
# Forward Pixel Detector

## HDI/VHDI Trace Characteristics

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# HDI/VHDI Traces

- Two copper layers separated by polyimide layer.
- Polyimide upper and lower cover coats.
- Signal traces typically run on bottom copper layer with signal current return path on upper copper layer.

# US CMS Forward Pixel Detector
# Panel Material Stack
(not to any scale)
04/14/2004
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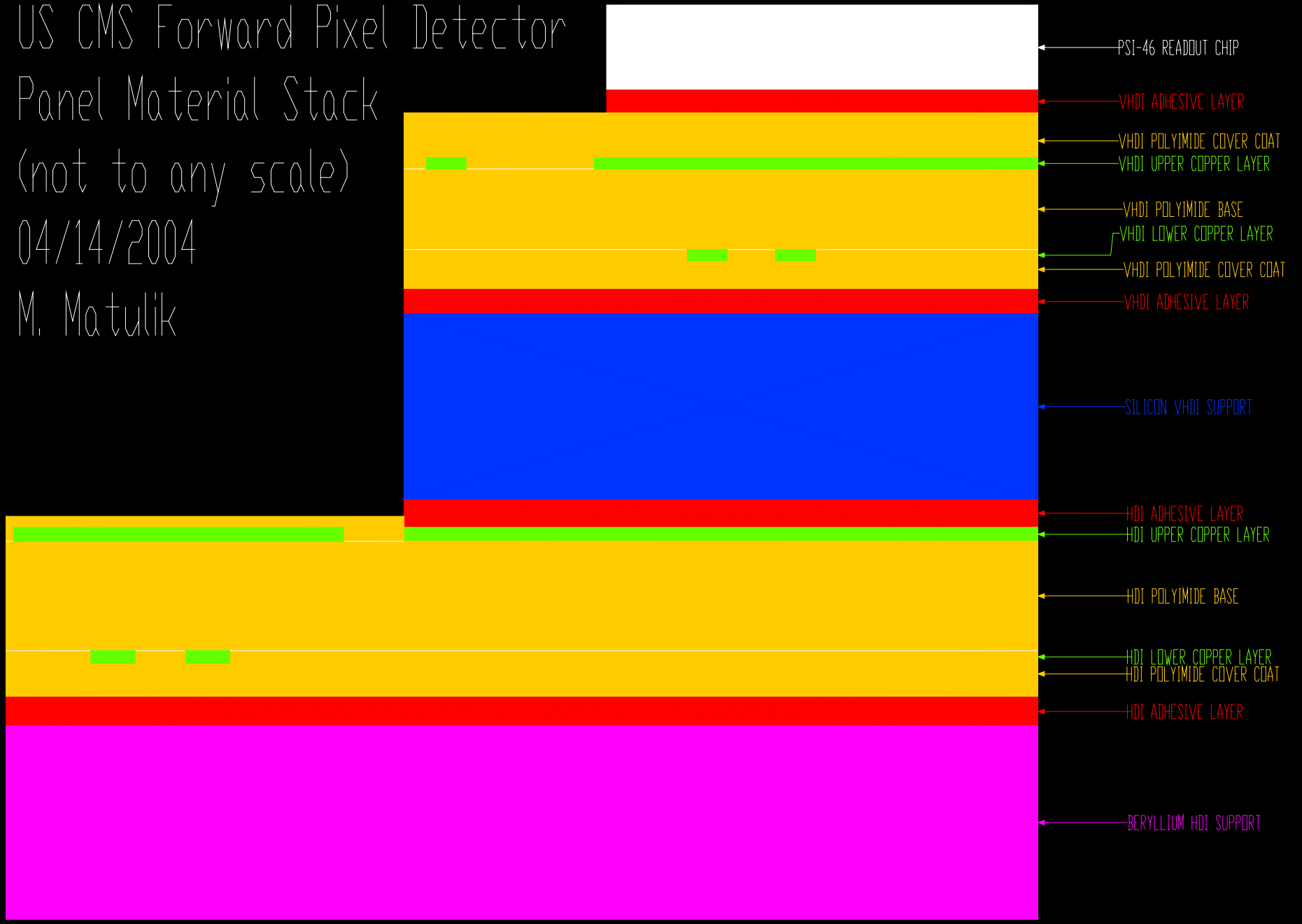


# HDI/VHDI Traces

- Signals propagating between Token Bit Manager (TBM) and PSI-46 readout chips must travel on traces found on both HDI and VHDI flexible printed circuits.
- To maximize signal fidelity, the characteristic impedance ($Z_0$) of traces on both circuits should be the same.
- $Z_0$ should be large enough to allow both the TBM and PSI-46 output drivers (assumed to be single-ended) to adequately drive required voltage levels.

# HDI/VHDI Traces

- Though the geometry of the traces and dielectrics on the VHDI and HDI circuits are thought to be the same, the structures used to support the two types of circuits are significantly different:
  - HDI supported by beryllium.
    - Beryllium is a good conductor.
    - Beryllium will be at ground potential.
  - VHDI supported by silicon.
    - Silicon is a poor conductor and likely to be a poor dielectric as well.
  - Signals traveling on these circuits are capacitively coupled to the support structures, affecting $Z_0$.

# HDI/VHDI Traces

- By adjusting trace widths and adhesive layer thicknesses, predicted values of $Z_0$ for traces on both circuits can be as high as ~ 50Ω.
  - Measuring the characteristic impedance of similarly constructed circuits suggest that the formulas used to predict $Z_0$ underestimate the value for the geometries found on circuits like this.
  - Prototype VHDI circuits delivered thus far don't lend themselves to accurately measuring trace characteristics.
  - Trace characteristics for both HDI and VHDI circuits will be verified using a polyimide test structure of appropriate geometries.

# Trace Capacitance Estimates

- To first order, characteristic impedance of a trace is inversely related to it's capacitance.
- Estimated trace capacitance, based on formula used to predict characteristic impedance, for VHDI traces is 98fF/mm ($Z_0$ = 50Ω).
  - Value matches well with trace capacitance predicted from finite element analysis of VHDI trace structure.

# Trace Capacitance Estimates

- Signal traces such as Clk, Cal/Trig/Rst and SDA are routed to all readout chips on a VHDI.
  - Load presented to TBM varies as trace length and depends on number of readout chips on particular VHDI.
  - Each readout chip presents an unknown additional capacitive load to a signal trace.
- The token passing loop is implemented as a daisy chain connection between the readout chips.
  - Each readout chip drives only one load.
  - The length of the trace driven depends on the position of the readout chip in the loop.

**Traces Characteristics**

**4/20/2004**

**VHDI Trace Lengths (mm)**

| | | | VHDI | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | 1 x 2 L | 1 x 2 R | 1 x 5 L | 1 x 5 R | 2 x 3 | 2 x 4 | 2 x 5 |
| Signal | Clk | | 14.9 | 14.9 | 39.2 | 39.2 | 62.4 | 78.6 | 94.8 |
| | Cal/Trig/Rst | | 13.7 | 13.7 | 38.0 | 38.0 | 61.8 | 78.0 | 94.2 |
| | SDA | | 16.1 | 16.1 | 40.4 | 40.4 | 60.8 | 77.0 | 93.2 |
| Token Loop | | In | 6.3 | 21.5 | 6.3 | 45.8 | 6.3 | 6.3 | 6.3 |
| | | Pass | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 | 6.8 |
| | | Out | 21.5 | 6.3 | 45.8 | 6.3 | 13.7 | 13.7 | 13.7 |

**VHDI Trace Capacitance (pF):** 9.80E-14 F/mm

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Clk | | 1.5 | 1.5 | 3.8 | 3.8 | 6.1 | 7.7 | 9.3 |
| Cal/Trig/Rst | | 1.3 | 1.3 | 3.7 | 3.7 | 6.1 | 7.6 | 9.2 |
| SDA | | 1.6 | 1.6 | 4.0 | 4.0 | 6.0 | 7.5 | 9.1 |
| Token Loop | In | 0.6 | 2.1 | 0.6 | 4.5 | 0.6 | 0.6 | 0.6 |
| | Pass | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| | Out | 2.1 | 0.6 | 4.5 | 0.6 | 1.3 | 1.3 | 1.3 |

**Capacitive loads (of unknown value) due to readout chips:**

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 | 2 | 5 | 2 | 6 | 8 | 10 |

**HDI Trace Length Estimates (mm)**

| | One way, to Plaquette #; | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| P3 | 84 | 54 | 24 | - |
| P4 | 77 | 54 | 42 | 13 |

**HDI Trace Capacitance (pF):** 9.80E-14 F/mm

| | | | | |
|---|---|---|---|---|
| P3 | 8.2 | 5.3 | 2.4 | - |
| P4 | 7.5 | 5.3 | 4.1 | 1.3 |

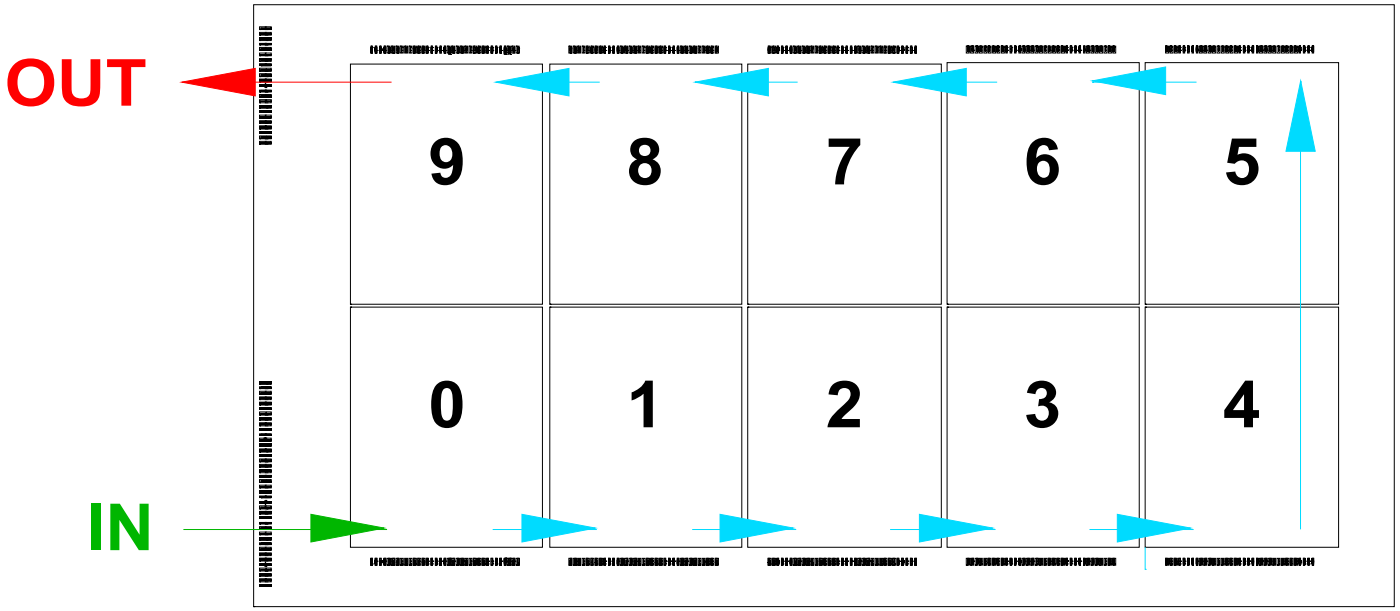
**Panel Trace Length Estimates (mm):**

| | 1 x 2 | 1 x 5 | 2 x 3 | 2 x 4 | 2 x 5 |
|---|---|---|---|---|---|
| P3 | - | - | 146 | 133 | 119 |
| P4 | 99 | 59 | 116 | 121 | - |

**Total Capacitance (pF)**

| | 1 x 2 | 1 x 5 | 2 x 3 | 2 x 4 | 2 x 5 |
|---|---|---|---|---|---|
| P3 | - | - | 14 | 13 | 12 |
| P4 | 10 | 6 | 11 | 12 | - |

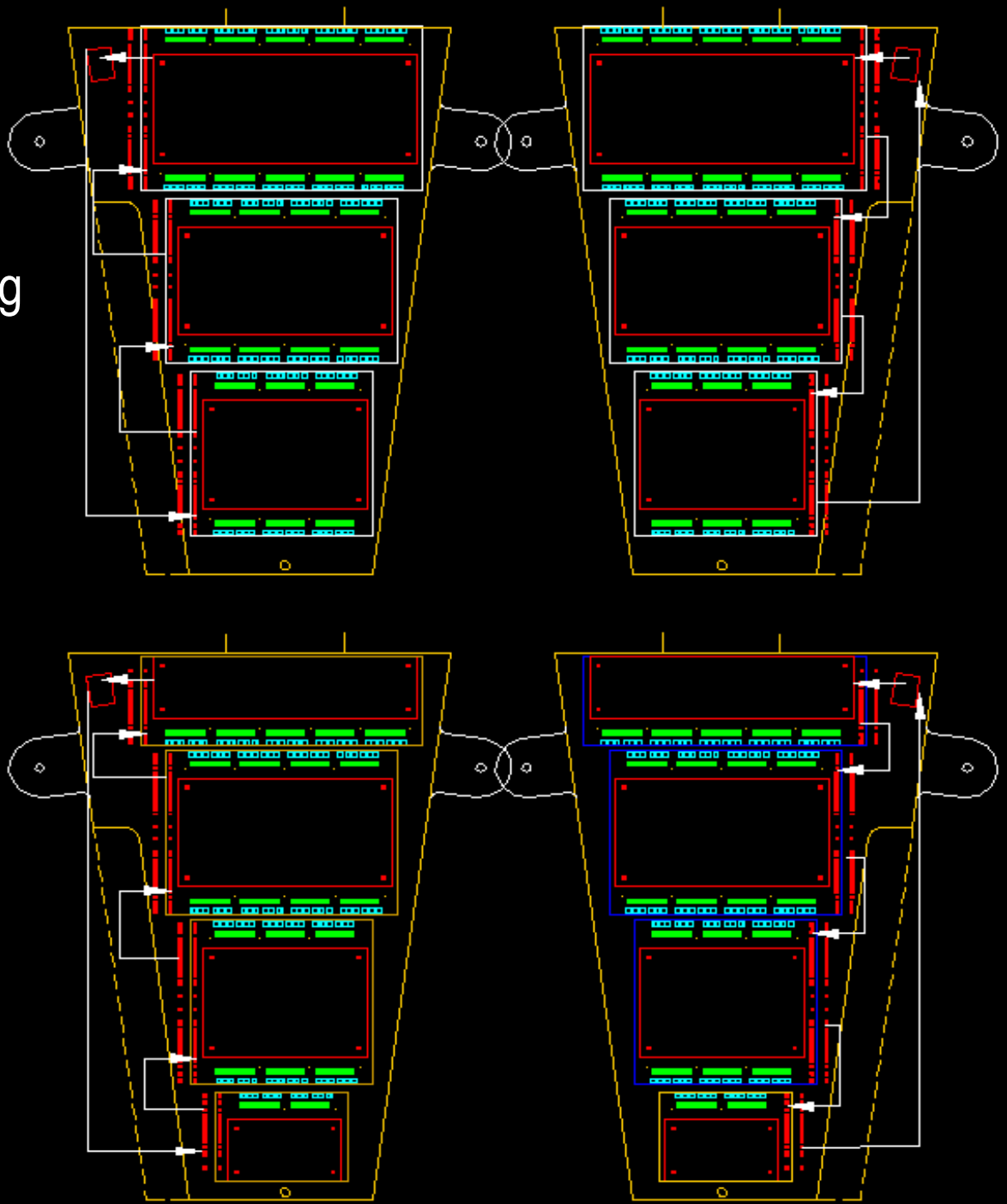
# VHDI Trace Considerations




2 x 5

Token Passing Loop on VHDI

Token passing paths on panels



# Conclusion

- Matching the characteristic impedance of traces found on both the HDI and the VHDI will minimize degradation of signals as they travel between the two circuits.
- Knowing the current sourcing capabilities of the output drivers and the input voltage threshold levels of the TBM and the PSI-46, one can determine the minimum value of characteristic impedance for the traces.
- The arrangement of plaquettes on a panel is such that the capacitive load for any combination of HDI and VHDI traces is expected to fall in the range of 6 to 14 pF.