2D Hall Arrays for High Resolution Tokamak Magnetic Field Imaging

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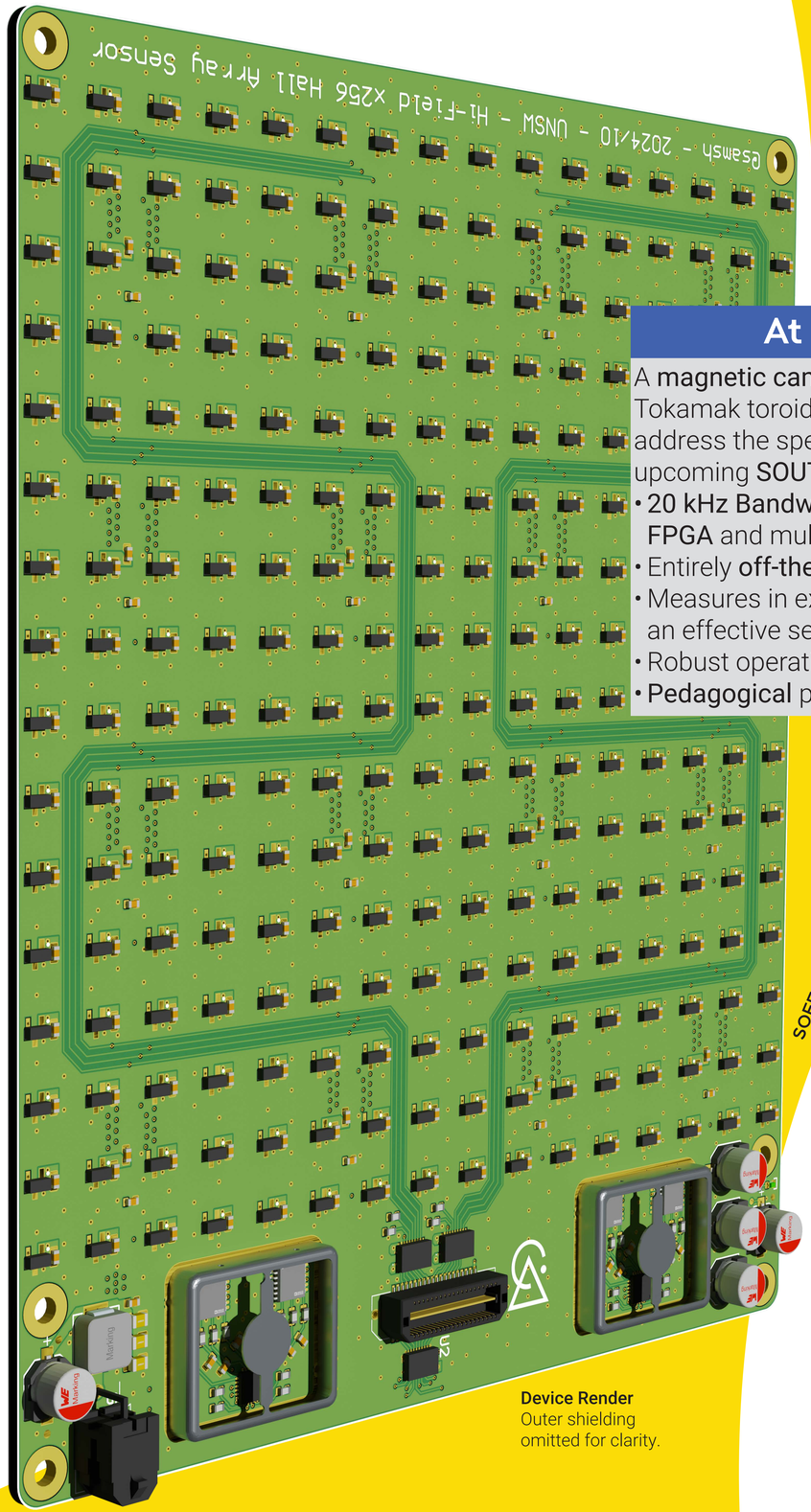


Device Render
Outer shielding omitted for clarity.

At A Glance

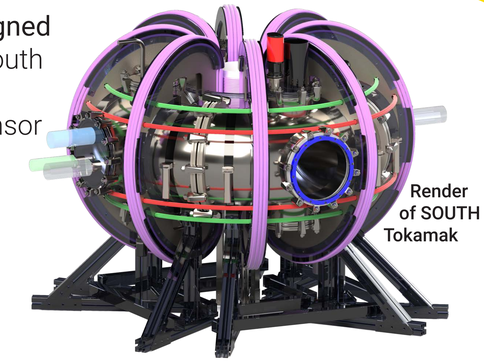
A **magnetic camera** designed to monitor Tokamak toroidal B fields, designed to address the specific requirements of the upcoming **SOUTH Tokamak**:

- **20 kHz Bandwidth** achieved through an **FPGA** and multiple ADCs
- Entirely **off-the-shelf** construction
- Measures in excess of **±150 mT**, with an effective sensitivity of ≈ **0.32 mT**
- Robust operation in harsh conditions
- **Pedagogical** potential

Motivations: The SOUTH Tokamak

The SOUTH Tokamak is an upcoming **undergraduate designed and built Tokamak** constructed at the University of New South Wales in Sydney, Australia. The project has many unique requirements, stemming from a **very tight budget**. This sensor is engineering focused (not a diagnostic), and is design to:

- Verify that the correct *B* field is being produced
- Validate our multiphysics simulations
- Catch manufacturing defects or deficiencies
- Avoid the requirement for more comprehensive and expensive field mapping solutions



Render of SOUTH Tokamak

Device Description

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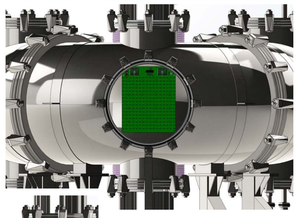
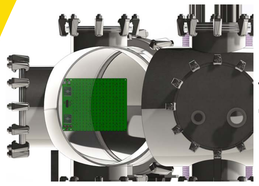
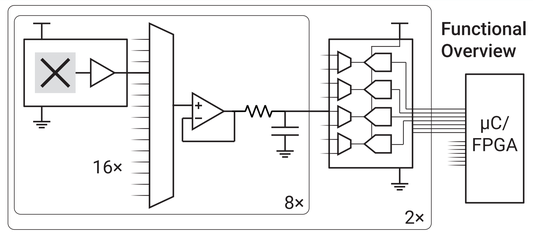


Radial Field Configuration



Toroidal Field Configuration



Functional Overview

256 discrete sensors are multiplexed into eight total ADCs which record data simultaneously, capturing the full 20 kHz of bandwidth when operated with an FPGA. A robust filtering and shielding solution prevents the ingress of high frequency noise. Hardware oversampling can decrease noise when the device is sampling slower with a micro-controller.

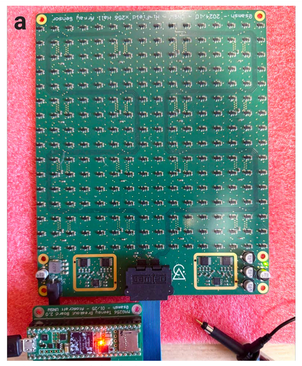
Scan the QR code for a complete overview (and Schematics)!

Specifications

Sensor Layout	16×16, 9 mm Pitch
Overall Dimensions	175×142 mm
B Field Range	>±150 mT
Analogue Bandwidth	20 kHz
Sampling Rate	>40 kSPS / Sensor
Mechanical Structure	6 Layer FR4 with ENIG
Number of Components	>600
ADC Bits	12, ~10.4 ENOB
Effective Sensitivity	~0.32 mT
Data Production Rate	>122.88 mbps
Power Consumption	~7.5 W

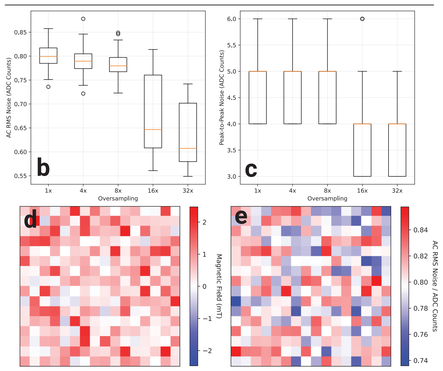
Preliminary Results

Completed Device



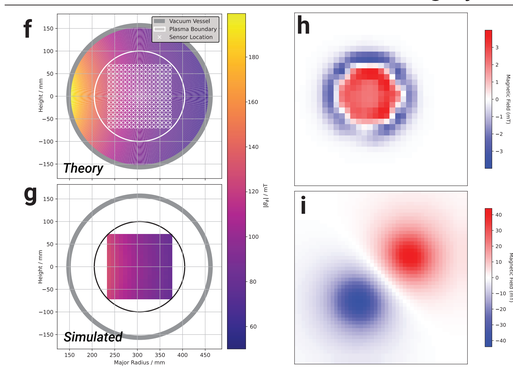
a) Assembled device connected to Teensy 4.1 Micro-controller via a SYZYGY connector + breakout.

Noise & Calibration



b) Sensor AC RMS Noise Statistics; **c)** Sensor Peak-to-Peak Noise Statistics; **d)** Sensor 1-Point calibration; **e)** Sensor AC RMS Noise Distribution

Imagery



f) Theory toroidal field with sensor geometry; **g)** Simulated reconstruction; **h)** Magnetic field of Apple MagSafe Charger; **i)** Magnetic field of Bar Magnet — Scan QR code for Videos!

This device will be used to aid in SOUTH's R&D, manufacturing and commissioning over the next 18-24 months, with toroidal measurements coming soon.

Learn More?

Acknowledgments

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