

Short Title of the Article

Table 1

Summary of power and readout services for the different regions of the ePIC SVT (slow-control and data links are differential pairs). A services group is one MOSAIX segment in the IB, and up to four EIC-LAS sensors in the OB and disks.

Region	Sensor	Electrical services group	# power lines	# slow-control links	# data links
IB	MOSAIX	MOSAIX segment	10	7	8
OB	EIC-LAS	up to 4 EIC-LAS	2	3	4
EE/HE	EIC-LAS	up to 4 EIC-LAS	2	3	4

1. Introduction

1.1. Low-mass services

Services to the SVT are of two types: electrical/fiber-optical (power, data and slow control) and cooling. Electrical services to the IB are routed from the hadron-going direction; services to the OB are routed from both the electron- and hadron-going directions. In the IB they are organized by MOSAIX segment; in the OB and disks, by group of up to four EIC-LAS. Table 1 summarizes the data, slow-control and power lines needed in the different SVT regions. It also illustrates the reduction achieved with serial powering: in the OB and disks, two lines including the return deliver to as many as four EIC-LAS the power that, in the IB, requires ten lines per MOSAIX segment. The current on these lines is that of a single EIC-LAS, reducing the current transmitted to the detector by up to a factor of four and correspondingly reducing the cable cross-section and material budget.

[TODO] JS: Comments on Table 7: On the slow control lines: In ITS3, a total of 8 slow control lines are brought to the SIB: (1) GCLK, (2) GRST_B, (3) SYNC, (4) SC_SRV_WR, (5) SC_SRV_RD, (6) SC_CORE_WR, (7) SC_CORE_RD, (8) TEST_OUT. Not sure if we need TEST_OUT brought to SIB, but need to check on this. Also, how do you get 10 power on the IB? The LEC has 4 positive domains (Supply & GND) plus PSUB (no GND), while the REC has 3 positive domains (Supply & GND) plus PSUB (no GND). So depending on if one counts the GND connections, this sums to either 9 or 16.

The FPCs electrically connect the MOSAIX, EIC-LAS and AncASIC to the segment and FPC interface boards and to the control boards. In the IB the FPC connects to the MOSAIX LEC; in the OB and disks a main FPC runs along the staves and disks, serving groups of up to four EIC-LAS and connecting to the AncASICs through bridge FPCs. The main FPC length is constrained to a maximum of 40 cm by signal-integrity and power-drop considerations; two and four main FPCs are needed on L3 and L4 respectively to cover the full stave length. To keep the mass low, the conductive tracks are aluminum ($X_0 = 8.9$ cm) rather than copper ($X_0 = 1.4$ cm), with a polyimide dielectric ($X_0 = 28.57$ cm). The baseline stack-up has two aluminum conductive layers ($\sim 15 \mu\text{m}$ each) separated by a polyimide substrate ($\sim 35 \mu\text{m}$), plus polyimide cover layers ($\sim 35 \mu\text{m}$ combined), for a total of $\sim 100 \mu\text{m}$ and a combined material budget of $\sim 0.06\%$ X_0 . Serial powering, and the daisy-chained slow-control configuration together reduce the number of signals to propagate. The minimum FPC width can therefore be as narrow as 6 mm, about one third of the 19 mm EIC-LAS width, which matters where the FPCs overlap the sensitive MAPS area.

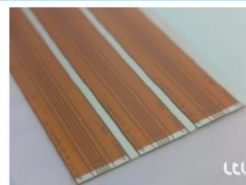
[TODO] ZY: unsure why L4 needs four main FPCs. The baseline stack-up does not seem to work for HS data transmission. The minimum FPC width of 6 mm needs to be checked.

Transmitting the 5.12 Gb/s sensor data over aluminum traces up to 40 cm long is the critical design aspect of these circuits, and it is being addressed experimentally. A prototype carrying aluminum traces of $70 \mu\text{m}$ line width at $150 \mu\text{m}$ pitch over a length of 18 cm has been characterized by measuring its scattering parameters and by time-domain reflectometry; the measured response was then used as the input to an eye-diagram simulation at 10.24 Gb/s—twice the EIC-LAS link rate, and the MOSAIX per-link rate—including the transmitter jitter, with neither pre-emphasis nor equalization applied (Fig. 1). A second, full-length prototype of an L4 circuit, 42 cm long, has been produced in adhesiveless aluminum-polyimide foil using single-point tape-automated bonding (SpTAB), in which ultrasonically welded aluminum ribbon leads join directly to the aluminum pads of the sensor and the AncASIC. This technique creates a monometallic joint, removes the need for a nickel-gold finish on the pads, halves the number of weld joints relative to wire bonding, and allows the joints to be encapsulated in glue after welding.

[TODO] Two numbers would strengthen the paragraph above. First, the eye opening or timing margin obtained from the 10.24 Gb/s simulation: the source (VERTEX 2026) shows the eye diagram but quotes no figure, so the text can presently say only that the chain was exercised, not that it passed with a stated margin. Second, whether the 18 cm prototype and the 42 cm L4 prototype are the same stack-up as the baseline described above, and whether signal integrity has been demonstrated at the full 40 cm main-FPC length rather than at 18 cm.

- Critical design aspect: transmission of high-speed data at up to **10.24 Gbps**, over **40 cm** long **aluminum traces**

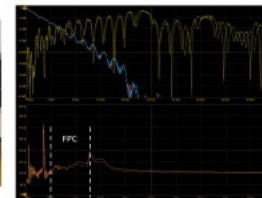
FPC prototype with Al traces



Aluminum 15um	LTU-15-10	Signals
Polyimide 35um		Die-35um
Polyimide 35um	Kapton	
Aluminum 15um	LTU-15-10	Die-35um
Polyimide 35um		GND (PowerHV)

Line width: $70 \mu\text{m}$
Pitch: $150 \mu\text{m}$
Length: 18 cm

- s-parameters and TDR measurements input to **eye-diagram simulation**



- Eye-diagram at 10.24 Gbps; FPC only; TX jitter included; no pre-emphasis, no equalization

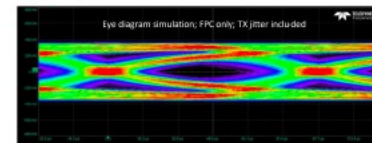


Figure 32: Candidate for fig:eye (measurement plot, ours). Eye diagram at 10.24Gb/s over an aluminium-trace FPC prototype, with the prototype photograph and the layer stack-up beside it, from the VERTEX 2026 talk. The eye is the enabling result that Section 5.3 currently states in a sentence. Note that the stack-up appears here as an inset: the manifest struck it as a figure of its own, and this is the form in which it can still be carried.

SVT NIM-A Article

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[FIGURE PLACEHOLDER]

expected file: `figures/fig-eye.pdf`

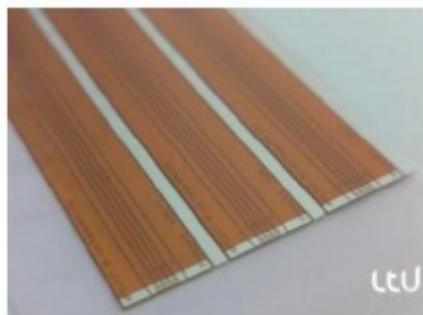
Simulated eye diagram at 10.24 Gb/s driven by the measured scattering parameters and time-domain reflectometry of the aluminum-trace prototype, with transmitter jitter included and neither pre-emphasis nor equalization applied. The caption must quote the eye opening or the timing margin as a number.

Figure 1: Eye diagram at 10.24 Gb/s obtained from a simulation driven by the measured scattering parameters and time-domain reflectometry of the aluminum-trace FPC prototype, with transmitter jitter included and without pre-emphasis or equalization. The rate is that of a MOSAIX link, twice the 5.12 Gb/s of the EIC-LAS link the Outer-Barrel circuits carry.

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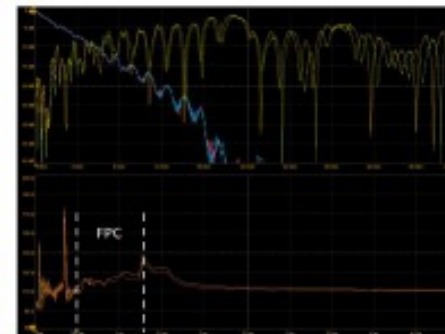
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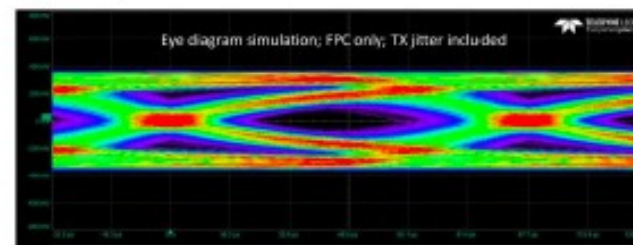


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