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Power, Readout and Service Hybrids for the CMS Phase-2 Upgrade

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The CMS Tracker Phase 2 Upgrade modules integrate DCDC powering stages and an optical transceiver to power and control the front-end hybrids. The strip-strip (2S) module contains a Service Hybrid (2S-SEH) with two stage DC-DC power conversion, an lpGBT with optical interface (VTRx+), high voltage biasing and temperature sensor ports. The pixel-strip (PS) module utilizes a separate two stage DCDC converter circuit (PS-POH) and a Readout Hybrid (PS-ROH) containing the communication interface. The design and performance of these three hybrids and their integration in their respective modules will be presented.

Summary (500 words)

Two module types (2S and PS) will be used in the Compact Muon Solenoid (CMS) Tracker Phase 2 Upgrade for the High Luminosity Large Hadron Collider (HL-LHC). The 2S modules contain a double strip sensor configuration with an active area of (10 × 10) cm2, wire bonded to two front-end hybrids that are powered and controlled by a service hybrid. The PS modules contain a strip sensor and a macro-pixel sensor of (5 × 10) cm2 wire bonded to two front-end hybrids interconnected with a power hybrid on one side and with an optical readout hybrid on the opposite side. The service and readout hybrids enable the optical transmission of clock, control and data at transmission speeds up to 5 Gbps for the 2S modules and up to 10 Gbps for the PS modules in the cold and radioactive environment of the Tracker.

The 2S-SEH integrates a two stage power converter. The first stage is using the BPOL12 ASIC to deliver 2.55V for the BPOL2V5 and the laser driver of the VTRX+ transceiver. The second stage is based on a BPOL2V5 ASIC, delivering 1.25V for the rest of the ASICs. Custom air core coils and shields were developed to fit with the constrained height and area of this hybrid and achieve the low noise requirements. The hybrid includes an lpGBT and a VTRx+ optical module. The hybrid is a five layers flexible circuit laminated on a carbon fibre stiffener, compensated against thermal expansion mismatches. A tight folded over area accommodates the high voltage biasing and temperature monitoring connectivity for both sensors.

The PS-POH is half the size compared to the 2S-SEH and is a four plus one layer polyimide and FR4 rigid-flex circuit. It integrates one BPOL12V ASIC, followed by two second stage BPOL2V5 ASICs, delivering 2.55V, 1.25V and 1.05V for the two front-end hybrids and the distant readout hybrid. To achieve a robust power integrity at module level, an additional flexible cable connects the power hybrid to the readout hybrid. Similarly to the 2S-SEH custom air core coils and micro-milled aluminium shield with solderable plating were used for the confined volume of this hybrid.

The PS Readout hybrid is made of a four layer carbon fibre stiffened flexible circuit containing the lpGBT ASIC and the VTRX+ transceiver to provide the readout and control of the PS module. It also provides auxiliary 1V25 power path from the flexible power cable to the front-end hybrids.

The PS-POH, PS-ROH and 2S-SEH were evaluated with test cards and prototype modules were built. In this contribution, the design considerations and practices for developing these circuits along with the monitor and control features that they support, will be presented. Power integrity simulations will be compared to measurements on the actual hybrids. Thermal performance and efficiency of the PS-POH shall be analysed. Finally, the performance of full PS and 2S skeletons (modules without sensors) constructed using these power, readout and service hybrids connected to their respective front-end hybrids, will be shown.

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