AN ERROR ANALYSIS OF THE ISO102
IN A SMALL SIGNAL MEASURING APPLICATION

High accuracy measurements of low-level signals in the presence of high isolation mode voltages can be difficult due to the errors of the isolation amplifiers themselves.

This error analysis shows that when a low drift operational amplifier is used to preamplify the low-level source signal, a low cost, simple and accurate solution is possible.

In the circuit shown in Figure 1, a 50mV shunt is used to measure the current in a 500VDC motor. The OPA27 amplifies the 50mV by 200X to 10V full scale. The output of the OPA27 is fed to the input of the ISO102, which is a unity-gain isolation amplifier. The 5kΩ and 1kΩ potentiometers connected to the ISO102 are used to adjust the gain and offset errors to zero as described in the ISO102 data sheet.

SOME OBSERVATIONS

The total errors of the op amp and the iso amp combined are approximately 0.6% of full-scale range. If the op amp had not been used to preamplify the signal, the errors would have been 74.4% of FSR. Clearly, the small cost of adding the op amp buys a large performance improvement.

After gain and offset nulling, the dominant errors of the iso amp are gain nonlinearity and power supply rejection. Thus, well regulated supplies will reduce the errors even further.

The rms noise of the ISO102 with a 120Hz bandwidth is only 0.18mVrms, which is only 0.0018% of the 10V full-scale output. Therefore, even though the $16\mu V/\sqrt{Hz}$ noise spectral density specification may appear large compared to other isolation amplifiers, it does not turn out to be a significant error term. It is worth noting that even if the bandwidth is increased to 10kHz, the noise of the iso amp would only contribute 0.016% FSR error.
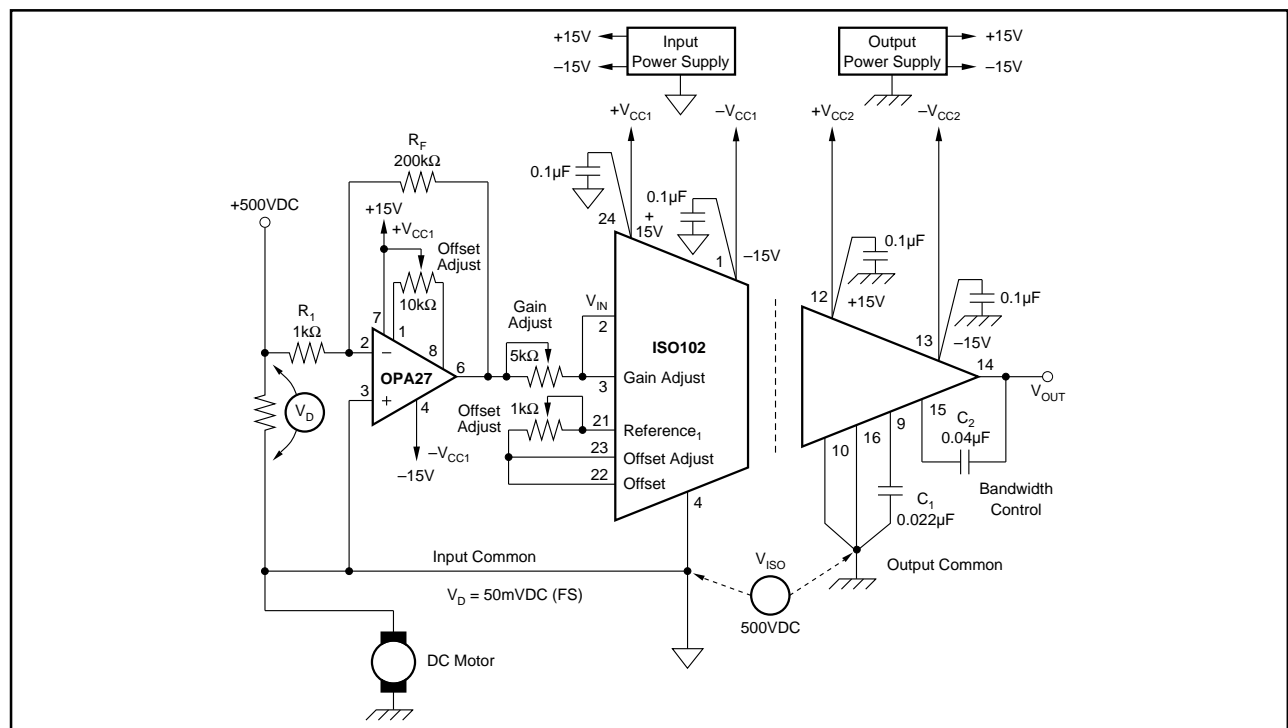

FIGURE 1. 50mV Shunt Measures Current in A 500VDC Motor.

THE ERRORS OF THE OP AMP AT 25°C (Referred to Input, RTI)

$$V_{E\,(OPA)} = V_D \left[1 - \frac{1}{1 + \dfrac{1}{\beta\,A_{VOL}}} \right] + V_{OS} \left[1 + \frac{R_1}{R_F} \right] + I_B R_1 + PSR + Noise$$

$V_{E\,(OPA)}$ = Total Op Amp Error (RTI)

V_D = Differential Voltage (Full Scale) Across Shunt

$$\left[1 - \frac{1}{1 + \dfrac{1}{\beta\,A_{VOL}}} \right] = \text{Gain Error Due to Finite Open Loop Gain}$$

β = Feedback Factor
A_{VOL} = Open Loop Gain at Signal Frequency
V_{OS} = Input Offset Voltage
I_B = Input Bias Current
PSR = Power Supply Rejection (μV/V) [Assuming a 20% change with ±15V supplies. Total error is twice that due to one supply.]

Noise = 5nV/$\sqrt{\text{Hz}}$ (for 1kΩ source resistance and 1kHz bandwidth)

ERROR$_{(OPA)}$ (RTI)	GAIN ERROR		OFFSET		PSR		NOISE
$V_{E\,(OPA)}$	$=50mV\left[1-\dfrac{1}{1+\dfrac{1}{10^6/200}}\right]$	$+$	$\left[0.025mV\left(1+\dfrac{1}{200}\right)+40\times10^{-9}\times10^3\right]$	$+$	$[20\mu V/V \times 3V \times 2]$	$+$	$[5nV\sqrt{120}\ (nVrms)]$
	$=$ 0.01mV	$+$	[0.0251mV + 0.04mV]	$+$	0.12mV	$+$	55nVrms
Error as % of FSR	$=$ 0.02%	$+$	[0.05% + 0.08%]	$+$	0.24%	$+$	0.00011%
After Nulling							
	$=$ 0.01mV	$+$	[0mV + 0mV]	$+$	0.12mV	$+$	55nVrms
	$=$ 0.13mV						
Error as % of FSR[1]	$=$ 0.02%	$+$	[0% + 0%]	$+$	0.24%	$+$	0.00011%
	$=$ 0.26% of 50mV						

NOTE: (1) FSR = Full-Scale Range. 50mV at input to op amp, or 10V at input (and output) of ISO amp.

THE ERRORS OF THE ISO AMP AT 25°C (RTI)

$$V_{E\,(ISO)} = \frac{1}{200}\left[\frac{V_{ISO}}{IMR} + V_{OS} + GE + Nonlinearity + PSR + Noise\right]$$

$V_{E\,(ISO)}$ = Total ISO Amp Error
IMR = Isolation Mode Rejection
V_{OS} = Input Offset Voltage
$V_{ISO} = V_{IMV}$ = Isolation Voltage = Isolation Mode Voltage
GE = Gain Error (% of FSR)
Nonlinearity = Peak-to-peak deviation of output voltage from best-fit straight line. It is expressed as ratio based on full-scale range.
PSR = Change in V_{OS}/10V x Supply Change

Noise = Spectral noise density x $\sqrt{\text{bandwidth}}$. It is recommended that bandwidth be limited to twice maximum signal bandwidth for optimum dynamic range.

ERROR$_{(ISO)}$ (RTI)		IMR		V_{OS}		GAIN ERROR		NONLINEARITY		PSR		NOISE	
$V_{E\,(ISO)}$	$=\dfrac{1}{200}\Big[$	$\dfrac{500VDC}{140dB}$	$+$	70mV	$+$	$20V\times\dfrac{0.25}{100}$	$+$	$\dfrac{0.75}{100}\times20V$	$+$	3.7mV x 3V x 2	$+$	$16\mu V\sqrt{120}$ (rms)	$\Big]$
	$=\dfrac{1}{200}\Big[$	0.05mV	$+$	70mV	$+$	50mV	$+$	15mV	$+$	22.2mV	$+$	0.175mVrms	$\Big]$
Error as % of FSR[1]	$=\dfrac{1}{200}\Big[$	0.0005%	$+$	0.7%	$+$	0.5%	$+$	0.15%	$+$	0.22%	$+$	0.00175%	$\Big]$
After Nulling													
$V_{E\,(ISO)}$	$=\dfrac{1}{200}\Big[$	0.05mV	$+$	0mV	$+$	0mV	$+$	15mV	$+$	22.2mV	$+$	0.175mVrms	$\Big]$
	$=\dfrac{1}{200}$	37.2mV											
	$=$	0.19mV											
Error as % of FSR	$=\dfrac{1}{200}\Big[$	0.0005%	$+$	0%	$+$	0%	$+$	0.15%	$+$	0.22%	$+$	0.00175%	$\Big]$
	$=$	0.37% of 50mV											
Total Error	$=$	$V_{E\,(OPA)}$	$+$	$V_{E\,(ISO)}$									
	$=$	0.13mV	$+$	0.19mV									
	$=$	0.32mV											
	$=$	0.64% of 50mV											

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