Pico MiniCT Board Build Simple-Circuit 2024

This is a replacement circuit for the N7VK Mini Curve Tracer. It utilizes the Raspberry Pi Pico 2 processor instead of the 80C51. Since the Pico has a USB interface, a serial to USB converter chip is not needed. The Pico 2 has no DACs and an external 12-bit SPI DAC was added for channel 0. DAC channel 1 is implemented using PWM and a low pass filter. Since this channel is used for base voltage and current stepping, a fast response is not required.

The original NKA DC to DC converters may no longer be available. A similar SIP part MEA type was substituted. As long as the pin form factor and 5V to ±9VDC output is present. About any 1W converter can work.

The resistors have been updated from the original circuit to accommodate the 3.3V reference levels. Expect about ±14.2V max from the collector output source and the same ±10V from the base source.

This is not a beginners build as there are two CNC milled single sided boards and multiple cable that need to be built. It is critical to use 1% metal film resistors in the analog circuits. In particular, the four 10K resistors and the four 49.9K (51K and 47K can work) resistors should be selected from a larger group of resistors and matched. They are used in differential circuits that require matching for common mode performance. Spots for trim resistors have been added to the analog board.

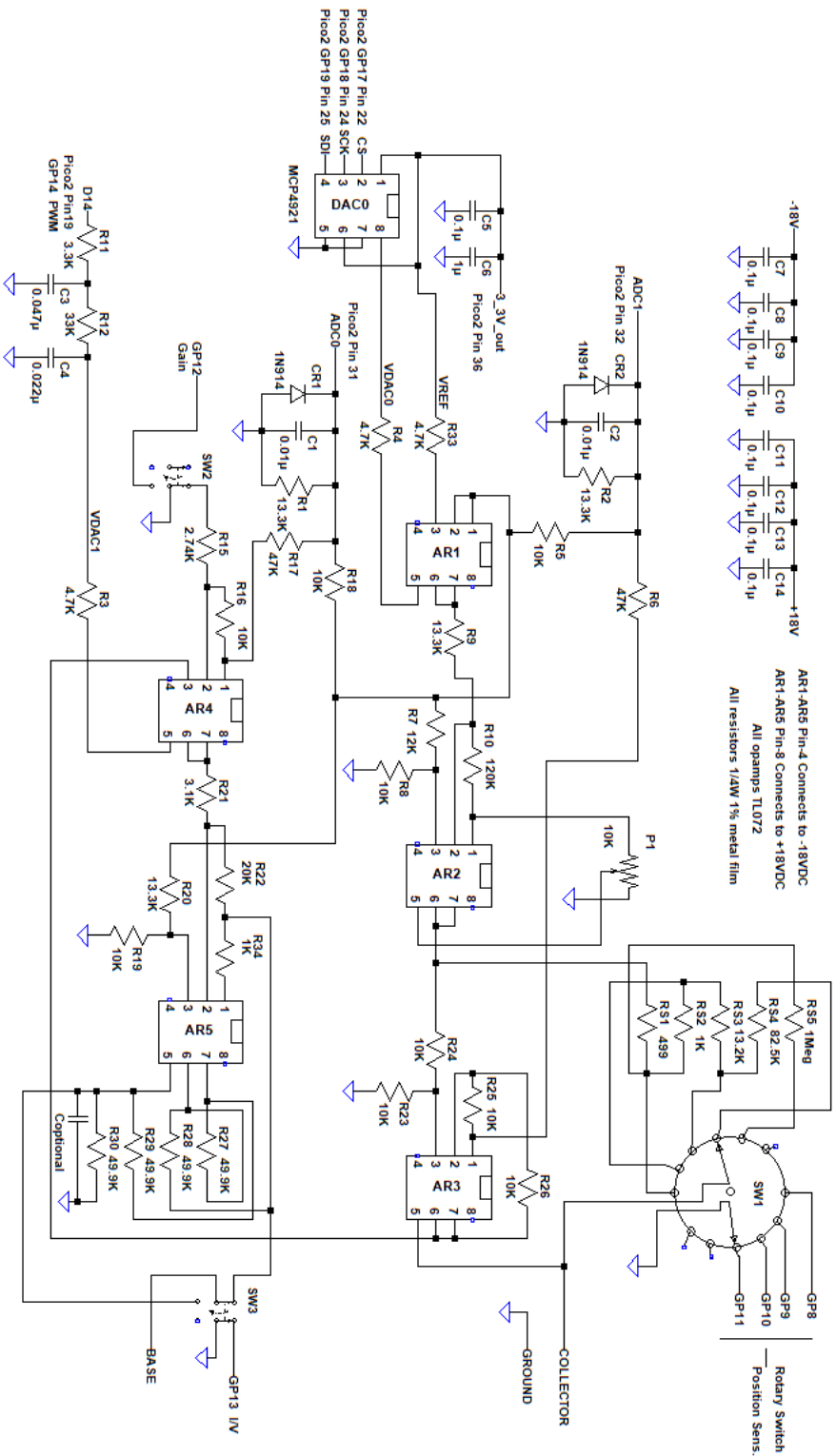
Use the following CNC files to mill the boards. The boards are single sided copper clad 70x100mm 2mm thick paper phenolic. The traces were milled with a 0.2mm tapered bit and the holes drilled with an 0.8mm bit. Mounting holes were enlarged to fil using a hand drilled 0.125” bit.

profile_ct_digital.gcode
drill_ct_digital.gcode
profile_ct_analog.gcode
drill_ct_analog.gcode

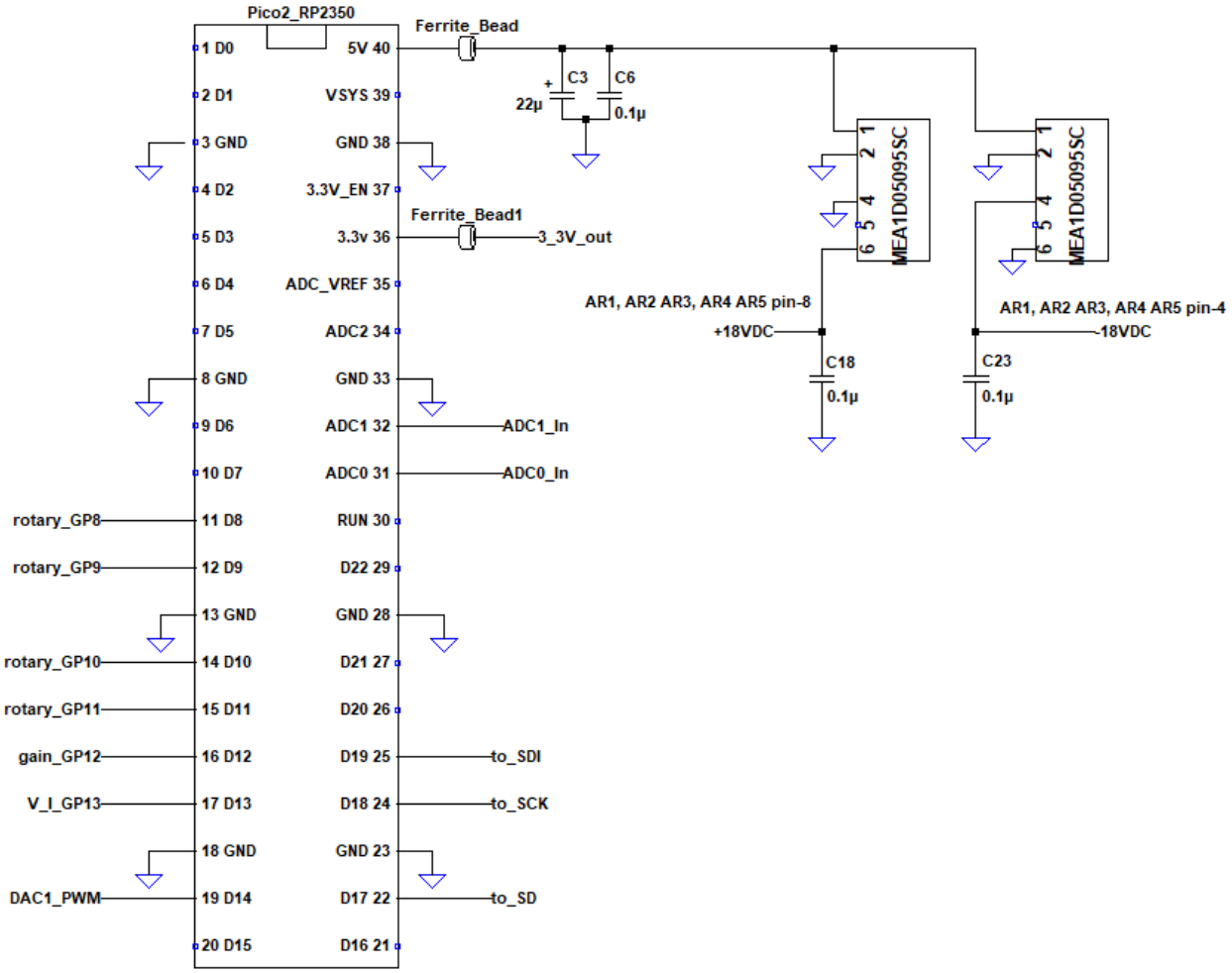
The application software is written using the Lazarus Free Pascal IDE. Compiled executables are provided for the PC, Raspberry Pi 32-bit and 64-bit operating systems. Source code for the application and for the Pico 2 is also provided. The compiled UF2 file for the Pico can be dropped into the Pico folder without using the Arduino IDE with Earle Philhower’s Arduino Pico.

Do not use a Pico model 1 for the project. Although it will function, the ADC is not up to the task.

When boards are completed, test for shorted traces. Shorts from copper burrs or solder bridges can damage components. The DC to DC converters will fail if the outputs are shorted. Also, the Pico inputs can be damaged if voltages other than 0 to 3.3V are applied to the I/O pins.



The schematic for the curve tracer analog chain. The DACs are on the digital board. Some supply capacitors are also on the digital board.



The schematic diagram for the digital section and dual supply of the curve tracer.

Parts List:

13	0.1uF ceramic capacitors
1	1.0uF ceramic capacitor
1	22uF electrolytic capacitor
5	TL072 8-pin DIP op amps
1	Pico 2 processor
1	MCP4921 DAC 8-pin DIP
2	Ferrite beads
2	1N914 diodes
3	0.022uF film capacitors
1	0.047 film capacitor
1	10K potentiometer
1	SPST toggle switch
1	DPST toggle switch
1	two gang 5 position rotary switch
2	Knobs
3	Banana Jacks
2	70mm x 100mm single sided boards
2	MEA1D0509SC 5V to +9V/-9V SIP DC to DC converters

~100 pin count 0.1” Male and Female Pins and Header strips

22 gauge stranded wire red and black

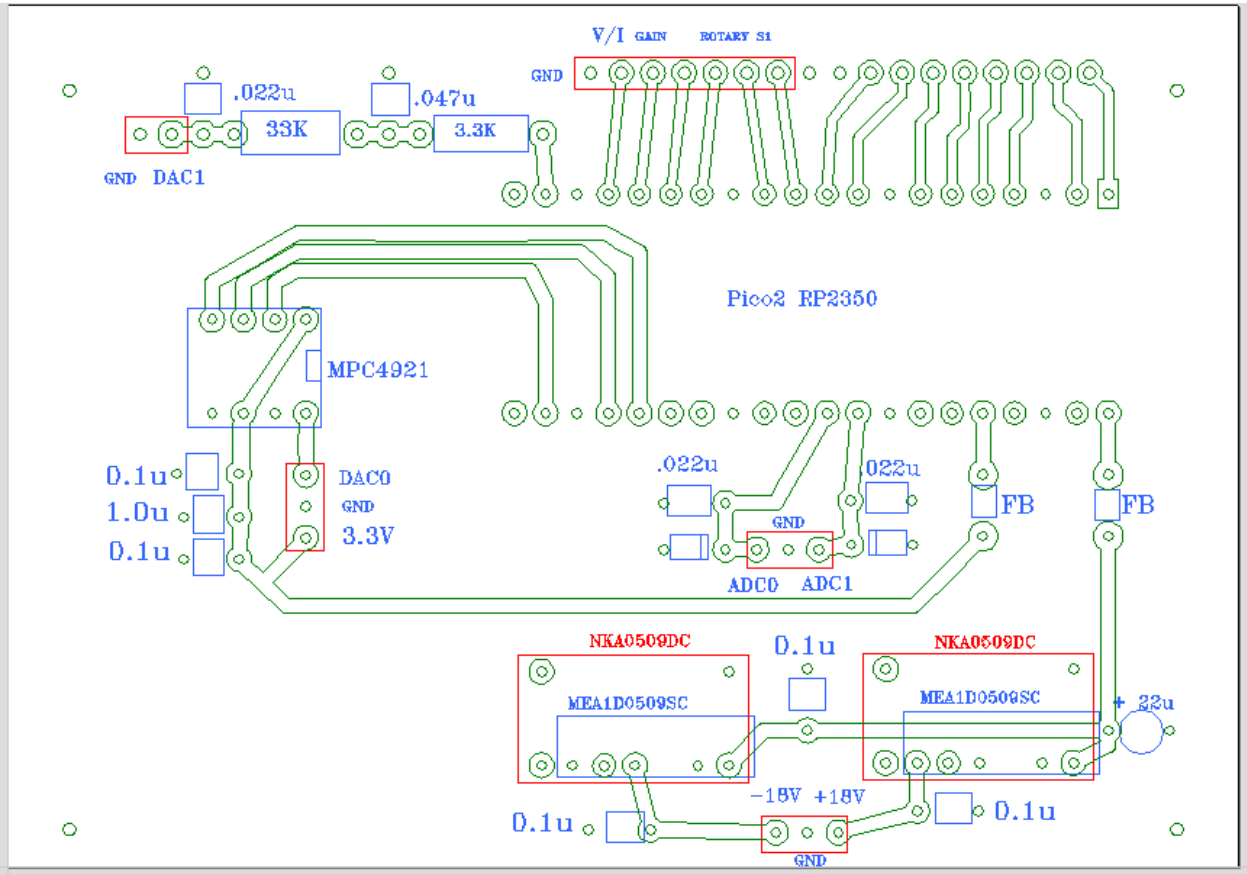
Carbon film resistors 1/4W 5%:

33K, 3.3K and misc. 1meg to 10meg selection for trimming

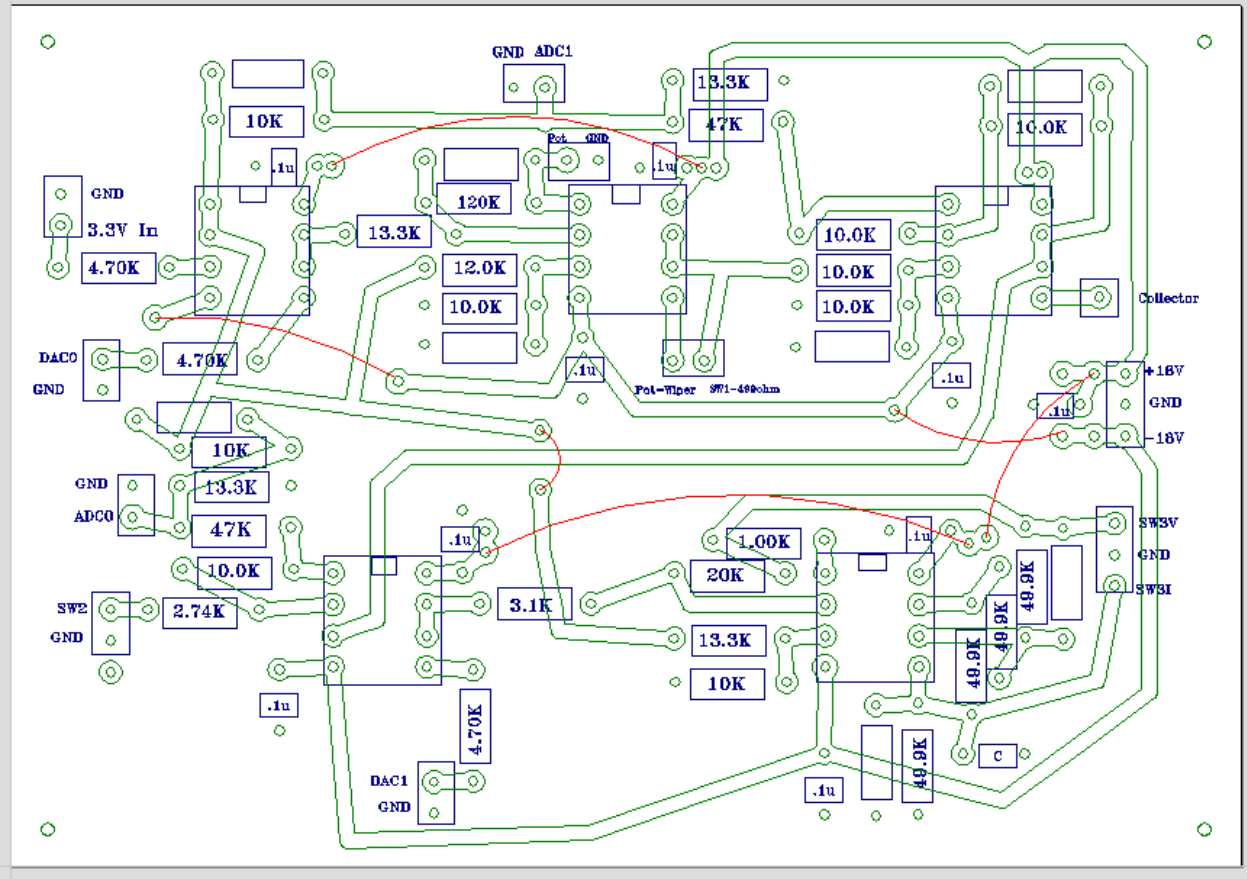
Metal film resistors 1/4W 1%:

3	4.7K
9	10K
4	49.9K
5	13.3K
2	47K
1	3.1K
1	2.74K
1	120K
1	12K
1	20K
2	1K
1	499 (use 1/2W)
1	82.5K
1	1meg

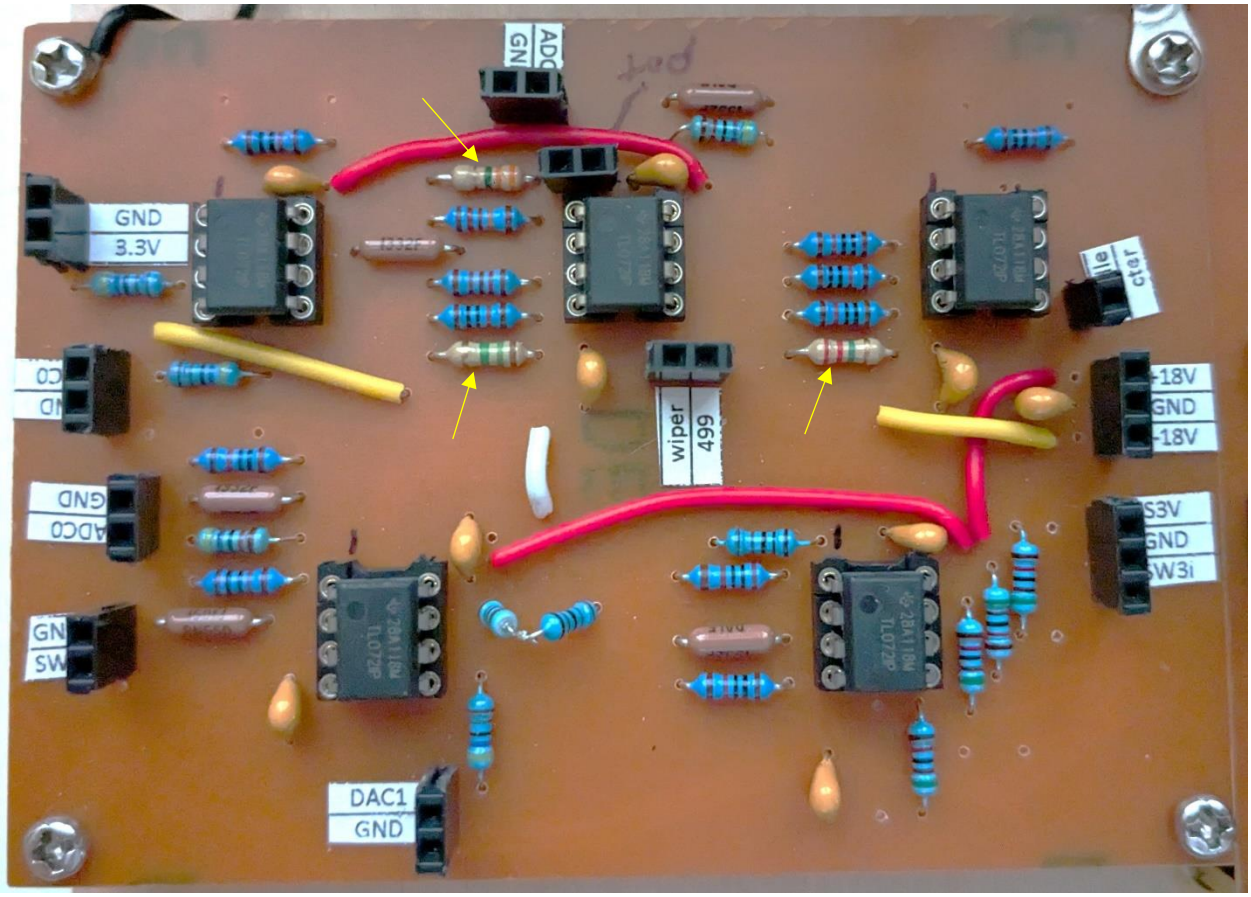
8	metal standoffs and screws
1	aluminum face plate, fit to size ~2.5” x 7” including ½” for right angle mount bend
1	1/2 “ wood base plate ~5” x 7”



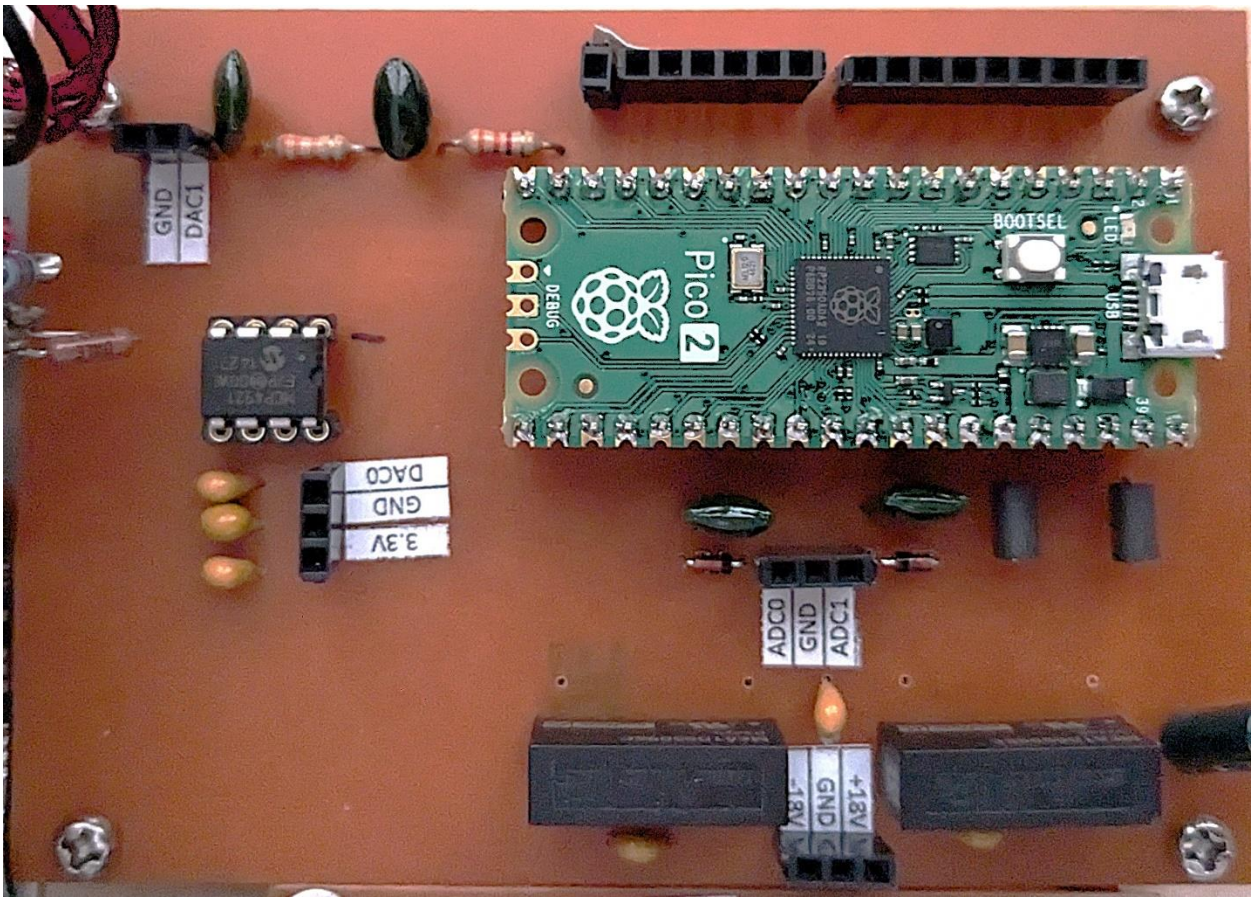
The parts layout for the digital board. The board can accommodate both SIP and DIP type DC to DC converters.



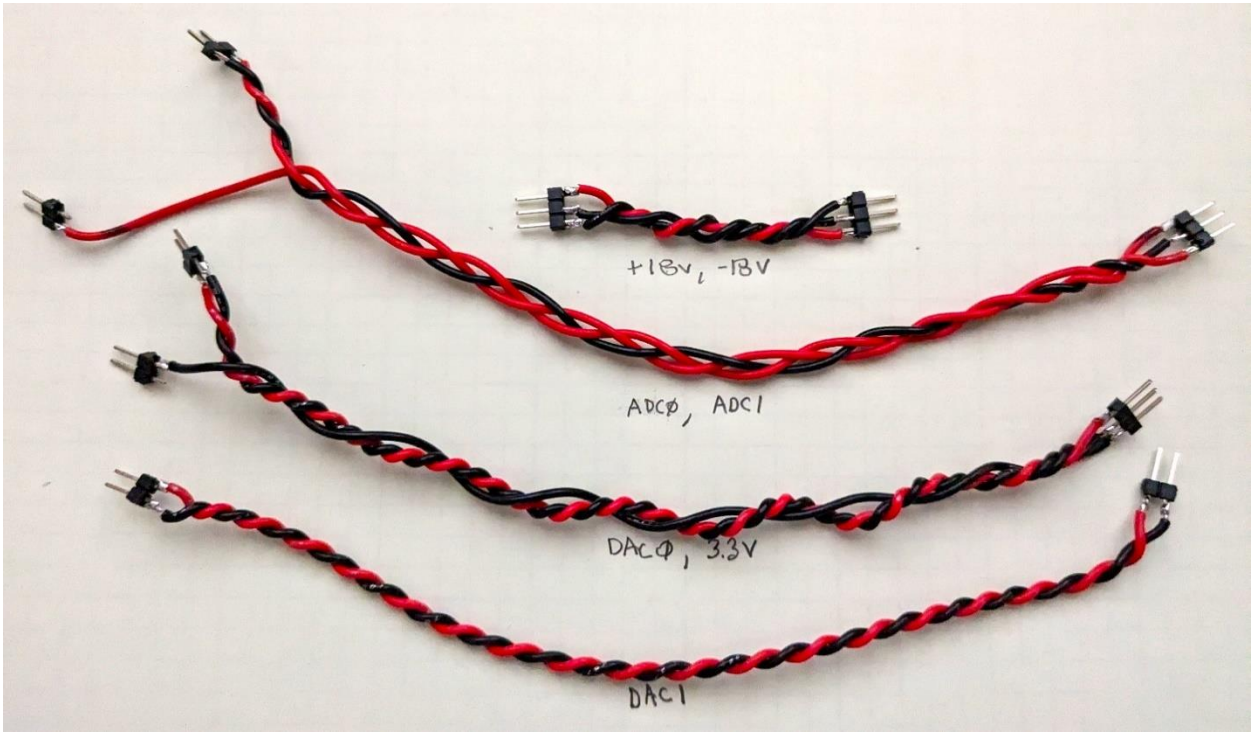
The parts layout for the analog board. There are six jumper wires required to connect 18V supply traces and one signal path.



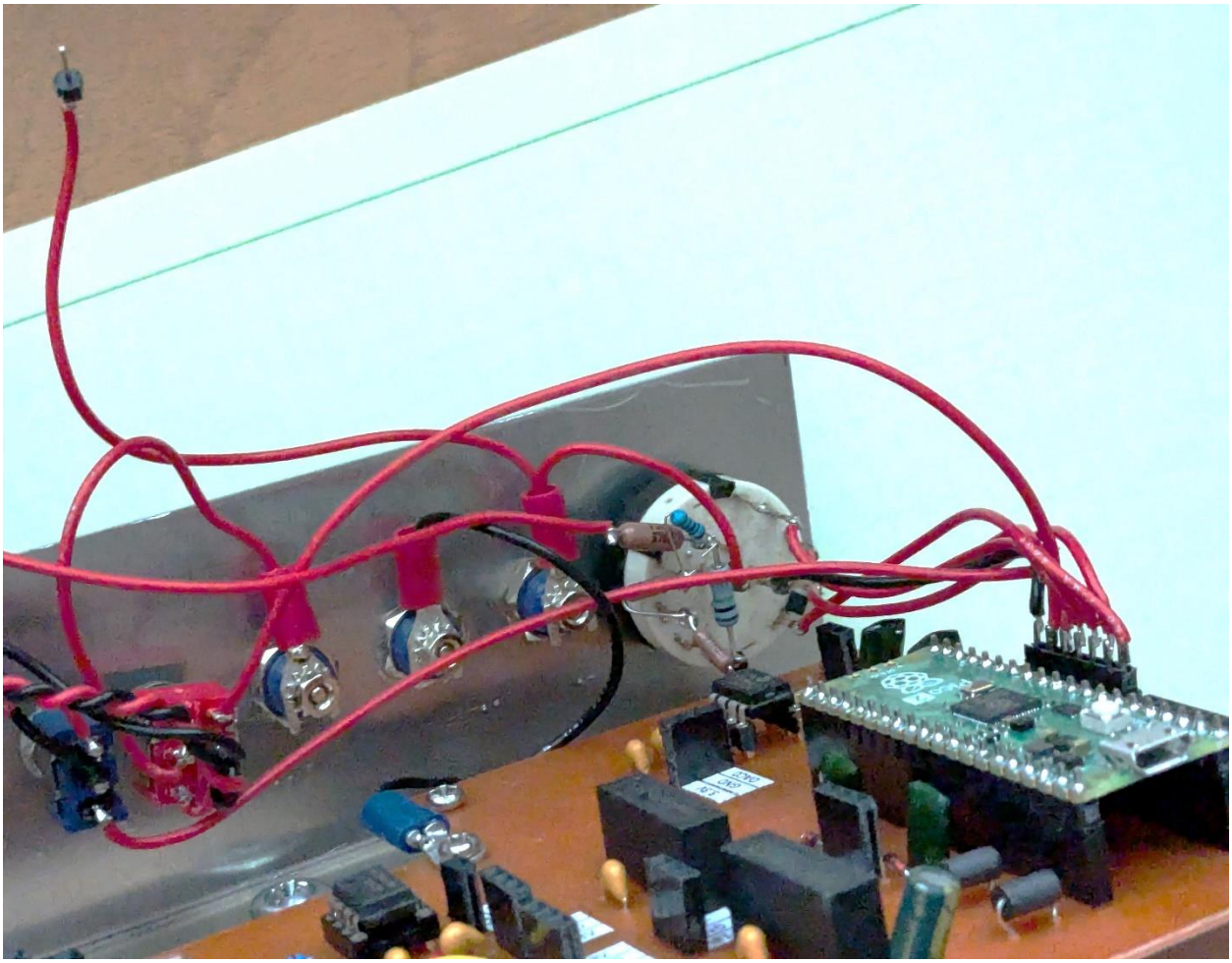
The analog board fully loaded with parts and jumper wires. Female 0.1” socket strips were cut to size and they are used for jump cable connections. The arrows point to trim resistors used to adjust the circuit. They will vary for your build but will be in the megohm range if required. It is a good idea to print some labels or write the connections on the board.



The digital board fully loaded.

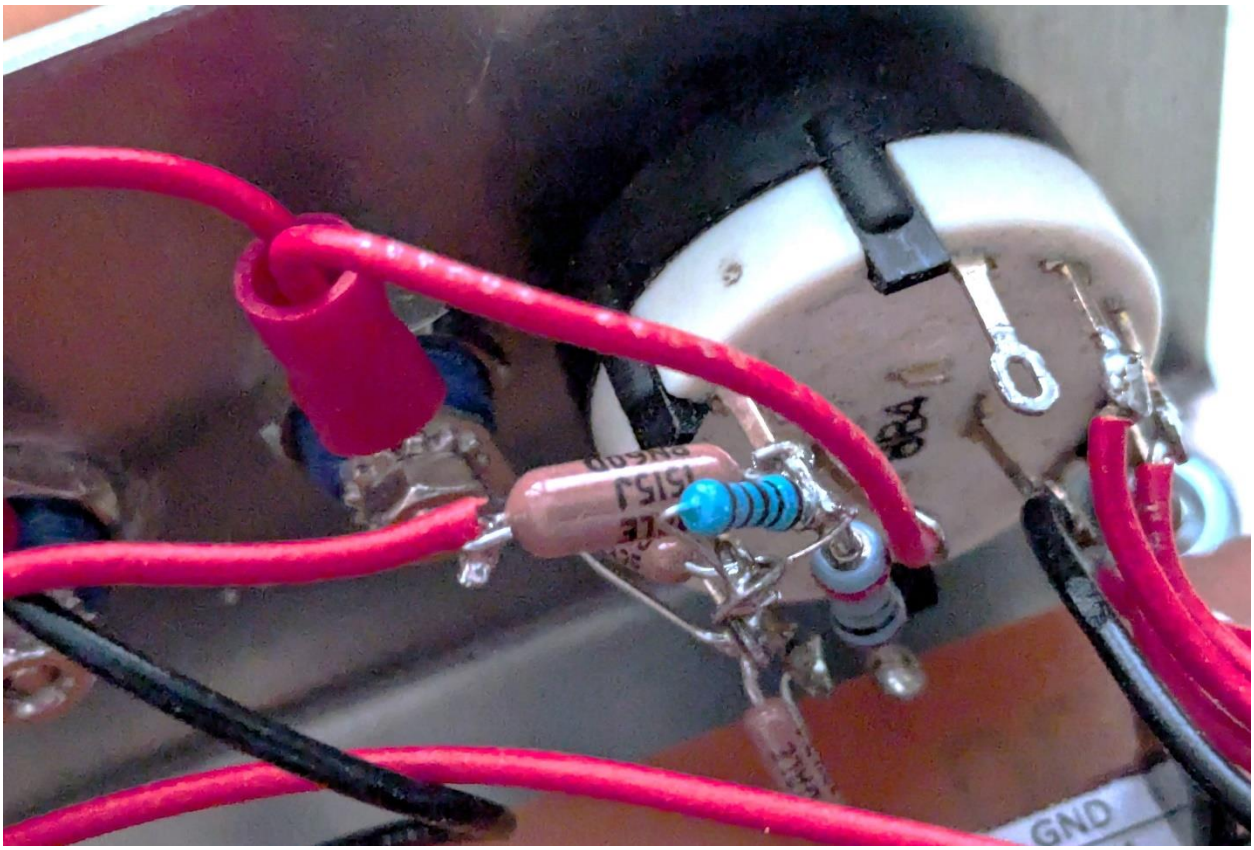


Interconnecting cables are made using stranded 22 gauge wire and 0.1” male header pins. The wires are twisted or woven to reduce noise.

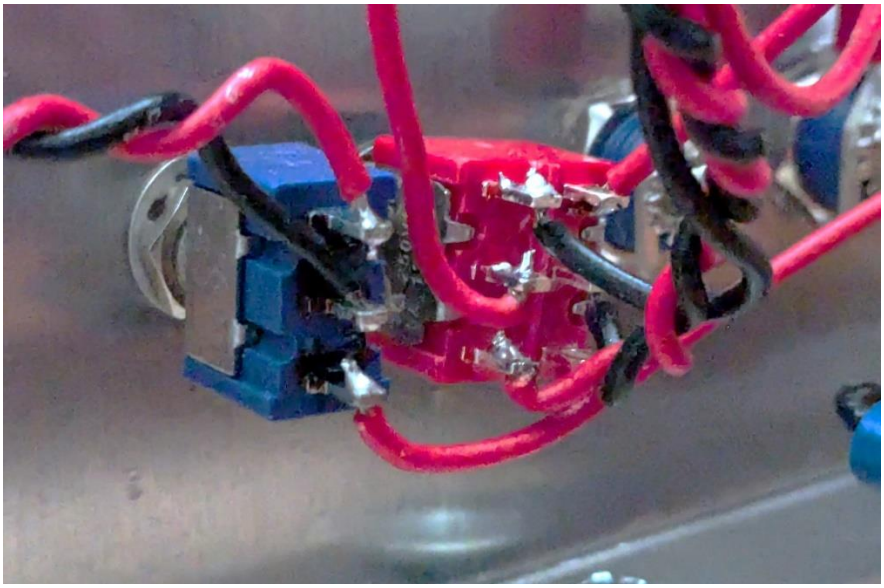


The rotary switch has two sections. One selects the collector series resistor. The other section shorts one of four digital inputs to ground acting as the switch position indicator. Two additional inputs connect to switches for the collector voltage gain (SW2) and the base voltage/current select (SW3). These inputs are shorted to ground for indication.

Caution should be made when connecting the digital input to SW3 which is a DPST switch. Miswiring could place a high voltage on the digital input and damage it. Check for ground to be present on the digital side.

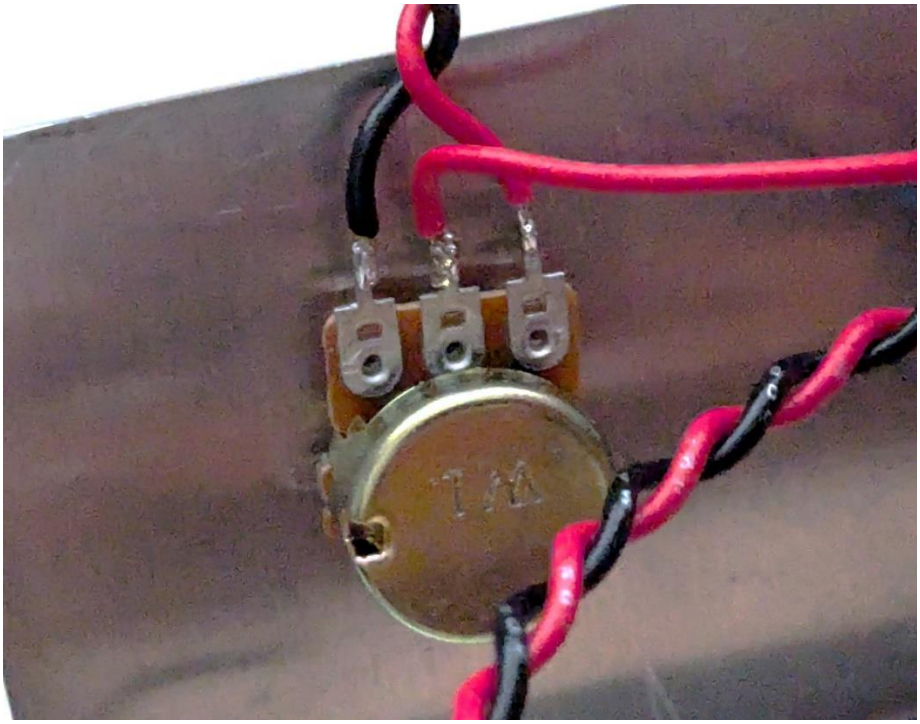


A close up of rotary SW1. The wiper tap connects to the collector banana terminal then to the analog board. The other wiper tap connects to ground. One end of the 499 ohm resistor connects to the switch and the other to a wire that connects to the analog board.

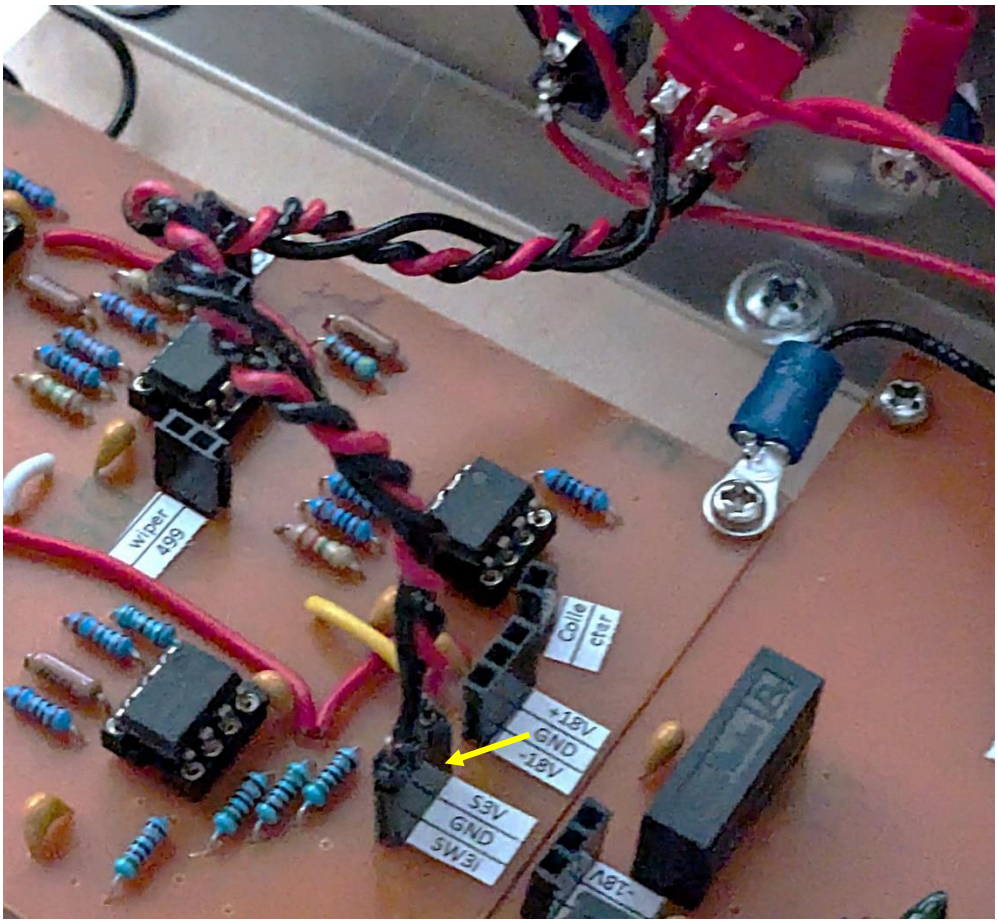


SW2 on the left is the gain switch. The center connection is ground. The bottom connects to the digital input and the top connects to the analog board.

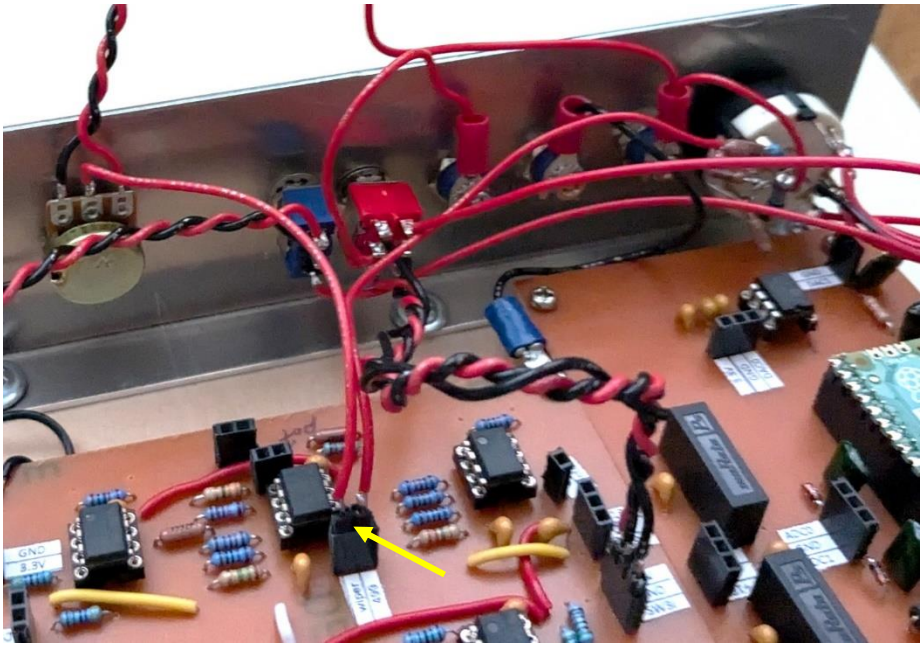
SW3 on the right is the base voltage/current select. The rightmost center connection is ground connecting to the analog board. The top right terminal connects to the digital input. The leftmost center pin connects to the base banana terminal. The bottom left terminal connect to the analog board current output and the top left terminal connects to the analog board voltage output.



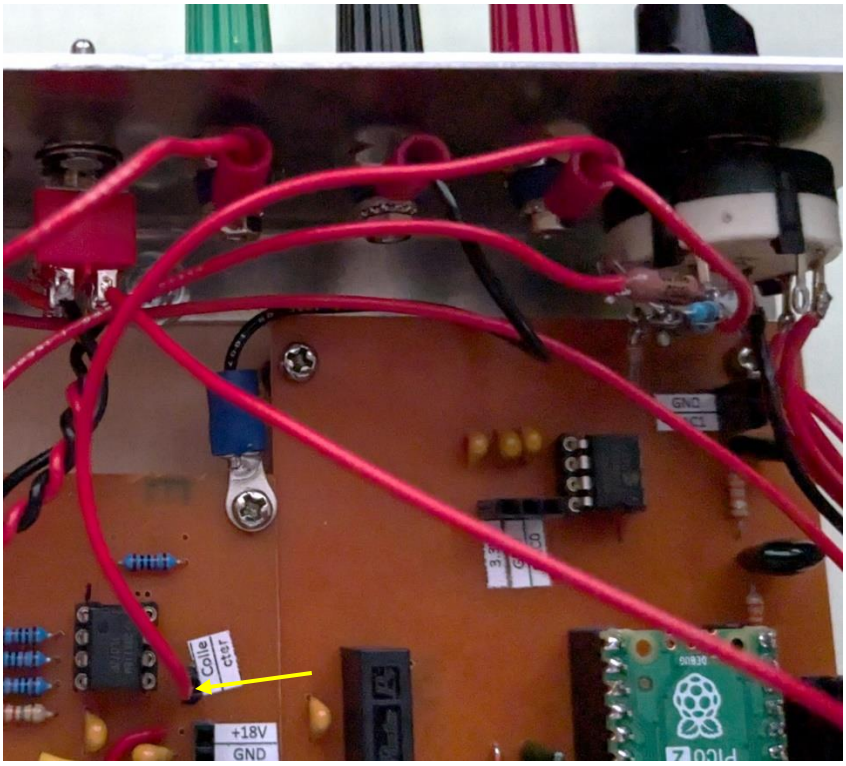
The potentiometer wiper connects to the analog board next to the 499 ohm resistor wire. The end terminations connect to the analog board with a ground feed, black wire, and signal generator feed red wire.



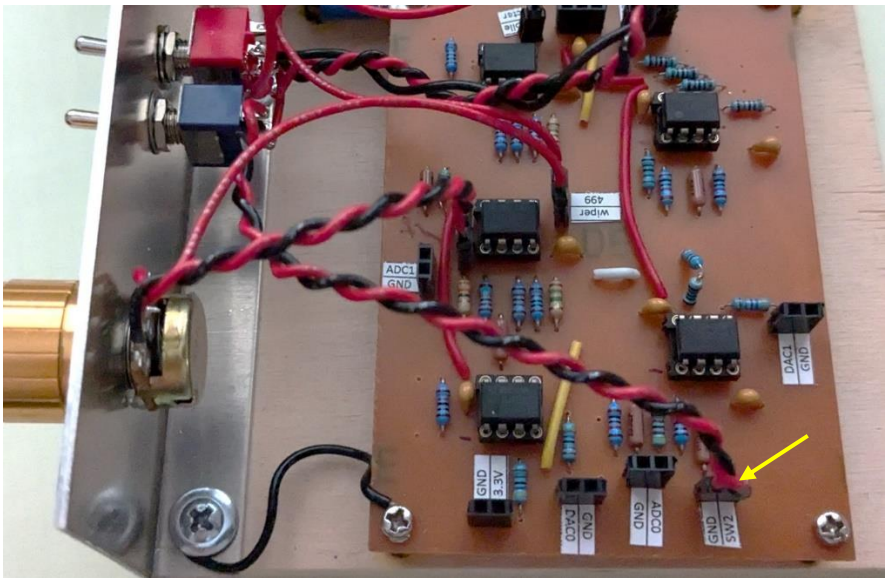
A three-wire cable connects SW3 to the board. Errata: The analog board has the cable inserted 180 degrees out. The red wire should be inserted into the SW3i pin.



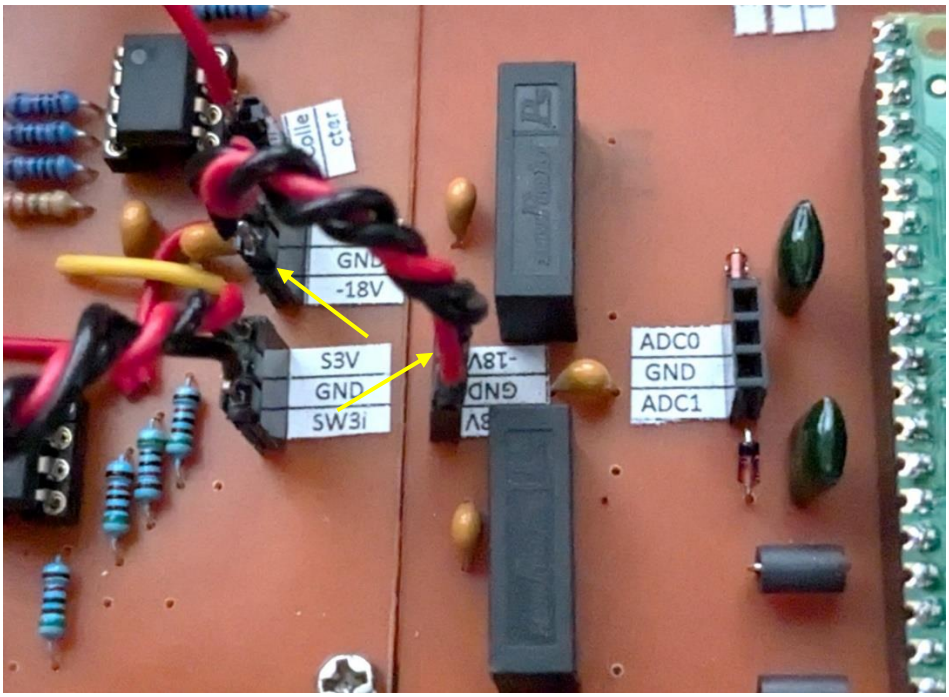
Two single wires, one from the pot wiper and the other from the 499 ohm resistor, use a single two pin connector.



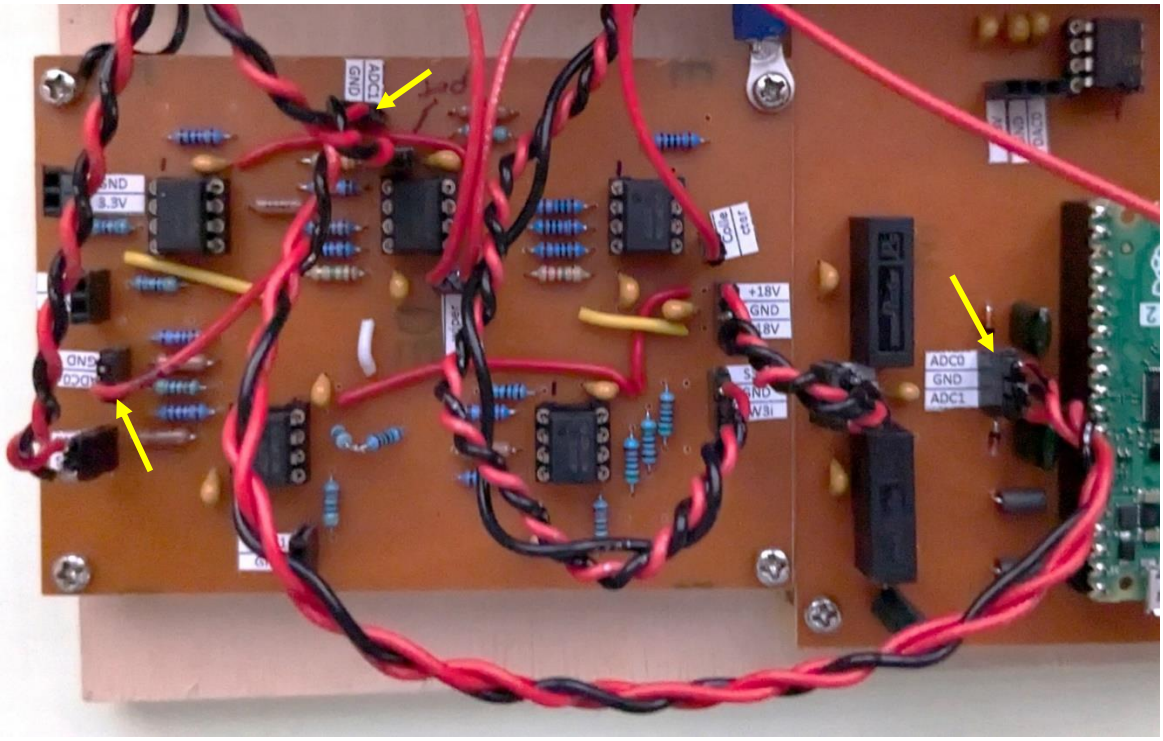
The collector wire connects to a single pin.



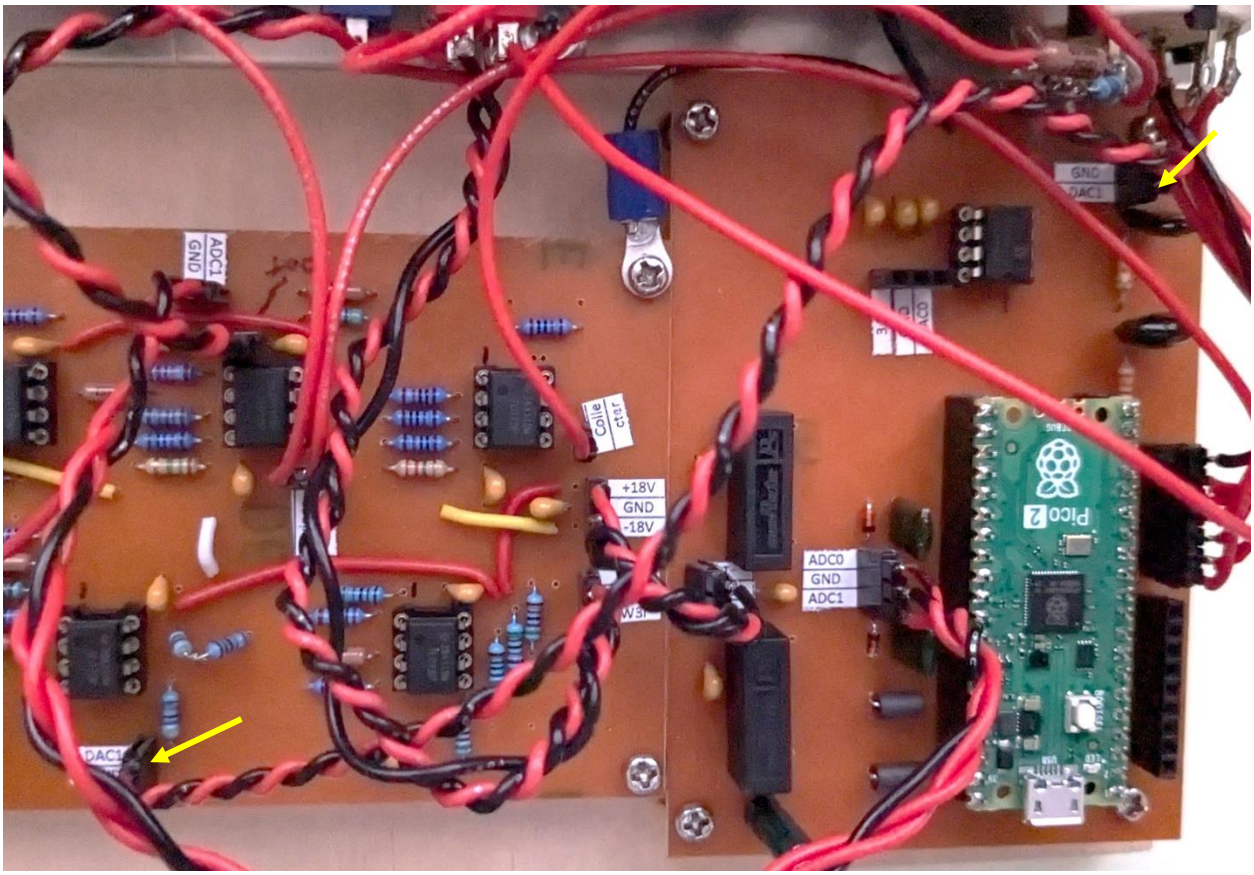
The SW2 twisted pair connects to the analog board near the right end.



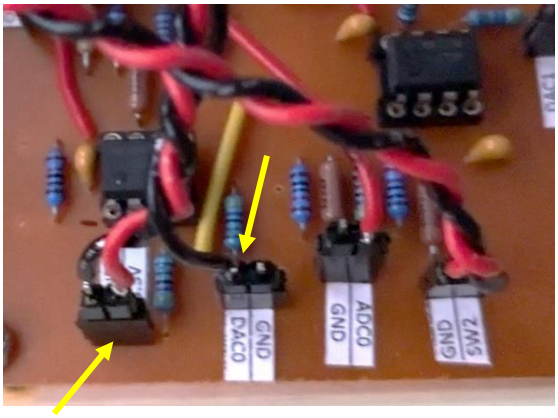
The three wire power jumper cable flips 180 degrees when connecting the analog and digital boards. Make sure to connect the correct pins. Shorting the DC to DC converters will cause them to fail.

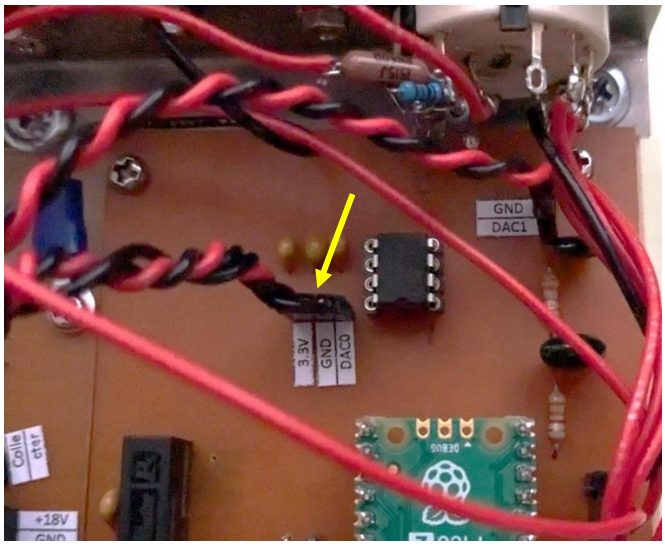


The ADC three wire cable splits into two connectors on the analog board.

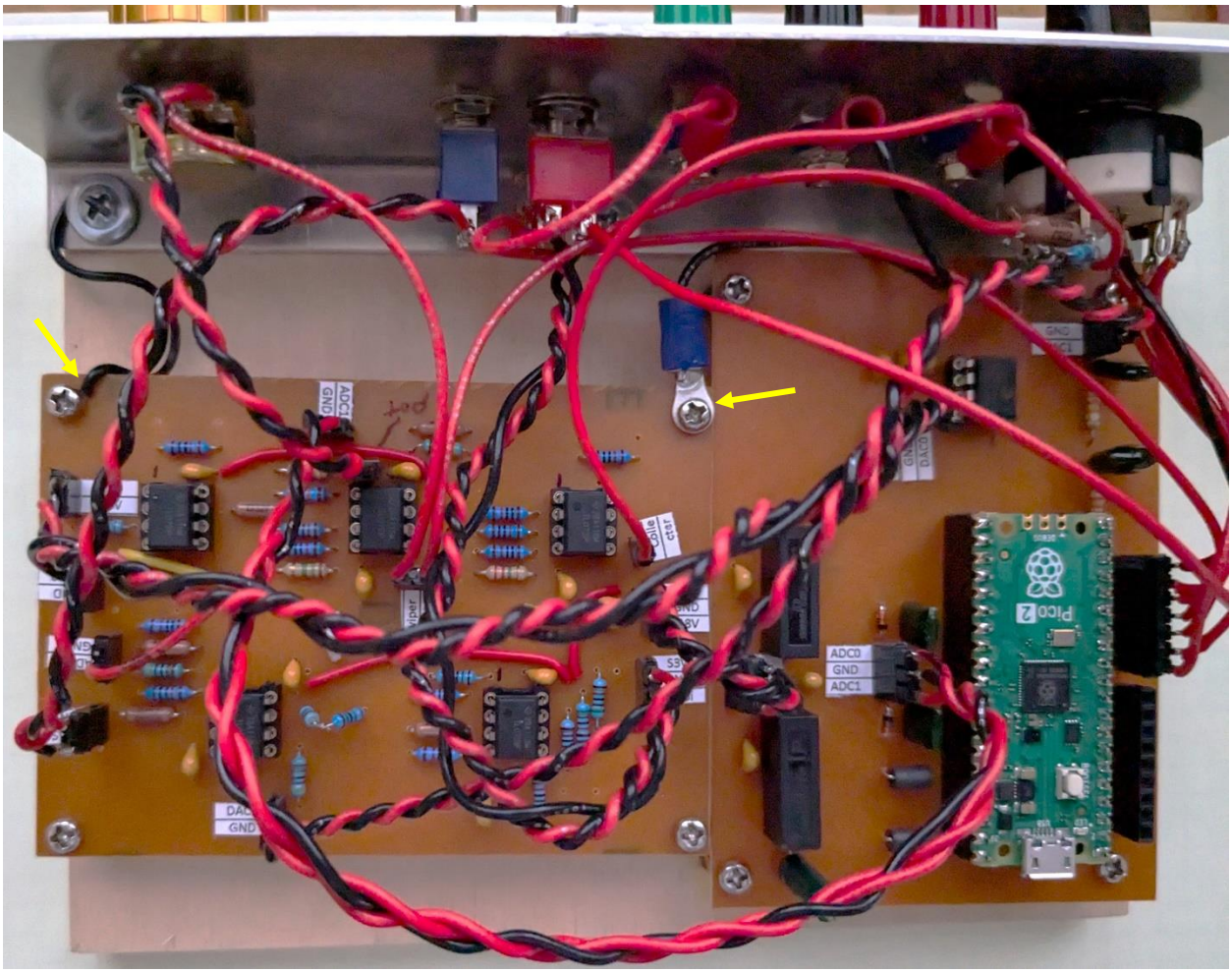


The DAC1 twisted pair cable is the longest run.

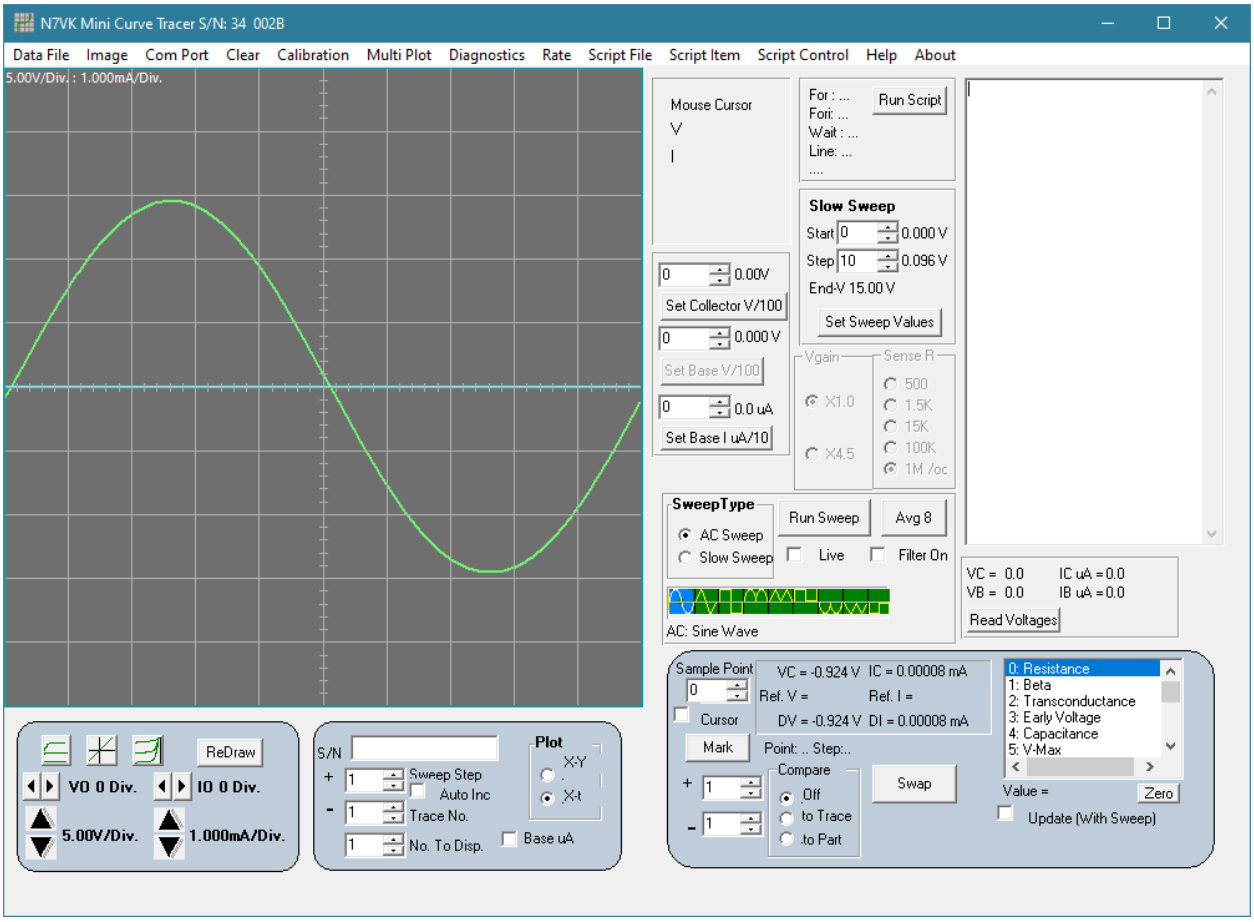


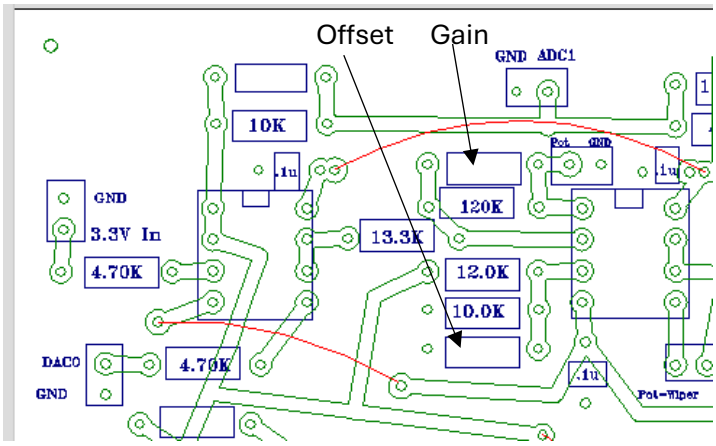


The DAC0/3.3V cable starts out as a three-pin connection on the digital board then spits into two connections on the analog board.

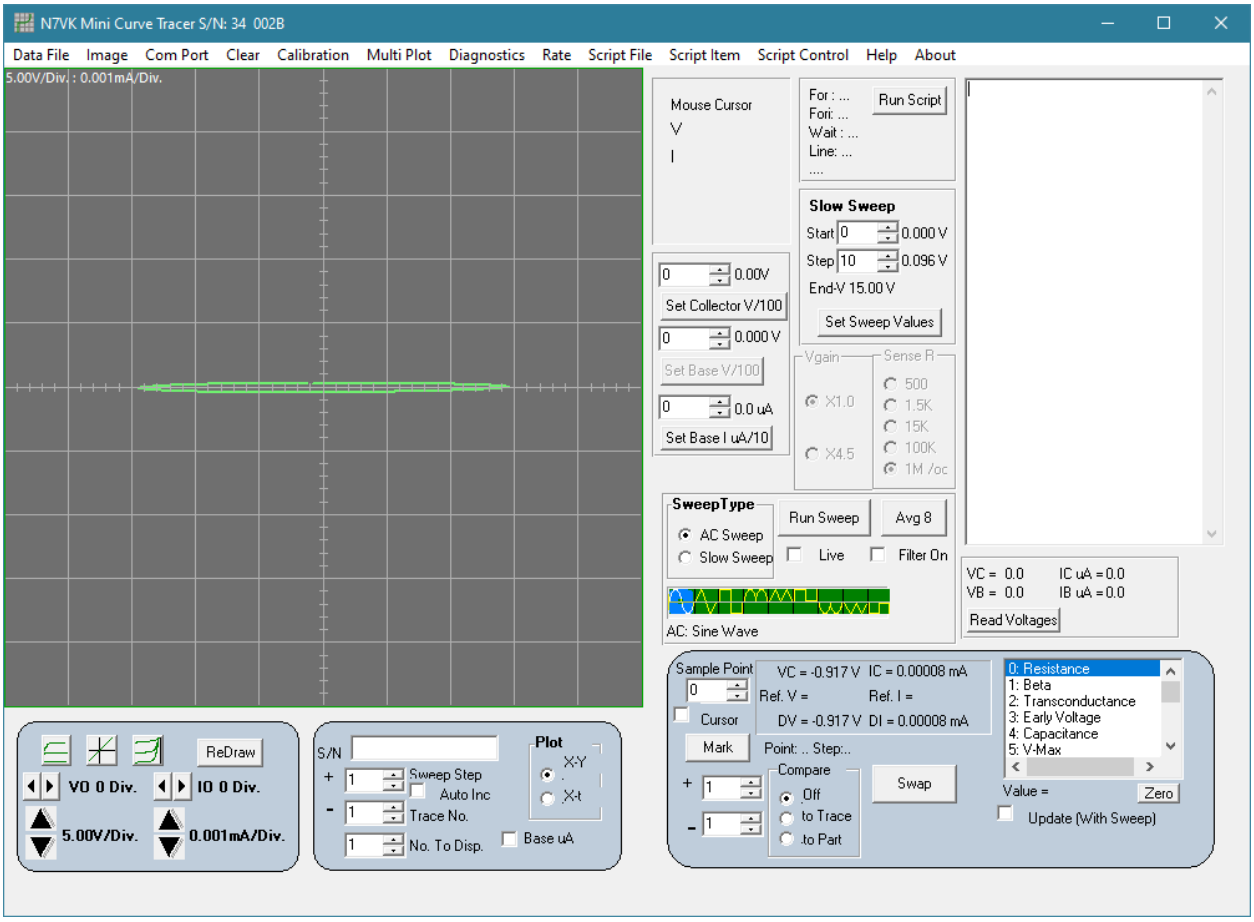


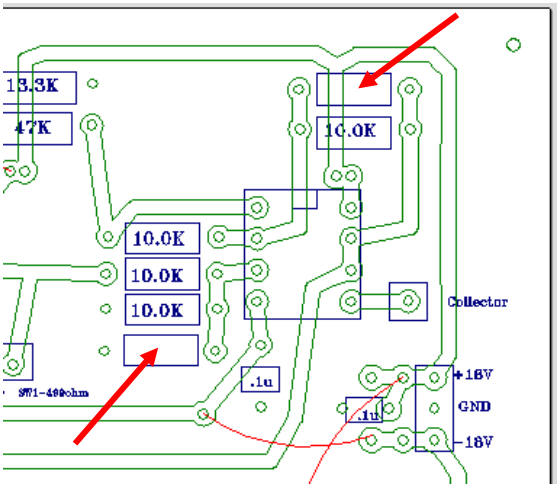
The completed curve tracer. Two ground connections are required. One connects the face plate and the other connects ground to the emitter/ground banana terminal. Metal standoffs are used and the connection is made through the mounting screws on the analog board. If you use nylon standoffs, you will need to solder the wires to the ground plane on the bottom of the board.



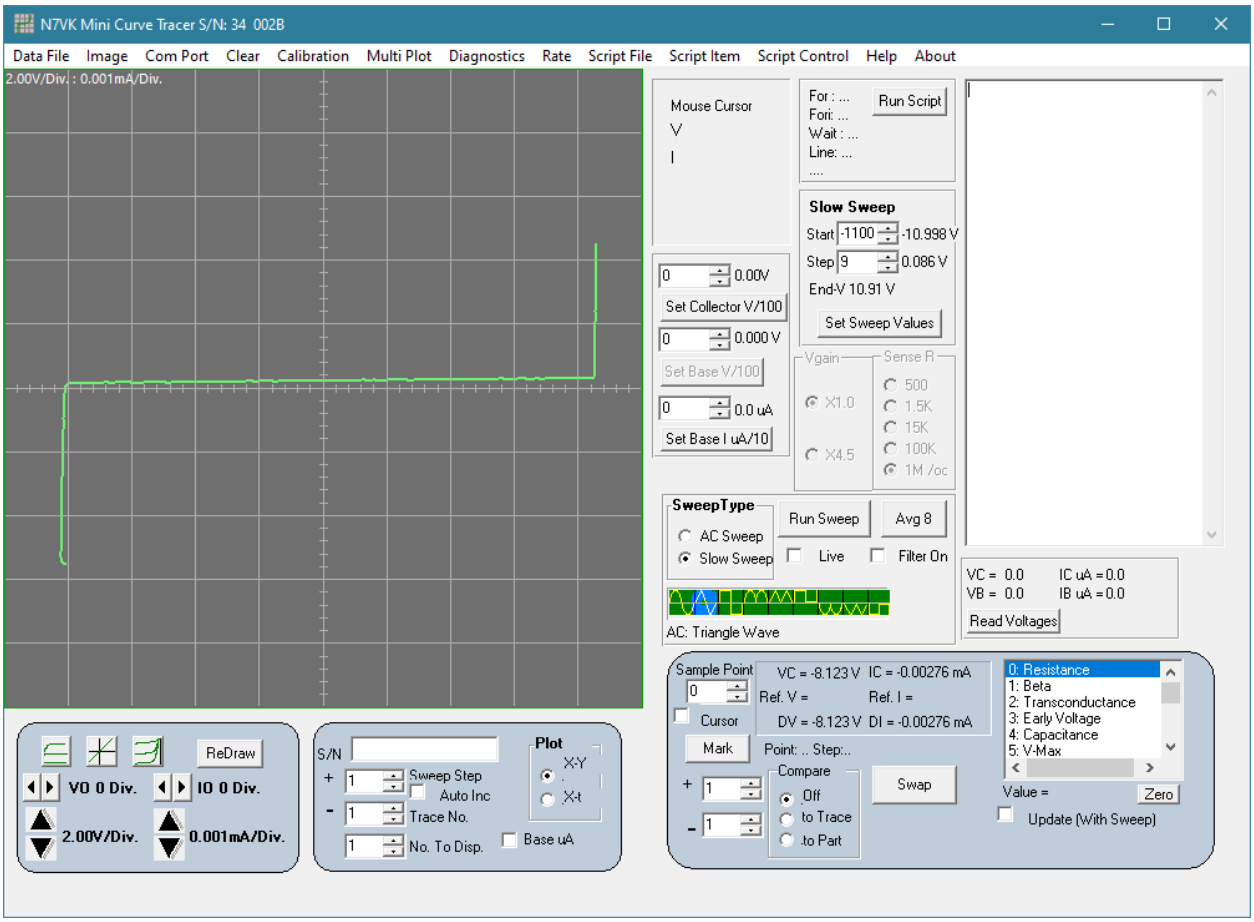


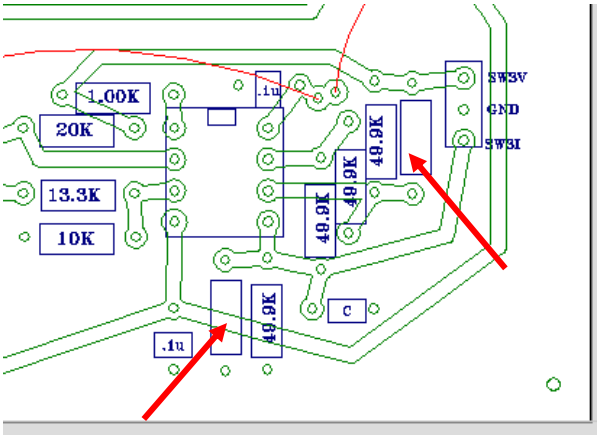
The collector output will need resistor trimming for magnitude and offset. If the voltage is too high, clipping will occur. Also, when the voltage exceeds the common mode voltage of the current sense differential amp, you will get errors in the current at the peak voltages. Around plus and minus 14V should work You may be able to get a slightly higher voltage.





Leave the collector open and set the resistor to 1meg and the plot to 0.001ma. You may need to calibrate the system before this check to adjust the zero. If the line is not horizontal, select a resistor that flattens the slope. Usually, it is several megohms. Try one of two trim resistor spots.





The current source circuit also uses a differential amp configuration. Connecting the collector to base allows measurement of the current source. The midline should be close to horizontal. If not, add a resistor to one of two spots to correct the slope.