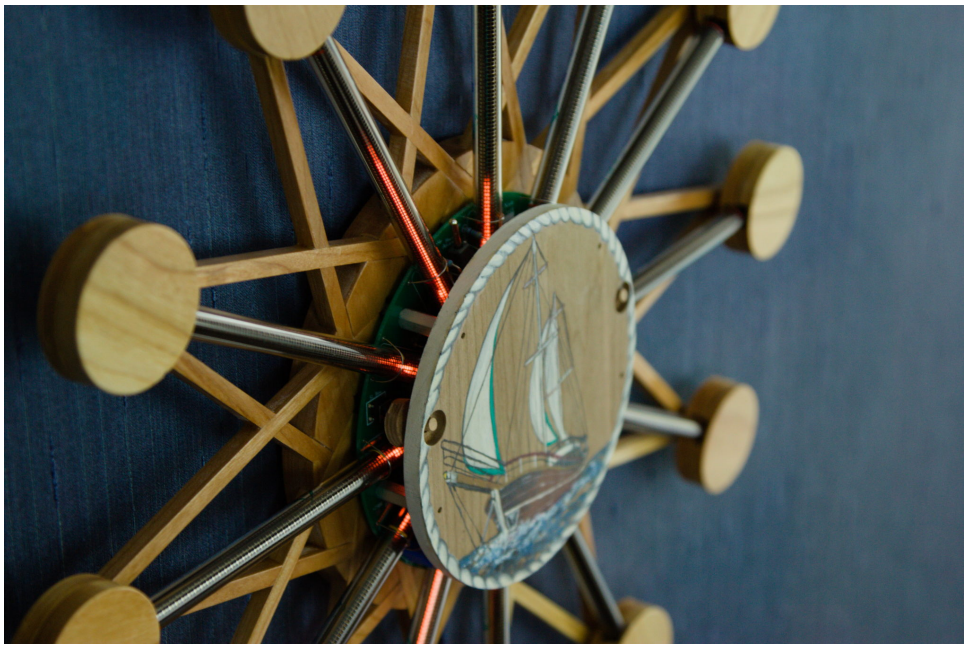
Nixie Star



Nixie Clock Kit

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1 Introduction

The Nixie Star Clock is the second clock kit I have developed. The aim was to have a kit that is reasonably easy to build with intermediate soldering skills ei. minimal SMD component. I also wanted a clock kit that once built any (even mine) wife would accept on their wall, even with a power cord hanging from it.

Obligitory Warnings

1. *This clock operates with high voltages present on much of the PCB as well as many of the component leads. Please be careful, this voltage my remain for some time after power is removed from the device.*

2. *Remember, with semiconductors and some other components, Static Kills! It is best if you work at a static free workspace and use a anti-static strap. Extra care should be given the th 15f super capacitor and the I.C.s*

3. *LM78L05 may be substituded with a 4931CZ50-AP, this part has the same foot print and slightly better specs, either piece works.*

4. *LM78L33 and LM78L05 Look the same!! Be sure you put the correct one in the correct place on the board. Though it may work for a while, the Super Cap cannot take 5 volts for long if at all!*

2 Reading the Clock

The tubes are lit up in three different lengths. The longest length reflects the course minute hand. It shows the time in 5 minute increments. The medium length reflects the hour. The movement the shortest length reflects the seconds passing by; rotating like a propeller on an airplane or the blades on a fan with the number of the lamps lit indicating the number of minutes past the five minute increment shown by the longest length.

For example:

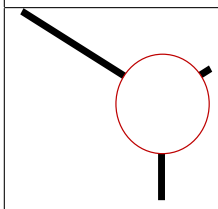
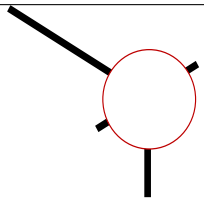
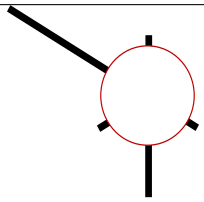
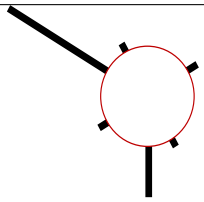
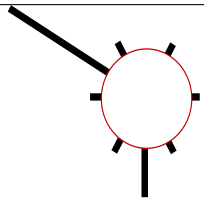
6:50	6:51	6:52	6:53	6:54
				

Table 1: Reading the Minutes

3 Setting the Time

There are 2 buttons on the face of the clock and one switch between the 11 and 12 o'clock lamps for setting the time.

The button on the right hand side of the face is the 'Fast Forward'. Pressing and holding it will advance the time by 10 minutes roughly once a second.

The button on the left hand side of the face is the 'Slow Forward'. Pressing and holding it advances the clock by 1 minute roughly once a second.

Pressing and holding both buttons will pause the clock at the current time until it is released.

Any of the above will set the internal time to the start of the minute.

The switch between the 11 and 12 o'clock lamps is to aid in Day Light Savings Time. Pushing the handle down towards the 11 o'clock lamp will move the hour hand back by 1 hour. Pushing the hand up towards the 12 o'clock hand advances the hour hand forward one hour. This switch can also be used to move the time forward or backwards by multiple hours by pressing it in the desired direction multiple times.

The easiest way to set the time is to set it to 1 minute past the current time and pause it until the real time reaches the time on the clock and releasing both buttons. The clock will do a dance then set itself to the time you set.

4 Required Tools and Skills

4.1 Electronics

- Soldering Iron with a small tip,
- Wire cutters,
- Needle Nose Pliers,
- Dremel Tool or small Saw (optional for cutting out the PCB)

4.2 Wood Case

- Wood Glue,
- Clamps,
- Xacto knife or equivalent
- Some basic wood working skills,
- Sandpaper both medium and fine grits
- Wood Glue
- Wood clamps
- Laquer or other wood finish

5 Schematics

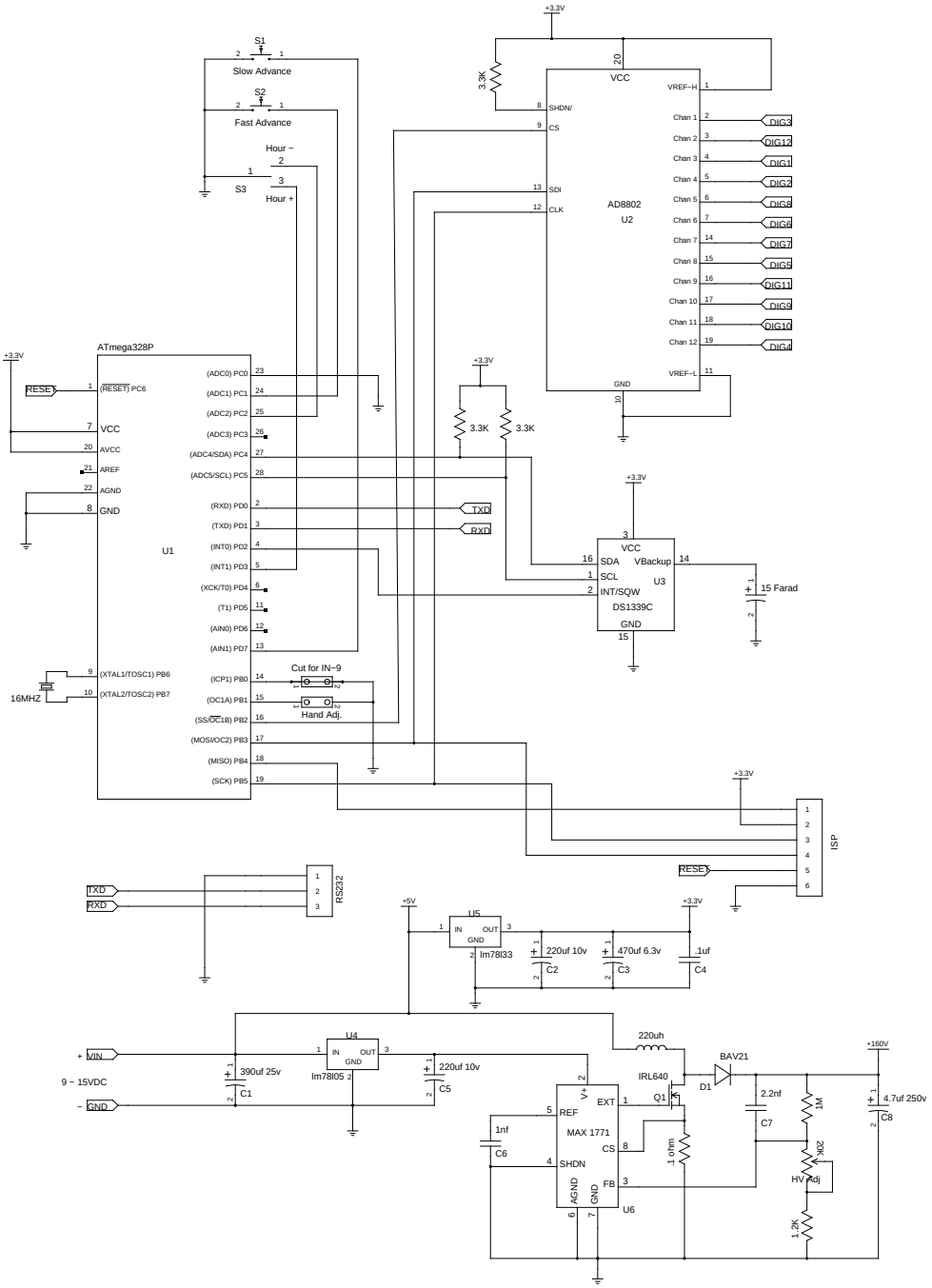


Figure 1: CPU and Peripheral Components

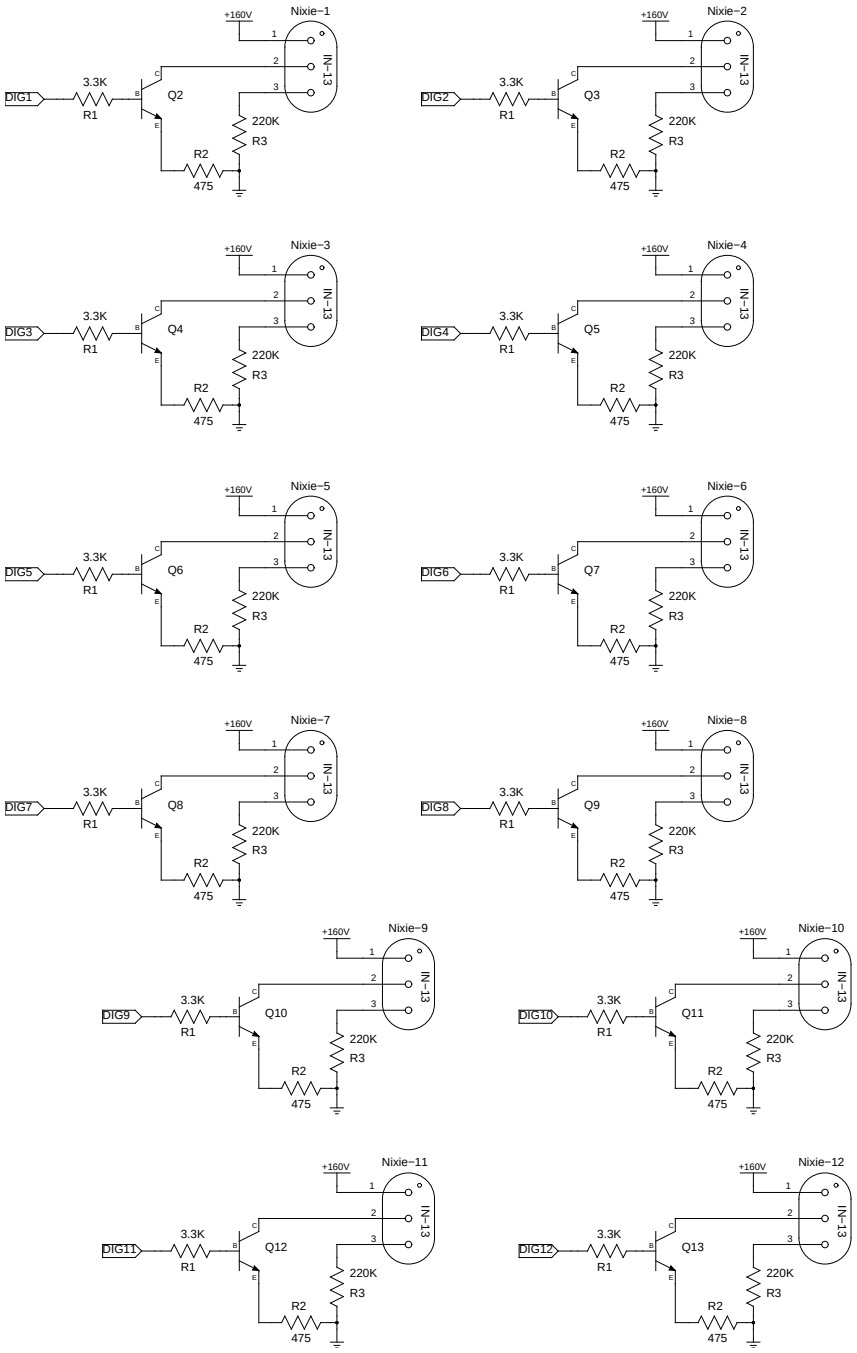


Figure 2: Nixie Display (Values shown for 15in clock)

6 Circuit Description

The clock operation is pretty straight forward. The Maxim DS1339C keeps the time. It has an internal crystal as well as circuitry to keep the super capacitor charged so it is ready for duty on the loss of power. This chip also feeds a 32Khz signal to the processor for it's timing reference.

The processor is an Atmel ATMega328. It controls the lamps as well as monitors the buttons. It's code is pretty much driven by the 32Khz signal from the clock chip. As needed it sends out the value to set the 12 channel D/A converter.

The D/A converter is a Analog Devices AD8802. It has 12 channel independent channels which are controlled through the SPI bus. It's output are tied to the 12 drivers for the nixie bar tubes.

The operation of the nixie bar tubes is pretty straight forward. There are two types of tubes. The slightly longer 3 terminal IN-13 tube and the shorter 2 terminal IN-9. My description will be put in the laymens terms as I understand them. The 3rd terminal on the IN-13 is tied through a high resistance to ground and helps ensure that the lamp lights from the bottom. The other two terminals are the cathode and the anode. The anode is tied directly to the 160V power supply while the cathode is tied to the collector of the NPN driver transistor. The D/A convert puts the desired voltage on the base of the transistor which allows current to flow through the transistor and the tube. As the voltage on the base increases, the current through the tube increases and more of the cathode is lit up.

The interesting tidbit I have learned is that the tube does not respond well to large increases or decreases in current which come to quickly, Especially fast decreases. The IN-9 is more sensitive to this than the IN-13.

To overcome this, you will see that the code makes the tubes grow and shrink in size as time causes the hands to move.

In addition to the above, there are also provisions to access the serial port and the ISP port for development. These are not populated in the kit as they are not needed for anything during normal operation.

7 PCB Assembly

Obligitory Warnings

Do not remove the center PCB from the outside square, contruction of the board will be easier if you leave it on until all of the parts are installed on the board.

Place the short standoffs on the bottom of the PCB and the long standoffs on the top. This will allow you to flip the board upside down when soldering. The holes for these while building the clock will be in the corners of the PCB.

7.1 Low Voltage Power Supply

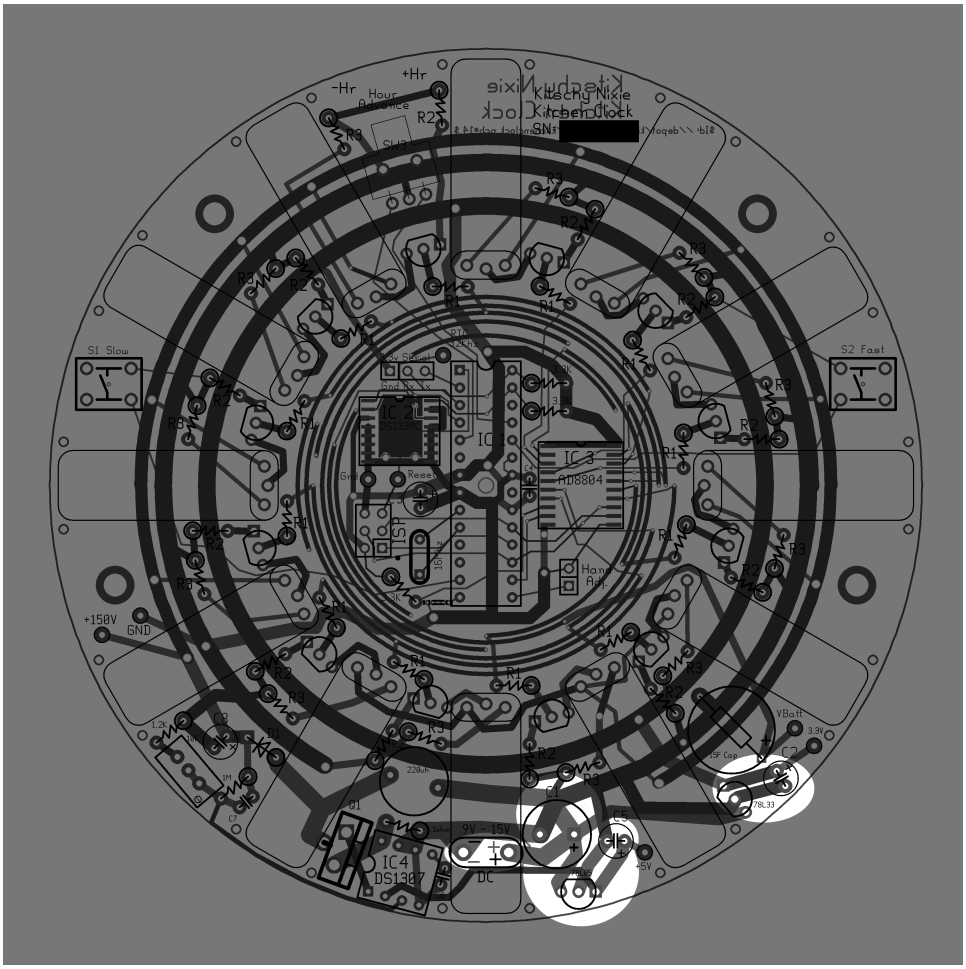


Figure 3: Low Voltage Power Supply Component Placement

- Install the C1 330uf cap, the C2 & C5 220uf caps being mindful of their polarity, followed 78l05 (or 4931CZ50-AP) and 78l33 regulators being careful to put them in the correct place and that you have them properly oriented.
- Now solder the provided 2 conductor wire with barrel jack to the two pins labeld ”9V - 15V DC”. Be sure to mount this wire onto the bottom of the PCB. It is important that the lead with the white stripe is place in the hole marked with a + sign. This marking in in the silk screen on top and in the copper on the bottom of the board.
- When you apply voltage, you should see 5.0 volts on the +5V test point and 3.3 volts 3.3v test point.
- Remove power.

7.2 High Voltage Power Supply

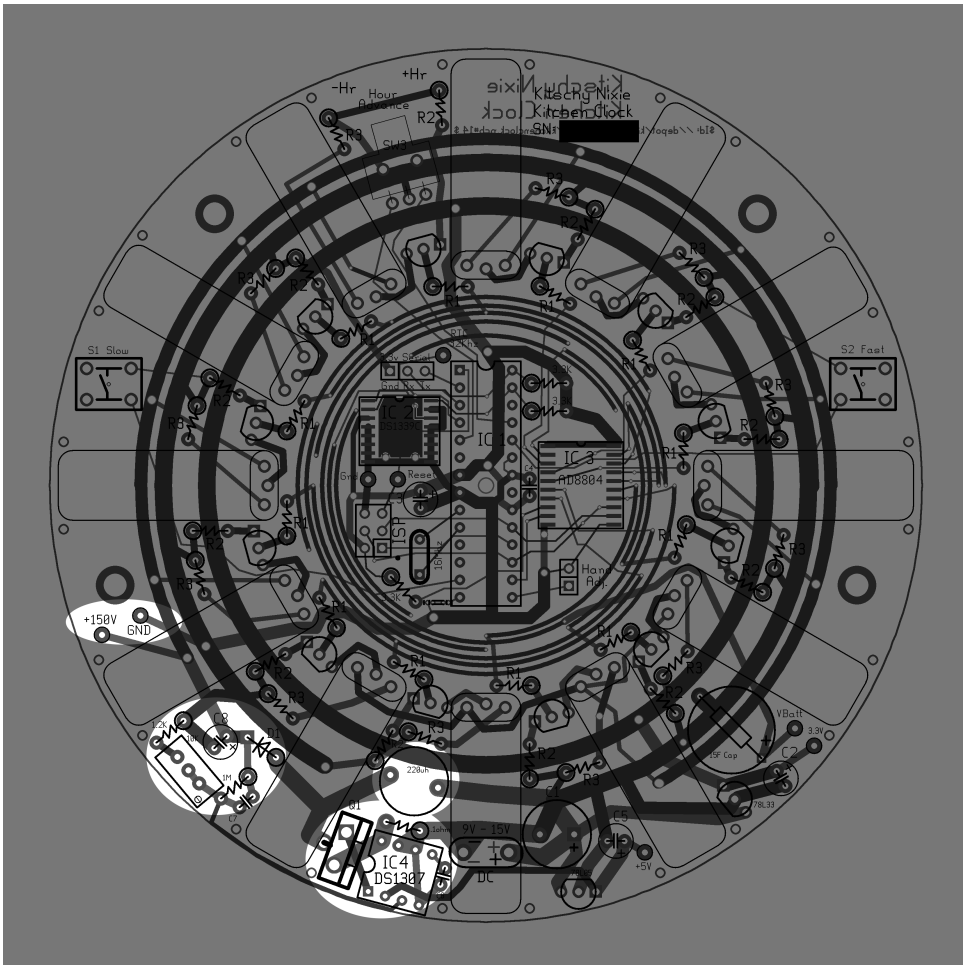


Figure 4: High Voltage Power Supply Component Placement

- Install the DS1307 IC, .1 ohm res., C7 2.2nf cap., 220uh coil (maybe substituded with a 150uh coil), C6 1nf cap., 1.2kohm res., C8 4.7uf cap. and diode (observe polarity for both of those parts) , and potentiometer.
- Solder in the IRLS640A MOSFET in. Insert it to where the leads just go through to the component side which will allow it to be bent over the DS1307 I.C.
- Apply power once again. Verify the presence of some voltage (hopefully above 50 volts) between the +150V pin and the GND pin.
- Adjust the potentiometer until this voltage reads 150V.
- Verify that there is no high voltage on any of the pins/pads of the unpopulated ICs.
- Remove power. For ease of assembly, you can unsolder the power cable at this time as well.

7.3 SMD Components

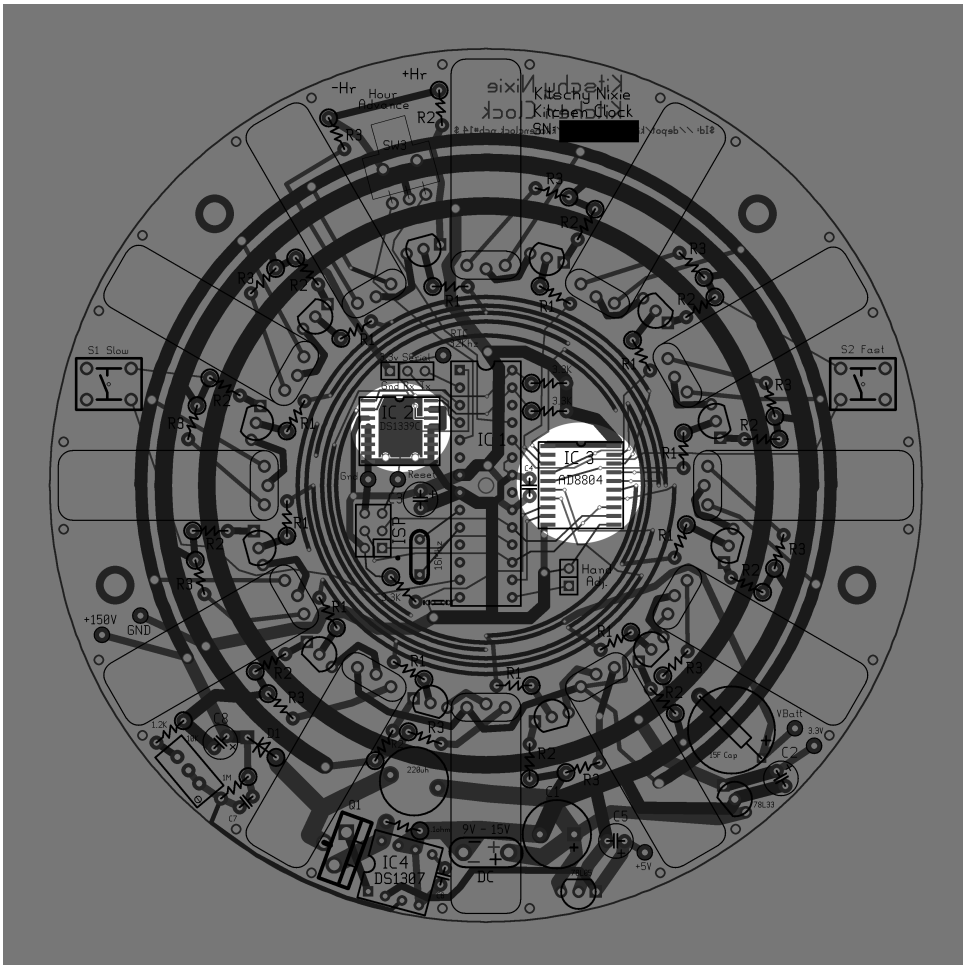


Figure 5: SMD Component Placement

The easiest way I found to solder the SMD chops on to the board is to tin one corner pad of the chip and then solder the chip to that corner. After this you can rotate the chip small amounts to make sure all of the pins are sitting properly on their pads. Then solder one of the other corners. After this you can solder the remaining pins. Use very small amounts of solder. It is very easy to create solder bridges.

- Solder the ADC8804 onto the board.
- Solder the DS1339C onto the board.

7.4 CPU Components

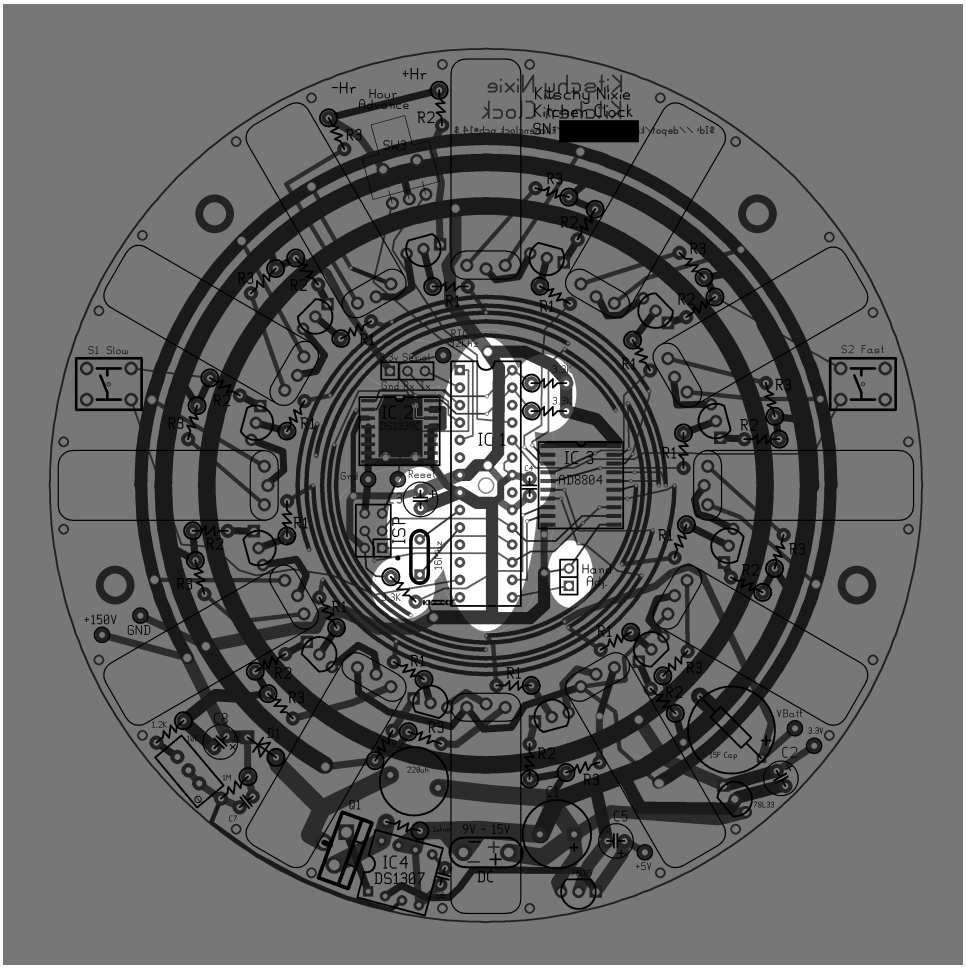


Figure 6: CPU Components Placement

Install the following:

- 16Mhz Crystal,
- C3 - 470uf Capacitor (Watch the polarity!),
- C4 - .1uf Capacitor,
- 3 3.3Kohm Resistors,
- 2 Pin Header labeled 'Hand Adj.'.
- 28 pin I.C. socket.

7.5 Switches

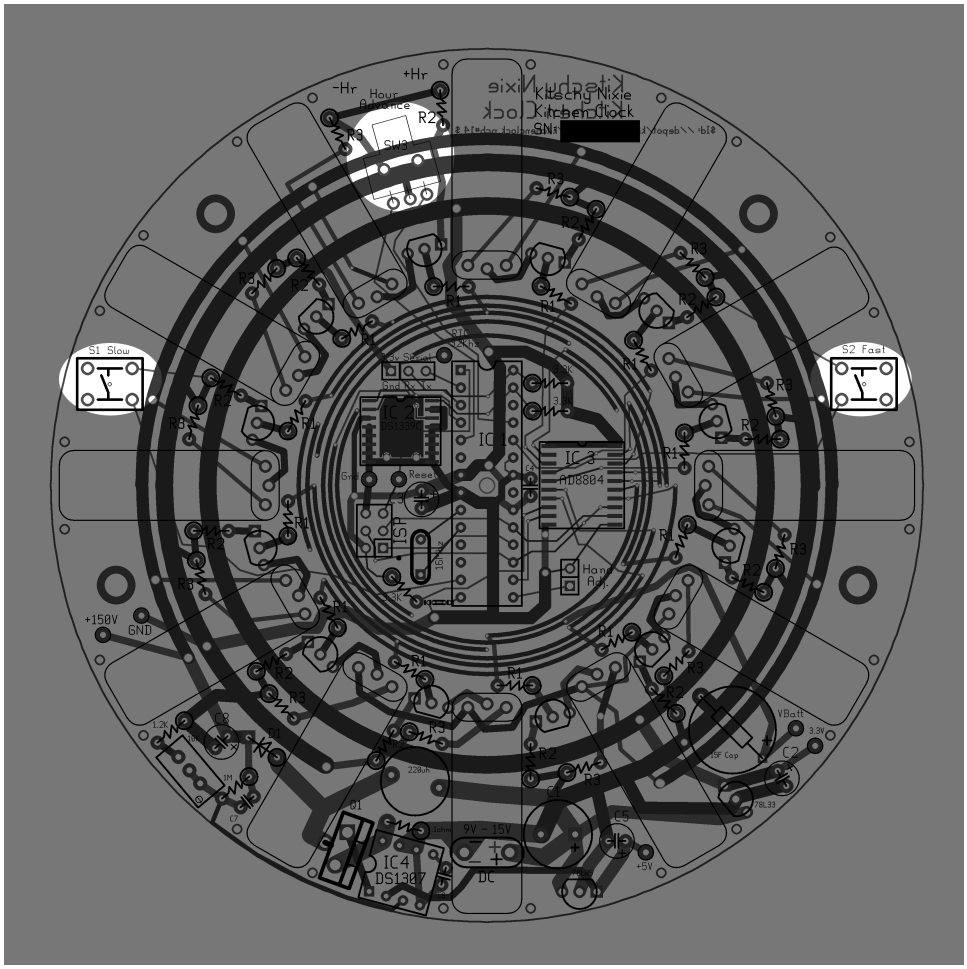


Figure 7: Switch Placement

Install the two Push Button Switches and the Toggle Switch

7.6 Transistors

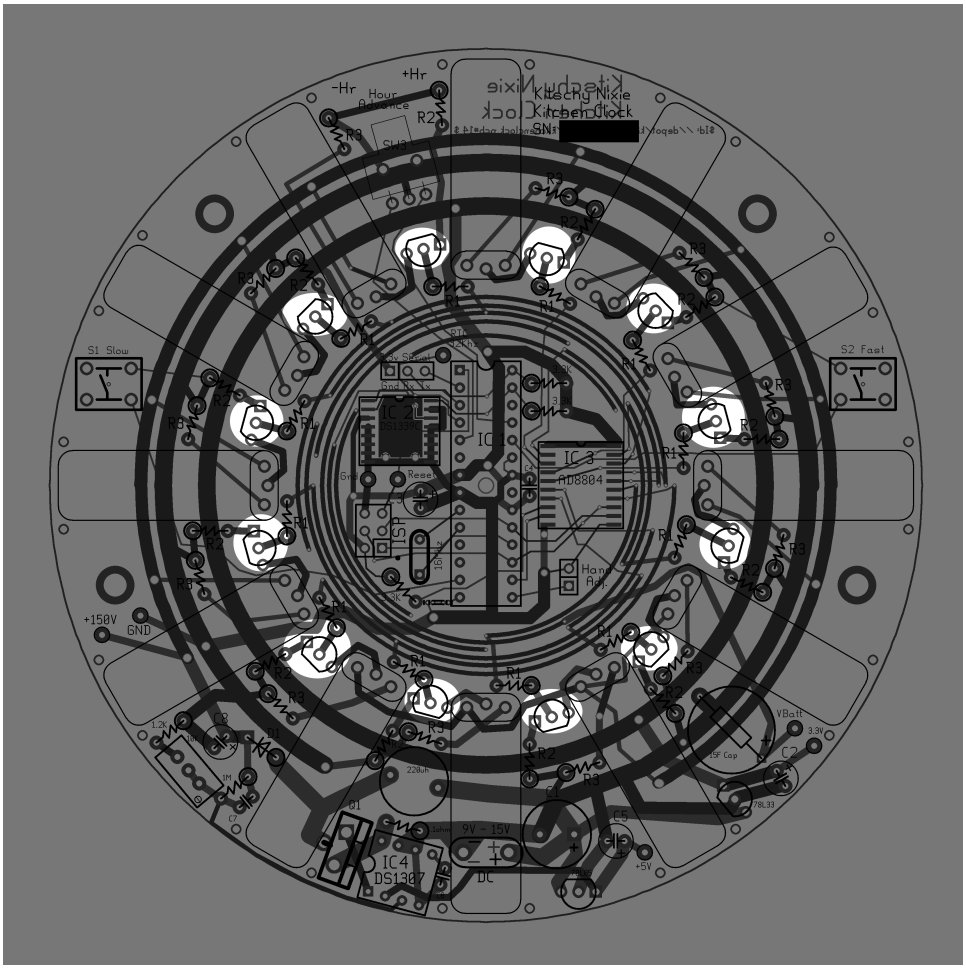


Figure 8: Transistor Placement

Solder in the 12 transistors now.

7.7 R1 Resistors

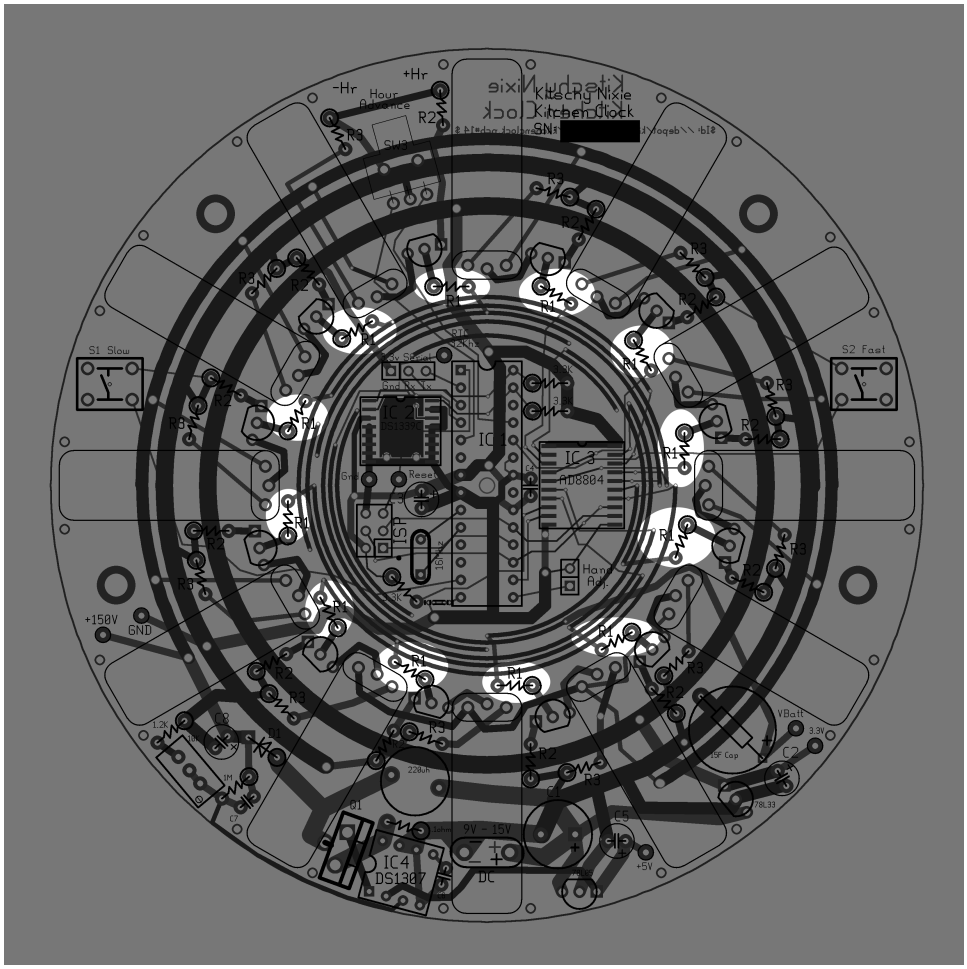


Figure 9: R1 Resistor Placement

Install either 3.3K for the IN-13 tube or 2.1K for the IN-9 tube for the R1 resistors where shown.

7.8 R2 Resistors

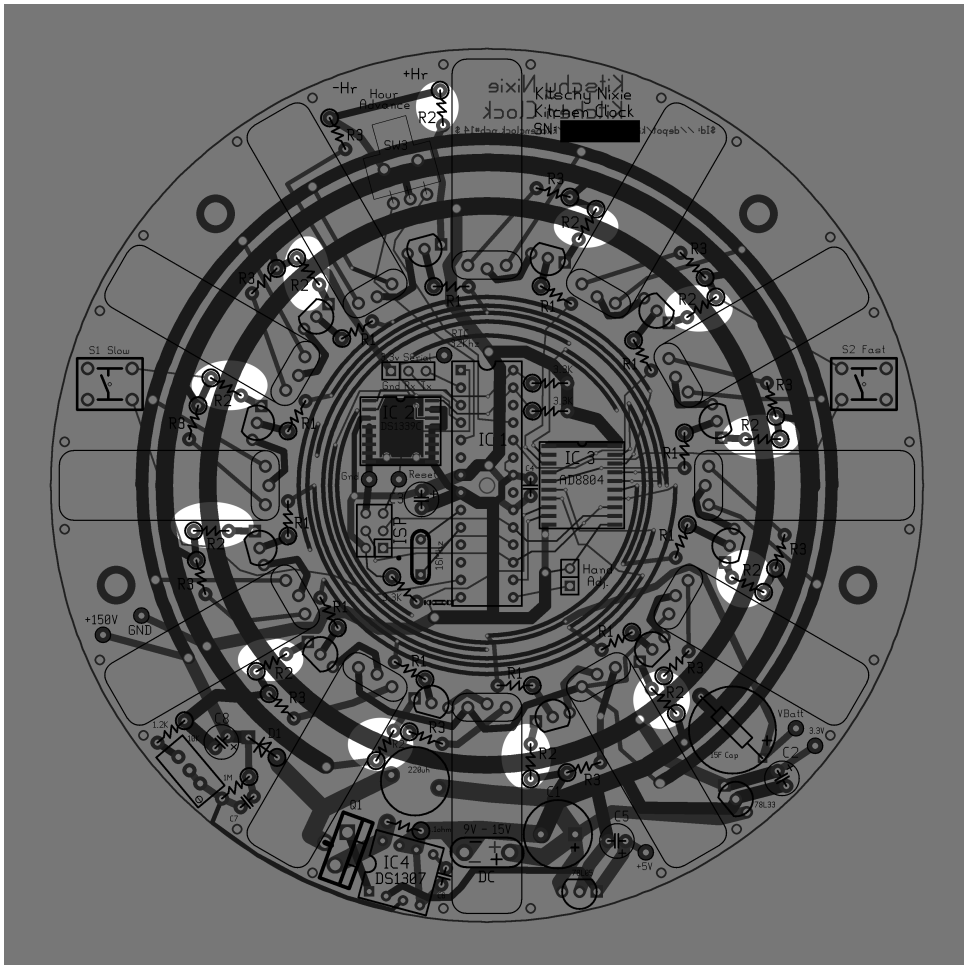


Figure 10: R2 Resistor Placement

Install either 475 ohm for the IN-13 tube or 168 ohm for the IN-9 for R2 resistors where shown.

7.9 R3 Resistors

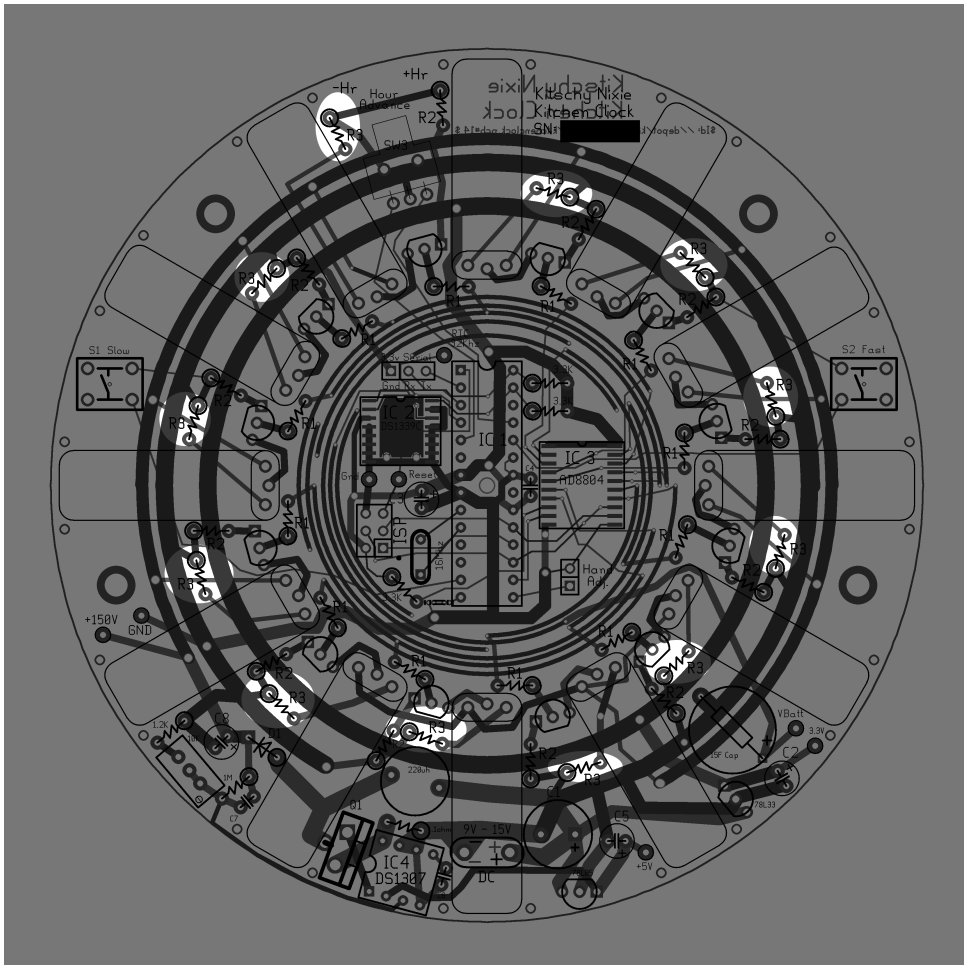


Figure 11: R3 Resistor Placement

For the IN-13 tube, install the 220K resistors for R3 where shown. R3 is not used with the IN-9 tube.

7.10 Super Capacitor

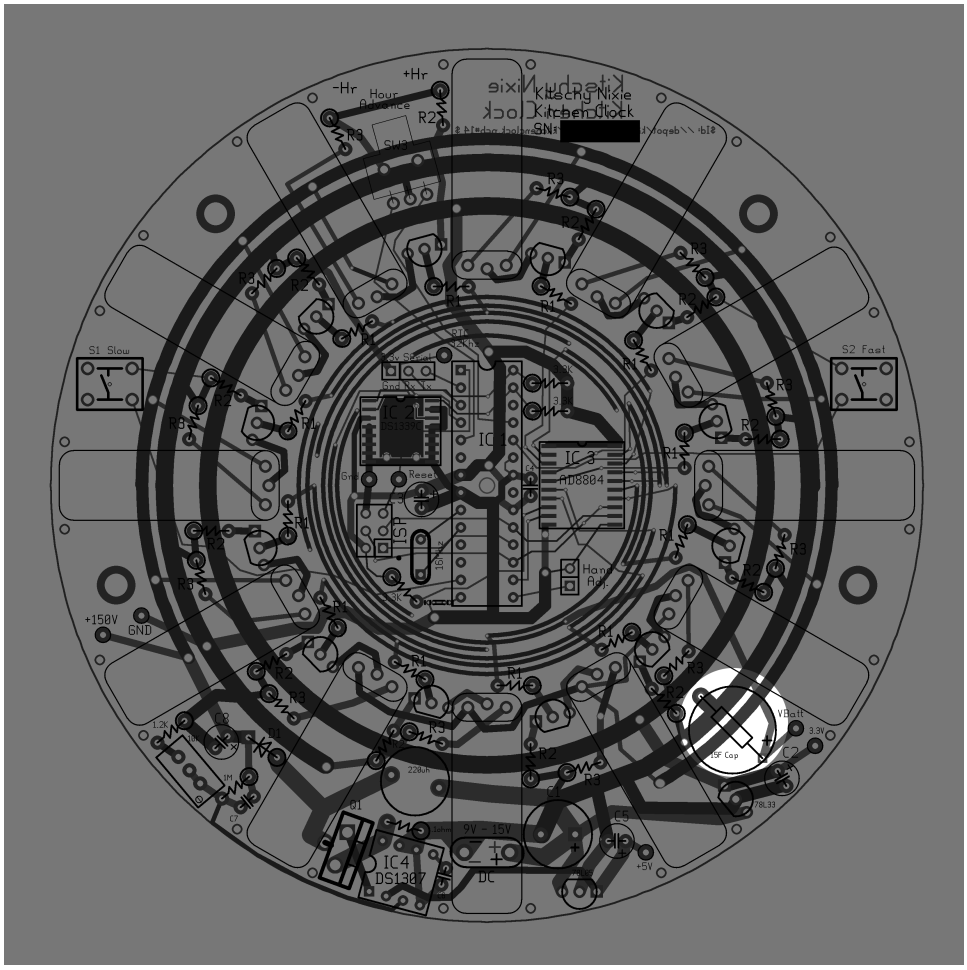


Figure 12: Super Capacitor Placement

Install the the Super Capacitor being mindful of it’s polarity.

7.11 Nixie Tubes

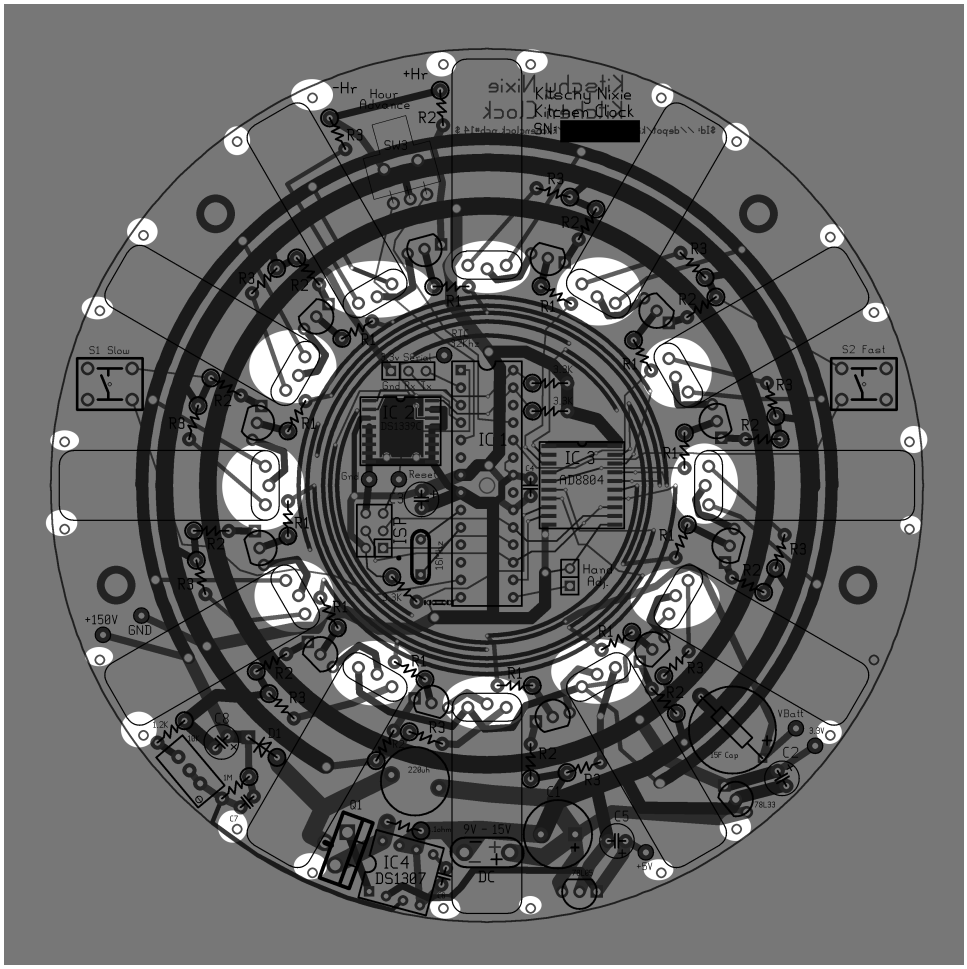
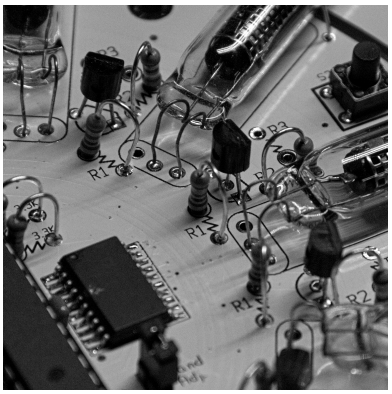


Figure 13: Nixie Tubes Placement

IN-9 / IN-13 Tube Leads!



1. *It is important that the leads of the tubes has a bend in them as shown in the drawing above. With out this bend you run the risk of cracking their bases when you install them in the case.*
2. *IN-9 Tubes are shown, note which holes the the leads go in. IN-13 tubes have 3 leads.*

Install the Nixie Tubes where shown. Each tube should be secured to the board with a 2 1/2" piece of the supplied bare nichrome wire between the holes on either side of the tube.The ends of the wire can be passed through the holes and twisted together on the bottom of the boar without soldering.

7.12 Install CPU

Install the CPU into the 28pin socket. Be sure to have pin 1 in the top right hand corner of the socket.

8 PCB Checkout

Plug the adapter in to the wall and power on the circuit.

The lights should light to some degree and you should be able to see the clock attempt to set it's self to some arbirary time.

Verify that there is between 130V and 150V on the 150V test point. Overall, higher voltage is not better.

Some of the lamps will not glow at full length. To fix this, place the Jumper across the *Hand Adj.* header. This will sequence the hands at full length. Allow this to run for at least 12 hours to allow the hands to 'burn in' and reach full length.

The lengths of the hands can be fine adjusted to some degree after the burn in time. Leave the jumber in place and click the *S2 Fast* button. This will move the active hand from hand to hand. Clicking the *S1 Slow* button will return it to the burn in mode. To adjust the length of any hand, use the *Hour Adj* switch located between the 11 O'clock tube and the 12 O'clock tube. The *Hr-* side will shorten the length, the *Hr+* side will increase the length. Don't be surprised when you click past the maximum length, the tube will shut off as you roll over the 8bit counter. Just click *Hr-* to bring it back.

Once you have all of the tubes adjusted, remove the *Hand Adj.* jumper. The clock should go to some time. If it does not, cycle power.

Gently break the outer square away from the inner circle of the PCB. Move the standoffs from the holes in the square piece to those of the clock.

Congratulations!!! You have completed the electronics portion of your clock. Set the time and Enjoy!

9 Case Construction

Handling the Boards!

Care must be taken when handling the boards. Especially the ones with the circles. If you just use presure to 'break' the small ribs holding the pieces to the boards, some of them will take a way a piece of wood from the piece. Half of the circles, this scar will be very visible. On the face and other pieces it won't be as nociable, but it will be seen on close inspection.

If you ordered the case, 5 wood boards should've been in the box as well. The 4 thin boards are a face board, a 'sticks' board and two circles boards. The Thick board has the base and 4 buttons of which two will be used.

9.1 Removing the Pieces from the Board

Using an exacto knife, or wire cutters (the knife is better), cut each of the ribs that hold the pieces to the boards. As you separate them from the boards group them, Each of the three sticks in a line should stay together. There is a long stick, a medium stick and a very short stick. There are top circles and bottom circles. You can tell the difference betweem them by the top circles not having holes or cuts of any sort on one of the flat sides.

Waste wood from the sticks

Keep the 'throw awy portion of the sticks board, some of this wood will be used below.

9.2 Circle Assembly Preperation

Lightly sand the flat surfaces of each circle. Smooth and sand the sides of the circles trying to remove as much evidence of the ribs as possible. Separate the bottom circles from the tops. The bottom circles have 2 holes drilled completely through.

9.3 Bottom Circle Assemblies

Cut 24 1 1/2in lengths of the scrap wood the sticks, smooth them and then glue them to the flat side of the 'bottom' circles, Use wood clamps to hold then until the glue sets.

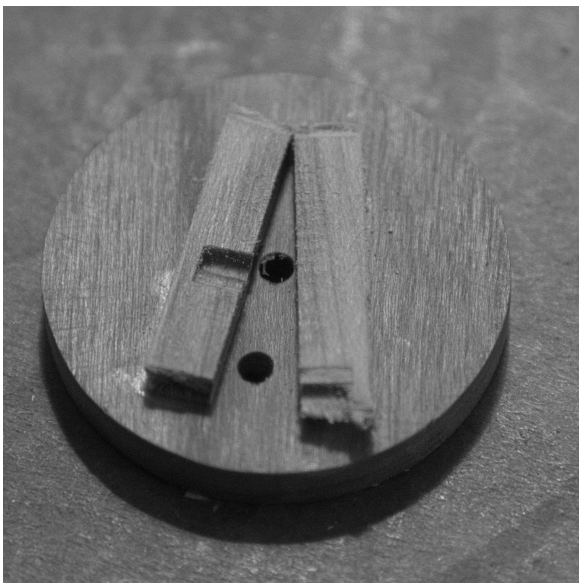


Figure 14: Circle Assembly

9.4 Top Circle Assemblies

Cut 3/8in pieces of dowel and glue and insert them into the small hole on the top circles.

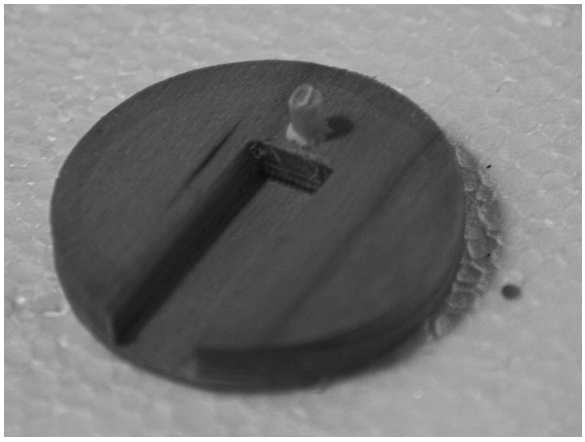


Figure 15: Top Circle Assembly

9.5 Base Preperation

Sand the top (the side with the grooves) and sides of the base. Smooth the sides where the ribs were.

9.6 Stick Assemblies

Lightly sand the sides of the sticks. Work with them a pair at a time, a long stick and a shorter stick (we sill worry about the short little nubs later in the process). These two pieces will go to gether as shown in Figure 16. Be carfull not to oversand them. Test them occasionally to see if they fit snuggly into the grooves in the base.

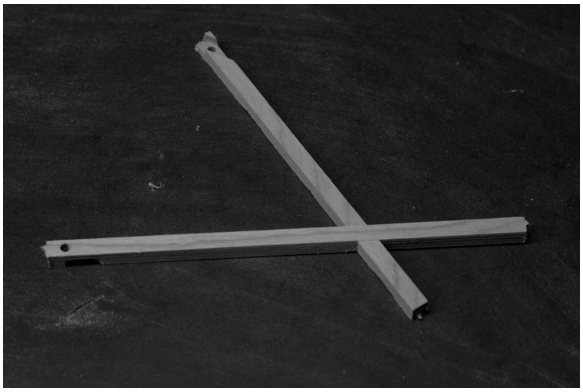


Figure 16: Stick Assembly

As a final test before glueing them together ensure they fit into the base as a unit as shown in Figure 17.

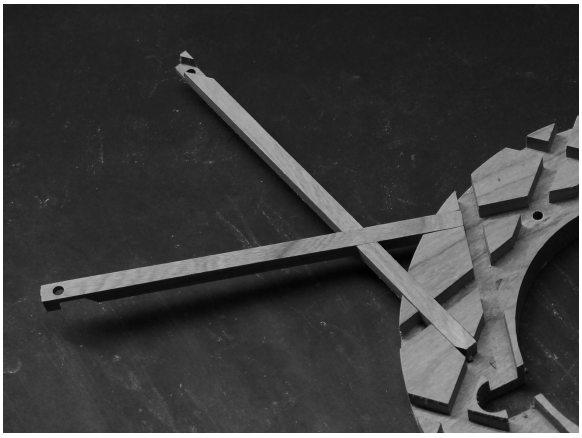


Figure 17: Stick Assembly Test

Once you are happy with the width of the sticks, glue the shorter stick to the longer stick.

Proceed to assemble all 12 pairs of sticks.

9.7 Base Assembly

Carefully insert each stick assembly into the base. Aply glue to the sides of the groove in the base. By doing this, the glue should not be squeezed out of the top as if it would be when applied to the sticks. Each of these assemblies will go in in the same direction. ei. long stick to the left, or long stick to the right. Watch that the ends of the sticks can be connected. If you get place the wrong stick on top, you will have a hard time getting them in the right position one the glue sets. Also, work hard to ensure the sticks come straight out from the base and are not pointing down to the surface or up to the sky. See Figure 18.

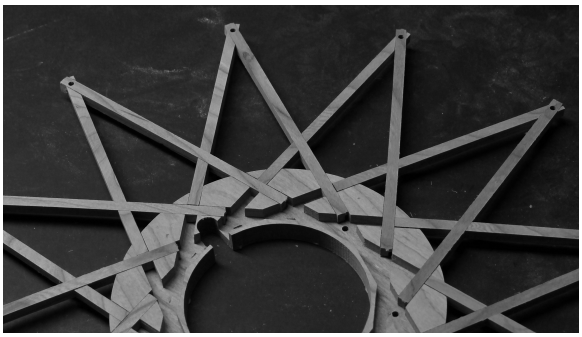


Figure 18: Base Assembly 1

Once all of the stick assemlblies are in place, glue the little nub pieces in the groove to give the apearance that the short stick extends as far as the long stick.

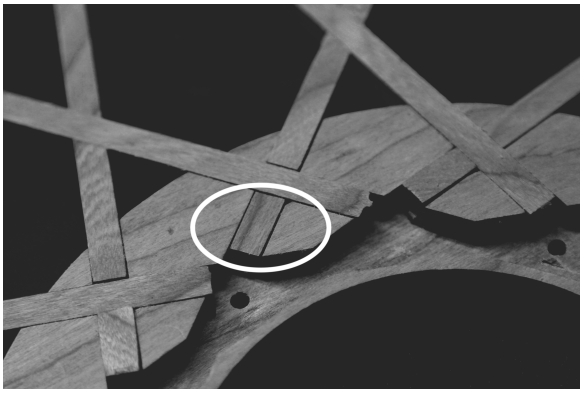


Figure 19: Installing Nubs

9.8 Sanding and Taping

After the glue has set, lightly sand the base and the sticks with the 220 grit sand paper. Be sure to follow the grain as close as possible. I found wrapping the sand paper over a small piece of half inch thick wood helps.

Clean the dust off using a damp paper towel.

Tape the tips of the wood where the two sticks joing to form a star. This will ensure a good surface for gluing the circle bottoms on. See Figure 20

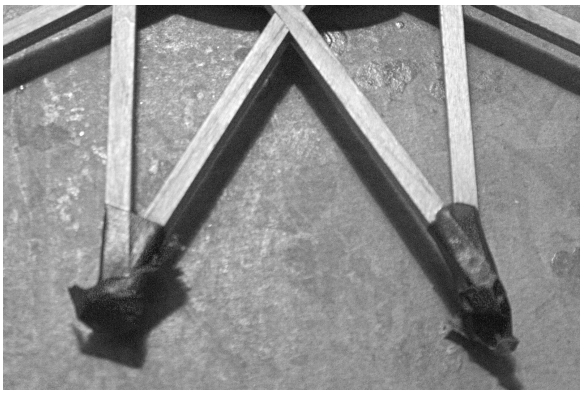


Figure 20: Taped Stick Ends

9.9 Finishing

Wood Finish Precautions

1. *It is important to read the warnings on the cans of finish you use. Always work outdoors or in a well ventilated area. the fumes are bad smelling and bad for you!*
2. *Work in a clean dust free area! Apply the finish in thin smooth coats.*

I recommend Deft Clear Wood Finish and a 1in. or 1 1/2in. brush. The following steps are for it. If you choose to use another finish. You can apply it now in a suitable manner and proceed to the subsection 9.11.

Figure 21: Finish and Brush

Apply one layer of finish on all surfaces, except the two pads on the bottom of the bottom circle assemblies. You want these to remain clean so they glue well. See Figure 14

After a two hour wait for the initial coat to dry, apply a two additionsl coats to the edges of all of the circles as well as the top surfaces of the top circles (this surfaces with no holes or cuts.) and the tops of the sticks and the base.

Be sure to allow a couple of hours to pass between the coats to ensure each coat is thouroughly dried before applying the subesequent coat.

9.10 Face Assembly

Using a nut driver using a gentle but firm pressure, slowly screw the 4 longer stand offs into the bottom side of the face being careful to ensure they go in straight. Do not over tighten! The figure below only shows 2 of the four standoffs.

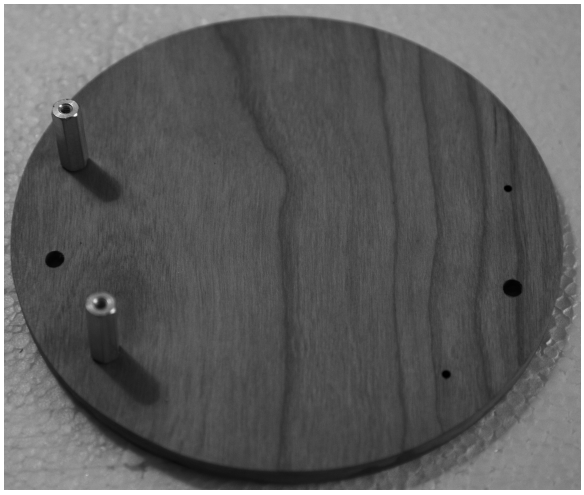


Figure 22: Finish and Brush

9.11 Final Case Assembly

After the glue has set, pin the ends together with 1/2in or so lengths of the 1/8 in dowel supplied. Besure to have at least 1/4in of stick showing on top. Apply glue to the bottom sufaces of the circle bottoms and attch them to then end of the stick having the dowel protrude through the hole in the circle

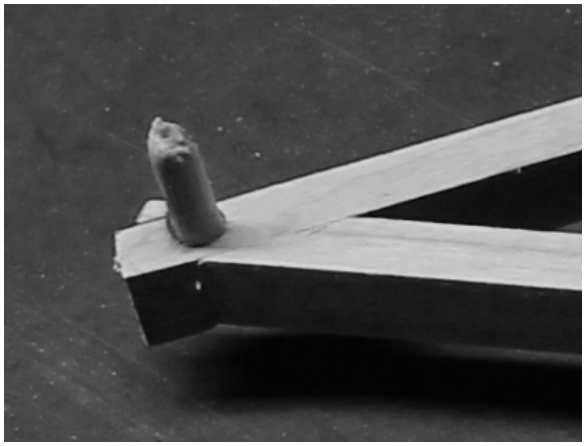


Figure 23: Installing pin

Be carefule to align the circle so the groove points directly to the center of the clock as this is where the tube will rest. The circle must be 'flat' (parallel) relative to all of the other surfaces.

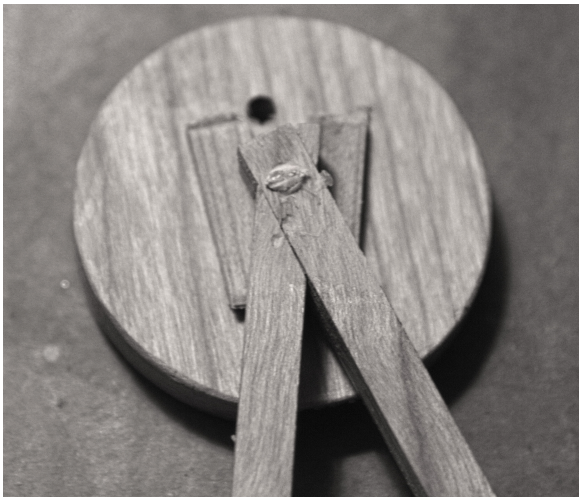


Figure 24: Installed Peg

Trim the dowel on the bottom and hold the circle to the sticks with clamp until the glue dries.

Trim off the excess dowel from within the groove on the bottom circle.

Figure 25: Trimmed Dowel

9.12 Attaching the Clock to the Case

For IN-13 clocks, place the face with the standoffs up into a soft protected surface to prevent scratches. Inset the small end of the the wooden buttons down into the two larger holes on the face. Then place the PCB on to the standoffs with the component side torwards the face. Now screw in the 4 smaller standoffs to secure the board to the face. Be sure to tighten the small standoffs well. The power cord can now be threaded through the center circle of the base and the board placed onto the base so the small standoffs line up with the holes in the base. Now place the short 4-40 screws through the bottom of the base and get them started into the standofs.

For the IN-9 clocks, place the small end of the wooden buttons through the holes on the back of the face. Thread the power cord of the clock through the whole in the base. Place the PCB on to the standoffs with the component side torwards the face. Now place a single long 4-40 screw through from the back of the base, through the PCB and get it started into the appropriate stand off. Be sure you have the face, PCB and base aligned correctly so all of the screws goe into the correct holes! Procede with the remaining screws. Be sure to not tighten the screws until thay are all in place.

For both clocks, align the tubes to fit into the grooves in the small circles. You can now tighten the screws to secure the clock to the base.

Gently press the insert the dowels of the each of the top cirles into the small holes of the bottom circles and gently press them together. **Do Not Glue**, they will stay in place and this will allow you to remove the clock from the base in the future if need be.

Congratulations!!! You have completed assembling the clock!

10 Parts List

Here is a list of the components by bag.

Bag 1 (IN-9 Clocks)
12 R1 2.1K Resistors
4 3/8” 4-40 Standoff (Only used during assembly)

Bag 1 (IN-13 Clocks)
12 R1 3.3K Resistors
4 3/8” 4-40 Standoff

Bag 2 (IN-9 Clocks)
12 R2 168/169 ohm Resistors
4 5/8” 4-40 Standoff

Bag 2 (IN-13 Clocks)
12 R2 475 ohm Resistors
4 5/8” 4-40 Standoff

Bag 3 (IN-9 Clocks)
4 7/8” 4-40 Screws

Bag 3 (IN-13 Clocks)
12 R3 220K Resistors
4 3/8” 4-40 Screws

Bag 4
1 C7 2.2nf Capacitor
1 C8 4.7 250V Capacitor
1 .1ohm Resistor
1 Q1 IRLS640 MOSFET
1 150uh/220uh Coil
1 20K Pot

Bag 5
2 SW1, SW2 Push Button Switches
1 SW3 SPDT Momentary Switch
3 3.3K Resistors
1 78L05 (L4931CZ50-AP) 5V Regulator

Bag 6
2 C2, C5 220uf 10V Capacitor
1 1.2 K Resistor
1 D1 BAV21 250V Diode
1.uf Capacitor

Bag 7
1 ATMega328 Processor
1 28 Pin Socket
1 470uf 6.3V Capacitor
1 78L33 3.3V Regulator

Bag 8
1 C1 390uf Capacitor
1 C6 1nf Capacitor
1 1M Resistor
1 16Mhz Crystal

Bag 9
1 15F Super Capacitor
1 DS1339C RTC I.C.
12 MPSA42 Transistors

Bag 10
1 AD8802 12 Channel A/D Converter I.C.
1 MAX1771 Boost Power Regulator
1 6 foot Cable Barrel Connector Assy.