Pre-Production Testing of the AMACStar ASIC at Penn for the ATLAS ITk Detector

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Abstract

The high-luminosity upgrade to the LHC (HL-LHC) requires a new inner detector, the Inner Tracker (ITk) detector. AMACStar is one of three application specific integrated circuits (ASICs) that will be installed on the ITk strip modules.

--- 18000 AMACStars will be produced

--- Wafers of these chips are tested at the Penn probe station

--- A comprehensive testing suite and grading scheme is applied to each chip

The results from the pre-production satisfy the required 90% yield needed for production goals.

ATLAS ITk

The ITk detector will replace the existing ATLAS tracker system. The ITk strips subsystem will be made of silicon modules. The modules are made up of silicon sensors and readout electronics, including three ASICs: the ABC (ATLAS Binary Chip), HCC (Hybrid Controller Chip), and AMAC chip (Autonomous Monitor And Control) [1].

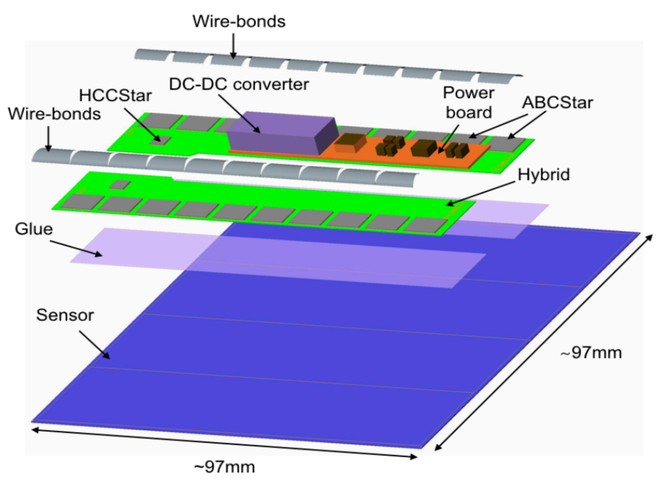

Figure 1: Schematic of an ITk strips module

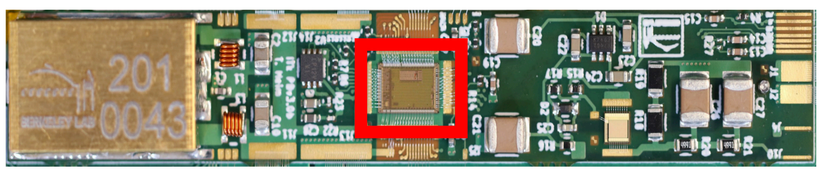

Figure 2: Image of a power board [2]. The AMAC chip is located directly in the center

The AMACStar Chip

The AMACStar chip contains a 16 channel ADC and interlock mechanism. It autonomously monitors temperatures, voltages, and currents and controls the module [3]. If vital quantities become too high, the chip can flag these issues and disable voltages.

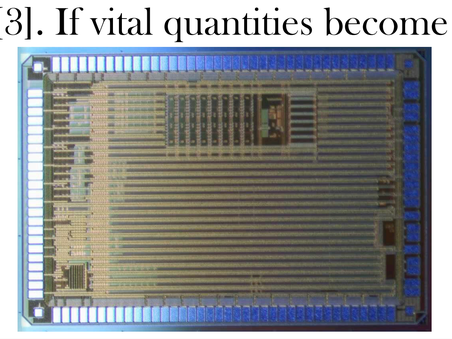

Figure 3: Image of a single AMACStar chip

Testing the AMACs

Over 60 combined digital and analog tests are used to evaluate the performance of every AMAC.

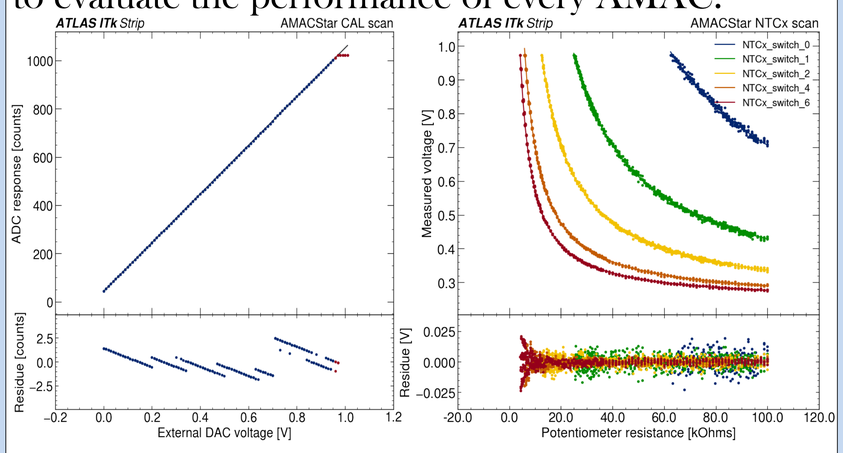

Figure 4: (left) CAL scan; (right) NTC scan ITK-2022-02)

Some of critical tests include calibration, NTC, DCDC current, and temperature scans.

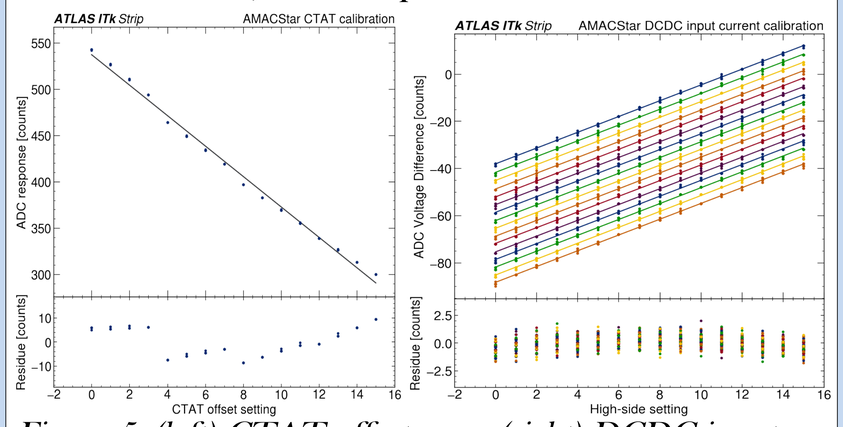

Figure 5: (left) CTAT offset scan; (right) DCDC input current calibration scan (ITK-2022-02)

Penn Probe Station

We use a probe station inside a clean room at Penn to probe shared wafers of HCCStar and AMACStar chips.

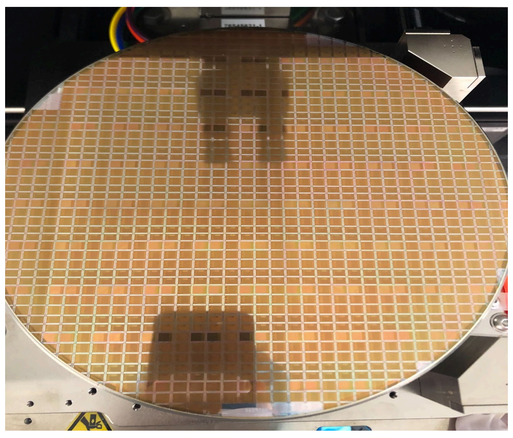

Figure 6: A shared wafer of HCCStar and AMACStar chips loaded in the probe station

Each wafer contains 487 AMACStars, which take about 27 hours to fully probe. After probing every AMAC, each chip is assigned a grade: Good, Accept, or Bad.

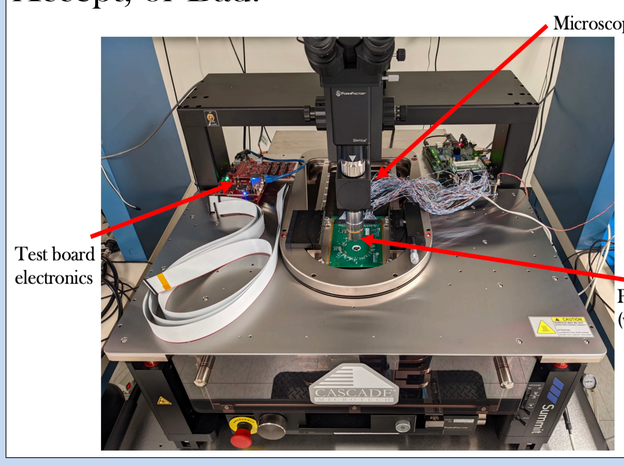

Figure 7: Image of the Penn probe station

Pre-Production and Priming Results

Grading parameters are used to assess the digital and analog performance of a given AMAC after we run our tests.

Grade	Description
Good (A)	Passed all digital and analog parameters
Accept (B)	Passed all digital and vital analog parameters
Bad (F)	Failed 1+ digital or vital analog parameters

3 wafers were probed for pre-production and 8 were used for production priming. Based on the detector requirements, a yield of 90% 'Good' chips is expected per wafer. We reached this goal during both, the pre-production and priming phases.

	Good	Accept	Bad
Wafer #1*	486 (99.8%)	0	1 (0.2%)
Wafer #2	447 (91.8%)	26 (5.3%)	14 (2.9%)
Wafer #3	473 (97.1%)	6 (1.2%)	8 (1.6%)
Priming	92.63%	4.65%	2.72%

**Only a fraction of the final parameters were developed for this wafer*

A total of 68 digital and 262 analog parameters were reviewed and deployed for the production priming wafers. This process finalized the testing suite and grading scheme for production.

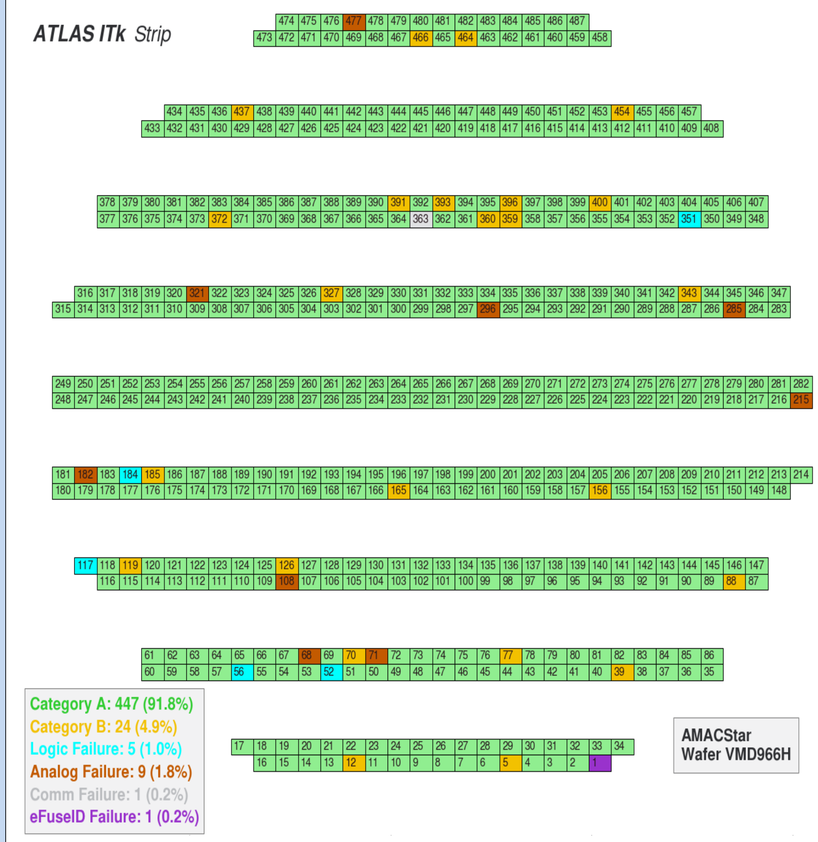

Figure 8: Example wafer map from one of the production priming wafers ITK-2022-02)

Conclusions and Future

Based on the strong performance of the AMACStar chip (as well as the HCCStar) throughout pre-production, the order for production wafers has been placed. The first batch will arrive in December 2022 and production is scheduled to begin in early 2023.

References

[1] ATLAS Collaboration, TDR for the ATLAS Inner Tracker Strip Detector, ATLAS-TDR-025.
[2] Karol Krizka, "Results of the Powerboard for ATLAS ITk Strip Barrel Modules." TWEPP 2019.
[3] ITk Strip Collaboration (2022) ATLAS ITk Electronics Specification: AMACStar ASIC: https://gitlab.cern.ch/atlasitkstrasic-group/AMAC/-/blob/star_doc/doc/Specification/AMACStar_Spec.pdf

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