COT Waveform Data

The COT has 2520 cells, with 12 sense wires per cell. The ASDQ has 8 channels per ASIC; 3780 ASDQs in the entire system. The ASDQ provides one analog output per 8-channel chip. We will bring a tiny fraction, approximately 32, of these out to the endwall on cables. These analog outputs are our only opportunity to see “raw” signals from the chamber. We would not only like to be able to view the signals while the beams are in collision, we would also like to be able to correlate the raw signals with the actual event environment. For example, if we see a pulse on a given wire, we would like to know what the measured drift time of that pulse was and what the event environment was like: Was it dense or sparse? Was the hit associated with a found track? The waveform data could also play an important role in calibrating and understanding the $dE/dx$ system. To be able to correlate the waveform data with the remainder of the event, we must digitize the analog waveform data and get it into the data stream.

The above plot shows what the analog output looks like on a scope. The original spec for the analog output was a differential emitter-follower capable of driving a maximum differential excursion of 150mV (75mV/leg) across a 50Ω cable. [I need to
check with Mitch Newcomer at Penn to see if this is still accurate or not. I believe he changed the gain in the end so that the maximum excursion is less than this.] The two complementary traces (top and bottom) are the two legs of the differential output, the middle trace is the difference of the two. The event shown is a cosmic ray. The amplitude is typical for a radial track, although in a realistic environment, the amplitude varies depending upon the angle and portion of the cell the track subtends.

For the chamber and ASDQ, typical rise times and shaping times are a few nanoseconds. This sets the scale for the digitization granularity. A point ever 2ns would be acceptable, larger times between points would become too granular.

The maximum drift time in Ar:Et is about 220ns. We would like to see the time since the previous beam crossing to understand to evaluate baseline shifts. We would also like to see some time after the maximum drift to investigate the arrival of late charge. These two criteria set our window of interest at a minimum of about 700ns.

Options

We foresee two ways to get waveforms into the data stream.

I. Waveform Digitizing Oscilloscope

Use a waveform digitizing module (FADCs). There are GHz scopes on the market (some that are VME modules) that will use 8 bit FADCs to digitize the data in 1ns bins. In fact this was the technique we used in Run I to digitize CTC waveform data using a LeCroy 7200 scope, but we never tried to get it into the data stream. The HP E1428A is a two-channel VME oscilloscope that samples at 1GSa/s.

The drawback with this technique is trigger timing and readout. There would be no way to buffer the data for a subsequent trigger as the remainder of the CDF DAQ system will do. The only way I see to get data from a scope into the DAQ system would be to take special triggers with a dedicated scan list. In other words, a scope won’t be able to wait for the L1 + L2 latency for a trigger decision. We would have to tell it to begin digitizing at a specific time and then issue L1, L2 accepts on the appropriate clocks so that the remainder of the COT was read out to coincide with the waveform. There is also the issue of development of DAQ software to readout any new module. The cost of these modules are about $10k each (HP quoted $11.4k for the HP E1428A), we could never hope to read out more than one or two channels at any give time.

II. Waveform Divider

Build a board that takes the analog waveform and digitizes it at many different thresholds. Run the output from each threshold into a different TDC channel. The following cartoon shows how this would work. The curve is the analog waveform. The set of 5 lines shows the discriminator response to the analog waveform for 5 different thresholds. The discriminator output level is different on each line just so that the different curves can be resolved.
In this case, we have 96 channels in a single TDC. We can make 96 copies of the waveform and pass the copies through 96 discriminators, each with a different threshold, and then run the outputs into a TDC. With 96 different thresholds, we effectively have a 7.6 bit FADC with 1ns binning. The advantage of this technique is that the TDC takes care of the L1/L2 latency and buffering. Also, this can go on during normal data taking: no special run or trigger is required. Additionally, the time window is large enough so that we can see µs timescales. This will be useful in understanding the effect of previous beam crossings. Finally, the COTD bank is already defined, so that there is no modification to the DAQ protocol necessary. Once the data is on tape, the waveform could be reconstructed from the data in the TDC. Another advantage to this technique is scalability. We would have the ability to read out more than one or two channels at a time. We would never propose to read out many channels, but the data volume coming from 4 or 5 would not be prohibitive, and the TDCs will be available as well.

**Waveform Divider -> TDC**

I’m open to either solution at this point, although I think the waveform divider into a Michigan TDC offers us more flexibility and has a better chance of ultimately yielding useful results. For this section, I’m assuming we’re going to use that approach.

**Questions**

There are a few issues that we could use some input/ideas on:
• We’ll want to be sensitive to baseline excursions, so we’ll need to set it up so that there is a pedestal. In other words, for an event that is perfectly quiet at baseline, I can imagine that there are 10 channels high for the entire time window and the other 85 channels low for the entire time window.
• Once a hit gets well above threshold, we care less about the exact shape and amplitude versus time. We could potentially get more mileage out of our multiple discriminators if the thresholds weren’t spaced linearly. In fact, if we could get meaningful information out of 48 channels, then we could digitize two waveforms per TDC.
• Instead of simply controlling the levels by only the discriminator thresholds, we could also vary the gain of the copies of the analog waveform. This would give us more range and flexibility in setting the levels. On the other hand it adds complication.

**Implementation:**

This board is continuously running, it needs no communication to the outside world. Nor does it need CDF_CLOCK or trigger information. Even so, since its output goes to a VME module, it seems reasonable to make this a VME board as well. There are several possible locations:

1. It could sit in a COT TDC crate on the endwall. The analog waveform data would come straight from the chamber on a single twisted pair.
2. It could sit in a muon TDC crate in the first floor counting room. The analog waveform data would have to be buffered/redriven up to the counting room. There are free slots in the muon crates. This is probably a good solution because it makes the translation board accessible. Also, we are going to want the analog waveforms available in the counting room anyway, so that we can look at them on a scope.
3. It could sit in the COT calibration crate on the second floor. Same as item 2 above, except the muon guys don’t let us in their crates.

In any of these cases, the outputs would be on four TDC type connectors, and short (3”) cables could jumper between the two boards. It would probably be useful to have an analog output on the front of the module so that we could look at waveforms while they are being acquired.