pCT PAD-E Operations

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This article is intended for use in operation and diagnostics of the Amplifier Digitizer Board (PAD-E). The PAD-E interfaces with the Silicon photomultiplier Interface Board (SIB) and provides bias and signal readout from the attached Silicon Photomultipliers (SiPMs).

I. HARDWARE SETUP

Required for the operation of the PAD-E, and the PAD-E software:

- 6V+, 3A+ Powersupply
- Ethernet or mini USB cable
- Computer running Windows XP or higher
- A computer fan (for the FPGAs)
- Male to male HDMI to mini HDMI

The PAD-E is assembled as follows:

First connect the power supply (OFF) to the PAD-E using a two pin terminal block connector or a 5mm DC jack connector. The PAD-E is to be powered with a minimum of 4.75V and no more than 5.10V and the maximum current draw for the device should be no more than 3.10A. Next connect the PAD-E to the computer using a mini USB or Ethernet cable. To attach the SIB, correctly orient the SIB so that the short and long sides of the socket align with the short and long sides of the connector on the PAD-E, then firmly press it onto the PAD-E. If using multiple PAD-Es: for time/trigger synchronization across all boards, an HDMI loop must be installed. This is accomplished by placing a jumper on the master board on the two leads labeled "Master Select", and installing an HDMI loop as follows:

1. Attach HDMI cable from "MASTER BUS OUT TO NEXT MASTER" on the master PAD-E to the "MASTER BUS IN FROM PREVIOUS MASTER" on the slave board.
2. Attach HDMI cable from "MASTER BUS OUT TO NEXT MASTER" on the slave board to the "MASTER BUS IN FROM PREVIOUS MASTER" on the master board.
3. If using more than two boards, perform the above steps, but instead of returning to the master board immediately, continue the chain to the last board in the stack, then connect "MASTER BUS OUT TO NEXT MASTER" on the last slave board to the "MASTER BUS IN FROM PREVIOUS MASTER" on the master board.

Attach a voltmeter to the two pins labeled "SIPM_BIAS." Upon powering the PAD-E, the voltage reading should be just above 4.00V. If the voltage reading is significantly higher than 4.00V (i.e. 60.0V) or much (i.e. 3.60V), immediately cut power to the board and consult the troubleshooting section.

II. SOFTWARE INSTALLATION & SETUP

Before installing the PAD-E software, be sure to install WinPcap and Pcap.Net drivers, available from http://www.winpcap.org/ and http://pcapdotnet.codeplex.com/, repsectively. Installation instructions for these drivers can also be found on their website. In the current version of the PAD-E software, installation can be performed seemlessly by running the *setup.exe*. This will create a folder in the Windows Start Menu labeled *Fermilab*. In this folder you will find a shortcut labeled *TB4* which can be used to start the software. After installation, the software will start automatically. Upon startup of the software, a window will be displayed showing information about the software version, as seen in figure 1. Once OK is clicked, it will bring up the RUN interface as seen in figure 2. The RUN interface will be used to connect PAD-Es to the computer, program PAD-Es, and set run parameters and take data.

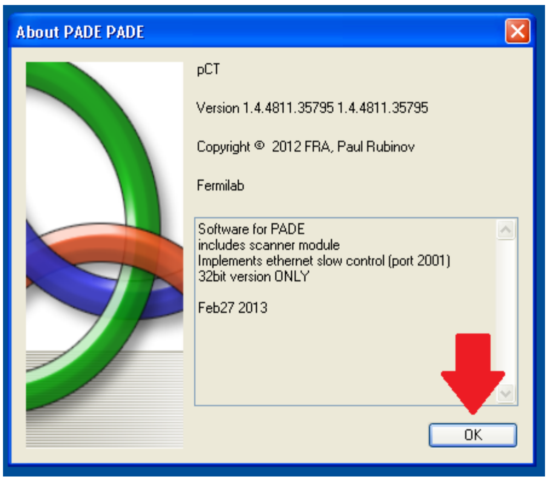

FIG. 1: The startup window.

Connection to the PAD-E can be made in one of two ways:

1. USB: If using USB, click "List Devices". If the PAD-E is properly connected via USB and powered-on, then the number of currently connected and powered devices should show. If an incorrect number displays, consult the troubleshooting section. Click Open, select the PAD-E to connect to, and then click "Open" on the dialog box. If the "Unavailable" is listed in the dialog box, click "Close", wait a few seconds, then repeat this step. After a PAD-E is connected, "OK" should appear in the status box to the right. The close button will close the connection to the PAD-E.

2. Ethernet: If using Ethernet, click "Choose" and select the appropriate Ethernet adapter, then click "Activate". Another dialog will appear asking for the serial number (SN) of the device; the serial number of the PAD-E is printed on a white label on the board. The first device that is added is the MASTER, and subsequent additions, through repetition of this step, are the SLAVES. If properly connected, the status box to the right will display OK. If the PAD-E fails to connect, consult the troubleshooting section. This method is effective when using more than one PAD-E simultaneously. The close button will close connection to all connected PAD-Es.

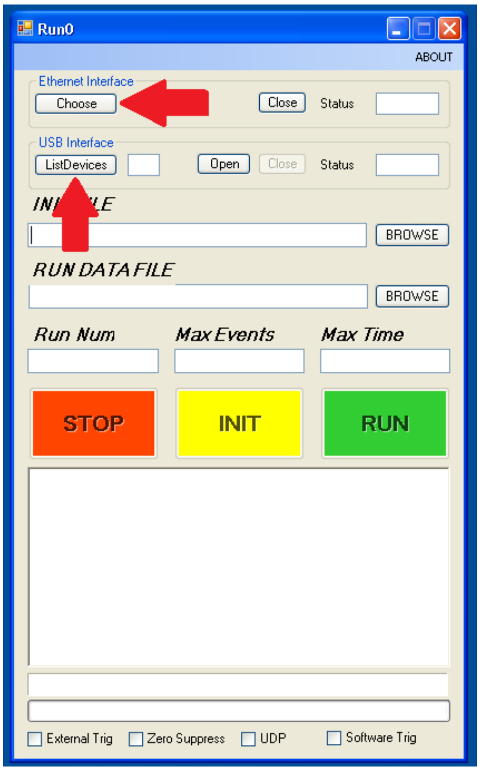

FIG. 2: The RUN interface at the program's startup.

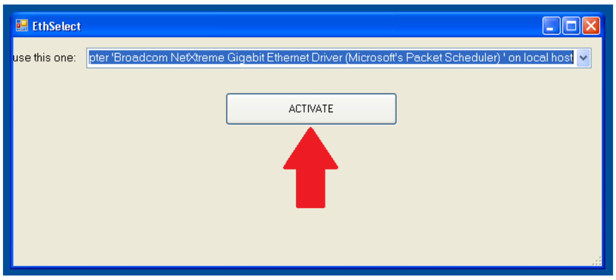

FIG. 3: The Ethernet selection menu.

Once the PAD-E(s) have been connected successfully, a small green box should appear displaying information about the board, including the serial number, firmware version, and type. If the firmware version reads 0, consult the troubleshooting section. To select another PAD-E, for setup/modification, simply click on the corresponding button, and settings specific to that board can be set/adjusted.

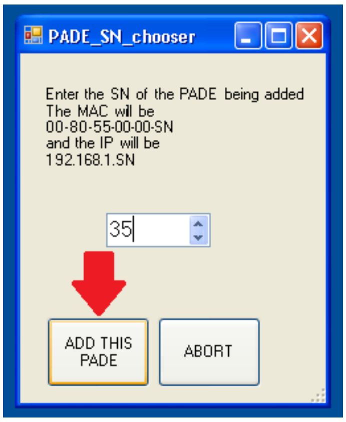

FIG. 4: The PAD-E assignment window.

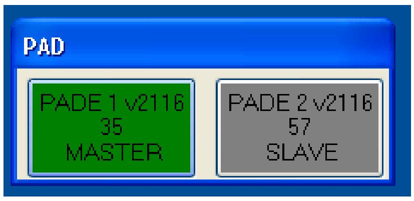

FIG. 5: Successfully added Master and Slave PAD-Es, where the selected PAD is in green.

After a board is connected to the computer successfully, it must be programmed using a setup file, which will set different ADC settings. This is done by clicking "Browse" under the INIT FILE heading and selecting the appropriate .tb4 setup file.

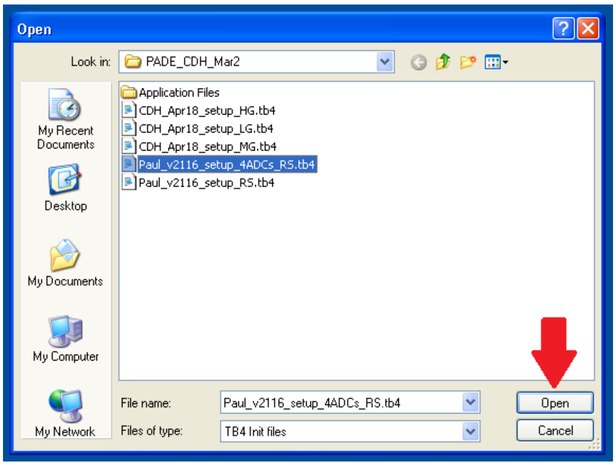

FIG. 6: A sample .tb4 setup file being selected.

After opening the setup file, its contents will be displayed in the box at the bottom of the interface. Once the contents are confirmed correct, clicking the yellow "INIT" button will program the PAD-E.

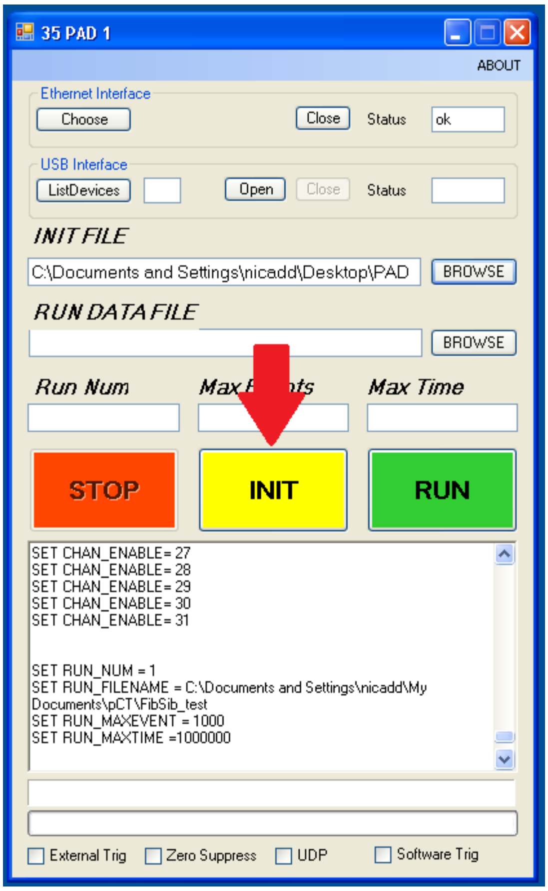

FIG. 7: The loaded .tb4 file with contents displayed in the lower window (pre-initialization)

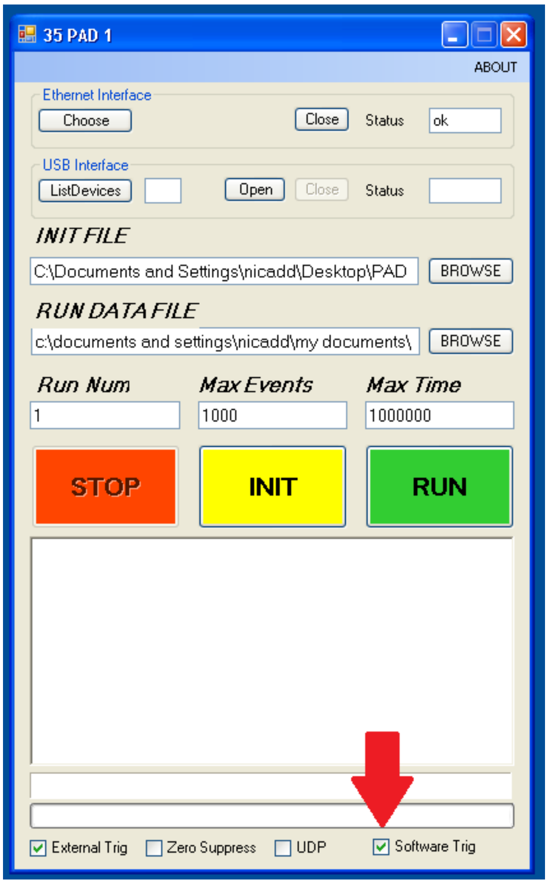

FIG. 8: The initialized PAD-E.

After programming the PAD-E, the Run Data File, Run Num, Max Events, and Max Time, boxes should be filled. They can be adjusted manually to set run parameters and name and location of the data file. At the bottom of the interface will be several check boxes. External Triggering will always be checked, regardless if Software Trigger is to be used. If Software triggering is to be used, then check the box. When using an Ethernet connection and wish to receive data or send it to another location, check the UDP box. This will cause data to be received in packet mode, rather than in ASCII format. The program will overwrite files without warning, so be sure the filename and run number are correct.

There are several menus in the PAD-E software. The most commonly used are: the previously seen "RUN" interface, "REGISTERS", "SCOPE", "HISTO", and "SCANNER". A description of each menu can be found below:

1. RUN: This is the main interface used for connecting and programming PAD-Es, setting run parameters, and taking data. The buttons under Ethernet Interface and USB Interface are used to connect to the PAD-Es. The "RUN" and "STOP" buttons start and end data acquisition, respectively. The INIT FILE browse button can be utilized to search for setup files to program the PAD-Es as well as

to search for files that set the bias and offsets for the SiPMs (also .tb4 extension). The RUN DATA FILE browse button can be used to specify as specific location and file to store collected data. The Run Num box displays the run number and can be manually set. The Max Events box is used to set the maximum number of events per run. The Max Time box sets the maximum time for data collection. External Trig is always checked and allows the PAD-E to be triggered. UDP enables/disabled packet mode for data collection. Software Trig is checked when no external triggering is used; even when no external triggering is used, External Trig remains checked.

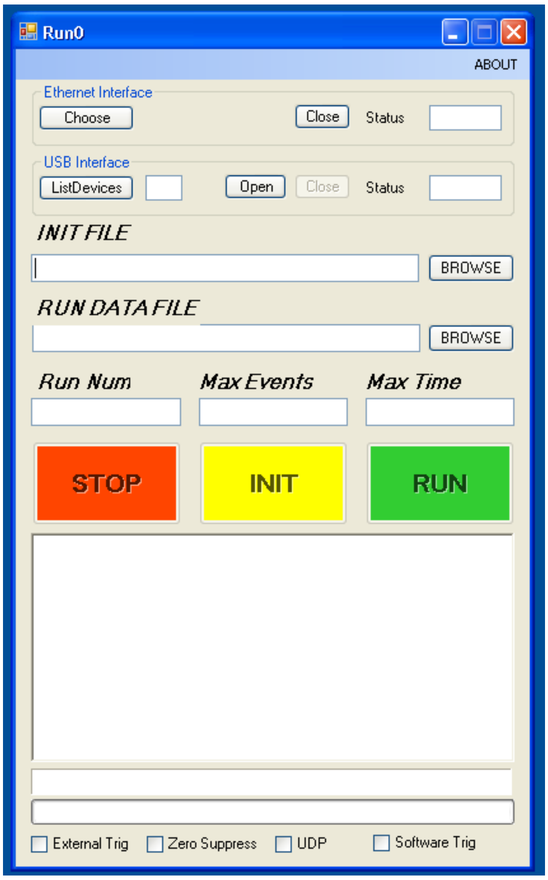

FIG. 9: The RUN window.

2. REGISTERS: This menu contains memory addresses that can be written to or read from using the buttons W and R, respectively. They can be used to obtain information from on-board monitoring such as voltage and current, or can be used to modify different PAD-E settings. All values that are written to the registers are in Hexidecimal, but readout may be in either hexadecimal or decimal.

   a. MAIN: This tab contains general status registers, ADC control, triggering, etc.

   b. BIAS: This tab contains registers that pertain to bias voltage, channel offsets, and voltage and current monitoring.

   c. FLASH: This tab contains registers relative to flashing the FPGA memory.

   d. EXPERT: This tab contains port status registers and advanced ADC control.

   e. ZS: This tab contains status and control registers, software triggering, zero suppression settings, and frame length registers.

   f. THR: This tab contains channel threshold registers.

   g. ETHER: This tab contains registers pertaining to Ethernet settings. (see technical information section for additional info.)

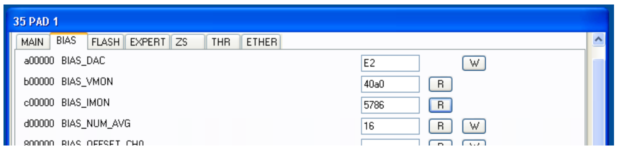

FIG. 10: The (truncated) REGISTERS window, with respective tabs.

3. ARRAYS: This menu allows reading data from specific locations in memory.

4. SCOPE: The scope allows one to see real-time data acquisition for one or multiple channels. Supports custom display ranges and infinite persist.

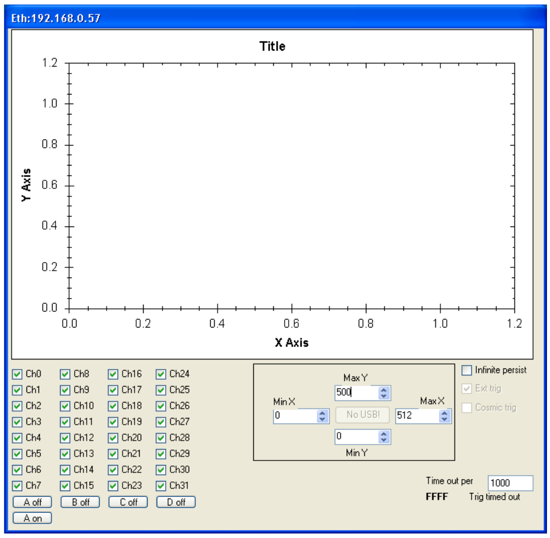

FIG. 11: The SCOPE interface prior to a run.

5. HISTO: The histo scanner allows for automated tuning of SiPMs and the ability to create a bias offset file. Can be used to fix the pedestals and

read the bias offsets of a PAD-E. Also contains an automated IV curve plotting tool. Supports saving of the displayed histogram. Can display one or multiple channels.

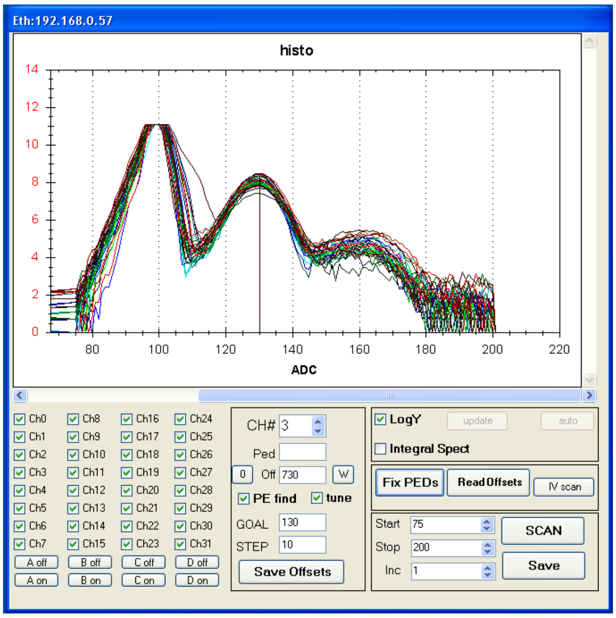

FIG. 12: The HISTO scanner window, with an example SiPM characterization.

6. Bias Offset: This menu allows for manual adjustment of channel bias offsets.

7. FLASH: This menu allows for the burning of the FPGA.

8. GBE: This menu [REQUEST INFORMATION]

9. Scanner: The scanner allows for real time display of ADC counts above a certain threshold. Allows for the display of one or multiple channels. The array of check boxes to the left are used to display one or multiple channels, the buttons below as control for columns. The LogY will set the plot to display with log y. Vth is a threshold that can be set; this will cause the program to only look for and display the number of counts that exceed the threshold. Sample per sets the sampling rate; a lower value results in a higher sampling rate, and vice versa. The SCAN button starts the scanner, and the CANCEL button stops the scanner. The scanner will write its display out to a file. The Y axis displays the number of counts, while the X axis displays the time; the display will scroll and overwrite itself once full.

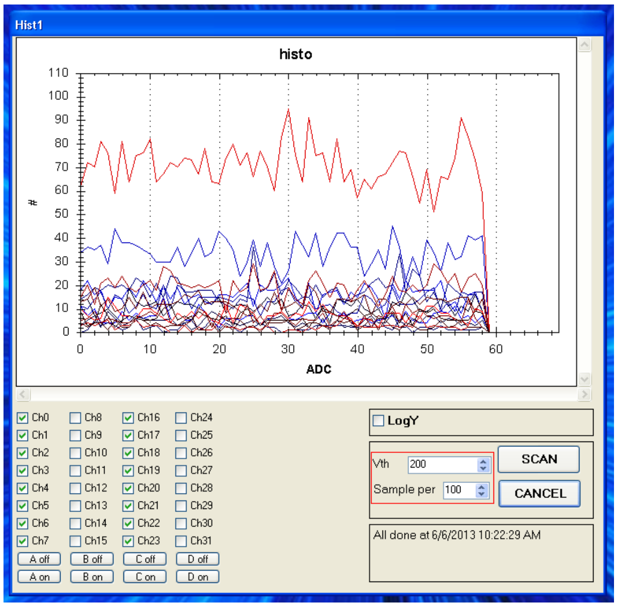

FIG. 13: The Scanner window during to a run.

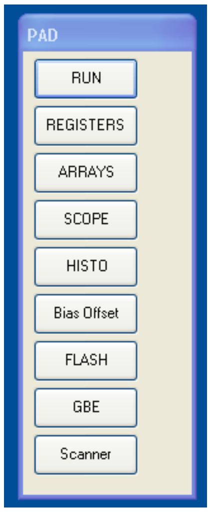

FIG. 14: The menus for the PAD-E software.

To check that the PAD-E connected is fully functioning, be sure that it is powered on and programmed with an appropriate setup file. If, upon power-up, the voltage across the SiPM Bias pins is above 4.10V, or the PAD-E is unable to be connected, consult the troubleshooting section. Open the Histo menu and turn on all channels, select "PE Find" and "LogY" and then click SCAN. If the PAD-E is operating properly, each channel should have a histogram displayed with one peak. If no peaks are showing or some are missing, consult the troubleshooting section. If all channels have some display, then the PAD-E is functioning properly and is ready for use.

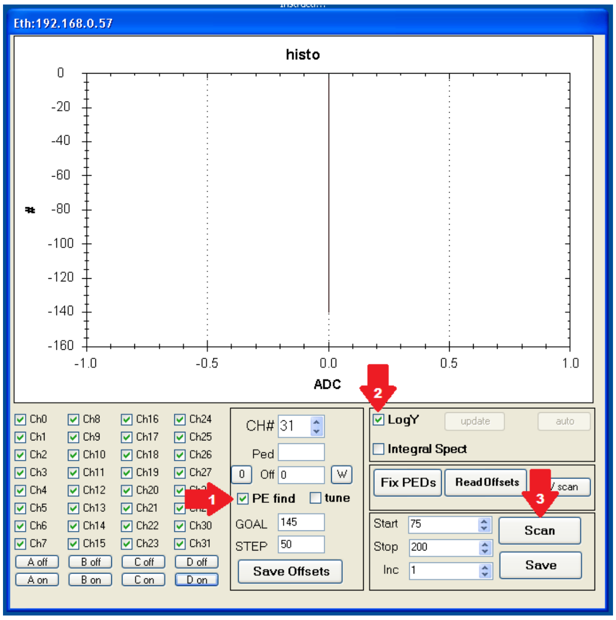

FIG. 15: The HISTO window, initial startup.

When the PAD-E is confirmed functional and connected and setup properly, one can tune SiPMs and take data. If a bias offset file is available, one can easily tune the SiPMs by simply using the Init-Browse button, opening the file, and initializing the PAD-E with that. If a bias offset file is not available, then the SiPMs can be automatically tuned using the Histo menu. Start by opening the Registers and selecting the Bias tab. Turn on current and voltage monitoring by writing 16 to the Bias_Num_Avg register. Read from the Bias_Imon register and be sure that the current is within the range, and does not exceed, 2c1 to 350 hex.

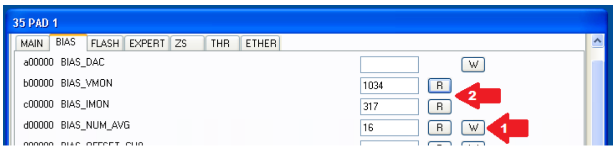

FIG. 16: The Registers window, with a value of 16 written into the BIAS_NUM_AVG with acceptable voltage and current readouts.

From the table provided, select an appropriate bias value and write that to the Bias_DAC register. Read the Bias_Imon again and be sure the current does not read FFFF, in such an event, consult the troubleshooting section (feel free to panic first however).

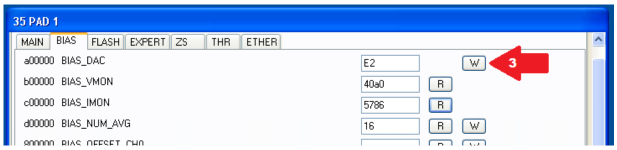

FIG. 17: The Registers window, now with a BIAS_DAC of E2 written in, with acceptable voltage and current readouts.

Now close the registers and open the Histo menu. Turn on the available channels, select PE find and LogY, then perform a scan. You should see all channels functioning (i.e. no dead channels or other oddities) as in the following figure.

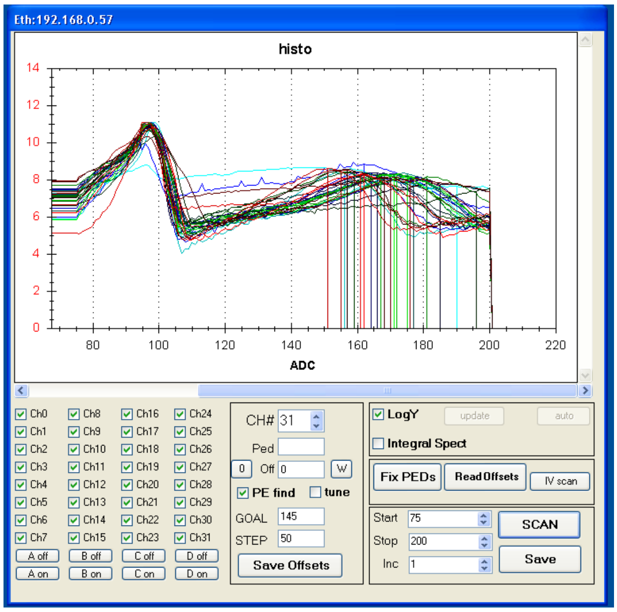

FIG. 18: The HISTO window after a scan, with no offsets applied to any channel.

Tuning of the SiPMs means that the bias of each device will be adjusted until the first photo-electron is a certain number of ADC counts (ADC), defined by the user. ADC counts are a unit of the number of analog to digital conversions. In the figure below, one can see several peaks or bumps in the histogram. Starting from the left, the first peak is the pedestal, the second, with the line below it, is the first PE, and any bumps to the right of that are second PEs, third PEs, and so on. All the devices should have a pedestal value at 100 ADC. If there is a device, or number of devices, whose pedestal is not at 100 ADC, one can click the Fix PEDs button to shift the pedestals of the offending channels to 100 ADC. The feature PE Find is used to drop a line at where the program sees the first PE. If the first PE is clearly visible, but the program is displaying the first PE at the second or third PE peaks, then consult the troubleshooting section. The LogY feature displays the histogram with a Log Y axis, making the PE peaks much more visible. The array of check boxes to the left turns on/off individual channels, and the buttons below, turning on/off columns. Each column pertains to the channels on each ADC chip (Analog to digital converter chip). In the lower center of the interface, there is a series of text boxes labeled CH#, Ped, Off, GOAL, and STEP. The box labeled CH#, displays what channel information in the Off box is being displayed. The Off box displays the offset of the current channel (as displayed by CH#). The value in this box ranges from 0-1000, decimal, 0 being no offset, and 1000 being maximum offset. This number is derived by the maximum bias offset being 3V and the data size being 11 bits. Thus, 3V/1024 dec, results in $\approx$0.003V/dec. The box labeled GOAL is the number of ADC counts you wish tune the first PE of the devices to. The first PE of the devices must start out higher than the goal; the program will only increase the bias offset until the goal is reached or passed; in other words, the offset will never be decreased to reach the goal. The STEP defines the bias offset step size, in decimal, to be used when reaching the goal, with 10 being the smallest step size and 1000 being the largest. When the tune box is checked and the SCAN button clicked, the program will complete several iterations of scanning and decreasing the offset until the goal is reached. The step size determines by how much the offset will be decreased during each iteration. The Save Offsets button will save the current tuning (bias offsets) of all channels to a .tb4 file. The Save button underneath the SCAN button will save an ASCII (.histo extension) of the histogram that is displayed. If a set of devices have been tuned on one PAD-E, and another PAD-E is selected, then the user must click Read Offsets to read the offsets from that PAD-E into the program's memory, otherwise the program will retain the offsets from the previous PAD-E and try to apply them to the newly selected board. During tuning it is advised to select a step size wisely. Too small of a step size will result in the program needing to complete many iterations in order to reach the goal consuming a large amount of time. Too large of a step size will result in a poor tuning as devices may fall significantly below the goal. A combination of different goals and step sizes can be utilized to shorten the amount of time tuning while still obtaining an accurate tune. If the tune is unsatisfactory, the button to the left of the Off text box is used to set the offset on all channels to zero. If a certain channel is problematic, the user can put in a custom offset in the Off box and click the W button to the right to write that offset to the channel. The following figures depict graphically how a characterization run is taken:

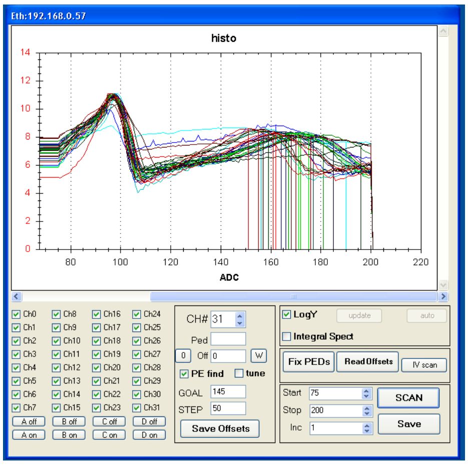

FIG. 19: Initial scan, no tuning and no offsets applied to any channel.

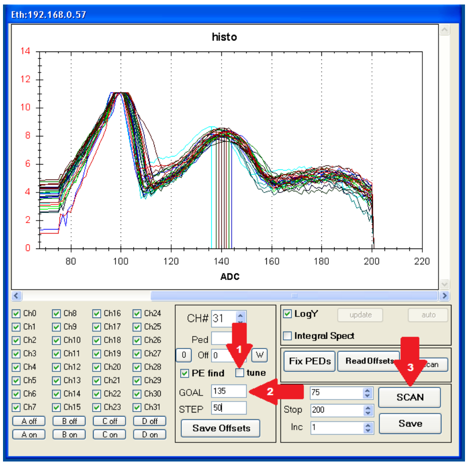

FIG. 20: After first tune with a new goal of 135 and after fixing the pedestals.

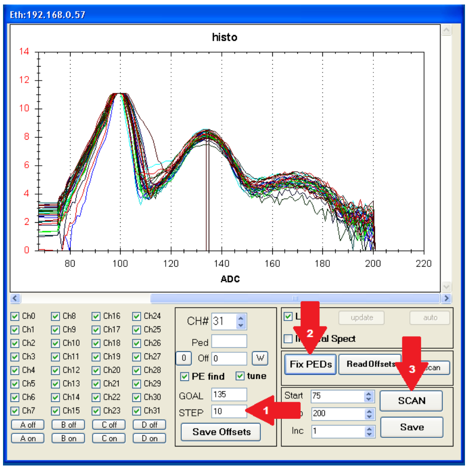

FIG. 21: After second tune with the next goal being 130 with steps of 10, and re-fixing the pedestals.

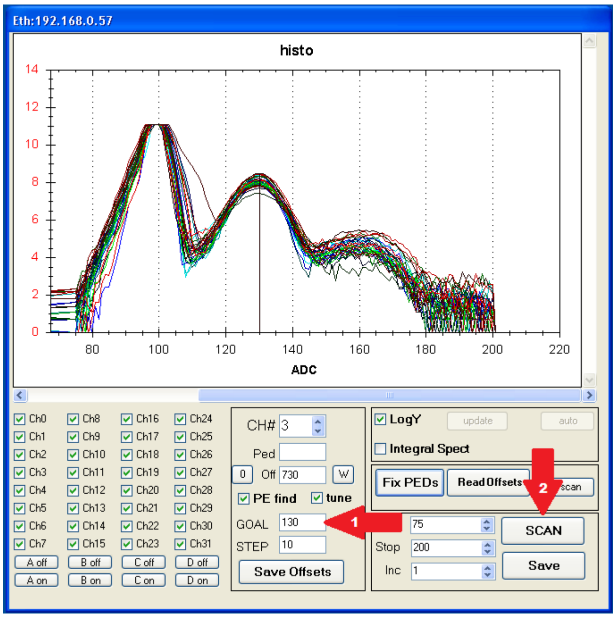

FIG. 22: The final result, channels all tuned to 130.

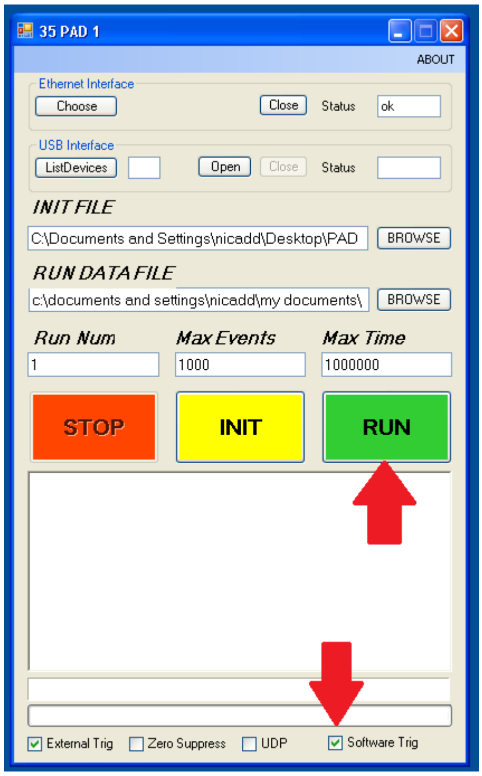

FIG. 23: The initialized PAD-E.

III. DATA COLLECTION

Once the devices are tuned, the user can begin data collection. During the programming/setup of the PAD-E, the RUN DATA FILE bar should be filled with a filepath. This filepath defines where the data will be stored and provides the base of the filename. The program will concatenate the base filename with the corresponding run number from Run Num, separated by an underscore (ex: 0428muons_3.dat; where 0428muons is the base filename, and 3 is the run number). Data will be saved in one of two ways, in ASCII form, or in packet form. If the data is saved in ASCII format, the data file will be easily readable, containing a channel number, time stamp, and data for each event. If the UDP box is checked then incoming data will be saved in packet form, which will later have to be unpacked to be useful for the user, but contains the same information when saved in ASCII format. The advantage of UDP is that data can be collected much faster. Most of the PAD-Es will not have a Lemo connector on the board for external triggering. In this case, the Software Trig box and External Trig must be checked. If a Lemo connector is present and external triggering will be used, then only the External Trig box must be checked. To start a collecting data, simply click RUN. Similarly, to stop data collection, simply click STOP. After each run, whether it has reached the maximum number of events or been manually stopped, the Run Num number will increment by one automatically.

IV. TECHNICAL SPECIFICATIONS

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V. TROUBLESHOOTING

Problem: "There is an abnormally high voltage on the power-up of the PAD-E."

> ***Solution:*** *Restart the PAD-E and reconnect or adjust all connections.*

Problem: "The voltage is unusually low on power-up."

> ***Solution:*** *There is a possible short in connections between the SIB and PAD-E, disconnect the SIB and check socket for conductive materials or replace the SIB. It is also possible that there is a bad or reversed device. So check the SiPMs and remove or correct the offending device.*

Problem: "An incorrect number of devices is displayed."

> ***Solution:*** *Check that the board has power and check the connection between the board and computer.*

Problem: "The PAD fails to connect on Ethernet."

> ***Solution:*** *Check that the board has powered and check the connection between the board and the computer. Check that the serial number entered matches the connected board. If an Ethernet switch is being used, troubleshoot the switch. It is possible that there is a bad Ethernet controller on the board.*

Problem: "The firmware version reads as a '0'."

> ***Solution:*** *Check that the PAD is powered and check the connection between the board and the computer. If Ethernet is being used then check to see that the serial numbers are correct. If connected properly, the board may be improperly burned, in which case the FPGA might require re-burning.*

Problem: "Some of the channels in the HISTO scanner are not displaying."

> ***Solution:*** *Check that those channels are enabled by looking at the check-box in HISTO. ADVANCED: If channels are enabled go to the setup file and check to make sure all ADC's are turned on and set up properly. If the problem persists then the ADCs on the board may be dead.*

Problem: "Bias_Imon (current) reads very high or is maxed out (FFFF)."

> ***Solution:*** *There is a possible short or bad connection with the SIB or SiPMs. Reconnect the SIB and ensure that it is free of conductive materials. If the problem does not lie in the SIB connection, check SiPMs for bad or reversed devices and remove or correct the offending device.*

Problem: "HISTO is identifiying second or third PE peaks as the first PE."

> ***Solution:*** *Use the Fix PEDs button to realign the channel(s). If the problem persists then the channel may need to be manually tuned to achieve the intended ADC.*

Problem: "The software hangs up when performing any scan."

> ***Solution:*** *Be sure that the PAD-E is properly initialized. Switching between PADs befire initialization is complete will cause it to be improperly programmed. Simply reinitialize the PAD.*