

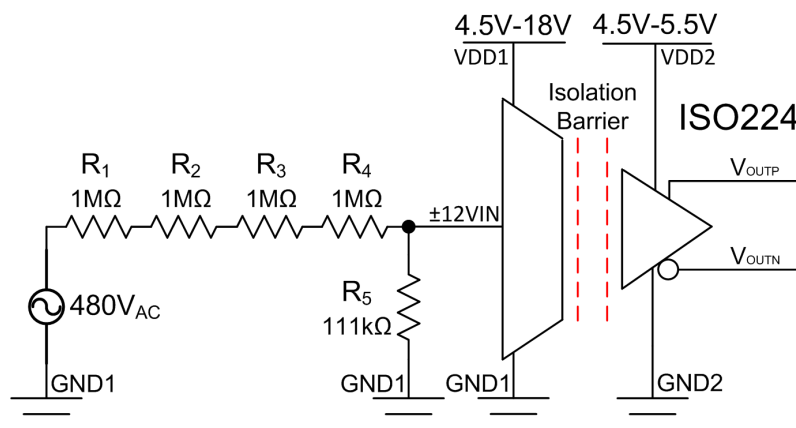
$\pm 480\text{-V}$ isolated voltage-sensing circuit with differential output

Design Goals

Voltage Source		ISO224 Input Voltage		ISO224 Output Voltage VDD2 / 2 Common-Mode ($V_{OUTP} - V_{OUTN}$)		Power Supplies	
V_{MAX}	V_{MIN}	$V_{IN, MAX}$	$V_{IN, MIN}$	$V_{OUT, MAX}$	$V_{OUT, MIN}$	VDD1	VDD2
+480V	-480V	+12V	-12V	+4V	-4V	4.5V–18V	4.5V–5.5V

Design Description

This circuit performs a $\pm 480\text{-V}$, isolated, voltage-sensing measurement utilizing the [ISO224](#) isolated amplifier and a voltage-divider circuit. The voltage-divider circuit reduces the voltage from $\pm 480\text{V}$ to $\pm 12\text{V}$ which matches the input range of the [ISO224](#). The [ISO224](#) is powered from both a high and low side power supply. Typically, the high side supply is generated using a floating supply or from the low side using an isolated transformer or isolated DC/DC converter. The [ISO224](#) can measure single-ended signals of $\pm 12\text{V}$ with a fixed gain of $\frac{1}{3}\text{V/V}$ and produces an isolated differential output voltage of $\pm 4\text{V}$ with an output common-mode voltage of $\text{VDD2} / 2$. The differential output voltage can be scaled as necessary using an additional operational amplifier such as the [TLV6001](#) as shown in [SBOA274](#) to interface with an ADC.



Design Notes

1. Verify the systems linear operation for the desired input signal range. This is verified using simulation in the **DC Transfer Characteristics** section.
2. Verify that the resistors used in the resistor divider circuit (R1–R5) are capable of dissipating the power supplied from the voltage source.
3. Verify that the voltage on the input of the ISO224 is less than $\pm 15\text{V}$ as stated in the absolute maximum ratings table of the data sheet and ensure that less than $\pm 10\text{mA}$ is applied to the input. If the system is susceptible to transients, consider adding a TVS diode to the input. See the *I-V Curve of the Input Clamp Protection Circuit* image in the [ISO224 Reinforced isolated amplifier with single-ended input of \$\pm 12\text{ V}\$ and differential output of \$\pm 4\text{ V}\$ data sheet](#) for additional details.

Design Steps

1. Calculate the ratio from the voltage source to the input of the ISO224 for the voltage-divider circuit.

$$\frac{12V_{\text{ISO224,INPUT}}}{480V} = 0.025$$

2. The typical input impedance of the ISO224 is 1.25MΩ. This impedance is in parallel with resistor R5 and must be considered when designing the voltage-divider circuit. Choose 1-MΩ resistors for R1, R2, R3, and R4. Using the ratio from the previous step and the following voltage-divider equation, solve for the equivalent resistance required for the voltage-divider parallel combination (||) of R5 and the ISO224 input impedance.

$$\frac{R_5 \parallel R_{\text{IN,ISO224}}}{R_1 + R_2 + R_3 + R_4 + R_5 \parallel R_{\text{IN,ISO224}}} = 0.025$$

$$\frac{R_5 \parallel R_{\text{IN,ISO224}}}{4M\Omega + R_5 \parallel R_{\text{IN,ISO224}}} = 0.025$$

$$R_5 \parallel R_{\text{IN,ISO224}} = 102564\Omega = R_{\text{EQ}}$$

3. Substituting 1.25MΩ for the ISO224 input impedance and using the following equation, solve for R5. Use the [analog engineer's calculator](#) to determine the closest standard value for R5.

$$R_{\text{EQ}} = 102564\Omega = \frac{R_5 \cdot R_{\text{IN,ISO224}}}{R_5 + R_{\text{IN,ISO224}}} = \frac{R_5 \cdot 1.25M\Omega}{R_5 + 1.25M\Omega}$$

$$102564\Omega(R_5 + 1.25M\Omega) = R_5 \cdot 1.25M\Omega$$

$$R_5 = 111.73k\Omega; \text{ closest standard value} = 111k\Omega$$

4. Verify that the equivalent resistance is close to the calculated resistance from step 2.

$$R_{\text{EQ}} = \frac{R_5 \cdot R_{\text{IN,ISO224}}}{R_5 + R_{\text{IN,ISO224}}} = \frac{111k\Omega \cdot 1.25M\Omega}{111k\Omega + 1.25M\Omega} = 101.947k\Omega$$

5. Verify that the voltage-divider circuit is within a reasonable error tolerance. For the following calculation, the input resistance of the ISO224 is assumed to be the typical value of 1.25MΩ and this results in an error of 0.6%. However, it is important to keep in mind that the input resistance will vary from device to device due to variations in the resistance of the internal clamp protection circuit. If the same calculation is performed using the minimum input resistance of 1MΩ, the error is 2.5%. If this error range is unacceptable then either a calibration must be performed or the resistance of the voltage-divider circuit can be scaled down.

$$\frac{101.947k\Omega}{4.101947M\Omega} = 0.02485$$

$$\text{Error}\% = \frac{|\text{Actual} - \text{Calculated}|}{\text{Calculated}} \cdot 100 = \frac{|0.02485 - 0.025|}{0.025} \cdot 100 = 0.6\%$$

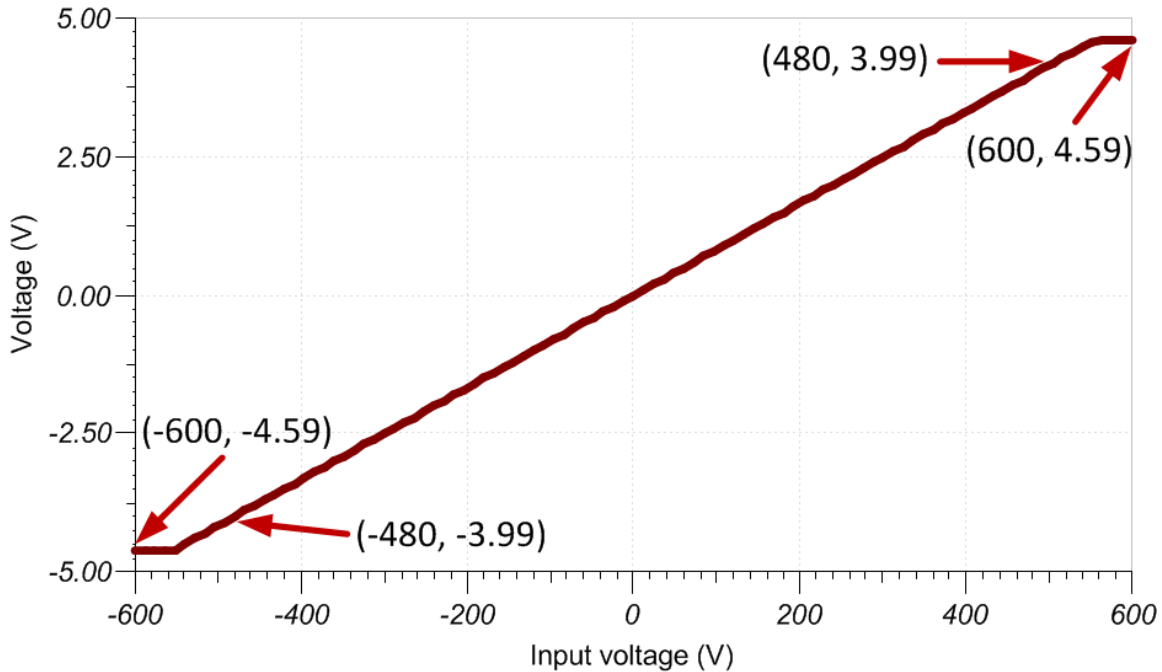
6. Calculate the current flowing through the voltage-divider circuit from the voltage source to ensure that the power dissipation does not exceed the ratings of the resistor. For additional details, please see [Considerations for High Voltage Measurements](#).

$$V = IR; \frac{V}{R} = \frac{480V}{4M\Omega + 111k\Omega} = 117\mu\text{A}$$

DC Transfer Characteristics

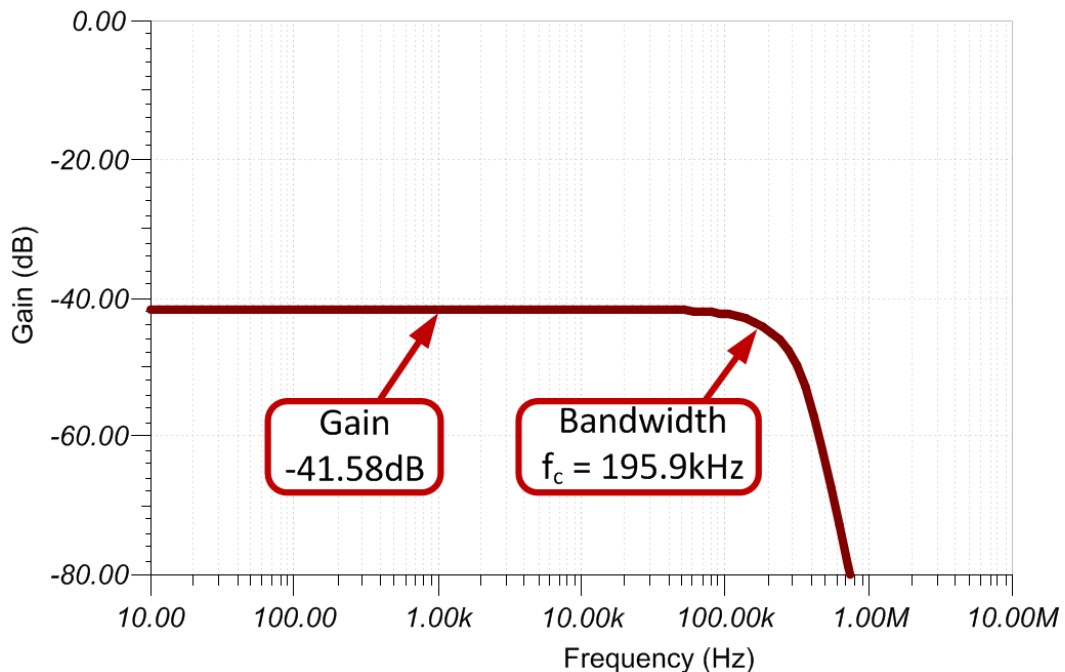
The following graph shows the simulated output for a $\pm 600\text{-V}$ input. The voltage divider scales the gain by $1/40$, and the ISO224 scales the gain by an additional $1/3$.

The transfer function shows the system gain is $1/40$ from the voltage divider and $1/3$ from the ISO224 (that is, $\text{Gain} \cdot V_{\text{IN}} = V_{\text{OUT}}$, $(1/40) \cdot (1/3) \cdot (480\text{V}) = 4\text{V}$).



AC Transfer Characteristics

The simulated gain is -41.58dB (or 0.008337V/V) which closely matches the expected gain for the voltage divider and [ISO224](#).



References

1. [Analog Engineer's Circuit Cookbooks](#)
2. SPICE Simulation File [SBAC232](#)
3. TI Precision Designs [TIDA-00835](#)
4. [TI Precision Labs](#)

Design Featured Isolated Op Amp

ISO224B	
VDD1	4.5V–18V
VDD2	4.5V–5.5V
Input Voltage range	±12V
Nominal Gain	$\frac{1}{3}$
V_{OUT}	Differential ±4V on output common-mode of VDD2 / 2
Input Resistance	1.25M Ω (typ)
Small Signal Bandwidth	275kHz
Input Offset Voltage and Drift	±5mV (max), ±15 μ V/°C (max)
Gain Error and Drift	±0.3% (max), ±35 ppm/°C (max)
Nonlinearity and Drift	0.01% (max), ±0.1 ppm/°C (typ)
Isolation Transient Overvoltage	7kV _{PEAK}
Working Voltage	1.5kV _{RMS}
Common-mode transient immunity, CMTI	55 kV/ μ s (min)
www.ti.com/product/ISO224	

Design Alternate Isolated Op Amp

AMC1311B	
VDD1	3V–5.5V
VDD2	3V–5.5V
Input Voltage range	2V
Nominal Gain	1
V_{OUT}	Differential ±2V on output common-mode of 1.44V
Input Resistance	1G Ω (typ)
Small Signal Bandwidth	220kHz
Input Offset Voltage and Drift	±1.5mV (max), ±15 μ V/°C (max)
Gain Error and Drift	±0.3% (max), ±45 ppm/°C (max)
Nonlinearity and Drift	0.01%, 1 ppm/°C (typ)
Isolation Transient Overvoltage	7kV _{PEAK}
Working Voltage	1.5kV _{RMS}
Common-mode transient immunity, CMTI	75kV/ μ s (min)
www.ti.com/product/AMC1311	

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