8 TEKTRONIX[1] 1502 MODIFICATION for WAVEFORM OUTPUT

When equipped with the X-Y Output Module, the Tektronix model 1502 TDR cable tester will provide analog outputs suitable for driving a chart recorder. These outputs consist of a ramping DC voltage for the X-axis signal and a variable DC voltage between about 0 and 1 VDC that is the Y-axis signal corresponding to the waveform display on the screen. The waveform is output over a 20-s interval after the toggle switch on the 1502 is depressed. This note describes a modification that will allow the TACQ.EXE program to toggle the output electronically using one pin of the computer's parallel port. When used with a suitable analog to digital conversion device, this allows the waveform to be digitized by the computer that is running TACQ. The toggling modification will be presented first, followed by two suggestions for analog to digital conversion that TACQ is able to use.

8.1 Modifying the Tektronix 1502 for Digital Toggling of Waveform Output

8.1.1 Parts List

Tektronix model 1502 TDR cable tester

X-Y Output Module for the cable tester

22 or 24 gage solid, insulated wire

Two 4-40 by ½ inch screws for mounting the relay circuit board to the bottom of the X-Y Output Module, and four to six 6-32 nuts for spacers between the circuit boards

Relay circuit board for toggling output. See Figures 8-1 to 8-3 below

Mylar plastic film for insulating relay circuit board

Optoisolator, GEH11AA1 or ECG3041 or TIL113 or MOC3030, or equivalent, 6 pin

Relay, 5 VDC, SPST, Radio Shack 275-232 reed relay or equivalent

4.7 kΩ resistor, 5%, carbon film

1 kΩ resistor, 5%, carbon film

NPN transistor, 2N2222 or ECG123A or equivalent

Switching diode, 1N914 or equivalent

One meter of four conductor stranded, 22 or 24 gage, tinned copper, shielded cable.

[1]The mention of trade or manufacturer names is made for information only and does not imply an endorsement, recommendation, or exclusion by USDA-Agricultural Research Service.

Switchcraft DIN straight cord plug type 05CL5M with 30° locking ring, 5 pins at 180°. Bought from Allied Electronics, Inc., Tel:800-433-5003, part no. 932-0154.

Switchcraft DIN receptacle type 57HA5F, for locking ring plug, 5 contacts at 180°. Bought from Allied, part no. 932-0185. See page 308 in Allied catalog no. 956.

8.1.2 Relay Circuit Board

Gerber files for the relay circuit board are TOGGLE.001 and TOGGLE-F.001 and may be downloaded from http://www.cprl.ars.usda.gov/programs. Figures 8-1 through 8-3 show the solder and component sides of the board. The TOGGLE.001 and TOGGLE-F.001 files have three images of the circuit board for ganging on a single copper clad board. Files TOG1.001 and TOG1-F.001 are the same but have only one image of the circuit. This is really a single sided board so only the solder side is strictly necessary. If it is not feasible to produce the single-sided printed circuit board, a piece of perf-board may be substituted with insulated wires replacing the circuit board traces.

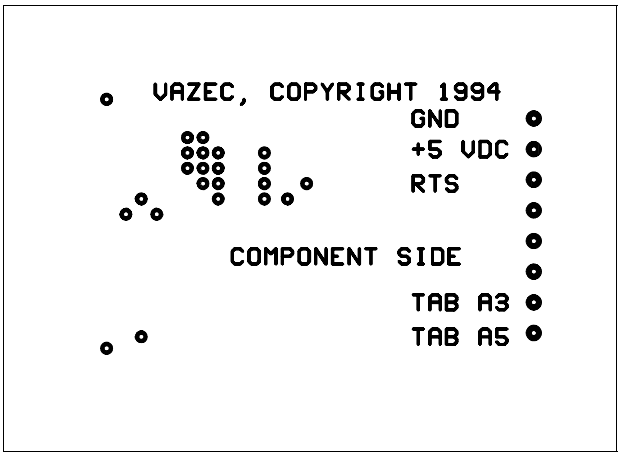

Fig. 8-1. Component side of the toggle relay PCB.

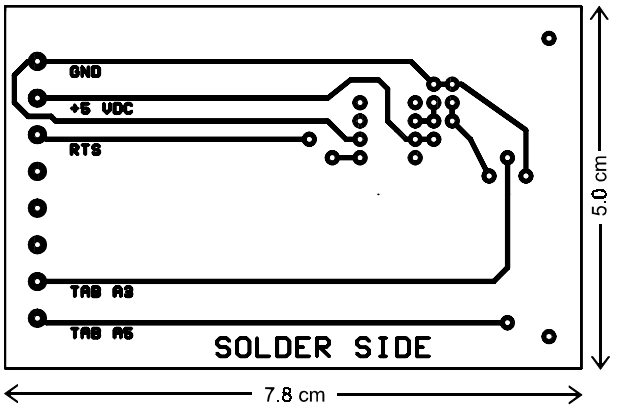

Fig. 8-2. Solder side of the toggle relay PCB.

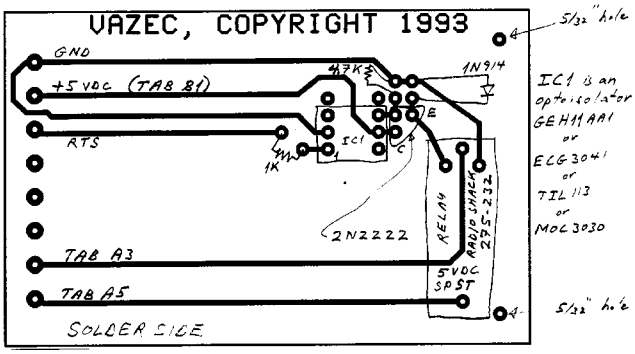

Fig. 8-3. Components and connections for the toggle relay PCB.

8.1.3 Assembly

The Switchcraft DIN plug is wired at one end of the shielded cable as follows. Connections should correspond to the positions shown for the DIN socket (receptacle) in Fig. 8-4.

Pin Number	Color	Use	
1	White	RXD	Unused or connected to the RXD pin of the computer's serial port if used with the DATAQ DI-130 A/D device (see 8.4)
5	Black	DTR	Unused or connected to the DTR pin of the computer's serial port if used with the DATAQ DI-130 A/D device
3	Green	GRND	Connected to ground pin of the computer's parallel port, or to the ground pin of the computer's serial port if used with the DATAQ DI-130 A/D device.
4	Red	RTS	Toggle signal, connected to pin 5 of the computer's parallel port, or connected to the RTS pin of the computer's serial port if used with the DATAQ DI-130 A/D device

The Switchcraft DIN socket is mounted in the face of the X-Y Output Module through a hole (about 1/2 inch) drilled in the face (Fig. 8-4). Use a set punch to dimple the face of the Module just above the word TEKTRONIX and centered between the R and O. Be sure that the Module is setting face up on the edge of a table and positioned so that the card edge connector (circuit board) is not taking the force of the blow. Lay the module on the table top on its side with the face plate overhanging the edge of the table and clamp the Module to the table top. Drill a 1/8 inch diameter pilot hole followed by a 1/4 inch hole, followed by successively large holes until the finish diameter is achieved. Set the module face up on the table's edge, again protecting the circuit board. Place the DIN socket in the hole and use the punch to mark one of the two screw holes. Drill the screw hole. Place the DIN socket in the large hole again and place and tighten the first screw. Now drill the second screw hole. Take the DIN socket out of the hole and solder four 20 cm long wires to the appropriate lugs as shown in Fig. 8-4. If the DATAQ DI-130 A/D device (see section 8.4) is not used then solder wires only to the lugs labeled RTS and GND in Fig. 8-5.

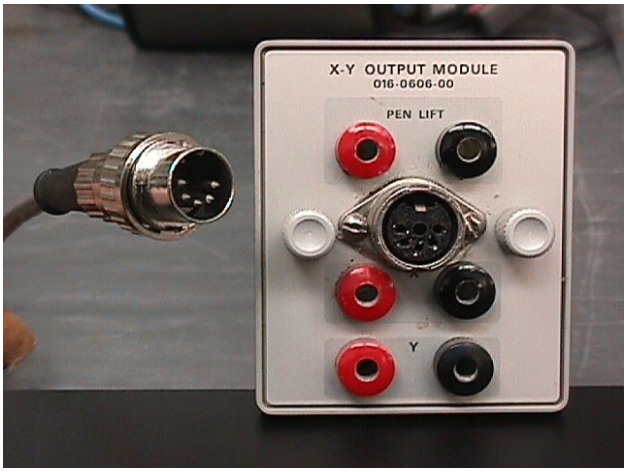

Fig. 8-4. DIN socket mounted in front of X-Y Output Module, and DIN plug on cable.

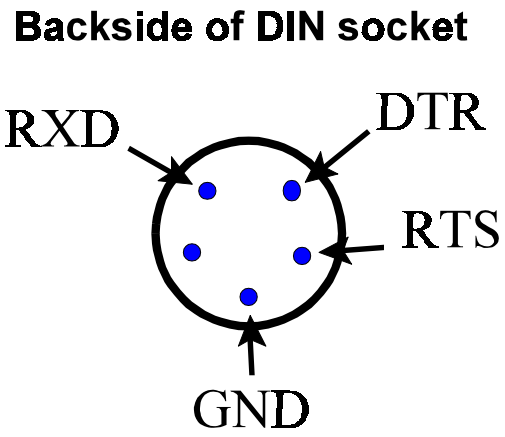

Fig. 8-5. Rear side of DIN socket.

Thread the wires through the ½ inch hole. The GND wire goes to the grounding lug on the bottom side of the circuit board of the X-Y Output Module. The RTS wire goes to the relay circuit board for toggling the 1502 to output a wave form (see relay circuit board below). Place the DIN socket in the ½-inch hole and use round head machine screws to bolt it to the face of the X-Y Output Module.

Place the X-Y Output Module on the table with the face towards you and the card edge connector facing away from you. The card edge connector has 20 gold tabs. Numbering the top set of tabs A1 through A10 from left to right you will see that tabs numbered A8, A9 and A10 are connected to traces on the circuit board. Numbering the bottom set of tabs B1 through B10 from left to right you will see that tabs B1, B8, B9 and B10 are connected to traces on the bottom side of the circuit board. Tabs A3 and A5 are unused. Drill a 1/16 inch hole through the circuit board about 1/16 inch behind tabs A3 and A5. Wires from tabs A3 and A5 will be connected to the relay circuit board. Strip and bend a 20 cm length of 22 gauge wire so that it comes up through a hole and just touches the back side of the gold tab. Solder the wire in place. Repeat for the other hole. Be careful not to put too much solder on the tab as this will interfere with the tabs seating fully with the card edge connector inside the cable tester (Fig. 8-6).

There is a grounding lug on the bottom side of the circuit board of the X-Y Output Module. Strip and tin the ends of a 20 cm wire and solder to the grounding lug (Fig. 8-7). This will connect to the relay circuit board. Strip and tin the ends of a 20 cm wire. Follow the circuit board trace that leads from tab B11 along the bottom side of the X-Y Output Module circuit board to one end of a resistor. This is the 5 VDC power line. Turn over the X-Y Output Module, and solder the wire to the end of the resistor that connects to this trace.

Drill 5/32 inch holes in the relay circuit board as indicated in the drawing. Solder the components into the relay circuit board as indicated in the drawing. Solder the wires from tabs A3 and A5 into the holes labeled A3 and A5 on the drawing. Solder the wire from the lug on the DIN socket that is labeled RTS in the drawing to the pad labeled RTS on the relay circuit board drawing.

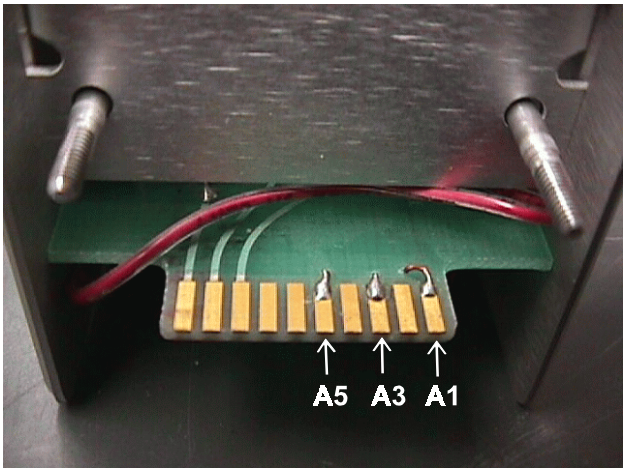

Fig. 8-6. Card edge connector of X-Y Output Module. The wire to tab A1 is used to provided power to an analog to digital conversion device described in Section 8.2.2.2.

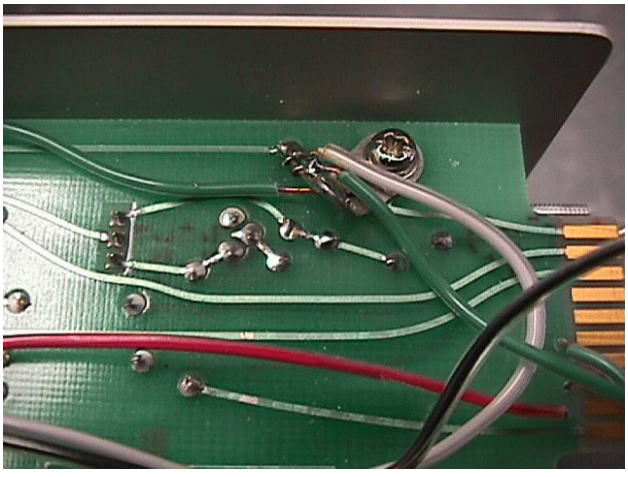

Fig. 8-7. Grounding lug on bottom side of X-Y Output Module circuit board.

Solder the wire that is connected to the grounding lug of the Module to the pad labeled GND on the relay circuit board drawing. Solder the wire that was connected to 5 VDC power (resistor on trace to tab B11) to the pad labeled +5 VDC on the relay circuit board (Fig. 8-8). Tape a piece of mylar plastic film over the solder side of the relay circuit board. There are four screws holding the X-Y Output Module circuit board in place. Remove the the two screws nearest the face plate and mount the relay circuit board below the Module circuit board using two longer screws. Use two slightly larger nuts between the circuit boards as spacers. Fold the excess wire out of the way, preferably between the two circuit boards.

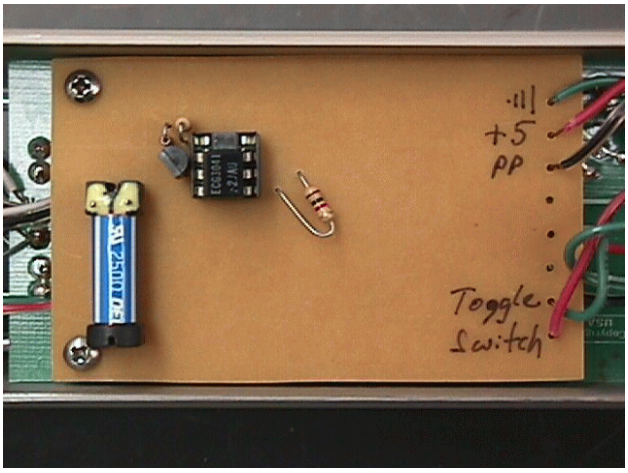

Fig. 8-8. The relay circuit board installed on the bottom of the X-Y Output Module. On the right side, from top to bottom, wires are connected to the grounding lug, to the resistor that is connected to tab B-11, to the RTS line (labeled PP here) on the DIN plug, and to tabs A3 and A5.

Remove the battery pack and the case from the cable tester after loosening the four screws in the two feet at the rear of the cable tester. Remove the two Al shields to expose the internal circuitry. Inside the cable tester, solder wires to the other side of the card edge connector corresponding to the wires that you have just soldered to the Output Module. Do this by removing the four mounting screws from the power supply board and moving the board out of the way so that you can get to the back side of the card edge connector. You may have to remove some of the wires plugged into the top of the power supply board in order to move it. Make sure you know how they go so they can be replaced later. Look below the power supply board and note the positions of the wires plugged into the bottom of the board. These sometimes come loose when the board is moved and you should know how they are connected so that you can check the connections when putting the board back in place. A strategically placed small screwdriver may serve to wedge the board out of the way while you are soldering. Strip and tin about 1/4 inch of 22 gauge solid wire, 40 cm long. Put a hook in the tinned end and use this to hook the lug on the backside of the card edge connector corresponding to tab A3. Pull the lug slightly upward to separate it from its neighbors and wrap the wire around some convenient part of the cable tester to keep tension on the wire (or have someone hold it for you). Using a small soldering iron, solder the wire to the lug. Repeat for the lug corresponding to tab A5. Replace the power supply circuit board making sure all connections are good. Route the long wires through the cable tester to the bottom side next to the toggle switch.

Remove the toggle switch from the face of the cable tester by unscrewing the rubber boot from the front side. The switch is sealed in place with silicone sealant and may be troublesome to remove. Do not remove any of the wires. Refer to Fig. 8-9 showing the backside of the switch. Note the two cross bars soldered between lugs on the back of the switch. The drawing shows these and you should be able to find lugs 1 and 3 as numbered in the drawing. Solder one of your wires (from tabs A3 and A5 of the card edge connector) to lug 1 and the other to lug 3 of the toggle switch. The polarity doesn't matter since this is a simple shorting circuit. Replace the switch, using a dab of silicone sealant (RTV) to re-seal it.

8.1.4 Testing

Test the circuit before connecting power. Plug the X-Y Output Module into the cable tester. Check resistance across the lugs 1 and 3 of the toggle switch. This resistance should be quite high (MΩ) indicating an open circuit. Check resistance between each lug and the cable tester chassis. Again the resistance should be quite high indicating an open circuit. Check resistance between the "battery" lug on the power supply board and the chassis. This resistance should be very high indicating an open circuit. Replace the chassis in the cable tester case and plug in a charged battery pack. Do not use AC power, the battery pack has a fuse on it that will protect the cable tester. Turn on the cable tester and check to see if there is a line on the screen. Push the toggle switch to see if the line turns into a slowly moving dot that crosses the screen from left to right.

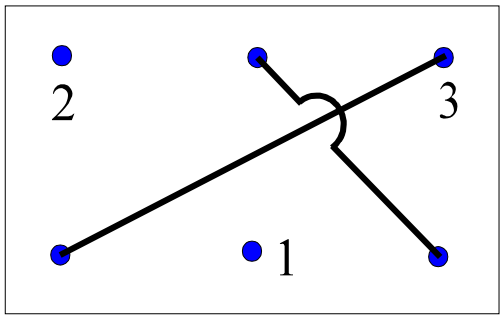

Fig. 8-9. Schematic of back side of toggle switch.

Connect the cable between the parallel port (or serial port if using the DATAQ DI-130) of the computer and the DIN connector on the X-Y Output Module. Run TACQ.EXE under DOS (not a DOS window under Windows 3.X or 9X, not even full screen) and press S to enter Software Setup. Press T to choose a TDR instrument and then A to enter the Advanced menu. Choose the "Computer Boards CI08 A/D card" by pressing the Enter key when that choice is displayed. A series of setting options will be displayed. At this time you may choose the defaults by pressing the Enter key. Also in Software Setup, configure the parallel port to use pin 5 to toggle the cable tester. Return to the main menu of TACQ and you will see an enhanced menu with an option to toggle waveform output from a Dynamax-modified 1502. Press T to toggle the cable tester. You should again see the slowly moving dot on the cable tester screen.

8.2 Digitizing the Waveform

The Y-axis output of the X-Y Output Module may be digitized in any number of ways to produce a computer readable data file representing the waveform. The TACQ program is written to use two models of analog to digital (A/D) conversion hardware, the Measurement Computing (Middleboro, MA, formerly ComputerBoards) model CI08 series or more recent versions of Measurement Computing A/D cards that are software equivalent, and the DATAQ Instruments, Inc. model DI-130 or equivalent more recent versions. The CI08 gives better timing between data points and is recommended. It also may be used to measure temperatures using thermocouples. Note that in TDR soil water content measurement, we convert the travel time of the step pulse to water content. The travel time is determined from the waveform; and, thus the waveform should accurately represent the distance (equivalent to time) between data points.

8.2.1 Using the Measurement Computing CI08 A/D Card

Installation of the CI08 is well-described by its manufacturer. Once installed in the computer, the Y-axis output and ground of the Output Module may be connected to the analog input of the

CIO8. Twisted pair wiring is suggested. Banana plugs may be used to plug directly into the Output Module. Run TACQ and press S to enter Software Setup. Then press T to choose a TDR instrument, followed by pressing A to enter the Advanced menu. Press the up and down cursor keys to see the options. Choose the "Computer Boards CI08 A/D card" by pressing the Enter key when that choice is displayed. A series of setting options will be displayed. Pay particular attention to the base address of the CI08 (see manufacturer's documentation). The default settings are for a CI08 used in conjunction with a Measurement Computing model MUX-32 multiplexer board. If you are not using the multiplexer you may need to change some of the settings. Note that the Measurement Computing parallel port A/D device and the National Instruments and Data Translation A/D devices are not supported in the current version of TACQ.

Connect a TDR probe to the cable tester and use the distance knob to display the probe wave form on the screen. Press "B" at the main menu of TACQ to acquire the wave form and check the acquired wave form against that shown on the cable tester screen.

Measurement Computing can be reached at www.computerboards.com or

Measurement Computing
(Formerly, ComputerBoards, Inc.)
16 Commerce Blvd.
Middleboro, MA 02346
USA

Tel: 508-946-5100
FAX: 508-946-9500

8.2.2 Using the DATAQ Instruments Serial Data Acquisition Module

8.2.2.1 Parts List

Tektronix model 1502 TDR cable tester.

X-Y Output Module for the cable tester.

DATAQ Instruments, Inc. model DI-130 serial data acquisition module. 150 Springside Drive, Suite B220, Akron, Ohio 44333-2473, Tel:800-553-9006, FAX:216-666-5434.

Switchcraft DIN straight cord plug type 05CL5M with 30° locking ring, 5 pins at 180°. Bought from Allied Electronics, Inc., Tel:800-433-5003, part no. 932-0154.

Switchcraft DIN receptacle type 57HA5F, for locking ring plug, 5 contacts at 180°. Bought from Allied, part no. 932-0185. See page 308 in Allied catalog no. 956.

One meter of four conductor stranded, 22 or 24 gage, tinned copper, shielded cable.

One 9 pin D-shell socket for connection to serial port of computer.

One 9 pin D-shell plug for connection to the DI-130.

One plastic hood for 9 pin D-shell socket.

22 or 24 gage solid, insulated wire.

Three screws for mounting DI-130 in X-Y output module, 4-40 or 6-32 by 3/8" flat head with nuts.

Two 4-40 by ½ inch screws for mounting relay circuit board to bottom of X-Y output module, and four to six 6-32 nuts for spacers between the circuit boards.

Parts for relay circuit board for toggling output. See section 8.1.1.

8.2.2.2 Assembly with DATAQ Hardware

The cable between the computer and DIN plug is constructed as describe above. The DIN plug is wired and mounted in the X-Y module of the Tektronix 1502 as described in section 8.3. The RTS wire is connected to the relay circuit board (Fig. 8-8) as described in section 8.1.3. The 20-cm wire connected to RXD on the DIN plug (if wired per section 8.1.3) should now be connected to pin 2 of the 9-pin D-shell plug. Note that this 9-pin plug will be on the inside of the X-Y Output Module so that it can be plugged into the DI-130. The 20-cm wire connected to DTR on the DIN plug should now be connected to pin 4 of the 9-pin plug. A separate wire should be connected between the grounding lug on the bottom side of the circuit board of the X-Y Output Module and pin 5 of the 9-pin plug. The wire connected to the grounding lug on the X-Y Output Module is thus also connected to the GND pin on the DIN plug (see section 8.1.3). Pin 1 of the 9-pin plug should be connected to power that you will connect to tab A1 of the card edge connector of the X-Y Output Module. Instructions for wiring the card edge connector appear below.

The DI-130 is mounted in the top of the X-Y Output Module (Fig. 8-10). Its plastic case will just slip inside the aluminum side walls of the X-Y Output Module. Position the case inside the top of the Output Module, with the top of the plastic box just below the top of the aluminum sides of the Output Module, and clamp it to the Module with a small C-clamp. Drill holes through the aluminum and plastic case near the top, avoiding the components inside the case. It is easy to find a spot to drill three holes, two on one side and one on the other. This is enough for rigid mounting. Remove the DI-130 and clean any debris out of it. Counter sink the holes in the outside of the X-Y Output Module to recess the heads of the flat head screws.

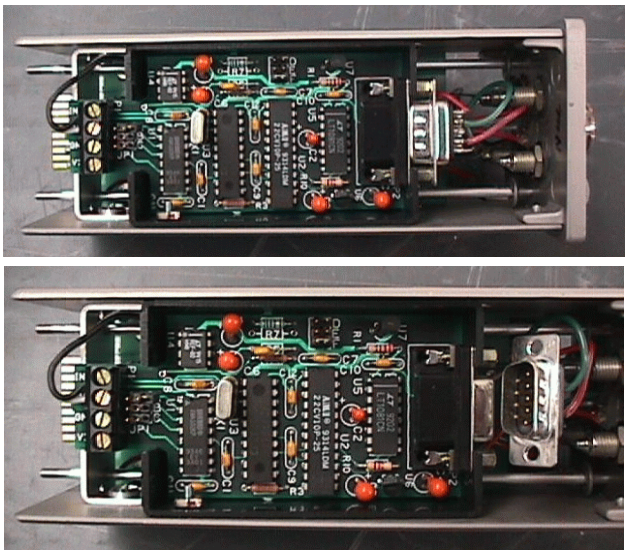

Fig. 8-10. The DI-130 A/D module installed in the X-Y Output Module. Top photograph is with the 9-pin D-shell plug connected to the DI-130. Bottom is with it unplugged.

Place the Output Module on the table with the face towards you and the card edge connector facing away from you. The card edge connector has 20 gold tabs. Numbering the top set of tabs A1 through A10 from left to right you will see that tabs number A8, A9 and A10 are connected to traces on the circuit board. Numbering the bottom set of tabs B1 through B10 from left to right you will see that tabs B1, B8, B9 and B10 are connected to traces on the bottom side of the circuit board. Drill a 1/16 inch hole through the circuit board about 1/16 inch behind and to one side of tab A1. Be careful to avoid the trace that is connected to tab B1 on the other side of the circuit board. A wire from tab A1 will carry battery power to the DI-130. Strip and bend a 20-cm length of 22 gauge wire so that it comes up through the hole and just touches the back side of the gold tab. Solder the wire in place (Fig. 8-6). Be careful not to put too much solder on the tab as this will interfere with the tab seating fully with the card edge connector socket inside the cable tester. Solder the wire that was connected to tab A1 to pin 1 of the 9-pin plug that will connect to the DI-130. This will supply unregulated 12 VDC battery power to the DI-130, which has its own 5 VDC regulator. Strip and tin two 20-cm lengths of wire and solder one to the wire connected to the X-Y Output Module circuit board at the pad labeled Y (this is the wire connected to the red Y output on the face of the Module). Solder the other wire to the wire connected to the pad labeled GND that is next to the pad labeled Y. This is the analog ground. Do not solder this to any other ground nor to chassis ground.

Plug the 9 pin connector, previously wired to the DIN socket, into the DI-130. Place the DI-130 in the Output Module, carefully folding the wires underneath it, and bolt it into place with the flat head machine screws. Connect the wire from the Y output ground to the minus input of the DI-130 (labeled IN -). Connect the wire from the Y output (pad labeled Y on the Module circuit board) to the plus input of the DI-130 (labeled IN +). This is a differential input. Test the modified X-Y Output Module as follows. Check resistance between the plus input and chassis ground and between the minus input and chassis ground. These should indicate open circuits. There should also be open circuits between all of the other connections that you made and chassis ground except for the GND connection on the relay circuit board and the GND connection on the 9 pin plug that is plugged into the DI-130.

Before proceding, ensure that the cable tester is not connected to AC power (not plugged in), and remove the battery pack if present. Remove the case as described in section 8.1.3. Inside the cable tester, solder a 15-cm wire to the other side of the card edge connector corresponding to the wire that you have just soldered to tab A1 of the Output Module. Do this by removing the four mounting screws from the power supply board and moving the board out of the way so that you can get to the back side of the card edge connector. You may have to remove some of the wires plugged into the top of the power supply board in order to move it. Make sure you know how they go so they can be replaced later. Look below the power supply board and note the positions of the wires plugged into the bottom of the board. These sometimes come loose when the board is moved and you should know how they are connected so that you can check the connections when putting the board back in place. A strategically placed small screwdriver may serve to wedge the board out of the way while you are soldering. Strip and tin about 1/4 inch of 22 gauge solid wire, 15 cm long. Put a hook in the tinned end and use this to hook the lug on the backside of the card edge connector corresponding to tab A1. Pull the lug slightly upward to separate it from its neighbors and wrap the wire around some convenient part of the cable tester to keep tension on the wire (or have someone hold it for you). Using a small soldering iron, solder the wire to the lug. Replace the power supply circuit board making sure all connections are good. Now solder the other end of the 15-cm wire to the “battery” connection on the power supply board. This is a source of unregulated 12 VDC power.

Connections for the relay circuit board should have already been made inside the cable tester per section 8.1.3.

8.2.2.3 Testing

Test the circuit before connecting power. Plug the X-Y Output Module into the cable tester. Check resistance across the lugs 1 and 3 of the toggle switch. This resistance should be quite high (MΩ) indicating an open circuit. Check resistance between each lug and the cable tester chassis. Again the resistance should be quite high indicating an open circuit. Check resistance between the "battery" lug on the power supply board and the chassis. This resistance should be very high indicating an open circuit. Replace the chassis in the cable tester case and plug in a charged battery pack. Do not use AC power, the battery pack has a fuse on it that will protect the cable tester. Turn on the cable tester and check to see if there is a line on the screen. Push the toggle switch to see if the line turns into a slowly moving dot that crosses the screen from left to right. Connect the cable between the serial port of the computer and the DIN connector on the X-Y Output Module and use the TACQ.EXE program to toggle the cable tester. You should again see the slowly moving dot on the cable tester screen. Connect a TDR probe to the cable tester and use the distance knob to display the probe wave form on the screen. Press "B" at the main menu of TACQ to acquire the wave form and check the acquired wave form against that shown on the cable tester screen.