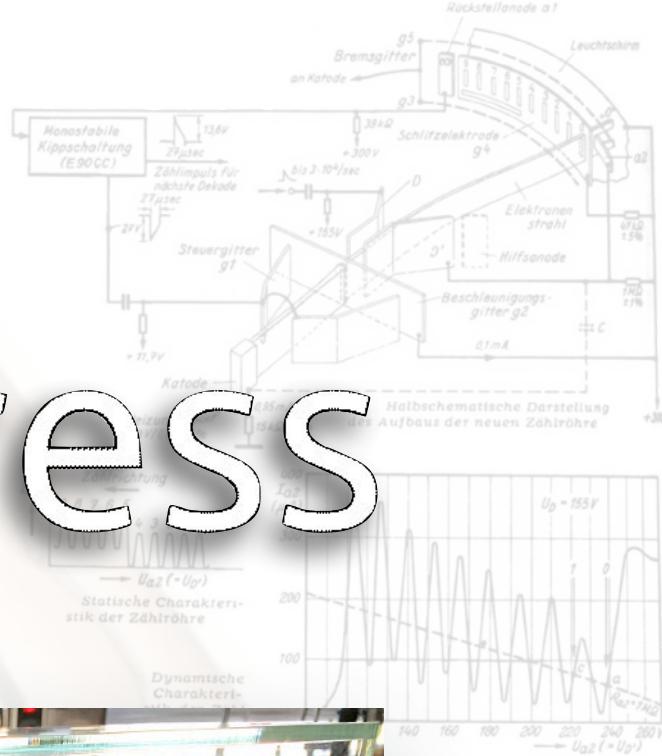


Fortress



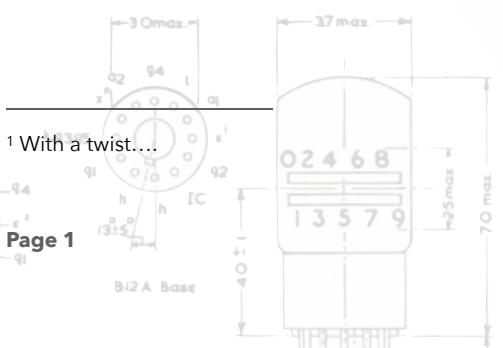
Fortress - An E1T Timepiece¹

Six Miniature CRTs In Action



¹ With a twist....

Page 1



Version 1.3

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Fortress

What is the Fortress? It's the culmination of an awful lot of work by two like-minded individuals who like to tinker with vintage display technologies and turn them into functional and unusual time-pieces.² This clock is somewhat unique in many respects. It is, to our knowledge, the only 'commercial' E1T clock deliberately offered for sale ever. Others have offered PCBs etc, but this is the *whole enchilada* and as such is a rarity to be treasured and enjoyed.³ Fortress is a combination of old-skool technology married with a very modern micro-controller and 21st century case construction and aesthetics. It offers lots of customisation options, such as different 'faces'⁴, light-guided LED colours, chimes, GPS or WiFi disciplined timekeeping and is also *open design and open source* in its publication philosophy to boot!

What's in the Box?

If you purchased a kit, then there are a few options available⁵ and your package will contain one of the following;

- A *Minimum Electronics Kit* - A set of PCBs and custom flyback transformer. This one is not for the *feint of heart* as there is significant SMD soldering to do.
- A *Standard Electronics Kit* - This is all the PCBs with the SMD work pre-soldered and all the components necessary to complete the electronics of the clock (without E1T tubes, these are either provided by you or purchased as extras with the kit).
- A *Standard Clock Kit* - This is all of the standard electronics (as above) with a simple case and cover so you can enclose the clock, light guides etc. Plug the tubes in and enjoy (after all your hard work soldering and testing of course).
- A *Premium Clock Kit* - The same as the standard clock kit with a premium case (you can discuss colour choices with us) and a solvent welded acrylic cover.

Why so many options? Well, we want to make this available in as wide a price range as possible as it's not an *inexpensive* proposition. We offer complete clocks also in both standard and premium versions, including one with a custom, anodized aluminium case.

What is an E1T Tube?



The plethora of methods developed during the late 1940's to the 1970's for displaying/counting numerical information were numerous and varied. These included incandescent displays (e.g. edge lit displays such as those from Non-Linear Systems⁶), neon gas based displays such as Nixie tubes⁷ and Dekatrons⁸, vacuum fluorescent displays⁹ (VFDs), light-emitting diodes¹⁰ (LEDs) and

² Stay tuned for more!

³ However, you can purchase *just the PCB's* if you wish....see, how's that for being flexible! 😊

⁴ And a whole programming language (Nuggle) so you can design your own colourful displays!

⁵ <http://www.sgitheach.org.uk/fortress.html#kits> - for all the details.

⁶ <https://stevenjohnson.com/nls/index.htm>

⁷ https://en.wikipedia.org/wiki/Nixie_tube

⁸ <https://en.wikipedia.org/wiki/Dekatron>

⁹ https://en.wikipedia.org/wiki/Vacuum_fluorescent_display

¹⁰ https://en.wikipedia.org/wiki/Light-emitting_diode



liquid crystal displays¹¹ (LCDs). Some of these possess a *certain charm*, such as nixie tubes and Dekatrons with their warm **orange**, neon derived, glow whilst others *not so much*¹². What makes the E1T (or S10S1, the East German Clone) stand out from these technologies is that it represents the adaptation of another vintage display technology, the *cathode ray gun*¹³ into a discrete counting device. The E1T uses a cathode ray and some neat tricks to display a green line in 10 positions, each cunningly numbered from 0 to 9. These were used in early counters (such as the one pictured on the right). A far more detailed explanation of how to electrically drive an E1T can be found later on in this document. There are also some great resources on the web for history and data about the E1T.¹⁴



Anatomy of a Fortress

The clock consists of the following components;

- Six E1T tubes encased with raked cast acrylic light guides.¹⁵
- Two acrylic light guide rod colons.
- PIR¹⁶ - so the clock can go to 'sleep' if no-one is in the room to bask in its beauty.
- Rotary encoder - to select the different 'faces' to the clock and also to adjust the volume.
- Infrared remote sensor¹⁷
- Two high quality downward firing speakers - the Fortress is capable of using .WAV files to play chimes and audio.¹⁸
- SD Card - this contains all the face file descriptors (Nuggle programs), audio files, chimes , system files and system.ini file.
- A removable plate at the rear to access both the SD card and the programming port on the CPU board.
- A GPS/WiFi antenna connector.
- PSU input socket (12V DC rated at a *minimum* of 5A output).¹⁹
- A case top/cover for the clock (depending on what kind of kit you purchased).

This manual contains all the instructions you need to complete the display board, main board, build the acrylic case and top and find the information to program the CPU etc. to get up and running.²⁰ Take your time, this isn't *too* complicated a build, but is not for the novice constructor. There are high voltages involved and as such **care should be taken at the appropriate testing points** throughout the build. These are pointed out as you proceed. We assume you know the

¹¹ https://en.wikipedia.org/wiki/Liquid-crystal_display

¹² Beauty is in the eye of the beholder....

¹³ https://en.wikipedia.org/wiki/Cathode-ray_tube

¹⁴ http://www.tube-tester.com/sites/nixie/different/e1t-tubes/E1T_philips/e1t-phil.htm; <https://www.dos4ever.com/E1T/E1T.html>

¹⁵ As interesting as the E1T is as a piece of vintage CRT technology, we thought we'd spruce things up with a little extra bling....which you can turn off if you so desire!

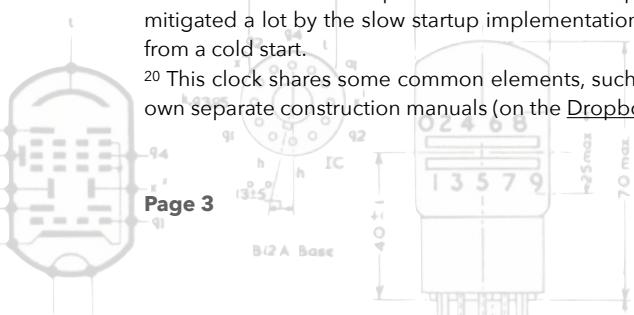
¹⁶ PIR - Passive InfraRed sensor.

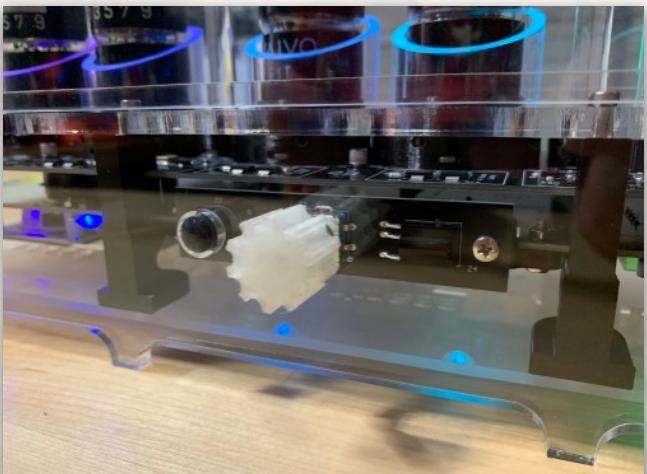
¹⁷ For clear acrylics, these are IR transparent, but opaque materials and aluminium cases have a cut-out for the IR receiver.

¹⁸ Some of it *quite amusing*.

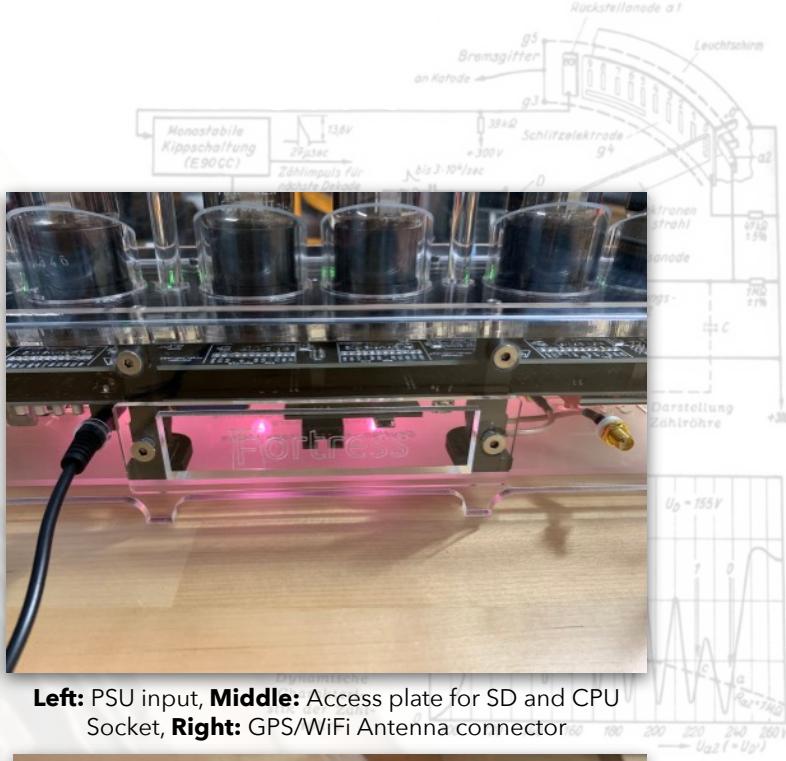
¹⁹ The clock doesn't require a continuous 5A input, but upon startup the heaters require quite a bit of *juice* to warm up. This is mitigated a lot by the slow startup implementation in the clock hardware, but current spikes of approximately 3A are not uncommon from a cold start.

²⁰ This clock shares some common elements, such as the SAM programmer, SAM CPU board, WiFi and GPS boards which have their own separate construction manuals (on the [Dropbox](#)).





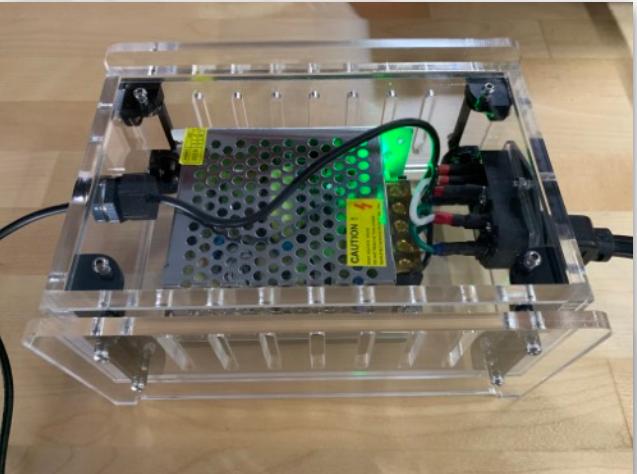
Left: PIR, **Middle:** Rotary Encoder, **Right:** InfraRed Receiver



Left: PSU input, **Middle:** Access plate for SD and CPU Socket, **Right:** GPS/WiFi Antenna connector



One of two speakers on the *underside* of the Fortress



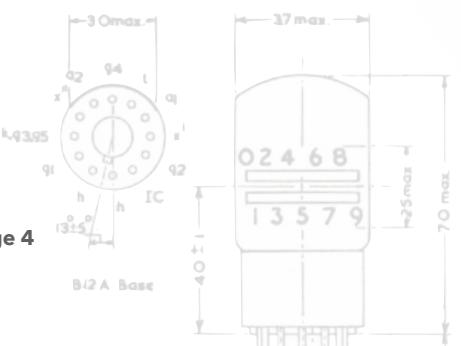
Custom 5A PSU for the Fortress

business end of a soldering iron, what various electronic components are, their necessary polarity, how to use a multimeter and possibly an oscilloscope (not necessary to complete the clock, but can be useful in troubleshooting a build).

Once you've completed the electronics, the case and the clock is operational, please take a look at the other manual for the pre-built clocks to learn about how to operate the clock, change faces, program etc, etc. You can find this in the same [Dropbox](#) location as the rest of the Fortress literature.

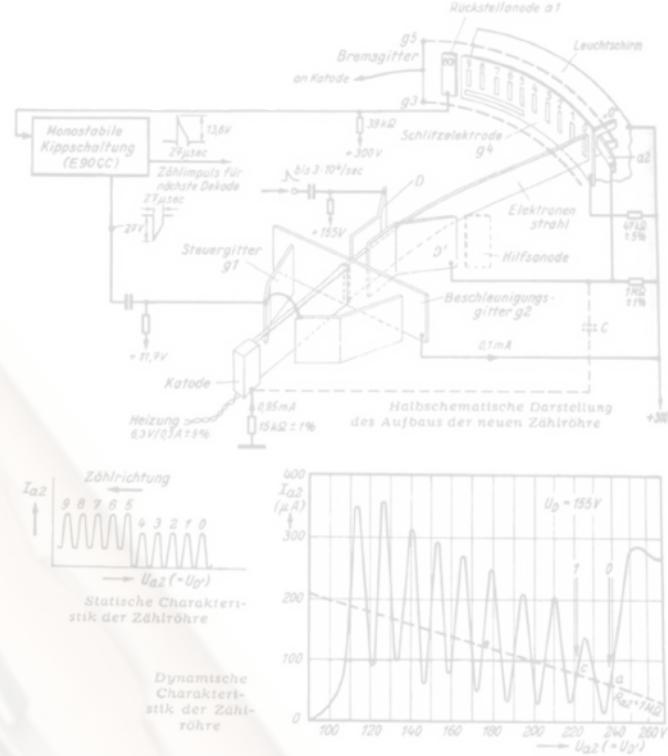
Any questions or concerns then please don't hesitate to contact us at either:

web.sgitheach@googlemail.com or stocksclocks@gmail.com



15.1.1.3

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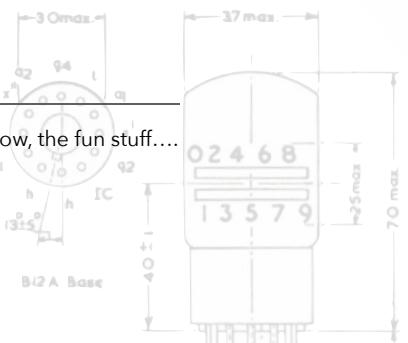
SAFETY AND LEGAL²¹

SAFETY, LEGAL & LICENSE CONSIDERATIONS



21 You know, the fun stuff....

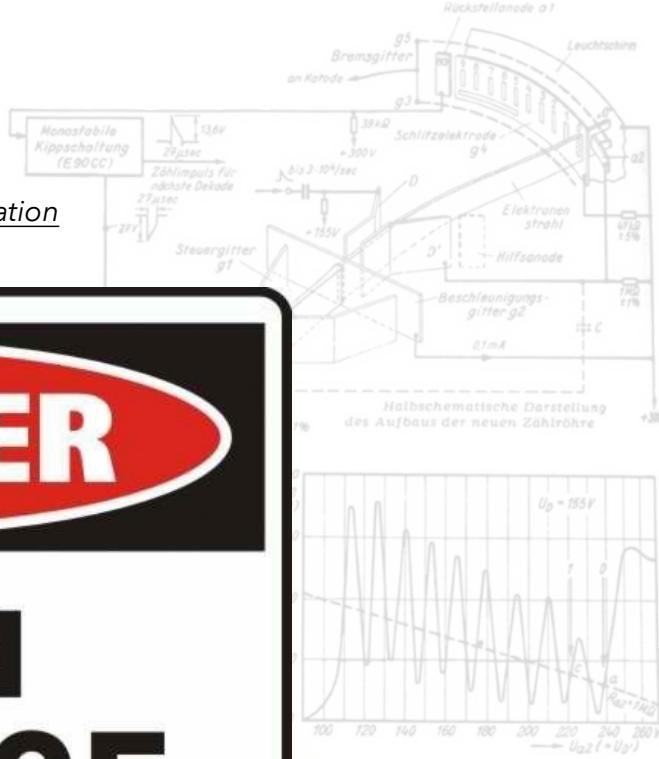
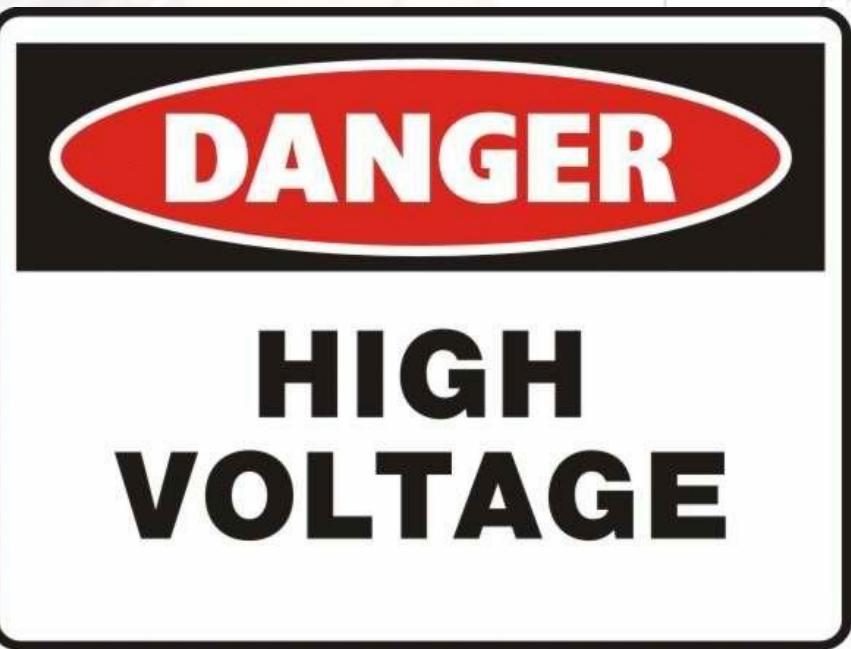
Page 6



Version 1.3

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Important Safety Information



Annex - Safety and Legal Statements

Safety Statement

Like all 'scope based clocks, The Fortress uses high voltages in order to operate the cathode ray gun inside the E1T tube. You need to respect this and other hazards inherent in these circuits.

Caution! The Fortress clock must be correctly earthed (grounded) using only a 3-core mains cable to a correctly earthed mains outlet.

Caution! The Fortress generates high voltages in the region of 300V during operation. These voltages are present on the main board, display board and base of the E1T tubes; These voltages may be maintained for a period of time after input power is removed.

Caution! Do not touch the electronics while the clock is in use or has been recently operated. Treat the clock with the same level of care and common sense as any mains-powered electrical device - do not expose to wet environments, keep out of the reach of children, animals etc. Do not eat!²²

Caution! Some components may be warm to the touch during use. This is a perfectly normal consequence of their operation, but you should remember it when handling the board or considering alternative clock enclosures.²³

Caution! The E1T tube envelope is made of glass and may be broken if the clock is dropped or inadvertently struck.²⁴

²² It wouldn't taste very good...

²³ Why you would give the rather exquisite case the clock is supplied in is beyond the author's imagination...

²⁴ Keep this out of the way of stray pets...



Legal Statement

The Fortress clock is built and documented with an Open Source philosophy in mind. All the source files including circuit diagrams, Eagle board, software and design files are provided under a Creative Commons ShareAlike 4.0 International license.

More specifically;

- i) 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/by-nc-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).

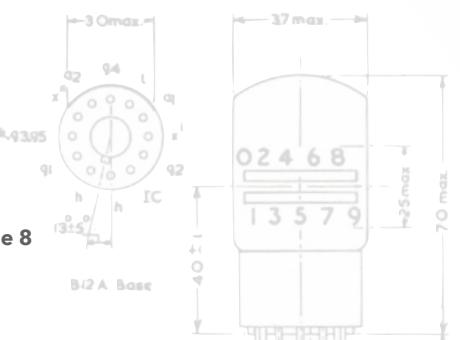
The Fortress Clock may be hazardous if not assembled and operated by suitably knowledgeable and practised persons or if abused. It is your responsibility to carefully review the documentation, the design and the kit contents, and to assure yourself that you have the necessary expertise to construct and/or operate the clock safely. In particular, it is also your responsibility to ensure that the completed clock 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 clock 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 this kit 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 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.

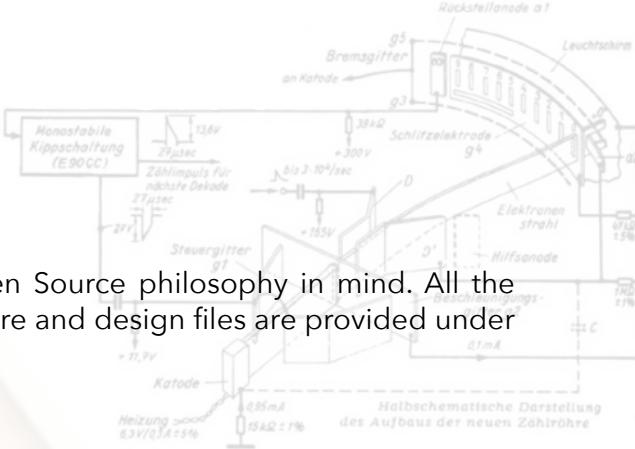
In summary, you own, construct and use the Fortress Clock entirely at your own risk. To the maximum extent permitted by law, we disclaim all liability for any and all adverse outcomes associated with your ownership, construction and use of this item.



Page 8



Version 1.3



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Atmel Licence

The Fortress firmware makes extensive use of the Atmel²⁵ libraries. The Atmel License (also given in every Atmel library file) is

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My distribution of the Atmel libraries as part of the open source firmware is in compliance with this license.

For further information visit <http://www.microchip.com>

LUFA Licence

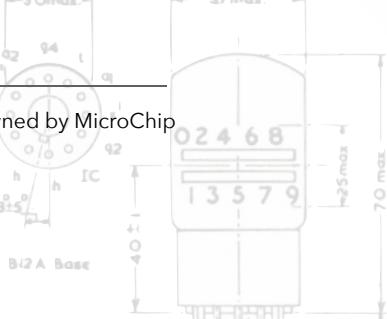
The Fortress uses an custom SAM3X8C core board and as such makes use of a programmer that uses LUFA.

LUFA Library

Copyright (C) Dean Camera, 2010.

dean [at] fourwalledcubicle [dot] com
www.fourwalledcubicle.com

²⁵ Now owned by MicroChip



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The author disclaim all warranties with regard to this software, including all implied warranties of merchantability and fitness. In no event shall the author be liable for any special, indirect or consequential damages or any damages whatsoever resulting from loss of use, data or profits, whether in an action of contract, negligence or other tortious action, arising out of or in connection with the use or performance of this software.

For further information see <http://fourwalledcubicle.com/LUFA.php>

Warranty Information

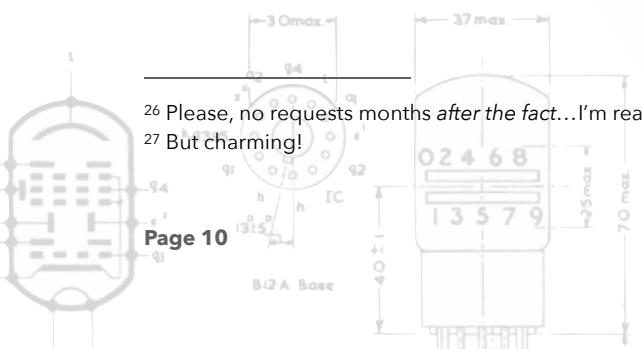
Upon receipt of the kit of parts, any missing or broken pieces will be replaced. It is incumbent upon the recipient to check the contents in a prompt²⁶ manner against the supplied parts lists found within the construction manuals. As a kit of parts, no warranty can be provided pertaining to the quality of construction and operation of the final product as this is the duty of the purchaser and is dependent upon their skill. The Fortress clock may be hazardous if not assembled and operated by suitably knowledgeable 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 clock within the supplied manuals. Due to the nature of the obsolete²⁷ technology employed in the Fortress clock (primarily the E1T tubes themselves), certain hazards are present, namely high voltages and fragile glass under vacuum and due care and attention should be paid when handling said items.

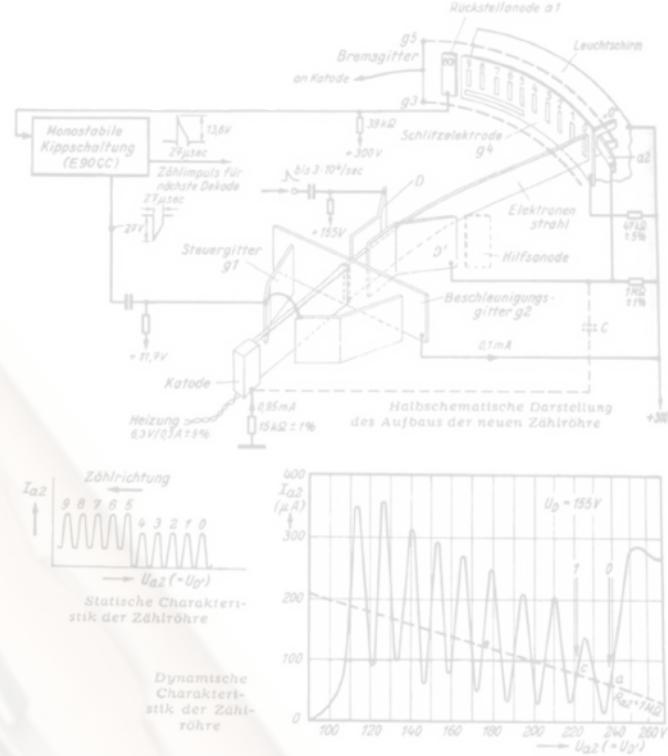
If you have purchased a complete operational clock then a limited warranty is provided in a separate document supplied with your documentation. If the clock kit or complete clock has arrived in a damaged state such that an insurance claim is likely to be made, then please notify us immediately (within 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.

²⁶ Please, no requests months after the fact...I'm reasonable but not that reasonable.

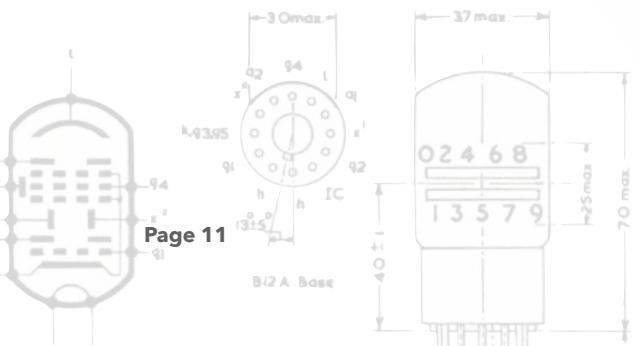
²⁷ But charming!





Display Board Assembly

Putting the E1T tubes to good use...



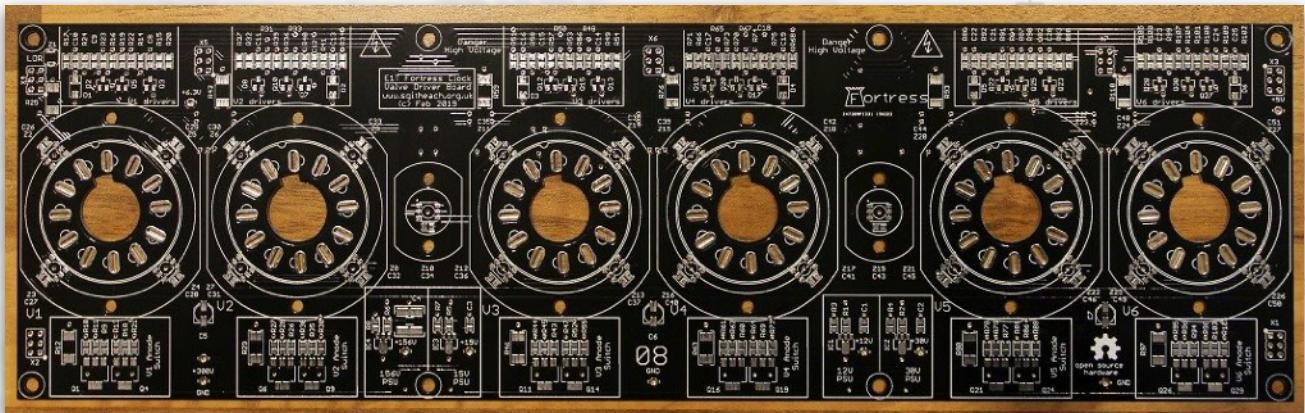
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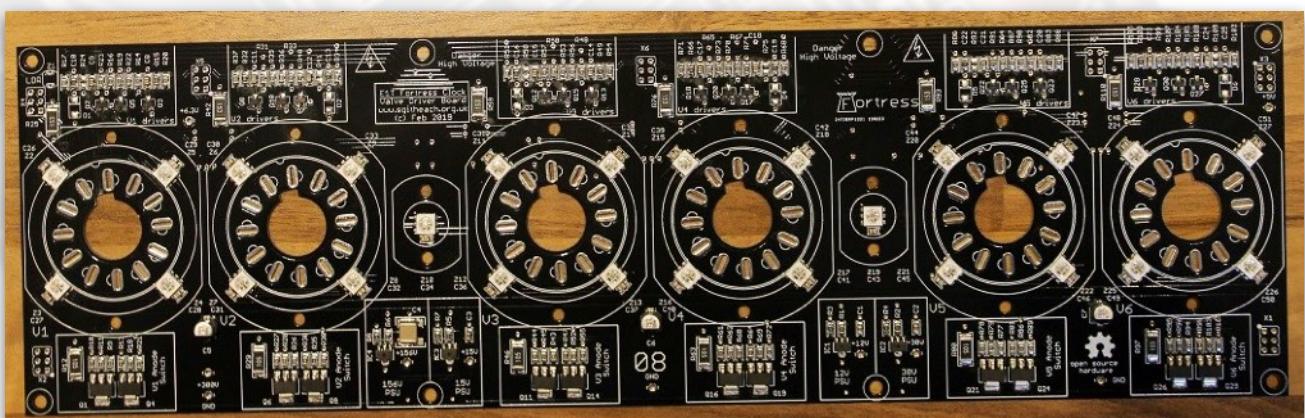
Assembling the display board

Introduction

This section assumes that all the SMD parts have been pre-soldered and only deals with fitting the through hole and 3D printed parts.



Un-populated Display Board



With SMD Components Fitted

The following parts are required..

Quantity	Description
1	Display PCB with all SMD parts fitted
7	2x3 2.54mm male pin headers (X1 to X7)
1	Light dependent resistor GL5516 (Z1) and to assemble:
1	• 3D printed LDR spacer
72	Tube pin sockets
6	E1T light guides and to assemble:
3	• 3D printed double E1T collars
18	• M3 square nuts
12	• M3 6mm screws

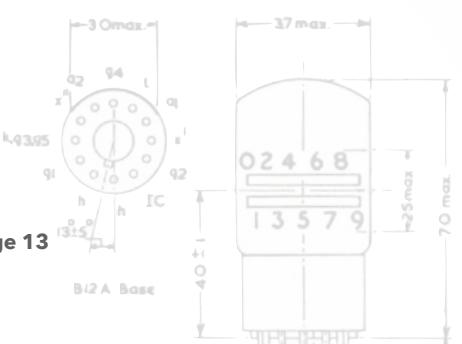
Quantity	Description
6	<ul style="list-style-type: none"> • M3 6mm grub screws
2	Colon light guides, and to assemble:
6	<ul style="list-style-type: none"> • M3 square nuts
2	<ul style="list-style-type: none"> • 3D printed colon collars
4	<ul style="list-style-type: none"> • M3 6mm screws
2	<ul style="list-style-type: none"> • M3 8mm grub screws
1	3D printed E1T and pin socket assembly tool
1	Defunct or badly worn E1T tube as assembly aide, otherwise use a new or good tube carefully
6	New or otherwise good E1T tubes (V1 to V6)

If any of these parts are missing from your kit (if purchased from us) then please let us know ASAP.



Completed Display Board (without tubes)

Update (30th Jan 2023) - Before proceeding further, now is a good time to read the hardware fix at the end of this document and install the necessary diodes. If you have purchased a kit after the update date, then they will be included in your parts.



Tools Required

- Flat blade screw driver
- Long arm 1.5mm Allen key (the long arm should be at least 70mm long)²⁸
- 3D printed tube spacer
- Soldering iron
- Solder
- Patience²⁹

Step 1 - LDR

Solder the LDR (Z1) using the 3D printed spacer.

Step 2 - Inter-board connectors

Solder the seven 2x3 pin headers (X1 to X7) to the board. N.B. they are soldered to the rear side of the board, not the component side! When soldering the seven pin headers correct alignment can be made easier by using the seven box headers on the main board as a guide. In any case you should ensure that the main board and display board fit together back-to-back correctly before continuing.

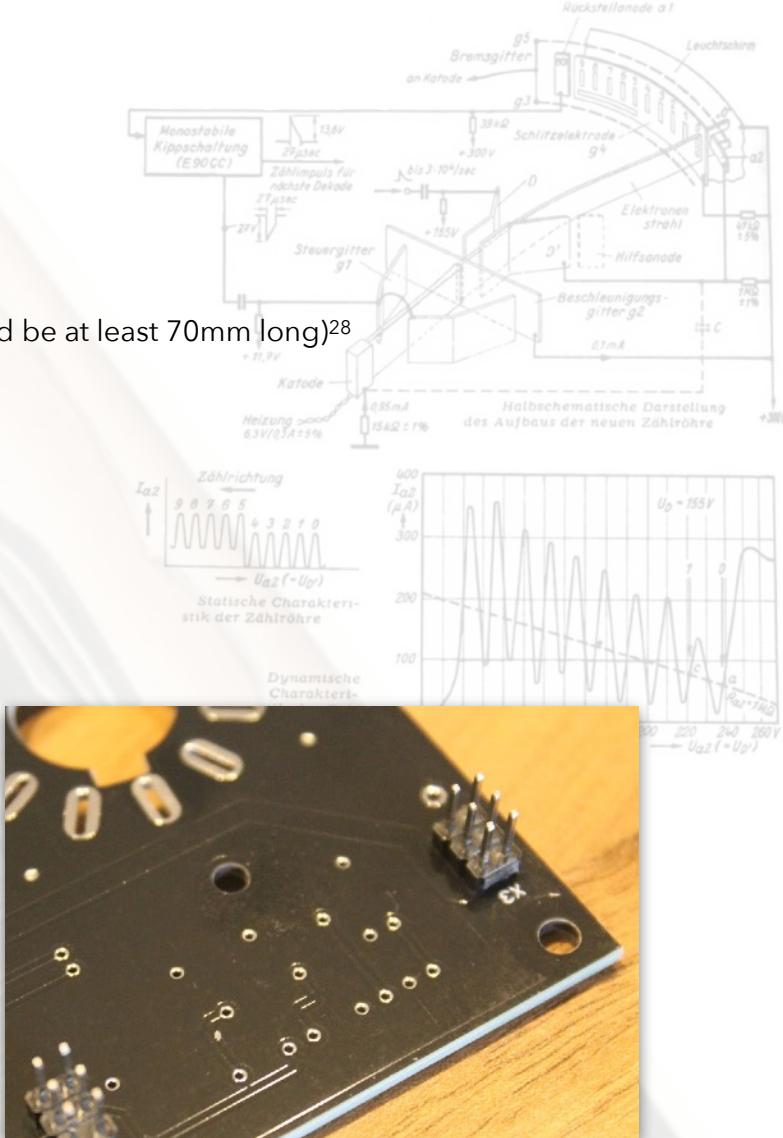
The remainder of this display board assembly manual deals with fitting the E1T pin sockets and the light guides. At this stage you should check that all the LEDs are working by fitting the display and main boards together and using the console³⁰ to issue commands to the LEDs.

The main board assembly and testing manual suggests such a test sequence and the console section describes the commands necessary and their usage.

Step 3 - Socket Pins

Flatten the metal nib on each of the tube pin sockets back into the hole that it was pressed from.

On the left is the original tube pin socket with the nib indicated; on the right is the required modification with the nib closed flat.



X1 to X7 are soldered on the **underside** of the display board



²⁸ The need for a long arm/Hex key won't be apparent during the construction here but will be essential when the boards have been installed in a case.

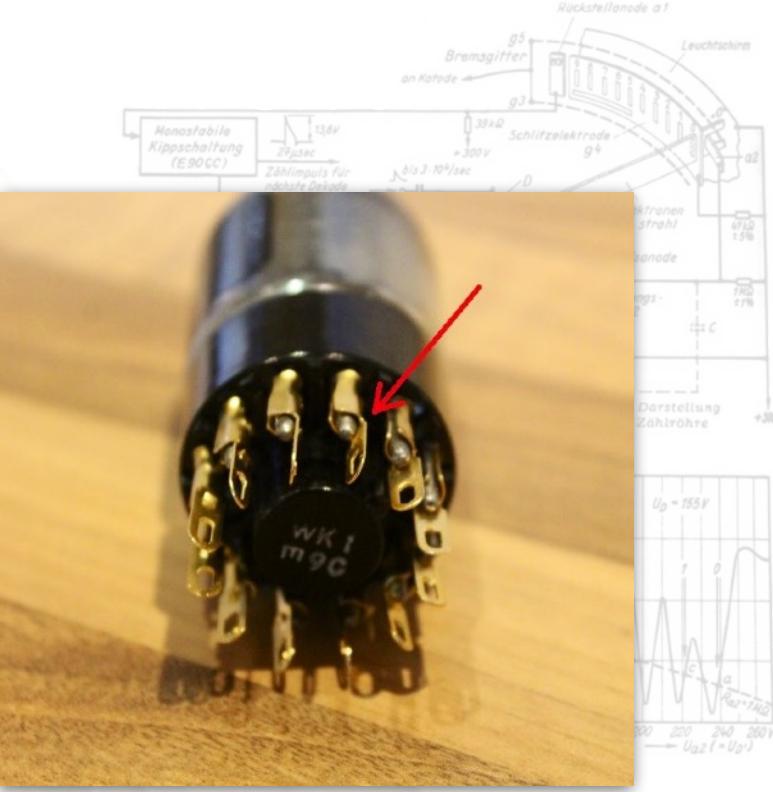
²⁹ Not readily available from a store....

³⁰ See Section 3 of the Operations Guide in the pre-built clock manual.

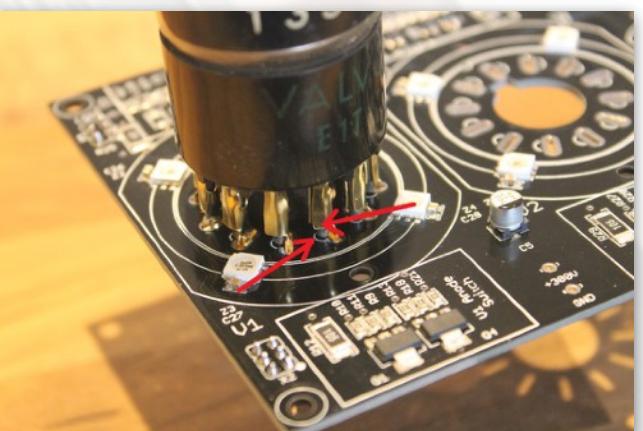


Step 4 - Preparing the socket pins for soldering

Push 12 modified tube pin sockets onto the pins of an E1T tube. The sockets should be pushed fully up against the base of the tube and should be rotated so that the flat side of each socket (indicated) is aligned radially to the tube and on the clockwise side when viewed from the base of the tube (see photo).

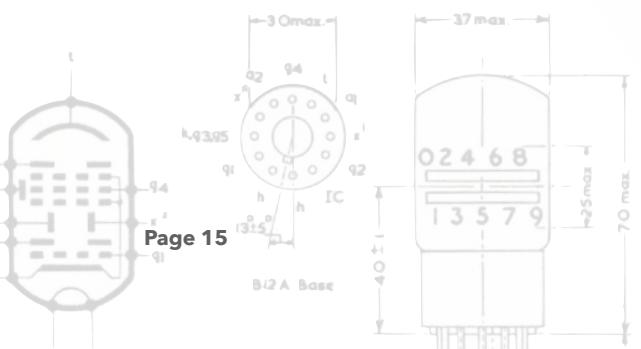
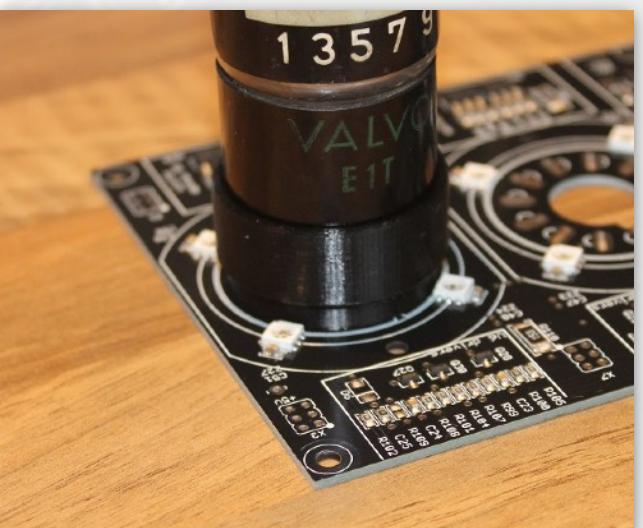


You can check that the socket tabs are correctly aligned radially by trying to fit the tube into the display PCB. You can also check that each pin on the E1T tube (indicated) is vertically above a small semi-circle on the PCB silkscreen (indicated by design no less!). Do not solder them yet!

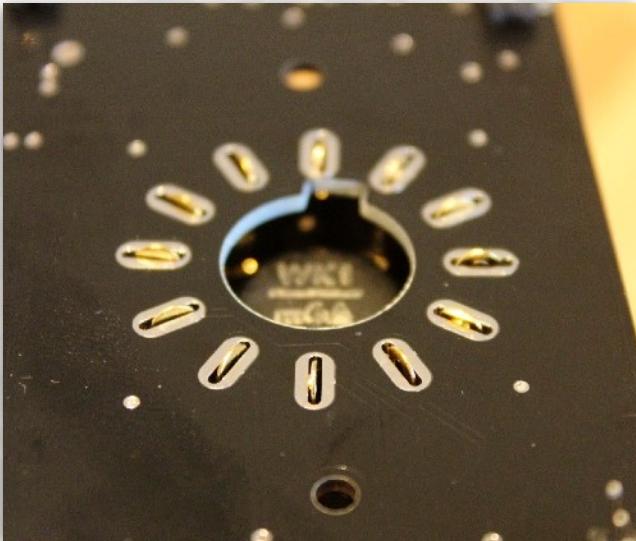


Step 5 - Final alignment and soldering

To ensure that the sockets are at the correct height above the board the supplied 3D printed E1T and pin socket assembly tool is slid over the sockets up to the E1T base. The spacer has an internal rebate at one end that fits against the tube base and an external rebate at the other end that should be touching the board.



Carefully flipping the board over without allowing the sockets and spacer to drop out will show that the tips of the socket tabs are just poking through the milled slots in the PCB. At this stage it is a good idea to just solder two of them on opposite sides and check that the aforementioned spacer assembly is still correctly flat against the PCB and the tube is vertical. Reheat as necessary to true up as needed before soldering the remaining pin tabs to the PCB.



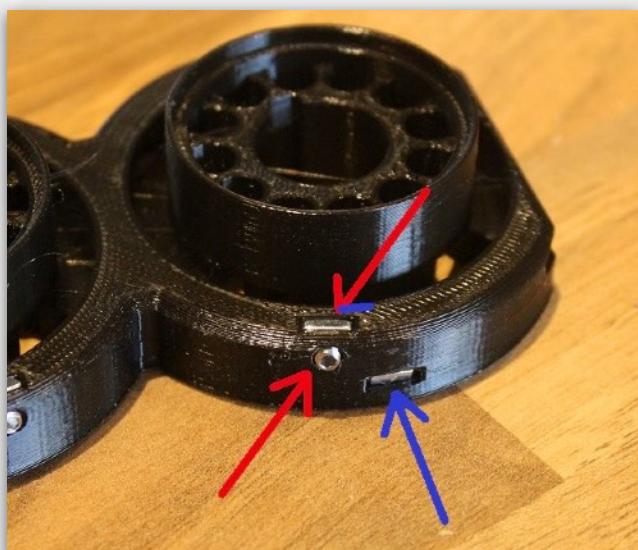
Step 6 - Rinse and Repeat

Remove the E1T and spacer assembly and repeat for the next E1T tube position. This will give you a total of 24 sockets soldered to the PCB ready for the first 3D printed collar. You will note that removing the E1T tube takes some gentle rocking from side to side to release it from the sockets. Keep this in mind for after installation of the E1T collar.

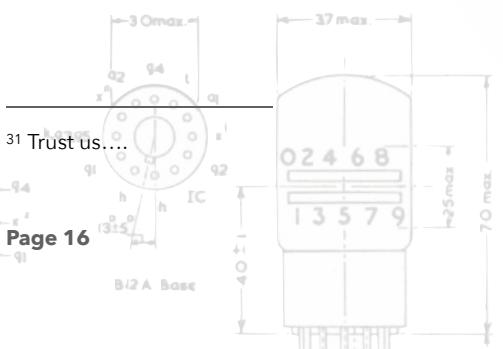


Step 7 - Preparing an E1T collar

Prepare the 3D printed E1T collar by fitting one M3 square nut into the vertical slot **indicated** and a 6mm M3 grub screw into the side hole. This will hold the M3 square nut in place. This step can be performed later but it is less fiddly if completed now.³¹ Repeat for the other vertical slot and grub screw. **Fit** four square nuts into the horizontal slots making sure that the thread in the nut is aligned to the hole on the underside of the 3D printed E1T collar.



³¹ Trust us....



Step 8 - Fitting an E1T collar

Slip the 3D printed E1T collar over the 24 sockets. It is a fairly tight fit and be **very, very careful** that you do not bend or crush any of the sockets during the process. Note that the 'key' for the E1T tube base must align with the key-way milled into the PCB. The key-way is on the back side of the PCB next to the tube driver transistors. Make sure that the E1T collar is flush to the PCB before finally securing it using four M3 6mm screws fitted from the underside of the board (these engage the four M3 square nuts inserted into slots in the printed collar). As mentioned before, removing the E1T tube can take a little effort! It's a good idea at this point to widen the socket pins slightly once the collar is in place using a small screw driver until insertion and removal of an E1T is slightly *less strenuous*. **Always remove and insert an E1T tube using the base of the tube and not the glass envelope!**

Step 9 - Rinse and Repeat x 2

Repeat steps 3 to 8 for the other four E1T tube positions using two more 3D printed E1T collars.

Step 10 - Colon Collar

Prepare the 3D printed colon collar by fitting one M3 square nut into the vertical slot and a 8mm M3 grub screw into the side hole to hold the M3 square nut in place. Fit the colon light guide assembly using two M3 6mm screws from the underside and the two M3 square nuts inserted into slots in the printed part. You can then insert the colon light guide and tighten it in place using the grub screw.



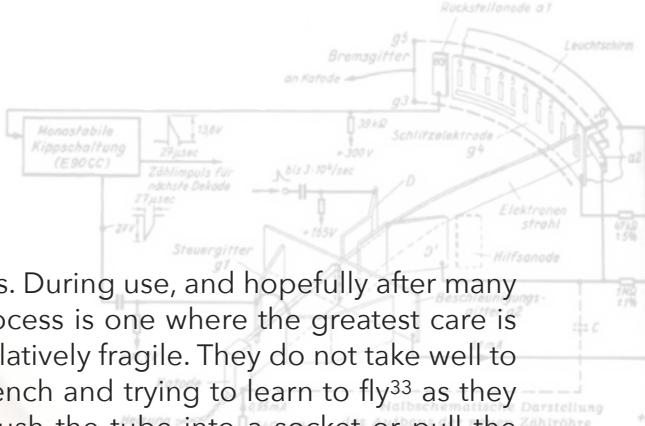
This completes the assembly of the display board (except for inserting your lovely E1T tubes that is, followed by the light guides).³²



Completed Display Board With Light Guides and E1T's

³² Parts List - A complete parts list is available as a CSV file on the project [Dropbox](#)





Fitting, Removing and Changing the E1T Tubes

When the clock is new you'll obviously need to fit the tubes. During use, and hopefully after many years of service a tube may need to be replaced. This process is one where the greatest care is needed. The tubes are old, made partly of glass and are relatively fragile. They do not take well to robust handling. They certainly don't like rolling off the bench and trying to learn to fly³³ as they simply don't have the knack³⁴. The best rule is only to push the tube into a socket or pull the tubes out of a socket by grasping the plastic base part of the tube and **not the glass**.

Tools required

- 1.5 mm long arm Allen key
- 3 mm Allen key

Preparing the case

Step 1

- If the clock is switched on, then switch it off.
- Remove the 12V DC power lead.
- If the clock has been on recently then wait say 5 minutes for the charge in various capacitors to dissipate.
- If fitted, lift off the dust cover (pretty obvious this one..).

Step 2

Remove the knob. There's a small grub screw securing it to the rotary encoder shaft. Loosen it.

Step 3

Remove the four M4 screws holding the front acrylic panel and pull forward to remove it:



³³ Another tee-shirt in my collection....

³⁴ "The Guide says there is an art to flying", said Ford, "or rather a knack. The knack lies in learning how to throw yourself at the ground and miss." - Douglas Adams, Life, the Universe and Everything



Step 4

Use a long arm 1.5mm Allen key to loosen the eight grub screws holding the acrylic light guides and remove the light guides. Of course, if you are changing just one tube then you will only need to remove the light guide for that tube, however, it can help to remove the adjacent light guide as well for easier access.

Removing E1T Tubes

Step 1

If the purpose is to remove a tube (or several tubes) then you can now grasp it around the plastic tube base and pull upwards. A very gentle rocking, slightly back to front, will ease the tube out of the socket.

Step 2

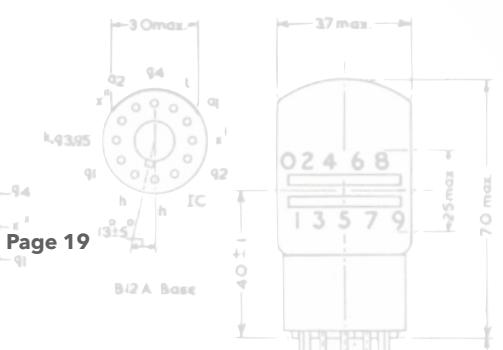
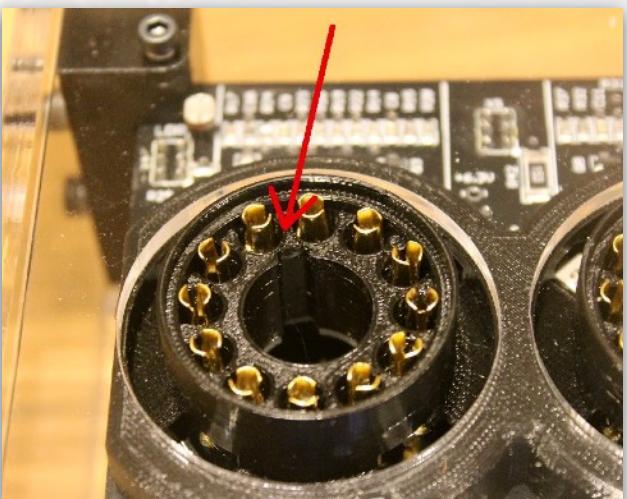
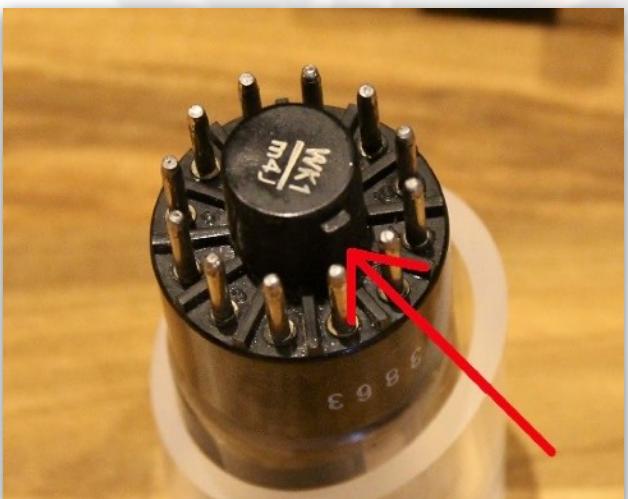
Place the removed tube somewhere secure.

Step 3

Repeat as necessary.

Fitting E1T Tubes

The tube must be inserted so that the key on the tube base is aligned with the slot in the 3D printed socket.



Step 1

Ensure that this alignment occurs as you insert the tube so the the pins engage with the pin contacts in the base. When you have the tube inserted by just a few mm make sure that the pin is going between the contact halves and has not pushed them to one side. This shows the correct fitment:

Step 2

The tube can then be fully inserted. A gentle rocking, slightly backwards and forwards, can help push the tube home:

Step 3

Repeat as necessary!

Reassembling the case

In famous³⁵ Haynes³⁶ style: Reassembly is a reversal of dismantling.

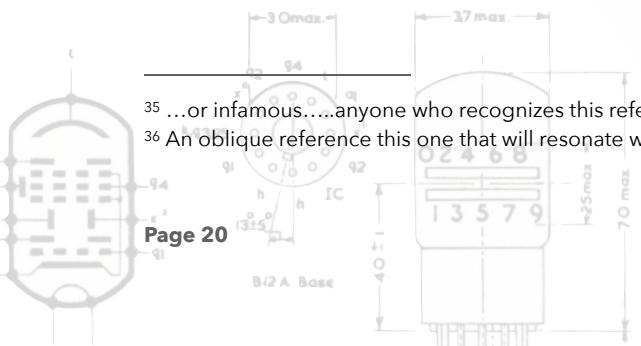


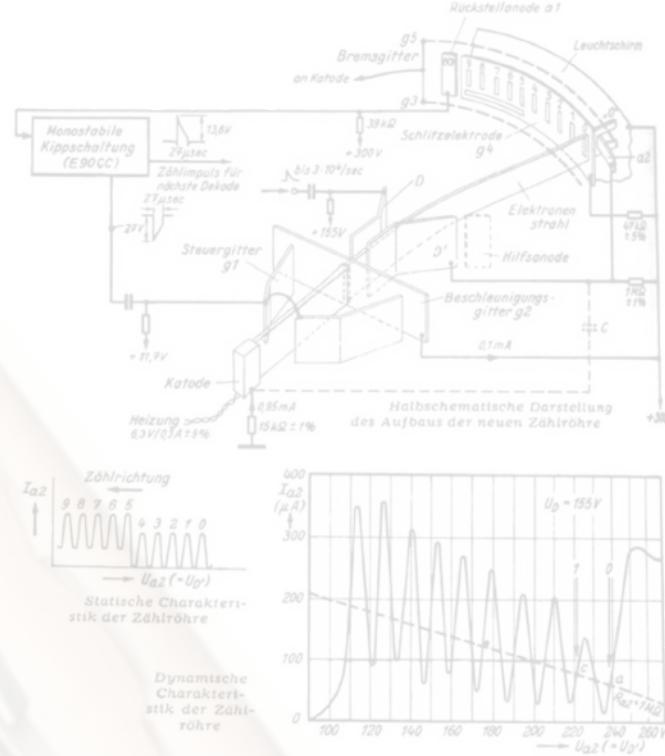
Fit the light guides and ensure they are seated correctly, level and rotated with the highest points towards the rear. Lightly tighten the grub screws so the light guides are gripped adequately. Do not over-tighten or you risk cracking the acrylic. Refit the front panel and then the knob. Pop the dust cover over the top. Plug in the 12V DC PSU lead and switch on.

Enjoy!

³⁵ ...or infamous.....anyone who recognizes this reference will certainly understand!

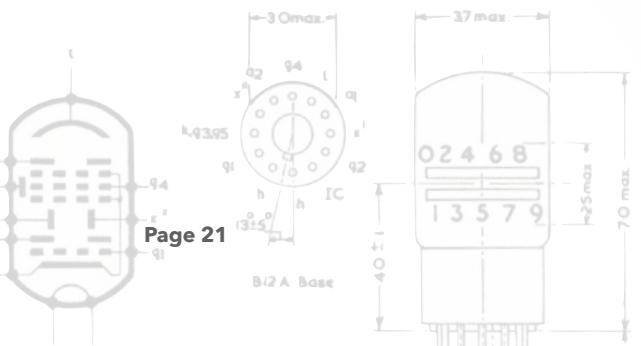
³⁶ An oblique reference this one that will resonate with a certain age group who used to work on their own cars..





Main Board Assembly

The heart of the beast...



Version 1.3

© Grahame Marsh/Nick Stock 2019-2022

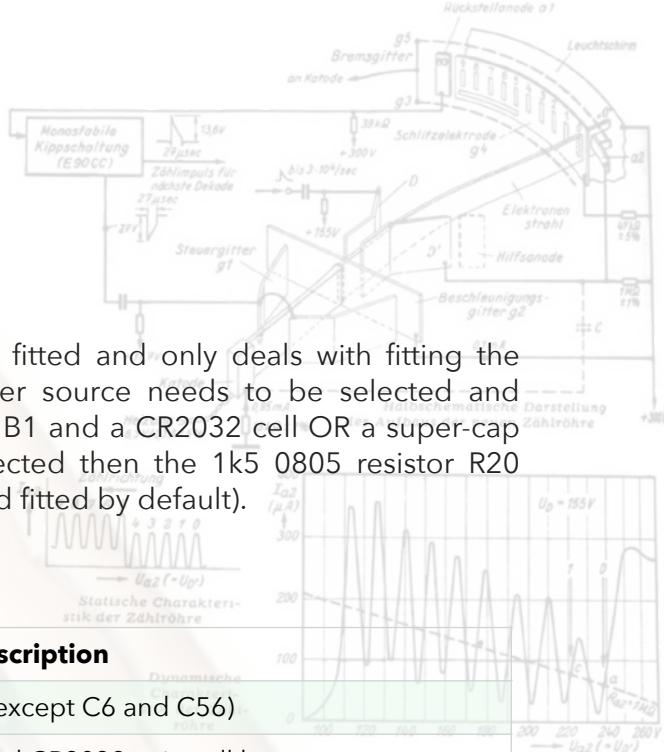
Assembling the Main Board

Introduction

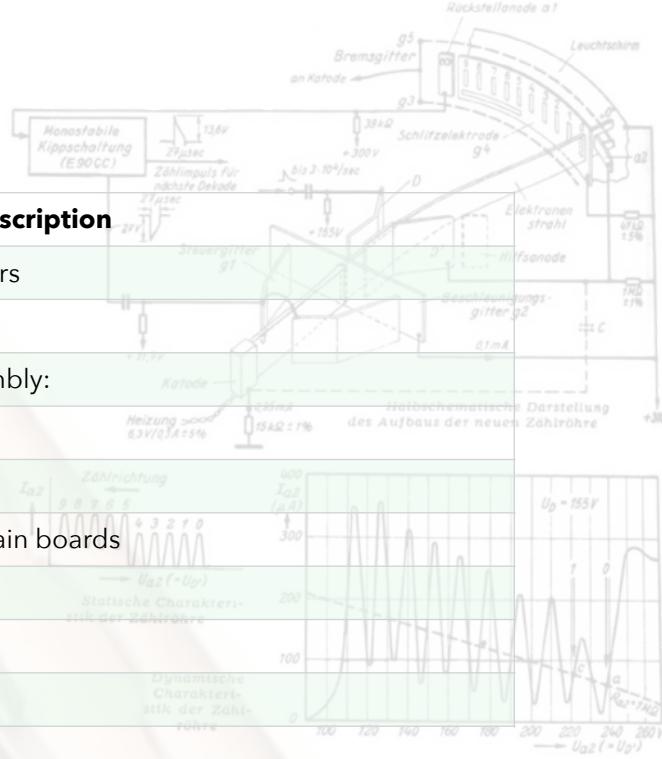
This section assumes that all the SMD parts have been fitted and only deals with fitting the through hole and 3D printed parts. The back up power source needs to be selected and appropriately fitted. This will be either the battery holder B1 and a CR2032 cell OR a super-cap C10. Both cannot be fitted. If the battery option is selected then the 1k5 0805 resistor R20 (located near to IC1 and IC4) is removed (it will be supplied fitted by default).

The following parts are required.

Quantity	Part Number	Description
1		Main PCB with all SMD parts fitted (except C6 and C56)
1	C10 or B1	1F 5V Supercap or Battery holder and CR2032 coin cell battery
1	C43	100µ 20V low-ESR electrolytic capacitor
2	C44, C45	4µ7 400V electrolytic capacitors
2	F1, F2	Fuse holders
1	F1	5A fuse
1	F2	2A Fuse
1	S1	External reset switch
1	TR1	Flyback transformer
1	X2	1x2 way 2.54mm male header and jumper (normally fitted)
1	X3	2x5 way 2.54mm female pin header
1		M3 11mm M-F stand-off pillar
1		M3 6mm screw
1		M3 nut
1	X4	2x8 way 2.54mm male pin header
8		Jumpers/Header shorts
2	X5, X6	50mm magnetically shielded speakers and for assembly:
16		<ul style="list-style-type: none"> • M3 6mm screws
8		<ul style="list-style-type: none"> • M3 15mm hex stand-off pillars
4		<ul style="list-style-type: none"> • Short lengths of wire
1	X7	2x5 way 2.54mm IDC header plug
1	X9	2.1mm barrel power socket
1	X10	2 way screw block
7	X11 - X17	2x3 way 2.54mm female pin headers - rear mounting
1	Z1	SAM3X8C plug-in board and for assembly:



Quantity	Part Number	Description
2		• 2x20 way 2mm female pin headers
1	Z2	SD card (formatted and preloaded)
6	Z5 - Z10	LED module diffusers and for assembly:
12		• M2 6mm screws
12		• M2 nuts
To assemble the display and main boards		
8		M3 25mm hex M-M standoffs
8		M3 11mm hex F-M standoffs
8		M3 6mm screws



The following parts are required by the control panel sub-board:

Quantity	Part Number	Description
1	S2	Rotary encoder (rear mounting)
1	X8	2x5 way 2.54mm board-to-ribbon cable connector, and 80mm
		Short length of ribbon cable
1		2x5 2.54mm IDC ribbon cable header socket
1	Z3	PIR sensor module (rear mounting)
1	Z4	IR receiver (rear mounting)

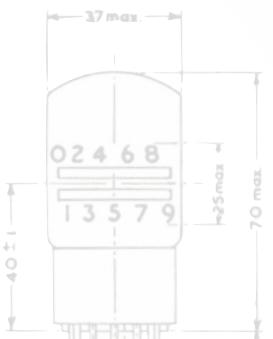
The following parts are optional and not normally fitted:

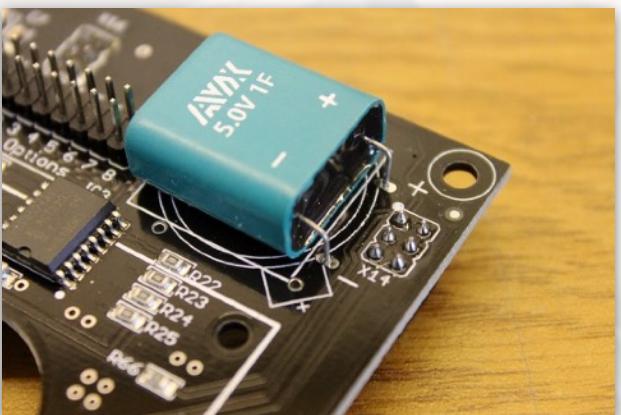
Quantity	Part Number	Description
2	C73, C74	2200 μ 16V electrolytic capacitors
1	X1	1x6 way 2.54mm male pin header
1	X18	2x5 way 2.54mm IDC header plug
1	C6	Value not specified
1	C56	Value not specified

Assembly

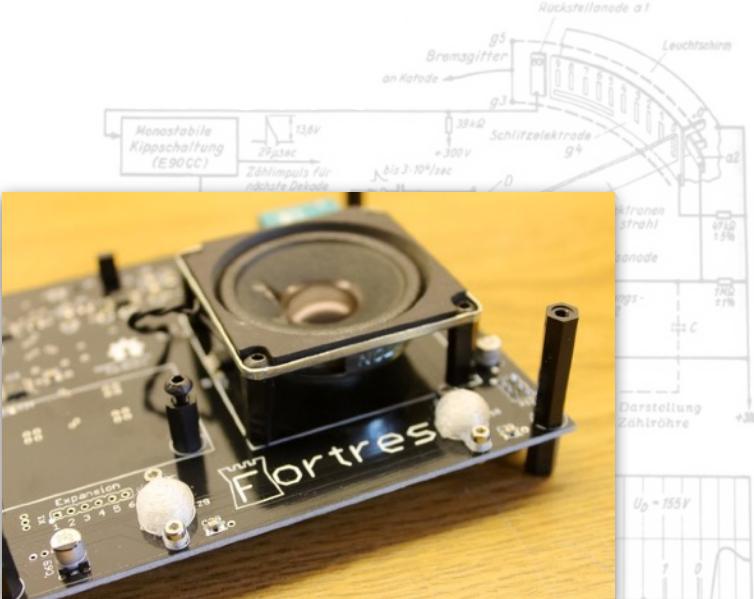
Step 1 - Separate the Boards

First cut the control panel sub PCB using a small hacksaw to separate the board from the main board. This will leave rough nubs along the edges which should be filed flat.

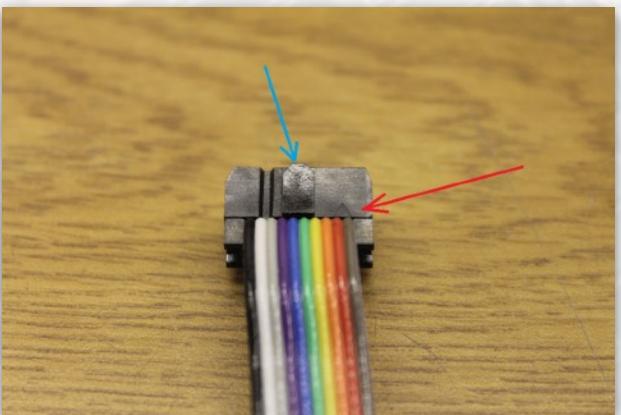




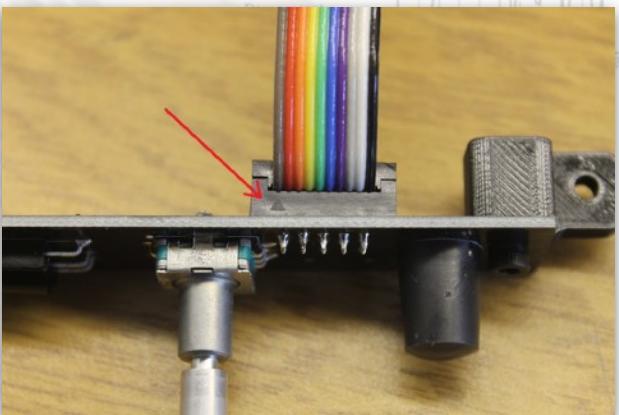
C10 Supercap Mounting



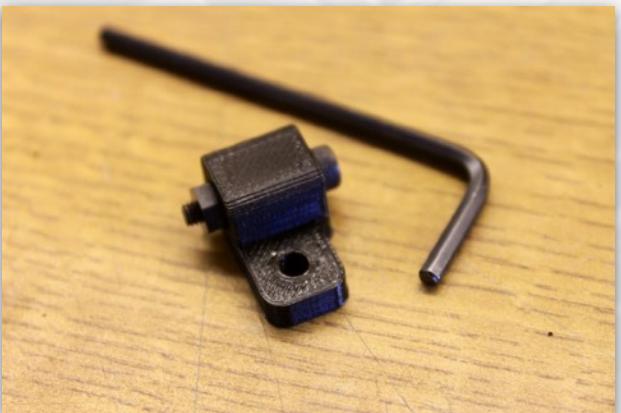
Speaker Mounting and Light Diffusers



Ribbon Cable Alignment - Note Arrow on Socket



Cable Connection to Sub Board - Note Arrow



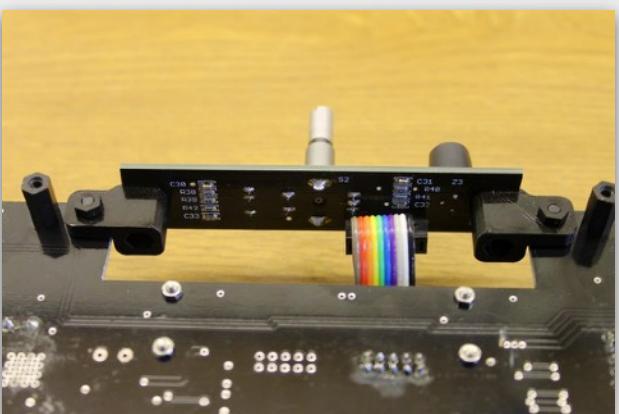
Use a M3 Screw to Seat the Nut in it's Hole



Rear View of Control Sub Board with 3D Mounts



Front View of Control Sub Board



Sub Board Mounted to Main Board



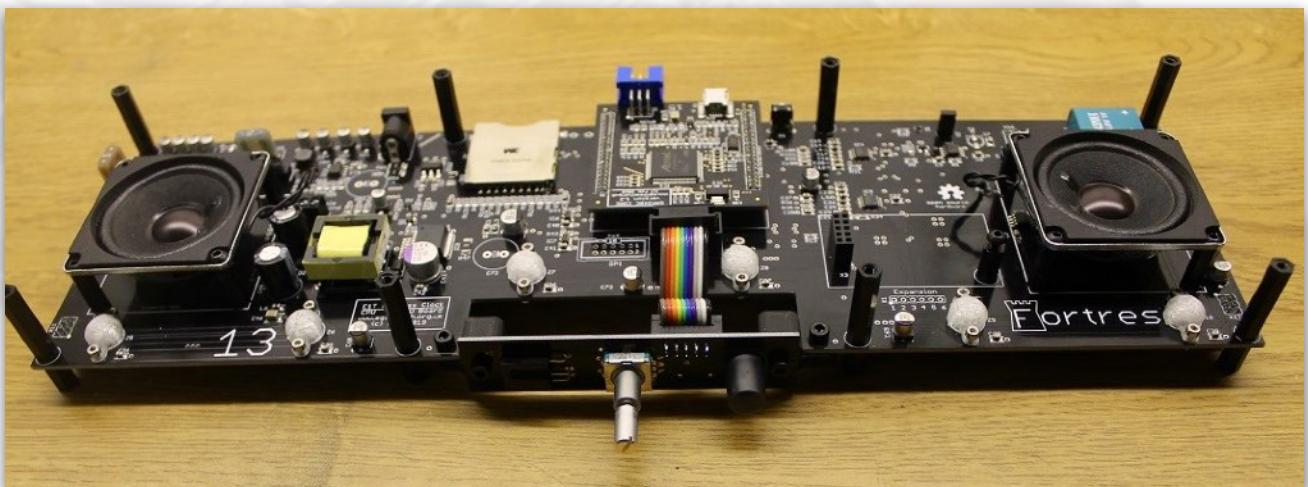
Step 2 - Fit the Through-hole Components

Assemble the main board by fitting all of the remaining through-hole components. There is no particular order required but it is recommended to start with the smallest components and end with the largest i.e. the speakers.

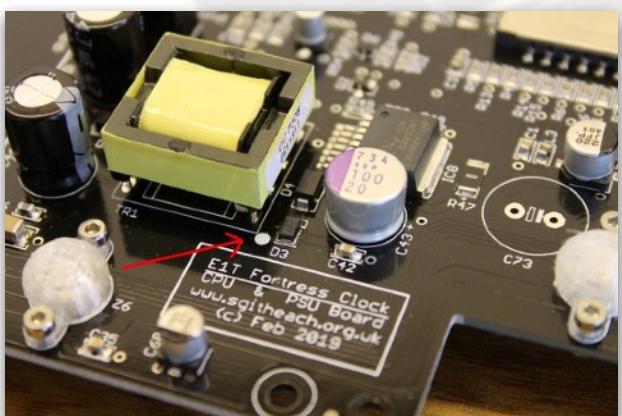
Many of the components must be fitted in a correct orientation:

- Supercap C10 or Battery Holder B1
- Electrolytic capacitors C43, C44, C45
- Flyback transformer TR1. Note the dot on the PCB - the side of the transformer that has the part information should be next to the dot (see photo below)
- Chassis earth bond screw block (X10) (**must be used if clock is encased in a conductive (i.e. metal) case material**).
- The front panel IDC connector (X7)

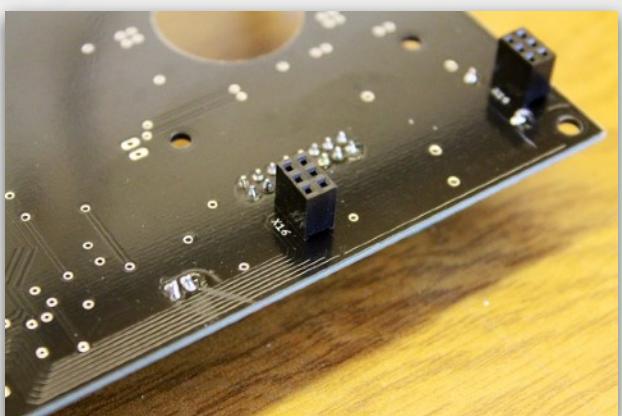
Other components have a required orientation but will only fit one way and others have no particular orientation.³⁷



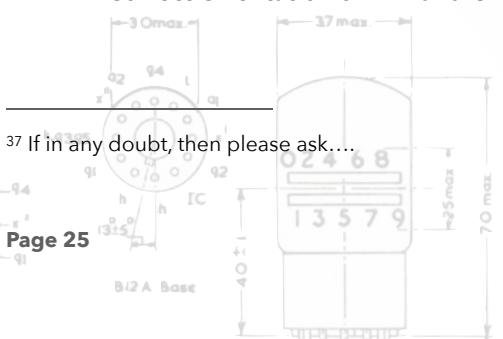
The Main Board in all its Assembled Glory
(standoffs are temporary for aiding construction)



Correct Orientation of TR1 and C43



Two of the seven 2x3 female pin headers



Step 3 - Jointing, Mounting and Legs

Eight M3 25mm, 11mm standoffs and 6mm long screws are provided to join the display board to the main board and provide "legs" for the clock to stand on during testing. They can be part of your case development or not as you choose.

Parts List - A complete parts list is available as a CSV file on the project Dropbox.

Testing

If you wish to carry out some testing of the main board when assembly is completed then here's a list of steps you might take.³⁸

1. Power Supplies

Start with the two fuses (F1, F2) missing, the SAM3X8C plug in (Z1) missing, the SD card (Z2) missing and the GPS/WIFI plug in missing.

Connect a 12V 3A DC power supply to the 2.1mm barrel jack and switch the power on.

Check the 12V DC is arriving on the main board. There are no test points but you can check using the pads of one of the unused large electrolytic capacitor stations (C73 or C74).

Check the 5V DC supply regulator using the ground pad on one of the large electrolytic capacitors and the end of the fuse socket F2 nearest the 5V regulator IC11.

Check the 3.3V DC supply regulator using the ground pad on one of the large electrolytic capacitors and one of the pads of R62 (the 1W SMD resistor between the 3.3V regulator IC12 and the SD Card Z2).

Switch off the 12V power supply and wait a few seconds for any residual charge to dissipate.

2. SAM3X8C Plug in

Fit Option Jumpers³⁹ 1 and 8, these make the clock start in test mode and verbose mode respectfully.

Fit the SAM3X8C plug in module⁴⁰ Z1. Take care to ensure that the 2mm headers are engaged correctly without bending any pins or plugging in the module offset from its correct position.

Fit fuse F2 (2A).

Connect the SAM3X8C programming/console box to the SAM3X8C plug in module and to a USB port on a computer.

Configure the Console Connection⁴¹.

³⁸ This is strongly recommended.

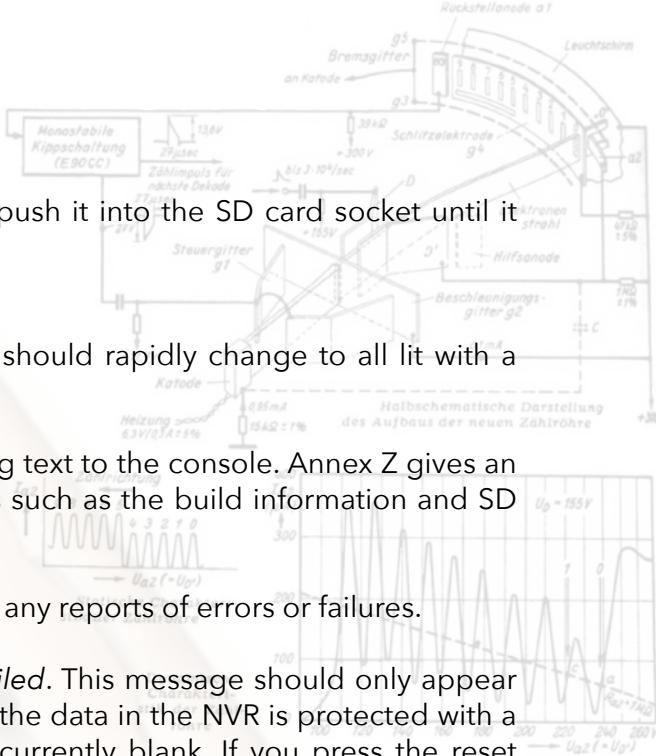
³⁹ See Section 2 of the Operations Guide in the pre-built clock manual.

⁴⁹ See Section 2 of the Operations Guide in the pre-built clock manual.

⁵⁰ The SAM3X8C plug in module is shipped tested and with the current firmware installed.

⁴⁰ The SAM3X8C plug in module is shipped tested and with the current
⁴¹ See Section 3 of the Operations Guide in the pre-built clock manual.





Check that the SD card⁴² is not write protected then push it into the SD card socket until it clicks and is retained by the socket⁴³.

Switch the 12V power supply on.

The bling LED modules may randomly light but they should rapidly change to all lit with a light pink colour.⁴⁴

The console should report the clock start up with a long text to the console. Annex Z gives an example start up text. This text will contain differences such as the build information and SD card serial number.

You should look through this long message looking for any reports of errors or failures.

You may see a message that the *Config CRC check failed*. This message should only appear when the clock is switched on for the very first time as the data in the NVR is protected with a CRC calculation which has failed as the NVR chip is currently blank. If you press the reset button to provoke the start up message again then the CRC error message should disappear.

If there are any messages then they should help pinpoint where the problem is.

3. Testing using the Console Menu commands

Console Menu⁴⁵ commands can be used to interrogate or change much of the clock hardware. Certain commands won't work in test mode and also commands that require the display board to be plugged in will have no visible effect.⁴⁶

3.1 Heater Power Supply

Give the command:

OUTS 6,1

The digital **OUT**put is **Set**. Output 6⁴⁷ is the 6.3V E1T heater power supply on/off control. Logical 1 will turn it on. You can measure the voltage on the heater fuse socket (F1) using the end closest to the speaker. If you connect the voltmeter before giving the command you should observe that the voltage takes several seconds to ramp up. This is the E1T heater "slow start" that prevents high in-rush current into the tubes.

Give the command:

OUTS 6,0

to turn the heater power supply off.

⁴² The SD card is preloaded with the files required by the firmware version on the SAM3X8C.

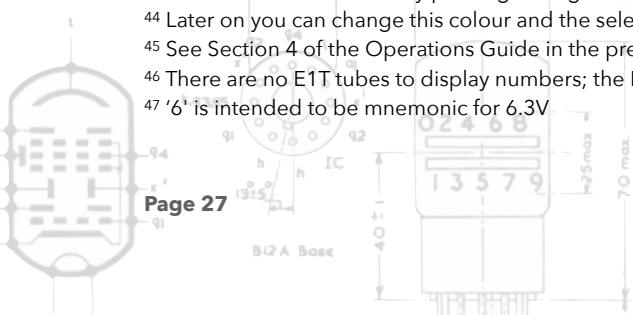
⁴³ The SD card is removed by pushing it in again and it will spring loose.

⁴⁴ Later on you can change this colour and the selection of LED modules lit.

⁴⁵ See Section 4 of the Operations Guide in the pre-built clock manual.

⁴⁶ There are no E1T tubes to display numbers; the LDR will always report a raw value of > 4090.

⁴⁷ '6' is intended to be mnemonic for 6.3V



3.2 +300V HT Power Supply

Take care with this test as 300V will be present on the main board when the flyback PSU has been started and for a long while after the flyback has been turned off.

Give the command:⁴⁸

OUTS 300,1

You can measure the voltage across capacitor C46 which is near to the big '13' on the main board.

Give the command:

OUTS 300,0

Now wait at least 30 seconds for the energy stored in the flyback capacitors to dissipate.

3.3 Further commands

There are too many commands to list here everything that you might try. Do not consider it obligatory to try out other commands but in doing so you can check that each of the clock's subsystems show some sign of life.

Many commands have a Report verb and others have Set or Use verb. A few have Continuous commands that are worth trying.

Examples

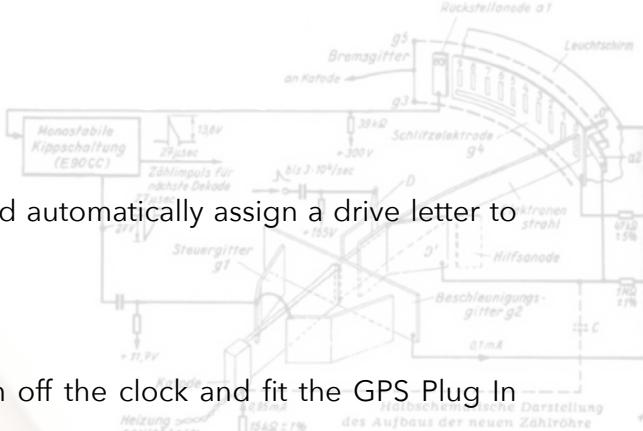
ADCR	To report ADC values read
BEPS 3,1000,1000	1kHz tone for 1 second
CHMU sftune1	Play a WAV file
DATR	The date will be wrong as it is not set yet
IRHC	Press keys on the handset, then esc on the PC keyboard
LEDK	All led module to black
LEDS 1,0,red	Led module Z5 will glow red
LOCR 2	Geolocation information ⁴⁹ from the SD card locale.ini file
OPTR	Option jumper settings
PIRC	PIR report '!' each time the PIR is hit, then press esc
ROTC	Rotary encoder continuous report, the press esc
SYSR 5	Example system report - random numbers

3.4. Testing USB Remote Disc Drive

Plug a USB port on your PC into the USB mini connector on the SAM3X8C plug in. Windows should enumerate the SD card as a USB mass storage device and identifies it as an "Atmel SD/MMC Card Slot USB Device" in the Windows Device Manager.

⁴⁸ '300' is intended to be mnemonic for +300V

⁴⁹ The “as-shipped” values are my house in Scotland, you should edit the file to put your own locale in!



An Explorer window should open and Windows should automatically assign a drive letter to the SD Card.

4. Testing the Optional GPS Plug In

If you are using the optional GPS Plug In then, switch off the clock and fit the GPS Plug In module. Switch the clock back on.

Previously, the start up messages identified that no Plug In was identified. This time the GPS plug In should be found and an additional line will appear saying that the GPS was initialised OK.

Give the command:

GPSC

and the NMEA sentences received from the GPS receiver will be echoed to the console. Press esc to stop.

Leave the clock running for several minutes and then give the command:

GPSR 0

The GPS report should return, inter alia, the date and time. If the GPS data is valid and the date and time appear correct⁵⁰ then give the command:

TIMU

This synchronises the clock's RTC with the GPS date and time. The **TIMR** command will report the raw UTC, in ISO format and with the time zone and daylight saving rules read⁵¹ from locale.ini on the SD card.

5. Testing the Optional WIFI Plug In

The ESP32-BIN module is far more complex than the GPS module; it requires configuring to connect to your WIFI router. It will not be dealt with here as the module has its own manual.

6. Initial Testing of the Display Board

The display board manual strongly suggests that the LEDs should be tested before the E1T sockets and colons are fitted. This allows any problems with the LEDs to be corrected without having to dismantle the sockets or colons.

Plug the display board into the main board. Make sure that all seven 2x3 headers are correctly engaged. Switch on the power supply. The clock will start up again in test mode.

⁵⁰ Remember the date and time are UTC.
⁵¹ The "as shipped" data is for my home in Scotland, you need to edit *locale.ini*!



Give the command:

LEDS 0, led_all, green

All 32 LEDs should light green. You can substitute red and blue to check that all the RGB emitters are ok if you wish.



Additionally, you can use the command:

OUTS 300, 1

to turn on the +300V PSU and then check the five test points on the display board for the correct voltages. Switch off the clock.

7. Testing the Display Board

These steps require that you have assembled the display board and have mounted six E1T tubes into their sockets.

Switch off the clock and wait a few minutes ...

Fit the heater supply fuse F1 (5A).

Flip the main board over and plug in the E1T display board. Make sure that all seven 2x3 headers are correctly engaged.

Switch the clock on and watch the long message appear on the console.

Additional commands that send control information to the E1T tubes will now work and the LDR will report a room ambient light level.

Enter the command:

OUTS 6,1

again and you should now see the E1T heaters start to glow. Now wait about 30 seconds to allow them to fully warm up. While you are waiting try the command:

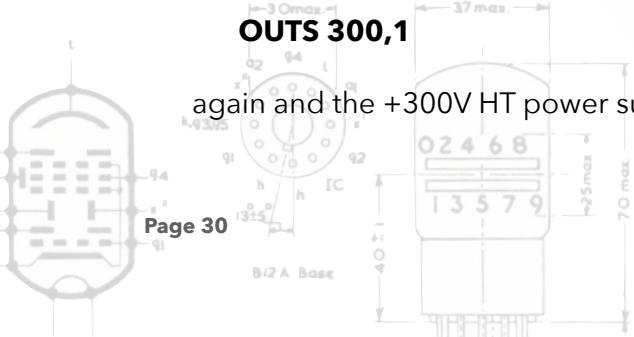
LDRC

The console will report the LDR raw value, clipped and converted to a %age brightness. Press esc to stop the continuous report.

Now enter the command:

OUTS 300,1

again and the +300V HT power supply will start.



!!! Warning! The clock now has +300V on the display and main boards. Take care !!!

Carefully measure the voltage on the five test points, labelled +300V, +156V, +18V, +12V, and +30V to ground, labelled GND.

Now enter the command:

E1TS 0, 0

and the leftmost tube should light in position 0. The E1TS command has the form:

E1TS tube, value

where **tube** can be 0 to 5 and **value** can be 0 .. 10. A value of 10 causing the tube to be blanked.

Therefore you can check that each tube will light and can be positioned. This is important as the E1T tubes are the main event in this clock!

You can also make a tube count continually using, for example, the command:

E1TC 3

This command makes tube 3 spin. You can make all six E1T tubes spin if you wish. You will see that the tubes spin asynchronously. Press esc to stop them spinning and then the command:

E1TK

to turn them all off and then the command:

OUTS 300,0

to turn off the +300V power supply. Allow at least 30 seconds for the +300V charge to disappear.

And then the command:

OUTS 6.0

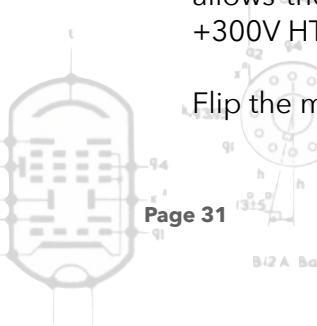
Or, just switch off the clock.

8. Test the clock in anger!

Remove the display board and flip the main board over.

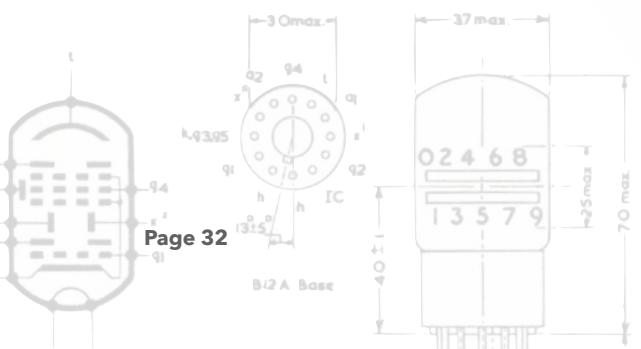
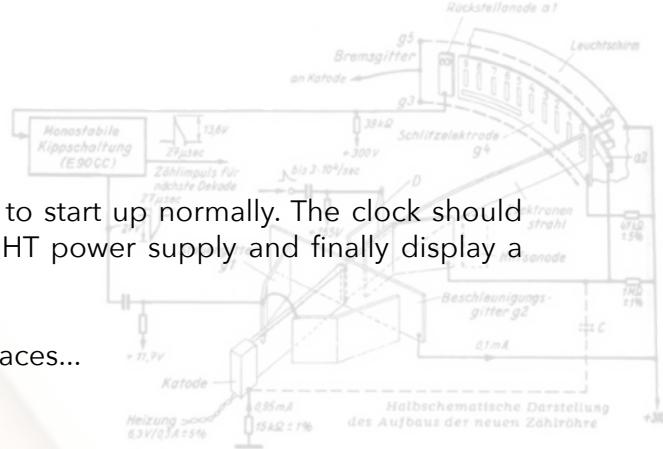
Remove option jumper 1 and fit option jumper 3. Removing option jumper 1 takes the clock out of test mode and into the normal operating i.e. clock mode. Fitting option jumper 3 allows the clock to automatically start up and shut down the 6.3V heater power supply and +300V HT power supply.

Flip the main board over and fit the display board again.



Switch the 12V power supply on and allow the clock to start up normally. The clock should automatically start the tube heaters, then the +300V HT power supply and finally display a clock face.

You can now start looking through the available clock faces...



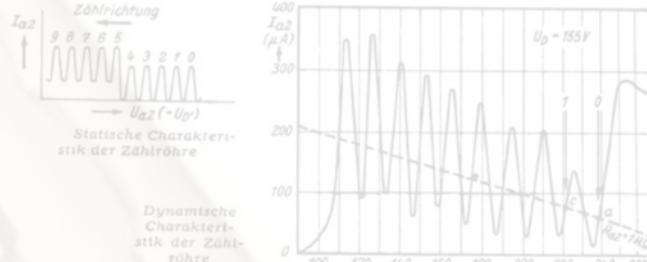
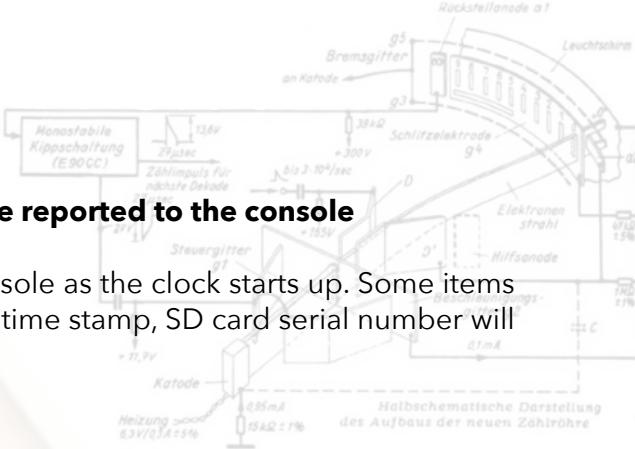
Annex 1 - Example verbose start up message reported to the console

This is an example of the verbose message sent to the console as the clock starts up. Some items will be different. Items such as the build number and date time stamp, SD card serial number will all be different.

```

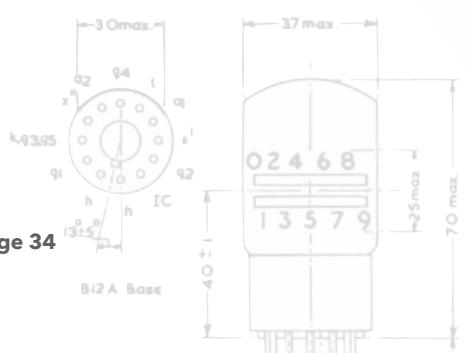
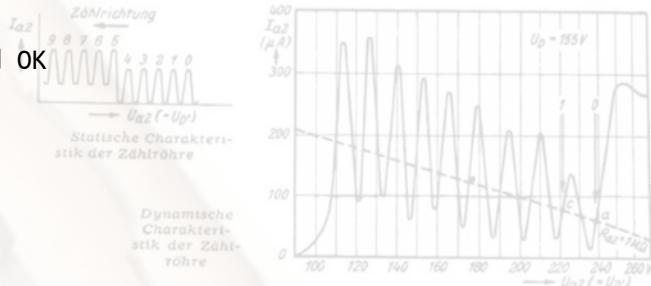
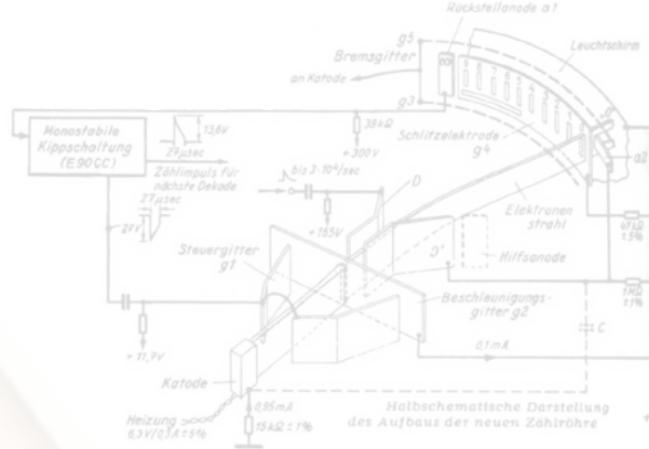
Fortress E1T Clock
Hardware Version = 1.0
Firmware Version = 1.0.42
Built on 3-Apr-2019 at 13:19:58
TWI Initialised OK
Options jumpers read=0xe7 OK
Bus Matrix has been adjusted by Po
SD Card Initialised OK
SD Card Report:
    number of slots: 1
    check result: No error
    card type: SD card
    card version: SD version 2.00
    card capacity: 968 MB
    write protected: 0
    clock: 25 MHz
    high speed: 1
    bus width: 4 bits
SD Card Mounted OK
File system report:
    File system: FAT32
    Volume label: FORTRESS
    Serial number: AE65-0694
    Total space: 964 MB
    Free space: 691 MB
File Paths Initialised
/
/system/
/runtime/
/wav/
/chime/
/nuggle/
MB85RC04V Initialised OK
Config Data Initialised OK
SPI Initialised OK
DMA Initialised OK
Task system Initialised OK
Constant Lookup Initialised OK
ADC initialised OK
    ADC Hardware Sense = 726, interpretation = Board 13
    ADC Plug-in = 4095, enum = 0, interpretation = None
    ADC LDR = 4095
    ADC Temperature = 984 = 24.3 degC
LDR brightness measurement Initialised OK
Bling Initialised OK
True RNG Initialised OK
LM48100Q Initialised OK
Beep Initialised OK
Chime system initialised OK
RTC initialised OK
RTC Report:
    UTC 2019-04-03 12:24:03
    ISO 20190403T122403Z
    LOC 2019-04-03 13:24:03
    Source using TCXO
Set using: menu command
...Loading daylight saving data
...Loading timezone data
Locale Information Initialised OK
Miscellaneous I/O pins Initialised OK
PIR Sensor Initialised OK
IR Receiver Initialised OK

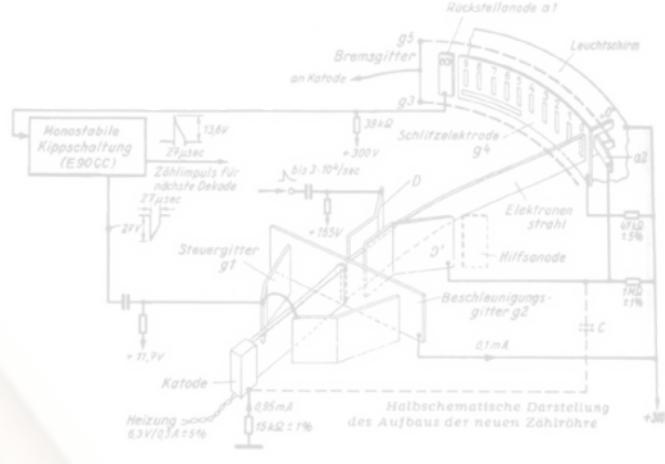
```



Clock pair number is 2
 Encoder Initialised OK
 E1T Driver Initialised OK
 System Variables Initialised OK
 Script Timers Initialised OK
 Script Lexer Initialised OK 0
 Expression Evaluator Initialised OK
 Script Parser Initialised OK
 Nuggle Initialised OK
 Clock Faces Initialised OK
 Sun calculations take 2958 uS
 Astronomical Stuff Initialised OK
 SD Card removable USB disc drive Initialised OK
 Menu and Help Initialised OK
 Events Dispatcher Initialised OK
 Clock is running in Test Mode

>





Simple Acrylic Case and Dust Cover

An enclosure for your E1T masterpiece.⁵²

⁵² Supplied from Scotland, cut in Wales and California....one well travelled piece of kit! Premium versions of the case and cover are also available, please see the website or contact us.



Introduction

This manual describes a case using 3 and 5mm thick laser cut clear acrylic and a dust cover made from 3mm thick clear acrylic, all held together using 3D printed parts. Notes on assembling the 3D printed parts are in the "Sgitheach - Låda" manual on the Sgitheach DropBox.⁵³

Acrylic Case

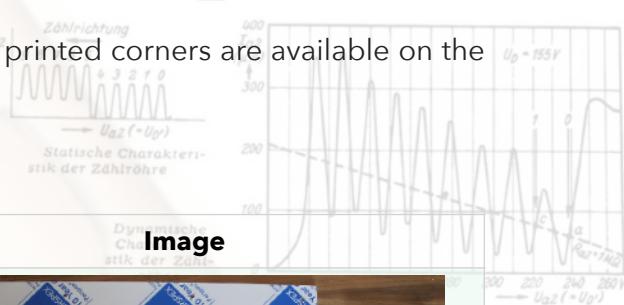
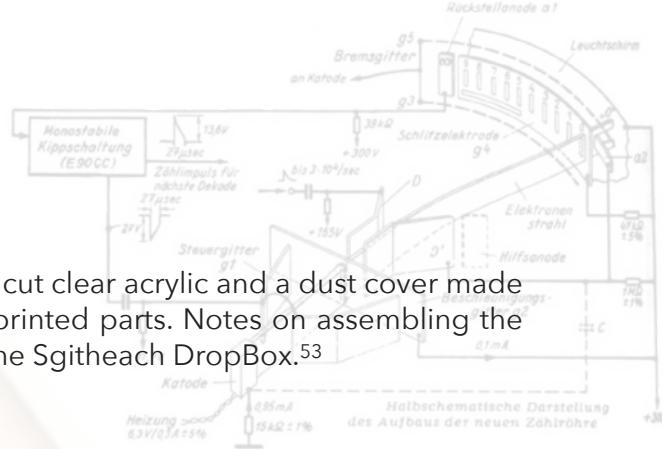
The DXF cutting plans for the acrylic and STL files for the 3D printed corners are available on the Fortress E1T Clock project DropBox.⁵⁴

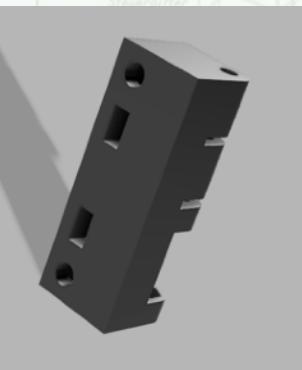
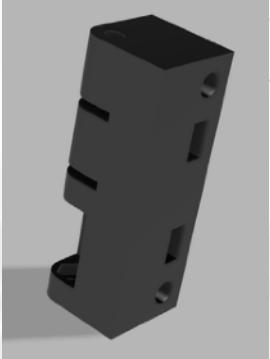
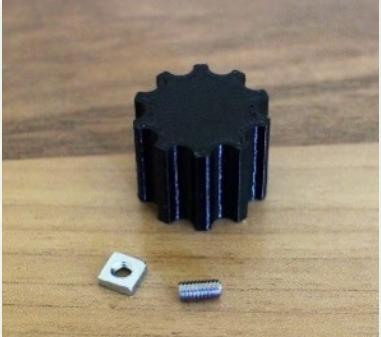
Parts List

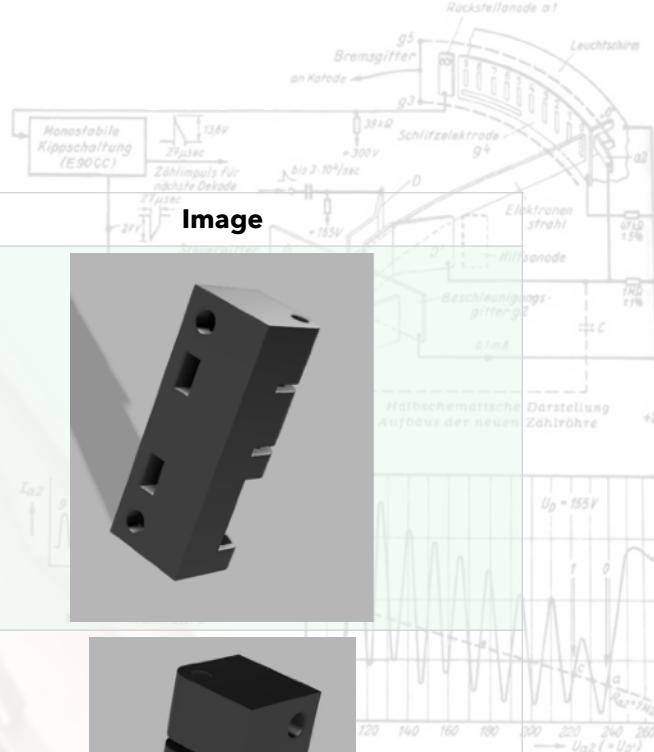
Quantity	Description	Image
1	Five pieces of 5mm thick laser cut acrylic (case top, front, back and two sides) and two pieces of 3mm thick laser cut acrylic (top and bottom plates). N.B. The lowest piece of laser cut acrylic shown here is as supplied in the kit and carries an engraved unique serial number. An alternative design is provided on the DropBox.	
2	Front Central Posts which go either side of the control panel. Note there are no M4 holes on the back or slots for M4 square nuts	
2	Back Central Posts which go either side of the rear access plate. These are different to the front central post above in that there are M4 holes and nut slots	

⁵³ <https://www.dropbox.com/sh/hgpgmiejyf3q76a/AACaXJGKsIjv5WJBnLjhEzja?dl=0>

⁵⁴ <https://www.dropbox.com/sh/6oeioya5ljh116/AAClQipdvQUYd7n6a6jbGigua?dl=0>



Quantity	Description	Image
2	Front Left Corner and Back Right Corner Posts. Note that when fitted to PCBs the M4 holes shown here will face forwards on the front left hand side and backwards on the rear right hand side	
2	Front Right Corner and Back Left Corner Posts. These parts are the mirror image of the Front Left and Back Right Corner Posts	
1 set	3D printed knob, M3 6mm grub screw and M3 square nut	
1 set	M3 and M4 nuts and screws, M4 thumb screws. <ul style="list-style-type: none">• 2 x M4 thumb screws• 8 x Black M3 40mm screws• 8 x Black M3 8mm screws• 16 x M3 nuts• 18 x Black M4 12mm screws• 20 x M4 square nuts	
1 set	3D printed SMA hole plug - Only if neither the WIFI or GPS options are used	



Tools Required

The following tools are essential to build the case:

- Pliers
- 1.5 mm Allen key
- 2.5 mm Allen key
- 3 mm Allen key
- Step cone drill or similar (see text)
- Slip joint pliers (channel-locks)
- Small tube of super-glue (maybe)

Assembly

Step 1

Before assembling the 3D printed parts it is worth checking that the 3mm and 4mm diameter holes clear using an appropriate diameter drill bit. Inspect the M4 slots for any printer filament threads and clear out using thin nose pliers/scalpel/sharp blade.

Step 2

The eight 3D printed posts have hex recesses that will accept M3 nuts. Use the Sgitheach - Låda manual for notes on their assembly. There are a total of sixteen nuts to insert into position.

Step 3

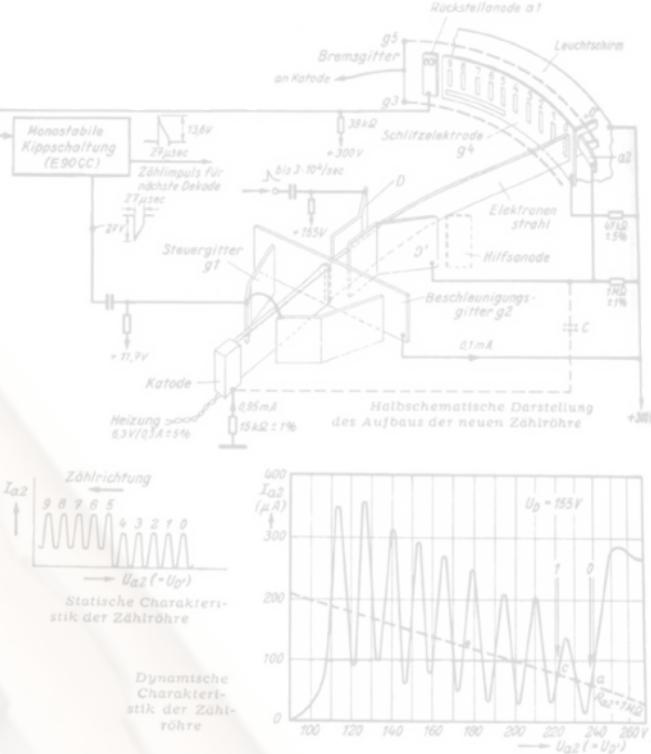
The two back central posts have slots that will accept M4 square nuts. Push the nuts into the slots. If any nut is loose then use a minimum quantity of glue to hold it in place making sure that the nut is centred in the slot so its thread aligns with the hole in the 3D printed part. There are a total of four nuts to position.

Step 4

The case assembly photographs below are made with the white protective film still attached to the acrylic only because it makes visualizing the assembly easier. You can just strip the film off and assemble the case immediately.⁵⁵

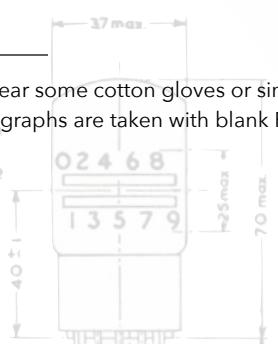
Step 5

If the boards are assembled after testing using the hex pillars supplied in the kit for that purpose, then remove the hex pillars and keep them in a box for some other project. Plug the main board⁵⁶ and the display board into each other. Then take the eight posts and push the PCBs into the slots in the posts. Here is an example of a corner post with the PCBs inserted. They are a tight fit.



⁵⁵ It's a good idea to wear some cotton gloves or similar to keep your grubby fingers leaving greasy marks over everything....;-)

⁵⁶ The assembly photographs are taken with blank PCBs. When you are assembling your built and tested boards, make sure you don't damage them.



Here are the eight posts in place:



At this point it is worth double-checking that the posts are in the correct order⁵⁷:

- The front central posts don't have M4 holes.
- The rear central posts do have M4 holes.
- The front corner posts have the M4 holes that are at the top and bottom facing forwards. The M4 nut slots are between the M4 holes.
- The rear corner posts have the M4 holes that are at the top and bottom facing backwards. The M4 nut slots are between the M4 holes.

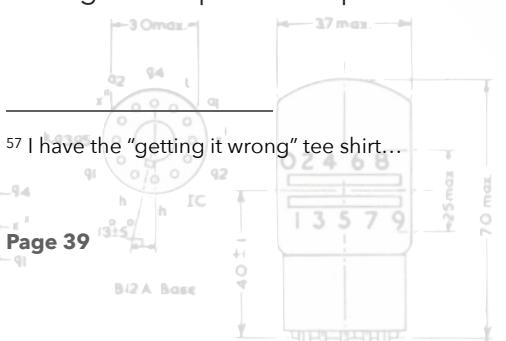
It also worth checking that the rotary encoder shaft and PIR align with their holes in the front acrylic panel. Locate the front acrylic panel and hold it up to the posts so the M4 holes roughly align. In doing this the holes for the rotary encoder and the PIR should slip over their respective parts and be close to centred. If the shaft and PIR do not align but collide with the acrylic then it almost certainly means that the two brackets that hold the front/sensor panel have been incorrectly fitted. If so, then go back and refit them and check that the holes in the acrylic align correctly.

Step 6

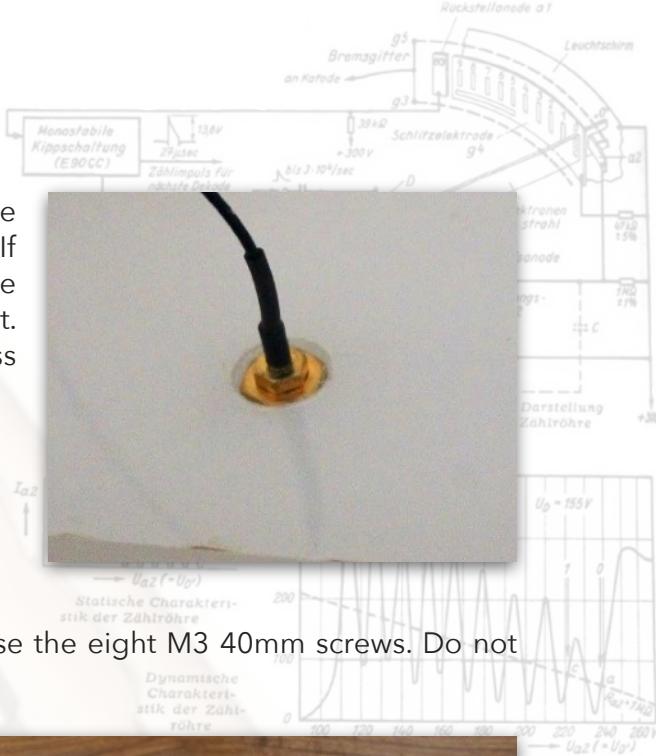
If the WIFI or GPS option is used then the hole in the back acrylic panel must be rebated so that sufficient thread sticks out for the antenna to mount correctly.

My weapon of choice is a step cone drill:

It is important to only rebate as far as is necessary for the SMA bulkhead connector. In practice a rebate depth of about 3mm appears adequate for the SMA bulkhead connectors used so far. It is also important to cut the rebate on what will be the inside of the back acrylic sheet i.e. cut into the side without the writing on the protective plastic sheet.



When in place, the back of the SMA bulkhead will be recessed into the acrylic. I don't use the supplied washers. If you are not using either the WIFI or GPS options then the hole can be filled with the 3D printed SMA hole plug part. Finger tightening this is adequate. Take care not to cross the thread.



Step 7

Place the top acrylic panel on the top of the clock and use the eight M3 40mm screws. Do not fully tighten the screws.



Step 8

Flip the clock over and place the bottom acrylic panel and use the eight M3 8mm screws. Do not fully tighten the screws. The panel should be placed so the speaker "grills" are over the speakers.



Step 9

Push eight M4 square nuts into the eight slots in the corner posts at one end. The nuts are intentionally loose and do not require glueing. In fact, they should not be glued. You need to work with care as it is fairly easy for the nuts to slip out. I keep the clock flat and level when I'm doing this. The end panel can be attached using four M4 12mm screws. Do not fully tighten the screws.



Step 10

Repeat Step 9 for the other end acrylic panel.

Step 11

Either:

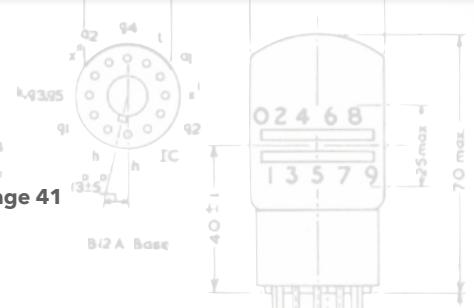
- If the WiFi sub board is being used, then push the WiFi SMA bulkhead connector through the rebated hole (Step 6) and mount tightly using its nut. (I don't use the washers).
- If the GPS board is being used, then push the pigtail SMA bulkhead connector through the rebated hole (Step 6) and mount tightly using its nut. (I don't use the washers). Connect the other end of the pigtail to the SMA connector on the GPS board.
- If neither are used then plug the SMA hole with the 3D printed SMA hole plug.

Step 12

Attach the rear panel using six M4 12mm screws. Do not fully tighten the screws.

Step 13

Attach the rear access panel cover using the two M4 thumb screws.



Step 14

Attach the front panel using four 12mm screws. Do not fully tighten the screws.



Step 15

In Steps 9, 10, 12 and 13 the sides, front and rear acrylic panels were fitted but the M4 screws were left loose. This arrangement was to allow some movement with the 3D printed corner posts to allow the case to be squared up neatly. Now tighten the M4 screws.

Step 16

Push a M3 square nut into the knob and hold it in place with a M3 6mm grub screw. Mount the assembled knob on the rotary encoder shaft and tighten the grub screw.



Here are some pictures of the case assembly *without* the pesky protective film on with fully populated boards.

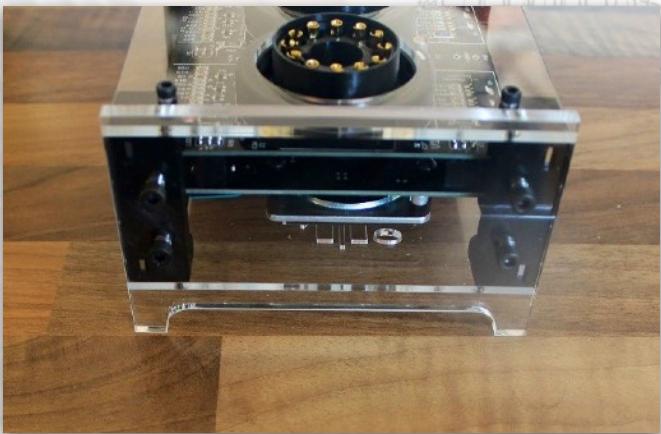


From Step 7 - Top acrylic attached to 3D printed posts





Top: From Step 8 - Bottom acrylic plate attached:
Right: Steps 9 and 10 - Side acrylic pieces attached:
Below: Back acrylic panel attached from Step 13 - note the rear access panel cover and the SMA hole plug:
Bottom: Steps 14 and 16 - Front plate attached with 3D printed rotary encoder knob in place.



Acrylic Dust Cover

The DXF cutting plans for the acrylic and STL files for the 3D printed corners are available on the Fortress E1T Clock project DropBox.⁵⁸

Parts List

Quantity	Description	Image
1	Five pieces of 3mm thick laser cut acrylic	
2	Låda corners, M3 nuts and screws: <ul style="list-style-type: none"> • 24 x M3 nuts • 24 x Black M3 10 mm screws • 4 x 3 way låda corners • 6 x 2 way låda corners 	

Tools Required

The following tools are essential to build the case:

- 2.5 mm Allen key/Allen screwdriver
- Slip joint pliers (channel-locks)

Assembly

Step 1

Before assembling the 3D printed parts it is worth checking that the 3mm diameter holes are clear using a 3mm diameter drill bit as appropriate.

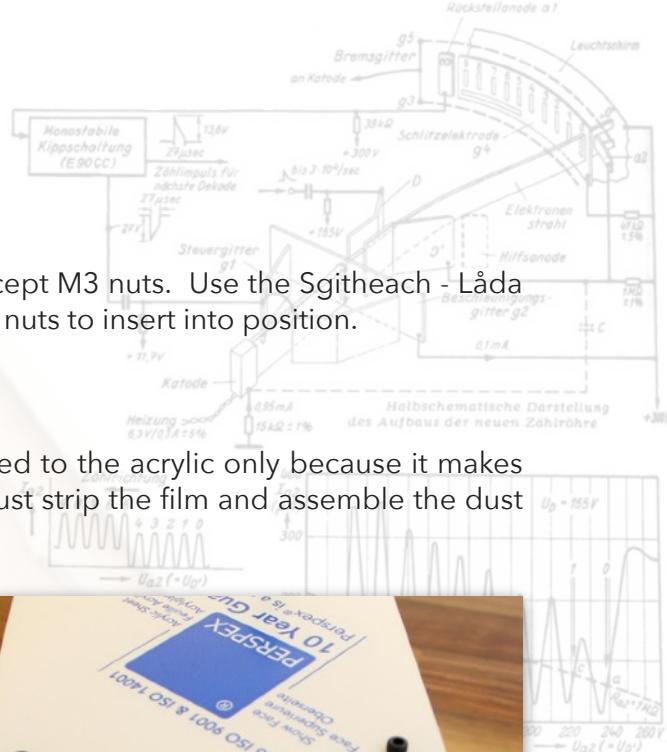
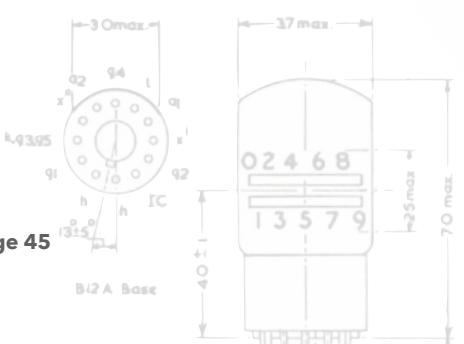


Step 2

The ten 3D printed corners have hex recesses that will accept M3 nuts. Use the Sgitheach - Låda manual for notes on their assembly. There are a total of 24 nuts to insert into position.

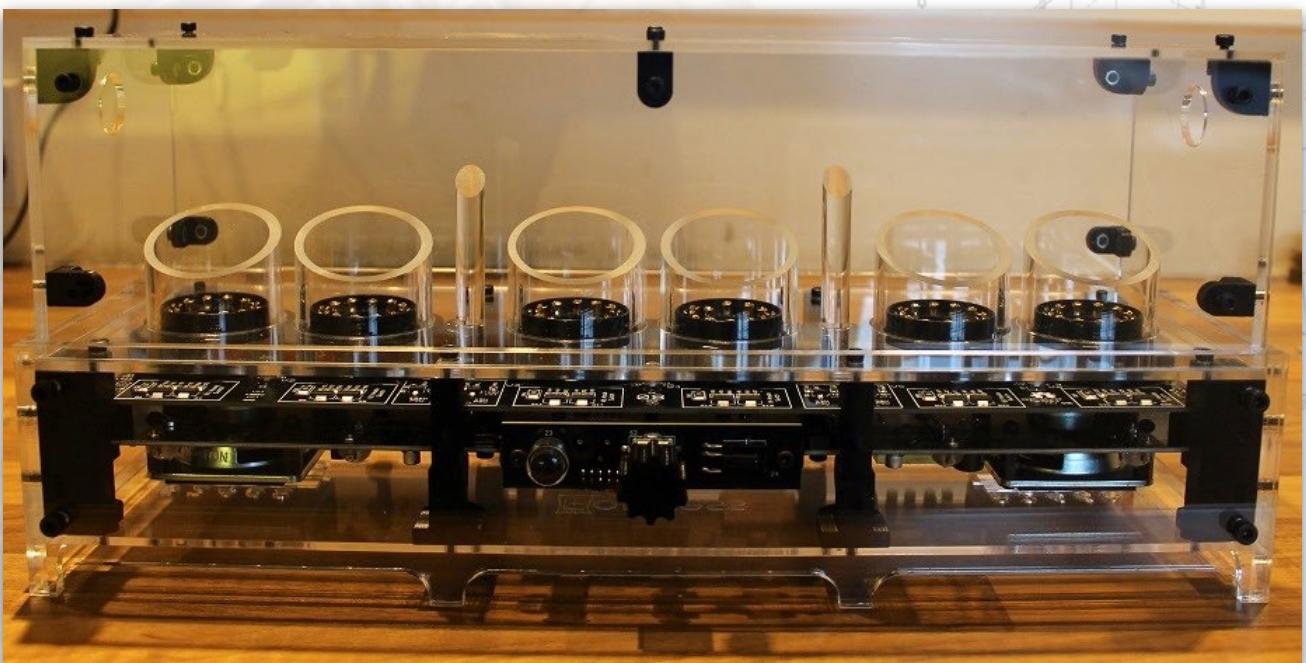
Step 3

Here is the case assembled with the white film still attached to the acrylic only because it makes visualising the case top assembly a little clearer. You can just strip the film and assemble the dust cover immediately.

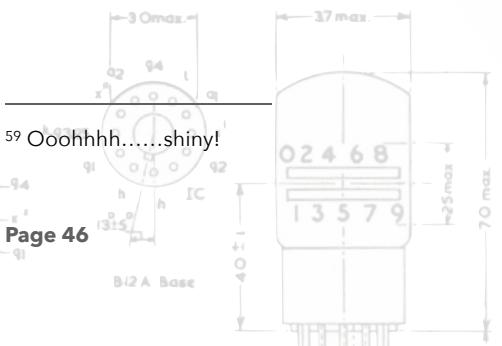
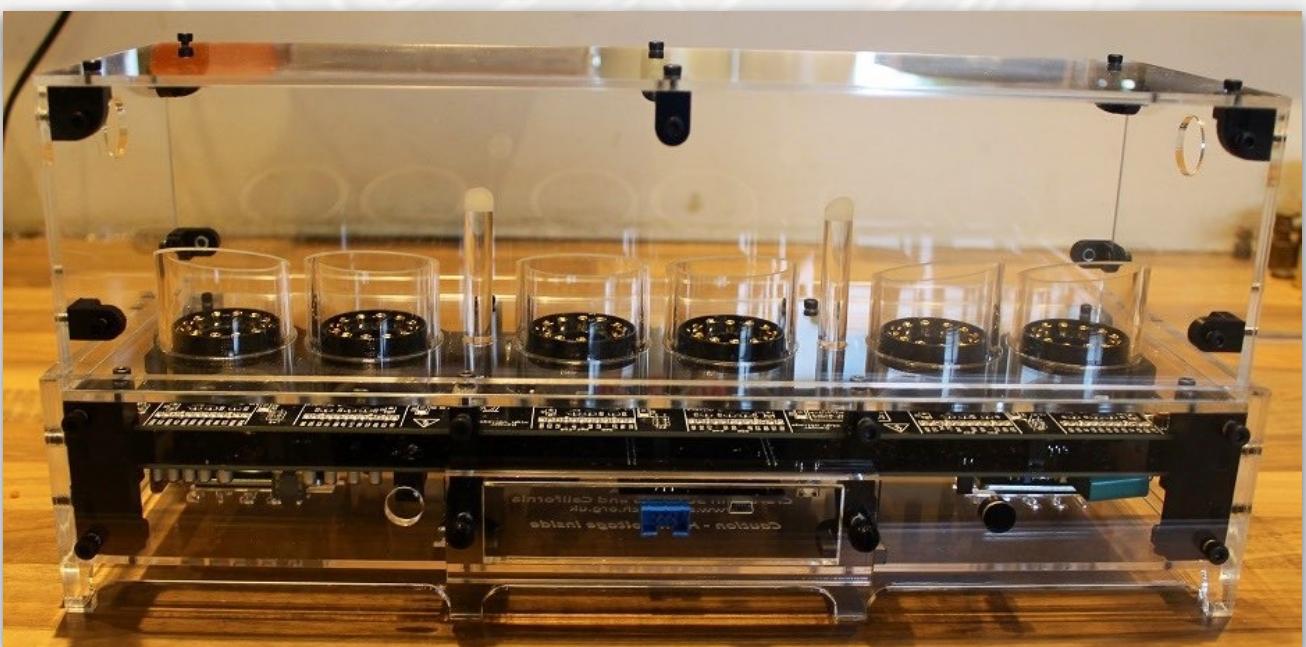


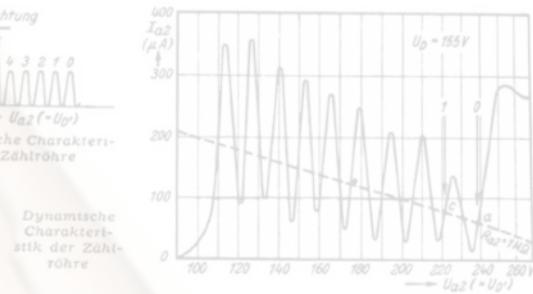
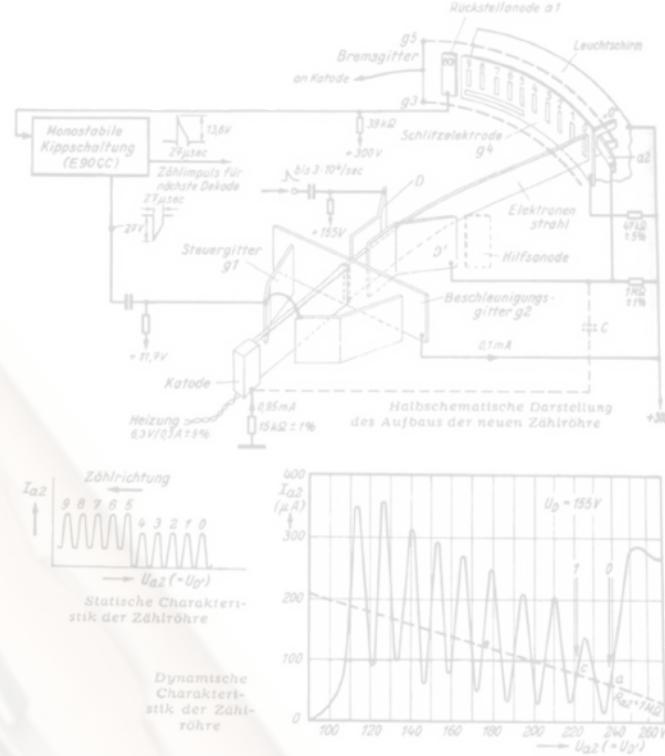
Complete Acrylic Assembly sans E1T Tubes⁵⁹

From the front...



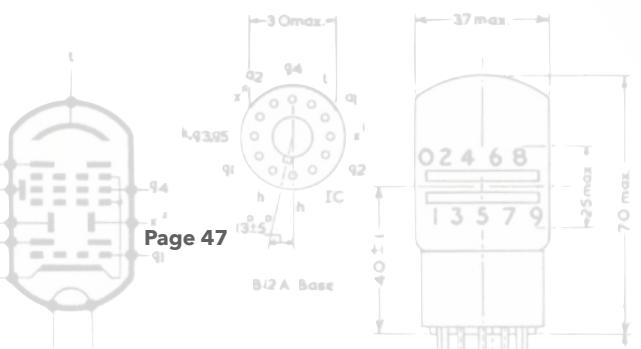
From the back....





Fortress - Case Supplemental

If you want to spin your own design...



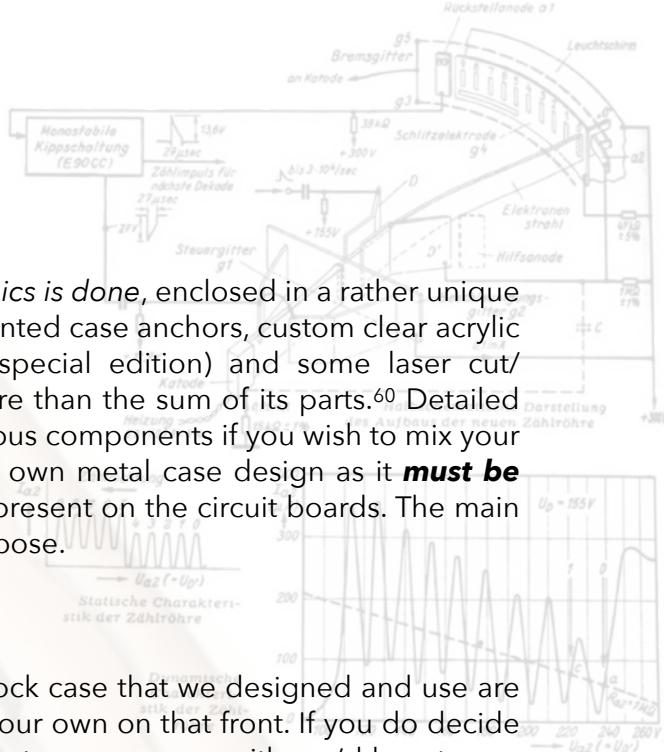
Introduction

The final Fortress clock is, *after all the complicated electronics is done*, enclosed in a rather unique case design that blends the old with the new. Using 3D printed case anchors, custom clear acrylic light guides, anodized aluminum body parts (for the special edition) and some laser cut/engraved top and bottom plates the whole becomes more than the sum of its parts.⁶⁰ Detailed within this supplemental are all the dimensions of the various components if you wish to mix your own. **Caution** should be taken if you decide to use your own metal case design as it **must be earth bonded** due to the potentially hazardous voltages present on the circuit boards. The main board has an earth bond connection point for just this purpose.

Main Case Design

The .dxf files of the various panels for the kit/complete clock case that we designed and use are available on the [Dropbox](#). You are, of course, free to roll your own on that front. If you do decide to go down that path, please send us some pictures of what you come up with, we'd love to see it!

The next pages detail the light guides that are *integral* to the clock as the 3D printed parts are designed to accommodate them on the main board. If you do decide to build the clock from scratch you will need to make (or source from us) these parts and the diagrams are here to aid in that effort.



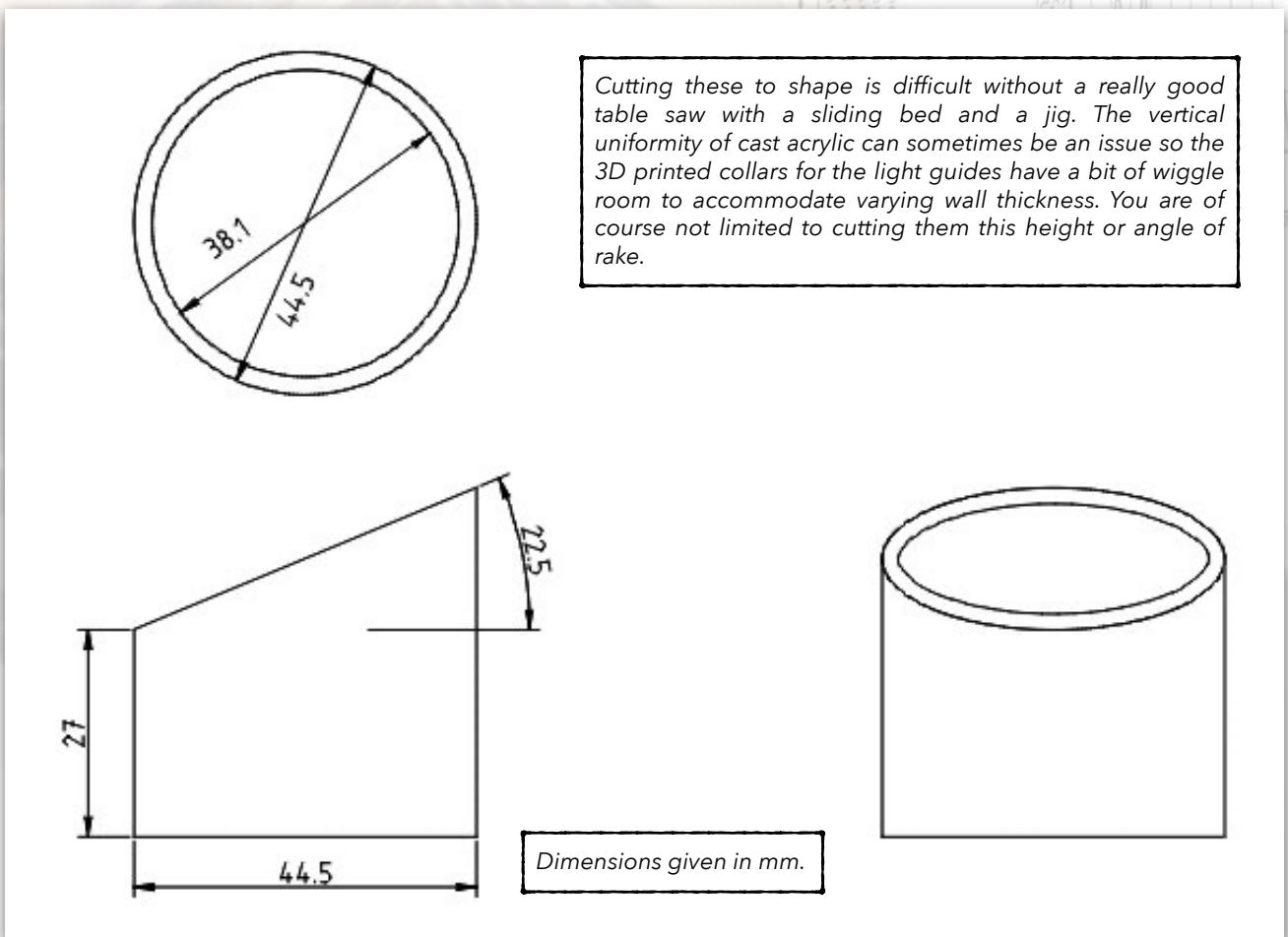
⁶⁰ Well, that's what we think anyway! ;)

Fortress E1T Clock Light Guide Design

E1T Light Guides

The material used is Clear Cast Acrylic Tube 1 3/4" (44.5mm) O.D. x 1 1/2 " (38.1mm) I.D.

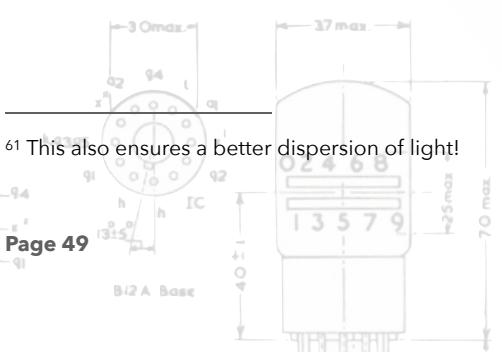
Do not use an extruded grade as this results in a pretty ugly looking light guide as the edges are rarely smooth and have a more ridged aesthetic.



Example Supplier:

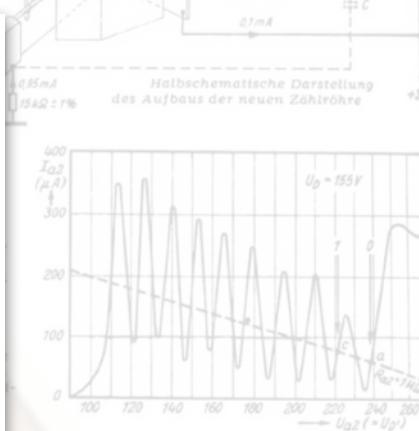
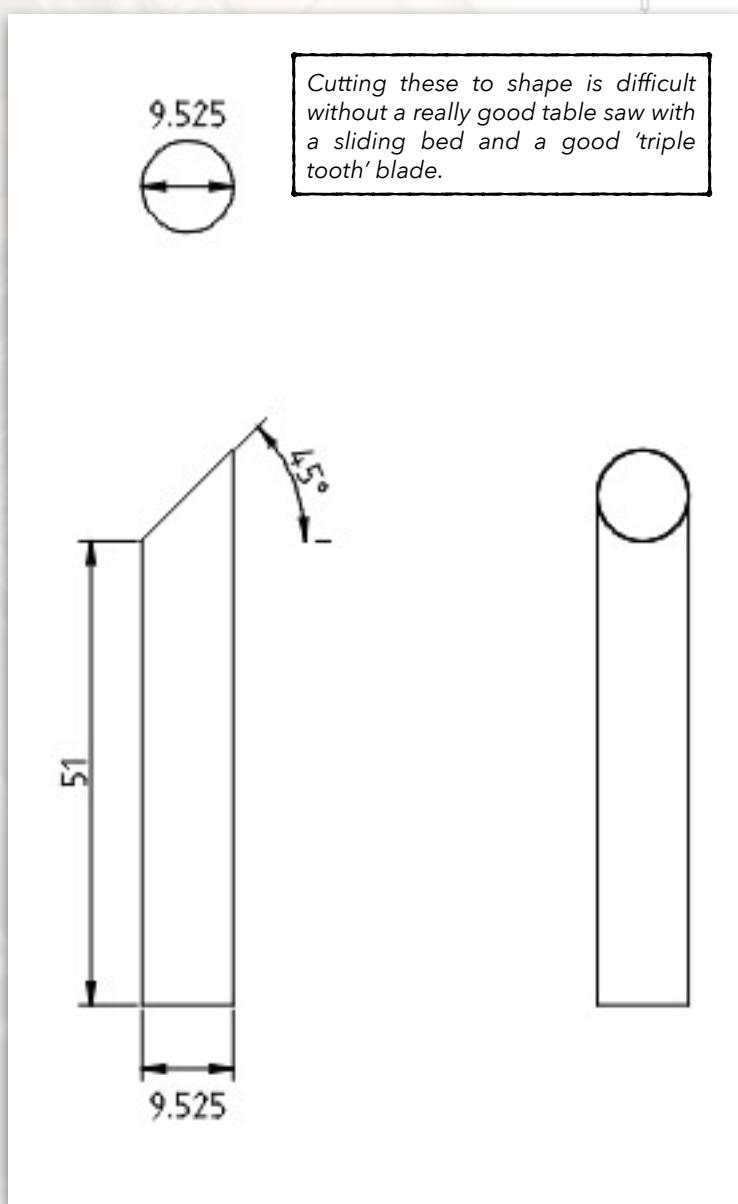
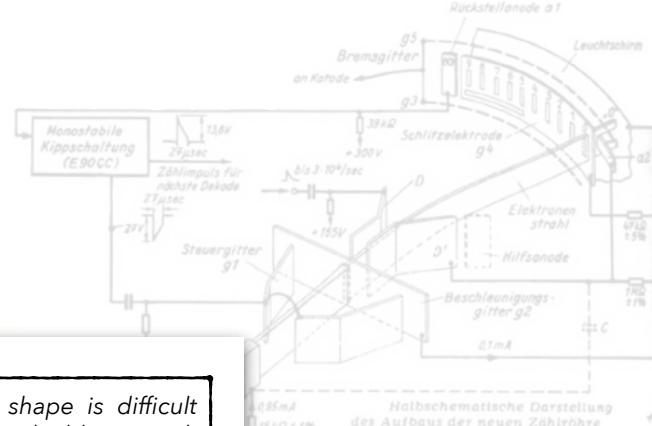
<https://www.mcmaster.com/8486k335>

The top edge should be finished using 220 grit wet and dry sand paper to remove all surface imperfections to leave a nice matte surface⁶¹. This is best accomplished by taping/affixing some wet and dry paper to a flat surface, spraying with water and sanding the top in a circular motion until all the striations from the blade cut are removed.



Colon Light Guides

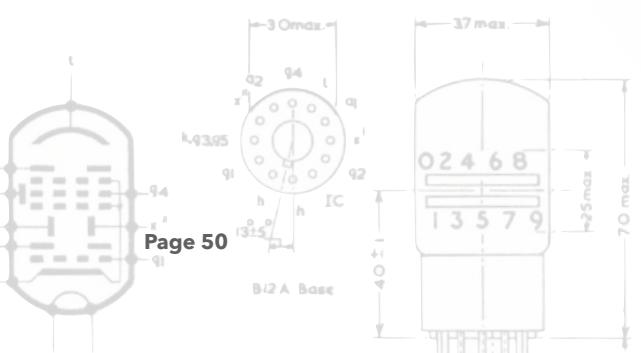
The material used is Clear Acrylic Rod 3/8 inch O.D.



Example supplier

<https://www.mcmaster.com/8531k15>

The top edge should be finished using 220 grit wet and dry sand paper in exactly the same way as described before.



Page 50

Version 1.3

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Initial Clock Setup and Operation

First, you'll need to find a good spot to place your clock, the best options being somewhere out of direct sunlight as this will washout the E1T displays and the LED highlighting. The clock does have an auto adjustment for the LED intensity based on the ambient light in the room.⁶² You will need to adjust a few things on the SD card so it knows which part of the world you're in. These details are kept in a file on the SD card called *locale.ini* in the System folder. You can edit this file using any simple text editor (i.e. Programmers Notepad, Text Edit, Windows Notepad, Text Wrangler etc...). The main thing you will want to change is in which time zone you're located and what DST (Daylight Saving Time) rules to use. Simply change the file accordingly and save your changes. If you're so inclined, you should probably also change your latitude and longitude.⁶³ You will also want to attach either the GPS/WiFi antenna to the back of the clock. If you're using the WiFi option you will need to enter your network credentials (SSID⁶⁴ and Password) in the *wifi.ini* file, again on the SD card in the System folder. Once that's all complete, plug in the PSU cable to the back of the clock and turn on the power. You will notice that the underside LED's will all light up and after about a minute, the E1T tubes will illuminate and countdown to 0.⁶⁵ You will then be greeted with the first of many available 'faces' of Fortress. To change from one to the next, either use the rotary encoder at the front of the clock or the remote control. To change the volume of any chime audio on a particular clock face simply press the encoder in and turn clockwise to increase and anti-clockwise to decrease (the volume level will be displayed on the two rightmost E1T tubes). You can also use the IR remote for the same purpose.



Powering up the Fortress - E1T tubes counting down on startup

Clock Customisation

One of the core principles embedded in an Open Source device such as Fortress is the ability to customise it by *understanding* how it ticks⁶⁶. Faces for the clock are written in a hybrid coding language called 'Nuggle' and exemplary examples are provided in a separate manual called 'The Nuggle Cookbook' available on the [Dropbox](#). As supplied, the Fortress comes with a pretty comprehensive set of 'faces' which combine both timekeeping, LED lighting schemes, solar information, screen savers, and the occasional light-hearted audio chimes. All of these are provided on the SD card and can be viewed and edited as needed.

⁶² This can be changed, like most other presets in the clock, by altering the *system.ini* file on the SD card.

⁶³ If you ask us nicely, we can set this all up for you beforehand....if you don't change this then the solar (sunrise etc.) information will be incorrect.

⁶⁴ SSID - Service Set Identifier - The given name to your local WiFi network.

⁶⁵ Why does it take this long you ask? Well, there's a lot going on behind the scenes....and the slow start of the E1T heaters hopefully prolongs their working life. If you want to see what checks etc. go on during startup, then see use of the serial console.

⁶⁶ See what I did there? Ha ha ha....

Clock Care and Troubleshooting

Fortress is a pretty special clock and as such should be suitably cared for to enable a long life and enjoyment for years to come. Please only clean the acrylic with a lint-free cloth (scratches aren't cool), and keep it away from prying fingers. There are high voltages employed within its confines and even though it is well protected accidents can happen. The E1T tubes are very valuable and (alas) a non-renewable resource, so please only operate the clock with the case top in place to protect them from accidental contact and stray flying objects.⁶⁷ As with most complicated electronic devices, sometimes things don't go according to plan.⁶⁸ If the clock, for any reason, doesn't operate correctly, the first thing to try is a hard reset by turning the power off, waiting 5 seconds then turning power back on. Pulling the PSU socket out and plugging it back in isn't ideal as this can also lead to hanging the CPU, so please only cycle power using the switch on the power supply. If *that* doesn't fix things, then please try using the serial console to see where things are *hanging up*. If *that* doesn't pinpoint the issue, then please contact us and we will help you to get things up and running again. This doesn't extend to failure of the E1T tubes as these are obviously out of our control and have a finite lifespan. We will, however, warranty any issue in the Fortress electronics due to premature component failure or faulty construction for 1 year after date of purchase. This does not extend to accidental events such as spilling drinks on the clock or dropping it on a hard floor etc.⁶⁹ This also only applies to pre-built clocks purchased directly from us. If you are having problems with kit construction we are here to help but some costs may be incurred for such assistance depending on whether shipping the clock is involved etc.

Questions?

We love old display technologies. We have a passion for bringing them back to life in unique and distinctive timepieces and putting them back on display. We also like hearing from people who share our interests in vintage electronics, so if you have any questions regarding Fortress or any other device offered by us, please reach out and contact us at either;

web.sgitheach@googlemail.com or stocksclucks@gmail.com

⁶⁷ This may seem a little OTT, but as a favourite author of ours once wrote, 'Scientists have calculated that the chances of something so patently absurd actually existing are millions to one. But magicians have calculated that million-to-one chances crop up nine times out of ten.'

68 This should be a rare event.

88 This should be a *rare* event.
89 Common sense should prevail here.

In-depth Troubleshooting

Introduction

Given the complexity of the Fortress E1T Clock it is difficult to give a completely comprehensive guide to the faults that might occur and how to find them. I would expect 99.9% of first time faults to be soldering problems, either a poor solder joint or a bridge between adjacent conductors.

Main Board testing

For main board troubleshooting it is easiest if the main board is not plugged into the display board and is laid with the components uppermost.

12V, 5V and 3.3V rails

The initial check must be to ensure that the 12V, 5V and 3.3V power supplies are all correct.

SAM3X8C plug in module

Once it is asserted that the 5V power supply is OK then the SAM3X8C plug in module can be tested. The first stage is to plug in the SAM3X8C programmer and use it as a serial console to check that a start up script is produced and the menu system is operating. The process is described in Section 3.

Given that the SAM3X8C plug in module has been tested before dispatch then, any problem found must be due to the SAM3X8C programmer. The build instructions contain detailed test processes that should have demonstrated that the programmer is working correctly.

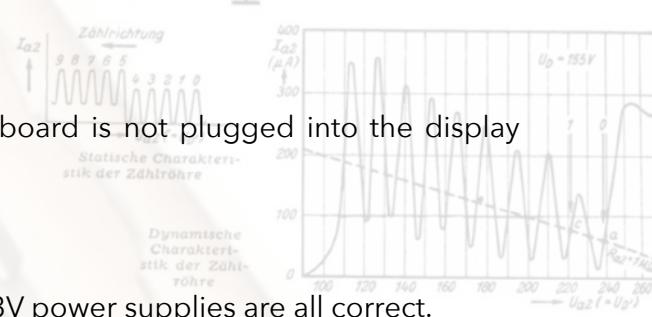
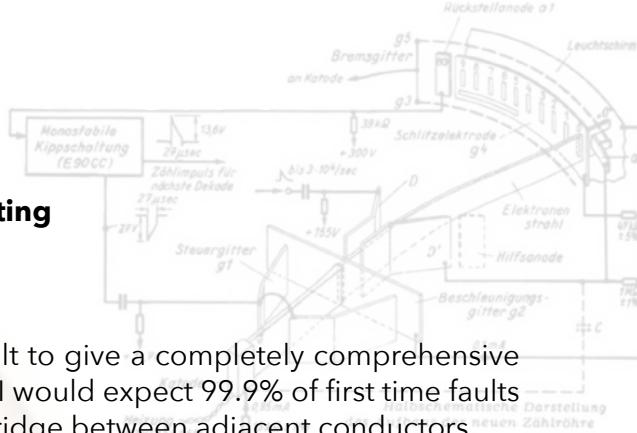
Remember that accidentally⁷⁰ pressing the "Erase" button on the programmer when connected and powered will erase the flash memory in the SAM3X8C. The chip will then require flashing again.

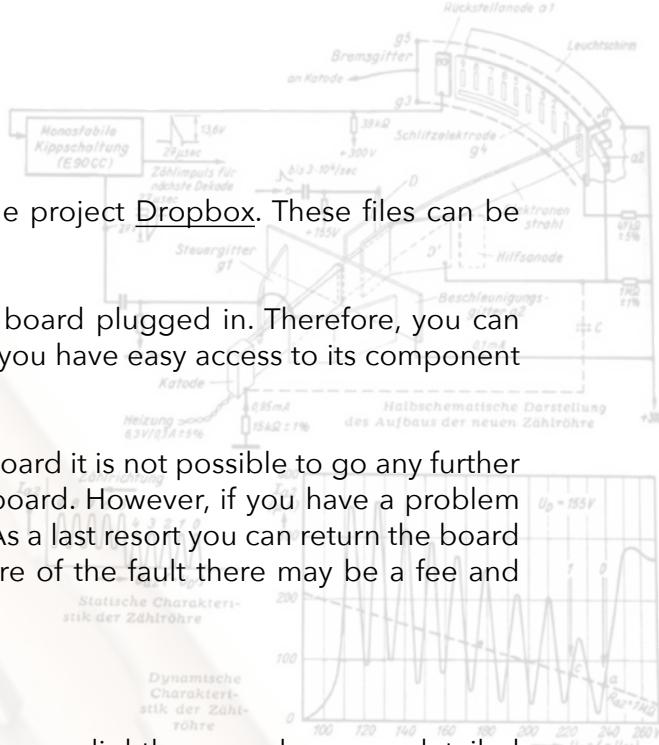
Main board in more detail

Once the console is operating and you can issue menu commands, you can move on to testing individual sections on the main board. To accomplish this it is probably best if you use the option jumpers to set the clock into verbose mode (fit jumper 8) and into test mode (fit jumper 1). For safety you can omit jumper 3 so that the +300V HT flyback and 6.3V heater power supply will not start.

To assist this process there are four sections of this manual which will help you:

- Section 2 of details the use of the option jumpers.
- Section 4 list all of the menu commands
- The *Main Board Assembly* section gives an example of the start up script sent to the console. This script may contain error reports.
- The *How It Works* is a breakdown of the schematics by function.





Additionally, the project Eagle⁷¹ files are contained on the project Dropbox. These files can be opened using the free Eagle version.

The main board will operate happily without the display board plugged in. Therefore, you can detach the display board and flip the main board over so you have easy access to its component side.

Obviously, given the number of subsystems on the main board it is not possible to go any further with advice on trouble shooting a problem on the main board. However, if you have a problem then please feel free to contact us and we will try to help. As a last resort you can return the board (to Scotland) and it will be fixed. Depending on the nature of the fault there may be a fee and maybe a return postage cost.

Display Board testing

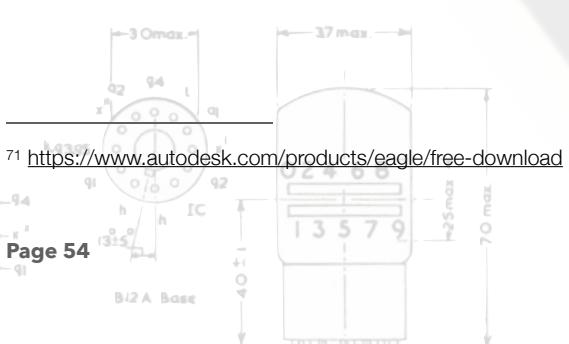
Because the E1T tubes and display board drivers for them are slightly unusual, a more detailed explanation is given here on what you might expect to find.

When probing points on the board, take extreme care that you do not accidentally short adjacent connections. There are a wide range of digital and power traces on the board. Shorting digital to power will almost certainly damage the SAM3X8C and possibly other components. Shorting power to ground will most likely damage the corresponding convertor or regulator.

Due to component tolerances the 300V, 6.3V and the four regulated voltages on the display voltages will vary. These are what I measured on the prototype clock:

Desired Voltage	Measured Voltage
300V	300.5V
6.3V	6.23V
156V	158.1V
30V	30.6V
15V	16.2V
12V	13.1V

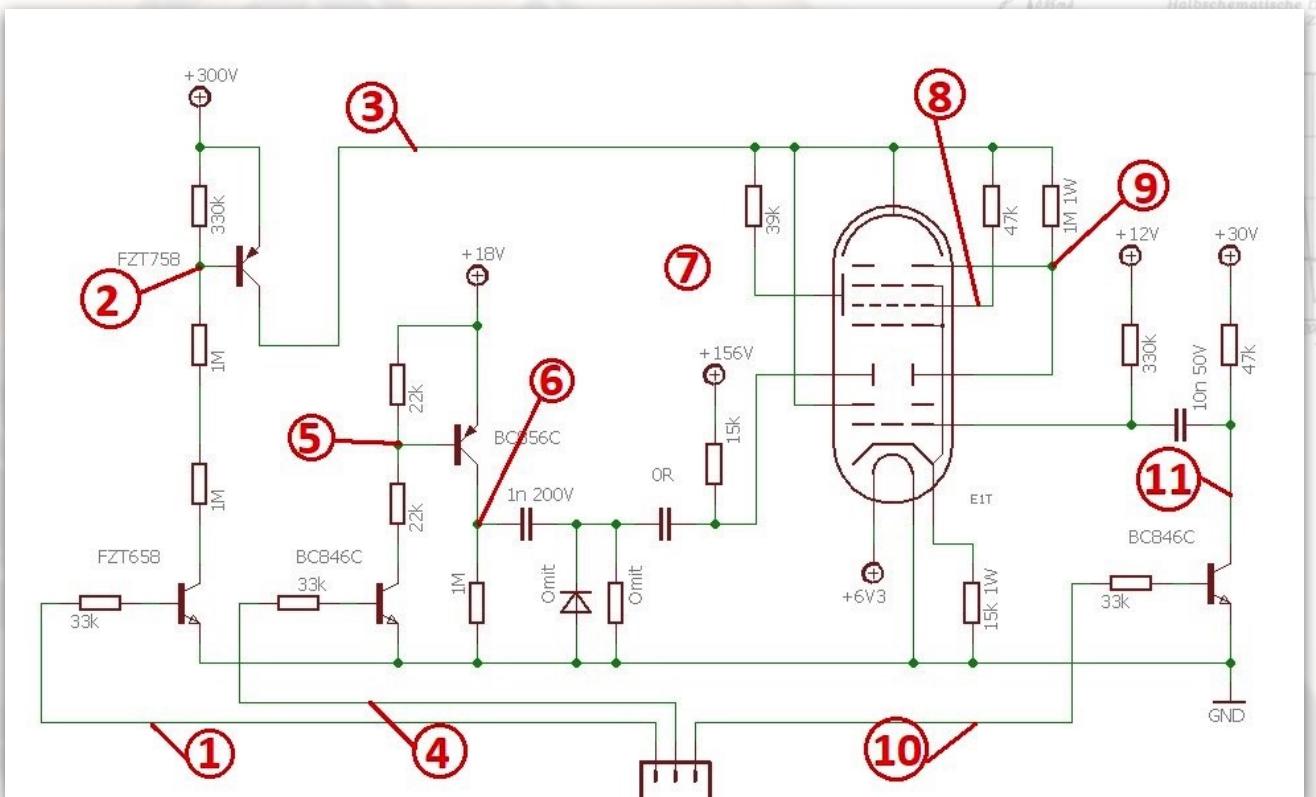
I had no problems with the variability you see here. Widely differing voltages from those listed indicates a problem of course.



⁷¹ <https://www.autodesk.com/products/eagle/free-download>

E1T Static Voltages

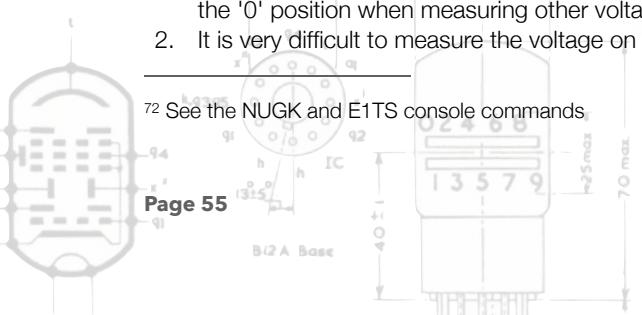
These voltages were measured⁷² with no Nuggle program running and an E1T glowing in position '0'. Under these conditions the HT switch transistors are conducting, the step pulse transistor is off and the reset transistor is conducting.

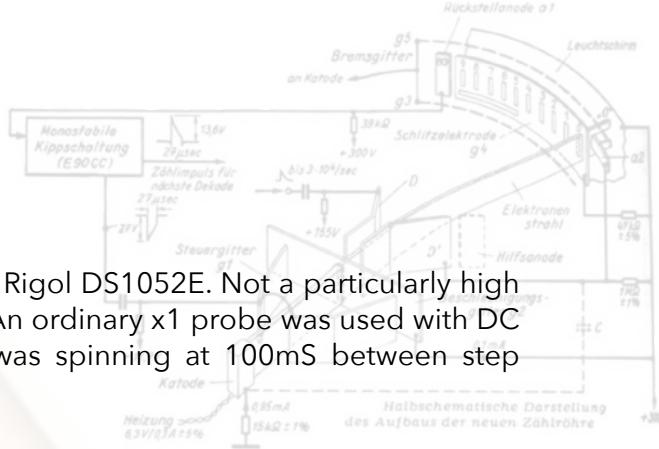


Point	Reference	Measured
1	Ground	3.28V
2	+300V	570mV
3	+300V	50mV
4	Ground	7mV
5	Ground	16.2V
6	Ground	0V
7	+300V	300.5V
8	Ground	260V
9	Ground	83V
10	Ground	3.28V
11	Ground	15mV

1. It is very difficult to measure the static voltage on point 5 without pulsing the tube so make sure you reset the tube to the '0' position when measuring other voltages.
2. It is very difficult to measure the voltage on point 9 without the tube stepping to position '9'

⁷² See the NUGK and E1TS console commands.



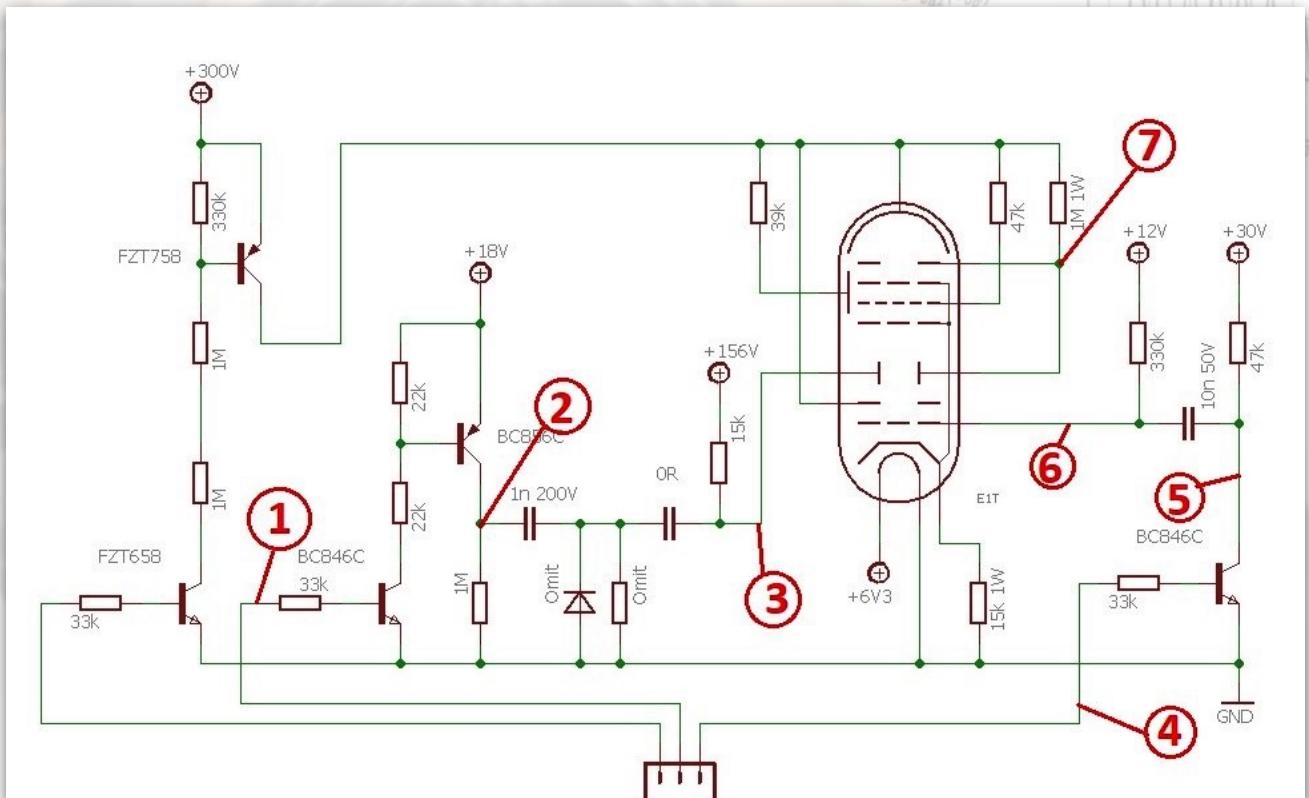


E1T Circuit Waveforms

The following oscilloscope images were captured using a Rigol DS1052E. Not a particularly high specification oscilloscope but good enough for this task. An ordinary x1 probe was used with DC coupling unless otherwise stated. In all cases the E1T was spinning at 100mS between step pulses using the console **E1TC** command.

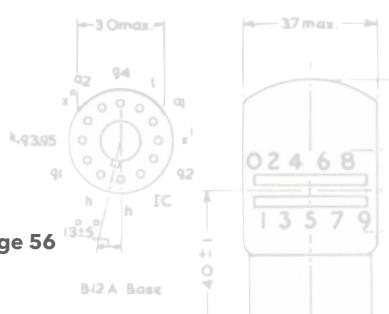
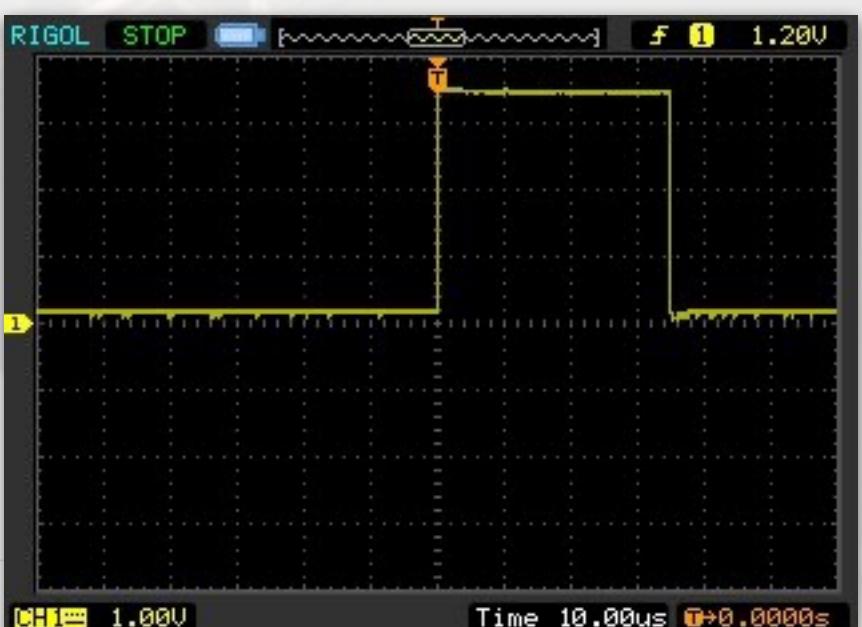
Schematic

The following waveforms were captured. The step pulse shaper used is by Ron Dekker.



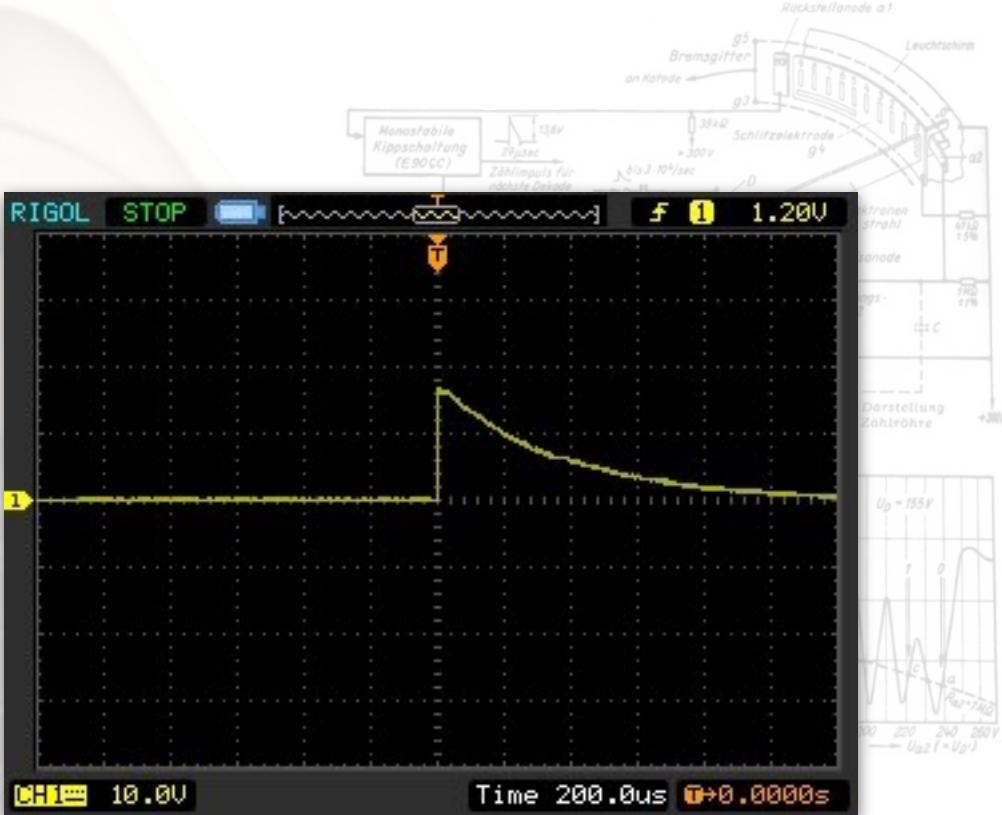
1. Step pulse input.

This is a connection from the SAM3X8C so shows a pulse 3.3V high and 33μS long.



2. Step pulse after the drive transistors.

This is the voltage on the collector of the PNP step driver transistor. It is about 18V in amplitude and has about a 1mS decay period.



3. Step deflection pulse.

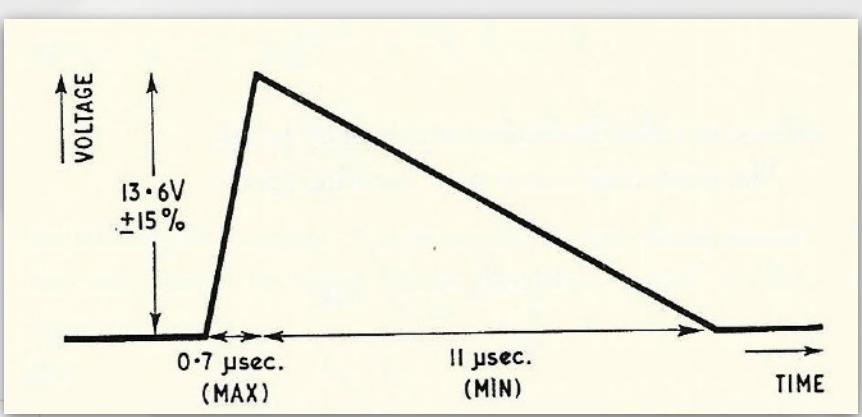
A $\times 100$ probe was used with DC coupling.

This is the pulse applied to the deflection plate x' in the E1T⁷³. The pulse rises quickly to 15.2V and then decays over a period of about 20 μ s.



The ideal waveform.⁷⁴

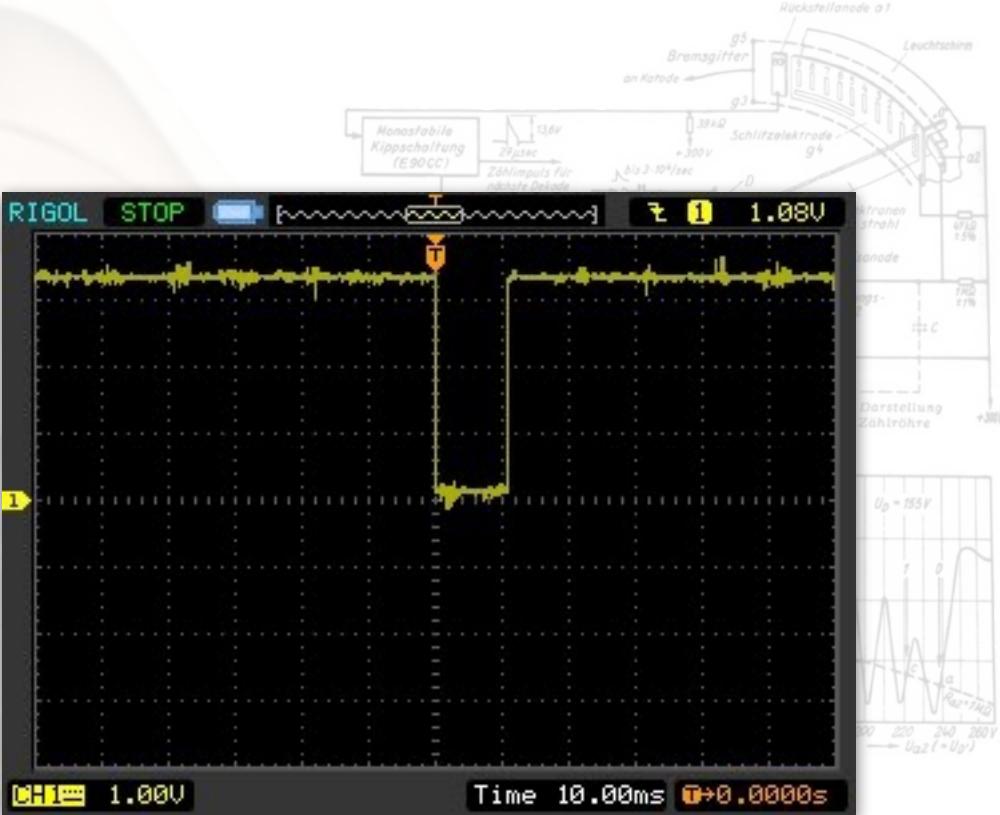
The measured waveform meets the requirements for the maximum rise time ($< 0.7\mu\text{s}$), the minimum decay time ($> 11\mu\text{s}$) and the pulse amplitude (actually 12% above 13.6V).



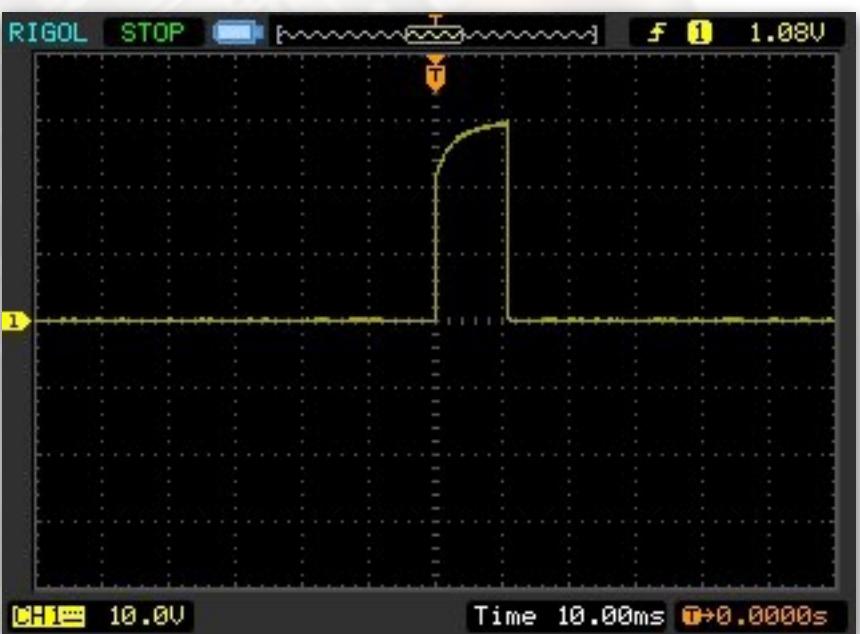
⁷³ J. B. Dance - E1T Decade Counting Circuits
⁷⁴ Dance - Fig 5.9

4. Reset pulse.

This is a connection from the SAM3X8C, a pulse 3.3V low and 10mS long.



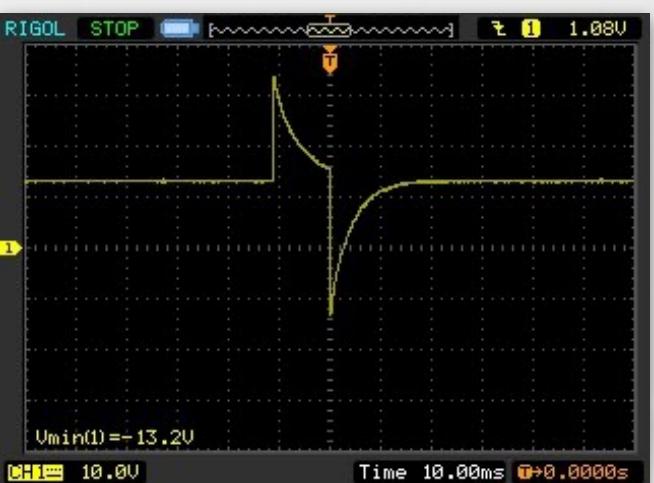
5. Reset pulse transistor collector.



6. E1T Grid.

This is the voltage on the E1T grid. The strong negative pulse to -13V cuts off the electron flow through the tube causing it to reset to position 0 when the current flow is re-established.

Normally the cathode potential is about 15V above ground and the grid is at 12V above ground. The -13V pulse means that the grid falls to about -28V with respect to the cathode. The tube requires -24V for cut off.

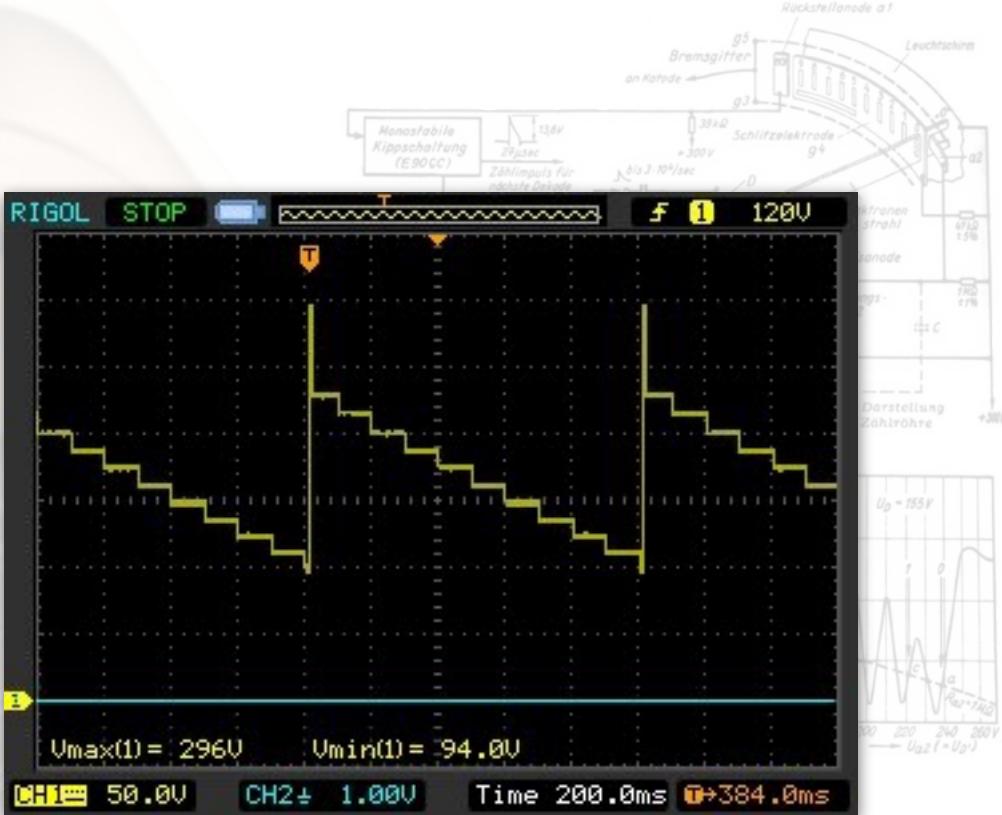


7. E1T Deflection Plate x'' and anode 2.

A x100 probe was used with DC coupling. In this image the cyan trace (channel 2) shows the position of the ground (0V).

A few observations:

The high pulse at the start of the cycle (below the T symbol) reaches nearly 300V or the +HT supply. This occurs when the negative pulse to the grid has cut off the electron flow. This will mean that when the tube is turned on again at the end of the reset pulse the beam will be in position '0' as required.



The voltage of the '0' step is about 228V and the lowest, just after '9', is 94V. Therefore the voltage per step is $(228 - 94)/10 = 13.4V$. This just about corresponds to the step voltage of 13.6V for counting.

Understanding E1T "Faults"

We call these "faults" but they are part of the charm of the E1T. From the Fortress clock point of view they are not faults of the Fortress clock but faults in the E1T tubes themselves. Before blaming the Fortress clock you might take some simple steps of swapping the tubes around to see if the fault moves or not. If the fault doesn't move then you can begin to suspect the clock hardware and not the tube.

Most E1T tubes do not light up perfectly from positions '0' to '9' in identical fashion. Manufacturing differences mean that the glow or glows have different intensities.⁷⁵ Other faults are real - the tube doesn't count or has physical defects.

Spurious lines

The most common 'faults' seen on an E1T, even perhaps most E1T tubes, are additional fainter lines: Here's a tube in position '3' with a fainter '2' lit. The explanation for this is asymmetrical deflection. Deflection plate x' operates at a fixed voltage but deflection plate x'' (as shown above using an oscilloscope) varies. This asymmetrical deflection causes the electron beam to widen as it moves towards the left (as seen from the electron gun) which is the higher numbered positions on the E1T.



⁷⁵ These tubes were made in the 1950's after all....



Dim Glows

Another occasional fault is that the selected position is not very bright. This tube has a remarkably dim '9'. It is still visible and brighter than the '8' and '7' additional lines. Therefore I use this tube in one of the 10's positions, for example 10's of hours, so the '9' is not used much. I do have the odd tube where the wanted line and the spurious lines are more or less the same brightness. I would use this tube in a units of seconds position so it changes every second, then the eye sees it steps through the sequence '3' ... '3' & '4' ... '5' and you can then read the '4' position correctly.

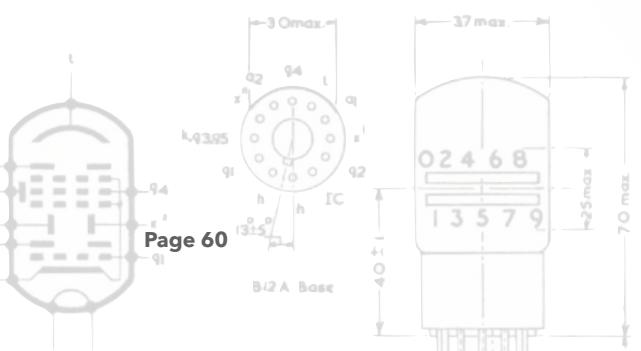
Burns

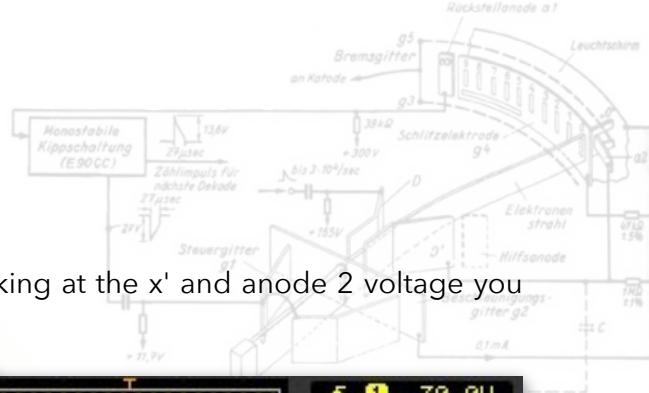
Look at position '6' - there is a black line showing the phosphor has been burned by the tube. This indicates that the tube has been left glowing in that position for a long time. This tube was sold as NOS but it is most clearly not!



Stuck Tube

The occasional tube is just plain stuck and won't budge whatsoever. Here's an E1T that just displays multiple lines with no movement. Who knows why. Clearly not of much use in a timepiece..





Miss-Counting

I have one tube that counts 0,2,3,4,5,6,7,8,9,9,0,2 ... Looking at the x' and anode 2 voltage you see:

You can see the step from the '0' position to the '2' position is twice the height of the other steps. Double stepping like this does not normally occur until the step pulse voltage is over 20V. Experimentally I tried reducing the step voltage but all that happened was that tube stopped stepping entirely at about 10V.

My conclusion is that this is a faulty tube and no tweak to the clock electronics would get the tube working.

The tube was given to a collector.



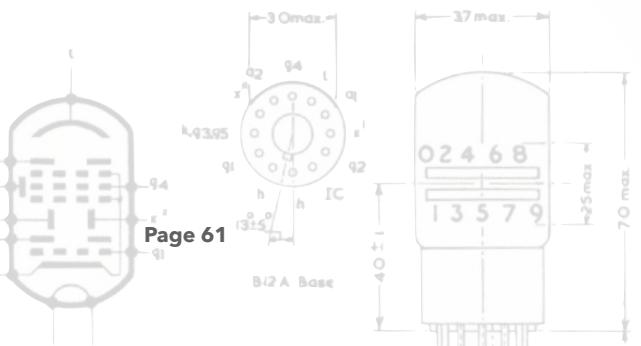
Crazy Lacquering

Some E1T tubes appear to have been lacquered. I know not why. With time the lacquer can be damaged or in extreme cases become crazed. It is not hard to remove the lacquer with a mild solvent such as isopropyl alcohol (IPA). If you decide to do so be careful not to damage the decal.



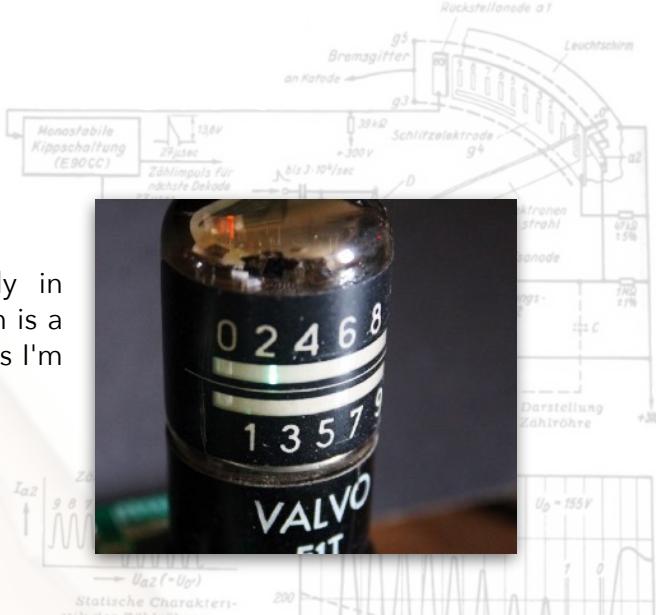
Damaged Decals

It is not unusual to buy second hand tubes that have scratched decals. Here the decal on the left is badly damaged. The decal on the right has a fairly small hole in the bottom left corner which would not really notice in use in a Fortress E1T Clock. (I hope to have replacement decals available at some stage, so all will not be lost.)



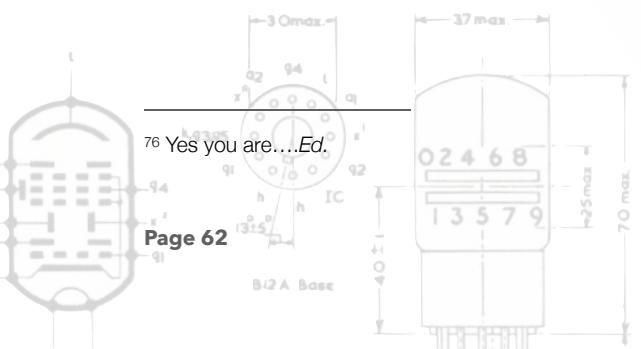
Offset Decals

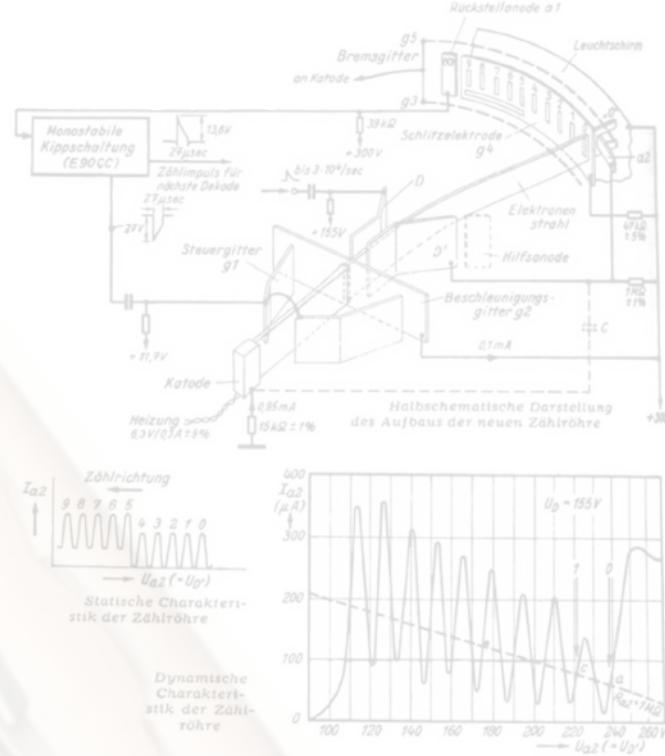
Occasionally, the decal has not been applied exactly in alignment with the glow positions. Here the glow position is a few mm to the right of the centre of the figure '2'. Perhaps I'm being a bit picky...⁷⁶



An Indicator of Tube Age?

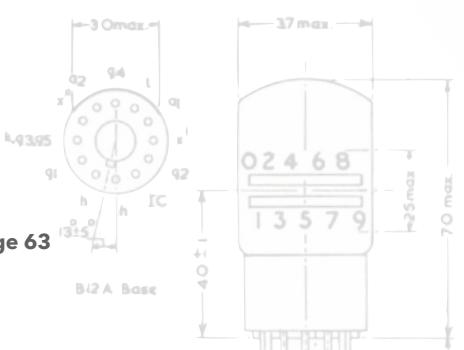
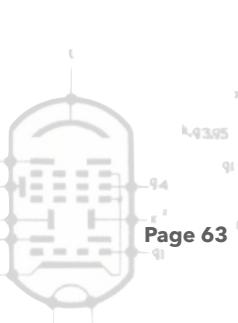
Apart from obvious signs of age such as dirt, grime or a damaged decal, there is little to indicate how well used a tube is. A physical observation I have made are NIB tubes have a top glass dome silvering that is bright and uniform. On tubes which are clearly used and old, the dome silvering is also usually not uniform or sometimes significantly worn away. The tube on the left is (what I believe to be) a new, unused tube. The silvering just reflects the ceiling and camera. However, the tube on the right shows a sort of "horseshoe" marking centred above the top of the heater/cathode. (This marking is inside the tube not on the outside of the glass). I have no proof that these markings occur with age as yet. I intend to document the visible changes to an E1T tube when I have a clock running in the house over a period of years. This said, I would be suspicious of an E1T sold as new/NIB/NOS that showed such markings.





Fortress - E1T Mis-stepping Fix

How to fix a troublesome display board



Version 1.3

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Introduction

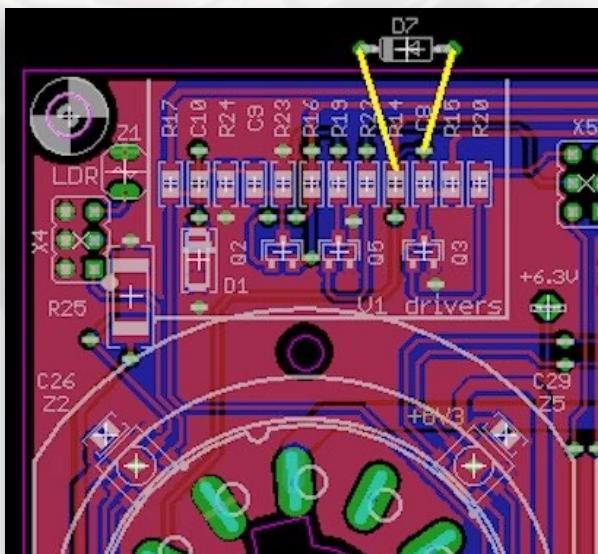
Now that there are number of Fortress clocks in the wild, a rare fault has appeared that affects the correct counting operation of the display board on a few clocks. This initially caused the designer some degree of consternation. However, a fix is afoot and hence this small addendum for kit builders out there that have noticed this issue with their device.

Symptoms

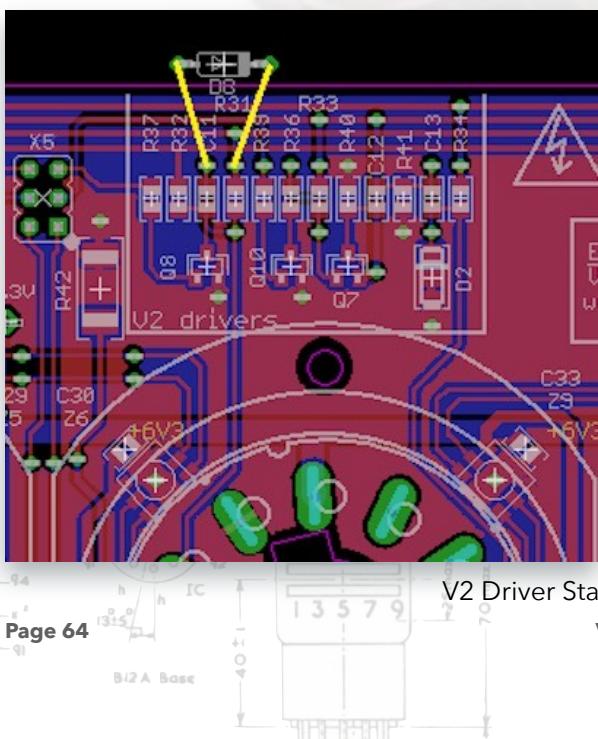
One (or more) of the tube stations would either not illuminate the '0' on the E1T, immediately stepping to 1 instead, or (more insidiously) take many minutes to do the same thing (think minutes or hours not displaying '0' when they should but instead mistakenly stepping to '1').

The Solution

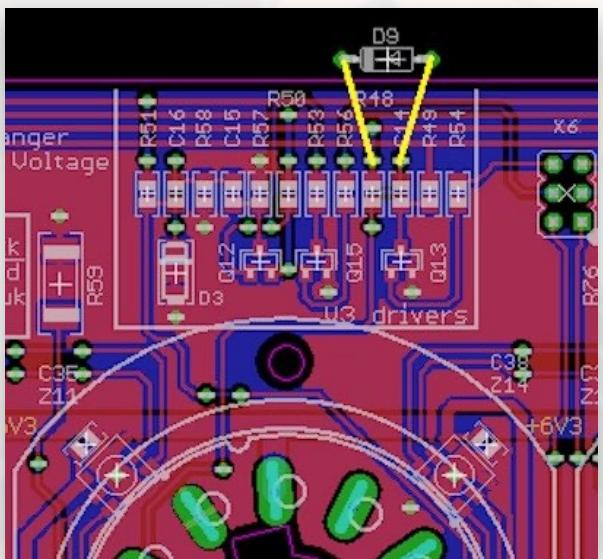
After a considerable amount of hair pulling, the fix for this issue is a mix of both software and hardware. Firstly, small signal diodes (1N4148 or similar) need to be soldered to the following locations on the display board (**note polarity of the diode at each station!**)



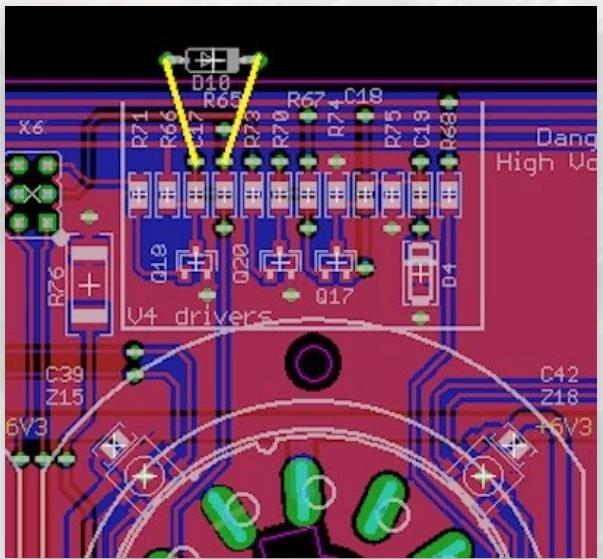
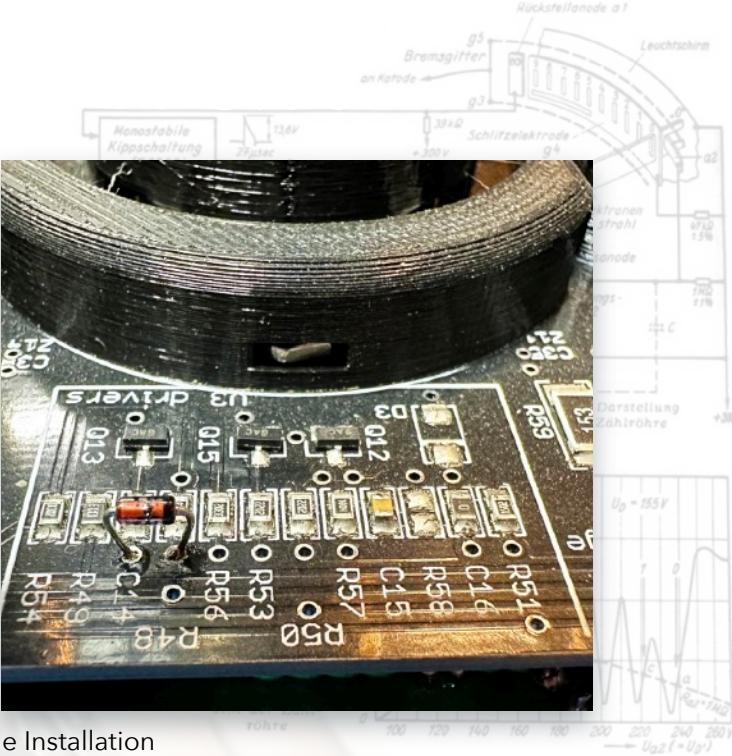
V1 Driver Station Diode Installation



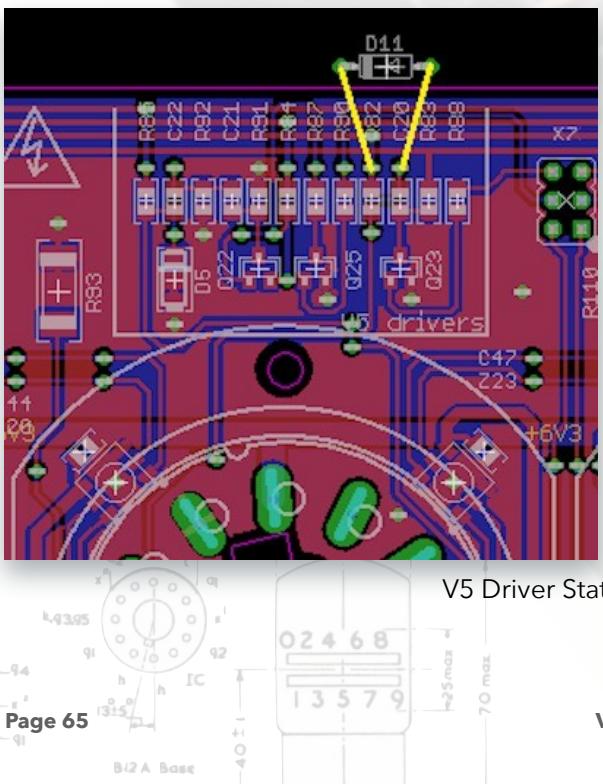
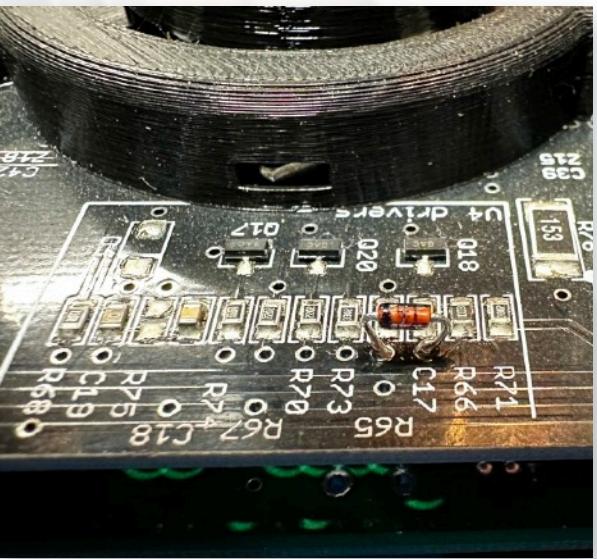
V2 Driver Station Diode Installation



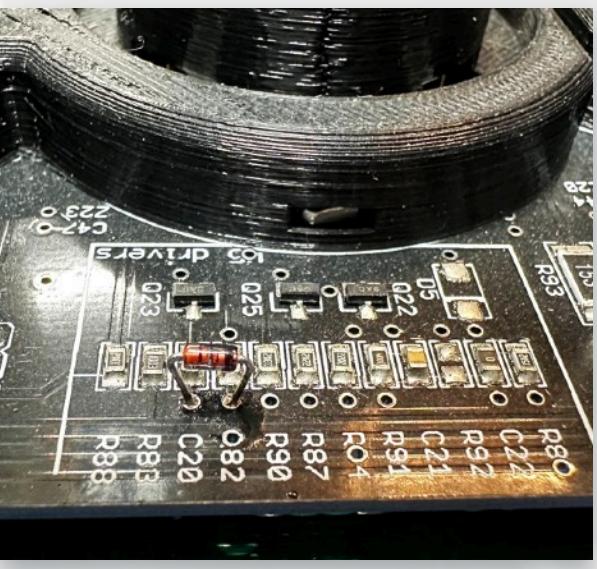
V3 Driver Station Diode Installation

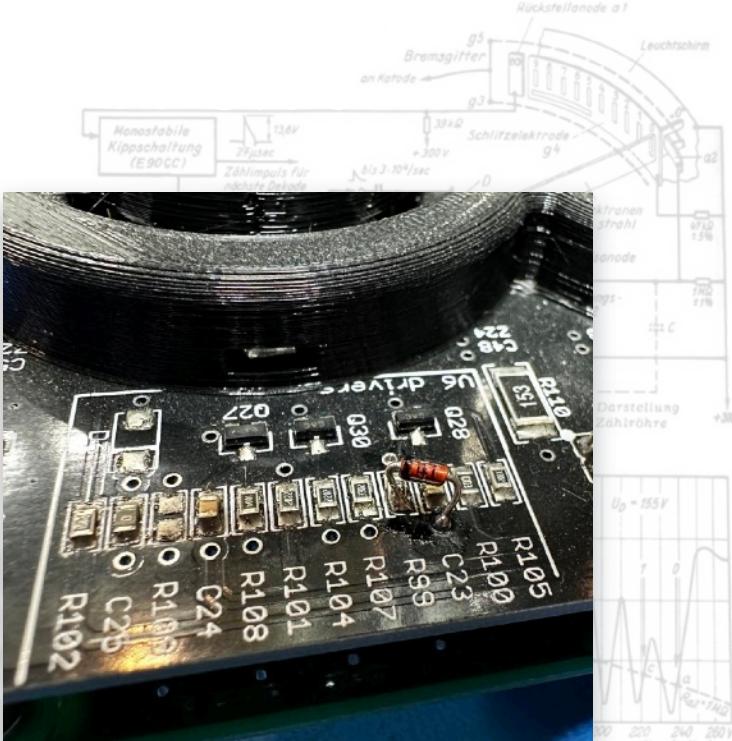
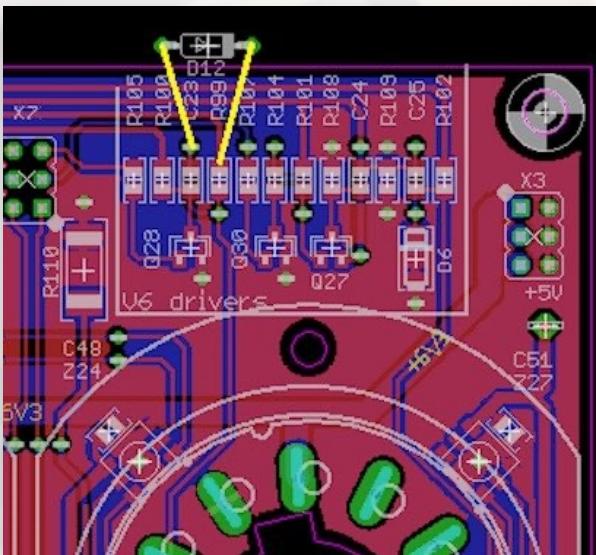


V4 Driver Station Diode Installation



V5 Driver Station Diode Installation





V6 Driver Station Diode Installation

As you'll note, there are some convenient vias to solder most of the diodes into (except for stations 1 and 6 where one side of the diode should be soldered to the 330K resistor tab).

The other part of the fix (if you're running version 1.1.7 or earlier of the firmware) is to update to 1.1.8 or higher (including updating the help.txt file on the SD card in the /system directory). Once completed, your Fortress clock should behave as it was intended.

