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Electronics Control and Dataflow between the Read-Out Module and the Front-End Electronics Systems

BaBar DAQ Group

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1. Introduction

The *BaBar* detector electronics system comprises a number of front-end electronics subsystems i.e. SVT (Vertex), DCH (Drift Chamber), DIRC (Particle ID), EMC (Calorimeter), IFR (Flux Return), and the TRG (Trigger) system. This document describes the electronics control and dataflow between the *BaBar* standard Read-Out Module (ROM) and the detector's front-end electronics. The front-end electronics systems are controlled from the ROM (electronics set-up, timing, clock, trigger accept, etc) and transmit data (register read-back or event data) back to the ROM via this interface. This document does not address the environmental monitoring and control of the detector (e.g., readout and control of temperature, pressure, currents, voltages, etc.). The environmental control and monitoring path is separate from the electronics control and dataflow path to and from the front-end electronics.

2. Electronics System Overview

Figure 1 shows a high-level block diagram of the electronics function blocks. The Data Acquisition (DAQ), Trigger, and Fast Control and Timing System (FCTS) crates are located in the Electronics House (EH) and are physically accessible during run periods. In this document, we refer to them as the Off-detector electronics. The subsystem-specific electronics, located on or near the detector within the radiation area, are referred to as the On-detector electronics. (The trigger sub-system is located in the EH but is connected to the DAQ like other sub-systems. Thus, the same rules as for the On-detector sub-systems are valid.)

The timing and control of the On-detector electronics is realized from *BaBar* standard Read-Out Modules (ROM) in DAQ crates in the EH via high-speed serial Control links (CLINK), and the data coming back from those electronics is transmitted on high-speed serial Data links (DLINK).

Several components in the Off-detector electronics are used for all the subsystems. In each DAQ crate, there are one Read Out Controller (ROC), one Fast Control Distribution Module (FCDM), and a number of Read Out Modules (ROM). The ROC is a *BABAR* standard high performance commercial VME master. The FCDM is a *BABAR* standard custom VME module which receives signals from the FCTS for distribution within a DAQ crate. The ROM consists of a *BABAR* standard commercial CPU board with a PCI-to-i960 PMC card, together with a custom DAQ card with a mezzanine personality module. The personality module interfaces to the FEE via optical fibers. For non-calorimeter systems the personality module supports one CLINK transmitter for control and timing, and one DLINK receiver for the data returning from the FEE. The personality module for the Calorimeter system holds two receiver links, called FLINKS. The CLINKs and DLINK/FLINKs are based on Hewlett Packard HDMP-1012/HDMP-1014 Gigabit-rate chip-sets and Finisar FTR8510 fiber optics transceivers. The system clock frequency for the *BABAR* sub-system electronics is 59.5MHz. The commands received by the ROM from the Fast-Control and Timing system as well as set-up commands with corresponding data originating on the ROM are serially applied to the GLINK transmitters. The Glink transmitters are here used as multiplexers, as illustrated in Figure 2. The data at each of the 16 inputs of the Glink transmitters are serialized data streams that are time-multiplexed onto a single high-speed link (16 x 59.5Mbit/s x 5/4 encoding overhead ~ 1.2 Gbit/s). For non-calorimeter systems, the Glink receivers are used as data demultiplexers. The receiver demultiplexes one single high-speed data stream to 16 slower (59.5 Mbit/s) serial data streams. This enables one ROM to send data to, and receive data from, up to 16 independent front-end electronics (FEE) sections in the On-detector electronics at 59.5 Mbit/s each. The data is stored in ROM memory.

The calorimeter system uses the standard personality module for control and register readback data. For the event data, a calorimeter specific personality module is used because the DAQ system receives continuous untriggered data

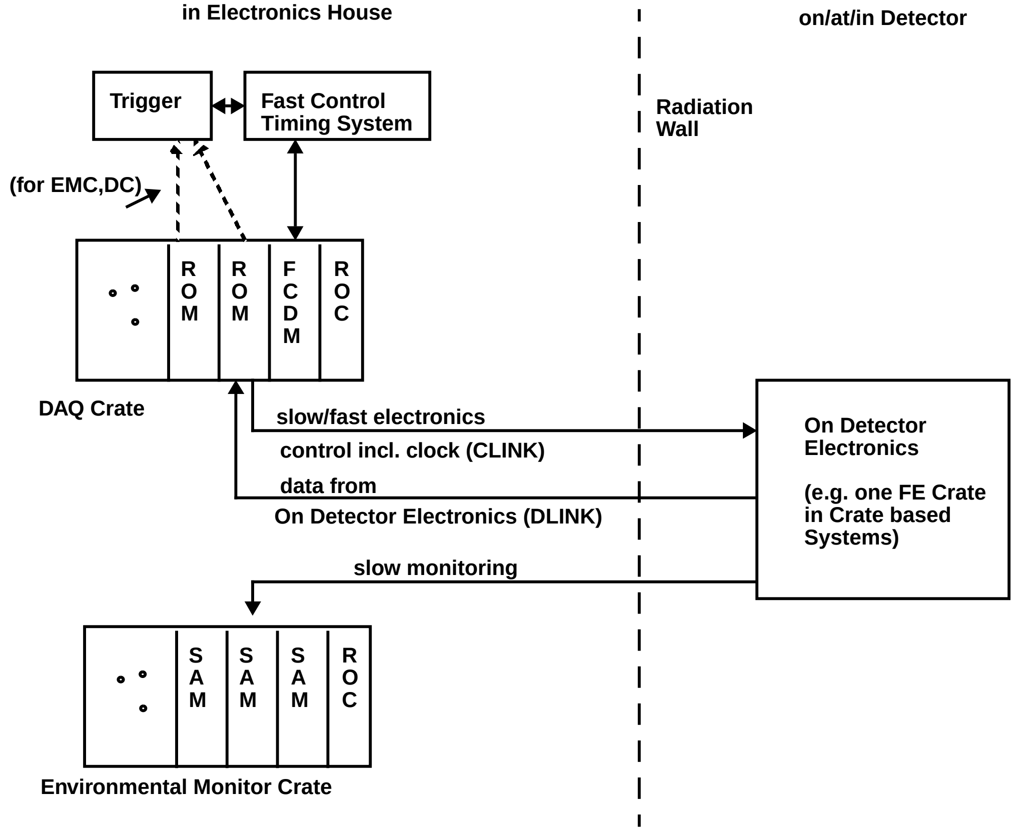

Figure 1: Overview of BaBar electronics.

streams from the FEE as opposed to triggered data. The calorimeter personality module holds two FLINKS and no CLINK. (The FLINK is similar to the DLINKs of the non-calorimeter systems.)

The data rate from the ROM to each of the 16 FEE sections is 59.5Mbit/s. The data rate from each FEE section to the ROM is 59.5Mbit/s, or 59.5Mbit/s/2, or 59.5Mbit/s/4, depending on the sub-system. As indicated in Figure 2, the clock for the FEE is extracted from the incoming serial stream by the Glink receiver on the multiplexer board and connected to each of the 16 FEE sections. That clock (59.5 MHz) is also used to drive the Glink transmitting the detector data back to the ROM. The clock signal driving the Glink is conditioned by a Phase-Lock-Loop (PLL) and delayed to account for cable delays between the multiplexer board and the FEE sections. Sub-systems using a sub-multiple of the 59.5 MHz clock for readout could divide the system clock e.g. on the multiplexer board.

3. Control of the On-Detector Electronics

We distinguish between two types of electronics control commands:

- Run-time commands: commands that can be executed during run time.

- Non-run-time commands: commands which cannot be executed during run time, but only during calibration, setup, or diagnostics time. (Both are transmitted via the CLINK at the same bit frequency.)

For non-run-time commands the exact time of occurrence must not be crucial. Examples are set-up commands as loading a calibration mask, calibration or threshold DACs, mode registers, etc. The data values associated with these commands (e.g. the mask pattern) are written via the ROC into ROM memory. After the ROM is instructed to send the specific command to individual FEE sections, the command as well as the associated data is sent to the On-detector electronics. The protocol controller on the ROM coordinates this transmission. The protocol controller has 16 data output lines clocked at 59.5MHz driving the CLINK transmitter, as shown in Figure 2. Note that each line carries serial data assigned to only one FEE section. The 16 serial data streams are multiplexed onto the high speed CLINK

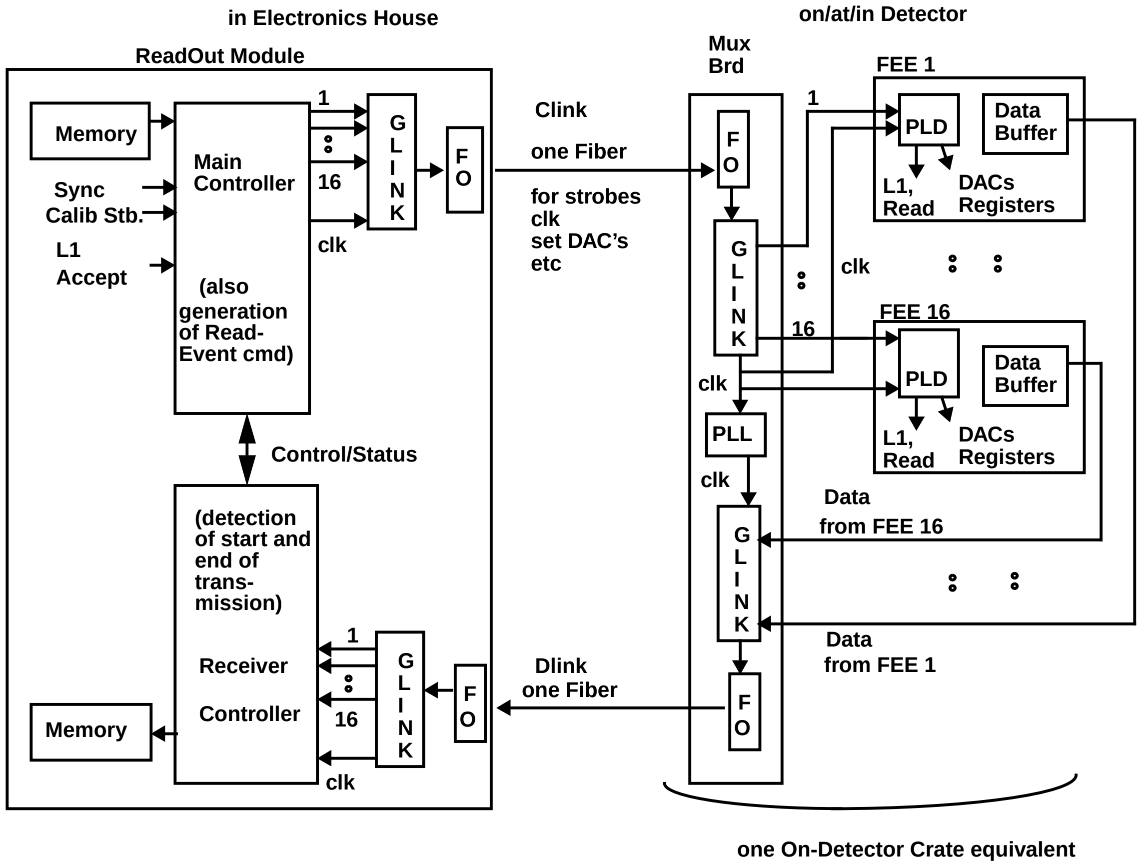

Figure 2: Control and dataflow to/from On-detector electronics.

which is received at the On-detector electronics end. The On-detector Glink receiver demultiplexes the data from the CLINK to 16 lines clocked at 59.5MHz, carrying the same information as the output of the protocol controller. Each of the 16 data lines is connected to a different FEE section. Since the information on the 16 data lines from the protocol controller is serialized, one can send a command to any combination of the 16 FEE sections. The transmission to any section can be disabled on the ROM. One cannot send different commands simultaneously to individual FEE sections connected to one ROM. Once the command to be sent is selected for a ROM, the only choices are to send it or not to any combination of FEE sections. The data associated with the command sent simultaneously to each FEE section can however differ from section to section. (The data written previously into the ROM memory is sent).

The only commands allowed during run time are Run-time commands. (These commands are of course also allowed during non-run time). The exact timing of occurrence is or can be crucial. Examples are timing synchronization commands, trigger accept signals, calibration or timing strobe commands, read event command, etc. The commands as well as the data values (not sub-system selectable) associated with those commands are received by the ROM from the FCDM and transmitted via the Protocol controller to the FEE sections. Note that some of these commands do not have to but can be time crucial e.g. for diagnostics purposes. Examples are calibration strobe or read event command. All commands for which the timing is or could potentially be crucial, either concerning the absolute timing or the relative timing, or coordination between ROMs are Run-time commands. All Run-time commands are predefined and can not be modified by a sub-system (same is true for the data field).

The idle state of the CLINK is indicated by the transmission of bits with a value zero rather than no transmission as used in packet transmission modes. This ensures that the On-detector electronics CLINK receiver can always extract the 59.5MHz clock and distribute it to its up to 16 FEE sections so that they can remain in timing synchronization with the rest of the detector's electronics.

With the architecture presented above, a common communication protocol for all subsystems has been developed to configure, control, and run the On-detector electronics. All electronics control and timing commands, run-time or non-run time, are encoded and transmitted over the CLINK, with no separate strobe, timing, or clock lines from the Off-detector electronics to the On-detector electronics.

The commands are encoded into five bits for a maximum of 32 main Op-codes. The command field is always transmitted Least Significant Bit (LSB) first and is always preceded with a start bit, a bit set to one, which indicates the start of transmission. There is always at least one leading zero before the start bit. When the system is initialized, e.g., after a power-up sequence, there are many (10,000s of) zeros which could be used to put e.g. a command state machine in the FEE in idle state. Also, the idle state of the link (transmitting zeros), ensures that zeros always precede a valid transmission.

Run-time commands span Op-codes 0 through B_{16} and are appended by a five bit data field. The command as well as the data bits are predefined and cannot be modified or determined by a sub-system.

Non-run time commands are assigned by each sub-system (preferable in descending order) and span Op-code $1E_{16}$ through C_{16}. They are appended with a five-bit address, and have a variable data field length. The address field of the non-run time (or subsystem specific) commands is always transmitted LSB first. This address is received by a FEE section and can be decoded internally to address various elements such as DACs, registers etc within a section or board. The address field can, however, also be used and interpreted as sub-command field. The data field is transmitted preferably LSB first, but in a few cases to simplify the hardware, this rule may be waved.

Commands which are not defined for a particular sub-system must still be actively decoded and treated as No-Op commands. There is no slow electronics configuration of On-Detector Electronics while in data taking (run time) mode. (As an example, pattern registers in the On-Detector Electronics can not be set while detector data is being received by the same ROM). Again, when the detector is in run mode, electronics set-up commands (all sub-system specific commands) can thus not be transmitted.

As indicated in Figure 1, the slow environmental control and monitoring path is separated from the On-detector electronics control path. As an example the signals from on-detector based sensors are connected to analog modules (SAM) in environmental monitoring crates, having their own readout controller.

We distinguish thus between:

- <u>Electronics control:</u>

  Non-run time commands: exact time of occurrence is not critical: set calibration/threshold/other DACs, set control/pattern/mask registers, etc. (Not allowed during run time)

  Run-time commands: could but don’t have to be time critical (prompt, fast):Trigger accept, Read event, Sync, Reset, calibration/timing strobe, etc. (Allowed during run time)

- <u>Environmental control/monitor:</u>

  Readout of temperatures, pressures, currents, voltages, etc.

  In the following chapters the electronics control commands are described.

3.1. Run-Time Commands

In this section the specifications for the run time commands are presented with a short explanation of how the on-detector electronics should respond. Generally, run time commands are received by the ROM from the FCTS and then transmitted to the on-detector electronics. The Read-Event command is presently generated on each ROM, but could also be generated on a higher level.

The format for these commands is: *z s c c c c c d d d d d*

z => one leading bit = 0 (link idle)
s => one start bit = 1
c => five command bits, LSB first

d => five data bits, LSB first

The five command bits form the Op-code which is interpreted by the FEE to perform a specific action. The interpretation (decoding) must be performed in a constant (over time), known number of clocks after the command is received.

The data bits are always sent with a run-time command and are **not** sub-system definable. They may be zero or have a significance. In either case, the on-detector electronics need to receive and accept these bits so as to not interpret the data bits as a new command.

The list of run-time commands follows.

Op-code: 0
Command: No Op
Data: 0
Description: No local Operation is required from the On-detector electronics. (Command still has to be decoded as No-Op so as to avoid wrongful action after e.g. a misread start-bit in case of a transmission error)

Op-code: 1
Command: Clear Readout
Data: Reserved
Description: Flush or Reset event buffers in the FEE sections. The content of the buffers is not necessarily modified but the pointers to the event buffers are reset so that when the next "L1 Trigger Accept" command is received, the first buffer is filled while the other ones are tagged empty. In the case of a system with FIFOs as event buffers, the FIFO full flags are false and the FIFO empty flags true after a "Clear Readout" command. After a "Clear Readout" command any events which may still be stored in the FEE are lost to the DAQ, thus there will be at least one "L1 Trigger Accept" command before the next "Read Event" command. This command must not be used to reset registers which can be written into with a subsystem specific (non-run time) command.

Op-code: 2
Command: Sync
Data: Reserved
Description: This command is used to resynchronize the timing of the FEE with the rest of the system. It resets the divide 2^n counters which are used to generate slower clocks in the FEE (e.g., sampling clock), any counter which has to do with timing, and counters whose state is returned to the DAQ. Any events stored in the event buffers may still be read out with subsequent "Read Event" commands.

Op-code: 3
Command: L1 Trigger Accept
Data: 5 Bits Trigger Tag
Description: The "L1 Trigger Accept" command is delivered to the FEE with a latency of 12us (minus 0 to 1us, trigger jitter)

"L1 Trigger Accept" commands can be delivered to the FEE as close as 2.2 μs apart from each other and are always followed eventually by a "Read Event" command (Op-code 4), unless a "Clear Readout" command is issued.

Since the "L1 Trigger Accept" commands may "stack up" the FEE of triggered systems must have several buffers to hold the data for subsequent events while one event is being read out.

When a triggered system's FEE receives an "L1 Trigger Accept" command, it transfers the state of relevant timing counters and data to the next available event buffer. Additionally, the trigger tag (data bits) received with the command bits is also stored within that same buffer. The DAQ will not send this command when its buffer occupancy model determines that no buffer in the FEE is available.

Op-code: 4
Command: Read Event
Data: reserved
Description: Send event from FEE to ROM

When a triggered system's FEE receives a "Read Event Buffer" command, it starts transferring the data held in the "oldest" not yet read event buffer since the last "Clear readout" to the ROM.

The ROM runs a model of the event buffer occupancy of the FEE. The ROM will never issue a new "Read Event" command until all data associated with a current "Read Event" has all been received by the ROM.

Minimum time between "L1 Accept" and its "Read Event" is 2.2us

Op-code: 5
Command: Timing or Calibration Strobe
Data: Reserved
Description: This command can be used to inject a known charge to the input of channels previously selected by calibration pattern registers. The value of the DACs and the content of the calibration pattern registers are written with subsystem specific (non-run time) commands. The "Timing or Calibration Strobe" command is followed with the 12usec latency by a "L1 Trigger Accept" command. The data is readout from the FEE with a "Read Event" command. This command can also be used for timing calibration. This command is under Run-time commands because there is the possibility that a system might need a timing signal (strobe) during run time.

Op-code: 6 - B_{16}
Command: Reserved
Data: Reserved
Description: These Op-codes are reserved for future uses. They should be acted on as a No Op command unless otherwise permitted.

3.2. Non-Run Time (Subsystem-Specific) Commands

The non-run time (or subsystem-specific) commands are generally used to configure the On-detector electronics and to verify proper operation of the electronics and the detector. Configuration consists of such actions as setting DAC values, writing calibration pattern, and channel enable registers. Verification consists of writing test patterns or reading back DAC values, ADCs, or registers to name a few examples. These commands are by nature not time critical (in respect to their occurrence absolute in time or relative to other FEE sections) electronics control commands and are never issued when the detector is in data taking mode. (Transmission speed to each FEE section is still 59.5 Mbit/s).

The format for these commands is: *z s c c c c c a a a a a d d d. . . .*

z => one leading bit = 0 (link idle)
s => one start bit = 1
c => five command bits, LSB first
a => five address bits (or sub-command bits), LSB first
d => n data bits, LSB first preferred, specified by users. (**n=0 for read commands!**)

The command format is the same for this group of commands as it is for the run-time commands; the five c bits form the Op-code. Two of the Op-codes in the non-run time (subsystem specific) group have been reserved. Op-code $1F_{16}$ is reserved for future expansion, and Op-code $1E_{16}$ has been dedicated as a subsystem reset which can be used to reset registers or the like as required. Op-codes 1D16 through C16 are defined for each subsystem.

The address can be used to select components on the FEE. For example, a 64-channel FEE may have 16 DACs to set the pedestal of 16 four-channel discriminators, addresses 0 through F_{16} would be used to select individual DACs when writing a value, and address $1F_{16}$ could be a broadcast address to write the same value in all 16 DACs. The address field can also be interpreted as sub-command field.

Write commands have generally associated data bits whereas read commands cannot have any data bits. As an example, writing a calibration pattern register may require 64 data bits, writing a DAC may require eight data bits, but reading the register back must not have any data bit as part of the command, only the command field and the address field are available. The data from the FEE register to the ROM will be transmitted over the DLINK.

Typical subsystem-specific commands are show below as examples.

Op-code:	$1D_{16}$
Command:	Write channel enable register
Address:	0 *(There is only one such register in this particular FEE).*
Data:	64 bits *(This FEE supports 64 subsystem channels*).
	LSB <= Channel 0MSB <= Channel 63.
	bit = 0 <= Disable channel
	bit = 1 <= Enable channel
Description:	Write 64-bit register to enable or disable individual channels.
	Bit 0 enables/disables channel 0, and bit 63 enables/disables channel 63.
	A bit set to zero disables the channel, while a bit set to one enables it.

Op-code:	$1C_{16}$
Command:	Write threshold DACs
Address:	0 - 15_{16}, $1F_{16}$ is broadcast *(There are 16 threshold DACs on this FEE).*
Data:	8 bits MSB first *(These are 8-bit DACs with serial input needing MSB first).*
Description:	Write 8-bit DACs individually addressed.

However, the same value can be written in all 16 DACs with one command when the address is 1F.

Op-code:	$1B_{16}$
Command:	Read channel enable register
Address:	0 *(There is only one such register in this particular FEE)*
Data:	n/a

Description: Read 64-bit channel enable register. The data is read back via the DLINK with channel 0 as the LSB and channel 63 as the MSB, in other words first-in first-out with command $1D_{16}$ above. The format of the data on the DLINK is a header followed by the data, as explained in the next section.

4. Data Flow from the On-Detector Electronics to the DAQ

All electronics read-back and event data from the On-detector electronics are transferred to the DAQ over the DLINK. The DLINK operates on the same principle as the CLINK, in that the high speed serial data contains information from up to 16 slower-speed serial data sources. The same Hewlett Packard and Finisar components are used as in the CLINK but now the source of the data is the On-detector electronics and the destination is the ROM. For non-calorimeter (triggered) systems, the ROM controls the event dataflow from the FEE via the Read-Event command. The event data has been written into a data buffer in the FEE on receipt of an L1 trigger accept command. After the ROM issues a read-event command to the FEE, the FEE starts transmission of that event data to the ROM. The receiver controller shown in Figure 2 detects the start of the data transmission and stores the data in ROM memory. The controller detects the end of data transmission and signals the status to the main controller.

The primary data from the On-detector electronics to the ROM is the event data, and secondary data is data read back from the On-detector electronics itself such as contents of registers or test patterns.

There are two types of data format accepted by the ROM over the DLINK: variable length and fixed length data.

Variable length data is typically event data when the FEE performs compression, e.g. zero suppression. The variable length data format has a header, a variable length data field, and a unique (compared to the data) trailer. The header, data field, and trailer must each have an even number of bytes. The first bit in the header is the start bit and must be set to one. The trailer must be unique so it can be distinguished from the data, however, the trailer must be the same for all FEE sections within a subsystem. Ideally the trailer should consist of zero's. The trailer must be followed by the idle state of the link (zero's). The 16 FEE sections which are transmitting data to the ROM over a DLINK must have the start bit aligned with each other. However, since the data field from one FEE section may be longer than the data field from another, the trailers are not usually aligned with each other.

Fixed length data can be event data or read-back data. The length of the data field may vary from command to command but is always the same for a particular command and for the 16 FEE sections transferring data over one DLINK.

A fixed-length data transfer still has a header and data, but is not required to have a trailer. (It must, however, be followed by the idle state of the link, i.e. zero's).

The construction of the header varies from subsystem to subsystem, and possibly within a subsystem, with the type of data being read out to the ROM. There are two categories of headers: headers sent with event data and headers sent with read-back data.

In general, an event data header contains, besides the start bit, the five-bit trigger tag data received with the "L1 Trigger Accept" command, the time the trigger occurred, and might have also a module type identification, serial number, status information, or other general information about the FEE section. The header should, if possible, contain information about the "occupancy" state of the FEE buffers, e.g. which buffer the data is from, or how many buffers are full/empty. This information can be used to verify the buffer model running on the ROM. A header for read-back does not require a trigger tag or time, these may be replaced by a copy of the command data field and address or other relevant information.

The variable length data trailer must be unique when compared to the data, and in most cases, 32 consecutive bits set at zero should satisfy this requirement.

Below two examples of data read out from the On-detector electronics are presented. The first example is a response to a "Read Event" command for a triggered sub-system which performs data compression. Therefore the data is of type variable length. The second example would be the FEE response to the command $1B_{16}$ "Read Channel Enable Register" presented as an example in the subsystem-specific commands section.

Example No. 1: Response to "Read Event" command.
Variable length data field.
Data read back from each FEE, four bytes header, 4 bytes/hit, four bytes trailer.

4 Bytes Header:	Start bit	1 bit = 1	
	Event data / Register data	1 bit = 1	1 = Data 0 = Register
	Trigger tag	5 bits	LSB first
	Reserved	1 bit	*to keep byte alignments*
	Trigger time	5 bits	LSB first
	Error code	3 bits	To be defined later
	FEE serial number	8 bits	LSB first
	Reserved or available	8 bits	*e.g., could be type of FEE*
4 Bytes Data/Hit	Channel number	6 bits	LSB first 64 channels on each FEE
		2 bits	
	TDC value	16 bits	LSB first
	ADC value	8 bits	LSB first
4 Bytes Trailer	Zeros	32 bits	all zeros

Example No. 2: Response to "Read Channel Enable" command.
Fix length data field.
Data read back from each FEE section, four bytes header, 8 bytes register data.

4 Bytes Header:	Start bit	1 bit = 1	
	Event data / Register data	1 bit = 0	1 = Data 0 = Register
	Command Op-code	5 bits	First-in, first-out
	Reserved	1 bit	*to keep byte alignments*
	Address received	5 bits	First-in. first-out *zeros in this case*

Error code	3 bits	To be defined later
FEE serial number	8 bits	LSB first
Reserved or available	8 bits	*e.g. could be type of FEE*
8 Bytes Data/HitChannel number	64 bits	LSB first, first-in, first-out

The FEE sections have several levels of event buffers implemented as registers or FIFOs. On each Trigger accept (L1 trigger accept) command from the ROM, an event is stored into an event buffer in the FEE. An event is read out to the ROM only after a Read event command is received by the FEE. So, after each Trigger Accept command there will be a Read event command. The minimum time from the Trigger accept to its Read event command is 2.2 µs. Note that there can (and will) be Trigger accept commands issued while the data of a previous event is still being read out to the ROM. In that case the next level of event buffer is filled. The number of event buffers depends on the system and is dependent on the readout time, the trigger rate, and the “allowable” dead-time. So, the order of Trigger accept and Read event commands could be Trigger, Read, Trigger, Trigger, Read, Read.

In other words, with a Trigger command an event buffer is filled on the FEE, and with a Read command the buffer is read out to the ROM. Since the ROM runs a model of the event buffers in the FEE (which is a requirement) the buffers in the FEE can not overrun. The ROM “knows” when the FEE can not accept additional Trigger commands, and inhibits the system from sending more Triggers (-> dead-time).

Event data can be substituted by register read-back data, when for diagnostics digital registers in the FEE are to be read back. The type of data could be marked by a type bit in the Header.

The Read event command is, at this time, generated on each ROM separately, which means the Read event commands of the ROMs in a system are not coordinated or synchronized.

5. Interface Specifications and Requirements on the ROM and FEE.

5.1. Requirements imposed on the transmitting section of the ROM

5.1.1. ROM must have serial fiber-optic transmitter to deliver electronics control commands to On-detector electronics (ODE). (SC-style connector)

5.1.2. The serial signal must be generated by multiplexing sixteen 59.5 Mbit/s serial lines using an HP Glink HDMP-1012 transmitter component with subsequent electrical/optical conversion. (specify mode)

5.1.3. Idle state of transmission link must be zero (no light)

5.1.4. The command protocol must adhere to the BaBar standard protocol described in this paper. (Run-time commands: leading zero, startbit, 5 command bits, 5 data bits; Non-run time (subsystem specific) commands: leading zero, start bit, 5 address bits, n data bits, n=0 for read commands, $0 <= n <= 2$ Mbits for write commands).

5.1.5. ROM does not send non-run time (sub-system specific) commands (set-up commands) when in run mode.

5.1.6. The minimum time between the start of transmission of subsequent Trigger accept commands must be 2.2 µs.

5.1.7. The minimum time between a Trigger accept command and its Read event command must be 2.2 µs. (The Read event follows the Trigger accept command)

5.1.8. The minimum spacing between the start of transmission of a Trigger accept command and a following Read event command that belongs to an earlier issued Trigger accept command is 15 nsec (one clock cycles).

5.1.9. The minimum time between the start of transmission of commands is 15 nsec (one clock cycles).

5.1.10. A buffer model (occupancy of FEE event buffers) must run in the ROM (or higher level) to ensure that the number of events stored at any time in the FEE does not exceed the number of allocated buffers.

5.1.11. The ROM must not transmit a Read event command if the FEE buffers are, according to the buffer model, empty.

5.1.12. The ROM must not transmit a Trigger accept command if all event buffers in the FEE are, according to the buffer model, occupied.

5.1.13. The jitter and phase stability of the Glink base clock must be better than +/- 0.5 ns (tbd).

5.1.14. The transmission of the commands (i.e. the calibration/timing strobe command) must be adjustable with increments of 16.8 ns (1/59.5 MHz). (This adjustability is on the ROM or in the FCTS.) Finer delay settings have to be implemented in the FEE.

5.1.15. ROM must be configurable to transmit commands to any combination of the 16 FEE sections. (Mask-off individual FEE sections).

5.2. Requirements imposed on the receiving section of the ROM

5.2.1. ROM must have serial fiber-optic link to receive data from the On-detector electronics. (SC-style connector, FINESAR transceiver)

5.2.2. Serial signal must be de-multiplexed into sixteen serial lines using an HP Glink receiver HDMP-1014 device. (specify mode)

5.2.3. The ROM must be capable of handling data received at rates of 59.5MBit/s, or 59.5MBit/s/2, or 59.5MBit/s/4 on each of the 16 demultiplexed lines.

5.2.4. The ROM must be capable of receiving data formatted according to BaBar standard protocol as described in this paper. Fixed length packets where ROM must count number of bits to determine the end of transmission, or variable length packets where ROM must determine end of event by detecting trailer. Type of transmission to be received is predetermined and command specific.

5.2.5. ROM must detect start of transmission of data received up to x us after data has been requested from the FEE. ROM must determine start of transmission by detecting start bit.

5.2.6. ROM must have time-out function in case that data expected from the FEE sections is not being received; (time-out range?)

5.2.7. ROM must be able to receive data from the FEE sections when one or more other sections are defunct or not connected (mask-off individual sections).

5.3. Requirements imposed on the receiving section of the On-detector electronics

5.3.1. ODE must have serial fiber-optic link to receive data from the ROM. (SC-style connector, FINESAR transceiver)

5.3.2. Serial signal must be de-multiplexed into sixteen serial lines using an HP Glink HDMP-1014 receiver device. (specify mode)

5.3.3. The ODE must be capable of handling data received at rates of 59.5MBit/s on each of the 16 demultiplexed lines.

5.3.4. The ODE must be capable of receiving and decoding data formatted according to BaBar standard protocol as described in this paper. (Run-time and non-run time (sub-system specific) command types).

5.3.5. All Commands are preceded by a minimum of one zero followed by a start bit (=1). (1 means light on fiber).

5.3.6. All command and address fields are received LSB first.

5.3.7. Run-time commands consist of 5 reserved command bits (0 through B_{16}) and 5 reserved data bits. Command and data bits are not sub-system definable. There are no address bits.

5.3.8. Non-run time (sub-system specific) commands consist of 5 command bits ($1D_{16}$ - C_{16}), 5 address or sub-command bits, and n data bits. n is dependent on the command. (0 <= n <= 2 Mbits for write commands, **n=0** for read commands).

5.3.9. Non-run time command $1F_{16}$ is reserved for future expansion.

5.3.10. Non-run time command $1E_{16}$ is used as sub-system reset.

5.3.11. A No-Op command or a command that is not defined must be decoded as no-operation.

5.3.12. The ODE must be capable of receiving commands spaced by 15 nsec (counted from the end of a command to the startbit of the following command). Exceptions are 1) Trigger accept commands which are spaced at minimum 2.2 µs and 2) Read event command which follows a Trigger accept command with a minimum of 2.2 µs. (Note that this is only true if the Read event command requests data from that Trigger accept command. If the Read event command request data from an earlier Trigger Accept command, the minimum spacing is 15 nsec.)

5.3.13. ODE must reset all timing or divide counters on sync command.

5.3.14. ODE must reset event buffer occupancy flags (or pointers) on Clear readout command.

5.3.15. ODE must save event data with trigger tag and state of timing counter in event buffer on Trigger accept command. (to be returned later to ROM on Read event command)

5.4. Requirements imposed on the transmitting section of the On-detector electronics.

5.4.1. ODE must have serial fiberoptics link with SC-style connector (FINESAR transceiver) to deliver event or read-back data to ROM.

5.4.2. Serial signal must be generated by multiplexing sixteen serial lines each at 59.5Mbit/s, 59.5Mbit/s/2, or 59.5Mbit/s/4 using an HP Glink HDMP-1012 transmitter device. (specify mode)

5.4.3. Idle state of transmission link must be zero. (no light)

5.4.4. ODE must not transmit data unless requested by ROM (Read event command or Read-back command). (See EMC exception)

5.4.5. The data structure must adhere to the BaBar standard protocol described in this paper. Data type can either be fixed length or variable length format. (See EMC exception)

5.4.6. Header field must precede data. (See EMC exception)

5.4.7. Start bit of Header in all 16 FEE sections connected to a ROM must be aligned in time.

5.4.8. Header and data format must be identical for all 16 FEE sections for a given command. (Number of data packets can be different from each FEE sections for variable length data transmissions).

5.4.9. Header field must be even number of bytes (one byte = 8 bits). Minimum Header field is thus 16 bits. Start bit is part of Header.

5.4.10. Data field for variable length data must be even number of bytes. (no requirements for fixed length data).

5.4.11. Unique (compared to data) trailer must follow variable length data transmission. Trailer should consist of even number of bytes with all bits zero. There is no explicit trailer required for fixed length data fields, but the data must be followed by the idle state of the link, i.e. zero's. (The ROM will test whether the fixed length data field is followed by zero's. The idle state of the link is thus interpreted as a trailer for fixed length data fields). (See EMC exception)

5.4.12. Transmission of event or read-back header, data, trailer (if any) must be continuous.

5.4.13. Maximum time between receipt of Read event command and start of transmission is 500 nsec.

5.4.14. EMC exception: The EMC system transmits its "event" data continuous, untriggered from the ODE to the ROM (no Header, trailer). All above requirements are however still valid for the register read-back data transmitted from the ODE to the dedicated read-back ROMs.