The LCLS BPM Data Acquisition System

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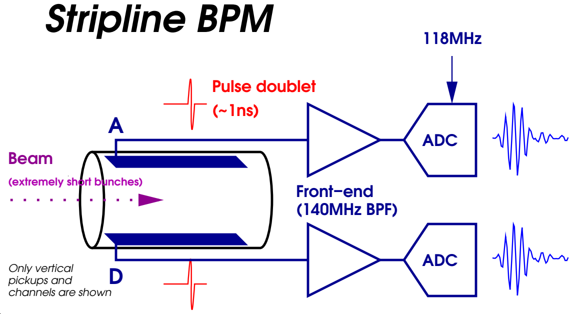
Requirements

- Stripline pickups (existing design)
- 10um resolution ~ 10^{-3} R (BPM radius R~10mm)
- System response time < 1ms
- EPICS integration
- Max. beam rate: 120Hz

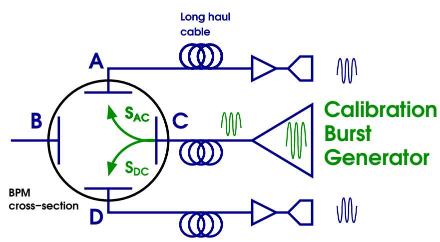
Stripline BPM



- Vert. position: y = (A − D)/(A + D)
- Small difference of big numbers -> dynamic range ~80dB needed
- Front–end reduces bandwidth (and SNR!) and increases signal level
- Undersampling of band–limited signal (~10MHz) in 3rd Nyquist zone
- ~100 significant samples

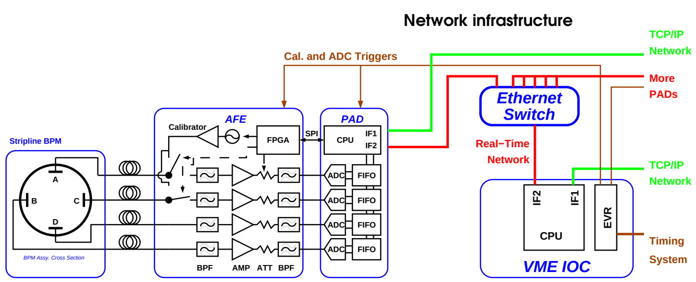
Calibration

- Difference in cable loss, drift in electronics etc. -> errors/drift in position reading
- Only ratio of gain in channels A + D matters
- -> Calibrate gA/gD ratio on–line



- Front–end electronics can inject a 140MHz burst into channel C. Calibration tone couples from stripline C to A and D. From ratio of amplitudes received by channels A and D the vertical branch can be calibrated
- Only depends on stability of stripline coupling ratio S_{AC}/ S_{DC}
- Horizontal pair B/C can also be calibrated by injecting cal. signal into A (not shown)
- Calibration cycles interleaved between beam pulses; max. data acq. rate: 360Hz (beam+2 cal.)

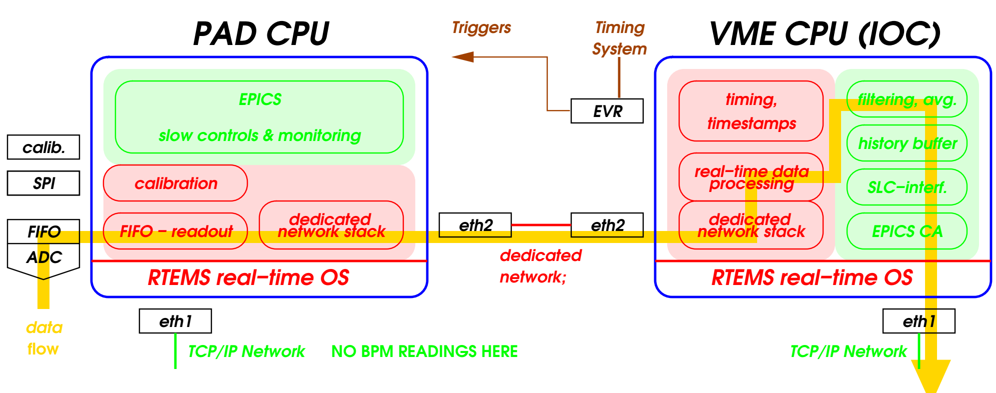
System Block Diagram



Stripline BPM assembly — Long–haul cables — Analog front–End with calibrator PAD digitizer with dual ethernet — VME computer with dual ethernet and HW–interface to timing system (EVR module)

- Use PAD digitizer developed for LLRF; added 2nd ethernet IF
- PAD: has ADCs, FIFOs, small CPU, 2 ethernet IFs
- PAD ships waveforms (4x128 samples) over dedicated ("real–time") network to powerful VME computer
- PAD CPU controls analog front–end via SPI interface (calibration mode, various attenuators etc.)
- Monitoring and slow controls of PAD over regular TCP/IP/EPICS
- VME computer (aka "IOC") has hardware interface to timing system (EVR) which provides triggers to calibrator and ADCs
- VME computer can process data from 10–20 attached PADs
- Dedicated ethernet switch; 100Mb/FD to multiple PADs, 1Gb uplink to VME IOC

Communication and Software Architecture



- Real–time OS on PADs and VME IOC
- High priority (HP) task on PAD reads FIFO
- HP task runs special IP/UDP stack (independent from regular TCP/IP) on both, PAD + VME using dedicated networking hardware -> deterministic data streaming
- Data rate not very high but response time <1ms required
- PAD does no pre–processing (CPU too slow; waveforms are a nice diagnostic)
- Throughput: ~1kB@360Hz / PAD
- Response: IOC provides x/y readings t EPICS in < 1ms
- Data are tagged with pulse–ID & timestamps