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GlueX Electronics Status and Plan

GlueX Electronics Group

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Abstract

This note summarizes the current state of the GlueX electronics systems, and describes the R&D required to fully specify the design. Institutional responsibilities are stated.

Summary of GlueX Detector Subsystems

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Detector	**Photon tagger**	**Pair spectrometer**	**Upstream Photon veto**	**Start counter**	**Central drift**	**Forward drifts**	**DIRC**	**Time-of-flight**	**Barrel calorimeter**	**Forward calorimeter**
Type	Scintillator	Si microstrip	Scintillator	Scintillator	Straw tube	Planar chamber	Quartz	Scintillator	Sci fibers	Lead glass
Channel count	140 fixed 120 movable	2048	112	40	3240	2,856 anode 11,424 cathode	2000 TDC 32 FADC	168	2112	2500
Signal source	PMT fixed SiPMT movable	Silicon microstrip	PMT	PMT	Straw tube	anode wires cathode strips	Multi-anode PMT	PMT	SiPMT	PMT
Physics signal	100 pe	22000 e	100 pe	100 pe	25 e	94 e	25 pe	500 pe	250 pe/GeV	250 pe/GeV.
Energy resolution	0.1% (segmentation)	N/A	$10\%/\sqrt{E}$	N/A	20%	N/A	N/A.	N/A	$2\% + 5\%/\sqrt{E}$	$3.6\% + 7.3\%/\sqrt{E}$
Time resolution	100 ps	25 ns	1 ns	350 ps	1 ns	1 ns	200 ps	80 ps	$150 + 50/\sqrt{E}$ ps	400 ps
Gain in detector	10^6	1	10^6	10^6	10^4	5×10^5	10^6	10^6	8×10^5	8×10^5
Typical charge	16 pC	3.5 fC	16 pC	16 pC	40 fC	7.5 pC anodes 1.5 pC cathodes	4 pC	80 pC	32 pC/GeV	32 pC/GeV
Preamp gain	no	10^4	no	no	10^3	44	10	no	no	no
Signal range	5	10	100	10	100	10 anodes 100 cathodes	10	10	160 pC max 1.6 pC min 0.16 pC lsb	160 pC max 1.6 pC min 0.16 pC lsb
Maximum single channel rate	5 MHz	1 MHz	1 MHz	10 MHz	600 KHz	140 KHz	250 KHz	6 MHz	1.4 MHz	2 MHz
Discrimination	constant fraction	no	no	constant fraction	no	yes (anode) no (cathode)	yes	constant fraction	yes	no
FADC	8 bits 250 Msps	8 - 12 bits 62.5 Msps	8 bits 250 Msps	8 bits 250 Msps	10 - 12 bits 125 Msps	Cathodes: 10 - 12 bits 62.5 Msps	8 bits 250 Msps	8 bits 250 Msps	8 bits 250 Msps 0.5 V fs	8 bits 250 Msps 0.5 V fs
TDC	62 ps	no	no	62 ps	no	Anodes: 125 ps	125 ps	62 ps	62 ps	no
Level 1 trigger	yes (low rate runs)	no	no	track count	no	no	no	track count	energy sum	energy sum

1 Introduction

The pipelined electronics for the GlueX detector requires approximately 20,000 ADC channels, 6,000 TDC channels, and 18,000 chamber preamplifier channels. There are currently no suitable commercially available options. Clocking, synchronization, discrimination, and trigger electronics will also be required. The plan is for the GlueX collaboration and Jefferson Lab to design suitable boards based on commercially available components. The chamber preamplifiers may require a custom chip; this is likely to be a modification of existing chips developed for other experiments.

Some detector parameters need to be specified more completely than what is in the current design report. A suitable TDC design exists at Jefferson Lab; this may need slight modifications for GlueX. There will be 2 types of ADCs. A ”fast” (250 Msps) flash ADC will provide charge and timing information for the channels instrumented with photomultipliers, while a ”slow” (possibly 62.5 Msps) flash ADC will digitize the tracking chamber signals.

2 Detector issues

2.1 Photon Tagger

The photon tagger design is based on scintillator, photomultipliers, and silicon photomultipliers. The JLab TDC in high resolution mode will provide timing measurements. 8 bit, 250 Msps ADCs will provide a charge measurement.

2.2 Beam Instrumentation

This includes a 2000 channel silicon strip pair spectrometer, a 32 channel scintillator hodoscope polarimeter, a small calorimeter, and an active collimator. Preamps and a readout system will be required for the silicon strips. A similar system in Hall B uses a slow analog multiplexer and an ADC to read it out. For GlueX, it may be desirable to use the same ADC as the tracking chambers. The scintillator polarimeter and calorimeter will use photomultipliers read by the ”fast” ADC. This beam instrumentation system needs further definition; in particular the required event acquisition rate must be specified.

2.3 Upstream Photon Veto

The 8 bit, 250 Msps ADCs will provide charge and time information for this scintillator and photomultiplier based detector.

2.4 Start Counter

Constant fraction discriminators, high resolution TDCs and 8 bit, 250 Msps ADCs will instrument this scintillator and photomultiplier based detector. A track count may be useful in the level 1 trigger decision.

2.5 Central Drift Chamber

Intended to provide tracking as well as dE/dX, it consists of 3240 1.6 cm diameter, 2 m long straw drift tubes read by ADCs. Further measurements and simulations will be required to finalize the preamplifier specifications and ADC bit depth and sampling rate. Algorithms for reducing the raw ADC samples into time and charge parameters need to be developed.

A full length prototype chamber exists at Carnegie Mellon University. Studies have begun to determine the optimal gas mixture. The chamber gain will be measured. Preamplifiers originally designed for the JLab CLAS detector will be used to provide signals for tests with TDCs and ADCs. It is important to collect data with a commercial flash ADC to provide input to the electronics design. Since there is currently no way to apply a magnetic field to the prototype chamber, simulations will be used to model the electron drift trajectories.

2.6 Forward Drift Chambers

This detector consist of 4 packages of 6 layers of planar drift chambers. It has the largest channel count of any GlueX detector. A small prototype exists and measurements have begun. The design report calls for TDC readout of the anodes, and ADC readout of the cathodes. The October 2004 detector review recommended considering the use of dE/dX information from these chambers to help with particle ID. Simulations will be needed to determine whether this information can be derived from the cathode ADCs, or whether the anodes should also be instrumented with ADCs instead of TDCs. In either case the preamps need further specification, and the required bit depth and sampling rate needs to be determined. It is important to collect data with a commercial flash ADC to provide input to the electronics design. It may be possible to apply a magnetic field to the small prototype chamber. Simulations can also be used to model the electron drift trajectories.

Algorithms for reducing the raw ADC samples to time and charge need to be developed. It may be desirable to use ADCs to read the anodes in any case so that common preamplifiers can be used for both the anodes and cathodes. Commonality with the CDC electronics is also desirable.

2.7 Cerenkov

The baseline design calls for a gas viewed by about 40 PMTs; but a quartz DIRC is also being considered which would require about 2000 PMT channels. In either case, TDCs with 125 ps resolution are specified along with ADCs to monitor the PMT gains. The gas option is presently not being actively engineered; the quartz option engineering is starting from a similar detector used in BABAR.

2.8 Time-of-flight

Consisting of scintillator bars viewed by fast PMTs, this detector design is fairly advanced. There have been several beam tests and NIM publications. The electronics consists of discriminators, 60 ps resolution TDCs, and 250 Msps ADCs. The only major decision remaining is whether to use constant-fraction or leading-edge discriminators. The ADCs will monitor the photodector gains and may be used to provide a time-walk correction to the TDC information. A track count will be used in the level 1 trigger decision.

2.9 Barrel Calorimeter

The physical design of this detector (lead and scintillating fibers) is well understood and prototyped. The choice of photodector is the subject of continued R&D, but is likely to be silicon PMs, a new but promising technology immune to the large fringe fields from the GlueX solenoid. This detector also provides Time-of-flight information for charged tracks. Currently, the design report has discriminators and TDCs to provide this information, but the 8 bit, 250 Msps ADCs alone may be adequate for this time measurement; further simulations should be done to study this. An energy sum from this detector is used in the level 1 trigger.

2.10 Forward Calorimeter

This detector is being recycled from E852 and RadPhi. The design is well understood, with the only issue being the high rate channels immediately adjacent to the beam hole. Low power bases for the FEU84-3 PMT have been prototyped, but work remains to understand how to best mass produce them. Indiana University is responsible for these bases. The readout electronics is 8 bit, 250 Msps ADCs. An energy sum from this detector is used in the level 1 trigger.

3 Electronics issues

3.1 Preamplifiers

Detector mounted preamplifiers will be required for the Central and Forward drift chambers. Preamplifiers may also be necessary for the Pair spectrometer silicon trackers and for the Cerenkov photodetectors.

There could be up to 3 types of drift chamber preamplifiers:

For the CDC anodes, the chamber gain is estimated to be 10^4 in which case a preamplifier with a gain on the order of 10^3 will be needed. The output should be differential to drive a twisted pair cable connected to an ADC.

Simulations should be done in conjunction with measurements to determine the optimum gain and time shaping requirements. The ATLAS TRT group found that the trailing edge of the chamber pulse contains useful information since it is correlated with electrons drifting in from the straw wall, providing a time calibration as well as a way to reject tracks coming from out-of-time interactions.

Measurements of the FDC prototype indicate a chamber gain of 5 X 10^5; the JLab CLAS preamps provide an additional gain of 44. Simulations should be done to determine whether the anodes, cathodes, or both should be used to provide dE/dX information. Additional simulations should be done to optimize the preamplifier time shaping characteristics. If only timing information is desired, the UPenn ASD chip and a TDC may be suitable. If charge information is desirable for dE/dX, a linear amplifier with differential outputs and an ADC is appropriate.

The prototype FDC cathodes are also instrumented with the JLab CLAS preamps. Simulations are needed to optimize the gain and shaping characteristics. This preamplifier should be linear with differential outputs to drive an ADC. This preamplifier needs to have low noise with the up to 80 pF of capacitance from the longest cathode strips.

It is desirable to minimize the number of different types of preamplifiers used in the GlueX tracking system. Existing designs may or may not be suitable. It may make sense to modify one of the existing UPenn designs (ASD, ASDBLR, ASDQ). Discussions have begun with UPenn to explore the options. The choice of preamplifier may influence the chamber design, gas choice, and will certainly need to be coordinated with the choice of TDC versus ADC for the FDC anodes, and the specification of bit depth and sampling rate where an ADC is used. The University of Alberta group is responsible for the chamber preamplifiers. The Canadian Microelectronics Consortium may be a source of affordable prototype chips.

3.2 TDC

Jefferson has designed and built 100 VME modules based on the University of Freiburg F1 chip which is commercially available through ACAM. This module has 64 channels in its standard resolution (120 ps) mode or 32 channels in high resolution (60ps) mode. Minor changes may be made in this module for GlueX.

3.3 ADCs

The present design report assumes 2 types of ADCs:

An 8 bit, 250 Msps version for the calorimeters and other photodetectors. The calorimeters require an energy sum which is used in the level 1 trigger.

A 10 - 12 bit, 62.5 or 125 Msps version for the tracking chambers.

A single channel prototype of an 8 bit, 250 Msps ADC in PCI format has been built at Indiana University. This has been tested and several collaborating institutions have copies. The Jefferson Lab Fast Electronics group is designing a 16 channel VME module based on the Maxim 112x series of pin-compatible converter chips. These chips provide 8, 10, or 12 bits at 170, 210, or 250 Msps. The energy sum required for the calorimeters will be implemented on an optional mezzanine card. Clock, trigger, synchronization and partial energy sum signals will be distributed over the backplane. This system is intended for use in the existing JLab experiments as a replacement for aging FASTBUS ADCs as well as for use by GlueX and other new experiments in the existing halls.

The drift chambers don't require a 250 Msps sampling rate, and 8 bits is insufficient. The present design specifies 10 bits at 125 Msps for the CDC anodes and 10 - 12 bits at 62.5 Msps for the FDC cathodes. Further simulations are required to understand what is actually needed. An R&D program to further reduce the sampling rates for the chamber ADCs through analog preprocessing (for example a ringing integrator) has the potential for significant cost savings and could make a dE/dX measurement from the FDC anodes affordable, as well as minimizing the number of different types of ADCs. The Indiana University Cyclotron facility is responsible for the tracking chamber ADC system.

The on-board algorithms for reducing the raw ADC samples into a charge and time measurement need further development, especially for the drift chambers. These algorithms also need to take into account any analog preprocessing.

3.4 Clocking and synchronization

The digitally pipelined electronics proposed for GlueX is assumed to be clocked in synchronization with the accelerator beam time structure. The distribution of the appropriate clock, reset, trigger, test, and monitor signals has been discussed (for example at the December 2004 electronics workshop), but a lot of work remains to be done. Jefferson Lab is responsible for this system.

3.5 Readout Bus

The present bus standard being used for the TDCs and proposed ADCs at Jefferson lab is VME64X. The VXS backplane is being considered for the next generation of these modules to distribute the sampling clock and other timing signals. Compact PCI and ethernet backplanes are possibilities being explored at Indiana University.

3.6 Trigger

Some GlueX trigger simulations were done in 2002 and are summarized in the design report. The present design specifies a hardware trigger based on calorimeter energy sums and a track count from the forward Time-of-flight detector. However, a lot of work remains to be done on this important aspect of the experiment. Some issues are:

Which detector elements should be included?

How should the trigger be partitioned between hardware (Level 1) and software (Level 3)?

Is there a plausible need for a level 2 trigger?

What background processes are the most important to reject?

Is the time estimate for the level 1 trigger of 3 μs realistic?

4 Simulation Priorities

The present drift chamber simulations should be expanded to include predicted pulse shapes. It will be important to understand the variation in pulse parameters due to particle trajectories and energies. The electronics response to the pulse should be modeled, and algorithms for reducing the the raw ADC samples determined. Successful extraction of physics parameters from the reduced data must be demonstrated.

Are the FDC cathode charge measurements adequate to provide dE/dX information, or is the anode charge required as well?

What is the optimum gain and time shaping for the chamber preamplifiers?

What ADC bit depth and sampling time is required for the chambers? Can additional shaping reduce these requirements? What algorithms will be implemented in the ADC hardware?

Much of this work can build on what has already been done by other experiments. [1] [2] [3] [4] [5] [6] [7]

What time resolution is needed for the level 1 trigger calorimeter energy sums?

Can adequate charged particle time-of-flight resolution be derived from the BCal ADCs or are TDCs needed as well?

What beamline instrumentation is needed and what are the electronics requirements?

5 Responsibilities, Management, and Milestones

Partitioning of the various aspects of GlueX electronics R&D among participating institutions has essentially been "self-assigned" based on interests and available personnel. This process has worked well, but as GlueX moves from an R&D phase into actual construction institutional responsibilities will need to be formalized. Another important clarification will be the responsibility for maintenance and repair of electronics. The design report describes a management structure, but this needs to be fleshed out. The design report also describes a "Technical Review Committee"; this will need to be implemented in order to review various aspects of the electronics design, especially those for which considerations beyond the strictly technical will influence the decision. Additional internal and external reviews will be required. Realistic milestones and dates must be determined. Additional manpower will be required; this is likely to be new hires at Jefferson Lab.

References

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