NCV3.1-16 NIXIE CLOCK

Assembling manual & user's guide

UG-02-16-REV-E
FW-REV-02

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1. Introduction

TubeHobby congratulates you on your choice and wishes enjoyable assembling process and to be a proud owner of long lasting, eye catching device. Thank you for your trust.

Nixie tubes are very much out of date in terms of technology and will never be used in mass production. Interesting fact is that nixie tubes never have been used as clock's readouts in their era. Warm glowing and exceptionally unusual appearance of nixies still catches everyone's eye, thus clocks with these tubes become very popular in these days. NCV3.1 kit mixes several decade old nixie tubes with the latest generation highly-integrated semiconductors and uses complex firmware to create charmingly unusual timepiece.

Nixie clock can generate voltage exceeding 200 Volts. Do not touch any soldering points when board is powered.

1.1 General terms

Nixie clock is an electrical device and cautious handling must be assured. In spite of the relatively low voltage board power supply, a high voltage is present onboard. It can generate voltages exceeding 200V and can cause electrical shock if handled inappropriately. Keep in mind that nixie tubes may be disabled during night time but the clock can wake up at any time. Therefore do not touch any component or soldering point when power is on. Safe assembling, connecting and operation of this clock are the user's responsibility. Do not install clock in a moisturized environment or outdoors. Keep the clock away from children. No responsibility is accepted for any kind of damage, injury or loss. Nixie clock hardware and firmware design is provided as is with no obligations and no warranty.

All components provided with the kit are new or never used before (new old stock) and by their manufacturer considered as free of defects. Components damaged during improper assembly will not be replaced free of charge.

In case of release a new firmware version, your clock may be upgraded sending it back to the TubeHobby (clock owner covers all shipping expenses forth and back), or purchasing a new preprogrammed microcontroller chip (please consider to use DIL socket for such event). Due to commercial reasons firmware code will not be disclosed.

The NCV3.1 nixie clock circuits and firmware or any part of it may not be copied and used for commercial reasons without written permission. However you are not restricted to modify your clock and/or resell it.

1.2 Acknowledgement

Here is a place to thank all of these clever people who shared their ideas and inputted comments while creating and supporting this clock kit. If you think something should be added to this guide or some functionality to the clock, do not hesitate to drop us a line. Thank you!

2 Assembling

2.1 General tips

To assemble this kit, some soldering skills and ability to separate electronic components are required. If this is the first kit you have ever attempted to assemble, you should pay close attention to the following suggestions and building tips to accomplish successful assembly.

To start assembly you will need the following tools and materials, which are necessary:

- One pair of small wire cutters;
- One pair of small “needle nose” pliers or tweezers;
- Low wattage “pencil type” soldering iron with a fine pointed tip. (About 25 to 40 watts would be fine);
- Tin/Lead alloy “rosin core” or “organic core” solder wire. Organic core flux must be removed from the assembly and this can be done with hot running water. RoHS type (Pb-free) solder requires higher soldering temperatures and good soldering skills are necessary, therefore for novices is not recommended;
- A clean, well lighted and ventilated work area;

Recommended tools but not absolutely necessary:

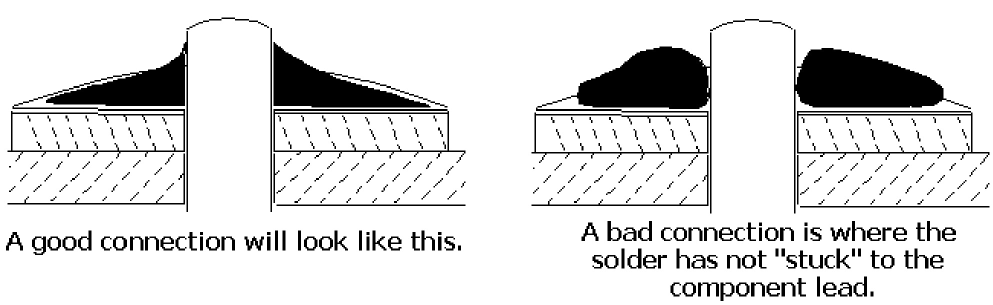
- Multimeter (ohmmeter and voltmeter). Will help you to sort out resistors without color table and measure voltages at some important circuitry points;
- Oscilloscope (very helpful tool for troubleshooting);
- Safety glasses. Especially needed when trimming wires. Also boiling flux and gasses can surprise you by propelling small hot solder droplets into your eyes!
- Small damp sponge for cleaning the hot solder iron tip;
- Vacuum operated solder extraction tool. (Known as a “solder sucker”, this spring loaded vacuum piston hand tool will extract molten solder from your assembly to aid in removing improperly installed or broken components);
- Solder Wick. (Braided wire “wick” is an alternative for the removal of molten solder. Both of these solder removing tools work well with some practice);
- Grounded “static mat” and wrist strap. (Provides a static free work surface to protect components that are sensitive to damage by static electricity. Generally all semiconductor devices are sensitive to static discharge). If protection device from static electricity is not used, be aware of discharge which may flicker from clothes or carpet made from artificial fibre while assembling;
- Component mounting frame. See picture below (A convenient, good quality mounting frame can be ordered from “*Conrad electronics*” http://www.conrad.com item # 811394);

holding frame for PCB

Be aware before you begin soldering, that some of the components in this kit are “polarized”. Meaning, they must be installed with one or more of their leads oriented in a particular direction. The detailed assembling guide will warn you of these.

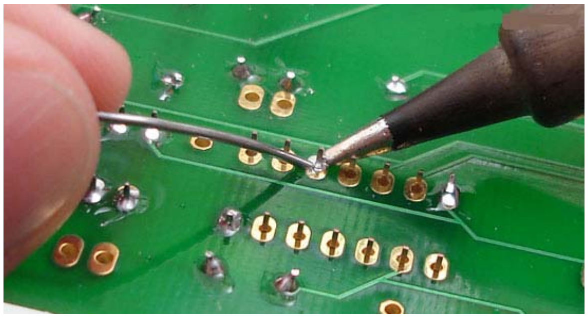
Don’t get in a big hurry. Paying close attention and building it right in the first time will prevent the frustration of having to troubleshoot to find and repair assembly errors later.

Use good soldering techniques. Don’t overheat the pads and landings on the circuit board as this could cause them to “lift” off of the board. Solder joint connections are best completed within 2 to 4 seconds after the iron heat is applied. If your solder iron has an adjustable temperature range, use the lowest effective temperature setting (too low temperature may result a bad contact soldering, usually it appears as a solder lack on the opposite side of the PCB; While too high temperature and/or too long soldering iron applying will cause overheating and lead to the PCB and/or component damage). Recommended temperature is about 400°C. Once a solder joint is made, avoid re-heating the connection unless it is absolutely necessary. A good quality solder joint will appear smooth and shiny. Not grainy and dull (too low soldering temperature) or chunky. When both the lead and the circuit board foil are heated at the same time, the solder will flow onto the lead and foil evenly. Solder should feather smoothly between the pad and the lead of the component, indicating good “wetting”. See picture below. Excessive solder will ball up around the component and may shorten it to the next trace onboard.



Example of good and bad soldered connection

When soldering, first touch the iron tip to the pad and component lead. Then apply the solder to the pad and the lead, not directly to the iron tip. After applying the solder, keep it heated for a second and then gently pull the solder iron away. Clean the hot iron tip on a moist sponge as frequently as needed. Keep only enough solder on the tip of your iron to keep it "tinned" and shiny.



Soldering

"Rosin core" flux does not need to be removed from your circuit board. However if you have an ultrasonic cleaner with suitable tank, board may be cleaned from rosin using alcohol and rinsed with hot water afterwards. After cleaning, board will look shiny.

If you use an "organic core" solder wire, the flux must be removed under running hot water within a couple of hours.

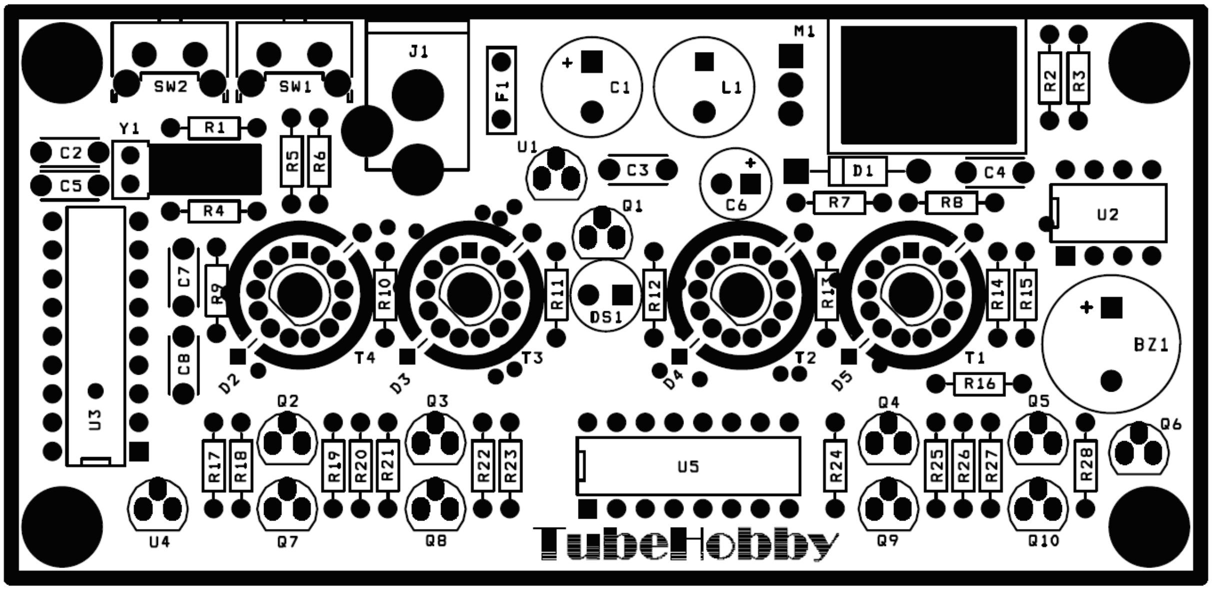
After the board is rinsed with hot water, make sure it is thoroughly dry, even underneath the components, before applying electrical power to the completed assembly. (A pressurized air flow or even a simple hair dryer can speed up this process). If you do not finish building the circuit board in a few hours and need to complete it another day, then wash the organic flux off of the board anyway, and finish the board at another time. The only advantage of organic flux is a cleaner appearing circuit board when you're done.

Do not use acid based flux under any circumstances while soldering. Acid will damage your clock board permanently.

Pay attention while clipping leads after soldering. Leave at least 1mm of wire, otherwise is risk to damage PCB or shorten traces while clipping too close. Use small enough and sharp wire cutters. Wear eye protection when soldering and when clipping leads.

2.2 Logic board assembly

All components used in this kit are through-hole type to ensure easy assembly without special tools and skills. All of them should be installed on the silk screened ink side of the circuit board, for except of the tubes which need to be installed on the opposite side of the board. Below is shown board where components are numbered from left to the right and from top to the bottom. The view is from silk screen ink side (component side).



Printed Circuit Board. Silk screen side

Place a check mark in the box next to each assembly instruction step. If you don't finish in one sitting, you'll find it easier to pick up right where you left off when you return to it later. Experienced users may find convenient to skip detailed steps below and assemble kit using part's list only.

Use ohmmeter (multimeter) to sort-out resistors, instead of examine coloured rings.

☐ Before beginning assembly, examine parts list included with this kit. Use it to count, identify and organize all of the components into separate piles. (Gather all components of the same value together). Nixie clock kit contains 80 parts in total.

2.2.1 Part's list

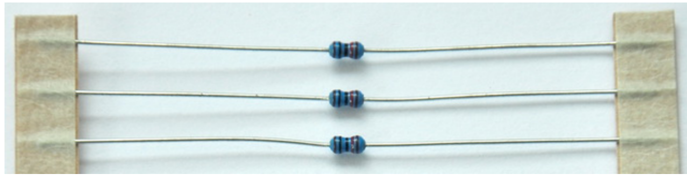
Item	Quantity	Reference	Part	Description
1	1	C1	470 uF * 16 V	Electrolytic Capacitor
2	2	C2, C5	15 pF * 50 V	Multilayer Ceramic Capacitor
3	3	C3,C4,C7	330 nF * 50 V	Multilayer Ceramic Capacitor
4	1	C6	1 uF * 250 V	Electrolytic Capacitor
5	1	C8	10 nF * 50 V	Multilayer Ceramic Capacitor
6	3	R1,R4,R17	1 Kilo Ohm	Metal film Resistor
7	2	R2,R3	220 Ohm	Metal film Resistor
8	12	R5,R6,R9,R10,R11,R13,R15, R16,R18,R21,R24,R27	10 Kilo Ohm	Metal film Resistor
9	1	R7	910 Kilo Ohm	Metal film Resistor
10	1	R8	15 Kilo Ohm	Metal film Resistor
11	5	R12,R14,R20,R23,R26	100 Kilo Ohm	Metal film Resistor
12	4	R19,R22,R25,R28	470 Kilo Ohm	Metal film Resistor
13	1	D1	UF4007	Fast Diode
14	4	D2,D3,D4,D5	3014UBC	Blue LED
15	6	Q1,Q6,Q7,Q8,Q9,Q10	MPSA42	NPN Transistor
16	4	Q2,Q3,Q4,Q5	MPSA92	PNP Transistor
17	1	M1	IRF640	N-channel MOSFET
18	1	U1	78L05	5V Stabilizer
19	1	U2	TC4427	MOSFET Driver
20	1	U3	PIC16F88-I/P	Microcontroller; Latest firmware Preloaded
21	1	U4	DS18B20	Digital Temperature Sensor
22	1	U5	K155ID1	High Voltage Driver
23	1	Y1	Q-0.032768-MTF32-12,5-10-T1-LF	32.768 KHz Quartz Oscillator 10 ppm
24	1	L1	RLB0914-221KL	220 uH Inductor
25	1	F1	T 60-050	0.6 A Fuse with Auto Recovery
26	1	BZ1	12G-2P	Buzzer
27	4	T1,T2,T3,T4	IN-16	Nixie tube
28	1	DS1	IN-3	Neon Bulb
29	1	J1	CP24-020A	Power Connector 2.1mm/5.5mm
30	2	SW1,SW2	KFC-A06-H9	Button
31	4	SP1,SP2,SP3,SP4	TFF-M3/20	20mm Standoff; M3 Thread
32	5	SC1,SC2,SC3,SC4,SC5	M3x6	M3 Screw; 6mm Length; Philips Type
33	1	NT1	M3	M3 Nut
34	1	PCB	NCV3.1-16	Printed Circuit Board; FR4 Type; 2-layer

* Some parts may be changed to similar or better performing without prior notification. Figure out by quantities or ask when doubt.

* Nixie tubes plastic separator color may vary depending on the current batch

* PCB soldermask color may vary depending on the current batch.

2.2.2 Resistors

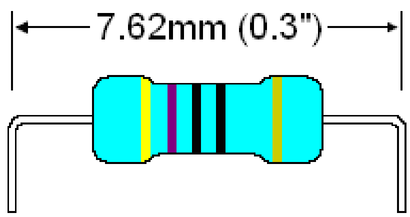


Resistors

Start by installing resistors, since they have the lowest shape. Resistors used in this kit are metal film type, 1/6W and are accurate within 1%. Since all of the values are now already separated, it is logical to install them in ascending order of their value. Not R1, R2, R3…and so on, but rather, the 220 ohm, the 1 kiloohm, all the 10 kiloohm, and so on. This should also reduce the amount of steps required. Resistors have coloured bands around their bodies to indicate their values.

Resistors are not polarized passive components. They may be inserted in either direction. For a more professional look, consider mounting resistors so that the color code bands read from top to bottom or from left to right.

☐ First, bend all 28 resistors, (still keeping them in their separate piles) so that their leads make 90° bends, 7.62mm apart (in order to convert metric values to imperial, divide these by 25.4). See figure below.



Resistor with bended leads

☐ Take two **220Ω** (ohm) resistors (color code: red, red, black, black, brown) and insert it into the circuit board at the location marked **R2** and **R3**. Bend the leads slightly on the bottom (solder side) of the board, to aid holding the component in place while you solder it to the board. Solder the components to the board and clip off the excess lead length.

☐ Insert three **1K** (1,000Ω) resistors (color code: brown, black, black, brown, brown) into clock board at the locations marked **R1, R4,** and **R17**. Solder these into place and clip off the excess lead length.

☐ The next value is **10K**. You should have twelve of these resistors (color code: brown, black, black, red, brown). Install the first five of these into clock board at the locations marked **R5, R6, R9, R10** and **R11**. Solder these into place and clip off the excess lead length.

☐ Install the next five **10K** resistors into clock board at the locations marked **R13, R15, R16, R18** and **R21**. Solder these into place and clip off the excess lead length.

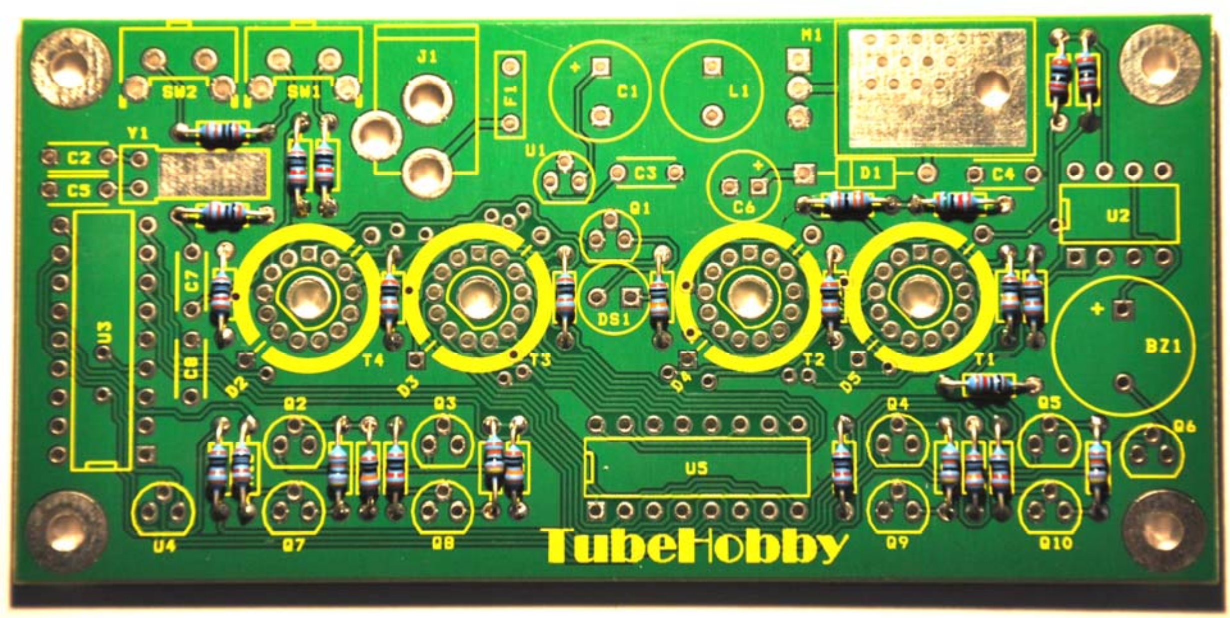
☐ Now collect the final two **10K** resistors and insert them into clock board at the locations marked **R24** and **R27**. Solder these into place and clip off the excess lead length.

☐ Insert the **15K** resistor (color code: brown, green, black, red, brown) into clock board at the location marked **R8**. Solder it into place and clip off the excess lead length.

☐ The next value is **100K**. You should have five of these resistors (color code: brown, black, black, orange, brown). Insert them into clock board at the locations marked **R12, R14, R20, R23** and **R26**. Solder these into place and clip off the excess lead length.

☐ Now, the next value to install is **470K** (color code: yellow, violet, black, orange, brown). You should have four of these in your kit. Insert them into clock board at the locations marked **R19, R22, R25** and **R28**. Solder these into place and clip off the excess lead length.

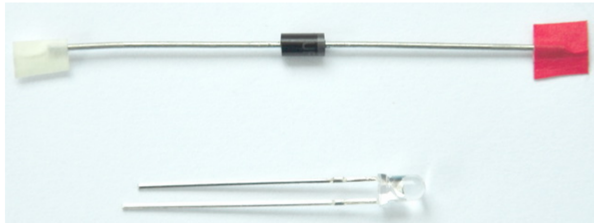
☐ The last value is **910K** (color code: white, brown, black, orange, brown). Insert it into clock board at the location marked **R7**. Solder it into place and clip off the excess lead length.



Resistors are assembled

You've completed the installation of all of the resistor values. Now would be a good time to re-examine your work. Look for unsoldered leads; solder "bridges" (shorts) between adjacent pads and traces; cold (grainy) solder joints; component values in the wrong locations, etc.

2.2.3 Diodes

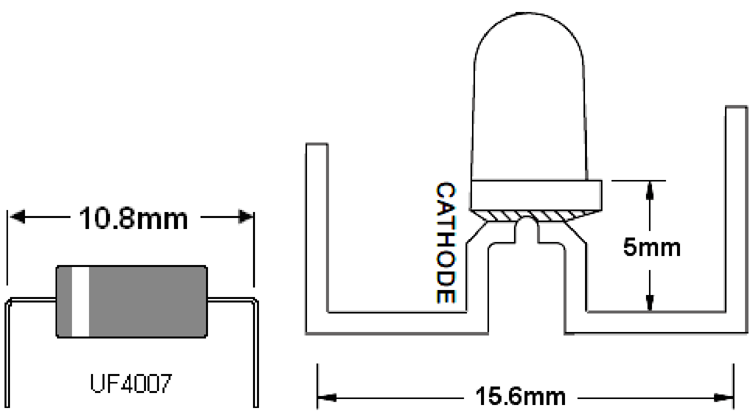


Diodes

The kit contains two types of diodes. The UF4007 is a high speed rectifying diode. It has plastic DO-41 type package. The 3014UBC is 3mm diameter blue color LED.

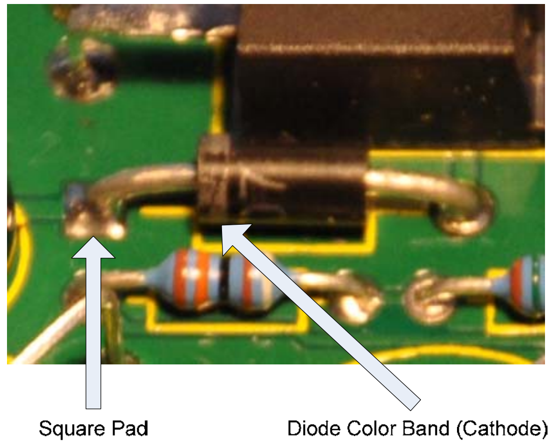
Diodes are polarized devices. The banded end of the D1 is the cathode. Install cathode into square pad and anode into round pad of the circuit board. Keep attention to silkscreen marking.

☐ Bend all 5 diodes as pictured below:



Diodes with bended leads

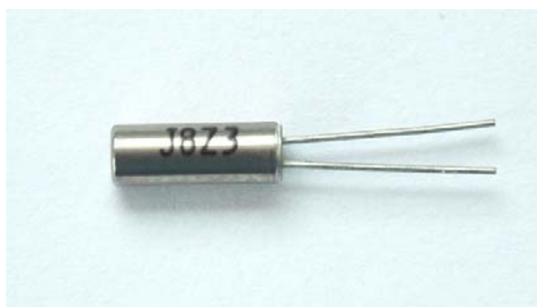
☐ Take the **UF4007** diode and install it into clock board at the location **D1**. Ensure that the direction of the diode matches the silk screen outline on clock board. Solder it into place and clip off the excess lead length.



UF4007 diode placing

☐ There are four 3014UBC LEDs included in clock kit. These diodes should be installed later when nixie tubes will be mounted. Do not install them right now there will be a step later.

2.2.4 Crystal



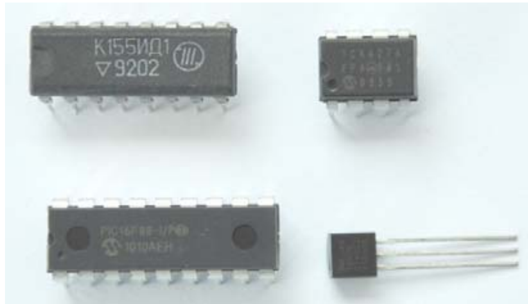
Crystal

One quartz XTAL is included in the clock kit. It has its own frequency set to 32768 Hz and is used as a precise time base.

Crystal is not polarized component. It may be inserted in either direction. Solder quartz crystal especially gently, because if overheated it may lose preset frequency and clock will lose its accuracy. Do not solder a body of the crystal, only the wires.

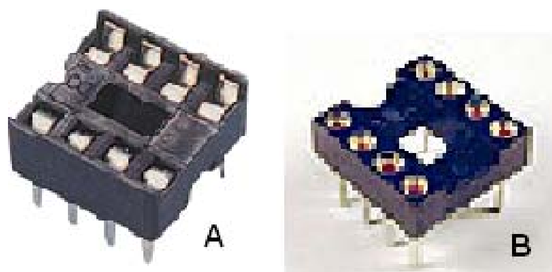
☐ Take the 32768 Hz crystal, (label may vary) and install it into clock board at the location **Y1**. Solder it into place and clip off the excess lead length. Do not overheat!

2.2.5 Integrated circuits



Integrated circuits

Integrated circuit may be easily damaged by heat when soldering and its short pins cannot be protected with a heat sink. Instead it is recommended to use an IC holder, called a DIL socket (*DIL = Dual In-Line*), which can be safely soldered into the circuit board. The integrated circuit is inserted into the holder later, when all soldering job will be over. Moreover, replacement could be easily done without soldering. It is strongly recommended to use them, especially for beginners.



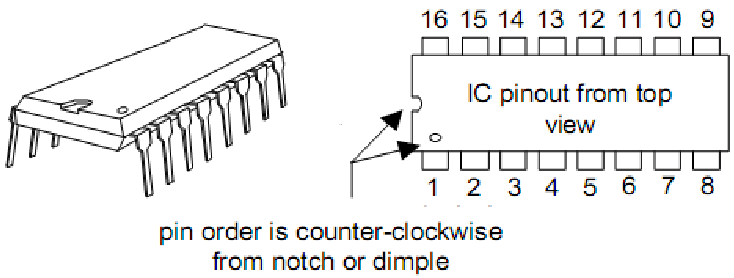
DIL sockets

Here is a place to mention that DIL sockets are available in several options and configurations. Ones called “Square DIL” (fig. above - A) are not as good as “Turned DIL” (B) in the terms of quality. Both of these sockets are available in different shapes and pin counts. For the NCV3.1 kit you will need the following DIL sockets*:

Pin count	Quantity	Part reference
8	1	U2
18	1	U3
16	1	U5

* DIL Sockets are not provided along with the kit, you may obtain them locally or do not use at all.

Integrated circuits are polarized semiconductor devices. Install pin #1 into square pad. See picture below. Keep attention to silkscreen marking.
If you decide to use sockets, then during the steps below install sockets instead of integrated circuits. Integrated circuits need to be installed in the last step, when all other components will be soldered into their places. To install integrated circuit, just gently push it into the socket (bend wires slightly if needed).



Integrated circuit

☐ **78L05** voltage regulator has TO92 package and does not require any socket. Bend the middle pin slightly backwards using tweezers so it will fit the footprint onboard. Insert it into location **U1** according to marking onboard, solder all three pins and clip off the excess length.

☐ The next IC is labeled **TC4427.** Natively it is MOSFET driver and also used as backlight LED switch. Take it (or 8-pin DIL socket) and install it into your board at the location **U2.** Ensure that the direction of the chip matches the silk screen outline on clock board. (Observe the notch or dimple in the case of the chip). Solder it into place.

If you are thinking about to program the PICmicro, it is strongly recommended to use 18-pin DIL socket at least for it. Just in case, if programmed inappropriately that chip will be bricked and you may need to replace it in a hard way.

☐ Take the preprogrammed PICmicro microcontroller labeled **PIC16F88-I/P** (or 18-pin DIL socket) and install it into location **U3.** Ensure proper positioning. (Observe the notch or dimple in the case of the chip). Solder it into place.

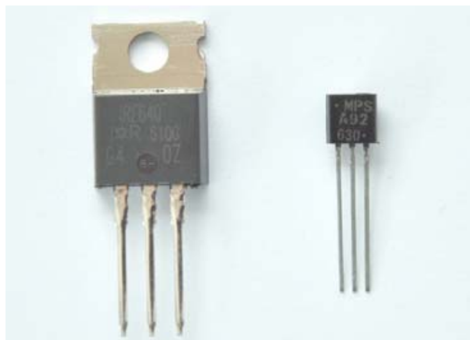
If the fully closed enclosure will be used, temperature sensor inside it may start to behavior some offset due to heat produced by nixie clock. To get rid of that, connection wires needs to be prolonged and the sensor itself routed outside of the enclosure or kept in touch with the case (if it is a good temperature conductor).

☐ **DS18B20** digital temperature sensor has TO92 package and does not require any socket. Bend the middle pin slightly backwards using tweezers so it will fit the footprint onboard. Insert it into location **U4**, solder all three leads and clip off the excess lead length.

☐ Insert the high voltage driver labeled **K155ID1** (or 16-pin DIL socket) into location **U5.** Ensure the orientation on the chip matches the silk screen outline on clock board. (Observe the notch or dimple in the case of the chip). Solder it into place.

Now you are finished the second major step. Take a break and afterwards examine your work. Verify whether all integrated circuits (or DIL sockets) are inserted the right way and matches labeling onboard. If DIL sockets are used do not insert integrated circuits right now, you will be reminded later. Once again look for unsoldered wires; solder “bridges” (shorts) between adjacent pads and traces, cold (grainy) solder joints, component values in the wrong locations, etc.

2.2.6 Transistors



<u>*Transistors*</u>

Nixie clock uses three types of transistors (11 pieces in total). MPSA42 is a general purpose NPN transistor, MPSA92 is a general purpose PNP transistor, and IRF640 is a N-channel MOSFET.

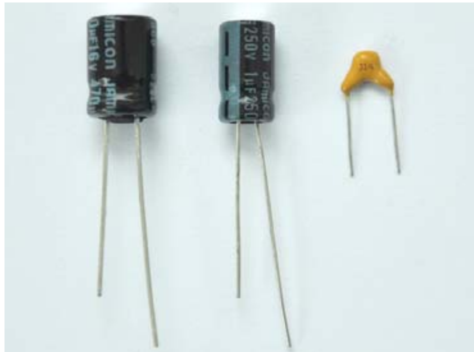
Transistors are polarized semiconductor devices. Insert them as shown on board silk screen layer printout. IRF640 transistor must be installed so that the labeled side will be on the top.

☐ Take the six MPSA42 transistors (labeled **42**), bend their legs slightly so that they will fit board footprint, and install them into clock board at the locations **Q1, Q6, Q7, Q8, Q9** and **Q10**. Solder them into place and clip off the excess lead length.

☐ The next transistors are MPSA92 type (labeled **92**). Take four of them, bend their legs slightly so that they will fit footprint onboard, and install them into clock board at the locations **Q2, Q3, Q4** and **Q5**. Solder them into place and clip off the excess lead length.

☐ The last transistor is **IRF640**. Bend all three pins down so that they make 90° bends 5mm away from the plastic package, while marking is on the top of package. Put this transistor into location **M1** and fasten it with M3 screw. Solder all three leads and clip off the excess length.

2.2.7 Capacitors



Capacitors

Nixie clock has 2 electrolytic and 6 multilayer ceramic capacitors.

Ceramic capacitors may be inserted in either direction however assembled clock will look more professional if all capacitors will be inserted in the same direction. Electrolytic capacitors are polarized passive devices. If the polarity marking band on these capacitors says negative, then the unmarked lead is the positive one. In this case, insert the negative lead into the hole located opposite the (+) positive indication of the silk screen outline on the board.

☐ Take the **470µF** electrolytic capacitor and install it into clock board at the location **C1**. Solder it into place and clip off the excess lead length.

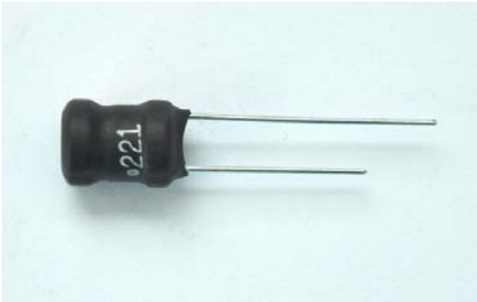
☐ Take the **1µF x 250V** electrolytic capacitor and install it into clock board at the location **C6**. Solder it into place and clip off the excess lead length.

☐ Take two **15pF** ceramic capacitors labeled **150** (**15**) and install them into clock board at the locations **C2** and **C5**. Solder them into place and clip off the excess lead length.

☐ Insert the **330nF** ceramic capacitors labeled **334** into clock board at the locations **C3, C4** and **C7**. Solder them into place and clip off the excess lead length.

☐ Insert the **10nF** ceramic capacitor labeled **103** into clock board at the location **C8**. Solder it into place and clip off the excess lead length.

2.2.8 Inductor



Inductor

Clock kit has one inductor. It is used in buck-boost type SMPS to step up voltage required for nixie tubes up to about 200 Volts.

Inductor is not polarized passive component. It may be inserted in either direction. Dot near one pin on the inductor means start of the winding.

☐ Take the 220µH inductor labeled **221** and install it into clock board at the location **L1**. Solder it into place and clip off the excess lead length.

2.2.9 Fuse

Fuse

Nixie clock uses auto-recovery fuse. It breaks at about 600-800mA and recovers shortly when load is removed. Fuse may be inserted in either direction.

☐ Insert the fuse labeled **T60-050** into clock board at the location **F1**. Solder it into place and clip off the excess lead length.

2.2.10 Buzzer

Buzzer

Nixie clock has alarm buzzer. It is simple electromechanical buzzer without generator, rated for 12 Volts.

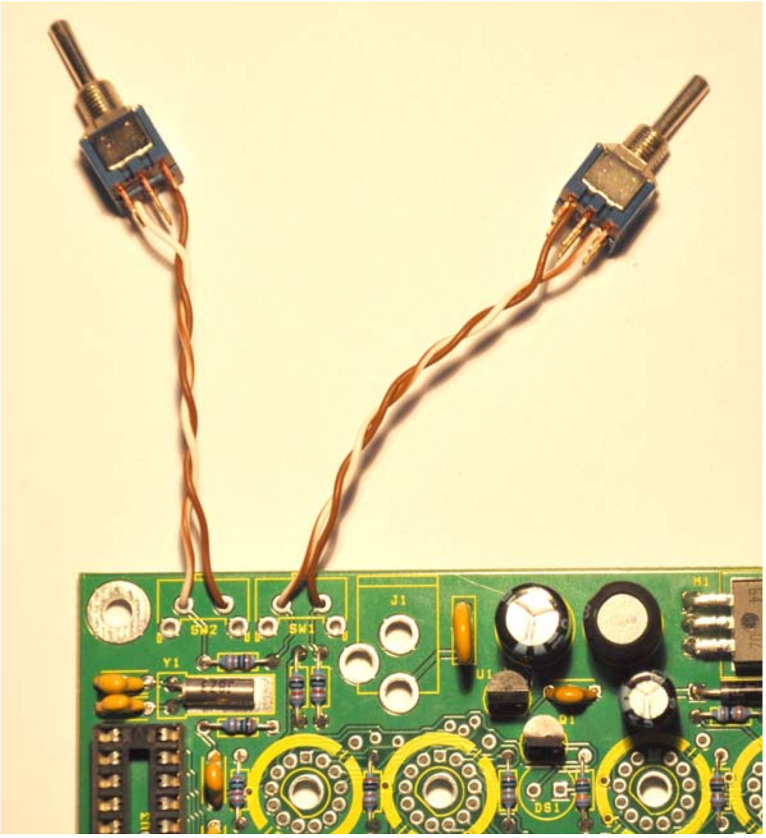
Buzzer is polarized device. Insert it so that "+" sign labeled onboard will match "+" sign on buzzer.

☐ Insert the buzzer labeled **12G-2P** into clock board at the location **BZ1**. Solder it into place and clip off the excess lead length.

2.2.11 Buttons

Button

Your board is equipped with two buttons; each of them has 6mm stick. These buttons are widely available with sticks of different length, so considering custom clock enclosure you may need other configuration. If you decide to use external buttons, just connect them to the two inner holes of each button' footprint with possibly shorter twisted wires (to avoid interference), the outer holes may be left unconnected (these are grounded). External buttons must have normally open contacts, no latch. According to voltage and current requirements – any button is compatible.



Wiring the external buttons

☐ Insert the **button** into clock board at the location **SW1**. Solder it into place. Insert next Button into clock board at the location **SW2** and solder it into place.

2.2.12 Power connector

Power connector

Clock kit got 2.1/5.5mm power connector. It is the most common type available.

☐ Insert the CP24-020A **(5,5/2,1mm, Power)** connector into clock board at the location **J1**. Solder one pin partially and align connector straightly. Solder the remaining pins. Fill enough solder to close holes.

2.2.13 Nixie Tubes

The hardest and most important step is to assemble nixie tubes. You should be extremely careful. On the quality and success of this step will belong the aesthetics of your clock.

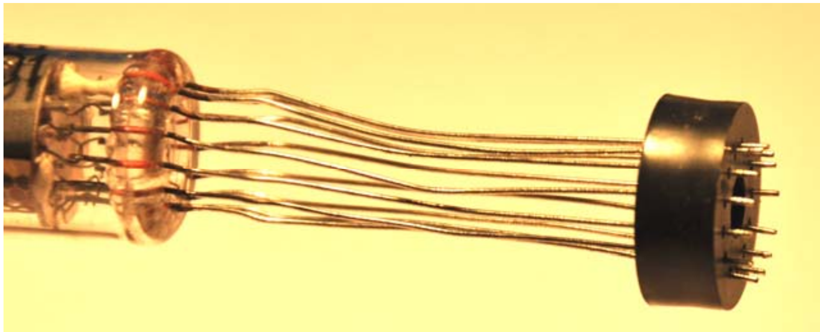
Nixie tubes have glass envelope, therefore do not bend wires close to glass, do not apply too much force trying to straighten and do not apply too much heat while soldering, otherwise it is risk to get glass cracked and inner gas may start to leak which will lead to the instant or premature tube failure.

Make sure whether plastic spacer has a hole in the center. Most spacers of IN-16 tubes have it, but some not. In such case remove plastic spacer and drill 4mm hole in the center. This hole is needed to get backlight to go through.

Locate pin #1 of the tube, it is coated by the white substance inside the tube, outside it is a small arrow on the glass just behind the plastic spacer pointed to the pin #1.

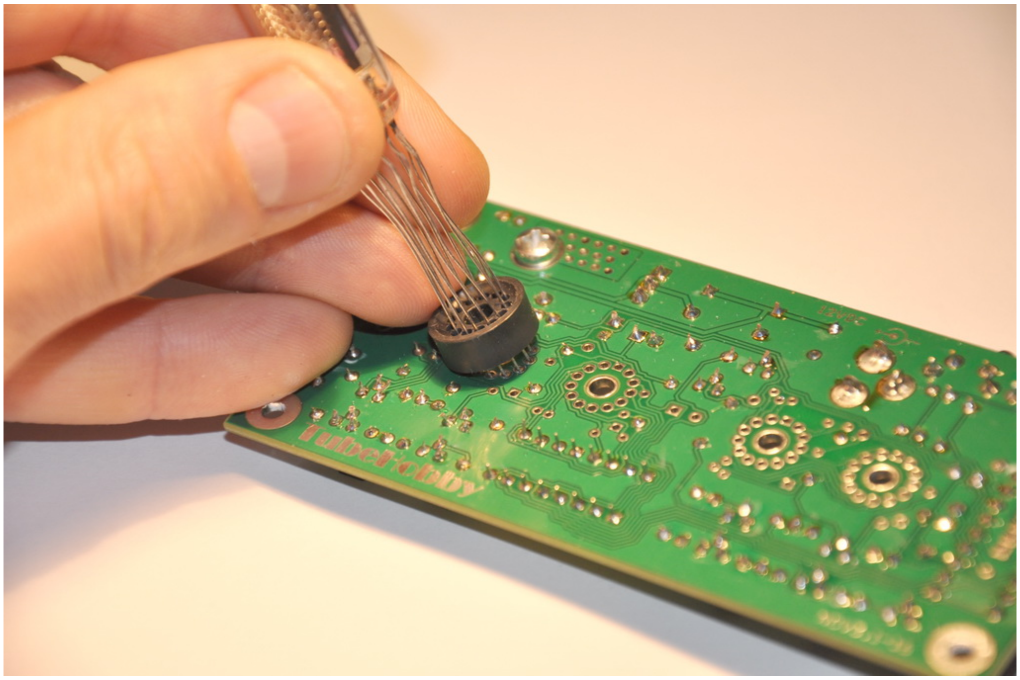
Pin #1 is shown by arrow on the middle of glass

Take the spacer out so that about 1-2mm of wire will be left till end. Do not remove spacer completely.

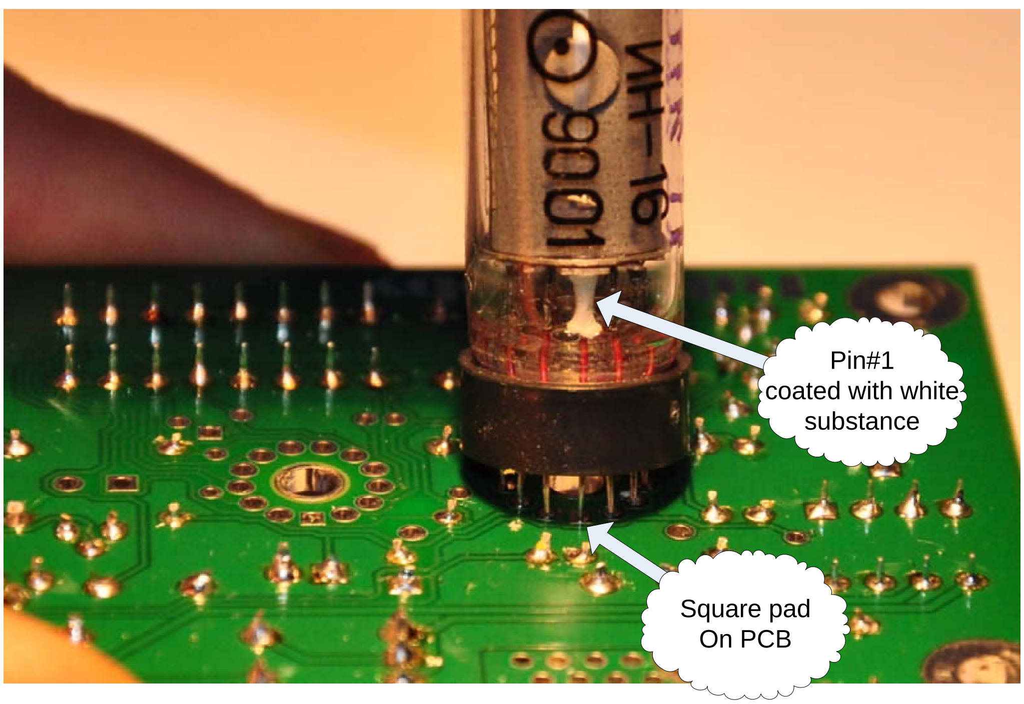


Placing spacer near the end of wires

☐ Insert **IN-16** tube into the PCB at the location **T1**. Pin #1 must go into square pad on the PCB. Keep spacer near the end of wires, so it will rule them into PCB easily. Tubes must be mounted on the opposite side of all remaining components. Make sure you are mounting on the right side. Before soldering check every tube whether pins are not shifted (see pictures below).



Insert nixie tube at the angle holding spacer near the end of wires

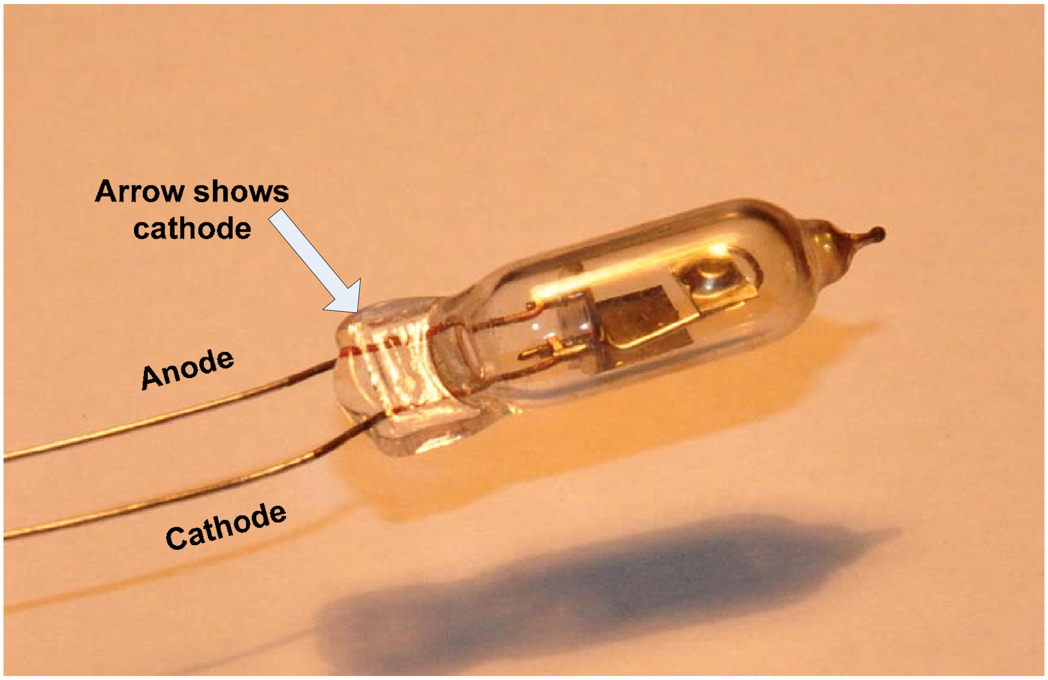


Pin #1 and footprint verification before soldering

☐ Insert remaining tubes at the locations **T2, T3** and **T4** fully so that their spacers get touched with the PCB. Place PCB at the angle so that tubes will touch the table. Align them carefully. Solder one top pin of every tube. Turn PCB upside down so that the other side of tubes will touch the table. Align them carefully. Solder one top pin of every tube again (the opposite pin). It is a good idea to cut wires now leaving about 0.5-1cm of them. This will make soldering job much easier. Solder third wire in the middle of two already soldered (for each tube). Align tubes again (do not apply too much force, rather reheat soldering point) and solder all remaining pins. Try to avoid contact between soldering iron and already assembled components as these may be melted or damaged. Once again do not apply soldering iron for too long as glass may get cracked from heat. When all pins are soldered, cut the remaining length of wires.

2.2.14 Column separator

Nixie clock uses IN-3 neon bulb as a column separator. These bulbs may have brownish glass from the factory and it does not make any influence to the performance. This bulb is polarized device and should be inserted into PCB accordingly. There is a small arrow pressed into glass at the bottom showing the cathode. Another convenient way is to sort out wires by the inner structure of the tube.



Neon bulb labeling

To hold IN-3 neon bulb adjusted while soldering, tape it to the closest nixie tubes.

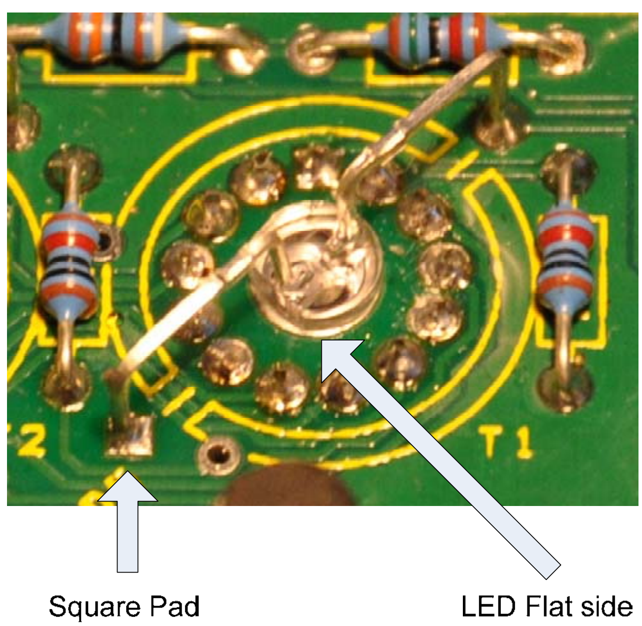
☐ Install **IN-3** neon bulb into PCB on the side where nixie tubes are mounted into location **DS1**. Anode must go into the square pad. This bulb has square lit shape, so adjust height accordingly. Solder both wires and clip off the excess lead length.

2.2.15 LEDs

At the step #2.2.3 LED wires were bent to fit custom footprint onboard. LED is polarized device and must be inserted as pictured below.

It is easy to touch tube spacer (and damage it) with soldering iron, therefore it is recommended to solder LEDs from the component side of the PCB while soldering LEDs.

☐ Install LEDs into clock board at the locations marked **D2**, **D3**, **D4** and **D5**. The pin near splayed edge must go into square pad (the labeling on PCB will guide you). Solder these into place and clip off the excess lead length.



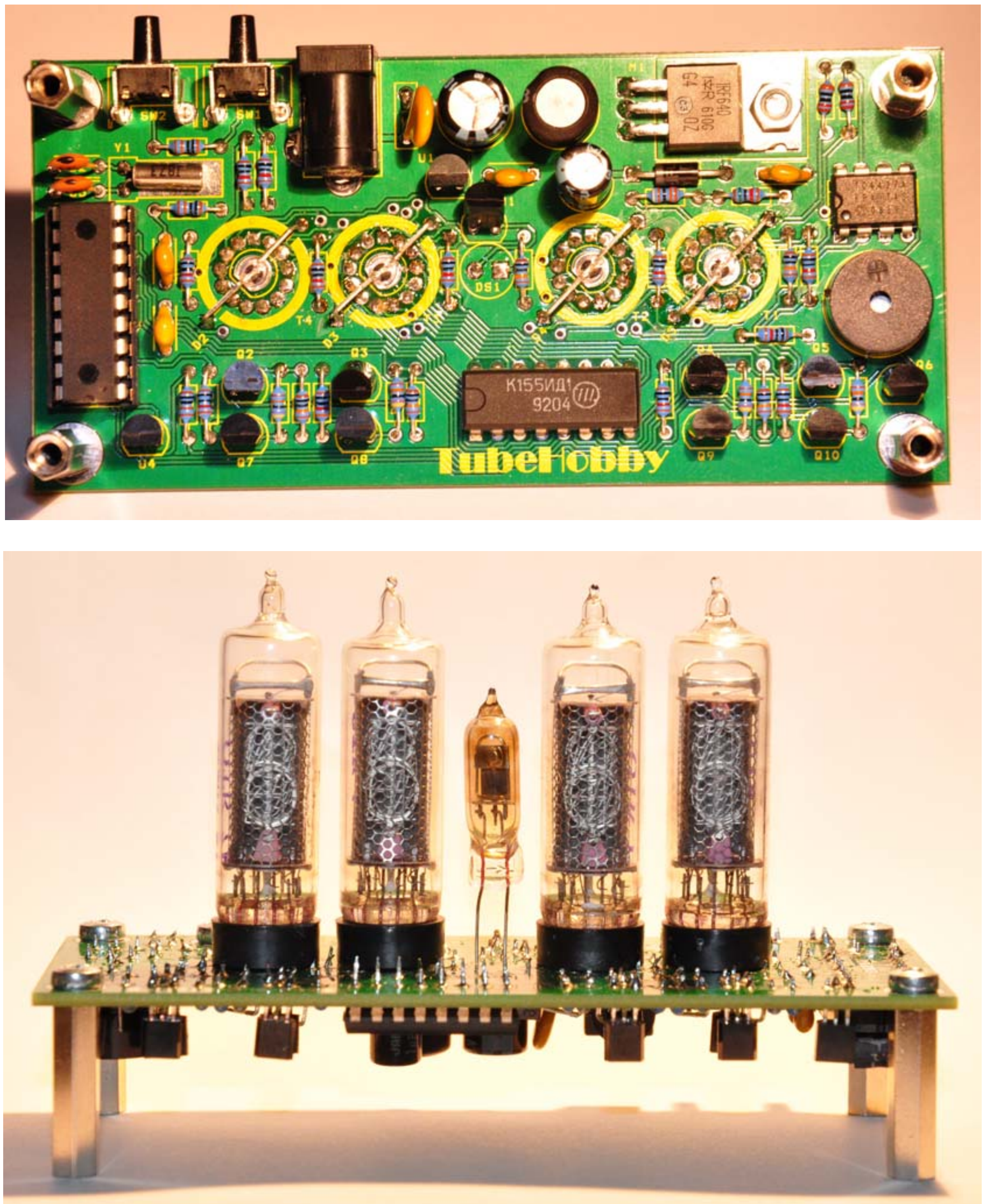
<u>*Backlight LED placing*</u>

These 3mm LEDs are available in almost every color. LEDs provided with the kit are blue. You may install different color LEDs if you wish. Just search for the brightest ones when choosing.

2.2.16 Finalizing

Clock kit has four 20mm metal standoffs. Screw these through holes at the edges of the board. Place standoffs on opposite to nixie tubes side, so they will work as a stand offs for now.

Insert U2, U3 and U5 integrated circuits into DIL sockets (if used). Keep attention to silk-screen ink marking and place ICs accordingly. Bend wires slightly is needed.



Assembled board

2.2.17 Power adaptor

Power adaptor is not included along with the kit. As these vary much across the world, you will easily get suitable one locally. It must provide **9-12V Direct Current** (meaning it must have internal rectifier) and will be capable to last **at least 600mA**, better 1000mA. It does not matter stabilized it or not. Double check whether it is not an AC-type and connector plug has positive inner. Measure it with voltmeter if unsure. Keep in mind, clock has no protection over power supply malfunction or wrong polarity and will be blown instantly if something will go wrong (for example AC-type power adaptor will damage clock instantly).

Many old equipment used suitable power adaptors for the nixie clock, e.g. routers, wireless phones, various chargers, toys, etc. Before buying check whether you may have one lying around.

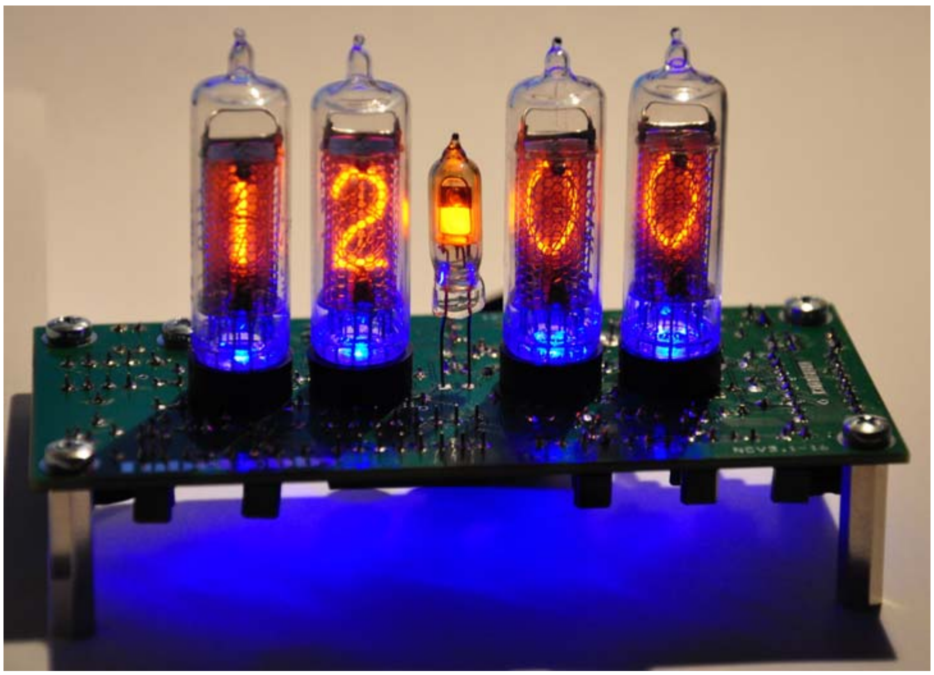
By the way, while many clocks are developed so that mains frequency is used as a time-base, here is not a case. Clock has its own quartz oscillator and does not care about mains frequency. Clock may be powered from 12V battery as well, e.g. in a car or an outdoor show. Everybody will ask you: wow, what is that?!

Power adaptor

2.2.18 First run

Now your clock board is fully assembled. Once again double check everything onboard prior to powering it. Do not get into a hurry. Make sure all steps before are completed, power supply is the right type and polarity.

Take power adaptor and connect it to the J1 connector. Plug adaptor into the mains socket. Remember, now your clock board is generating voltage exceeding 180V, be careful and do not touch any of the soldering points onboard otherwise you may get electrical shock. Your clock should begin to count time. All settings are set to defaults so that clock should work optimally. You may change them later. <u>If you don’t see your clock running at this point, disconnect power adaptor and go to troubleshoot chapter.</u>



<u>Nixie Clock running</u>

3 Troubleshooting

3.1 Software reset

<u>Before any troubleshooting always perform clock’s software reset</u>. This will eliminate the possibility of the wrong settings influence. All settings, including tubes’ lifetime counter will be reset to the default values.

To get your clock reset, keep both buttons depressed and connect power supply to the J1 connector. The backlight will blink once and nixie tubes will follow in a few seconds. Release both buttons and disconnect power supply. Connect it again. Your clock’s firmware is reset now. After a short cycle, time shown is 12:00.

3.2 Testing the tubes

To get tubes cycled for whatever reason, hold SW1 depressed while connecting the power supply, release button when tubes will start to cycle indefinitely. One of the reasons could be so called “cathode poisoning” prevention or fixing. This may happen when tubes have not been used for a very long time or some of the cathodes have not been used. These poisoned shapes lit partially but not full. Run tubes cycled until all cathodes fixes. To cancel cycling, disconnect power supply.

3.3 Tips for troubleshooting

Follow the suggestions below if you can’t get your kit to work.

- Carefully check that the components are fitted correctly, are in the right place and position;
- Check the colors of resistors bands against the assembly chapter of this manual; it is easy to mix them up. Pay particular attention to electrolytic capacitors, integrated circuits and diodes. Are they the right way around?
- Check whether transistors, integrated circuits, diodes and capacitors haven't been soldered into the board backwards;
- Check all soldering points. A good solder joint looks shiny and smooth and covers the hole completely;
- Hold your board up to the light. If any light shows through a hole then more solder is needed;
- Check that large blobs of solder are not causing short circuits, particularly with chip sockets. If too much solder has been used it is often better to remove it completely using a solder sucker and then to re-solder;
- Also check for streaks of solder bridging tracks, and any hairline cracks in tracks. Hairline cracks can be repaired by soldering over the gap;
- Examine power supply adaptor whether it is the right type. Test it using voltmeter;

The best thing to do is to get someone else to perform the steps above for you as probably you will not be able to check your own work adequately.

If everything looks good, connect power supply again. Perform measurements extremely carefully as shortened circuit (with probes) may blow your clock permanently.

- Measure voltage across C1 capacitor. It should be at least 9V but not more than 16V;
- Measure voltage across C3 capacitor. It should be 5V;
- Measure voltage across U3 pin #5 and pin #14. It should be 5V;
- Measure voltage across C6 capacitor. It should be 185V;
- Check for oscillations of correct frequency and amplitude across C2 capacitor. Use oscilloscope. See chapter *hardware description* for waveform example.
- Check for TTL level pulses on U3 pins #7, #8, #9, #10 with oscilloscope or with frequency meter (some multimeters have this function). Repeat rate is about 124Hz.

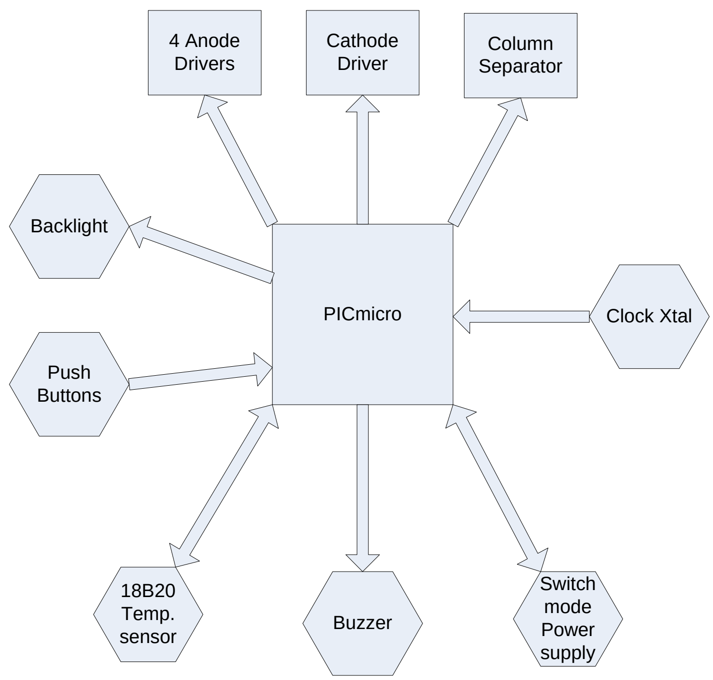
Read operational description of this manual and try to understand how your clock is working. It will start to make sense what you see on your oscilloscope.

TubeHobby runs a repair service for these kits. When contacting try to provide as much information as you can (see steps above) and attach a short video clip if your clock is running but not as intended. Once you will provide enough information to understand what is going on, we will point you to the right direction. Please contact us by email: info@tubehobby.com

3.4 Hardware description

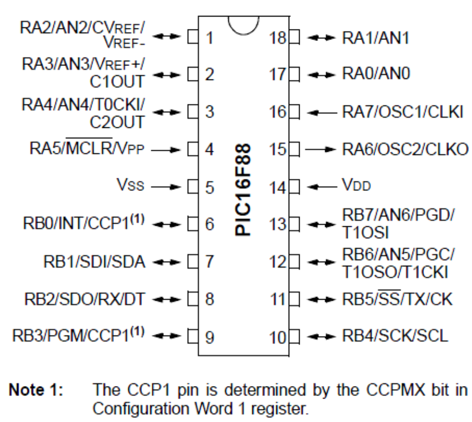
3.4.1 PICmicro

The clock has round-robin scheduler driven firmware. Meaning many quasi concurrent processes are handled at a time. This enables to make highly integrated controller which is responsible for all subsystems onboard. These subsystems will be described in detail in this chapter later.



System diagram

A "heart" of the system is the PICmicro microcontroller. It runs from internal oscillator at 8MHz. The pinout of the microcontroller is pictured below. One analog input is being used to monitor high voltage power supply output via RA4 (pin #3). CCP1 module is selected to the RB0 (pin #6).



PIC16F88 Pinout

Table bellow represents firmware assignments to the PICmicro pins.

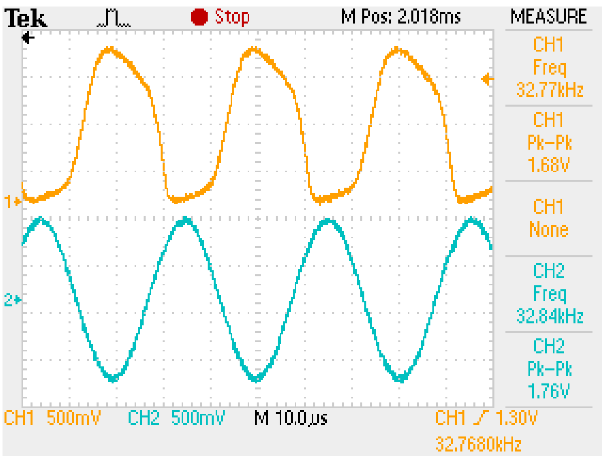
Pin#	Port	Description	Input/ Output	Analog/ Digital	Value
1	RA2	Cathode address bit #2	O	D	N/A
2	RA3	Cathode address bit #3	O	D	N/A
3	AN4	SMPS Voltage feedback	I	A	0-5V
4	RA5	SW1 button input	I	D	Act. High
5	VSS	Ground	N/A	N/A	0
6	CCP1	SMPS PWM control	O	D	N/A
7	RB1	First tube anode control	O	D	N/A
8	RB2	Second tube anode control	O	D	N/A
9	RB3	Third tube anode control	O	D	N/A
10	RB4	Fourth tube anode control	O	D	N/A
11	RB5	LED backlight PWM control	O	D	N/A
12	T1OSO PGC	Timebase XTAL generator output Programming interface bus clock	O I	D D	32768Hz N/A
13	T1OSI PGD	Timebase XTAL generator input Programming interface data bus	I I/O	D D	32768Hz N/A
14	VDD	Power supply	N/A	N/A	+5V
15	RA6	SW2 button input Buzzer control	I O	D D	Act. High N/A
16	RA7	Column separator control 1W bus control (for temperature sensor)	O I/O	D D	N/A N/A
17	RA0	Cathode address bit #0	O	D	N/A
18	RA1	Cathode address bit #1	O	D	N/A

PICmicro comes preprogrammed and should start executing firmware when powered. Since it runs from 5 Volts power supply, clock has U1 to do the stabilizing job. It is a good idea to measure voltage across U3 pin #5 and U3 pin # 14 to make sure there is 5V (acceptable range 4.8V – 5.2V) even if your clock is working as intended.

3.4.2 Real time clock

For time counting internal oscillator does not provide required accuracy therefore an external 32.768KHz oscillator (Y1) is connected PICmicro pins #12 and #13. Internally these pins are selected to be used with the TIMER1 module which is used as a RTC. The drawback of such solution is that these pins mutually are used for programming which becomes a bit tricky (for more information on how to program go to *programming* section of this manual).
A waveforms across C2 (generator output) and C5 (generator input) capacitors representing correct operation of Y1 oscillator should look like pictured below. If your clock time counting is not accurate enough, it is possible to adjust it either way:

- Use software correction (refer to the *software* chapter of this manual)
- Select C2 and C5 capacitors (1pF decrease in capacitance leads to about +1sec/day and vice versa). Useful range 12pF - 22pF.



Y1 oscillator waveforms
(CH1-U3 pin #12; CH2-U3 pin #13)

The crystal oscillator circuit may need to be checked if clock is working but does not count time, or count it wrong. Make sure the waveforms looks similar to these provided above and measure frequency which must be close to 32.768 kHz.
Another meaning to check these waveforms is to make sure the software on the PICmicro is running at all. For example your clock does not show any signs of life, so the first measure should be to check power of the PICmicro (5V between pin #5 and pin #14 of the U3) and then measure waveforms shown above. If there is power but no oscillations it would suggest that something is wrong with the PICmicro.

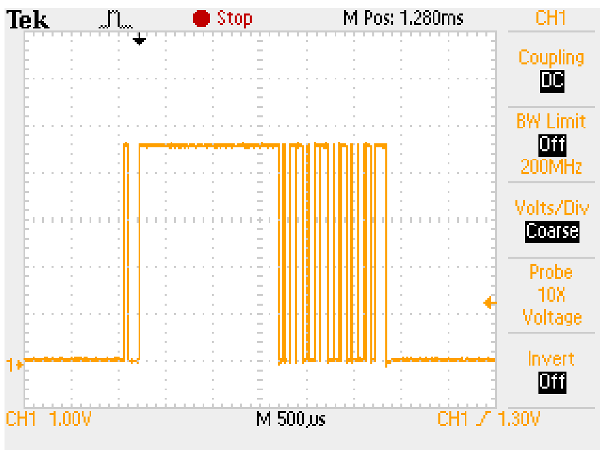
3.4.3 Buttons

The PICmicro firmware is controlled by two buttons SW1 and SW2 connected to the RA5 and RA6 port respectively. While SW2 shares the same RA6 port with a buzzer. Buttons does provide HIGH logic level when depressed. When no alarm is present PICmicro uses RA6 port for SW2 input. When alarm is being occurred, RA6 port changes its direction to the output and provide signal to the buzzer. SW2 in such event is ignored. When alarm is over, RA6 port changes its direction back to the input and works as a SW2 input again. To make buzzer sound louder a simple repeater is implemented using Q6 transistor.

In order to test buzzer circuit, depress and release SW2 button – a click sound should be audible from the buzzer, while when pressing SW1 – no sound.

3.4.4 Temperature sensor

The DS18B20 temperature sensor is connected to the PICmicro via RA7 port. This port is used as a column separator output as well. Since the DS18B20 uses 1wire communication protocol it is immune from the 2Hz pulses for the column separator and such toggles does initiate temperature sensor reset by each pulse. While PICmicro firmware is set to the temperature display state, it calls 1W protocol routine and starts communicating via RA7 port with the temperature sensor. Temperature sensor recognizes commands sent and starts temperature conversion followed by data transfer, column separator blinks for a fraction of a second during communication. A typical 1W-protocol waveform captured on RA7 port (pin #16 U3) is shown below.



1W communication
(U3 pin #16)

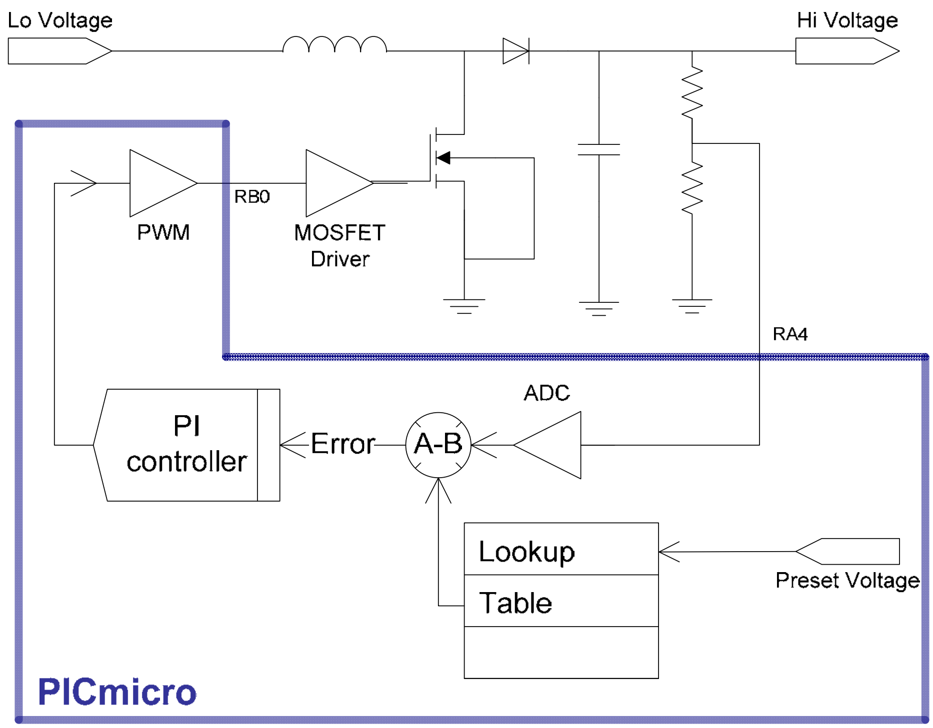
Note clock must be set to the temperature readout state in order to look for 1W communication on the bus. Column separator signal go through repeater on Q1 transistor because it switches high voltage bulb.

Please be careful while writing your own software, this bus must never be pulled up by the PICmicro, there is a pull up resistor dedicated to do that (R17). Otherwise both, PICmicro and DS18B20 may start to use bus simultaneously and will blow each other.

3.4.5 Switched mode power supply

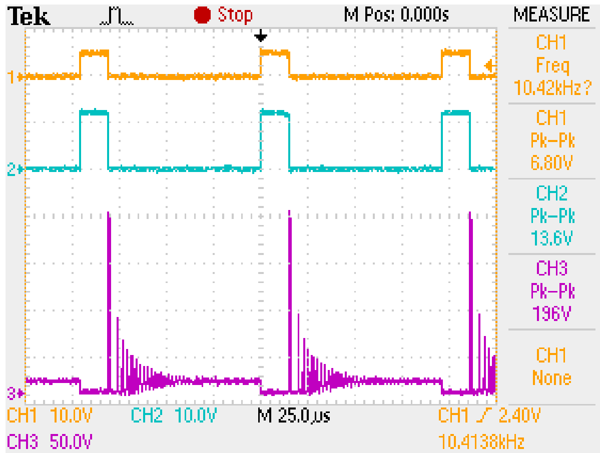
The general SMPS concept was taken from *Microchip application note TB053* with minor modifications. It uses boost converter topology which is the simplest solution considering high voltage and low current required for nixie tubes. Basically when MOSFET is closed, current flows through inductor from low voltage power supply thus magnetic field created by the coil is being stored into inductor core. Shortly when MOSFET is being set to open, magnetic field generates current in coil which through diode is stored into capacitor. Output voltage is monitored via resistor divider and converted into the digital form via PICmicro internal ADC via port RA4 (U_FEEDBACK signal). At that time lookup table provides preset voltage reference in order to calculate output voltage mismatch (error). Error signal is provided to Proportional-Integral controller implemented in software, which calculates correction magnitude. Signal from PI controller is provided to the PICmicro internal PWM controller which handles MOSFET timing. In order to ensure high efficiency MOSFET must be switched from on-to-off and vice versa as fast as possible. Since MOSFET gate works as a capacitive load and to maintain fast switching a dedicated MOSFET-driver is connected to the PICmicro port RB0 (CCP1).

This is a digital closed loop system with ability to change output voltage by software as well as shut-off power supply during preset night hours.

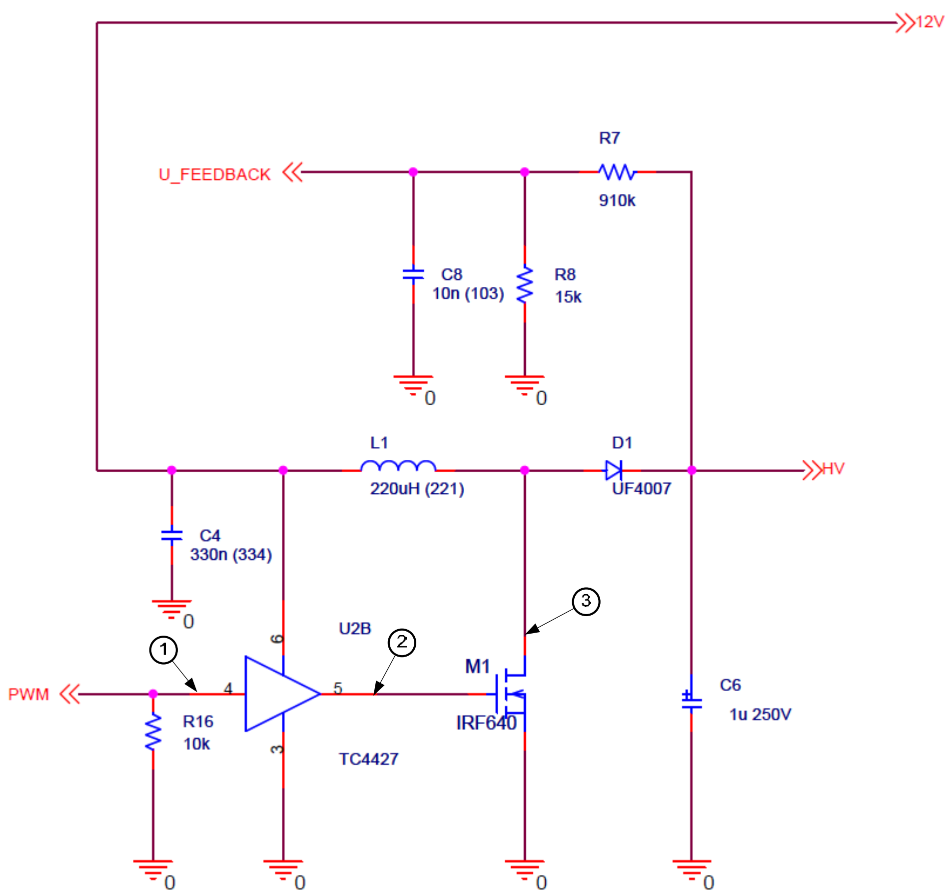


Simplified SMPS diagram

Typical SMPS PSU waveforms are pictured below.



SMPS waveforms
(CH1-U2 pin #4; CH2-U2 pin #5; CH3-M1-Drain)



SMPS schematics

The waveform above on channel #1 shows SMPS pulses provided by the PICmicro. Pulse width may vary depending on the SMPS load. During preset night-shut-off hours PWM duty is set to 0, meaning no PWM pulses are being provided.

The waveform on channel #2 shows SMPS pulses amplified by the MOSFET driver (U2). Basically it is an amplified version of previous waveform. It may be useful testing MOSFET and its driver.

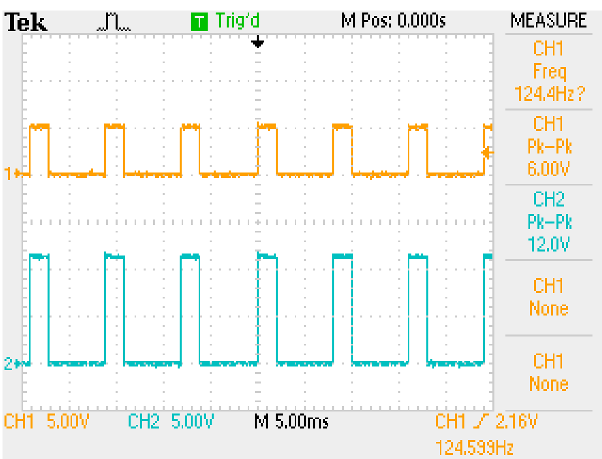
The waveform on channel #3 shows voltage swings across inductor. During the low pulse just before the high spike, inductor gathers its magnetic field. It is important not to get it saturated. If the end of the low pulse, just before the high spike tends to round up, it shows saturation and SMPS overload. Actually, if this will happen, after a moment fuse will disconnect the circuit.

Waveform is sampled on the M1 MOSFET drain (pin #2). For correctly working SMPS it should look similar to this. This is a high voltage measurement. Always set oscilloscope probe to 1:10 or higher divider or check manual whether it can measure such voltage.

In order to troubleshoot high voltage SMPS measure voltage across C6 capacitor. It should be in a range of 160V-200V according to voltage setting via clock menu (default 185V). If there is 0V, check F1 fuse and external power supply. If there is 12V (voltage provided by external power supply) do a *software reset* and check with oscilloscope for waveforms as pictured above. If no pulses are there something is wrong with the PICmicro.

3.4.6 LED backlight

Backlight signal to the LEDs is provided by the PICMicro (U3 pin #11). Because backlight is provided with selectable intensity, it is PWM driven. Pulse width may vary depending on selected LEDs intensity. PWM signal from the PICmicro goes through U2 where it gets amplified and then LEDs are powered. LE diodes are connected in serial pairs D2-D3 and D4-D5. If one LED in pair fails it will affect the remaining LED.

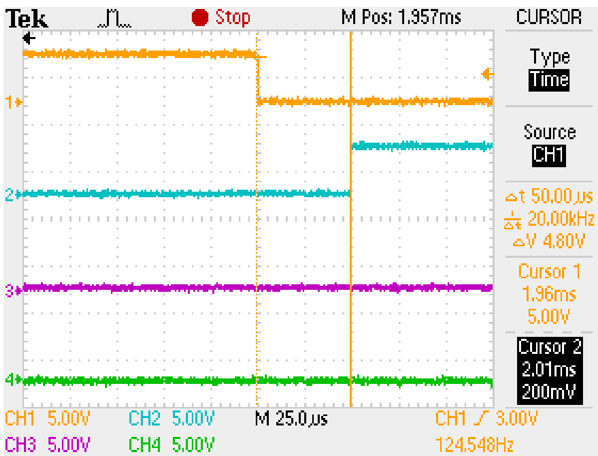


<u>*Backlight PWM waveform*</u>
<u>*(CH1-U3 pin #11; CH2-U2 pin #7)*</u>

3.4.7 Tube drivers

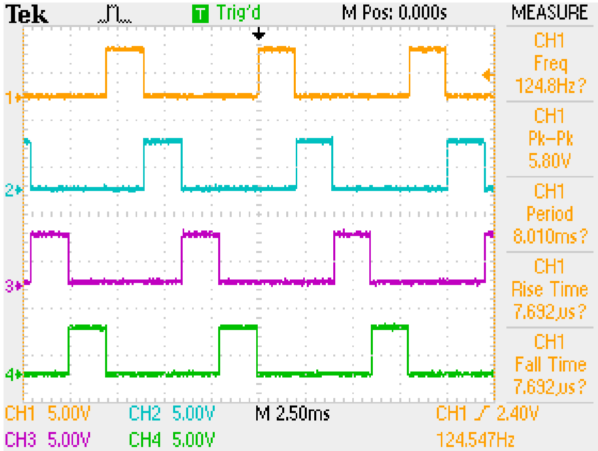
Nixie clock is designed to operate in multiplex mode. Tubes are driven in 4x1 mode meaning only one tube is enabled at any particular moment. Tubes flashes in a row one by one far faster than humans' eye can distinguish creating an illusion of constant display. Multiplex repeat rate is close to 124Hz. To compensate brightness loss due to partial time enable a higher working current is selected according to manufacturer recommendations. This operating mode was the most common during nixie era.

All ten cathodes of all four tubes are connected in parallel. In order to be able display different digits on different tubes, each tube has its own anode driver which is basically a high voltage switch. Only one anode driver can be open at a time. In order to prevent ghosting, between switching anode drivers a "dead" time is introduced when all anode drivers are closed. Below is magnified waveform when T1 anode driver is being closed (orange line) and after 50µS T2 anode driver (cyan line) is being open.



Anode drive "dead" time

During "dead" time cathode driver change its output according to the next displayed digit. Basically cathode driver changes its output four times for each display cycle. Whole tube driving routine is timer-interrupt driven in order to prevent flicking and maintain even brightness.

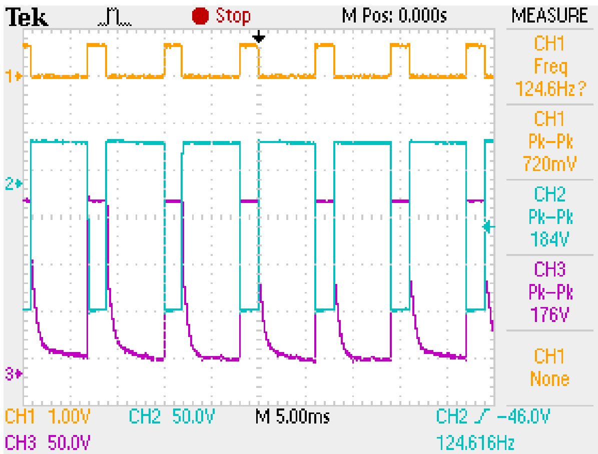


PICmicro provides anode drive pulses shifted in time for each tube
(CH1-U3 pin #7; CH2-U3 pin #8; CH3-U3 pin #9; CH4-U3 pin #10)

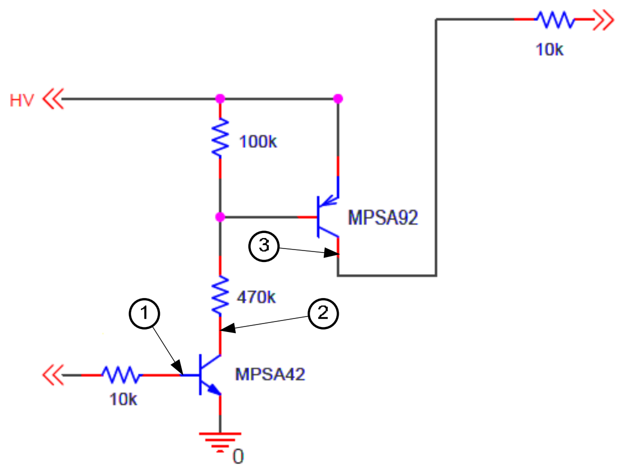
While troubleshooting consider, if there is a problem with one tube while all remaining are intact the most likely cause is due to anode driver or tube itself. If problem follows through all four tubes, it may be caused by cathode driver (U5) or any of the tubes.

If there constantly ghosts one of the digits through all tubes but not related to any other digit, the most likely somewhere is a short to ground, commonly soldering issues or defective cathode driver (U5). If ghosting is related to other digits, there could be two scenarios, only one tube fails or faulty shapes follow through all four tubes.

If ghosts only one tube then anode driver is needed to be checked. According to schematics identify which transistors are used for faulty tube anode drive and examine waveforms with oscilloscope. Below is example how pulses should look. This is a high voltage measurement. Always set oscilloscope probe to 1:10 or higher divider or check manual whether it can measure such voltage.



Anode driver waveforms
(CH1-NPN-Base; CH2-NPN-Collector; CH3-PNP-Collector)



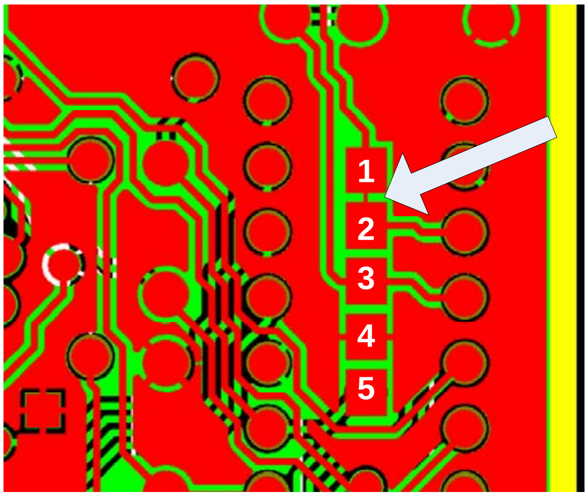
NOTE (x) Waveforms on these points are provided. Number means oscope channel.

Anode driver schematics

If ghosting follows through all four tubes, measure resistance between appropriate cathodes across all tubes and try to found one with the lowest resistance (it may differ very little, but still differ). The one with lowest resistance most likely causes the problem. Look for soldering and if it looks ok, the tube is likely bad and needs to be replaced.

3.4.8 Programming interface

Board has dedicated programming interface which is routed to the JP1 connector. As pictured below it consists of five pads on the top side of the PCB. Programming interface shares same PICmicro pins with Y1 XTAL therefore both are connected in parallel. *Microchip* recommendation is to disconnect Y1 crystal during programming otherwise it is risk to damage it. It is enough to disconnect any pin of the XTAL instead of booth. Following mentioned above, programming connector pins #1 and #2 have etched small jumper between cutting which XTAL is being disconnected. This jumper needs to be cuted before programming and shortened again afterwards.



Programming connector has etched jumper between pin #1 and pin #2

During debugging phase or with intention to program multiple times you may consider soldering 220 ohm resistor between pins #1 and #2 of programming connector which will protect XTAL from damage and enables programming at once (jumper between pin #1 and #2 must be cut). Resistor may do some influence to clock accuracy, but generally it will work more or less ok. When finished, remove 220 ohm resistor (if used) and shorten #1 and #2 pins with solder permanently.

Programming connector

As you know internal PICmicro *Timer1* oscillator uses the same pins as programming interface. In software, if *Timer1* is enabled in *synchronized counter mode* it is impossible to program PICmicro and even erase it*. In such event these pins (*T1OSI*, *T1OSO*) are assigned to internal PICmicro *T1OSC* hardware and messing up with the programming communication. Thus it is very important to preserve way to disable *Timer1* oscillator externally (e.g. using buttons). An example of such could be the following code snippet placed in beginning of the main code (after proper *Timer1* initialization):

```
if(RA6)
{
    T1CON = 0;
}
```

This will disable *Timer1* hardware if SW2 is depressed. During programming cycle PICmicro may be reset multiple times so keep SW2 depressed during whole programming cycle. T1 module will not work until programmer is connected. During programming board must have power supply connected. Never connect or disconnect programmer while power supply is connected (always disconnect power supply first).

Never press SW1 while programmer is connected. It may damage your programmer.

*sometimes becomes possible to erase PICmicro playing with the power supply voltage (to the whole board). Somewhere between 4V and 6V PICmicro does not initialize properly and does not start program form memory while erasing already becomes possible. Try to change voltage in small steps (e.g. 0.1V) and try to erase each time. This is not documented feature of the PICmicro, use it at your own risk.

PICkit-2 USB programmer from *Microchip* (*part # PG164120*) has been tested to program nixie clock and performed well. Moreover it has a logic analyzer tool which may be useful for troubleshooting. Connect programmer to the NCV3.1 nixie clock programming interface as following:

PICKIT2	**Nixie Clock PGM Connector**	**Description**
1	5	Vpp/_MCLR
2	NA	VDD
3	4	VSS (Ground)
4	3	PGD
5	2	PGC
6	NA	Auxiliary

Consider to use 18-pin DIL socket for the PICmicro in order to preserve the original chip with the original firmware. Change it with the blank chip for custom programming. If you do not change the chip, you will overwrite the original firmware at the first programming attempt and the original firmware can't be recovered anymore.

4 Software

The clock's firmware is driven by Round-robin scheduler and consumes more than 3K of internal program memory.

Firmware is programmed so that all settings and tube's lifetime counter values are stored in the internal flash memory and are kept safely during the power outage. Constantly the time shown is saved each minute into the memory. When not powered, clock does not count time and date however it will follow with the time saved prior to shut off (seconds are set to 30 in such event). During short outages this helps to keep time close to actual.

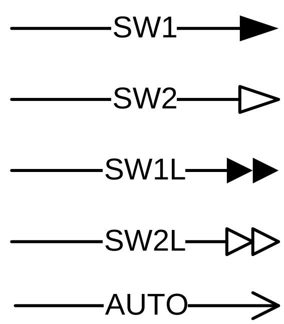
4.1 Firmware updates

Current version of firmware: v02

NOTE: In order to update the firmware please send the PICmicro chip or whole nixie clock board back for re-programming. Alternatively a preprogrammed chip with the latest firmware could be ordered. Please contact us by email: info@tubehobby.com

4.2 Clock’s menu

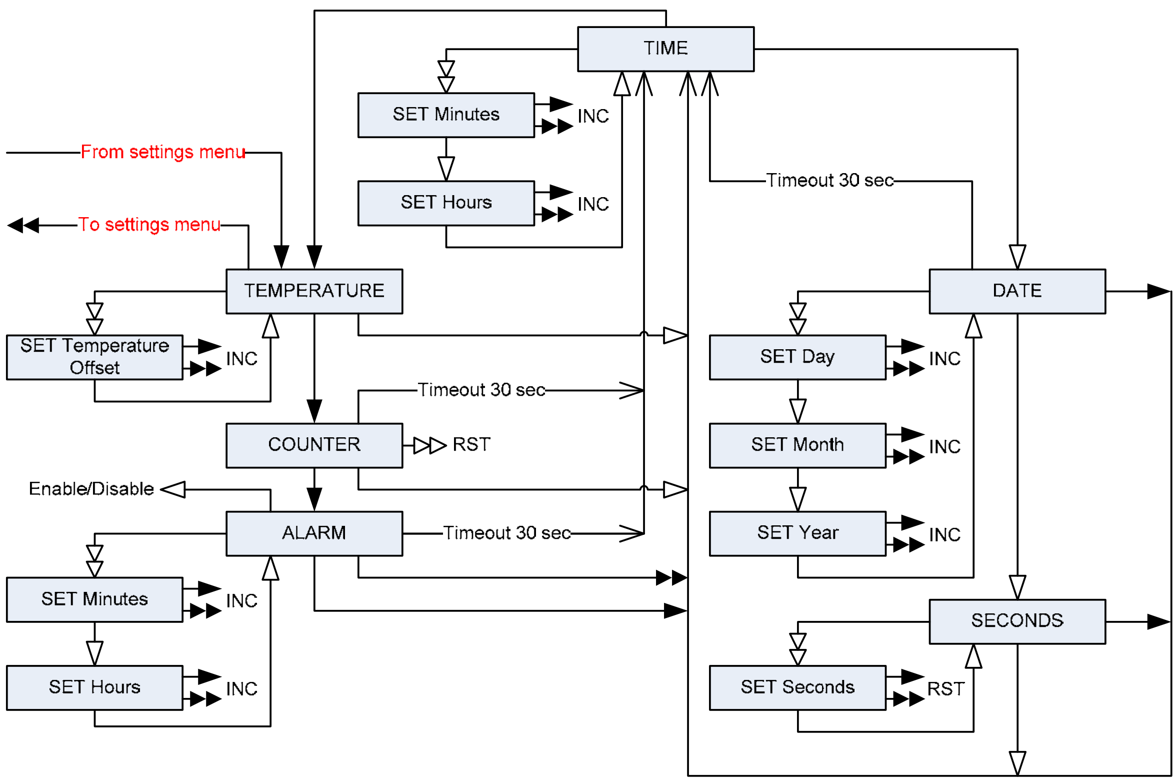
NCV3.1 nixie clock has 2 buttons. Each button depressed shortly or prolonged behavior differently. Short push is considered depress and release within 5 sec, while to cause action for prolonged push, hold button for more than 5 sec. Below is shown menu transition vectors where SW1 and SW2 means buttons (short push), L means prolonged push and AUTO means timeout. Timeout occurs automatically after 30 sec passed from the last button depress. These arrows differ by end shape. Whole menu transitions are shown using arrows in this style.



Menu transitions

When clock is powered it automatically enters the TIME state. A short push to SW1 button will change the TIME state into the TEMPERATURE state. Next short push to SW1 button will enter COUNTER state where tube’s lifetime hours are counted. A short push to SW1 again will enter ALARM state where an alarm-clock may be set. Next short push of any button will return to the TIME state again. A short push to the SW2 button will enter the DATE state, next short push to the SW2 will enter SECONDS state.

If the clock is left in some states and none of the buttons are pressed within 30 seconds, timeout occurs and the clock automatically returns to the TIME state (these transitions are shown with arrow with "Timeout 30 sec" labeled on it).



Main menu diagram

4.3 Setting time

When being in TIME state, push and hold the SW2 button. After 5 seconds, the minute readout will start blinking. A short push to SW1 will increase value by 1 while long push to SW1 will to start to count fast.

A short push to SW2 will enter hour setting mode and hour readout will start blinking. A short push to SW1 will increase the hour value by 1 while long push to SW1 will start to count fast. A short push to SW2 again will escape the time setting mode and the clock will return to the actual time display (TIME state).

In order to set seconds, enter the SECONDS state (pushing SW2 twice from TIME state) and depress SW2 for 5 seconds. Seconds' readout will start blinking. A short press to the SW1 will reset seconds to 00. To exit settings mode press SW2 shortly. During the setting of seconds, time is not rounded (e.g. when the seconds are reset, the minutes value will remain the same). If 12-hour mode is selected, the clock will automatically convert time to the 24-hour format during settings and convert it back on exit.

Default time 12:00:30 (12PM). Range 00:00:00…23:59:59.

4.4 Setting date

When being in DATE state, push and hold the SW2 button. After 5 seconds, day readout will start blinking. A short push to SW1 will increase value by 1 while long push to SW1 will to start to count fast.

A short push to SW2 will enter month setting mode and month readout will start blinking. A short push to SW1 will increase value by 1 while long push to SW1 will to start to count fast.

A short push to SW2 again will enter year setting mode and year readouts' two last digits will start blinking. A short push to SW1 will increase value by 1 while long push to SW1 will to start to count fast.

A short push to SW2 again will escape the date setting mode and the clock will return to the DATE state.

During settings all months have day values 1-31 to set, but when clock is counting time, it takes care to the amount of days in particular month and leap year correction. In order to toggle date display format from DD-MM to MM-DD go to *settings* menu below.
Default date 2010-08-01. Range 2010-01-01…2050-12-31.

4.5 Temperature

In TEMPERATURE state clock shows actual ambient temperature. Some enclosures may have more or less closed space and temperature readout offset is needed to correct the value. To set temperature offset value hold SW2 for 5 seconds. Then using SW1 enter desired offset value. A short push to SW1 will increase value by 1 while long push to SW1 will to start to count fast. Blinking numbers means negative value, constantly lit – positive. One number is equal to 0.5 degrees Celsius. To exit temperature offset settings mode press SW2 shortly.

In order to toggle temperature display format from Celsius to Fahrenheit go to *settings* menu below.

Default offset 00. Range -20…+20 (-10ºC…+10ºC).

4.6 Tubes lifetime counter

Tubes lifetime counter is counting hours constantly when tubes are lit. This may give you an idea of remaining lifetime of nixie tubes. When being in COUNTER state press SW2 for 5 seconds in order to reset counter.

Default counter value 0000. Range 0000…9999.

4.7 Alarm-clock

Nixie clock has one alarm-clock. When being in ALARM state hold SW2 to set alarm time. After 5 seconds, the minute readout will start blinking. A short push to SW1 will increase value by 1 while long push to SW1 will to start to count fast.

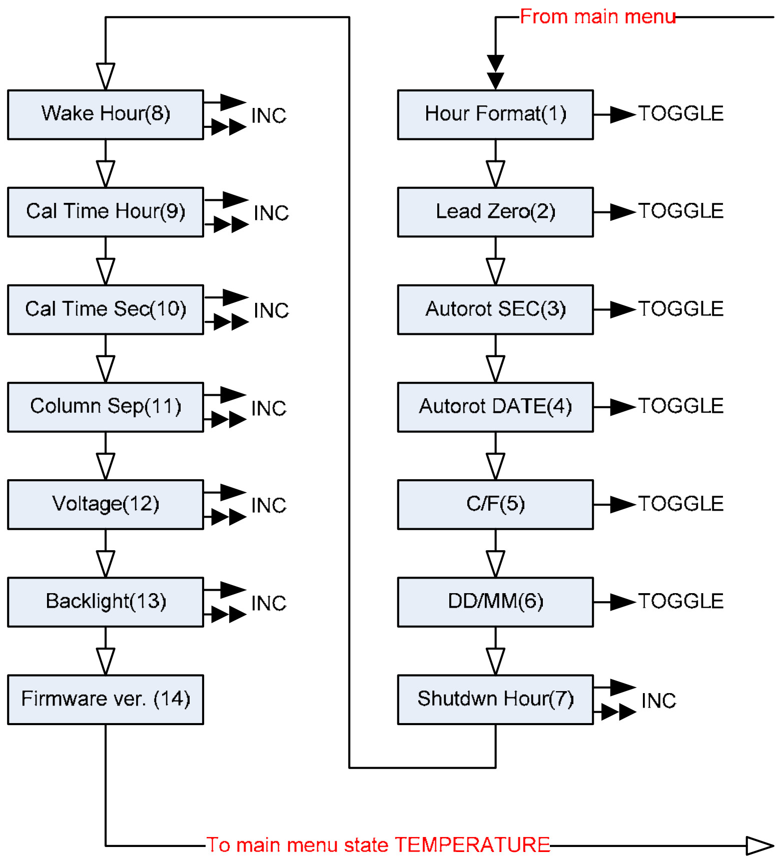
A short push to SW2 will enter hour setting mode and hour readout will start blinking. A short push to SW1 will increase the hour value by 1 while long push to SW1 will start to count fast. A short push to SW2 again will escape the time setting mode and the clock will return to the alrm time display (ALARM state).

Toggle alarm enable/disable shortly pushing SW2. An enabled alarm is shown by enabled column separator. Enabled alarm occurs once each day and takes one minute, unless SW1 is pressed during alarm (alarm will stop sounding).

Default alarm time 07:00; Disabled. Range 00:00…23:59.

4.8 Settings menu

To enter settings menu press SW1 for 5 seconds while being in TEMPERATURE state. Left two readouts show setting number (01-14), right two - setting value. Select each setting using SW1, go to next setting using SW2. All settings are written into EEPROM on exit from settings menu when pushing SW2 in FIRMWARE VER. (14) state. If something goes wrong or you do not want to save values you've just entered, disconnect power supply before exiting settings menu.



4.8.1 Hour format (1)

Selectable hour format 12hour (01) or 24 hour (00).
Default 00 (24 hour). Range 00…01.

4.8.2 Leading zero suppression (2)

Selectable leading zero suppression (01) or no suppression (00) on hour readout.
Default 00 (no suppression). Range 00…01.

4.8.3 Autorotate seconds (3)

Each minute between 50 and 59 seconds, seconds is shown in TIME state automatically. 01 – enabled, 00 – disabled.
Default 01 (enabled). Range 00…01.

4.8.4 Autorotate date (4)

Each minute between 45 and 49 seconds, date is shown in TIME state automatically. 01 – enabled, 00 – disabled.
Default 01 (enabled). Range 00…01.

4.8.5 Celsius / Fahrenheit (5)

Selectable temperature readout in Celsius (00) or Fahrenheit (01).
Default 00 (Celsius). Range 00…01.

4.8.6 Date format (6)

Selectable date readout format in DD/MM (00) or MM/DD (01). MM- Month; DD- Day.
Default 01 (MM/DD). Range 00…01.

4.8.7 Shutdown hour (7)

Clock readout may be shut-off during the nigh in order not to disturb and to prolong tubes lifetime. During whole preset period clock readout and blue LED backlight will be shut off. Either button press during shut-off will wake clock for 30 sec. When alarm occurs during shut-off, display will be enabled automatically during alarm time. Shut-off can only occur in TIME state.
Selectable shut down hour.
Default hour 23 (11PM). Range 00…23.

4.8.8 Wake hour (8)

This is a previous setting follow-up. Set wake hour (until which clock readout will be disabled). If shut-off and wake hours are set to the same value, display shutdown will never occur.
Default hour 07 (7AM). Range 00…23.

4.8.9 Calibrate time. Hour (9)

Clock accuracy can be calibrated by adding or subtracting preset amount of seconds after each preset amount of hours passed. The amount of hours can be selected in this step.
Default amount of hours 01. Range 01…99.

4.8.10 Calibrate time. Seconds (10)

This is a previous setting follow-up. Select amount of seconds which will be added (or subtracted) when amount of hours (set in previous step) will be passed. Seconds to be added is constantly lit; Seconds to be subtracted is blinking. In order to keep time as is (neither adding nor subtracting) set 00.
Default amount of seconds 00. Range -20sec…+20sec.

4.8.11 Column separator mode (11)

While displaying time column separator can work in one of the four modes.

- 00 – Disabled;
- 01 – Enabled to constantly lit;
- 02 – Blink 2Hz;
- 03 – AM/PM mode. (lit when PM).

Default mode 02 (Blink 2Hz). Range 00…03.

4.8.12 High voltage (12)

Nixie clock switched-mode-power-supply is designed such that high voltage, required for nixie tubes, could be controlled by software. Higher voltage enables higher brightness but decreases the lifetime of the tubes. Voltage is controlled in 5V steps. Only the last two digits are shown (e.g. 60 means 160V; 85 means 185V; 00 means 200V).

Default voltage 85 (185V). Range 60…00 (160V…200V).

4.8.13 Backlight intensity (13)

Nixie tubes have blue LED mounted underneath. These have selectable brightness to be adopted for best appearance. 00 – Disabled; 01 – Full brightness; 07 – Most dim.

Default brightness 03. Range 00…07.

4.8.14 Firmware version (14)

This step has no settings. It is intended to display current firmware version.

Current version 02.

5 Technical data

5.1 Software

- Time display
  - 12-hour mode
  - 24-hour mode
  - AM/PM display
  - Programmable leading zero suppression
  - Autorotate Date display
  - Autorotate Seconds display
- Date display
  - DD/MM mode
  - MM/DD mode
  - Leap year correction
- Programmable column separator (4 – modes)
- Programmable tubes shut-down during night time
- Visual effects
- Tube's lifetime counter
- Cathode poisoning prevention
- Tube testing routine
- Tubes backlight with programmable brightness
- Temperature display
  - Celsius readout
  - Fahrenheit readout
  - Programmable offset auto correction
- Alarm clock
- Programmable power supply voltage (160V…200V)
- Time accuracy auto correction
- All settings and time are stored into EEPROM memory

5.2 Hardware

- Microchip PIC16F88 main controller
- Programming interface
- Drive mode: 4x1 multiplex
- High voltage power supply with PWM – PI controller and software shut-down
- Dedicated MOSFET driver for high efficiency SMPS
- 2 pushbuttons
- Temperature sensor (0…+99ºC)
- Tubes backlight 4 blue LED
- Alarm buzzer
- Power supply: 9-15V @ 600-1000mA DC; 5.5/2.1mm jack with positive inner. *recommended 12V 1A DC PSU. It does not matter stabilized or not*
- Auto recovery fuse
- High precision (10ppm) timebase XTAL

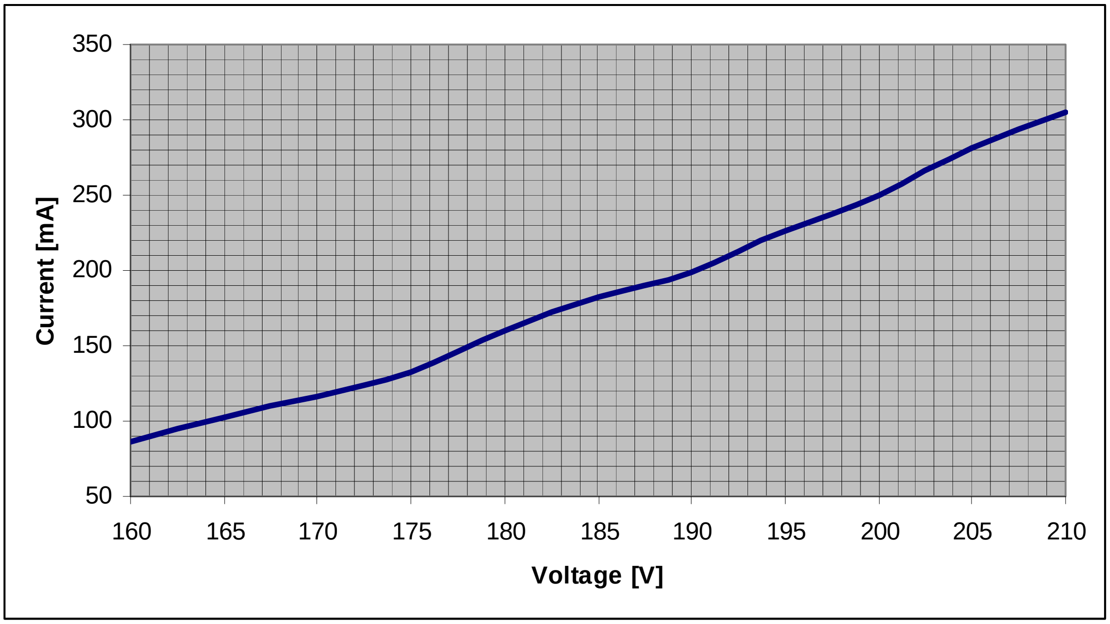
5.3 Mechanical data

- PCB
  - FR4 material
  - Two layers
  - Metal plated holes
  - HAL finishing
  - Solder mask on both sides
  - Silk screen one side
  - Size 105mm x 50mm x 1.5mm (Length, Width ,Thickness)

- IN-16 tube
  - Arabic digits 0-9
  - Correct “5”
  - Shape height 13mm
  - Tube height 42mm + 5mm plastic spacer
  - Expected lifetime 5000 hours or more

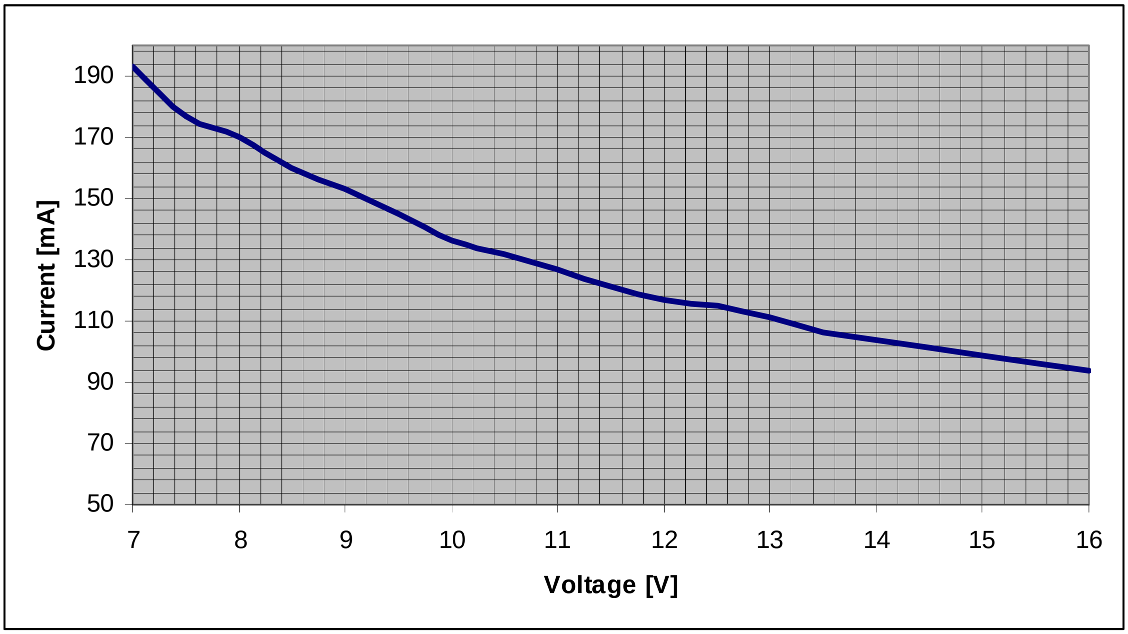
6 Performance measurements

The following measurements have been performed with the NCV3.1-16 nixie clock.

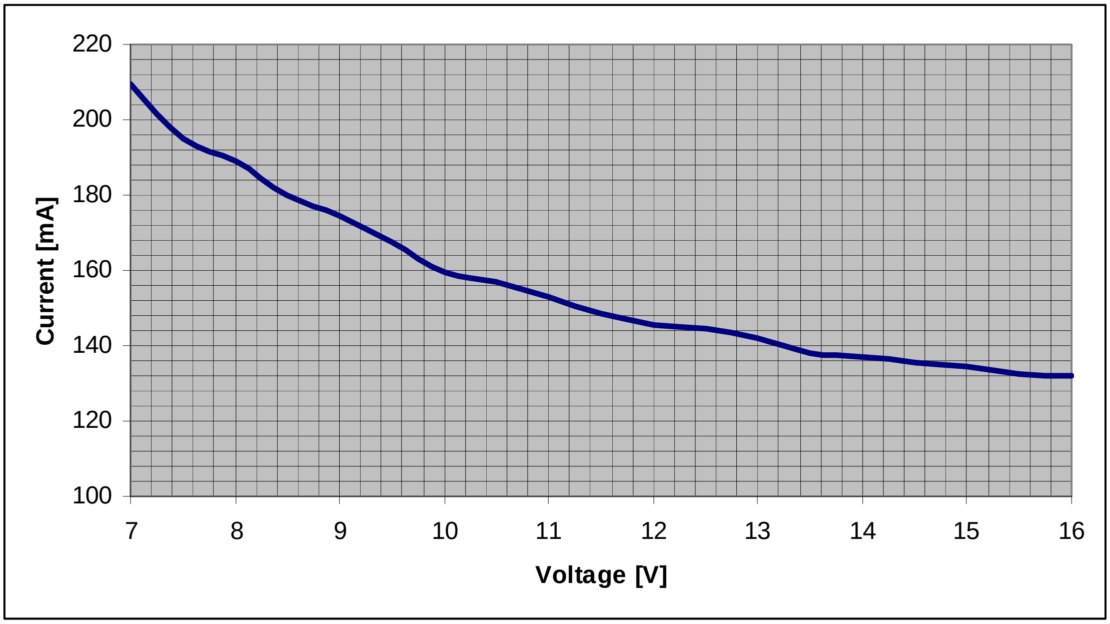


Graph above shows current consumption according tubes' voltage. Power supply set to 12V. Backlight off. Backlight, if enabled at full intensity, adds 24mA to whole range. Please note, voltages above 200V are limited by firmware in order to protect IRF640 MOSFET.

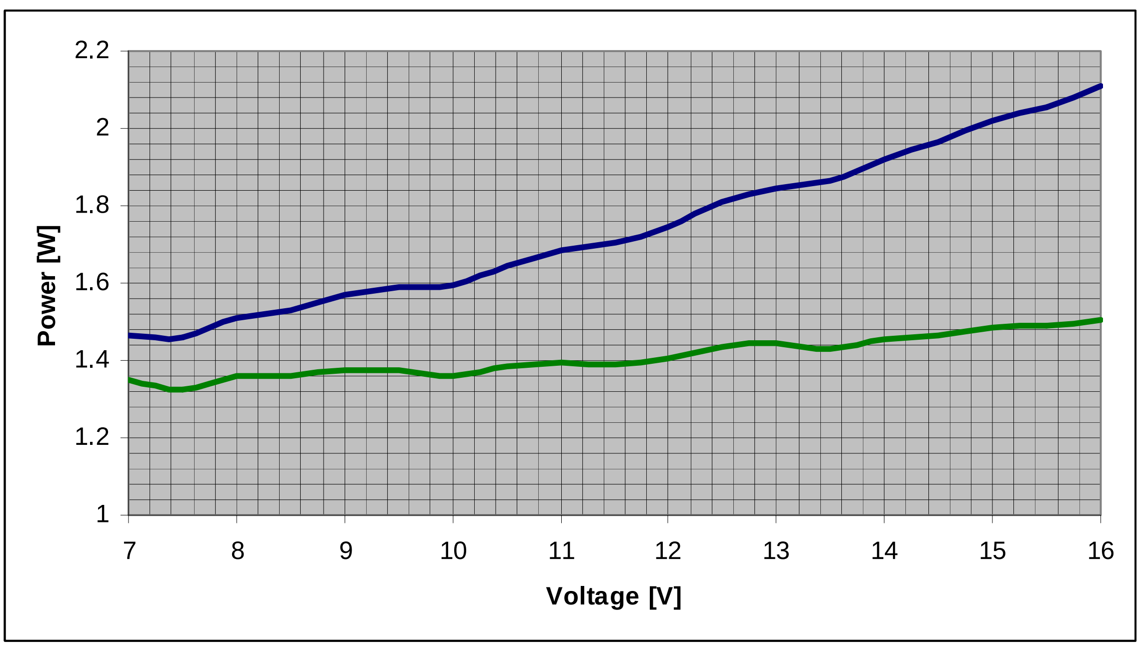
Next graph shows current consumption according to power supply voltage. Tubes' voltage set to 170V. No backlight.

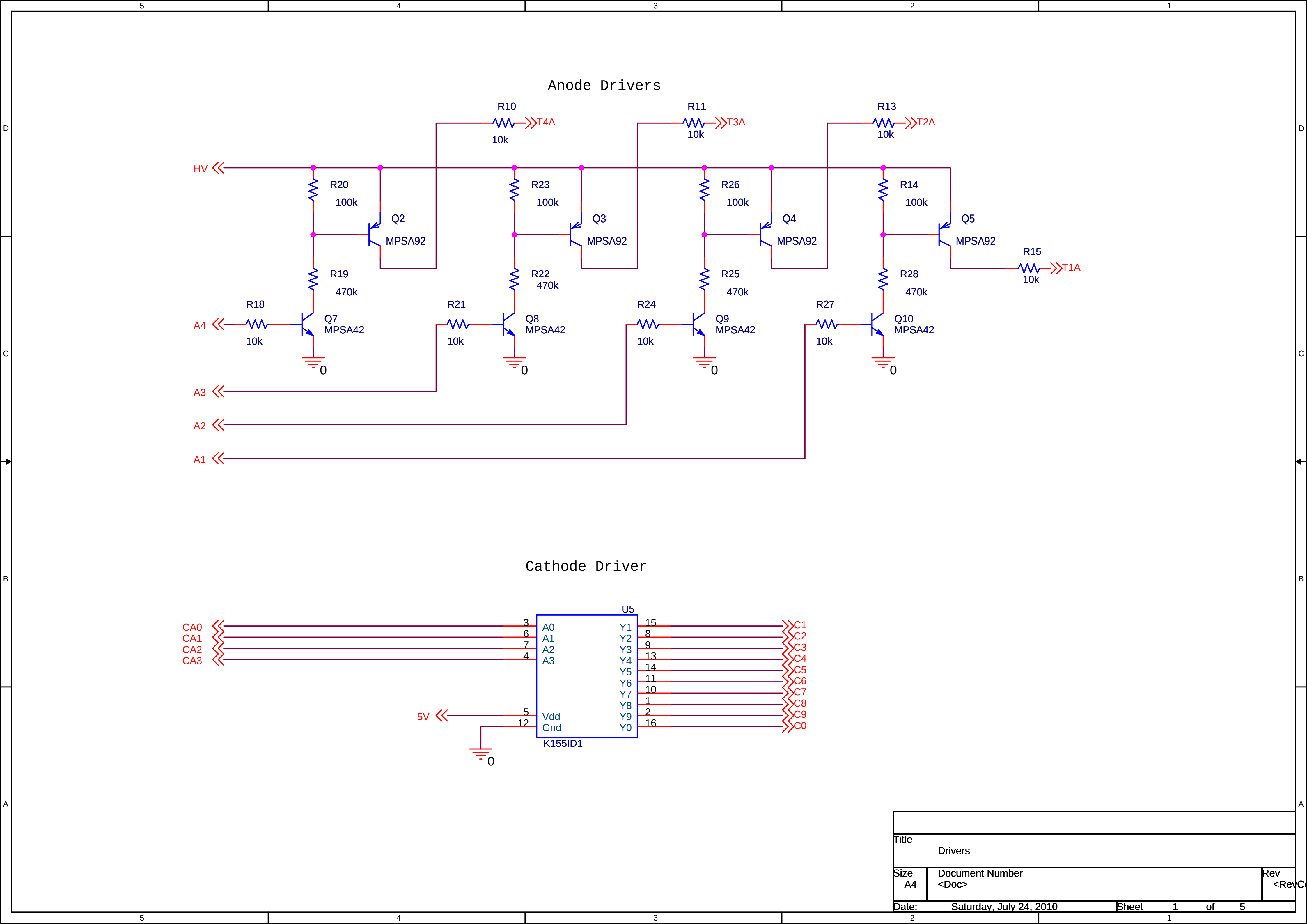


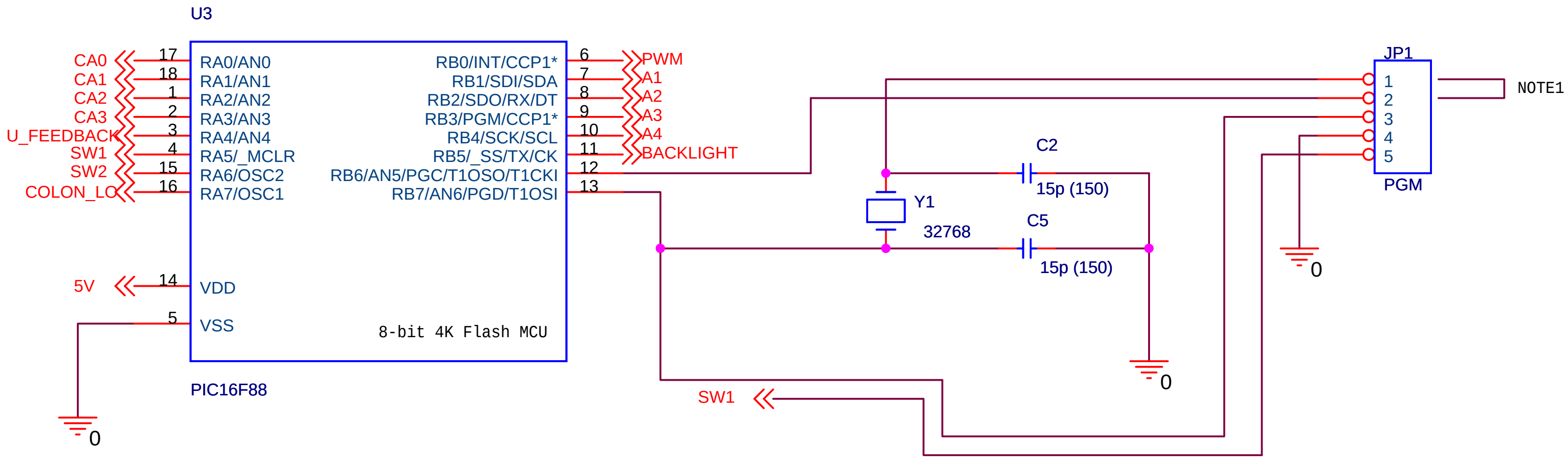
Graph below shows current consumption according to power supply voltage. Tubes' voltage set to 170V. Backlight enabled at full intensity.



Below is shown power consumption graph according to power supply voltage. Tubes' voltage is set to 170V. Blue line shows power consumption with backlight enabled at full intensity, green without backlight.

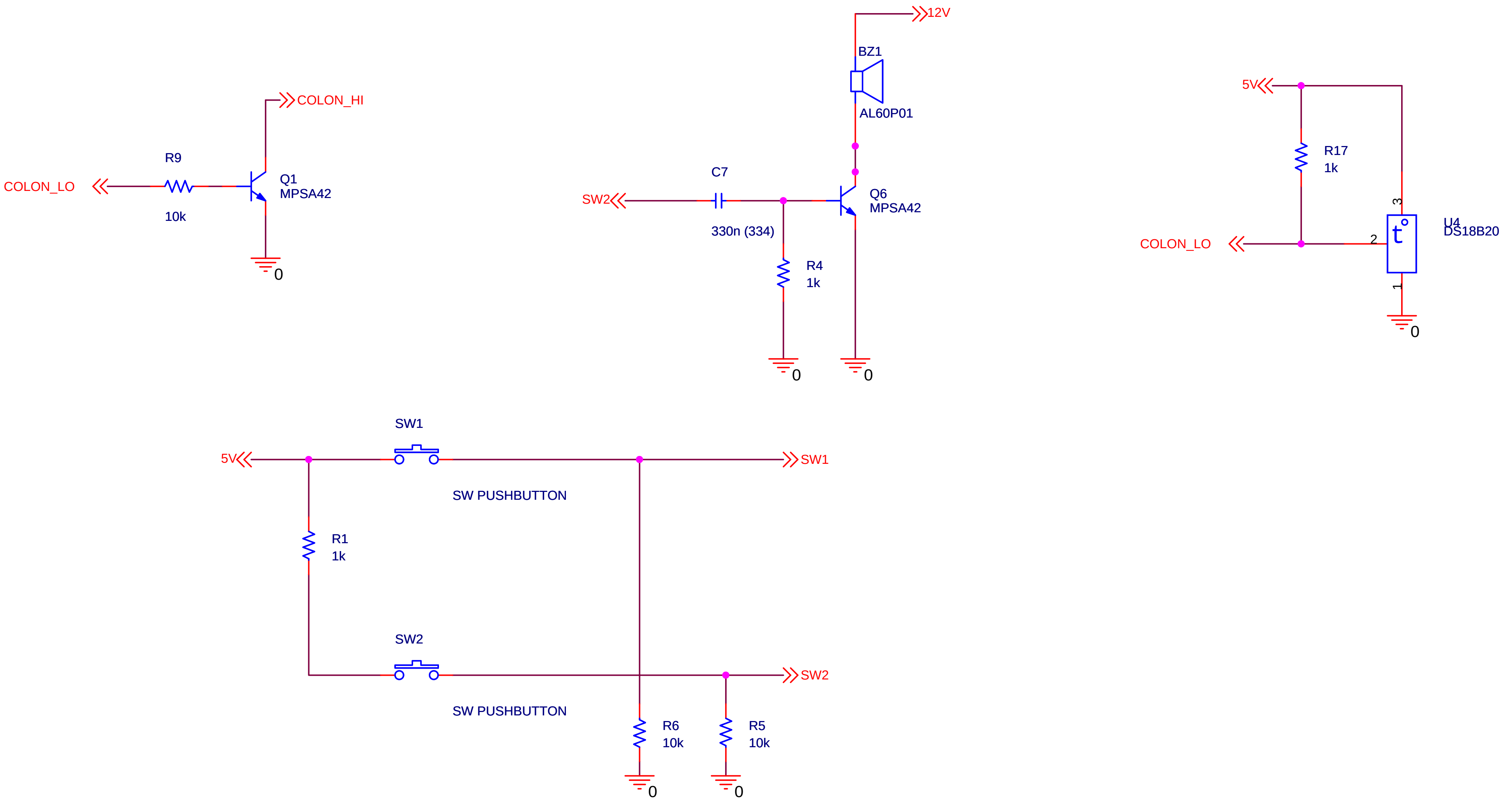



Anode Drivers
HV
R10 10k T4A
R11 10k T3A
R13 10k T2A
R15 10k T1A
R20 100k
R23 100k
R26 100k
R14 100k
Q2 MPSA92
Q3 MPSA92
Q4 MPSA92
Q5 MPSA92
R19 470k
R22 470k
R25 470k
R28 470k
R18 10k
R21 10k
R24 10k
R27 10k
Q7 MPSA42
Q8 MPSA42
Q9 MPSA42
Q10 MPSA42
A4
A3
A2
A1
0
Cathode Driver
U5
K155ID1
CA0 3 A0
CA1 6 A1
CA2 7 A2
CA3 4 A3
5V 5 Vdd
12 Gnd
Y1 15 C1
Y2 8 C2
Y3 9 C3
Y4 13 C4
Y5 14 C5
Y6 11 C6
Y7 10 C7
Y8 1 C8
Y9 2 C9
Y0 16 C0
Title
Drivers
Size A4
Document Number
<Doc>
Rev
<RevCo
Date: Saturday, July 24, 2010
Sheet 1 of 5



NOTE1 - Jumper between JP1 pin #1 and pin #2 is etched on the PCB. It must be removed during programming otherwise should be left inserted. For more information refer to the user's guide.

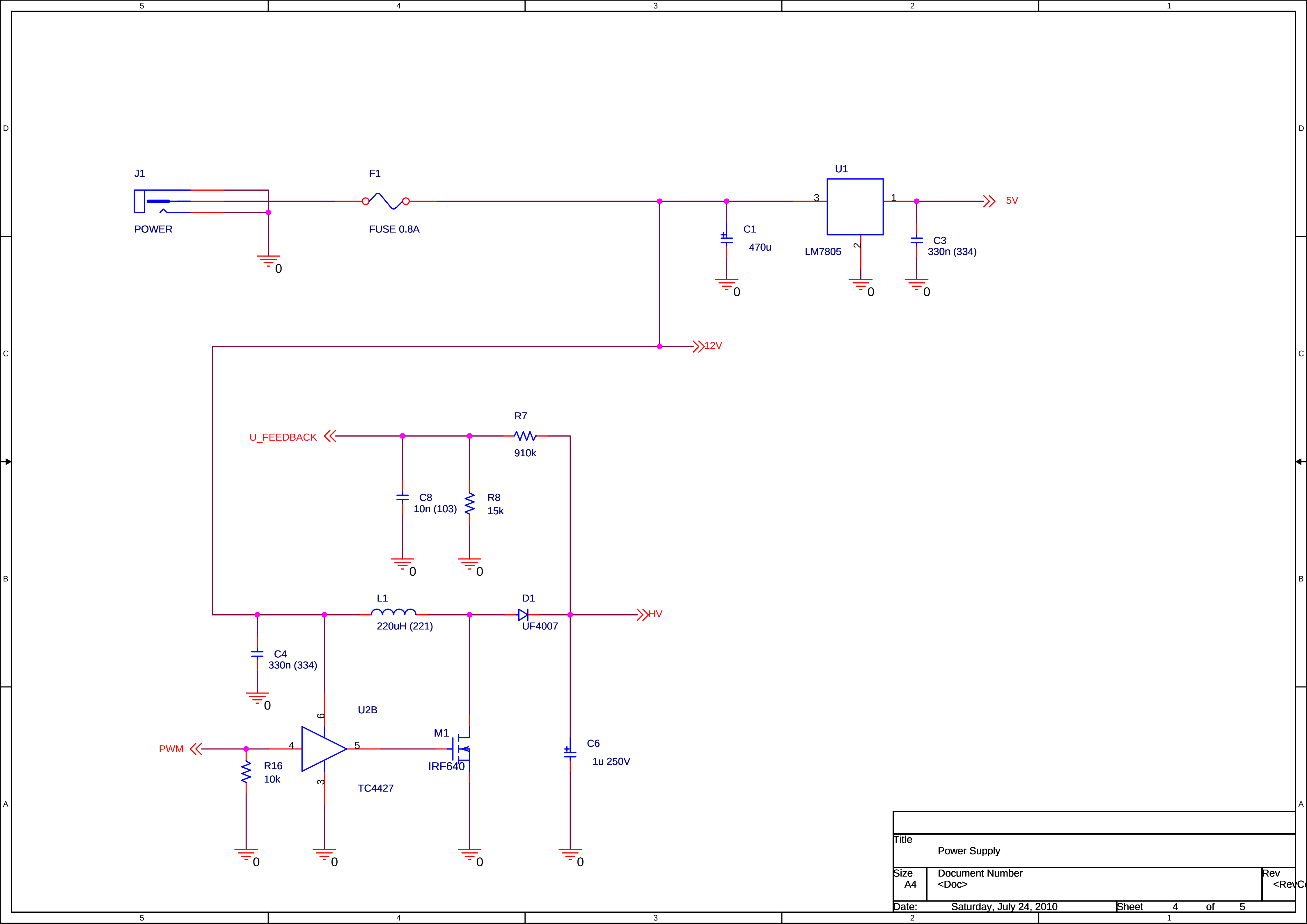
Title	Microcontroller Unit	
Size A4	Document Number <Doc>	Rev 1.0
Date: Saturday, January 01, 2011	Sheet 2 of 5	



Title
Peripheral

Size A4 | Document Number <Doc> | Rev <RevCo

Date: Saturday, July 24, 2010 | Sheet 3 of 5


J1
POWER
0
F1
FUSE 0.8A
U1
3
1
2
LM7805
5V
C1
470u
C3
330n (334)
0
0
0
12V
U_FEEDBACK
R7
910k
C8
10n (103)
R8
15k
0
0
L1
220uH (221)
D1
UF4007
HV
C4
330n (334)
0
U2B
6
4
5
3
TC4427
PWM
R16
10k
M1
IRF640
C6
1u 250V
0
0
0
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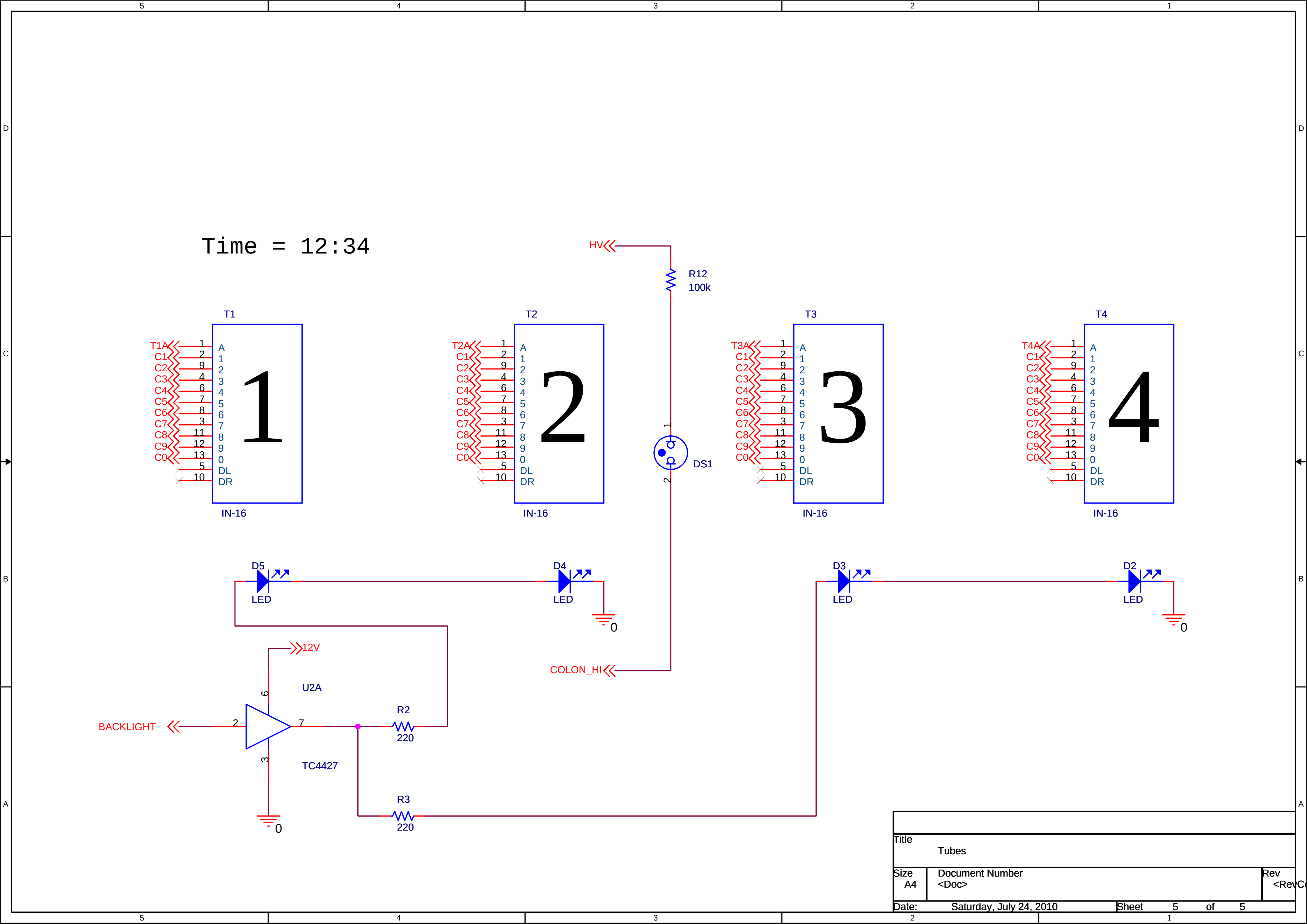
Title
Power Supply
Size
A4
Document Number
<Doc>
Rev
<RevCo
Date: Saturday, July 24, 2010
Sheet 4 of 5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HV
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100k
DS1
COLON_HI
T1
T2
T3
T4
IN-16
T1A
T2A
T3A
T4A
C1
C2
C3
C4
C5
C6
C7
C8
C9
C0
A
DL
DR
1
2
3
4
D5
D4
D3
D2
LED
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TC4427
BACKLIGHT
R2
220
R3
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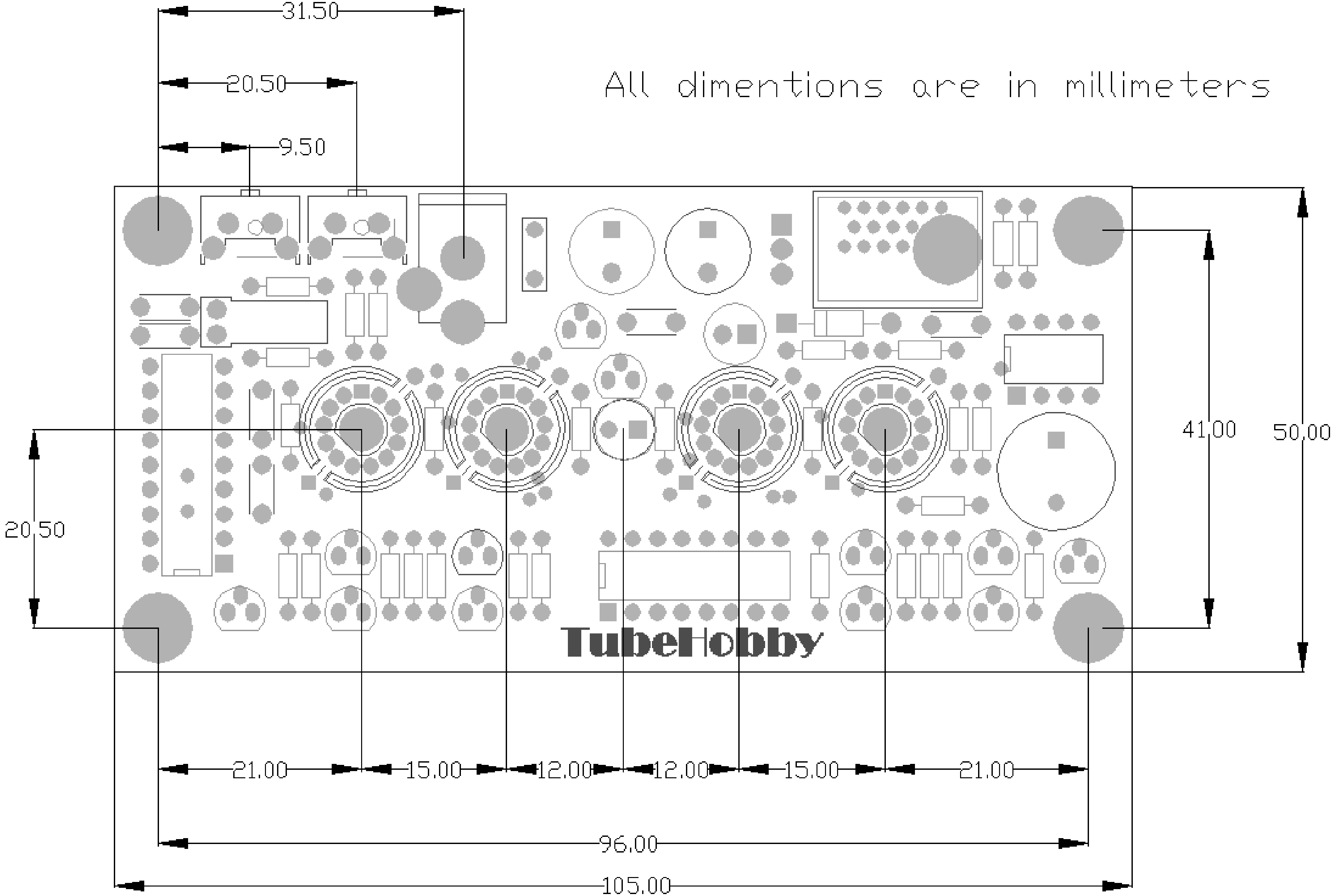
Date:
Saturday, July 24, 2010
Sheet 5 of 5



All dimentions are in millimeters
31.50
20.50
9.50
41.00
50.00
20.50
TubeHobby
21.00
15.00
12.00
12.00
15.00
21.00
96.00
105.00

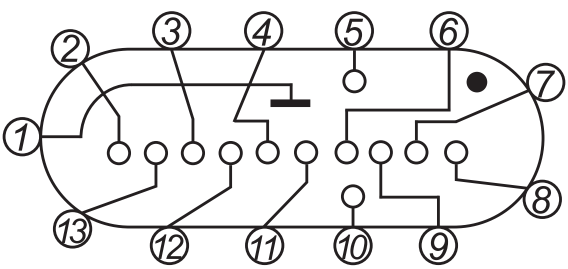
GAS DISCHARGE INDICATOR
DIGITAL IN-16

TECHNICAL SPECIFICATIONS

Digital gas discharge indicator IN-16, with ten cathodes in the shape of arabic numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9 and two cathodes shaped in the form of the sign “comma”, is used for the visual indication of electrical signals in the form of digits in stationary and portable electrical appliances.

Gas-filled capsule form factor is “B”.

Electrode-to-pin connection schematic



Pin numbering starts clockwise from the first pin, which is labeled on the component capsule by an arrow. The pin numbering scheme above is valid when the component is observed from the bottom.

Pin	Electrode name
1	Anode
2	Cathode “1”
3	Cathode “7”
4	Cathode “3”
5	Cathode “comma”
6	Cathode “4”
7	Cathode “5”
8	Cathode “6”
9	Cathode “2”
10	Cathode “comma”
11	Cathode “8”
12	Cathode “9”
13	Cathode “0”

MAIN TECHNICAL SPECIFICATIONS

Parameter name, units of measurement	Norm	
	less than	not more than
Required voltage for gas discharge to occur, V	—	170
Current required for number display, mA		2
Current required for “comma” display, mA	—	0.3
Luminosity, kJ/m²	150	—
Viewing angle, deg	± 15	—

Precious metal content

Does not contain any precious metals.

Non-ferrous metal content

Does not contain any non-ferrous metals.

INSPECTION INFORMATION

Indicator IN-16 complies with technical specifications 3.341.045 ТУ.

QA Stamp ОТК 12

Client representative Stamp

Follow-up testing conducted ______________________
date

QA Stamp Area	Client representative Stamp Area

USAGE INSTRUCTIONS

1. Instructions for application and usage — compliance with ГОСТ В 20368-74 and ОСТ П 339.003-75.

2. Indicators that are used in a one-cathode mode, are only guaranteed to perform correctly on the working cathode.

3. When driven by an alternating current with a cycle of less than 100 µs, the best performance is achieved when one of the commas is used as a “pilot electrode” with a current of 0.7—1.5 µA.

4. If the load resistor is installed on the anode, best performance of the “comma” cathodes is achieved by driving them with 20V lower than the digit cathodes.

5. For best performance of the indicator, it it recommended that the circuit and power supply element be chosen in such a fashion, as to provide the correct range of cathode voltages with the least decrease in the components’ lifelength.

Due to this, it is recommended that a regulated power supply be used with a tolerance of less than ± 5% and a resistor with a tolerance of less than ± 5%.

6. Recommended mode of operation for the indicator under a constant or alternating currrent load with a frequency of 50 Hz.

Power supply voltage, V	190	200	250	300	220
	constant				effective
Load resistor value, kΩ	18	22	39	56	33

As the driving voltage on the indicator increases, the time it takes for the indicator to display the digits decreases dramatically.

7. In order to eliminate the glowing halo on idle cathodes, it is recommended that you provide them with a voltage of plus 60—110 V relative to the cathode used (indicated).

8. If the indicator is used in such a place that it is not being affected by other sources of light and the effect of the surrounding energy sources is lessened due to the indicator being encased in a metal capsule, in order to avoid the possible increase in the voltage and the ready-time of the indicator (the time it takes for the indicator to display the digits), it is recommended that you use artificial lighting with a luminosity level of not less than 40 lumens or one of the “comma” symbols as a “pilot” electrode with a current in its circuit of 0.7—1.5 µA.

9. When creating solder joints, make sure that the soldering iron is located not less than 5 mm from the glass capsule. Be sure to use a clip to divert the heat generated in the soldering process away from the glass capsule. Avoid multiple soldering and de-soldering procedures.

For convenient mounting, the indicators may already be mounted on panels.

10. During the use of the indicators, there may appear glowing regions on the cathode support structures or cathodes that are not covered with gas discharge glow that do not prevent the visual identification of the digits and are less than 2 mm.