Software Evaluation and Irradiation Test of the SBS Technologies Model 620 PCI-to-VME Bus Adapter

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Abstract

Several detectors at the CERN LHC accelerator may need to place the readout, trigger and DAQ electronics implemented in a VME standard on the periphery of the detector in the experimental hall. Among these detectors are, for example, the Endcap Muon Systems of the Atlas and CMS experiments. These electronics boards must be able to withstand the LHC radiation environment expected in these areas.

While most of the boards for such applications are custom detector specific designs, the main VMEbus Master can be a commercial off-the-shelf (COTS) device if it is tolerant to the expected radiation levels. The other requirements of a VMEbus controller typically include a high speed connection to a remote host computer, high VME bandwidth, affordability and stable software support and maintenance. Only a few commercial devices on the market comply with these requirements, but none of them are qualified for a radiation environment. One of these devices is the Model 618/620 PCI-to-VME bus adapter available from SBS Technologies [1].

Software evaluation was based on comparison of performance of the TriDAS Hardware Access Library (HAL) [2] against the SBS Application Program Interface (API) [3]. HAL is a library developed for the CMS Data Acquisition System. It is a high level interface which allows a user friendly hardware access to VME or PCI modules. The purpose of the library is to provide a set of flexible tools which allow to change a significant portion of user's hardware and system software architecture with only minimal changes in the already developed code. The test measured the average time needed to write and read a 16-bit VME register from a PC running Red Hat Linux 7.0. The results of the irradiation test allowed us to obtain the limit of the Total Ionizing Dosage that the Model 620 adapter may withstand.

I. Overview of the Model 618/620 Bus Adapter

The adapter consists of two cards: a short form factor PCI card and a 6U*220 mm VMEbus card. The two cards are connected by a fiber-optic cable of total length up to 500 m. Models 618 and 620 are physically and functionally identical with one exception. Model 618 has a loopback diagnostic feature for programmable input/output (PIO) transfers; Model 620 does not. The fiber-optic cable consists of 50 um multimode fiber with duplex SC connectors. We have tested the Model 620 adapter with an optical cable of 25 m length.

The Model 618/620 interconnects the PCI and VME systems at the physical level using two methods of intersystem communication: Memory Mapping (MM) and Direct Memory Access (DMA). MM supports bidirectional random access from either system, the PCI bus master can access memory in the VMEbus system through a window in PCI memory address space, and the VMEbus bus master can access PCI memory from a window in VMEbus address space. The Model 618/620 supports two DMA techniques: Controller Mode DMA (with data rates up to 35 Mbytes/sec) and Slave Mode DMA (with data rate up to 13 Mbyte/sec)

The Model 618/620 adapter permits each bus to operate independently. The VMEbus adapter responds to and generates A32/A24/A16 accesses and supports D32/D16/D8 data widths. D32 and D16 Block Mode Transfers are also supported. The VME bus adapter can provide the system clock, reset and bus timeout feature as well as single-level and four-level Priority/Round-Robin arbitration. All seven VMEbus interrupts can be passed to the PCI system. Software drivers for Windows NT/98, VxWorks, IRIX, HP-UX, Linux and Solaris are available from SBS Technologies.

II. Software Evaluation

HAL is a library that contains a software layer between the user program and the driver software to access hardware. It is developed for the on-line environment of the CMS experiment at CERN. The library has been designed in order to allow the user to reuse the already written code with assumptions that the hardware and system-level software may change during long period from the initial design to commissioning at the LHC. "BusAdapter" classes implement an interface to the various hardware drivers. Several Bus Adapters are contained in the existing distribution available for downloading from the web page [2].

Our test measured the average time needed for a 16-bit VME PIO read/write access using a SBS Model 620 on a 200MHz and 1.4GHz PC running Red Hat Linux release 7.0, kernel 2.2.16-22. Access time was measured using the API supplied in the SBS Technologies Model 1003 Support Software v1.0 [3] as well as using two methods of access within the TriDAS HAL ver-01-10.

Of these two methods of using the HAL, the first performed accesses by using the HAL's VMEDevice class directly, and the second performed the access by using a VmeBusAdapter class, SBS620x86LinuxBusAdapter, directly. The VMEDevice class is a higher level of abstraction above the VmeBusAdapter classes. It uses symbolic item names for registers rather than addresses. The VMEDevice class takes an item name and extracts information from an address table, which can be stored in an xml file and contains the information like: address, byte-size, etc. The class passes this retrieved information to a VmeBusAdapter object to perform the actual VME access. This overhead can be reduced by just retrieving and saving this information from the address table once and calling a VmeBusAdapter object manually.

The VmeBusAdapter classes are device specific classes that serve as a direct wrapper to the device driver or API. An example of a VmeBusAdapter class is SBS620x86LinuxBusAdapter. These classes inherit the properties of a generic VmeBusAdapter class called VMEBusAdapterInterface, which provides virtual functions to perform the VME read/writes.

On a 200MHz PC using the SBS API software to directly issue a 16-bit PIO read/write VME access took on average 19.0 microseconds to issue a read command and 17.3 microseconds to issue a write command. On this same system, performing identical accesses using the TriDAS HAL's VMEDevice class took on average 64.0 microseconds to issue a read command and 63.0 microseconds to issue a write command. Using a HAL VmeBusAdapter class directly, it took on average 38.7 microseconds to issue a read command and 37.0 microseconds to issue a write command.

Performing the above tests on a 1.4GHz PC, the following was found. Using the SBS API it took on average 5.4 microseconds to issue a read command and 5.0 microseconds to issue a write command. Using the HAL's VMEDevice class took on average 9.8 microseconds to issue a read command and 9.2 microseconds to issue a write command. Using a HAL VmeBusAdapter class directly, it took on average 7.4 microseconds to issue a read command and 6.9 microseconds to issue a write command.

The results are summarized in Table 1. As one can see, the SBS API that is a low level software interface, provides the fastest access to hardware, while the HAL library, as an intermediate software level, provides slower access.

Table 1: VME access times for various classes

Class	PIO read, us	PIO write, us
200 MHz processor		
SBS API	19.0	17.3
HAL VMEDevice	64.0	63.0
HAL VmeBusAdapter	38.7	37.0
1.4 GHz processor		
SBS API	5.4	5.0
HAL VMEDevice	9.8	9.2
HAL VmeBusAdapter	7.4	6.9

III. IRRADIATION TEST

The irradiation test of the VME board of the 620 VMEbus adapter set was conducted with a 63 MeV proton beam at the Crocker Nuclear Laboratory at the University of California, Davis (UCD). The 620 VME board was placed on a passive extender outside of the 6U VME crate and irradiated by protons at a rate of 1rad/s for Si while 16-bit PIO and DMA read/write accesses were performed on a 8 Mbyte VME memory board through the VMEbus. Since the memory board was residing in the crate, it wasn't affected by the irradiation. The proton beam at UCD can be focused up to ~7 cm in diameter (Figure 1), still providing a uniform exposure, so we used four scans of the board that allowed us to irradiate all critical components. Among these components are several programmable logic devices (from Altera, Xilinx, Lucent, Lattice, Atmel).

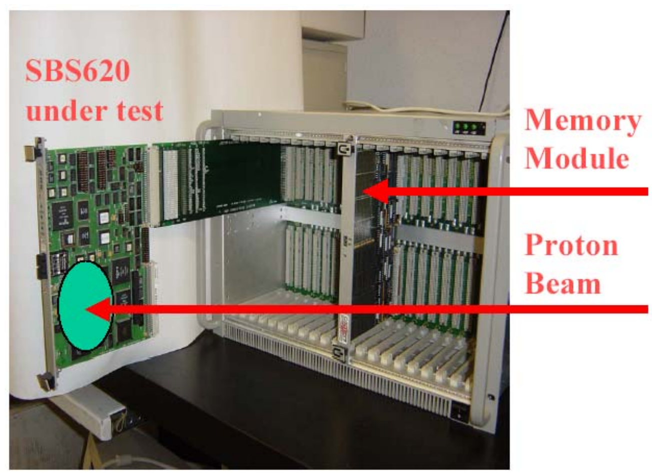

Figure 1: SBS620 adapter on an extender board

Software ran a repetitive loop issuing PIO (2 bytes per access) and DMA (100 bytes per access) read/write commands to memory board. The top two corners and the lower right corner of the 620 board were each exposed with 1KRad of radiation with no errors being detected. These areas were populated primarily by Xilinx and Lattice programmable chips and discrete logic devices (drivers, registers etc). The same is not true for the lower left corner, which is the only part of the 620 board with two Altera PLD EPM7192SQC160 and one

EPM7064STC100 PLD. After 250 Rads of exposure a DMA read error occurred, followed by a DMA read/write error after 445 Rad, and then a DMA write error at 516 Rad. Since 100 bytes were read/wrote per DMA access and 2 bytes were read/wrote per PIO access, the occurrence of only DMA errors may be statistical rather than an indication of DMA access being more susceptible to radiation effects. Finally, after 766 Rads of exposure, the board stopped functioning with the driver being unable to reload even after subsequent power downs of the VME crate and PC.

Altera EPM7064 and EPM7192 PLD are members of the MAX7000 family of EEPROM-based programmable devices. Most likely, the failure occurred due to degradation of the configuration memory.

IV. CONCLUSION

We have performed an irradiation test and software evaluation of the SBS Technologies Model 620 PCI-to-VME bus adapter. Our test measured the average time needed to write and read a 16-bit VME register from a PC running Red Hat Linux 7.0. The results of measurements on 1.4GHz PC showed that using of SBS API provides ~80% faster access to VME register than HAL's VMEDevice class and ~40% faster access than HAL's SBS620x86LinuxBusAdapter class directly.

During the irradiation test of the 620 VME board an occasional errors were observed starting from 250 Rad, and the board stopped functioning at 766 Rad of radiation. The most susceptible to radiation component on board turned out to be the Altera PLD. We also noticed that the SBS Technologies is periodically replacing some programmable components on 620 boards, while providing the same functionality. For example, on the most recent version of the VME 620 board we have, all Xilinx FPGAs were replaced by Lucent programmable devices, but the Altera EPM7192 and EPM7064 PLD's are still in their places. Such changes on the component level may affect board tolerance to radiation.

V. REFERENCES

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