SPIR-110: U of S RG174 Cable Assembly for CAEN 792AA QDC

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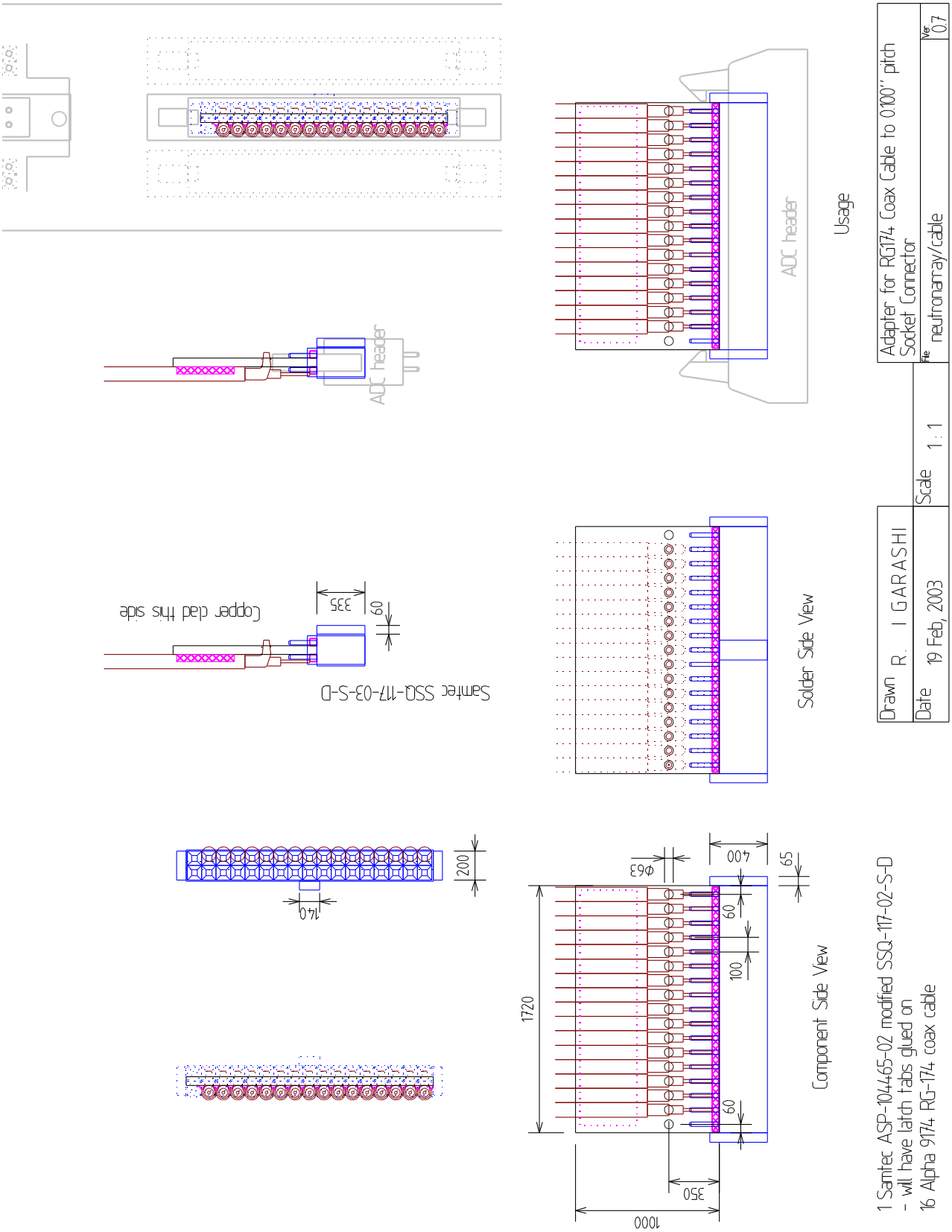
28th August 2003

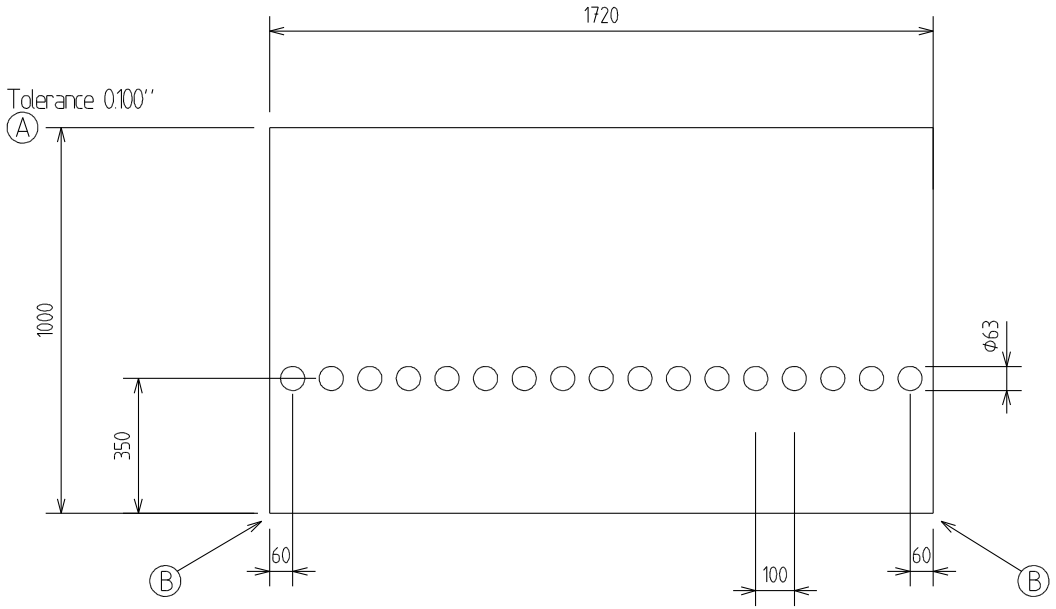
Contents

1 Introduction

This report describes a cable assembly that accepts BNC connections at one end and a 17-pin rectangular header similar to those used in ribbon cables at the other end. As explained in the preliminary report this is needed in order to use the CAEN V792AA QDC with existing 50Ω analog electronics for the Blowfish neutron detector array.

2 Diagrams


ADC header
Usage
ADC header
Solder Side View
Component Side View
Copper clad this side
Samtec SSQ-117-03-S-D
Adapter for RG174 Coax Cable to 0.100" pitch Socket Connector
Drawn R. I GARASHI
Date 19 Feb, 2003
Scale 1 : 1
File neutronarray/cable
Ver 0.7
1 Samtec ASP-104465-02 modified SSQ-117-02-S-D - will have latch tabs glued on
16 Alpha 9174 RG-174 coax cable



Notes:

1) Tolerance on hole positions +/- 0.010''
2) Do not damage copper around holes.
3) Remove burrs and sharp edges
4) Dimensions are in 1/1000 inch
5) 17 holes per board
6) Tolerance on sides +/- 0.010'' except (A) +/- 0.100''
7) Corners (B) need to be square
8) Diameter of holes is 0.063'' (1/16'')

Drawn R. I GARASHI		Adapter for RG174 Coax Cable PCB Machining
Date 19 Feb, 2003	Scale 2 : 1	File: neutronarray/cablepcb Ver: 0.7

3 Assembly Instructions

The assembly process can be conceptually divided into 5 parts:

1. Prepare the BNC connector end of the cable (Section 3.2).
2. Fix the header and the circuit board together (Section 3.5).
3. Attach the other end of the cable to the circuit board (Sections 3.3 and 3.6).
4. Test the assembly (Sections 3.4 and 3.8).
5. Label and Finish the assembly (Sections 3.7, 3.9 and 3.10).

Once one has become proficient at building the cable assemblies, it should take approximately 8 man hours to make a single assembly. The actual time it requires to make a cable assembly will be three days because one must wait for epoxy to cure at three stages.

3.1 Measuring and Cutting Cable

The following tools and parts are required:

- RG 174 50Ω coaxial cable
- Wire cutters
- Measuring tape

1. As discussed previously, the cable assembly will be 3 meters long. There can be problems in attaching the BNC connectors, Thus, it is recommended that the initial length of the cables be 310 cm. The excess will be trimmed shortly before attachment to the circuit board.
2. There are 16 cables per assembly, and it is recommended that all 16 be measured and cut in one session. The most convenient way to measure them is to mark off 310 cm on the floor of a large space, like an infrequently used hallway or room.
3. Pull the requisite length of one cable, then cut. Having two people for this step is advisable.

3.2 The BNC Connector

The following assumes a Paladin LC CST - mini is being used to strip the cable, and Amphenol 31-315-RFX BNC connectors are being used.

Caution: wear protective eye wear. The braided cable produces metal filings that can spring away from the trimmed cable ends. Also, use a brush or paper towel to sweep off any working surfaces instead of bare skin. The filings become painful slivers very easily.

There are two phases for attaching the BNC connector: 1) stripping the coax cable, 2) attaching the BNC assembly.

3.2.1 Stripping the Cable

The following tools and parts are required:

- Paladin LC CST - mini cable stripper
- Knife or razor blade

Caution: Do not cut or nick the braid, dielectric or core conductor in any of the following steps except where instructed. Test the cable stripper on a test cable to ensure the blades are set to the proper depth.

The cable is stripped as follows:

1. Before the cable is stripped, slide on the outer ferrule such that the wider end points to the end of the cable.
2. Hold the cable stripper with the arrows on the sides pointing up. You should see a diagram of a stripped cable end. This indicates which way the cable should be inserted.
3. Squeeze the lever under the cable stripper to open its jaws.
4. Holding the cable against the inner yellow clamp, insert the cable in the direction indicated by the diagram so that it fully straddles the inner yellow clamp. Do not release the lever until it is placed satisfactorily. The end of the cable should not stick out more than 1 mm, though it may stick out a little.
5. When you are satisfied with the cable end's placement, release the lever.
6. Put your a finger in the loop on the cable stripper, look on the side for the arrows, and turn the cable stripper around in the indicated direction 4 times.
7. Open the jaws, and remove the cable. Try to avoid dragging the cable across the blades. The cable should be slit in 3 places.
8. Pull off the outer jacket.
9. Pull off the clear plastic dielectric from the core conductor. There should be a $\sim$2mm wide strip of exposed dielectric, 3-4mm of exposed core conductor and $\sim$9mm of exposed braid.
10. With a knife, make a 5-7 mm longitudinal incision in the end of the outer insulator.

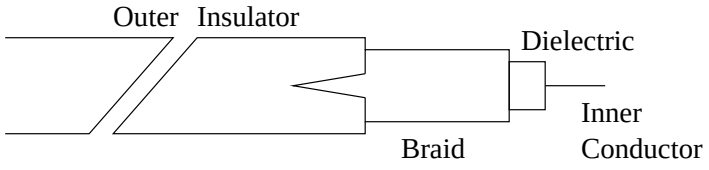


Figure 1: The stripped coaxial cable as described in section 3.2.1.

3.2.2 Attaching the BNC Assembly

The following tools and parts are required.

- Amphenol CTL-2 crimp tool
- Amphenol 31-315-RFX connector parts.

The Amphenol 31-315-RFX connector assembly consists of 4 parts: the body, the ferrule, the Teflon sleeve, and the contact. The Amphenol CTL-2 crimp tool is recommended for crimping.

1. Slightly flare the end of the cable braid. Wiggling the end can help start a flare. This facilitates the insertion of the Teflon sleeve and of the inner ferrule. DO NOT comb out the braid.
2. Slide the Teflon sleeve over the dielectric and under the braid until the end of the sleeve is flush with the end of the dielectric.
3. Place the center contact on the cable core conductor so that it butts against the dielectric and Teflon sleeve. If it does not butt against the dielectric, the core may be too long and should be trimmed. Note, there should be no reason for trimming the core any shorter than 3mm.
4. On the crimp tool, identify the .068” cavity. It should be thinner than the other cavities. Place the cable end with contact in that cavity on one jaw and close the crimp tool just enough for the other jaw to make contact with the contact. Make sure the contact is butted against the dielectric then squeeze the crimp tool fairly hard. The crimp tool is ratcheted and will not release until enough pressure has been applied. You will hear or feel a notable click. If the jaws were closed too much before inserting the piece, push on the small lever between the handles to release them.

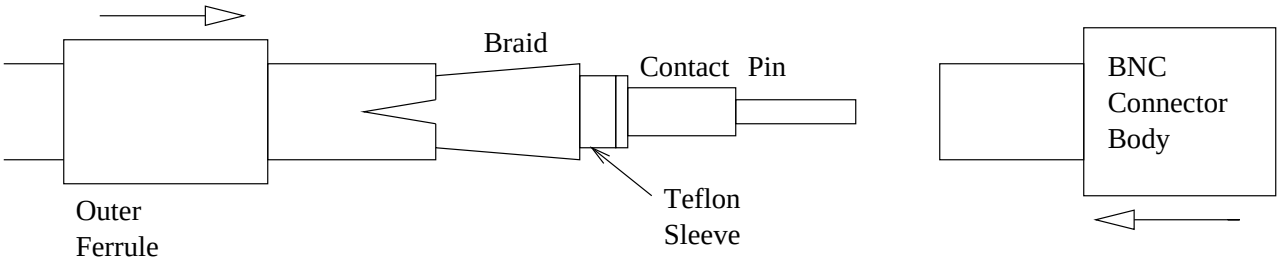


Figure 2: Attaching the BNC connector after crimping the contact pin.

5. Slide the cable end into the connector body so that its inner ferrule slides UNDER the braid. Push until the contact either snaps into place or until the flare on the contact is no longer recessed at the base of the insulator inside the body.
6. Slide the outer ferrule over the braid and up against the connector body.
7. Identify the .178” cavity on the crimp tool . Place the connector in that cavity on one jaw and close the crimp tool just enough for the other jaw to make contact with the ferrule. Make sure the ferrule is butted against the connector body then squeeze the crimp tool fairly hard until the ratchet releases.

3.3 Preparing the Other End of the Cable

The following parts and tools are needed:

- 14 gauge wire strippers
- Adjustable wire strippers

Caution: Do not cut or nick the braid, dielectric or core conductor in any of the following steps except where instructed. Test the cable stripper on a test cable to ensure the adjustable blade is set to the proper depth and the 14 gauge wire stripper does not nick the braid.

1. Measure the cables and trim down to 3m length. The easiest way to do this is to create a template cable of the correct length and cut all cables using that template.
2. Using 14 gauge wire strippers, cut the outer jacket for about 10mm from the unterminated end of the coax cables. Do NOT cut the braid in the process. Use your fingers to pull the outer jacket away. Do NOT try to pull the jacket away using the wire strippers.
3. Comb out about 8 mm of the braid, and twist together to form a ground line.
4. Strip 5 mm of dielectric from the core conductor using an adjustable wire stripper. You may need to twist the core to prevent it from fraying during testing and soldering.

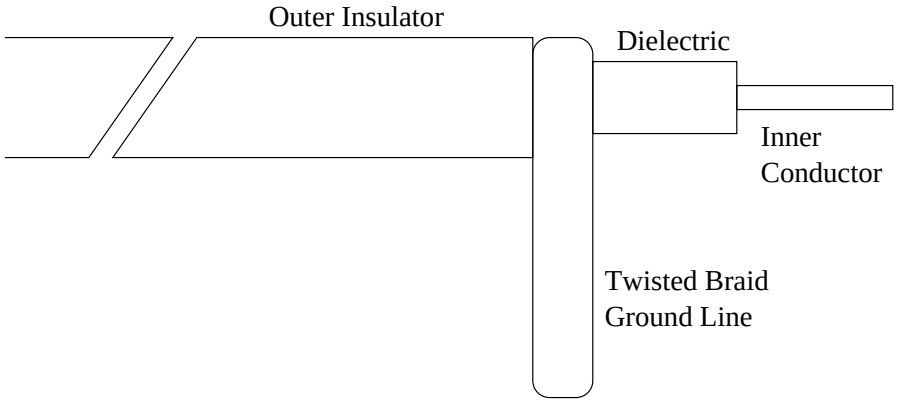


Figure 3: The other end of the cable prepared for testing and soldering.

3.4 Testing the Cable

The following parts and tools are needed:

- Tektronix 2465B 400MHz Oscilloscope (need 3 channels)
- BNC Model 8010 Pulse Generator

1. Plug the TRIG OUT of the pulser into a channel of the scope (for example channel 4). Ensure that there is no impedance mismatch. If an impedance mismatch exists, the setup will work sporadically at best. If a 50Ω cable needs to be plugged into a 1MΩ port, such as channel 4, use a t-junction and a 50Ω terminator. See figure 4.

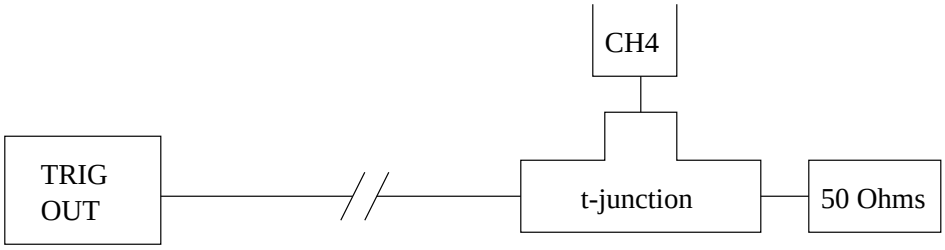


Figure 4: Connection of the trigger to channel 4 of the scope with a t-junction and 50Ω terminator.

2. Plug another cable into the 5V MAX connector on the pulser. The other end of the cable should be plugged into a t-junction and that t-junction should be connected to a channel on the scope (for example channel 3).

3. Connect a known good coaxial cable from the t-junction of the previous step to another channel (for example channel 2). Ensure that this channel has a 50Ω impedance. See figure 5.

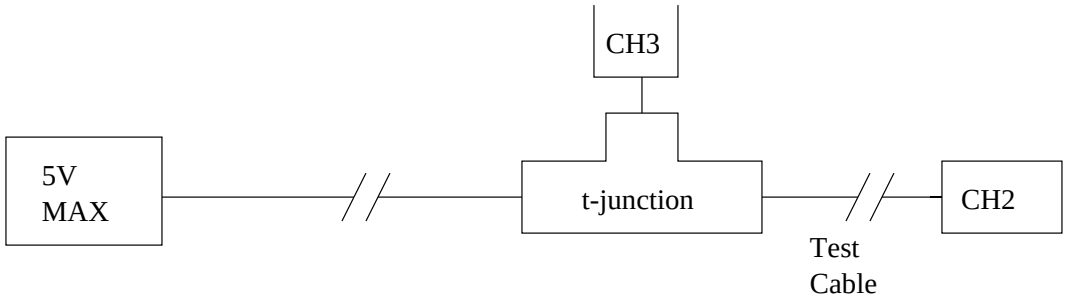


Figure 5: Connection of the 5V pulser output to scope channel 3 (1MΩ), to the test cable and finally to channel 2 (50Ω).

4. You will want to use the following settings on the pulse generator:

   - Freq = 1MHz (gives visible line on scope)
   - Delay = 0.03μs (minimal delay)
   - NORM/COMPL to NORM
   - Amplitude about half way for now
   - width = 0.1μs

   The width can be further adjusted while viewing the pulse on the scope. The width controls on the pulser used to create this document are flaky so the setting above may not be what is needed.

5. You will need to use the following setting on the oscilloscope:

   - Trigger slope: +
   - Trigger source: your trigger source (e.g. channel 4)
   - Delay: will vary with cable length (e.g. $\sim 20\mu$s)

- Ensure all channels have the proper impedance

Note that on this scope, channels 3 and 4 support only 0.5 and 0.1V/div with an impedance of 1MΩ

6. Adjust the amplitude on the pulser and the delay and scales on the scope to obtain a square wave with fairly short rise and fall time with a fairly large voltage (∼4 or 5V).

7. Observe the various characteristics of the known good cable comparing the pulse from before and after it propagates down the cable (e.g. comparing channels 2 and 3). Make note of the amplitude attenuation, signal width, rise time and fall time of the square wave on both channels.

8. Connect the crimped BNC end of a cable built in the previous steps to channel 3 and use clips to connect the other end to channel 2. Compare this to the previous step with the known good cable. Some signal degradation should occur due to the unshielded portion of the new cable.

9. Make sure to gently pull and twist the BNC connection to ensure that it is properly crimped and is not loose. Observe the scope while doing this to ensure that the signal does not change by applying stress to the BNC connector.

3.5 Attaching the Header to the Circuit Board

The following tools and parts are needed:

- Soldering iron set on 700^{o}F
- Precut circuit board (should have 17 holes)
- 1 17-pin Samtec SSQ header with center ridge
- Rosin solder flux (water soluble or "No Clean")
- Pair of latex gloves

The cables are attached to the circuit board as follows:

1. Sand down the NON-copper side of the circuit board. This will allow the epoxy to be applied in section 3.10 to better bond with the board.

2. When working with the rosin solder flux, it is advisable to wear protective gloves as the rosin is unpleasant when in contact with skin.

3. Apply a band of solder flux to the copper side along the long edge of the board nearest to the holes in the board. The band should extend from the edge of the board to the holes in the board (about 9mm).

4. Tin that band by applying the soldering iron to the fluxed region at one end and melting solder on the copper (not on the soldering iron). Slowly slide the iron down the band of flux. Caution: do not leave the iron on one spot too long, as that will cause delamination of the copper.

5. If the header's pins are not tinned, apply flux to them and tin all of them by applying the soldering iron to one pin and melting solder on the pin (not on the iron). Tin pins out of sequence to reduce the accumulation of heat in the body of the header, e.g. tin pin 1, pin 8, pin 2, pin9, etc.

6. Slide the tinned edge of the board between the pins of the header with the center ridge on the copper side of the board. See section 2 for diagrams.

7. Align the pins to the holes in the board, then "tack" the pin on one end of the header to the board with some solder. If the header is not aligned satisfactorily, remelt the solder and realign the header. Tack down the other end of the header.

8. When the header is tacked down satisfactorily, proceed to solder the pins on the solder side of the circuit board. Solder pins out of sequence to reduce heat accumulation in the header and the board, e.g. pin 2, pin 10, pin 3, pin 11, etc. Don't forget to solder the tacked pins at the ends. Do this only on the solder side.

3.6 Attaching Cables to the Circuit Board

The following parts and tools are needed:

- Soldering iron set at 700°F
- circuit board with header created in section 3.5
- 16 coaxial cables created in 3.2 and 3.3.
- Wire Cutters
- Rosin solder flux
- Latex gloves
- Tweezers
- Electronics solder

Notice that there are 17 pins on the header and only 16 cables. Refer to section 2 for diagrams of the cable assembly and note which pin is not being used.

1. Gloves are recommended for this section as the solder flux is unpleasant when in contact with skin.

2. Soldering should be performed in a well ventilated area.

3. Flux and tin the core conductor and the end of the ground line. Caution: use needle-nose pliers or similar as heat a heat sink between the tinned area and the dielectric to minimize heating the dielectric.

4. Thread the ground line through one of the holes in the circuit board, from the active side to the ground side. The cable should be on the active side, and the ground line should be sticking out of the ground side.

5. Once the ground line is though the hole, tin the ground line. Solder the ground line to the pin, if possible and to the copper board, if necessary.

6. Using tweezers, place the tinned core conductor against the corresponding pin on the header (on the component side). You may need to use the wire cutters to trim the copper conductor in order for it to make proper contact.

7. Place some solder on top of the core conductor so that it will melt when the soldering iron is set on top.

8. Place the soldering iron on top of the solder and core conductor (i.e. sandwiching the core against the pin and melting the solder). As soon as the solder melts, remove the soldering iron. Be careful to minimize melting of the dielectric using the tweezers.

3.7 Labelling the Cables

The following parts and tools are needed:

- Computer with printer or printed labels
- Clear packing tape
- Scissors
- Marker
- Log book 121

1. If no pre-printed labels are available, print columns of numbers from 0 to 15. Notice that 6 and 9 look exactly the same. Either print the word 'six' and 'nine' or use underscores to differentiate between the two.

2. Find the first cable either by using a DMM or by physically sorting through the cables. Pin 0 is the one furthest away from the unused pin and pin 15 is the pin next to the unused pin.

3. Cut three lines off the column of numbers.

4. Cut a 4cm strip of packing tape and place the numbers on the packing tape so that the numbers are clearly visible through the tape. Or, if the numbers will stick to the cable themselves, attach them to the cable.

5. Tape the numbers to the cable.

6. The cable needs a unique identification number. Look on the third last page of the log book numbered 121 for a cable registry. Find the next available number.

7. Repeat the above steps to number the BNC ends of the cable and using a marker, mark the number on the copper part of the fiberglass board.

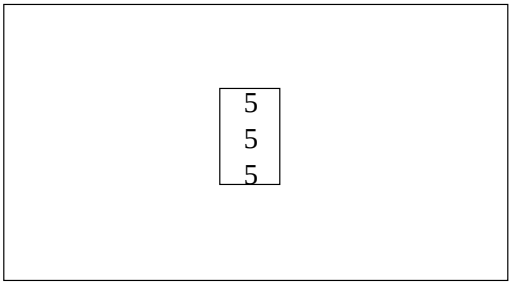


Figure 6: Label made using a column of numbers and packing tape.

3.8 Testing the Assembly

The following parts and tools are needed:

- Tektronix 2465B 400MHz Oscilloscope (need 3 channels)
- BNC Model 8010 Pulse Generator

1. Configure scope and pulser as described in section 3.4.
2. Connect a cable from the new assembly to the t-junction connecting the scope to the pulser 5V MAX. In the example, this was attached to channel 3.
3. Connect the corresponding pins to the open channel of the scope (e.g. channel 2). To do this, one may need to build a special connection cable. Make a coaxial cable with a BNC connector on one end and two pins on the other as shown in figure 7.

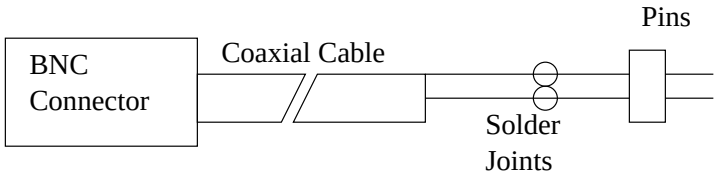


Figure 7: Test cable used for testing completed assemblies.

4. Perform the same tests as in section 3.4.
5. Now, choose a cable, for example cable 0. Attach the test cable to the pins connected to cable 1. It is important to match the impedances on the dangling ends. Attach a 50Ω terminator to the BNC end of cable 1 and attach a 50Ω resistor to channel 0 on the header. See figure 8.
6. nothing should appear on the scope. Now, set the scope to the maximum vertical sensitivity (e.g. 2mV). A function should appear on the scope. This function is cross-talk from cable 0. Since there is a short distance where the inner core is not protected, cross talk is bound to occur. The cross-talk on cable 1 should be less than one percent of the signal on cable 0. Now, move to the next cable, in this example it is cable 2. Again measure the cross talk. There should be very-little cross-talk on cable 2. Cable 3 should experience virtually no cross-talk.

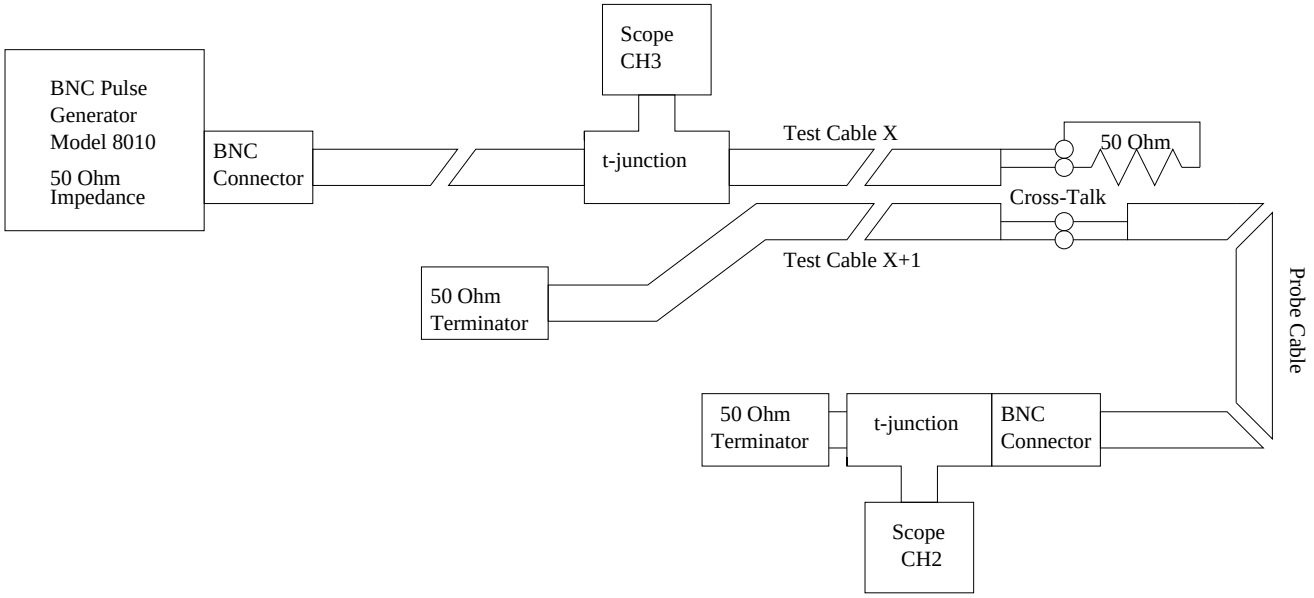


Figure 8: Setup used to test the cross talk observed on the cable.

7. Measure the cross talk on nearby cables for all 16 cables in the assembly.
8. For details on cable testing results, see [3].

3.9 Tying the Cables

- Three cable ties
- Electrical tape
- Scissors

1. Cables should be tied in order to keep them for tangling. A cable tie 15cm from the board will help reduce stress on individual cables at their connections with the board.
2. Further cable ties along the cables will help reduce tangling.
3. Since the ends may need to spread out, a cable tie near the BNC connector is not recommended. Instead, using electrical tape can keep the cable ends from becoming tangled and the tape can be easily removed later.
4. Using scissors, clip off the ends of the ties and save them for later steps.

3.10 Finishing the Assembly

The following parts and tools are needed:

- Electrical tape

- Polyethylene
- Five minute epoxy
- Scissors
- Latex gloves
- Weight (such as a book)
- Small pieces of fiberglass
- Scotch tape

3.10.1 First Epoxy

The cables need to be glued to the circuit board. Latex gloves are recommended for this step. Also, epoxying should be done in a well ventilated area.

1. The first application of epoxy should be between the cables and the board. Using one of the cable tie ends saved from the previous step, apply a moderate layer of epoxy between the cables and the board.
2. Epoxy will not bond with the latex gloves so one may wish to wrap the cable end in a glove to prevent it from sticking to the table or the weight while the epoxy hardens.
3. Set an object, such as a book, on the cables to hold them against the board. Be careful that the weight does not damage the cable assembly.
4. The epoxy needs a couple hours to harden before the weight can be removed. It should be left to harden overnight before the next layer is applied.

3.10.2 Second Epoxy

The second application of epoxy should encase the cables. Again, gloves are recommended for this step.

1. Epoxy should be applied liberally to the exposed side of the cables. Do not apply epoxy over the pins.
2. To mould the epoxy, wrap the newly epoxied cables in polyethylene.
3. Electrical tape can be used to keep the polyethylene in place.
4. Allow the epoxy to harden and remove the polyethylene after a few hours. The epoxy should be left overnight to harden before the next step.

3.10.3 Third Epoxy

It is desirable that the cable assembly be held into the ADC using the clips. However, the clips can not grab onto the assembly. Thus, small pieces must be added to the cable assembly so that the clips may latch to it.

Again, gloves are recommended for this step.

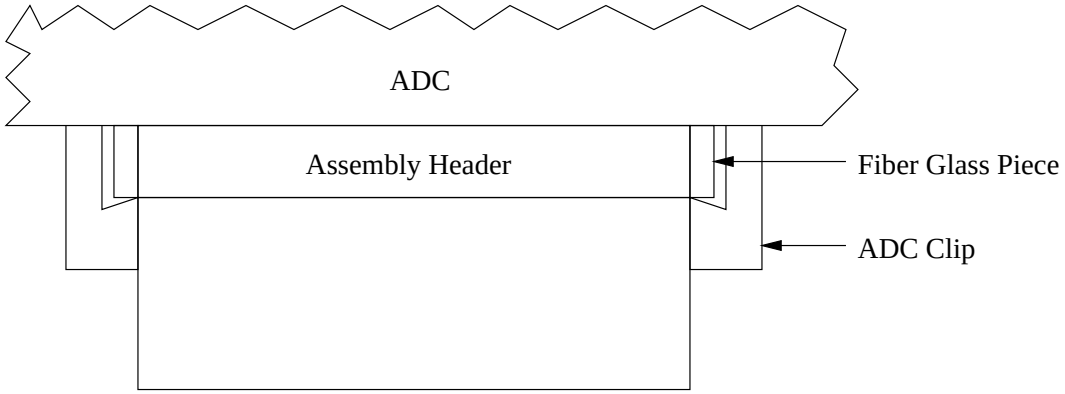


Figure 9: Clips latching onto a cable assembly.

1. Obtain two small pieces of fiberglass, such as the corner cut off of a passive analog splitter if splitters are being manufactured at the same time.
2. Epoxy the small pieces to the sides of the header.
3. Scotch tape may be used to hold the pieces on while the epoxy hardens for a few hours. The assembly should be left overnight to harden to ensure that the pieces of fiber glass are securely attached.

3.10.4 What not to Epoxy

The circuit board and header should not be epoxied together. If the cable is violently pulled, the pins will come out of the header before serious damage is done to any expensive equipment that the cable is attached. Thus, the cable is sacrificed to protect more expensive equipment. The perpetrator should then be beaten mercilessly with a large stick.

3.11 The End

The following parts and tools are needed:

- Log book 121

Congratulations! You have completed a cable assembly. A cable registry is maintained in log book 121 starting on the third last page. You should register your cable to ensure sequential numbering.

A Cable Registry

The following is from the cable registry in log-book 121. It is up-to-date as of August 2003.

Cable assemblies numbered 1 through 14 were created during the summer of 2003 by Ward Wurtz. These cables are 304cm long and a pulse takes 15.2ns to travel down a cable.

Cable assemblies 1,2,4-7,9-12 were sent to Duke University and assemblies 3,8,13 and 14 remained at the U of S.

B Photographs of Completed Assemblies

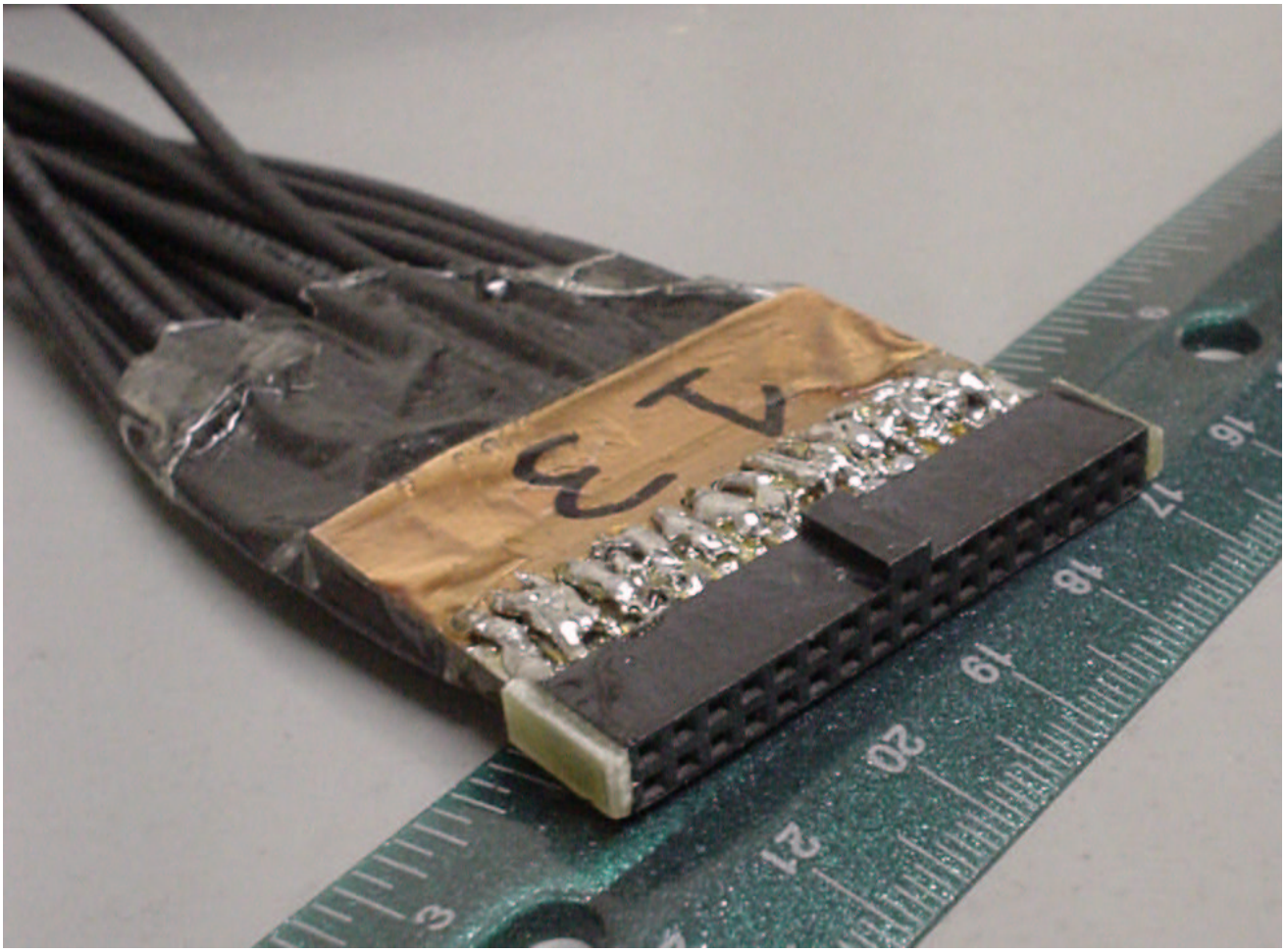


Figure 10: Ground plane of a completed cable assembly.

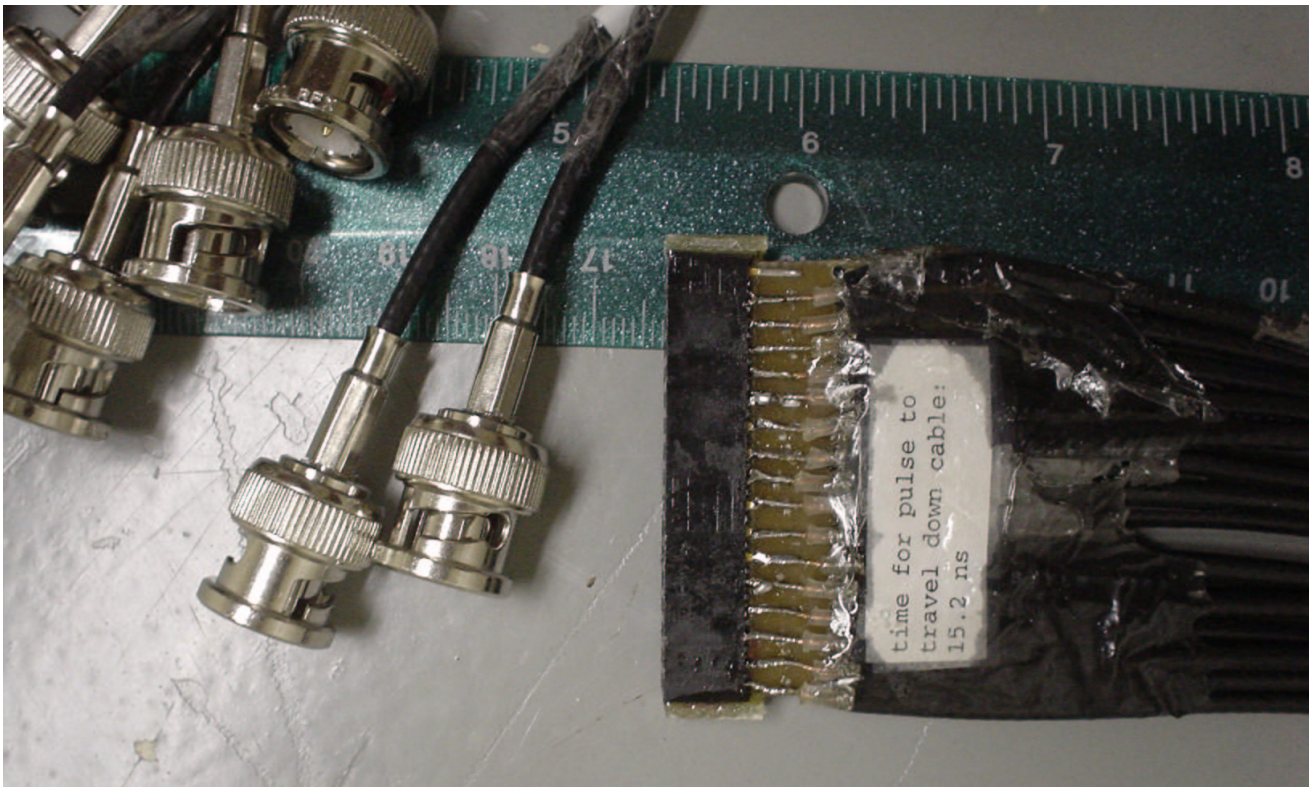


Figure 11: Active side of a completed cable assembly.

References

[1] Amphenol Corporation. *Assembly Instructions-C26.* www.amphenolrf.com. (Copy can be found in log book 121.)

[2] Ru Igarashi. *SPIR-109 Design Considerations for Cable Adaptors for CAEN V792AA QDC in the Blowfish Electronics.* Internal Document, 2003.

[3] Jennifer Robb and Ward Wurtz. *SPIR-112 Cross-talk and Attenuation Tests for Cables and Splitters Used with CAEN 792AA VME QDC.* Internal Document, Summer 2003.

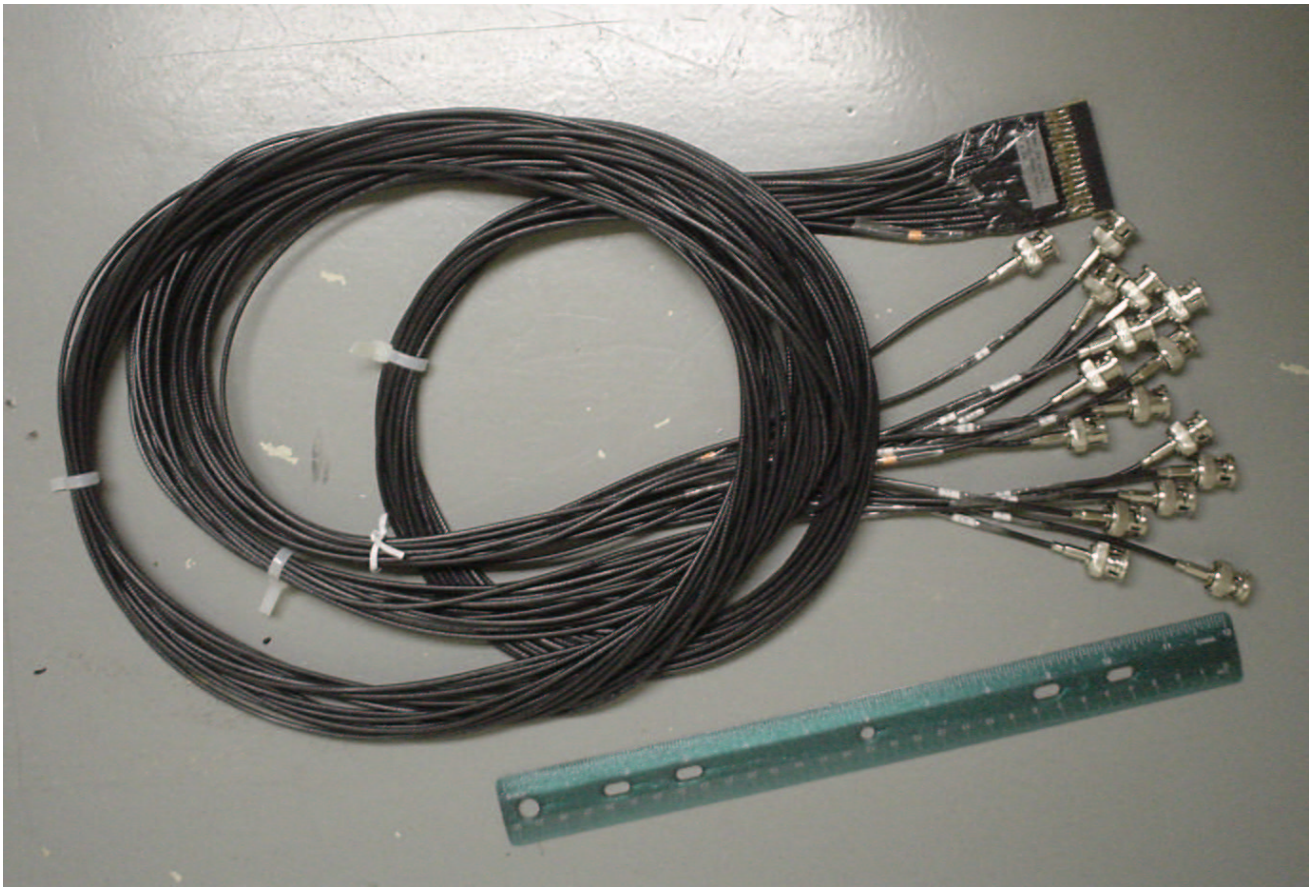


Figure 12: Complete cable assembly.