Gain Error

TI Precision Labs – Current Sense Amplifiers

Quiz

Gain Error – quiz

1. Select all of the following that are true:
   a) Total device gain error consists of gain error for a specified temperature range, gain error drift, and linearity.
   b) Relative gain error is directly proportional to the input sense voltage.
   c) Gain error is the dominant error source at high sense voltages.
   d) Gain error is only valid in the linear output region.
   e) If a CSA device's gain error is calibrated at room temperature, the only gain error left is gain error temperature drift.
   f) Shunt resistor tolerance can be considered a gain error.

Gain Error – quiz

2. Using the following datasheet specifications for the INA302, what is the maximum total device gain error for the A2 variant if ambient temperature can vary from 0°C to 105°C?
   a) ±0.215 %
   b) ±0.205 %
   c) ±0.19 %
   d) ±0.18 %

6.5 Electrical Characteristics

at T_A = 25°C, V_{SENSE} = 0 V, V_{REF} = V_S / 2, V_S = 5 V, V_{IN+} = 12 V, V_{LIMIT1} = 3 V, and V_{LIMIT2} = 3 V (INA302) or 2 V (INA303) (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
G	Gain	A1 versions		20		V/V
		A2 versions		50		
		A3 versions		100		
	Gain error	V_{OUT} = 0.5 V to V_S – 0.5 V, A1 versions		±0.02%	±0.075%	
		V_{OUT} = 0.5 V to V_S – 0.5 V, A2 versions		±0.05%	±0.1%	
		V_{OUT} = 0.5 V to V_S – 0.5 V, A3 versions		±0.1%	±0.15%	
		T_A= –40°C to +125°C		3	10	ppm/°C
	Nonlinearity error	V_{OUT} = 0.5 V to V_S – 0.5 V		±0.01%		

Gain Error – quiz

3. A system has performed a two-point calibration at 80°C on the INA185A4 to negate offset and gain error. Using the specifications below, what is the maximum device gain error if the ambient temperature can vary from 60°C to 95°C? Assume the max gain error drift value is ±8 ppm/°C.

6.5 Electrical Characteristics

at T_A = 25°C, V_{SENSE} = V_{IN+} – $V_{IN–}$, V_S = 5 V, V_{REF} = V_S / 2, and V_{IN+} = 12 V (unless otherwise noted)

PARAMETER		CONDITIONS		MIN	TYP	MAX	UNIT
E_G	Gain error	V_{OUT} = 0.5 V to V_S – 0.5 V, T_A = –40°C to +125°C	A1, A2, A3 devices		±0.05%	±0.2%	
			A4 device		±0.07%	±0.25%	
	Gain error drift	T_A = –40°C to +125°C			1.5	8	ppm/°C
	Nonlinearity error	V_{OUT} = 0.5 V to V_S – 0.5 V			±0.01%		

Gain Error- quiz

4. The INA253 is a current-sense amplifier with an integrated 2 mΩ shunt resistor so error specifications are slightly different compared to other CSAs. Given the specifications below, what are the worst-case (maximum and minimum) gain values in mV/A for the INA253A2 (200 mV/A typical) if temperature can vary from 0°C to 100°C?

7.5 Electrical Characteristics

at T_A = 25 °C, V_S = 5 V, I_{SENSE} = IS+ = 0 A, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
G	Gain	INA253A1		100		mV/A
		INA253A2		200		
		INA253A3		400		mV/A
	System gain error(3)	GND + 50 mV ≤ V_{OUT} ≤ V_S – 200 mV, T_A = 25°C		±0.05%	±0.4%	
		T_A = –40°C to +125°C			±45	ppm/°C
	Nonlinearity error	GND + 10 mV ≤ V_{OUT} ≤ V_S – 200 mV		±0.01%		

Answers

Gain Error – quiz

1. Select all of the following that are true:
   a) Total device gain error consists of gain error for a specified temperature range, gain error drift, and linearity.
   b) Relative gain error is directly proportional to the input sense voltage.
   c) Gain error is the dominant error source at high sense voltages.
   d) Gain error is only valid in the linear output region.
   e) If a CSA device's gain error is calibrated at room temperature using a two-point calibration, the only gain error left is gain error temperature drift.
   f) Shunt resistor tolerance can be considered a gain error.

Gain Error – quiz

2. Using the following datasheet specifications for the INA302, what is the maximum total device gain error for the A2 version if ambient temperature can vary from 0°C to 105°C?

a) ±0.215 %

b) ±0.205 %

c) ±0.19 %

d) ±0.18 %

6.5 Electrical Characteristics

at T_A = 25°C, V_{SENSE} = 0 V, V_{REF} = V_S / 2, V_S = 5 V, V_{IN+} = 12 V, V_{LIMIT1} = 3 V, and V_{LIMIT2} = 3 V (INA302) or 2 V (INA303) (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
G	Gain	A1 versions		20		V/V
		A2 versions		50		
		A3 versions		100		
	Gain error	V_{OUT} = 0.5 V to V_S – 0.5 V, A1 versions		±0.02%	±0.075%	
		V_{OUT} = 0.5 V to V_S – 0.5 V, A2 versions		±0.05%	±0.1%	
		V_{OUT} = 0.5 V to V_S – 0.5 V, A3 versions		±0.1%	±0.15%	
		T_A= –40°C to +125°C		3	10	ppm/°C
	Nonlinearity error	V_{OUT} = 0.5 V to V_S – 0.5 V		±0.01%		

Gain Error – quiz

2. Using the following datasheet specifications for the INA302, what is the maximum total device gain error for the A2 variant if ambient temperature can vary from 0°C to 105°C?
   a) ±0.215 %
   b) ±0.205 %
   c) ±0.19 %
   d) ±0.18 %

$$Max\ total\ gain\ error = E_{G\_Total}$$
$$E_{G\_Total} = E_{G\_25C} + \frac{\Delta E_G}{\Delta °C} * \Delta T_A + E_{Linearity}$$
$$E_{G\_Total} = 0.1\% + 10\frac{ppm}{°C} * 10^{-4} * (105°C - 25°C) + 0.01\%$$
$$E_{G\_Total} = 0.1\% + 0.08\% + 0.01\%$$
$$E_{G\_Total} = 0.19\%$$

Gain Error – quiz

3. A system has performed a two-point calibration at 80°C on the INA185A4 to negate offset and gain error. Using the specifications below, what is the maximum device gain error if the ambient temperature can vary from 60°C to 95°C? Assume the max gain error drift value is ± 8 ppm/°C.

6.5 Electrical Characteristics

at T_A = 25°C, $V_{SENSE} = V_{IN+} - V_{IN-}$, V_S = 5 V, $V_{REF} = V_S / 2$, and V_{IN+} = 12 V (unless otherwise noted)

PARAMETER		CONDITIONS		MIN	TYP	MAX	UNIT
E_G	Gain error	V_{OUT} = 0.5 V to V_S – 0.5 V, T_A = –40°C to +125°C	A1, A2, A3 devices		±0.05%	±0.2%	
			A4 device		±0.07%	±0.25%	
	Gain error drift	T_A = –40°C to +125°C			1.5	8	ppm/°C
	Nonlinearity error	V_{OUT} = 0.5 V to V_S – 0.5 V			±0.01%		

Answer: Max gain error is ± 0.026 %

Gain Error – quiz

3. A system has performed a two-point calibration at 80°C on the INA185A4 to negate offset and gain error. Using the specifications below, what is the maximum total device gain error if the ambient temperature can vary from 60°C to 95°C? Assume the max gain error drift value is ± 8 ppm/°C.

Gain error at the calibrated temperature (80°C) is now limited to just linearity (±0.01%). The maximum temperature change from 80°C is |60°C – 80°C| = 20°C. So the maximum total gain error over the expected temperature range is calculated as:

$$Max\ total\ gain\ error = \frac{\Delta E_G}{\Delta °C} * \Delta T_A + E_{Linearity}$$

$$Max\ total\ gain\ error = 8\frac{ppm}{°C} * 10^{-4} * |60°C\ - 80°C| + 0.01\%$$

$$Max\ total\ gain\ error = 0.016\% + 0.01\%$$

Answer: Max total gain error is ± 0.026 %

Gain Error- quiz

4. The INA253 is a current-sense amplifier with an integrated 2 mΩ shunt resistor so error specifications are slightly different compared to other CSAs. Given the specifications below, what are the worst-case (maximum and minimum) gain values in mV/A for the INA253A2 (200mV/A typical) if temperature can vary from 0°C to 100°C?

7.5 Electrical Characteristics

at T_A = 25 °C, V_S = 5 V, I_{SENSE} = IS+ = 0 A, V_{CM} = 12 V, and V_{REF1} = V_{REF2} = V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
G	Gain	INA253A1		100		mV/A
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		INA253A3		400		mV/A
	System gain error(3)	GND + 50 mV ≤ V_{OUT} ≤ V_S – 200 mV, T_A = 25°C		±0.05%	±0.4%	
		T_A = –40°C to +125°C			±45	ppm/°C
	Nonlinearity error	GND + 10 mV ≤ V_{OUT} ≤ V_S – 200 mV		±0.01%		

Answer: Maximum gain is 201.495 mV/A and minimum gain is 198.505 mV/A

Gain Error- quiz

4. The INA253 is a current-sense amplifier with an integrated 2 mΩ shunt resistor so error specifications are slightly different compared to other CSAs. Given the specifications below, what are the worst-case (maximum and minimum) gain values in mV/A for the INA253A2 (200 mV/A typical) if temperature can vary from 0°C to 100°C?

$$Max\ total\ gain\ error = E_{G\_Total} = E_{G\_25C} + \frac{\Delta E_G}{\Delta °C} * \Delta T_A + E_{Linearity}$$

$$E_{G\_Total} = 0.4\% + 45\frac{ppm}{°C} * 10^{-4} * (100°C - 25°C) + 0.01\%$$

$$E_{G\_Total} = 0.4\% + 0.3375\% + 0.01\%$$

$$E_{G\_Total} = 0.7475\%$$

$$G_{MAX} = 200\frac{mV}{A} * \left(1 + \frac{0.7475\%}{100}\right) = 201.495\frac{mV}{A}$$

$$G_{MIN} = 200\frac{mV}{A} * \left(1 - \frac{0.7475\%}{100}\right) = 198.505\frac{mV}{A}$$

Answer: Maximum gain is 201.495 mV/A and minimum gain is 198.505 mV/A