ADS124S08: Noise calculations and calibration

Pedro Mietto83 Prodigy 130 points
Community Member

Part Number: ADS124S08

Hello experts,

I'm using an ADS124S08 for NTC measurements, and while going thru noise calculations, I ended up with some rather bad results. I hope you can help me understand what's really going on and how to improve the system resolution.

My design currently implements a **Two-Wire Low-Side** topology, and my main concern is related to the precision required by the reference resistor, and noise impact due to resistance tolerance and temperature drift.

I'm considering using a **0.05%** tolerance resitor and **10 ppm/ºC** coefficient. This presents a good cost/benefit ratio. It seems higher precision resistor are much more expensive.

As for the noise calculations, I'm using the equations from reference **slau520a - 3-Wire RTD Measurement System Reference Design.**

For the calculations below, I have the following parameters:

- Vin(max) = 0,735V (result from Rref, NTC and IDAC current calculation)
- Gain = 1

The resistance tolerance error I get, using equations 38-40, is:

- Gain error = 0.04998%
- Gain error noise = **367,45 uV**

The temperature drift error I get, using equations 56-60, is:

- Temperature Delta = 65 - 15 = 50ºC
- Resistance drift = 0.05%
- Gain Error due to Resistance drift = **367,45 uV**

Total Noise from those two sources alone equals **525,05 uV** (square-root sum), and using equation for effective resolution from the component datasheet (eq 1), yields an ENOB of **11,479**.

In addition, this ENOB give me a resistance resolution of **5,25 ohms**, when my system needs **3,08 ohms**.

The questions are:

1. Are those calculations correct? The final ENOB and resolution numbers seems correct?

2. How can I improve the situation, without recurring to a very expensive reference resistor?
3. Is it possible to calibrate during manufacturing process to remove the tolerance error? Is yes, how can that be done? (what kind of setup is needed, what tools are needed, how long it could take, etc..)

Best regards.

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over 5 years ago

Bob Benjamin *over 5 years ago* TI__Guru** 113595 points

Hi Pedro,

Uncalibrated error can often be an issue, but let's back up a couple of steps. What is the value of the reference resistor you intend to use? What is the value IDAC current you intend to use? And what is the value of the NTC you are planning to use?

As another point of reference I would suggest taking a look at this cookbook circuit which is a little closer in design than the one you are referencing:

http://www.ti.com/lit/an/sbaa329/sbaa329.pdf

As far as the error calculations, you are using the correct process for the gain error of the resistor. If the reference is 1V, then the ENOB would appear correct. However the resistance resolution would depend on the reference resistor value. Here it would be helpful to know the values you are using to see if there can be some improvements.

As far as calibration, the simplest approach is to use a 2 point calibration and use a line slope method. One point would be with a shorted input to remove system offset, and the second point would be a voltage applied (such as 735mV) to determine the gain slope. This removes the initial resistor gain error. There is not much you can do about the drift of the resistor unless you use a more expensive one that has better characteristics.

Best regards,

Bob B

Pedro Mietto83 *over 5 years ago in reply to Bob Benjamin* Prodigy 130 points

Hello Bob,

First of all, thanks for the quick reply.

I'll make sure to take a good look at the suggested cookbook, I haven't seen that before.

Here are the required design data:

- **Reference resistor = 7500 ohms**
- **IDAC current value = 100 uA**
- **NTC range from 811 ohms @ 55°C up to 7352 @ -5 °C**

As an additional bit of information, the required resistance resolution of 3 ohms comes from the need to detect change from 49.9 °C to 50.0 °C. From this resistance, I'm getting a required ENOB of 12.495, but I'm not very sure I made the correct calculation here...

Regarding the two-point calibration method, do you know if that's a viable procedure at volume production? I mean, considering the time and setup required to do that? In fact, I'm interested about how the industry managed to solve this issue, without recurring to expensive high precision resistors.

Best regards.

Bob Benjamin *over 5 years ago in reply to Pedro Mietto83* TI__Guru** 113595 points

Hi Pedro,

Can you show me precisely how you are making you ENOB calculations? In your original post you are showing ENOB 11.479 and now you are showing 12.495. Is the latter number what you think you need to get for 3 Ohms resolution?

7500/3 = 2500 total counts required. 2^12.495 = 5772 which would be 7500/5772 or 1.3 Ohm resolution.

Calibration is certainly doable, but will add additional cost. The cost of calibration versus cost of the resistor may be similar. What you really need to consider is the cost of resistor values 7500 Ohms or greater. Let's say you use a 10k with tolerance of 0.01% and 5ppm drift. This will bring the gain error down significantly and may not be as costly as you might think. $2.15 per piece in small quantity and 0.87 in 1k reels. Although the reference value is greater you should still see 12.83 bits ENOB resulting in resolution of 1.37 Ohm. There may be some values between 7.5k and 10k with similar pricing that would improve resolution.

Best regards,

Bob B

Pedro Mietto83 *over 5 years ago in reply to Bob Benjamin* Prodigy 130 points

Hello Bob,

I'm calculating ENOB based on equation (1) from the ADS124 datasheet:

Effective Resolution = ln[(2 · VREF / Gain) / VRMS-Noise] / ln(2)

And I think my calculations were wrong, based on what the example you provided.

So I'm redoing the target ENOB calculation:

Rntc = Rref * Output Code / (2^23 * Gain)

If I have Gain = 1 and Output Code = 1, and also changing the 2^23 to 2^(ENOB-1), I have:

2^(ENOB-1) = Rref / Rntc

ENOB = 1+ Log_2 (Rref/Rntc) = 1+ Log_2 (7500/3) = **12.28**

So this sets my target ENOB and I can use the Effective Resolution equation above to calculate ENOB from the VRMS total noise. Does this makes sense?

Last thing, thanks very much for the calibration and Rref suggestions. I think I'll look into using the 10k 0,01% 5ppm resistor, and keep the two-point calibration method as a backup, if we find out in the future that we'll need to improve the resolution.

Best regards.

Bob Benjamin *over 5 years ago in reply to Pedro Mietto83* TI__Guru** 113595 points

Hi Pedro,

You do not need to subtract the 1 from the ENOB (which then gets added in your final equation). The reason being is the converter resolution is actually higher than the required result. As the measurement is ratiometric, each code represents a resistance value based on the full-scale resistance.

You can see by dividing the total codes from your ENOB calculation to see the resistance resolution. 2^12.28 is 4973 and 2^11.28 is 2487 codes or counts. There is a little rounding error, but you can see that for 3 Ohm resolution you would need 2500 intervals of 3 Ohm to get 7500. 5000 codes is 1.5 Ohm.

Best regards,

Bob B

Pedro Mietto83 *over 5 years ago in reply to Bob Benjamin* Prodigy 130 points

Bob,

Thank you very much for your support.

It was very helpful and we managed to build confidence in our numbers and understanding.

Best regards.