The CDC High-Voltage Board

GlueX-doc-928 (version 3)

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Abstract

This document will describe the CDC on-chamber high-voltage board. The purpose of this board is to connect the wires in the CDC to high voltage and to couple the signals coming off these wire to the preamplifier. The preamplifier is designed to be monuted to the high-voltage board. It is also anticpated that the board will provide strain-relief for the signal cables going from the preamplifiers to the Flash ADC system.

Introduction

The purpose of the High-Voltage board (HVB) is to connect high-voltage to the wires in the Central Drift Chamber (CDC) and to couple the signals from those wires to the preamplifier cards which are mounted to the HVBs. In doing this, there are several functions that the board performs. First, it is a low pass filter on the high-voltage input to remove ripples from the line. Second, it needs to limit sudden large currents in the case of a chamber wire breaking and shorting the high-voltage to ground. Finally, it has high-pass filter which is used to capacitively couple the signal wires to the preamplifer cards. This document is quite similar to the one for the FDC [1] and many of the calculations done there are repeated or assumed in this document.

The High-Voltage Board

The HVB for the CDC is shown in Figure 1. Because all the elctronics on the CDC is on one end of the chamber, this board has to serve two purposes. First, it needs to connect the high voltage (HV) to the wire in the straw tube (connection wire). It also has a connection for the shield around the connecting wire (shield). The resistors R_1 and R_2 serve as current limiting resistors to protect the system from shorts on the chamber wires. They also serve as part of a low-pass filter built with R_1–C_1 and $R_2 - C_2$ which remove high-frequency noise coming from the high-voltage power supply. Caparcitor C_3 serves as a blocking capactior to isolate the input of the preamp from the high voltgage. It is also part of a high-pass filter built using R_3 and C_3 which passes the signals observed on the wire to the preamp.

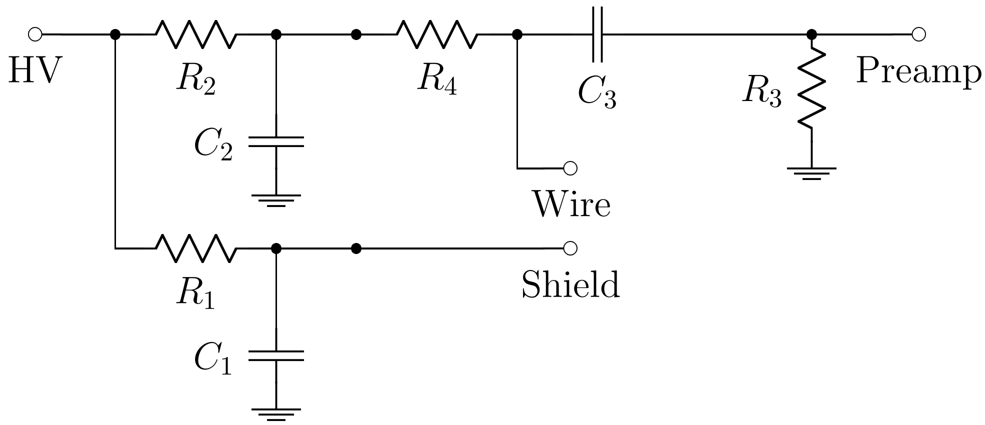

Figure 1: The CDC High-Voltage Distribution Board. In the final design, we anticpate that R_1, R_2 and R_4 are $1\,M\Omega$ while R_3 is $100\,k\Omega$. The decoupling capacitor C_3 will be $330\,pF$. The nominal design calls for C_1 and C_2 to be the same as C_3 to minimize components.

The CDC

The capacitance of the straw-tubes of the CDC are a clasic freshman physics problem. The tube have a radius of $8\,mm$ and surround a $20\,\mu m$ diameter wire. In the prototype, the tubes are $2\,m$ long, but this may be shortened to about $1.5\,m$ in the final chamber. The potential difference between two difference between two different radii around the wire is given as

$$V(r_1) - V(r_2) = \frac{\lambda}{2\pi\epsilon_0} \ln\left(\frac{r_1}{r_2}\right)$$

where λ is the charge per unit length and ϵ_0 is the dielectric of the vacuum. The capacitance of this system can then be computed to be

$$C = \frac{2\pi L\epsilon_0}{\ln\frac{r_1}{r_2}}$$

Using the nominal values of the CDC, we find an expected capacitance of about $16\,pF$. We will use a value of twice this to represent the chamber, $C_{CDC} = 32\,pF$.

The De-coupling Circuit

The combination of C_3 and R_3 in Figure 1 forms a high-pass filter which decouples the high-voltage from the preamplifier input, allowing the observed signal to get to the input of the preamplifier.

If we now focus on the decoupling part of the circuit which connects the wire to the preamplifier, we want the the series combination of C_3 in Figure 1 with C_{CDC} to be at least 90 % of C_{CDC} (so as to allow 90% of the stored charge to pass to the preamplifier). This means that we should choose C_3 to be at least $320\,pF$. In order to protect the preamplifier by minimizing stored energy, we want C_3 to be as small as possible. For this reason, we take $C_3 = 330\,pF$. These capacitor should be "Negative-Positive-Zero" (NP0) capacitors which is the standard choice for temperature stability and *low-noise*. For R_3 of $10\,K\Omega$, the characteristic frequency of the high pass filter is

$$\begin{aligned} \omega_{RC} &= \frac{1}{R_3 C_3} \\ \omega_{RC} &\approx 3 \times 10^5 s^{-1} \\ f_{RC} &\approx 50\,KHz \end{aligned}$$

which for a high-input impedance preamplifier, means that frequencies well above $50\,KHz$ are completely passed by the circuit.

Component	Value	Tolerance
R_1	$1\,M\Omega$	20%
R_2	$1\,M\Omega$	20%
R_3	$10\,k\Omega$	20%
R_4	$1\,M\Omega$	20%
C_1	$330\,pF$	
C_2	$330\,pF$	
C_3	$330\,pF$	

Table 1: The nominal choice of component values for the CDC HVB.

Filter Circuits

The circuits involving C_1 and C_2 are low-pass filters used to filter high-frequency noise off the the High-voltage lines. for R_2 and R_3 on the order of $1\,M\Omega$ and C_1 and C_2 taken to be the same value as C_3, the charateristic frequency of the filters is $f_{RC} \approx 500\,Hz$.

Mounting the HVB

The HVB is mounted on the outside of the up-stream gas plenum of the CDC. There are small stand-offs which attach it to the gas plenum. Each board is connected to 24 wires on the CDC which are fed through the plenum in groups of 12 wires. There are options on the board to connect the shield either to high-voltage or to ground. These boards are mounted normal to the surface of the plenum, causing them to stick from the end of the chamber.

The preamp cards are then attached to the HVB and finally the signal cable coming off the preamp has strain-relief provided by the HVB.

Figure 2 shows a side-view on one HVB mounted to the plenum of the CDC. Two 12-wire connectors bring the wires out from the CDC and connect to the HVB. The preamplfier in then mounted to a tounge sticking out of the opposite end of the HVB. The preamp is both attached to the board, but also gets strain relief for the signal cables from the board.

If we assume that we need $0.5\,cm$ between high-voltage pad on the input of the board, then for a 24 channel card, we need a $13\,cm$ long edge on the board. Taking this length to specify the needed real estate on the gas plenum, we show a possible design that would allow us to mount the needed 150 boards on the gas plenum. This is in Figure 4. At this point, this layout is not optimized, it is only shows a proof of principle in the mounting of the electronics.

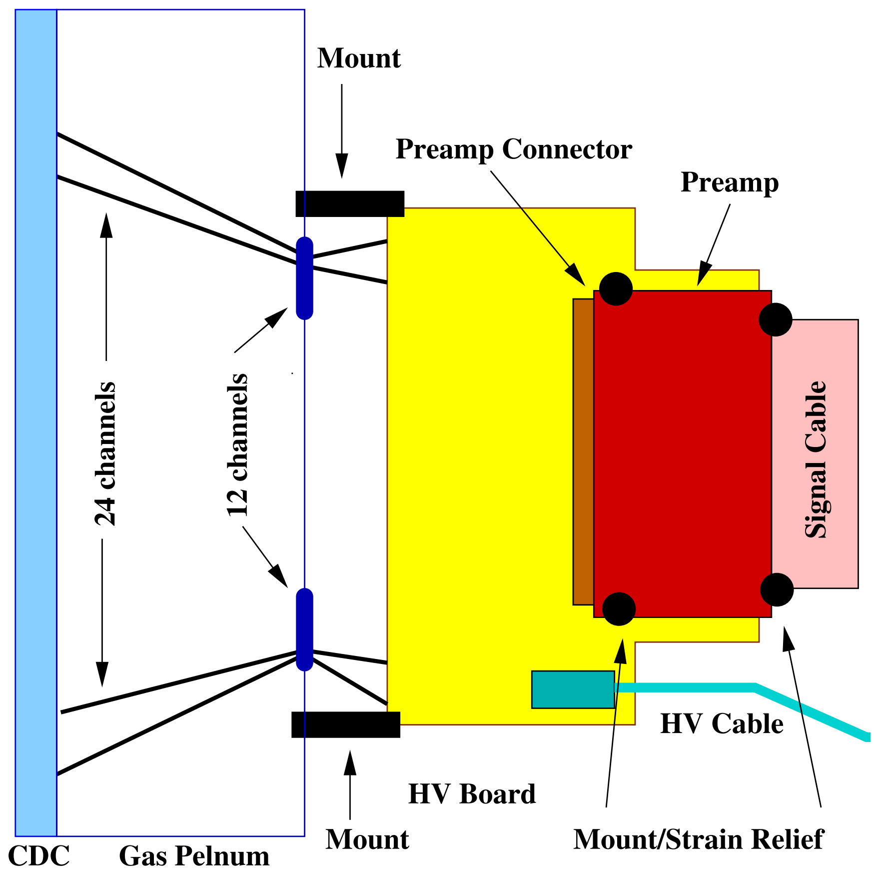

Figure 2: A schematic drawing of how the high-voltgage and preamp boards are mounted to the CDC. The HV boards are crewed onto the plastic gas plenum of the CDC. Each care connects to 24 channels of the CDC which are fed through two gas feed throughs as shown. The preamp mounts to the HV board and the signal cables then come off the preamp. It is assumed that the preamp will be attached to the high-voltage board and there will be strain-relief for the signal cable on the high-voltage board.

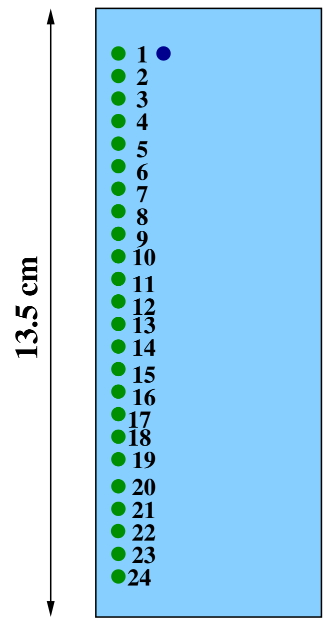

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Figure 3: A sketch of the high-voltage card with 24 channels. The card is 13.5 cm long, which allows for 0.5 mm between HV wires and extra space on the end of the card for mounting to the chamber gas plenum.

The Prototype Board

The prototype HVB was built to match the 16-channel CLAS preamplifier. It was also built oversized to faciltate soldering and unsoldering of components and wires. A trace layout for this board is shown in Figure 5. There are some key features that should be noted. First, the grey area is a grounding plane that is on one side of the circuit board. In addition, there are two traces that can be connected to the high-voltage. The one closest to the right-hand side of the schematic in in Figure 5 is connected to the shield around the wire that goes to the chamber. It can be connecetd to either the ground or the high voltage on the card. The nominal connection is to the high voltage. The second line trace connects to the wires and is capacitively coupled to the preamp connector. The board is such that the signals jump over the high-voltage trace in the capacitor.

Changes that need to be made for the final board include the following:

1. Increase the number of channels from 16 to 24 to match the GlueX preamp.

2. Reduce the size of the board.

3. Add the tab on the back side of the board to support the preamplifier.

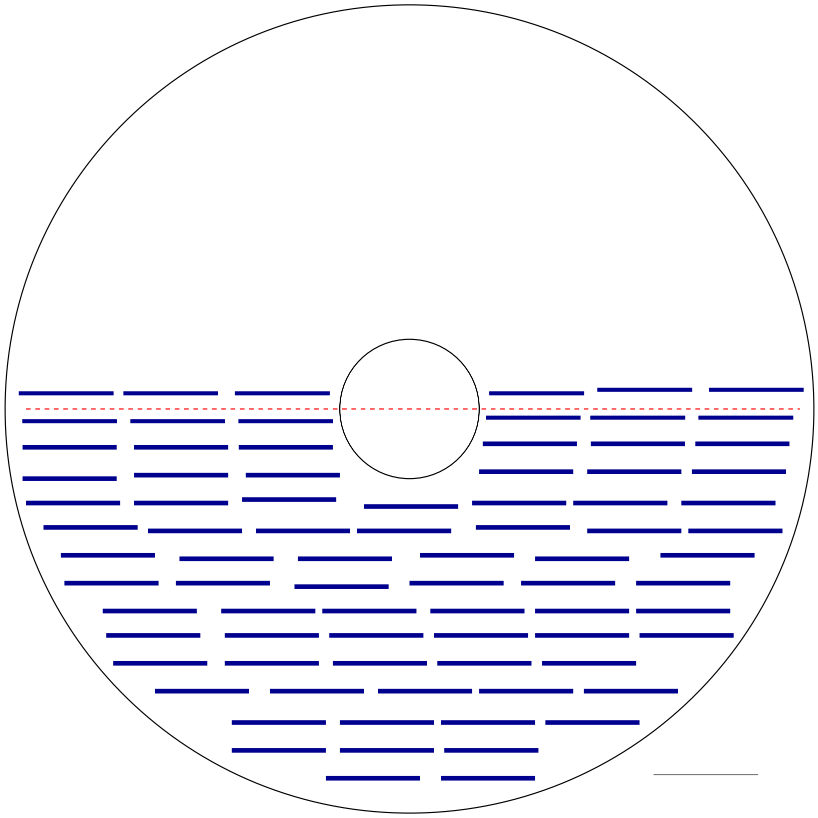

Figure 4: A sketch of the high-voltage cards layed out on the downstream endplate of the CDC. The sketech shows 75 cards placed on the lower half of the chamber. There would be a second 75 cards on the upper half of the chamber for a total of 150 cards. This is sufficient for 3552 channels.

4. Change the preamplifier connector to accomodate the GlueX preamp.

5. Change both the type and direction of the High-voltage connector to match the GlueX specifications.

References

[1] Dan Carman, **FDC On-Chamber Electronics**, GlueX-doc-753, February 2007.

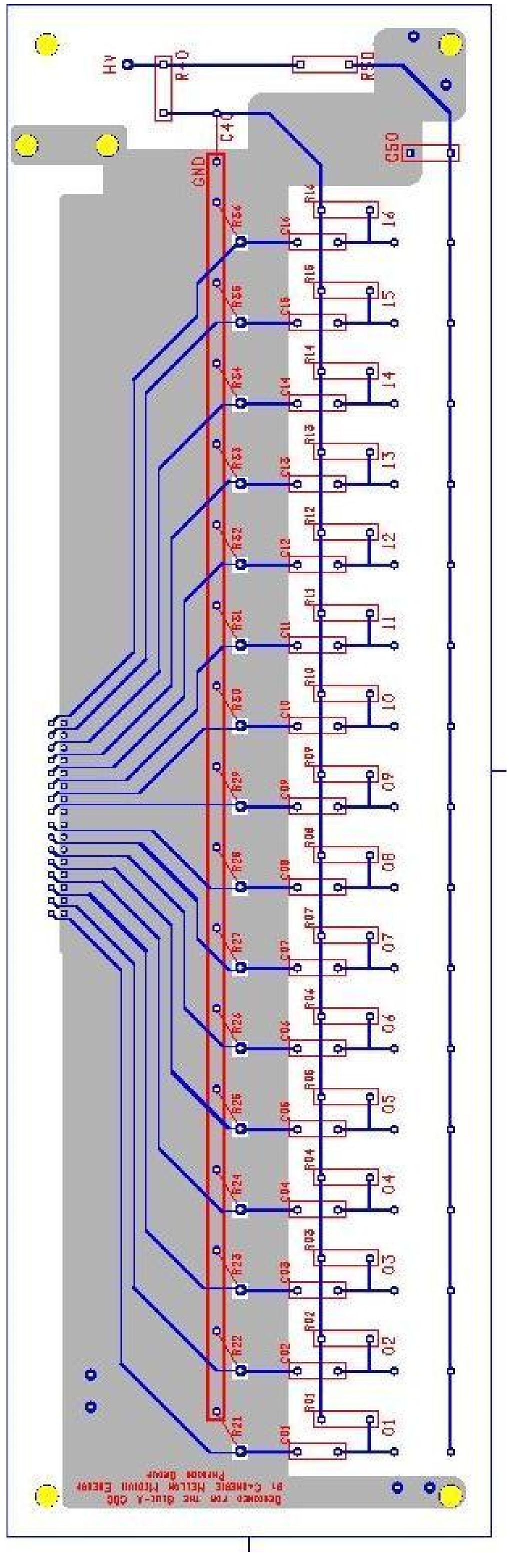

Figure 5: The trace layouts on the prototype board. The grey area indicates grounding on the backside of the circut board.