



**ISO213**

## Two-Port Isolated, Low Profile ISOLATED INSTRUMENTATION AMPLIFIER

### FEATURES

- GAIN RANGE: 0.5 - 5000
- $\pm 10V$  INPUT SIGNAL RANGE
- INSTRUMENTATION AMPLIFIER INPUTS
- $\pm 40V$  INPUT OVER VOLTAGE PROTECTION
- 12-BIT ACCURACY
- LOW PROFILE (Less Than 0.5" High)
- SMALL FOOTPRINT
- EXTERNAL POWER CAPABILITY ( $\pm 14V$  at 3mA)
- SYNCHRONIZATION CAPABILITY
- SINGLE 12V TO 15V SUPPLY OPERATION
- LOW POWER (45mW)

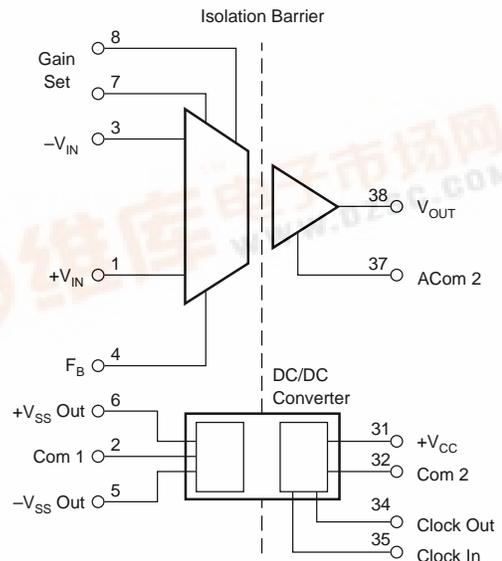
### APPLICATIONS

- INDUSTRIAL PROCESS CONTROL: Transducer Channel Isolator for Thermocouples, RTDs, Pressure Bridges, Flow Meters
- 4mA TO 20mA LOOP ISOLATION
- MOTOR AND SCR CONTROL
- GROUND LOOP ELIMINATION
- ANALYTICAL MEASUREMENTS
- POWER PLANT MONITORING
- DATA ACQUISITION/TEST EQUIPMENT ISOLATION
- MULTIPLEXED SYSTEMS WITH CHANNEL TO CHANNEL ISOLATION

### DESCRIPTION

ISO213 signal isolation amplifier is a member of a series of low-cost isolation products from Burr-Brown. The low-profile ZIP plastic package allows PCB spacings of 0.5" to be achieved, and the small footprint results in efficient use of board space.

To provide isolation, the design uses high-efficiency, miniature toroidal transformers in both the signal and power paths. An uncommitted instrumentation amplifier on the input and an isolated external bipolar supply ensure the majority of input interfacing or conditioning needs can be met.



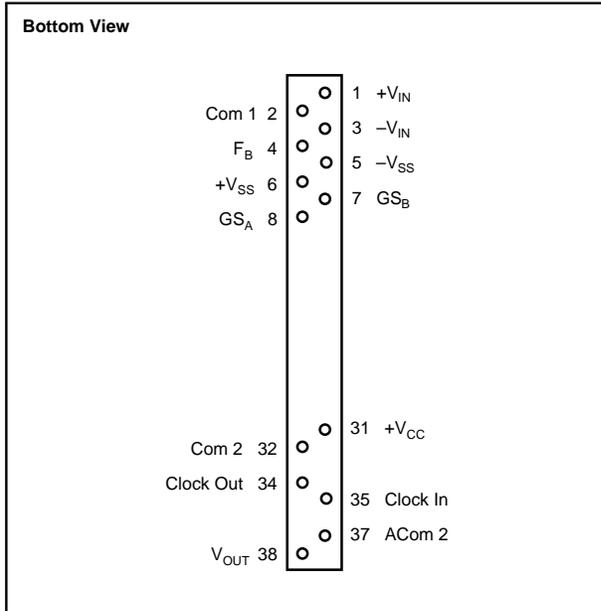
# SPECIFICATIONS

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

PARAMETER	CONDITIONS	ISO213P			UNITS
		MIN	TYP	MAX	
<b>ISOLATION</b>					
Voltage					
Rated Continuous					Vrms
AC, 50/60Hz		1500			VDC
DC		2120			
Rated 1 min					Vrms
AC, 50/60Hz		2500			Vrms
100% Test (AC, 50Hz)	Partial Discharge	2500			
	1s <5pC				
Isolation-Mode Rejection <sup>(1)</sup>	$V_{ISO} = \text{Rated}$				
	Continuous 50/60Hz				
AC			115		dB
DC			160		dB
Barrier Resistance			$10^{10}$		$\Omega$
Barrier Capacitance			15		pF
Leakage Current <sup>(2)</sup>	$V_{ISO} = 240\text{Vrms}, 60\text{Hz}$			3	$\mu\text{Arms}$
	$V_{ISO} = 240\text{Vrms}, 50\text{Hz}$			2.4	$\mu\text{Arms}$
<b>GAIN</b>					
Equation			$G = (1 + 50k/R_G)/2$		
Initial Error	$G = 0.5$		$\pm 0.2$	$\pm 3$	% FSR <sup>(8)</sup>
Gain vs Temperature	$G = 0.5$		10	50	ppm of FSR/ $^\circ\text{C}$
Non-Linearity <sup>(3)</sup>	$V_O = -5\text{V to } +5\text{V}, G = 0.5$		0.01	0.025	%FSR
<b>INPUT OFFSET VOLTAGE</b>					
Offset Voltage RTI				$\pm 0.5 \pm 25/G$	mV
vs Temperature					$\mu\text{V}/^\circ\text{C}$
vs Power Supply <sup>(4)</sup>	$G = 0.5, V_{CC} = 14\text{V to } 16\text{V}$		$\pm 5 \pm 35/G$		mV/V
			$\pm 3$		
<b>INPUT CURRENT</b>					
Bias			$\pm 1$	$\pm 10$	nA
Offset			$\pm 1$	$\pm 10$	nA
<b>INPUT</b>					
Linear Input Range <sup>(5)</sup>	$G = 0.5$	$\pm 10$	$\pm 12$		V
Common-Mode Rejection	$V_{CM} = \pm 10\text{V}, \Delta R_S = 1\text{k}\Omega$				
	$G = 0.5$	73	90		dB
	$G = 5$	89	110		dB
	$G = 50$	98	120		dB
	$G = 500$	100	125		dB
Impedance					
Differential			$10^{10} \parallel 3$		$\Omega \parallel \text{pF}$
Common-Mode			$10^{10} \parallel 6$		$\Omega \parallel \text{pF}$
<b>OUTPUT</b>					
Output Impedance			3		k $\Omega$
Voltage	Load = 1M $\Omega$	$\pm 5$			V
Ripple Voltage <sup>(6)</sup>	f = clk		1		mVp-p
Output Noise	f = 0 to 5kHz		20		$\mu\text{V}/\sqrt{\text{Hz}}$
<b>FREQUENCY RESPONSE</b>					
Small Signal Bandwidth	$V_{IN} = 1\text{Vp-p}, -3\text{dB}, G = 0.5$		1		kHz
Full Signal Bandwidth	$V_{IN} = 10\text{Vp-p}, -3\text{dB}, G = 0.5$		200		Hz
<b>ISOLATED POWER OUTPUTS</b>					
Voltage Outputs ( $\pm V_{SS}$ ) <sup>(7)</sup>	3mA	$\pm 13$	$\pm 14$		VDC
vs Temperature			7		mV/ $^\circ\text{C}$
vs Load			180		mV/mA
Current Output <sup>(7)</sup>					
(Both Loaded)	$V_{SS} = \pm 13\text{V}$	3	6		mA
(One Loaded)	$V_{SS} = \pm 13\text{V}$	4	6		mA
<b>POWER SUPPLIES</b>					
Rated Voltage	Rated Performance		15		V
Voltage Range <sup>(5, 9)</sup>			11.4 to 16		V
Quiescent Current	No Load		3	6	mA
<b>TEMPERATURE RANGE</b>					
Specification		0		+70	$^\circ\text{C}$
Operating		-25		+85	$^\circ\text{C}$

NOTES: (1) Isolation-mode rejection is the ratio of the change in output voltage to a change in isolation barrier voltage. (2) Tested at 2500Vrms 50Hz limit 25 $\mu\text{A}$  (barrier is essentially capacitive). (3) 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. (4) Power Supply Rejection is the change in  $V_{OS}$ /Supply Change. (5) See max  $V_{OUT}$  and  $V_{IN}$  vs Supply Voltage in typical performance curves. (6) Ripple is the residual component of the barrier carrier frequency generated internally. (7) Derated at  $V_{CC} < 15\text{V}$ . (8) FSR = Full Scale Output Range = 10V. (9) Minimum supply voltage is given as 11.4V. This is the minimum supply to ensure a  $\pm 5\text{V}$  output swing can be achieved. The ISO213 actually works down to a minimum supply of 4V as shown in the typical performance curve "Max  $V_{OUT}$  and  $V_{IN}$  vs Supply Voltage."

## PIN CONFIGURATION



## ABSOLUTE MAXIMUM RATINGS

Supply Voltage Without Damage .....	18V
Continuous Isolation Voltage Across Barrier: .....	2500Vrms
Storage Temperature Range .....	-25°C to 100°C
Lead Temperature (soldering, 10s) .....	+300°C
Amplifier Output Short-Circuit Duration .....	Continuous to Common
Output Voltage to Com 2 .....	±V <sub>CC</sub> /2

## ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Burr-Brown 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 INFORMATION

MODEL	PACKAGE	PACKAGE DRAWING NUMBER <sup>(1)</sup>
ISO213P	38-Pin Plastic ZIP	326

NOTE: (1) For detailed drawing and dimension table, please see end of data sheet, or Appendix D of Burr-Brown IC Data Book.

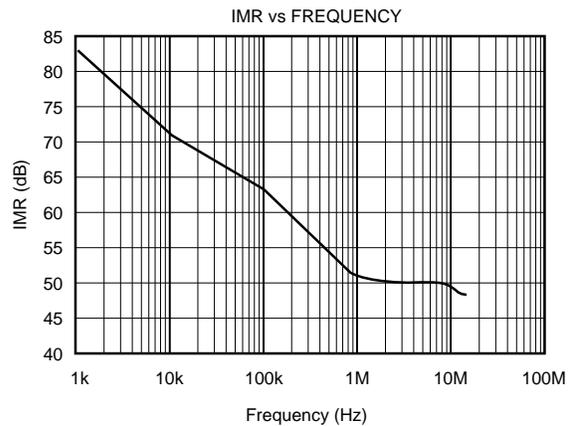
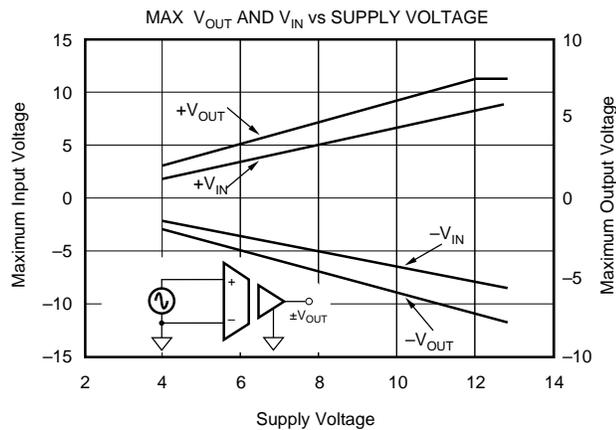
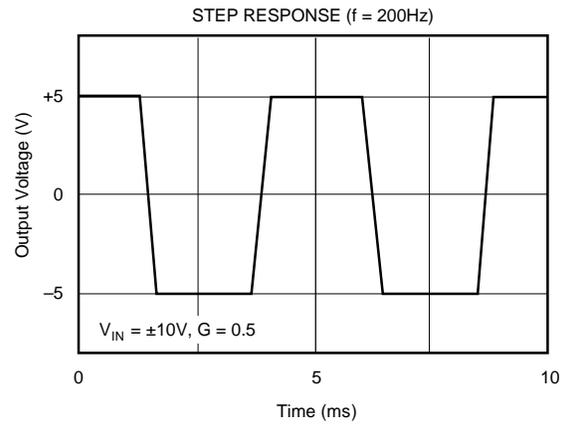
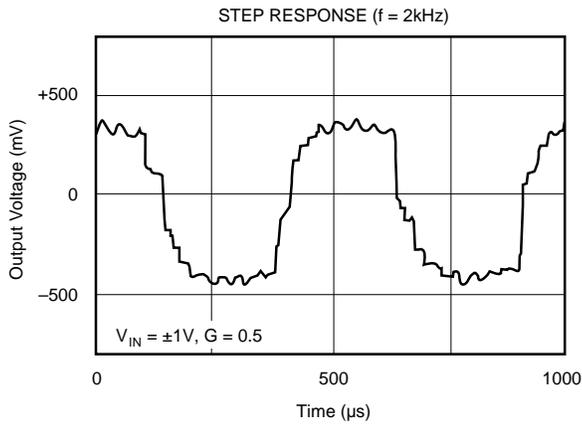
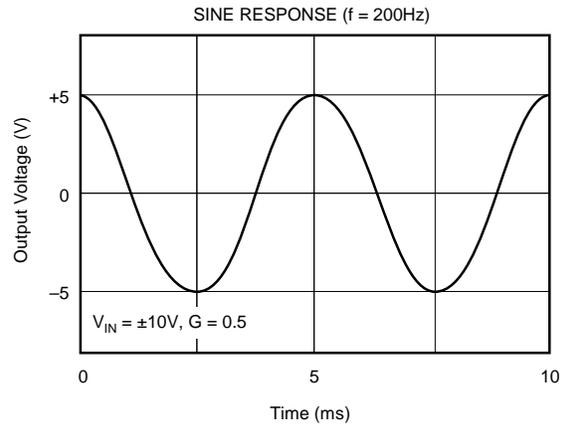
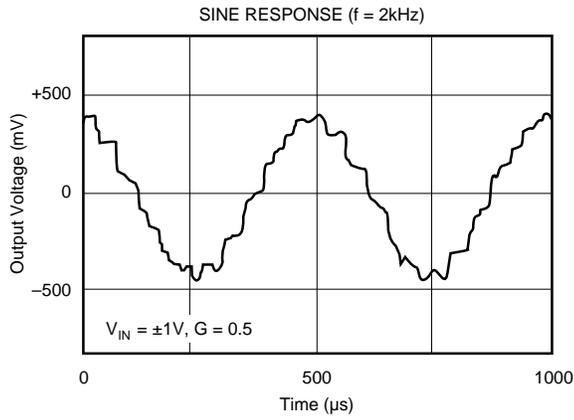
## ORDERING INFORMATION

MODEL	PACKAGE	OPERATING TEMPERATURE RANGE	ISOLATION RATING 1 MIN
ISO213P	38-Pin Plastic ZIP	-25°C to +85°C	2500Vrms

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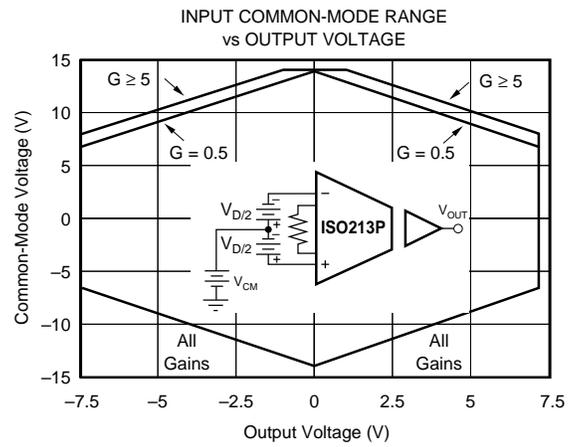
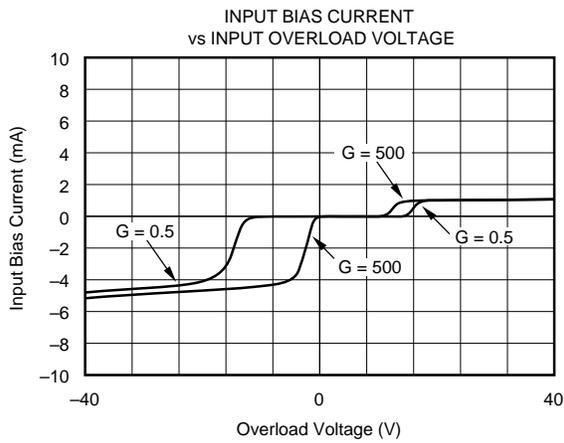
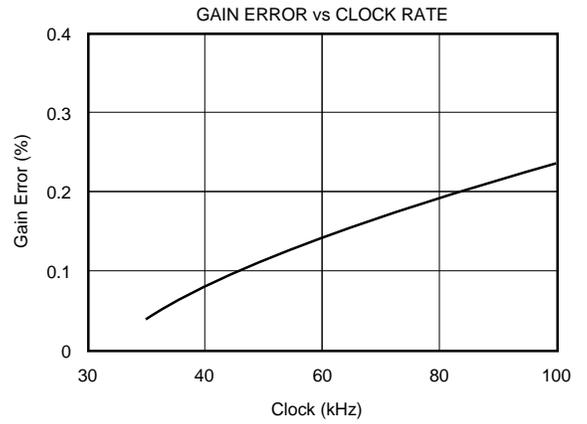
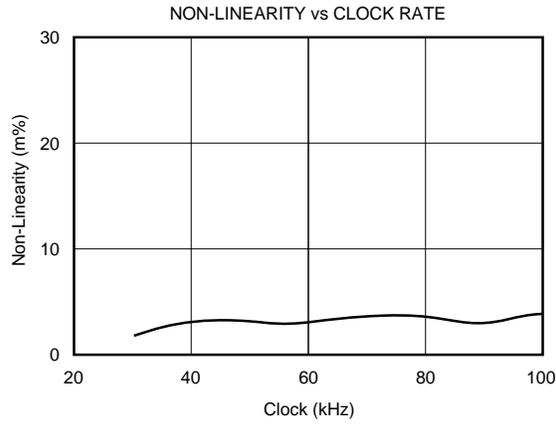
# TYPICAL PERFORMANCE CURVES

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



# TYPICAL PERFORMANCE CURVES (CONT)

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



## DISCUSSION OF SPECIFICATIONS

ISO213 is intended for applications where isolation and input signal conditioning are required. The best signal-to-noise performance is obtained when the input amplifier gain setting is such that  $F_B$  pin has a full scale range of  $\pm 10V$ . The bandwidth is internally limited to typically 1kHz, making the device ideal for use in conjunction with sensors that monitor slowly varying processes. To power external functions or networks, 3mA at  $\pm 14V$  typical is available at the isolated port.

### LINEARITY PERFORMANCE

ISO213 offers non-linearity performance compatible with 12-bit resolution systems (0.025%). Note that the specification is based on a best-fit straight line.

### INPUT PROTECTION

The inputs of ISO213 are individually protected for voltages up to  $\pm 40V$ . For example, a condition of  $-40V$  on one input and  $+40V$  on the other input will not cause damage. Internal circuitry on each input provides low series impedance under normal signal conditions. To provide equivalent protection, series input resistors would contribute excessive noise. If the input is overloaded, the protection circuitry limits the input current to a safe value of approximately 1.5mA to 5mA. The typical performance curve “Input Bias Current vs Input Overload Voltage” shows this input current limit behavior. The inputs are protected even if the power supplies are disconnected or turned off.

### USING $\pm V_{SS}$ TO POWER EXTERNAL CIRCUITRY

The DC/DC converter in ISO213 runs at a switching frequency of 25kHz. Internal rectification and filtering is suf-

ficient for most applications at low frequencies with no external networks connected.

The ripple on  $\pm V_{SS}$  will typically be 100mVp-p at 25kHz. Loading the supplies will increase the ripple unless extra filtering is added externally; a capacitor of 1 $\mu F$  is normally sufficient for most applications, although in some cases 10 $\mu F$  may be required. Noise introduced onto  $\pm V_{SS}$  should be decoupled to prevent degraded performance.

## THEORY OF OPERATION

ISO213 has no galvanic connection between the input and output. The analog input signal is multiplied by the gain of the input amplifier and accurately reproduced at the output. A simplified diagram of ISO213 is shown in Figure 2. The design consists of a DC/DC converter, an uncommitted input instrumentation amplifier, a modulator circuit and a demodulator circuit with a gain of 0.5. Magnetic isolation is provided by separate transformers in the power and signal paths.

The DC/DC converter provides power and synchronization signals across the isolation barrier to operate the instrumentation amplifier and modulator circuitry. It also has sufficient capacity to power external input signal conditioning networks. The uncommitted instrumentation amplifier may be configured for signal buffering or amplification, depending on the application.

The modulator converts the input signal to an amplitude-modulated AC signal that is magnetically coupled to the demodulator by a miniature transformer providing the signal-path isolation. The demodulator recovers the input signal from the modulated signal using a synchronous technique to minimize noise and interference.

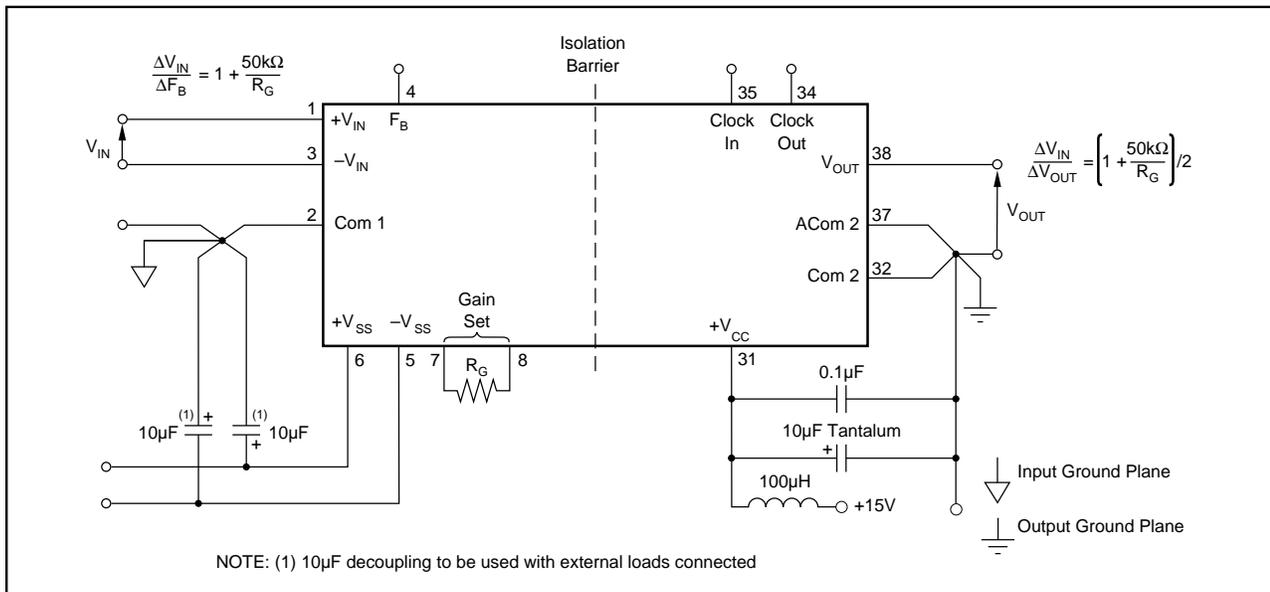


FIGURE 1. Power Supply and Signal Connections Shown for Non-Inverting, Unity Gain Configuration.

## ABOUT THE BARRIER

For any isolation product, barrier integrity is of paramount importance in achieving high reliability. ISO213 uses miniature toroidal transformers designed to give maximum isolation performance when encapsulated with a high dielectric-strength material. The internal component layout is designed so that circuitry associated with each side of the barrier is positioned at opposite ends of the package. Areas where high electric fields can exist are positioned in the center of the package. The result is that the dielectric strength of the barrier typically exceeds 3kVrms.

## ISOLATION VOLTAGE RATINGS

Because a long term test is impractical in a manufacturing situation, the generally accepted practice is to perform a production test at a high voltage for some shorter time. The relationship between actual test voltage and the continuous derated maximum specification is an important one. Historically, Burr-Brown has chosen a deliberately conservative one:  $V_{TEST} = (2 \times ACrms \text{ continuous rating}) + 1000V$  for ten seconds, followed by a test at rated ACrms voltage for one minute.

Recent improvements in high voltage stress testing have produced a more meaningful test for determining maximum permissible voltage ratings, and Burr-Brown has chosen to apply this new technology to the manufacture and testing of ISO213.

## PARTIAL DISCHARGE

When an insulation defect such as a void occurs within an insulation system, the defect will display localized corona or ionization during exposure to high voltage stress. This ionization

requires a higher applied voltage to start the discharge and a lower voltage to extinguish it once started. The higher start voltage is known as the inception voltage and the lower voltage is called the extinction voltage. Just as the total insulation system has an inception voltage, so do the individual voids. A voltage will build up across a void until its inception voltage is reached. At this point, the void will ionize, effectively shorting itself out. This action redistributes electrical charge within the dielectric and is known as partial discharge. If the applied voltage gradient across the device continues to rise, another partial discharge cycle begins. The importance of this phenomenon is that if the discharge does not occur, the insulation system retains its integrity. If the discharge begins and is allowed to continue, the action of the ions and electrons within the defect will eventually degrade any organic insulation system in which they occur. The measurement of partial discharge is both useful in rating the devices and in providing quality control of the manufacturing process. The inception voltage of these voids tend to be constant, so that the measurement of total charge being redistributed within the dielectric is a very good indicator of the size of the voids and their likelihood of becoming an incipient failure.

The bulk inception voltage, on the other hand, varies with the insulation system and the number of ionization defects. This directly establishes the absolute maximum voltage (transient) that can be applied across the test device before destructive partial discharge can begin.

Measuring the bulk extinction voltage provides a lower, more conservative, voltage from which to derive a safe continuous rating. In production, it's acceptable to measure at a level somewhat below the expected inception voltage and then de-rate by a factor related to expectations about the

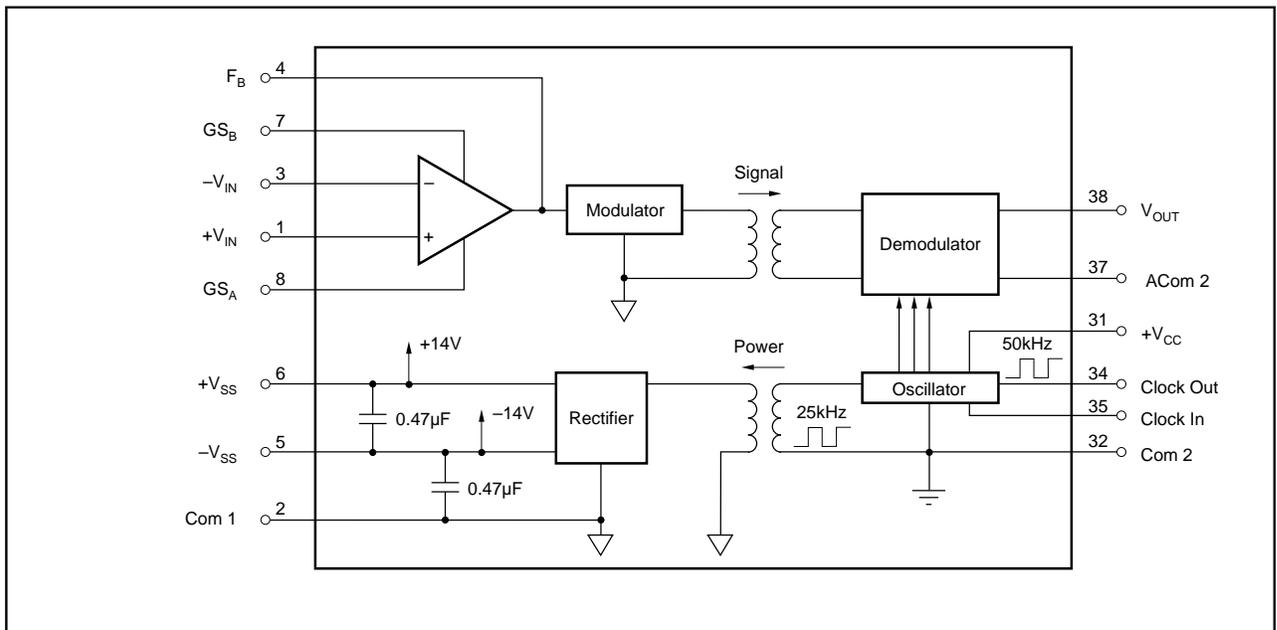


FIGURE 2. Simplified Diagram of Isolation Amplifier.

system transients. The isolation barrier has been extensively evaluated under a combination of high temperatures and high voltage to confirm its performance in this respect. ISO213 is free from partial discharges at rated voltages.

## PARTIAL DISCHARGE TESTING IN PRODUCTION

This test method provides far more qualitative information about stress withstand levels than did previous stress tests. It also provides quantitative measurements from which quality assurance and control measures can be based. Tests similar to this test have been used by some manufacturers such as those of high voltage power distribution equipment for some time. They employed a simple measurement of RF noise to detect ionization. This method was not quantitative with regard to energy of the discharge and was not sensitive enough for small components such as isolation amplifiers. Now, however, manufacturers of HV test equipment have developed means to measure partial discharge, and VDE, the German standards group, has adopted use of this method for the testing of opto-couplers. To accommodate poorly defined transients, the part under test is exposed to a voltage that is 1.6 times the continuous rated voltage and must display  $<5\text{pC}$  partial discharge level in a 100% production test. Where transients are not present on an applied voltage and the bulk inception voltage is not exceeded, degradation will not take place. This is the case where OEM production testing is performed to satisfy regulatory requirements. The normal test is to apply a relatively slow ramp to a defined test voltage. Maintain that voltage for 1 minute and then ramp to zero. Where this test voltage is less than or equal to the partial discharge test voltage it can be seen that degradation will not occur. Hence ISO213 is guaranteed to withstand a continuous test voltage for 1 minute at the partial discharge test voltage.

## INSTALLATION AND OPERATING INSTRUCTIONS

### POWER SUPPLY AND SIGNAL CONNECTIONS

As with any mixed analog and digital signal component, correct decoupling and signal routing precautions must be used to optimize performance. Figure 1 shows the proper power supply and signal connections.  $V_{CC}$  should be bypassed to Com 2 with a  $0.1\mu\text{F}$  ceramic capacitor and  $100\mu\text{H}$  inductor as close to the device as possible. Short leads will minimize lead inductance. A ground plane will also reduce noise problems. If a low impedance ground plane is not used, signal common lines, and ACom 2 should be tied directly to the ground at the supply and Com 2 returned via a separate trace to the supply ground.

To avoid gain and isolation mode (IMR) errors introduced by the external circuit, connect grounds as indicated in Figure 3. Layout practices associated with isolation amplifiers are very important. In particular, the capacitance associated with the barrier, and series resistance in the signal and

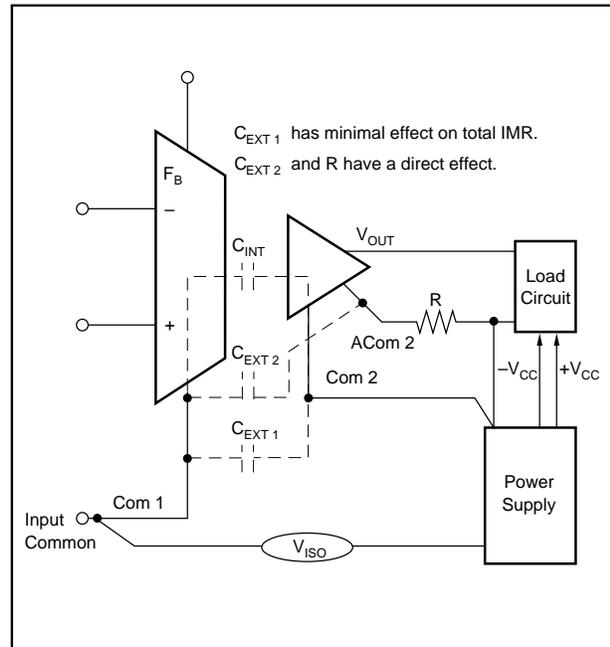


FIGURE 3. Technique for Connecting Com 1 and Com 2.

reference leads, must be minimized. Any capacitance across the barrier will increase AC leakage and, in conjunction with ground line resistance, may degrade high frequency IMR.

### VOLTAGE GAIN MODIFICATIONS

The uncommitted instrumentation amplifier at the input can be used to provide gain, signal inversion, or current to voltage conversion. The standard design approach for any instrumentation amplifier stage can be used, provided that the full scale voltage appearing on  $F_B$  does not exceed  $\pm 10\text{V}$ .

Also, it should be noted that the current required to drive the equivalent impedance of any feedback network is supplied by the internal DC/DC converter and must be taken into account when calculating the loading added to  $\pm V_{SS}$ .

### ISOLATED POWER OUTPUT DRIVE CAPABILITY

On the input side of ISO213, there are two power supplies capable of delivering  $3\text{mA}$  at  $\pm 14\text{V}$  typical to power external circuitry. When using these supplies with external loads, it is recommended that additional decoupling in the form of  $10\mu\text{F}$  tantalum bead capacitors, is added to improve the voltage regulation. Loss of linearity will result if additional filtering is not used with an output load. Again, power dissipated in a feedback network must be subtracted from the available power output at  $\pm V_{SS}$ .

If ISO213 is to be used in multiple applications, care should be taken in the design of the power distribution network, especially when all ISO213s are synchronized. It is best to use a well decoupled distribution point and to take power to each ISO213 from this point in a star arrangement as shown in Figure 4.

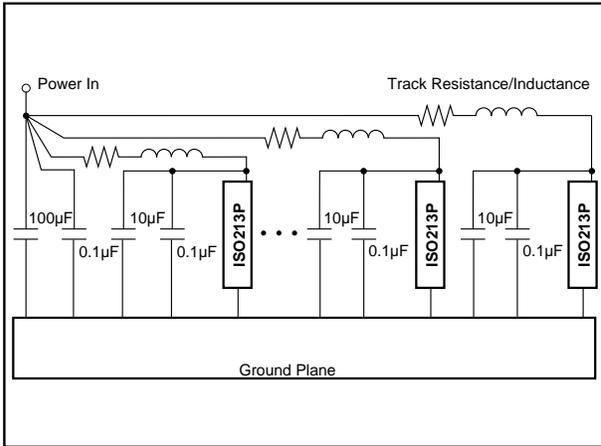


FIGURE 4. Recommended Decoupling and Power Distribution.

### NOISE

Output noise is generated by residual components of the 25kHz carrier that have not been removed from the signal. This noise may be reduced by adding an output low-pass filter (see Figure 9). The filter time constant should be set below the carrier frequency. The output from ISO213 is a switched capacitor and requires a high impedance load to prevent degradation of linearity. Loads of less than  $1M\Omega$  will cause an increase in noise at the carrier frequency and will appear as ripple in the output waveform. Since the output signal power is generated from the input side of the barrier, decoupling of the  $\pm V_{SS}$  outputs will improve the signal to noise ratio.

### SYNCHRONIZATION OF THE INTERNAL OSCILLATOR

ISO213 has an internal oscillator and associated timing components, which can be synchronized. This alleviates the requirement for an external high-power clock driver. The typical frequency of oscillation is 50kHz. The internal clock will start when power is applied to ISO213 and Clk In is not connected.

Because the oscillator frequency of each ISO213 can be marginally different, “beat” frequencies ranging from a few Hz to a few kHz can exist in multiple amplifier applications. The design of ISO213 accommodates “internal synchronous” noise, but a synchronous beat frequency noise will not be strongly attenuated, especially at very low frequencies if it is introduced via the power, signal, or potential grounding paths. To overcome this problem in systems where several ISO213s are used, the design allows synchronization of each oscillator in a system to one frequency. Do this by forcing the timing node on the internal oscillator with an external driver connected to Clk In (Figure 5). The driver may be an external component with Series 4000 CMOS characteristics, or one ISO213 in the system can be used as the master clock for the system. An alternative where a specific frequency is not required is to lock all ISO213s together by joining all Clk Ins. This method can be used to lock an unlimited

number of ISO213s. See Figure 6, 7, and 8 for connections in multiple ISO213 installations.

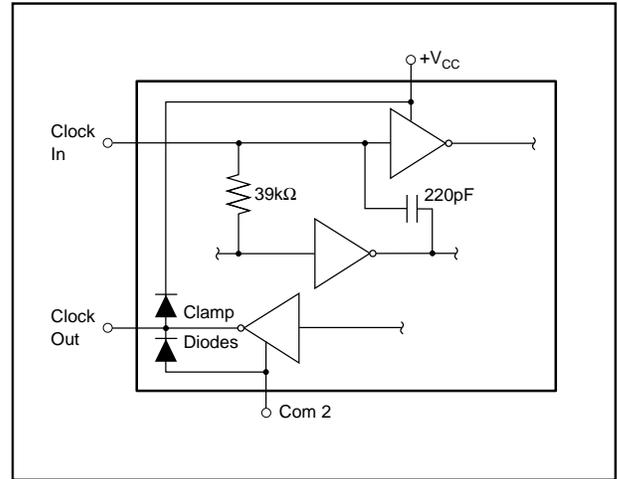


FIGURE 5. Equivalent Circuit, Clock Input/Output. Inverters are CMOS.

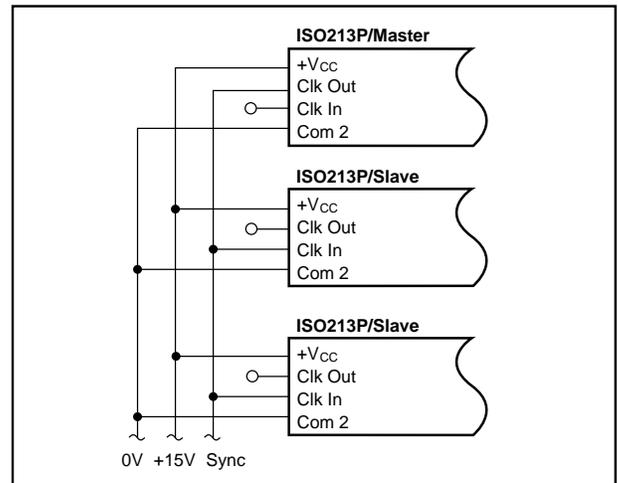


FIGURE 6. Oscillator Connections for Synchronous Operation in Multiple ISO213P Installations.

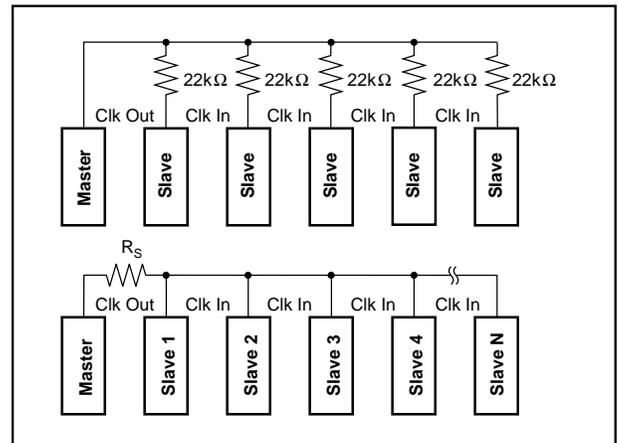


FIGURE 7. Isolating the Clk Out Node.

## CHARGE ISOLATION

When more than one ISO213 is used in synchronous mode, the charge which is returned from the timing capacitor (220pF in Figure 5) on each transition of the clock becomes significant. Figure 7 illustrates a method of isolating the “Clk Out” clamp diodes (Figure 5) from this charge.

A 22kΩ resistor (recommended maximum) together with the 39kΩ internal oscillator timing resistor (Figure 5) forms a potential divider. The ratio of these resistors should be greater than 0.6 which ensures that the input voltage triggers the inverter connected to “Clk In”. If using a single resistor, then account must be taken of the paralleled timing resistors. This means that the 22kΩ resistor must be halved to drive two ISO213s, or divided by 8 if driving 8 ISO213s to insure that the ratio of greater than 0.6 is maintained. The series resistors shown in Figure 7 reduce the high frequency content of the power supply current. Figure 8 can be used where a specific frequency of operation is not required.

## APPLICATIONS

ISO213 isolation amplifier, together with a few low cost components, can isolate and accurately convert a 4-to-20mA input to a ±10V output with no external adjustment. Its low height (0.43" (11mm) ) and small footprint (2.5" x 0.33" (57mm x 8mm) ) make it the solution of choice in 0.5" board spacing systems and in all applications where board area savings are critical.

ISO213 operates from a single +15V supply and offers low power consumption and 12-bit accuracy. On the input side,

two isolated power supplies capable of supplying 3mA at ±14V typical are available to power external circuitry.

## APPLICATIONS FLEXIBILITY

In Figure 9, ISO213 +V<sub>ss</sub> isolated supply powers a REF200 to provide an accurate 200µA current source. This current is used via the 1.5kΩ resistor to set the output to -5V at 4mA input.

The primary function of the output circuitry is to add gain, to produce a ±10V output and to reduce output impedance. The addition of a few resistors and capacitors provides a low pass filter with a cutoff frequency equal to the full signal bandwidth of ISO213, typically 200Hz. The filter response is flat to 1dB and rolls off from cut off at -12dB per octave.

The accuracy of REF200 and external resistors eliminates the need for expensive trim pots and adjustments. The errors introduced by the external circuitry only add about 10% of ISO213 specified gain and offset voltage error.

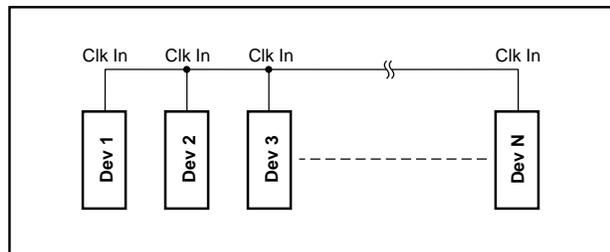


FIGURE 8. Recommended Synchronizing Scheme.

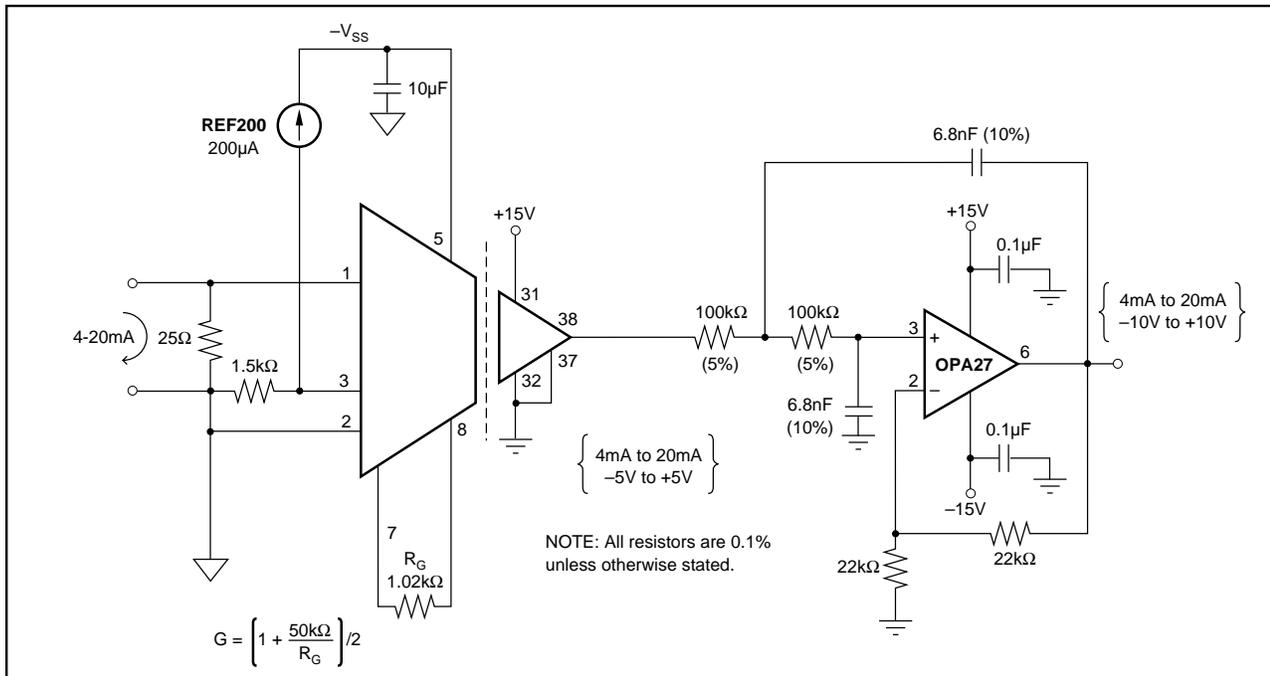


FIGURE 9. Isolated 4-20mA Current Receiver with Output Filter.

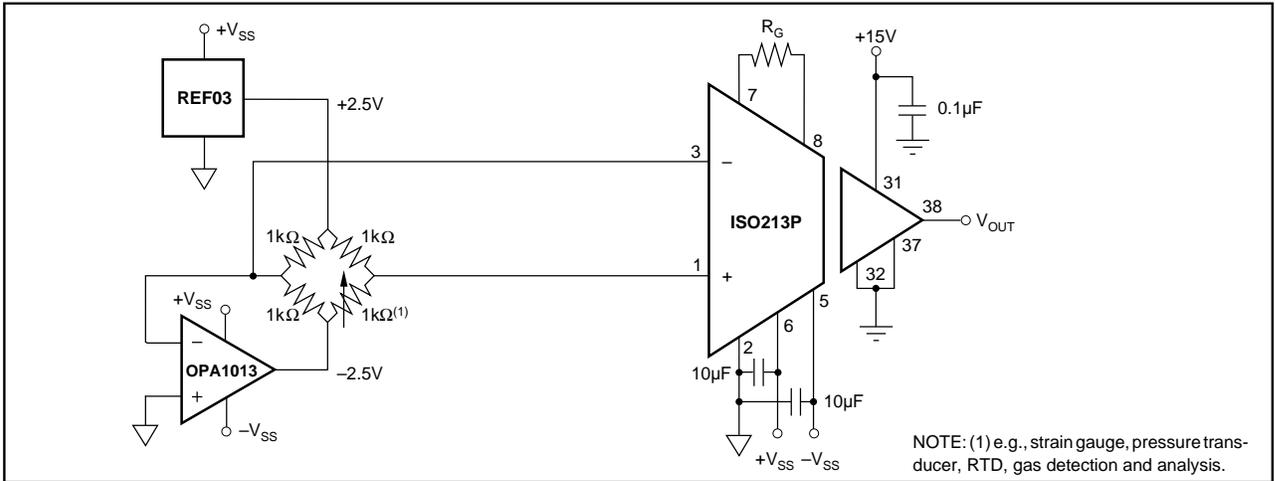


FIGURE 10. Instrument Bridge Isolation Amplifier.

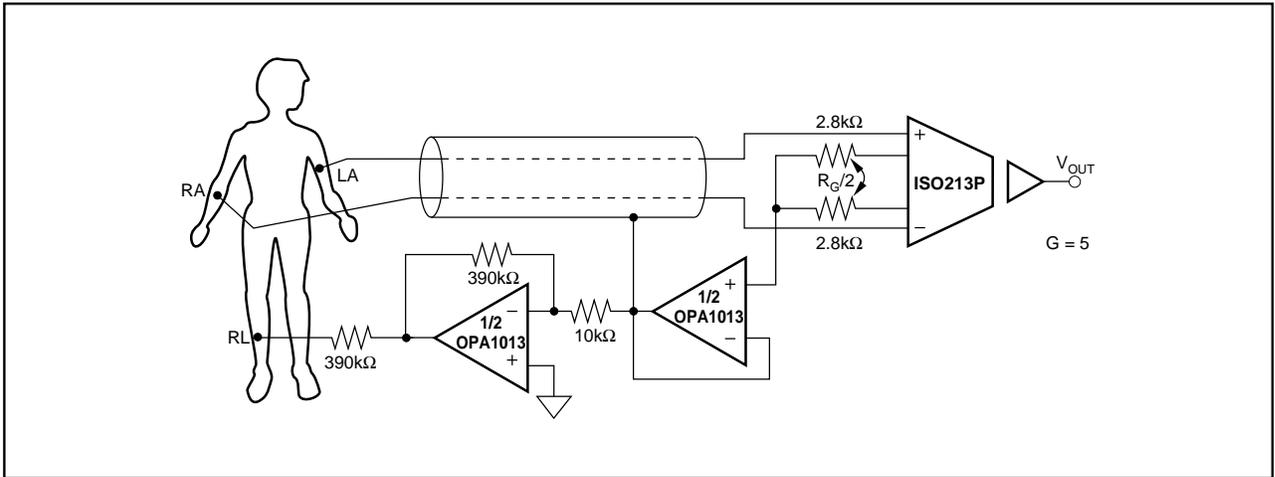


FIGURE 11. ECG Amplifier With Right-Leg Drive.

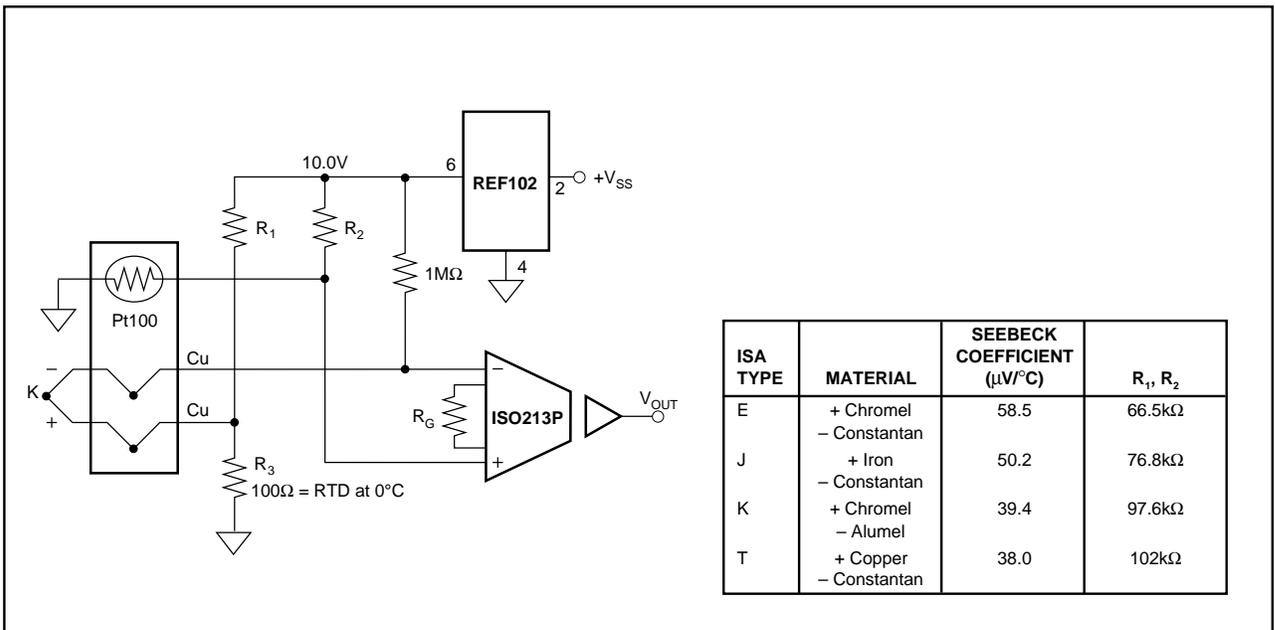


FIGURE 12. Thermocouple Amplifier With Cold Junction Compensation and Down-Scale Burn-Out.

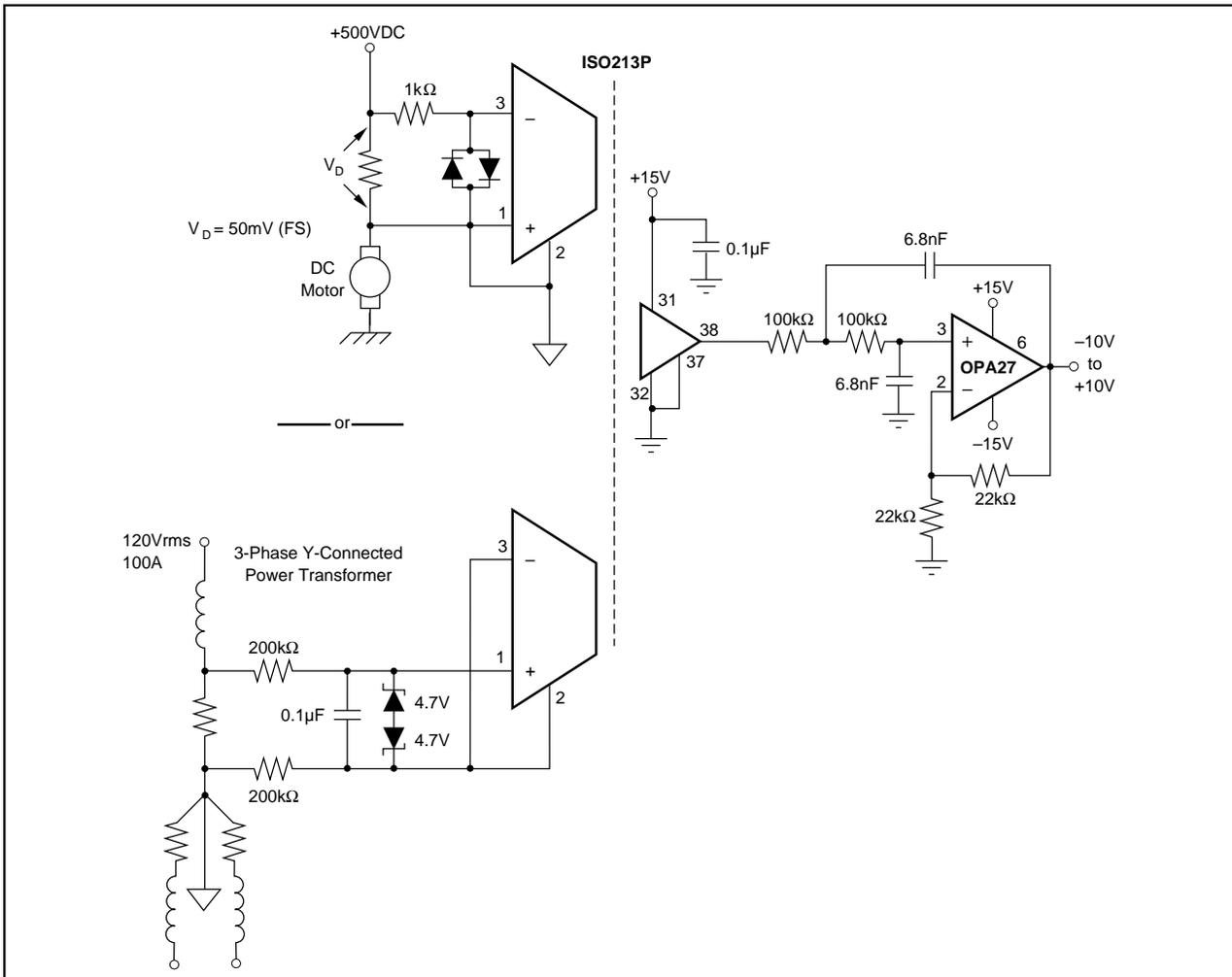


FIGURE 13. Isolated Current Monitoring Applications.

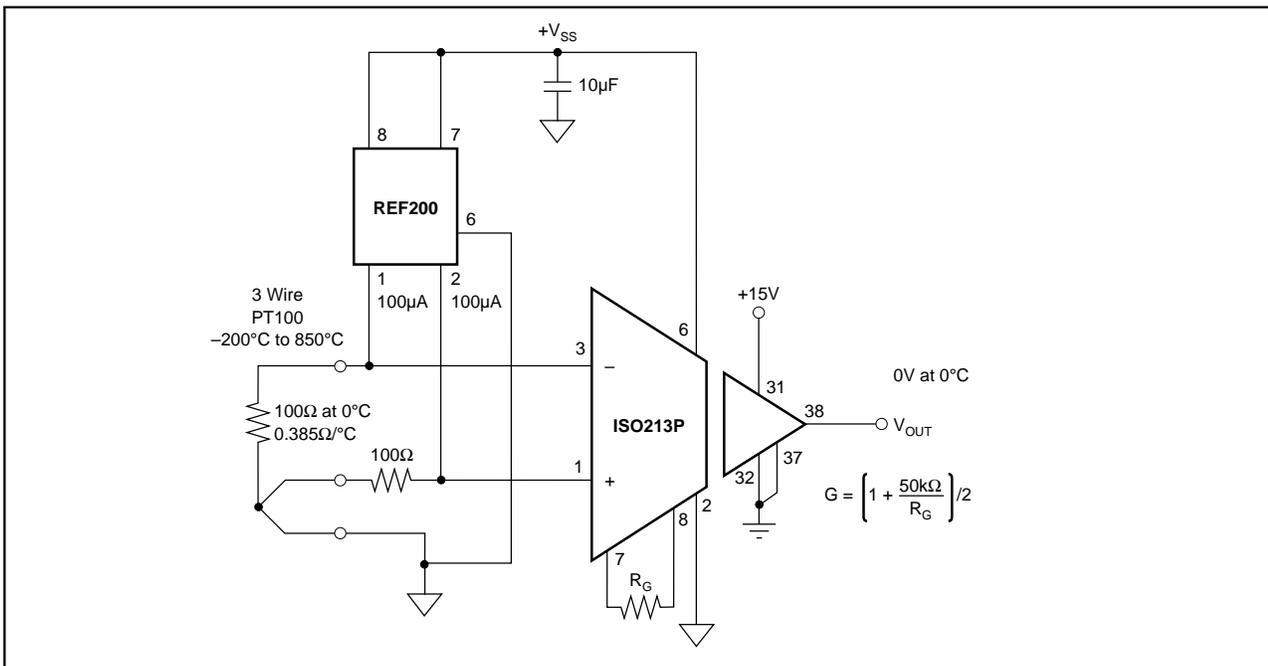


FIGURE 14. Isolated Temperature Sensing and Amplification.

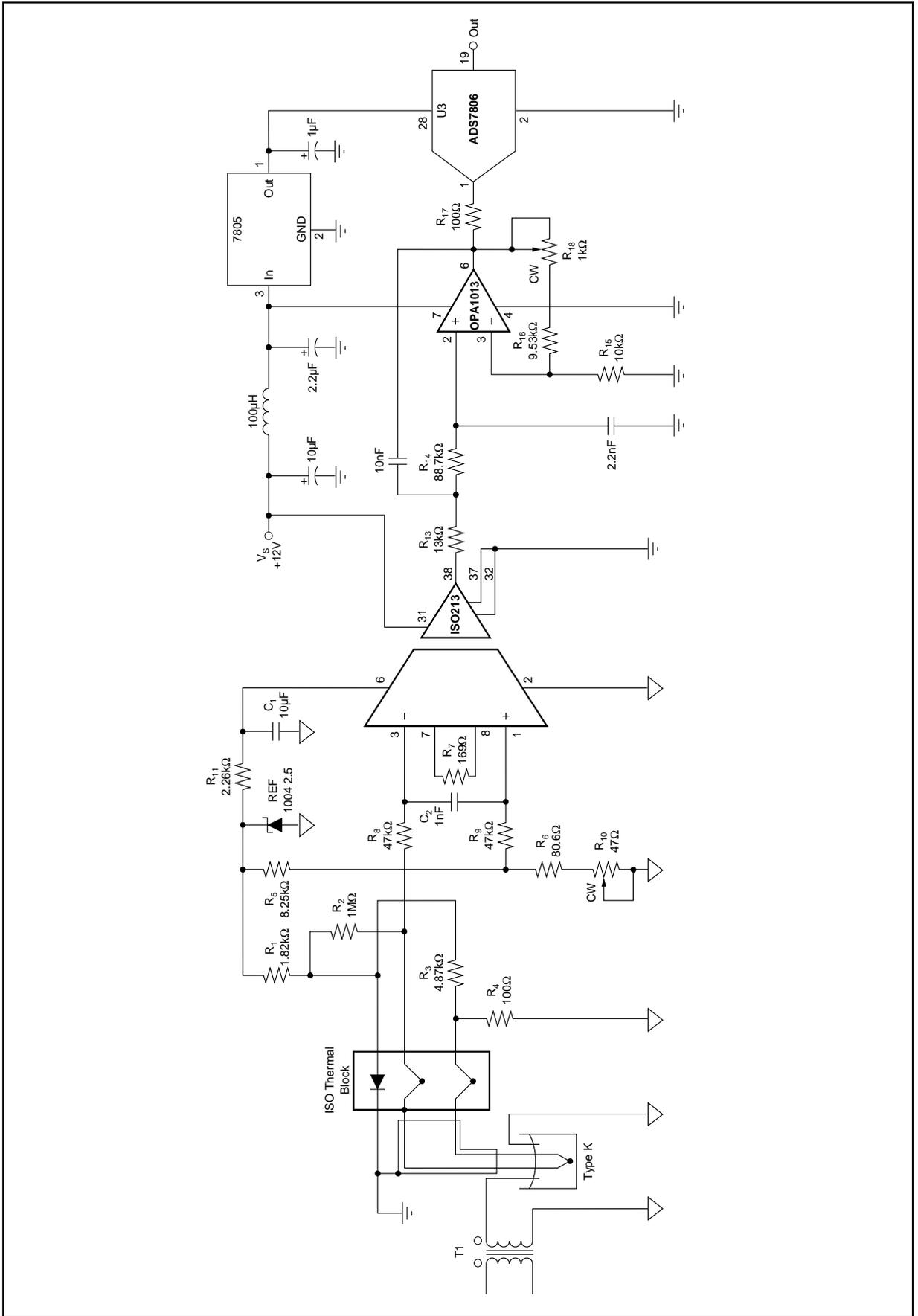


FIGURE 15. Complete Temperature Acquisition System.