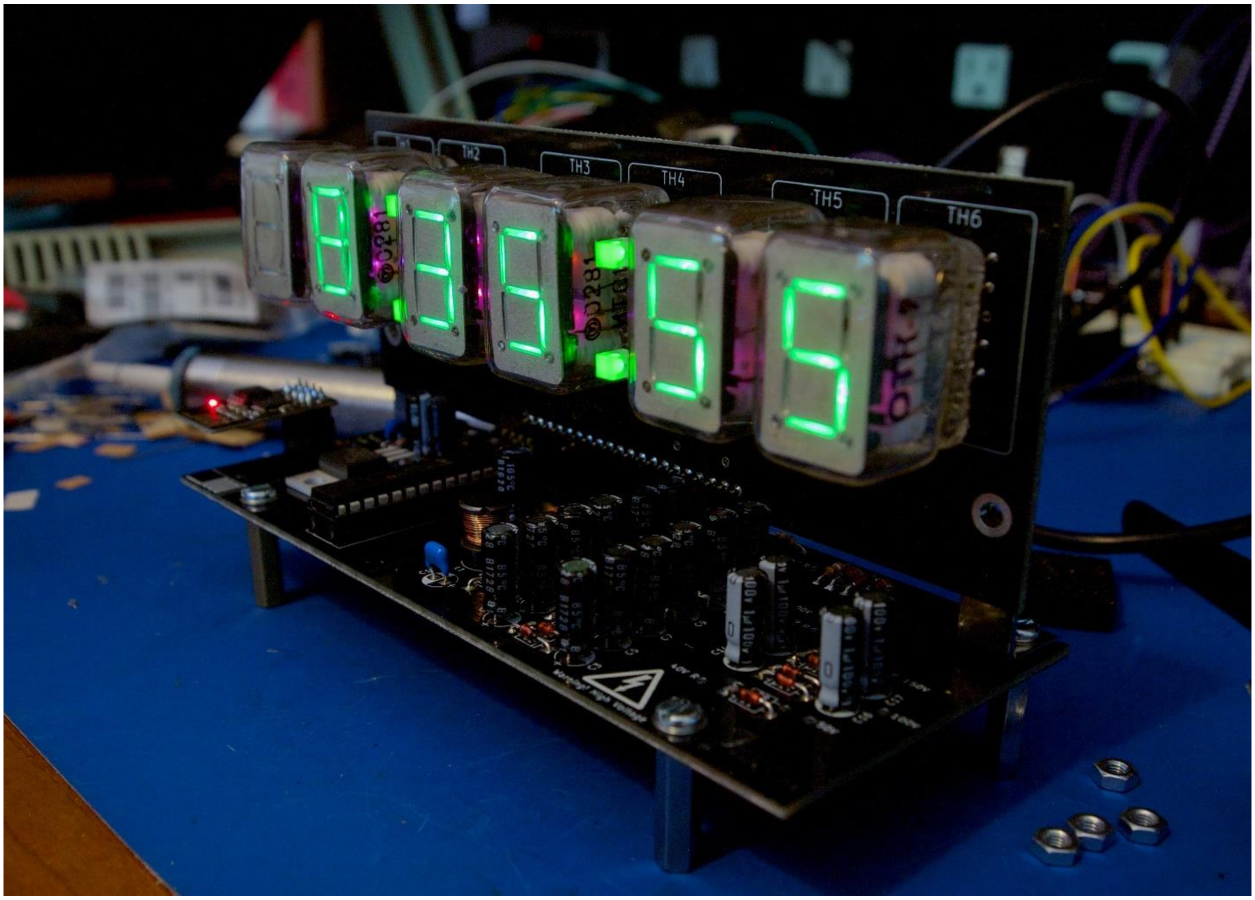
ITS1A Clock



Contents

Safety

This is a kit of parts, not a finished item. The person assembling this kit must be familiar with the design of these specific PCBs and with the assembly of electronics in general, including but not limited to: being able to identify components, their location on the board and being qualified in the use of assembly equipment such as soldering irons and other tools and being able to determine the correct and safe functioning of this kit.

Any 'instructions' provided with this kit are guidelines only, and the assembler must be qualified to determine the correctness, or not, of those instructions. If they have any concerns about the correct functioning of the kit once assembled, they must cease all work and proceed no further.

No case is provided with this kit, the assembler must provide their own case.

The completed PCB (ITS1A Clock Kit) generates voltage differences of up to 450V between certain parts of the PCB. THESE VOLTAGES MAY BE LETHAL. Therefore assembly should only be undertaken by people qualified to work with these voltages, and who can guarantee that the completed product meets all local safety requirements and certifications during operation. Furthermore, the finished article must be in a casing that isolates people from access to these voltages during operation.

Certain parts of the PCB may maintain high voltage after it is unplugged from a power source, therefore care must be taken to ensure that these voltages are not present prior to accessing the contents of the case.

Introduction

Read through all of these instructions before starting. If, after doing so, you are not sure about your ability to safely assemble this board, stop now.

Check that you have all the parts listed in the Bill of Materials.

Bill of Materials

Main Board		
D1-D18	18	DIODE GEN PURP 100V 200MA DO35
Z1	1	DIODE ZENER 3.2A 39V DO35
Z2, Z5	2	DIODE ZENER 100V 500MW DO35
Z3, Z4 - 2%	1	DIODE ZENER 75V 500MW DO35
R4	1	RES 12K OHM 1/4W 5% CF MINI
R2	1	RES 180 OHM 1/2W 5% CF MINI
R8	1	RES 6.2K OHM 1/4W 5% CF MINI
R7	1	RES 3.9K OHM 1/4W 5% CF MINI
R3, R1	2	RES 470K OHM 1/4W 5% CF MINI
R6, R17, R18	3	RES 1 OHM 1/8W 5% CF AXIAL
R5, R13, R14	3	RES 10K OHM 1/4W 5% CF MINI
R11, R12	2	RES 100K OHM 1/4W 5% CF MINI
R10, R15, R16	3	RES 1M OHM 1/4W 5% CF MINI
R9	1	RES 10M OHM 1/8W 5% CF AXIAL

Q1	1	TRANS PNP 300V 0.5A TO-92, **MPSA92**
Q2	1	TRANS NPN 300V 0.5A TO-92, **KSP42**
L1	1	FIXED IND 220UH 640MA 450 MOHM
C1	1	CAP CER 0.22UF 100V X7R RADIAL
C2-C17,C20-C21	18	CAP ALUM 1UF 20% 100V RADIAL
C18	1	CAP ALUM 220UF 20% 10V RADIAL
C19	1	CAP CER 1000PF 50V C0G RADIAL
C22	1	CAP CER 100PF 50V NP0 RADIAL
C23	1	CAP CER 0.1UF 25V Y5V RADIAL
IC1	1	IC I/O EXPANDER I2C 16B 28SDIP, **MCP23017**
J3	1	MINI USB,RCPT, R/A, DIP, B TYPE,
U1	1	IC REG LINEAR 3.3V 500MA TO220-3, **TC1262**
U2	1	ESP-01
U2 Socket	1	ESP-01 SOCKET 8POS
S1	1	SWITCH TACTILE SPST-NO 0.05A 12V
Brackets	2	BRACKET UNIVERSAL CLEAR HOLE
IC1 Socket	1	CONN IC DIP SOCKET 28POS TIN
M1	1	IC REG BCK BST INV ADJ 1.5A 8DIP, **MC33063**
J2	1	CONN HEADER .100" DUAL R/A 8POS
J1	1	CONN HEADER FMALE 20POS .1" GOLD
	6	MACH SCREW PAN HEAD SLOTTED M3
	2	HEX NUT 0.217" M3
	6	WASHER SPLIT LOCK M3 STEEL
	4	HEX STANDOFF M3 BRASS 18MM
Display Board		
Display board: R1, R2, R3, R4	4	RES 47K OHM 1/4W 5% CF MINI
LED1-4	4	LED GREEN DIFFUSED ICE CUBE T/H
J1	1	CONN HEADER .100" SNGL R/A 20POS

Main Board

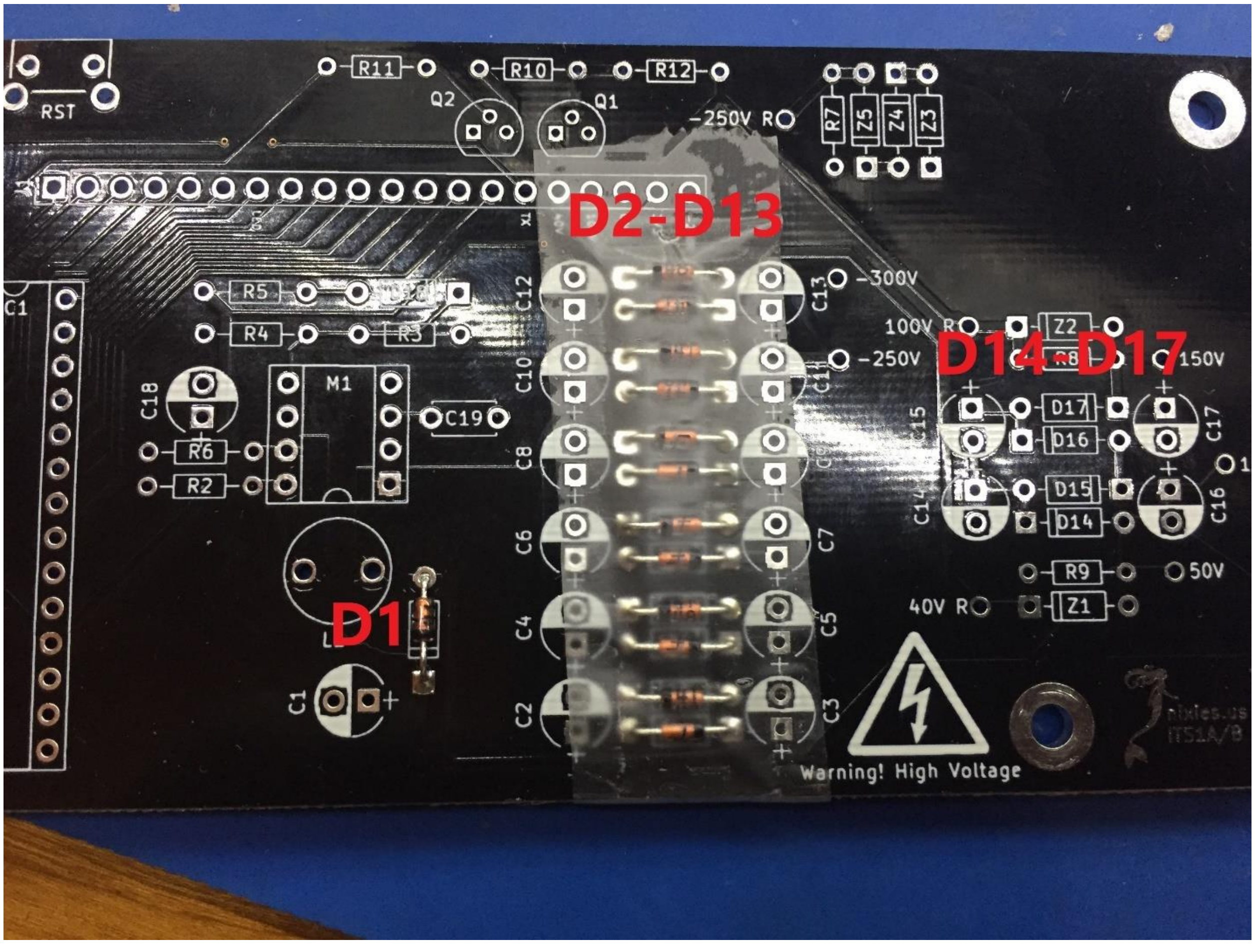
Please note that some of the pictures are from a previous revision of the board. This revision includes additional resistors in a few places. This is nothing to worry about.

In addition, you may see some pictures with the USB connector on the bottom of the board. In this revision the USB connector goes on the top of the board.

Diodes

Diodes are polarized. The end with the band should line up with the band on the symbol on the PCB (or the lead on that end should go through the square hole). Note that all of these diodes (D1-D18) are the ones that are loose in the bag. They do not have paper tabs attached to them.

Start by soldering D1, Then D2-D13 as shown in the picture below. Use some tape to hold them all in place while you do it. Note that the diode direction alternates as in the picture below. It is important you get this right!



Follow up with D14-D17 (again, note that the polarity alternates), and finally D18.

That is all the regular diodes!

Resistors

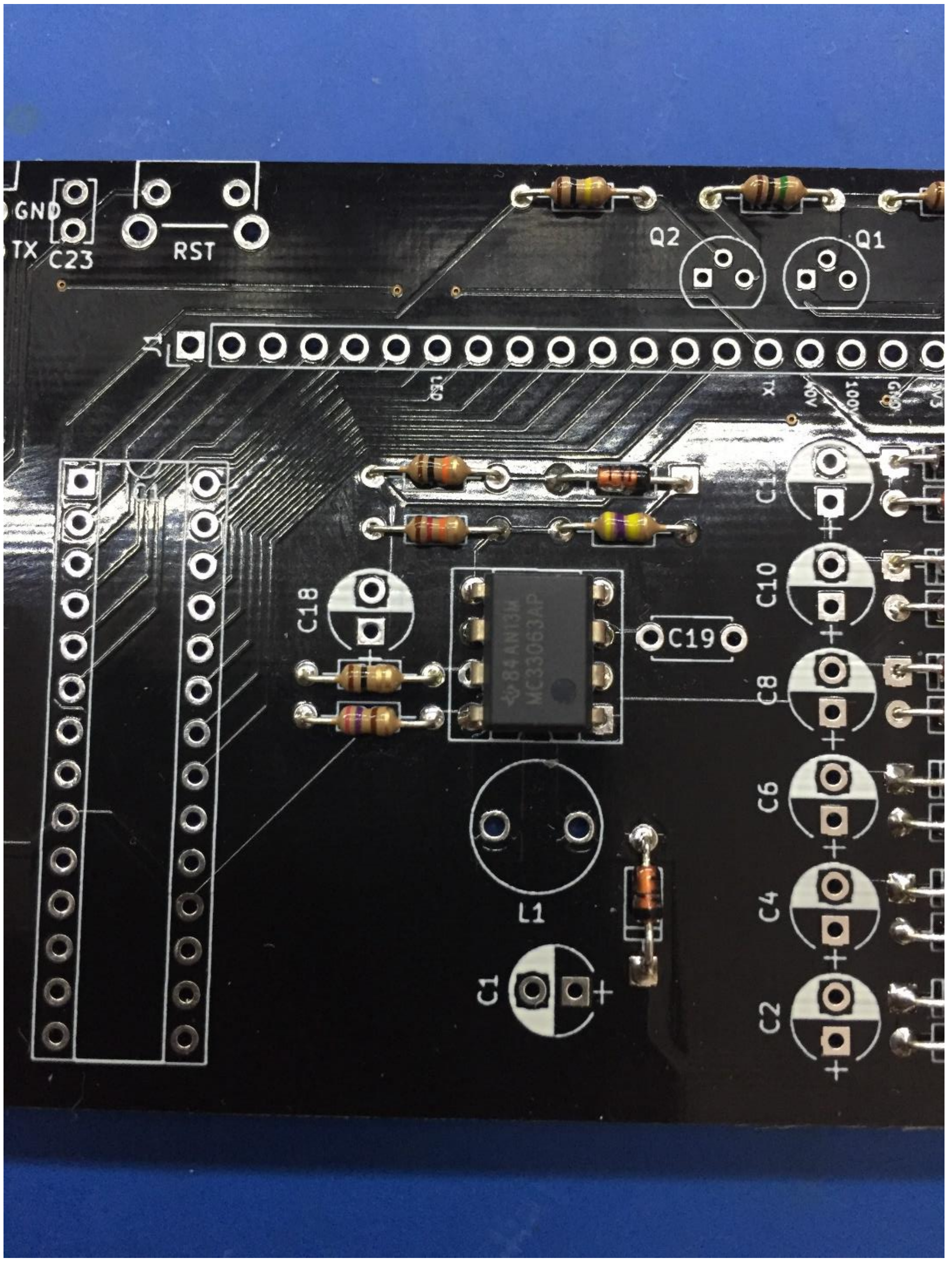
Solder in all the marked resistors: R1-R18. Note that R2 is bigger than the others – bend the leads close to the body. Also note that there are two sets of resistors marked R1-R4. The ones that are all the same value are for the display board, not this board – those will have LED written on the paper strip.

Zener Diodes

Solder in the Zener diodes. Z1-Z5 Again, pay attention to the polarity. There are a mix of Zener voltages, so make sure you solder the right ones. All of the Zener diodes have paper tabs attached to the leads. The loose diodes are regular diodes that you should have already soldered in.

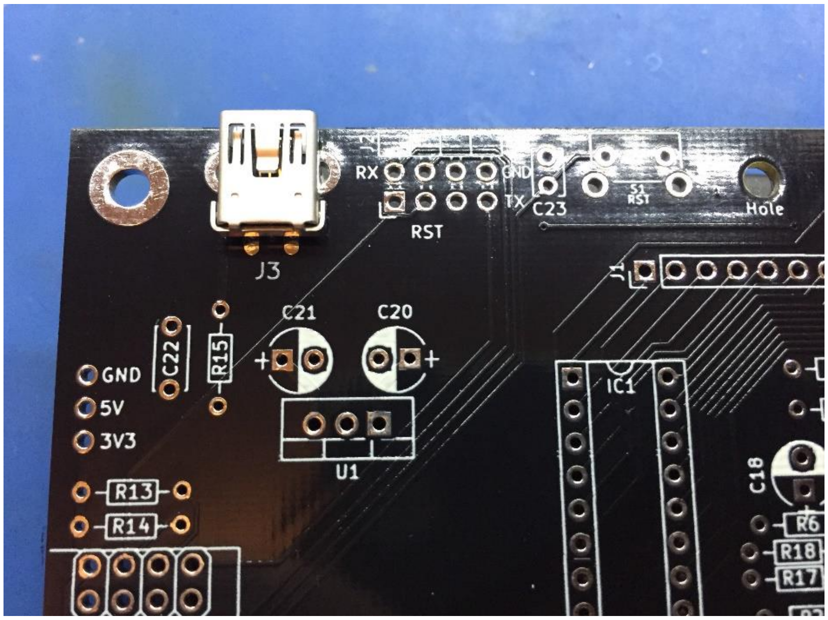
M1

Solder in M1. Check the polarity: The pin 1 marker should be near the L1 footprint as in this picture:


GND
TX
C23
RST
Q2
Q1
J1
C18
C19
MC33063AP
L1
C1
C2
C4
C6
C8
C10
C11

J3

Solder in J3 – the Mini USB socket. Not all the pins need to be soldered – there is no data connection. This should go on the top side of the board like this:

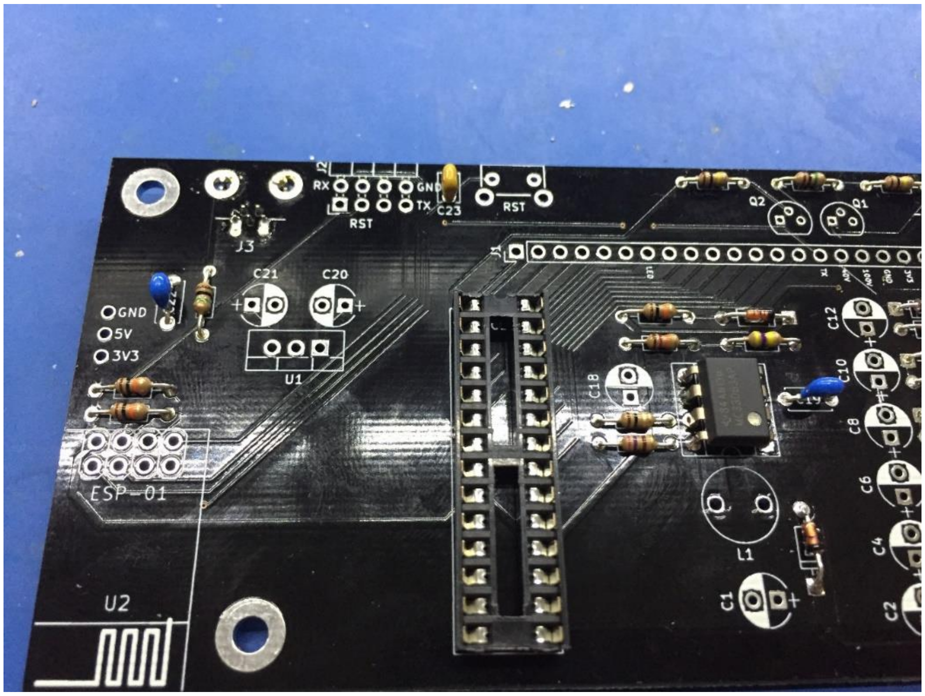


Ceramic Capacitors

Solder in the ceramic capacitors C1, C19, C22 and C23.

IC1 Socket

Solder in the IC1 socket. The notch should point towards the back of the board:

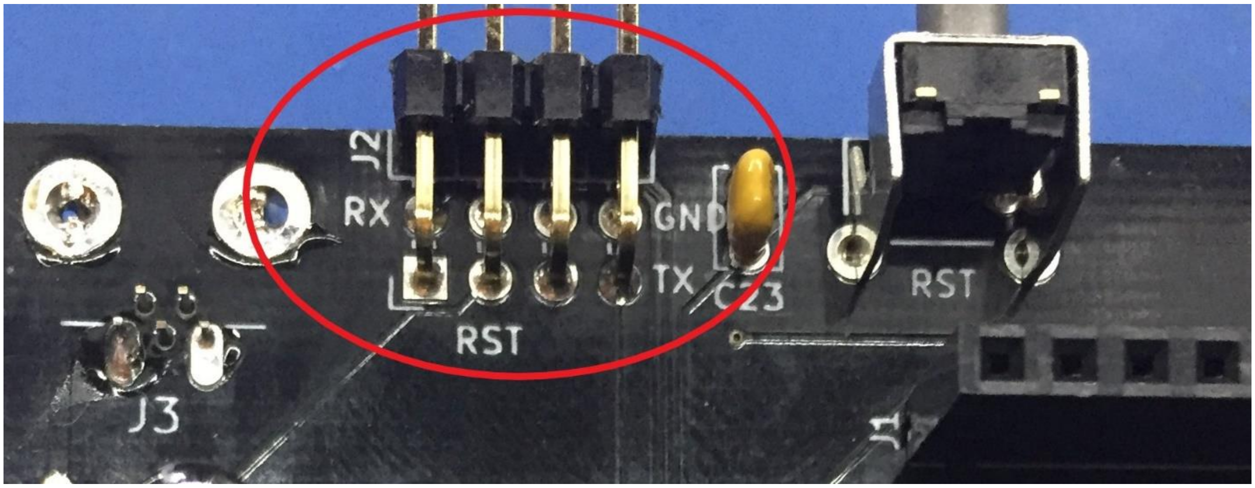


Transistors

Solder in Q1 and Q2. Bend the leads beforehand to match the hole layout on the board. Make sure you put the right transistor in the right holes!

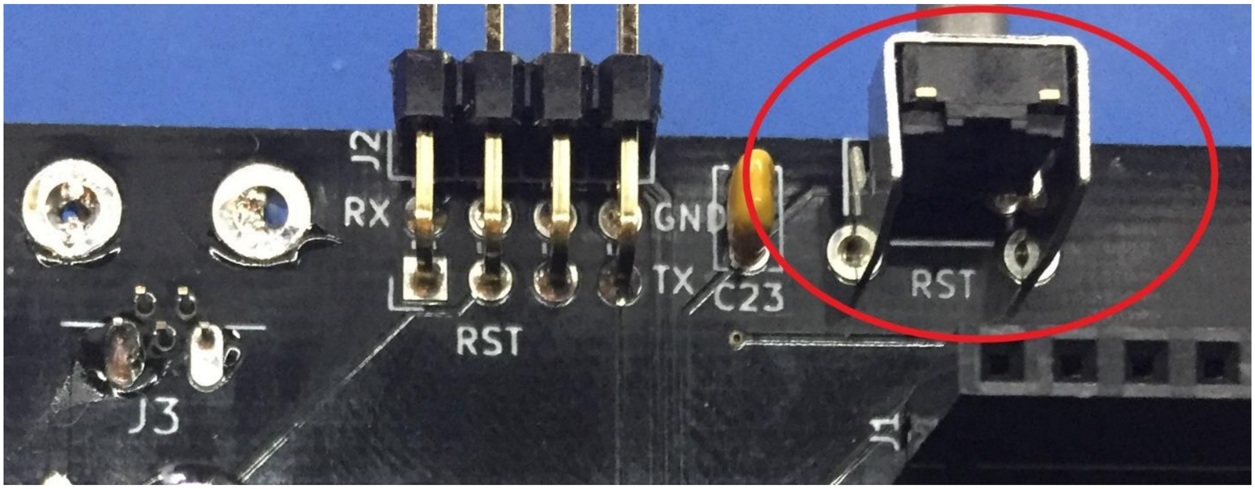
Programming Header

If you think you might want to program the clock with the ESP-01 in place, solder in the programming header J2. However I have found that most programmers don't work through this:



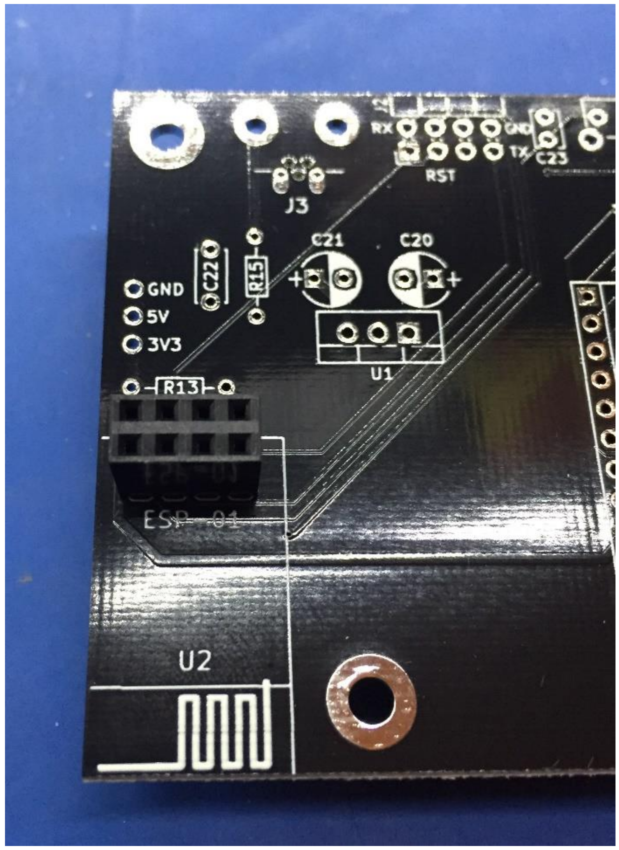
Reset Button

Solder in the reset button as below:



ESP-01 Socket

If you want to be able to remove the ESP-01 (for example to program it in an external programmer) solder in the 4x2 ESP-01 header. I would recommend this:



Inductor

Solder in L1, the inductor.

Electrolytic Capacitors

Electrolytic capacitors are polarized. The negative lead must go in the negative hole and the positive lead in the positive hole. The capacitors have a white stripe on the negative side, this should be lined up with the white marking on the PCB footprint – the lead on that side should go through the round hole.

Solder in C18, this is the 220uF capacitor next to M1.

Solder in C2-C13. All of the stripes will face the same way. One technique to get them to line up nicely is to use tape along the tops to hold them in place.

Solder in C14-C17. All of the stripes will face the same way, **but this will be the opposite way of C2-C13**.

Solder in C20 and C21.

Power Test

You can test the power now. You need to do this test **before** you solder in the voltage regulator. Once that is in, the power supply will be disabled unless the EPS-01 enables it. **As mentioned at the beginning of this document: This PCB generates very high voltages that may be lethal. Furthermore, it can take several minutes for those voltages to drop to safe levels after power has been removed because of charged capacitors.**

It is beyond the scope of this document to suggest ways of troubleshooting any problems.

Plug a Mini USB cable into the USB socket on the PCB. Plug the other end into a USB power supply. Unplug it if you see smoke!

Test the voltages in the following order. If any step fails the test, do not continue with the other tests. Instead trouble-shoot and fix the voltage that is incorrect before proceeding.

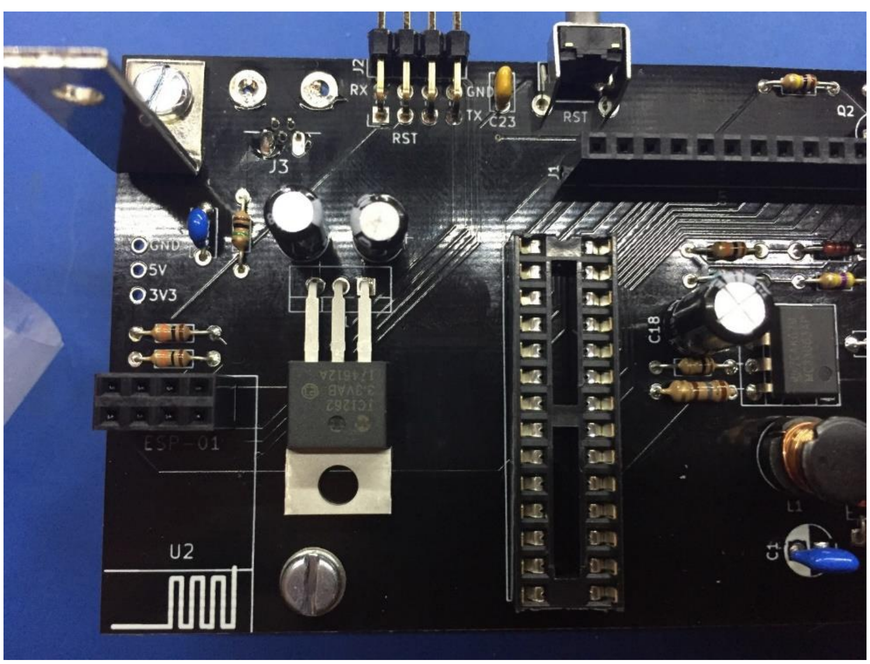
1. Measure the 5V test point.
2. Now check the voltage at the 50V test point. This should be around 45V (50V was optimistic).
3. Check the voltage at the 150V test point. It should be around 135V (i.e. 3x45V)
4. Check the voltage at the 100V R test point (not the 100V test point – note the *R*). It should be around 100V ± 5V.
5. Check the voltage at the -300V test point. It should be around -270V (i.e. 6x45V).
6. Check the voltage at the -250V R test point (not the -250V test point – note the *R*). It should be around -250V ± 8V.

Unplug the power supply. Monitor the voltage on the 150V test point. The 1MΩ bleeder resistor should drain the 150V arm within a second. Monitor the voltage on the -300V check point (you will install a bleeder resistor for this later). Only proceed once this has dropped to a safe level (e.g. <40V). You can short it to GND to speed up the process, but this can cause sparks to fly!

Voltage Regulator

After this is soldered in, the HV power will be disabled until the ESP-01 is plugged in and enables it, so you **must** perform the power test before doing this.

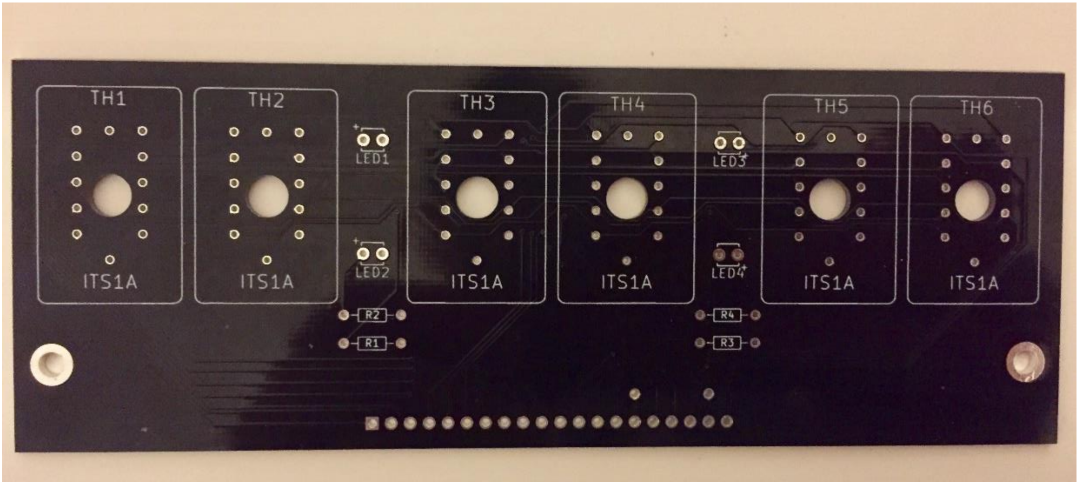
Solder in U1. This needs to be in the correct orientation. Use the photo below as a reference. You can bend the legs so that it lays flat on the PCB as shown in the photo below:



Plug the power back in and check that you get 3.3V at the 3V3 test point.

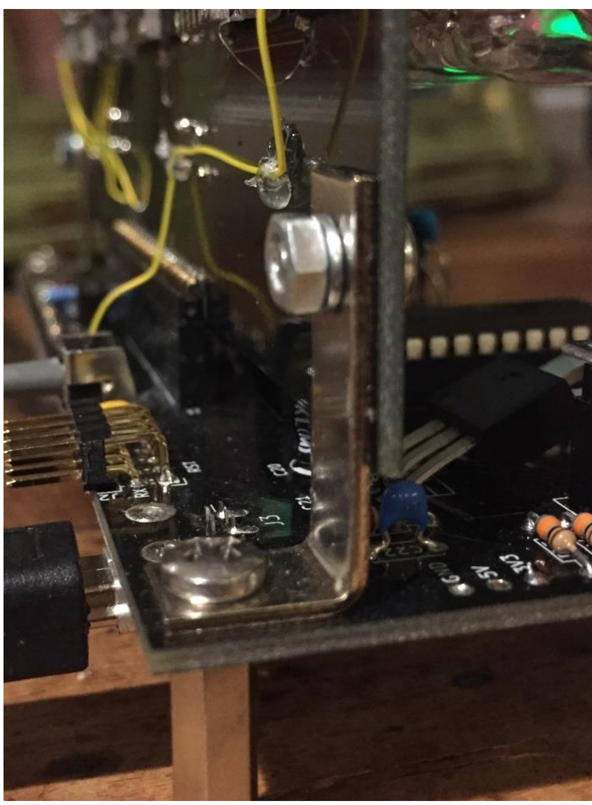
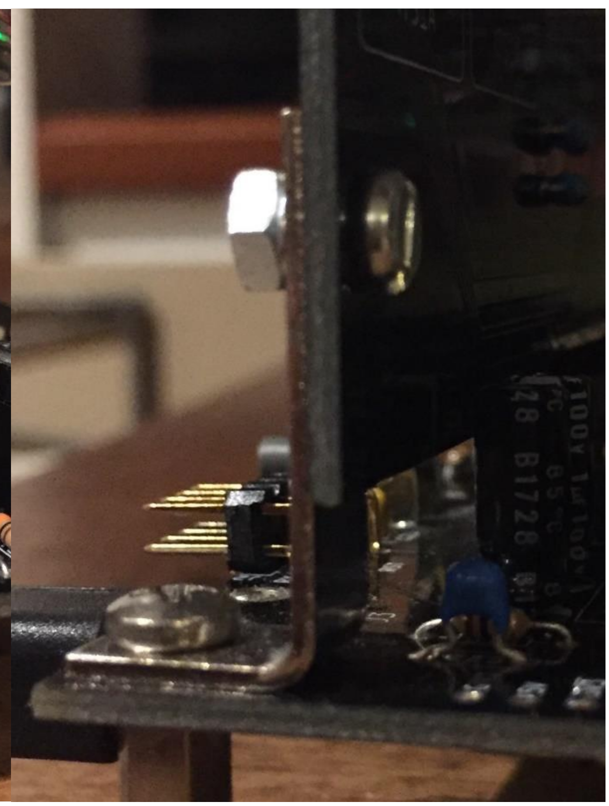
Display Header and Connector

This is a picture of the front of the display board. This is the side the tubes will be visible from.



Connectors

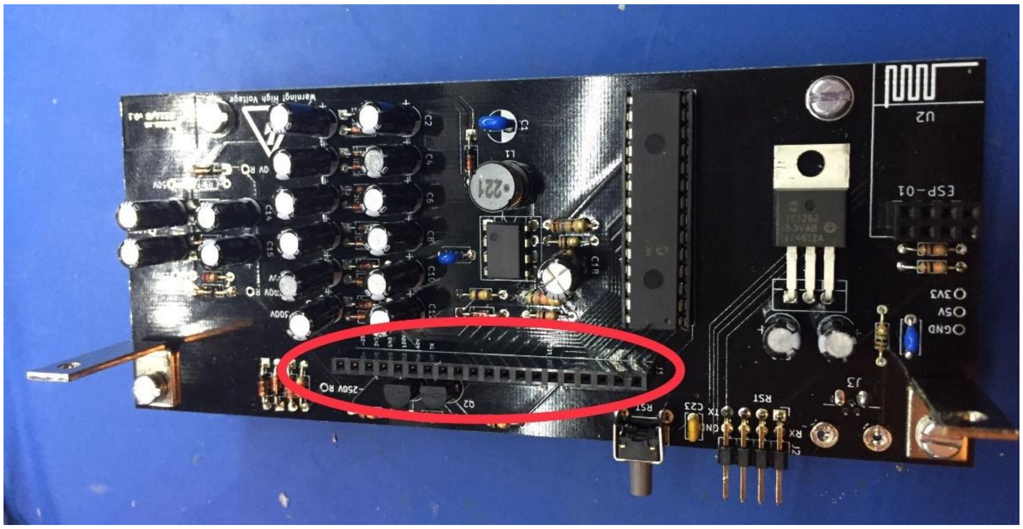
It connects at right-angles to the main board. A 1x20 socket is soldered to the main board, and a 20-pin right-angled header is soldered to the display board. The two are held together using right-angled brackets:



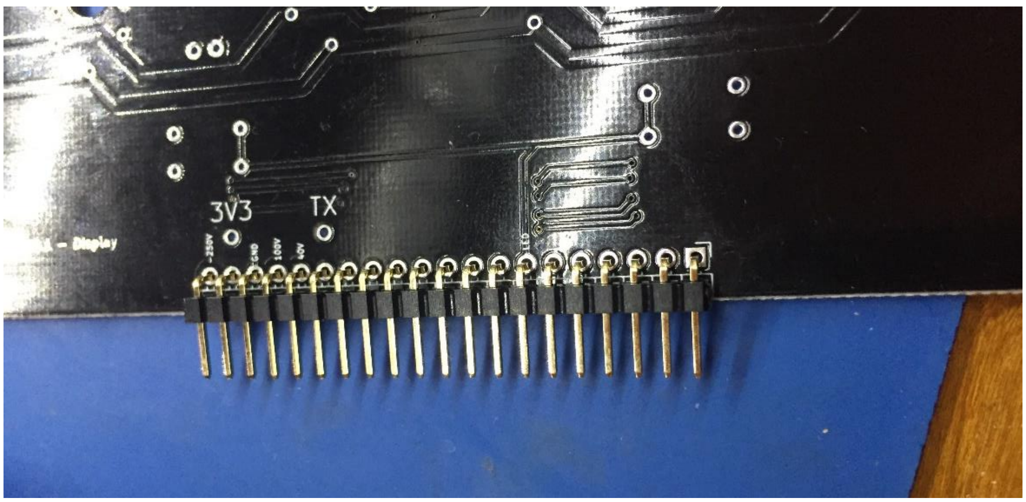
This is one way to make sure that everything lines up, when the socket and header are soldered in place:

1. Install the brackets on the main board.

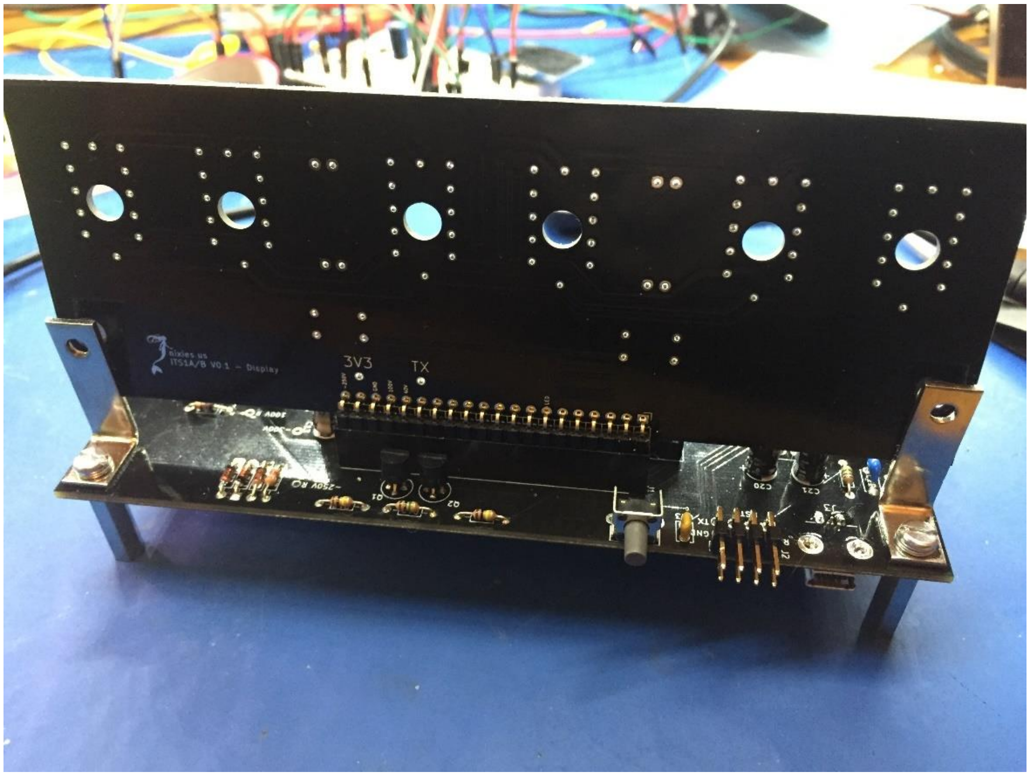
2. Insert the 1x20 socket into the main board, but do not solder it in place:



3. Insert the 1x20 right-angled header in to the display board as in the picture below, but do not solder (note that this is the back of the display board).



4. Insert the header+display board in to the socket on the main board:



5. Secure the display board to the brackets with the nuts and bolts provide.
6. Solder the socket to the main board – making sure it is flush with the board.
7. Solder the right-angled header to the display board.
8. Un-bolt the display board and remove it for the following steps.

Resistors

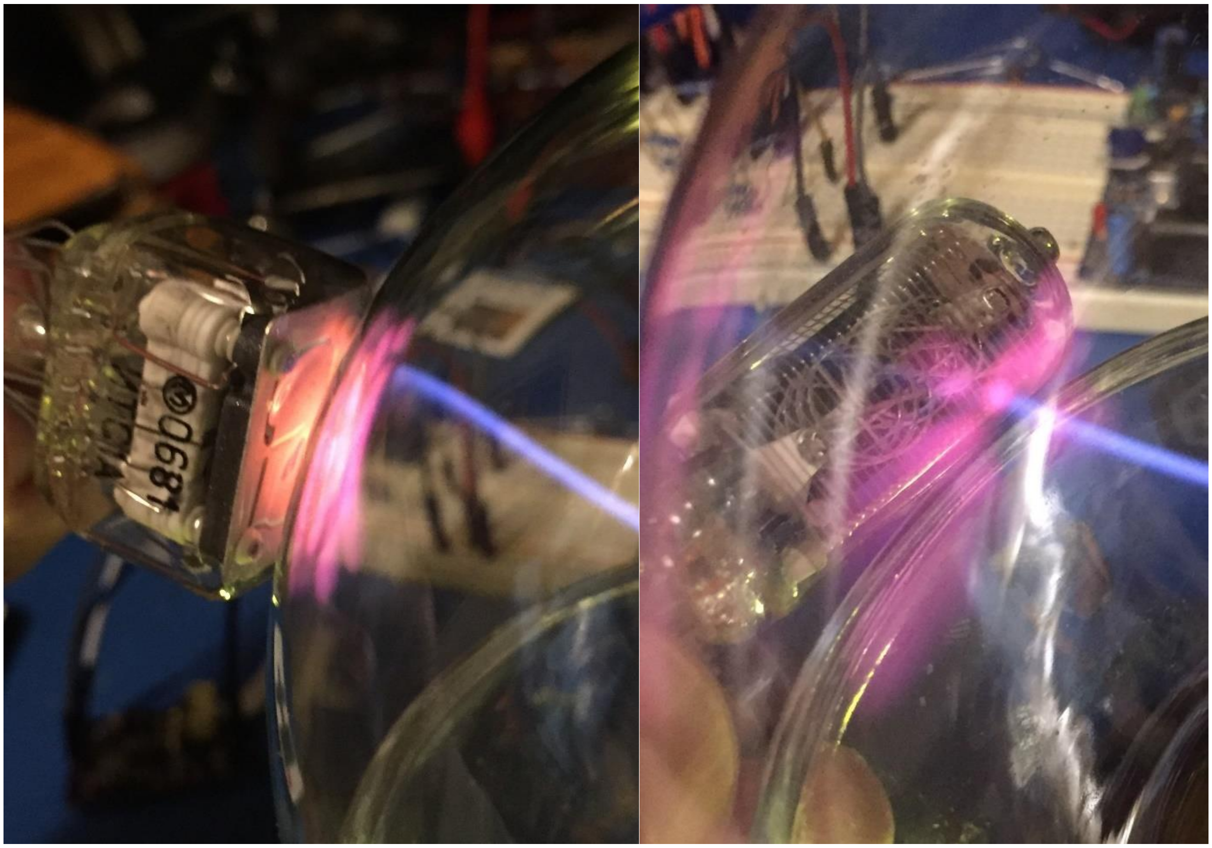
Solder the 47K resistors (Display: R1-R4) into place. You can choose whether you want these on the front or the back.

Check the Tubes

Before you solder in the tubes, you should check that they work. Removing a broken tube is not easy. There are a couple of things that can be checked before they are soldered in.

The first is to check that there are no shorts between the pins.

The second is to check that the tubes contain neon. The easiest way to do this is to hold them next to a plasma globe, or anything that generates a few KV. Plasma globes are fairly cheap these days. Check Amazon, ebay, Walmart, a toy store, a party store etc. etc. If there is neon in the tube, you should see an orange glow inside it like the image on the left. The image on the right is of a nixie tube with no neon in it. There is no orange glow inside it:



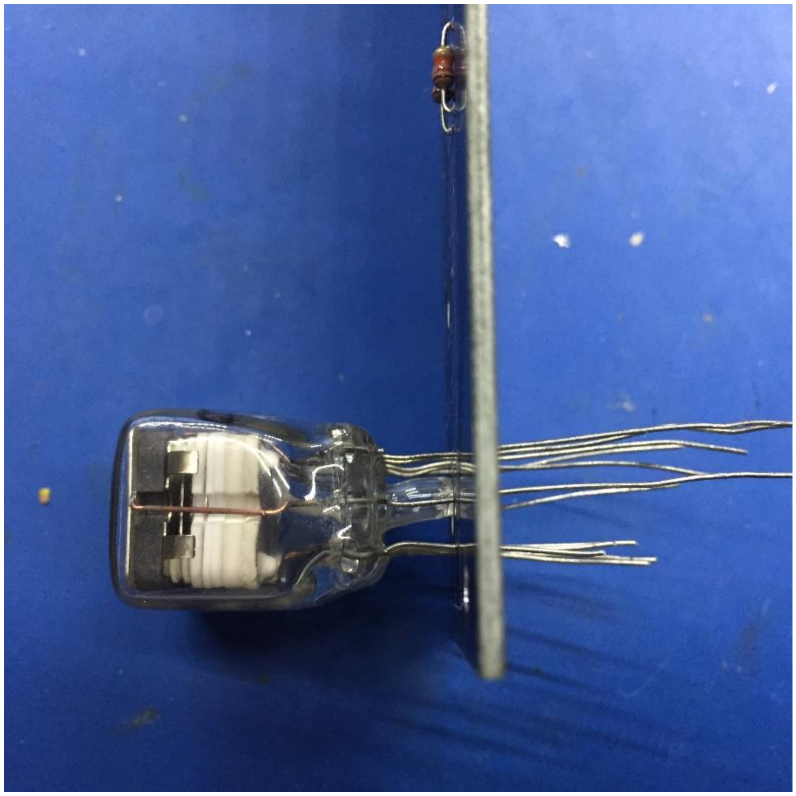
Solder the Tubes

There are holes in the display board that were intended to allow the nipple on the tube to pass through. In fact, on the first tube I installed the nipple was at a sharp angle to the tube and did not line up with the hole, so I ended up installing all the tubes so that the nipple did not go through the PCB. This turned out pretty well, and meant that I didn’t have to straighten the leads on the tube all the way up to the glass. In fact, I have heard reports that the leads of ITS1A/B tubes can sometimes snap off at or near the glass, so you should avoid applying too much force in that vicinity anyway.

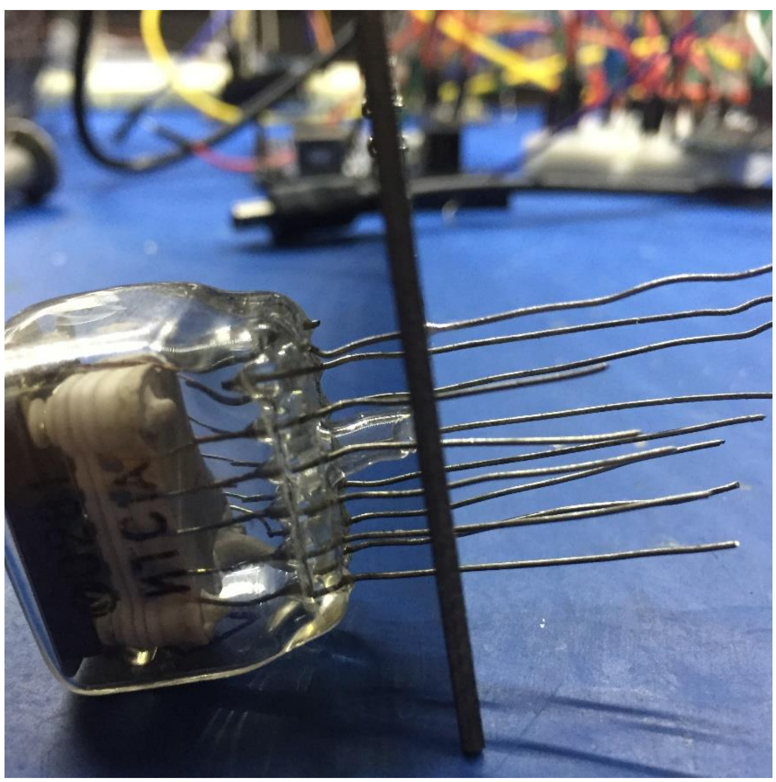
Once the leads are reasonably straight, starting with any lead you like, work around the tube and trim each one slightly shorter than the last. This will make it easier to insert the leads in to the holes because you only have to insert one lead at a time.

Now insert the leads into one end or the other of the display board, from the same side as the outlines. You will notice that the tubes have two missing leads. These should match up with the missing holes on the footprints. In other words, you **can’t** install the tubes upside-down!

In the next picture you can see the trimmed leads, and the nipple I was describing:



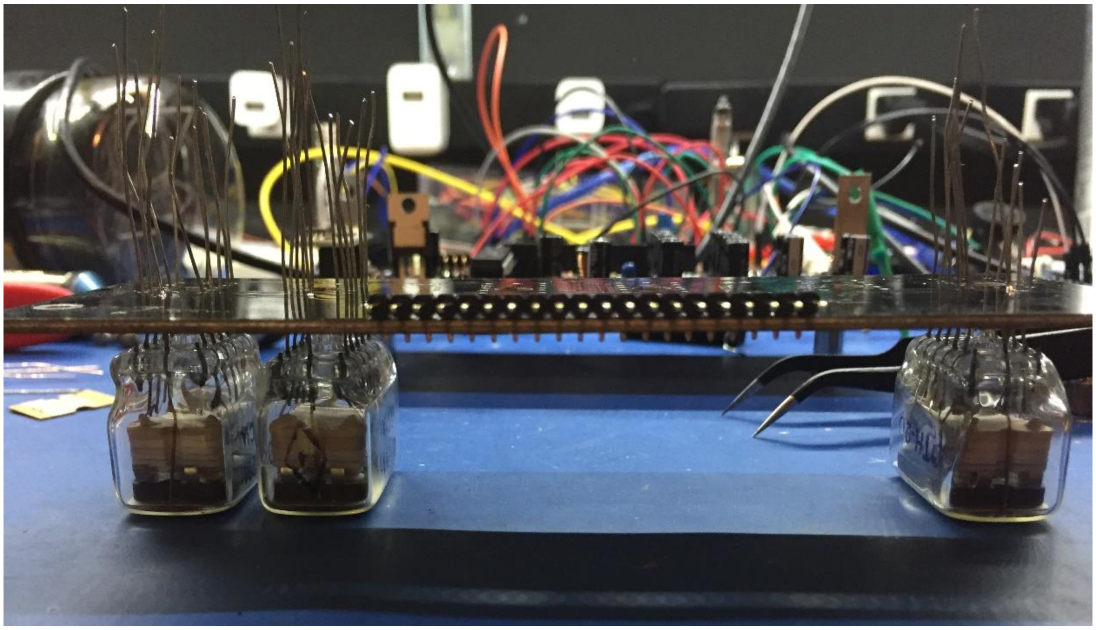
Once you have all the leads inserted, you will notice that the tube is quite firmly held in place, however line up the tube so that that it is sitting roughly square, then solder one of the leads.



Next repeat this sequence at the other end of the display board. Now insert all of the rest of the tubes, leaving them unsoldered.

Now you will want to try and get them as square as you can. This will take some trial and error. Here is one suggested sequence:

1. Lay the assembly down on your work surface as in the picture below.



2. Adjust the two tubes on the ends until the board is level with the display surface. You could make a jig to do this by cutting small pieces of material such as wood to hold the PCB at the same height on all sides, or you could just keep re-soldering and measuring.
3. Once you are happy that the two end tubes are square and the PCB is level with the work surface, adjust the remaining tubes and tack them in place with by soldering a single lead.
4. Eyeball the results. Do the tubes line up properly? If not, repeat the above steps.
5. When everything looks OK. Solder another lead in place opposite the previous lead. Check again.
6. If everything is still OK. Do another lead. Etc. etc.
7. Trim the leads flush with the back of the PCB!

Colon LEDs

LEDs are polarized components. The anode hole on the display board is marked with a little '+' symbol. The **long** lead of the LED will go in this hole.

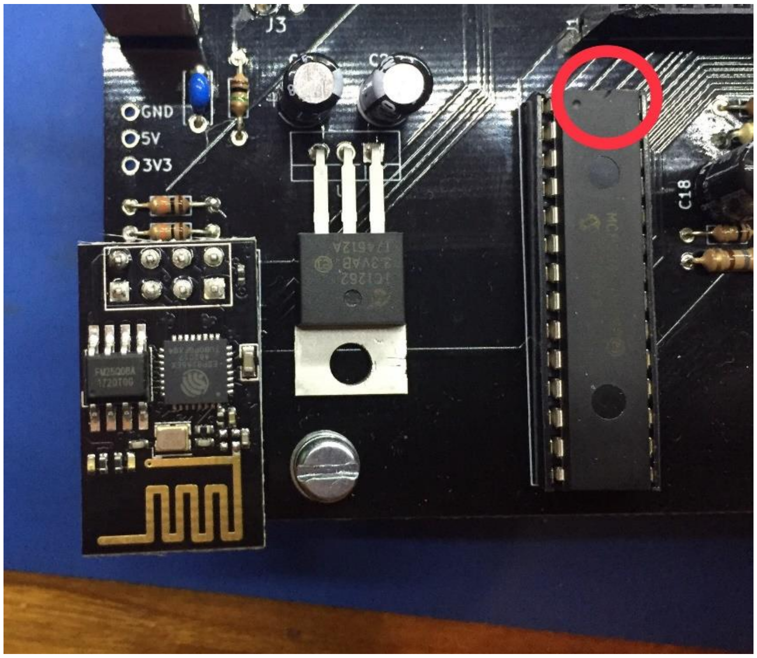
Decide how far in you want to insert the LEDs, then solder them in place. At first, just solder one lead so it is easy to rectify any mistakes.

Final Assembly

Final Assembly

Insert IC1 into its socket. For some reason that I will never understand, the pins on an IC never line up with the holes in the socket. You will need to bend them slightly. Use whatever method you are comfortable with to do this. Make sure the chip is oriented correctly! The notch should be next to the 1x20 socket that the display board plugs in to – it is circled in the next picture.

Insert the ESP-01. Either solder it in place or insert it into the socket you soldered earlier.



Insert the display board into the socket on the main board. Bolt it in place.

Check the resistance between ground and the bottom pin of one of the tubes – this is the anode 2 pin – it should be around 470k.

The Moment of Truth

Insert the USB lead into the socket on the main board, insert the other end into a USB adapter. If you see smoke, unplug it!

The red LED on the ESP-01 should come on (if it has one, there are several variations of the ESP-01). After a few moments, the tubes should display all ones. Then it will start counting up – with each tube one ahead of the tube to its left. This is intended to test that all of the segments light up and extinguish properly. In addition, the colon leds should blink on and off.

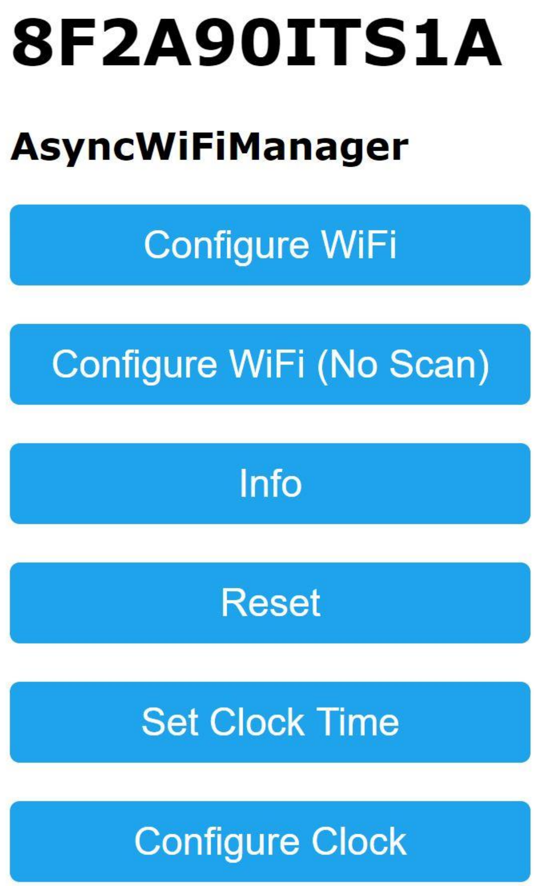
If not all segments light, or some segments stay lit when they shouldn't **don't panic**. First of all, leave it running for a few minutes to see if it fixes itself. In fact, the datasheet recommends that if the tubes haven't been used for a month or more, you should run them for at least 10 minutes. They have probably been unused for a lot longer than 1 month!

The -250V line is the key one that affects segment brightness and whether they come on or not. It can sometimes take a few minutes to stabilize, and it can take the tubes a little while to warm up. Chances are that any unlit segments will come on after a few minutes, provided the digits are changing – for example when the date is displayed. If they still don't come on after 10 minutes, check the -250V line – it needs to be at least -235V.

If segments stay on when they should go off, you can increase the *Reset Pulse Length* in the *Extra* config screen. Generally you will want this value to be as low as possible as that will reduce flicker, but you also want segments to go out!

Initial Configuration

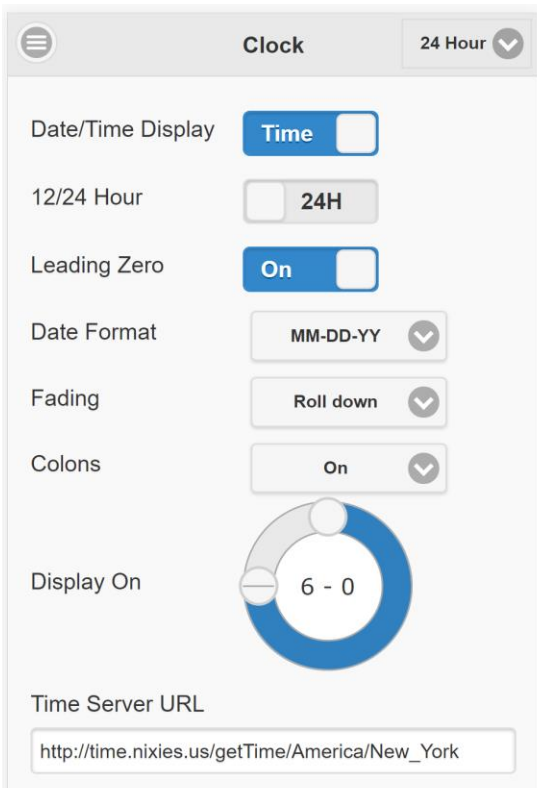
All configuration of the clock is done via a web interface. The clock will publish a WiFi access point whose name ends in *ITS1AClock*. Connect to it – the password is *secretsauce*. When you connect to it, you should then be taken to a captive portal that will display this page:



- You can set the time on the clock right from this page. Hit the *Set Clock Time* button. It will set the time to whatever the time is on your phone/PC. The clock should stop counting and display the time. The display might go blank – this is because it is pre-configured to only be on between 6am and 10pm. You can change this in the main config screen:
- You can also configure the clock right from the captive portal. Hit the *Configure Clock* button!
- *Configure WiFi* and *Configure WiFi (no Scan)*, allow you to connect the clock to a router. If you do this the clock will synchronize time with a time server on the internet and you can configure the clock by pointing a browser at http://its1aclock.local/. This page also allows you to rename the clock, which will also rename the access point.

Configuration

The clock is configured via a web browser, either from the captive portal (which is displayed when you connect to the clock's access point), or by connecting to http://its1a.local/ once you have connected the clock to a router. Some browsers/routers don't understand the .local domain. For these you will need the IP address. You can get this by connecting to the clock's access point and hitting the *Info* button. The main config screen looks like this:



When the clock is connected to the internet via a router, it will synchronize with a time server at http://time.nixies.us/getTime. You will need to know your timezone. There is a list here. The example in the picture above is for Eastern Standard Time. The clock will automatically adjust for DST in the given timezone.

You can access other settings by hitting the menu button at the top left (the three lines in a circle).

Any change you make will take immediate effect, but it won't be saved to flash for up to 1 minute – i.e. if you reset or power-cycle the clock before the changes are written to flash, the changes will be lost.

Presets

The clock allows you to store up to five presets – these are named collections of settings. You can access the presets by hitting the menu button on the top-right of the screen – it is labelled with the currently selected preset. *24 Hour* in the picture above. The menu won't go away unless you either select a different preset, or use the main menu button.

Any change you make while a preset is selected, will be saved to that preset.

If there is no preset menu visible, it is because the settings on that screen affect all presets, for example the Alexa config screen.

Alexa

You can control the clock from Alexa. You have to make Alexa discover devices while the clock is turned on, literally say ‘Alexa, discover my devices’. My Alexa claims not to have found any new devices, but it really has, so ignore that. If you look at the Alexa config screen on the clock, you will see all the ‘switches’ that can be turned on and off. For example, you can say ‘Alexa turn on date’ and it will display the date. Say ‘Alexa turn off date’ and it will switch back to the time.

The names of these ‘switches’ can be changed on the Alexa config screen on the clock. You will have to re-discover devices after you have done this.

Backlighting and Underlighting

You decide!

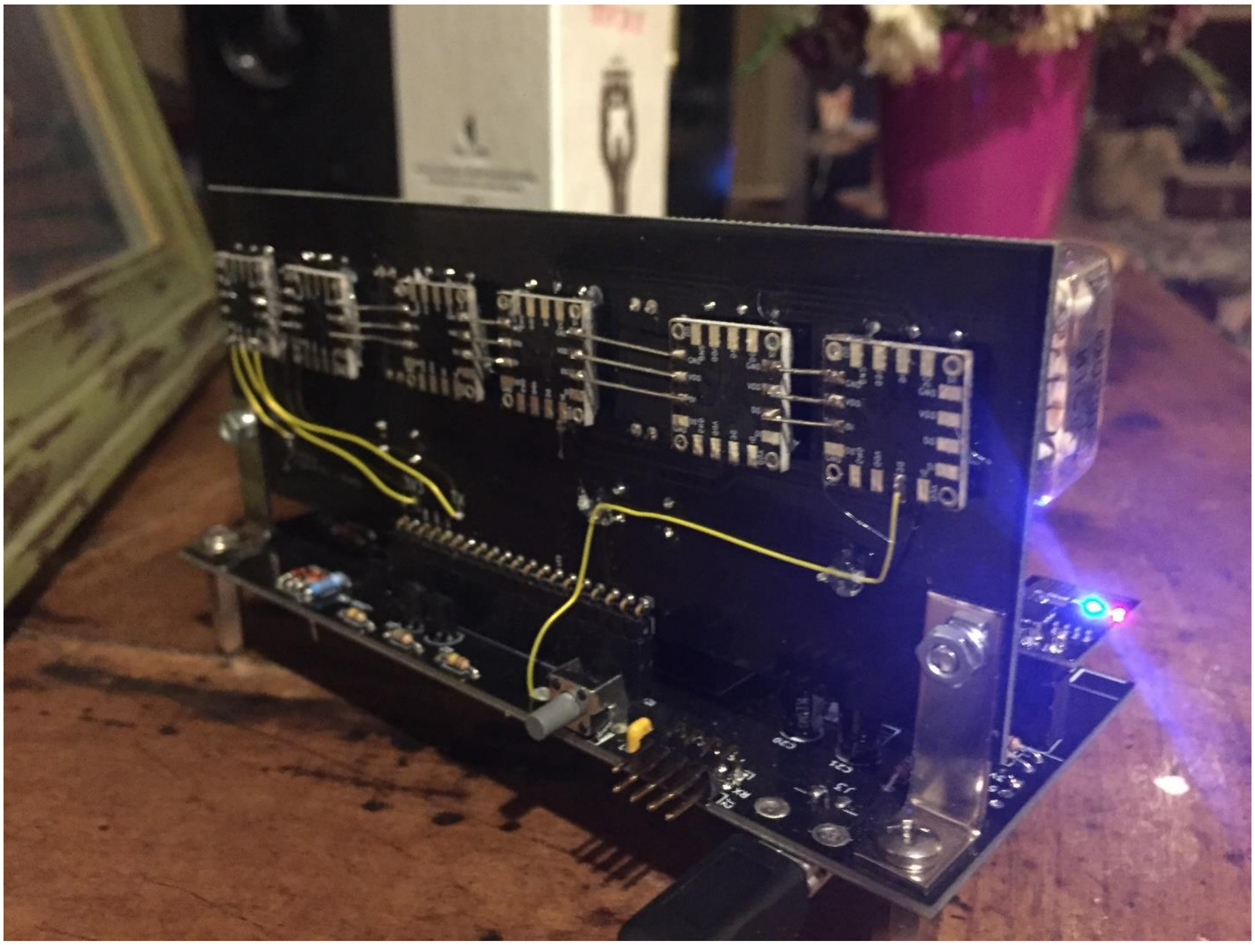
There are signal lines to the display board that will drive a string of Neopixels, and the software has a screen that allows you to configure what they display. However if you want backlighting, you will have to figure out how to wire some neopixels up and mount them.

There are solder points marked GND, 3V3 and TX. TX should be wired to data-in on the first neopixel, then you daisy-chain the rest together, connecting data-out to data-in.

The software is configured to drive up to 10 neopixels in groups of 6 and 4, so you can have underlighting as well as backlighting.

One builder of this kit bought a bunch of neopixel modules like these and mounted them on short tubes to stand them off the back of the board – You need the [WS2812B modules](#):

I also designed some tiles some small PCBs that take surface-mount 3535 neopixels from [PCBWAY](#). You will need to be able to solder surface-mount components for these, and then figure out how to mount them without shorting anything out:



Motion Sensor

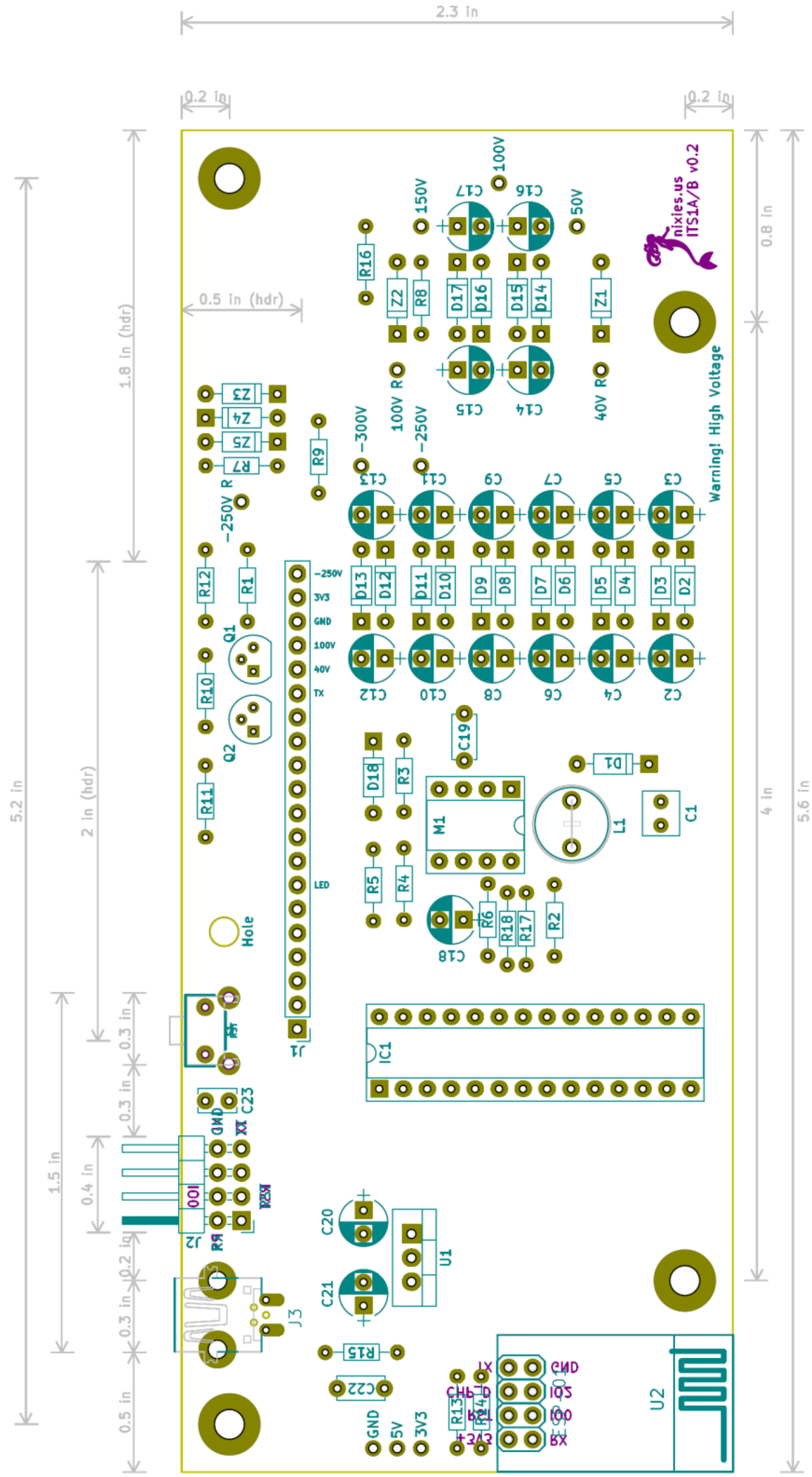
Another option: The software includes support for a motion sensor. It should be powered by 5V and have a 3V3 signal output. A value of 3V3 should indicate that motion has been detected.

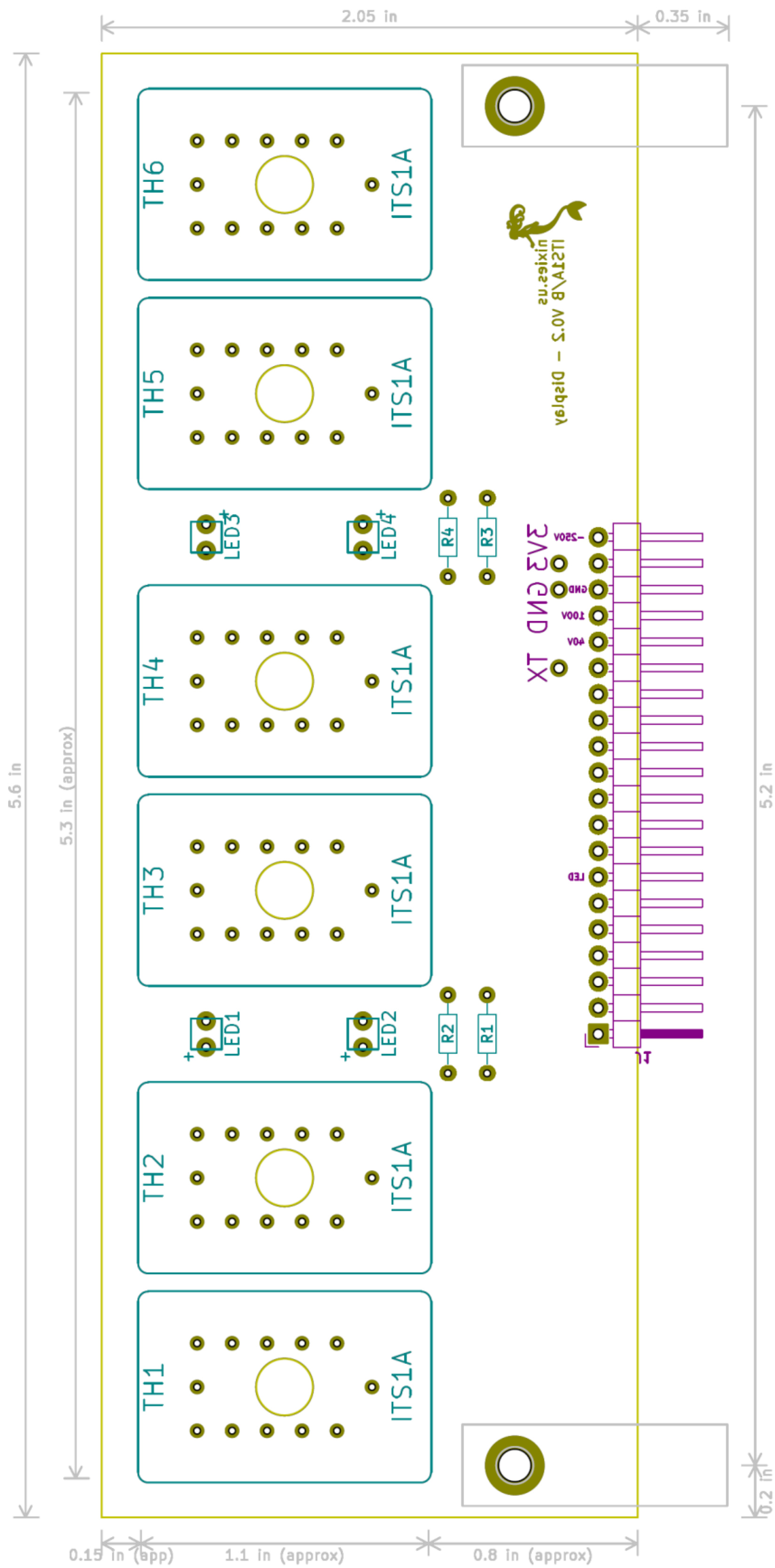
Attach the signal output to the pin (or hole) marked RX on the programming header at the back. Attach 0V/ground to any convenient GND point on the board. Likewise, attach +5V to any convenient +5V point on the board.

Personally I find it useful to connect an LED across signal and 0V, so I can see if the sensor is actually working. If you do, don't forget a current-limiting resistor!

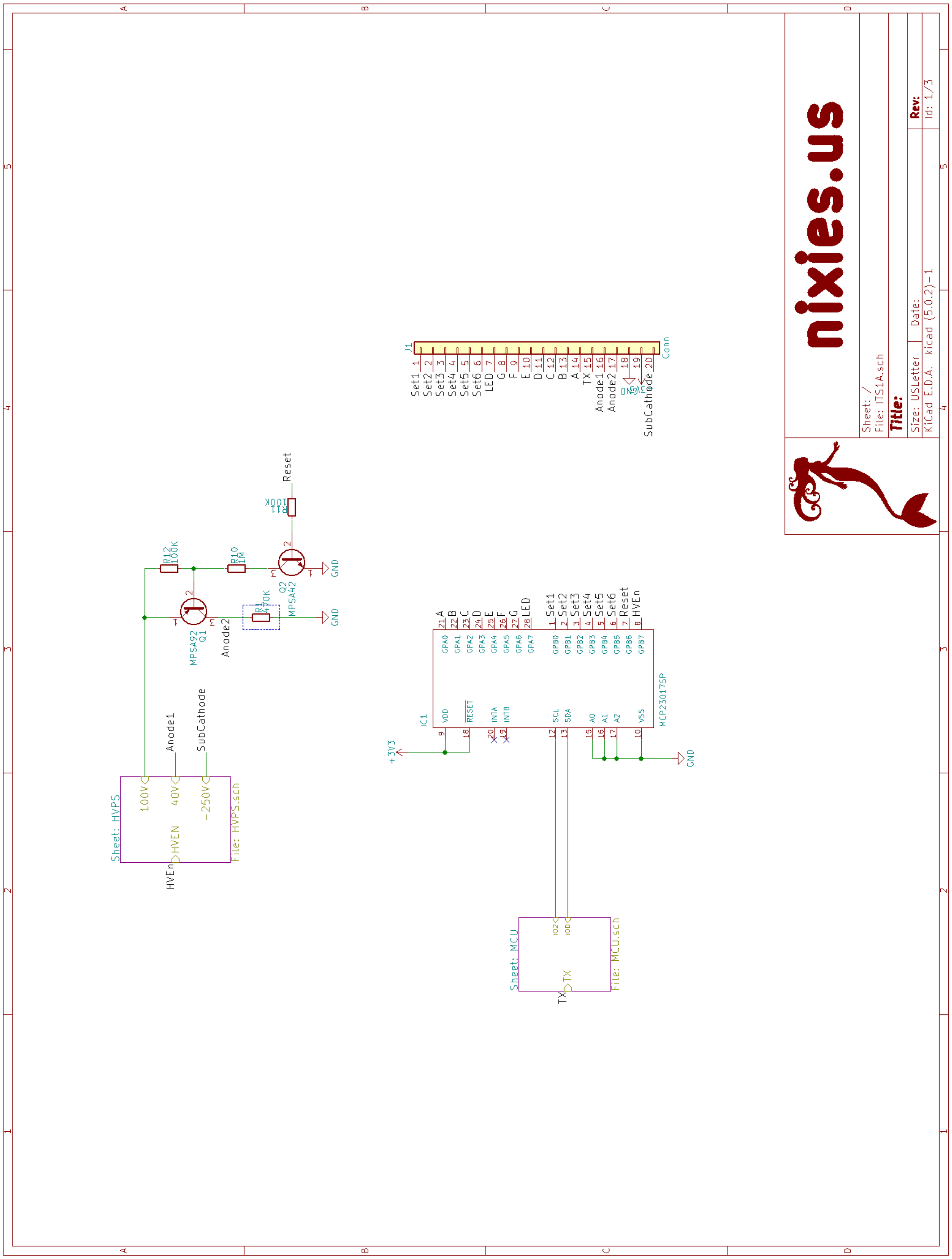
The clock will work fine without a motion sensor attached – it is only used if you connect one.

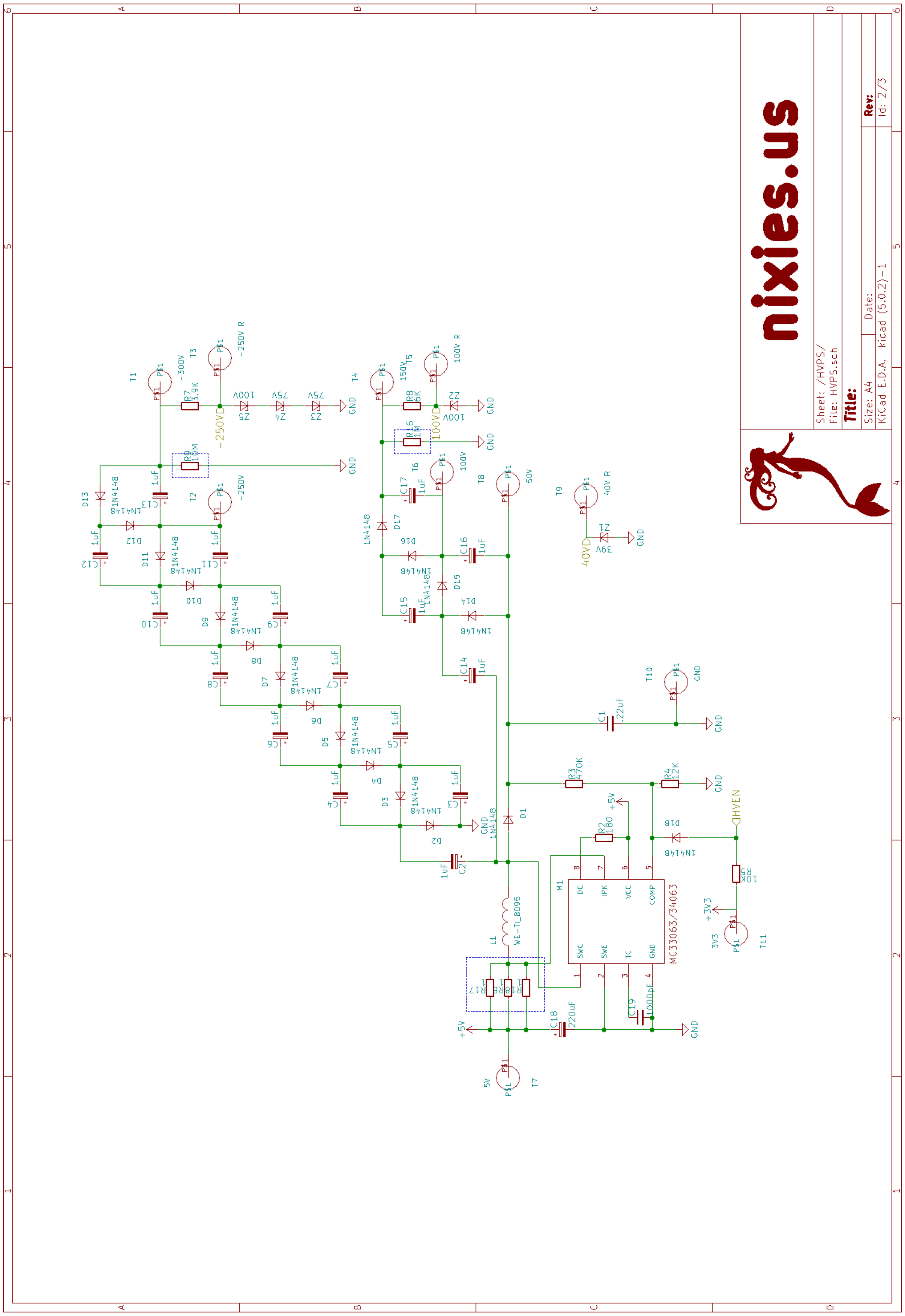
Appendix A – PCB




2.05 in
0.35 in
5.6 in
5.3 in (approx)
5.2 in
0.2 in
0.15 in (app)
1.1 in (approx)
0.8 in (approx)
TH6
TH5
TH4
TH3
TH2
TH1
ITS1A
LED1
LED2
LED3
LED4
R1
R2
R3
R4
3V3 GND TX

Appendix B – Schematic




nixies.us
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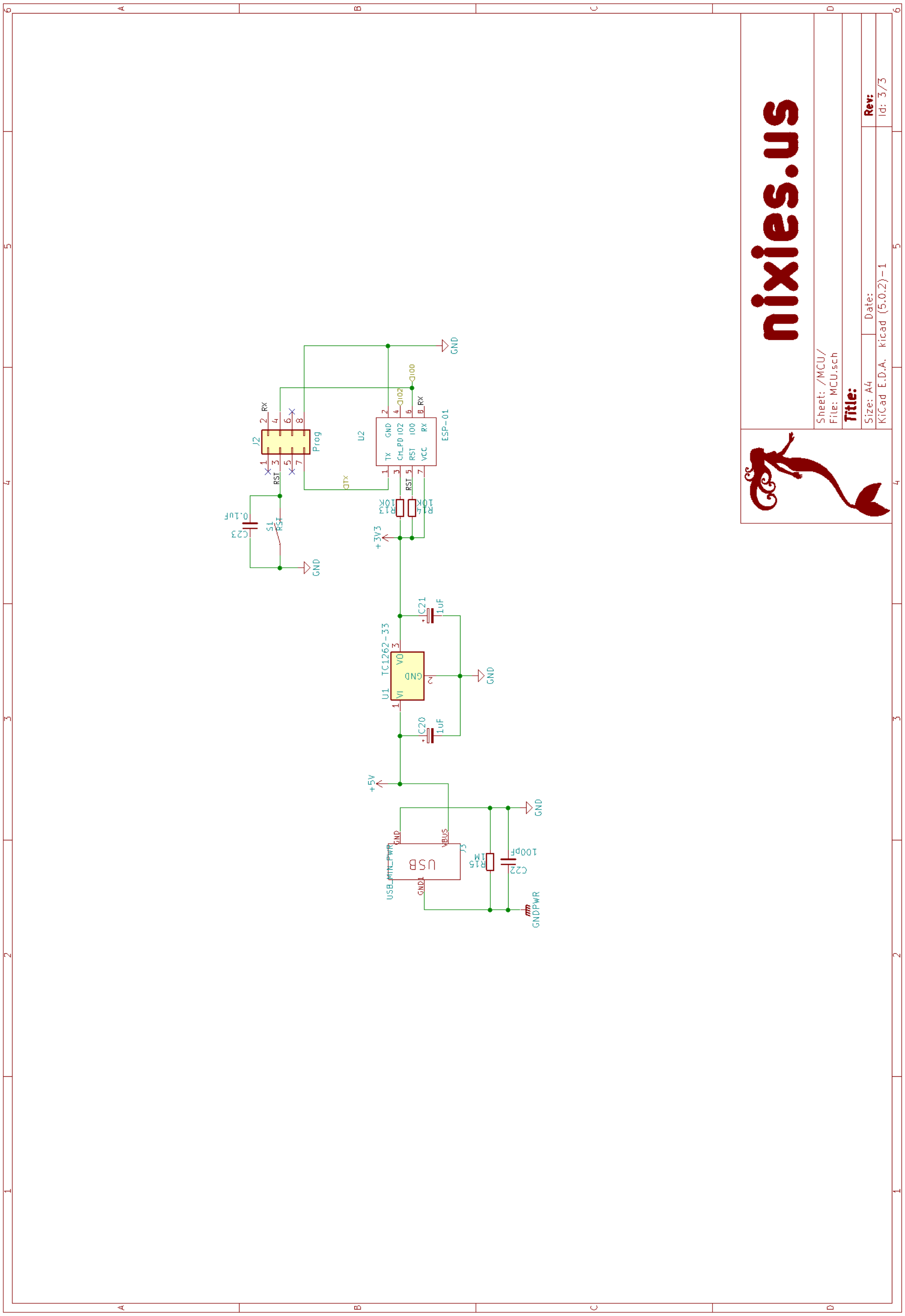
Title:
Size: A4
Date:
KiCad E.D.A. kicad (5.0.2)-1
Rev:
Id: 2/3
MC33063/34063
WE-TL8095
HVEN


nixies.us
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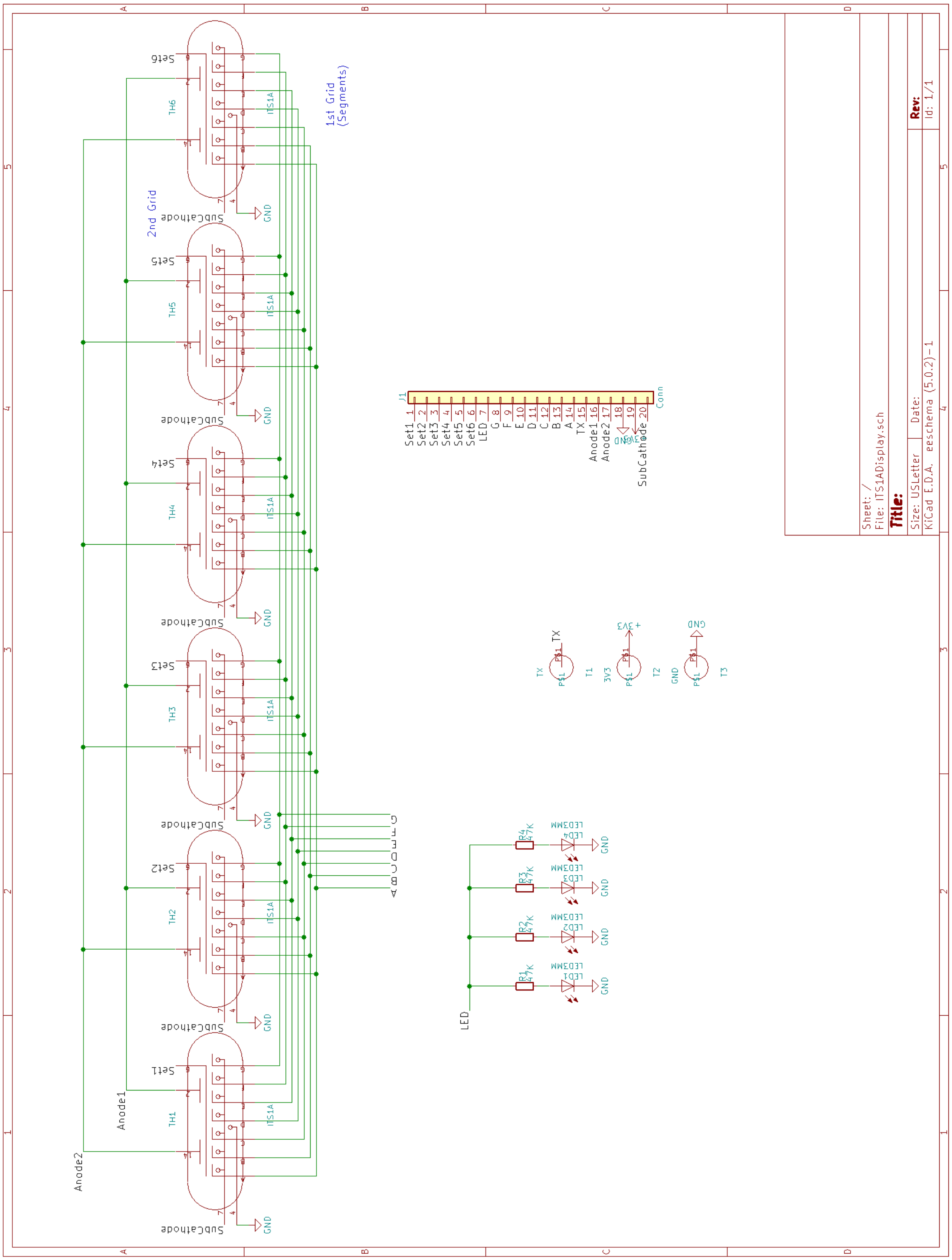
Date:
Rev:
KiCad E.D.A. kicad (5.0.2)-1
Id: 3/3
J2
Prog
U2
ESP-01
GND
TX
CH_PD
IO2
IO0
RST
RX
VCC
R13
R14
10K
C23
0.1uF
S1
RST
+3V3
U1
TC1262-33
VI
VO
GND
C20
C21
1uF
+5V
J3
USB
USB_MINI_PWR
VBUS
R15
1M
C22
100pF
GNDPWR


1st Grid
(Segments)
2nd Grid
Anode1
Anode2
TH1
TH2
TH3
TH4
TH5
TH6
ITS1A
SubCathode
GND
Set1
Set2
Set3
Set4
Set5
Set6
LED
J1
Conn
+3V3
Sheet: /
File: ITS1ADisplay.sch
Title:
Size: USLetter
Date:
KiCad E.D.A. eeschema (5.0.2)-1
Rev:
Id: 1/1