Power and LED Calibrations

2nd milliQan Collaboration Meeting

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Introduction

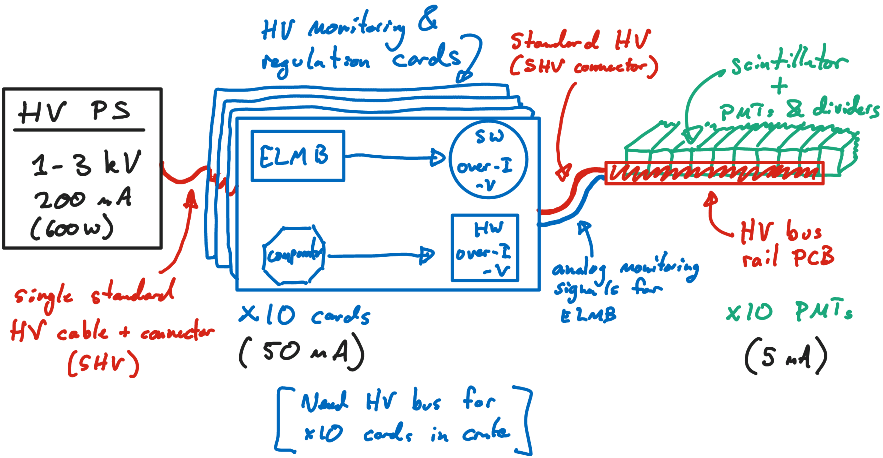
- Goals for this presentation:
  1. Some (moderately advanced) plans for powering
     - Two main proposals, and some options for the prototype
     - Specific feedback here will be appreciated, we have some questions
  2. Some (very initial) plans for LED calibration
     - Bit rougher still, but some considerations to discuss

Power Supplies: Designs for Final System

Basic Sketch

- 400 tubes to power per section!
  - Between 1 kV to 3 kV per tube
  - Between 0.2 to 0.5 mA per tube
- Expense is mostly in the HV supplies: goal is to minimize the number of supplies
  - Expect $\mathcal{O}(4)$ HV supplies per section
  - This depends on the PMTs of course: is the choice final?
- The fun part of design: how to power 400 tubes with 4 power supplies
  - Basic idea: each power supply powers 10 "distribution cards," which monitor and regulate the HV
    - Each dist. card powers a single HV bus which powers $\mathcal{O}(10)$ PMT's
  - **Key assumption**: we won't need to tune HV of individual PMTs (just groups of $\mathcal{O}(10)$)
  - Individual PMT regulation significantly increases cost and complexity
- Two options for implementation here (cheap and simple, vs. expensive and fancier)

Sketch of Basic (Simpler) Design

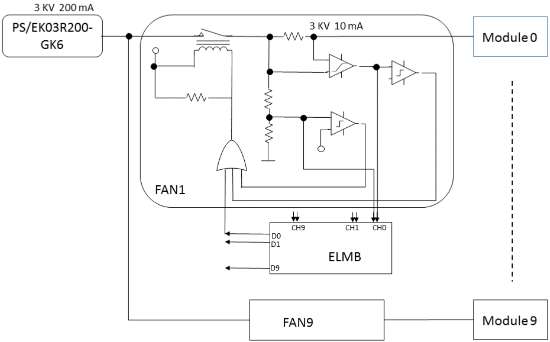


- Example PS: Glassman PS-EK03R200-GK6
  - Would have plenty of margin: 200 mA supply, only need 50 mA

Why Distribution Cards?

- Need safety and control mechanisms for delivering power to the tubes
- Would plan to use CERN-standard ELMB board for this
  - Simple output signal for overcurrent/voltage to monitor
  - Digital signal can be monitored by software as well
  - ELMB can take inputs from delivery boards to monitor actual voltage and current delivered
- Relay can control overcurrent/voltage using a comparator, outputs from ELMB
- Also need regulation system to program/set voltage for outputs
  - Want some amount of “local” control, not just at the power supply
- Distribution cards let us take care of both issues

Example Distribution Card Design

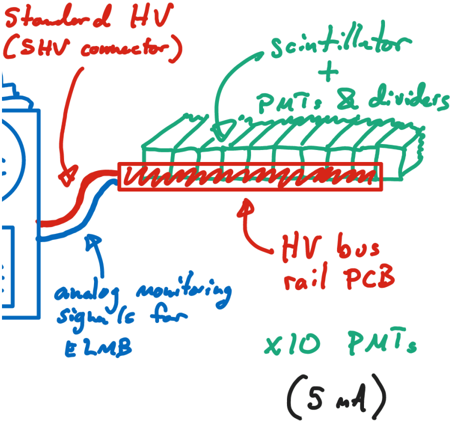


- NB: all share one HV bus, so one cable into a rack of dist. cards
- Probably cleanest to put distribution racks inside the interlock
    - One HV power cable per power supply through interlock

Module Size Considerations

- Big question: how many PMTs to power by each distribution card?
- Some considerations:
  - Probably need a 4U rack space per distribution card
    - If these live inside the interlock, space is limited: don't want so many distribution cards
  - Number of distribution cards sets the granularity of the powering
    - Can adjust the voltage of each set of 10 PMT's
    - Is this sufficient for our physics goals?
    - Depends a little bit on how good the local calibration is (which offline can correct for per-PMT differences)
  - Probably want power and readout to work together (for mechanical purposes, etc.)
  - PMT's are in 20x20 array: module size should factorize naturally

Module Base Card

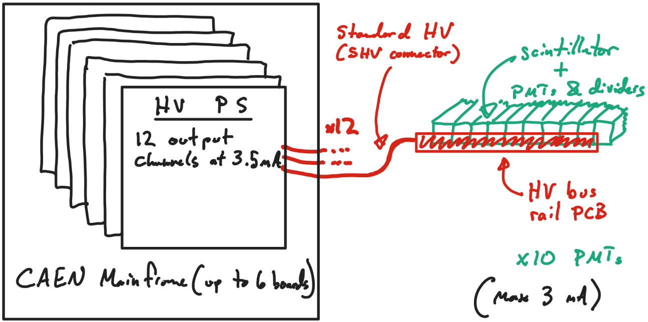


- A single long PCB (one HV bus) that would connect to $\mathcal{O}(10)$ PMTs
- We imagine a single long board that could slide in and out of the array
- If the module powers 10 PMTs, could have one slide in on each side of the array
  - If we want smaller regions, access becomes more difficult: how to access "interior" modules, if we can't slide them in and out?
- What kind of variation in HV are expected in center vs. side?

Summary of Basic Design

- Name of power supply
  - Fairly basic supply, no remote programming, etc.
- HV power supplies fan out to distribution cards
  - Distribution cards ensure safety and regulate voltages
- Distribution cards fan out to PMTs (module card)
- Example per section: 4 PS's, 10 cards per PS, 10 PMTs per card
- Estimate total cost: $\mathcal{O}(\$50k)$
  - Depends on final specs for PMT: may need to lower cards per PS, depending on power needs
- Module card design highly dependent on decisions for readout: should synchronize as much as possible!
  - Space constraints will also strongly influence this

A Fancier Design



- Using CAEN SY55S7LC Mainframe and A7435 HV Boards

Differences to the Basic Design

- CAEN system doesn't need distribution cards
  - Each CAEN "mainframe" can use 6 HV boards; each HV board has 12 or 24 HV output channels: these *channels* replace our distribution cards
    - Would still probably limit to 10 PMTs per channel because of power limitations
    - Would aim for 100-200 PMTs per HV board, 2-5 HV boards per mainframe for complete design
  - Would still need module cards: same as in basic design
- Advantages:
  - Less custom design from us: more robust?
  - Each distribution channel is remote programable!
- Disadvantages:
  - CAEN distribution boards live on the PS/mainframe: would need more cables through interlock (one cable per module)
  - Would cost more: $\mathcal{O}(\$100k)$

Power Supplies: Goals for Prototypes

Prototype Design

- Prototype should be 1 PS, and we should validate a few assumptions:
  1. Deliver whatever range of HV and current needed for various PMTs
  2. Deliver all stages of the system: PS $\rightarrow$ distribution board $\rightarrow$ module card
  3. Demonstrate that we don't need per-PMT HV settings
     - Make several distribution boards/ module cards (varying in number of PMTs, 1-10)
     - Demonstrate that performance with "large" module is $\approx$equivalent to small modules (or even per-PMT regulation?)
  4. Demonstrate slow-control for reading out ELMB (work with readout team)
- This mostly assumes the basic design, but similar requirements for a Caen prototype
- Any other thoughts/requirements?

Some Thoughts on LED Calibration

What's Our Goal for LED Calibration?

- Absolute energy calibration can be supplied by Am241 source
- But PMTs can drift over time: need relative calibration *in-situ*
  - Correct for drifts between Am241 calibrations
- The trick is to deliver a system where *consistent* light is delivered to each PMT
  - If the amount of light drifts as well, then the calibration is useless
- Especially if HV is delivered via modules, local PMT calibration is very important
  - Can correct offline for differences induced by "unoptimal" HV settings

How to Deliver Consistent Light?

- If each PMT has its own LED, each LED can drift separately
  - → Easiest answer: use one LED pulser per section
- How to split one pulser to 400 PMTs?
  - → Split by optical splitter, delivered via fiber optic cable
  - Unlikely to get a uniform amount of light per PMT, but that's ok in principle (normalized by Am241)
  - However, need to ensure *splitting system* won't drift either!
- How to minimize drift in splitting system?
  - → Making the splitting system *smaller*: use more LED pulsers, split to fewer places
    - Use photodiodes on each LED to monitor relative calibration between different LEDs
    - Monitor output per LED carefully
    - More sophisticated LED system is probably cheaper and simpler than programming each PMT's HV system
- How small to go? LED per PMT, per module?
  - Need **physics benchmarks** to decide on this design: how precise does the calibration need to be?

Thoughts for Prototype

- Will definitely want an LED system for the prototype to study some of these issues
- LED split between 10 PMTs is a simple goal
  - But this wouldn't let us validate that the splitting isn't drifting...
  - Again, depends on precision needed for the design
  - Can probably test and study range of splitter's drift

Conclusions

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- Have two main designs for power delivery for milliQan
  - Key assumption: per module powering, intead of per PMT
  - Both designs will ultimately depend on the final PMT choice
    - And prototype design depends on the range of PMTs to be studied
  - Budget more or less understood for both designs
- LED calibration is less advanced
  - Key challenge is to control relative drift at each PMT from the light sources
    - More pulsers and monitoring can control this to some extent
  - Good room for others to join as well :)

Thank you for your attention!

Backup