Quick Testing of Skipper-CCD Packages

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The OSCURA Experiment

OSCURA is an experiment whose main purpose is to search for DM (dark matter) particles with masses a few orders of magnitude below the mass of the proton using **Skipper-CCDs**. It searches for DM electron interactions within the silicon of the detector.

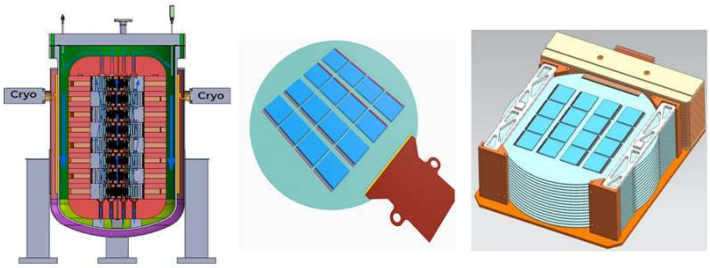

Fig 1: (a) OSCURA (10 Kg Skipper-CCD experiment) (b) MCM (16 Skipper-CCDs) (c) Super Module (16 MCMs)

CCDs (Charged-Coupled Devices) are arrays of coupled capacitors that can move charge from one pixel to another neighboring pixel. The charge can then be collected via a sense node. The **Skipper-CCD** is a special type of **CCD** that allows multiple charge measurements without corrupting the charge packet. By averaging these consecutive measurements, it can reach sub-electron noise levels (See Fig 2).

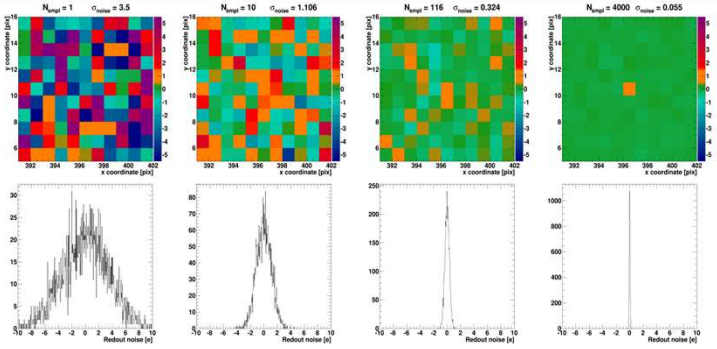

Fig 2: (Top) Images obtained with a Skipper-CCD using 1, 10, 116, and 4000 samples. (Bottom) Charge distribution of the pixels in the images on the top.

The MCM Quick Tester

OSCURA **(Fig 1 a)** will have 10-Kg of active silicon in the form of Skipper CCDs. This corresponds to approximately 24,000 sensors, where 16 CCDs will be grouped together in a package called Multi-Chip Module (MCM) **(Fig 1 b)**. Subsequently, 16 MCMs will then be grouped together to form a Super Module **(Fig 1 c)**. OSCURA will require these MCMs to be mass-produced and therefore a fast and efficient test will be needed. The initial stage of testing will consist of measuring a resistance value between the lines in the MCM and comparing it with known values of working detectors. Current tests involve using electromechanical switches that can take up to 30 minutes to test a single MCM. We will instead implement solid-state relays that will be able to perform the tests almost instantaneously. In addition, we can test the CCDs as we build the MCMs in order to detect faulty units early in the production process.

Hardware

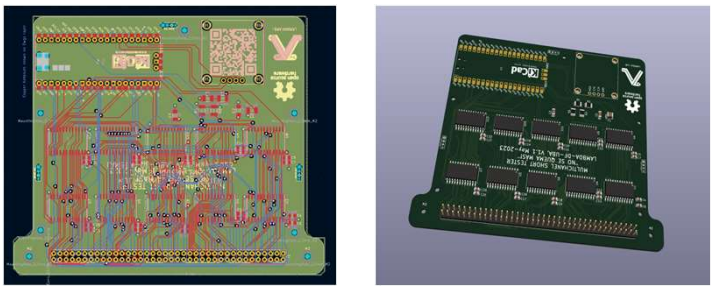

Fig 3: (left) The printed circuit board of the MCM Quick Tester (right) 3D view of the PCB

Using KiCad, the PCB was updated to contain 4 layers where two additional layers constitute the power and ground planes. Additionally, coupling capacitors were added to each Multiplexer. The planes and coupling capacitors will help reduce EMI (Electromagnetic Interference) emissions and improve the quality of the signal on the traces. Moreover, in most designs, each active component on the board is connected to both power and ground and therefore connecting them to the planes is much simpler than routing the power and ground trees with traces.

Software

MicroPython was selected as the programming language for the Raspberry Pi Pico. A function was developed to take in a channel number as input and generate an output by applying an external voltage across the terminals of the solid-state relay. A nested loop was then constructed to measure the resistance between all possible channel combinations using simple voltage division. Results were sent to a computer and then analyzed by a python script. A summary after a test of a failed MCM can be seen in **Figure 4**.

First Set of Results

```
pi@rpiccdtest1:~/Soft/m300Soft/data/MCM_dataTest $ python ../../claudio_analysis_CCDres.py MCM23_Cramic_AllCCDs_AllBonded_Packed_retest_vsub_m8V_clean
ed_allDG_removed_col4__RESISTANCE_2022-09-09T15:30:05.850102.csv
short to self: 192/192 passed
H-clock isolation: 6048/6048 passed
TG isolation: 378/378 passed
V-clock isolation: 567/567 passed
Video/VDD: 3780/3780 passed
Drain/RD: 378/378 passed
P+: 189/189 passed
N+: 189/189 passed
VSUB: 189/189 passed
Failed RTDs: pin 67 (RTD3) to pin 68 (RTD4) = 9.9e+37 (range 2000, good range 70-140)
Failed RTDs: pin 67 (RTD3) to pin 68 (RTD4) = 1703605.838 (range 10000000, good range 70-10000.0)
Failed RTDs: pin 67 (RTD3) to pin 68 (RTD4) = 9.9e+37 (range 20000, good range 70-140)
Failed RTDs: pin 68 (RTD4) to pin 67 (RTD3) = 9.9e+37 (range 2000, good range 70-140)
Failed RTDs: pin 68 (RTD4) to pin 67 (RTD3) = 1801414.883 (range 10000000, good range 70-10000.0)
Failed RTDs: pin 68 (RTD4) to pin 67 (RTD3) = 9.9e+37 (range 20000, good range 70-140)
RTDs: 372/378 passed
==================================
Total: 12282/12288 passed, 6 failed
MCM NOT OK
==================================
pi@rpiccdtest1:~/Soft/m300Soft/data/MCM_dataTest $
```

Fig 4: First set of results of the MCM Quick Tester. Some resistances are out of range. This MCM did not pass the test.

Acknowledgement

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