Random
Sequencer
Documentation

PCB v2.1
September 2012
by Tom Whitwell

Additions: Steven Grimley-Taylor - December 2012

This is an adaptation of the original documentation by Tom Whitwell.

It is augmented with images and instructions which are specific to the full kits sold via www.thonk.co.uk in late 2012 and early 2013.

All support requests should be directed to this thread on Muffwiggler:

http://www.muffwiggler.com/forum/viewtopic.php?t=60740

Where Tom, Steve and the rest of the module DIY community will be able to give you advice on your build.

IF YOU HAVE AN ACRYLIC/PLASTIC PANEL FROM THONK, THEN WATCH THIS VIDEO ON PAINTING THE PANEL FIRST!

https://vimeo.com/54711135

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The Random Sequencer is a circuit that produces random control voltages. These can be completely random, or they can be locked into loops that repeat every 8, 16 or 32 steps.

It was inspired by the long history of shift register pseudorandom synth circuits, including the Triadex Muse, Buchla 266 Source of Uncertainly, Ken Stone's gated comparator and Grant Richter's Noisering. This circuit includes a transistor noise generator, so should create true random binary sequences. However, the structure of the sequencer and the nature of the digital-to-analog converter used seem to give a particular character - tones that rise and fall in a particular way.

Block
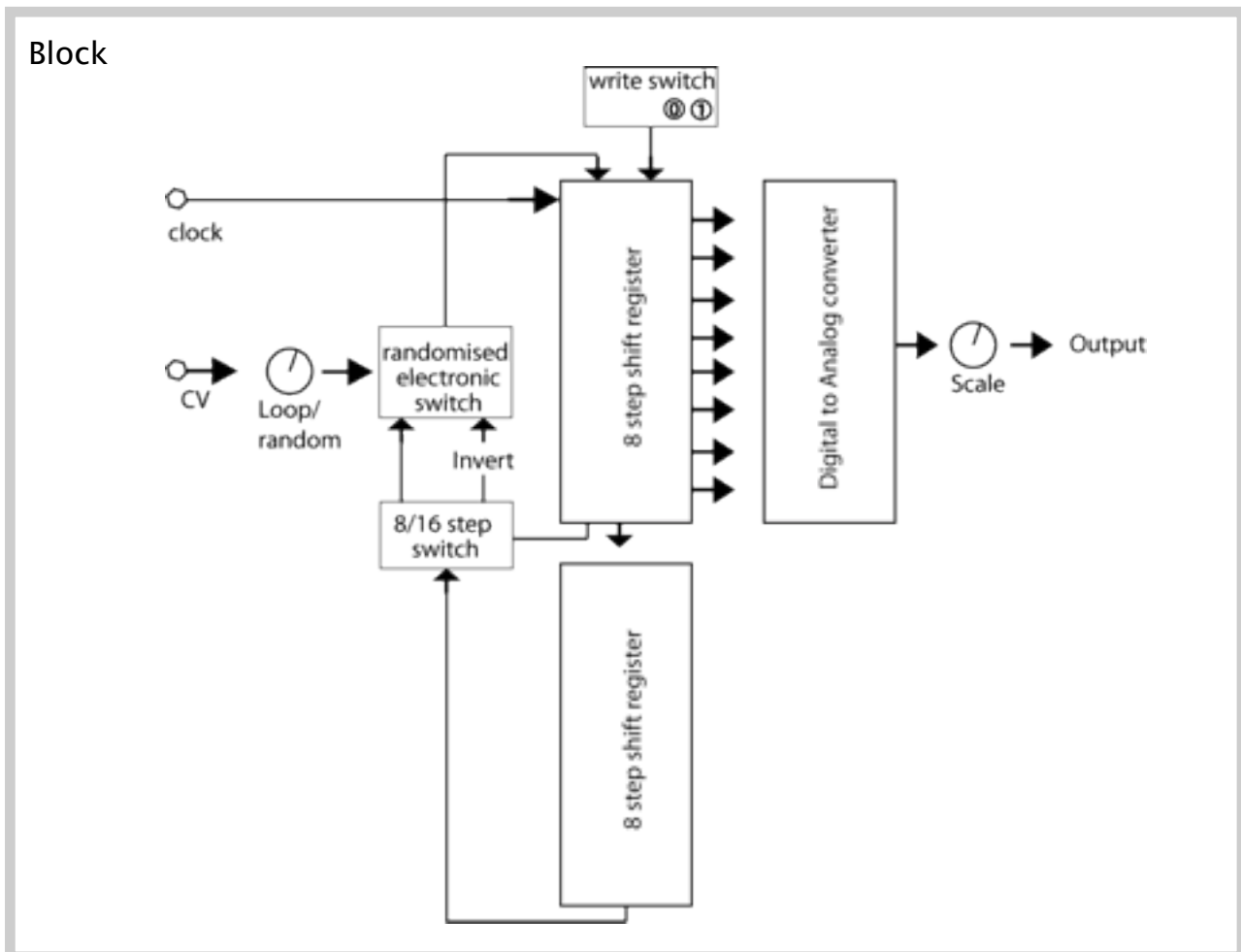
How the module works

This is a binary sequencer, based around a 16 bit memory circuit called a shift register.

NB: You cannot program this sequencer to play specific tunes. You cannot save sequences. You can never go back to a sequence that has changed.

It's designed as a sequencer that you can steer in one direction or another, not one that you can program precisely.

Each clock pulse moves the binary sequence one step through the 16 bit memory. Step 1 is copied to step 2, and so on. What happens to step 16? It's copied to step 1, but may be transformed along the way.

At any moment, the first 8 of the memory positions are being read by the digital to analog converter.
00000000 = 0 = minimum voltage, around 0v
11111111 = 256 = maximum voltage, around 10v
10000011= 131 = around 5v

With the main knob at 5pm and the length switch UP, a 16 bit sequence will loop forever.
With the main knob at 5pm and the length switch DOWN the 16 bit sequence is split in half, with the 8th step linked to the 1st step.

Things get interesting when the main knob is not at 5pm. The knob controls a randomised switch connecting the end of the loop to its start.

In a binary system, there are obviously just two options. It can take the last bit and accurately write it into the first bit. Or it can write inaccurately, flipping a 0 to a 1, or a 1 to a 0.

The knob (and the associated CV input) determine how likely each bit is to be flipped:
At 3pm, maybe 1 bit in 10 will be flipped. The loop will change gradually.
At 12 noon, 5 bits in 10 will be flipped. The loop is filled with random data that never repeats.
At 7pm, every bit will be flipped, and the loop becomes a mobius loop.

In effect, the sequence doubles in length. With the length switch UP, 16 steps will play, then those 16 steps will be repeated, inverted. NB: This is a binary inversion, not a melodic or CV inversion. The effect on the output voltage will be hard to predict, but the loop will repeat after 32 steps, not 16.

How the circuit works
The Clock input goes through an Op-Amp Comparator to boost weak clocks. R9 and R3 are a voltage divider to set the trigger voltage.

The two 4015 chips are dual 4-bit shift registers, so there are 4 pins that receive the clock signals.

The output of each shift register is connected to the input of the next via a 10K resistor with a 1n cap to ground, to delay the signal. (This fix is one of many elements drawn from Ken Stone's gated comparator circuit).

Eight shift register outputs are connected to the LEDs, the optional Expansion port and the DAC inputs. The LEDs are not buffered (Ken Stone uses transistor buffers in his Gated Comparator, which is probably a good idea, but it seems to work without them).

The DAC is connected according to the datasheet, driving one gate of the TL074, with a simple attenuator pot on the output.

The noise circuit is a basic reverse-bias transistor noise circuit, boosted by inverting op amp stages with capacitors to remove the offset. The front panel noise output is not independently buffered, so it's possible using this output could have an impact on the rest of the circuit in some situations.

The switch part of the circuit works like this: White noise flows into a comparator, with the reference

voltage set by a combination of the main knob and the CV input (summed by IC1A). Using a transistor inverter, two gates of the 4016 are set up as a SPDT switch, routing the end of the shift register loop either straight back to the start of the loop, or back via another transistor inverter.

Bill of Materials
Most of the components are straightforward off-the-shelf parts, but the parallel PCB construction means some components are very specific.
Sockets: The board is designed for 3.5mm vertical jacks from http://erthenvar.com/ model PJ-301b. If you're not using these sockets, the lug nearest the top of the board carries the signal.

The DAC0800 is also known as a DAC-08. This part of the circuit could be replaced by R-2R resistor ladder, as seen in Ken Stone's Gated Comparator.
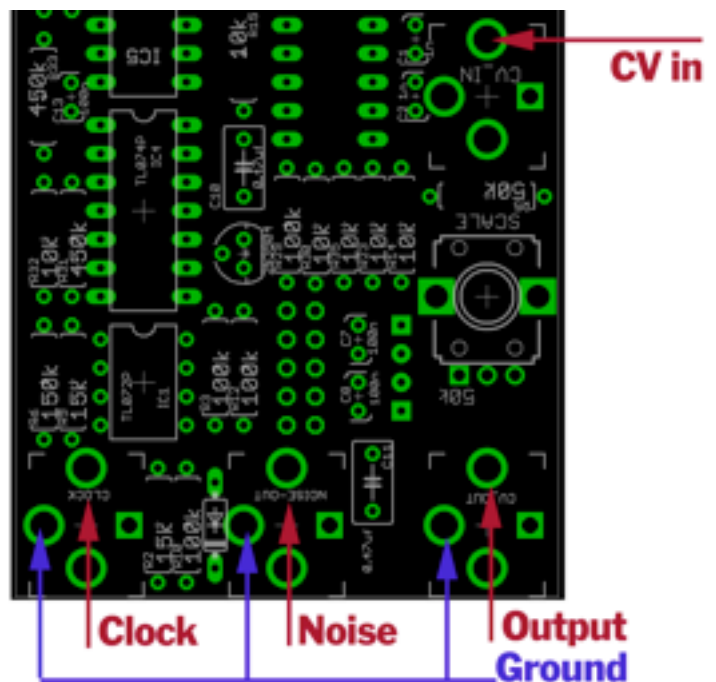
The LED Bar Graph module could easily be replaced on this PCB by individual LEDs, which might be easier to mount in a drilled panel - put the shorter LED legs towards the edge of the board. The LED current protection resistors can be adjusted according to the LEDs used.

I've used an eight way 330 ohm resistor network (RN1) for ease of installation, but it should be possible to hack one together - 8 resistors connected to one wire going to ground at the pin connected with a cross (a neat example here: http://flic.kr/p/65UmMd).

R19 is there to increasing the total resistance of RN1 (Without it, the circuit draws rather high current, but you could use a jumper if you have a higher value of RN1). The Clock LED has it's own current limiting resistor, R13.

I used 1% resistors in many places, because I had them handy. I do not think any of the component values are very critical - nothing needs to be trimmed or calibrated.

Potentiometers: Both pots are voltage dividers, any reasonable value should work. I've used 50k & 100k.

The PCB is designed for 9mm vertical pots from Alpha, Bourns or other manufacturers like this:

RECOMMENDED PCB LAYOUT
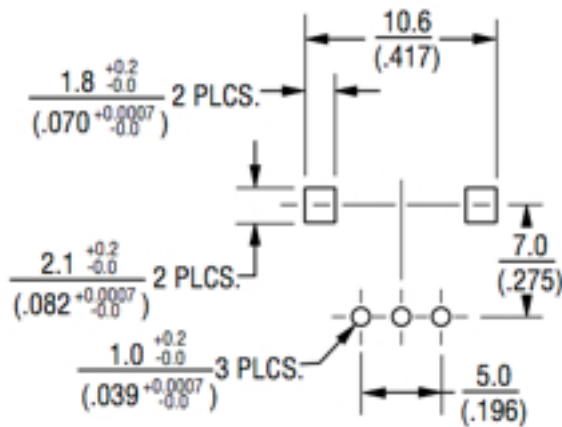
I used one with a 25mm D shaft for the main control, and a 12mm knurled for the smaller control.

Switches: These red-bodied solder tag switches are pretty common. Two ranges are Salecom T80-T switches from Rapid or Bitsbox, or E-Switch 100 range from Mouser.
The LENGTH switch is a standard SPDT ON/ON switch.
The WRITE switch MUST be centre off SPDT - and ideally a momentary (ON) OFF (ON).

Expansion Port

The expansion port surfaces the clock pulses, and the 8 shift register outputs that go to the DAC. It is not buffered.

Pinout:
1-8: Data channels from the shift register. 1 = Most significant bit, 8 = Least significant bit
9: Ground
10: Clock

Building the circuit

I've found the 4015 shift register chips to be slightly unpredictable. If the sequence won't loop properly, swap the chip and throw out the old one. I've no idea why this happens, but Navs reported the same thing building his Bitsy. This is why the two 4015 chips are on the back of the board, not hidden behind the panel.

Quirks

Feeding the module from a multed clock input can sometimes give strange results - clearing a looped sequence. I've no idea why this happens.

PCB Versions

PCBs versions are marked in the silkscreen

v1 Personal prototype, not released

v2 Original shared PCB design, May 2012. Includes incorrect polarity of C6, Please read the addendum at http://musicthing.co.uk/modular/?p=211 before building this board.

v2.1 September 2012. Fixed the polarity of C6, and removed a couple of spurious rectangular milling instructions from the gerber files.

```
Hardware, pots, switches, lights:
1               5+5 pin 0.1 inch Power Header
1               10 pin 0.1 inch header
1               Length Switch: SPDT ON-NONE-ON
1               Write Switch: SPDT (ON)-OFF-(ON)
2    50k        ALPHA-9MM vertical Pot CHANGE, SCALE

4    PJ-301B    3.5mm socket
1    DC10       Kingbright DC10 LED Bar Graph
3               16 pin DIL socket (.3 inch)
2               14 pin DIL socket (.3 inch)
1               8 pin DIL socket (.3 inch)


Capacitors:
2    0.47uf     Polybox Cap             C10, C11
4    1n         Ceramic Cap             C1, C2, C3, C4
1    10n        Ceramic Cap             C9
2    10uf       Electrolytic Cap        C5, C6
5    100n       Ceramic Cap             C7, C8, C12, C13, C14


Resistors:
2    1k         Resistor                R17, R18
1    6.8k       Resistor                R26
12   10k        Resistor                R1, R8, R14, R15, R16, R23,
                                        R24, R27, R28, R30, R32, R35
2    15k        Resistor                R2, R9
1    51k        Resistor                R5
7    100k       Resistor                R3, R4, R10, R12, R22,
                                        R25, R29
1    150k       Resistor                R6
1    330R       8-commoned Resistor Network      RN1
2    470k       Resistor                R31, R33
1    560R       Resistor                R19
1    820R       Resistor                R13


Semiconductors:
1    1N4148     1N4148 Diode            D2
2    4015       Shift Register          IC2, IC3
1    4016       Bilateral Switch        IC5
1    DAC0800    Digital/Analog Conv     U$2
1    TL072      TL072                   IC1
1    TL074      TL074                   IC4
3    2N3904     Transistor: 2N3904      T1, T2, T3
```

Example Mouser Project: http://bit.ly/MRGqRF access id: bc8a4a43bf

NOTE: This Mouser Project does not contain identical parts to those shipped by Thonk as complete kits.

IC5C 4016N
IC5D 4016N

START_OF_LOOP

END_OF_LOOP

IC5A 4016N
IC5B 4016N

+12V
GND

R3 10k
R24 100k
T2 2N3904
R25 100k
R4 100k

IC4D TL074P
NOISE
IC1A TL072P
R6 150k

R22 100k
R23 10k
R35 10k
CHANGE 50k
R5 50k
PJ-301B
CU_IN

DAC0800
U52
B8-LSB REF+ VREF- COMP V+ V- IOUTB IOUT B1-MSB VLC

C14 100n
R27 10k
R28 10k
+12V
-12V
10n

IC4A TL074P
R26 6.8k

SCALE 50k
GND
CV_OUT
PJ-301B

IC4B TL074P
R31 450k
R32 10k
R30 10k
R29 100k
C10 0.47uf
2N3904 T1
Remove collector

IC4C TL074P
R33 450k
NOISE
C13 100n
C11 0.47uf
NOISE-OUT
PJ-301B
GND

DN2-10 ... DN1-10
RN1 330R
R19 550R
R13 820R
CLOCKIN

EXPANSION
10 CLOCKIN
9 GND
8 B8
7 B7
6 B6
5 B5
4 B4
3 B3
2 B2
1 B1

IC2B 4015N
IC2A 4015N
IC3B 4015N
IC3A 4015N

C12 100n
R8 10k
R7 10k
R15 10k
R16 10k

C1 1n
C2 1n
C3 1n
C4 1n

START_OF_LOOP
ADD_F21
R18 1k
R17 1k
R21 1k

8/16_STEPS
16 steps
8 steps
END_OF_LOOP_2

IC1B TL072P
D2 1N4148
CLOCKIN
R12 100k
R9 15k
R10 100k
R3 100k
R2 15k
PJ-301B
CLOCK

C7 100n
C8 100n
+12V
-12V

Power
POWER
C5 10uf
C6 10uf
+12V
GND
-12V

The top of the board...

... where most of the components go.

Start with the resistors
and the diode in BAG A

NOTE: The resistor network (RN1) is included in BAG C

NOTE

Leave the 560R resistor (R19) unsoldered for now. This is soldered vertically and we will come back to this later on.

Start with the resistors
and the diode in BAG A

Tom says: I usually check each one with a
multimeter, because I can't read the coloured
bands

Thonk say: We did this for you!
Note that resistors are not polarised, so it doesn't
matter which way round you solder them.
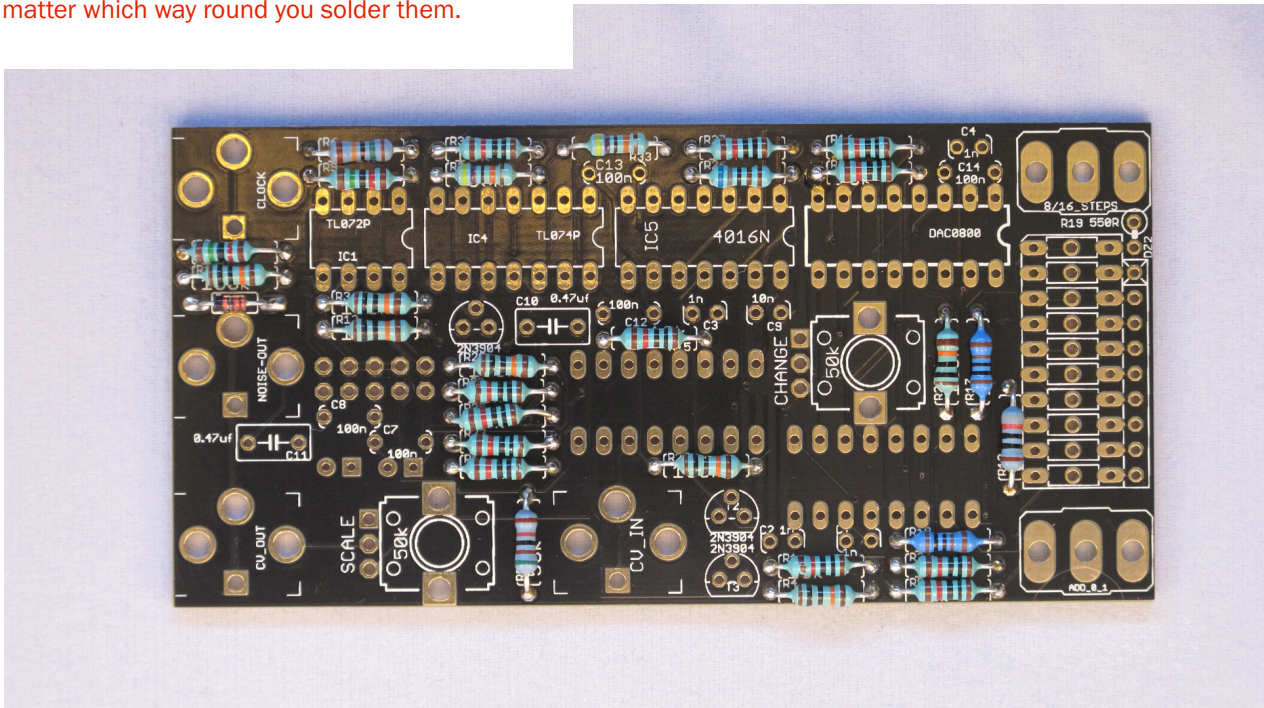
Note Diode orientation

The black stripe on the component is
at the same end as the white stripe on
the PCB.

THIS COMPONENT MUST BE SOLDERED
WITH THE ORIENTATION SHOWN
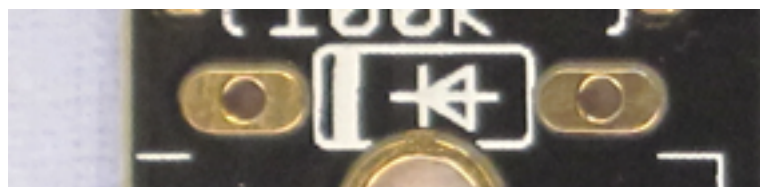
Now move on to BAG B
Capacitors + Transistors

NOTE

The two Electrolytic Capacitors can be found in **BAG C**

MUSIC THING MODULAR
TURING MACHINE
RANDOM SEQUENCER

BAG B
(CAPACITORS + TRANSISTORS)

WWW.THONK.CO.UK

Start by soldering the five 100n Ceramic Caps

In the kit shipped in December 2012 these are blue.

C7, C8, C12, C13, C14
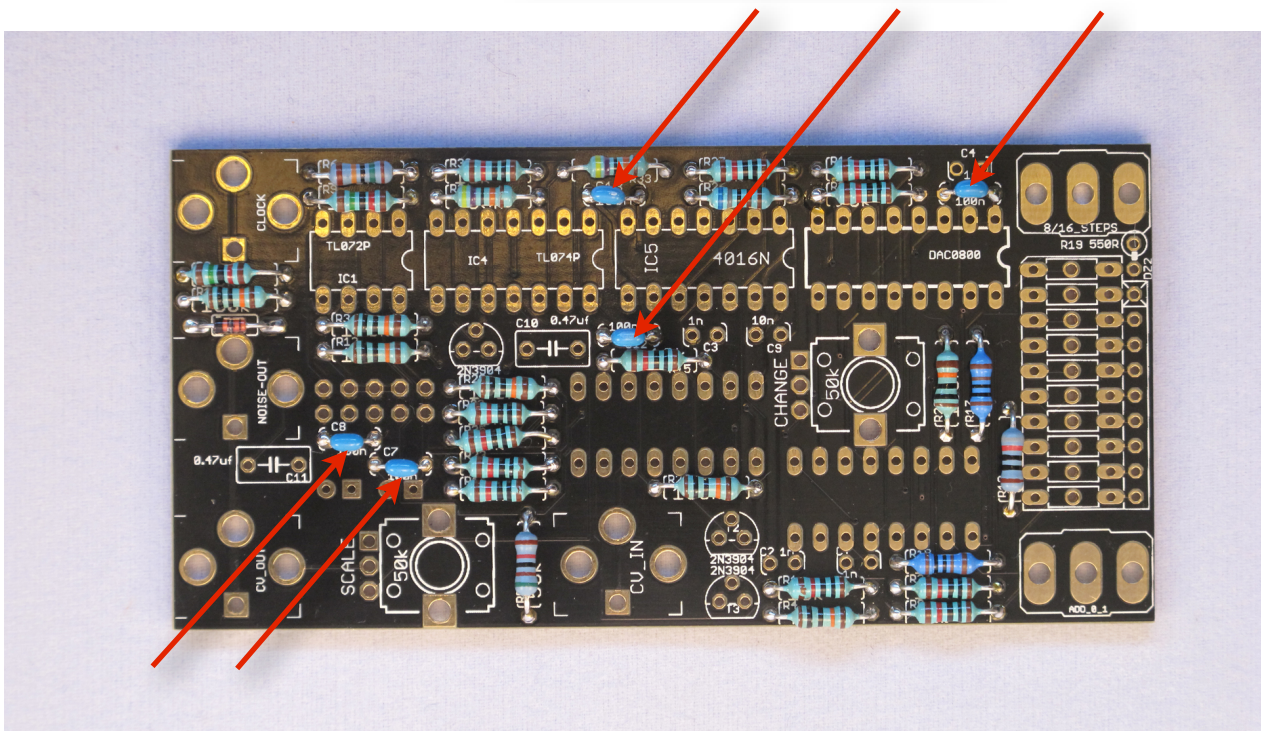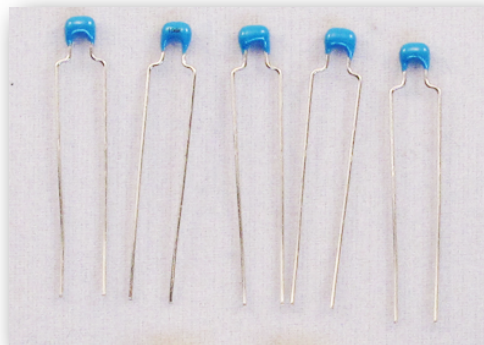
Solder the single 10n
Ceramic Cap – C9

In the kit shipped in December 2012 these are orange.
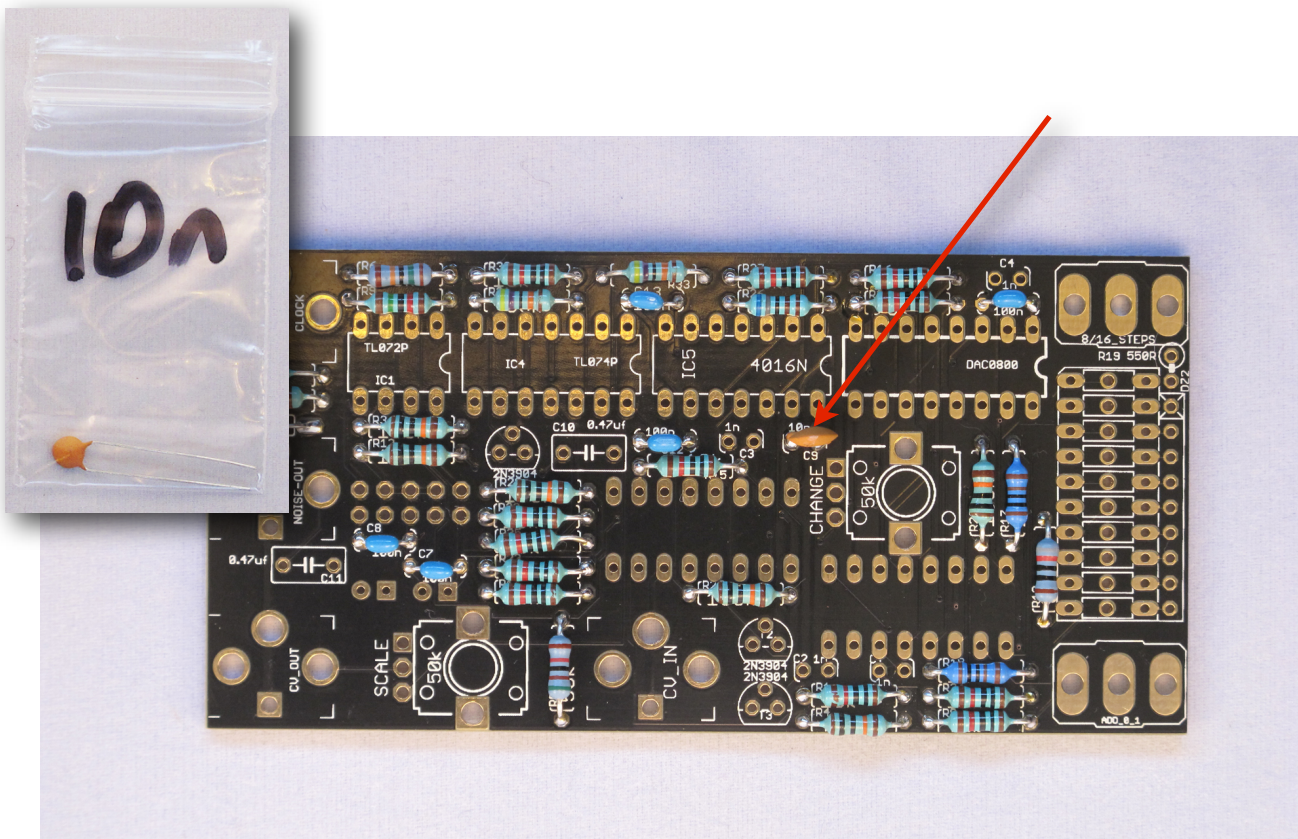
Solder the four 1n
Ceramic Caps

In the kit shipped in December 2012 these are orange.

C1, C2, C3, C4
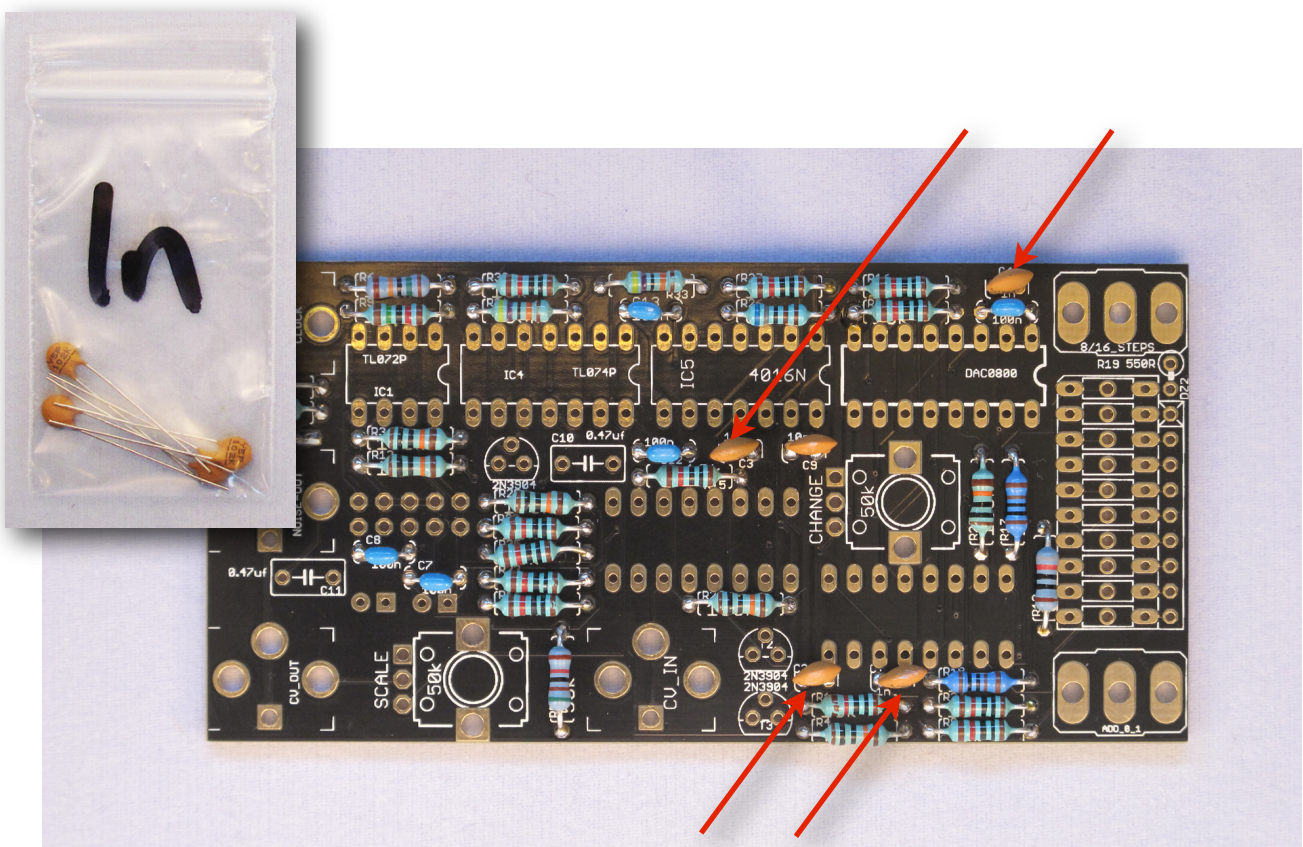
Solder the two 0.47uF
Poly Box Caps

In the kit shipped in December 2012 these
are yellow.

C10, C11
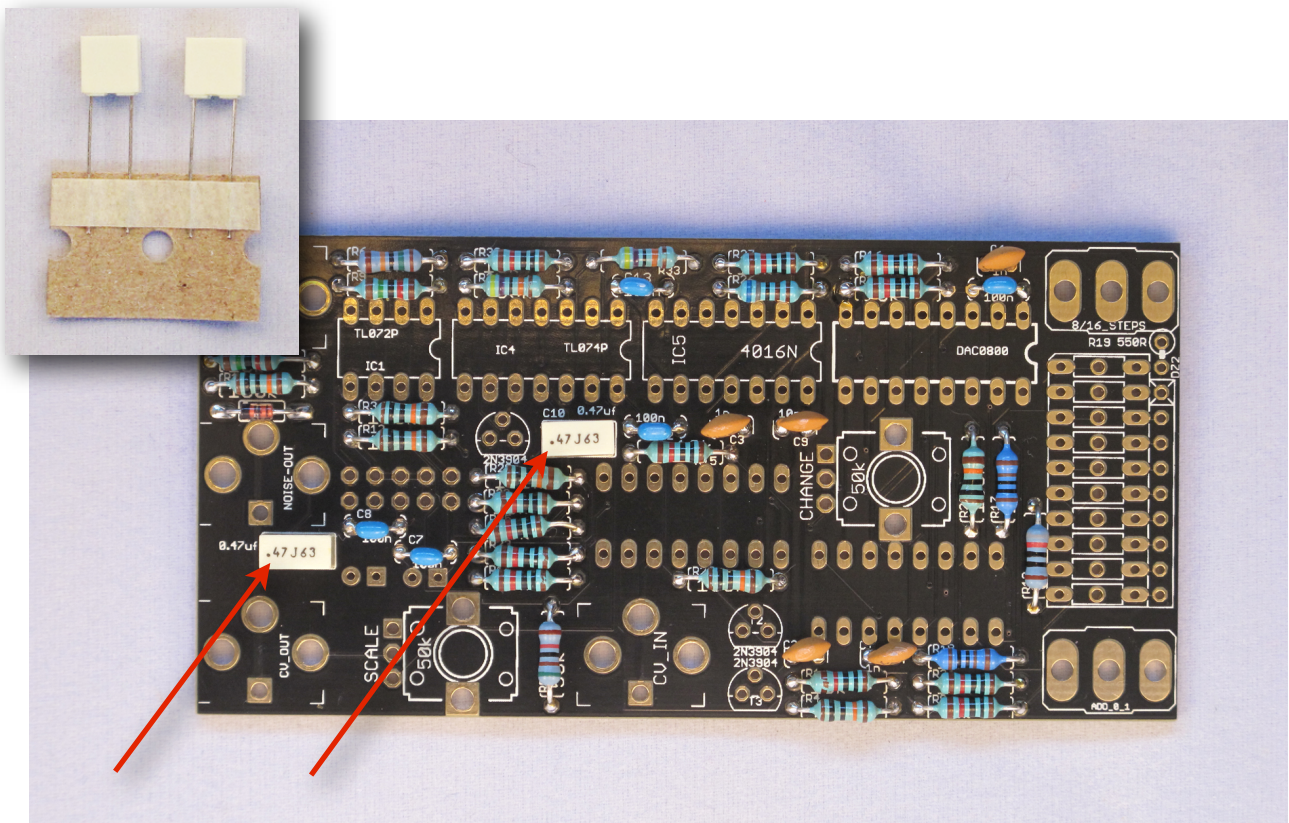
Solder the three 2N3904
Transistors

Note the orientation, the semi-circular shape of the component must follow the silkscreen on the PCB.

T1, T2, T3
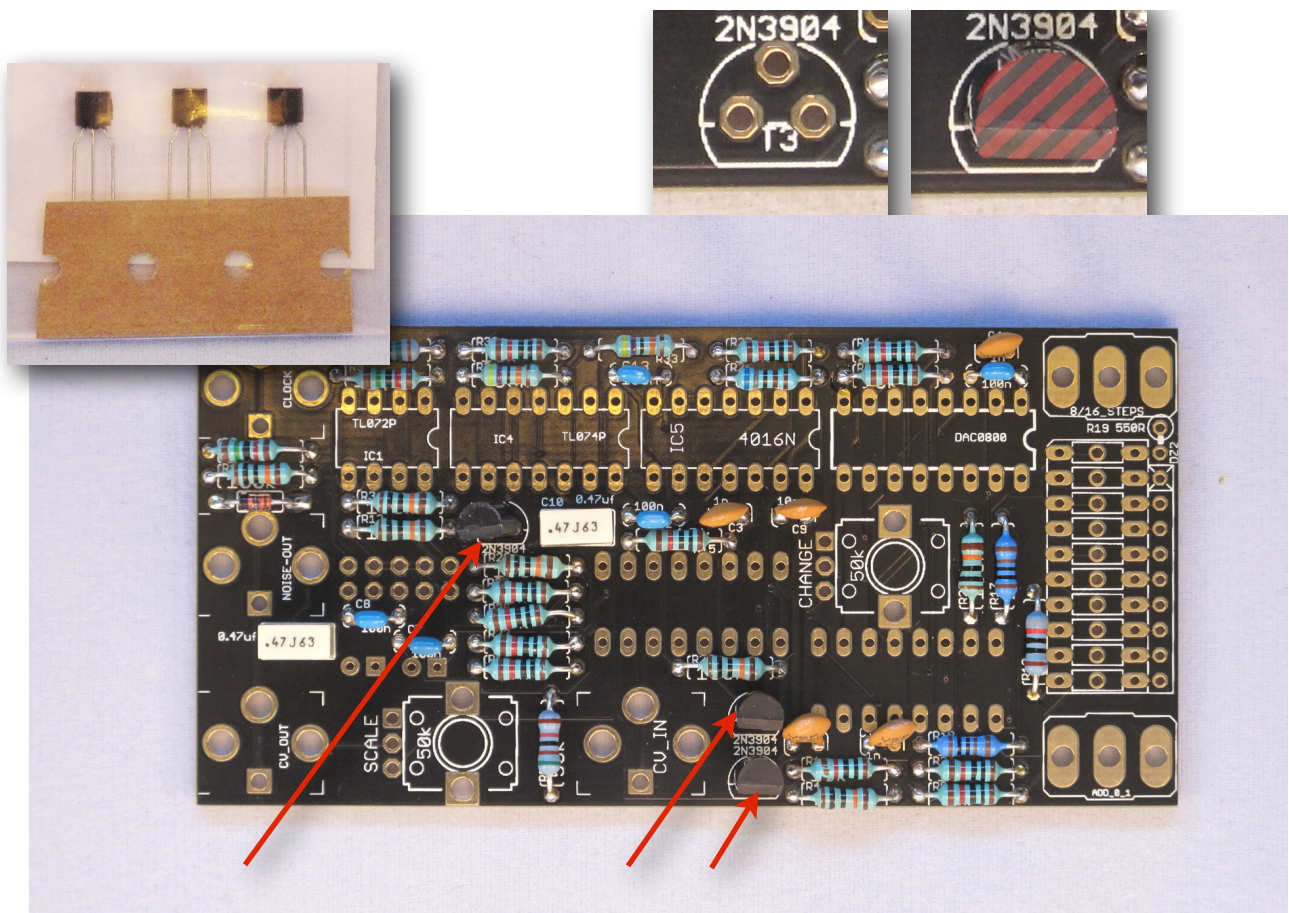
Solder the 560R resistor

You put this to one side earlier, now is a good time
to solder this part. Note the vertical orientation.
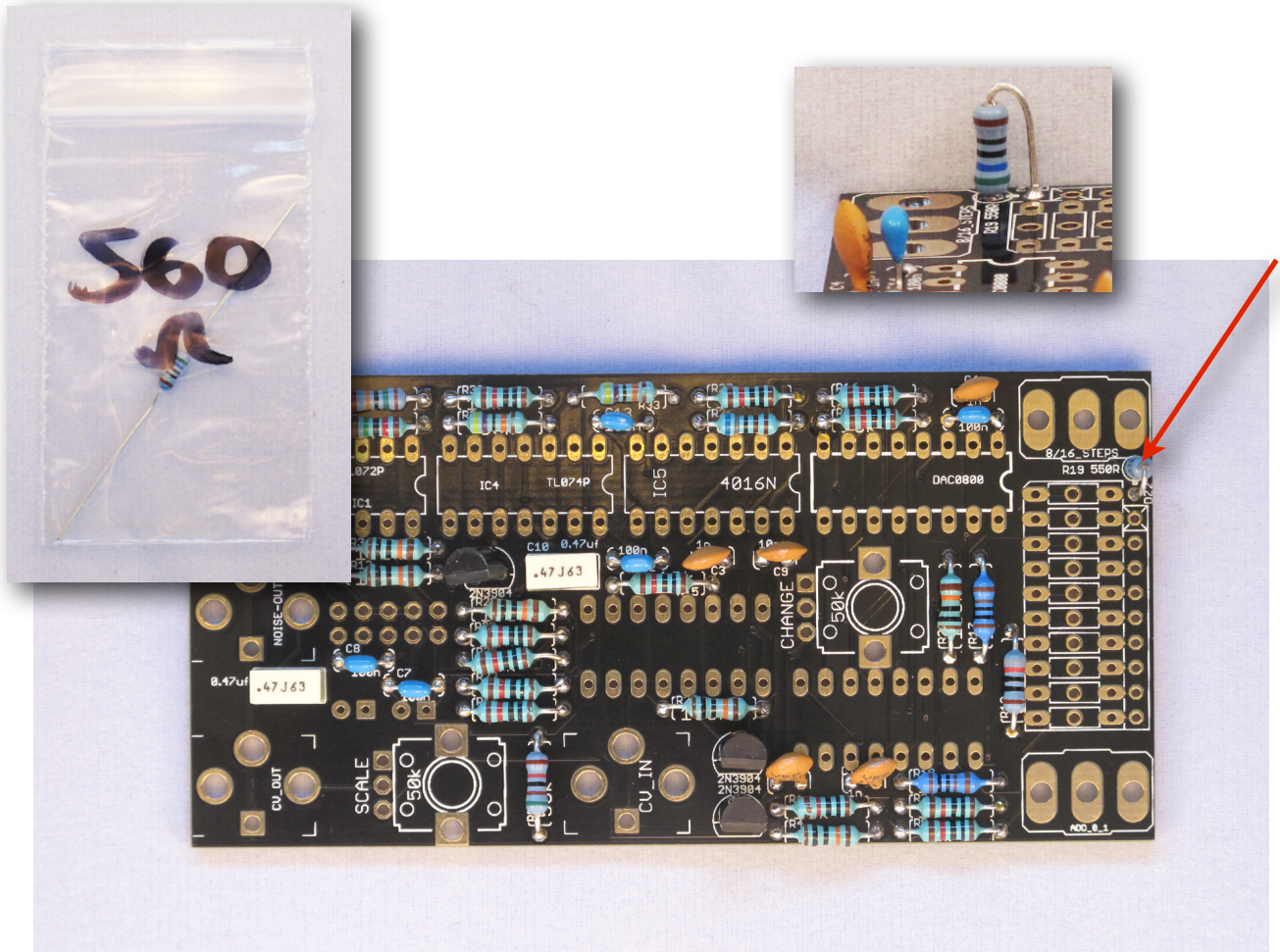
Now move on to BAG C. Hardware.

Solder the four IC sockets

NOTE: The semi-circular cut outs at one end of each socket MUST match the silkscreen graphic on the PCB

1x 8 pin socket
2x 14 pin socket
1x 16 pin socket
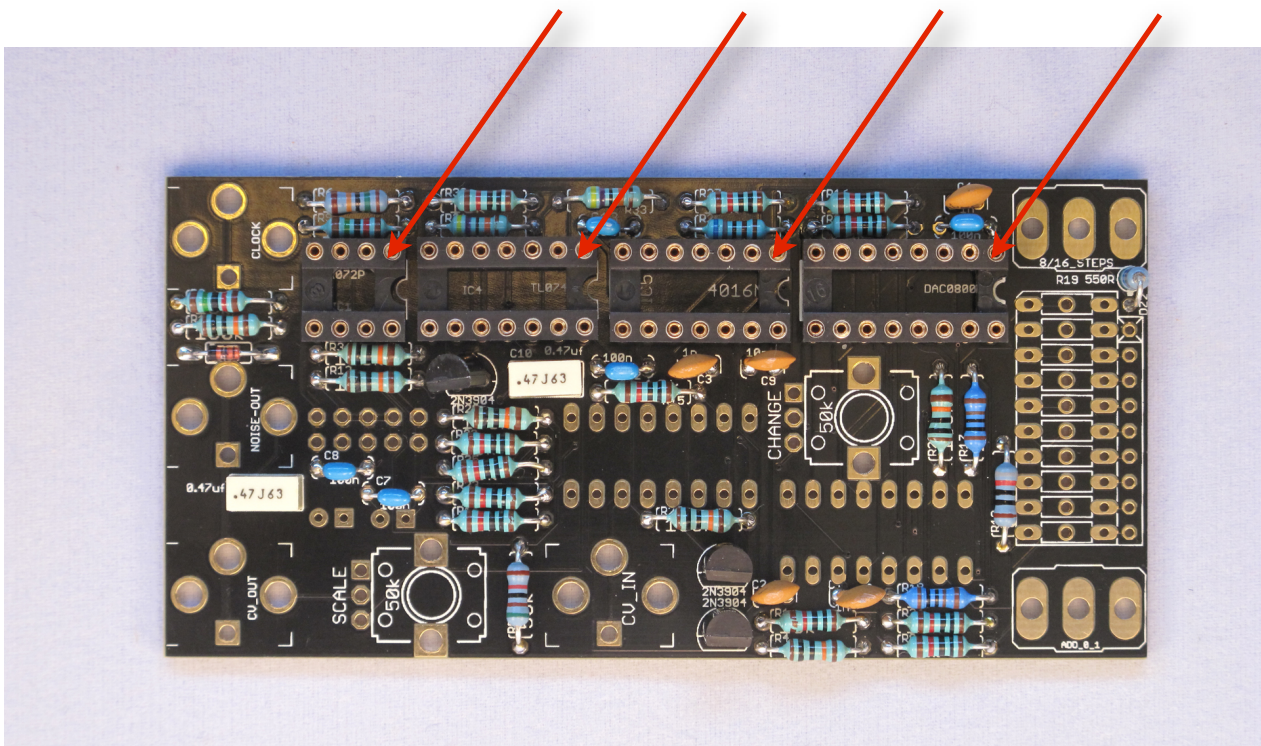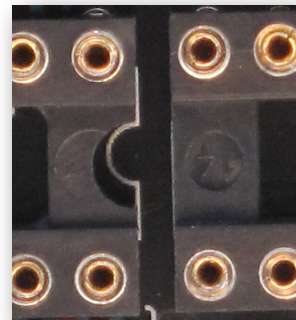
Flip the PCB.
Solder the two IC sockets

NOTE: The semi-circular cut outs at one end of each socket MUST match the silkscreen graphic on the PCB

2x 16 pin socket
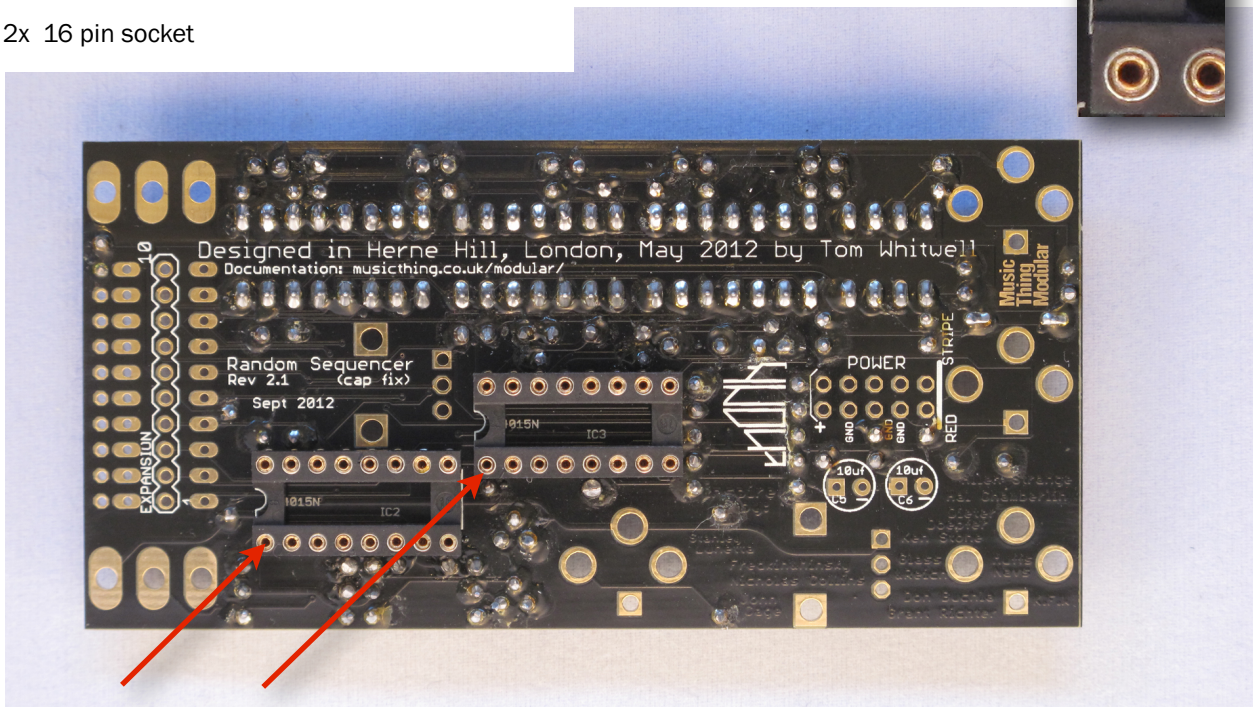
Solder the ten pin expansion header.

NOTE: You must solder this BEFORE you solder the LED block! The expansion header is technically optional, but it will be impossible to change your mind later.

1x 10 pin header
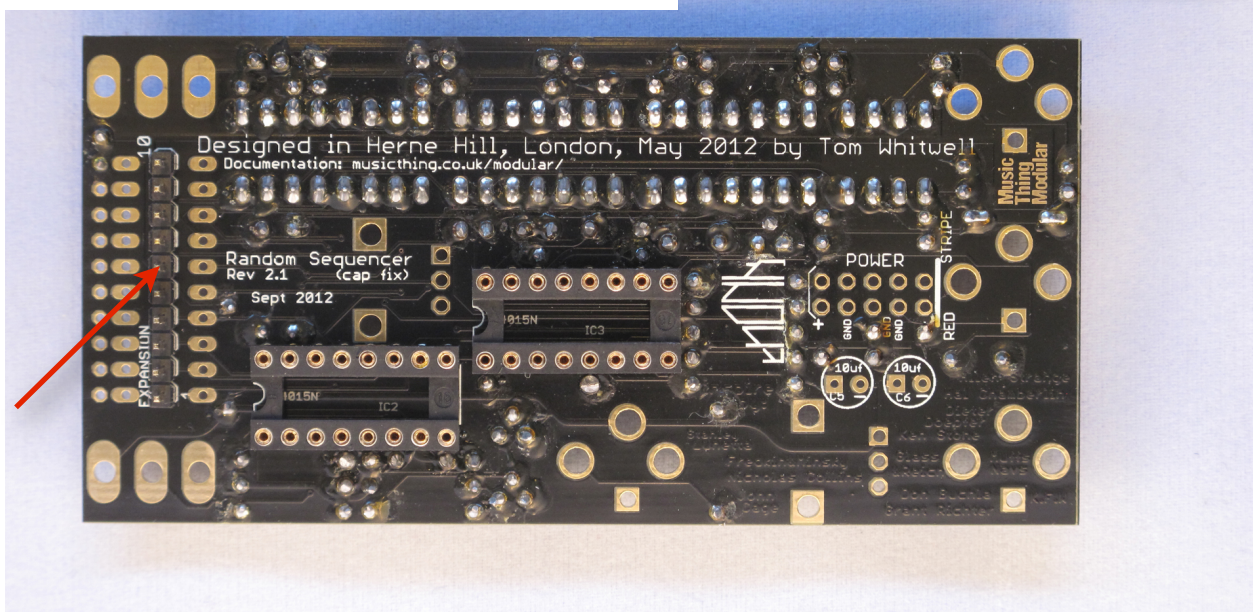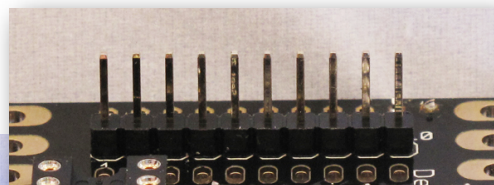
Solder the two 10uF Electrolytic Caps.

NOTE: Correct orientation of these caps is VITAL.
NOTE: These images are ONLY relevant for PCB rev 2.1
previous revisions had incorrect markings on the PCB.

C5, C6
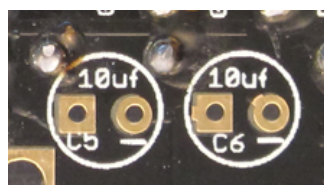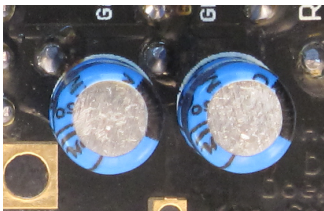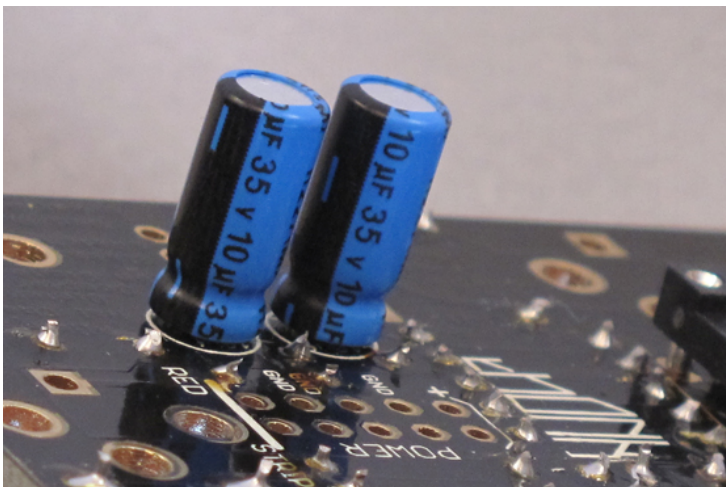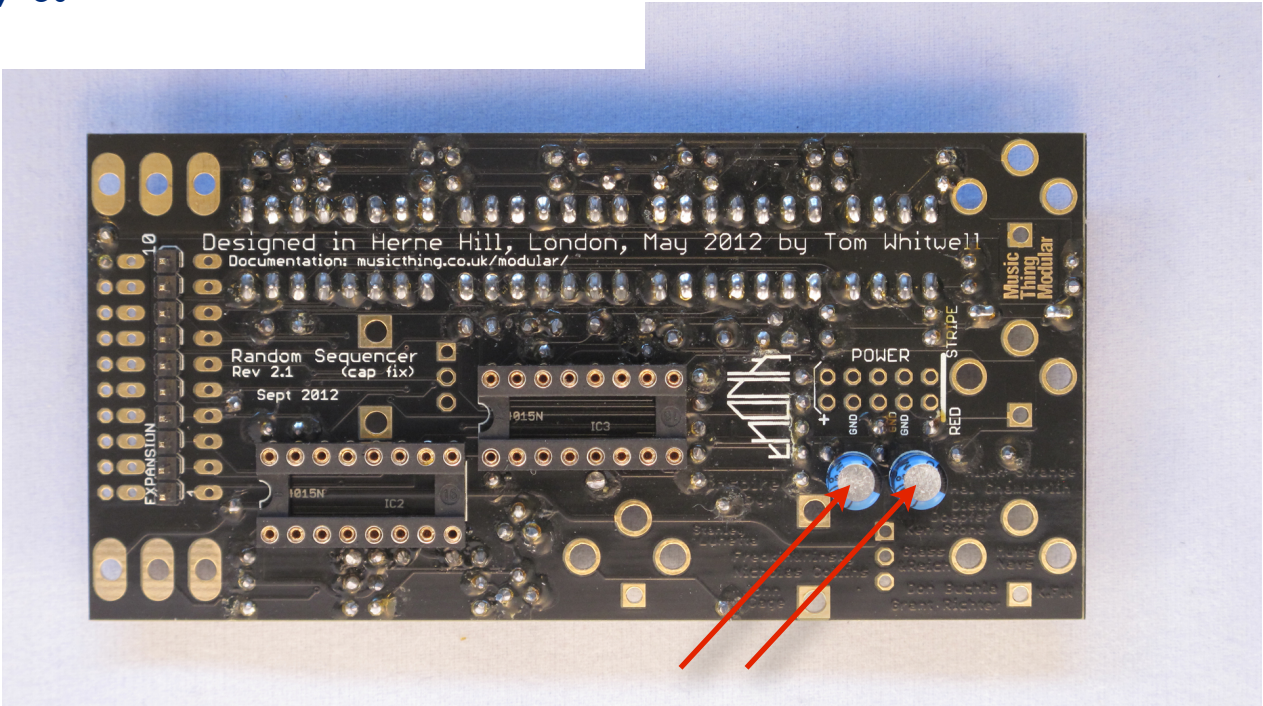
NOTE
Only the negative terminal is marked on the PCB. The negative lead is shorter than the positive lead and is also indicated by the black stripe on the blue cylindrical body

Solder the ten pin Eurorack power header.
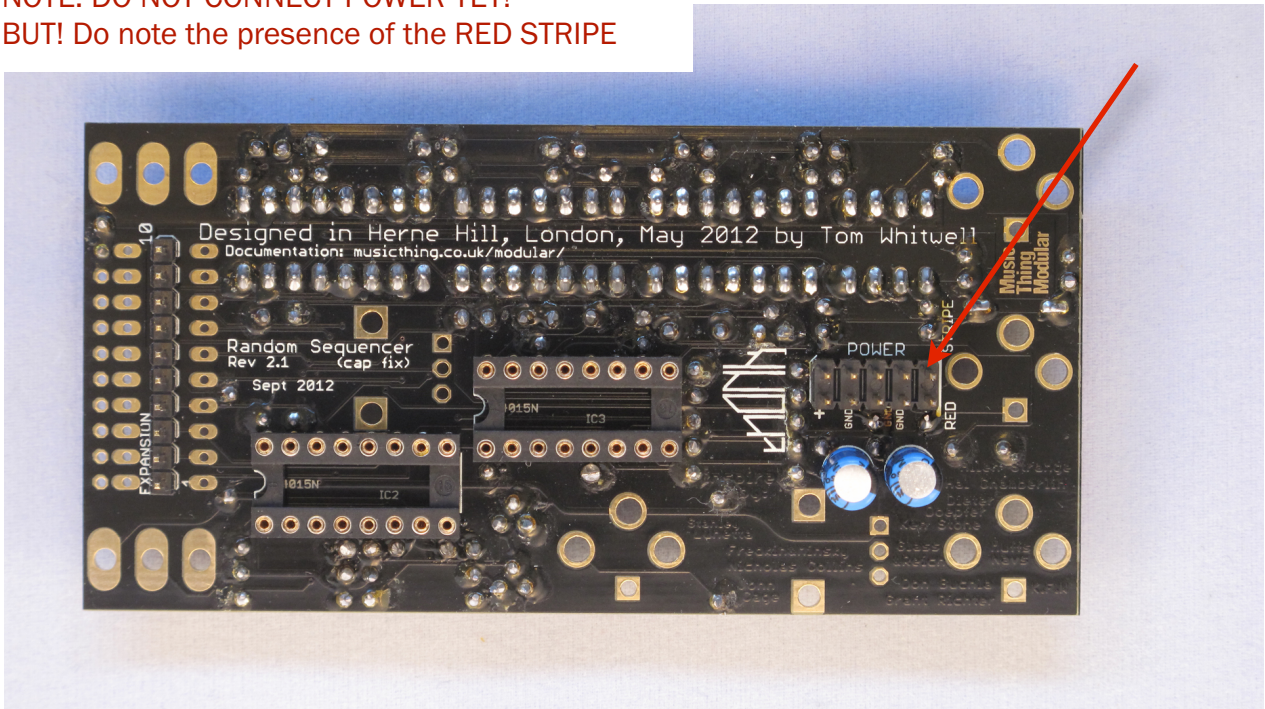
Solder the Resistor Network.

NOTE: The orientation matters. Make sure the grey line on the body of the component is aligned with the hole marked with the cross on the PCB.

NOTE: This part is in BAG C, next to the LED Block on the black foam. It's easy to miss.
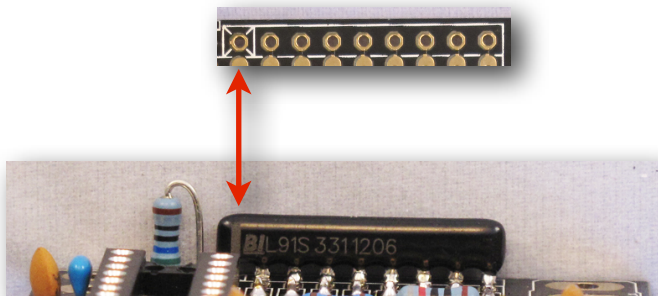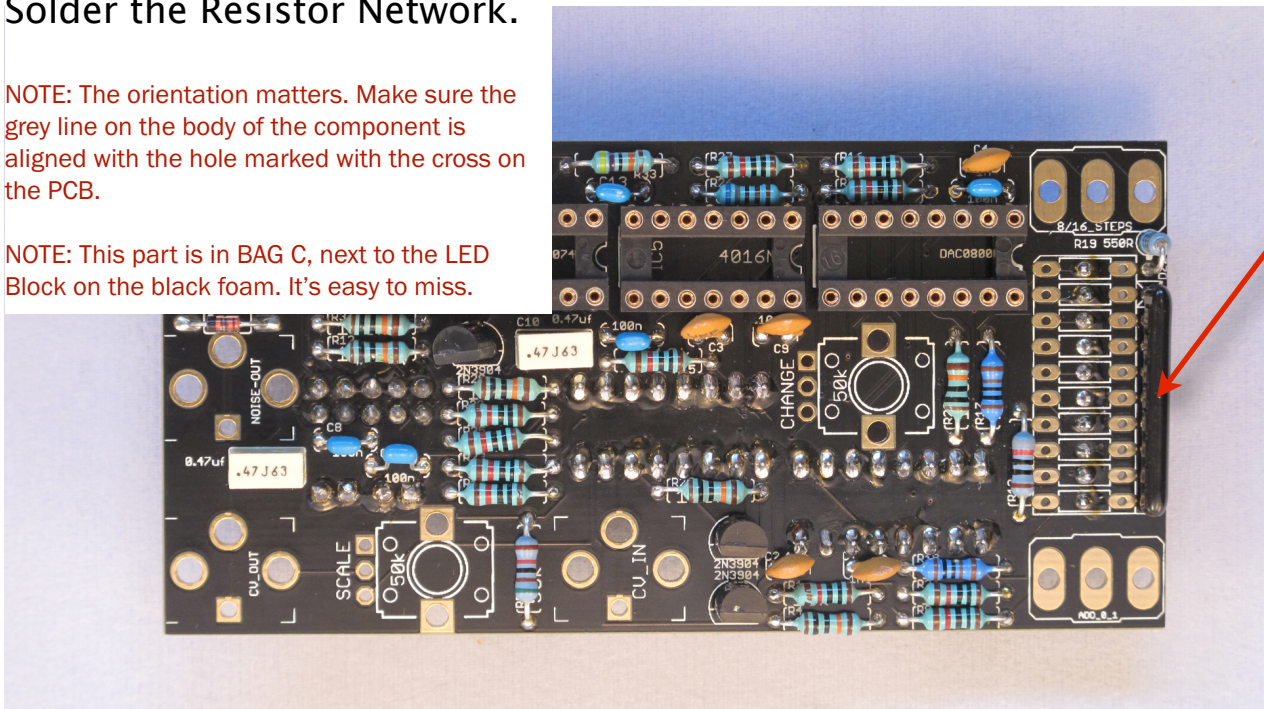
Solder the LED Block.

NOTE: The orientation matters.

One corner of the LED bar graph module is flattened - make sure you align this with the silkscreen. You might want to lift the module up a little, so it's closer to the acrylic panel, but it's certainly not necessary.
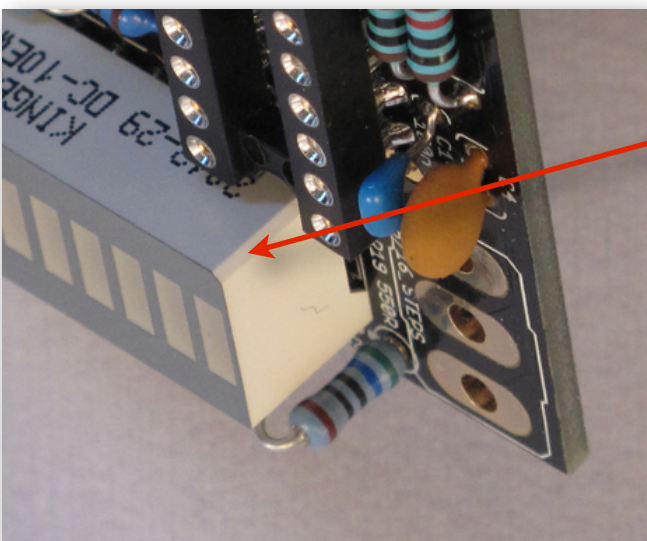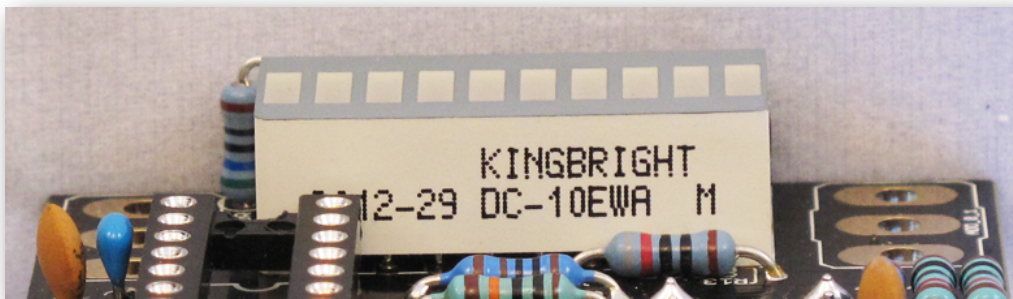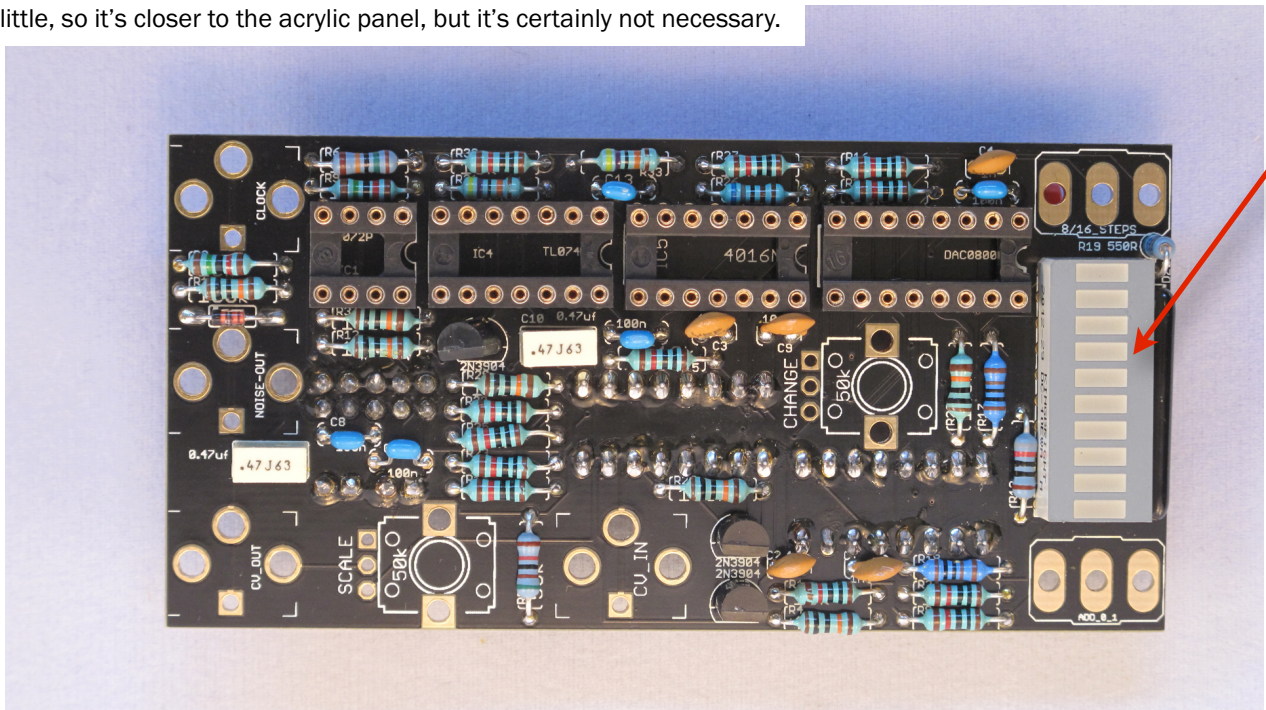
Flattened Corner
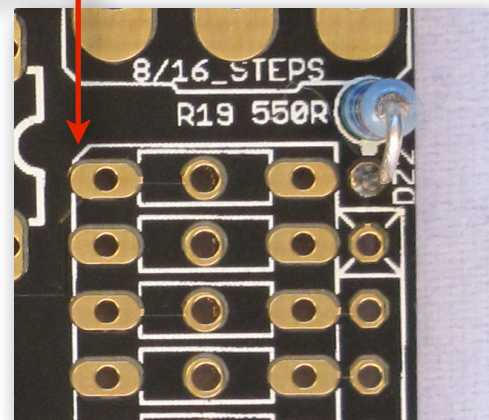
Solder the four Jack sockets.

These snap into the board. Note the jack orientation.
It is important to make sure these are square and the base is flat to
the PCB. Hold firmly in place when you solder to ensure this.
Solder all 4 points on each pot.
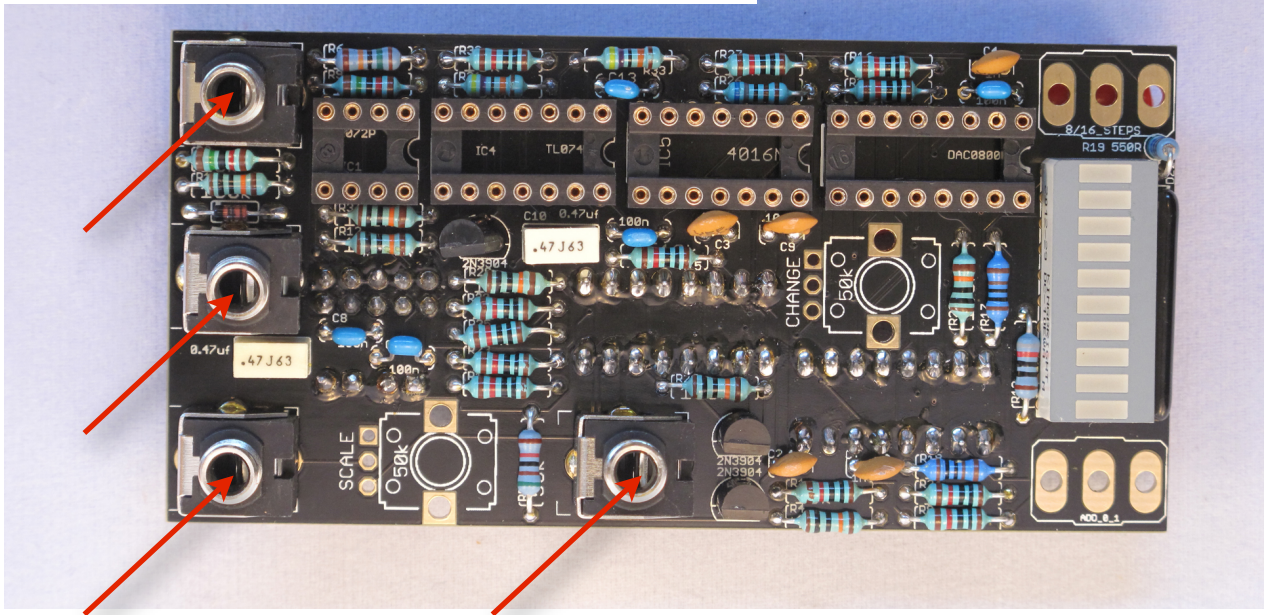
Solder the two Potentiometers.

These snap into the board. Note the small pot with the plastic shaft is
the SCALE pot and the larger pot with the metal shaft is the CHANGE
pot. Solder all 5 points on each pot.

NOTE: Remove the nut and washer from the larger metal pot, they are
not required.
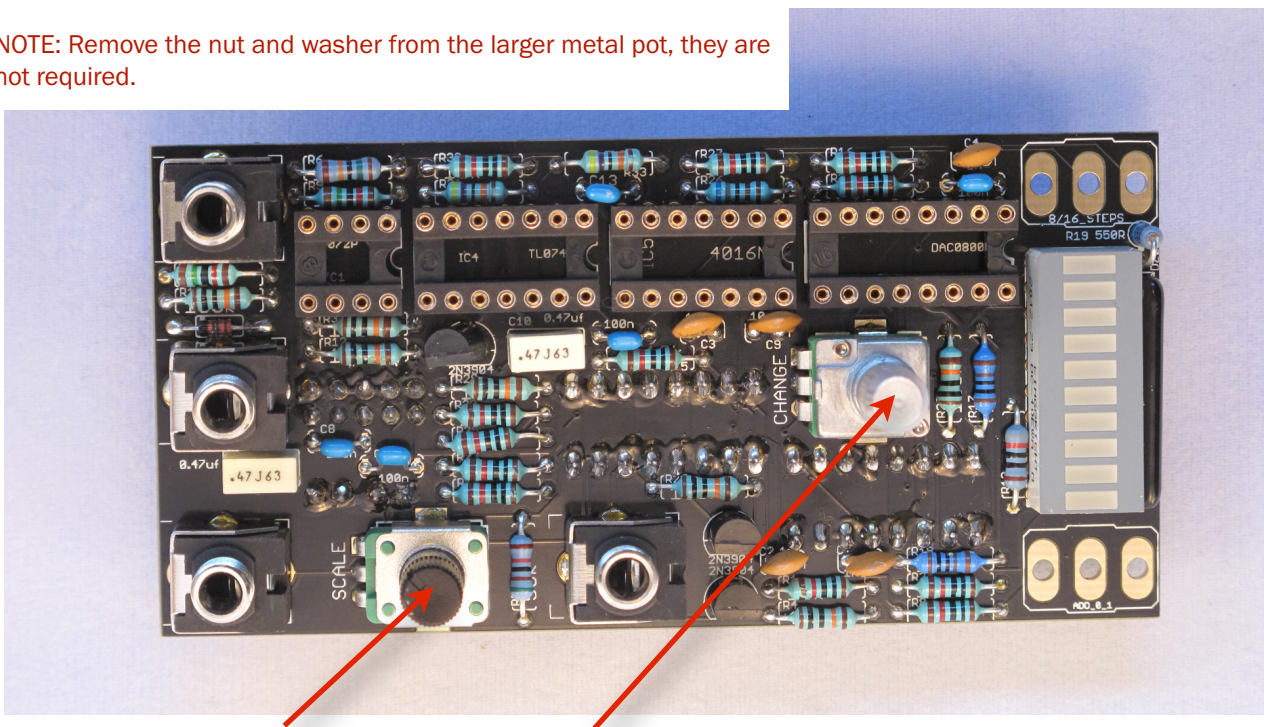
Solder the two switches.

Solder all 3 points on each switch.

NOTE: Orientation does not matter, both switch types can be flipped 180 degrees and will still work perfectly. The two switches are different however

Length Switch: SPDT ON-NONE-ON
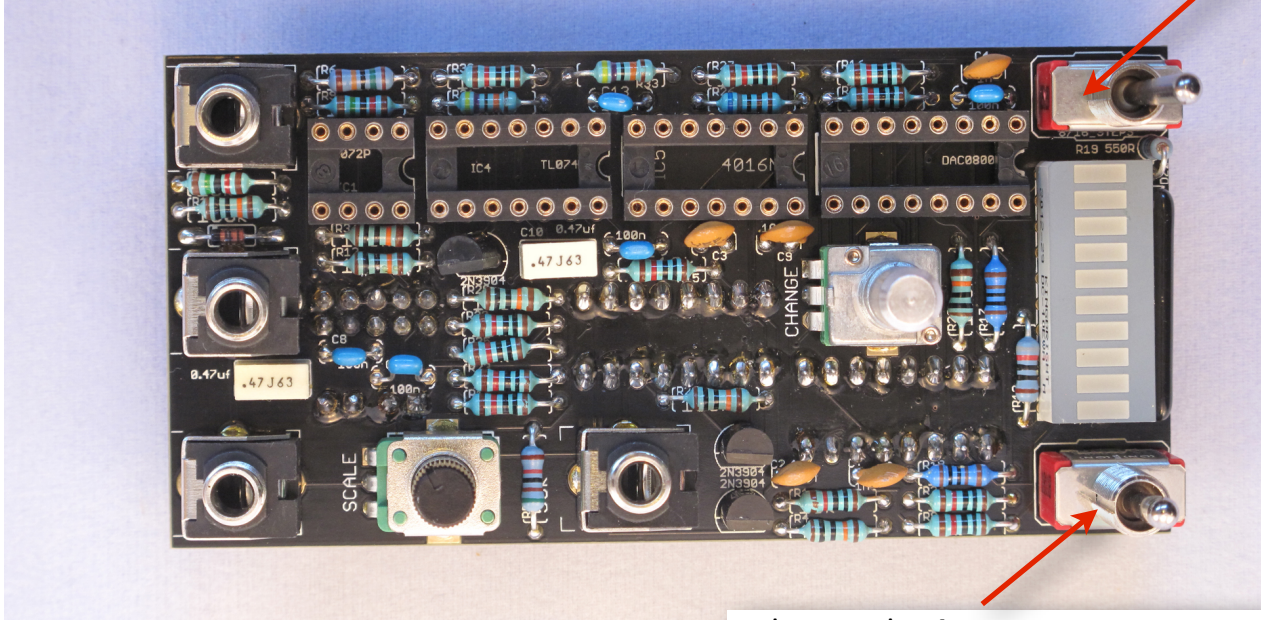
Write Switch: SPDT (ON)-OFF-(ON)
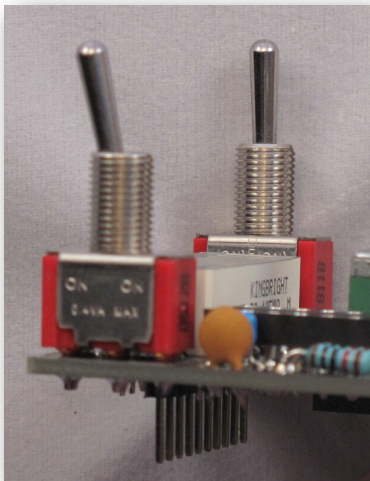
NOTE

The `Write Switch: SPDT (ON)-OFF-(ON)` lever rests in the centre. The lever can be thrown in either direction but spring loading always returns it to the centre.

The `Length Switch: SPDT ON-NONE-ON` lever only has two positions, up or down. It is not spring loaded.

SOLDERING COMPLETE

At this stage you may want to power up the module and use a multimeter to check the expected +12v, -12v, GND connections to the IC sockets, according to the data sheets.

Inserting the six ICs

NOTE: You need to bend the pins inwards slightly towards the main body of the IC or they won't fit the sockets. I often hold the IC body at either end between my finger and thumb and gently depress each row of pins on a tabletop, so they just bend slightly to bring the pins almost perpendicular to the IC body. It's easy to damage them like this if you've never done it before.. so you can also use pliers.

It is vital you take care of the orientation! With the exception of the small TL072, the ICs all have a semi-circular indentation which matches the same shape on the PCB silkscreen and the IC socket.
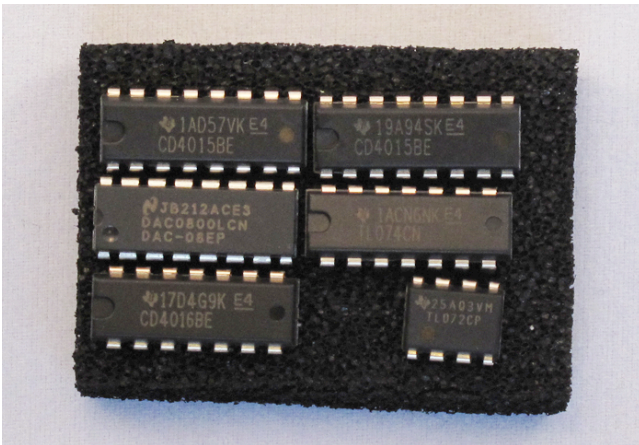
DAC800   CD4016   TL074   TL072
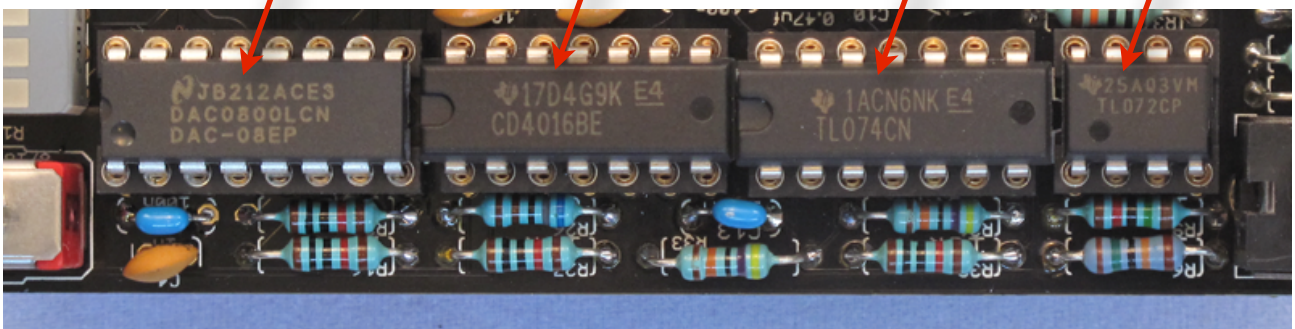
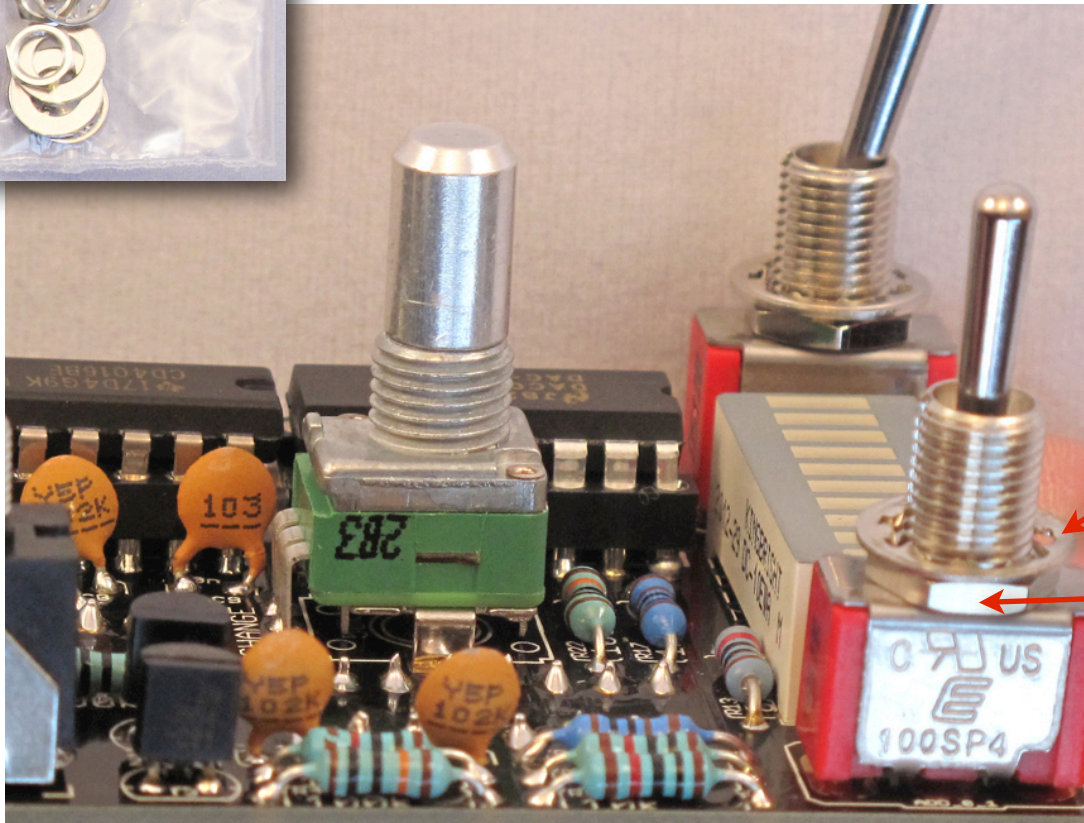CD4015   CD4015

Mounting the Panel

First take the small bag containing the switch hardware. Hand tighten one nut to the base of each switch and then place a single locking washer on top (the type with teeth)

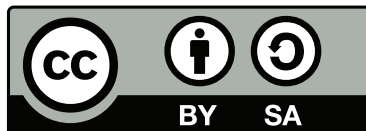You can discard the larger solid washers, these are not used.

Note the larger metal pot has had the nut and washer removed. These are not required. Place the front panel onto the PCB, ensuring the panel is flush with the jacks and the switches (the highest points of contact). Use the remaining two switch nuts to secure them to the front panel, use the bag with the 4 jack nuts to secure those also. Finally add the knob and you are done.
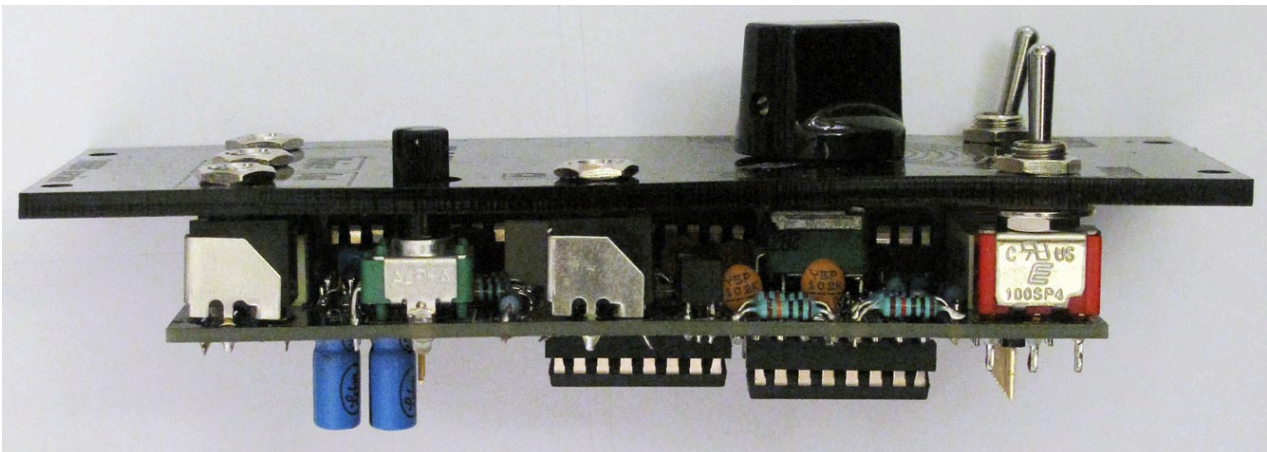
Open Source Hardware

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