6 IN-12 Nixie Tube Clock Kit Assembly Instructions

V2.0

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.

BY BUILDING THIS KIT, YOU ACKNOWLEDGE AND AGREE THAT PETER J. JENSEN, LLC, AND ITS MEMBERS, BEAR NO RESPONSIBILITY (OR AS LITTLE AS IS PERMISSIBLE BY LAW) FOR ANY HARM TO PERSON, PROPERTY, OR ANYTHING ELSE ANYBODY CAN THINK OF, DUE TO YOU WORKING WITH THESE DANGEROUS, POTENTIALLY LETHAL VOLTAGES OR BUILDING THIS KIT.

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 and 6 tube Nixie clock kits offered by Peter J. Jensen, LLC are simple designs, presented in a minimalist aluminum enclosures. 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 power 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 blow, 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 1 watt 51k Ohm resistor (R49) limits the current flow, and the zener keeps the voltage at about 5V DC. A 100uF electrolytic capacitor (C2, blue canister) 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, a 16MHz clock crystal and two 33pF capacitors (C98 and C99) are used with the microcontroller. The clock crystal is accurate to 20ppm. The microcontroller counts clock cycles to keep track of time. A correction factor can be added to adjust for oscillator error.

Two buttons are used to adjust the time and change clock settings. One 0.1uF filter capacitor and 1MOhm pull-down resistor go with each button. The filter capacitor will prevent false double-edge readings by slowing the edge transition time of the button signal.

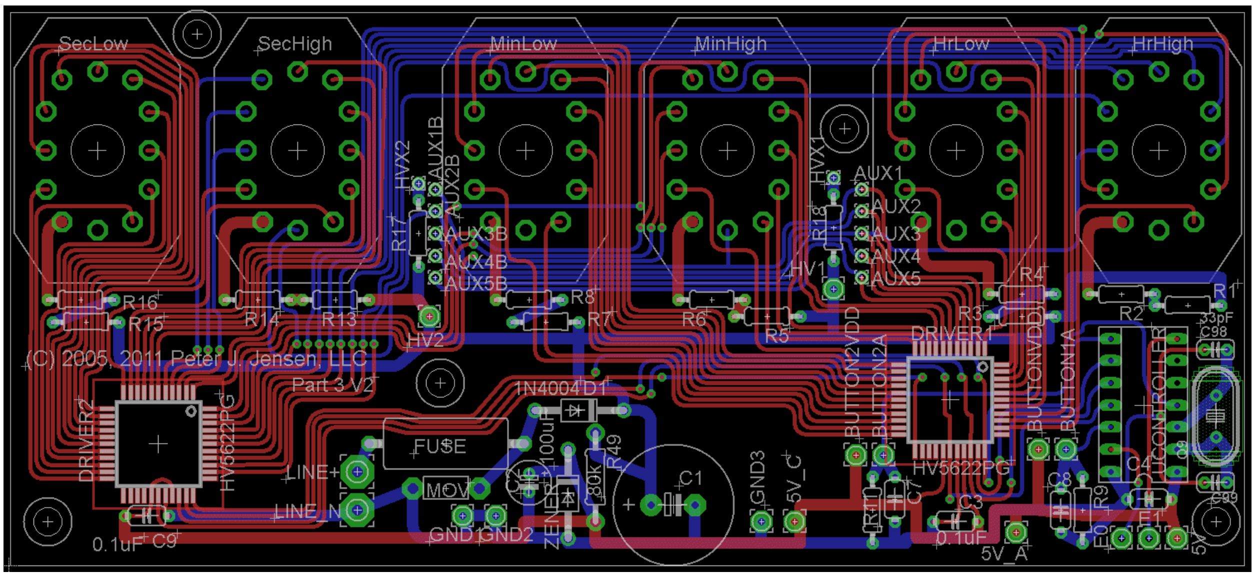
To turn on power to a nixie tube digit, the pin corresponding to the digit is grounded. R1 through R8 limit the current through the nixies to approximately 2.5mA.

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



Parts List

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

Count	Description	Appearance	Purpose
6	4-40 Machine Screws	Screws	For mounting electronics into enclosure
2	Buttons, Black	Buttons	For setting time and other settings
1	Capacitor – 100uF	Smaller blue canister	Filter capacitor for 165V power
1	Capacitor – 33uF	Large blue canister	Filter capacitor for 5V power
5	Capacitors – 0.1uF	Yellow	Filter capacitors
2	Capacitors – 33pF	Yellow, “U” shaped	Crystal oscillator capacitors
1	Clock Crystal, 16MHz	Metal, 2 pins	Time reference
1	Clock Crystal Spacer	Small, flat plastic spacer with notches for the clock crystal pins	Keeps the clock crystal canister from accidentally touching metal pads or traces on the PCB.
1	DIP Socket, 14 pin	Black, 14 pins	Holds microcontroller
1	Enclosure	Aluminum enclosure, with milled holes	Enclosure for nixie clock
1	Fuse, 250mA	Metal and Glass	Circuit protection
	Heat Shrink Tubing	Black tube	For attaching buttons to PCB
3	Hex Standoffs	Aluminum, with female 4/40 screw holes in each end	For mounting electronics into enclosure
2	High Voltage Drivers	Surface Mount Chip, 44 pins	Controls individual cathode elements in the Nixie tubes
1	Microcontroller – PIC16F6xx	Black, 14 pins, fits in DIP socket	Keeps time and controls nixies
1	MOV (Metal Oxide Varistor) 130V	Red Disk	Circuit protection
6	Nixies, IN-12	Glass with metal pins	For displaying time
1	PCB	Green board	For mounting electronic parts
1	Power Cord	Black cord with power plug on one end, stripped wire on the other	Power
1	Rectifier	Black with white stripe	Power Supply for nixies
1	Resistor – 51kΩ, 1Watt	Stripes: Green-Brown-Orange	Dropping resistor for 5V power
12	Resistors– 33kΩ, ¼ Watt	Stripes: Orange-Orange-Orange	Current limiting resistors to nixies
2	Resistors– 1MΩ, ¼ Watt	Stripes: Brown-Black-Green	Pull-down resistors for buttons
4	Rubber Feet	Clear rubber, self-adhesive bottoms	Feet for enclosure

8	Self tapping metal screws for enclosure	Screws	For mounting end-caps of enclosure
	Solder	Metallic wire	For soldering components
1	Strain Relief	Black plastic	For mounting power cord through back enclosure plate
	Wire	Black coated wire	For attaching buttons to PCB
1	Wire Crimp	Ring shaped	For grounding chassis
1	Zener Diode, 5.1V	Orange with black stripe	5V Power regulation for logic

Parts Placement

Sped up my XT; ran it on 220v! Works greO?_|. -
Anonymous

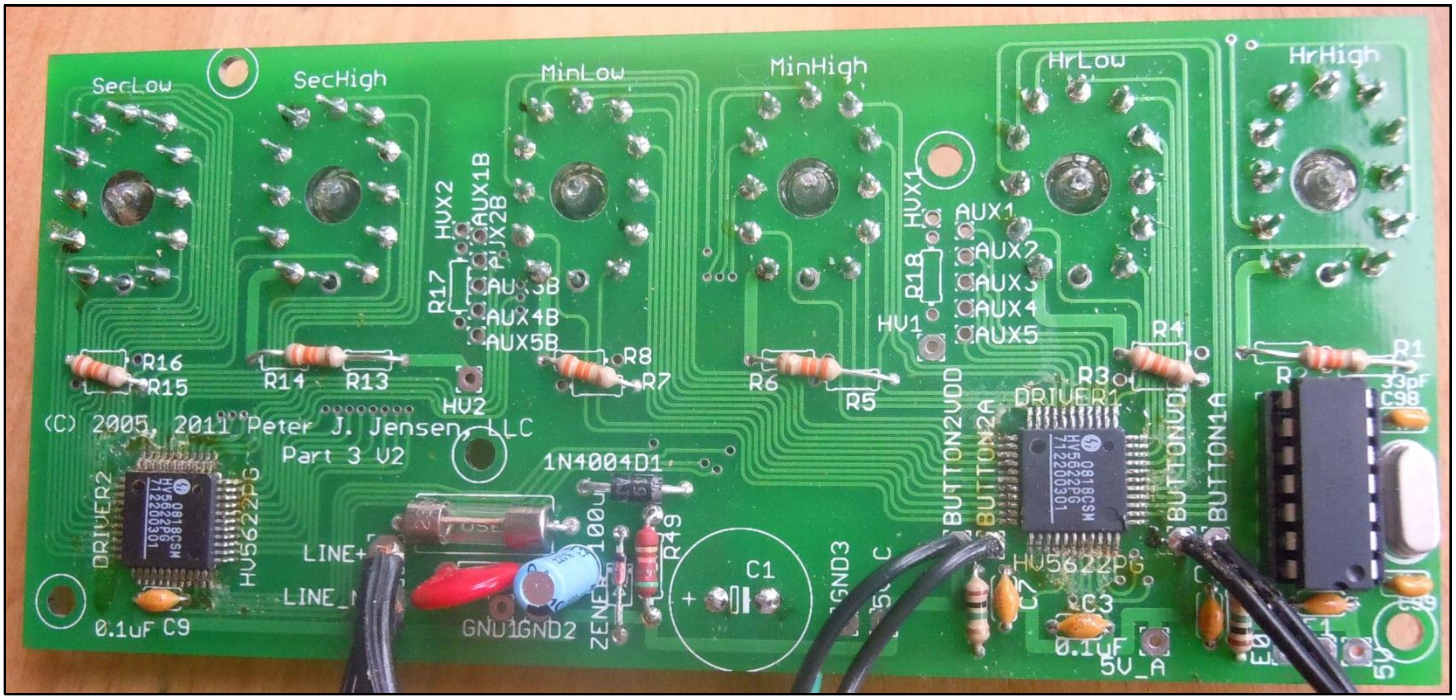
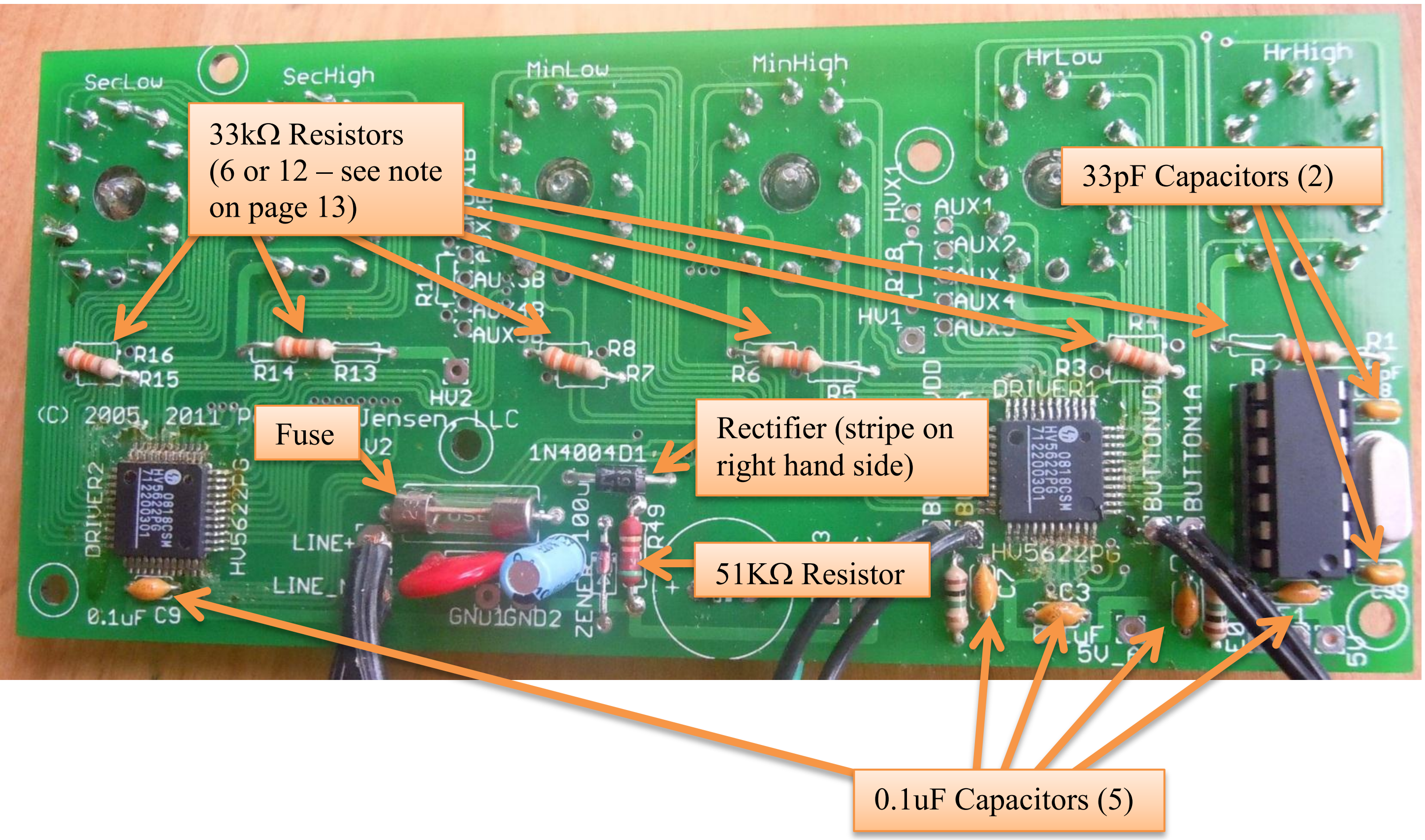
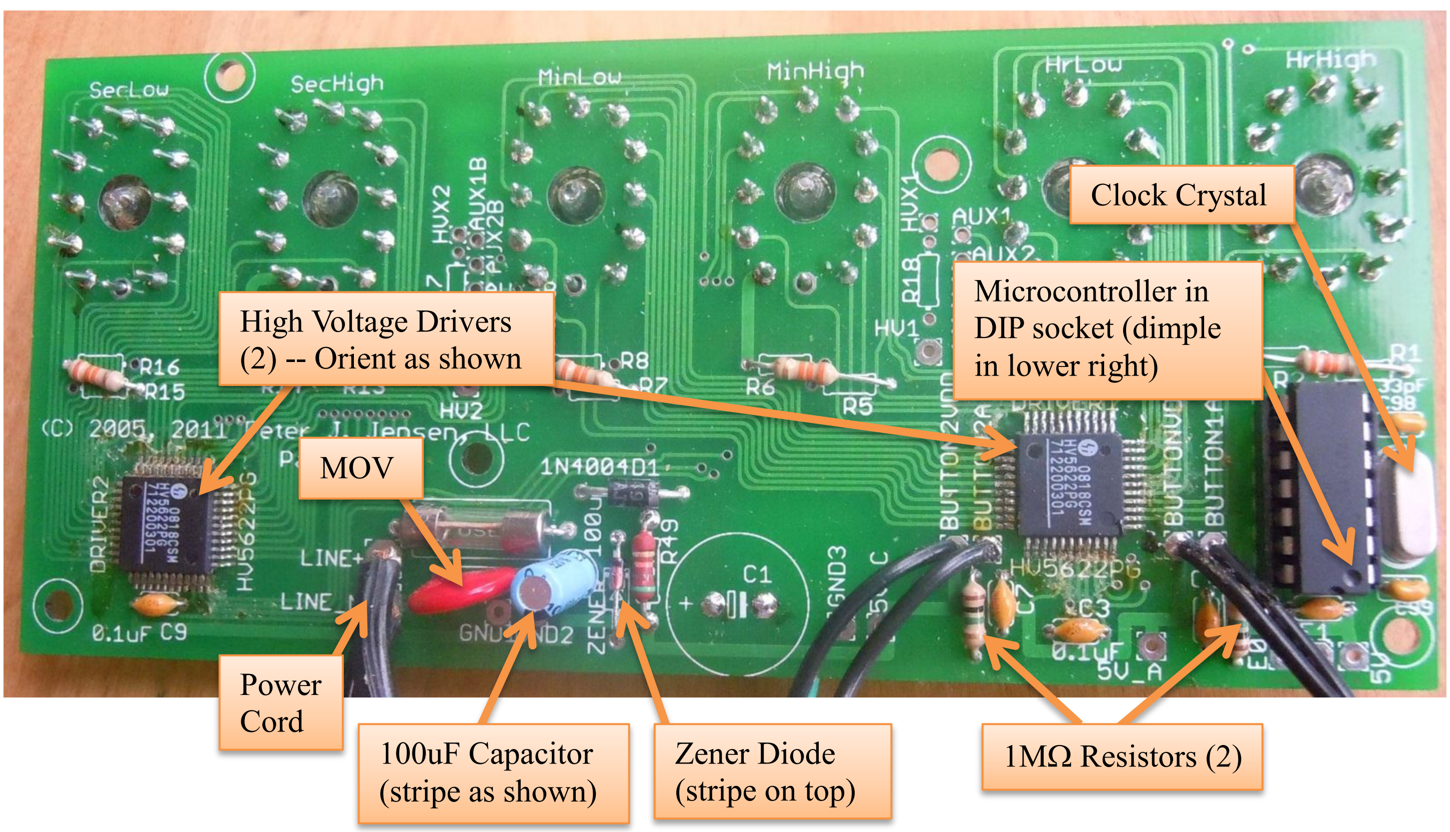


Figure 1 Assembled PCB Part Placement

Figure 1 shows the parts placed on the board. Following are pictures with the part descriptions, and then notes describing how best to go about soldering the parts.


33kΩ Resistors (6 or 12 – see note on page 13)
33pF Capacitors (2)
Fuse
Rectifier (stripe on right hand side)
51KΩ Resistor
0.1uF Capacitors (5)


Clock Crystal
Microcontroller in DIP socket (dimple in lower right)
High Voltage Drivers (2) -- Orient as shown
MOV
Power Cord
100uF Capacitor (stripe as shown)
Zener Diode (stripe on top)
1MΩ Resistors (2)

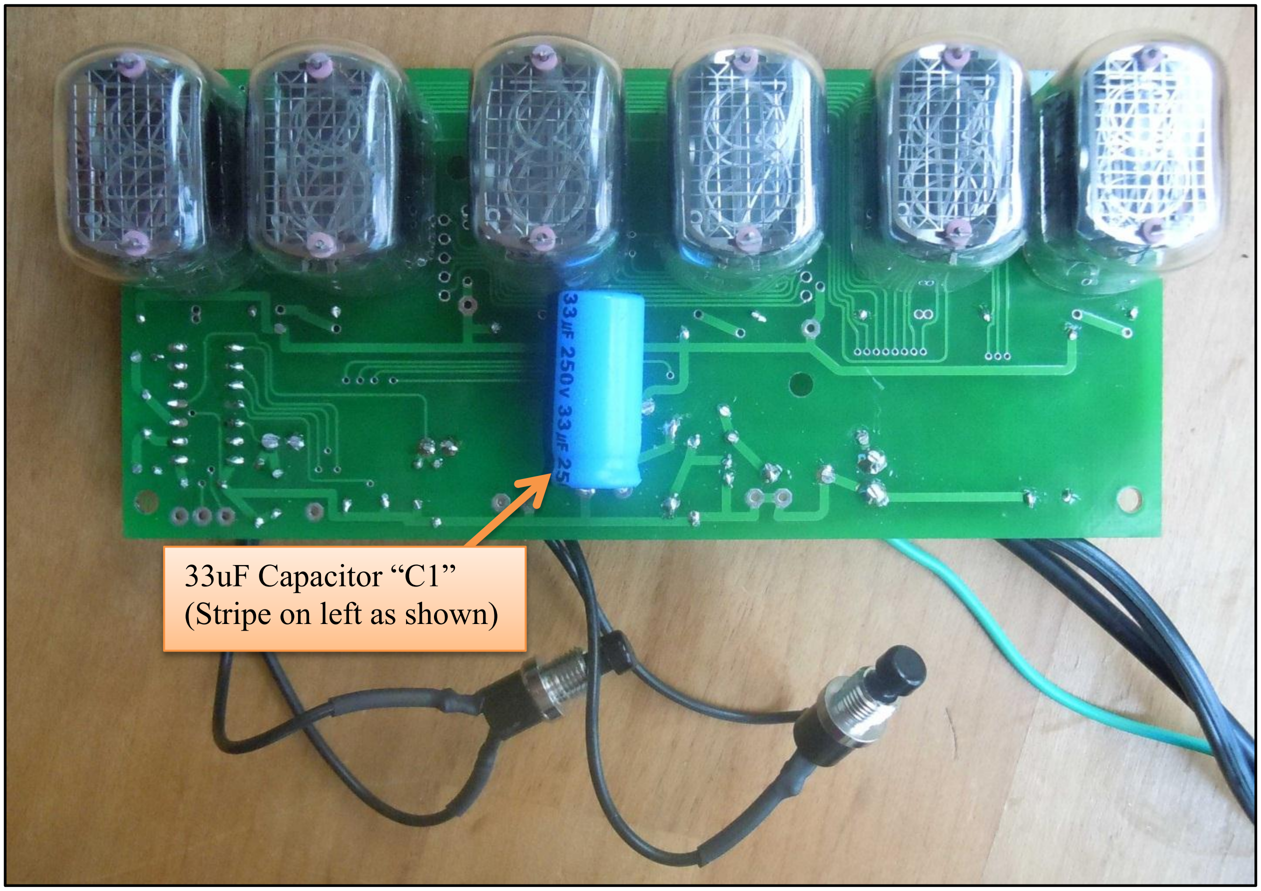
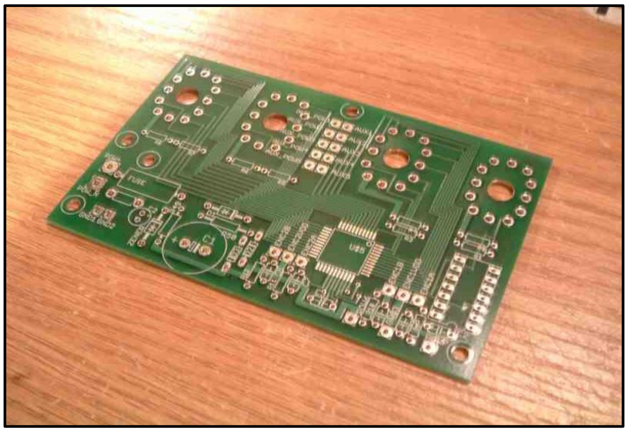


Figure 2 "Back" of PCB (which is the "front" of the clock)

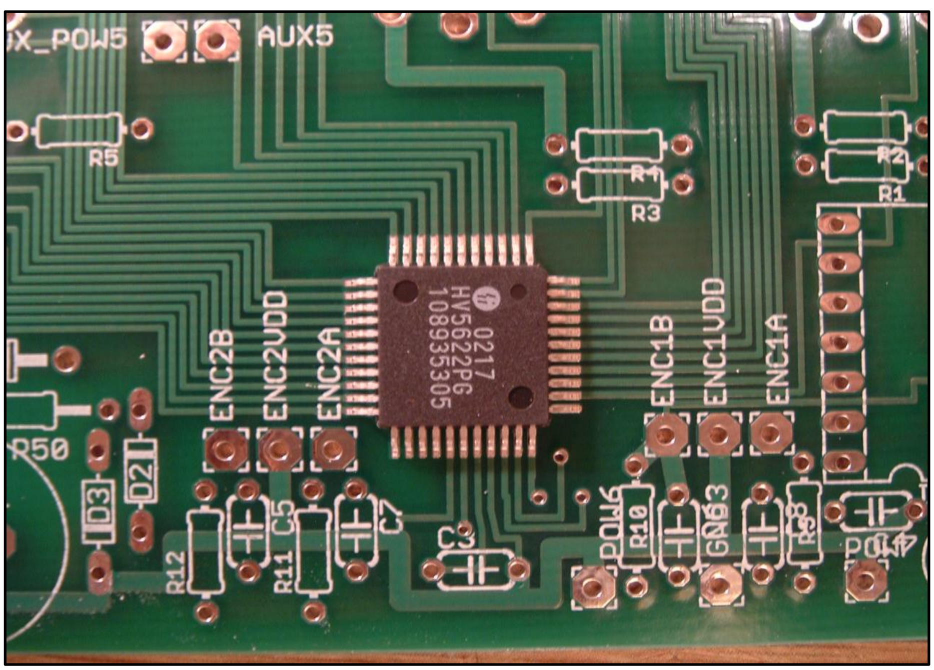
Assembly Notes

Some of the pictures in this section are from different clock models. The concept being described is the same, even if the PCB looks slightly different.

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

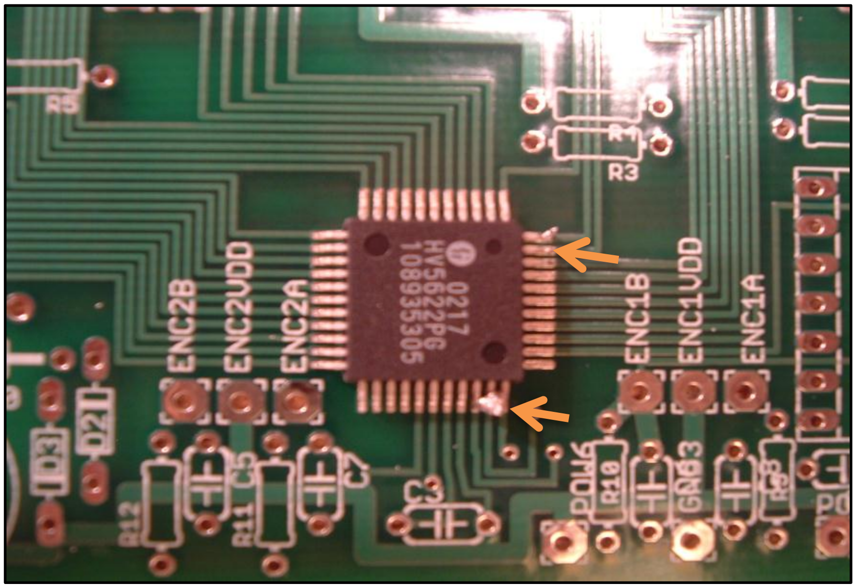


2) Locate one of the surface-mount high voltage driver chips. Place it on the PCB on the position marked DRIVER1. **Notice the orientation and pin alignment**. The top of the chip goes to the right (the pin-1 dot is in the upper right). Each pin should rest on exactly one pad. See picture.



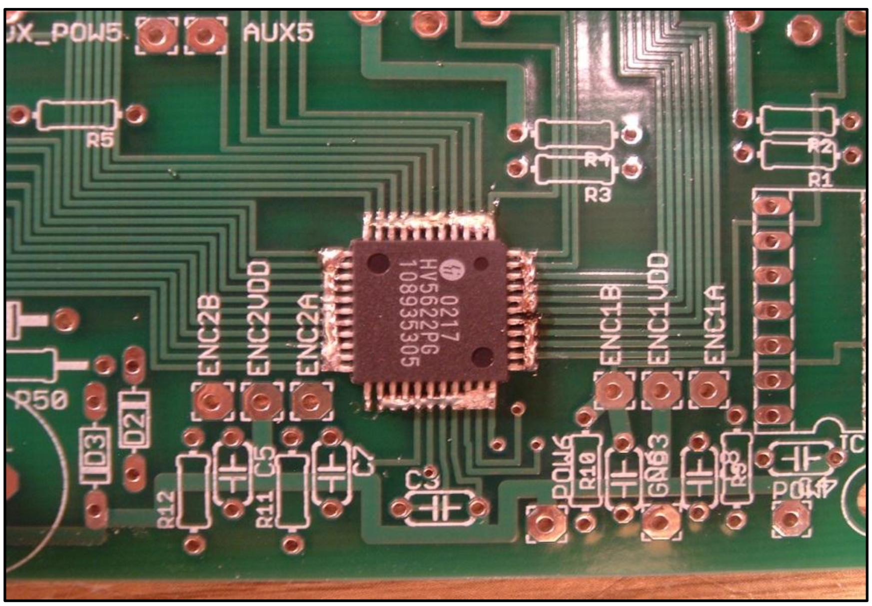
3) The goal of this step is to tack-solder a driver chip in place, so the pins can be soldered without the chip sliding around. Place a small drop of solder on the tip of the iron, and gently immerse the upper right pin of the driver chip in the solder without actually touching the pin with the iron.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

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

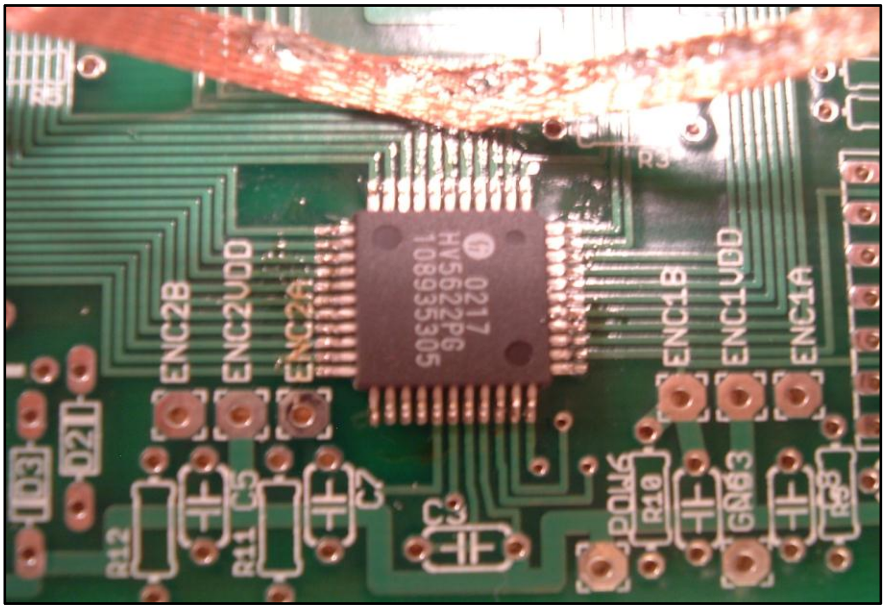


5) Double-check that the driver pins are placed exactly over the pads. Now is the time to correct a misalignment by melting the tack solder, and twisting the part gently while the solder is liquid.

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.



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.

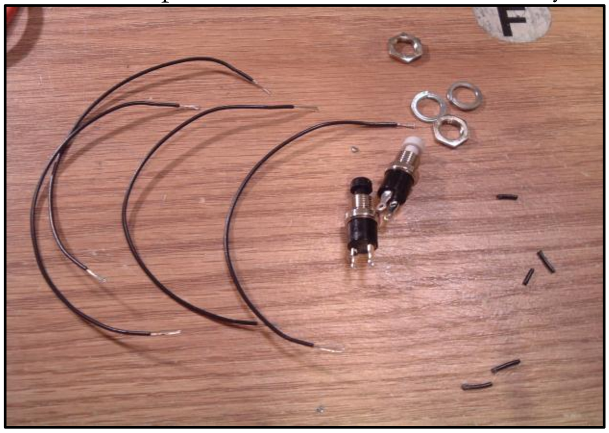
9) Repeat steps 2-8 with the second high voltage driver chip, placing it on the position marked DRIVER2. Both drivers are aligned the same way, with the pin-1 dot in the upper right.

10) Next, solder the clock crystal by first sliding the plastic spacer over the crystal pins. The spacer is sandwiched between the crystal and the PCB. If the spacer is missing or becomes lost, use a small piece of electrical tape between the clock crystal and the PCB instead. The purpose of the spacer is to keep the metal clock crystal canister from accidentally touching a pad or trace on the PCB.

11) Solder the rest of the components on THE FRONT SIDE of the PCB (the side with writing on it) as shown at the beginning of this chapter. **Proceed to the next steps before soldering the power cord, buttons, nixies and capacitor C1. Also, see the following note about the 33k Ohm resistors:**

ADDITIONAL: Some kit builders have reported that the nixies are not lighting all the way. This is due to insufficient current in the Nixies. The two 33kOhm resistors for each Nixie results in very little current to each nixie, which was done to extend the tube life. To reduce the chance of flickering or incompletely firing nixies, a single 33kOhm resistor can be used instead of a pair. Even with only one resistor per nixie, the current draw is well within specifications. The pictures at the beginning of this chapter show only 1 resistor per nixie being used, and this is now the recommended configuration.

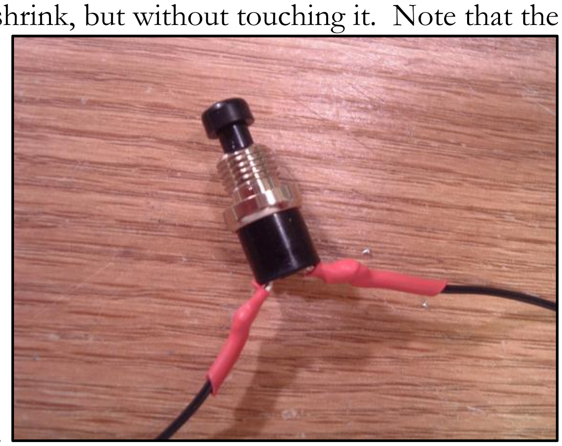
12) The goal of the next steps is to attach the buttons. The kit now includes two black buttons instead of the black and white button pictured. Both buttons are exactly the same regardless of color.



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

14) 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. **IMPORTANT: only bend the leads on the buttons out ONCE. Do not try to bend them back or adjust them, or they will break.**

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. Note that the heat shrink may be a different color than pictured (shown in red here).



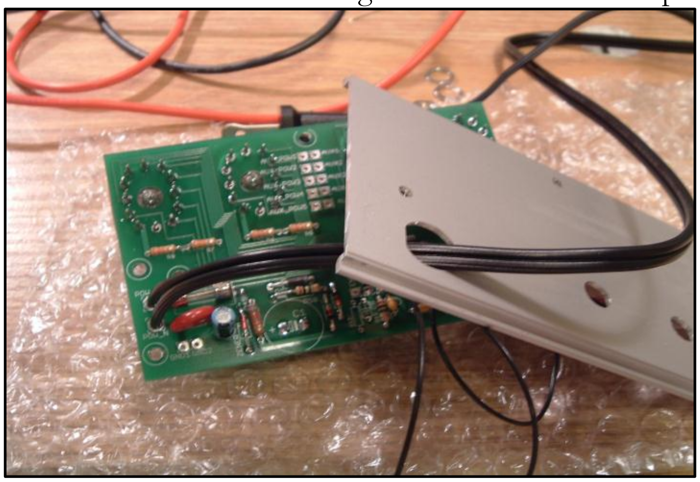
15) The buttons are now ready to solder as shown in the pictures at the beginning of this chapter.

16) The 33uF capacitor C1 can be soldered on the front or back of the PCB (shown in this manual soldered on the back). However, in either case, the leads will need to be bent 90 degrees so the capacitor lies flat as shown. This capacitor is too tall to fit in the enclosure if soldered vertically.

17) Solder in the nixies. Look inside the glass and find the number "3" or "7" cathode wires, and make sure they are top side up. The nixie pins are symetric, so it's possible to solder them top-side-down, so make sure not to do that.

18) Solder only ONE pin on each nixie, and then test-fit the clock in the enclosure. Make sure all the nixies fit though the holes. If necessary, heat up the soldered pin on a nixie to adjust its position. Once everything fits, solder the rest of the pins.

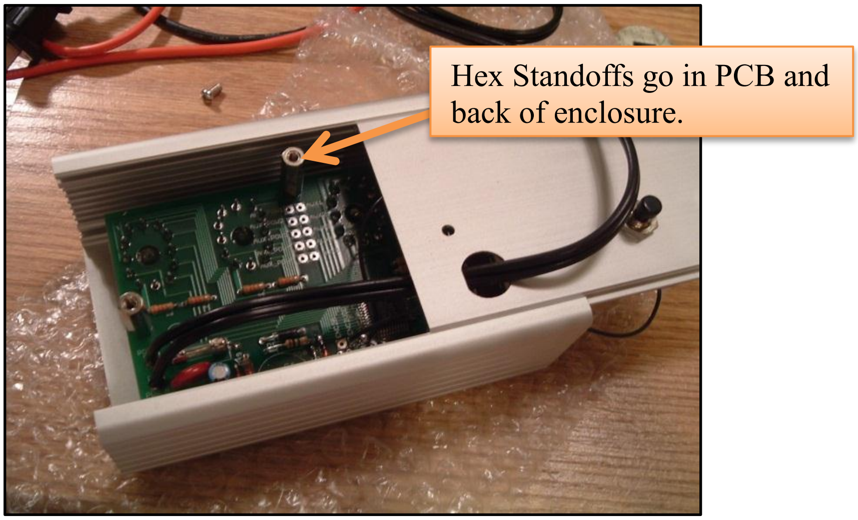
19) The power cord must be passed through the enclosure back-plate before soldering, as shown. The GREEN cord is not connected to the PCB. The other two conductors are soldered as shown in the earlier pictures. It does not matter which conductor goes to wich of the two power cord connection pads (LINE+ or LINE_N).



20) When all the parts are soldered on the PCB, it's time to assemble the enclosure.

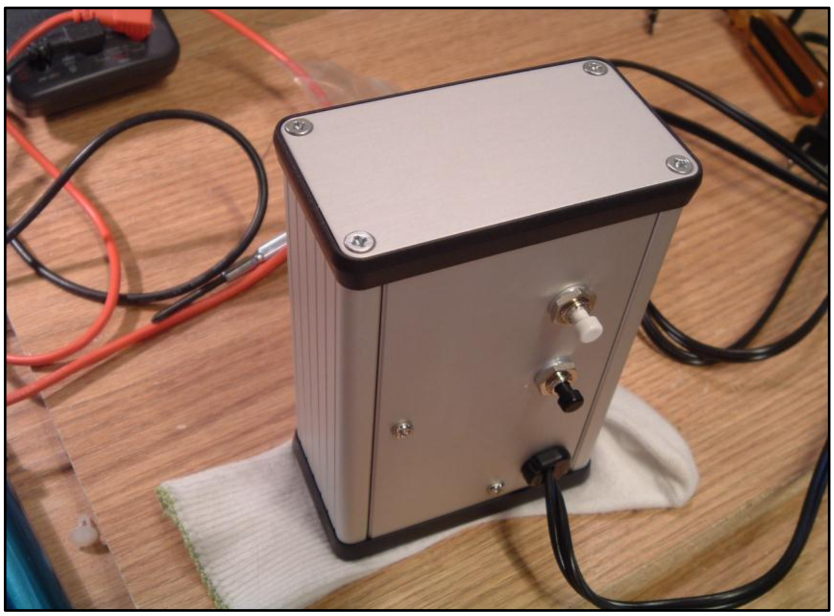
21) Place the buttons through the two button holes as shown.

22) Screw the hex standoffs into the holes on the PCB that line up with the small holes on the back plate of the enclosure. The PCB with nixies can now be put into the enclosure front, the back plate snapped in place, and screwed to the other side of the hex standoffs.



23) 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. If you have trouble getting this step completed, you may wish to use a small file and enlarge the hole slightly.

24) Finally, the end plates of the enclosure can be screwed in place.



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 with a wire. De-solder one resistor from each pair, and solder in a stripped segment of wire in its 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 light 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 erratically.

Symptom: Blue electrolytic capacitor explodes.

> **Cause**: Capacitor installed backwards. Order a new capacitor.

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.

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. ALWAYS COUNT TO 15 AFTER TURNING OFF THE POWER BEFORE TOUCHING THE CIRCUIT. This allows time for the capacitors to discharge. Even with this precaution, be wary of the capacitors, and check the voltage on the blue electrolytic capacitors with a voltmeter before touching the circuit.

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 checked 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@tubeclock.com

Instructions For 6-Tube IN-12 and IN-14 Clocks

Thank you for purchasing this hand-made Nixie clock. The clock has several features which allow you to customize its operation.

To Set the Time:

Press and hold one button at a time. Pressing the left button changes the hours, and pressing the right button adjusts the minutes. Changing the minutes sets the seconds back to 0.

Changing Settings:

There are 4 groups of settings.
Pressing then releasing both buttons at the same time will move to the next setting group. When viewing a setting, pressing one button at a time will either increase or decrease the value of the setting.
After a few seconds of not pressing any buttons, the clock will toggle back to the time display automatically.

Setting Group 1: *24 vs. 12 Hour mode*. Press either button (but not both) to highlight the number 12 or 24. If 24 is highlighted, the clock will show 24 hour time. If the 12 is highlighted, it will show 12 hour time.

Setting Group 2: *Brightness*. The clock will display a number on the middle two nixies, between 00 and 10, which is the default brightness level. 10 is the brightest, and 00 is the darkest (nixies off). Press the right button to decrease the brightness setting, and the left button to increase it.

Setting Group 3: *Auto-Dim*. The nixie clock can be set to automatically lower the brightness between two specified hours in the day (such as between 09 and 17 hundred hours, or when you are not at home). There are three, two digit numbers shown at once. The left two nixies show the start hour (0 to 23) of the auto-dim. The middle two nixies show the end time of the auto dim. And the right two nixies show the brightness level (00 to 10). Each time both buttons are pressed and released, the setting being changed will move from start hour, to end hour then to brightness level. You can tell which value is being edited because it will be highlighted. If the start and end hours are the same, the auto-dim is disabled.

Setting Group 4: *Time adjustment*. The internal oscillator may up to 0.005% fast or slow, causing the clock to be slightly fast or slow. To compensate, a small adjustment can be added to the internal time counter. To calculate the correction factor, set the time to a reliable source (i.e., www.time.gov). Wait at least a couple of days, and record how many seconds the clock is fast or slow. The correction factor can be found on the attached table, or calculated as follows:

$$CF = 3100 - (65536000 * (\text{Number of seconds fast}) / (\text{Duration of test}))$$

The (Duration of test) is the time, in seconds, that the clock was allowed to run. If the clock was slow, then (Number of seconds fast) will be a negative number. The number to enter in the middle two nixies is CF/64, rounded down. The number to enter in the right two nixies is the remainder of CF/64.
The factory default value for the time adjustment is 48 28.

Enjoy your clock! If you encounter any trouble, please e-mail me, Peter Jensen, at jensen@tubeclock.com.

Table of Time Adjustment settings for IN12 and IN-14 clocks.

Set the time adjustment factor to (48 28) and then accurately measure how fast the clock is over the course of 24 hours, 72 hours, or 240 hours. The longer the test, the more accurate the adjustment setting can be.

After the test, change the time adjustment factor to the settings in the tables below.

NOTE: All time accuracy tests must be done with the time adjustment setting set to (48 28) during the test.

24 Hour Test

Number of seconds in test	86400		
Seconds FAST (use the negative number if it's slow)	**CF**	**First 2 Digits**	**Second 2 Digits**
-4	6134	95	54
-3	5376	84	0
-2	4617	72	9
-1	3859	60	19
0	3100	48	28
1	2341	36	37
2	1583	24	47
3	824	12	56
4	66	1	2

72 Hour Test (3 days)

Number of seconds in test	259200		
Seconds FAST (use the negative number if it's slow)	**CF**	**First 2 Digits**	**Second 2 Digits**
-12	6134	95	54
-11	5881	91	57
-10	5628	87	60
-9	5376	84	0
-8	5123	80	3
-7	4870	76	6
-6	4617	72	9
-5	4364	68	12
-4	4111	64	15
-3	3859	60	19
-2	3606	56	22
-1	3353	52	25
0	3100	48	28
1	2847	44	31
2	2594	40	34
3	2341	36	37
4	2089	32	41
5	1836	28	44
6	1583	24	47
7	1330	20	50
8	1077	16	53
9	824	12	56
10	572	8	60
11	319	4	63
12	66	1	2

240 Hour Test (10 days)

Number of seconds in test	864000		
Seconds FAST (use the negative number if it's slow)	**CF**	**First 2 Digits**	**Second 2 Digits**
-40	6134	95	54
-39	6058	94	42
-38	5982	93	30
-37	5907	92	19
-36	5831	91	7
-35	5755	89	59
-34	5679	88	47
-33	5603	87	35
-32	5527	86	23
-31	5451	85	11
-30	5376	84	0
-29	5300	82	52
-28	5224	81	40
-27	5148	80	28
-26	5072	79	16
-25	4996	78	4
-24	4920	76	56

-23	4845	75	45
-22	4769	74	33
-21	4693	73	21
-20	4617	72	9
-19	4541	70	61
-18	4465	69	49
-17	4389	68	37
-16	4314	67	26
-15	4238	66	14
-14	4162	65	2
-13	4086	63	54
-12	4010	62	42
-11	3934	61	30
-10	3859	60	19
-9	3783	59	7
-8	3707	57	59
-7	3631	56	47
-6	3555	55	35
-5	3479	54	23
-4	3403	53	11
-3	3328	52	0
-2	3252	50	52
-1	3176	49	40
0	3100	48	28
1	3024	47	16
2	2948	46	4
3	2872	44	56
4	2797	43	45
5	2721	42	33
6	2645	41	21
7	2569	40	9
8	2493	38	61
9	2417	37	49
10	2341	36	37
11	2266	35	26
12	2190	34	14
13	2114	33	2
14	2038	31	54
15	1962	30	42
16	1886	29	30
17	1811	28	19
18	1735	27	7
19	1659	25	59
20	1583	24	47
21	1507	23	35
22	1431	22	23
23	1355	21	11
24	1280	20	0
25	1204	18	52
26	1128	17	40
27	1052	16	28
28	976	15	16
29	900	14	4
30	824	12	56
31	749	11	45
32	673	10	33
33	597	9	21
34	521	8	9
35	445	6	61
36	369	5	49
37	293	4	37
38	218	3	26
39	142	2	14
40	66	1	2