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## Test system for the PS Front-End Hybrid High Voltage filter for the CMS Phase-2 Outer Tracker Upgrade

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*As part of the CMS Phase Two Outer Tracker upgrade, a test card was developed to test the sensor bias high voltage filters present in the PS-FEH-R hybrids. The test card can test up to four hybrids at the same time. The test functions are voltage measurement, leakage current measurement and resistance measurement. A software test procedure was written to control the card and to perform the data acquisition.*

### Summary (500 words)

A multiplexing test system was developed to enable the functional characterization of all the hybrid circuits used in the tracker. Each hybrid type is associated with a compatible test card. The PS front-end hybrids require two different test cards due to mechanical constraints: one to verify the readout functionality and a second one to verify the high voltage bias filter present on the right side PS-FEH. The last card is fully compatible with the test system. The card is controlled via USB on the front panel and via the backplane connector, using a USB to SPI converter chip used to interface with various sensors. A three-channel ADC to SPI measures the voltage corresponding to the different test characteristics. In addition, the test card must be operated at  $-35^{\circ}$  and a temperature sensor is implemented to retrieve the card temperature.

Because of the presence of high voltage in the system, a protection logic was added to follow set steps with a state machine to avoid damages in the test card and on the hybrid. The test procedure is then forced to follow a safe measurement sequence with developing hazardous high voltage discharges in the hybrid and in the test card.

The high voltage is provided externally by a power supply which is controlled by ethernet. A dedicated library was written to send and read SCPI commands to perform actions and obtain measurements.

The hybrids are placed on the test card using a 3D printed mechanical socket. They are connected to the test card using flex-PCB jumpers. These jumpers were designed to safely stand the high voltage required to test the hybrids.

The high voltage is also controlled on the board using solid state relays which completely isolate the high voltage from the low voltage logic. With those, it is possible to connect the four hybrids sequentially or to parallelize the measurements by connecting them all at the same time. This can be set in the test procedure, but the interconnection of these is still bounded by the state machine, meaning it must be in the default state to connect or disconnect any hybrid.

The measurements are made using an analog-to-digital converter. The high voltage is divided by a resistive voltage divider and then connected to the ADC input with a range between  $-1000\text{V}$  and  $+1000\text{V}$ . The leakage current measurement uses a precision shunt resistor, the voltage being measured across it with a range between  $-250\text{ nA}$  to  $250\text{ nA}$ . The resistance measurement is performed by applying a defined current to the filter, the voltage across the filter representing the resistance. For this test the filter must be completely disconnected from the high voltage input and the capacitors must be discharged to avoid damaging the system, with a range up to  $16\text{ k}\Omega$ . For each measurement, the range is defined by an operational amplifier.

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