TLM Development Meeting Minutes 11/27/12

Attendees: M. Olson, J. Zagel, J. Anderson, D. Schoo, D. Peterson, N. Eddy, & T. Leveling

Location: Penthouse

Time: 1100 to 1215

Prepared by: T. Leveling

Discussion:

1. There was a brief discussion on developments with the TLM detector since the last meeting which includes construction details described in “TLM Ion Chamber Preliminary Design” located at the TLM website: <http://www-muon.fnal.gov/Personnel/Leveling/TLMs.htm> Most notable was the successful implementation of the heartbeat resistor on the 10 foot TLM temporarily installed in the AP30 service building.
2. T. Leveling stated that it would be desirable to have three prototype TLM electrometers by May 2012 when beam operation is scheduled to return. Several TLM beam studies drive this time frame:
	1. First, a series beam tests with the 125’, 250’, 338’ TLMs and a heartbeat resistor connected in series to a single electrometer while installed at pbar. The idea is to check whether the detectors connected in series at a given loss point would give a linear response (3x) compared with single TLM response at the same loss point.
	2. Second, two of the pbar detectors would then be removed from pbar and subsequently installed at locations within MI (MI40 abort line or the MI 30 collimation region), and Booster (Long 3 extraction). Beam studies could then continue at MI and Booster where TLM response to more severe beam loss conditions can be studied.
	3. The third TLM electrometer could be used at pbar for additional studies with the remaining TLM, located in Linac with the 10 foot detector, connected to an existing TLM at NuMI, or located with the third pbar TLM at another location, for example, Seaquest.
3. There are two ongoing efforts for TLM electrometer development and each was discussed.
	1. Dave Peterson lead a discussion with a prototype electrometer he has developed since the last meeting. Charge is collected and digitized with the Burr-Brown Products DDC112. An output pulse of variable length is produced. The leading edge of the pulse represents 0.5 nC and the trailing edge represents 0.5 nC such that a single pulse represents 1 nC as has been a specified requirement. John Anderson pointed out that a variable length pulse, especially a longer one, could be interpreted by the MUX system as a constant high level and is consequently, incompatible with the MUX system. Dave said that he will change the pulse such that a single rising edge of TTL pulse represents 1 nC. **NOTE:** **John has subsequently told us that Greg and Randy verified that the MUX network is in fact edge triggered. The 50% duty cycle waveform from the prototype electrometer should work correctly when connected to MUX.** The integration time needs to be a minimum of 500 us; Dave has the integration time set to 600 us. Full scale on the integrator is 350 pC . The pulse output of the electrometer is rate limited to about 62 Hz so that the ~70 Hz MUX sampling rate is not exceeded. Charge is stored and released at 62 Hz until the remaining charge is depleted to a level where a lower rate and with a characteristic time constant of ~20 seconds is applied. Incoming charge from the TLM detector is damped with high impedance resistors to prevent swamping the digitizer circuit. The input resistor is split to form a voltage divider circuit. One resistor of common value to all electrometers resides on the electrometer side. The second resistor is incorporated in the TLM detector and is sized for the particular TLM application. In the event of an extreme beam loss condition, it would be possible to produce very high voltage on the TLM signal which could potentially swamp the electrometer. A high impedance FET op amp will be used to monitor the junction of the voltage divider. In the event a preset voltage level is sensed, the electrometer keep alive circuit would be dropped out to interrupt the delivery of additional beam. The use of this technique would prevent loss of information due to very high beam loss conditions and prevent additional high beam loss from occurring when it might not be measured. In this way, it can be guaranteed that the time-weighted average beam loss limits would not be exceeded.
	2. Next, Dan Schoo discussed his work using an analog circuit approach which is comparable to the Chipmunk electrometer. Parts for the analog approach have been obtained, but unavoidable circumstances have impeded progress. Dan is hopeful that a demonstration unit can be available in the next several weeks, certainly in time for testing early next spring.
4. There was some discussion about what technology might be used with the electrometer for providing the TTL pulse output. Dave’s prototype currently uses a microprocessor because it was readily available. FPGAs, CPLDs, and microprocessors were discussed. The output of the various digital controllers (uC, cpld, fpga) are easily adaptable and can be used to set the parameters of the pulse output , electrometer safety manager circuitry algorithms, etc. Nathan believes any of the options can do the job.  Some research is needed to determine which technology will be best suited for our application and safety system. It was also discussed that the technology used would be compatible with either the analog or digital electrometer designs. Nathan suggested that Dave look for an appropriate device while Dan pursues development of the analog electrometer.
5. The digital electrometer design requires a little work (connectors, container) to get it ready for a trial. The intention is to install the 10 foot TLM with heartbeat resistor in the Linac in the very near future.
6. T. Leveling pointed out that there isn’t any written guidance from the DOE on what constitutes an acceptable electrometer design for a safety system. From discussions with various individuals at Fermilab, the common theme is that we just need to use “good engineering judgment”. A NRC document,
 <http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7006/cr7006.pdf>

is available which might be useful to help guide and support our decision to use FPGAs, CPLDs, or other technology in conjunction with the TLM electrometer/safety system.
7. POST MEETING NOTES: There is one clarification to make on the voltage divider mentioned in 3a. The main purpose of the total resistance is to prevent swamping the electrometer with charge collected for moderate beam loss. The voltage divider with high impedance FET sensor prevents prolonged beam operation with severe losses. A standard resistor will be chosen for the electrometer so that electrometers are completely interchangeable. The value of the resistor on the TLM detector cable is only based upon the length of the cable. No consideration of the application should be required. For example, for a 1E12 beam loss, at 8 GeV at A2B7, 320 nC of charge is produced. Cable capacitance is 22.2 pF/foot. Since the instantaneous peak voltage of the cable center conductor is V=Q/F, an instantaneous voltage of 43 volts would be produced on a 338 foot cable while a 115 volts would be produced on a 125 foot cable seeing the same beam loss. The maximum current the electrometer can accept is given by:

The total resistance required to prevent swamping the electrometer for the 125 foot cable with a 1E12 beam loss at 8 GeV is given by:

The total resistance required to prevent swamping the electrometer for the 338 foot cable with a 1E12 beam loss at 8 GeV is given by:

The shortest TLM detector cable planned for at this time is 168 feet which would be used in the AP service building s at the straight sections and would require a total resistance of 146 MΩ.

A 10 foot prototype cable currently in use would require a 2.5 GΩ resistor; however, there is a practical limitation on the amount of charge such a short cable can collect because, for example, the 1E12 beam loss at A2B7 is distributed over a longer distance of about 25 feet.

From the TLM Dynamic Range requirements document, Table 1, the maximum average current necessary to be collected is on the order of 51 nA. The electrometer can measure charge at a rate 10X higher than this. The FET op amp on the voltage divider would interrupt beam operation would eliminate the need for an electrometer to operate at even higher beam losses which most accelerators will be capable of producing.

The bottom line is that a little additional thought is required on the value for the electrometer fixed resistor. The length- dependent, TLM detector cable resistors can be determined once the electrometer resistor value is determined.

Some care must be taken to not make the total resistance too large since this could delay charge collection which could potentially reduce the detector bias and negatively affect TLM charge collection efficiency.
8. Dan Schoo has provided pdf files for candidate analog technique electrometer which have been added to the TLM work page.
9. During the meeting, there was some discussion about what action could be taken in the event the TLM cable was damaged, for example, cut, crushed, etc. The first thought was that the study mentioned in 2a could show that simply cutting out the bad section of cable, terminating the cable with plastic end parts and simply connecting the new ends with HV and signal cable might work. Dave Peterson has determined that kits are available to join the HJ5-50 cable. Consequently, damaged cable can be repaired with manufactured parts intended for this purpose. In fact, the use of such splices during TLM installation would be beneficial to eliminate cable waste.