

# **Milagro Front-end Electronics Manual**

**Including: The analog (small signal and high voltage distribution) boards, the ecl (digital) boards, their associated crates, and their low voltage power supplies.**

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## Section 1: Overview

A block diagram of the Milagro front–end electronics systems can be found in Figure 1. This document will describe in some detail the center part of this diagram (the analog card, the digital card, their crates and backplanes and their power supplies). This document will NOT describe the CAEN high voltage supply, the phototubes and bases, or the LeCroy Fastbus electronics and the scalar system.

The purpose of this document is to provide a summary of the workings of the analog and digital cards and to serve as a reference to assist with debugging when a problem with the front–end electronics arises.

### Figure 1 in detail:

The analog card resides in a modified 12U VME cage (or crate). The digital card (sometimes called the ECL card) resides in a modified 6U VME cage. These two cages are attached to each other through two 3U backplanes. Signal and high voltage inputs into the analog card are made through SHV connectors attached to the back panel of the card. Outputs and features of this card include 3 adjustment pots at the top front of the card, the solar analog header (not currently used) below these trim pots and the ADC header below this. All low voltages and ECL signal information are communicated through the backplane. The Analog card requires +5.0 V and –5.0 V supplies. For a more complete description of the analog card, please see Section 4.

The digital card requires a single –5.2 V supply. Its outputs include (from the top of the front panel) the TDC header providing TOT information for the TDC, Lemo trigger sum outputs, and scalar outputs (both header and Lemo). The digital card is described in more detail in Section 5.

a) Since the analog card is mounted backwards with respect to the front of the electronics racks, what we mean by "front" and "back" on this card can be confusing. In this document, We will refer to the side of the analog board with the brass panel which screws into the cage as the back of the card.

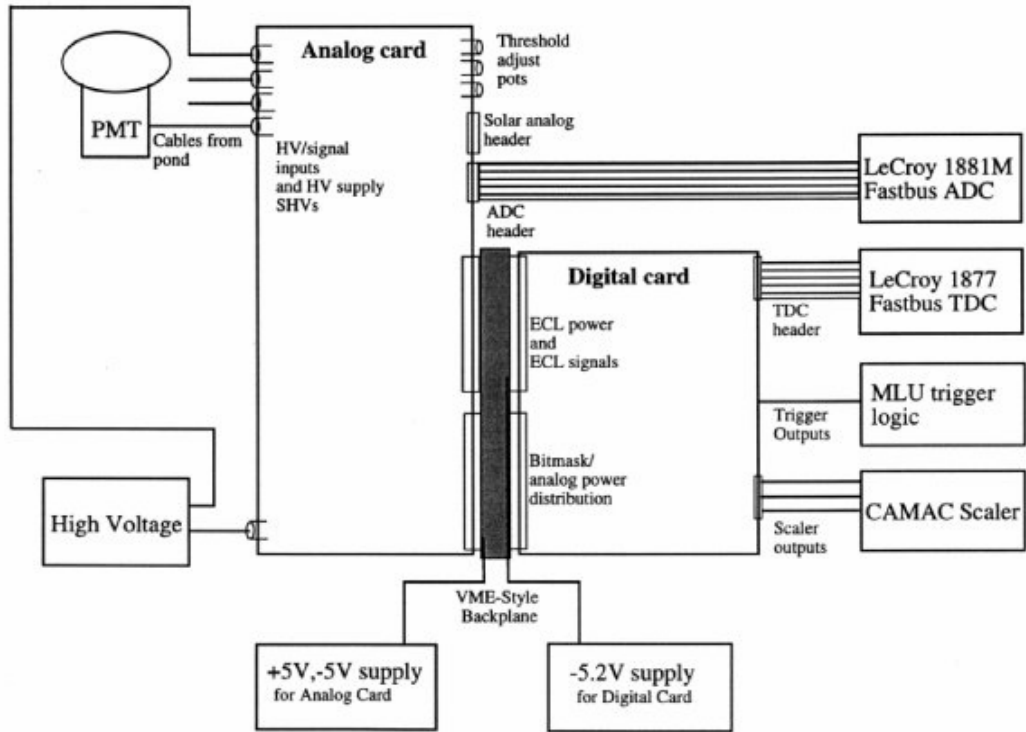


Figure 1: Block diagram of the front end boards and connectivity.

## Section 2: The Low Voltage Power Supplies

### A. The low voltage supplies for the analog cards.

Currently, we use supplies made by Acopian to provide +5V and -5V to the analog cards. The individual part number of these switching supplies is W5MT100, which is a 100A (@40degC) supply with a voltage adjustment range of approximately +/-0.25V. These supplies are integrated into a custom package for us by Acopian, and as a package they have the unique part number S10742. The output voltage and total current drawn is displayed on the front panel. A front panel switch selects between monitoring of the two supplies. It is possible to inhibit the supplies electronically, adjust the output voltage remotely, and monitor the output voltage through a barrier strip on the back of the supply. See the S10742 schematic in Appendix I for more detail. General operating instructions for the individual W5MT100 supplies can be found in this Appendix as well. The output voltage can also be adjusted by a trimpot located on the back of each supply. This can be adjusted either from the side or through a small hole in the back panel of the supply.

These supplies are equipped with over voltage and over current protection. Should an over voltage condition be encountered, the supply needs to be completely unplugged in order to reset over voltage "fuse".

Both voltage supplies have a crate temperature monitor installed (Bud type TS-22). These monitors are attached to the top of the analog crate and are designed to shut off the power supplies via their remote switch if the crate temperature exceeds a settable threshold. They act as fuses which are normally CLOSED and they open when the temperature exceeds the preset threshold. Should this trip the supply, the threshold temperature can be increased slightly, but it should not be increased by more than 5 degrees without first consulting with someone familiar with the front-end electronics. Keep in mind that these temperature sensor switches require that the measured temperature drop at least 5 degrees below the limit set on their dial before they will reset.

During Milagrato, each of the voltages was provided to the analog cards by two Kepco RMX-05-N power supplies connected in parallel (four supplies total for the two voltages). Each of these supplies is capable of providing 50A at 5V and at a temperature of 40 °C. This is enough current to easily supply one full crate of analog cards, since the maximum current draw at +5V or -5V should be 80A for 20 cards. This Kepco supply unit is now a spare supply for Milagro. Note that temperature sensors connected to this supply should be normally OPEN and close on temperature rise (Bud type TS-15).

A complete manual for the Kepco RMX supplies is available at UCSC if this is desired.

## **B. The low voltage supply for the digital cards.**

For Milagro, the digital cards are powered by a single W5MT100 supply packaged as the custom part number S10741 by Acopian. This supply has all of the same features described in part A above. Its overview schematic may also be found in Appendix 1.

All voltages supplied to the crates can also be monitored directly at the crate through the bit mask control/distribution board which should be located in the left most slot in the digital crate. Because of resistive losses in the cables, etc. it is best to check the crate voltages at this point to determine their value most accurately.

For Milagrato, the negative voltage ( $-5.2\text{V}$ ) was supplied to the digital cards by a single switching power supply (Jeta model G1801-5-L). This supply can produce 360A at 5 V at 40 °C. This supply is capable of powering up to three digital crates, and it requires an 208/230 VAC nominal input voltage. The output voltage on this supply can be adjusted by means of a trimpot accessed by removing the right side panel on the supply case. This adjustment can be made with the power supply case in its rack. When the load on this supply is significantly changed (such as going from powering one nearly full crate to two nearly full crates) the output voltage will most likely need to be adjusted. The output voltage and current can be monitored on the front panel of the supply case.

## **Section 3: Crates and Backplanes**

As mentioned in Section 1, the analog crate is 12U high 340mm deep and the digital crate is 6U high 280mm deep. These crates are custom mounted back-to-back to form the analog and digital crate system.

The crate system backplane is made up of two 3U backplanes. The upper row of connectors is bussed as J0 (Dawn 06-1002277-21D) for most pins (which means they just pass straight through without bussed connections). This connector passes the ECL signals from the analog to the digital card and it distributes power to the digital card. ECL signals are passed on rows b and c in pairs (with pin 1b being low and pin 1c being low\_bar then 2b high and 2c high\_bar, and so on through pins 32). Negative voltage is distributed on pins 17a-32a and ground on pins 1a -14a. The discriminated analog sum is passed to the digital card on pins 15a and 16a. See Appendix 3, Pages 3 and 4 for these assignments.

Since the current draw on the digital boards approaches 5 amps per card, power must be distributed adequately to each card to avoid voltage sag or overheating of traces. The power bussing is accomplished by means of a 0.125 inch by 0.5 inch copper bus bar with power fed from both ends of the bar for a full crate. Each connector is attached to this bar by a 20mil by 250mil copper strip. This assures a voltage drop of less than 10mV over the backplane. Connections from all low voltage power supplies to the crate bus bars are made with 4 gauge wire.

The lower backplane (Vero 222-63530K) is fully bussed (uncommitted) with the bit bask signals distributed to each card on pins 10c-24c (see Appendix 2 Page 6 ). Positive voltage is distributed to the analog cards on pins 32a-c and pins 25a-31a. Negative voltage is distributed on pins 1a-c and pins 2a-7a. Ground is carried on pins 2b-7b, 26b-31b, 2c-7c, and 26c-31c. The bus bars used on this backplane are similar to those described for the ECL backplane; however, power is distributed to each analog card through the power planes in the backplane PC board with tie in points to the 0.125 inch x 0.5 inch copper bars every 1.6 inches. Within a given connector, power pins are tied together with a 20 mil by 100 mil copper strip.

In general, the crate and backplane should need nearly no maintenance. If a short in the backplane is suspected then someone familiar with the front-end electronics should be contacted. It is in principle simple to fix such a problem (once everything has been taken apart!) but finding the location of the short may require someone familiar with the backplane.

## Section 4: The Analog Card

Full schematics for the analog card may be found in Appendix 2. The layout of the analog card is shown in Figure 2. Some of the important features are identified in this figure. The card is divided into two parts: the high voltage section containing all of the HV distribution and the signal pickoff, and the analog section containing sensitive analog components (primarily in surface mount packages) to begin the processing of the phototube signals. The card is divided into 16 channels. "Easily" serviceable parts include two fuses for the positive and negative voltages located near the lower backplane connector. It has been our experience that these fuses have a tendency to blow when the card is being actively probed (with a scope probe, for example). These are surface mount, 5A fuses and they are soldered directly to the board. Fully loaded, an analog board should draw 3.65A at +5V and 4.25A at -5V.

There are three setable thresholds located on the front of the card. Beginning from the top most trim pot, these are the low discriminator threshold (typically around 30 mV), the high discriminator threshold (typically around 80 mV), and the analog sum discriminator threshold. Test points for these thresholds are located directly below each trim pot, and

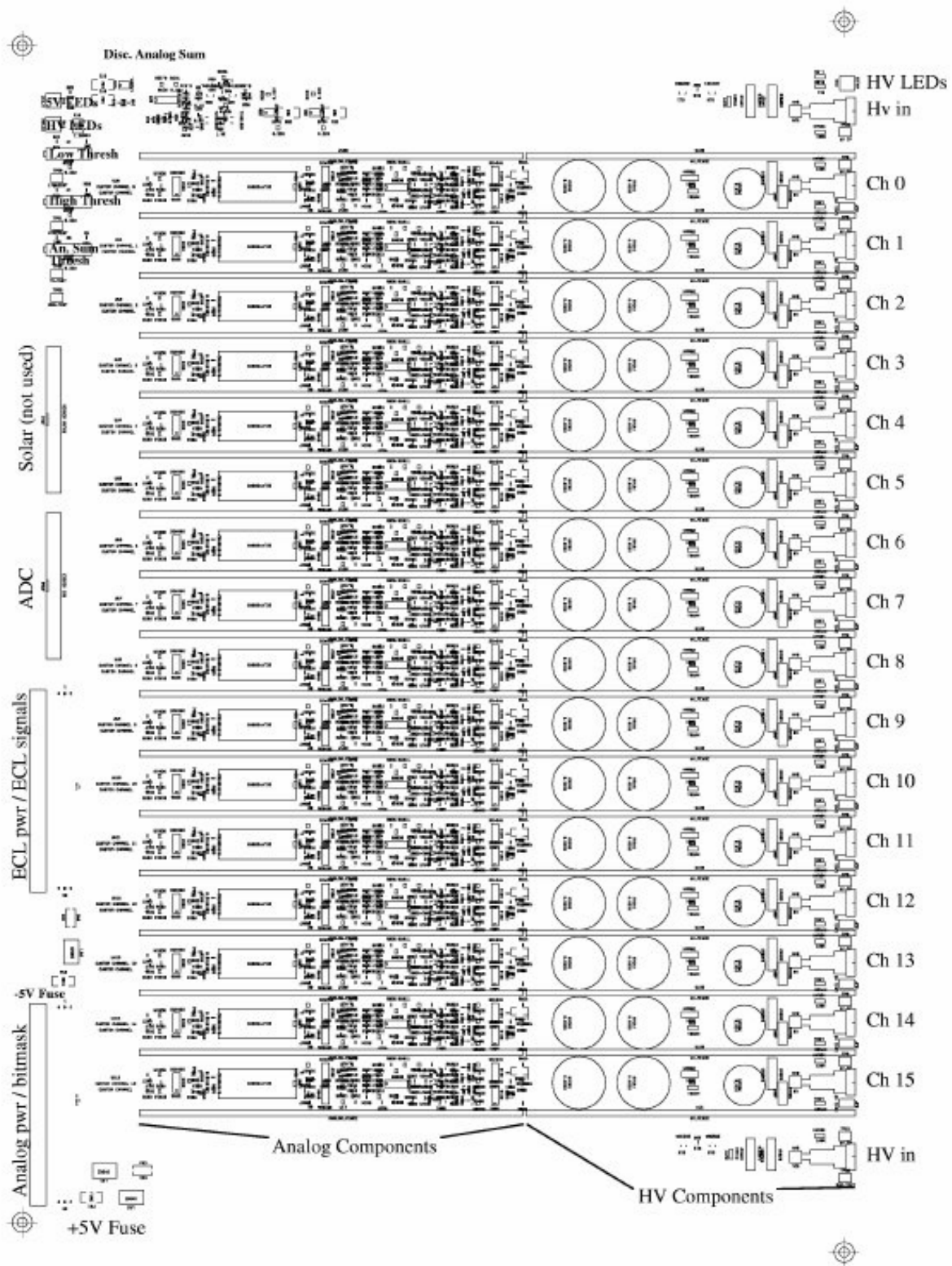


Figure 2: An overview of the Analog card.



ground is located on the lowest (black) test point. Below these are the solar analog header (currently not used), and the ADC header.

### **A. The high voltage section**

The high voltage section of a single channel is shown in more detail in Figure 3. On this figure is also shown a HV input below the single channel. All pins with marked with an X are at high voltage when the HV supply is enabled. Be aware that two surface traces (also marked with an X) carry high voltage on each channel. Only people familiar with the analog boards and appropriately trained should probe these boards with the high voltage on. It is possible to disconnect the high voltage and send a pulse generator signal into the channel input SHVs in order to check the functionality of the analog section of these boards.

High voltage test points, which are made by a simple voltage divider (components HVR03 and HVR04) make available the high voltage applied divided by 1000. These are located above each channel SHV on the back panel. Signal test points are located below each channel SHV. These two pin headers provide an opportunity to look directly at the phototube signal picked off by a 100 pF HV capacitor with high impedance termination (HVC05 and HVR05). The oscilloscope probe capacitance will slightly distort this pulse, so it is best to use a low capacitance probe, such as an active FET probe, for this purpose. The input high voltage can be tested near the input HV SHVs. These input HV SHVs are the top most and the bottom most connectors on the back panel.

On the left most side of the high voltage section, the "picked off" analog signal is located on a surface trace running from the two large 33nF capacitors (which are connected in parallel) to the input of the analog section of the board (marked as "IN" in Figure 4).

Other components in this section include HVR02 which is the high voltage set resistor. This is a socketed resistor which can be changed to adjust the high voltage level on a given channel. The 10nF capacitor HVC04 provides filtering for the distributed high voltage.

It is not unusual for high voltage capacitors to fail. In this case, it is useful to note that removing the socketed HV set resistor will remove high voltage from the 33 nF and 100 pF capacitors for that channel. Removing all of these resistors and replacing them one at a time is often an effective way to narrow down a problem in the high voltage section of the analog board.

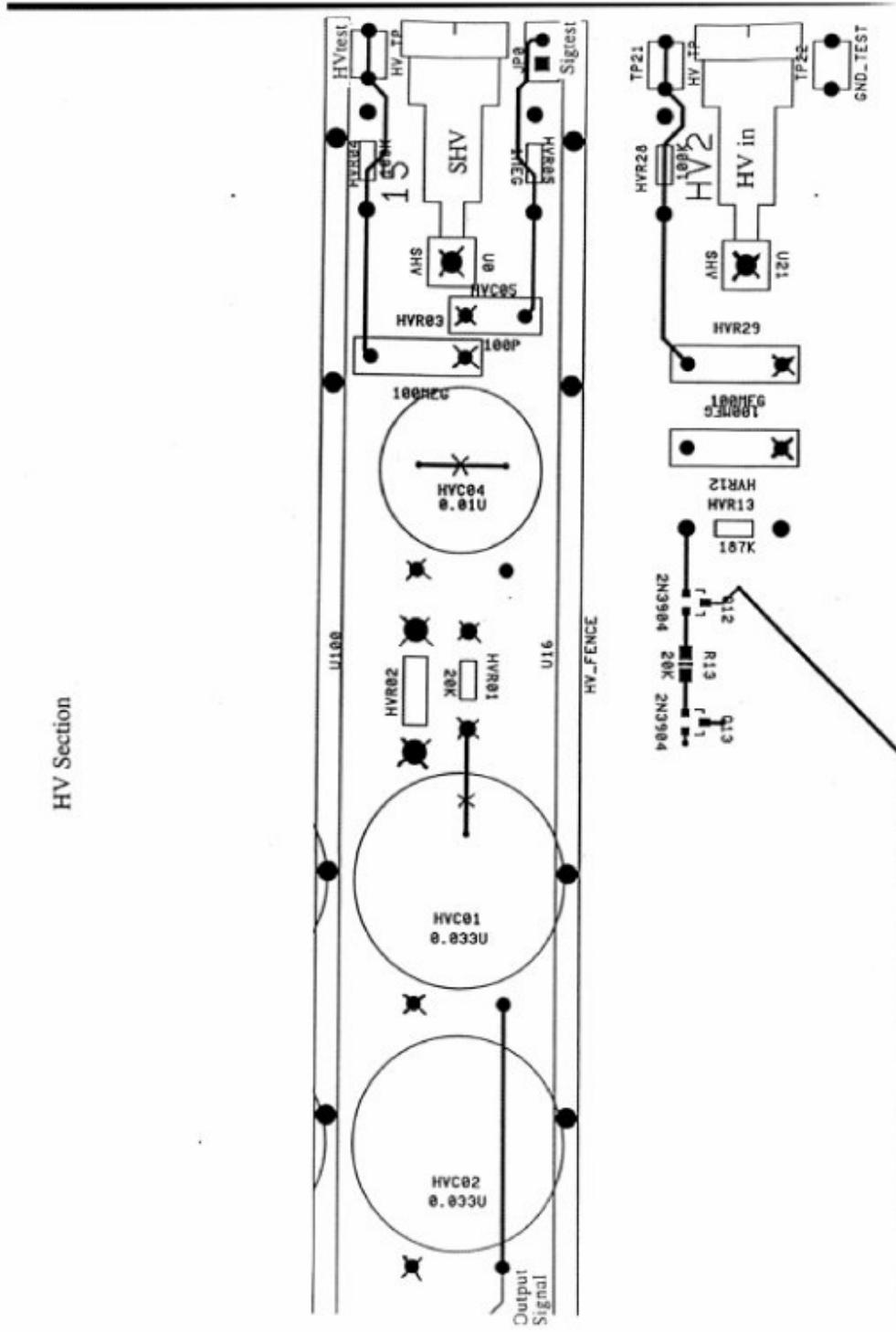


Figure 3: Single channel high voltage section. All of the pads and traces marked with an X are at high voltage.



## B. The analog section

The layout of a single analog channel is found in Figure 4. Even enlarged, it is difficult to make out the components on this figure, so for functionality it is best to refer to the single channel schematic for the analog section in appendix 2, Page 3.

Beginning from the input of the channel (marked as  $\hat{IN}$  in Figure 4), the signal generally travels to the left through the channel. Directly below the input are a pair of diodes in a SOT-23 package. These along with the  $20\ \Omega$  resistor directly above these diodes in the figure provide input protection for the circuit. If a high voltage capacitor fails or arcing is observed, these components will most likely need to be replaced. To be safe, the  $75\ \Omega$  termination may need replacement as well. The single-ended input pulse is then split and sent into two MAX435 transconductance amplifiers. As indicated in the figure, the signal is now split into the high threshold and low threshold portions of the circuit. The MAX435 produces a fully differential signal. This same chip is also used in the ADC and solar sections of the circuit. The low and high threshold pulses are integrated with a time constant of approximately 80 ns and they have a final differential gain of approximately 7 for the low threshold and 1 for the high threshold. These two differential signals are capacitively coupled into the discriminator part of the circuit (the inputs circled on the AD96687 and marked as LOW and HIGH in the figure).

As an example, if one sends a 100 mV (single ended) pulse into the circuit at  $\hat{IN}$ , one expects to see approximately a +350mV and -350mV pair of pulses at the low threshold inputs to the discriminator (at LOW) and a +50mV and -50mV pair of pulses at the inputs to the high threshold discriminator (at HIGH). These differential pulses should always be identical in amplitude and decay time. As a general rule, nearly all of the signals transported in the analog section of this board (including the ECL level pulses created) are differential, so if a pair of signals does not look alike, or one side is missing, then something is wrong.

It is worth noting that the high threshold signals are split off just before they are capacitively coupled to the AD96687 and are also sent to the ADC, the analog sum, and solar parts of the circuit. This introduces the complication that a problem with the high threshold input to the AD96687 may be caused by one of these other parts of the circuit (a short at the input to the first ADC MAX435, for example).

All ECL outputs are differential ECL level pulses (-0.8 and -1.8V). The low threshold discriminated ECL pulse can be probed on the pads circled at the bottom of the discriminator section. These resistors are the  $680\ \Omega$  tie downs to VEE (-5.2 V) for the ECL pulses. The high threshold ECL pulses can be probed at a symmetric location at the top of this section. If a signal is coming into the inputs of the AD96687 but the discriminated pulse is absent or incorrect (and the discriminator level is set correctly) then most likely either one of the power pins on the AD96687 is not making contact, or one of the  $680\ \Omega$  pulldown resistors is not making contact or is shorting. The two columns of resistors and capacitors directly to the left of the AD96687 form the hysteresis for this chip. Even if these are disconnected the output should be present (although perhaps with more jitter).

The ADC section of a channel includes two more MAX435s and the (large) through-hole analog delay chip. The input to the ADC section can be probed at the places indicated as "ADC predelay" on the figure. The input to the delay chip can be probed, but this is a very low amplitude pulse. The output of the ADC section may be probed as indicated by "ADC" at the right lower part of the ADC section.

The outputs which proceed to the analog sum for each channel are located immediately to the left of the delay chip. Since it is impossible to probe the signal at this point, it is necessary to do this after the input to the analog sum section at the very top of the board. Finally, the solar section of each channel is the left most part of the circuit. Currently, all of the passive components for this section are loaded (the MAX435 for this section was left off of the board for Milagrato).

## Section 5: The Digital Card

A layout of the digital card may be found in Figure 5. The full schematics for this circuit are found in Appendix 3. There are also 16 channels on this board, although it is more difficult to separate these channels by eye since some components are shared between two channels. The fuse listed in the figure is located on the solder side of the board. This is also a soldered in 5A surface mount fuse. Each board should draw approximately 4.4A at  $-5.2V$ .

On the front of this board, below the power LED, is located the low and high sum LEDs. These will flash if greater than about 9 phototubes pass their respective threshold. The TDC header provides low and high threshold edges for the LeCroy 1877 TDC. The discriminated analog sum Lemo output contains this signal which was created on the analog board. The low and high multiplicity Lemo outputs provide a signal equal to  $N(mV)$  times the number of phototubes passing that threshold. Currently,  $N = 25 mV$ . The solar physics header contains individual scalar signals for each channel. These differential ECL signals are approximately 20ns long for Milagrito boards (S/N001–S/N020) and equal to the low threshold pulse length for more recent boards (S/N021 and higher). These boards with S/N021 and above also contain an additional lemo output marked "solar" directly above the discriminated analog sum lemo containing a copy of the low threshold trigger signal.

The next four Lemo connectors contain the scalar OR combinations listed on the figure. These can be combined by inserting any of the three jumpers near the center of the figure. The final two Lemo outputs are the OR of all low threshold and high threshold hits respectively.

An enlarged view of two channels is shown in Figure 6. Several components are shared by two channels: the MC10115 quad line receiver is split over two high and low threshold pairs. The termination and tie down resistor networks R3 and R4 are also split between the two channels as shown. Note that all surface mount resistors and capacitors are mounted on the solder side of the board and are not shown in this figure.

To trace the signals through a single channel, refer to appendix 3, Page 2. Briefly, each channel functions as follows: after the differential high and low threshold signals enter the line receiver (MC10115) single ended ECL signals produced are split to create the TDC time-over-threshold pulses, the scalar pulses and the multiplicity outputs.

To create the TDC outputs, we must assure that the pulse is at least 20ns long for both thresholds. Thus a 20ns long pulse is formed with a MC10130 latch (U3A and U4A) and this pulse is ORed with the input pulse. The high threshold pulse is then delayed by about 10ns (R5, R6, C0) which when combined with transit time delays in the chips produces a 20–30ns delay in the high threshold at the output.

For large phototube pulses, characteristics of the low threshold amplifier saturation (produced back on the analog board) will cause the length of the low threshold

discriminated ECL pulse to decrease. In order to assure that the low threshold pulse is longer than the high threshold pulse, a 40ns separation between the falling edges of these pulses is forced (R9, R10, C1). Finally the inverted low threshold pulse (the output of U1B) is ORed with the (~20ns delayed) high threshold pulse to form the output to the TDC. In effect, the high threshold takes a bite out of the middle of the low threshold pulse so that the edges encountered are in the order: low start, high start, high stop, and low stop.

The multiplicity pulse for each channel is formed by the second half of the MC10130 latches (U3B and U4B) and it has a width of approximately 200ns.

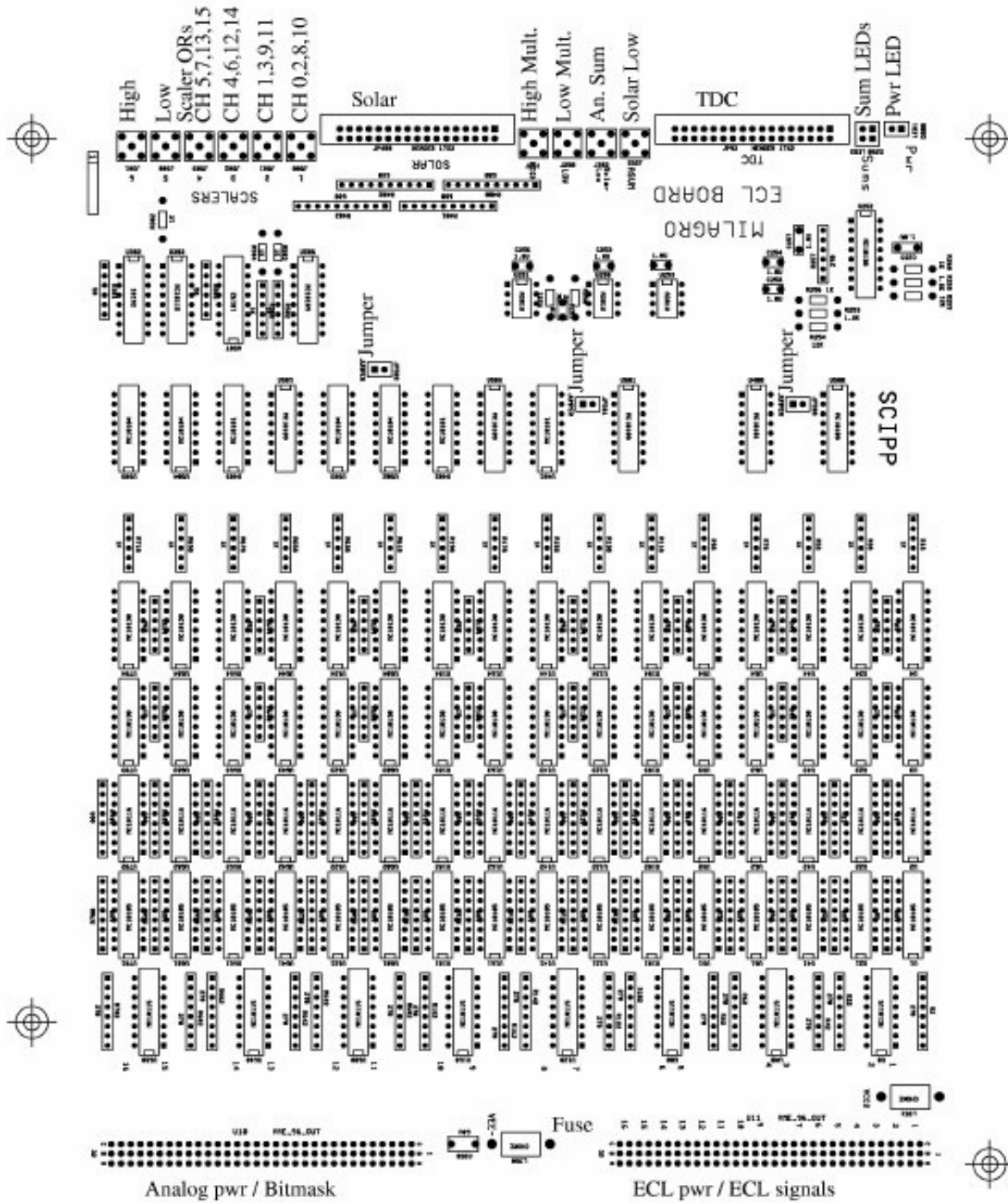


Figure 5: The layout of the Digital (ECL) board.



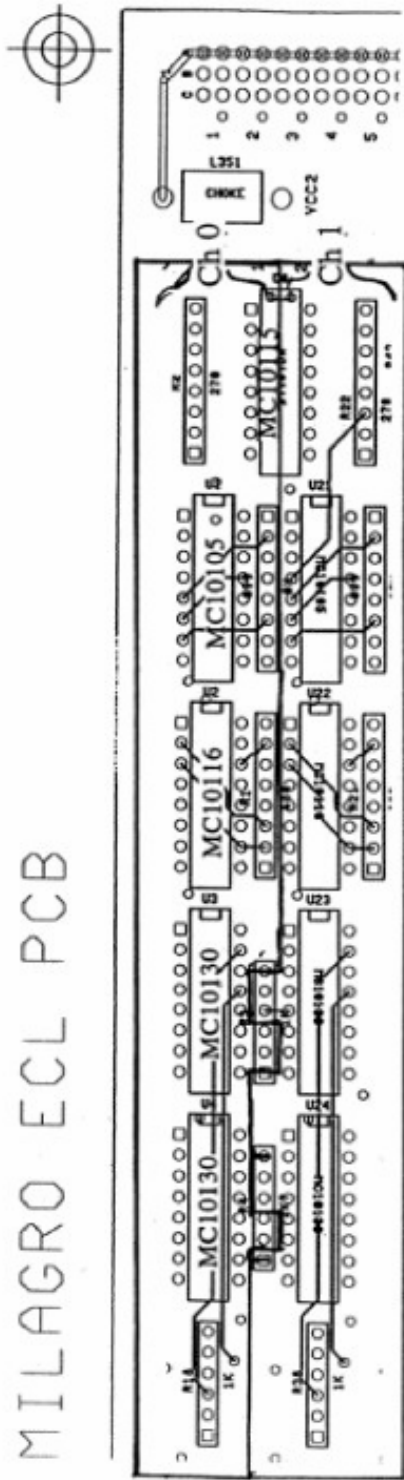


Figure 6: Two channels from the ECL board. The MC10115 is shared by these two channels.

## Section 6: What to do if it doesn't work

I apologize if parts of this section sound very much like what one would ask undergraduate physics laboratory students: "Is it plugged in? Is it turned on?". I don't mean to insult anyone's intelligence: the suggestions begin with the obvious just to be sure something simple is not overlooked. Whenever an output is missing, checking to make sure the module has power (usually just a quick glance at the power LEDs) should be the first step. Also be aware that this section doesn't discuss training issues (what training is needed to perform which diagnostic functions).

### 1. No power to the crate(s)

Check to make sure the temperature sensor has not shut off the crate power. Give the sensor time to cool down (remove it from the top of the crate if necessary). It may take several minutes for the device to reset. This device is normally closed, so if the temperature exceeds that which is set on its dial, the resistance between its two leads will be large. If the system is reset and the temperature sensor trips again after some time, then increase the temperature setting by as much as 5 or 10 degrees: please make a note of any changes in this setting. Under no circumstances should the temperature be increased above 100 °F except for short periods when diagnosing problems.

Check the voltage both at the crate and at the power supplies. The voltage at the power supplies can be checked by both the analog meters on the front panel (note that on the analog power supplies there is only one voltage and one current meter for both voltages. A switch labeled with a 1 and 2 position switches between these two supplies) and by a test point located on the front panel. Also note the current drawn by each supply. Our three crates should draw between 50A and 75A at each voltage (see sections 4.0 and 5.0 for the current drawn per module). If there is no voltage at the crate (test points are located in the bit mask distribution module in the left most slot of the digital crate) but the supply has voltage then check continuity on the cables leading from the supplies. On both power supplies, there are power connection studs on the back of the supply covered by G10 covers: cables can be disconnected and reconnected at this point.

If still in doubt, cycle the power on the power supply. All supplies have a separate over temperature shutoff at the supply. If this has tripped it will take at least one minute with the power switched off for this to reset. It is best to switch off AND unplug the supply. There are individual fuses on each of the analog supplies and on the digital supply located in fuse holders near the low voltage outputs. These are difficult to get to but if nothing else works, it might be worth checking these.

Remember that all of these supplies are capable of supplying a large amount of current, so care should be exercised when diagnosing problems.

## **2. No power to a specific module**

Probably the 5A on board fuse has blown (see Figures 2 and 5). Unless the card was being probed, or you have a reason to believe that a temporary short occurred, the problem may still exist. Before replacing the fuse, check the resistance between power and ground at the board side of each fuse. The resistance of an unplugged digital board should be about 80  $\Omega$  between  $-5.2\text{V}$  and ground. On the analog board resistances between  $+5\text{ V}$  and ground and  $-5\text{V}$  and ground should be 10s of  $\text{k}\Omega$  for an unplugged board. On MAX435s pins 1 and 14 are  $+5\text{V}$  and pins 7 and 8 are  $-5\text{V}$ . All through holes for fences between channels on the analog board are at ground.

Because I'm paranoid, I ALWAYS check the resistance between power and ground after I replace or modify anything on a board, and I would encourage anyone else working on these boards to do the same. Paranoia loves company.

## **3. No TDC signal out of a specific channel**

First verify that there is a signal going into the analog card. Test at the analog test point below the channel SHV on the rear of the analog card or look at the channel with a separate pickoff box. Make sure this channel is getting high voltage by probing the HV test point just above the channel. Always be suspicious of connectors: as you know, we have had problems with the SHV connections at the back of the analog card and at the patch panel at the past. These should all now be fixed, but a quick check of the impedance of the cable is always a good idea. You may also want to swap the suspicious channel with one that is known to work at the input to the analog card: see if the problem follows the cable/connector/pmt or see if it stays with the specific channel on the analog/digital boards.

For testing the TDC and ADC outputs, it is easiest to disconnect the high voltage input(s) to the entire board and insert a pulse generator signal into the input SHV on the channel in question. Choose a "phototube-like" signal with a reasonably large amplitude (500mV for example) to make the signals easier to see and a rate of no more than 10kHz or so. Check for a signal with a scope probe on one side of the differential signal at the TDC connector. Connect to the crate or the shield of a Lemo connector on the board for ground. Remember that this signal will be at ECL levels, so it can be difficult to trigger on. If it is possible to use a trigger or secondary output of the pulse generator for the trigger, this should work best.

The digital board can be put on an extender so that it sticks out of the crate, or it can be probed on the bench with a separate power supply and adapter connector. In this position, test to see if the ECL threshold signals are entering this card. Refer to Appendix 3, page 2

for the correct pins on the MC10115 to probe. If there is no signal at this point try touching up the appropriate pins on the ECL signal backplane connector on the ECL card (Appendix 3, page 3). If there is still a problem, then the analog board will need to be probed (which probably requires removing it from the crate and attaching it to supplies on the bench, since the crates are rather full). Consult with someone familiar with these cards before doing this.

If the problem lies in the digital board, one quick thing to do is to touch up the solder joints on power and ground pins on the chips in that channel. The traces which connect power and ground pins to their respective planes on this board were made rather thick, so cold solder joints have a tendency to form on these pins. Boards with serial numbers 1–21 were soldered by hand while boards with S/N022 and above were wave soldered. It is more likely that the hand soldered boards will have problems with their ground connections, from our experience. The signals can be traced through the single channel using the schematic in Appendix 3. Note that when the board is run on its extender, power and ground connections are not excellent, and the voltage drop over this extender card is substantial.

#### **4. No ADC signal out of a specific channel**

The ADC signal for a 1PE pulse has an amplitude of only a few mV, so this can be difficult to see at the ADC connector. If you are patient, you should be able to see ADC pulses with a 5–10mV trigger threshold from the PMT, or you can input a pulse generator pulse. Disconnect the input high voltage and insert a pulse generator signal into the channel as described in question 3. On the ADC connector (see Figure 2) the two pins at the bottom of the connector are ground. If a signal is not seen on the pins of the channel in question with a scope probe, then the analog board will need to be probed on the bench.

With the card connected to power supplies on the bench, probe the input to the high–threshold discriminator (Figure 4, Section 4B: pins 9 and 10 of the AD96687). If there is a signal present at this point, then the problem is after the input to the first ADC MAX435. Refer to section 4B for where to look in the ADC section of the board. The most probable cause is a bad solder connection on one of the ADC MAX435s or perhaps a dead component. If there is no signal present at the input to the discriminator, or if only half of the signal is there then the problem is either at the input to the ADC section, at the input to the solar section, at the input to the analog sum, or back near the MAX435 on the high threshold input. Again, refer to Section 4B to find these. See also problem 7 in this section. A problem back at the high threshold input will also mean that there are no or incorrect high threshold TDC hits.

#### **5. Large pedestal fluctuations**

Make sure that the shielded ribbon cable from the ADC output on the analog board to the LeCroy ADC has its shield connected to the bottom two pins on the connector. A

transformer card should also help reduce these fluctuations. If neither of these help, then suspect the ground connections on the analog card as a whole or the power filtering capacitors on the ADC MAX435s. Touch up the solder joints on the chokes (located near the fuses) for both powers and ground. Also touch up the connections on the four 0.22  $\mu\text{F}$  capacitors near the two MAX435s for this ADC channel. These are the slightly larger (1206 size) brown components two on either side of the MAX435s.

## **6. Low ADC gain**

The most probable cause of this is a problem with the gain set resistors on the two ADC MAX435s or the termination of the delay. You may need to consult with someone familiar with the analog boards to locate these. It is also worth checking to make sure that the differential gain of the high threshold is approximately one (see the description of the analog section in Section 4).

## **7. No high threshold hits**

This can be a rather tricky problem to diagnose because a large number of problems can produce this effect. For starters, make sure the high threshold trim pot is set correctly (this should effect all channels in the card). If this isn't the problem then the card will need to be tested on the bench. Check the pins of the AD96687 labeled "HIGH" in Figure 4 to see if a signal is entering the comparator, and check its output marked ECL high. If the signal is getting lost somewhere in the chip then check (resolder) the power, ground, input and output legs of this chip and the 680 $\Omega$  pull down resistors. If the signal isn't making it to the AD96687 you may still be in luck: the problem may be flaky solder connection at the high threshold input MAX435 or the two transistors following this (see the schematic for the single channel, Appendix 2). These transistors have a tendency to short underneath the components: the resistance between legs on the transistors should be at least 1K $\Omega$ . When in doubt, touch these connections up with the soldering iron.

## **8. Problems with the multiplicity outputs or sum LEDs**

In the past, all of the problems we have had with these outputs involve cold solder joints on the power and ground pins on chips which make up these sums on the ECL board. Refer to the schematics in Appendix 3 and Figure 5 to locate these. Solder connections on the two resistors (1.8K and 12K) which form a voltage divider in the sum LED section of the board are also prone to this problem. These cold solder joints are more likely to occur on boards which were hand soldered (S/N 021 and below).

## **9. Power and ground are shorted on the analog board**

The first thing I did when I encountered this problem on a full board was panic. It is actually not too difficult to find the culprit (assuming there is only one problem!). The most likely place for power and ground to short is under one of the AD96687s or under

one of the filtering capacitors (the larger brown passive components). You may be able to find the problem under an AD96687 visually and use an iron and some flux to draw the offending solder-bit out or to a pad. If the problem is not obvious connect an ohm meter to power and ground and carefully run the hot air soldering pencil over each IC and over the capacitors. When you get near the problem area and begin to melt the solder bridge you should see the resistance between power and ground change. This usually narrows down the problem to one component.

## **10. Large fluctuations in the TOT stops or starts**

First, check to make sure the input signal from the phototube is OK. Perhaps the easiest way to do this is to swap two neighboring channels on the back of the analog board and see how this effects the problem. If the input signal looks reasonable, check to make sure the hysteresis loop is connected (the row of capacitors and resistors to the left of the AD96687 discussed in Section 4). It wouldn't hurt to resolder the filtering capacitors on the AD96687 (the larger brown passive components near this chip) and those near the input MAX435s.

## **11. Missing scalar signals**

Again, the typical cause is a cold solder joint on the power or ground pins of one of the MC10101s, MC10104s, or MC10109s. Refer to Appendix 3 and resolder any suspicious pins.

## **12. The high voltage supply trips**

Unplug the individual channel SHV connections to the phototubes and make sure that a cable, base, or phototube is not the problem. If a board will not hold high voltage with all phototube channels unplugged, first suspect one of the HV capacitors. Removing all of the socketed resistors (HVR02) will eliminate both of the 33nF and the 100pF capacitors from the circuit. Put these back in one at a time to see which channel is the problem then replace any HV capacitors in question. If the board will not hold high voltage with all socketed resistors removed then it could either be one of the 10nF filtering HV capacitors, or a more serious problem. At this point, I would check the board for burned marks (indicating a place where the high voltage and ground may have shorted) and if you find this then the entire board may be toast: shorting high voltage to the ground plane internally in the board is one of my nightmares.

## **13. The high voltage current is erratic**

The current drawn as indicated on the front panel of the CAEN supply should be very constant. If this is jumping around then past history indicates it is a problem with a cable or a wet connector. Try disconnecting phototubes from the back of the analog board and see if this is the problem.

#### **14. Cross talk between channels**

We went to rather extreme measures to assure that cross talk between channels on the analog boards was minimal. If a larger than expected signal is present from a phototube (such as if a base is arcing producing a several volt pulse with a long decay time) then crosstalk will be seen. If the grounding on the two 210 $\Omega$  termination resistors at the input MAX435s (R003 and R016) or the 75 $\Omega$  termination on the input is not present, then cross talk problems will occur. Also, if one of the copper fences becomes dislodged, cross talk can increase.

#### **15.No signal from both the high and low threshold of one channel after arcing or other catastrophic events on the analog board**

The analog boards have two components designed to act as fuses should the input voltage get too large. Looking at Figure 4, the single channel small signal section, just at the point marked IN, there is a 20  $\Omega$  resistor (R001) and a 3 pin surface mount diode pair (D001). Check to see if the resistor is blown (quite often this will be charred). If so, replace both the resistor and the diode pair. Also check the 75  $\Omega$  termination resistor, this may also need to be replaced. If these components are replaced and there is still no signal, then test the low and high threshold MAX435s with a pulse generator on the bench. It could be that one of these was also destroyed. After making sure that a signal is going into each MAX435 (pin 2), you can test the outputs at the input to the AD96687 (pins 7 and 8 for the low threshold and 9 and 10 for the high).

## Section 7: Daily and Regular Maintenance

In addition to data acquisition summary plots which are monitored daily, several things on the front-end system should be monitored everyday during a shift. These take only a few seconds to check.

1. Check to make sure all low voltage power LEDs are on. These include pair of green LEDs on the front of the analog card and the single red LED on the front of the digital card.
2. Check all high voltage LEDs (a pair of red LEDs on the front of the analog card). The intensity of these lights is proportional to the high voltage applied. They turn on at several hundred volts and increase in brightness as the voltage increases. If one of these lights is much dimmer or brighter, this could indicate a problem.
3. Check the low and high sum LEDs on the front of the digital card. These should flash periodically, but they should not be on steady. Remember that these depend of the number of tubes connected to a board, the depth of the water in the pond, etc. so not all rates will be the same.

Other items to monitor periodically include:

1. Check the value of the low voltages at the power supplies and at the crates.
2. Check the distributed high voltage values and currents on the front panel of the CAEN supply.
3. Check the low and high threshold values with a DVM at the test point at the top of the analog board above the ADC output ribbon cable.