Amplificador de Instrumentación real

# **ANÁLISIS DE ERRORES**

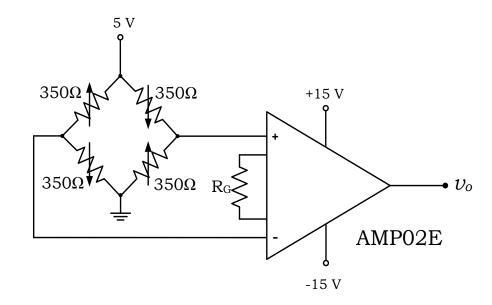


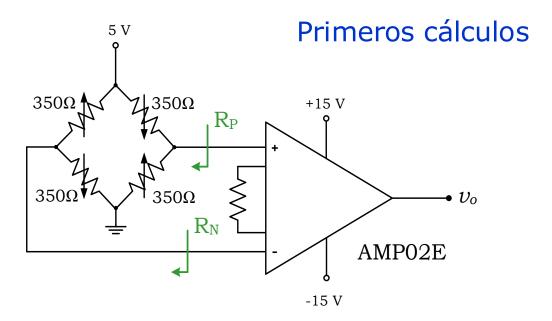
#### Ejercicio E5. Circuito acondicionador: cálculo de errores

Pregunta: En el acondicionador de la figura, calcular el máximo error que introduce el amplificador de instrumentación en la medida

#### DATOS:

- $\Box$  FSR<sub>1</sub> = 20 mV
- $\Box$   $V_D(FS) = 20 \text{ mV}$
- $\Box$  -40°C  $\leq$  T  $\leq$  85°C
- $\square$  R<sub>G</sub> = 86,6  $\Omega$
- $\square$  R<sub>G</sub>: 0,1% TOL y TC = 15 ppm/°C



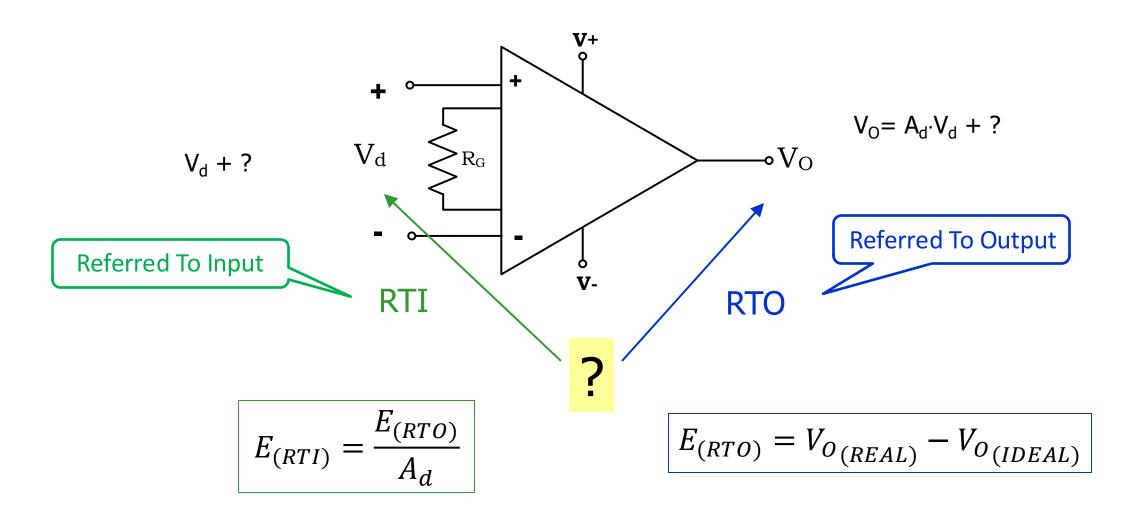


V<sub>D</sub> y V<sub>C</sub> de salida del puente.

Ganancia del AI.

Cálculo de R<sub>P</sub> y R<sub>N</sub>.

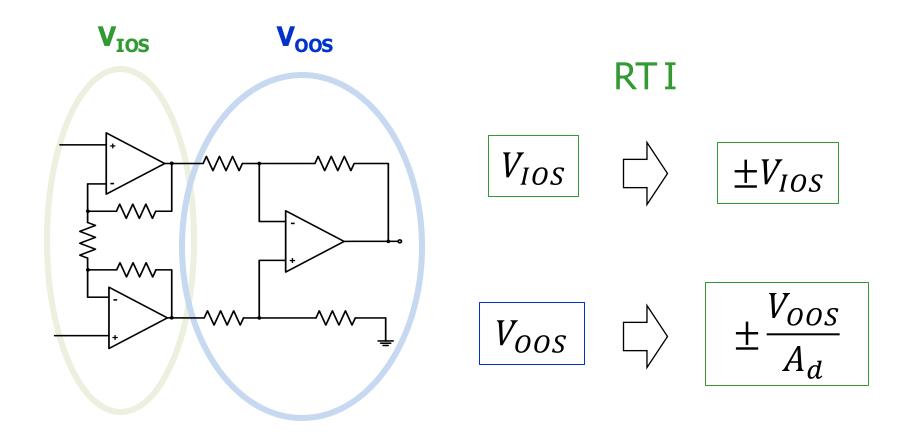
# Conceptos previos



#### Estimación pormenorizada del error: Fuentes de Error

- $\triangleright$   $V_{IOS}$ ,  $V_{OOS}$
- $\succeq$  TC[V<sub>IOS</sub>], TC[V<sub>OOS</sub>]
- $\triangleright$   $I_B, I_{OS}$
- $\succeq$  TC[I<sub>B</sub>], TC[I<sub>OS</sub>]
- **™** CMR
- > PSR
- 🖎 en
- > NL
- ≥ EG
- $\succeq$  TC[A<sub>d</sub>]
- Tolerancia R → EG
- $^{\sim}$  TC[R]  $\rightarrow$  EG

#### Efecto de la tensión de offset



# Efecto de la tensión de offset

# AMP02-SPECIFICATIONS

				AMP02E		
Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE						
Input Offset Voltage	$V_{IOS}$	$T_A = +25^{\circ}C$		20	100	μV
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	200	μV
Input Offset Voltage Drift	$TCV_{IOS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		0.5	2	μV/°C
Output Offset Voltage	$V_{OOS}$	$T_A = +25$ °C		1	4	mV
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		4	10	mV
Output Offset Voltage Drift		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	100	μV/°C
Power Supply Rejection	PSR	$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$				
		G = 100, 1000	115	125		dB
		G = 10	100	110		dB
		G = 1	80	90		dB
		$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$				
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$				
		G = 1000, 100	110	120		dB
		G = 10	95	110		dB
		G = 1	75	90		dB

### Efecto de la tensión de offset

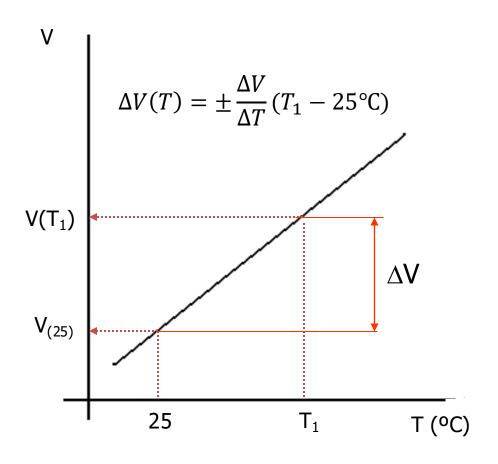
### AMP02-SPECIFICATIONS

Parameter	Symbol	Conditions	Min	Typ	С Мах	Units
OFFSET VOLTAGE Input Offset Voltage  Input Offset Voltage Drift Output Offset Voltage	V <sub>IOS</sub> TCV <sub>IOS</sub> V <sub>OOS</sub>	$T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$ $T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$		20 50 0.5 1 4	100 200 2 4 10	μV μV μV/°C mV mV

	E <sub>(RTI)</sub>	) (V)	$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$			
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido		
V <sub>IOS</sub> = 100 uV						
V <sub>oos</sub> = 4 mV						

		$Error_{(RII)}(V)$	$%FSR = \frac{Errc}{}$	$\frac{or_{(R\Pi)}(V)}{FSR_r}$ · 100
	Expresión del error (V)	Error (V)	OS. G NO Corregidos	OS. G SI Corregidos 25°C
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578.36} = \pm 6.9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IC}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{oos}] = 100 \mu V / {}^{\circ}C = \frac{\Delta V_0}{\Delta C}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
$I_B=10nA; I_{OS}=5nA$	$\pm \left[I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N)\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150  pA / {}^{o}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$		$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR = 110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR = 110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$		0	0
$e_{np-p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% se supone para FSR (±13 NL <sub>real</sub> =0,006·[26/(20·10·3·578,36)]=0,0.	$ \pm V_D \cdot \frac{NL_{real}(\%)}{100} $	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5 \% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$	$\frac{G=577,79}{G=578,94}$ $\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_G] = 15 \ ppm / {}^{o}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^{6}$ $R_G' = R_g \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$	$\frac{G=577,84}{G=578,92}$ $\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	MAYIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,2378< td=""></error<1,2378<></td></error<2,31387<>	-1,22687 <error<1,2378< td=""></error<1,2378<>

# Efecto de la temperatura en las tensiones de offset



$$TC_{V_{IOS}} = \frac{\Delta V_{IOS}}{\Delta T}$$

$$\Delta V_{IOS_{(RTI)}} = \pm \left[TC_{V_{IOS}} \times (T - 25^{\circ}\text{C})\right]$$

$$TC_{V_{OOS}} = \frac{\Delta V_{OOS}}{\Delta T}$$

$$\Delta V_{OOS_{(RTI)}} = \pm \frac{1}{A_d} \left[TC_{V_{OOS}} \times (T - 25^{\circ}\text{C})\right]$$

#### Efecto de T en las tensiones de offset

# AMP02-SPECIFICATIONS

				AMP02E		
Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE						
Input Offset Voltage	$V_{IOS}$	$T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$		20 50	100 200	μV μV
Input Offset Voltage Drift Output Offset Voltage	TCV <sub>IOS</sub> V <sub>OOS</sub>	$-40^{\circ}\text{C} \le \text{T}_{\text{A}}^{N} \le +85^{\circ}\text{C}$ $\text{T}_{\text{A}} = +25^{\circ}\text{C}$		0.5 1	2 4	μV/°C mV
output offset voltage	1003	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		4	10	mV
Output Offset Voltage Drift Power Supply Rejection	TCV <sub>OOS</sub> PSR	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$ V <sub>S</sub> = ±4.8 V to ±18 V		50	100	μV/°C
		G = 100, 1000	115	125		dB
		G = 10	100	110		dB
		$G = 1 V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V} -40^{\circ}\text{C} \le T_A \le +85^{\circ}\text{C}$	80	90		dB
		G = 1000, 100	110	120		dB
		G = 10 G = 1	95 75	110 90		dB dB
INPUT CURRENT						
Input Bias Current	$I_{\mathrm{B}}$	$T_A = +25^{\circ}C$		2	10	nA
Input Bias Current Drift	TCIB	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		150	г	pA/°C
Input Offset Current Input Offset Current Drift	I <sub>OS</sub> TCI <sub>OS</sub>	$T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$		1.2 9	5	nA pA/°C

#### Efecto de T en las tensiones de offset

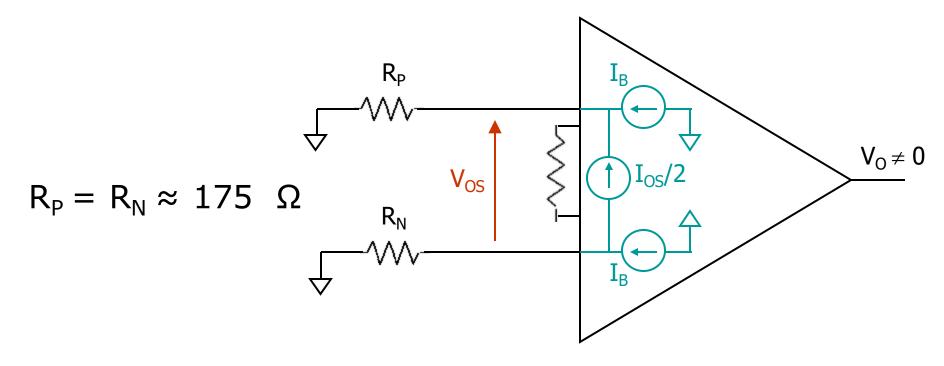
# AMP02-SPECIFICATIONS

					AMP02E	2	
Parame	eter	Symbol	Conditions	Min	Typ	Max	Units
OFFSE	T VOLTAGE						
Input	t Offset Voltage	$V_{IOS}$	$T_A = +25^{\circ}C$		20	100	μV
			$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	<u>20</u> 0	μV
	t Offset Voltage Drift	$TCV_{IOS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		0.5	2	μV/°C
Outp	ut Offset Voltage	$V_{OOS}$	$T_A = +25^{\circ}C$		1	4	mV
			$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		4	10	mV
	ut Offset Voltage Drift	TCV <sub>oos</sub>	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	100	μV/°C
Powe	r Supply Rejection	DCB	$V_0 = \pm 1.8 \text{ V} \text{ to } \pm 1.8 \text{ V}$				

		$E_{(RTI)}(\%) = 100 \cdot E_{(I)}$	$_{RTI)}(V) / FSR_{i}(V)$	
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido
$TC[V_{IOS}] = \frac{\Delta V_{IOS}}{\Delta T} =$ $= 2 \mu V / {}^{\circ}C$				
$TC[V_{oos}] = \frac{\Delta V_{oos}}{\Delta T} =$ $= 100 \ \mu V / ^{\circ} C$				

		$Error_{(RII)}(V)$	%FSR = Erro	$\frac{Dr_{(RII)}(V)}{FSR_I} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}=100 \mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
$I_B=10nA; I_{OS}=5nA$	$\pm \left[I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N)\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150  pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR = 110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{npp}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>real</sub> =0,006·[26/(20·10·3·578,36)]=0,0134%FSR	$\pmV_{\rm D}\cdot\frac{N\!L_{\rm real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_{D}}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0,5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ G = 578,94	$\frac{V_{D}}{G} \cdot (G_{R} - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_G] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $R_G' = R_g \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

# Efecto de las corrientes de polarización y de offset: I<sub>B</sub> e I<sub>OS</sub>



Como, generalmente, desconocemos el signo de  $I_B$  e  $I_{OS}$ , calcularemos:

$$V_{OS(RTI)} = \pm \left[ I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} (R_P + R_N) \right]$$

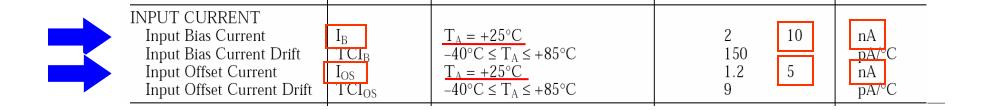
# Efecto I<sub>B</sub> e I<sub>OS</sub>

# AMPO2—SPECIFICATIONS ELECTRICAL CHARACTERISTICS (@ $V_S = \pm 15$ V, $V_{CM} = 0$ V, $T_A = +25$ °C, unless otherwise noted.)

			AMP02E			
Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE						
Input Offset Voltage	$V_{IOS}$	$T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$		20 50	100 200	μV μV
Input Offset Voltage Drift	$TCV_{IOS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}}^{\text{C}} \le +85^{\circ}\text{C}$		0.5	2	μV/°C
Output Offset Voltage	V <sub>OOS</sub>	$T_A = +25^{\circ}C$		1	4	mV
0.4.4.000.4.14.15.10	TOU	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		4	10	mV
Output Offset Voltage Drift	TCV <sub>OOS</sub> PSR	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$ V <sub>S</sub> = ±4.8 V to ±18 V		50	100	μV/°C
Power Supply Rejection	rsk	$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$ $G = 100, 1000$	115	125		dB
		G = 100, 1000 G = 10	100	110		dB dB
		G = 1	80	90		dB
		$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$				
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		100		170
		G = 1000, 100	110	120		dB
		G = 10 $G = 1$	95 75	110 90		dB dB
		G = 1	13	90		иБ
INPUT CURRENT	т	T . 25°C		2	1.0	A
Input Bias Current	I <sub>B</sub>	$T_A = +25^{\circ}C$		2 150	10	nA
Input Bias Current Drift Input Offset Current	$egin{array}{c} {\sf TCI_B} \ {\sf I_{OS}} \end{array}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$ $\text{T}_{\text{A}} = +25^{\circ}\text{C}$		150 1.2	5	pA/°C nA
Input Offset Current Drift	TCI <sub>OS</sub>	$-40^{\circ}\text{C} \le T_{\text{A}} \le +85^{\circ}\text{C}$		9	J	pA/°C

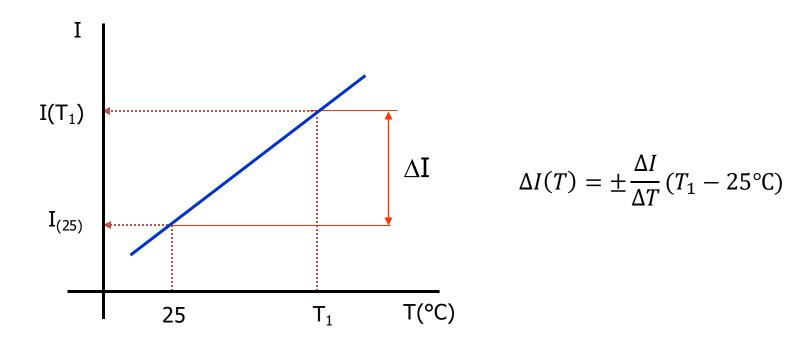
# Efecto de I<sub>B</sub> e I<sub>OS</sub>

	E <sub>(RTI)</sub> (	$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$			
	Expresión error (V)	Expresión error (V) Error (V)		OS, G corregido	
$I_B = 10nA$					
$I_B = 10nA$ $I_{OS} = 5nA$					



		$Error_{(RII)}(V)$	$%FSR = \frac{Erro}{}$	$\frac{r_{(R\Pi)}(V)}{FSR_I} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
$V_{OOS}$ =4 $mV$	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
$I_B=10nA; I_{OS}=5nA$	$\pm \left[ I_{B} \cdot \left( R_{P} - R_{N} \right) + \frac{I_{OS}}{2} \cdot \left( R_{P} + R_{N} \right) \right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150  pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR = 110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np\cdot p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>rea</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm  V_{\scriptscriptstyle D} \cdot \frac{N L_{\rm real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0.57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0.58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_G] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $R_G = R_z \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

# Efecto de la temperatura en l<sub>B</sub> e l<sub>OS</sub>



Como, generalmente, desconocemos el signo de I<sub>B</sub> e I<sub>OS</sub> calcularemos:

$$\Delta V_{OS(RTI)} = \pm \left[ TC_{I_B}(T - 25)(R_P - R_N) + TC_{I_{OS}}(T - 25) \frac{(R_P + R_N)}{2} \right]$$

# Efecto de la temperatura en la e los

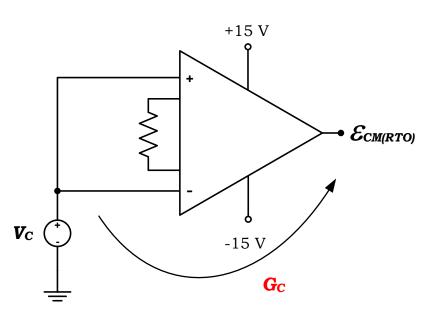
			<u> </u>	AMP02E	•	
Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE Input Offset Voltage  Input Offset Voltage Drift Output Offset Voltage  Output Offset Voltage Drift Power Supply Rejection	V <sub>IOS</sub> TCV <sub>IOS</sub> V <sub>OOS</sub> TCV <sub>OOS</sub> PSR	$\begin{split} T_A &= +25^{\circ}C \\ -40^{\circ}C \leq T_A \leq +85^{\circ}C \\ V_S &= \pm 4.8 \text{ V to } \pm 18 \text{ V} \\ G &= 100, 1000 \\ G &= 10 \\ G &= 1 \\ V_S &= \pm 4.8 \text{ V to } \pm 18 \text{ V} \\ -40^{\circ}C \leq T_A \leq +85^{\circ}C \\ G &= 1000, 100 \\ G &= 10 \\ G &= 1 \\ G &= 1 \end{split}$	115 100 80 110 95 75	20 50 0.5 1 4 50 125 110 90	100 200 2 4 10 100	μV μV μV/°C mV mV μV/°C dB dB dB dB
INPUT CURRENT Input Bias Current Input Bias Current Drift Input Offset Current Input Offset Current	I <sub>B</sub> TCI <sub>B</sub> I <sub>OS</sub> TCI <sub>OS</sub>	$T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$ $T_A = +25^{\circ}C$ $-40^{\circ}C \le T_A \le +85^{\circ}C$		2 150 1.2 9	10 5	nA pA/°C nA pA/°C

# Efecto de la temperatura en la e los

	E <sub>(RTI)</sub> (V	$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$		
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido
$TC[I_B] = \frac{\Delta I_B}{\Delta T} =$ $= 150 \ pA/^{\circ} C$				
$TC[I_{OS}] = \frac{\Delta I_{OS}}{\Delta T} =$ $= 9 \ pA/^{\circ} C$	=			
	INPUT CURRENT Input Bias Current Input Bias Current Drift Input Offset Current Input Offset Current Input Offset Current Drift Input Offset Current Drift	$T_{A} = +25^{\circ}C$ $-40^{\circ}C \le T_{A} \le +85^{\circ}C$ $T_{A} = +25^{\circ}C$ $-40^{\circ}C \le T_{A} \le +85^{\circ}C$	2 10 nA 150 pA/°C 12 5 nA pA/°C	]

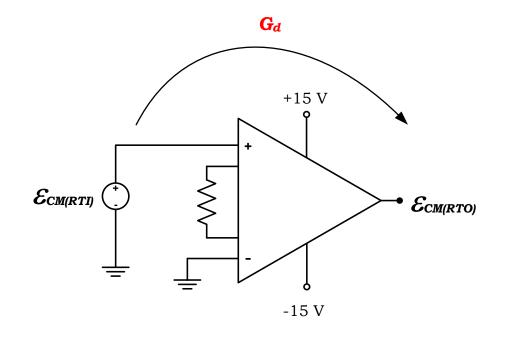
		$Error_{(RII)}(V)$	$%FSR = \frac{Erro}{}$	$\frac{\partial r_{(RH)}(V)}{FSR_I} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}=100  \mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
I <sub>B</sub> =10nA; I <sub>OS</sub> =5nA	$\pm \left[ I_{B} \cdot (R_{P} - R_{N}) + \frac{I_{OS}}{2} \cdot (R_{P} + R_{N}) \right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150 \ pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR = 110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np\cdot p}=0.4~\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>rea</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm V_{\rm D} \cdot \frac{NL_{\rm real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0.0134}{100} = \pm 2.68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0,5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$		$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_G] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $R_G = R_g \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

#### Efecto de la Tensión en Modo Común



$$E_{CM(RTO)} = A_C \times V_C \quad CMR_{AI} = \frac{A_d}{A_C}$$

$$E_{CM(RTO)} = \frac{A_d}{CMR_{AI}} \times V_C = \frac{A_d}{10^{\frac{CMRR_{AI}}{20}}} \times V_C$$



$$E_{CM(RTI)} = \frac{E_{CM(RTO)}}{A_d} = \frac{V_C}{CMR_{AI}} = \frac{V_C}{10^{\frac{CMRR_{AI}}{20}}}$$

i Igual que hacíamos con el AO!

#### Efecto de la Tensión en Modo Común

				AMP02E		
Parameter	Symbol	Conditions	Min	Тур	Max	Units
INPUT						
Input Resistance	$R_{IN}$	Differential, $G \le 1000$		10		GΩ
-		Common-Mode, $G = 1000$		16.5		$G\Omega$
Input Voltage Range	IVR	$T_A = +25^{\circ}C$ (Note 1)	±11			V
Common-Mode Rejection	CMR	$V_{CM} = \pm 11 \text{ V}$				
		G = 1000, 100	115	120		dB
		G = 10	100	115		d₿
Va bay TC así		G = 1	80	95		dB
No hay TC, así		$V_{CM} = \pm 11 \text{ V}$				
que elegimos el		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		100		470
•		G = 100, 1000	110	120		dB
caso peor en T		G = 10	95	110		dB
		G = 1	75	90		dB
GAIN						
Gain Equation	$G = \frac{50 \text{ k}\Omega}{R_G} + 1$	G = 1000			0.50	%
Accuracy	$G = \frac{30 \text{ K}_{22}}{D} + 1$	G = 100			0.30	%
	K <sub>G</sub>	G = 10			0.25	%
		G = 1			0.02	%
Gain Range	G		1		10k	V/V
Nonlinearity	_	G = 1  to  1000		0.006		%
Temperature Coefficient	$G_{TC}$	$1 \le G \le 1000 \text{ (Notes 2, 3)}$		20	50	ppm/°C

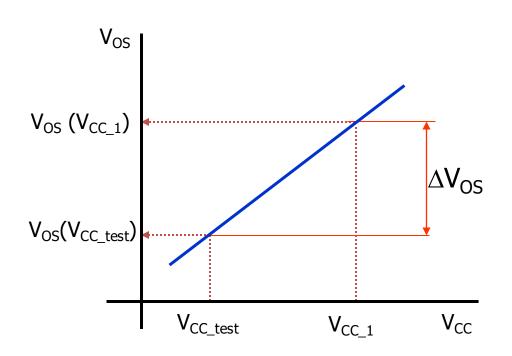
#### Efecto de la Tensión en Modo Común

Parameter	Symbol	Conditions	Min	AMP02F Typ	Max	Units
INPUT						
Input Resistance	$R_{IN}$	Differential, G ≤ 1000		10		GΩ
	1 "	Common-Mode, G = 1000		16.5		GΩ
Input Voltage Range	IVR	$T_A = +25^{\circ}C \text{ (Note 1)}$	±11			V
Common-Mode Rejection	CMR	$V_{CM} = \pm 11 \text{ V}$				
v		G = 1000, 100	115	120		dB
		G = 10	100	115		dB
		G = 1	80	95		dB
		$V_{CM} = \pm 11 \text{ V}$				
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$				
		G = 100, 1000	110	120		dB
		0 10	OF	110		-ID

	E <sub>(RTI)</sub> (V)		$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$		
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido	
CMRR = 110 dB					

		$Error_{(RII)}(V)$	$%FSR = \frac{Erro}{}$	$\frac{P_{(R\Pi)}(V)}{FSR_t} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}=100~\mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
I <sub>B</sub> =10nA; I <sub>OS</sub> =5nA	$\pm \left[ I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N) \right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150  pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9^{\circ}10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np.p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>real</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm  V_{\rm D} \cdot \frac{NL_{\rm real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$	$\frac{V_{D}}{G} \cdot (G_{R} - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_{G}] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^{6}$ $R_{G} = R_{g} \pm \Delta R = R_{G} \pm \frac{\Delta R_{G}}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

#### PSR: rechazo a las variaciones de la alimentación (V<sub>CC</sub>)



$$\Delta V_{OS(RTI)}(V_{CC_1}) = \pm \frac{\Delta V_{OS}}{\Delta V_{CC}} (V_{CC_1} - V_{CC_test})$$

Como:

$$PSRR = 20 \log \left( \frac{\Delta V_{CC}}{\Delta V_{OS}} \right)$$



$$\Delta V_{OS(RTI)} = \pm \frac{\Delta V_{CC}}{10^{\frac{PSRR}{20}}}$$

i Igual que hacíamos con el AO!

#### PSR: rechazo a las variaciones de Vcc

# AMP02-SPECIFICATIONS

				AMP02H	<u>-</u>	
Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE						
Input Offset Voltage	$V_{IOS}$	$T_A = +25^{\circ}C$		20	100	μV
I	TO V	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	200	μV
Input Offset Voltage Drift	$TCV_{IOS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		0.5	2	μV/°C
Output Offset Voltage	$V_{OOS}$	$T_A = +25^{\circ}C$ -40°C \le T_A \le +85°C		$\frac{1}{4}$	$\frac{4}{10}$	mV mV
Output Offset Voltage Drift	$TCV_{OOS}$	$-40^{\circ}\text{C} \le T_A \le +85^{\circ}\text{C}$ $-40^{\circ}\text{C} \le T_A \le +85^{\circ}\text{C}$		50	100	μV/°C
Power Supply Rejection	PSR	$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$		30	100	μνν
Tower supply regestion	1 011	G = 100, 1000	115	125		dB
		G = 10	100	110		dB
No hay TC, así		G = 1	80	90		dB
		$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$				
que elegimos el		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$	110	120		4D
caso peor en T		G = 1000, 100 G = 10	110 95	120 110		dB dB
рост от		G = 10 G = 1	75	90		dB
INPUT CURRENT						
Input Bias Current	$ m I_B$	$T_A = +25^{\circ}C$		2	10	nA
Input Bias Current Drift	TCI <sub>B</sub>	$-40^{\circ}\text{C} \le T_{\text{A}} \le +85^{\circ}\text{C}$		- 150		pA/°C
Input Offset Current	$I_{OS}$	$T_A = +25^{\circ}C$		1.2	5	nA
Input Offset Current Drift	$TCI_{OS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		9		pA/°C

#### PSR: rechazo a las variaciones de Vcc

# AMPO2-SPECIFICATIONS

				AMP02I	E	
Parameter	Symbol	Conditions	Min	Typ	Max	Units
OFFSET VOLTAGE						
Input Offset Voltage	$V_{IOS}$	$T_A = +25^{\circ}C$		20	100	μV
•		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	200	μV
Input Offset Voltage Drift	$TCV_{IOS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		0.5	2	μV/°C
Output Offset Voltage	$V_{OOS}$	$T_A = +25^{\circ}C$		1	4	mV
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		4	10	mV
Output Offset Voltage Drift	$TCV_{OOS}$	$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$		50	100	μV/°C
Power Supply Rejection	PSR	$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$				
		G = 100, 1000	115	125		dB
		G = 10	100	110		dB
		G = 1	80	90		dB
		$V_S = \pm 4.8 \text{ V to } \pm 18 \text{ V}$				
		$-40^{\circ}\text{C} \le \text{T}_{\text{A}} \le +85^{\circ}\text{C}$				
		G = 1000, 100	110	120		dB
		C 10	0.5	110		1D

	E <sub>(RTI)</sub> (	<b>V</b> )	$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$		
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido	
PSR=110dB					
1311-11005					

		$Error_{(RII)}(V)$	$%FSR = \frac{Erro}{}$	$\frac{or_{(R\Pi)}(V)}{FSR_I} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
$I_B=10nA; I_{OS}=5nA$	$\pm \left[I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N)\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150  pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR = 110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np.p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% se supone para FSR (±13V) NL <sub>red</sub> =0,006·[26/(20·10·3·578,36)]=0,0134%FSR	$\pm  V_{\scriptscriptstyle D} \cdot \frac{NL_{\scriptscriptstyle real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0.0134}{100} = \pm 2.68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_G] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $R_G = R_g \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

# Efecto del ruido

				AMP02E		
Parameter	Symbol	Conditions	Min	Тур	Max	Units
OUTPUT RATING Output Voltage Swing Positive Current Limit Negative Current Limit	V <sub>OUT</sub>	$T_A = +25^{\circ}\text{C}$ , $R_L = 1 \text{ k}\Omega$ $R_L = 1 \text{ k}\Omega$ , $-40^{\circ}\text{C} \le T_A \le +85^{\circ}\text{C}$ Output-to-Ground Short Output-to-Ground Short	±12 ±11	±13 ±12 22 32		V V mA mA
NOISE Voltage Density, RTI  Noise Current Density, RTI Input Noise Voltage	i <sub>n</sub> e <sub>n</sub> p-p	$\begin{split} f_O &= 1 \text{ kHz} \\ G &= 1000 \\ G &= 100 \\ G &= 10 \\ G &= 1 \end{split}$ $f_O &= 1 \text{ kHz}, G &= 1000 \\ 0.1 \text{ Hz to } 10 \text{ Hz} \\ G &= 1000 \\ G &= 100 \\ G &= 10 \end{split}$		9 10 18 120 0.4 0.4 0.5 1.2		nV/√Hz nV/√Hz nV/√Hz nV/√Hz pA/√Hz μV p-p μV p-p

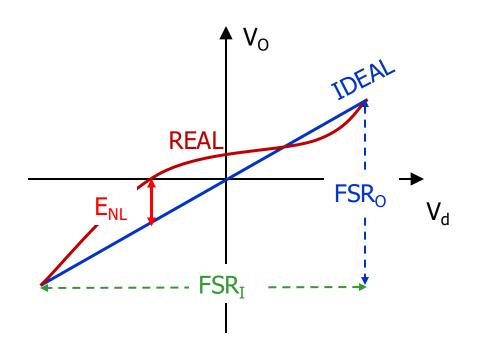
# Efecto del ruido

		E <sub>(RTI)</sub> (V)	$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$		
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido	
$e_{np-p} = 0.4 \mu V_{p-p}$					

Noise Current Density, RTI Input Noise Voltage	i <sub>n</sub> e <sub>n</sub> p-p	f <sub>O</sub> = 1 kHz, G = 1000 0.1 Hz to 10 Hz	0.4	pA√Hz
Input Proper Voltage	on P P	G = 1000 G = 100 G = 10	0.4 0.5 1.2	μV p-p μV p-p μV p-p

	$Error_{(RII)}(V)$		$%FSR = \frac{Error_{(RII)}(V)}{FSR_I} \cdot 100$		
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)	
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$		±0,5	0	
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0	
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65	
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05	
I <sub>B</sub> =10nA; I <sub>OS</sub> =5nA	$\pm \left[I_{B} \cdot (R_{P} - R_{N}) + \frac{I_{OS}}{2} \cdot (R_{P} + R_{N})\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0	
$TC[I_B] = 150  pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0	
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\frac{1}{\sqrt{{}^{o}C} = \frac{\Delta I_{OS}}{\Delta T}} \qquad \frac{\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_{p} + R_{N})}{\Delta T} \qquad \pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}}$		±0,00047	±0,00047	
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0	
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0	
$e_{np.p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001	
2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>real</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm V_D \cdot \frac{NL_{real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134	
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0	
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325	
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$	$\frac{V_{D}}{G} \cdot (G_{R} - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>	
$TC[R_G] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $R_G = R_g \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>	
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>	

#### Efecto de la NL



$$NL(V) = (V_{o(REAL)} - V_{o(IDEAL)})_{max}$$

$$NL(\%FSR_O) = \frac{\left(V_{o\ (REAL)} - V_{o\ (IDEAL)}\right)_{max}}{FSR_O} \times 100$$

En el catálogo se da en módulo

Con ello la tensión de error se calcula:

$$E_{NL\ (RTO)}(V) = \pm \frac{NL}{100} FSR_O$$

$$E_{NL\ (RTI)}(V) = \frac{E_{NL\ (RTO)}(V)}{A_d} = \pm \frac{NL}{100} \frac{FSR_O}{A_d} = \pm \frac{NL}{100} FSR_I$$

#### Detalle para el cálculo del error por NL

- El fabricante expresa la NL (%) de forma relativa al FSR<sub>O (AI)</sub>(V) del AI que viene determinado por el parámetro Output Voltage Swing
- P.ej., si el Output Voltage Swing =  $\pm 13 \text{ V} \rightarrow \text{FSR}_{O(AI)}(V) = 26 \text{ V}$
- Hay que determinar la NL<sub>real</sub> (%) para el rango de fondo de escala del circuito, que no tiene que ser el mismo que el del AI.
- P.ej., si el FSR<sub>O</sub> (V) = 10 V, la no linealidad relativa del circuito es:

$$NL_{real}(\%) = NL_{AI}(\%) \frac{FSR_{O(AI)}(V)}{FSR_{O}(V)} = NL_{AI}(\%) \frac{26V}{10V}$$

El error de NL en tensión puede obtenerse referido a la entrada o a la salida:

$$\varepsilon_{NL\_RTI}(V) = \frac{NL_{real}(\%)}{100} \cdot FSR_I(V) \qquad \qquad \varepsilon_{NL\_RTO}(V) = \frac{NL_{real}(\%)}{100} \cdot FSR_O(V)$$

$$FSR_O(V) = A_d \cdot FSR_I(V)$$

#### Efecto de la NL

#### **ELECTRICAL CHARACTERISTICS** (@ $V_S = \pm 15 \text{ V}$ , $V_{CM} = 0 \text{ V}$ , $T_A = +25 ^{\circ}\text{C}$ , unless otherwise noted.)

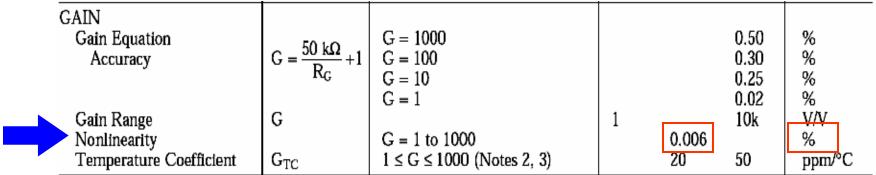
				AMP02E	<u> </u>	1
Parameter	Symbol	Conditions	Min	Тур	Max	Units
OUTPUT RATING						
Output Voltage Swing	V <sub>OUT</sub>	$T_A = +25^{\circ}\text{C}, R_L = 1 \text{ k}\Omega$	±12 ±11	±13 ±12		V
Positive Current Limit		$R_L = 1 \text{ k}\Omega$ , $-40^{\circ}\text{C} \le T_A \le +85^{\circ}\text{C}$ Output-to-Ground Short	111	22		mA
Negative Current Limit		Output-to-Ground Short		32		mA

NL para ±13v en la salida→NL para un *FSR<sub>a</sub>=26V* 

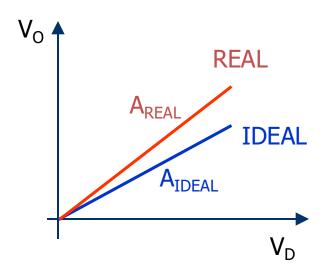
		FSR <sub>o</sub> =26V				
GAIN Gain Equation Accuracy	$G = \frac{50 \text{ k}\Omega}{R_G} + 1$	G = 1000 G = 100 G = 10 G = 1			0.50 0.30 0.25 0.02	% % % %
Gain Range Nonlinearity Temperature Coefficient	G G <sub>TC</sub>	G = 1  to  1000 $1 \le G \le 1000 \text{ (Notes 2, 3)}$	1	0.006 20	10k 50	V/V % ppm/°C

### Efecto de la NL

	E <sub>(RTI)</sub> (V)		$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$		
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido	
NL=0,006% para FSR (±13V)					



		$Error_{(RII)}(V)$	$%FSR = \frac{Erro}{}$	$\frac{or_{(R\Pi)}(V)}{FSR_I} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$	A STATE OF THE PARTY OF THE PAR	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
I <sub>B</sub> =10nA; I <sub>OS</sub> =5nA	$\pm \left[I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N)\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np.p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>real</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm V_{\rm D} \cdot \frac{NL_{\rm real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_G] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $R_G = R_g \pm \Delta R = R_G \pm \frac{\Delta R_G}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>



$$E_{RTO}(V) = V_{O_{real}} - V_{O_{ideal}} = \underbrace{\left(A_{d_{real}} - A_{d_{ideal}}\right) \cdot V_{D}}_{EG}$$

$$EG(\%) = \frac{\left(A_{d_{real}} - A_{d_{ideal}}\right)}{A_{d_{ideal}}} \cdot 100$$

En el catálogo se da en módulo

Con ello la tensión de error se calcula:

$$E_{RTO}(V) = \pm \frac{EG(\%)}{100} \cdot A_{d_{ideal}} \cdot V_D$$



$$E_{RTO_{max}}(V) = \pm \frac{EG(\%)}{100} \cdot A_{d_{ideal}} \cdot FS_{I}$$

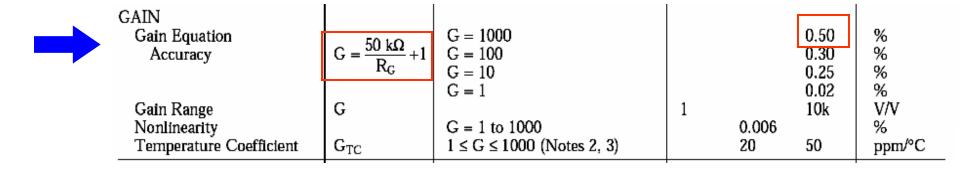
$$E_{RTI_{max}}(V) = \pm \frac{E_{RTO_{max}}(V)}{A_{d_{ideal}}} = \pm \frac{EG(\%)}{100} \cdot FS_{I}$$

$$E_{RTI_{max}}(\%FSR_I) = \pm \frac{E_{RTI_{max}}(V)}{FSR_I} \cdot 100$$

#### **ELECTRICAL CHARACTERISTICS** (@ $V_S = \pm 15 \text{ V}$ , $V_{CM} = 0 \text{ V}$ , $T_A = +25 ^{\circ}\text{C}$ , unless otherwise noted.)

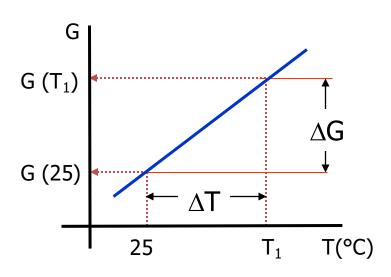
D	C1-1	014	36:-	AMP02E	1/	TI-14-
Parameter	Symbol	Conditions	Min	Тур	Max	Units
INPUT						
Input Resistance	R <sub>IN</sub>	Differential, G≤1000		10		GΩ
•		Common-Mode, G = 1000		16.5		$G\Omega$
Input Voltage Range	IVR	$T_A = +25^{\circ}C$ (Note 1)	±11			V
Common-Mode Rejection	CMR	$V_{CM} = \pm 11 \text{ V}$				
v		G = 1000, 100	115	120		dB
		G = 10	100	115		dB
		G = 1	80	95		dB
		$V_{CM} = \pm 11 \text{ V}$				
		$-40^{\circ}$ C $\leq T_{A} \leq +85^{\circ}$ C				
		G = 100, 1000	110	120		dB
		G = 10	95	110		dB
		G = 1	75	90		dB
GAIN						
Gain Equation	5010	G = 1000			0.50	%
Accuracy	$G = \frac{50 \text{ k}\Omega}{R} + 1$	G = 100			0.30	%
•	$R_{G}$	G = 10			0.25	%
		G = 1			0.02	%
Gain Range	G		1		10k	V/V
Nonlinearity		G = 1 to 1000		0.006		%
Temperature Coefficient	G <sub>TC</sub>	$1 \le G \le 1000 \text{ (Notes 2, 3)}$		20	50	ppm/°C

	E <sub>(RTI)</sub> (V)		$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$	
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido
$EG = \frac{\Delta G}{G} \cdot 100 =$ $= 0.5\%$				



		$Error_{(RII)}(V)$	$%FSR = \frac{Erro}{}$	$r_{(RH)}(V) \cdot 100$ FSR <sub>I</sub>
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
$I_{B}=10nA; I_{OS}=5nA$	$\pm \left[I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N)\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150 \ pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np-p}=0,4~\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% <u>se supone para</u> FSR (±13V) NL <sub>real</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm V_D \cdot \frac{NL_{real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0.0134}{100} = \pm 2.68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0.5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50  ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ G = 578,94		$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_{G}] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^{6}$ $R_{G} = R_{g} \pm \Delta R = R_{G} \pm \frac{\Delta R_{G}}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	LÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

### Efecto de la T en la ganancia



$$TC_G(\%) = \frac{\frac{\Delta A_d}{A_{dideal}}}{\Delta T} \cdot 100$$

Un incremento en T, llevará a un incremento en la ganancia que es equivalente a un error de ganancia (EG)

$$\Delta G = \frac{TC_G(\%)}{100} \cdot \Delta T \cdot A_{d_{ideal}} \equiv EG$$

Con ello la tensión de error se calcula:

$$E_{RTO_{max}}(V) = \pm \Delta A_d \cdot V_{d_{max}} = \pm \Delta A_d \cdot FS_I = \pm \frac{TC_G(\%)}{100} \cdot \Delta T \cdot A_{d_{ideal}} \cdot FS_I$$

$$E_{RTI_{max}}(V) = \frac{E_{RTO_{max}}(V)}{A_{d_{idagl}}} = \pm \frac{TC_G(\%)}{100} \cdot \Delta T \cdot FS_I \qquad \Box \qquad E_{RTI_{max}}(\%FSR_I) = \pm \frac{E_{RTI_{max}}(V)}{FSR_I} \cdot 100$$



$$E_{RTI_{max}}(\%FSR_I) = \pm \frac{E_{RTI_{max}}(V)}{FSR_I} \cdot 100$$

 $FS_{O}$ 

## Efecto de T en la ganancia

**ELECTRICAL CHARACTERISTICS** (@  $V_S = \pm 15 \text{ V}$ ,  $V_{CM} = 0 \text{ V}$ ,  $T_A = +25 ^{\circ}\text{C}$ , unless otherwise noted.)

Domentos	Sumb at	Conditions	Min	AMP02E	Mare	I Imita
Parameter	Symbol	Conditions	Min	Тур	Max	Units
INPUT						
Input Resistance	R <sub>IN</sub>	Differential, $G \le 1000$		10		GΩ
•		Common-Mode, $G = 1000$		16.5		GΩ
Input Voltage Range	IVR	$T_A = +25^{\circ}C \text{ (Note 1)}$	±11			V
Common-Mode Rejection	CMR	$V_{CM} = \pm 11 \text{ V}$				
J		G = 1000, 100	115	120		dB
		G = 10	100	115		dB
		G = 1	80	95		dB
		$V_{CM} = \pm 11 \text{ V}$				
		$-40^{\circ}$ C $\leq T_{A} \leq +85^{\circ}$ C				
		G = 100, 1000	110	120		dB
		G = 10	95	110		dB
		G = 1	75	90		dB
GAIN						
Gain Equation	<b>5</b> 0.4.0	G = 1000			0.50	%
Accuracy	$G = \frac{50 \text{ k}\Omega}{R_G} + 1$	G = 100			0.30	%
	$R_{G}$	G = 10			0.25	%
		G = 1			0.02	%
Gain Range	G		1		10k	V/V
Nonlinearity		G = 1 to 1000	-	0.006		%
Temperature Coefficient	$G_{TC}$	$1 \le G \le 1000 \text{ (Notes 2, 3)}$		20	50	ppm/°C

	E <sub>(RTI)</sub> (V)		$E_{(RTI)}(\%) = 100 \cdot E_{(RTI)}(V) / FSR_i(V)$	
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido
$TC[G] = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6} =$ $= 50 \text{ ppm/}^{\circ} C$				

GAIN Gain Equation Accuracy	$G = \frac{50 \text{ k}\Omega}{R} + 1$	G = 1000 G = 100			0.50 0.30	% %
3	$R_{G}$	G = 10 G = 1			0.25 0.02	% %
Gain Range Nonlinearity	G	G = 1 to 1000	1	0.006	10k	V/V %
Temperature Coefficient	$G_{TC}$	$1 \le G \le 1000 \text{ (Notes 2, 3)}$		20	50	ppm/°C

		$Error_{(RII)}(V)$	%FSR = Erro	$\frac{P_{(RH)}(V)}{FSR_t} \cdot 100$
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)
$V_{IOS}$ =100 $\mu V$	$\pm V_{IOS}$	+100.10-6	±0,5	0
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0
$TC[V_{IOS}] = 2 \mu V / {}^{\circ}C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05
$I_{B}=10nA; I_{OS}=5nA$	$\pm \left[ I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N) \right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0
$TC[I_B] = 150 \ pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0
$e_{np-p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001
1. NL=0,006% 2. NL=0,006% se supone para FSR (±13V) NL <sub>rest</sub> =0,006·[26/(20·10·3·578,36)]=0,0134%FSR	$\pm  V_{D} \cdot \frac{NL_{real}(\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0.0134}{100} = \pm 2.68 \cdot 10^{-6}$	±0,0134	±0,0134
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0,5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ G = 578,94	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6} \left  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6} \right $	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>
$TC[R_{G}] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^{6}$ $R_{G} = R_{g} \pm \Delta R = R_{G} \pm \frac{\Delta R_{G}}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>
	ESTIMACIÓN DEL ERROR M	IÁXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>

### Ahora nos fijamos en R<sub>G</sub>:

¿Qué error produce su Tolerancia?

¿Qué error produce su Coeficiente de Temperatura?

Como  $R_G$  forma parte de la ganancia del AI:  $A_d = \left(1 + \frac{2R_3}{R_G}\right)$ , cambios en el valor de  $R_G$  llevarán a cambios en la Ganancia.

Así, tanto la Tolerancia como el Coeficiente de Temperatura de  $R_G$ , llevarán a un error de ganancia.

### Error de ganancia debido a la Tolerancia de R<sub>G</sub>

$$A_{d_{ideal}} = 1 + \frac{2R_3}{R_G}$$
 y  $A_{d_{real}} = 1 + \frac{2R_3}{R_G(1 \pm Tol)}$ 

$$EG_{R_G} = A_{d_{real}} - A_{d_{ideal}} = \frac{2R_3}{R_G(1 \pm Tol)} - \frac{2R_3}{R_G} = \pm \frac{2R_3 \cdot Tol}{R_G(1 \pm Tol)}$$

Normalmente Tol << 1, con ello:

$$EG_{R_G} \cong \pm \frac{2R_3 \cdot Tol}{R_G}$$

Que expresado en %:

$$EG_{R_G}(\%) = \frac{A_{d_{real}} - A_{d_{ideal}}}{A_{d_{ideal}}} 100 = \pm \frac{\frac{2R_3 \cdot Tol}{R_G}}{1 + \frac{2R_3}{R_G}} 100 = \pm \frac{2R_3 \cdot Tol(\%)}{R_G + 2R_3}$$

... pero como es habitual que:

$$A_{d_{ideal}} = \left(1 + \frac{2R_3}{R_G}\right) \gg 1 \rightarrow R_G \ll 2R_3 \rightarrow EG_{R_G}(\%) \cong \pm Tol(\%)$$

# Efecto del Error de ganancia debido a la Tolerancia de $R_{\rm G}$

	E <sub>(RTI)</sub> (V)		$E_{(RTI)}(\%) = 100 \cdot E_{(I)}$	$_{RTI)}(V) / FSR_{i}(V)$
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido
$R_G =$				
$R_G = 86,6 \pm \frac{0,1}{100} \cdot 86,6\Omega$				

### Error de ganancia debido al Coef. de Temp. de R<sub>G</sub>

Definición de TC:

$$TC(\%) = \frac{\frac{\Delta R_G}{R_G}}{\Delta T} \times 100 = \frac{Tol(\%)}{\Delta T}$$

Por tanto, los resultados de EG debidos a la Tolerancia de R<sub>G</sub> son válidos ahora, sin más que sustituir:

$$Tol(\%) = TC(\%) \cdot \Delta T$$

Con ello:

$$EG_{R_G}(\%) \cong \pm \frac{2R_3 \cdot TC(\%) \cdot \Delta T}{R_G + 2R_3}$$



$$EG_{R_G}(\%) \cong \pm TC(\%) \cdot \Delta T$$

# Efecto del Error de ganancia debido al Coeficiente de Temperatura de R<sub>G</sub>

	E <sub>(RTI)</sub> (V)		$E_{(RTI)}(\%) = 100 \cdot E_{(I)}$	RTI)(V) / FSR <sub>i</sub> (V)
	Expresión error (V)	Error (V)	OS, G no corregido	OS, G corregido
$TC[R_G] = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^6$ $= 15  ppm/^{\circ}  C$				

		$Error_{(RII)}(V)$	$%FSR = \frac{Errc}{}$	$\frac{Error_{(RH)}(V)}{FSR_I}$ · 100	
	Expresión del error (V)	Error (V)	OS, G NO Corregidos	OS, G SI Corregidos 25°C)	
$V_{IOS}=100 \mu V$	$\pm V_{IOS}$	±100·10 <sup>-6</sup>	±0,5	0	
V <sub>OOS</sub> =4mV	$\frac{\pm V_{oos}}{G}$	$\pm \frac{4 \cdot 10^{-3}}{578,36} = \pm 6,9 \cdot 10^{-6}$	±0,033	0	
$TC[V_{IOS}] = 2 \mu V / \circ C = \frac{\Delta V_{IOS}}{\Delta T}$	$\pm \frac{\Delta V_{IOS}}{\Delta T} (T - 25)$	$\pm 2 \cdot 10^{-6} \cdot (-40 - 25) = \pm 130 \cdot 10^{-6}$	±0,65	±0,65	
$TC[V_{OOS}] = 100 \mu V / \circ C = \frac{\Delta V_{OOS}}{\Delta T}$	$\pm \frac{1}{G} \frac{\Delta V_{OOS}}{\Delta T} (T - 25)$	$\pm \frac{1}{578,36} \cdot 100 \cdot 10^{-6} \cdot (-40 - 25) = \pm 11,2 \cdot 10^{-6}$	±0,05	±0,05	
I <sub>B</sub> =10nA; I <sub>OS</sub> =5nA	$\pm \left[I_B \cdot (R_P - R_N) + \frac{I_{OS}}{2} \cdot (R_P + R_N)\right]$	$\pm \left[0 + \frac{5 \cdot 10^{-9}}{2} \cdot (175 + 175)\right] = \pm 8,75 \cdot 10^{-7}$	±0,004	0	
$TC[I_B] = 150 \ pA / {}^{\circ}C = \frac{\Delta I_B}{\Delta T}$	$\pm \frac{\Delta I_B}{\Delta T} \cdot (T - 25) \cdot (R_P - R_N)$	0	0	0	
$TC[I_{OS}] = 9 pA / {}^{\circ}C = \frac{\Delta I_{OS}}{\Delta T}$	$\pm \frac{1}{2} \cdot \frac{\Delta I_{OS}}{\Delta T} \cdot (T - 25) \cdot (R_p + R_N)$	$\pm \frac{1}{2} \cdot 9 \cdot 10^{-12} \cdot (-40 - 25) \cdot (175 + 175) = \pm 1,02 \cdot 10^{-7}$	±0,00047	±0,00047	
CMR =110 dB	$V_{MC(RTI)} = V_C \cdot 10^{\frac{-CMR}{20}}$	$2.5 \cdot 10^{\frac{-110}{20}} = 7.9 \cdot 10^{-6}$	0,039	0	
PSR =110 dB	$\pm 10^{\frac{-PSR}{20}} \cdot (V_{CC1} - 15)$	$\pm 10^{\frac{-110}{20}} \cdot (15 - 15) = 0$	0	0	
$e_{np\cdot p}$ =0,4 $\mu Vpp$	$e_{np} = \frac{e_{np-p}}{2}$	$e_{np} = \frac{0.4 \cdot 10^{-6}}{2} = 0.2 \cdot 10^{-6}$	±0,001	±0,001	
1. NL=0,006% 2. NL=0,006% se supone para FSR (±13V) NL <sub>rest</sub> =0,006·[26/(20·10 <sup>-3</sup> ·578,36)]=0,0134%FSR	$\pm V_{\rm D} \cdot \frac{N L_{\rm real} (\%)}{100}$	$\pm \frac{20 \cdot 10^{-3} \cdot 0,0134}{100} = \pm 2,68 \cdot 10^{-6}$	±0,0134	±0,0134	
$EG = 0.5\% = \frac{\Delta G}{G} \cdot 100$	$\frac{\pm V_D}{G} \cdot \Delta G$	$\pm \frac{20 \cdot 10^{-3}}{578,36} \cdot \frac{0,5}{100} \cdot 578,36 = \pm 100 \cdot 10^{-6}$	±0,5	0	
$TC[G] = 50 \ ppm / {}^{\circ}C = \frac{\Delta G}{\Delta T} \cdot \frac{1}{G} \cdot 10^{6}$	$\pm \frac{V_D}{G} \cdot \frac{\Delta G}{\Delta T} \cdot (T - 25)$	$\pm 20 \cdot 10^{-3} \cdot 50 \cdot 10^{-6} (-40 - 25) = \pm 65 \cdot 10^{-6}$	±0,325	±0,325	
$R_G = 86.6 \pm \frac{0.1}{100} \cdot 86.6\Omega$ $G = 577,79$ $G = 578,94$	$\frac{V_{D}}{G} \cdot (G_{R} - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,57) = -19,71 \cdot 10^{-6}  \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,58 = 20,06 \cdot 10^{-6}$	-0,098 <error 0,1<="" <="" td=""><td>-0,098<error 0,1<="" <="" td=""></error></td></error>	-0,098 <error 0,1<="" <="" td=""></error>	
$TC[R_{G}] = 15 \ ppm / {}^{\circ}C = \frac{\Delta R}{\Delta T} \cdot \frac{1}{R} \cdot 10^{6}$ $R_{G} = R_{g} \pm \Delta R = R_{G} \pm \frac{\Delta R_{G}}{\Delta T} \cdot (T - 25)$ $G = 577,84$ $G = 578,92$	$\frac{V_D}{G} \cdot (G_R - G)$	$\frac{20 \cdot 10^{-3}}{578,36} \cdot (-0,52) = -17,98 \cdot 10^{-6} \qquad \frac{20 \cdot 10^{-3}}{578,36} \cdot 0,56 = 19,36 \cdot 10^{-6}$	-0,089 <error<0,098< td=""><td>-0,089<error 0,098<="" <="" td=""></error></td></error<0,098<>	-0,089 <error 0,098<="" <="" td=""></error>	
	ESTIMACION DEL ERROR M	IAXIMO TOTAL	-2,26387 <error<2,31387< td=""><td>-1,22687<error<1,23787< td=""></error<1,23787<></td></error<2,31387<>	-1,22687 <error<1,23787< td=""></error<1,23787<>	

### Conclusiones: Ajustes

Los errores que provoquen un offset (constante) en la salida pueden corregirse con un ajuste.

- $\Box$   $V_{IOS}$ ,  $V_{OOS}$
- $\Box$   $I_{B}$ ,  $I_{OS}$
- ☐ CMR
- **E**G
- TC[Vios], TC[Voos]
- $\Box$  TC[IB], TC[Ios]
- PSR
- ☐ NL
- en, in
- $\Box$  TC[G]

Se podrían corregir

No se pueden corregir

## Conclusiones

V <sub>IOS</sub>	100 μV	0,5 %
V <sub>OOS</sub>	4 mV	0,033 %
I <sub>OS</sub>	5 nA	0,004 %
CMR	110 dB	0,039 %
EG	0,5%	0,5 %
$R_G$	0,1%	0,1 %
<b>e</b> npp	0,4 µVpp	0,001 %
TC V <sub>IOS</sub>	2 μV/°C	0,65 %
TC V <sub>OOS</sub>	100 μV/°C	0,05 %
TC I <sub>OS</sub>	9 pA/°C	0,00047 %
TC G	50 ppm/°C	0,325 %
TC R <sub>G</sub>	15 ppm/°C	0,1 %
NL	0,006%	0,0134 %

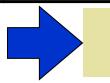


### Conclusiones

V <sub>IOS</sub>	100 μV	0,5 %	
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<b>e</b> npp	0,4 µVpp	0,001 %	
TC V <sub>IOS</sub>	2 μV/°C	0,65 %	
TC V <sub>OOS</sub>	100 μV/ºC	0,05 %	
TC I <sub>OS</sub>	9 pA/°C	0,00047 %	
TC G	50 ppm/°C	0,325 %	
TC R <sub>G</sub>	15 ppm/°C	0,1 %	
NL	0,006%	0,0134 %	







1,1%

# Conclusiones: Simplificaciones

1. El error de ganancia (*EG*) está dado en un *%G* y está relacionado con el con el *%FSR* que se pretende calcular, según estas fórmulas:

FSR unipolar	FSR Bipolar y simétrico	FSR Bipolar y no simétrico
%FSR = %G	%FSR = %G/2	%FSR=100· V <sub>Dmax</sub>  ·ΔG/FSR <sub>RTO</sub>

- 2. En la mayoría de los casos el % de tolerancia de la RG coincide con el % G, y por tanto con el %FSR que se pretende calcular.
- 3. La variación con la temperatura de la *R<sub>G</sub>* puede calcularse como un % *de la R<sub>G</sub>*, que coincide con la variación en %*G*, y este, coincide con el %*FSR* que se pretende calcular.
- 4. Aunque los errores tienen signo, en la mayoría de ellos se desconoce cual es, por lo que se cuantificaría como "±error", por este motivo para calcular el "error total" se suman los valores absolutos de todos los errores máximos y el resultado del error sería "± error total".
- 5. Con *impedancias bajas*, el efecto de las corrientes de offset, polarización y ruido es *despreciable*.
- 6. Con *ganancias elevadas* el efecto de la tensión de offset de la etapa de salida es *despreciable*.

# Conclusiones: Simplificaciones

	$V_{IOS}$	100 μV	0,5 %
	V <sub>oos</sub>	4 mV	0,033 %
(5)	I <sub>US</sub>	5 n/\	0.004.0%
(5)	-05	J	
	CMR	110 dB	0,039 %
(1)	EG	0,5%	0,5 %
(2)	$R_G$	0,1%	0,1 %
(muy bajo)	<b>e</b> npp	0,4 µ₩pp	0,001%
	TC V <sub>IOS</sub>	2 μV/°C	0,65 %
	TC V <sub>OOS</sub>	100 μV/°C	0,05 %
	TC I	9 pA/0C	0.00047 %
(5)	10105	5 pr 1, C	0,0000
	TC G	50 ppm/°C	0,325 %
(3)	TC R <sub>G</sub>	15 ppm/°C (tol=0,0975%)	0,1 %
	NL	0,006%	0,0134 %
·			2,3 %

## Conclusiones: Simplificaciones

