PMP15038 Test Results

System Description

The reference design introduces a circuitry to improve the current and voltage control accuracy of the LM5175 evaluation board (LM5170EVM-BIDIR). LM5170 is a multiphase bidirectional current controller. It operates at BUCK mode when require current flowing from high voltage side to low voltage side, or BOOST mode when require current flowing from low voltage side to high voltage side. The LM5170 integrates 5-A MOSFETs driver to improve the converting efficiency. Its diode emulation feature can help to prevent negative current through synchronous MOSFET. Others features include multiphase operation to increase current capability and efficiency, programmable or adaptive dead-time and so on. The LM5170 is suitable for high current battery test system which requires charging and discharging battery under current and voltage control signal. However, its integrated current amplifier is not good enough to achieve lower than 0.05% current accuracy. And LM5170 doesn't integrated voltage control loop to regulate the battery voltage. To solve the two problems, the PMP15038 is designed as in Figure 1. A 1mΩ resistor is placed between the LM5170EVM and the battery. A precision, high-voltage instrumentation amplifier senses the current through the battery. This current is regulated by the precision operational amplifiers OP07 to the current reference signal. The battery voltage is also sensed and regulated using precision operational amplifiers.

The current capability of the PMP15038 is set to 50A. However, the LM5170 can actually support higher current if lower voltage rating power MOSFET and higher current inductor are selected.

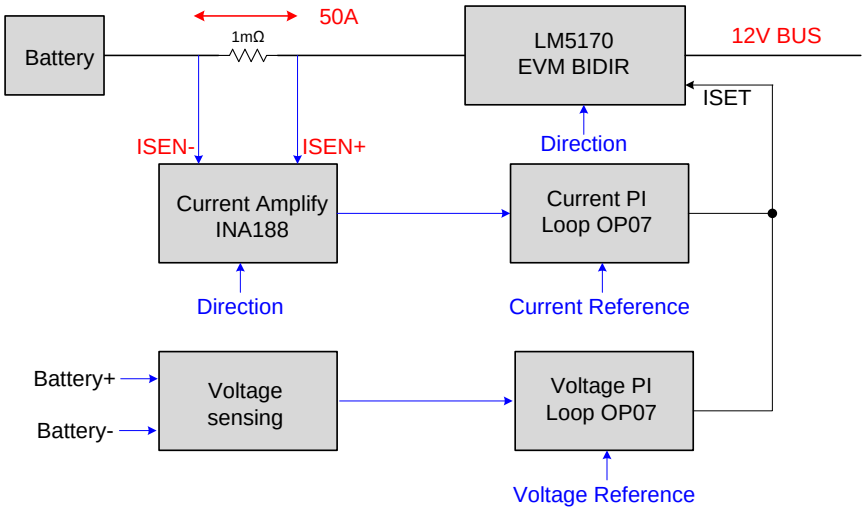

Figure 1: Block Diagram of the PMP15038

The detail circuit of current control loop is shown in Figure 2. The ISEN+ and ISEN- are connected the current sensing resistor in the LM5170EVM. The U1 SN74LV4053A converts the bidirectional battery current to one direction based on the DIR pin logic. The INA188 amplifies the voltage drop of the sensing resistor by approximately 100 times. The U3 OP07 controls battery current equal to the current reference signal IREF. The ISETA in the output of the U3 is connected to the ISETA pin of the LM5170EVM.

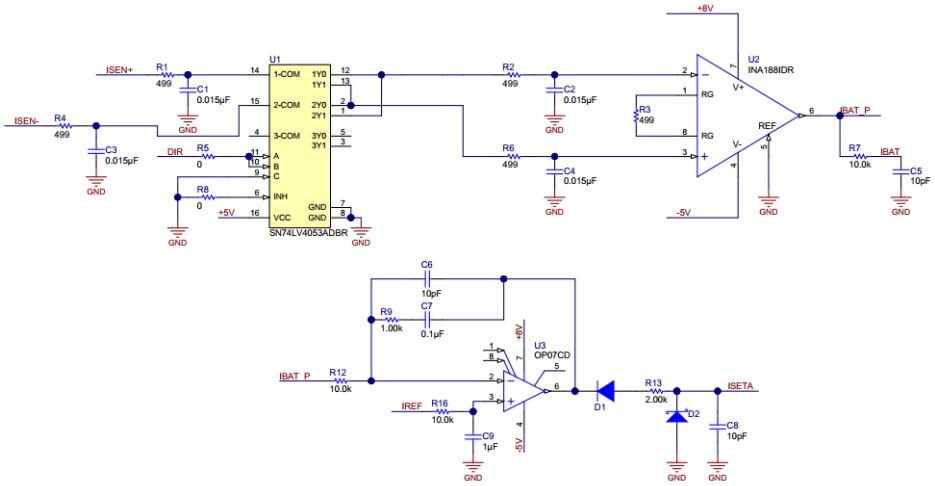

Figure 2: Current Control Loop of the PMP15038

The voltage control loop circuitry is shown in Figure 3. The BAT+ and BAT- are connected to the positive and negative node of the battery respectively. The U7 controls the battery voltage to the voltage reference VREF. The output of the U7 is also connected to the ISETA pin of the LM5170.

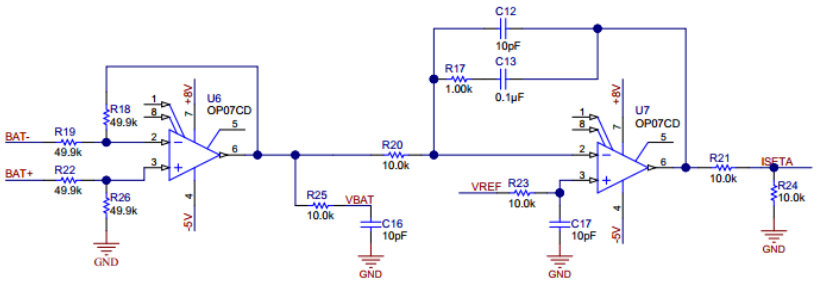

Figure 3: Voltage Control Loop of the PMP15038

Some modifications of LM5170EVM are required to make the system to operate:

- Bypass the breaker with the1mΩ current sensing resistor as shown in Figure 4.
- Disable the breaker Q5, Q6, Q8, Q9 by reducing the gate to source resistor to 10KΩ
- Pull down SYNCOUT pin with 10KΩ.

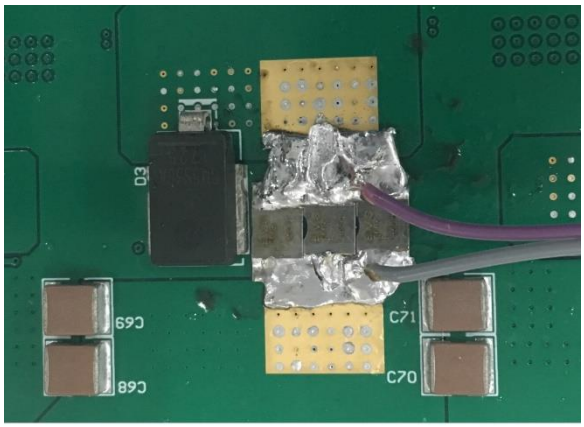

Figure 4: Current Sensing Resistor

The photo of the PMP15038 is shown in Figure 5. The small PCB is the current and voltage control circuit. The large PCB is LM5170EVM-BIDIR. The 12-V BUS connects to the high voltage side of LM5170EVM and the battery connect to the low voltage side. The small PCB circuit is powered by the 12-V bus. And it control LM5170EVM output voltage and current through the ISETA pin.

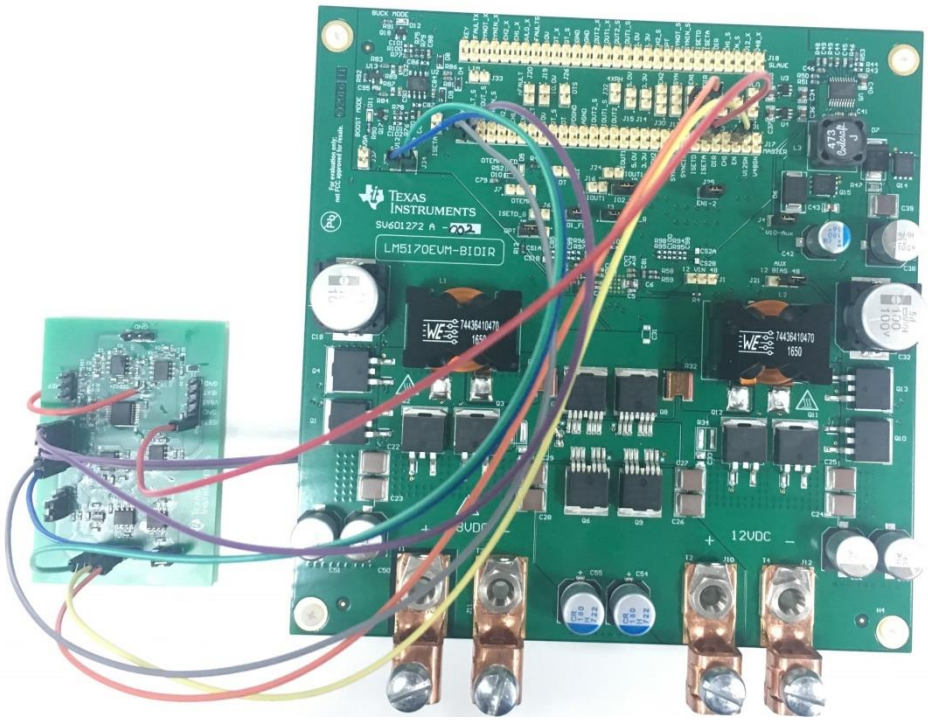

Figure 5: Board Image of the PMP15038 connected to the LM5170EVM

Test Result

In the reference design, the current accuracy depends on the current sensing resistor, the gain and offset of the current amplifier INA188 and the offset of the OP07CD. These parameters vary from device to device. To achieve good current control accuracy, the total gain and the offset of the designed circuit should be calibrated. In BUCK mode, the battery current is 39.999 A if the current reference signal is 4.01713 V; and battery current is 10.0295 A if the current reference signal is 1.0212 V. from these two data, the real gain and offset can be calculated as following:

$$gain = \frac{IOUT2 - IOUT1}{ISET2 - ISET1} = \frac{39.999 - 10.0285}{4.0713 - 1.0212} = 9.82607$$

$$OffSet = IOUT1 - gain \cdot ISET1 = 10.0285 - 9.82607 \times 1.0212 = -0.00588$$

Using the gain and offset, the current reference and actually output current in bench test are shown in table 1.

Table 1: Reference Current Vs Actual Current at BUCK Mode

Reference Current (A)	1.0082	1.9633	4.9130	10.0285	20.0442	30.0629	39.999	50.0059
Actual Current (A)	1.0073	1.9622	4.9134	10.0285	20.045	30.063	39.999	50.003

The Figure 6 shows the full scale (FS) accuracy of the reference design at BUCK mode condition. The data is better than 0.05%. The current accuracy in boost mode can also be calibrated with same method.

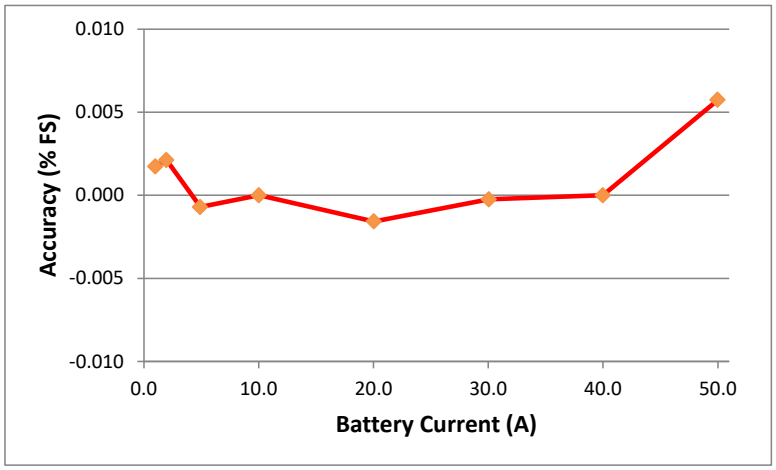

Figure 6 Battery Charging Current Accuracy

Because the common-mode rejection ratio is limited, the output current would change with the battery voltage. As shown in Table 2, the output current decrease 2mA (0.004% of full scale current) if battery side voltage increases from 0.5V to 5V.

Table 2: Output current VS battery voltage

Battery Voltage (V)	0.05	1.0	2.0	3.0	4.0	5.0
Actual Current (A)	10.002	10.002	10.0015	10.001	10.0005	10.000

To measure the voltage loop accuracy, bulk capacitors are used to simulate the battery. The voltage is calibrated using the method in current calibration. After calibration, the regulated battery voltage at 1-A output current is shown in Table 3. The differential is much lower than 0.5mV.

Table 3: Reference Voltage Vs Actual Voltage

Reference Voltage (V)	0.04968	0.4988	0.99788	1.99434	2.9912	3.98935	4.98531
Actual Voltage (V)	0.04969	0.49882	0.99788	1.99433	2.99116	3.98935	4.98526

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