LarTPC Electronics Meeting
Current Work at MSU

http://www.pa.msu.edu/~edmunds/LArTPC/Talks/Talk_Feb_2010/

Fermilab  Dan Edmunds  23-February-2010
History of the MSU LArTPC Electronics Work

- Built a small warm DAQ system for the Bo LArTPC
- Built a warm DAQ system with cold Bias Voltage distribution for the ArgoNeuT LArTPC
- About one year ago Stephen Pordes ask us to work on a small multiplexed readout DAQ system that would operate cold in LArTPC test cryostats
Motivation and Goals of Our Current Work

- Test this DAQ system in the Bo LArTPC
- Provide a DAQ system for the “no pump out” long drift LAPD LArTPC at Fermi
- Gain experience with multiplexed readout and cold electronics in a LArTPC DAQ system
- Gain experience with digital signals inside the LArTPC cryostat
- Work on ideas to reduce the cost of the DAQ system for a big detector (3 box to 2 box system)
3 Box LArTPC DAQ System

Bias Voltage Connection

Shield Box on the Cryostat

Shaper and Line Driver

"DAQ Racks"

ADC and DAQ Readout

Network Connection

Bias Voltage Resistor

DC Blocking Capacitor

TPC Wire

Cryostat

Rev. 17-FEB-10
Project Sections of our Current Work:

1. Characterize components at LN2 temperature
2. Inside the cryostat
   - Preamplifier
   - Filter
   - Multiplexer
   - Line Driver
   - Digital Control of the Multiplexer
3. At the Cryostat Feedthrough
   - Passive Noise Filters: power supply, analog common mode, digital control signal coupling transformers
4. In the DAQ Rack
   - Back of the backplane card: power supply regulators, analog signal receivers, digital control signal drivers
   - Firmware for the ADF-2 VME Readout Card
5. DAQ system software
2 Box LArTPC DAQ System

Bias Voltage Connection

TPC Wires

Preamp Shaper

Mux. Ctrl.

Line Driver

Multiplexer

Feedthrough and Passive Noise Filters

Mux. Control

Diff. Analog

Power

Diff. Analog Receiver

Supply Power

Digital Control

"DAQ Racks"

ADF-2 Card

ADC and VME Readout

Back

of the VME Crate

Front

Cryostat

Rev. 17-FEB-10
Design Considerations:

- Operate at RT or LN2 temperature without significant adjustment
- Per readout card have a single twist-flat cable running inside:
  - 4 differential analog signals
  - 2 differential digital control signals
  - 3 power supplies (6 conductors)
  - 8 grounds (16 conductors)
  - 50 – 100 mV signal levels
- Control electrical noise inside the cryostat
Cold MOSFET Preamplifier

R1 = 100M Ohm
R2 = 375 Ohm
R3 = 18.6k Ohm
R4 = 100k Ohm
R5 = 27k Ohm
R6 = 1.0k Ohm
R7 = 2.0k Ohm
R8 = 100 Ohm
R9 = 100 Ohm
R10 = 100 Ohm on CMB-16
R11 = 100 Ohm on CMB-16
R12 = 10 Ohm on CMB-16

C1 = 1.8 pF
C2 = 10 nF
C3 = 10 nF
C4 = 47 nF
C5 = 47 nF
C6 = 47 nF
C7 = 47 nF
C8 = 47 nF
C9 = 47 nF on CMB-16
C10 = 47 nF on CMB-16
Cold 3-Pole Filter

The Drift Velocity is 1.5 mm/usec in a 500 V/cm field. For a 3 to 5 mm plane spacing the risetime will be 2 to 3.3 usec. For now pick a 2.5 usec peaking time or about 64 kHz.

\[
\begin{align*}
R1C1 \quad \text{Tau} \quad 1.64 \quad \text{usec} & \quad R2C2 \quad \text{Tau} \quad 560 \quad \text{nsec} & \quad R3 \quad = \quad 845 \quad \text{Ohm} & \quad R5C4 \quad \text{Tau} \quad 500 \quad \text{nsec} & \quad R6C5 \quad \text{Tau} \quad 110 \quad \text{nsec} \\
R1 \quad = \quad 2k \quad \text{Ohm} & \quad R2 \quad = \quad 10k \quad \text{Ohm} & \quad L1 \quad = \quad 560 \quad \text{uH} & \quad R5 \quad = \quad 49.9k \quad \text{Ohm} & \quad R6 \quad = \quad 499 \quad \text{Ohm} \\
C1 \quad = \quad 820 \quad \text{pF}d & \quad C2 \quad = \quad 56 \quad \text{pF}d & \quad C3 \quad = \quad 2.2 \quad \text{nF}d & \quad C4 \quad = \quad 10 \quad \text{pF}d & \quad C5 \quad = \quad 220 \quad \text{pF}d \\
R2/R1 \quad = \quad 5.0 & \quad 1/\sqrt{L1 \times C3} \quad = \quad 901k & \quad R5/R4 \quad = \quad 5.0 \quad \text{See the Cold} \\
R3/(2 \times L1) \quad = \quad 754k & \quad \text{Mux Circuit} \\
Wo > v \quad \rightarrow \quad \text{underdamped}
\end{align*}
\]
Cold 3-Pole Filter

R13 = 6.8k Ohm
R14 = 800 Ohm
R15 = 6.8k Ohm
R16 = 800 Ohm

Amp #1

Amp #2

R17C11 1.64 usec  R18C12 560 nsec  R19 = 845 Ohm
R17 = 2k Ohm   R18 = 10k Ohm   L1 = 560 uH
C11 = 820 pF   C12 = 56 pF   C13 = 2.2 nF

R21C14 500 nsec
R21 = 49.9k Ohm
C14 = 10 pF

Rev. 15-DEC-09

+6V

R23

C15 = 47 nF
C16 = 47 nF
Collection Plane Signal
Preamp and Filter
Cold Analog Multiplexer

Analog Inputs from the Buffers

Ch. Y0
Ch. Y1
Ch. Y2
Ch. Y3
Ch. X0
Ch. X1
Ch. X2
Ch. X3

MAX461B

Multiplexer Outputs to the Line Driver Inputs

Ch Adrs Q0
Ch Adrs Q1

D1
+6V

Rev. 29-OCT-09
Cold MOSFET Line Driver

Input from the Cold Mux

R1 = zero Ohm
R2, R4 = 115 Ohm
R3 = 0 Ohm
R5, R6 = 10k Ohm
R7, R8 = 1.5k Ohm
R9, R10 = 36.1k Ohm
R11 = 2.7k Ohm
R12, R13, R14 = 49.9k Ohm
R15, R16 = 499 Ohm
C1 = zero pF
C2 = 100 or 120 pF
C3, C4, C5 = 10 nF

Rev. 22-SEPT-09
Line Driver and Cable Response

Δ: 80.0mV
@: −29.8mV

Ch1 Pk−Pk  37.68mV
Ch1→Ch4 Pha
No period
2nd wfm

20 Jul 2009
16:10:36
Cold Digital Control Signal Receiver

Rev. 22-OCT-09
Cold Multiplexer Digital Control

Channel Address to the Cold Analog Multiplexer

Rev. 26-OCT-09
Warm Digital Control Signal Driver

ADF-2 FPGA
Access Signal
e.g. Mux
Increment Clock

Short Twisted Pair

C1 R1
1:1
MCL T1-6

Warm Differential Digital Control Signal

Twisted Pair Line to the Cryostat

R1 = 412 Ohm
R2 = 51 Ohm
R3, R4 = 25 Ohm
C1 = 10 nF
Output from the Chain: Buffer, Multiplexer, Line Driver, Cable, and VME ADF-2 (ADC) Card Checking for Crosstalk
2 Channel Preamp-Filter Card

- 4 layer with ground fill on all layers
- double via connections
- relieved ground plane under Hi Z traces
- compromise between size and ease of modification
16 Channel Mother Board
Engineering Comments:

If Fermi is going to be involved with the DAQ system for a large LArTPC detector (e.g. LBNE) then the electrical engineering work for that system should start soon.

- Technical Challenges
- Cost Control
- Remote Assembly and Operation

DAQ system engineering needs to be integrated with the mechanical and cryogenic engineering.

We should “prove” that a fully thought out warm electronics system will not work before committing to put “all” of the electronics inside.
As far as I know the HEP community has no examples of a large system operating for 10 or 20 years without needing to work on its electronics.

This is a one detector experiment, i.e. it must work.

A thin wall stainless steel vessel will not shield electrical noise. There is no “ground” inside and there is no shield inside.

Need a respected “Noise Czar” early (e.g. now).
Lots of room for DAQ design work:
- Filtering of the hit data
  Inline Digital and Offline
  Slope dependent hit filtering
  Raw data beauty vs information content
- Data Compression: Coding, ROI Readout
- Triggering: Beam Spill vs Continuously Alive

Low Temperature Components:
- Some just don't work.
- Subtle problems.
- Circuit implications.
Backup
2 Box LArTPC DAQ System

Cryostat

Bias Voltage Connection

Bias Voltage Resistor

DC Blocking Capacitor

TPC Wire

Shaper, ADC and DAQ Readout

Shield Box on the Cryostat

Network Connection

Rev. 17-FEB-10