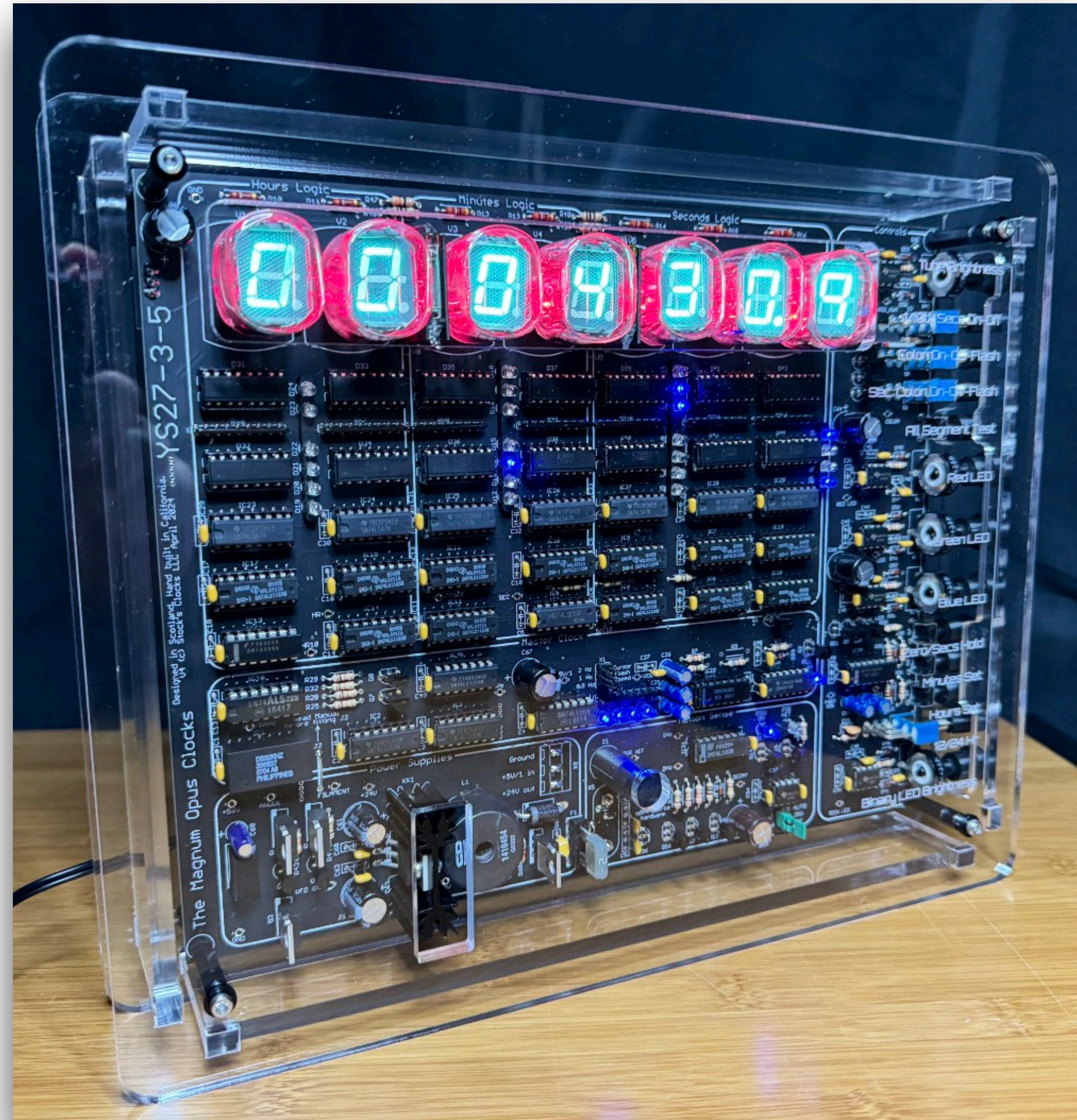
‘Time Will TTL’



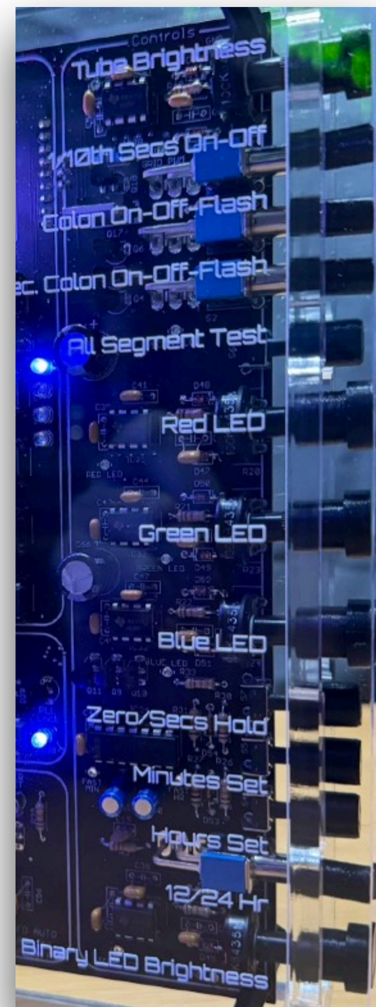
- VFD Version -

A TTL Clock Using Vacuum Fluorescent Tubes

Introduction

Why? Well, it would appear that I (we) just can't get enough of old display technologies! With the amazing help from my friend Grahame[1], I cajoled him into helping design a series of clocks using old display tubes (VFD, nixies and dekatrons) and only TTL logic with about as many knobs, switches and LEDs as possible. It also has one more digit than some may deem necessary.[2] This followed on from his rather remarkable use of TTL to drive a cathode ray tube, resulting in the SCTTL clock.[3] I think the end result turned out quite nice and it's certain to attract people's attention when on display.[4] The clock also follows some of the design aesthetic of the KoolKlox (also available as a kit from the StocksClocks website here).

Clock Features



- Seven IV-22 or YS27-3 vacuum fluorescent[5] tubes (VFDs) with a switchable 1/10ths seconds tube.
- Tube brightness pot.
- Switchable colons using DM160 VFD tubes, with adjustable speed (0.5/1/2 Hz via jumper).
- 12/24 hr switch.
- Minutes/Hours set + Seconds hold buttons.
- Tube backlighting with adjustable Red, Green and Blue colours.
- Binary counting LEDs with adjustable brightness.
- Tube 'all-segment' test button.
- Socketed tubes for easy replacement (if necessary).
- Alternative seconds colon [switchable].
- Optional battery backup to keep time keeping circuit energized during power outages.
- PIR (Proximity Infra-Red sensor) to turn off the tubes after a period of time (can be defeated with a jumper).

This manual will both help to explain how the clock works and also, for the very adventurous kit builders, instruct on how to build the electronics and case. It is designed with an Open Source Hardware philosophy, like most of the clocks that I have had the fortune to have been (a small) part of.

Read on....

[1] https://www.sgitheach.org.uk/
[2] But not me **obviously**....
[3] https://www.sgitheach.org.uk/scope4.html; https://stocksclocks.com/index.php/scope-clock-ttl-scttl/
[4] A nixie and dekatron version are in the works too...
[5] https://en.wikipedia.org/wiki/Vacuum_fluorescent_display

Legal Statement

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

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

The hazards of this kit include, but are not limited to 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 this VFD 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.

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 as prompt manner as possible against the supplied parts lists found within the construction manual. As a kit of parts, no warranty can be provided pertaining to the quality of construction and operation of the final product as this is the duty of the purchaser and is dependent upon their skill. The VFD clock may be hazardous if not assembled and operated by suitably knowledgable persons and it is the owners responsibility to carefully review all the supplied documentation. The authors have made their best attempts to explain and detail the construction and hazards associated with operation of the clock within the supplied documentation. If you have purchased a complete operational clock, then a limited warranty is provided in a separate document supplied with your purchase. 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 me immediately (within a few days of receipt). It is also likely that photographic evidence will be asked for to make an insurance claim. No refunds on partially or fully constructed kits are possible.

About Open Source

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A further note...

This is by no means a beginners electronics kit... there are a LOT of things to solder and static sensitive devices are used. Use a good quality leaded solder. You will need a multimeter, good quality tools and some patience. An oscilloscope may prove handy should you need to do any troubleshooting. The effort is well worth it, but if you feel it is outside your comfort zone, I can provide fully built clocks for an extra cost (building one can take upwards of 7 to 8 hours).

How a VFD tube works

Noritake Itron Corporation still makes all sorts of VFD displays to this day...

A vacuum fluorescent display (VFD) is a display device once commonly used in consumer electronics equipment such as video cassette recorders, car radios, and microwave ovens.

They operate on the principle of cathodoluminescence[6], roughly similar to a cathode-ray tube[7], but operating at much lower voltages. Each VFD tube has a phosphor[8]-coated carbon anode[9] that is bombarded by electrons emitted from the cathode filament[10]. In fact, each VFD is a triode[11] vacuum tube because it also has a mesh control grid.

IV-3 type 7-segment VFD

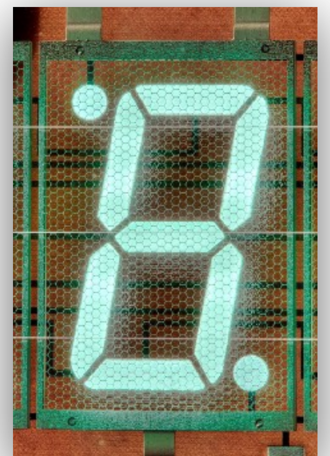
Unlike liquid crystal displays [LCDs][12], a VFD emits very bright light with high contrast and can support display elements of various colours. Standard illumination figures for VFDs are around 640 cd/m^2 with high-brightness VFDs operating at 4,000 cd/m^2, and experimental units as high as 35,000 cd/m^2 depending on the drive voltage and its timing. The choice of colour (due to the nature of the phosphor used) and display brightness significantly affect the lifetime of the tubes, which can range from as low as 1,500 hours for a vivid red VFD to 30,000 hours for the more common green ones. Cadmium was commonly used in the phosphors of VFDs in the past, but the current RoHS[13] compliant VFDs have eliminated this metal from their construction, instead

[6] https://en.wikipedia.org/wiki/Cathodoluminescence
[7] https://en.wikipedia.org/wiki/Cathode-ray_tube
[8] https://en.wikipedia.org/wiki/Phosphor
[9] https://en.wikipedia.org/wiki/Anode
[10] https://en.wikipedia.org/wiki/Hot_cathode
[11] https://en.wikipedia.org/wiki/Triode
[12] https://en.wikipedia.org/wiki/Liquid-crystal_display
[13] https://en.wikipedia.org/wiki/RoHS

using phosphors consisting of a matrix of alkaline earth and very small amounts of group III metals, doped with very small amounts of rare earth metals.

VFDs can display seven-segment numerals, multi-segment alpha-numeric characters[14] or can be made in a dot-matrix format to display different alphanumeric characters and symbols. In practice, there is little limit to the shape of the image that can be displayed: it depends solely on the shape of phosphor on the anode(s).

The first VFD was the single bar indicator DM160 by Philips in 1959. The first multi-segment VFD was a 1967 Japanese single-digit, seven-segment device made by Ise Electronics Corporation. The displays became common on calculators and other consumer electronics devices. In the late 1980s hundreds of millions of units were made yearly



Macro image of a VFD with 3 horizontal tungsten wires and control grid

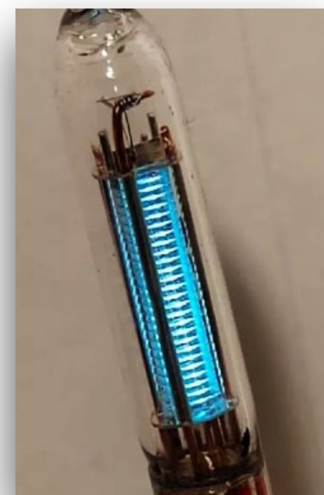
The device consists of a hot cathode (filaments), grids and anodes (phosphor) encased in a glass envelope under high vacuum. The cathode is made up of fine tungsten wires, coated by alkaline earth metal oxides (barium, strontium and calcium oxides), which emit electrons when heated to 650°C by an electric current. These electrons are controlled and diffused by the grids (made using photochemical machining), which are made up of thin (50 micron) stainless steel. If electrons collide with the phosphor-coated anodes, they fluoresce, emitting light. Unlike the orange-glowing cathodes of traditional vacuum tubes, VFD cathodes are efficient emitters at much lower temperatures, and are therefore essentially invisible. The anode consists of a glass plate with electrically conductive traces (each trace is connected to a single indicator segment), which is coated with an insulator, which is then partially etched to create holes which are filled with a conductor like graphite, which in turn is coated with phosphor. This transfers energy from the trace to the segment. The shape of the phosphor will determine the shape of the VFD's segments. The most widely used phosphor is zinc-doped copper-activated zinc oxide, which generates light at a peak wavelength of 505 nm.

The cathode wire to which the oxides are applied is made of tungsten or ruthenium-tungsten alloy. The oxides in the cathodes are not stable in air, so they are applied to the cathode as carbonates, the cathodes are assembled into the VFD, and the cathodes are heated by passing a current through them while inside the vacuum of the VFD to convert the carbonates into oxides.

[14] http://www.sgitheach.org.uk/vfd3a.html

The principle of operation is identical to that of a vacuum tube triode. Electrons can only reach (and "illuminate") a given anode element if both the grid and the anode are at a positive potential with respect to the cathode.

Besides brightness, VFDs have the advantages of being rugged, inexpensive, and easily configured to display a wide variety of customized messages, and unlike LCDs, VFDs are not limited by the response time of rearranging liquid crystals and are thus able to function normally in cold, even sub-zero, temperatures, making them ideal for outdoor devices in cold climates. Early on, the main disadvantage of such displays was their use of significantly more power (0.2 watts) than a simple LCD. This was considered a significant drawback for battery-operated equipment like calculators, so VFDs ended up being used mainly in equipment powered by an AC supply or heavy-duty rechargeable batteries.

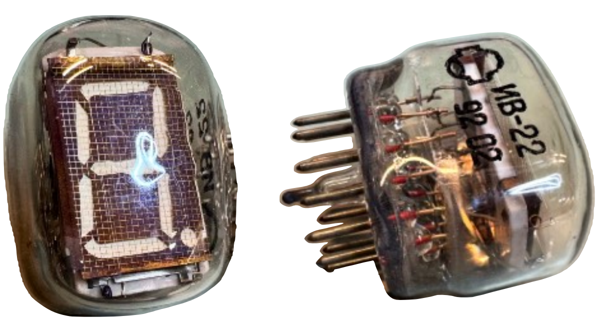


From the mid-1980s onwards, VFDs were used for applications requiring smaller displays with high brightness specifications, though now the adoption of high-brightness organic light-emitting diodes OLEDs[15] is pushing VFDs out of these markets.

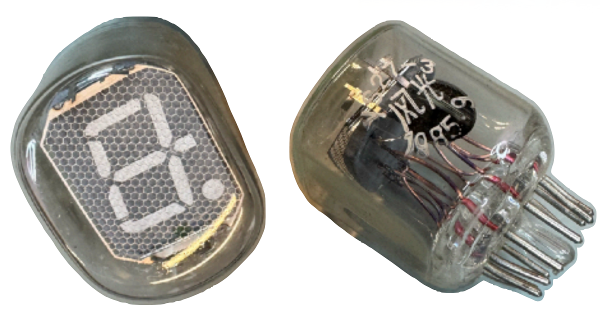
As mentioned previously, the first VFD was the single indication DM160, by Philips.[16] It could easily be driven by transistors, so was aimed at computer applications as it was easier to drive than a neon tube and had longer life than a light bulb. Below you will see that this venerable VFD is used as a colon between the hours, minutes and seconds tubes in the clock.

Suitable Display Tubes

The clock hardware is designed to operate two[17] types of VFDs, the common IV-22[18] type VFD and the ‘less’[19] common Chinese YS27-3[20] variant.



Soviet era IV-22 VFD Tubes



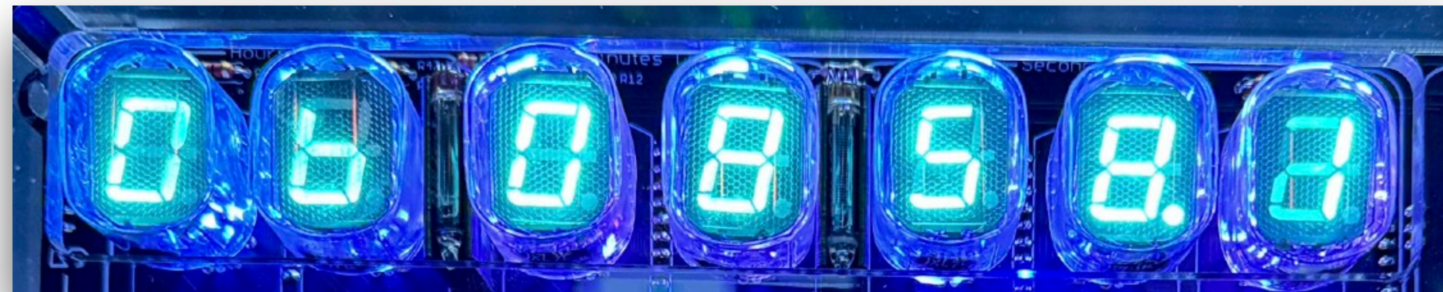
Chinese YS27-3 VFD Tubes

[15] https://en.wikipedia.org/wiki/OLED
[16] http://www.r-type.org/exhib/aai0056.htm ; http://www.r-type.org/pdfs/dm160.pdf
[17] More may follow….
[18] https://www.tube-tester.com/sites/nixie/dat_arch/IV-22.pdf
[19] Well, less common around these parts!
[20] https://www.tube-tester.com/sites/nixie/dat_arch/chinese_databook-02.pdf

These tubes have the same voltage requirements and roughly similar physical dimensions, the IV-22 having a slightly larger glass envelope. However, they have some minor internal differences. The YS27-3 has an 8th anode which is to the right of the centre horizontal anode. This 8th anode is not used in this clock. The pinouts for the two tubes are different so two tube specific PCBs were designed as an easier solution than using tube specific jumpers or adapters.

The Intent!

The clock electronics aims at displaying the time using seven 7-segment VFD tubes, separated by a VFD tube as a colon (twice, one between HH and one between MM). LEDs are used to add some bling. In practice we are heading here:



The clock is divided into **4 major** sections to achieve this:

- Time Keeping
  - Accurate master oscillator
  - Dividers to 1Hz pulses
  - 1/10th second counter
  - Seconds divider counter
  - Minutes divider-counter
  - Hours divider-counter

- VFD tubes
  - Seven 7 segment VFDs
  - Two VFD colon tubes
  - Convert the BCD time data to 7 segment illumination
  - High voltage anode and grid drivers

- LED Bling

- Power supplies
  - +24V VFD anode and grid supply
  - +1.32V VFD filament supply
  - +24V bling LED power
  - +5V digital and clock power
  - Room occupancy detection

A word about power supplies

Voltages are measured with reference to ground which is the negative lead of the 24V supply to the whole clock. Ground connections on the schematics are normally called GND. Therefore, a measured voltage described as, say, 90V means +90V with respect to clock ground.

The clock Eagle schematics refer to the following voltage supplies: The schematics are available in a separate PDF so you can view them side by side with the descriptions in this part of the manual.

Eagle Schematic Reference	Voltage	Function
+48V	+48V DC	Colon VFD anode supply
+24V	+24V DC	Main power supply to the clock. Supplies to, inter alia, 5V digital supply, display VFD anodes and grids, VFD bling LEDs
+5V	+5V DC	Main digital electronics power supply, VFD filament supply, colon grid bias
+5V/1	+5V DC	Clock timekeeping digital electronics power supply. This power supply can be from a back up battery that will keep the timekeeping function running when the main 24V power is switched off (i.e. the clock will maintain the correct time). If the back up battery is not available then +5V/1 is connected to +5V.

Time Keeping!

Master 32.768kHz TCXO[21]

The Master Clock oscillator IC1 from which all the clock timing signals are derived is a DS32KHZ[22] IC. This is a temperature compensated crystal oscillator (TCXO). The output is accurate to ±2ppm (±1 min/yr) from 0 °C to +40 °C.

It has an output frequency of 32.768kHz and has three uses:

- Timekeeping (after division to 1Hz)
- Master signal to 10Hz generator
- The colon display timing

The TCXO is powered by the optional timekeeping +5V/1 battery backed up supply line (optional).

[21] Eagle Schematic Page 1/17

[22] https://www.analog.com/media/en/technical-documentation/data-sheets/DS32KHZ.pdf

Master clock dividers[23]

Two 74LS393[24] dual 4-bit binary counters, IC2 and IC3, take the 32.768kHz signal from IC1 and divide it by two 16 times. The final output is 0.5Hz. The divider outputs are used as follows:

IC	Output	Frequency Hz	Use
IC2A	Q_A	16384	Unused (other than they are intermediate values on the way down)
IC2A	Q_B	8192	
IC2A	Q_C	4096	
IC2A	Q_D	2048	
IC2B	Q_A	1024	
IC2B	Q_B	512	
IC2B	Q_C	256	
IC2B	Q_D	128	
IC3A	Q_A	64	
IC3A	Q_B	32	
IC3A	Q_C	16	
IC3A	Q_D	8	
IC3B	Q_A	4	
IC3B	Q_B	2	Colon flash
IC3B	Q_C	1	Colon flash, 1Hz signal to seconds divider and 10Hz generator
IC3B	Q_D	0.5	Colon flash

The first bling LEDs are 4 LEDs that show the state of the outputs from IC3B. The outputs are buffered by 4 gates from a 74LS05[25], namely IC4A, IC4B, IC4C and IC4D. These are inverters with open-collector outputs. The LEDs are powered by the PWM +5V/2 supply. The colon flash output is selected by X1 and buffered by gates IC4E and IC4F. Finally the 1Hz output from IC3B Q_C is passed to the seconds divider.

[23] Eagle Schematic Page 1/17
[24] https://www.ti.com/lit/ds/symlink/sn54ls393.pdf
[25] https://www.ti.com/lit/ds/symlink/sn74ls05.pdf

Unit Seconds Divider[26]

The unit seconds divider comprises 4 negative-edge triggered flip-flops[27] in two 74LS112[28], IC6 and IC7. The Q outputs on each flip-flop give the seconds time as a BCD[29] number, the LSB[30] from IC6A Q and the MSB from IC7B Q. IC5A is a 74LS00[31] NAND[32] gate that detects the illegal count of 10 (1010 in BCD). The output from this gate goes low when this count is detected causing IC6 and IC7 to be cleared to zero. Therefore, the BCD value proceeds from 0 to 9 and the output comprises the 4 bit signal SEC_A, SEC_B, SEC_C and SEC_D.

There is an output from the last stage to the tens of seconds divider.

IC6 and IC7 $\bar{Q}$ outputs run 4 bling LEDs which show the seconds count at any time as a BCD number. These LEDs are powered by the PWM +5V/2 supply. Resistor R1 and the SEC_HOLD signal are part of the time-setting logic and will be discussed later.

Tens of Seconds Divider[33]

The tens of seconds divider comprises three 74LS112 flip-flops. Gate IC5B, another 74LS00 NAND gate, detects the illegal count of 6 (110 in BCD) which clears IC8A, IC8B and IC9A to zero. Therefore, the BCD value proceeds from 0 to 5 and the output comprises the 3 bits SEC10_A, SEC10B and SEC10_C. The SEC10C signal is passed forward to the unit minutes divider.

IC8A, IC8B and IC9A $\bar{Q}$ outputs run 3 bling LEDs which show the tens of seconds count at any time as a BCD number. These LEDs are powered by the PWM +5V/2 supply. Resistor R2 and the SEC10_HOLD signal are part of the time-setting logic and will be discussed later.

Unit Minutes Divider[34]

The unit minutes divider is a repeat of the unit seconds divider with flip-flops IC9B, IC10A, IC10B and IC11A dividing and NAND gate IC5C detecting the illegal 1010 state and clearing the divider to zero. The output comprises the 4 bit signal SEC10_A, SEC10_B, SEC10_C and SEC10_D. The output from the last stage goes to the tens of minutes divider.

Again the flip-flop $\bar{Q}$ outputs run 4 bling LEDs which will show the minutes count at any time as a BCD number.

[26] Eagle Schematic Page 2/17
[27] https://en.wikipedia.org/wiki/Flip-flop_(electronics)
[28] https://www.silicon-ark.co.uk/datasheets/sn74ls112a-datasheet-texas-instruments.pdf
[29] https://en.wikipedia.org/wiki/Binary-coded_decimal
[30] https://en.wikipedia.org/wiki/Bit_numbering
[31] https://www.ti.com/lit/ds/symlink/sn74ls00.pdf
[32] https://en.wikipedia.org/wiki/NAND_gate
[33] Eagle Schematic Page 2/17
[34] Eagle Schematic Page 3/17

Tens of Minutes Divider[35]

The tens of minutes divider is a repeat of the 10's seconds divider with flip-flops IC11B, IC12A and IC12B dividing and NAND gate IC5D detecting the illegal 110 state and clearing the divider to zero. The output comprises the 3 bit signal MIN10_A, MIN10_B, and MIN10_C. The output from the last stage goes to the unit hours divider.

Again the flip-flop $\bar{Q}$ outputs run 3 bling LEDs which will show the minutes count at any time as a BCD number.

Unit and Tens Hours Divider[36]

This is more complex than the seconds and minutes dividers as two cases must be dealt with:

- A 12 Hour clock that counts 01 to 12 and reset to 01 on the illegal count of 13
- A 24 Hour clock that counts 00 to 23 and reset to 00 on the illegal count of 24

The units of hours divider comprises the flip-flops IC14A, IC14B, IC15A and IC15B. They have a 4 bit output HR_A, HR_B, HR_C and HR_D. Again, their $\bar{Q}$ outputs run 4 bling LEDs to show the hour count.

The tens of hours divider comprises the flip-flops IC17A and IC17B. They have a 2 bit output HR10_A and HR10_B. Again, their $\bar{Q}$ outputs run 2 bling LEDs to show the tens of hours count.

The selection of 12 or 24 hour operation is made by switch S1 ON-ON.

12 Hour Clock: NAND gate IC13D detects the illegal state of binary 1010 in the units divider and clears the units flip-flops to zero. This means that decimal 09 changes to decimal 10. NAND gate IC16A detects the illegal state of binary 010011 (2 BCD bits from the tens counter and 4 BCD bits from the units counter) and this means that decimal 12 changes to 01. IC13C and IC13B combine the two clear signals to clear the hours flip-flops. Note that IC14A (BCD bit A) is not cleared as it is always in the required state. It is 0 when the flip-flops are cleared from decimal 09 to decimal 0 and is 1 when they are set to decimal 01.

24 Hour Clock: The units of hours counter operates as before ensuring that decimal 09 changes to decimal 10 and decimal 19 changes to decimal 20. IC16B detects the illegal state of binary 100100, decimal 24, and clears decimal 23 to decimal 00 as IC14A is in the correct state. R3 and C15 were found to be necessary so the glitches did not cause unwanted flip-flop clearing.

[35] Eagle Schematic Page 3/17
[36] Eagle Schematic Page 4/17

1/10th Second Divider[37]

This divider completes the time divider to provide a rapidly changing 1/10th second display.[38] The divider requires a drive signal of 10Hz. This is not readily available from the master clock divider that starts off at 32768Hz. Therefore a 10Hz signal needs to be generated. A free running oscillator could have been used but it is likely to drift and the display would look 'amateur'. Going back to the beginning, a master oscillator could be used that divides to both 10Hz and 1Hz. Oven controlled crystal oscillators OCXO[39] at 10MHz are commonly available on eBay, but that would require a much long divider chain.

The approach taken here is to use a phase-locked-loop PLL[40] that runs at 10Hz and is locked to the 1Hz signal derived from the master oscillator. The voltage controlled oscillator VCO[41] and phase detector[42] is IC22, the venerable 4046[43] and IC21 a decade counter 74LS90[44] provides a stand-alone divide by 10 function. These two ICs provide a 10Hz signal for the 1/10th seconds divider. IC20C and IC20D 4001 NOR gates detect that the PLL is locked and a LED provides an indication of lock.

The 1/10th of second divider is a repeat of the seconds divider. With IC18A, IC18B, IC19A and IC19B dividing and IC13A detecting the illegal 1010 state and clearing the divider to zero. The divider can also be cleared when the seconds counter is cleared by IC20A and Q1.

The output comprises the 4 bit signal 10THSEC10_A, 10THSEC10_B, 10THSEC10_C and 10THSEC10_D.

Again the flip-flop $\bar{Q}$ outputs run 4 bling LEDs which will show the 1/10th second count at any time as a BCD number. Resistor R4 and the 10SEC_HOLD signal are part of the time-setting logic and will be discussed later.

VFD tubes

Tens Hours Display[45]

The BCD to 7 segment decoder IC 74LS47[46] IC23 takes the tens hours HR10_A and HR10_B BCD signals and converts them into the segment pattern of anodes in the VFD tube to illuminate. Since

[37] Eagle Schematic Page 5/17
[38] Eye candy.... and not a small amount of prototyping to get right.....
[39] https://en.wikipedia.org/wiki/Crystal_oven
[40] https://en.wikipedia.org/wiki/Phase-locked_loop
[41] https://en.wikipedia.org/wiki/Voltage-controlled_oscillator
[42] https://en.wikipedia.org/wiki/Phase_detector
[43] https://www.ti.com/lit/an/scha002a/scha002a.pdf
[44] https://www.ti.com/lit/ds/symlink/sn54ls93.pdf
[45] Eagle Schematic Page 6/17
[46] https://www.ti.com/lit/ds/symlink/sn7447a.pdf

there is no HR10_C and HR10_D signals the C and D inputs are tied low. The Lamp Test LT input is described below.

The A to G segment outputs go low when it is required for the segment to light. Photo-couplers D31 and D32, 4 channel LTV847[47] devices, are used to couple the outputs from IC23 to the anodes of the VFD V1. The VFD power supplies for the anodes, grid and filament are described below. The schematic shows the YS27-3 VFD, the IV22 is almost identical, except it doesn't have anode 'h' which is unused in this design anyway. The decimal point DP anode is also not used (except for seconds tube - see below).

Units Hours Display[48]

This is identical to the Ten Hours display except that the BCD to 7 segment decoder IC24 receives signals from HR_A, HR_B, HR_C and HR_D.

Tens Minutes Display[49]

This is identical to the Ten Hours display except that the BCD to 7 segment decoder IC25 receives signals from MIN10_A, MIN10_B and MIN10_C. The D input is tied low.

Units Minutes Display[50]

This is identical to the Ten Hours display except that the BCD to 7 segment decoder IC26 receives signals from MIN_A, MIN_B, MIN_C and MIN_D.

Tens Seconds Display[51]

This is identical to the Ten Hours display except that the BCD to 7 segment decoder IC27 receives signals from SEC10_A, SEC10_B and SEC10_C. The D input is tied low.

Units Seconds Display[52]

With one important difference, this is identical to the Ten Hours display with the BCD to 7 segment decoder IC28 receiving signals from SEC_A, SEC_B, SEC_C and SEC10_D. The difference is that the decimal point is used! This DP separates the units seconds from the 1/10th seconds VFD. Switch S2 ON-OFF-ON selects how the DP is lit. It can be:

[47] https://www.mouser.co.uk/datasheet/2/239/LTV-8X7_series_201610_-1544776.pdf
[48] Eagle Schematic Page 7/17
[49] Eagle Schematic Page 8/17
[50] Eagle Schematic Page 9/17
[51] Eagle Schematic Page 10/17
[52] Eagle Schematic Page 11/17

- The colon is flashing (see the master clock schematic for the signal)
- The colon is off
- The colon is on

1/10th Seconds Display[53]

This is nearly identical to the previous displays except that the BCD to 7 segment decoder IC29 receives signals from 10THSEC_A, 10THSEC_B, 10THSEC_C and 10THSEC_D. The significant difference with all the other displays is that the filament can be switched off by switch S3 ON-OFF if the user doesn't want the 'eye-candy'.[54]

Colons[55]

Between the hour and minutes VFDs, and between the minutes and seconds VFDs are two DM160 VFD indicator tubes used as colons. These tubes, V8 and V9, have their cathode filaments biased above ground by the pairs of resistors in the 5V supply (R46 – R49). When the grids are biased positive to 5V current can flow through the tubes and the display is illuminated. When the grids are connected to ground they are now biased negative and current does not flow. Switch S8 ON-OFF-ON is used to select the grid bias and selects if the colons are off, permanently on or are flashing at 0.5Hz, 1Hz or 2Hz as set by the position of jumper X1 on the master clock schematic.

Time Setting Switches[56]

When the clock is first switched on the various time keeping counters wake up with random settings. The clock therefore needs a means to set the right time![57]

The clock has three buttons to set the time. Button S1 OFF-(ON) advances the hours at the rate of 1 hour per second when pressed. Normal operation is when switch S1 is open, C50 is charged via R26 and D36. The output of the Schmitt-trigger inverter 74LS14[58] IC34F is low. The low signal enables the bus buffer 74LS125[59] IC35A and this allows the MIN10_C output from the minutes divider to pass forward to the hours divider. Q7 inverts the output of IC34F, the high signal disables the bus buffer IC35B. When S1 is pressed C50 is discharged via R27. The discharge period acts to debounce[60] any jitter as the contacts of S1 close. The Schmitt-trigger provides a sharp output transition from low to high. Now IC35A is disabled and IC35B is enabled. This allows a 1Hz signal to pass from the Master Clock to the hour divider.

[53] Eagle Schematic Page 12/17
[54] Why you'd want to do that is beyond me....
[55] Eagle Schematic Page 16/17
[56] Eagle Schematic Page 14/17
[57] A small detail...
[58] https://www.ti.com/lit/ds/symlink/sn54ls14-sp.pdf
[59] https://www.ti.com/lit/ds/symlink/sn74ls125a.pdf
[60] https://en.wikipedia.org/wiki/Switch#Contact_bounce

Button S2 operates in the same way as S1, using IC34E, Q8, IC35C and IC35D to pass the SEC10_C output from the seconds divider or the 1Hz signal to pass from the Master Clock to the minutes divider.

Button S3 operates differently, when closed it turns on Q9, Q10 and Q11 and these clear the tens of seconds and units of seconds dividers[61]. Resistors R1, R2 and R4 prevent excess current flow out of IC5A, IC5B and IC13A respectively.

Bling

<u>BCD LED brightness control[62]</u>

The digital clock has arrays of LEDs that tell the time using BCD. Rather than select the current limiting resistor with each LED to give a fixed brightness, the clock uses the venerable 555[63] timer, IC30, as a variable mark-space PWM signal to switch the P-Channel MOSFET Q3. The drain of this MOSFET supplies power to all of the LEDs using the power supply called +5V/2. The trim pot R19 can adjust the mark-space ratio from about 0.5% to 95% giving almost complete control of the LED brightness. The PWM frequency is about 100 Hz.

<u>VFD Backlight LED brightness control[64]</u>

Each of the seven LEDs has a RGB LED package located underneath. These SMD packages have three separate LEDs. The modules are chained together and run from the +24V power supply. Again, IC31 is a variable mark-space PWM signal to switch the N-Channel MOSFET Q4. The drain connects to the low voltage end of the module red LED chain and its source connects to ground. IC34C inverts the output of the timer. Trim pot R20 can adjust the mark-space ratio and hence LED brightness. The module's green and blue LED chains are controlled with the same circuit built round IC32 and IC33 respectively. Since each colour LED has its own brightness control you can blend the 3 colours to produce the colour tone and overall brightness that you like.

<u>VFD Lamp Test[65]</u>

When S6 OFF-(ON) is pressed the lamp test LT input on the seven BCD to 7 segment decoder ICs is pulled low. This overrides the BCD data and turns on all the segments, displaying the number '8'.

[61] Eagle Digital/Analogue Schematic Page 2/11
[62] Eagle Schematic Page 13/17
[63] https://en.wikipedia.org/wiki/555_timer_IC
[64] Eagle Schematic Page 13/17
[65] Eagle Schematic Page 14/17

Room Occupancy - PIR Sensor and Clock Shutdown Timer[66]

The clock uses the PIR[67] Z1 to monitor room occupancy and a timer to shut down the display after an elapsed period of inactivity. When the PIR senses movement its output pin voltage rises. This has two effects, the first is to turn on a LED to show that the PIR has been "hit"; the LED being buffered by Q15. The second effect is to turn on the MOSFET Q16. This brings the base of the PNP transistor Q12 down to ground which turns it on. C54 is charged via Q12, R36 and D55. When the PIR is not sensing movement, C54 is slowly[68] discharged through Q13 and R38. When C54 is charged, the voltage on the input of the 555 timer IC36 is high, the 555 timer's output is low. The output is inverted by gate IC20B which has two effects, the first is to turn on LED D56 buffered by Q14 to show that the VFDs are "on" and the second effect is to send a power supply 'on' signal to the PSU to turn on the VFD anode and filament power supplies. When the voltage on the inputs of the 555 falls to ⅓ of the supply voltage, about 1.7V, the 555 output goes high. This turns off the LED, the VFD anode and the filament PSU. The clock stays in this condition until the PIR is hit and the cycle starts again.

Power Supplies

+24V PSU[69]

The clock is powered by an external 24V DC 2A power supply such as a wall wart. Over-current protection is provided by F1, over-voltage protection by D61 and reverse polarity protection by Q23. The protected +24V DC supplies the 5V regulator, the anodes and grids of the display VFDs, the +48V power supply for the DM160 anodes, the backlight bling LEDs and the external back-up battery and charger board.

+48V PSU

The DM160 colon tubes require an anode voltage of around 50V. A supply at 48V is obtained by using an isolated 24V to 24V DC convertor Z2. This stands on the +24V supply.

+5V PSU

The 5V digital power supply uses a LM2576-5[70] monolithic integrated circuit with a +5V fixed output. It is a step-down (buck)[71] switching regulator and just uses the typical application note diagram. This power supply is called +5V. J1 is normally fitted but it can be lifted to measure the +5V digital supply current to the clock if necessary.

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66 Eagle Schematic Page 15/17
67 PIR = Passive Infra-Red, https://industrial.panasonic.com/sa/products/pt/papirs/models/EKMC1601112
68 With the values shown the timer runs for about 20 – 25 minutes
69 Eagle Schematic Page 17/17
70 https://www.ti.com/lit/ds/symlink/lm2576hv.pdf
71 https://en.wikipedia.org/wiki/Buck_converter

Optional +5V DC digital battery back up power supply connection

An option for the clock is a battery backup for the time keeping section. If the battery back up is used then J2 is **not** fitted and the battery board is connected to X8. The power supply to the timekeeping logic is called +5V/1. The battery board and X8 are not part of the standard build. **This manual will not discuss the battery backup electronic design any further,**[72] but details on its use with the clock and a matching case housing are described later.

Normally J1 is fitted.

+24V Display VFD Grid supply[73]

To illuminate a display VFD, 24V on the grids are required. This grid supply can be pulse width modulated (PWM) and this gives a means to adjust the display VFD brightness. A 555 timer IC35 uses exactly the same circuit as the bling LED PWM. The MOSFETs Q18 and Q17 level shift the voltage to 24V.

Anode and Filament supply

The room occupancy sensor and shut down logic control the display VFD 24V anode supply using MOSFETs Q19 and Q21 as voltage level shifters and the filament supply for all VFDs using Q20 and Q22 high side current sources.

Epilogue

A microcontroller makes things a lot, simpler but perhaps not so much of a challenge, fun or educational?

[72] https://www.sgitheach.org.uk/batterybu.html

[73] Eagle Schematic Page 16/17

Building the Kit

Now comes the fun part! Please check the supplied parts with the table given below. If you find that something is missing or doesn't make sense, please contact[74] me as soon as possible. **Pay attention** to the correct orientation of appropriate parts (diodes, electrolytic capacitors, resistor networks, IC sockets, ICs and transistors).

Tick	Quantity	Part No.	Value	Description
☐	1	IV22-08 or YS23-7-06 PCB	Circuit Board	Can't do much without this... :)
☐	14	D29, D45, D46, D47, D48, D49, D50, D51, D52, D53, D54, D55, D58, D59	1N4148	Signal diodes - note orientation
☐	3	R36, R46, R48	100R	Resistors (1/4W Carbon Film). Always measure with a multimeter **before** installing.
☐	3	R5, R37, R38	100k	
☐	18	R3, R7, R17, R18, R21, R22, R25, R26, R28, R29, R30, R32, R33, R34, R39, R40, R44, R50	10k	
☐	1	R6	1M	
☐	3	R27, R31, R45	1k	
☐	1	R35	2k2	
☐	2	R47, R49	33R	
☐	1	R43	39k	
☐	3	R1, R2, R4	470R	
☐	1	R8	6k8	
☐	1	R41	8k2	
☐	1	R9	omit	
☐	1	J1	Link	Fit
☐	1	J2	Link	**Do not fit** if Battery Backup is used.
☐	7	R10, R11, R12, R13, R14, R15, R16	39R 1W	Metal Film
☐	1	D62	1N5822	Schottky diode - note orientation
☐	1	D60	1N4742	12V 1W Zener diode - note orientation
☐	6	8-Pin DIL Sockets	DIL8	IC Sockets - Notch to the left.
☐	11	14-Pin DIL Sockets	DIL14	
☐	34	16-Pin DIL Sockets	DIL16	
☐	1	D61	TVS	Bidirectional TVS diode

[74] stocksclocks@gmail.com

Tick	Quantity	Part No.	Value	Description
☐	53	C1, C2, C3, C4, C5, C6, C7, C8, C9, C10, C11, C12, C13, C14, C16, C17, C18, C19, C20, C22, C23, C24, C27, C28, C29, C30, C31, C32, C33, C34, C35, C36, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C52, C53, C55, C56, C57, C58, C59, C61	100nF	Capacitors [ceramic]
☐	1	C15	220pF	
☐	12	RN1, RN2, RN3, RN4, RN5, RN6, RN7, RN8, RN9, RN10, RN11, RN12	330R	Resistor Networks - Note that RN2, RN3, RN4 and RN5 are on the reverse of the PCB. Also, note that the dot on the component aligns with the 1 on the PCB (RN1 is different to the rest..)
☐	2	C21, C26	10µF	Electrolytic Capacitors - Note orientation as per silkscreen.
☐	3	C25, C50, C51	1µF, 50V	
☐	1	C67	2µ2 100V	
☐	5	C62, C63, C64, C65, C66	1000µF 10V	
☐	1	C60	100µF 35V	
☐	1	C54	470µF 10V	
☐	16	Q1, Q2, Q4, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q14, Q15, Q16, Q18, Q21, Q22	2N7000	N Channel MOSFET - note orientation
☐	5	Q3, Q17, Q19, Q20, Q23	IRF9540	P Channel MOSFET - note orientation
☐	1	Q13	MSPA06	NPN Transistor - note orientation
☐	1	Q12	MPSA56	PNP Transistor - note orientation
☐	31	D1, D2, D3, D4, D5, D6, D7, D8, D9, D10, D11, D12, D13, D14, D15, D16, D17, D18, D19, D20, D21, D22, D23, D24, D25, D26, D27, D28, D30, D56, D57	3mm LED	See Notes and Check Orientation! Remember to use the laser cut spacers for all of them.
☐	1	F1 + fuse holder	2A Fuse	MiniBlade Fuse + Holder
☐	1	Z2	IEB0124S24	DC/DC Converter
☐	1	L1	100µH	Inductor
☐	1	X7	Power Jack	Use supplied spacer - see notes.
☐	4	X2, X3, X4, X5	1 x 3 Headers	Female Header Sockets
☐	1	X6	1 x 3 Header	Male Header Pins + Header Shorts
☐	1	X1	2 x 3 Header	
☐	5	R19, R20, R23, R24, R42	100k	Potentiometers
☐	1	IC38	LM2576	5V Regulator IC
☐	1	KK1	Heatsink	Including nut and screw for IC38 - See notes.

Tick	Quantity	Part No.	Value	Description
☐	1	IC34	74HC14N	Hex schmitt trigger INVERTER
☐	2	IC5, IC13	74LS00N	Quad 2-input NAND gate
☐	1	IC4	74LS05N	Hex INVERTER, open collector
☐	12	IC6, IC7, IC8, IC9, IC10, IC11, IC12, IC14, IC15, IC17, IC18, IC19	74LS112N	Dual J-K negative edge triggered FLIP FLOP, preset and clear
☐	1	IC35	74LS125N	Quad bus BUFFER, 3-state
☐	1	IC16	74LS20N	Dual 4-input NAND gate
☐	2	IC2, IC3	74LS393N	Dual 4-bit decade and binary COUNTER
☐	7	IC23, IC24, IC25, IC26, IC27, IC28, IC29	74LS47N	BCD to seven segment DECODER/ DRIVER
☐	1	IC21	74LS90N	Decade, divide by twelve and binary COUNTER
☐	1	IC20	CD4001N	Quad 2-input NOR
☐	1	IC22	CD4046N	Micropower PLL
☐	1	IC1	DS32KHz	TCXO
☐	6	IC30, IC31, IC32, IC33, IC36, IC37	NE555	General Purpose Timers
☐	14	D31, D32, D33, D34, D35, D36, D37, D38, D39, D40, D41, D42, D43, D44	LTV847	4 Channel Optocoupler
☐	4	S4, S5, S6, S7	Pushbutton	Switch
☐	2	S1, S3	Toggle Switch	On-On
☐	2	S2, S8	Toggle Switch	On-Off-On
☐	1	Z1	EKMC1601112	PIR + 3D printed mount - see notes.
☐	2	V8, V9	DM160	Colon VFDs + 3D printed mounts - see notes.
☐	7	V1, V2, V3, V4, V5, V6, V7	IV22 or YS27-3	VFD Tubes + Pins - see notes.
☐	1	X8	3 Terminal Block	Optional - see notes.
☐	13	Switch and Button caps	3D Printed	See construction notes.

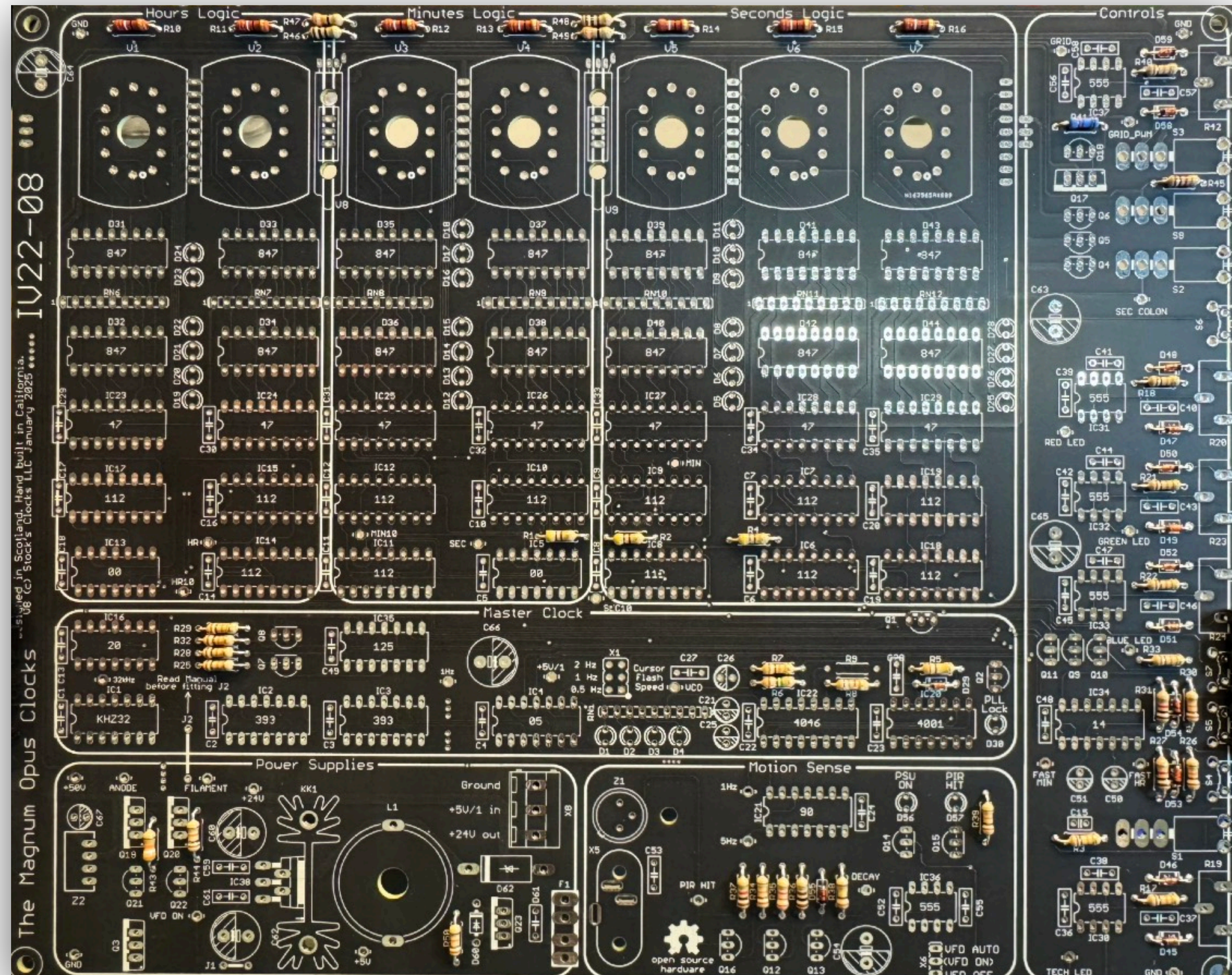
Bling LED Sub-board

Tick	Quantity	Part No.	Value	Description
☐	1	Bling Board V2	PCB	Can't do much without this… :)
☐	7	D1, D2, D3, D4, D5, D6, D7	SMD5050	Tricolour LED Modules
☐	2	R1, R3	510R	Resistors (1/4W Carbon Film)
☐	1	R2	82R	

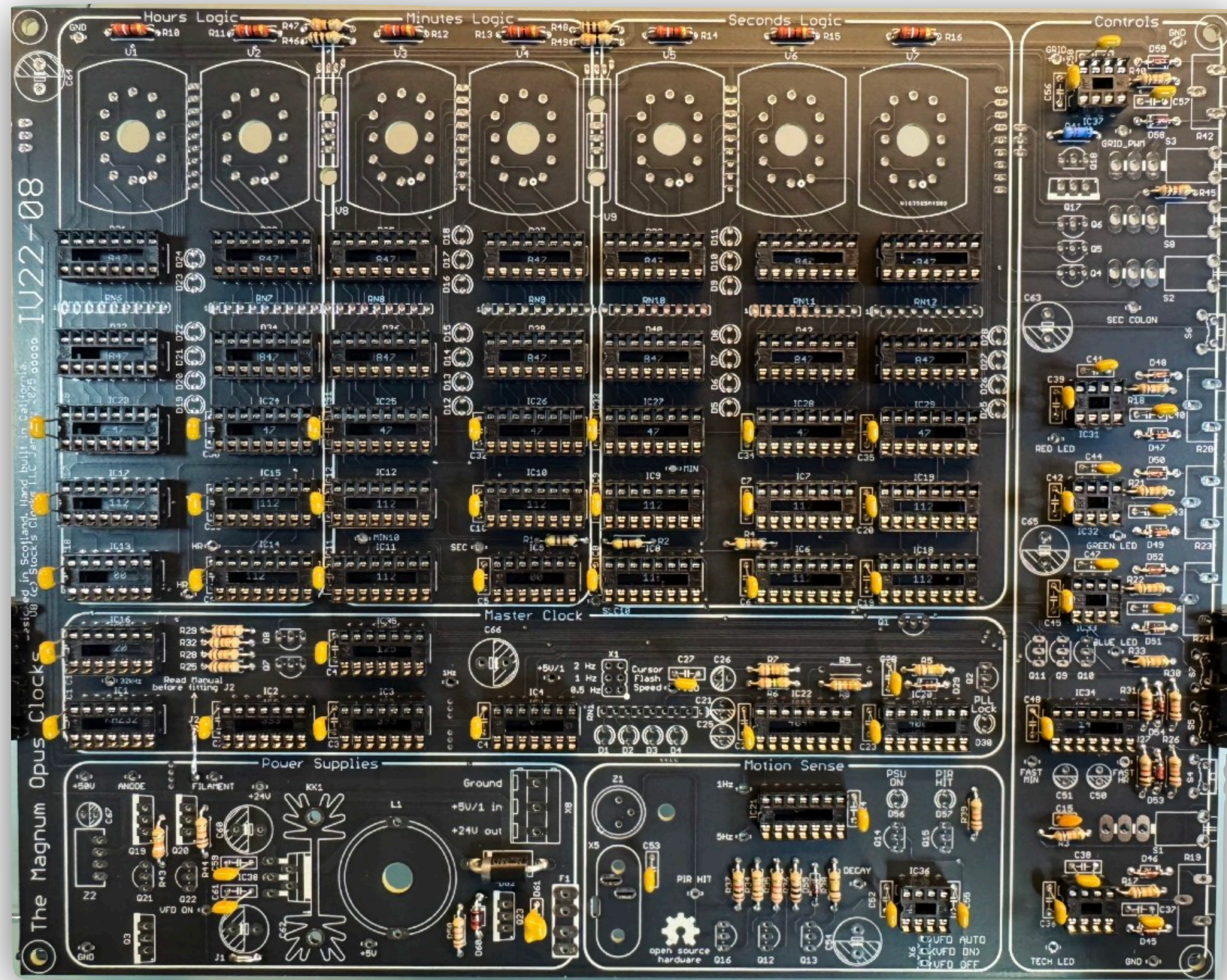
Tick	Quantity	Part No.	Value	Description
☐	3	Blue, Red, Green	Links	Fit
☐	4	X1, X2, X3, X4	1 x 3 Headers	Male Header Pins
☐	7	D1, D2, D3, D4, D5, D6, D7	Light Guides	3D printed acrylic holders + acrylic
☐	14	14 x M2 screws + nuts		Hardware for Light Guides

It's easiest (in my experience) to start with the smallest parts first and work your way up to the largest component(s). The table above has the parts sorted with that in mind, with the smallest (mostly) first. This is up to you of course, and depends on your experience level. Take your time, once done you'll be looking at your handiwork for a long time.

Construction notes and pictures.

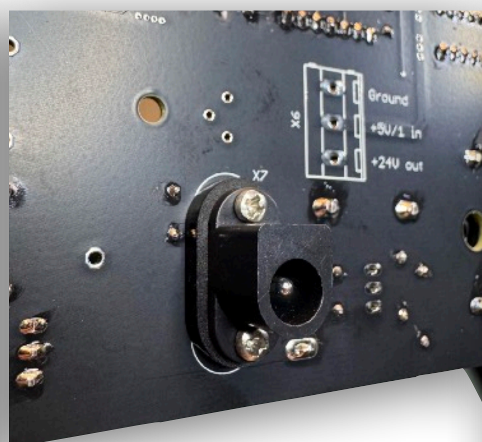


All resistors and small signal diodes fitted



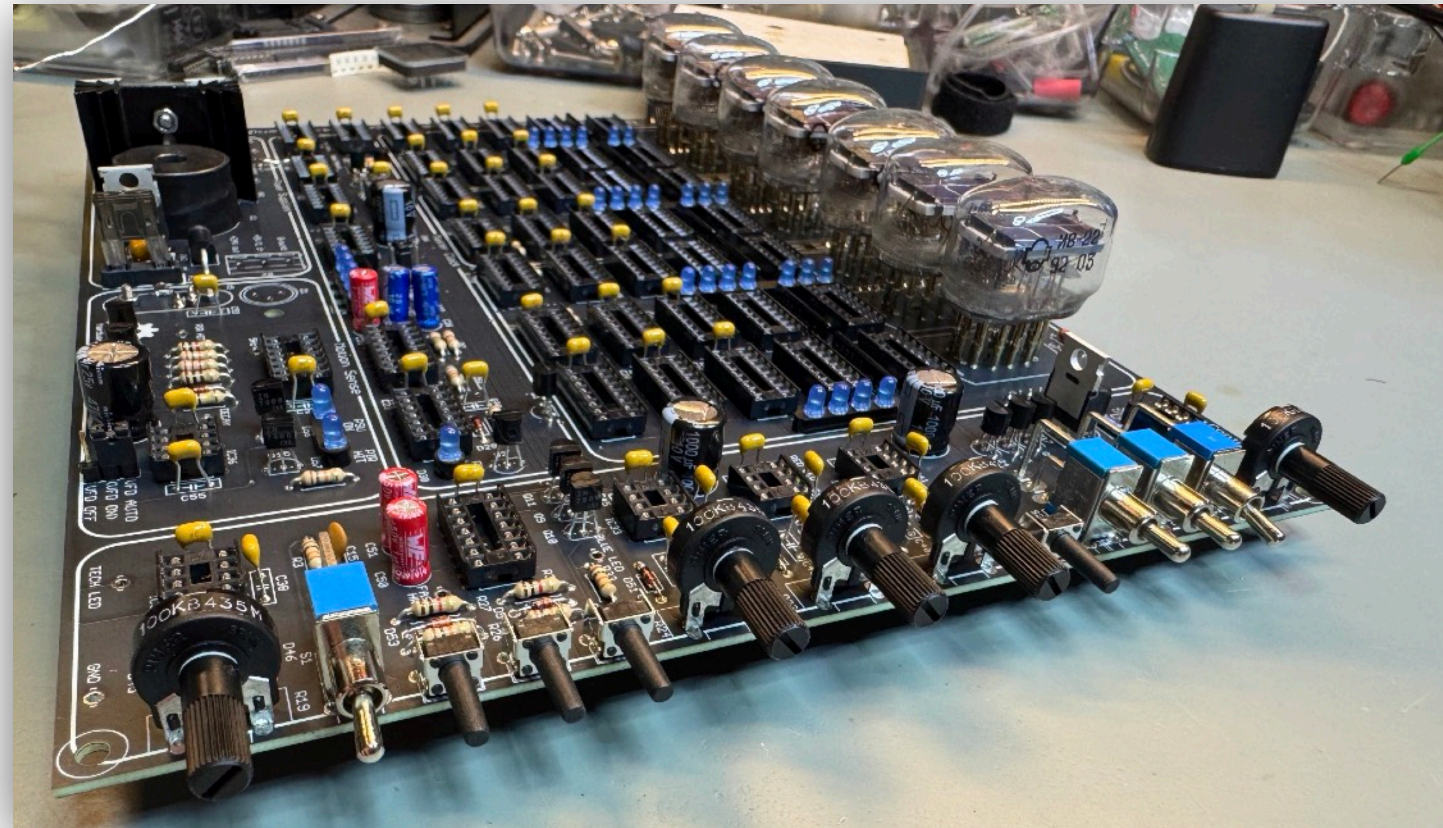
All IC sockets and remaining diodes installed

Note the included LED spacers to help align the height and spacing. Make sure LEDs are installed correct way around!

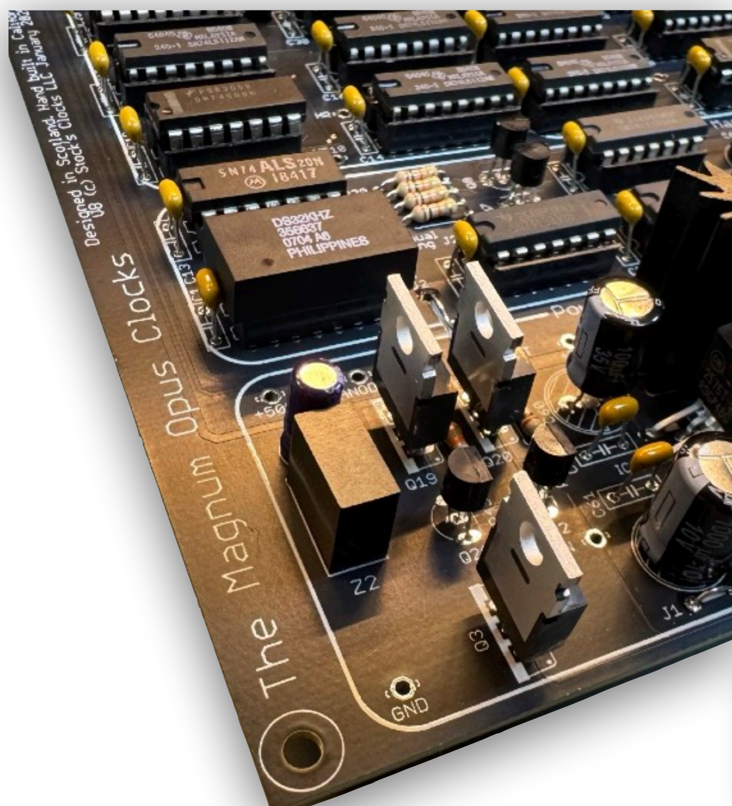


Note the spacer to mount the DC input socket on the **rear** of the PCB attached using 2 M2 x 10mm screws and nuts.

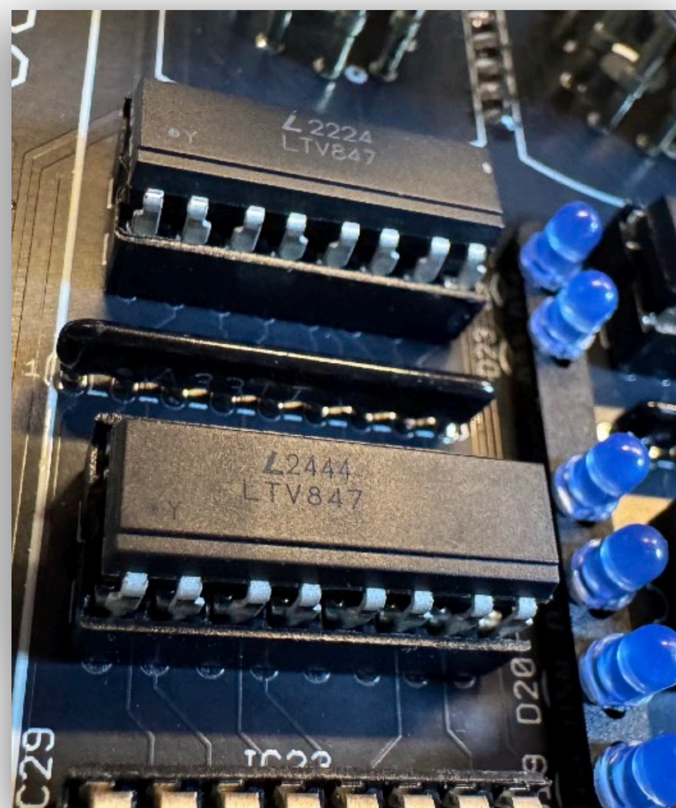
Securely mount IC38 to its heatsink using the supplied M3 x 6mm screw and nut.



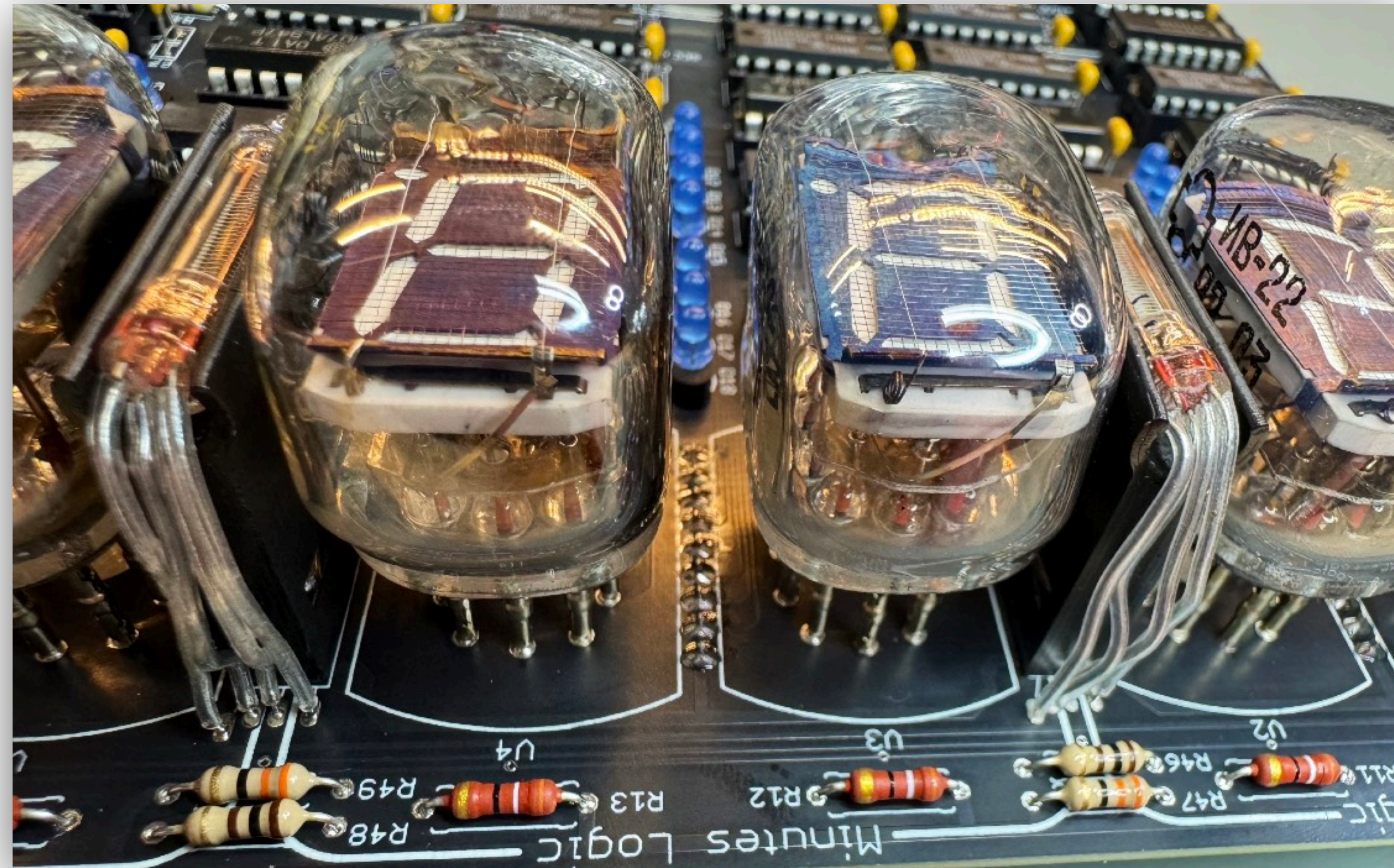
Capacitors, transistors, potentiometers and switches installed. Note the neat and straight alignment of the switches etc.



Note the DS32KHz orientation and all the notches on the ICs to the left - all ICs are oriented the same way.

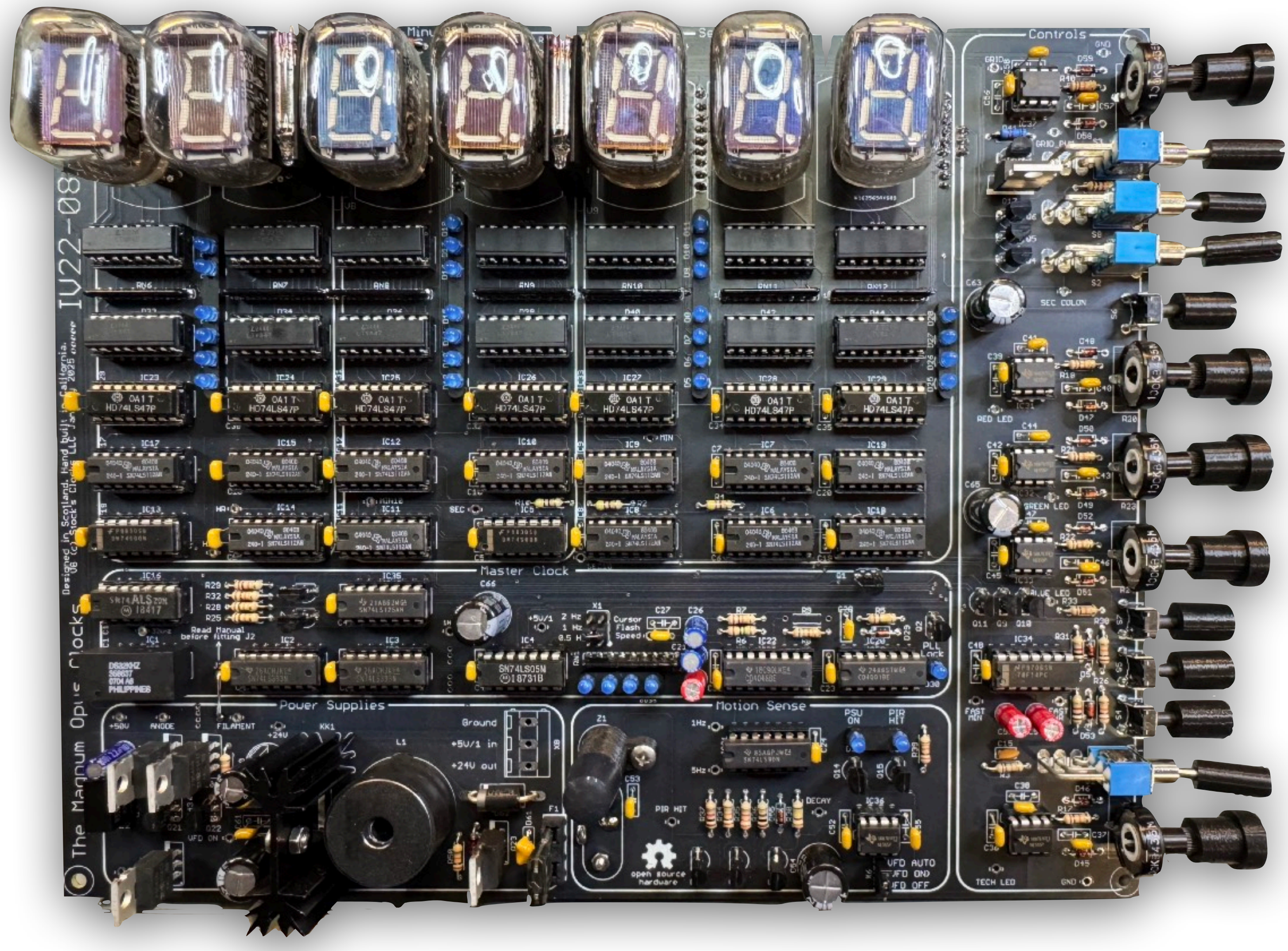


The LTV847 optoisolators are installed as above and note orientation of the resistor networks (check RN1!).



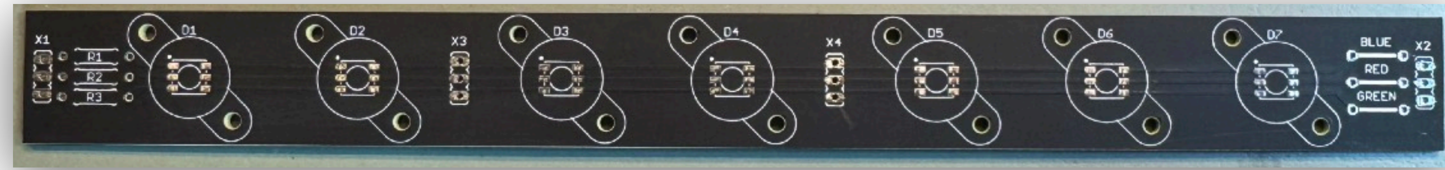
The DM160 tubes slide into their 3D printed mounts, attached to the PCB by virtue of captive square nuts installed in their bases and screwed in place. It is a good idea to add heat-shrink to the leads to avoid accidental shorts, as they are quite close together. Note that the display window of the tube points forward and the leads match the orientation on the PCB for ease of installation. You will want to make sure that they are aligned with the mid-line of the VFDs for the best aesthetics. When installing the IV22's, it is advisable to lightly sand each pin to remove oxidation, install a set of socket pins on each tube then solder in place, making sure that they are all seated against the PCB appropriately.

The PIR stands on a 3D printed mount that is attached to the PCB. You will need to solder three lead wires to the PIR contacts and feed them through. This can be accomplished by attaching the mount and feeding the wires from the underside of the PCB, soldering them to their respective pins on the PIR, mounting the PIR flat on top of the standoff then soldering the leads in place.

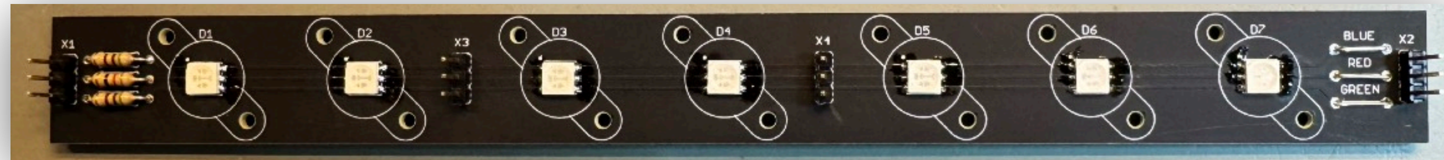


The completed PCB! Note that R9 is not fitted (as per instructions). Also X8, which is an optional header block when using the battery backup board is also not populated here. See the battery backup section at the end of this manual.

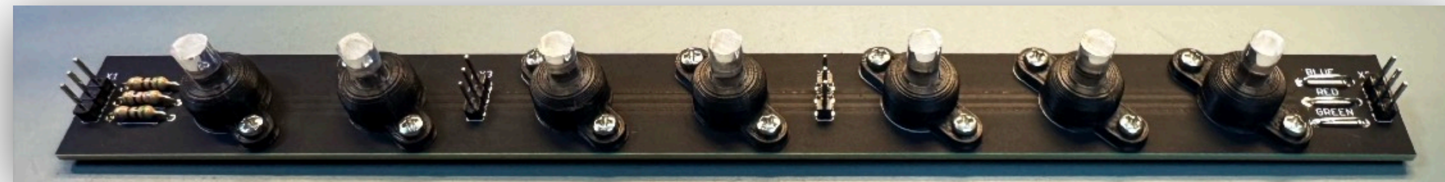
Note that the kit comes with decorative 3D printed pieces to go on all the 'twiddly' bits and that they are appropriately labelled. The potentiometer knobs maybe a little tight or loose due to tolerances, so either the use of a small file on the 3D printed part may be necessary or a small piece of paper (or similar) to help with a tight enough grip. They do need to grasp the knurled part of the potentiometer enough to turn smoothly. Take care not to bend the potentiometers back when installing the knobs if they are too tight. These are all optional, the clock is perfectly functional without them, but they finish things off nicely (I think?).



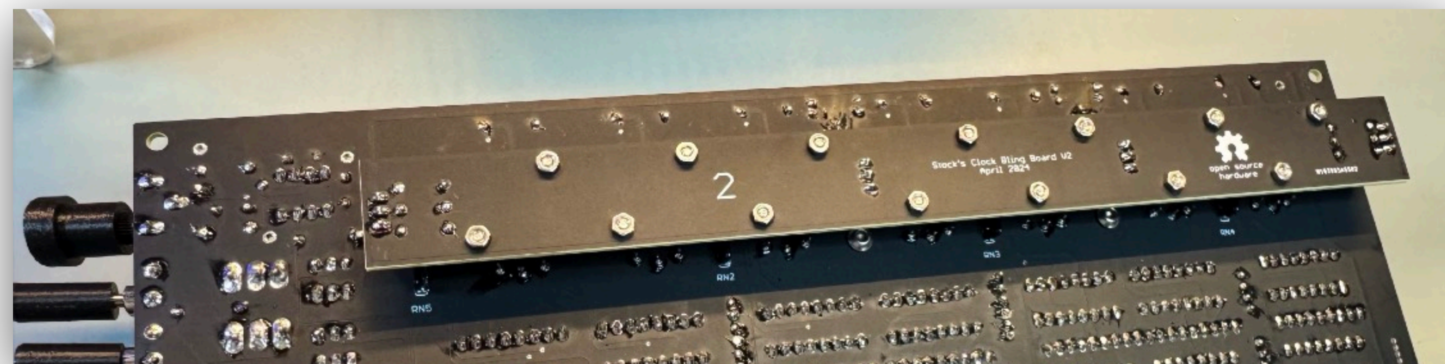
The Bare Bling Board



Connectors, SMD LEDs, links and resistors installed - Note the dot on the PCB aligns with the notch on the LED case. Don't use too much heat when soldering the LEDs, a solder flux pen will make it easier if you have one at hand.



3D printed light guide holders go over the LEDs and are attached with M2 screws and nuts. The acrylic can be a tight fit and be sure not to damage the LEDs when installing. The lengths of these are slightly different depending on whether the IV22 or YS27-3 VFD tubes are used.



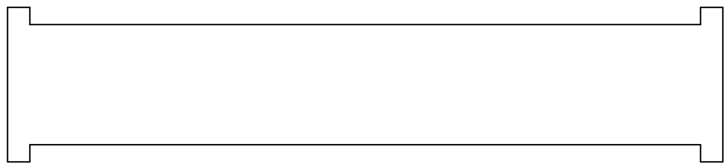
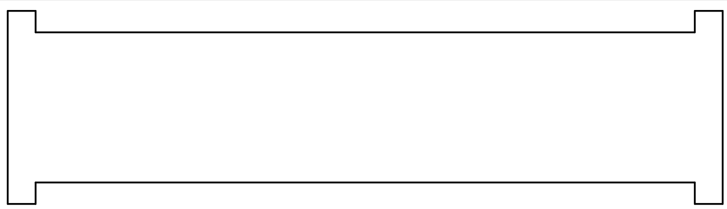
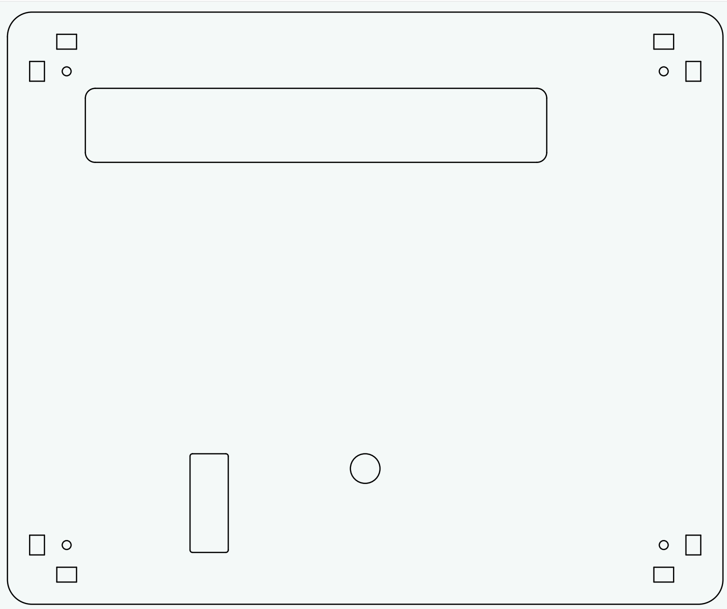
The Bling board installs from the rear of the main PCB, it can only fit one way around.....

Once you've finished everything and it (hopefully!) looks correct, insert the header shorts on X1 and X6 as appropriate and apply power and check that the clock is functioning properly. The clock requires 24V DC with a minimum 1A current, center positive. Check that all the switches and potentiometers do what they're supposed to do, the binary LEDs work correctly and the hours and minutes can be set correctly etc. Ninety-nine percent of issues with building kits tend to either be incorrect orientation of a component (diode, capacitor, IC, transistor) or a bad solder joint or short. All the ICs in this clock have the same orientation, notch to the left. If you're having trouble then feel free to send an email.[75] It is also a good idea to check that all the IC legs are in the sockets correctly!

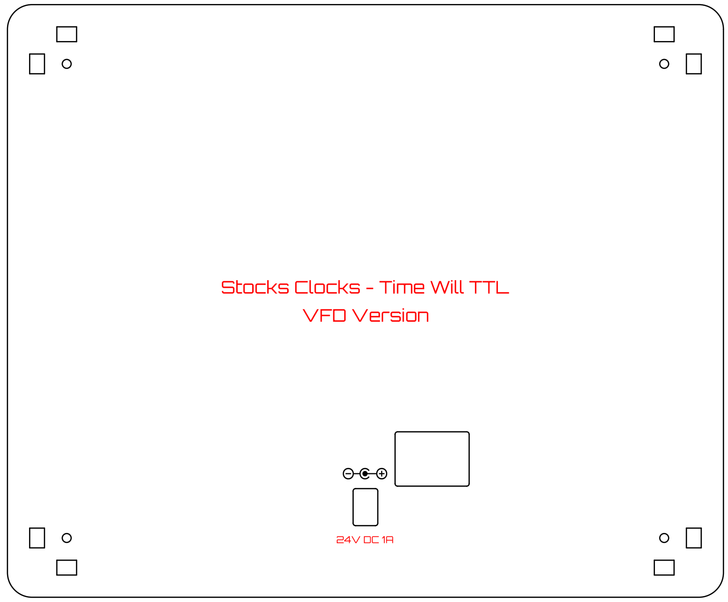
[75] stocksclocks@gmail.com

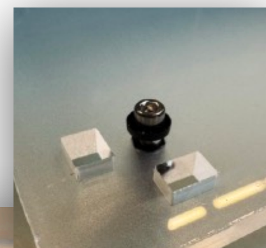
Case Construction

Now comes the time to put the clock board in its case. Please check the supplied parts with the table given below. If you find that something is missing or doesn't make sense, please contact[76] me as soon as possible.

Tick	Quantity	Part No.	Description
☐	4	M3 x 20mm	Male/Female standoffs
☐	4	M3 x 25mm	Female/Female standoffs
☐	8	M3 washers	
☐	8	M3 x 12mm screws	Socket head screws
☐	2	Top and bottom side panels	
☐	1	Right hand panel	
☐	1	Left hand panel	
☐	1	Front Panel (IV22 and YS27-3 have slightly different sized tube opening)	

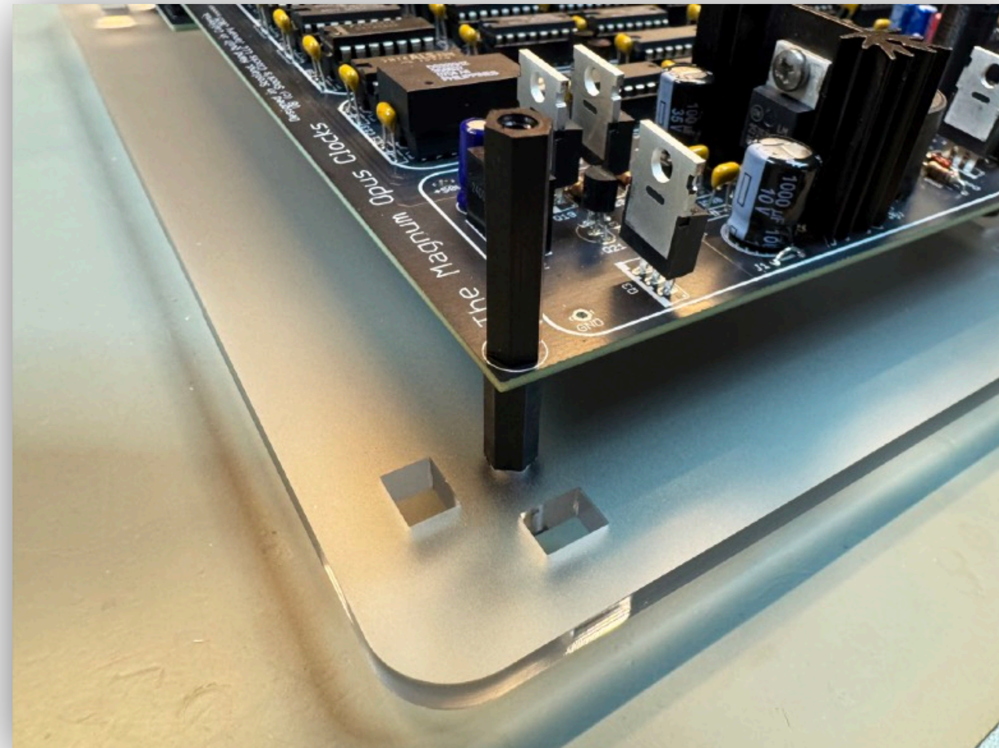
[76] stocksclocks@gmail.com

Tick	Quantity	Part No.	Description
☐	1	Rear Panel (Frosted or Clear depending on order)	

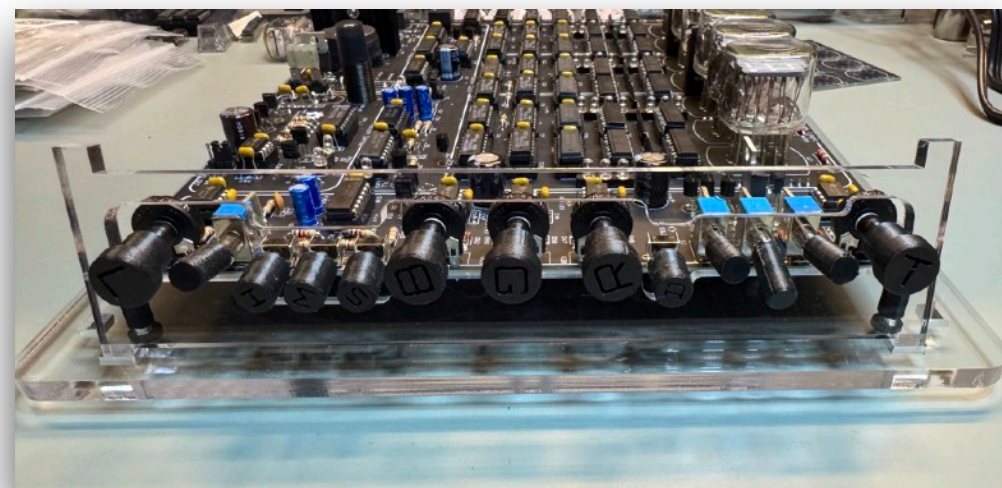


Start with the back plate, peel off the protective paper and insert M3 x 12mm socket head screws from the back, using a black washer and then attach the M3 x 20mm male/female standoffs at each corner. Don't tighten them completely at this point.

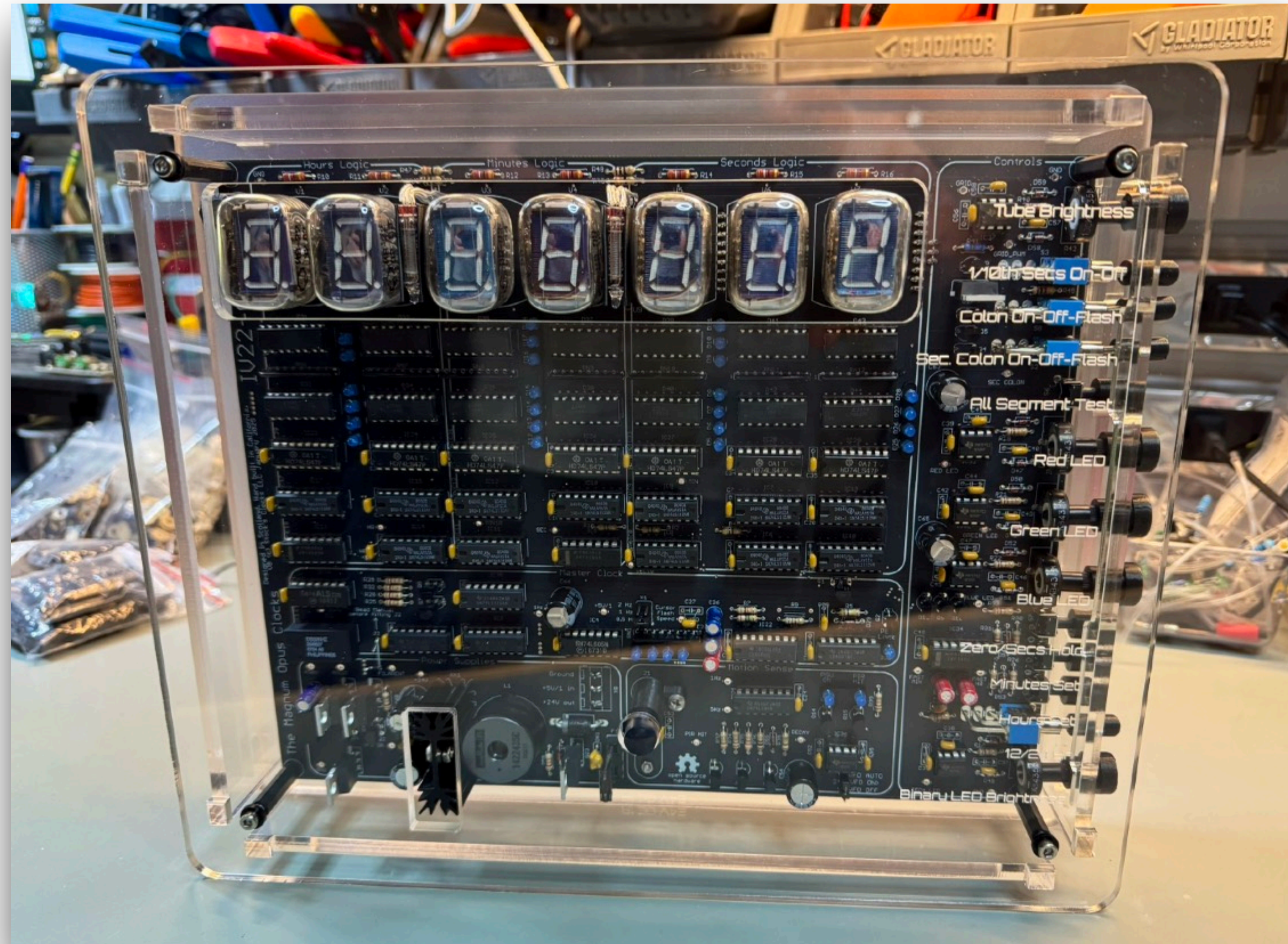
Place the PCB over the standoffs (right way up!) and then add 4 of M3 x 30mm female/female standoffs. Hand tighten them.



Now remove the protective layers off of the side acrylic pieces. Install them around the edges as appropriate. You'll note the piece that goes over the switches needs a little finesse, but it will fit snuggly and is cut to place one way around only.

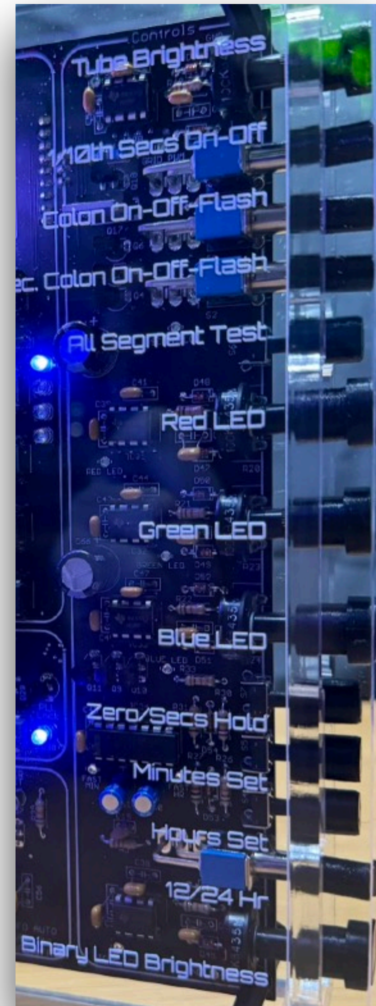


The last step is to remove the protective film from the front plate, insert over the side pieces making sure the notches match the holes in the acrylic, then using another 4 washers and M3 x 12mm socket head screws attach the front plate. Place the whole clock vertically on a flat surface and make sure that it lays true. Tighten the screws on the front and back and that completes the case construction!



The Completed IV22 TTL Clock

Operational Notes



The clock should only be powered by a 24V centre positive DC power supply (5.5/2.1 barrel) with a minimum current supply of 2A.[77]

Operating the clock should be fairly obvious, but here's a breakdown of all the twiddly bits…

- **Tube Brightness** - does what it says!
- **1/10th Secs On-Off** - For those that don't like the dance of the 1/10ths of seconds, feel free to turn it off!
- **Colon On-Off-Flash** - Three-way switch to make the DM160 tubes flash according to the frequency set by the X1 jumper (0.5, 1 or 2 Hz), stay static or turn off.
- **Sec. Colon On-Off-Flash** - Both the YS27-3 and IV22 tubes contain a decimal point, this switch controls this the same way as the Colon On-Off-Flash switch.
- **All Segment Test** - Press this button to illuminate all the segments on every VFD tube to test.
- **Red LED** - Controls the brightness of the **RED** LED.
- **Green LED** - Controls the brightness of the **GREEN** LED.
- **Blue LED** - Controls the brightness of the **BLUE** LED. Adjusting all three of these allows your own colour palette of backlighting!
- **Zero/Secs Hold** - Resets the seconds VFDs to zero and keeps them there until you release the button.
- **Minutes Set** - Use to set the correct Minutes time.
- **Hours Set** - Use to set the correct Hours time.
- **12/24 Hr** - Toggle between 12 and 24[78] timekeeping. You may need to cycle through the hours once to reset the hour counters correctly after changing.
- **Binary LED Brightness** - Controls the brightness of all the LEDs on the clock PCB (Binary counting, PIR and PLL Lock)

Note that this clock will not be as accurate as a GPS or WiFi disciplined device, it's base frequency is derived from a TCXO and as such will drift over time, but that was never the point… :)

Enjoy!

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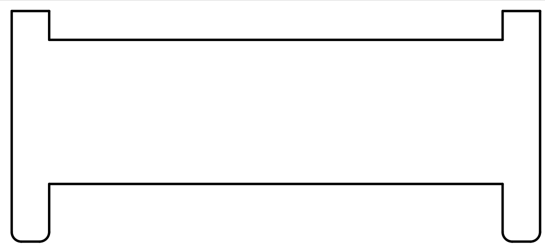
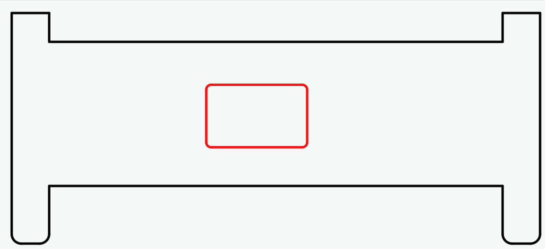
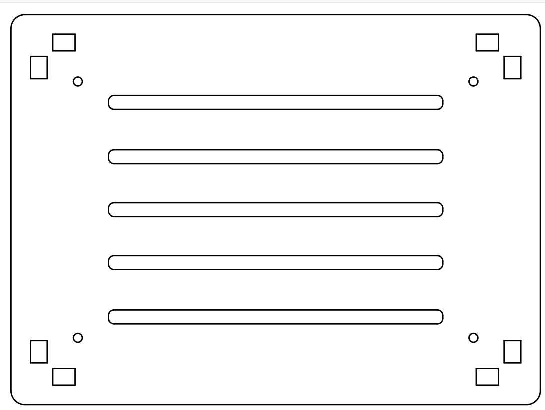
[77] Supplied with kits and complete clocks in the USA. For customers elsewhere on the globe, you will need to source an appropriate supply locally.

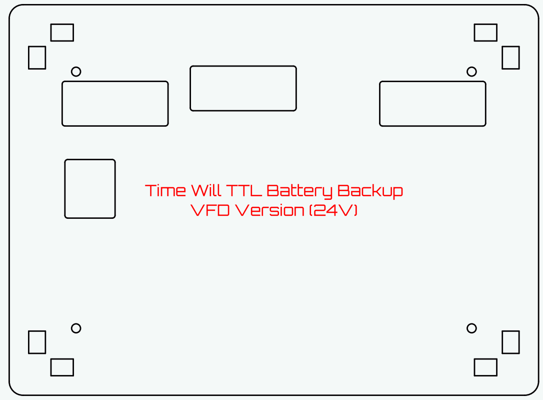
[78] Military time to our American audience…

Battery Backup Option

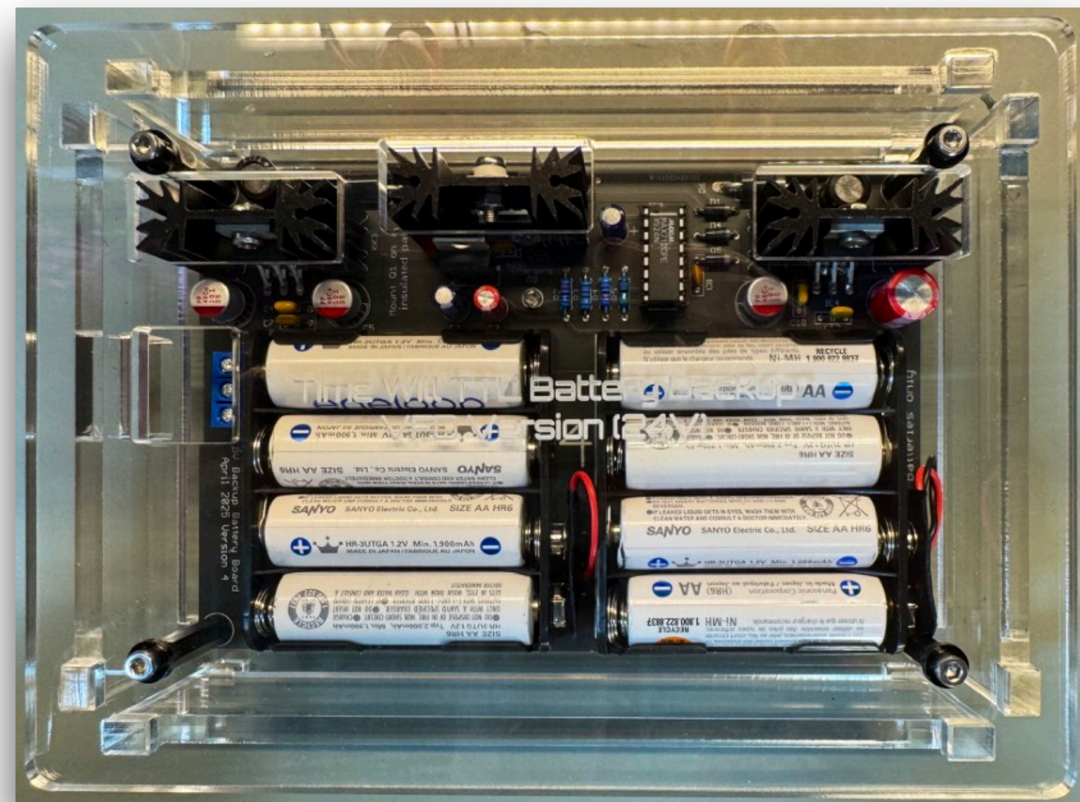
Your clock is happily telling the time, minding its own business, when suddenly the power goes out and now the time is lost![79] Well, if you don't want to keep setting the time after this happens, then the battery backup option is for you! Construction of the electronics is discussed elsewhere.[80]

Tick	Quantity	Part No.	Description
☐	4	M3 x 5mm	Male/Female standoffs
☐	4	M3 x 25mm	Female/Female standoffs
☐	8	M3 washers	
☐	4	M3 x 12mm screws	Socket head screws
☐	4	M3 x 10mm screws	Pan head screws
☐	2	Top and bottom side panels	
☐	1	Right hand panel	
☐	1	Left hand panel (note this should fit with the opening inline with the 3-way screw connector)	
☐	1	Base panel	

[79] The Horror! Microprocessors do sometimes have advantages… :)
[80] See the TTL Clock Battery Backup Manual

Tick	Quantity	Part No.	Description
☐	1	Front panel	

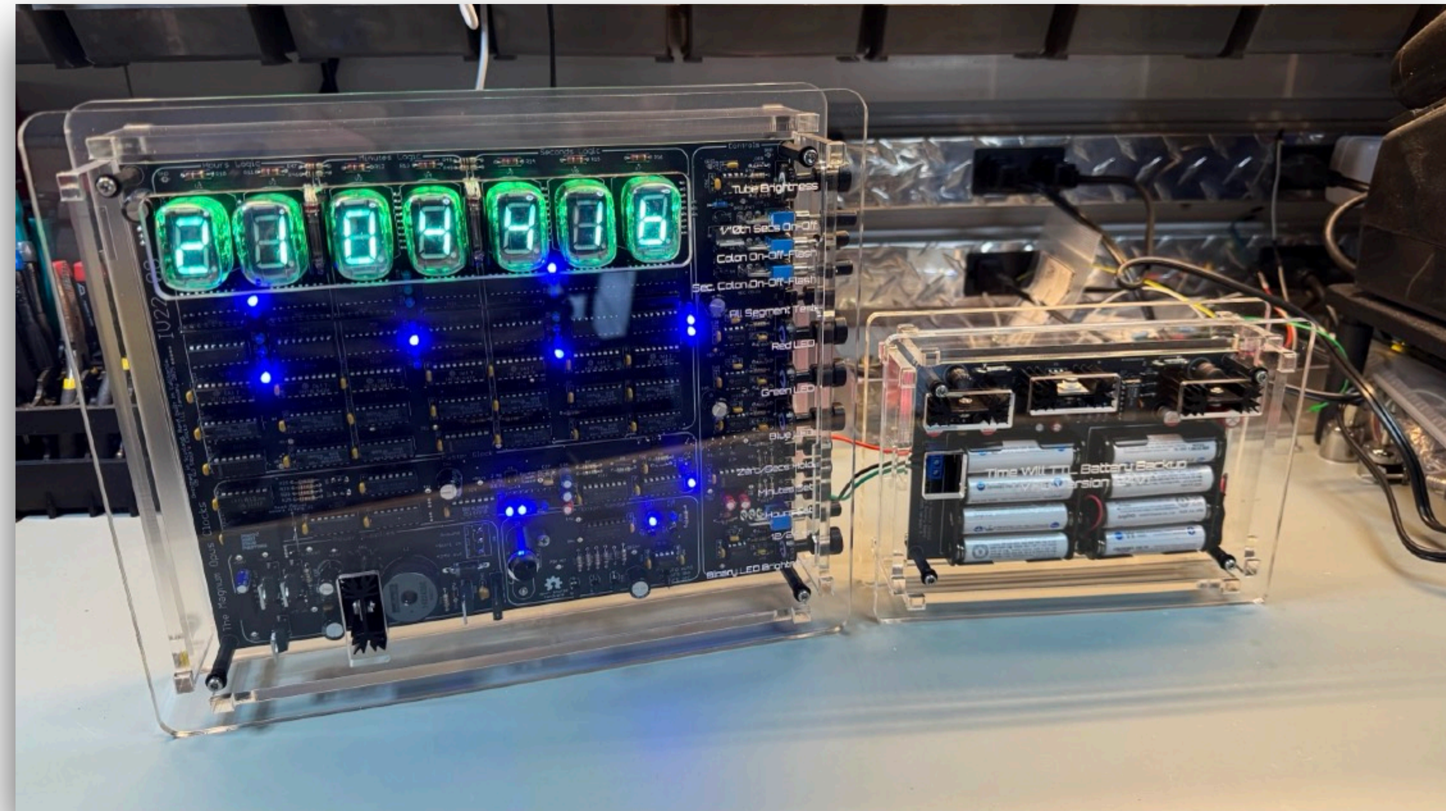
Construction of the case should be self evident and follows the same process as the case for the clock.



Installed in an optional standalone case

To use the battery backup board, you will need 3 wires to connect the 24V, 5V and GND from the rear of the clock and the connector on the backup board. Do not hook this up with the clock powered up. These will be supplied with any kit or completed clock if ordered with the backup board.[81] **Note that if you opt for the battery backup, the clock will only operate if the battery backup is connected (unless you reconnect jumper J2).**

[81] With bootlace ferrules no less...

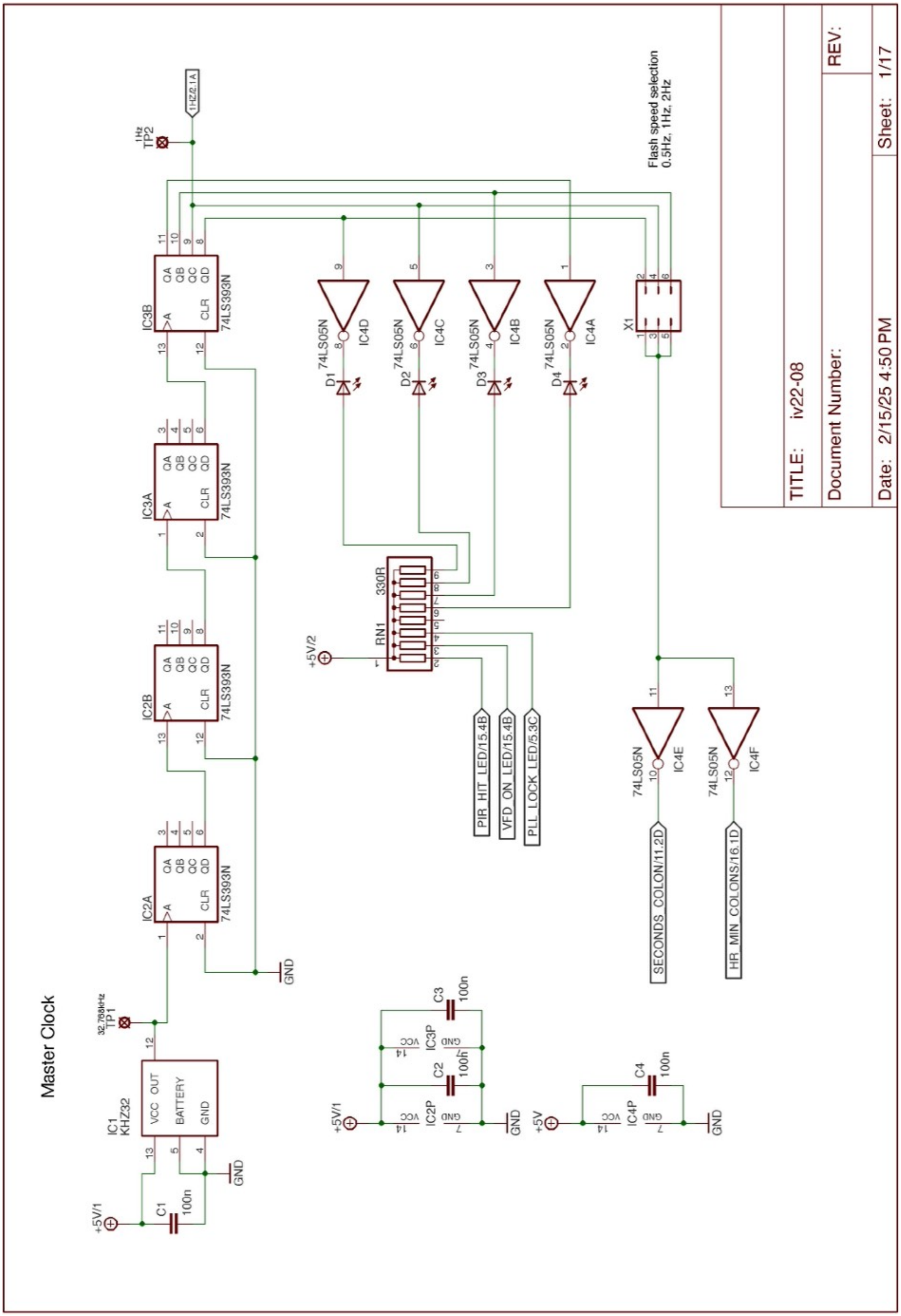


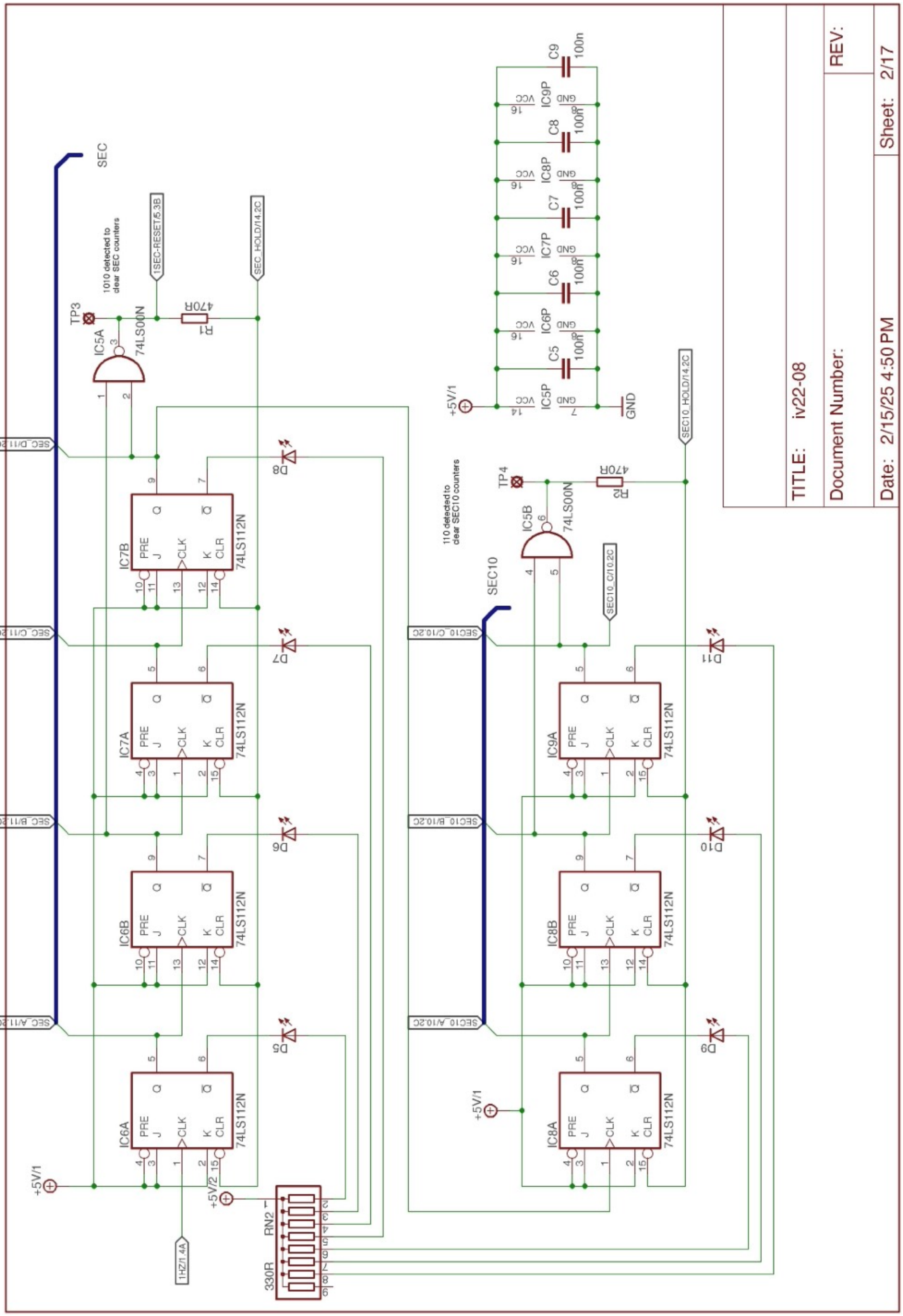
The completed IV22 clock and its battery backup doing their thing….

You're done! Enjoy the clock and if you have any comments, please don't hesitate to contact[82] me.

[82] stocksclocks@gmail.com

Eagle Schematics

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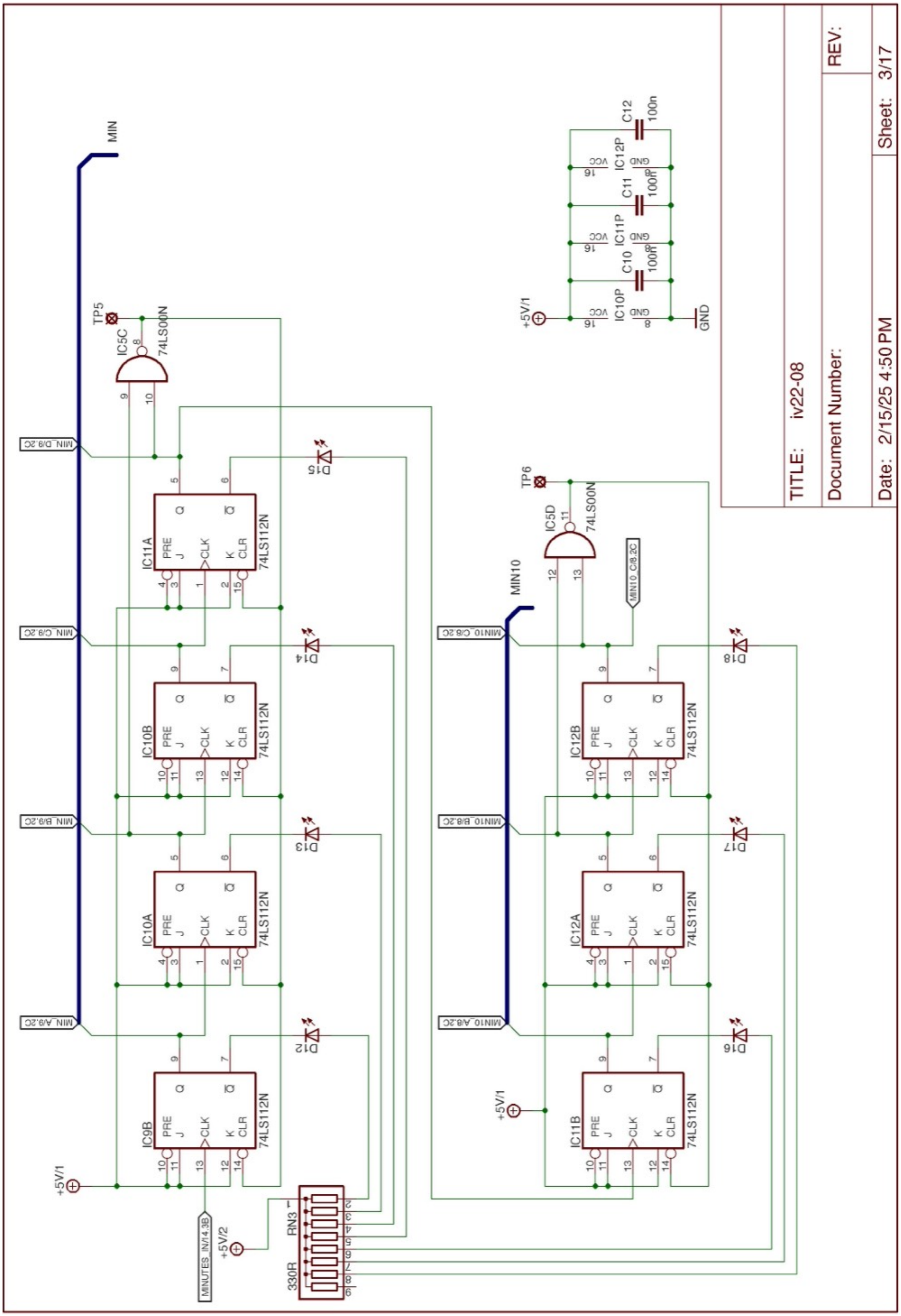
Document Number:
Date: 2/15/25 4:50 PM
Sheet: 2/17
REV:
SEC
SEC10
1010 detected to clear SEC counters
110 detected to clear SEC10 counters
TP3
TP4
IC5A
IC5B
74LS00N
R1
R2
470R
1SEC-RESET/5.3B
SEC_HOLD/14.2C
SEC10_HOLD/14.2C
SEC10_C/10.2C
SEC_D/11.2C
SEC_C/11.2C
SEC_B/11.2C
SEC_A/11.2C
SEC10_C/10.2C
SEC10_B/10.2C
SEC10_A/10.2C
IC6A
IC6B
IC7A
IC7B
IC8A
IC8B
IC9A
74LS112N
PRE
J
CLK
K
CLR
Q
D5
D6
D7
D8
D9
D10
D11
RN2
330R
1HZ/1.4A
+5V/1
+5V/2
GND
IC5P
IC6P
IC7P
IC8P
IC9P
VCC
C5
C6
C7
C8
C9
100n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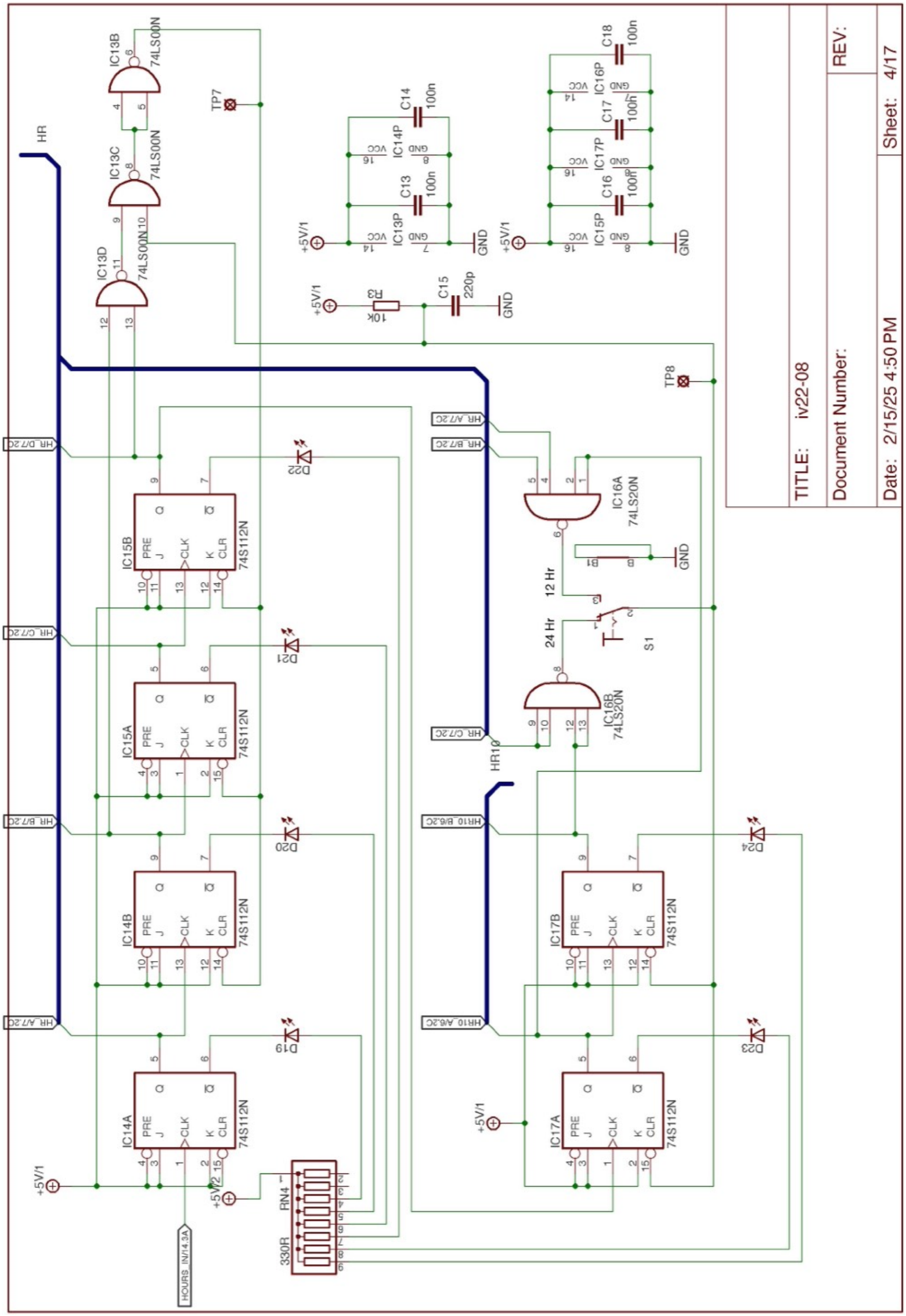
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 3/17
MIN
MIN10
IC5C
IC5D
74LS00N
TP5
TP6
IC9B
IC10A
IC10B
IC11A
IC11B
IC12A
IC12B
74LS112N
MIN_A/9.2C
MIN_B/9.2C
MIN_C/9.2C
MIN_D/9.2C
MIN10_A/8.2C
MIN10_B/8.2C
MIN10_C/8.2C
MINUTES_IN/14.3B
RN3
330R
+5V/1
+5V/2
GND
C10
C11
C12
100n



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Document Number:
REV:
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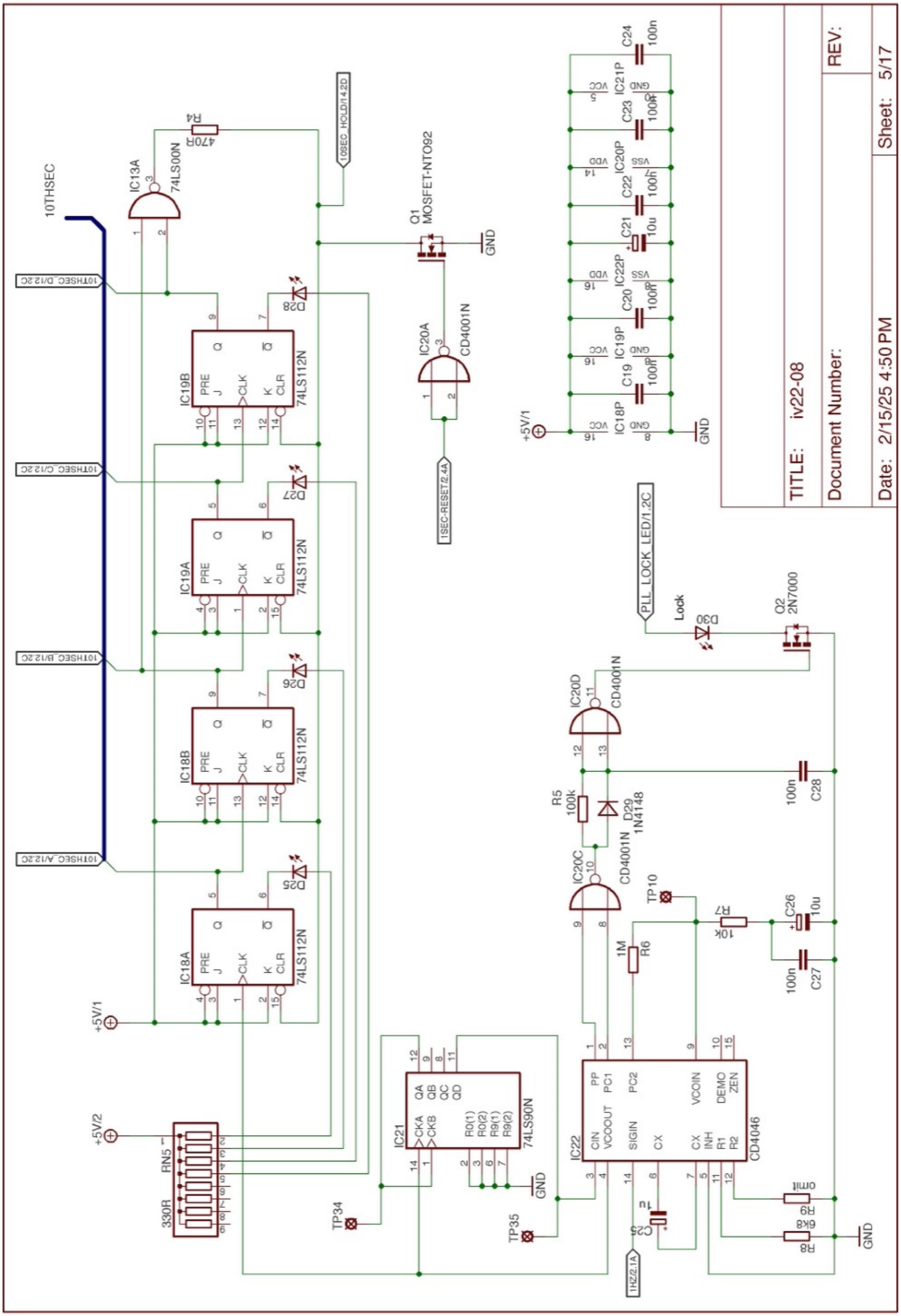
Sheet: 4/17
IC13B 74LS00N
IC13C 74LS00N
IC13D 74LS00N
IC14A 74S112N
IC14B 74S112N
IC15A 74S112N
IC15B 74S112N
IC16A 74LS20N
IC16B 74LS20N
IC17A 74S112N
IC17B 74S112N
TP7
TP8
HR
HR10
HR_A/7.2C
HR_B/7.2C
HR_C/7.2C
HR_D/7.2C
HR10_A/6.2C
HR10_B/6.2C
HOURS_IN/14.3A
D19
D20
D21
D22
D23
D24
RN4
330R
R3 10k
C15 220p
C13 100n
C14 100n
C16 100n
C17 100n
C18 100n
IC13P
IC14P
IC15P
IC16P
IC17P
VCC
GND
+5V/1
+5V/2
12 Hr
24 Hr
S1
B1
PRE
CLK
CLR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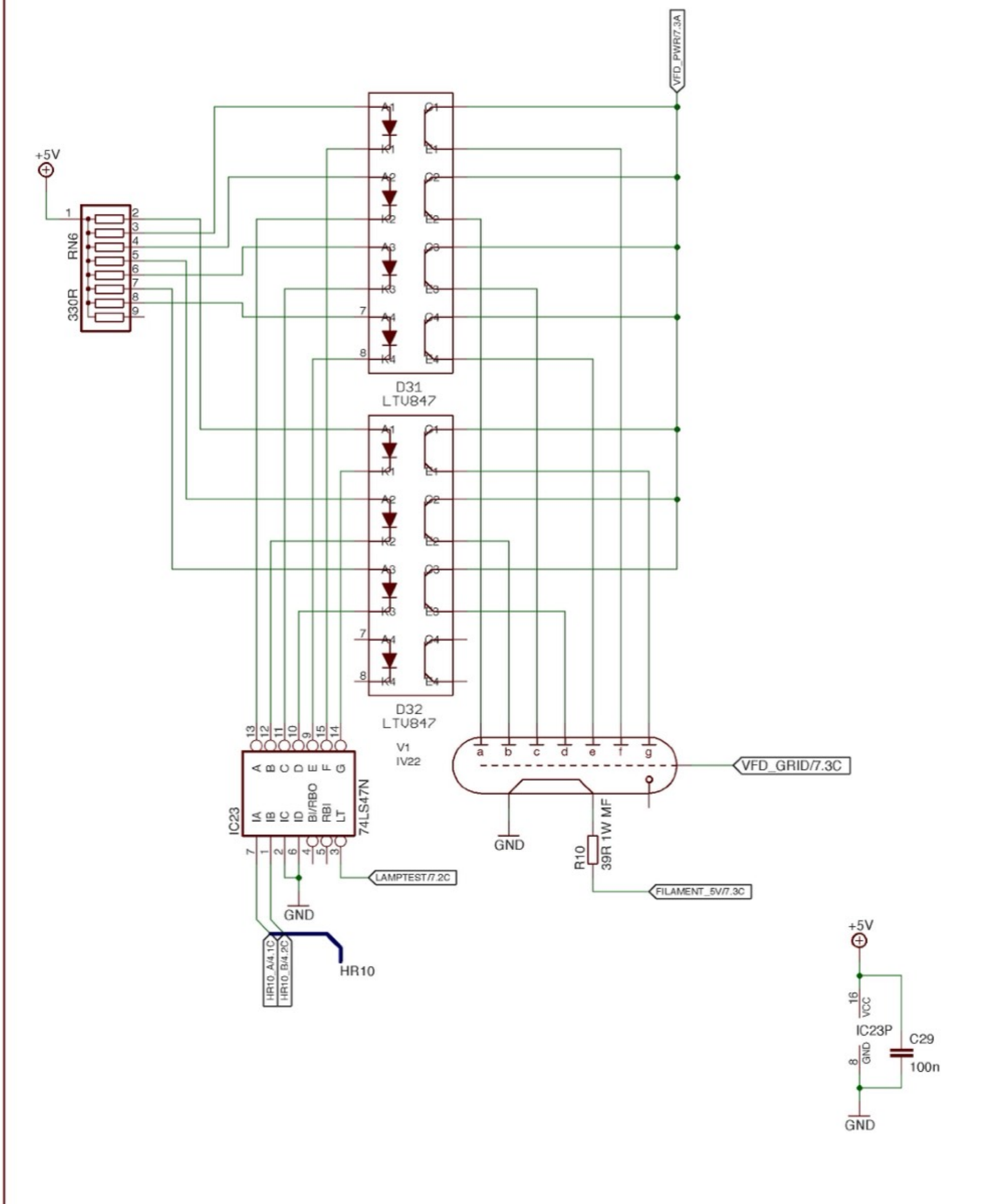
Sheet: 5/17
10THSEC
10THSEC_A/12.2C
10THSEC_B/12.2C
10THSEC_C/12.2C
10THSEC_D/12.2C
10SEC_HOLD/14.2D
1SEC-RESET/2.4A
PLL_LOCK_LED/1.2C
1HZ/2.1A
IC13A 74LS00N
R4 470R
Q1 MOSFET-NTO92
IC20A CD4001N
IC18A 74LS112N
IC18B 74LS112N
IC19A 74LS112N
IC19B 74LS112N
D25
D26
D27
D28
RN5 330R
IC21 74LS90N
IC22 CD4046
TP34
TP35
TP10
IC20C CD4001N
IC20D CD4001N
R5 100k
D29 1N4148
C28 100n
R6 1M
R7 10K
C26 10u
C27 100n
C25 1u
R9 omit
R8 6k8
D30 Lock
Q2 2N7000
C24 100n
C23 100n
C22 100n
C21 10u
C20 100P
C19 100P
IC18P
IC19P
IC20P
IC21P
IC22P
+5V/1
+5V/2
GND

V1.2



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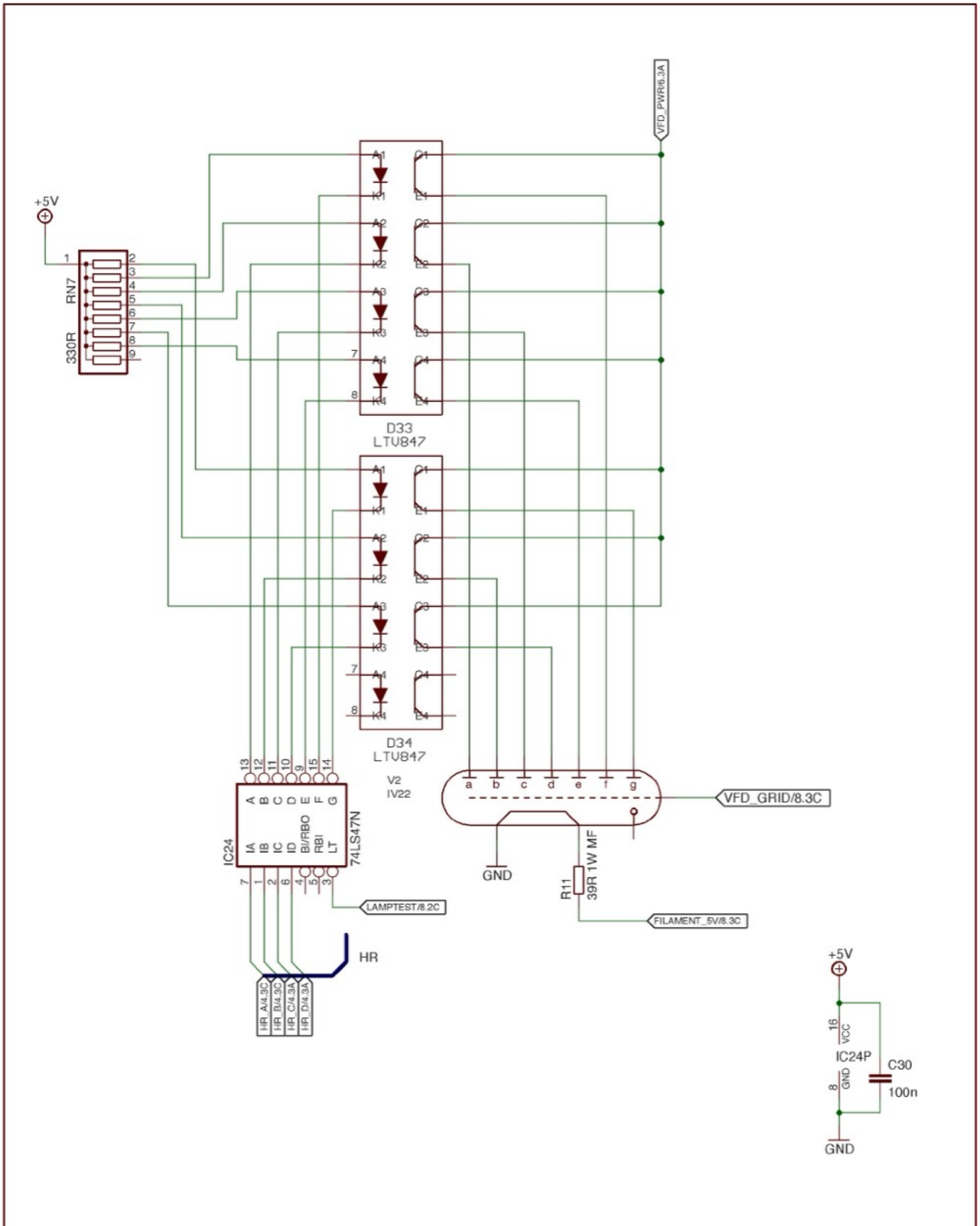

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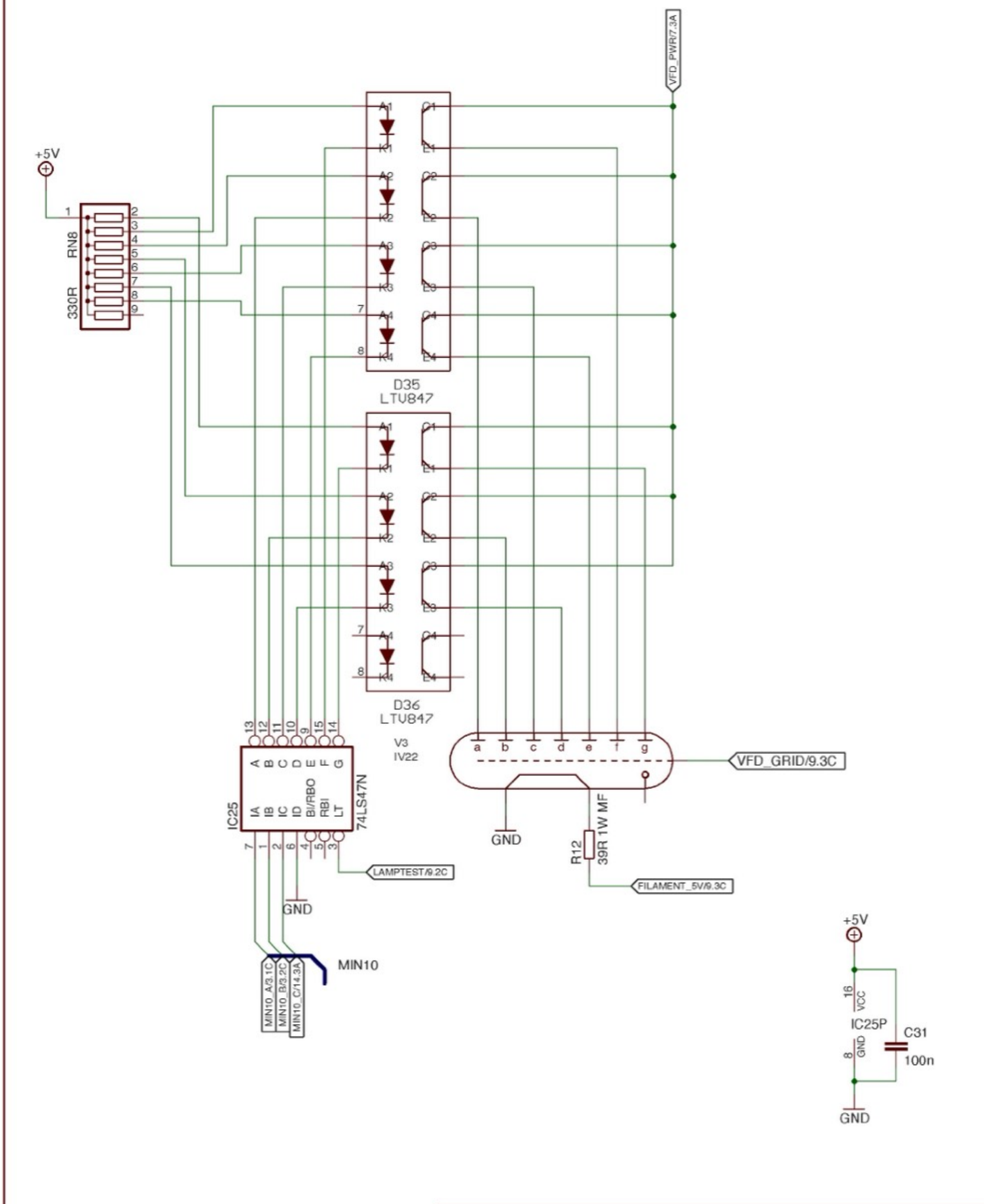
Date: 2/15/25 4:50 PM	Sheet: 7/17



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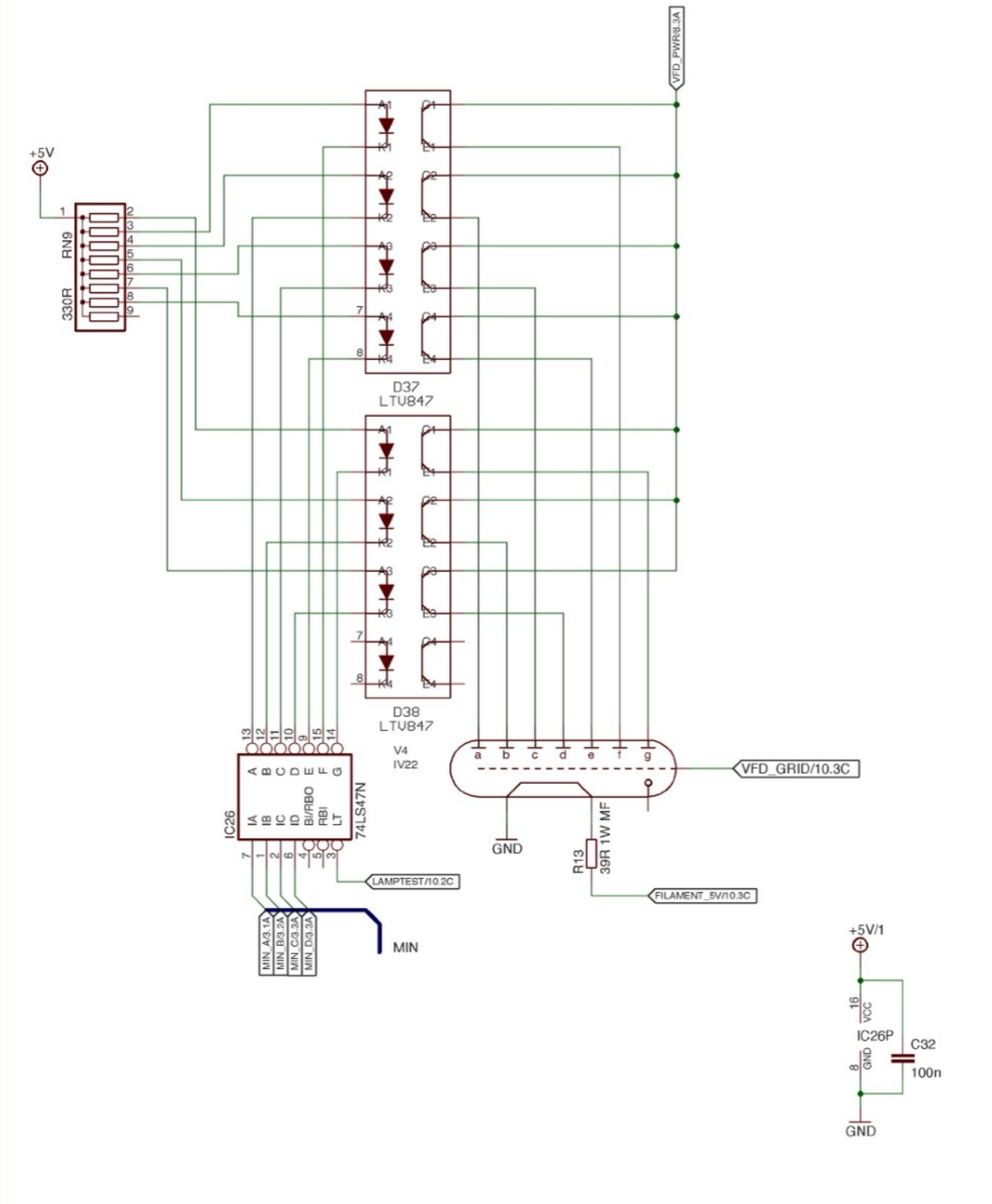
Date: 2/15/25 4:50 PM	Sheet: 8/17



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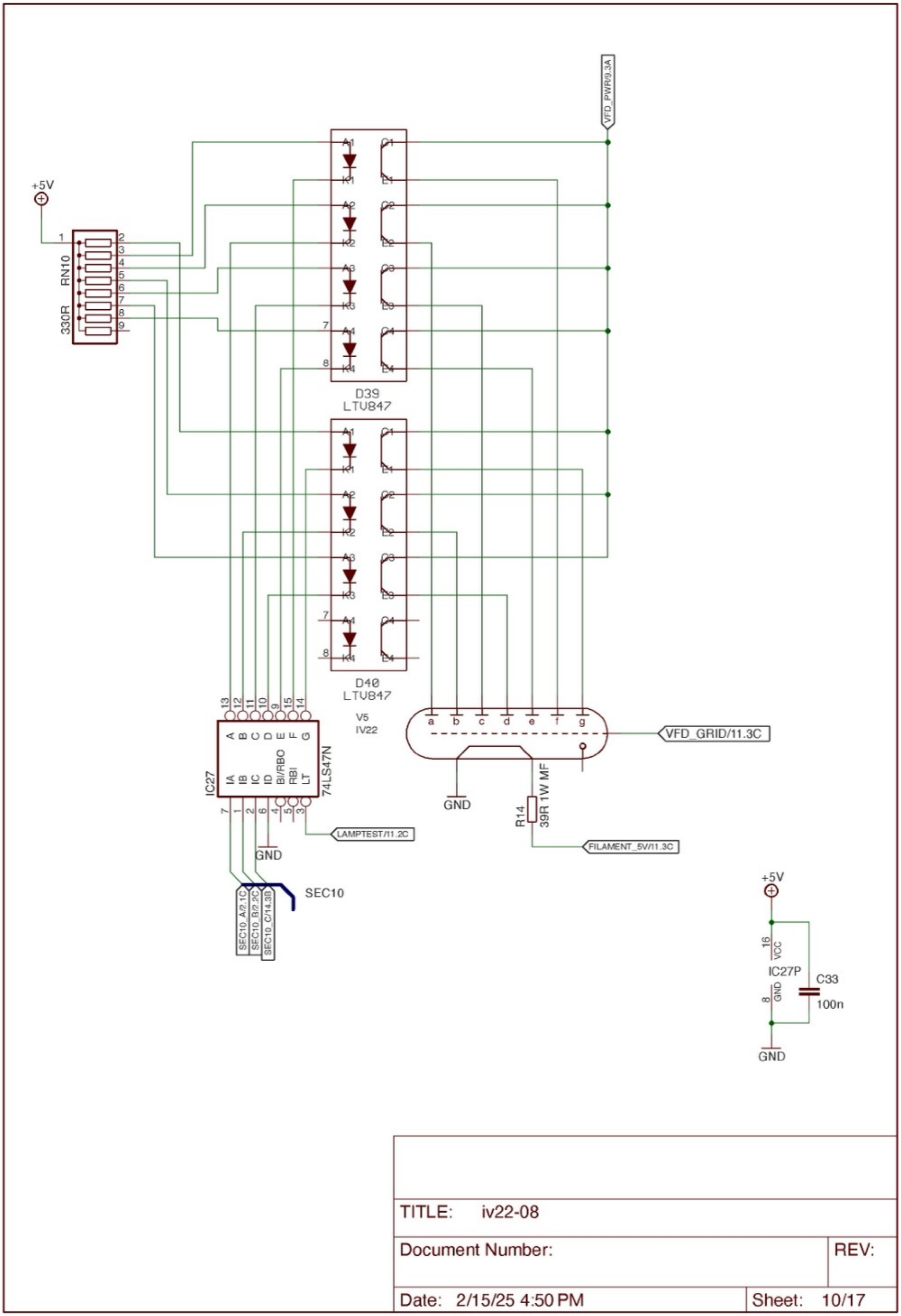
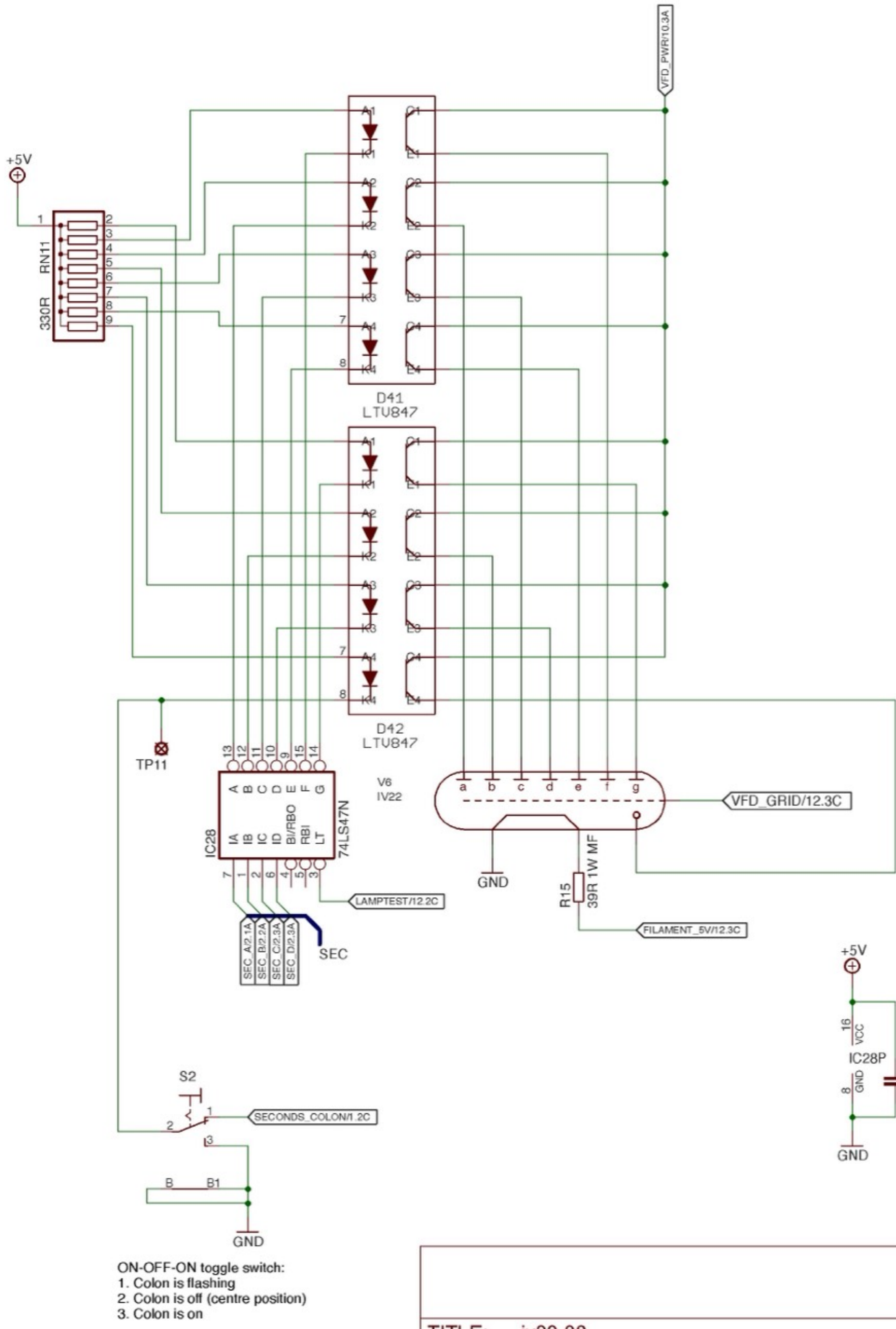
Date: 2/15/25 4:50 PM Sheet: 9/17



VFD_PWR/9.3A
+5V
RN10
330R
D39
LTV847
D40
LTV847
V5
IV22
VFD_GRID/11.3C
IC27
74LS47N
GND
LAMPTEST/11.2C
R14
39R 1W MF
FILAMENT_5V/11.3C
SEC10
SEC10_A/2.1C
SEC10_B/2.2C
SEC10_C/14.3B
IC27P
C33
100n
TITLE: iv22-08
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 10/17



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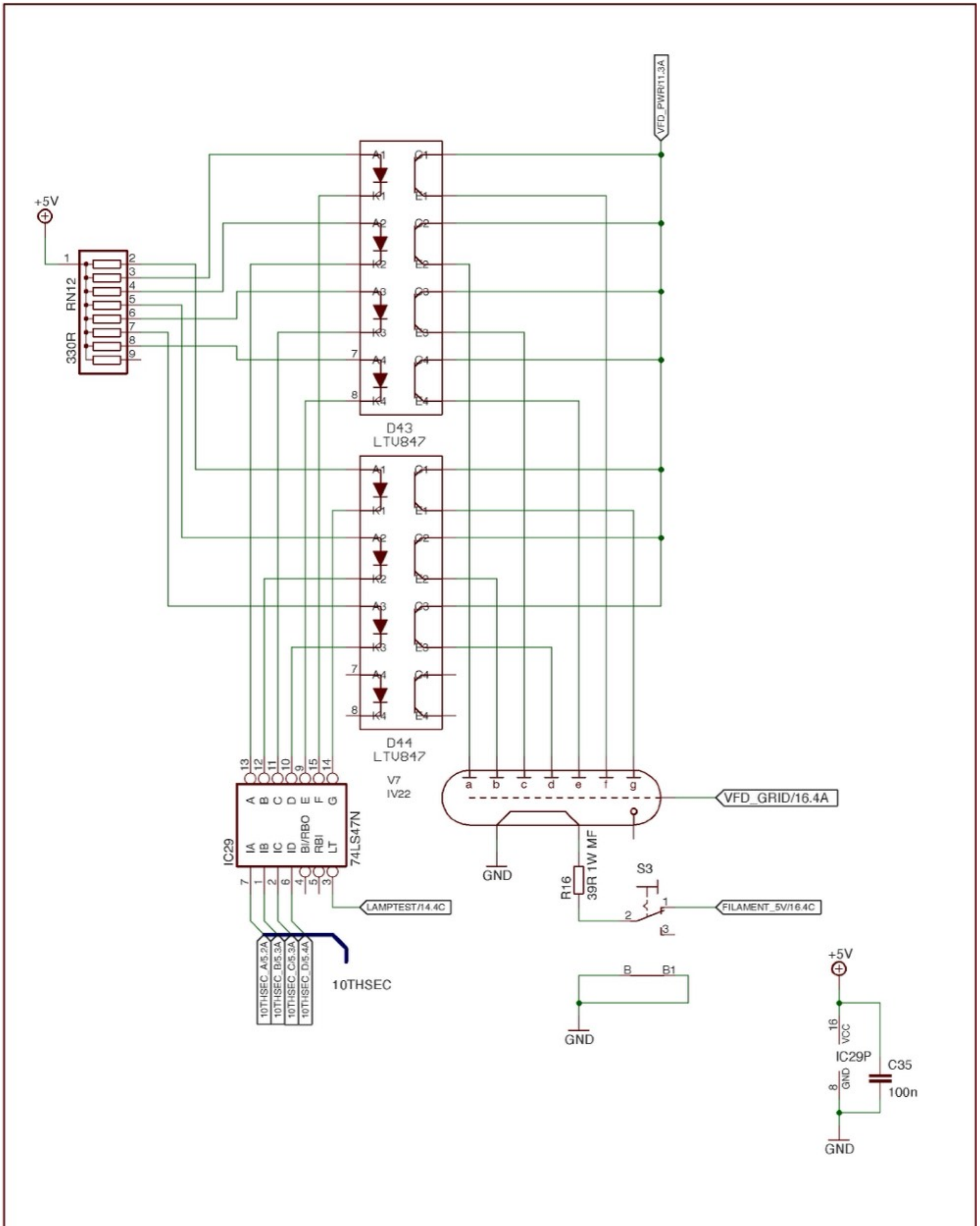

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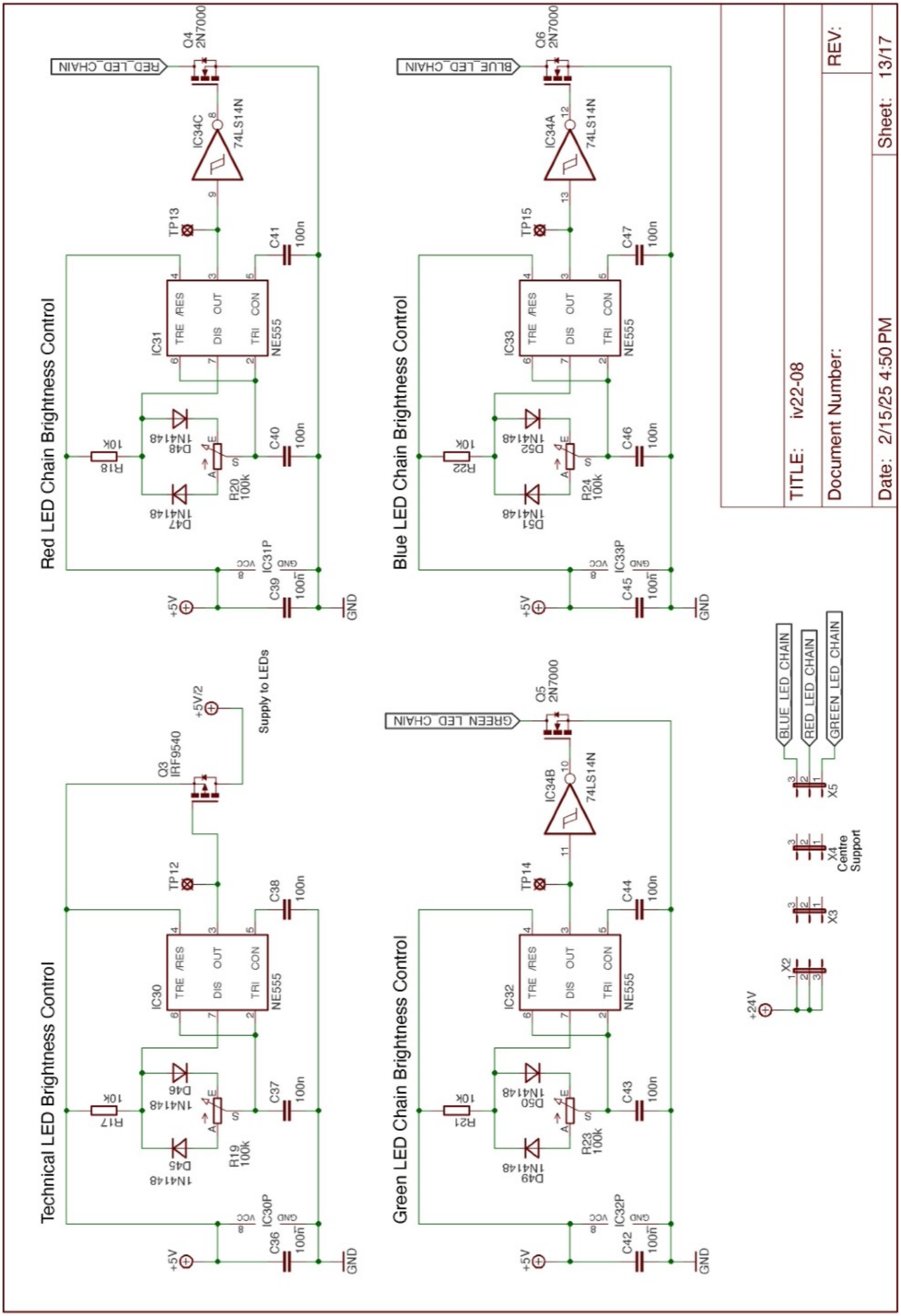
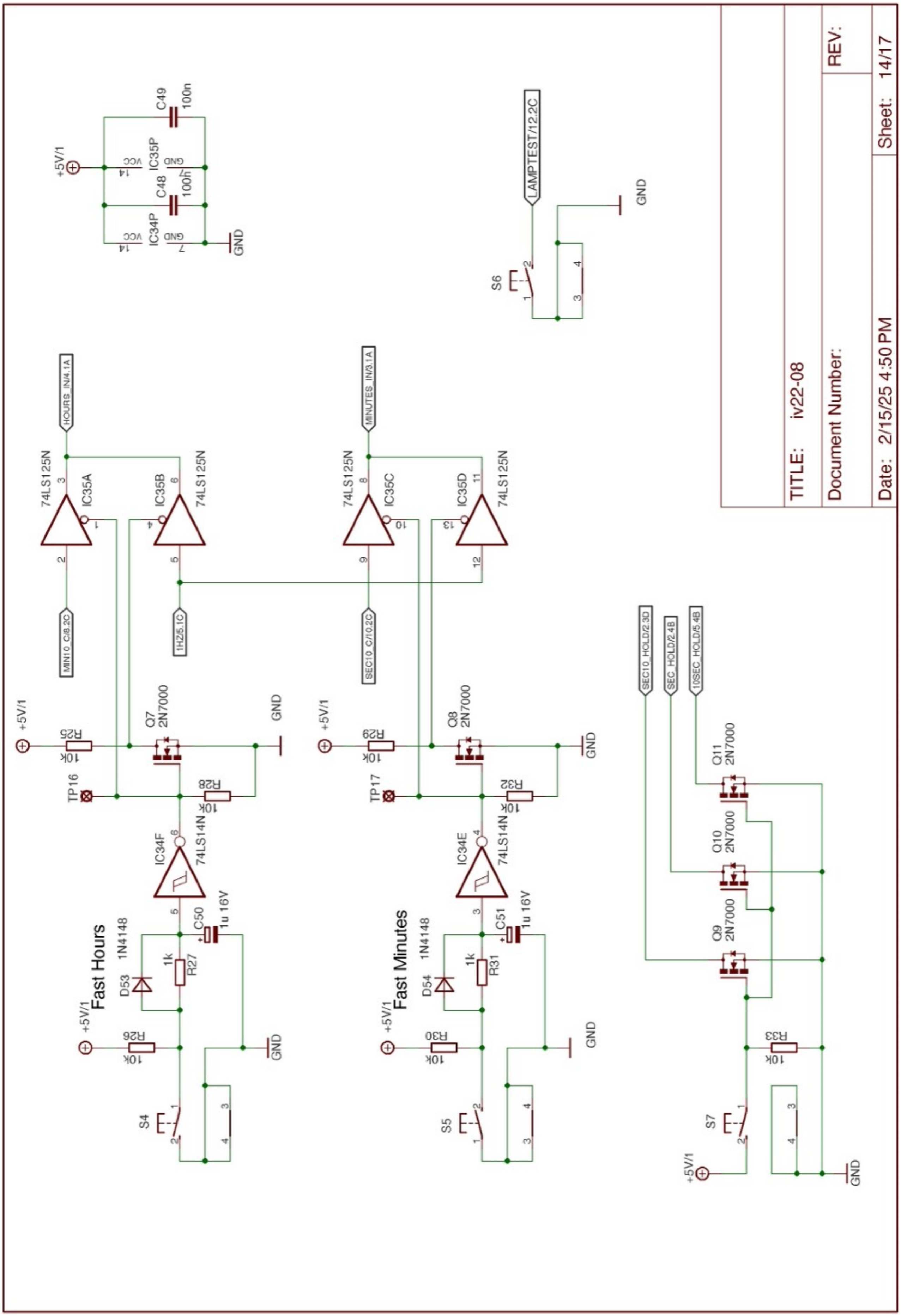
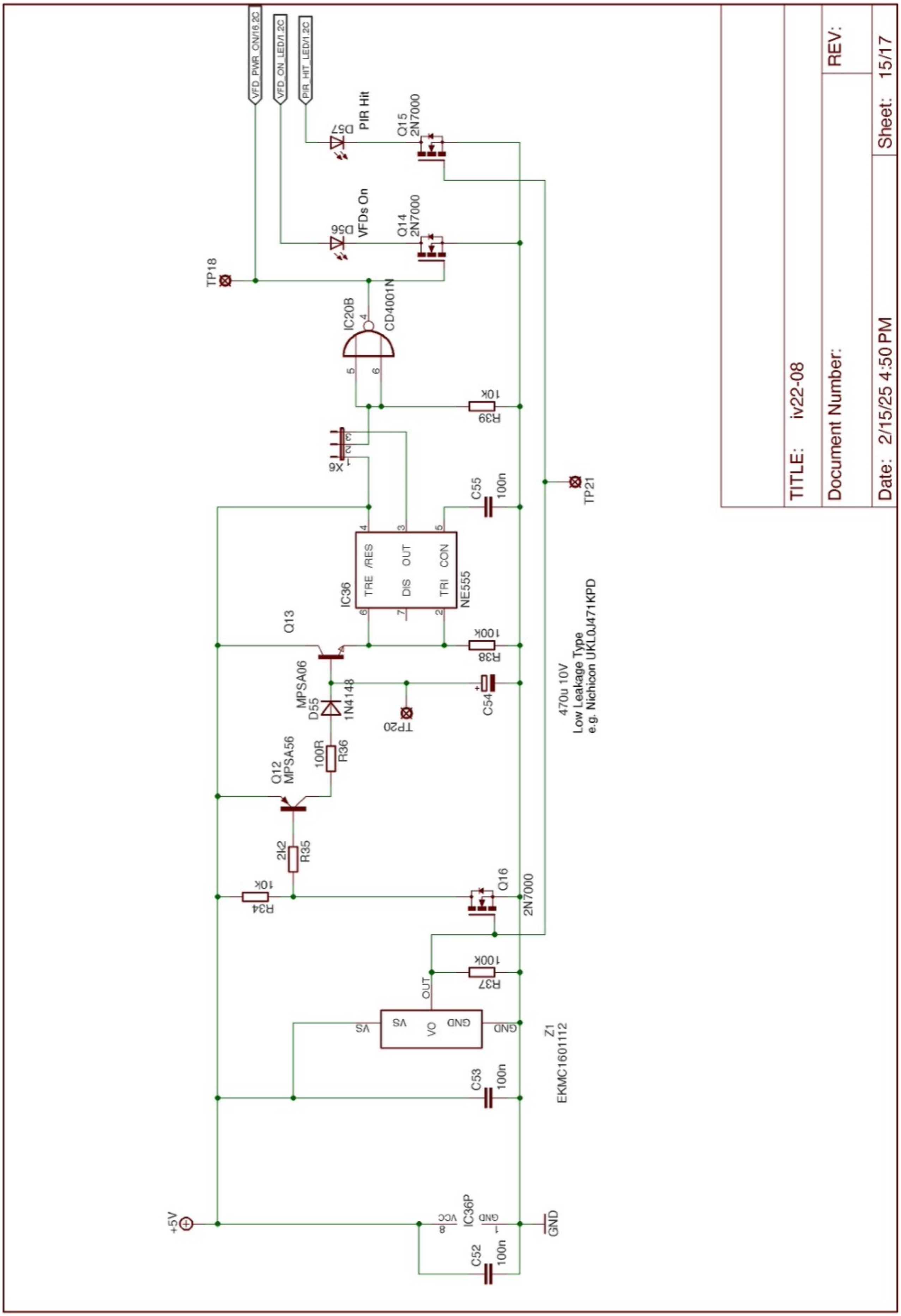
Document Number:	REV:
Date: 2/15/25 4:50 PM	Sheet: 12/17

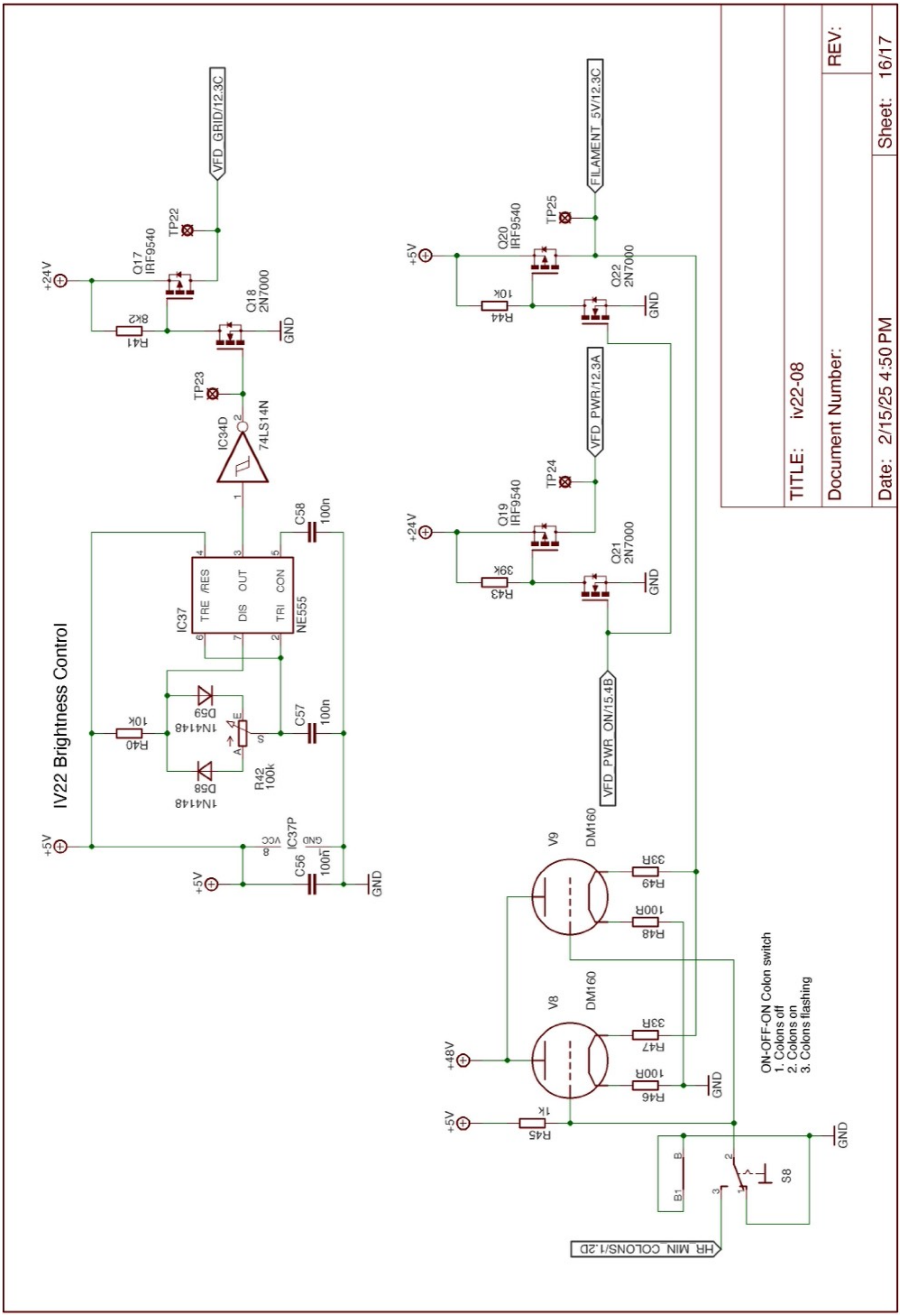

Technical LED Brightness Control
Red LED Chain Brightness Control
Green LED Chain Brightness Control
Blue LED Chain Brightness Control
Supply to LEDs
RED_LED_CHAIN
GREEN_LED_CHAIN
BLUE_LED_CHAIN
Q3 IRF9540
Q4 2N7000
Q5 2N7000
Q6 2N7000
IC34A 74LS14N
IC34B 74LS14N
IC34C 74LS14N
IC30 NE555
IC31 NE555
IC32 NE555
IC33 NE555
X2
X3
X4 Centre Support
X5
+24V
+5V
+5V/2
GND
TITLE: iv22-08
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 13/17

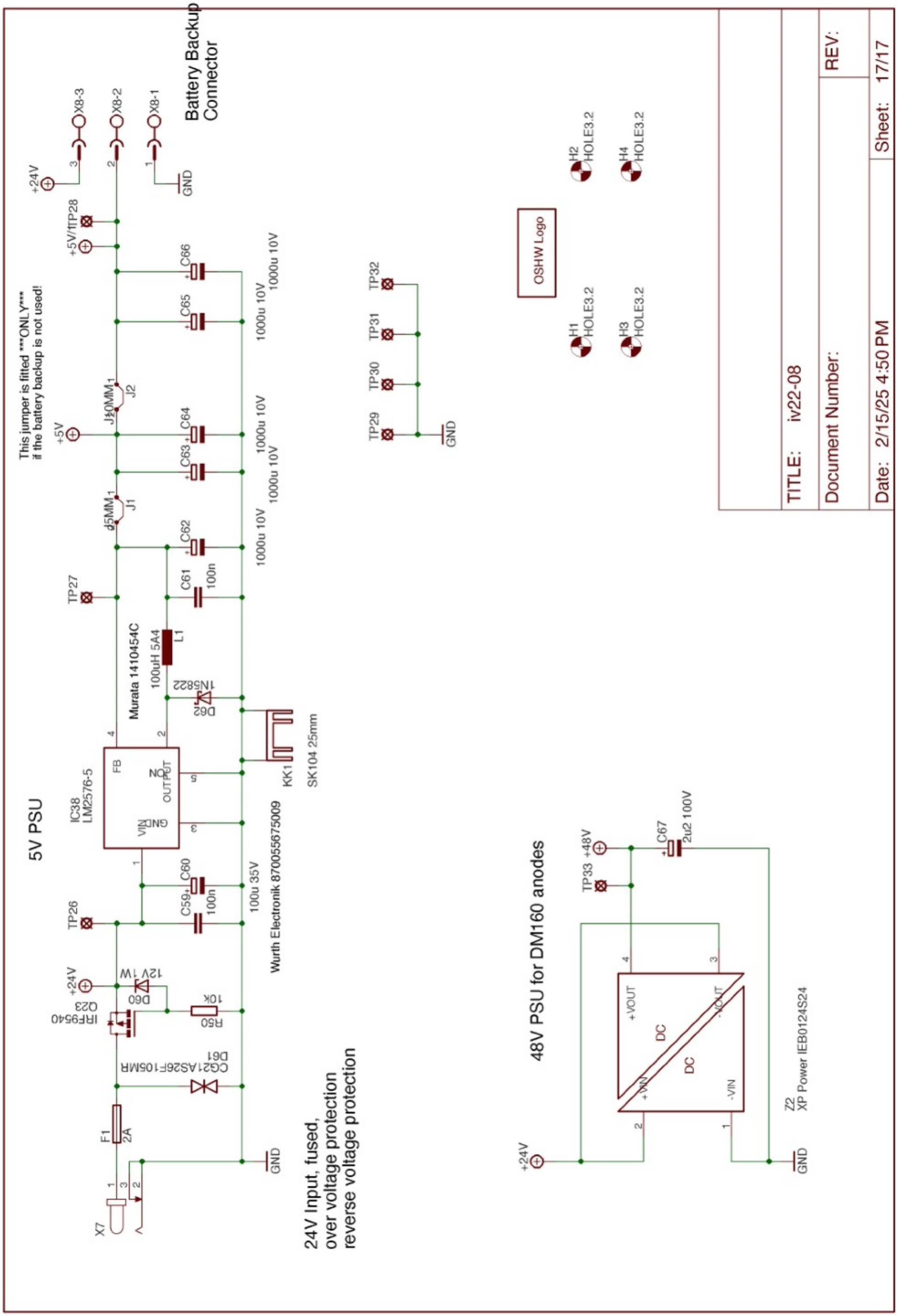


TITLE: iv22-08
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 14/17
Fast Hours
Fast Minutes
HOURS_IN/4.1A
MINUTES_IN/3.1A
MIN10_C/8.2C
1HZ/5.1C
SEC10_C/10.2C
SEC10_HOLD/2.3D
SEC_HOLD/2.4B
10SEC_HOLD/5.4B
LAMPTEST/12.2C
IC35A 74LS125N
IC35B 74LS125N
IC35C 74LS125N
IC35D 74LS125N
IC34F 74LS14N
IC34E 74LS14N
IC34P
IC35P
VCC
GND
C48 100n
C49 100n
C50 1u 16V
C51 1u 16V
D53 1N4148
D54 1N4148
R25 10K
R26 10K
R27 1k
R28 10K
R29 10K
R30 10K
R31 1k
R32 10K
R33 10K
Q7 2N7000
Q8 2N7000
Q9 2N7000
Q10 2N7000
Q11 2N7000
TP16
TP17
S4
S5
S6
S7
+5V/1
GND



TITLE: iv22-08
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 15/17
VFD_PWR_ON/16.2C
VFD_ON_LED/1.2C
PIR_HIT_LED/1.2C
PIR Hit
D57
Q15
2N7000
VFDs On
D56
Q14
2N7000
TP18
IC20B
CD4001N
R39
10k
X6
C55
100n
TP21
IC36
NE555
TRE
/RES
DIS
OUT
TRI
CON
Q13
MPSA06
R38
100k
D55
1N4148
TP20
C54
470u 10V
Low Leakage Type
e.g. Nichicon UKL0J471KPD
Q12
MPSA56
R36
100R
R35
2k2
R34
10k
Q16
2N7000
R37
100k
Z1
EKMC1601112
VS
VO
GND
OUT
C53
100n
+5V
IC36P
VCC
GND
C52
100n


IV22 Brightness Control
TITLE: iv22-08
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 16/17
VFD_GRID/12.3C
FILAMENT_5V/12.3C
VFD_PWR/12.3A
VFD_PWR_ON/15.4B
HR_MIN_COLONS/1.2D
ON-OFF-ON Colon switch
1. Colons off
2. Colons on
3. Colons flashing
IC37 NE555
IC34D 74LS14N
IC37P
Q17 IRF9540
Q18 2N7000
Q19 IRF9540
Q20 IRF9540
Q21 2N7000
Q22 2N7000
TP22
TP23
TP24
TP25
R40 10k
R41 8k2
R42 100k
R43 39k
R44 10k
R45 1k
R46 100R
R47 33R
R48 100R
R49 33R
C56 100n
C57 100n
C58 100n
D58 1N4148
D59 1N4148
V8 DM160
V9 DM160
S8
+5V
+24V
+48V
GND


5V PSU
24V Input, fused,
over voltage protection
reverse voltage protection
48V PSU for DM160 anodes
Battery Backup
Connector
This jumper is fitted ***ONLY***
if the battery backup is not used!
IC38
LM2576-5
Murata 1410454C
100uH 5A4
Wurth Electronik 870055675009
100u 35V
SK104 25mm
1N5822
IRF9540
12V 1W
CG21AS26F105MR
XP Power IEB0124S24
2u2 100V
1000u 10V
OSHW Logo
HOLE3.2
TITLE: iv22-08
Document Number:
REV:
Date: 2/15/25 4:50 PM
Sheet: 17/17