Digital Active Pixel Array (DAPA)
for Vertex and Tracking Silicon Systems

PROJECT

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Introduction

The concept of digital silicon sensor for vertex and tracker application is proposed. It is based on advanced type of active element and sophisticated digital architecture. Very fast binary readout is combined with approximately 8 μm space resolution.

4×4 cm^2 sensor composed of four 2×2 cm^2 quarters should be produced as a regular microelectronic device on low resistivity silicon wafers.

Basic element is about 25×25 μm^2 pixel with binary readout.
It includes active sensor, low power amplifier and a few logical elements with parallel and serial outputs.

Basic type of active sensor is a fully depleted diode in 10 μm thick epitaxial layer on regular low resistivity silicon wafer with individual very low power amplifier and FF.
The pixel outputs are connected into DAP “strips”.
Each strip consists of about 800 pixels. 2 cm long strips have 25 μm pitch according to the pixel size plus gap.
Individual strip electronics and memory are positioned on the end of the strip near the quarter’s edge.

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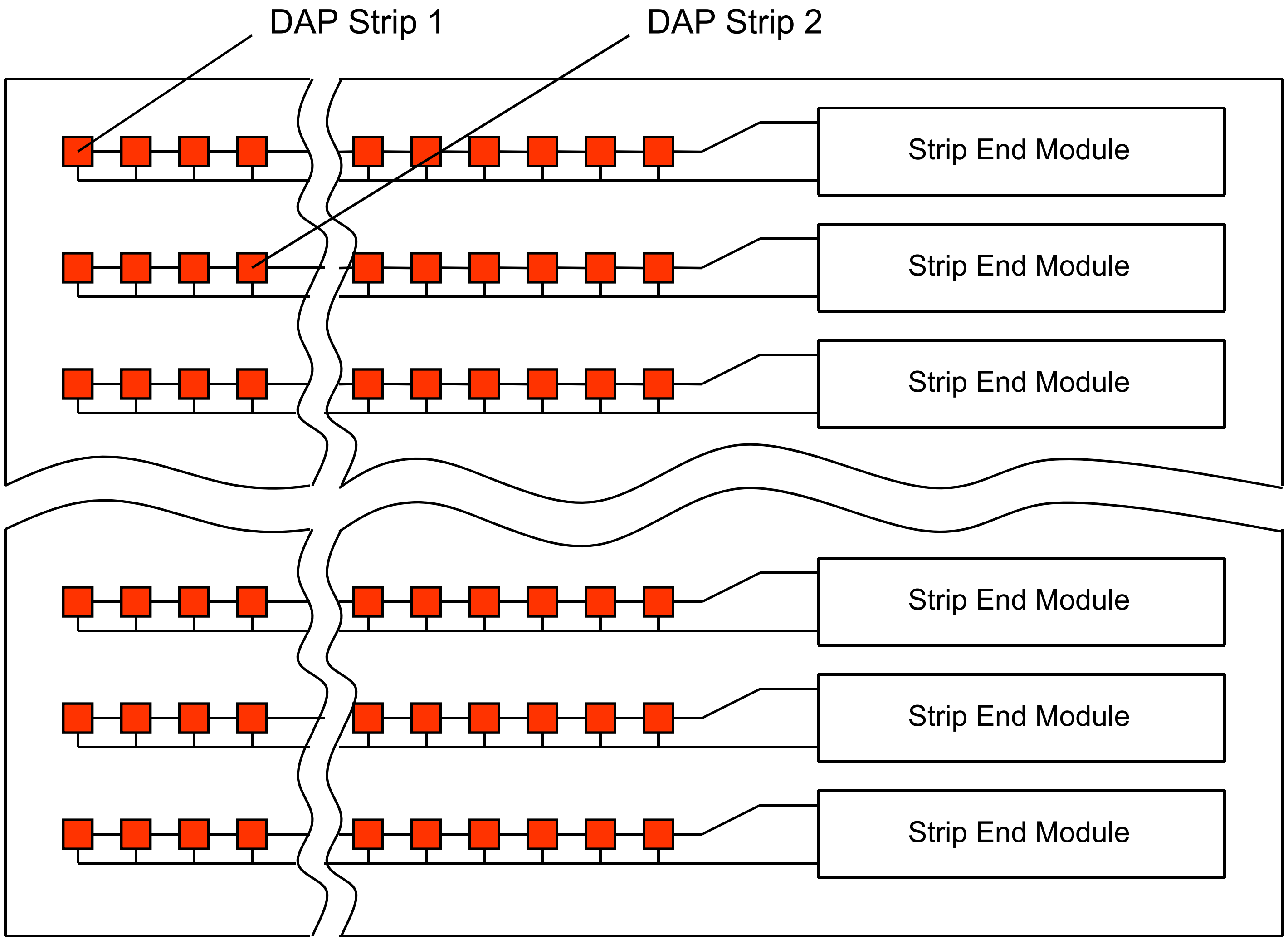
DAPA Readout Concept



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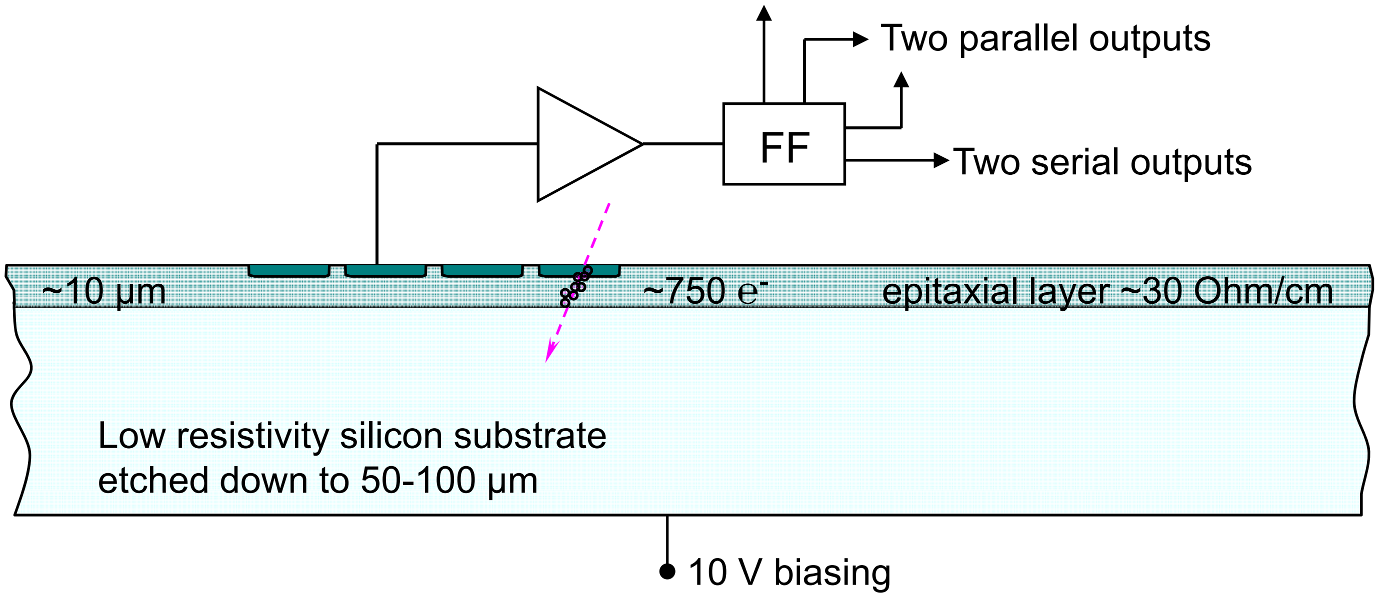
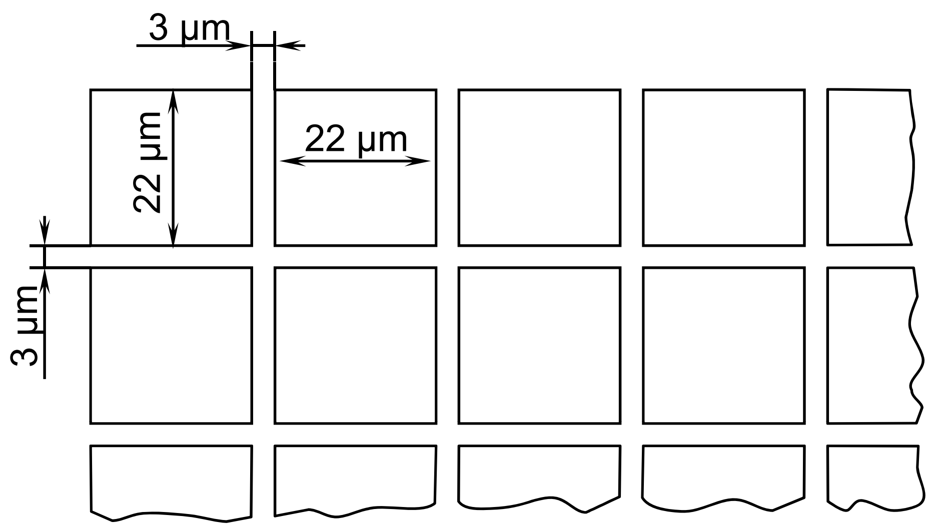
DAPA Individual Pixel





DAPA Sensor Parameters (approximated)

Pixel active area size 22×22 μm^2

Pixel pitch in both directions 25 μm

Active area thickness ~ 10 μm (can be increased)

Collected charge ~750 e^- →$1.2 \cdot 10^{-16}$ C

Charge collection time ~ $0.3 \cdot 10^{-9}$ s

Epitaxial layer resistivity ~20-40 Ohm/cm

Depletion voltage ~10 V

Pixel to backplane capacitance ~$6 \cdot 10^{-15}$ F

Pixel to 4 neighbour pixel capacitance ~$4 \cdot 10^{-15}$ F

Amplifier input capacitance 10-20 $\cdot 10^{-15}$ F

Pixel total capacitance ~$25 \cdot 10^{-15}$ F

Pulse height on amplifier input ~5 mV

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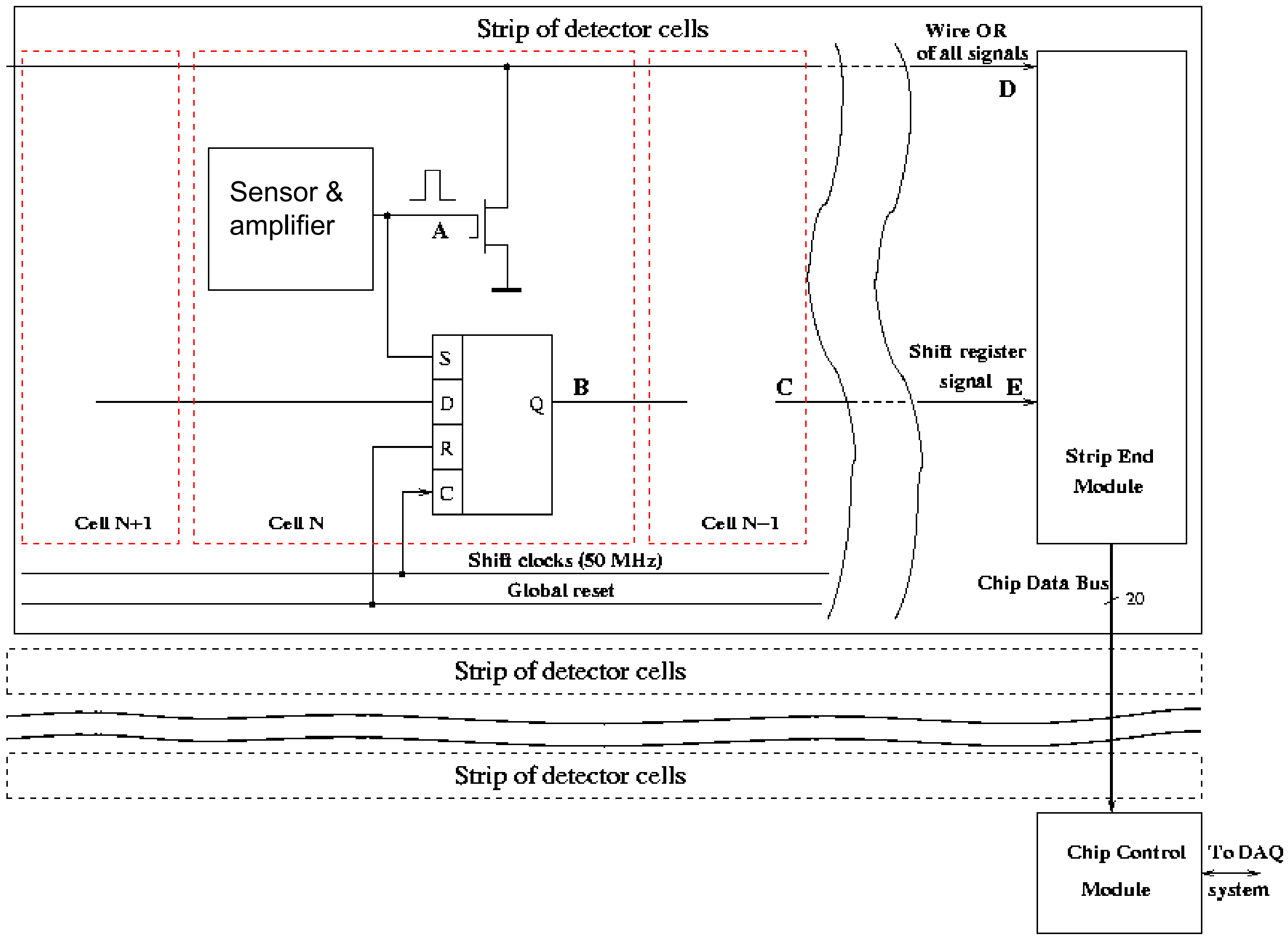
DAPA Strip Readout Structure
(one direction readout)



DAPA Overview

Within each strip all pixel signals are connected to one wire OR line through gate A. If a charged particle crosses ANY pixel which belongs to that strip, a short pulse (not potential) appears on the wire OR line. This pulse activates circuits which register signal arrival time. It can also be used to generate a fast first level trigger. This part of DAPA works as usual microstrip detector with 25 μm pitch and binary readout.

The same signal from the charged particle hit sets individual FF in the given pixel into “1” logical state. Serially connected FFs within strip work as a shift register. Every clock period information about hits in the entire strip is shifted one step toward strip end. After certain number of shifts, hit signal will reach strip end, where it’s arrival time will also be registered. Delay between first (wire OR) signal and this (shift register output) signal is used to determine hit position within the strip. If occupancy is not very high, the system gives exact time/space picture with 8 micron resolution in both coordinates with only one direction readout. In this case ambiguity will strongly depend on clock frequency.

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DAPA Overview
(continuation)

We suppose that about 100 MHz frequency can be used if DAPA detectors works as independent system without collider (bunch) synchronization (at GSI, for example).

If a few particles hit the same strip during one circle, it creates an ambiguity in pixel identification along a strip. It could be a case when occupancy and event rate are very high (CBM Vertex, for example). To prevent ambiguity identical readout schematic exists in perpendicular direction. A probability to get occasional coincidence in two lines of 800 pixel each is negligible.

For LC application clock period corresponds to bunch period within a bunch train. This case we don’t need shift register to work permanently. It has to be a clock train synchronized with bunch train +800 additional pulses to read out the whole strip pixels.

Rather simple controller is positioned on the edge of each quarter. It collects already zero suppressed information from all 800 strips and sends it via one serial output as its (quarter) number, strip number, time stamp and pixel on strip number. Actually it’s complete event address is space and time for a further on-line and off-line analysis.

Additional fast output exists for a first level trigger generation.

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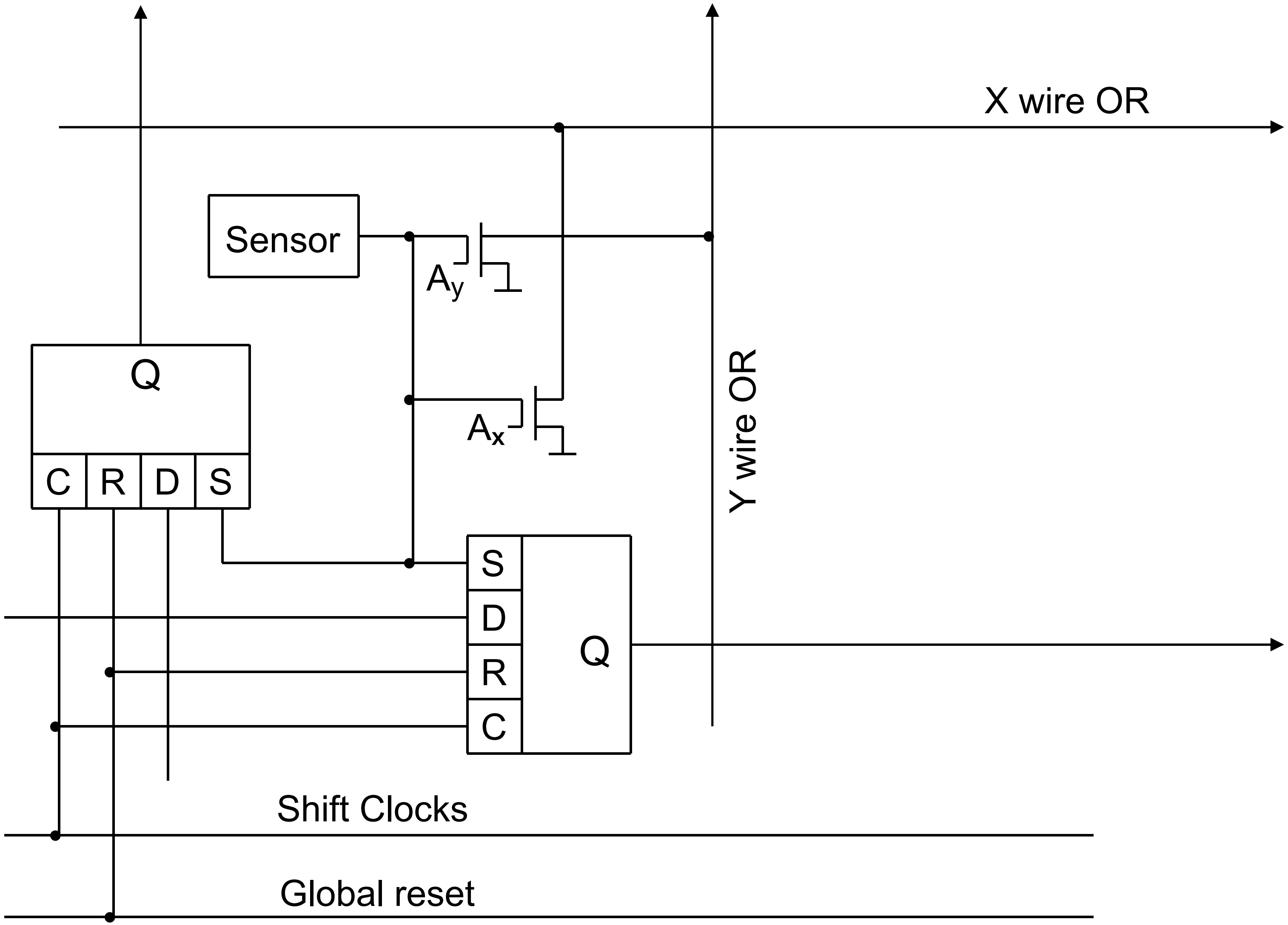
DAPA Two Orthogonal Readout Structure



Two Orthogonal Readout Properties

With two orthogonal readouts two wire ORs transfer fast signals to both perpendicular sides of the 2x2 cm^2 DAPA quarter. The same is organized for serial readout (shift register). Double number of strip end modules is required accordingly. This DAPA version gives very serious advantages and can be used in a few ways:

1. As a regular DAPA device with fast strip/time registration and pixel position determination through the shift register. Using only X wire OR and registers.
2. As a double sided microstrip detector with binary readout. Only X and Y wire ORs are in use.

   Both shift registers are stopped by switching off the shift clock.
3. Two fast OR readouts can be combined with one shift register serial readout. It saves power which is required to operate digital electronics.
4. Both fast and both shift readouts are in use. Probability of ambiguity will be negligible in this case and clock frequency can be seriously decreased to reduce power consumption.
5. By switching on and off shift clocks and changing its frequency, one can adjust DAPA properties during the experiment depending on current situation.

DAPA Advantages

1. Completely integrated electronics.
2. Completely integrated zero suppression.
3. One line serial output.
4. Good space resolution on both coordinates. Even for a worst scenario it works as a thin double sided microstrip detector with binary readout, 8 μm resolution and all mentioned advantages.
5. DAPA with two orthogonal readouts can appear as very flexible device which properties can be adjusted according to experimental requirements in any moment without any hardware changes.
6. Because of single side structure it can be produced on a thick regular substrate and after that thinned down to 50-100 microns.
7. DAPA has to be radiation hard detector due to very thin sensors.
8. More simple mechanical support and assembly procedure comparing with double sided microstrip detectors because of DAPA single side structure.
9. Much higher reliability because of an absence of many interconnections.
10. It is expected that DAPA system cost will be approximately the same as silicon microstrip detector system which requires electronic chips, interconnections and a lot of qualified manpower for sensor/chip assembly and tests.

Conclusion

- DAPA device can appear as a charged particle detector Nuclear physicists were dreaming about.

- It will be simple, convenient and reliable device for many future experiments including ILC, GSI and Super LHC, when dE/dX measuring is not required.