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Transmission Lines Implementation on HDI Flex Circuits for the CMS Tracker Upgrade

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The CMS tracker upgrade at HL-LHC relies on hybrid modules build on high density interconnecting flexible circuits. They contain several readout ASICs having high speed digital ports required for configuration and data readout, implemented as SLVS differential pairs. This paper presents the connectivity requirements on the CMS tracker hybrids; it compares several transmission line implementations in terms of board area, achievable impedances and expected crosstalk. The properties obtained by means of simulations are compared with measurements made on a dedicated test circuit. The different transmission line implementations were tested using a custom 65nm SLVS driver and receiver prototype ASIC.

Summary

A major upgrade of the CMS Tracker detector is today under development to address the new challenges brought in by the HL-LHC. The new CMS Tracker will be made of two types of modules. The outer tracker 2S modules contain two parallel strip sensors of 10 × 10 cm2 enabling the identification of stubs required for the track triggering function. The inner tracker PS modules contain a strip sensor and a macro pixelated strip sensor of 5 × 10 cm2, providing additional track information along the Z-axis. The front-end electronics of these different modules are based on binary readout ASICs (CBC3, SSA, MPA) assembled on high density interconnecting (HDI) flexible circuits.

The 2S modules topology is based on eight CBC3 binary readout ASICs that are interfaced to a concentrator ASIC. Each CBC3 ASIC provides six output SLVS differential pairs operated at 320 Mbps to send its data to the concentrator ASIC. In addition to these high-speed differential pairs, two clocking lines and one fast control line, implemented also as 320 Mbps SLVS pairs, are broadcasted to the eight readout ASICs. In total, more than fifty high-speed SLVS pairs have to be connected on the 2S flexible front-end hybrid circuit. The CBC3 driving capabilities impose that the minimal pair impedance should be greater than 70 ohms, with an optimum of 100 ohms. Considering the available hybrid build-up geometry, four different implementations of differential pairs were selected and studied on thin (25 µm) and thick (50 µm) core HDI flexible circuits: edge coupled microstrip, edge coupled stripline, broadside coupled stripline and broadside coupled offset stripline.

The electrical characteristics of the proposed SLVS implementations were obtained through electromagnetic simulation tools. The variability of the results as a function of the simulation tool used, has set the need to build a dedicated evaluation hybrid circuit. A dedicated driver and receiver ASIC, designed for the PS module ASICs, was used to drive the four types of differential pairs. The test hybrid was built on a thick core flexible circuit as its topology yields larger differential impedances. The pairs were characterized in a first step with a VNA on bare hybrids. The obtained impedances for edge coupled stripline and microstrips were matching those obtained by simulations. The broadside coupled and offset striplines showed impedances lower from those expected through simulations, probably due to the stack-up thickness and etch variations. An SLVS driver ASIC prototype was used to drive the four types of pairs on this circuit: eye diagrams were measured on each pair and their properties were compared.

The regular microstrip solution on a thin core flexible HDI hybrid was found to be the preferred baseline implementation. The broadside coupled striplines seem to have too low impedance for this application. If the routing space is not sufficient using a microstrip geometry, the thick core flexible HDI hybrid with edge

coupled striplines would become necessary to obtain a differential impedance of eighty ohms. These two solutions will be applied in the layout of future 2S and PS hybrid circuits for the CMS tracker upgrade.

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