shunt resistor), voltage/current reading (ADC), and voltage/current setting (DAC).



1. Analog Front End and Controller	2. Buck and Boost PWM Controller
AD8450/AD8451	ADP1972/ADP1974

3. Microcontroller	4. ADC	5. DAC	6. Reference	7. MOSFET Driver	8. Power Management	9. Multiplexer
ADuC7060/ADuC7061	AD7173-8/AD7175-2	AD5686R/AD5668/ AD5676R	ADR3450/ADR4550	ADuM7223	ADP2441/ADP7102/ ADM8829	ADG528F/ADG5408/ ADG658/ADG1406/ ADG1606

System Theory of Operation

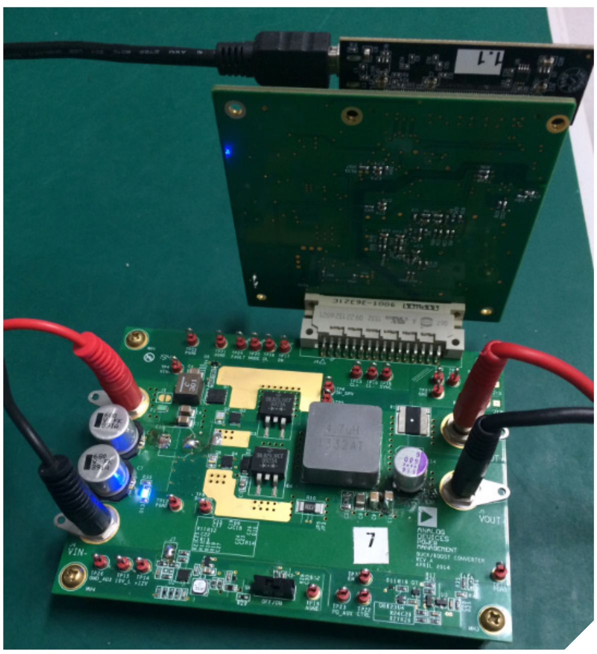
There are two main functions of the previously diagrammed dc bus: one is to charge the battery, the other is to discharge the battery, which is determined by the mode signal of AD8450/AD8451 and ADP1972/ADP1974. For each function, there are two modes: constant current (CC) mode and constant voltage (CV) mode. Two DAC channels control the CC and CV setpoints. The CC setpoints determine how much current is in the loop in CC mode in both charge and discharge functions. CV setpoints determine the battery potential when the loop goes from CC to CV, and also determine the charge and discharge functions.

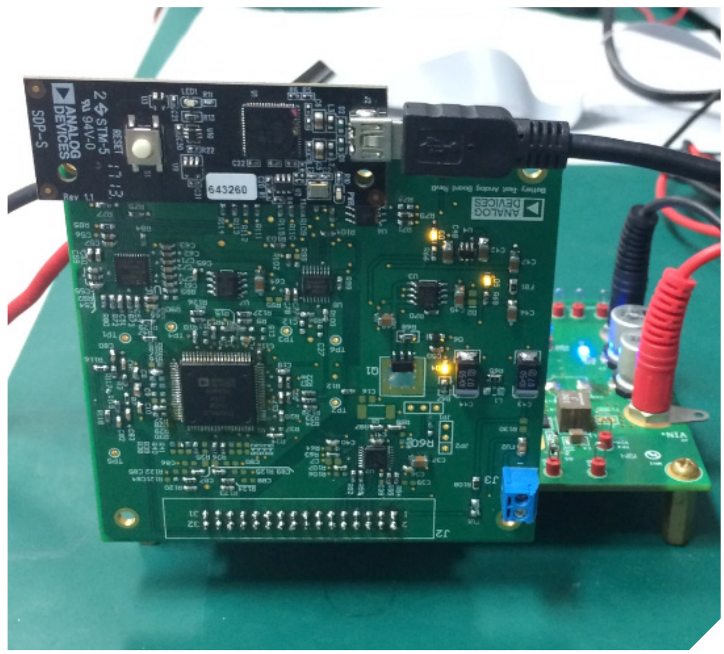
The AD8450/AD8451 precision analog front end and controller measure the battery voltage with an internal difference amplifier PGDA and measure current with an internal instrumentation amplifier PGIA with an external shunt resistor (R_S). Then the AD8450/AD8451 compares the current and voltage to the DAC setpoints with an internal error amplifier and external compensation network, which are used to determine the loop function—CC or CV. After this block, the output of the error amplifier goes to PWM controller ADP1972/ADP1974 to determine the duty cycle of the MOSFET power stage. The loop completes with an inductor and capacitor. The descriptions in this section are for both charge and discharge functions, since ADP1972/ADP1974 is a buck and boost PWM controller.

In this implementation, the ADC receives the readings for voltage and current for the loop, but that is not part of the control loop. The scan rate is unrelated to the control loop's performance, so a single ADC can measure current and voltage on a large number of channels in multichannel systems. In addition, a single processor only needs to control the CV and CC setpoints, mode of operation, and housekeeping functions, so it can interface with many channels.

System Performance

The ADP1972 and AD8450 demo board is made to verify efficiency and accuracy. The dc bus input is 12 V and the maximum charging/discharging current is 20 A for this asynchronous buck and boost power system.





Efficiency: the efficiency of the demo board is ~90% at its maximum rating, with 20 A CC mode for both charge and discharge with a 3.3 V load. To achieve this number, the external diode, shunt resistor, inductor, and MOSFETs are optimized. ADP1974 is also evaluated on this demo board, and the synchronizing mode helps the system efficency to go up to 96%.

Accuracy: after initial accuracy has been calibrated, the accuracy of the current includes drift in temperature, linearity over the full current range (0 A to 20 A), short term stability (noise), and CMRR over the full voltage range (0 V to 3.6 V). The typical current accuracy of the ADI solution verified on a demo board is less than 0.01% under 25°C (±10°C). A similar analysis can be performed for voltage accuracy, which is also less than 0.01% verified on this demo board.

Notes: if you need more information on demo boards, please contact ADI with the information at the end of the article or our sales representative.

Main Products

Part Number	Description	Benefits
Precision Analog Front End and Controller		
AD8450	A precision programmable gain instrumentation amplifier (PGIA) measures the battery's charge/discharge current and a programmable gain difference amplifier (PGDA) measures the battery's voltage; PGIA gains are 26, 66, 133, and 200; PGDA gains are 0.2, 0.27, 0.4, and 0.8; programmable OVP, OCP fault detection, current sharing and balancing	Low offset voltage and gain drift for current and voltage measurement; 3 ppm/°C; high CMRR for current and voltage measurement; fast hardware loop control; current sharing and alarming enabler
AD8451	Precision instrumentation amplifier (PGIA) measures the battery's charge/discharge current and a programmable gain difference amplifier (PGDA) measures the battery's voltage; PGIA gain is 26, PGDA gain is 0.8	Low offset voltage and gain drift for current and voltage measurement; 3 ppm/°C; high CMRR for current and voltage measurement; fast hardware loop control
Buck and Boost PWM Controller		
ADP1974	Synchronous, voltage mode, pulse width modulation (PWM) controller for buck or boost, dc-to-dc, applications; input voltage range: 6 V to 60 V; adjustable frequency from 50 kHz to 300 kHz; programmable maximum duty cycle	COMP input-compatible with AD8450/AD8451; excellent PWM linearity with high amplitude PWM sawtooth 4.0 V p-p; synchronization output or input with adjustable phase shift
ADP1972	Asynchronous, voltage mode, pulse width modulation (PWM) controller for buck or boost, dc-to-dc, applications; input voltage range: 6 V to 60 V; adjustable frequency from 50 kHz to 300 kHz; programmable maximum duty cycle	COMP input compatible with AD8450/AD8451; excellent PWM linearity with high amplitude PWM sawtooth 4.0 V p-p; synchronization output or input with adjustable phase shift
Microcontroller		
ADuC7060	ARM7TDMI® core, 16-/32-bit RISC architecture; integrated dual 8 kSPS, 24-bit ADC; 5-channel primary ADC and up to 8-channel auxiliary ADC; ADCs operate in single-ended or differential input modes; PGA in primary channel and buffer in auxiliary channel; single 14-bit voltage output DAC; 32 kB flash, 4 kB SRAM; UART serial I/O and I²C; up to 14 GPIO; 16-bit, 6-channel PWM	Low power consumption; integrated precision ADC and DAC; on-chip precision reference ±10 ppm/°C; 48-lead LFCSP and LQFP
ADC		
AD7173-8	31.25 kSPS, 24-bit, low power, eight full differential/16 single-ended channel multiplexed Σ-Δ ADC	High speed, high resolution; precision 2.5 V reference 3.5 ppm/°C; precision analog buffer
AD7175-2	250 kSPS, 24-bit, two full differential/four single-ended channel multiplexed Σ-Δ ADC	High speed, high resolution; precision 2.5 V reference 2 ppm/°C; true rail-to-rail analog buffer
DAC		
AD5676R	16-bit, 8-channel DAC; ±3 LSB INL (max); 50 M SPI interface; 2 ppm/°C reference	High resolution, high linearity, integrated; 20-lead TSSOP package; 2 ppm/°C reference
AD5689R	16-bit, 2-channel DAC; ±2 LSB INL (max); selectable gain of 1 and 2; 50 M SPI interface	High resolution, high linearity; precision 2.5 V reference 2 ppm/°C
AD5668	16-bit, 8-channel DAC; SPI bus; on-chip 1.25 V/2.5 V, 5 ppm/°C reference	Integrated; 16-lead TSSOP, 16-lead LFCSP
Reference		
ADR3450	5 V reference, very low drift: 8 ppm/°C (max), 2.5 PPM/°C (typ); low noise: 35 µV p-p @ 0.1 Hz to 10 Hz; long time stability: 30 ppm/$\sqrt{1000\ hr}$	Low drift, good stability, low cost reference; many choices for output voltage in ADR34xx family
ADR4550	5 V reference, very low drift: 2 ppm/°C (max); low noise: 2.8 µV p-p @ 0.1 Hz to 10 Hz; long-term stability: 25 ppm/$\sqrt{1000\ hr}$	Low drift, very good stability and low noise reference, many choices for output voltage in ADR45xx family
Power Management		
ADP2441	36 V input, 1 A synchronous buck regulator; switching frequency of 300 kHz to 1 MHz	High input voltage; high efficiency of up to 94%
ADP7102	20 V input LDO, 300 mA output current; low noise: 15 µV rms; seven fixed versions and adjustable version	High input voltage, low noise LDO
ADM8829	Charge pump voltage inverter; input +1.5 V to +5.5 V inverted to –1.5 V to –5.5 V output; 25 mA output current	Simple, 99% voltage conversion efficiency
MOSFET Driver		
ADUM7223	4 A isolated, half-bridge gate driver; high frequency operation: 1 MHz (max); 3.3 V to 5 V input logic; 4.5 V to 18 V output drive	Independent and isolated high-side and low-side outputs
Multiplexer		
ADG528F	8-channel multiplexer; ±15 V dual supply operation; fault and overvoltage protection (–40 V to +55 V)	Fault and overvoltage protection; latch-up proof
ADG5408	8-channel multiplexer; ±9 V to ±22 V dual supply operation; 13.5 Ω on resistance	High voltage rail, latch-up proof; low on resistance
ADG658	8-channel multiplexer; ±6 V dual supply operation; <1 nA leakage current; 50 Ω on resistance	Low leakage; low on resistance

Design Resources

Reference

- **APM (Application Per Month)**
  Li-Ion Battery Test Equipment Solutions—
  www.analog.com/APM/battery_solution_2011_en.pdf
- ADI Li-Ion Battery Formation/Grading Equipment Solution—
  www.analog.com/APM/battery_solution_2015_en.pdf

- ***Analog Dialogue***
  Accurate Analog Controller Optimizes High Efficiency Li-Ion Battery Manufacturing—*www.analog.com/en/analogdialogue/li_ion_battery*

- **AD8450/AD8451 Compensator Design Tool—**
  www.analog.com/en/AD8450

To view additional gas detector resources, tools, and product information, please visit:
www.analog.com/en/instrumentation

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