Performance of a Low-parasitic Frequency Domain Multiplexing Readout

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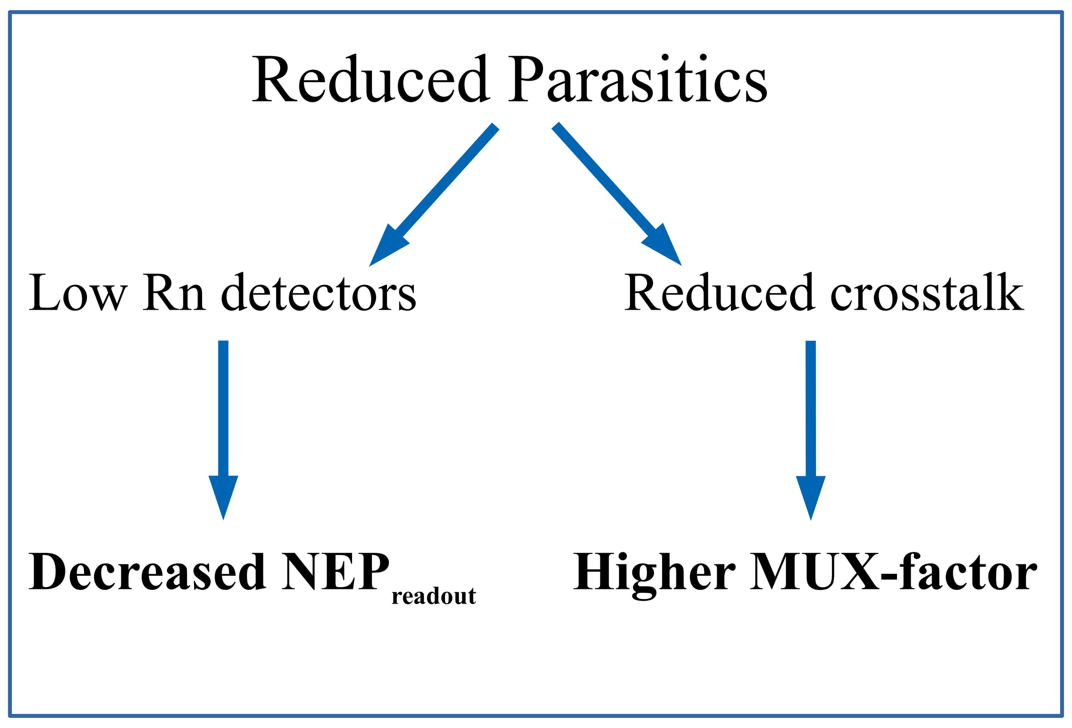
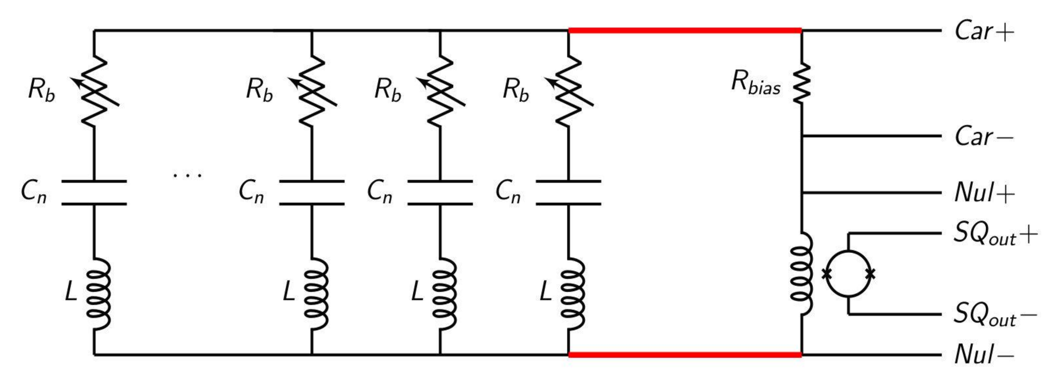
Abstract

Frequency-domain multiplexing is a readout technique for transition-edge sensor bolometer arrays used in modern CMB experiments. Here we present design details and performance measurements for a **low-parasitic frequency-domain multiplexing readout.** In this prototype system, low parasitic impedance reduces crosstalk between readout channels. This allows **higher multiplexing factors**, and enables operation of lower-resistance bolometers, which **decreases the contribution of readout noise to the total NEP** by decreasing the required voltage bias. The MfMux system has demonstrated warm overbiased noise comparable to SPT-3G readout hardware, as well as a factor of two improvement in parasitic resistance compared to SPT-3G hardware. Ongoing work seeks to further reduce parasitic impedances, leading to a lab demonstration of a readout with low-resistance bolometers.

Key benefits

- Decreased stray resistance enables **operation of low-R_n bolometers**.
  - This **reduces $NEP_{readout}$** because the bolometers can be operated with lower V_{bias}.
- Reduced crosstalk enables denser packing of bolometers in frequency space
  - **This allows for higher multiplexing factors and improved scalability.**
- Leverages much of the existing DfMux architecture, which has proven on-sky performance
- Drop-in replacement for 3G-style LC boards

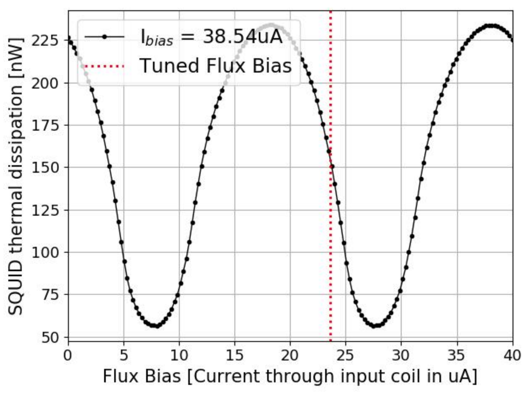




Schematic of the dfMux readout. The wires highlighted in red run between the LC resonators and the SQUID. Stray impedance in these wires create a voltage divider effect which is the dominant source of crosstalk in the existing dfMux system.

Next Steps

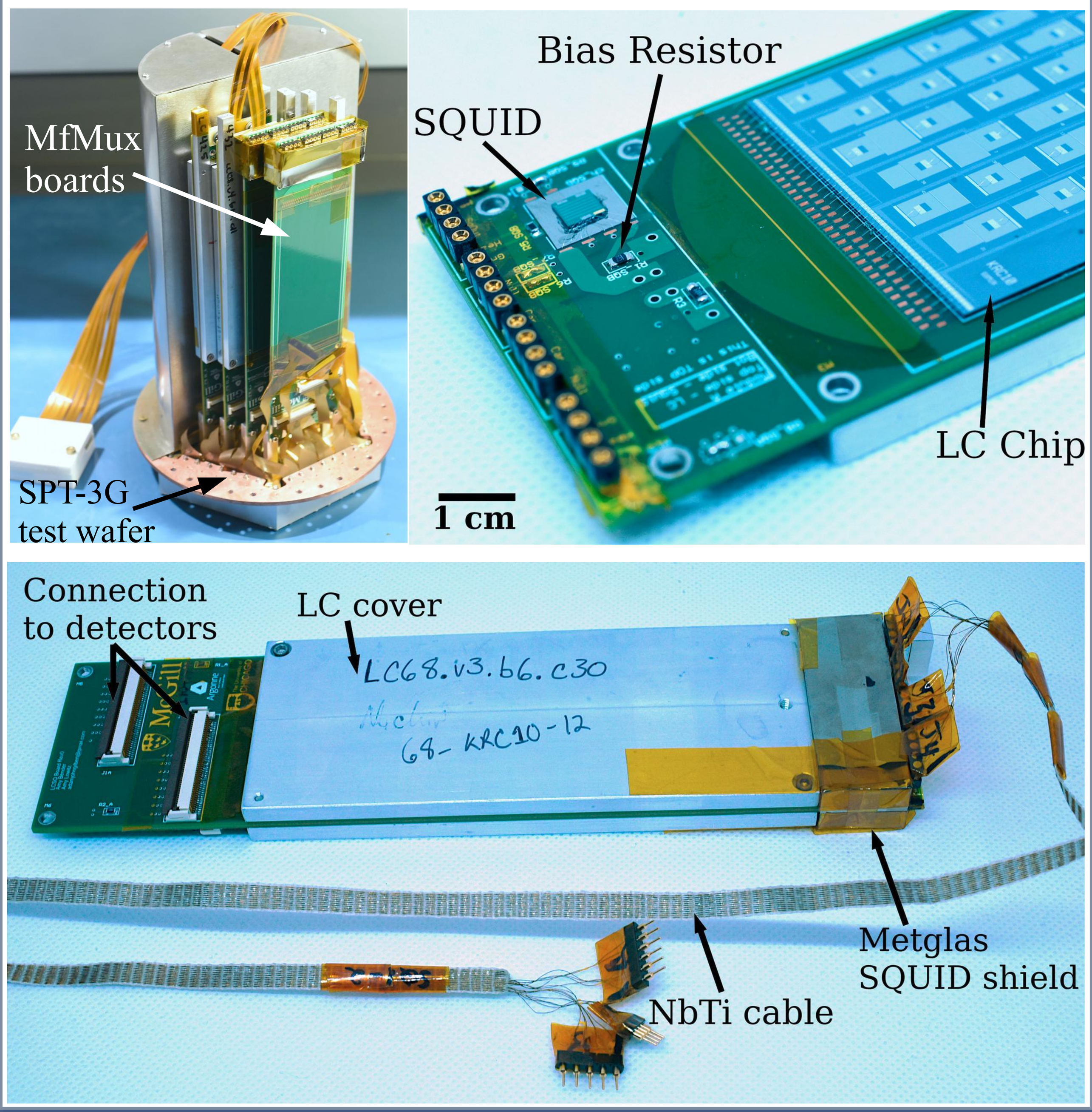
- SQUID improvements
  - Lower thermal dissipation required for operation at scale with a sorption refrigerator



- Noise and Crosstalk Characterization
- Low-R bolometer integration
  - Testing with calibrated resistors, and eventually low-R bolometers
- Scaling
  - Testing with a larger number of combs

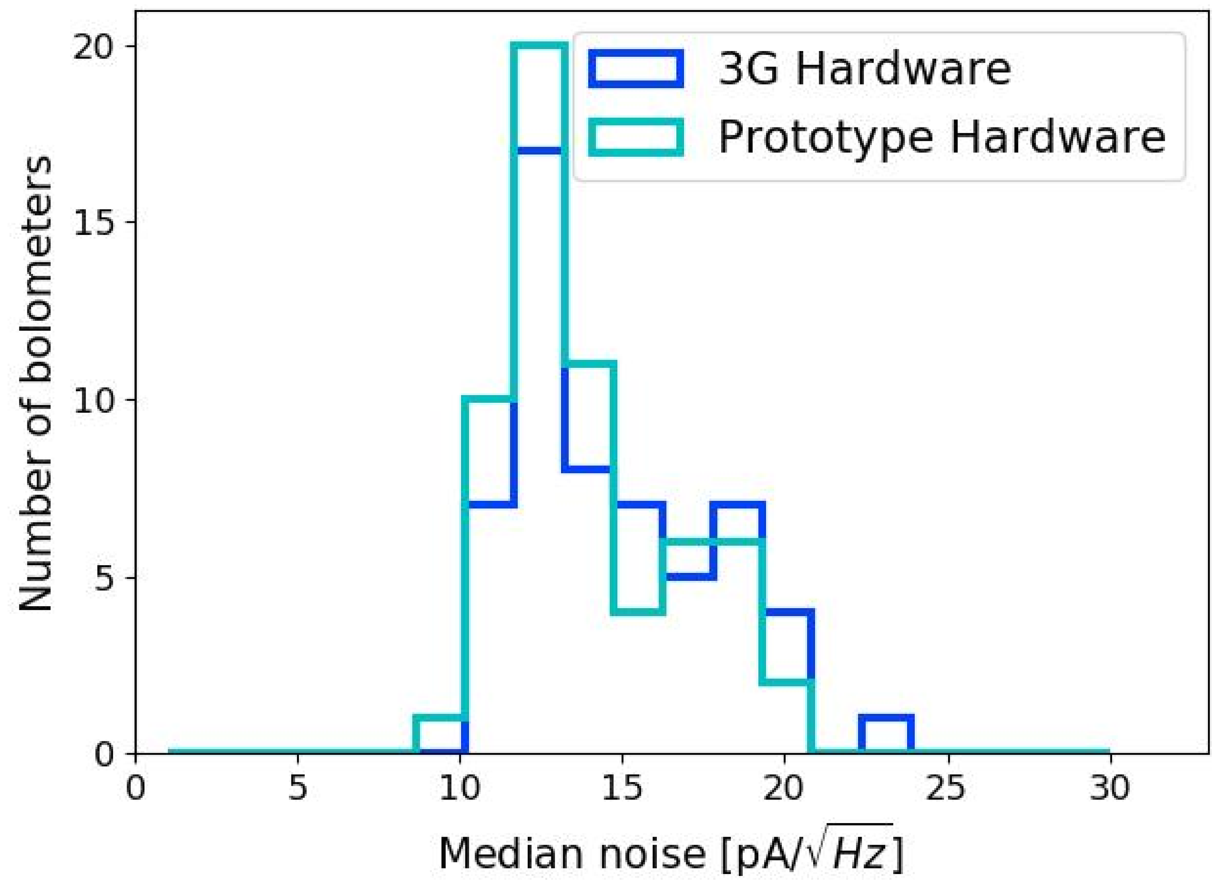
Design and Implementation

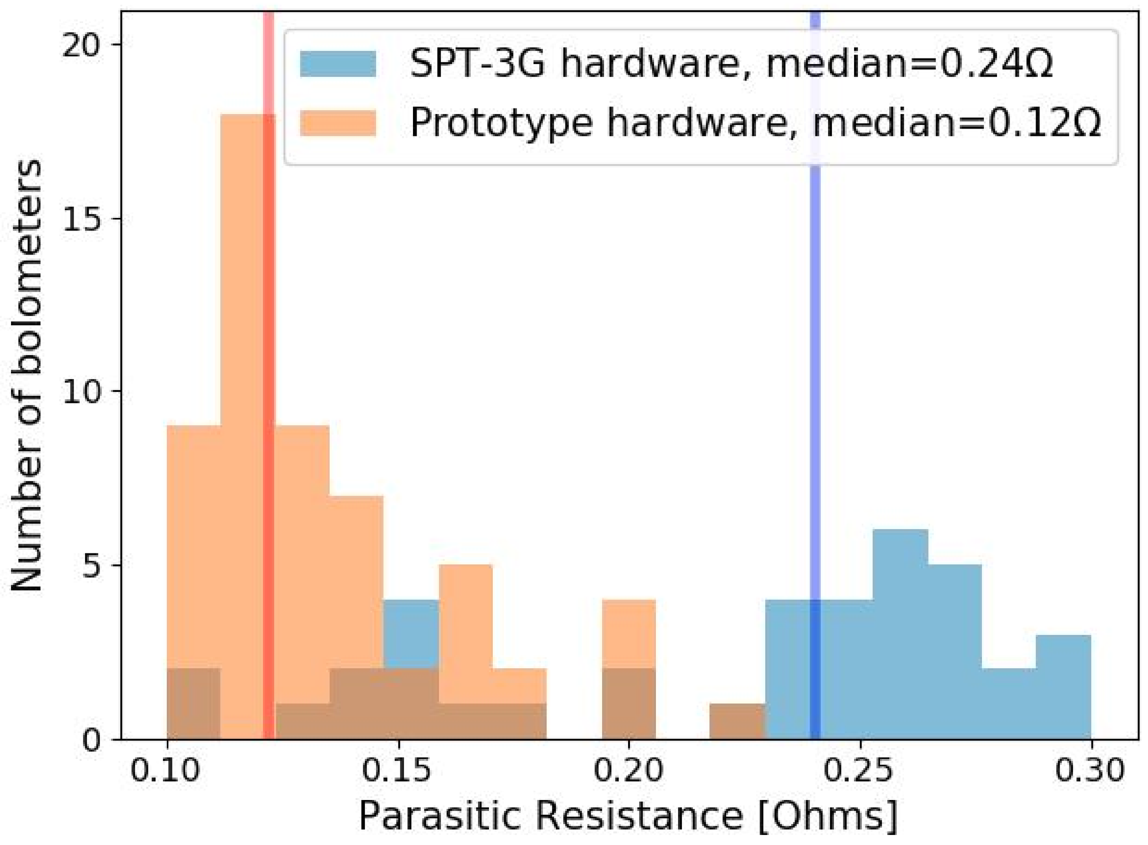
- Moving the SQUID from the 4 K stage to the 250 mK stage
- This reduces the wiring length between the SQUID and LC chip
  - Reduced parasitic impedance
    - Reduces crosstalk
    - Enables operation of low-resistance bolometers
  - Improves scalability
- Retained as much of the existing DfMux design as possible.
  - This reaps the benefits of **reduced crosstalk, reduced parasitic resistance, and improved scalability, while retaining as much technological maturity as possible.**
- **Magnetic shielding** for the SQUID is provided by six layers of Metglas.
- The prototype boards are sized so they can be a **drop-in replacement** for SPT-3G-style LC boards in any of the SPT-3G testbeds or, in principle, the telescope itself.



Performance

(Below Left) The warm overbiased **noise performance** of the MfMux system is comparable to the performance of the standard SPT-3G DfMux hardware in the same laboratory testbed (shown) and on-sky. **(Below Right)** The median **parasitic resistance** of the MfMux prototype is half that of 3G DfMux hardware under the same laboratory testing conditions. Vertical lines indicate the medians.





(Below Left) We have **operated 57 (of a possible 58) bolometers** on a single comb simultaneously in the TES superconducting transition to a fractional resistance of $0.2xR_n$. Shown are RP curves for three representative bolometers. The 'bendback' feature results from the parasitic resistance, which is significant compared to the bolometer resistance when very deep in the superconducting transition.
(Below Right) Performance of the NIST SA13 SQUIDs is similar at 3.8 K, 2.4 K and 257 mK, with small improvements in peak-to-peak voltage and transimpedance at lower temperatures. Shown is a v-phi curve for a representative SQUID at three temperatures.