Application Brief

Precision High-Voltage Current Sensing Using Zener-Shifted Floating Ground and Isolated Digital Interface

Introduction

This application brief describes a compact, radiation tolerant design for accurate current measurement in high-voltage power systems where direct measurement is not possible due to limitations of available devices. By using a shifted *ground* for the sensing part of the design, low-voltage tolerant devices can be used to measure the current through a shunt resistor where the common-mode voltage is 200 to 400V.

Application

High-voltage DC buses (80–400V) are increasingly adopted in space applications to minimize conduction losses, enabling lighter cables and connectors for mass-constrained systems. However, radiation tolerant current sense ICs are limited to less than 100V inputs, complicating integration in electric propulsion thrusters, lunar surface power generation, high-voltage battery banks, and solar panel arrays.

Key Benefits

Higher voltage enables thinner cables, cutting system weight by up to 30%.

Radiation tolerant; 30krad, 43MeV·cm2/mg

High voltage isolation: up to 3000V (ISOS141-SEP), scalable with part selection.

Ease of integration: Digital SPI output to MCU/FPGA; no analog signals crossing voltage barrier.

Circuit Description and Block Diagram

The design utilizes a Zener-shifted floating ground technique that allows a low-voltage current sense amplifier and an ADC to operate safely, far beyond standard IC ratings. For this application, a 4.7V zener diode was chosen. The characteristics of this part ensure that the Zener voltage does not exceed the maximum input voltage of the ADC. To create a *regulated* voltage, the Zener diode must be reverse biased with enough current to maintain the breakdown voltage. This current plus the current supplied to the amplifier and ADC passes through the bias resistor. Select a value of R bias based on the supplied voltage, Zener diode current, and the supply current needed.

$$R\,bias = \frac{V_{in} - V_z}{I\,z + I\,amp + ADC} \quad (1)$$

A shunt resistor is used to generate the voltage input for the current sense amplifier. This voltage is amplified by a gain of 20V/V and connected directly to the ADC. The input range of the ADC is limited to the supply voltage set by the zener diode. This means that the usable voltage range on the sense resistor is 0V to: 4.7V

$$V_z \,/\, 20\,V/V \quad (2)$$

$$4.7V \,/\, 20 = 235mV \quad (3)$$

Adding a digital isolator to the ADC output allows the SPI data from the ADC to be utilized by a processor or FPGA operating at a normal voltage with a 0V ground reference.

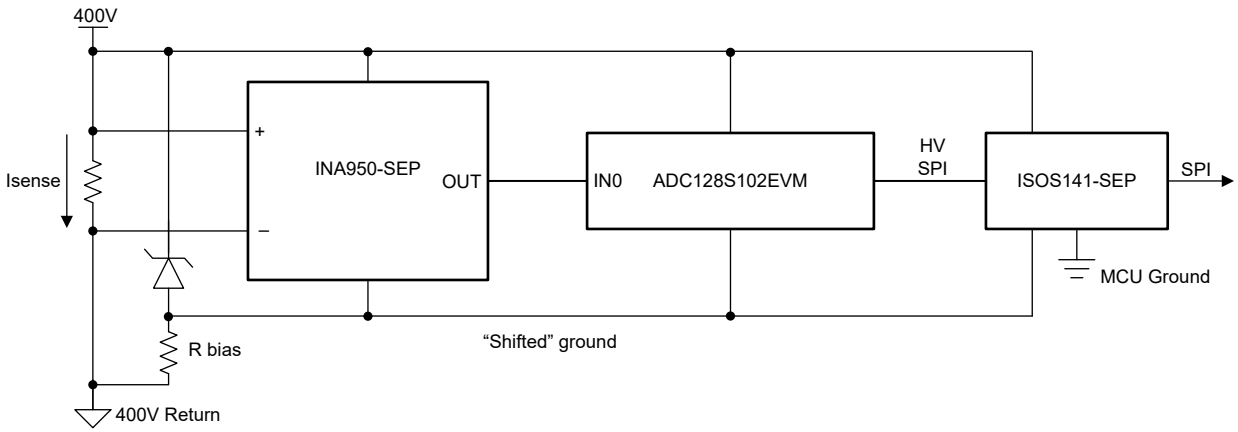

Figure 1. Simplified Block Diagram

Testing

Circuit was tested by connecting INA950-SEP, ADC128S102-SEP, ISOS141-SEP EVMs according to the block diagram in Figure 1. The voltage across the sense resistor adjusted in increments from 0 to 220mV. The corresponding sampled voltage was recorded from the ADC GUI. Test data was collected using the ADC128S102 EVM GUI and the ADC-PHI_PRU_EVM board.

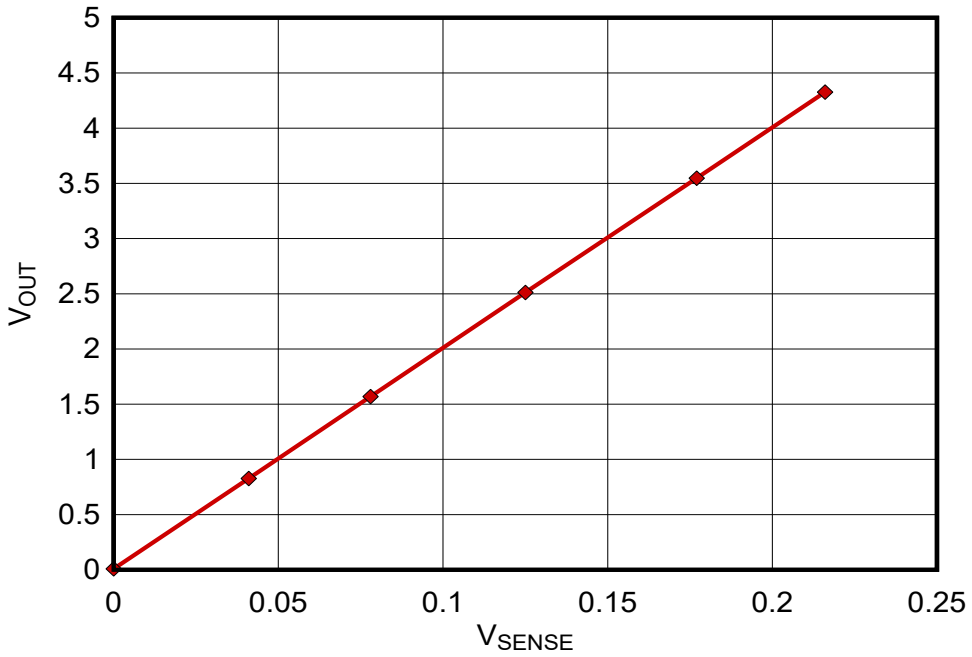

Figure 2. Test Data

Target Applications

Space propulsion (Hall/Ion thrusters): 300–1000V; precise thrust vectoring through current control.

Lunar power grids: 400–1000V DC distribution; fault detection in harsh environments.

High-voltage battery banks: 400–800V packs; state-of-health monitoring.

Solar array strings: 600–1500V; per-string current for maximum power point tracking.

Additional Resources

Space-enhanced-product, 2.7V to 80V, 1.1MHz, ultra-precise, current-sense amplifier

Radiation-tolerant, eight-channel, 50-kSPS to 1-MSPS, 12-bit analog-to-digital converter (ADC)

Radiation tolerant quad-channel, 3/1 digital isolator in space enhanced plastic

Digital Isolator Design Guide

Adapter card to connect precision ADC evaluation modules to TMDS64GPEVM or TMDS243GPEVM PRU

Radiation Handbook for Electronics

Space Products Selection Guide

TI E2E Forums

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