Application Report
A Simple Battery Simulator

![Texas Instruments]

ABSTRACT

When using TI battery fuel gauges, some features need to be tested quickly, such as valid charge termination and other SOC related features. It might take some time if a real battery is used. A power supply can speed up the process but more output channels are needed for multi-cell gauges. Using the simple battery simulator described in this application report makes it easier to test gauge features when professional equipment are unavailable.

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Trademarks

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1 Circuit Operation Principle

Gauges supporting different number of cells might be used according to the needs of different applications. Single cell gauges like BQ27Z561 or multi-cell gauges such as BQ40Z50 and BQ40Z80 need different number of battery cells during an application or testing. The simulator circuit described in this application report can provide up to four outputs working as batteries while supporting discharge and charge functions with the help of an external adjustable resistor. Figure 3-1 shows the schematic of the circuit.

As can be seen in the schematic, this circuit consists of three main sections. The first section provides a 5-V bias and reference voltage to the rest of the circuit for determining current flow direction. The second section controls current direction to simulate charge and discharge after comparing simulated battery voltage and charger voltage. The third section is a resistor divider network, simulating individual cell outputs to the gauge.

1.1 5-V Bias and Reference

The first section of the circuit is shown on Figure 1-1. This section provides power and references for the second section. A shunt regulator device, TLV431, and a simple resistor divider network are used to generate 5-V bias power and 2.5-V references V1 and V2 from 16-V DC supply on the Vin pin.
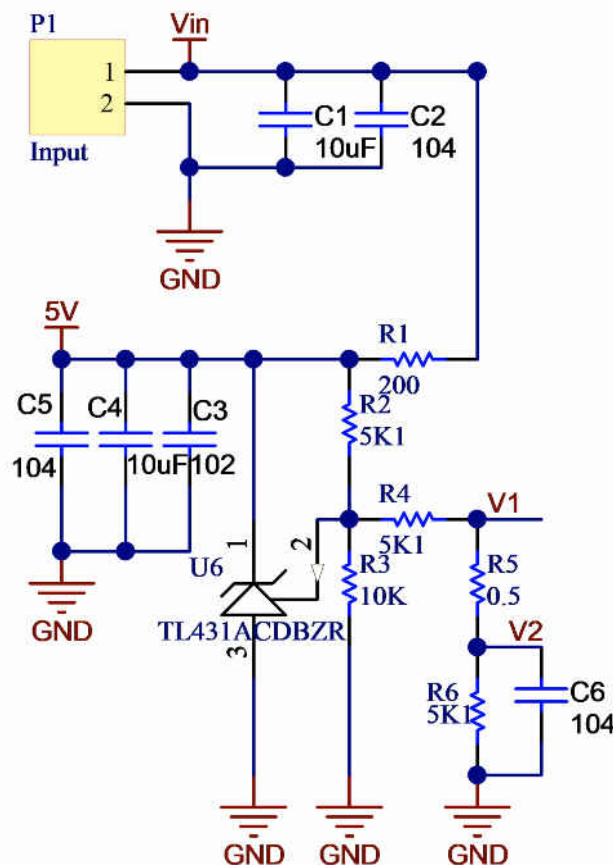

Figure 1-1. 5-V Bias and Reference

1.2 Compare and Control

Figure 1-2 is the second section of the simulator circuit, which compares the voltge on Vin and Vout pins and controls FETs Q1 and Q2 in order to simulate charge or discharge process of the battery.
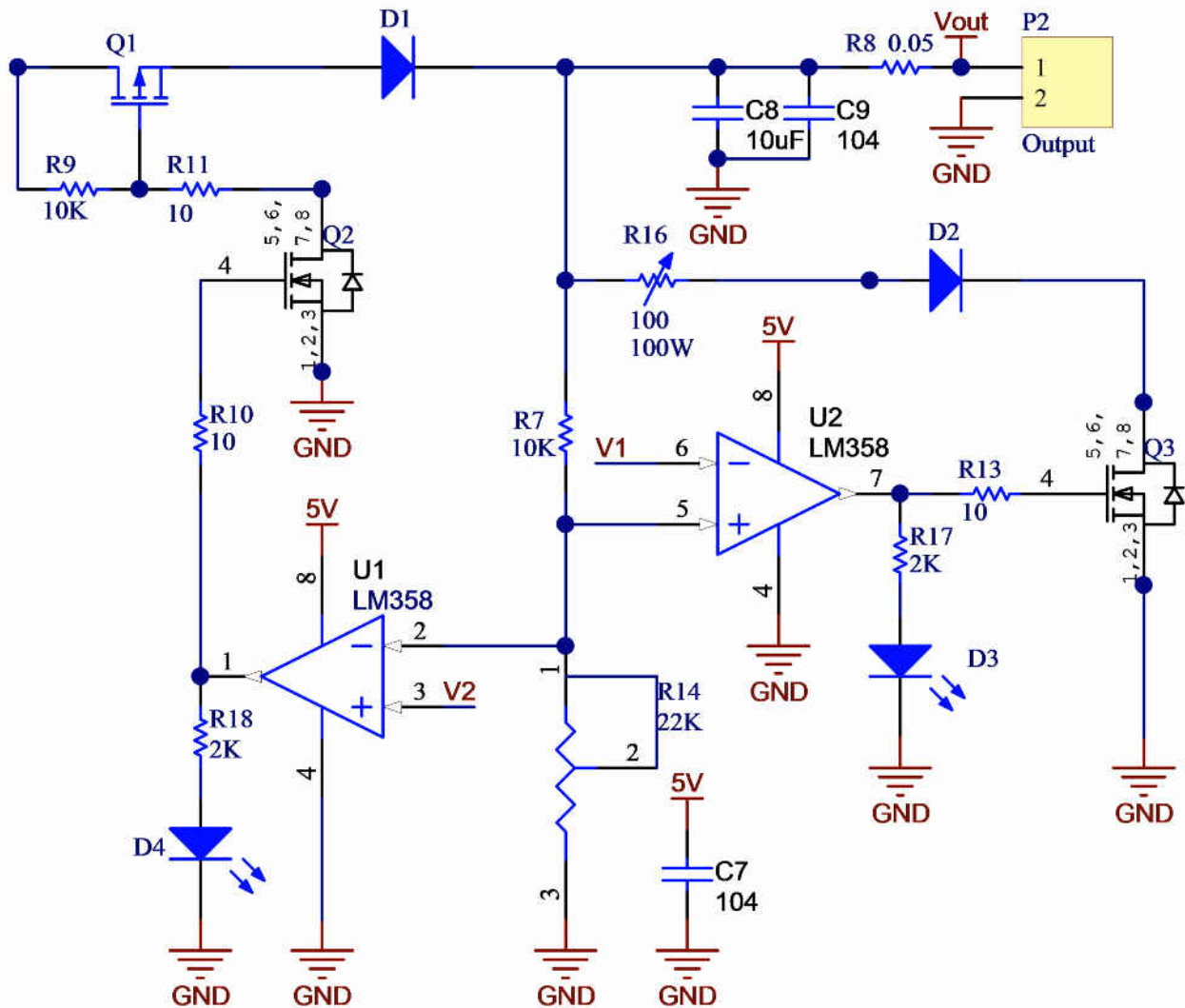
Figure 1-2. Compare and Control Circuit

A TI dual standard operational amplifier, LM358, is used as comparator and driver of the FETs. First channel of LM358, U1 on the schematic, controls NFET Q2 according to the comparision results of reference V2 and Vout after being divided by R7 and R14. If Vout voltage on the inverted pin of LM358 is lower than V2, the output of U1 becomes high and closes Q2. PFET Q1 then will be closed since its gate is pulled low by Q2, providing a path for current flow from Vin to Vout. The load connected to the PACK pin of the gauge determines the magnitude of the current, but the current should not exceed the rates of components, Q1 and D1, which is around 3 A in this example.

Second channel of LM358, U2, compares V1 and Vout at the non-inverted pin of U2. If Vout is higher, indicating a charger connection, the output of U2 turns high, thus closing Q3, opening Q1 and Q3. This creates a current flow path from Vout through D2 and Q3. With this current path, a battery charge process can be simulated. R16 is an adjustable 100-W resistor, which controls the simulated charge current. This resistor is connected to the board externally, so a different resistor can be used regarding actual test requirements.

1.3 Resistor Divider Network

The third section of the simulator circuit is a simple divider network consisting of four adjustable resistors as shown on Figure 1-3, each corresponding to one cell output to the gauge. If more than four cells are needed, the user can modify the circuit and increase the number of cell outputs. The voltage of each cell can be adjusted individually but this will influence the sum voltage of other three cells because total voltage Vout is constant. However, during gauge function evaluation, usually only one cell voltage needs to be changed, with the others

being kept in a certain range. In this situation, the user can adjust all cell voltages to the same value first, then change the voltage of the cell as needed. In this way, the voltage of the other three cells changes but stays the same with each other.

Figure 1-3. Resistor Divider Network

2 Application Guide

Before using the board as a simulator, resistors should be adjusted so that the circuit works properly. Set up the board by following the list below:

1. Apply 16-V DC power to Vin pins.
2. Adjust R14, make sure LED D4 is on, indicating a discharge simulation of the battery.
3. Measure simulated cell outputs to make sure they are in the gauge safe voltage range.
4. Connect cell outputs to the gauge, check voltage readings of each cell and adjust the resistor network so that the voltage of each cell is the same.
5. For battery charge simulations, connect a load to R16, adjust R14 to the other direction to turn on charge FET Q3. LED D3 will turn on at this point, indicating a battery charge simulation.

After setting up the board, charge and discharge simulations can be done. Individual cell voltage can be adjusted when performing cell based validations. Charge and discharge directions can be changed by the circuit after comparing Vin and Vout voltages, or can be changed manually by adjusting R14, directions can be seen easily on DSG and CHG LEDs D3 and D4. If total output voltage needs to be changed, Vin voltage can be adjusted accordingly.

Figure 2-1 shows an application example of the simulator circuit connected with a BQ40Z50 EVM. Refer to bq40z50EVM Li-Ion Battery Pack Manager Evaluation Module User Guide for application information on the BQ40Z50 EVM. After finishing setup steps 1 to 3 listed above, connect cell outputs of the simulator (pins 1N to 4P) to cell inputs of the BQ40Z50 EVM (pins 1N to 4P) and then perform step 4. Connect the load or charger to PACK+ and PACK- pins of BQ40Z50 EVM and connect the gauge to bqStudio through EV2400. Charge and discharge simulations can be performed to evaluate the features of BQ40Z50 battery fuel gauge with this setup.
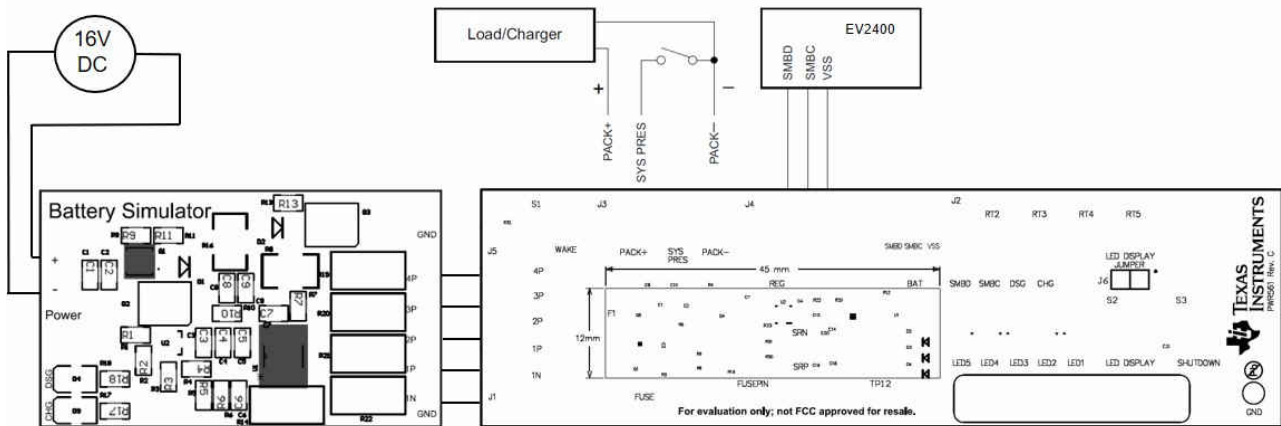

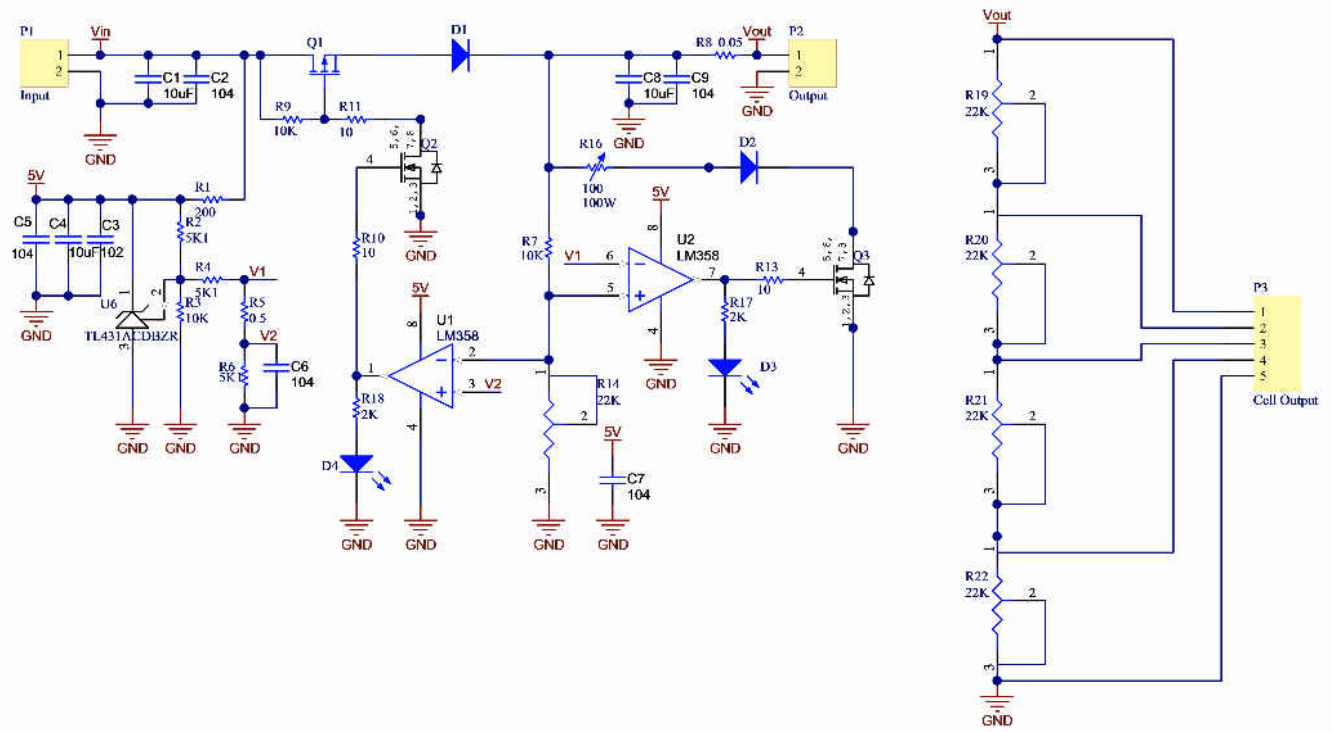**Figure 2-1. Connection of the Simulator Circuit and BQ40Z50 EVM**

3 Schematic

Figure 3-1. Schematic

4 Revision History

DATE	REVISION	NOTES
June 2021	*	Initial Release

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