Calculating amplifier + ADC total noise: design examples

TI Precision Labs – ADCs

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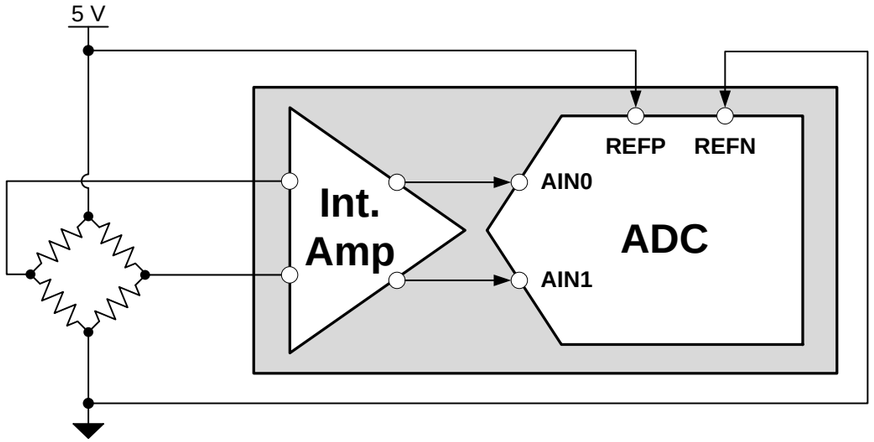
Presented by Alex Smith

DE#1: Internal vs external amplifiers

**For more information, watch the Precision Labs video on system noise parameters for low-speed delta sigma ADCs

Type	Parameter	Value
System specs**	Input voltage max (V_{IN})	10 mV
	Output data rate	60 SPS
	Noise target	250 nV
	Dynamic range	15.3 bits

ADC + internal amp (G_{MAX} = 128 V/V)



$$VREF = 5\ V$$

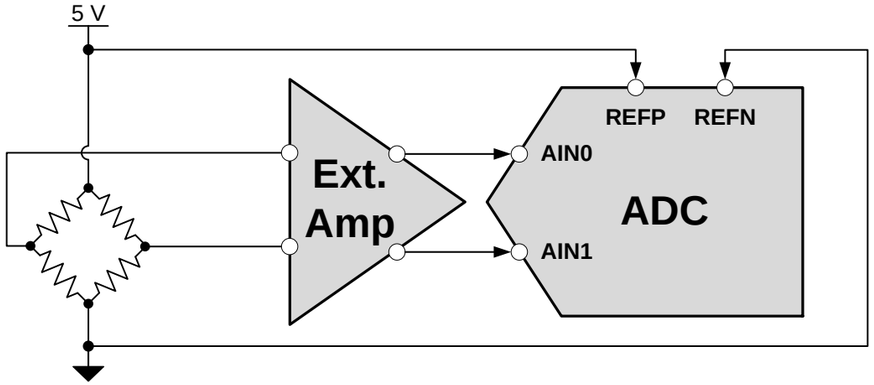
$$FSR_{ADC\ (G=128)} = \frac{\pm VREF}{Gain} = \pm 0.039\ V$$

$$\%\ Utilization\ (max) = \frac{V_{IN}}{FSR_{ADC\ (G=128)}} = \frac{10\ mV}{2 * 39\ mV} = 12.8\%$$

Is such low % utilization acceptable?

OR

ADC + external amp (G_{MAX} = 500 V/V)



$$VREF = 5\ V$$

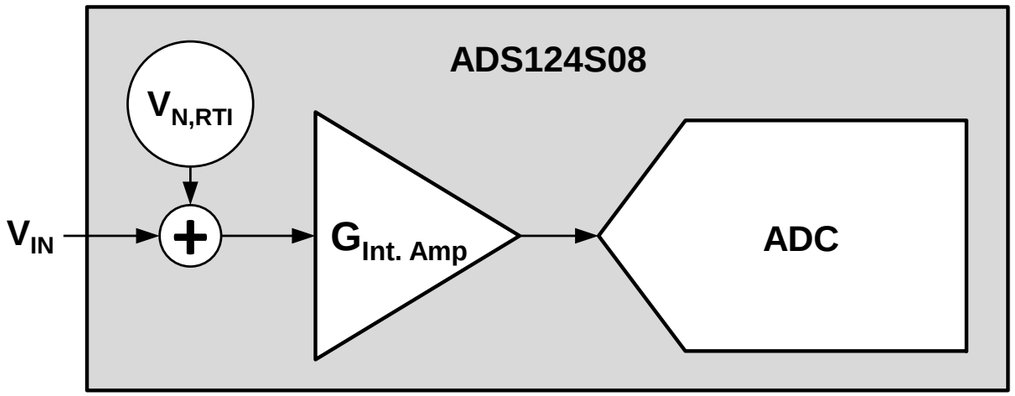
$$FSR_{ADC\ (G=1)} = \frac{\pm VREF}{Gain} = \pm 5\ V$$

$$Ext.amp\ gain\ (max) = \frac{FSR_{ADC\ (G=1)}}{V_{IN}} = \frac{5\ V}{0.01\ V} = 500\ {}^{V}/_{V}$$

Do you need such a large gain?

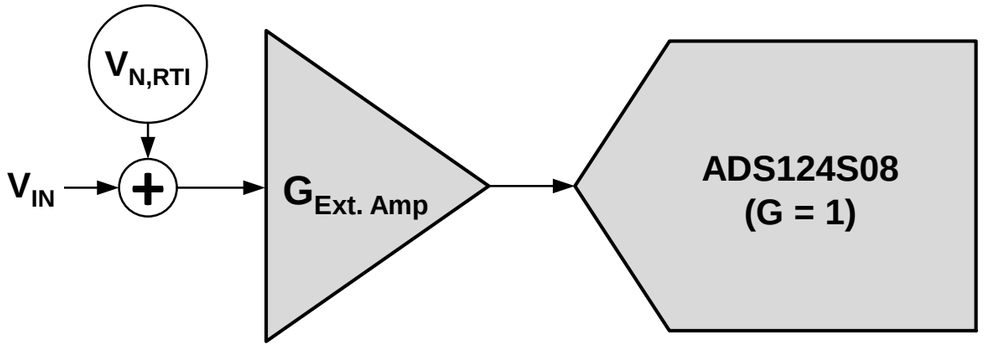
DE#1: Selecting components + calculating noise

ADC + internal amp equivalent noise model



$$V_{N,RTI} = \sqrt{(V_{N,AMP})^2 + \left(V_{N,ADC}/G_{ADS124S08}\right)^2}$$

ADC + external amp equivalent noise model



$$V_{N,RTI} = \sqrt{(V_{N,AMP})^2 + \left(V_{N,ADS124S08}/G_{Ext.\ AMP}\right)^2}$$

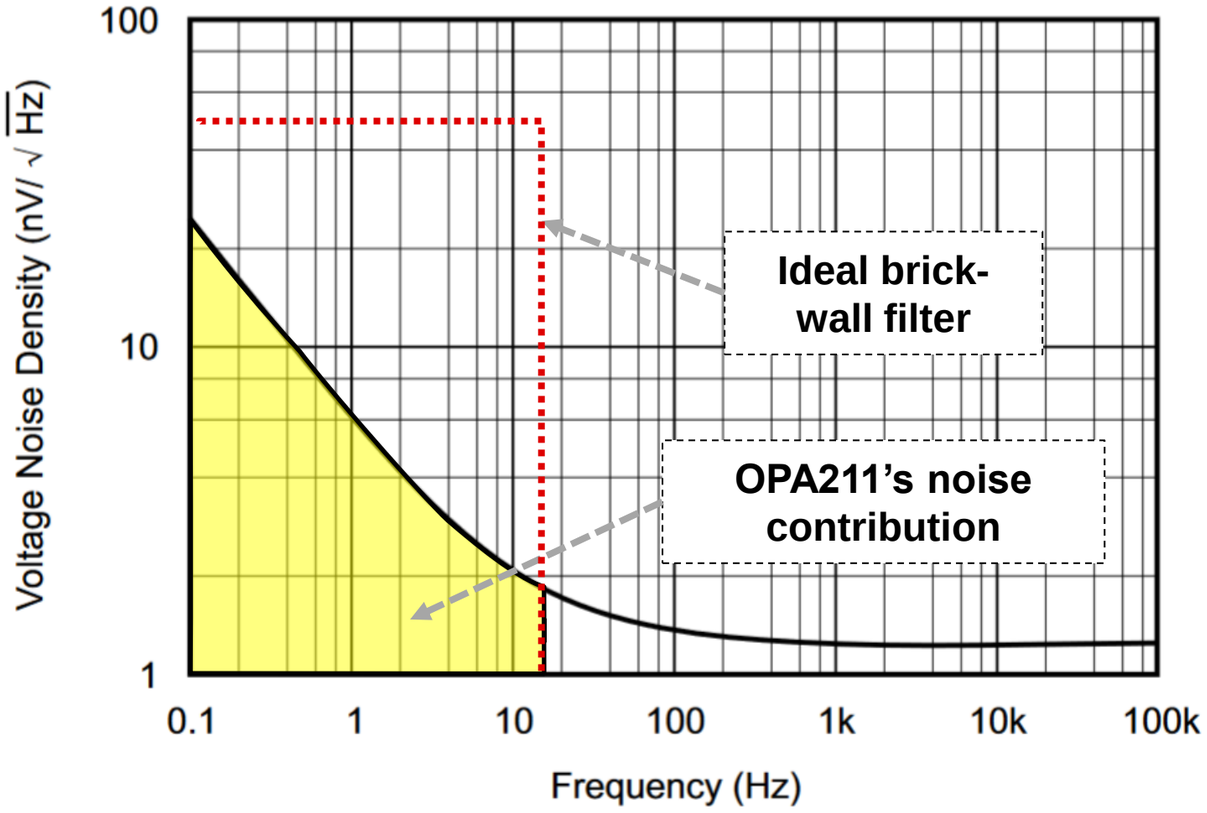
Directly from ADC datasheet → calculations not required

Component voltage noise @ 60 SPS (ENBW = 16 Hz) (nV_{RMS})

Device	Gain							
	1	2	4	8	16	32	64	128
ADS124S08	1,400	700	370	210	120	110	100	89
OPA211	?							
OPA378	?							
OPA192	?							

Calculate using $V_{N,RTI}$ equation

DE#1: OPA211 system noise contribution



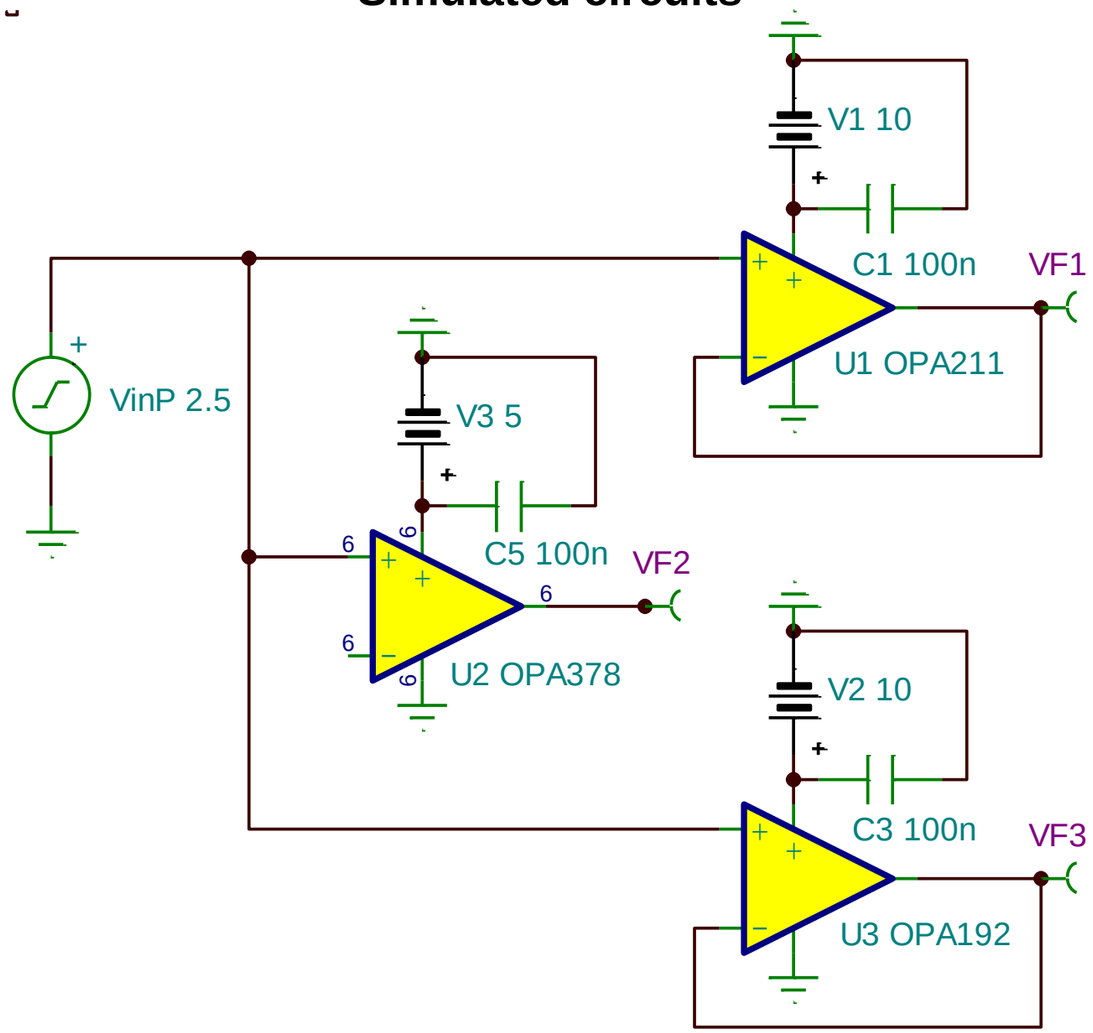
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input voltage noise	f = 0.1 to 10 Hz		80		nV_{PP}
Input voltage noise density	f = 10 Hz		2		nV/√Hz
	f = 100 Hz		1.4		nV/√Hz
	f = 1 kHz		1.1		nV/√Hz

$$V_{N,AMP} = 18.5\ nV_{RMS}$$

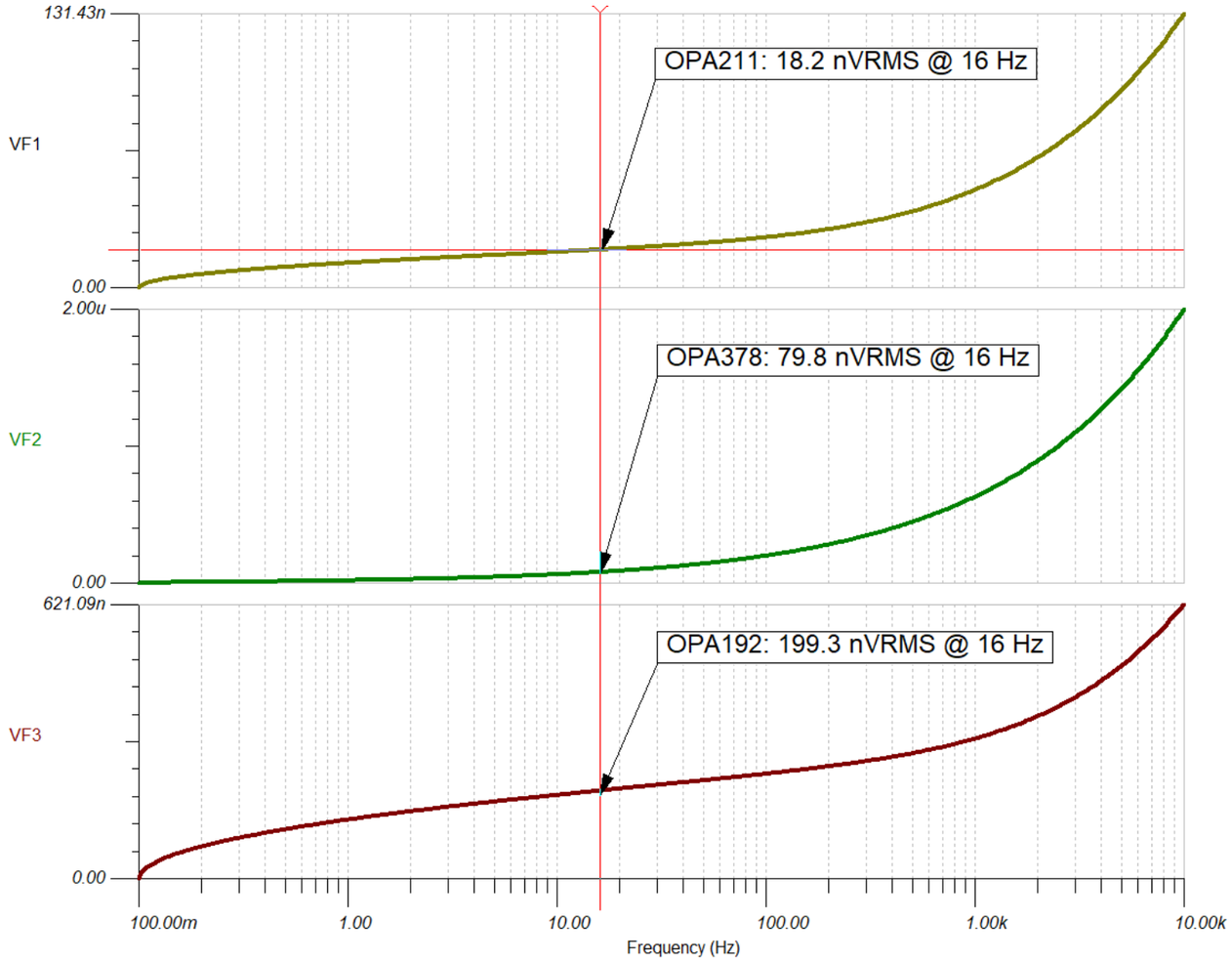
View the Precision Labs modules on amplifier noise to learn more

DE#1: Simulating amplifier noise

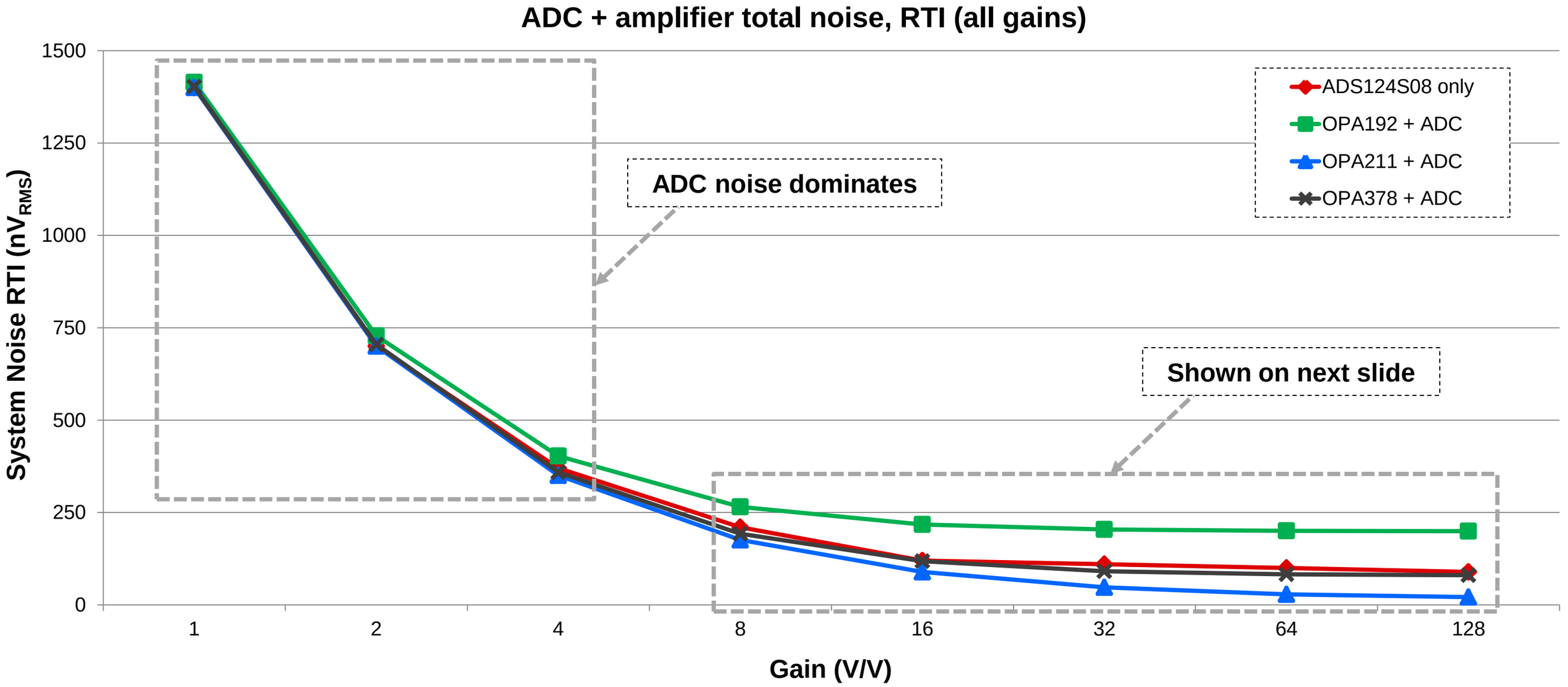
Simulated circuits



Total output noise



DE#1: ADC + amplifier total noise vs gain



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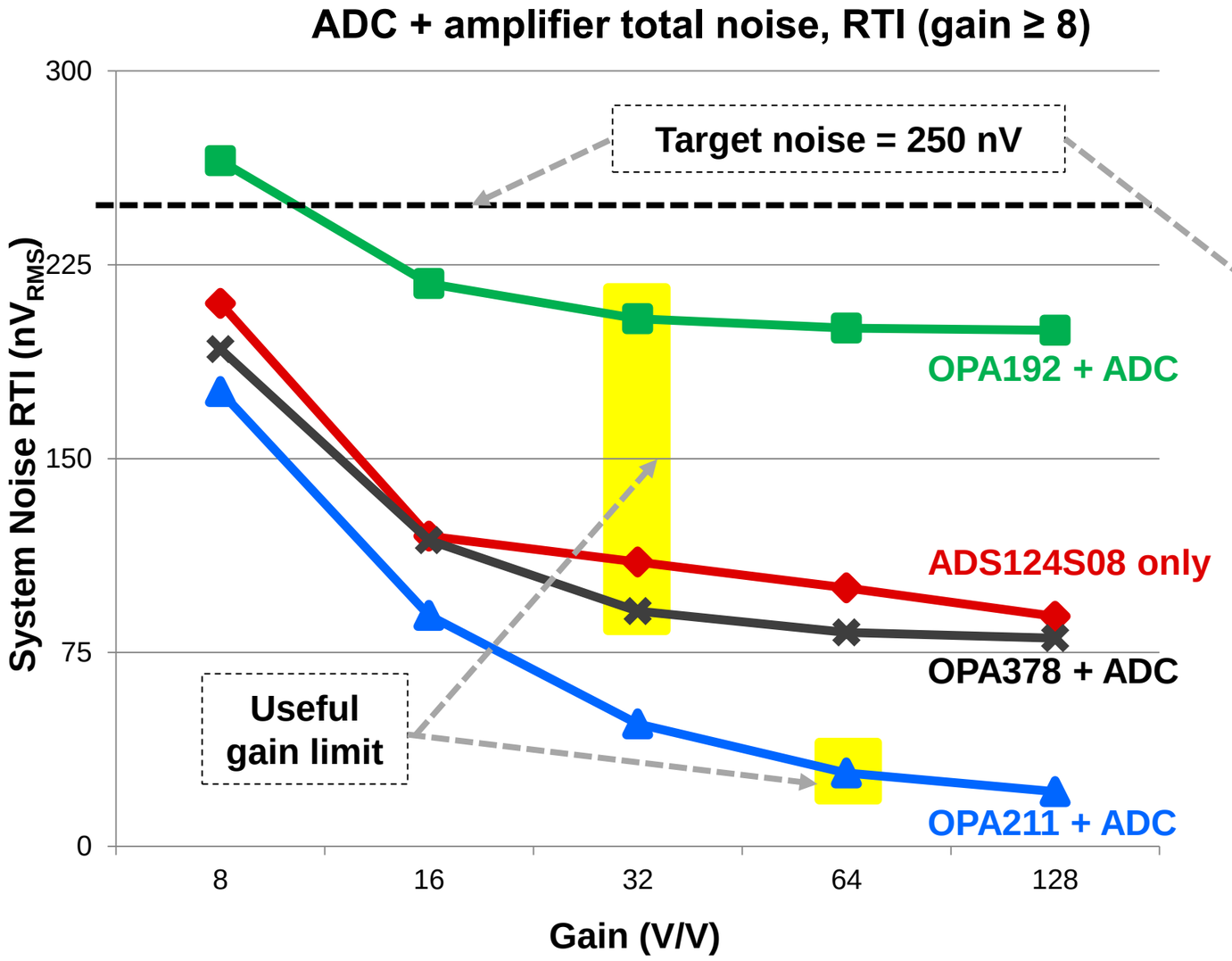

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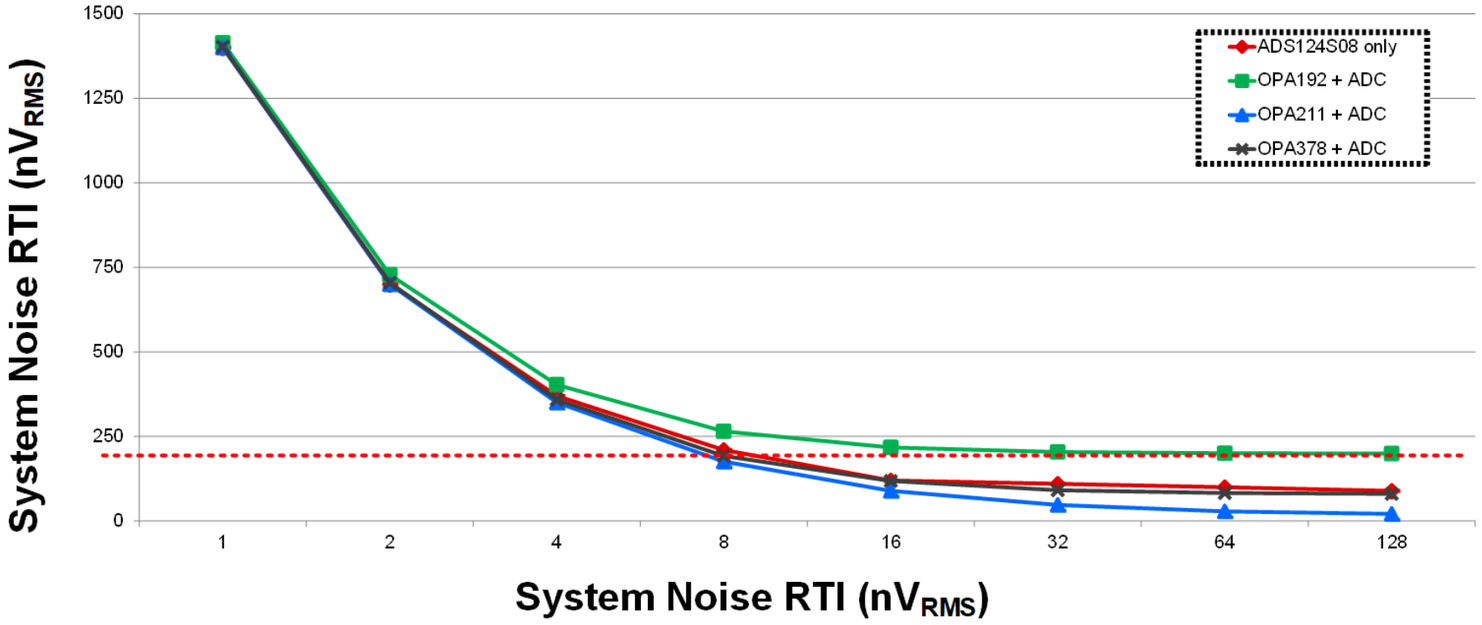
Thanks for your time!
Please try the quiz.

Quiz: Calculating amplifier + ADC total noise

1. For the figure below the system noise RTI for the OPA192 is constant for gains greater than 16V/V. Why?
   a) The system is limited by ADC noise performance at this point.
   b) The system is limited by amplifier noise at this point.



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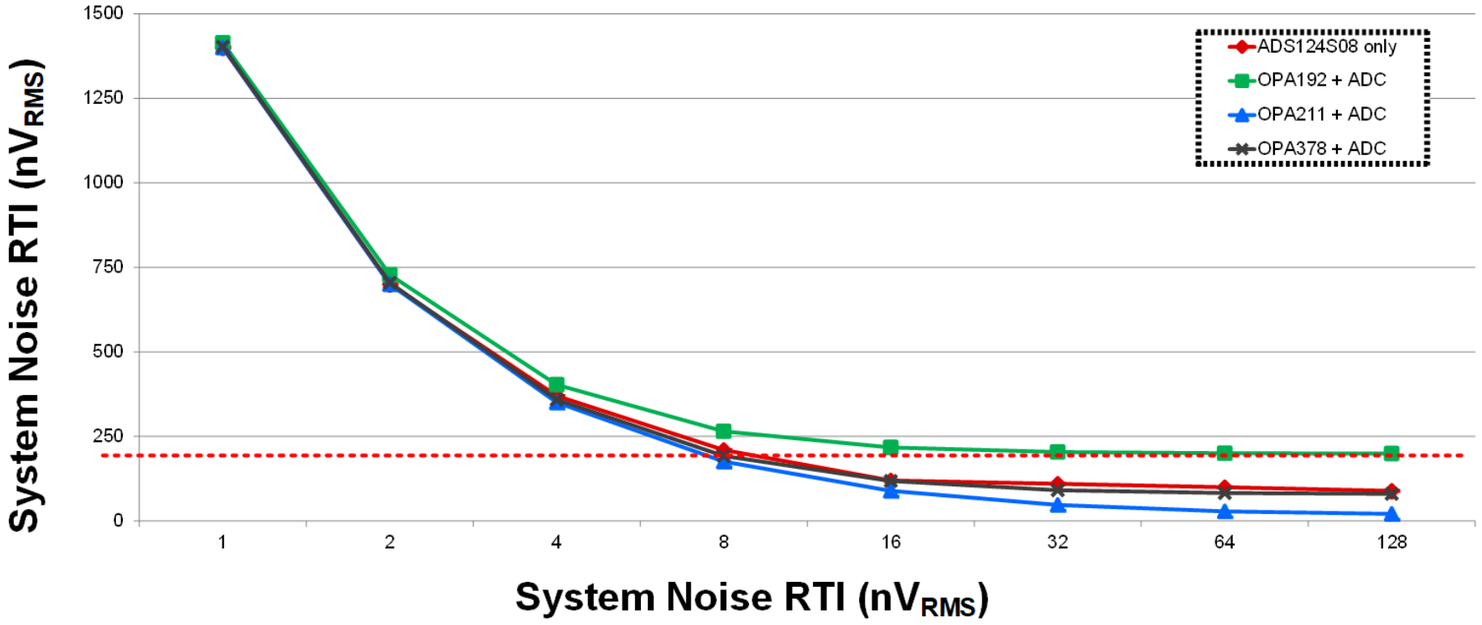
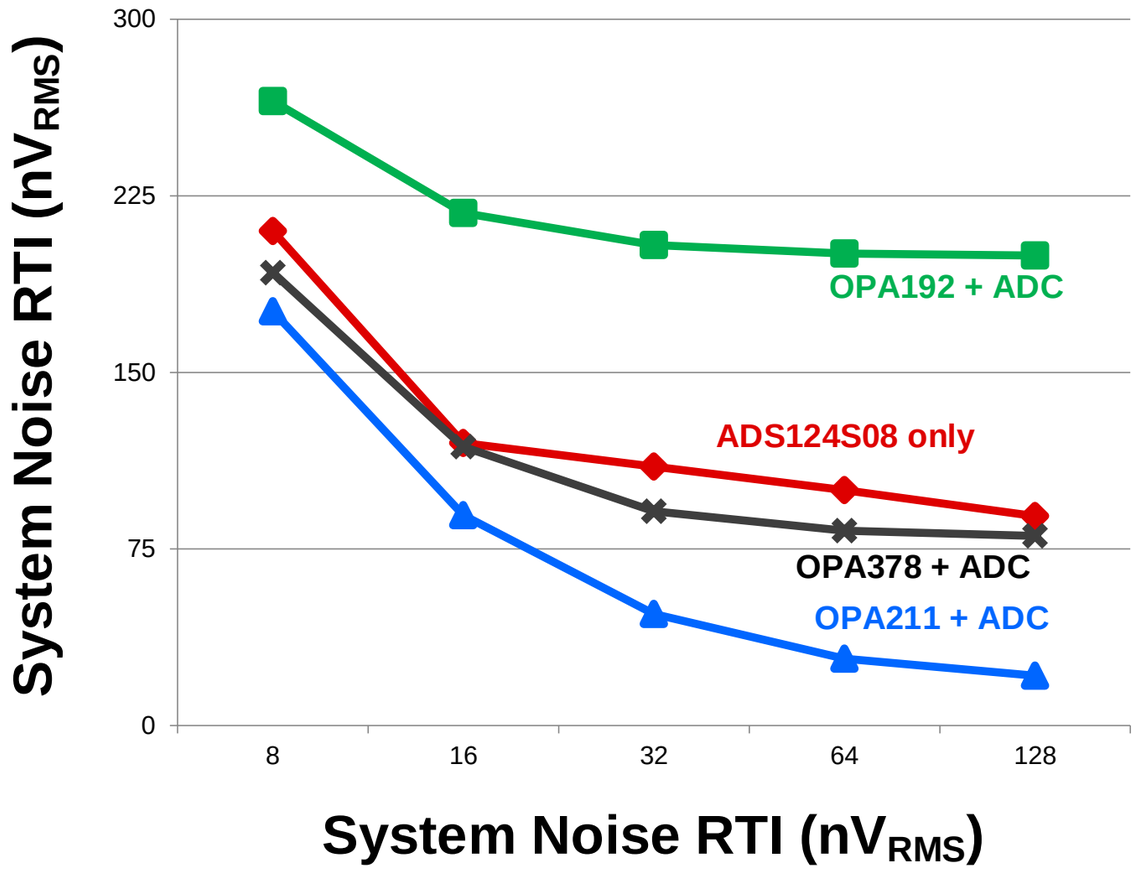


Quiz: Calculating amplifier + ADC total noise

2. Assume the noise target is 150nVrms. Which amplifier cannot meet required performance for any gain value?
   a) OPA192
   b) ADS124S08 only
   c) OPA378
   d) OPA211



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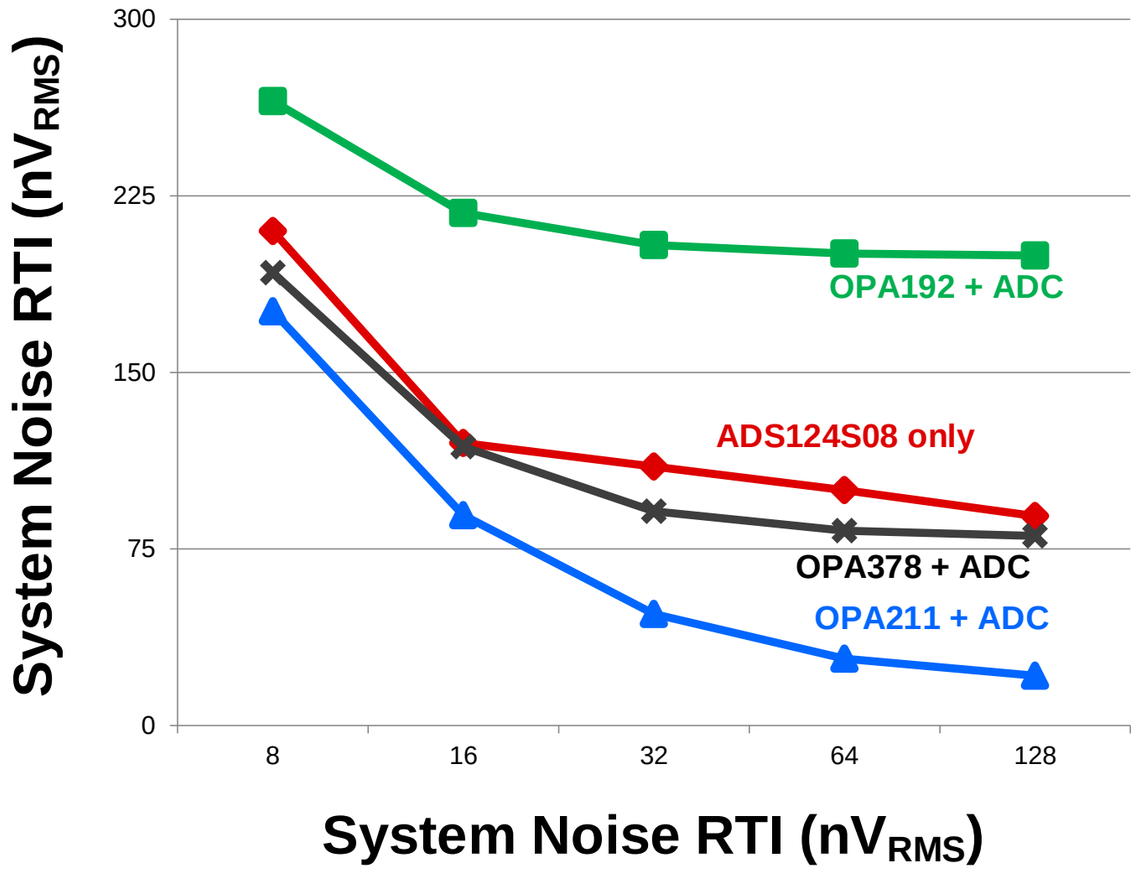

Quiz: Calculating amplifier + ADC total noise

3. (T/F) For DC precision delta sigma converters the internal PGA often has noise performance that is better than discrete amplifiers. Furthermore, discrete amplifiers that are better than the internal buffer are typically high performance op amps that will significantly increase the system cost.
   a) True
   b) False

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   a) True

   b) False

Thanks for your time!