Application Report
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ISO224 Fail-Safe Output Feature

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ABSTRACT

The ISO224 is a reinforced isolated amplifier that allows bipolar inputs up to ±12 V using a single supply on the high-side of the device. This unique feature simplifies the design of the isolated power supply and reduces the overall system cost. Additionally, the ISO224 offers an integrated high-side supply voltage detection feature known as the Fail-Safe output feature, which simplifies system-level diagnostics. The Fail-Safe output is active when the device's high-side power supply, VDD1, is missing independent of the input signal on the V_{IN} pin. This document will describe the Fail-Safe output feature of the ISO224 in detail.

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1 Introduction to ISO224 Applications

The ISO224 operates from two power supplies, VDD1 and VDD2, which are typically 5 V as shown in Figure 1. The common-mode output is set to VDD2/2 which will be 2.5 V in this case. There are three different conditions of the device to consider when evaluating the ISO224 Fail-Safe output feature: normal operation, missing input, and the Fail-Safe output.

- Normal operation results in a $\pm V_{IN}/3$ differential output centered on a common-mode voltage of 2.5 V.
- An input of 0 V or a missing input will result in a differential output of 0 V, also centered on a common-mode voltage of 2.5 V.
- The ISO224 Fail-Safe output feature will activate when the high-side supply, VDD1, is missing and this will result in VOUTP and VOUTN being driven to GND2.

Since analog to digital converters (ADC) are typically configured to measure differentially directly from the output of the ISO224, this presents a challenge as the ADC cannot distinguish the difference between the missing input and the Fail-Safe output. The three different states are shown below in Figure 1 .

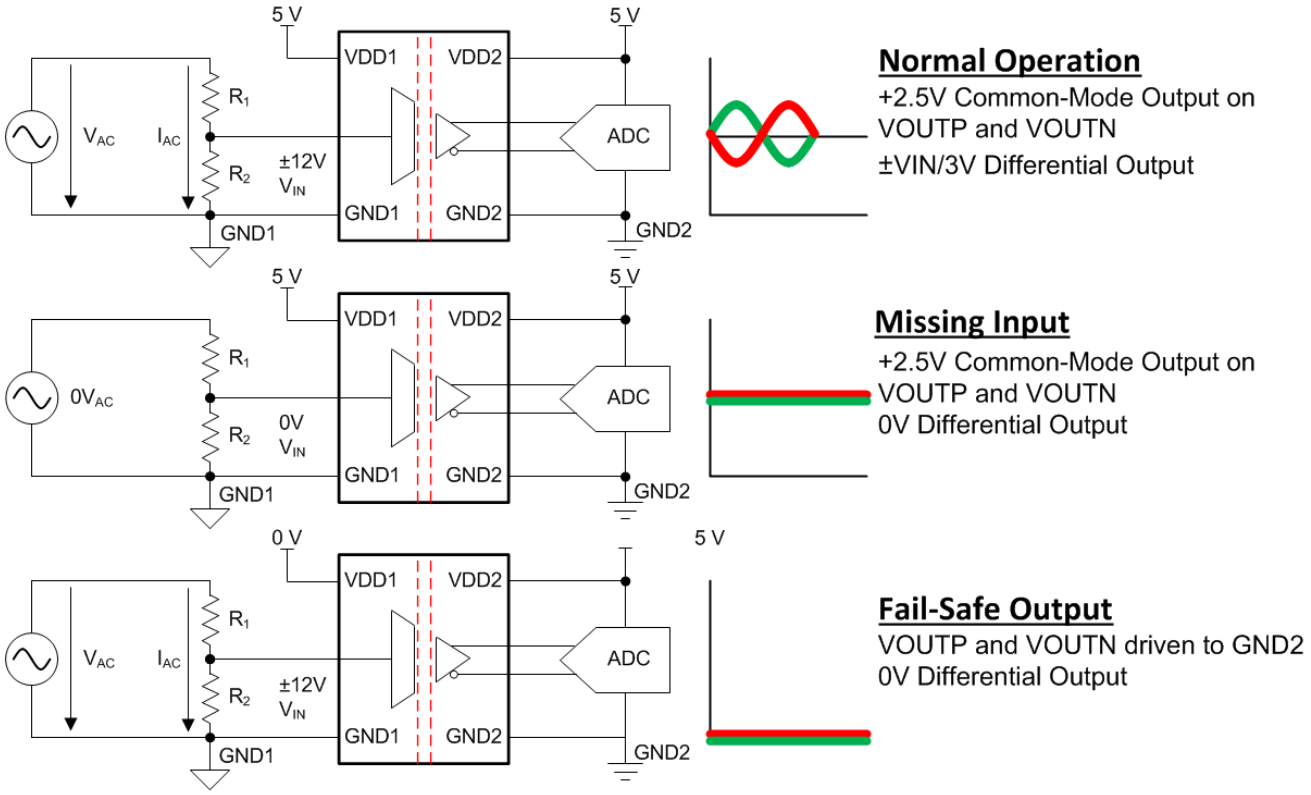

Figure 1. The Three States of the ISO224

2 Distinguishing Between a Missing Input and the Fail-Safe Output

In order for the system's controller to distinguish between a missing input and the Fail-Safe output, it is necessary to create an additional signal to act as a flag for the controller so that operation can be halted when the high-side supply is missing. The simplest and most cost effective way to do this is to add a comparator circuit which will monitor the common-mode output voltage level of the ISO224. The next section will cover an example topology of the ISO224, the TLV9001 amplifier as an analog comparator, and a generic ADC.

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3 ISO224 Fail-Safe Output Feature with a Comparator

Adding a comparator to the signal chain that monitors the common-mode output voltage magnitude will create a signal that distinguishes between a missing input and the Fail-Safe output of the ISO224. Texas Instruments TLV9001 is a rail-to-rail output amplifier that is well-suited for this application and an example topology of the ISO224, the TLV9001 amplifier used as an analog comparator, and a generic ADC is shown below in Figure 2. VDD2 is the only power source required for this topology which simplifies the design and reduces system cost.

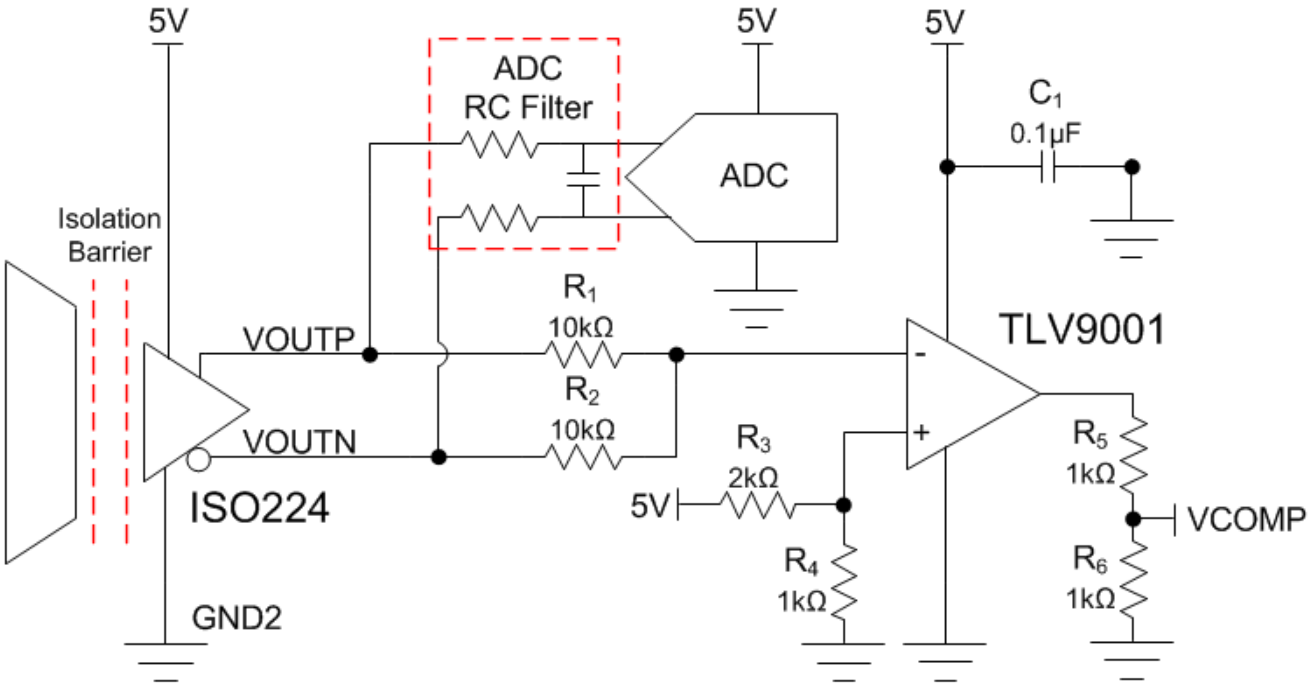

Figure 2. ISO224 with TLV9001 Comparator Topology

The comparator works by comparing the voltage on the negative input to the voltage on the positive input. When the voltage on the positive input is greater than the voltage on the negative input, the comparator output will go high, thus creating a signal flag for the controller. In this case, the common-mode output voltage of the ISO224 is derived by averaging the differential output of the ISO224 through R1 and R2 which is connected to the negative input of the comparator. In order for the comparator to work properly, a voltage must be generated on the positive pin of the comparator that is lower than the common-mode voltage of 2.5 V and greater than GND2+100 mV. The voltage on the positive pin is created through a voltage divider network formed by R3 and R4, in this case 1.66 V. Lastly, it is important to keep the acceptable input voltage range of the controller in mind. For the MSP430 and C2000 product families, this means that the signal flag must be less than 3.3 V in magnitude. The output voltage magnitude of the comparator is equal to the power supply of the comparator, 5 V in this case. This is stepped down to 2.5 V by the voltage divider circuit R5 and R6 in order to bring the output, V_{COMP}, within the 3.3 V limits set by the controller. As a result, V_{COMP} will equal either GND2 for acceptable operation or 2.5 V for Fail-Safe mode. The three states of the ISO224 and their corresponding V_{COMP} outputs are shown in Table 1 below.

Table 1. ISO224's Different Conditions of V_{COMP}

VDD1	Input	Working Mode	Common Mode Output	V_{COMP}
Active	Active	Normal	2.16 V to 2.86 V	Low Voltage
Active	0	Missing Input	2.16 V to 2.86 V	Low Voltage
Missing	Missing or 0	Fail-Safe	0 V	High Voltage

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4 ISO224 and TLV9001 Topology Equations

The following section will cover equations relevant to the circuit topology in Figure 2. Setting these voltages appropriately will ensure that the ISO224 and TLV9001 operate as intended.

The ISO224 requires VDD2 to be between 4.5-5.5 V and the common-mode output voltage range of the ISO224 can be calculated using Equation 1:

$$(0.48\sim0.52)\times VDD2=(0.48\sim0.52)\times(4.5V\sim5.5V)=2.16V\sim2.86V \quad (1)$$

To ensure that the comparator output is functioning as intended, it is necessary to set the positive input voltage $V_{IN}+$ of the TLV9001 to be less than 2.16 V but greater than GND2+100 mV. $V_{IN}+$ can be calculated using Equation 2:

$$\frac{R4}{R3+R4}\times VDD2=\frac{1}{3}\times(4.5V\sim5.5V)=1.5V\sim1.83V \quad (2)$$

This input voltage meets the input criteria set by the TLV9001, however the input of the following MCU must also be considered. In the case of Texas Instruments MSP430/C2000 family this means that the output of the comparator must be 3.3 V or less. With this in mind, R5 and R6 will be used in a resistor divider configuration to step the VDD2 input of the TLV9001 down to an acceptable voltage. This can be seen in Equation 3:

$$\frac{R6}{R5+R6}\times VDD2=\frac{1}{2}\times(4.5V\sim5.5V)=2.25V\sim2.75V \quad (3)$$

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5 ISO224 and TLV9001 Implementation Results

Figure 3 shows the positive and negative output of the ISO224, VDD1, and the TLV9001 as a comparator during normal operation and the Fail-Safe output. The blue (#1) and red (#2) traces at the top of the figure are the positive and negative output voltages VOUTx of the ISO224, respectively. The green (#3) trace is high-side supply VDD1 and the pink (#4) trace at the bottom of the figure is the comparator output V_{COMP}. Figure 3-a shows that when VDD1 is turned on, V_{COMP} transitions from high to low and the ISO224 transitions from the Fail-Safe output to normal operation. On the right in Figure 3-b, VDD1 is turned off and the ISO224 activates the Fail-Safe output. A reversal will occur on the outputs of the ISO224 before they are driven to GND2, and V_{COMP} transitions from low to high.

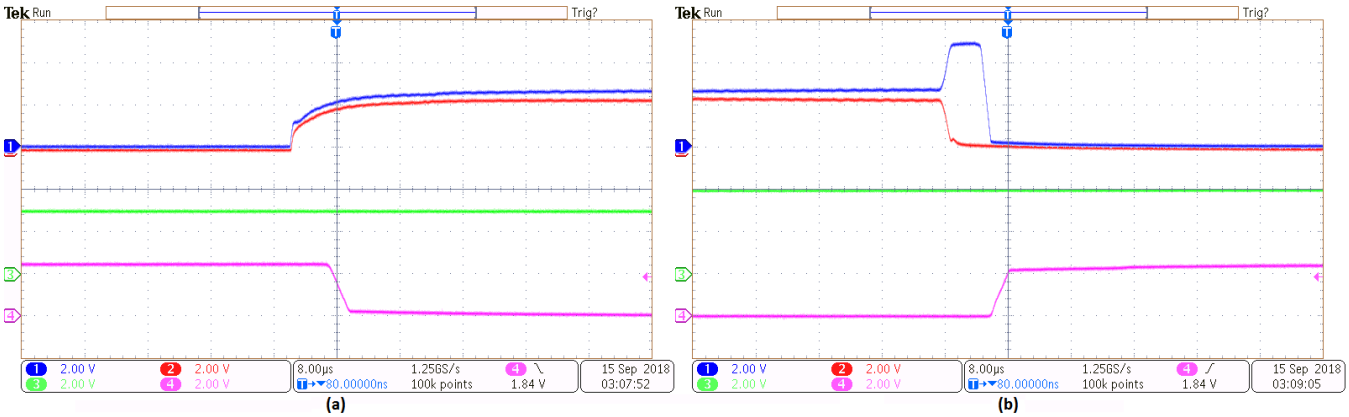

Figure 3. Implementation Results

6 Conclusion

This application note introduces three basic states for the ISO224; normal operation, missing input, and the ISO224's Fail-Safe output feature. The Fail-Safe output feature is further expanded upon with an example circuit employing the use of a comparator, corresponding equations, and experimental data.

7 Additional Resources

The following documents are available for download through TI.com.

- Texas Instruments, ISO224 Reinforced Isolated Amplifier With Single-Ended Input of ±12 V: Datasheet
- Texas Instruments, TLV900x Low Power, RRIO, 1-MHz Operational Amplifier for Cost-Sensitive Systems: Datasheet
- Texas Instruments, SBAA229 Interfacing a Differential-Output (Isolated) Amplifier to a Single-Ended Input ADC: Technote.

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