Automated Signal Monitoring of LT8228 Buck–Boost Converter

Rahul Raj, Bhanu Pratap, and Chandana HB

Abstract The use of DC systems has increased with the increase in renewable energy systems. DC power converters are widely used for transferring electrical energy with minimal losses. The power converters used in industries have different types of monitoring pins whose readings need to be measured automatically to keep track of power flow. This paper will discuss the automation of monitoring pins of the LT8228 bidirectional buck–boost controller using Arduino Uno to estimate the actual current flow through the device. For this purpose, DC2351A is used, which is a demo board for LT8228. Evaluating the current flowing through the circuit is necessary to find the actual power consumed by the load, which can be stored in a database for billing energy consumed.

Keywords Bidirectional DC–DC converter · LT8228 · DC2351A · Arduino Uno

1 Introduction

Energy can be harnessed directly from the sun, even in cloudy weather. Solar energy is used worldwide and is increasingly popular for generating electricity or heating and desalinating water as it is affordable, reliable, and sustainable. According to Sustainable Development Goal—SDG7, the world must ensure access to affordable and clean energy by 2030 [1]. Solar energy can play a significant role in achieving this goal and can be accessed easily in any part of the world without much initial cost. In 2020, the total installed capacity of solar energy was 773,200 MW [2].

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To transmit solar energy, a DC–DC converter is widely used. The DC–DC converter is an electromagnetic device used to convert one voltage level to another voltage level [3]. Its power level ranges from a low level of small batteries to a high level, like high voltage transmission. In transmission, high voltage is preferred over low voltage to decrease transmission losses; for this purpose, DC–DC converter is used. DC transmission is preferred over AC transmission as losses in DC transmission are negligible compared to AC transmission [4].

There are various types of DC–DC converters, such as buck converter, boost converter, buck–boost converter. For smooth transfer of power in both the direction for buck and boost mode, bidirectional DC–DC converters are used. Bidirectional converters can be used to step up the voltage as well as step down the voltage.

Voltages step up when the power is injected into the transmission line and step down when the power has to be taken from the nano-grid. One of the types of bidirectional controllers is LT8228 [5] from analog devices. This controller features buck and boost mode up to 100 V, and current and voltage can be controlled using various pins in the controller.

UNO is probably the most popular Arduino board in the world which is equipped with an Atmega328P processor. Arduino Uno boards operate at 16 MHz. Its 32 KB of program memory, 1 KB of EEPROM, and 2 kB of RAM [6]. It quickly became the industry standard for development boards. This pin header makes the Arduino Uno compatible with most development board shields.

When the power is to be transferred, it is necessary to record the amount of power being transferred for billing of energy used. For this purpose, the controller has two monitoring pins that estimate the output and input current as measuring high current from a microcontroller requires extra setup, which will increase the system price. The signal from these pins need to be observed automatically and record the power being transferred. The 10-bit ADC of Arduino UNO is one of the limitations in measuring the low voltages in these monitoring pins [7].

This paper will discuss the automation of monitoring of signals using Arduino Uno to measure the very low voltage which will estimate the actual current flowing through the circuit. Section 2 presents a brief idea about the bidirectional DC-DC converter and its structure and operation. In Sect. 3, the LT8228 controller and DC2351A demo board connection to the Arduino board have been discussed. The software requirements and calculations for comparing results have been explained in Sect. 4. Experimental results are presented in Sect. 5. Finally, the conclusion is given in Sect. 6, followed up by references.

2 Working of Bidirectional DC–DC Converter

A common DC–DC conventional converter can only transfer power in one direction, which is not helpful when a battery needs to be interfaced, or two sources are to be connected with each other. A bidirectional DC–DC converter is used to transfer power in both directions in a situation like an energy source connected to a motor,

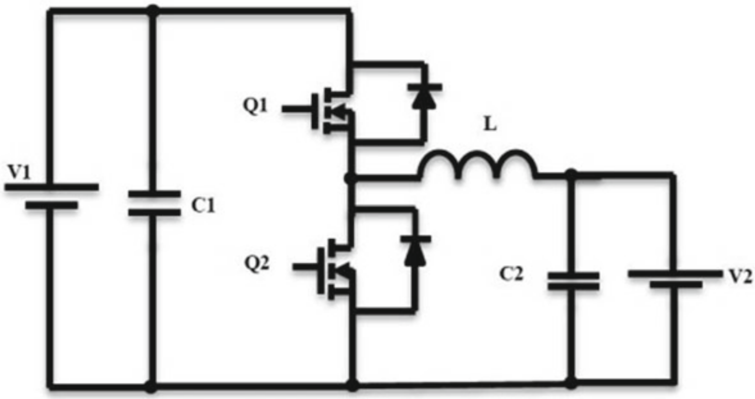

Fig.1 DC–DC bidirectional buck–boost converter [8]

usually in electric vehicles. This bidirectional converter controls the voltage level, and it is used for bucking and boosting the voltage level by controlling the switching circuit. A bidirectional DC–DC converter is also known as a half-bridge DC–DC converter. Many topologies are available, like Cuk, SEPIC, and flyback. The basic buck and boost circuit are connected anti-parallel in this type of converter. It can work in both directions [8].

Mode 1: Buck Mode

In this mode, the voltage at the output side will be lesser than on the input side, but the power on both sides remains the same in ideal conditions. This can be achieved by making the switch in series with the parallel combination of diode and inductor.

In Fig. 1, input supply is given at V1 and output at V2. The switch Q1 and Diode D2 begin conduction, and the circuit operates as the buck converter. Switch Q2 and Diode D1 remain off all the time.

Mode 2: Boost Mode

In this mode, the voltage at the output side will be more than the voltage on the input side, but the power remains the same in ideal conditions. This can be achieved by making the inductor in series with the parallel combination of the switch and the diode.

In Fig. 1, input supply is given at V2 and output at V1. Switch Q2 and Diode D1 begin conduction, and the circuit operates as the boost converter. Switch Q1 and Diode D2 remain off all the time.

3 Hardware Setup Description

Demo board DC2351A is used to measure the monitoring pin voltages [9], as shown in Fig. 2. This board features an LT8228 controller for controlling the output current and voltage.

The DC2351A board is a 500W bidirectional DC-DC converter that can be used as a boost and buck converter by controlling the ground pin. It consists of four protection MOSFETs that offer reverse voltage, reverse current, and short circuit protection on both sides. It also consists of 8 operating MOSFETs that support buck and boost operation. DC2351A board has all the monitoring pins at the bottom, which can be connected to analog inputs of Arduino Uno for calculating the current in the circuit. The pin diagram of LT8228 is shown in Fig. 3. LT8228 consists of gate control and control to the operation of DC2351A, including enabling and switching frequency. It offers features like under-voltage protection and overvoltage protection. It is convenient as the output can be controlled by controlling the input to the feedback pins of the controller. The monitoring outputs are sourced by this controller, which senses input current to the board and gives scaled output.

The simulation of DC2351A has been shown in Fig. 4. The principal aim of this setup is to keep continuous track and measure the IMON1 pin and IMON2 pin. IMON1 pin will give the equivalent voltage for current flowing from the V1 side, and the IMON2 pin will provide the equivalent voltage for current flowing from the V2 side.

Monitoring pins of DC2351A are connected to the 10-bit ADC of Arduino, and the reference voltage of Arduino is set to 1.1 V internally. Since the 10-bit ADC cannot measure low voltage accurately so, using oversampling library, the analog

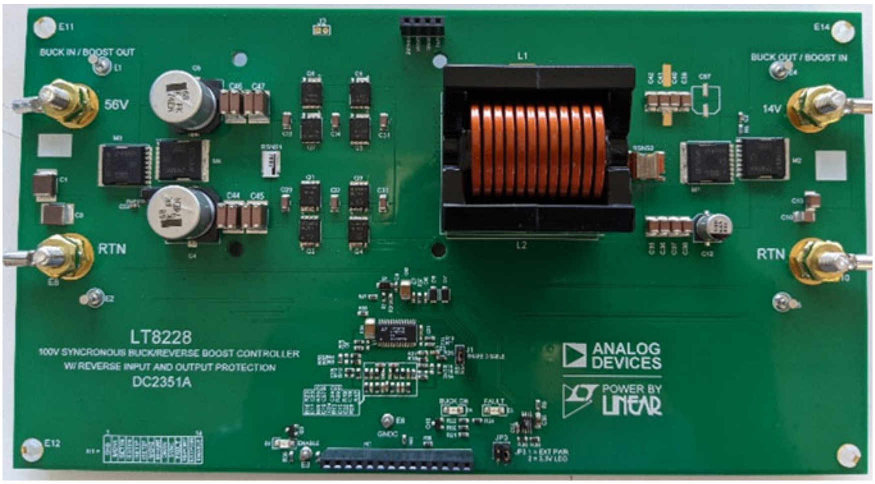

Fig. 2 DC2351A demo board [9]

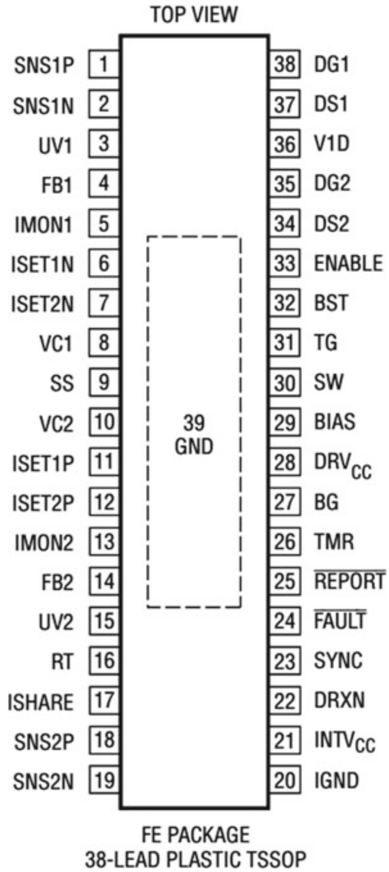

Fig. 3 LT8228 pin configuration [5]

readings are oversampled to 16-bit, which can measure the low voltage accurately. In Fig. 5, the whole setup for measuring monitoring pins with Arduino Uno is shown.

4 Software Requirements

Arduino IDE is an open-source software where electronics can be built easily and efficiently with lower costs in a microcontroller platform and is used for writing the code and for uploading it to the microcontroller. Arduino UNO includes features like ROM, RAM, and flash memory. It also consists of a 5 and 3.3 V supplies along with a few GND points [10].

The method used to get the monitoring pin output is oversampling. Library for oversampling was included named Oversample.h [11]. The internal reference was set

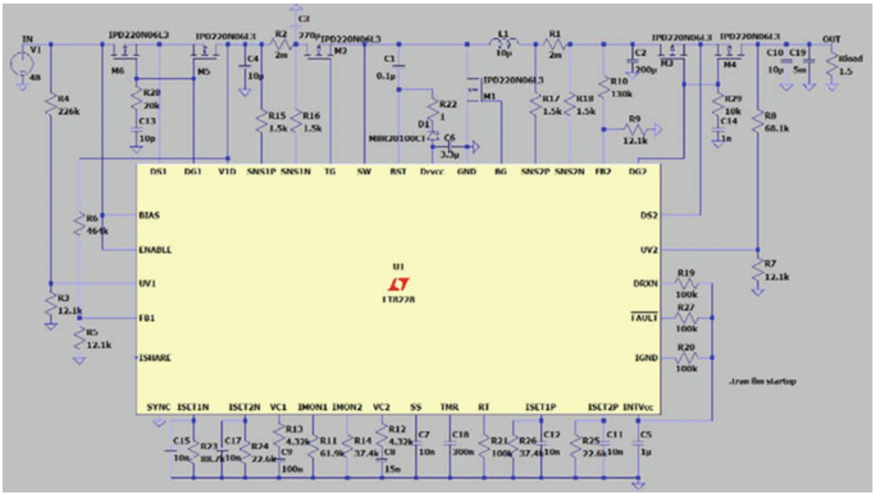

Fig. 4 Circuit diagram of DC2351A

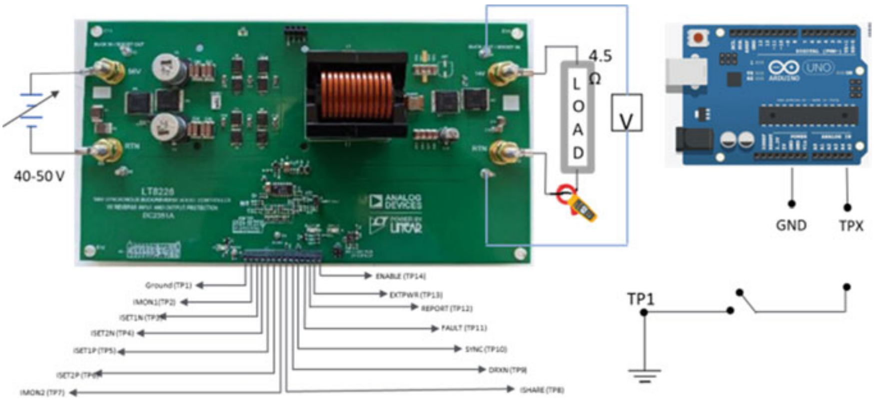

Fig. 5 Hardware setup (proposed work)

for analog reference voltage, and the measured voltage was automatically recorded in an Excel sheet. Part of the Arduino IDE code is shown in Fig. 6.

Following formula has been used to convert the analog reading from Arduino to the actual voltage across pins, which is used when oversampler is set to 16-bit.

$$\text{Pin Voltage(mV)} = \frac{\text{Analog Reading}}{65{,}536} \times 1.1 \times 1000$$

Following formula is used to estimate the actual current flowing through the circuit from the voltage measured from IMON1 and IMON2 pins.

```
void loop()
{
  long scaled0 = sampler0->readDecimated();
  long scaled1 = sampler1->readDecimated();
  long scaled2 = sampler2->readDecimated();
  long scaled3 = sampler3->readDecimated();
  long scaled4 = sampler4->readDecimated();
  long scaled5 = sampler5->readDecimated();
 IMON1 = (((scaled0/65536.00000)*1.1)*1000);
 ISET1N = (((scaled1/65536.00000)*1.1)*1000);
 ISET2N = (((scaled2/65536.00000)*1.1)*1000);
 ISET1P = (((scaled3/65536.00000)*1.1)*1000);
 ISET2P = (((scaled4/65536.00000)*1.1)*1000);
 IMON2 = (((scaled5/65536.00000)*1.1)*1000);
```

Fig. 6 Arduino code on Arduino IDE

$$\text{Computed Current(mA)} = \frac{\text{Pin Voltage}}{40{,}200} \times 750{,}000$$

The milli-volt is measured across the monitoring pins using Arduino ADC using the above method. This voltage is converted to the current flowing through the resistance of monitoring pins. The current then can be scaled to the actual current flowing through the circuit using the scaling factor as per the datasheet of DC2351A.

The current is estimated from the above formula. As the output voltage is already set by choosing the appropriate resistance in the feedback pin while designing the converter, the total power transferred can be calculated using the estimated current and known output voltage.

This calculated power can be transferred to the database and can be used for the billing of power consumed by the user.

5 Experimental Result

The graph for comparing the output current measured using an oscilloscope and using monitoring pins was plotted while keeping the input voltage to DC2351A board constant and varying the load resistance. The current plot for buck mode is shown in Fig. 7, and for boost, mode is shown in Fig. 8.

Similarly, in Figs. 9 and 10, the input current versus input voltage is plotted while keeping the load resistance of DC2351A as constant.

It is evident from the above figures that the computed current converging to the actual current in both buck mode and boost mode. Thus, the difference

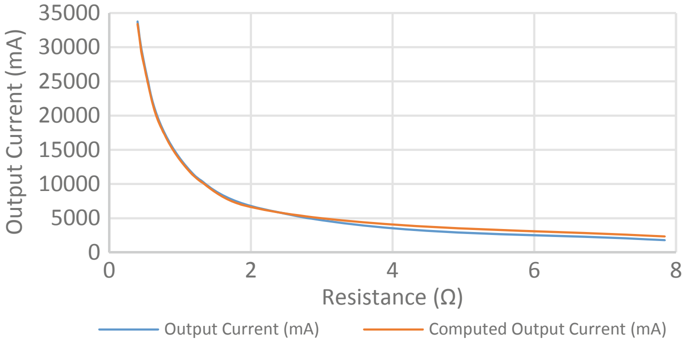

Fig. 7 Comparison between computed and actual current versus load resistance in buck mode

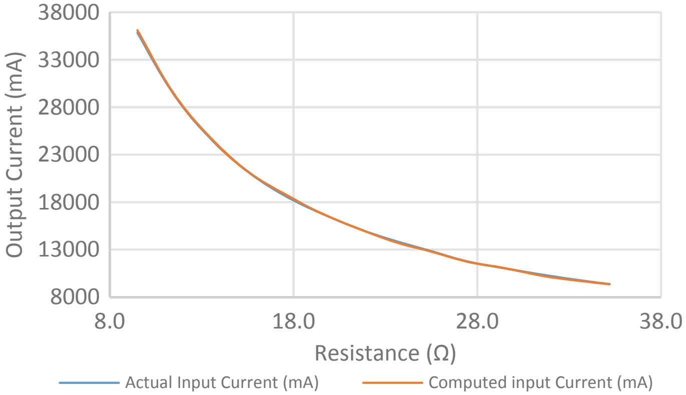

Fig. 8 Comparison between computed and actual current versus load resistance in boost mode

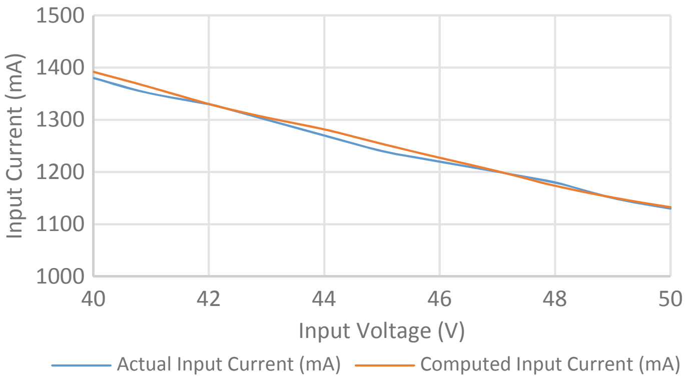

Fig. 9 Comparison between computed and actual current versus input voltage in buck mode

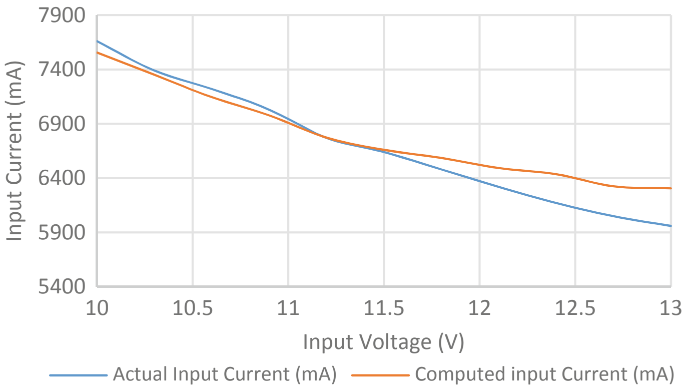

Fig. 10 Comparison between computed and actual current versus input voltage in boost mode

between computed current using Arduino ADC readings and current measured using oscilloscope, i.e., actual current is very less.

6 Conclusion

Measurement of power is a necessary factor when transferring the power. For measuring high current, additional equipment is required conventionally. By using monitoring pins of LT8228, the output current can easily be calculated with good accuracy and very low cost. Arduino Uno was able to calculate the output current, and it has been observed that by increasing the resolution of ADC by oversampling the readings, the overall calculated current is almost equal to the actual current flowing in the circuit measured using the oscilloscope's current probe. By oversampling the ADC pin of Arduino, the power transferred using a DC–DC converter can be easily calculated using signal monitoring on monitoring pins of DC2351A without using expensive current sensors separately.

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