VFPIX Silicon Telescope Design Document

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Abstract

A silicon strip detector based telescope is being designed for the purpose of testing a under-development silicon pixel detector for the VFPIX upgrade of CMS.

Here is documented the goals, constraints, and design decisions of the telescope.

Todo list

Contents

1 Introduction

2 Overview of Previous Work

This project is an iteration and redesign of an existing telescope. Previous work[2] has been done to design a versatile SMC/BPB with features including the ability to chain multiple PBPs together to add aditional legs to the telescope. The SMC, in particular, was well designed to allow the sensor strips to oriented $\pm 45^o$ with respect to the plane of the BPB. This allows different sensors strips to be oriented either parallel or perpendicular to each other. The same telescope hardware can then be configured to measure to various degrees either vertical or horizontal accuracy by flipping the SMCs so the sensor strips align with either axis. This general design will be kept for the next iteration of the telescope, however the SMCs themselves will be iterated upon as described in **??**.

Work has also been done to improve the readout properties of the APC128 chips.[1] The APC128 has the unfortunate problem of a relatively weak output that has trouble driving a readout line at high frequencies. A proposed solution was to add a simple emitter-follower circuit on the BPB to reduce the load on the APC128 output and drive the line going to the ADCs with the transistor. This resulted in an improved readout speed of 250ns per channel. It is hoped that by using a dedicated differential line-driver instead of the basic emitter-follower, an even better readout speed can be achieved.

It has also been discovered that there is significant variation between APCs where, all other things being equal, the output levels will vary from chip to chip by as much as 50mV.[1] However, this can be compensated for by adjusting the value of the Aref input per chip.

The precision of a strip telescope with charge sharing can be dramatically imporoved by improving its signal-to-noise ratio (SNR). It has been demonstrated that by using a somewhat more complex readout pattern, wherein some background noise is removed by subtracting adjacent values in the readout pipeline, the SNR can be increased to approximately 25.An improvement from the 5-10 seen without this trick.[1]

3 System Components

The telescope consists of the following main components.

1. **Silicon Strip Sensor**

   > Find documentation for strip sensors.

2. **Analog Pipeline Chip x128 (APC128)** The APC128 (fig. 1) is a silicon chip designed for reading out charge from Silicon strip sensors. Each APC128 contains 128 channels. The sensor being used each have 512 strips. Therefore, each sensor requires four APC128 chips to read them out. The APC128's normal operation is as follows:

3. **Sensor Mount Card (SMC)** The SMC holds the Strip Sensor, 4 APC128, and some auxillary components to facilitate the operation of the APC128.
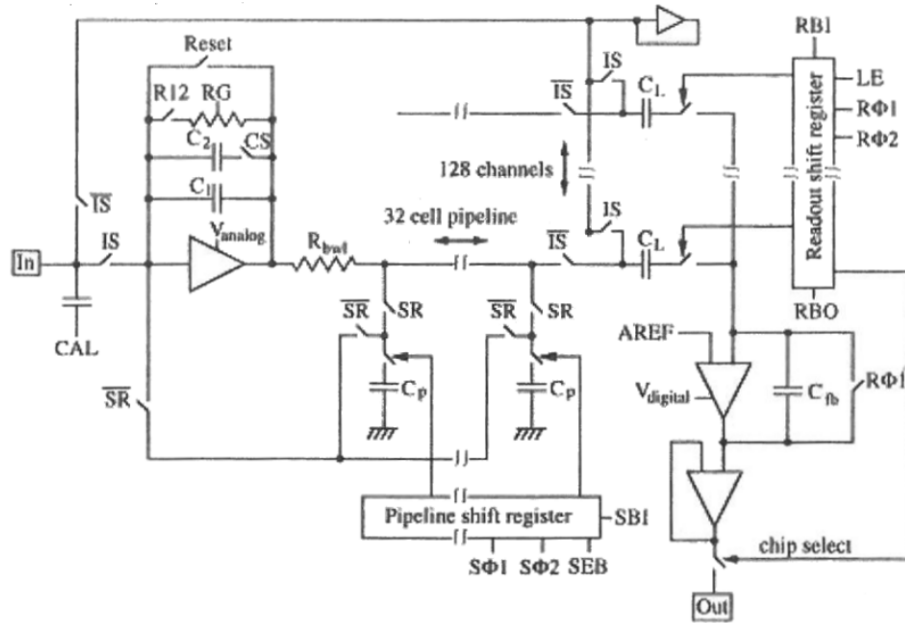
Figure 1: A schematic diagram of the APC128 chip.

4. **Back-Plane Board (BPB)** The BPB holds four SMCs. Its job is to physically hold the SMCs in place as well as route the signals between the SMC and the TRB.

5. **Telescope Readout Board (TRB)** The TRB is responsible for controlling the operation of the telescope. This means it must generate the control signals for the APC128 chips as well as the ADCs that will digitize and serialize the data being read from the APC128s. It will also contain an FPGA with supporting hardware to allow it to communicate with a connected PC via a USB connection. It must also

4 Performance Targets

- **SNR:** 40

- **Readout Speed:** 100ns/channel → 8kHz readout of entire telescope

- **Pipeline Speed:** 40MHz, will vary with source

4.1 Precision/Accuracy Targets

For characterizing pixel sensors with pixel pitch as small as 25μm, a tracking precision of 5μm is desired. To achieve this, we require a SNR of better than 40

check precision targets

4.2 Speed Targets

5 Hardware Proposal

5.1 Silicon Strip Sensor

The silicon micro-strip sensors that will be used to measure particle tracks in the telescope have 512 strips each. Fig. 2 shows the layout of a sensor.
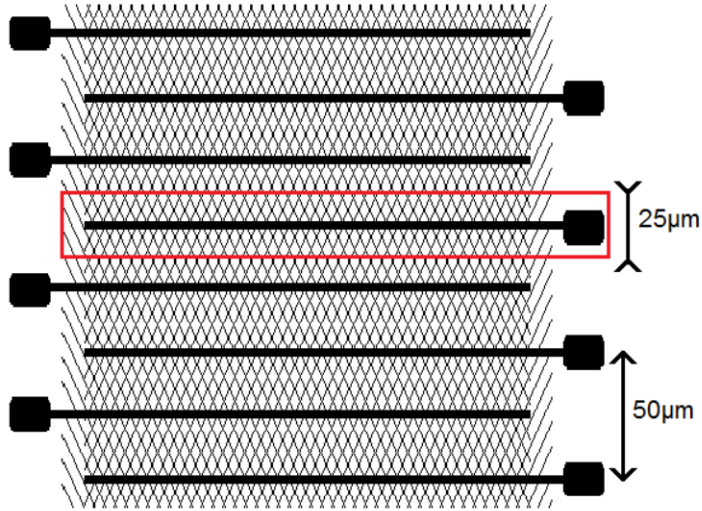

Figure 2: Layout of a silicon micro-strip sensor. As shown, there are 25μm between strips. The strips are divided between 2 layers so the separation between strips on the same layer is 50μm

5.2 Analog Pipeline Chip (APC128)

The APC128 will be used to read charge from the silicon strip sensor.

5.3 Sensor Mount Card (SMC)

The design choices of the SMC are especially critical becuase it is responsible for ensuring optimal operation of the APC128 chips, both in control and readout.

The readout of the APC128 is analog so it is more susceptible to noise and interference than a digital signal would be.

The SMC will be subject to the highest radiation fluence of the entire system which limits the choices of hardware that can be placed on the it. Any FLASH memory dependent hardware will be subject to single-event-upsets(SEUs).

Because of these restrictions, only the minimum hardware necessary to ensure high quality APC128 operation and output will be placed on the SMC.

This hardware consists of a 2-channel differential-line driver amp. The chosen amp is the ADA4950-2. Two of these will be placed on each SMC, as close as possible to the APC128s to minimize the capacitave load on the outputs.

It has been determined (see sec. 2) that to achieve optimal operation of each APC128 in the telescope, it is important to be able to set each APC128s Aref voltage individually. To do this, four pots will be placed on each SMC to allow for idividual calibration of each APCs Aref value.
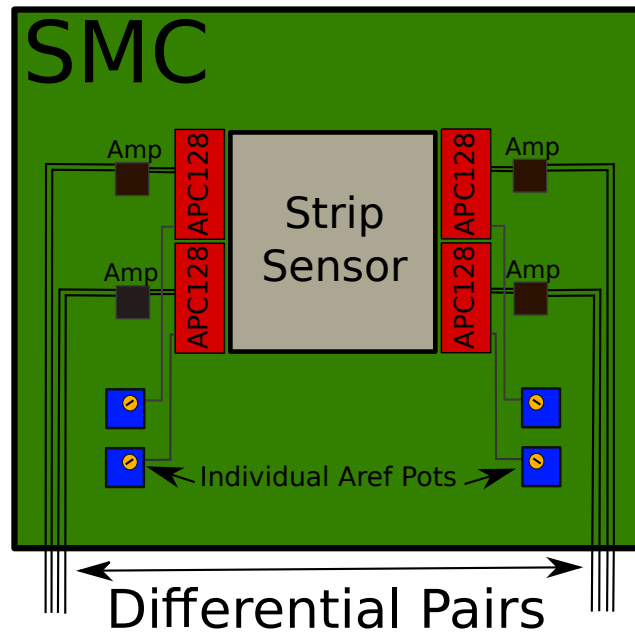

Figure 3: An illustration of the SMC. Not shown: APC128 control signals

5.4   Back-Plane Board (BPB)

The primary jobs of the BPB are to route signals between the TRB and the SMCs and hold the SMCs in place.

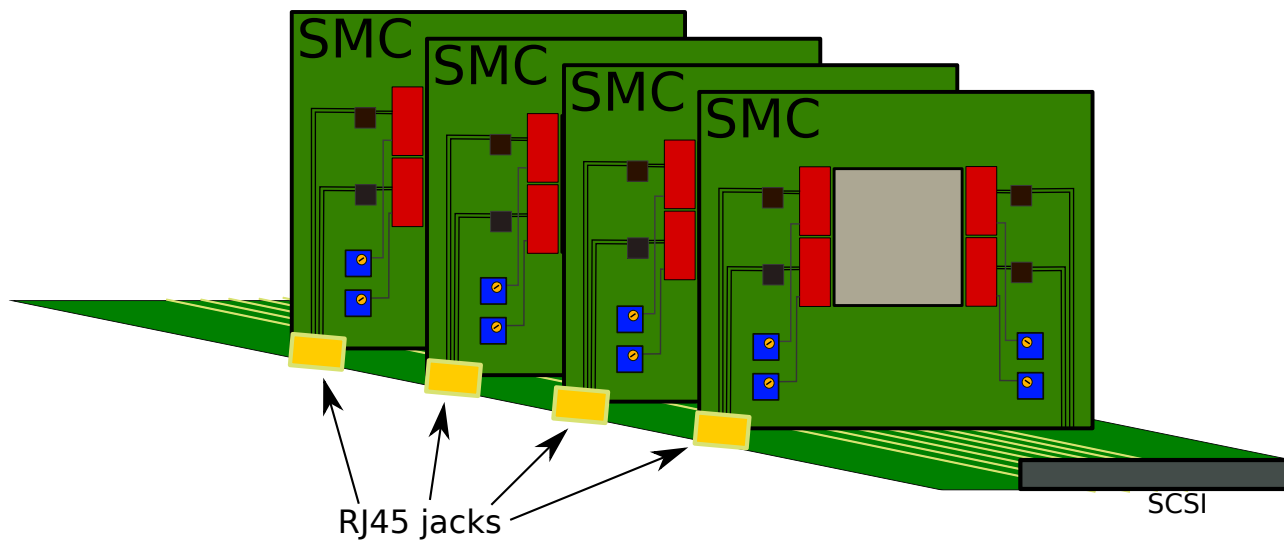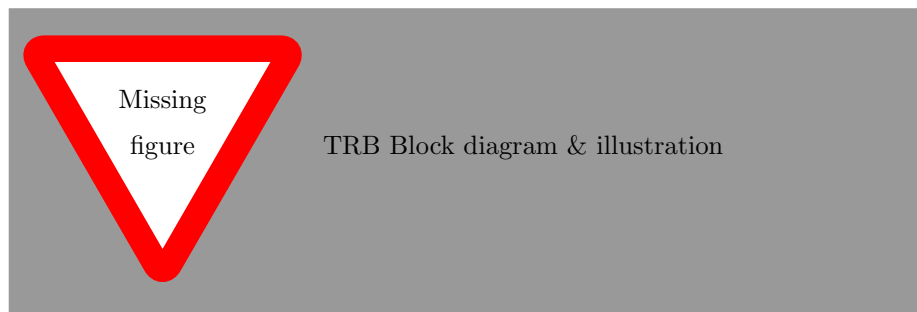decide placement of ADCs, either on TRB or BPB

Figure 4: An illustration of the BPB

5.5 Telescope Readout Board (TRB)

Missing figure

TRB Block diagram & illustration

6 Timeline

Fill in time-line

References

[1] Adrian Ryser. Semesterarbeit - pixel telescope. 2013.

[2] Paul Turner. Design and implementation of a high resolution telescope for cms pixel detector characterization. June 2012.