Application Note

Simplify Your Current Sensing Design in Negative Output Power Supply Designs

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ABSTRACT

In medical systems or industry systems, designer often need to monitor system current in case fault, monitor system power status or current for control system. There are many current sensing amplifier available in the market but most of them are designed for sensing current in a positive output power supply applications and cannot directly be used for negative output power supply designs. This application note introduces four methods to use TI designs to sense current for a negative output power supply.

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1 Current Sensing

In medical system or industry system, designers often need to monitor system current in case fault, monitor system power status, or current control. There are many current sensing designs available in the market but most of the sensing designs are designed for sensing current in a positive output power supply application and cannot directly be used for negative output power supply designs. This application note introduces four options to use TI designs to sense current for a negative output power supply.

2 Key Challenges of Current Sensing for Negative Power Supply

Measure current of negative power supply is not straightforward like measure current for positive power supply since the common input voltage for most current sensing amplifier in market is large than -22V. for -24V or -48V negative power supply applications in industry, there is almost no current sensing amplifier can meet -24V or -48V common input voltage specification in market. By floating the ground pin of current sensing amplifier, designer can make the input common voltage in range of current sensing amplifier, but output voltage potential is a negative voltage and out of range for most ADC. Then, it is not convenient for the designer to do post processing.

3 Proposed Current Sensing Designs for Negative Power Supply

TI has four designs that can easily to measure current for a negative power supply. Every design has benefits. Designers can select one design for specific specification and applications such as cost, performance, safety, and package.

3.1 Hall Current Sensor

Hall current sensor is a excellent choice design for negative current sensing. Designer can directly series the hall current sensor with negative power supply since hall current sensor in general is a galvanically isolated and capable of monitor DC or AC current. TI design and produce more than ten high performance hall current sensors to meet most industry applications. TMCS1108 is a galvanically isolated Hall-effect current sensor capable of DC or AC current measurement with high accuracy, excellent linearity, temperature stability, low cost and small package. the 0 approximately 20A input current range with 80kHz bandwidth with four sensitivity options (50mV/A, 100mV/A, 200mV/A, and 400mV/A) can meet lots of applications. the typical circuit shown in Figure 3-1. The circuit is quite simple and straightforward.

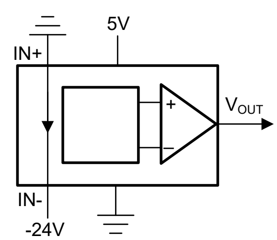

Figure 3-1. Current Sensing for Negative Power Supply Based Hall Current Sensor

The function between input current and output voltage as formula 1 shows. Here, Vo is output voltage of hall current sensor, I_L is load current, and G is gain of hall current sensor.

$$V_o = G \times I_L \quad (1)$$

One drawback for hall current sensor is that there is error of input offset current. This can potentially introduce some errors in some conditions especially the input current less than 100mA.

3.2 Current Sensing Based Isolated Amplifier

The second design to measure a current for negative power supply is to use an isolated amplifier. Figure 3-2 shows a typical circuit. TI had released lots of isolated amplifier to meet market requirements to sense voltage or current. AMC1202 is an isolated amplifier for current sensing with ±50mV input range and 1000V working isolated voltage. The isolation barrier separates parts of the system that operate on different common-mode voltage levels and protects the low-voltage side from hazardous voltages and damage. With this character, the designer can measure the sensing resistor on the high common voltage rails.

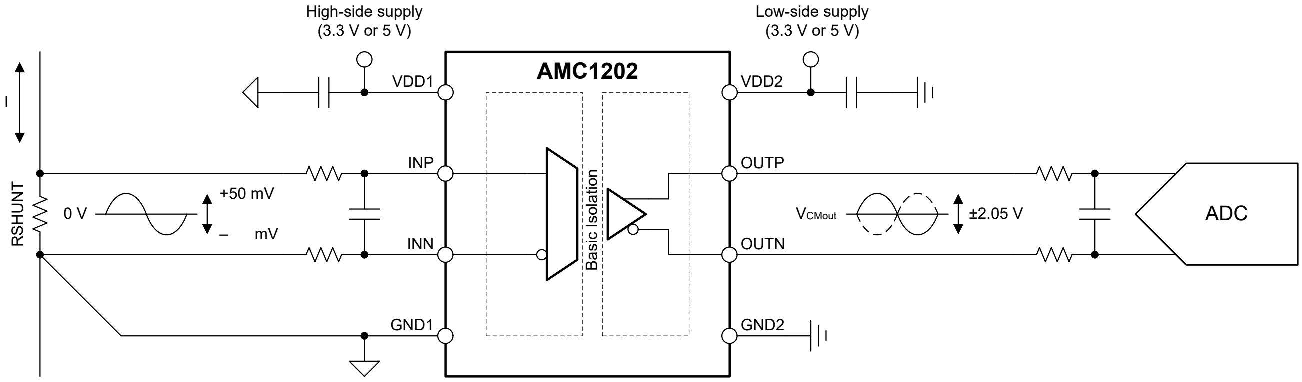

Figure 3-2. Current Sensing for Negative Power Supply Based Isolated Amplifier

The gain of AMC1202 is 41. Assume the sense resistor is Rs, output voltage of AMC1202 is Vo. Then, the current of negative power supply is:

$$I_L = \frac{V_O}{41 \times R_S} \quad (2)$$

An isolated power supply is necessary for power high side circuit of AMC1202. TI has several isolated power supply with compact size that can meet this application. Among these modules, UCC12040 is one of the parts with good performance, small size, and low cost.

3.3 Current Sensing Based Isolated ADC

The third design is based isolated ADC, reference Figure 3-3. TI had released several isolated ADC to meet market requirements for measure high voltage or current with high common voltage safely. AMC131M01 is one of the parts as an excellent choice to meet current sensing for negative power supply. The benefits of AMC131M01 is that it integrated an isolated power supply and then simple the design, cost down and reducing total PCB area. Customers do not need to ever add another isolated power supply. The AMC131M01 also features an integrated programmable gain amplifier (PGA) that provides gains of 1, 2, 4, 8, 16, 32, 64, and 128. The internal reference voltage is 1.2V. Assume ADC result is D, gain of PGA is G, sensing resistor is R. Then the load current I is:

$$I_L = \frac{D \times 1.2}{16666216 \times G \times R_{Shunt}} \quad (3)$$

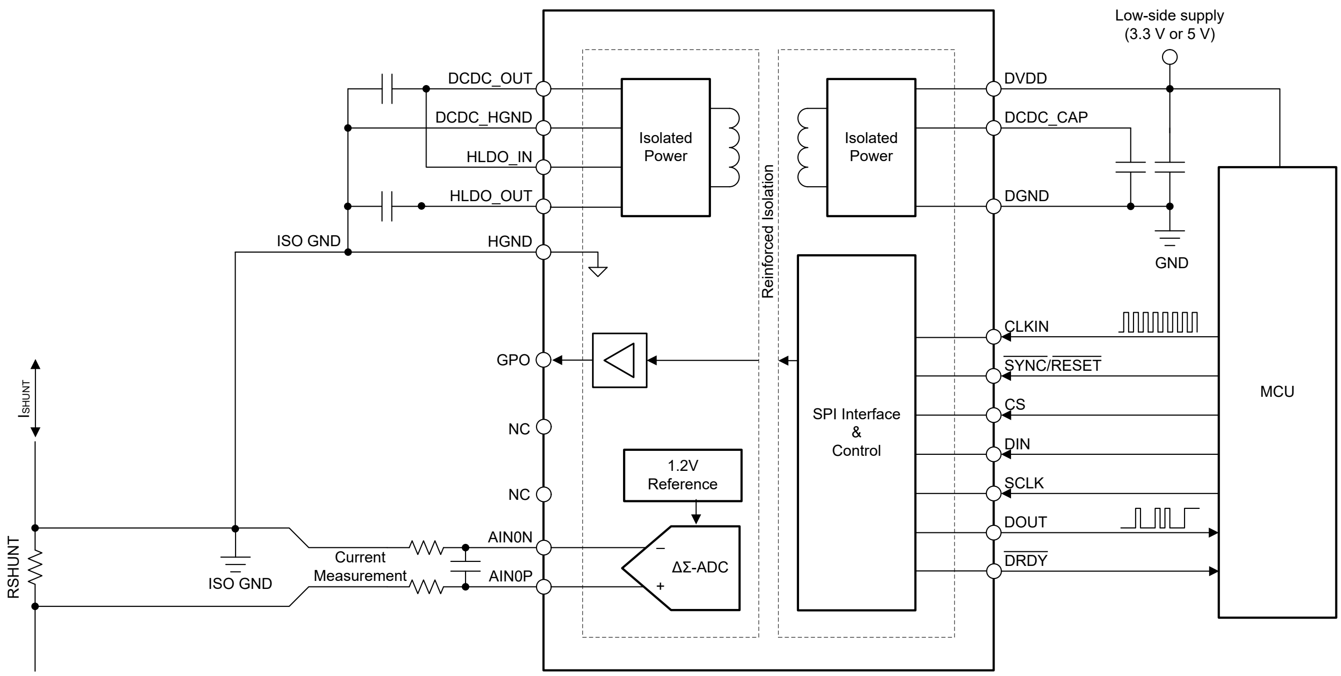

Figure 3-3. Current Sensing for Negative Power Supply Based Isolated ADC

3.4 Current Sensing Based Difference Amplifier

For sensing current of a negative power supply, the designer potential firstly considers a current sensing amplifier since these parts was widely used for current sensing with designed for performance, compact package, low cost and sourcing easy. However, there almost has no current sensing amplifier that can endure common input voltage less than -22V in market for current sensing amplifier.

the difference amplifier INA145 or INA146 was proposed in here for sensing load current for a negative power supply. INA145 and INA146 is comprised by two stage amplifiers. The first stage is a difference amplifier and was used to remove common input voltage but amplify the difference voltage. The second stage is a non-inverter amplifier to amplify the difference voltage again since the difference voltage is quite small. refer figure 4 for details. the common input voltage range for INA145 and INA146 is ±30V and ±100V respectively. This can meet most application for sensing load current for a negative power supply.

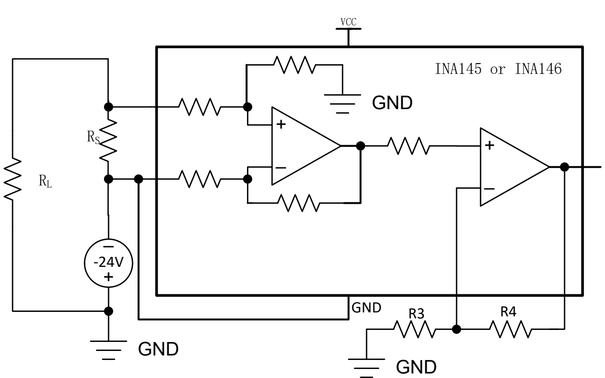

Figure 3-4. Current Sensing for Negative Power Supply Based Difference Amplifiers

The recommendation is to not have the designer use a precise amplifier and resistor to build a difference amplifier since the common-mode rejection is related with accuracy of external resistor. This is pretty hard for designer to receive best common-mode rejection by external resistor even 0.1% resistor was used. For INA145 and INA146, best common-mode rejection was received by on-chip precision resistors which are laser-trimmed to achieve accurate gain and high common-mode rejection. Note: To design proper operation of INA145 or INA146, the voltage at the non-inverting input of internal amplifier must be within the linear operating range.

The voltage is determined by the simple 1:1(INA145) or 10:1(INA146) voltage divider between pin 3 and pin 1. This voltage must be between V– and (V+) – 1V. Figure 3-4 shows the negative power supply of INA145 was connected to -24V.

Assume sensing resistor is R**s**, load current is **Is**, feedback resistor is R**4**, input resistor is R**3** and output voltage is V**o**, Then the output voltage for monitor current as formula 4 shows.

$$V_O = I_S \times R_S \times \left(1 + \frac{R_4}{R_3}\right) \quad (4)$$

4 Summary

This application note introduced four methods to monitor load current for a negative power supply. Every method has benefits. In an actual application, the designer can select any method for a specific application under constraint of performance, safety, PCB area, cost, and so on. Table 4-1 shows the different design features for designer reference and the designer can then select the best design for a specific application.

Table 4-1. Comparison Table Between Four Current Sensing Methods

Item	Hall Sensor	Isolated amplifier	Isolated ADC	INA145/6
Precision	Good	Better	Best	Better
Common voltage range	70 to approximately 400V	800V to approximately 2000V	500V to approximately 1500V	±30V or ±100V
Design difficulty	Easy	Middle	Middle	Easy
Package	Middle	Large	Largest	Smallest
Cost	Low	High Cost	Highest Cost	Lowest

5 References

1. Texas Instruments, *AMC1202 Precision, ±50-mV Input, Basic Isolated Amplifier*, data sheet.
2. Texas Instruments, *UCC12040 High-Density, Low-EMI, 3-kVRMS Basic Isolation DC/DC Module*, data sheet.
3. Texas Instruments, *AMC131M01 1-Channel, 64-kSPS, Simultaneous-Sampling, 24-Bit, Reinforced Isolated Delta-Sigma ADC With Integrated DC/DC Converter*, data sheet.
4. Texas Instruments, *AMC131M01 1-Channel, 64-kSPS, Simultaneous-Sampling, 24-Bit, Reinforced Isolated Delta-Sigma ADC With Integrated DC/DC Converter*, data sheet.
5. Texas Instruments, *INA146 High-voltage, Programmable Gain Difference Amplifier*, data sheet.
6. Texas Instruments, *INA145 Programmable Gain Difference Amplifier*, data sheet.

6 Revision History

Changes from Revision * (May 2024) to Revision A (October 2024)	Page
• Updated the numbering format for tables, figures, and cross-references throughout the document	1
• Added additional references	5