Construction, Explanation and Testing Guide for an Electrostatic Deflection Cathode Ray Tube Tester

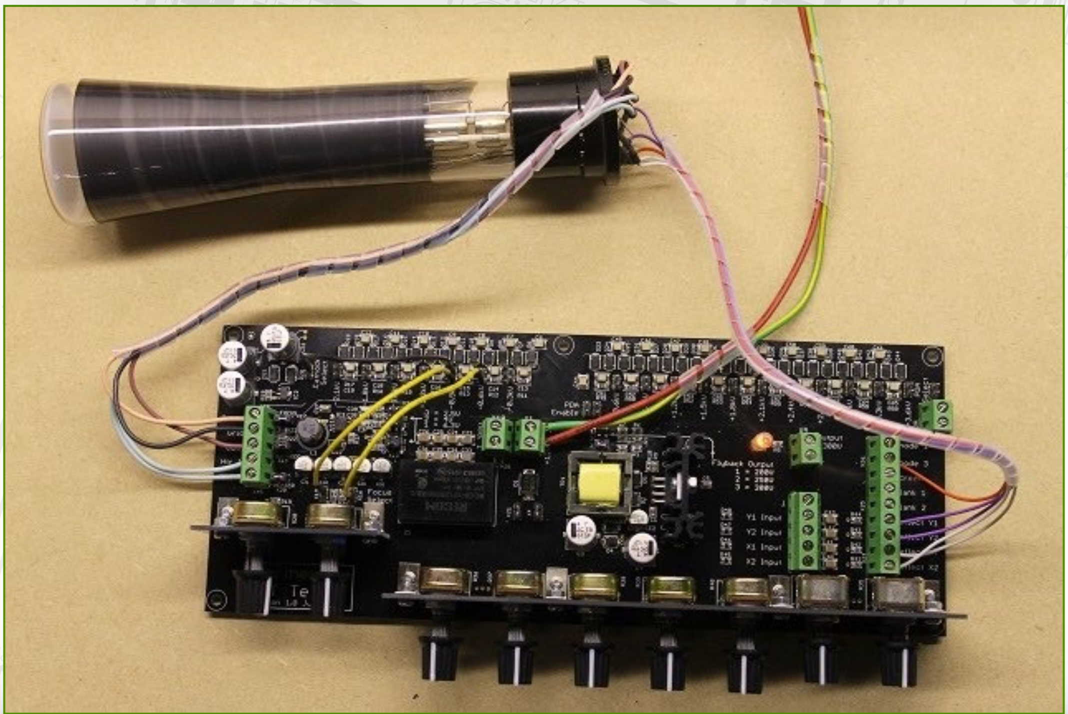

Table of Contents

Safety Statement

The CRT Tester and additional extensions[1] use high voltages in order to operate. You need to respect this and other hazards inherent in these circuits and devices.

Caution! The CRT Tester can generate high voltages from -2.1kV to +3.6kV during operation. Only operate if you are familiar with the use of high voltage equipment and the precautionary measures need to operate safely. If in doubt, ask a qualified electrician or contact us directly.

Caution! Do not touch any of the electronics while the CRT Tester is in use or has been recently operated, including any devices currently powered by the CRT tester. Treat the CRT Tester and any connected items with the same level of common sense as any mains-powered electrical item – do not expose to wet environments, keep out of the reach of children, animals etc. Do not eat!

Caution! Some components may be warm to the touch during use.[2] This is a perfectly normal consequence of their operation, but you should remember it when handling the boards or when considering alternative enclosures.

[1] Currently a custom PSU, Dekatron Tester, E1T Tester, NIMO Tester and maybe *more to come…*
[2] Why are you touching them!!

Legal Statement

The CRT Tester and add-ons are built and documented with an Open Source[3] philosophy in mind. All the source files including circuit diagrams, Eagle board and case design files are provided under a Creative Commons ShareAlike 4.0 International license.

More specifically:

- You may share, copy and redistribute the material in any medium or format.
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- For further information, please see the following URL: http://creativecommons.org/licenses/bync-sa/4.0/ or send a letter to Creative Commons, PO Box 1866, Mountain View, CA 94042, USA.

In addition you should note the following (in the event that there is any conflict between these notes and the License given above, then the License shall take priority).

The CRT Tester, PSU and additional testing devices may be hazardous if not assembled and operated by suitably knowledgeable and practiced persons or if abused. It is your responsibility to carefully review the documentation, the design and the kit contents and to assure yourself that you have the necessary expertise to construct and/or operate the tester safely. In particular, it is also your responsibility to ensure that the completed tester meets any necessary safety and other regulations or guidelines for such items in your jurisdiction. In that respect, any supplied enclosure is intended as a basis for you to customise the final tester to meet such regulations. It is possible that in some jurisdictions, a completely different type or construction of enclosure may be required to obtain regulatory compliance. Assembly instructions in the kit documentation are intended as a starting point, to be amended or not according to the judgement and expertise of a suitably qualified constructor.

The hazards of these kits include, but are not limited to, high voltages, the generation of heat during operation, the presence of toxic substances within the components of the kit, the presence of high vacuum within the cathode ray tube under test (if any) and the presence of sharp and/or fragile glass and metal items. Not all components within this kit comply with the Restriction of Hazardous Substances regulations (RoHS), though compliant components have been selected in most cases.

In summary, you own, construct and use the CRT Tester and any additional extension devices entirely at your own risk. To the maximum extent permitted by law, we disclaim all liability for any and all adverse outcomes associated with your ownership, construction and use of this item.

Warranty Information

Upon receipt of the kit of parts, any missing or broken pieces will be replaced. It is incumbent upon the recipient to check the contents in a prompt manner against the supplied parts lists

[3] https://en.wikipedia.org/wiki/Open-source_hardware

found within this manual. As a kit of parts, no warranty can be provided pertaining to the quality of construction and operation of the final product as this is the duty of the purchaser and is dependent upon their skill. The CRT Tester and extensions may be hazardous if not assembled and operated by suitably knowledgable persons and it is the owners responsibility to carefully review all the supplied documentation. The authors have made their best attempts to explain and detail the construction and hazards associated with operation of the tester etc within this manual. Within the CRT Tester, PSU, Dekatron Tester, E1T tester and NIMO tester, certain hazards are present, namely high voltages and due care and attention should be paid when handling said items. If you have purchased a complete operational tester PSU or other device then a limited warranty is provided in a separate document supplied with your documentation. If the CRT Tester kit, complete CRT Tester or other unit has arrived in a damaged state such that an insurance claim is likely to be made, then please notify us immediately (within a few days of receipt). It is likely that photographic evidence will be asked for to make the insurance claim.

No refunds on partially or fully constructed kits are possible.

Introduction

Over a period of a few years I have amassed quiet a few CRTs[4]. To test any of these tubes I generally put a test set up together consisting of a couple of old Heathkit IP17[5] high voltage power supplies and another EHT power supply. This combination was not very satisfactory and I started to look at building a dedicated CRT tester. I wanted a tester that would enable more than just confirmation that a spot on the tube could be obtained but would allow X and Y movement and grid modulation. I also want to be able to test more modern tubes which can have additional electrode connections such as screens, deflection blanking and separated acceleration anodes. I wanted to be able to make *measurements*.[6]

Look at those beauties!: Back row, left to right: CV5125, 5SP7: Middle row, left to right: SE5F, 6ЛО1И, 09D, 130BXB31: Front row, left to right: CV1522, D10/230, CV2175, 3ЛО1И, CV2272, DG7/32, CV2320, DG7/52A, ACR10, 7ЛО1М, 2BP1. These are all in range of the tester's capabilities!

The basic design came out to:

- CRT heater supply limited to about 6W, say:
  - 6.3V at 0.6A
  - 4V at 1.1A
  - 2.5V at 2A
- Grid voltage adjustable from -5V to -120V w.r.t. the cathode.
- Focus anode voltage adjustable over a wide range.
- Acceleration anode voltage selectable up to about +2kV w.r.t. the cathode.
- PDA[7] voltage selectable up to about +5kV w.r.t. the cathode.
- Deflection plate voltage difference from -300V to +300V.
- Adjustable deflection blanking, acceleration anode and other electrode voltages.
- AC coupled inputs to the X and Y deflection plates and grid modulation (Z axis).
- 12V DC supply, I would probably use a bench PSU.
- Provision for current and voltage instruments.
- Simple and manually operated - no micro-controller or PC[8] in sight!

This design gave some limitations:

- CRT heater could not supply, for example, 6.3V 1.2A heaters, but there are some simple workarounds to this which are described in the Operations Manual.
- Multi gun CRTs could not have their guns operated simultaneously.
- Electrostatic deflection and focus CRTs only (no magnetic deflection and focus).
- Trace rotation coils not tested (for non-circular CRTs).
- CRTs requiring >5kV PDA voltages are out of the scope of this tester, but a spot should still be obtained.

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[4] http://www.r-type.org/articles/art-116.htm
[5] http://www.sgitheach.org.uk/ip17.html
[6] The horror!
[7] Post Deflection Acceleration
[8] or Mac! ;)

There are a number of things these manuals will not teach you

- How to hand solder competently
- How to read a component value
- How to orientate a component correctly
- How to handle static sensitive devices
- How a CRT works
- Why you need a CRT Tester!

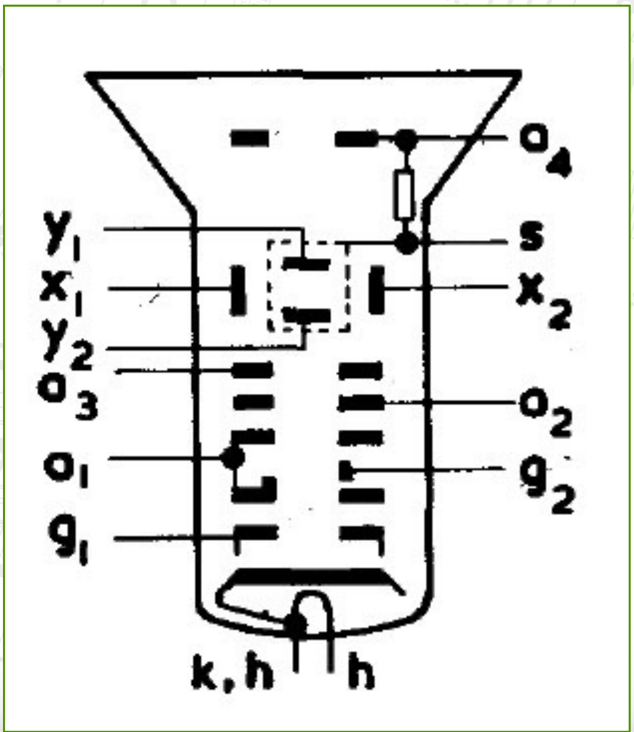
If you're not comfortable with any of these considerations, then this project is probably not for you.

How it Works

Introduction

The CRT Tester is designed to test typical oscilloscope tubes including more modern tubes with additional electrodes. For example the Brimar D13-611 CRT:

- Heater connections, h and h, one common with the Cathode, k
- Brightness control grid, g1
- Separate 1st Anode, a1, which is also part of the beam blanking
- Deflection beam blanking electrode, g2
- Focus anode, a2
- Acceleration anode, a4
- Deflection plates, x1, x2, y1 and y2
- Screen electrode, s
- PDA, a4



Such complex CRTs require a fair few controls and voltages to operate correctly.

The CRT Tester is designed around operating the deflection plates in the range 0 - 300V and final acceleration anode at mean deflection plate voltage of 150V[9]. The required voltage difference between the cathode and the final acceleration anode is achieved using an -EHT generator. Therefore, if the data sheet for a CRT says the final acceleration anode voltage should be 2000V, this is the voltage relative to the cathode and could be achieved with a final acceleration anode voltage, relative to ground) of 150V and a cathode voltage of -1850V.

If the CRT has a PDA then an +EHT generator provides a voltage above the final acceleration anode voltage. Hence, continuing the example, if the data sheet indicated a PDA voltage of 4000V is required relative to the cathode, and the cathode potential was already -1850V then the required PDA voltage is 2150V.

A grid voltage more negative than the cathode is required for beam brightness control.

[9] You will see later that these voltages can be adjusted to suit the requirements of "low voltage" CRTs.

A range of CRT bases permanently wired for use with the CRT Tester. As I test CRTs I make up a permanent wired base if it is a type that I am likely to use again.

A variable voltage, typically a few hundred volts positive to the cathode is required for beam focus.

A power supply is required for the CRT heater. Typical heaters use 2.5V (at 2A), 4V (at around 0.9 - 1.1A) and 6.3 V (at 0.15 - 0.6A) are very common.

The other electrodes, separate anode 1, beam deflection blanking, screens etc. usually require a voltage around the same voltage as the final acceleration anode.

A step towards the schematics

All of the power to operate the CRT, except the heater, come from a flyback converter[10]. This uses a 12V DC input and has a secondary rated to produce 150V DC i.e. when rectified. However, it is immediately doubled to 300V and this voltage is used as the feedback control voltage in the flyback converter. This 300V is used with potentiometers to control the acceleration anode, deflection, blanking and screen voltages.

Pulses from the flyback converter are passed to a negative CW[11] voltage multiplier. So it produces voltages in multiples of -300V i.e. -300V, -600V, -900V down to -2100V. The take off point selected sets the cathode voltage. A potentiometer can be linked to the -EHT take off points to set a suitable range for the focus anode.

Pulses from the flyback converter are passed to a positive CW voltage multiplier, so it produces voltages in multiples of +300V from +600V to +3600V. If needed, the take off point selected sets the PDA voltage.

A further secondary winding on the flyback transformer is rectified to produce the negative grid bias (with respect to the cathode).

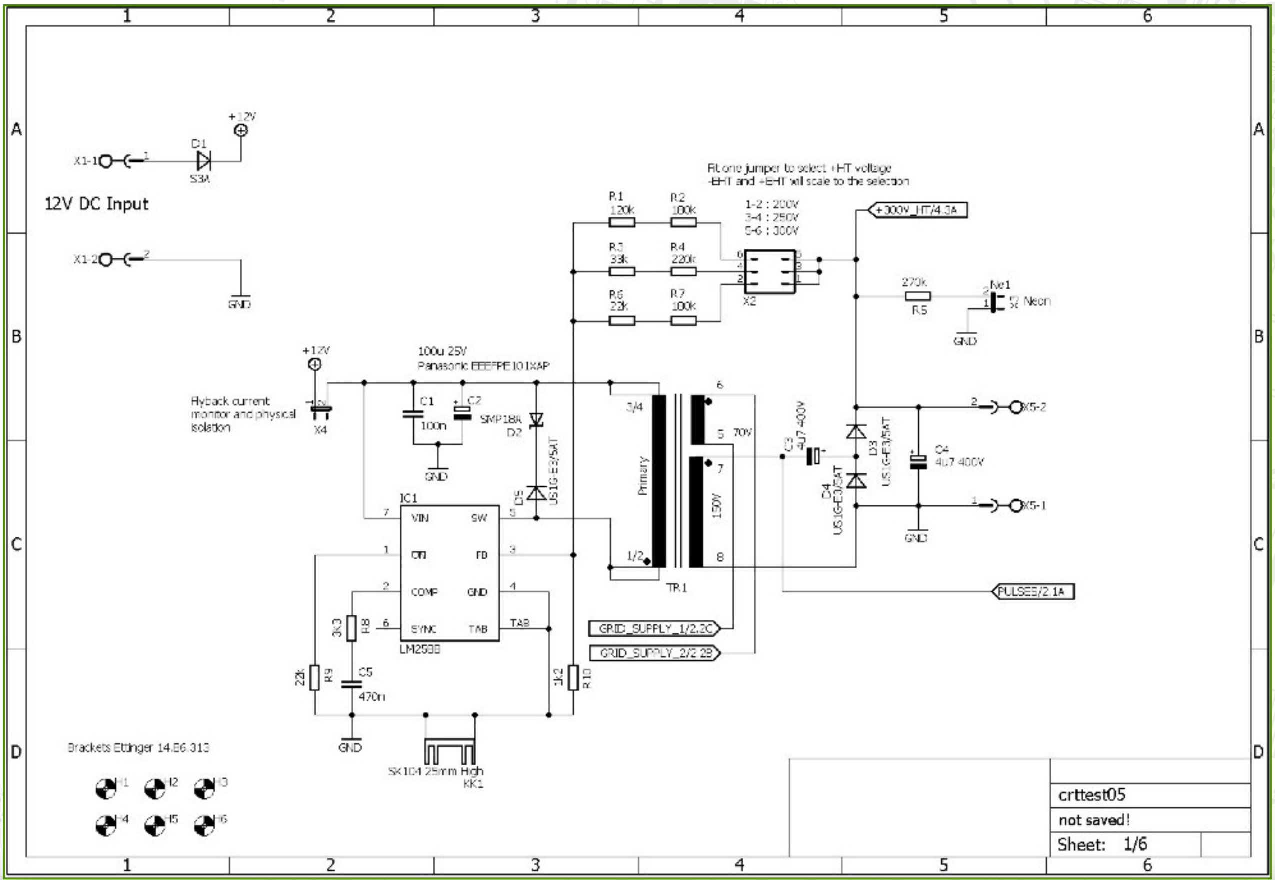
Finally, an isolated power supply, also fed from the 12V DC input is used to power the CRT heater.

The schematic breaks across 5 sheets

1. Flyback converter and 300V +HT supply
2. -EHT cathode supply, focus anode control voltage, grid control voltage
3. Heater PSU
4. Deflection plate, anode (other than the focus anode), screen, defection blanking
5. +EHT PDA supply

[10] http://www.dos4ever.com/flyback/flyback.html
[11] https://en.wikipedia.org/wiki/Cockcroft%E2%80%93Walton_generator

Schematic 1 of 5: +HT Supply

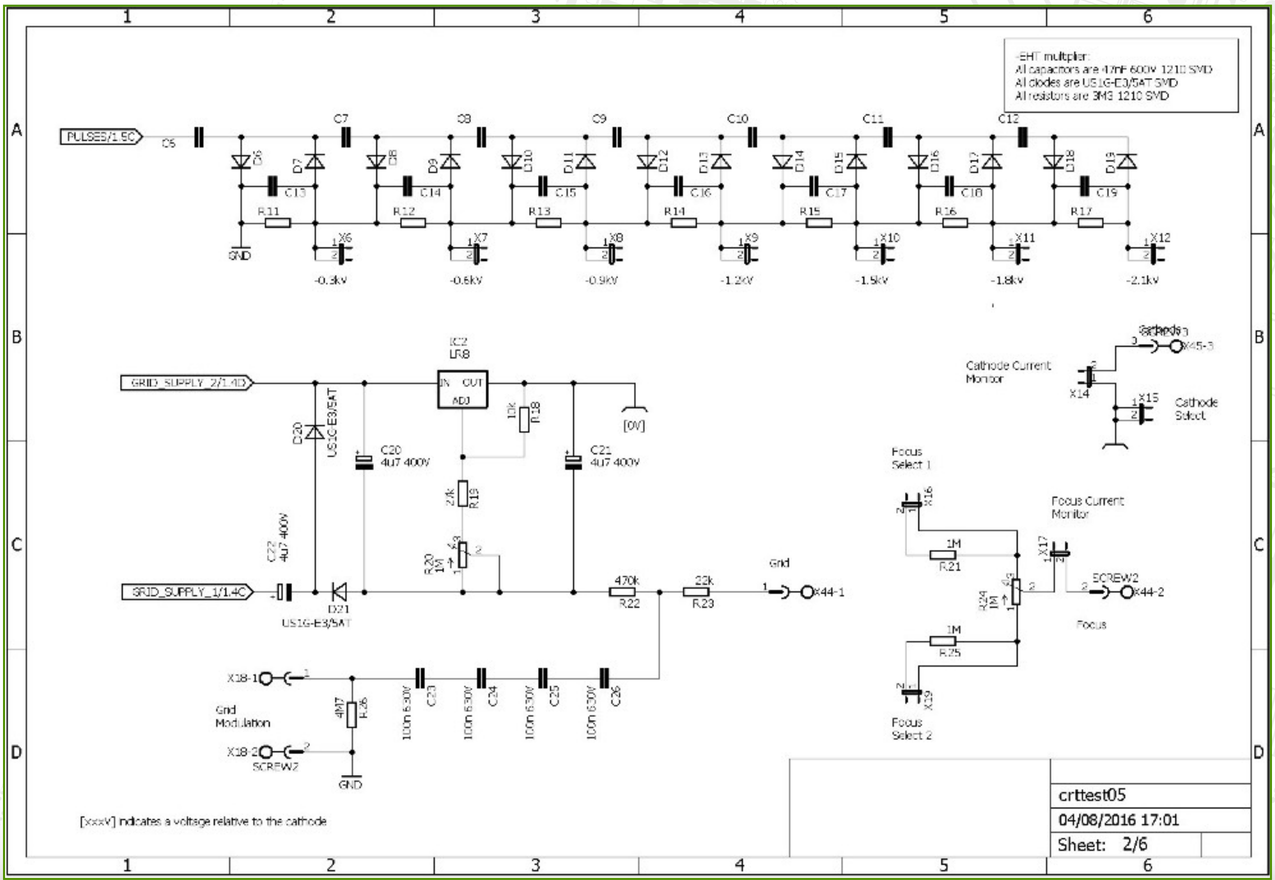


IC1 is a specialist flyback converter integrated circuit that drives the custom manufactured flyback transformer TR1. The output from the transformer passes through a voltage doubler (D3, D4, C3, C4) and produces 300V DC. Control of this voltage is made by a feedback loop to IC1. Note that the feedback is made via a jumper header (X2) so that different potential dividers in the feedback loop can be used to select operating voltages other than 300V. You can also select 200V or 250V operation and these other voltages can help when testing “low voltage” CRTs.

Note the neon[12] that is lit using the +HT supply to give a visual warning that the board is at high voltage.

[12] Because you can never have enough neon in your life…

Schematic 2 of 5: -EHT multiplier, cathode, grid and focus anode supplies



This schematic breaks into 3 subsections:

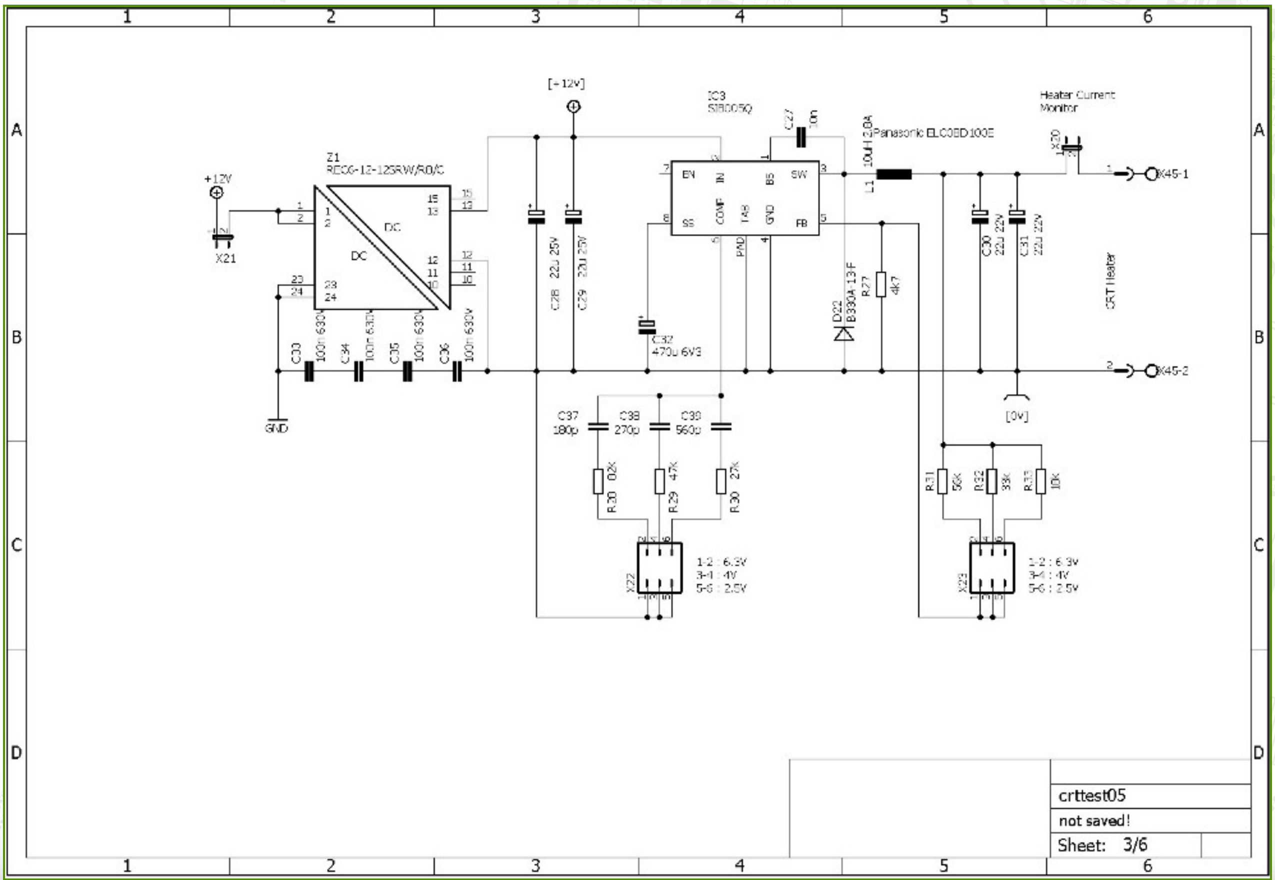
- A CRT cathode supply consisting of an -EHT multiplier chain (D6 to D19, C6 to C19) with take off points (X6 to X12) on every stage and a connection to the CRT cathode using a "jumper wire"[13] from the cathode select header X15 to one of the -EHT take off points.
- A grid power supply which uses a secondary winding on flyback transformer rectified and doubled (D20, D21, C20 and C22) and regulated by IC2. The output voltage can be adjusted between about -5V and -120V (relative to the cathode) using potentiometer R20. The grid voltage can be modulated by a signal applied to connector X18.
- A focus anode supply using the potential divider R21, R24 and R25. The voltage range is selected by connecting Focus Select 1 and Focus Select 2 headers using jumper wires to take off points on the -EHT multiplier.

Note that you can monitor the cathode current and focus anode current by attaching suitable panel meters[14] to headers X14 and X17 respectively. Normally, these jumper headers are closed with jumper pins.

[13] In this manual a "jumper wire" is a purpose made cable using either 3kV rated insulation wire and crimp pins to select the cathode focus and, using 5kV rated insulation wire, the PDA voltage.

[14] Remember that the heater, cathode and focus anode can be at around -2kV with respect to ground. Therefore modern LED/LCD panel meters are unlikely to be suitable. Look for old style analogue moving coil meters.

Schematic 3 of 5: Heater supply



It should be remembered that the CRT heater must not be at a significant potential difference to the cathode. In the case of the example above using the Brimar D13-611 CRT the cathode and one side of the heater are electrically connected inside the CRT. Therefore the CRT heater PSU must operate at or about the cathode potential. Looking at the schematic you can see that this isolation is achieved using a DC-DC power brick[15] Z1.

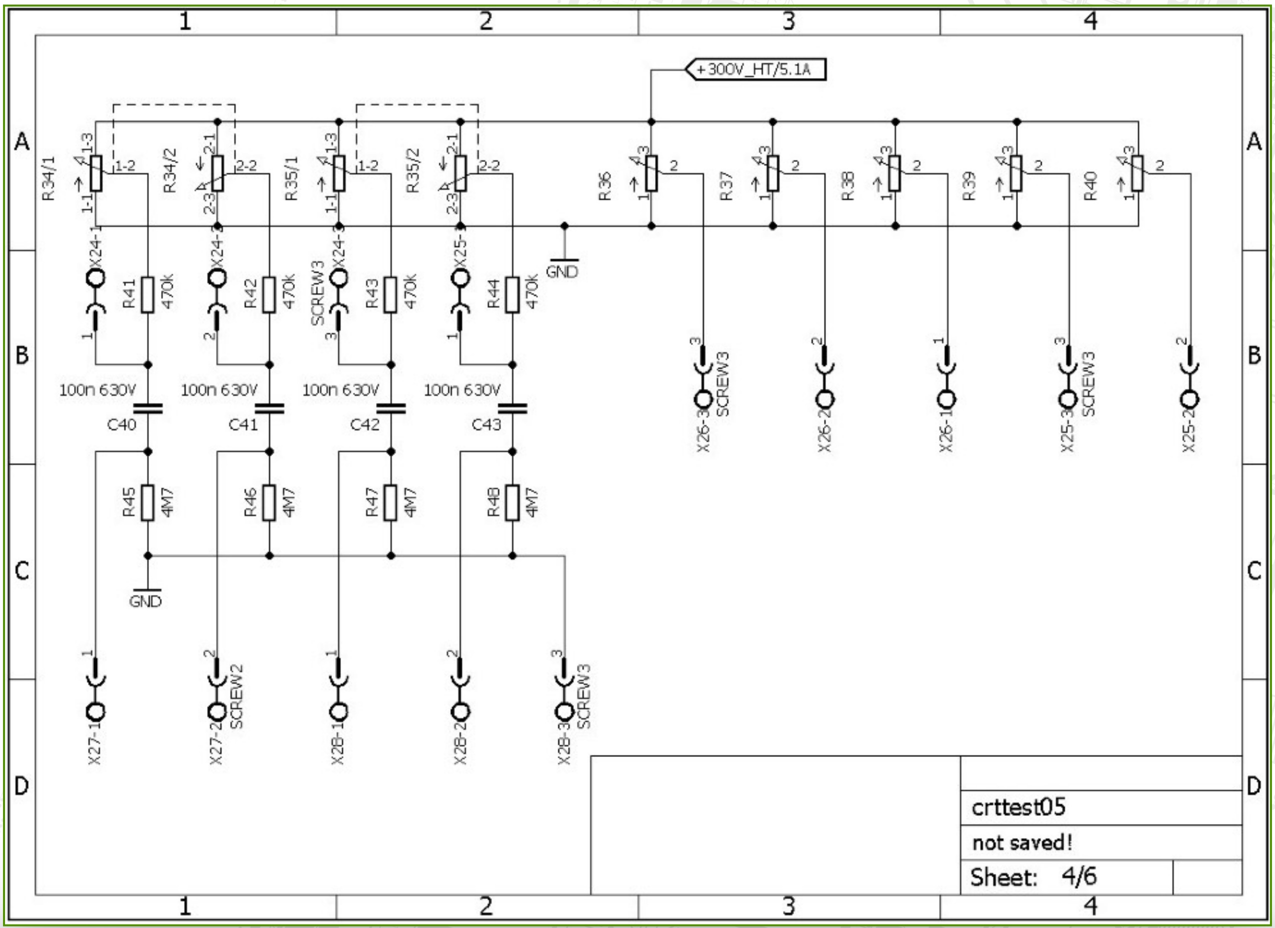
The power brick selected will produce 12V DC and 6W of power. It is therefore suitable for the heaters found in most single beam CRTs but will not power, for example, a 6.3V 1.2A heater.[16]

IC3 is a step down converter[17] with its feedback resistors, selected by X23 (and compensation network, selected by X22) able to select output voltages of 2.5V, 4V and 6.3V.

The heater current can be measured by attaching a suitable panel meter to header X20. Normally this jumper header is closed with a jumper pin.

[15] This is an elegant way to achieve several kV isolation but I would be the first to acknowledge that it's *not a cheap solution*.
[16] The Operations Guide illustrates a simple work around for this problem.
[17] https://en.wikipedia.org/wiki/Buck_converter

Schematic 4 of 5: Acceleration anode, screen, deflection controls



Dual gang potentiometer R34 is wired back to back so as the wiper on one half varies from 0V to 300V and the wiper on the other half varies from 300V to 0V. The voltage difference between the two wipers therefore varies from 300V to -300V. The centre voltage difference (0V) is at 150V and so the same as the intended nominal final acceleration anode voltage. The two potentiometer wipers are connected to X axis deflection plates.

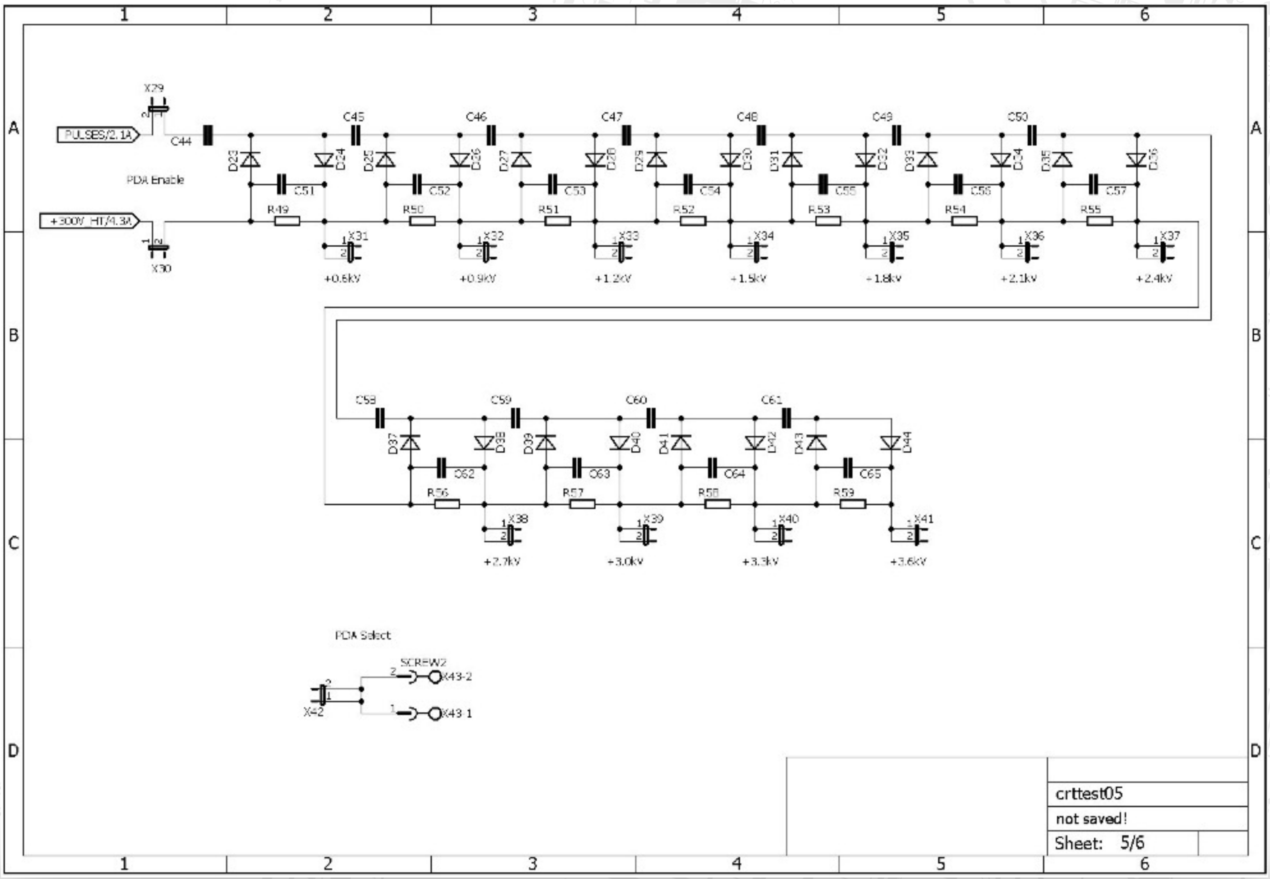
Similarly dual gang potentiometer R35 is connected to the Y deflection plates.

Signals can be applied to the deflection plates through X27 and X28 connectors.

Finally, R36 to R40 are single gang potentiometers where the wiper can be varied from 0V to 300V and so the mean voltage is 150V. They are labelled Anode 1, Anode 3, Geometry/Shape[18], Blanking 1 and Blanking 2. They are intended to be versatile and are an independent means of applying the given voltage range to any appropriate electrode within the CRT.

[18] Normally the “screen” electrode.

Schematic 5 of 5: +EHT PDA supply



The PDA +EHT supply is a second CW voltage multiplier fed from the flyback converter. The first voltage doubler in this chain is effect the same doubler on the output of the flyback converter (see schematic 1) so the first take off point on the +EHT multiplier is +600V or +0.6kV. There are 12 multiplier stages with an output voltage of, in theory, +3.6kV. However, losses are such that the take off point marked +3.6kV actually delivers about +3.5kV.[19]

With the cathode connected to the -2.1kV take off point and the PDA connected to the +3.6kV take off point, it does give a PDA potential of about 5.6kV with respect to the cathode which is a fine ceiling.[20]

<u>In Conclusion</u>

This has been a bit of a whistle-stop tour of the schematics, but hopefully a simple enough explanation of how the CRT tester works.

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19 Not too shabby though.

20 The Operation Guide section suggests how higher PDA voltages can be achieved, up to 10kV.

Kit Overview

To some extent this depends on what you have ordered. Two kits are currently offered.

- The *bare minimum kit* that consists of just the two custom components - the PCB and flyback transformer. If you have gone down this route then I assume you know what you are doing, where to buy all the components and how to build the thing i.e. you are an *experienced* constructor. I'm not going to teach my grandmother to suck eggs and instruct you on what, how, why, when etc. but I will be able to offer some help so do look at the Annexes.

- You have bought a *standard kit* that consists of the PCB with all the SMD parts fitted and the through hole components and mechanical parts.

The assumption I will make is that you have ordered a complete *standard kit*.

Kit Inventory

Despite our best and concerted efforts, there may be small errors in this document. If you find something that looks like an error or something that you are simply not sure about then please contact us!

This component list is for the *standard* CRT Tester kit with all the SMD parts pre-fitted. Check that these parts are present in the PSU kit bag(s) and use the table below to tick them off. If you find any missing components please notify us immediately so they can be supplied.

Photo 1: The standard kit contents straight outta the box.

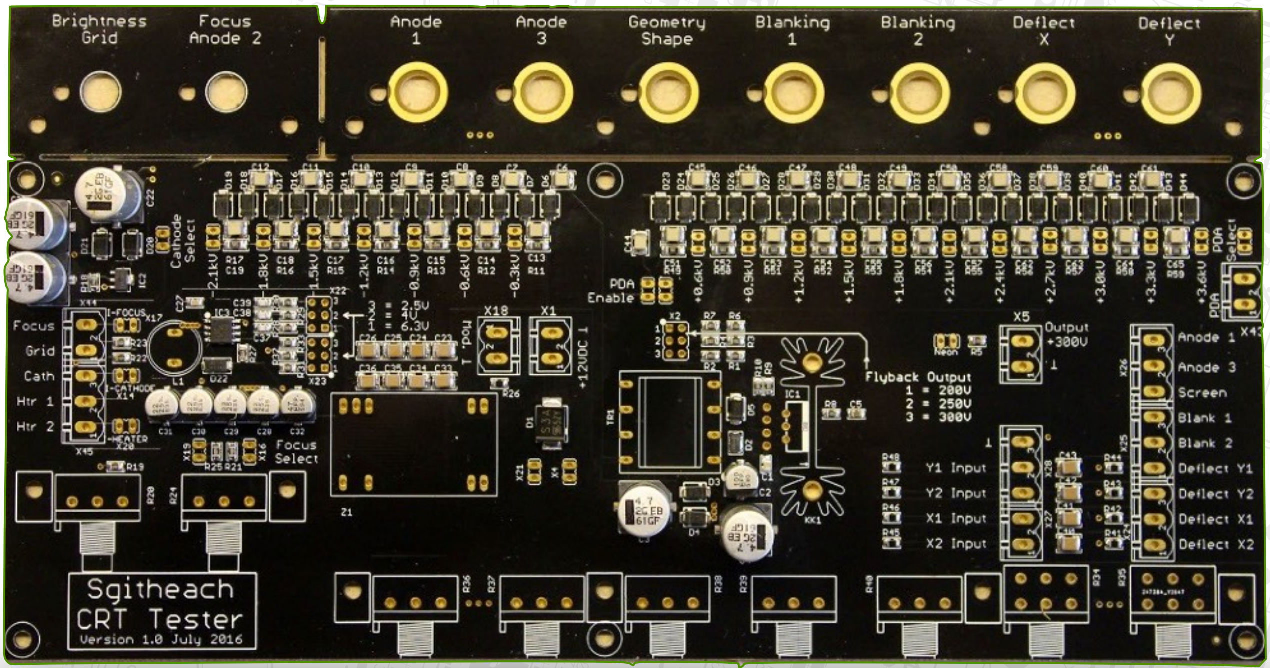


Photo 2: The PCB with the SMD parts pre-fitted

Please give the PCB a once over looking for any missing SMD parts. There should of course be none missing with all SMD part locations occupied.

Tick	Quantity	Value	Part Number
	1	LM2588-ADJ	IC1
	1	SK104 25mm high heatsink and clip	KK1
	1	10μH inductor	L1
	7	1M linear pots	R20, R24, R36 - R40
	2	1M dual gang linear pots	R34, R35
	1	Flyback transformer	TR1
	6	Two screw connectors	X1, X5, X18, X27, X43, X44
	5	Three screw connectors	X24 - X26, X28, X45
	30	1 x 2 headers	X3, X4, X6 - X21, X29 - X42
	3	2 x 3 headers	X2, X22, X23
	8	Jumper pins for jumper headers	
	1	DC-DC brick	Z1
	9	Knobs	R20, R24, R34-R40

Tick	Quantity	Value	Part Number
	2	Insulated shaft extensions	R20, R24 
	6	M3 brackets	
	1	M3 6 nuts, 12 bolts 6 washers to fit brackets	
	1	Neon and stand off	Ne1
	8	Crimp pins	
	4	EHT cable 3 colours	
	1	Length of heat shrink tubing	
	1	PCB with all SMD parts fitted	

Put the components back in their bags until you are ready to build the CRT Tester.

Kit Inventory - Damaged or missing parts?

Upon receipt of the kit of parts, any missing or broken pieces will be replaced if discovered. It is incumbent upon you, the recipient, to please check the contents in a prompt manner (within a few months) against the supplied parts lists found within this construction manual.

If the CRT Tester kit has arrived in a damaged state such that an insurance claim is likely, then notification should be made immediately (within a few days of receipt). It is likely that photographic evidence will be asked for to make any insurance claim.

At this time you should review your ability to build and safely operate this CRT Tester!

If you wish to return the kit then now is the best time to do so. No refund will be available for a partial built kit. As long as the returned kit is complete, the refund will be as well. The cost (postage and insurance) of returning the kit is, appropriately, yours to bear and the refund will not include the postage and insurance that I have paid. Additionally, if the kit is returned from outside the EU then the possibility exists that the UK Tax Man will demand a slice of its value and you will be accountable for this cost as well.

Kit Assembly - Tools

The kit provides all the necessary components, but you need to have the necessary tools! The minimum equipment required is listed in the left column of the table below, but it will make things easier if you also have some or all of the items from the right column. A multimeter is absolutely essential to confirm that operating voltages are correct.

Essential	Useful
Fine tipped and large tipped soldering iron	Magnifying glass (essential if your eyesight is aging…)
Thin cored solder	Wire-stripping tool
De-soldering braid	De-soldering pump
Quality side cutters for cropping component leads	Anti-static wrist strap and work mat
Multimeter, preferably one with an EHT probe capable of reading up to 4kV	Small crimping tool
Screwdrivers, small pliers etc.	
12V DC 1.5A (minimum) PSU. Correctly earthed/grounded using a three core mains/line cable with the ground/earth connected to the negative lead of the DC output. An isolated output type is unsuitable.	Bench PSU with voltage and current read outs and over current protection

This is not an overly difficult kit to construct. Providing you can solder neatly and follow the assembly instructions accurately, there should be no problems. Lots of light, some magnification and de-soldering braid to remove excess solder work every time for me.

The last "tool" is you and your time - this kit has a fair few components that have been individually bagged to help you build the kit without error. Take your time, take breaks and enjoy the experience!

Beyond the kit

The kit is complete except no additional parts are provide for the connection of the kit to the CRTs you want to test! There are just too many types of CRT bases, some of which can be very hard to buy and have to be fabricated. See the Operations Manual for guidance and examples.

It is recommended to mount the CRT Tester inside a case that is closed when the tester is under power. An additional enclosure case kit is available.

If you wish you can add permanent meters to the kit. You might add voltmeters and ammeters and produce a really snazzy piece of gear.

Rather than the plentiful use of jumper headers to select the various voltage options you might consider adding switches in their place. If you do this, pay **very careful attention** to the voltages involved as you may be switching up to 3.6kV and so the switch and its wiring must be appropriately rated.

Building the CRT Tester

Separating the boards

Before mounting any of the through hole components the two potentiometer panels should be carefully separated using a hacksaw..

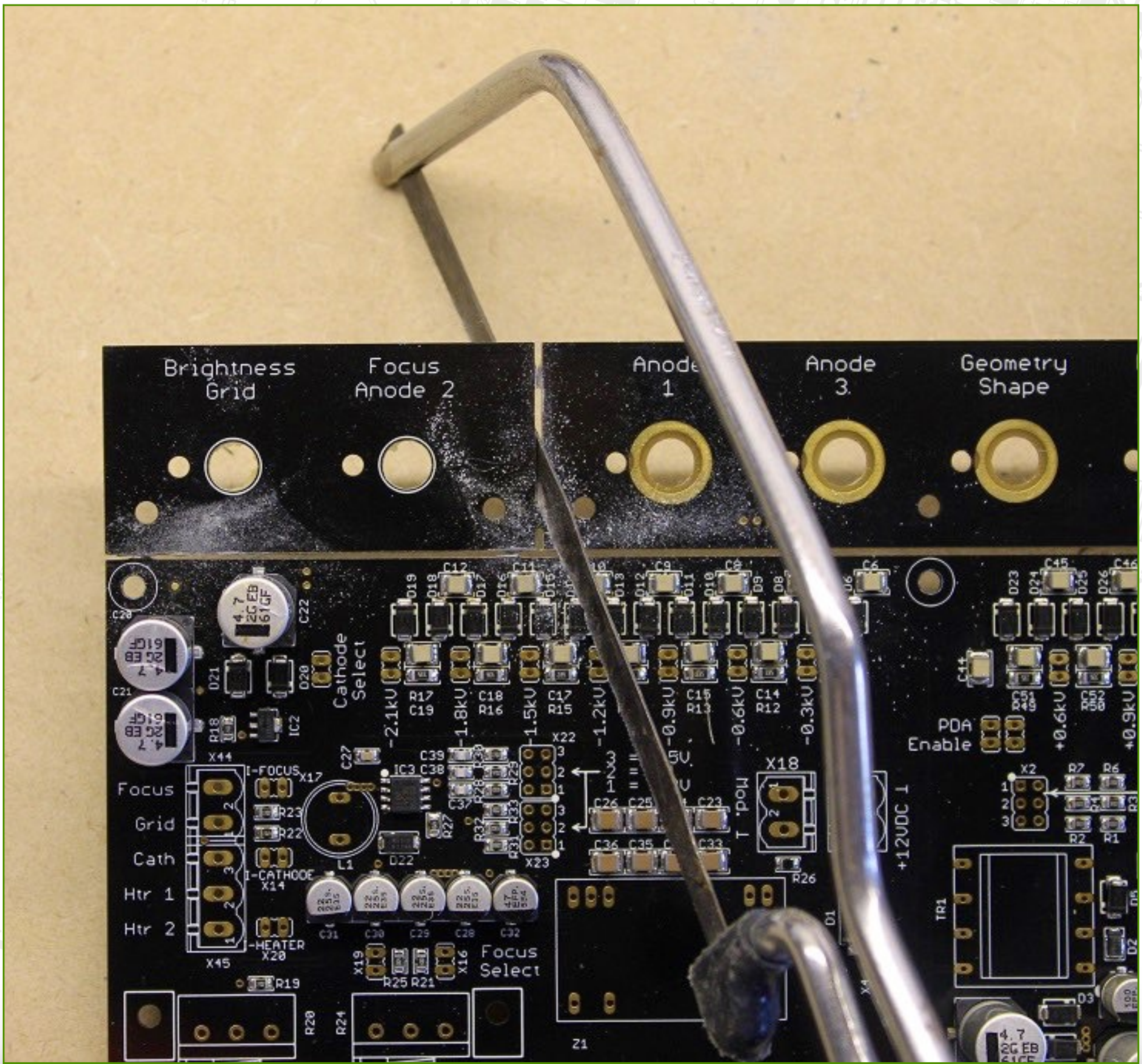


Photo 3: Using a hacksaw blade to separate the panels.

Photo 4: 'Nubs' to be carefully filed down…..

Through Hole Part Installation

The through hole components should be installed by fitting the smallest first and finishing with IC1 and its heatsink. The tick box list below gives a suggested order. Note that the board does not have component values marked and you should be careful to ensure that you are inserting the correct component into the correct place. Finally, some components must be inserted in the correct orientation. The silkscreen guides you to the correct positions.

There is one permanent wire link to fit during construction and this is identified in the text when this link is fitted.

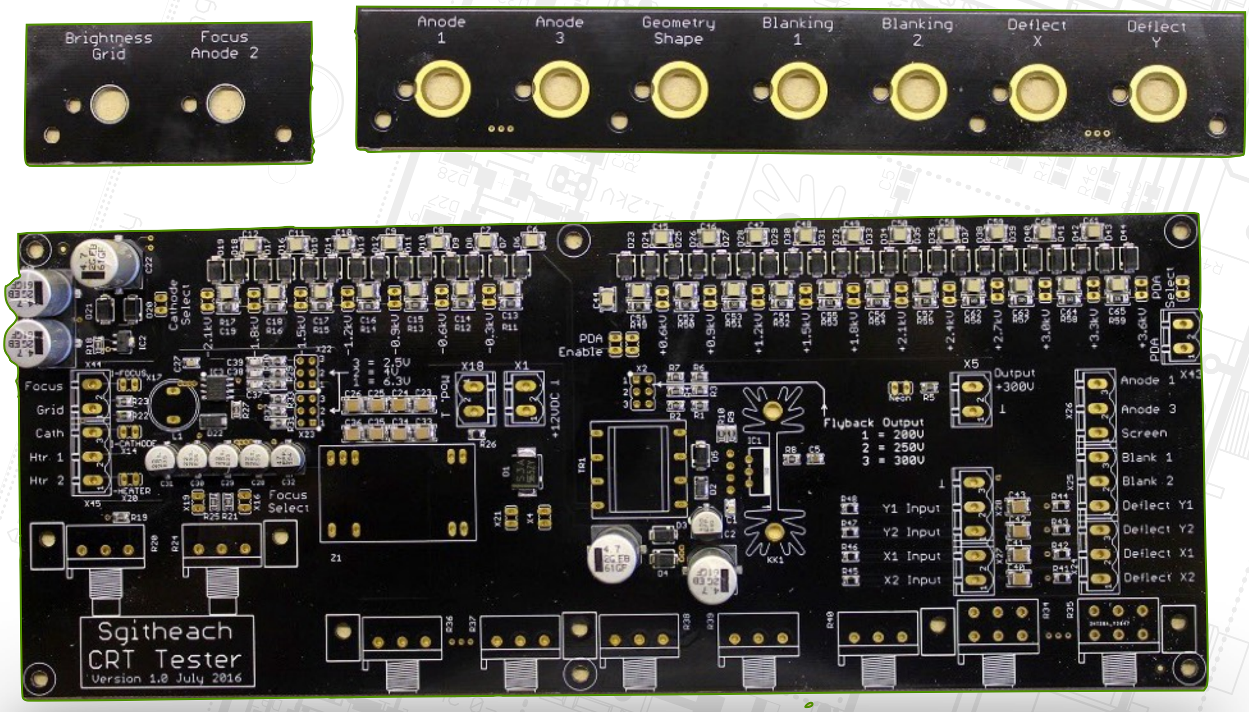


Photo 5: Main board and the two potentiometer front panels.

Focus Anode and Brightness Control Panel Assembly

Tick each box as the component is fitted:

Tick	Quantity	Value	Part Number	Notes
	2	1M linear pots	R20, R24	Focus anode and Brightness
	2	Knobs	R20, R24	
	2	Insulated shaft extensions	R20, R24	
	2	M3 brackets		use M3 nut, bolt and washer

Do not fit the panel to the main board at this time.

<u>Acceleration Anode, Deflection etc. Control Panel Assembly</u>

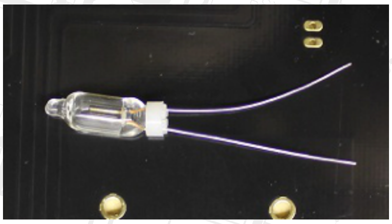
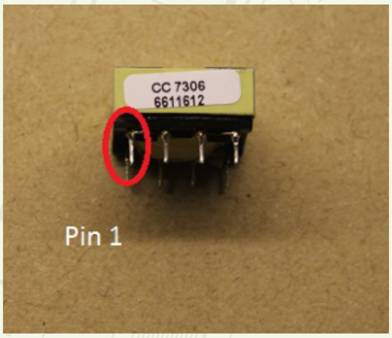
Tick each box as the component is fitted:

Tick	Quantity	Value	Part Number	Notes
	4	M3 brackets		use M3 nut, bolt and washer. It is easier to fit these first before the pots. Threaded holes go on the bottom (**see note below**)
	5	1M linear pots	R36 - R40	Anode1, Anode 2, Geometry, Blanking 1 and Blanking 2
	2	1M dual gang linear pots	R34, R35	Deflect X and Deflect Y
	7	Knobs	R34 - R40	

Note:

- Unfortunately one of the M3 bracket mounting holes is very close to a mounting hole used to support the board in the case. When mounting the board to the in the case it is easier to first mount the board on the 3D printed support and then put the bracket in place. Therefore, it is best to not put this particular right angle bracket in at this point and instead install it once the PCB is attached to the 3D printed mounts in the case.

Main board Assembly

Tick	Quantity	Value	Part Number	Notes
	29	1 x 2 headers	X4, X6 - X21, X29 - X42	X6 to X12 are the take off points along the -EHT multiplier chain (-0.3kV to -2.1kV) on the PCB, likewise X31 to X41 are the take off points along the +EHT multiplier chain (+0.6kV to +3.6kV).
	3	2 x 3 headers	X2, X22, X23	
	1	10μH inductor	L1	
	1	DC-DC	Z1	The pins only allow this to be fitted one way round
	6	Two screw connectors	X1, X5, X18, X27, X43, X44	The blocks should face outwards from the board, except the X and Y input block which can face either way. Note the blocks connect together to make larger 'blocks' to fit appropriately.
	5	Three screw connectors	X24 - X26, X28, X45	
	1	Neon and stand-off	Ne1	Fitted near R5  Note use of stand-off.
	1	Flyback transformer	TR1	 Pin 1 aligns with the dot on the PCB.
	1	SK104 25mm heatsink	KK1	Fix with clip (see note)
	1	LM2588-ADJ	IC1	Mount on KK1

- When fitting IC1 it can prove easiest to loosely fit the IC to the heat sink KK1 first and fit both the IC and the heat sink together. This ensures the IC is mounted at the correct height for the mounting clip in the heat sink.

Tick	Quantity	Notes
	1	Fit the Focus Anode and Brightness Control Panel Assembly and secure it with M3 bolts
	1	Fit the Acceleration Anode, Deflection etc. Control Panel Assembly and secure it with M3 bolts
	1	Solder one wire link between the Acceleration Anode, Deflection etc. Control Panel Assembly and the Main Board - there are stations for 6 links.

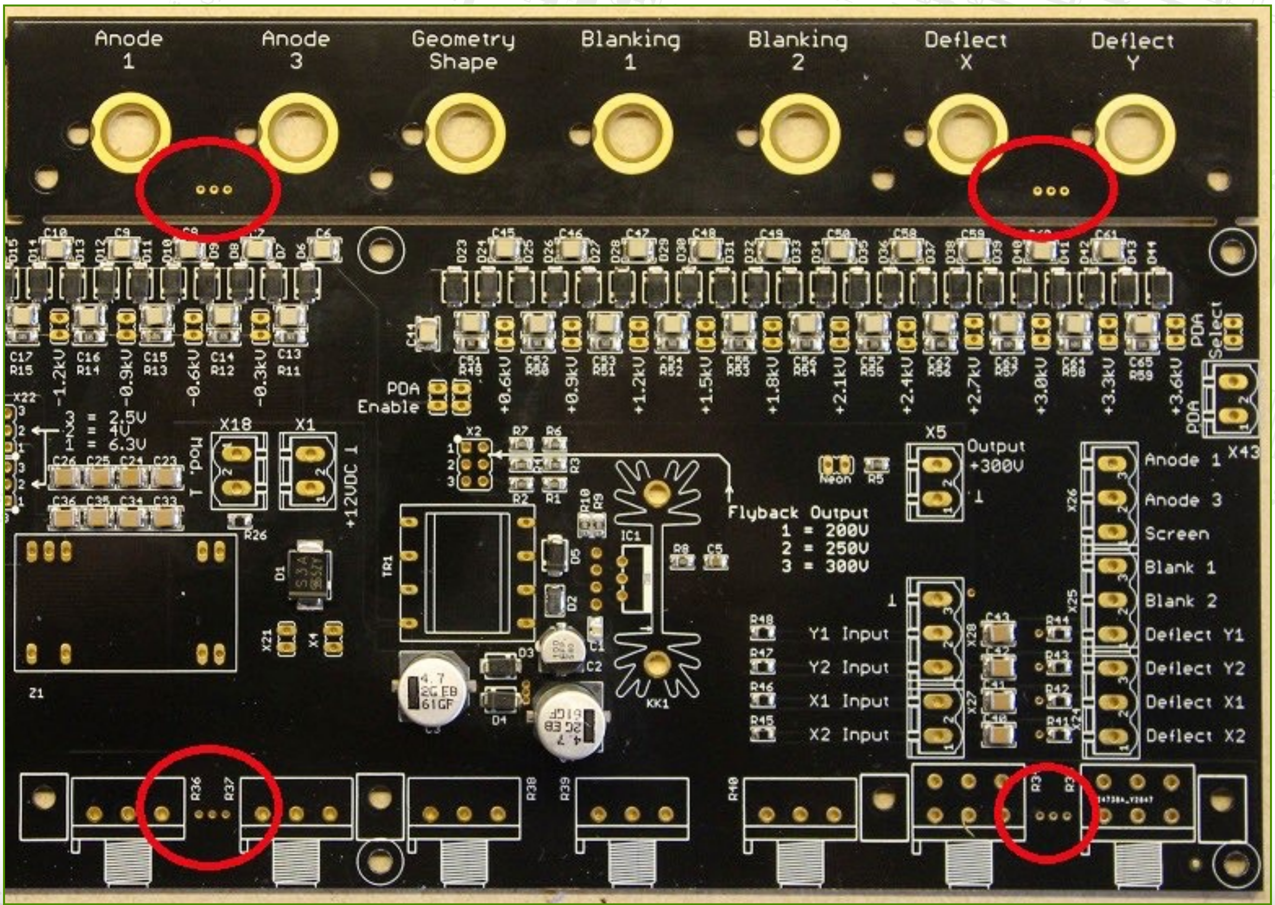


Photo 7: Location of the six holes available as front panel earth bonds.

<u>Jumper Wire Assembly</u>

The board uses four jumper wires to select the required cathode voltage, focus voltage range (two wires) and, if required, one to select the required PDA voltage. These wire links use high voltage wire, crimped pins and are insulated with heat shrink tubing. Ideally you should use a pukka[21] crimp tool but otherwise bend the crimp pin closed using piers and perhaps solder the joint to get a firm fitting.

[21] Pukka is a word of Hindi and Urdu origin, literally meaning "cooked, ripe" and figuratively "fully formed", "solid", "permanent", "for real" or "sure". In UK slang, it can mean "genuine" or simply "very good"

Tick	Quantity	Value	Notes
	8	Crimp pins	
	4	EHT cable 3 colours	Insulate using heat shrink tubing
	1	Length of heat shrink tubing	See above…😀

Three colours of high voltage wire are provided. Two lengths of grey/green for the focus anode connections, brown for the cathode and red[22] for the PDA connection.

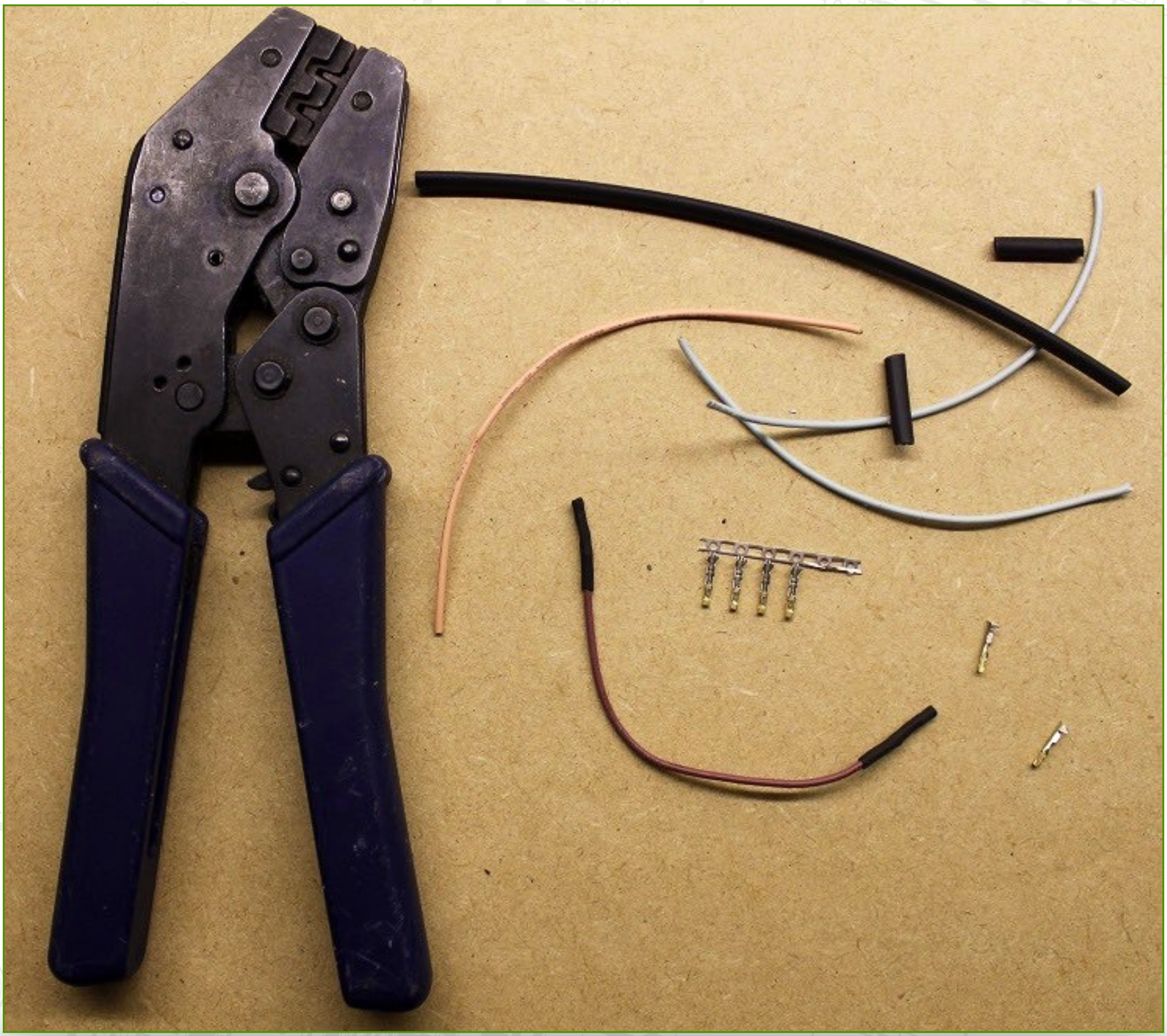


Photo 8: Jumper wire assembly - Crimp Tool is not part of the kit!

[22] I was using pink and not red wire when I took this photograph

Initial Testing

At this point all of the headers have been fitted but under no circumstances should any jumper wires have been fitted or jumper pins on jumper headers.

These notes will take you through testing the CRT Tester's sections in stages. During these tests voltages will be present that will give a nasty shock and are potentially lethal. I cannot be held responsible for any accident or injury resulting from performing these tests. Carrying out these tests implies that you agree with these conditions. The board has many capacitors that will remain charged for some time after power is removed from the board.

When you have switched off the power to the board you should wait several minutes for the charge to be dissipated.

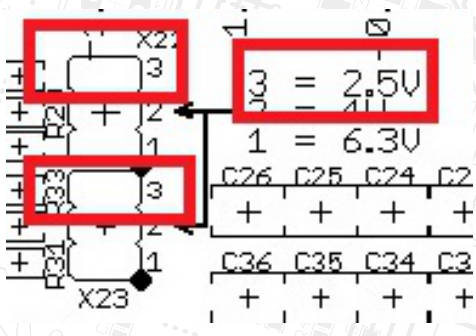
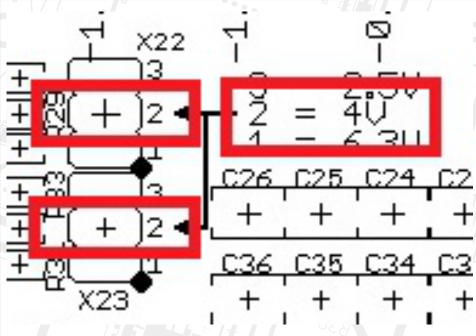
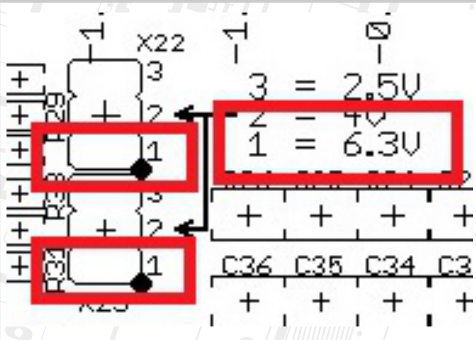
In many cases you will be making measurements using a multimeter of voltages that are low (say 6.3V) but also very high (up to 4kV) with respect to true ground potential.[23] If you are uncertain, then connect your multimeter with the board unpowered, power up the board and note the reading, remove power from the board and then wait a few minutes for the capacitors to discharge.

Do not rely entirely on the neon bulb being unlit. It only monitors the HT voltage and it only shows that the voltage has dropped below its sustaining voltage. The neon does not indicate any charge on the -EHT, +EHT multipliers or the grid power supply.

[23] A cheap and cheerful voltmeter may not cut it here…

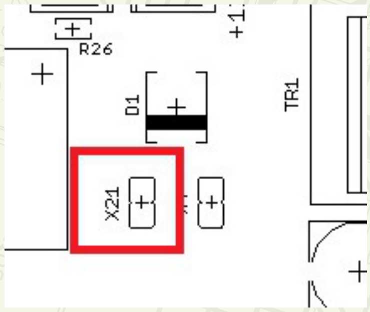
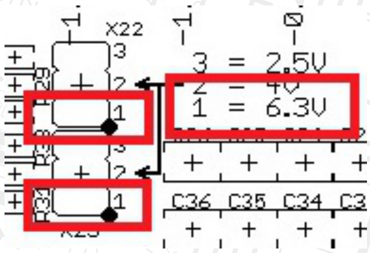
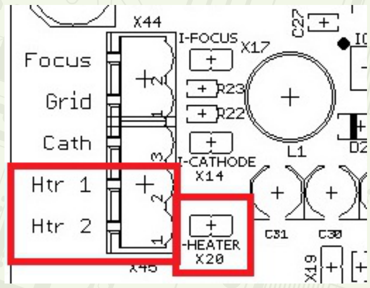
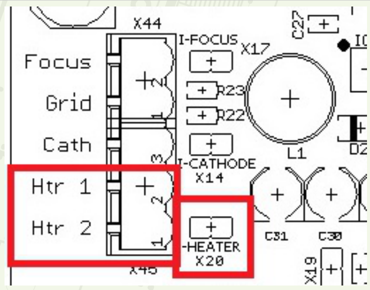
Testing the CRT Heater Supply

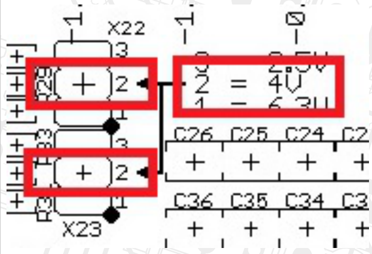
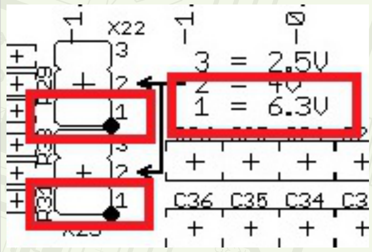
The voltage produced by the CRT heater SMPS is set using two jumper pins, one on jumper header X22 and one on jumper header X23.

Output Voltage	Jumper Header	Jumper pin to fit	Board Image
2.5V	X22	3	
	X33	3	
4.0V	X22	2	
	X23	2	
6.3V	X22	1	
	X23	1	

Carry out the following instructions ticking each off as completed successfully. Only low voltages, 12V or less should be present during this test.

Note: If your bench PSU has a very fast current trip then you may need to set the current limit a bit higher as the current draw when the heater PSU starts is considerable as the capacitors are charged. The same observation is made when you are testing the flyback PSU later.

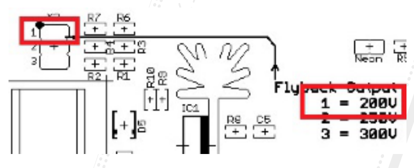
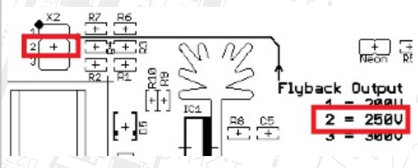
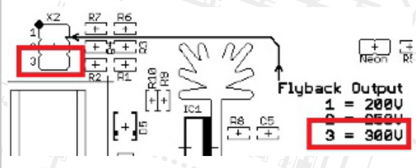
Tick	Instruction	Board Image
	<u>Starting condition:</u> No jumper pins or jumper wires are fitted!	
	The CRT heater is enabled by fitting a jumper pin to jumper header X21 this supplies power to the DC-DC brick that powers the CRT heater SMPS	
	Fit jumper pins across position 1 on jumper header X22 and position 1 on jumper header X23 to select 6.3V operation	
	Fit a jumper pin on the heater current monitoring jumper header (“I-HEATER” X20) this connects the CRT heater SMPS to the heater outputs on screw connector X45	
	Connect a 12 V DC Power supply to the board screw connector X1. Ideally this should be a current limited bench PSU set to 1.5A (see note below)	
	Switch the Bench PSU **ON**	
	The neon does NOT glow	
	Measure the voltage between Htr1 and Htr2 terminals on screw connector X45. The voltage should be about 6.3V, probably in the range 6.2 to 6.4 volts	
	If the 12V DC bench PSU has a current meter then it should read about 80mA	
	Switch the Bench PSU **OFF**	

Tick	Instruction	Board Image
	Move the jumper pins to position 2 on X22 and position 2 on X23 to select 4V operation	
	Switch the Bench PSU **ON**	
	Measure the voltage between “Htr1” and “Htr2” terminals on screw connector X45. The voltage should be about 4V, probably in the range 3.9 to 4.1 volts	
	If the 12V DC bench PSU has a current meter then it should read about 80mA	
	Switch the Bench PSU **OFF**	
	Move the jumpers to position 3 on X22 and position 3 on X23 to select 2.5V operation	
	Switch the Bench PSU **ON**	
	Measure the voltage between “Htr1” and “Htr2” terminals on screw connector X45. The voltage should be about 2.5V, probably in the range 2.4 to 2.6 volts	
	If the 12V DC bench PSU has a current meter then it should read about 80mA	
	Switch the Bench PSU **OFF**	
	Moving the jumper pins on X22 and X23 back to position 1 to select 6.3V heaters. This is the most commonly used setting and you might think of it as the “default” position for these jumpers.	
	Remove the jumper pin across jumper header X21 as the CRT heater PSU can be disabled for the next tests	

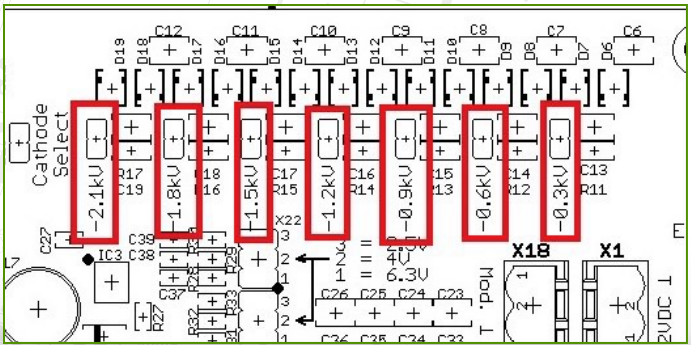
Testing the +HT supply and cathode voltage -EHT supply

These tests are made with the flyback converter enabled and therefore voltages from -2.1kV to +300V will be present on the board.

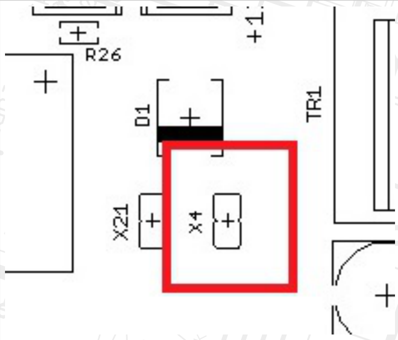
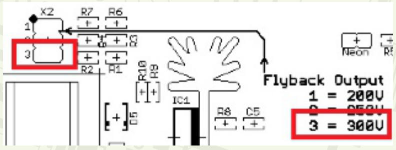
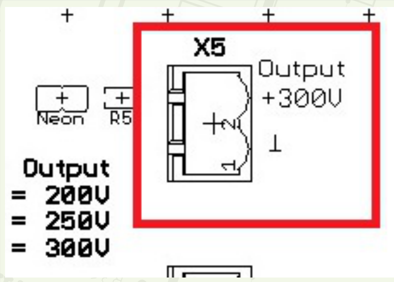
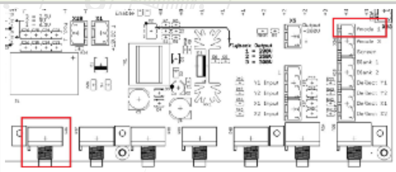
The +HT voltage is set by a single jumper pin fitted to the “Flyback Output” selector jumper header X2. This sets the voltage to either +200V, +250V or +300V. When the +HT voltage is varied the voltages down the -EHT multiplier chain, when enabled, are scaled accordingly:

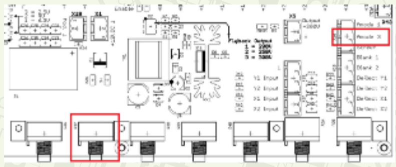
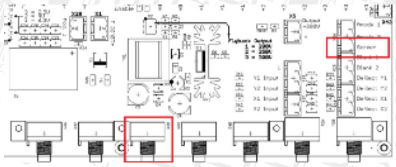
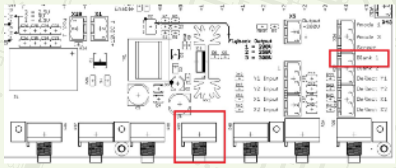
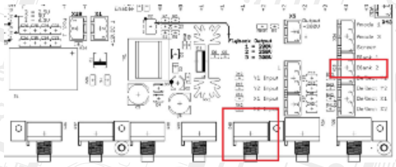
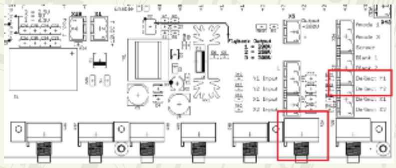
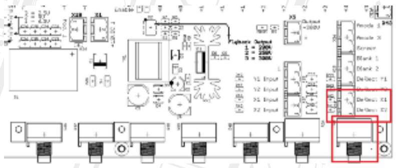
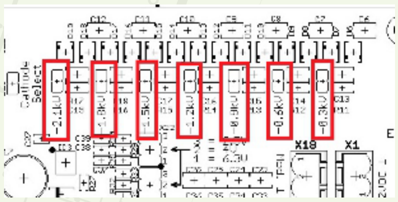
Position of “Flyback Output” selector jumper pin					
1		2		3	
					
+HT Voltage					
+200V		+250V		+300V	
-EHT voltages	**+EHT voltages**	**-EHT voltages**	**+EHT voltages**	**-EHT voltages**	**+EHT voltages**
-0.2kV	+0.4kV	-0.25kV	+0.5kV	-0.3kV	+0.6kV
-0.4kV	+0.6kV	-0.5kV	+0.75kV	-0.6kV	+1.2kV
-0.6kV	+0.8kV	-0.75kV	+1.0kV	-0.9kV	+1.5kV
-0.8kV	+1.0kV	-1.0kV	+1.25kV	-1.2kV	+1.8kV
-1.0kV	+1.2kV	-1.25kV	+1.5kV	-1.5kV	+2.1kV
-1.2kV	+1.4kV	-1.5kV	+1.75kV	-1.8kV	+2.4kV
-1.4kV	+1.6kV	-1.75kV	+2.0kV	-2.1kV	+2.7V
	+1.8kV		+2.25kV		+3.0V
	+2.0kV		+2.5kV		+3.3kV
	+2.2kV		+2.75kV		+3.6kV

The cathode and focus voltages are selected by using jumper wires to one of the jumper headers, referred to here as “take off points”, in the -EHT multiplier chain labelled “-0.3kV” down to “-2.1kV” on the board (and X6 to X12 on the schematic). The second purpose of this test is to check that the correct voltages appear along the -EHT multiplier chain.



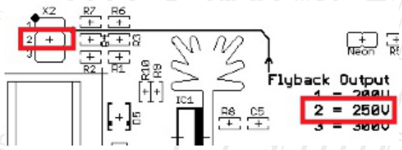
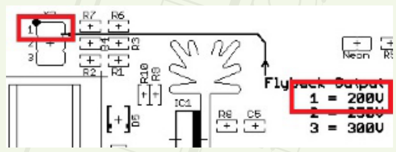
Carry out the following instructions ticking each off as completed successfully:

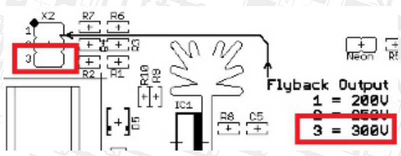
Tick	Instruction	Board Image
☐	Starting condition: • Jumper pin across position 1 on X22 • Jumper pin across position 1 on X23 (although the heater PSU is disabled) • No other jumper pins or jumper wires are fitted!	
☐	Set all the potentiometers to approximately mid-travel	
☐	Fit a jumper pin on jumper header X4 to enable the power to the flyback converter that power the -EHT multiplier chain, the +HT supply, the grid supply and, when enabled, the +EHT PDA multiplier supply	
☐	Fit a jumper pin to position 3 on the "Flyback Output" selector jumper header X2. This selects the +HT voltage at +300V	
☐	Switch the Bench PSU **ON**	
☐	The neon should **GLOW**	
	Check +HT	
☐	Measure the voltage on the "+300V Output" screw connector X5. It should be about +300V, probably in the range +295 to +305 volts	
☐	If the 12V DC bench PSU has a current meter then it should read about 230 mA	
	Check Acceleration Anode, Deflection etc. Output swings	
☐	Measure the voltage between the "Anode 1" on screw connector X26. Rotate the "Anode 1" potentiometer R36 and the output voltage should vary from 0V when fully anti-clockwise to +300V (actually the voltage measured on the +300V output screw connector) when fully clockwise	

Tick	Instruction	Board Image
	Repeat for the “Anode 3” screw connector output and its respective potentiometer	
	Repeat for “Screen” screw connector output and its respective potentiometer	
	Repeat for “Blank 1” screw connector output and its respective potentiometer	
	Repeat for “Blank 2” screw connector output and its respective potentiometer	
	Measure the voltage between the “Deflect Y1” and “Deflect Y2” screw connectors. Rotate the the “Deflect Y” potentiometer and the voltage should vary from -300V (or as noted previously) when fully anti-clockwise to +300V when fully clockwise	
	Repeat for the “Deflect X1” and “Deflect X2” screw connectors and the “Deflect X” potentiometer	
	<u>Check -EHT</u>	
	Measure the voltage between the “-0.3kV” header and ground (such as the 12VDC negative lead connected to connector X1). It should be about -300V	
	Go down the multiplier chain, measuring the voltage at each take off point noting the voltage drops by -300V at each take off point. So you should read about -600V, -900V … down to -2100V. You need a suitable multimeter or a multimeter equipped with an EHT probe!	
	<u>Safe Shut Down Procedure</u>	
	Switch the Bench PSU **OFF**. The neon will extinguish after a few seconds.	
	Wait about a minute and measure the +HT voltage on the +300V Output screw connector X5. It should be very low < 10 volts	

Tick	Instruction	Board Image
	Measure the voltage on the “-2.1kV” take off point on -EHT multiplier chain and check that it is very low < 10V	

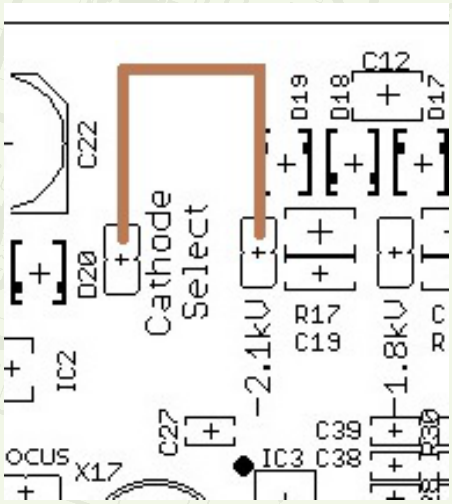
With measurements and experience you will be able to determine how long it takes for the voltages on the board to drop to a safe level. For now exercise caution!

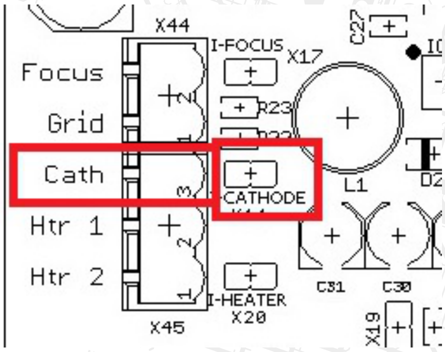
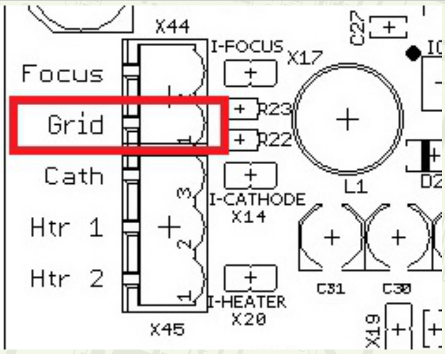
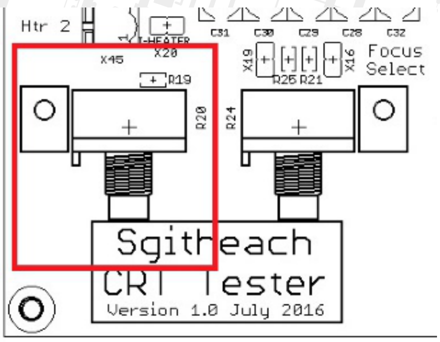
Tick	Instruction	Board Image
	Move the jumper pin to position 2 on the “Flyback Output” selector jumper header X2. This selects the +HT voltage at +250V	
	Switch the Bench PSU **ON**	
	The neon should **GLOW** (slightly dimmer than before)	
	Check +HT	
	Measure the voltage on the “+300V Output” screw connector X5. It should be about +250V, probably in the range +245 to +255 volts	
	If the 12V DC bench PSU has a current meter then it should read about 160 mA	
	Optional: Repeat the potentiometer swing tests and -EHT voltage multiplier chain voltages noting that the measurements are scaled to -250V steps	
	Switch the Bench PSU **OFF**. The neon will extinguish after a few seconds	
	Use the safe shut down procedure as above	
	Move the jumper pin to position 1 on the “Flyback Output” selector jumper header X2. This selects the +HT voltage at +200V	
	Switch the Bench PSU **ON**	
	The neon should **GLOW** (even dimmer than before)	
	Check +HT	
	Measure the voltage on the +300V Output screw connector X5. It should be about +200V, probably in the range +195 to +205 volts	
	If the 12V DC bench PSU has a current meter then it should read about 120 mA	
	Optional: Repeat the potentiometer swing tests and the -EHT voltage multiplier chain voltages noting that the measurements are scaled to -200V steps	

Tick	Instruction	Board Image
☐	Switch the Bench PSU **OFF.** The neon will extinguish after a few seconds.	
☐	Use the <u>safe shut down procedure</u> as above	
☐	Move the jumper pin to position 3 on the “Flyback Output” selector jumper header X2. This selects the +HT voltage at +300V. This is the most commonly used position and corresponds to the +HT, -EHT and +EHT voltages on the silkscreen so it is considered the default position for jumper header X2.	

Testing the Grid power supply.

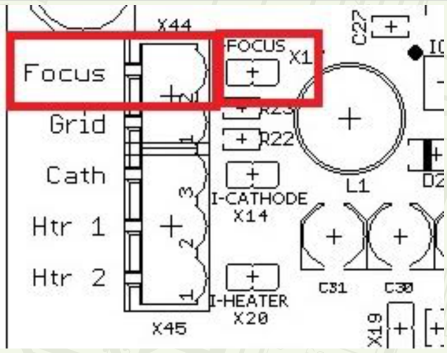
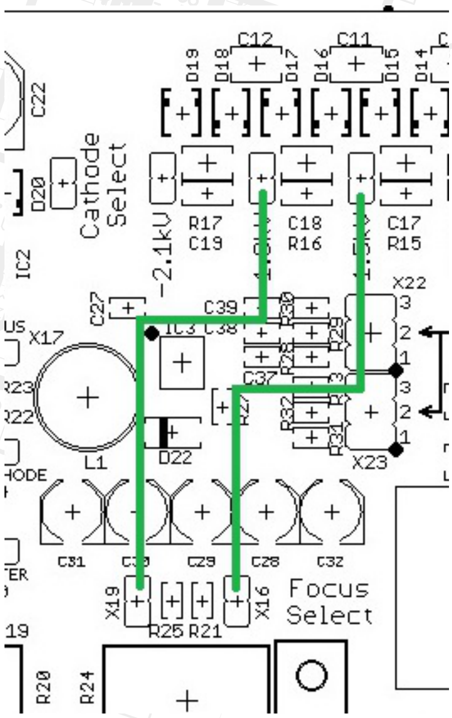
Carry out the following instructions ticking each off as completed successfully.

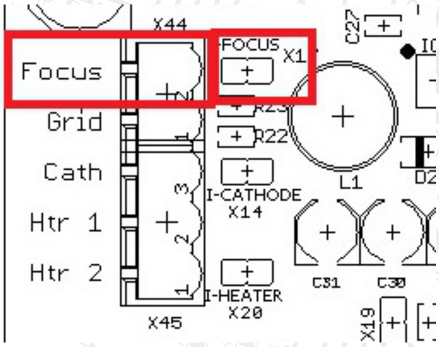
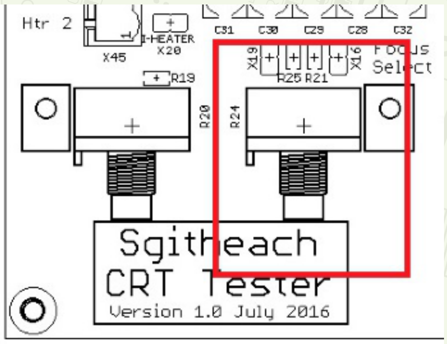
Tick	Instruction	Board Image
☐	<u>Starting condition:</u> • Jumper pin across position 1 on jumper header X22 • Jumper pin across position 1 on jumper header X23 (although the heater PSU is disabled) • Jumper pin across position 3 of jumper header X2 (selects +300V flyback output) • Jumper pin across jumper header X4 (flyback enabled) • No other jumper pins or jumper wires fitted!	
☐	Fit the brown jumper wire from the “-2.1kV” -EHT multiplier take off point to the “Cathode Select” header near D20 (labelled X15 on the schematic)	

Tick	Instruction	Board Image
	Fit a jumper pin to the cathode current monitoring point jumper header (labelled “I-CATHODE” X14) to supply the cathode voltage to screw connector X45	
	Switch the Bench PSU **ON**	
	The neon should **GLOW**	
	Measure the voltage between the cathode screw terminal “Cath” on X45 and the “Grid” screw terminal on X44.	
	Swing the “Brightness” potentiometer R20 and note that the voltage varies from about -120V fully anti-clockwise to about -5V fully clockwise. The exact voltages you get at each end of the travel of potentiometer R20 may vary from these limits as the potentiometer resistance value tolerance is only 10%. The range you get should provide enough voltage swing to fully blank the CRT beam and to allow a bright spot to be developed in most, if not all, CRTs.	
	Switch the Bench PSU **OFF**. The neon will extinguish after a few seconds.	
	Use the safe shut down procedure as above	
	Leave all jumper pins and jumper wire in their current positions	

Testing the Focus Anode (Anode 2) Supply

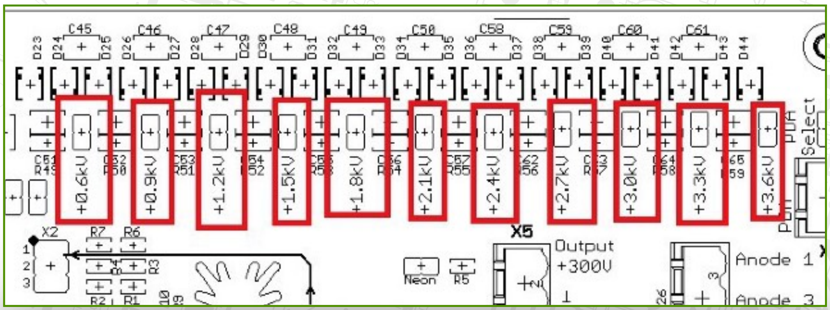
Carry out the following instructions ticking each off as completed successfully.

Tick	Instruction	Board Image
	Starting condition: • Jumper pin across position 1 on jumper header X22 • Jumper pin across position 1 on jumper header X23 (although the heater PSU is disabled) • Jumper pin across position 3 of jumper header X2 (selects +300V flyback output) • Brown jumper wire between the Cathode Select and -2.1kV -EHT multiplier take off point • The I-CATHODE jumper header X14 jumper pin in place • No other jumper pins or wire jumpers fitted!	
	Fit a jumper pin to the focus current monitoring point jumper header (labelled “I-FOCUS” X17) to supply the focus anode voltage to screw connector X44	
	Fit a green/grey jumper wire from the -1.8kV take off point on the -EHT multiplier chain to the “Focus Select” connector jumper header X19, selecting the pin which is closest to the -EHT multiplier chain.	
	Fit a second green/grey jumper wire from the -1.5kV take off point on the -EHT multiplier chain to the “Focus Select” connector jumper header X16, selecting the pin which is closest to the -EHT multiplier chain.	

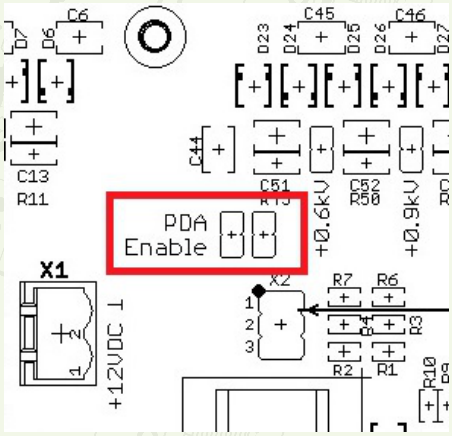
Tick	Instruction	Board Image
	Switch the Bench PSU **ON**	
	The neon should **GLOW**	
	Measure the voltage between the cathode screw terminal "Cath" on X45 and the "Focus" screw terminal on X44	
	Swing the "Focus Anode 2" potentiometer R24 and note that the voltage varies from about 380V fully anti-clockwise to about 460V fully clockwise. The exact voltages you get at each end of the travel of potentiometer R24 may vary from these limits as the potentiometer resistance value tolerance is only 10%. This test just illustrates the focus control in operation. as the actual voltage swing is selected using the wire jumpers on the -EHT voltage multiplier take off points and the connections made to the positions available on jumper headers X16 and X19. These choices are examined in detail in the Operations Manual.	
	If the 12V DC bench PSU has a current meter then it should read about 230 mA as before	
	Switch the Bench PSU **OFF**. The neon will extinguish after a few seconds.	
	Use the safe shut down procedure as above	
	Leave all jumper pins and jumper wires in their current positions	

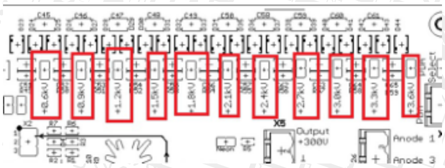
Testing the +EHT Supply

The purpose of these tests is to check the +EHT multiplier chain used to supply high voltages to a given CRT's PDA electrode (if present).



Carry out the following instructions ticking each off as completed successfully.

Tick	Instruction	Board Image
	Starting condition: • Jumper pin across position 1 on jumper header X22 • Jumper pin across position 1 on jumper header X23 (although the heater PSU is disabled) • Jumper pin across position 3 of jumper header X2 (selects +300V flyback output) • Jumper pin across X4 (flyback enabled) • Brown jumper wire between the Cathode Select jumper header and -2.1kV -EHT multiplier take off point • The I-CATHODE X14 jumper pin in place • Grey/green jumper wires in place between the -1.8kV take off point on the -EHT multiplier chain to the "Focus Select" connector jumper header X19 and between the -1.5kV take off point on the -EHT multiplier chain to the "Focus Select" connector jumper header X16, selecting the pin which is closest to the -EHT multiplier chain in both cases. • No other jumper pins or wire jumpers fitted!	
	Fit a jumper pin to the two "PDA Enable" jumper headers (X29 and X30 on the schematic) to enable the +EHT multiplier.	
	Switch the Bench PSU **ON**	
	The neon should **GLOW**	
	If the 12V DC bench PSU has a current meter then it should read about 330 mA	

Tick	Instruction	Board Image
☐	Measure the voltage between the “+0.6kV” take off point jumper header and ground (such as the 12VDC negative lead connected to connector X1). It should be about +600V	
☐	Go up the multiplier chain, measuring the voltage at each take off point noting the voltage increases by +300V at each take off point. You should read about +900V, +1.2kV … up to +3.6kV. You need a suitable multimeter or a multimeter equipped with an EHT probe. You may find the 300V increment drops off as you reach the end of the multiplier chain as the losses become significant. Typically you might find +3.5kV on the +3.6kV take off point.	
☐	Switch the Bench PSU **OFF**. The neon will extinguish after a few seconds.	
☐	Use the safe shut down procedure as above	
☐	Optional: Repeat the test with jumper pin moved to across position 2 of jumper header X2 (selects +250V flyback output) and note the scaled +EHT voltages	
☐	Optional: Repeat the test with jumper pin moved to across position 1 of jumper header X2 (selects +200V flyback output) and note the scaled +EHT voltages	
☐	If you have carried out either or both of these optional tests then move the jumper pin on jumper header X2 back to position 3 (selects +300V flyback output)	

At this point I recommend removing the two +EHT “PDA Enable” jumper pins so that the +EHT multiplier chain is not left enabled by accident for the next tests.

Optional: Testing with a CRT

At this point all of the voltages have been checked to be within approximate limits. I think that it is now worth checking the CRT Tester with a real CRT.[24] However, I can only illustrate the CRT Tester in use as it depends on the actual CRTs you have to hand. I'm going to use the commonly available 50mm diameter American 2BP1 CRT in this worked example. You may now have to switch to the Operations Manual section to work out the correct set up for a CRT that you choose to use.

N.B. The 2BP1 CRT, the CRT base and the connecting wires from the base to the CRT Tester are not part of the kit!

First look at the data sheet for the 2BP1[25]:

Key information is:

- 6.3V 0.6A heater
- Operating conditions give for Anode 3 (CRT Tester name) at 1kV (and 2kV) (Grid 2/Anode 2 on the data sheet)
- Grid voltage at -67.5V maximum (Grid No. 1 on the data sheet)
- Focus Anode 2 (CRT Tester name) voltage range 150 - 280V (Anode 1 on the data sheet)
- Small-shell duodecal 12-pin12E base with pin connections given

This data sheet illustrates a problem commonly found with CRT data sheets which is that CRT manufacturers often name the electron gun electrodes differently! It is important that you work out the function of each electrode to map it to the correct CRT Tester connection. For example, if you were to simply connect the named 2BP1 data sheet Anode 2 to the CRT Tester Anode 2 connection and connect the named 2BP1 data sheet Anode 1 to the CRT Tester Anode 1 connection the CRT would simply not fire up correctly, if at all. It might even be damaged (see Table below).

Data Sheet Connection	CRT Tester Connection
Heater	Heater
Cathode	Cathode
Grid No. 1	Grid
Anode 1	Anode 2
Grid No. 2/Anode No. 2	Anode 3 (Anode 1 is connected internally)
Deflecting Electrode	Deflection Plate

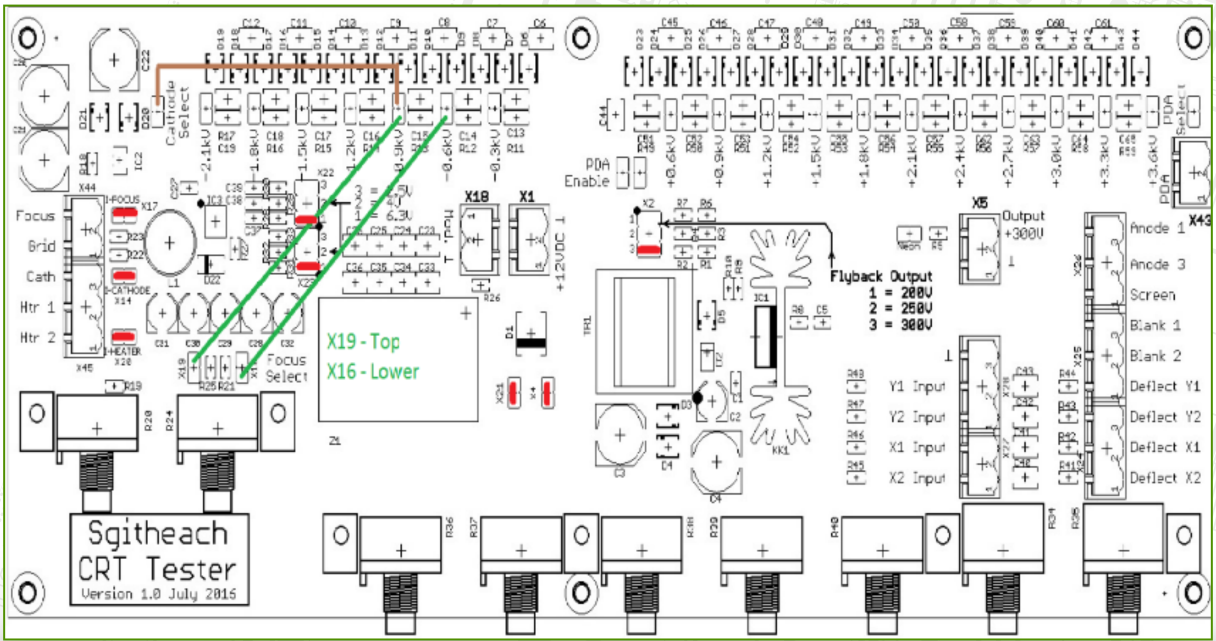
I will use the +300V "Flyback Output" position 3 and the 6.3V heater option by selection position 1 on X22 and X23.

The nominal Anode 3 voltage is 150V (the mean deflection plate voltage for an undeflected spot and half of the 300V flyback HT voltage) to ground. To get a difference of 1kV between the cathode and Anode 3 means the cathode needs to be at -850V, therefore I will use the -0.9kV take off point as the closest. I will connect one end of the focus potentiometer to the tap that the cathode is using (-0.9kV) and include the 1M resistor and connect the other end of the focus

[24] This is after all the whole point of the device….
[25] https://frank.pocnet.net/sheets/049/2/2BP1.pdf

potentiometer to the -0.6kV take off point. This will give a voltage range of 150 - 300V for the focus anode relative to the cathode.

The 2BP1 has no PDA electrode, so the PDA will not be enabled and the “PDA Enable” jumper are both left open. The 2BP1 does not have a separate Anode 1, or Screen or use Deflection Blanking - so these connections are all left unused. A small-shell duodecal 12-pin 12E CRT base is wired to connect the grid, cathode, two heater connections, focus Anode 2, Anode 3 and the four deflection plates.



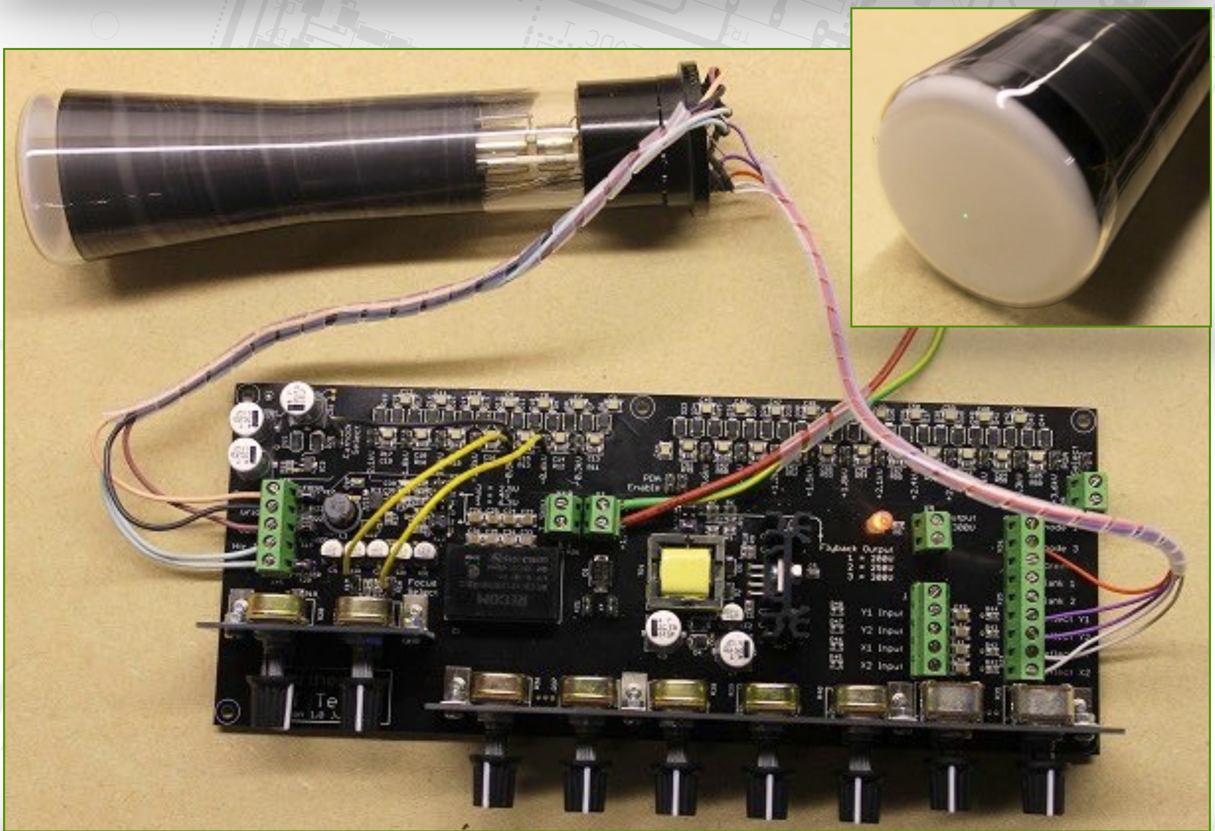


Photo 9: An unenclosed CRT tester and 2BP1 CRT giving a nicely focused spot!

Some experimentation with the Anode 3 voltage, which effects the spot astigmatism, improved the spot shape.

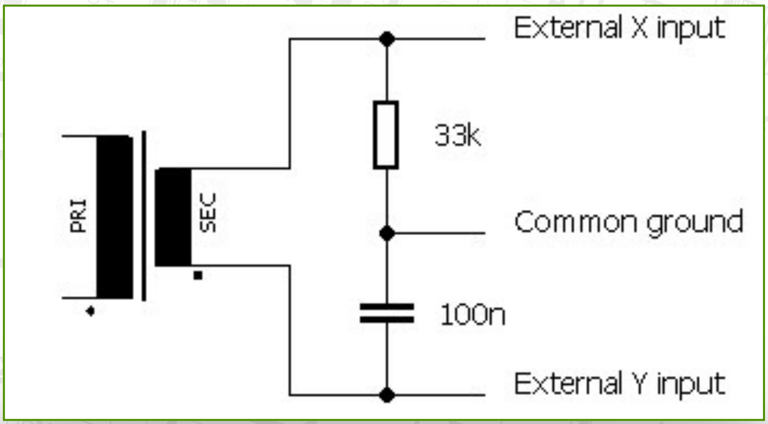
It is then possible to reconfigure the jumper wires to connect the "Cathode Select" to the -1.8kV take off point. This together with the 150V Anode 3 voltage makes the tube operate at 1.95kV or very close to the second operating point on the data sheet of 2kV.

I made some measurements:

Anode 3 voltage	1050V	1950V
Grid voltage for a barely visible spot relative to the cathode	-43V	-78V
Anode 2 voltage for good focus relative to the cathode	230V	413V
Deflection of spot to the tube edge: (difference between plate voltages):		
X	108V	174V
Y	62V	125V

Extra Credit: Circular beam deflection and modulation

So far the tests have just manipulated the spot manually - brightness, focus and position. Now I want to try applying waveforms to the X and Y deflection plate inputs and the beam modulation (Z axis) input.[26]



For this I'm going to use an old trick[27] of using an AC transformer output, a resistor and a capacitor to achieve a 90° phase shift:

The phase shift will be 90° when the reactance of the capacitor equals the value of the resistor. Therefore, for me in the UK, at 50Hz:

$$\text{Reactance} = \frac{1}{2 \times \pi \times f \times C} = \frac{1}{2 \times \pi \times 50 \times 1e^{-7}} = 31800 \text{ ohms}$$

So a 33k standard resistor is about right. Use a 27k standard resistor in 60Hz lands. The transformer has a 50V RMS secondary but a wide range of secondary voltages will produce a useable display:

Photo 10: Sine and cosine waves applied to the X and Y deflection plate connections

[26] Using additional parts and equipment that are not part of the kit.
[27] Older than me anyway…..The Oscilloscope Book E.N. Bradley First published 1951.

Finally, I can apply a 10V square wave from a bench signal generator to the external beam modulation input connector X18 which causes the beam to brighten on the positive half cycles. I this case the signal generator was set to 300Hz, six times my 50Hz mains frequency. Again this was an old technique to determine an unknown frequency which is a fairly near the ratio of the local mains frequency.

Photo 11: 300 Hz square wave beam modulation!

Many CRTs available on eBay do not have their respective bases and the correct ones are nearly impossible to find. Many modern CRT bases use pins that are about 1mm in diameter so pin receptacles (commonly available on eBay) can be used to make a flexible cable assembly.

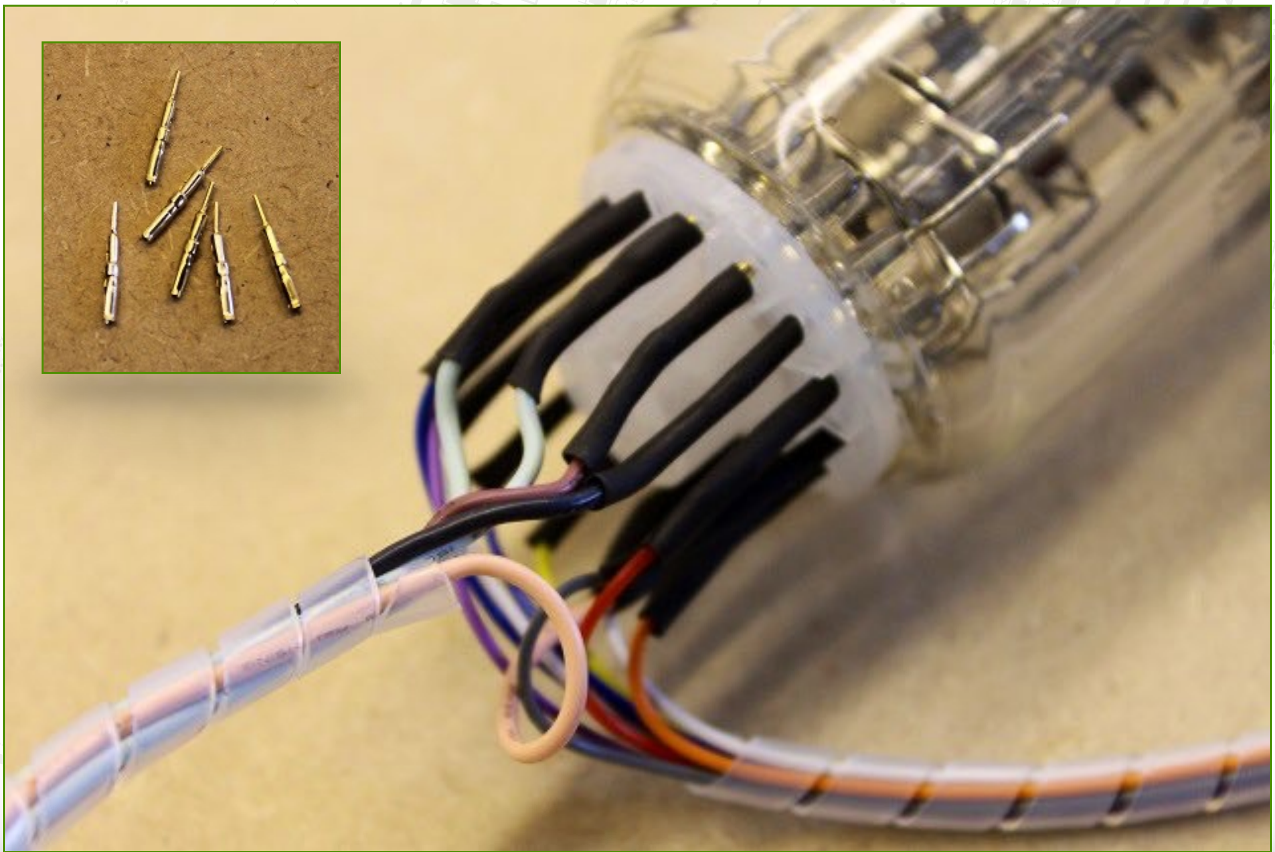


Photo 12: A flexible but temporary CRT base using 1mm I.D. pins readily available on eBay etc (pins illustrated top left).

Annex 1 - Detailed Parts Lists

This parts list is provided for anyone buying the minimum kit to help source the components.

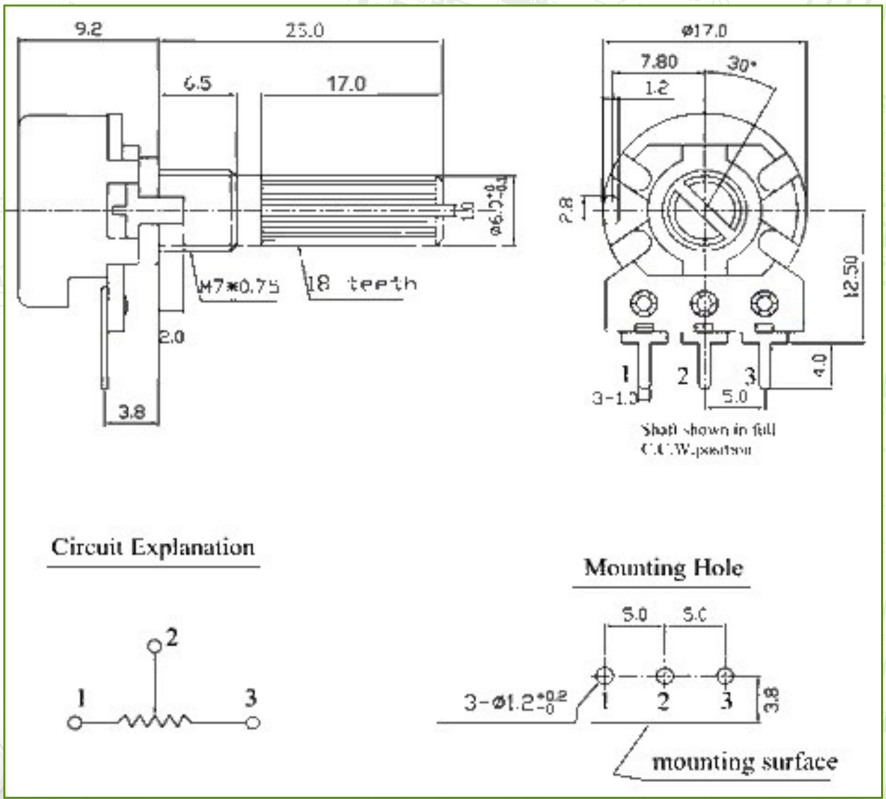
Quantity	Part	Value	Other Value	Package	Notes	Source	Order Code
1	C1	100n	25V	SMD 0805		Farnell	2496943
1	C2	100u	25V	PANASONIC D		Farnell	1539488
5	C3, C4, C20 - C22	4u7	400V	PANASONIC G		Farnell	2326350
1	C5	470n	25V	SMD 0805		Farnell	2497003
36	C6 - C19, C44 - C65	47n	400V	SMD 1210		Farnell	1890491
12	C23 - C26, C33 - C36, C40 - C43	100n	630V	SMD 1210		Farnell	211118
1	C27	10n	50V	SMD 0805		Farnell	1759246
4	C28 - C31	22u	25V	PANASONIC D		Farnell	969670
1	C32	470u	6.3V	PANASONIC D		Farnell	2065955
1	C37	180p	50V	SMD 0805	A	Farnell	1709047
1	C38	270p	50V	SMD 0805	A	Farnell	1709081
1	C39	560p	50V	SMD 0805	A	Farnell	1710257
1	D1	S3A	50V 3A	SMC		Farnell	7277970
1	D2	SMP18A	18V 400W	DO-220		Farnell	1812530
41	D3 - D21, D23 - D44	US1G-E3/5AT		SMA		Farnell	9551824
1	D22	B330A-13-F		DO214AC		Farnell	1843685
1	IC1	LM2588-ADJ		TO-220-7		Farnell	9493719
1	IC2	LR8		SOT89R		Farnell	2448526
1	IC3	SI8005Q		HSOP8	B	Digikey	
1	KK1	SK104		38mm tall		Farnell	1892327
1	L1	10uH	2.8A	CHOKE-11D		Farnell	2309742
1	Ne1	Neon				Farnell	1139247
1	Ne1	Spacer		5mm dia. 3mm tall		Farnell	9555137
1	R1	120k		SMD 0805		Farnell	9332510
1	R2	180k		SMD 0805		Farnell	9332731
2	R3, R32	33k		SMD 0805		Farnell	9333053
1	R4	220k		SMD 0805		Farnell	9332839
1	R5	270k		SMD 0805		Farnell	9332960
3	R6, R9, R23	22k		SMD 0805		Farnell	9332820
1	R7	180k		SMD 0805		Farnell	9332731
1	R8	3k3		SMD 0805		Farnell	9333045
1	R10	1k2		SMD 0805		Farnell	9332499
18	R11 - R17, R48 - R59	3M3	400V	SMD 1206		Farnell	1576224
1	R18	10k		SMD 0805		Farnell	9332391
2	R19, R30	27k		SMD 0805		Farnell	9334270
2	R21, R25	1M	400V	SMD 0805		Farnell	1506149
1	R22	470k		SMD 0805		Farnell	9333282
7	R20, R24, R36 - R40	1M			D	Ebay	
1	R26	4M7		SMD 0805		Farnell	2352630
1	R27	4k7		SMD 0805		Farnell	9333266
1	R28	82k		SMD 0805		Farnell	9333592
1	R29	47k		SMD 0805		Farnell	9333274
1	R31	56k		SMD 0805		Farnell	9333380
1	R33	18k		SMD 0805		Farnell	9332723
2	R34, R35	1M	dual gang		D	Ebay	
4	R45 - R48	4M7	400V	SMD 0805		Farnell	2352630
4	R41 - R44	470k	400V	SMD 0805		Farnell	2352624
1	TR1	Q1396-01	Custom made			Sgitheach	
6	X1, X5, X18, X27, X43, X44	SCREW2		MC000048		Farnell	2008019
3	X2, X22, X23	HEADER2X3		HEADER2X3		Ebay	
30	X3, X4, X6 - X21, X29 - X42	HEADER1X2		HEADER1X2		Ebay	
5	X24 - X26, X28, X45	SCREW3		MC000049			2008020
1	Z1	REC6-12-12SRW/R8/C			E	Digikey	
1	PCB					Sgitheach	
9	Knobs					Ebay	
6	Brackets	14.86.313				Farnell	1466883
1	M3 nuts, washers, bolts. Heat shrink tube, crimp pins, 3kV rated wire				C	Ebay etc	

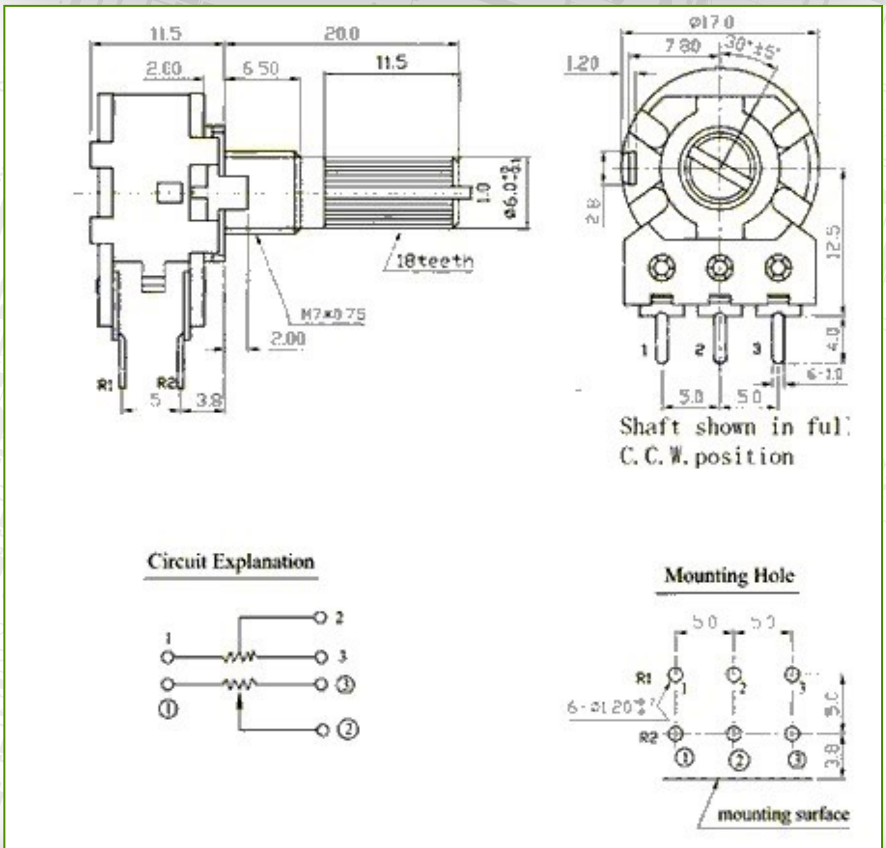
Notes

A	Actually bought on Ebay to avoid high postage cost to the UK from USA
B	Digikey order code SI-8005Q-TL - Sanken SI-8005Q-TLCT-ND
C	M3 nuts, bolts washers, pot shaft insulators etc.
D	McManager
E	REC6-1212SRW/R8/C-ND

Annex 2 - Potentiometer Dimensions

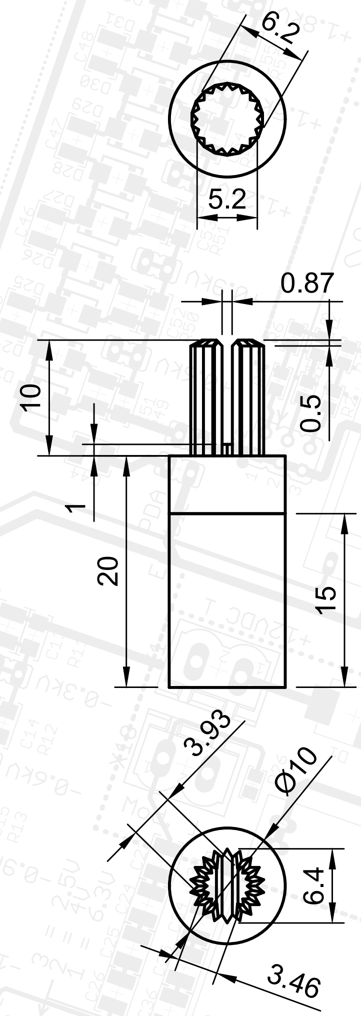
The potentiometers must have specific dimensions to fit the boards.





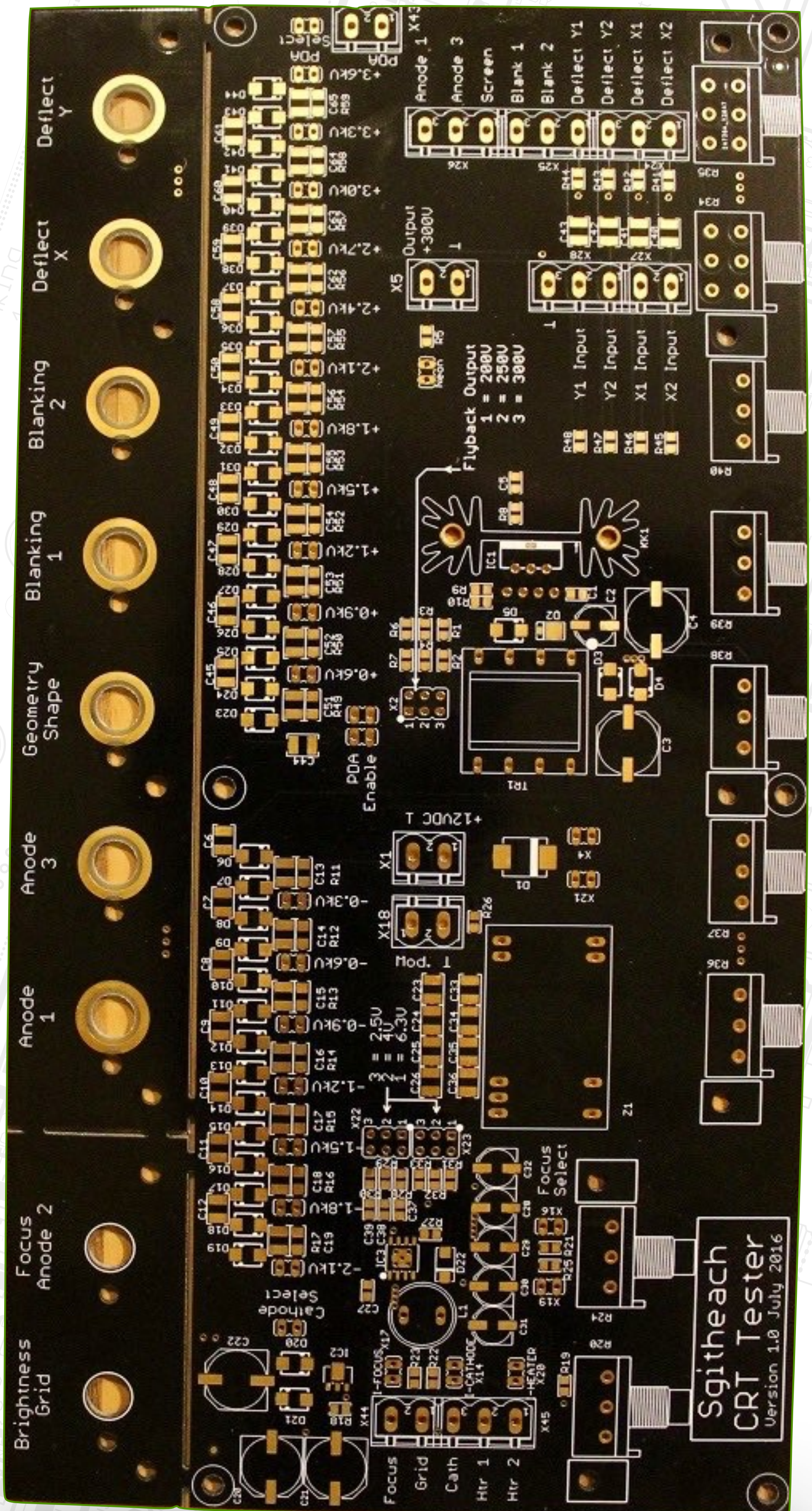
Annex 3 - Brightness and Focus potentiometer insulated shafts

These shafts insulate and space the brightness and focus control shafts which may be at near the cathode voltage, possibly -2.1kV to true ground. Made from a non-conductive material.

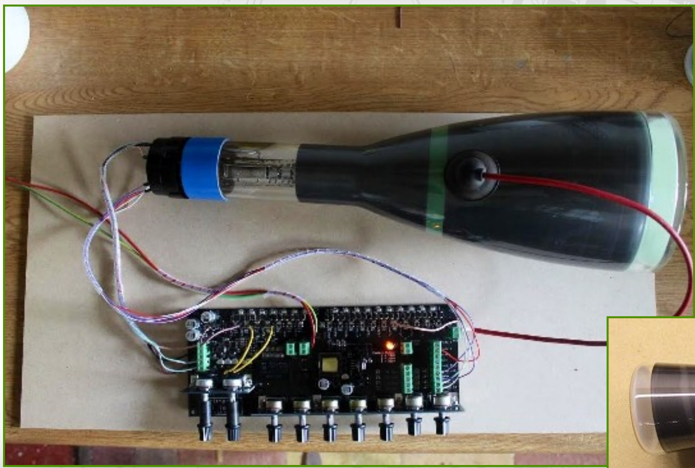


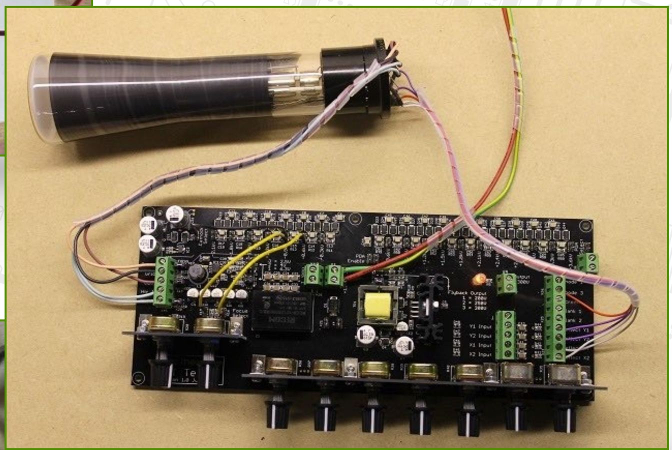
Dept.	Technical reference	Created by	Approved by
		Grahame Marsh 30/01/2017	
		Document type	Document status
		Title: CRT Tester Pot Extension A	DWG No.
			Rev. / Date of issue / Sheet 1/1

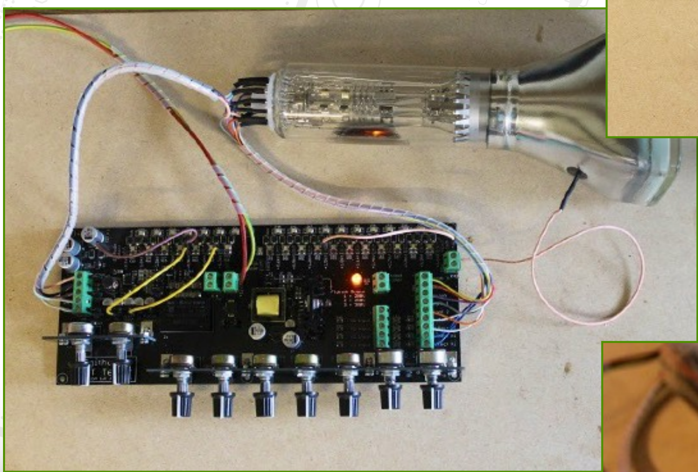
Annex - 4: Bare PCB



Operations Guide for an Electrostatic Deflection Cathode Ray Tube Tester







How to Safely and Effectively You Your CRT Tester

Operations Guide

The construction and testing manual is meant to be used once only as you build and commission the CRT Tester. This manual provides a reference to the key control information once the CRT is operating.

A Safety Reminder

During use there will be present voltages on the CRT Tester and CRT that will give a nasty shock and are potentially lethal. I cannot be held responsible for any accident or injury resulting from performing using the CRT Tester. Using the CRT Tester implies that you agree with these conditions. The board has many capacitors that will remain charged for some time after power is removed from the board.

When you have switched off the power to the board you should wait several minutes for the charge to be dissipated.

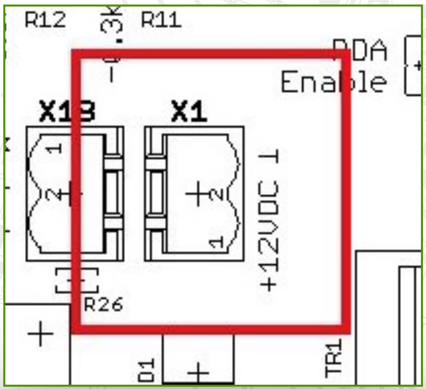
In many cases you may be making measurements using a multimeter of voltages that are low (say 6.3V) but also very high (up to 4kV) with respect to true ground potential.

If you are uncertain, then connect your multimeter with the board unpowered, power up the board and note the reading, remove power from the board and then wait a few minutes for the capacitors to discharge.

Do not rely entirely on the neon bulb being unlit. It only monitors the +HT voltage and it only shows that the voltage has dropped below its sustaining voltage. The neon does not indicate any charge on the -EHT, +EHT multipliers or the grid power supply.

Power Requirements

A 12V 1.5A DC regulated power supply should be connected to X1, the 12V DC screw terminals. Note polarity of the wires![28]



The power supply should not be an isolated type but the negative lead should be connected to mains/line ground/earth. The power supply should be plugged into a correctly grounded/earthed mains/line outlet.

Details of a custom power supply that can be built for the tester are presented in a section of this manual.

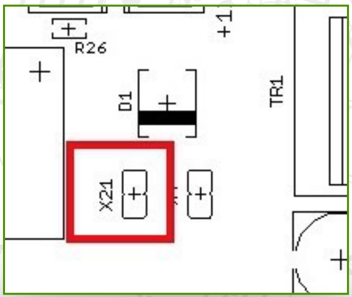
[28] There is an idiot diode on the board….

Selecting the Heater Power Supply Operation

The CRT heater power supply is limited to about 5.5W DC output. It is suitable for supplying a wide variety of CRTs. For example:

- 2.5V 2A (5W)
- 4.0V 1A (4W)
- 6.3V 0.6A (3.8W)

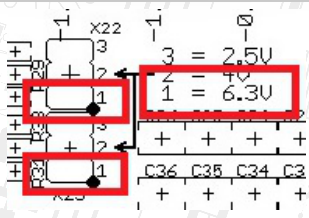
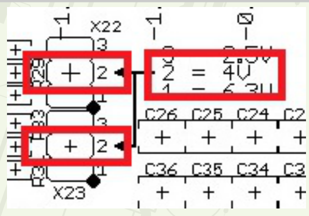
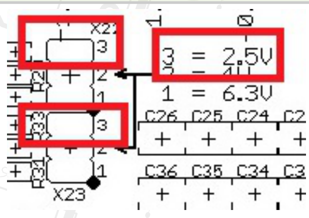
Heater Power Supply Enable



The CRT heater power supply is enabled by fitting a jumper pin to jumper header X21.

Heater Power Supply Voltage Selection

The CRT heater power supply output voltage is set using jumper headers X22 and X23 as follows:

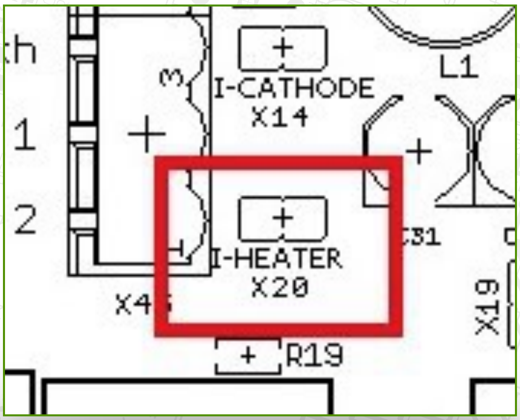
Voltage Required	Jumper pin position - X22	Jumper pin position - X23	Board Images
6.3V	1	1	
4V	2	2	
2.5V	3	3	

It is recommended that jumpers are always left in one of the positions on X22 and the corresponding position on X23. If you wish you might consider 6.3V a "default" setting as it is the most common heater voltage found.

Under **<u>no circumstances</u>** should more than one jumper pin be fitted to X22 or to X23.

CRT Heater current monitoring point

If you wish, the current into the CRT heater can be monitored by connecting a suitable panel meter to I-HEATER X20. Such a panel meter must be rated for operation at the cathode potential of -2.1kV.[29]

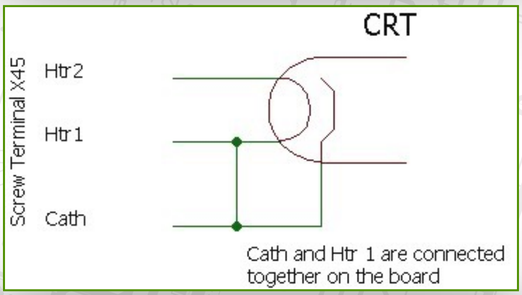


If a panel meter is not used then the jumper header X20 must be closed using a header pin.

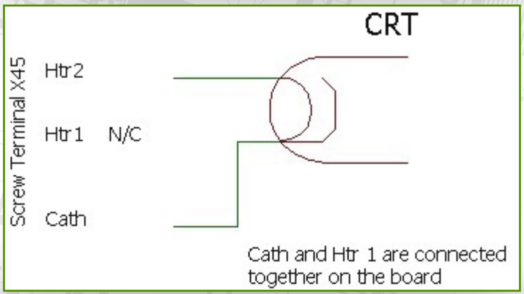
CRT Heater connection

N.B. the Cathode and Htr 1 connections on the board are connected together.

The CRT heater is connected to the Htr1 and Htr2 connections on screw terminal X45. Most CRTs have separate pin connections to the heater and cathode. The Htr1 and Htr2 connections on X45 are connected using suitable wire[30] to the CRT heater pins.

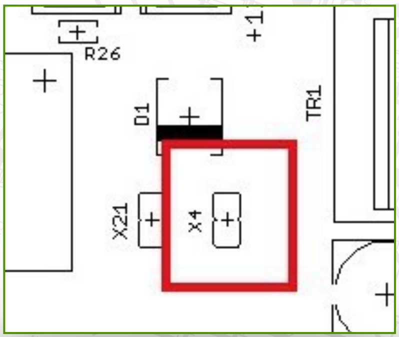


Some CRTs have the cathode and one side of the heater connected together internally[31]. In this case the Htr2 connection on X45 must be used to supply the CRT heater only pin, the Htr 1 connection on X45 can be left unconnected and the common heater/cathode connection made to the Cath connection on X45:



[29] This makes many modern LED or LCD based meters unsuitable, so use an old style moving coil meter!
[30] See Annex B
[31] This saves a pin on the CRT base..

Selecting the flyback converter +HT voltage and -EHT/+EHT step voltage



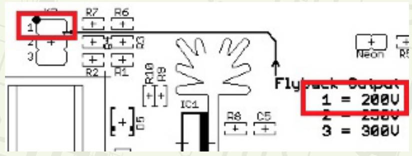
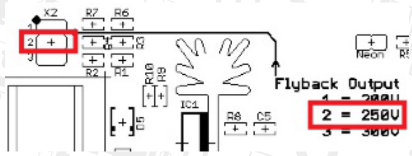
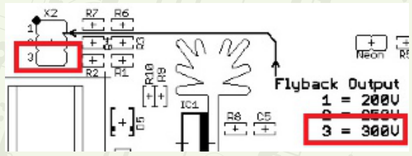
Enabling the flyback converter

The flyback converter is enabled[32] by fitting a jumper pin to jumper header X4:

When you have the board connected to a 12V DC power supply and the flyback converter enabled then the neon will **glow** to warn you.

Selecting the flyback output +HT voltage

The flyback converter can be set to have an output voltage of 200V, 250V or 300V by the position of a jumper pin on jumper header X2 as follows:

Desired +HT Voltage	Jumper position on X2	Board Images
200V	1	
250V	2	
300V	3	

A jumper pin must always be fitted to one of the 3 positions on X2. Under **no circumstances** should more than one jumper pin be fitted to X2.

The flyback converter also generates the -EHT and, if enabled, +EHT multiplier chains. The steps in the multipliers are set in proportion to the flyback converter +HT voltage selected. The board is only marked with the +300V settings:

[32] If you are just testing the heater of a CRT, it is safer not to enable the flyback converter so you then know that low voltages < 12V DC are present on the board.

Flyback Output +HT Voltage					
+200V		+250V		+300V	
-EHT voltages	**+EHT voltages**	**-EHT voltages**	**+EHT voltages**	**-EHT voltages**	**+EHT voltages**
-0.2kV	+0.4kV	-0.25kV	+0.5kV	-0.3kV	+0.6kV
-0.4kV	+0.6kV	-0.5kV	+0.75kV	-0.6kV	+1.2kV
-0.6kV	+0.8kV	-0.75kV	+1.0kV	-0.9kV	+1.5kV
-0.8kV	+1.0kV	-1.0kV	+1.25kV	-1.2kV	+1.8kV
-1.0kV	+1.2kV	-1.25kV	+1.5kV	-1.5kV	+2.1kV
-1.2kV	+1.4kV	-1.5kV	+1.75kV	-1.8kV	+2.4kV
-1.4kV	+1.6kV	-1.75kV	+2.0kV	-2.1kV	+2.7V
	+1.8kV		+2.25kV		+3.0V
	+2.0kV		+2.5kV		+3.3kV
	+2.2kV		+2.75kV		+3.6kV

Which output voltage to use is discussed next.

A “low voltage PDA” is perhaps an oxymoron - although I have included the +EHT voltages for operation at +200V and +250V it is most unlikely they would be used as CRTs with a PDA are invariably high voltage tubes and you would use the +300V operating condition.

Selecting the Cathode Operating Voltage

Calculating the required cathode voltage

You should inspect the CRT data sheet[33] for a recommended final acceleration anode[34] voltage (in terms of this CRT tester, this is referred to as “Anode 3” but data sheets will often number it differently). Let this voltage (which is relative to the cathode) be V_{a3}.

The connection to Anode 3 and the other electrodes is discussed later.

You now need to decide on the flyback output +HT voltage. This is a bit of a suck-and-see choice but in general CRTs requiring < 1kV on anode 3 will best be operated at either +200V or +250V flyback output voltage. You may find other limitations in the data sheet that require lower operating voltages. The majority of CRTs will probably work fine at the +300V setting. Let this voltage be V_{+HT}.

The CRT tester operates using potentiometer to divide the flyback +HT voltage for the electron gun anodes (other than the focus anode), deflection plates, any screen etc. A nominal position for these potentiometers is half way so the voltage will be (V_{+HT} / 2).

The required cathode operating voltage can now be calculated

$$V_{cath} = (V_{+HT}/2) - V_{a3}.$$

For example, the 2BP1[35] CRT has an example working voltage of V_{a3}[36] = 2000V so operating the flyback converter at +300V output voltage gives

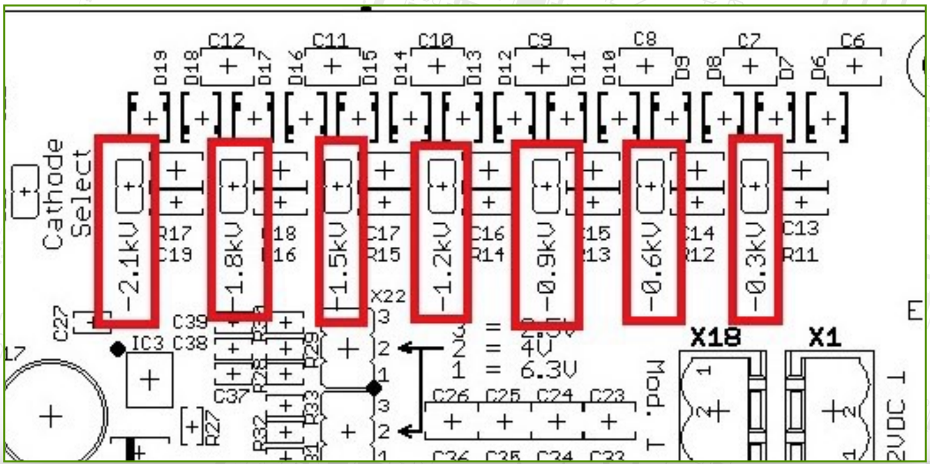
$$V_{cath} = (300/2) - 2000 = -1850V$$

Inspecting the available -EHT voltages shown in the table above shows that the nearest take-off point is at -1.8kV.

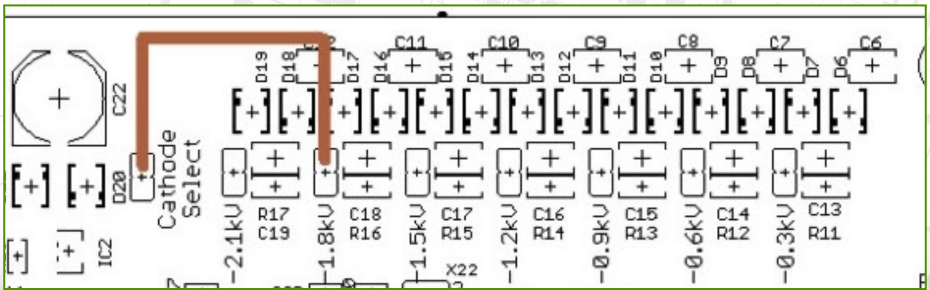
[33] You have got the CRT data sheet right? If you don’t then you’re on your own…..
[34] The anode in the electron gun immediately in front of the deflection plates. Not any PDA voltage.
[35] http://www.mif.pg.gda.pl/homepages/frank/sheets/049/2/2BP1.pdf - Thank you Frank…
[36] The 2BP1 data sheet calls this “Anode No. 2”.

Selecting the cathode voltage take-off point

The -EHT multiplier chain has a jumper header as a take-off point at each step:

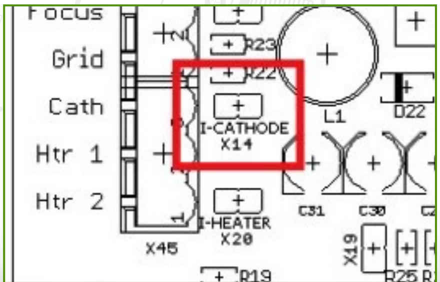


The selected take-off point can be linked using a jumper wire to the cathode select jumper header:



Under **no circumstances** should more than one jumper wire be fitted between a -EHT take-off point and the Cathode Select jumper header. Under **no circumstances** should any of the -EHT take-off points be connected together!

CRT Cathode current monitoring point



If you wish, the current into the CRT cathode can be monitored by connecting a suitable panel meter to I-CATHODE X14. Such a panel meter must be rated for operation at the cathode potential of -2.1kV.[37]

If a panel meter is not used then the jumper header X14 must be closed using a header pin.

CRT Cathode connection

The Cath connection on X45 is connected using suitable wire[38] to the CRT cathode pin.

[37] This make many modern LED or LCD based meters unsuitable so use an old style moving coil meter.
[38] See Annex B.

N.B. the Cathode and Htr 1 connections on the board are connected together.

The Grid Operating Voltage

Grid Voltage Range

The CRT Tester provides a grid voltage continuously adjustable over the range -120V to -4V.

Grid voltage

There are no jumper settings that affect the grid voltage. The grid voltage is set entirely by potentiometer R20.

Anti-clockwise rotation makes the grid voltage more negative and so reduces brightness or causes the spot to become extinct.

Clockwise rotation increases the grid voltage (so it become less negative with respect to cathode) so increasing the spot brightness. N.B. do not leave a bright spot on the CRT, or any spot for that matter, for a long time or you can damage, burn, the phosphor.

CRT Grid connection

The Grid connection on X44 is connected using suitable wire[39] to the CRT grid pin.

[39] See Annex B

Selecting the Focus Anode Operating Voltage Range

Preamble

N.B. Not all CRTs have a separate focus anode connection pin. Some CRTs are called "automatic focus" tubes and the focus anode is typically connected internally to the cathode. For these CRTs none of this section applies.[40]

Calculating the Required Focus Voltage Range

You should inspect the CRT data sheet for the recommended voltage range required for spot focus at the final acceleration anode voltage you have selected. Sometimes this is given as a single voltage and a range in which case you should take a range about ±20% or so around the single voltage. Call the lower voltage V_{a2_low} and the higher voltage V_{a2_high}. These voltages are specified as relative to the cathode, so you can determine the voltage range relative to ground by adding them to the -EHT take-off point voltage connected to the cathode, $V_{cathode\_takeoff}$.

$$V_{a2\_low\_takeoff} = V_{cathode\_takeoff} + V_{a2\_low}$$

and

$$V_{a2\_high\_takeoff} = V_{cathode\_takeoff} + V_{a2\_high}$$

For example, the 2BP1 CRT has an example working voltage of V_{a3}[41] = 2000V a focus anode[42] voltage range of V_{a2_low} = 300V to V_{a2_high} = 560V. We have selected the cathode voltage take-off point of -1800V previously so,

$$V_{a2\_low\_ideal} = -1800 + 300 = -1500V$$

This is exactly on one of the take-off points so we can use

$$V_{a2\_low\_takeoff} = -1.5kV$$

and

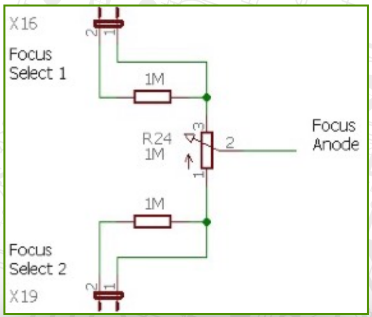
$$V_{a2\_high\_ideal} = -1800 + 560 = -1240V$$

Inspecting the available -EHT voltages shown in the table above shows that the nearest take-off point is at -1.2kV which is close as things go so we will use

$$V_{a2\_high\_takeoff} = -1.2kV$$

[40] Hint: Read the data sheet.
[41] The 2BP1 data-sheet calls this "Anode No. 2"
[42] The 2BP1 data-sheet calls this "Anode No. 1"

The CRT Tester has two points where the low focus anode voltage is connected and two for the high focus anode voltage. The arrangement is as depicted here:



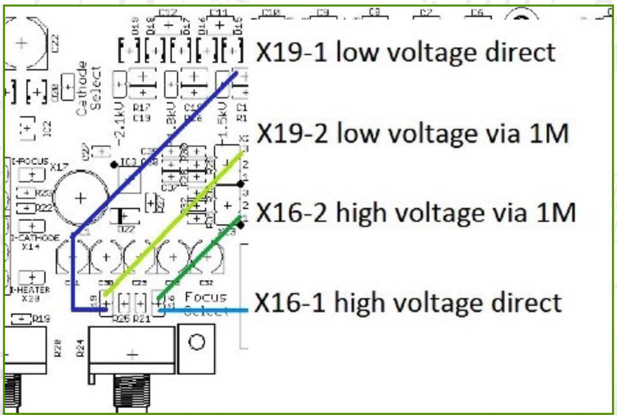
This arrangement allows a bit more flexibility in selecting the actual voltage range available across the focus potentiometer R24. In the 2BP1 worked example the two take-off points are connected to the direct connections pin 1 on X16 and pin 1 on X19. However, suppose the focus anode voltage range was 300 to 450V. The low voltage remains the same but the higher voltage is;

$$V_{a2\_high\_ideal} = -1800 + 450 = -1350V$$

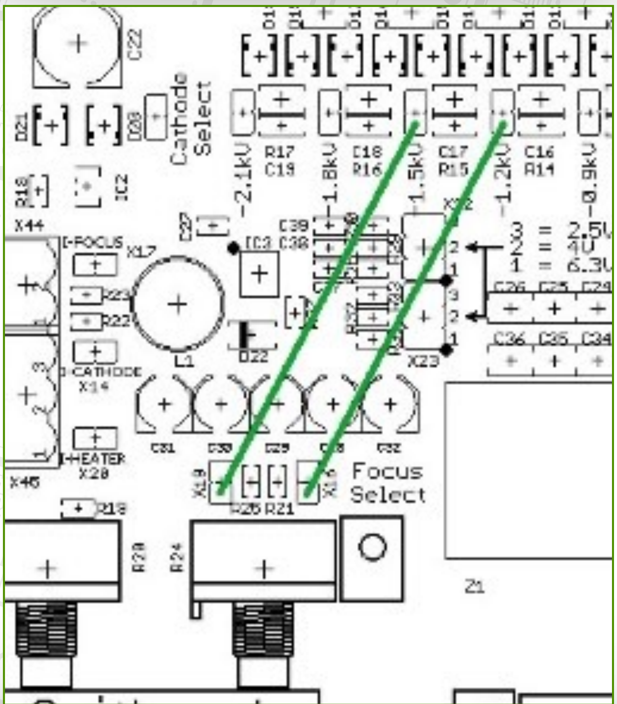
Inspecting the available -EHT voltages shown in the table above shows that the nearest take-off point is at -1.2kV which is not very close[43] so;

$$V_{a2\_high\_takeoff} = -1.2kV$$

However, in this case we connect the take-off point to pin 2 on X16 to bring the extra series 1M resistor into use. This then gives the required range across the focus potentiometer R24. In practice these resistors are not demanded to be used but they reduce the voltage range across the potentiometer and so can make its operation smoother. The arrangement on the board of the two connection points to include the 1M resistors or to go directly to the focus potentiometer is:

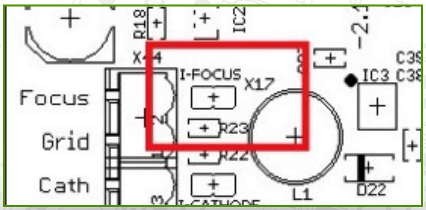


Going back to the actual 2BP1 example, the selected take-off points can be linked using jumper wires to the focus select jumper headers nearest the focus potentiometer to use the direct connection:



In practice if you find that the focus potentiometer has reached the end of its travel before the spot has come into focus then it is just a case of moving one or both of the jumper wires (with the power off!) in the direction of travel to get a wider voltage range.

43 Connecting to the -1.5kV take-off point gives no range...



CRT Focus current monitoring point

If you wish, the current through[44] the CRT focus anode can be monitored by connecting a suitable panel meter to I-FOCUS X17.[45]

If a panel meter is not used then the jumper header X17 must be closed using a header pin.

CRT Focus connection

The Focus connection on X44 is connected using suitable wire[46] to the CRT focus anode pin.

[44] Remembering that current can flow out of as well as into the focus anode you'll probably want to use a centre zero meter.
[45] As has been mentioned before, this makes many modern LED or LCD based meters unsuitable so use an old style moving coil meter. Such a panel meter must be rated for operation at the cathode potential of -2.1kV.
[46] See Annex B

Anode 1, Anode 3, Screens[47], Deflection Electrodes

Preamble

CRTs will have a bunch[48] of electrodes that all operate around the same potential. These include the acceleration anodes and deflection plates. Other electrodes can include screen and grids to improve spot shape or geometry and deflection blanking plates. The CRT Tester includes a row of potentiometers connected between the +HT supply and ground to provide continuously adjustable voltages over the range. Two double gang potentiometers are provided, wired so as one travels ground to V_{+HT}, the other travels V_{+HT} to ground. The mean voltage between the two gangs is always (V_{+HT} / 2) these are useful for testing deflection plate response.

All the potentiometers are wired in identical manner (other than the reversed half of the dual gang ones as noted) and so are fully interchangeable in their use. The labelling “Anode 1”, Anode 3” etc. is purely nominal.

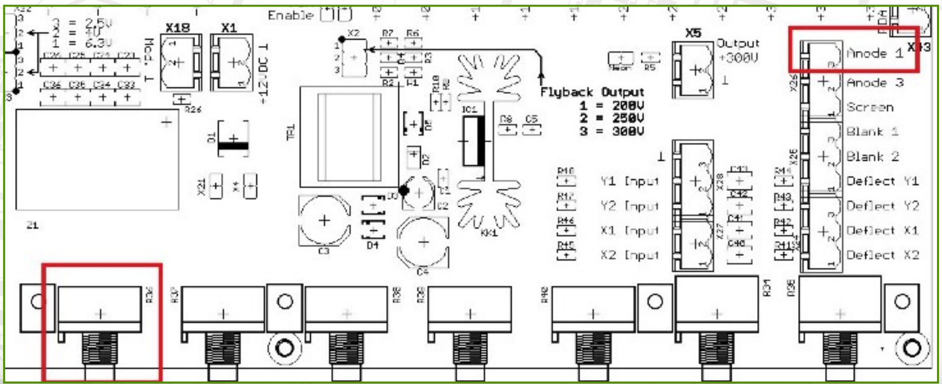
Electrode Voltage Range

The voltage range is fixed at ground to V_{+HT} which has been set to get the required cathode to final acceleration anode voltage.

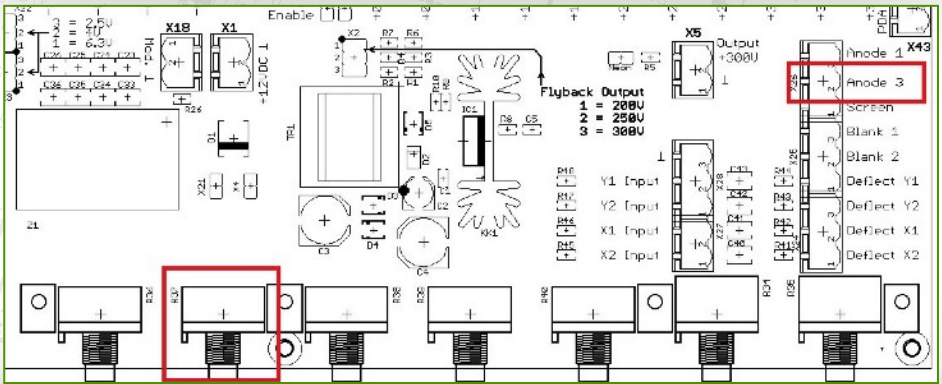
CRT Electrode Connection

The electrode connections on X24 - X26 is connected using suitable wire to the appropriate CRT pins and the voltage on each connector is manipulated with the corresponding potentiometer:

Anode 1 (first acceleration anode) potentiometer and screw connector.



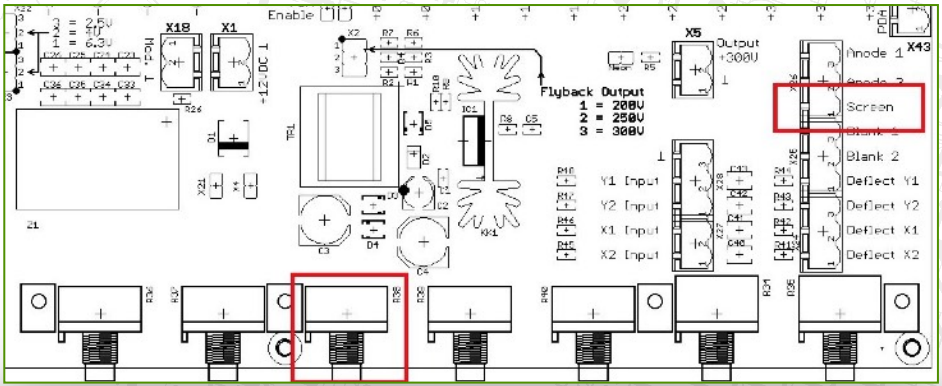
Anode 3 (final acceleration anode) potentiometer and screw connector.



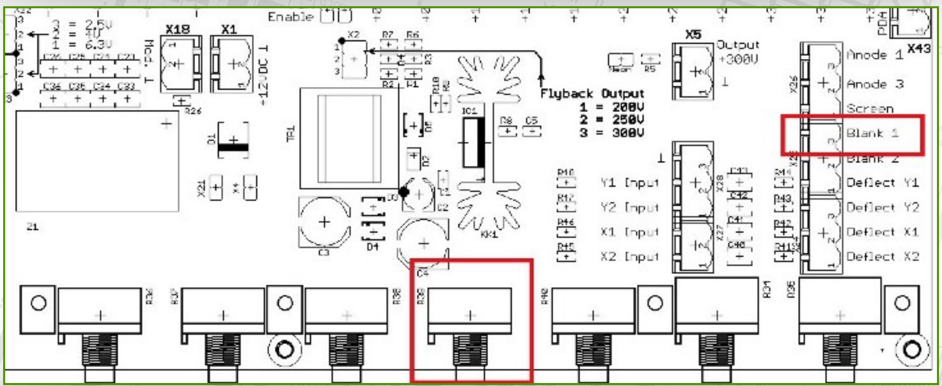
47 https://en.wikipedia.org/wiki/Major_Bloodnok

48 That’s a technical term…

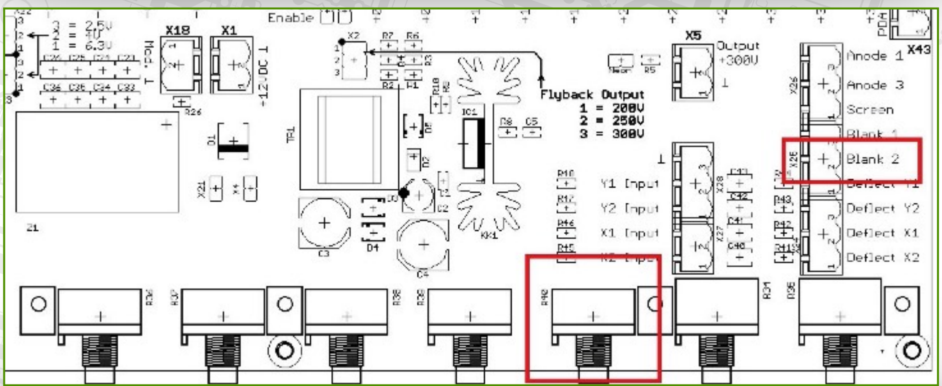
Screen/Geometry potentiometer and screw connector.



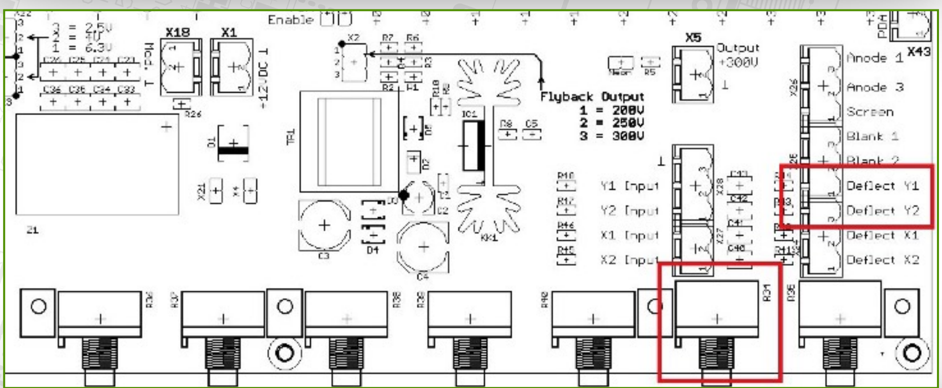
Deflection Blanking 1 potentiometer and screw connector.



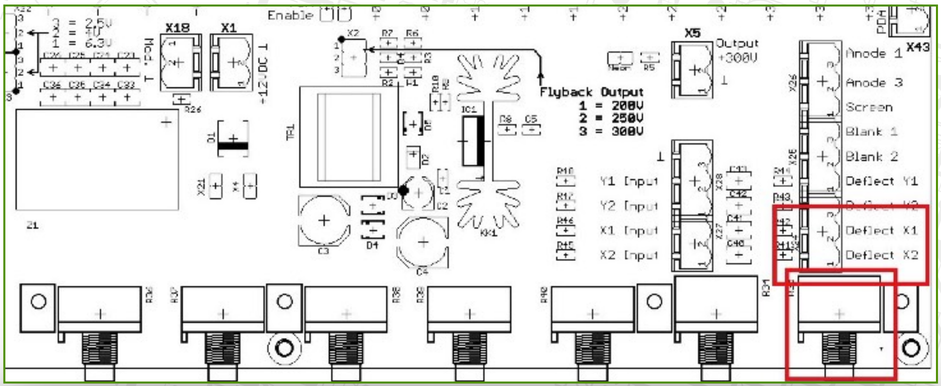
Deflection Blanking 2 potentiometer and screw connector.



Y Deflection potentiometer and screw connectors.



X Deflection potentiometer and screw connectors.



For example, the 2BP1 CRT has a first acceleration anode[49] which is connected internally to the final acceleration anode[50] and brought out to one pin on the base. The CRT has four deflection plates brought out to separate pins on the base. Therefore 5 wires are used to connect these electrode connections to the Anode 3, Deflect X1, Deflect X2, Deflect Y1 and Deflect Y2 screw terminals. The Anode 1, Screen, Blank 1 and Blank 2 screw connectors and their corresponding potentiometers are unused.

[49] Called Grid No. 2 on the data sheet.
[50] Called Anode No. 2 on the data sheet.

<u>Selecting the PDA Operating Voltage</u>

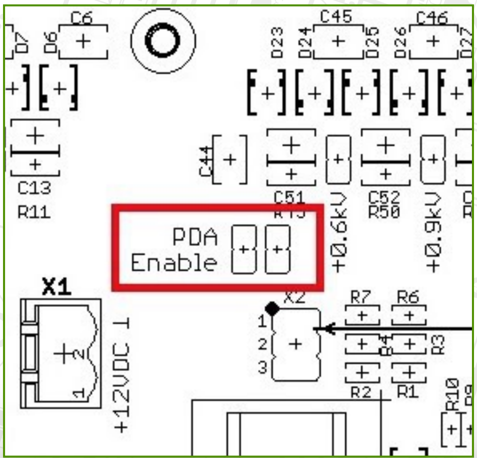
Preamble

Some CRTs have a post-deflection acceleration electrode as a means to obtain a bright spot without loosing deflection sensitivity by accelerating the electron beam after it has been through the deflection plates.[51]

PDA Power Supply Enable

The PDA power supply is enabled by fitting two jumper pin to jumper headers:

For safety, I recommend only fitting these jumpers when you actively want to use the +EHT multiplier chain. Normally, do not fit these jumpers.



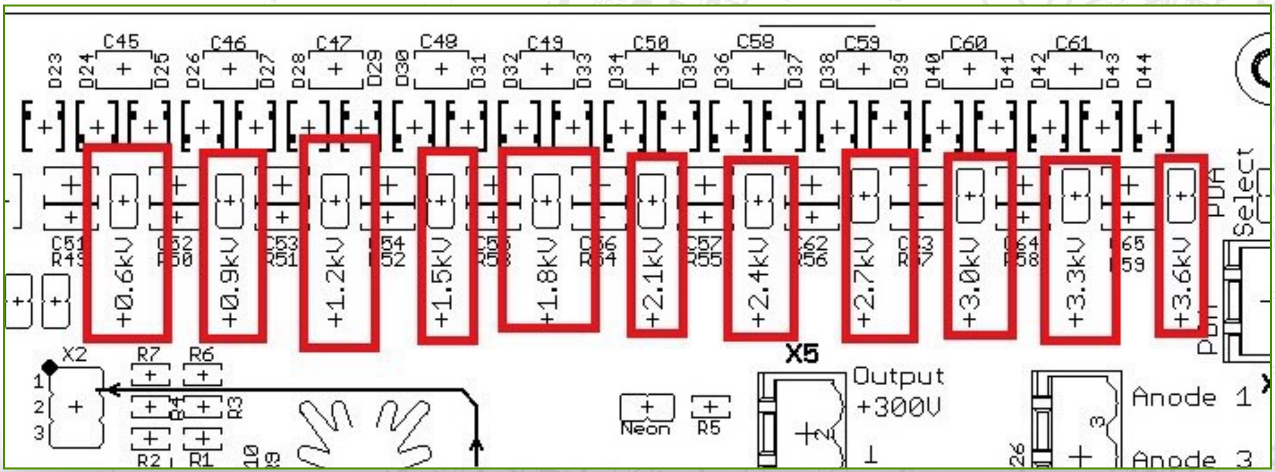
PDA Power Supply Voltage Selection

This table is repeated from the section above on selecting the flyback output voltage.

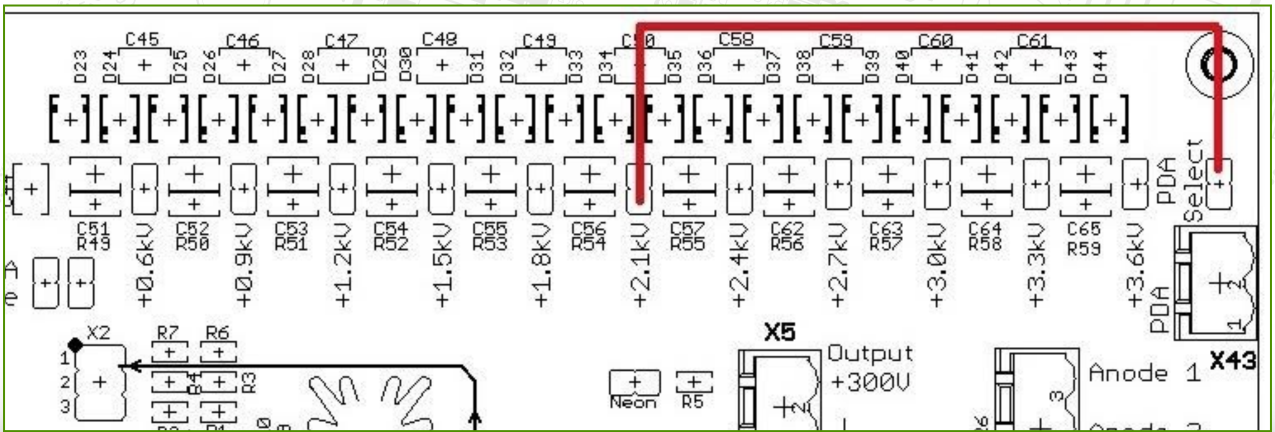
Flyback Output +HT Voltage					
+200V		+250V		+300V	
-EHT voltages	**+EHT voltages**	**-EHT voltages**	**+EHT voltages**	**-EHT voltages**	**+EHT voltages**
-0.2kV	+0.4kV	-0.25kV	+0.5kV	-0.3kV	+0.6kV
-0.4kV	+0.6kV	-0.5kV	+0.75kV	-0.6kV	+1.2kV
-0.6kV	+0.8kV	-0.75kV	+1.0kV	-0.9kV	+1.5kV
-0.8kV	+1.0kV	-1.0kV	+1.25kV	-1.2kV	+1.8kV
-1.0kV	+1.2kV	-1.25kV	+1.5kV	-1.5kV	+2.1kV
-1.2kV	+1.4kV	-1.5kV	+1.75kV	-1.8kV	+2.4kV
-1.4kV	+1.6kV	-1.75kV	+2.0kV	-2.1kV	+2.7V
	+1.8kV		+2.25kV		+3.0V
	+2.0kV		+2.5kV		+3.3kV
	+2.2kV		+2.75kV		+3.6kV

[51] It does what is says on the tin!

The supply for the PDA is available on a series of jumper header take-off points on the +EHT multiplier chain similar to the -EHT multiplier chain.

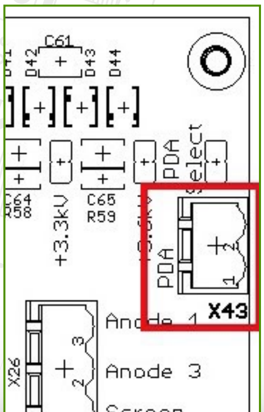


The selected take-off point can be linked using the red jumper wire to the cathode select jumper header for example, linking the PDA select to the +2.1kV take-off point:



Under **no circumstances** should more than one jumper wire be fitted between an +EHT take-off point and the PDA Select jumper header.

Under **no circumstances** should any of the +EHT take-off points be connected together!



CRT PDA Connection

The PDA electrode connection X43 is preferably connected using a pukka PDA wire and cap[52] or some suitable wire[53] to the PDA socket on the CRT. The connection needs to be secure and isolated given the voltages concerned!

[52] These do turn up on eBay from time to time and can also be bought along with CRTs pulled from old oscilloscopes

[53] See Annex B (like a broken record……)

[Left]: A pukka PDA wire and cap - safety first! [Right]: An example of a PDA socket on a CRT

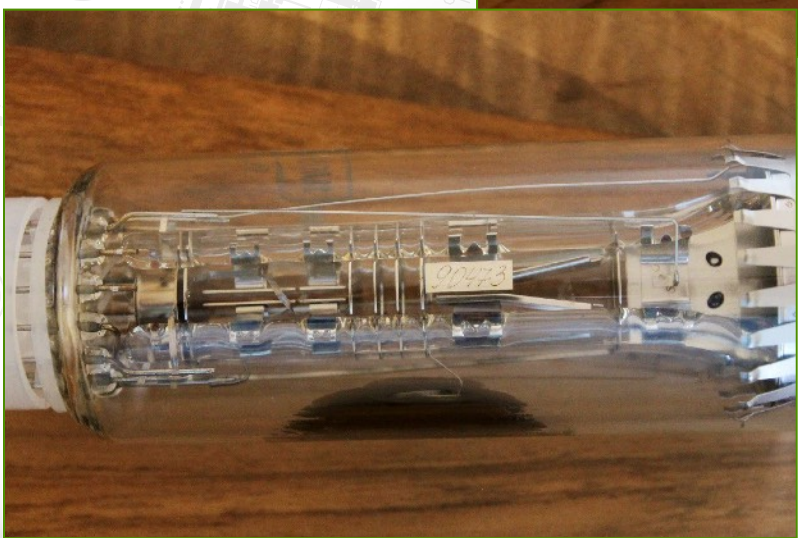
2BP1 Example

So far a simple worked example for the 2BP1 CRT has been used. This CRT does not have a PDA so is not an exemplary CRT I can use. Therefore, the next section is a worked example for a more complex CRT.

Трубка 11ЛО3И однолучевая

Preamble

The Soviet[54] 11ЛО3И CRT is a single beam rectangular oscilloscope tube:



What a beauty! Let's get it fired up…..

[54] The tube I have is dated February 1989 and the Soviet Union dissolved in December 1991.

11ЛО3И Data sheet

Трубка 11ЛО3И однолучевая (11ЛО-3И, 11ЛО 3И, 11Л03И, 11Л0-3И, 11Л0 3И)
Для визуального наблюдения электрических процессов з радиоэлектронных устройствах.
Цвет свечения экрана - **зеленый.**
Размер рабочей части экрана **50х80мм.**

Однолучевая трубка 11ЛО3И с одной ступенью послеускорения, с бланкирующими пластинами, с экраном прямоугольной формы с плоской поверхностью. Предназначена для визуального наблюдения электрических процессов з радиоэлектронных устройствах. **Однолучевые трубки 11ЛО3И** предназначены для визуального наблюдения однократных или медленно изменяющихся во времени электрических процессов в радиоэлектронных устройствах. Цвет свечения экрана - зеленый. Размер рабочей части экрана 50х80мм. Ширина сфокусированной линии не более 0,5мм.

Выводы электродов: 1, 14 - подогреватель; 2 - катод; 3 - модулятор; 4 - второй анод (ускоряющий); 5-бланкирующие пластины; 6 - четвертый анод (промежуточный); 7 - первый анод (фокусирующий); 8, 11 - временные отклоняющие пластины X_1, X_2; 9 - третий анод; 10, 13 - сигнальные отклоняющие пластины Y_1, Y_2; 12 - сетка; А - пятый анод. Оформление - стеклянное бесцокольное с боковым выводом. Масса 0,5кг

Основные параметры прибора однолучевая трубка 11ЛО3И
при $U_Н$ = 6,3В; U_{a1} = 200…400В; U^*_{a2} = 1000В; U^{**}_{a3} =±50В; U^{**}_{a4} = ±50В; U^{**}_{a5} = 1500В; $U^*_{зап}$ = -(20…50)В.
где * - напряжение, измеренное относительно катода,
** - напряжение, измеренное относительно первого анода

Наименование	Не менее	Не более
Ток накала, А	0,085	0,105
Ток первого анода, мкА		2
Ток второго анода, мкА		100
Ток третьего анода, мкА		10
Ток четвертого анода, мкА		2
Ток пятого анода, мкА		150
Ток сетки, мкА		10
Ток бланкирующих пластин, мкА		5
Ток катода, мкА		500
Ток утечки между катодом и подогревателем, мкА		30
Ток утечки в цепи модулятора, мкА		5
Яркость свечения экрана, кд/м^2	5	
Яркость паразитного свечения, кд/м^2		0,05
Чувствительность, мм/В:		
временных отклоняющих пластин X_1, X_2	0,7	
сигнальных отклоняющих пластин Y_1, Y_2	0,9	
Геометрическое искажение, %		5
Время послесвечения, с	10^{-3}	
Время готовности, с		45
Наработка, ч	500	
Критерии годности при наработке:		
яркость свечения экрана, кд/м^2 .	4	
ширина сфокусированной линии, мм		0,6
Емкости между электродами, пФ:		
катод - все электроды		7
модулятор - все электроды		9
пластина X_1 - пластина X_2		6
пластина Y_1 - пластина Y_2		4

Предельные эксплуатационные данные однолучевая трубка 11ЛО3И

Наименование	Не менее	Не более
Напряжение накала, В	5,7	6,9
Напряжение второго анода, кВ	0,8	1,2
Напряжение пятого анода, кВ	1,2	1,65
Напряжение модулятора, В	-150	-1

In Russian Obviously….

How good is your Russian? Here's a rough[55] translation:

Tube 11LO3I single beam (11LO-3I, 3I 11LO, 11L03I, 11L0-3I, 11L0 3I). For visual monitoring of electrical processes electronic devices. Light colour screen - green. The size of the working part of 50x80mm screen.

Single beam tube 11LO3I, with the blanking plates with rectangular screen with a flat surface. Designed for visual observation of electric processes and electronic devices. 11LO3I tubes are designed for visual observation of single or slowly time-varying electrical processes in the radio-electronic devices.

Light colour screen - green.
The size of the working part of 50x80mm screen.
The width of focused line of not more than 0.5 mm.

Base pins:

- 1, 14 - Heater
- 2 - Cathode
- 3 - Grid (modulator)
- 4 - Second anode (accelerating)
- 5 - Blanking plate 5
- 6 - Fourth anode (intermediate)
- 7 - First anode (focusing)
- 8, 11 - Deflection plates X1, X2
- 9 - Third anode
- 10, 13 - Deflection plates Y1, Y2
- 12 - Net (screen?[56])
- Fifth anode - side pin

Design - wedge base glass with the side pin.
Weight 0.5kg

The main parameters of the device single beam tube 11LO3I:
Heater = 6.3V
a1 = 200 ... 400 V
* a2 = 1000V
** a3 = ± 50V
** a4 = ± 50V
** a5 =1500V
* Grid = -20 ... -50V

where
* voltage measured relative to the cathode
** The voltage measured relative to the first anode, a2

[55] If you can improve the translation then please let me know!
[56] No other mention of this connection is made. Tracing the connection inside the tube looks like it connects to a screen band near the Y deflection plates

Parameter	No Less Than	No More Than
Heater current A	0.085	0.105
first anode current μA		2
second anode current μA		100
third anode current μA		10
fourth anode current μA		2
fifth anode current μA		150
grid current μA		10
blanking plate current μA		5
Current cathode μA		500
The leakage current between the heater and the cathode μA		30
Leakage current modulator circuit μA		5
Brightness of the screen, cd/m2	5	
Brightness parasitic glow cd/m2		0.05
Sensitivity mm / V:		
deflection plates X1, X2	0.7	
deflection plates signal Y1, Y2	0.9	
geometric distortion %		5
afterglow time s	0.001	
warm up time s		45
after hours	500	
criteria of life at work:		
brightness of the screen cd/m2	4	
width of focused line mm		0.6
capacitance between the electrodes pF:		
cathode - all electrodes		7
grid - all electrodes		9
X1 plate - X2 plate		6
Y1 plate - Y2 plate		4

Connections to the CRT Tester

Pin	Function	Connection
1	heater	X45 - Htr 1
2	cathode	X45 - Cath
3	grid	X44 - Grid
4	acceleration anode	X26 - Anode 3
5	blanking plate	X25 - Blank 1
6	intermediate anode	X25 - Blank 2
7	focus anode	X44 - Focus
8	X1	X24 - Deflect X1
9	intermediate anode	X26 - Anode 1
10	Y1	X25 - Deflect Y1
11	X2	X24 - Deflect X2
12	Screen	X26 - Screen
13	Y2	X24 - Deflect Y2
14	heater	X45 - Htr 2
side pin	PDA	X43 - PDA

This tube is so complex that every output connection has been used.

Operating Condition Calculations

The heater uses 6.3V and is less than 5.5W input power so no special treatment is required.

The acceleration anode (a2 on the 11ЛО3И data-sheet, Anode 3 in the CRT Tester naming) in the voltage relative to the cathode should be 1000V. I shall use the +300V +HT setting for the flyback converter.

The required cathode operating voltage can now be calculated

$$V_{cath} = (V_{+HT}/2) - V_{a3} = (300/2) - 1000 = -850V$$

The nearest take-off point on the -EHT multiplier chain is -0.9kV so I will use it.

The focus anode (a1 on the 11ЛО3И data-sheet, Anode 2 in the CRT Tester naming) voltage range is given as 200 - 400 V relative to cathode.

$$V_{a2\_low\_ideal} = -900 + 200 = -700V$$

The nearest take-off point lower (more negative) than this is the -0.9kV, the same as the cathode

$$V_{a2\_low\_takeoff} = -0.9kV$$

and

$$V_{a2\_high\_ideal} = -900 + 400 = -500V$$

The nearest take-off point higher (less negative) than this is the -0.3kV point:

$$V_{a2\_high\_takeoff} = -0.3kV$$

This is a voltage span of 600V between the two take-off points. The 11ЛО3И only wants a 200V span which is conveniently centred in the span so the two 1M resistors can be used to produce a 200 - 400V range on the focus potentiometer.

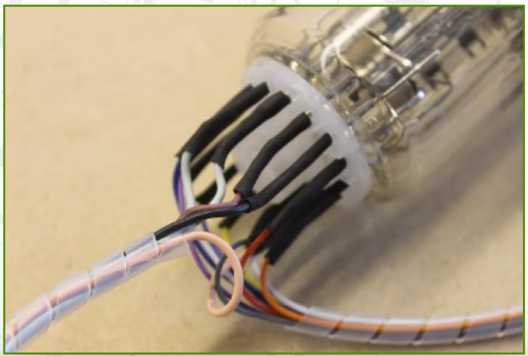
The other anode, blanking deflection plate and screen are all connected to the other potentiometer outputs.

Finally, the data sheet says that the PDA (a5) should be 1500V relative to a2.

$$V_{PDA} = 150 + 1500 = 1650V$$

This is inconveniently half way between two +EHT take-off points of +1.5kV and +1.8kV. I will select the lower point, +1.5kV, initially and maybe try the higher point to see the effect on spot brightness.

Wiring Harness



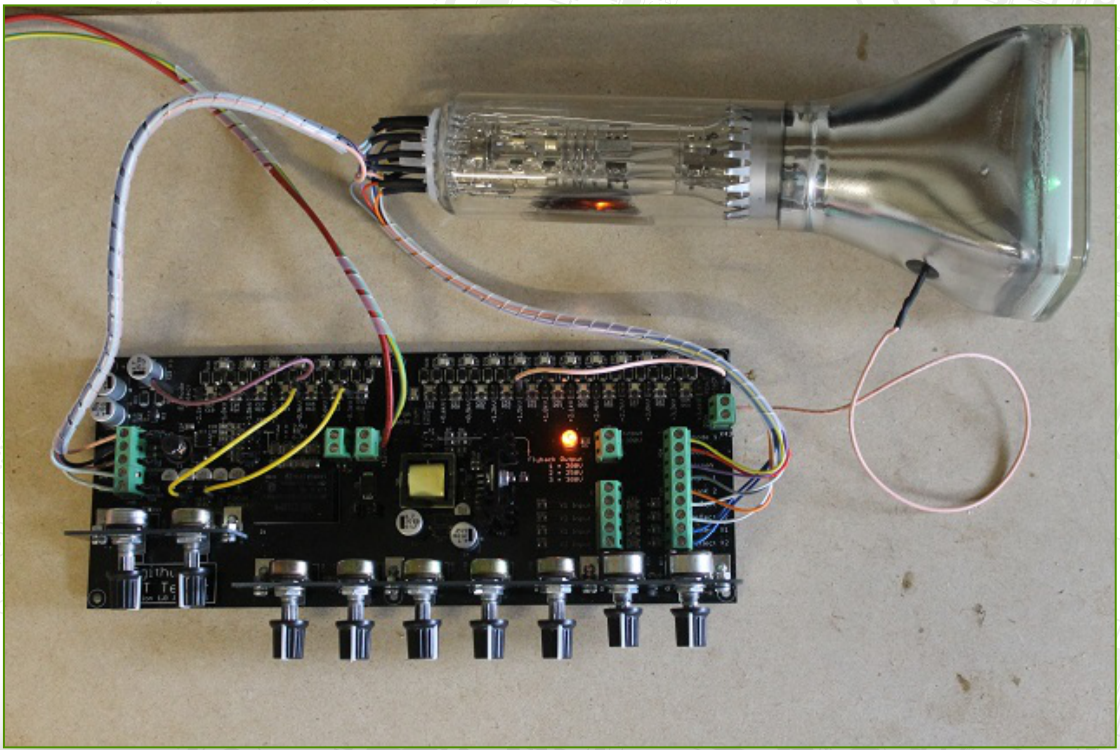
I don't have a base for the this CRT or a pukka PDA connector for the side pin so I will have to fabricate a connector harness and perhaps 3D print a base and side cap later.

I used receptacles with a 1mm internal diameter, soldered leads to them and insulated and strengthened the joint with heat shrink tubing.

N.B. Never, never, never[57] solder wires directly to the pins of a CRT.

[57] Never, never, never, never…..

The Live Test



Setting this tube up correctly is complex. With so many adjustments to make, getting a spot that is small and round over the whole face could prove a lengthy task. The CRT Tester allowed an initial investigation of the process and the X/Y position controls allow any variation in the spot over the tube face to be investigated. Mission accomplished!

Annex A

Work Around for a CRT needing more than 5.5W heater power

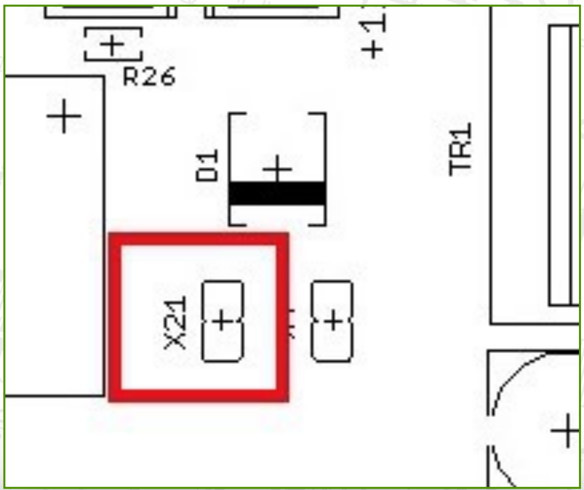
The CRT Tester Version 1.1 heater power supply is limited to a power output of about 5.5W. This is makes it suitable for many CRTs but some CRTs may have a greater heater power requirement. For example, some double beam CRTs require a 6.3V x 1.2A = 7.6W supply. The work around is to use a secondary 6.3V transformer. Such a transformer must:

- Be insulated for operation of the secondary at -2.1kV
- Be able to output the required voltage and current for the CRT under test
- Have its secondary floating - it must not be grounded/earthed

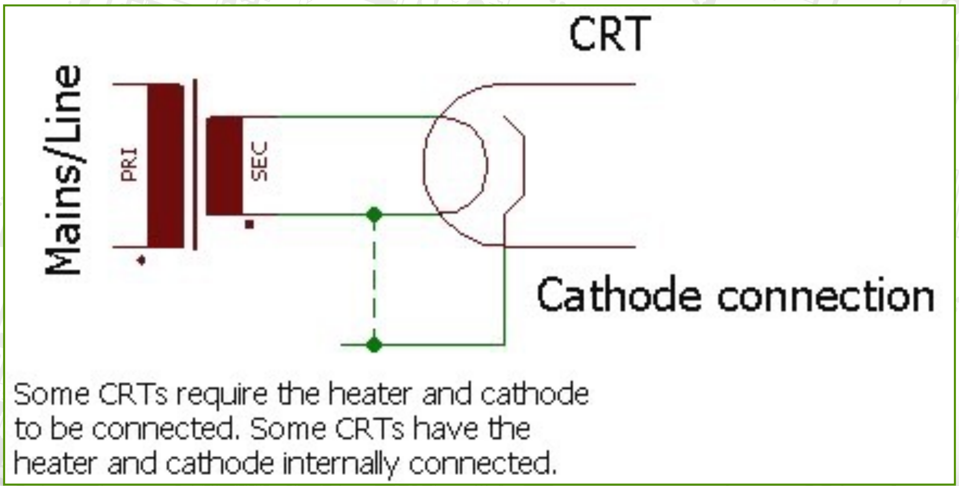
To use a secondary transformer the on-board heater power supply must be disabled by removing any jumper to jumper header X21:

The heater voltage jumper headers X22 and X23 are ignored and can be left in any setting.

The heater connections to screw terminal X45, Htr1 and Htr2 must not be connected.



The secondary transformer is wired as follows:



This technique can also be used if the heater voltage requirements is other than 2.5V, 4V or 6.3V.

Annex B

Suggested off board connection wire

The *Grid, Focus, Cathode, Htr 1 and Htr 2* connections can have a potential of down to -2.1kV (and slightly more negative for the Grid). The wire must be suitably insulated such as CnCTech silicone insulated 22AWG hook up wire:

http://www.cnctech.us/pdfs/3239-22-1-0500-007-1-TS.pdf

Digikey have a variety of colours and lengths:

http://www.digikey.com/product-search/en/cables-wires/single-conductor-cables-hook-up-wire/1638740?k=cn104

The *PDA connection* can have a potential of up to +3.6kV. The wire must be suitably insulated such as Daburn PVC 22AWG insulated test lead wire:

Digikey have a nice red one...

https://www.digikey.com/product-detail/en/daburn-electronics/2722-22-R-C/W2722R-100-ND/95106

The remaining wires have a potential of up to +300V and many brands of hook up wires are suitable.

Annex C

Testing CRTs which require PDA voltage > 5.6kV w.r.t. Cathode

Preamble

With the cathode voltage select linked to the -2.1kV take off point and the PDA linked to the +3.6kV take off point (actually +3.5kV in practice) this gives a PDA maximum voltage of about 5.6kV with respect to the cathode. This voltage difference cannot always be used as some CRTs require a specific ratio between the final acceleration anode voltage and the PDA voltage. Additionally, some CRTs have multiple PDA connection sockets and require a voltage profile to be applied. For example the DuMont[58] 5AWPx CRT (a real beauty) requires a PDA voltage of 10.3kV (w.r.t. the cathode) and has no less than 4 sockets:

DuMont 5AWP2 CRT - A High Voltage Monster!

EHT PDA add-on

An add-on board is planned that will deliver up to about 8 - 10kV to test CRTs such as the DuMont 5AWPx. The stand-alone board has been designed, prototype built and a kit is being developed.

Use the contact email address on the web page for further information.

[58] https://en.wikipedia.org/wiki/Allen_B._DuMont

Annex D

A Simple Pattern Generator

Preamble

The CRT Tester Construction and Testing Manual concluded by testing a 2BP1 CRT by applying 50Hz sine and cosine signals from a phase shift network to the deflection plate inputs and a square wave at 300Hz to the grid modulation input to chop the ellipse:

2BP1 example from the construction manual

A more permanent stand-alone solution was sought.

Pattern generator add-on

An add-on board is planned that will carry:

- A fixed frequency sine/cosine oscillator (about 180Hz)
- Two high voltage deflection amplifiers
- A variable frequency square wave oscillator (about 150Hz - 2kHz)
- A deflection blanking amplifier

The stand-alone board has been designed, a bread board version built and a prototype/kit is being developed.

Use the contact email address on the web page for further information.

Annex E

<u>Testing the E1T Scaler Decade Tube</u>

Preamble

The E1T[59] tube is a highly specialised cathode ray tube. It is a display tube (0-9), a counter and can store 3.5bits of information - just fantastic!

There is a lot of information on Ron Dekker's website.[60]

The operate the E1T requires up to 300V +HT and a 6.3V heater supply and easily falls within the capabilities of the CRT Tester power supply to operate this tube.

E1T Tube Tester

With Ron Dekker's kind permission an add-on board, using his design[61] has been developed. This is available as a kit, details of which can be found later on in this manual.

Use the contact email address on the web page for further information.

59 http://www.r-type.org/pdfs/e1t.pdf
60 http://www.dos4ever.com/E1T_clock/E1T.html; http://www.dos4ever.com/E1T/E1T.html
61 http://www.dos4ever.com/trochotron/troch.html

Annex F

Testing CRTs with a Trace Rotation Coil

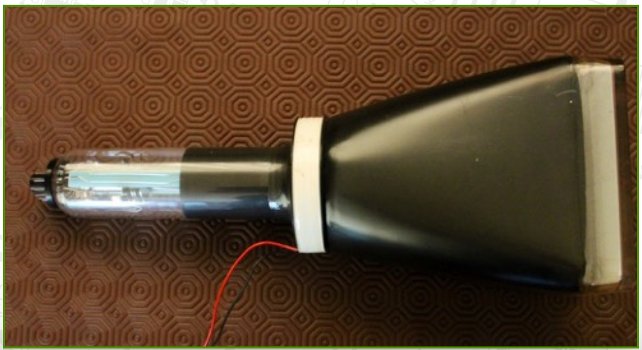
Preamble

Rectangular CRTs require a trace rotation coil so the CRT trace can be aligned to the CRT face. A trace rotation coil is typically a coil mounted somewhere on the neck or flare of the CRT through which a DC current, typically a few mA, is passed. This creates a fixed magnetic field that causes the electron beam path to be skewed. The coil design and current influence the magnitude of the skew. The direction of the current flow through the coil changes the direction of skew appearing as clockwise or anti-clockwise rotation of the image if the current direction is reversed.

Any scope clock using a rectangular CRT that is worth its salt should implement trace rotation so the the image is nicely parallel with the side of the CRT's face.

In each of the examples below the CRT Tester was used to power the CRT.

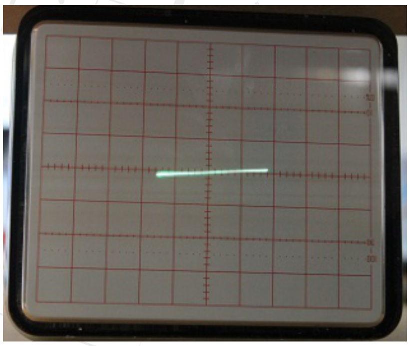
Example 1



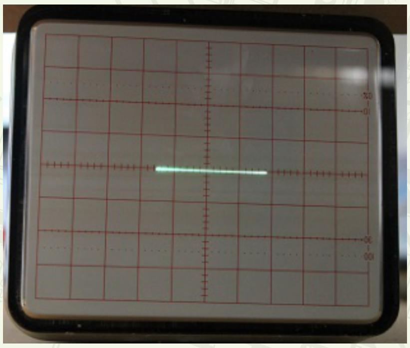
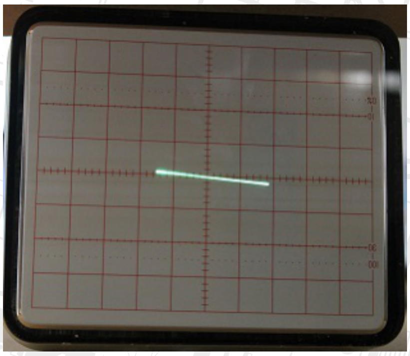
First I shall show the effect of trace rotation using a Toshiba 130BTB31 CRT. This is a rectangular CRT (104mm x 84mm) and comes with a trace rotation coil attached to the neck.[62] I measured the coil resistance as 220 ohms and the applied power from an adjustable bench power supply such that the trace rotation was easily visible.

I applied about 60V peak-to-peak at 50 Hz to the X deflection inputs on the CRT Tester to produce a horizontal line (see also the Simple Pattern generator in Annex D as this can be used to generate a horizontal line).

The following three photographs show the trace rotated in each direction and the zero current case. I picked this tube for the demonstration as it has a built in graticule so the change in position of the line is easy to see.

Applied Voltage	Calculated Current	Image
-3V	-13.6 mA	

[62] Unless some Muppet has removed it….

Applied Voltage	Calculated Current	Image
0V	0 mA	
3	+13.6 mA	

Example 2

This example uses the small Soviet 6ЛО1И rectangular CRT (40mm x 30mm) commonly available on eBay. I have never seen a trace rotation coil or specification for this rectangular CRT so I wound my own at the top of the flared section:

I used about 400 turns of 0.125mm diameter enamel coated wire between two foam rubber cheeks. The winding has a resistance of about 105 ohms. The very fine wire was terminated with two leads using general purpose hook up wire and the coil finished with black PVC tape.

Again I applied about 60V peak-to-peak at 50 Hz to the X deflection inputs on the CRT Tester to produce a horizontal line.

The following three photographs show the trace rotated in each direction and the zero current case. I used nothing more than a 9V PP3 battery to provide power.

Applied Voltage	Calculated Current	Image
-9V	-90 mA	
0V	0 mA	
+9V	+90 mA	

If you look at the zero current case you can clearly see the line is sloping upwards from left to right. A clock face drawn on this CRT would be rotated anti-clockwise by this amount - not good - illustrating that trace rotation is essential on rectangular CRTs.

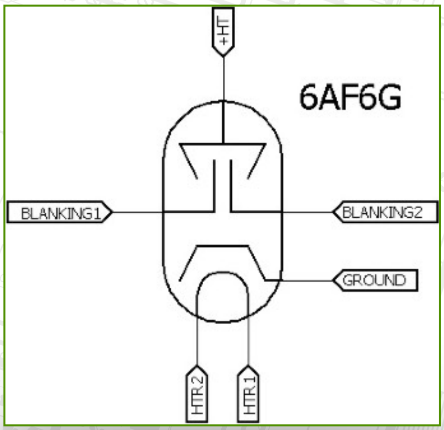
Annex G

Testing other tubes, valves and neon goodies…

Preamble

With some thought and ingenuity a range of other valves and tubes can be tested in a qualitative or semi-quantitative fashion. In this Annex I am not trying to give definitive procedure for testing particular tubes but give a flavour of how you can use the CRT Tester for work other than its primary function.

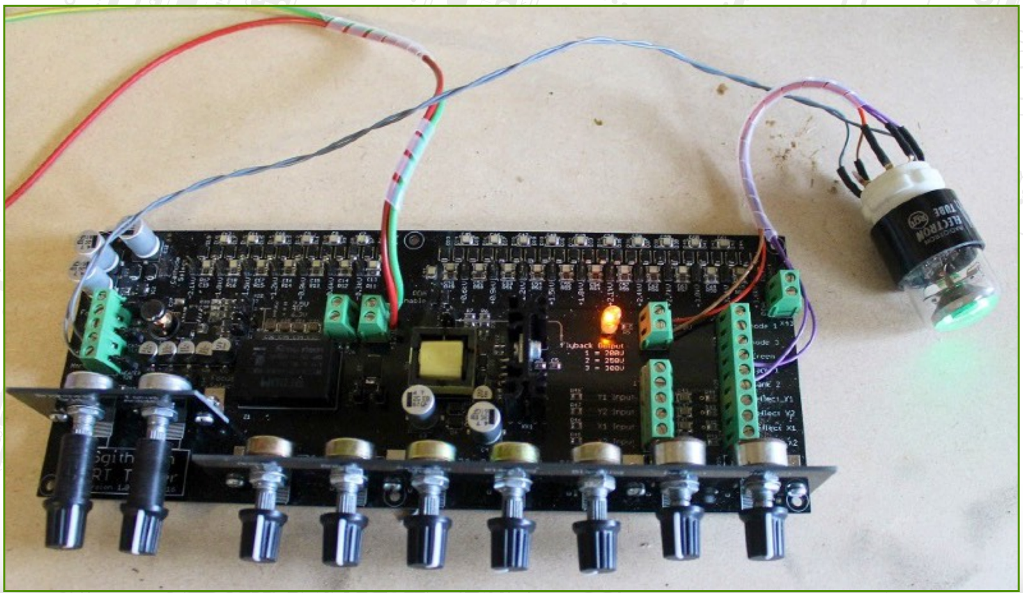
1. Magic Eye Indicators[63]



Magic eye indicators are another specialist type of cathode ray tube.

For example, the 6AF6G[64] magic eye indicator has two independent units with a common target and cathode. The CRT Tester can be configured easily to test this tube with no additional components

- The focus and cathode select jumper wires are not required and must be removed
- The heater voltage selector is set to 6.3V
- The +HT voltage selector is set to +200V
- The tube is connected as follows:
  - Target to +300V HT output (this will actually be +200V)
  - Cathode connected to ground
  - The heater connected to HTR1 and HTR2
  - The ray control electrodes are connected to Blanking 1 and Blanking 2 (although in practice they can be connect to any of the variable voltage outputs).



The setup looks like this.

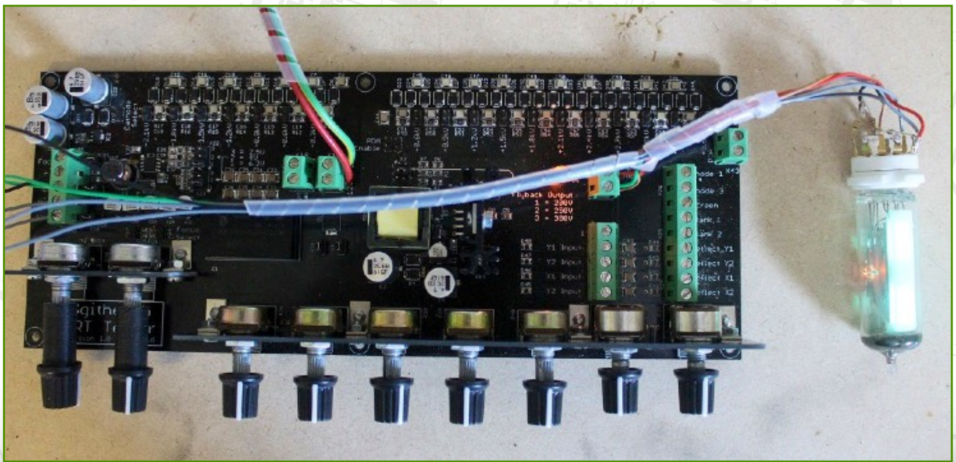
[63] https://en.wikipedia.org/wiki/Magic_eye_tube
[64] https://frank.pocnet.net/sheets/201/6/6AF6G.pdf

The ‘Magic Eye’ shadows move as the blanking 1 and blanking 2 potentiometers are ‘twiddled’

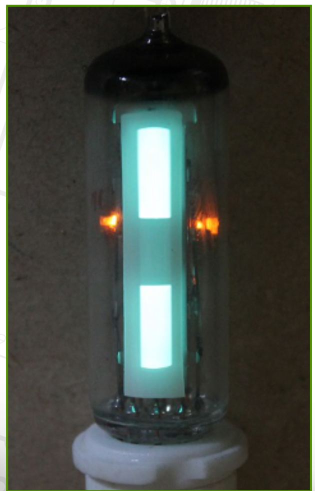
Another example is the EM87[65] magic eye. This valve contains a triode section so can be made very sensitive.

The CRT Tester can be configured easily to test this tube with a couple of additional resistors:

- The focus and cathode select jumper wires are not required and <u>must</u> be removed
- The heater voltage selector is set to 6.3V
- The +HT voltage selector is set to +250V
- The tube is connected as follows:
  - Target to +300V HT output (this will actually be +250V)
  - Cathode connected to ground
  - The heater connected to HTR1 and HTR2
  - The anode and deflection plate are connected to +HT via a 100k resistor
  - The grid is connected to the CRT grid connector via a 3M3 resistor and 220k resistor to ground
  - The CRT cathode connector, “Cath”, is connected to ground otherwise the grid supply would float



The setup looks like this.



…and the tube glows! Adjusting the brightness control changes the shadow length in the tube.[66]

[65] https://frank.pocnet.net/sheets/010/e/EM87.pdf
[66] Just like your Grandparents’ old tube radio…

2. Nixie[67] Tubes

The +HT output can be used to ignite a nixie table to test the tube functions i.e. it glows and is not soft. Visual inspection of the cathode can be made for any poisoning and so on.

The CRT Tester is configured as follows:

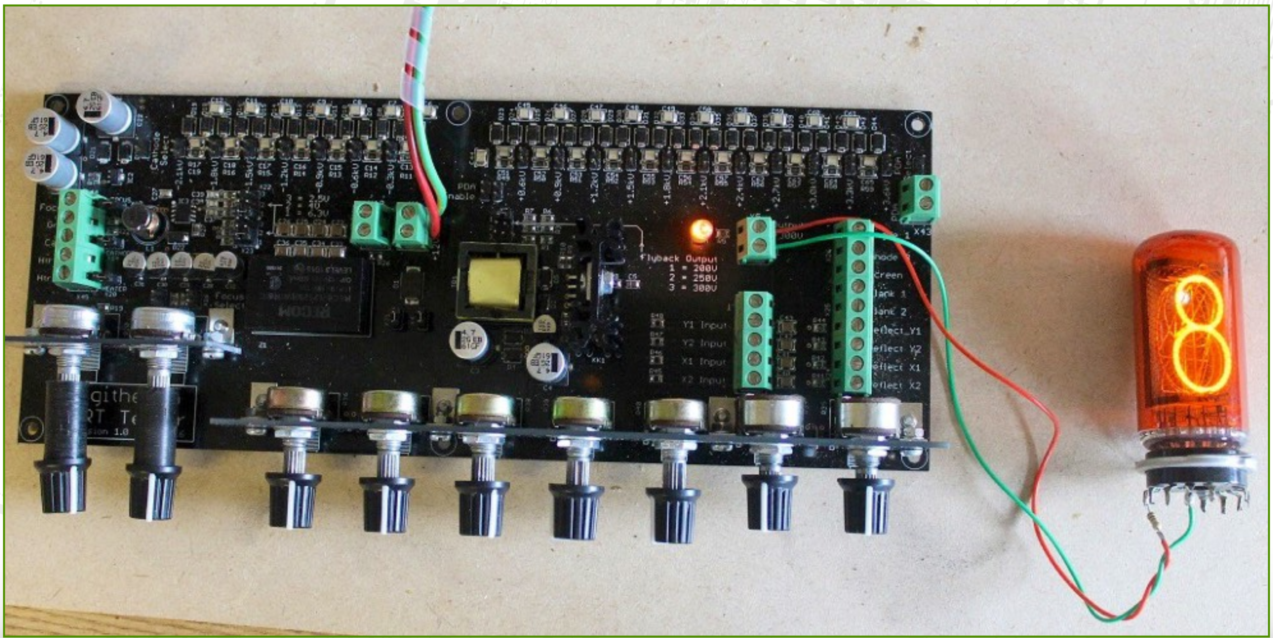
- The +HT output selector is set to +200V
- The anode of the nixie tube is connected to the +HT output via a suitable current limiting resistor
- The cathode to be lit is connected to ground

The value of the current limiting resistor is calculated knowing the required current through the tube for its data sheet (Ik), the maintaining voltage of the tube (Vm) and knowing that the +HT voltage is 200 V using:

$$Ra = (200 - Vm) / Ik$$

So for a ZM1040[68], allowing a 4mA cathode current and with a maintaining voltage of 140V the anode resistor is

$$Ra = (200 - 140) / 4 = 15\ k\Omega^{69}$$



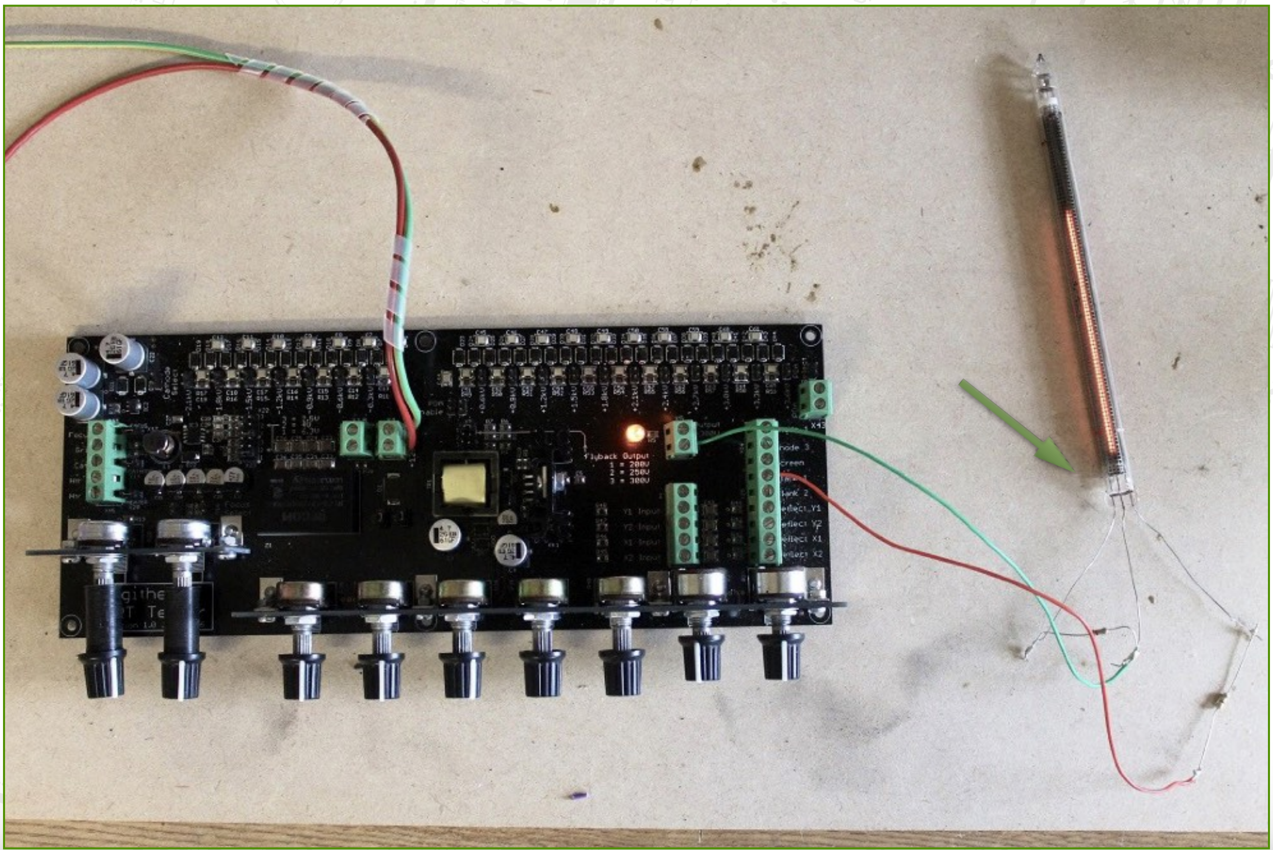
[67] https://en.wikipedia.org/wiki/Nixie_tube
[68] https://frank.pocnet.net/sheets/045/z/ZM1040.pdf
[69] As per the data sheet!

3. Neon Bar-graph Indicators

The CRT Tester can be used to ignite and vary the illuminated length of a neon bar-graph type indicator tube in a fairly crude fashion.

For example, for the ИН-13[70] indicator tube, the CRT tester is configured as follows:

- The +HT output selector is set to +200V
- The anode of the indicator tube is connected to an adjustable output such as the blanking 1 output via a suitable current limiting resistor. I used 39k. This is to protect the tube in case the potentiometer is turned fully clockwise. It will limit the length of the bar illuminated.
- The cathode to is connected to ground
- The auxiliary cathode is connected to ground via a 220k resistor

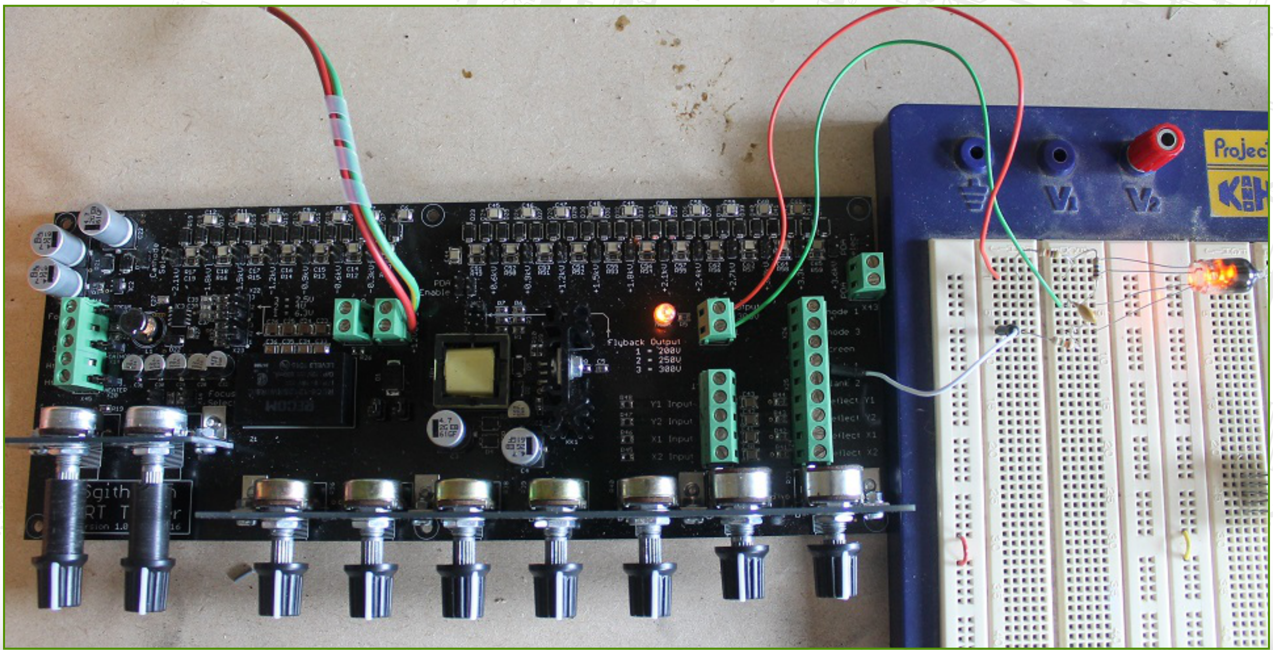


[70] http://www.tube-tester.com/sites/nixie/dat_arch/IN-13.pdf

4. Igniting Trigger Tubes and Making Measurement

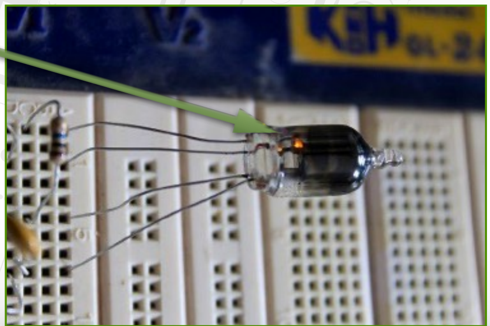
For example, the CRT Tester can test the trigger breakdown characteristic of the Z700U[71] trigger tube (these are primarily intended for use in decade counting and switching circuits) as follows.

- The +HT selector is set to +200V
- The trigger tube anode is connected to the +HT output via a 47k resistor
- The priming electrode is connected to ground via a 10M resistor
- The trigger electrode is connected to ground via a 100p 500V capacitor and connected to the blanking 1 output via a 3M3 resistor.

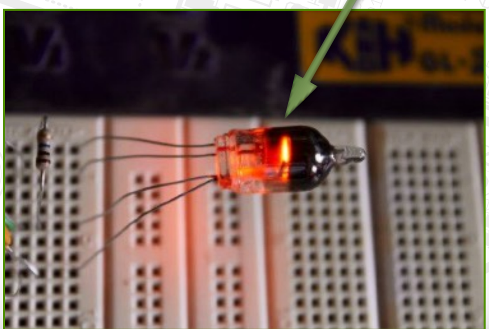


The blanking 1 potentiometer is turned fully anti-clockwise and the CRT Tester is switched on.

The priming electrode in the trigger tube will ignite:

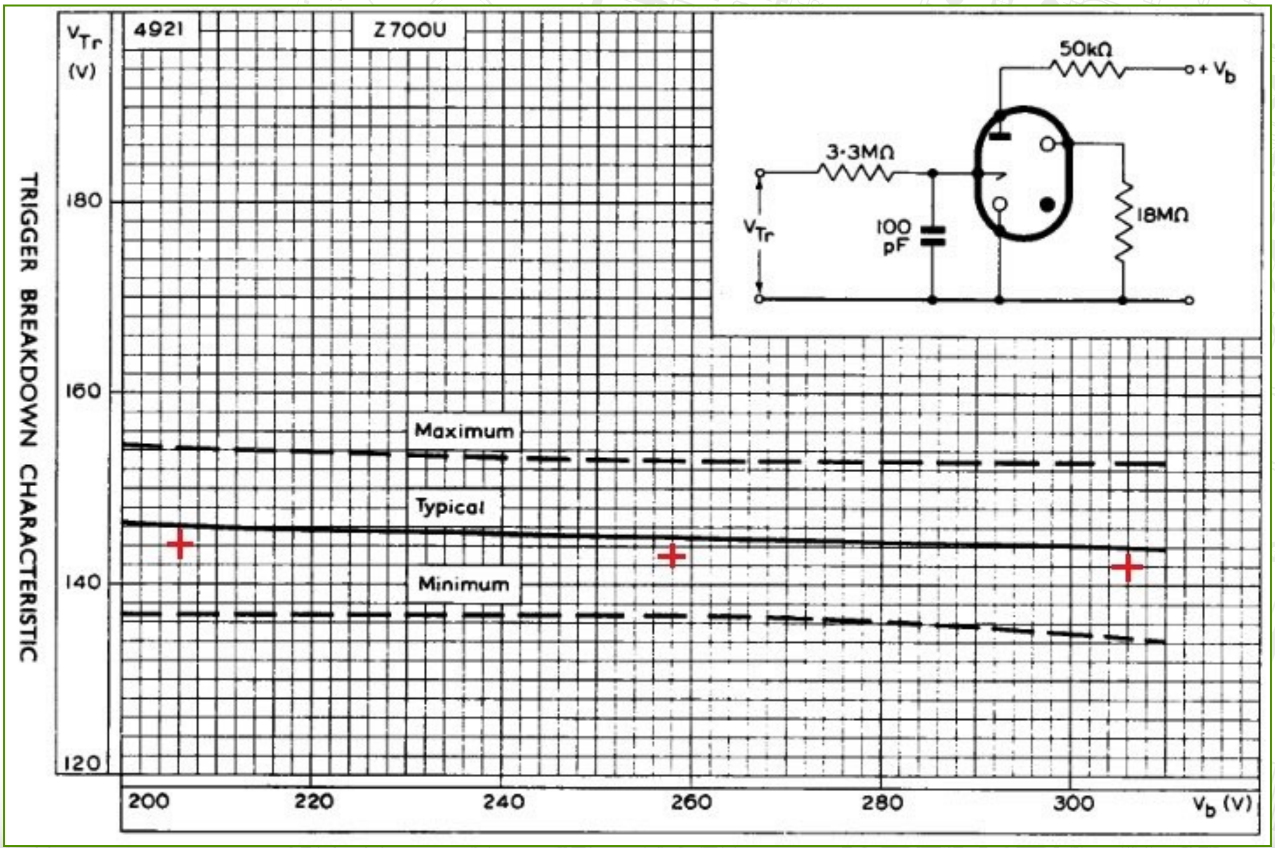


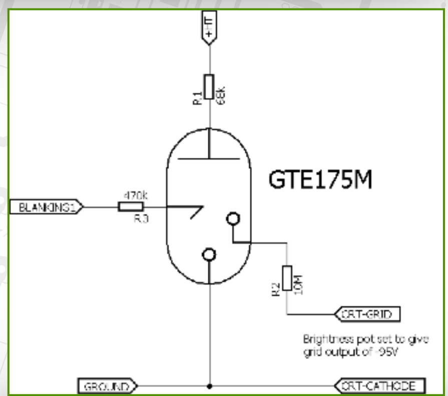
The blanking 1 potentiometer is advanced until the trigger tube main gap ignites:



The trigger electrode voltage need to ignite the main gap can be measured. The test can be repeated at a +HT output selector position of +250V and +300V and the results compared to the data sheet:

71 https://frank.pocnet.net/sheets/129/z/Z700U.pdf





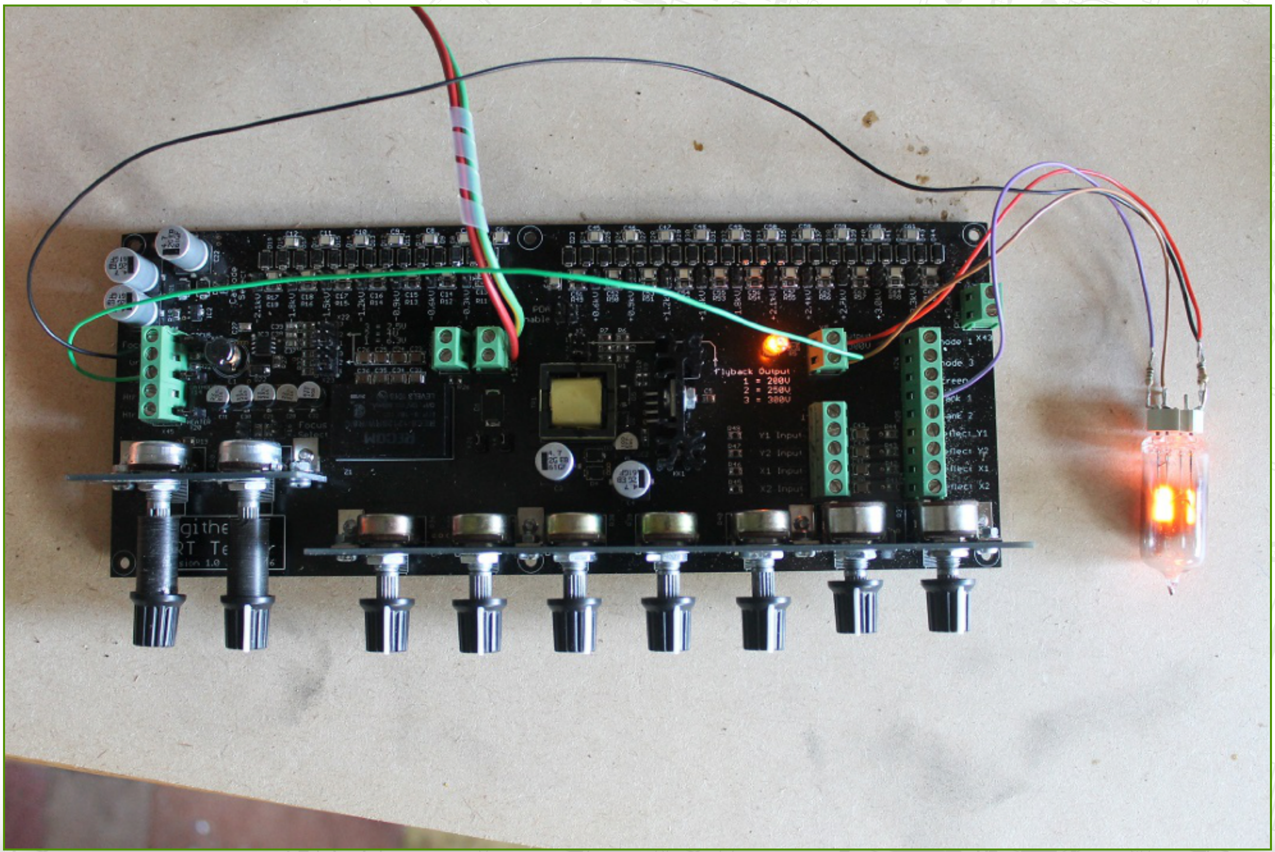
As a second example, the trigger breakdown characteristic of a GTE175M[72] (designed for dekatron coupling circuits and as a general purpose trigger tube). This tube as a primer electrode that requires a -120V supply so I shall use the grid supply to provide this.

The CRT is set up as follows.

- The focus and cathode select jumper wires are not required and must be removed
- The +HT voltage selector is set to +300V
- The tube is connected as follows:
  - Cathode connected to ground
  - The anode is connected to the +HT output via a 68k resistor
  - The CRT cathode connection terminal, “Cath” is connected to ground (the grid supply will otherwise be floating)
  - The priming electrode is connected to the CRT grid connection terminal via a 10M resistor
  - The trigger electrode is connected to the blanking 1 output via a 470k resistor.

The brightness potentiometer can be set about mid position and the blanking 1 potentiometer turned fully anti-clockwise. The CRT Tester is turned on.

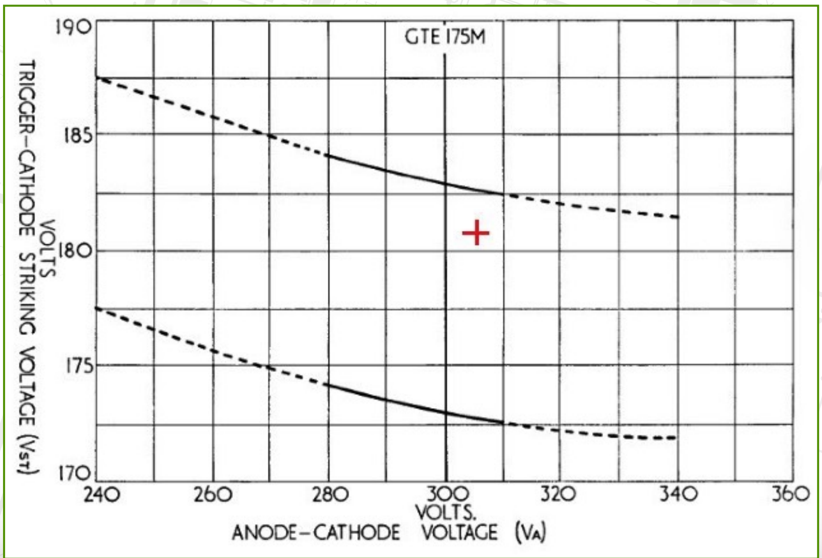
[72] https://frank.pocnet.net/sheets/022/g/GTE175M.pdf



The brightness potentiometer is adjusted to give a grid voltage (to ground) of -95V. The primer electrode in the GTE175M will happily glow:

The blanking 1 potentiometer is advanced until the main gap ignites:

I measured this voltage as 181V.

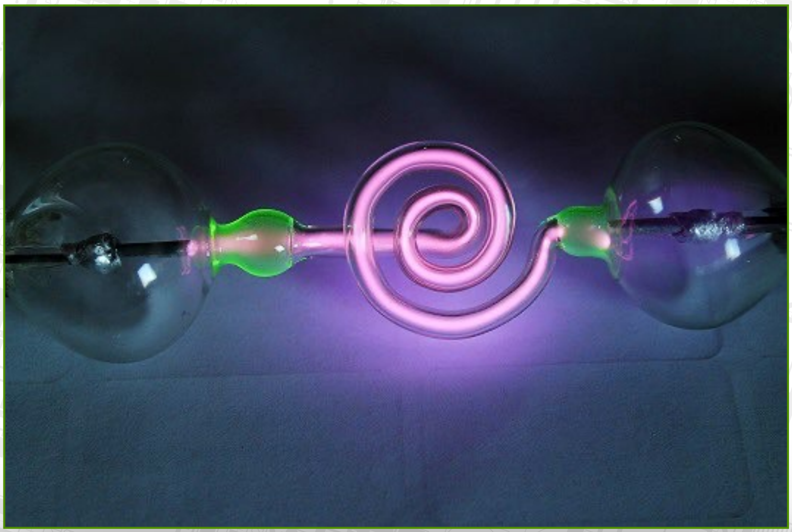


I measured an anode voltage of 150V with main gap ignited; the data sheet says this voltage should be 150V ± 5V so it is right on the money.

5. Geissler[73] Tubes

These are an early gas discharge tube. Reproduction tubes can often be bought on eBay. They require several kV to ignite. Either the -EHT or +EHT (or both) multiplier can be used to ignite the discharge. The exact voltage requirement and the value of the series current limiting resistor will depend on the exact Geissler tube you are using so I cannot give much in the way of numerical values.

Here is one I happen to own:



6. NIMO[74] Tubes

These are a form of CRT where an image is created on a phosphor screen by selecting an appropriate grid which selects a stencil to shape the electron beam.

They require a 1.1V AC or DC supply for the heater and a grid voltage of -6V for cut off and +4V for display. Both the heater and grid requirement are outside the scope of the CRT Tester. However, they require an anode voltage of about 2.5kV which is well within the +EHT multiplier's capabilities. Therefore the CRT Tester could potentially be used as the +EHT supply to test a NIMO tube. A board for doing just that is now available, see later on in this manual.

7. Dekatron[75] Glow Transfer Counting Tubes

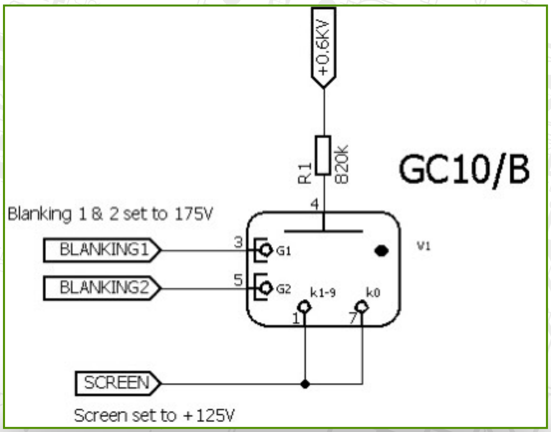
Let's have some fun with a GC10/B[76] dekatron.

The purpose here is to check that the dekatron does glow and is not soft and to demonstrate that the dot can be moved between cathodes.

[73] https://en.wikipedia.org/wiki/Geissler_tube
[74] https://en.wikipedia.org/wiki/Nimo_tube
[75] https://en.wikipedia.org/wiki/Dekatron
[76] http://www.tube-tester.com/sites/nixie/datdekat/GC10-4B_ETL/gc10-4b-etl.htm

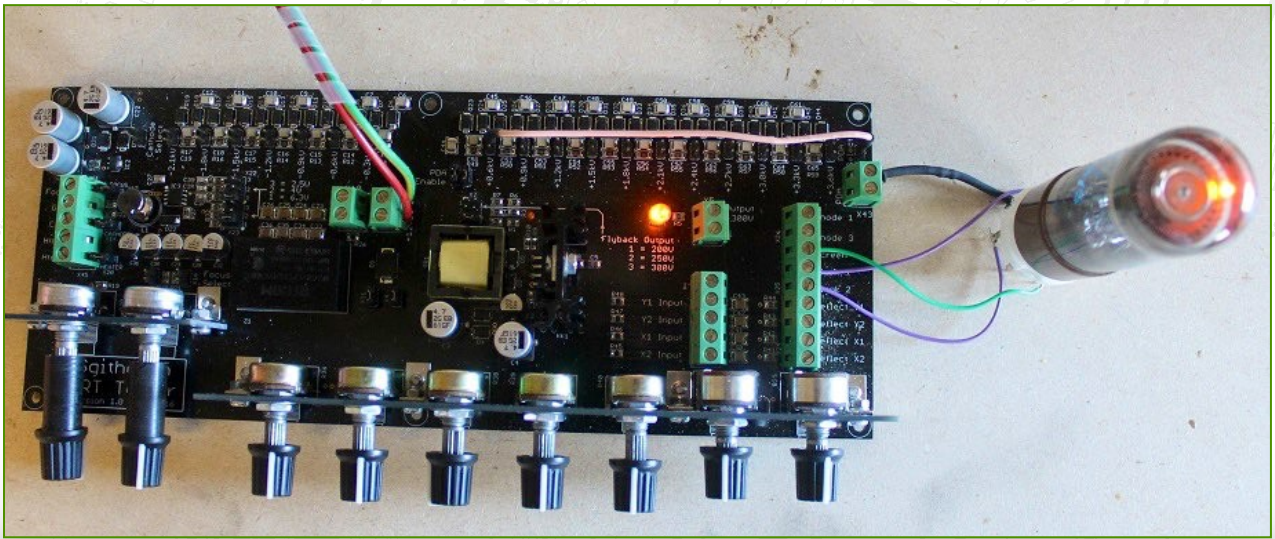
The CRT Tester is set up as follows:

- The PDA enable jumpers are both fitted
- The flyback output is set to +300V
- The +0.6kV take off point is selected by fitting a wire jumper to the PDA select
- The GC10/B anode is connected to the PDA output
- The Screen potentiometer output is connected to the cathodes
- The blanking 1 and 2 potentiometers outputs are connected to the GC10/B guide electrodes G1 and G2 respectively.



The CRT Tester is turned on then using a multimeter:

- The Screen potentiometer output voltage is set to 125V
- The Blanking 1 is set to 175V
- The Blanking 2 is also set to 175V



You will see one cathode glowing. If you switch the CRT Tester off and on again then another cathode will glow.

Using the guide electrodes which are connected to the blanking 1 and blanking 2 potentiometers it is possible to move the glow from the lit cathode to the next cathode.

This is the starting point with a cathode lit and the two guide electrode voltage high.	

Now rotate the Blanking 1 potentiometer fully anti-clockwise. As you do this you will see the glow transfer from the cathode onto the next electrode which is a Guide 1. This is reversible, if you turn the pot back you'll see the glow transfer back onto the cathode.	
Leaving the Blanking 1 potentiometer fully clockwise, rotate the Blanking 2 potentiometer fully anti-clockwise as well. The glow become shared between the two guide electrodes.	
Leaving the Blanking 2 potentiometer full clockwise, rotate the Blanking 1 potentiometer clockwise roughly back to its starting position. You will see the glow slide off guide 1 and become shared between the guide 2 electrode and the next cathode.	
Finally, rotate the Blanking 2 potentiometer clockwise roughly back to its starting position and you will see the glow transfer fully onto the cathode.	

Success, you have counted once. The dekatron can count pulses at the rate of a few kHz so you need to get quick with those potentiometers.

If you reverse the sequence by moving Blanking potentiometer 2 first then the glow will transfer anti-clockwise back to the starting cathode.

There is now a stand alone ‘Dekatester’ kit available that works with the CRT Tester to run Dekatrons. See later on in this manual and the website for ordering information.

Constructing The Case For Your CRT Tester

Putting the CRT Tester in a Good Home[77]

[77] Sorry the Soviet 11Л06И CRT is not included….

Introduction

This construction guide is for a case made from CNC milled 5mm clear acrylic and custom designed låda[78] 3D printed parts.[79] The complete kit includes all the nuts, bolts, banana plugs and jacks, heat shrink tubing, hook up wire and spiral wire tidy, wire ties and other items. Everything needed in other words![80]

Note: some of the photographs of the case were made using a prototype case which had not been laser engraved. A few holes were also removed during development.

Tools Required

The following tools are essential to build the case:

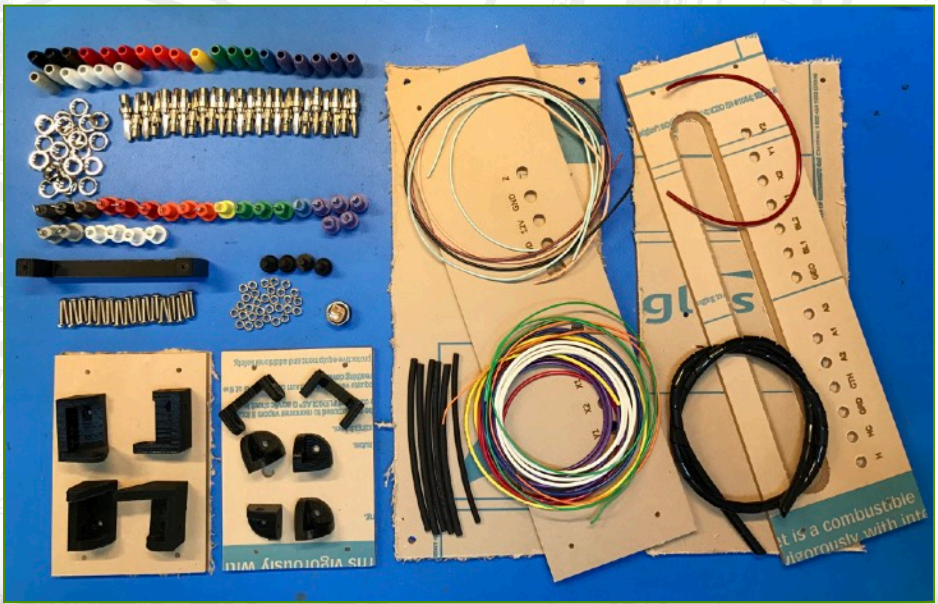
- Small and medium flat blade screw drivers
- Medium cross-head screw driver
- Small adjustable spanner (wrench)
- 2mm hex key (Allen key or Allen wrench)
- Slip joint pliers (channel-locks) or similar (see text)
- Wire cutters
- Wire strippers
- Ruler
- Soldering iron, solder

The following tools are useful

- Hot air gun - for shrink wrap insulation

Component List

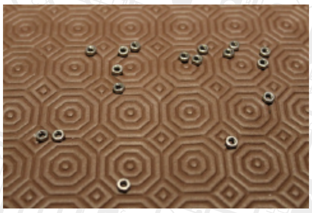
The case will arrive as a flat pack of clear acrylic and all of the remaining components in resealable polythene bags.



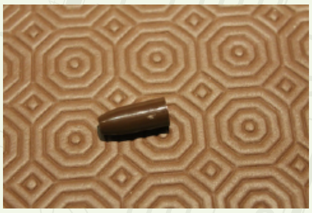
Check that all these components are present in the CRT Tester kit and tick them off (list on next page). Any missing components should be noted so they can be supplied (email below):

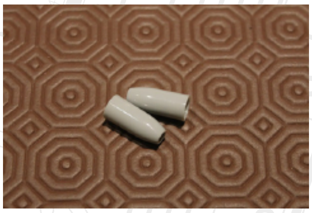
---

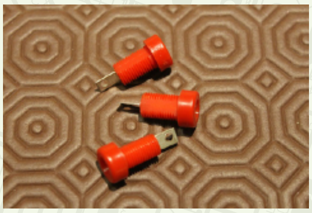
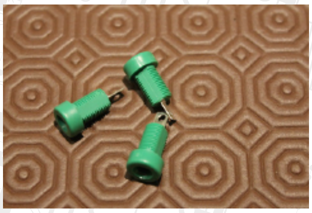
[78] http://wyolum.com/lada-a-custom-project-box-system/
[79] If you don't currently have a 3D printer…..get one, you won't regret it.
[80] If you have any suggestions on how to improve/change then we're all ears. Contact me at nickstock@gmail.com

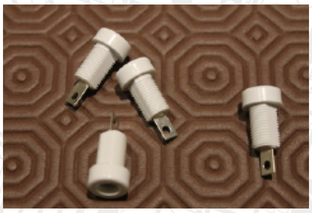
Tick	Quantity	Value	Image
	28	M3 nuts	
	30	14 mm M3 hex head bolts	
	1	Wire tidy clip	
	4	Black nylon thumb screws	
	1	Låda PCB support front right (FR)	
	1	Låda PCB support front left (FL)	

Tick	Quantity	Value	Image
	1	Låda PCB support back right (BR)	
	1	Låda PCB support back left (BL)	
	2	Låda PCB support centre	
	4	Låda lid supports	
	1	Handle	

Tick	Quantity	Value	Image
	1	2.1 mm DC Input Jack	
	2	Black banana plug body	
	1	Brown banana plug body	
	3	Red banana plug body	
	3	Orange banana plug body	
	1	Yellow banana plug body	
	3	Green banana plug body	

Tick	Quantity	Value	Image
	1	Blue banana plug body	
	5	Violet banana plug body	
	2	Grey banana plug body	
	4	White banana plug body	
	25	Banana plug cores	
	2	Black banana socket	
	1	Brown banana socket	

Tick	Quantity	Value	Image
☐	3	Red banana socket	
☐	3	Orange banana socket	
☐	1	Yellow banana socket	
☐	3	Green banana socket	
☐	1	Blue banana socket	
☐	5	Violet banana socket	
☐	2	Grey banana socket	

Tick	Quantity	Value	Image
	4	White banana socket	
	25	Banana socket nuts	
	500mm	Black EHT wire	
	500mm	Brown EHT wire	
	500mm	Pink EHT wire	
	500mm	Off-White EHT wire	
	400mm	Red EHT wire	
	800mm	Red HT Wire	
	900mm	Orange HT wire	
	900mm	Green HT wire	
	600mm	Blue HT wire	
	1300mm	Violet HT wire	
	1300mm	White HT wire	
	300mm	Heat Shrink Tubing	

Tick	Quantity	Value	Image
☐	0.5M	Spiral wire wrap	

<u>Acrylic Component Identification</u>

There are only six acrylic parts that make up the case. Note, these photographs were taken of a prototype case before the laser cut labelling was added.[81] The photos will enable you to distinguish the parts and which way round they are fitted.

The photographs below are for identification only and have not been taken to the same scale.

1. Front[82]

Easily identified by the large chamfered slot which faces outwards:

2. Back - Remarkably, this is the same size as the front! This photograph is the view from the rear with the larger hole (the 12V DC 2.1mm jack) offset to the right.

[81] You will obviously need to peel the paper of the parts supplied….gloves or some form of hand covering are recommended to stop getting nasty finger prints all over that *lovely clear acrylic*…..

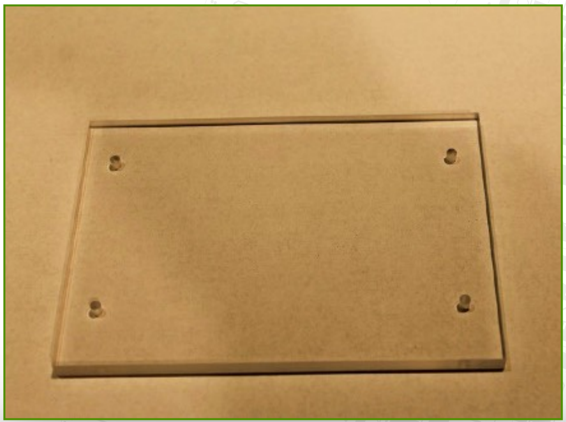
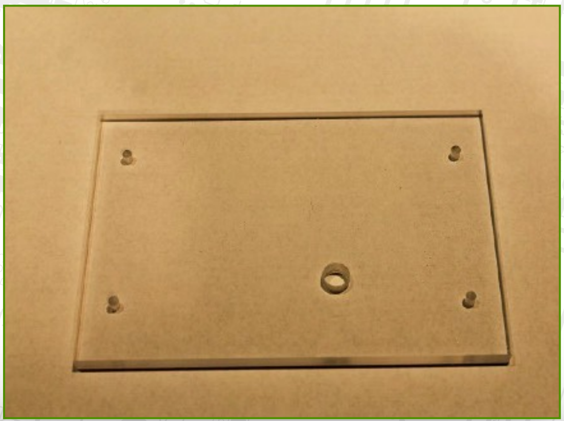
[82] Yours will be laser engraved, obviously….

3. Top (Identified by the two holes that the handle is fitted to and the 4 corner holes that the knurled thumb screws fit).

4. Bottom (note centre holes are to the left a bit!)

5. Side pieces

When viewed from the outside, the large hole for the PDA jack is offset to the right on the right hand side piece.

Case assembly

Case assembly is not hard and the description that follows illustrate two methods of wiring the CRT Tester between the PCB and the jacks around it. If you are an experienced constructor then you will probably only need to glance through the next few pages and then build the case how you wish.

1. Completing the låda[83] parts.[84]

These eight parts have hex recesses that will accept M3 nuts. The recesses are a very tight fit so the nuts can become captive. The method I prefer is to use slip joint pliers[85] (channel-locks) to squeeze the nut down into the recess. Moderate force is needed and the nut needs to be aligned above the recess or there is a risk that the components will be break.[86]

An alternative method is to position the nut above the recess and heat the nut gently with the tip of a soldering iron so that it melts the PLA[87] polymer (melting point around 150-160 °C) and can then be gently pushed down into the recess. There are a total of 28 M3 nuts to position. Note that the top lid parts have only two M3 nuts fitted. The third hole will have been drilled and tapped to take the thumb screws.

2. Wiring the jacks

Wire the jacks with over-length wires so that they can be insulated with heat shrink tubing prior to fitting them to the acrylic so no there's hot air gun near the acrylic or Låda parts. There are 25 jacks in total to be soldered. The colour, function, position, appropriate wire and cut lengths to use are presented in the following tables:

---

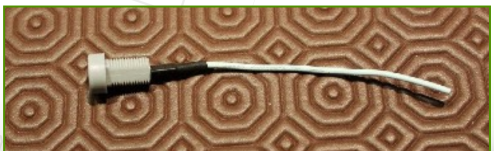
83 I have to admit some disappointment when I discovered that låda means "box" in Swedish - I was hoping for something more *evocative*
84 A more comprehensive guide to using Låda parts can be found in the Sgitheach Commoners Manual (see Dropbox)
85 Such as tongue-and-groove pliers also known as water pump pliers, adjustable pliers, groove-joint pliers, arc-joint pliers, multi-grips, tap or pipe spanners, gland pliers, etc, etc…..
86 All the låda parts are inspected before shipment - due to tolerance issues on different 3D printers, your LADA parts may already have the captive nuts melted into their respective holes…you're welcome…if you print your own, then the nut hole dimension may need altering
87 PLA - Polylactic acid - https://en.wikipedia.org/wiki/Polylactic_acid

2.1 Front Panel Jacks.[88]

The cut length needed depends on the wiring plan you are planning to use, either _under_ or _over_ the board (these length are supposed to be a guide to a generous length but without being overly long and they are not *precise*).

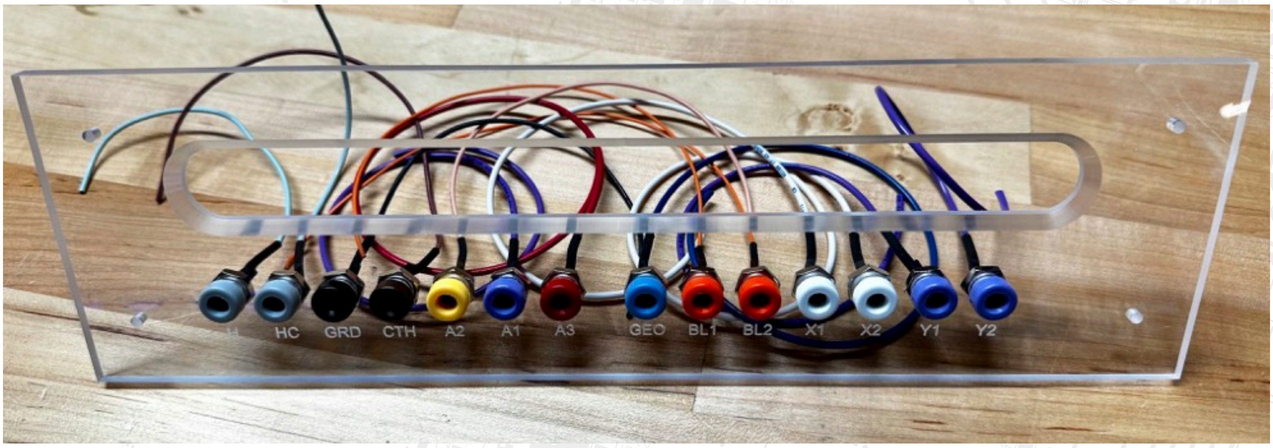
Position	Engraving	Function	Socket Colour	Wire	*Over* length (mm)	*Under* length (mm)
A	H	Heater 1	Grey	EHT	150	80
B	HC	Heater 2	Grey	EHT	170	80
C	G	Grid	Black	EHT	180	120
D	CTH	Cathode	Brown	EHT	190	120
E	A2	Focus Anode 2	Yellow	EHT	190	150
F	A1	Anode 1	Violet	HT	290	200
G	A3	Anode 3	Red	HT	310	200
H	GEO	Geometry/Shape	Blue	HT	290	150
I	BL1	Blanking 1	Orange	HT	240	120
J	BL2	Blanking 2	Orange	HT	230	120
K	X1	X1 Deflection	White	HT	280	100
L	X2	X2 Deflection	White	HT	270	100
M	Y1	Y1 Deflection	Violet	HT	230	80
N	Y2	Y2 Deflection	Violet	HT	200	80

Example of one grey jack socket soldered to the grey EHT cable and insulated with a 15mm length of heat shrink tubing:

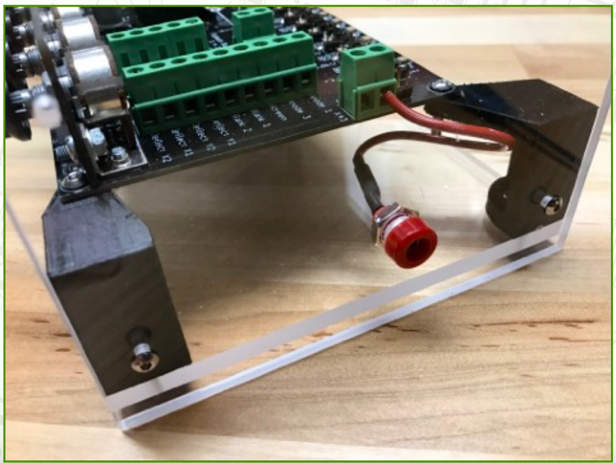


[88] The front panel in your kit now has laser engraved markings to show which socket is which….neat huh?

This is what the front panel should look like when all the jack sockets are in place.[89]

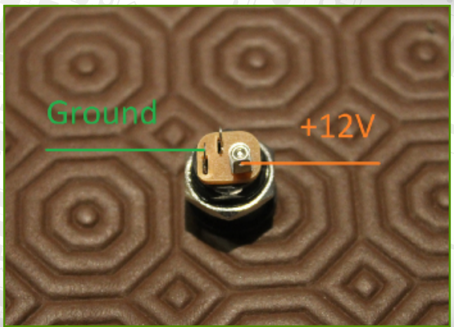


2. Right Hand Side Panel Jack



There is a single jack on the right hand side for the PDA connection. The red EHT cable supplied is used for this purpose (see right for an example of *over* board wiring). In an abundance of caution, there is an extra large piece of heat-shrink tubing to go over the first piece to add insulation to the metal connector.

A special note on wiring the 12V DC 2.1mm input jack is required! This jack has 3 pins and must be wired for the correct polarity:

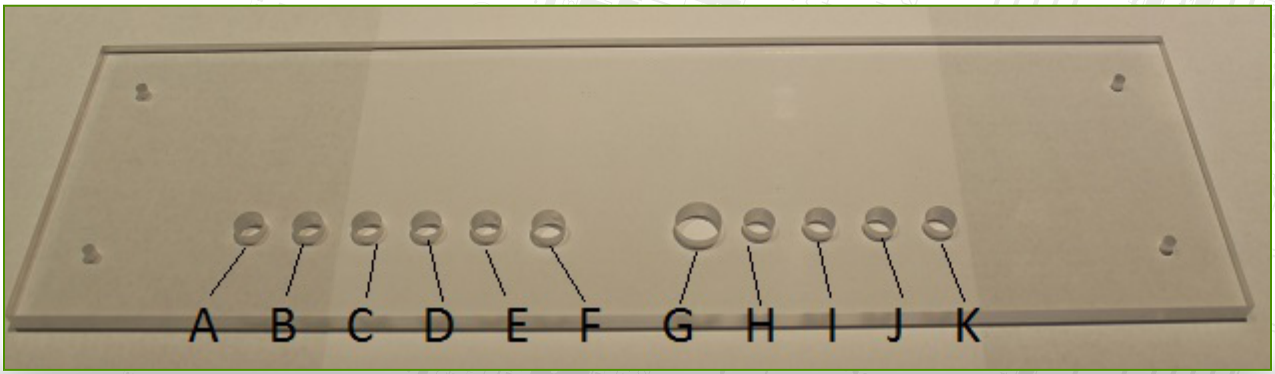


I would perform a polarity "sanity check" with a power supply and multimeter

[89] Take care when screwing the nuts on the socket threads…the plastic isn't very forgiving of cross-threading, so please don't force them.

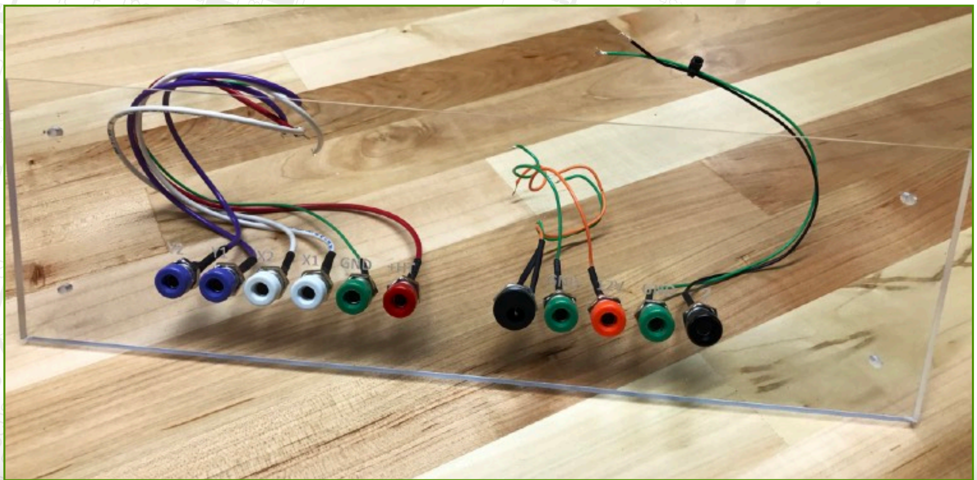
2.3 Back Panel Jacks

Looking from the back..



Position	Engraving	Function	Socket Colour	Wire	*Over* length (mm)	*Under* length (mm)
A	Y2	Y2 deflection input	Violet	HT	190	100
B	Y1	Y1 deflection input	Violet	HT	210	100
C	X2	X2 deflection input	White	HT	260	100
D	X1	X1 deflection input	White	HT	270	100
E	GND	Ground	Green	HT	220	100
F	+HT	+300V output	Red	HT	280	100
G		12V DC 2.1mm input	Black (not a banana jack)	HT HT	120 (x2)	70 (x2)
H	GND	Ground	Green	HT	120	90
I	12V	+12V DC	Orange	HT	130	90
J	GND	Ground	Green	HT	230	100
K	Z	Z input	Black	HT	220	100

This is what the rear panel should look like when all the jack sockets are in place.



 Version 1.5

Wiring under or Wiring over?[90]

There are now basically two ways to proceed according to your taste. The wiring between the PCB and the jacks can be made under or over the PCB. Both wiring plans will be described and you can choose. There is no reason to not have a hybrid version with some of each. You have the choice of soldering the wires directly to the PCB or wiring them to the screw terminals provided with the CRT Tester electronics kit (see the CRT Tester construction manual).

Plan A - The Stock Plan - The wiring goes over

For his prototype case, Nick chose to route all the wiring over the PCB and use the screw terminals…[91]

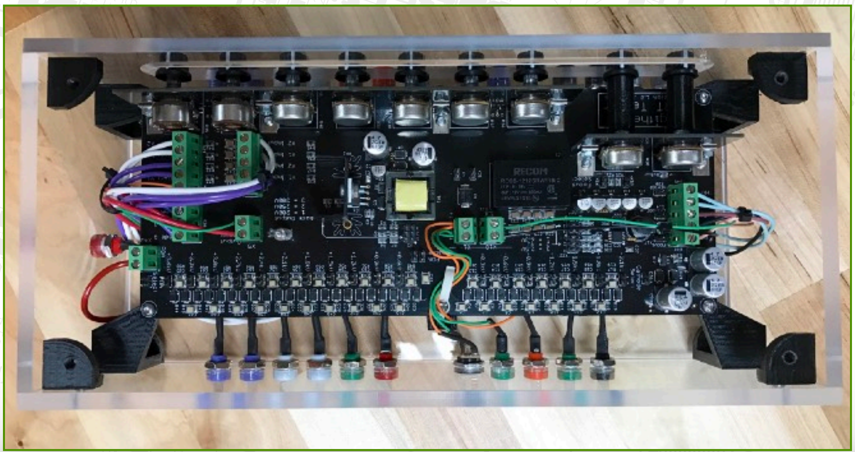
This method has some disadvantages:

- It uses more wire than the direct soldering route.
- It obscures some of the top of the board (minor complaint).

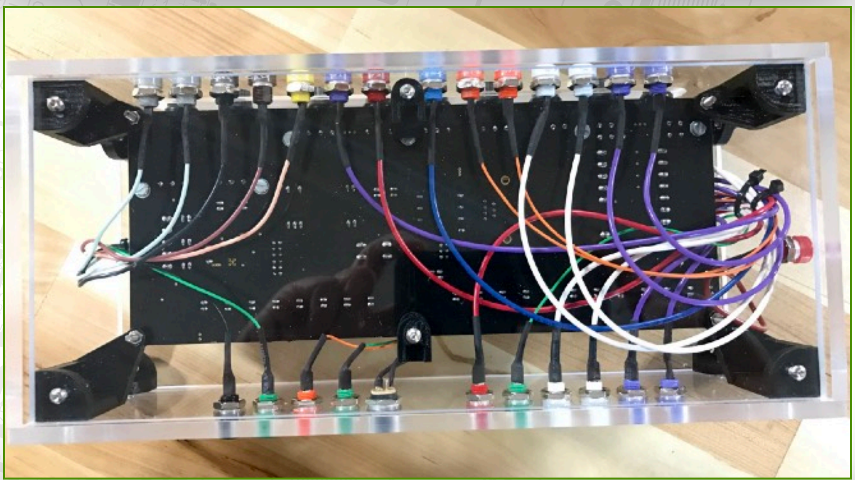
The advantages are:

- If you need to repair the board for any reason, it's easy to take apart (as opposed to de-soldering).
- Wiring the correct socket to the correct connector is straightforward.

With this wiring configuration the top of the board looks like this:



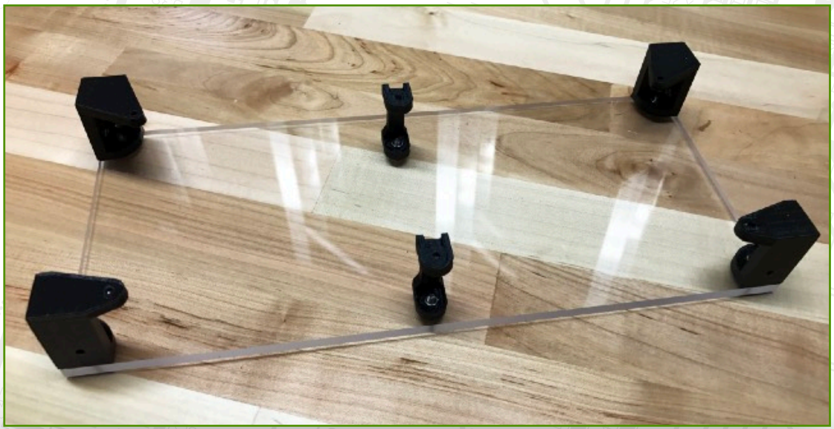
And the underside of the Stock build looks like this:



[90] Decisions, decisions…..
[91] Silly me thought that was what they were there for!

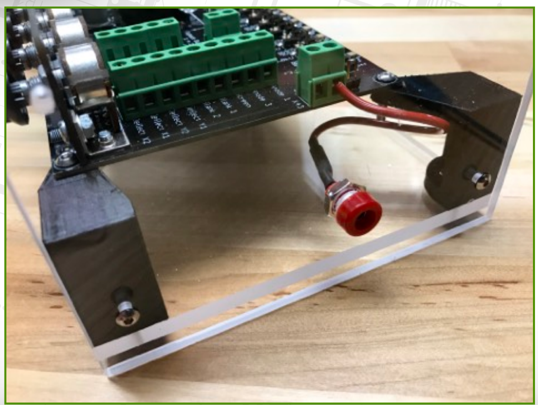
If this is the route you want to take, read on…if not, skip forward to see Plan B.

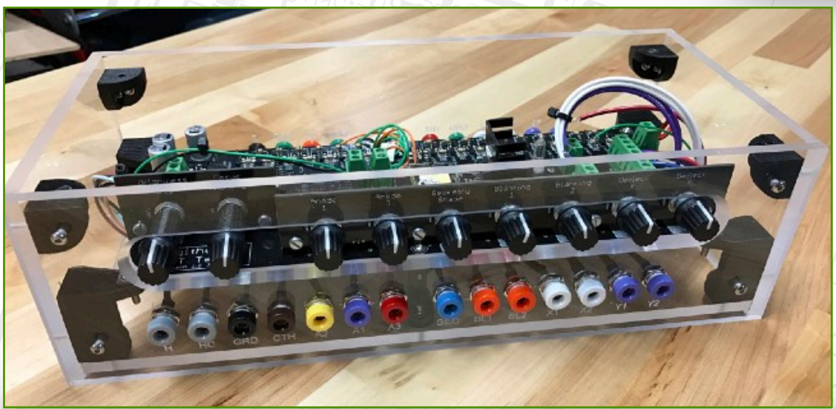
Start by attaching the PCB supports with the supplied M3 screws to the base plate…note that the centre supports are arranged as pictured to the left of center. Note that each of the corner pieces has raised lettering on the inside for locating (FR - Front Right, FL - Front Left…etc).



Then attach the PCB to the six supports using (you guessed it) six more M3 screws. You'll need to temporarily remove the screws in the potentiometer board that 'get in the way' and rethread them after the PCB is attached to the supports.

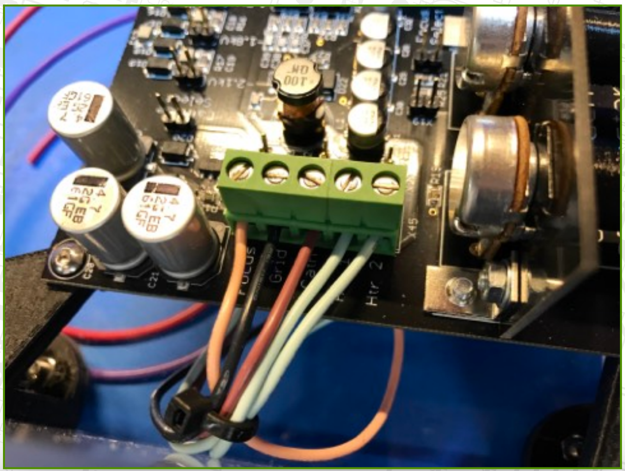
Take the side panel with the PDA hole and put the red socket jack with the EHT red wire and affix with 2 screws as shown. Then attach the red wire to the PDA terminal on the board. I decided to route it around the back of the PCB support so as not to bend the metal jack tab too much, but feel free to route it as you see fit.



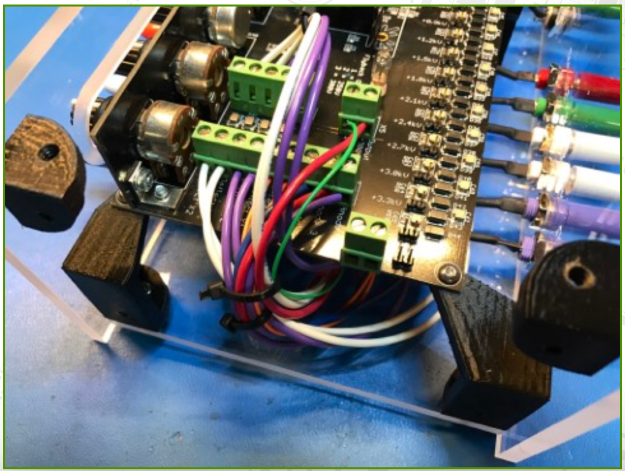


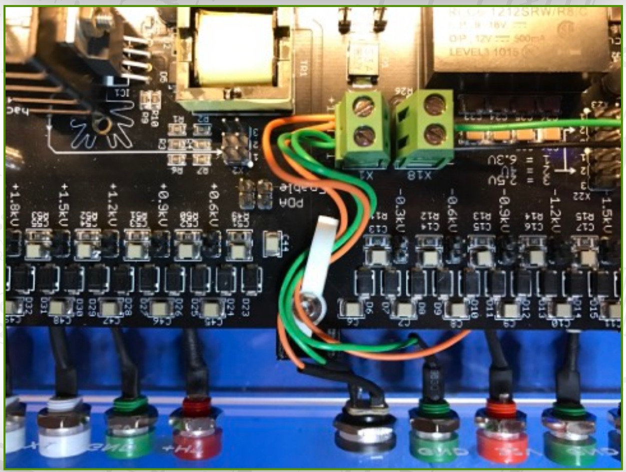
Take the pre-wired front panel and feed the wires under the board and attach the front to the Låda pieces as shown.

Attach all the wires to the relevant screw terminals and double check that you wire the correct ones to the correct terminals! Here you can see the EHT wiring terminating at the left hand side of the board. You can use a cable tie here and there to tidy things up a little.

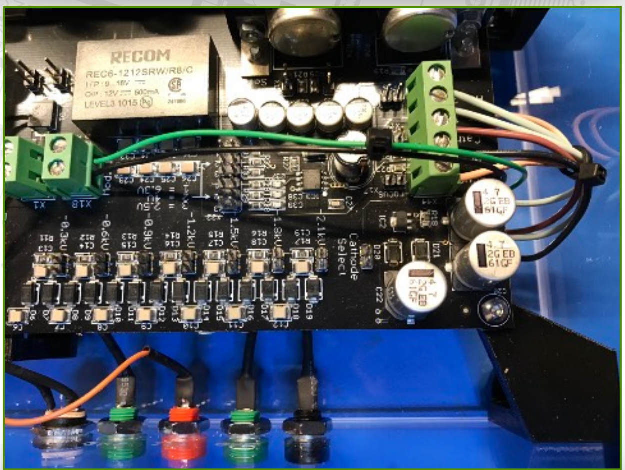


Follow the same procedure with the rear panel (this can get a bit fiddly) and connect all the respective wires to their respective terminals (feed them to the left of the board when looking from the rear). Use the included wire clip to tidy the 12V/GND leads from the rear as shown below in the photos.



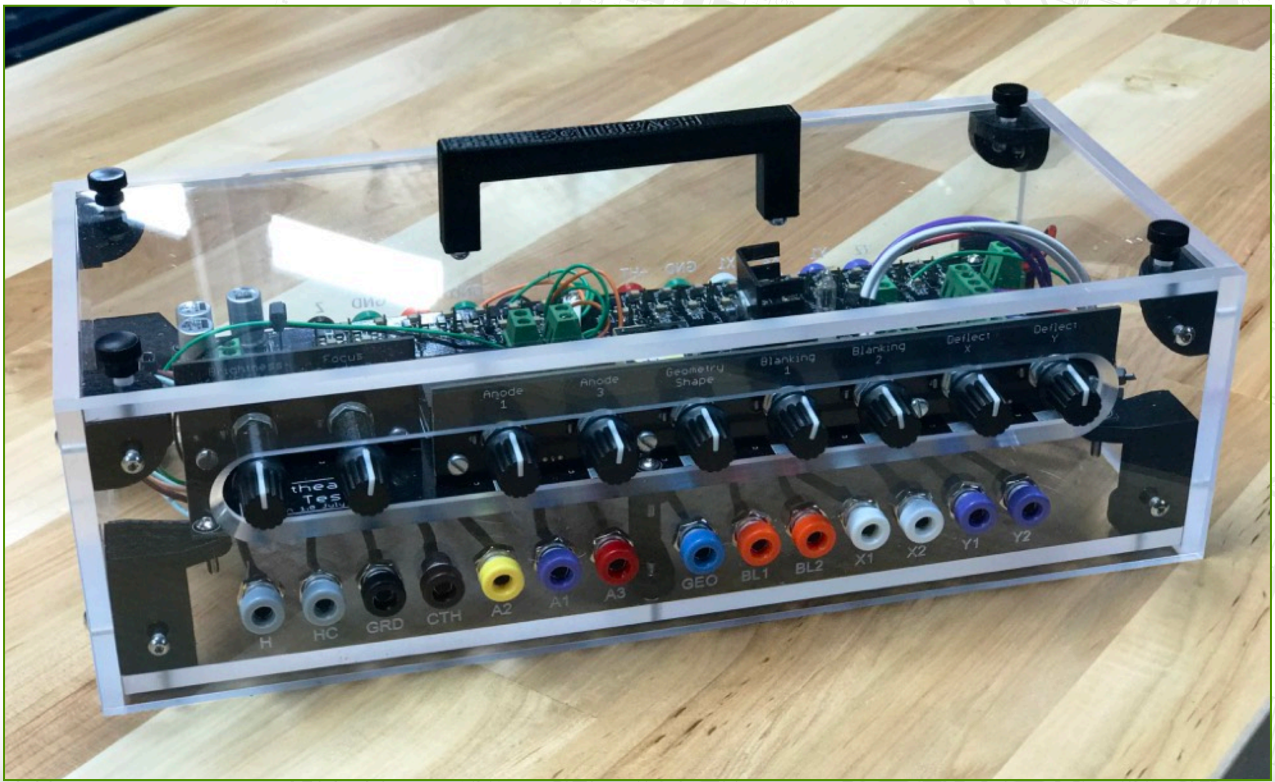


Top Left: All the wiring in place and tidy (with side panel removed for clarity): **Top Right**: Wire clip keeping the 12V/GND wire in place. **Bottom Right**: Wiring for the Z input and associated GND connection.



The final steps involve attaching the other side piece (obvious I know), then attaching the top Låda pieces (note that these only have M3 nuts in the side positions and the top is threaded for the included thumb screws. The handle screws in to the top with the remaining M3 screws (the handle is pre-threaded).

The end result!



Use the remaining wire[92] to make up the necessary leads with the supplied banana plugs to start testing your CRTs! (or other high voltage devices)[93]

---

[92] There will be some left overs and make sure you use the correct rated wire for the EHT connectors (H, HC, GRD, CTH, A2 and PDA)
[93] As detailed in the Operations Manual.

Plan B - The Marsh Plan - The wiring goes under

For his prototype case, Grahame chose to route all the wiring under the PCB and solder the wires directly to the PCB.

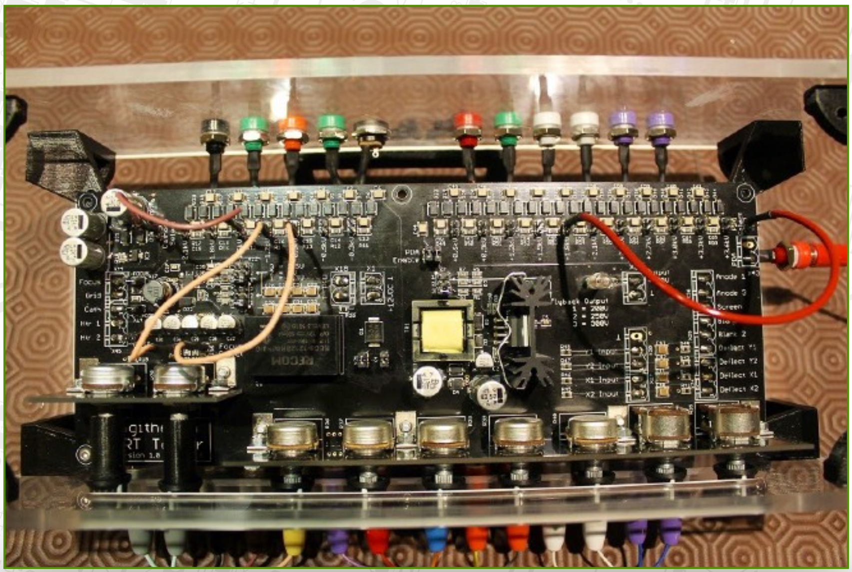
This method has some disadvantages:

- The soldered wiring will make it difficult to remove the PCB again from the case
- The wiring reduces easy access to the through hole soldering under the board making maintenance (in case of accidents which lets the magic smoke out)
- There is no bottom silkscreen so care is needed with the leads to ensure the correct hole in the PCB is routed to the correct jack

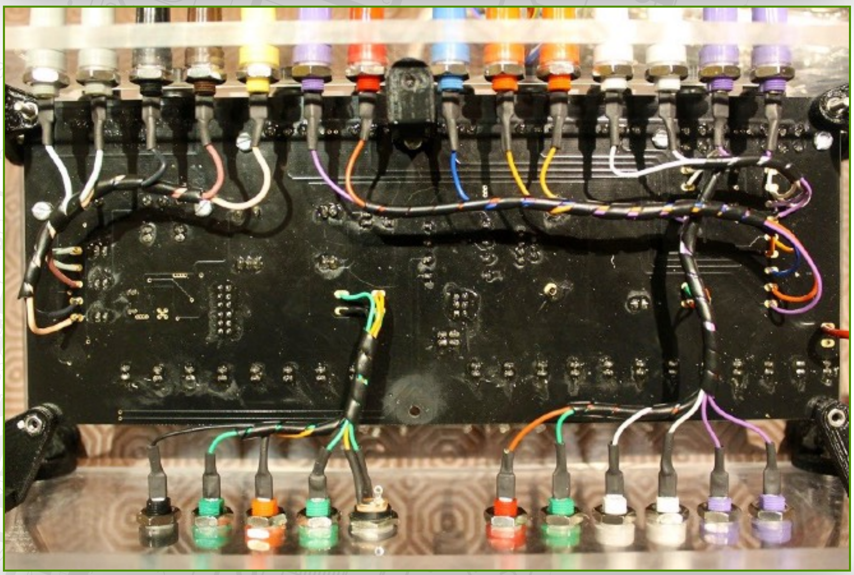
The advantages are:

- The top of the board remains fully open giving easy access to the SMD components and all the configuration jumpers

With this wiring configuration the top of the board looks like this:

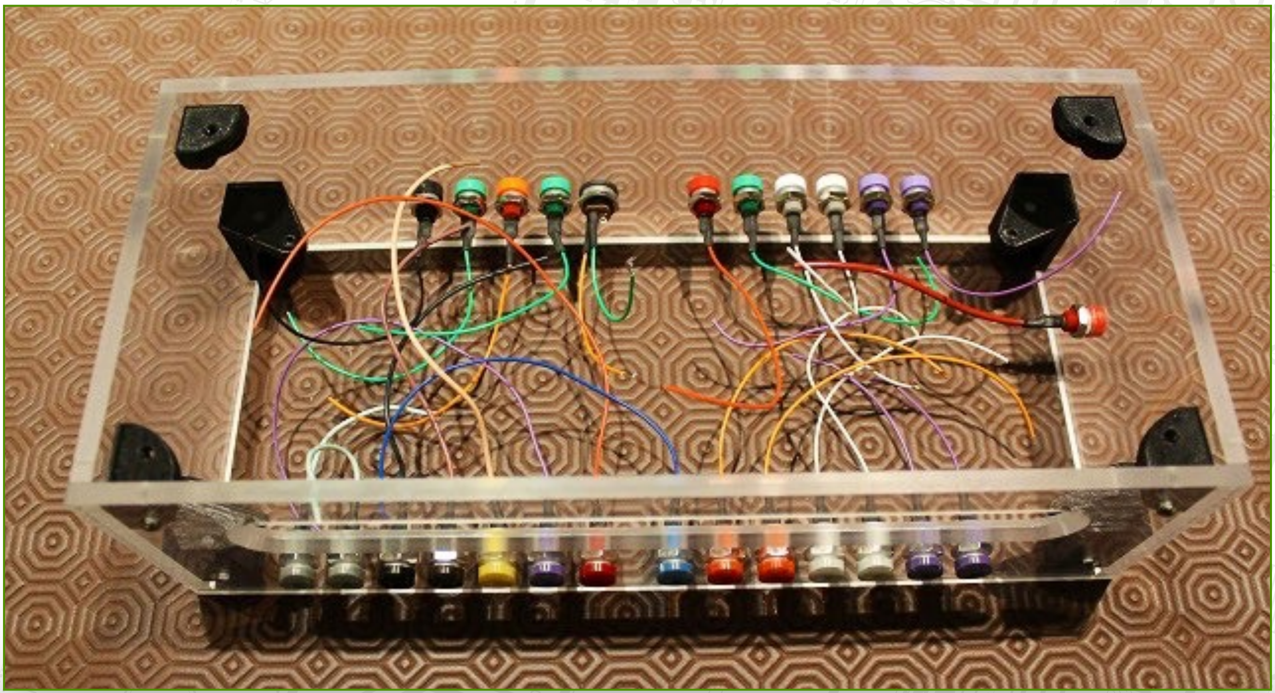


And the underside of the Marsh build looks like this:[94]



[94] I will refrain from comment (*Ed.*).

The sides can be bolted together using the eight Låda 3D printed parts. The top four parts are identical and can be fitted to any corner, just ensure the threaded hole is uppermost. The lower four parts are all different but are labelled on the inside to indicate their correct position when you view the CRT Tester from the front. However, don't fit the front right (FR) bracket yet... you'll see why next.



You can now mount the PCB in the case. You should also mount the two central PCB supports on the PCB to be in place when the bottom is screwed in place.

In doing these operations you will find two problems - the PCB support pillar screw in the front centre of the PCB is difficult to fit because the bracket between R37 and R38 gets in the way and the support corner next to R35 is interfered with by the bracket there.

The work around for each are simple enough and done before the board is put in the case.

The first is dealt with by removing the M3 nut and bolts holding the bracket between R37 and R38 and push the hex M3x14 bolt into the hole. The bracket can be remounted and then a PCB central support can then be fitted and the bolt tightened.

The second is a similar process. The bracket next to R35 is removed and a M3x14 screw fitted through the hole. The bracket can be refitted and then the FR corner PCB support fitted.

The PCB with its two fitted support can be put in the case and mounted onto the remaining PCB supports.

Other wiring plans

There are many other schemes. For example you could mount the screw terminals under the board and route the wires under as well. Or you could wire above the board and solder the wiring in place. Or any other hybrid you invent.[95]

[95] Just be sure to be mindful that you use the correct voltage rated wire if you decide to build your own case!

Annex A - Suggested wire to use

LT and HT wire

Any wire with a voltage rating of 600V to 1kV (very common multi-colour hook up wire) is suitable for all the board to jack wiring EXCEPT as listed below.

EHT wire (other than the PDA)

Any wire with a voltage rating of up to 3kV is suitable for the connections to the heater (2 off), grid, cathode and focus (A2) jacks. The wire supplied with the kit is made by CnC Tech:

http://www.cnctech.us/pdfs/3239-22-1-0500-007-1-TS.pdf

And sold by Digikey in lengths from 7.62m to 152.4m[96]

Colour	Digikey Part Number
	CN104B-25-ND
	CN104N-25-ND
See Footnote	CN104A-25-ND
	CN104W-25-ND

EHT wire for the PDA

Any wire with a voltage rating of up to 5kV for the connection to the PDA jack is suitable. The wire supplied with the kit is made by Poloma Electronics and has DigiKey part number 501-1282-ND.

[96] Or 25 ft to 500 ft for you Imperialists…Orange was out of stock when putting this together, hence the rather nasty shade of pink was used (we all make mistakes).

Annex B Mouser Banana Plug Part Numbers

Johnson/Cinch Connectivity Solutions

https://cinchconnectivity.com/OA_MEDIA/drawings/dr-1080303001.pdf

Colour	Mouser Part Number
	108-0303-001
	108-0308-001
	108-0302-001
	108-0306-001
	108-0307-001
	108-0304-001
	108-0310-001
	108-0312-001
	108-0313-001
	108-0301-001

In case you wish to purchase more[97]

[97] These plugs are rated to 3.5kV RMS, maximum of 15A rating. If you decide to buy different ones, please make sure to use the appropriate isolated jacks and plugs.

CRT Tester - A Simple Power Supply

A Robust Power Supply For Your CRT Tester[98]

[98] A purpose designed PSU so you don't have to tie up your bench supply - Also has a separate 15V rail for extra utility!

Introduction

The CRT Tester project needs a 12V DC supply to operate. I was using a bench PSU but it became inconvenient when I wanted to use both the CRT Tester and the bench PSU together. So I have built this simple 12V PSU to power the CRT Tester complete with a 15V auxiliary output as well.

This construction guide includes a case made from laser cut 5mm clear acrylic and custom designed låda[99] 3D printed parts.[100] The complete electronics and case kit includes all the nuts and bolts, banana plugs, hook up wire. Everything in one word.[101]

Acknowledgements

My thanks to Wyolum for the whole låda case construction concept that works so well with 3D printed parts and laser cut acrylic panels.

Tools Required

The following tools are essential to build the case:

- Small and medium flat blade screw drivers
- Small cross head screw driver
- Small adjustable spanner (wrench)
- Slip joint pliers (channel-locks) or similar (see text)
- Wire cutters
- Wire strippers
- Soldering iron, solder
- Hot air gun for heat shrink tubing

This is not an overly difficult kit to construct. Providing you can solder neatly and follow the assembly instructions accurately, there should be no problems. Lots of light, some magnification and de-soldering braid to remove excess solder work every time for me.

The last "tool" is you and your time - this kit has a only few components to fit and they have been bagged to help you build without error. Take your time, take breaks and enjoy the experience!

Kit Overview

To some extent this depends on what you have ordered. Two kits are offered:

- The bare minimum kit that consists of just the PCB. If you have gone down this route then I assume you know what you are doing, where to buy all the components and how to build the thing i.e. you are an experienced constructor. I'm not going to teach my grandmother to suck eggs and instruct you on what, how, why, when etc.

- You have bought a standard kit that consists of the PCB with all the SMD parts fitted and the through hole components, mechanical parts and acrylic case.

The assumption I will make is that you have ordered a complete standard kit.

---

[99] http://wyolum.com/lada-a-custom-project-box-system/
[100] I have to admit some disappointment when I discovered that låda means "box" in Swedish - I was hoping for something more *evocative*
[101] Well, one sentence if you're being pedantic about it..

Component List

The case will arrive as a flat pack of clear acrylic and all of the remaining components in resealable polythene bags.

Upon your receipt of the kit of parts, any missing or broken pieces will be replaced if discovered. It is incumbent upon you, the recipient, to check the contents in a prompt manner (within a few months) against the supplied parts lists found within this construction manual.

If the CRT Tester PSU kit has arrived in a damaged state such that an insurance claim is likely then notification should be made immediately (within a few days of receipt). It is likely that photographic evidence will be asked for to make any insurance claim.

At this time you should review your ability to build and safely operate this CRT Tester PSU!

If you want to return the kit then now is the time to do so. No refund will be available for a partly built kit. As long as the returned kit is complete, the refund will be as well. The cost (postage and insurance) of returning the kit is yours to bear and the refund will not include the postage and insurance that I paid. Additionally, if the kit is returned from outside the EU then the possibility exists that the UK Tax Man will demand a slice of its value and you will be accountable for this cost as well.

A table of the complete kit contents follows on the next pages. Please use it to double check that everything is present and correct.

Component List - PCB and Mounted Components

Tick	Quantity	Description	Part Number
	4	100n	C1, C2, C7, C10
	6	2200µ 25V	C3, C4, C5, C6, C8, C9
	1	3mm yellow LED	D1
	1	3mm red LED	D2
	1	50V 4A bridge rectifier	D3
	1	1N5822	D4
	1	3mm green LED	D5
	1	7815	IC1
	1	LM2576-ADJ	IC2
	1	38mm SK104 heatsink	KK1
	1	6mm bolt, washer and nut	mounting IC2 onto KK1
	1	100µH 2.65A	L1
	4	4k7	R1, R2, R6, R7

Tick	Quantity	Description	Part Number
	1	10k	R3
	1	470R	R4
	1	1k2	R5
	2	Switch	SW1, SW2
	1	2 x 15V RMS 24VA transformer	TR1
	4	Self tapping screws	mounting TR1 on the PCB
	2	2 way screw connectors	X1, X3
	1	3 way screw connector	X2
	1	Bare PCB (no SMD parts!)	

Component List - Case and Mechanical Components

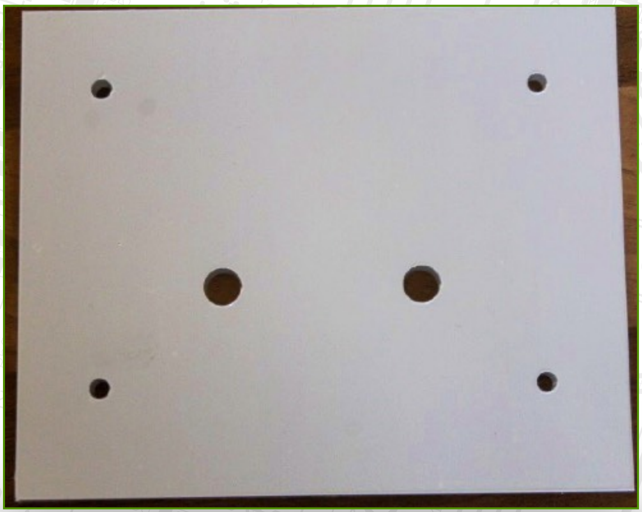
Tick	Quantity	Description
	1	Orange 4mm banana jack
	1	Green 4mm banana jack
	1	Wire gland
	1	Wired 2.1mm barrel plug
	1	Mains inlet connector, fuse folder, switch and indicator neon
	1	1.5A fuse
		Quantities of mains rated wire, some orange and green hook up wire, cable ties, heat shrink tubing
	7	Crimp spade connectors
	6	Acrylic case components (see next section)
	30	M3 nuts for låda parts
	26	M3 12mm bolts for låda parts
	4	M3 bolts 6mm long for PCB mounting
	2	M3 12mm bolt, washer and nut for mains inlet mounting
	4	3D printed låda PCB support and corner
	6	3D printed låda corner

Acrylic Panel Identification

There are only six acrylic panels that make up the simple case. The identification photographs were taken with the protective film in place.

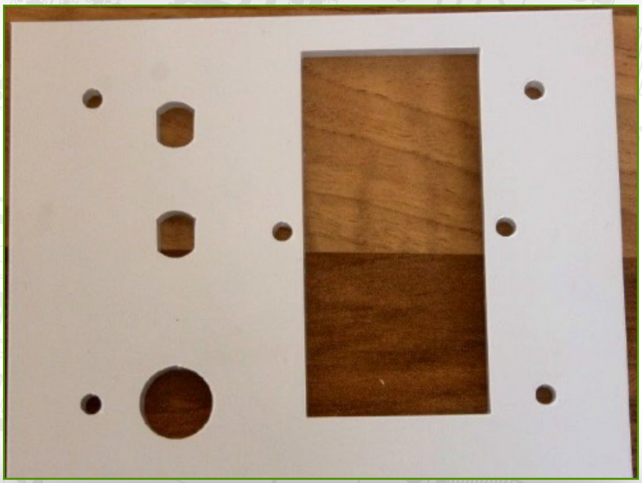
1. Front panel

Easily identified by the two holes which takes the switches through the front panel:



2. Back panel

Identified by the “double D” holes for the jacks and the large cut out for the mains inlet:



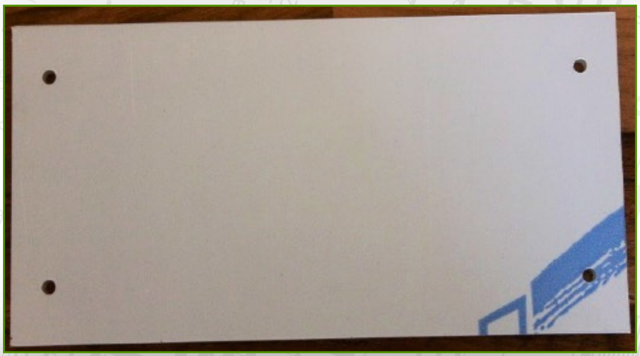
3. Top Panel

Identified by the 4 holes for the top mounting bolts:

4. Bottom Panel

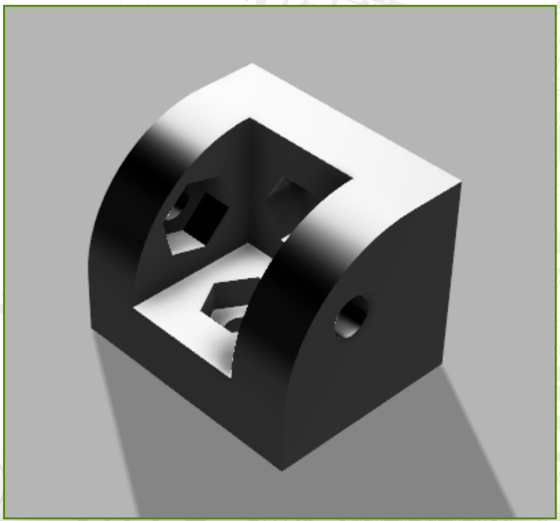
Same size as the top but 6 holes:

5. Right and left hand panels

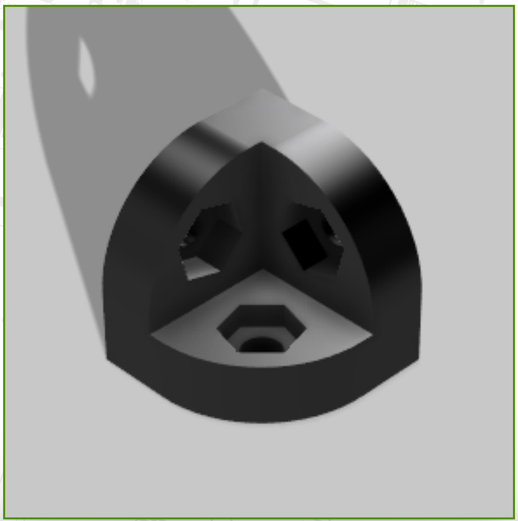


Låda Part Identification

1. PCB Support and corner



2. Corner



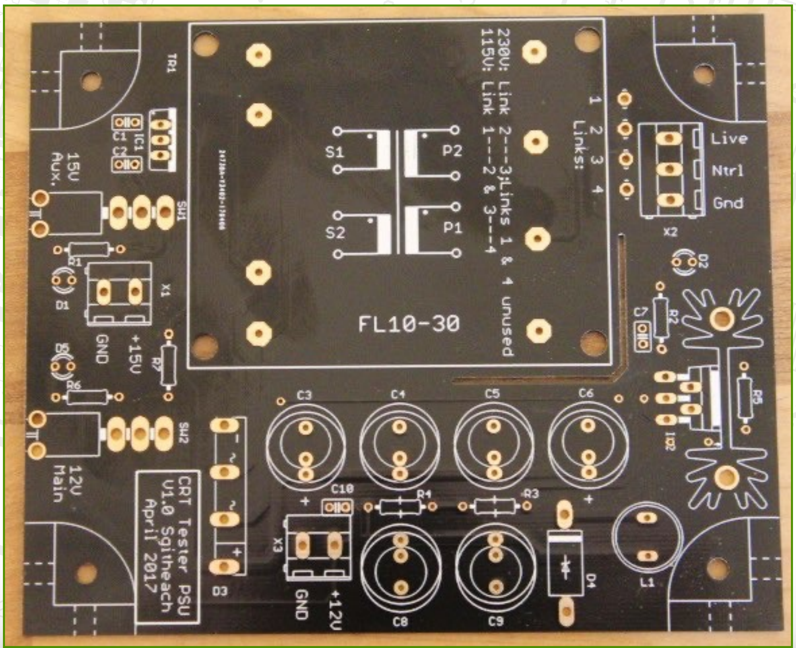
Constructing the CRT Tester PSU

There are a number of things these manuals *will not* teach you:

- How to solder competently
- How to read a component value
- How to orientate a component correctly
- How to handle static sensitive devices
- How the CRT Tester PSU or the CRT Tester itself works
- What you need a CRT Tester or this PSU

If you're not comfortable with any of these considerations, then this project is probably not for you.

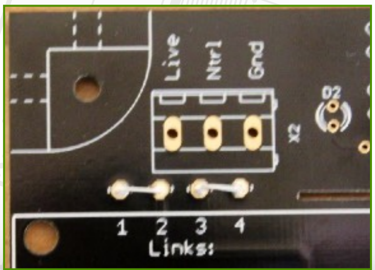
Building the PCB



The tick box list below gives a suggested construction order. Note that the board does not have component values marked and you should be careful to ensure that you are inserting the correct component into the correct place. Finally, some components (e.g. diodes) must be inserted with the correct polarity and others (e.g. ICs) must be inserted in the correct orientation. The PCB silkscreen guides you as to the correct position and orientation.

Before mounting any components you should install the links that match your operating voltage. The links are located between the transformer TR1 and connector X2:

- 115V operation - Link 1 to 2 and link 3 to 4



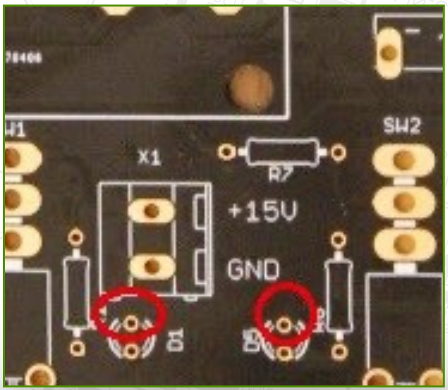
- 230V operation - Link 2 to 3 and positions 1 and 4 are unused

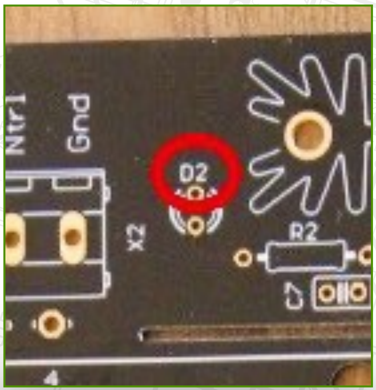
The components are installed from the smallest capacitors and resistors up to the largest component, the mains transformer.

Tick	Quantity	Value	Part Number	Comments
	4	100n	C1, C2, C7, C10	
	4	4k7	R1, R2, R6, R7	
	1	10k	R3	
	1	470R	R4	
	1	1k2	R5	
	1	3mm yellow LED	D1	Note polarity! See note 1
	1	3mm red LED	D2	Note polarity! See note 1
	1	3mm green LED	D5	Note polarity! See note 1
	1	100uH 2.65A	L1	
	1	1N5822	D4	Note polarity!
	1	50V 4A bridge rectifier	D3	Note orientation!
	2	Switch	SW1, SW2	See note 2
	6	2200µ 25V	C3, C4, C5, C6, C8, C9	Note polarity!
	1	LM2576-ADJ	IC2	See note 3
	1	7815	IC1	Note orientation!
	1	38mm SK104 heatsink	KK1	
	1	6mm bolt, washer and nut		Mounting IC2 onto KK1
	1	2 way screw connector	X1	
	1	3 way screw connector	X2	
	1	2 way screw connector	X3	
	1	2 x 15V RMS 24VA transformer	TR1	See note 4
	4	Self tapping screws		Fitted under the PCB to secure TR1 on the PCB

Notes

1. The red circles mark the **short** LED lead.





2. Ensure that the switch body is flush to the PCB or alignment with the holes in the acrylic case will be difficult

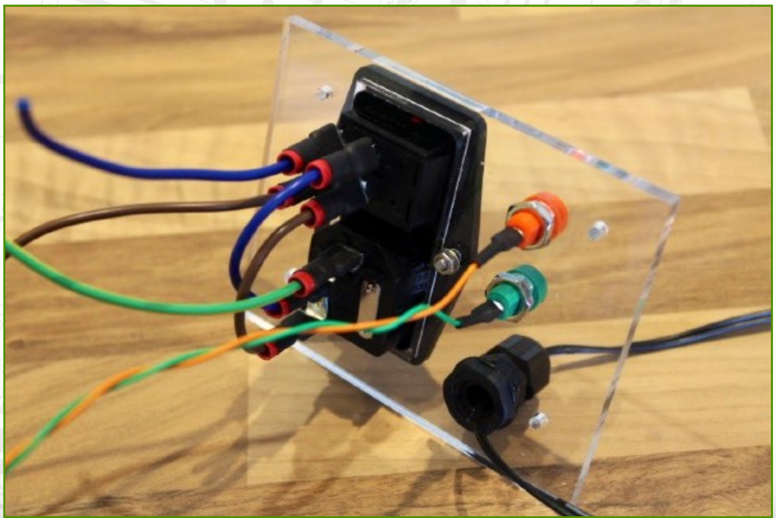
3. You may find it easiest to attach IC2 to KK1 loosely before fitting IC2 and KK1 into the PCB together

4. Getting the stiff transformer pins straight and aligned with the holes in the PCB can be a fiddly step - so please be patient.

<u>Case assembly</u>

Case assembly is not hard, if you are an experienced constructor then you will probably only need to glance through the next few pages and then build the case in whatever order you wish.

1. Wire the back panel



The fuse holder can be popped open and the fuse put in to the mains inlet connector. The mains wiring shown here is the brown and blue European colours but the kit will also include white and black[102] for the US standard.

The mains inlet connector is mounted using a pair of 12mm M3 bolt, washer and nut. The cable gland is fitted and the 12V DC cable threaded through (do not fully tighten the cable gland until the wire has been connected to the PCB so its length remains adjustable). And the banana jacks are fitted and wired. Heat shrink tubing is used to protect all the wiring.

[102] Remember - Black - Hot, White - Neutral.

2. Completing the låda parts

These eight parts have hex recesses that will accept M3 nuts. The recesses are a very tight fit so the nuts can become captive. The method I prefer is to use slip joint pliers[103] (channel-locks) to squeeze the nut down into the recess. Moderate force is needed and the nut needs to be aligned above the recess or there is a risk that the components will be break.

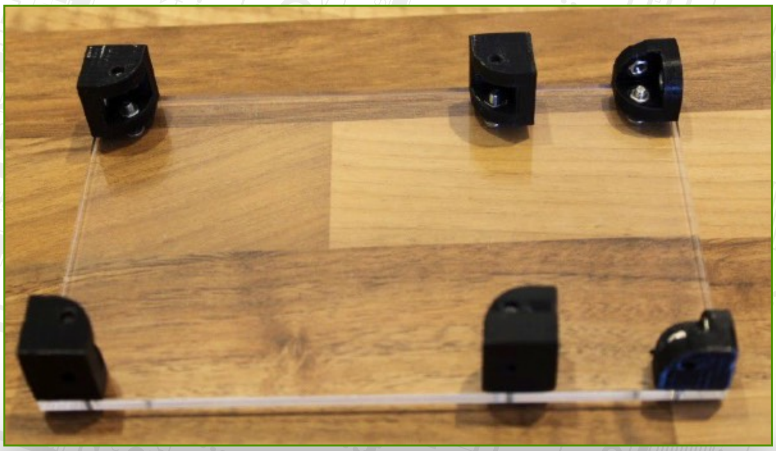
There are a total of thirty M3 nuts to position:

- The six låda corner parts (has three holes) have three nuts fitted (eighteen nuts in total).
- Two of the PCB support/corner parts (has four holes) have all four nuts fitted (eight nuts in total).
- The other two PCB support/corner parts only have the end (not the side) recesses used (four nuts in total).

Due to the variability of 3D printing, occasionally a nut may be slightly too loose or may even fall out of its hex recess. If this is the case use the tiniest drop of superglue to fix it in place.

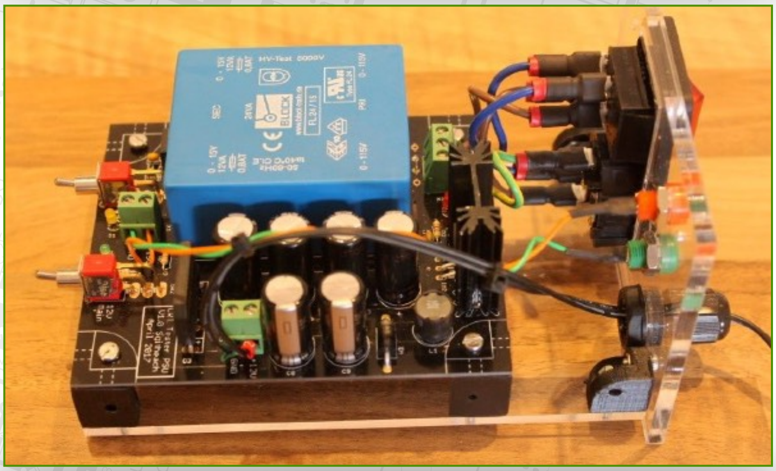
3. Bottom six låda parts

The bottom acrylic panel takes 2 corner låda parts (RHS in this photo), 2 PCB support låda parts with only the top and bottom hex recesses fitted with nuts (centre pair) and 2 PCB support låda parts with all 4 hex recesses fitted with nuts (LHS). 12mm M3 bolts are used.



4. Fitting the PCB and rear panel in place

This photo shows the PCB mounted onto the PCB Support låda parts using 6mm M3 bolts and the rear panel mounted using 12mm M3 bolts. The wiring has been completed and tidied using a couple of cable ties.



Now is a probably a good time to test the PSU so any mistakes can be corrected before the rest of the acrylic case is assembled. See the next section

[103] Such as tongue-and-groove pliers also known as water pump pliers, adjustable pliers, groove-joint pliers, arc-joint pliers, multi-grips, tap or pipe spanners, gland pliers…etc etc….

5. Complete the case

Now just work methodically bolting the remaining acrylic panels, PCB and låda parts together, this should be fairly self-evident. If anything doesn't line up or fit then you have assembled the puzzle incorrectly. Try not to scratch the acrylic or leave finger marks on the inside.

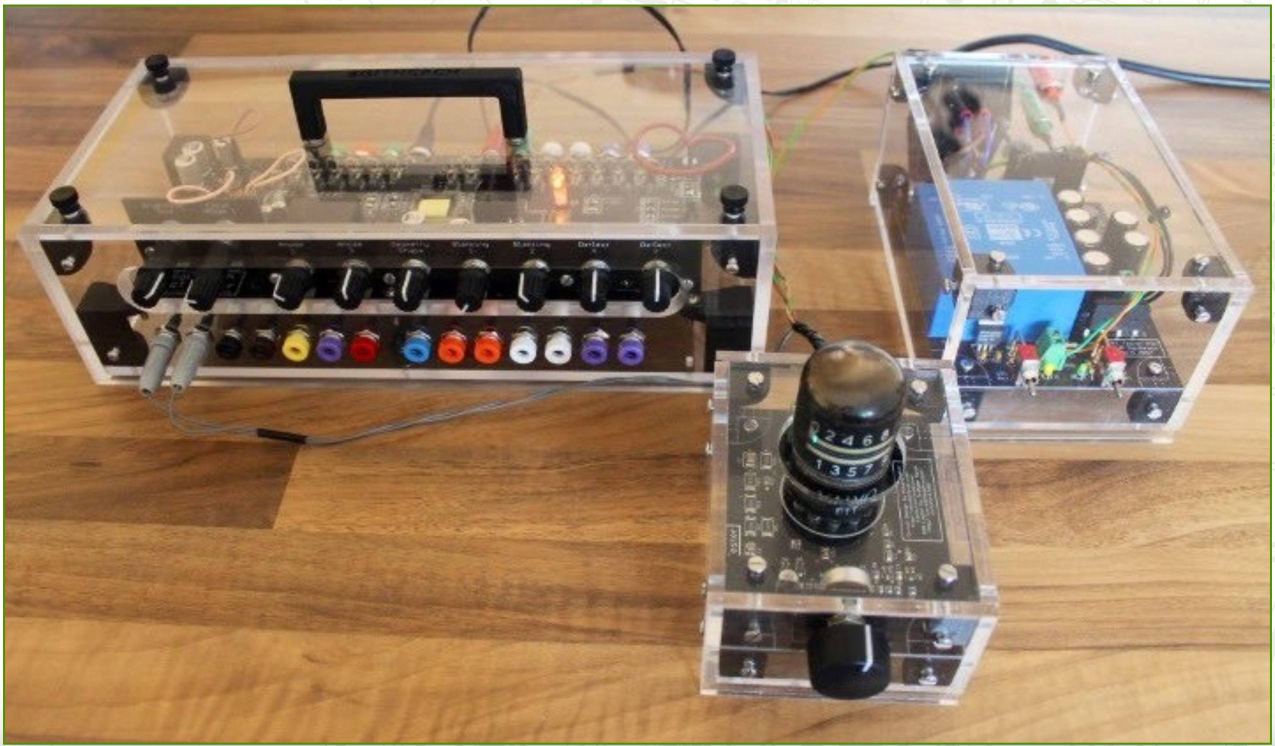
Testing the CRT Tester PSU

Although not an essential step you can test the PCB before completing the acrylic case.

Safety - this test will be carried out with mains connected to the board. During these tests, mains voltage will be present that will give a nasty shock and is potentially lethal.

☐	Move both SW1 and SW2 switches to the up (off) position
☐	Connect a mains cable to the mains inlet connector and switch on
☐	Depending on the position of the mains on/off switch the neon might or might not glow so move the switch so that it glows.
☐	LED D2 should glow and the other two LEDs should remain dark
☐	Move switch SW1 (leftmost switch) down
☐	LED D1 should glow as well.
☐	Measure the voltage across screw connector X1 = about 15V Measure the voltage across the orange and green banana jacks = again, about 15V
☐	Move switch SW2 (leftmost switch) down
☐	LED D5 should glow as well.
☐	Measure the voltage across screw connector X3 = about 12V Measure the voltage across the 2.1mm 12V barrel connector. NB it is most important that the centre hole is the positive lead = again about 12V
☐	Switch off the on/off switch and unplug the mains lead
☐	The LEDs will continue to glow for a while as the capacitors take time to discharge (the board is off load)
☐	In the few minutes that the test has taken no component should be even slightly warm

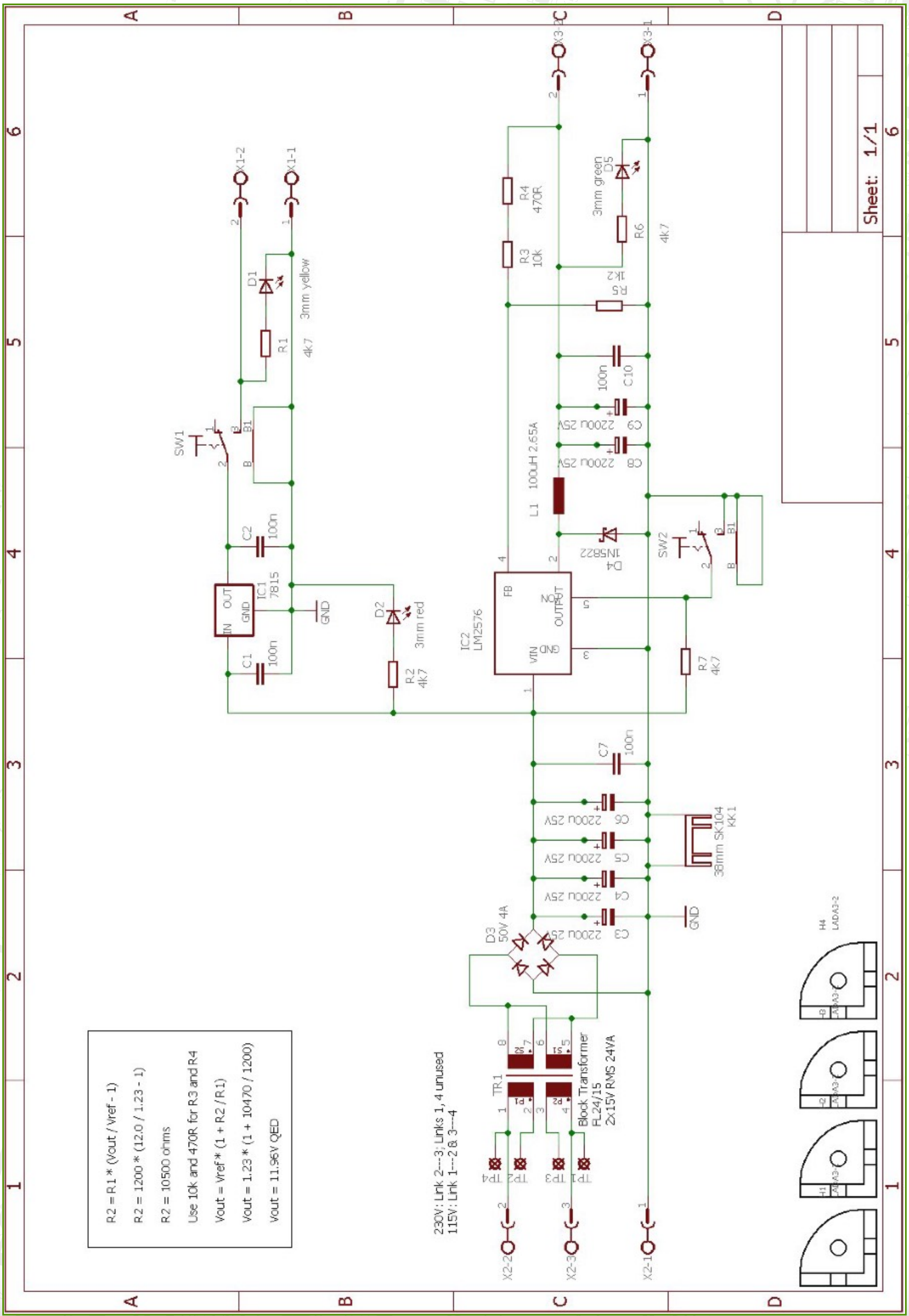
The CRT Tester PSU can now be plugged into the CRT Tester itself to confirm its operation under load.



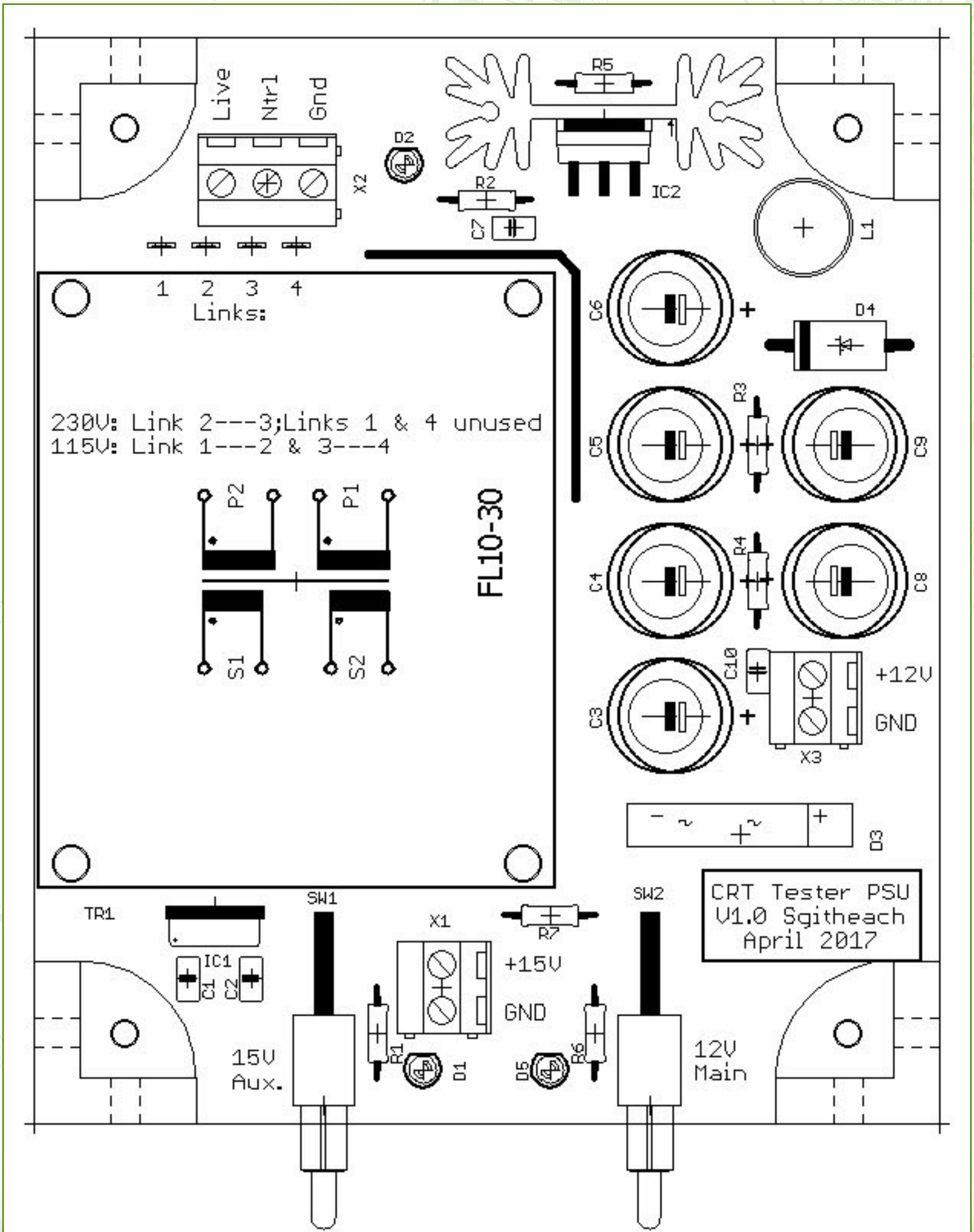
The above photo shows the completed tester in all its glory driving the CRT tester which in turn is powering another member of the test suite, the E1T Tester.

Wasn't that fun?

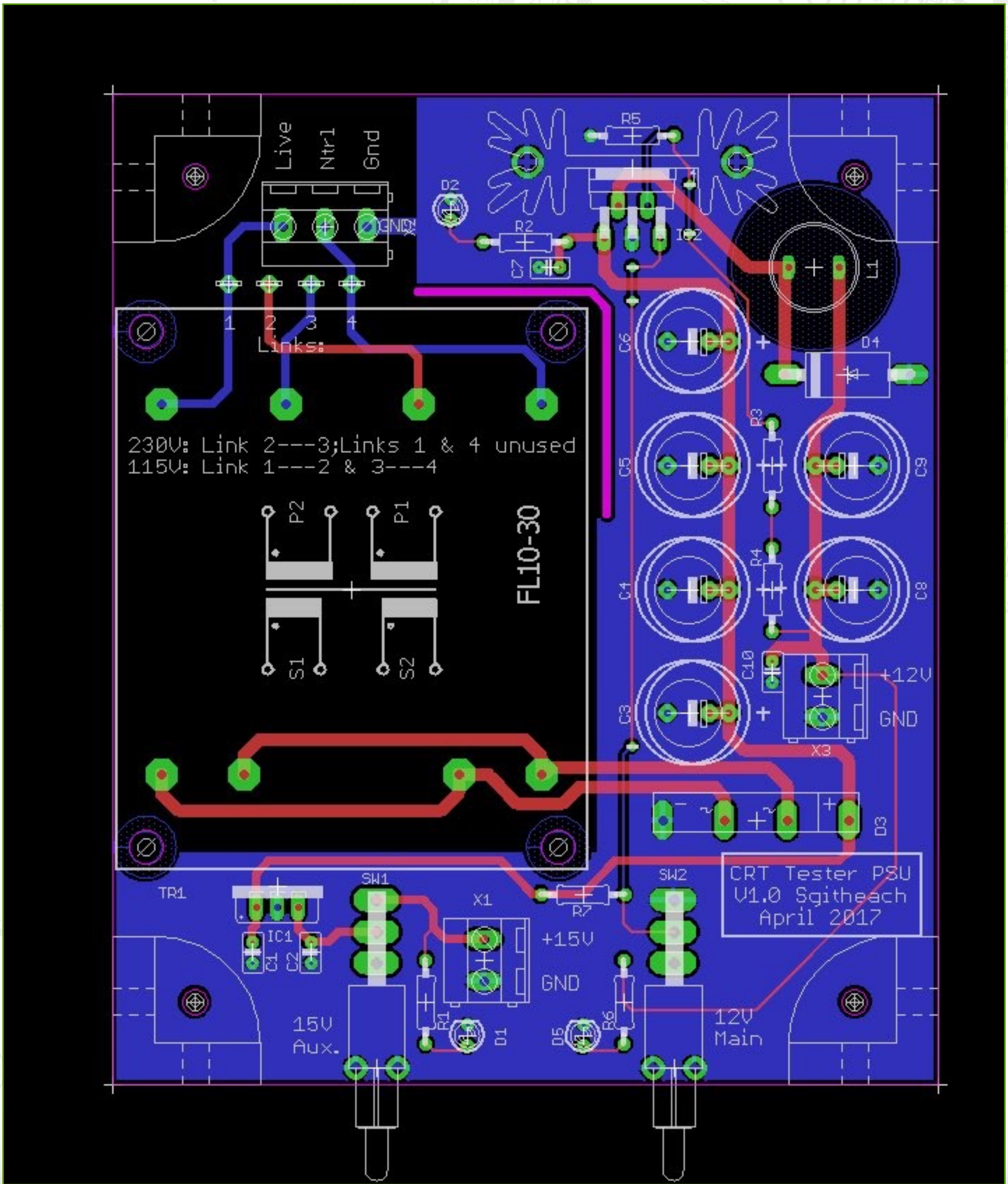
Annex I - Schematic



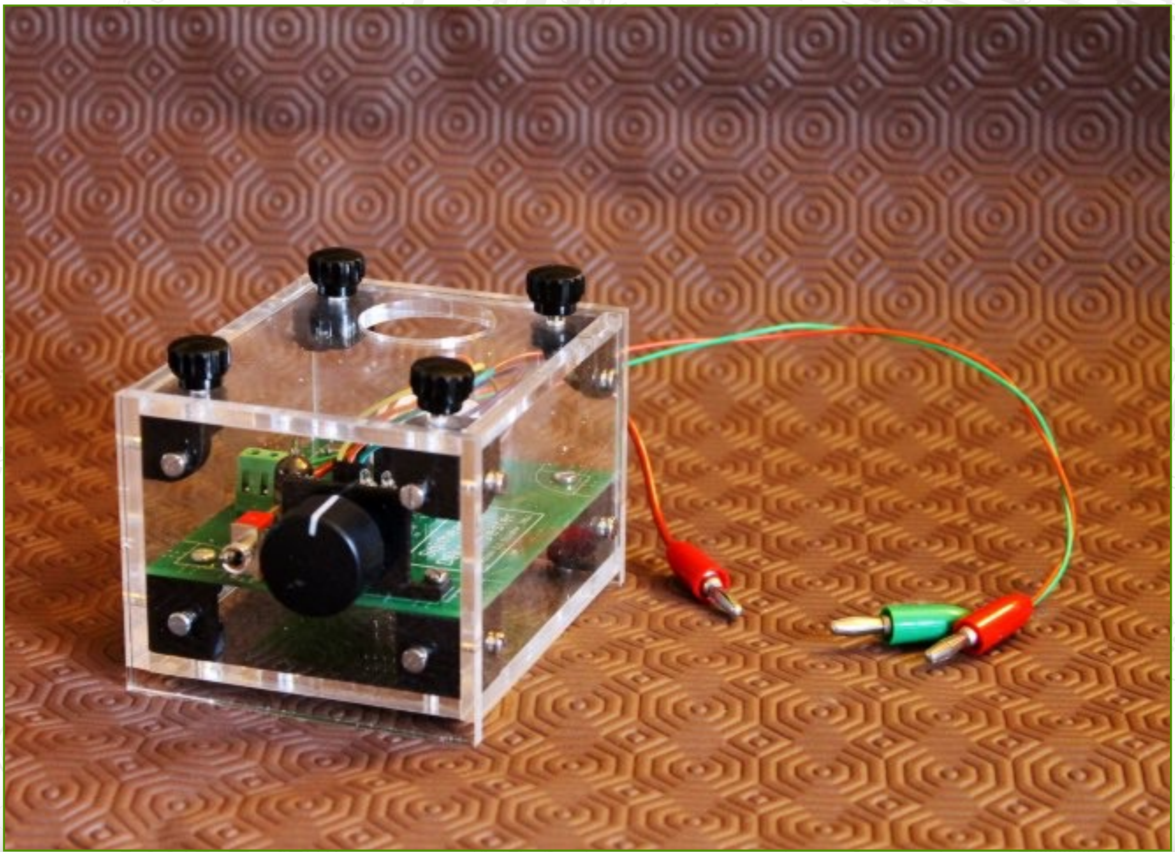
Annex II - PCB Silkscreen



Annex III - PCB Layout



Octal Dekatron Tester - A CRT Tester Extension Unit



Extend The Capabilities of Your CRT Tester - Test a Dekatron!

Introduction

This is a simple Dekatron Tester to check that it will glow and count pulses. It basically checks for life in a tube. The tester is equipped with an octal valve socket that can be configured by a simple patch panel. Dekatrons with other bases can be connected using wire jumpers from a suitable base to the patch panel.

The tester will double up as a dekatron spinner for your workshop!

The Dekatron Tester is limited to the common or garden variety of two guide electrode “double pulse tubes”. Tubes with odd/even guide electrodes are tested by connecting the odd an even electrodes together and treating it as a normal double pulse tube.

It is not designed to test “low voltage” dekatrons such as the GS10J and tubes with “routing electrodes”.

This construction guide includes a case made from laser cut 5mm clear acrylic and custom designed låda[104] 3D printed parts.[105] The complete electronics and case kit includes all the nuts and bolts, banana plugs, hook up wire and spiral wire tidy. Everything in one word.[106]

Acknowledgements

My thanks to Wyolum for the whole låda case construction concept that works so well with 3D printed parts and laser cut acrylic panels.

Tools Required

The following tools are essential to build the case:

- Small and medium flat blade screw drivers
- Small adjustable spanner (wrench)
- Slip joint pliers (channel-locks) or similar (see text)
- Wire cutters
- Wire strippers
- Soldering iron, solder

This is not an overly difficult kit to construct. Providing you can solder neatly and follow the assembly instructions accurately, there should be no problems. Lots of light, some magnification and de-soldering braid to remove excess solder work every time for me.

The last “tool” is you and your time - this kit has a only few components to fit and they have been bagged to help you build without error. Take your time, take breaks and enjoy the experience!

---

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105 I have to admit some disappointment when I discovered that låda means “box” in Swedish - I was hoping for something more *evocative*

106 Well, one sentence if you’re being pedantic about it..

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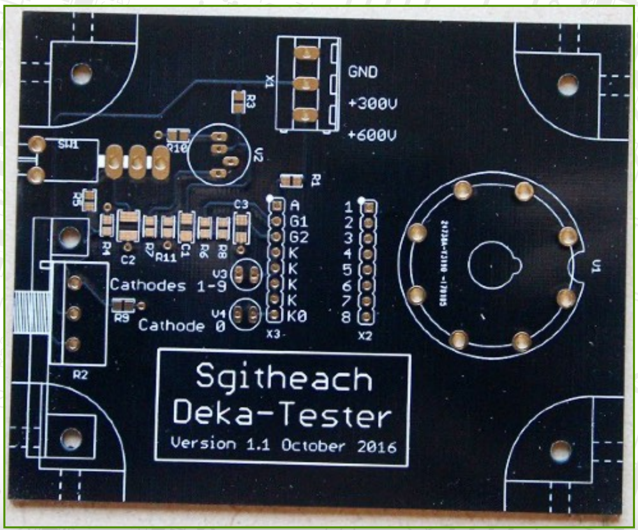
- You have bought a standard kit that consists of the PCB with all the SMD parts fitted and the through hole components, mechanical parts and acrylic case.



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Component List

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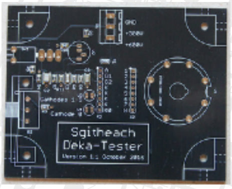
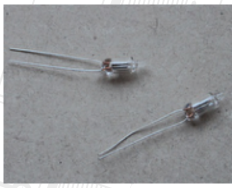
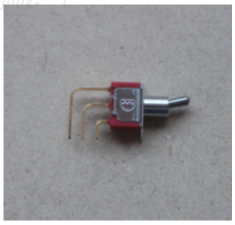
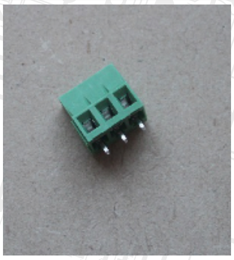
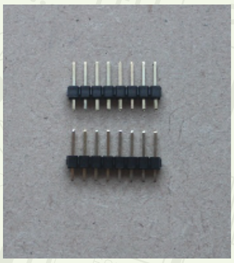
If the Dekatron Tester kit has arrived in a damaged state such that an insurance claim is likely then notification should be made immediately (within a few days of receipt). It is likely that photographic evidence will be asked for to make any insurance claim.

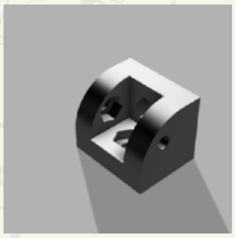
At this time you should review your ability to build and safely operate this Dekatron Tester!

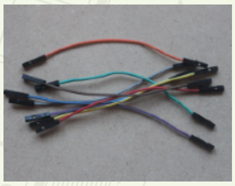
If you want to return the kit then now is the time to do so. No refund will be available for a partly built kit. As long as the returned kit is complete, the refund will be as well. The cost (postage and insurance) of returning the kit is yours to bear and the refund will not include the postage and insurance that I paid. Additionally, if the kit is returned from outside the EU then the possibility exists that the UK Tax Man will demand a slice of its value and you will be accountable for this cost as well.

A table of the complete kit contents follows on the next pages. Please use it to double check that everything is present and correct.

Tick	Quantity	Description	Image
	1	PCB with all SMD parts fitted	
	1	1M potentiometer (R2)	
	1	Knob for potentiometer	
	1	Z700U trigger tube (V2)	
	2	Wire ended neon bulbs (V3 & V4)	
	1	Printed stand-offs for the neon bulbs and trigger tube (V2 - V4)	
	1	Switch (SW1)	

Tick	Quantity	Description	Image
	1	3D printed bracket for potentiometer (R2)	
	1	3 way screw terminals to make a 3 way terminal for (X1)	
	2	8 way 2.54mm spaced pin header (X2, X3)	
	1	PCB mounting octal valve base (V1)	
	24	M3 nuts for låda parts	
	24	M3 bolts 12mm (nominally) long for låda parts	

Tick	Quantity	Description	Image
	4	Case top knurled M4 10mm thumb screws	
	4	M4 nuts for for låda parts to accept the knurled thumbs screws	
	3	M3 bolts 6mm (nominally) long for PCB mounting The front right corner of the PCB is sandwiched between the right side of the potentiometer support bracket and the låda PCB support.	
	1	M3 12mm bolt, washer and nut for the left side of the potentiometer bracket mounting	
	4	3D printed låda PCB support	
	4	3D printed låda top support this has two M3 nut holes and one M4 nut hole to accept the top knurled thumb screw	

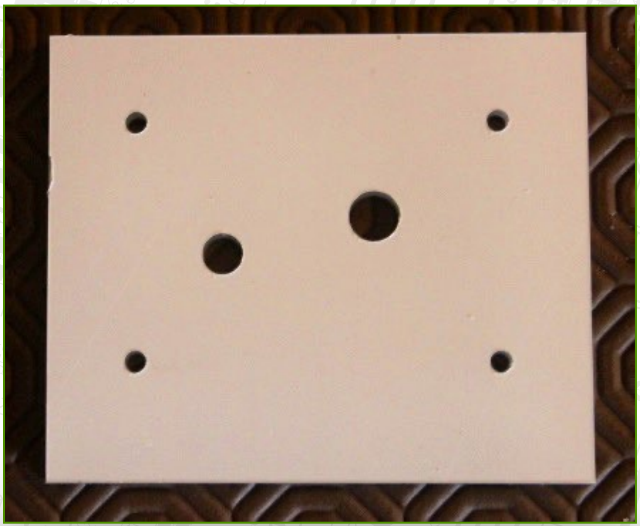
Tick	Quantity	Description	Image
☐	2	Red plug bodies (X1-1 & X1-2)	
☐	1	Green plug body (X1-3)	
☐	3	Plug cores (X1-1 - X1-3)	
☐	0.3m	Red HT wire (X1-2)	
☐	0.3m	Red EHT wire (the thicker of the two red wires) (X1-1)	
☐	0.3m	Green wire (X1-3)	
☐	8	Jumpers (X2 to X3)	
☐	0.1	Spiral wrap	

Acrylic Panel Identification

There are only six acrylic panels that make up the simple case. The identification photographs were taken with the protective film in place.

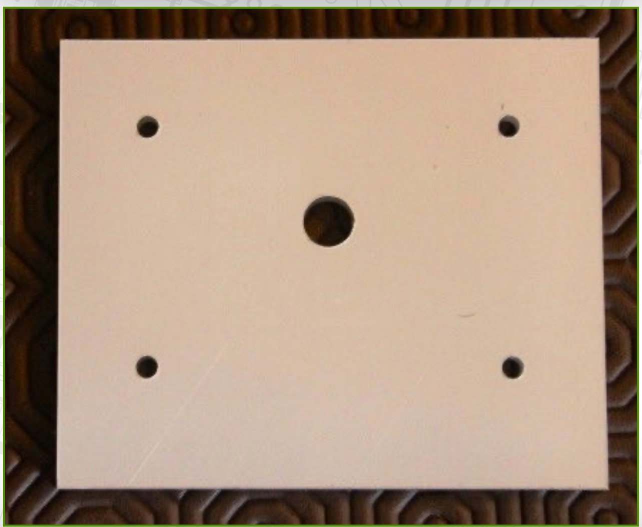
1. Front panel

Easily identified by the two holes which takes the potentiometer shaft and toggle switch through the front panel:



2. Back panel

Identified by the single hole which takes wires through the back panel:



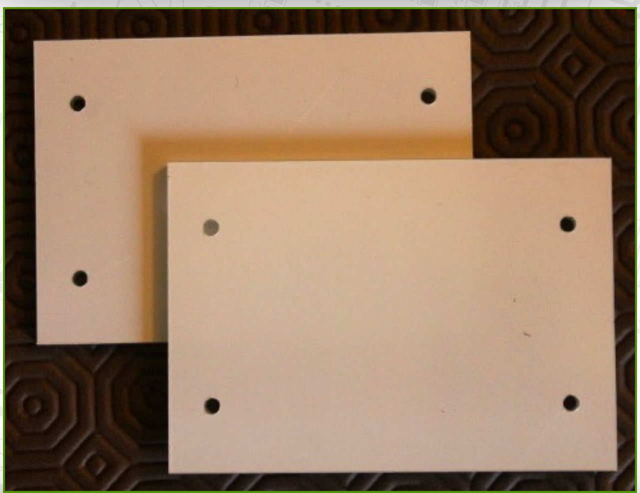
3. Top Panel

Identified by the large hole for the dekatron under test:

4. Bottom Panel

Same size as the top but without the big hole!

5. Right and left hand panels



Constructing the Dekatron Tester

There are a number of things these manuals *will not* teach you:

- How to solder competently
- How to read a component value
- How to orientate a component correctly
- Why you need a E1T Tester

If you're not comfortable with any of these considerations, then this project is probably not for you.

Completing the PCB

All the SMD parts come pre-fitted. This just leaves the few remaining through hole parts:

- The 1M potentiometer (R2) attached to the PCB using the bracket bolted to the PCB.[107]
- The toggle switch (S1)
- Octal valve base - make sure you align it correctly.
- The 3 way screw connectors X1

[107] I find it easier to mount the potentiometer on the bracket, then bolt the bracket to the PCB, then when everything is correctly aligned, solder the pins on the potentiometer.

- 8 way headers X2 and X3
- The wires are attached to there respective coloured plugs and then connected to the 6 way screw terminal as follows[108]
  - Red EHT wire/plug to the 600V screw terminal
  - Red HT wire/plug to the 300V screw terminal
  - Green wire/plug to the ground screw terminal
- The three wires can be wrapped in the spiral to tidy them

Case assembly

Case assembly is not hard, if you are an experienced constructor then you will probably only need to glance through the next few pages and then build the case how you wish.

1. Completing the låda parts

These are constructed as described before in this manual (see section on CRT Tester Case)

2. Fitting the PCB in place

Now just work methodically bolting the acrylic panels, PCB and låda parts together. If anything doesn't line up or fit then you have assembled the puzzle incorrectly. Try not to scratch the acrylic or leave finger marks on the inside.

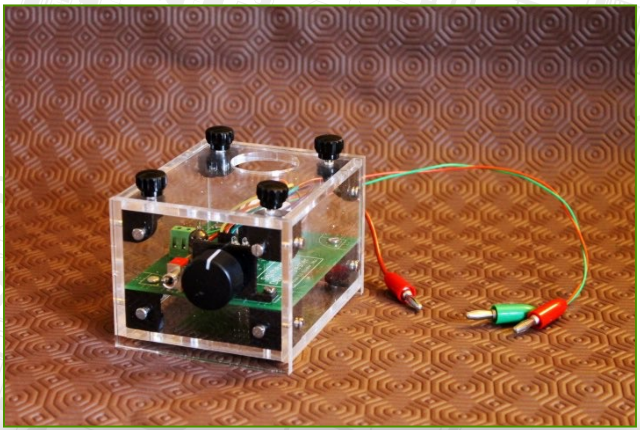
3. Fit the Knob

You do what it says on the tin.

4. Fit the top

You should check that the top and the four knurled thumb screw fit.

5. Finished kit!



Testing a Dekatron

Using the Dekatron Tester with the Sgitheach CRT Tester you configure the tester as follows:

- HT configured for 300V operation
- Flyback enabled
- PDA multiplier enabled
- PDA 0.6kV jumper selected

The Dekatron Tester is plugged into the CRT Tester jacks as follows (assuming you are using the CRT Tester case):

- The red plug with the HT cable is plugged into the 300V output jack on the back panel and the green jack is plugged into the adjacent green ground jack.
- The red plug with the EHT cable is plugged into the PDA output jack on the right panel.

[108] Remember to thread the wires through the hole in the back acrylic case component.

1. Testing a GC10/B[109] Counting Tube

This dekatron has the usual connections for the anode, two guides, cathode 0 and cathodes 1 - 9 common on a single pin. The patch panels are set up with 5 jumpers:

Patch panel X3	Function	Octal patch panel X2	Dekatron Electrode
1	Anode	4	Anode
2	Guide 1	3	1st Guides
3	Guide 2	5	2nd Guides
4	Cathode 1 - 9	1	Common cathodes
5	Cathode 1 - 9	not used	
6	Cathode 1 - 9	not used	
7	Cathode 1 - 9	not used	
8	Cathode 0	7	Cathode "0"

2. Testing a GC10/4B[110] Computing Tube

This is identical to the GC10/B except four of its main cathodes are brought out to separate pins. These additional cathodes allow a computing tube to produce output pulses at counts other than just every 10 input pulses. The patch panels are set up with all 8 jumpers. Three of the additional main cathode pins are connected to the common cathode pin.

Patch panel X3	Function	Octal patch panel X2	Dekatron Electrode
1	Anode	4	Anode
2	Guide 1	3	1st Guides
3	Guide 2	5	2nd Guides
4	Cathode 1 - 9	1	Common cathodes
5	Cathode 1 - 9	6	Cathode "A"
6	Cathode 1 - 9	2	Cathode "D"
7	Cathode 1 - 9	8	Cathode "C"
8	Cathode 0	7	Cathode "B"

The patch panel X3 connection 8 can be swapped from to the octal patch panel X2 connection 7 to connection 2, 6 or 8 and you will note that the cathode "0" neon flashes when the illuminated dekatron cathode is in a different position. You can also connect two main cathodes together (you will need to make up a jumper lead to do this) to see the cathode 0 neon (V4) flash more than once during a full revolution. For example, if you connect the dekatron cathodes "D" and "B" together you will see that V4 flashes twice per revolution at equal intervals as the dekatron has been wired as a divide-by-5 computing tube.

[109] http://www.tube-tester.com/sites/nixie/datdekat/GC10B_ETL/gc10b-etl.htm
[110] http://www.tube-tester.com/sites/nixie/datdekat/GC10-4B_etelco/gc10-4b-etelco.htm

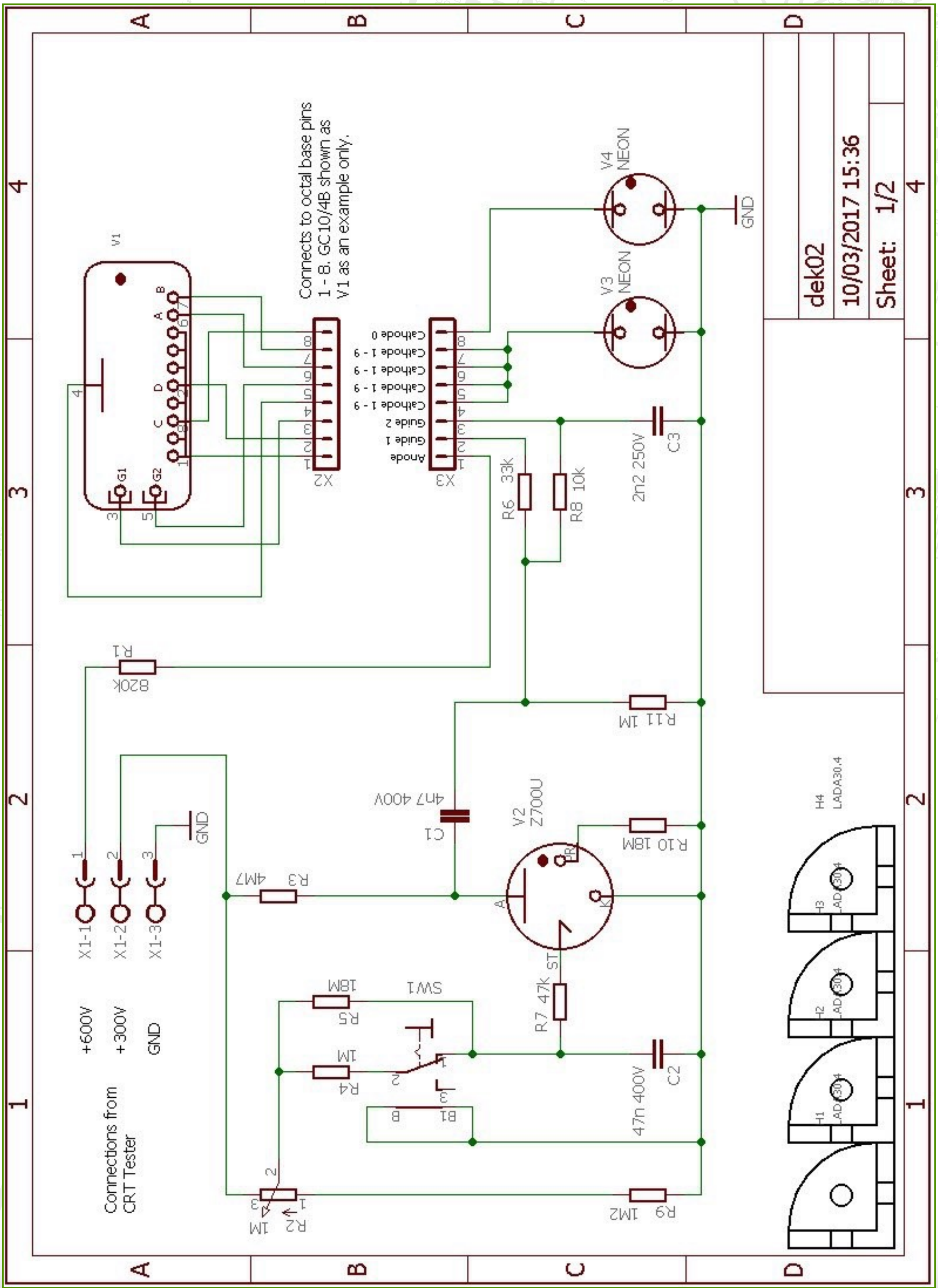
3. Testing a Soviet ОГ4[111] (OG4)

This dekatron has the usual connections for the anode, two guides, cathode 0 and cathodes 1 - 9 common on a single pin. The patch panels are set up with 5 jumpers:

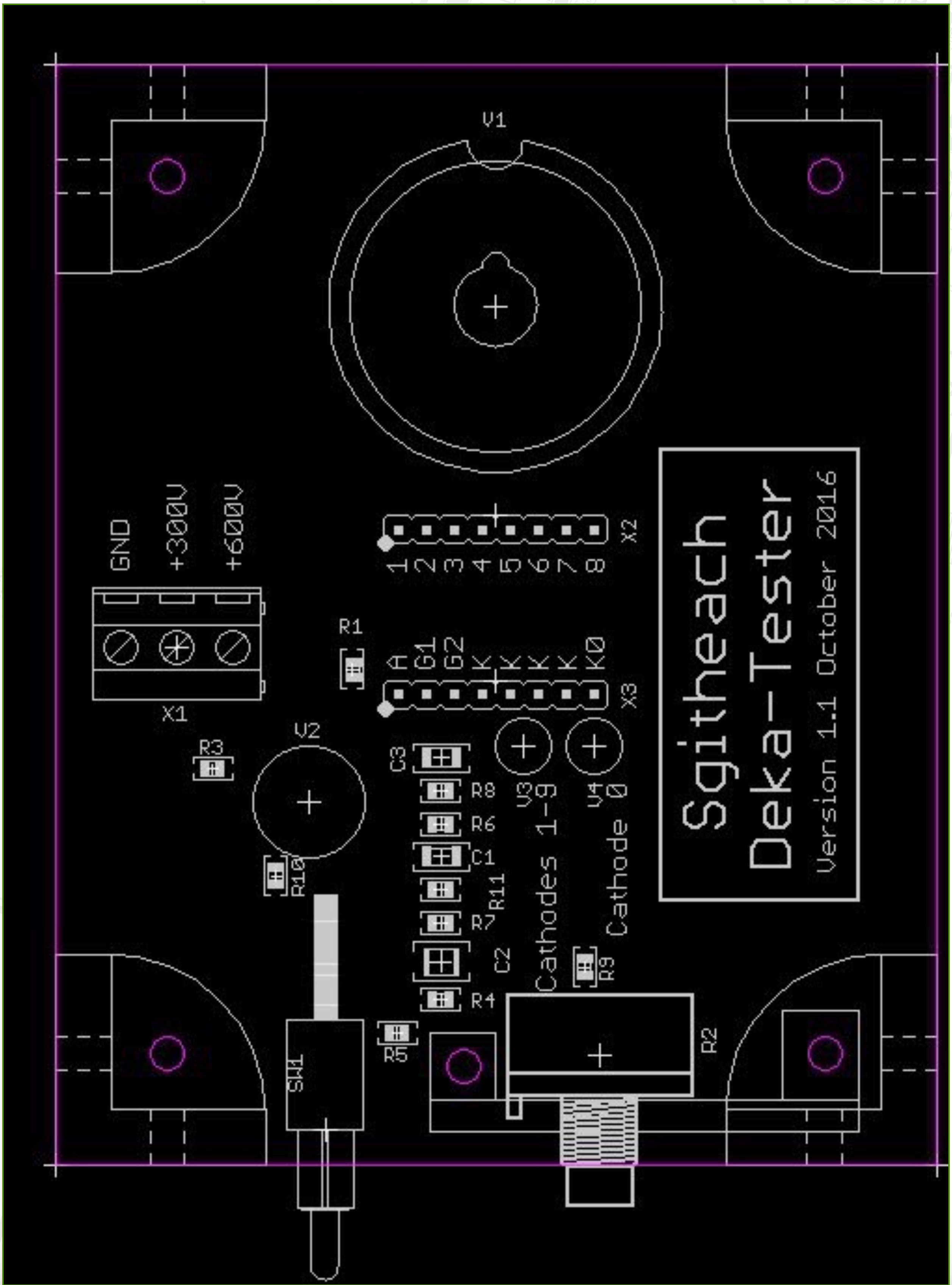
Patch panel X3	Function	Octal patch panel X2	Dekatron Electrode
1	Anode	3	Anode
2	Guide 1	4	1st Guides
3	Guide 2	6	2nd Guides
4	Cathode 1 - 9	8	Common cathodes
5	Cathode 1 - 9	not used	
6	Cathode 1 - 9	not used	
7	Cathode 1 - 9	not used	
8	Cathode 0	1	Cathode “0”

[111] http://www.tube-tester.com/sites/nixie/datdekat/OG4/og4.htm

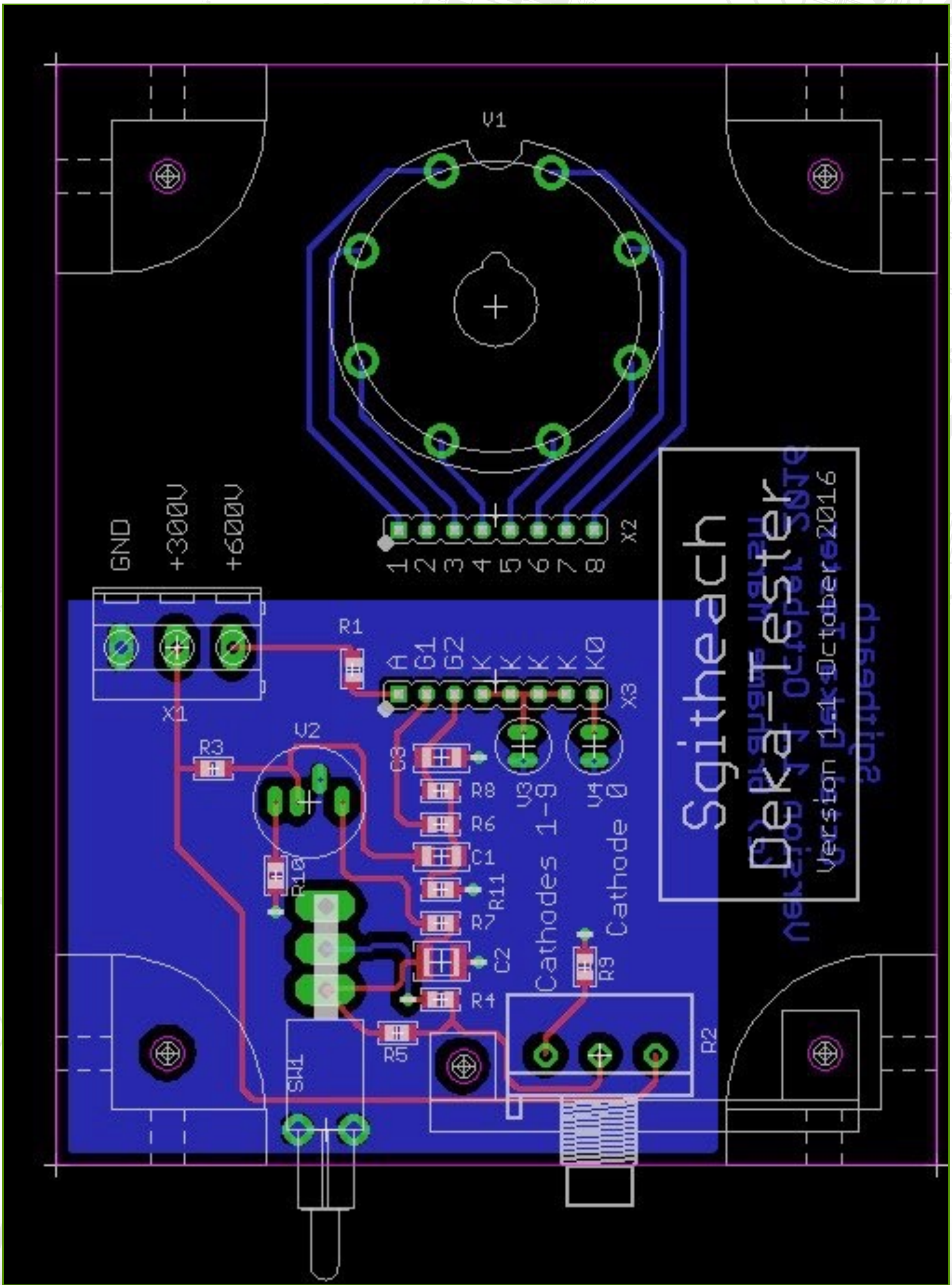
Annex I - Schematic



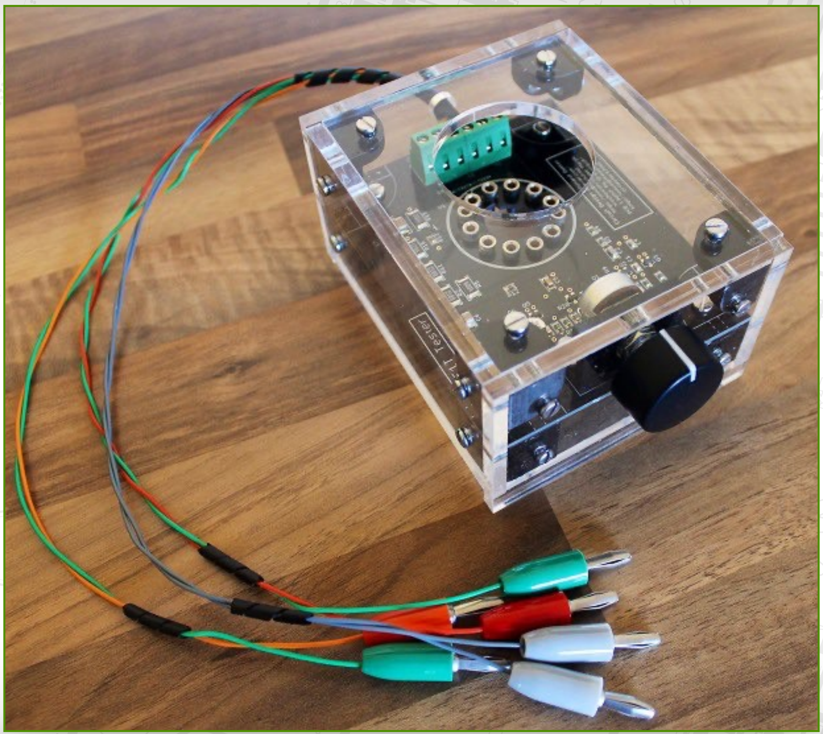
Annex II - PCB Silkscreen

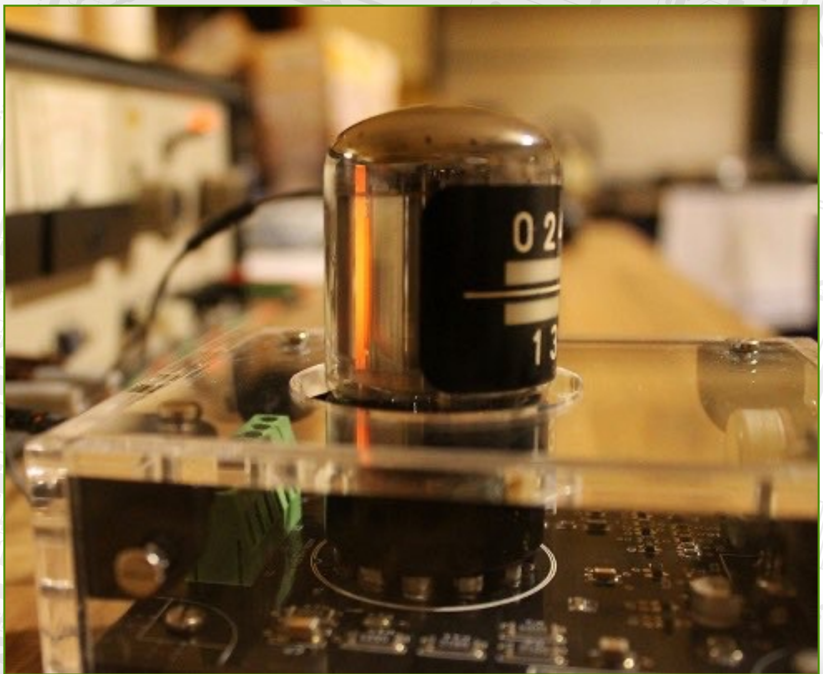


Annex III - PCB Layout



E1T Tester - A CRT Tester Extension Unit





Extend The Capabilities of Your CRT Tester[112] *- Test an E1T Tube!*

112 OK, I'll admit that you 'just' need any 15V DC, 6.3V AC and 300V DC supply to run the E1T tester, but this does it *in style*….

Introduction

Over a period of some years I purchased a number of E1T decade scaler tubes with the intent of making six of them into a clock. I decided to test them and started looking for the correct voltages, pulses and so on to experiment with. This quickly lead me to Ronald Dekker's tester and clock design.

This is the E1T Tester designed by Ron Dekker.[113] His web page also describes how this fascinating tube works. Therefore, I'm not going to deal with that within these pages, but crack on with the construction of Ron's design which I offer here as a kit. In a lot of respects I was left with very little to do - all the heavy lifting had been done for me.

But…. if you are going to use one of these amazing tubes then you must first read about its development.[114]

This construction guide includes a case made from laser cut 5mm clear acrylic and custom designed låda[115] 3D printed parts.[116] The complete electronics and case kit includes all the nuts and bolts, banana plugs, hook up wire and spiral wire tidy. Everything in one word.[117]

Acknowledgements

My thanks to Ron Dekker for allowing me to use his design and reproduce it in this way.

And my thanks to Wyolum for the whole låda case construction concept that works so well with 3D printed parts and laser cut acrylic panels.

Tools Required

The following tools are essential to build the case:

- Small and medium flat blade screw drivers
- Small adjustable spanner (wrench)
- Slip joint pliers (channel-locks) or similar (see text)
- Wire cutters
- Wire strippers
- Soldering iron, solder

This is not an overly difficult kit to construct. Providing you can solder neatly and follow the assembly instructions accurately, there should be no problems. Lots of light, some magnification and de-soldering braid to remove excess solder work every time for me.

The last "tool" is you and your time - this kit has a only few components to fit and they have been bagged to help you build without error. Take your time, take breaks and enjoy the experience!

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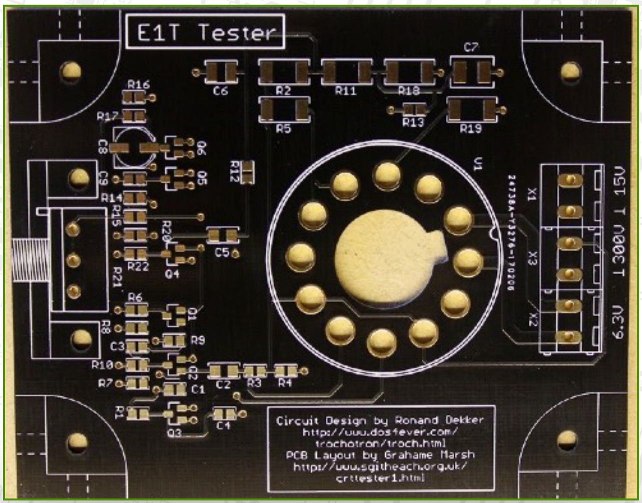
113 http://www.dos4ever.com/trochotron/TROCH.html
114 This is the *proper* thing to do…http://www.dos4ever.com/E1T/E1T.html
115 http://wyolum.com/lada-a-custom-project-box-system/
116 I have to admit some disappointment when I discovered that låda means "box" in Swedish - I was hoping for something more *evocative*
117 Well, one sentence if you're being pedantic about it..

Kit Overview

To some extent this depends on what you have ordered. Two kits are offered:

- The bare minimum kit that consists of just the PCB. If you have gone down this route then I assume you know what you are doing, where to buy all the components and how to build the thing i.e. you are an experienced constructor. I'm not going to teach my grandmother to suck eggs and instruct you on what, how, why, when etc.



- You have bought a standard kit that consists of the PCB with all the SMD parts fitted and the through hole components, mechanical parts and acrylic case.

The assumption I will make is that you have ordered a complete standard kit.

Component List

The case will arrive as a flat pack of clear acrylic and all of the remaining components in resealable polythene bags.

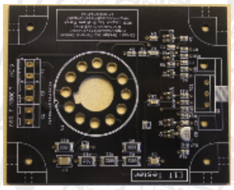
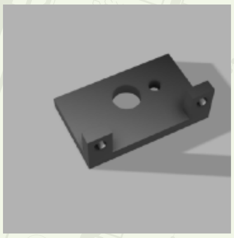
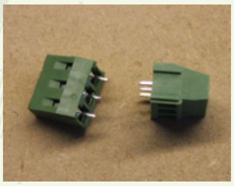
Upon your receipt of the kit of parts, any missing or broken pieces will be replaced if discovered. It is incumbent upon you, the recipient, to check the contents in a prompt manner (within a few months) against the supplied parts lists found within this construction manual.

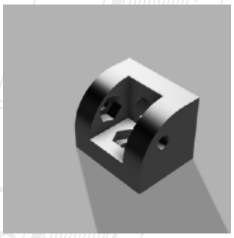
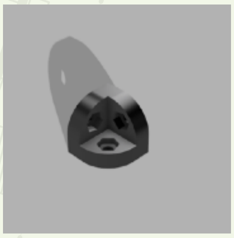
If the E1T Tester kit has arrived in a damaged state such that an insurance claim is likely then notification should be made immediately (within a few days of receipt). It is likely that photographic evidence will be asked for to make any insurance claim.

At this time you should review your ability to build and safely operate this E1T Tester!

If you want to return the kit then now is the time to do so. No refund will be available for a partly built kit. As long as the returned kit is complete, the refund will be as well. The cost (postage and insurance) of returning the kit is yours to bear and the refund will not include the postage and insurance that I paid. Additionally, if the kit is returned from outside the EU then the possibility exists that the UK Tax Man will demand a slice of its value and you will be accountable for this cost as well.

A table of the complete kit contents follows on the next pages. Please use it to double check that everything is present and correct.

Tick	Quantity	Description	Image
	1	PCB with all SMD parts fitted	
	1	1M potentiometer (R21)	
	1	Knob for potentiometer	
	1	Bracket for potentiometer	
	12	Pin Receptacles	
	2	3 way screw terminals to make a 6 way terminal for (X1, X2, X3)	

Tick	Quantity	Description	Image
	28	M3 nuts for låda parts	
	24	M3 bolts 12mm (nominally) long for låda parts	
	4	M3 bolts 6mm (nominally) long for PCB mounting	
	2	M3 12mm bolt, washer and nut for potentiometer bracket mounting	
	4	Låda PCB support	
	4	Låda top support	

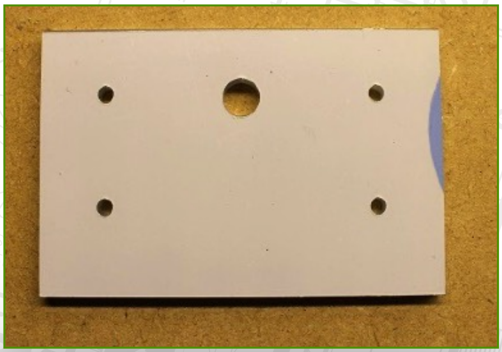
Tick	Quantity	Description	Image
	1	Red plug body	
	1	Orange plug body	
	2	Green plug bodies	
	2	Grey plug bodies	
	6	Plug cores	
	0.3m	Red wire	
	0.3m	Orange wire	
	0.6m	Green wire	
	0.6m	Grey wire	

Tick	Quantity	Description	Image
	0.1m	Spiral wrap	

<u>Acrylic Panel Identification</u>

There are only six acrylic panels that make up the simple case. The identification photographs were taken with the protective film in place.

1. Front and back (identical) panels



Easily identified by the hole which takes the potentiometer shaft through the front panel and the wires through the back panel.

2. Top Panel

Identified by the large hole for the E1T under test:[118]

[118] Pretty obvious that one….well, they're all pretty obvious when you look at them…..😀

3. Bottom Panel

Same size as the top but without the big hole!

4. Right and left hand panels

Constructing the E1T Tester

There are a number of things these manuals *will not* teach you:

- How to solder competently
- How to read a component value
- How to orientate a component correctly
- How to handle static sensitive devices
- How the E1T tube or this E1T Tester works
- Why you need a E1T Tester

If you're not comfortable with any of these considerations, then this project is maybe not for you.

Completing the PCB

All the SMD parts come pre-fitted. This just leaves the few remaining through hole parts:

- The 1M potentiometer (R21) attached to the PCB using the bracket bolted to the PCB.[119]
- The twelve tube (V1) pin receptacles. I use an E1T tube as a guide to make sure the receptacles are correctly aligned.
- The two 3 way screw connectors are jointed together and soldered on the board as a single 6 way connector for X1, X2 and X3.
- The wires are attached to their respective coloured plugs and then connected to the 6 way screw terminal as follows:[120]
  - Orange wire/plug to 15V screw terminal
  - Red wire/plug to 300V screw terminal
  - Green wires/plugs to the ground two connections adjacent to the 15V and 300V screw terminals
  - Grey wires/plugs to the 6.3V tube heater connection screw terminals

Case assembly

Case assembly is not hard, if you are an experienced constructor then you will probably only need to glance through the next few pages and then build the case how you wish.

1. Completing the låda parts

These are constructed as before - see CRT Tester Case section.

2. Fitting the PCB in place

Now just work methodically bolting the acrylic panels, PCB and låda parts together. If anything doesn't line up or fit then you have assembled the puzzle incorrectly. Try not to scratch the acrylic or leave finger marks on the inside.

Testing an E1T tube

Using the E1T tester with the Sgitheach CRT Tester you configure the tester as follows:

- Heater configured for 6.3V operation
- HT configured for 300V operation
- Flyback enabled
- PDA multiplier disabled
- Cathode voltage, Focus voltage and PDA voltage selection jumper wires all removed. It is particularly important that the cathode voltage selection jumper is removed.

The E1T tester is plugged into the CRT tester jacks as follows (assuming you are using the CRT Tester case):

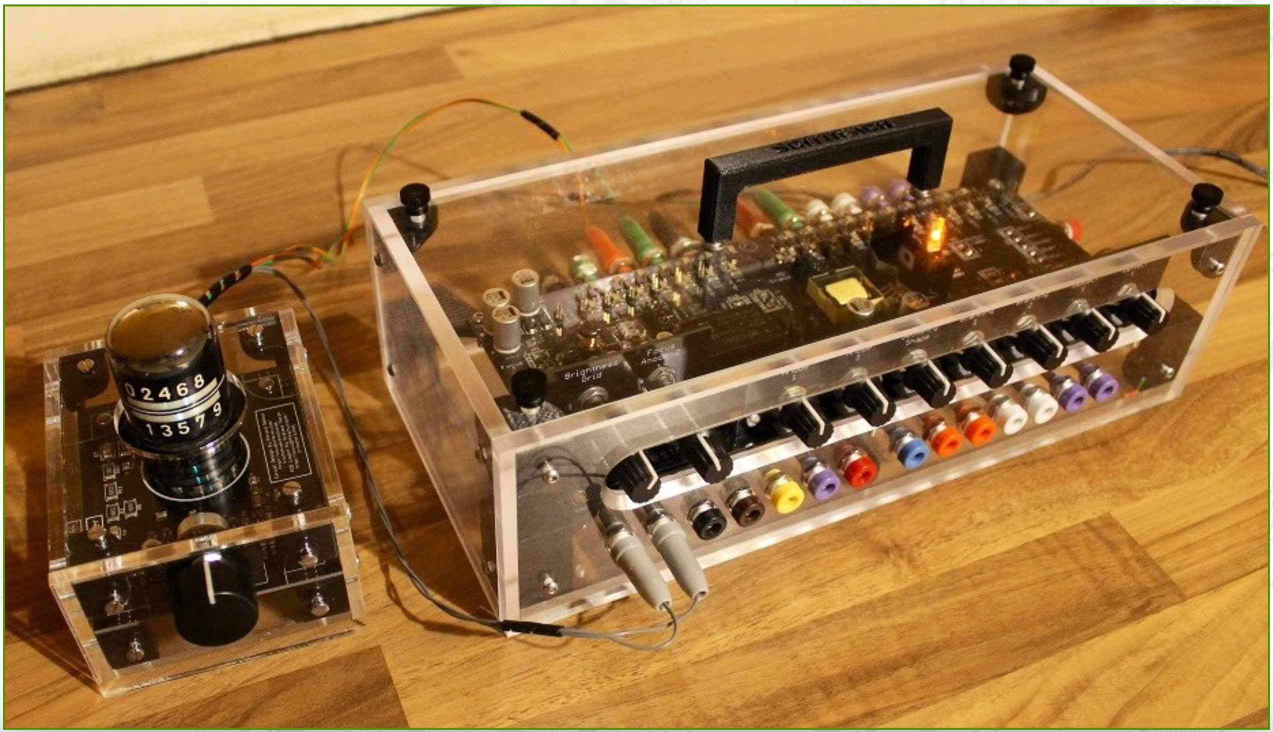
- The two grey plugs are plugged into the grey heater output jacks on the front panel
- The orange jack is plugged into the orange 12V DC out jack on the back panel and its partner green jack plugged into the adjacent green ground jack
- The red jack is plugged into the 300V output jack on the back panel and its partner green jack plugged into the adjacent green ground jack.

[119] I find it easier to mount the potentiometer on the bracket, then bolt the bracket to the PCB, then when everything is correctly aligned, solder the pins on the potentiometer.
[120] Remember to thread the wires through the hole in the back acrylic case component

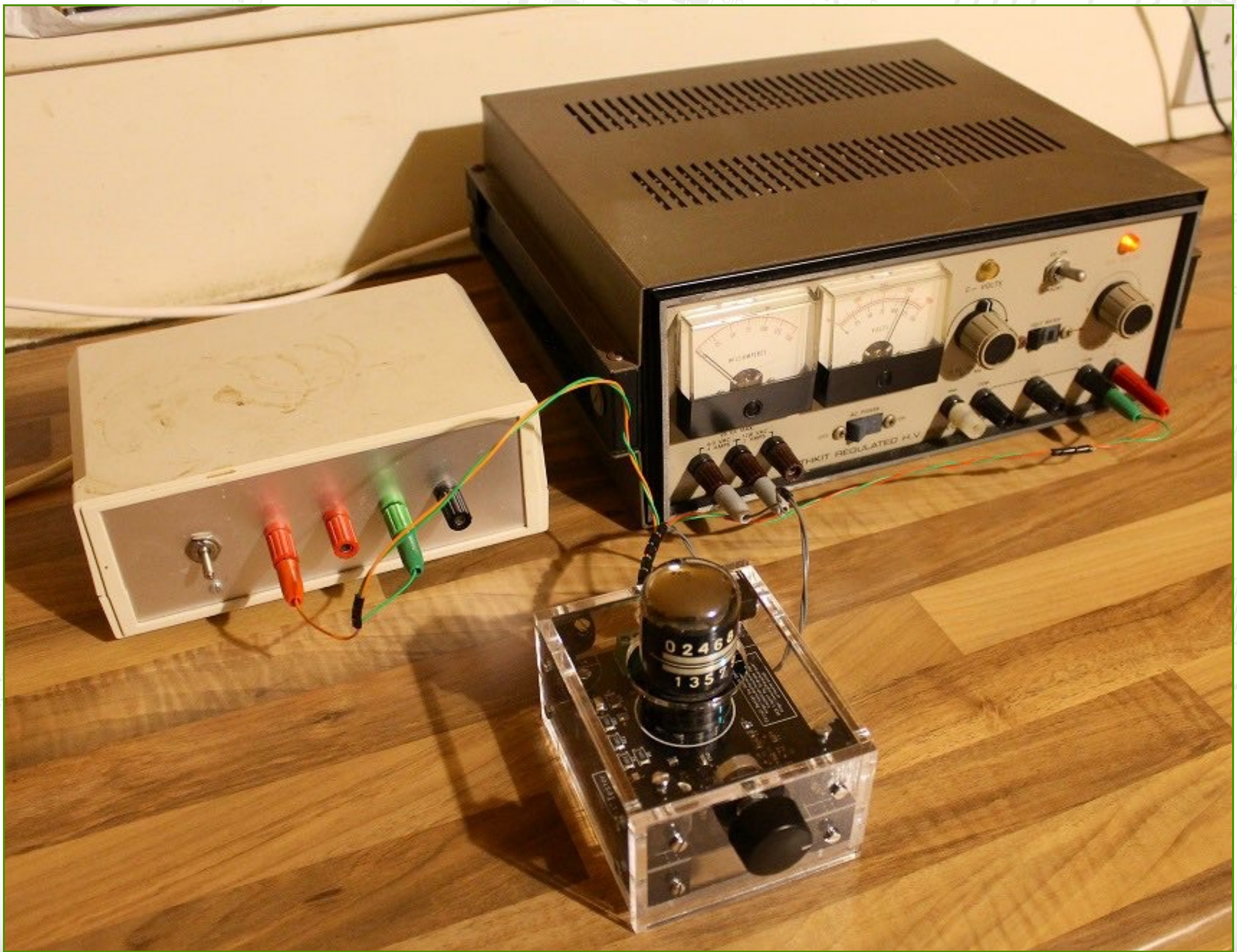
Note: **Caution!**

- Swapping over the red and orange jacks will, with absolute certainty, destroy the E1T Tester and possibly damage the CRT Tester.
- Inverting the red and its partner green jacks may damage the CRT Tester
- Inverting the orange and its partner green jacks may damage the E1T Tester

Hint: the jacks and plugs are colour coded to help you!



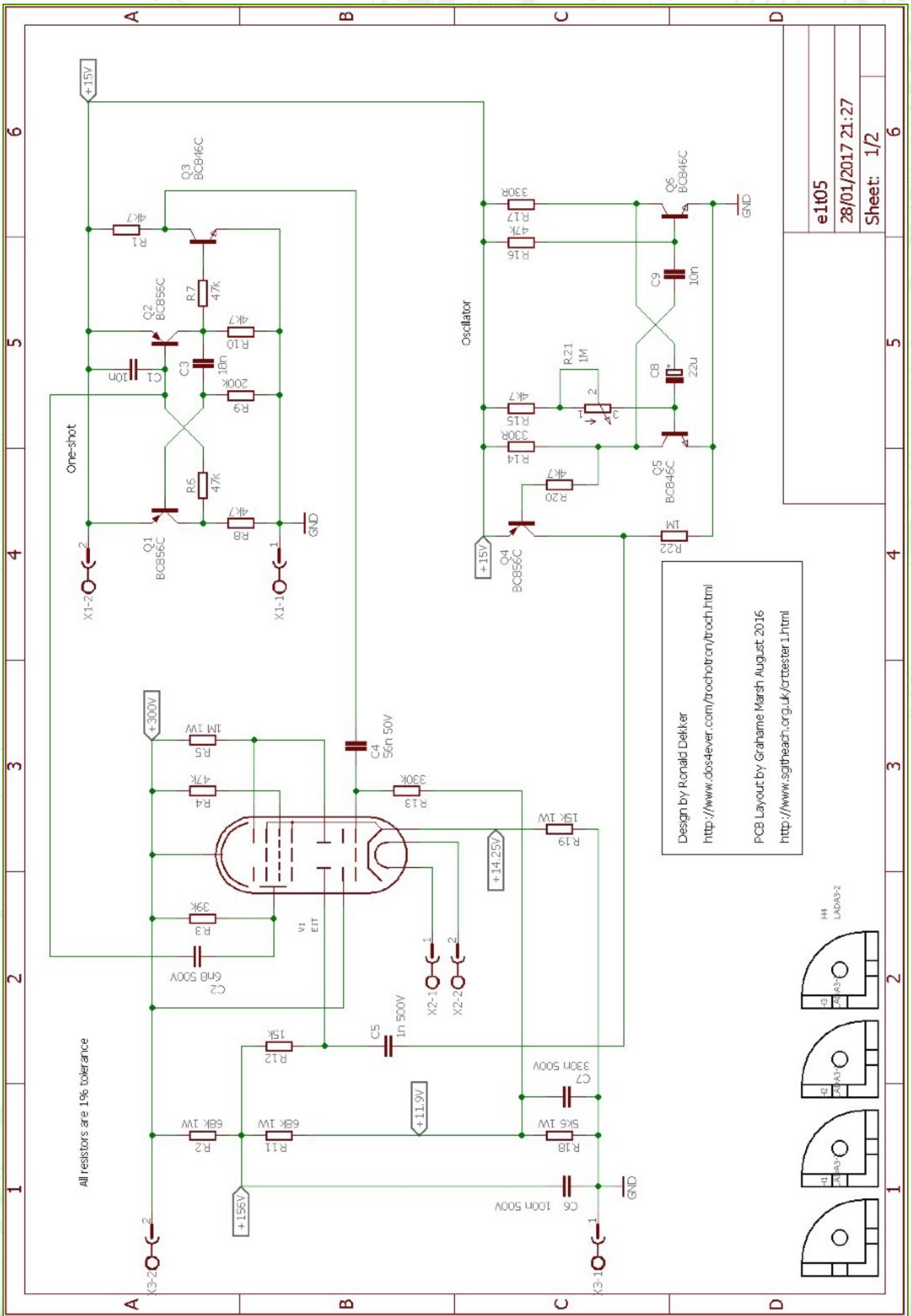
It is not necessary to use the CRT Tester as the power supply. Any power supplies that deliver 6.3V AC for the tube heater, 300V DC HT supply and 12 - 15V DC are likely to be entirely suitable. Here is the E1T tester being operated by a small 15V DC power supply and my trusty Heathkit IP17 PSU set to provide 300V DC HT and 6.3V AC for the heater:[121]



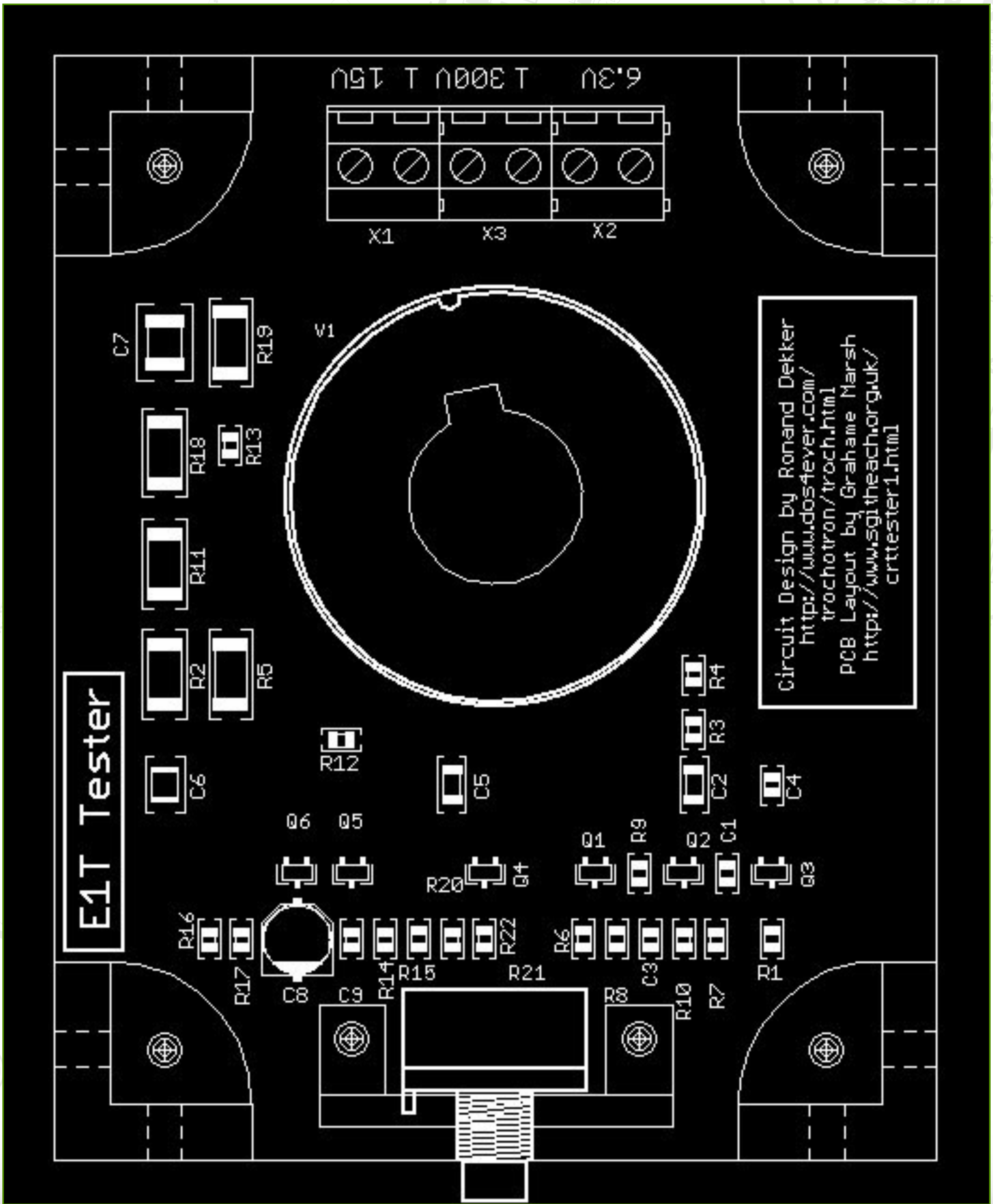
[121] Not as *classy* though….but respect for the old school…

Annex I - Schematic

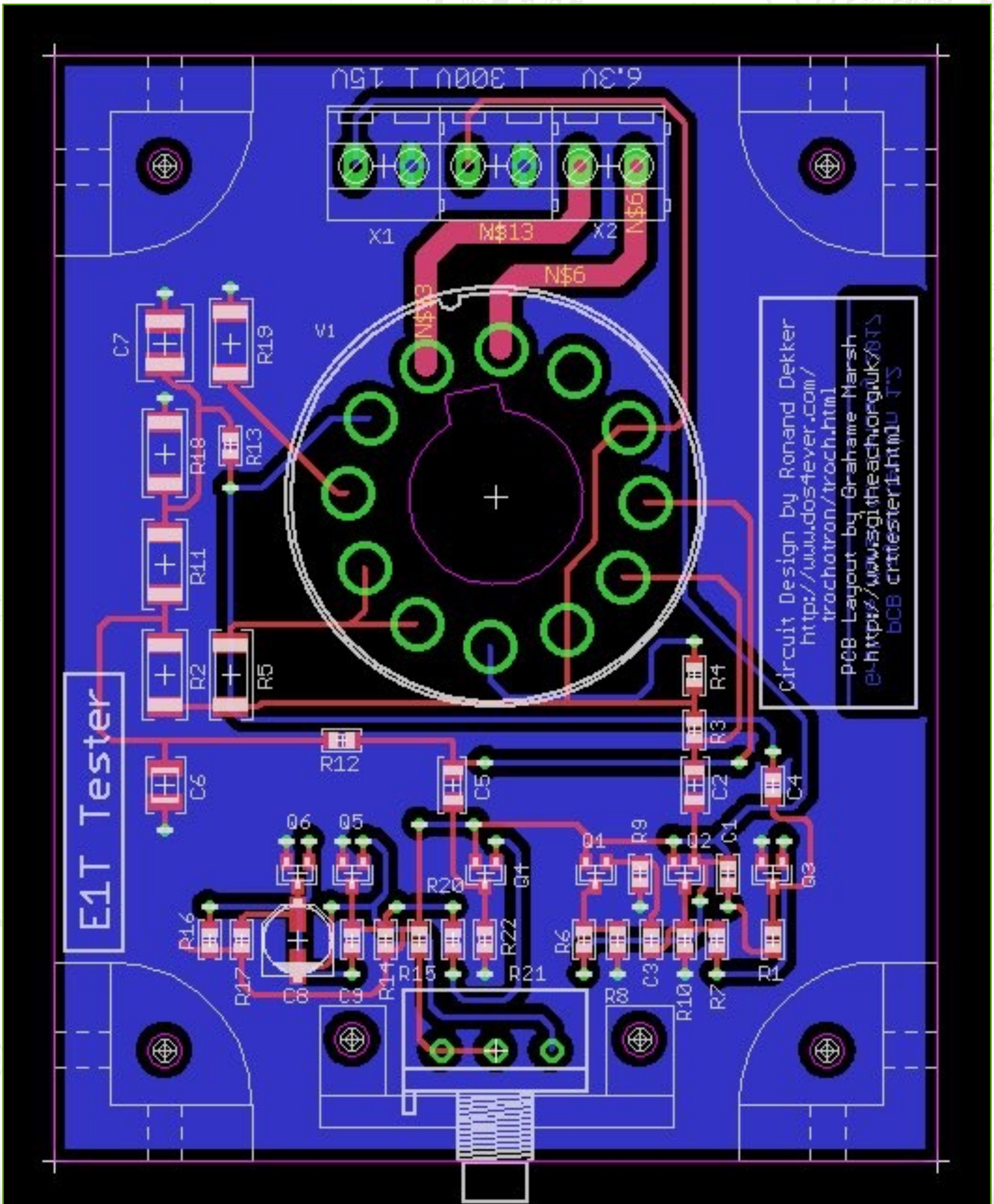
This is taken directly from Ron Dekker's design although the parts have been renumbered:



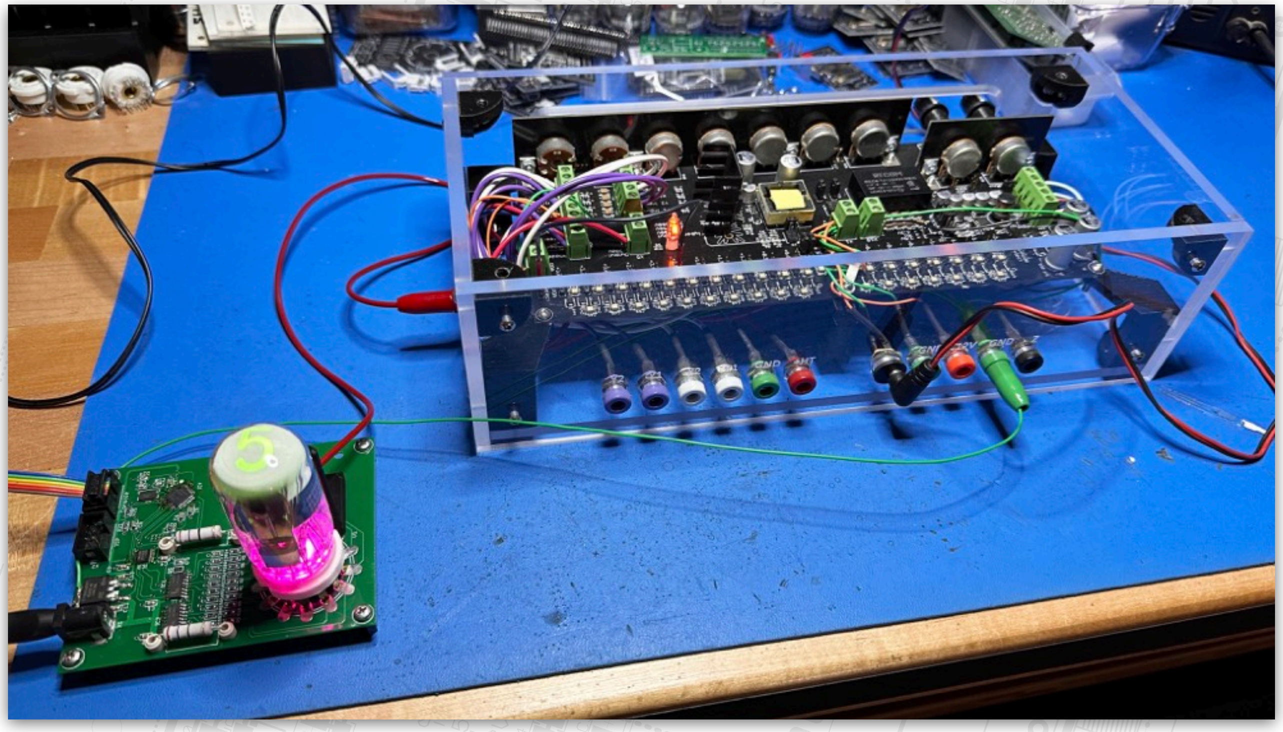
Annex II - PCB Silkscreen



Annex III - PCB Layout



NIMO Tester - A CRT Tester Extension Unit



Extend The Capabilities of Your CRT Tester - Test a NIMO Tube!

Introduction

NIMO tubes are *rare.* They're yet another example of the proliferation of different designs to indicate numerical information during an explosion in technologies in the 1960's.[122] If you're lucky enough to own one (or more!), then look no further on a neat tester board to illuminate them and explore different digit transitions, lighting effects and even a rudimentary single digit clock mode.

This schematic and PCB was designed to confirm the design of the grid drivers, the filament power supply and the cathode bias. Operated with a 12VDC supply, but approx. 2kV is needed to operate a NIMO on it's anode (this is where the CRT tester comes in handy…).

The board is also designed to allow the testing of connectors to the anode pip. The board has a APA102C tricolour LED to experiment with bling lighting effects under the tube. Finally, the board uses an ATMEGA328PB to experiment in software to try visual effects such as digit to digit cross fading.

Schematics

A description of the circuit and design follows.

Grid Drivers, Filament supply, Cathode Bias

IC3 (CD40109B) is a level shifter for the 5V outputs from the microcontroller to the 12V required by the data shift registers. Four signals are level shifted:

- Serial data from the SPI MOSI pin
- Serial clock from the SPI SPCK pin
- The data strobe that moves the clocked data to the outputs
- The shift register enable pin (when the shift registers are not enabled the shift register outputs are hi-Z)

Two 8-bit shift registers with individual output bits, serially chained together, IC1 and IC2 (MC14094B) and are required to give 10 output lines (so 6 outputs are unused).

The data output signals (QS or Q'S) from the first shift register are linked to the data input on the second shift register. Therefore, the SPI needs to send just two bytes of data to select which grid (or grids) to use. Either QS or Q'S can be used but normally Q'S should be used by closing the soldered link and QS ignored.

Each shift register output is pulled low using 10k resistors. Each grid on the NIMO tube is connected to a shift register output via a 1M resistor to limit grid current. When a shift register output is off (data bit '0') the grid voltage is 0V (ground). When a shift register output is on (data bit '1') the grid voltage is 12V. The filament is biased to about 6V (see below) so the grid voltage is switched between -6V and +6V relative to the filament (cathode) this means the digit image for that grid is either off (not shown) or on (visible) respectively.

The heater supply uses the 12V DC supply and two 27R 3W resistor in each side of the filament supply to give the correct filament voltage/current and bias the filament (cathode) to about 6V.

Finally, the MOSFET Q1 can be used to turn the filament power on or off.

[122] https://en.wikipedia.org/wiki/Nimo_tube

Microcontroller, serial console and bling LED

IC4 (ATMEGA328PB) SPI ports are used to generate the serial data and clock signals for the NIMO grid shift registers and the tricolour bling LED. N.B. the 'B' silicon version must be used. The microcontroller clock uses a 20MHz crystal. Z1 (APA102C0 is the bling LED module. A serial console is connected (to X4) to control the operation of the board. The serial port connector (X4) is compatible with the Sgitheach SAM3X8C programmer/console (as a console only, it will not program the IC4). An Atmel AVR ISP is plugged into X2 to program IC4.

Finally, IC5 is a linear voltage regulator to supply 5V to board circuits.

Sourcing the components

None of the components (except the NIMO) are particularly rare. All of the common components (Rs, Cs, ICs, sockets) etc can be bought from the usual stockists (Mouser, Digikey, Farnell).

The PCB mounting compactron base can be purchased off eBay although prices vary widely so shop around. It is also useful to purchase an old compactron type vacuum tube so as to loosen the sockets of any purchased base without damaging a very *valuable* NIMO.

The RF Finger stock is from

https://www.surplussales.com/RF/RFFingerstk-1.html

Parts List

Tick	Quantity	Part	Value	Package
	11	C1 - C8, C11 - C13	100n	0805
	2	C9, C10	22p	0805
	2	IC1, IC2	MC14094B	SO16
	1	IC3	CD40109B	TSSOP16
	1	IC4	ATMEGA328PB	TQFP32
	1	IC5	7805	D2PAK
	10	R1 - R10	1M	0805
	13	R11 - R22, R25	10k	0805
	2	R23, R26	27R 3W	through hole
	4	R23, R26	Ceramic stand-offs	
	1	R24	22R	0805
	1	Q1	SI2318CDS	SOT23-3
	1	V1	Compactron Base	

Tick	Quantity	Part	Value	Package
	1	V1	NIMO tube	
	1	V1	3D Printed bling shield	
	1	V1	3D Printed anode EHT connection	
	1	V1	RF Finger Stock	(FFS) 97-0520-02
	1	X1	DC10 power socket	
	1	X2, X4	2x3 IDC box header	
	1	Y1	20MHz crystal 18p	ABM3 or ABM7
	1	Z1	APA102C	5050
	1	Z1	3D Printed bling shield	

Notes
1. IC4 - ATMEGA328PB must be the B silicon version
2. Y1 - ABM3 is easier to hand solder than ABM7
3. V1 - STL files for 3D printed parts from the project Dropbox
4. R23, R26 - Ceramic spacer to hold the resistors away from the PCB
5. Z1 - APA102C has a reputation for being sensitive to temperature so don't cook it when soldering, use low temperature solder

The board should not challenge anyone used to soldering SMD parts, although the CD40109B does have quite fine pitched pins, so take care not to introduce any shorts.

No ground connection for the EHT anode supply is provided (my error) so you must solder a lead onto board ground somewhere (the ground tab on IC5 is a good spot for this).

The 3D printed bling shield is dropped over Z1 (APA102C) before the Compactron base is soldered in place. Its function is to reduce horizontal light scatter. It's not entirely necessary, but has it's benefits.

The RF finger stock (made from very springy beryllium copper alloy) has a sticky pad that is used to fix it to the recess in 3D printed anode EHT connection. Fix with the hinge at the edge nearest the wire hole and the open end uppermost. When fixed, solder the EHT wire on near the hinge end and press the wire into the recess and out through the hole (don't try to solder the wire when the tab is in place, the heat *will* melt the PLA of the 3D printed part). The anode connection assembly is bolted to the M3 hole nearest the NIMO tube. The RF finger stock should press against the NIMO anode pip when the tube is inserted into the socket.

As mentioned before, ***it is strongly recommended*** that you buy another compactron tube (say, off eBay). The connections on a new compactron base can be very tight and you can use the "sacrificial" tube to open the connections and allow the NIMO to be more easily plugged it. What would you rather break - a $5 compactron or a $300 NIMO[123]? There are some rectifiers and power pentodes that have a very robust disposition, ideal for this purpose.

[123] Yes, they really can be that expensive *if you can find them*…

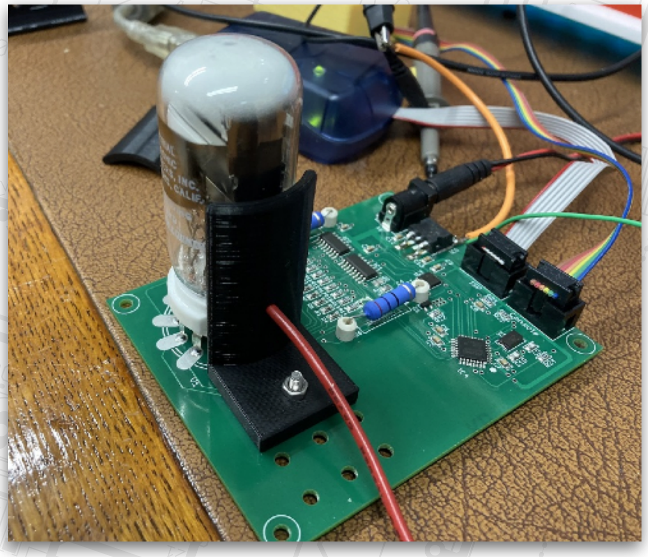
Anode Connector Assembly (in pictures).

Render of 3D printed part

Printed in black PLA on a Prusa Mk3S+

With the Be-Cu Finger Stock glued in place

EHT (3kV rated) wire soldered and routed down the slot and through the hole



Mounted in place on the NIMO tester board

Programming the Firmware

Unlike the other CRT Tester extensions described in this manual, this one has some extra functionalities by way of the ATMega328PB control and a serial port. Hence, you will need to program the chip using the usual protocols.

A standard Atmel ISP 6 way header is provided (X2) to program the ATM328PB.

The required fuse settings are:

- Extended - 0xFC
- High - 0xD9
- Low - 0xFF

The latest firmware as either a HEX or ELF file can be downloaded from the project DropBox.

Using the Firmware

Connect a SAM3X8C Programmer/Console to the 6 way Console header (X4). Run your favourite serial console software (I use TeraTerm) and configure it to 115200,8,1,N.[124]

Press the Reset button on the Programmer/Console and an introductory message should appear. If your serial console software is in monochrome and contains a load of escape sequences then enter

MONO

The display will not include the colour change strings, you can press the Reset button again to see the start up message clearly. (Hint: TeraTerm does recognise the colour change strings and is recommended for that reason.) The selected colour or monochrome state is saved to EEPROM.

Now enter

HELP

and the list of current commands will appear.

The operating commands all consist of 4 characters, the first 3 characters are what the command acts on (i.e. the noun) and the last letter is the action that is going to happen (i.e. the verb). For example

LEDK

will Kill, i.e. turn off the bling LED, and

NIMS 7

will Set the NIMo tube to display the number 7. This example shows the addition of an argument to the command.

The current list of 3 letter nouns are

FIL	switch the NIMO filament on/off
LED	commands for the bling LED
NIM	commands for the NIMO tube driver
SYS	system information
TIM	time/clock commands

Each of these nouns can be followed by the verb ? which will give further help on that noun. For example

NIM?

will list all the commands for the NIMO tube driver.

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[124] Mac users can easily use the Terminal 'Screen' command. Once you've plugged in your console to a USB port and the tester is on, type *ls /dev/tty.** This will give you a list of all the serial ports available. Then type *screen /dev/tty.usbmodem<insert prior number here> 115200*.

Miscellaneous commands that don't follow the 3+1 rule are:

COLR switch the display to colour
HELP display basic command information and arguments
MONO switch the display to monochrome

FIL in depth

The intent of this command is to allow the filament to rest when it is not needed but also to examine how fast the filament lights and cools.

FIL has only three commands. **FIL?** for help. **FILS** to turn the filament on and off, and **FILR** to report on the filament state. N.B. The filament is *on* by default after a reset..

LED in depth

The intent of this command is to assess the effectiveness of under lighting a NIMO through the centre of the compactron base. Experiments with the LED are important to decide if the bottom lighting LED could be used in production clocks or other devices. **LED** has six commands:

LED? for help.

LEDB v which sets the global brightness to value **v** which is a value from 0 .. 31 and is entered as a decimal number. The global brightness has a value of 10 be default after a reset or a **LEDK** command.

LEDC continually rotate the LED hue (using a HSV model). Stop by pressing {esc} or using the **LEDK** command.

LEDK turns off the bling led by setting its value to 0x000000. The default brightness value of 10 is restored. Hue rotation is stopped.

LEDR report on the current global brightness and colour values etc.

LEDS x sets the LED module to colour **x.** The argument is the colour value entered as a hexadecimal number in the form 0xBBGGRR where BB is a hexadecimal number 00 .. FF giving the blue intensity, GG the green intensity and RR the red intensity.

Examples

LEDS 0xFF	full red intensity
LEDS 0x800080	mid magenta

By default after a reset the colour value is set to 0x008000 mid green.

NIM in depth

This, of course, is the most important command set! The intent is not only to prove the driver hardware but also to start experiments and trials on visual effects.

The current firmware has 4 special effects. Some effects can be combined together:

- Gapped - a short blank period is inserted when the displayed character is changed.

- Fading - a displayed character fades from the current one to the new one
- Chaos - a series of random character are shown before the desired one
- Spinning - the intermediate characters are shown when changing from one character to another, a complete cycle can be shown, spinning the display

NIM has ten commands

NIM? for help.

NIMB n which sets the brightness of the NIMO using PWM on the grid data to reduce the time the NIMO tube is on for. The value of n is 0 .. 100 % decimal number, where a value of 100 means the PWM is not used to reduce the tube brightness i.e. brightness is at a maximum value.

NIMC continually increment the displayed number, rolling '9' to '0', once per second. Press {esc} or use the **NIMK** command to stop.

NIMF n fade between changing digits where **n** is the period of the fade in mS. **n** = 0 turns the effect off.

NIMG n insert a gap of **n** mS between characters. **n** = 0 turns the effect off

NIMH n, m show **n** random characters each for **m** mS before showing the desired character. Does not use fading or gapping.

NIMK turns the displayed character off, turns off any fading, chaos, spinner or gap timers, turns off a continual display, set the PWM brightness control to 100%.

NIMP n, m spin through intermediate characters to the desired display character. The intermediate characters can be a complete cycle repeated n times. The delay between each character change is **m** mS. Does not use fading or gapping.

NIMR list current NIMO driver settings.

NIMS n displays the character **n** on the NIMO, **n** = 0..9

NIMT n, m show the time by showing 10's hours, unit's hours, 10's minutes, unit's minutes and then a blank period in a continual loop. **n** sets the period in mS that each of the characters are shown for and **m** sets the blanking period in mS before the cycle starts again.

<u>**SYS** in depth</u>

These are miscellaneous system commands. There are three:

SYS? for help.

SYSR lists the complied version, date and time.

SYST lists the current multitasking system settings.

<u>**TIM** in depth</u>

These commands adjust the RTC time (not at all accurate) used by the **NIMT** command.

TIM? for help

TIMR time report

TIMS hh:mm set the current time for the RTC.

Initial Command Tour

You can dive straight in start putting your own commands in but perhaps it is useful to give an initial list of commands to try and then you can experiment further.

Start with the tester connected to the power supplies and the console firmware running. Press the reset button on the console box and the start up message should appear.

Enter **FILR** and you should see the filament is on.

Enter **LEDC** and watch the tube bling LED continually rotate its hue... enjoy!

Enter **NIMC** and watch the NIMO tube continually count 0 .. 9 and repeat. Each count step takes 1000mS.

Enter **NIMG 100** and you will see a short (100mS) blanking gap inserted between each character change. Try **NIMG 250** for a longer blanked gap.

Enter **NIMG 0** to stop the gapped effect.

Enter **NIMF 250** and watch the characters cross fade as they change.

With the cross fading running, enter **NIMG 100**. The effect is now a combination of the gapped effect and the fade effect. The character fades to blank (250mS), remains blank for a period (100mS) and then changes from the blank to the next character (in 250mS).

While the tube is displaying characters, enter **FILS 0** and then **FILS 1** and you can see how fast the filament turns off and on - much faster than a CRT.

Enter **NIMK** to turn off the continual change, gap effect, fade effect and leave the tube blanked.

Now enter **NIMS 0** and the character '0' will be displayed. Now enter **NIMS 9** and, not surprisingly, the character '9' is displayed immediately. Enter **NIMS 0** again to return the display to '0'.

Now let's look at the spin command by entering **NIMP 0, 100**. Then enter **NIMS 9**. You will see the displayed character changes from '0' to '9' showing each of the intermediate characters for 100mS. Now enter **NIMP 2, 50** and then **NIMS 5**. This time the character is displayed for only 50mS but the characters spin through each character twice, which is what the first parameter, 2 in this case, controls.

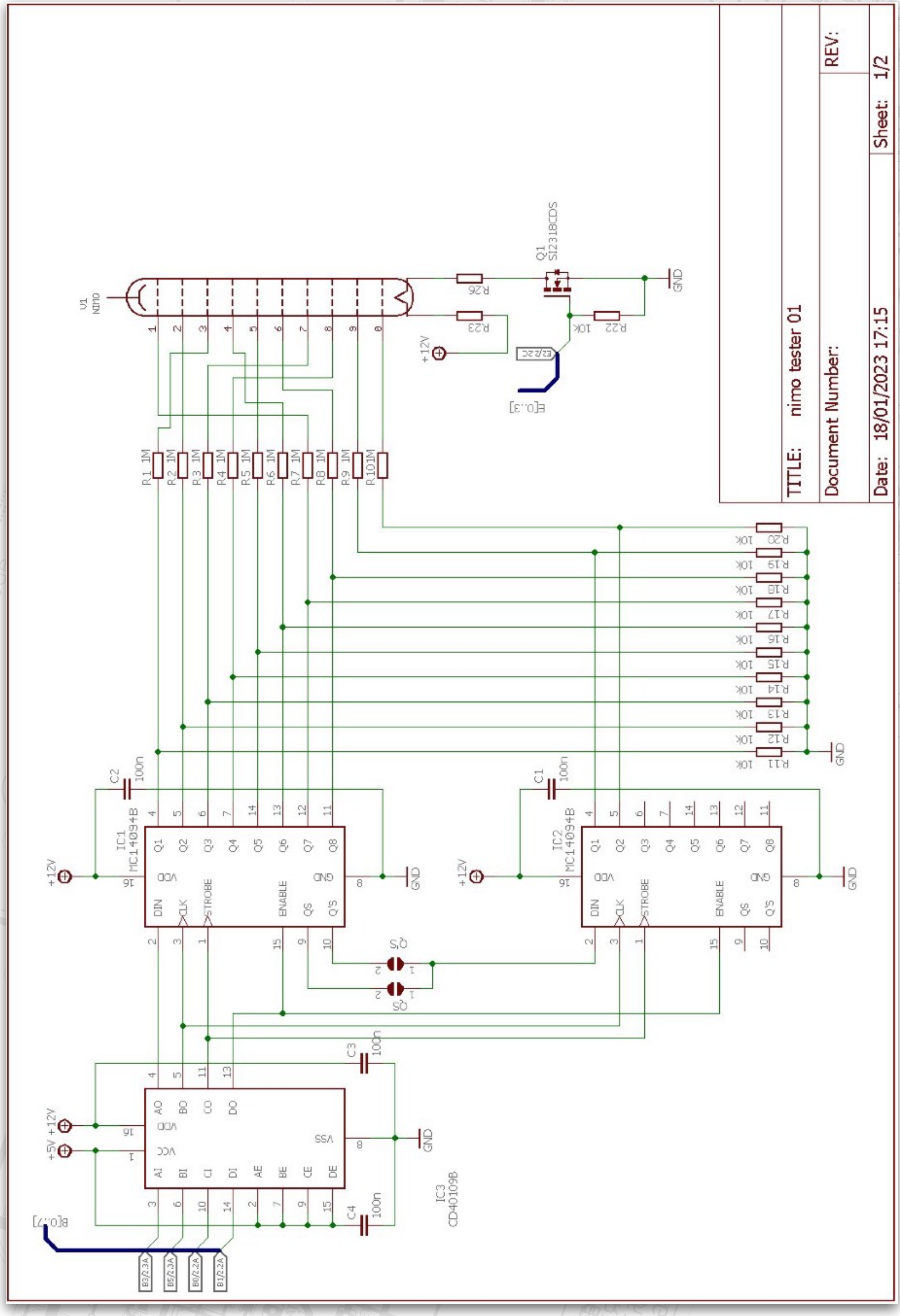
Now enter **NIMH 10,100** which is not unlike the **NIMP** command but it shows, in this example, 10 random characters for 100mS each before the final character. So enter **NIMS 5** to see the effect.

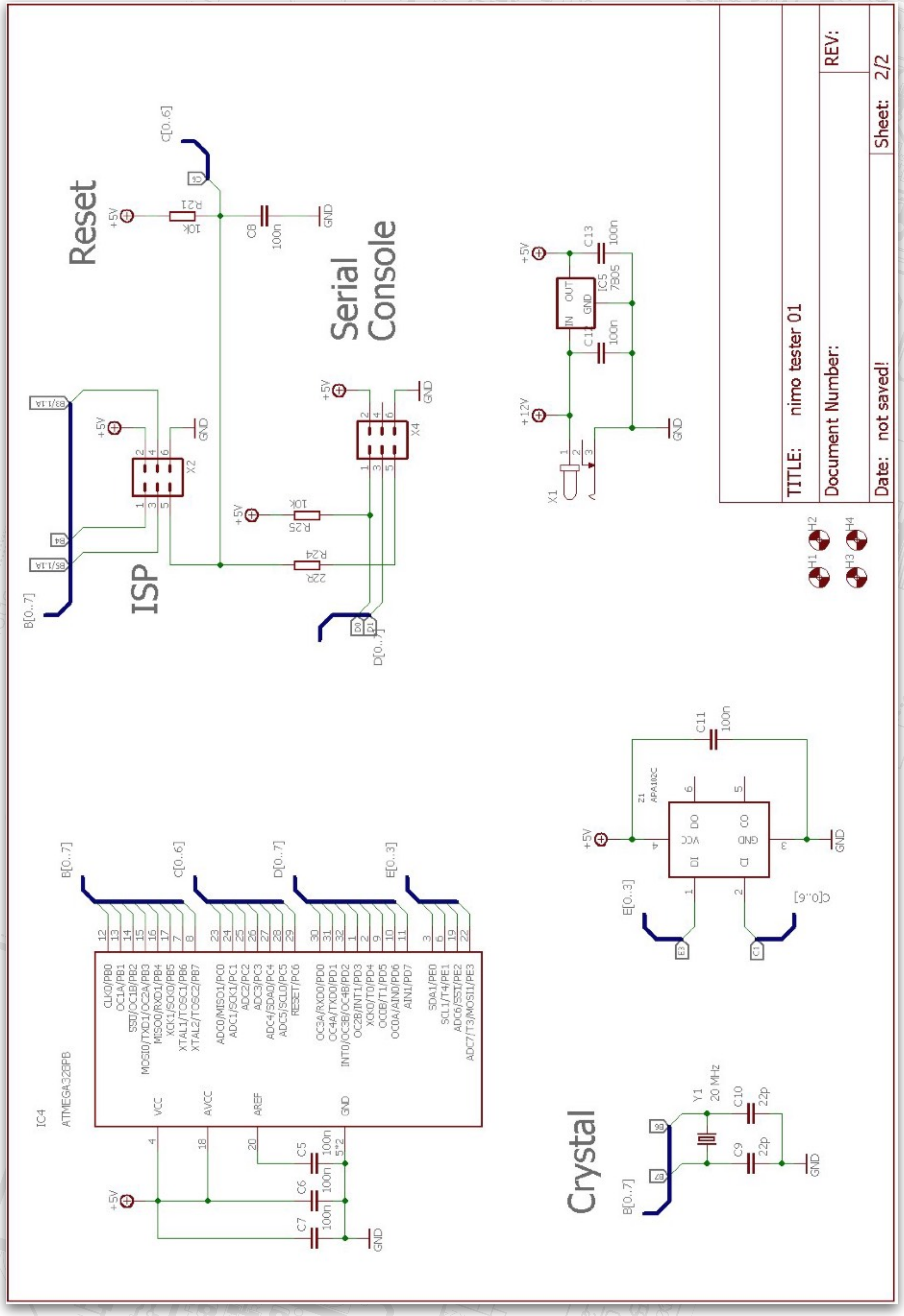
You can also use the **NIMC** command with the **NIMP** and **NIMH** commands to see the effects as the tube counts.

Enter **NIMK** to turn off all the current commands and effects.

Enter **TIMS hh:mm** using the current time, e.g. **TIMS 16:32**. You can try the **TIMR** command to see the RTC changing. Now enter **NIMT 500,2000** and **NIMG 100** and watch the clock operate. You can now play with the effects to see how the display changes are affected.

Annex I - Schematics




Reset
Serial Console
ISP
Crystal
ATMEGA328PB
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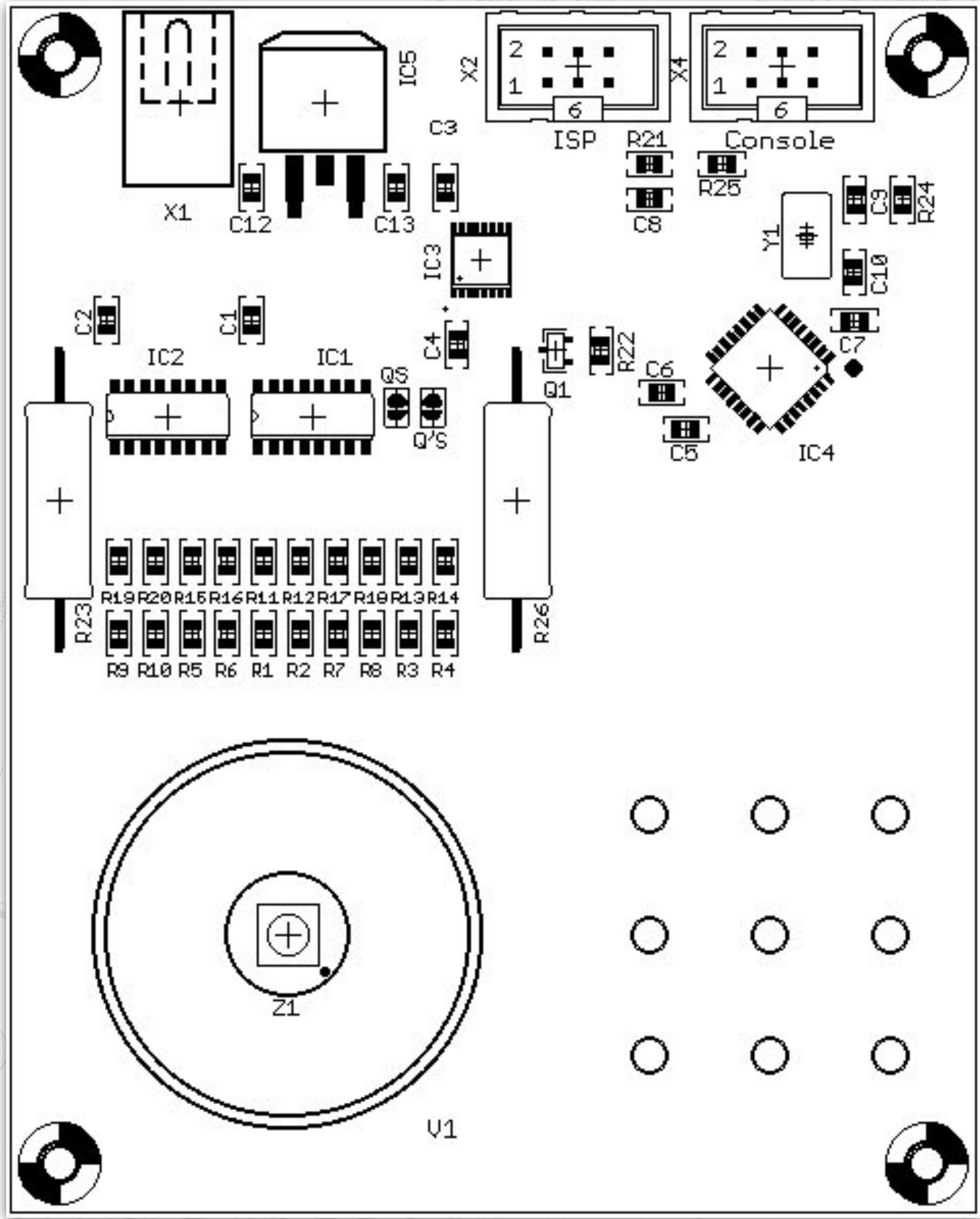
Annex II - PCB Layout



 Version 1.5