…Synth DIY: a White Noise generator (part 1 of 2)

WHAT IS WHITE NOISE?

We've all heard white noise in synth patches – it sounds like the wind, adds breath to a pad, rattle to a snare. It's also a useful source of randomness for modulation, either directly or via a sample and hold circuit.

Technically 'white' noise comprises all frequencies at all amplitudes. Despite this sounding complicated, we can generate white noise very simply. It happens naturally in transistors and all we have to do is amplify it.

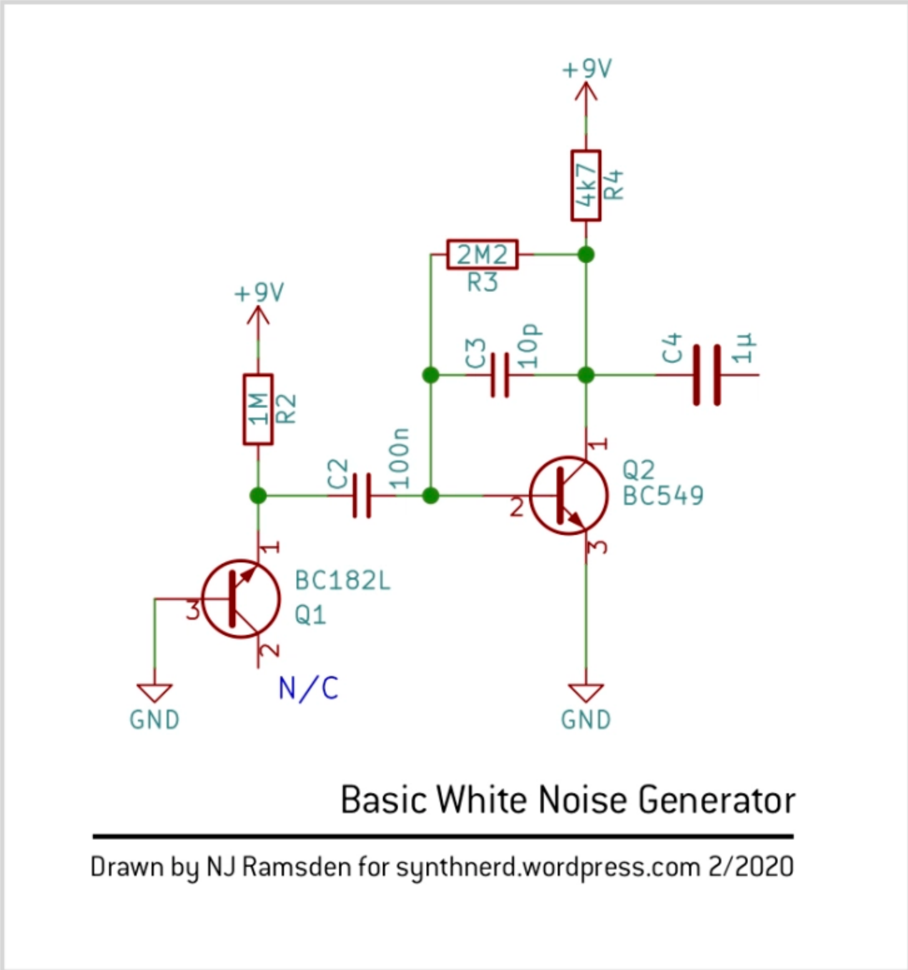
Once we have our white noise, we can filter it. Different colours (https://www.soundonsound.com /sound-advice/q-what-do-different-colours-noise-do) represent different frequency content. Many synthesizers only provide white noise, but some also offer pink, which has the high frequencies rolled off. Occasionally you'll see noise labelled as blue, red, or brown.

METHOD

I decided to make this circuit using discrete components only – no ICs for once! You could use opamps instead for the amplifier stages, but the transistor circuit is compact and runs from a single supply, in this case 9 volts. Battery power is more than adequate.

BASIC WHITE NOISE GENERATOR

Please Note: the R and C numbering in this schematic accidentally begin at 2 rather than 1. This does not affect placement, values, or operation. These identification markers are corrected on the full schematic in Part 2 (https://synthnerd.wordpress.com/2020/03/27/synth-diy-a-white-noise-generator-part-2/).
Also note the pin arrangement for Q1 will vary depending on your choice of transistor.



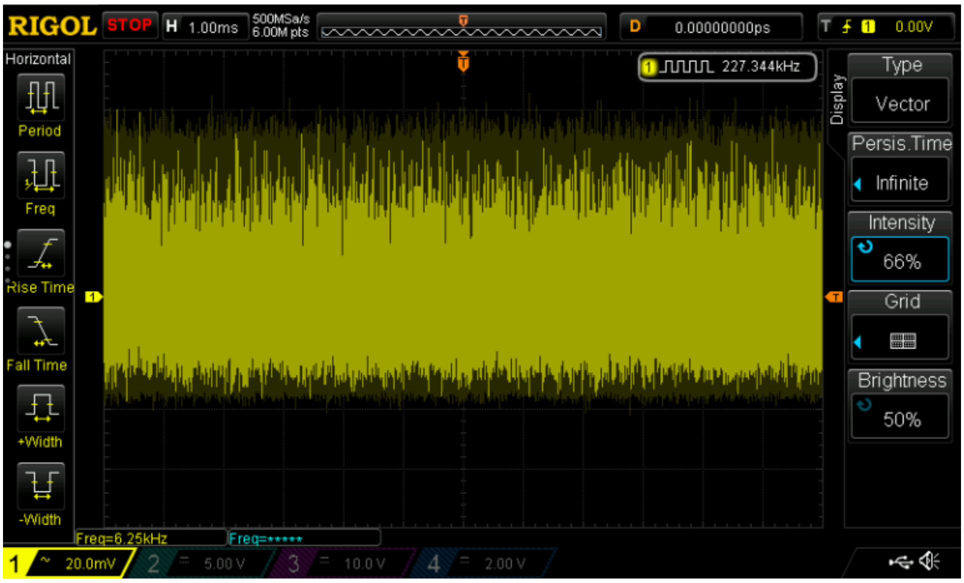
(https://synthnerd.files.wordpress.com/2020/03/basic-wn-generator-schem.jpg)
Basic discrete transistor white noise generator schematic

HOW IT WORKS

The noise itself comes from the first transistor, Q1. In most circuits, the voltage at the base of an NPN would be higher than that at the emitter, allowing current to flow between the collector and the emitter (transistor basics here (https://www.digikey.com/en/articles/techzone/2017/dec/transistor-basics) if you need them, there's no shortage of guides on the internet). However, for noise purposes we reverse that – we hold the emitter higher than the base. We also leave the collector unconnected. If the reverse voltage applied is sufficient, it produces noise that we can amplify and use.

Here I'm using a BC182L. This component will require some experiment on your part. Every transistor has a different breakdown voltage (ie., the reverse base-emitter voltage that produces the noise), and every transistor will give different noise quality. I had good results with the BC182L, but I recommend trying whatever NPN devices you have at hand. If you have an oscilloscope, testing each transistor along with just resistor R2 (here I'm using a 1M resistor) is enough to compare a few examples. My selected BC182L with 1M on 9V gave noise levels up to 100mV peak-to-peak. The output was measured at the emitter.

The following image shows a sample from my Rigol 1054z oscilloscope. Horizontal divisions are 1ms, vertical divisions are 20mV. The bright band is the momentary snapshot, the dark band behind it is the signal smoothed out over time. You can see the signal is around 100mV from its highest to lowest point. This is pretty much the strongest result I got from any of my transistor stock.



(https://synthnerd.files.wordpress.com/2020/03/bc182l-noise.png)
Oscilloscope display of breakdown noise in a BC182L transistor

I also tried several other silicon NPN transistors – nothing special, just what I had handy. In order to get something in the region of 100mV p-p I had to change the resistor value for each of them. Here's a quick list of my results:

BC107 — 200k
BC108 — 640k
BC182L — 1M
BC547 — 150k
BC549C — 270k
2N3904 — 200k

These values are a guide only. You should adjust up or down as required – lower value to get a higher output. Something between 100k and 1M should give you useable noise from a broad range of transistors, so don't worry if what you have isn't listed here.

BUFFERING THE NOISE

The rest of the circuit around the second transistor Q2 is an amplifier. I won't describe here how this works (feel free to research common emitter amplifiers (http://hyperphysics.phy-astr.gsu.edu/hbase/Electronic/npnce.html)), but with these parts the output was around 2V p-p. That should be loud enough for audio testing if you don't have a scope. You could substitute an opamp stage here, which I won't detail. Consider it homework ;).

Note the 10pF capacitor. This isn't essential. In fact, the noise has a higher peak-to-peak level without it (see images below) but it will sound different. This small value capacitor rolls off the harsher top end frequencies, making the basic 'white noise' smoother. Adjust, or omit, to your taste.

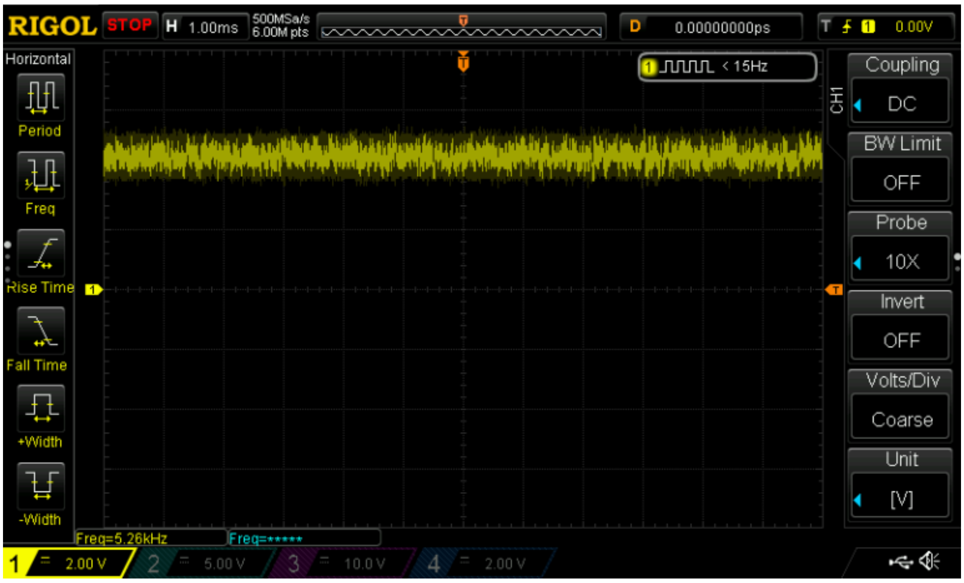
I recommend prototyping this circuit hooked up to something you can listen with, as well as see the signal on a screen. The component values are not set in stone, and it's worth experimenting.

Noise after 1st stage with 10pF capacitor in place

Noise after 1st stage without 10pF capacitor in place

(https://synthnerd.files.wordpress.com/2020/03/noise-figure-with-and-without-10pf-cap.jpg)
White Noise figure with and without 10pF capacitor in feedback of transistor buffer stage

Finally for this stage we can add a capacitor on the output. This will decouple the output from any DC bias when we hook it to something else. You can see the DC bias in effect on the next image. Consider that we are using a single-sided 9V DC supply. The noise has to happen between two positive voltages. Audio signals should be centred around 0V. Any difference between 0V and the centre of the audio signal is the DC offset, and this can cause various problems such as distortion or even speaker damage. The DC offset in the image below is around 4.5V (the dotted horizontal line at the centre of the grid is 0V, the major divisions are 2V).



(https://synthnerd.files.wordpress.com/2020/03/1st-stage-output-dc-offset.png)
White Noise output from first stage buffer showing DC offset

The next image shows the same noise signal taken from after the capacitor but measured as an AC signal to remove the offset. See how it is bipolar around the centre point.

(https://synthnerd.files.wordpress.com/2020/03/1st-stage-output-with-1uf-cap.png)
White Noise output from first stage buffer with DC offset removed

This is enough for a standalone white noise source, and if you choose your components well the output should be enough for audio. You may wish for more gain if you're using this with a Eurorack modular or similar. Modular synth levels are around 10V p-p, and we're not going to reach that with a 9V supply. Feel free to experiment with a 12V supply though. If you want to get a more substantial output, you can use a bipolar supply and an opamp gain stage instead of the second transistor. Alternatively, we'll be adding an output stage later anyway.

PART TWO (https://synthnerd.wordpress.com/2020/03/27/synth-diy-a-white-noise-generator-part-2/) NEXT – ADDING A FILTER AND OUTPUT BUFFER