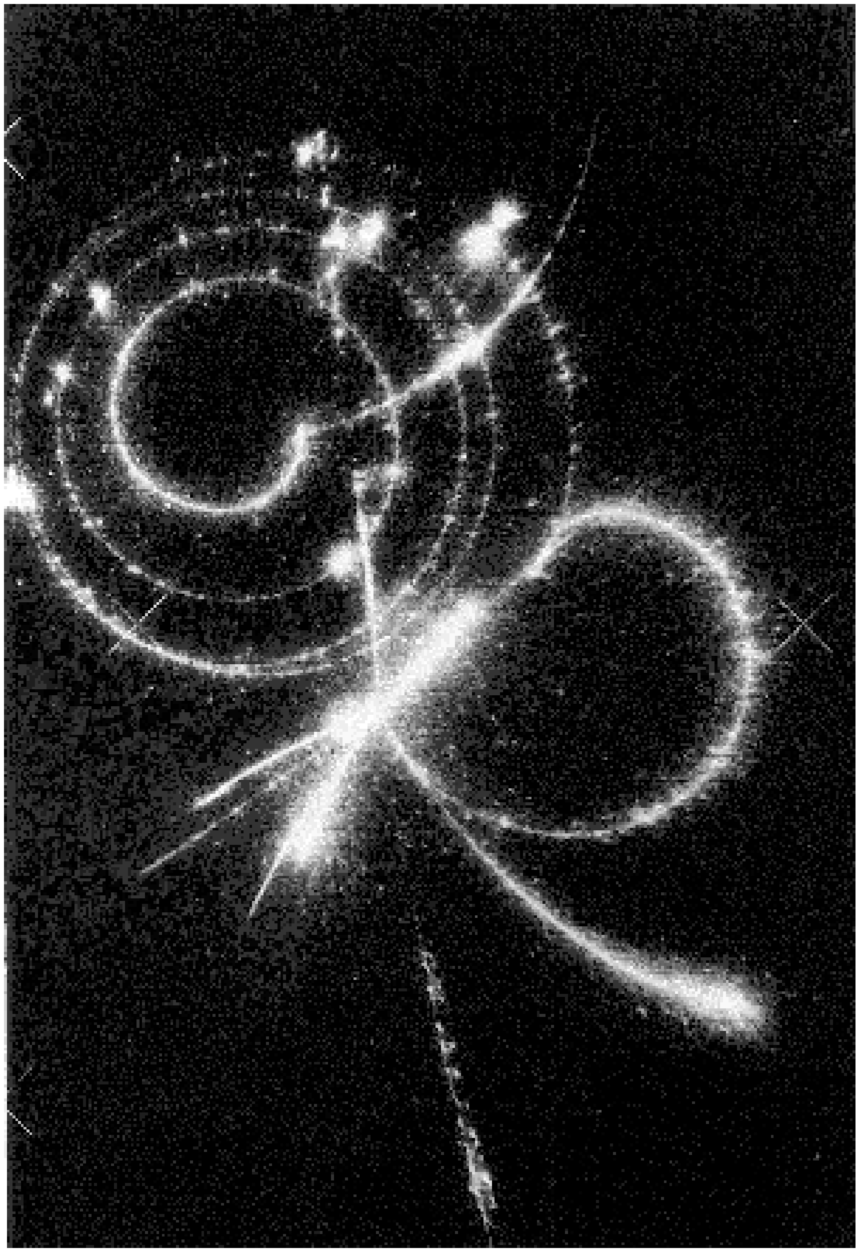

The C.R.O.P. Book

Version 2.0

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Illustrated by Timothy Struble

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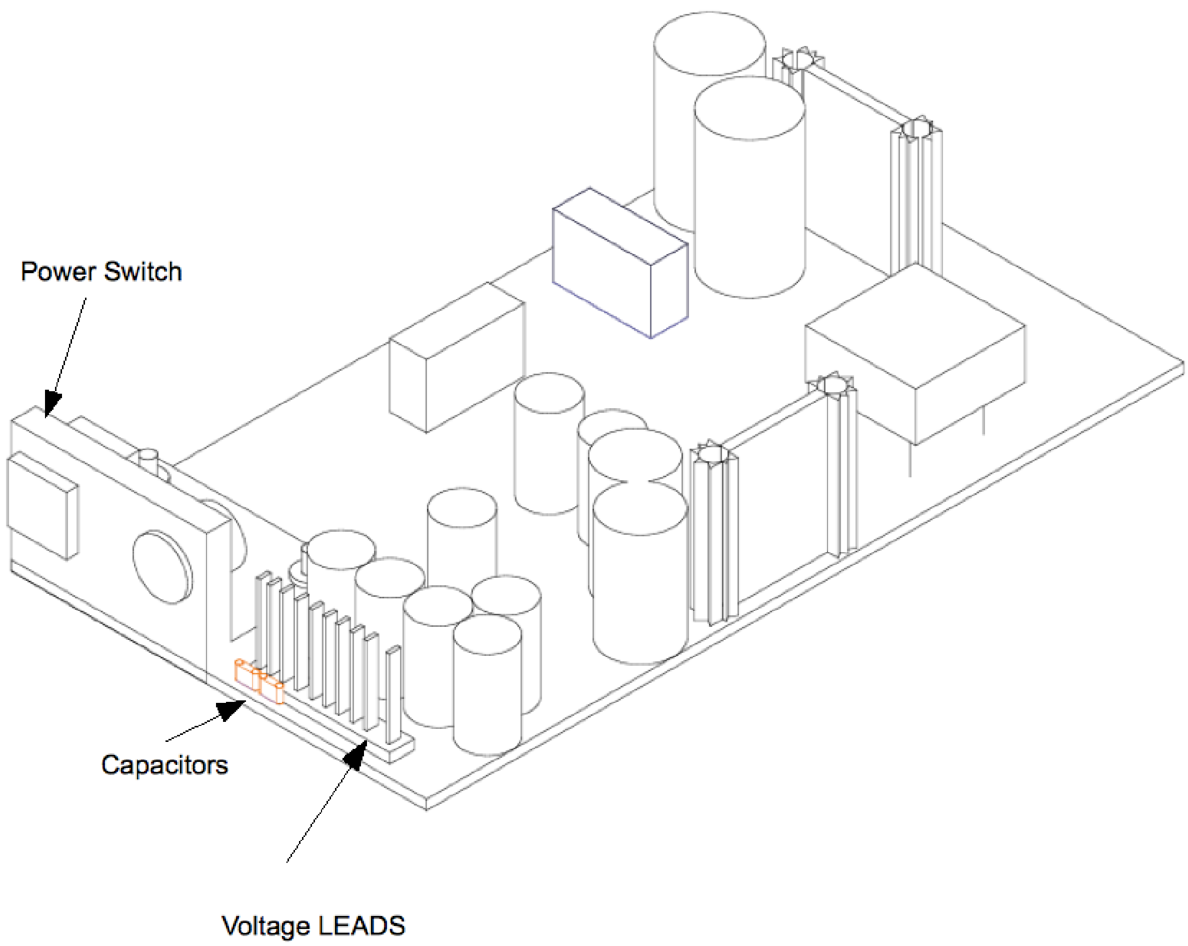
Power Supplies

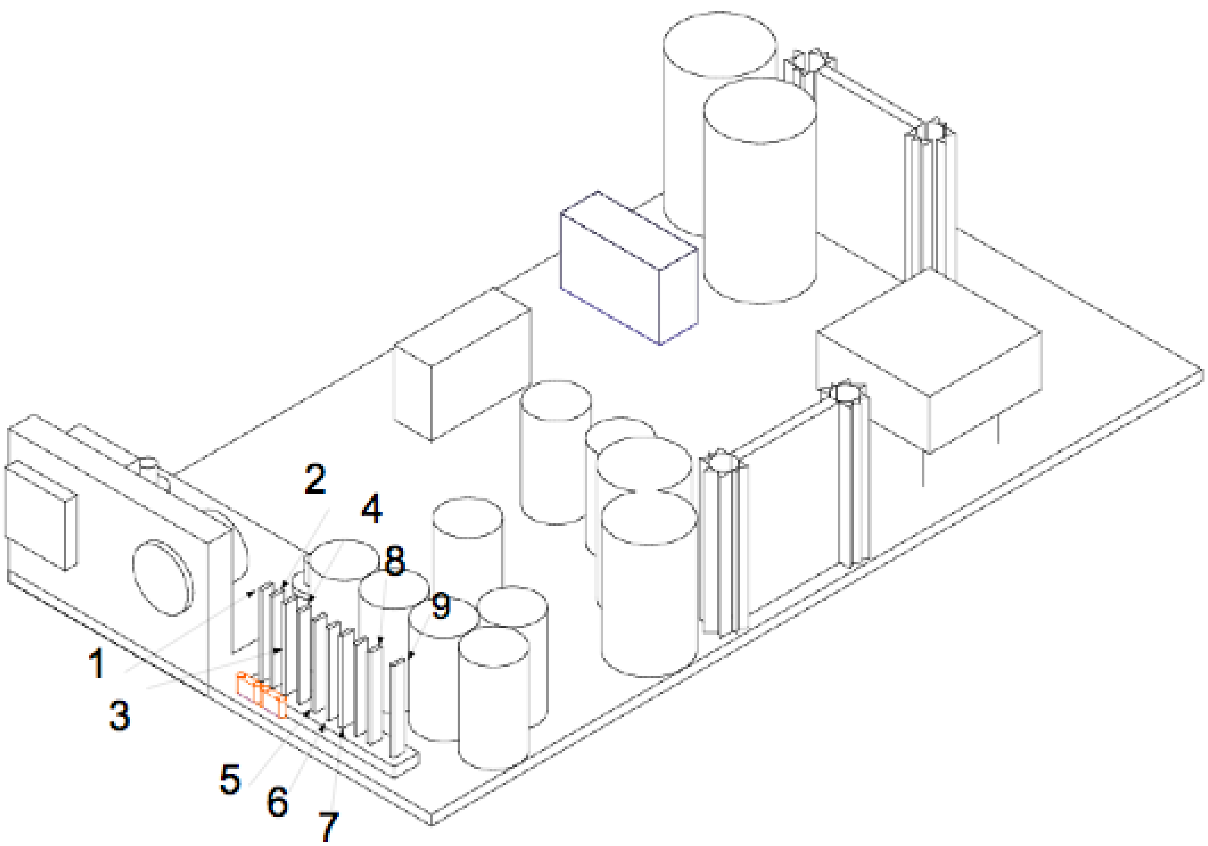
Testing Low Voltage Supplies

Before we can construct power supplies for the use of running the particle detectors, we have to test the individual pieces to ensure their functionality. When I was first working on the project, the previous generation of CROP workers had left no instructions on how anything was to be tested or built. After about a year of trial and error, I managed to create the first of the power supplies attributed to my generation of workers. I named it after myself (Tim Jr.). This supply was eventually given away to one of the schools to run their detectors and has yet to be returned to the project. Not getting power supplies returned (or if they are returned, they are almost always broken) is part of the project's nature and thus we are constantly having to make new ones. That being said, the first piece of supply that needs to be tested is the low voltage supply. It is easy to identify due to its large size. An artist's rendition of the supply lies below:



The first step in getting these low voltage supplies ready to be tested is replacing the frontal capacitors that are highlighted on the previous page (50 Micro Farads). You can try to test the low voltage supply without replacing them (there is a possibility that the low voltage supply works with its original capacitors intact), however, I personally have needed to replace these capacitors on 98% of all the supplies that I tested. Thus, I now just replace them immediately to save time. Removing the capacitors is not difficult. One simply needs to heat the solder connecting them to the board and pull them off. A soldering iron is more than adequate to do this task. Once completed, the actual testing can begin.

The method of testing the low voltage supply involves measuring the voltage differences between the Leads. By placing the probes of a voltage meter between the individual Leads, the meter will display the voltage difference between them (assuming it is in the correct mode (for us, this is direct current - DC)).



The diagram above illustrates the pin numbers that will be referenced on the next page. The following is data that is typical of a good power supply. Remember that each low voltage supply is different and a difference of a volt or so will not influence the total performance of the supply. The following chart gives approximate values for the voltage differences between the Leads. If a spot is listed as NA, then its value is not important for the supply.

PINS	1	2	3	4	5	6	7	8	9
1	0	9	NA	NA	NA	NA	NA	NA	NA
2	9	0	NA	NA	NA	NA	NA	NA	NA
3	NA	NA	0	5 to 11	NA	NA	NA	NA	NA
4	NA	NA	5 to 11	0	NA	NA	NA	NA	NA
5	NA	NA	NA	NA	0	NA	NA	5	NA
6	NA	NA	NA	NA	NA	0	NA	17	NA
7	NA	NA	NA	NA	NA	NA	0	NA	NA
8	NA	NA	NA	NA	5	17	NA	0	NA
9	NA	NA	NA	NA	NA	NA	NA	NA	0

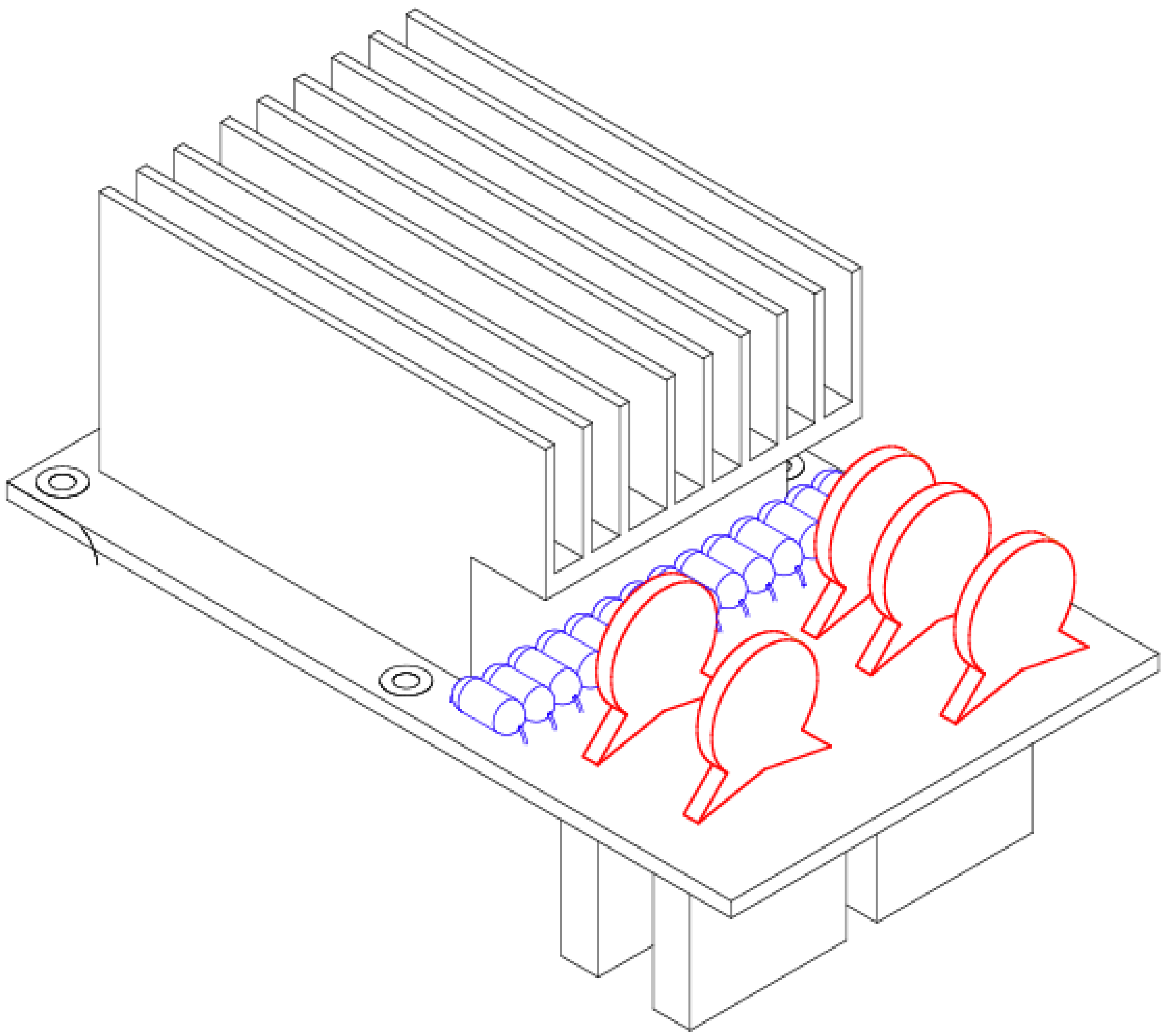
Measurements given in Volts

Once the pins have been tested, all that is left is attaching the final piece to the low voltage supply. This is simply a cable that attaches to the pins. Due to how hard this piece was to draw, we have included a photo. If the pins of the low voltage supply are facing you, then this piece attaches with the green wire on pin 9 and the orange wire on pin 1.

Testing the High Voltage (HV) Pod

This is easily the simplest test that we do in CROP. It is the final piece that requires testing before we begin construction of the supply itself. There are a couple safety issues. It is possible to give yourself one hell of a shock from the high voltage pod if you touch it with your bare hands (I have done this four times, once was very bad). So learn from my mistakes and wear gloves while handling the HV pod and keep it away from conductive objects. That being said, let's get started.

The first step is locating the HV pod. It is the second largest piece in the supply. An image of it is below.

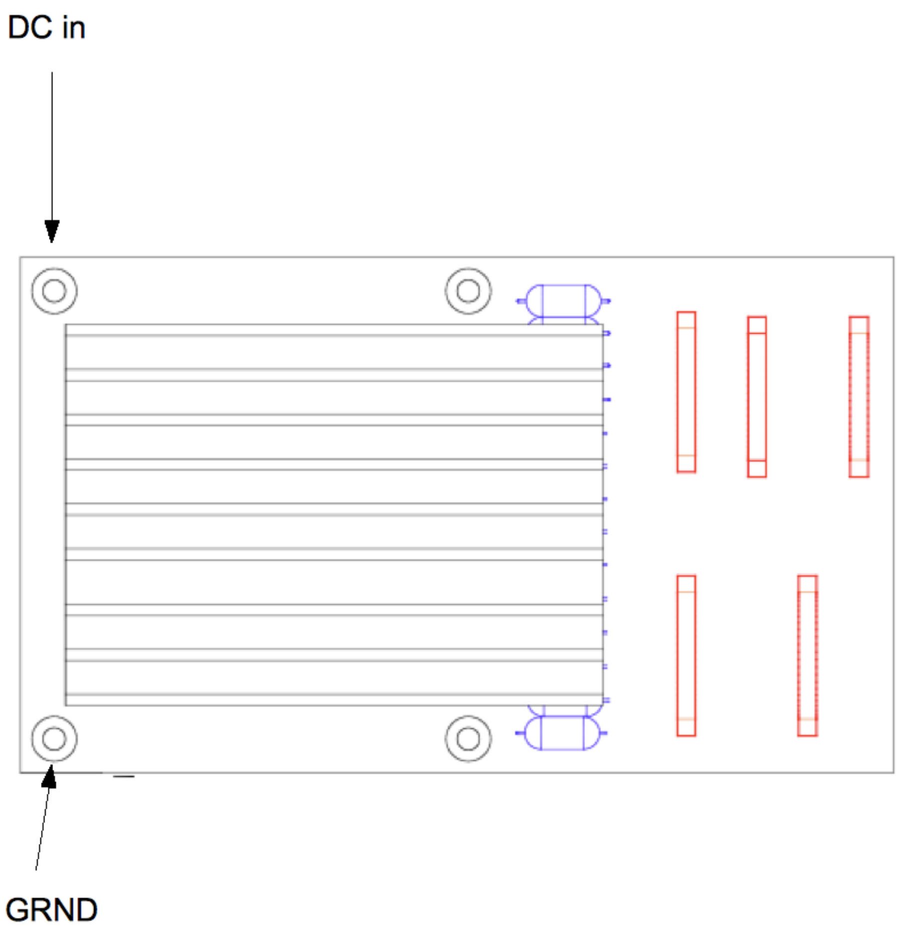


The high voltage pod requires other voltage to power it; it then amplifies that voltage and exports it through the cable connectors at its base. There are two options for providing a voltage to the HV pod. First, it is possible that CROP has a low voltage power supply strictly for this use (we did in my days). This is the easiest method.

However, if such a supply is not at your disposal, then you will use a tested low voltage supply from the previous section.

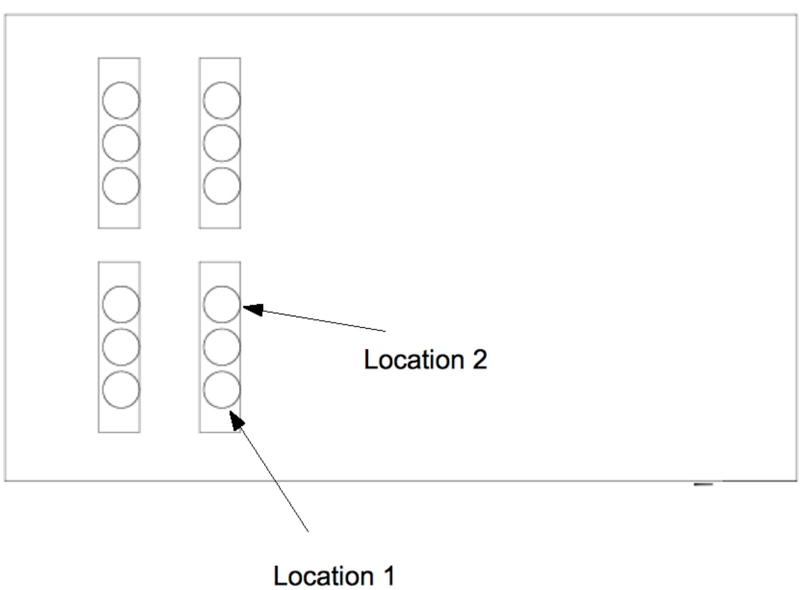
Option 1: If you have a dedicated low voltage power supply, set it at about 5V, then connect the positive output (red) to the connector marked DC in and the negative connector (black) to the opposing site labeled ground (GRND or 0v).

Option 2: If you are using a low voltage supply from the previous section, place the brown wire on DC in, and the black on the GRND.



The next step in the process involves checking the voltage being amplified by the high voltage pod. Doing this requires specialized equipment. The easiest method, that we have found, is to use a voltmeter. In order for the voltmeter not to be destroyed through measuring the extremely large voltages involved, a high-voltage probe needs to be attached. The high voltage probe is easy to identify because it is a very large cone attachment that is roughly eight times the size of a normal voltage probe. An image of one is one the following page.

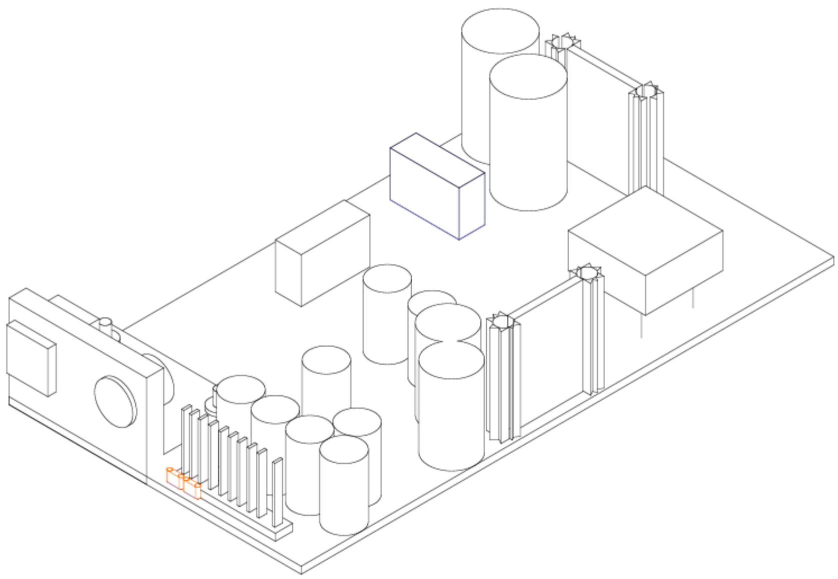
Once the probe is attached, the high voltage can be measured. To do this, place the large probe and the grounding wire in the two outermost holes of the output sockets (the white rectangles with holes in them). The hole in which you place either of the instruments does not matter. If you have it reversed, the voltage will simply be read as negative (we are interested in the absolute value). The high voltage probe will divide the actual voltage by 1000 before it is displayed on the meter (display says 1V there is really 1000V emanating from the supply). A reading of over .9 V from the meter means that the power supply is working properly.



Soldering Power Supply Parts

Parts and descriptions:

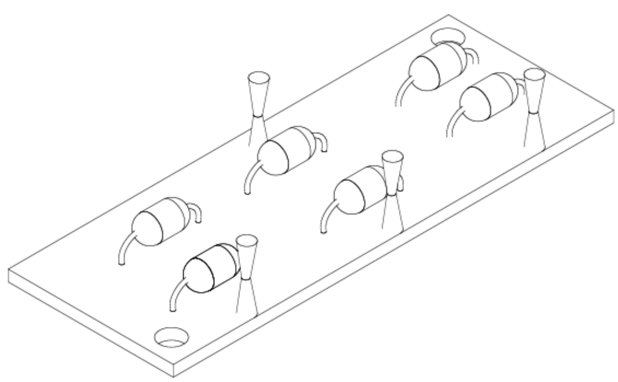
1. **Low Voltage Supply (LVS)** – large blue/black board with many capacitors.



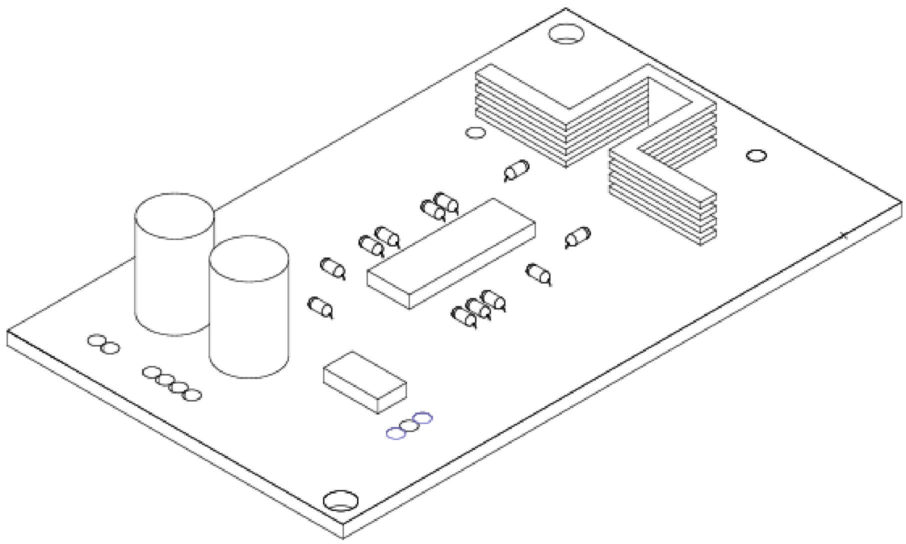
Must have attached:

a. Power cord with switch
b. Black clip with colored wires. Strip gray surrounding plastic with a razor blade.

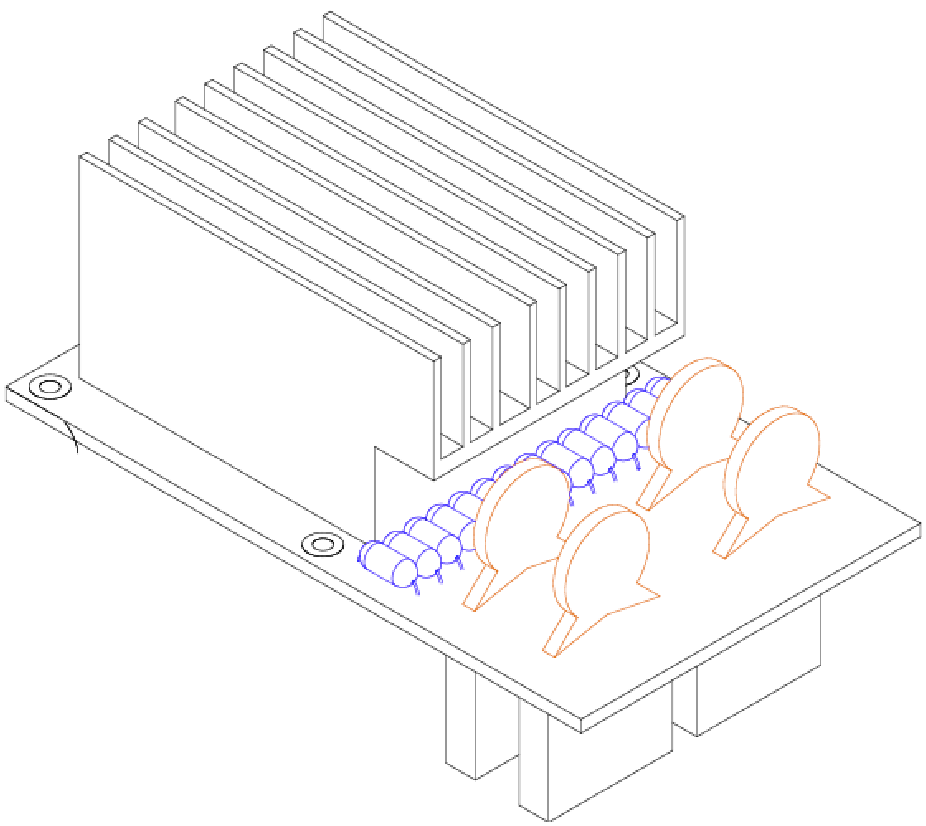
2. **Tan Resistor board (RB)** – small board with several large blue resistors. May already be attached to LVS. May have a pink ground 'pin' attached.



3. **Voltage Divider (VD) [aka Board We Don't Know What It Does]** – Comes prepackaged with several colored wires extending off.



4. **High Voltage Supply (HVS) –** Green board with orange capacitors and black metal ridged object



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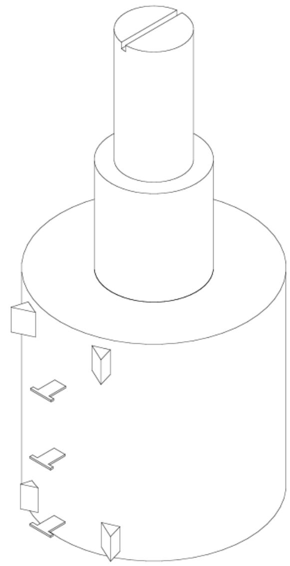
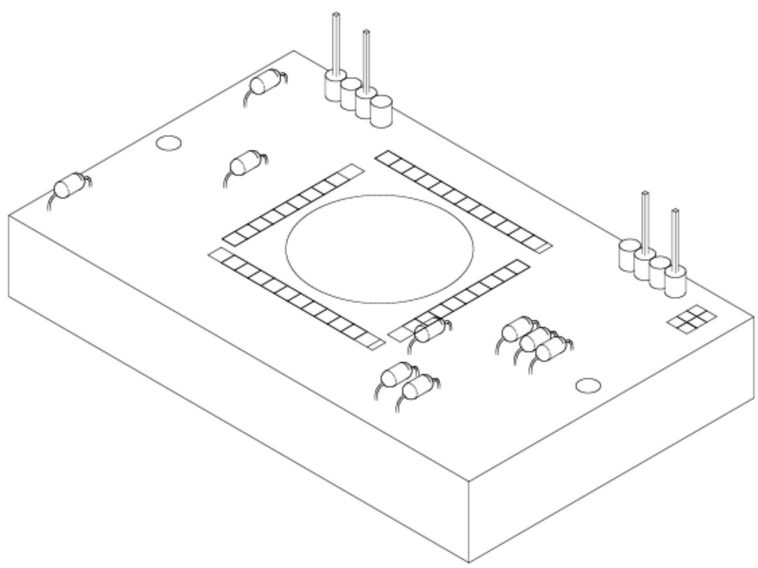
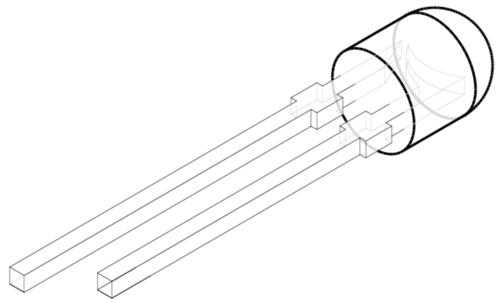
5. **Potentiometer (P)** – Blue adjustable potentiometer with three metal terminals.



6. **LCD Display (LCD)** – Green circuit board with black case and display. Be sure to have an outside holder with screws as well.
   a. Two terminals labeled “P1” on the back should NOT be soldered together.



7. **Light Emitting Diode (LED) –** Small clear light (turns red when on).



8. **Resistor (R)** – Used to lower voltage to LED.

Hints/Tips:

1. Solder everything together before putting into power supply metal case.

2. Twisting and braiding wires together may avoid confusion/entanglement. Zip ties are also helpful for this.

3. The colored wires from the LVS do not need to be very long. They can be clipped to about 6 to 8 inches without detriment.

4. Generally, things may be soldered together in any order.

5. Be sure all parts work (especially LVS and HVS) before soldering. This will save you a lot of grief!

Careful when turning on and off!!

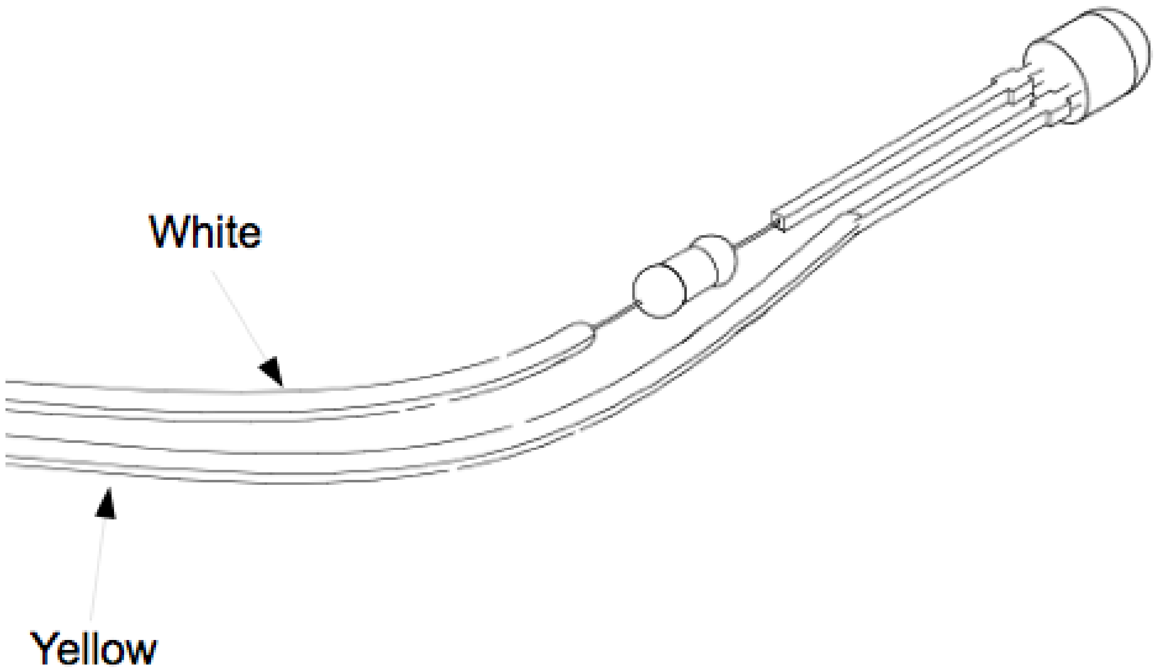
Place on a non-conductive surface, wait several moments for capacitors to discharge, and handle with a glove or cloth!!

Wiring

Wires from the Low Voltage Supply

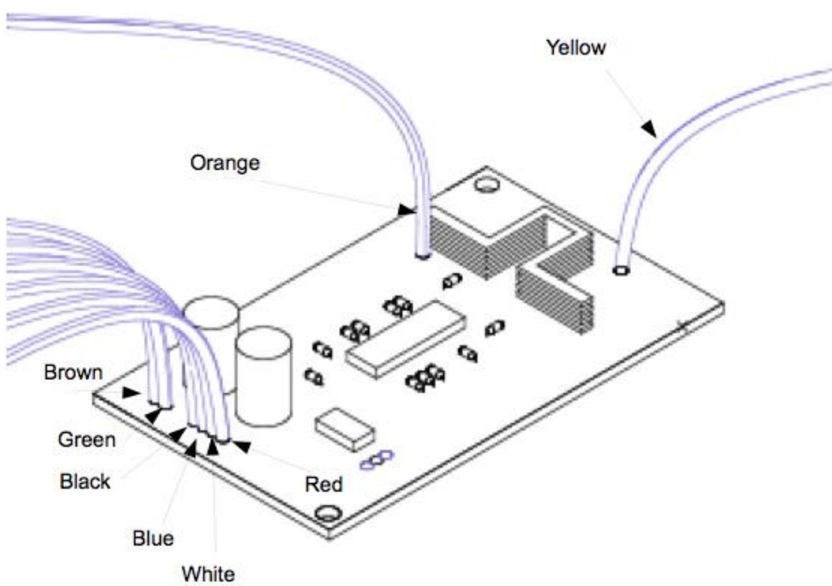
White & Yellow: [R] & [LED]

1. Connect in series with **[R]** and **[LED]**. As in, connect white wire to resistor; resistor to long lead of LED; and other LED lead to the yellow wire.
   a. R can be on either lead of LED.
   b. Cover in electrical tape or liquid electrical tape to avoid exposed wiring.



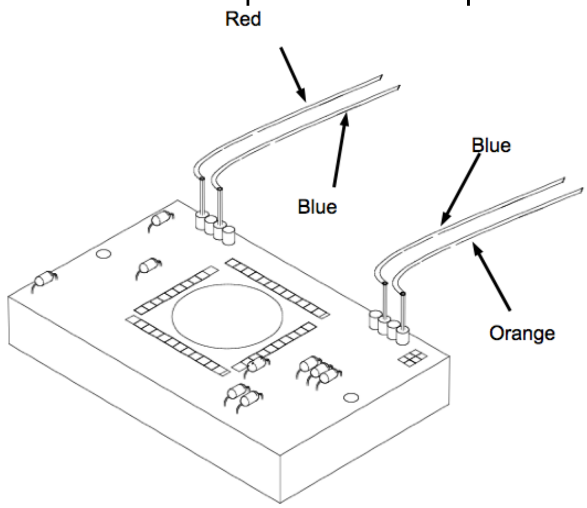
Black, Red, & Brown: [VD]

1. These wires go in spots close to the two large capacitors. Strip ends of wires and solder into each hole.
   a. Red goes to hole labeled “V-“
   b. Black goes to hole labeled “GND”
   c. Brown goes to hole labeled “V+”



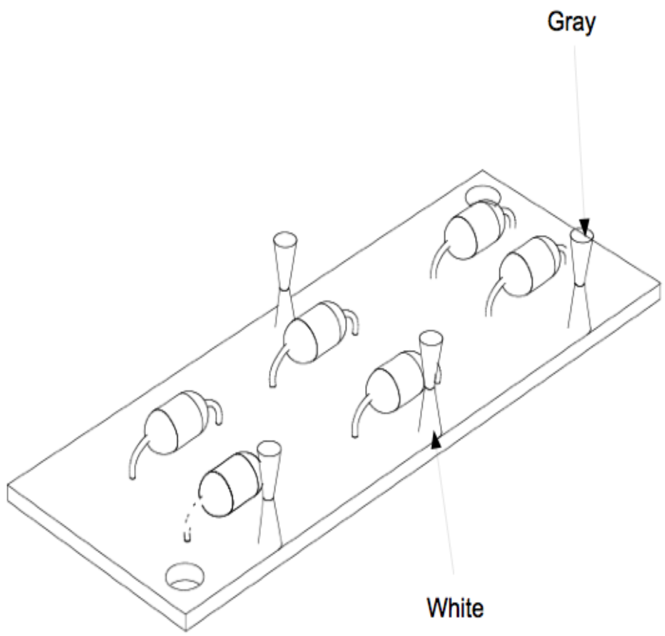
Orange & Blue: [LCD]

1. These go to the LCD pins labeled "9V". These are below the blue/white adjusting dial.
   a. Orange goes to the outside pin.
   b. Blue goes to the inside pin.
   c. Cover exposed metal with liquid electrical tape.



Gray & White: [RB]

1. These should already be attached to the tan resistor board.
   a. White goes to middle metal pin of three on one side.
   b. Gray goes to end pin of three, the one with the hole farthest from it and resistors are closest.



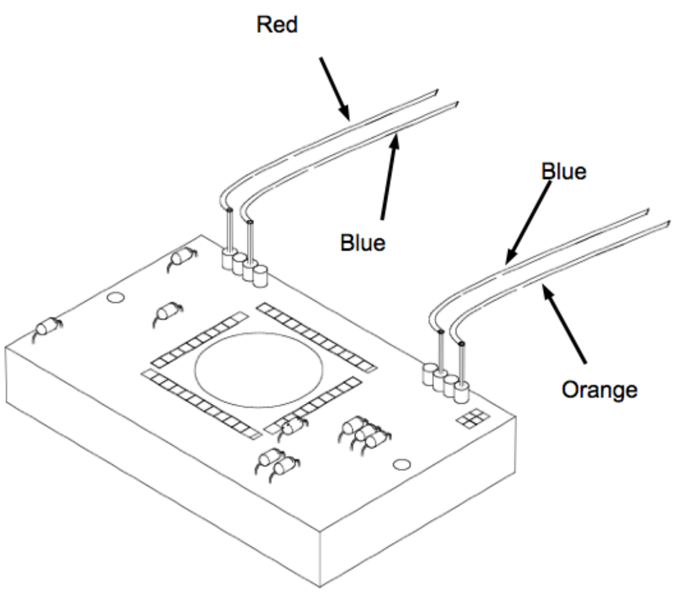
***Green* & Black:**

1. These wires do not connect to anything. Trim and make sure to leave no wire exposed.

Wires from Voltage Divider:

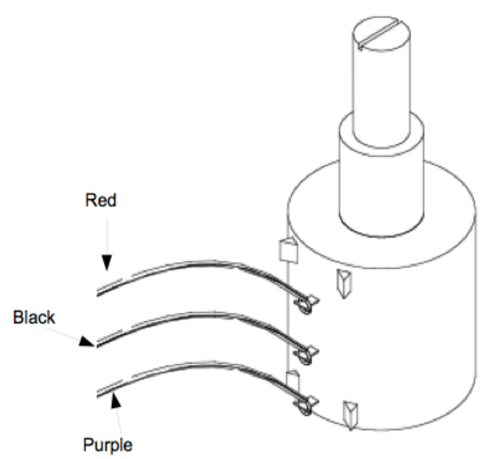
***Red* & *Blue*: [LCD]**

1. These go to the LCD similar to previous Orange/Blue wires from LVS, but on the pins labeled IN- and IN+.
   a. Red goes to the outside pin.
   b. Blue goes to the inside pin.
   c. Cover with liquid electrical tape.



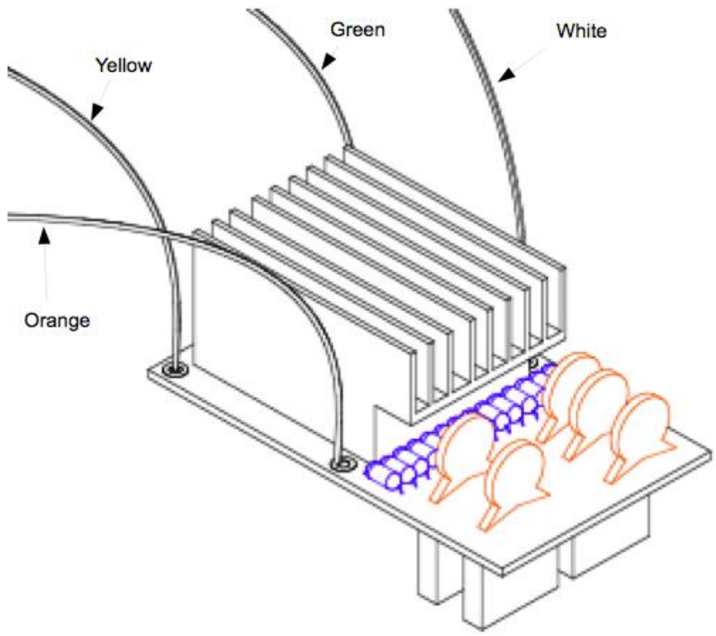
Black, Purple, & Red: [P]

1. These go to the metal terminals on the potentiometer.
   a. Red goes to the pin closest to the adjust knob.
   b. Black goes to the center pin.
   c. Purple goes to the farthest pin, closest to the base.



Green, White, Orange, & Yellow: [HVS]

1. Solder onto the rings below the black ridged object.
    a. Yellow to circle labeled “GND”
    b. Green to “DC IN”
    c. Orange to “SENSE”
    d. White to unlabeled circle near copper coil.



Testing:

1. Place everything on a non-conductive surface, such as a book.

2. Plug LVS into wall socket, flip switch to turn on.
    a. Be sure LED lights up! If not, the white and yellow wires may be switched!

3. Turn potentiometer until LCD displays 1000 Volts.

4. Using a high voltage probe and a voltmeter, test voltage from HVS.
    a. Any two opposite pins will work. Touch each terminal of the high voltage probe to a metal pin inside the plastic clips: [x O x]

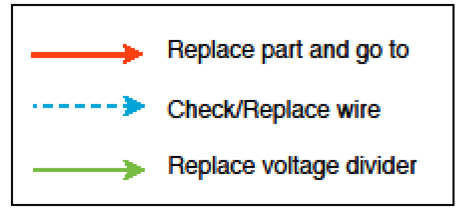
b. If voltage reads zero, then something doesn't work or a connection is bad.

5. Adjust the LCD display until it reads the actual voltage.
   a. Use a screwdriver, find the small twist-adjust knob (blue and white) on the back side of the LCD.

6. Change potentiometer until LCD displays 1350V.
   a. Repeat testing with voltmeter and adjusting LCD.

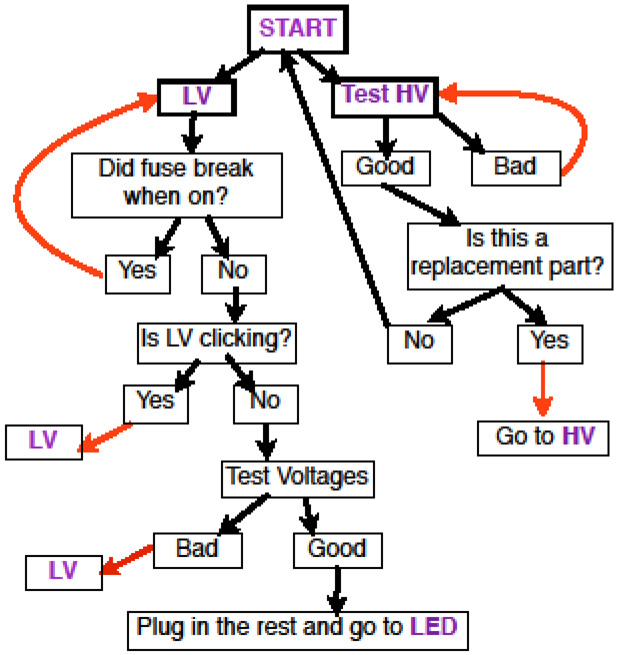
7. Repeat with 1000V to check consistency. Small deviations (about 3-5V) are okay. The smaller, the better.

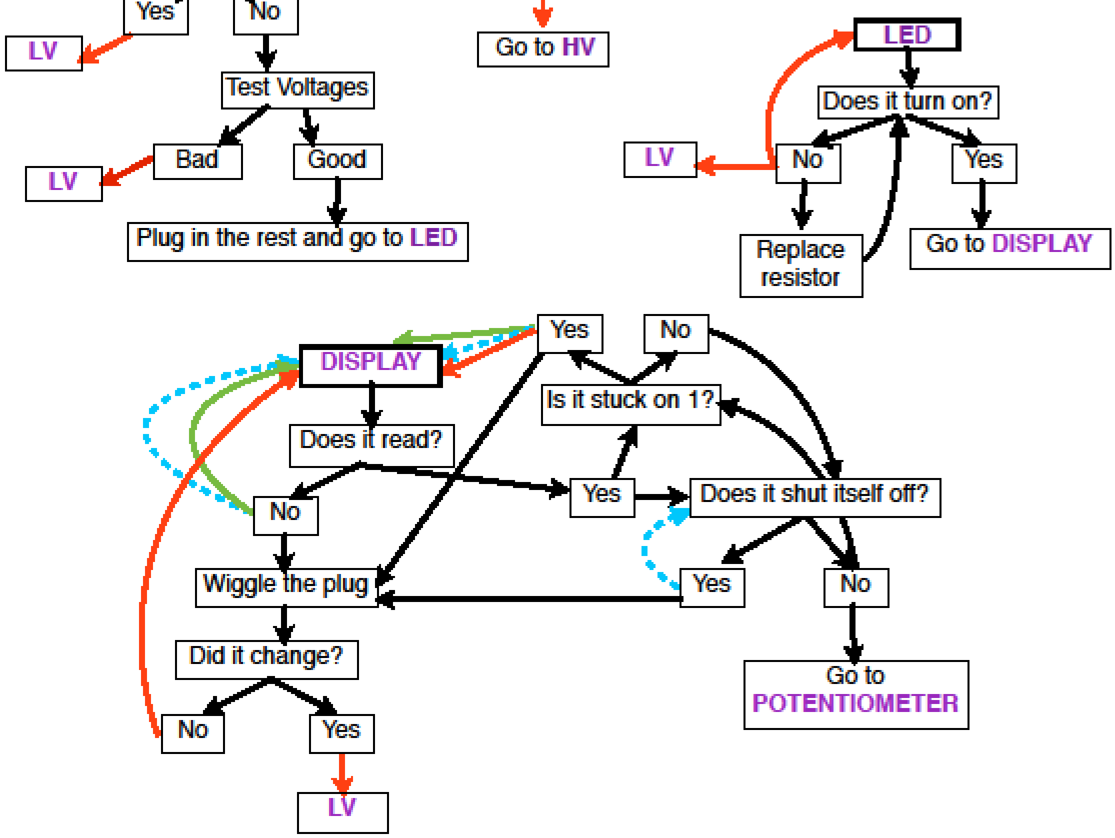
Power Supply Testing and Troubleshooting

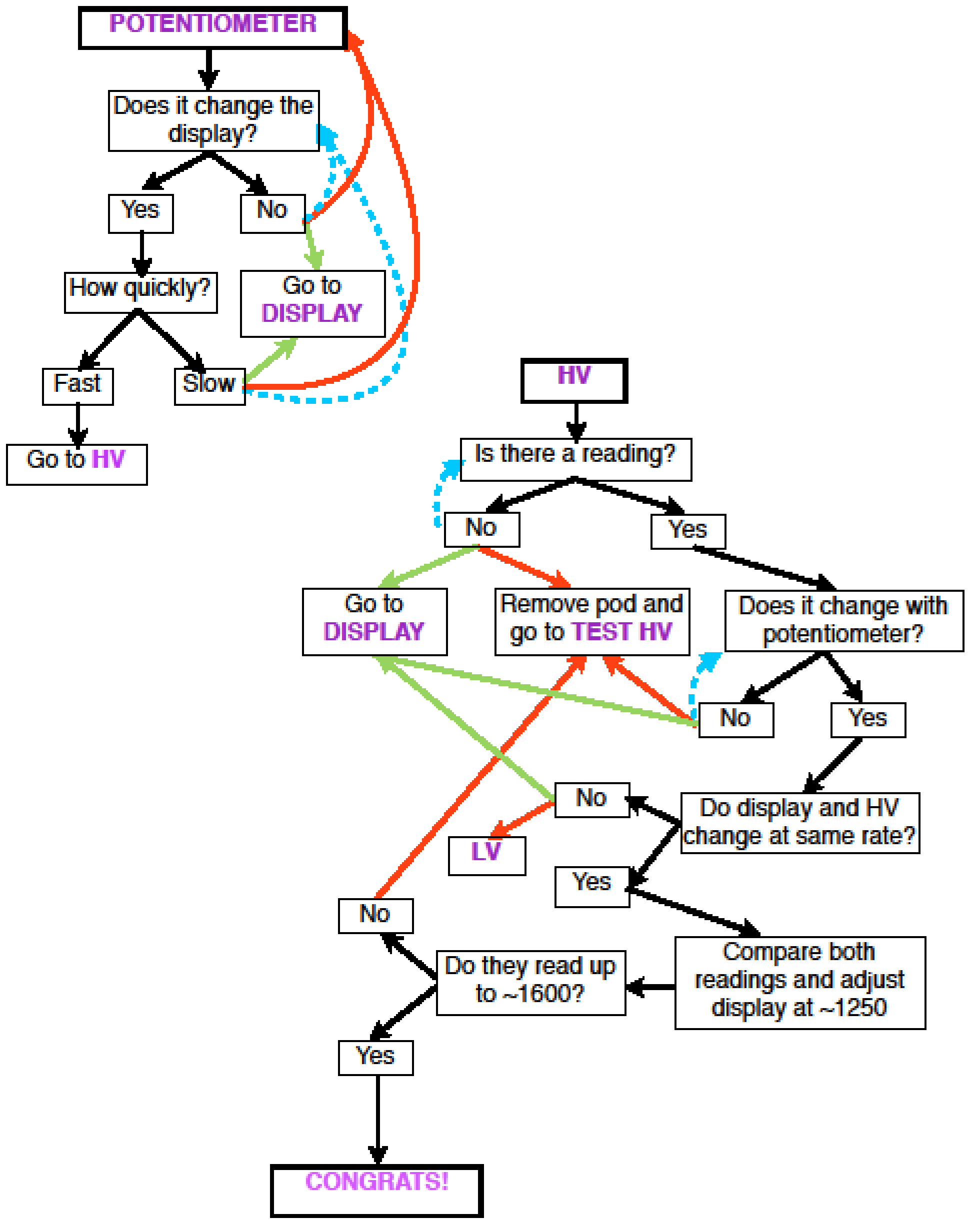


Tips for safety and reliability:

- cover connection of wires with heat shrink
- if soldering wire into port, use minimal exposed wire
- don't let solder cross two ports
- do not solder if part is turned on
- turn off whole assembly if there is smell of burned electronics
- make sure all capacitors are there and secure






POTENTIOMETER
Does it change the display?
Yes
No
How quickly?
Go to DISPLAY
Fast
Slow
Go to HV
HV
Is there a reading?
No
Yes
Go to DISPLAY
Remove pod and go to TEST HV
Does it change with potentiometer?
No
Yes
No
Do display and HV change at same rate?
LV
Yes
No
Compare both readings and adjust display at ~1250
Do they read up to ~1600?
Yes
CONGRATS!

<u>Detectors</u>

Scintillator Block

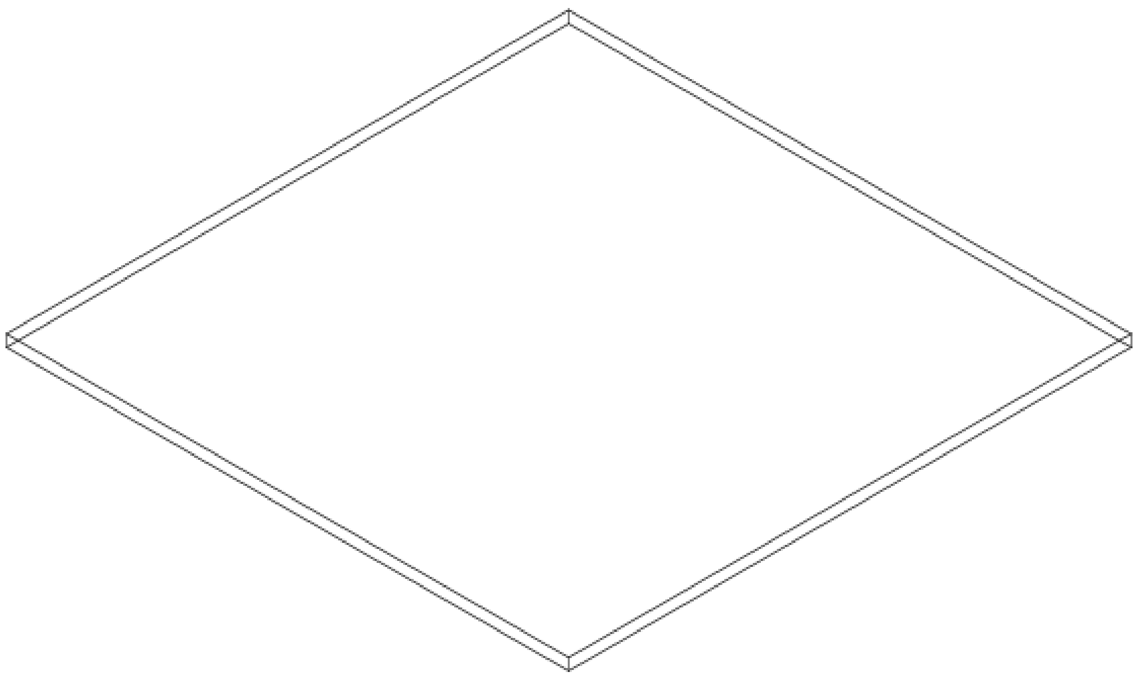
Choosing a block

Choose a scintillator block with these properties:

1. Mostly square, approximately 2 ft by 2 ft and ½ inch thick.

2. Not warped or bent or cracked.

3. As smooth on the surfaces as possible (e.g. no old glue from previous PMT collars)



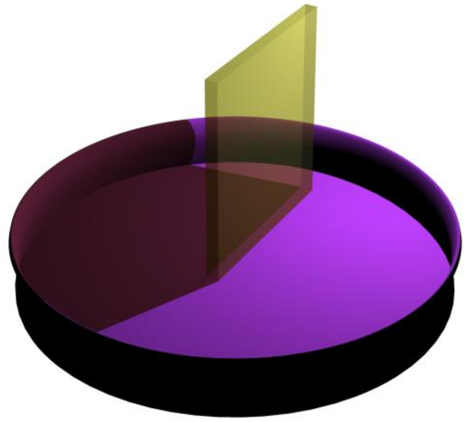
Smoothing the Sides (not always necessary)

1. Take block to machine shop

2. Talk to man running shop about how to take off jagged edges (there are about 6 ways to do this).

3. Perform chosen method

Sanding the block



1. Lay a plastic children's pool down in an open area. This is meant to minimize the amount of scintillator dust that gets on the floor and spreads out. Use a chair or stool to sit on while sanding the block.

2. Place the block on edge. Using a razor blade, run along the top edge of the block several dozen times back and forth. Use a gentle force, enough so that scintillator dust scrapes off easily.

3. Turn the block on another edge and run the razor blade along this edge many times. Continue with all edges (not the faces!). Repeat with razor until all edges are smooth and flat.

4. Place paper towels (or other paper) beneath scintillator block to avoid scratching up edges with the bottom of the pool.

5. Once edges are all smooth from the razor, switch to a sanding block. Use a medium-fine grain first (e.g. 1200). Wet the sand paper using a bucket of water. Sand all edges in a similar fashion as previously done with razor.

6. Switch to a finer grain, such as 2000. Repeat.

7. Sand once more with a finer grain, such as 2500. Repeat for all edges. Typically 3 or 4 different sand papers makes the edges smooth enough. A simple test is: can you see through the block on edge clearly?

Polishing the block

1. Gather A LOT of paper towels.

2. Place a dime-sized drop of plastic polish on a handful of paper towels.

3. Rub polish into one edge of scintillator block.

4. Continue with all edges. Repeat polishing until edges of essentially 100% see-through.

5. Polish the faces. This will take significantly more polish and more time. Be sure all scrapes and scuffs are gone.
   a. Use a circular motion for best results.

b. Some scratches may be too deep. Keep trying to polish it to the best of your ability!

Collar for the block

1. Lay the scintillator block on one face on a large cleared table top. Place newspaper or paper towels underneath it so that the face does not get scratched.

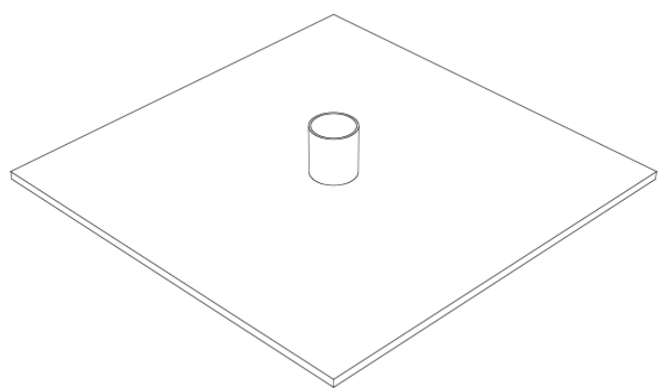
2. Find a PVC pipe “collar”. These are typically white or spray painted black.

3. Calculate the center of the face of the block (diagonals work easiest).

4. Coat one edge of the PVC pipe with PVC cement.

5. Gently set the collar at the center of the face, taking extra care to avoid excess PVC cement from getting to other areas of the block.

6. Use a book or another heavy object to weigh down the collar. Wait a day for the collar to dry.



Covering the block with aluminum foil

1. Using heavy duty aluminum foil, find the “shiny” side (more reflective, less opaque). You will be covering the block in such a way that the shiny side is facing the inside of the block (so photons inside the scintillator will be reflected by the foil)

2. Cover the entire block with aluminum foil sheets. This is best done in a “wrapping” fashion. Another individual can help by lifting the block up so that sheets can be placed underneath.

3. SHINY SIDE IN!!!

4. Use scotch tape to tape the edges of the aluminum foil to itself. You are essentially making a shell or case of aluminum foil around the block. Cover it ENTIRELY.

5. DO NOT TAPE DIRECTLY TO THE BLOCK!! Some overlap of the foil will be necessary. Avoid too much overlap, however. Be efficient with the foil.

6. Around the collar may be tricky. Use smaller pieces of aluminum foil. You CAN tape directly to the collar.

7. Edges may also be a problem. As before, be efficient. Pretend you are wrapping a present.

8. All outside aluminum edges MUST be taped down.

9. One layer of aluminum is all that is needed.

Casing the Block

1. You will need: black paper casing with center hole, cardboard sheet (about the size and thickness of the block), black rubber square with center hole (for collar), plenty of black electrical tape (you may need to use thick and thin versions)

2. Set the cardboard down. Place your aluminum foiled block on top of it. Place the black casing on top of the block.
    a. The black paper casing may not fit exactly as blocks are slightly variable in size. The electrical tape later will help keep it down.

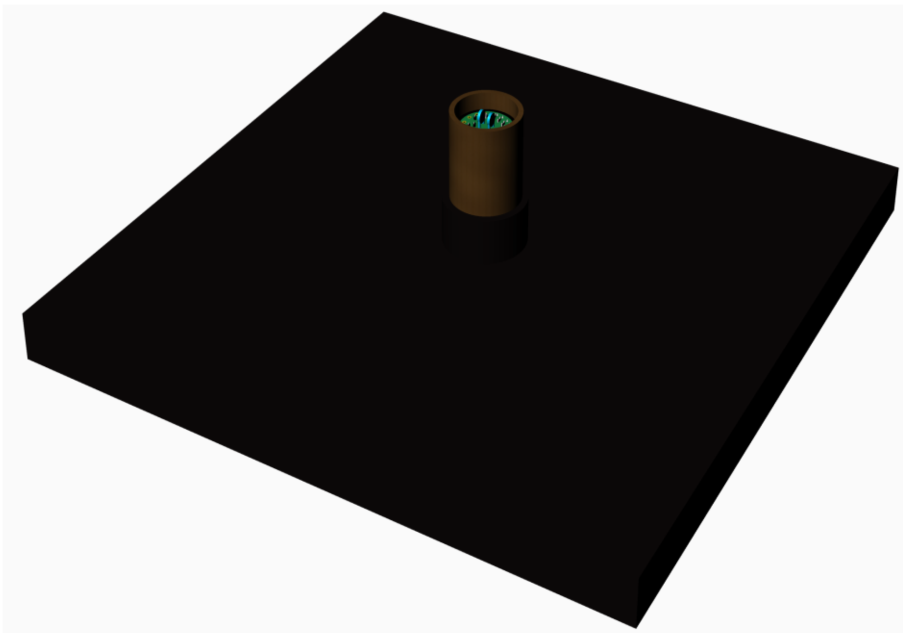
There is another alternative method of casing the block. Place a black casing with no hole down on the table. Place the cardboard inside the casing and then put the aluminum foiled block on top of the cardboard and black casing. Place the black paper over the block and then finally place the black casing with the black rubber square over the block to seal it. This method is better because the other method has the cardboard exposed to the elements. With the plastic casing, the detector is less likely to be destroyed by water damage.

3. Snugly fit the black rubber square over the collar.

4. Use the electrical tape to tape down:
    a. Around all the edges and corners to the block and cardboard.
    b. Around rubber square.
    c. Around collar.

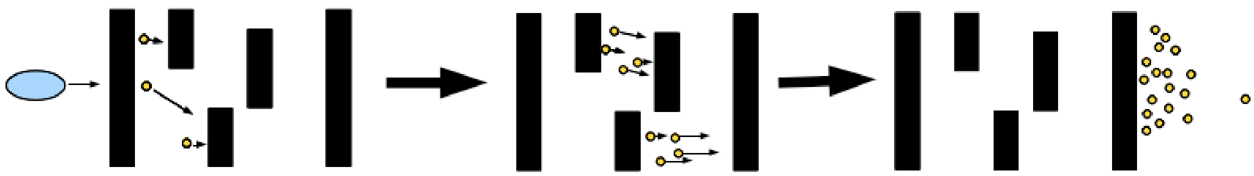
5. Be sure to not stretch out the electrical tape. Place it as is when taping. Stretching it makes it less light tight.

6. Your goal is essentially to make the detector COMPLETELY LIGHT TIGHT. Meaning, NO LIGHT can enter. Tape every nook and cranny. Corners and the collar are exceptionally vulnerable.

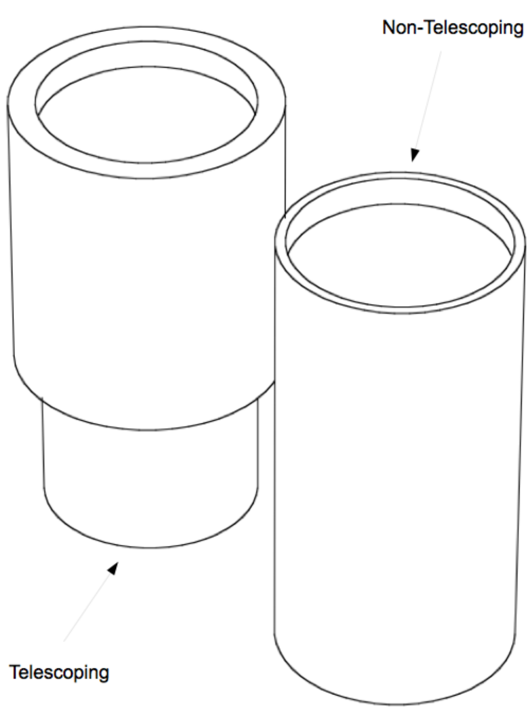


Photomultipler Tubes (PMTs)

Photomultiplier tubes (abbreviated as PMTs) are the most important piece of the detector and also the most difficult piece to test and work with. To understand the PMT is to understand the entire detector. Photomultipliers work through a method of signal gain to create a strong signal from a small incident. When a cosmic ray intersects with the block of scintillator, a burst of photons is released into the detector. When one of these photons enters the PMT, it collides with a plate that releases electrons into the tube. These electrons collide with more plates, and eventually an avalanche of electrons is created as a signal. A diagram is shown below.



In CROP you will be exposed to two different types of photomultiplier tubes: telescoping and non-telescoping.



Telescoping Tubes

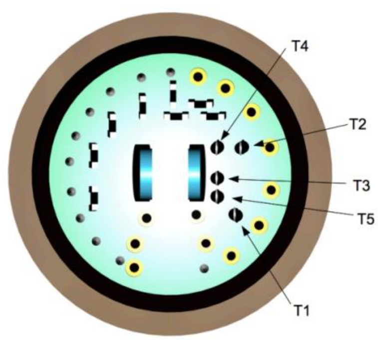
The telescoping tubes were donated by a project that completed its run. These tubes were brought to CROP from Utah, and require extensive testing to see how well they work. An illustration of one of these PMTs is below

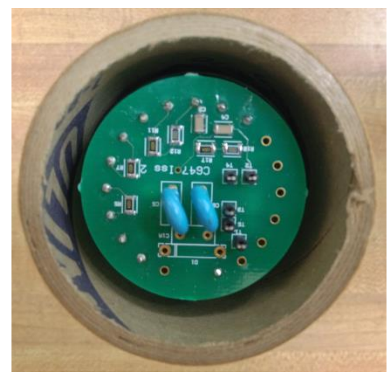
Some of these tubes do not work at all, others may need to be repaired before they can function, but what is true of all of them is that they need to be cleaned. Light enters the tube through its base which is placed in contact with a polished block of scintillator. Therefore having the glass surface on the base of the PMT as transparent as possible creates a more optimal path for the light to travel through. The bottoms of the PMTs often have large amounts of glue stuck to them. Acetone provides a method of dissolving the glue, and alcohol removes other oils and dirt. Once you have cleaned the bottom, use the alcohol to clean the top too

If you are working with a “new” batch of the telescoping PMT’s you will notice that they have gray power cables. To this day I have no idea how the previous project got away with using these cables because they begin to break down at 600V. The PMTs run at 1300V-1800V. Due to the fact that our project lacks the magical ability to not burn through the cable, we have to replace them. In the lab you will find standard high voltage cables (in my day it was red). Replacing the cables for these PMTs is not very difficult. One simply removes the outer casing of the red HV cable, unbraids the copper wire, strips the plastic surrounding the inner HV wire, and solders them to the PMT. Copper wire goes in the place marked 0V, inner HV wire goes to place marked HV. Cover them with electrical tape to insulate the electricity.

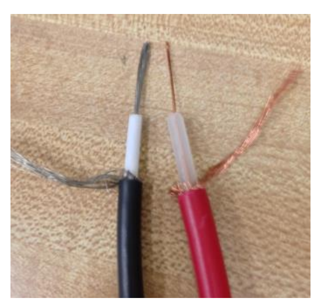
Non-Telescoping Tubes

We have different PMTs from a company called “Electron Tubes.” These PMTs have higher efficiencies, higher thresholds, and operate at a higher voltage. When running a threshold scan on these PMTs you will have to use a higher voltage than the recommended 1350 volts the “Efficiency Testing” chapter suggests. It is not uncommon for them to run at their peak efficiency at around 1800V. There are a couple things that need to be mentioned when dealing with these new PMTs. First and foremost is that you many need to place them in their tubes to begin with. To do this you slide them into a cardboard tube that has been cut into sections. You then have to caulk the top, outer edge of the PMT to make it light tight. However, this alone is not enough to seal light out of the tube. There is a gap between the top circuit board and the cardboard tube. You either have to put special high resistance caulk to seal it, which is purchased through Dr. Kelty at the electronics shop, or place a cap on the top of the PMT that is light tight. After you put the PMT in its tube, you now have the task of wiring it.

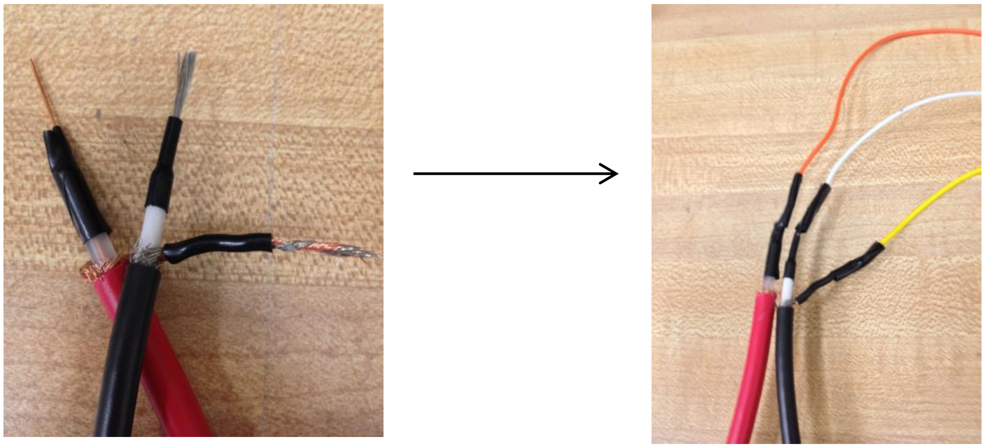




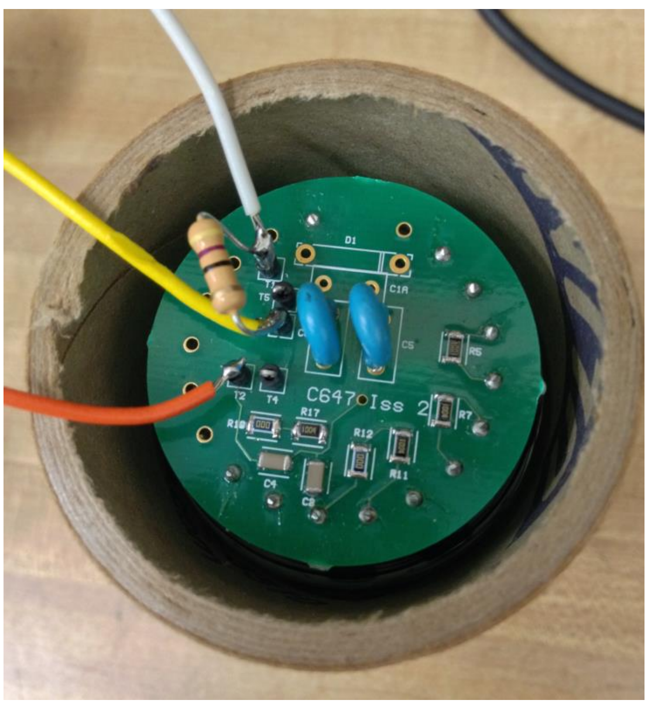
First, you must acquire about three feet of a red high voltage (HV) cable and a black signal cable. Strip both wires at the ends so you have about two inches of bare wire to work with. It may be difficult to strip since the wires are rather thick. Unbraid both of the outer wires and cut about 2/3 of the outer wire away. Strip the inner wire about an inch from the top.



Twist the two outer wires together (this is referenced as ground) and wrap the three wires with heat shrink or electrical tape to prevent you from getting shocked. Then, gather three colored wires. I have chosen orange, yellow, and white. Solder the white wire to the inner wire of the black signal cable. Solder the orange wire to the inner wire of the red HV cable. Solder the yellow wire to the twisted outer wires. (Make sure to not make the jumper wires long and completely cover any exposed wiring with heat shrink for protection of potential shocks)



Solder the ground wire to T1 on the PMT, and then solder the high voltage wire to T2 and the signal wire to T3. Then place a 50 Ω resistor between T1 and T3. A 50 Ω resistor has the color bands of gold, black, dark red, and yellow. Cap or caulk the PMT so it is light tight. Now you are ready to test it. If the PMT is new, make sure you remove the black sticker at the bottom of the PMT so it can receive signals!

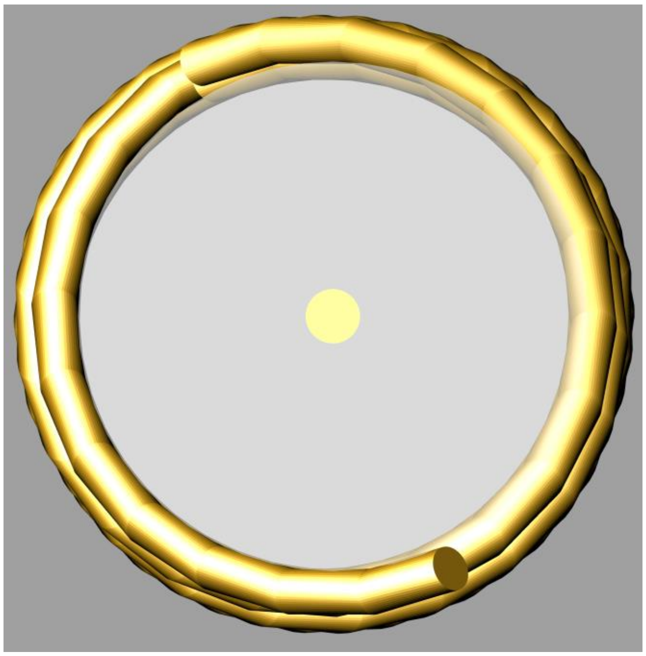


Creating a Power Cable

Note: Follow steps 1-6 to create the end of the cable that connects to the PMT (though there are a few extra steps described on page 27 for non-telescoping PMTs). Continue with steps 7-8 to create the end of the cable that plugs into the power supply.

1. Cut yourself a piece of red HV cable, about three feet long.

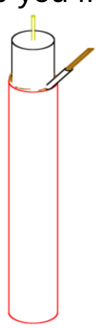
2. Cut away two inches of the outside plastic on one end of the cable. The end of the cable should look like the illustration below.

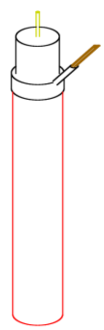


3. Unravel the braided copper wire, and twist 1/3 of it together, cut away the rest.

4. Use a wire stripper to remove the plastic surrounding the central wire in the cable

5. Place heat-shrink over the braided wire; shrink it using a heat gun. This will keep you from receiving a nasty shock later.

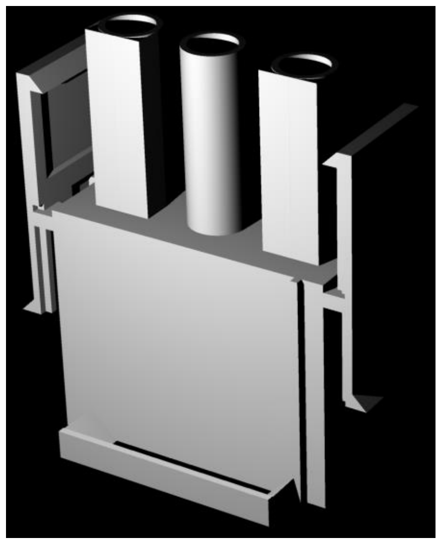




6. Place heat-shrink at the point of your first incision into the wire, shrink it. This once again keeps you safe against electricity.

7. Obtain 2 female ended high-voltage pins and solder them to the two ends you have created.

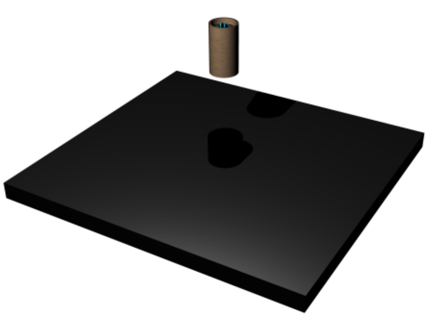
8. Obtain a voltage head and insert the pins. They will click when fully inserted. If you have the flat part of the voltage head facing down and away from you, you will place in the ends such that the grounding wire (one covered in black heat-shrink) is on the right.

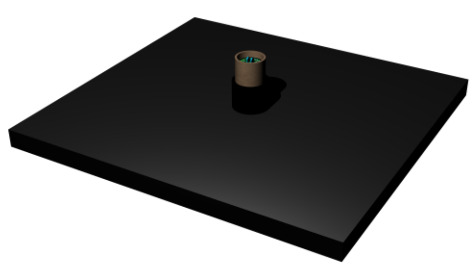


This is an illustration of the voltage head used in CROP. Notice the strip of plastic down the length of the rectangular portion. This line indicates the space in which the **High Voltage** wire is placed.

Gluing a PMT

Before gluing on the PMT, make sure the PMT has been cleaned with acetone as described on page 26. Gluing a PMT is a rather simple task. First, place optical grease on the glass portion of the PMT and the remaining open surface inside the collar. Place the PMT inside the collar and press firmly. Wrap the collar up to the PMT with electrical tape so light does not enter through the top.



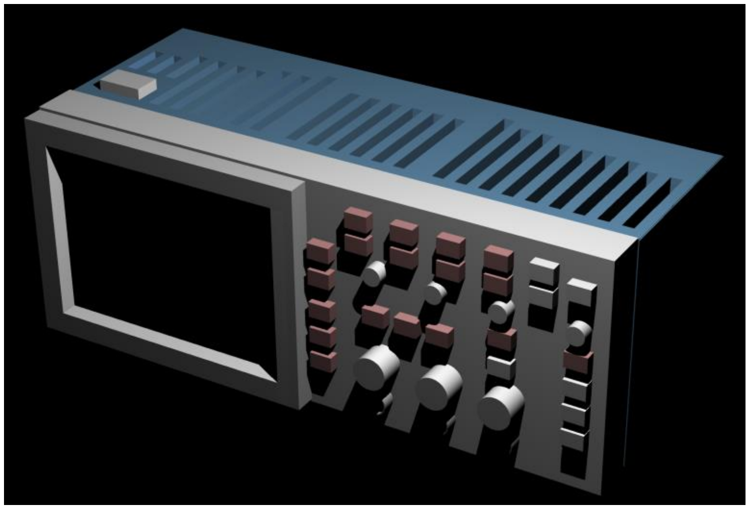


PMT Testing

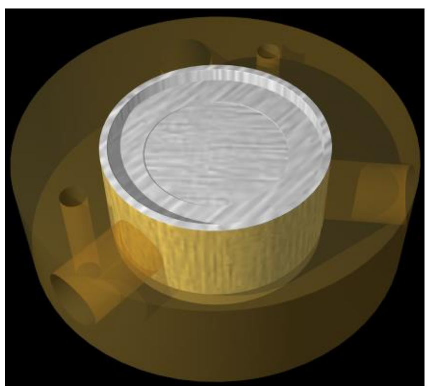
Alpha Testing

Supplies needed

Oscilloscope



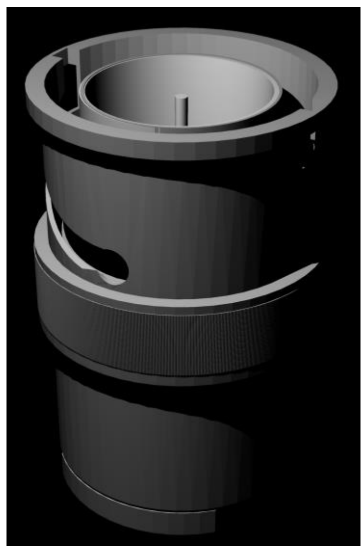
Alpha Source



Black Covering (PBC pipe wrapped in electrical tape)

Signal Splitter (T Connector)

Terminator



1. Using the thin black electrical tape (¾ inch wide), tape the alpha source to the photomultiplier tube. (Make sure the correct side of the source is facing the tube window)

2. Place the cap over the window and tape it to the sides of the tube using the thick electrical tape (2 inch wide). Make sure it is securely taped to the tube to avoid light leaks.

3. The T connector is already on the oscilloscope with a 50 ohm terminator on one end. Plug the signal cable into the other end. A drawing of an oscilloscope is on the next page.

4. Plug the high voltage cable into a power supply. Turn it on and slowly increase the voltage until the display reads 1300V.

5. Look for the signal on the oscilloscope. (Good: 1V/div and 250ns/div. Bad: 100mV/div and 25ns/div)

6. Record the PMT number and the average height and width of the signal as seen on the oscilloscope. Record the noise band as with Monkey Box testing (pages 34-35). Sketch a scope image.

7. Using pliers, wiggle the signal and the high voltage cables close to the solder joints on the tube to see if the signal does these two things:
   a. If the cables must be held in a certain position for the signal to appear.
   b. If the signal becomes noisy once the cables are wiggled.

8. Record any problems noticed with the PMT and set aside to be fixed if necessary.

9. Slowly decrease the voltage on the power supply to zero and turn off. Disconnect the tube from the oscilloscope and power supply. Remove the alpha source.

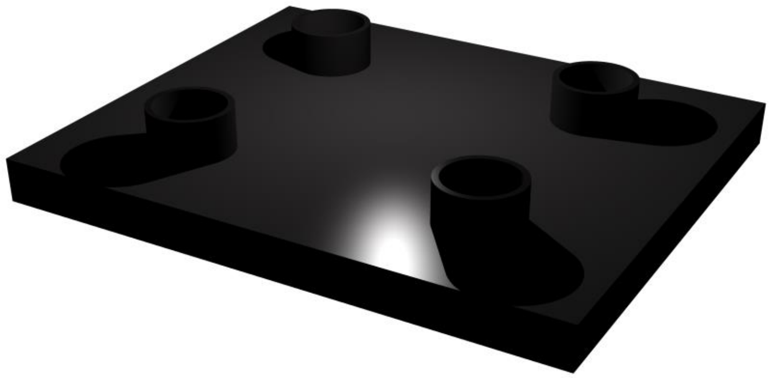
Important notes:

1. Never connect or disconnect the PMT from the power supply if the supply is on.
2. Always turn the power up and down SLOWLY.
3. Never expose the uncovered tube window to outside light (room, outdoors, etc) while
   the tube is being powered by the power supply.

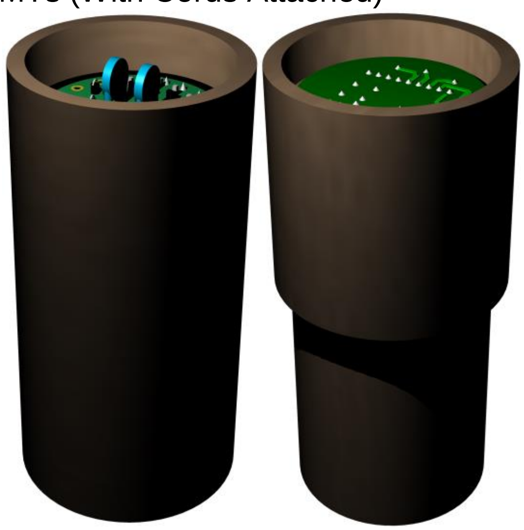
Monkey Box Testing

Supplies Needed

Monkey Box



At Least Four Untested PMTs (With Cords Attached)

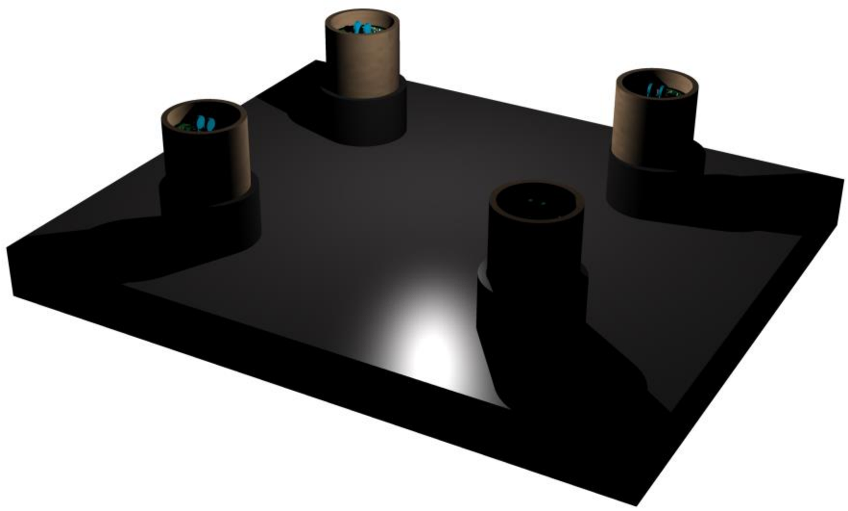


Power Supply

Notes: This is one of the most frustrating and tedious jobs that we do. You test four of the PMTs at a time. The smallest light leak in any of the collars (or tape attaching the collars to the PMTs) will make it such that you have to retest all four PMTs, even if you have already done three of them.

1. Place four PMTs in the monkey box. Make sure their bottoms rest flat against the base of the monkey box.

2. Tape the PMTs to collars, carefully in order to not to let in any light leaks.



3. Set 20.0mV/div and 25 ns/div, then judge noise level and adjust Trigger level to 20-100mV range until a rate between 60-100 Hz.

4. Reset scale to see full pulses (about 100 mV/div). Estimate typical range of pulses.

5. Lower sensitivity to 2.0mv/div and turn to 5µs/div. Find width of noise in volts.

You want:

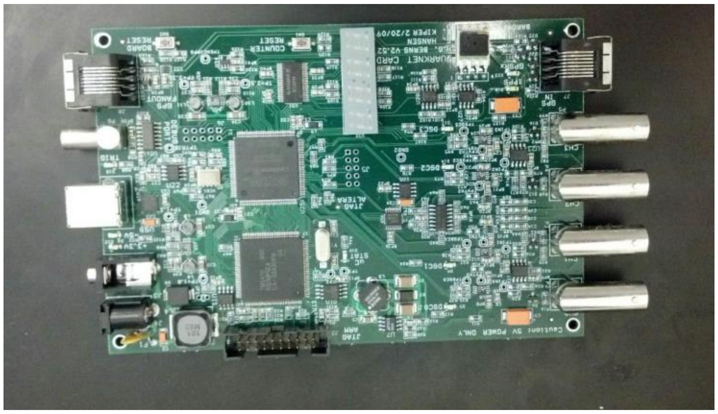
Small trigger/threshold level (about 60mV)
Large pulse heights (100-200mV)
Small noise band (1.0mV)

Getting Started

This section will discuss installing the drivers for the DAQ card, specific programs needed for troubleshooting, and the CROP software with additional supportive software needed to run the program.

Installing Drivers for DAQ

These are the following steps to find and install the driver for the new DAQ (picture below).

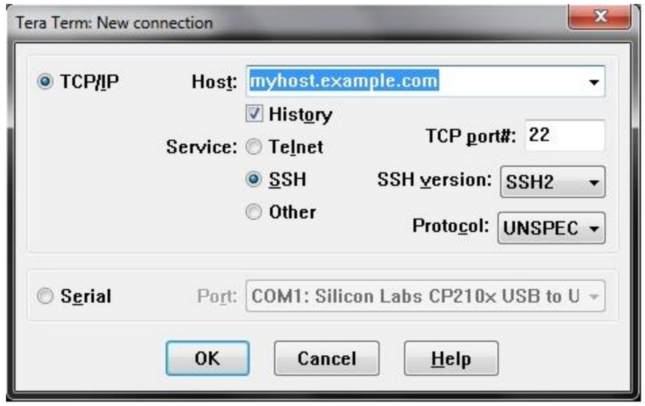


1. Go to: https://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx and select **VCP Driver Kit for Windows** (currently the DAQ software only works with XP to Windows 7).

2. Unzip the folder named CP210x VCP Windows and then click on CP210xVCPInstaller_x##.exe to install the driver. Depending on your architecture for your PC, click on _x86 for 32-bit and _x64 for 64-bit.

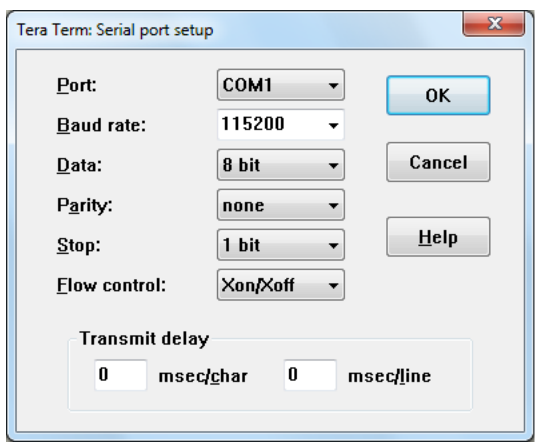
3. To make sure everything is properly installed and to help with further setup on other scans, a program called TeraTerm will need to be installed. Doing a Google search for TeraTerm is all that is required to find it or go to their homepage which is http://ttssh2.sourceforge.jp/index.html.en.

4. Once this program is installed, click on the program. A window will pop up similar to the image on the next page:

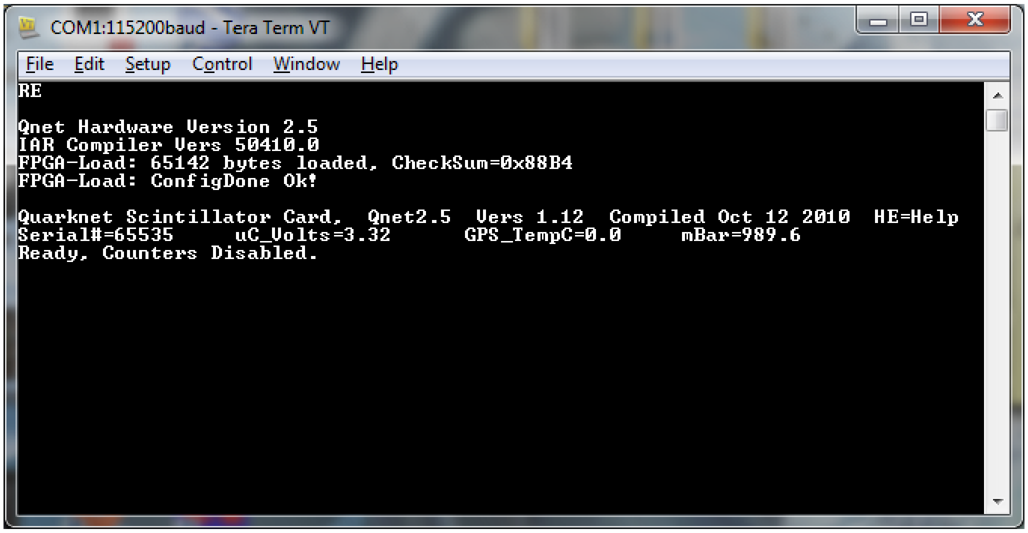


5. Select the “Serial” option and then click on “Port”. The COM# will be different depending on the configuration of your PC. It will sometimes change depending on what USB port the card is plugged into or by manually changing the properties of the card (this will be discussed at a later time for configuring the card to work with the software). Make sure that Silicon Labs CP210x USB to UART Bridge is selected. Then click “OK”.

6. After that, go to “Setup” and select “Serial port”. Make sure that the serial port setup is identical to the image below for the baud rate, data, parity, stop and flow control. Once this is done click “OK”.



7. These past steps just configured the card so that the computer can properly interact with it. With TeraTerm still open, type **RE** (reset everything) in the command terminal. If you are not allowed to type anything in the terminal then something was missed in the setup. Please start at the beginning and try again. Once RE is typed in the terminal, two things will happen. The DAQ card will flash its LEDs and the terminal should look like the image on the next page. If these two things happen, then everything is correctly setup and the card is ready for scans.



These are the following steps to find and install the driver for the old DAQ (picture below).

1. To install the driver for the old DAQ, all one has to do is install the 4.0 software. The software has the driver bundled together.

Installing CROP Software

This section will discuss the installation of CROP's homegrown software created in LabVIEW. These following steps work for version 4.0 and version 5.0.

1. There will hopefully be two methods to install the software. These two are by compact disc or by downloading the software from our website http://crop.unl.edu/.

2. Using a disc, copy the folder CROP Installer 4.0 or 5.0 to your computer. The location of this folder is up to you. Once the website download is available, do the same thing as stated for the disc.

3. Once the folder is copied over to your PC, open it and select setup.exe. This will start the install progress. This will install the CROP software and additional National Instruments addons so that the software works properly.

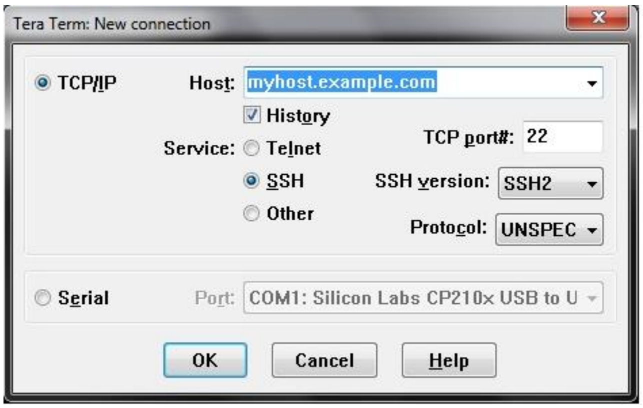
4. When the installer is finished, the software will still not open because it needs LabVIEW Run Time Engine version 8.5 or higher. Doing a Google search for LabVIEW Run Time Engine 8.5 is all that is required to find it or go to http://joule.ni.com/nidu/cds/view/p/id/861/lang/en. If you are using version 5.2.1 or higher, the run time engine should already be installed due to the additional addons. If this is the case then disregard the next step.

5. Select LabVIEW85RuntimeEngineFull.exe on the website or another similar version and install it. Once this installation is complete then the CROP software should be running properly.

Setup and Configure

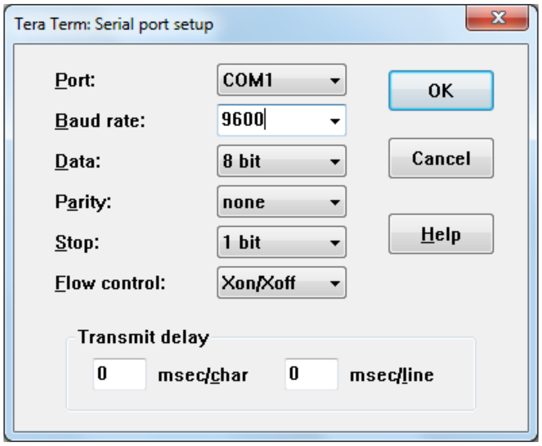
This section will discuss the setup and configuration for the DAQ card and software so that everything works properly without any errors. It is the same instructions as those ensuring that the drivers and TeraTerm were working properly after installation. These steps must be followed every time the card and software are used.

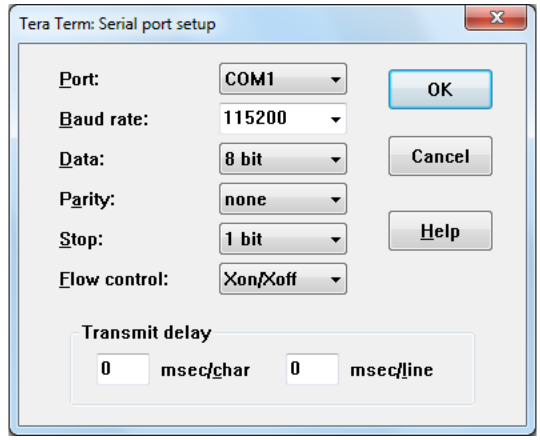
1. To setup the DAQ card to make sure everything is properly configured. Click on TeraTerm. A window will pop up similar to the image below:



2. Select the “Serial” option and then click on “Port”. The COM# will be different depending on the configuration of your PC. It will sometimes change depending on what USB port the card is plugged into or by manually changing the properties of the card (this will be discussed at a later time for configuring the card to work with the software). Make sure that Silicon Labs CP210x USB to UART Bridge is selected. Keep in mind what COM the card is connected to because this will be used later to setting up a scan. Then click “OK”.

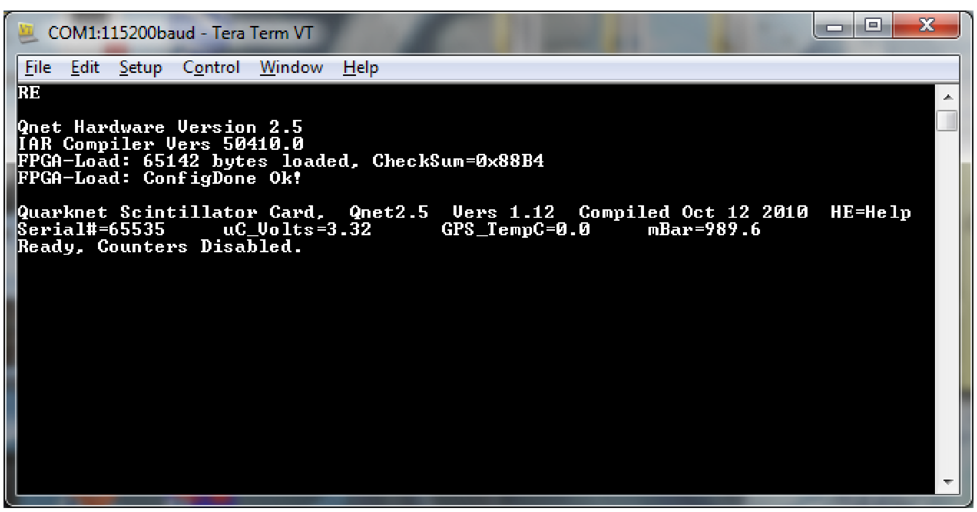
3. After that, go to “Setup” and select “Serial port”. Make sure that the serial port setup is identical to the images on the next page for the baud rate, data, parity, stop and flow control. Once this is done click “OK”.





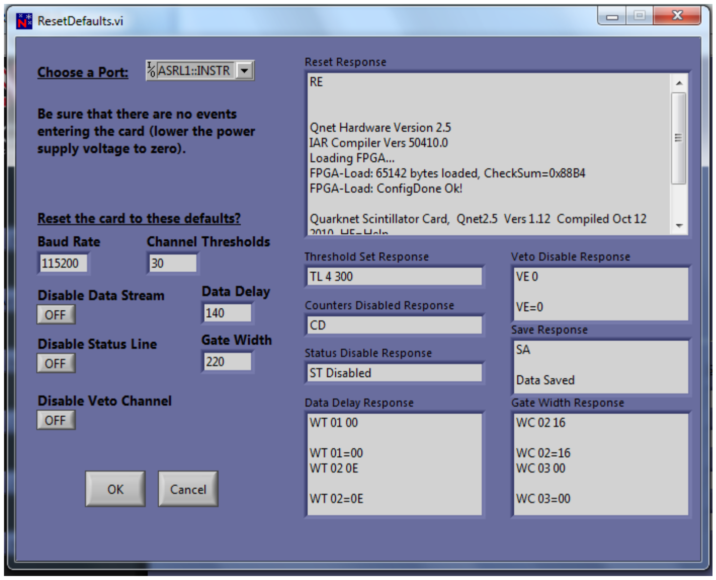
(Images for the serial port setup, Left – Old DAQ card; Right – New DAQ card)

4. These past steps just configured the card so that the computer can properly interact with it. Regarding the new DAQ card, one can make sure everything is properly configured. To do this, TeraTerm still open, type **RE** (reset everything) in the command terminal. If you are not allowed to type anything in the terminal then something was missed in the setup. Please start at the beginning and try again. Once RE is typed in the terminal, two things will happen. The DAQ card will flash its LEDs and the terminal should look like the image below. If these two things happen, then everything is correctly setup and the card is ready for scans.



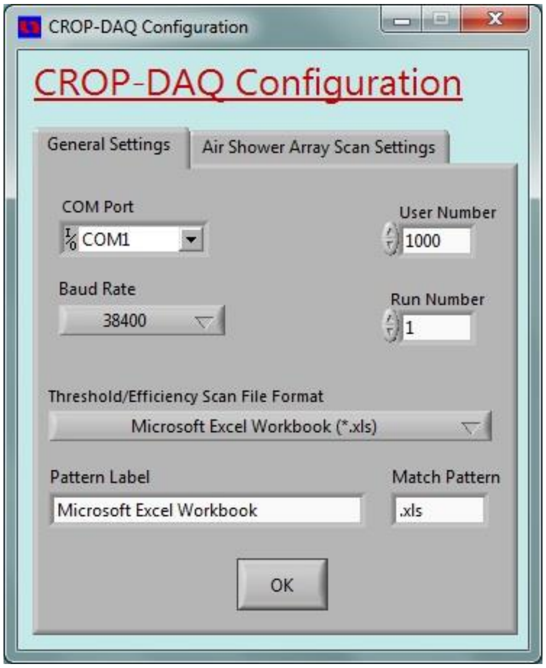
5. With the card properly communicating with the PC, start up the CROP software. Depending on which version you are using, there are a few extra steps. In version 5.0, the software allows you to reset the card and make sure that the card is properly communicating with the software and PC. To do this, run the “Reset Card Defaults” mini program by selecting it in the “Tools” menu in the CROP DAQ program. Then select the port that the

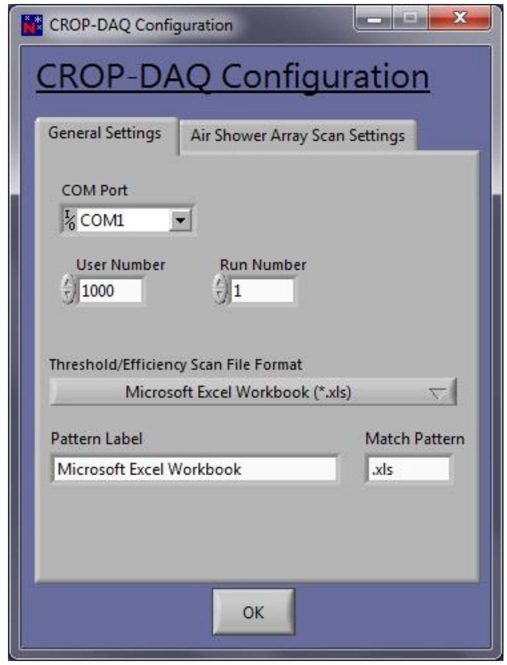
DAQ card is connected to (this tends to lag a bit so please wait patiently). Simply click “OK” and wait for responses. The responses should look like the image below. Click the “X” to close the mini program. If it does NOT look like the responses below, then “hard reset” the card by unplugging and plugging back in. Try it again.



6. Once resetting the card is done for the new DAQ card only; continue on to configure the card for both new and old by selecting “Configuration” in the “Tools” menu. This is where remembering what COM the card is connected to is important. Select the COM# that the card is connected to and then click “OK”. Images of the configuration menu are shown on the next page.

7. This is also a perfect time to input your User Number so that when doing specific scans such as the Array Shower Scan the number will be included in the stored data.





(Images for the Configuration menu, Left – Old DAQ card; Right – New DAQ card)

8. After following these past steps, the card is officially ready to do a scan! Please read the troubleshooting section because there are known to be a few errors that come up if not specially treated.

Troubleshooting

This section will discuss possible errors or problems that might come up and how to fix them. These can occur during certain scans or random bugs.

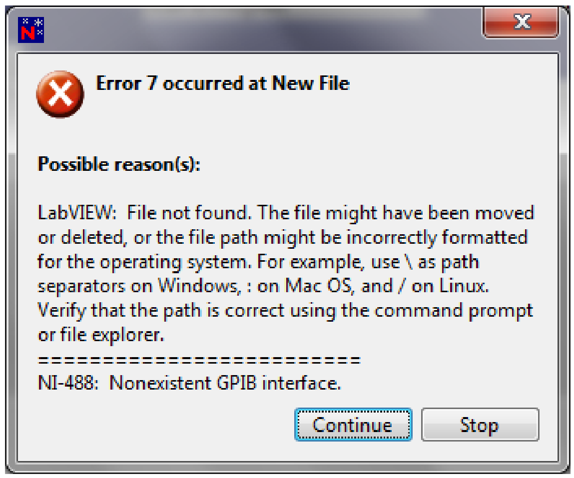
CROP Software Freezes

In version 5.0 there is an “Abort” button at the bottom left hand side of the program. This a kill button if anything happens to freeze. If more problems occur, such as it won’t unfreeze or the program won’t close at all, use “control alt delete”, click “start task manager”, select the CROP program under the application tab and then click “end process”.

Program Won't Open

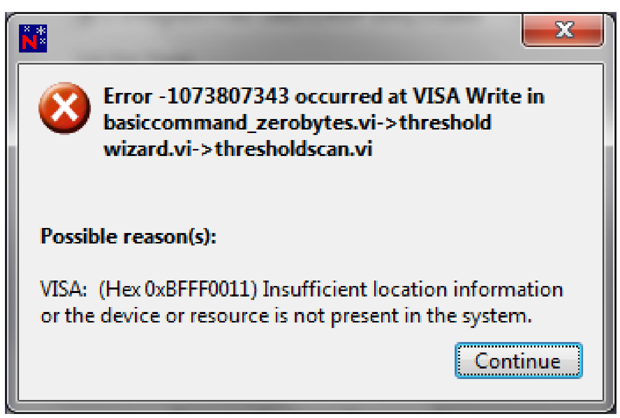
If the program won't open it might mean that the PC still thinks it is running so use "control alt delete", click "start task manager", under process tab select CROP DAQ.exe and then "end process".

Error 7 (File Not Found)



This error occurs when starting an array scan or experiment scan. The error means that the correct path to store the data from the scan is not present. To fix this problem, create a folder named Crop Data in your C: drive. This will be where all the array and experiment scans data will be stored.

Error -1073807343 (Device Not Present)



This error comes up when the PC, DAQ card, or software card was improperly configured once you click on a scan. The program is looking for the DAQ card but due to the improper configuration, the software errors out. Go back to section Setup and Configure to make sure nothing was missed. Even if all steps are followed in the Setup and Configure section there is a chance that the program might still error out due to a bug in the Configuration menu (refer back to step 7 in the setup and configure section). This bug is found to occur more on Window 7 PCs than Windows XP.

To fix this issue, we are going to manually set the DAQ card to COM1, as this is usually the default option in the configuration menu for the DAQ software. Depending on which version (XP to Windows 7) of your operating system, a few steps will be different.

1. Click on the “Start” (for Windows 7 it is a windows icon), this is usually located on the bottom left hand side of the screen.

2. Click on “Control Panel”.

3. The next few steps are where XP and Windows 7 are different. For Windows 7, click on “Hardware and Sound” and then “Devices and Printers”. The DAQ card should be in the unspecified category named Silicon Labs CP210X USB to UART Bridge. It will also display the current COM#. For Windows XP, click on “System” and click on the “Hardware” tab. Click on “Device Manager” and locate and click the category “Ports”. Once clicked, the DAQ card will be displayed with the same name above and the current COM#.

4. Right click on the name of the card and select “Properties”. Next click on the “Hardware” tab and select “Properties” at the bottom of the window.

5. For Windows 7, click on the “Change settings” at the bottom of the “General” tab. Click on “Port Settings” and then “Advanced”. Once this is selected, Find “Com Port Number” and selected COM1. For Windows XP, do all the previous steps above other than “Change settings”. If COM1 is in use, find the location of the device that is using COM1 and change it to another COM by a similar method above.

6. When the COM# is turned to 1, click on Ok until all the windows are closed

Scans

This instructions for the Threshold and Efficiency Scans described here are for the old DAQ card and 4.0 software. There are some minor changes for the new DAQ card and 5.0 software, so if that is the equipment to be used, see page 60 for the differences.

Threshold Scan

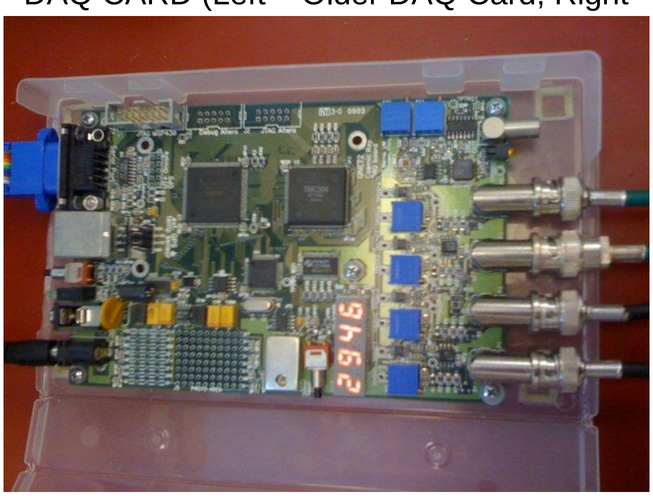
In order to test the detectors that we create, it is necessary for us to determine what the “background noise” is that we read from them. If you plug a detector into an oscilloscope you will notice that the frequency of strikes that it reads varies by the trigger level that is chosen. When the trigger level on the scope is very low it is not uncommon to get readings in the kilohertz. If your detector is within a solid building, then the frequency of strikes should be from 80-110 Hz. The rest of these signals are background noise. Put simply, they are voltage jumps within the wire unrelated to what we are measuring. In order to “tune” our detectors so that they will pick up cosmic rays and not this background noise, it is necessary to determine the threshold voltage of the photomultiplier tube. In other words find the voltage level of the background noise produces and only accept signals above that level.

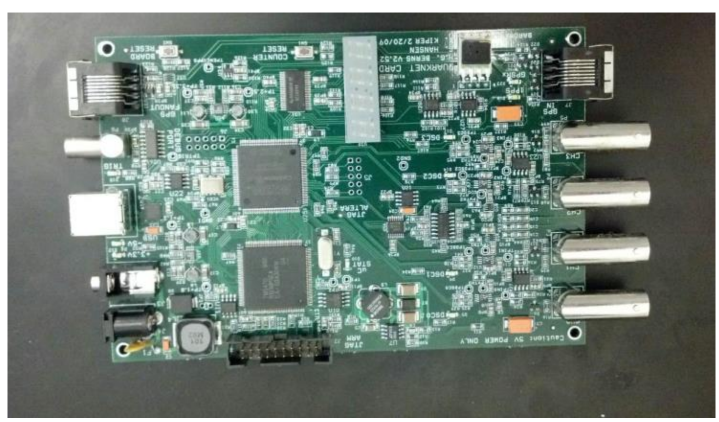
The CROP DAQ software has a method of determining this voltage. In essence, the software takes readings from the DAQ card as you constantly increase the amount of voltage necessary for a signal to get through. You can use up to 4 detectors at a time for testing.

The following guide for Threshold scans is for the old DAQ card and 4.0 software. There are some minor changes for how the new DAQ card and 5.0 software works; please read the following section on page 60 before continuing if this is the equipment you are going to use.

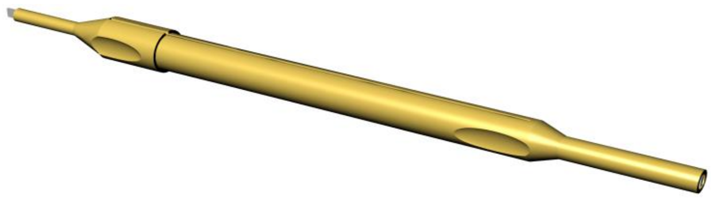
Equipment

DAQ CARD (Left – Older DAQ Card; Right – New DAQ Card)

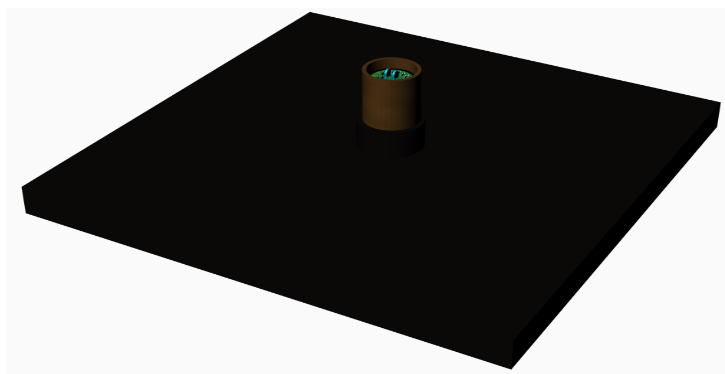




CROP Screwdriver (Required only for old DAQ Card)



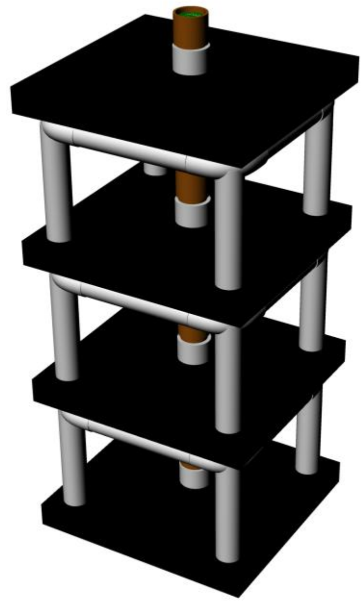
Detectors



HV Supply

Instructions

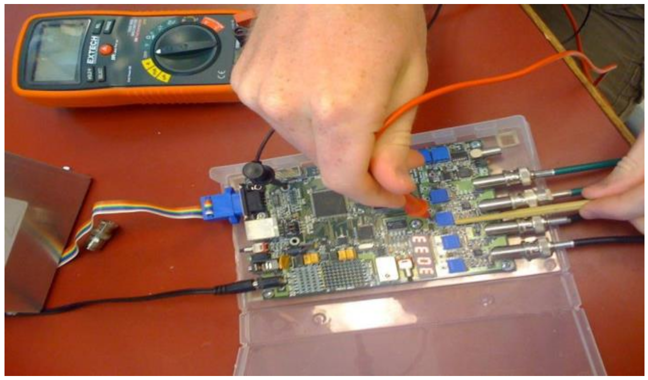
1. Stack your detectors in a tower.



2. Hook up the power cords to a HV power supply and set to 1350 V

3. Plug in the Signal Cables to the DAQ Card

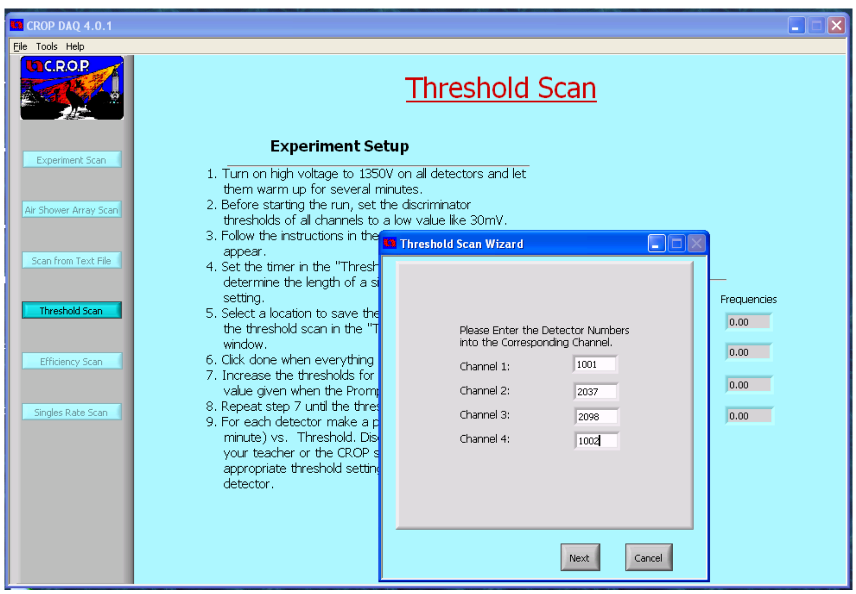
4. Using a CROP screwdriver (a jeweler's screwdriver will also work) set the thresholds on the DAQ cards to 30 mV
   a. This requires use of a meter.
   b. You change the meter to measure voltage
   c. Place the ground from the meter on one of the large, circular, metal holes
   d. Place the Vin probe on hole the metal indent above the blue potentiometer you are adjusting
   e. Tighten or loosen the potentiometer to change the threshold voltage. (which can be viewed on the screen of the voltmeter)



5. Open the CROP DAQ program.

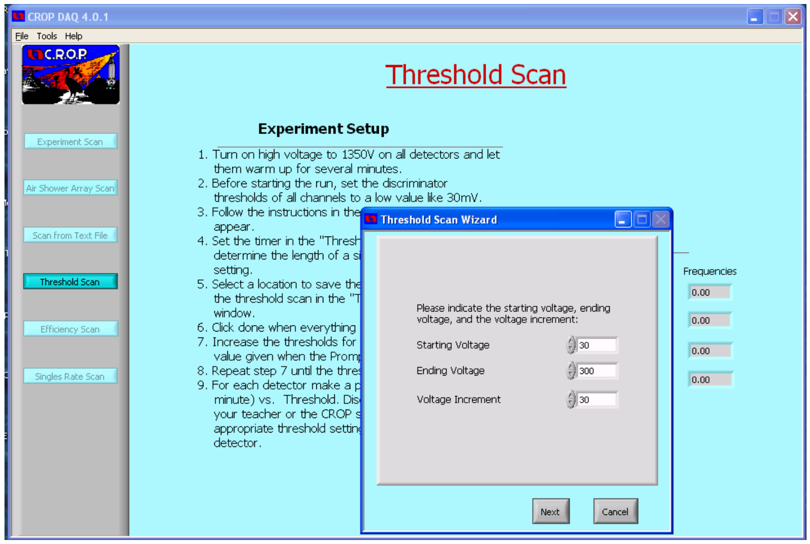
6. Click "Threshold Scan"

7. A window should appear prompts you to enter the detector numbers. These are located on the PMTs



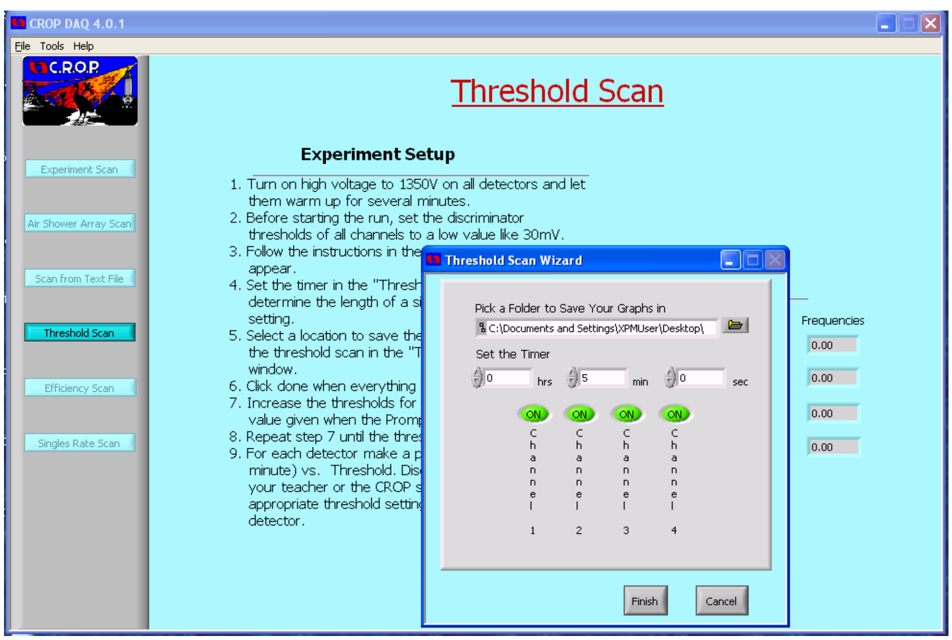
8. Click next on the window

9. A second window should appear asking for you to set the starting, ending, and increment voltages for the DAQ Card. Usually we keep these to be the given values 30mV to 300mV.

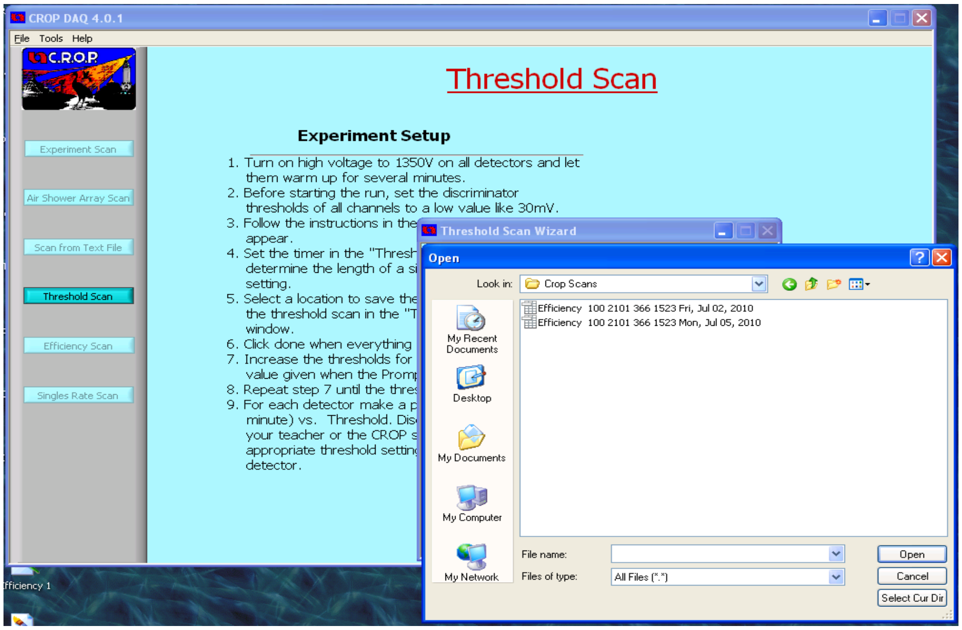


10. Click "Next"

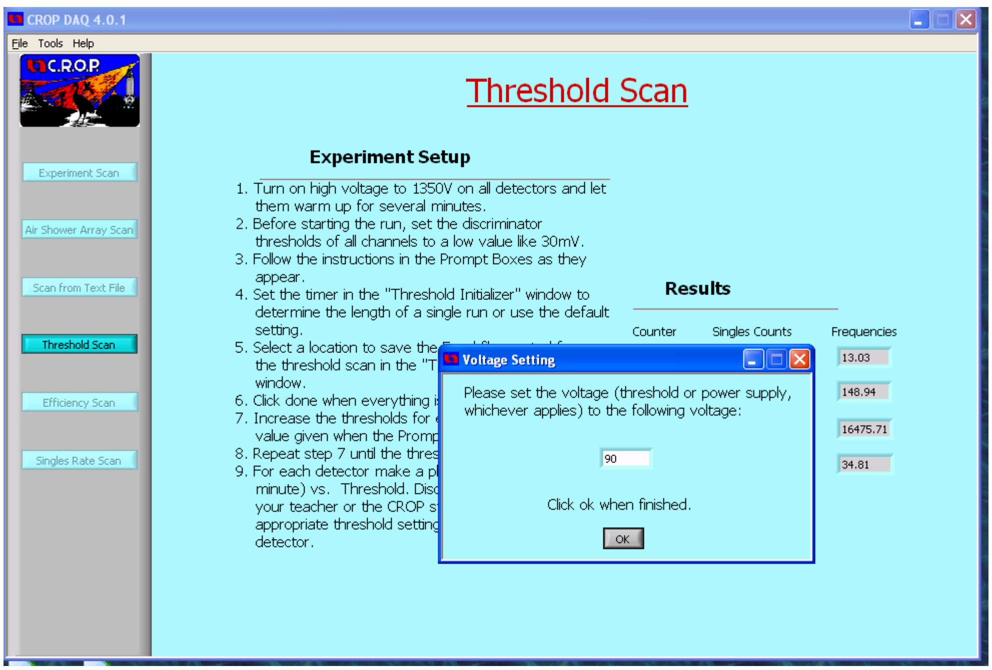
11. A new window should emerge that prompts the user to select a location to save the scan results. Click the open folder icon to select a location. This window will also ask you for the length of time you wish to test the threshold for each voltage increment. Normally we assign 5 minutes, however any amount of time over 3 minutes should work.



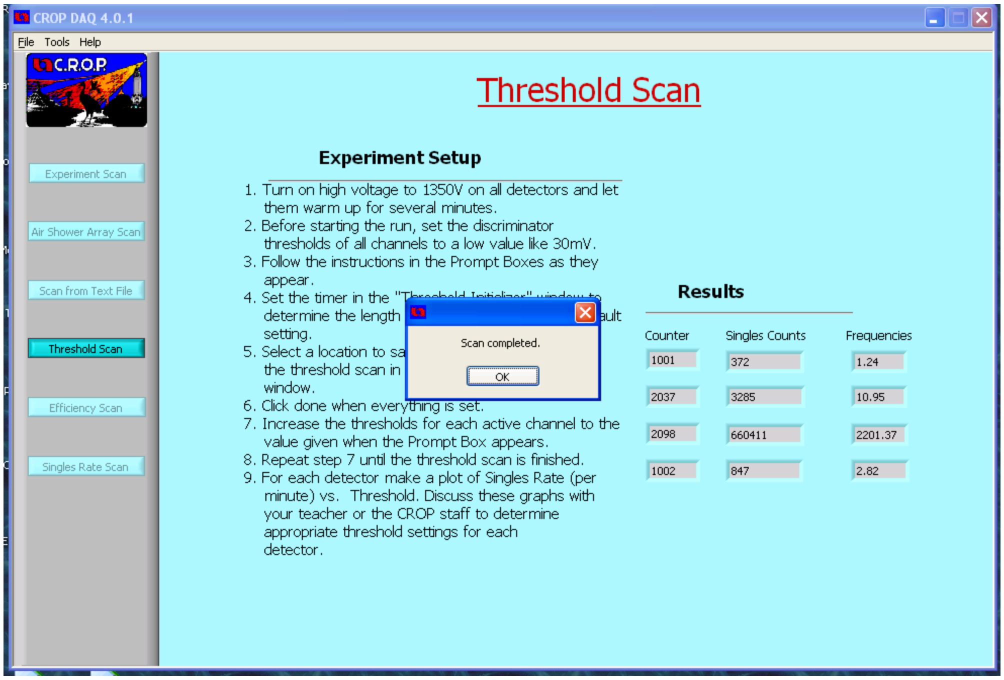
12. Select your scanning folder with the "select current directory" button.



13. After selecting next, you will begin the scan. Throughout the scan you will be prompted to change the threshold voltages to values listed on the screen.

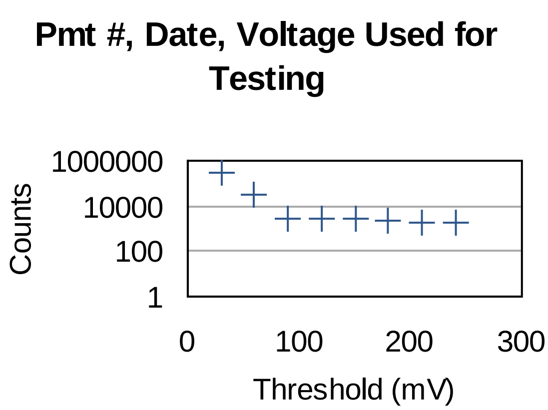


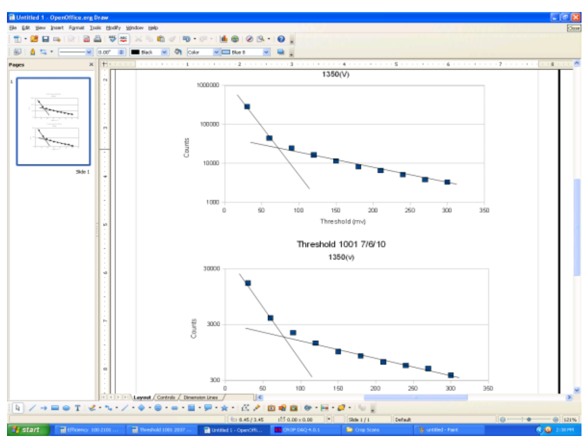
14. After the scan completes, you will be brought to the following window. Click OK



15. Go to the saved file and open it in a spread sheet. Plot the data in the following format.

16. To find the threshold, plot the noise line (the bottom line) and the signals line (top left line). If you are doing this in open office you can simply copy the charts in to Open Office Draw. Print these and attach them to the corresponding detectors.





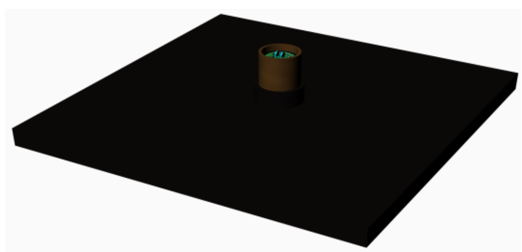
Efficiency Scan

Efficiency testing is a process used to determine how well the detectors function. To do this requires the use of what are called “trigger counters.” These are counters whose efficiencies have already been mapped and deemed worth using. The process works via a method of linear strikes. Cosmic rays travel in very quick, straight lines. If you have detectors stacked vertically, it is possible for a particle to pass through all of the detectors. Now let’s suppose that the top and bottom detector said that this particle passed through them, but the two detectors in the middle didn’t get a reading on it. In this situation, it is very likely that the particle did go through all four detectors, but the center two simply missed it. We calculate efficiency by dividing the number of particles that went though all four detectors by the number that the top and bottom detected.

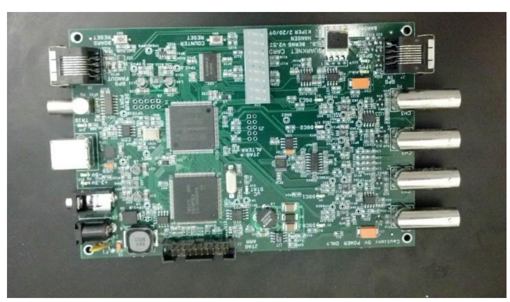
The following guide for the Efficiency scans is for the old DAQ card and 4.0 software. There are some small changes on how the new DAQ card and 5.0 software works; please read the section on page 60 before continuing if this is the equipment you are going to use.

<u>Equipment</u>

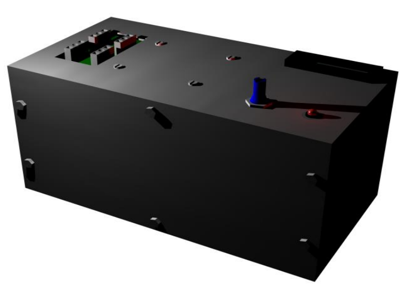
4 detectors: 2 untested and 2 triggers



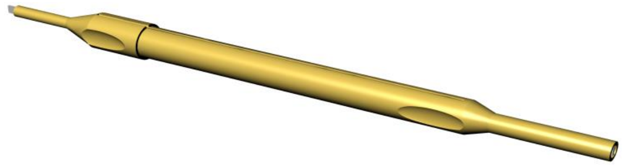
DAQ CARD (Left – Older DAQ Card Right – New DAQ Card)



2 Power Supplies

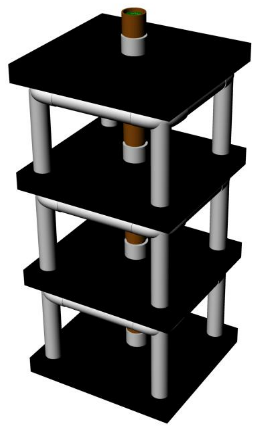


CROP Screwdriver (Required for old DAQ card only)



Instructions

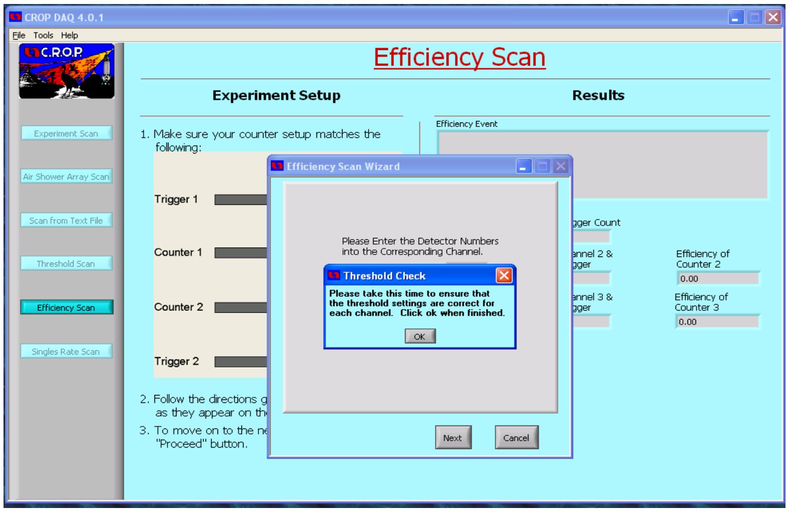
1. Stack the detectors into a tower with the top and bottom detector being the triggers



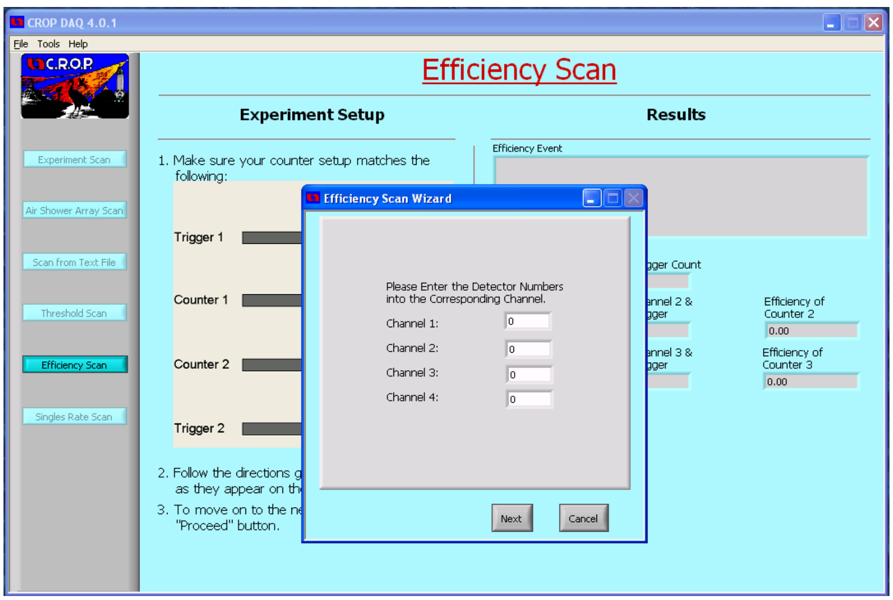
2. Plug the two trigger detectors into one power supply, and the non-tested detectors into the other. Turn the voltage of the triggers to a level in which they both have high efficiency.

3. Enter the thresholds of the detectors into the DAQ card.

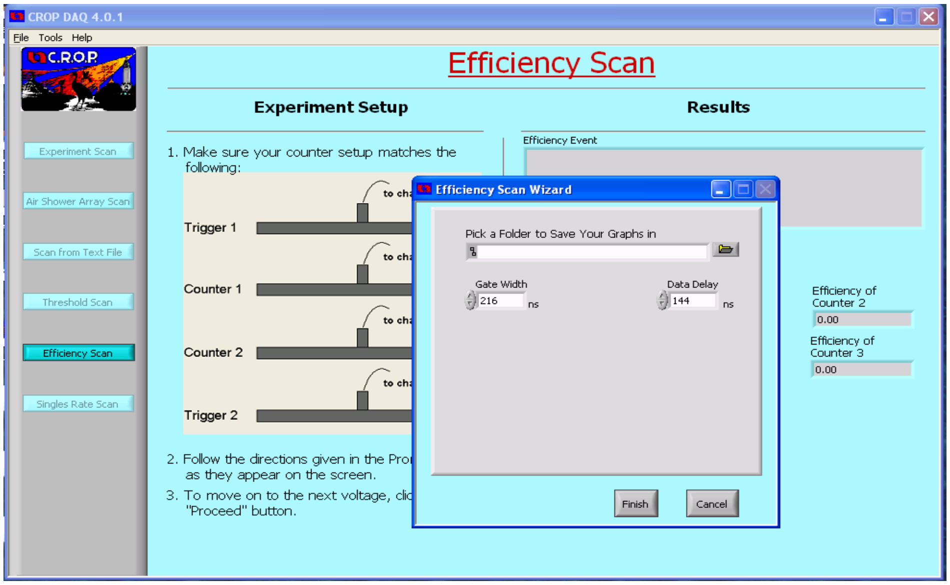
4. Start the CROP DAQ program and select “Efficiency Scan.” A dialogue box will appear asking if you entered the thresholds. You have, so select OK.



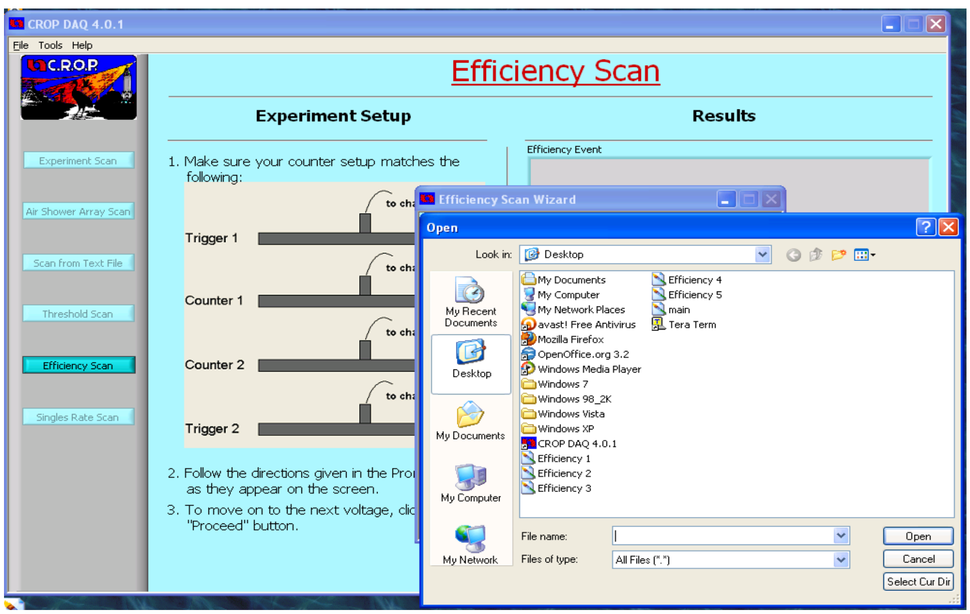
5. A screen will appear that asks you to enter PMT numbers into their correct channels. Do so and click Next.



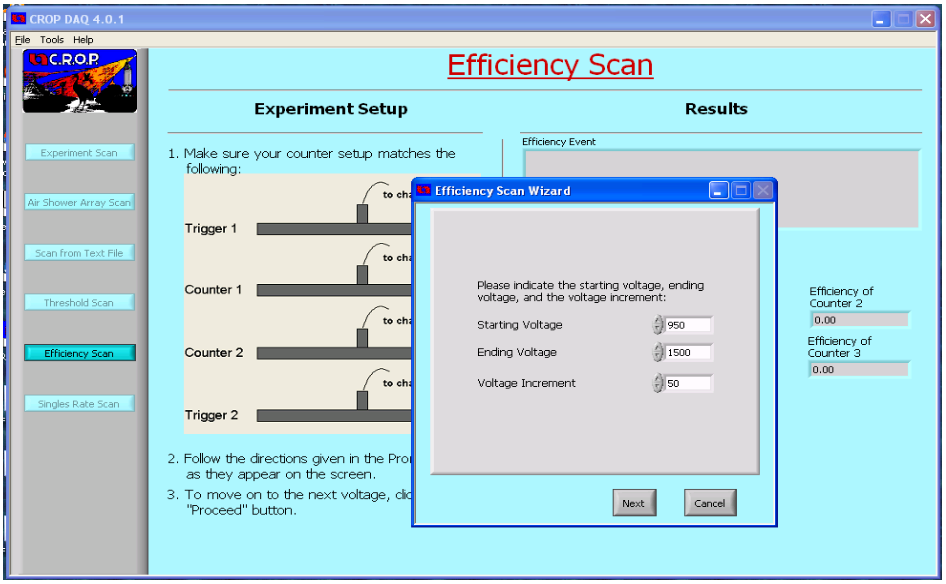
6. You should then see a box that asks you to pick a folder to enter your data into. Click on the small folder icon.



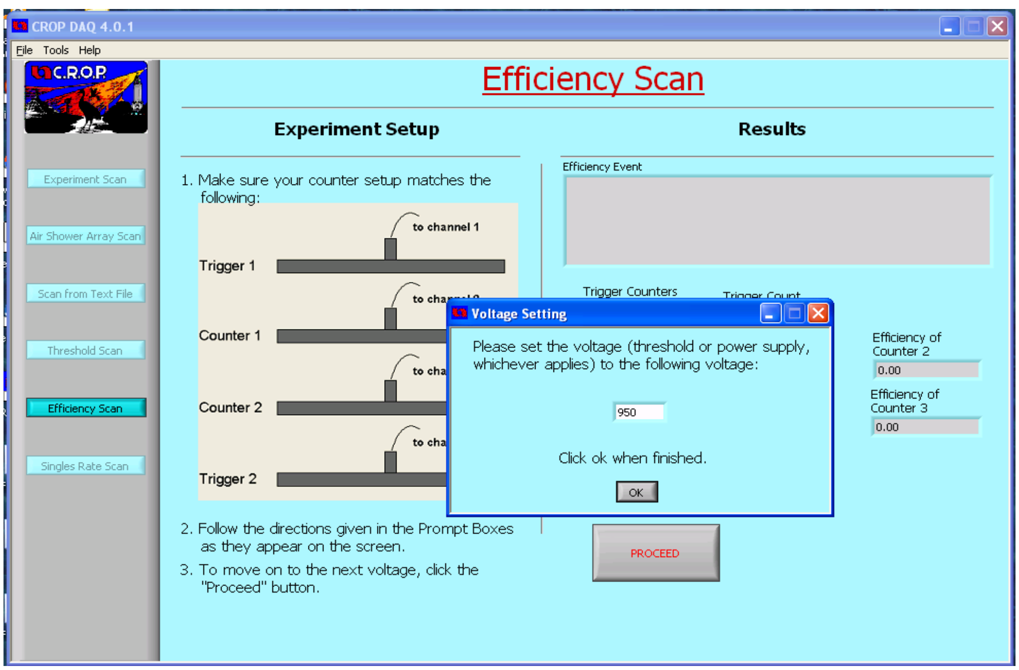
7. Double click on the folder you wish to place the scan into. Then click "Select Cur Dir"



8. The next window asks you for the starting and finishing voltage for the scan. Generally we start at 950 and go to 1350 V or higher.

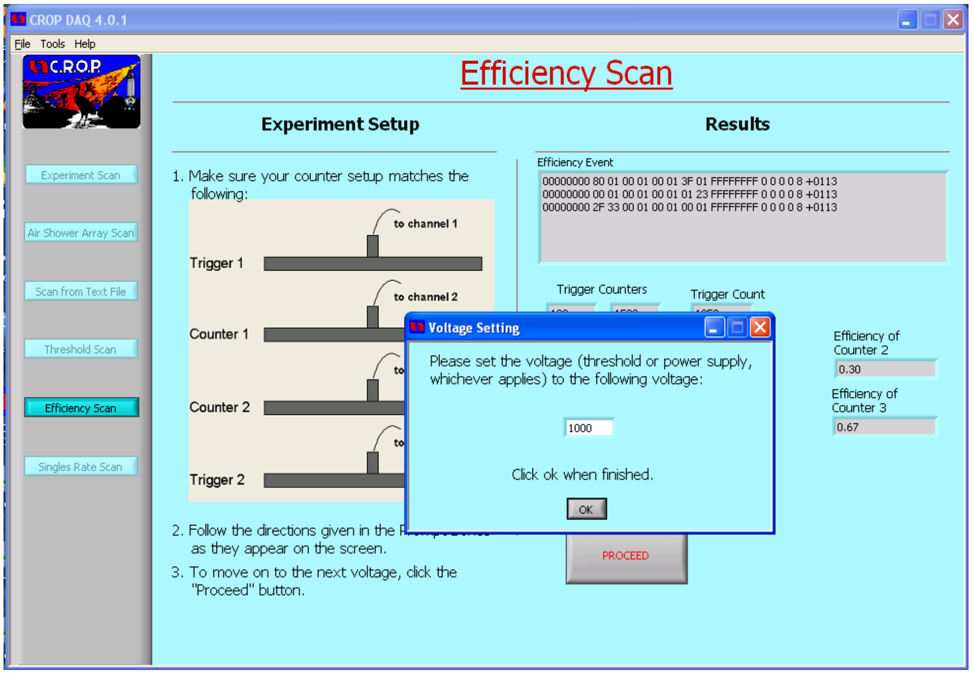


9. The program will tell you to change the voltage of the untested detectors to 950. Do so and click "OK"

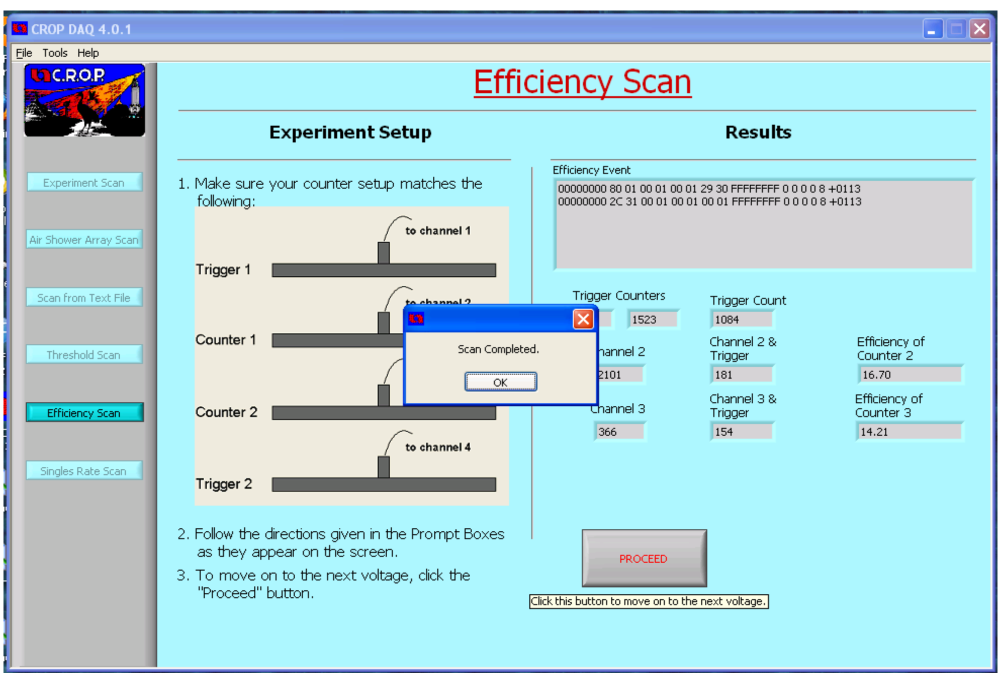


10. When the text box labeled "trigger count" gets over 1000, click proceed.

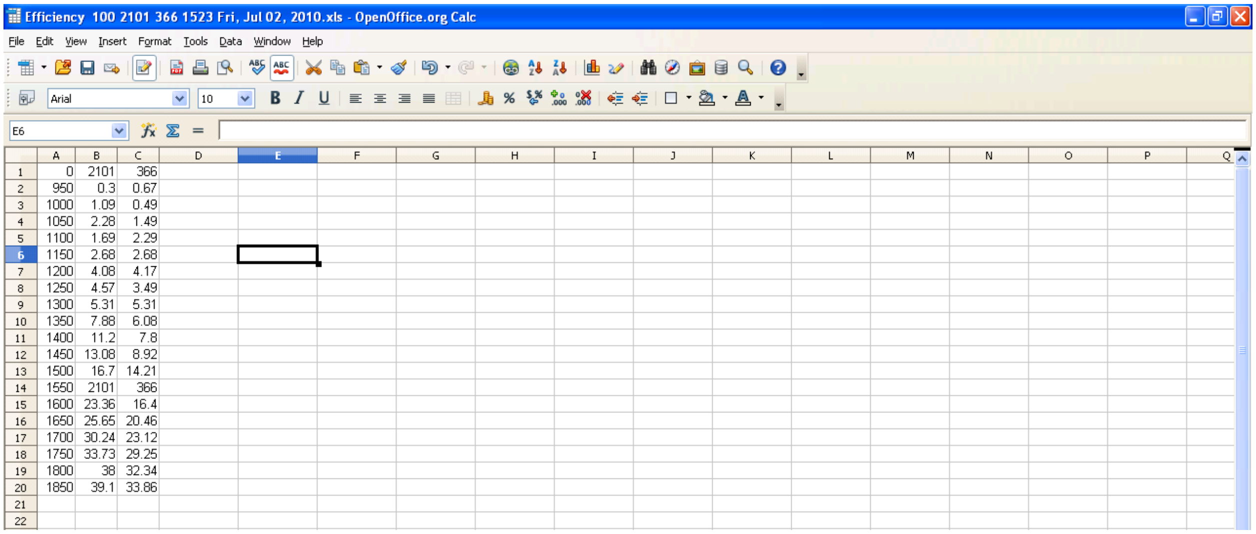
11. Increment the voltage of the untested counters by 50V. Then click "OK" on the window.



12. Repeat steps 10-11 until the scan finishes.

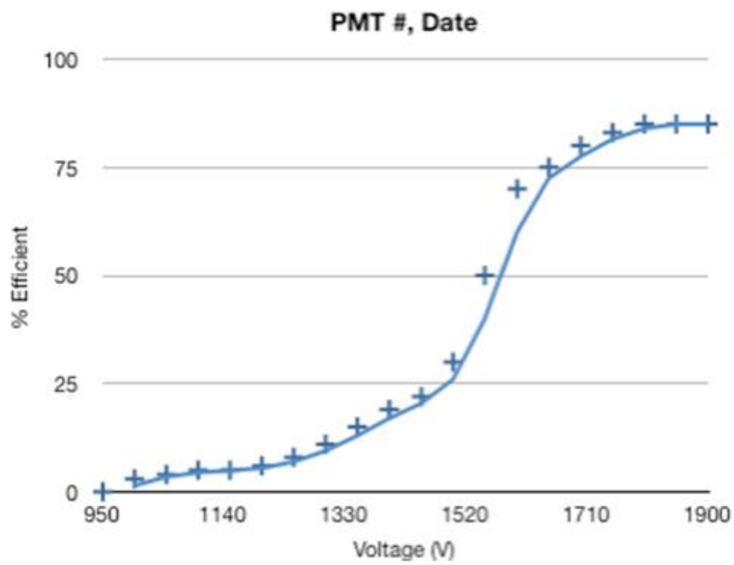


13. Open the file in which you saved the data using a spreadsheet. The first column will be the voltage, while the second and third columns will be the detectors efficiencies at those voltages. The first row are the detector numbers



	A	B	C
1	0	2101	366
2	950	0.3	0.67
3	1000	1.09	0.49
4	1050	2.28	1.49
5	1100	1.69	2.29
6	1150	2.68	2.68
7	1200	4.08	4.17
8	1250	4.57	3.49
9	1300	5.31	5.31
10	1350	7.88	6.08
11	1400	11.2	7.8
12	1450	13.08	8.92
13	1500	16.7	14.21
14	1550	2101	366
15	1600	23.36	16.4
16	1650	25.65	20.46
17	1700	30.24	23.12
18	1750	33.73	29.25
19	1800	38	32.34
20	1850	39.1	33.86
21			
22			

14. Graph the data into a scatter plot. Label it as shown in the diagram below. The best fit line is pretty, but not necessary.

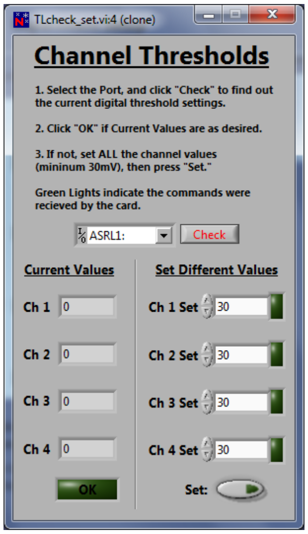


New DAQ and 5.0 Software

Threshold Scan for 5.0 Software

The differences in the Threshold scan from the 5.0 software to the 4.0 software are very small. The new DAQ card allows electronic control of the threshold voltage so the program will automatically set the threshold to 30mV and go through the 30mV step increment up to 300mV by itself. This allows you to leave the program and card alone until the scan is complete. After this difference, follow the steps before this for the threshold scan (page 48).

Efficiency Scan for 5.0 Software



The biggest difference between the 5.0 software and the 4.0 software is again the new card allows electronic changes of the threshold voltages. There is only one extra step which requires you to input the thresholds. This pop out prompt is called “Channel Thresholds”. Make sure that the correct port is selected. Then input the threshold voltages found in the threshold scan for the correct power supply voltage. Once the threshold voltages are entered then click “select” and then “set”. The image to the right shows the channel threshold prompt. After this extra step, follow the steps before this for the efficiency scan (page 54).

Experiment Scan

Experiment Scan is one of the five scans that can be done in the DAQ software. This scan is rarely used in CROP. It enables you to do an experiment that requires specific conditions. This usually requires discussing with a professor or someone that knows what they want and attempting to fulfill it with this scan. The experiment scan allows the user to customize a scan with a variety of options. These include repeated runs, setting up specific date and time to run a scan, the length of time for the scan to run, and to record data or not. If record data is chosen, then the data will be stored in a text file. This can be analyzed by using the Scan from Text File option in the software. Once these options are chosen, additional settings are available. These settings are as follows: Preset DAQ card settings, Veto Settings, Data Delay, Gate Width, Veto Width, and Coincidence level. Within the Preset DAQ card settings, the options that are available are default, muon telescope, muon decay, array scan simulation. The user also has the ability to choose to eliminate specific detector channels and to shut off the GPS data.

Once the scan is configured to the user’s specifications, the scan will start. When the scan is active, there are three tabs showing specific information about the data being collected. The first tab, Data Acquisition, displays the raw data collected by the detectors and interpreted by the DAQ card. The second tab, Counts, displays the amounts of counts per detector and the amount of coincidences between different sets of detectors. The third tab, Debugging, displays the first set of information that the DAQ card submits when starting the scan and the threshold levels of each detector.

Air Shower Array Scan

Air shower array scan is one of the five scans that can be done in the DAQ software. This is used to take experimental data from particle showers. The setup usually requires setting up 4 detectors in an array on a roof of a building. This can also be done in many other setups in different locations but the most common is a roof with a detector at each corner. With the current software version 5.2 and older, this scan requires a folder named Crop Data in the C: drive for this scan to work properly. If one does not do this, then a path error will pop up which can be viewed in the Troubleshooting section. This is the path location where all the experimental data is collected. This data is stored in a text file which can be read and analyzed by the Scan from Text File option in the software.

Scan from Text File

Scan from Text File is the only option in the software which is not a scan that deals with the detectors directly. The name of this option describes what it does effectively. It takes a text file from a past scan which would be from the array or experiment scan and it analyzes the data. This analyzing gives the user a variety of options to organize and view the data from the chosen text file.

There are five tabs in this given option: Event Parser, Events & Coincidence Analysis, Event & Coincidence Counts, Singles Counts Analysis, and Debugging. Event Parser tab allows the user to select a range of time to view raw data that fits to the specifics that the user selects. This can be viewing data that has coincidences between any given detectors to only viewing one detector with valid GPS. The Event & Coincidence Analysis tab allows the user to select a range of time to view the number of events in a graph. There is also a histogram showing the coincidences between the detectors. The Event & Coincidence Counts tab is similar to the Counts tab in the experiment scan. It displays the amounts of counts per detector and the amount of coincidences between the detectors while also listing event statistics. The Singles Counts Analysis tab has two graphs that display the amount of events over time for each specific detector and change in singles counts over time. The Debugging tab is similar to the Debugging tab in the experiment scan. It displays the first set of information that the DAQ card submits when starting the scan and other information such as GPS data.

Singles Rate Scan

Singles rate scan is one of the five scans that can be done in the DAQ software. Single rate scan is a scan where you can look at the detectors at a specific set of conditions such as a set threshold and time. It is very similar to threshold scan but instead of it constantly increasing in voltage increments by manual or electronic (5.0 software) control, it only stays at the condition you set it to until it is stopped. In other words, it is just one of the increments of the threshold scan. This is useful if there is something strange going on at a set threshold and you just want to look at the detector at that value or the threshold scan program is giving you errors. You could do a whole threshold scan manually using this kind of scan if need be. This scan however does not create a excel file such as the threshold, so the user will have to manually copy over the data into a file if one chooses to do a whole threshold scan.