The Eleventh International Conference on Sensor Device Technologies and Applications
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Elemental Giant Magnetoresistance (GMR) Sensors for Neuromorphical Applications

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Càndid Reig received the B.Sc., M.Sc., and Ph.D. degrees in Physics from the University of Valencia, Valencia, Spain, in 1994, 1995, and 2000, respectively. In 1997, he was with Radiaciones y Microondas S.A., Madrid, Spain. He joined the Department of Applied Physics, University of Valencia, where he developed his doctoral thesis. In 2001, he was an Assistant Professor with University Miguel Hernández, Elche, Spain. In 2002, he was an Assistant Professor with the University of Valencia and a Post- Doctoral Fellow with INESC-MN, Lisbon, Portugal, working on sensors integration. He is, since 2007, an Associate Professor with the Department of Electronic Engineering, University of Valencia, where he teaches and does research. His current research interests include the development of printed antennas as well as sensors (mainly gas and magnetic) integration at the integrated circuit level. He has also served as external consultor for Analog Devices during 2013 and 2015.

He has been a researcher and principal investigator in different national and international scientific research projects. He has advised 3 PhD students within these topics. He has published more than 40 journal papers, contributed more than 50 works to conferences, edited a book, and co-authored six book chapters. Dr. Reig actively participates in periodic international conference program committees, in research journals' editorial boards as well as acting as a referee for different research journals. He was the General co-Chair of ENICS (Valencia, 2007), the IEEE Sensors Conference (Valencia, 2014), MIC-Sensors (Valencia, 2020) and he is currently the Chair of the Spanish Chapter of the IEEE Sensors Council.

He was a co-recipient of the IETE-J C Bose Memorial Award in 2011 and the MSJ Best Publication Award in 2014.

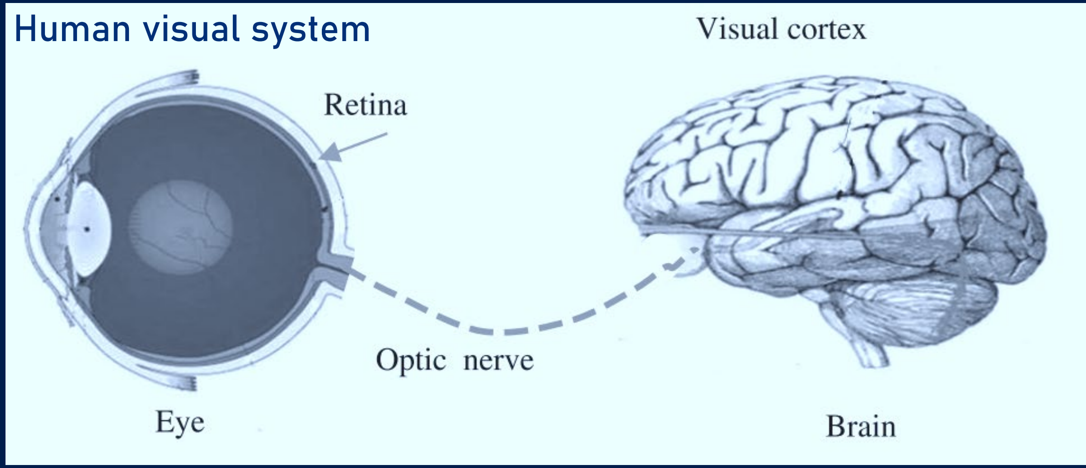
OUTLINE

- Introduction
- Implementation
- Results
- Conclusions

VISION SENSORS

EVENT DRIVEN (ED) VS. FRAME DRIVEN (FD)

- Standard artificial vision sensors use arrays of optical sensors (such of photodiodes) for capturing an image (**frame**) by sequentially reading of each element of the array (**pixel**).
- **Bioinspired** (**neuromorphic** / **retinomorphic**) artificial vision sensors try to mimic the biological vision process by integrating vision sensors with asynchronous parallel computing (such as artificial neural networks).
- As a result, serial "spiking" signals are produced for coding the image in an **event driven** approach.



Advantages of the ED approach

- Using asynchronous schemes
- Easier serialization.
- Higher processing speed.

The same paradigm can also be applied for other biological senses to provide auditory and olfactory ED sensors.

Address Event Representation (AER)

Selective Change Driven (SCD)

- Standard CMOS technologies provide routes for the integration of solid state sensors with processing.
- Many different implementations of address event representation (AER) can be found.
- The Selective Change Driven (SCD) approach will be considered.

Definition of SCD sensor

An SCD sensor delivers, under requirement, the illumination level and the address of the pixel with the highest change since the last reading

Advantages of the ED approach

- Optimal use of the processor
- The illumination output is an output.
- Pixels with high changes are always read.

- For implementing an SCD sensor on a standard CMOS technology, two circuits need to be considered:

Winner-Take-All (WTA), for selecting the highest magnitude change (analog).

Pixel addressing circuit, for identifying the pixel with the highest magnitude change (digital).

The same scheme can also be applied for other sensors apart from vision sensors.

Objective

Developing Giant Magnetoresistance (GMR) sensors for Adress Event Representation (AER) applications

What is GMR?

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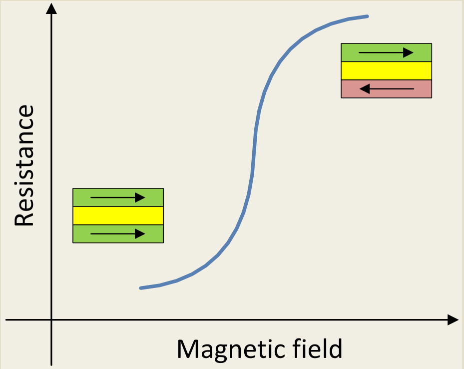
GMR= Giant MagnetoResistance

Giant MagnetoResistance

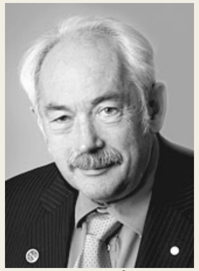
GMR is a significant change of the resistance with the external magnetic field observed in **multilayered structures** at **room temperature**.

$$MR = \frac{R^{\uparrow\downarrow} - R^{\uparrow\uparrow}}{R^{\uparrow\uparrow}}$$



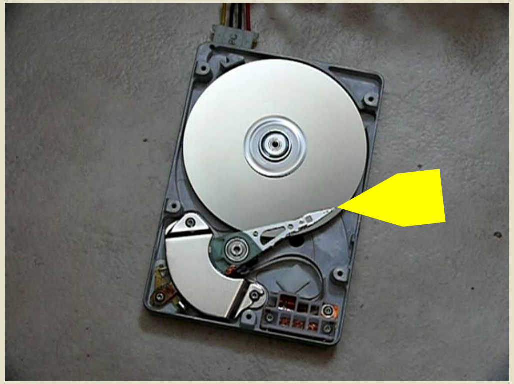
Nobel Prize in Physics (2007)

A. Fert



P. Grünberg

Digital applications



Analog applications

Magnetic field measurement

Biotechnology
Compass
Angle measurement
Traffic control
Space applications
Electric current measurement

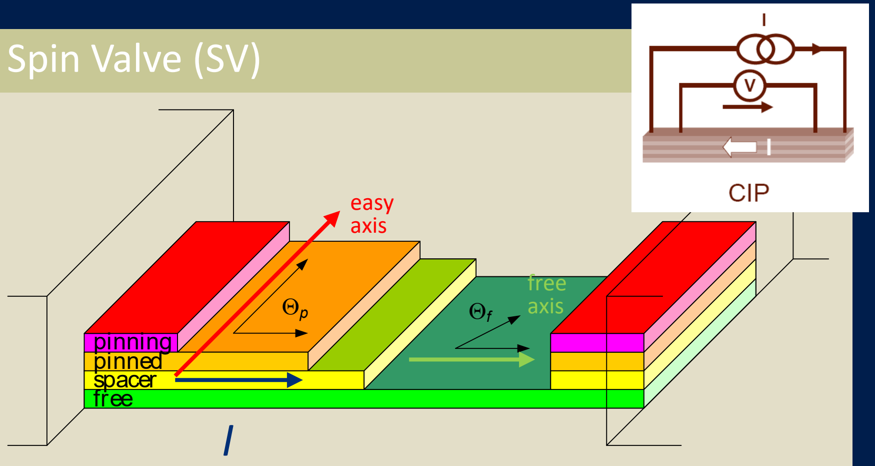
Properties

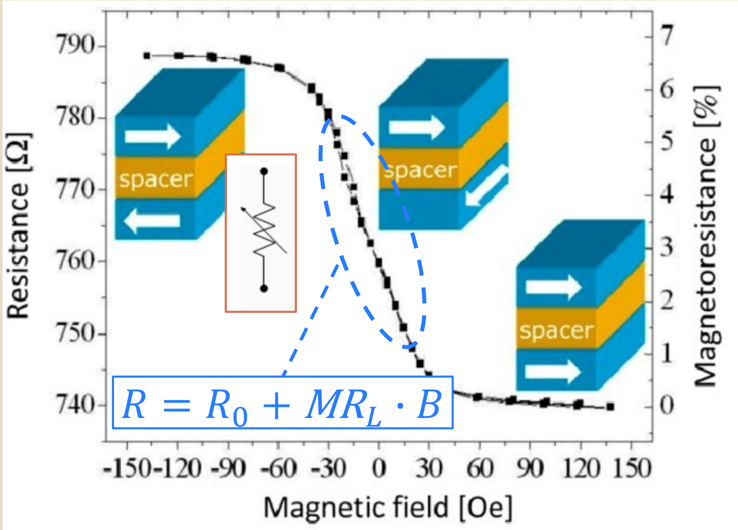
High sensitivity
Mesurement of in plane fields
High scale of integration
Design flexibility
Compatibility with CMOS

Linear GMR Structures

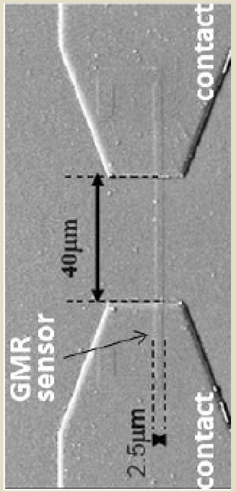
Spin valves – Crossed axis

Spin Valve (SV)





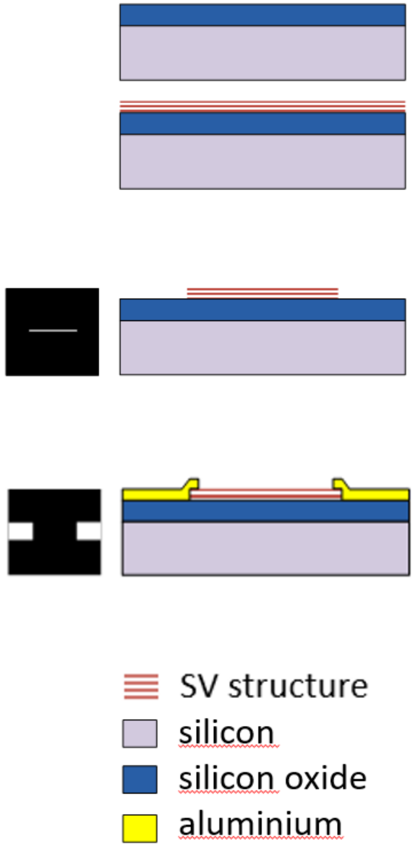
Typical SV device



Typical SV structure

Ta2nm
MnIr8nm
CoFe2.4 nm
Cu2.2nm
CoFe2nm
NiFe3nm
Ta2nm

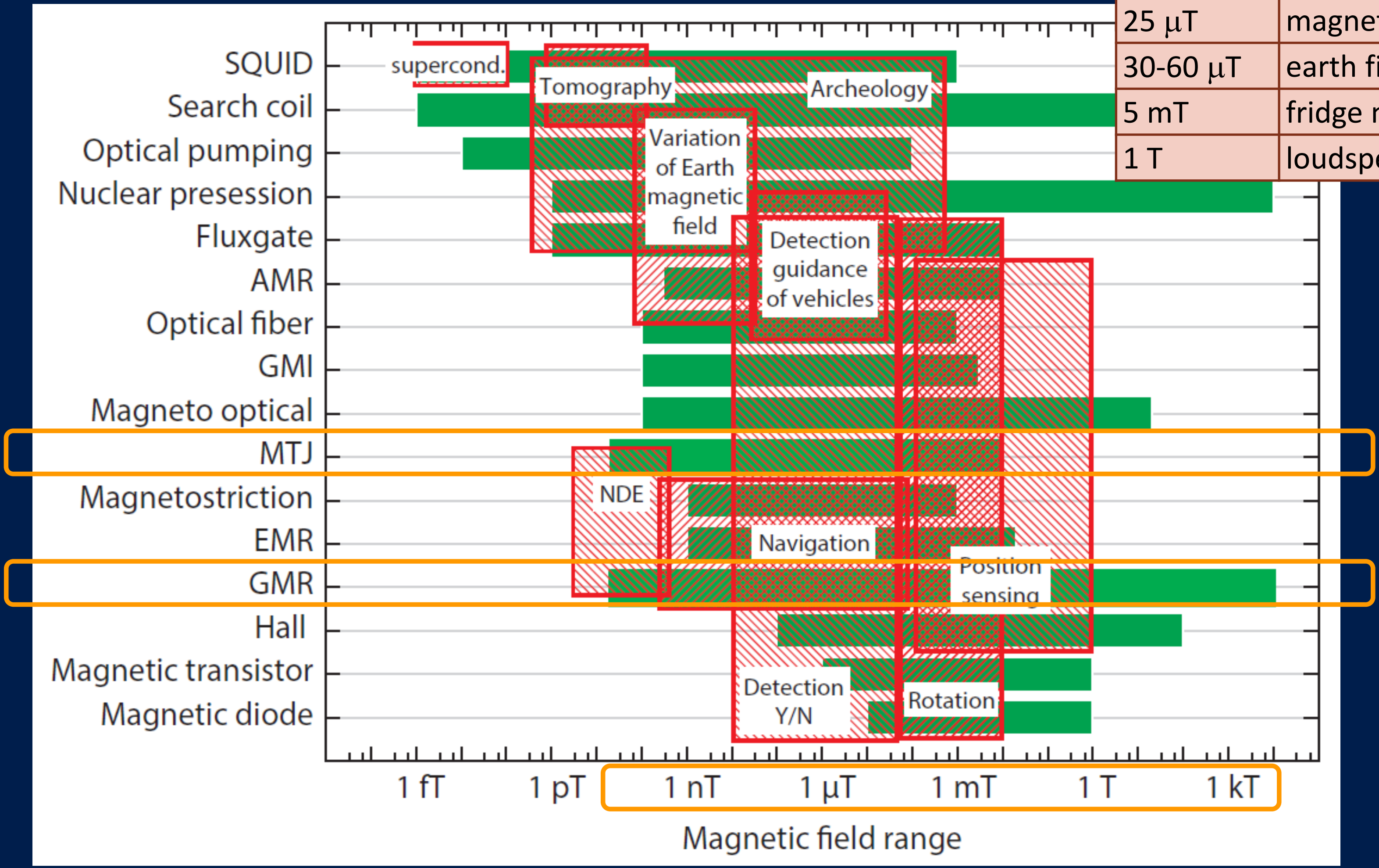
Microfabrication process



APPLICATION RANGE

MAGNETIC FIELD SENSING

1 pT	human brain
25 μT	magnetic tape
30-60 μT	earth field
5 mT	fridge magnet
1 T	loudspeaker magnet

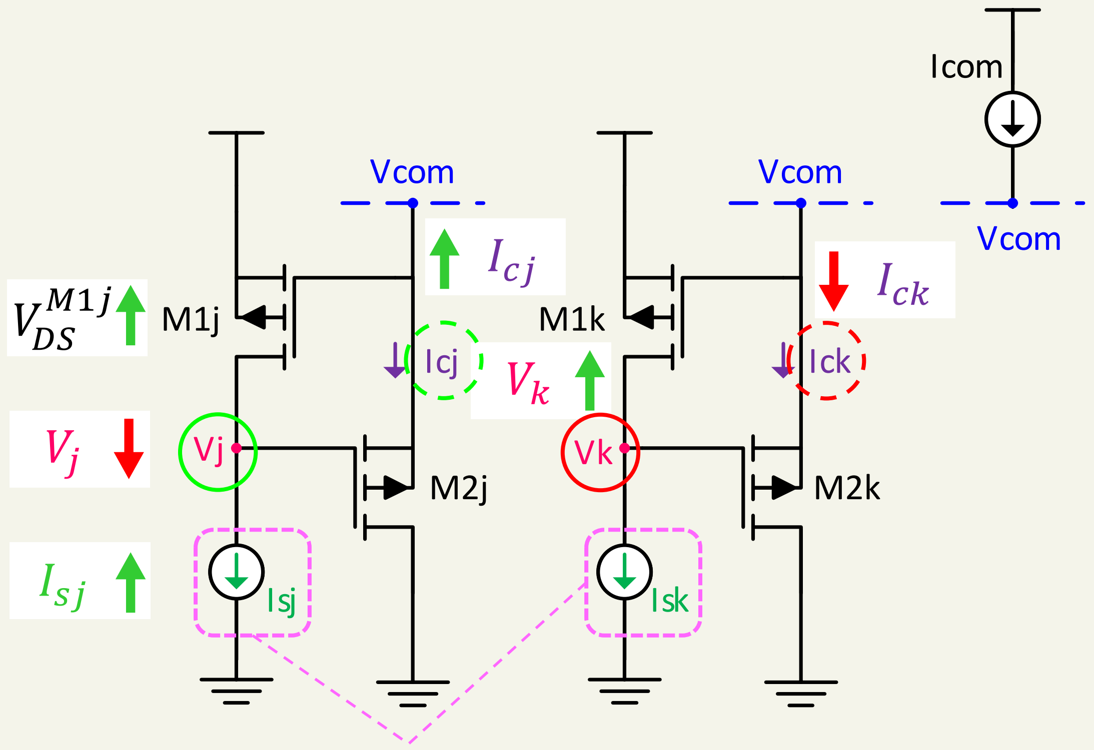


Outline

Winner Take All (WTA) circuits

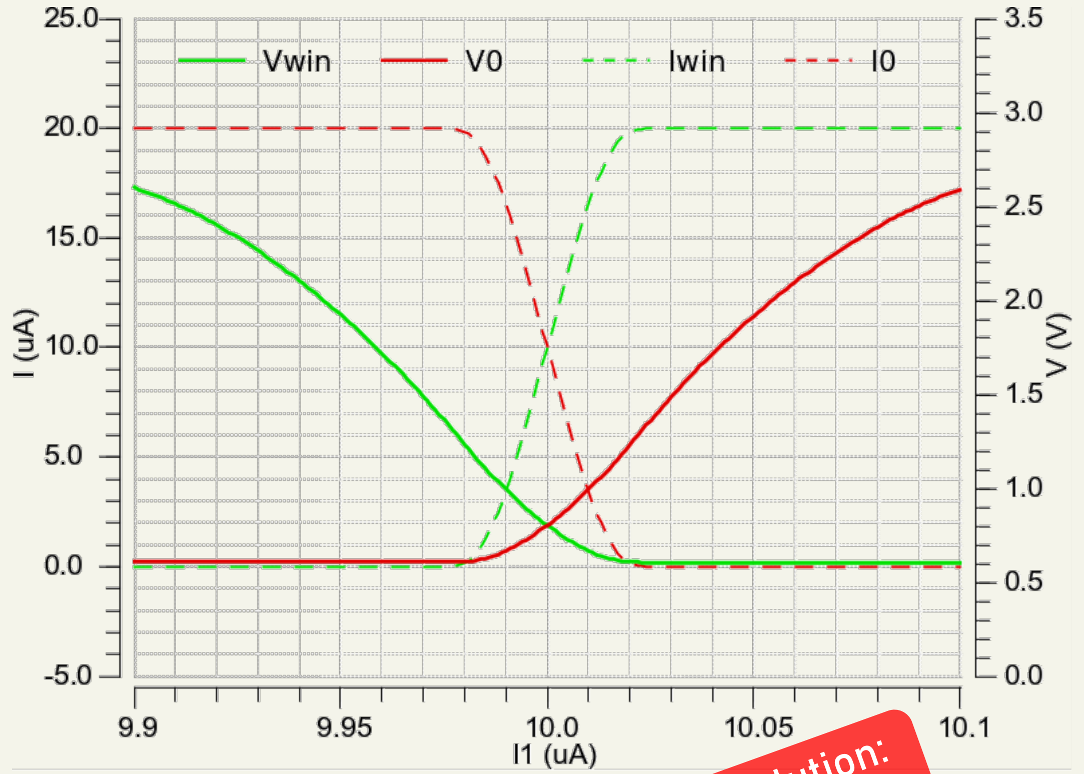
Lazzaro's Cell

PMOS implementation



Simulated response (AMS 0.35 um)

$W_1 = W_2 = 20$ μm
$L_1 = L_2 = 10$ μm
$I_{com} = 20$ μm

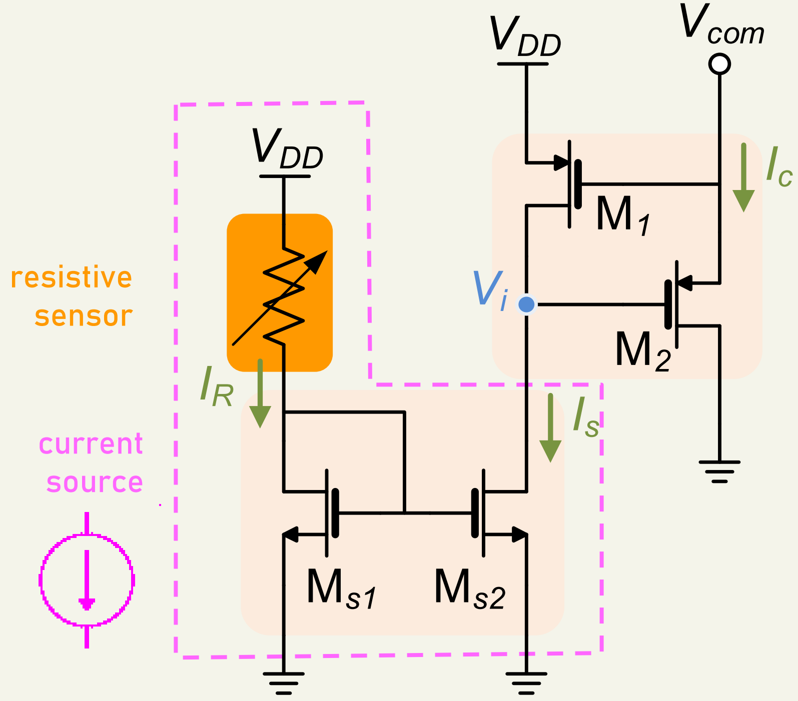


resolution: 50 nA

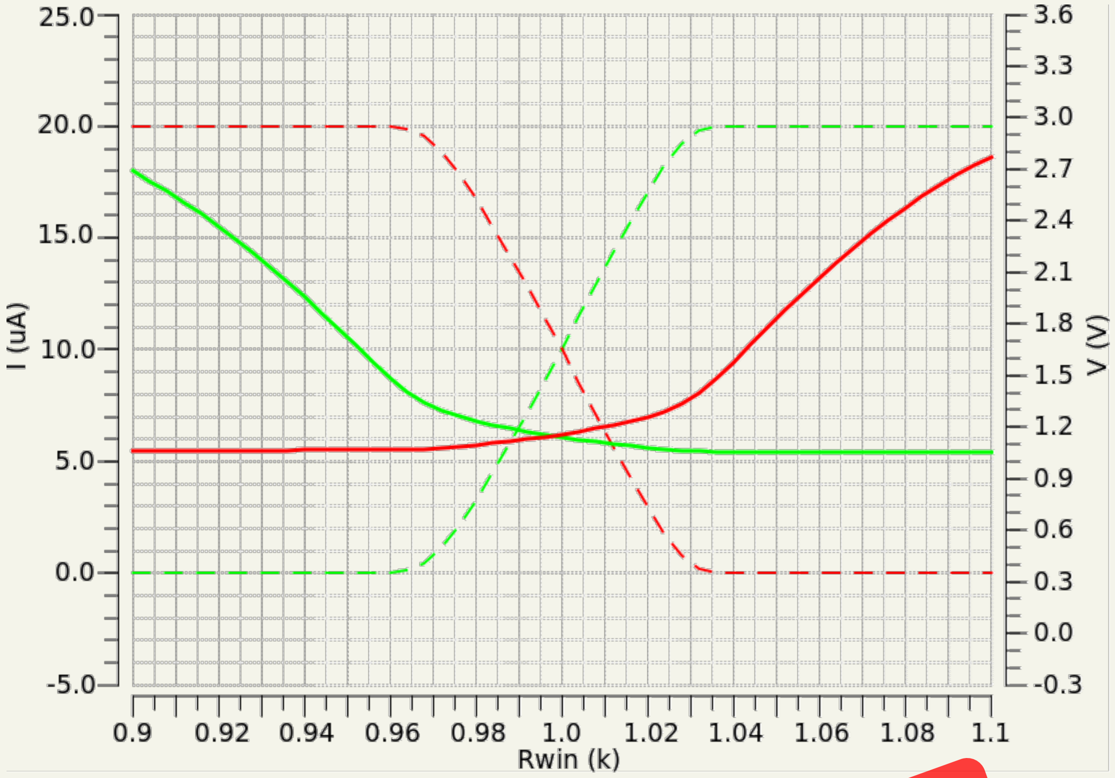
INCLUDING RESISTIVE SENSORS

WITHIN THE LAZZARO'S CELL

Integration of GMR sensors



Simulated response



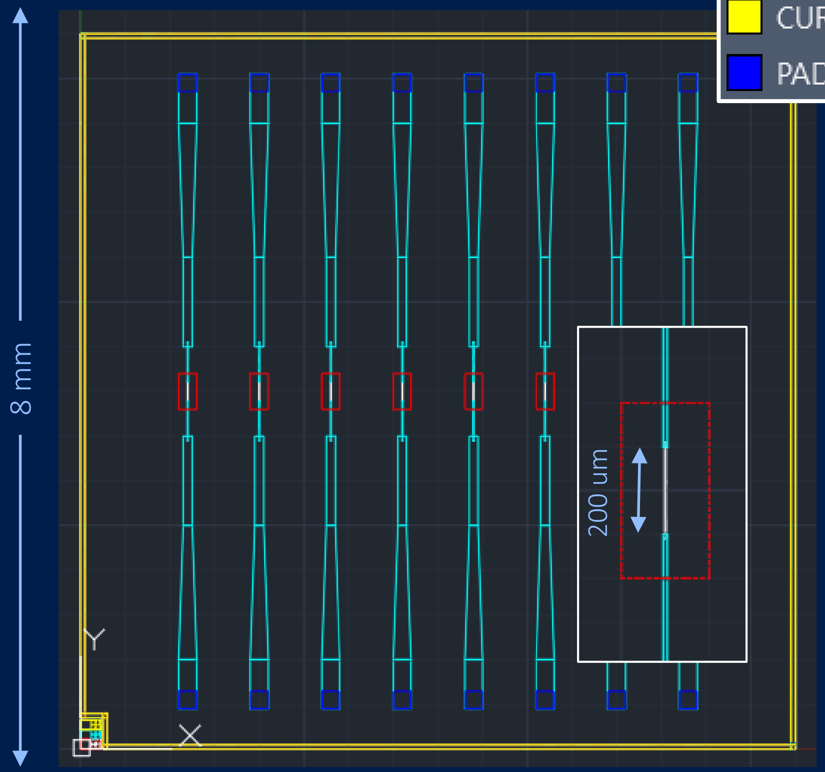
resolution: ~10% (1 kΩ)

GMR Sensors Design

Masks Set

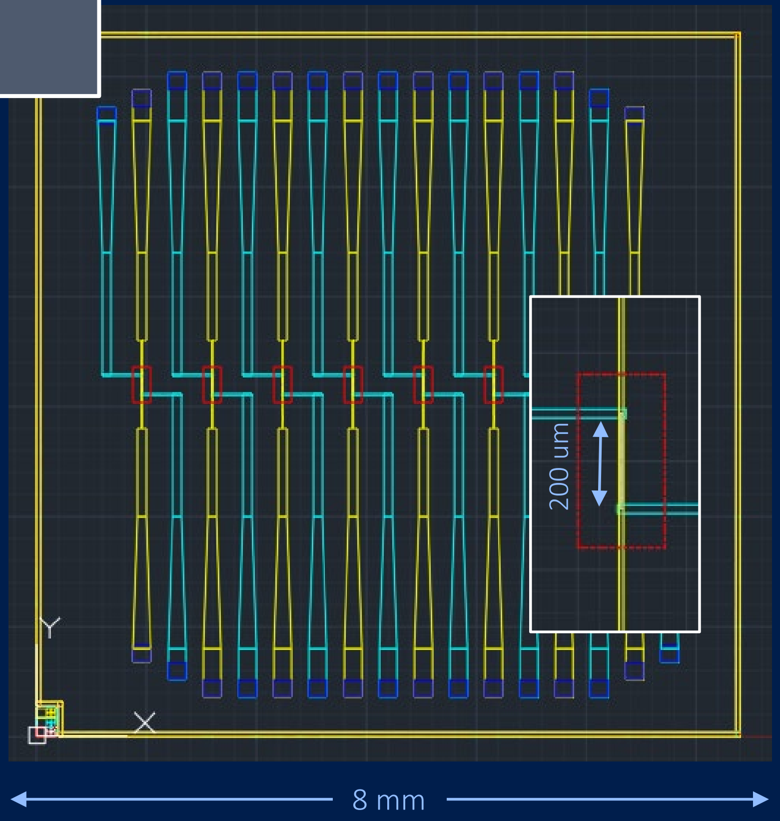
R_0 ~ 1 kΩ

1x8 sensing elements

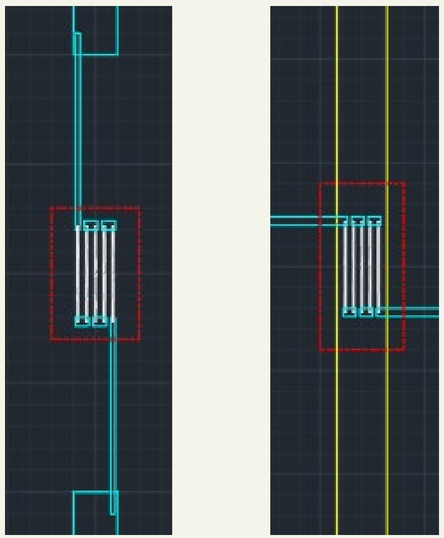


SV10
SV12
CONT
CURR
PADS

1x8 sensing elements
(with current strips)



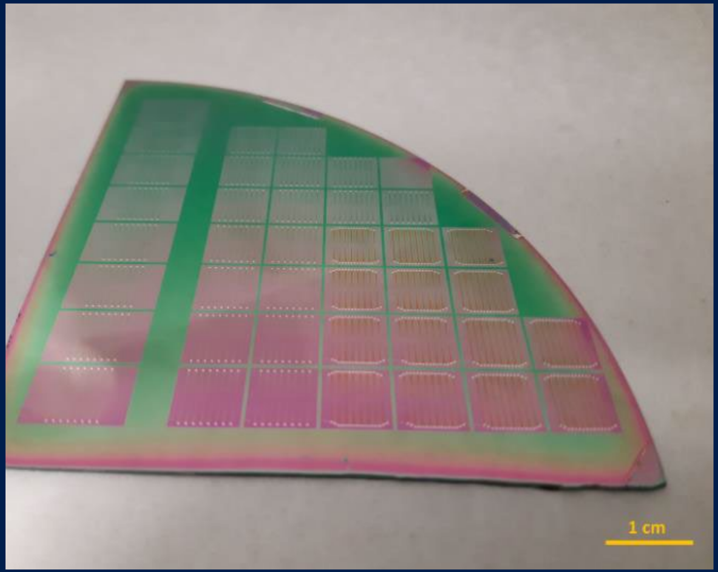
R_0 ~ 5 kΩ

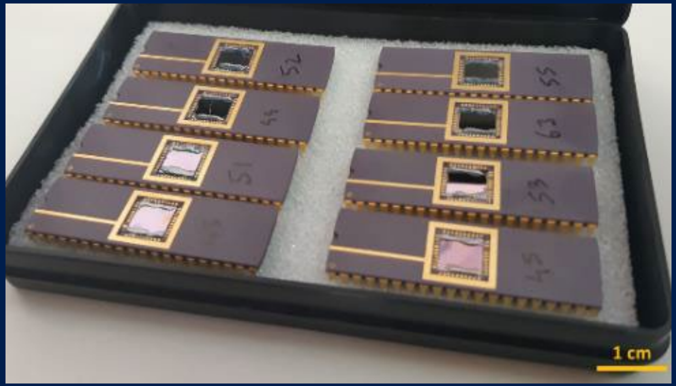


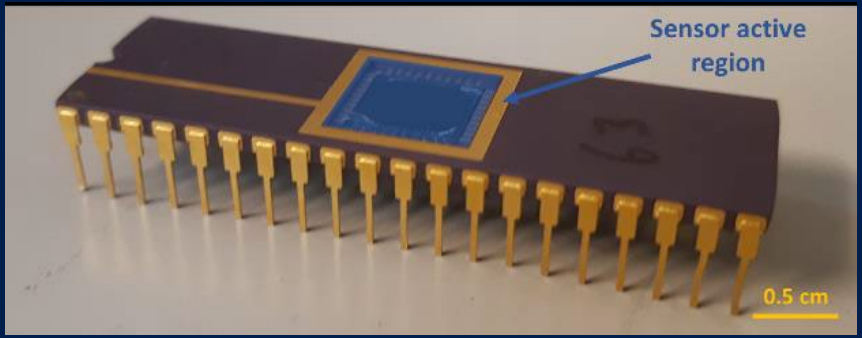
Outline

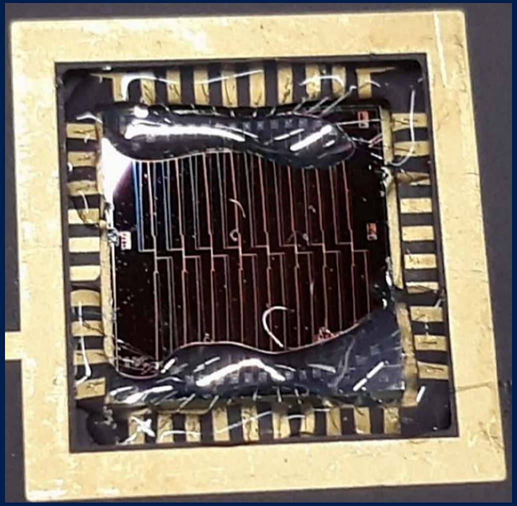
GMR Sensors Designs

Chips

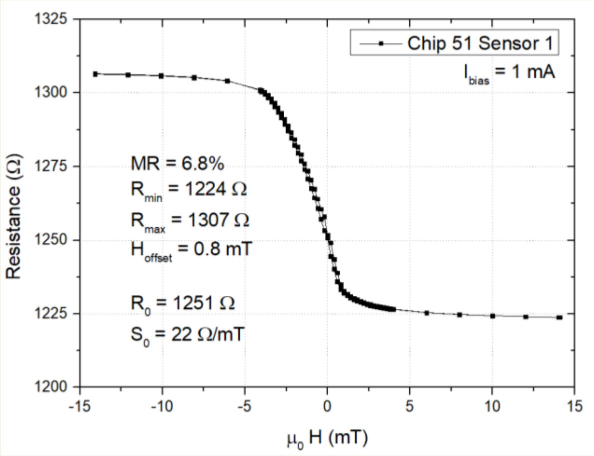




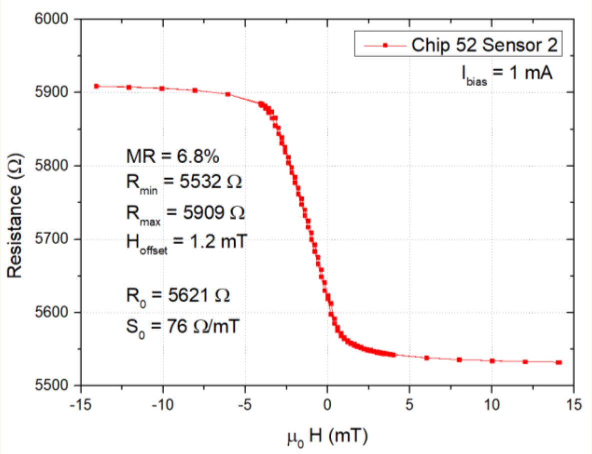




$R_0 \sim 1\ k\Omega$



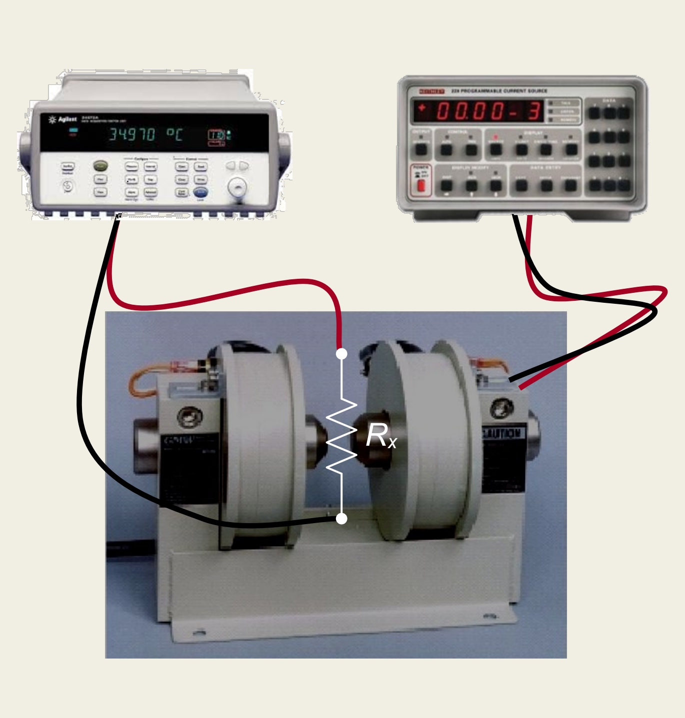
$R_0 \sim 5\ k\Omega$



Static characterization

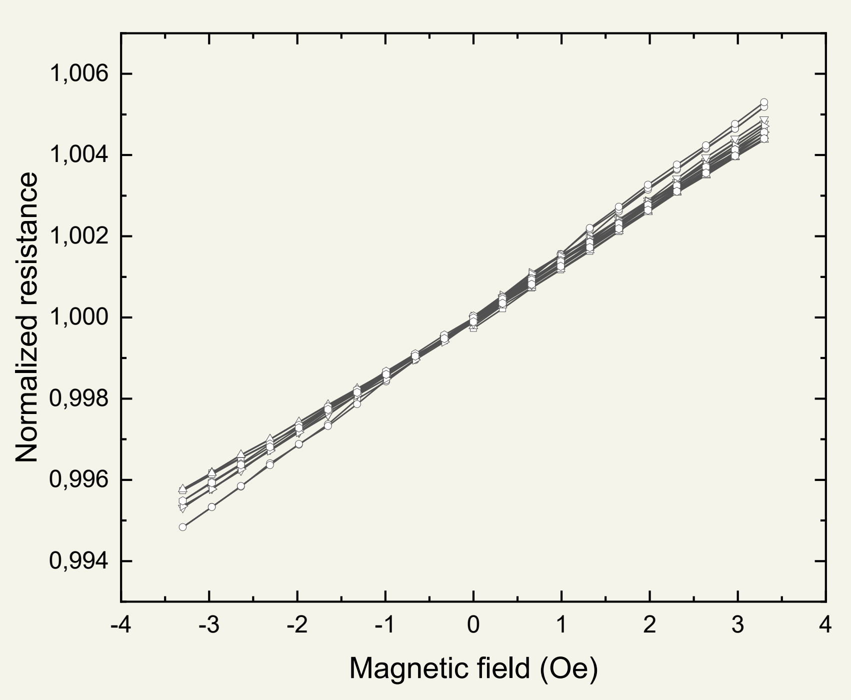
Magnetic field

Experimental setup



Automatized measurement GPIB/LabView

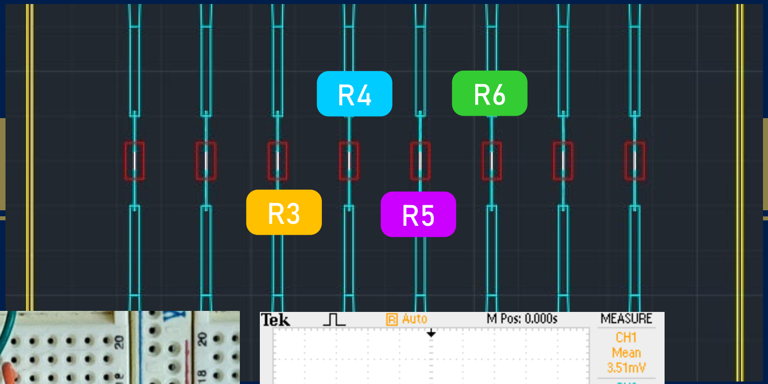
Results

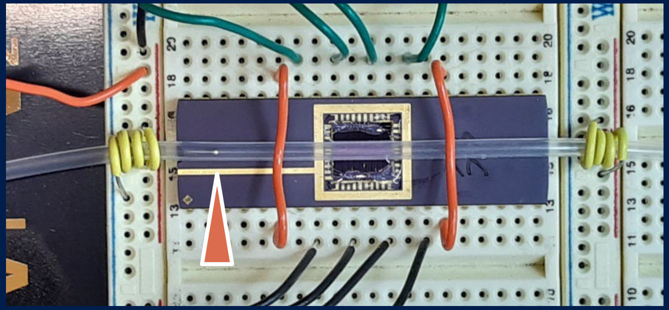


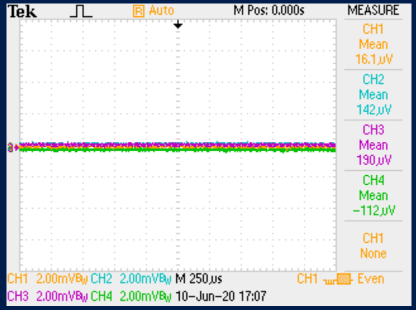
R_0 [Ω]	MR [%]
1165±5	1,66±0.04

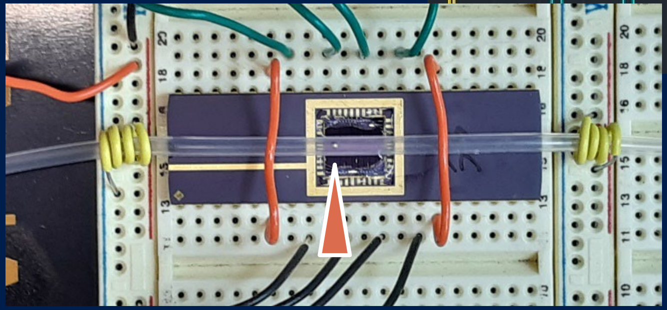
MAGNET DETECTION

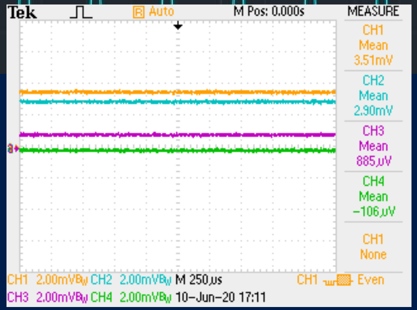
AS A FUNCTION OF THE POSITION

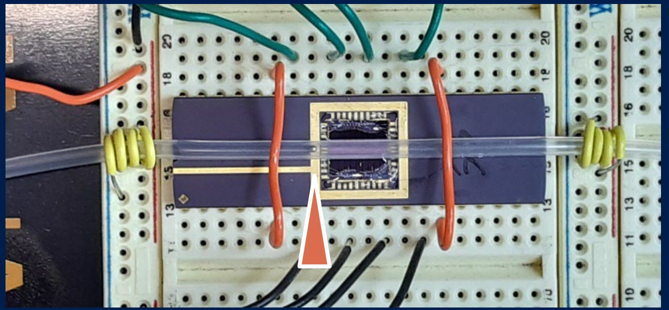


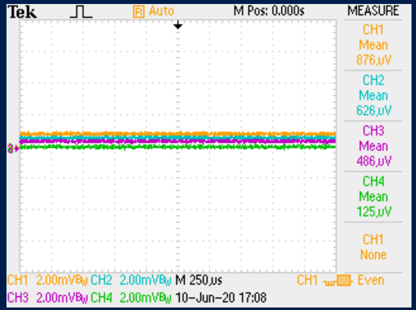


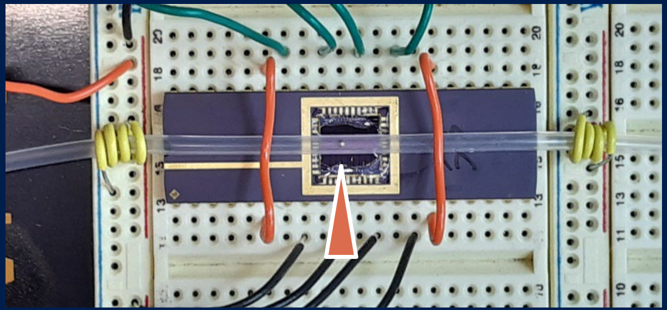


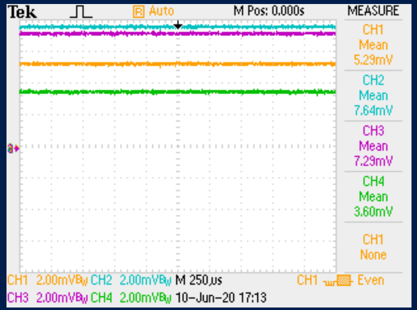


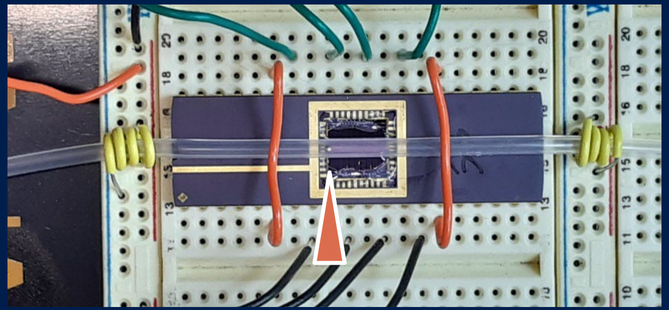


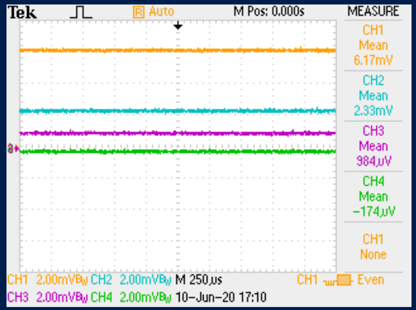


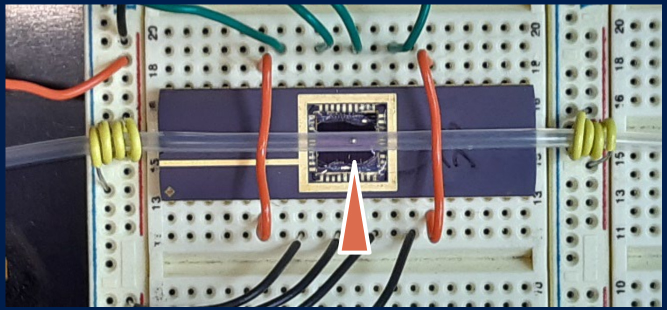


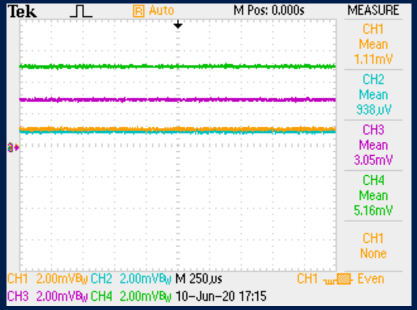












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CONCLUSIONS

… AND FUTURE WORK

- GMR can be integrated within basic WTA circuits in AER approaches.
- Preliminary results are promising
- Application on magnetic field scanning will be evaluated in the near future. GMR/TMR sensing arrays will be considered.

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PID2019-105556GB-C32

Thank you!

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