

Readout technology in France Time and Frequency Mux. for TES Readout

D. Prèle, M. Piat, F. Voisin, T. Decourcelle, C. Perbost, A. Tartari, G. Bordier, C. Chapron, C. Beillimaz, S. Chen
on behalf of QUBIC and X-IFU collaborations



Towards a next space probe for CMB observations and cosmic origins exploration

19 mai 2016 - CERN

Outline

1 QUBIC readout chaine - TDM

- 1 : 128 TDM multiplexer topology
- Readout chain
 - SQUID stage
 - Cryogenic integrated circuit
- Multiplexed signal

2 ATHENA X-IFU readout chaine - FDM

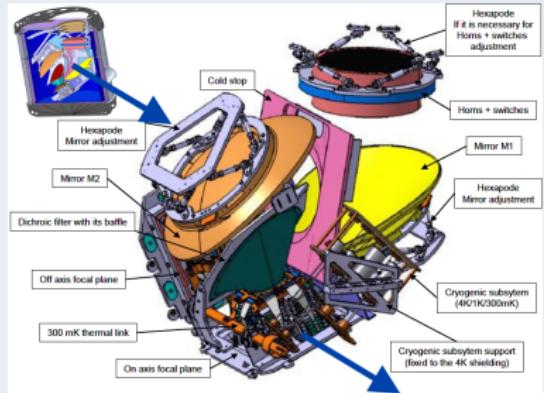
- The X-IFU instrument
- Readout chain
- ASIC development for the X-IFU instrument

Q & U Bolometric Interferometer for Cosmology - QUBIC

Cosmology experiment for B-mode polarization of the Cosmic Microwave Background



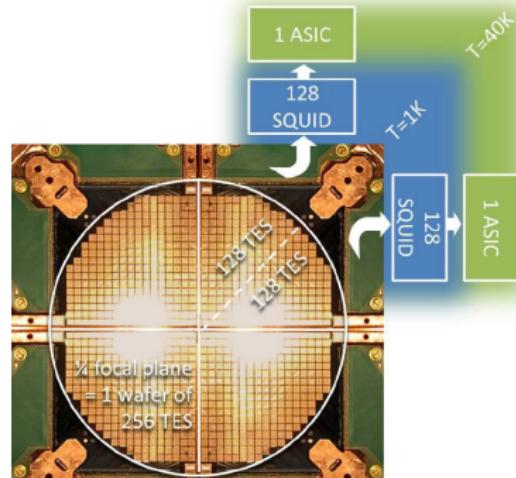
Bolometric Fizeau interferometer



- 45cm window / 14°field-of-view
- 400 back/back horn (looking sky)
- 400 switches (self calibration)
- Off-axis Gregorian (combiner)
- 2×1024 filled array (150/220GHz)

NbSi TES focal plane imager

- Interference fringes (synthesized image)
- 1024 NbSi TES on 4 wafers ($\times 2$ freq.)

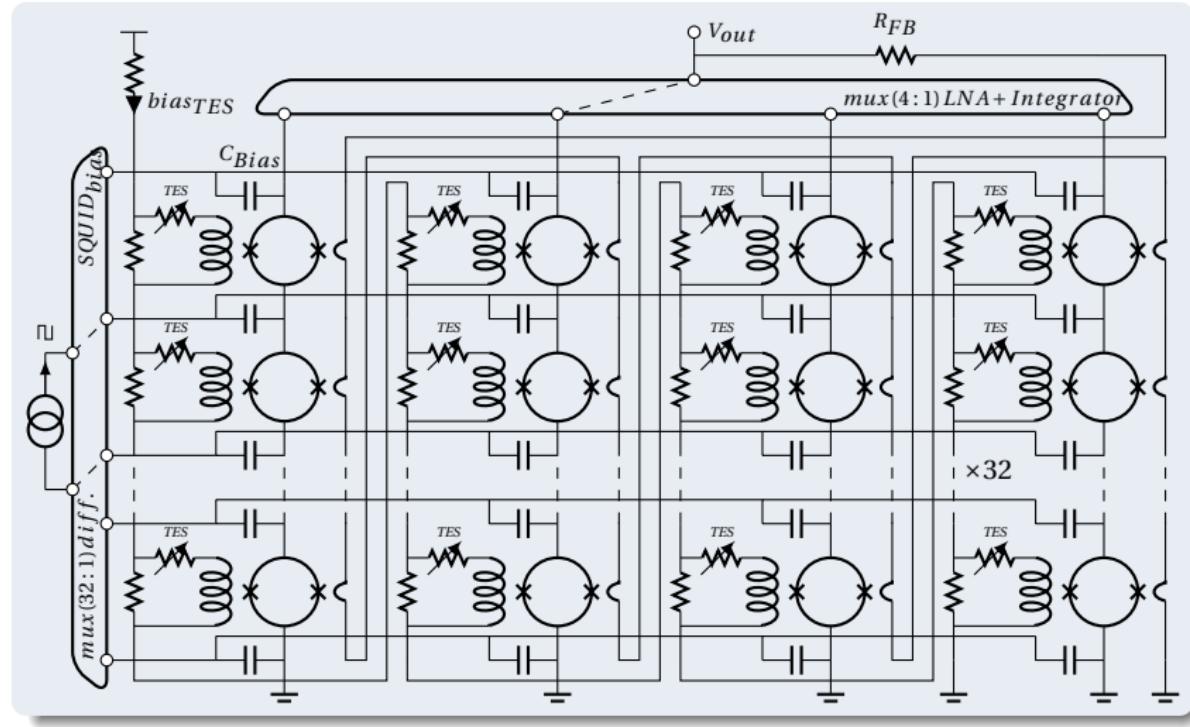


Present work, sub-system :

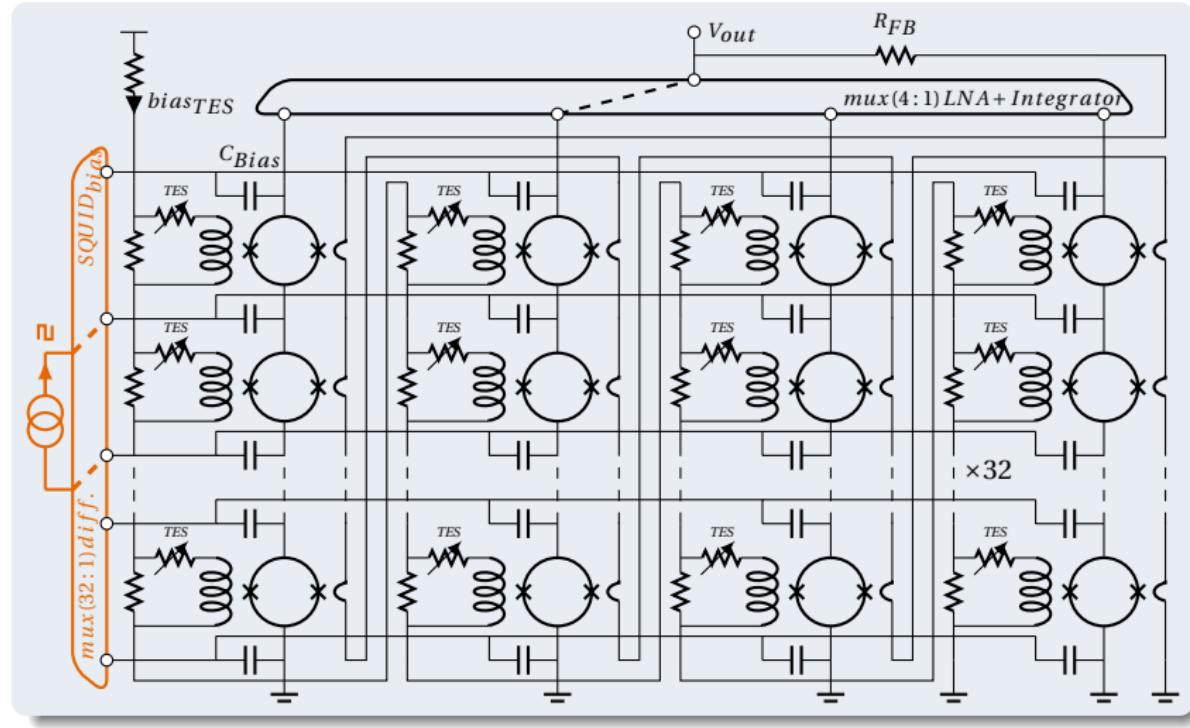
256 TESs, 256 SQUIDS (TDM), 2 ASICS (LNA + bias)



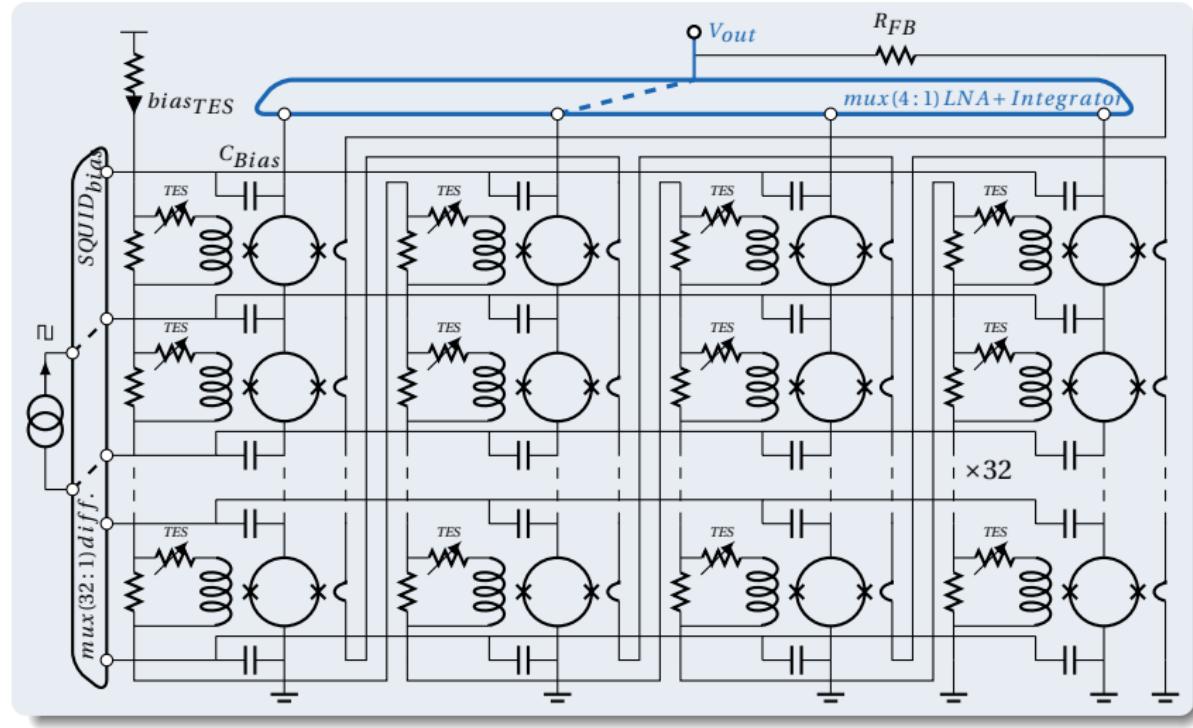
TES readout topology based on 2D multiplexing scheme



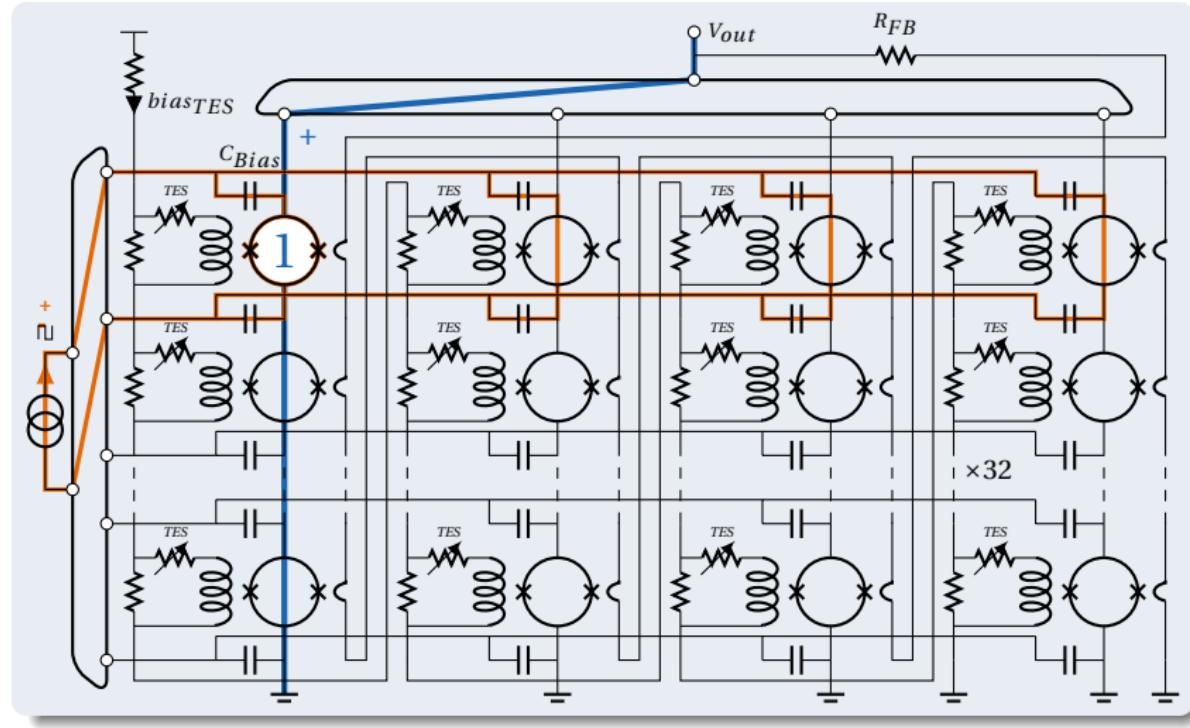
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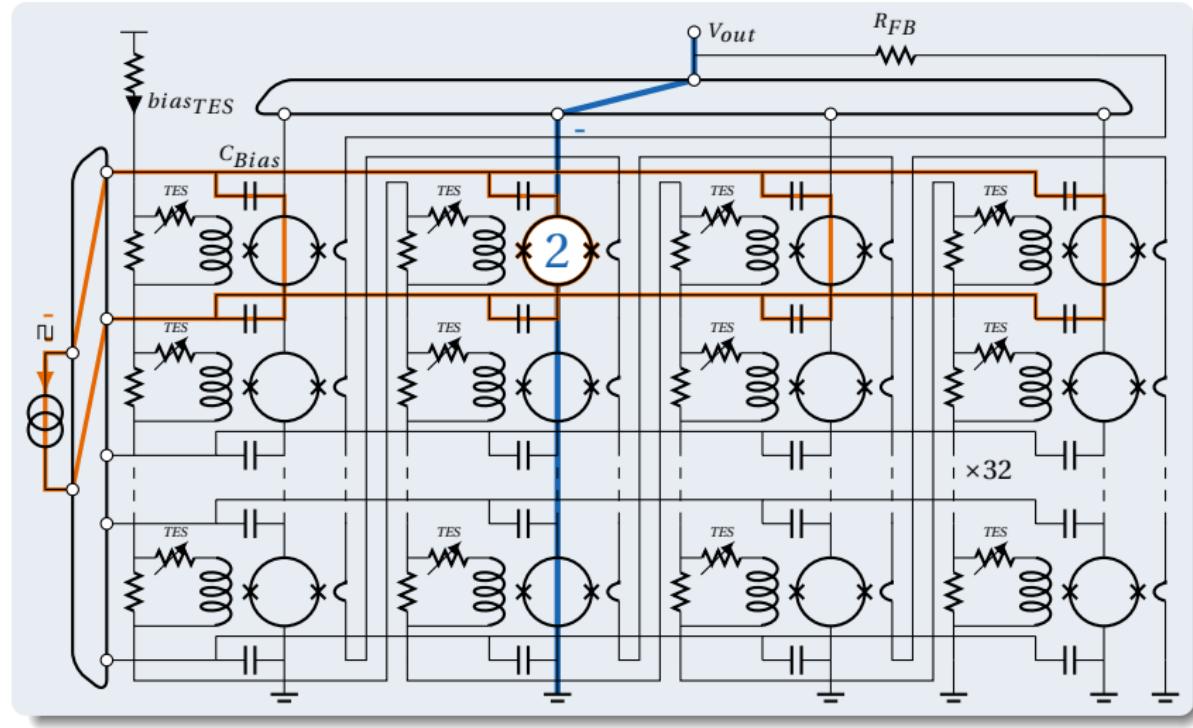
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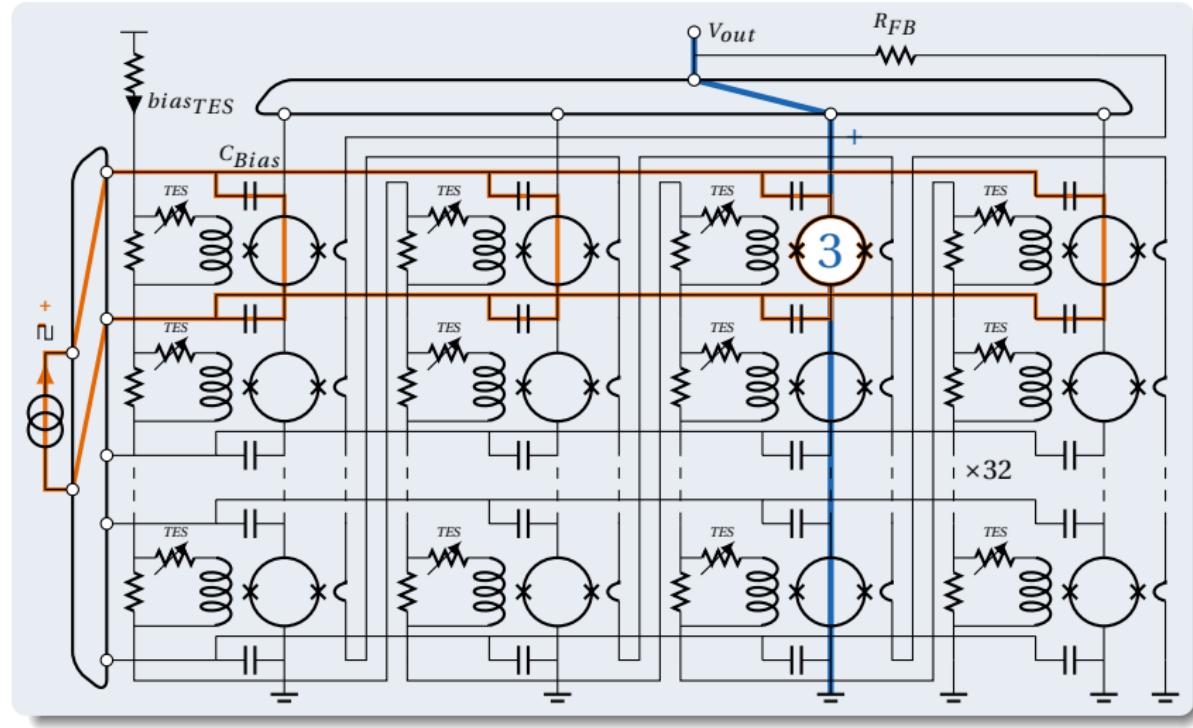
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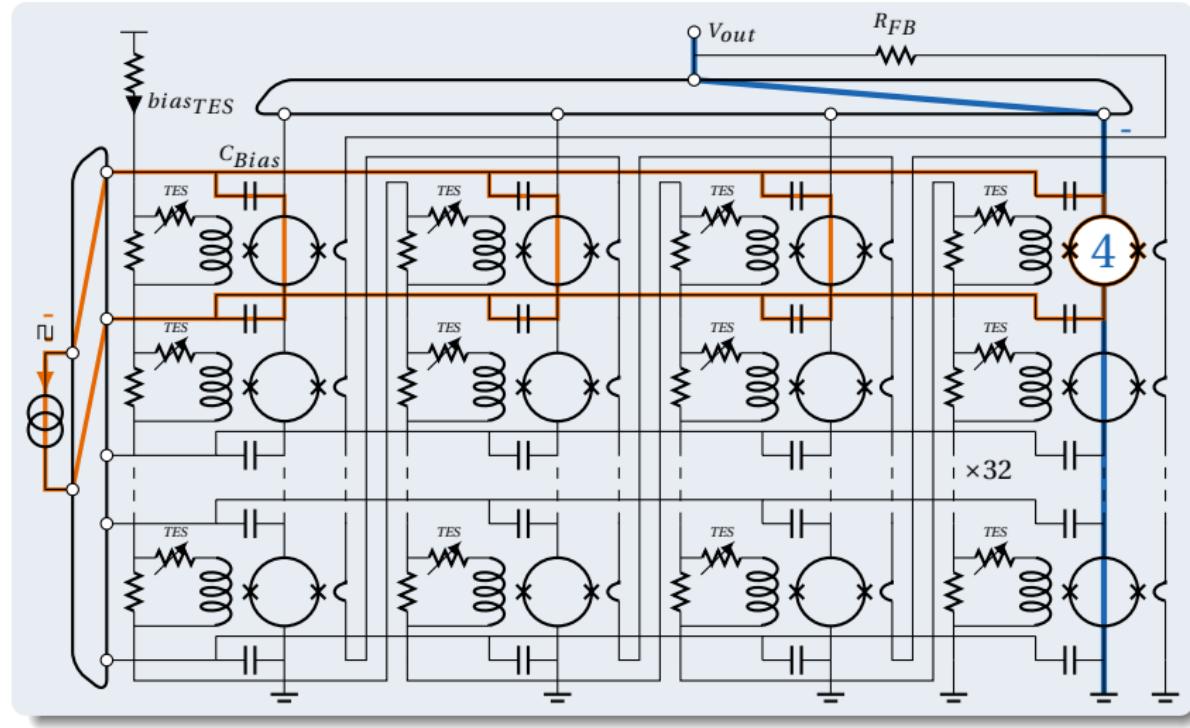
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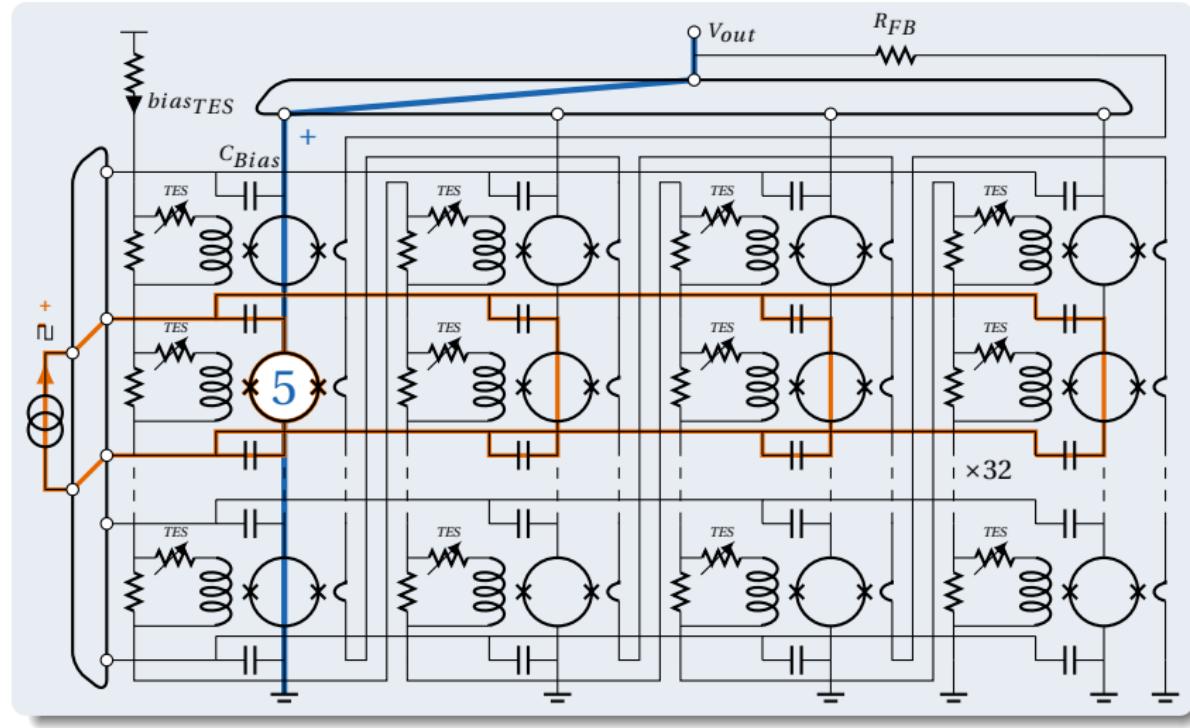
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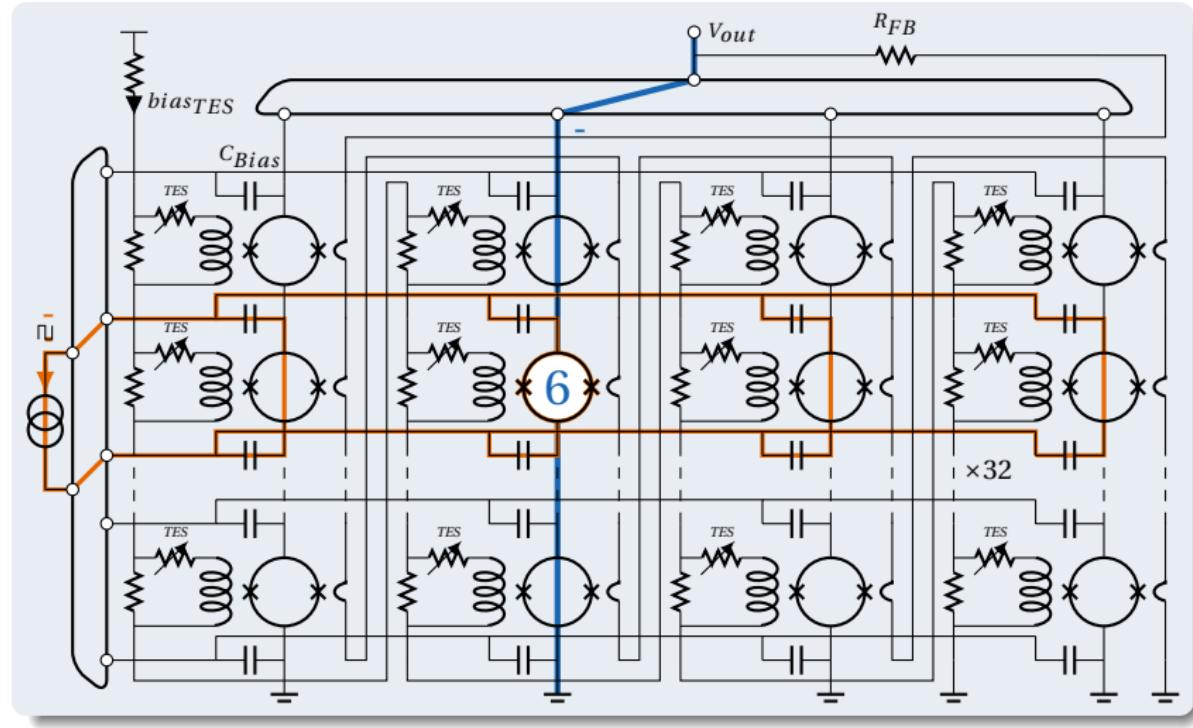
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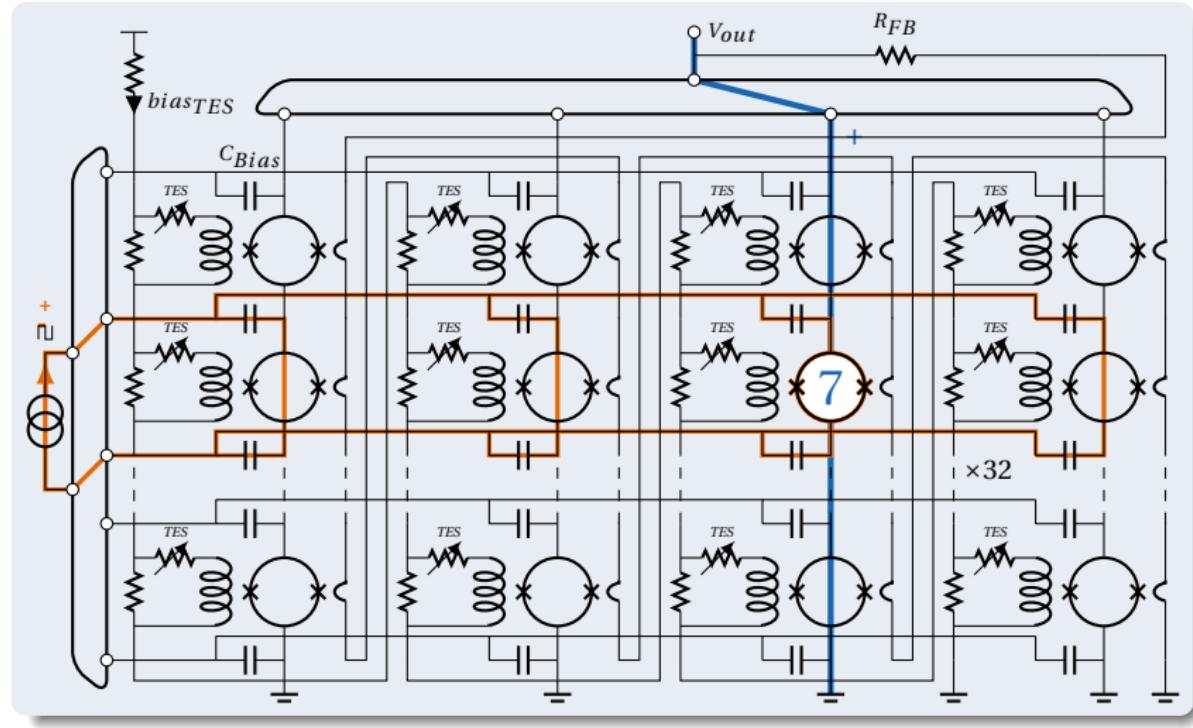
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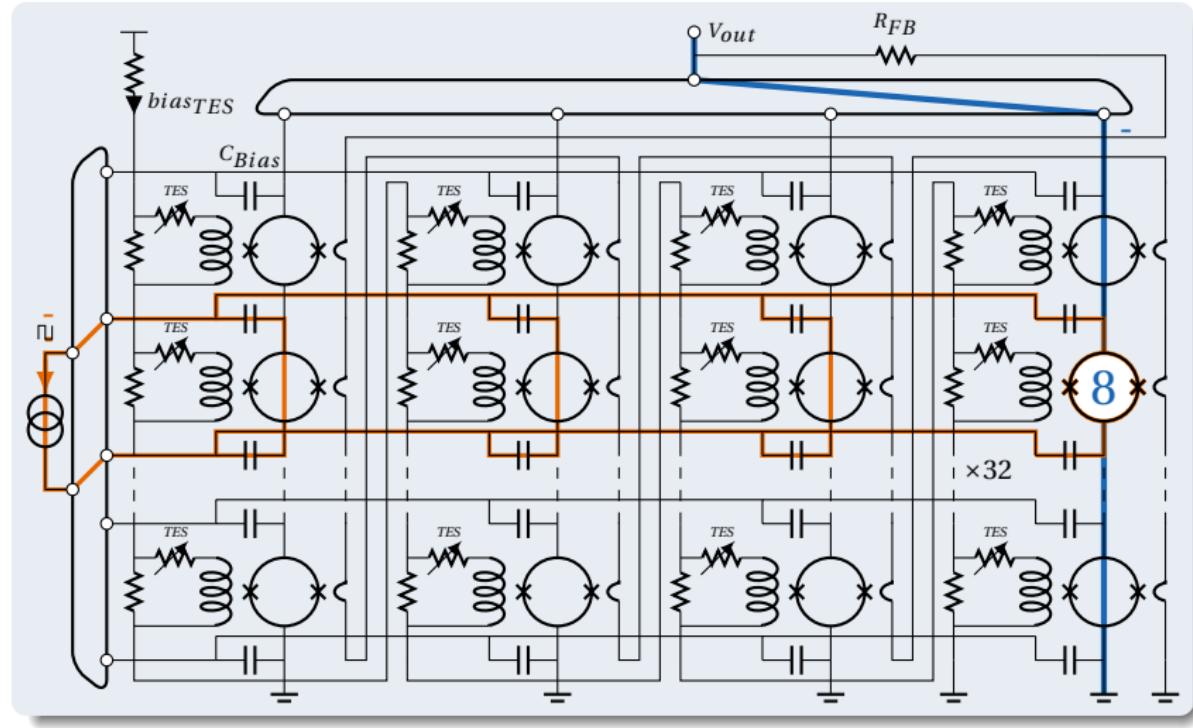
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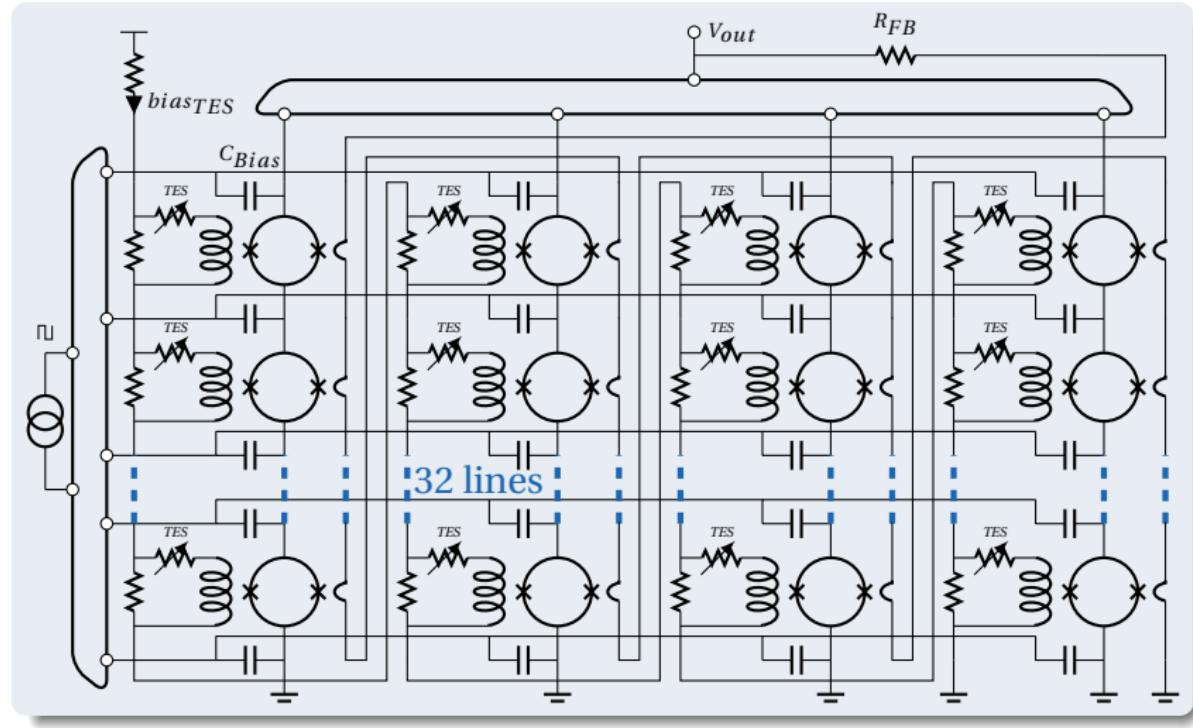
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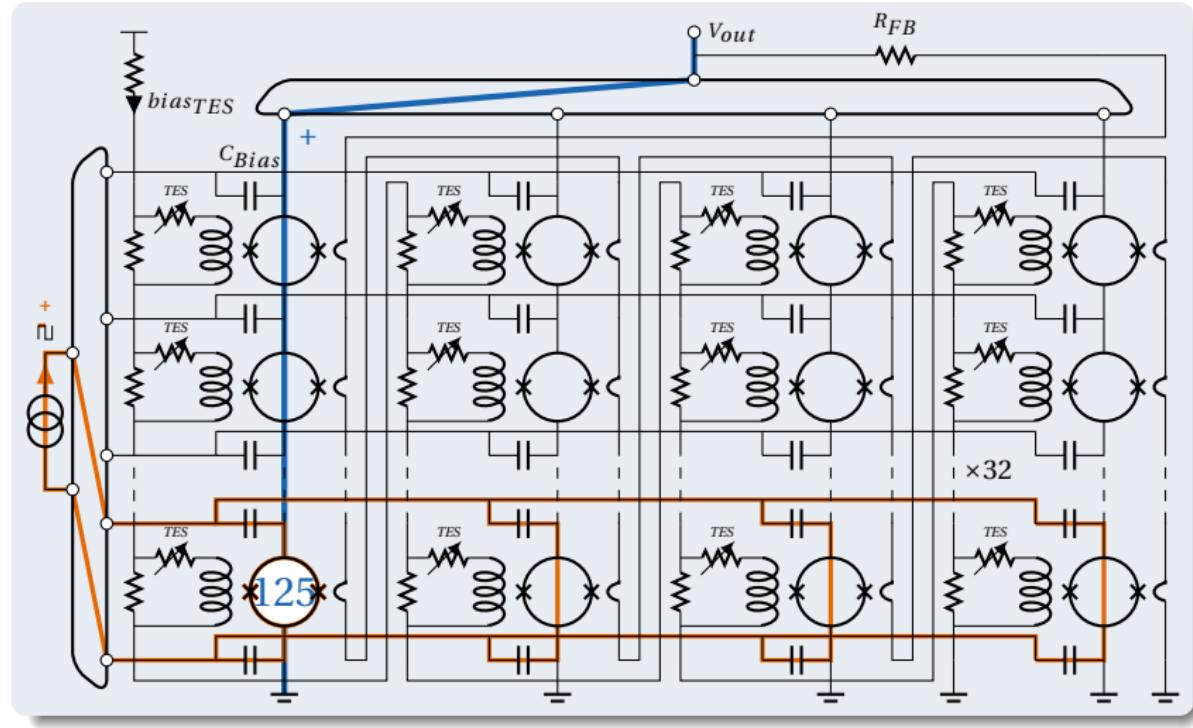
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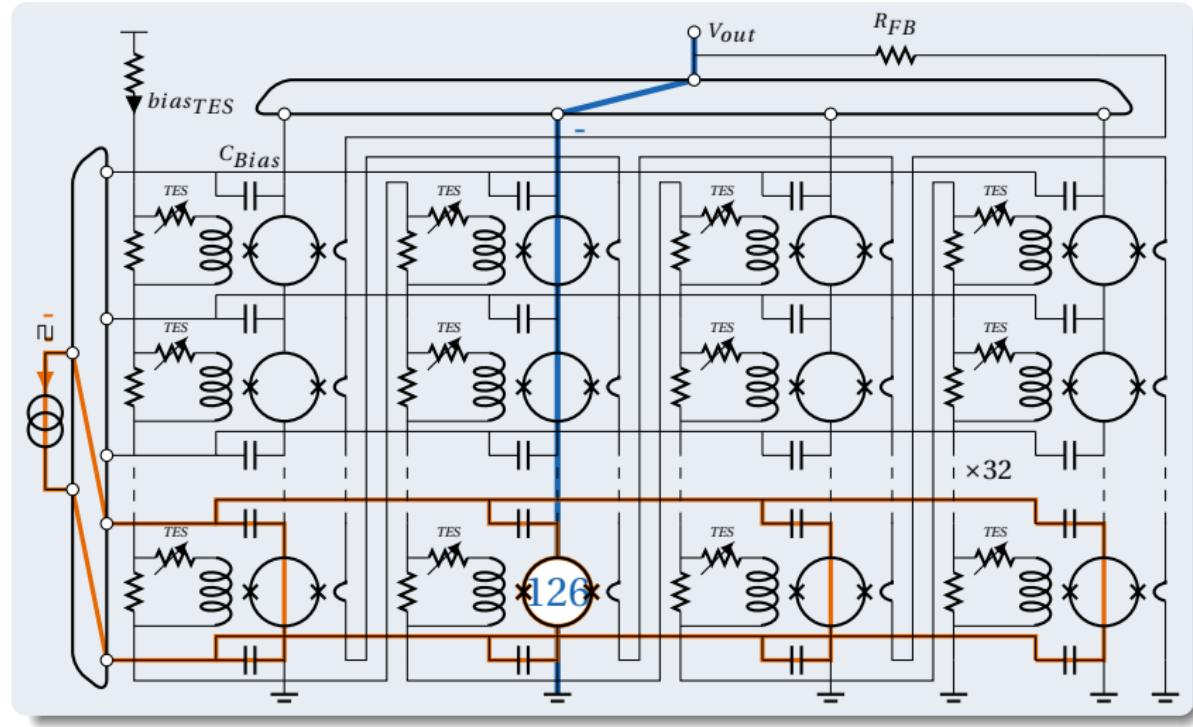
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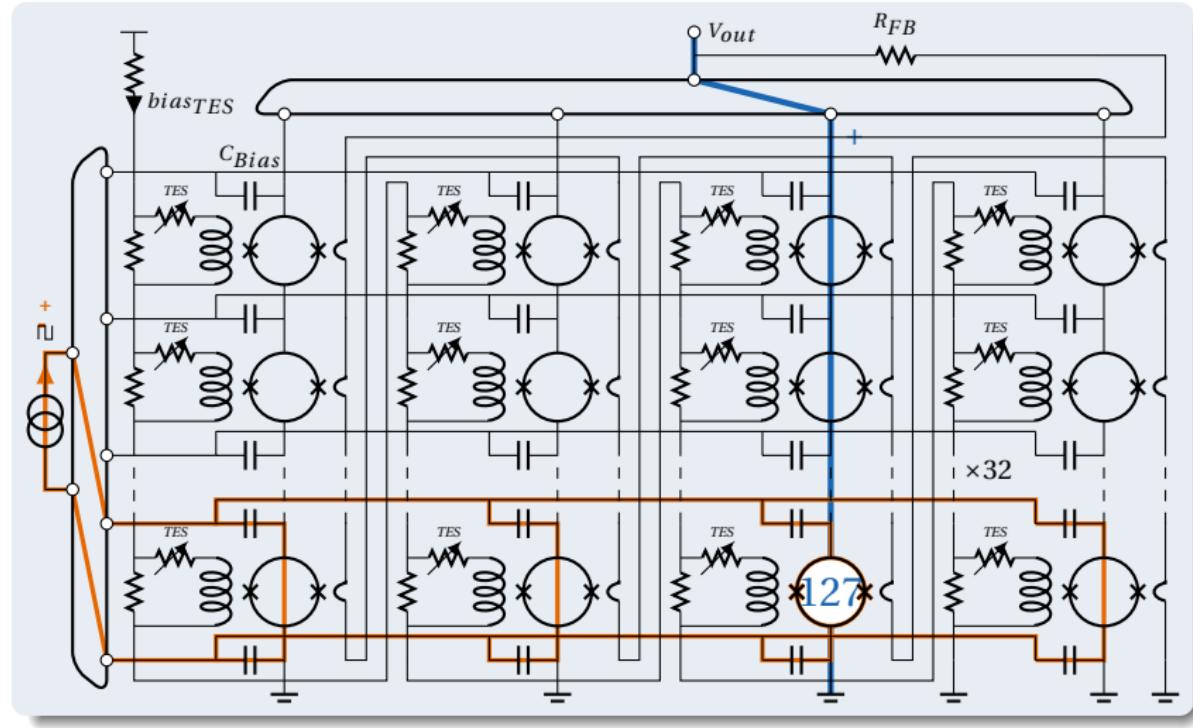
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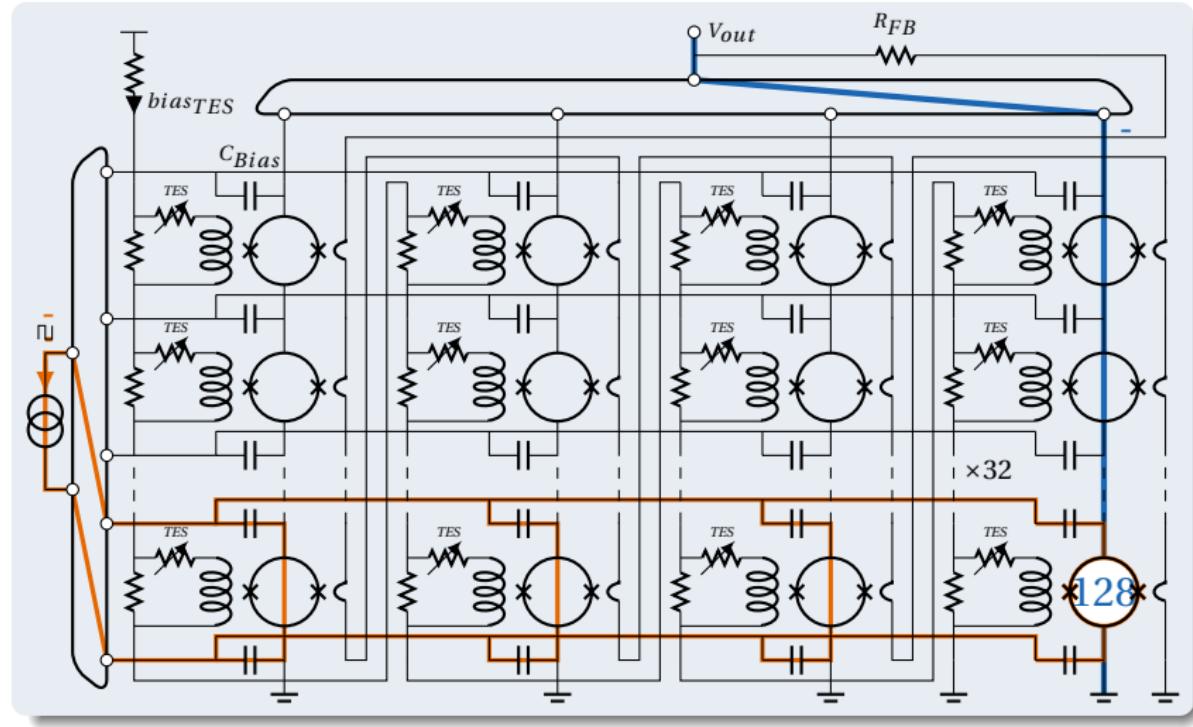
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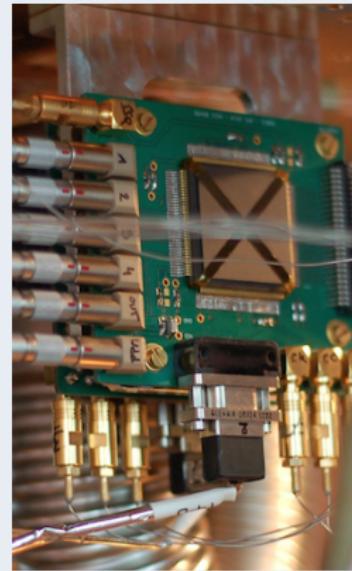
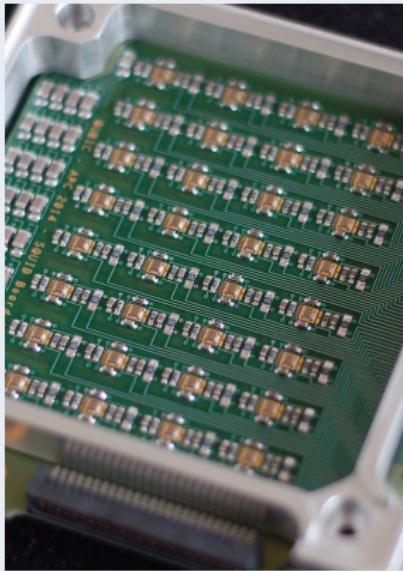
TES readout topology based on 2D multiplexing scheme



Time domain SQUID multiplexer for QUBIC

QUBIC Readout sub-system : 256 TES, 256 SQUIDS, 2 ASICs

Sub-system : NbSi TES (300 mK) + 256 SQUIDs (1K) + 2 ASICs (40K)

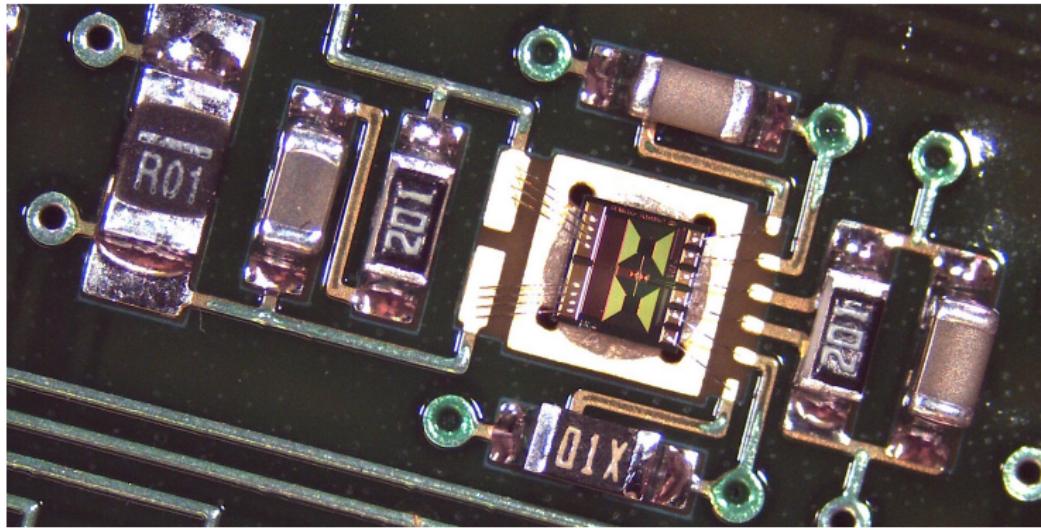


Integration of this sub-system in a dilution fridge for readout test



SQUID glued and wire bonded on a PCB

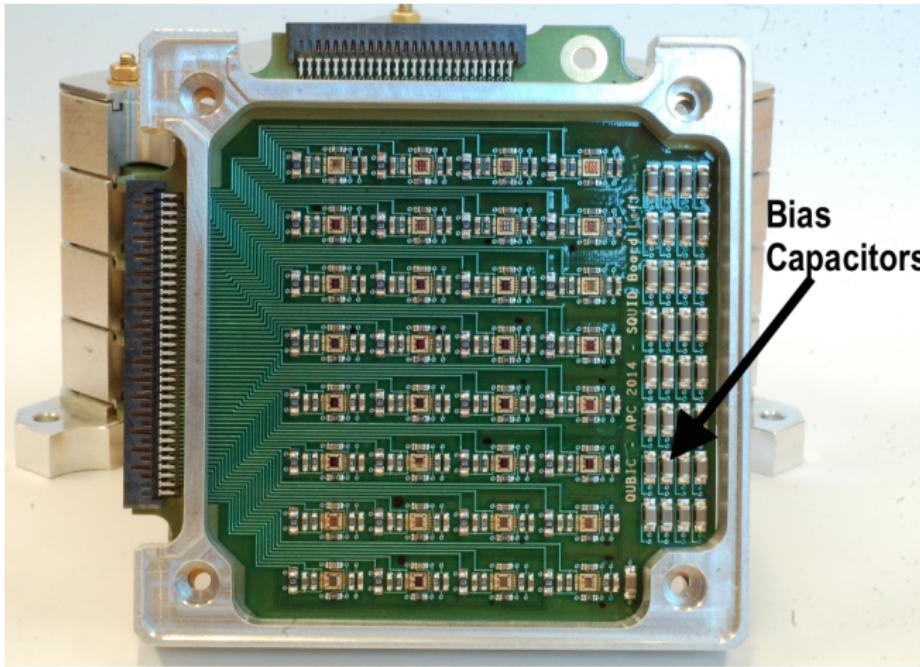
StarCryoelectronics SQ680 specific design.



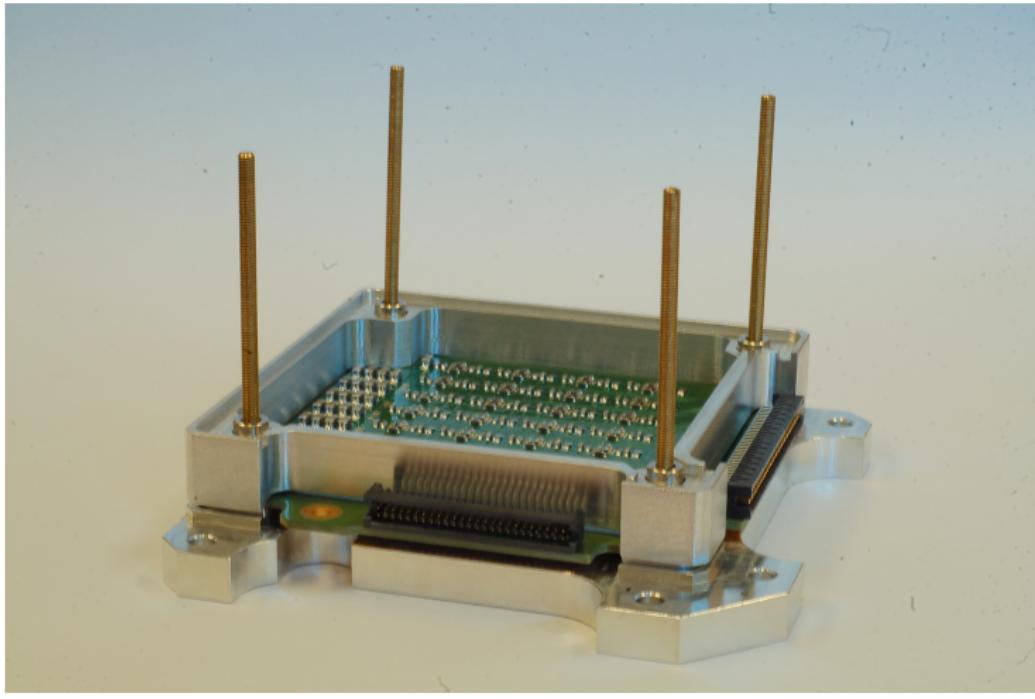
Solder plated track (no parasitic resistances)
Shunt resistor and filter devices



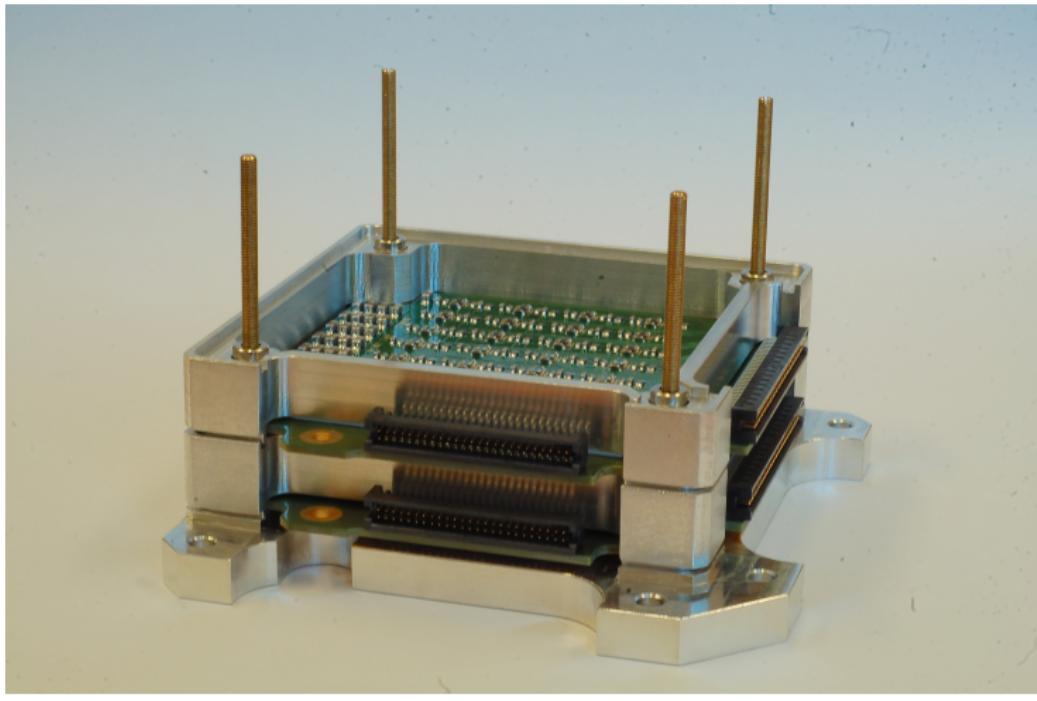
32 SQUIDS glued and wire bonded on a PCB



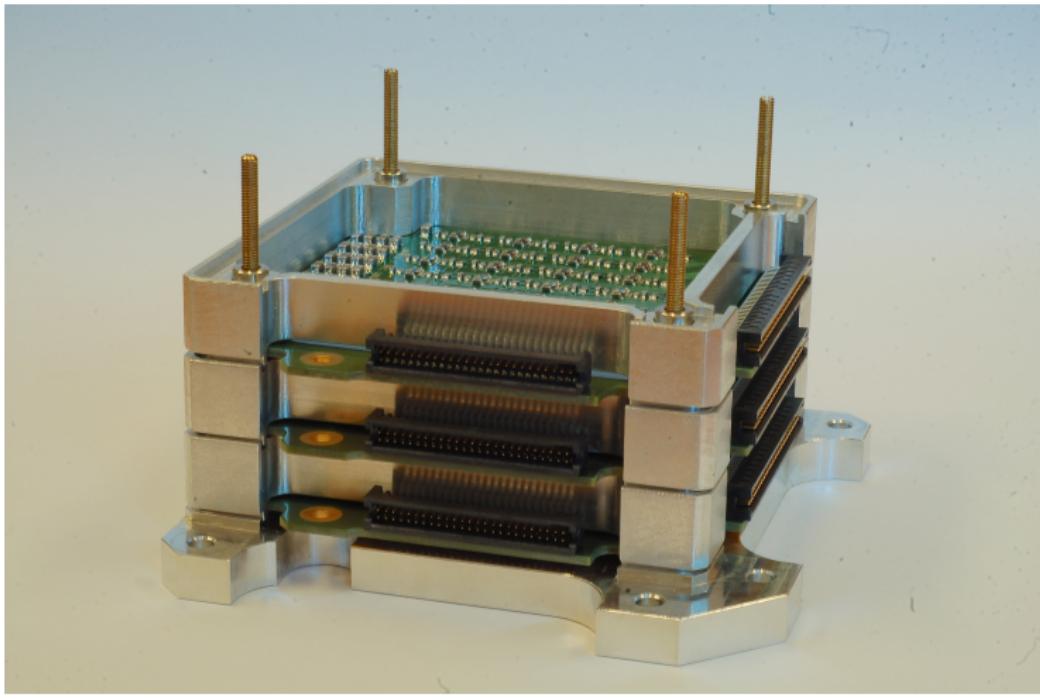
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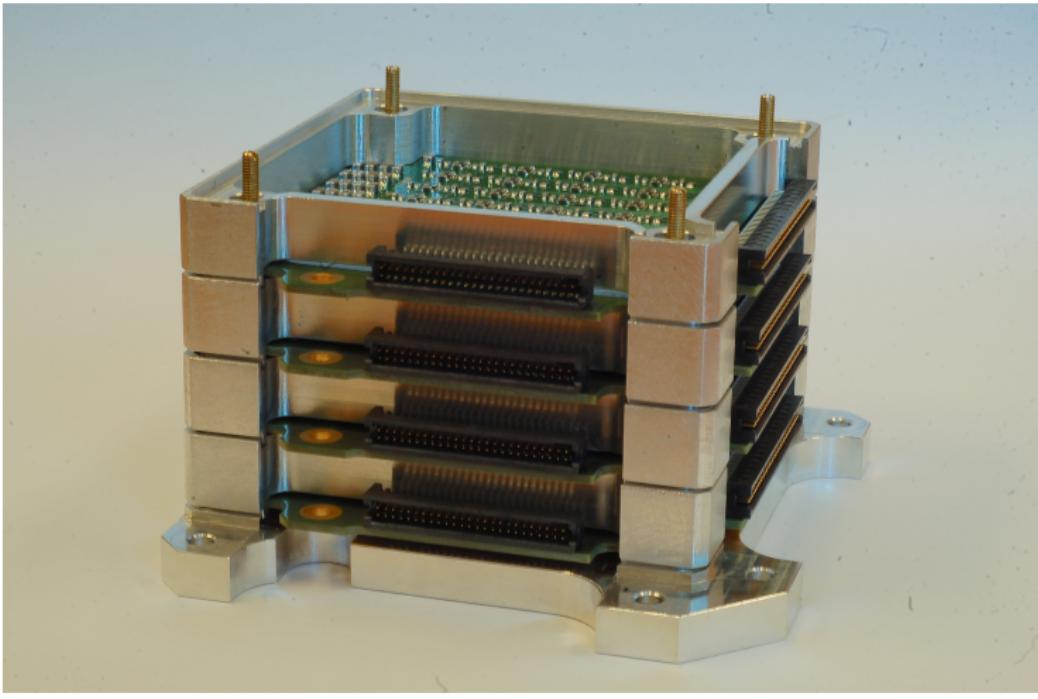
64 SQUIDs glued and wire bonded on a PCB



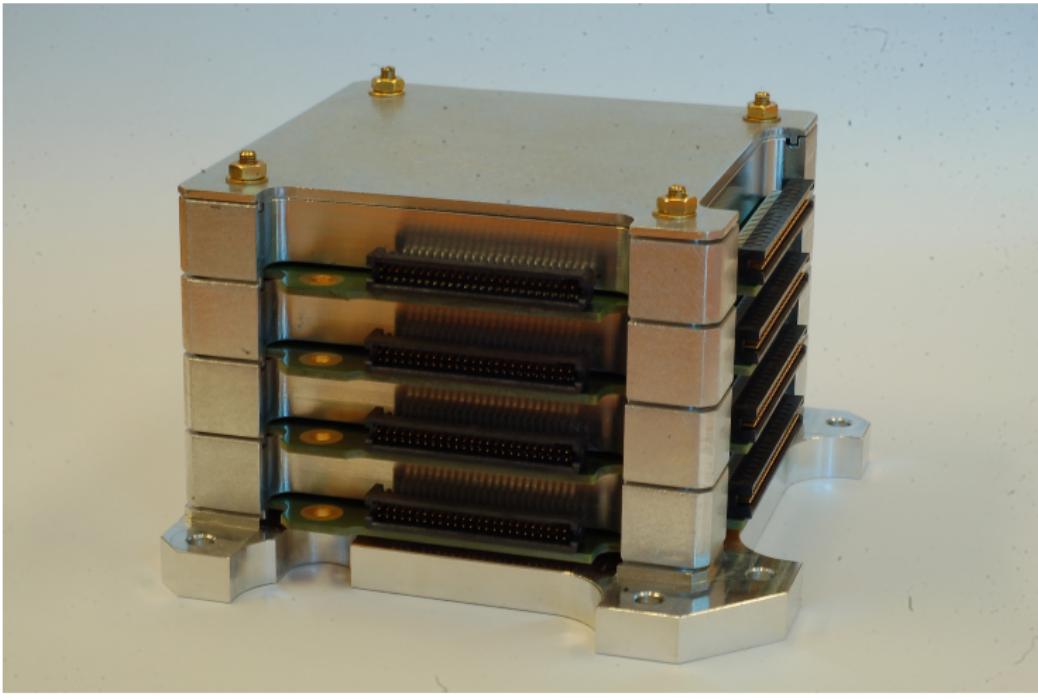
96 SQUIDs glued and wire bonded on a PCB



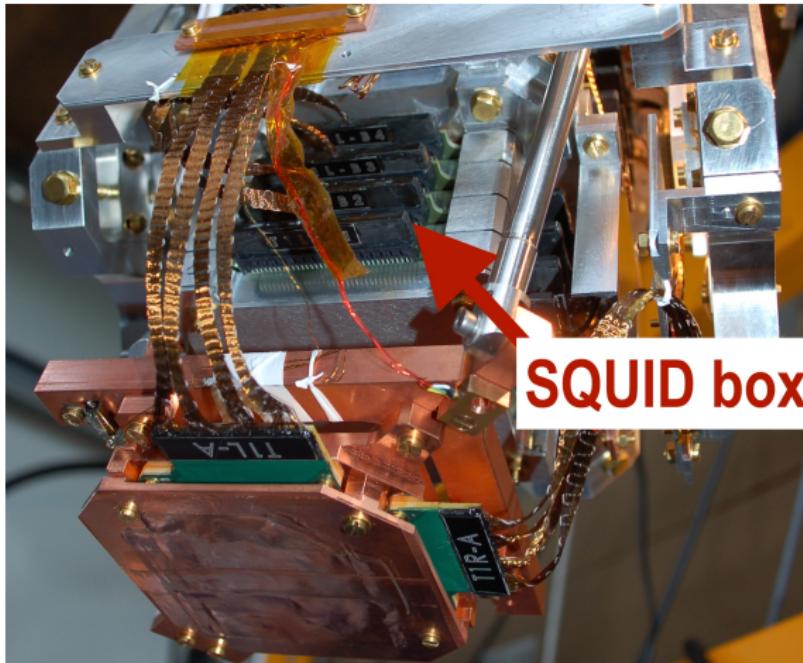
128 SQUIDs glued and wire bonded on a PCB



128 SQUIDs glued and wire bonded on a box

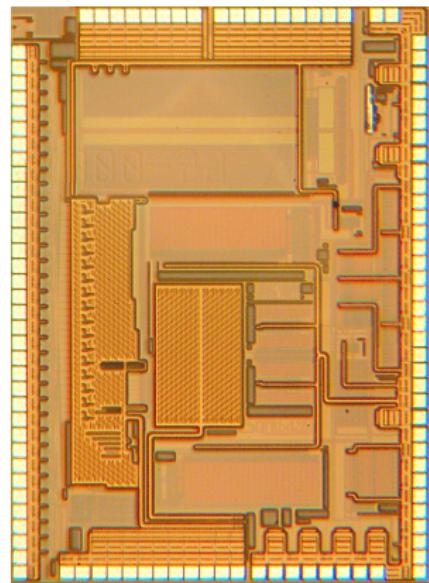
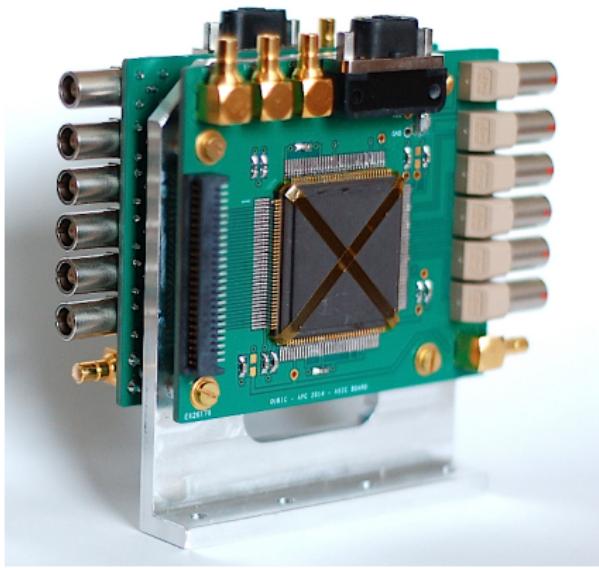


SQUIDs glued and wire bonded on a box

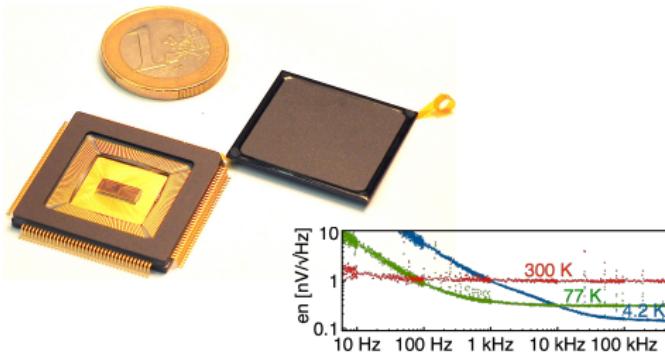


SQUID box

ASIC Stage (Application Specific Integrated Circuit)



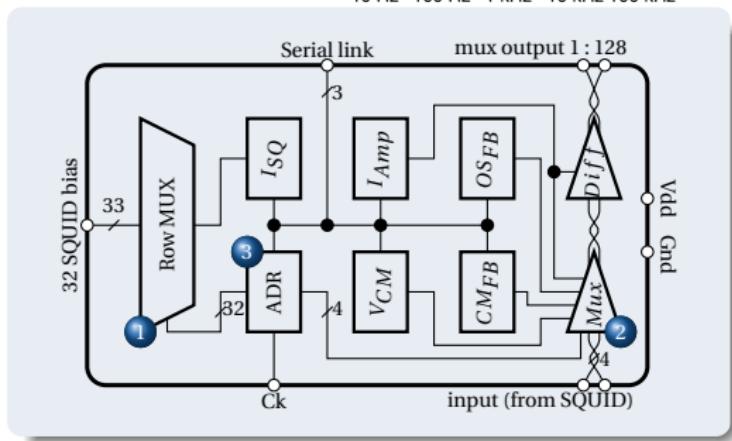
SiGe ASIC for cryogenic 1:128 TD SQUID M



BiCMOS SiGe ASIC

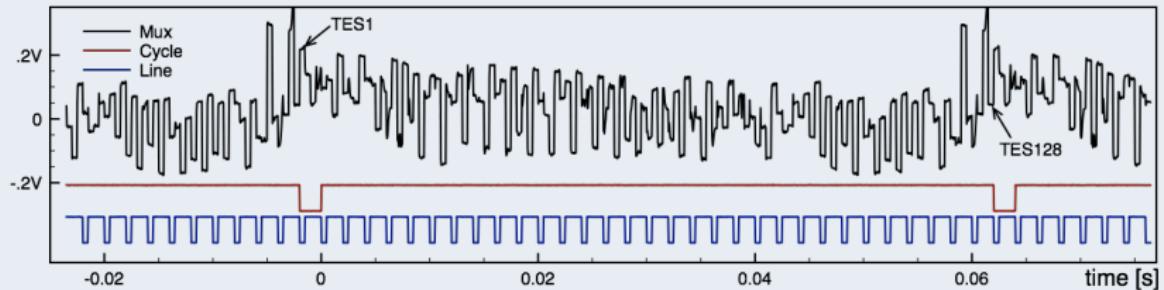
350nm AMS technology

- ① **SQUID rows addressing:**
Biasing through capacitors with AC multiplexed current sources (1 : 32)
- ② **Low noise amplifier with multiplexed inputs:**
FLL preamplifier column mux. (1 : 4)
- ③ **Digital addressing circuit controlled by external Ck**



Multiplexed time line

1:128 multiplexing rate



A 128 Multiplexing Factor Time-Domain SQUID Multiplexer
D. Prèle, F. Voisin, M. Piat, T. Decourcelle, C. Perbost, C. Chapron, D. Rambaud, S. Maestre, W. Marty, L. Montier
J. Low Temp Phys 2016



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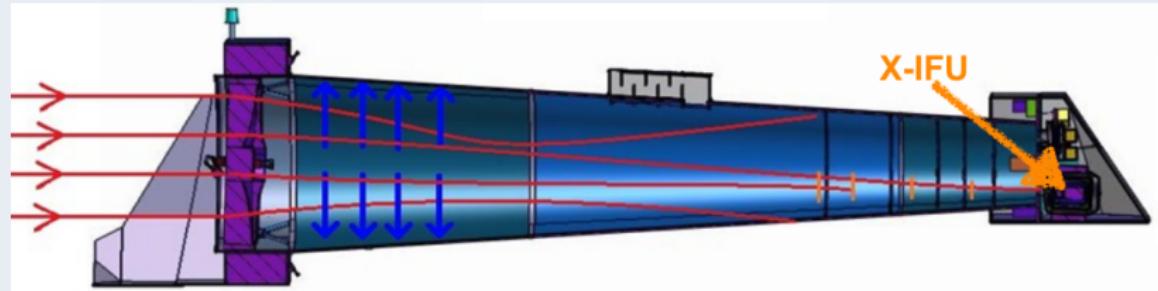
- The X-IFU instrument
- Readout chain
- ASIC development for the X-IFU instrument



Advanced Telescop High-ENergy Astrophysics - ATHENA

The Hot and Energetic Universe 

X-ray Integral Field Unit - X-IFU



- **4k TES** micro-calorimeter cooled down to 50 mK
- 2.5eV resolution @ 6keV
- **Frequency Domain Multiplexing - FDM**
- 40 Multiplexing factor
- SQUID Baseband feedback

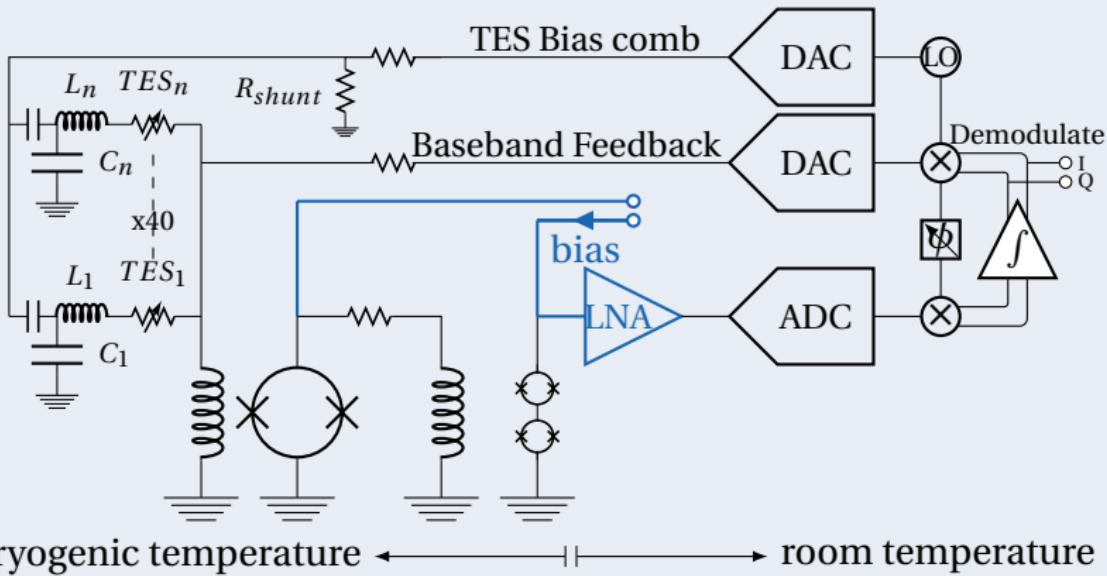




Frequency domain SQUID multiplexer for X-IFU

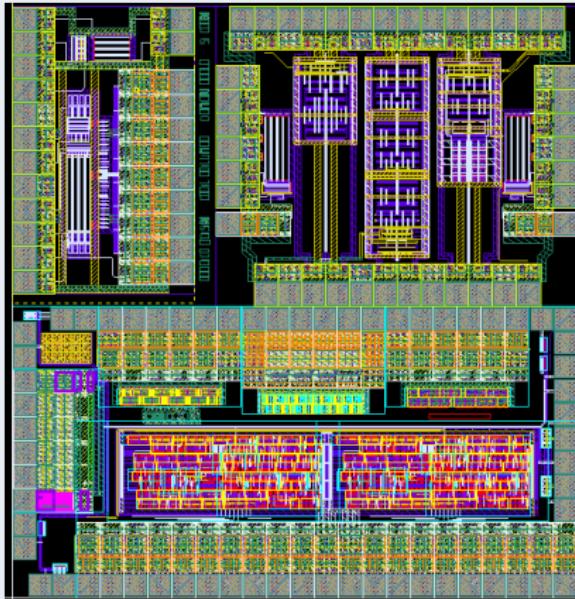
X-IFU Readout sub-system : 40 TES, 1 SQUID, 1 SQUID array, 1/8 ASIC

Sub-system : FDM with ASICS for LNA and SQUID biasing



Athena warm asic for X-IFU electronic - AwaXe

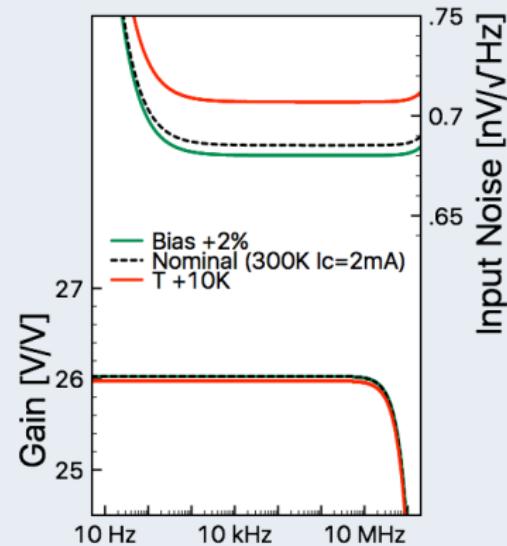
AwaXe v1



SiGe BiCMOS 0.35 AMS technology

All the ASIC design for this space application is made using Rad-Hard by Design library

Warm/Room LNA performances



Gain stability with no-feedback for the X-IFU/Athena
D. Prèle, F. Voisin et al. in preparation for SPIE

Summary

- Full TES detection chaine for CMB application QUBIC
- Integration & operation of the Time Domain Multiplexer
- Use of cold ASIC for SQUID biasing in TDM

In preparation:

- ① ASIC development for the X-IFU instrument
 - ② Low noise amplification and SQUID biasing for FDM (already design)
- also ASIC possibly used instead of power consuming FPGA ?

