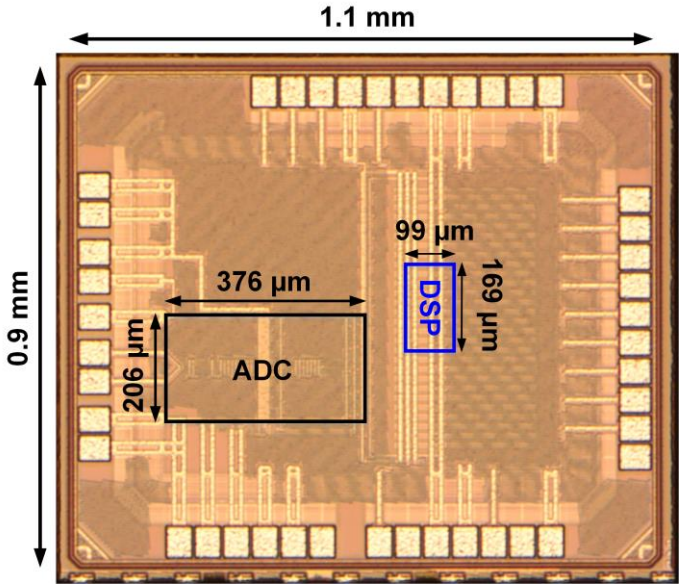

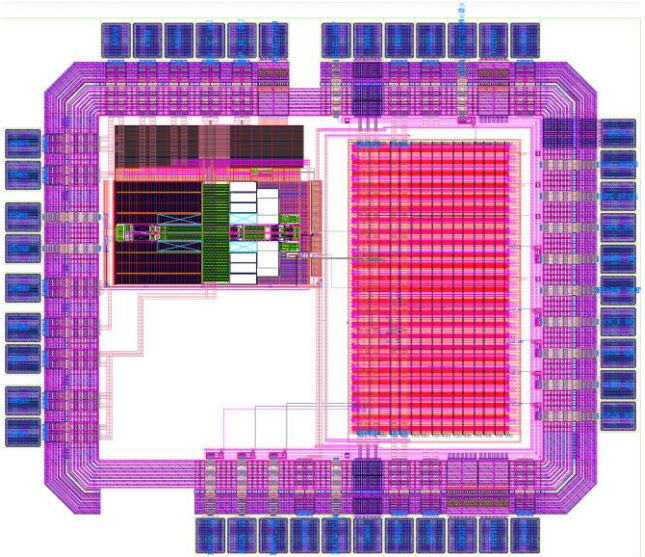

Virtual Research Presentation Conference

A Quadrature Bitstream Integration CTΔ∑ Phasemeter

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Program: SURP

Assigned Presentation # RPC-213 SP20024

Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

Abstract

Phase measurements are critical for accurate detection of gravitational waves using heterodyne interferometry. We present a phasemeter employing a quadrature bitstream integration technique using a continuous time sigma delta modulator (QBI-CTΔΣ). This approach results in less than 0.4° phase error over a 360° input phase sweep and occupies 0.094 mm^2.

Problem Description

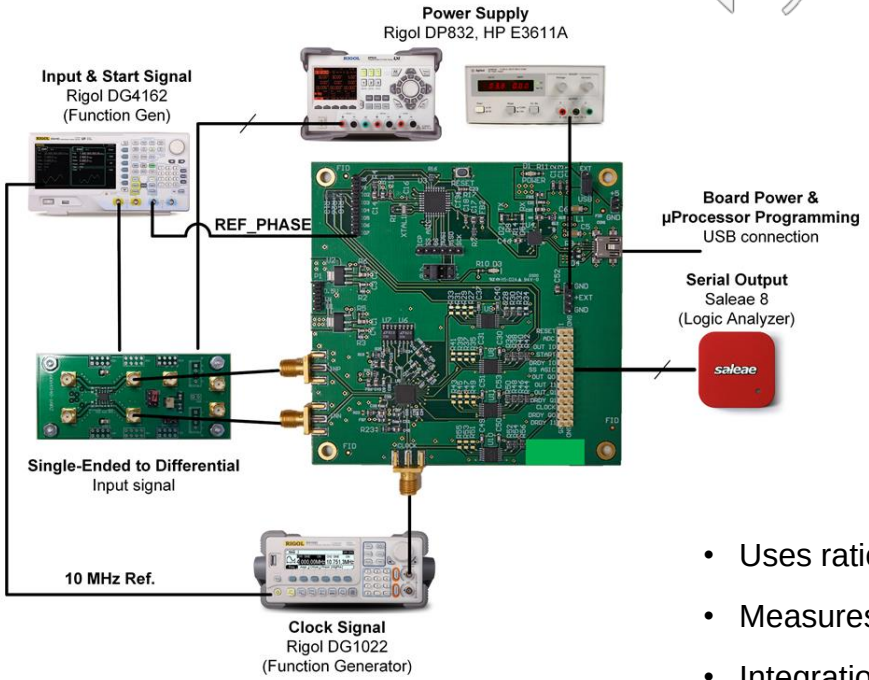
a) LISA mission planned to launch in the 2030's

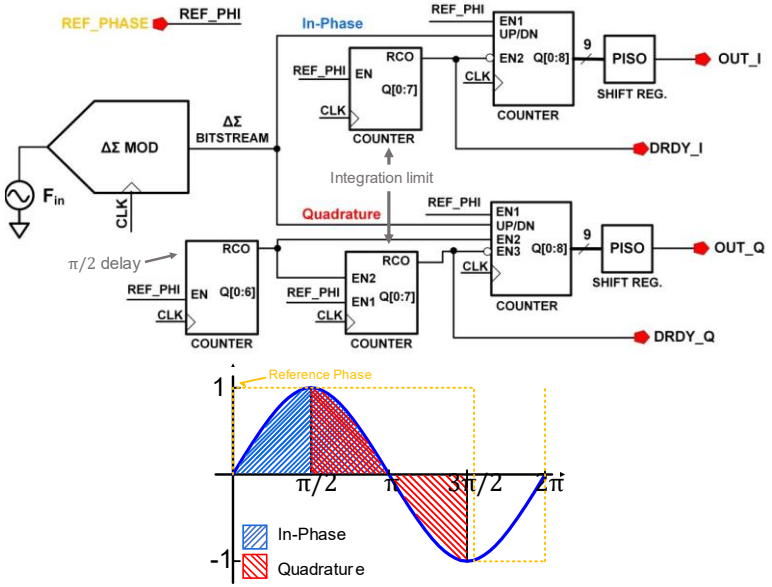
b) Phasemeter is a critical part for gravitational wave detection

c) Current solutions use power-hungry FPGAs

d) ASIC design focused only on phase measurement requiring only 111 µW

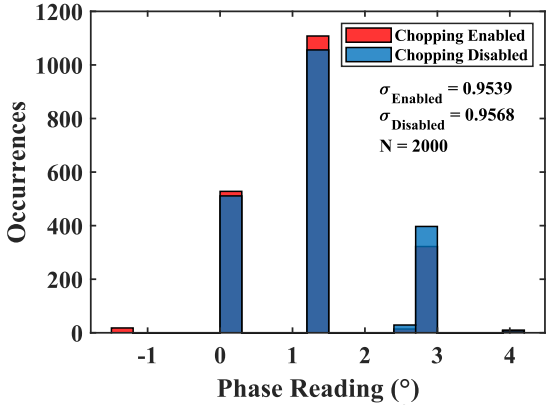
Methodology



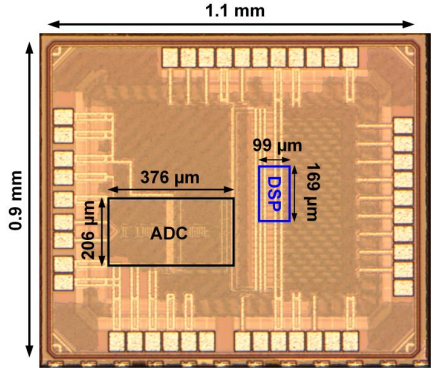


- Uses ratiometric integration since modulator and input frequencies are both kno
- Measures phase with regard to a reference phase
- Integration is performed in the digital domain

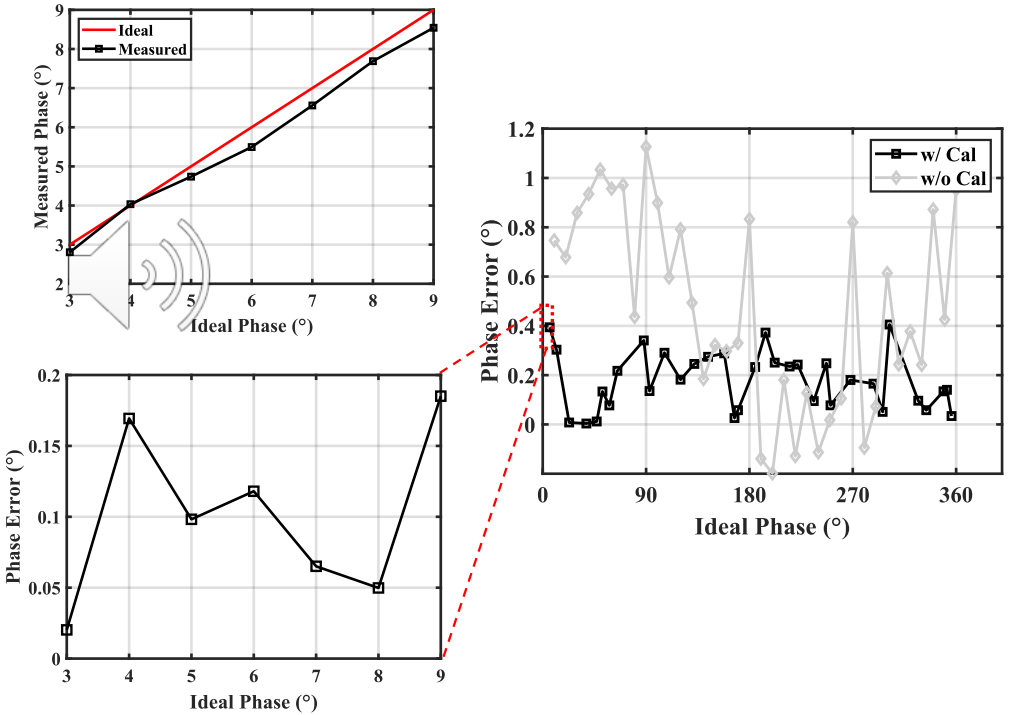
Results



Phase noise measurement histogram (un-calibrated data)



Chip micrograph with an active area of 0.094mm^2

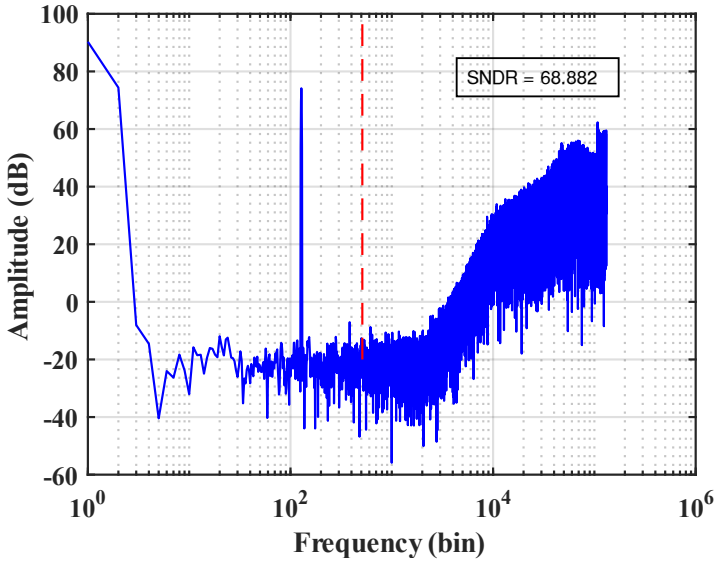


Phase error where each measurement represents an average of 500 samples

Results Comparison

	This Work	ADI AD5933	JSSC '20 [2]	ISSCC'18 [1]	TI-AFE4300
Technology [nm]	**40**	-	65	130	-
Supply [V]	**1**	3.3	0.5	0.6	3
Phase Error [°]	**<0.19°** (3°-9°) **<0.45°** (0°-360°)	[A]<0.8° (0°-7°) [A]<1.05° (0°-360°)	<0.4° (3°-8°)	-	<0.69°
Power [µW]	**111.6**	33000	9.26	0.05 [C]7.05	2910
Energy/Reading [nJ]	**27.7**	-	[D]900	[E]1.41	-
Area [mm^2]	**0.094**	-	4.83	0.0039	-
SNDR [dB]	**68.88**	60	[B]44.64	50.3	-
Frequency (kHz)	**4**	1-100	20	0.02-5	8/16/32/64

[A]Estimated from datasheet [B]SFDR [C]Includes bias & clock power [D]10 Hz output filter [E]5 kHz output



Publications and References

[1] M. El Ansary *et al.*, “50nW 5kHz-BW opamp-less ΔΣ impedance analyzer for brain neurochemistry monitoring,” in *2018 IEEE International Solid - State Circuits Conference - (ISSCC)*, Feb. 2018, pp. 288–290.

[2] K. Kim, J.-H. Kim, S. Gweon, M. Kim, and H.-J. Yoo, “A 0.5-V Sub-10-μW 15.28-mΩ/√Hz Bio-Impedance Sensor IC With Sub-1° Phase Error,” *IEEE Journal of Solid-State Circuits*, vol. 55, no. 8, pp. 2161–2173, Aug. 2020.