MuPix9 - a HV-MAPS prototype with serial powering

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The Mu3e Experiment

Mu3e is going to search for the charged lepton flavour violating decay at PSI in Switzerland. In the standard model of particle physics the decay of one muon to three electrons is suppressed. The decay of one muon to three electrons is suppressed (99%). The observation of the \(\mu \rightarrow e^+ e^- e^-\) decay would be a clear sign of physics beyond the standard model. The demands on a pixel detector that can discover these rare events are high:
- Vertex resolution of O(100 µm)
- Time resolution below 20 ns
- Detector thickness is limited to 50 µm
- High efficiency and low noise

These requirements are fulfilled by monolithic HVCMOS sensors. A series of prototypes have been developed for the Mu3e experiment. The newest member of this family is MuPix9.

MuPix9 - Achievements of the Predecessor

The MuPix8 is a large scale prototype with a total area of 100 x 200 pixels. The pixel size is 80 x 81 µm². The pixel to vssa of the amplifier can be fine tuned by 4 tune bits (Fig. 4). To verify the functionality all components have been tested individually.

Serial powering concept

Previous versions of MuPix were designed for parallel powering. In order to reduce the powerlines on the flexprint the serial powering concept is tested with MuPix9. Several sensors are powered serially on different voltage levels. The simplest way is to connect the ground of one sensor to vdd of the next and so on. Amplifier's vssa = 0.9 V would be created from vdd = 1.8 V by LDO (Option 1).

![First light of MuPix9](image)

An innovative way to supply several sensors by serial powering is to connect vdd of the previous sensor, vssa to ground of the next sensor. Separate regulators are used for analog and digital part (Option 2).

Power Regulator

Each sensor has two regulators that can be arbitrarily connected to form the schemes shown below (center). The regulators are designed for small temperature, supply voltage and current dependency. Three elements form the regulator: The bandgap regulator (blue) generates a well defined reference voltage. This voltage is used by two amplifiers (red) to provide the gate voltage for power transistors. Each of these components has four tune bits for fine adjustment.

![Power Regulator Schematic](image)

To verify the functionality all components have been tested individually. The band gap regulator provides a nearly constant reference voltage independently of the supply voltage (Fig. 1). For fine adjustment 4 bits can be used (Fig. 2).

Amplifier and NMOS power transistor regulate voltage for a wide range of current (Fig. 3). The level of the amplifier can be fine tuned by 4 tune bits (Fig. 4).

PMOS regulator was not working properly due to small drive strength of amplifier.

![Amplifier output current (mA)](image)

Summary and Outlook - MuPix10

The characterization of both MuPix8 and MuPix9 is still ongoing. A precision measurement of the timer is planned, as well as a more detailed investigation of the current driven matrices of MuPix8. Measurement of MuPix9 using SlowControl and Serial Powering is scheduled. All the information gained from these measurements is going to be used to design the next full reticle (~20 x 20 mm²) sensor, the MuPix10.