IDEC Chip Design Contest

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Cryogenic Baseband Amplifier in 28nm CMOS Process for Quantum Computing

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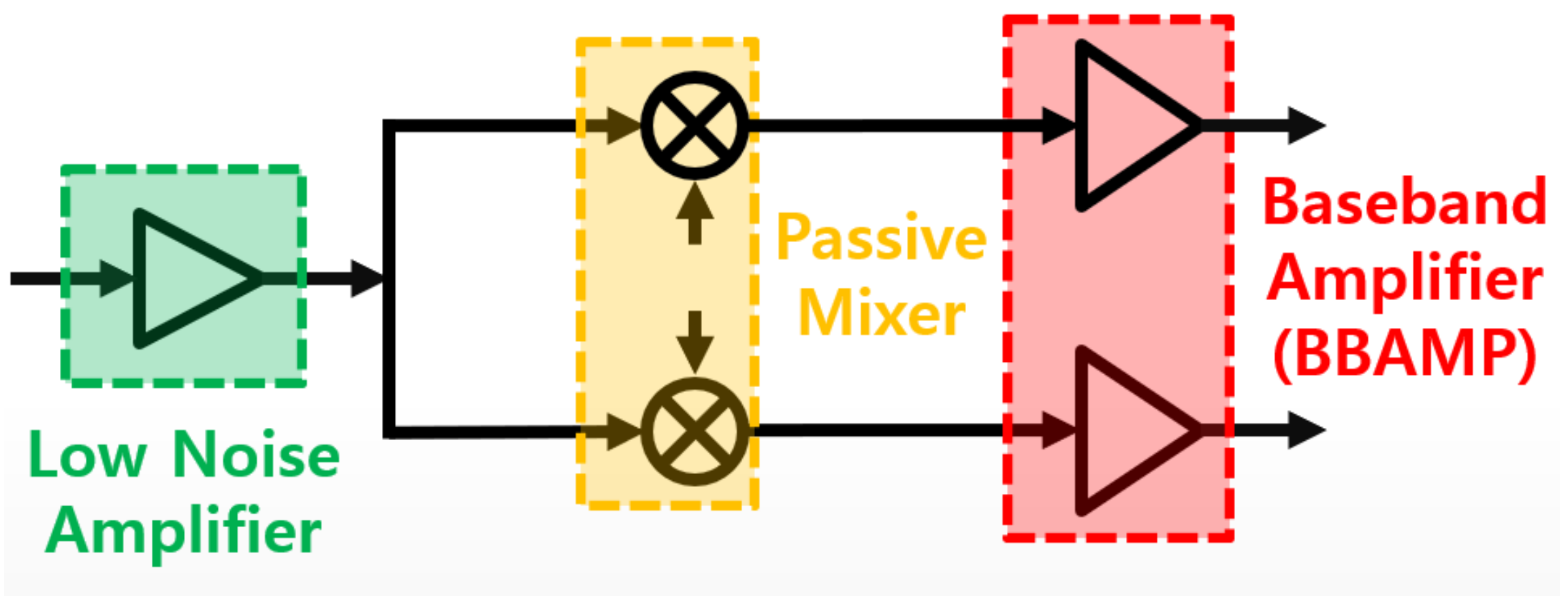
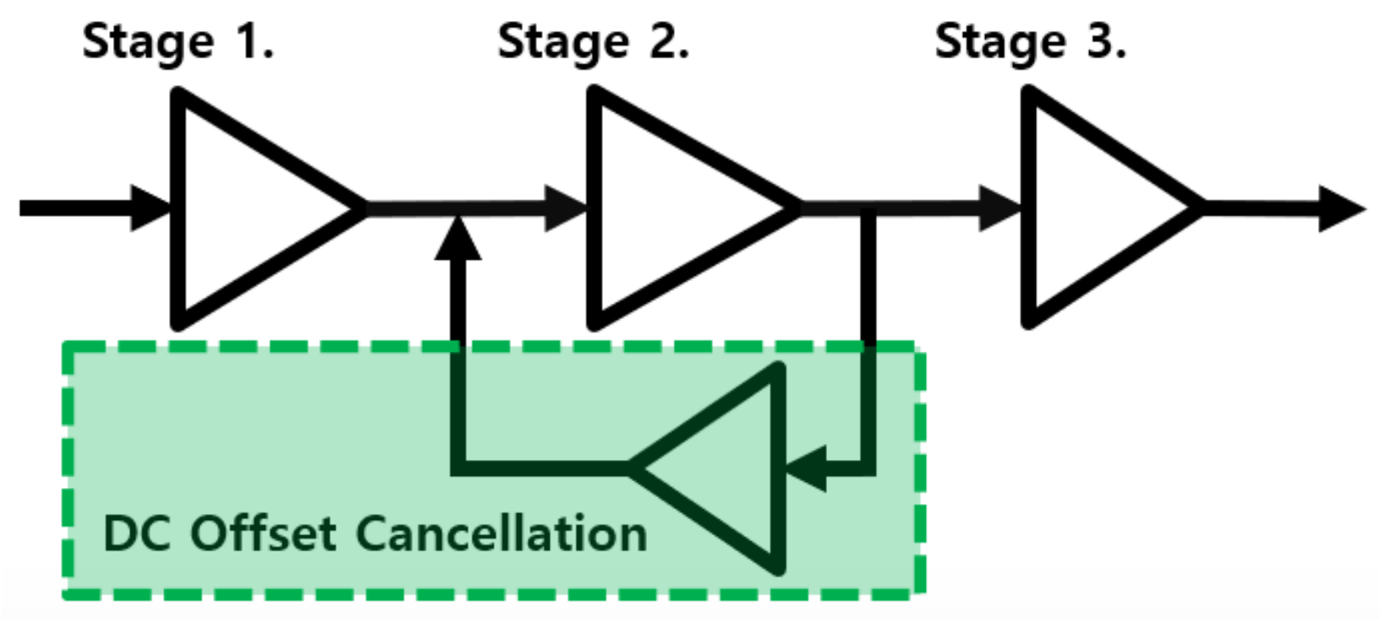
Introduction

- ◆ The reliance on bulky room-temperature instrumentation limits the scalability of superconducting quantum computing systems. Integrating signal processing at cryogenic temperatures is essential for compact and scalable architectures
- ◆ This work presents a cryogenic baseband amplifier (BBAMP) for quantum readout, which amplifies weak down-converted signals directly after the mixer, reducing the need for room-temperature amplification.

Circuit Design

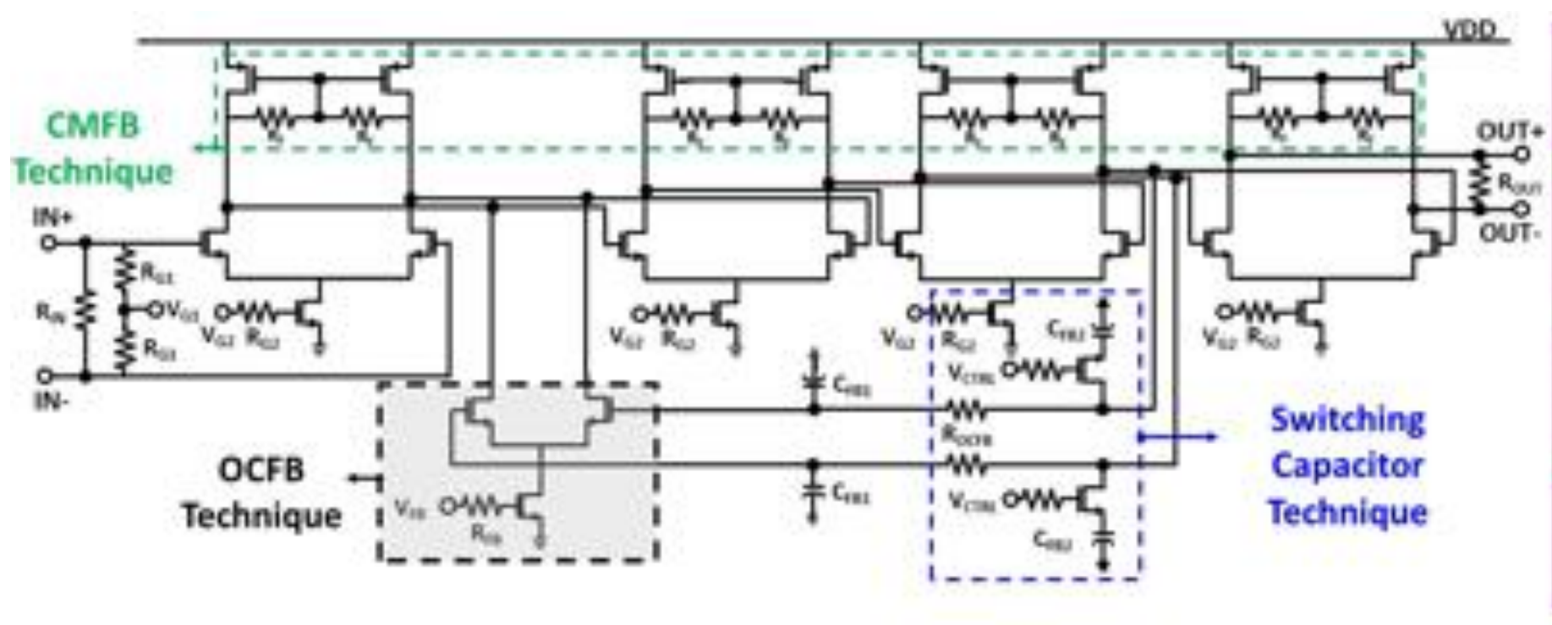


Quantum Readout Block Diagram

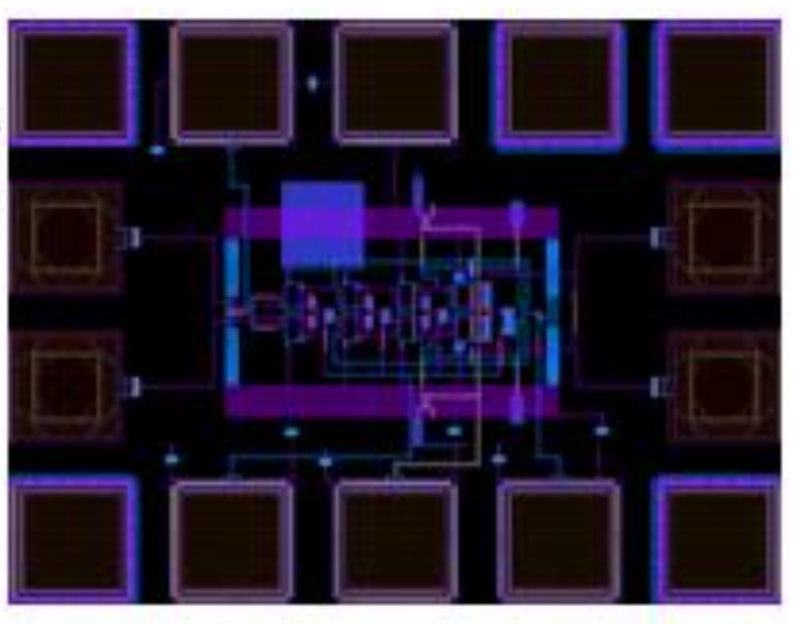


Baseband Amplifier Block Diagram

- ◆ Modern quantum control and readout platforms are typically built around external measurement hardware operating at room temperature. While effective, this approach introduces significant overhead in terms of interconnect complexity, signal integrity degradation, and overall system cost.
- ◆ The integration of quantum control and readout circuits necessitates their operation within a cryogenic environment, typically implemented using a dilution refrigerator.



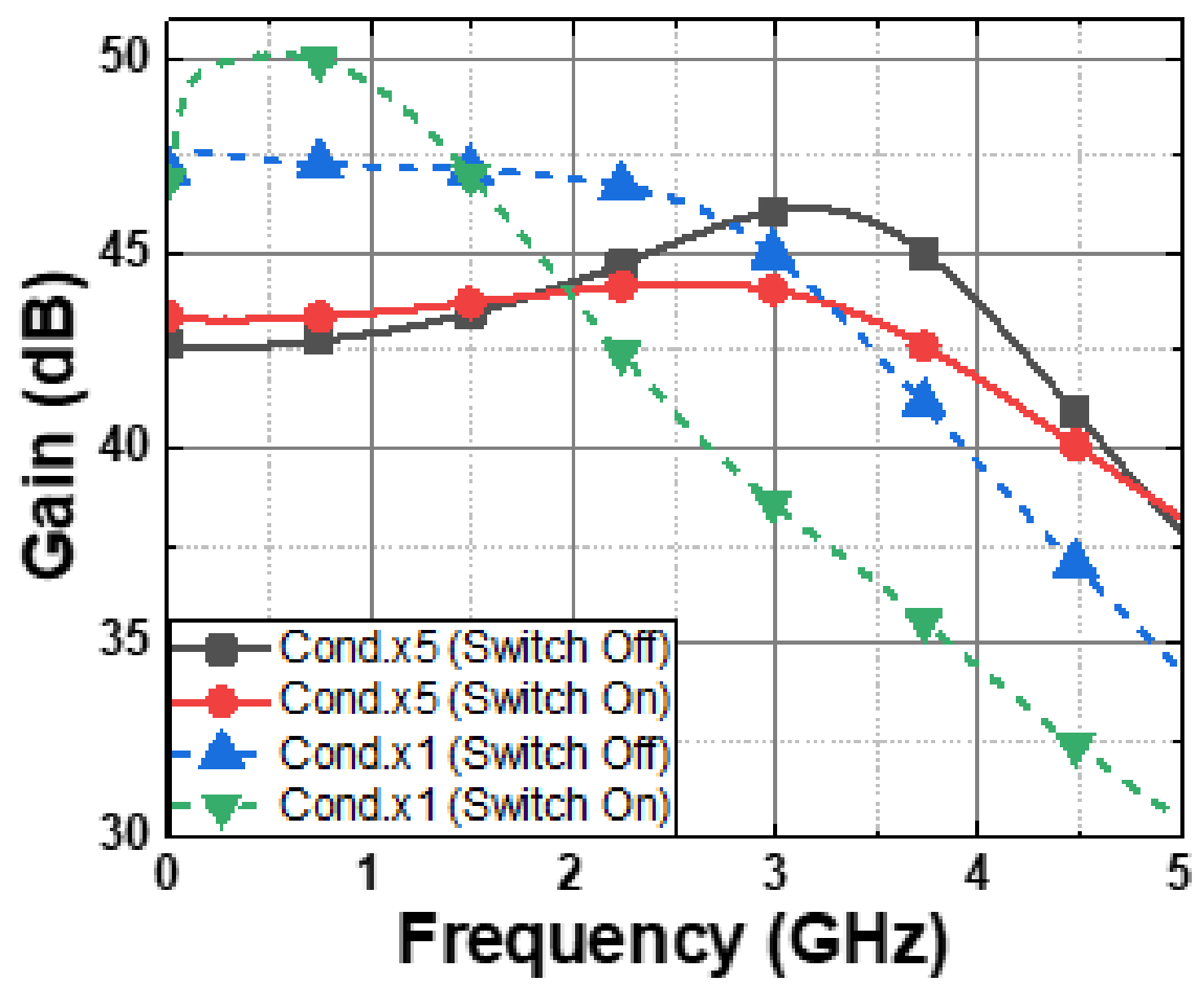
Schematic

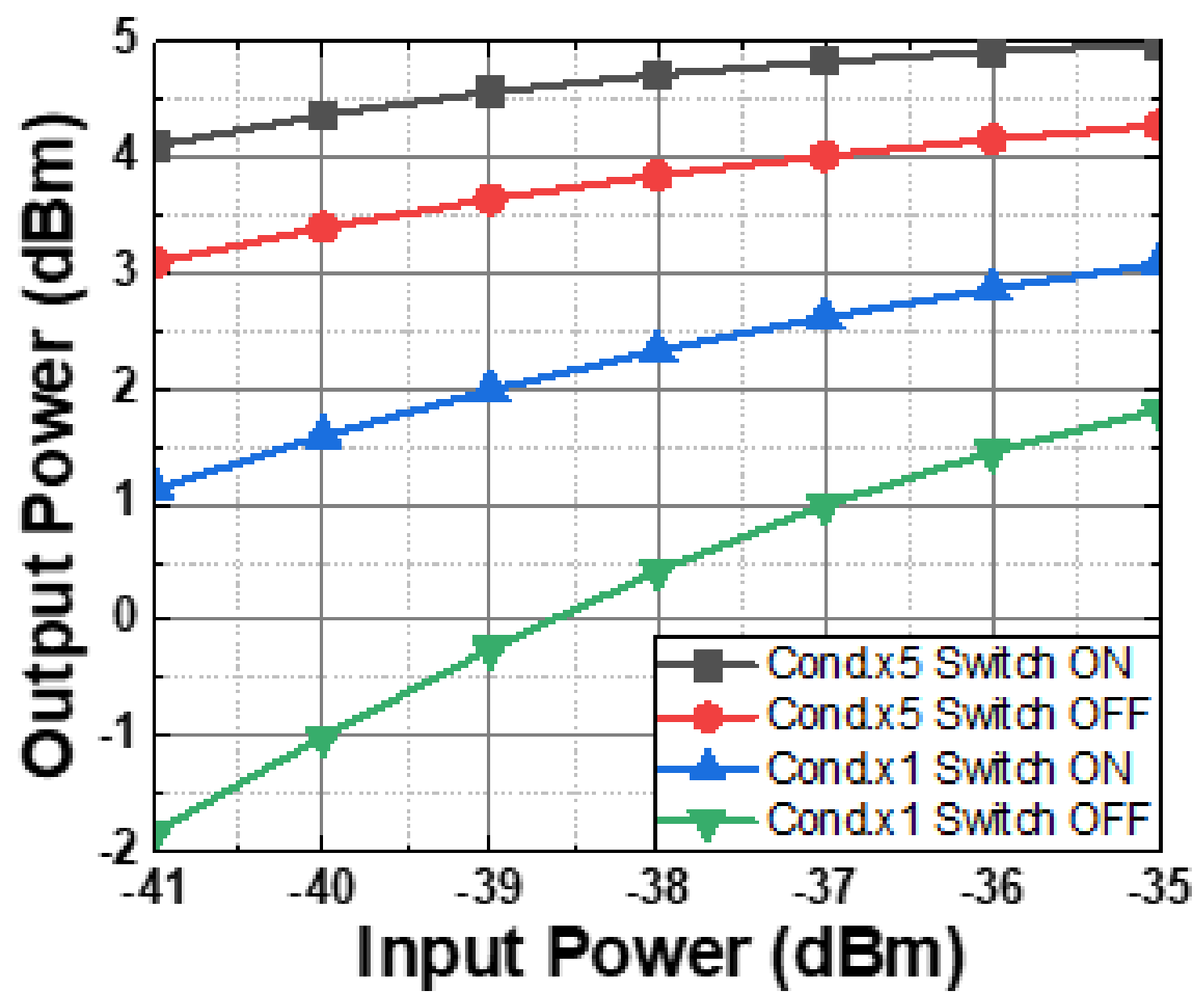


Layout

- ◆ Various amplifier topologies, including common-source, common-gate, and cascode structures, are commonly employed in analog circuit design. In this work, a common-mode feedback-based fully differential common source architecture is selected due to its capability to achieve high gain with robust operation under cryogenic conditions.

Results





- ◆ **This chip is fabricated Samsung 28nm CMOS process.**
- ◆ **The 3-dB bandwidth is 2.9 GHz from DC to 2.9 GHz.**
- ◆ **Gain is 45 dB with 23 mW power consumption, excluding the buffer.**
- ◆ **Chip size is 0.48 mm × 0.62 mm.**

BB Amp. Comparison Table

Ref.	Tech.	Gain (dB)	Bandwidth	OP_{1dB} (dBm)	Power (mW)
[1]	40nm CMOS	12-28	DC – 10GHz	-3	20
[2]	28nm CMOS	35	DC – 400MHz	8	25.6
[3]	40nm CMOS	30	100MHz – 1.5GHz	-10	N/A
[4]	SiGe BiCMOS	11-31	DC – 700MHz	-18	N/A
This Work	28nm CMOS	36.9	4.6GHz – 8.2GHz	0.75	23.4*
This Work	28nm CMOS	45.7	DC – 2.9GHz	1.89	22.4*

* : Excluding the buffer Stage

[1] T. H. Jang, D. M. Kang, S. H. Kim, C. J. Lee, S. Jun, H. Park, J. H. Kim, and C. S. Park, “120-GHz Wideband I/Q Receiver Based on Baseband Equalizing Technique,” IEEE Journal of Solid-State Circuits, vol. 56, no. 6, pp. 1697–1707, Jun. 2021

[2] H. Razavi and B. Razavi, “A 0.4–6 GHz Receiver for Cellular and WiFi Applications,” IEEE Journal of Solid-State Circuits, vol. 57, no. 9, pp. 2640–2657, Sept. 2022

[3] Y. Peng et al., "A Cryo-CMOS Wideband Quadrature Receiver With Frequency Synthesizer," IEEE Journal of Solid-State Circuits, vol. 57, no. 8, pp. 2374–2386, Aug. 2022.

[4] R. C. Kwende, D. Rosenstock, C. Wang, and J. C. Bardin, “Design and Characterization of a 6-mW Cryogenic SiGe IC for Superconducting Qubit Readout,” IEEE Transactions on Microwave Theory and Techniques, vol. 73, no. 1, pp. 234–242, Jan. 2025

Conclusion

The realization of an on-chip cryogenic baseband amplifier (BBAMP) in this work enables efficient amplification of weak readout signals in quantum systems. By providing sufficient gain at cryogenic temperatures immediately after the mixer stage, the proposed BBAMP reduces the dependency on bulky room-temperature amplification chains. This approach supports the development of compact and scalable, fully integrated quantum readout architectures

Acknowledgement

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