36V Programmable Gain, Voltage Output, Bi-Directional Zerø-Drift Series CURRENT SHUNT MONITOR

Check for Samples: INA225

FEATURES

- Wide Common-Mode Range: 0V to 36V
- Offset Voltage: ±125µV (Max)
- Accuracy
  - ±0.5% Gain Error (Max over temperature)
  - 0.5µV/°C Offset Drift (Max)
  - 10ppm/°C Gain Drift (Max)
- Programmable Gains:
  - G1=25V/V
  - G2=50V/V
  - G3=100V/V
  - G4=200V/V
- Quiescent Current: 350µA (max)
- Package: MSOP-8

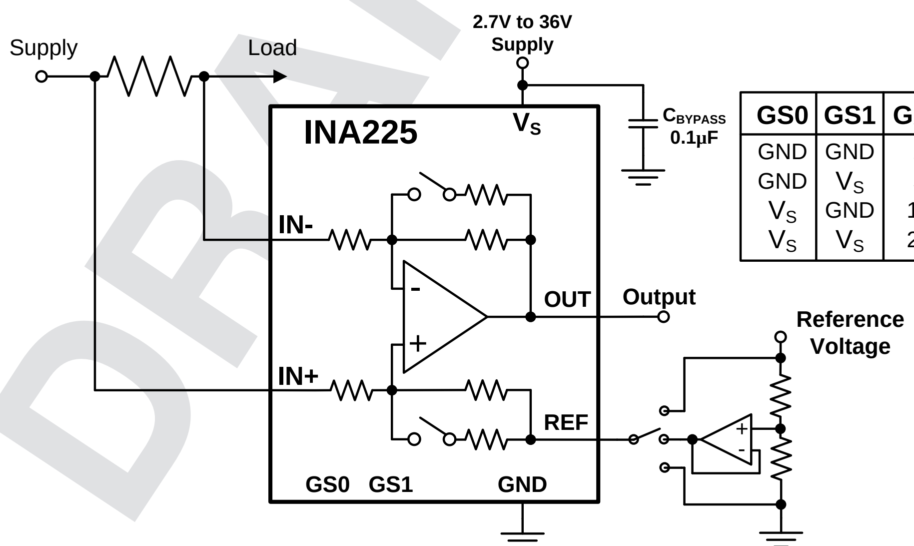
APPLICATIONS

- Computers
- Power Supplies
- Telecom Equipment
- Power Management
- Test & Measurement

DESCRIPTION

The INA225 is a voltage output current shunt monitor that can sense drops across shunts at common-mode voltages from 0V to 36V, independent of the supply voltage. The four gain versions are selectable using external gain select pins to choose between gains of 25, 50, 100 and 200. The low offset of the Zerø-Drift architecture enables current sensing with maximum drops across the shunt as low as 10mV full-scale while maintaining high accuracy measurements.

The INA225 operates from a single +2.7V to +36V power supply, drawing a maximum of 350µA of supply current. It is specified over the extended operating temperature range (–40°C to +125°C), and offered in an MSOP-8 package.



GS0	GS1	GAIN
GND	GND	25
GND	V_S	50
V_S	GND	100
V_S	V_S	200

Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PACKAGE/ORDERING INFORMATION(1)

PRODUCT	PACKAGE	PACKAGE DESIGNATOR	PACKAGE MARKING
INA225	MSOP-8	DGK	TBD

(1) For the most current package and ordering information, see the Package Option Addendum located at the end of this data sheet, or refer to our web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

Over operating free-air temperature range, unless otherwise noted.

		INA225	UNIT
Supply Voltage		+40	V
Analog Inputs, V_{IN+}, V_{IN-} (2)	Differential (V_{IN+})–(V_{IN-})	–40 to +40	V
	Common-Mode (3)	GND –0.3 to +40	V
REF Input		GN D–0.3 to (V_S) + 0.3	V
Output(3)		GND –0.3 to (V_S) + 0.3	V
Input Current into Any Pin(3)		5	mA
Operating Temperature		–55 to +150	°C
Storage Temperature		–65 to +150	°C
Junction Temperature		+150	°C
ESD Ratings:	Human Body Model (HBM)	TBD	V
	Charged-Device Model (CDM)	TBD	V

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(2) V_{IN+} and V_{IN-} are the voltages at the IN+ and IN– pins, respectively.
(3) Input Voltage at any pin may exceed the voltage shown if the current at that pin is limited to 5mA.

THERMAL INFORMATION

THERMAL METRIC(1)		INA225	UNITS
		TBD	
		TBD	
θ_{JA}	Junction-to-ambient thermal resistance	TBD	°C/W
θ_{JCtop}	Junction-to-case (top) thermal resistance	TBD	
θ_{JB}	Junction-to-board thermal resistance	TBD	
ψ_{JT}	Junction-to-top characterization parameter	TBD	
ψ_{JB}	Junction-to-board characterization parameter	TBD	
θ_{JCbot}	Junction-to-case (bottom) thermal resistance	TBD	

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range, **T_A = –40°C to +125°C.**
At T_A = +25°C, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_S = +5V, V_{IN+} = 12V, and V_{REF} = V_S/2, unless otherwise noted.

PARAMETER		CONDITIONS	INA225 MIN	INA225 TYP	INA225 MAX	UNIT
INPUT						
Common-Mode Input Range	**V_{CM}**		**0**		**36**	**V**
Common-Mode Rejection	**CMR**	**V_{IN+} = 0V to +36V, V_{SENSE} = 0mV**	**100**	**120**		**dB**
Offset Voltage, RTI[1]	V_{OS}	V_{SENSE} = 0mV			±125	μV
vs Temperature	**dV_{OS}/dT**			**0.1**	**0.5**	**μV/°C**
vs Power Supply	PSRR	V_{SENSE} = 0mV		±0.1	±10	μV/V
Input Bias Current	I_B	V_{SENSE} = 0mV	42	53	68	μA
Input Offset Current	I_{OS}	V_{SENSE} = 0mV		±0.02		μA
Reference Input Range	**V_{REF}**		**0**		**V_S**	**V**
OUTPUT						
Gain	G			25, 50, 100, 200		V/V
Gain Error		**V_{OUT} = 0.5V to V_S - 0.5V**		**±0.1**	**±0.5**	**%**
vs Temperature				**3**	**10**	**ppm/°C**
Nonlinearity Error		V_{SENSE} = –5mV to 5mV		±0.01		%
Maximum Capacitive Load		No sustained oscillation		1		nF
VOLTAGE OUTPUT[2]		**R_L = 10kΩ to GND**				
Swing to V_S Power-Supply Rail				**V_S – 0.05**	**V_S – 0.2**	**V**
Swing to GND				**V_{GND} + 0.001**	**V_{GND} + 0.01**	**V**
FREQUENCY RESPONSE						
Bandwidth						
Gain=25V/V	BW	C_{LOAD} = 10pF		150		kHz
Gain=50V/V	BW	C_{LOAD} = 10pF		150		kHz
Gain=100V/V	BW	C_{LOAD} = 10pF		100		kHz
Gain=200V/V	BW	C_{LOAD} = 10pF		60		kHz
Slew Rate	SR			0.4		V/μs
NOISE, RTI[1]						
Voltage Noise Density				50		nV/√Hz
DIGITAL INPUT						
Input Capacitance				3		pF
Leakage Input Current		0 ≤ V_{IN} ≤ V_S		0.1	1	μA
Input Logic Levels						
V_{IL}			0		0.6	V
V_{IH}			2		V_S	V
POWER SUPPLY						
Operating Voltage Range	**V_S**		**+2.7**		**+36**	**V**
Quiescent Current	I_Q	V_{SENSE} = 0mV		300	350	μA
Over Temperature					**375**	**μA**
TEMPERATURE RANGE						
Specified Range			–40		+125	°C
Operating Range			–55		+150	°C

(1) RTI = referred-to-input.
(2) See Typical Characteristic curve, *Output Voltage Swing vs Output Current* (Figure 10).

PIN CONFIGURATIONS

DGK PACKAGE
MSOP-8
(TOP VIEW)

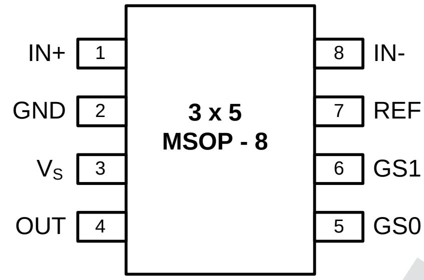


Table 1. PIN DESCRIPTIONS

PIN NO.	NAME	DESCRIPTION
2	GND	Ground
5	GS0	Gain select
6	GS1	Gain select
8	IN-	Connect to load side of shunt resistor.
1	IN+	Connect to supply side of shunt resistor.
4	OUT	Output voltage
7	REF	Reference voltage
3	V_S	Power Supply, 2.7V to 36V.

TYPICAL CHARACTERISTICS

At T_A = +25°C, V_S = +5V, V_{IN+} = 12V, and V_{REF} = V_S/2, unless otherwise noted.

INPUT OFFSET VOLTAGE PRODUCTION DISTRIBUTION

FPO

Figure 1.

OFFSET VOLTAGE vs TEMPERATURE

FPO

Figure 2.

COMMON-MODE REJECTION PRODUCTION DISTRIBUTION

FPO

Figure 3.

COMMON-MODE REJECTION RATIO vs TEMPERATURE

FPO

Figure 4.

GAIN ERROR PRODUCTION DISTRIBUTION

FPO

Figure 5.

GAIN ERROR vs TEMPERATURE

FPO

Figure 6.

TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, V_S = +5V, V_{IN+} = 12V, and V_{REF} = V_S/2, unless otherwise noted.

GAIN vs FREQUENCY

Figure 7.

POWER-SUPPLY REJECTION RATIO vs FREQUENCY

Figure 8.

COMMON-MODE REJECTION RATIO vs FREQUENCY

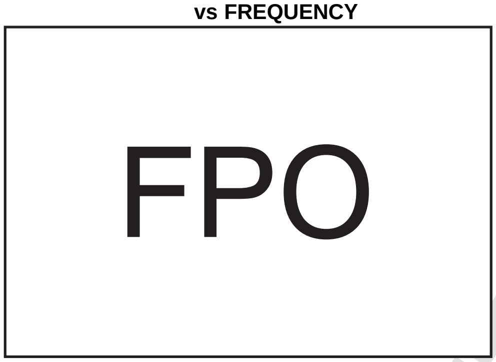


Figure 9.

OUTPUT VOLTAGE SWING vs OUTPUT CURRENT

Figure 10.

INPUT BIAS CURRENT vs COMMON-MODE VOLTAGE with SUPPLY VOLTAGE = +5V

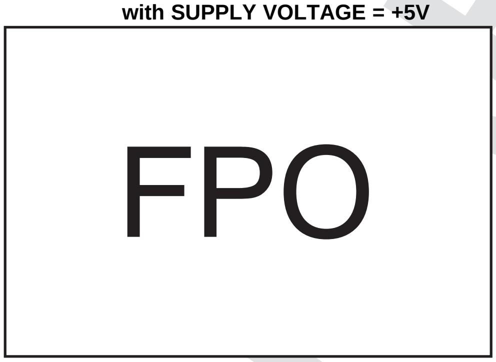


Figure 11.

INPUT BIAS CURRENT vs COMMON-MODE VOLTAGE with SUPPLY VOLTAGE = 0V (Shutdown)

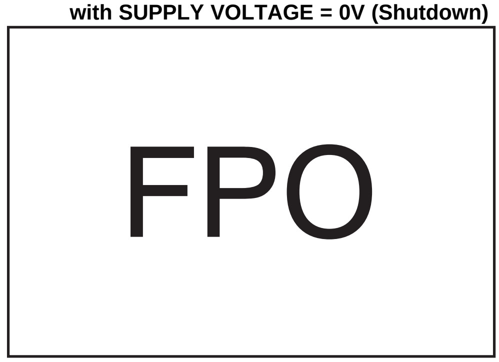


Figure 12.

TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, V_S = +5V, V_{IN+} = 12V, and V_{REF} = V_S/2, unless otherwise noted.

INPUT BIAS CURRENT vs TEMPERATURE

Figure 13.

QUIESCENT CURRENT vs TEMPERATURE

Figure 14.

INPUT-REFERRED VOLTAGE NOISE vs FREQUENCY

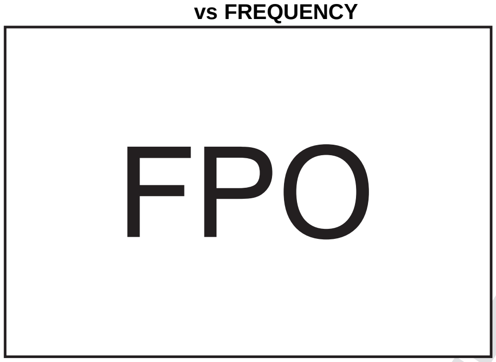


Figure 15.

0.1Hz to 10Hz VOLTAGE NOISE (Referred-to-Input)

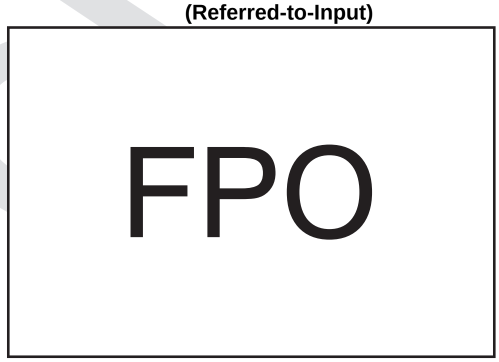


Figure 16.

STEP RESPONSE ($10mV_{PP}$ Input Step)

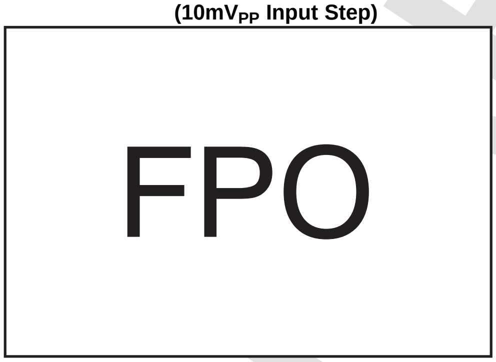


Figure 17.

COMMON-MODE VOLTAGE TRANSIENT RESPONSE

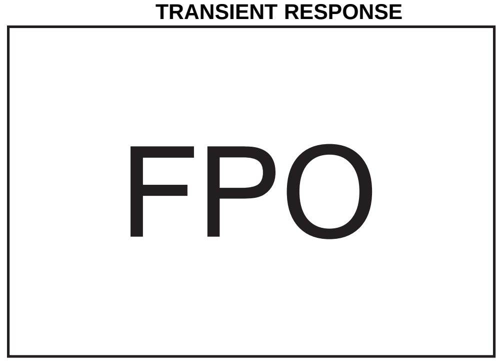


Figure 18.

PRODUCT PREVIEW

TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, V_S = +5V, V_{IN+} = 12V, and V_{REF} = V_S/2, unless otherwise noted.

INVERTING DIFFERENTIAL INPUT OVERLOAD

Figure 19.

NONINVERTING DIFFERENTIAL INPUT OVERLOAD

Figure 20.

START-UP RESPONSE

Figure 21.

BROWNOUT RECOVERY

Figure 22.

APPLICATION INFORMATION

BASIC CONNECTIONS

Figure 23 shows the basic connections of the INA225. The input pins, IN+ and IN–, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance.

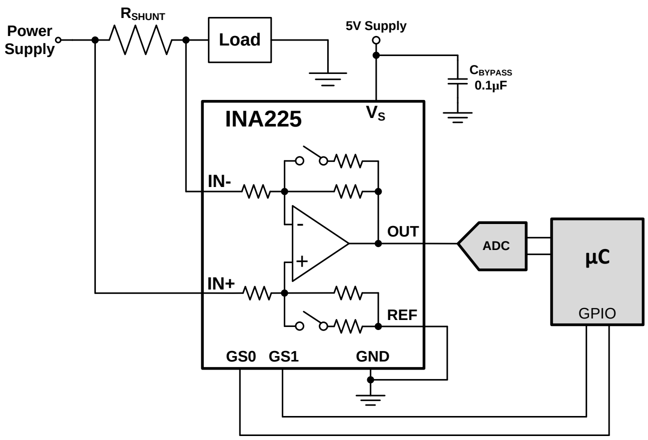


Figure 23. Typical Application

Power-supply bypass capacitors are required for stability. Applications with noisy or high impedance power supplies may require additional decoupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device pins.

On the RSW package, two pins are provided for each input. These pins should be tied together (that is, tie IN+ to IN+ and tie IN– to IN–).

POWER SUPPLY

The input circuitry of the INA225 can accurately measure beyond its power-supply voltage, V_S. For example, the V_S power supply can be 5V, whereas the load power supply voltage can be as high as +36V. However, the output voltage range of the OUT terminal is limited by the voltages on the power-supply pin. Note also that the INA225 can withstand the full –0.3V to +36V in the input pins, regardless of whether the device has power applied or not.

SELECTING R_S

The zero-drift offset performance of the INA225 offers several benefits. Most often, the primary advantage of the low offset characteristic enables lower full-scale drops across the shunt. For example, non-zero-drift current shunt monitors typically require a full-scale range of 100mV. The INA225 series gives equivalent accuracy at a full-scale range on the order of 10mV allowing for the reduction of the shunt power dissipation by an order of magnitude without sacrificing the measurement accuracy.

UNIDIRECTIONAL OPERATION

Unidirectional operation allows the INA225 to measure currents through a resistive shunt in one direction. The most frequent case of unidirectional operation sets the output at ground with no input signal by connecting the REF pin to ground. In unidirectional applications where the highest possible accuracy is desirable at very low inputs, bias the REF pin to a convenient value above 50mV. This brings the output into the linear range of the device and avoids the swing limitations in the output stage allowing for detection of inputs at or very near zero.

A less frequent case of unipolar output biasing is to bias the output by connecting the REF pin to the supply; in this case, the quiescent output for zero input is at quiescent supply. This configuration would only respond to negative currents (inverted voltage polarity at the device input).

BIDIRECTIONAL OPERATION

Bidirectional operation allows the INA225 to measure currents through a resistive shunt in two directions. In this case, the output can be set anywhere within the limits of what the reference inputs allow (that is, between 0V to V_S). Typically, it is set at half-scale for equal range in both directions. In some cases, however, it is set at a voltage other than half-scale when the bidirectional current is nonsymmetrical.

The quiescent output voltage is set by applying voltage to the reference input. Under zero differential input conditions the output assumes the same voltage as is applied to the reference input.

INPUT FILTERING

An obvious and straightforward location for filtering is at the output of the INA225; however, this location negates the advantage of the low output impedance of the internal buffer. The input then represents the best location for implimenting external filtering. Care must be taken in the selection of the filter component values as these components can affect the device's measurement accuracy. The input resistors should be kept as low a value as possible with a recommended maximum value of 10Ω. Increasing the value of the input filter resistance beyond 10mΩ will result in a smaller voltage signal present at the INA225 input pins than what was developed across the current sense shunt resistor.Figure 24 shows a filter placed at the input pins.

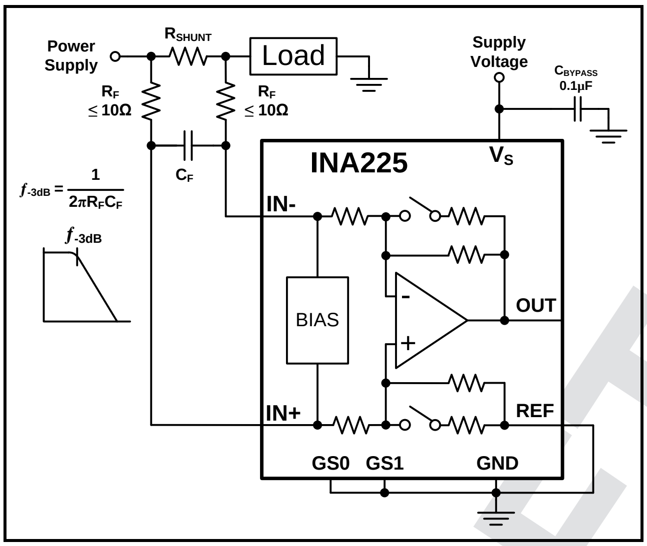


Figure 24. Input Filter

Using the lowest possible resistor values minimizes both the initial shift in gain and effects of tolerance. The effect on initial gain is given by :

Where R_{FILTER} is the value for external filter resistor.

SHUTTING DOWN THE INA225 SERIES

While the INA225 series does not have a shutdown pin, its low power consumption allows powering from the output of a logic gate or transistor switch that can turn on and turn off the INA225 power-supply quiescent current.

However, in current shunt monitoring applications. there is also a concern for how much current is drained from the shunt circuit in shutdown conditions. Evaluating this current drain involves considering the simplified schematic of the INA225 in shutdown mode shown in Figure 25.

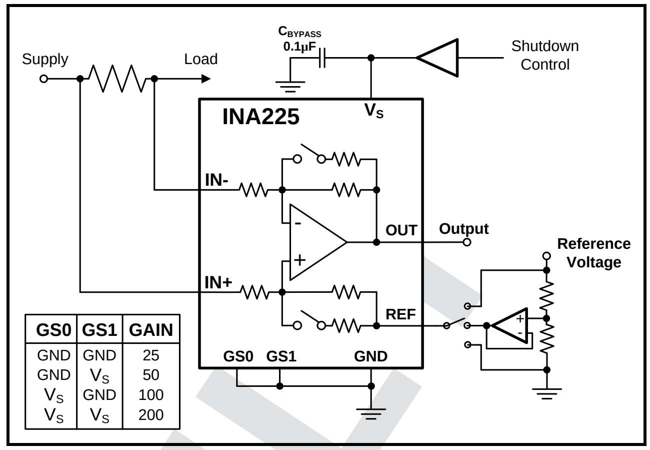


Figure 25. Basic Circuit for Shutting Down INA225 with Grounded Reference

Note that there is typically slightly more than **1MΩ** impedance (from the combination of 1MΩ feedback and 5kΩ input resistors) from each input of the INA225 to the OUT pin and to the REF pin. The amount of current flowing through these pins depends on the respective ultimate connection. For example, if the REF pin is grounded, the calculation of the effect of the 1MΩ impedance from the shunt to ground is straightforward. However, if the reference or op amp is powered while the INA225 is shut down, the calculation is direct; instead of assuming 1MΩ to ground, however, assume 1MΩ to the reference voltage. If the reference or op amp is also shut down, some knowledge of the reference or op amp output impedance under shutdown conditions is required. For instance, if the reference source behaves as an open circuit when it is unpowered, little or no current flows through the 1MΩ path.

Regarding the 1MΩ path to the output pin, the output stage of a disabled INA225 does constitute a good path to ground; consequently, this current is directly proportional to a shunt common-mode voltage impressed across a 1MΩ resistor.

As a final note, when the device is powered up, there is an additional, nearly constant, and well-matched 50μA that flows in each of the inputs as long as the shunt common-mode voltage is 3V or higher. Below 2V common-mode, the only current effects are the result of the 1MΩ resistors.

REF INPUT IMPEDANCE EFFECTS

As with any difference amplifier, the INA225 series common-mode rejection ratio is affected by any impedance present at the REF input. This concern is not a problem when the REF pin is connected directly to most references or power supplies. When using resistive dividers from the power supply or a reference voltage, the REF pin should be buffered by an op amp.

In systems where the INA225 output can be sensed differentially, such as by a differential input analog-to-digital converter (ADC) or by using two separate ADC inputs, the effects of external impedance on the REF input can be cancelled. Figure 26 depicts a method of taking the output from the INA225 by using the REF pin as a reference.

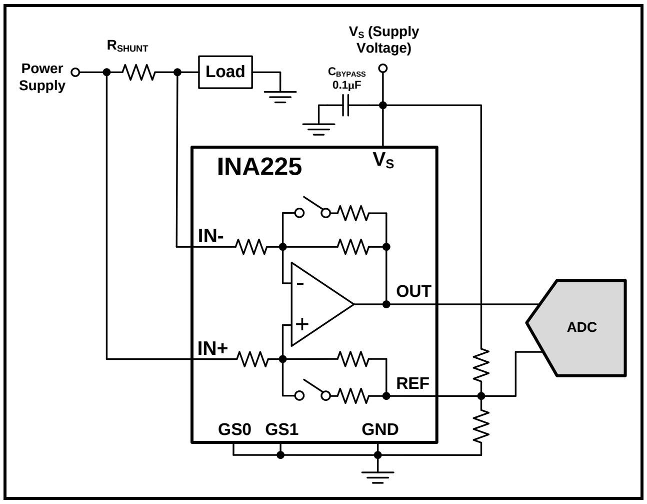


Figure 26. Sensing INA225 to Cancel Effects of Impedance on the REF Input

USING THE INA210 WITH COMMON-MODE TRANSIENTS ABOVE 26V

With a small amount of additional circuitry, the INA225 series can be used in circuits subject to transients higher than 26V, such as automotive applications. Use only zener diode or zener-type transient absorbers (sometimes referred to as *Transzorbs*)— any other type of transient absorber has an unacceptable time delay. Start by adding a pair of resistors as shown in Figure 27 as a working impedance for the zener. It is desirable to keep these resistors as small as possible, most often around 10Ω. Larger values can be used with an effect on gain that is discussed in the section on input filtering. Because this circuit is limiting only short-term transients, many applications are satisfied with a 10Ω resistor along with conventional zener diodes of the lowest power rating that can be found. This combination uses the least amount of board space. These diodes can be found in packages as small as SOT-523 or SOD-523.

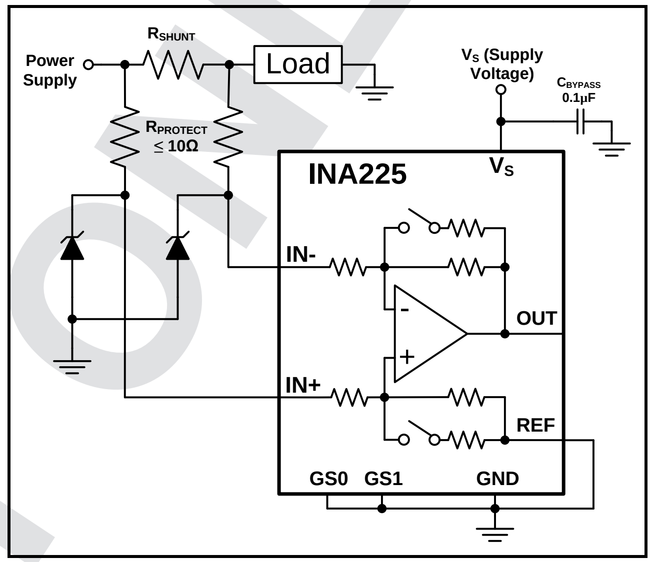


Figure 27. INA225 Transient Protection Using Dual Zener Diodes

In the event that low-power zeners do not have sufficient transient absorption capability and a higher power transzorb must be used, the most package-efficient solution then involves using a single transzorb and back-to-back diodes between the device inputs. The most space-efficient solutions are dual series-connected diodes in a single SOT-523 or SOD-523 package. This method is shown in . In either of these examples, the total board area required by the INA225 with all protective components is less than that of an SO-8 package, and only slightly greater than that of an MSOP-8 package.