4 Tube Nixie Clock Kit
Assembly Instructions

v1.4

Scary Warning

DANGER: BUILDING THIS KIT INVOLVES WORKING WITH DANGEROUS, POTENTIALLY LETHAL VOLTAGES. POWER LINE VOLTAGES ARE DANGEROUS. IF YOU ARE NOT EXPERIENCED WORKING WITH DANGEROUS, POTENTIALLY LETHAL VOLTAGES, RETURN THE KIT FOR A REFUND. IF YOU DO NOT ACCEPT FULL RESPONSIBILITY FOR WORKING WITH THESE POTENTIALLY LETHAL VOLTAGES, RETURN THE KIT FOR A REFUND.

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Overview

It doesn't matter how new an idea is: what matters is how new it becomes
— Elias Canetti

The Nixie tube was introduced in 1954, and provided the display for early voltmeters, frequency counters, and multimeters, before being replaced by LCDs and LEDs in the 1970s. They were also found in the first desktop calculators, and even as the display for the Apollo guidance computer. Once utilized primarily in research and military equipment, Nixies are now prized for their retro aesthetics, and featured in this hand-crafted clock. For more history of the Nixie tube technology, see Wikipedia history of the Nixie at http://en.wikipedia.org/wiki/Nixie_tube.

The 4 tube Nixie clock kit offered by Peter J. Jensen, LLC is a simple design, presented in a minimalist aluminum enclosure. Time is set by two buttons on the back; one advances the hours, the other minutes. The digits fade from one number to the next as the time changes.

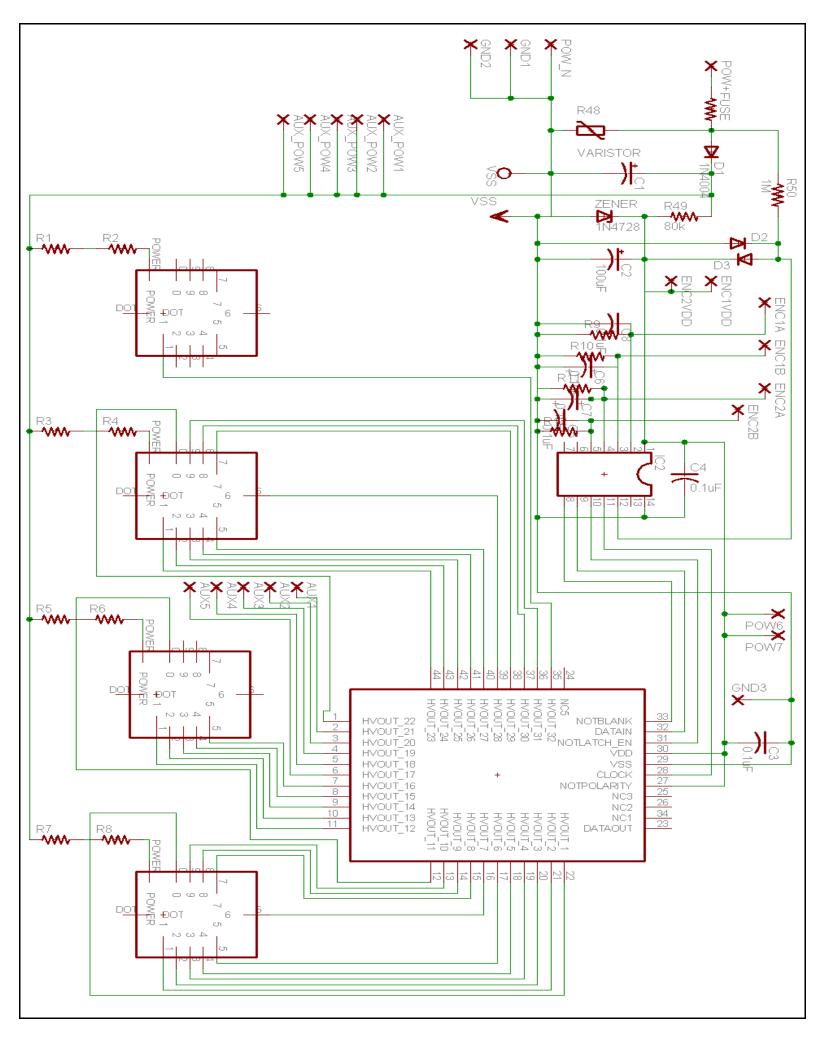## Circuit Description – (skip if you like)

The design of this clock is intended to be as simple as possible. This lowers both the part count and cost, simplifies assembly, and reduces error.

The input power line (115V, 60Hz) provides both power and the time base for the clock.

The input power first passes through a 0.25 amp fuse, and is jumpered by a 130V AC metal oxide varistor (MOV). Should the input power exceed 175VDC, the MOV will short out the input, passing a large current through the fuse. The fuse will then trip, and shut down the circuit. If this happens, the clock will need to be repaired by replacing the fuse, but a potentially dangerous overvoltage situation will have been avoided.

There are two power supplies derived from the input line: one 163V DC for high voltage driving of the nixies; and a second 5V DC for powering the driver and microcontroller.

The high voltage supply is provided by a half wave rectifier (D1), from the power line, fed into a 33uF capacitor (C1). This will provide ~163V DC to drive the nixies.

The low voltage supply is provided by a resistor and a Zener diode acting as a voltage divider. The ½ watt 82k Ohm resistor (R49) limits the current flow, and the Zener keeps the voltage at about 5V DC. A 100uF capacitor (C2) across the Zener filters the 5V power supply, keeping it stiff, and allowing the clock to go without power for 5 to 10 seconds without losing the time.

For keeping track of time, two diodes (D2 and D3) are placed across the power line input to the 5V DC line and to the ground line. A 1M Ohm (R50) resistor limits the current. Because of these two diodes, the output at the 1M Ohm resistor looks like a 5V square wave at 60Hz (the power line frequency); the square wave does not exceed 5V because of D3, and it does not drop below ground because of D2.

The micro-controller is programmed to count the transitions of this square wave at its input pin 12. The power line provides a very reliable clock source, courtesy of the power company.

For setting the time, the PCB and schematic are labeled for four encoder inputs. However, because the micro-controller running without an external crystal was unable to reliably capture quadrature encoder inputs, buttons are used instead. Encoder inputs 1B and 2B are not used. Button 1 connects ENC1A to ENC1VDD, and Button 2 connects ENC2A to ENC2VDD. C5 through C8 and R9 through R12 are debounce low-pass filters on the buttons.

The input pins 2 and 4 on the micro-controller read the button inputs. Inputs 3 and 5 are left unused.
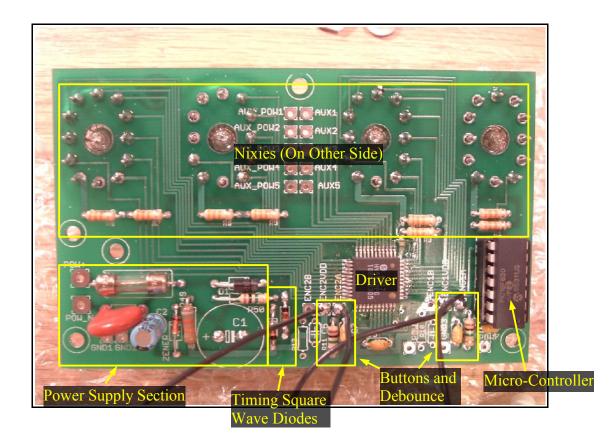
To turn on power to a nixie tube digit, the pin corresponding to the digit is grounded. R1 through R8 limit the current through the nixies to approximately 2.5mA.

The high voltage driver surface mount device (SMD) is serial programmed by the micro-controller to ground pins based on the time to be displayed. For interested parties, the data sheet for the driver chip can be found at:

http://www.supertex.com/pdf/datasheets/HV5622.pdf

The micro-controller data sheet can be found at:

http://ww1.microchip.com/downloads/en/DeviceDoc/40039c.pdf

Nixies (On Other Side)

AUX_POW1 AUX1
AUX_POW2 AUX2
AUX_POW4 AUX4
AUX_POW5 AUX5

Driver

Micro-Controller

Buttons and Debounce

Power Supply Section

Timing Square Wave Diodes

Parts List

It is good to have friends in all parts.
– French Proverb

Name	Count
Button - Black	1
Button - White	1
Capacitor – 0.1uF	4
Capacitor – 100uF	1
Capacitor – 33uF	1
Dip Socket -- 14Pin	1
Enclosure	1
Fuse	1
Hex Standoff – 13/16"	2
High Voltage Driver SMD	1
Microcontroller PIC16F630	1
MOV, 130V	1
Nixies – IN12	4
PCB (Printed Circuit Board)	1
Power Cord	1
Rectifier	1
Resistor – 82kOhm 1/2 Watt	1
Resistor 1MOhm 1/4 Watt	3
Resistor 33kOhm 1/4 Watt	8
Strain Relief	1
Switching Diode	2
Wire Crimp	1
Zener Diode – 5.1V	1
Heat Shrink Tubing	
Wire	
Copper Desoldering Braid	

Illustration 1 Assembled Board - Back

Illustration 2 Assembled Board - Front

Labels on board:
- Nixies (On Other Side)
- 33k Resistors
- 33uF Capacitor (On Back)
- Rectifier
- Driver
- Fuse
- MOV
- Zener Diode
- Diodes
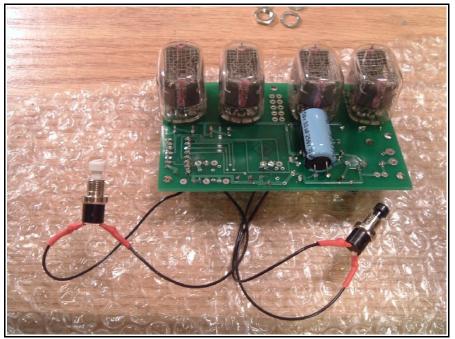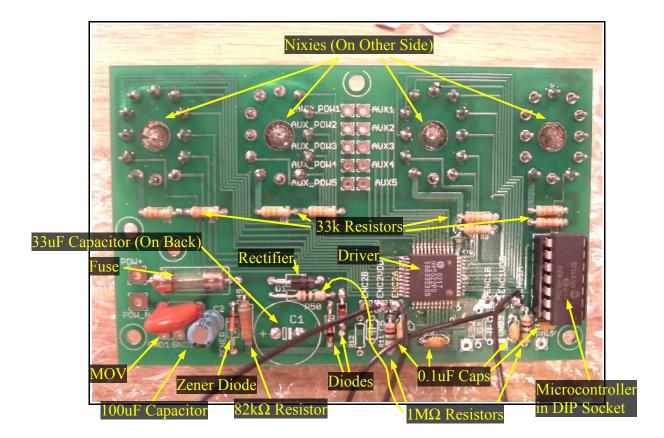- 0.1uF Caps
- Microcontroller in DIP Socket
- 100uF Capacitor
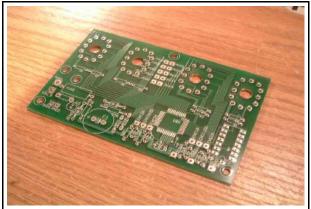- 82kΩ Resistor
- 1MΩ Resistors

Update: The board now has a place for an extra capacitor (C9) across the signal diodes. This is not pictured above. The new additional capacitor C9 goes above the Rectifier, and the Rectifier has been moved slightly up and to the left. Please see step 30.

Assembly Instructions

There are different approaches one can take to assembling this clock. Often the best approach is to build the power supply first, and test it before putting on any of the other parts. However, for this kit I find it easiest to place the High Voltage Driver surface mount chip first. As the first chip placed, the board can lie flat, making placement of the chip and its tiny leads simpler.

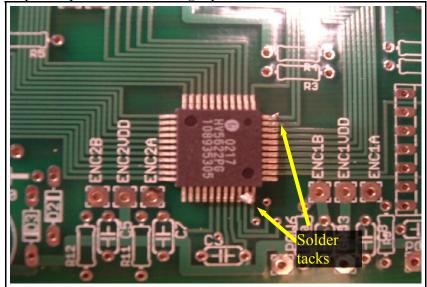1) Locate the PCB, and lie it flat on the work surface

2) Locate the Driver surface mount chip, and place it on the PCB. **Notice the orientation and pin alignment**. The top of the chip goes to the right (the pin 1

dot is in the upper right). Each pin should rest on exactly one pad. See picture.
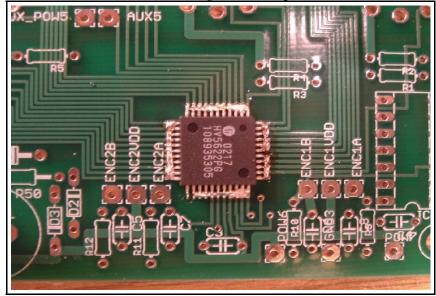
IMPORTANT:
Use the dots to
align the driver chip,
not the printed text.
The text is sometimes
upside down.

3) The goal of this step is to tack solder the Driver chip in place, so the pins can be soldered without the chip sliding around. Place a small drop of solder on the tip of the iron, and gently immerse the upper right pin on the High Voltage Driver chip in the solder without actually touching the pin with the iron. Allow a little solder to stick to the pin.

4) Repeat step 3 with the lower right pin on the Driver.
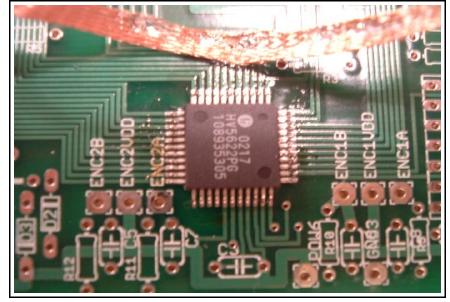

5) Double-check that the Driver pins are placed exactly over the pads. Now is the time to correct a misalignment by melting the tack solder, and twisting the part gently while the solder is liquid.

6) The goal of this step is to get solder around every lead on the Driver; excess solder will be removed later. Solder a thin layer of solder over all the pins on the Driver. Do not worry at all about solder bridging over adjacent leads. All that matters is that every lead has solder on it. You will probably notice the solder wick under the leads as they are covered in solder. A small covering of solder will suffice, do not use so much solder as to create large balls. See picture:
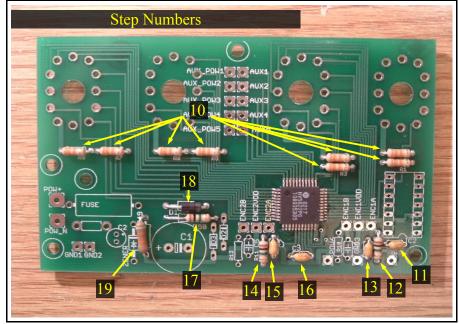

7) The goal of this step is to remove the excess solder on the Driver. Use copper solder braid to wick up the excess solder by placing the braid over the soldered leads, and applying the hot iron to the other side of the braid. The solder on the leads will melt and capillary action will pull it into the braid. Don't worry about pulling off all the solder; some of the solder has wicked around the leads to the pads, and will not be pulled up into the braid. If you have trouble melting the solder on the leads through the braid, try either increasing the iron heat, using a

larger tip, or dabbing a small amount of solder on the iron to get the flow started.
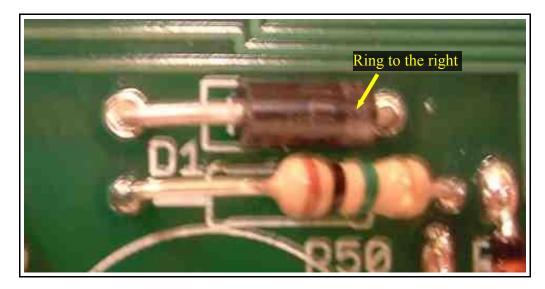

8) Check the leads of the Driver for solder bridges (shorts) with a magnifying glass or good eyes. Double-check the contacts with a multi-meter. To do this, visually follow the traces from the Driver out to a mounting hole, and test for connectivity by placing one probe on the Driver lead, and the other on the mounting hole to which the trace connects. Leads without traces on the top of the board are not used and need not be checked. Check for bridges by placing the probes on adjacent leads and making sure there is no contact.

9) In the next steps, the passive components will be placed.

10) Solder the 8 33kOhm resistors (Orange-Orange-Orange-Gold stripes) in their mounting holes. Snip off the extra lead wire on the back.
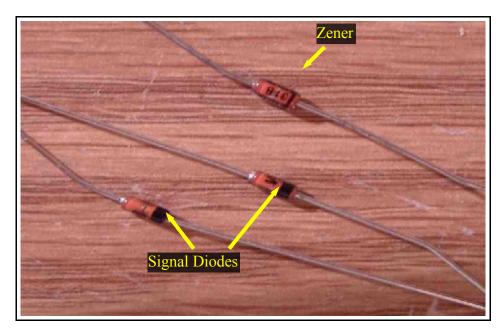

11) Solder a 0.1uF Capacitor in its holes under IC2, in the lower right. Snip off the extra lead wire on the back.

12) Solder one 1MOhm (Brown-Black-Green-Gold stripes) in its spot at R9 in the lower right of the board. Snip off the extra lead wire on the back.

13) Solder a 0.1uF Capacitor in its holes at C8, next to the resistor placed in the previous step. Snip off the extra lead wire on the back.

14) Solder one 1MOhm (Brown-Black-Green-Gold stripes) at R11 under the ENC2A mount point. Snip off the extra lead wire on the back.

15) Solder a 0.1uF Capacitor in its holes at C7, next to the resistor placed in the previous step. Snip off the extra lead wire on the back.

16) Solder a 0.1uF Capacitor at C3, under the Driver chip. Snip off the extra lead wire on the back.

17) Solder a 1MOhm (Brown-Black-Green-Gold stripes) at R50, just over the large capacitor mounting point C1, in the lower left hand portion of the board. Note that the leads will need to be extended for the resistor to span the two mounting holes. Snip off the extra lead wire on the back.

18) Solder the black Rectifier at D1. NOTE THE ORIENTATION.
IMPORTANT: a new capcitor (C9) has been added to the kit. This capacitor now goes directly above the 1M Ohm resistor, and the rectifier D1 has been moved slightly up and to the left. This is slightly different than the picture below. The ring

on the rectifier goes to the right, as drawn on the board and shown in the picture. Snip off the extra lead wire on the back.
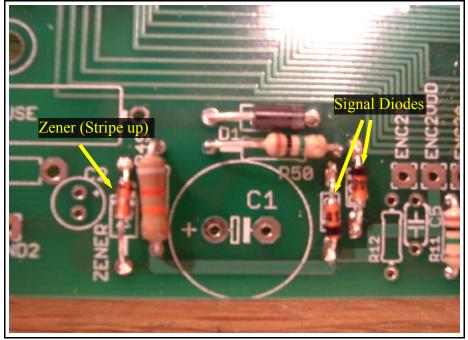

19) Solder the 82kOhm resistor (Grey-Red-Orange-Gold stripes) at R49 on the lower left of the board. Snip off the extra lead wire on the back.

20) The next steps will solder the Zener diode and the two signal diodes. Do not confuse these diodes; they look very similar. The two signal diodes should be taped together.
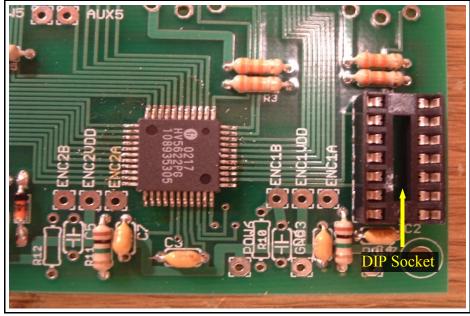

21) Solder the Zener diode, stripe towards the top of the board, in the place marked ZENER. MAKE SURE THE STIPE IS TOWARDS THE TOP OF THE

BOARD. Snip off the extra lead wire on the back.

22) Solder signal diode D3 in its spot, with the stripe toward the BOTTOM of the board. This is the left hand diode, and the stripe goes towards the bottom of the board. Snip off the extra lead wire on the back.
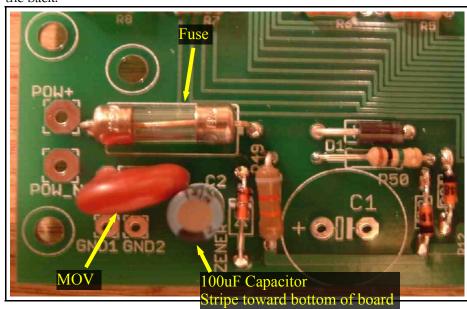
23) Solder signal diode D2 in its spot, with the stripe toward the TOP of the board. This is the right hand diode, and the stripe goes towards the top of the board. Snip off the extra lead wire on the back.

24) Solder the 14 pin DIP <u>SOCKET</u> (not the micro-controller) into the IC2 position at the lower right hand of the board. The orientation of the socket does not matter.

DIP Socket

25) Solder the fuse in place in the lower left of the PCB. Snip off the extra lead wire on the back.

Fuse

MOV

100uF Capacitor
Stripe toward bottom of board
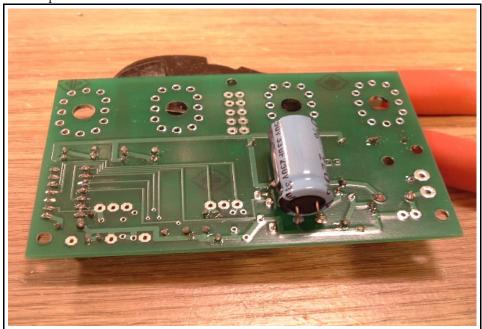
26) Solder the MOV in place. Orientation does not matter. Snip off the extra lead wire on the back.

27) Solder the 100uF capacitor (this is the smaller of the two blue electrolytic capacitors) at position marked C2. ORIENTATION MATTERS. The black (negative) strip must be towards the bottom of the board.

28) Place the PIC micro-controller in the 14-pin socket. ORIENTATION MATTERS. The pin-1 dimple in the chip must be towards the bottom of the board. It may be necessary to press the pins in towards the chip in order to get them to align with the socket holes. Make sure the micro-controller is seated completely in the socket.

PIN 1 Dimple towards bottom of board

29) The goal of this step is to attach the 33uF capacitor in its place labeled C1, but on the back of the board, and bent down flat. Flip the board over and solder the 33uF capacitor on its side. See picture. ORIENTATION MATTERS. Make sure the stripe (negative lead) goes through the hole **without** the "+" symbol on the PCB. The strip will be towards the center of the board.

30) Quality check: Review the board and look for any missing or bad solder joints. Confirm that the zener diode has its strip towards the top of the board. Confirm the the rectifier has its strip on the right. Confirm that the physically smaller 100uF capacitor has its strip toward the bottom of the board. Confirm that the physically larger 33uF capacitor has its stripe towards the center of the board. Confirm that the driver chip has its pin-1 dimple in the upper right (the writing on the chip is aligned so the chip's top faces to the board's right). Confirm that the micro-controller has its pin-1 dimple towards the bottom of the board.

IMPORTANT ADDITON: A kit builder reported that his clock was running fast. After some investigation, it was hypothesized that, living in the middle of a city and in a building with old wiring, the might be excessive line noise at his location. The line noise could couple through the 1MOhm resistor and two switching diodes which make the 60Hz square-wave signal that the micrcontroller uses to keep time.

To correct for this problem, an additional 0.1uF capacitor, C9, is now included in the kit. C9 should be soldered in. Previously there were no holes on the circuit board for this, but the new circuit board now has a place for this capacitor (C9). Please put the 0.1uF capacitor in position C9 above the 1M Ohm resistor.

31) The goal of the next steps is to attach the buttons.

32) Cut the wire into 4 pieces, each about 4 inches long. Strip about 1/4" from the ends of each piece of wire.

33) Bend the leads of the buttons out. Thread a stripped wire end through the hole in each button lead, wrap the wire around the lead, and solder.

34) Slide a short piece of heat shrink over each wire and button lead, and shrink in place with heat gun or hair dryer. If a heat gun or hair dryer is not available, the heat shrink can be shrunk with careful use of the soldering iron, placed close

enough to heat up the heat shrink, but without touching it.

35) Solder the 2 open ends of the wires for the black button onto the board at ENC2VDD and ENC2A.

36) Solder the 2 open ends of the wires for the white button into ENC1VDD and ENC1A.

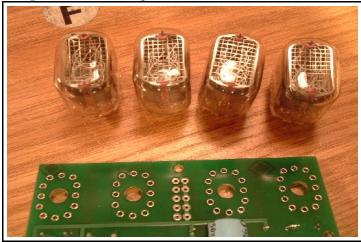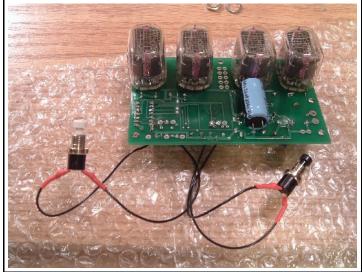37) The goal of the next steps is to solder in the Nixie tubes.

38) Place the 4 Nixie tubes into the mounting holes on the back of the board (the side with the physically larger 33uF Capacitor). ORIENTATION MATTERS. There is an arrow on the glass pointing to pin 1, which should be towards the bottom of the PCB when placed. To check alignment when the Nixie is in place, look for the number "3" and "4" filaments in the Nixies, and make sure they are right-side-up (top of the numbers towards the top of the board).

39) Turn the board over, holding the Nixies in Place, and solder 1 pin on each Nixie. The Nixies should now stay in place as you turn the board over, and check that the Nixies are resting flat against the board. If they are not, hold a hot soldering iron against the pin that was soldered, and press the Nixie flat against the board. When the solder melts, it will allow the Nixie to move; when the iron is removed, the solder will harden and keep the Nixie in position.

40) DOUBLE-CHECK that the Nixies are all oriented with the top of the numbers towards the top of the board.

41) Solder all the pins on the Nixies.

42) The goal of the next steps is to connect the power cord and test the clock.

43) Crimp the wire crimp to the green lead on the power cord. If you do not have a crimping tool, you may solder this on instead.

44) Disassemble the enclosure if it has arrived assembled. There are 4 screws on each side plate to remove, and the back panel will slide off.

45) Place the power cord leads through the large hole in the corner of the sliding back plate from the enclosure. Note that this picture shows a 2-wire plug. The kit now ships with a three-wire grounded plug for added safety.

46) Place the one of the black power cord leads through the hole on the board marked POW+, and the other black power cord lead through the hole marked POW_N. Solder and snip off the excess lead on the back.

47) Again review the board, checking the orientation of parts and looking for missing solder points.

48) Keep the sliding back panel away from the board, and the buttons clear of the board. Place the board on a non-conductive surface, with the Nixies up so you can view them. Plug in the board. The Nixies should light up and read 1:00 (NOTE: the left hand Nixie will not light up, you must press the buttons and set the time to 10:00, 11:00 or 12:00 for the left hand Nixie to light). If the Nixies do not light, double go recheck all part orientations and solder joints. See troubleshooting section at end of this document.

49) Unplug the board and count to 15 to allow time for the capacitors to discharge.

50) Place the buttons through the two holes on the sliding back plate. Place a lock washer on each button, and screw in the nut.

51) On the board, place a screw through each of the mounting holes, one in the top center, and another on far left of the board. Screw the hex standoff in place.

52) Slide the board into the enclosure front, sliding in from the right as you face the back of the clock. Slide the backplate on as you go. The leads from the buttons may need to be bent all the way out to clear the micro-controller as you slide in the back plate. (Alternative: you can bend the front panel wider open top-to-bottom, and snap the back panel straight in. Just be careful not to distort the front panel. This method works very well.) Note again that a 2-wire power cord is shown in the

picture. The 3-wire power cord will have a green lead which is not yet connected.

53) Slide the backplate all the way on. Place a screw through the hole in the top-center of the backplate into the hex standoff but do not tighten completely.

54) Place the green wire from the grounding cord through the hole in the backplate with the other two power cord leads. Place the second mounting screw through the hole on the left of the back plate, through the crimp connector on the green wire, and then into the second hex standoff. The green ground wire is now mechanically connected to the enclosure, wedged between the hex standoff and the back plate, on the inside of the enclosure. Make sure the end plate is flush with the ends of the front plate, and tighten both mounting screws.

55) Position the power cord so that the split leads are inside the enclosure, and the rest remains out of the enclosure. With pliers, press the black plastic strain relief around the power cord. Press it closed as tightly as possible, as this will make insertion into the hole easier. Carefully push the strain relief through the hole until it snaps in place. You will likely need to use pliers to keep the strain relief tight around the

power cord until it is inside the hole. Be careful not to scratch the case with the

pliers.

56) Place the bevels on the enclosure, and then screw on the end-plates.

57) Clean off the clock, plug it in, set the time, and you're done

Troubleshooting

Bygone troubles are good to tell. – Yiddish Proverb

This section will be increased as I hear from those who have built the kit, and the troubles they have had. Here is a list of mistakes I have made building the clock, and problems kit builders have reported.

Symptom: Some numbers (usually 2 and 5) do not light up completely. The top bar of the number 5, for example, does not light up all the way across.

Cause: Not enough current in Nixies. Due to variations in individual nixies, more current may be needed in some tubes for the nixies to light up completely. The kit design limits the current to a very low level, to maximize Nixie life. However, the current can be doubled, and still be well within the Nixies rated current.

To correct the problem, replace one of each pair of 33k Ohm resistors (placed in step 10) with a wire. De-solder one resistor from each pair, and solder in a stripped segment of wire in it's place. It does not matter which of the resistors from each pear is replaced, but it is very important that there be at least one resistor left in each pair.

This will reduce the resistance between the Nixie anode and the voltage source, thus increasing the current and make the whole number light. Note that all the nixies should have their current increased, even if only one requires the change, so that they will all glow at the same brightness. Making this change does not put the Nixies out of spec, and they should still last many years.

Symptom: Multiple digits lighting at the same time in one of the Nixies

Cause: Solder bridge on the leads of the driver chip. Inspect the leads of the driver chip and locate the bridge. Remove using de-solder braid.

Symptom: Random numbers or no numbers appear on clock

Cause: Micro-controller not installed in socket, or installed upside down. Check micro-controller installation. Also, the driver leads should be checked for shorts and opens. If the lead from the driver to the low voltage power line is open, the driver will not operate and the clock will behave irradically.

Symptom: Blue Electrolytic capacitor explodes

Cause: Capacitor installed backwards. Order a new capacitor.

Symptom: Extra 0.1uF capacitor in kit, whats it for?

Cause: Capacitor is for power line signal filtering – see step 30.

Symptom: Fuse blows right away when power is applied

Cause: 33uF Capacitor installed backwards, rectifier D1 is installed backwards, or there is a solder bridge somewhere. The fuse will need to be replaced with a 0.25 Amp equivalent.

Symptom: Clock does not keep time

Cause: Signal diodes installed backwards. Check signal diode orientation. Also check micro-controller is firmly seated, and 1MOhm resistor R50 is soldered properly.

General Checkout:

With the power off:

1) Check all the solder points and re-solder anything that looks suspicious.

2) Check the orientation of the capacitors, diodes, the driver chip, and the micro-controller

3) Check the orientation of the nixies.

DANGER: When working with the clock with power on, there are lethal voltages present. If you are at all uncomfortable with working with high voltages, do not attempt to fix problems with the power on.

If you do feel you can work with live power-line voltages (~165V DC, 120V AC), you can check the following with the power on:

1) There should be approximately 5V DC across the zener diode. This can be as low as 3.5V DC and things are still ok.

2) There should be at least 163V DC across the physically larger 33uF capacitor (C1) leads. This is the supply to the Nixies.

If there is no 163V DC on across C1, then the fuse has likely blown. This will need to be replaced. This can be check by measuring the AC voltage across the fuse. If it is not near zero, then the fuse has blown.

If the voltage across the Zener is low, then something in the control logic is likely shorting out. Check the orientation of the micro-controller and the two signal diodes. Check the orientation of the driver chip. Check the connections on the driver chip.

Contact me if you are having trouble. Reach me at

support @ PeterJJensen . com