FORWARD PIXEL MONITOR and CONTROL— L. Cremaldi

We require a pixel hardware monitoring system to feed back basic system parameters providing fail-safe operation and quick shutdown in case of a cooling failure. Radiation hard components are required. In addition to this hardware monitoring FAST HISTOGRAMING through the FED will be available during data-taking operation. Monitoring through the FEC fiber-I2C link is also available during normal detector operation. There are obvious cases where the detector can be in some danger during FED or FEC OFF/FAIL periods. We then rely on a “dual monitor scheme” through a direct twisted pair connection to sensors via the ”Tracker Service Cable”.

![Dual Monitoring Concept](image)

Table 1: Quantities of interest which require slow and fast monitoring.

<table>
<thead>
<tr>
<th>Monitor/Control Sensor Device</th>
<th>Speed</th>
<th>Readback</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Leakage Current meter</td>
<td>FAST</td>
<td>Power Supply</td>
<td>Bias Supplies</td>
</tr>
<tr>
<td>II. Temperature RTD</td>
<td>FAST</td>
<td>Twisted/DCU2</td>
<td>Service Tube</td>
</tr>
<tr>
<td>III. Radiation Dose-RADFETS</td>
<td>SLOW</td>
<td>Twisted/DCU2</td>
<td>Service Tube</td>
</tr>
<tr>
<td>PIN diodes</td>
<td>SLOW</td>
<td>Twisted/DCU2</td>
<td>Service Tube</td>
</tr>
<tr>
<td>IV. Humidity-Mass Spec KMX2000</td>
<td>SLOW</td>
<td>Twisted</td>
<td>Service House</td>
</tr>
<tr>
<td>V. FC72 Leak Mass Spec</td>
<td>SLOW</td>
<td></td>
<td>Service House</td>
</tr>
<tr>
<td>VI. FC72 Flow Chiller</td>
<td>FAST</td>
<td>Coax</td>
<td>Service House</td>
</tr>
<tr>
<td>VII. Alignment Laser?</td>
<td>SLOW</td>
<td>DCU2</td>
<td>Service Tube</td>
</tr>
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</table>

**SLOW Monitoring** requires one to several readouts per minute. **FAST monitoring** requires readout at the order 100μs time scale, a scale set by the detector warmup time caused by coolant blockage. This data is likely Buffered and Flushed at some point.
II. DCU2

The "TrackerService cable" will provide a fast monitoring option which is independent of the FED and FEC. The pixel FEC will provide a slow I2C command port connected through the service cable to the service cylinder breakout panel and then possibly to a DCU2 chip mounted on a circuit board near the forward disks, Figure 1. One DCU2 chip is required to monitor 12-blades (4 RTDS on the I/O coolant channels, 1 radiation monitor, 1 alignment monitor).

DCU2 through I2C- A radiation hard ADC (20mV - 2.5V) with 6 inputs and a 10µA and 20µA current source has been developed for the tracker. It houses an on-chip temperature sensor. It is controlled and readout through a I2C serial interface. The chip is packaged in a small LPCC24 format (www.asat.com). The current sources can be used to drive a thermistor or platinum resistor for temperature measurement.
III. LEAKAGE CURRENT  \[ I \sim T^{3/2} \exp \left( \frac{E_g}{2kT} \right) \]

Increase in leakage current I will be an indication of slow radiation damage processes and temperature fluctuations superimposed. Leakage current can be monitored at the detector bias supplies. Presently six blades are be supplied by 2 bias supplies* or 1 supply for 3 blades. A rapid rise leakage current could indicate a flow blockage, leak, or bias short. Perhaps a rise in leakage current of $\Delta I / I > 5\%$ could be easily detected. A 5% rise in leakage current will represent a 2.5% change in $\Delta T / T$ or at $T \sim 300K \Rightarrow 7.5$ degK temperature rise. *Assuming 20nA per irradiated pixel or 50µA per detector x 45 per blade = 2.25mA leakage current per blade. (Eg~1.12eV for Si)

\[ \Delta I / I \sim \alpha \Delta T / T \]

- A coolant flow blockage can be detected as a $\Delta I / I$ transition.
- Common mode problems (excessive current drain, etc.) involving plaquettes may be detectable.
- Single detector problem (1/45) will likely go unnoticed.

![Leakage Current at different Temp](image)

**Figure 3: Leakage Current versus Temperature.**
LEAKAGE CURRENT SIMULATION

- From a simulation of blade and plaquette temperature vs flow we can see the leakage current effect. (10nA/pix)
- Flow is obstructed dropping from 12 cc/s to 6cc/s in a channel.
- A temperature rise and leakage current jump are seen in conjunction.

Figure 5- Leakage current simulation
IV. DEDIATED TEMPERATURE MONITOR

Leakage current will depend on radiation damage and temperature change. In order to unfold the two, a direct temperature monitoring is used. **Platinum resistors, RTDs** (PT1000’s) and some thermistors*, are radiation hard devices well suited to this application. * (Si Tracker uses NTC MuRata thermistors NTSA0XH103F type.)

**Hardwired through Service Cable**

A set of PT1000 resistors can be **read through Service Cable**. In the case that service cable heating and resistance is a problem a 3 or 4-pt scheme can be used. One pair can be use for excitation current and a second pair for readout.

![Figure 4: Direct readout of RTD / PT1000.](image)

III. RADIATION DOSE MONITOR

We believe the instantaneous rates should be monitored independently of FED and FEC readout, thus through the tracker service cable. Beam rates can be monitored insuring stable beam conditions prior to turning on and to providing an independent source of measurement other than the pixel detectors themselves. **PIN diodes** have been used in the past, but will suffer damage during operation. Radiation hard **diamond pad detectors** may fill this niche. These PIN diodes or diamond detectors could be mounted on the service cylinders.
IV. HUMIDITY and FC72 LEAK

The ability to detect water vapor and FC72 in the service tube is essential. A very low relative humidity must be insured before cool-down to –10°C to prevent icing damage to the pixel arrays. Ice may be burned off by natural detector heating but this scenario should be prevented.

A humidity gauge, HYGROMETRIX HMX2000 device, will be radiation tested and incorporated in to the service cylinder flow volume or flush line. This device will have sensitivty to a FC leak in addition to H₂O!

Figure 5: HMX2000 humidity monitor.

FC72 vapor in the dry N2 flush gas may be first indication of a coolant leak. Residual gas analysis (mass spec) of the flushing gas will indicate water vapor.

V. FC72 FLOW

Presently FC72 refrigeration units have temperature T, flow F, and pressure P monitoring. In case of a refrigerator failure a backup will kick in. The T, F, P from refrigeration units are fed in to the SCADA/JCOP system. In the event that this system is down a direct link from pixel chillers to power supplies is envisioned Figure 3.

VI. ALIGNMENT

At present the pre-software pixel alignment is based on careful positioning and measurement of the rail system relative to the outer Si detector. A translating to fiducials on the pixel detector proper is made. Relative fiducials on each blade will be surveyed and measured to 50µm. with coolant flow.
VII. PIXEL MONITOR BOARD

Due to lack of space on the pixel blade it is reasonable to conceive of a separate Monitor Board mounted to the service cylinder. This board might hold active and passive devices, connectors, etc. Active devices would tap power from the service cylinder lines.

Each board would handle monitoring of 1/2 disk, then up to six boards needed. Each board would measure 2 coolant input temperatures (RTDs) and 2 output temperatures (RTDs). For that 1/2 wheel. This requires 2 DCU’s if fiber I2C is used or 4-8 twisted pair lines depending on 2,3,or 4pt contacts. One HMX humidity chip would be mounted to one or two of the boards and be read out thru the DCU or twisted pair. Finally a PIN Diode (pad) for radiation monitoring could be mounted and used as an active beam halo device.

A Dummy Service Tube with such devices could be installed during the 1st year of tracker running, allowing the Pixel Detector to be integrated in the DAQ from the onset.

Figure 6: Pixel Detector Monitoring Board on Service Tube.