

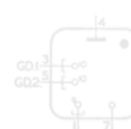
Harwell



Harwell - A Dekatron Timepiece

Seven Glow Transfer Tubes Tell The Time

Base
(underside view)



I.O.



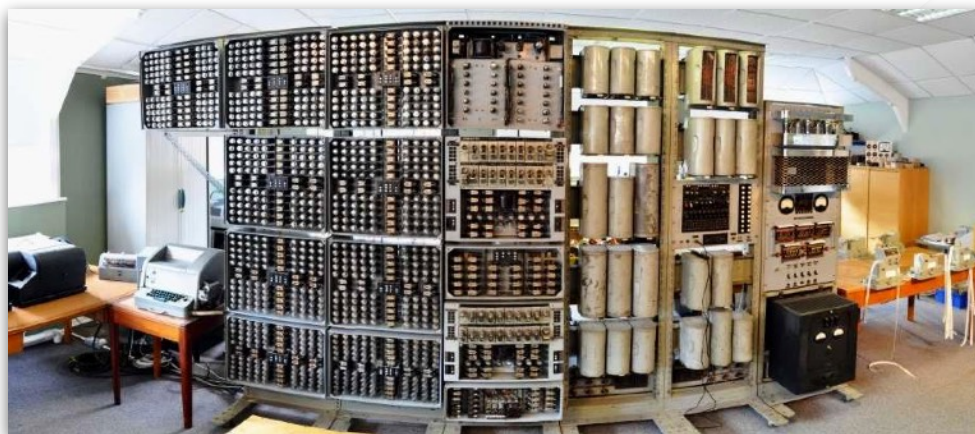
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72				
B	85				

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Harwell¹

What is the Harwell? It's a rather special timepiece that uses seven vintage neon counting tubes to tell the time among other *interesting* things. After completing the Fortress E1T clock,² our attention turned to a relic of the early computational age, the Dekatron tube. The clock is named after one of the early relay based computers of the 1950's that made heavy use of these neon filled counting tubes.³



Combining a modern micro-controller with some more cool 'old-skool' technology, we think we've constructed a pretty interesting homage to the computing/counting days of yore. It is also, to our knowledge, the only 7 tube 'commercial' Dekatron clock

deliberately offered for sale ever. It offers lots of customisation options, such as different 'faces',⁴ light-guided LED display, 'chimes', GPS or WiFi disciplined timekeeping and is also *Open Design and Open Source* in its publication philosophy to boot!

What's Included in the Box?

If you purchased a complete clock, then you'll be receiving the following in the box:

- A Harwell Dekatron clock, 6 tested GC10B Dekatrons, 1 tested GC12/4B Dekatron⁵ and either a GPS or WiFi module (both come with external antennae, depending on your order)
- A pre-built 2A power supply and IEC mains cable.⁶
- A custom programmer used to update firmware and act as a serial console connection.
- An infrared remote.



¹ Throughout this document, you will note the use of hyperlinks which both lead you to external references as well as internal bookmarks.

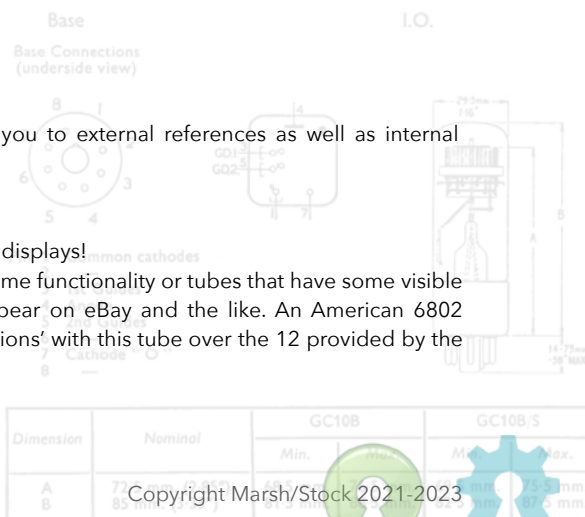
² <http://www.sgitheach.org.uk/fortress.html>

³ https://en.wikipedia.org/wiki/Harwell_computer

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

⁵ We can currently offer NOS tubes, tubes of unknown usage but look NOS with the same functionality or tubes that have some visible signs of wear but still function well. These are now quite rare, but occasionally appear on eBay and the like. An American 6802 dekatron variety clock is also available, the faceplate differs slightly due to the 10 'stations' with this tube over the 12 provided by the GC12/4B. NOS 6802 tubes are also available.

⁶ If readily available to us for your part of the world.....

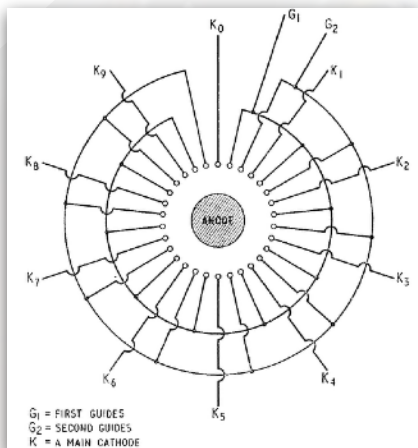


If you purchased a clock kit, then you'll be receiving the following in the box (or boxes):

- A complete kit to build the clock - all the PCBs with SMD parts fitted, all the through hole components to solder, an IR remote and the hardware needed to assemble the boards.
- 6 tested GC10B (or variants) and 1 tested GC12/4B (7 tested GC10B if you prefer). The "quality" of the tubes from apparently NOS down to *well used* is yours to decide (and pay for)!
- An optional kit for either a GPS or WiFi module.
- A kit to build a dedicated 12V 2A power supply.
- A kit to build a custom programmer which will be used to update firmware and act as a serial console connection.
- Optional case kits for the clock and power supply.

What is a Dekatron??

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 Systems⁸), neon gas based displays such as Nixie tubes⁹ and Dekatrons, vacuum fluorescent displays¹⁰ (VFDs), light-emitting diodes¹¹ (LEDs) and liquid crystal displays¹² (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*¹³.



A Dekatron is a glow transfer tube or sometimes known as a cold-cathode counting tube. They operate by passing an ionized glow around a ring of cathodes by means of an electrical pulse to intermediate guide cathodes. They came in three basic forms, counting tubes, selectors and register tubes. As such, they were very useful in their day for counting electrical inputs such as in a frequency counter, or radiation counter. For a detailed description of their operation, see the 'Dekatron Tube - How It Works' section taken from the *Electronic Counting Circuits* by J. B. Dance.



⁷ <https://en.wikipedia.org/wiki/Dekatron>
⁸ <https://stevenjohnson.com/nls/index.htm>
⁹ https://en.wikipedia.org/wiki/Nixie_tube
¹⁰ https://en.wikipedia.org/wiki/Vacuum_fluorescent_display
¹¹ https://en.wikipedia.org/wiki/Light-emitting_diode
¹² https://en.wikipedia.org/wiki/Liquid-crystal_display
¹³ Beauty is in the eye of the beholder....

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72				
B	85				

Anatomy of Harwell

The clock consists of the following components;

- Seven Dekatron tubes encased in acrylic light guides.¹⁴
- Two MTX90 thyratrons as colons.
- PIR¹⁵ - 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 sensor and handset which can also select clock faces and adjust the volume. It can also be used to control other clock functions.
- Two high quality speakers - the Harwell is capable of using .wav files to play chimes and audio.¹⁶
- 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 jack (12V DC rated at a *minimum* of 2A output).

Initial Clock Setup and Operation

After you've completed your clock build, 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 displays and the LED highlighting. The clock does have an auto adjustment for the LED intensity based on the ambient light in the room.¹⁷ 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.¹⁸ You will also want to attach either the GPS or WiFi antenna to the back of the clock. If you're using the WiFi option you will need to enter your network credentials (SSID¹⁹ 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 LEDs will all light up and after about a 15 seconds, the Dekatron tubes will illuminate and do a little dance. You will then be greeted with the first of many available 'faces' of Harwell. To change from one to the next, either use the rotary encoder at the front of the clock or the remote control (see page [151](#) for a full breakdown of the available remote control operations). 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 Dekatron tubes). You can also use the IR remote for the same purpose.

¹⁴ As interesting as the Dekatron is as a piece of vintage neon technology, we thought we'd spruce things up with a little extra bling....which you can turn off if you so desire!

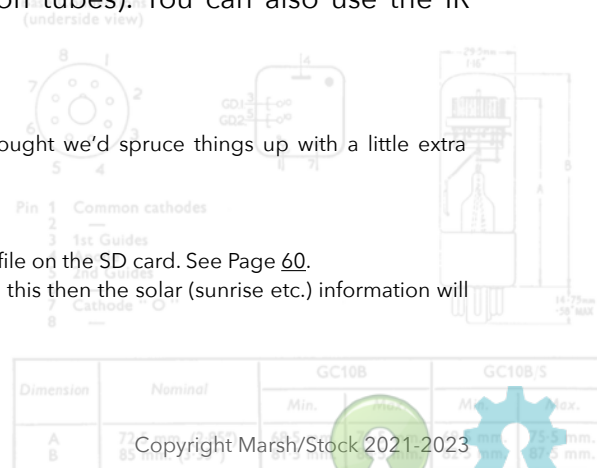
¹⁵ PIR - Passive InfraRed sensor.

¹⁶ Some of it *quite amusing*.

¹⁷ This can be changed, like most other presets in the clock, by altering the *system.ini* file on the SD card. See Page [60](#).

¹⁸ 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.

¹⁹ SSID - Service Set Identifier - The given name to your local WiFi network.



Clock Customisation

One of the core principles embedded in an Open Source device such as Harwell is the ability to customise it by *understanding* how it ticks.²⁰ Faces for the clock are written in a hybrid coding language called 'Nuggle'. As supplied, the Harwell 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 chime set. All of these are provided on the SD card and can be viewed and edited as needed. For a detailed description of the standard Face Distribution set start at page [81](#).

Clock Care and Troubleshooting

Harwell 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 Dekatron tubes are very valuable and (alas) a non-renewable resource, so please only operate the clock out of the way of *stray flying objects*... 😊. As with most complicated electronic devices, sometimes things don't go according to plan.²¹ 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 (see Page [120](#)) to see where things are *hanging up*. The troubleshooting guide in this clock kit construction manual should also be consulted. 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 Dekatron tubes as these are obviously out of our control and have a finite lifespan. We will, however, warranty any issue in the Harwell 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.²² This warranty 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.

About the Harwell Clock and UTC

Throughout this manual and engraved on the clock itself is the the acronym UTC²³. Strictly speaking the clock does not use UTC but uses an approximation (a *very close* approximation) to it. When using a GPS plug-in module to set the time it will be GPS Time as converted by the GPS module, when using a WiFi module it will be time from a SNTP server and when using neither it will be the time that you set as the user. Each of these time values, GPS, WiFi or User will include some delay from what is actually received and used by the clock. For example, when the clock "ticks" one second, it takes about 40mS before the Dekatron glow positions start to be updated. This may not seem much but for time accuracy nerds it is a huge amount of time. Therefore, when you read "UTC" think that it is the clock's approximation to actual UTC. One important matter is that the clock does use this approximation to UTC internally and any changes to your local time

²⁰ See what I did there? Ha ha ha....

²¹ This should be a rare event.....

²² Common sense should prevail here.

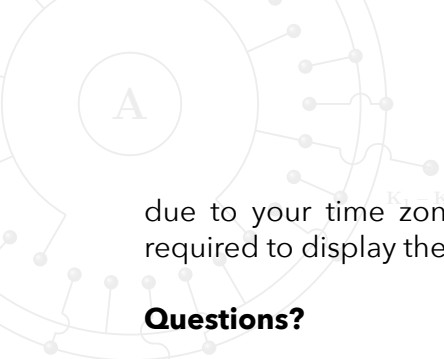
²³ https://en.wikipedia.org/wiki/Coordinated_Universal_Time

Pin 1	Common cathodes
2	—
3	1st Guides
4	Anode
5	2nd Guides
6	—
7	Cathode "O"
8	—



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72				
B	85				

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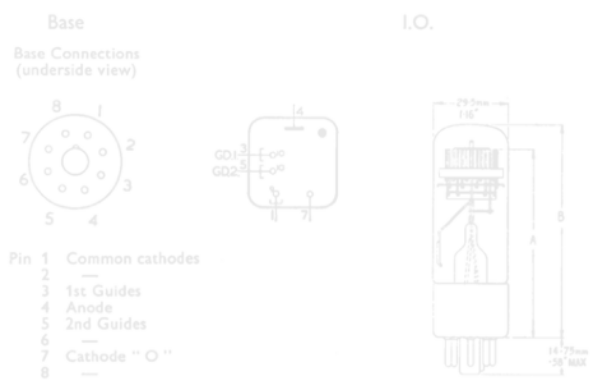


due to your time zone and daylight saving adjustments are applied by the clock when it is required to display the local time.

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 Harwell or any other device offered by us, please contact us at either;

sgitheach.org.uk or stocksclocks.com



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72				
B	85				





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Safety Information and Legal

Information on how to use the clock safely, warranty information and the Open Source philosophy involved.

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The meat and potatoes of the kit - assembling the boards.

Troubleshooting

If things don't go according to plan during the construction.

Assembling The Case

Putting your hard work into a professional looking enclosure.

Harwell Clock Distribution Faces

A list of all the clock 'faces' supplied on the SD card and descriptions of their function.

Harwell Clock Operation Manual

Technical aspects of the Harwell Clock design and its operation. It also covers the basics on how to modify aspects of the clock to suit your tastes and also troubleshooting.

How The Clock Works

Technical description of all the subsystems and circuitry that makes the clock tick along with schematics.

How a Dekatron Works

An Extract From Dance's "Electronic Counting Circuits" describing how these wonderful vintage devices operate.

The Harwell Dekatron Computer

An excerpt by Kevin Murrell of the Computer Conservation Society and The National Museum of Computing, UK on restoration of the original Harwell Dekatron Computer

Nuggle Supplemental For The Harwell V1.3 and Below

Nuggle specific code additions for the clock for firmware versions up to 1.3.0.

Nuggle Supplemental For The Harwell V1.4

Nuggle specific code additions for the clock for firmware versions 1.4.0 and above.

Annexes

Any questions or concerns, then please don't hesitate to contact us at either of the following

sgitheach.org.uk or stocksclocks.com

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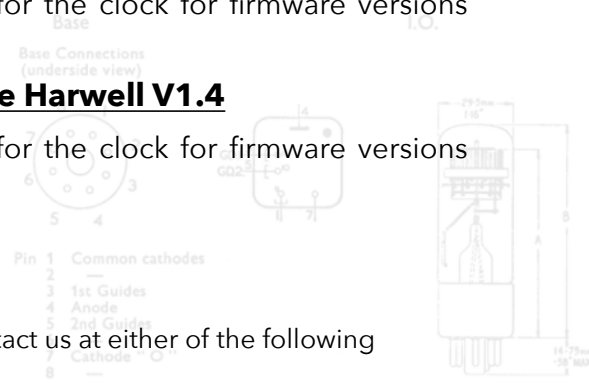
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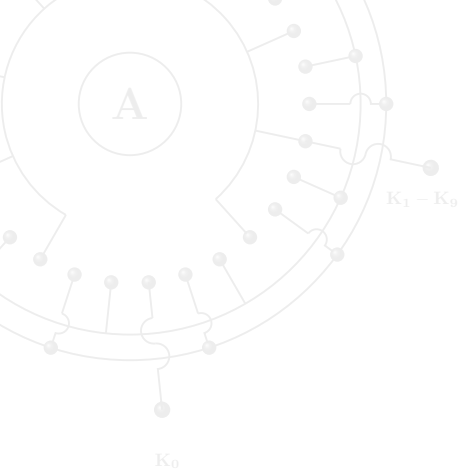
Pages 236 - 251



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75			75.5	
B	85			87.5	

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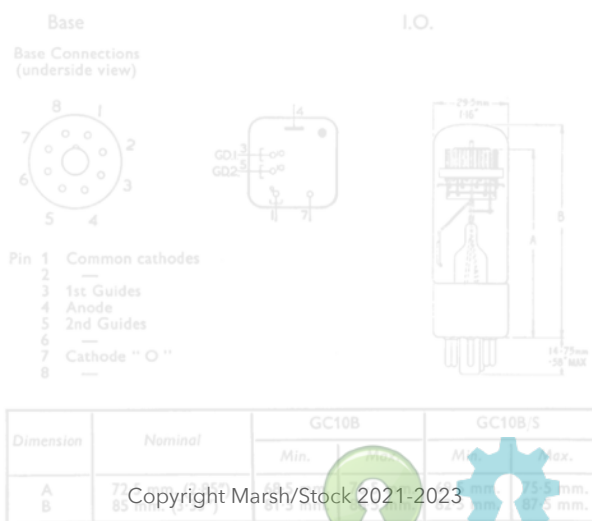




SAFETY AND LEGAL²⁴

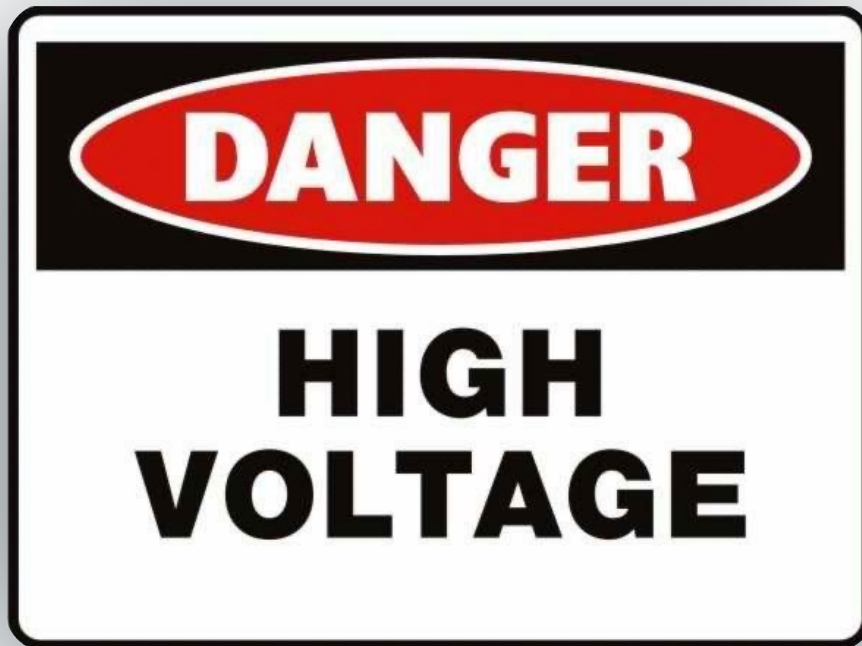
SAFETY, LEGAL & LICENSE CONSIDERATIONS

²⁴ You know, the fun stuff....





Important Safety Information



Safety and Legal Statements

Safety Statement

Like all Dekatron clocks,²⁵ The Harwell uses high voltages in order to operate the Dekatrons. You need to respect this and other hazards inherent in these circuits.

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

Caution! The Harwell generates high voltages in the region of 500V during operation. These voltages are present on the power supply board and base of the Dekatron 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!

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.²⁶

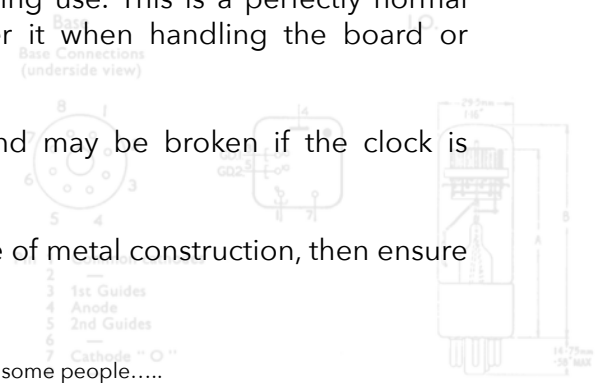
Caution! The Dekatron tube envelope is made of glass and may be broken if the clock is dropped or inadvertently struck.²⁷

Caution! If you have built the clock into your own custom case of metal construction, then ensure

²⁵ Rare beasts they are...

²⁶ We're pretty proud of the way the supplied case came out, but you just can't please some people....

²⁷ We have replacements, but they'll cost you....



Dimension	Nominal	GC10B		GC10B/S	
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B	85				

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that the case is earthed/grounded by connecting it to the screw connector on the PSU board provided for *exactly* this purpose.

Legal Statement

The Harwell 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;

- You may share, copy and redistribute the material in any medium or format.
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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 Harwell 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 any 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 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 Harwell 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.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72				
B	85				

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Atmel Licence

The Harwell firmware makes extensive use of the Atmel²⁸ 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

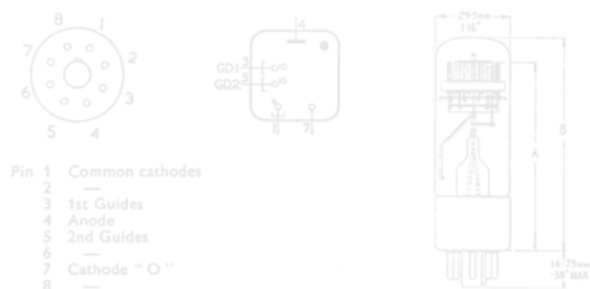
The Harwell uses a custom SAM3X8C core board and as such makes use of a programmer that uses LUFA.

LUFA Library
Copyright © Dean Camera, 2010.

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

²⁸ Now owned by MicroChip

Base Connections
(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72				
B	85				

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

JSMN minimalist JSON parser - <https://zserge.com/jsmn/> - MIT License

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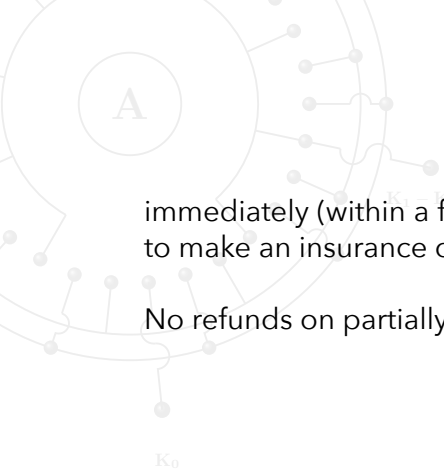
Warranty Information

Upon receipt of the kit of parts, any missing or broken pieces will be replaced. It is incumbent upon the recipient to check the contents in a prompt manner against the supplied parts lists 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 Harwell 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 obsolete technology employed in the Harwell clock (primarily the Dekatron 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

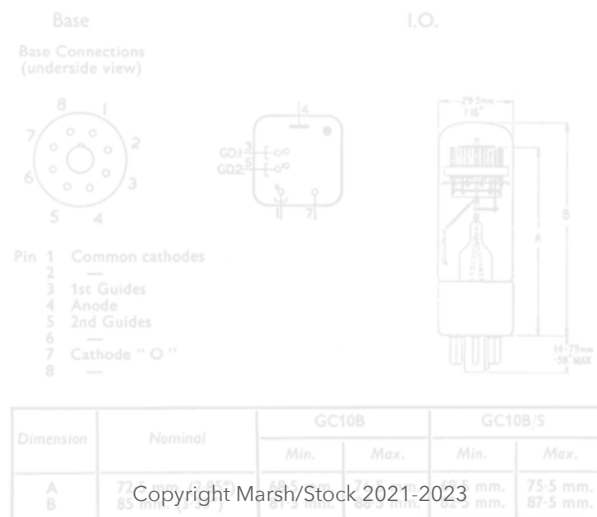
Dimension	Nominal	GC10B		GC10B/S	
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A	75			mm.	75.5 mm.
B	85			mm.	87.5 mm.

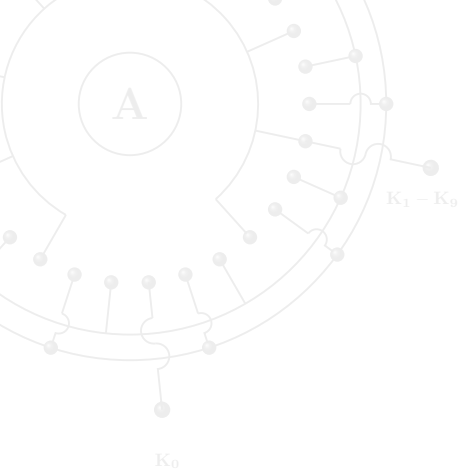




immediately (within a few days of receipt). It is likely that photographic evidence will be asked for to make an insurance claim.

No refunds on partially or fully constructed kits are possible.





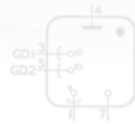
Harwell Clock - Kit Assembly Manual

How to Build Your Dream Dekatron Timepiece

Base Connections (underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	75.5 mm.
B	85			87.5 mm.	87.5 mm.





Harwell Kit Assembly

Introduction

The Harwell Dekatron Clock has five PCBs to assemble:

- K_0 • PSU board
- Main board
- Dekatron driver board
- Front panel board
- Downward firing bling board

There are other boards that are common to several Sgitheach clocks that may need assembly:

- SAM3X8C plug-in board
- SAM3X8C programmer and console board
- Optional WiFi plug-in
- Optional GPS plug-in

This section assumes that all the SMD parts have been fitted and only deals with fitting the through hole and 3D printed parts. Full instructions for these common boards can be found in "Sgitheach - Commoners.pdf" on the Sgitheach Public dropboxes that you can find here...

<http://www.sgitheach.org.uk/harwell.html#documentation>

As a general rule of thumb, it is ideal to solder components in the order of smallest to largest, unless otherwise noted in the instructions. ***This is by no means a beginners electronics kit.*** Although the majority of components are already fitted (SMD), there are still some complicated and detailed steps to follow. There are also high voltages involved, so if you are not comfortable following these instructions please contact us to either return the kit for a full refund (minus shipping costs), or discuss purchasing a fully built unit. If you have any questions, then please don't hesitate to contact us.²⁹

Tools and Hardware Required

- Flat blade screw driver
- Allen³⁰ keys (1.5mm, 2.0mm, 2.5mm and 3.0mm³¹)
- Soldering iron
- Pliers
- Side cutters
- Wire strippers
- DuPont connector crimper³²
- Hacksaw blade
- Fine File
- Long M3 spanner³³

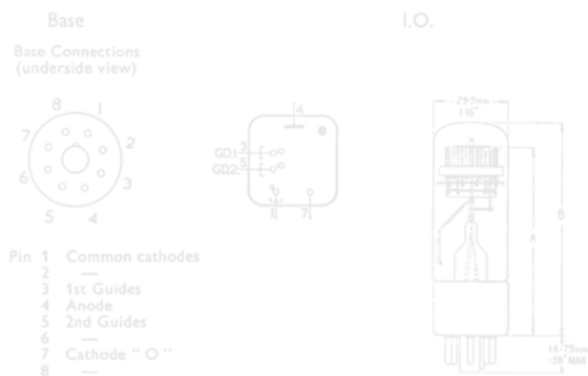
²⁹ web.sgitheach@googlemail.com or stocksclocks@gmail.com

³⁰ Or hex key for our American colleagues..

³¹ The kit includes a long arm 1.5mm key

³² These can be squeezed with pliers and soldered if necessary

³³ A long 3D printed M3 spanner (wrench) is included with the kit



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

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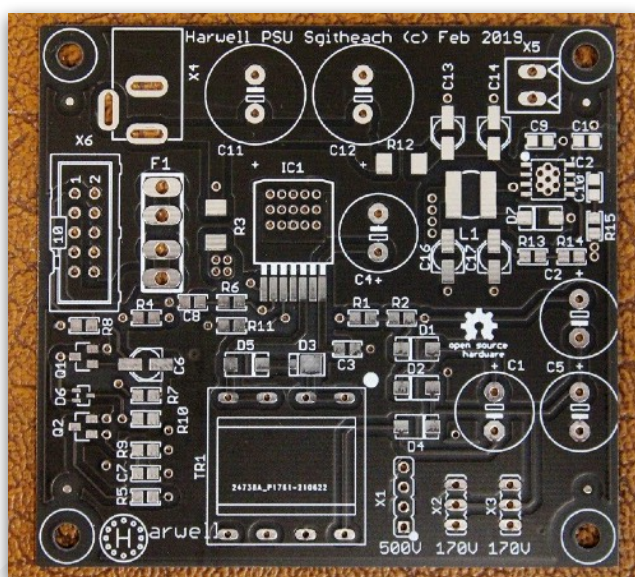


- Hot air gun (for heat shrink tubing)
- Heat shrink tubing, cable ties, solder
- UV cured glue (or superglue or something similar)
- Connecting wire³⁴
- Felt tipped marker pen
- IPA solvent
- USB cables
- Patience³⁵

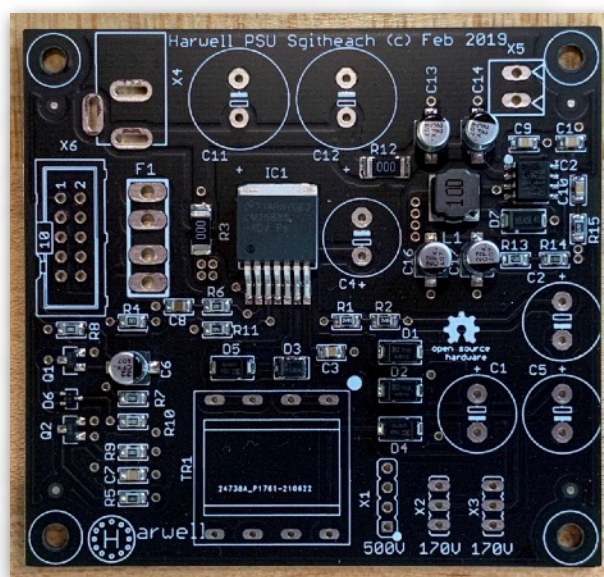
Optional are:

- An Atmel AVR programmer with a 6 way ISP connector and suitable software³⁶

PSU Board Assembly



Unpopulated PSU Board



SMD Populated PSU Board

Parts

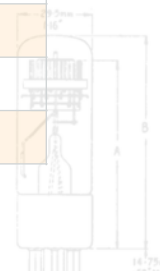
The following parts are required:

Quantity	Parts	Description
1	TR1	Flyback transformer
3	C1, C2 & C5	4µ7 400V electrolytic capacitors
1	C4	100µ 20V low ESR electrolytic capacitor
1	F1	Fuse holder and 2A fuse
1	X1	4 x 1 way 2.54 header pins, 4 x 1 way DuPont connector
2	X2 & X3	3 x 1 way 2.54mm header pins, 3 x 1 way DuPont connector

³⁴ A selection of wire and ribbon cable is included in the kit.

³⁵ Alas, in short supply these days...

³⁶ The AVR's and SAM chips come pre-programmed, the ESP32 is not programmed.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



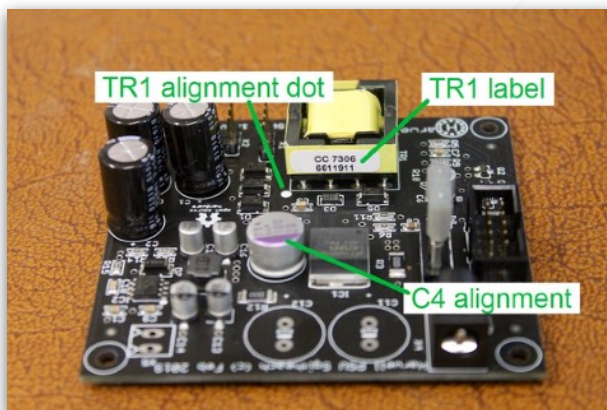
Quantity	Parts	Description
1	X4	2.1mm barrel jack
1	X5	Chassis bond screw connector
1	X6	5 x 2 way IDC socket and plug
1		Connecting wire (red, orange, green), 10 way ribbon cable

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

The following parts are optional and not normally fitted:

Quantity	Parts	Description
2	C11 & C12	2200 μ F 16V electrolytic capacitors

Finished board



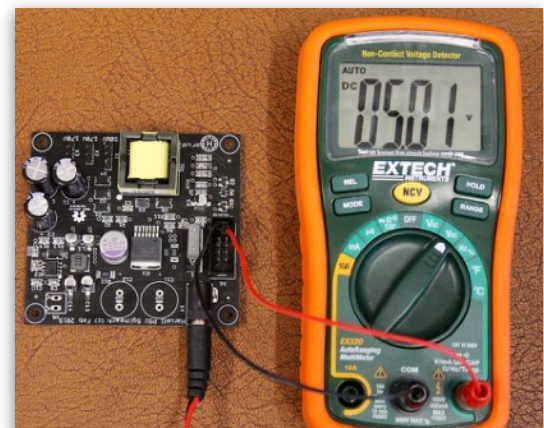
The Completed PSU Board (note **numbers** on X6 for orientation)

Of note;

- Note the orientation of C4.
- Note the orientation of TR1 (the label is on the same side the alignment dot).
- Note the orientation of C1, C2 and C5.
- X5 **must** be fitted if the clock is installed in a metal case, in which case, the connector provides a connection for earth bonding wires.
- C11 and C12 are not fitted.
- Note the orientation of X6 (match to the outline on the PCB).

Initial testing

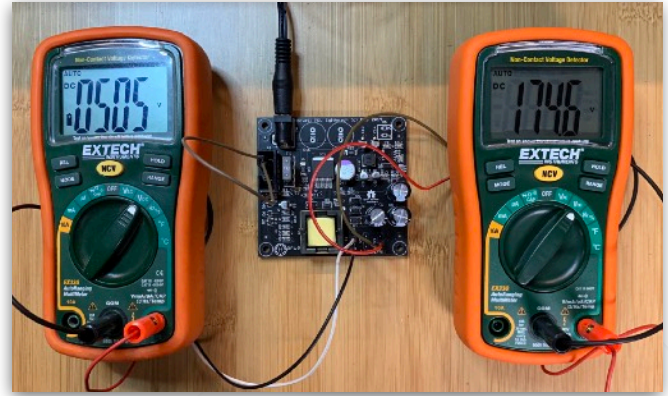
1. Connect a 12V DC PSU and check the 5V PSU works by measuring the voltage between pins 9 and 10 on X6 (see the numbers in **red** on the picture above).
2. Connect a jumper between pin 1 on X6 and pin 3



Dimension	Nominal	Clearance		GC108/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

on X6. This will enable the flyback PSU.

3. **DANGER** the board now has about 500V available.
4. Measure the voltage between the inner and one of the outer pins on X2 or X3 - should be about 170V.
5. Measure the voltage between one of the inner pins and one of the outer pins on X1 - should be about 500V.
6. Remove the pin 1 to 3 link and 12V supply and wait for the 500V/170V outputs to become safe - check with a multimeter.
7. Check if any component has become warm - there should not be any.
8. Optional - go back to step 1 except leave the board running for a while (perhaps 30 minutes) before moving to step 6 and then step 7 again.
9. Power down the clock and continue building...



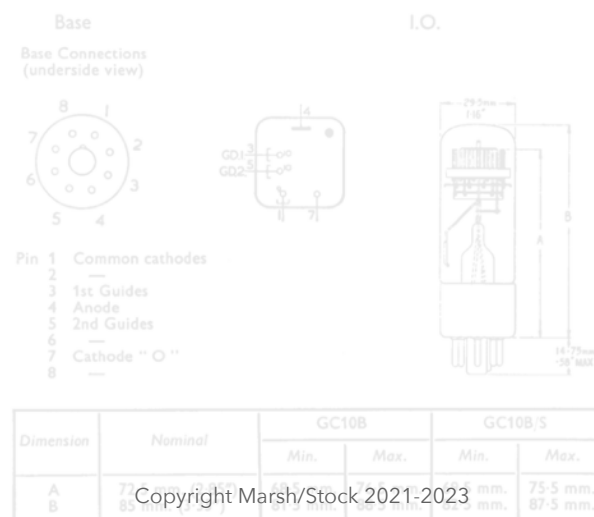
Notes

- The 170V supply to X2 and X3 is connected to the centre pin only, with ground connected to the two outer pins. They are 3 way connectors.
- The 500V supply to X1 is connected to the two central pins only, with ground connected to the two outer pins. It is a 4 way connector. Thus polarity of the HV connectors plugged into X1, X2 or X3 does not matter. Since the 170V are 3 way connectors and the 500V is a 4 way connector it becomes obvious which header to plug into which connector.³⁷
- The wiring to the headers does not have to be 3 cores for X2 and X3 and 4 cores for X1. In both cases only one wire to the inner pin (or pins) for the HV connection, and one wire to one of the outer pins for the ground connection is required.

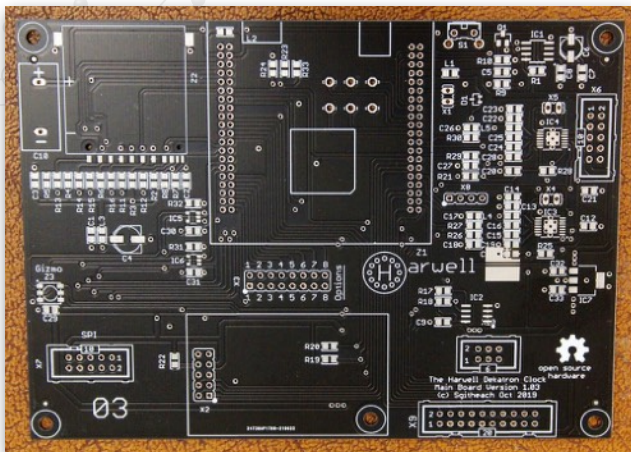
Recommended wiring colours

- Ground - **green**
- 170V - **orange**
- 500V - **red**

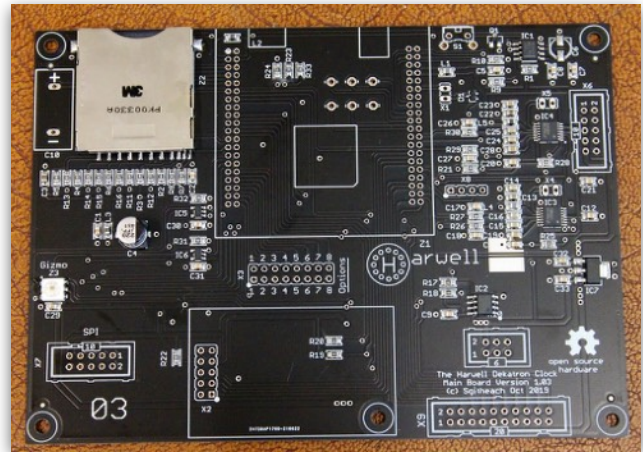
³⁷ Unless you are a complete wazzock.....look it up.



Main Board Assembly



Unpopulated Main Board



With SMD Components Installed

Errata

The keen eyed observer will note the the 2x3 IDC box header to the left of the “Open Source Hardware” logo is missing it’s identifier - this is in fact X10.³⁸

Parts

The following parts are required

Quantity	Parts	Description
1	C10	1F 5V supercap
1	S1	Reset switch
1	X1	2 x 1 2.54mm header pins and jumper
1	X2	5 x 2 way female header
1		M3 11mm stand off, nut, bolt and nylon washer
1		Optional GPS or WiFi plug in module
1	X3	8 x 2 2.54mm header pins and jumpers
2	X4, X5	2 x 1 2.54mm header pins, 2 x 1 DuPont connectors
1	X6	5 x 2 way IDC socket and plug
1	X9	20 x 2 IDC socket and plug
1	X10	3 x 2 IDC socket and plug
2	Z1	40 x 2 2mm female header
1	Z1	SAM3X8C plug in module
1	Z2	2GB SD Card

³⁸ Well spotted...whether this gets fixed or not in another iteration remains to be seen....

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

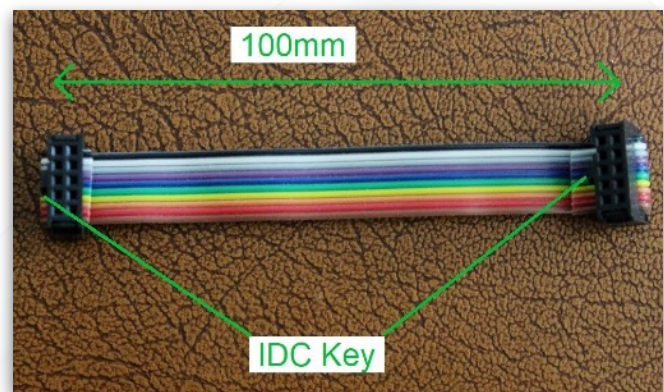


The following parts are optional and not normally fitted:

Quantity	Parts	Description
1	C6	Not specified
1	X7	5 x 2 way IDC socket and plug
1	X8	4 x 1 2.54mm header pins, 4 x 1 Dupont connector

Assemble the ribbon cable as follows:

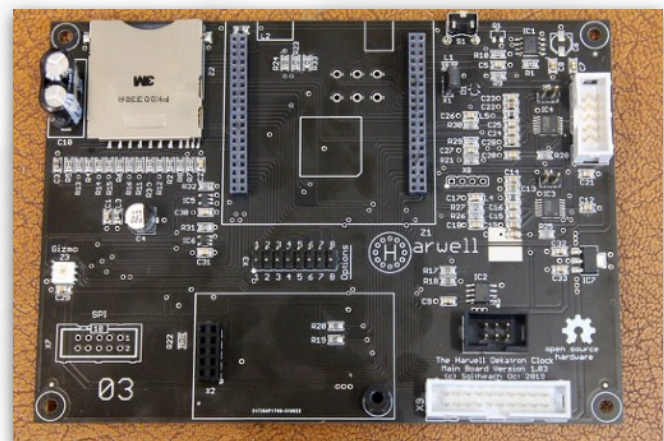
There will be no twists or turns in the cable if you assemble the ribbon cable this way positioning the keys as shown. Do not make the cable substantially shorter than the 100mm distance shown or else it will not reach. Start with a length of about 140mm of ribbon cable.



Finished Board

Of note:

- Note orientation of C10, X6, X9 and X10
- C6, X7 and X8 are not fitted
- When fitting the two 2mm spaced 2x20 headers for Z1 take extreme care. The pins are quite delicate and can be bent under the part quite easily. Ensure that both of the headers are completely flat to the board. I recommend initially soldering just one pin at each end and then checking that all the pins are through their holes and the part is flat before soldering the remaining pins.



Board with all the through hole components fitted

Initial Testing

1. Link the board to the PSU board using a 10 way ribbon cable assembled using the IDC headers.
2. Assemble the two 2x1 DuPont headers and connect to two 8ohm speakers.³⁹ Make the left speaker lead about 250mm long and the right speaker lead about 350mm long. They can be shortened during chassis assembly if you wish. Black is the recommended colour.
3. Plug in the SAM3X8C module and check it has not been plugged in offset on the connector. (If you plug the module incorrectly you are like to cause irreparable damage to it).

³⁹ The speakers are in the front panel parts list

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

4. Using a SD card adaptor write the latest image to the SD Card⁴⁰ (i.e. using a PC etc.).
5. Plug the SAM3X8C programmer/console into the SAM3X8C plug in module.
6. Insert the jumper on X1.
7. Insert jumpers on position 1 (test mode) and position 8 (verbose console) of X3. Do not fit jumpers 2 to 7.
8. Do not install a GPS or WiFi plug-in.
9. Plug the 12V DC lead into the PSU board and apply power.
10. Check nothing gets warm...
11. Program the SAM3X8C⁴¹ using BOSSAC (see separate programming instructions⁴²).
12. Run the console software⁴³ and power cycle the clock (see separate instructions for connecting console software to the clock⁴⁴) if you just programmed it.
 - The clock's console uses standard escape codes to highlight and colour the text sent to the console. If your console software doesn't support these escape codes (Tera Term does) and they appear on the console then consider swapping the console software or fit option jumper 4 which will revert the display to just black and white.
13. Watch the start up script looking for error or warning messages. At this time there should be three:
 - A warning saying that the config CRC check has failed - this is expected as the NVRAM chip where the config data is held has never been used before. This error message should disappear when the clock is restarted.
 - A warning that the flyback has not been enabled - we will do this in a bit.
 - An error that the TWI Dekatron system report has failed - this is not surprising as we have not plugged the Dekatron board in yet.
14. During the start up script the on board tri-colour LED will light up pink⁴⁵ but then turn blue when the script has finished running. The test mode menu prompt '?' should appear.
15. Experiment with the menu commands (start with the HELP command, see the Operations Manual). The LED commands can test the on-board LED module. The commands that require additional hardware to be plugged in will fail or produce odd results. Menu commands you might try include:

⁴⁰ The SD Card will come preloaded with the latest image so you may omit this step or just check that the SD Card is loaded with folders and files

⁴¹ The SAM3X8C comes programmed and tested.

⁴² See the Sgitheach 'Commoners' manual - SAM3X8C Programmer section

⁴³ We use Tera Term: <https://tssh2.osdn.jp/index.html.en>

⁴⁴ *Vide infra*

⁴⁵ The colour in the standard colour list is called "tomato"



- **ADCR** - report on ADC readings⁴⁶
- **BEPS 1,440,1000** - tone for one second from the left speaker
- **CONR** - report on constants stored
- **CONG red** - return value of the red constant in decimal and hex
- **EXPG (sqrt(25)+10)*4** - evaluate an expression
- **OPTR** - option jumper settings
- **OUTR** - digital I/O report
- **STRR 3** - memory usage
- **STRR 1** - SD card report (and so on.....)⁴⁷



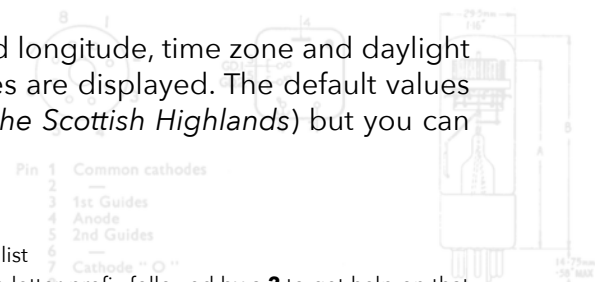
Testing the Main Board

16. Plug the USB connector on the SAM module into a PC (or whatever) and check that the SD Card appears as a removable drive.
17. If using the WiFi module then edit the file `/system/wifi.ini` to use your local network SSID and password. You can also edit the file to put your other preferences for DNS and SNTP servers, although the default values will work fine.
18. You can also edit `/system/locale.ini` to set your latitude and longitude, time zone and daylight saving settings and other preference values on how values are displayed. The default values will work fine for now (*but the clock will think it is still in the Scottish Highlands*) but you can edit them later.

⁴⁶ You may see that the chip temperature is a bit weird - this is on the firmware bug fix list

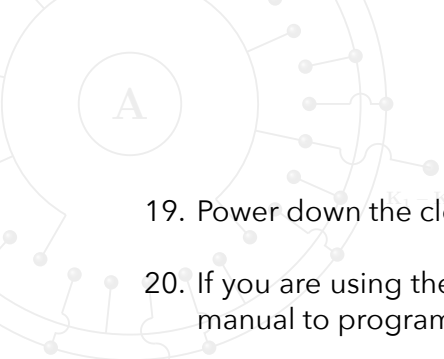
⁴⁷ Enter **HELP** and a list of available commands will be given. Enter a command three letter prefix followed by a **?** to get help on that command e.g. **SUN?**

Base Connections
(underside view)

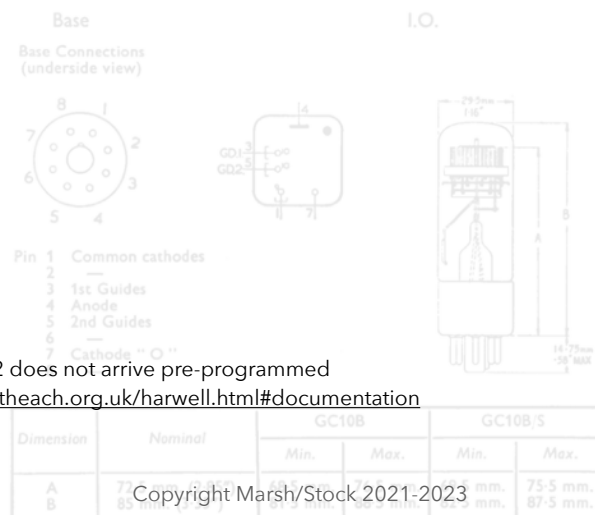
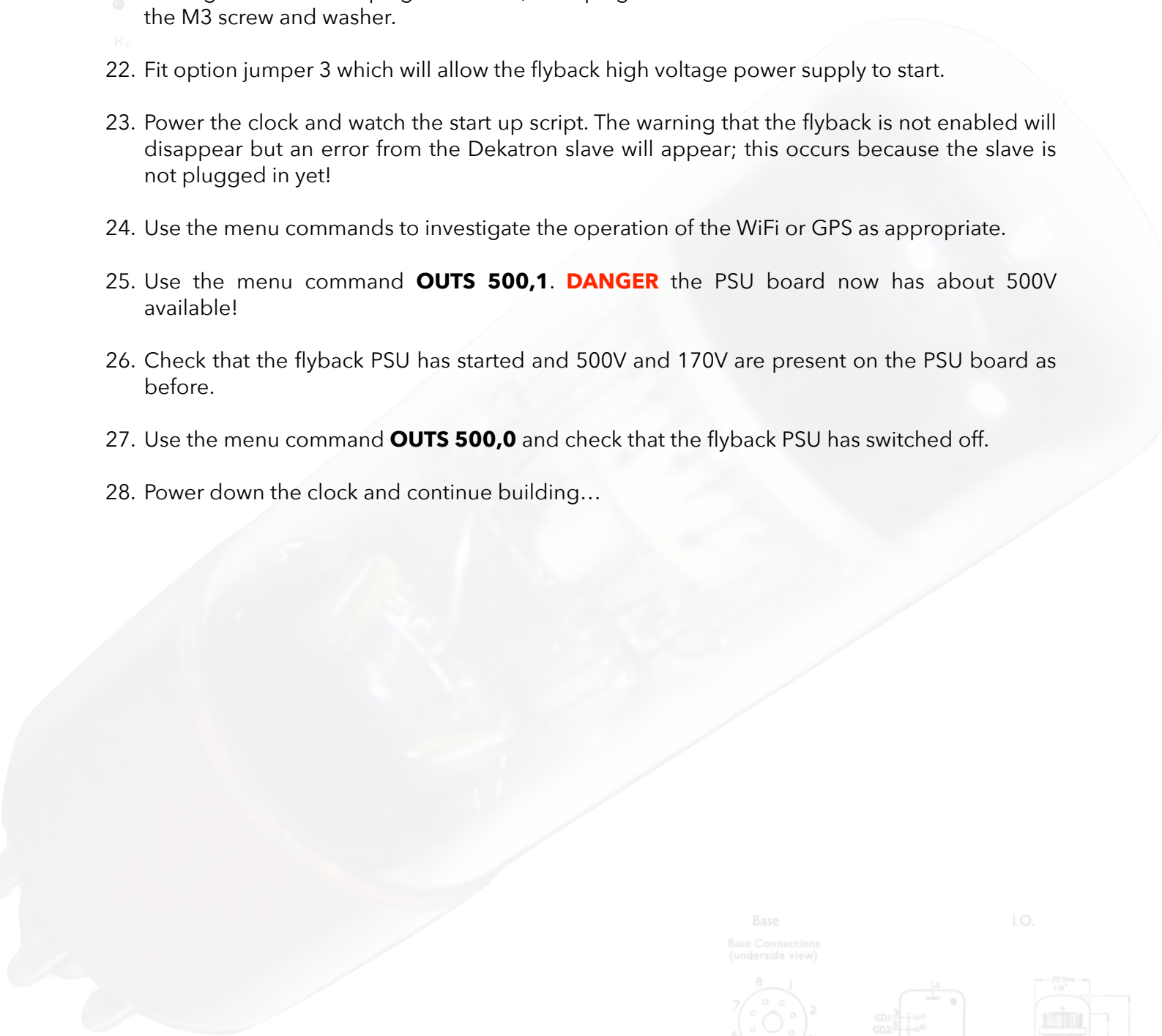


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





19. Power down the clock.
20. If you are using the WiFi module then you can now follow the instructions in the WiFi module manual to program⁴⁸ the ESP32.⁴⁹
21. If using a WiFi or GPS plug in module, then plug it into the main board and fix it down with the M3 screw and washer.
22. Fit option jumper 3 which will allow the flyback high voltage power supply to start.
23. Power the clock and watch the start up script. The warning that the flyback is not enabled will disappear but an error from the Dekatron slave will appear; this occurs because the slave is not plugged in yet!
24. Use the menu commands to investigate the operation of the WiFi or GPS as appropriate.
25. Use the menu command **OUTS 500,1**. **DANGER** the PSU board now has about 500V available!
26. Check that the flyback PSU has started and 500V and 170V are present on the PSU board as before.
27. Use the menu command **OUTS 500,0** and check that the flyback PSU has switched off.
28. Power down the clock and continue building...



⁴⁸ The WiFi board requires some assembly before it can be programmed so the ESP32 does not arrive pre-programmed

⁴⁹ See the Sgitheach 'Commoners' Manual - Section on ESP32 Plug In - <http://www.sgitheach.org.uk/harwell.html#documentation>

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	



Further Initial Testing

This stage is to further test the GPS or WiFi options if fitted. If the interfaces have been working correctly in last stage then this testing is perhaps unnecessary. However, if there are problems then using these tests may help. They simplify the amount of clock functions that are running so there is less risk of interaction problems:

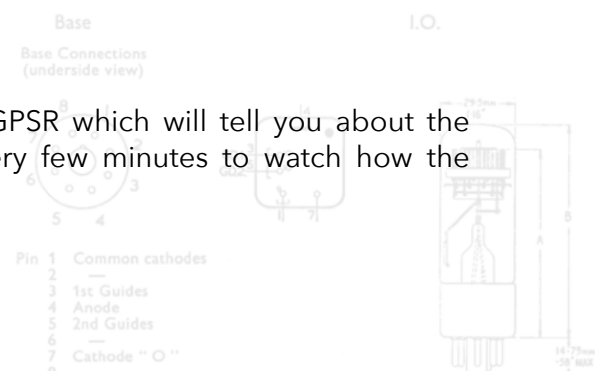
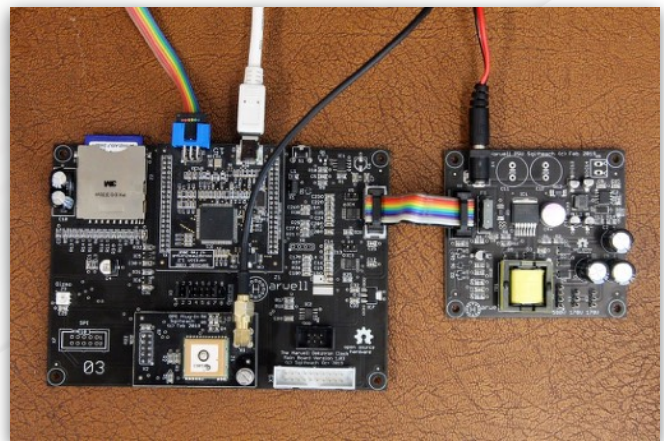
1. Fit option jumper 2 which will put the GPS or WiFi interface into “pass through” mode.

WiFi Pass Through Testing

1. Connect the console terminal and set the console to use CR+LF for both received and sent new lines.
2. Power the clock boards.
3. The clock will partially start up but then say “WiFi Pass-Through Mode”. You will be offered a cursor but with no input prompt as with normal clock menu operations (there is no menu now). The console is connected directly to the serial interface on the ESP32 module. You can now enter ESP32 AT interface commands.
4. Enter the command AT and press enter. The ESP32 module should reply OK. You can now use other AT commands found in the ESP32 AT Manual.⁵⁰
5. When finished power down the clock, remove option jumper 2 and set the console back to CR for newlines.

GPS Pass-Through and Further Testing

1. Connect the console terminal.
2. Power the clock boards.
3. The clock will partially start up but then say “GPS Pass-Through Mode”.
4. The clock will now echo all of the GPS NMEA statements to the console. There is no interaction with the output.
5. When bored, power down the clock and remove option jumper 2.
6. Power the clock again and try out the GPS command GPRG which will tell you about the current GPS data. You can try this command again every few minutes to watch how the satellite data changes.

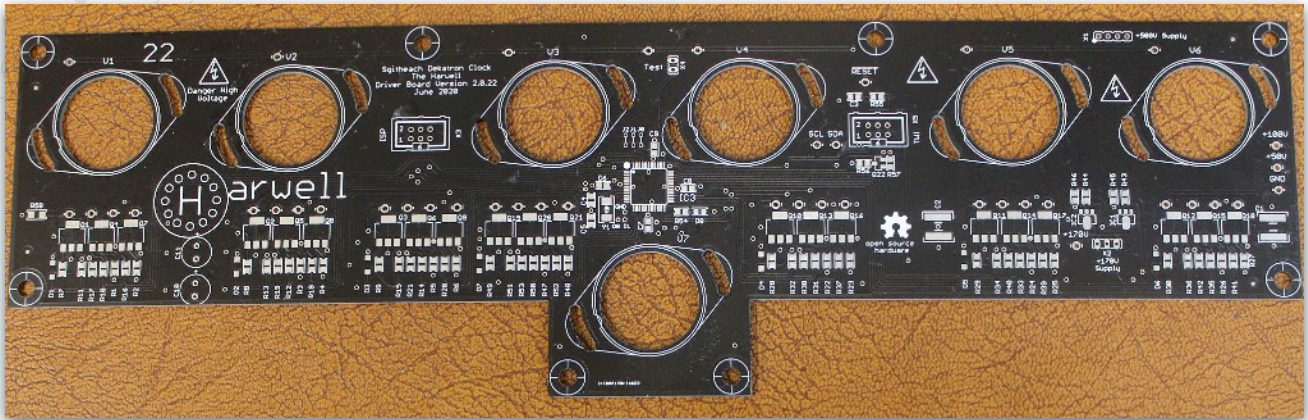


⁵⁰ See the Sgitheach ‘Commoners’ Manual - Section on ESP32 Plug In - <http://www.sgitheach.org.uk/harwell.html#documentation>

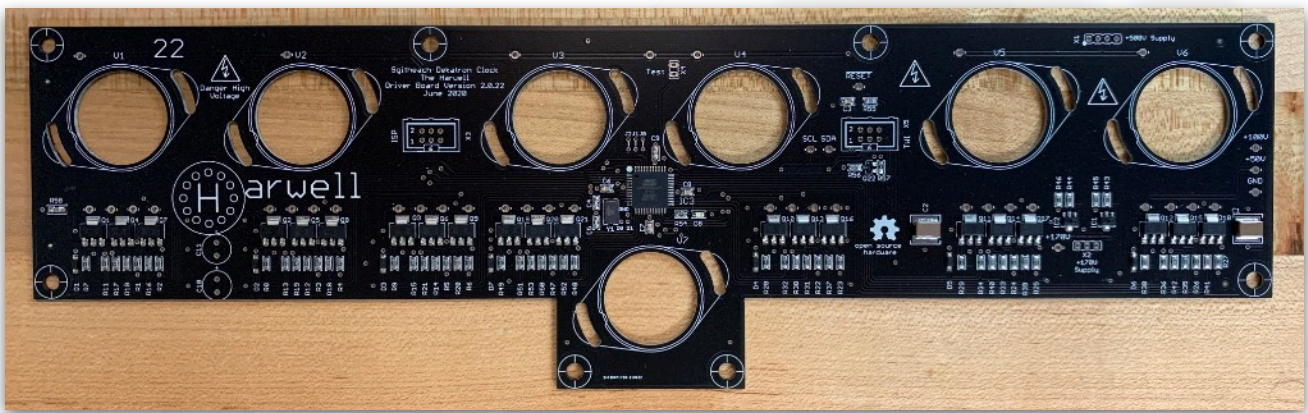
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Dekatron Driver Board Assembly



Unpopulated Dekatron Driver Board



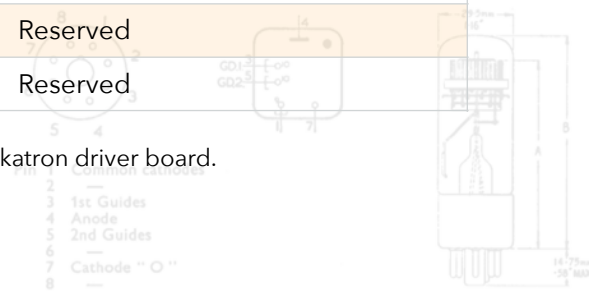
Dekatron Driver Board with SMD Components Fitted

The Dekatron board is designed to use several different tube types. As such, there are three jumper positions situated between V3 and V4 on the board. Jumpers J0, J1 and J2 inform the Dekatron driver board which types of Dekatrons have been fitted.

J0	J1	J2	Interpretation
Open	Open	Open	Force the bootloader to run (1)
Closed	Open	Open	V1 - V6 are GC10B or GC10/4B or similar, V7 is GC12/4B
Open	Closed	Open	V1 - V7 are GC10B
Closed	Closed	Open	Soviet OF4 (2) - Currently not enabled
Open	Open	Closed	American 6802
Closed	Open	Closed	Reserved
Open	Closed	Closed	Reserved
Closed	Closed	Closed	Reserved

Notes:

- (1) See the manual section on programming the ATMEGA324PA on the Dekatron driver board.
- (2) It does what it says on the tin. Do not use!



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Driver Board Assembly for British GC10B and GC12/4B Dekatrons

The following parts are required.

Quantity	Parts	Description
2	C10 & C11	10 μ F 160V electrolytic capacitors
7	R54 - R60	620k Ω 0.5W through hole resistors
6	V1 - V7	Octal sockets
6	V1 - V6	GC10B Dekatrons or variants
1	V7	GC12/4B Dekatron
14		M3 x 6mm screws
42		M3 SS washers
14		M3 nuts
1		Wire, shrink wrap and cable ties
1	X1	4 x 1 2.54mm header pins, 4 x 1 DuPont connector
1	X2	3 x 1 2.54mm header pins, 3 x 1 DuPont connector
1	X3	3 x 2 IDC socket
1	X4	2 x 1 2.54mm header pins and jumper
1	X5	3 x 2 IDC socket and plug



Dekatron Driver Board Completed - British GC10 and GC12/4B Dekatron



Errata

R61 (22k 1206 SMD resistor near V1 and Q1) is labelled on the silkscreen as R58.⁵¹

In particular

- Orientation of C10 and C11.
- Orientation of V1 - V7 sockets - see notes that follow.
- R54 - R60 should be mounted close to the octal socket.
- Orientation of X3 and X5.
- Fit J0, and leave J1 or J2 open.⁵²

Notes

The octal sockets are mounted with the key way (between pins 1 and 8) pointing in a south west direction when viewed from the front and the board in its normal orientation.

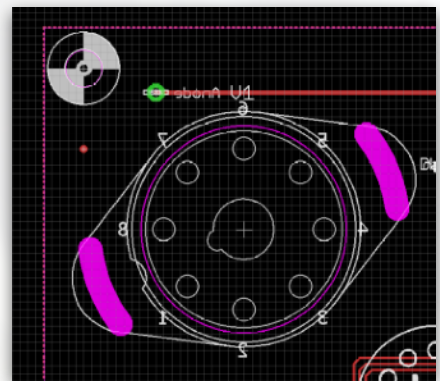
Example: V1 viewed from *component* side (see right).

The octal sockets are secured using M3 screws, washers and nuts with the *nut on the top* (component, socket flange) side and the *screw on the reverse side*. Three washers are used with each nut and bolt with one washer used as a spacer between the PCB and the socket flange. The complete stack comprises:

- Screw (on the reverse side)
- Washer
- PCB
- Washer
- Octal socket flange
- Washer
- Nut (on the component side)

Do not fully tighten, only to the point where the socket can still rotate with some friction.

GC10xx/GC12/4B wiring - wire colours are unimportant, just be consistent.⁵³



V1 - M3 nuts on **component** side

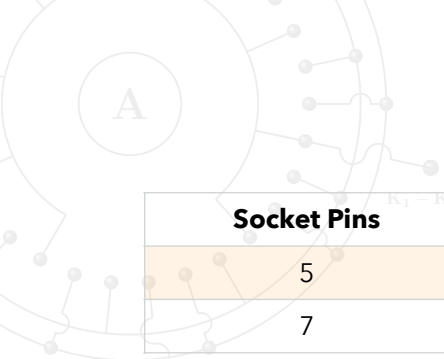
Socket Pins	Function	PCB Pad Label ⁵⁴	Standard Wire Colour
1, 2, 6 and 8 linked	Common cathodes	K	Brown
3	Guide 1	G1	Blue
4	Anode	Anode via 620kΩ resistor	Red (extra length for V7)

⁵¹ B'gg'r't

⁵² These jumpers will be used to tell the MEGA that different Dekatrons, such as American or Soviet, are in use. With only jumper J0 fitted, the MEGA expects GC10B or GC10/4B Dekatrons in the V1 - V6 positions and a GC12/4B in the V7 position.

⁵³ You can use a single colour - the wiring looks rather sharp when all in black but you must be more careful that the socket pins are wired to the correct pads on the PCB.

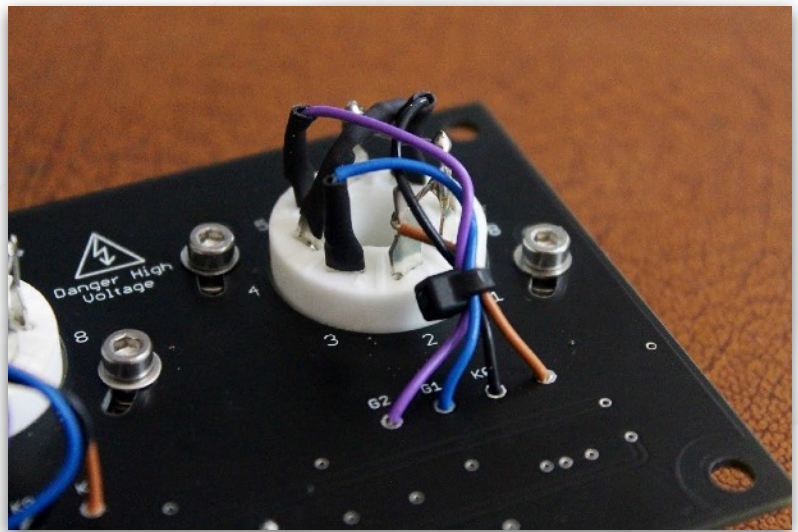
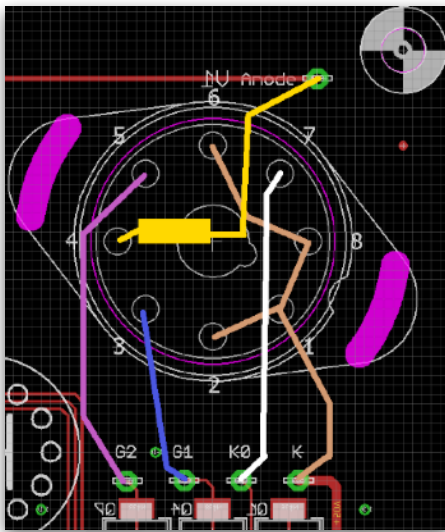
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



Socket Pins	Function	PCB Pad Label	Standard Wire Colour
5	Guide 2	G2	Purple
7	Cathode 0	K0	Black

Notes:

- Mount the resistor close to pin 4 (shown in yellow below). Sleeve the resistor and wire in heat shrink.
- Use shrink wrap to make the socket connection look neat.
- Use cable ties to neatly bundle the wires.
- Make sure there is a little 'give' in the wires to allow moderate rotation of the socket for Dekatron alignment if necessary.



V1 wiring as viewed from the back of the PCB. Note the socket head screws are on the rear of the board.

- Repeat for V2 to V7.
- The pads for V2 are below (S)
- The pads for V3 are below and right (SE)
- The pads for V4 are below and left (SW)
- The pads for V5 are below (S)
- The pads for V6 are below (S)
- The pads for V7 are above and right (NE)

Special note: the anode connection for V7 is a long wire and the need to mount the resistor close to the socket is most important with this tube.

Base Connections (underside view)

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Driver Board Assembly for British GC10B Dekatrons

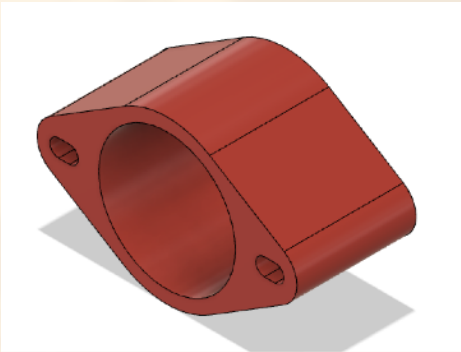
The assembly for using 7 GC10B Dekatrons is identical to the assembly when using 6 GC10B and a GC12/4B Dekatron except that only J1 is fitted and J0, J2 are left open.

Driver Board Assembly for Soviet OF4 Dekatrons

The Soviet OF4 Dekatron is not supported mechanically, electrically or in the firmware at this time.⁵⁴

Driver Board Assembly for American 6802 Dekatrons

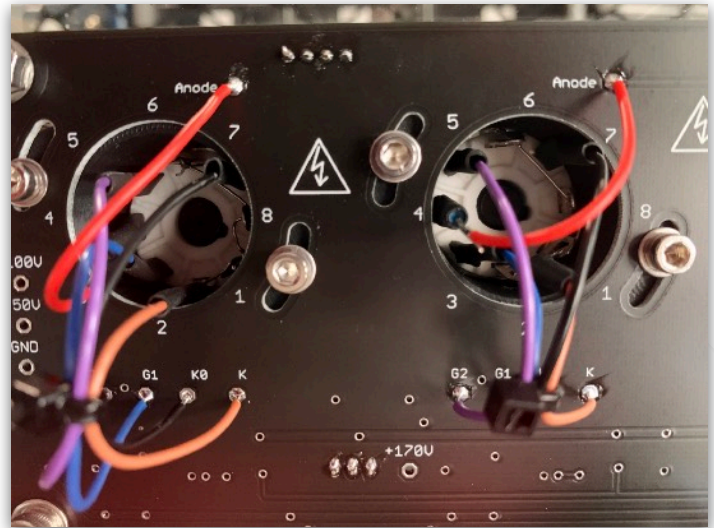
Parts required.

Quantity	Parts	Description
2	C10 & C11	10 μ F 160V electrolytic capacitors
7	R54 - R60	620k Ω 0.5W through hole resistors
7	V1 - V7	Octal sockets
7	V1 - V7	6802 Dekatrons or substitutes
7	6802 Tube Spacers	
42		M3 SS washers
14		M3 x 30mm screws
14		M3 nuts
1		Wire, shrink wrap and cable ties
1	X1	4 x 1 2.54mm header pins, 4 x 1 DuPont connector
1	X2	3 x 1 2.54mm header pins, 3 x 1 DuPont connector
1	X3	3 x 2 IDC socket
1	X4	2 x 1 2.54mm header pins and jumper
1	X5	3 x 2 IDC socket and plug

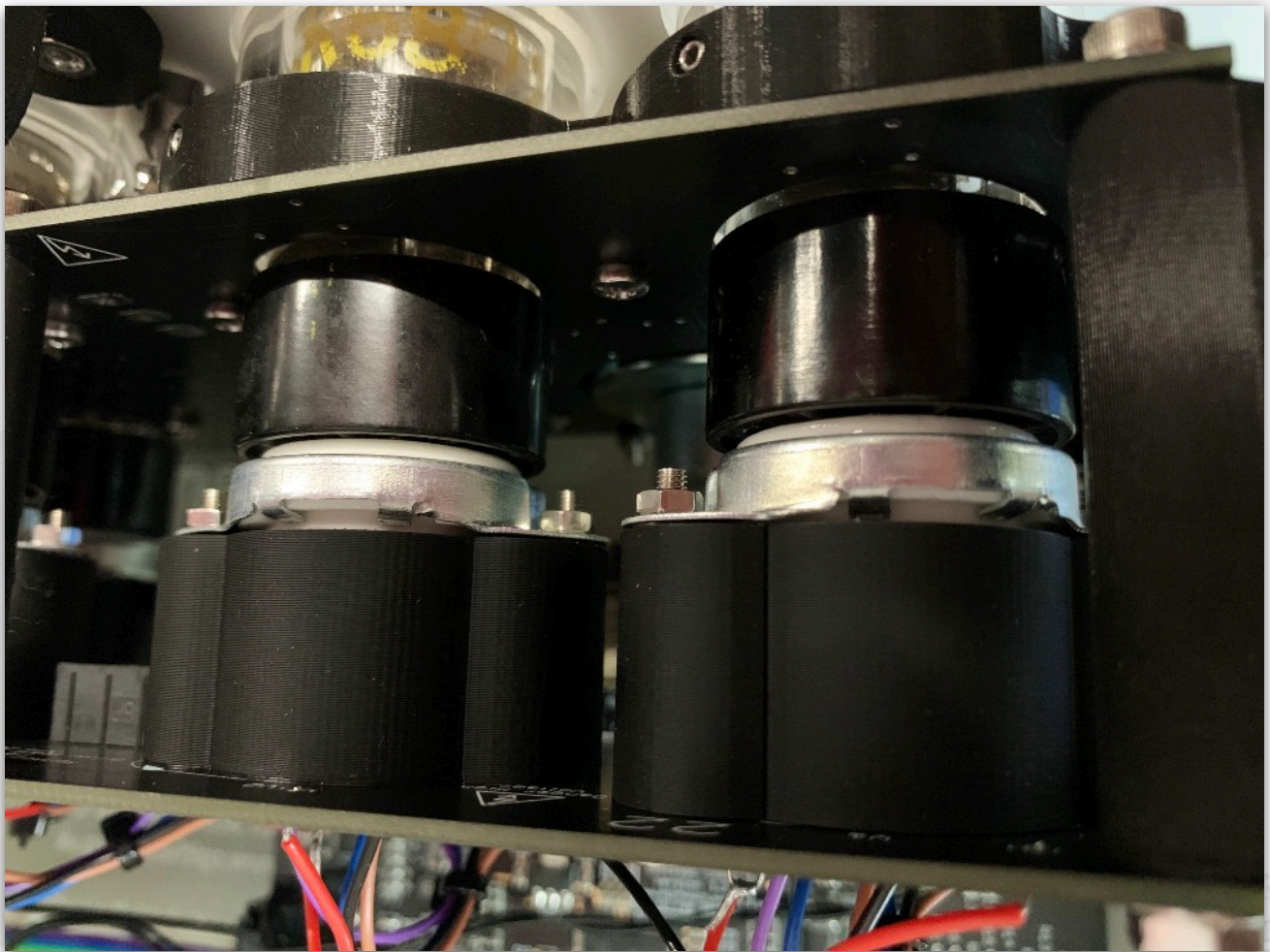
⁵⁴ Why you may ask? Well, the quality control on the OF4 style tubes leaves a lot to be desired. They tend to not have clear faces and quite a bit of tolerance in their glass bulb linearity. That, and it's a lot of bloody work to redo the display boards to accommodate the different pin layout etc...

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

The assembly is identical to that detailed for the GC10B and GC12/4B Dekatrons, however, due to the shorter bulb of the 6802 a spacer is needed to offset them. Also note that J2 is closed and J0 & J1 are left open (see Table on Page 25) After wiring a socket, pass the wires through the spacer and attach to the board using the same method as for the aforementioned GC10B/GC12/4B type. Remember the socket heads should be on the rear of the board as pictured. Also, make sure that you have the socket orientated correctly with the 'key' pointing to the "8 o'clock" position when viewed from the front.



Here you can see the tubes inserted into the offset sockets on the Dekatron board.⁵⁵



- Pin 1 Common cathodes
- 2 1st Guides
- 3 Anode
- 4 2nd Guides
- 5 Cathode "O"
- 6
- 7

⁵⁵ The observant amongst you will note that these spacers look a *little different* to the pictured ones in the table - these were prototypes which worked just as well thank you very much... :)

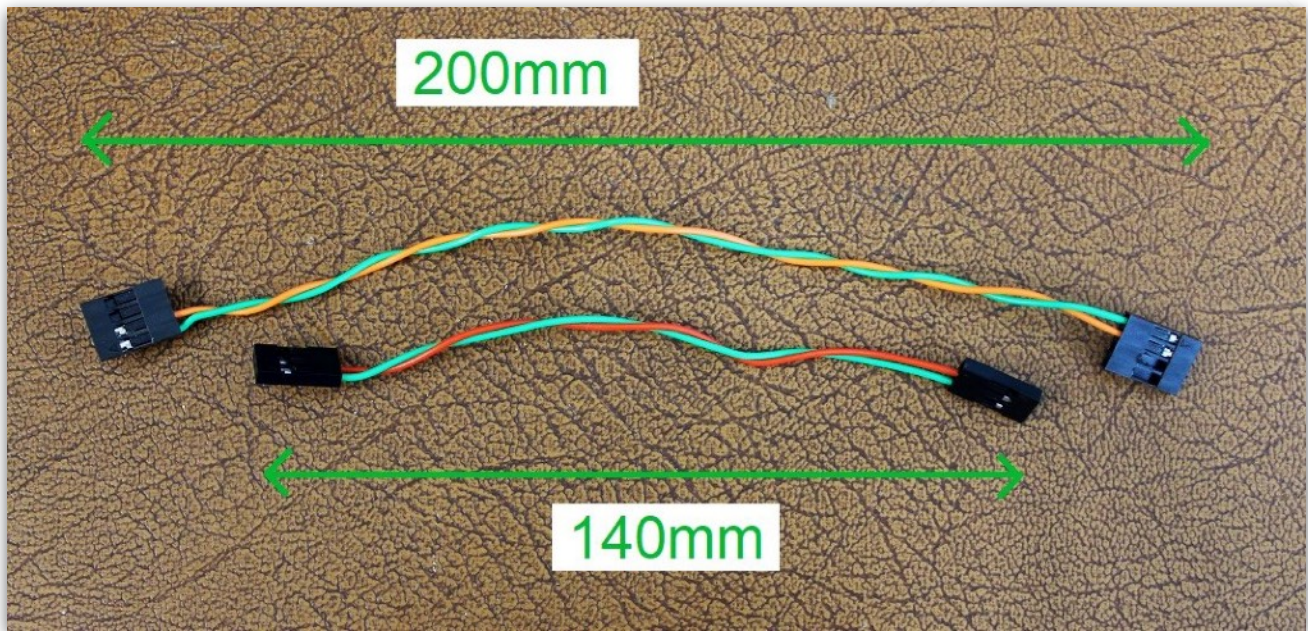
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



Lead preparation for all Dekatron types

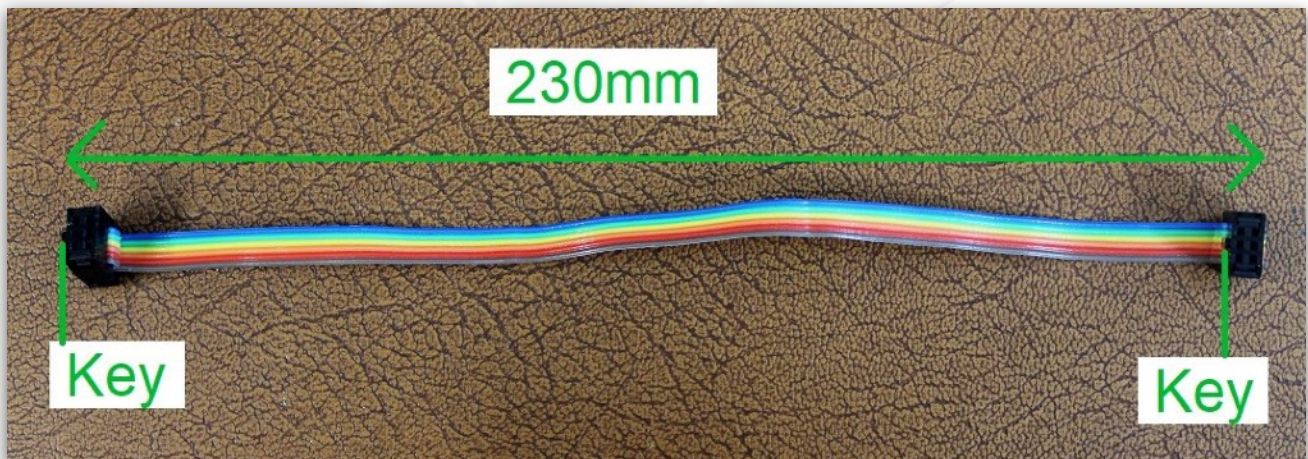
Prepare leads for the 500V and 170V connections to the PSU Board:

- 170V connection - 3 way connector - green to one of the outer - red to the centre pad
- 500V connection - 4 way connector green to one of the outer - orange to one of the centre pair.



Dekatron Board HT Cables

Assemble the 6 way ribbon cable to connect the Dekatron driver board to the main board: Start with a length of about 270mm ribbon cable and pay attention to the key orientation.



Technical diagrams showing the pinout and dimensions of Dekatron tubes. The pinout table is as follows:

Pin	1	2	3	4	5	6	7	8
	Common cathodes	—	1st Guides	Anode	2nd Guides	—	Cathode "O"	—

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Programming the microcontroller

See the separate manual section on programming ATMEGA324PA. Instructions on how to compile the bootloader and firmware for this are provided at the end of this manual (see Operations Section 5 [here](#)). The clock comes with the microcontroller preprogrammed with the latest firmware version.

The board must be powered to program the AVR. The TWI connector X5 should be linked to the main board connector X10 using the assembled ribbon cable. The two high voltage connections do not have to be made for programming.

Initial Testing

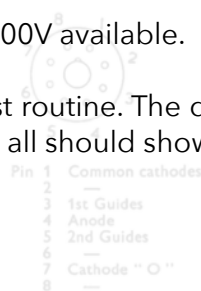
The following steps are taken to test the board:

1. Insert the Dekatrons in their respective sockets noting that V1 to V6 are GC10B or GC10/4B or similar 10 cathode tubes and V7 is a GC12/4B 12 cathode tube.⁵⁶ **Caution** - When inserting the tubes, **DO NOT USE THE GLASS BULB** as the means to insert them, this will lead to breaking the glass vacuum seal.⁵⁷ Only use the base of the tube to install them into the sockets. This is standard operating procedure for vintage tubes of this type. They can sometimes be reticent to go in the sockets. You can gently open the socket pins with a screwdriver if necessary.
2. Connect the 170V supply to connector X2 from the PSU Board connector X3.
3. Connect the 500V supply to the connector X1 from the PSU Board connector X1.
4. Make sure jumpers 1, 3 and 8 are fitted to the option headers on the Main Board.
5. Connect the Dekatron Board TWI header to the main board using a 6 way ribbon cable.
6. A jumper should be placed on the Test header X4 on the Dekatron Board.
7. The clock Main Board should be connected to a serial console terminal in the same way as when the Main Board was tested.
8. The 12V power can be applied to the PSU Board and you can watch the start up process on the terminal. The complaint that the Dekatron TWI connection does not work should not appear.
9. During the start up sequence the Dekatrons are enumerated and the Dekatron report should not give any errors.
10. **DANGER** both the Dekatron and PSU boards have about 500V available.
11. All of the Dekatrons should light and enter a repeating test routine. The dot on the tubes are spun, moved etc. All the Dekatrons should be glowing and all should show some movement.

⁵⁶ Other combinations are accounted for - See page 25.

⁵⁷ And possibly cutting yourself with broken glass....

Base Connections
(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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12. You can see the Dekatron report again using the menu command **DEKR**.

13. Enjoy the display for a while and then power down the clock.

14. Remove the jumper from X4.

Further testing

1. Power up the clock again (now with the Dekatron Test jumper X4 missing) and watch the start up sequence again.

2. The Dekatron report will now show that the test jumper is open.

3. At the menu prompt give the command **OUTS 500,1**

4. **DANGER** both the Dekatron and PSU boards have about 500V available.

5. You will see that the Dekatrons light in random positions. Give the command **DEKK** which will zero all of the Dekatrons.

6. The Dekatrons are not in test mode but the clock main board is in test mode. Therefore you can now give commands to see the effects on the Dekatrons. Enter the command **DEK?** to see the available options. Examples are:

- **DEKN 0,0,0,100** - this will slowly spin the first Dekatron
- **DEKN 1,0,1,10** - fast spin the next tube in the opposite direction
- **DEKP 2,15, linear,1000** - 1 second pendulum on the next tube
- **DEKS 3,27,1,20** - show or highlight a position
- **DEKW 4,0,10,100** - highlight two positions
- **DEKO 5, 2, 10000** - spin a tube once very, very slowly
- **DEKN 6,0,1,5** - very fast spinner

7. Play some more, trying other commands.

8. When tube 5 completes its single spin use the **DEKR** command and note that cathode zero now shows true.

9. If you're using NOS Dekatrons, you may notice that the glow doesn't lay at the end of the cathode and can appear anywhere along the length of the metal guide. Let's call this *sleeping sickness*.⁵⁸ We recommend letting all the Dekatrons spin for 24 hrs to *wake them up*. This will also be a good soak test⁵⁹ for the electronics. Use the **DEKN** command to get them all running. Enjoy the light show!

10. Then power down the clock.

Base Connections
(underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



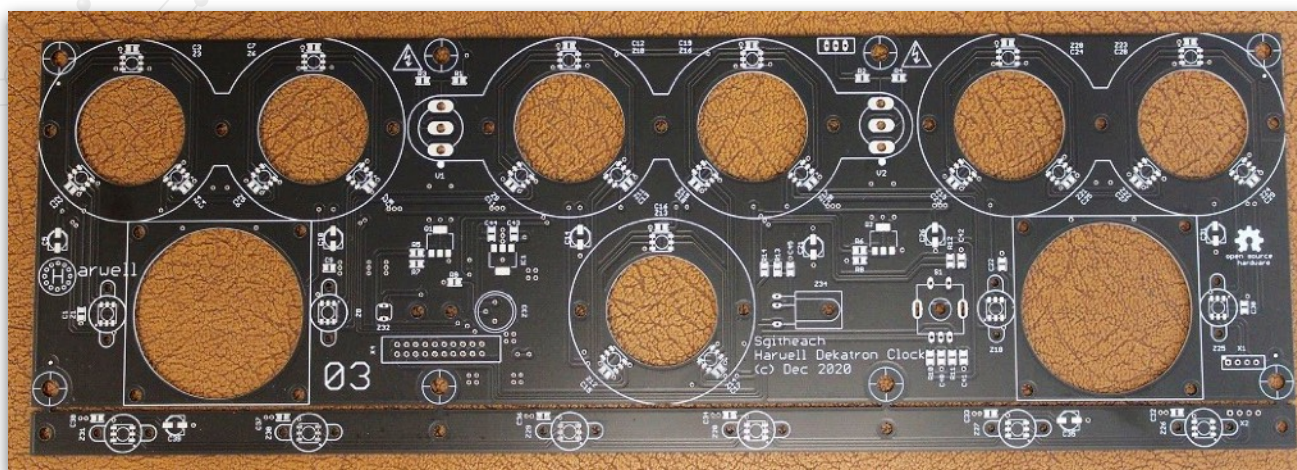
⁵⁸ They've probably been sitting on a dusty shelf or warehouse for over 60 years....

⁵⁹ https://en.wikipedia.org/wiki/Soak_testing

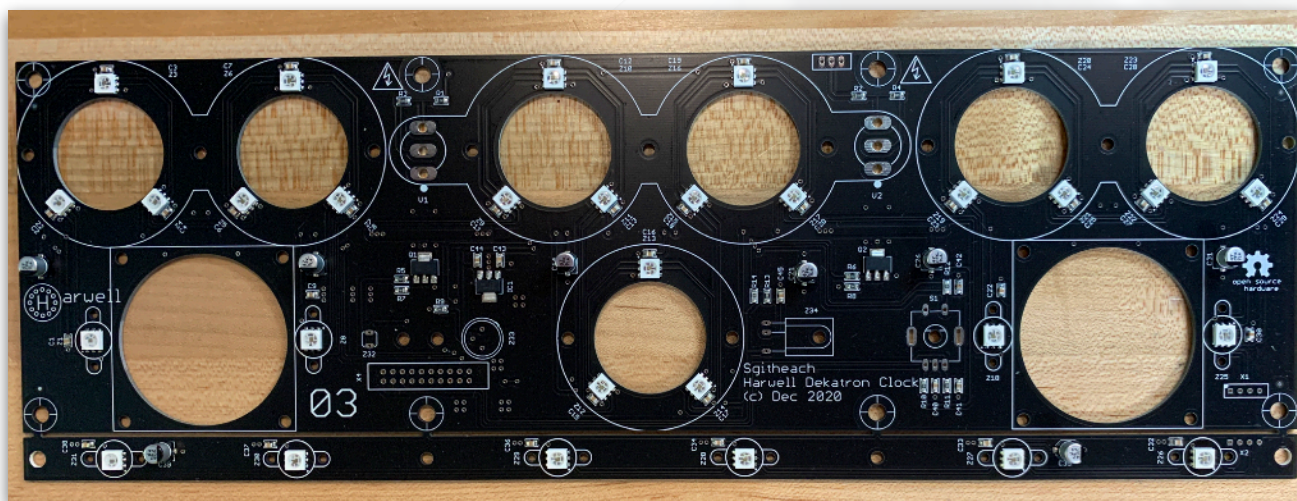
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Front Panel and Downward Firing Bling Board Assembly



Unpopulated Front Panel (above) and SMD Populated (below)



N.B Connectors X2 and X4 are mounted on the back of the PCBs and not on the component side - see the instructions and photos below

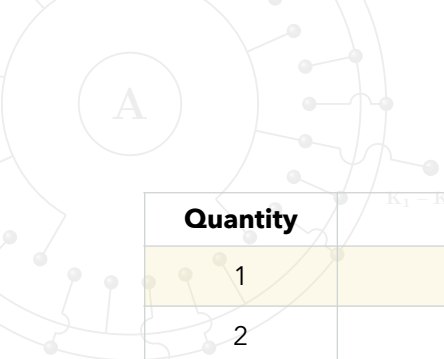
Parts

The following parts are required.

Quantity	Parts	Description
4		3D printed Dekatron collars (all different)
11		M3 x 12mm screws
18		M3 square nuts
7		M3 x 6mm grub screws
1	S1	Rotary encoder
2	V1, V2	MTX90 thyratrons
1	X1	4 x 1 way 2.54 header pins, 4 x 1 way Dupont connector

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





Quantity	Parts	Description
1	X2	4 x 1 way 2.54 header pins, 4 x 1 way Dupont connector
2	X3	3 x 1 way 2.54 header pins, 3 x 1 way Dupont connector
1	X4	10 x 2 IDC socket and plug, 20 way ribbon cable
4	Z1, Z8, Z18, Z25	Speaker bling diffuser with acrylic light guide
6	Z26 - Z31	Downward firing bling diffuser
20		M2 x 6mm screw and nut
1	Z32	LDR
1		LDR and PIR 3D printed stand off
2		M3 x 10mm screw, nylon washer and square nut
1	Z33	PIR module
1	Z34	IR receiver
1		IR receiver stand off 3D printed part
1		M3 x 10mm screw, nylon washer and square nut
2	Z35, Z36	8R speakers
8		M3 x 12 mm screw, nylon washer and nut
2		Speaker 3D printed stand off

Notes

- The speakers, Z35 and Z36, have no board connections but are wired directly to 2x1 DuPont connectors that plug into X4 and X5 on the Main Board
- See [Annex B](#) for identification of the 3D printed parts

Finished Boards



Component side - All through hole parts installed and 3D printed parts fitted

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





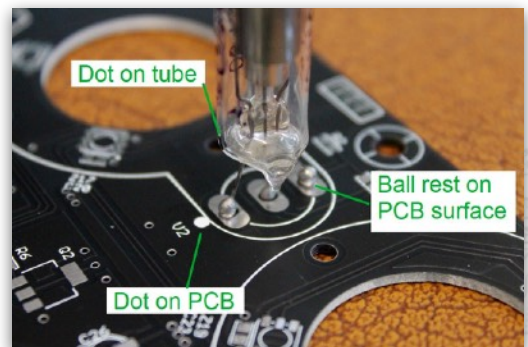
Rear (copper) side - Highlighted in red are X1, X3 and X4 fitted on this side

Detail of the downward firing bling board - X2 fitted on the rear side away from the LED's and their 3D printed diffusers



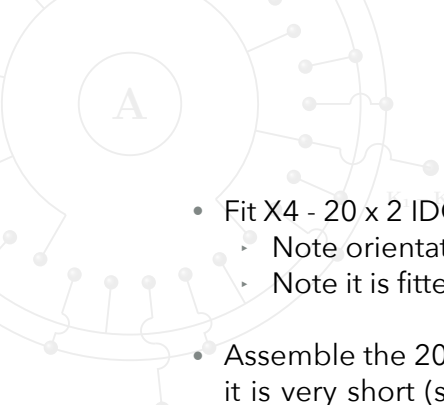
In Particular - Stage 1

- Before assembly, split the boards (cut with a hacksaw) and clean the nubs from both boards (by filing).
- The various sensors are mounted on the PCB. They are mounted on 3D printed stand-offs to bring them forward and close to or through the case front as required. Some of the sensors will need their leads extending (resistor lead off-cuts or thin wire are ideal). Note that they are attached by using a square M3 nut that is inserted into the base of the 3D printed part which is then used to screw the part in place from the rear of the PCB. Use the **black** nylon washers for the PIR/LDR mount.
- Check that the 3D printed parts fit in place as expected and do not foul on any SMD part. **Do not fit them** until the LED bling modules have been tested - see below.
- The MTX90 thyratrons are soldered with their balls resting on the top surface and with the painted dot on the body aligned to the dot on the PCB.
- **Fit X1 to the back** of the PCB and not the component side.
- **Fit X2 to the back** of the downward pointing bling LED board.
- **Fit X3 to the back** of the PCB.



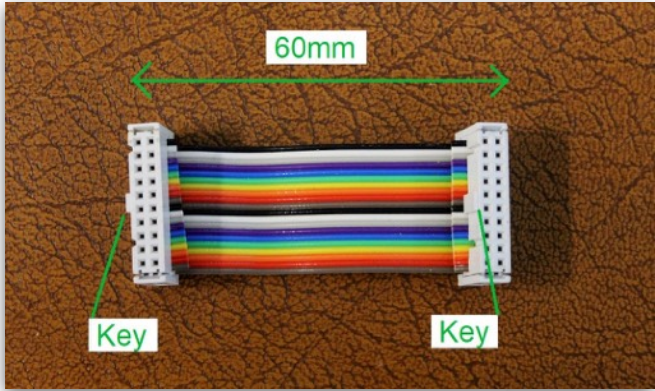
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



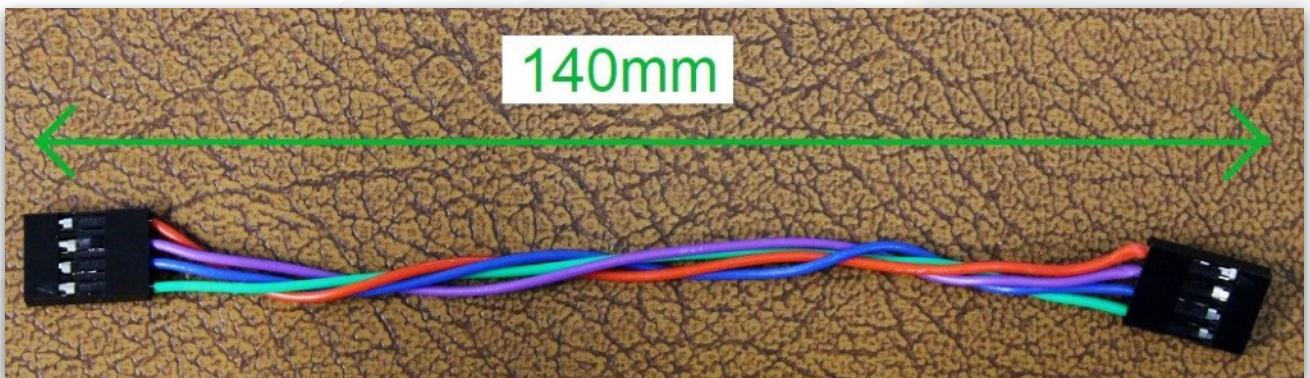


- Fit X4 - 20 x 2 IDC box header - **to the back of the PCB.**
 - Note orientation!
 - Note it is fitted to the back of the PCB and not the component side.⁶⁰

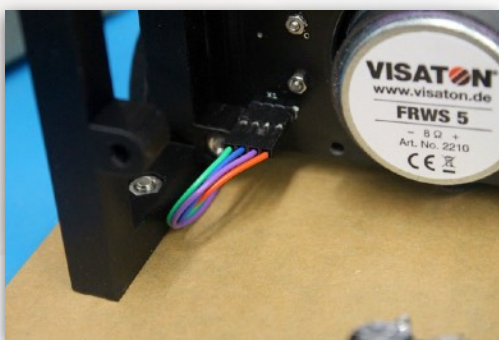
• Assemble the 20 way ribbon cable. Follow this picture carefully or else the cable won't fit as it is very short (start with about 100mm of ribbon cable): The 20 way cable links the front panel board (X4) to the main board (X10) as follows:



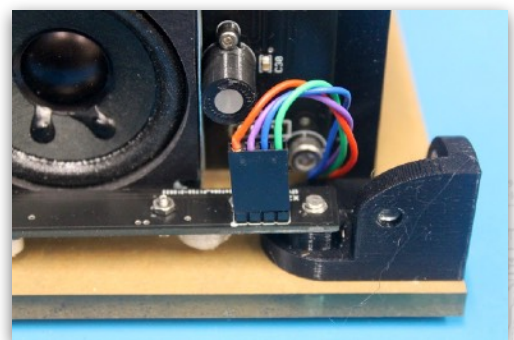
- Assemble the 4 way link between the front panel board (X1) and the downward firing bling board (X2).



The actual colours are unimportant but you must know which way around the cable plugs in. **Failure to plug this link in correctly will probably destroy all the LEDs on the downward firing bling board and possibly damage other parts of the clock (see pictures below).**



Note that the **red** wire is closest to the speaker on both the rear and front of the clock for reference.



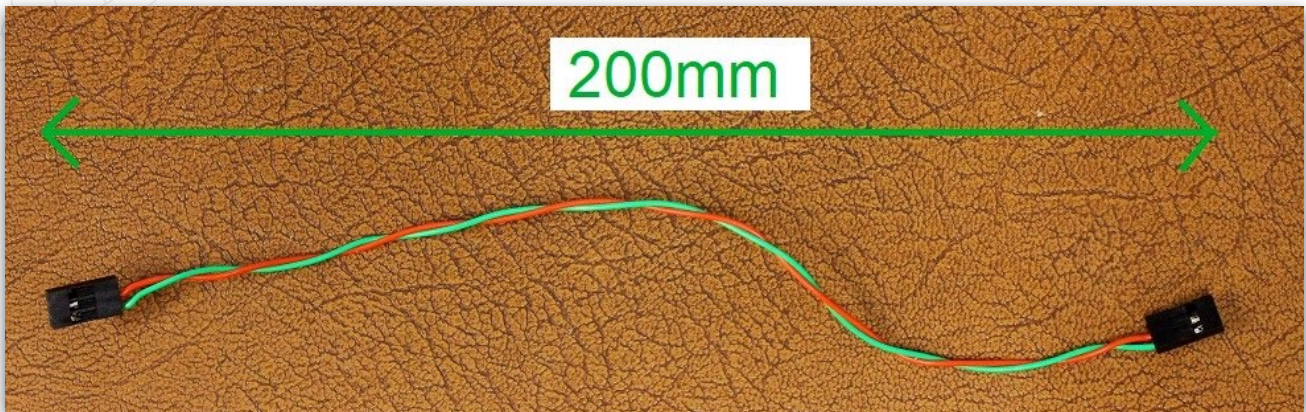
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

⁶⁰ You have been told! (more than once).

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



- Assemble a lead for the 170V connection to the PSU Board: 3 way connector - green to one of the outer - red to the centre.



Initial Testing - Stage 1

1. Plug in the assembled 20 way ribbon cable to connect X4 to X10 on the Main Board.
2. Plug the 4 wired 4x1 DuPont connector lead into the downward firing bling LED board. N.B. This connector can be plugged in two ways round. Ensure that the plug is correctly orientated with the same order of the wires leaving the front panel board as arrive at the plug.⁶¹ See the notes above!
3. The Main Board should be connected to the PSU Board by the 10 way ribbon cable.
4. There is no requirement to have the Dekatron Board connected. There is no requirement to connect the 170V link cable to the PSU board.
5. Power the PSU board and using the console issue LED bling commands to make sure all of the LED modules can be illuminated. Example commands are: (which will light all 32 bling LEDs in red, green and then blue).

LEDS 0,0xffffffff,red
LEDS 0,0xffffffff,green
LEDS 0,0xffffffff,blue



⁶¹ Failure to do this will probably smoke all the LEDs on the board....don't do it!

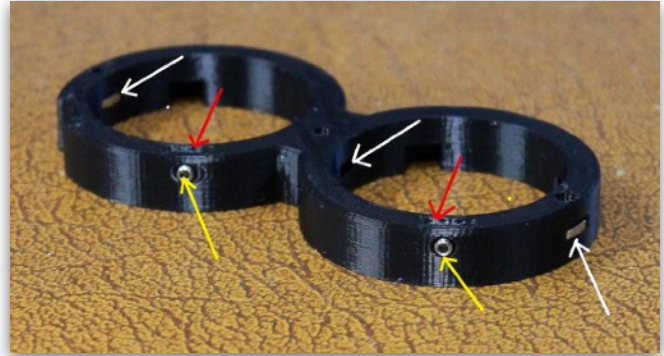
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

6. Power down the clock.
7. Disconnect the board and continue assembly.

In Particular - Stage 2

- Cover the 6 downward firing bling LEDs with their diffusers.
- Fit the four Dekatron light guide collars:

- Prepare the four 3D printed Dekatron light guide collars by fitting two (one on Dekatron V7) M3 square nut into the vertical slot indicated (red) and a 6mm grub screw into the side hole (yellow). This will hold the square nut in place. Repeat for the other.

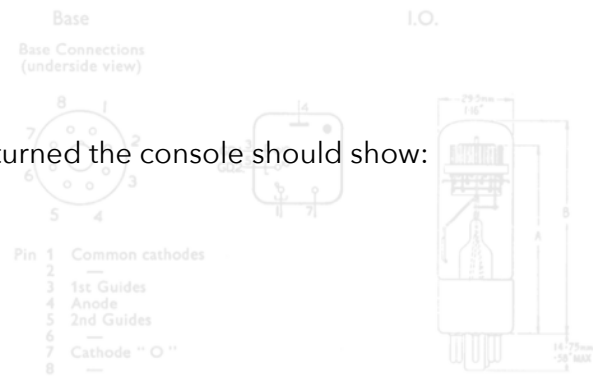


- Fit three (two for Dekatron V7 light guide collar) M3 square nuts into the horizontal slots (white) making sure that the thread in the nut is aligned to the hole in the underside of the 3D printed collar.
- Secure each light guide to the Front Panel PCB using three M3 12mm socket head screws (two on Dekatron V7). Two collars are very similar but have cut-ways so as not to foul the PCB corner mounting holes.

- Fit the Dekatron light guides (from the case kit if you purchased it, or else your own light guides) into the collars. Tighten the grub screw to *gently* hold the light guides in place. Due to tolerances in the available acrylic, they may be a pretty good friction fit to start with.
- After all the light guides are in place and secured, mount the speakers to the front of the PCB on the speaker spacers. Take the speaker leads out to the rear of the PCB using the gap between the speaker and the PCB. The nuts and washers go behind the PCB and the screws through the speaker mounting hole and spacer from the front. You will note that you may have to screw these in tightly to clear the lip of the speaker surround. This is by design.

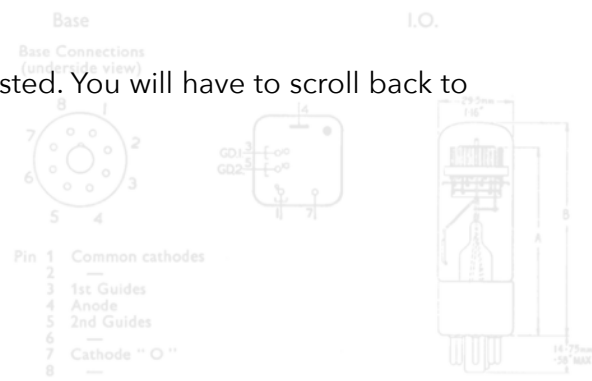
Initial Testing - Stage 2

1. Reconnect the boards together, this time plug the speakers into the Main board and the 170V voltage connector into the PSU board.
2. Test the board using menu commands.
3. Test the rotary encoder using the **ROTC** command. When turned the console should show:
 - U turned clockwise
 - D turned anti-clockwise
 - + turned clockwise when depressed
 - - turned anti-clockwise when depressed



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

4. Press `esc`
5. Test the LDR with the command **LDRC** and the console will display a list of the LDR brightness value. These should be 0 in a dark room and 100 when well illuminated
6. Press `esc`
7. Test the PIR with the command **PIRC** and the console will display an exclamation mark ! each time the PIR registers a movement.
8. Press `esc`
9. Test the IR handset with the command **IRHC** and the console will display a character assigned to the key press on the handset:
 - D from CH-
 - C from CH
 - U from CH+
 - < from ||<<
 - > from >>|
 - - from -
 - + from +
 - = from EQ
 - H from 100+
 - T from 200
 - 0 from 0
 - 1 from 1
 - and so on
10. Press `esc`
11. Test the colons by using the command **OUTS 500,1** to turn on the flyback convertor and then the command **COLS 1,100** to fully light the left colon and **COLS 2,10** to dimly light the right colon.
12. Use the command **OUTS 500,0** to turn off the flyback convertor.
13. Test the speaker connections by playing a chime file, try **CHMU liberty** ... enjoy!
14. While playing give the command **VOLS 1,5** and the volume will reduce, use **VOLS 1,10** to restore it.
15. Give the command **CHMR** and all the chime files will be listed. You will have to scroll back to look at all the entries.⁶²
16. Power down the clock and continue with the testing.



⁶² At the time of writing this manual, there are over 550 chime files..

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

Whole Clock Testing

It should now be possible to test the whole clock together. This can be done with the boards laid out on the bench or partially assembling the clock into its case.

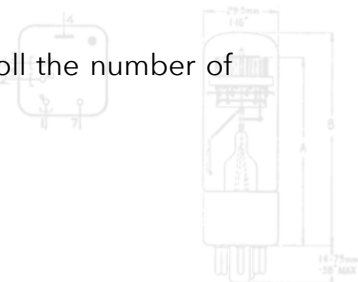
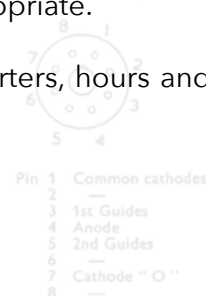
Initial set up

- Remove option jumper 1. Only option jumpers 3 and 8 should be fitted now.
- The PSU should be connected to:
 - The Main Board using a ribbon cable.
 - The two 170V connections to the Dekatron Board and the Front Panel Board.
 - The 500V connection to the Dekatron Board.
- Additionally connected are:
 - The ribbon cable from the Main Board to the Front Panel Board.
 - The ribbon cable from the Main board to the Dekatron Board.
 - The two speaker connected to the Main Board.
- The Test Jumper on the Dekatron Board should not be fitted.
- The seven Dekatrons should be inserted and the M3 screws and bolts holding their sockets in place should be slack enough to allow the Dekatrons to be rotated but held in place by friction.

First Power Up

- Power up the clock!
- The console output should not show any errors.
- As the clock starts up the Dekatrons will light and be enumerated as in test mode.
- The clock will wake from sleep and then face 1 will run (unless you have edited the initial face number on the SD card). Face 1 is a blank face so the Dekatrons will switch off.
- Enter the command **FACS 5** and press enter, this selects face 5:
 - Dekatrons will show hh:mm:ss while the colons flash and for 10 seconds show dd:mm:yy with the colons steady.
 - The function Dekatron will indicate time or date as appropriate.
 - When showing the time the clock will tick.
 - The clock uses "Derby Chimes" and will chime the quarters, hours and toll the number of hours.
 - Bling is a simple rotating colour pattern.

Base Connections
(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	

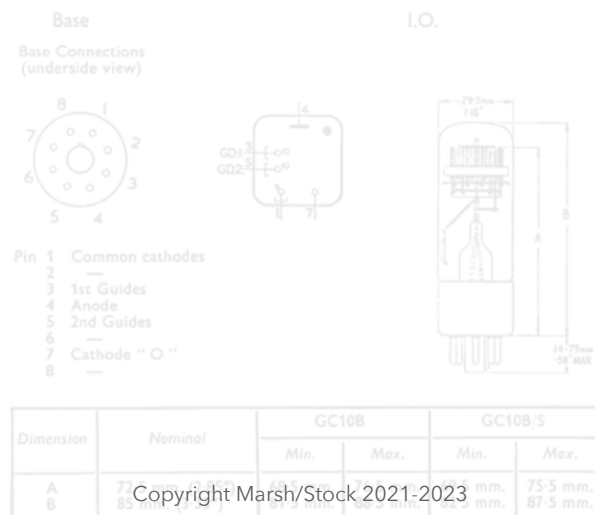
6. Leave the clock running for a while, say a few hours, to be confident that everything is as it should be. If you have problems with particular hardware then perhaps insert the test mode option jumper 1 and use the menu commands to investigate.⁶³

If you have any issues with parts of the build not working as expected, please also look at the troubleshooting guide in the next section of this manual.

Dekatron Tube Cathode '0' Alignment

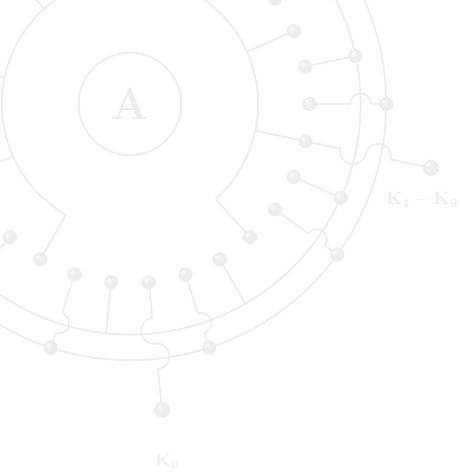
If all is successful, at this stage you may notice that the glowing dots on the Dekatrons do not align correctly on some of the tubes - i.e. when showing a '0' the glowing dot is not exactly at the top (12 o'clock). Rotating each tube so the 0 cathode is at the top can be accomplished as the Dekatron socket fixing nuts and screw run in curved slots on the Dekatron PCB. Details of how to do this safely are detailed in Annex H.

If you wish, skip this stage now and wait until you are building the clock into its case.



⁶³ Turn the power off first though....





Harwell Clock - Troubleshooting

How to Debug Your Dream Dekatron Timepiece

Base Connections
(underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

I.O.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

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Harwell Technical Troubleshooting Guide⁶⁴

1. Introduction

This guide is aimed at people who have built a Harwell Clock Kit and are trying to find solutions to any problems with it.

Given the complexity of the Harwell Dekatron Clock, it is difficult to provide a comprehensive guide to the faults that might occur and how to find them, but this should cover the majority.

The expectation of 99.9% of first time faults would be:

- A missed or poor/cold solder joint.
- A solder bridge between adjacent conductors.
- A badly made up board to board ribbon cable.
- A badly made or incorrectly positioned inter-board connector (DuPont headers).
- A plug-in module (SAM3X8C, WiFi or GPS).

Soldering faults are not just limited to joints that you have made but also, unfortunately, could include the SMD parts that come pre-fitted.⁶⁵

This guide will avoid asking you to inspect solder joints as it assumes you will do so before probing with a meter or oscilloscope. However, it will help by suggesting the areas that you should look at..

Software Bugs - Send a Bug report please!

All the hardware that you have put together is pretty useless⁶⁶ without the firmware that brings it all to life. Firmware exists in the following components:

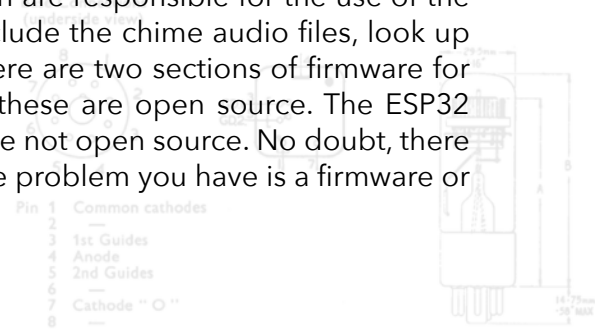
- Programmer/console box (MEGA16U2).
- Main board (SAM3X8C).
- Dekatron board (MEGA324PA).
- WiFi plug in if used (ESP32).
- Nuggle files on SD card.
- Data files on SD card.

Of these, the programmer/console box firmware is the simplest and most mature in its development. The main board SAM3X8C is the main clock firmware and the most complex. It also reads and executes the Nuggle files on the SD card which are responsible for the use of the Dekatrons, bling and sound. The data files on the SD card include the chime audio files, look up tables for such things as time zone and DST change data. There are two sections of firmware for the Dekatron board, a boot-loader and clock operation. All these are open source. The ESP32 uses standard libraries from the manufacturer and are therefore not open source. No doubt, there will be errors in the firmware and data files. If you think that the problem you have is a firmware or

⁶⁴ Everything you wanted to know but dare not ask....

⁶⁵ Despite pretty intensive inspection prior to shipping....

⁶⁶ Although quite charming in appearance...



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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data problem then please email us a bug report!⁶⁷

Inspection prior to shipping

The PCBs are 100% inspected using a stereo zoom microscope with the aim of looking for SMD joints that are not correctly reflowed, solder bridges between pins, parts that have 'squirmed'⁶⁸ or solder balls (which are then removed). However, the odd joint can still be missed during the board inspection. Using this guide these remaining, hopefully rare, faults can be found.

Another class of possible faults is that an incorrect part has been placed or incorrectly orientated. The board SMD parts are placed using a Lite Placer⁶⁹ Pick and Place machine. This would mean that an incorrect component was loaded for the machine to use. This would be a common fault across a batch of PCBs being made, so the first board from a batch is inspected for the component values fitted. This will catch labelled resistor, semiconductor, larger inductor and electrolytic capacitor errors. Unlabelled (usually small ceramic) capacitors and unlabelled inductors⁷⁰ will slip through this inspection but many can then be tested using a SMD component probe.⁷¹ The inspection program should also locate parts that have a specific orientation requirement, e.g. diodes or electrolytic capacitors, ICs, that have been placed back-to-front.

The SAM3X8C programmer/console board comes with the MEGA16U2 part programmed so the board is known to be electrically working as far as permitting programming.

The SAM3X8C plug-in board comes fully assembled, the SAM3X8C part programmed with the current firmware and tested in a Harwell Clock. Therefore, this plug-in is the most reliable of all the PCBs making up the Harwell Clock kit.

Schematics and Layouts

You will also find it useful to refer to the schematics elsewhere in this guide or by looking at the Eagle⁷² files obtained from the project Dropbox(s).

Problem not solved?

If you cannot clear the apparent fault using these notes and your own experience then please do contact us (you should have our direct email addresses or use the email address on the web sites) to help. There is a repair service if you do not want to tackle the fault finding yourself. This will normally involve posting the problem board(s) to Scotland or San Diego.

PSU Problems

5V power missing or incorrect or overheating?

- The voltage is set by resistors R13 (43k) and R14 (4k7) - an installation error.
- Has the fuse F1 (2A) blown?

⁶⁷ Currently we're not offering any bug bounty, but we may add you to our Christmas card list....

⁶⁸ Technical term for parts that decided that they just didn't want to stay in place and cooperate....

⁶⁹ <https://www.liteplacer.com/>

⁷⁰ The Harwell Clock only uses one unlabelled inductor so this should not be a problem...

⁷¹ I use a MASTECH MS8911 Smart SMD Tester

⁷² You can download Eagle from <https://www.autodesk.co.uk/products/eagle/free-download> the free version (do not pay a subscription!). This will allow you to view but not edit or save the Eagle files available from the project Dropbox.



- Have you correctly placed the IDC box header X6?

170V or 500V power missing or incorrect or overheating?

- Has any electrolytic capacitor (C1, C2, C4, C5) been fitted with the incorrect orientation?
- Has the flyback transformer (TR1) been fitted with incorrect orientation?
- Have you correctly linked the pins on the IDC header X6 to enable the flyback converter?

Main Board Problems

In all cases check the solder of the two 2x20 2mm sockets that the SAM3X8C plugs into are correctly soldered and that none have been bent during fitting. Make some basic voltage tests by testing that the 5V power is correct, the 3.3V power on the main board is correct and the 3.3V power on the SAM3X8C plug-in (it has its own regulator) is correct.

Unless stated otherwise, this guide assumes that you have the clock running in test mode (main board jumper 1 fitted) and the console is attached so you can give the clock commands. But...

SAM3X8C is not working

The SAM3X8C plug-in is tested and programmed with the current firmware before it is shipped. Have you plugged the SAM3X8C plug in module out of alignment with the sockets on the main board? This is a serious accident which will cause damage to the module and/or main board.

Did you have the console/programmer box plugged in and accidentally pressed the erase button? If so, you will need to program the SAM3X8C again - see Operating manual for firmware uploading instructions.

Console is not working

Console operation is tested before the SAM3X8C plug-in is shipped.

- Did the console/programmer box work correctly? Especially the loop back test.
- Check the setting of the serial software you are using (see Page 9 of this guide).

USB remote drive not working

USB remote drive operation is tested before the SAM3X8C plug-in is shipped.

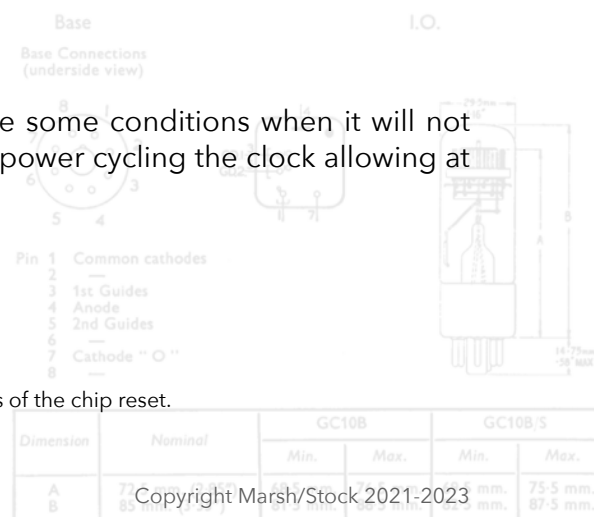
- Are you using a USB cable known to be good?⁷³

Reset button not working or is intermittent

The SAM3X8C only has a "soft"⁷⁴ reset function and there are some conditions when it will not operate. One example is immediately after programming. Try power cycling the clock allowing at least 5 seconds off in the on-off-on cycle..

⁷³ This is surprisingly common in my experience....

⁷⁴ "Soft" is my word... read the SAM3X8C documentation to understand the limitations of the chip reset.



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		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	

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- You can try the reset button on the console/programmer box. Do not press the erase⁷⁵ button in error!
- Look at the soldering around IC1.

RTC operation not working or produces error messages

Problems with the GPS or WiFi plug-in are dealt with separately. The RTC used is within the SAM3X8C and there is an external 32kHz TXCO⁷⁶ on the SAM3X8C plug-in.

During software development it proved possible to set the SAM3X8C RTC registers into an impossible state and the RTC then stopped ticking. In normal use this can't occur. When the clock is power cycled or if the reset button is pressed the RTC is not stopped, but is maintained by the energy stored in the onboard super-cap. To allow the RTC to be fully reset (a normally fitted jumper is provided on the main board (X1 near to the reset switch). The procedure used is to switch the clock off, remove the X1 jumper, refit the X1 jumper and power the clock back up. RTC problems have not been seen (other than during software development) but if problems do appear then the process above (removing X1 etc.) should be tried first.

TWI/I2C Errors

The SAM3X8C has two TWI interfaces, 0 and 1:

- TWI0 connects to
 - Left audio amplifier.
 - Right audio amplifier.
 - NVR.
- TWI1 connects to
 - Dekatron driver board.

The error message should say which system is in error. During the start up initialisation checks are made for both TWIs for correct operation:

- Each TWI is tested for "lock-up"⁷⁷ faults. If a fault occurs then the clock will ask to be power cycled. This normally clears the fault.
- Checks are made that each TWI can "talk"⁷⁸ to each of the chips it expects to be connected to. If a chip fails to communicate with the TWI then that will set you looking in particular areas (see below).

Audio amplifier or amplifiers not working correctly

The stereo audio amplifiers are each connected to the SAM3X8C for beep noises (using PWM outputs) and to play chime audio files (using DAC outputs) so there are a total of four audio connections to check. Therefore, how you proceed will depend on what is working:

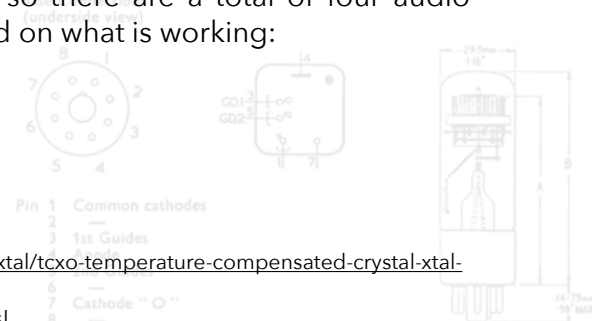
- Beep noises.
- WAV noises.

⁷⁵ The erase button will do exactly what it says on the tin...

⁷⁶ https://www.electronics-notes.com/articles/electronic_components/quartz-crystal-xtal/tcxo-temperature-compensated-crystal-xtal-oscillator.php

⁷⁷ Search the interwebs on "twi clock lock up" to find many references and discussions!

⁷⁸ Called "probe" tests.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5 mm			75.5 mm	
B	85 mm			87.5 mm	

- Left channel.
- Right channel.

Before you start looking at the boards you should check the start up script as the clock will detect that:

- It cannot communicate with one or both audio channels using the TWI interface.
- If one or both audio amplifiers report a fault.

Failure to communicate over the TWI requires tracing of the TWI signals. Additionally, the TWI is shared with the NVRAM chip. So is that working or not?

The audio amplifier faults that will be detected are:

- The speaker connection is open circuit.
- The speaker connection is a short circuit.
- The speaker connection is shorted to ground or 5V.
- The amplifier is drawing too much current.
- The amplifier has gone into thermal overload.

Which of these faults has occurred is reported by the **VOLR** command - for example:

The next thing to check is to make sure that the clock has not been muted and so beep and chimes are being suppressed by the firmware:

- When option jumper 7 is fitted the audio amplifiers are not turned on so no sounds will play no matter what other settings have been tried.
- No audio will sound if the volume controls are set to 0. Use the **VOLR** command to check the volume control setting (should be in the range 0x01 to 0x1f for sounds to be heard (see above).

```
>volr
Muted/Sound Report:
Option jumper 7          sound
Out of hours            sound
Fault(s)                mute
Chime volume           sound
Beep volume            sound

Amplifiers Report:
Channel                Left      Right
Chip                   0        1
Address                0xf8    0xfa
Chime Volume           0x09    0x09
Beep Volume            0x08    0x08
Mode control           0x14    0x14
  Input 1              1
  Input 2              1
  Power                1
Diagnostics            0x12    0x12
  I Limit              1
  Reset                0
  Continuous           0
  Enable               1
Fault detection tests  0x00    0x00
  O/P Short            1
  O/P Open             1
  O/P Rail short      1
  OCF                  1
  TSD                  1
Fault Status           OK       Fault
Fault Report: Chip 1 - Output open circuit
```

Finally, the clock firmware will suppress chimes and beeps if the time is within the chime_off to chime_on time period⁷⁹ set in the [volume] section in *system.ini*. Again, the **VOLR** command lists the sound or muted decisions.

- Check the soldering around IC3 (left channel) and IC4 (right channel).

Base Connections (underside view)



⁷⁹ By default this period is set so that the chimes are not suppressed.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

NVR Errors

When the clock starts the NVR is checked for errors using a previously saved checksum. If the checksum is inconsistent then “factory default” settings are loaded and a warning is sent to the console. This message will appear the very first time the clock is run and then will only appear again if option jumper 6 is fitted to reset the NVR contents back to the factory default settings.

You can use the command **STRR 2** to examine the NVR contents. Here's a snapshot of the current NVR contents on my test clock:

Here you can see the computed CRC checksum. The last byte in the data area should contain the same value. If the NVR cannot be read correctly by the TWI then it will be most likely that the data will all be read as FF or 00.

- Check the soldering around IC2.

```
>strr 2
NVRAM Report:
Capacity      512 bytes
Used          445 bytes (86%)
CRC           0x96 0K
Config data:
0000 01 02 01 0a 09 a1 00 00 00 a1 00 00 00 aa 01 00
0010 00 00 01 03 00 00 00 01 1b 00 00 00 51 01 00
0020 6c fa 02 00 00 00 00 00 00 55 aa 55 aa 00 00 00
0030 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0040 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0050 00 00 00 00 ff ff 00 00 00 00 00 00 00 00 00
0060 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0070 00 00 00 00 00 00 00 00 00 00 00 00 01 00 00
0080 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0090 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00a0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00b0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00c0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00d0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00e0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
00f0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0100 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0110 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0120 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0130 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0140 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0150 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0160 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0170 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0180 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
0190 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01a0 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
01b0 00 00 00 00 00 00 00 00 00 00 00 00 00 96 00
```

File and SD Card Errors

The requirements for the SD card are 2GB,⁸⁰ formatted FAT32 and not write-protected. When the clock starts any failure with the SD card correctly installing/operating will be reported to the console. The clock kit comes with a prepared and tested SD card so initial faults are most likely to be soldering. As with any disc storage, it is recommended that you back up the SD card. Although you will always be able to get a “factory default” image from the project Dropbox, you will lose any customisation you have done. Once the card is installed and files are being read, it is still possible to get file or SD errors. Therefore some useful commands are:

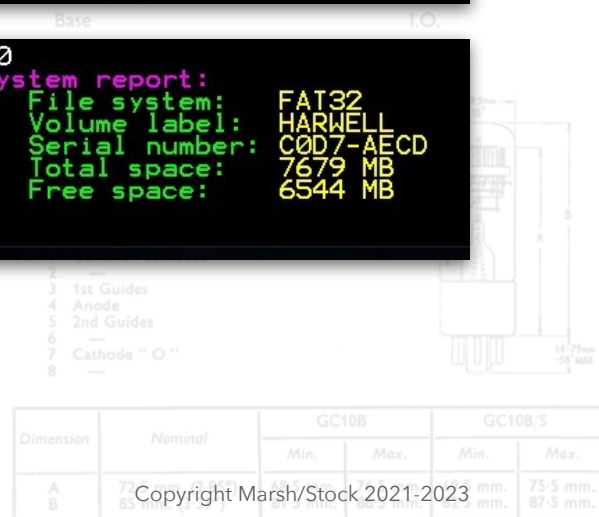
The **STRR 1** command can be used to get basic information on the SD card:

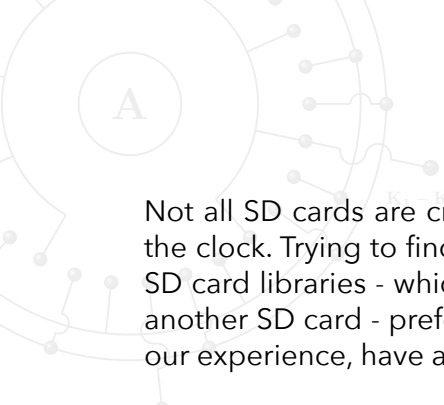
```
>strr 1
SD Card Report:
number of slots: 1
check result: No error
card type: SD high capacity card
card version: SD version 3.0X
card capacity: 7687 MB
write protected: 0
clock: 50 MHz
high speed: 1
bus width: 4 bits
```

The **STRR 0** command can be used to get basic information on the file system. This should correspond with what is seen using a SD card reader in, say, Windows explorer.

```
>strr 0
File system report:
File system: FAT32
Volume label: HARWELL
Serial number: C0D7-AECD
Total space: 7679 MB
Free space: 6544 MB
```

⁸⁰ Or larger, but at this time I have only tested up to 8GB in size.





Not all SD cards are created equal! It has been noticed that some SD cards do not work well in the clock. Trying to find out why has been very difficult as the errors occur deep within the Atmel SD card libraries - which are complex to say the least. If you get errors then the first step is to try another SD card - preferably a different size and/or different manufacturer. Sporadic file errors, in our experience, have always come down to a problem with a specific SD card.

If you get an error from a specific file⁸¹ about missing data and this is one that you have edited then are you sure you have not inadvertently left a typo behind? Files should only be edited using a pure text editor and never a word processor. When copying files to another SD card make sure that you do not copy the CACHE.DAT hidden file in the system folder (or delete it if you have copied it). The file will be recreated for the specific SD card when the clock is restarted.

The chime files must not be fragmented. Use the command **CHMT** to test the files for fragmentation. The command will try to defragment any fragmented files. If problems persist or occur on a SD card copy, then you can try deleting all the files in the CHIMES folder and then using the **CHMC** command to recreate the chime files. Be warned, this is a ___long___ process.

- Check the soldering around Z1.

Bling not working correctly

A) The LEDs light up randomly and do not change, including the LED module on the main board

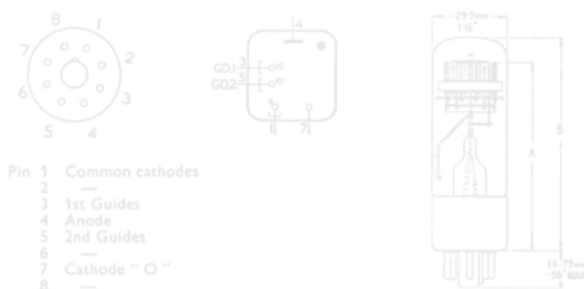
- Check the soldering around IC5, IC6 and Z3.
- Check that the SPI signals are being transmitted by the SAM.

X7 is the SPI expansion port (not normally fitted) but it is an easy point to pick up the SPI signals. Pins are as follows:

1. /CS2
2. /CS3
3. MOSI
4. MISO
5. /CS0
6. SPCK
7. /CS1
8. Ground
9. 3.3V
10. Ground

/CS1, /CS2, /CS3 and MISO are unused in the current firmware. /CS0 enables the SPI for the LED transmission, MOSI is the data stream and SPCK the clock.

Base Connections (underside view)



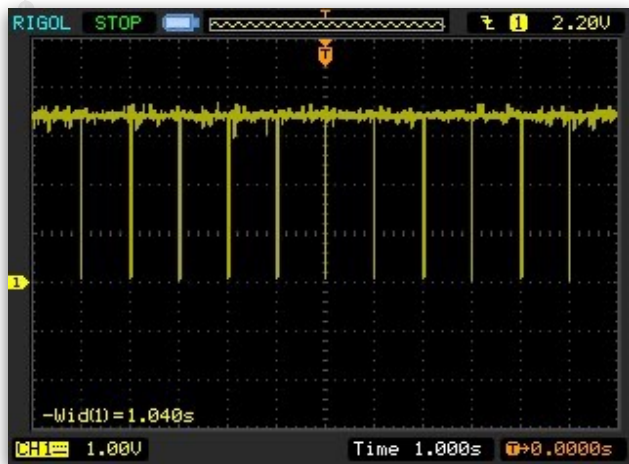
- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode " O "
- 8 —

⁸¹ Editable files such as INI, CSV etc.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5 mm			75.5 mm	
B	85 mm			87.5 mm	



Give the command **LEDC** using the console. This will cause the repeated transmission of a changing data stream once per second. Set your oscilloscope⁸² to examine a 3.3V digital signal. Set the timebase to 1s per division and you should see a /CS0 line that drops to 0V (enable) every second (left image). Set the timebase to 200uS per division and you can see a /CS0 pulse that lasts a little less than 1mS (right image).

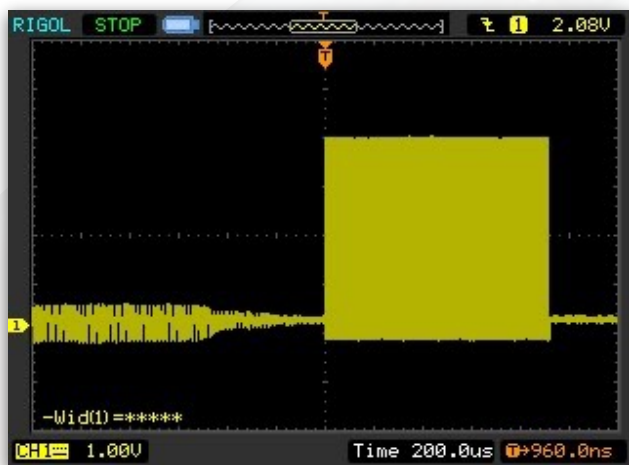


3.3V /CS0 1s/division



3.3V /CS0 200µs/division

Examine the SPCK and you should see a long burst of positive going pulses⁸³ that last during the /CS0 pulse (left image). Reducing the timebase to 20 uS per division and you can see there are a series of SPCK pulses (right image).



Base
Base Connections
(underside view)



- Pin 1 Common cathodes
- 2
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6
- 7 Cathode "O"

I.O.

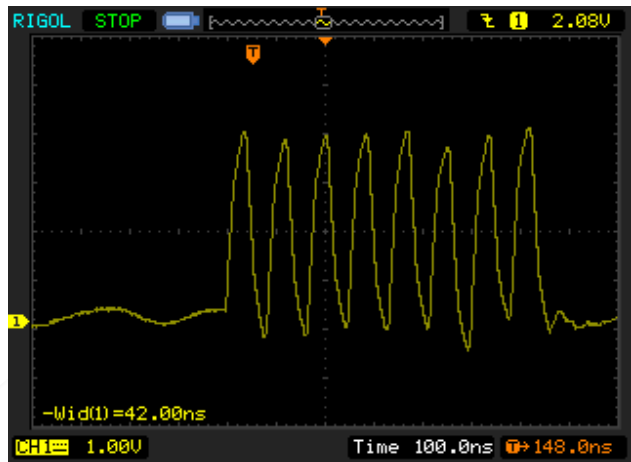
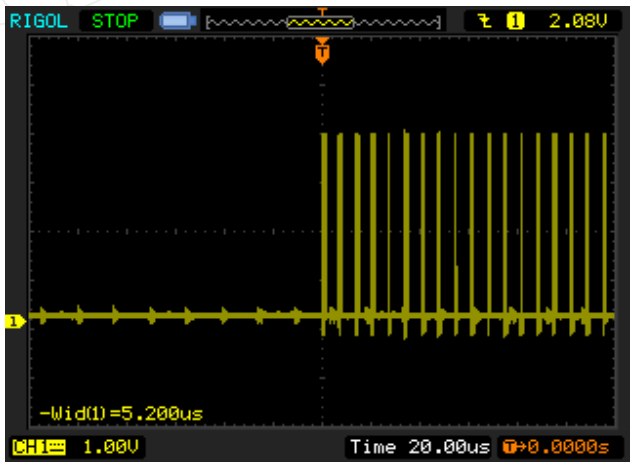


⁸² If you have one. If not, may we suggest you get one? :)

⁸³ The images that follow are poor due to the speed of my oscilloscope but will give you an indication of what you should expect. People with a faster scope than my 50MHz Rigol DS1052E will see truer images.

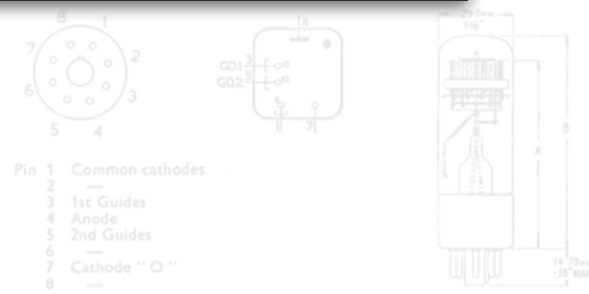
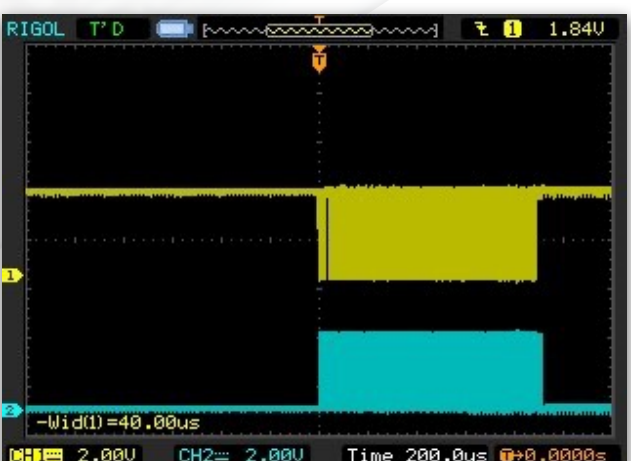
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

Reducing the timebase to 20 μS per division and you can see there are a series of SPCK pulses (left image below). Reducing the timebase further to 100nS per division and the SPCK resolves to 8 individual clock pulses (right image below).



This is one byte of data being transmitted. A complete frame of data being sent to the LEDs consists of a 32 bit start frame, thirty-two 32 bit data frames and a 32 bit end frame; so a total of $32 + 32 * 32 + 32 = 1088$ SPCK pulses sent. The SPCK frequency is 12MHz, so each full clock pulse cycle takes about 83nS (the scope measures the actual pulse width at 42nS which is not bad for a cheap 'scope).

Moving SPCK to channel 2 (blue) and examining MOSI⁸⁴ (yellow). Reduce the vertical size to view both waveforms and set the timebase back to 1s per division. This looks like the MOSI data are negative going pulses, but as seen below, they are positive pulses but MOSI is high when data is not being transmitted (image left). Reducing the time base again so that one pulse is expanded shows multiple pulses (image right).



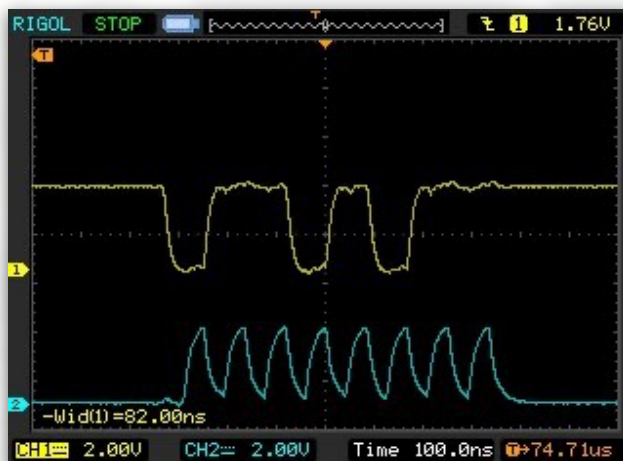
⁸⁴ Master Out Slave In - data transmission pulses to the LEDs.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

Again, to see the individual data pulses, here the first four pulses are examined - this is the 32 bit start frame (left). The start frame always has the value 0x00000000 so the MOSI is low for each SPCK pulse. Moving the horizontal position left to examine the next four bytes (right). This is the first data frame and will be used by the first LED module in the chain which is Z3 on the main board.⁸⁵ Now changing data is seen on the MOSI line. The data bytes are from left to right are: global control, blue intensity, green intensity and then red intensity (0xCCBBGGRR).



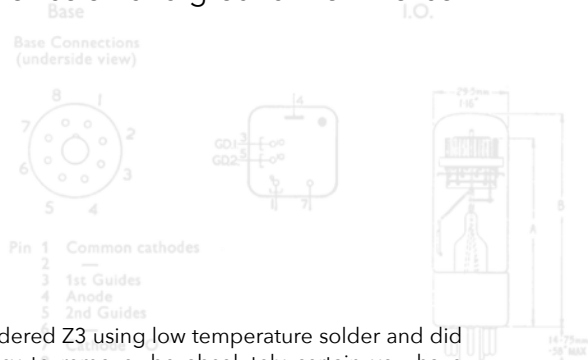
Decreasing the timebase further and moving the horizontal position to examine one of the colour intensity bytes will show slowly changing data pattern. For example:



This has been an in-depth look at the colour data sent to the LEDs by looking at the data available from the SAM3X8C SPI pins. The starting fault condition was that the bling was not working at all. The next step is to move on to the switched buffers - IC5 and IC6. Use the oscilloscope to examine the

- Control pins (pin 1 on each IC) and you should find the /CS0 signal.
- Input pins (pin 2) and you should find the MOSI signal on IC5 and SPCK on IC6.
- Output pins (pin 4) and you should find the corresponding signal but now at 5V.

If the signals are present, then examine the input pins on Z3 and you should find the MOSI data on pin 1 and SPCK on pin 2. If the two signals are present as well as 5V and ground then the last conclusion is that Z3⁸⁶ must be faulty.



⁸⁵ Labelled "Gizmo" but I don't remember why...

⁸⁶ These devices are known to be sensitive to the soldering temperature so I hand soldered Z3 using low temperature solder and did not use the reflow oven. However, don't leap into changing the part - it is not easy to remove; be absolutely certain you have exhausted all other possibilities first.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



B) The LEDs light up randomly or remain black and do not change, except the LED module on the main board

The LED on the main board lights up a pink colour at first then changes to blue when the clock has started up test mode.⁸⁷

1. Examine the output pins (5 and 6) soldering.
2. Examine the soldering of the large ribbon cable IDC male header (X9) especially connections 18 and 20.
3. Inspect the 20 way ribbon cable connecting to the front panel.
4. You can use an oscilloscope to check that the SPCK and MOSI signals are available on X9 pins 18 and 20 respectively (see below).
5. Bling fault finding is continued in the Front Panel Problem section.

Example of bling SPI signals on X9:

The SPCK is in blue and each pulse is 8 clock pulses; MOSI is in yellow. You can see the first 18 bytes of data being sent to the front panel board. The first 4 SPCK pulses visible have MOSI at ground and so represent the 32 bit value 0x00000000 which is the start frame. The next 4 SPCK pulses also have a MOSI value of 0x00000000. This data corresponds to where the colour data was for the LED module X3 on the main board. That module has used the data and has not transmitted it again, it has sent 0x00000000 instead which must appear to the next module as a sort of repeated start frame. This is how the APA102C transmits data to long chains of modules.



Front Panel Not Working (or in part)

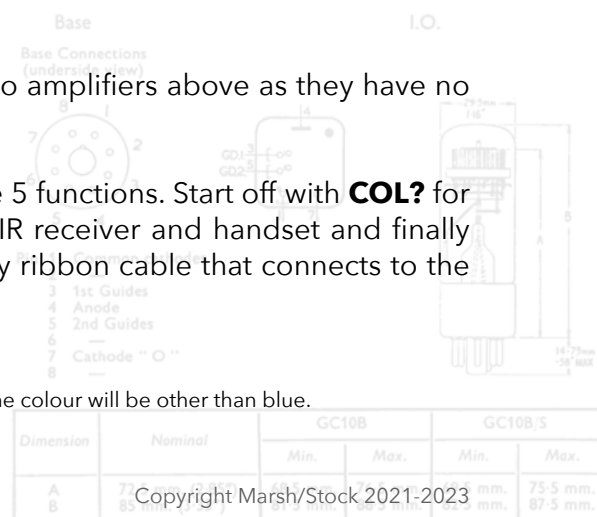
The front panel controls are

- MTX90
- LDR
- PIR
- IR receiver.
- Rotary encoder.
- Continued chain of LED modules.

The speakers on the front panel are dealt with under the audio amplifiers above as they have no electrical connection to the board.

There are a range of commands that can be used to test these 5 functions. Start off with **COL?** for the colons, **LDR?** for the LDR, **PIR?** for the PIR, **IRH?** for the IR receiver and handset and finally **ROT?** for the rotary encoder. If nothing works then the 20 way ribbon cable that connects to the main board must be suspect.

⁸⁷ If the clock switches to a mode other than test mode, e.g. bootloader mode, then the colour will be other than blue.



Next to check are the 5V and 3.3V power rails on the board. If the MTX90 colons are not lighting then check the 170V power is present.

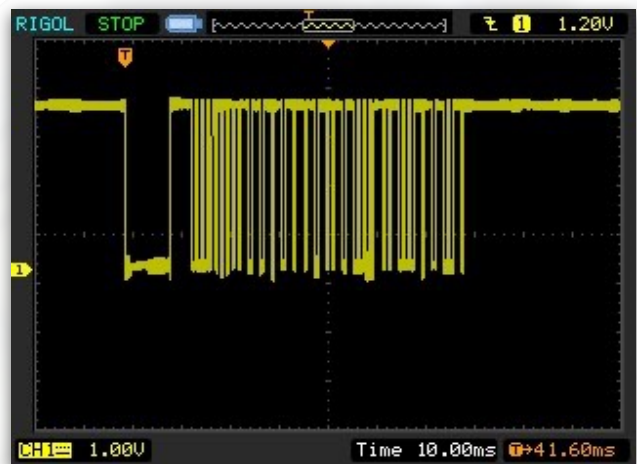
IR Receiver

In order that multiple Sgitheach clocks can share the same IR Handset there is a system used called "pairing" where a specific key sequence is needed before the clock will recognise key presses. Control of pairing is in the [ir] section of *system.ini*. The IR receiver can also be fully disabled here. For test purposes it is probably best to turn off pairing.

The **IRHC** command is useful as it will display a character on the console for each key pressed. The characters are sent to the console irrespective of the pairing state.

- Is there a (good) battery in the IR handset? If new, has the plastic tab been removed?

If you want to check the IR signal using an oscilloscope then the output from the IR receiver will look like this at 10mS per division timebase and 1V per division vertical sensitivity:

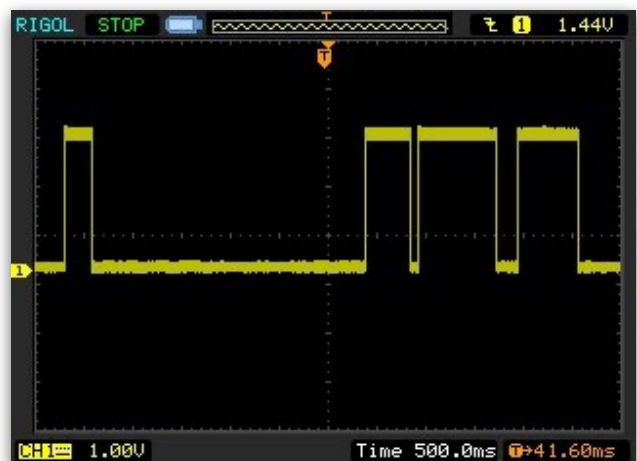


The data changes according to the key pressed. Using the schematics and board layouts you can trace this signal back to the SAM3X8C plug in module. Because an off-the-shelf IR handset has been bought from eBay that uses standard codes, there is always the possibility that other IR handsets or appliances will interfere with the clock. Apart from separating the appliance from the clock there are not many solutions. Gratifyingly, to date, only one case of interference (a domestic dehumidifier unit) has been reported.

PIR Sensor

Control of the PIR sensor is found in the [pir] section of *system.ini*. The PIR can be fully disabled here. The **PIRC** command is useful as it will display a ! character on the console each time it senses a hit. When nothing is sensed, the PIR output voltage is zero, when it senses a warm body moving the output rises to 3.3V.

If you want to check the PIR signal using an oscilloscope then the output from the PIR sensor will look like this at 500mS per division timebase and 1V per division vertical sensitivity when waving a hand in front of the sensor:



Using the schematics and board layouts you can trace this signal back to the SAM3X8C plug in module.

Dimension	Nominal	GC108		GC108/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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LDR room brightness sensor

The LDR sits in a simple potential divider with one side of the LDR connected to ground and the upper resistor connected to 3.3V. The junction of the potential divider is sensed using an ADC channel. In a light room the LDR resistance will be low and so the junction potential will be low. In a dark room the LDR resistance will rise and the junction potential will rise as well.

Control of the LDR sensor is found in the [pir] section of *system.ini*. The **LDRC** command is useful as it will display the LDR raw value and the interpreted brightness (0 - 100%) once per second. To check operation, use a voltmeter on the junction to ground and note how the voltage changes as the illumination on the LDR is altered.

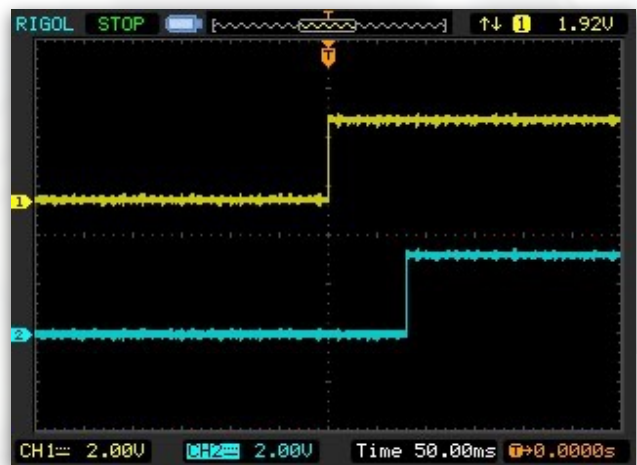
Using the schematics and board layouts you can trace this signal back to the SAM3X8C plug in module.

Rotary Encoder

Control of the rotary encoder is found in the [encoder] section of *system.ini*. The encoder can be fully disabled here. The ROTC command is useful as it will display a character (+, -, U or D) on the console each time the encoder is rotated. The rotary encoder has three outputs for the switch and two phase outputs. Each output is tied high. The switch output is high when not depressed and low when depressed.

The phase outputs alternate between both being high and both being low on each indent when rotated. Between indents the phases do not change together but change at different times, the order depends on the direction of rotation.

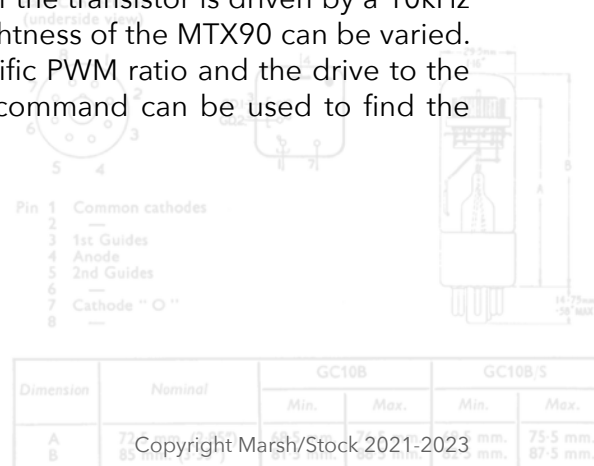
Using an oscilloscope you can see the voltage on each phase changing, 50mS per division timebase and 2V per division vertical sensitivity:

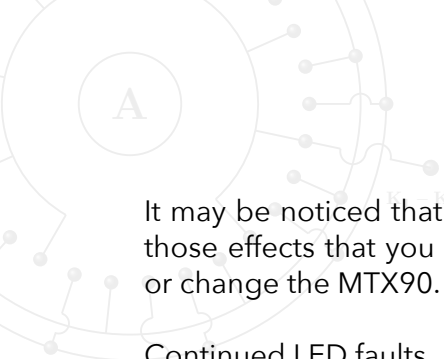


Using the schematics and board layouts you can trace this signal back to the SAM3X8C plug in module.

MTX90 Colons

The anodes and triggers are connected via resistors to the +170V supply. The cathodes are connected to ground via a high voltage transistor. The base of the transistor is driven by a 10kHz PWM signal from the SAM3X8C. In this way the apparent brightness of the MTX90 can be varied. In test mode, the **COLS** command can be used to set a specific PWM ratio and the drive to the transistor base examined using an oscilloscope. The **COLR** command can be used to find the current settings.





It may be noticed that a MTX90 can flicker, especially at 100% PWM (fully on). This is just one of those effects that you sometimes see with aged neon filled devices.⁸⁸ Either live with the charm or change the MTX90.

Continued LED faults.

The most common fault with the LED chain is that they only light up to a point. This normally indicates a soldering fault on either the outputs from the last to light or the inputs to the next one not lit. The 4 wire link between the front panel and the downward firing LED board must have been inserted correctly.⁸⁹ Failure to insert it correctly will have almost certainly fried the six LEDs on the plug in board.

Dekatron Driver Board

The Dekatron driver board uses an ATMEGA324PA as a TWI slave to receive short commands from the SAM3X8C. It then carries out the required pulsing of the Dekatron guide electrodes to move the dot without further commands by the master.

Dekatron board faults are broadly two types - TWI problems and Dekatron driving problems. Any TWI problem should be investigated first.

TWI Problems

When the clock is started the SAM3X8C TWI master looks to see if the ATMEGA324PA slave will respond to commands. If it can't then a "probe failed" error line will appear in the console start up listing.

Things to check include

- The 6 way ribbon cable from the main board to the Dekatron board is constructed correctly.
- There is 3.3V on the Dekatron board (supplied over the 6 way cable).
- You will need to inspect soldering on both the main board and Dekatron board.

Dekatron - Common Tube Issues

Dekatron tubes operate at low pressure, glass seal failures can leak air into the tube. Leaky tubes can be identified as the silver mirroring turns white due to the reaction with oxygen. Such tubes are entirely useless and will not work. This goes for pretty much every tube/valve that operates under vacuum or low pressure inert gas and has a 'getter flash' like this.

This example is obviously not a Dekatron, but the (rectifier) tube on the left has leaked:



⁸⁸ Cut them some slack, they've been sleeping *for decades*...
⁸⁹ This was mentioned *ad nauseam* in the construction notes..

A	72	mm	Max.	mm	Max.
B	85	mm	Max.	mm	Max.
		Copyright Marsh/Stock 2021-2023		75.5 mm	87.5 mm



Tubes that have seen considerable operating life can have mirroring around the cathode and guide rings. This mirroring darkens the glass and reduces visibility of the glowing indicator dot. The mirroring is caused by metal sputtered from the cathodes. Such mirroring cannot be reversed and will be the eventual fate of all Dekatrons.⁹⁰ The Dekatron on the right has mirrored so much that the anode, guides, and cathodes are no longer visible:



The sputtering that occurs in normal operation erodes the cathodes. In extreme cases, a cathode (usually cathode '0') can be completely eroded away. Such tubes are also quite useless. This example shows cathode '0' badly eroded. This Dekatron actually still works! However, I suspect its days are numbered. This phenomena is usually seen in Dekatrons that have been used in some form of counter where this tube hasn't *counted much* but remained operational.



The plastic base⁹¹ of a Dekatron is glued to the glass. The glue is brittle and can fail giving a "loose" base. It is not hard to re-glue the base to the glass using UV cured adhesive or superglue. However, in an extreme case the loose base can cause the wire connections between the glass tube and the base pins to break. With time, effort (and luck), such breaks can be repaired but normally a broken base will mean the tube is now useless. Because of the risk of the glass and base separating it is always best to insert and remove a tube from a socket by grasping the base only.

Because these Dekatron tubes are about 50 - 60 years old it is expected that some will have become erratic and will not count correctly. This applies to devices which are apparently new and unused (usually referred to as NOS, New Old Stock). If a tube counts erratically or "sticks" on one position then it can be "reactivated"⁹² by running it in a Dekatron "spinner"⁹³ for a few days. Even so, some intransigent tubes just won't start working again.

Having read through this section you might realise that it is also a checklist for buying tubes from dealers, eBay etc. Sadly many tubes are sold as "untested" but they are severely defective on just physical inspection.⁹⁴ We stock NOS tubes that are all tested prior to shipping. Supplies are limited though.

⁹⁰ Say it isn't so! This is why we have a PIR installed on the clock, so they're only operating when there is someone in the room to view their beauty...

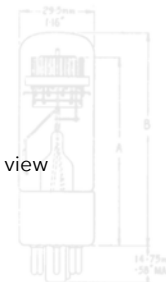
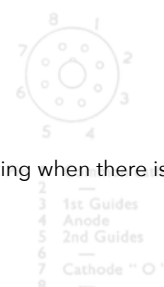
⁹¹ Not all Dekatrons have plastic/bakelite bases...

⁹² For want of a better term..

⁹³ <http://www.electricstuff.co.uk/dspin.html>

⁹⁴ I have seen on eBay a broken oscilloscope cathode ray tube that was held together with sticky tape!

(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Dekatron Driving Problems - All

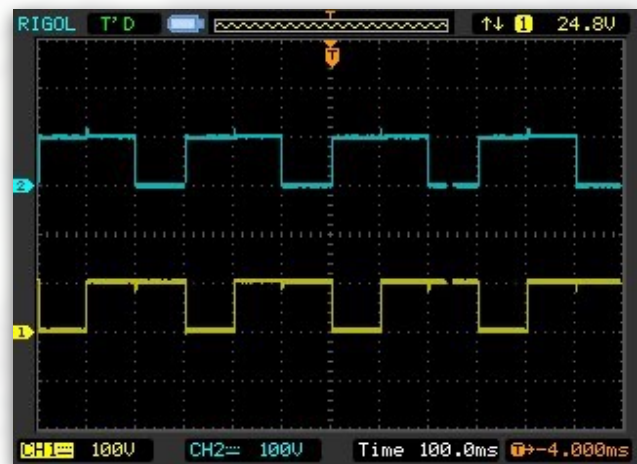
At this stage the TWI is working which shows that the ATMEGA324PA is running.

- If the Dekatrons are not glowing then check the 500V supply and check the Dekatron connections (with the power off!).
- If the Dekatrons light but do not move then check the 50V and 100V supplies.
- Check that J0 - J2 are correctly wired for the tubes you are using.

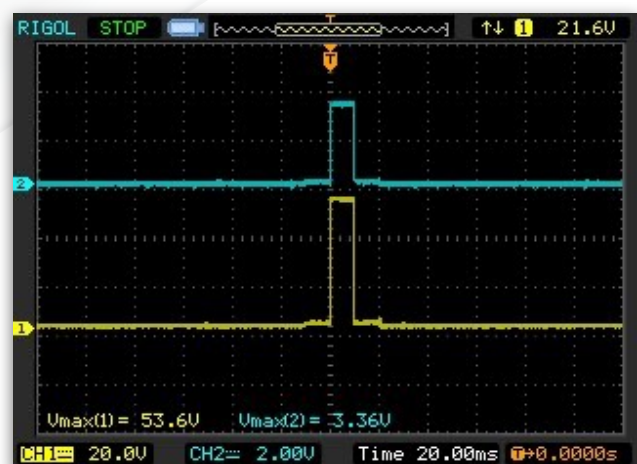
Dekatron Driving Problems - One (or a few)

If you only have one or a few tubes that don't operate correctly then you can move the tubes around to try to decide if it is the tube that is "bad" or if there is a problem with the particular station on the Dekatron board. If the tubes are all ok and the voltages are correct, then a malfunction in a single station is most likely a soldering fault. If you want to test a single station then put the clock into test mode. Turn on the 500V power supply using **OUTS 500,1** and then set the tube station you want to test spinning, with, for example **DEKN 5, 0, 0, 100** which will set tube V6 spinning.

You can examine the two guides, the voltage will pulse as the tube is stepped using an X10 probe, 100mS per division timebase and 100V per division vertical sensitivity you will see a series of 100V pulses. The tube steps when the voltage falls to 0V and the glow rests on a cathode when both guide electrodes are at 100V.



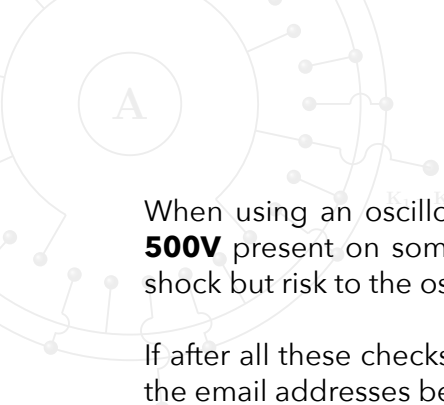
You can examine the operation of the circuit that detects when cathode '0' is glowing and checking that the sensed condition is passed to the MEGA324PA. For one channel, set the oscilloscope vertical sensitivity to 20V per division and connect it to the collector of the PNP transistor in the sense circuit. The other channel can be set to 2V per division and connected at the centre of the potential divider from the collector to ground. The timebase can be set to 20mS per division. You should find an approximately 50V peak corresponding to the glow resting on cathode '0' on the collector and a 3.3V peak at the potential divider.



- Pin 1 Common cathodes
2 —
3 1st Guides
4 Anode
5 2nd Guides
6 —
7 Cathode "0"
8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

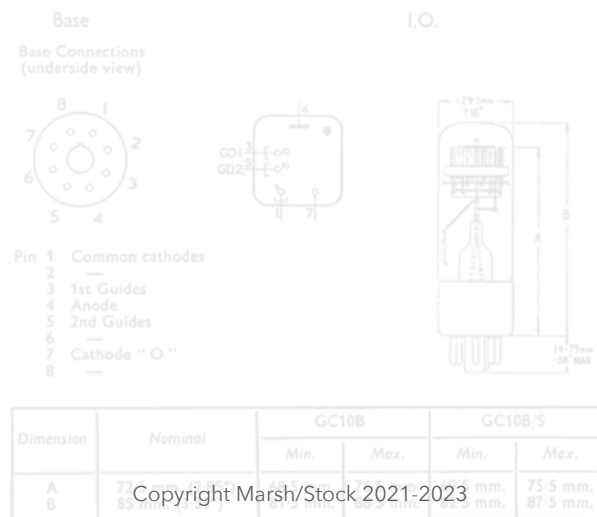


When using an oscilloscope probe on the Dekatron board remember that there will be up to **500V** present on some of the tracks and components. There is not only the risk of an electric shock but risk to the oscilloscope input circuits if the probe comes into contact with the 500V rail.

If after all these checks you still have issues with your Harwell, then please contact us at either of the email addresses below and we will try our best to help you.

K0

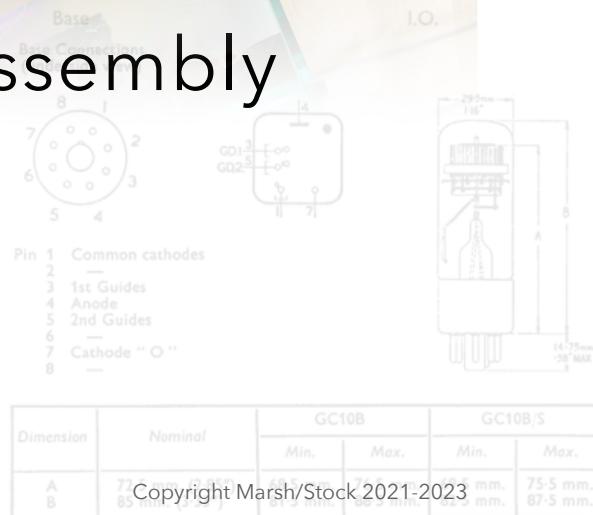
sgitheach.org.uk or stocksclocks.com





Harwell Clock - Case Assembly

How to Enclose Your Dream Dekatron Timepiece





Harwell Case Assembly

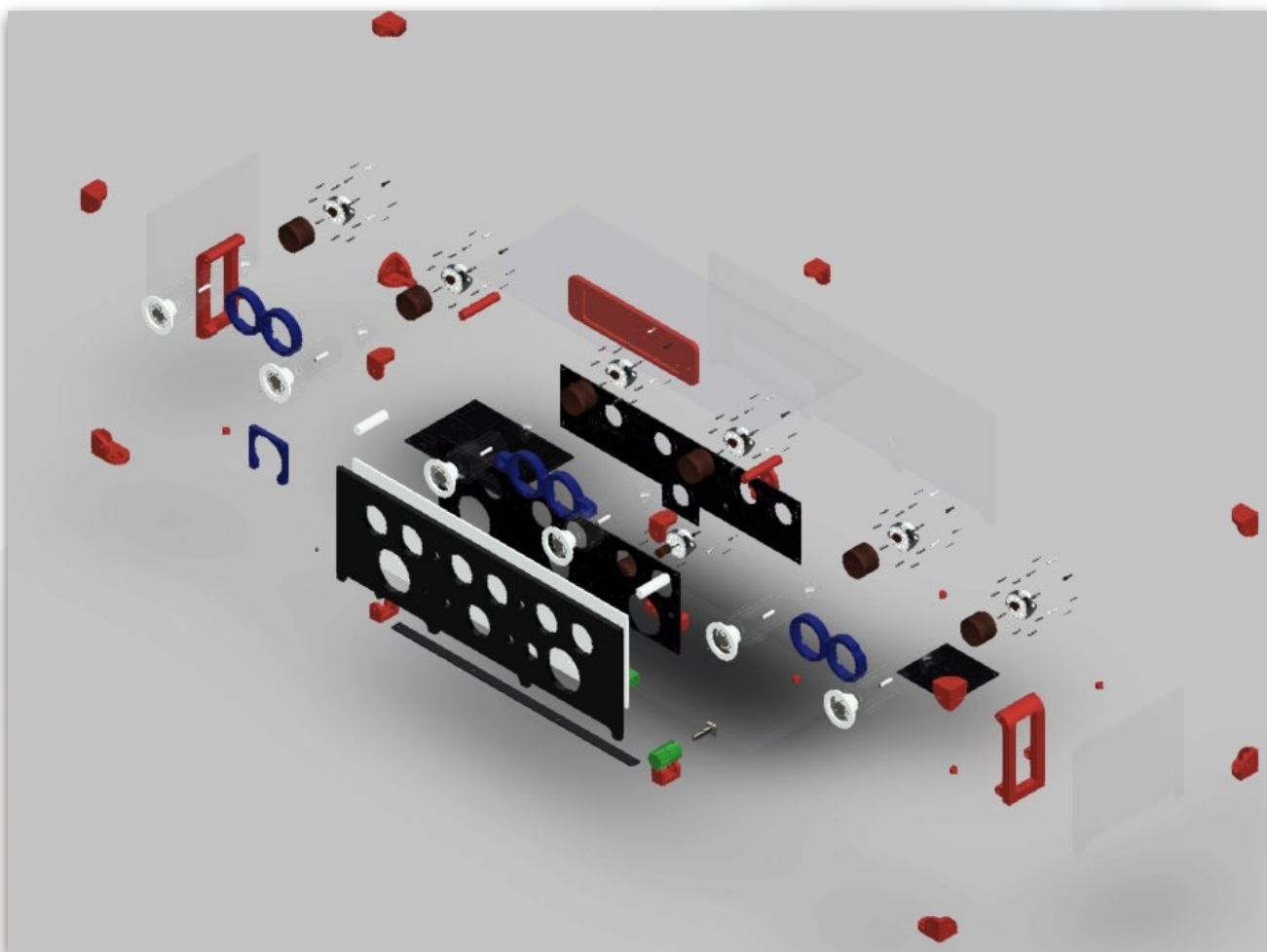
Introduction

3D Virtual Model

The construction was documented using Autodesk Fusion 360. A public link to the design is:

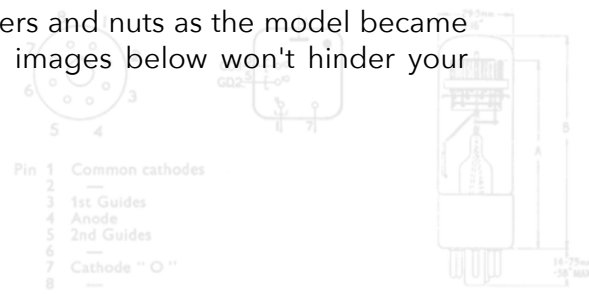
<https://a360.co/3grLVtb>

This 3D model can be rotated, zoomed, have parts hidden from view etc. Therefore, if you have any difficulty in understanding how parts fit together then this might help. You can even virtually explode the clock:



(underside view)

In developing this model I chose not to add the screws, washers and nuts as the model became very cluttered. Hopefully their absence from the model and images below won't hinder your assembly.

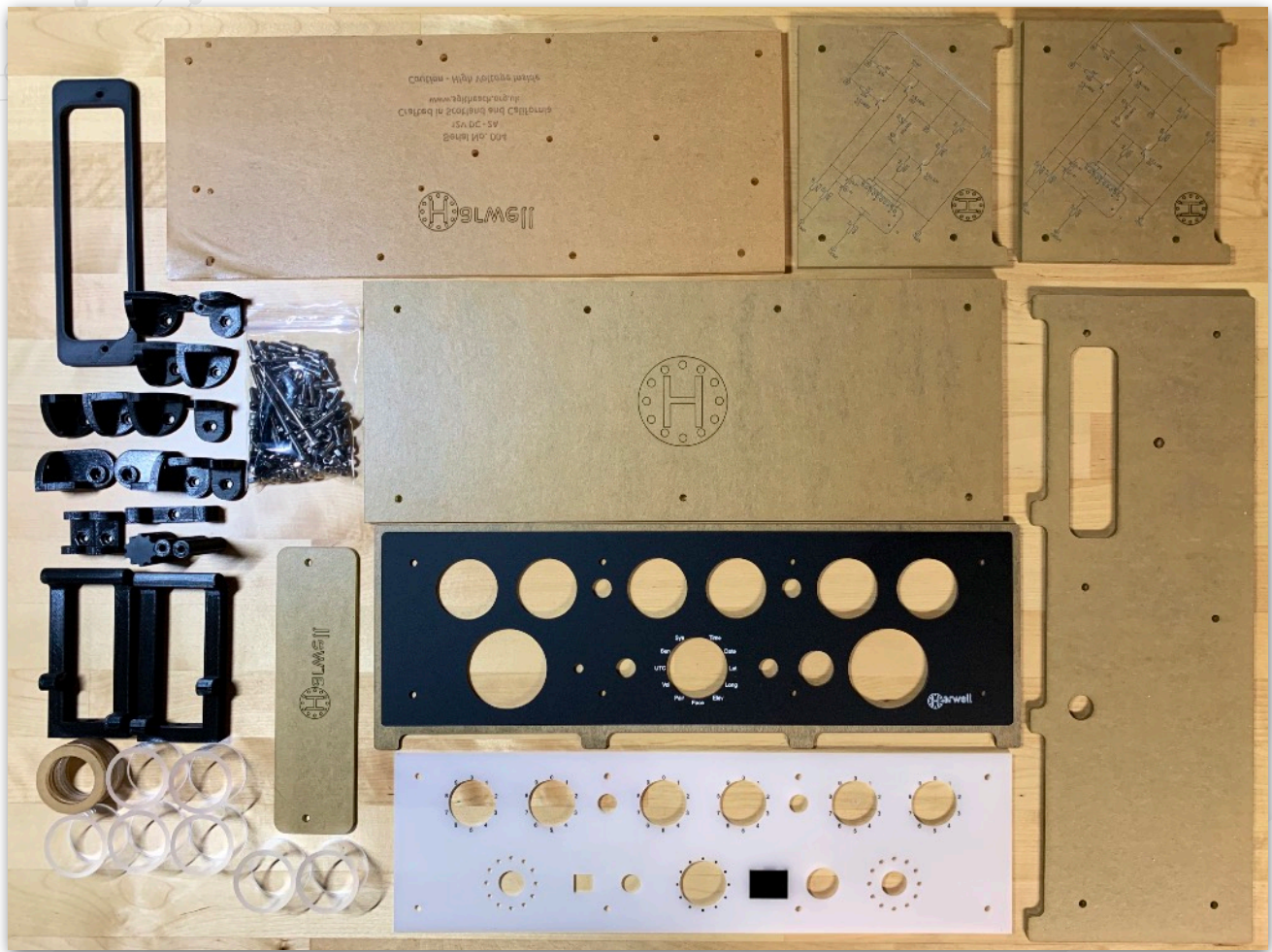


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



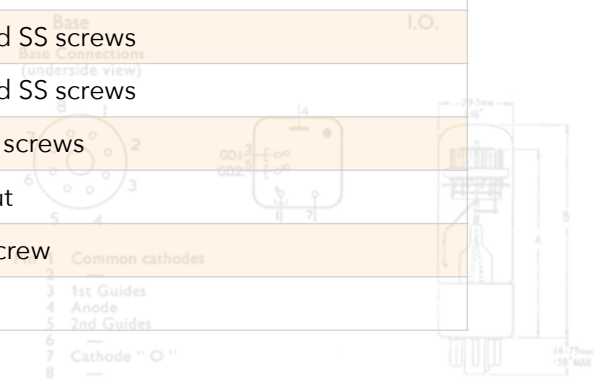


The Harwell Dekatron Clock Case has a *lot of parts*.⁹⁵



Quantity	Description
51	M4 SS nuts
14	M4 SS washers
6	M4 x 8mm socket head SS screws
34	M4 x 10mm socket head SS screws
2	M4 x 12mm socket head SS screws
3	M4 x 16mm socket head SS screws
2	M4 x 20mm socket head SS screws
4	M4 x 60mm socket head SS screws
2	M4 x 16mm thumb screws
1	M3 square nut
1	M3 6mm grub screw
8	M3 nuts

⁹⁵ Lovingly crafted I might add...



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

Quantity	Description
8	M3 washers
8	M3 x 16mm socket head SS screws
23	3D Printed Parts (see Annex D)
23	Acrylic Parts (see Annex G)

The following parts are optional and not normally fitted:

Quantity	Description
1	3D printed plug for the GPS or WiFi antenna connector hole if neither are used.

Construction notes.

We suggest that you closely follow this assembly guide. It can be difficult to fit some boards or screws if they are not fitted into the case at the *right time*. The assembly guide will also show which size screws are used to fit each part so as to avoid problems. *Remember* that you are working with plastics - both PLA (polylactic acid) and acrylic (PMMA) - these are relatively weak in some ways and over tightening of screws may lead to fracture. Slightly tighter than finger tight will be entirely adequate. The case is mainly constructed from 1/4 (approx. 6mm) acrylic which is very stable. Many of the 3D printed parts have embedded nuts. The procedure for fitting these is in the Låda section of the "Sgitheach Commoners" manual.⁹⁶ Again, the nuts should be fitted just right - if the nut is too tight⁹⁷ then you can break the part with excess force and if too loose it can drop out during assembly.⁹⁸ Follow the guidance in the manual and you should be fine.

Remember that the acrylic can scratch and so only remove the protection when you are ready to fit the part. Acrylic sheets are also notorious for picking up a static charge and attracting dust/fingerprints. Try to work in a clean environment and wipe down your work surface before starting. IPA (no not the beer...) is a good solvent to clean acrylic, just take care not to use an abrasive cloth. Finally, at some stage of the assembly it is probably worth repeating some of the basic tests on the boards to confirm nothing has come adrift - the assembly guide below will suggest these points.

Case assembly broadly follows a rough front to back, and bottom to top route with the case sides and top being fitted last. See [Annex D](#) for the identification of the 3D printed parts and [Annex G](#) for the identification of the laser cut acrylic parts.

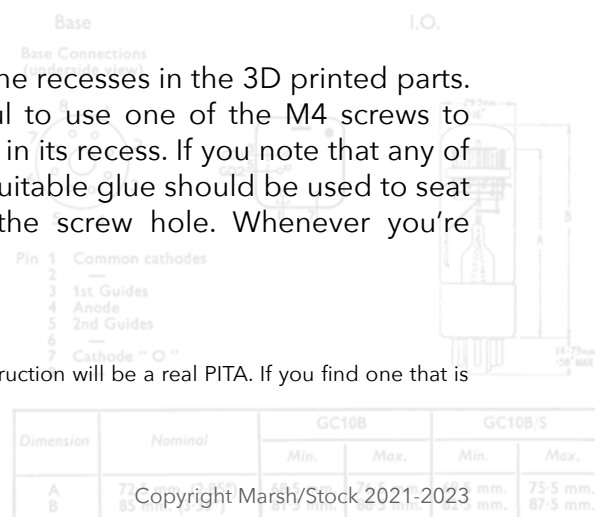
Fitting the nuts

At this time it is probably worth fitting the M4 nuts into all of the recesses in the 3D printed parts. There are a total of 47 nuts to fit. I find it particularly useful to use one of the M4 screws to accomplish this and tighten them until the nut is firmly seated in its recess. If you note that any of the nuts are loose in their socket at this point, a small dab of suitable glue should be used to seat them correctly and tightly, taking care not to glue over the screw hole. Whenever you're

⁹⁶ On the Dropbox...

⁹⁷ 3D printing has its tolerances...

⁹⁸ The case is very complicated. Having a nut drop out towards the end of the construction will be a real PITA. If you find one that is loose, then we recommend gluing the offending nut in place.



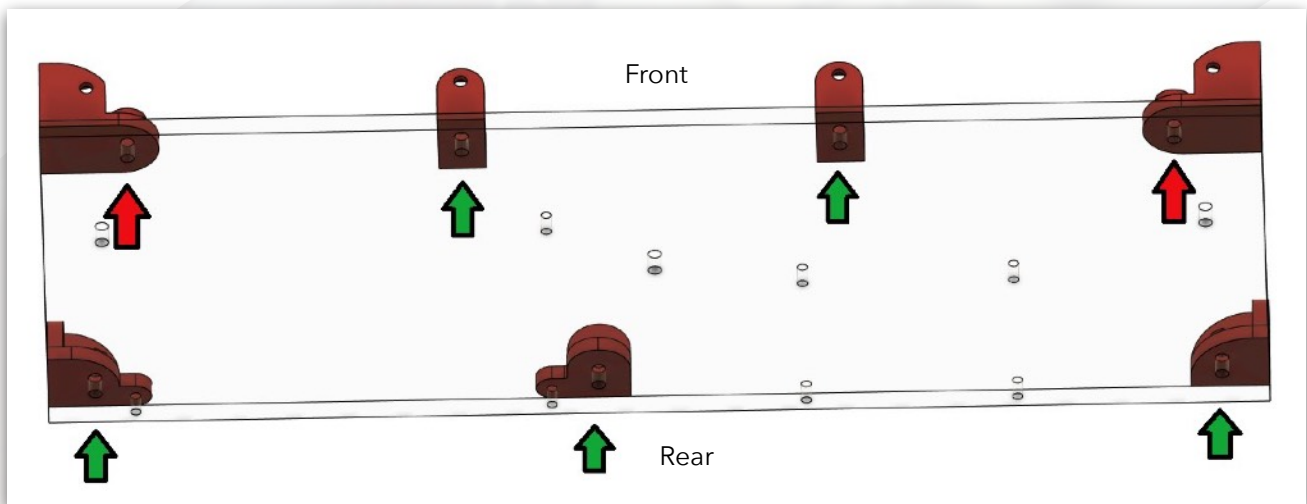
tightening the screws into the 3D parts when putting the case together, try not to put too much forward force on the screw as this can dislodge the nut and retracing your steps can be a PITA.

Assembling the base board and its 3D parts

Parts and hardware needed are:

Quantity	Description
1	Acrylic base plate
1	3D part - Centre Back Bottom
1	3D part - Left Back Bottom
1	3D Part - Left Front Bottom
2	3D Part - Centre Front Bottom
1	3D Part - Right Front Bottom
1	3D Part - Låda M4 3x15
5	M4 x 10mm socket head screws
2	M4 x 20mm socket head screws

This is the view of the underside of the acrylic base (with the engraving removed for less clutter) from the front. The red filled arrows are M4 20mm screws and the green are 10mm screws.



The top row in this image consists of the Left Front Bottom, Right Front Bottom and two Centre Front Bottom 3D printed parts. The forward faces of these parts will eventually have the clock's front panel screwed into the recessed nuts held in these parts. Make sure these nuts are really firmly gripped in the 3D printed shell. For a "belt and braces" approach glue the nuts in place even if they apparently don't need it. Later on the assembly process when you do screw the front panel on, if any of these nuts pop out then considerable amount of disassembly⁹⁹ and back-tracking will be required to put them back in.¹⁰⁰

⁹⁹ The toys will be thrown out of the pram....

¹⁰⁰ Don't say we didn't warn you....and ask us how we know...

Base I.O.

Pin 1 Common cathodes
 2 ---
 3 1st Guides
 4 Anode
 5 2nd Guides
 6 ---
 7 Cathode "O"
 8 ---

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

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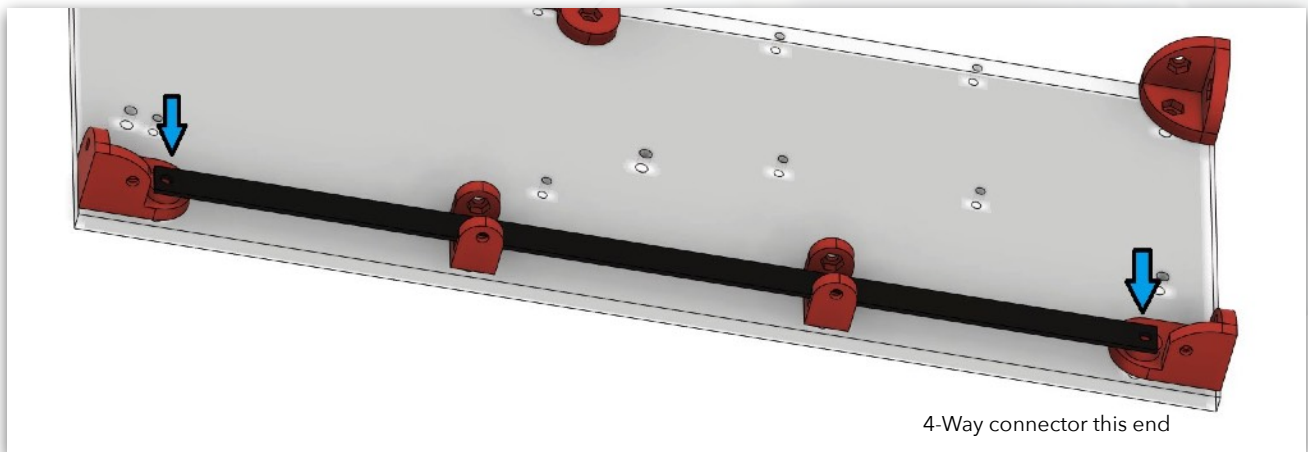


Mounting the Downward Firing Bling Board

Parts and hardware needed are:

Quantity	Description
1	Acrylic base as fitted so far from last step
2	M4 nuts
2	M4 washers
1	Assembled and tested downward firing bling board with the LED diffusers all fitted

Fit the downward firing bling board over the two M4 20mm screw threads and secure in place using 2 M4 washers and nuts (light blue arrows). The four way connector to the board should be on the right hand side when viewed from the front.



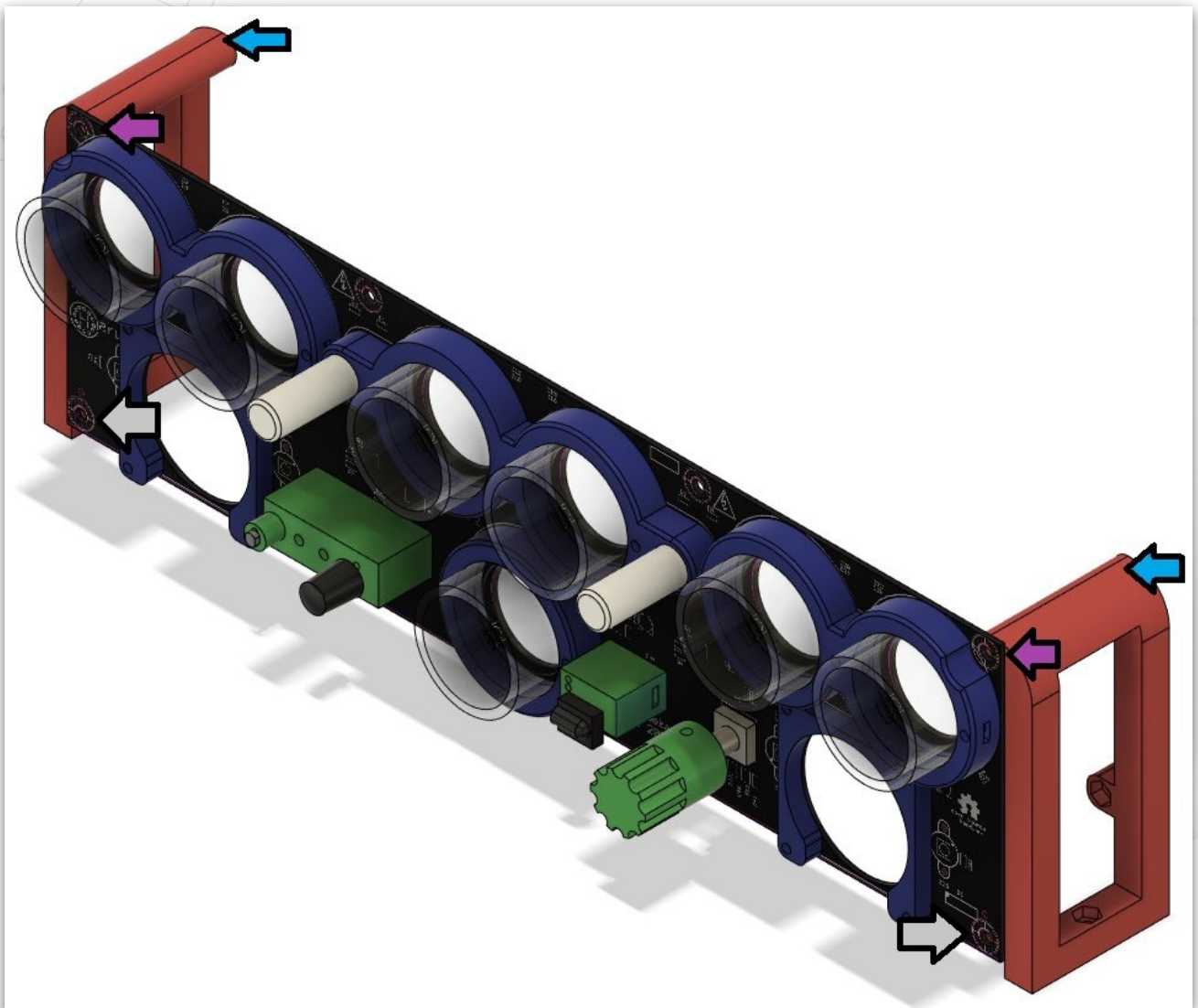
Mounting the Front Panel Board

Parts and hardware needed are:

Quantity	Description	
1	Acrylic base as fitted so far from last step	
1	3D Part - Vertical Support Left	
2	3D Part - Vertical Support Right	
2	M4 x 8mm socket head screws	I.O.
2	M4 x 12mm socket head screws	
2	M4 x 16mm socket head screws	
2	M4 x 60mm socket head screws	
6	M4 washers	
2	M4 nuts (additional to those installed in the Låda)	
1	Assembled and tested Front Panel Board	

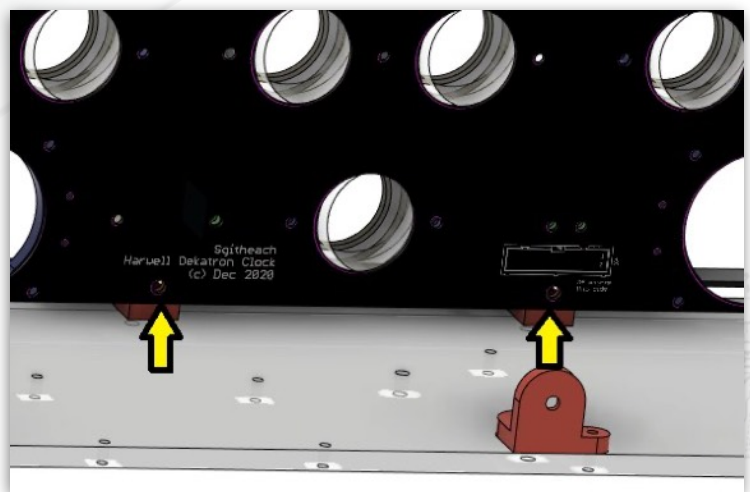
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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The first step is to mount the left and right vertical supports on the Front Panel PCB using two M4 x 12mm screws (grey) and washers, and two M4 x 60mm screws (purple) using washers and nuts (light blue) to temporarily secure everything in place.

Next, place the Front Panel board with its end supports and secure the board to the base using the two Front Centre Bottom 3D printed parts with two M4 x 8mm screws (yellow) and washers.

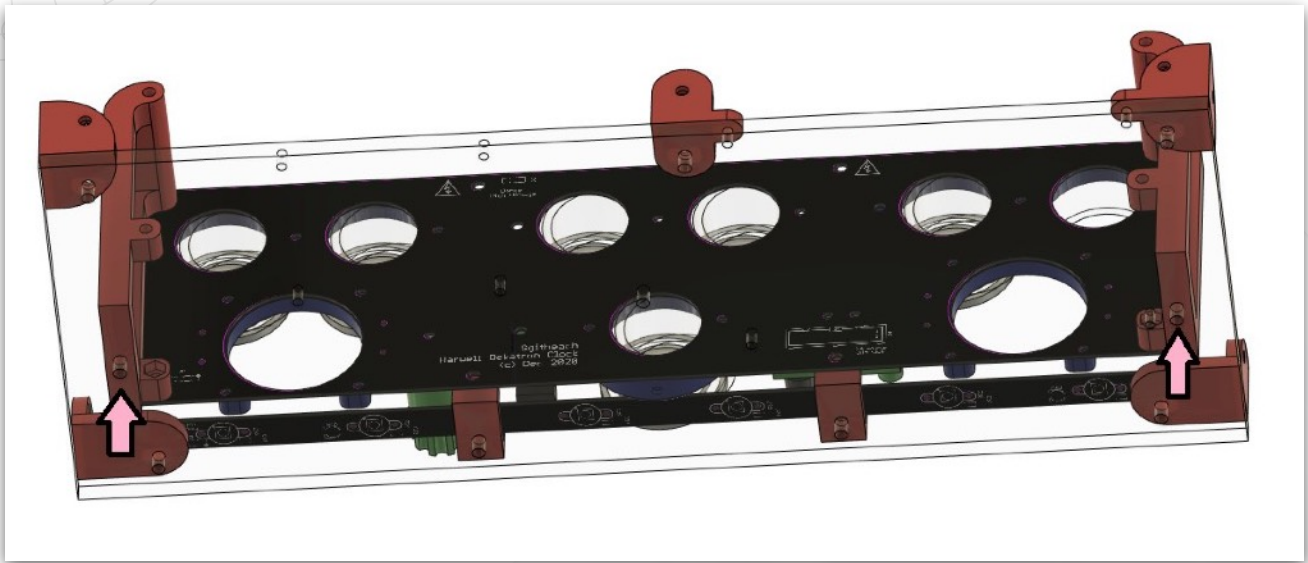


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm	
B	85			87.5 mm	

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Finally, use two M4 x 16mm screws (pink) from underneath the case to secure the vertical supports to the acrylic base plate.

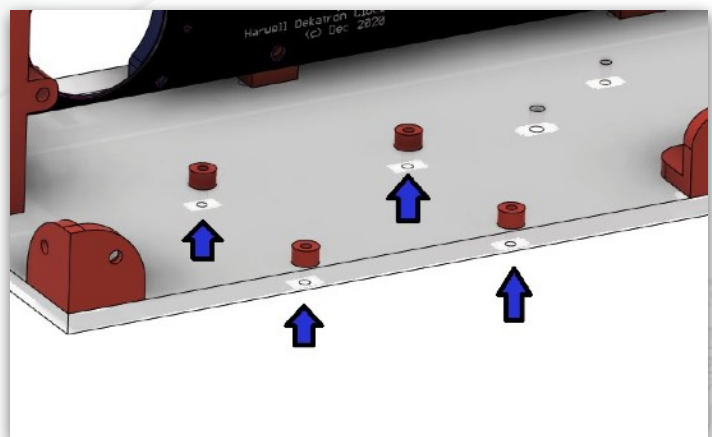


Mounting the PSU Board

Parts and hardware needed are:

Quantity	Description
1	Acrylic base as fitted so far from last step
4	3D Part - PCB Spacer
4	M3 nuts
4	M3 washers
4	M3 x 16mm socket head screws
1	Assembled and tested PSU Board

Fit four M3 16mm screws from the underside and slide over the 3D printed PCB spacers. The spacers should be a fairly tight fit and hold the screws in place.¹⁰¹

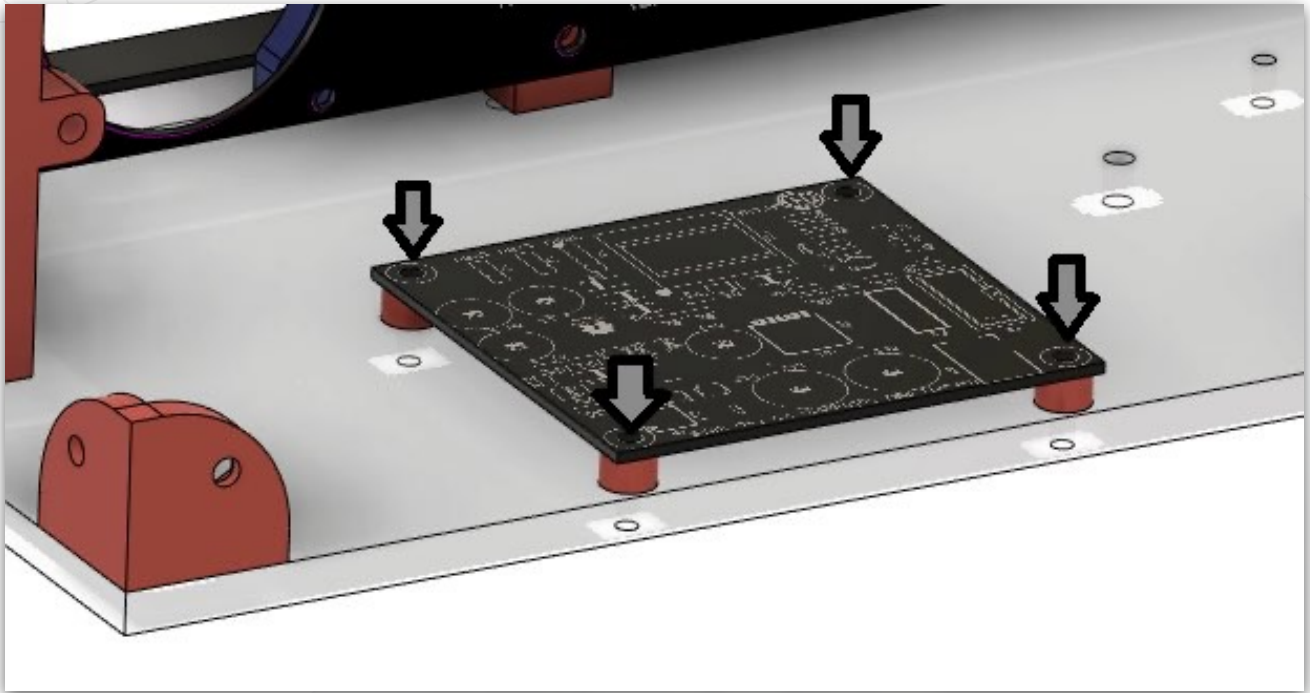


¹⁰¹ You may need to hold the spacer in place and screw the screws in with an Allen key (socket head screwdriver for the US amongst us.)

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



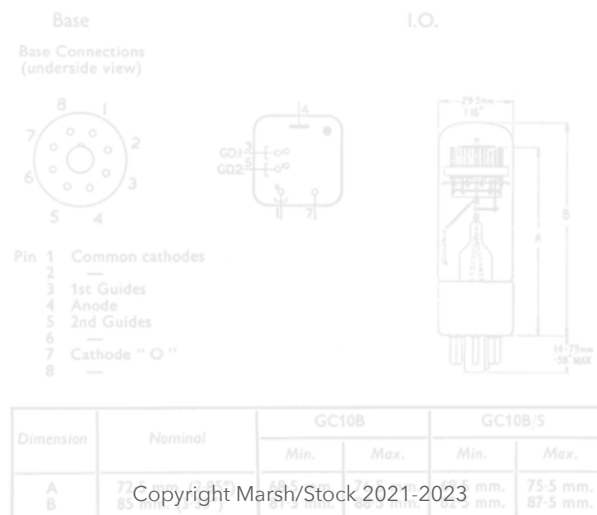
Now flip the base right side up and place the PSU board on the 4 screws. The power input jack should be at the rear obviously. Secure the PCB in place using 4 M3 washers and 4 M3 nuts (dark grey).



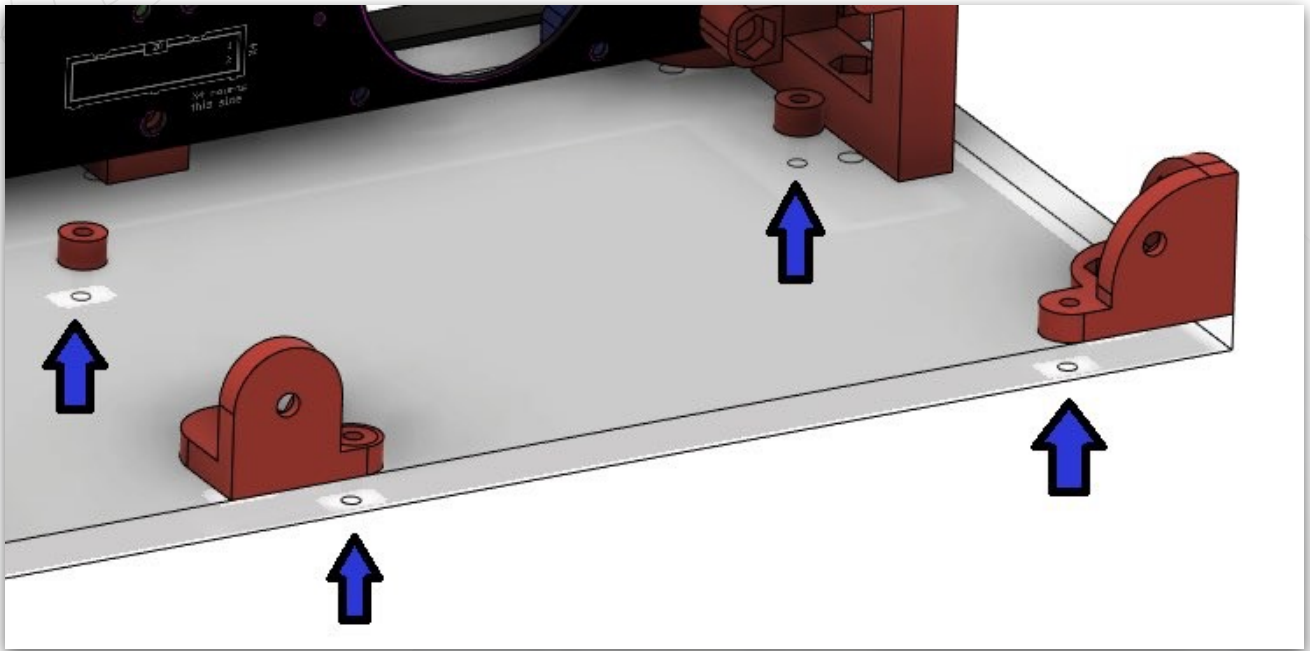
Mounting the Main Board

Rinse and repeat with the Main board, parts and hardware needed are:

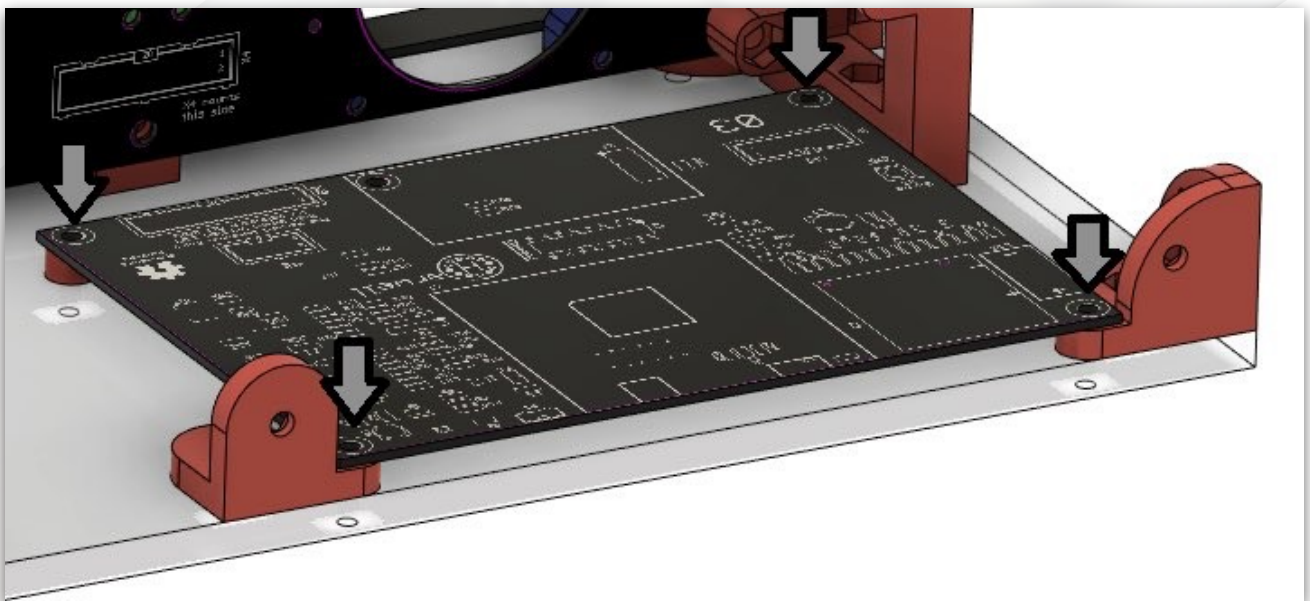
Quantity	Description
1	Acrylic base as fitted so far from last step
2	3D Part - PCB Spacer
4	M3 nuts
4	M3 washers
4	M3 x 16mm socket head screws
1	Assembled and tested Main Board



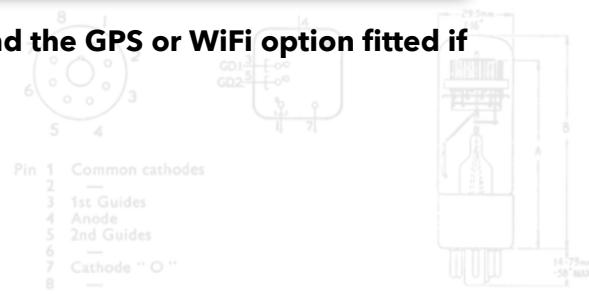
Fit four M3 x 16mm screws from the underside and slide over a 3D printed PCB spacer for the two that don't go through a rear 3D printed part.



Now flip the base right side up and place the Main board on the four screws. The SAM3X8C plug-in should be at the rear obviously. Secure the PCB in place using four M3 washers and four M3 nuts (dark grey).



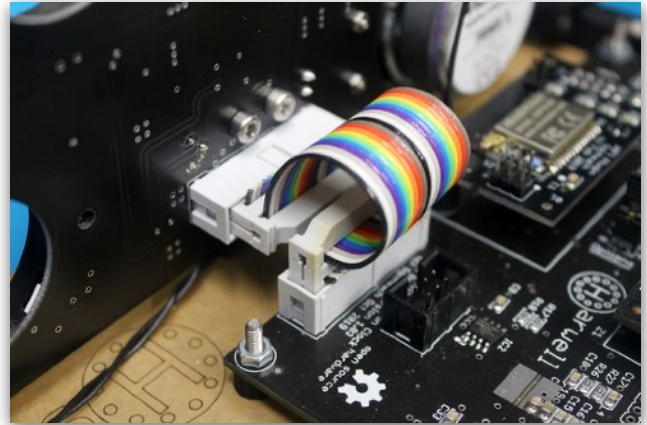
At this time you should have the SAM3X8C board fitted and the GPS or WiFi option fitted if you are using one.



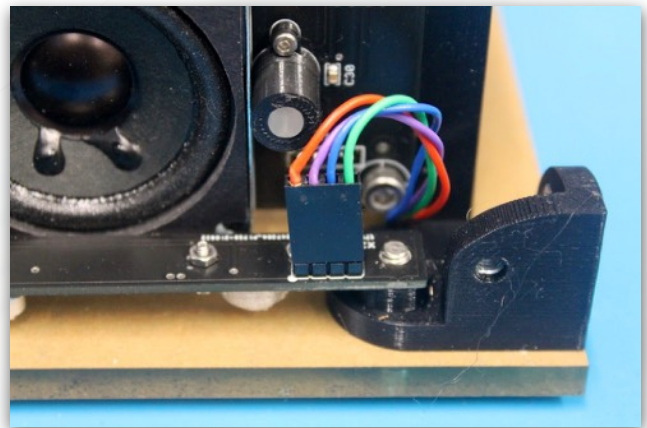
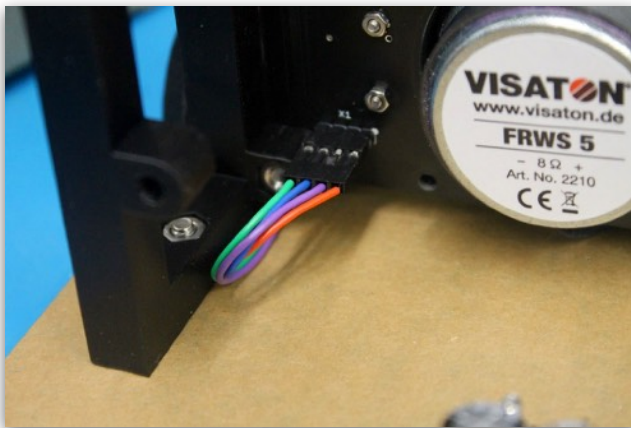
Dimension	Nominal	GC10B		GC108/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm	
B	85			87.5 mm	



Now fit the 20 way ribbon cable between the main board and the front panel board. (note that the paper is still on the acrylic in this picture, yours should be removed at this stage..).



Also, fit the 4 way cable from the front panel board and the downward firing bling board.



Remember the dire warning from before - the orientation of the four wires is very important. In these photos you can see the red wire is nearest the speaker in both cases. Note the white dot on the PCBs, this is there for this specific alignment purpose.

Install the Dekatron assembly

We suggest that assembly of the Dekatron board into the case is made with the Dekatron tubes themselves plugged in as it is much easier to fit them at this point. The following hardware is required.

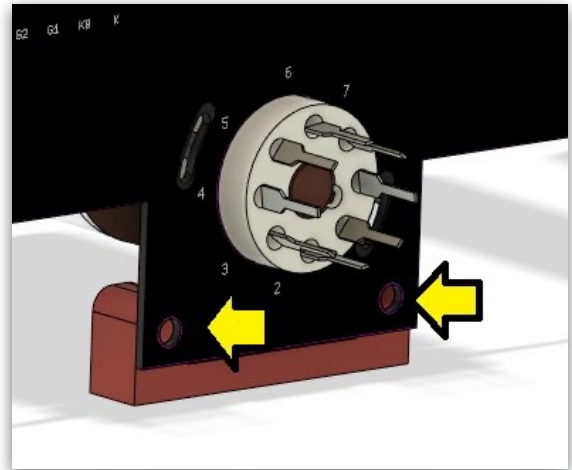
Quantity	Description
1	Acrylic base as fitted so far from last step
2	M4 x 10mm socket head screws
1	M4 x 16mm socket head screw
2	M4 x 60mm socket head screws
6	M4 washers
2	M4 x 8 mm socket head screws
2	3D Part - Vertical Top Spacer
1	3D Part - Vertical Support Middle
1	Assembled and tested Dekatron board with the Dekatrons fitted

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



Attach the middle vertical support 3D printed part to the Dekatron board below V7 using two M4 x 8mm screws (yellow) and washers.

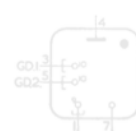
Now remove the M4 nuts and washers that were temporarily used when fitting the front panel board to free the M4 x 60mm screws.



Thread the two Vertical Top Spacers to M4 x 60mm screws (pink). This will now mean you have four threaded ends free.



Base Connections (underside view)

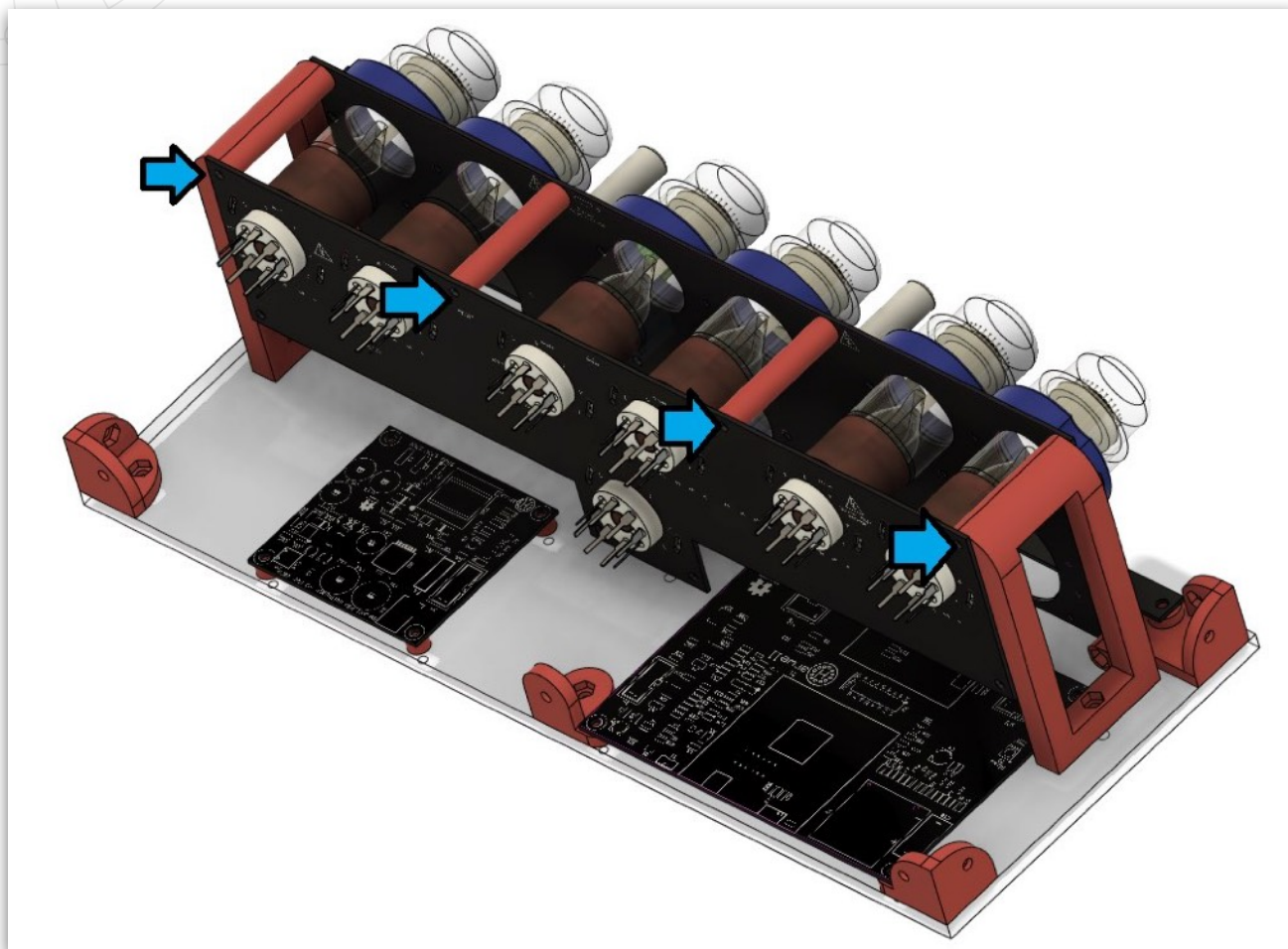


- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm	
B	85			87.5 mm	

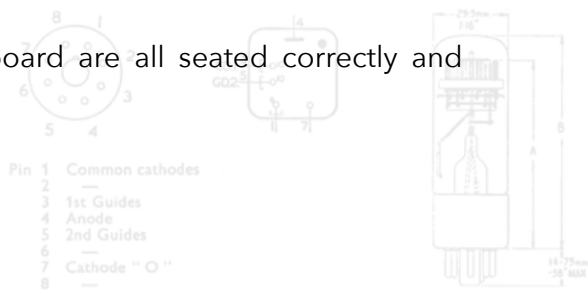
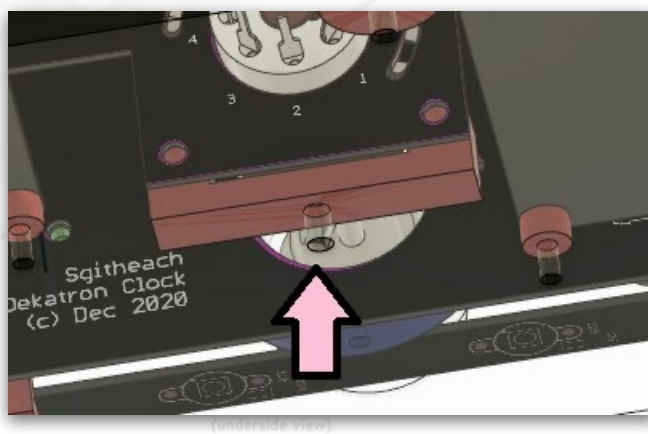


Attach the Dekatron board using four M4 washers and nuts on the M4 x 60mm screw threads (blue).



On the underside of the base plate, use a M4 x 16mm screw to attach the vertical support middle 3D printed part. At this point all of the holes cut in the acrylic base plate should be occupied!

The high voltage wiring from the Dekatron and front panel boards can now be refitted. The 6 way ribbon cable from the Dekatron board to the main board can be refitted. You should double check that the 20 way ribbon cable between the front panel and the main board and the 4 way cable to the downward firing bling board are all seated correctly and haven't come loose.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	75.5 mm.
B	85			87.5 mm.	87.5 mm.



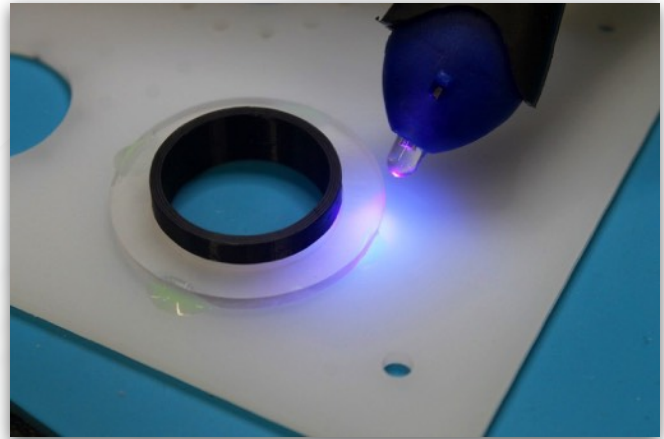
Retesting

The clock is now electrically complete again and can be retested before continuing with case assembly.

***Danger* Remember when testing there will be up to 500V present on the clock boards.** When you have switched the clock off, allow several minutes for the capacitors to discharge.

Make up the Front Panel Light Diffusion Assembly

The light from the bling LEDs passes through light guides to the front panel. Here the light is diffused and forms a backlight to the Dekatron number decal. The diffusion takes place through a spreader and a translucent white diffuser panel. The spreaders can be glued onto the rear (the Dekatron side) of the diffuser. I used UV cured glue. The kit contains a small 3D printed alignment ring (the black item in this photo) to help hold the spreader concentric with hole in the diffuser. Whichever glue you use, you should try to avoid the glue migrating between the two acrylic parts but use it to form a bead on the edge.



In my case I just used four small blobs and cured each as soon as I had deposited it so the glue didn't run into the gap. The diffuser rings are deliberately oversized for the aperture at the front, so if a small amount of adhesive does wick into the gap, it should be OK.

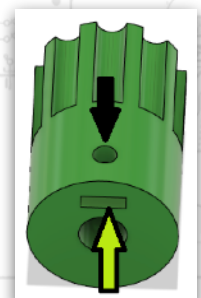
Mounting the front panel

If you haven't done so already now is the time to make up the knob for the rotary encoder and fit it over the shaft. Parts required:

Quantity	Description
1	M3 x 6mm grub screw
1	M3 square nut
1	3D Printed Part - Knob

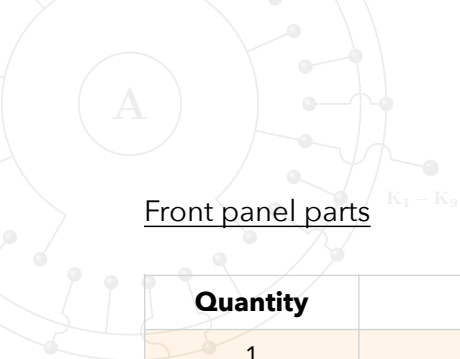
Push a square M3 nut up the slot (light green arrow) and use a M3 6mm grub screw (black arrow) to hold it in place.

The knob can now be fitted over the shaft and the grub screw tightened. Later on you can loosen the grub screw to set how much of the knob protrudes from the front panel. It is important to not attach it too close to the base of the rotary encoder as you can prevent its push-in function.



Dimension	Nominal	Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

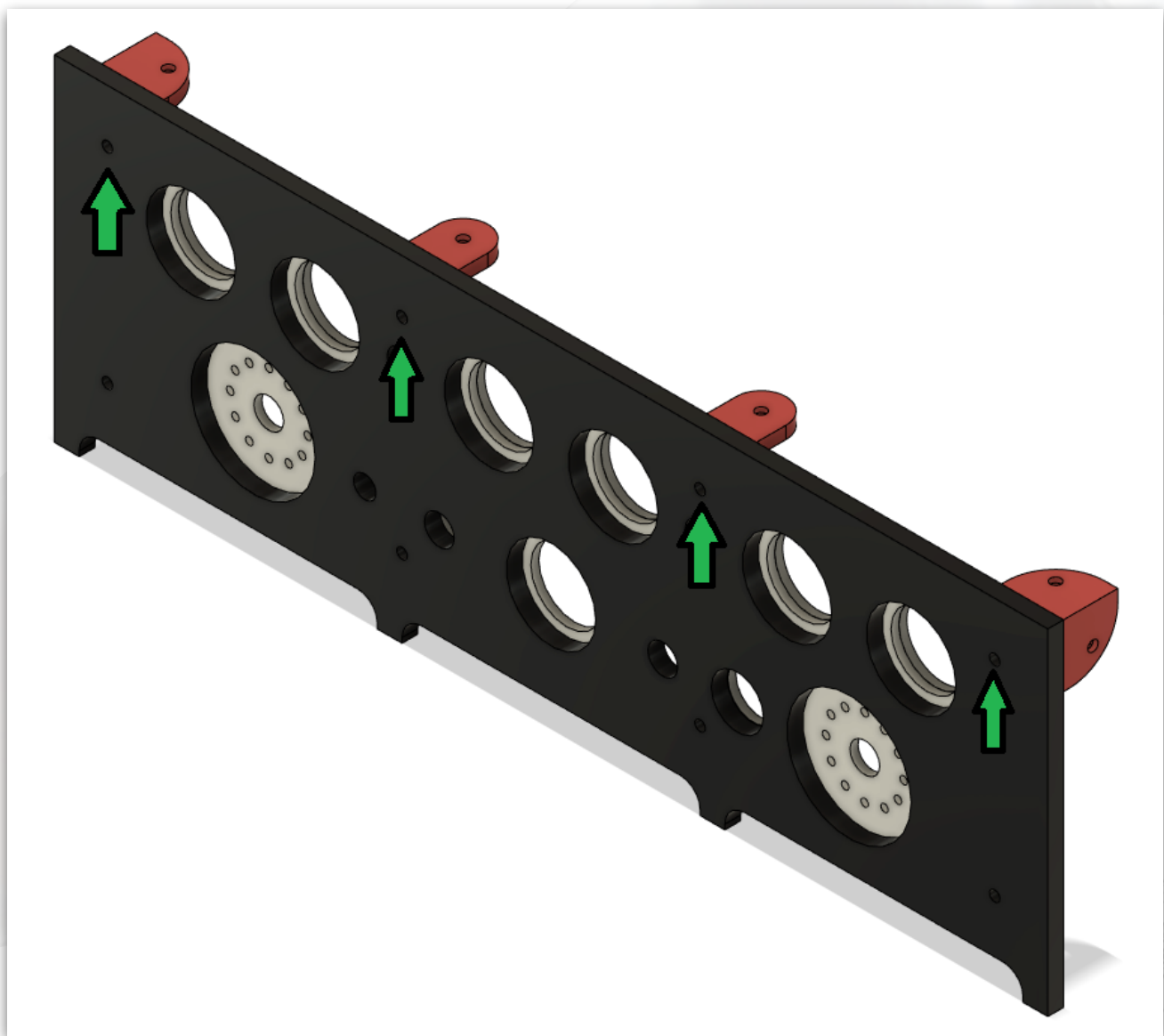
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Front panel parts

Quantity	Description
1	Laser cut acrylic diffusion assembly
1	Laser cut acrylic front panel
K_0 4	M4 x 10mm socket head screws
2	Låda M4 3x15
2	Låda M4 2x15

Use four M4 x 10mm screws (green) and the four Låda 3D printed parts to pin the acrylic front panel and diffuser panel together.



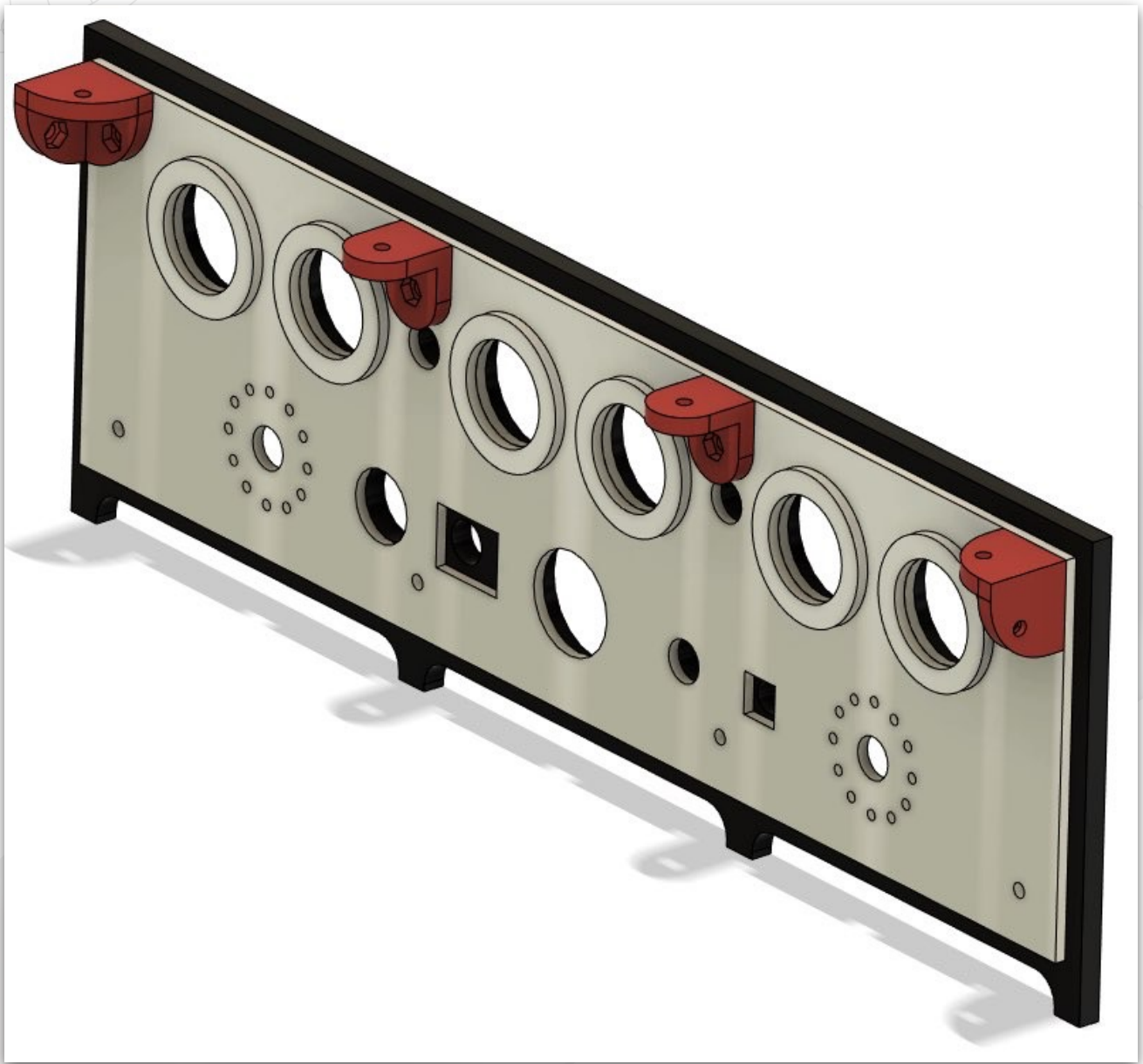
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

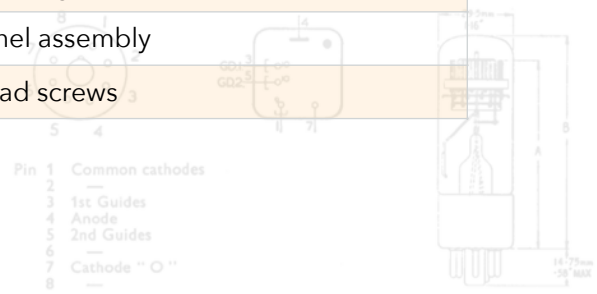


It should now look like this (note - the diffuser plate now comes with a black IR window glued in place):



Attaching the front panel to the rest of the clock: Parts required:

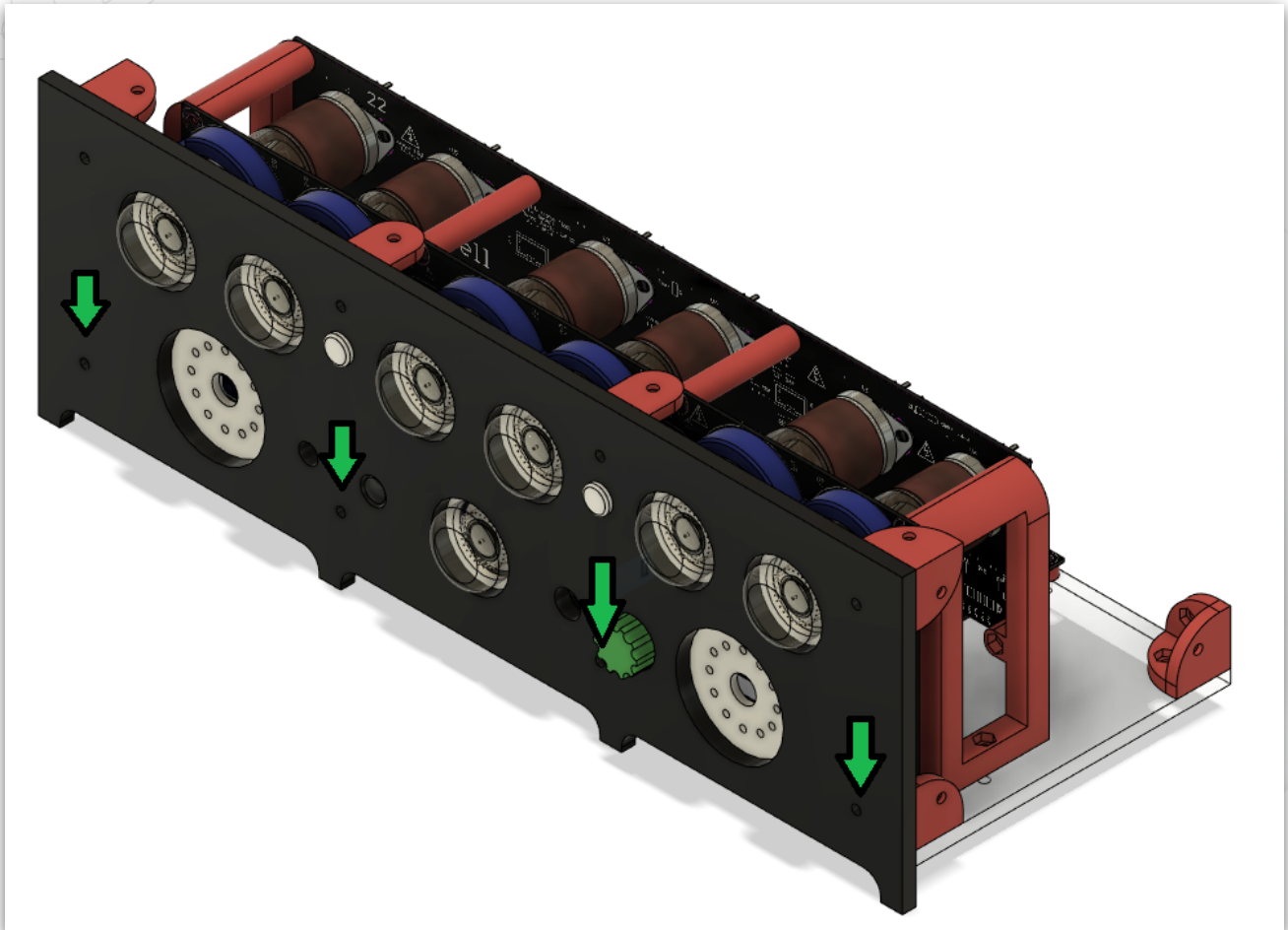
Quantity	Description	Base	I.O.
1	Clock as fitted with everything so far	Base Connections	
1	Laser cut acrylic front panel assembly		
4	M4 x 10mm socket head screws		



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



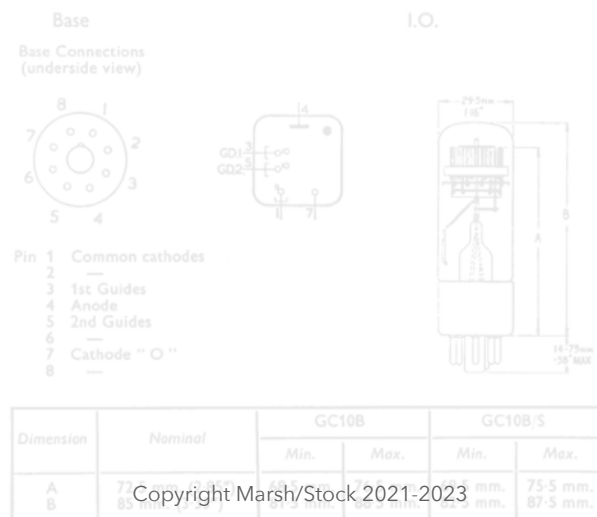
Mount the front panel assembly from the last step onto the whole clock assembly using four M4 x 10mm screws (green). Your pile of parts should be getting seriously depleted by now!



This is not the time to accidentally push a M4 nut out of its 3D printed part. You will find a considerable amount of disassembly and back-tracking will be needed to refit them.¹⁰²

Dekatron Alignment

Now is a good time to align the Dekatron cathode '0' to the 0 mark (12 o'clock) on the case. See [Annex H](#) for instructions on how to safely accomplish this.



¹⁰² You were warned some time ago....

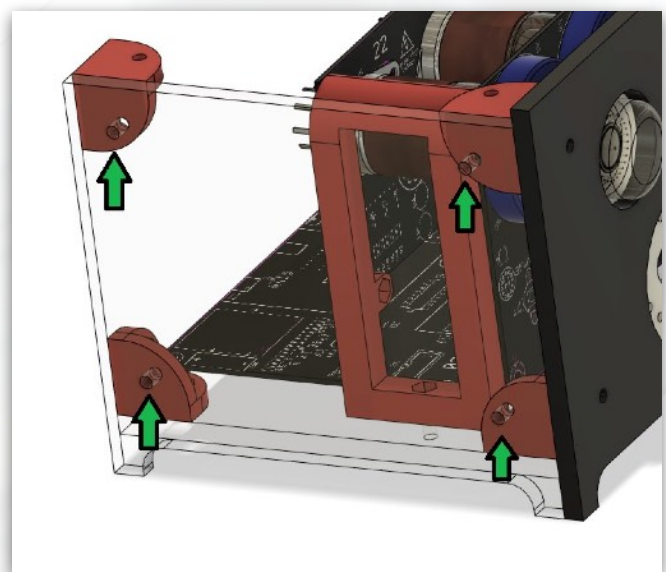
The remains of the case

You should now have six 3D printed parts left, just four pieces of laser cut acrylic and a small pile of hardware:

Quantity	Description
1	Clock as fitted with everything so far
2	Laser cut acrylic sides
2	3D Printed Part - Låda M4 3x15
8	M4 x 10mm socket head screws

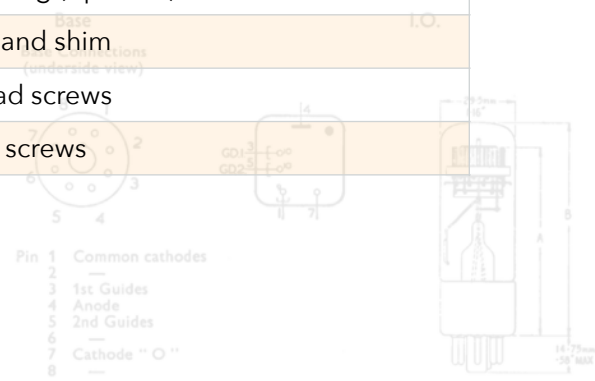
First mount the two side acrylic panels. Attach one of the side acrylic panels using M4 x 10mm screws and the back top Låda M4 3x15 corner (green). Note that the side pieces are not identical, the holes are offset to fit either the right or left side accordingly.

Repeat for the other side.

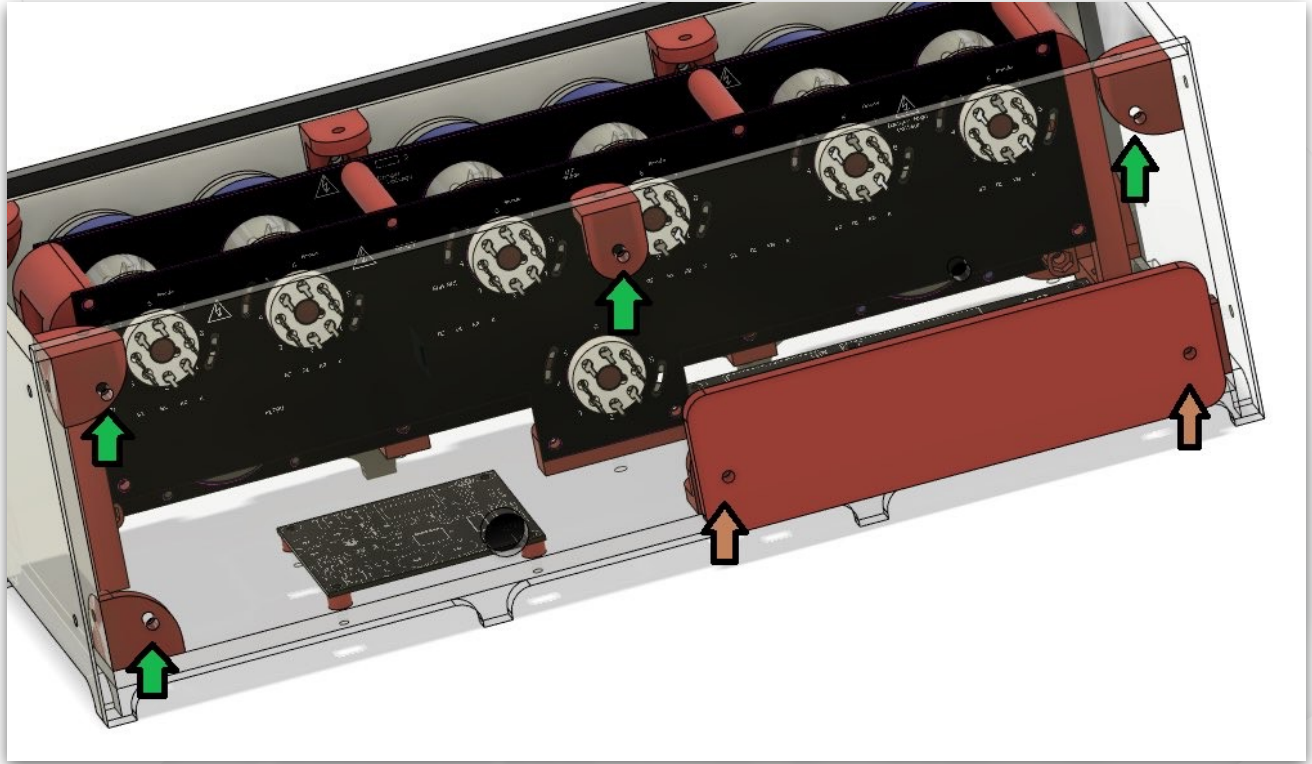


Next mount the back acrylic panel.

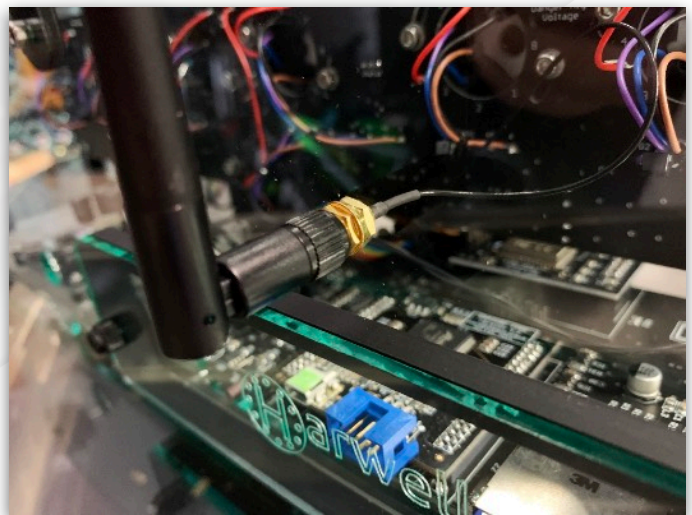
Quantity	Description
1	Clock as fitted with everything so far
1	Laser cut acrylic back panel
1	3D Printed Part - Låda M4 2x15
1	3D Printed Part - Hole blanking (optional)
1	Laser cut cover plate and shim
4	M4 x 8mm socket head screws
2	M4 x 16mm thumb screws



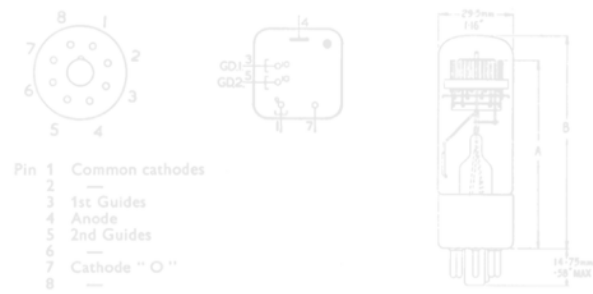
Attach the back panel using three M4 x 10mm screws (green), attach the Låda M4 2x15 using a fourth M4 10mm screw and then fit the access cover and shim using two M4 x 16mm thumb screws (note the picture below shows a 3D printed part, but the kit is supplied with a laser cut cover and 3D printed shim plate).



If used, the SMA connector for the WiFi/GPS antenna can be bolted through the back panel. Do not use the spring washers that come with the SMA socket or else an electrical connection between the socket and the antenna/antenna lead will not be made (not enough socket proud of the case). If you are not using a WiFi or GPS option then you can use the two hole plug 3D printed parts to close off the hole.



(underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



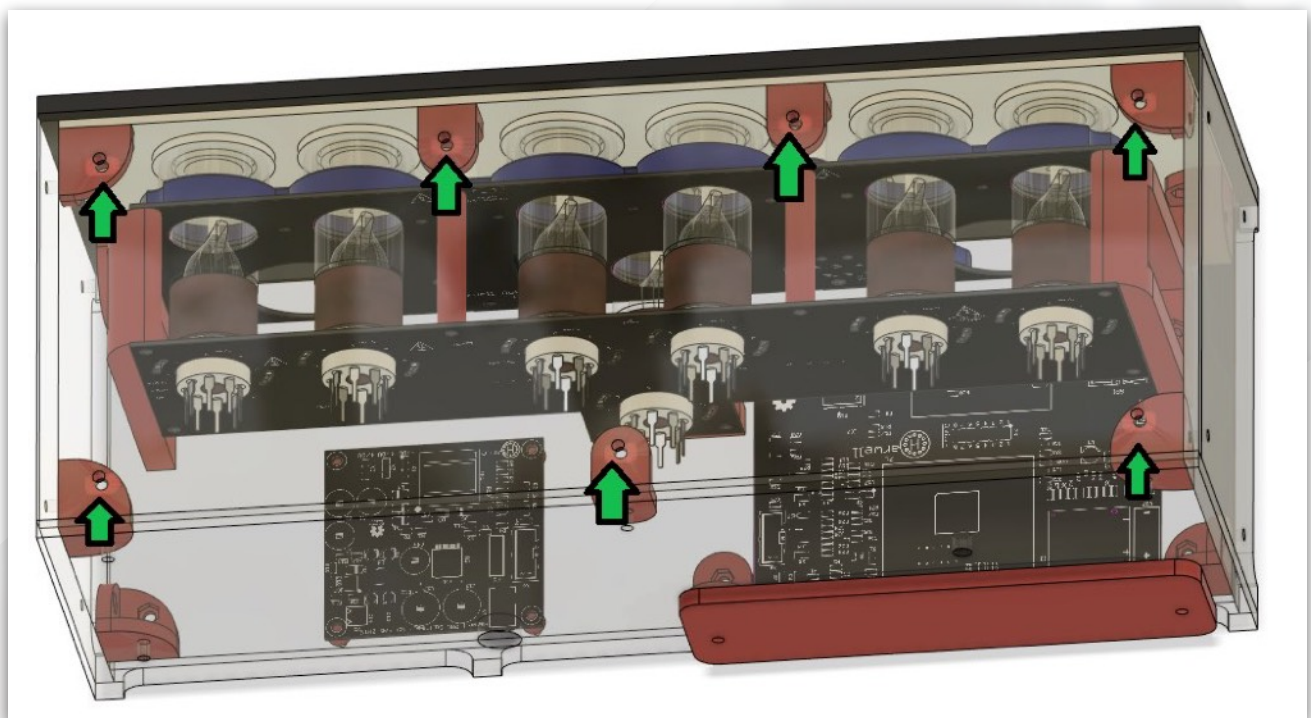
The final parts.

$K_1 - K_0$

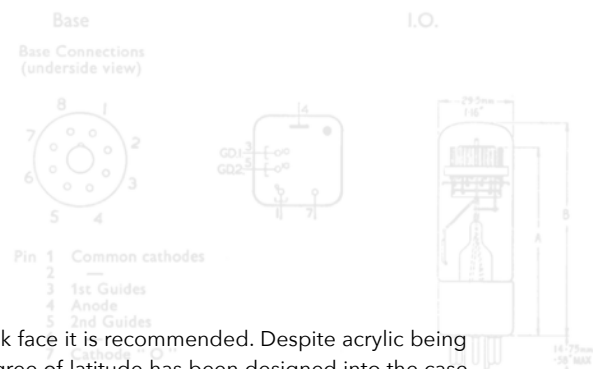
Quantity	Description
1	Clock as fitted with everything so far
7	M4 x 10mm socket head screws

K_0

At this stage you may need to adjust the light guides so that they are flush with the diffuser discs on the white acrylic plate.¹⁰³ This can be accomplished by loosening the grub screw and pulling the light guide forward a little, then retightening the screw. All that remains now is to screw the top cover to the clock using 7 M4 x 10 mm socket head screws (green). You will note that the completed clock differs slightly from the model below by virtue of the overhang of the front and back panels. This is by design so as to keep sharp corners to a minimum.



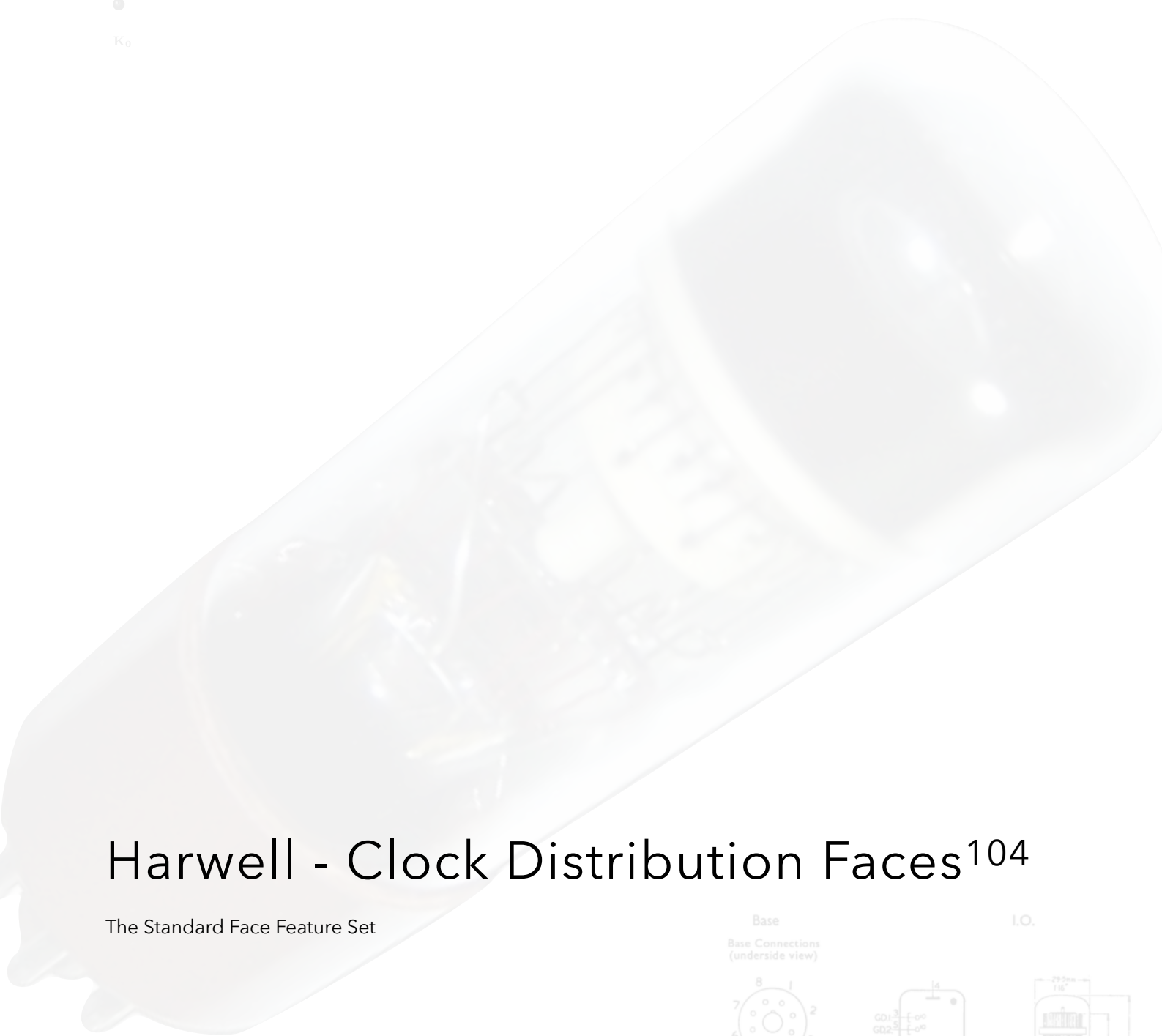
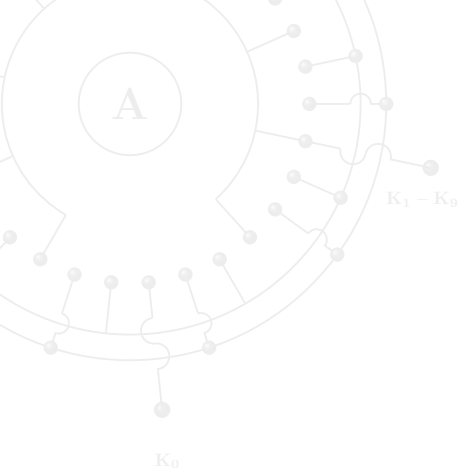
Plug it in and enjoy! See the operations section to play with all the faces, capabilities and even make your own displays!



¹⁰³ This isn't absolutely necessary, but for even and consistent illumination of the clock face it is recommended. Despite acrylic being sold as specified thicknesses, the variation in batches can be quite striking. Some degree of latitude has been designed into the case build to accommodate these variances.

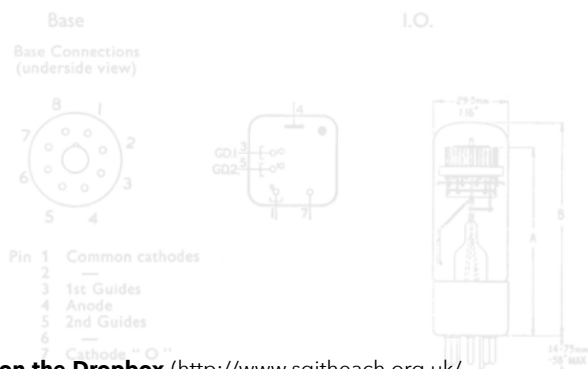
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





Harwell - Clock Distribution Faces¹⁰⁴

The Standard Face Feature Set



¹⁰⁴ For the latest Harwell Faces distribution, see the Harwell Face Supplemental on the Dropbox (<http://www.sgitheach.org.uk/harwell.html#documentation>)

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5 mm			75.5 mm	
B	85 mm			87.5 mm	



Introduction

This manual section describes the clock “faces” that you will find on the supplied SD card (or the standard set you download should you be building the clock yourself). Whilst you can just use these distribution faces and their numbering and arrangement, you are encouraged to rearrange the faces and pick the ones to commonly use yourself. You are also encouraged to edit the face files, change the sound files and reconfigure the displayed clock faces to your own amusement. If you take the plunge and decide to start coding your own faces, then please share with us!!¹⁰⁵

Clock Face Numbering

There is only one rule: clock faces must be numbered between 1 and 999999.

The rest of this description should not be taken as hard and fast rules - this is just how the faces are arranged on the SD card at distribution - all can be changed at your whim.

Clock faces are normally selected on the Harwell Clock by:

- Turning the rotary encoder when not pressed in.
- Pressing the CH- or CH+ keys on the handset.
- By “dialling” in number using the 0 to 9 keys and pressing EQ.

To select quickly and easily, I arrange my favourite faces to be in the number range 1 to 9 and other good clock faces that I might occasionally want to use in the range 10 to 99. This minimises the ‘travel’ distance using the encoder and key presses when using the IR handset. I use numbers above 100 to display all the clock faces (even repeating the favourite ones) in logical groups so that the full range is available for use and for demonstration.

Clock Face Filenames and Number Assignment

Clock faces are Nuggle program files living in the `/nuggle` folder on the SD card with `.nug` file extensions. The `[faces]` section in the `nuggle.ini` file¹⁰⁶ is used to link a required clock face number to a Nuggle file.

For example:

`[faces]`

`4 = awest`

will make the `awest.nug` program execute when clock face number 4 is selected.

Note that whilst face numbers can only be used once, the Nuggle filenames can appear more than once. Therefore in addition to the assignment of `awest.nug` to face number 4, you could have:

`152 = awest`

further down the list. This enables you to build clusters of popular face numbers in the list.

¹⁰⁵ We look forward to what you come up with..... this is Open Source *after all*.

¹⁰⁶ In the `/system` folder on the SD card



The diagrams show the base connections (underside view) and a side view of the clock base. The base connections diagram labels pins 1 through 8: 1st Guides, Anode, 2nd Guides, Cathode, and two empty pins. The side view diagram shows dimensions A and B, and a note '14.75mm ±0.05mm'.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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My Favourite Clock Face Selection

Whilst you can choose yourself how to use the face numbers, I use faces 1 to 9 for my favourites, as the effort to select one of them is therefore minimal. In all cases these faces are duplicates of main grouped clock faces with numbers 100 and above. You will need to look there for the detail of each clock face.

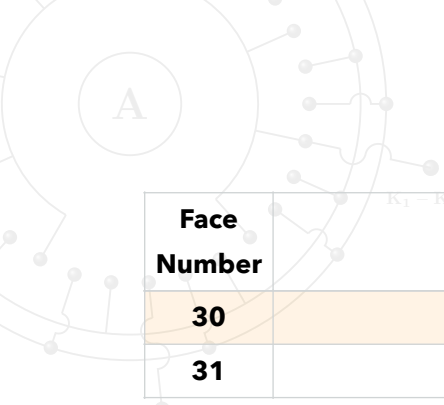
Face Number	Description	Grouped Face Number	Filename
1	Blanked clock - all dekatrons are off and bling set to black	400	<i>blank.nug</i>
2	Simple time with spinner, no bling, no chimes	105	<i>datetime.nug</i>
3	Date and time with lots of bling and TinTan chimes	200	<i>datetime.nug</i>
4	Date and time, bling, no chimes	121	<i>datetime.nug</i>
5	Date and time, bling and Derby chimes	123	<i>datetime.nug</i>
6	Original Star Trek Themed	160	<i>startrek.nug</i>
7	Holy Grail Themed	192	<i>holyclck.nug</i>
8	Date and time with daily changing chimes	124	<i>datetime.nug</i>
9	Star Wars Themed	180	<i>starwars.nug</i>

Don't forget these are *my favourites* only. If you find that the bling is not quite the right shade or you want different timing - the face is not entirely satisfactory¹⁰⁷ - then please look at editing the faces selected list or the Nuggle files themselves. However, I do recommend keeping clock face 1 as the blank display. In some cases an error condition in a Nuggle program needs a clock face to move to. I use face 1 for this purpose.

Face Number	Description	Grouped face number	Filename
10	Holy Grail Story	190	<i>holyclck.nug</i>
11	Black Knight Fight	191	<i>black.nug</i>
12	Next Generation Star Trek (incomplete)	161	<i>startrek.nug</i>
13	PIR Game	350	<i>pir.nug</i>
14	Larsen Scanner	430	<i>larsen.nug</i>
15	Cuckoo Clock	125	<i>datetime.nug</i>
20	Sun Rise	300	<i>sun.nug</i>
21	Sun Set	301	<i>sun.nug</i>
22	Sun Position	302	<i>sun.nug</i>

¹⁰⁷ .. for these extremely rich merchants life eventually became rather dull and it seemed that none of the worlds they settled on was entirely satisfactory: either the climate wasn't quite right in the later part of the afternoon, or the day was half an hour too long, or the sea was just the wrong shade of pink. And thus were created the conditions for a staggering new form of industry: custom-made luxury planet building. - H2G2 Douglas Adams.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Face Number	Description	Grouped face number	Filename
30	RTC Sync	962	syncrtc.nug
31	Tick Adjustment	963	rtcfine.nug

Distribution Clock Faces in Groups

Standard Date and Time Faces 100 -

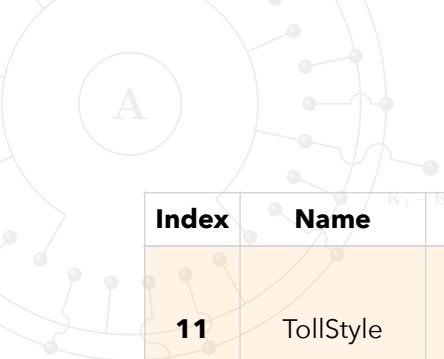
About datetime.nug:

This nuggle file is used for faces that show the time and/or date. It takes a lot of arguments to configure its use (text in *italics* are either system constants or constants define in *constants.ini*):

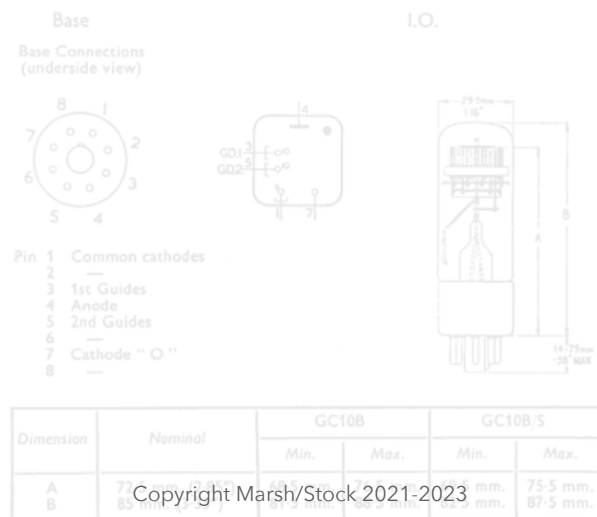
Index	Name	Type	Details
1	FaceTitle	string	This will appear on the console when the face has run
2	ShowTime	integer	0 <i>false</i> time not shown (default) 1 <i>true</i> time shown 2 <i>decimal</i> (special) shows time in decimal hh.frac
3	ShowDate	boolean	<i>True</i> will show the date, default is <i>false</i>
			If both ShowTime and ShowDate are true then the date is show between 40 and 50 seconds during each 1 minute cycle
4	ColonStyle	integer	0 <i>cs_none</i> show neither colons (default) 1 <i>cs_left</i> show the left colon 2 <i>cs_pair</i> show both colons 3 <i>cs_right</i> show the right colon
5	ColonTime	integer	The PWM value (0 - 100) when the time is shown
6	ColonDate	integer	The PWM value (0 - 100) when the date is shown
7	SpinStyle	boolean	<i>True</i> will spin the Dekatrons as seconds and minutes advance
8	TickStyle	integer	0 <i>ts_none</i> none (default) 1 <i>ts_tick</i> one chime file used 2 <i>ts_ticktock</i> two chime files used on alternate seconds
9	ChimeName	string	The base name of the chimes to use. The clock will add to the name to derive the quarterly and toll chime filenames
10	ChimeRotate	integer	0 <i>cr_none</i> use ChimeName if given (default) 1 <i>cr_daily</i> change the chime file each day 2 <i>cr_hourly</i> one chime set per hour 3 <i>cr_quarterly</i> one chime set per 15 minutes

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.






Index	Name	Type	Details
11	TollStyle	integer	0 <i>os_none</i> no tolls (default)
			1 <i>os_chime</i> tolls based on chime name
			10 <i>os_westc</i> special case for west-c bells
			20 <i>os_ships</i> ship's bells
12	BlingStyle	integer	0 <i>bs_none</i> none (default)
			1 <i>bs_single</i> single colour simple bling, all and down in BlingColour1
			2 <i>bs_double</i> colour all in BlingColour1 down bling in BlingColour3
			3 <i>bs_down</i> down bling only BlingColour1
			4 <i>bs_resistor</i> resistor colour codes
			5 <i>bs_rainbow</i> rotating rainbow bling
			6 <i>bs_chase</i> fast rotating bling single colour
			7 <i>bs_swirl</i> fast rotating HSV rainbow
13	BlingColour1	integer	Colour values which can be hex a decimal in the form 0xRRGGBB where RR is the red intensity 00 to ff, and so on for GG green and BB blue. Standard colour constants can be used, e.g. <i>dim red</i>
14	BlingColour2	integer	
15	BlingColour3	integer	
16	BlingColour4	integer	
17	BlingColour5	integer	




Time Only Faces 100


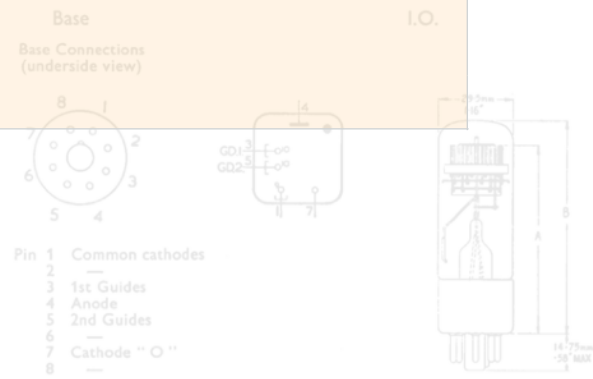
Face Number	100	
Nuggle file	datetime.nug	
Arguments	Time Only, true	
Description	Show the time only with no bling or colons	
Colons	None	
Bling	None	
Chimes	None	



Face Number	101	
Nuggle file	datetime.nug	
Arguments	Time Only- Red Bling, true, , cs_pair, 10, , , , , , , bs_double, smolder, dimred	
Description	<ul style="list-style-type: none"> Shows the time only, dim red bling, colons flash dimly, no chimes V1 to V6 - show the time V7 - indicate Time 	
Colons	Dim flash	
Bling	Dim red colours	
Chimes	None	

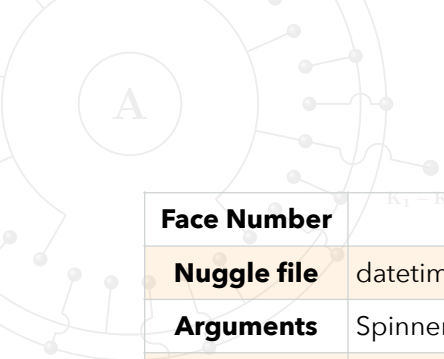


Face Number	102	
Nuggle file	datetime.nug	
Arguments	Time Only- Blue/Cyan Bling, true, , cs_pair, 100, , , , , , , bs_double, deepblue, dimblue	
Description	<ul style="list-style-type: none"> Shows time only, dim blueish colours, colons flash bright, no chimes V1 to V6 - show the time V7 - indicate Time 	
Colons	Bright flashing	
Bling	Blueish colours	
Chimes	None	

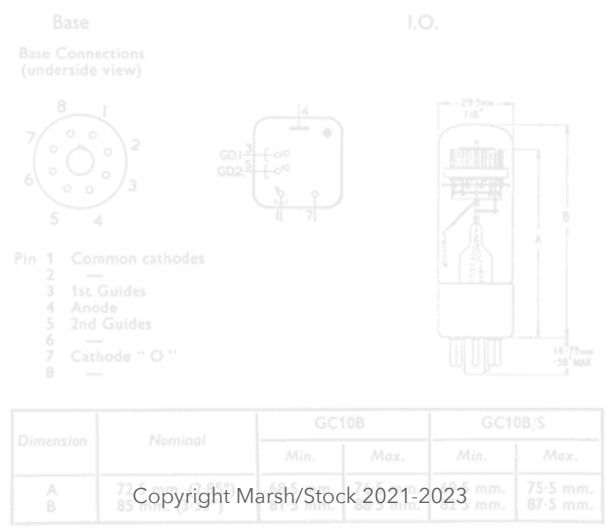
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.







Face Number	$K_1 - K_0$	105	
Nuggle file	datetime.nug		
Arguments	Spinner & Time Only, true, , , , , true		
Description	<ul style="list-style-type: none"> • Time only - spinning dekatrons - no bling, colons or chimes • V1 to V6 - show the time • V7 - indicate Time 		
Colons	None		
Bling	None		
Chimes	None		

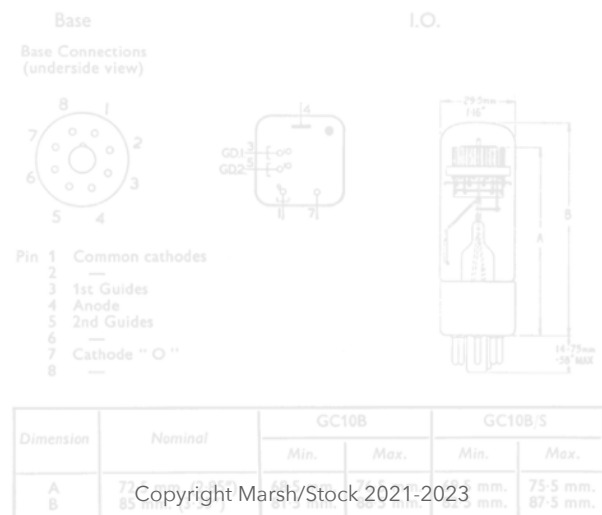
Face Number		106	
Nuggle file	datetime.nug		
Arguments	Spinner & Time Green Bling, true, , cs_pair, 100, , true, , , , , bs_single, darkgreen		
Description	<ul style="list-style-type: none"> • Time only - green bling with spinning dekatrons • V1 to V6 - show the time • V7 - indicate Time 		
Colons	Flashing		
Bling	All green bling		
Chimes	None		

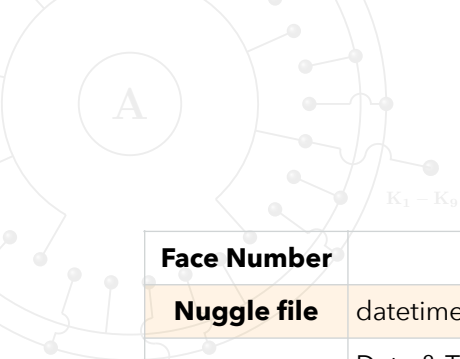


Date and Time Faces

Face Number	121		
Nuggle file	datetime.nug		
Arguments	Date & Time - Rainbow Bling, true, true, cs_pair, 100, 25, , , , , , bs_rainbow		
Description	<ul style="list-style-type: none"> Show the date and the time, use rotating rainbow hued bling, colons and no chimes V1 to V6 - date and time V7 - indicate Date or Time as appropriate 		
Colons	Flashing and bright for time, steady and dim for date		
Bling	Rotating rainbow hued		
Chimes	None		

Face Number	123		
Nuggle file	datetime.nug		
Arguments	Date & Time - Rainbow Bling, true, true, cs_pair, 100, 25, , ts_tick, derby, , os_chime, bs_rainbow		
Description	<ul style="list-style-type: none"> Show the date and time, use rotating rainbow bling, colons and Derby chimes V1 to V6 - date and time V7 - indicate Date or Time as appropriate 		
Colons	Flashing and bright for time, steady and dim for date		
Bling	Rotating rainbow hued		
Chimes	derby*.wav		

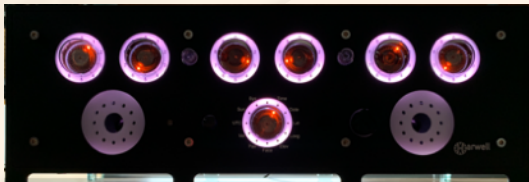




Face Number	124	
Nuggle file	datetime.nug	
Arguments	Date & Time - Rainbow Bling & Rotating Chimes, true, true, cs_pair, 100, 25, , ts_tick, a-west, cr_daily, os_chime, bs_rainbow	
Description	<ul style="list-style-type: none"> Show the date and the time, use rotating rainbow hues bling, colons and Westminster chimes initially then change the chimes each day. V1 to V6 - date and time V7 - indicate Date or Time as appropriate 	
Colons	Flashing and bright for time, steady and dim for date	
Bling	Rotating rainbow hues	
Chimes	west-a*.wav initially then any of the clock chime file sets	

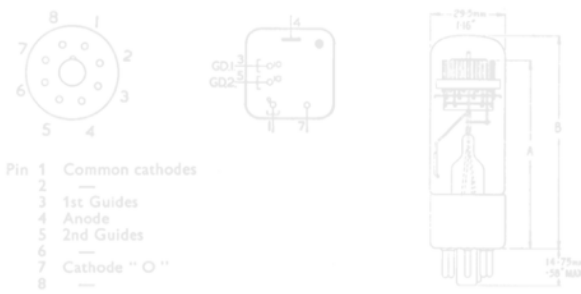


Face Number	125	
Nuggle file	datetime.nug	
Arguments	Date & Time Cuckoo Clock, true, true, , , , , ts_ticktock, cuckoo, , os_chime, bs_single, wheat	
Description	<ul style="list-style-type: none"> Show the date and the time, use single colour bling, no colons and Cuckoo toll noises. V1 to V6 - date and time V7 - indicate Date or Time as appropriate 	
Colons	Flashing and bright for time, steady and dim for date	
Bling	wheat	
Chimes	cuckoo*.wav	



Base I.O.

Base Connections (underside view)




Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.




Time Only Faces with Clock Chimes and no Bling

Not all of the available chimes are demonstrated here.


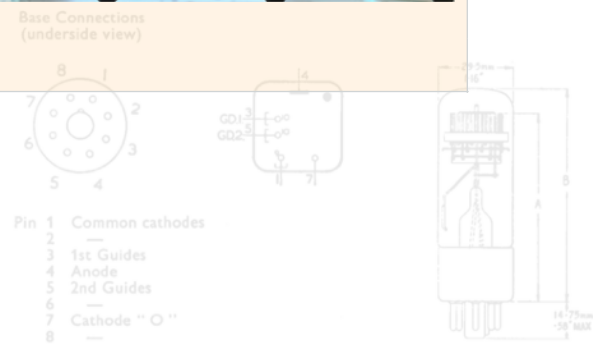
Face Number	130	
Nuggle file	datetime.nug	
Arguments	Time Only - No Bling - Westminster A, true, , cs_pair, 100, , , ts_ticktock, a-west, , os_chime	
Description	Westminster Chimes (alternative A)	
Colons	None	
Bling	None	
Chimes	west-a*.wav	



Face Number	131	
Nuggle file	datetime.nug	
Arguments	Time Only - No Bling - Westminster B, true, , cs_pair, 100, , , b-west, , os_chime	
Description	Westminster Chime (alternative B)	
Colons	None	
Bling	None	
Chimes	west-b*.wav	



Face Number	132	
Nuggle file	datetime.nug	
Arguments	Time Only - No Bling - Westminster C, true, , cs_pair, 100, , , c-west, , os_westc	
Description	Westminster Chime (alternative C)	
Colons	None	
Bling	None	
Chimes	west-c*.wav	


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.




Face Number	135
Nuggle file	datetime.nug
Arguments	Time Only - No Bling - Ave Maria, true, , cs_pair, 100, , , , amaria, , os_chime
Description	Time only with no bling, Ave Maria chimes
Colons	None
Bling	None
Chimes	amaria*.wav




Face Number	136
Nuggle file	datetime.nug
Arguments	Time Only - No Bling - Whittington, true, , cs_pair, 100, , , , whit, , os_chime
Description	Whittington Chimes
Colons	None
Bling	None
Chimes	whit*.wav




Face Number	137
Nuggle file	datetime.nug
Arguments	Time Only - No Bling - St Stephens, true, , cs_pair, 100, , , , steph, , os_chime
Description	St. Stephen's Chimes
Colons	None
Bling	None
Chimes	steph*.wav



Face Number	140
Nuggle file	datetime.nug
Arguments	Time Only - No Bling - Ship's Bells, true, , cs_pair, 100, , , , ship, , os_ships
Description	Ship's Bells
Colons	None
Bling	None
Chimes	ship*.wav



Pin 1 Common cathodes
2 —
3 1st Guides
4 Anode
5 2nd Guides
6 —
7 Cathode "O"
8 —

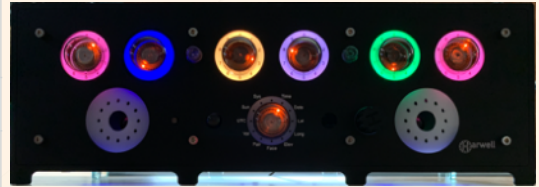


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

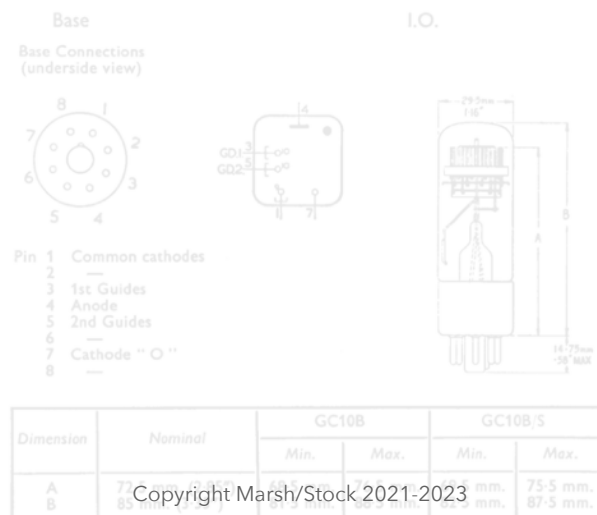


Unusual Clock Faces

Face Number	150	
Nuggle file	datetime.nug	
Arguments	Time Only- Resistor Bling, true, , cs_pair, 100, , , , , , bs_resistor, 100	
Description	Show the time and light the bling on each dekatron using the resistor colour code.	
Colons	Flashing	
Bling	<ul style="list-style-type: none"> V1 - V6 - colour according to the value shown using resistor colour codes V7 - indicates time Downward is coloured dark blue 	
Chimes	None	




Face Number	151	
Nuggle file	datetime.nug	
Arguments	Decimal Time - minimal bling, decimal, , cs_left, 100, , , , , , bs_single, 100	
Description	<ul style="list-style-type: none"> Show the time as hours and the minutes and seconds as a decimal fraction. So 10:30 would be shown as 10:5000. V1 V2 - hours V3 - V6 - fractional hours V7 - indicate Time 	
Colons	The left colon acts as a separator between hours and fractional hours. Flashes.	
Bling	All dark blue colour	
Chimes	None	




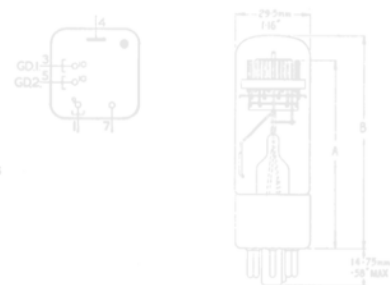
Fun Themed Faces¹⁰⁸

About startrek.nug:

This file takes only one argument: 0 for original Star Trek¹⁰⁹ or 1 for Next Generation Star Trek¹¹⁰

Face Number	160	
Nuggle file	startrek.nug	
Arguments	0	
Description	<p><i>Original Star Trek tribute face</i></p> <ul style="list-style-type: none"> • Two scientists (blue), two command officers (yellow) and two red-shirts beam down to a planet with purple a landscape and green skies. • Something bad on the planet, well, does what happens to red-shirts... • V1 to V6 show the time • V7 spins 	
Colons	None	
Bling	<ul style="list-style-type: none"> • V1 V2 - red (security) • V3 V4 - yellow (command officers) • V5 V6 - blue (scientists) • V7, speakers - green (the sky) • Downward - purple (the landscape) 	
Chimes	<ul style="list-style-type: none"> • ost_*.wav for chimes, credits, transporter noise and tolls • laser0.wav for a gun noise 	
IR/Encoder Controls	> ' (play) do the job yourself	

Face Number	161	
Nuggle file	startrek.nug	
Arguments	1	
Description	<p>Star Trek Next Generation tribute</p> <p><i>Incomplete</i> (but has some functionality)</p>	

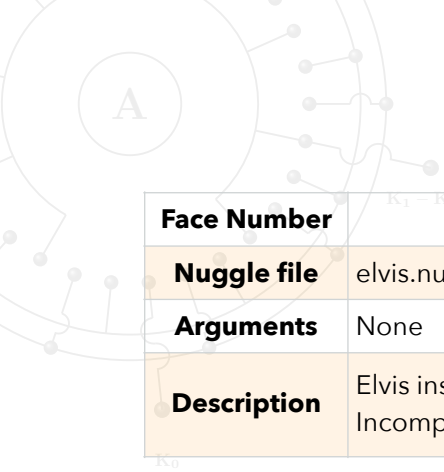


¹⁰⁸ Well, we think they're fun....

¹⁰⁹ https://en.wikipedia.org/wiki/Star_Trek (if you have to look at this, then we're lost for words.....)

¹¹⁰ https://en.wikipedia.org/wiki/Star_Trek:_The_Next_Generation

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Face Number	170	
Nuggle file	elvis.nug	
Arguments	None	
Description	Elvis inspired clock face Incomplete (but has some functionality)	



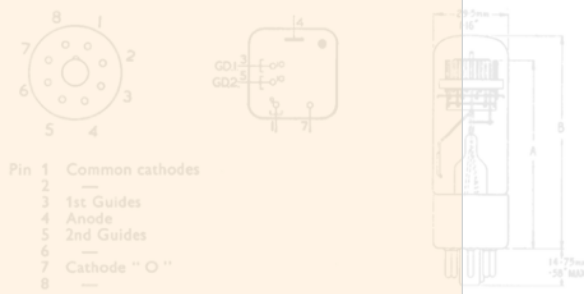
Face Number	180	
Nuggle file	starwars.nug	
Arguments	None	
Description	Star Wars tribute face.	
Colons	Flashing	
Bling	<ul style="list-style-type: none"> Normally rotating blue/green hues. Blue/Green and Red during a duel with white flashes when the sabres collide! Orange during face shutdown. 	
Chimes	sw*.wav	
IR/Encoder Controls	> ' (play) will start the light sabre duel!	



Face Number	190	
Nuggle file	holygrl.nug	
Arguments	None	
Description	<ul style="list-style-type: none"> Tells the Holy Grail story. An excerpt is played each minute. The story can be started, stopped and restarted. Takes about 3 hours to tell the whole story. Story status is saved to NVR so the face will restart where it was left. V1 to V6 show the time, V7 orbits slowly. 	
Colons	Dim when the story is halted, bright and flashing when the story is being told.	
Bling	Slowly rotating hue varied bling across dekatrons V1 to V6 and downwards.	
Chimes	hg*.wav	
IR/Encoder Controls	<ul style="list-style-type: none"> > ' (play) will stop and start the story When being told: <ul style="list-style-type: none"> 'EQ' will restart the story ' <<' (prev) will replay the last excerpt. '>> ' (next) will move onto the next excerpt. 	

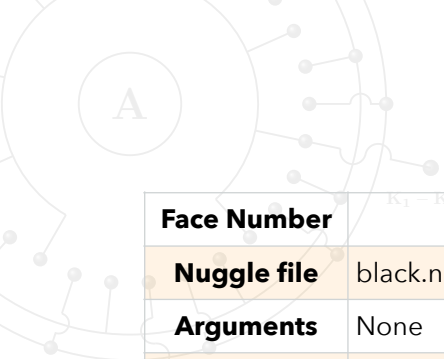


(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

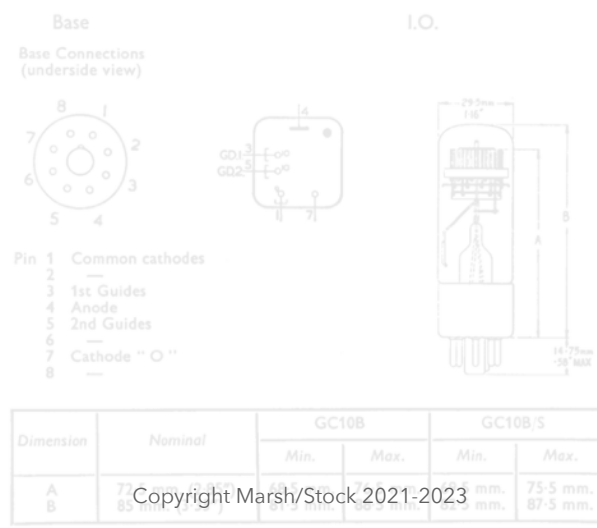




Face Number	191	
Nuggle file	black.nug	
Arguments	None	
Description	<ul style="list-style-type: none"> The Black Knight and King Arthur Fight! <i>On the hour or on demand!</i> V1 to V6 show the time normally and V7 indicates Time. During the fight the date is shown and V7 highlights Date. 	
Colons	Flashing	
Bling	Starting green and turning red during the fight. Things do get a bit messy.	
Chimes	<ul style="list-style-type: none"> hg059.wav for the introduction. hg*.wav for 15 minute "chimes" clipclop.wav for the second tick noise 	
IR/Encoder Controls	<ul style="list-style-type: none"> > ' (play) will provoke the combatants! <<" (prev) will silence the 'clip-clop' second tick '>>' (next) will play the 'clip-clop' second tick 	



Notes - The Black Knight fight clip-clop status is stored in NVR and will be restored when the face is shown again.



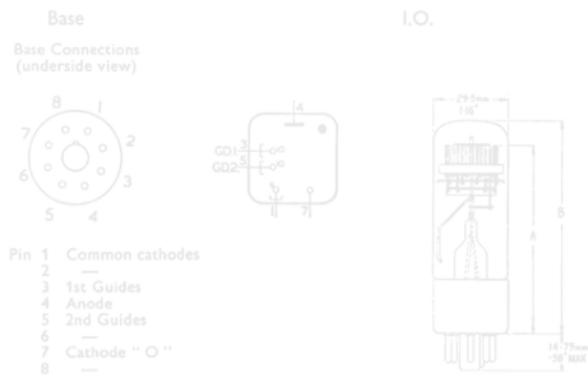
Face Number	192	
Nuggle file	holyclck.nug	
Arguments	None	
Description	<ul style="list-style-type: none"> This face uses Holy Grail excerpts for quarterly and hourly chimes and hour tolls. V1 to V6 show the time normally and V7 indicates Time. 	
Colons	Flashing	
Bling	Rotating rainbow hues	
Chimes	<ul style="list-style-type: none"> hgtitle.wav at the start hg*.wav for the 15 minute "chimes" hgt*.wav for randomly selected tolls clipclop.wav for the second tick noise 	
IR/Encoder Controls	<ul style="list-style-type: none"> <<" (prev) will silence the 'clip-clop' second tick '>>' (next) will play the 'clip-clop' second tick 	



Notes - The Holy Grail Clock clip-clop status is stored in NVR and will be restored when the face is shown again.

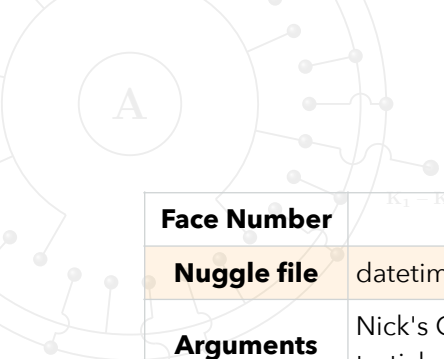
Clock Faces that are blingy-blinged to death (almost) 200 -

Face Number	200	
Nuggle file	datetime.nug	
Arguments	Nick's Clock 1 - Blinged to death, true, true, , , , true, ts_tick, tintan, , os_chime, bs_chase	
Description	Time, date, spinning dekatrons. swirling blue bling, ticks and chimes	
Colons	None	
Bling	Blue swirl	
Chimes	TinTan chimes	

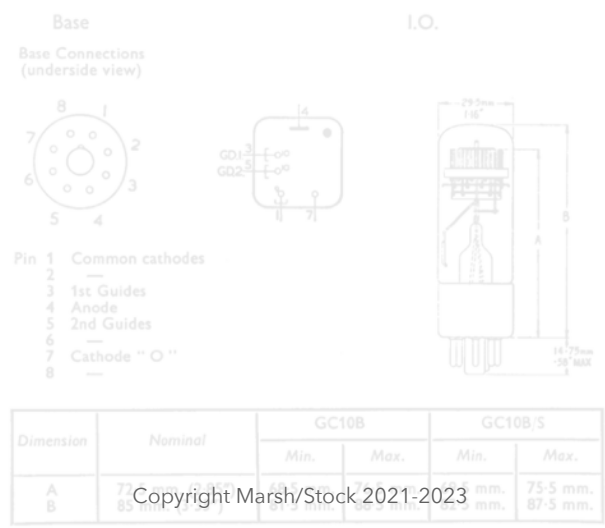


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





Face Number	201	
Nuggle file	datetime.nug	
Arguments	Nick's Clock 2 - OMG, true, true, , , , true, ts_tick, derby, , os_chime, bs_swirl	
Description	Time, date, spinning dekatrons, swirling, hue changing bling, ticks and chimes	
Colons	None	
Bling	Hue varying swirl	
Chimes	Derby	



Astronomical Faces 300 -

About sun.nug: sun.nug has only one argument:

1. Display sunrise time.
2. Display sunset time.
3. Current sun position, azimuth and altitude.

K₀

Face Number	300	
Nuggle file	sun.nug	
Arguments	1	
Description	<ul style="list-style-type: none"> • Sun rise time on dekatrons V1 - V4 as HH:MM. V5 and V6 show 00. • Bling colour is used to show if the sun does not rise. • Dekatron V7 indicates Time and Sun. 	
Colons	Left colon is lit if HH:MM is displayed	
Bling	<ul style="list-style-type: none"> • If the sun does rise this day then yellow, purple and blues are used to light the bling. • If the sun stays below the horizon all day then dark blue lights the bling. • If the sun stays above the horizon all day then yellow lights the bling 	
Chimes	None	

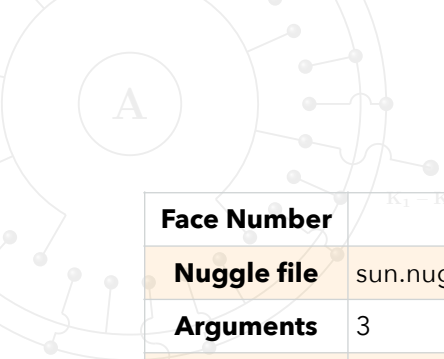


Face Number	301	
Nuggle file	sun.nug	
Arguments	2	
Description	<ul style="list-style-type: none"> • Sun set time on dekatrons V1 - V4 as HH:MM. V5 and V6 show 00. • Bling used to show if sun does not rise. • Dekatron V7 indicates Date and Sun. 	
Colons	Left colon is lit if HH:MM is displayed	
Bling	<ul style="list-style-type: none"> • If the sun does rise this day then yellow, purple and blues are used to light the bling. • If the sun stays below the horizon all day then dark blue lights the bling. • If the sun stays above the horizon all day then yellow lights the bling 	
Chimes	None	



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	





Face Number	302	
Nuggle file	sun.nug	
Arguments	3	
Description	<ul style="list-style-type: none"> Sun position in the sky as Azimuth (0 - 359 degrees) and Altitude (-90 to +90 degrees) from the observer's position. The display is updated once per minute. V1 to V3 show the azimuth. V4 shows the count towards the next update i.e. it orbits one per minute. V5 and V6 show the sun's altitude, the sign is shown using the bling. V7 indicates Long and Sun 	
Colons	None	
Bling	<ul style="list-style-type: none"> If the sun does rise this day then yellow, purple and blues are used to light the bling. If the sun stays below the horizon all day then dark blue lights the bling. If the sun stays above the horizon all day then yellow lights the bling 	
Chimes	None	



Games 350 -

Face Number	350	
Nuggle file	pir.nug	
Arguments	None	
Description	<ul style="list-style-type: none"> Start the game and the walk towards the clock trying not to let the PIR see you if it does then the colons will light and the number of times you have been seen will be counted on the tubes. Bling will react and a chime will sound. V1 - V6 count the number of hits. V7 spins slowly and reverses direction each time you are seen. 	
Colons	Dimly lit normally, bright when the PIR sees you.	
Bling	Normally green but V7 and the speaker bling lights red when the PIR sees you.	
Chimes	uhoh.wav when the PIR sees you	




- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



"Screen Saver" Faces 400 -


Face Number	400	
Nuggle file	blank.nug	
Arguments	None	
Description	The flyback is switched off, bling is all off	
Colons	None	
Bling	All bling is black (unlit)	
Chimes	None	

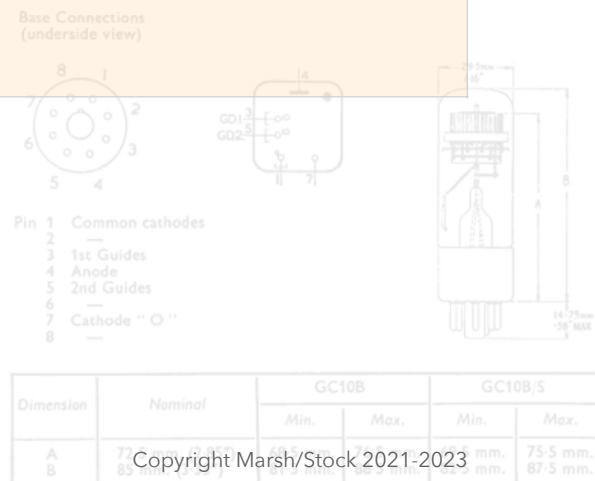
About runner.nug:


These face sets are "screen savers" as they ensure all the cathodes are exercised on all of the Dekatrons. The nuggle file takes two arguments:


Runner spins each tube V1 to V6 and lights their bling which then fades. V7 just spins slowly in time with the spinning moving from tube to tube.


Index	Name	Type	Details
1	Speed	integer	The step rate in mS (default = 1000)
2	Colour	integer	<ul style="list-style-type: none"> Colour values which can be hexadecimal in the form 0xRRGGBB where RR is the red intensity 00 to ff, and so on for GG green and BB blue. Standard colour constants can be used, e.g. yellow (Default is limegreen)

Face Number	401	
Nuggle file	runner.nug	
Arguments	None	
Description	Spin each tube V1 to V6 in turn taking one second to spin each tube. Blinged.	
Colons	None	
Bling	Lime green pulse and fade on V1 - V6, none on V7, downward bling lit	
Chimes	None	



Face Number	402	
Nuggle file	runner.nug	
Arguments	150	
Description	Identical to 401 but much faster	
Colons	None	
Bling	Lime green pulse and fade on V1 - V6, none on V7, downward bling lit	
Chimes	None	

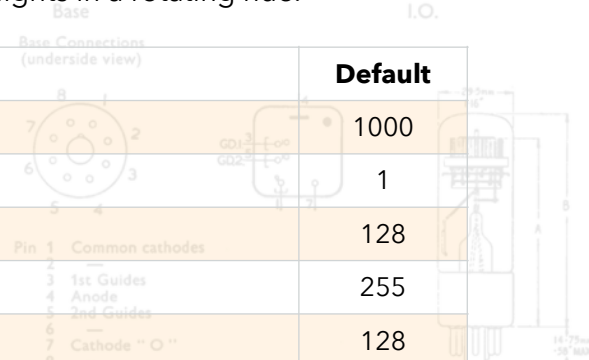
Face Number	403	
Nuggle file	runner.nug	
Arguments	2000, yellow	
Description	Identical to 401 but slower and yellow	
Colons	None	
Bling	Yellow pulse and fade on V1 - V6, none on V7, downward bling lit	
Chimes	None	

Face Number	410	
Nuggle file	picker.nug	
Arguments	None	
Description	Randomly pick a tube and cathode position, randomly light its bling	
Colons	None	
Bling	Randomly selected	
Chimes	None	

About rainbow.nug

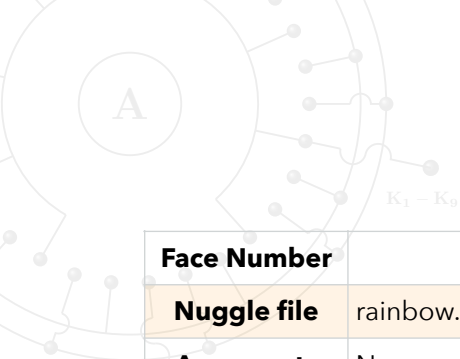
A random tube is given a random cathode position. The bling lights in a rotating hue.

Index	Name	Type	Details	Default
1	Speed	integer	The random change period in mS	1000
2	Inc	integer	Hue change per step	1
3	Span	integer	Hue span across the bling	128
4	Sat	integer	HSV Saturation	255
5	Val	integer	HSV Value	128



Dimension	Nominal	GC108		GC108/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

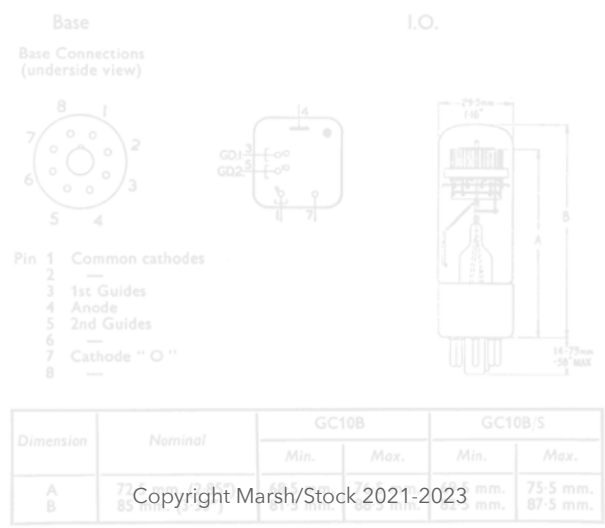




Face Number	420	
Nuggle file	rainbow.nug	
Arguments	None	
Description	Default case	
^{K₀} Colons	None	
Bling	Rainbow hues across the bling	
Chimes	None	


Face Number	421	
Nuggle file	rainbow.nug	
Arguments	, 10	
Description	As 420 but with more rapid hue changes	
Colons	None	
Bling	Rainbow hues across the bling	
Chimes	None	

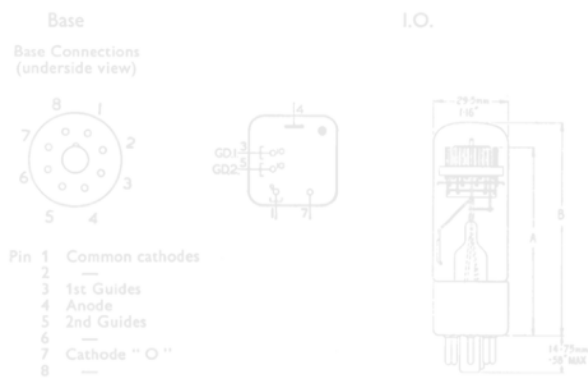
Face Number	422	
Nuggle file	rainbow.nug	
Arguments	10, , 64	
Description	Fast cathode changes	
Colons	None	
Bling	Slow changing hue and a smaller span	
Chimes	None	



A "Larson Scanner"¹¹¹ is traditionally red and sweeps back and forth.^{112,113,114}

Index	Name	Type	Details	Default
1	Speed	integer	The step rate in mS	100
2	Mode	integer	0 - Larson fixed colour 1 - Larson rotating hue 2 - Wiggle fixed colour 3 - Wiggle rotating hue	0
3	Colour	integer	<ul style="list-style-type: none"> Fixed mode (0, 2) colour Colour values which can be hex a decimal in the form 0xRRGGBB where RR is the red intensity 00 to ff, and so on for GG green and BB blue. Standard colour constants can be used, e.g. yellow 	Red
4	Fade	integer	Fade rate factor	B0
5	Hue	integer	Starting HSV Hue	Random
6	dHue	integer	Rate at which hue changes per step	10
7	Sat	integer	HSV Saturation	255
8	Val	integer	HSV Value	240

Face Number	430	
Nuggle file	larson.nug	
Arguments	None	
Description	Traditional Larson Scanner	
Colons	None	
Bling	Red	
Chimes	None	




¹¹¹ https://en.wikipedia.org/wiki/Glen_A._Larson


¹¹² [https://en.wikipedia.org/wiki/Cylon_\(Battlestar_Galactica\)#Original_Cylons](https://en.wikipedia.org/wiki/Cylon_(Battlestar_Galactica)#Original_Cylons)


¹¹³ <https://en.wikipedia.org/wiki/KITT>


¹¹⁴ Note the large number of credits - Glen A Larson was accused and fined for plagiarism...

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

Face Number	431	
Nuggle file	larson.nug	
Arguments	, 1	
Description	Rotating Hue Scanner	
Colons	None	
Bling	Changing hue	
Chimes	None	

Face Number	432	
Nuggle file	larson.nug	
Arguments	25, , yellow, 0xC0	
Description	Fast yellow scanner	
Colons	None	
Bling	Yellow	
Chimes	None	

Face Number	433	
Nuggle file	larson.nug	
Arguments	, 2, lightgoldenrodyellow	
Description	Wiggle mode bright single colour	
Colons	None	
Bling	Lightgoldenrodyellow	
Chimes	None	

Face Number	434	
Nuggle file	larson.nug	
Arguments	, 3, , , 1	
Description	Wiggle Rotating Hue Scanner	
Colons	None	
Bling	Slow changing hue	
Chimes	None	

- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —




Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.




About technicl.nug:

Technicl.nug takes one argument which is the number of the technical aspects of the clock to display or control. Chimes, the IR handset and the rotary controller are not used.



Face Number	900	
Nuggle file	technicl.nug	
Arguments	1	
Description	<ul style="list-style-type: none"> Clock hardware version number MM.mm is shown on V3 - V6 V7 lights Sys and Time marks 	
Colons	RH colon is lit	
Bling	V3 - V6 lit in green, downward bling lit in olivedrab	
Chimes	None	



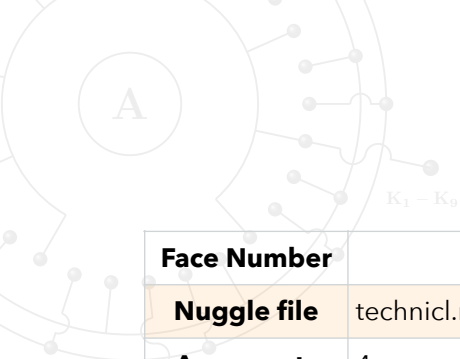
Face Number	901	
Nuggle file	technicl.nug	
Arguments	2	
Description	<ul style="list-style-type: none"> Clock firmware version MM.mm.bb is shown on V1 - V6 V7 lights with Sys and Date 	
Colons	Both colons light	
Bling	All lit using wheat, chocolate and goldenrod	
Chimes	None	



Face Number	910	
Nuggle file	technicl.nug	
Arguments	3	
Description	<ul style="list-style-type: none"> Latitude (from locale.ini) is shown on V3 - V6 (range 0 - 90 degrees) V7 lights with Lat 	
Colons	RH colon is lit	
Bling	<ul style="list-style-type: none"> V3 - V6 are lit in green V7 is lit in red if the location is north of the equator and blue if south Downward bling are goldenrod 	
Chimes	None	

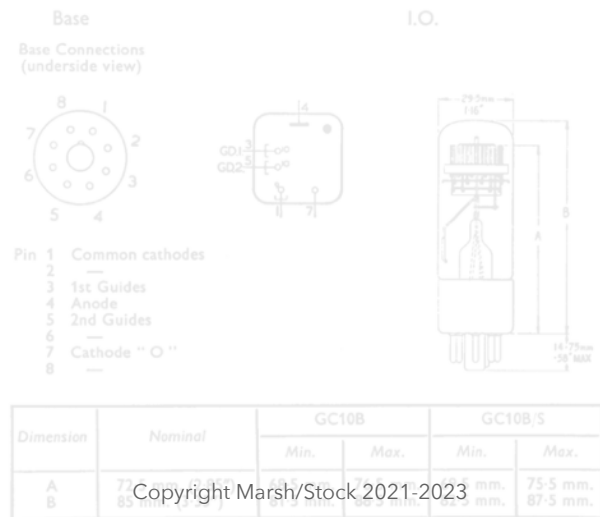
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Face Number	911	
Nuggle file	technicl.nug	
Arguments	4	
Description	<ul style="list-style-type: none"> Longitude (from locale.ini) is shown on V2 - V6 (range 0 -180 degrees) V7 lights with Long 	
Colons	RH colon is lit	
Bling	<ul style="list-style-type: none"> V2 - V6 are lit in green V7 is lit in red if the location is east of Greenwich and blue if west Downward bling are goldenrod 	
Chimes	None	



Face Number	912	
Nuggle file	technicl.nug	
Arguments	5	
Description	<ul style="list-style-type: none"> Elevation (from locale.ini) is shown on V1 - V6 (range 0 -999999m , in theory!) V7 lights with Elev The value shown will be in feet if the user preferred units are set to feet (in locale.ini) otherwise in metres 	
Colons	<ul style="list-style-type: none"> V1 - V7 are lit in greenish blue Downward bling are goldenrod 	
Bling	<ul style="list-style-type: none"> V2 - V6 are lit in green V7 is lit in red if the location is east of Greenwich and blue if west Downward bling are goldenrod 	
Chimes	None	



Face Number	920	
Nuggle file	technicl.nug	
Arguments	6	
Description	<ul style="list-style-type: none"> • Chip temperature, the value shown will be °F (range 32 - 212) if the user set preferred units are set to °F (in locale.ini) or otherwise °C (range 0 - 100) • V7 shows Sys and Long • The display is updated every second. • N.B. the results are very odd - on my bug list to review 	
Colons	None	
Bling	<ul style="list-style-type: none"> • The chip temperature is used as the hue value for V5, V6 (°C) and V4 - V6 (°F) • Downward bling are goldenrod. 	
Chimes	None	



Face Number	921	
Nuggle file	technicl.nug	
Arguments	7	
Description	<ul style="list-style-type: none"> • Room brightness read by the LDR (range 0 - 100%) on V4 - V6 • V7 shows Sys and Lat 	
Colons	None	
Bling	<ul style="list-style-type: none"> • V4 - V6 bling are steel blue • Downward bling are goldenrod. 	
Chimes	None	



Face Number	930	
Nuggle file	technicl.nug	
Arguments	8	
Description	<ul style="list-style-type: none"> • WiFi module presence, connection and SNTP time validity. • V7 shows Sys and Elev 	
Colons	<ul style="list-style-type: none"> • Left colon shows if the WiFi module is connected. • Right colon shows if the clock's last attempt at a SNTP fetch produced a valid time 	



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

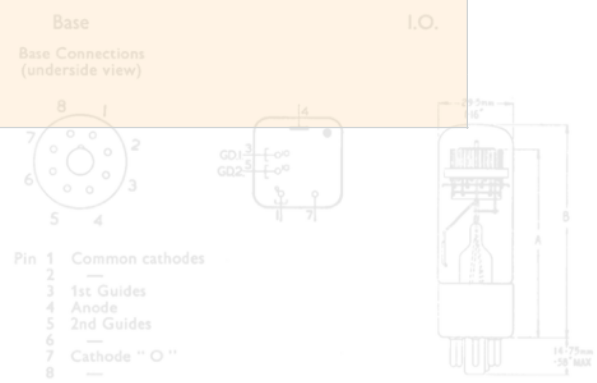




Bling	If there is no WiFi module detected then downward bling are dark blue, if a module has been detected then the downward bling are goldenrod	
Chimes	None	

Face Number	940	
Nuggle file	technicl.nug	
Arguments	9	
Description	<ul style="list-style-type: none"> GPS module presence and SNTP time validity. V1, V2 show the number of satellites in view and V5, V6 show the number in use. V7 shows Sys and Elev 	
Colons	Both lit if the GPS data is valid	
Bling	If there is no GPS module detected then downward bling are dark blue, if a module has been detected then the downward bling are goldenrod	
Chimes	None	

Face Number	950	
Nuggle file	technicl.nug	
Arguments	10	
Description	<ul style="list-style-type: none"> Shows the pairing status. V7 shows Pair. V1 - V6 will show the pair number. 	
Colons	None	
Bling	<p>The V7 bling will light:</p> <ul style="list-style-type: none"> Dark blue is pairing is disabled White if enabled but not active Red if enabled but not paired Green if enabled and paired <p>Downward bling are goldenrod.</p>	
Chimes	None	

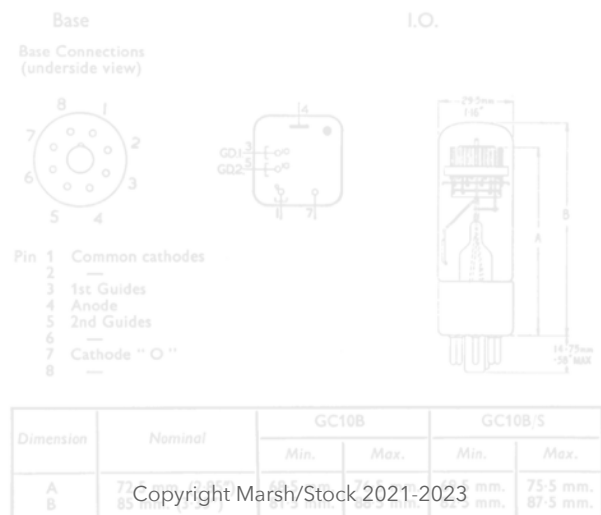


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Date and Time Related

Face Number	960	
Nuggle file	timeset.nug	
Arguments	None	
Description	<ul style="list-style-type: none"> This face can be used to set the RTC UTC time using the IR handset. When run the dekatrons V1 - V6 show the current time but with seconds set to 00. V7 indicates Time. The IR handset is used to change the numbers shown and then accept or cancel the shown time. 	
Colons	None	
Bling	The dekatron currently being edited (V1 - V6) is lit in dark green, the rest are unlit.	
Chimes	<ul style="list-style-type: none"> notify.wav - when accepting the time shown out.wav - when making changes uhoh.wav - on error - trying to set an impossible time 	
IR/Encoder Controls	<ul style="list-style-type: none"> '0' - '9' - use this number on the selected digit and step onto the next, roll over 'T' - the 200+ key cancels the edit and goes to clock face 1 (the blank face) 'P' - the '> ' is also a cancel key '<' - step to the previous dekatron, roll under '>' - step to the next dekatron, roll over '=' - accept the currently displayed time and go to clock face 1 (the blank face) 	



Face Number	961
Nuggle file	dateset.nug
Arguments	None
Description	<ul style="list-style-type: none"> This face can be used to set the RTC UTC date using the IR handset. When run the dekatrons V1 - V6 show the current date. The IR handset is used to change the numbers shown and then accept or cancel the shown date.
Colons	None
Bling	The dekatron currently being edited (V1 - V6) is lit in violet, the rest are unlit.
Chimes	<ul style="list-style-type: none"> notify.wav - when accepting the date shown out.wav - when making changes uhoh.wav - on error - trying to set an impossible date
IR/Encoder Controls	<ul style="list-style-type: none"> 0' - '9' - use this number on the selected digit and step onto the next, roll over 'T' - the 200+ key cancels the edit and goes to clock face 1 (the blank face) 'P' - the '> ' is also a cancel key '<' - step to the previous dekatron, roll under '>' - step to the next dekatron, roll over '=' - accept the currently displayed date and go to clock face 1 (the blank face)

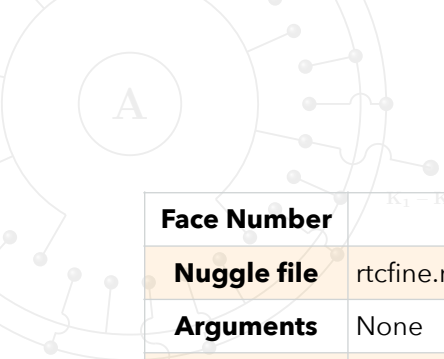


Face Number	962
Nuggle file	syncrtc.nug
Arguments	None
Description	<ul style="list-style-type: none"> Try to sync the clock with the GPS or WiFi module. V7 will indicate Time and Date The clock will then go to face 1 (blank).
Colons	None
Bling	The bling will briefly flash green on success or red on failure
Chimes	None
IR/Encoder Controls	None

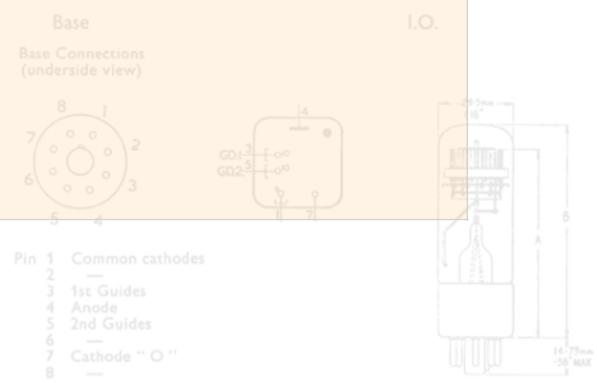


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



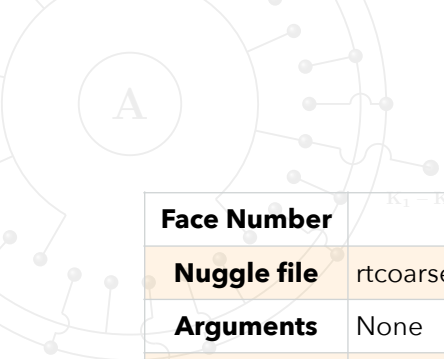


Face Number	963
Nuggle file	rtcfine.nug
Arguments	None
Description	<ul style="list-style-type: none"> This is an experimental face - it is used to make small adjustments to the RTC tick repetition so that when the clock chimes a tick sound it is in time with another "reference clock" tick. The face can delay between 0 and 990mS in 10mS steps. Operate the face by listening to the two clocks tick and adjust the delay so they tick in unison. V1 - V4 - current delay in mS V5 - V6 - seconds count V7 indicates Sys and Time Set the tick volume before running this face as the encoder and volume buttons ('+' '-') on the encoder are overridden. Stop the operation by moving to another face and the last delay value will be preserved in NVR. Use in conjunction with face 964.
Colons	None
Bling	<ul style="list-style-type: none"> V1 - V4 - lit in dark red V5 - V6 - dark yellow V7 - dark magenta
Chimes	tick1.wav is played for audible synchronisation
IR/Encoder Controls	<p>Encoder -</p> <ul style="list-style-type: none"> rotate right adds 100mS rotate left deducts 100mS pushed in and rotate right adds 10mS pushed in and rotate left deducts 10mS. <p>IR handset -</p> <ul style="list-style-type: none"> '>> ' add 10mS, ' <<' deducts 10mS '+' adds 100mS '-' deducts 100mS '> ' restore starting delay value

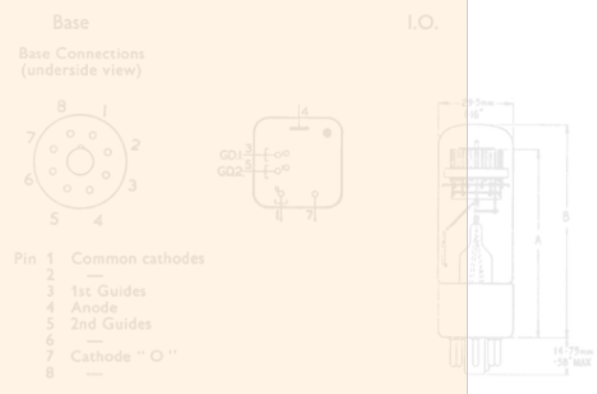


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





Face Number	$K_1 - K_0$	964
Nuggle file	rtcoarse.nug	
Arguments	None	
Description	<ul style="list-style-type: none"> This is an experimental face - it is used to make coarse adjustments to the time fetched by the WiFi (using SNTP) of GPS (by parsing NMEA statements). The adjustment can be used to coarsely adjust for different timings and latencies between the clock and a "reference clock". The adjustment can be from -10 seconds to +10 seconds in 1 second steps. Operate the face by watching the seconds dekatrons (V5, V6) and the second hand of your reference clock. Adjust the timings so the Harwell and the reference clock are reasonably close when showing the seconds e.g. when one clock shows 00 so does the other. V1 - V4 - current adjustment in seconds V5 - V6 - seconds count V7 indicates Sys and Time Set the tick volume before running this face as the encoder and volume buttons ('+' '-') on the encoder are overridden. Stop the operation by moving to another face and the last adjustment value will be preserved in NVR. Use in conjunction with face 963. 	
Colons	None	
Bling	<ul style="list-style-type: none"> V1 - V4 shows dark red for positive adjustments, black (unlit) for zero adjustment and dark blue for negative adjustment V5 - V6 show dark yellow V7 shows dark magenta 	
Chimes	tick1.wav is played for audible synchronisation	
IR/Encoder Controls	Encoder - <ul style="list-style-type: none"> rotate right adds 1S rotate left deducts 1S IR handset - <ul style="list-style-type: none"> '+' adds 1S '-' deducts 1S '> ' restore starting delay value 	



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			mm.	75.5 mm.
B	85 mm			mm.	87.5 mm.



And Finally....

Face Number	999	
Nuggle file	reset.nug	
Arguments	None	
Description	Clock will be given a hardware reset after a 10 second count down	
Colons	None	
Bling	Orange turning black	
Chimes	bark.wav during last 4 seconds	
IR/Encoder Controls	None	

Tests, Aids, Examples 1000 -

Nuggle Tests

This basket of tests perform simple tests on the Nuggle lexer, parser and expression evaluator. They send results to the console only and do not use the Dekatrons. Some tests use the bling and colons. For Dekatron tests and examples see below. These Nuggle tests are all made using test1.nug which takes just one argument which is the number of the test to perform.

Face number	Argument	Purpose
1001	1	Writes "Hello World" to the console in magenta
1002	2	Tests If, Else, IfEnd, Incl, Decl, Succ(), Pred()
1003	3	Test For .. To/DownTo, ForEnd, Break, Continue
1004	4	Test Call, Return , including Call with arguments
1005	5	Test Repeat ... Until, Break, Continue
1006	6	Test While ... WhileEnd, Break, Continue
1007	7	Test Loop ... LoopEnd, Break, Continue
1008	8	Test Beep
1009	9	Test NVR, Push, Face This face runs (or chains to) face 1100 (t_dest.nug) which then uses NVR() and Pop() to retrieve and use the data.
1010	10	Test number functions Abs, Sqr, Sqrt, Min, Max, Pred, Succ, Odd, Even, Encode, High, MidHigh, MidLow, Low, LoCase, UpCase, Random, VerifyDate, VerifyTime, GPIO, NVR, FacePred, FaceSucc, IndexOf
1011	11	Test stack procedures and functions Push, Pop(), Peek(), Empty(), Flush
1012	12	Test Timer, Timer()

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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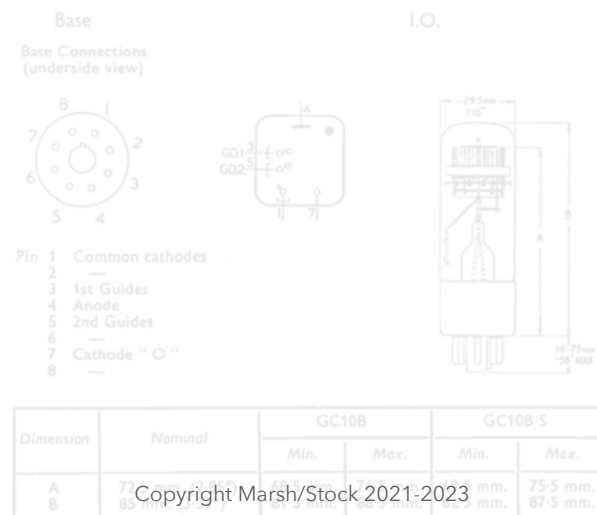
These Nuggle tests are all made using test2.nug which normally takes just one argument which is the number of the test to perform.

Face number	Argument	Purpose
1013	2	Test Jump
1014	3	Test expression evaluator unary+, unary-, ! ~ * / + - << >> & && ^ == != > >= < <==, test precedence
1015	4	Test TimeZone, Restore
1016	5	Test Reset (see note 1)
1017	6	Bling Bling Test Fill, GradientRGB, GradientHSV, Fade, Transmit
1018	7	Test Colon
1019	8	Test Switch, Case, CaseEnd, SwitchEnd
1020	9	Test CallOn, JumpOn
1021	10	String Tests StrCopy, StrWrite, StrLeft, StrRight, StrMiddle, StrCat, StrLen, IndexOf, StrEval, StrPos
1022	11	Argument Test FaceArg (see note 2)
1023	12	Text 8 bit colour palette
1024	13	Text TextColour, TextAttribute
1025	14	Square root Sqrt(-1) of a negative number error test
1026	15	Divide by zero 1 / 0 error test
1030	none	Event testing Event_Start, Event_encoder, Event_IR, Event_PIR, Event_Tick, Event_Fast, Event_Sleep, Event_Leave

Notes:


1. Reset is inhibited in the Nuggle file to prevent accidental triggering. It needs to be enabled before it can be tested. Instructions are in the file.
2. The argument list (in *nuggle.ini*) for these tests is:

11, apple pie, yellow, false, 0x12345689, -42



Alignment Aid

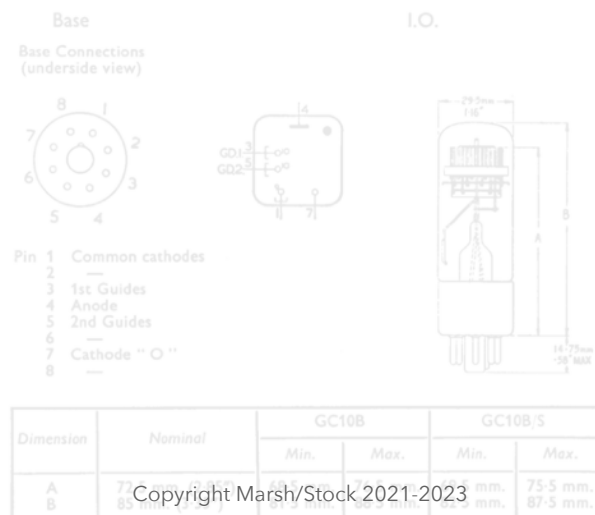
$K_1 - K_9$

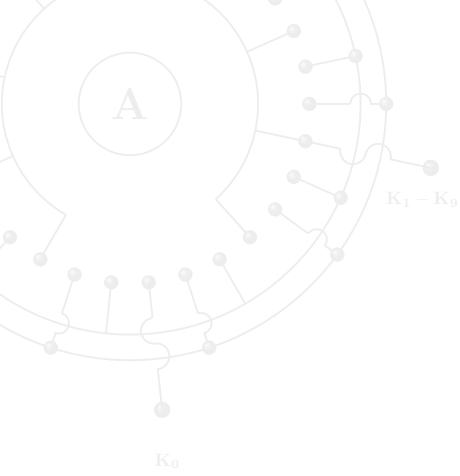
Face Number	1200	
Nuggle file	align.nug	
Arguments	27	
Description	All dots are sent to cathode '0' to assist in tube rotation and clamping so that cathode '0' is at the 12 o'clock position.	
Colons	None	
Bling	None	
Chimes	None	
IR/Encoder Controls	None	

Dekatron Display Test/Example Faces

These all use dekatest.nug using a single argument to select the test to perform.

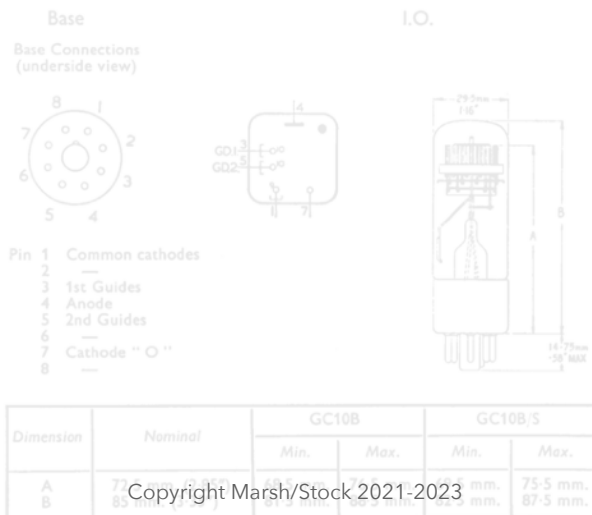
Face number	Argument	Purpose
1300	1	Zero all the dekatrons
1301	2	Move V1 to position 0, V2 to position 1 etc.
1302	3	Move V1 to cathode 0, V2 to cathode 1 etc.
1303	4	Spinner examples
1304	5	Spinner examples
1305	6	Spinner examples
1306	7	Orbit a random tube once per second
1307	8	Highlight points
1308	9	Show two points on each tube
1309	10	Pendulum examples





Harwell Clock - Operations Manual

How to Use Your Dream Dekatron Timepiece



Harwell Operations¹¹⁵

1. Introduction

This section describes most of the technical aspects of the Harwell Dekatron Clock design and its operation. It also covers the basics on how to modify aspects of the clock to suit your tastes.

Subjects covered:

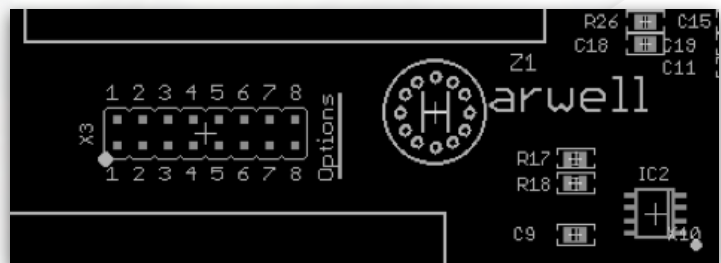
- The main board option jumpers
- Console connection
- Console menus
- Programming the microcontrollers
- Accessing the clock SD card, directories and files
- Adding or changing chime WAV files
- Adding or changing Nuggle files
- Compiling the SAM3X8C firmware
- Infrared remote
- Dekatron 7 version (Annex A)

Stand-alone manuals describe the Nuggle programming language, clock construction from a kit of parts, programming the WiFi module (if used) and others. These can be found on the Dropbox links provided here...

<http://www.sgitheach.org.uk/harwell.html#documentation>

2. Main Board Option Jumpers

There are eight jumpers on the main board (component X3 near the centre of the board near the clock logo) which can select operating options that need to be decided as the clock is initially starting up. Jumpers¹¹⁶ must only be fitted or removed when the clock is switched off.



The options jumpers are numbered 1 to 8 and control the following:

Option jumpers 1 and 2 - These work together giving 4 operational conditions:

Neither jumper fitted: Clock enters the "normal" operation - this will be the common setting.

Jumper 1 only fitted: Start in Test Mode - when fitted the clock starts into "test mode" rather than "normal mode". In test mode most of the high level clock automation is stopped. All of the clock sub-systems like the SD card, the LDR etc. all operate but the sleep system, automatic clock start up etc. are held off. This enables the clock low level systems to be tested using the console menus without interference from the high level clock automation.

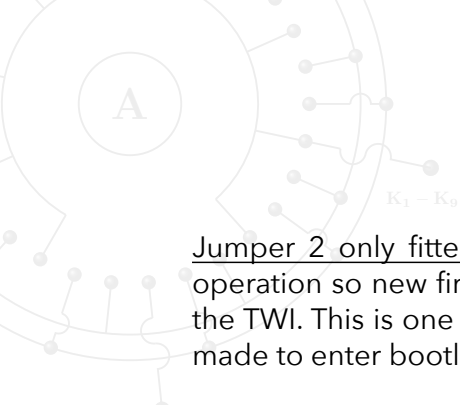
¹¹⁵ Everything you wanted to know but dare not ask....

¹¹⁶ Header shorts for those on the other side of the pond.....

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Jumper 2 only fitted: Start the Dekatron card bootloader - the clock will start bootloader operation so new firmware can be uploaded to the MEGA324PA on the Dekatron card using the TWI. This is one of the methods to force bootloader operation, normally the clock can be made to enter bootloader mode using menu commands.

Both jumpers 1 and 2 fitted: Plug-in module pass-through mode - all of the clock's normal operations are stopped except the console is connected directly to the serial port on the plug-in module, i.e. the WiFi module or GPS module. In the case of the WiFi module it enables commands to be typed and sent to the ESP32-BIT and its responses seen. In the case of the GPS module the console shows all the NMEA text data from the module.

Option 3: Permit automatic PSU start up - the 500V/170V flyback HT PSU will normally start up automatically when required. Fitting this jumper allows the PSU to start automatically. This option (of not fitting the jumper) is primarily for safety. The flyback PSU can still be started manually using the console. See the OUTS command.

Option 4: Console colour output: When the jumper is not fitted the text output will use escape sequences to produce a colour highlighted output. If your console program does not support the escape sequences used or if you prefer a B/W display then fit the jumper.

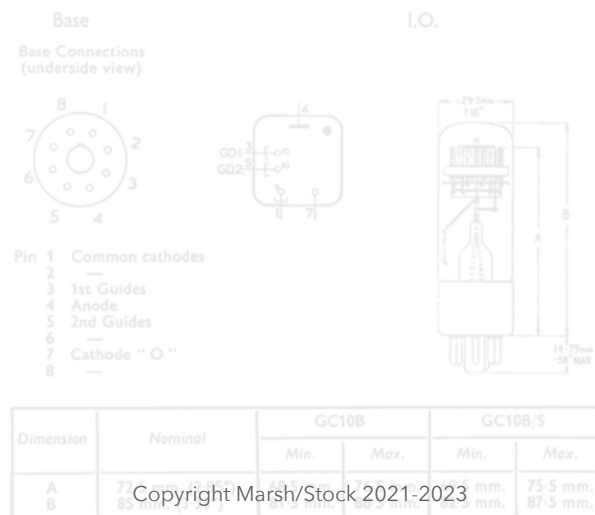
Option 5: SD card USB remote drive only operation: If you fit this jumper the clock will start up only as a USB remote drive for the SD card. You can use the clock in this mode without any interference from any clock operation that want to compete for access to the SD card. It is significantly faster with this jumper fitted. Use this mode if you don't own a SD card USB reader.

Option 6: Non-volatile RAM clear: The clock has a small memory chip that is "non-volatile" in that its contents are not lost when the clock is switched off. The chip can be cleared to the default settings by fitting this jumper and starting the clock. Once the clock has started up, the clock can be switched off and the jumper removed.

Option 7: Forced audio mute: Fitting this jumper will force the clock to be entirely quiet. It will not beep or play chimes. The setting cannot be overridden using the IR handset, the rotary encoder or using the console commands. The clock will remain entirely quiet!¹¹⁷

Option 8: Verbose scripts: When the clock is starting up and operating normally, detailed progress messages will be sent to the console. These messages are different to the Nuggle debug settings in the lexer, parser and expression evaluator.

¹¹⁷ Wife approved.....



3. Console Connection

The console is a simple text-based user interface that allows many clock settings to be adjusted and tested. It is an imported debug tool when writing Nuggle programs. The console hardware is also the SAM3X8C programmer.

The SAM3X8C programmer

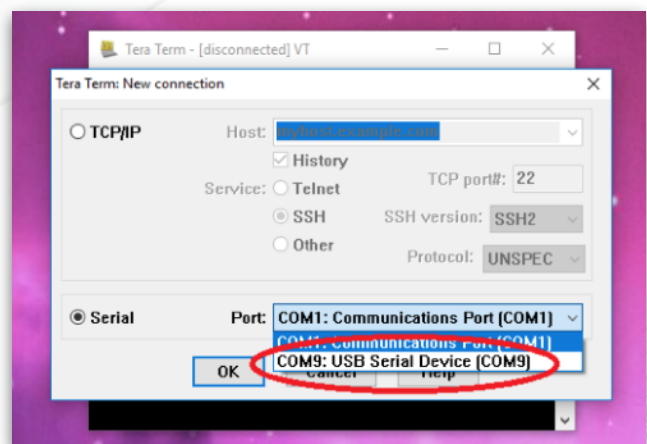
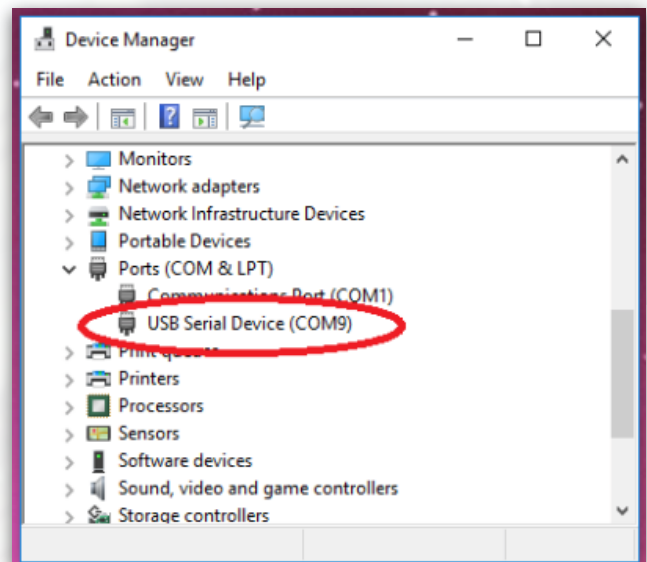
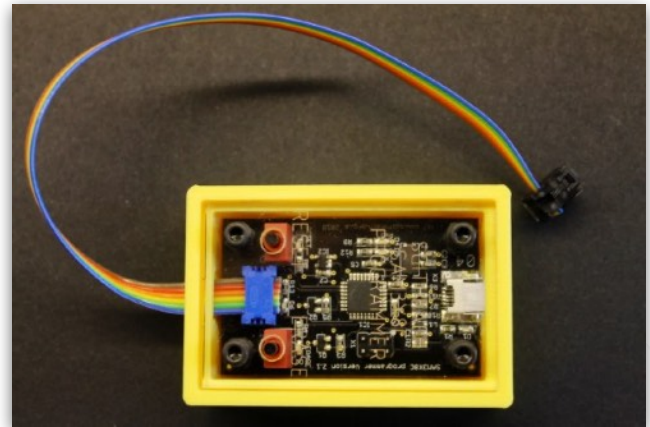
The programmer is plugged into the Harwell processor plug-in board using a 6-way ribbon cable and IDC connector. Plug the USB mini connector into a computer USB port using a suitable cable. The tests here that rely on the computer assume you are using a PC with Windows 10 installed. I cannot cover other operating systems as I have neither a Linux or MAC system.¹¹⁸

The PC should enumerate the board and a standard serial device interface installed. Look in the Device Manager and under the Ports (COM & LPT) a new USB Serial Device (COMxx) should have appeared. Where COMxx will be replaced by the COM port now assigned. Note the number as it will be needed later. In my case the port number was COM9. If you are uncertain which USB Serial Device has just appeared (you may have others) then disconnect and reconnect the board and look for the device that disappears and then reappears.

Warning! When using the programmer as a console connection be careful not to accidentally press the "Erase" button or else you will erase the flash contents of the SAM3X8C. Not the end of the world but probably a nuisance as you will need to re-flash the SAM.

You should also see the power LED D1 next to the USB mini connector glowing. If you look carefully, then you will see the SAM connection LED D6 next to the ribbon cable connector glowing as some power bleeds through to it.

Run a serial console program - I often use Tera Term¹¹⁹. Set the serial port to the COM number you noted in step 1 above. Configure the serial

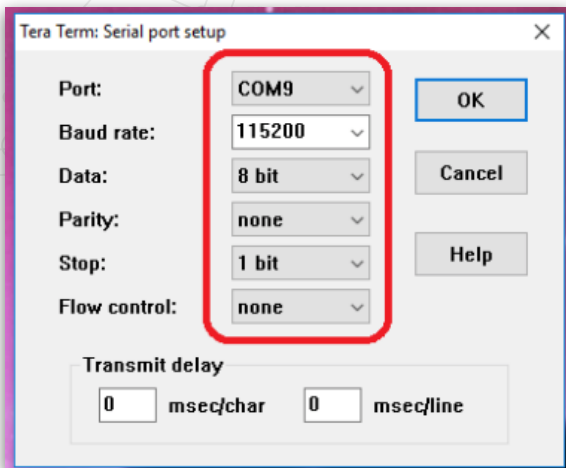


Selecting COM9 Serial Port in Tera Term

¹¹⁸ MAC has a built in console ability using the 'Screen' command. It does not support coloured text output though.

¹¹⁹ <http://tssh2.osdn.jp/>

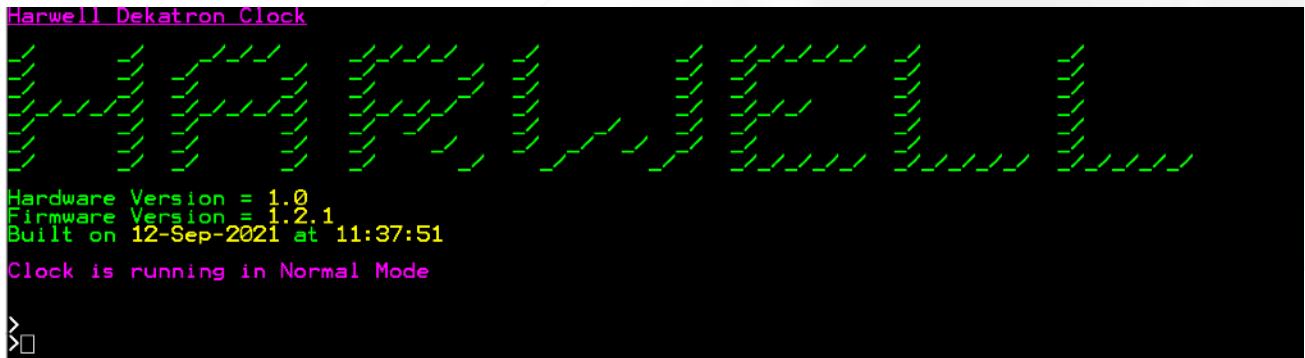
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



Setting up the Serial Port in Tera Term

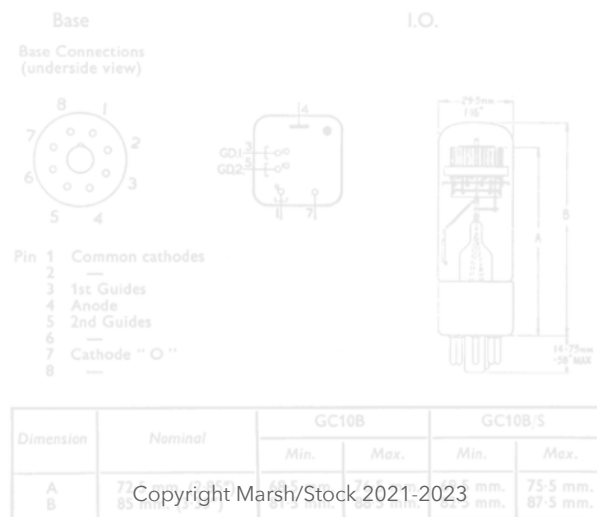
console to something like 115200, 8, N, 1 with no flow control.

When power is applied to the Harwell and the reset button on the clock pressed briefly you should see a simple welcome message¹²⁰. Something like (without option jumper 8 fitted):



Clock Start-Up Welcome Message

¹²⁰ Or a much longer one if the “verbose” jumper 8 is fitted.



4. Console Menus

The console menus are a simple, text-based system to allow commands to be entered that can run Nuggle programs, alter clock settings, interrogate system settings etc.

All commands are four letter keywords like DATG and SYSR. The first three letters are the name (or noun) of the part of the clock that the command acts on and the last letter is the action (or verb) that is to take place.

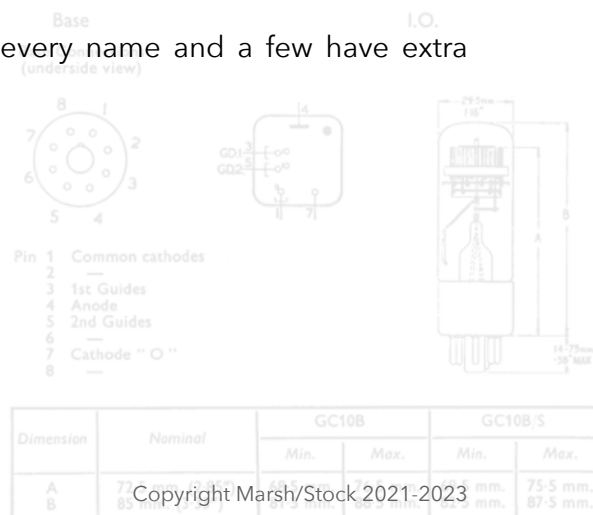
All text can be upper or lower case.

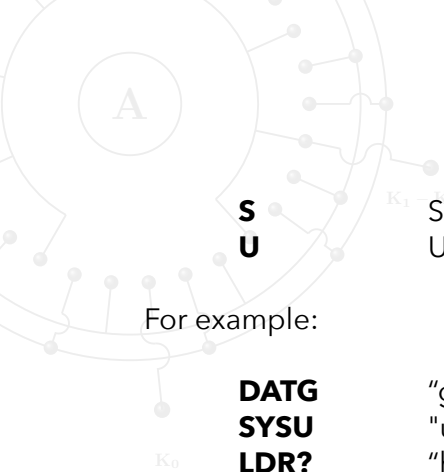
The three letter names/noun are:

ADC	ADC readings and interpretation
BEP	BEEp tests
BOO	BOOtloader operation
CHM	CHiMe system
COL	COLon commands
CON	CONstants interrogation
DAT	clock DATE
DEK	DEKatron tube control
EXP	EXPRession evaluator
FAC	FACe command help message
GPS	Global Positioning System (if fitted)
IRH	InfraRed Handset
LDR	Light Dependent Resistor (measures ambient light)
LED	LED bling controls
LOC	LOCale reports
NUG	NUGgle commands
OPT	OPTion settings
OUT	digital OUTputs
PIR	PIR controls
ROT	ROTary encoder controls
RTC	Real Time Clock commands
STR	SToRage information
SYS	SYStem information
TIM	clock TIME
VAR	system VARiable value interrogation
VOL	left and right amplifier VOLume controls
WIF	WIFi controls (if fitted)

The single letter actions/verb - not all actions operate with every name and a few have extra action letters:

?	name help
C	Continuous or pass-through mode
G	Get current setting
H	action Help
L	Load data again
K	Kill, turn function off
R	Report





S
U Set a value
Use the named device (in some way)

For example:

DATG "get" the current date
SYSU "use" the system - a parameter sets how
LDR? "help", LDR help information
LEDK "kill", turn all bling LEDs off

Some commands have mandatory parameters, for example:

TIMS 12:00:00 "set" the TIME to midday
OUTS 500,0 "set" digital OUTput for the 500V HT (500) supply off (0)

In all cases the 3 letter name with a ? will list the actions for it, together with any mandatory or optional parameters. Typing the command HELP will list the available commands.

Command entry

Commands are entered at a '>' text prompt. If the prompt is not there press return key and a '>' should appear. The '>' text prompt changes depending on clock mode. In normal mode it is '>', in test mode '?', in bootloader mode it is '^' , and '!' when the Dekatron board is running in demonstration mode (the board "test" jumper is fitted).

The entry editor is very simple. With only the following control keys having a use:

- Backspace (BS) - deletes the last character typed or is ignored at the start of the line.
- Escape (Esc) - deletes the whole entry.
- Return - enters the command for use.

ADC readings and interpretation

The Harwell clock uses four ADC channels to sense the main board hardware version, sense the plug-in board, measure the ambient light level and to report the SAM3X8C core temperature.

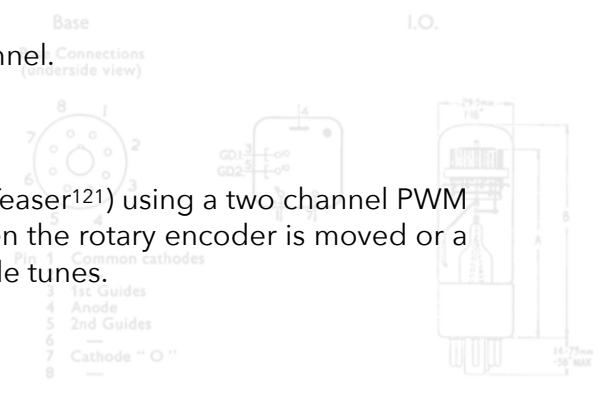
ADC?	ADC command help message
ADCR	Report the current ADC values and offer interpretation of the hardware channels and convert the SAM3X8C core temperature into °C

See also the LDR commands for more information on that channel.

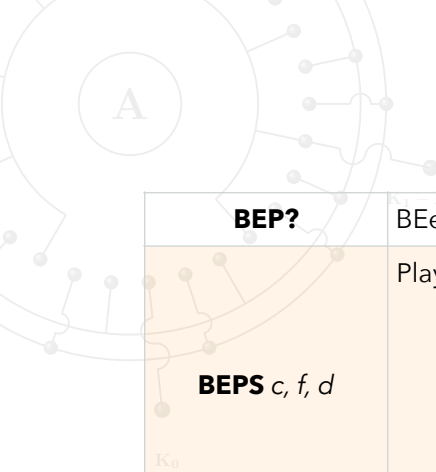
Beep tester

The clock can make beep-beep noises (but the clock is not a Teaser¹²¹) using a two channel PWM generator. It is used for warnings, making irritating noises when the rotary encoder is moved or a key is pressed on the IR handset and can be used to play simple tunes.

¹²¹ <https://h2g2.com/entry/A100503>



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



BEP?	BEEp command help message
BEPS <i>c, f, d</i>	Play a beep c = channel 1 = right 2 = left 3 = both f = frequency 30 .. 5000 Hz d = duration 10 .. 5000 mS
BEPU <i>n</i>	Play a pre-defined beep sequence 0 .. 4

See also the VOLume commands.

BOOtloader commands

These commands are used to upload new firmware to the MEGA324PA on the Dekatron board using the TWI.

BOO?	BOOtloader command Help message
BOOA <i>file</i>	From normal mode, BOOtloader All will switch to bootloader mode, then test the files for errors, erase the MEGA324PA, then write the file to it, then verify that the written data is correct and then finally switch to normal mode.
BOOD <i>file</i>	Dump the BOOtloader file contents to the console
BOOE	Erase the MEGA 324PA flash memory using the BOOtloader
BOOG <i>addr</i>	Get a single page (128 bytes) using the BOOtloader from flash memory
BOOR	BOOtloader Report
BOOV <i>file</i>	BOOtloader Verify that the firmware is the same as the file
BOOW <i>file</i>	Write the BOOtloader file
BOOY	From normal clock mode switch to the BOOtloader mode
BOOZ <i>file</i>	Check that the gives file an Intel HEX8 file.

All the commands except **BOO?**, **BOOD**, **BOOY** and **BOOZ** require the bootloader to be running. The command **BOOY** does not operate in bootloader mode. Use the **DEKY** command (Dekatron reset) to go from bootloader mode back to normal mode.

The *file* must be in the root folder on the SD card. It must be an Intel HEX8 format file. The full filename must be given including the .hex extension. The file name must be in DOS 8.3 format.

The *addr* must be a decimal number, for example:

BOOG 28672 will list the first 128 bytes of the bootloader firmware near the top of flash memory.

Base

IO

Pin 1 Common cathodes
2 —
3 1st Guides
4 Anode
5 2nd Guides
6 —
7 Cathode "O"
8 —

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

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ChiMe system tests

CHM?	ChiMe command help message
CHMK	Kill, stop the current playing chime
CHMR	Will list the available chimes to play with information on each chime
CHMU <i>name</i>	Play the chime by giving its name, quotes and file extension are not used example: chmu strk12

See also the VOLume commands.

COLon commands

COL?	COLon command Help message
COLG <i>n</i>	Get COLon <i>n</i> settings, left colon = 1, right colon = 2
COLK	Kill, turn off, both COLons
COLR	Report all COLon settings
COLS <i>n, b</i>	Set COLon <i>n</i> to brightness <i>b</i> = 0..100

CONstants interrogation

Clock has a number of standard constants and clock specific standard constants held in the *constants.ini* file on the SD card. These can be used in Nuggle programs and in other *ini* files instead of numbers. The **CON** commands allows you to check these constants.

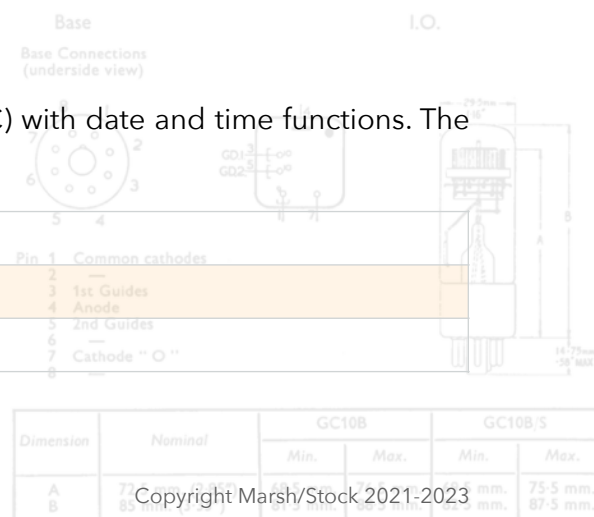
CON?	CONstants command help message
CONG	Will return the value in decimal and hexadecimal of a known constant example: cong red will reply: red = 16711680 0xff0000
CONL	Reload constants file
CONR	Will report the number of constants known and the memory used (heap) to hold them

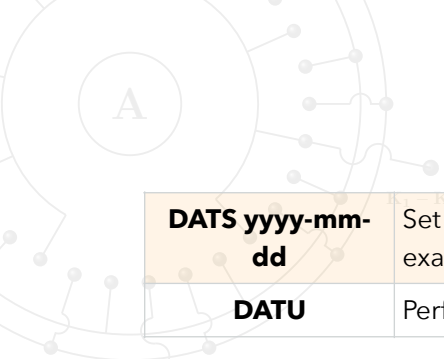
See the Nuggle manual section 2 for more information on constants.

DATE from RTC

The SAM3X8C microcontroller contains a real time clock (RTC) with date and time functions. The **DATE** command allows you to get and set the date.

DAT?	DATE command help message
DATG	Get the current UTC date
DATR	Report the date for UTC, ISO and local.



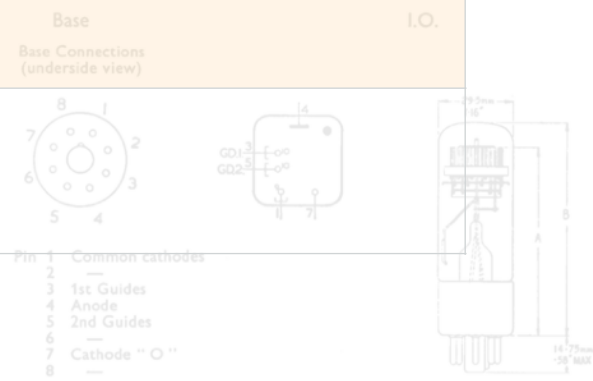


DATS yyyy-mm-dd	Set the UTC date example: dat 2018-1-14
DATU	Perform a synchronisation with the plug-in WIFI or GPS module

See also the **TIME** command.

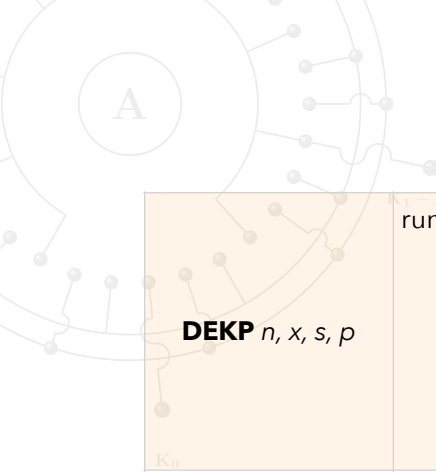
Dekatron commands

DEK?	Dekatron command Help message
DEKC <i>n, c, d, p</i>	move Dekatron n = tube 0..6 c = cathode 0..9 (0..11 for V7) d = direction 0..3 (see notes) p = pace mS per dot moved
DEKC <i>n, c, d, p</i>	move Dekatron n = tube 0..6 c = cathode 0..9 (0..11 for V7) d = direction 0..3 (see notes) p = pace mS per dot moved
DEKG <i>n</i>	Get Dekatron tube position n = tube 0..6
DEKI <i>n</i>	Idle a Dekatron tube n = tube 0..6
DEKJ	idle all Dekatron tubes
DEKK	Kill, set all DEKatrions to zero quickly
DEKL	reload the driver settings from Dekatron.ini file
DEKM <i>n, x, d, p</i>	Move dot to a new position n = tube 0..6 x = position 0..29 (0..35 for V7) d = direction 0..3 (see notes) p = pace mS per dot moved
DEKN <i>n, x, d, p</i>	spiN a Dekatron tube n = tube 0..6 x = starting dot position 0..29 (0..35 for V7) d = direction 0..1 p = pace mS per dot moved
DEKO <i>n, d, p</i>	spin a Dekatron Once tube n = tube 0..6 d = direction 0..1 p = pace mS per dot moved



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





DEKP <i>n, x, s, p</i>	run Dekatron Pendulum n = tube 0..6 x = starting dot position 0..29 (0..35 for V7) s = style 10 = linear 20 = gravity p = pace - mS per swing (10..10000)
DEKQ <i>n</i>	move a Dekatron glow to the nearest cathode n = tube 0..6
DEKR	Dekatron Slave Report
DEKS <i>n, x, d, p</i>	Show a value on a Dekatron n = tube 0..6 x = starting dot position 0..29 (0..35 for V7) d = direction 0..1 p = pace mS per dot moved
DEKW <i>n, c1, c2, p</i>	show tWo cathodes on a Dekatron n = tube 0..6 c1 = cathode 0..9 (0..11 for V7) c2 = cathode 0..9 (0..11 for V7) p = pause period mS
DEKY	reset the Dekatron driver TWI slave
DEKZ <i>n</i>	Zero a Dekatron n = tube 0..6

Direction codes are

- 0 = forwards, clockwise
- 1 = backwards, anticlockwise
- 2 = shortest route
- 3 = longest route

EXpression evaluator

The Nuggle parser (the part that actually runs the Nuggle program) contains an expression evaluator that will evaluate numerical and boolean expressions. It will use available Nuggle variables if a Nuggle program is running.

EXP?	EXpression evaluator help message	Base	I.O.
EXPG	Enter an expression for evaluation example: expg red >> 10 returns:decimal = 16320 hex = 0x3fc0 example: expg red > blue returns:decimal = 1 hex = 0x1 Since numerically constant red has a larger value than the constant blue so the value 1, boolean true, is returned	<p>Base Connections (underside view)</p> <p>Pin 1 Common cathodes Pin 2 — Pin 3 1st Guides Pin 4 Anode Pin 5 2nd Guides Pin 6 Cathode Pin 7 — Pin 8 —</p>	

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



See the Nuggle manual and the Nuggle Harwell Supplemental for more information on Nuggle expressions and the numbers, operators, functions, constants, variables etc. that the clock uses.

FACe Command Help Message

FACG	Return the index number of the current displayed face
FACL	Reload the face index table from [faces] section in <i>nuggle.ini</i>
FACR	Clock face report
FACS <i>n</i>	Change the displayed face to face index number <i>n</i>

GPS plug-in module tests

These command require the GPS module to be installed (obviously).

GPS?	GPS help message
GPSC	Put the console into an operation where all text received from the GPS module is continuously played. Press the Esc key to stop.
GPSR <i>n</i>	GPS report where <i>n</i> = 0 - report data validity, geolocation etc. <i>n</i> = 1 - report on satellite data
GPSU	Hardware reset and restart the GPS Module

IR Handset tests

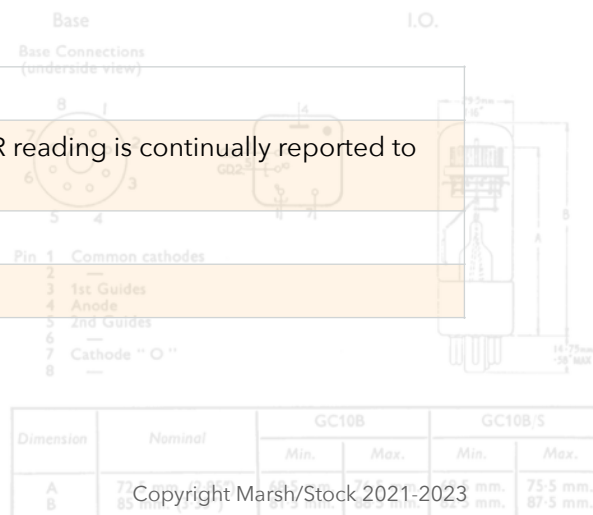
Operation of the IR handset can be tested.

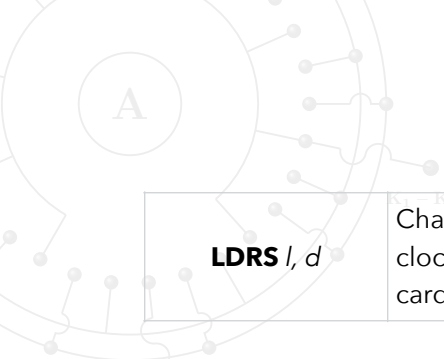
IRH?	IR Handset help message
IRHC	Put the console into an operation where all IR Handset keypresses are played to the console. Press the Esc key to stop.
IRHR	IR Handset settings report.

LDR sensor controls

Values returned by the LDR can be observed. Useful to test under varying light conditions to set the brightness range parameters.

LDR?	LDR sensor help message
LDRC	Put the console into an operation where the LDR reading is continually reported to the console. Press Esc to stop.
LDRG	Get the current LDR threshold values
LDRR	LDR settings and reading report.





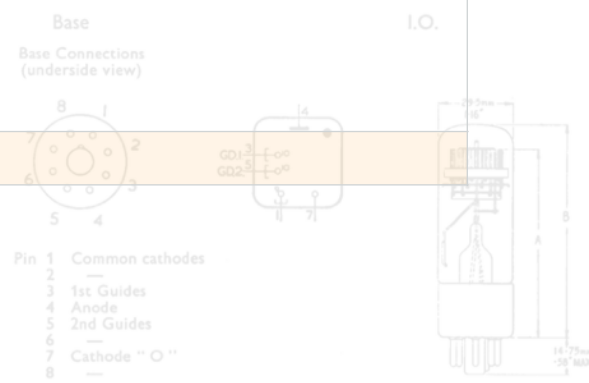
LDRS *l, d*

Change the LDR light and dark threshold values. The values are not retained if the clock is switched of. For a permanent change the [ldr] section in system.ini on the SD card should be edited.

LED bling-bling controls

Try different bling LED module brightness and colour controls. Brightness can be static or dynamic. Colours can be entered as RGB or HSV formats.

LED?	LED bling-bling help message
LEDA <i>fxd</i>	set the bling brightness setting to static level fxd = 1 .. 31 static level not > 10 is recommended
LEDB <i>min,max</i>	set the bling brightness setting to dynamic level using the ambient light level measured by the LDR min = level corresponding to 0% LDR brightness max = level corresponding to 100% LDR brightness
LEDK	kill, turn off all LED modules
LEDR	LED module report
LEDS <i>0, grp, rgb</i>	Set a group of LEDs to the specified RGB colour. Groups and RGB colour values are explained in the Nuggle manual. example: leds 0, 0x3f, 0xff will light the downward pointing LEDs in blue
LEDS <i>1, num, rgb</i>	Set a single LED to the specified RGB colour. example: leds 1, 23, 0xff0000 will light the right-hand colon LED in red
LEDU	Restore default brightness settings.
LEDV <i>0, grp, hsv</i>	Set a group of LEDs to the specified HSV colour. Groups and HSV colour values are explained in the Nuggle manual. example: ledv 0, 0x3f, 0x80ffff will light the downward pointing LEDs in aqua
LEDV <i>1, num, hsv</i>	Set a single LED to the specified HSV colour



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



LOCaLe reports

Report locale information such as DST, time zone, geolocation and user preferred formats.

LOC?	LOCaLe report help message
LOCR n	Locale reports: $n = 0$ - DST rules showing the selected rule if any $n = 1$ - time zones showing the selected time zone $n = 2$ - geolocation information read from the SD card $n = 3$ - user preferred date and time formatting settings

NUGgle programs

Run, list, stop etc. Nuggle programs.

NUG?	NUGgle program help message
NUGG	List the running Nuggle program from the info file
NUGR	Report on the running Nuggle program
NUGS $name$	Run the Nuggle program name
NUGU	Dump the running Nuggle info and data as a hexadecimal table

OPTion jumpers

Get, set and report the main board option jumpers. In particular note that the set command can override the physical jumper position so tests can be made without fitting or removing a jumper.

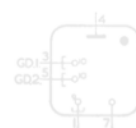
OPT?	OPTion jumper help message
OPTG n	Get the current setting of option jumper n $n = 1 \dots 8$
OPTR	Report position of all jumpers
OPTS n, v	Set the position of option jumper n to v $n = 1 \dots 8$ $v = 0 1$ this is a firmware setting that overrides the hardware/physical jumpers
OPTU	Restore the firmware settings to the hardware/physical positions

digital OUTput controls

Get, set and report on a limited range digital IO pins.

OUT?	Digital OUTput help message
-------------	-----------------------------

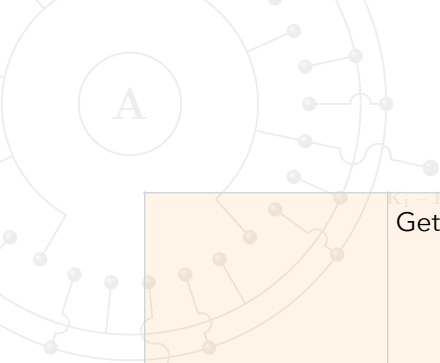
Base Connections (underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





OUTG n	Get the current setting of digital output n $n = 5$ Port A Pin 5 on board back $n = 7$ Port A Pin 7 on board back $n = 10$ Port A Pin 11 on X8 pin 3 $n = 11$ Port A Pin 11 on X8 pin 2 $n = 25$ Port B Pin 25 on board back $n = 28$ Port B Pin 28 on board back $n = 29$ Port B Pin 29 on board back $n = 31$ Port B Pin 31 on board back $n = 500$ Flyback 500V enable
OUTR	Report all settings
OUTS n, v	Set the digital output n to value v $n =$ as above $v = 0 1$

PIR sensor

Operation of the PIR can be tested.

PIR?	PIR sensor help message
PIRC	Put the console into an operation where all PIR hits are played to the console by printing an exclamation mark. Press the Esc key to stop.
PIRR	PIR sensor report

Real Time Clock commands

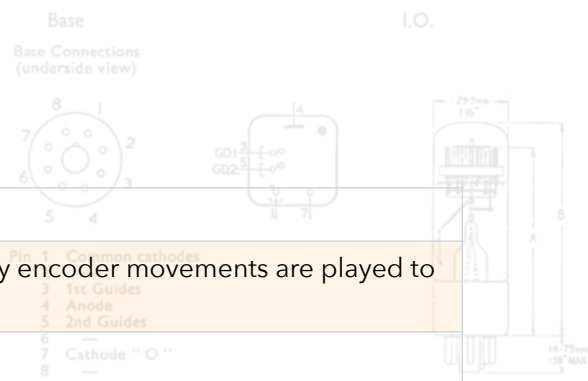
RTC?	RTC command Help message
RTCJ n	Set RTC fine offset
RTCR	RTC Report
RTCU	Use the plug-in (WiFi or GPS) to Sync the RTC
RTCZ	Compare the RTC to the plug-in

The RTC fine adjustment, **RTCJ**, is provided to allow the RTC to be deliberately delayed by up to a second to synchronise the clock to another clock.

ROTary encoder tests

Operation of the rotary encoder can be tested.

ROT?	ROTary encoder help message
ROTC	Put the console into an operation where all rotary encoder movements are played to the console. Press the Esc key to stop.
ROTR	Rotary encoder report



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm	
B	85			87.5 mm	



SToRage reports

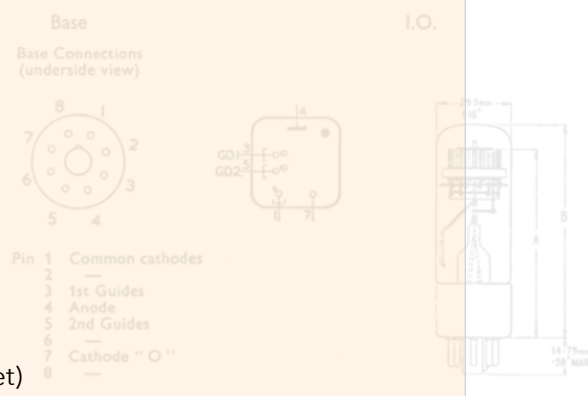
Report on the various memory/storage media in the clock.

STR?	SToRage reports help message
STRR n	Storage report n $n = 0$ - file system $n = 1$ - SD Card $n = 2$ - NVRAM $n = 3$ - memory - see SYSR 0

SYStem reports and actions

A variety of system reports and actions to invoke.

SYS?	SYStem help message
SYSC n	Continuous ADC readings $n = 0$ - chip temperature $n = 1$ - direct LDR reading $n = 2$ - repeat plug-in reading $n = 3$ - repeat board reading
SYSR n	System report n $n = 0$ - memory use $n = 1$ - SAM3X8C chip identification $n = 2$ - SAM3X8C core temperature °C $n = 3$ - task system status $n = 4$ - demonstrate floating point errors $n = 5$ - demonstrate random number generation $n = 6$ - version and build information $n = 7$ - sleep report $n = 8$ - profiler report $n = 9$ - usage log report $n = 10$ - SYSL command line $n = 11$ - heap data $n = 12$ - 256 colour palette $n = 13$ - text attributes
SYSU n	System actions: $n = 0$ - invoke sleep $n = 1$ - wake up $n = 2$ - shut down the clock (requires reset) $n = 3$ - reset the clock $n = 4$ - reload the help file index $n = 5$ - reload the DST data $n = 6$ - reload the time zone data $n = 7$ - reload your geolocation $n = 8$ - reload formatting preferences $n = 63$ - fatal error display test (requires reset)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	



TIME from RTC

The SAM3X8C micro-controller contains a real time clock (RTC) with date and time functions. The **TIME** command allows you to get and set the date.

TIM?	TIME help message
TIMG	Get the current UTC time
TIMR	Report the date for UTC, ISO and local.
TIMS <i>hh:mm:ss</i>	Set the UTC time example: tims 12:30:00
TIMU	Perform a synchronisation with the plug-in WIFI or GPS module

See also **DAT** commands.

system VARIABLE report and interrogation

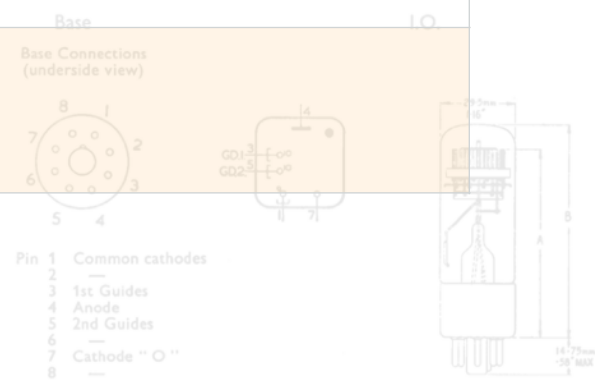
Nuggle programs can access system information using so-called system variables. These values are variable in that the system will change them but the user cannot (at least within a Nuggle program). They are therefore considered read-only.

VAR?	System VARIABLE help message
VARG <i>name</i>	Get the current value of a system variable, in both decimal and hexadecimal example: varg latitude returns: latitude = 57662 0xe13e
VARR	Report system variable usage

amplifier VOLUME control

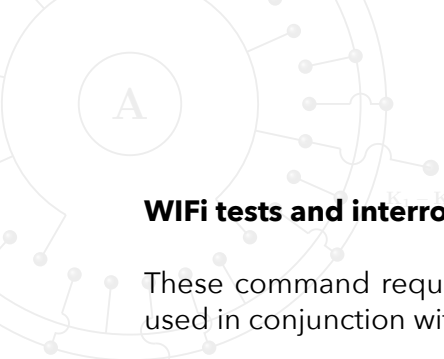
Get and set the beep and chimes volume control settings. Report on the audio amplifiers.

VOL?	amplifier VOLUME control help message
VOLG	get the beep and chimes volume settings
VOLR	report
VOLS <i>c, v</i>	Set the volume for beep or chimes, where n = 0 - beep n = 1 - chimes v - volume setting 0 .. 31



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

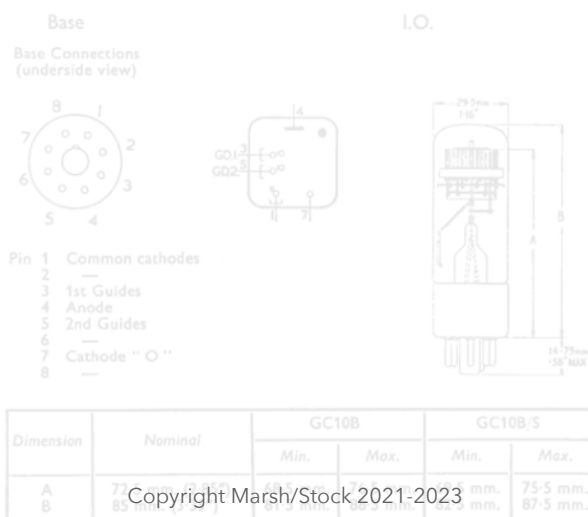
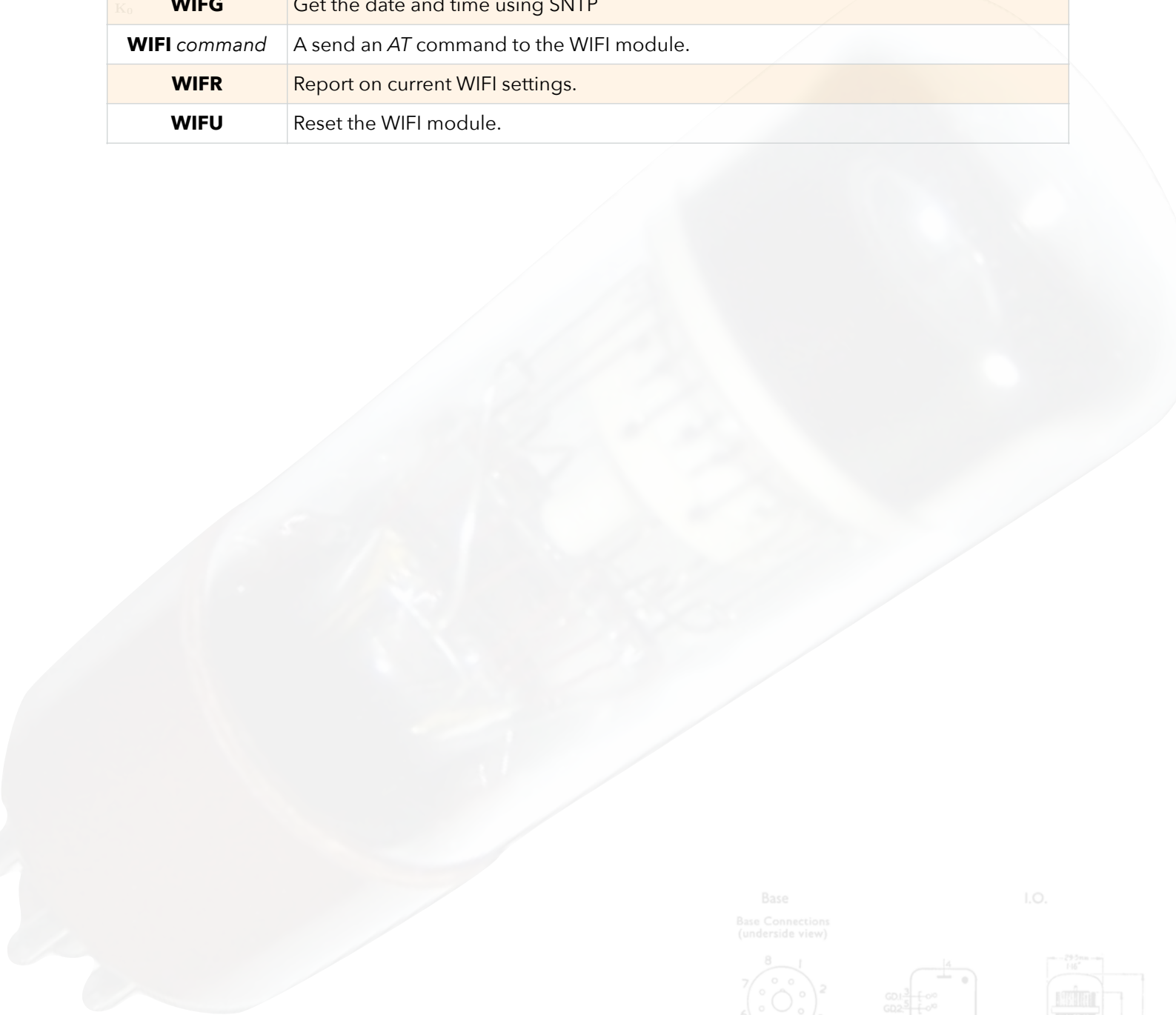




WiFi tests and interrogation

These commands require the WiFi module to be installed (obviously). They should be read and used in conjunction with the ESP32-BIT documentation.

WIF?	WiFi help message
WIFG	Get the date and time using SNTP
WIFI command	A send an AT command to the WiFi module.
WIFR	Report on current WiFi settings.
WIFU	Reset the WiFi module.



5. Programming the microcontrollers

5.1 SAM3X8C

This is a simplified and shortened guide to programming the SAM3X8C. For a complete description see the SAM3X8C section in *Sgitheach Commoners* manual. As a programmer the programmer/serial console board uses the BOSSA¹²² programming utility to talk to the bootloader in the SAM3X8C. There has been some uncertainty over which versions of BOSSA work with which micro-controllers. Therefore it is recommended that you do not download the latest version of BOSSA but use the version you will find on the Dropbox as this is known to work with the SAM3X8C. The steps to set up and use the BOSSA programming tool are as follows:

1. Download

Download the SAM3X8C programming files from the Dropbox into a suitable directory on your PC (or whatever). You will find a version of BOSSA called bossac.exe and a batch file called samprog.bat. Note the directory name where you have put these files.

2. Using BOSSA directly from a command prompt

From a Command Prompt window you can run the batch file using:

```
\pathto\samprog comxx \pathto\xxxxx.bin
```

where comxx is the COM number that the board is using¹²³ and xxxxx.bin is the binary image of the firmware you want to program into the flash.

example:

```
d:\bossa\samprog COM9 d:\harwell\firmware\harwell.1.0.0.bin
```

When the batch file is run you will see the erase LED flash, followed by the reset LED followed by the RxD and TxD LEDs as the binary data is transferred. Note that as the same COMxx connection is used for both the serial connection and the programmer, the programmer will not run while the serial port is connected. Additionally, unplug the SD card USB connection if in use.

3. Update the SD card

Transfer any new files from the SD card image on the Dropbox to the clock's SD card. The release notes will tell you which. In a particularly large update a whole new image may be needed which will again require your locale data to be edited. It is recommended that you keep the clock's SD card image backed-up on your PC (or Mac...).

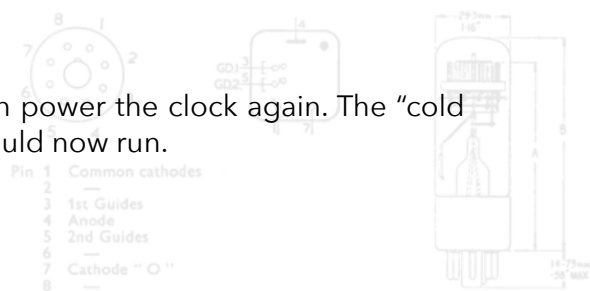
4. Restart the clock

Switch off the Harwell clock and wait a few moments and then power the clock again. The "cold boot" is a requirement of the SAM3X8C. The new firmware should now run.

¹²² <https://github.com/shumatech/BOSSA>

¹²³ using the method in section 3 above

Base Connections
(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

5.2 Programming the MEGA324PA

The Dekatron board of the Harwell clock uses an ATMEGA324PA to control the Dekatrons and provide the large number of I/O lines needed. It connects to the SAM3X8C microcontroller using a TWI.¹²⁴ The ATMEGA324PA needs to be programmed and there are a couple of methods to accomplish this.

It should be remembered that the kit can come with it pre-programmed with the current firmware. However, you may need to be able to program it again to take advantage of any clock firmware upgrades.¹²⁵

A built and fully tested Harwell clock comes with the latest firmware already installed of course.

Quick Start

If you prefer not to read this somewhat long and turgid description of using the bootloader to update the firmware in the ATMEGA324PA then follow these simpler instructions:¹²⁶

1. Plug the clock USB port into your PC and the SD card will appear as a removable drive.
2. Copy the new firmware to the root directory of the SD Card. The filename must be in 8.3 format for example *m324.hex*.
3. Plug the console into the clock and a USB cable and check that you can give menu commands.
4. Enter the command **BOOA m324.hex** (using your filename if different) and the clock will update the firmware, a process that takes about 30 seconds.

If no error messages appear then that is job done.

An in depth look at programming the ATMEGA324PA

Method 1: Using an AVR ISP - bootloader not used

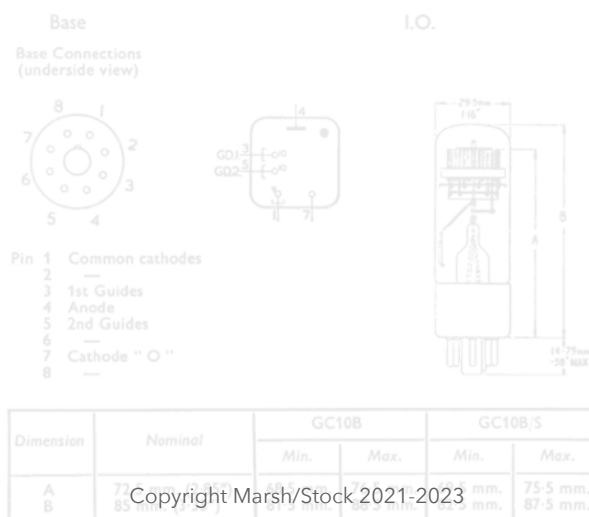
If you own an AVR ISP (and know how to use it) then you can use it to burn the ATMEGA324PA firmware and fuses.

The AVR ISP uses the standard 3 x 2 header connection. It is plugged into X3 between V2 and V3 on the Dekatron board.

¹²⁴ Two Wire Interface - AVR speak for I2C.

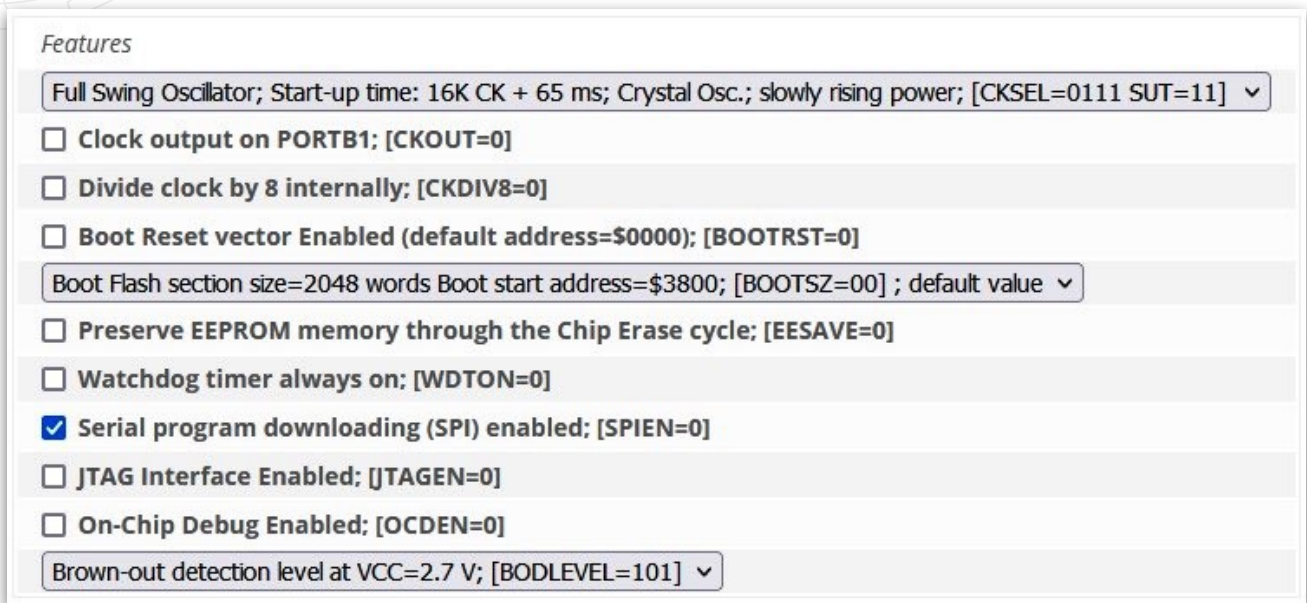
¹²⁵ Bug fixes etc..

¹²⁶ This assumes that the clock has been preloaded with the bootloader.



5.2.1 Set the fuses

Using your favourite AVR ISP software set the fuses to:¹²⁷



This gives:

Low Fuse - 0xF7
 High Fuse - 0xD9
 Extended Fuse - 0xFD

For example, if you were using AVRDUDE with a USBTiny¹²⁸ then you would type the following:

```
avrdude -c USBTiny -P usb -b 19200 -B 8 -p m324pa -U lfuse:w:0xf7:m -U hfuse:w:0xd9:m -U efuse:w:0xfd:m
```

5.2.2 Burn the firmware

Then using your favourite AVR ISP software burn the firmware. The file from the distribution Dropbox will have a name like "Dekatron.1.2.1.hex", the numbers identifying the version, currently 1.2.1. Of course, the board must be powered when programming.

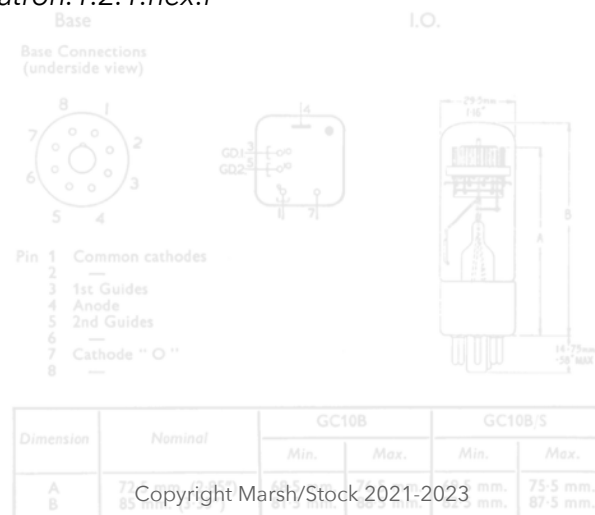
For example:

```
avrdude -c USBTiny -P usb -b 19200 -p m324pa -U flash:w:Dekatron.1.2.1.hex:i
```

This completes the programming.

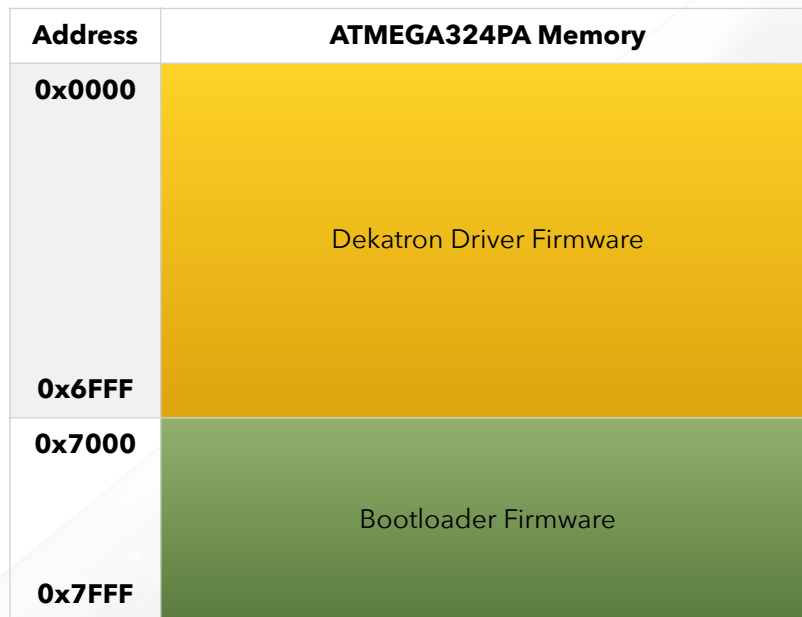
¹²⁷ Image taken from <https://www.engbedded.com/fusecalc/>

¹²⁸ This is a pretty common arrangement...



Method 2: Using the TWI bootloader

The TWI bootloader allows the programming or re-programming of the ATMEGA324PA microcontroller using the TWI with the SAM3X8C instead of a traditional programmer used in method 1. Once the bootloader is programmed into the microcontroller, it remains until the chip is erased. The bootloader allows a simple extension to the main clock firmware to download an Intel hex file into the microcontroller. The bootloader firmware sits in the top 4K of the flash memory leaving the remaining 28K for the Dekatron driver firmware:



Under normal conditions both the driver and bootloader firmware sections are present in the flash memory with this method. When the clock is started (or reset) the bootloader firmware in the ATMEGA328PA is first run. It determines if it is desired and safe for the driver firmware to run. If that is the case then execution is switched to the driver firmware and the bootloader has no further role in clock operation.

Why might it not be desired to run the driver firmware? The commonest case is when the driver firmware is to be updated. Why might it not be safe? When the part is brand new the driver firmware section is completely erased (all memory locations are set to 0xFF). Therefore, it would not be good to try and execute a program that is not there!

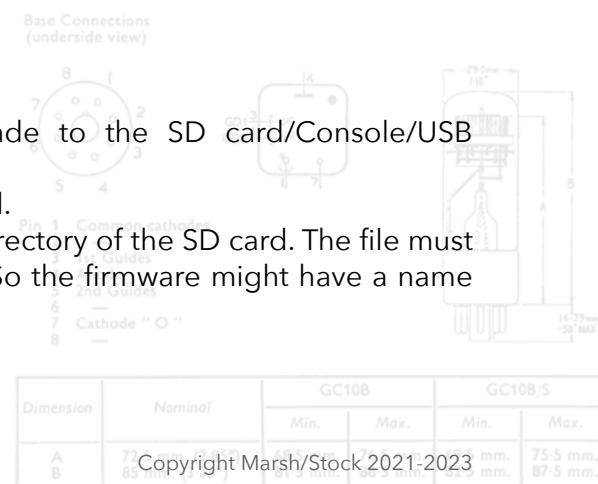
5.3. Using the bootloader to update the driver firmware

This will be the commonest case so let's discuss it first. Other cases are variations on this one.

The pre-requisites are:

- Functioning Harwell Clock powered and access made to the SD card/Console/USB connectors.
- Console connected so menu commands can be entered.
- The new driver firmware has been copied to the root directory of the SD card. The file must be an Intel hex¹²⁹ format file saved with an 8.3 name. So the firmware might have a name

¹²⁹ Strictly an I8HEX format file. https://en.wikipedia.org/wiki/Intel_HEX



such as *m324.hex* but is just the distribution file, for example, *Dekatron.1.2.1.hex* rename and copied to the SD card.¹³⁰

The SD card root directory will look something like this:

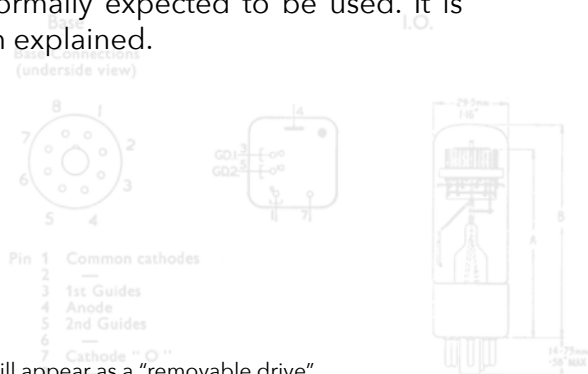
Name	Date modified	Type	Size
CHIMES	03/10/2020 18:28	File folder	
include	23/05/2020 16:59	File folder	
nuggle	23/05/2020 16:59	File folder	
RUNTIME	31/12/2006 23:00	File folder	
system	23/05/2020 16:59	File folder	
wav	23/05/2020 16:58	File folder	
m324.hex	28/07/2021 10:34	HEX File	25 KB
system.ini	29/11/2020 15:33	INI File	15 KB

The bootloader console menu commands all start with **BOO**.¹³¹ Many of the commands will only be accepted when the bootloader is running. Two commands will operate in normal clock mode and in bootloader mode:

BOO?	Simple help message
BOOA filename	All function executed: <ul style="list-style-type: none"> • switch to bootloader mode (BOOY) • check file (BOOZ filename) • erase flash (BOOE) • write file to flash (BOOW filename) • verify flash and file match (BOOV filename) • switch to normal mode (DEKY)
BOOD filename	Display the contents of the hex file
BOOZ filename	Read and test the given hex filename. The file is tested against the expected I8HEX format

In these instructions, it is assumed that the filename is *m324.hex*.

BOOA is a wrapper command that executes a series of individual commands in sequence to use the bootloader function. This is the way the bootloader is normally expected to be used. It is easier to understand once the individual commands have been explained.



¹³⁰ You can copy the file using a USB cable connected to your PC where the SD Card will appear as a "removable drive".

¹³¹ Don't be scared by this....Boo!

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



Using the other three commands on the console gives:

```

COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
>boo?
Bootloader commands
B00? this help message
B00A file test, erase, write and verify in order
B00D file display hex file contents
B00E erase flash
B00G addr read a page (128 bytes) of memory
B00R bootloader report
B00V file verify flash against file
B00W file write file to flash
B00Y enter bootloader mode
B00Z file test hex file formatting
All commands except B00?, B00D, B00Y & B00Z require the bootloader to be running
Command B00Y does not operate in bootloader mode. Use DEKY (dekatron reset)
to enter normal mode.

>booz m324.hex
Intel Hex file formatting is Ok

>bood m324.hex
0000 22 c1 00 00 3d c1 00 00 3b c1 00 00 39 c1 00 00 " . . . = . . . : . . . 9 . . .
0010 37 c1 00 00 35 c1 00 00 33 c1 00 00 31 c1 00 00 7 . . . 5 . . . 3 . . . 1 . . .
0020 2f c1 00 00 2d c1 00 00 2b c1 00 00 29 c1 00 00 / . . . - . . . + . . . ) . . .
0030 27 c1 00 00 25 c1 00 00 23 c1 00 00 21 c1 00 00 ' . . . % . . . # . . . ! . . .
0040 0c 94 4d 0b 1d c1 00 00 1b c1 00 00 19 c1 00 00 . . . M . . . . . . . . . .
0050 17 c1 00 00 15 c1 00 00 13 c1 00 00 11 c1 00 00 . . . . . . . . . .
0060 0f c1 00 00 0d c1 00 00 0c 94 3b 0c 09 c1 00 00 . . . . . . . . . .
0070 07 c1 00 00 05 c1 00 00 03 c1 00 00 e6 02 9e 04 . . . . . . . . . . ; . . .
0080 f0 02 33 03 5a 03 cf 03 0a 04 9e 04 58 04 9e 04 . . . 3 . Z . . . . . . . . . . X . . .
0090 e6 02 0e 07 10 07 1f 07 21 07 31 07 1f 07 21 07 C . ! . o . . . ! . . . 1 . . . ! . . .
00a0 43 07 21 07 6f 07 95 07 21 07 ca 07 f0 07 21 07 . . . . . . . . . . . . . . . .
00b0 2c 08 36 08 52 08 70 08 8b 08 86 08 5f 0e 67 0e . . . 6 . R . P . C . . . . . . . . . . g .
00c0 98 0e a9 0e 94 0e 9f 0e 80 0e b1 0e b9 0e . . . . . . . . . . . . . . . .
00d0 df 0e f4 0e 01 0f 13 0f 21 0f 3d 0f 74 0e 58 0f . . . . . . . . . . ! . = . t . X .

```

Note that the full filename, including the .hex extension is entered. The **BOOD** output can be very long so is truncated in this screenshot.

To activate the bootloader so it can be used to write new firmware to the flash you use the **BOOY** command.

```

BOOY Enter bootloader mode

```

Note that the command prompt has changed from a greater than¹³² symbol '>' to a caret '^'. The '^' is used to indicate the console is now in bootloader mode.

```

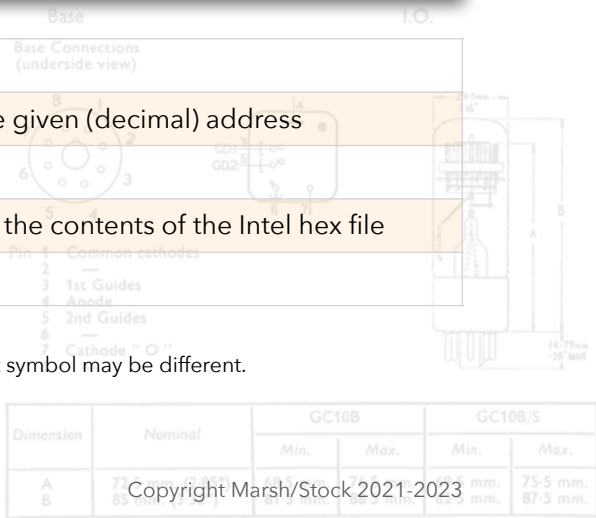
COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
>booy
^

```

Commands that now operate in addition¹³³ to **BOO?**, **BOOD** and **BOOZ** are:

BOOE	Erase Dekatron driver flash memory area
BOOG <i>addr</i>	Display 128 bytes of flash memory starting at the given (decimal) address
BOOR	Provide a bootloader report
BOOV <i>filename</i>	Verify the contents of the flash memory matches the contents of the Intel hex file
BOOW <i>filename</i>	Write the Intel hex file to flash memory

¹³² A '>' is shown here but if the clock is operating in a different mode then the prompt symbol may be different.
¹³³ **BOOY** no longer operates as the clock is now in bootloader mode.



You can now use **BOOE** to erase the driver flash area, **BOOW** to write a new Intel hex file and then **BOOV** to verify the flash contents against the hex file:

When erase, write and verify operations are underway the LED on the board will flash¹³⁴ and then return to a steady on state when the commands are finished.

Two other commands are **BOOG** and **BOOR**: **BOOG** displays a single 128 byte (a "programming page") from flash memory, for example:¹³⁵

```

COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
^booz m324.hex
Intel Hex file formatting is Ok

^booe
Erasing...
Erase took 958 mS

^boow m324.hex
Writing...
Write took 15846 mS

^boov m324.hex
Verifying...
Verify took 9361 mS
^
  
```

```

COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
^boog 0
0000 22 c1 00 00 3d c1 00 00 3b c1 00 00 39 c1 00 00 " . . . = . . . 3 . . . 9 . . .
0010 37 c1 00 00 35 c1 00 00 33 c1 00 00 31 c1 00 00 / . . . 5 . . . 1 . . .
0020 2f c1 00 00 2d c1 00 00 2b c1 00 00 29 c1 00 00 ' . . . - . . . + . . . ) . . .
0030 27 c1 00 00 25 c1 00 00 23 c1 00 00 21 c1 00 00 , . . . % . . . # . . . ! . . .
0040 0c 94 4d 0b 1d c1 00 00 1b c1 00 00 19 c1 00 00 . . . M . . .
0050 17 c1 00 00 15 c1 00 00 13 c1 00 00 11 c1 00 00 . . .
0060 0f c1 00 00 0d c1 00 00 0c 94 3b 0c 09 c1 00 00 . . . ; . . .
0070 07 c1 00 00 05 c1 00 00 03 c1 00 00 e6 02 9e 04 . . .
^
  
```

BOOR gives a report on the bootloader and current settings:

Version and *Compiled* are obvious, *LED* and *Test state* are the onboard LED and the test jumper (X4) states, *Jumpers* is the interpretation of the three tube selection jumpers J0, J1 and J2.

```

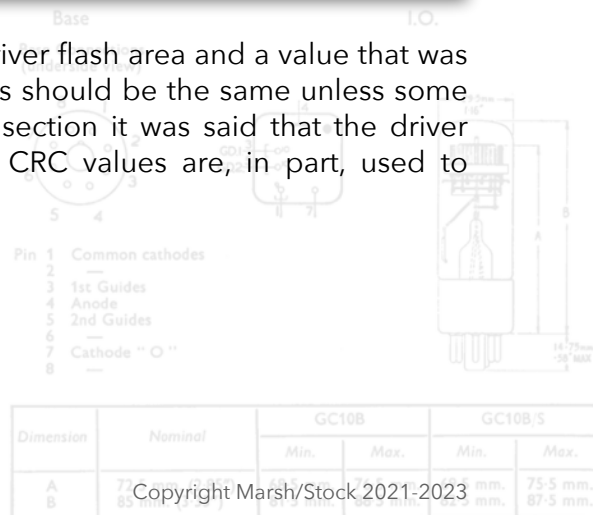
COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
^boor
Dekatron Board Bootloader Report
Version: 1.2.0
Compiled: 28 Jul 2021 at 11:17:35
LED state: off
Test state: open
Jumpers: British GC10 and GC12
EEPROM CRC: 0x80
Flash CRC: 0x80
Reason: Magic number found
Signature: 0x1e9511
Fuses: Low:0xf7 High:0xd8 Extended:0xfd
^
  
```

The two CRC¹³⁶ values are a computed CRC for the current driver flash area and a value that was computed when the flash is verified (using **BOOV**). The values should be the same unless some corruption has occurred. In the opening description of this section it was said that the driver firmware would be run if it was safe to do so. These two CRC values are, in part, used to determine that safety.

¹³⁴ To try to convince you that something is going on...

¹³⁵ Me thinks the author was enjoying some of these acronyms.... Ed.

¹³⁶ https://en.wikipedia.org/wiki/Cyclic_redundancy_check



Finally, the signature and fuse are read from the microcontroller. The signature should always be 0x1e9511¹³⁷ and the fuses should be those needed for correct bootloader operation of the ATMEGA324PA (see section 4 below).

This report should confirm what you know already!

Returning to the **BOOA** command. This command wraps all the individual commands in sequence to write the new file to the ATMEGA324PA together with all the test and verify steps. For example:

```
COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
>booa m324.hex
Intel Hex file formatting is Ok
Now in Bootloader mode
Erasing...
Erase took 958 mS
Writing...
Write took 16036 mS
Verifying...
Verify took 9289 mS
Now in Normal mode
>|
```

5.4. What could possibly go wrong?

With something as arcane as a bootloader there must be some chance¹³⁸ of things going wrong. The most likely problems will occur if the *write* phase of the bootloader is interrupted, for example, loss of power to the clock or a problem reading the SD card.

During bootloader development attempts were made to upset various processes to ensure that clock would recover, albeit with some intervention.

These are not experiments that you are expected to repeat!

Example: Loss of power.

Tested by switching the clock off during the **BOOA** write phase¹³⁹... On power on again, the clock detected there is a problem with the Dekatron firmware and entered bootloader mode by itself:

You can see here that the reason for entering bootloader mode was that the Flash CRC failed. Therefore it was doing its job correctly.

```
Clock is running in Bootloader Mode
^boor
Dekatron Board Bootloader Report
Version: 1.2.0
Compiled: 28 Jul 2021 at 11:17:35
LED state: on
Test state: open
Jumpers: British GC10 and GC12
Flash CRC: 0xb2
Saved CRC: 0x00
Reason: Flash CRC failed
Signature: 0x1e9511
Fuses: Low:0xf7 High:0xd8 Extended:0xfd
```

Example: Other problems

I ran a version of the bootloader that made it look like that the Dekatron driver flash is corrupted but the stored CRC made it look like the flash is OK. The "faulty" Dekatron driver made the clock hang.

¹³⁷ The signature of an ATMEGA324PA.

¹³⁸ "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." - Terry Pratchett, *Mort*

¹³⁹ I also tried yanking out the SD card, removing the TWI cable from the main board and anything else I could think of...



There are three ways out of this hole

1. Set jumper and reboot the clock

It might be possible for the firmware to sort itself out. To try this, remove option jumper 1 on the main board and fit option jumper 2. Power the clock and if successful clock will restart in bootloader mode and allow you to erase and write the flash again. This method is simple and fairly non-invasive but may not always work.

2. Remove the tube selection jumpers on the Dekatron card

On the Dekatron card the three jumpers J0, J1 and J2 are normally used to select the type of Dekatrons in use (British, American, Soviet), however, there is a special setting of all jumpers open (none fitted/closed) that the bootloader recognises as telling it to run.

It is necessary to partly dismantle the clock to remove the jumper(s) using a soldering iron but it is a pretty reliable way to restore a clock from major flash/EEPROM corruption.

Having removed all the links (only link J0 in my case as I am using British tubes) the clock restarted into bootloader mode and the **BOOR** command showed:

Here you can see that the CRC values are the same so did not force the clock into bootloader mode. But the reason for the bootloader mode start was *Jumper settings* showing that the bootloader correctly detected that all the jumper J0, J1 and J2 were open. After writing a new bootloader firmware (**BOOW**), verifying the write (**BOOV**), then the required links are reinstated.



```
COM31:115200baud - Tera Term VT
File Edit Setup Control Window Help
^boor
Dekatron Board Bootloader Report
Version: 1.2.0
Compiled: 28 Jul 2021 at 11:17:35
LED state: on
Test state: open
Jumpers: Force Bootloader
Flash CRC: 0x32
Saved CRC: 0x32
Reason: Jumper settings
Signature: 0x1e9511
Fuses: Low:0xf7 High:0xd8 Extended:0xfd
```

This is a pretty drastic process but it should work against some pretty weird failures¹⁴⁰ or accidents that might occur during the write or verify phases.

3. Use an AVR ISP

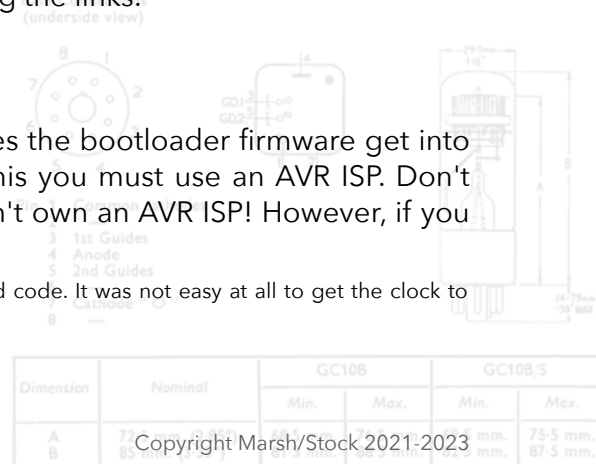
However, if you have an AVR ISP but are using the bootloader to avoid the hassle of using the AVR ISP then you will be able to recover from any bootloader corruption by using it to erase the whole of the flash (Dekatron driver and bootloader firmware) and then reprogram the bootloader firmware. See the following section. This will avoid de-soldering the links.

5.5 Programming the bootloader firmware

The £46,172.48 question¹⁴¹, if you have spotted it, is how does the bootloader firmware get into the top of the flash memory in the ATMEGA324PA? To do this you must use an AVR ISP. Don't forget to order the kit with the bootloader installed if you don't own an AVR ISP! However, if you

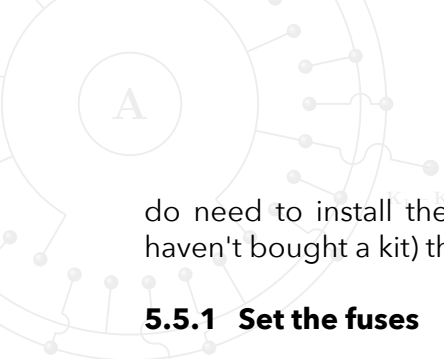
¹⁴⁰ They are most likely to occur during code development that with finished, tested code. It was not easy at all to get the clock to misbehave such that this measure was required.

¹⁴¹ \$64000 at today's exchange rate...well, when this document was originally written!



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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do need to install the bootloader firmware (for example you have modified the code or you haven't bought a kit) then the steps are.

5.5.1 Set the fuses

Using your favourite AVR ISP software set the fuses to:

Features

Full Swing Oscillator; Start-up time: 16K CK + 65 ms; Crystal Osc.; slowly rising power; [CKSEL=0111 SUT=11] ▾

Clock output on PORTB1; [CKOUT=0]

Divide clock by 8 internally; [CKDIV8=0]

Boot Reset vector Enabled (default address=\$0000); [BOOTRST=0]

Boot Flash section size=2048 words Boot start address=\$3800; [BOOTSZ=00] ; default value ▾

Preserve EEPROM memory through the Chip Erase cycle; [EESAVE=0]

Watchdog timer always on; [WDTON=0]

Serial program downloading (SPI) enabled; [SPIEN=0]

JTAG Interface Enabled; [JTAGEN=0]

On-Chip Debug Enabled; [OCDEN=0]

Brown-out detection level at VCC=2.7 V; [BODLEVEL=101] ▾

This gives:

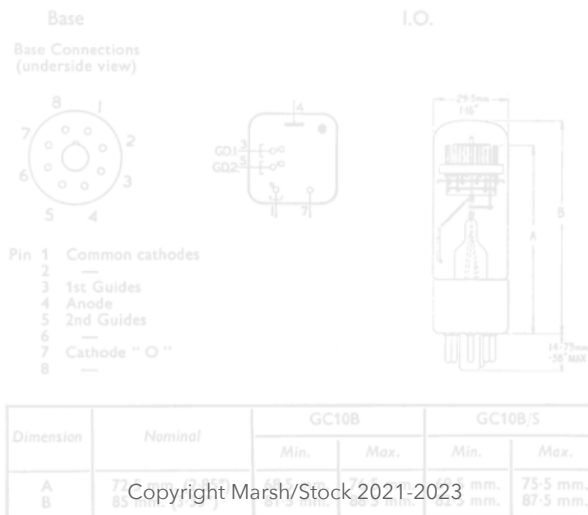
- Low Fuse - 0xF7
- High Fuse - 0xD8
- Extended Fuse - 0xFD

These are almost the same as in 1.1 above, just one bit has changed to activate the boot reset vector.

5.5.2 Burn the firmware

Then using your favourite AVR ISP software burn the firmware. The file from the distribution dropbox will have a name like "bootloader.1.2.1.hex", the numbers identifying the version, currently 1.2.1. The board must be powered when programming.

This completes the programming.



6. SD Card Access, Folders and Files

To inspect or change the SD card contents it can either be removed and plugged into a reader or a USB cable can be plugged into the SAM3X8C board and your PC, then the SD card will appear as a "USB Drive"¹⁴² with a drive letter assigned.

The operating system uses the classic DOS 8.3 file name format and not long filename formats. The filenames are however case insensitive so lowercase filenames and extensions are permitted. Like any file system you should occasionally back up the contents of the SD card. I just keep the contents mirrored to a folder on my PC. Whilst the clock does write files to the SD card for its own purposes, all of them can be regenerated by the clock and so there is normally no need to back up the SD card until you have made changes by editing a file, adding new .WAV or .NUG files etc. or perhaps when a new firmware version has been installed.

Root Folder

The root folder contains the following:

File Name	Description
system.ini	Paths to files, controls for the amplifier volume, PIR, IR handset, encoder, LDR, bling-bling and sleep.
chimes	Clock use only - stores prepared chime files
nuggle	Nuggle source code files
runtime	Clock use only - stores runtime Nuggle
system	See below
wav	Chime WAV files

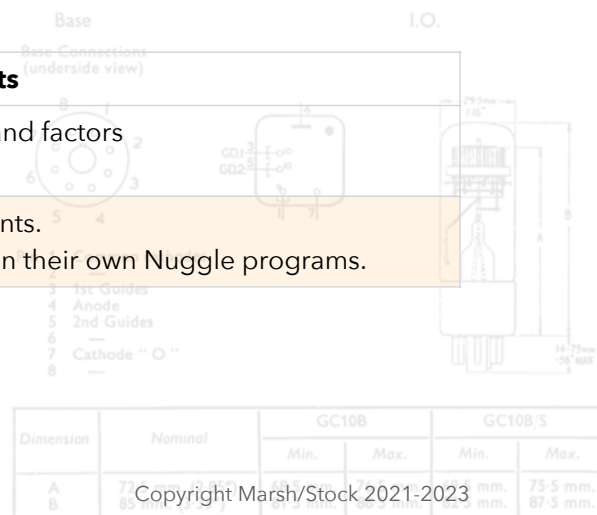
System.ini is an important file for you to read through and edit. The file is self documented and contains many options for you to select, such as your preferred chime muting times, the clock IR remote pair number, the parameters used for various clock beeps etc. It also contains a number of system allocation factors (e.g. file path names). These won't need changing unless you start to seriously delve into the clock's firmware.

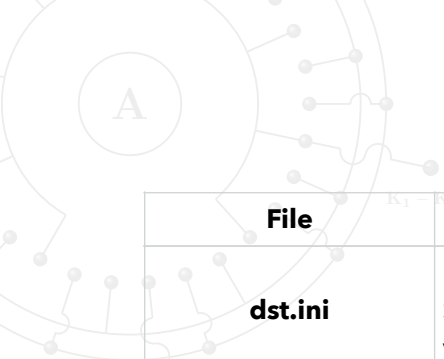
System Folder

This folder contains several files that you will need to edit and data files that you will need to reference.

File	Contents
astro.ini	Contains astronomical calculation controls and factors (minimal contents for the Harwell Clock).
constant.ini	Constant name to value look up table contents. The user can add additional values for use in their own Nuggle programs.

¹⁴² In the Device Manager it appears as an "ATMEL SD/MMC Card Slot USB Device"





File	Contents
dst.ini	Daylight saving time rules for the various countries that use DST. Should not require editing. If a rule needs to be changed then expect a new version of the file from me.
help.txt	The help messages used by the menu console. So when you enter ADC? for example, the help text is read from this file. Should not require editing.
locale.ini	An important file for you to edit. See below.
nuggle.ini	An important file for you to edit. See below.
timezone.csv	World time zone location, names, short name, and offsets. Countries the use DST will have two entries. Examine this file for your locale information. Should not require editing. If an entry needs to be changed then expect a new version of the file from me.
wifi.ini	An important file for you to edit. See below.

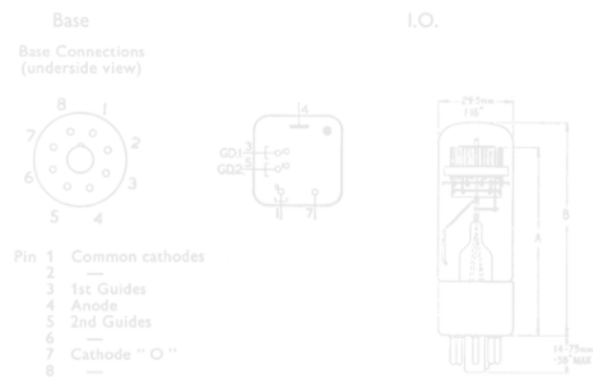
Note: In the system folder there is a hidden file "CACHE.DAT". This file contains indices for locating chime files quickly and is unique to the SD card. It is important that this file is not copied and transferred to another SD card as the chime system will not operate correctly.

locale.ini is used to store your location information. You should read through this file and edit the entries as directed in the documentation within the file.

- The [location] information is used to calculate your local sunrise and sunset times.
- [datefmt], [timefmt] Your date and time format preferences.
- [timezone] Unless you are in the UK you will need to change the time zone name and you may need to change the DST rule.

nuggle.ini holds, *inter alia*, the look up table from a Nuggle program filename on the SD card to a numerical index value that the clock uses to select a clock face. This is an important function of this file as it allows you to make a list of the clock faces that you like best and place them close together so you can use the rotary encoder or IR handset to select them. It is also used to control the Nuggle parser, lexer and expression evaluator. You probably won't need to change these settings unless you delve deeply in to Nuggle.

wifi.ini is used if you are using the WiFi plug in module. The only editing you must do to this file is to enter your WiFi log in credentials. You can read through the remaining sections in the file and make other changes as you see fit. They allow you to change the DHCP, SNTP and DNS settings.¹⁴³



¹⁴³ If you don't know what these are then just leave alone and use the default settings.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



7. Adding or changing Chime WAV files

Introduction

The Harwell Clock uses WAV files to sound chimes and make other noises. The clock hardware uses the two 12 bit Digital to Analogue Converter (DAC) outputs from the SAM3X8C each passed through a Low Pass Filter (LPF) to an audio amplifier feeding a small speaker.

Input WAV file requirements

The input file requirements are:

- WAV file format¹⁴⁴
- Sample rate not higher than 44100Hz
- Uncompressed
- Up to 32 bit format (not 64 bit)
- DOS 8.3 file naming i.e. no long filenames

The input file can be:

- 8 bit unsigned, or
- 16 bit signed
- mono or stereo

Converting other formats

As long as another format file, such as a MP3, can be converted to a WAV format file then it should be possible to use it. For file conversion I recommend the free Audacity¹⁴⁵ software. Using this software you can export the file as a WAV format readable by the Harwell. It also enables you to play and edit the file. You can blend several files together and add effects like echo and reverb. Have fun!

Copying the WAV file to the SD card

All WAV files must be copied to the WAV folder in the root directory of the SD card. You can access the SD card using the methods described in section 6 of this chapter.

Pre-processing the WAV files for use

The Harwell Clock does not use the WAV file directly while playing a chime or sound effect. Instead a preprocessor first converts the WAV file into a format that is directly compatible with the DAC requirements:

- Unsigned 8 bit data is converted to signed 12 bit data.
- Signed 16 bit data is converted to signed 12 bit data.
- Mono data is saved as two identical stereo channels.
- Channel tags are added that direct the left data stream to DAC0 and the right data stream to DAC1.

¹⁴⁴ <https://en.wikipedia.org/wiki/WAV>

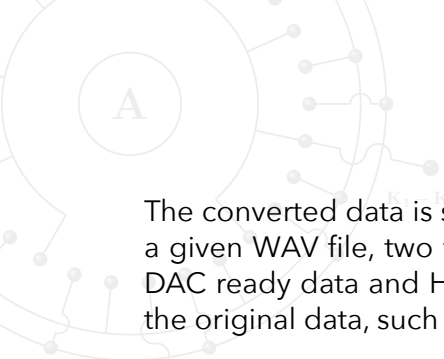
¹⁴⁵ <https://www.audacityteam.org/>

Base Connections
(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5			75.5	
B	85			87.5	

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The converted data is saved to a directory called CHIMES in the root directory of the SD card. For a given WAV file, two files with the same name are created with extensions CHM containing the DAC ready data and HDR containing set up data such as the sample rate and information about the original data, such as if it was mono or stereo.

The console menu command **CHMC** is used to run the WAV file pre-processor. To connect the console see section 3 above and to use the menu commands, section 4.

Before giving the CHMC command ensure that the RTC contains the correct data and time as the file timestamps are used to determine which WAV files need to be updated.

When the command is given all clock functions are stopped and, if connected, the USB drive is disconnected by the firmware. The clock firmware then:

- Creates the CHIMES directory if it does not exist.
- Scans the WAV directory for WAV files.
 - If the corresponding CHM and HDR files don't exist in the CHIMES directory then it creates them and proceeds with the conversion.
 - If the CHM and HDR files exist then it replaces them if the WAV file is newer.
- When all the conversions have been completed the Harwell Clock resets itself and the clock restarts.

N.B. The file pre-processor is quite a slow operation. Conversion of a file can take several seconds to many minutes. Therefore, if you are converting several files go and make a cup of coffee and have a piece of cake...

Other useful menu commands

CHMK	Chime Kill	Stop the chime currently playing
CHMR	Chime Report	List all the preprocessed files available with some key data
CHMU <i>name</i>	Chime Use	Play the given named chime

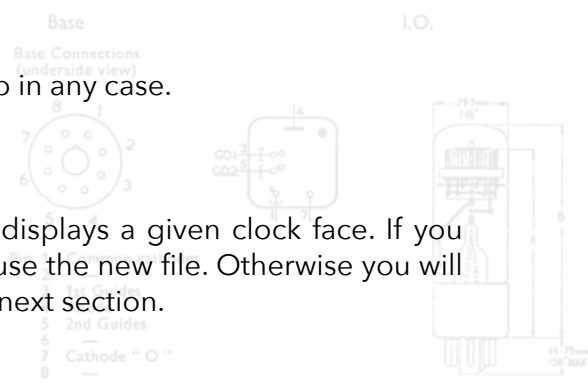
Un-fragmented file requirement

For speed, the chime CHM files are read directly by the low-level disc functions and not using the higher level FAT32 functions. To play correctly, this means that a CHM file must not be fragmented. If a chime "breaks up" when playing then it is an indication that the file is fragmented. The best process to defragment an SD card is to copy the files contents to a directory on your PC. Delete all of the SD card contents, then copy the saved copy back again. I do not recommend using a defrag tool on the SD card. You can use the **CHMT** to determine if any files are fragmented.

You'll need to keep a copy of the SD card contents as a back up in any case.

Using new chime files

The chimes are played by statements in the Nuggle file that displays a given clock face. If you have replaced a file with the same name then the Nuggle will use the new file. Otherwise you will need to edit the Nuggle text - this is not at all difficult - see the next section.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



8. Adding or changing Nuggle programs

Nuggle is a simple programming language used by Sgitheach clocks. It describes how the display devices such as VFD, CRT, Dekatron or E1T tubes, bling LEDs, chime system will be used. The Harwell clock comes with a large number of Nuggle files available so you can review these to see actual Nuggle source text examples.

All Nuggle programs reside in the **nuggle** folder and always have the extension `.nug`¹⁴⁶. They are simple text files.

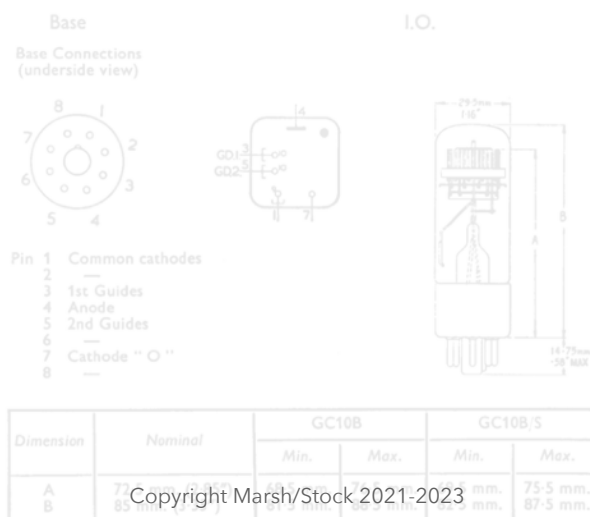
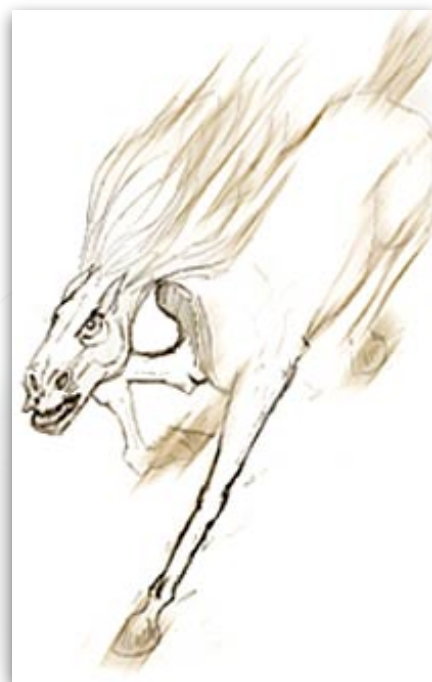
If you edit and save an existing Nuggle file then, when that face is shown again, the clock firmware will see that the date stamp on the file is newer than before so it will process the file and display the modified face.

If you create a file with a new filename (for example by editing an existing file and then saving the modified file into a new filename) then you now need to assign an index number to the file as Nuggle files are selected to run by a number and not the filename directly. To do this, you edit **nuggle.ini** and in the [faces] section you create a new entry with an unused index and your filename (the instructions are with **nuggle.ini**)=

. Next, you force the clock to reload the indices by using the **NUGL** menu command (or power cycling the clock or pressing the reset button). The newly indexed file should be selectable using the IR handset or the rotary encoder.

Whilst this looks like a complex process at first sight, remember that you have created or modified a clock face without having to resort to modifying the clock source code, compiling the C and burning the SAM3X8C.

Have fun with Nuggle! To help you, there is a generalised, clock independent Nuggle manual, a manual specific for the Harwell Clock and a Nuggle cookbook.¹⁴⁷



¹⁴⁶ Could it be anything else?

¹⁴⁷ In preparation....

9. Compiling the Firmware for the Harwell Clock

9.1 Compiling the SAM3X8C firmware

Introduction

These notes are to help you install the final release 1.2.1 firmware source code and how to compile it. The output of this process are binary files that are identical to the binary files available on the Dropbox. These notes are not a tutorial on using Atmel Studio and assume you have a good working knowledge of Atmel Studio 7.0 and where everything is.

At this time I am using:

- Atmel Studio 7.0.1931
- Atmel Framework version 3.35.1
- Windows 10 - NT6.2.92000.0
- ARM/CNU C Compiler 6.3.1

Distribution file download and installation

The firmware source code files for the SAM3X8C are distributed as Atmel Studio Template files. You copy the *Sgitheach 1.2.1.zip*¹⁴⁸ from the Dropbox to the Studio Template directory. On my PC this is:

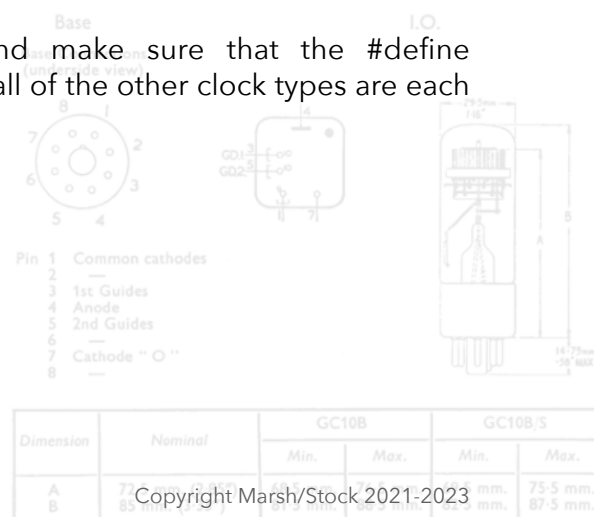
```
c:\users\grahame\documents\visual studio 2015\my exported templates
```

so it will definitely be in another location on your system!

Creating a project and compiling the SAM3X8C firmware

- Run Atmel Studio and start a new project.
- The new project dialogue box should now show an installed C/C++ template called "Sgitheach Clocks 3X8X.1.2.1". Select this file and set the name to "Harwell01" or whatever you want and the location to where you want the project files to be placed.
- Remove/delete the *Device_Setup* folder and all of its contents.
- Remove/delete the *main.c* file at the bottom of the explorer window (leaving the *main.c* that is inside the *src* folder).
- Open the *conf_version.h* file in the *config* folder and make sure that the `#define HARWELL_DEKATRON_CLOCK` is not commented out but all of the other clock types are each commented out.
- Change the Solution Configuration to **Release**.
- Open the project properties dialogue and change:

¹⁴⁸ Or the latest and greatest on the [Dropbox](#)...



- Compiler General - untick the default char type and default bit field type checkboxes if ticked.
- Compiler Optimisation - change the level to **Optimise size (-Os)**.
- Compiler Optimisation - add, if missing, **-fdata-sections -fstack-protector-all**.
- Compiler Symbols - if present, delete the **printf=iprintf** and **scanf=iscanf** symbols.
- Compiler Symbols - add, if missing, **BOARD=USER_BOARD** and delete any other **BOARD=** symbols.
- Compiler Symbols - add, if missing, **STACK_CHK_GUARD=0xa242b7f0**.
- Linker Miscellaneous - add, if missing, Other objects - **-Wl,-defsym=HEAP_SIZE=0x10000**.
- Build the solution, the output should show no errors, warnings or messages.

• The output tab should show (exactly):

```

Program Memory Usage      :      335056 bytes      63.9 % Full
Data Memory Usage        :      24112 bytes      24.5 % Full
  
```

You have now compiled a version identical to the *Sgitheach 1.2.1.bin* file on the documentation links provided at <http://www.sgitheach.org.uk/harwell.html#documentation>. The source code is now yours to modify¹⁴⁹!

9.2 Compiling the MEGA324PA firmware

You only need to do this if you wish to modify or explore the source code. This section assumes you have installed Atmel Studio 7 and know how to use it.

The firmware source code file for the MEGA324PA bootloader is distributed as an Atmel Studio Template file. You should copy the file *Dekatron.1.2.1.zip* from the website links at <http://www.sgitheach.org.uk/harwell.html#documentation> to a suitable directory on your system. Then

- Run Atmel Studio.
- Select File - Import - Project Template...
- Select the file *Dekatron.1.2.1.zip* from the directory where you saved it and press OK.
- Atmel Studio should say that a project template has been successfully imported.
- Select File - New - Project...
- The new project dialogue box should now show an installed C/C++ template called *Dekatron.1.2.1*. Select this file and set the name to *mydeka.1.2.1* or whatever you want and the location to where you want the project files to be placed.
- Open the project properties dialogue and in the Toolchain tab:
 - In the AVR/GNU C Compiler General tab:
 - Untick the default char type and default bit field type checkboxes.
- Change the Solution Configuration to Release.

¹⁴⁹ If you dare! :-)

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



- In the Solution Explorer window delete the main.c file at the end of the tree (not the main.c file under the src indent).
- Build the solution, the output should show no errors, warnings or other messages!

The output tab should show (exactly):

```
Program Memory Usage : 9338 bytes 28.5 % Full
Data Memory Usage : 1479 bytes 72.2 % Full
```

You have now compiled a version identical to the Dekatron.1.2.1.hex file on the [Dropbox](#)¹⁵⁰. The source code is now yours to modify!

9.3 Compiling the MEGA324PA Bootloader

You only need to do this if you wish to modify or explore the source code. This section assumes you have installed Atmel Studio 7 and know how to use it.

The firmware source code file for the MEGA324PA bootloader is distributed as an Atmel Studio Template file. You should copy the file bootloader.1.2.1.zip from the [Dropbox](#) to a suitable directory on your system. Then;

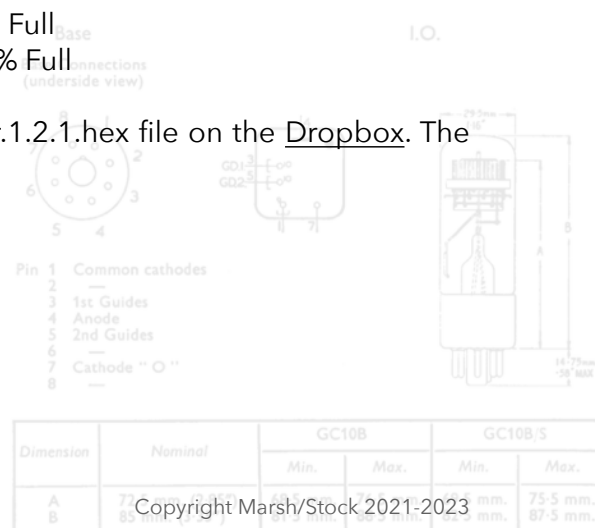
- Run Atmel Studio.
- Select File - Import - Project Template...
- Select the file bootloader.1.2.1.zip from the directory where you saved it and press OK.
- Atmel Studio should say that a project template has been successfully imported.
- Select File - New - Project...
- The new project dialogue box should now show an installed C/C++ template called bootloader.1.2.1. Select this file and set the name to myboot.1.2.1 or whatever you want and the location to where you want the project files to be placed.
- Open the project properties dialogue and in the Toolchain tab:
 - In the AVR/GNU C Compiler General tab:
 - Untick the default char type and default bit field type checkboxes.
 - And in the Linker Memory Settings tab add this entry to the FLASH segment if not present:
 - .text=0x3800
- Change the Solution Configuration to Release.
- In the Solution Explorer window delete the main.c file at the end of the tree (not the main.c file under the src indent).
- Build the solution, the output should show no errors, warnings or other messages!

The output tab should show (exactly):

```
Program Memory Usage : 2580 bytes 7.9 % Full
Data Memory Usage : 439 bytes 21.4 % Full
```

You have now compiled a version identical to the bootloader.1.2.1.hex file on the [Dropbox](#). The source code is now yours to modify!

¹⁵⁰ Or whatever the latest version is.....



10. InfraRed Remote Control

The IR handset is used to remotely and conveniently change the way the Harwell Dekatron clock is operating. The keystrokes on the IR handset can be overridden by certain Nuggle face scripts that are running. The description here is the default use of the IR keys. You should check with the Harwell Clock Distribution Faces section to see if a particular face overrides the key use described here (not many actually do).

By default, the IR handset will automatically start to repeat a transmission if the key is pressed and held down.

The default key functions described here assume a starting condition of the clock displaying a clock face. By default the clock beeps on each keystroke to give some audio feedback that the clock has received the key press.

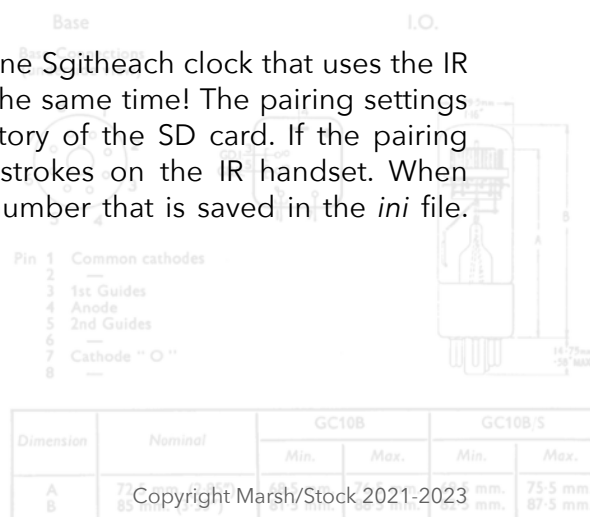


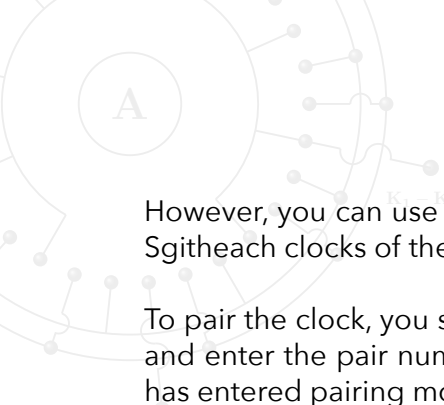
Key	Default Action
CH-	Go to the clock face before the current face in the clock face list.
CH	Show the current clock face number for a few seconds before returning to the face
CH+	Go to the clock face after the current face in the clock face list.
 <<	Decrease the beep volume. The clock will beep and the tubes will display the current volume level (0 - 31).
>> 	Increase the beep volume. The tubes will display the current volume level (0 - 31).
> 	Start the clock "pairing" keystroke sequence - see below.
-	Decrease the chime volume level. The tubes will display the current volume level (0 - 31).
+	Increase the chime volume level. The tubes will display the current volume level (0 - 31).
EQ	Unused - however the 'EQ' key is used by many key stroke sequences described below.
0 ... 9	Start the entry of a new clock face number keystroke sequence - see below.
100+	Unused - however the '100+' key is used by many key stroke sequences described below
200+	Unused - however the '200+' key is used by many key stroke sequences described below

Pairing Keystroke Sequence

The "Pairing" function is only needed if you have more than one Sgitheach clock that uses the IR handset so that both clocks don't respond to key presses at the same time! The pairing settings are located in the [ir] section of *system.ini* in the root directory of the SD card. If the pairing function is disabled then the clock will respond to all keystrokes on the IR handset. When enabled, the clock must be "paired" by entering the clock number that is saved in the *ini* file. Recommended numbers are (so far):

1. Scope Clock Due
2. Fortress E1T Clock
3. The Harwell Dekatron Clock





However, you can use any number you wish in the range 1 to 999999. Obviously if you have two Sgitheach clocks of the same type then you'll need to give them different numbers.

To pair the clock, you start by pressing the '>||' key. All Sgitheach clocks respond to this key press and enter the pair number entry mode. By default the left colon will light blue to show the clock has entered pairing mode and the rest of the bling will be black.

Then enter the pairing number by using:

- The numbers '0' to '9' to enter a number.
- The '100+' key acts as a "backspace" key and deletes the last number entered.
- The '200+' key acts as an "escape" key and the entry of the pairing number is cancelled.
- Press the 'EQ' key when you have entered the correct number.

By default, the pairing number you enter is saved to NVR so it will be restored the next time the clock is restarted.

When the 'EQ' key is pressed, only the Sgitheach clock with the corresponding pairing number will respond to other key strokes.

Hint:

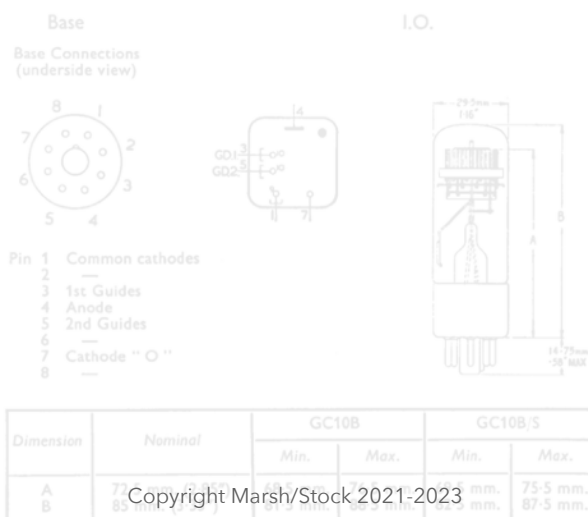
Clock face 950 and console menu command **IRHR** will show the pairing number and status.

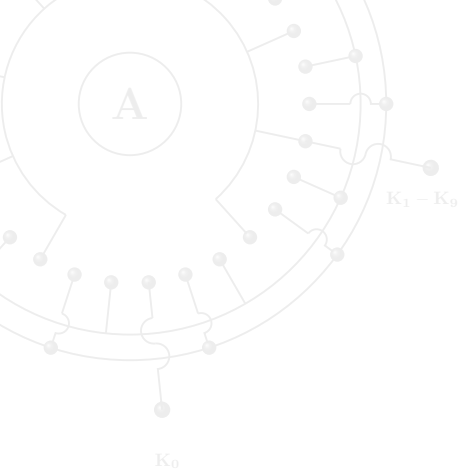
New Face Keystroke Sequence

A face number can be dialled in using the number keys. When the first number key is present then it will be displayed on the tubes. By default the left colon will light green to show the clock has entered face number entry mode and the rest of the bling will be black.

- Use the numbers '0' to '9' to enter the rest of the number.
- The '100+' key acts as a "backspace" key and deletes the last number entered.
- The '200+' key acts as an "escape" key and the entry of the pairing number is cancelled.
- Press the 'EQ' key when you have entered the correct number.

If you enter a number with no corresponding face, then face 1, blank by default, will be displayed.

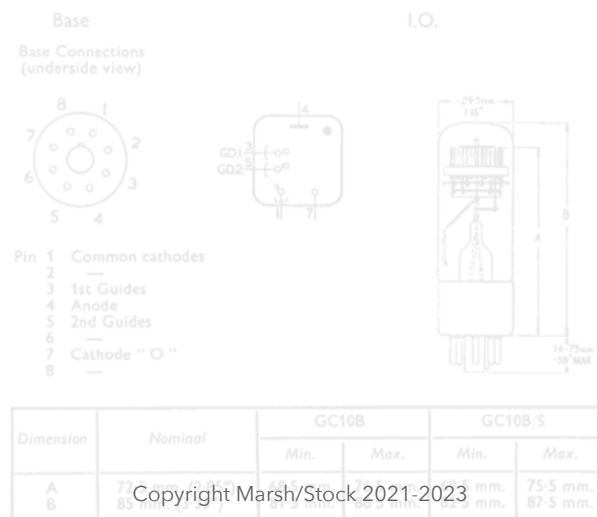




Harwell Clock - How It Works

What Makes The Clock Tick¹⁵¹

¹⁵¹ You'd think that joke would get old....but...





Harwell's Inner Workings...

Introduction

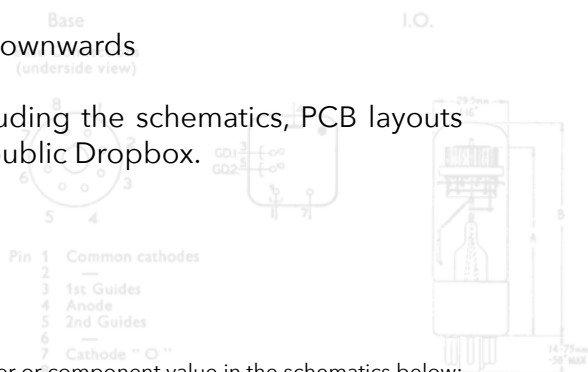
The Harwell Clock schematic diagrams are spread across over a dozen pages and many of the individual pages have several subsystems on them. This Harwell manual section is a walk through of the schematic drawings.

Subsystems

The clock consist of the following subsystems:

- SAM3X8C micro-controller - this is mounted on its own PCB that plugs into the clock's main PCB
- +5V power supervisor
- SD card
- NVRAM (non-volatile random access memory)
- Super Cap backup power supply for the RTC
- User selected option jumpers
- Hardware version detection
- Stereo audio amplifiers
- A front panel sub-board carrying:
 - PIR (passive infrared) motion detector
 - IR (infrared) receiver
 - Rotary encoder
 - Speakers
 - LDR (Light Dependent Resistor) to measure ambient room light level
 - Two neon filled MTX90 tubes for colons
 - Tricolour (red, green, blue) LED (light emitting diode) modules to bling¹⁵² the clock
- +500V, +170V, +100V and +50V 10mA power supply to run the Dekatrons and MTX90 tubes
- +5V and +3.3V power supplies to run all the analogue and digital electronics
- An optional WiFi module
- An optional GPS receiver
- Seven tube display drivers mounted on a sub-board
- The seven display drivers are controlled by a MEGA324PA TWI slave
- Each tube driver consists of:
 - A circuit to cause the first guide electrode to glow
 - A circuit to cause the second guide electrode to glow
 - Detection that cathode '0' is glowing
- Further Tricolour LED modules that are arranged to fire downwards

Now let's look at these in more detail. The Eagle files¹⁵³ including the schematics, PCB layouts and Gerbers are all open design and available on the project public Dropbox.



¹⁵² Or pimp if you prefer.....hey, we won't judge...

¹⁵³ Only the part numbers in the Eagle files are up to date. Do not rely on a part number or component value in the schematics below; they are to illustrate function and operation only.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

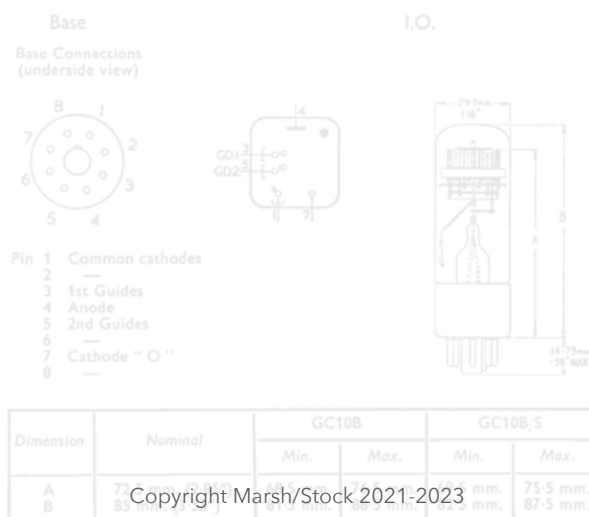
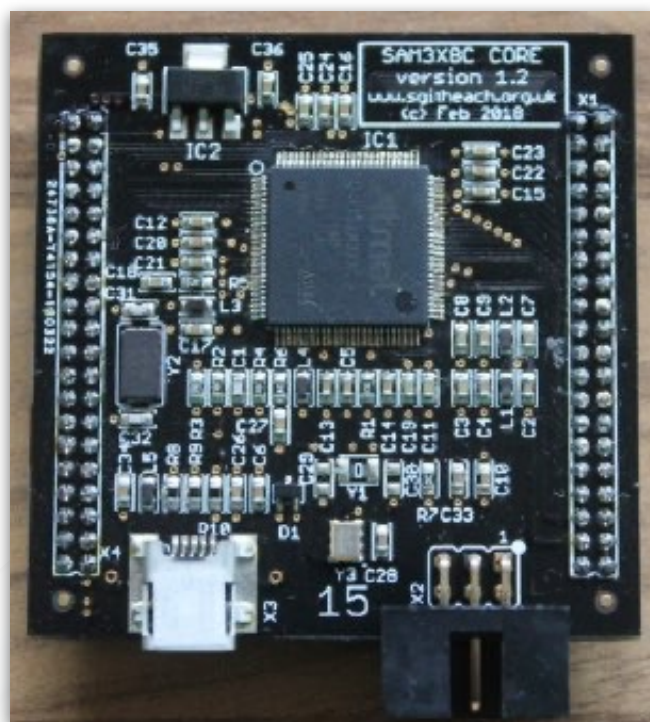
1.0 SAM3X8C Microcontroller Plug-in

Arduino fans may recognise this number in relation to the Arduino Due¹⁵⁴ as it uses the SAM3X8E micro-controller. The SAM3X8C¹⁵⁵ is a smaller sibling in a 100 pin package and has less I/O pins but internally it is more or less the same, has the same flash memory (512K) and runs at 84MHz clock speed. The Arduino Due implementation is somewhat restricted as only a selection of the available I/O pins and facilities are available externally. The Arduino Due is limited in shape to conform with other Arduino types (not that this is a bad thing).

The SAM3X8C plug is a four layer PCB measuring 52mm x 52mm:

It carries:

- Native USB port.
- Separate 3.3V regulator .
- 6 pin programming port.¹⁵⁶
- Filtering and decoupling according to the Atmel data sheet.
- 12MHz crystal for the system oscillator.
- Either a 32768Hz crystal or a 32768Hz TCXO (temperature compensated crystal oscillator) for the RT.
- All I/O pins, power, reset etc. lines are brought out to two 2 x 20 way headers.
- External power requirements are 5V and 3V battery for RTC backup.
- JTAG support is not implemented.
- PA8 and PA9 I/O pins are available on the headers but are used by the programmer.

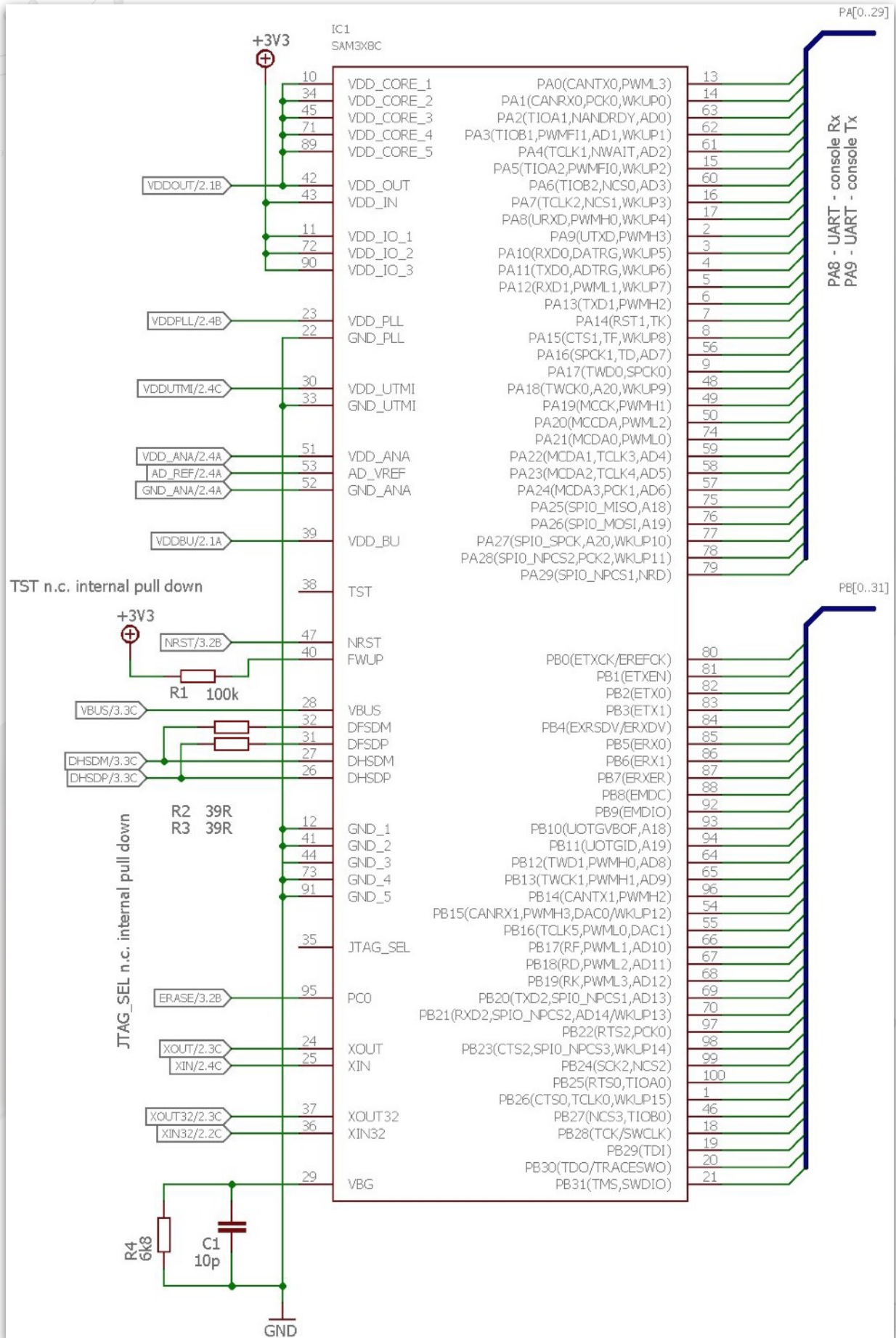


¹⁵⁴ <https://store.arduino.cc/arduino-due>

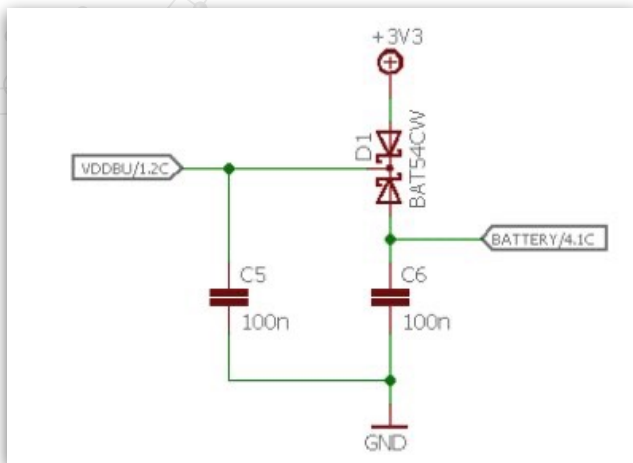
¹⁵⁵ <https://www.microchip.com/wwwproducts/en/ATSAM3X8C>

¹⁵⁶ For use with the Sgiteach SAM programmer ONLY and not any old Atmel product

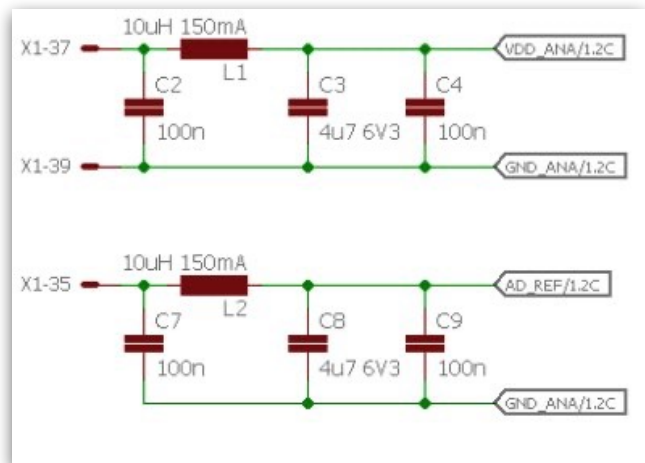
1.1 SAM3X8C schematic



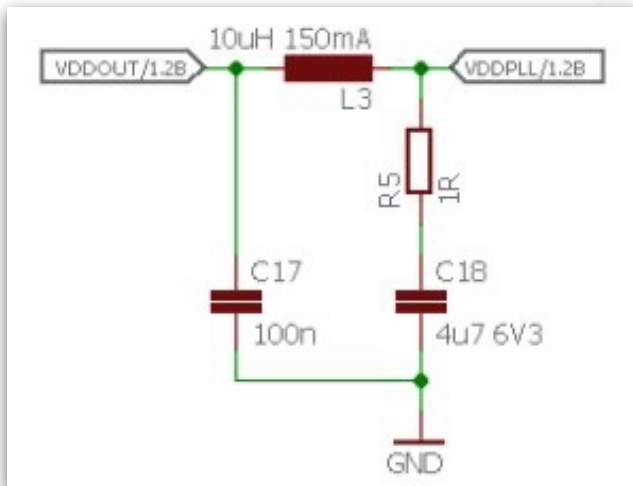
1.2 Battery Backup



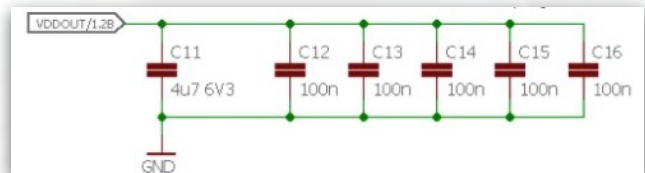
1.3 Analogue Decoupling



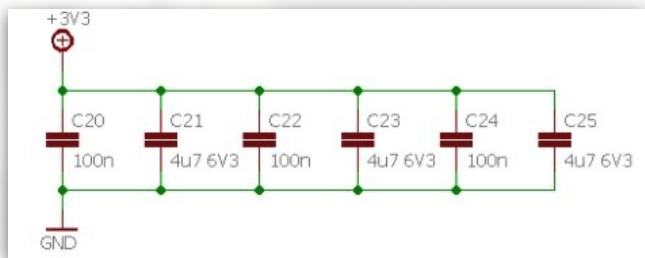
1.4 PLL Decoupling



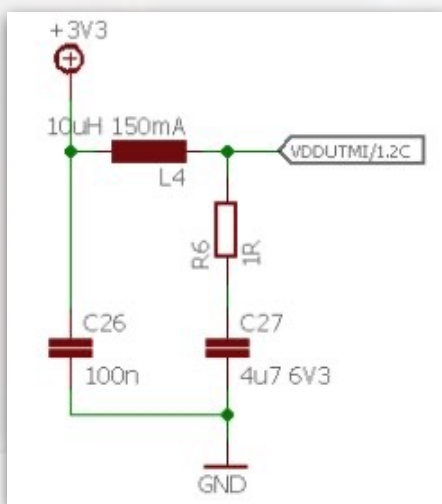
1.5 Core Decoupling



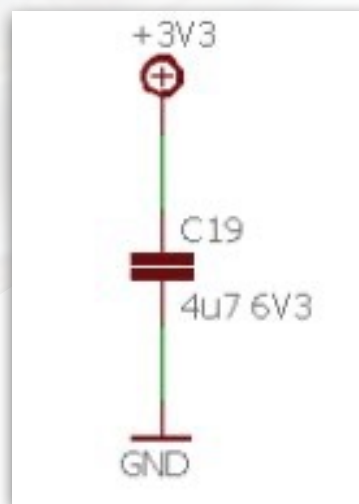
1.6 IO Decoupling



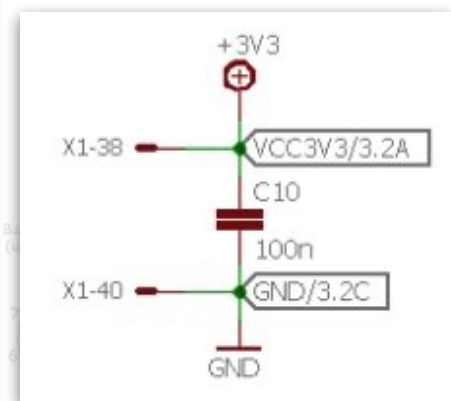
1.7 UTMI Decoupling



1.8 3.3V IN Decoupling



1.9 3.3V OUT



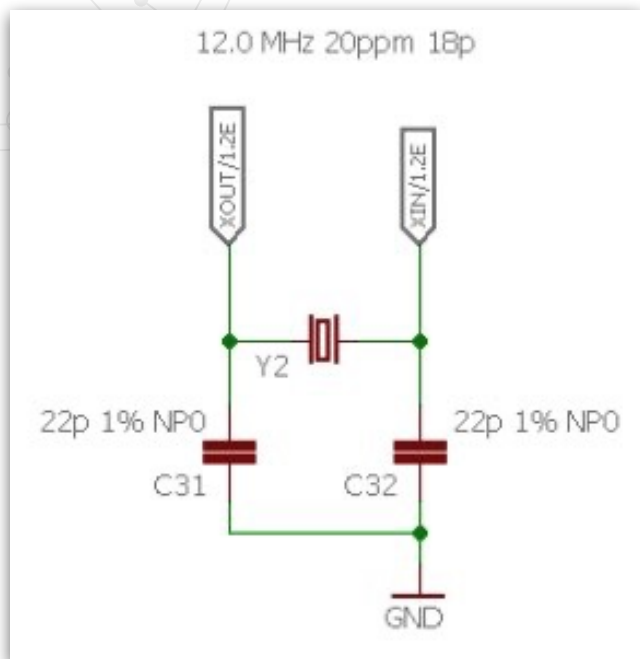
- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



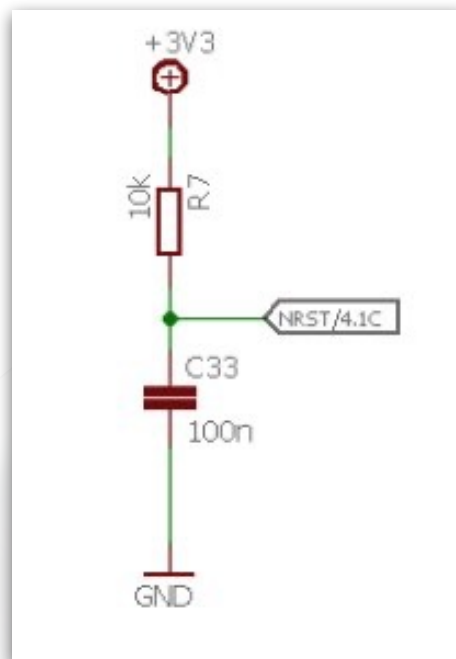
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



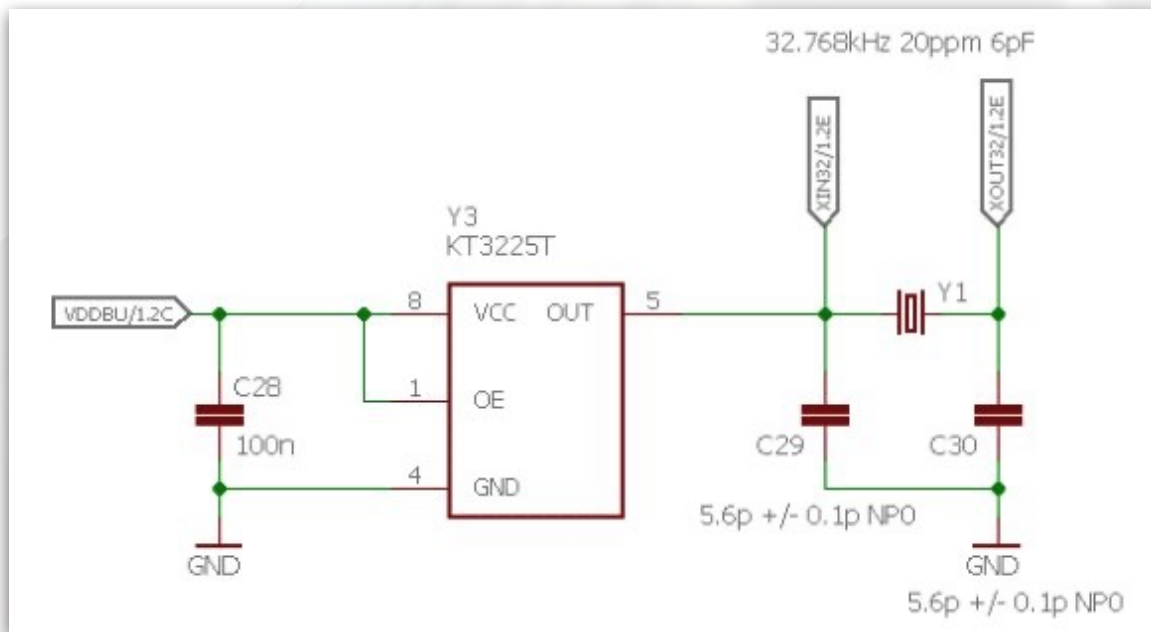
1.10 System Oscillator 12MHz Crystal



1.12 Reset

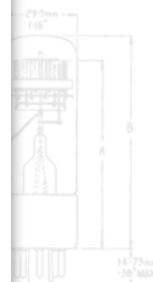
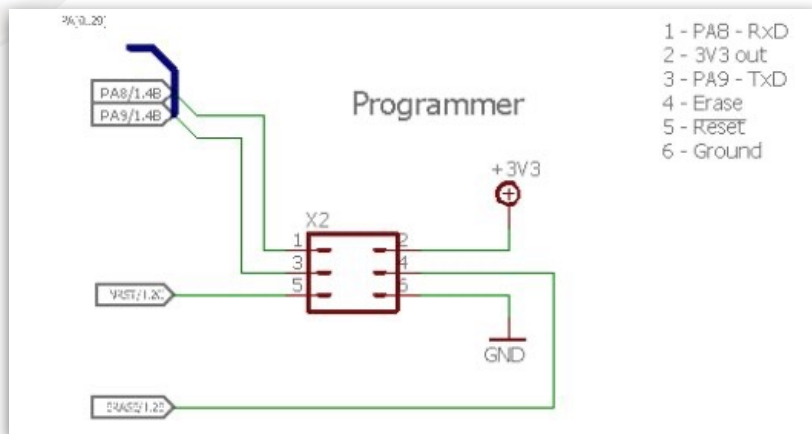


1.11 RTC Oscillator Options



1.13 Programmer Socket

The connections made here are for the Sgitheach SAM3X8C programmer only. No other programmer can be plugged in directly.

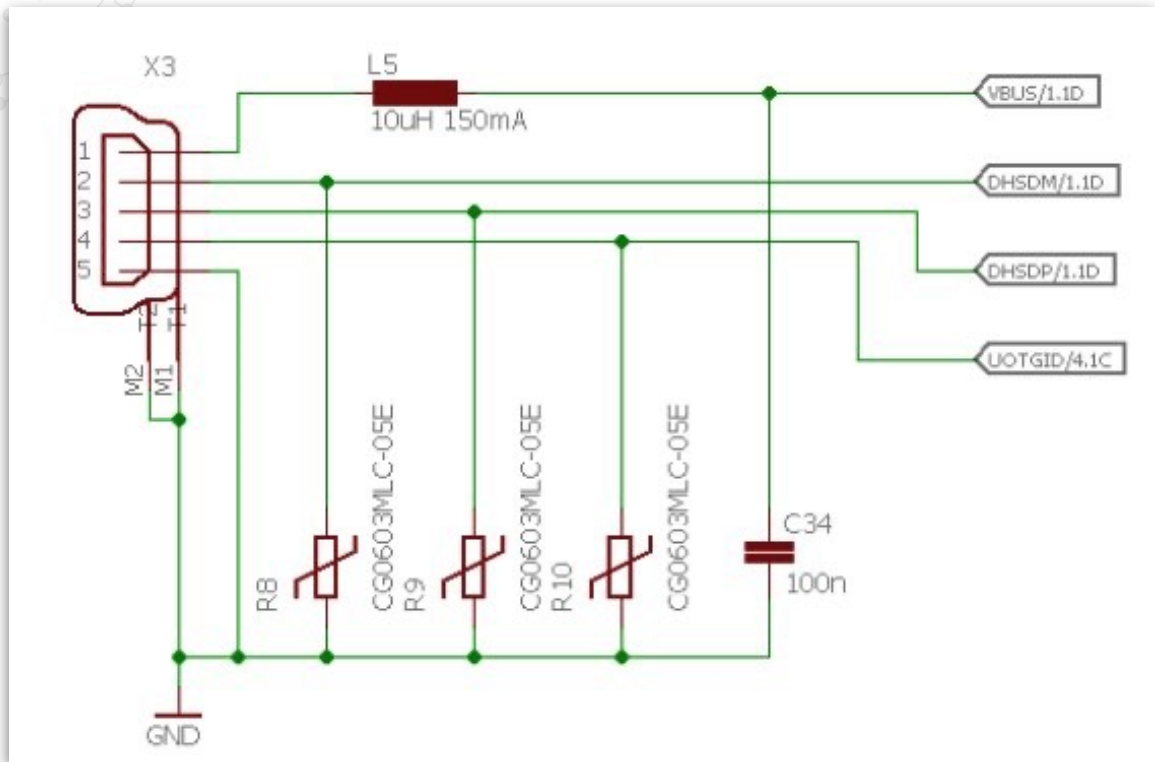


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

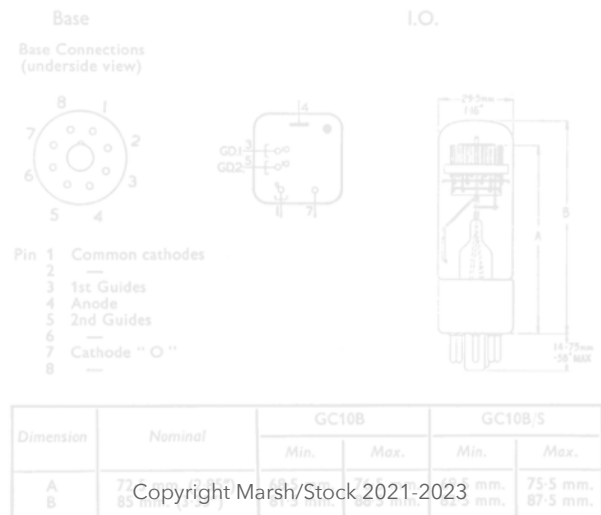
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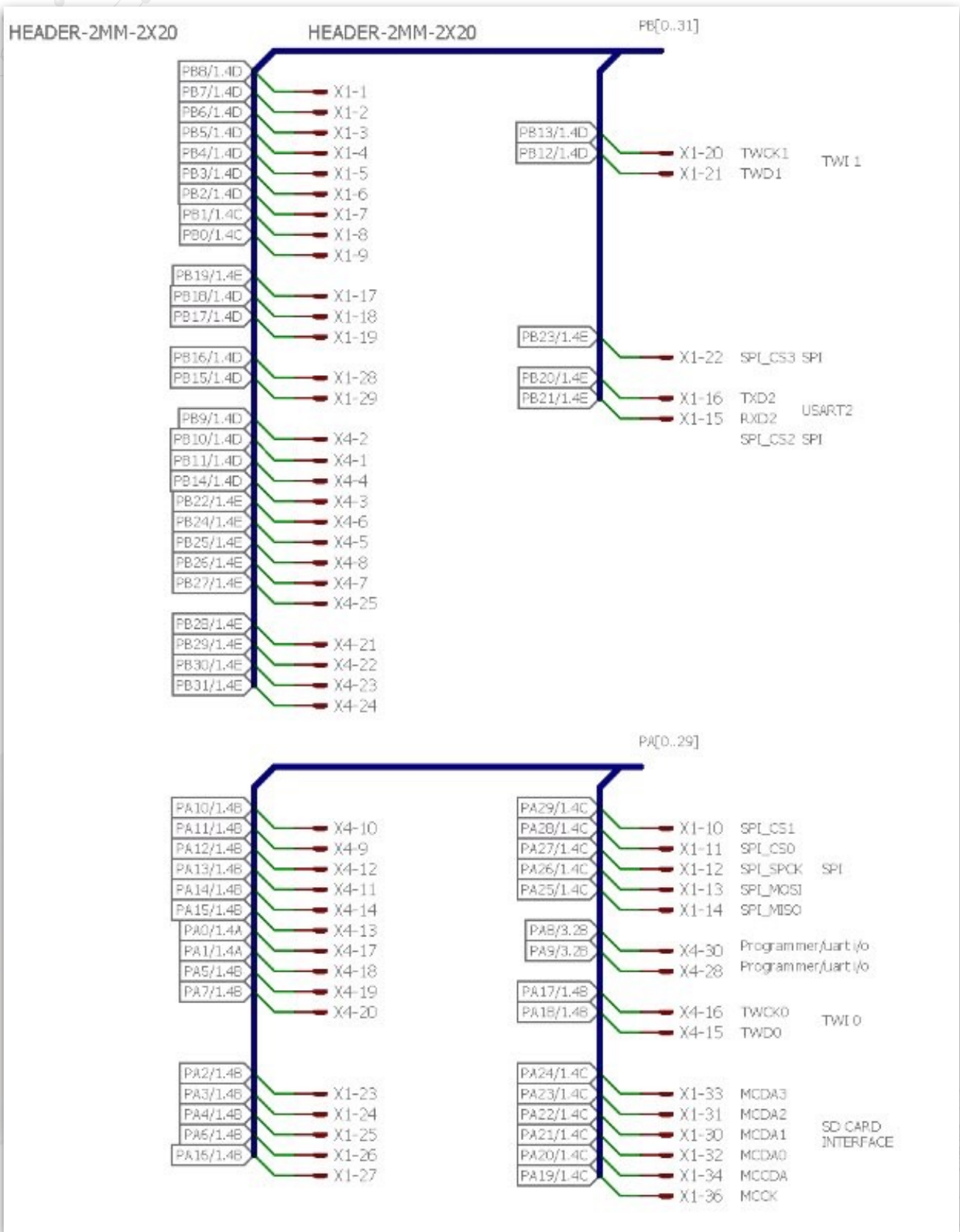
1.14 USB Socket



The USB socket cannot be used to power the plugin board. The board can only be powered using connections to the headers.



1.15 Header Connectors



To conserve space 2mm spaced headers are used instead of the more usual 2.54mm spaced headers.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

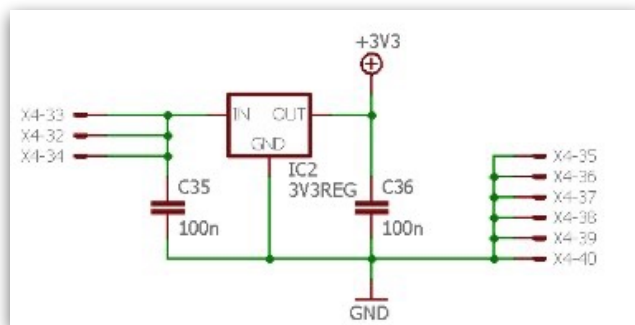
Copyright Marsh/Stock 2021-2023



1.16 Miscellaneous Connectors



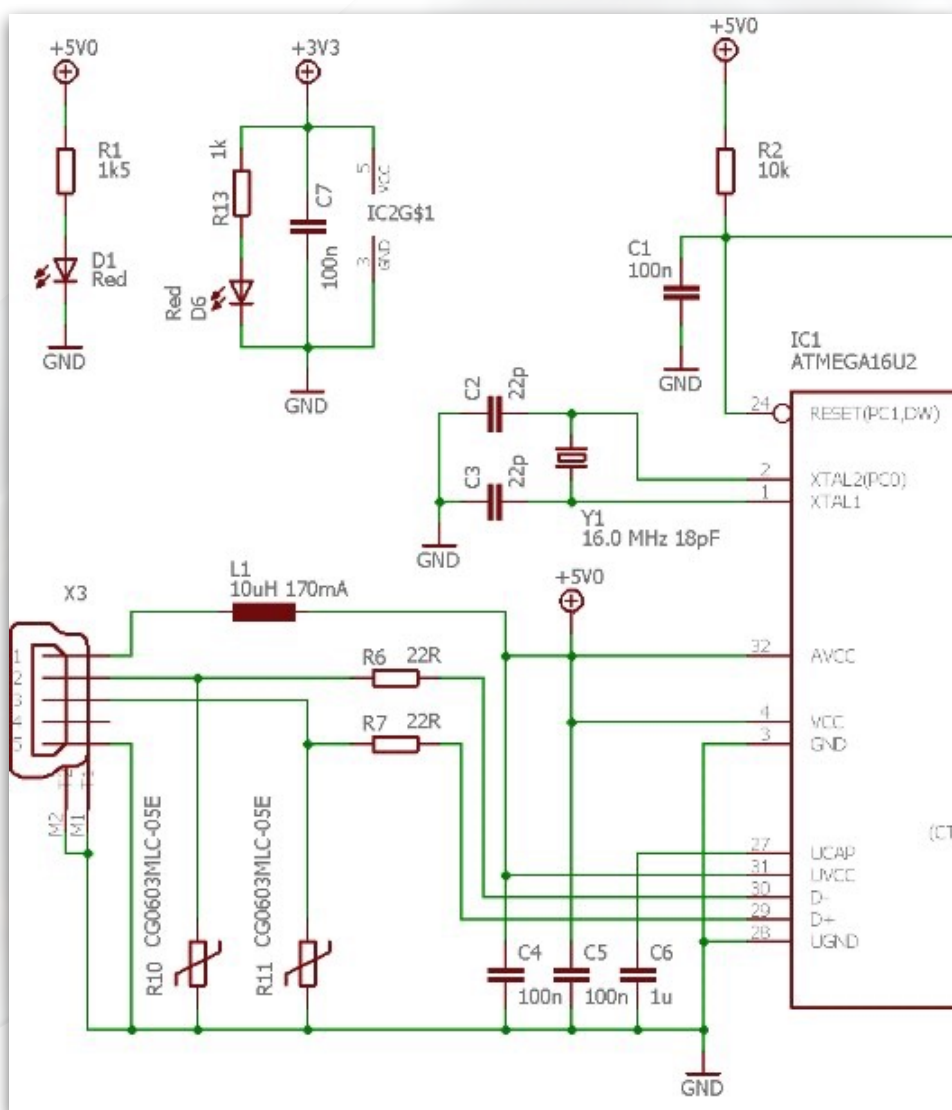
1.17 3.3V PSU



This regulator can be used to supply power but care must be taken not overload it.

2.0 SAM3X8C Programmer

- 5V power indicator
- 3.3V power indicator
- Reset circuit
- 16MHz clock oscillator
- USB socket and interface
- Decoupling

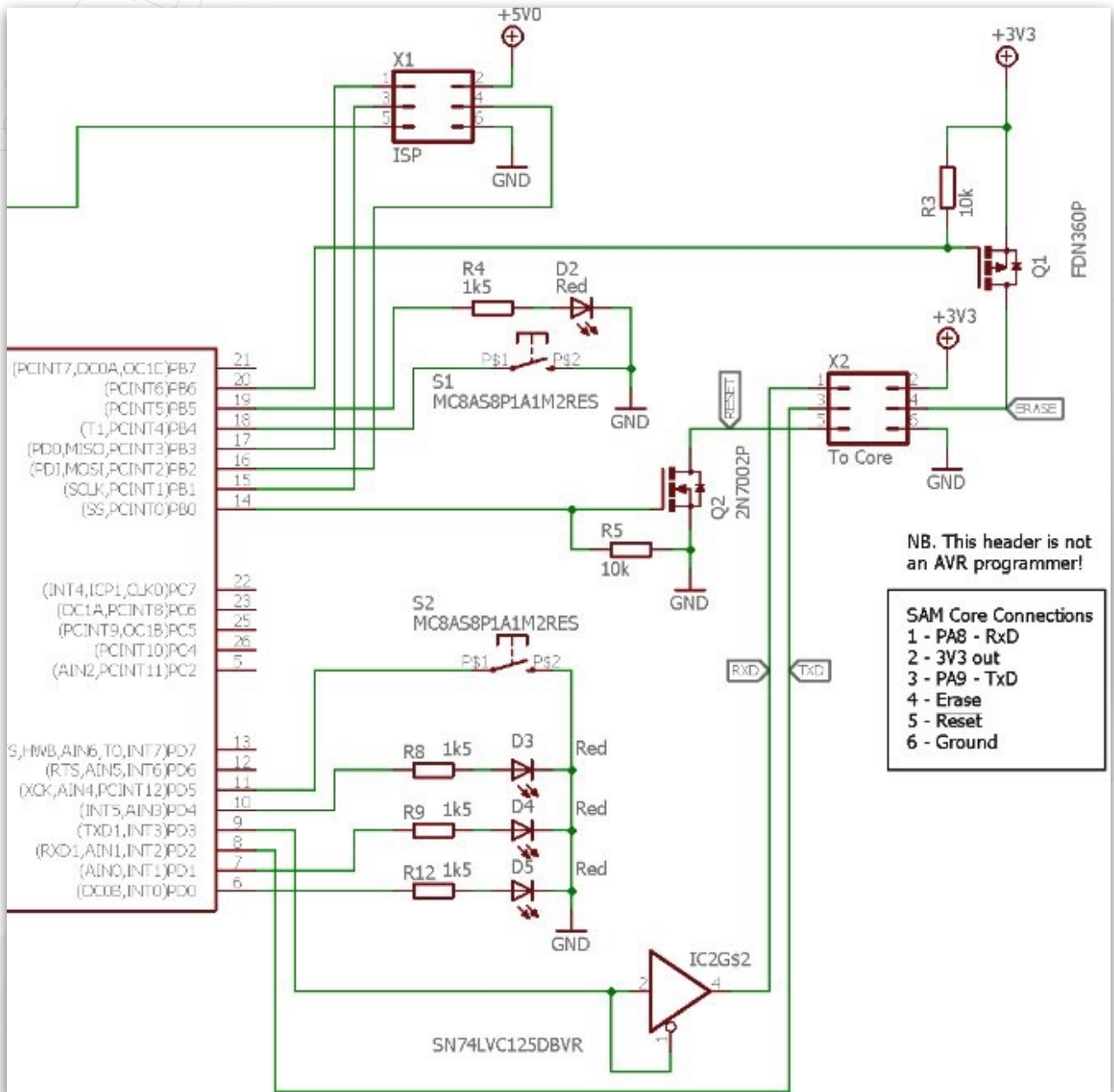


- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





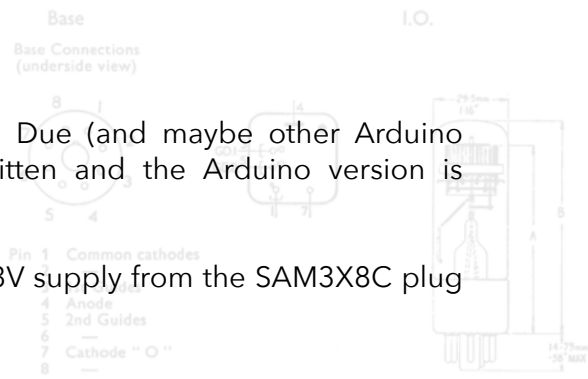
NB. This header is not an AVR programmer!

SAM Core Connections
 1 - PA8 - Rx/D
 2 - 3V3 out
 3 - PA9 - Tx/D
 4 - Erase
 5 - Reset
 6 - Ground

- MEGA16U2 ISP socket
- Connection to SAM
- Indicator LEDs for Reset, Erase, data Tx and data Rx
- Level shifter for Tx data
- Drivers for SAM Reset and Erase lines
- Optional control switches

This is more or less the programmer used on the Arduino Due (and maybe other Arduino versions as well). The firmware has been completely rewritten and the Arduino version is incompatible with this hardware.

The programmer requires both the USB 5V supply and the 3.3V supply from the SAM3X8C plug in board to function.



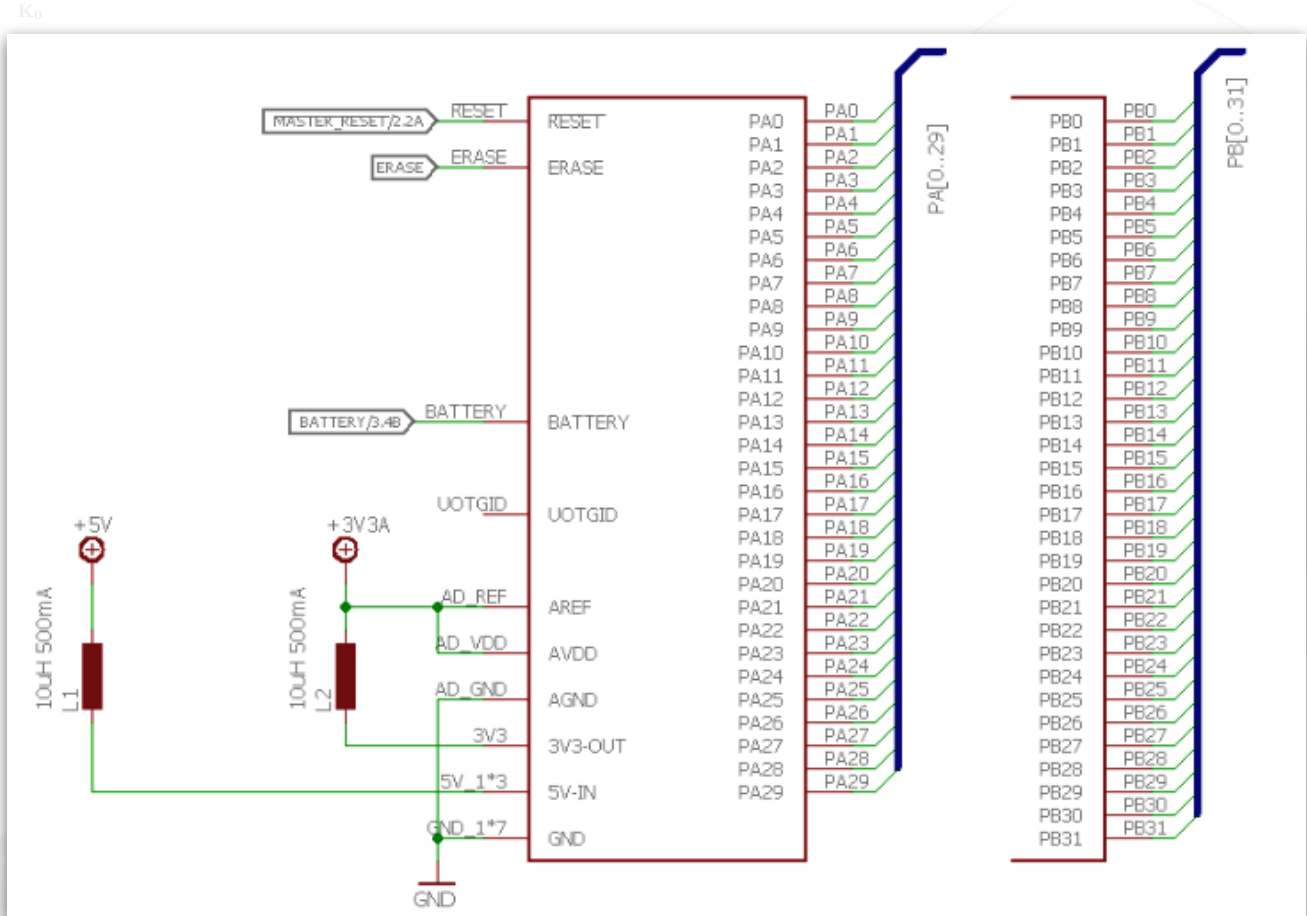
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm	
B	85			87.5 mm	



3.0 Harwell Main Board

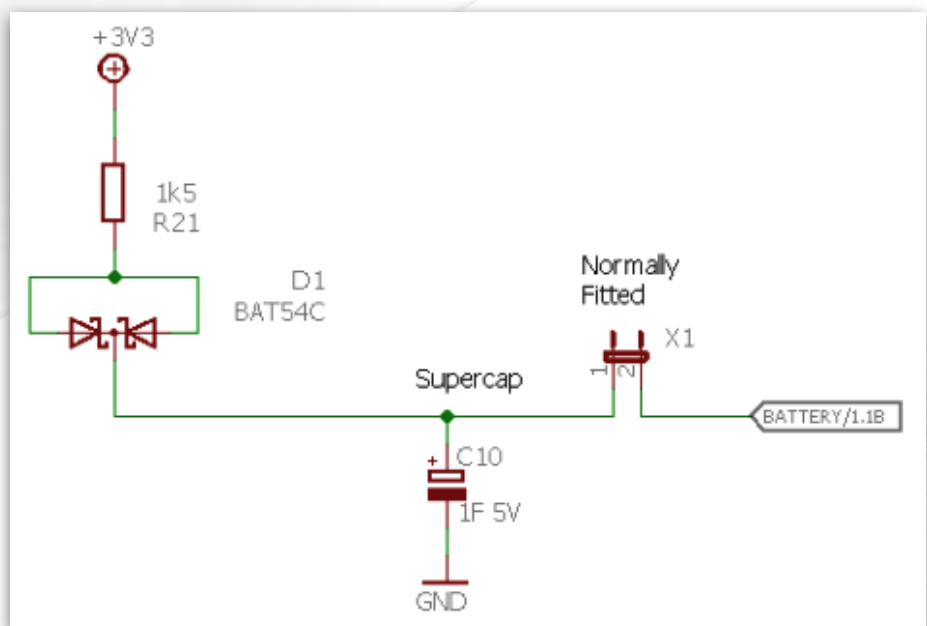
The main board carries the bulk of the digital and analogue electronics. The board is designed to mount horizontally in the case so that its various external connectors etc. are made available through the case rear panel.

3.1 SAM3X8C Plug-in



3.2 RTC Back up power

X1 allows the back up power supply PSU to be disconnected from the SAM3X8C so all of the registers in the chip can be reset to factory default values.



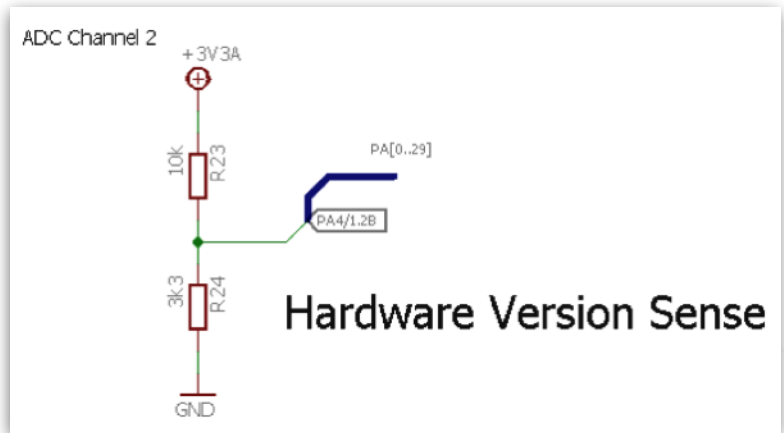
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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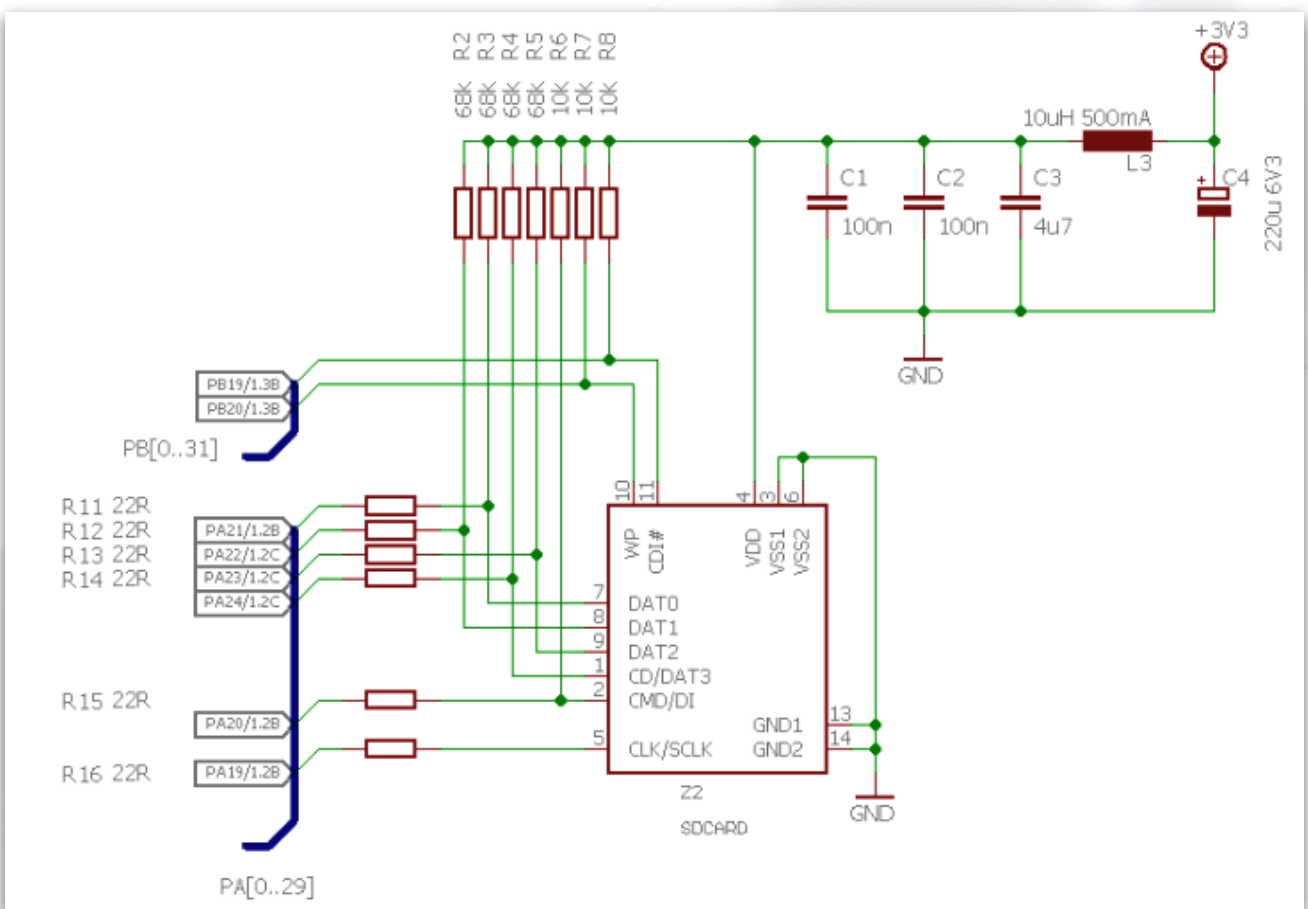


3.3 Hardware Version Sense

A unique resistor potential divider allows the firmware to detect the hardware version.

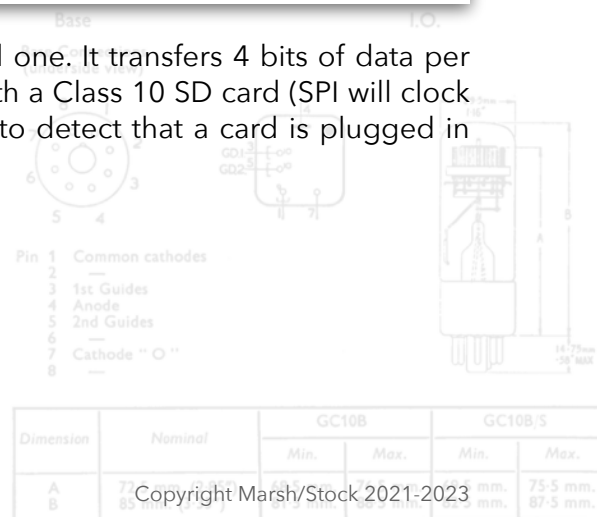


3.4 Storage - SD Card

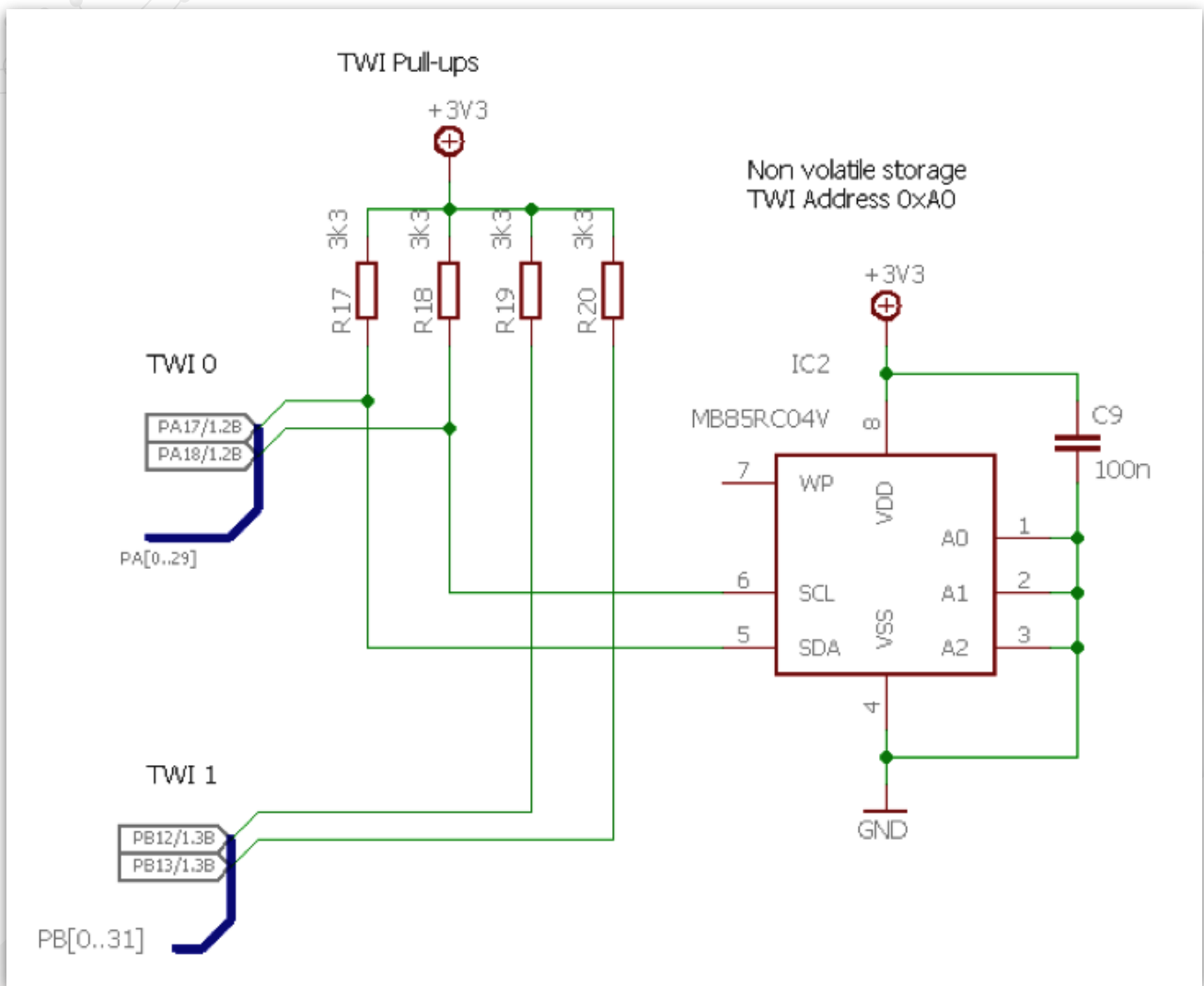


This is a native SD card interface¹⁵⁷ and not a slow SPI based one. It transfers 4 bits of data per clock cycle (the SPI transfers 1 bit) and will clock at 50MHz with a Class 10 SD card (SPI will clock at 10MHz). This is roughly 20 times faster. I/O pins are used to detect that a card is plugged in and whether it is write protected or not.

¹⁵⁷ SAM3X8C data sheet - Chapter 37

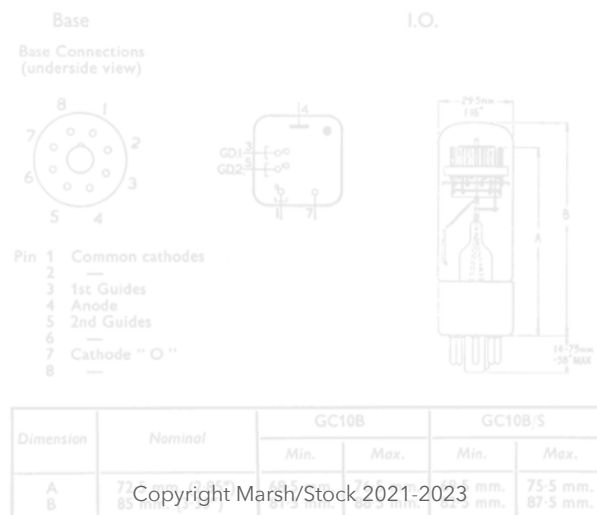


3.5 Storage - Non-Volatile RAM (NVR)

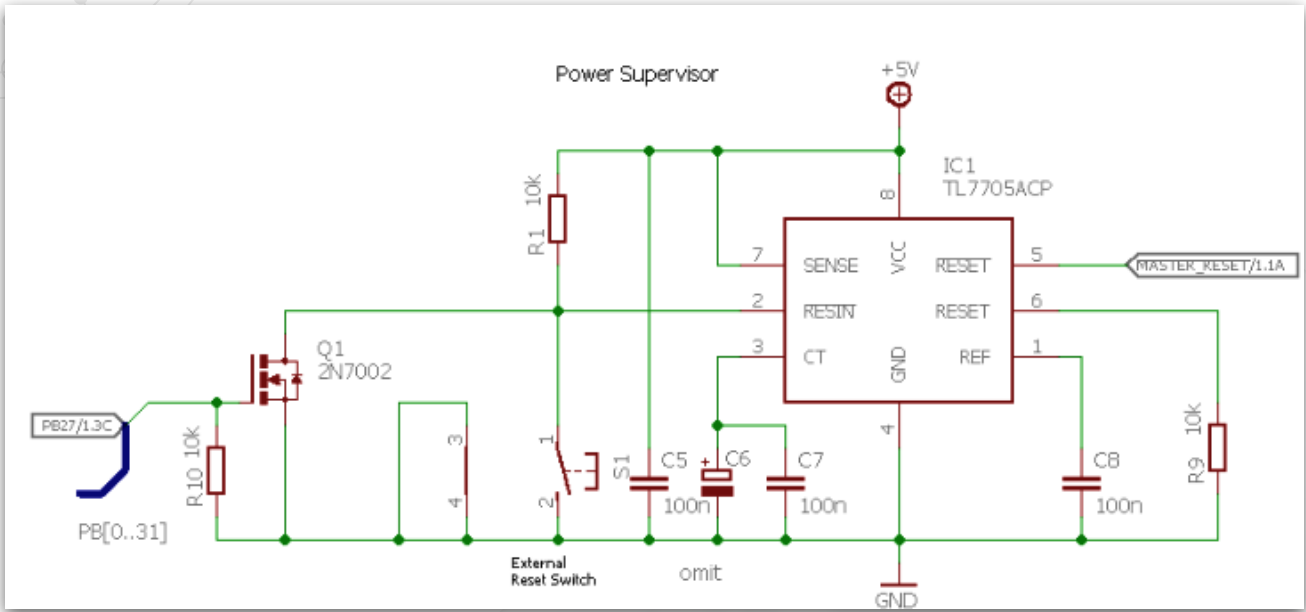


The SAM3X8C has no internal EEPROM so some TWI (I2C) NVR¹⁵⁸ is provided to hold data when the clock is switched off and can also be used to pass information between clock faces. The required TWI pull up resistors are here for both TWI ports.

¹⁵⁸ <https://www.fujitsu.com/uk/Images/MB85RC04V.pdf>



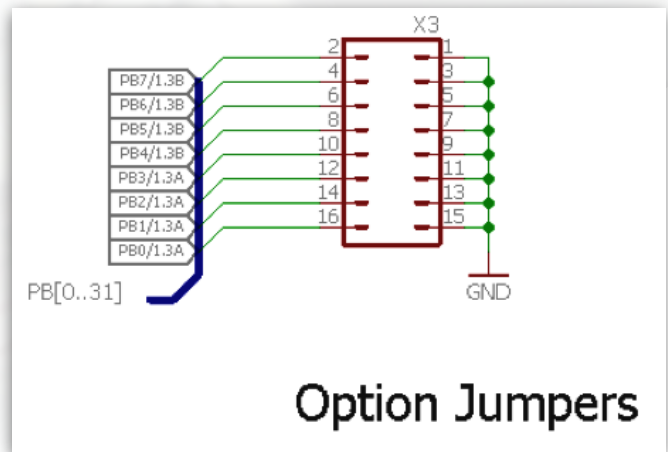
3.6 Reset and Power Supervisor



This handles low 5V detection causing the SAM3X8C to reset. Reset can also be accomplished by the switch or the SAM by pulling the gate of Q1 high.

3.7 Option Jumpers

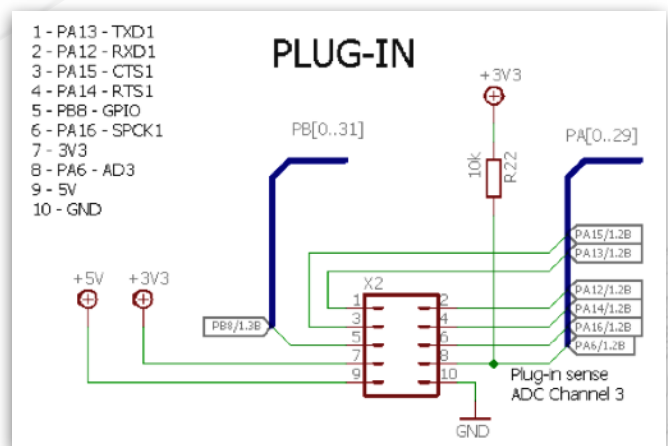
The firmware uses these jumpers to configure the clock without having to use any more complex hardware like the SD card. The settings are described in the Operations Guide section.



Option Jumpers

3.8 Plug-in Module Select

Optional add-ons include a GPS receiver or a WiFi adapter to allow the clock to automatically set the date and time. See below.



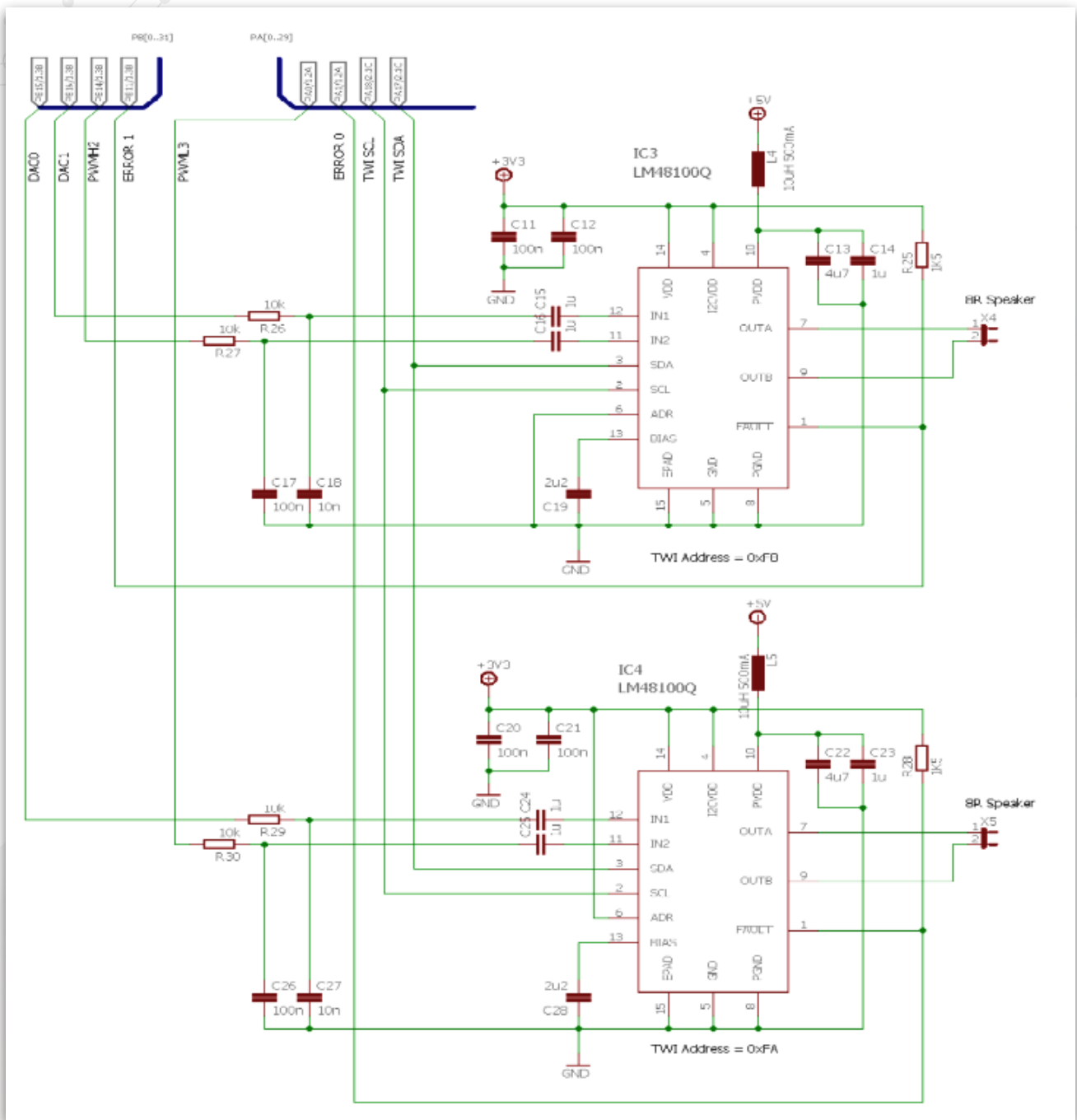
- 1 - PA13 - TXD1
- 2 - PA12 - RXD1
- 3 - PA15 - CTS1
- 4 - PA14 - RTS1
- 5 - PB8 - GPIO
- 6 - PA16 - SPCK1
- 7 - 3V3
- 8 - PA6 - AD3
- 9 - 5V
- 10 - GND

PLUG-IN

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

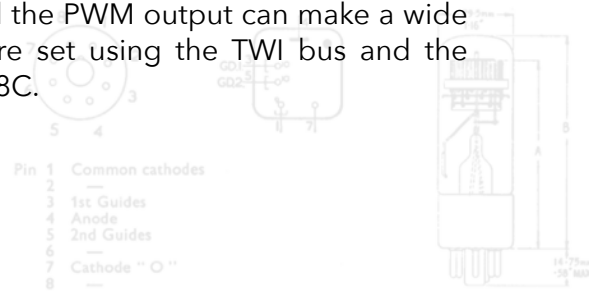


3.9 Audio Amplifiers



The stereo audio amplifier¹⁵⁹ each take signals from the SAM3X8C digital to analogue (DAC) converter outputs and from pulse width modulated (PWM) I/O pins. Four signals in total. The DAC outputs are used to play WAV files from the SD card and the PWM output can make a wide variety of simple beep-beep noises. The volume controls are set using the TWI bus and the amplifier chips can report error conditions back to the SAM3X8C.

¹⁵⁹ www.ti.com/lit/ds/symlink/lm48100q-q1.pdf

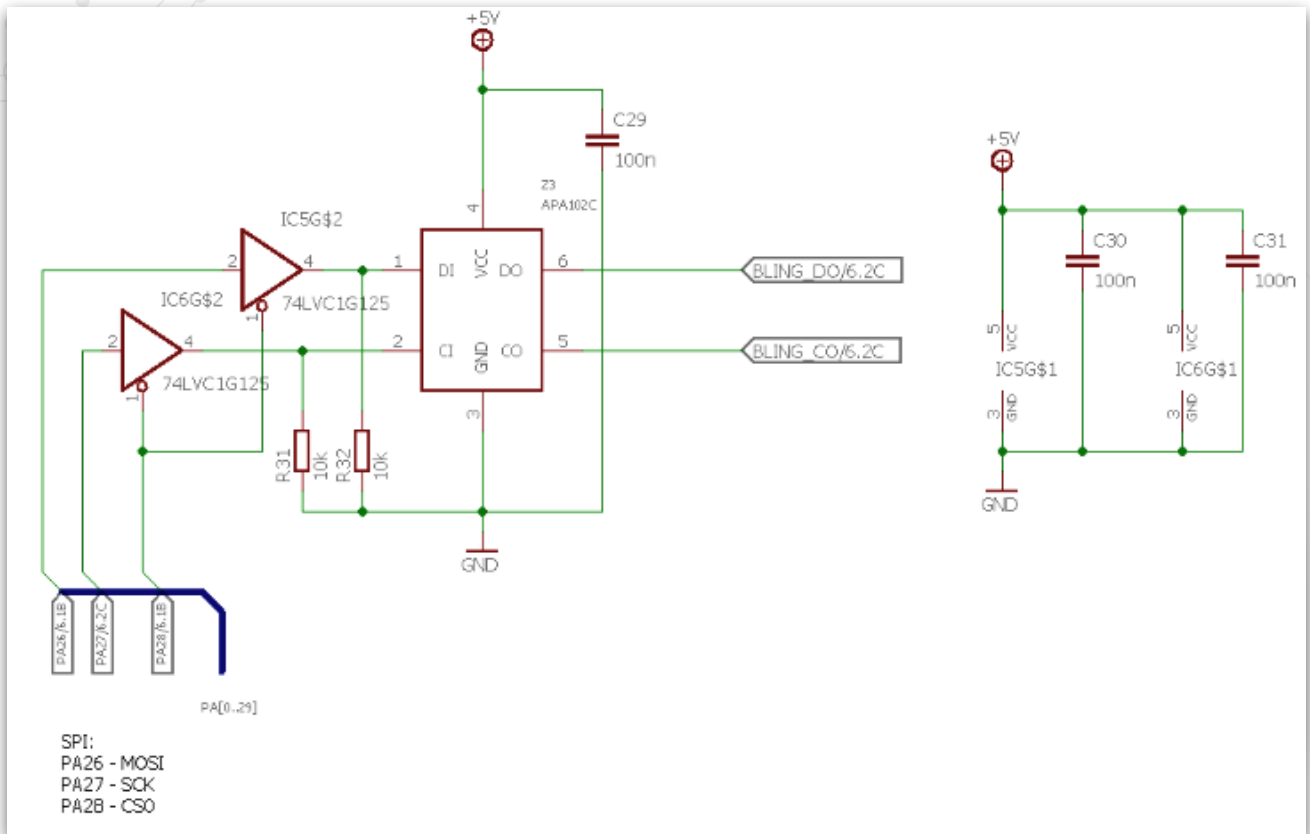


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

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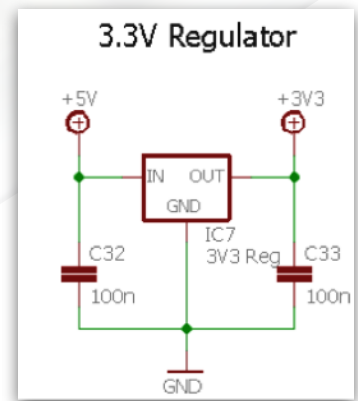


3.10 Bling

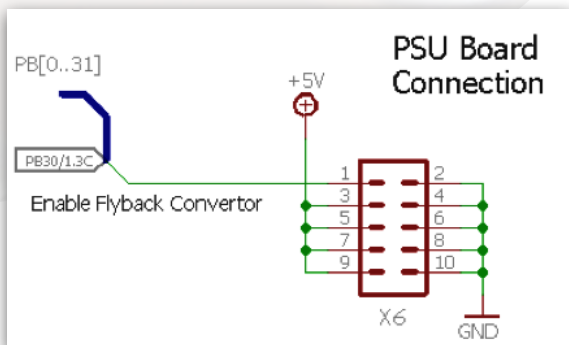


3.11 Local +3.3V Power Supply

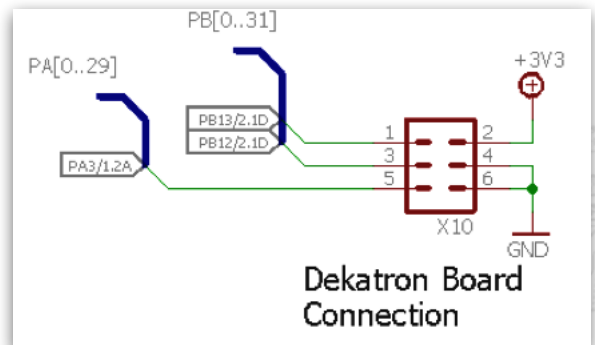
Many of the subsystems on the main board require +3.3V top operate and a local regulator is provided.



3.12 Power Board Connector



3.13 Dekatron Board Connector

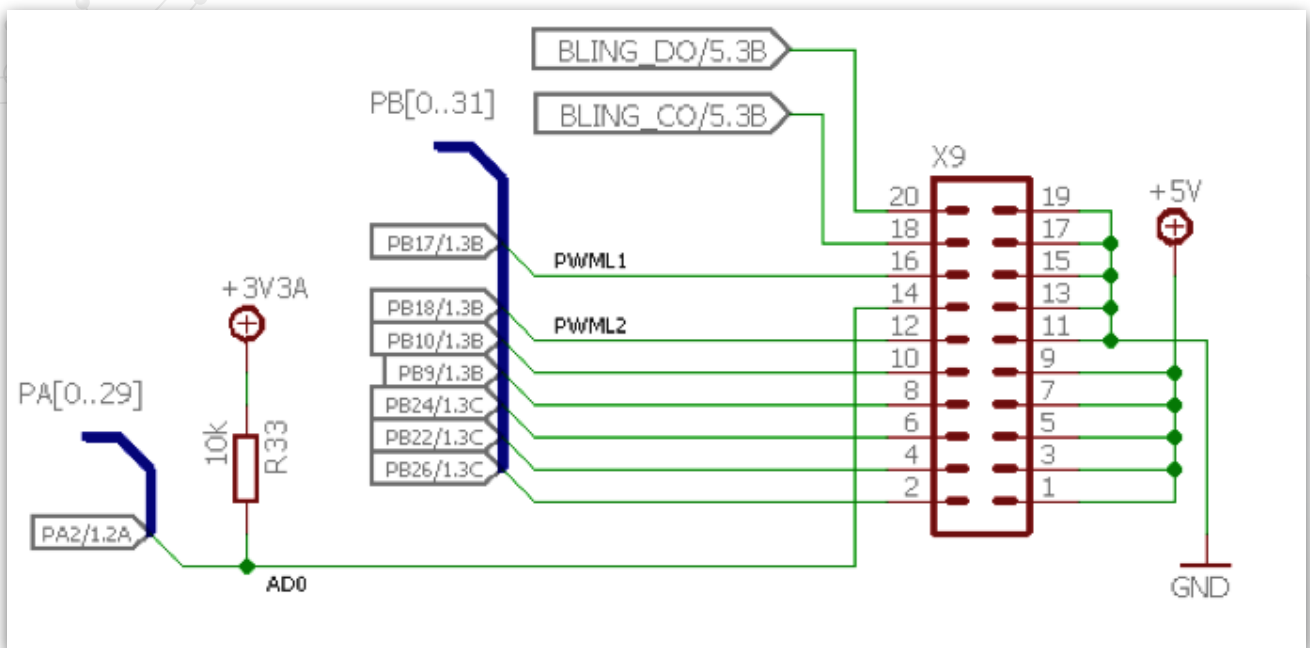


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

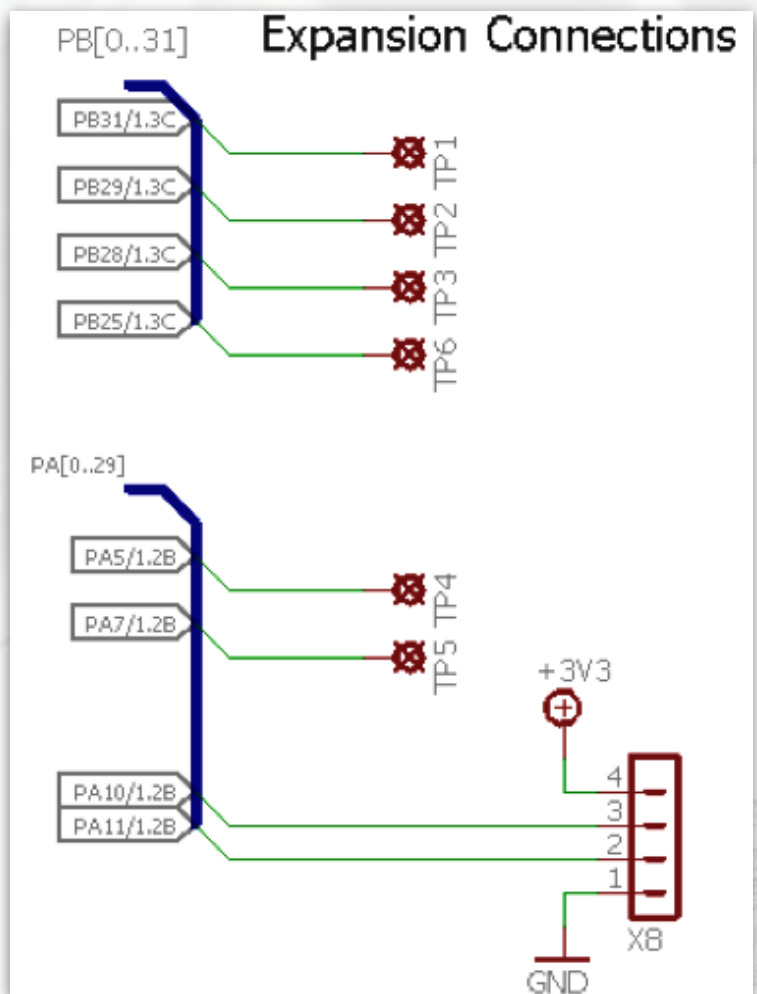
Copyright Marsh/Stock 2021-2023



3.14 Front Panel Board Connector



3.15 Expansion Connectors (otherwise unused pins)



- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

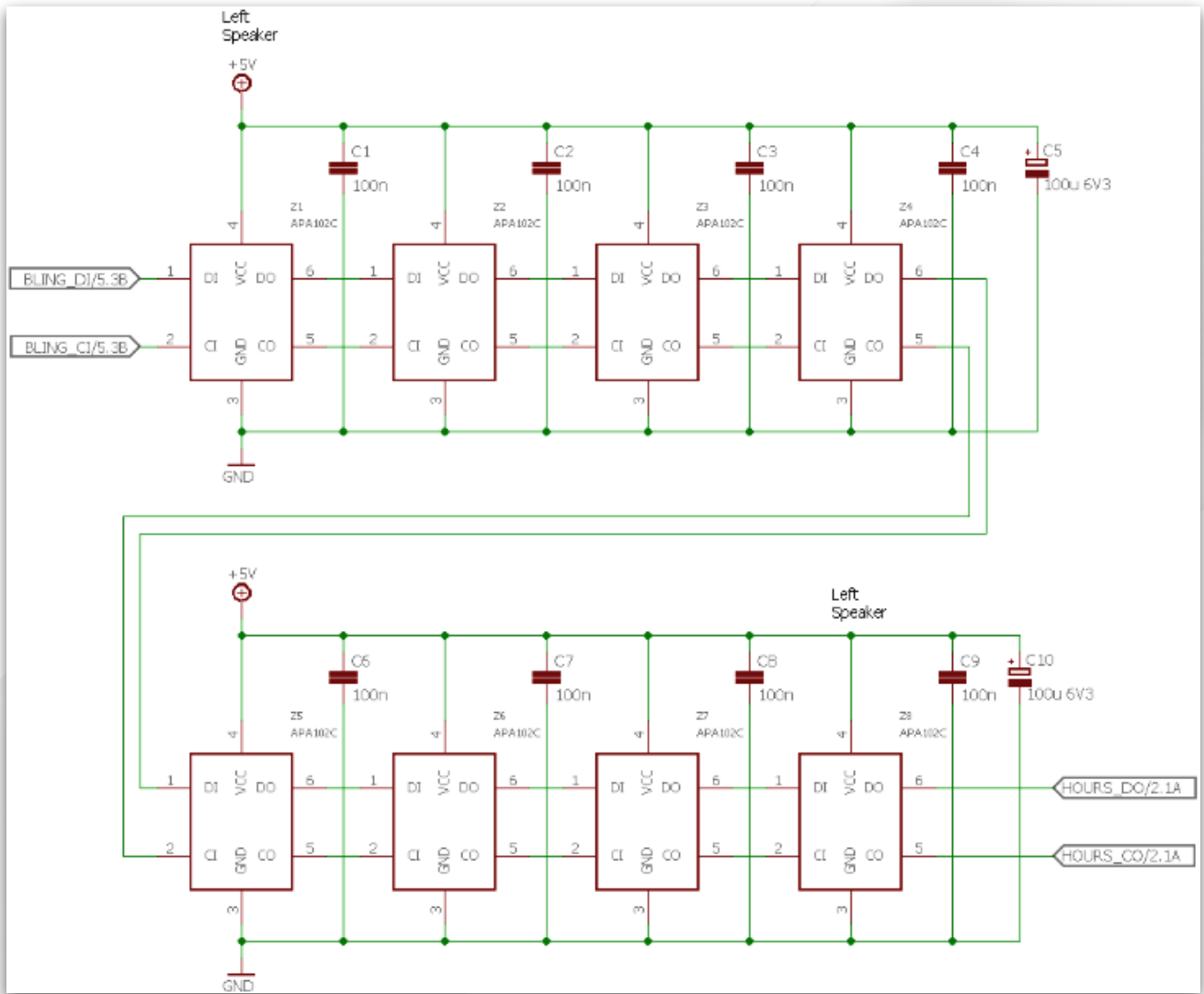


4.0 Front Panel Board

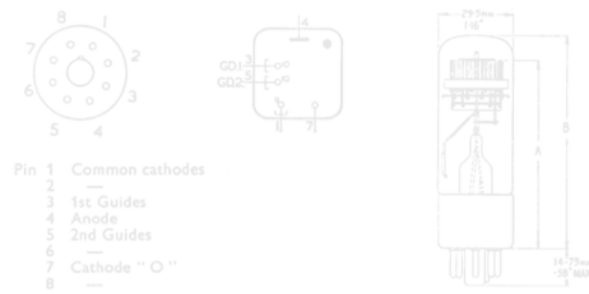
The front panel board carries the forward firing bling, the MTX90 colons, the IR, PIR, rotary encoder and the LDR. There is also a local 3.3V regulator. Connections are made to the main board and the PSU board.

The speakers are mounted on the PCB but connect directly to the main board.

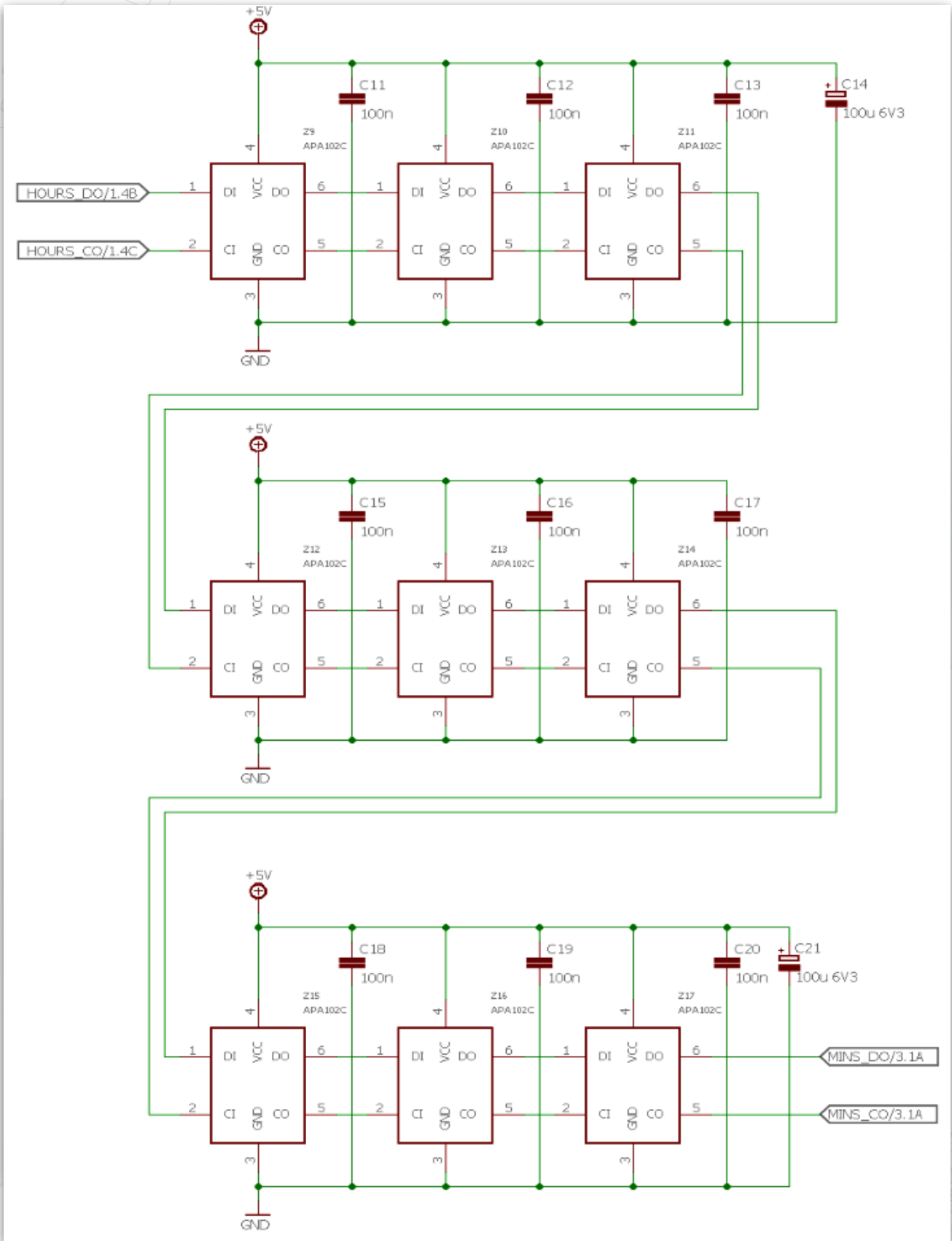
4.1 Bling



Base I.O.
Base Connections (underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

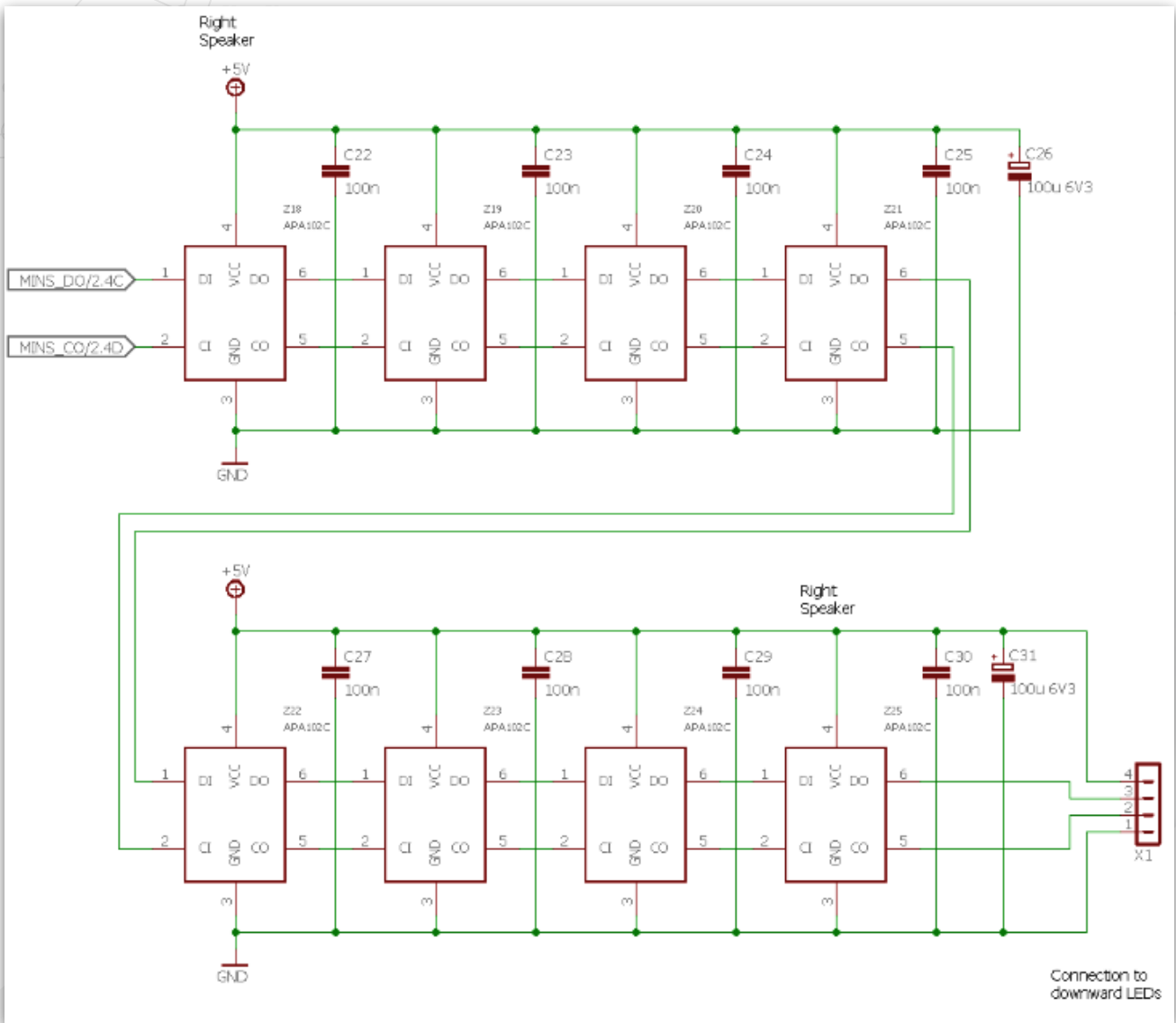


- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

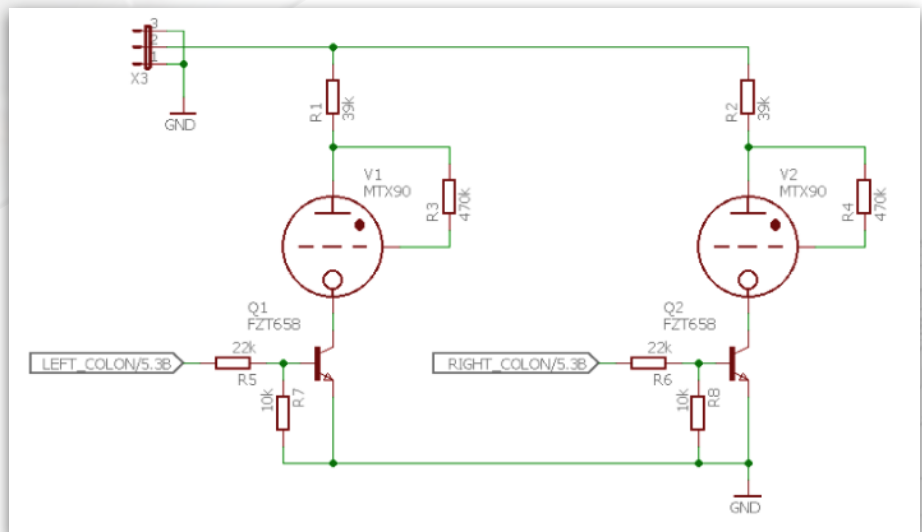




X1 connects to the downward firing bling board.

4.2 MTX90 Colons

X3 connects to one of the 170V outputs on the PSU board.

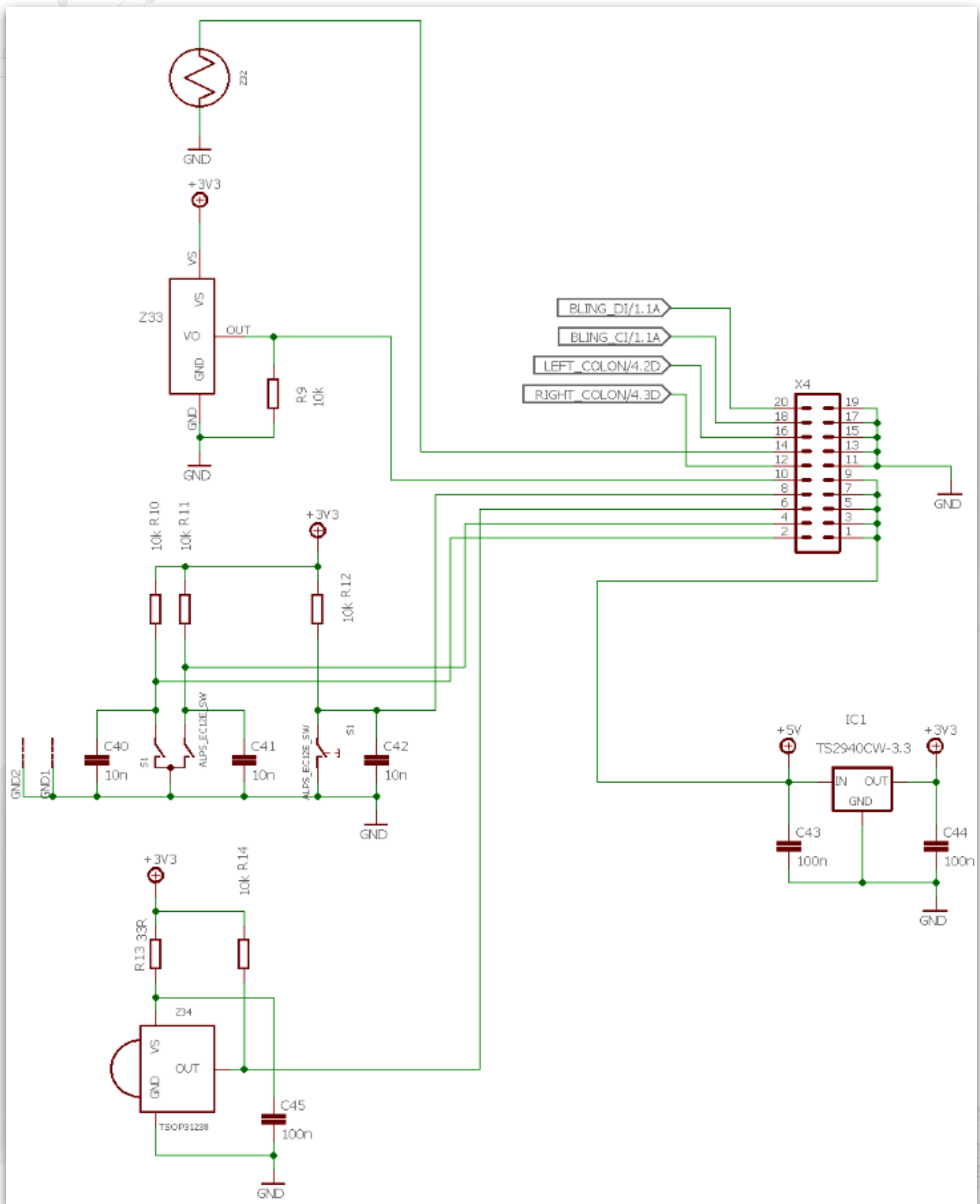


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

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4.3 PIR, IR, Encoder, LDR, Main Connector and Local 3.3V PSU



Connector X4 receives the serial bling data and the colon PWM brightness signals. It returns the signals from the IR, PIR, encoder and LDR. +5V is also received.

- Pin 1 Common cathodes
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



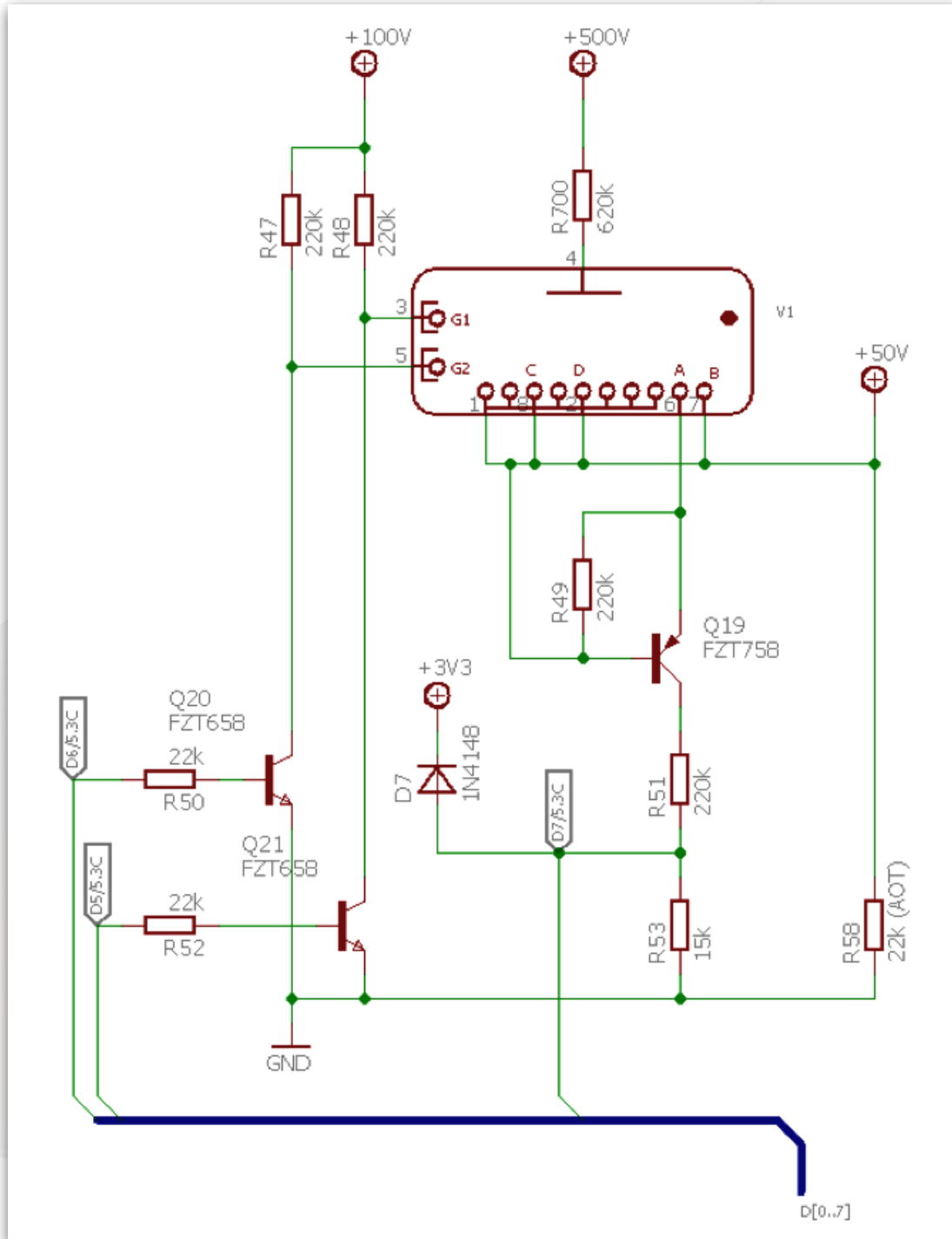
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



5.0 Dekatron Board

This board carries the seven Dekatrons, their driver transistors, local 50V and 100V power supplies and an ATMEGA324PA microcontroller as a TWI slave that manages all the Dekatron drivers.

5.1 Dekatron Driver

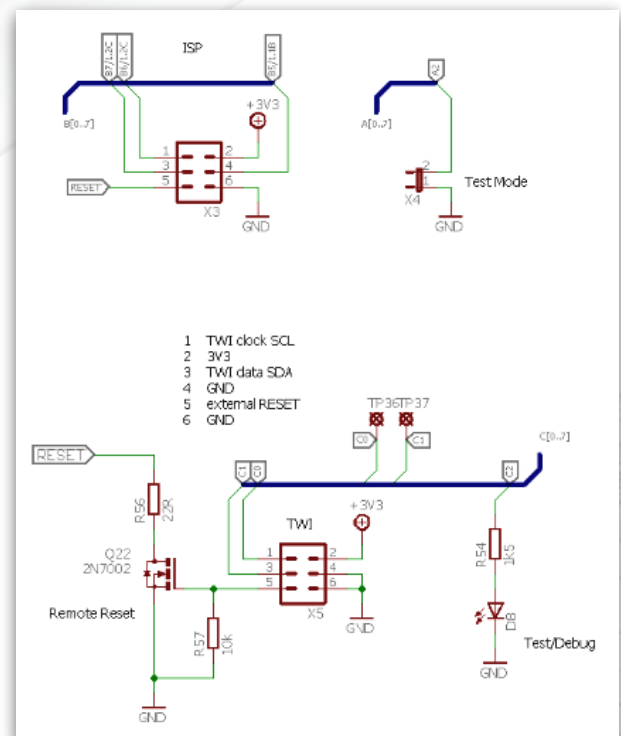
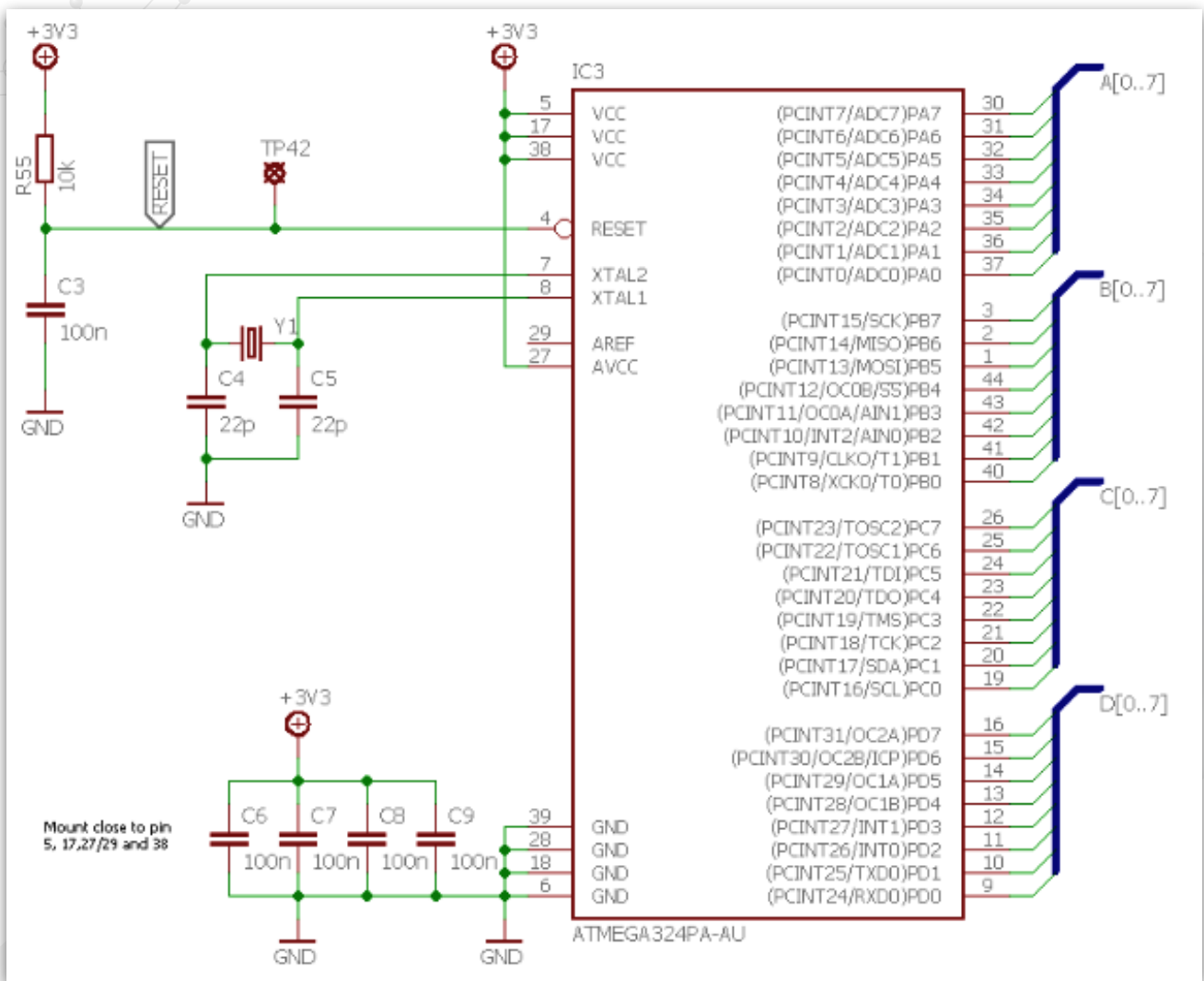


This is one of the seven identical drivers. Q20 and Q21 will pull their respective guide electrodes low causing them to glow. Q19 detects current flow through cathode '0' so is used to determine if that cathode is glowing. The anode resistor R700 is not mounted on the PCB.

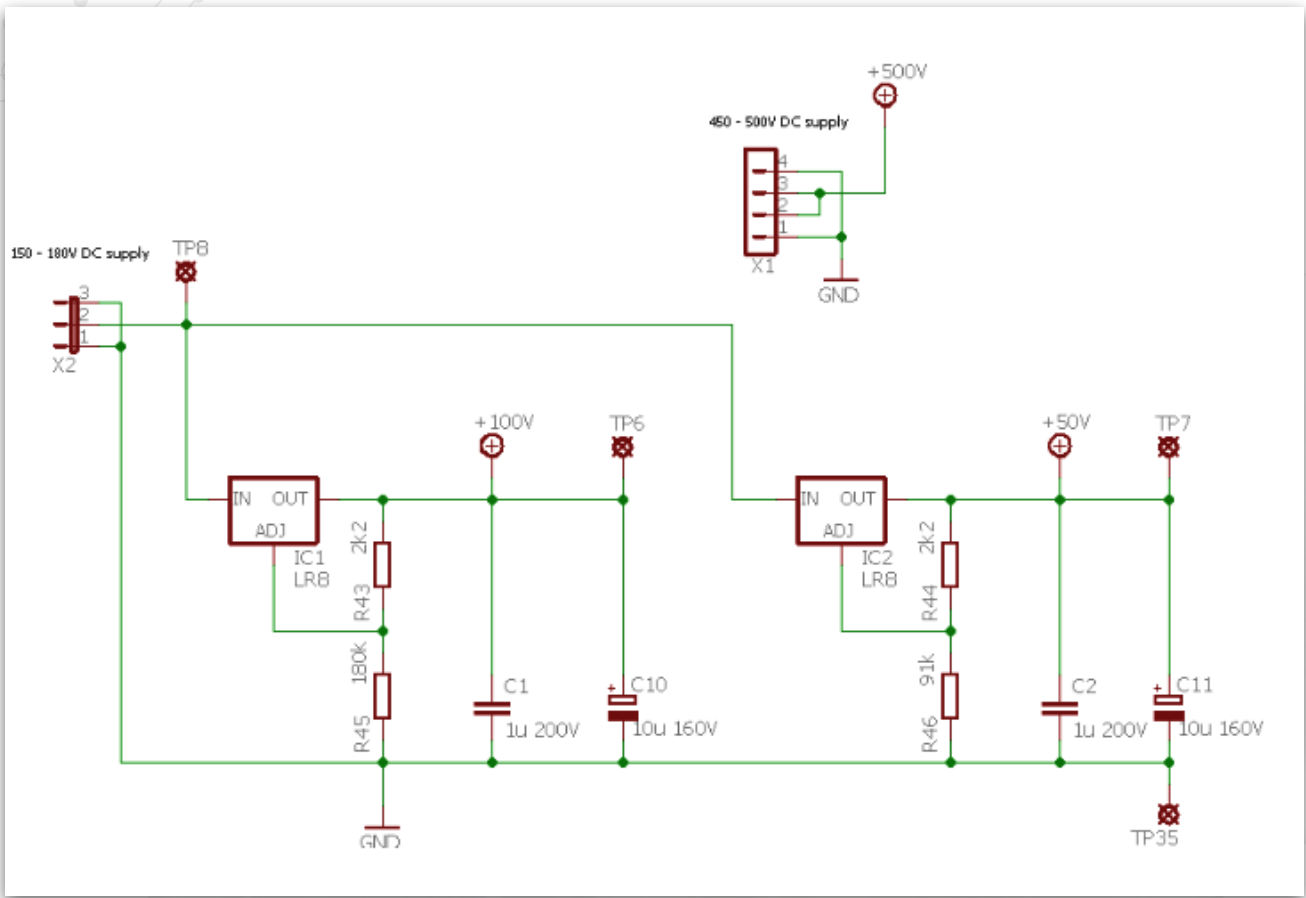
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



5.2 Microcontroller



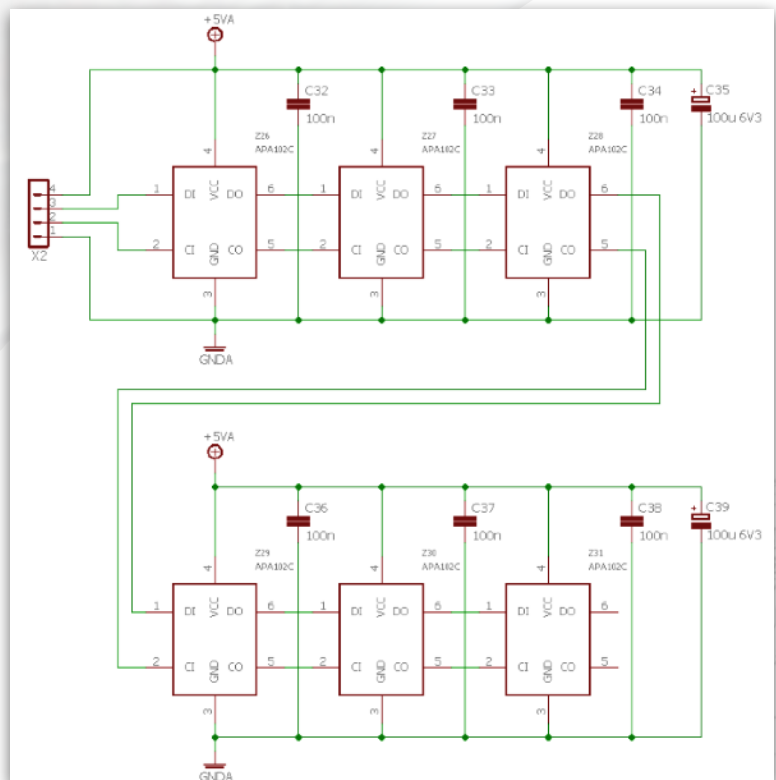
5.3 Power Supplies and Power Connectors



The board connects to the +500V and +170V outputs on the PSU board.

6.0 Downward Bling Board

X2 connects to the front display board.



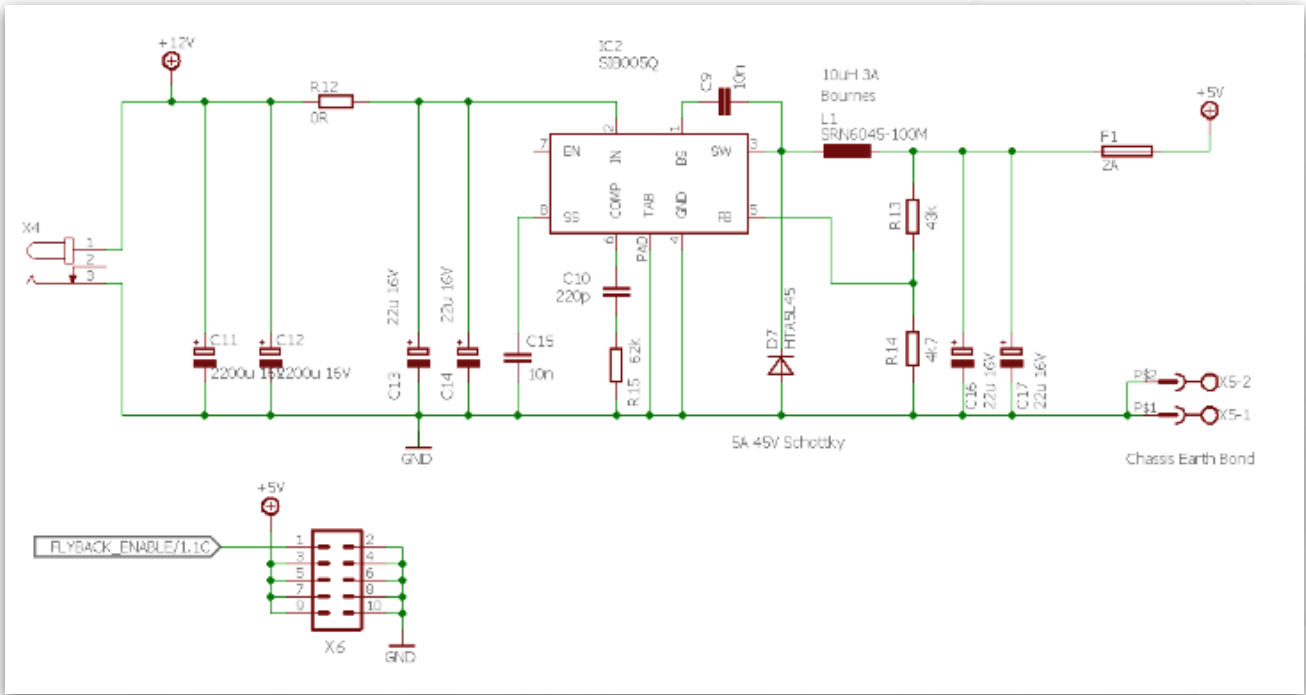
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75.5			75.5	75.5
B	87.5			87.5	87.5



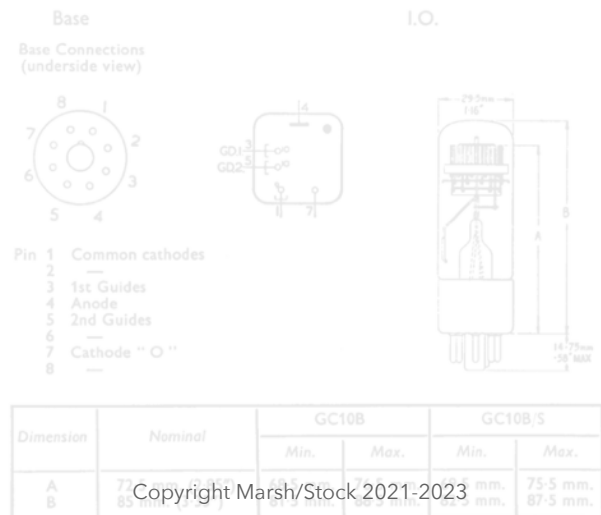
7.0 Power Supply Board

The power supply board carries the bulk of the power supply electronics. The board is designed to mount horizontally in the case so that its 12V DC supply jack is made available through the case rear panel.

7.1 5V Power Supply



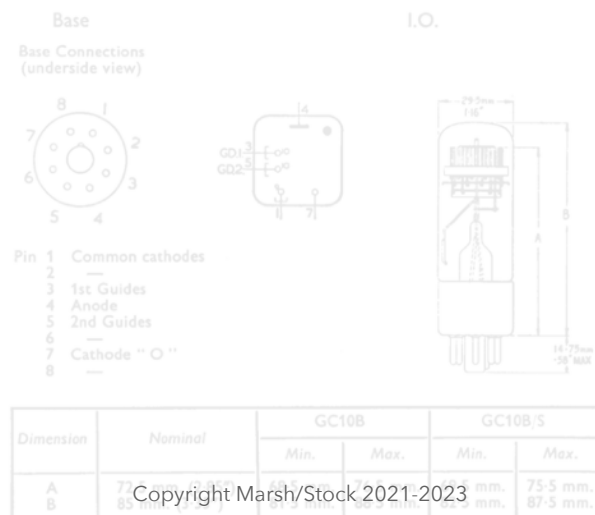
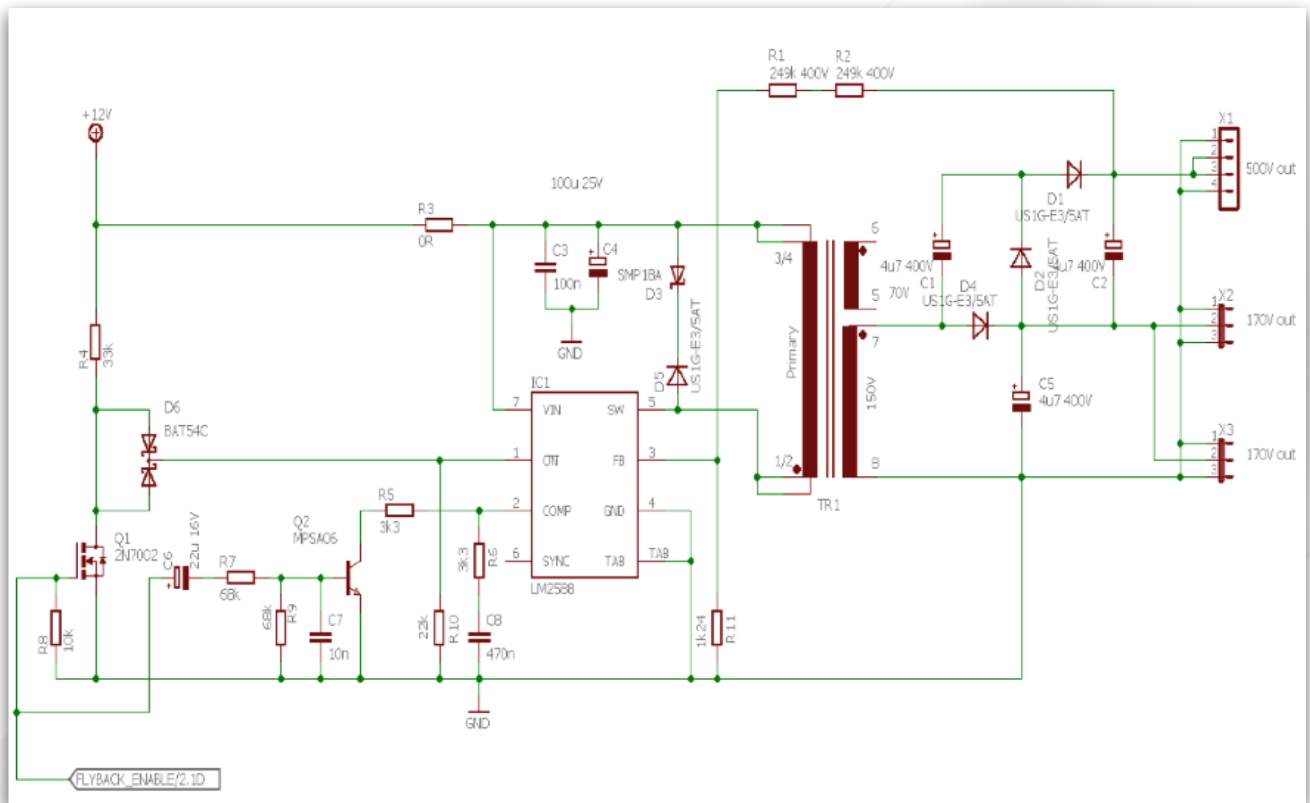
The 5V Power supply is a simple step down convertor. X5 is a ground connector that must be used to connect any metal case to the clock ground.



7.2 +500V and +170V Power Supply

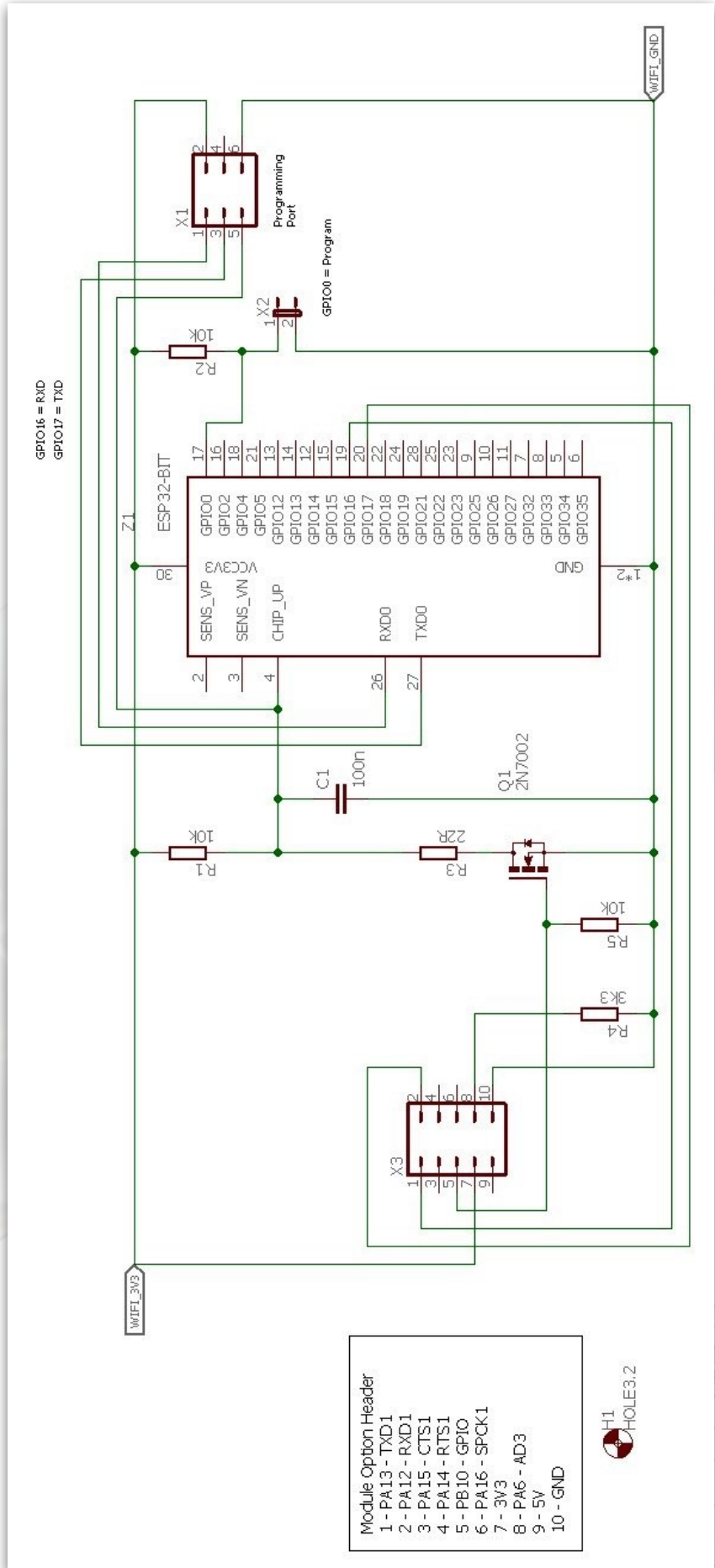
The Dekatron anodes require +500V to operate, the guide drivers require +50V and +100V to operate (on the Dekatron board) so are supplied by the +170V power supply. The MTX90 colons require a +170V supply.

This power supply is a simple flyback converter using a custom transformer. It is a very robust supply. Q1 acts as a level converter and makes the logic positive: a 3.3V input is required to switch the converter on. The circuit around Q2 provides a soft start to the converter.



8.1 WiFi Plug In

This uses an ESP32-BIT module. Serial data is transferred to the SAM3X8C. The module can be reset using Q1. Programming the ESP32 is accomplished using the SAM programmer and fitting the program jumper.



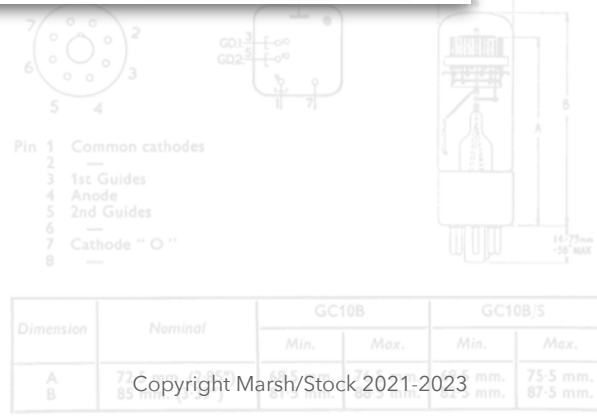
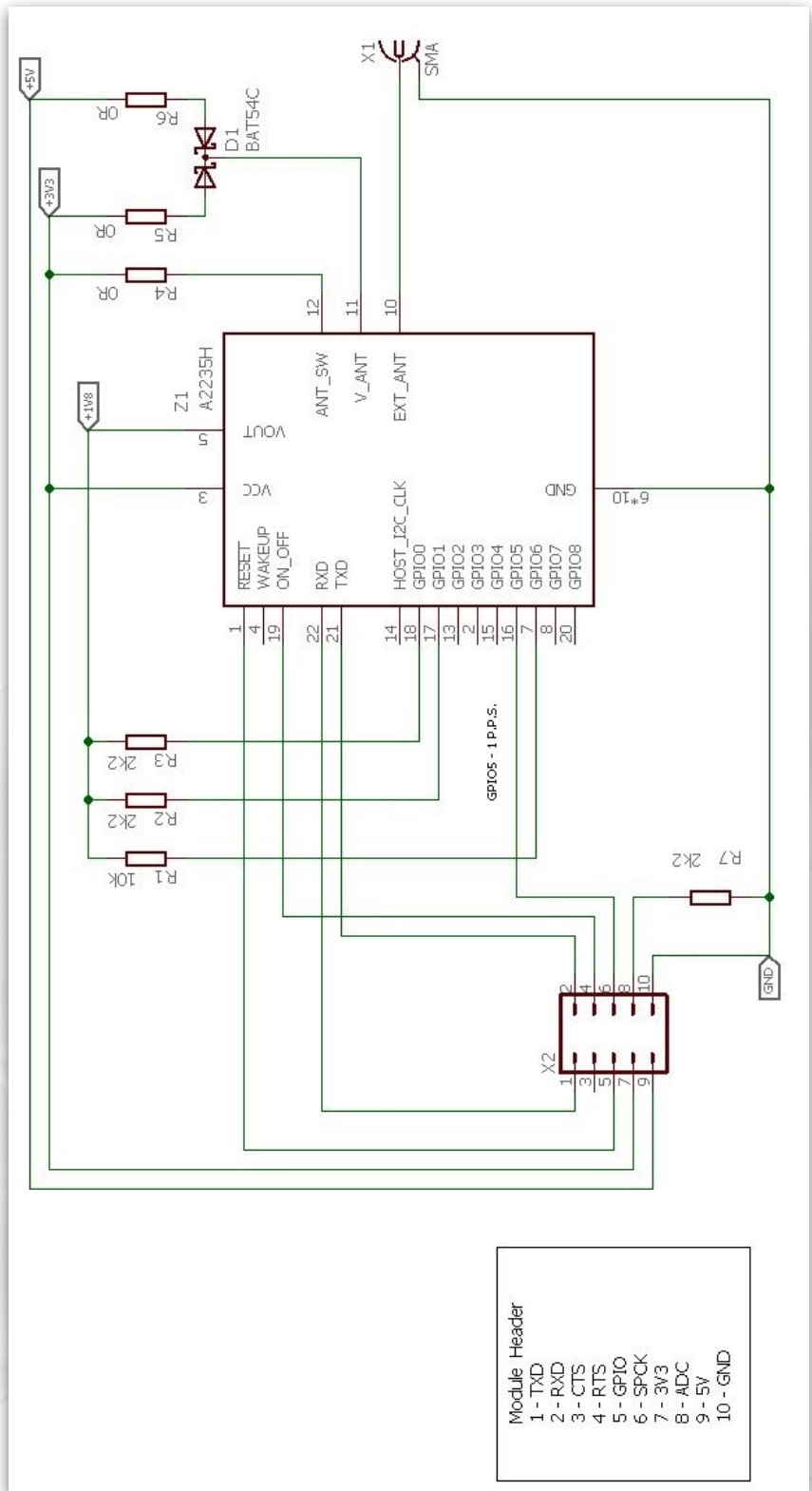
Dimension	Nominal	GC108		GC108/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

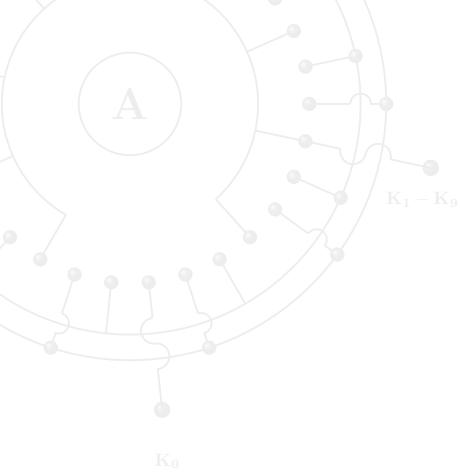
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8.2 GPS Plug In

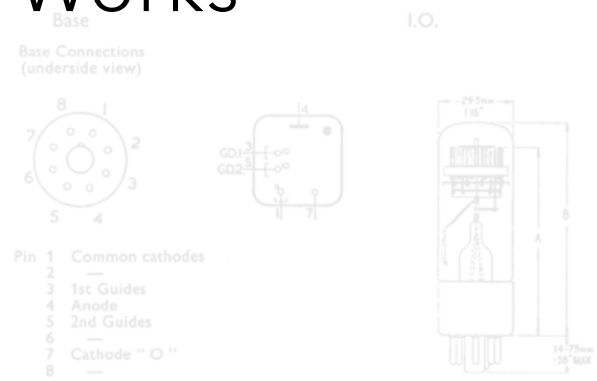
Serial data as NMEA statements are transferred from the GPS module to the SAM3X8C. The use of an external active antenna is selected using R4, R5 and R6. The schematic here shows the GPS plug in using the A2235H GPS module. A second plug in may be supplied which uses the A2200A GPS module - see the Sgitheach Commoners manual for complete details of both modules.





Dekatron Tube - How It Works

A Glow Transfer Tube in Action



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5 mm	72.5	72.5	75.5	75.5
B	85 mm	85	85	87.5	87.5

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An Extract From Dance's "Electronic Counting Circuits"

4.1 INTRODUCTION

One of the disadvantages of trigger tube counting circuits is that ten of the tubes are required in each decade. Great efforts have, therefore, been made to design cold cathode tubes one of which can replace ten trigger tubes in counting circuits; the resulting polycathode tubes are one of the most commonly used devices in medium speed counting equipment. Most of them can count at frequencies up to four thousand pulses per second, some up to twenty thousand, whilst two types can count at up to one million pulses per second.

Most polycathode tubes require a greater H.T. supply voltage than trigger tube counting circuits, but they usually pass a smaller current than trigger tubes. In common with most other cold cathode tubes, the polycathode counting tubes have a very long life when they are correctly used. The number of components required per decade is usually less when a polycathode tube is being used than when trigger tubes are employed, but a more complicated input circuit may be necessary.

4.1.1 Construction

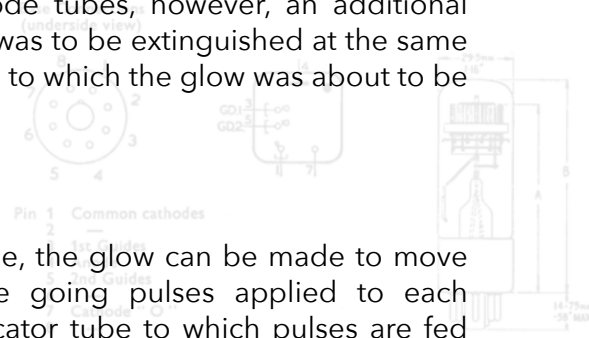
In practice, simple polycathode gas filled tubes for decade counting usually consist of twenty, thirty or forty cathodes placed around a single common anode. Groups of the cathodes are joined together internally so that the number of external connections is reasonably small. A discharge takes place between the anode and one of the cathodes when the tube is in operation and a 'negative' glow is formed. The position of the glow can be observed through the dome of the glass envelope and provides a visual indication of the state of the count. Most of the tubes are fitted into an escutcheon on which the digits are marked, but a few of the tubes do not require an escutcheon.

The tubes have the same basic properties as the simple cold cathode gas filled tubes described in Chapter 3. The striking voltage is normally much greater than the maintaining voltage. If a discharge is taking place to one of the cathodes, it can be transferred to an adjacent cathode by the application of a negative going pulse to the latter. The coupling between the two cathodes takes place automatically by means of the ions provided by the discharge at the first cathode. Cathodes adjacent to the discharge are much more strongly primed than any of the other cathodes.

The coupling components which are used in trigger tube circuits are not required when polycathode tubes are used. No priming electrodes are required, since a discharge is always taking place to one of the cathodes when the tube is in operation. After the transfer has taken place, the discharge to the cathode which was initially glowing is normally extinguished automatically by the fall of anode voltage. In some of the earlier polycathode tubes, however, an additional positive going pulse had to be applied to the cathode which was to be extinguished at the same time that the negative going pulse was applied to the cathode to which the glow was about to be transferred.

4.1.2. Types of Tubes

If a tube contains only ten cathodes around a common anode, the glow can be made to move from cathode to cathode by suitable successive negative going pulses applied to each succeeding cathode in turn. This is the principle of the indicator tube to which pulses are fed



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



from a counting circuit. Such a simple tube with only ten cathodes cannot actually perform the counting operation itself, since a circuit is said to be able to count only if it changes its state when successive input pulses are fed into the circuit along the same wire. Indicator tubes (as opposed to counting tubes) require pulses to be fed successively to each of the cathodes along different wires; they are described in Chapter 10. In counting tubes at least one additional cathode (known as a transfer or guide cathode) is placed between each two adjacent main cathodes. The discharge does not remain at any transfer cathode for more than a very short time. The main cathode at which the glow rests corresponds to a certain digit which can be read from the escutcheon which surrounds the domed end of most of the tubes. If only one transfer cathode is employed between each two main cathodes, all of the transfer cathodes are normally connected together. Negative going pulses to be counted are applied to all of the transfer cathodes, but the discharge can move only to a transfer cathode which is adjacent to the main cathode which is initially glowing, since no other transfer cathode is appreciably primed by the ions from the discharge. At the end of the pulse the discharge is made to travel from the transfer cathode to the next main cathode, usually by means of a positive bias which is applied to the transfer cathodes.

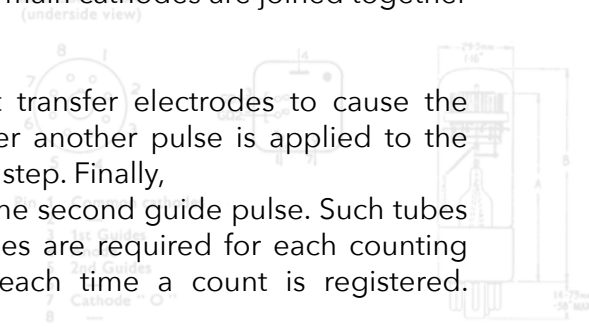
4.1.3 Asymmetrical Tubes

If only ten transfer electrodes are employed and they are all connected together, the electrode geometry must be asymmetrical so that the discharge can travel around the tube only in the desired direction. For example, the main cathodes may be so shaped that the discharge can pass only to the transfer electrode which is one step in a clockwise direction from the main cathode which is initially glowing. The discharge may be prevented from returning to the previous main cathode at the end of the pulse by the effect of a parallel capacitor and resistor from each main cathode to earth. Whilst the discharge remains at a main cathode the capacitor charges and subsequently holds this cathode at a positive potential whilst the discharge is at the succeeding transfer cathode. This technique employing directional main cathodes is used in the S.T.C. G10/241E 'Nomotron' counting tube. In other types of counting tubes both the main and transfer cathodes are directional. The counting speed is then not limited to such an extent by the effect of the cathode circuit time constant, since the latter does not control the direction of rotation of the discharge. The Elesta EZIOB tube employs this principle. Tubes which use directional asymmetrical electrode structures cannot be used for reverse counting (subtraction).

4.1.4 Symmetrical Tubes

In many other types of tube two transfer electrodes are employed between each two of the main cathodes. The tubes themselves are symmetrical in each direction and the direction of the rotation of the discharge is determined by the timing of the applied input pulses. All of the transfer cathodes which are on the clockwise side of the main cathodes adjacent to them are joined together and are known as the first guides (see Fig. 4.1). Similarly all of the transfer electrodes which are on the anticlockwise side of the adjacent main cathodes are joined together and are known as the second guides.

In operation a negative going pulse is applied to the first transfer electrodes to cause the discharge to move one step and a fraction of a second later another pulse is applied to the second guide electrodes so that the discharge moves another step. Finally, the discharge moves to the next main cathode at the end of the second guide pulse. Such tubes are known as double pulse tubes, since two successive pulses are required for each counting operation. Three distinct stepping operations take place each time a count is registered.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

Examples of those tubes operating on this particular principle are the Mullard Z504S, the Ericsson GC10B and the Sylvania 6476.

Another type of symmetrical tube has ten main cathodes and thirty transfer cathodes surrounding a common anode. The Ericsson GC10D is a tube of this type and is known as a single pulse Dekatron, since only one pulse is fed to the circuit to operate this tube.

4.1.5 Counter and Selector Tubes

The 'zero' main cathode of almost all tubes is brought out to a separate base pin so that an output pulse can be taken from for triggering the next decade. In many counting tubes which are intended for use in simple straightforward counting circuits, the other nine main cathodes are brought out to a single common base pin. Such tubes are known as counter tubes.

Some tubes, such as the Mullard Z504S and the Ericsson GS10C/S, have each main cathode connected to a separate base pin so that an output pulse can be obtained from the circuit after any desired number of counts. This pulse may be used to initiate some external action. Such tubes are known as selector tubes and must be used when electrical readout from any cathode is required. They can perform any function which can be carried out by counter tubes.

Counter tubes can sometimes be manufactured rather more cheaply than the equivalent type of selector tube. In addition, the user of counter tubes has fewer soldered connections to make than the user of selector tubes.

Some tubes are also manufactured in which some but not all of the main cathodes are connected to separate base pins; they are useful in bidirectional counting circuits. A typical example is the Ericsson GC10/4B.

4.1.6 Scale of Twelve

Cold cathode tubes are available with ten main cathodes for decade counting and also with twelve main cathodes for counting on a scale of twelve. Other types of counting tubes, such as EIT tubes and Trochotrons, are not manufactured for scale of twelve operation, presumably because of a lack of demand.

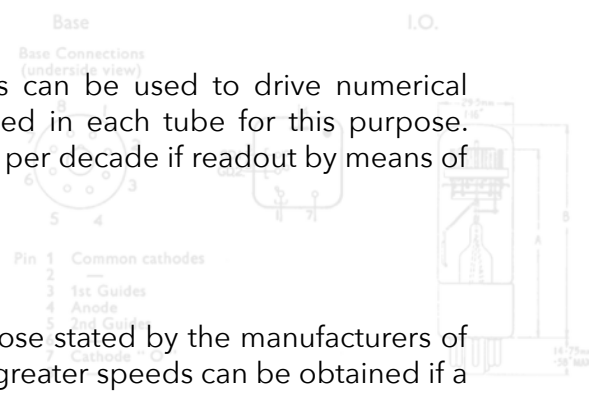
Scale of twelve tubes are useful when pence are to be counted, since one output pulse is provided for each twelve pence counted. Tubes with twelve main cathodes are also useful dividing the number of input pulses by three, four, six or twelve (for example, in conjunction with a decade tube for converting one pulse per second into one pulse per minute).

4.1.7 The Operation of Numerical Indicator Tubes

The Ericsson GCA10G counter and GSA10G selector tubes can be used to drive numerical indicator tubes directly, ten additional anodes being provided in each tube for this purpose. Other cold cathode decade tubes require ten amplifier stages per decade if readout by means of a numerical indicator tube is required.

4.1.8 Maximum Counting Speed

The maximum counting speeds quoted in this Chapter are those stated by the manufacturers of the tube concerned. In some cases operation at considerably greater speeds can be obtained if a



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

stabilised power supply and close tolerance components are used and if the input pulses are accurately controlled in amplitude and duration. Some manufacturers seem to be rather more conservative in their maximum frequency ratings than others. Generally, however, it is not wise to attempt to appreciably exceed the maximum counting speed quoted by the manufacturers of the tube if a reliable counting circuit is required.

Some indication of the safety margin which is available for any tube when it is operating at a certain speed may be obtained by varying the anode resistor (and hence the anode current) of the tube when it is operating at that speed in order to ascertain the anode current range for satisfactory operation. The actual readings of the anode current should be taken whilst the discharge is stationary in the tube. The anode current should not be allowed to exceed the maximum value for the tube concerned, although input pulse frequencies greater than the maximum recommended for the tube being used may be tried. The anode current range over which satisfactory operation is obtained normally becomes smaller as the operating frequency is increased in the region of the maximum published frequency for the tube. A stabilised H.T. supply is, therefore, normally desirable if the maximum possible operating frequency is required at the expense of circuit simplicity. Tests for reliability of counting using various input pulse amplitudes and/or durations are also very helpful in assessing whether or not a particular tube will operate satisfactorily at a certain counting speed.

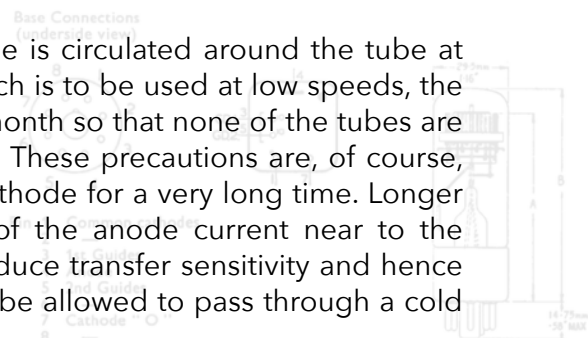
Most double pulse tubes have a maximum counting speed of about 4,000 pulses per second, but other types can operate at up to 10,000, 50,000 or 100,000 pulses per second. The single pulse GC10D and the S.T.C. Nomotron can operate at up to 20,000 pulses per second whilst the Elesta EZ10B and ECT100 can count up to one million pulses per second.

The maximum counting speed may be reduced at high temperatures (above about 60° C) owing to the increased pressure of the gas. Substances which can poison the electrode surfaces may also be given off from the glass envelope if the ambient temperature increases, but these substances will not settle on the cathodes if the discharge is circulated. The maximum speed of operation may also be reduced at temperatures below -15 °C.

4.1.9 Life

The life of most types of polycathode gas filled tube is normally many tens of thousands of hours (tens of years). If, however, the discharge is allowed to remain at one cathode and is never circulated, minute amounts of material may be sputtered from the electrodes and be deposited on the adjacent cathodes. The discharge characteristics are different for sputtered nickel and pure nickel and after the discharge has rested at one cathode for a very long time, longer input pulses may be needed for the operation of the tube. The tube may then be considered to be at the end of its useful life, although longer pulses may be used to drive it at low speeds. The sputtered material from the cathodes may also darken the inside surface of the glass envelope.

Longer life can be obtained from some tubes if the discharge is circulated around the tube at least once per week. Alternatively in a multidecade scaler which is to be used at low speeds, the positions of the tubes may be interchanged about once per month so that none of the tubes are used in the slowest decade for more than a month at a time. These precautions are, of course, required only when the discharge is likely to remain at one cathode for a very long time. Longer life may be obtained from some types of tube if a value of the anode current near to the minimum recommended value is used. This may, however, reduce transfer sensitivity and hence the maximum operating speed somewhat. No current should be allowed to pass through a cold



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75			mm.	75.5 mm.
B	85			mm.	87.5 mm.

cathode tube in the reverse direction, since this will probably result in damage to the surfaces of the cathodes.

4.1.10 Design for Optimum Anode Current

The current flowing through the tube should be within the limits specified by the manufacturer. A current greater than the specified maximum value leads to excessive sputtering of material from the cathodes and to short life, whilst a current below the specified minimum value will result in reduced transfer sensitivity and hence to unreliable counting or reduced operating speed. High speed tubes generally require a greater anode current than the simple 4 kc/s double pulse tubes.

The potential across a cold cathode tube is almost independent of the current flowing through the tube provided that it is being operated in the 'normal' region of the characteristic. The current which flows through the tube can be calculated by applying Ohm's Law to the circuit :

$$V_b - V_m = I_a(R_a + R_h)$$

- V_b is the H.T. supply voltage
- V_m is the tube maintaining voltage
- I_a is the tube anode current
- R_a is the anode resistance
- R_h is the cathode resistance

A minimum value for the H.T. supply voltage is quoted by the tube manufacturers. If a smaller supply voltage than this is used, the tube may not strike when the voltage is first applied. Since the tubes are not primed, there may be a delay of up to about a minute before they strike if a value of H.T. supply voltage near to the minimum recommended value is employed.

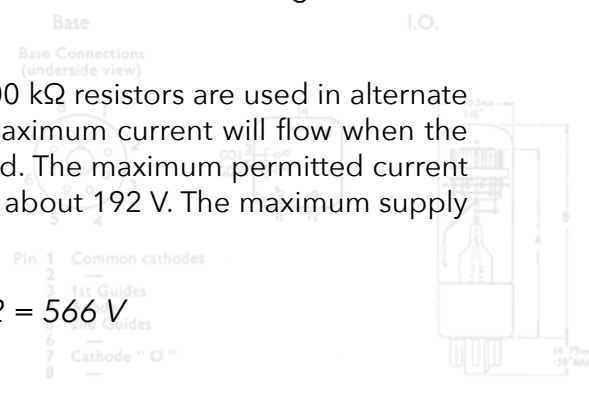
There is normally no upper limit to the H.T. supply voltage which can be used provided that the cathode current is kept within the rating of the tube by a suitable choice of resistor values. In most cases the H.T. supply need not be stabilised.

When the value of R_a has been chosen, the maximum value of the supply voltage may be calculated from the above equation by substituting for I_a the maximum permissible value of the tube current and for R_k the smallest value of resistor which is to be used in any of the cathode circuits of the tube. (The maximum current flows in that cathode circuit which has the smallest value of cathode resistor.)

Similarly the minimum value of the supply voltage may be calculated by using the same equation and substituting in it the minimum permitted value of the tube current and the largest value of cathode resistor which is to be used in any cathode circuit.

In the case of the GS10C/S, for example, let us assume that 100 kΩ resistors are used in alternate cathode circuits and that the anode resistor is 680 kΩ. The maximum current will flow when the discharge rests at one of the cathodes which is directly earthed. The maximum permitted current for the GS10C/S tube is 550μA and the maintaining voltage is about 192 V. The maximum supply voltage is, therefore, given by :

$$V_{b \max} = (0.00055 \times 680,000) + 192 = 566 \text{ V}$$



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

The minimum recommended anode current is 250 μA . The anode current will have its smallest value when the discharge is resting at one of the cathodes connected to a 100 k Ω resistor. The minimum supply voltage is therefore given by

$$V_{b \text{ min}} = 0.00025(680,000 + 100,000) + 192 = 387 \text{ V}$$

This value is slightly below the minimum recommended value for reliable striking (400 V). The mean of the maximum and minimum values of H.T. supply voltage, that is 475 V, may be used as the H.T. supply voltage design value.

It might appear that this mean value could vary by +90 V or have a 64 V R.M.S. ripple. If variations of this magnitude did occur, however, the change in current flowing through the cathode resistors would cause a variation of about 110 V on the nominal output voltage of 30. This might well cause unsatisfactory operation of the circuits into which the output voltage is fed.

The circuits of some of the tubes are fairly critical and it is therefore usually advisable to employ a circuit which has been designed and thoroughly tested by the manufacturers of the tube concerned as the basis of any design for a piece of counting equipment.

4.2 4 kc/s DOUBLE PULSE TUBES

Some of the most commonly used cold cathode counter tubes function on the double pulse principle. The electrode structure of a double pulse selector tube is shown in Fig. 4.1. The anode is a circular metal disc placed near to the domed end of the tube (Plates 6 and 7). Thirty identical rods of small diameter are placed symmetrically around the anode; they are the main cathodes and the transfer cathodes. There are two transfer electrodes between each two main cathodes. All of the first guides are joined together and all of the second guides are joined together. In a counter tube (as opposed to a selector tube) the main cathodes K1 to 1(9 are also brought out to one common external connection.

The basic circuit for the normal operation of the tube is shown in Fig. 4.2. The tube may be represented as shown, the circular structure being illustrated as a linear one for convenience. The square brackets near each set of transfer electrodes indicate that there are more than one first guide and more than one second guide in the tube. The main cathodes are normally at earth potential whilst both sets of guide cathodes have a quiescent positive potential which is determined by the source of bias voltage. When an H.T. supply of over 400 V is connected to the circuit, one of the main cathodes will strike preferentially to any guide cathode, since the guide bias renders the anode to main cathode potential greater than the potential between the anode and any guide. As soon as ignition has taken place at any one main cathode, the potential between the anode and that main cathode will drop from the striking voltage to the

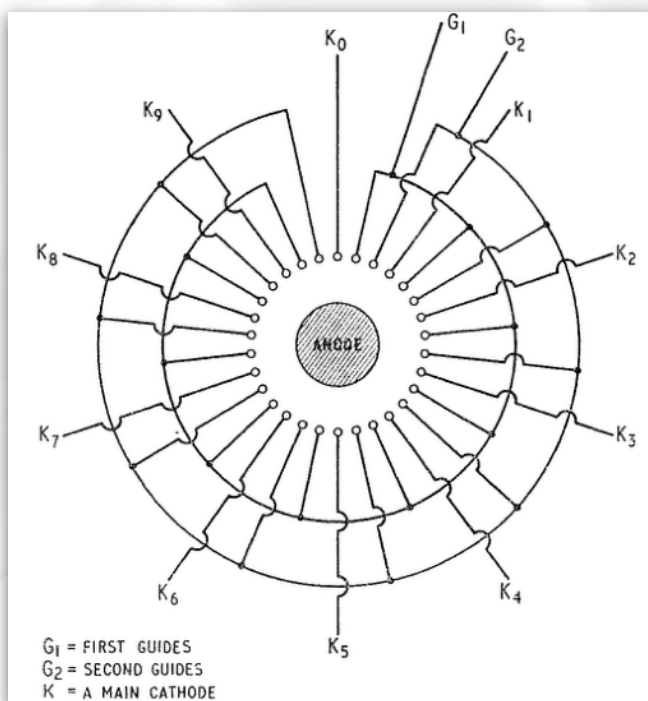
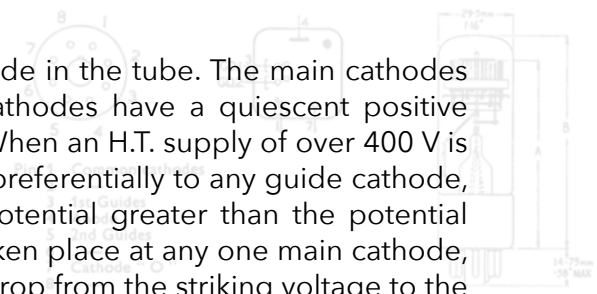


Fig. 4.1 The electrode structure of a double pulse selector tube



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75			mm.	75.5 mm.
B	85			mm.	87.5 mm.



maintaining voltage owing to the fall of potential across the anode resistor, R_a . The anode potential is then below the striking voltage to any other cathode and, therefore, the discharge will occur at only one main cathode.

4.2.1 Double Pulse Counting

The counting operation is performed in three stages. A negative going pulse is first applied to all of the first guide electrodes so that they fall in potential, to a value which is appreciably below earth potential. In a typical double pulse tube with a maintaining voltage of 190 V, the priming effect of the ions from the discharge at the main cathode reduces the striking voltage at the two adjacent guide electrodes to approximately 200 V, whilst the striking voltage at the cathode three positions away is reduced to about 250 V. If the glowing cathode is earthed, the potential difference between the anode and the first guide will be 200 V when the first guide potential has fallen to -10 V. The first guide which is adjacent to the main cathode, therefore, commences to strike when it is at this potential. No other first guide is sufficiently primed for striking to occur.

As the guide potential falls further, the current to the guide increases so that the operating point moves to the flat portion of the anode voltage/anode current characteristic where the voltage between the anode and the first guides is almost constant and independent of the current flowing. The anode potential falls with the potential of the first guides so that the potential difference between these electrodes is constant and equal to the maintaining voltage for the tube concerned. This fall of anode voltage results in the voltage between the anode and the main cathode falling below the maintaining voltage of this gap and the discharge to the main cathode is, therefore, extinguished.

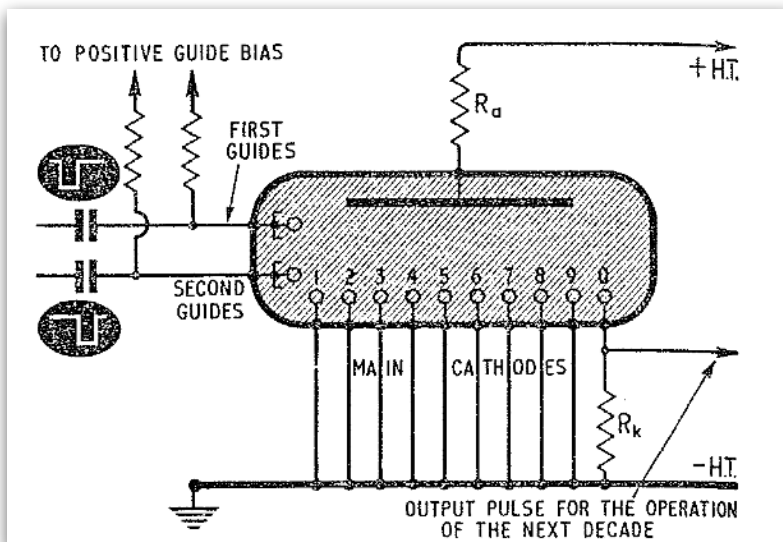


Fig. 4.2 The basic circuit for the operation of a double pulse tube

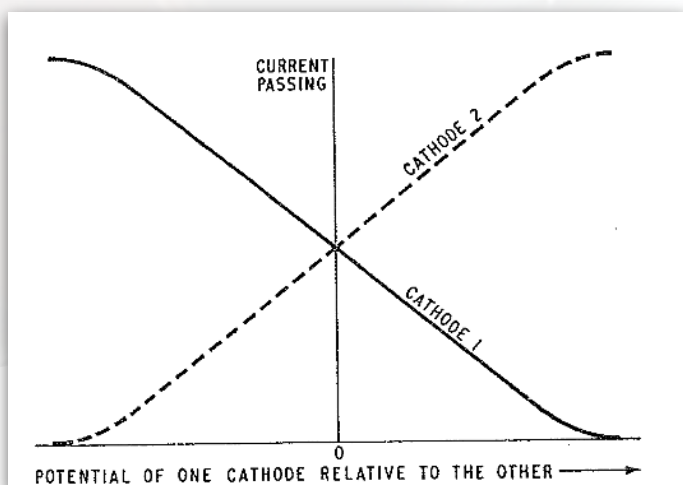


Fig. 4.3 The transfer characteristic for two similar cathodes in a cold cathode tube

The transfer characteristic of the tube for any two adjacent cathodes is of the form shown in Fig. 4.3. It can be seen that as the current passing to the cathode which is about to glow increases, the current passing to the cathode which was initially glowing decreases and the total anode current remains more or less constant.

It should be noted that the guide electrode, which is one position in an anti-clockwise direction from the discharge at the main cathode, is a second guide. The discharge shows no tendency to move in an anti-clockwise direction to this electrode, since the second guide electrodes are still

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5

receiving a positive bias.

The discharge has thus moved one step in a clockwise direction to the first guide and now primes the succeeding second guide. If the pulse now ceased, however, the discharge would return to its original position at the main cathode owing to the positive guide bias. When the discharge has been fully transferred to the first guide electrode, a negative going pulse is applied to the second guide electrodes so that their potential is reduced to a value which is appreciably below that of the main cathodes and which is approximately equal to that of the first guides which are still receiving a pulse. The pulse to the first guides terminates soon after the application of the second guide pulse and the first guide potential rises towards the bias voltage. The anode potential also rises so that the anode to first guide voltage is kept constant at the maintaining voltage of the tube. Soon the anode to second guide primed striking potential of about 200 V is reached. The second guide which is primed then strikes and the anode voltage falls until the anode to second guide potential is equal to the maintaining voltage of the tube. The anode to first guide potential is now below the maintaining voltage for this gap and the discharge at the first guide is extinguished. The discharge has now moved two positions clockwise.

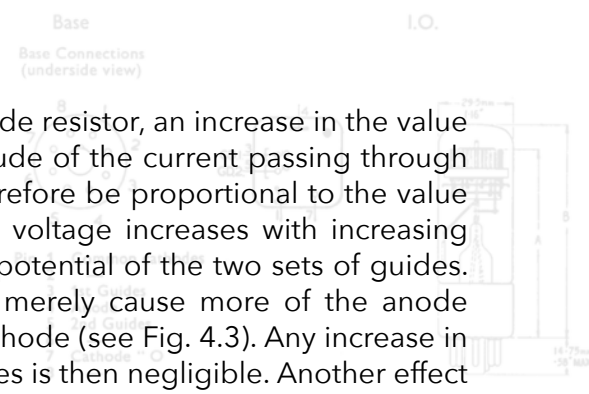
Finally, when the second guide pulse terminates, the anode voltage again rises, since the anode to second guide potential tends to remain constant at the maintaining voltage. When the potential of the second guides reaches about 10 V above earth whilst returning to the quiescent bias potential, the discharge will move one further step in a clockwise direction to the next (primed) main cathode. There is obviously no tendency for the discharge to move in an anti-clockwise direction to the first guide, since this electrode is at a positive potential with respect to the main cathode and the anode to first guide striking potential is, therefore, not reached. One of the purposes of the guide bias is to cause transference of the discharge to the main cathode at the end of the second guide pulse. The three successive stepping operations have now been completed and one count has been registered.

The guides are used to determine the direction in which the discharge rotates in the tube. If the second guides receive a negative going pulse and subsequently the first guides receive a similar negative going pulse just before the termination of the second guide pulse, the discharge will move in an anti-clockwise or reverse direction. Circuits for addition or subtraction can, therefore, be constructed using double pulse tubes.

When the anode current flows to the zero cathode, K0, the voltage produced across the cathode resistor (see Fig. 4.2) can be used to trigger the next decade. The output pulse is not suitable for feeding directly to the counting tube of the next decade, but must be fed into a coupling circuit which amplifies it, changes its polarity and converts it into the required double pulse.

4.2.2 Cathode Resistor and Guide Bias Values

If the cathode resistor is small in value compared with the anode resistor, an increase in the value of the cathode resistor will not appreciably affect the magnitude of the current passing through the tube. The output voltage available at the cathode will therefore be proportional to the value of the cathode resistor if the latter is small. As the cathode voltage increases with increasing values of cathode resistor, however, it will approach the bias potential of the two sets of guides. Further increases in the value of the cathode resistor then merely cause more of the anode current to flow to the adjacent guides and less to the main cathode (see Fig. 4.3). Any increase in the output voltage as the value of the cathode resistor increases is then negligible. Another effect



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5			mm.	75.5 mm.
B	85			mm.	87.5 mm.

occurs if the guides receive a large positive bias (say +100 V) in an attempt to prevent the above effect from limiting the output voltage. The maintaining voltage of the tube is virtually constant and as the cathode at which the discharge is occurring becomes more positive, the potential of the anode will increase by the same amount as that of the cathode. The non-glowing cathodes remain at earth potential, however, and therefore the potential between them and the anode has increased. The discharge may, therefore, spread somewhat to the adjacent cathode gaps and these may break down at an anode-cathode potential difference of about 250 V which corresponds to a cathode potential of less than +60 V. The glow is especially likely to jump back to the previous main cathode, however, if that cathode has not completely deionised.

The optimum value of the guide bias is normally a compromise between a high value which would result in limited tube life and a low value which would limit the output pulse amplitude. A guide bias of about +40 V is about the maximum which is recommended for 4 kc/s tubes ; if this value of bias is used, an output pulse of about 35 V across a 150 kΩ resistor can then be obtained. Under carefully controlled conditions output pulses of 65 V across 200 Ω cathode resistors have been obtained with a guide bias of +65 V, but these operating conditions are not recommended for general use.

4.2.3 Negative Cathode Bias

An increased output pulse amplitude can be obtained by returning the cathode load resistors to a source of negative voltage. For instance, if they are returned to a -20 V line, a 50 V output signal can be obtained if the cathodes rise to +30 V when passing a current. The anode potential will then rise to only +220 V (for a tube with a maintaining voltage of +190 V), so that there is no danger of an adjacent cathode striking. The bias potential of the output cathode may also be employed to bias the succeeding valve in the coupling stage to cut off, the cathode of the coupling valve being earthed.

When a negative bias is applied to the output cathode(s), the minimum amplitude of the pulses applied to the first guides must be increased by an amount equal to the negative bias. This ensures that the guides fall in potential by an amount which is sufficient to cause reliable transfer of the discharge from the negatively biased cathodes to the first guides.

It is not wise to return the output cathode load resistor to a bias voltage which is more negative than -20 V, or the discharge may transfer correctly from the output cathode to the first and second guides and then suddenly jump back to it, as it will still be primed somewhat and is at a greater negative potential than the succeeding main cathode. Most of the circuits published by the Ericsson Company for their tubes have the output cathodes returned via the cathode resistor to a -20 V line. The Mullard/Philips circuits employ a -12 V line for the same purpose.

The potential of any cathode which is used to generate an output pulse should not be allowed to rise to within ten volts of the positive guide bias potential or the glow discharge may fail to transfer from it to the succeeding first guide owing to the possibility of current sharing between the main cathode and the preceding second guide electrode.

The maximum recommended value of the cathode resistor in any main cathode circuit is given by the equation:

$$R_k = \frac{(V_g + V_k - 10)R_a}{(V_b - V_m - V_g + 10)}$$

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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the output voltage for any value of R_k is given by:

$$V_{out} = \frac{(V_b - V_m + V_k)}{(R_a + R_k)}$$

where V_g is the positive guide bias and V_k is the output cathode negative bias. The other symbols are as defined earlier for equation (1) in Section 4.1.10.

If the values of $V_g = +40$ V and $V_k = -12$ V (as recommended in Mullard/Philips circuits) are used, the maximum value of R_h is found to be 140 k Ω . The preferred value of 120 k Ω is, therefore, recommended and output pulses of 30 V are obtained.

4.2.4 Output Pulse Shape

When the discharge is transferred to the main cathode, the current does not increase very suddenly, but depends on the instantaneous value of the potential difference between the main cathode and the guide from which the discharge is transferred (see Fig. 4.3). The rate of rise of the leading edge of the output pulse is approximately equal to the rate of decay of the trailing edge of the second guide pulse. The transfer from the second guide to the main cathode may not take place at the same potential difference at various positions in the tube and there can be jitter in the time at which the leading edge occurs. The trailing edge of the output signal is produced by the leading edge of the first guide pulse which is usually quite sharp; the trailing edge of the output signal is, therefore, more suitable for use when the pulse is to be employed as a form of time marker.

The duration of the output pulse is approximately equal to the time during which neither set of guides is receiving a pulse.

4.2.5 Input Pulse Requirements

It is essential that the pulses applied successively to the two sets of guides should be of a suitable amplitude and duration and that they should be correctly timed with respect to each other. Transfer can be effected by a number of types of waveform, but for maximum speed of operation the optimum waveforms are rectangular pulses which have a slight overlap in time as shown in Fig. 4.4. It is not usually practical to construct input circuits which convert a single input pulse into two almost perfectly shaped rectangular overlapping pulses for the guides, although a suitable circuit for this purpose has been described. In actual practice pulses similar to those shown in Fig. 4.5 are usually used. Although the second guide pulse is very different in shape from the ideal pulses of Fig. 4.4, the only disadvantage in the use of pulses of the shape shown in Fig. 4.5 is that the maximum operating speed of the tube is slightly reduced. The pulse for the second guides is normally obtained by integrating the first guide pulse by means of a simple resistance-capacitance circuit.

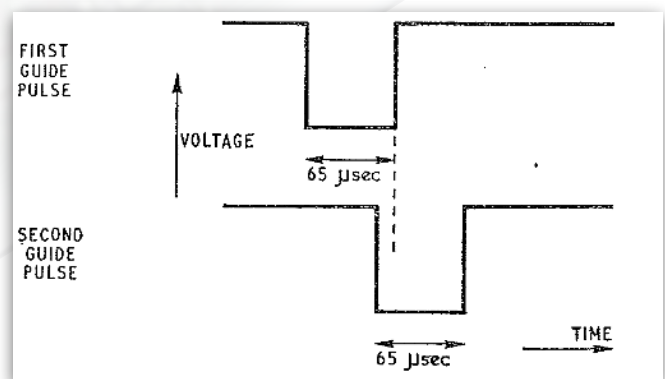


Fig. 4.4 Ideal rectangular negative going pulses for feeding to the first and second guides

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

If the pulse to the second guides is applied too soon after the pulse to the first guides, the discharge will not have been fully transferred to the first guides and the preceding second guide will still be primed to some extent. The discharge will be pulled forward to the first and second guides at the same time as it is being pulled backwards to the preceding second guide with the probable result that no transfer at all will take place. If the first pulse terminates appreciably before the beginning of the second pulse, the glow will transfer to the first guide, but during the interval between the two guide pulses it will return to the main cathode from which it came. When the second guide pulse is applied, it will move one further step in an anti-clockwise direction to the second guide preceding the main cathode at which the discharge initially rested. Finally at the end of the second guide pulse the discharge will return to the initial position at the main cathode.

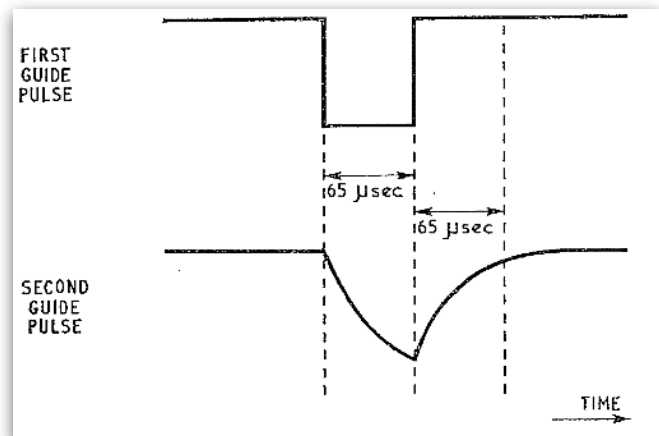


Fig. 4.5 Practical waveforms for 4 kc/s double pulse tubes. The second guides pulses are obtained by integrating the pulses applied to the first guides

New tubes may count correctly if a small gap is present between the two guide pulses, but a minimum overlap of one or two microseconds is essential if the tube characteristics have been affected by long stand-by periods.

4.2.6 Pulse Duration

The pulse applied to the first guides must be of sufficient duration for three successive processes to take place. First of all, the discharge must be established at the first guides and the anode to main cathode glow must be extinguished. Secondly, the priming of the succeeding second guide electrode must take place and, finally, the second guide preceding the main cathode which was initially glowing must have time to become deionised. These processes take a total time of about 65 μsec , but a nominal first guide pulse width of about 75 μsec is recommended so that an adequate allowance can be made for tolerances, etc.

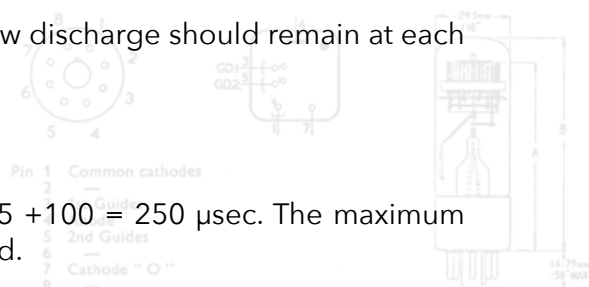
Similarly the pulse applied to the second guide electrodes must be of a sufficient duration for three similar processes to occur. The discharge must be formed at the second guide electrodes and extinguished at the first guides. Secondly, the succeeding main cathode must be primed. In addition the main cathode which was previously glowing must be deionised, but this last process can occur during the total time in which the pulses are applied to the first and second guide electrodes. The required pulse duration to the second guides is about the same as that to the first guides and a minimum of about 75 μsec is recommended.

If the guide bias is 40 V +10 %, it is recommended that the glow discharge should remain at each main cathode for at least 100 μsec .

4.2.7 Maximum Counting Speed

The total time occupied by the three separate steps is $75 + 75 + 100 = 250 \mu\text{sec}$. The maximum speed of operation is, therefore, about 4,000 pulses per second.

Base Connections
(underside view)



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75			mm.	75.5 mm.
B	85			mm.	87.5 mm.

4.2.8 Pulse Amplitude

The use of guide pulses of fairly large amplitude generally results in the most reliable counting. The upper limit of the pulse amplitude is set by the breakdown of the main cathode to guide gap which occurs at a potential of about 140 V. The guide to main cathode voltage should always be appreciably less than this figure or the adjacent main cathode may act as an additional anode, in which case the surface of the electrode would be ruined. In addition, if the guide pulses are too large in amplitude, it is possible for an unprimed guide to strike.

The minimum pulse amplitude which must be applied to the guide electrodes to accomplish the transfer is a function of the pulse duration. It is also dependent on the guide bias ; the greater the positive guide bias, the greater the negative pulse voltage required to overcome this bias and to cause the transfer to occur. If the minimum permissible pulse duration of 65 μsec is employed, the potential difference required between a primed cathode and anode for transfer is about 231 V for Mullard/Philips tubes. The amplitude of the pulse which must be applied to the primed guide cathode is $(231 - V_m)$ where V_m is the maintaining voltage. This pulse amplitude is equal to approximately 35 V. If the pulse length is increased to 100 μsec or more, the required anode to cathode potential is reduced to 214 V so that the negative guide pulses need have an amplitude of only about 18 V. A further increase of pulse length will not reduce the required pulse amplitude any further. These figures apply to the least favourable tubes at the start of life.

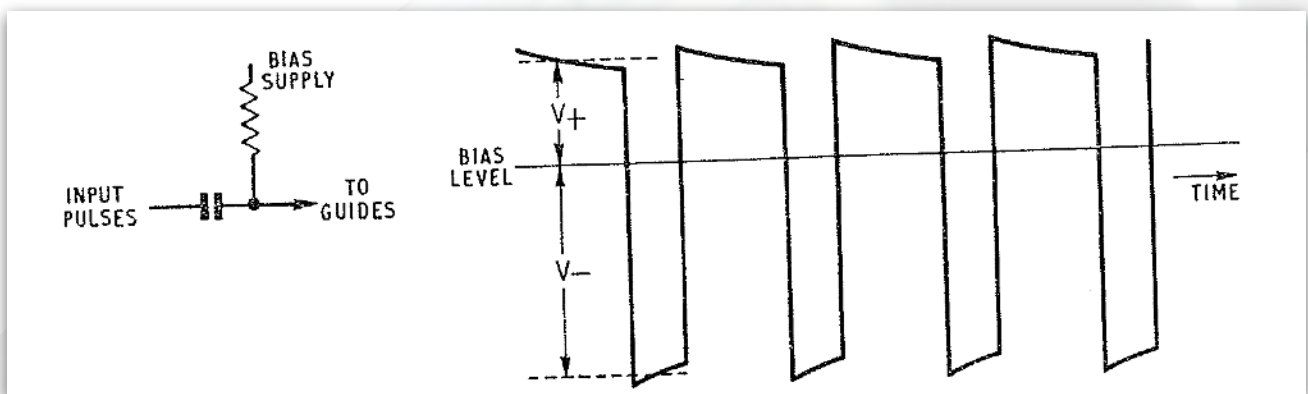


Fig 4.6 Instantaneous guide potential plotted against time

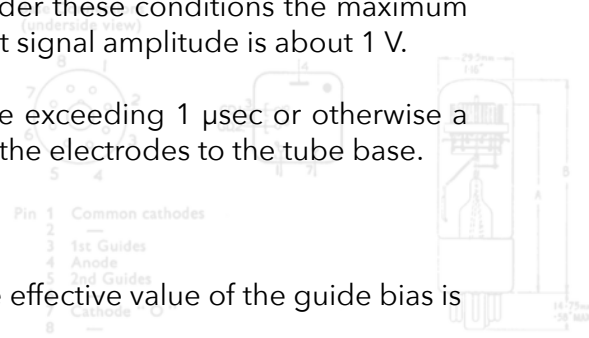
An optimum anode to guide voltage during the pulse of $V_m + 80 \pm 120$ V is recommended for Mullard/Philips 4 kc/s double pulse tubes. This is equivalent to applying a negative pulse to the first guide equal in amplitude to $V_g + 80 \pm 20$ V where V_g is the positive guide bias voltage. It is also recommended that the second guides should receive a pulse of about the same amplitude. A positive guide bias of $+40$ V $\pm 10\%$ is recommended.

If high speeds are not required, 4 kc/s double pulse tubes may be operated with a guide bias of +8 V. Pulses of -15 V in amplitude will then drive the tube. Under these conditions the maximum counting speed is about 700 pulses per second and the output signal amplitude is about 1 V.

The leading edge of the guide pulses should have a rise time exceeding 1 μsec or otherwise a discharge may occur between two of the leads which connect the electrodes to the tube base.

4.2.9 Guide Bias Circuit

When the pulses are fed to the guides through a capacitor, the effective value of the guide bias is



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



different from the applied bias voltage. When a train of rectangular pulses is passed through a capacitor to the guides (Fig. 4.6), the potential at the guide is such that the area of the waveform above the horizontal line representing the applied bias is equal to the area below this line. If the pulse applied to one set of guides is 60 μsec in duration with inter-pulse spacings of 190 μsec and the total voltage swing ($V_+ + V_-$) is 80 V, it can easily be shown that V_+ will be 19.2 V. V_+ is effectively added to the steady bias applied to the guides. If the repetition rate is halved, the interval between the pulses becomes 440 μsec and V_+ falls to 10 V. Thus if either the pulse amplitude or the mark to space ratio can vary and the tube is to be operated at fairly high speeds, it is essential to use clamping diodes to ensure that the guide bias is kept constant.

The internal resistance of the bias supply for the guides (R in Fig. 4.7) also requires some consideration. Immediately after a pulse is applied to the guides, the coupling capacitor, C, begins to charge from V_g through the resistor R and also from the current passing through the tube; this charging current also passes through the internal resistance R' of the source of the guide pulses. The potential of the guide rises and if C is small it may rise so much that the discharge moves from the guide whilst the pulse is still being applied to it. R and C should, therefore, be large during the time that the pulse is applied so that C does not charge appreciably from V_g .

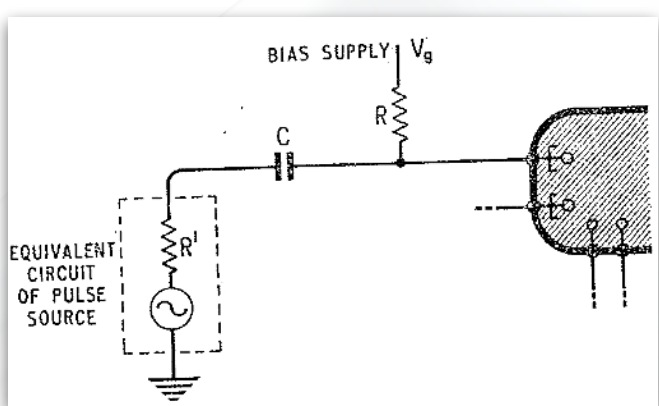


Fig. 4.7 Bias supply impedance

At the end of the guide pulse, however, it is desirable that R and C should be small so that C can be discharged through R and R' in series before the next pulse arrives.

In practice one satisfactory arrangement consists in the use of a fairly large value for C and a diode for R. The diode presents a large impedance during the pulse, but its resistance is very low as C discharges by sending a current through it in the forward direction. The use of a potentiometer to supply the guide bias for a number of double pulse tubes is only permissible when the potential divider resistance values are so low that the guide currents of all stages together cause a bias change of only a few volts. Adequate decoupling should be provided.

4.2.10 Basic Guide Integrator Circuit

Normally two suitable separate input pulses are not available for the operation of a double pulse tube and therefore the pulse required for the second guides must be obtained from that applied to the first guides. In practice the second guide pulse is almost always obtained by passing the first guide pulse through a simple integrating circuit (see Fig. 4.8). The pulse is delayed by the desired amount, but its amplitude may be reduced somewhat by the integrating circuit. The circuit design is fairly critical, since a compromise between the desired second guide pulse amplitude, width

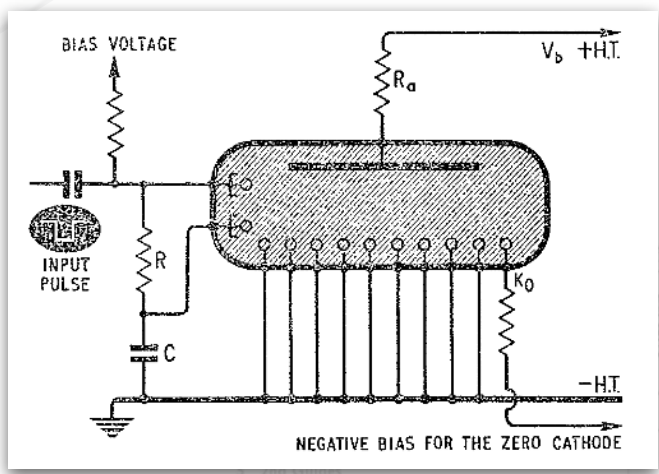


Fig. 4.8 The basic RC integrator circuit for obtaining

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	75			mm.	75.5 mm.
B	85			mm.	87.5 mm.



and delay must be made. Numerous pulse shapes are possible, but satisfactory results will normally be obtained if a voltage at least equal to the minimum recommended transfer voltage is maintained for at least the minimum recommended transfer time with a suitable overlap. The form of the integrated second guide pulse is shown in Fig. 4.5.

When the negative going input pulse of about 120 V in amplitude is applied to the input of the circuit of Fig. 4.8, the first guide potential falls and the capacitor C begins to charge from the negative pulse. The time constant for this charging is determined by the values of R and C; by a suitable choice of these components the potential of the second guides can be made to reach the transfer potential after any desired time.

At the end of the input pulse the first guide potential rises immediately to the guide bias voltage, but the capacitor C takes time to discharge through the resistor R and the bias supply resistors. The second guide potential thus rises exponentially to the guide bias level as shown in Fig. 4.5 and the transfer is then complete.

4.2.11 Anode Capacity

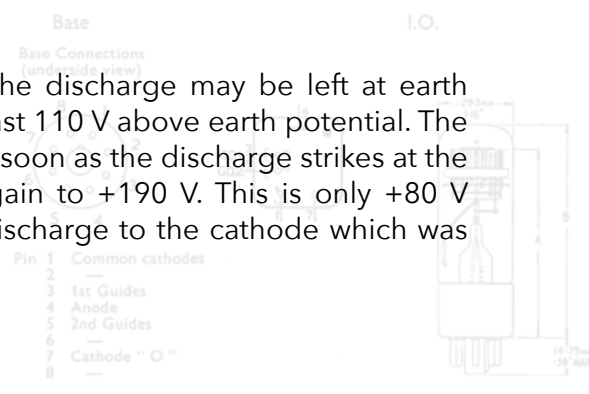
If the tube anode to cathode capacity is excessive, the anode potential may be prevented from rising rapidly as the guide potential rises at the end of the second guide pulse. The anode to second guide potential may then fall below the maintaining voltage of the tube so that the glow is extinguished. The anode voltage will rise and ignition may occur at any of the ten main cathodes. This difficulty is most likely to occur when the trailing edge of the second guide pulse is steep; for this reason the slope of the trailing edge should not exceed 100 μ sec. Stray anode circuit capacitance should also be minimised by soldering the anode resistor directly to the tag of the tube base. The problems associated with the anode circuit capacity become much more acute when high speed cold cathode tubes are used.

4.2.12 Reset

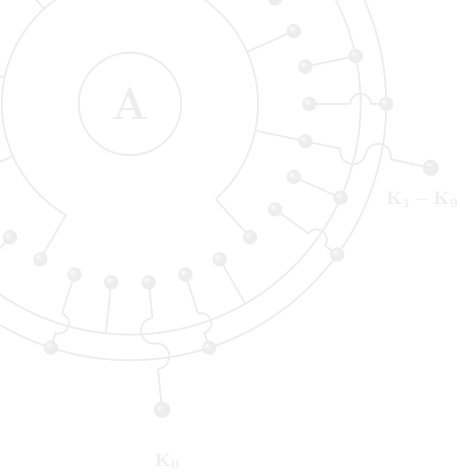
When a discharge is present at any place in a 4 kc/s double pulse tube, the striking voltage of any anode to cathode gap does not exceed about 300 V. The discharge may, therefore, be reset to zero (or, in the case of a selector tube, to any desired digit) by causing the above potential difference to be present for a short time across the gap to which it is desired transfer the discharge. There are two basic methods by which this may be accomplished.

If the glowing cathode is earthed, the anode potential will be about +190 V with respect to earth. If any other cathode receives a pulse which reduces its potential to at least 110 V below earth potential, this cathode will strike. The anode voltage will fall to +80 V so that the potential across the tube is equal to the maintaining voltage. The cathode which was initially glowing will therefore be extinguished.

Alternatively the cathode to which it is desired to transfer the discharge may be left at earth potential and all of the other cathodes may be pulsed to at least 110 V above earth potential. The anode potential will commence to rise towards +300 V, but as soon as the discharge strikes at the desired anode-cathode gap, the anode potential will fall again to +190 V. This is only +80 V higher than the potential of all the other cathodes and the discharge to the cathode which was initially glowing will, therefore, be extinguished.

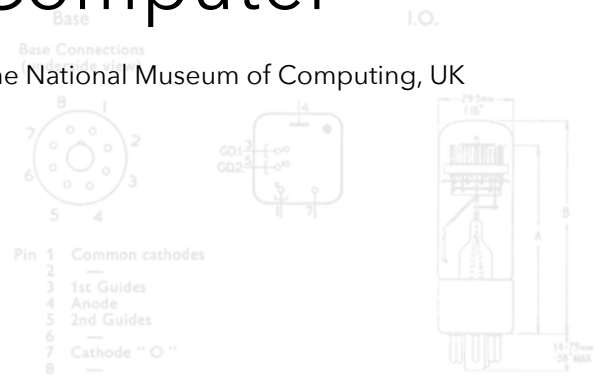


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



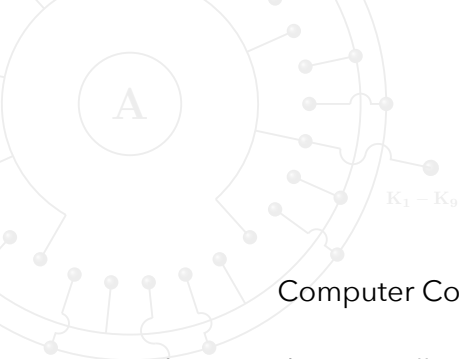
The Harwell Dekatron Computer

An Excerpt by Kevin Murrell - Computer Conservation Society and The National Museum of Computing, UK



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72	72	72	75.5	75.5
B	85	85	85	87.5	87.5





The Harwell Dekatron Computer

Kevin Murrell

Computer Conservation Society and The National Museum of Computing, UK

Abstract. The Harwell Dekatron Computer is a very early digital computer designed and built by the British Atomic Energy Research Establishment in 1952. The computer used British Post Office relays for control and sequencing, and Dekatron counting tubes for storage. After several years' service, it was passed to a college where it was used to teach computer programming, before being lost to various storage centres. In 2008 the machine was re-discovered and the decision was made to restore the computer to working order. This paper describes the machine and the choices and decisions made during the restoration process.

Keywords: Harwell Dekatron Computer, restoration, WITCH, National Museum of Computing, Dekatrons.

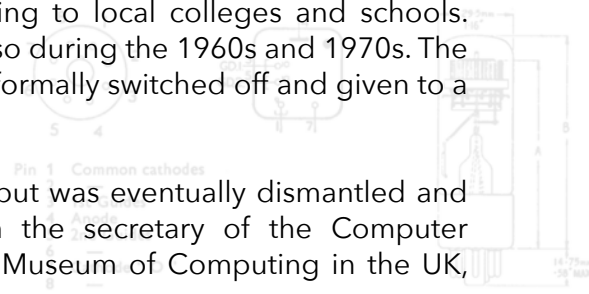
Introduction: Restoring the Harwell Dekatron Computer

Design of the computer began in 1949 using techniques that were generally well understood, and used components that were available to the Harwell engineers at the time. There seem to have been remarkably few problems with the design when it came to commissioning the machine and running the first few tests, and the computer was completed and first made to work properly in April 1951 using just two of the store units. This was sufficient to prove the machine was functioning correctly, and to allow simple programs to be written to test the machine more fully. By 1952, the team had added the remaining Dekatron store units and handed the computer over to the theoretical physics division for proper use.

The very conservative design of the computer was quite deliberate as it led to a reliable workhorse that could be left unattended to plough through a long series of calculations. Harwell kept precise records of the work done by the computer, and in a paper published in 1953 it was reported that in its first year with the division, from May 1952 to February 1953, the machine ran on average 92½ hours each week or for 55% of the total available time. Typically any lost time was when the machine had finished its allotted tasks and was waiting for its operators to arrive the next morning!

By 1957, the mathematicians at Harwell were making little use of the Dekatron Computer, but did not wish to see the machine broken up, so an imaginative competition was devised to make further use of the computer and give it a new home in education. On the 25th February 1957, Wolverhampton and Staffordshire College of Technology announced to the world they had won the competition and would soon receive the computer from Harwell. The official commissioning day in Wolverhampton was Wednesday, 4th December 1957, and at this point the machine was re-christened 'WITCH' - the 'Wolverhampton Instrument for Teaching Computation from Harwell'. The college quickly established both a full time degree and a Diploma in Technology, and ran regular courses, many in the evening, to introduce computing to local colleges and schools. Computing moves at a frenetic pace, and this was especially so during the 1960s and 1970s. The college made full use of the computer until 1973 when it was formally switched off and given to a local museum.

The computer was displayed in the museum for some time, but was eventually dismantled and put into long-term storage. In 2008, the author, by then the secretary of the Computer Conservation Society and a founder trustee of The National Museum of Computing in the UK,



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

discovered a few parts of the machine and set about tracking down the remains of the computer. Quite quickly we discovered the bulk of the computer, albeit broken down into many pieces.

By now, there was a feeling of genuine excitement that this machine could be restored to working order and presented again for the public to see and appreciate. The work on collecting information about the machine continued in earnest, and again fate intervened when at an unrelated BCS (British Computer Society) meeting, we were given the contact details for Ted Cooke-Yarborough who was living near Abingdon - not far from Harwell. Ted was able to contact Dick Barnes, and very soon a meeting was arranged to tell them of our re-discovery of the machine and our plans for its restoration. The project team travelled to Abingdon in March 2009 to meet the two engineers to show them the results of our investigations and discuss our hopes to restore the machine to full working order. Barnes had kept a scrapbook of newspaper cuttings that proved very useful in understanding the history of the machine.

In April 2009 the project team wrote a formal restoration project plan to define what we hoped to achieve, what we needed to complete the project, and to detail any risks along the way. This plan was presented to the Computer Conservation Society (CCS) in May 2009 and was accepted as a new CCS Working Party. The CCS also kindly offered funds towards the initial costs of the project.

Some of the considerations we discussed were:

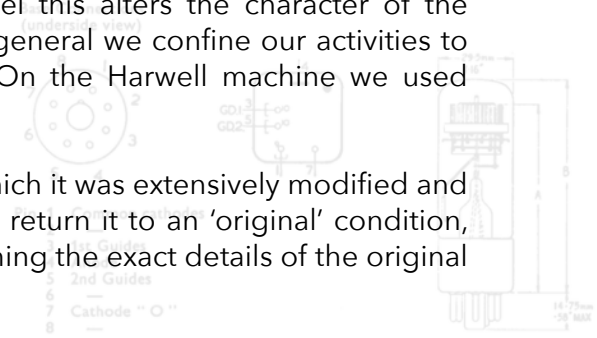
- Might we simply re-assemble the machine back to its original condition?
- Is enough of the original system available to consider its restoration to working order?
- Do we have the necessary tools and documentation?
- Do we have the sufficient spare parts that might be needed?
- How do we decide what might be replaced?
- Is original software available or accessible?
- Do we have the funds and the space to do this?

In September 2009, the machine was moved to its new home - the Large Systems Gallery at the National Museum of Computing. Even before any restoration work commenced, it was already attracting the curiosity of visitors, many of whom had never seen a computer looking anything like this machine with its rows of Dekatrons, valves and trigger tubes, and mysterious grey canisters filled with relays.

Our objective therefore was to restore the machine to a state where it could be reliably and safely operated for demonstration to the public and the many educational and corporate groups who visit the museum.

In common with all our restoration work, the philosophy is to change as little as possible, particularly external appearance. Although it may be tempting to re-spray a rusty old machine, as one might routinely do when restoring a classic car, we feel this alters the character of the machine - we want our historic exhibits to look their age! In general we confine our activities to cleaning and conservation to prevent further degradation. On the Harwell machine we used electrolysis to treat the areas worst affected by rust.

This computer has had a uniquely long working life, during which it was extensively modified and repaired. We decided early on that we would not attempt to return it to an 'original' condition, and indeed, as work progressed, it became clear that establishing the exact details of the original design would be rather difficult in some areas.



Dimension	Nominal	GC108		GC108/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

Particularly in the power supplies, it was necessary to replace failed elderly components that are no longer available, some of these being quite prominently visible. In those cases the original components have been left in place, with the much smaller modern replacement components hidden from view. This helps to ensure the machine retains its unique character.

Restoration work fell into three main categories: relays, mechanical, and electronics. The machine came with full circuit diagrams, and an excellent detailed technical description written by Dick Barnes at Harwell. There was also a reasonable quantity of spare components.

Once work had begun in earnest we quickly discovered that the machine deviated from the diagrams in a number of areas, and furthermore that modifications had been made for which documentation hasn't survived. This has made the work more challenging than it might otherwise have been, and efforts are still on-going to fully document the machine in its current state.

Relays

The machine was built using Post Office 3000 type relays, which were at the time a mature and well understood technology. They were designed to operate for decades in the harsh environment of a telephone exchange, and consequently were extremely well made. A number of relays were discovered with bent contacts, and one concern was they may have been deliberately set out of normal adjustment to compensate for some timing problem within the design of the machine. In the event we have discovered very few areas that depend critically on relative relay timings.

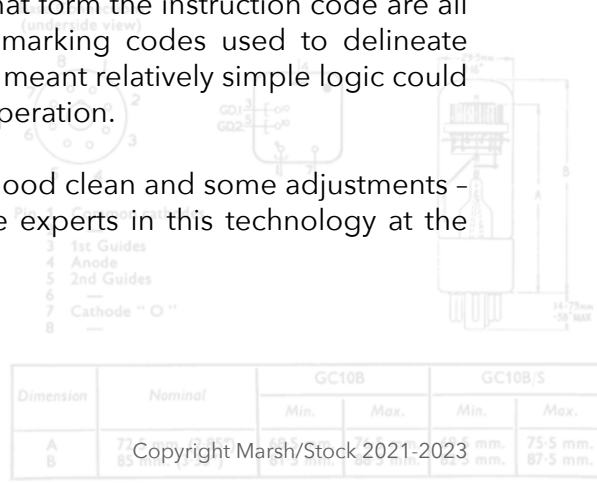
The long and tedious job of relay adjustment has been rewarded by relatively trouble free operation of the complex relay logic of the machine, which at the time of writing has been working for over two years. During this period the machine has been regularly demonstrated to museum visitors by means of a simple program that reads from two tape readers alternately using block search and transfer control instructions. We anticipate an on-going need for periodic cleaning and adjustment of the relay sets.

Mechanical

The output equipment consists of a Creed 7B printer, a Creed 75 tele-printer and a Creed 7TR re-perforator. All of these were specially modified at Harwell to operate with this machine. The printer and re-perforator date from the early 1940s, and so pre-date the rest of the machine by quite a few years.

The standard Creed models used serial I/O - a more primitive version of the RS-232 serial port which until recently could be found on every modern PC. By contrast this machine uses parallel 5-wire I/O. There are standard 5-bit character codes, but in common with many other early computers this machine used a custom character set. One reason for this was to simplify the logic required to assure correct operation - thus the numbers 0-9 that form the instruction code are all represented by combinations of two holes, and the block marking codes used to delineate program or data sections by combinations of three holes. This meant relatively simple logic could detect when an unexpected code was encountered and halt operation.

Restoration of these machines involved nothing more than a good clean and some adjustments - they really were built to last! Again we are fortunate to have experts in this technology at the museum who were able to carry out the work.



Electronics

Sequence control is entirely relay based, but arithmetic is all electronic, built using valves, trigger tubes and Dekatrons. There are also two high voltage power supply units - the rectifier unit converts the AC mains into several high DC voltages, and the stabiliser unit generates about a dozen precise DC voltages for use in the various circuits.

The rectifier unit has been extensively modified during the operational life of the machine, and now sports a variety of rectification technologies dating from the 1950s (copper oxide) to the present day (silicon diodes). We had to replace some of the original copper oxide rectifiers with modern components, but others had already been replaced during the machine's time at Wolverhampton. The other major problem in this unit was a leaking oil-filled transformer, eventually solved by copious use of Araldite. All the transformers in the machine were tested to ensure the insulation was still in good condition.

Once the power supplies were operating reliably we turned our attention to the pulse generator, which is one of the most complex parts of the machine. Its main job is to generate various sequences of pulses to step the Dekatrons, but it also has a hand in starting arithmetic operations, deciding when they are complete, and controlling the transfer and carry units which perform the actual addition and subtraction operations. Some of the subtler (and undocumented) aspects of its operation only became clear when it was back on the racks and interacting with the rest of the machine.

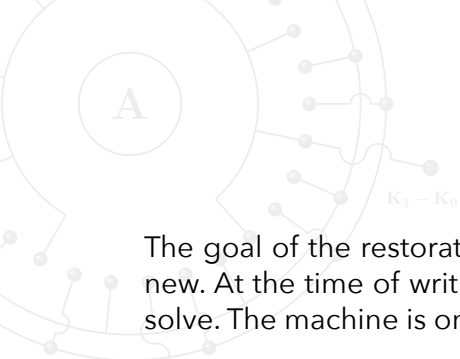
The majority of the work was done with the pulse generator on the bench, with a few switches connected up to provide control inputs. We found around half a dozen failed components - mainly diodes and capacitors. The other major issue has proven to be the high-speed trigger tubes which start and stop the Dekatron used in the pulse generator to count out ten pulses. We had a large supply of spare tubes that came with the machine, but the majority turned out not to work. We were lucky to find a supplier who allowed us to test their entire stock of several hundred, but this only yielded a small number of working ones, and some of these no longer work at the time of writing. The most likely explanation is the gas has escaped around where the pins enter the base - this is surprising since the problem of making valves reliably gas tight had been largely solved by the early 1950s. Keeping the machine running long term will eventually require a modification of these circuits to use a more reliable type of trigger tube.

The remainder of the units in the arithmetic rack were repaired one at a time on the bench with the help of the pulse generator and power supplies. These consist of the two halves of the accumulator, which also contain plug-in transfer and carry modules, and the translator unit that converts between 5-wire code and Dekatron compatible pulse trains. The translator is used both when reading numbers from tape into store and when printing out from store. No major issues were found with any of these units bar a handful of failed components.

With the arithmetic rack completed we turned our attention to the stores. The only major problem that Dekatrons suffer from is contamination of adjacent electrodes due to the glow being left on one cathode for a long period of time. This results in 'sticky' operation - either the glow won't reliably step past a particular cathode, or jumps straight over it. Both of these problems cause an incorrect answer. Luckily the process can be reversed by simply allowing the Dekatron to 'spin' for a long enough period.

No detailed operational log of the machine survives, but it's likely some of these faults have been present for many years and were probably partly responsible for the unreliability which we know the machine developed in its later life. These circuits must only just have worked when the machine was new, and hence even small component value changes caused a problem.

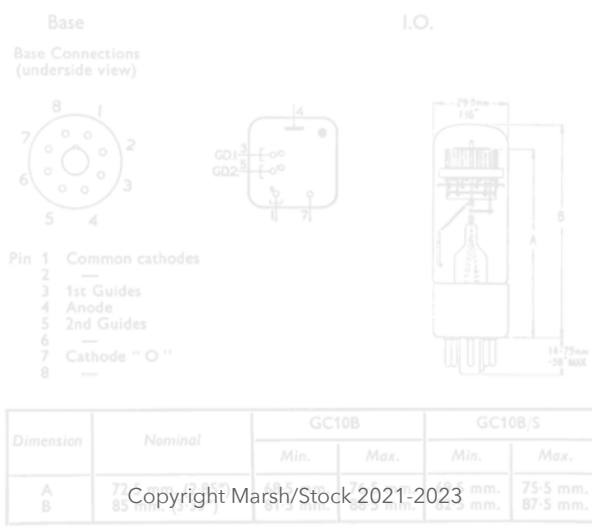
Dimension	Nominal	GC10B		GC10B S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

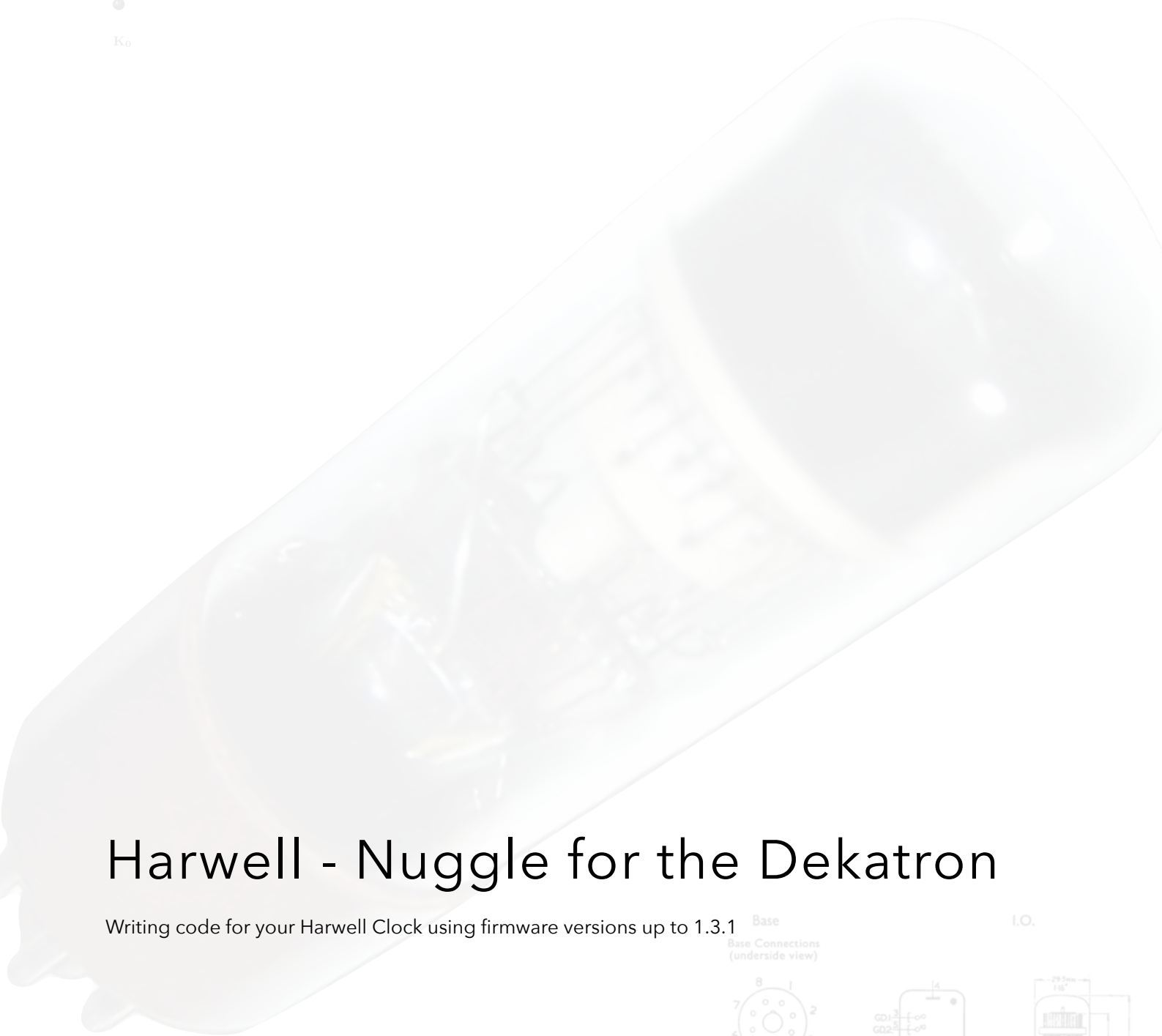
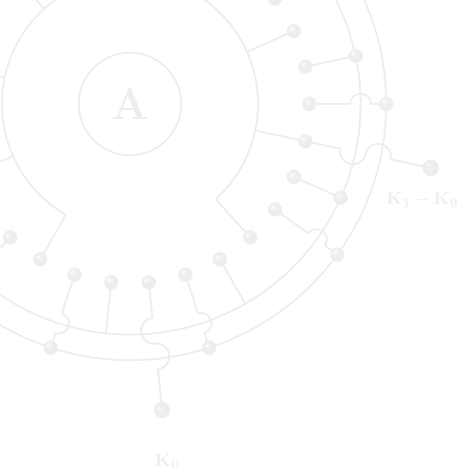


The goal of the restoration was to have the machine fully working and as reliable as it was when new. At the time of writing this has largely been achieved, with only a few reliability issues left to solve. The machine is once again able to run the original programs written for it in the 1950s.

The museum plans to produce teachers and students information packs about the machine that can be downloaded in advance of their visit. The packs will include detailed instructions on how the machine is programmed, example programs and potential programming challenges. We also hope to include a software emulation of the computer so that students can prepare programs prior to their visit, and then on the day actually run them on the live machine.

Very little remains of the history of computing in the UK from the late 1940s and early 1950s, and we are very lucky that this machine has led such a charmed life and managed to 'avoid the chop' on several occasions. Its important early role in pioneering nuclear technology, its long second life in education, and its third life as a museum exhibit enthusing young people, can now continue as an active machine enthusing and helping train a new generation of engineers and programmers.





Harwell - Nuggle for the Dekatron

Writing code for your Harwell Clock using firmware versions up to 1.3.1

Base

Base Connections
(underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



I.O.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	

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1. Introduction

Nuggle¹⁶⁰ supplementary documentation for the Harwell Dekatron Clock

2. Basic Language Elements

Reserved Words

Reserved words that are new or have a specific meaning for the Harwell version of Nuggle are:

Colon, Dekatron, Dekatron6, Dekatron7, DekatronReset, Effect, Flyback, GPIO, Saver, WriteDekatron

5. Program Heading and Program Block

System Defined Number Variables

There are no additional system defined number variables for the Harwell Clock.

Statement Part

Harwell Clock specific events are described in section 10.

7. Functions

Harwell Clock specific function designators are as follows:

Standard System Functions

Colon

Syntax: Colon (*side*)

Returns the intensity value from the colon indicator given by *side*. The returned value will be in the range 0 (off) to 100 (maximum brightness). The argument *side* can be 1 for the left colon and 2 for the right colon.

Dekatron

Syntax: Dekatron (*tube*)

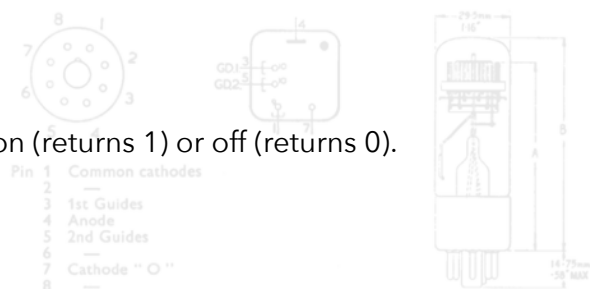
Returns the position of the Dekatron tube. The value will be from 0 to 9 if the tube is glowing and has 10 cathodes and 0 to 11 if it has 12 cathodes, or -1 if the tube position is undefined as the flyback supply is off.

Flyback

Syntax: Flyback ()

Returns the boolean value if the Dekatron HT supply is on (returns 1) or off (returns 0).

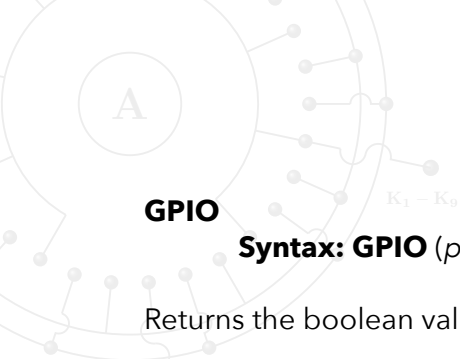
Base Connections
(underside view)



¹⁶⁰ See the Sgitheach Nuggle Manual for details

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





GPIO

Syntax: GPIO (*pin*)

Returns the boolean value of the GPIO *pin* as follows:

Pin	Location	SAM3X8C port and pin
K_0 5	Back of PCB	Port A Pin 5
7	Back of PCB	Port A Pin 7
10	Pin 3 Connector X8	Port A Pin 10
11	Pin 2 Connector X8	Port A Pin 11
25	Back of PCB	Port B Pin 25
28	Back of PCB	Port B Pin 28
29	Back of PCB	Port B Pin 29
31	Back of PCB	Port B Pin 31
500	500V flyback on/off	N/A

9. Procedures

Colon

Syntax: Colon *side, intensity*

Set the colon indicated by *side* to brightness *intensity*. The argument *side* can be 1 for the left colon and 2 for the right colon. The *intensity* argument takes a value from 0 (colons are dark) to 100 (colons are at maximum brightness).

Dekatron

Syntax: Dekatron *tube, value*

Move the glow on the tube to the position *value*. The tubes are number 0 (leftmost) to 5 (rightmost) on the top row and 6 (one, centred) on the bottom row. The Dekatron tubes electrodes are 0 (top) clockwise to 9 if the tube has 10 cathodes and 0 (top) clockwise to 11 if the tube has 12 cathodes.

Dekatron6

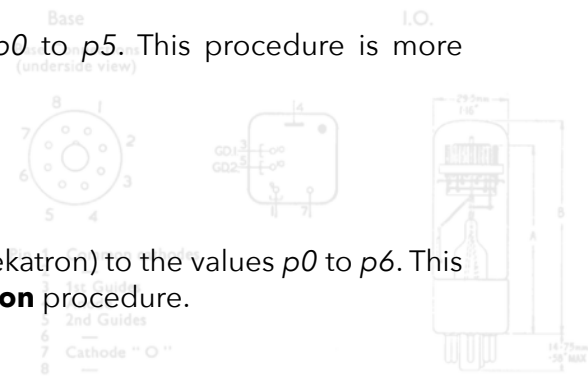
Syntax: Dekatron6 *p0, p1, p2, p3, p4, p5*

Set dekatrons V1 to V5 (the top row) to the values *p0* to *p5*. This procedure is more efficient than using the **WriteDekatron** procedure.

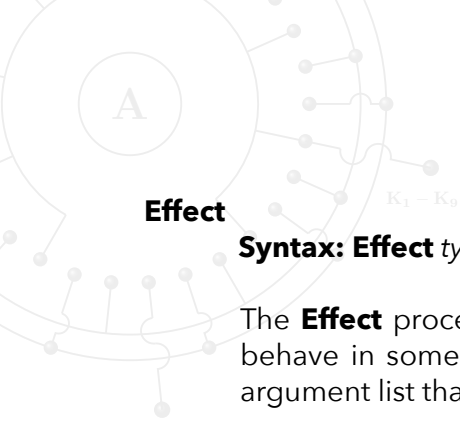
Dekatron7

Syntax: Dekatron7 *p0, p1, p2, p3, p4, p5, p6*

Set dekatrons V1 to V5 (the top row) and V6 (bottom Dekatron) to the values *p0* to *p6*. This procedure is more efficient than using the **WriteDekatron** procedure.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Effect

Syntax: `Effect type [, ...]`

The **Effect** procedure is a macro command that causes a single, or all the Dekatrons, to behave in some way. The first argument is always the effect type and is followed by an argument list that varies according to the effect type.

The effect *type* can be any value from:

Value	Effect Action	Constant name
0	move to a specified cathode (see note 1)	effect_cathode
1	idle (stop any other effect operating) a specified Dekatron and leave the dot where it is	effect_idle
2	idle all dekatrons	effect_idle_all
3	move the dot and go idle	effect_move
4	spin a Dekatron once and go idle	effect_once
5	operate the Dekatron as a pendulum	effect_pendulum
6	show or highlight a position	effect_show
7	continuously spin a Dekatron	effect_spin
8	show or highlight two dot positions	effect_two
9	move a Dekatron to position 0	effect_zero

Notes: **1.** You can specify a glow position by a cathode value or a dot value, note that quite simply $dot = 3 * cathode$ but it is more efficient to use the `effect_cathode` as the multiplication takes place in C rather than Nuggle.

Some of the procedures take a *direction* argument which can be any value from:

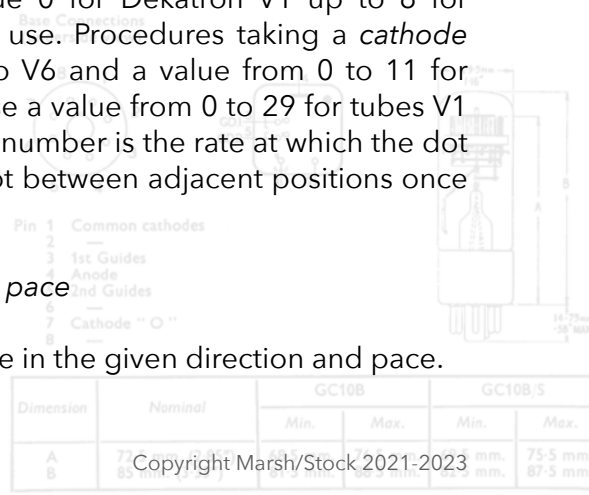
Value	Effect Action	Constant name (2)
0	move forwards i.e. clockwise	dir_forward
1	move backwards i.e. anticlockwise	dir_backward
2	take the shortest route	dir_shortest
3	take the longest route	dir_longest

Notes: **2.** These constant names are also used by the bling GradientHSV procedure.

Procedures taking a *tube* number must use the value 0 for Dekatron V1 up to 6 for Dekatron V7. Constants V1, V2 ... V7 are defined for use. Procedures taking a *cathode* number must use a value from 0 to 9 for tubes V1 to V6 and a value from 0 to 11 for Dekatron V7. Procedures taking a *dot* number must use a value from 0 to 29 for tubes V1 to V6 and a value from 0 to 35 for Dekatron V7. A *pace* number is the rate at which the dot moves per mS e.g. a value of 1000 would move the dot between adjacent positions once per second.

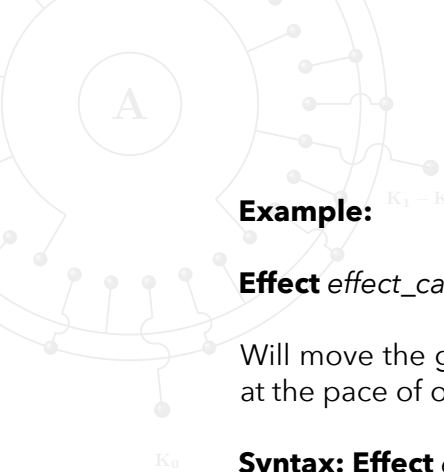
Syntax: `Effect effect_cathode, tube, cathode, direction, pace`

Move the glow position to the required cathode on tube in the given direction and pace.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





Example:

Effect `effect_cathode, V7, 6, dir_shortest, 100`

Will move the glow on the bottom Dekatron, V7, to the cathode, taking the shortest route at the pace of one dot every 100mS

Syntax: Effect `effect_idle, tube`

Stop any other effect that Dekatron tube is operating and leave the dot where it is.

Syntax: Effect `effect_idle_all`

Stop effects on all Dekatrons.

Syntax: Effect `effect_move, tube, dot, direction, pace`

Move the glow position to the required dot on tube in the given direction and pace.

Syntax: Effect `effect_once, tube, direction, pace`

Spin the Dekatron tube once using the *direction*¹⁶¹ and pace given.

Example:

```

For toob := V1 To V6
    Effect effect_once, toob, dir_forward, 10
ForEnd
  
```

Spin Dekatrons V1 to V6 once rapidly in a clockwise direction

Syntax: Effect `effect_pendulum, tube, dot, style, period`

Make the Dekatron act in a the fashion of a pendulum. Dekatron *tube* is used. The starting position is given by *dot*. The glow position will “fall” towards the bottom dot the continue “up” to the corresponding dot position when it will reverse direction and fall again. This cycle is repeated. The rise and fall speed is set by two arguments. The *style can be linear*, where an equal amount of time is spent with each dot glowing, and, *gravity* where the time spent with each dot glowing decreases as the glow position descends then increases again as the dot rises. The *gravity style* gives a simulation of a mechanical pendulum. The *period* value is the time in mS for one swing of the pendulum; there and back again takes 2 * *period* mS.

Example:

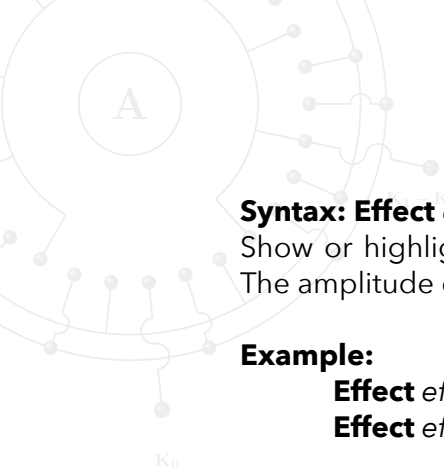
Effect `effect_pendulum, V7, 12, linear, 500`

Dekatron V7 swings back and forth each second in a linear pendulum fashion.



¹⁶¹ Because the starting and ending glow positions are the same *dir_shortest* and *dir_longest* have no meaning and *dir_forward* will be used

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.



Syntax: Effect *effect_show, tube, dot, swing, pace*

Show or highlight, a given *dot* position by oscillating the glow position either side or it. The amplitude of the oscillation is given by *swing* and the rate of motion by *pace*.

Example:

Effect *effect_show, V3, minutes / 2, 3, 10*

Effect *effect_show, V4, minutes / 2, 3, 10*

Highlight the dot position on V3 and V4 based on the *minutes* system variable value.

Syntax: Effect *effect_spin, tube, dot, direction, pace*

Spin a Dekatron *tube*, continuously. The spinner will start from position *dot*, move in *direction*¹⁶² at the given *pace*.

Example:

Effect *effect_spin, V3, 0, dir_forward, 100*

Effect *effect_spin, V4, 0, dir_backward, 100*

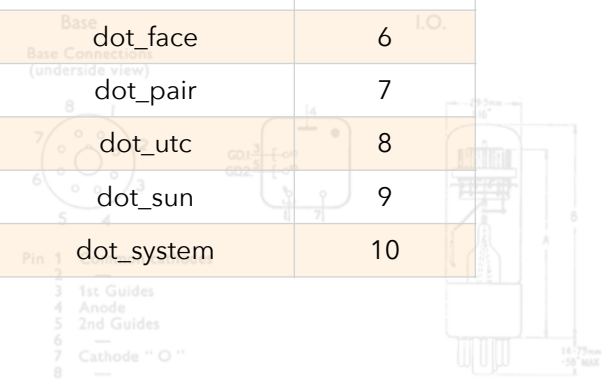
This will spin V3 and V4 in opposite directions. Both Dekatrons will start at the top.

Syntax: Effect *effect_two, tube, cathode1, cathode2, pause*

Highlight two cathodes on Dekatron tube by rapidly moving between them and pausing on each. The two positions are given by *cathode1* and *cathode2*. The pause time is in mS.

Dekatron V7 at the bottom of the clock has engraved labels so the Dekatron can be used to indicate what is displayed on the top six Dekatrons. Each of the labels has a corresponding constant that can be used in this effect.

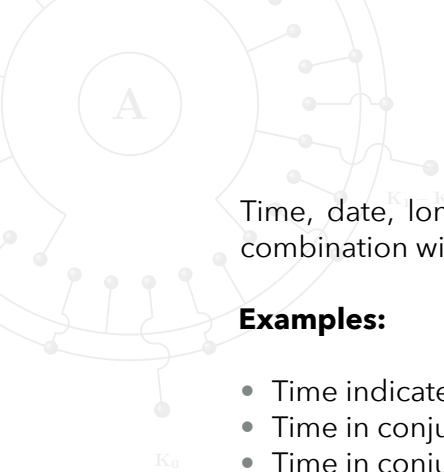
Label	Meaning	Constant	Cathode
Idle	the V7 indicator function is not used	dot_idle	0
Time	a time is displayed	dot_time	1
Date	date	dot_date	2
Long	longitude	dot_longitude	3
Lat	latitude	dot_latitude	4
Elev	elevation	dot_elevation	5
Face	face number is shown or being changed	dot_face	6
Pair	pair value is shown or being changed	dot_pair	7
UTC	date or time is UTC	dot_utc	8
Sun	time, longitude, latitude relate to the sun	dot_sun	9
Sys	system data	dot_system	10



¹⁶² Because this is a spinner, only *dir_forward* and *dir_backward* have meaning

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





Time, date, longitude, latitude, elevation, face and pair can be used in isolation or in combination with UTC, sun and system to give more meanings:

Examples:

- Time indicated alone means the local time is being shown
- Time in conjunction with UTC means that UTC time is being shown
- Time in conjunction with sun shows that a sun related time (such as sun rise or set time)
- Time in conjunction with system shows that the hardware version is being displayed

Obviously the last bullet example is not intuitive and you need to know the system+ meanings. The system dot can be joined with:

Second dot indicated	Meaning
Time	hardware version
Date	firmware version
Long	core temperature
Lat	LDR data
Elev	GPS data
Face	WiFi data

The effect_two is used primarily to display on Dekatron V7 what the other six are being used for.

Example:

```
WriteDekatron "%02d%02d%02d", hour, minute, second
Effect effect_cathode, V7, dot_time, dir_shortest, 1
```

will show the time on dekatrons V1 to V6 and indicate "time" on Dekatron V7.

Example:

```
WriteDekatron "%02d%02d%02d", utc_hour, utc_minute, utc_second
Effect effect_two, V7, dot_utc, dot_time, 1000
```

The UTC time is shown on dekatrons V1 to V6 and, "UTC" and "Time" shown on Dekatron V7.

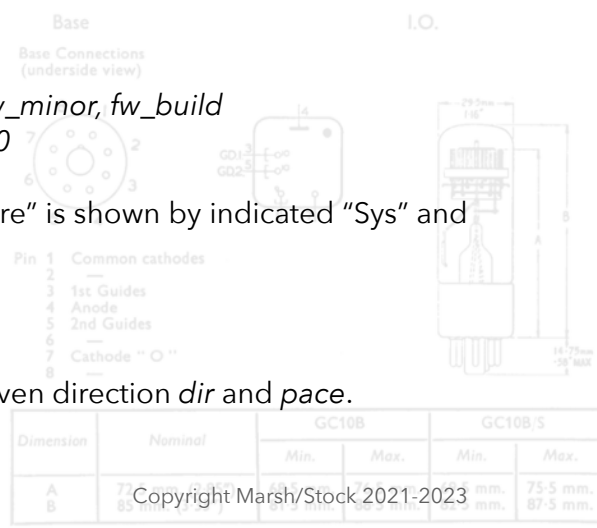
Example:

```
WriteDekatron "%02d%02d%02d", fw_major, fw_minor, fw_build
Effect effect_two, V7, dot_system, dot_date, 1000
```

The firmware version is shown on V1 to V6 and "firmware" is shown by indicated "Sys" and "Date" on Dekatron V7.

Syntax: Effect effect_zero, tube, dir, pace

Move the glow on Dekatron tube to cathode 0 in the given direction dir and pace.



Syntax: Effect *effect_zero_all*

Move the glow on all the Dekatrons to cathode 0.

Flyback

Syntax: Flyback *state*

K₀ Turns the Dekatron HT supply to *state*. Where *state* is true (1) or off (0).

GPIO

Syntax: GPIO *pin, value*

This sets the state of a GPIO *pin* to logical 1 if *value* is true and logical 0 if *value* is false. The available values of *pin* and the GPIO port and pin controlled are as follows:

Pin	Location	SAM3X8C port and pin
5	Back of PCB	Port A Pin 5
7	Back of PCB	Port A Pin 7
10	Pin 3 Connector X8	Port A Pin 10
11	Pin 2 Connector X8	Port A Pin 11
25	Back of PCB	Port B Pin 25
28	Back of PCB	Port B Pin 28
29	Back of PCB	Port B Pin 29
31	Back of PCB	Port B Pin 31
500	500V flyback on/off	N/A

Saver

Syntax: Saver *value*

Specify the "screen saver" display to be used with the current clock face overriding the default saver. The argument value is the index of a Nuggle program defined in *nuggle.ini*.

Example:

Saver 402

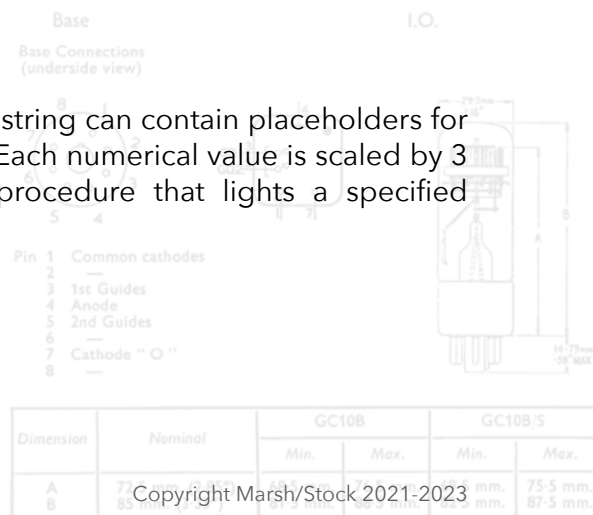
WriteDekatron

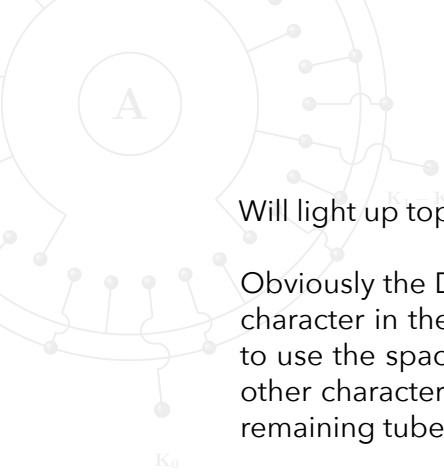
Syntax: WriteDekatron *Str, [, ...]*

Writes the string *Str* to the top six Dekatron tubes. The string can contain placeholders for the optional comma separated arguments that follow. Each numerical value is scaled by 3 to light the correct cathode (unlike the Dekatron procedure that lights a specified electrode).

Example:

WriteDekatron "012317"





Will light up top row of six Dekatrons using this test pattern.

Obviously the Dekatron tubes are limited to displaying the numbers '0' to '9' so any other character in the string *Str* will be ignored by the corresponding tube. It is recommended to use the space character. Only the first six characters of the string will be used and any other characters that follow are ignored. If the string is shorter than 6 characters then the remaining tubes are not changed.

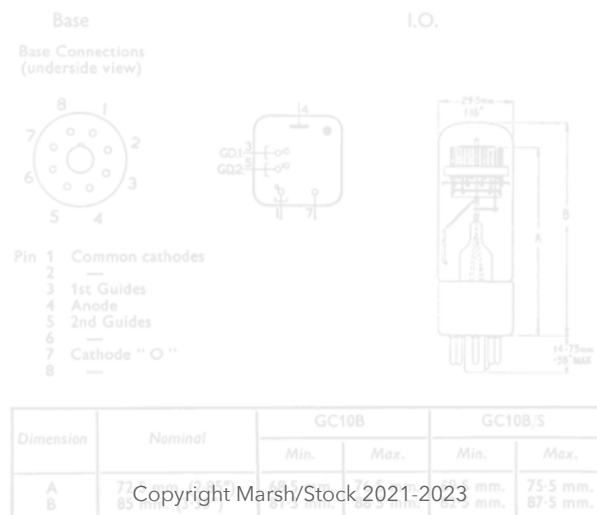
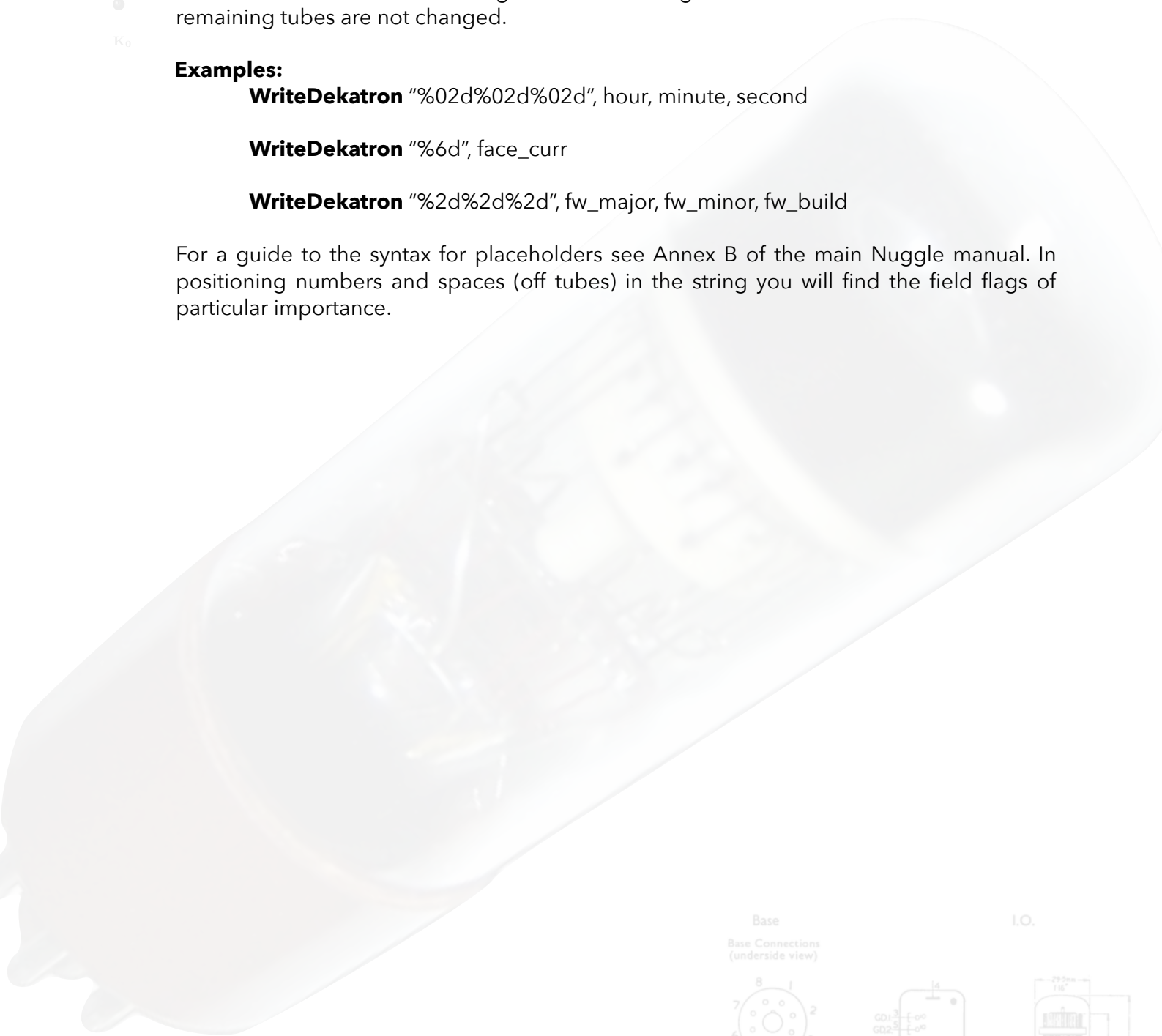
Examples:

WriteDekatron "%02d%02d%02d", hour, minute, second

WriteDekatron "%6d", face_curr

WriteDekatron "%2d%2d%2d", fw_major, fw_minor, fw_build

For a guide to the syntax for placeholders see Annex B of the main Nuggle manual. In positioning numbers and spaces (off tubes) in the string you will find the field flags of particular importance.



10. Events

Event Happenings

There are no additional event happenings.

Event Default Actions

The Harwell Dekatron clock has the following event default actions:

Event Label:	Default Action:
event_encoder:	If the clock is asleep (any stage) it wakes up. Clock face or sound volume changed. See below.
event_ir:	If the clock is asleep (any stage) it wakes up. See below for other default functions.
event_pir:	If the clock is asleep (any stage) it wakes up.
event_sleep:	The event occurs as the clock wakes up from being asleep and the clock goes from being awake progressively to being asleep. See below.
event_enter:	None
event_leave:	When the Nuggle program is stopping.
event_tick:	None

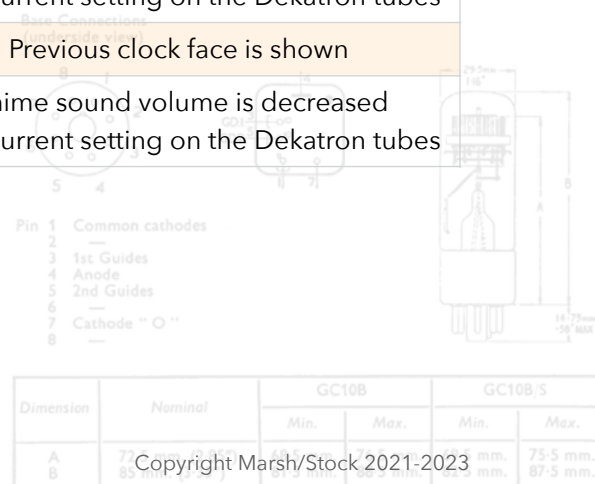
Default Encoder Events

If the encoder is moved clockwise when displaying a clock face, then the next clock face is displayed, if anti-clockwise then the previous face is displayed.

If the encoder button is pressed and it is moved clockwise then the chime sound volume increases, if moved anti-clockwise, then the sound volume decreases.

In summary:

arg_encoder value	Happening	Default Actions
U'	Turned clockwise	Next clock face is shown
+'	Press and turn clockwise	Chime sound volume is increased show current setting on the Dekatron tubes
D'	Turn anticlockwise	Previous clock face is shown
-'	Press and turn anticlockwise	Chime sound volume is decreased show current setting on the Dekatron tubes



Default IR Handset Events

The IR Handset has default actions for all of the buttons.

You can change the volume of the chimes and the beeps, set the pairing number, select a clock face directly or by scrolling through available faces and finally enquire what face number is currently displayed.

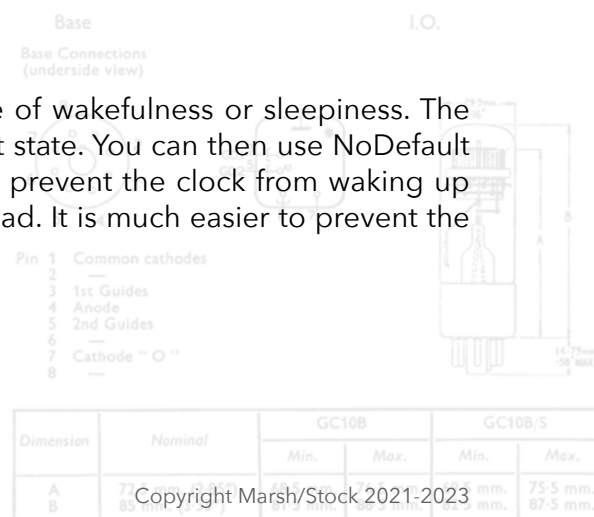
arg_ir value	Happening - button pressed	Default Actions
'U'	CH+	Next clock face is shown
'D'	CH-	Previous clock face is shown
'C'	CH	Display current face on Dekatron tubes
'+'	+	Chime sound volume is increased show current setting on the Dekatron tubes
'-'	-	Chime sound volume is decrease show current setting on the Dekatron tubes
'>'	<<	Beep sound volume is increased show current setting on the Dekatron tubes
'<'	>>	Beep sound volume is decrease show current setting on the Dekatron tubes
'P'	>	Start pair number entry
'0' ... '9'	0 ... 9	Start face number entry
'='	EQ	Pairing number or face number accepted
'H'	100+	In pairing or face entry mode delete last number
'T'	200+	Escape from pairing or face entry mode and discard the entry

Pairing number entry is started with the '>||' key and allows the entry of a number, if it matches the clock pair number then the other keys will operate.

Face number entry allows you to immediately go to a face, if you know its number, without using the CH- and CH+ keys repeatedly.

Default Sleep Events

Invoked when the clock wishes to either go to a higher state of wakefulness or sleepiness. The system variable arg_sleep contains a code to tell you the next state. You can then use NoDefault or Default to allow the state change or not. Obviously, if you prevent the clock from waking up then you will need to use a range of Nuggle commands instead. It is much easier to prevent the clock going to sleep again.



Wake up from being asleep

During the wake up cycle - fully asleep to fully awake - the following states are passed through and actions are taken. The timings of some stages are adjustable in the [sleep] section of system.ini on the SD card.

arg_sleep value	Constant	Actions	[Sleep] key
14	awake_flybackonreq	Request to turn on flyback PSU	
15	awake_flybackon	Flyback PSU turned on	flyback_on = 2 seconds delay
17	awake_complete	Flyback is turned on	
18	awake_release	Request to go to fully awake status	
3	awake_fully	The clock is fully awake	

Going to sleep

During the sleep cycle - going from fully awake to fully asleep - the following states are passed through and actions are taken. The timings of some stages are adjustable in the [sleep] section of system.ini on the SD card.

arg_sleep value	Constant	Actions	[Sleep] key
4	sleep_savercall	Request to invoke the screen saver	
5	sleep_saver	Screen saver displayed	screen_saver = 10 ; minutes delay
6	sleep_flybackoffreq	Request to turn off the flyback PSU	
7	sleep_flybackoff	Flyback PSU turned off	flyback_off = 10 ; minutes delay
9	sleep_release	The clock is about to be fully asleep	
2	sleep_fully	The clock is fully asleep (idle)	

If a wake from sleep trigger is received during these stages the going to sleep process is reversed and the value of *arg_sleep* will change to the relevant waking up state.

If you want to see these processes in action then use the sleep debug system at level 3 (set in system.ini) or write a Nuggle program to do so.

Sleep states, 0, 1, 10, 13 and 16 are used internally and are not sent to the event handler. Sleep states 8, 11 and 12 are not used and are never called.

If the **Default** action takes place at step 5 then the screen saver Nuggle program is run and your program loses control. Your program is then not run again until step 3 has been reached in the wake up cycle. The upshot of this is that your Nuggle program will only receive event steps 4 and 5.



Default Start Events

The default start events are to:

- Set all the Dekatrons to cathode '0'
- Clear all the LEDs to off i.e. black.
- Stop any chime that is playing
- Stop any beep that is sounding
- Set both colons to off, i.e. set the brightness PWM signal to 0 for both colons.

Using **NoDefault** will allow one Nuggle program to take over the display from another without any jitter.

Default Tick Events

The RTC ticks each second and generates an event. The value of the system variable `arg_tick` is set as follows:

arg_tick value	Constant	Highest tick period that has occurred
0	tick_second	1 second
1	tick_minute	1 minute
2	tick_hour	1 hour
3	tick_day	1 day
4	tick_month	1 month
5	tick_year	1 year

For example, a 1 day tick only occurs at 00:00:00 local time. And another example, the year tick only occurs at 00:00:00 on 1st January each year. Time is always local time and takes into account DST and the time zone. The clock UTC tick is not used to generate events.

Miscellaneous Procedures

Clear

Syntax: Clear

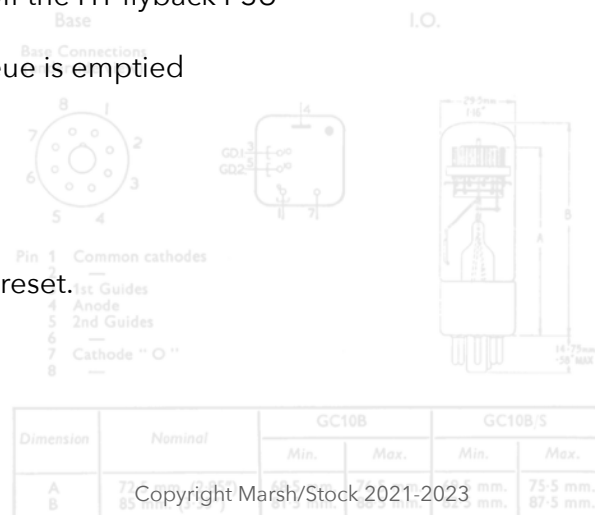
The following happens:

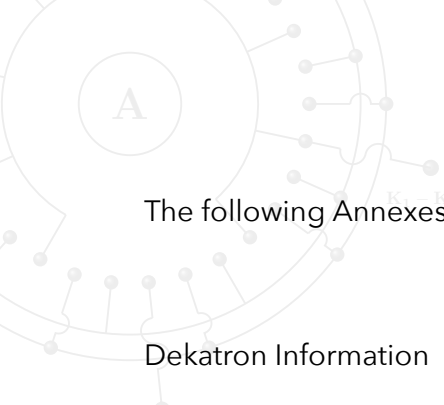
1. Dekatron and colon tubes are blanked by turning off the HT flyback PSU
2. All bling LED are set to *black*, i.e. off
3. Any beep in progress is stopped and the beep queue is emptied
4. Any chime in progress is stopped

DekatronReset

Syntax: DekatronReset

Causes the Dekatron driver slave microcontroller to be reset.



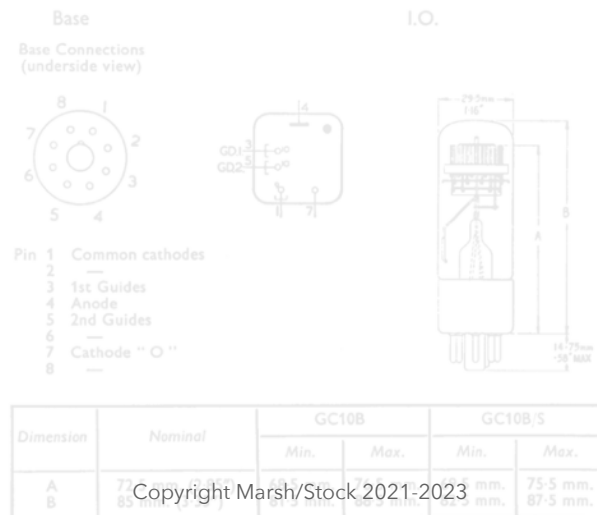


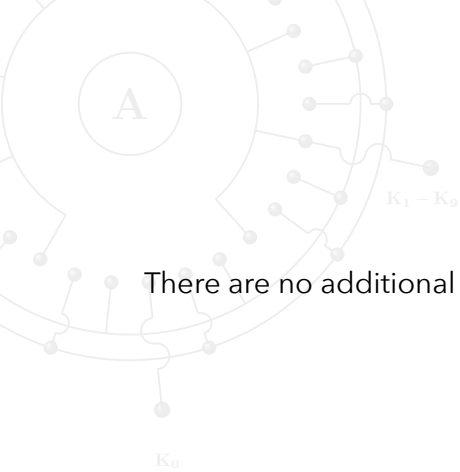
The following Annexes correspond to those detailed in the general Nuggle manual.

Annex A System Variables

Dekatron Information

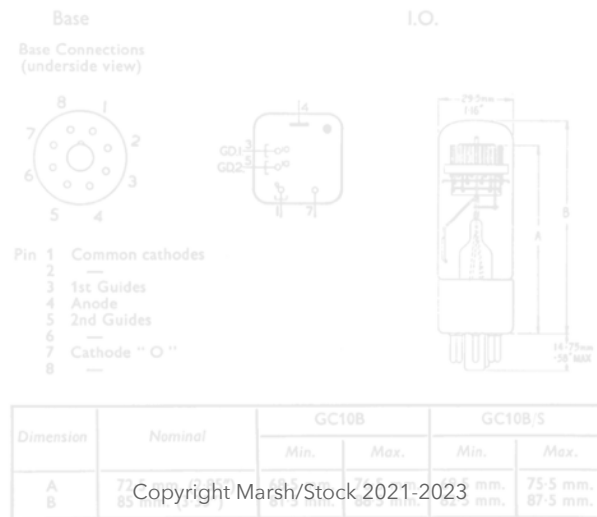
Variable Name	Function	Notes
type12	Is V7 a 12 cathode Dekatron?	boolean





Annex C Fatal Error Messages

There are no additional fatal error messages.

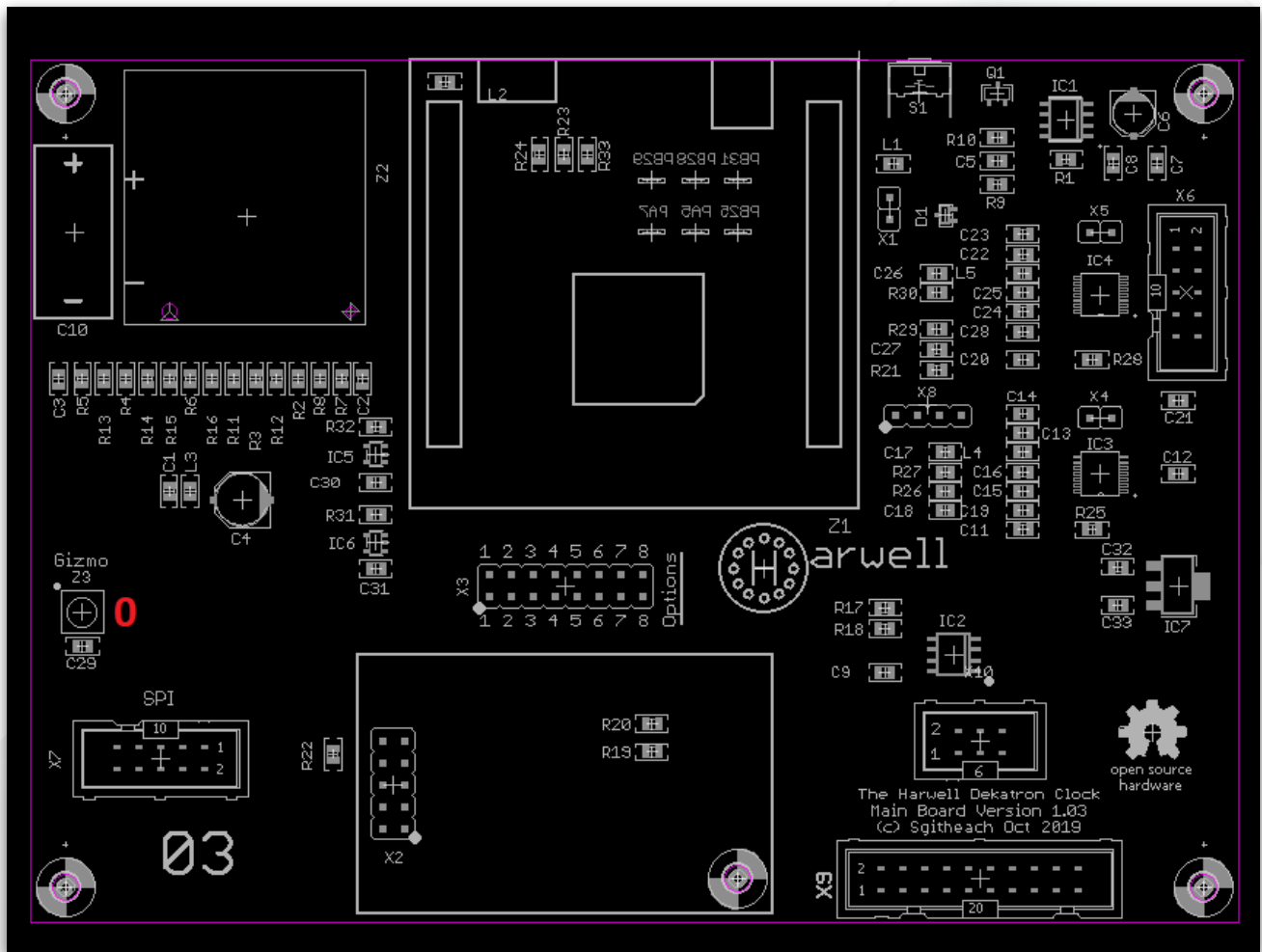


Annex D Bling LED Numbering

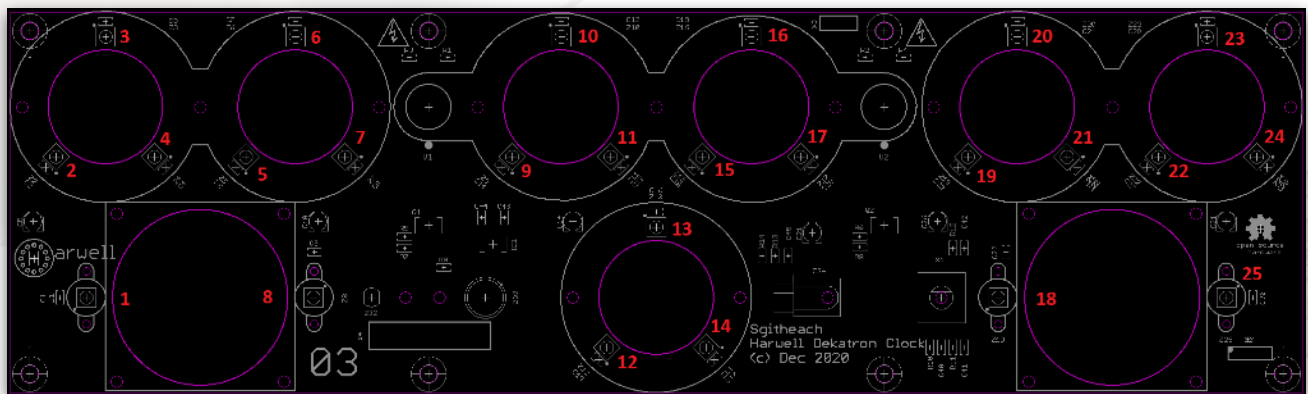
Example of use:

Colour red, 14
Colour red, 23

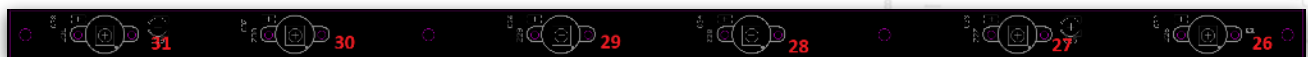
Position numbers of the bling LED modules as viewed from the silkscreen side of the PCB.



Only one bling LED on the Main Processor board - '0'



Bling LED numbering on the light guide board - 1 to 25

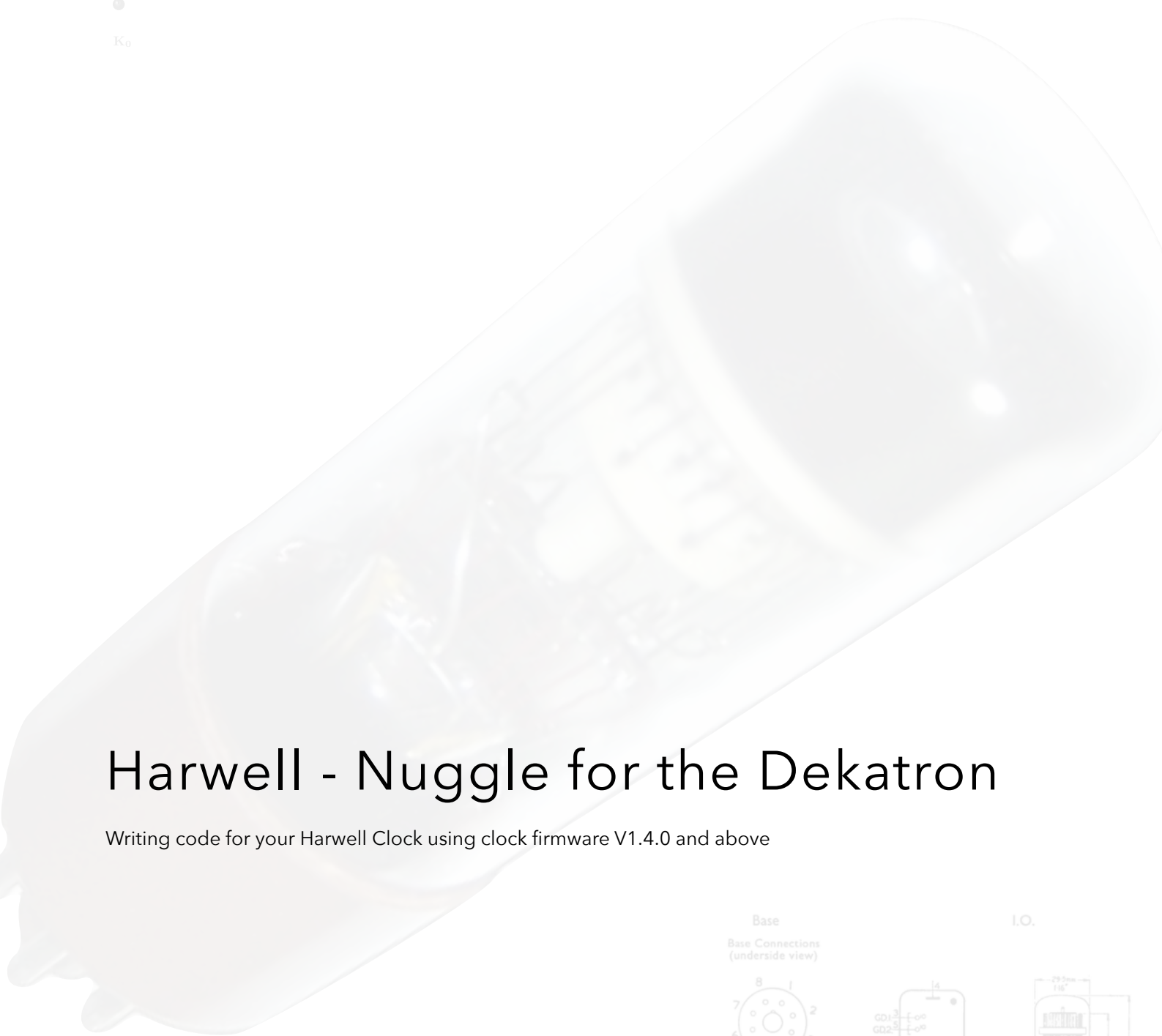
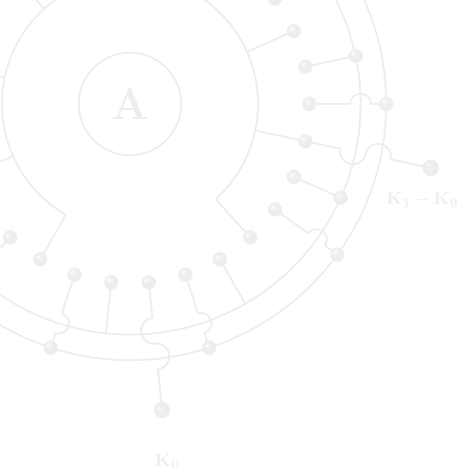


Bling LEDs 26 to 31 on the downward illumination board

	Nominal	Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

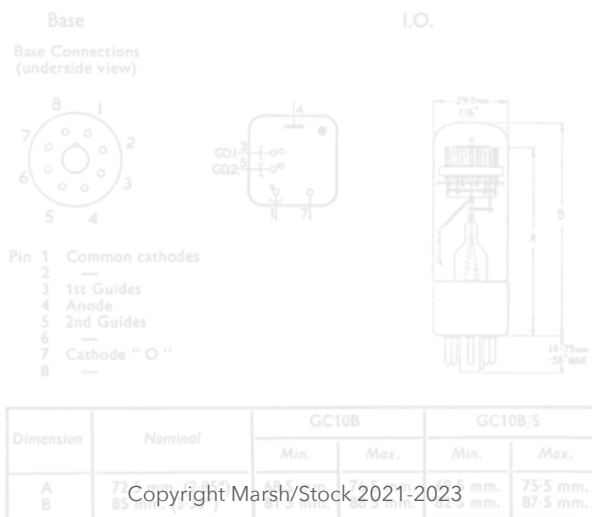
Copyright Marsh/Stock 2021-2023





Harwell - Nuggle for the Dekatron

Writing code for your Harwell Clock using clock firmware V1.4.0 and above



1. Introduction

Nuggle¹⁶³ supplementary documentation for the Harwell Dekatron Clock using clock firmware from version 1.4.0

2. Basic Language Elements

Reserved Words

Reserved words that are new or have a specific meaning for the Harwell version of Nuggle are:

Colon, Dekatron, Flyback, GPIO, Saver

5. Program Heading and Program Block

System Defined Number Variables

There are no additional system defined number variables for the Harwell Clock.

Statement Part

Harwell Clock specific events are described in section 10.

7. Functions

Harwell Clock specific function designators are as follows:

Standard System Functions

Colon

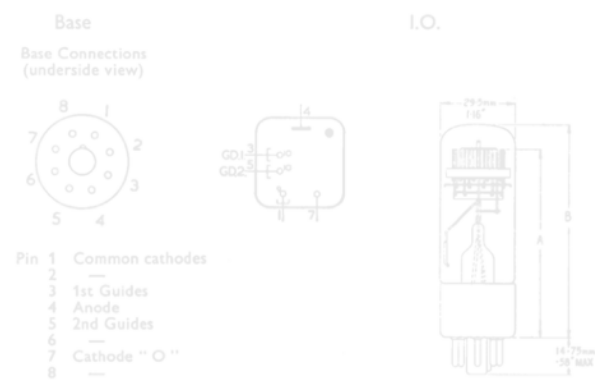
Syntax: Colon (*side*)

Returns the intensity value from the colon indicator given by *side*. The returned value will be in the range 0 (off) to 100 (maximum brightness). The argument *side* can be 1 for the left colon and 2 for the right colon.

Flyback

Syntax: Flyback ()

Returns the boolean value if the Dekatron HT supply is on (returns 1) or off (returns 0).



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	

¹⁶³ See the Sgitheach Nuggle Manual for details

GPIO

Syntax: GPIO (*pin*)

Returns the boolean value of the GPIO *pin* as follows:

Pin	Location	SAM3X8C port and pin
K_0 5	Back of PCB	Port A Pin 5
7	Back of PCB	Port A Pin 7
10	Pin 3 Connector X8	Port A Pin 10
11	Pin 2 Connector X8	Port A Pin 11
25	Back of PCB	Port B Pin 25
28	Back of PCB	Port B Pin 28
29	Back of PCB	Port B Pin 29
31	Back of PCB	Port B Pin 31
500	500V flyback on/off	N/A

9. Procedures

Colon

Syntax: Colon *side, intensity*

Set the colon indicated by *side* to brightness *intensity*. The argument *side* can be 1 for the left colon and 2 for the right colon. The *intensity* argument takes a value from 0 (colons are dark) to 100 (colons are at maximum brightness).

Dekatron

Syntax: Dekatron *dekaAction* [, *arguments*]

All Nuggle **Dekatron** procedures are of the form:

Dekatron *dekaAction, arg0, arg1, arg2...*

Where **Dekatron** is a reserved word (command) and is the lead-in to all bling procedures. *dekaAction* is a constant value for the action you want the dekatron displays to perform such as change a dot position, read a dot position and so on; *arg0, arg1, arg2...* are the other arguments needed by the action execution. Because the *dekaAction* constants are all predeclared any error will be flagged if you try to reuse the identifier for another purpose.

Procedures taking a *tube* number must use the value 0 for Dekatron V1 up to 6 for Dekatron V7. Constants V1, V2 ... V7 are defined for use. Procedures taking a *cathode* number must use a value from 0 to 9 for tubes V1 to V6 and a value from 0 to 11 for Dekatron V7. Procedures taking a *dot* number must use a value from 0 to 29 for tubes V1 to V6 and a value from 0 to 35 for Dekatron V7.

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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A pace number is the rate at which the dot moves per mS e.g. a value of 1000 would move the dot between adjacent positions once per second. If the pace is omitted then a default value of 10mS is used.

Procedures taking a *direction* can use these constants:

Value	Action	Constant name
0	move forwards i.e. clockwise	dir_forward
1	move backwards i.e. anticlockwise	dir_backward
2	take the shortest route	dir_shortest
3	take the longest route	dir_longest

The constant names are also used by the **Bling** *blGradientHSV* procedure. If *direction* is omitted then *dir_shortest* is used by default.

In the following syntax action list, arguments within square brackets [] can be omitted and default values will be used.

Dekatron *dekaCathode*

Syntax: **Dekatron** *dekaCathode*, tube, position [, direction, pace]

Move the dot position to the required cathode on the tube to position n the given direction and pace.

Example:

Dekatron *dekaCathode*, V7, 6 , , 1000

Move the dot on dekatron V7 to cathode 6 in the default direction (shortest) at the rate of 1 movement per second i.e. slowly!

Dekatron *dekaGet*

Syntax: **Dekatron** *dekaGet*, numvar, tube

Return the dot position of tube in the number variable *numvar*.

Example:

#Number TubePos

Dekatron *dekaGet*, TubePos, V1

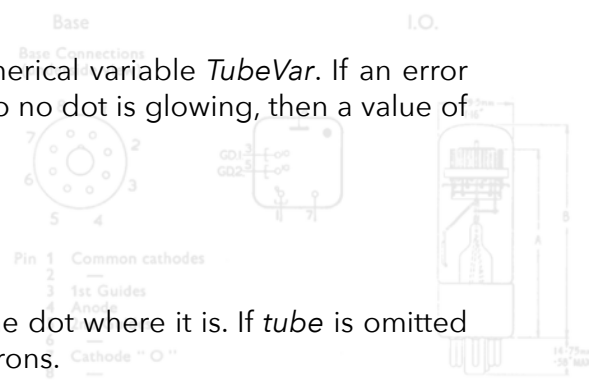
This will return the position of dekatron V1 in the numerical variable *TubeVar*. If an error occurs, for example if the flyback power supply is off so no dot is glowing, then a value of 0 is returned.

Dekatron *dekaldle*

Syntax: **Dekatron** *dekaldle* [, tube]

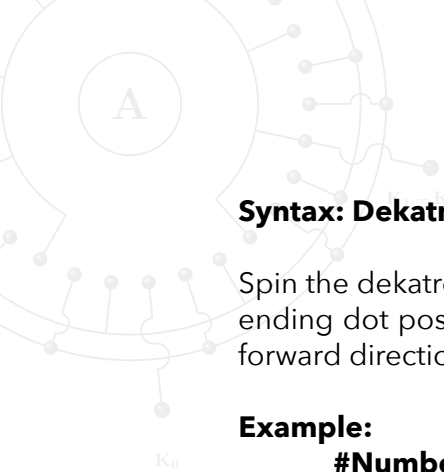
Stop any action that the *tube* is operating and leave the dot where it is. If *tube* is omitted then the *dekaldle* action will be applied to all the dekatrons.

Dekatron *dekaOnce*



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





Syntax: Dekatron *dekaOnce, tube [, direction, pace]*

Spin the dekatron tube once in the given *direction* and *pace*. Because the starting dot and ending dot positions are the same, shortest and longest directions have no meaning and forward direction will be used. Forward is also the default direction.

Example:

```
#Number Toob
For Toob := V1 to V6
    Dekatron dekaOnce, toob
ForEnd
```

Spin dekatrons V1 to V6 once in a clockwise direction.

Dekatron *dekaPendulum*

Syntax: Dekatron *dekaPendulum, tube [, dot, style, period]*

Make the dekatron act in the fashion of a pendulum. Dekatron *tube* is used. The starting position is given by *dot* (default 12). The glow position will “fall” towards the bottom dot the continue “up” to the corresponding dot position when it will reverse direction and fall again. This cycle is repeated. The rise and fall speed is set by two arguments. The style can be *linear*, where an equal amount of time is spent with each dot glowing, and, *gravity* where the time spent with each dot glowing decreases as the glow position descends then increases again as the dot rises (default *linear*). The gravity style gives a simulation of a mechanical pendulum. The period value is the time in mS for one swing of the pendulum; there and back again takes 2 * period mS (default 500mS giving one complete swing per second).

Example:

```
Dekatron dekaPendulum, V7, , , 5000
```

Dekatron V7 swings as a linear pendulum starting from dot 12 and taking 10S for a complete swing there and back.

Dekatron *dekaReset*

Syntax: Dekatron *dekaReset*

Causes the Dekatron driver slave microcontroller to be reset.

Dekatron *dekaSet*

Syntax: Dekatron *dekaSet, tube, position [, direction, pace]*

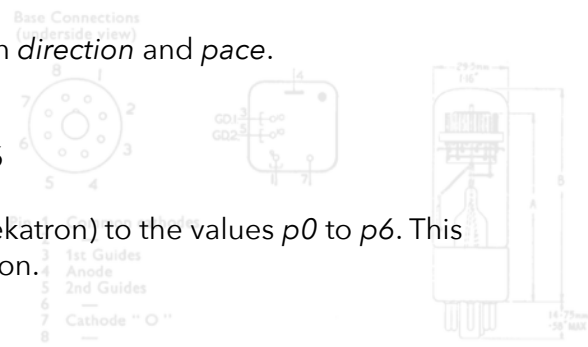
Move the glow on dekatron tube to position at the given *direction* and *pace*.

Dekatron *dekaSeven*

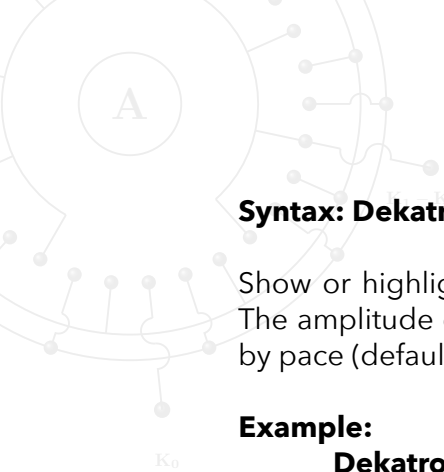
Syntax: Dekatron *dekaSeven, p0, p1, p2, p3, p4, p5, p6*

Set dekatrons V1 to V6 (the top row) and V7 (bottom Dekatron) to the values *p0* to *p6*. This procedure is more efficient than using the dekaText action.

Dekatron *dekaShow*



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5 mm			75.5 mm	
B	85 mm			87.5 mm	



Syntax: **Dekatron** *dekaShow, tube, dot [, swing, pace]*

Show or highlight, a given *dot* position by oscillating the glow position either side or it. The amplitude of the oscillation is given by *swing* (default value 3) and the rate of motion by *pace* (default value 10 mS).

Example:

Dekatron *dekaShow, V3, minutes / 2*

Dekatron *dekaShow, V4, minutes / 2*

Highlight the dot position on V3 and V4 based on the minutes system variable value.

Dekatron *dekaSix*

Syntax: **Dekatron** *dekaSeven, p0, p1, p2, p3, p4, p5*

Set dekatrons V1 to V6 (the top row) to the values p0 to p5. This procedure is more efficient than using the *dekaText* action.

Dekatron *dekaSpin*

Syntax: **Dekatron** *dekaSpin, tube [, dot, direction, pace]*

Continuously spin a Dekatron tube. The spinner will start from position *dot* (default value 0, i.e. at the 12 'o'clock position), move in *direction* (because this is a spinner, only *dir_forward* and *dir_backward* have meaning) at the given *pace* (default 33 mS).

Example:

Dekatron *dekaSpin, V3, , , 100*

Dekatron *dekaSpin, V4, , , dir_backward, 100*

This will spin V3 and V4 in opposite directions. Both dekatrons will start at the top.

Dekatron *dekaTwo*

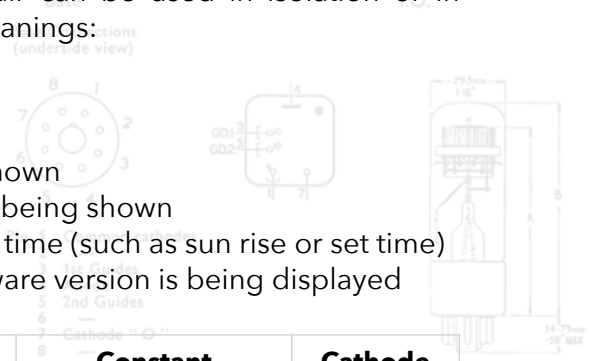
Syntax: **Effect** *effect_two, tube, cathode1, cathode2 [, pause]*

Highlight two cathodes on Dekatron tube by rapidly moving between them and pausing on each. The two positions are given by *cathode1* and *cathode2*. The pause time is in mS (default value 1000 mS). Dekatron V7 at the bottom of the clock has engraved labels so the Dekatron can be used to indicate what is displayed on the top six dekatrons. Each of the labels has a corresponding constant that can be used in this action.

Time, date, longitude, latitude, elevation, face and pair can be used in isolation or in combination with UTC, sun and system to give more meanings:

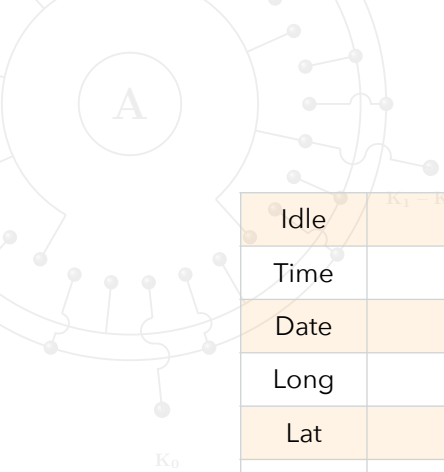
Examples:

- Time indicated alone means the local time is being shown
- Time in conjunction with UTC means that UTC time is being shown
- Time in conjunction with sun shows that a sun related time (such as sun rise or set time)
- Time in conjunction with system shows that the hardware version is being displayed



Label	Meaning	Constant	Cathode				
			GC10B	GC10B/S			
			Min.	Max.	Min.	Max.	
A		72			75.5 mm		
B		85			87.5 mm		





Idle	the V7 indicator function is not used	dot_idle	0
Time	a time is displayed	dot_time	1
Date	date	dot_date	2
Long	longitude	dot_longitude	3
Lat	latitude	dot_latitude	4
Elev	elevation	dot_elevation	5
Face	face number is shown or being changed	dot_face	6
Pair	pair value is shown or being changed	dot_pair	7
UTC	date or time is UTC	dot_utc	8
Sun	time, longitude, latitude relate to the sun	dot_sun	9
Sys	system data	dot_system	10

Obviously the last bullet example is not intuitive and you need to know the system+ meanings. The system dot can be joined with:

Second dot indicated	Meaning
Time	Hardware version
Date	Firmware version
Long	Core temperature
Lat	LDR data
Elev	GPS data
Face	WiFi data

The *dekaTwo* action is used primarily to display on Dekatron V7 what the other six are being used to display.

Example:

Dekatron *dekaWrite*, "%02d%02d%02d", hour, minute, second

Dekatron *dekaCathode*, V7, dot_time

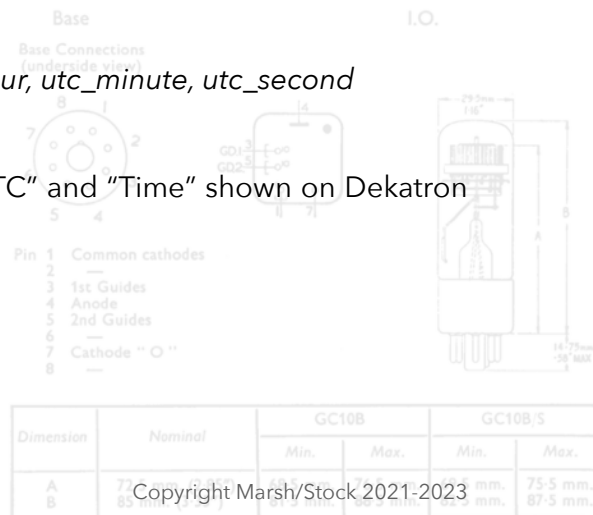
Will show the time on dekatrons V1 to V6 and indicate "time" on Dekatron V7.

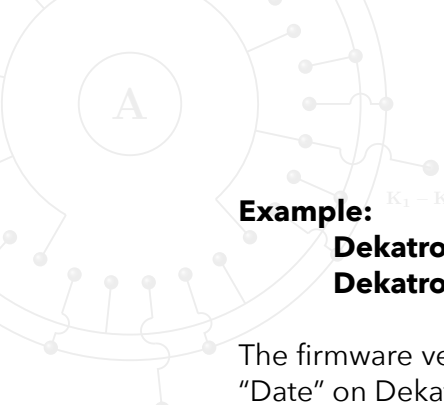
Example:

Dekatron *dekaWrite*, "%02d%02d%02d", utc_hour, utc_minute, utc_second

Dekatron *dekaTwo*, V7, dot_utc, dot_time

The UTC time is shown on dekatrons V1 to V6 and, "UTC" and "Time" shown on Dekatron V7.





Example:

Dekatron *dekaWrite*, "%02d%02d%02d", *fw_major*, *fw_minor*, *fw_build*
Dekatron *dekaTwo*, *V7*, *dot_system*, *dot_date*

The firmware version is shown on V1 to V6 and "firmware" is shown by indicated "Sys" and "Date" on Dekatron V7.

Dekatron *dekaWrite*

Syntax: **Dekatron** *dekaWrite*, *str* [, ...]

Write the string *str* to the top six dekatrons, V1 .. V6. The string can contain placeholders for the optional comma separated arguments that follow. Each numerical value lights the cathode corresponding to the character '0' ... '9' in the string.

Example:

Syntax: **Dekatron** *dekaWrite*, "012375"

Will light up the top row of dekatrons in this test pattern.

Obviously the Dekatron tubes are limited to displaying the numbers '0' to '9' so any other character in the string *str* will be ignored by the corresponding tube. It is recommended to use the space character. Only the first six characters of the string will be used and any other characters that follow are ignored. If the string is shorter than 6 characters then the remaining tubes are not changed.

Examples:

Dekatron *dekaWrite*, "%02d%02d%02d", *hour*, *minute*, *second*

Dekatron *dekaWrite*, "%6d", *face_curr*

Dekatron *dekaWrite*, "%2d%2d%2d", *fw_major*, *fw_minor*, *fw_build*

For a guide to the syntax for placeholders see Annex B of the main Nuggle manual. In positioning numbers and spaces (off tubes) in the string you will find the field flags of particular importance.

Dekatron *dekaZero*

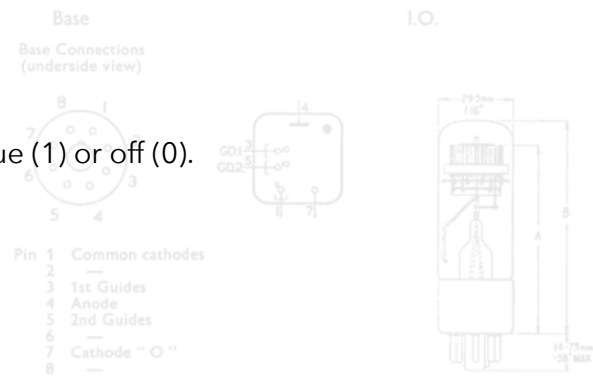
Syntax: **Dekatron** *dekaZero* [, *tube*, *direction*, *pace*]

Move the glow on dekatron *tube* position to cathode '0' (12 o'clock). If *tube* is omitted then all the dekatrons are zeroed and any direction and pace values are ignored. Zeroing all tubes simultaneously is meant to be a fast as possible action.

Flyback

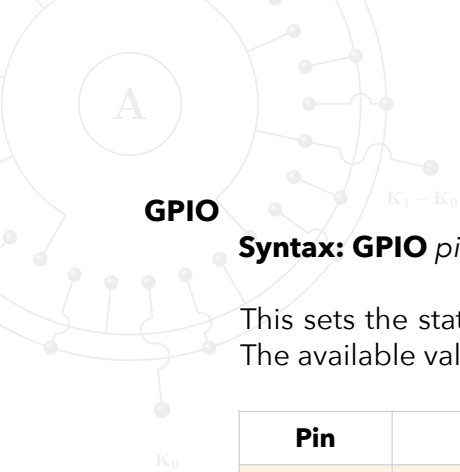
Syntax: **Flyback** *state*

Turns the Dekatron HT supply to *state*. Where *state* is true (1) or off (0).



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5





Syntax: GPIO *pin*, *value*

This sets the state of a GPIO *pin* to logical 1 if *value* is true and logical 0 if *value* is false. The available values of *pin* and the GPIO port and pin controlled are as follows:

Pin	Location	SAM3X8C port and pin
5	Back of PCB	Port A Pin 5
7	Back of PCB	Port A Pin 7
10	Pin 3 Connector X8	Port A Pin 10
11	Pin 2 Connector X8	Port A Pin 11
25	Back of PCB	Port B Pin 25
28	Back of PCB	Port B Pin 28
29	Back of PCB	Port B Pin 29
31	Back of PCB	Port B Pin 31
500	500V flyback on/off	N/A

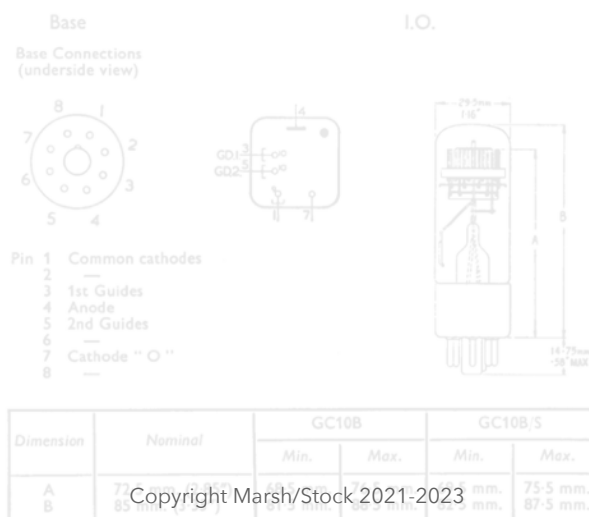
Saver

Syntax: Saver *value*

Specify the "screen saver" display to be used with the current clock face overriding the default saver. The argument value is the index of a Nuggle program defined in nuggle.ini.

Example:

Saver 402



10. Events

Event Happenings

There are no additional event happenings.

Event Default Actions

The Harwell Dekatron clock has the following event default actions:

Event Label:	Default Action:
event_encoder:	If the clock is asleep (any stage) it wakes up. Clock face or sound volume changed. See below.
event_ir:	If the clock is asleep (any stage) it wakes up. See below for other default functions.
event_pir:	If the clock is asleep (any stage) it wakes up.
event_sleep:	The event occurs as the clock wakes up from being asleep and the clock goes from being awake progressively to being asleep. See below.
event_enter:	None
event_leave:	When the Nuggle program is stopping.
event_tick:	None

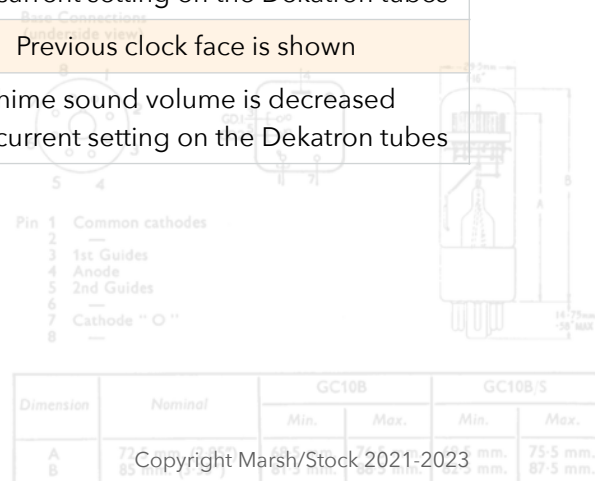
Default Encoder Events

If the encoder is moved clockwise when displaying a clock face, then the next clock face is displayed, if anti-clockwise then the previous face is displayed.

If the encoder button is pressed and it is moved clockwise then the chime sound volume increases, if moved anti-clockwise, then the sound volume decreases.

In summary:

arg_encoder value	Happening	Default Actions
U'	Turned clockwise	Next clock face is shown
+'	Press and turn clockwise	Chime sound volume is increased show current setting on the Dekatron tubes
D'	Turn anticlockwise	Previous clock face is shown
-'	Press and turn anticlockwise	Chime sound volume is decreased show current setting on the Dekatron tubes



Default IR Handset Events

The IR Handset has default actions for all of the buttons.

You can change the volume of the chimes and the beeps, set the pairing number, select a clock face directly or by scrolling through available faces and finally enquire what face number is currently displayed.

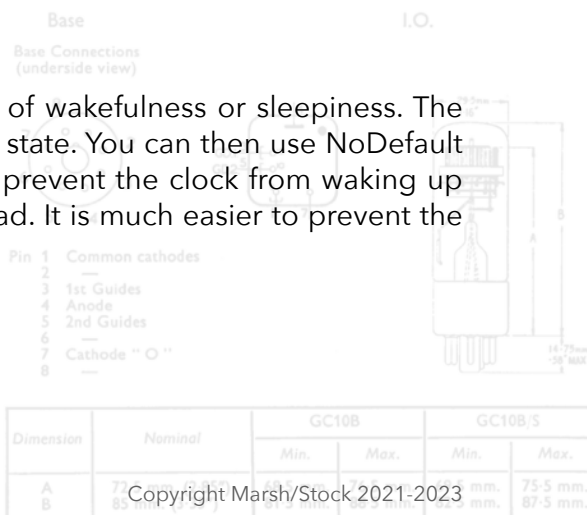
arg_ir value	Happening - button pressed	Default Actions
'U'	CH+	Next clock face is shown
'D'	CH-	Previous clock face is shown
'C'	CH	Display current face on Dekatron tubes
'+'	+	Chime sound volume is increased show current setting on the Dekatron tubes
'-'	-	Chime sound volume is decrease show current setting on the Dekatron tubes
'>'	<<	Beep sound volume is increased show current setting on the Dekatron tubes
'<'	>>	Beep sound volume is decrease show current setting on the Dekatron tubes
'P'	>	Start pair number entry
'0' ... '9'	0 ... 9	Start face number entry
'='	EQ	Pairing number or face number accepted
'H'	100+	In pairing or face entry mode delete last number
'T'	200+	Escape from pairing or face entry mode and discard the entry

Pairing number entry is started with the '>||' key and allows the entry of a number, if it matches the clock pair number then the other keys will operate.

Face number entry allows you to immediately go to a face, if you know its number, without using the CH- and CH+ keys repeatedly.

Default Sleep Events

Invoked when the clock wishes to either go to a higher state of wakefulness or sleepiness. The system variable arg_sleep contains a code to tell you the next state. You can then use NoDefault or Default to allow the state change or not. Obviously, if you prevent the clock from waking up then you will need to use a range of Nuggle commands instead. It is much easier to prevent the clock going to sleep again.



Wake up from being asleep

During the wake up cycle - fully asleep to fully awake - the following states are passed through and actions are taken. The timings of some stages are adjustable in the [sleep] section of system.ini on the SD card.

arg_sleep value	Constant	Actions	[Sleep] key
14	awake_flybackonreq	Request to turn on flyback PSU	
15	awake_flybackon	Flyback PSU turned on	flyback_on = 2 seconds delay
17	awake_complete	Flyback is turned on	
18	awake_release	Request to go to fully awake status	
3	awake_fully	The clock is fully awake	

Going to sleep

During the sleep cycle - going from fully awake to fully asleep - the following states are passed through and actions are taken. The timings of some stages are adjustable in the [sleep] section of system.ini on the SD card.

arg_sleep value	Constant	Actions	[Sleep] key
4	sleep_savercall	Request to invoke the screen saver	
5	sleep_saver	Screen saver displayed	screen_saver = 10 ; minutes delay
6	sleep_flybackoffreq	Request to turn off the flyback PSU	
7	sleep_flybackoff	Flyback PSU turned off	flyback_off = 10 ; minutes delay
9	sleep_release	The clock is about to be fully asleep	
2	sleep_fully	The clock is fully asleep (idle)	

If a wake from sleep trigger is received during these stages the going to sleep process is reversed and the value of *arg_sleep* will change to the relevant waking up state.

If you want to see these processes in action then use the sleep debug system at level 3 (set in system.ini) or write a Nuggle program to do so.

Sleep states, 0, 1, 10, 13 and 16 are used internally and are not sent to the event handler. Sleep states 8, 11 and 12 are not used and are never called.

If the **Default** action takes place at step 5 then the screen saver Nuggle program is run and your program loses control. Your program is then not run again until step 3 has been reached in the wake up cycle. The upshot of this is that your Nuggle program will only receive event steps 4 and 5.



Default Start Events

The default start events are to:

- Set all the Dekatrons to cathode '0'
- Clear all the LEDs to off i.e. black.
- Stop any chime that is playing
- Stop any beep that is sounding
- Set both colons to off, i.e. set the brightness PWM signal to 0 for both colons.

Using **NoDefault** will allow one Nuggle program to take over the display from another without any jitter.

Default Tick Events

The RTC ticks each second and generates an event. The value of the system variable `arg_tick` is set as follows:

arg_tick value	Constant	Highest tick period that has occurred
0	tick_second	1 second
1	tick_minute	1 minute
2	tick_hour	1 hour
3	tick_day	1 day
4	tick_month	1 month
5	tick_year	1 year

For example, a 1 day tick only occurs at 00:00:00 local time. And another example, the year tick only occurs at 00:00:00 on 1st January each year. Time is always local time and takes into account DST and the time zone. The clock UTC tick is not used to generate events.

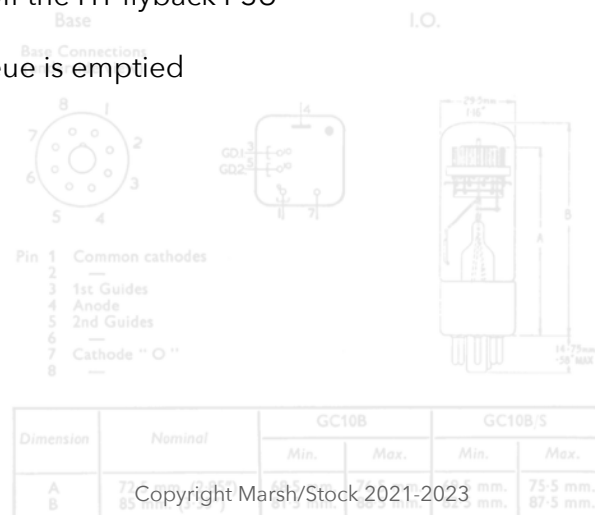
Miscellaneous Procedures

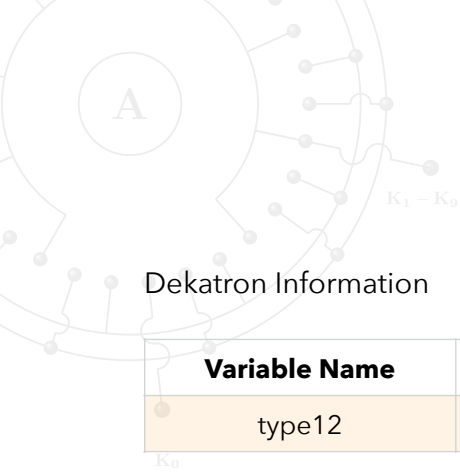
Clear

Syntax: Clear

The following happens:

1. Dekatron and colon tubes are blanked by turning off the HT flyback PSU
2. All bling LED are set to *black*, i.e. off
3. Any beep in progress is stopped and the beep queue is emptied
4. Any chime in progress is stopped

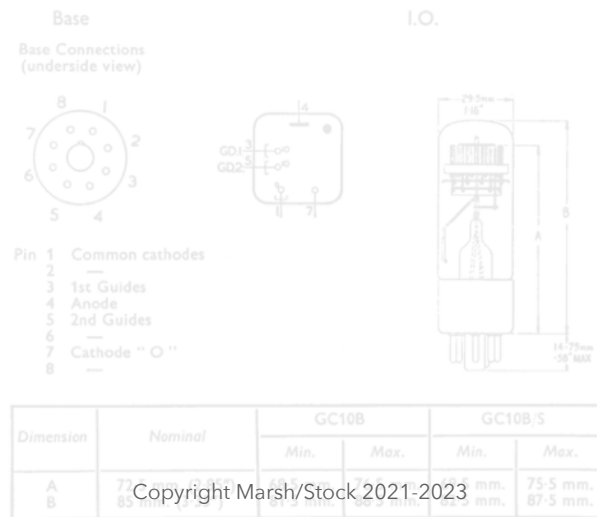


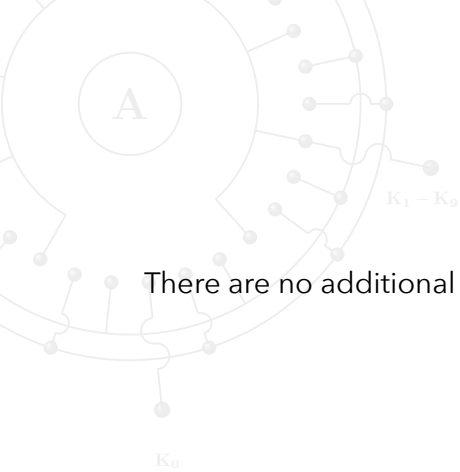


Dekatron Information

Annex A System Variables

Variable Name	Function	Notes
type12	Is V7 a 12 cathode Dekatron?	boolean





Annex C Fatal Error Messages

There are no additional fatal error messages.



Base
Base Connections
(underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

I.O.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

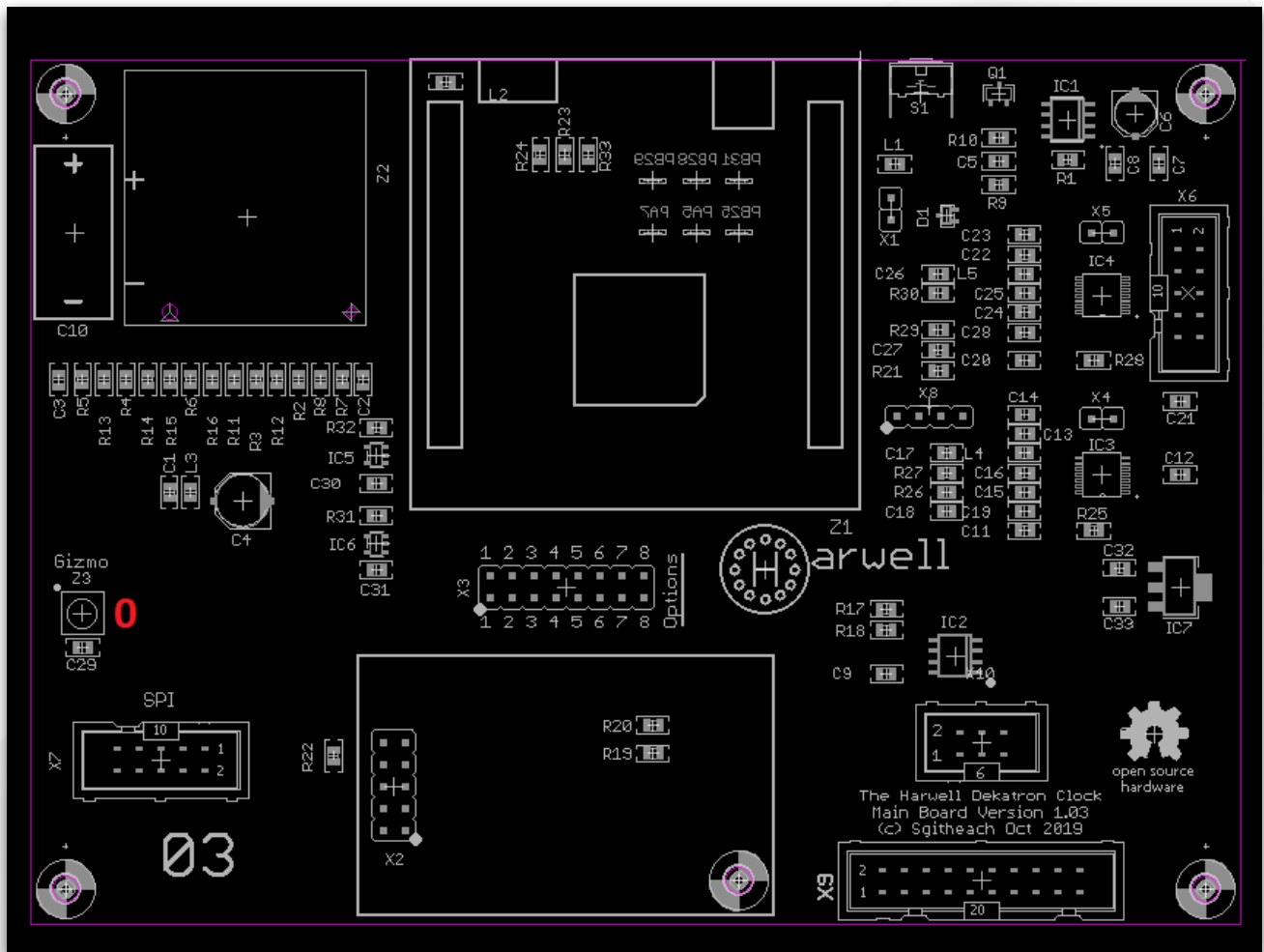


Annex D Bling LED Numbering

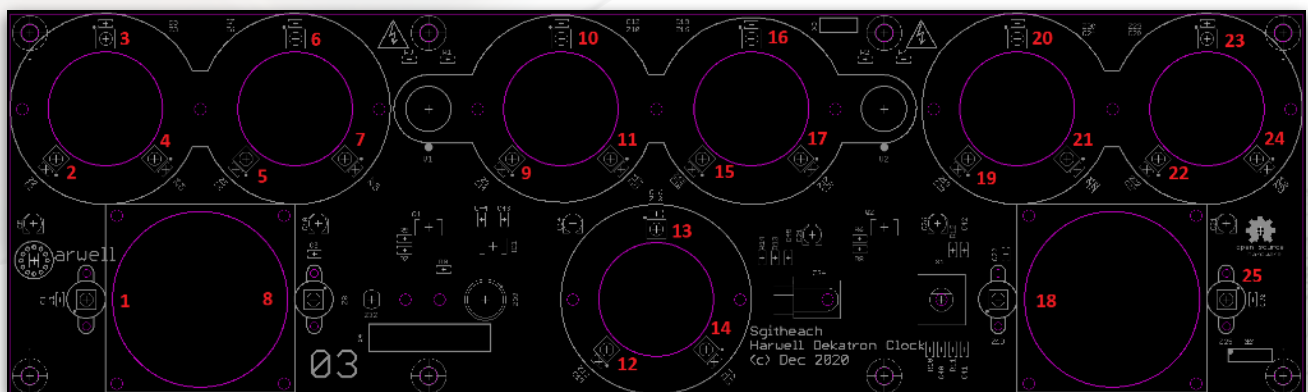
Example of use:

Colour red, 14
Colour red, 23

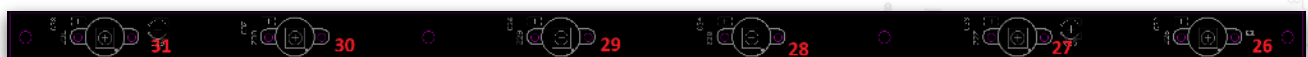
Position numbers of the bling LED modules as viewed from the silkscreen side of the PCB.



Only one bling LED on the Main Processor board - '0'



Bling LED numbering on the light guide board - 1 to 25

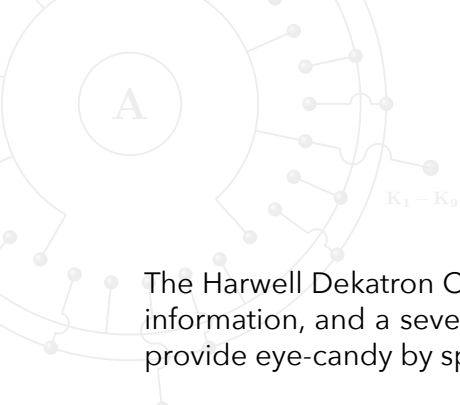


Bling LEDs 26 to 31 on the downward illumination board

	Nominal	Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Annex A - Dekatron 7 Usage

The Harwell Dekatron Clock uses six 10 cathode Dekatrons in a row to show date, time and other information, and a seventh Dekatron (V7) below to indicate what is being displayed. V7 can also provide eye-candy by spinning, acting as a pendulum and showing other effects.

The standard case is engraved around V7 to indicate what is being shown on the six Dekatrons. V7 can be a 12 cathode Dekatron (GC12/4B) or use a more common 10 cathode Dekatron. The case engraving changes accordingly.

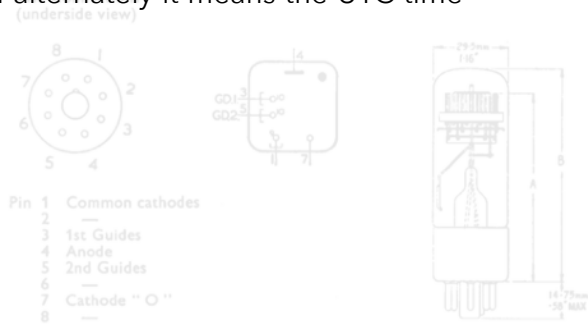
12 cathode function engravings (from the top clockwise) are

- (no engraving)
- Time
- Date
- Lat
- Long
- Elev
- Face
- Pair
- Vol
- UTC
- Sun
- Sys

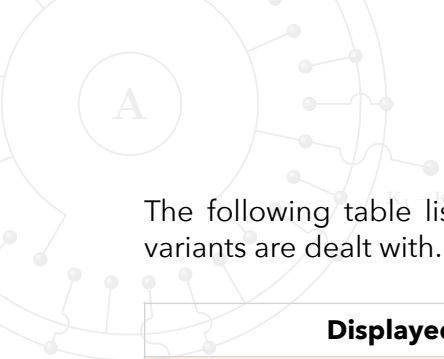
and the 10 cathode engravings are

- Sys
- Time
- Date
- Lat
- Long
- Elev
- Face
- Pair
- Vol
- UTC

However, there are more things to display than there are available cathodes, so V7 sometimes uses a mode where two cathodes are alternately illuminated to highlight two functions. For example, when Time alone is indicated it means that the current local time (adjusted for DST and time zone) is displayed, but when Time and UTC are indicated alternately it means the UTC time is being shown.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72.5 mm			75.5 mm	
B	85 mm			87.5 mm	

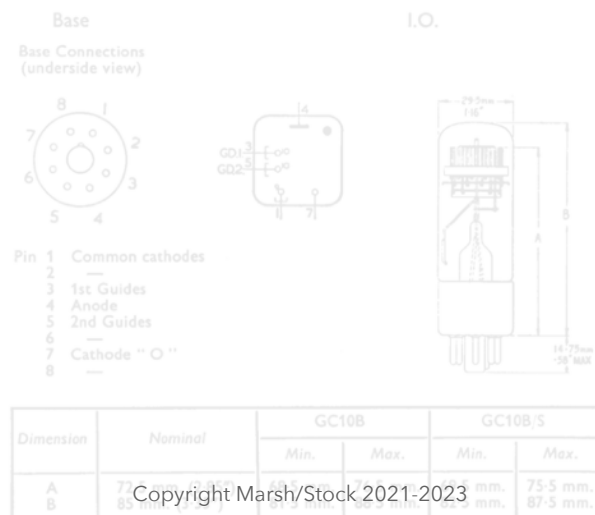


The following table lists the displayed value, how V7 is used and how the 10 or 12 cathode variants are dealt with.

Displayed Value	12 cathode engraving	10 cathode engraving
Local Time		Time
Local Date		Date
UTC Time		UTC + Time
UTC Date		UTC + Date
Latitude (note 1)		Lat
Longitude (note 2)		Long
Elevation		Elevation
Sunrise	Sun+Time	Pair+Time
Sunset	Sun+Date	Pair+Date
Sun's azimuth	Sun+Long	Pair+Long
Sun's elevation	Sun+Elev	Pair+Elev
Current face number or face number entry		Face
Current Pair number or pair number entry		Pair
Current chime or beep volume		Vol
Hardware version		Sys+Time
Firmware version		Sys+Date
Chip temperature		Sys+Long
LDR reading		Sys+Lat
GPS information		Sys+Elev
WiFi information		Sys+Face
Idle	Idle (note 3)	Sys

Notes.

1. The bling LEDs are used to indicate north or south of the equator.
2. The bling LEDs are used to indicate east or west of Greenwich.
3. Idle is not engraved.

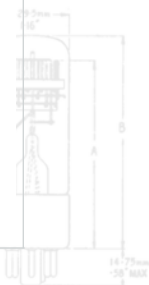




Annex B - Front Panel 3D Printed Part Identification

Quantity	Parts	Description
K ₀ 1	Leftmost (Dekatron V1 & V2) Light Guide Collar	
1	Middle (Dekatron V3 & V4, MTX90 V1 & V2) Light Guide Collar	
1	Rightmost (Dekatron V5 & V6) Light Guide Collar	
1	Bottom (Dekatron V7) Light Guide Collar	
1	IR Spacer	

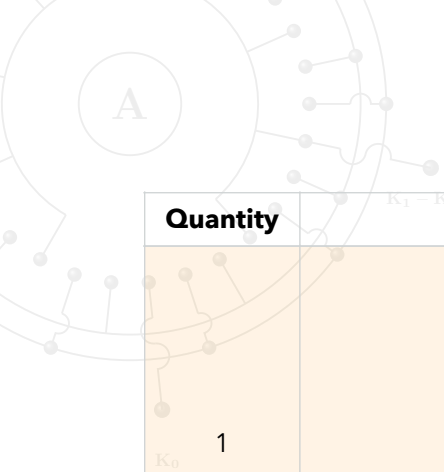
5 2nd Guides
6
7 Cathode "O"
8

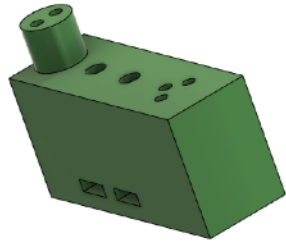

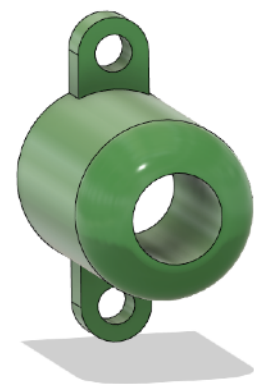
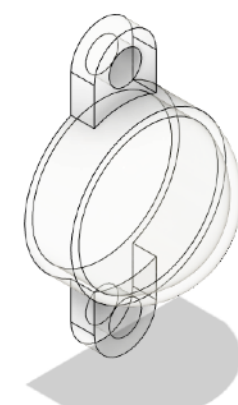


Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.

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Quantity	Parts	Description
1	LDR and PIR spacer	
2	Speaker spacer	
4	Speaker Light Guide Holder	
6	LED Diffuser	

- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	

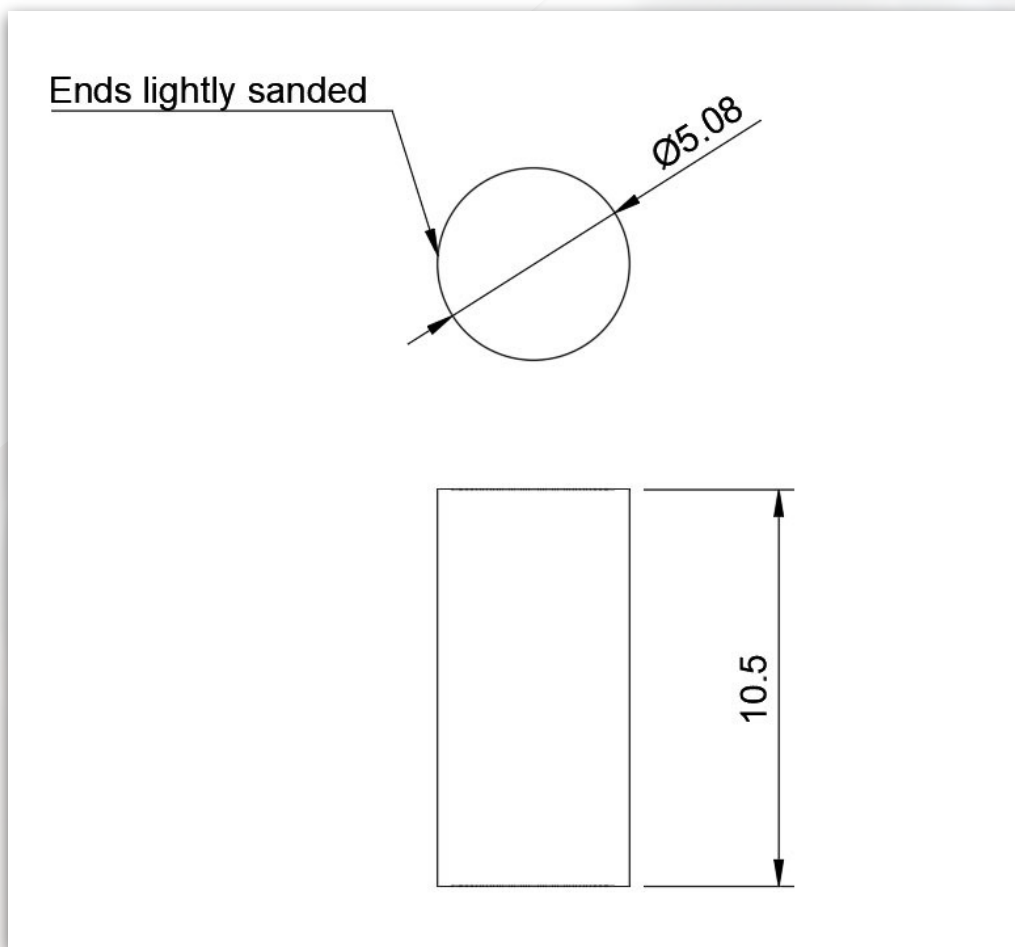


Annex C - Front Panel Speaker Light Guide

Made using 5.08mm diameter acrylic rod with the ends lightly sanded to help with light dispersion. It should be a tight fit inside the 3D printed speaker bling part.

Left and Right refer to the view of the clock from the front. Top, bottom, back, front are as you would expect. These parts are normally printed with black PLA. The Fusion 360 project file and the individual STL files are available from the project Dropbox which can be found at <http://www.sgitheach.org.uk/harwell.html#documentation>.

Many parts require the press fit of M4 nuts. Guidance on doing this correctly so the nuts are a good fit and without breaking the printed part are in the Låda section of the "Commoners" manual on the Sgitheach Public Dropbox.¹⁶⁴



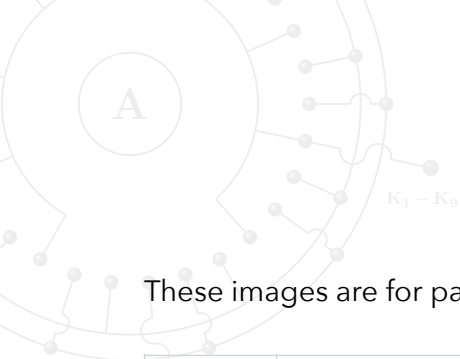
I.O.

Base Connections
(underside view)



¹⁶⁴ <http://www.sgitheach.org.uk/harwell.html#documentation>

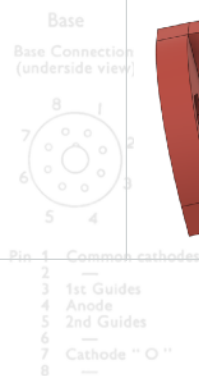
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	



Annex D - 3D Printed Case Parts

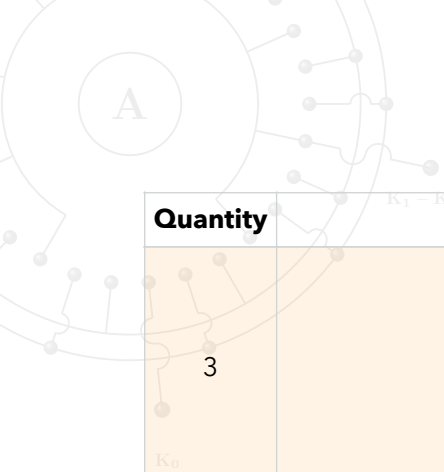
These images are for part identification only and are not to scale or even to the same scale!

Quantity	Description	Image
1	Centre Back Bottom	
1	Left Back Bottom	
1	Left Front Bottom	
2	Centre Front Bottom	
1	Right Front Bottom	



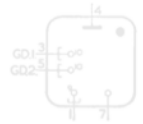
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





Quantity	Description	Image
3	Låda M4 2x15	
5	Låda M4 3x15	
6	PCB Spacer	
1	Vertical Support Middle	
1	Vertical Support Left	

Base Connections (underside view)



- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	





Quantity	Description	Image
1	Vertical Support Right	
2	Vertical Top Spacer	
1	Knob	
1	GPS/WiFi hole plug (Optional)	
1	Concentric Aid	

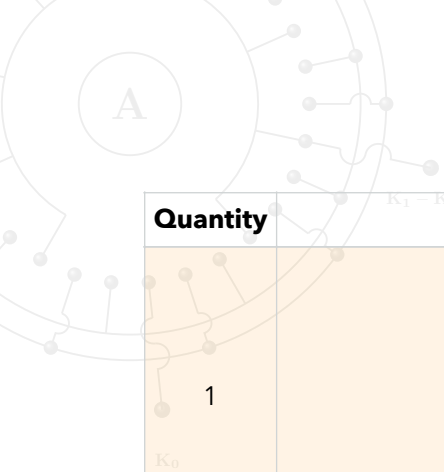


- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

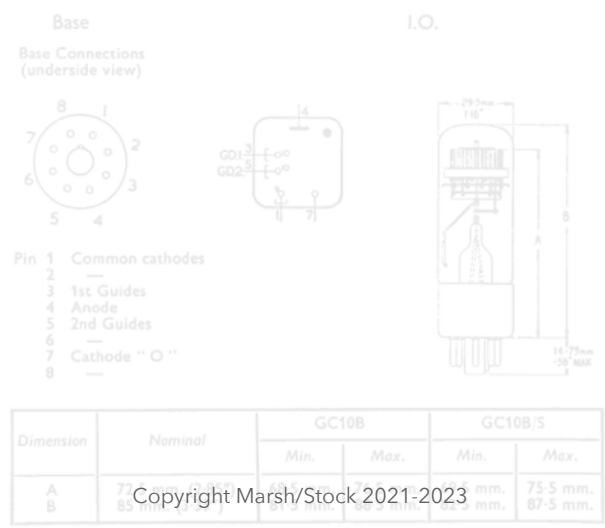


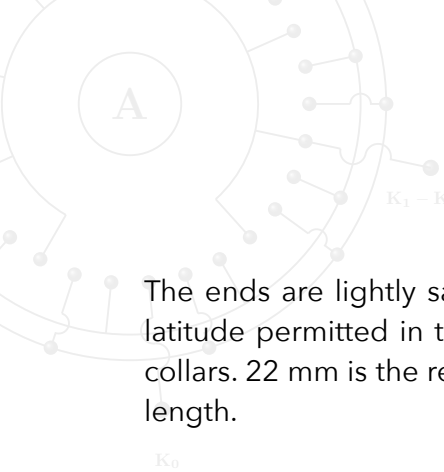
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	





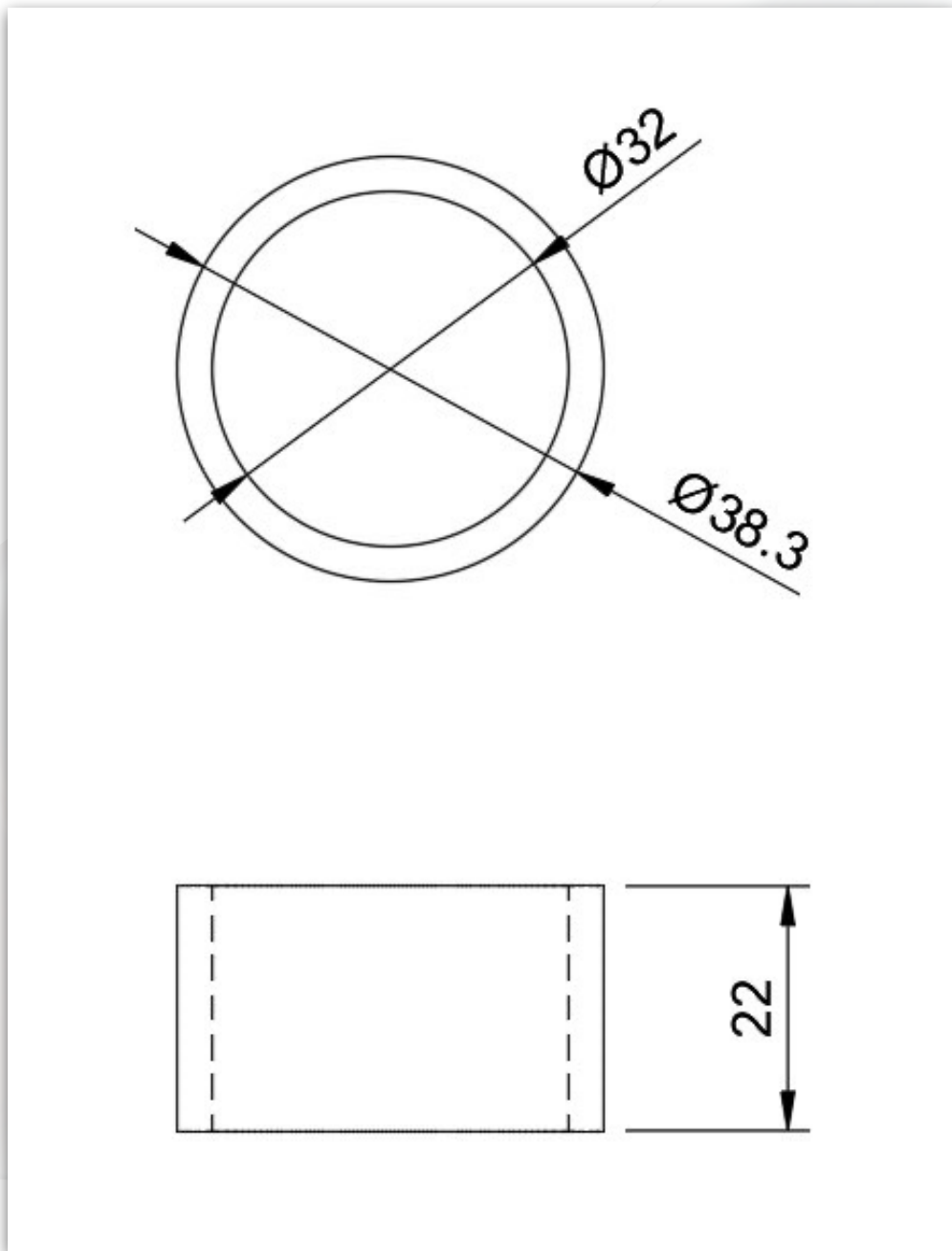
Quantity	Description	Image
1	Cover Plate Shim	



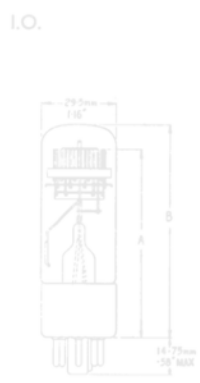


Annex E - Dekatron Light Guide Specification

The ends are lightly sanded with wet 400 grit wet paper to aid light dispersion. There is some latitude permitted in the length of these guides by virtue of the grub screws in the 3D printed collars. 22 mm is the recommended maximum length and 20 mm is the recommended minimum length.

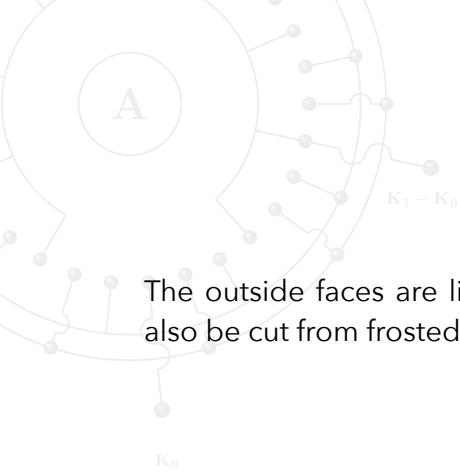


- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —



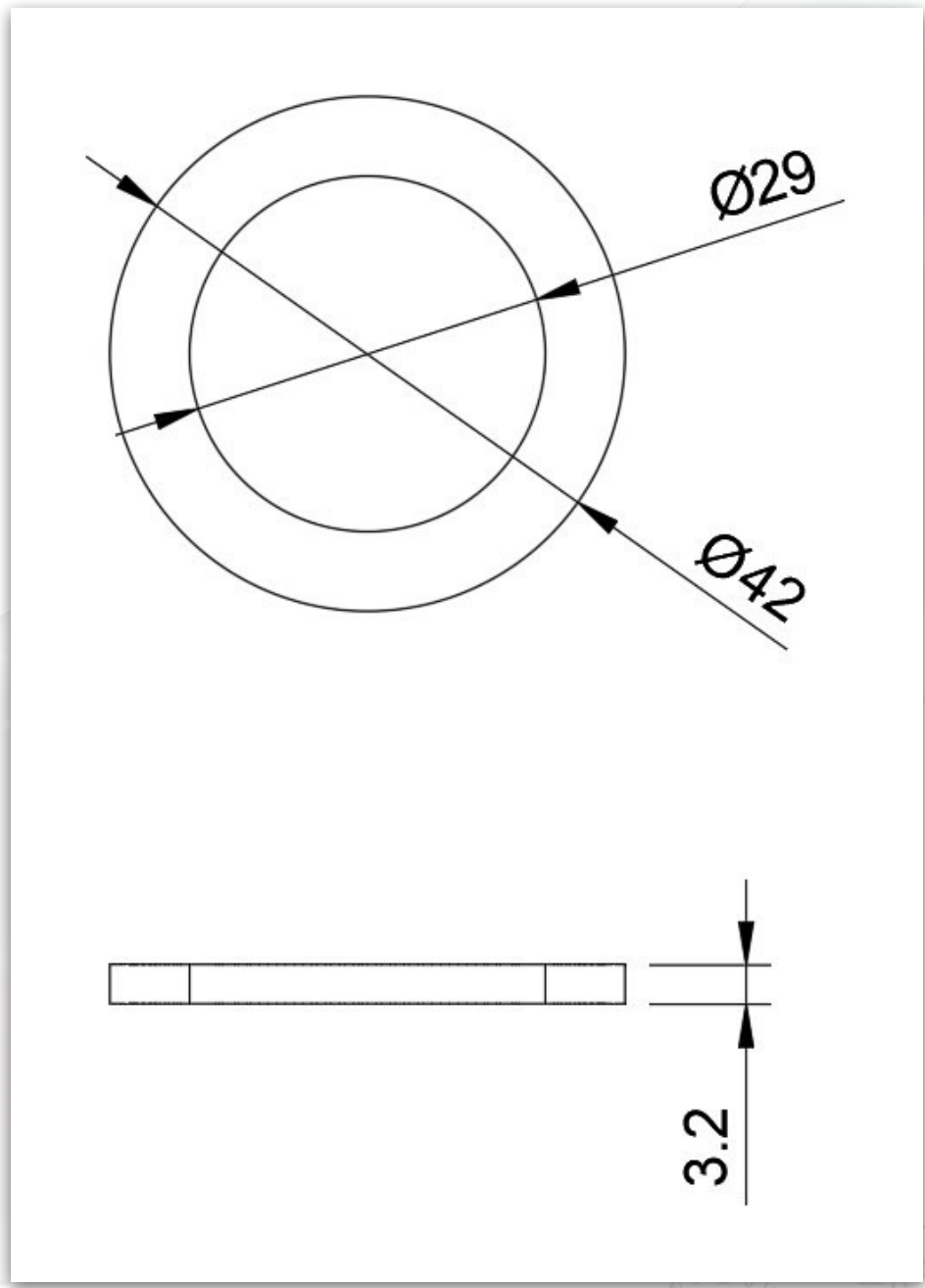
Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	





Annex F - Dispersion Ring Specification

The outside faces are lightly sanded with 400 grit wet paper to aid light dispersion. These can also be cut from frosted acrylic to skip the sanding step.



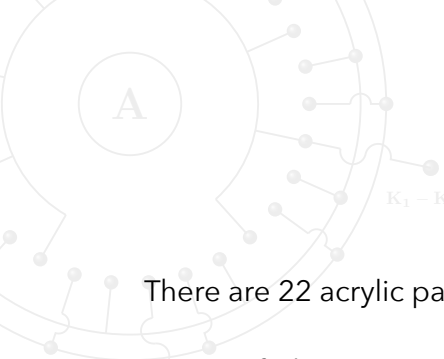
- Pin 1 Common cathodes
- 2 —
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

I.O.



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	





Annex G - Laser Cut Acrylic Part Identification

There are 22 acrylic parts in the case kit.

Some of the parts are optionally reverse engraved. Therefore make sure you fit with the engraving on the inside so the engraving is viewed through the acrylic.

For simplicity the engraving has been omitted.

These images are for part identification only and are not to scale or even to the same scale!

Quantity	Description	Image
1	Base	
2	Side	
1	Back	

- 2 ---
- 3 1st Guides
- 4 Anode
- 5 2nd Guides
- 6 ---
- 7 Cathode "O"
- 8 ---



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5 mm.	
B	85			87.5 mm.	





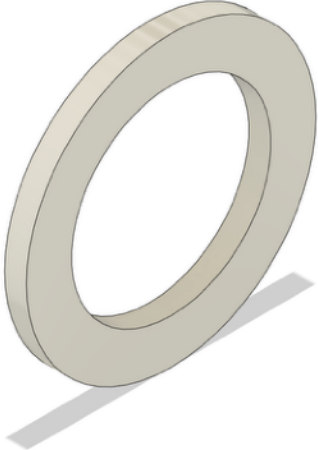
Quantity	Description	Image
1	Cover plate	
1	Top	
1	Front Diffuser (white)	
1	Front Panel (black)	
7	Dekatron Light Guide	

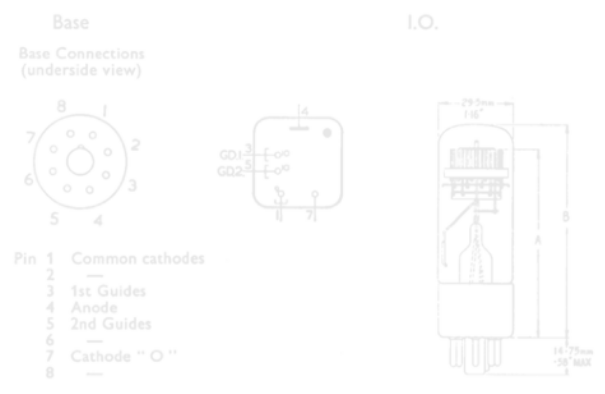
- 5 2nd Guides
- 6 —
- 7 Cathode "O"
- 8 —

Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			mm.	75.5 mm.
B	85			mm.	87.5 mm.





Quantity	Description	Image
7	Dispersal Ring	



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72			75.5	75.5
B	85			87.5	87.5



Annex H - Procedure for the Safe Rotation of the Dekatrons

The specification for the GC10xxx Dekatrons says that the alignment of cathode '0' to the tube's base is $\pm 12^\circ$. We can do a lot better than that by adjusting the Dekatrons by rotating their sockets:

Before - cathode 0¹⁶⁵ lit and way off:



After adjustment - aahhh, much better:

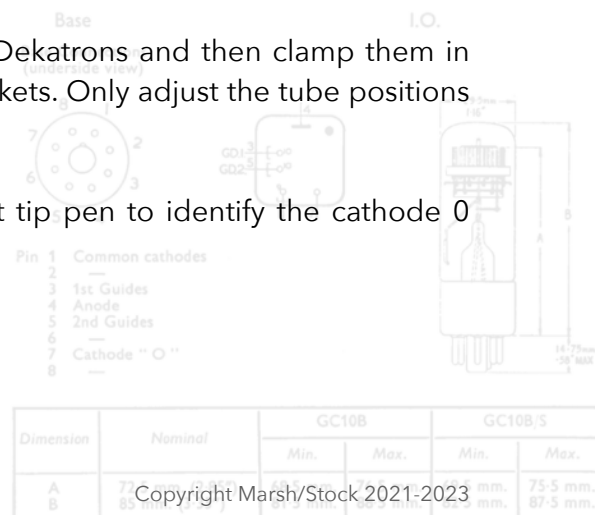


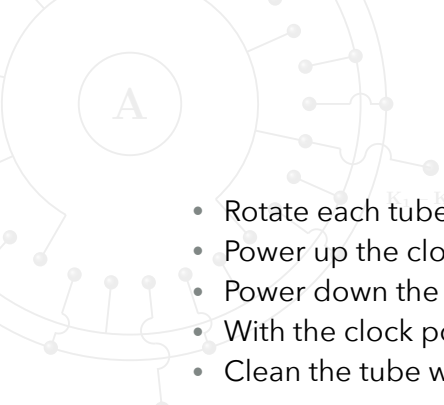
Rotating each tube so the 0 cathode is at the top can be accomplished as the Dekatron socket fixing nuts and screw run in curved slots on the Dekatron PCB. A long arm 3D printed M3 spanner is provided in the kit to help reach the nuts while using an Allen key on the reverse side. Power the clock and enter the command **FACS 1200** into the console and press enter. This is a simple alignment face that positions all the Dekatrons to illuminate cathode 0.

To adjust the Dekatron dot position you need to rotate the Dekatrons and then clamp them in position by tightening their fixing screws and bolts on the sockets. Only adjust the tube positions by touching them when the clock is not powered!

- Mark the position of the dot on each tube using a felt tip pen to identify the cathode 0 position.
- Power down the clock.

¹⁶⁵ That is cathode 0 lit and not the adjacent guide electrode...

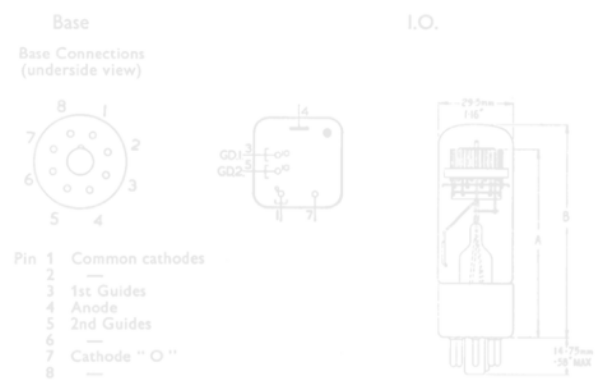




- Rotate each tube so the felt tip pen marked cathode is at the top/12 o'clock position.
- Power up the clock and go back to face 1200 to double check your positions.
- Power down the clock, finesse any positions if necessary and repeat your double check.
- With the clock powered down, tighten each screw and bolt to clamp each socket in place.
- Clean the tube with a small amount of solvent such as IPA to remove the marks.

The need to rotate each tube into a position is entirely dependent on the tube internal assembly. Rotating V7 can be a problem as there is not much tube to grab hold of. If the screws are loose enough then the front glass dome can offer enough purchase to rotate the tube. If you need to remove any Dekatron, or all of them, I suggest you subtly mark a number on each tube so they can be put back in the same socket.

It may occur to you that you could rotate the Dekatrons while the clock is powered and the Dekatrons are glowing and not mark cathode 0 positions with a pen etc. **This is very dangerous and is discouraged in no uncertain terms.** If you do rotate the tubes while the clock is powered, then you do so entirely **at your own risk.**



Dimension	Nominal	GC10B		GC10B/S	
		Min.	Max.	Min.	Max.
A	72 mm			75.5 mm	
B	85 mm			87.5 mm	

