VARCReadOut User's Manual

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1. Introduction

1.1. General Description

VARCReadOut was written as debugging and developing tool for MINOS far detector front-end electronics. Primary use of it was meant to be able to fully exercise all of the capabilities of the electronics and to quickly identify all existing problems. The software was expanded to be a mini data acquisition system, but it was never meant to be such, and for reasons of speed of read-out and processing, can handle limited amount of data flow.

VARCReadOut is a GUI application written in C++. Its user-friendly interface makes it easy to learn to use all of the capabilities of the application. A user can open an arbitrary number of windows designed to perform various tasks. The windows are grouped under 4 different hierarchical levels pertaining to the relevant part of the electronics: VXI crate, VARC (**VA** chip **R**ead-out **C**ontroller), VFB (**V**A **F**ront-end **B**oard), and VA chip. The functionality of all the windows will be described below.

1.2. Running VARCReadOut

VARCReadOut requires the presence of National Instruments MXI-2 VME interface. Prior to running *VARCReadOut*, the user must run *Resman*, an application provided by National Instruments VXI software package. *VARCReadOut* will not be able to detect whether *Resman* was or was not run, and in the latter case, the VXI resources will not be initialized, and therefore the application will not work.
NOTE: all application using the VXI bus must be closed befor *Resman* can be run.

2. Main Tree View

2.1. Functionality

Main Tree View is meant to be used as the central control window during a session. By right-clicking in the window, a pop-up menu will appear pertaining to the highlighted level of the tree. When the program is started, only the tree root: VXI crate appears. Right-clicking will bring up a menu with options VXI raw I/O and Add VARCs. By selecting the latter option, *VARCReadOut* will search for all available VARCs inserted into the crate, and will add up to 6 corresponding leaves to the tree. Associated with each VARC leaf are 12 VFB leaves, each having 3 VA chip sub-leaves. Right-clicking on any tree leaf will display the available menu options.

NOTE: Main Tree View will always remain open in non-maximized state.

3. Menus

The main menu has some additional options which are not available through pop-up menus. These are explained below.

3.1. Add

This menu group duplicates the Add VARCs menu item available in the pop-up menu, and can also be used to open a Pedestal Monitor and a Time Stamp monitor. The former can be used to obtain a real-time histogram of events read out from the buffers; the latter – to obtain a distribution of time stamps readout from the buffers. Look below for a more detailed description of these dialog windows.

3.2. Workspaces

The Workspaces menu group duplicates all the commands to open working windows that can be accessed from the pop-up menus. Here, the enabled commands are those that pertain to the currently selected component plus all of the components closer to the root. Thus, if a particular VA chip is selected, the user can open windows pertaining to that chip, the VFB that houses the chip, the corresponding VARC, as well as Raw VXI I/O.

3.3. Error Tracking

There are certain conditions that may turn on one or more VARC error registers. These are not inserted into the data flow, rather the user has to check the error registers for presence of errors, if there is a need to do so. *VARCReadOut* provides a way of automatic error checking. The errors can be checked with a periodicity of 1, 2, or 5 seconds. One can enable error checking on all ETCs (**E**vent **T**imestamp **C**ontroller; each ETC houses 2 VFBs), or any combination of the six ETCs.
NOTE: items in this menu group are only enabled when the Main Tree View is the active window.

3.4. View

View menu group contains the standard windows options of hiding and showing the status bar and the toolbar. The additional menu item, which is accessible only when the Main Tree View is the active window, can be used to show the version of the FPGA's on the VARC. Master clock, slow controls, ETC, and sparsifier versions of firmware are included in the associated pop-up dialog box.

4. Working Windows

All of the working windows in *VARCReadOut 3.0* are described in the section below. Possible uses are also included in the description.

4.1. VXI Raw I/O

Whenever the user desires a low-level access to the registers, VXI Raw I/O window is extremely helpful. It is not expected, however, that a non-expert electronics user will get much use of this window, since it requires knowing the address of the particular register. Both address and data are expected to be in hexadecimal representation.

4.2. VARC-level Windows

All of the windows below are only available when at least one working VARC was found in the crate. The desired VARC leaf in the Main Tree View must be selected to get access to the corresponding board.

4.2.1. VARC Settings

This window contains all of the options that the sparsifier, the ETCs, and the master clock have. The functionality of these options is described in the table below. For a more detailed description, refer to the VARC user's manual.

Master Clock Settings	
Clock from the VARC	In running mode, clocks for all VARCs will be generated externally. The user has an option of generating the clocks on the VARC. If, however, the board cannot detect an external clock, it automatically switches to generating clocks itself.
Enable Executes	When an ETC is in the automatic mode, it needs to get executes for triggerless pedestals or for cal-injects. Master Clock takes care of this setting.
Manual Slow Control	This option should only be used for testing. Manual control of VFB clock or data lines can be obtained this way. Software will be driving the line at a frequency of a few hundred Hertz if this option is enabled.

ETC Settings	
Hold Delay	The length of delay between the trigger and the sampling time on the VA chip, in units of 12.5 ns.
Read-out period	The frequency of the ADC clock, in units of 50 ns with an offset of 50ns.
Enabled Chips	The user may disable any combination of chips on an ETC. Any data coming from those chips will not get readout.
Fake Data	Used for testing only. When enabled, for every trigger that the ETC gets, the time stamp and the ADC value are both transferred as preset values.
Auto	Enables the automatic mode for cal-injects or triggerless pedestals. In this mode, the ETC expects an execute to generate respective event.
ETC Mode	Any ETC can independently be in any of the 4 modes: disabled, cal-inject, triggerless pedestals, or normal.
Sparsifier Settings	
VARC ID	A VARC is assigned an identification number which ranges from 0 to 3. This will be used by DAQ for easier data sorting downstream.
Buffer Switching	Enables automatic (50 ms) readout buffer switching.
Data Sparsification	Enables digital threshold comparison of data. Can be used to mask out pedestals and only keep “real” events in the data.
C.M. Correction	Enables Common Mode Correction. Of the 22 channels read back from a VA chip, 4 (#1, 19, 20, 21) can be used to make automatic common mode noise subtraction.
Pedestal Subtraction	Enables automatic pedestal subtraction at the sparsifier. This option can be used to make all pedestals appear at a fixed value.
Manual Sparsifier	Used in testing mode. If the data is coming as triggerless pedestals, common mode correction, pedestal subtraction, and sparsification will be automatically ignored. If the user does indeed want to enable a combination of those settings, manual sparsifier option needs to be enabled.
External Trigger Input	The limo connector on the VARC can be used as external trigger input. A word of special format will be written into the buffer.
Force Test Patter to Buffer	Pressing on this button, disables the ETCs, and writes out a test pattern of walking 1’s into the corresponding read-out buffer.

In the lower left corner there is a check box, which indicates whether the settings were changed by the user since last initialization or refreshing of the values. The default values of the settings can be changed by double-clicking on an open area of the window. A dialog box confirming the change will appear before they can be changed. From then on, *Initialize to Default Settings* will write the saved settings to **all** ETCs.

4.2.2. Graphic Buffer Read-out

Although not very practical for data readout, this window is rather handy to analyze the test pattern produced by the sparsifier. Data is displayed graphically in vertical columns, each row in the column corresponding to a 32-bit word read back from the buffer. White pixels represent a 0, black represent a 1. The user can change the selected word by either scrolling down or by left-clicking the mouse in the desired location. Any one of the two buffers can be readout at any particular time. Unfortunately, only half of the buffer fits on one page. In order to look at the second half of the buffer, the user must click the appropriate page. If the *Test* check box is enabled, the data is compared to an expected pattern of walking 1’s. In this mode a white pixel is a correct 0, a black pixel is a correct 1, a red pixel is a 1 that should be a 0, and a green pixel is a zero that should be a 1. By selecting the *Data* check box, the user enables interpretation of the data. The information coded in two 32-bit words is displayed in the right side of the lower part of the screen.

4.2.3. Buffer Read-out

This window serves multiple purposes.

- Single readouts. There are 2 ways to read-out the data and display it right away. These are implemented with corresponding buttons on the screen: *Read Buffer* and *Read New Data*. To use the former method, the user must type in the number of words to be readout and select the source buffer. This feature can be very useful if there is no constant flow of data or when it is desired to look at events singly (e.g. cal-inject or pedestals). The latter method is typically more practical if there is a constant flow of data. In this case, if buffer switching is not enabled, the software switches the read-enabled buffer on the VARC and reads out the data from the presently read-enabled buffer. If, on the other hand, buffer switching is enabled, the software waits for the buffers to switch, and then does the readout. The number of words readout is displayed in the edit box in the top left-hand corner of the window, the buffer from which the data was readout is displayed in the area "Readable buffer".
- Continuous read-out. If the user expects a slow constant flow of data, this feature is of great help. During the specified time (in ms), the computer will keep on reading out the buffers. All of the data will then be displayed in the list.

  NOTE: in order for this option to work, buffer switching must be enabled.
- Long runs. This option is designed to make *VARCReadOut* a mini-DAQ system. The data from any single VARC will be readout continuously and written to the file specified by the user. The user can specify the length of the run or the run can be interrupted at any time after it began. The time stamps included in the data have a range from 0 to 1 second. If time sequence of events is desired, software generated 1 second time stamps can be included into the output file.
- Display options. In most cases, it is not necessary to display all of the data read from a buffer. By default, the window will only display the first 300 data words. If it is necessary to look at all the data, the option *Do not display all data* must be unselected. As a check that the data coming from the VARC is not corrupted, the check button *Alert to bad data* is included. If the option is enabled, prior to displaying the data, the software looks to see that the following conditions are satisfied:
  - Lower word MSB is not on.
  - Upper word MSB is on.
  - Lower word and upper word parities are even.
  - Time stamp value is less than 640 million.
  - Selected VFB value is less than 12
  - Selected VA chip value is less than 3
  - Selected VA chip channel value is less than 22
  - Header is not equal to zero.

  If any of the above conditions are false, a pop-up dialog box shows all of the words that it found corrupt.

4.2.4. View/Edit Pedestals

Functionalities of this window make it handy for many reasons. In combination with *VARC Settings* and *Buffer Read-out* windows, one can do all of the data acquisition necessary.

- Pedestal runs. Prior to doing a run, the user should select which part of the electronics the run applies to. By default, the root of the tree (inside the window), the VARC is selected. There are two ways of doing the pedestal runs, which is determined by whether the *Triggerless Run* option is selected, or not. In the first case, corresponding ETCs will be put into triggerless pedestal mode, and software will attempt to issue executes for triggerless pedestals. For the latter case to work, buffer switching must be enabled. Data is being constantly readout and averaged until a specified number of events is not accumulated for any one channel or until the user interrupts the run. At the end of the run the averaged values of ADC on each VA chip channel are displayed in the list.

- RAM access. Four buttons allow the user to read all corresponding or write selected pedestal and threshold values to the RAM on the VARC. When writing pedestals or thresholds, if no values are selected, the user is given an option to change all the currently displayed pedestals.
  NOTE: before being written to the RAM, values are rounded off to the closest whole number.
  NOTE: negative numbers will be written as 2's compliments. One has to be careful to avoid such a confusion.
  NOTE: for the duration of the reading or writing all of the ETCs are disabled and then returned to the original mode. This is done to prevent corruption of read/write data.
- Manipulation of list entries. All of these buttons are self-explanatory. As with writing pedestals, if no items are selected and *Subtract a Number*, *Add a Number*, or *Set Selected Peds* are pressed, the user will be given an option to perform the selected operation on all values in the list or abort the operation.
  NOTE: by double-clicking left mouse button on a list entry, a dialog box will appear prompting to set the selected value to any chosen value. Double-clicking on the top row, give a possibility to change all of the values.
- One-shot Triggerless Peds. Pressing the button will send an execute to the corresponding VFB, VA chip or the whole VARC (depending on the part of the tree selected on the left). In order to receive this trigger as pedestals, the ETC(s) have to be set to triggerless pedestal mode and VA chips must be enabled.
- Cal-inject. The user has an option of injecting charge to a particular chip of a particular ETC. This can either be done singly or multiple times.
  NOTE : if you want to inject charge to chip 0 of VFB#1, you need to select ETC#0 and set chip value to 3.

4.2.5. Block Transfer Timing

This very simple window has the only purpose of testing the speed of block transfers. Sadly, *VARCReadOut 3.0* can only do 32-bit transfers. As one can easily check, it takes about 20 ms to readout the full buffer. This only means that *VARCReadOut* cannot handle information from more than one VARC, which is not a consideration since it wasn't meant to do that in the first place.

4.3. VFB-level Windows

4.3.1. VFB Slow Controls

An essential part of the settings of the electronics, slow controls enable the user to power the voltage regulators on the VFB (ASD-lite 3.3V supply, VA positive rail and individual VA negative rails) and change the bias settings, namely V_{fp}, V_{fs}, I_{sha_bias}, dynode threshold and cal-inject charge. All of these settings are controlled by 7-bit DACs. The ADC on the front-end board can be used to read out the voltage on the regulators and the temperature sensor on the board.

The default settings can be changed by double-clicking on an open part of the window. A dialog box will appear asking for confirmation, just like when changing default settings in VARC Settings window. The only settings that are stored are the DAC values. By default, all voltage regulators are brought up in active state.

NOTE: the threshold is bipolar with 64 being ~0V. Therefore, in order to get valid results the threshold value must be between 0 and 64.

4.3.2. DAC Scan

This window is meant to be used very infrequently. The purpose of the scan of the multi-dimensional parameter space is to determine the best operating point for the front-end electronics. The scan is performed over V_{fp}, V_{fs}, I_{sha_bias}, hold delay, and readout period, with cal-inject scan and pedestal calculations done at every point.

4.3.3. Cal-inject Scan

The quickest way to verify that the VFB and the attached chips all work is to perform a cal-inject scan over all channels of all chips on the board. Using this window, the user needs to specify the range of charge values for the scan, step size of values, and number of points per charge setting per channel. Once the scan is complete, it is easy to look at the gain curves of all chips and channels using the drop lists. The other parameters that one may need to specify are the limits for calculating the gain and at which charge value to calculate the non-linearity. Typically, one will want to use the lower range of the scan for calculating the gain (default is between 0 and 30) and the upper-most value for calculating the non-linearity (default is 127).

One can have the window produce a graphic dump of the results into a PostScript file by checking the appropriate box. The user can define the filename, and can also label the VFB with a corresponding serial number. If the number is typed in, by default the filename will be "VFB[*serial number*]_cal_scan.ps". This can be changed, if desired. If a file with the given name exists, the user will be alerted and given an option to change the file name.

4.3.4. Spectra Display

This window was designed to have a quick way of looking at the spectra of all channels of enabled VA chips of the selected VFB. Prior to taking data, the user should make sure that data is actually coming. No sparsifier, ETC, master clock, or slow controls settings will be changed by the window. Data will be acquired for as long as is desired, but only the last 20000 events are kept. (NOTE: opening this window requires 2.6MB of memory, so don't get carried away opening multiple windows.)

A run can be started and stopped with the same button. The user has an option of seeing all events, or make a cut on the range of acceptable ADC values. If the limits are changed, to enforce them the check box must be clicked.

4.4. VA Chip-level Windows

4.4.1. Oscilloscope View

Frequently it is instructive to look at the pulse shape as it is coming from the VA chip. Oscilloscope View window is designed to do that as quickly as possible. Once the scan is begun, the software scans through specified hold delay values, changing the delay after every buffer switch. At each value of the delay it reads out up to six points for the specified channel of the selected chip. The points are then displayed. The user has an option of looking at a pulse created with cal-injects (default state). In this case, it is up to the user to change the charge value through VFB Slow Controls. The second option is to look at the pulses that are coming back from other triggers. This method would be less practical if the pulse height varies from event to event. Moreover, the algorithm requires a constant flow of data, i.e. at least one even in each readout cycle.

Data can also be written out to a file by selecting appropriate check box.

NOTE: Buffer switching must be enabled for this display to work.

4.4.2. Cal-inject Scan

This scan is a simpler version of cal-inject scan on the VFB level. The advantage is possibility of writing data out to a file and the scan goes considerably faster.

4.5. Monitors

4.5.1. Pedestal Monitor

Pedestal monitor is a tool designed to histogram events coming from a particular channel. To accumulate data in the monitor, one needs to be reading out new data in *Buffer Read-out* window. The data gets sent to the monitor if it is open, and the monitor is updated in real time.

The user can zoom in using the arrows on the right side of the screen. Accumulated data can be cleared by double-clicking on the graph.

4.5.2. Time Stamp Monitor

Time stamp monitor works in very much the same way as the pedestal monitor does, but instead it produces a distribution of time stamps. One can look at the raw distribution of time stamps, modulus 16, or modulus 8. Ideally, the number of entries in odd and even bins should be closely matched.

5. Shortcut Keys

The following shortcut keys are enabled in *VARCReadOut 3.0*.

Key	**Action**	**Available from windows**
F2	View VARC Version	Main Tree View
F4	Open/Close Time Stamp Monitor	All
F5	Open/Close Pedestal Monitor	All