

So you want to read
out your detectors....

KICP Summer School

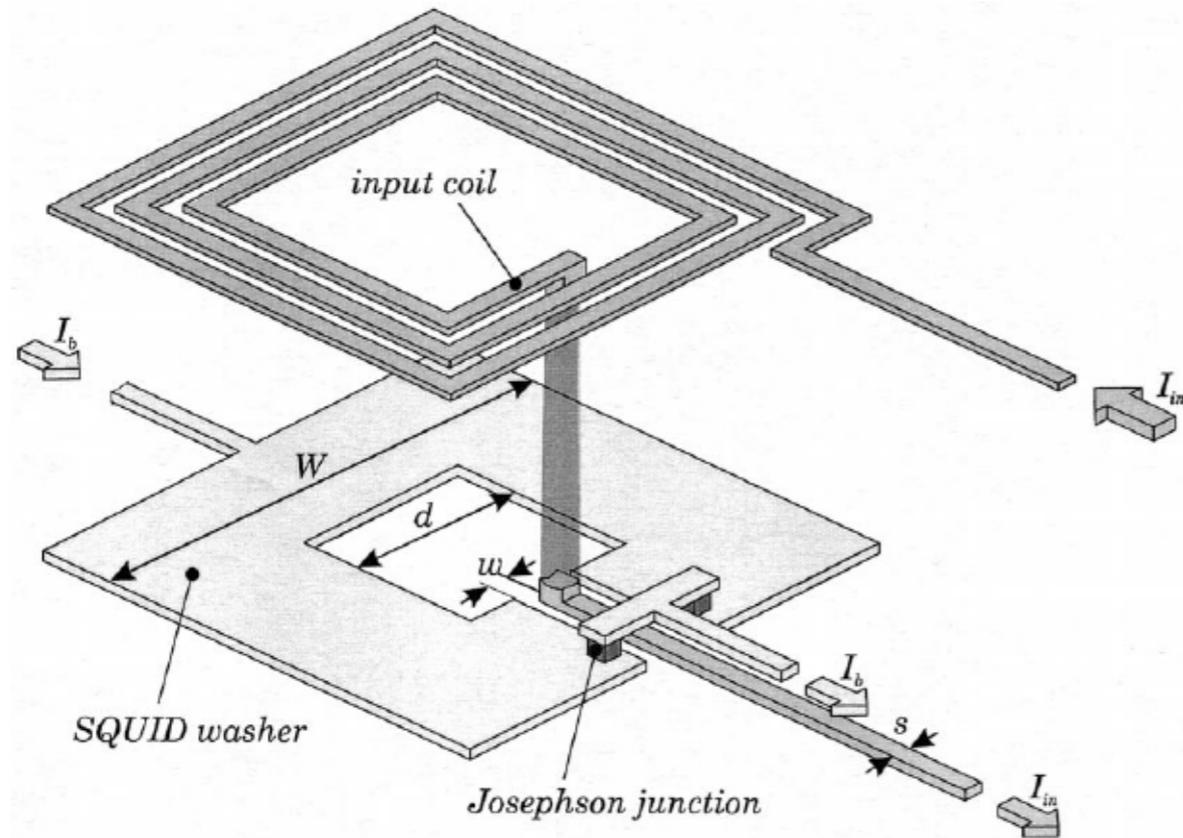
What I wanted to talk about

- SQUIDs
- amplitude modulation
- frequency modulation
- fMux
- tMux
- mu-Mux
- systematics (noise, crosstalk)
- control systems (FPGAs)
- HEMTs
- ADCs/ DACs
- Noise sources

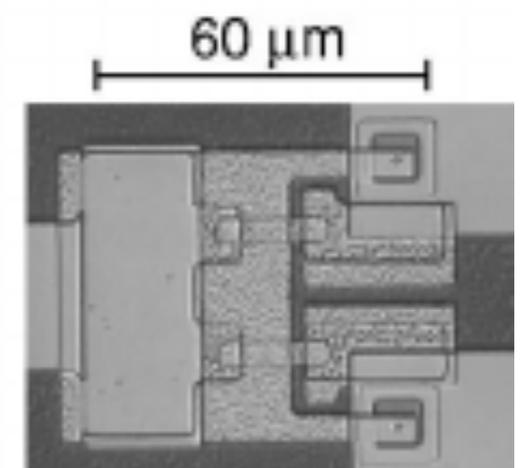
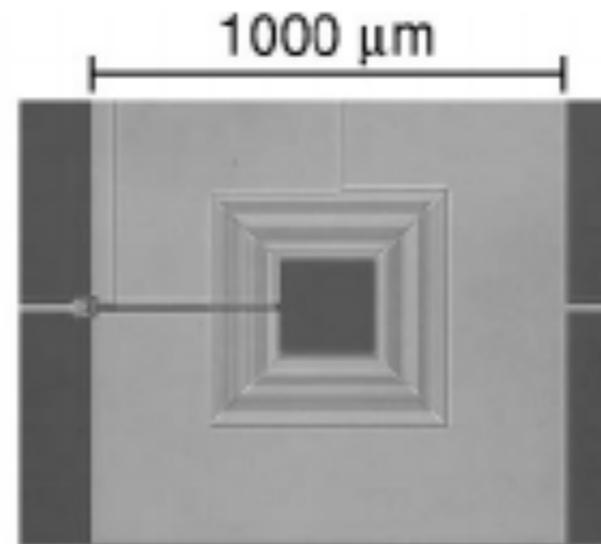
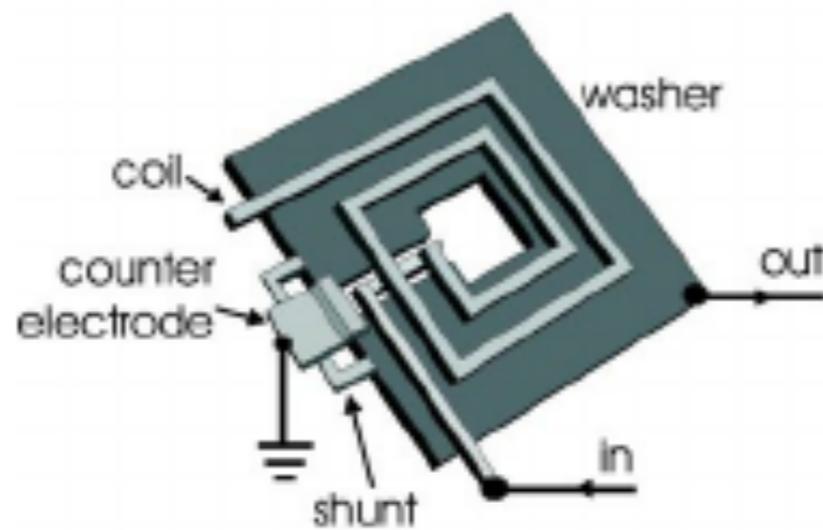
But what I'll do realistically

- building blocks for the DC SQUID voltage-flux response
- 3 strategies for multiplexing readout
- give you some references to start you on further reading

Example DC SQUID: Flat Washer



Accurate measurement of small currents using a CCC with DC SQUID readout
DOI: 10.1016/S0924-4247(00)00339-3



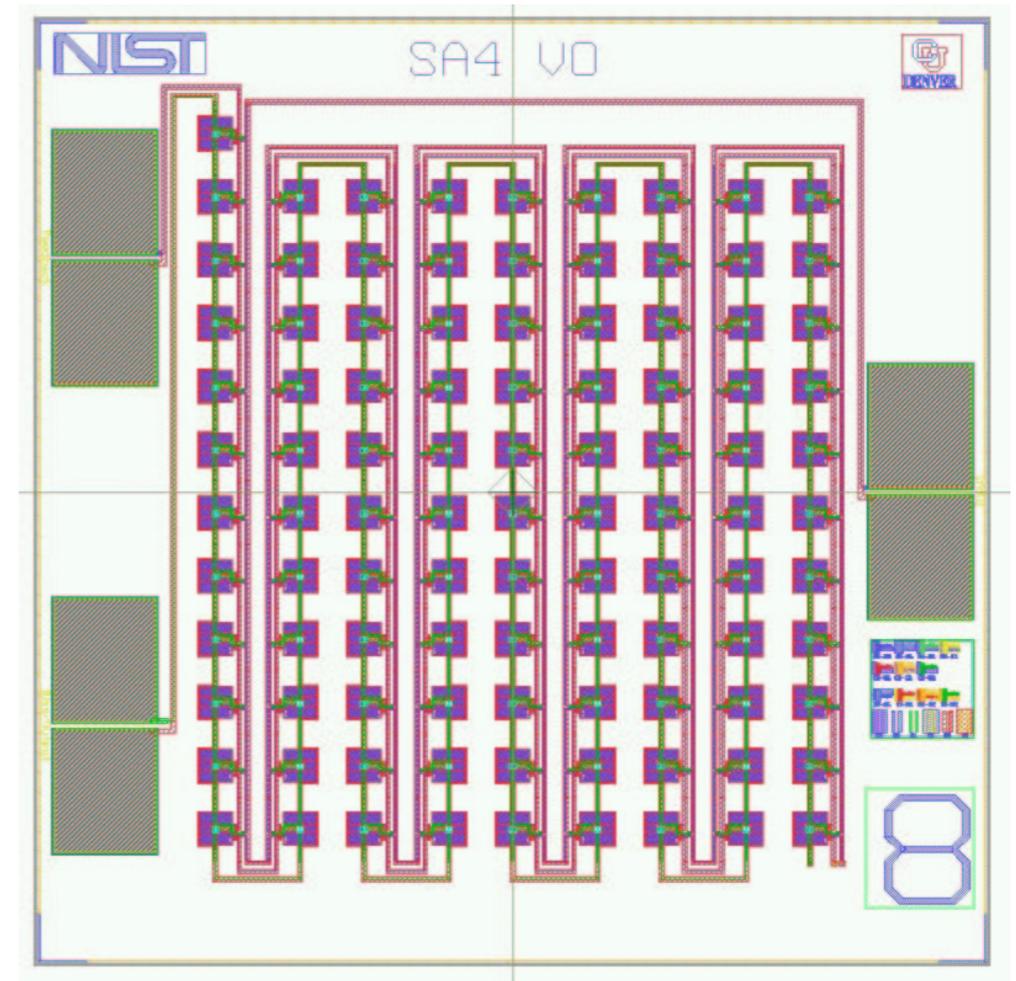
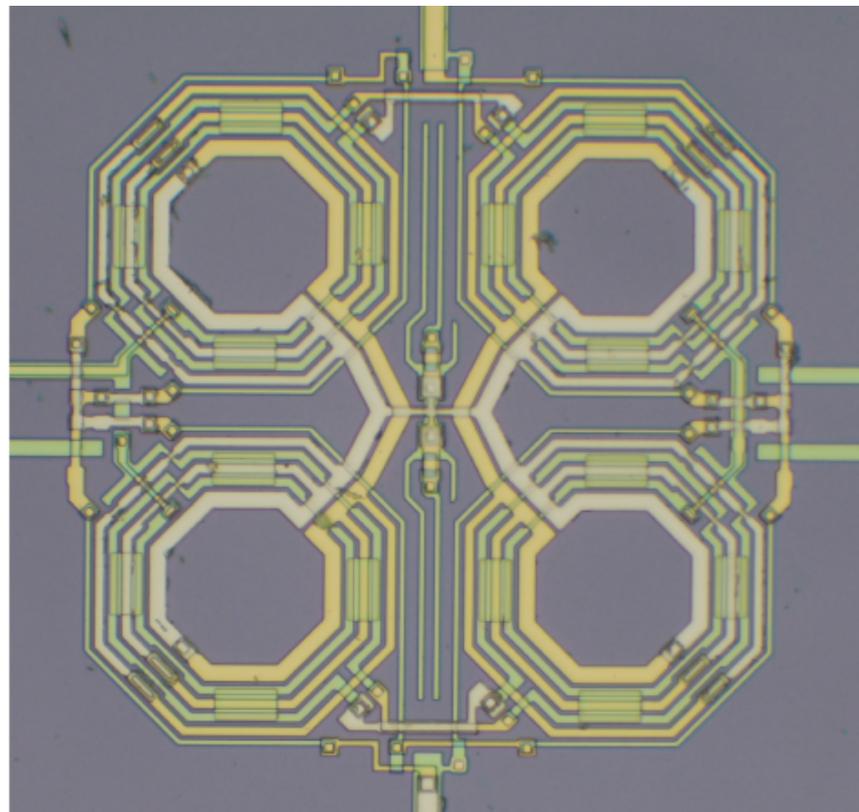
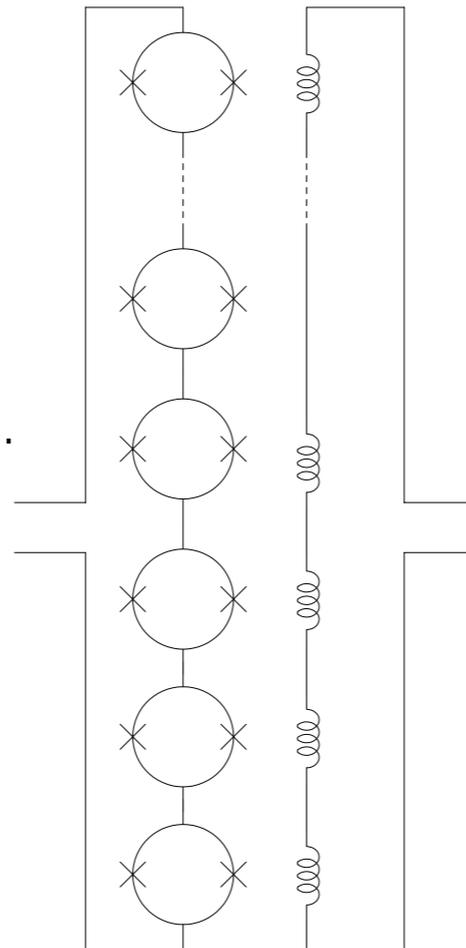
(a)

(b)

(c)

SQUID Arrays

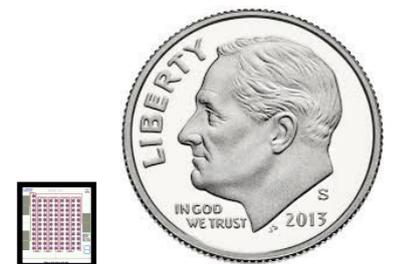
Lanting thesis.



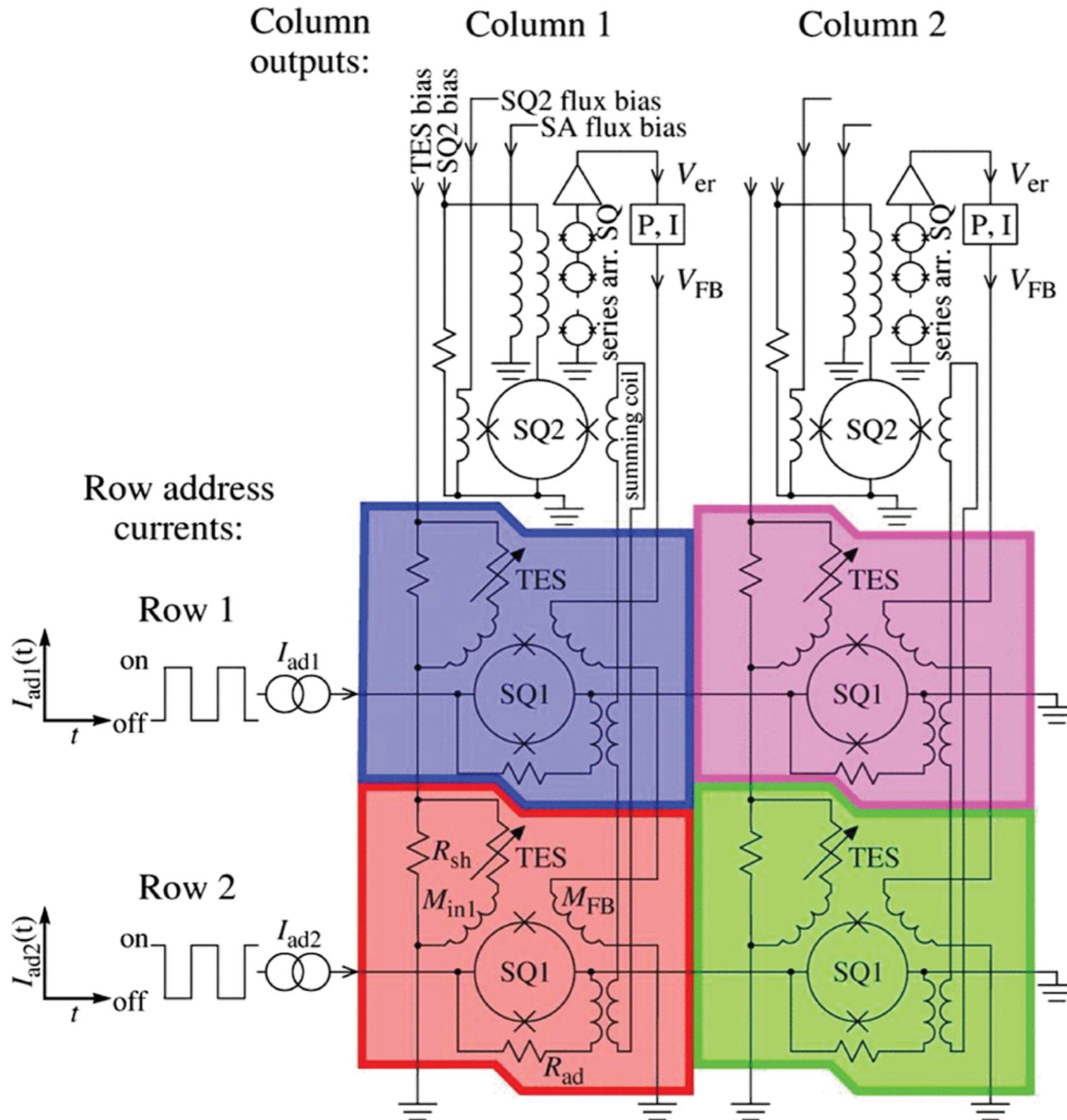
Size = 4.5 mm x 4.5 mm

Time-Division SQUID
Multiplexers With
Reduced Sensitivity to
External Magnetic
Fields: DOI: 10.1109/
TASC.2010.2091483

DC SQUID series array amplifiers
with 120 MHz bandwidth:
DOI: 10.1109/77.919577



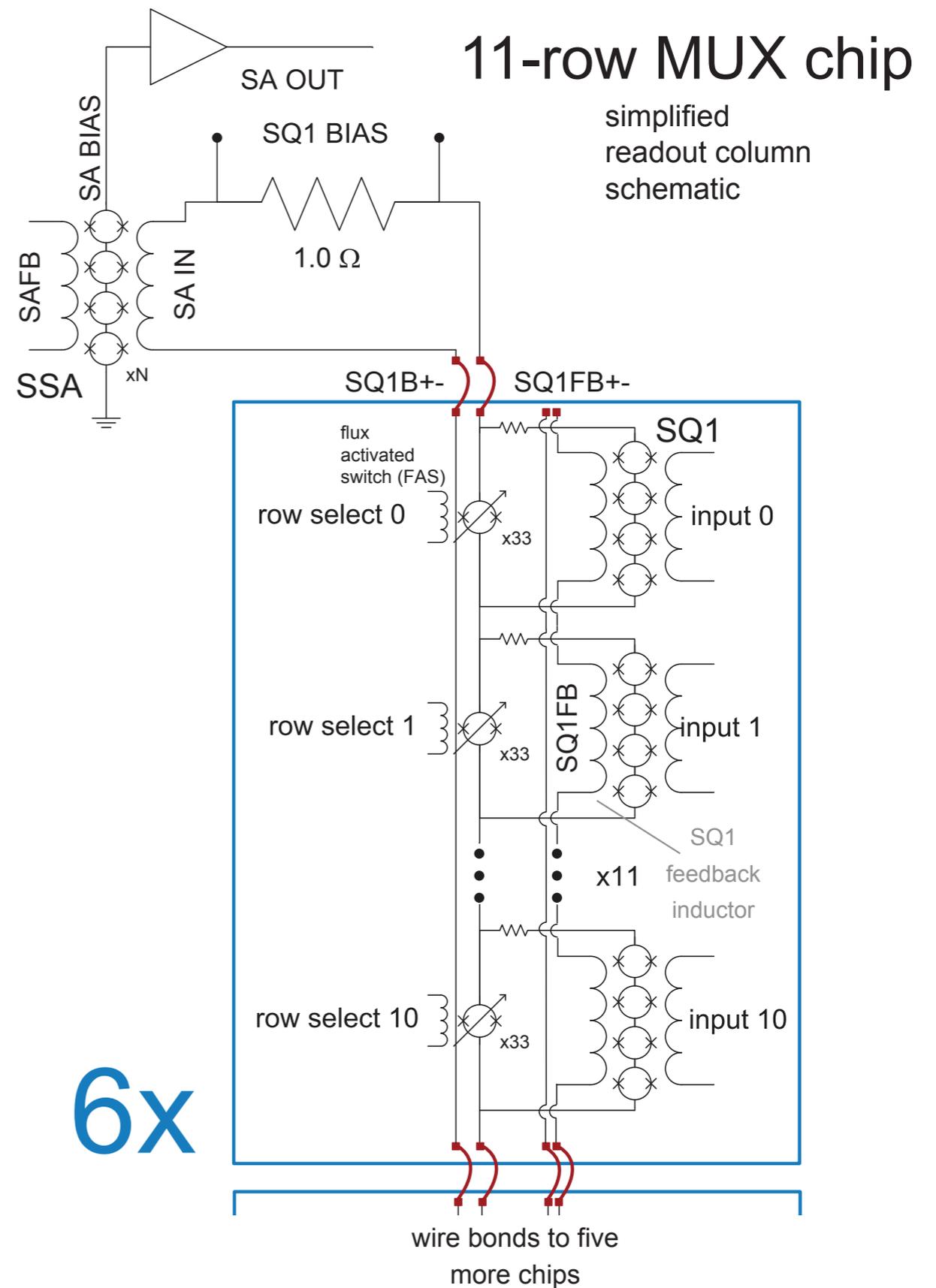
Time Division Multiplexing



Time-division SQUID multiplexer for the readout of X-ray microcalorimeter arrays: DOI: 10.1016/j.nima.2003.11.314

Time-Division SQUID Multiplexers With Reduced Sensitivity to External Magnetic Fields: DOI: 10.1109/TASC.2010.2091483

Recent 2-Stage TDM



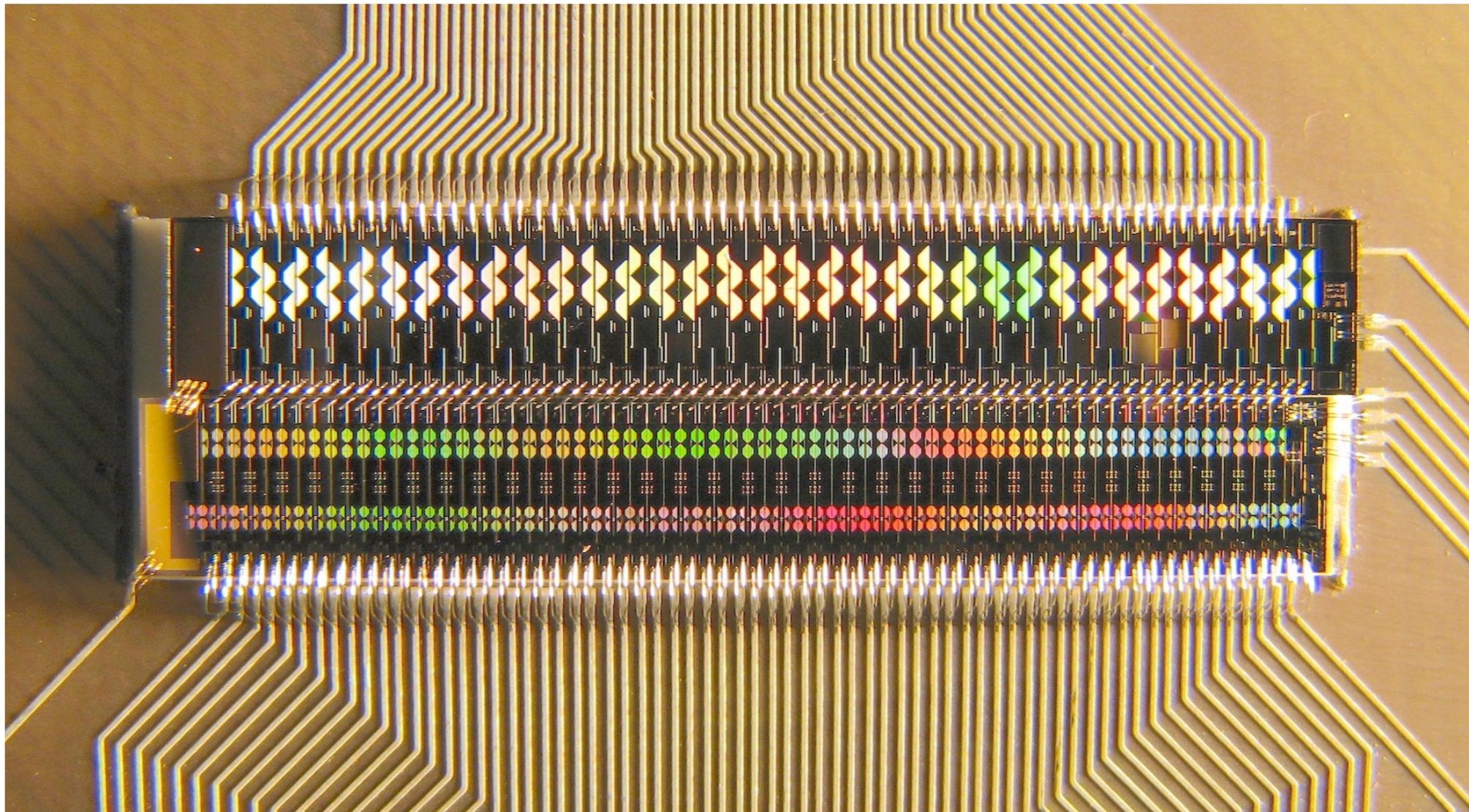
Readout of two-kilopixel transition-edge sensor arrays for Advanced ACTPol:
DOI: 10.1117/12.2233895

CMB Experiments Using TDM

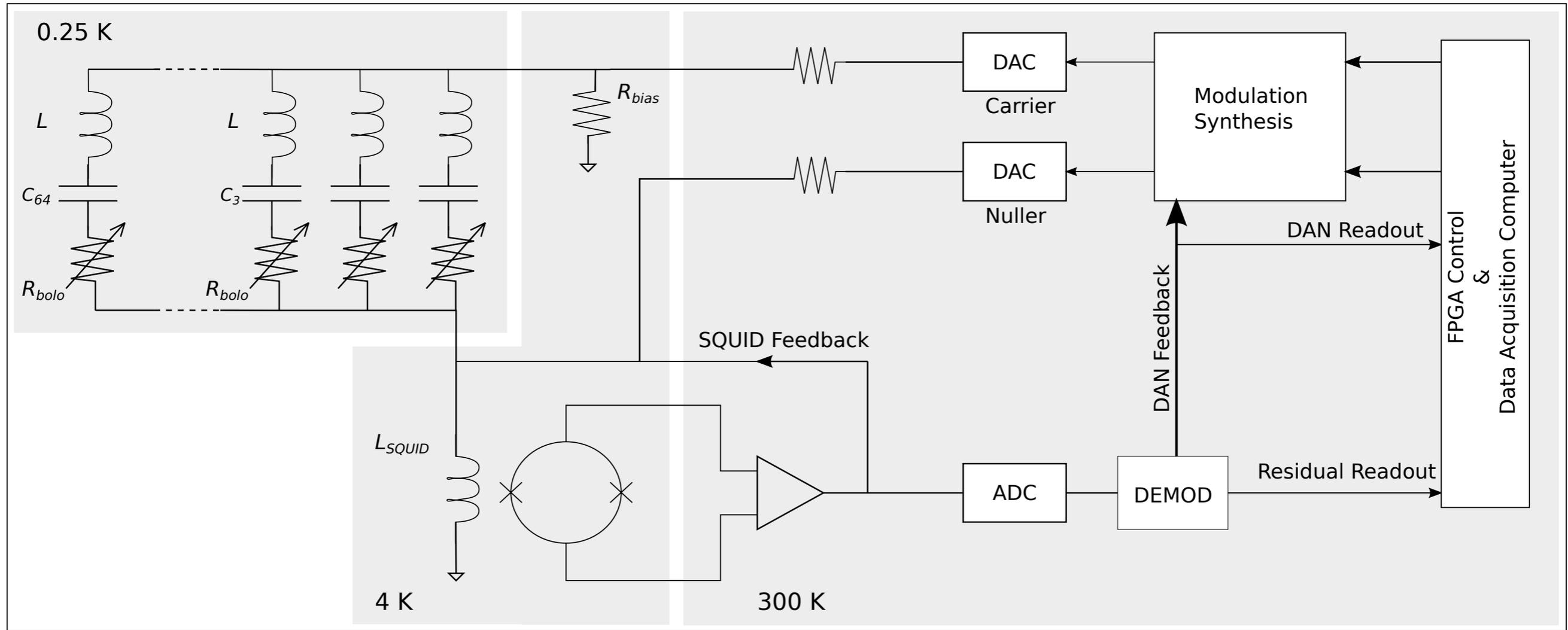
- ACT
- SPIDER
- BICEP/KECK

SPIDER 3 stage Mux Chip:
1 column of 33 rows

A.Rahlin thesis



Frequency Division Multiplexing



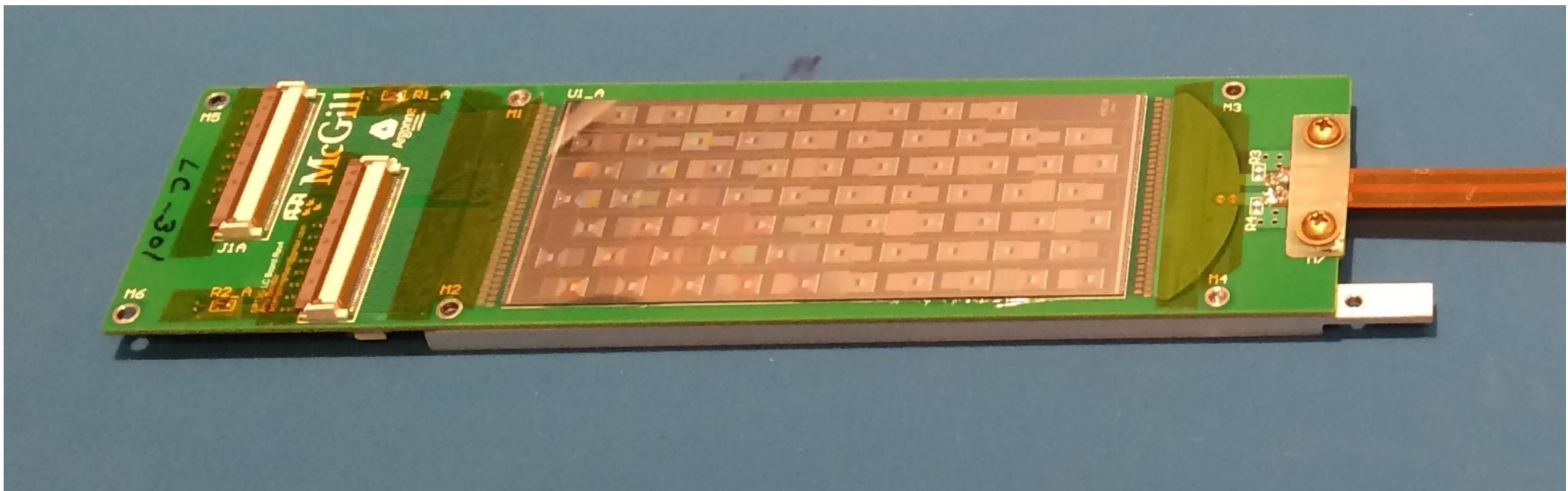
Digital frequency domain multiplexing readout electronics for the next generation of millimeter telescopes: DOI:10.1117/12.2054949

Frequency multiplexed superconducting quantum interference device readout of large bolometer arrays for cosmic microwave background measurement: DOI:10.1063/1.4737629

CMB Experiments Using FDM

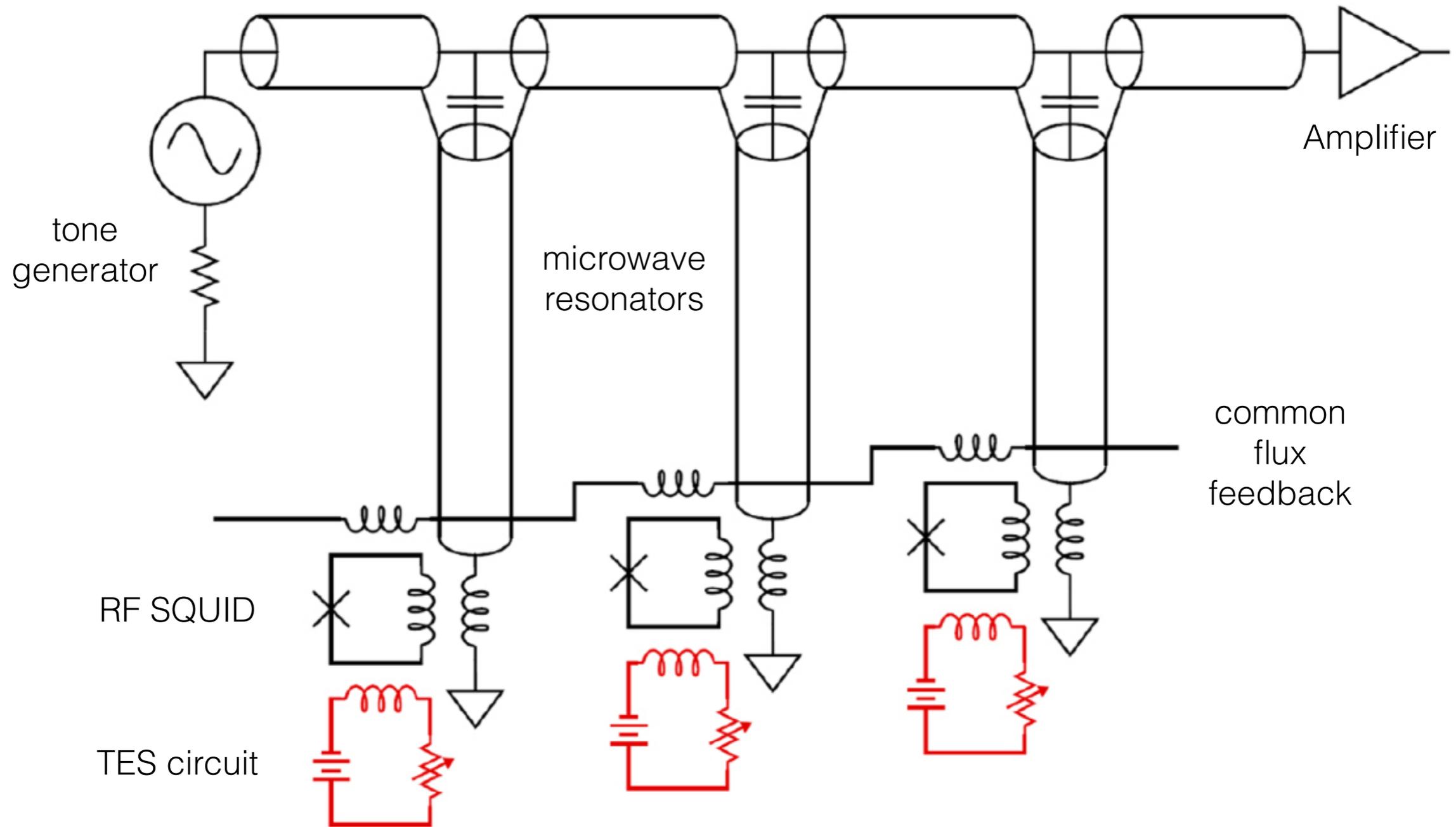
- SPT
- POLARBEAR
- EBEX

SPT-3G inductive-capacitive
filter chip



μ -Mux

Not on a CMB telescope yet, but in the future...



Review of superconducting transition-edge sensors for x-ray and gamma-ray spectroscopy:

DOI: 10.1088/0953-2048/28/8/084003

Microwave SQUID MUX

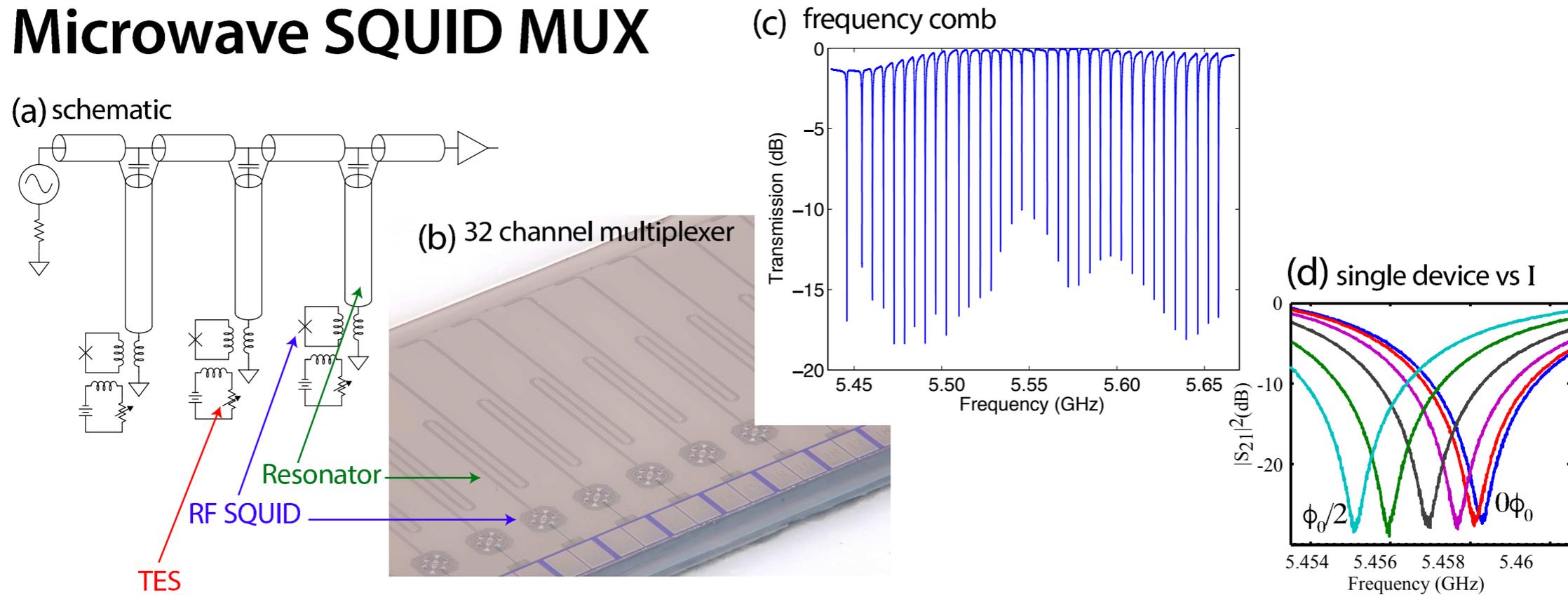


Figure 74: Overview of the the microwave SQUID multiplexer. (a) Schematic of the circuit. (b) Photograph of a 32-channel μ MUX chip. (c) S_{21} transmission measurement of the μ MUX with 32 active channels. (d) Variation of single readout channel transmission curves to applied input magnetic flux (or equivalently applied current when inductively coupled).