

SBOS074C – SEPTEMBER 1997 – REVISED SEPTEMBER 2005

# Precision Lowest-Cost ISOLATION AMPLIFIER

## FEATURES

- 100% TESTED FOR HIGH-VOLTAGE BREAKDOWN
- RATED 1500Vrms
- HIGH IMR: 140dB at 60Hz
- 0.010% max NONLINEARITY
- BIPOLAR OPERATION:  $V_O = \pm 10V$
- DIP-16 AND SO-28
- EASE OF USE: Fixed Unity Gain Configuration
- $\pm 4.5V$  to  $\pm 18V$  SUPPLY RANGE

## DESCRIPTION

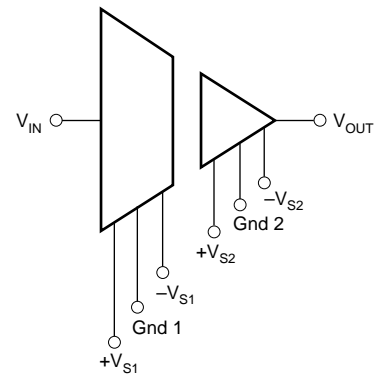
The ISO124 is a precision isolation amplifier incorporating a novel duty cycle modulation-demodulation technique. The signal is transmitted digitally across a 2pF differential capacitive barrier. With digital modulation, the barrier characteristics do not affect signal integrity, resulting in excellent reliability and good high-frequency transient immunity across the barrier. Both barrier capacitors are imbedded in the plastic body of the package.

The ISO124 is easy to use. No external components are required for operation. The key specifications are 0.010% max nonlinearity, 50kHz signal bandwidth, and  $200\mu V/^\circ C$   $V_{OS}$  drift. A power supply range of  $\pm 4.5V$  to  $\pm 18V$  and quiescent currents of  $\pm 5.0mA$  on  $V_{S1}$  and  $\pm 5.5mA$  on  $V_{S2}$  make these amplifiers ideal for a wide range of applications.

The ISO124 is available in DIP-16 and SO-28 plastic surface mount packages.

## APPLICATIONS

- INDUSTRIAL PROCESS CONTROL: Transducer Isolator, Isolator for Thermocouples, RTDs, Pressure Bridges, and Flow Meters, 4-20mA Loop Isolation
- GROUND LOOP ELIMINATION
- MOTOR AND SCR CONTROL
- POWER MONITORING
- PC-BASED DATA ACQUISITION
- TEST EQUIPMENT



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## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

Supply Voltage .....	±18V
$V_{IN}$ .....	±100V
Continuous Isolation Voltage .....	1500Vrms
Junction Temperature .....	+150°C
Storage Temperature .....	+125°C
Output Short to Common .....	Continuous

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability.



## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

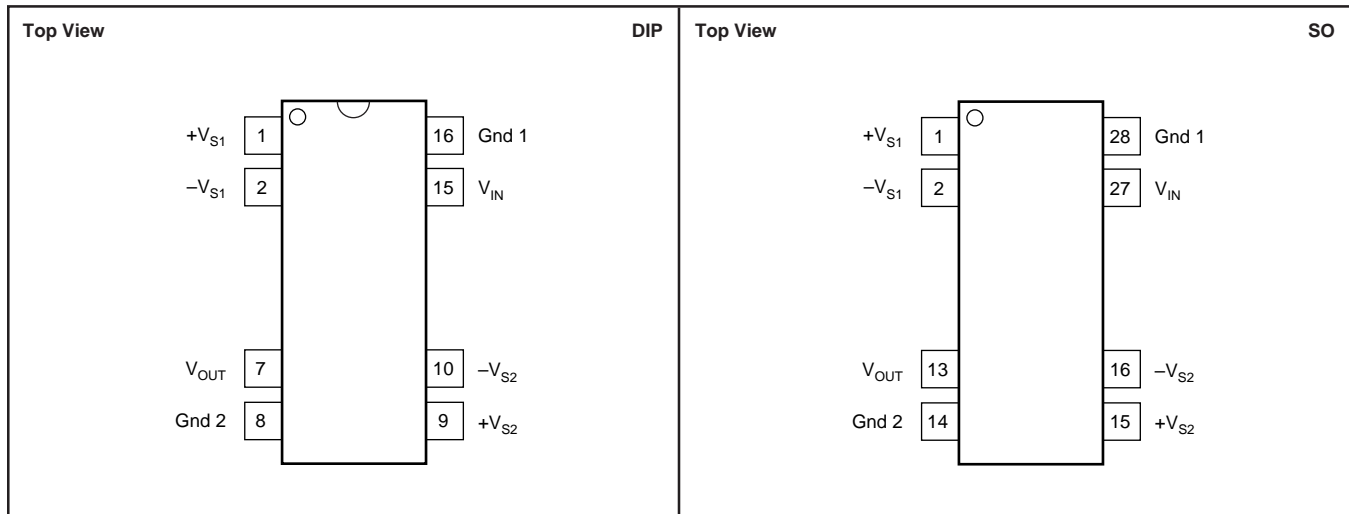
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

## PACKAGE/ORDERING INFORMATION<sup>(1)</sup>

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
ISO124P	Plastic DIP-16	NVF	-25°C to +85°C	ISO124P	ISO124P	Rails, 50
ISO124U	Plastic SO-28	DVA	-25°C to +85°C	ISO124U	ISO124U	Rails, 28
"	"	"	"	ISO124U	ISO124U/1K	Tape and Reel, 1000

NOTE: (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).

## PIN CONFIGURATIONS



# ELECTRICAL CHARACTERISTICS

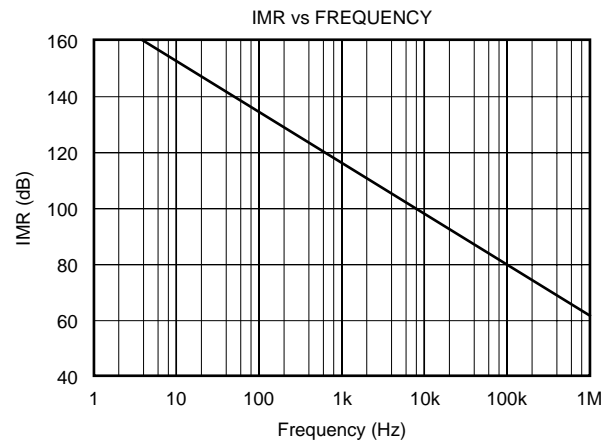
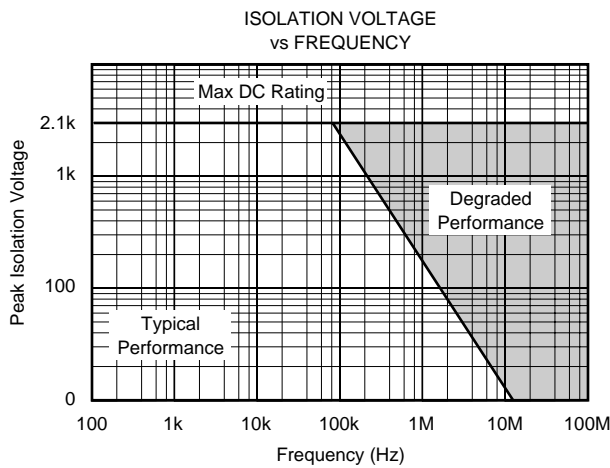
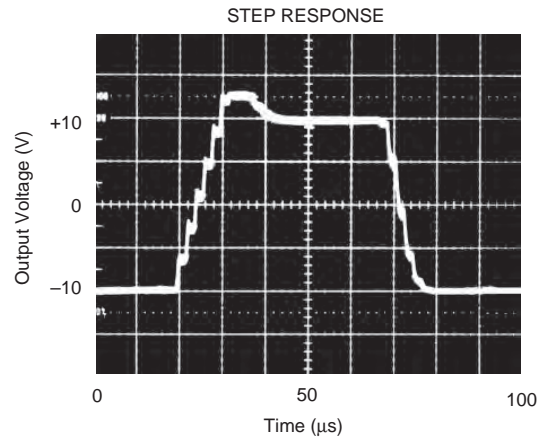
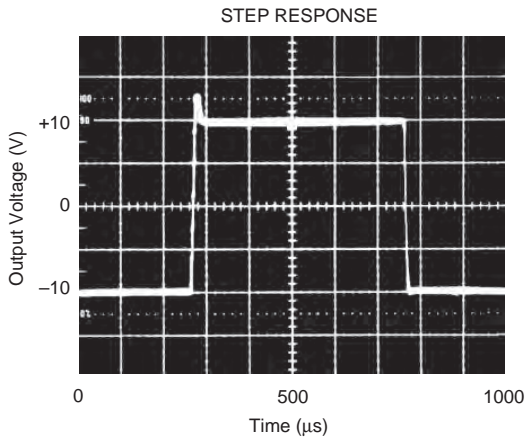
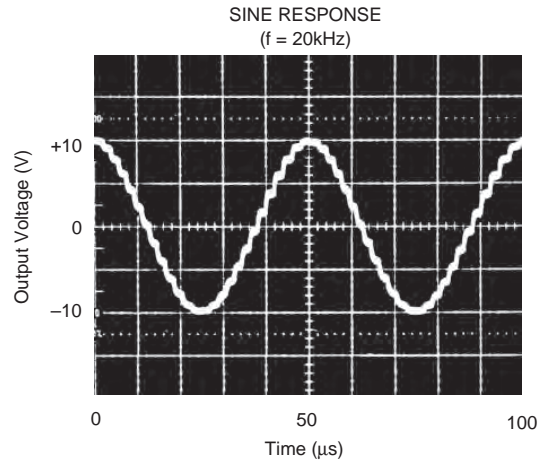
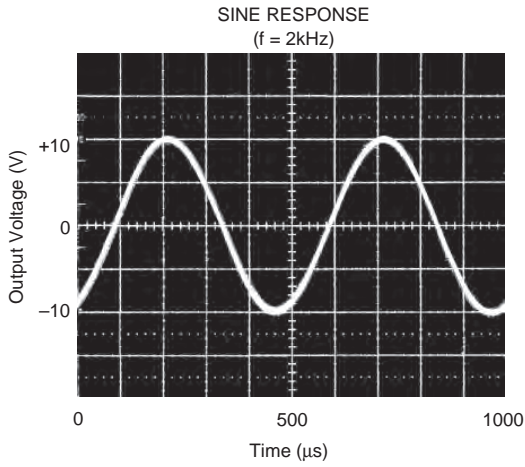
At  $T_A = +25^\circ\text{C}$ ,  $V_{S1} = V_{S2} = \pm 15\text{V}$ , and  $R_L = 2\text{k}\Omega$ , unless otherwise noted.

PARAMETER	CONDITIONS	ISO124P, U			UNITS
		MIN	TYP	MAX	
<b>ISOLATION</b> Rated Voltage, continuous ac 60Hz 100% Test <sup>(1)</sup> Isolation Mode Rejection Barrier Impedance Leakage Current at 60Hz	1s, 5pc PD 60Hz  $V_{ISO} = 240\text{Vrms}$	1500 2400	140 $10^{14} \parallel 2$ 0.18	0.5	Vac Vac dB $\Omega \parallel \text{pF}$ $\mu\text{Arms}$
<b>GAIN</b> Nominal Gain Gain Error Gain vs Temperature Nonlinearity <sup>(2)</sup>	$V_O = \pm 10\text{V}$		1 $\pm 0.05$ $\pm 10$ $\pm 0.005$	$\pm 0.50$  $\pm 0.010$	V/V %FSR ppm/ $^\circ\text{C}$ %FSR
<b>INPUT OFFSET VOLTAGE</b> Initial Offset vs Temperature vs Supply Noise			$\pm 20$ $\pm 200$ $\pm 2$ 4	$\pm 50$	mV $\mu\text{V}/^\circ\text{C}$ mV/V $\mu\text{V}/\sqrt{\text{Hz}}$
<b>INPUT</b> Voltage Range Resistance		$\pm 10$	$\pm 12.5$ 200		V k $\Omega$
<b>OUTPUT</b> Voltage Range Current Drive Capacitive Load Drive Ripple Voltage <sup>(3)</sup>		$\pm 10$ $\pm 5$	$\pm 12.5$ $\pm 15$ 0.1 20		V mA $\mu\text{F}$ mVp-p
<b>FREQUENCY RESPONSE</b> Small-Signal Bandwidth Slew Rate Settling Time 0.1% 0.01% Overload Recovery Time	$V_O = \pm 10\text{V}$		50 2  50 350 150		kHz V/ $\mu\text{s}$  $\mu\text{s}$ $\mu\text{s}$ $\mu\text{s}$
<b>POWER SUPPLIES</b> Rated Voltage Voltage Range Quiescent Current: $V_{S1}$ $V_{S2}$		$\pm 4.5$	$\pm 15$  $\pm 5.0$ $\pm 5.5$	$\pm 18$  $\pm 7.0$ $\pm 7.0$	V V mA mA
<b>TEMPERATURE RANGE</b> Specification Operating Storage Thermal Resistance, $\theta_{JA}$ $\theta_{JC}$		-25 -25 -40	100 65	+85 +85 +125	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}/\text{W}$ $^\circ\text{C}/\text{W}$

NOTES: (1) Tested at 1.6 X rated, fail on 5pC partial discharge. (2) Nonlinearity is the peak deviation of the output voltage from the best-fit straight line. It is expressed as the ratio of deviation to FSR. (3) Ripple frequency is at carrier frequency (500kHz).

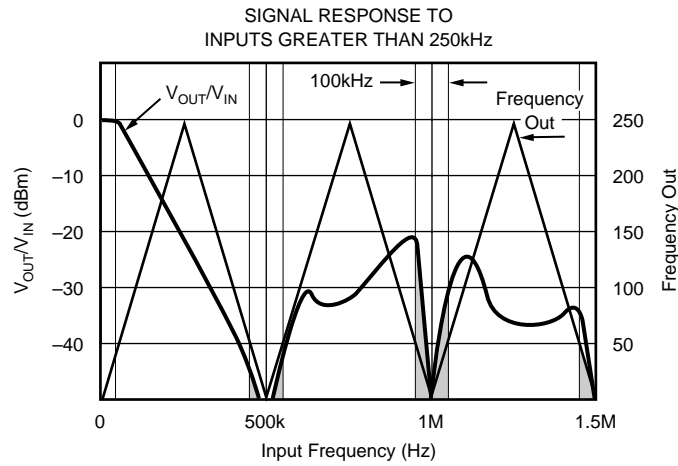
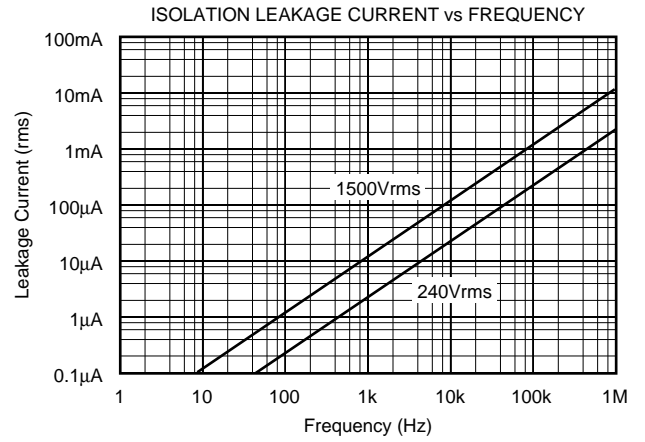
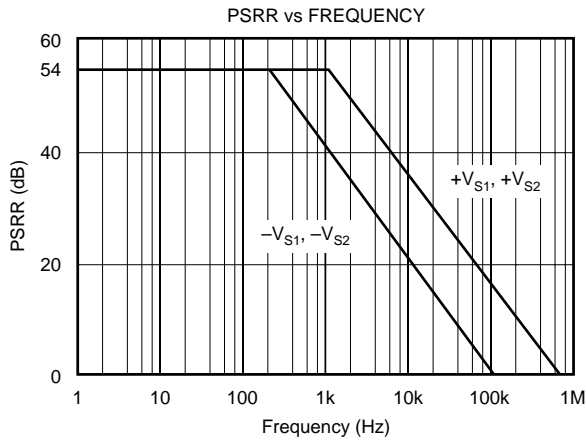
# TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ , and  $V_S = \pm 15\text{V}$ , unless otherwise noted.



# TYPICAL CHARACTERISTICS (Cont.)

At  $T_A = +25^\circ\text{C}$ , and  $V_S = \pm 15\text{V}$ , unless otherwise noted.



(NOTE: Shaded area shows aliasing frequencies that cannot be removed by a low-pass filter at the output.)

# THEORY OF OPERATION

The ISO124 isolation amplifier uses an input and an output section galvanically isolated by matched 1pF isolating capacitors built into the plastic package. The input is duty-cycle modulated and transmitted digitally across the barrier. The output section receives the modulated signal, converts it back to an analog voltage and removes the ripple component inherent in the demodulation. Input and output sections are fabricated, then laser trimmed for exceptional circuitry matching common to both input and output sections. The sections are then mounted on opposite ends of the package with the isolating capacitors mounted between the two sections. The transistor count of the ISO124 is 250 transistors.

## MODULATOR

An input amplifier (A1, as shown in Figure 1) integrates the difference between the input current ( $V_{IN}/200k\Omega$ ) and a switched  $\pm 100\mu A$  current source. This current source is implemented by a switchable  $200\mu A$  source and a fixed  $100\mu A$  current sink. To understand the basic operation of the modulator, assume that  $V_{IN} = 0.0V$ . The integrator will ramp in one direction until the comparator threshold is exceeded. The comparator and sense amp will force the current source to switch; the resultant signal is a triangular waveform with a 50% duty cycle. The internal oscillator forces the current source to switch at 500kHz. The resultant capacitor drive is a complementary duty-cycle modulation square wave.

## DEMODULATOR

The sense amplifier detects the signal transitions across the capacitive barrier and drives a switched current source into integrator A2. The output stage balances the duty-cycle

modulated current against the feedback current through the  $200k\Omega$  feedback resistor, resulting in an average value at the  $V_{OUT}$  pin equal to  $V_{IN}$ . The sample-and-hold amplifiers in the output feedback loop serve to remove undesired ripple voltages inherent in the demodulation process.

# BASIC OPERATION

## SIGNAL AND SUPPLY CONNECTIONS

Each power-supply pin should be bypassed with  $1\mu F$  tantalum capacitors located as close to the amplifier as possible. The internal frequency of the modulator/demodulator is set at 500kHz by an internal oscillator. Therefore, if it is desired to minimize any feedthrough noise (beat frequencies) from a DC/DC converter, use a  $\pi$  filter on the supplies (see Figure 4). The ISO124 output has a 500kHz ripple of 20mV, which can be removed with a simple 2-pole low-pass filter with a 100kHz cutoff using a low-cost op amp (see Figure 4).

The input to the modulator is a current (set by the  $200k\Omega$  integrator input resistor) that makes it possible to have an input voltage greater than the input supplies, as long as the output supply is at least  $\pm 15V$ . It is therefore possible, when using an unregulated DC/DC converter, to minimize PSR related output errors with  $\pm 5V$  voltage regulators on the isolated side and still get the full  $\pm 10V$  input and output swing. See Figure 9 for an example of this application.

## CARRIER FREQUENCY CONSIDERATIONS

The ISO124 amplifier transmits the signal across the isolation barrier by a 500kHz duty-cycle modulation technique. For input signals having frequencies below 250kHz, this system works like any linear amplifier. But for frequencies

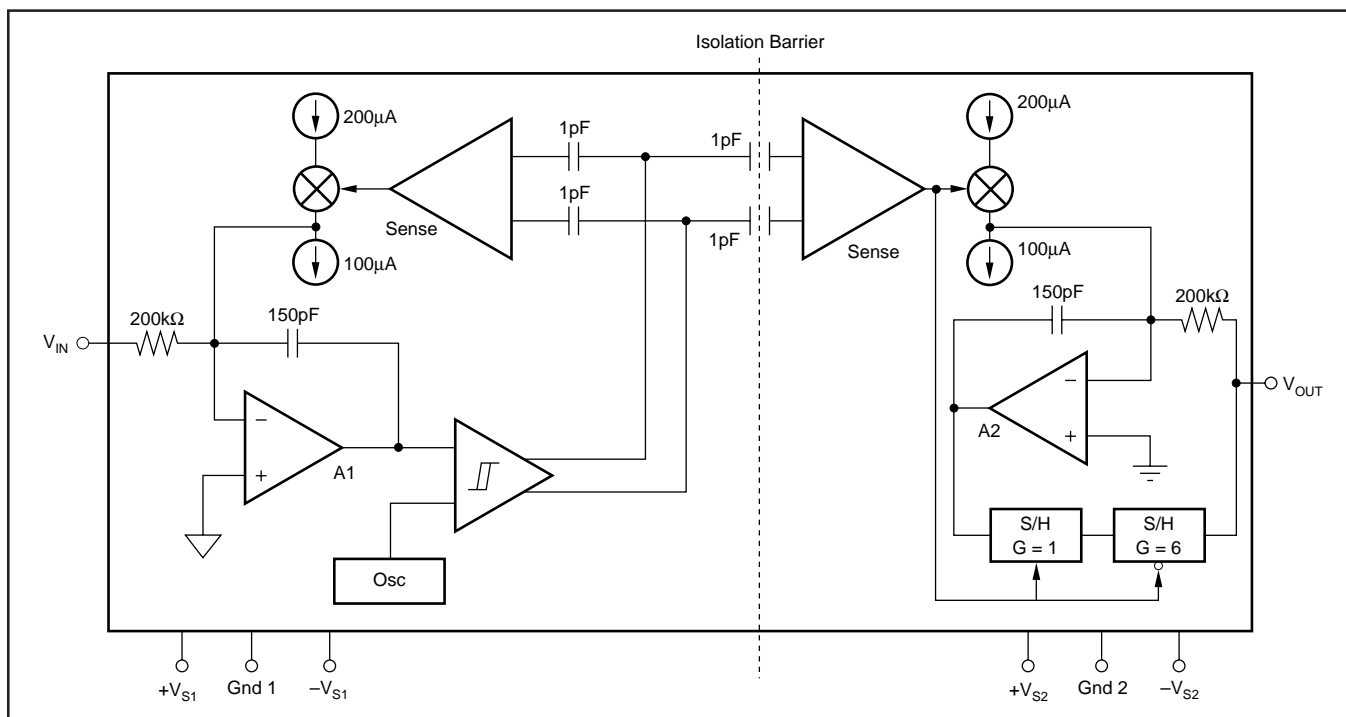


FIGURE 1. Block Diagram.

above 250kHz, the behavior is similar to that of a sampling amplifier. The typical characteristic “Signal Response to Inputs Greater Than 250kHz” shows this behavior graphically; at input frequencies above 250kHz, the device generates an output signal component of reduced magnitude at a frequency below 250kHz. This is the aliasing effect of sampling at frequencies less than 2 times the signal frequency (the Nyquist frequency). Note that at the carrier frequency and its harmonics, both the frequency and amplitude of the aliasing go to zero.

### ISOLATION MODE VOLTAGE INDUCED ERRORS

IMV can induce errors at the output as indicated by the plots of IMV vs Frequency. It should be noted that if the IMV frequency exceeds 250kHz, the output also will display spurious outputs (aliasing) in a manner similar to that for  $V_{IN} > 250\text{kHz}$  and the amplifier response will be identical to that shown in the “Signal Response to Inputs Greater Than 250kHz” typical characteristic. This occurs because IMV-induced errors behave like input-referred error signals. To predict the total error, divide the isolation voltage by the IMR shown in the “IMR versus Frequency” typical performance curve and compute the amplifier response to this input-referred error signal from the data given in the “Signal Response to Inputs Greater Than 250kHz” typical characteristic. For example, if a 800kHz 1000Vrms IMR is present, then a total of  $[(-60\text{dB}) + (-30\text{dB})] \times (1000\text{V}) = 32\text{mV}$  error signal at 200kHz plus a 1V, 800kHz error signal will be present at the output.

### HIGH IMV dV/dt ERRORS

As the IMV frequency increases and the dV/dt exceeds 1000V/μs, the sense amp may start to false trigger, and the output will display spurious errors. The common-mode current being sent across the barrier by the high slew rate is the cause of the false triggering of the sense amplifier. Lowering the power-supply voltages below ±15V may decrease the dV/dt to 500V/μs for typical performance.

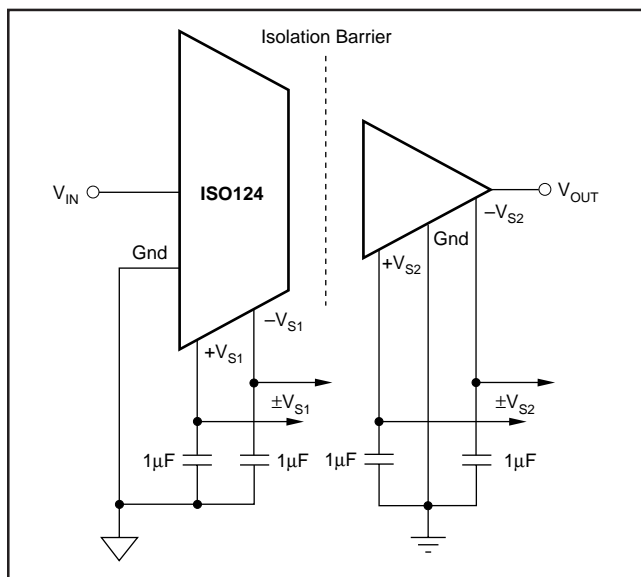


FIGURE 2. Basic Signal and Power Connections.

### HIGH VOLTAGE TESTING

Texas Instruments has adopted a partial discharge test criterion that conforms to the German VDE0884 Optocoupler Standards. This method requires the measurement of minute current pulses ( $< 5\text{pC}$ ) while applying 2400Vrms, 60Hz high-voltage stress across every ISO124 isolation barrier. No partial discharge may be initiated to pass this test. This criterion confirms transient overvoltage ( $1.6 \times 1500\text{Vrms}$ ) protection without damage to the ISO124. Lifetest results verify the absence of failure under continuous rated voltage and maximum temperature.

This new test method represents the “state-of-the art” for non-destructive high-voltage reliability testing. It is based on the effects of non-uniform fields that exist in heterogeneous dielectric material during barrier degradation. In the case of void non-uniformities, electric field stress begins to ionize the void region before bridging the entire high-voltage barrier. The transient conduction of charge during and after the ionization can be detected externally as a burst of 0.01-0.1μs current pulses that repeat on each ac voltage cycle. The minimum ac barrier voltage that initiates partial discharge is defined as the “inception voltage.” Decreasing the barrier voltage to a lower level is required before partial discharge ceases and is defined as the “extinction voltage.” We have characterized and developed the package insulation processes to yield an inception voltage in excess of 2400Vrms so that transient overvoltages below this level will not damage the ISO124. The extinction voltage is above 1500Vrms so that even overvoltage induced partial discharge will cease once the barrier voltage is reduced to the 1500Vrms (rated) level. Older high-voltage test methods relied on applying a large enough overvoltage (above rating) to break down marginal parts, but not so high as to damage good ones. Our new partial discharge testing gives us more confidence in barrier reliability than breakdown/no breakdown criteria.

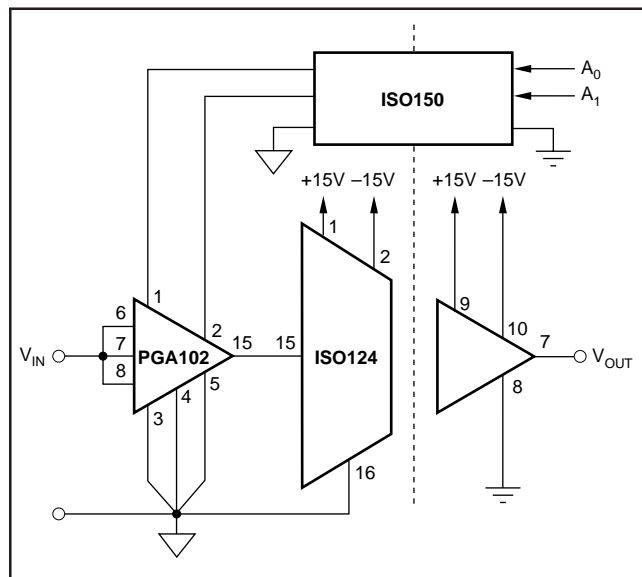


FIGURE 3. Programmable-Gain Isolation Channel with Gains of 1, 10, and 100.

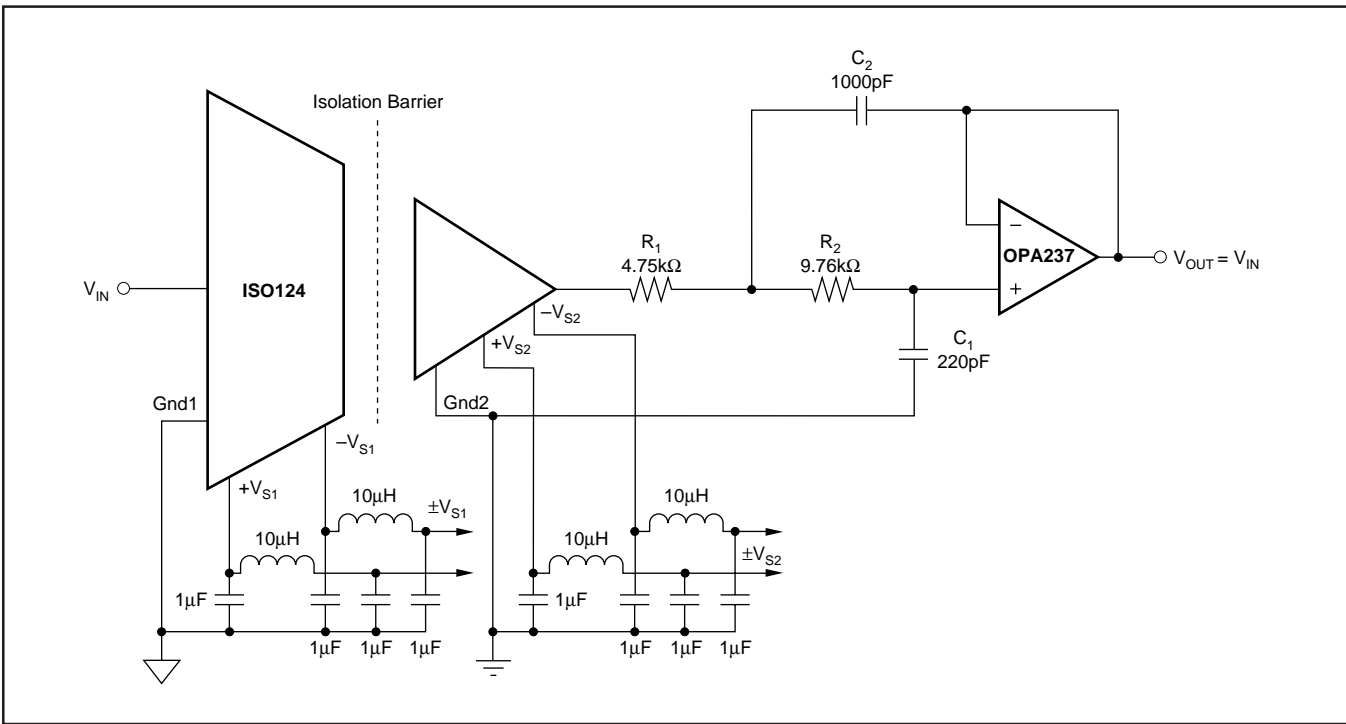


FIGURE 4. Optional  $\pi$  Filter to Minimize Power-Supply Feedthrough Noise; Output Filter to Remove 500kHz Carrier Ripple. For more information concerning output filters refer to Application Notes SBOA012 and SBFA001.

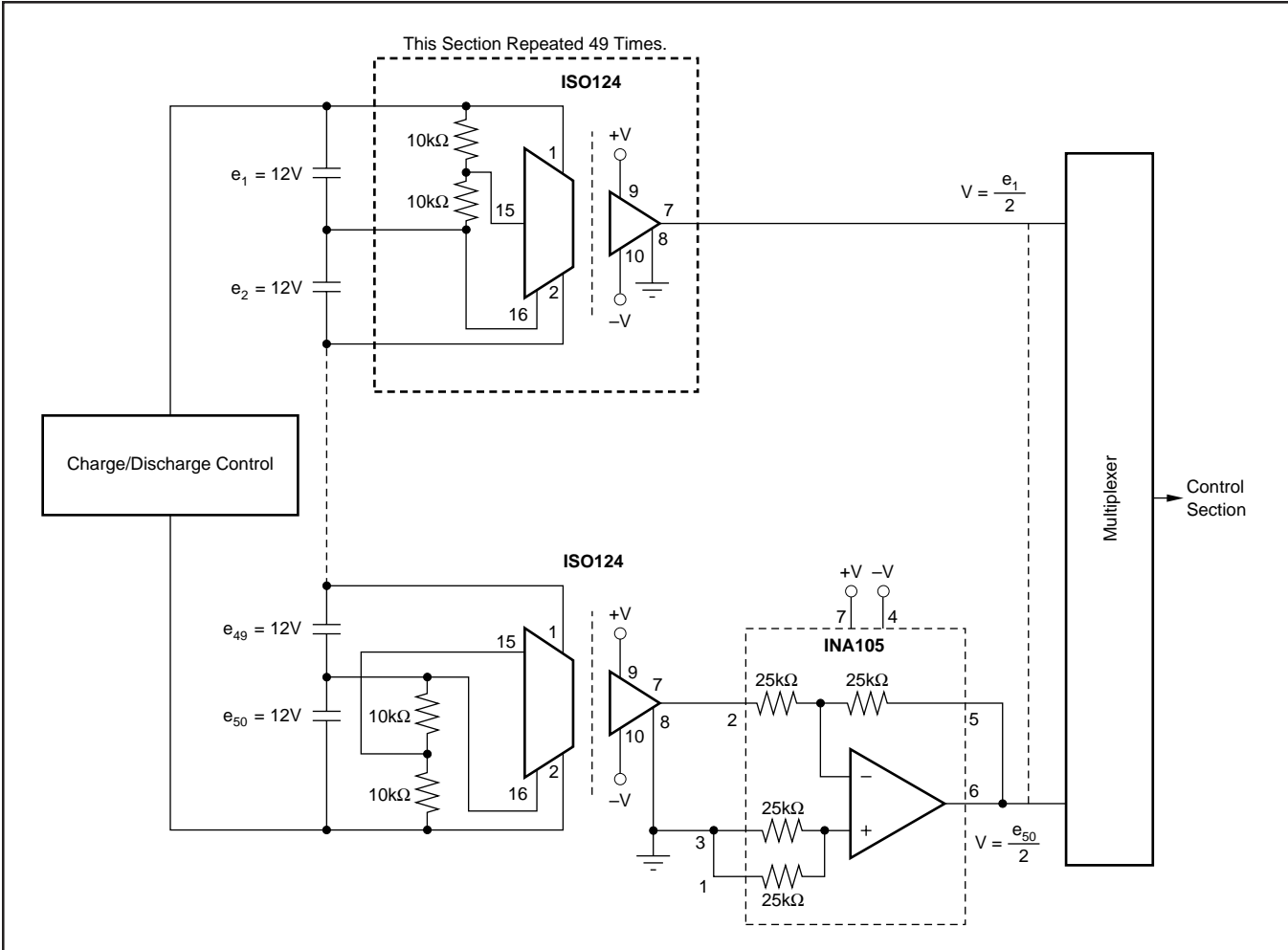


FIGURE 5. Battery Monitor for a 600V Battery Power System. (Derives input power from the battery.)



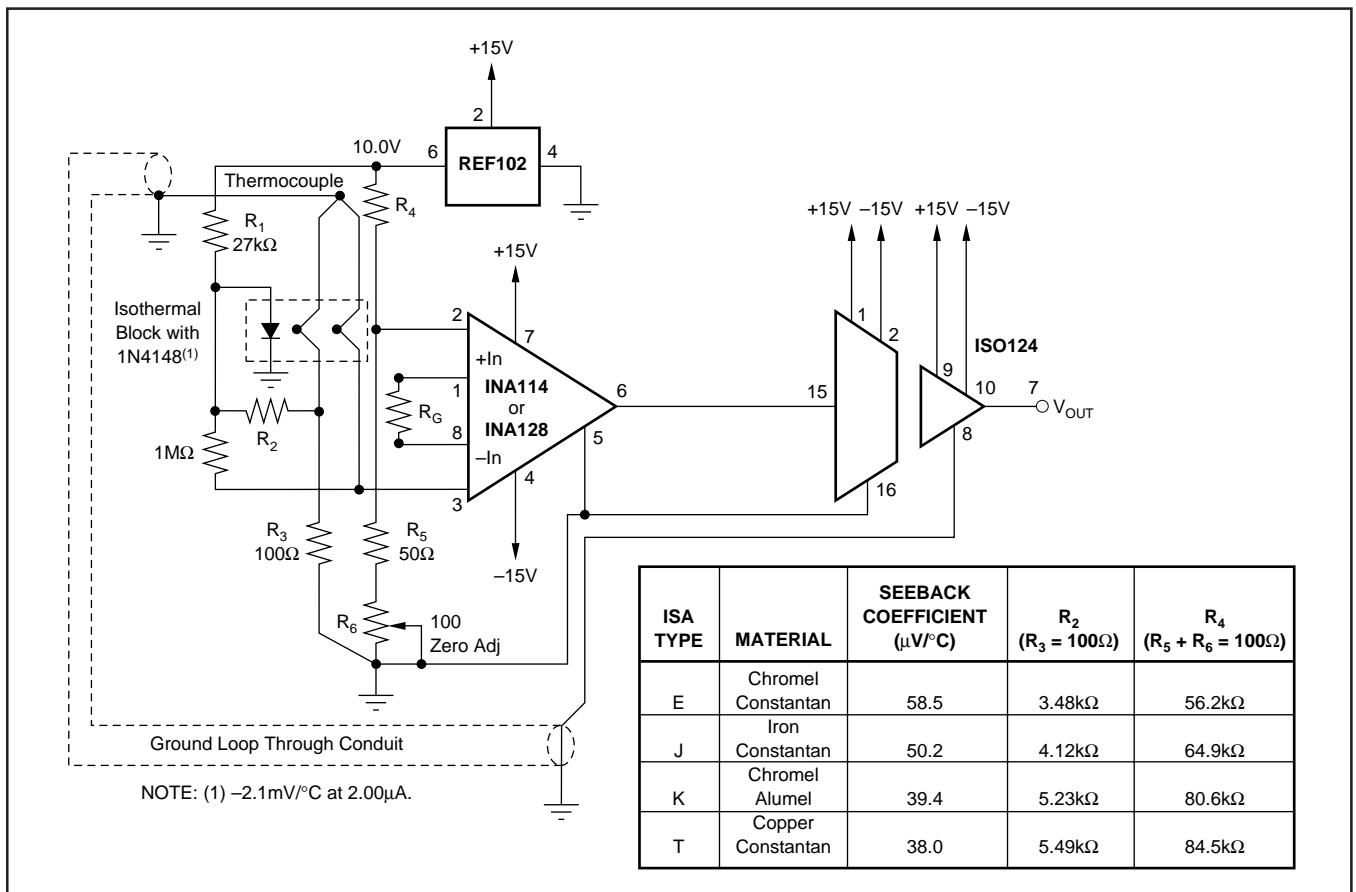


FIGURE 6. Thermocouple Amplifier with Ground Loop Elimination, Cold Junction Compensation, and Up-scale Burn-out.

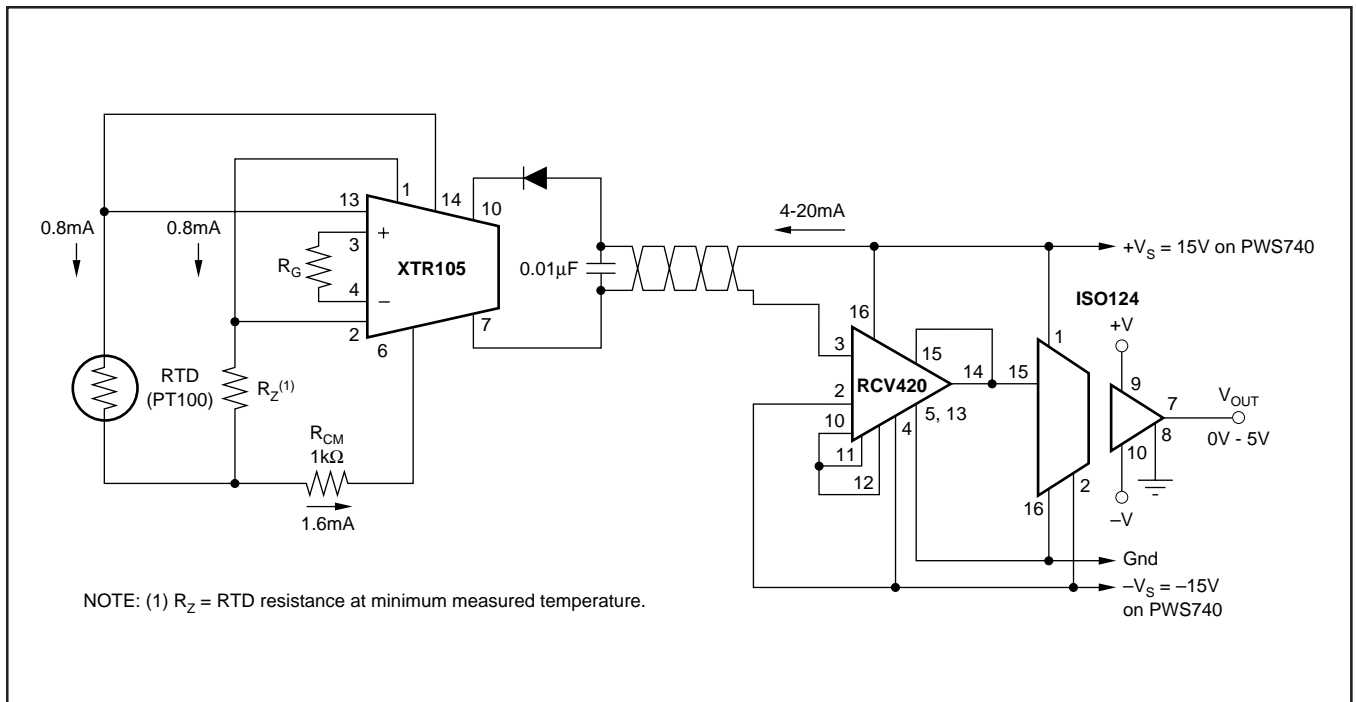


FIGURE 7. Isolated 4-20mA Instrument Loop. (RTD shown.)

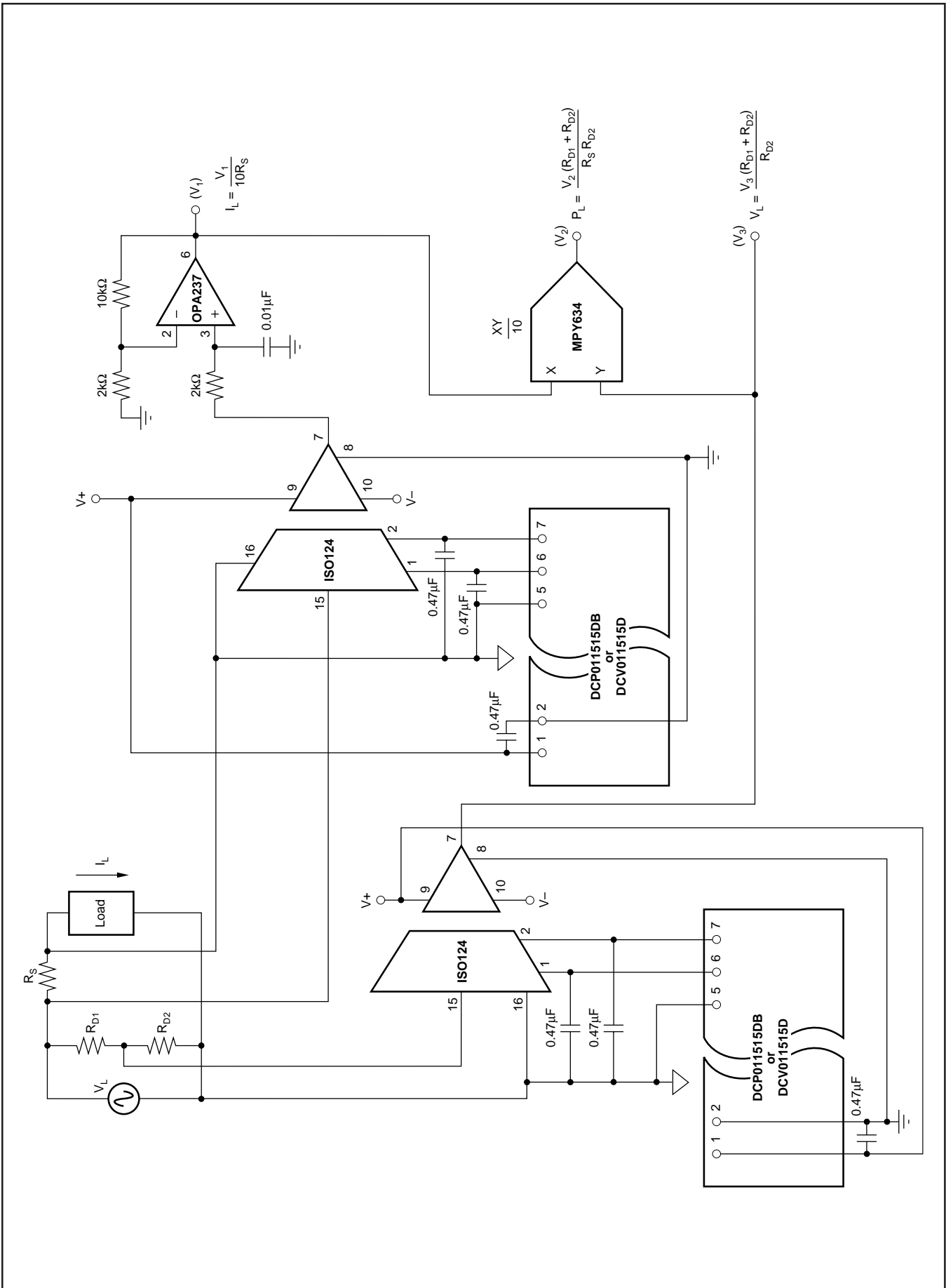


FIGURE 8. Isolated Power Line Monitor.

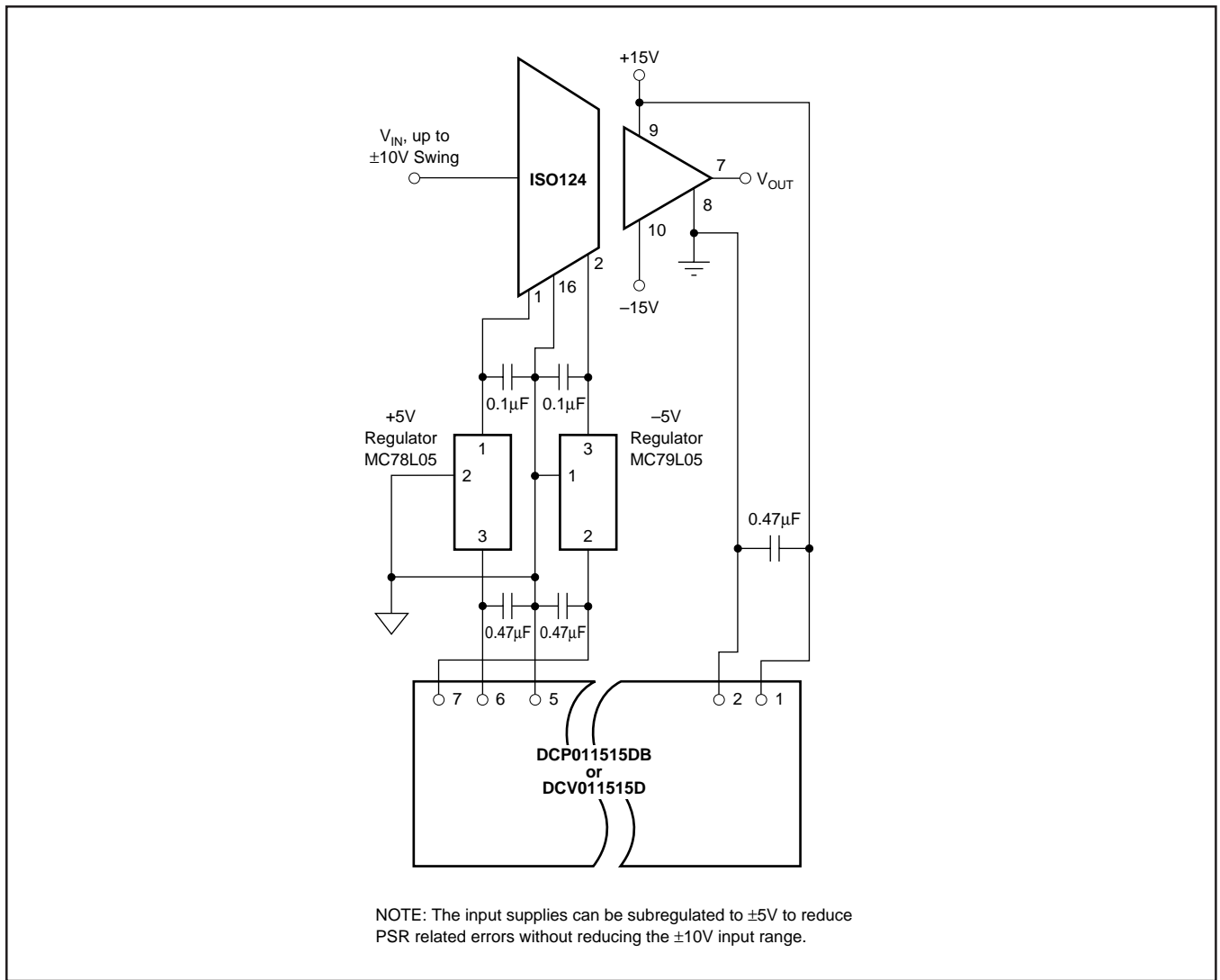


FIGURE 9. Improved PSR Using External Regulator.

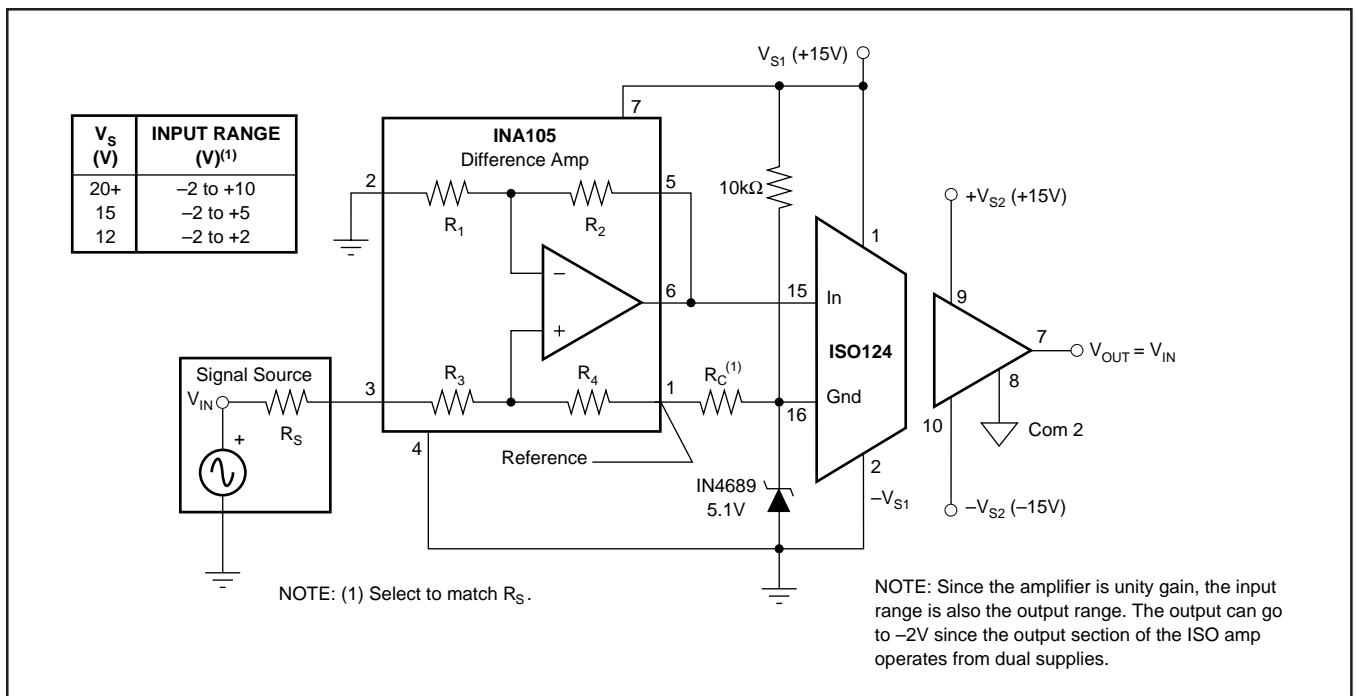


FIGURE 10. Single-Supply Operation of the ISO124 Isolation Amplifier. For additional information refer to Application Note SBOA004.

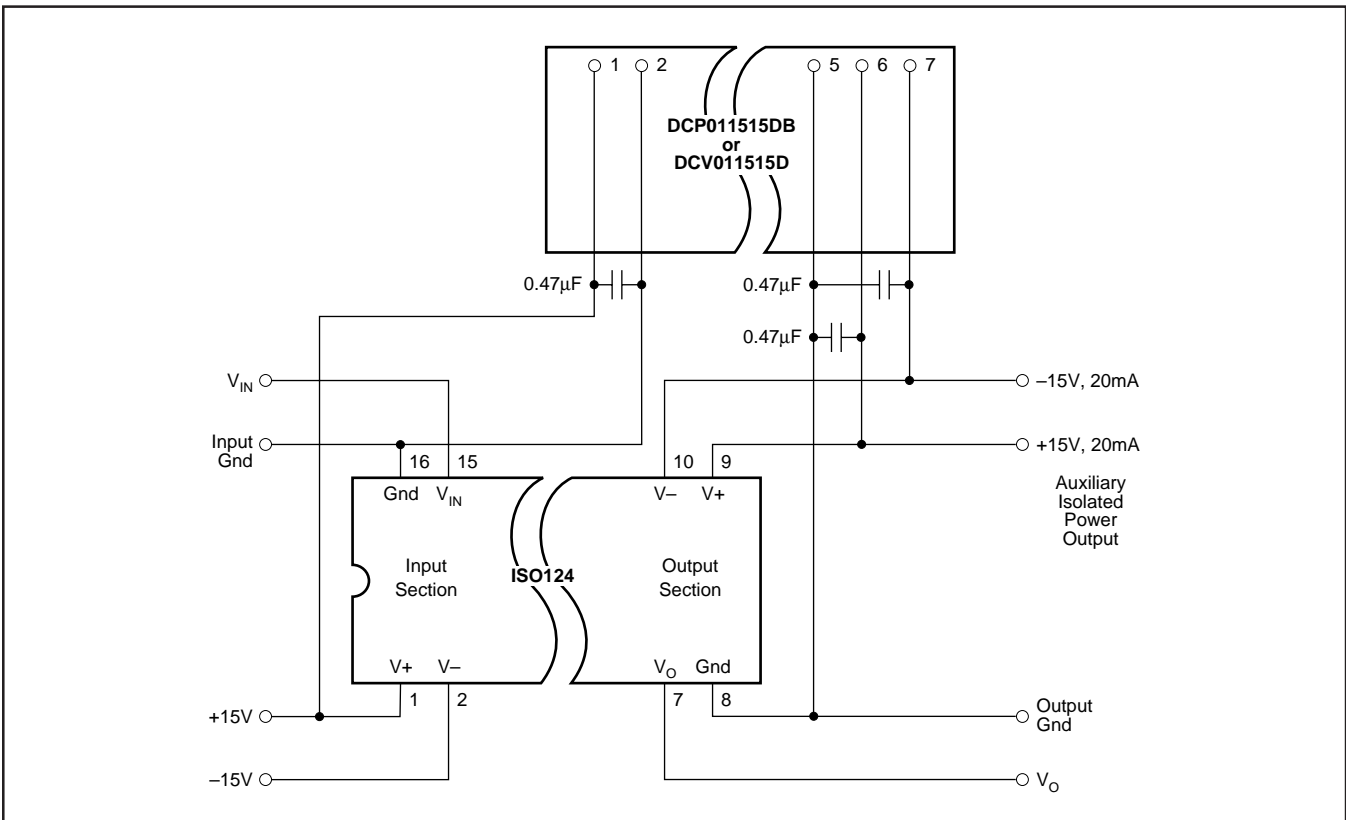


FIGURE 11. Input-Side Powered ISO Amp.

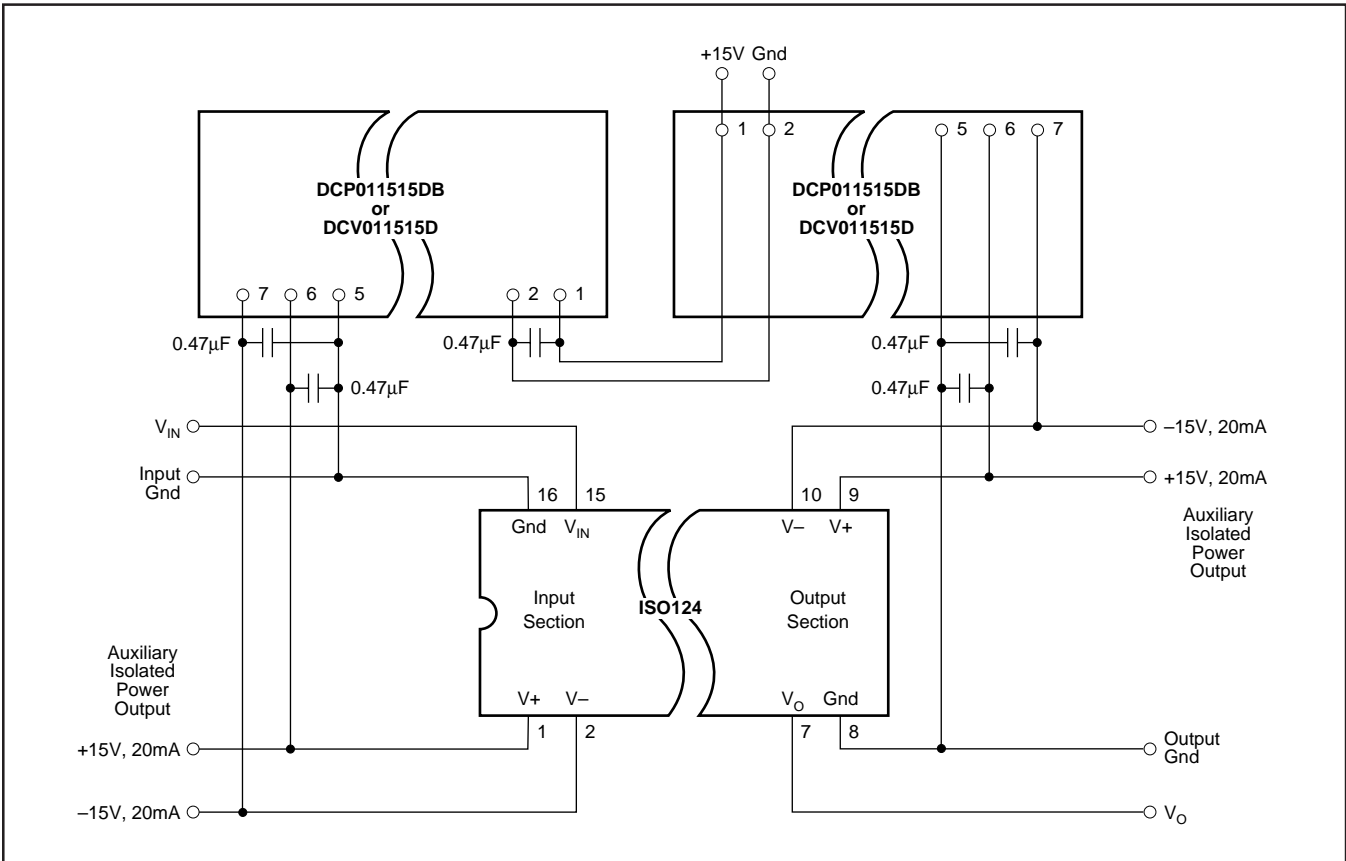


FIGURE 12. Powered ISO Amp with Three-Port Isolation.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
ISO124P	ACTIVE	PDIP	NVF	8	25	Pb-Free (RoHS)	CU NIPDAU	N / A for Pkg Type	-25 to 85	ISO124P	<a href="#">Samples</a>
ISO124U	ACTIVE	SOIC	DVA	8	20	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-25 to 85	ISO 124U	<a href="#">Samples</a>
ISO124U/1K	ACTIVE	SOIC	DVA	8	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-25 to 85	ISO 124U	<a href="#">Samples</a>
ISO124U/1KE4	ACTIVE	SOIC	DVA	8	1000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-25 to 85	ISO 124U	<a href="#">Samples</a>
ISO124UE4	ACTIVE	SOIC	DVA	8	20	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-3-260C-168 HR	-25 to 85	ISO 124U	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

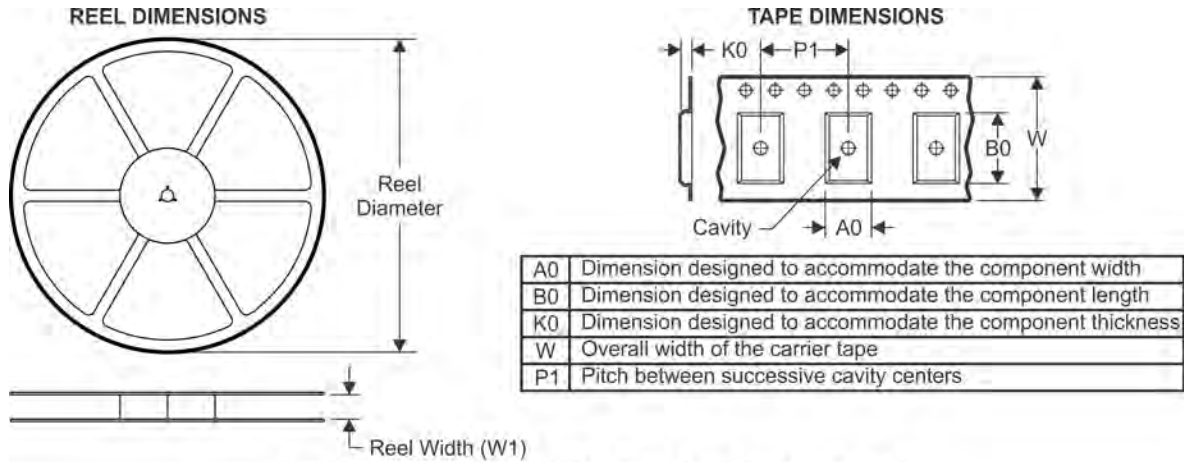
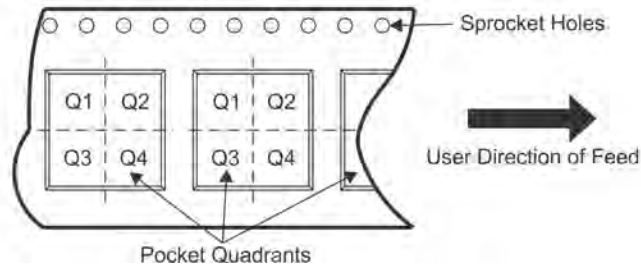
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
ISO124U/1K	SOIC	DVA	8	1000	330.0	24.4	10.9	18.3	3.2	12.0	24.0	Q1

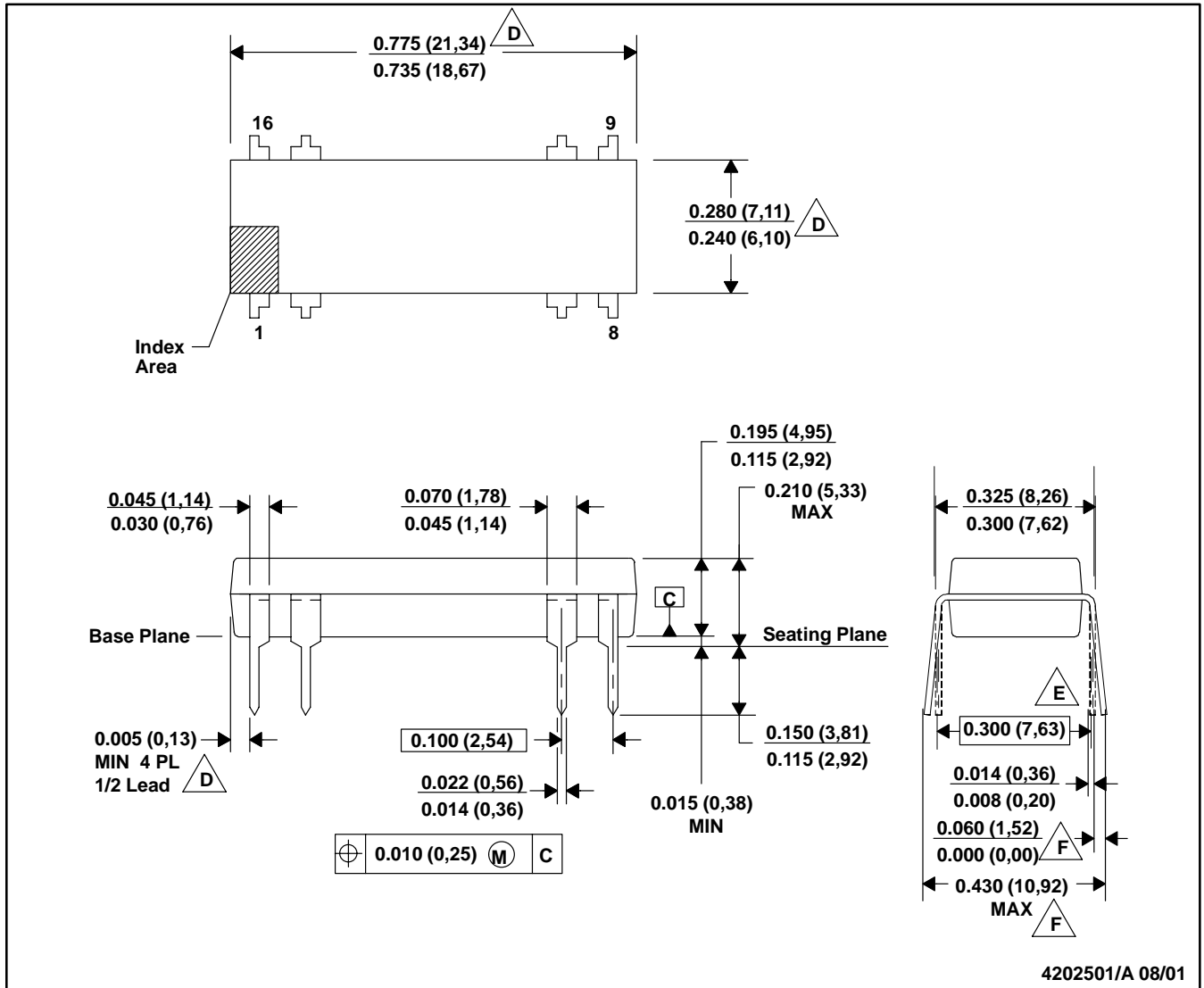
**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ISO124U/1K	SOIC	DVA	8	1000	367.0	367.0	45.0

NVF (R-PDIP-T8/16)

PLASTIC DUAL-IN-LINE



- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. Falls within JEDEC MS-001-BB with the exception of lead count.
- $\triangle D$ . Dimensions do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.010 (0,25).
- $\triangle E$ . Dimensions measured with the leads constrained to be perpendicular to Datum C.
- $\triangle F$ . Dimensions are measured at the lead tips with the leads unconstrained.
- G. A visual index feature must be located within the cross-hatched area.



