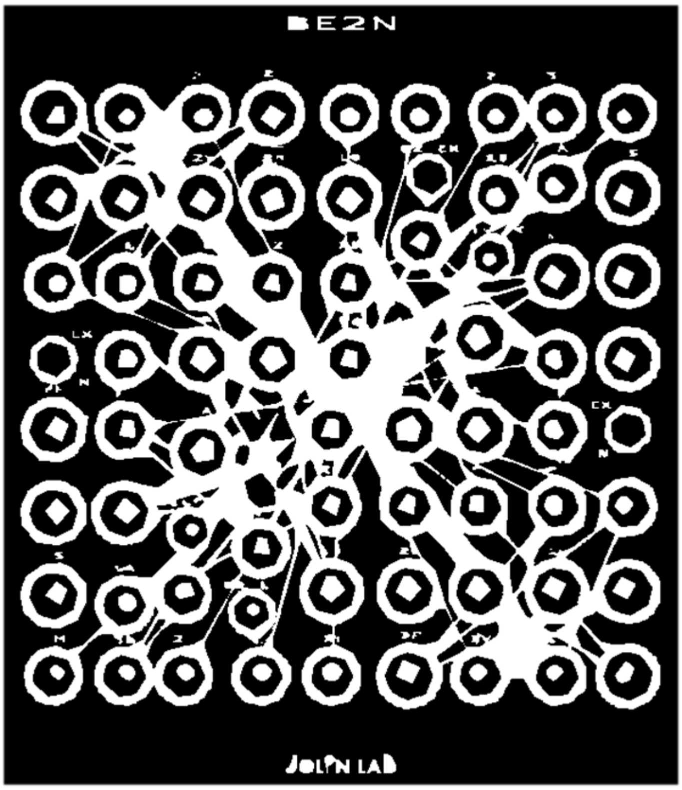
BE2N

is a 22HP eurorack module with two specular Benjolins at its core.
It is intended as a redesign strictly for no-commercial use.
Use it to test and expand your soldering abilities and to investigate this circuit incredible sonic capabilities.
There are some tiny components involved - TSSOP op and 0402 - so be ready to it.

Federico Intrisano



Authors and credits:

To *Rob Hordijk* creator and original designer of the Benjolin - a mentor and a genuine synth wizard.
To *Peter Edwards* - aka Casper Electronics - for his early and extensive work on the Rungler expansions and mods.
To *Forest Caver*, for his eurorack open source adaptation of the Benjolin which this version is based on.
To *Derek Holzer* from Macumbista for the tip on the Rungler bit out implementation.

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WHAT IS A BENJOLIN?

The Benjolin designed by Rob Hordijk in 2009, was intended as kit to be used in educational workshops to promote synth DIY. The idea is that people can build a medium complexity electronic circuit in a controlled environment and box it later at home[1].

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Rob Hordijk words on electro-music.com:

*"**Notes on the oscillators:***
A SSM2164 gain cell is used as a current source to charge/de-charge the cap of the integrating opamp. The next opamp toggles its output of ~+/-5V is exceeded. On the output of the integrating opamp is the triangle wave, on the output of the toggling opamp is the pulse wave. Then the pulse is fed back into the SSM2164 gain cell to reverse charging polarity after the toggling opamp toggles. The SSM2164 has an exponential control curve, so no additional exponential converter is needed. Frequency control range spans some 18 octaves.
The summing opamp that controls the CV input of the SSM2164 has two extra diodes to prevent its output voltage to give the gain cell a higher gain than unity gain (which wouldn't work well on this osc)
See datasheet of the SSM2164 for further details.

What the $#%$ is a rungler?
The purpose of the rungler is to create short stepped patterns of variable length and speed. One could categorize the circuit somewhere halfway between a plain S&H and a shiftregister-based pseudorandom generator. It needs two frequency sources to work and basically creates a complex interference pattern that can be fed back into the frequency parameters of the driving oscillators to create an unlimited amount of havoc.

The rungler is basically a CMOS shift register clocked by one oscillator and receiving its data input from the other oscillator. The output bits of the shiftregister are used as a binary code 'to do something with'. E.g. in the Benjolin the last 3 stages of the shift register for a 3 bit code that is fed into a 3 bit DA converter. This DA eight level output voltage is fed back to the oscillator frequency

[1]https://sdiy.info/wiki/Rob_Hordijk_Benjolin

control inputs. The output of the DA is the 'rungler CV signal'. To describe the rungler waveform in similar terms as like a sine wave or pulse wave I call it a 'stepped havoc wave'.

When the rungler signal is fed back to the frequency parameters of the oscillators it will change the triangle waveforms and pulse widths of the oscillator outputs, making other types of havoc waves, like a 'pulsed havoc wave' and a 'sloped havoc wave'. Note that it is these properties of stepped, sloped and pulsed that are of interest in the waves.
(The Dutch composer Jan Boerman formulated an idea in the 1960s about audio signals that are in-between pitched and unpitched. Havoc waves are probably somewhere in that region, maybe a bit similar to granular synthesis stuff. I haven't really thought deeply about this myself, but Boerman has certainly always been an inspiration to me to try to go into that in-between territory.)

The rungler will try to find a balanced state. In this way it behaves according to principle from Chaos Theory. There seems to be an unlimited amount of possible balanced states and when a balanced state is just slightly disturbed it can be noted that it takes a little time to find the next balanced state, with noticeable bifurcations, etc. Note that a new balanced state is defined by the exact position of the control knobs plus the previous state it was in.

The first rungler experiments I did were back in 1980 I think, and there are quite a lot of variations possible on the rungler idea. In the Benjolin design the data input for the shiftregister is not just the pulse from the second oscillator but the XOR of this pulse and the last bit of the shift register (inspired on the pseudorandom generator). The XOR is the transistor/opamp combination that actually forms a controllable unity gain/minus unity gain amplifier, a very simple ringmodulator, so to speak.

Tip: An interesting option is to feed the three bits at the end of the shiftregister into the 3 'selection' inputs of a CMOS 4051 eight-to-one/one-to-eight analog switch and e.g. quickly switch between eight audio signals. You can take these three bits from the pins 2, 3 and 12 on the 4021.

The shiftregister used should not be too long, four to eight stages already do a perfect job. Some CMOS shiftregisters can recirculate, which would hold the pattern.

One can expand by having multiple parallel shiftregisters alternatingly clocked on positive and negative flanks of the oscillator pulse and e.g. using the triangles from the oscillators to crossfade between multiple DAs on the multiple shiftregisters, etc. By expanding the number of oscillators and shiftregisters the number of available havoc waves explodes. Basically, the rungler is an open-ended circuit that can be expanded and chained into multi-rungler networks.

In the current issue of Leonardo Music Journal (issue 19) is an article about the Blippoo Box, the Benjolins Big Brother, and there is more on the rungler circuit in the article as well as some other thingies I used in the Benjolin as well.

Imho a rungler circuit works best in an analog electronics implementation. It is definitively more alive and surprising due to the slight instabilities in the analog circuitry. I did digital implementations, but they can't beat the 'organic behavior' of the analog versions. But this is just personal taste...

Notes on the filter:

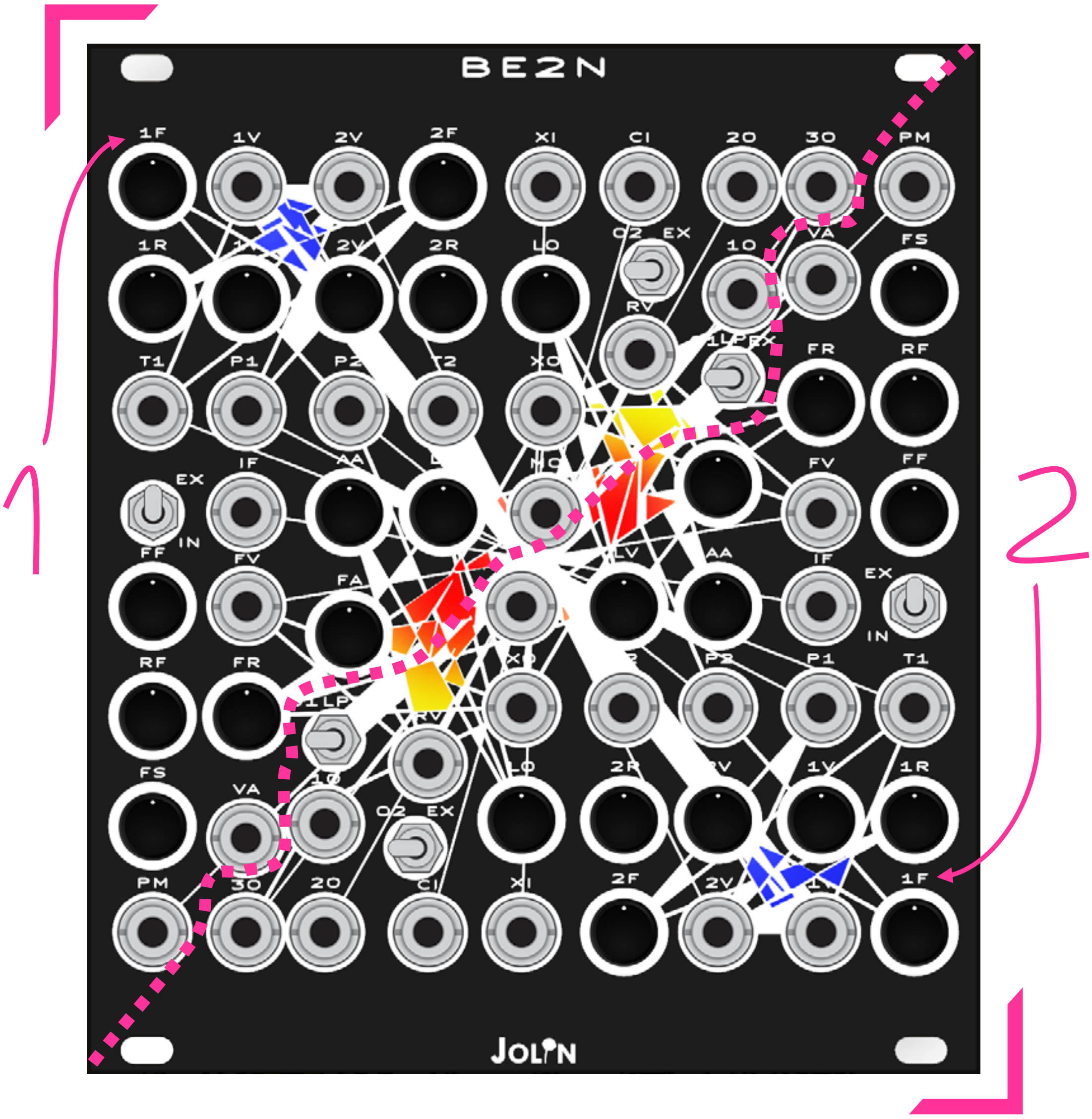
The filter is a plain vanilla 2-pole state variable with some added tricks. Two SSM2164 gain cells drive integrating opamps to create the poles. Like in the oscillators care is taken that the gain cells cannot amplify more than unity gain. (The oscillators can take a little over unity gain, but filter poles really don't like this at all). The cutoff frequency range is again something like 18 octaves.

The input signal into the filter:
The two triangle waves from the oscillators are 'compared' to create one single PWM wave. If one osc is tuned into the LFO range and the other is in audio range you will hear the classic PWM effect. When both are tuned into the audio range it sounds like a ringmodulator effect. To this PWM wave is added a bit of the stepped rungler wave and this final mix is the input into the filter.

There is a relatively small resistor over the resonance feedback pot to give the (linear) pot a slight antilog curve, a curve that feels more natural on a resonance control knob. When resonance is increased there is also a bit of the filter input signal subtracted from the input signal through the resonance pot, to balance the output level between low resonance and high resonance settings.

Finally, there is a simple trick that takes just one resistor but creates some all-harmonics distortion ('tube-like' distortion) by skewing the output waveform; the original more sine-like resonance peak is skewed to a more sawtooth-like waveform. This is explained in detail in the Leonardo Music Journal article. It makes use of the sine-cosine relationship between the outputs of both poles, the explanation why it works is quite complex but to implement it all it takes is only one resistor. And it makes a significant difference in the sound of a filter.”

INTERFACE



The line above divides the controls of the two Benjolins.
They are specular and mirrored.

Considering Benjolin One – top left corner – this is the legenda:

blue: input red: out

- 1F - Oscillator one frequency
- 1V - Oscillator one frequency input modulation[2]
- 2V - Oscillator two frequency input modulation[3]
- 2F - Oscillator two frequency
- XI - XOR[4] input

[2] Normalled internally to Benjolin Two oscillator two triangle out.
[3] Normalled internally to Benjolin Two oscillator one triangle out.
[4] *XOR* is a logical operator whose output is true when either of two inputs are true but not both.

- ❖ CI - Clock input
- ❖ 2O - Rungler bit 2 out – blue led[5]
- ❖ 3O - Rungler bit 3 out – red led
- ❖ 1R - Rungler amount on oscillator one
- ❖ 1V - Attenuator of oscillator one frequency input modulation
- ❖ 2V - Attenuator of oscillator two frequency input modulation
- ❖ 2R - Rungler amount on oscillator one
- ❖ LO - Rungler loop offset
- ❖ 02 EX - Switch to select the Rungler shift register clock source: from oscillator two or from an external clock plugged in CI input
- ❖ 1O - Rungler bit 12 out – green LED
- ❖ T1 - Oscillator one triangle out
- ❖ P1 - Oscillator one pulse out
- ❖ P2 - Oscillator two pulse out
- ❖ T2 - Oscillator two triangle out
- ❖ XO - XOR out
- ❖ RV - Rungler sum output
- ❖ 01 LP EX - Switch to select the Rungler shift register serial in source: Oscillator one (Rungler signal), loop or external input
- ❖ EX IN - Switch to select the filter audio input - from an external signal or from
- ❖ the internal compared oscillators waves
- ❖ IF - Filter audio input
- ❖ AA - Filter audio input attenuator
- ❖ LV - Filtered out level
- ❖ MO - Main Out = Filtered out
- ❖ FF - Filter frequency
- ❖ FV - Filter frequency CV input[6]
- ❖ FA - Filter frequency CV input attenuator
- ❖ RF - Filter resonance
- ❖ FR - Filter Rungler amount
- ❖ FS - Filter Sweep[7]
- ❖ VA - Vactrol VCA input - it effects the MO - filtered out
- ❖ PM - PWM out

[5] The order of operation is pin 2, 12, 3. These outputs are great drum triggers.

[6] Normalled internally to Benjolin Two oscillator two triangle out.

[7] It sweeps the filter cutoff up and down, controlled by the triangle wave coming from oscillator two.

Build Notes:
Follow the .html interactive BOM to place all the components.
There is no detailed guide, just some tips:

- Cut out POT5 back metal tag to avoid it touching the soldered power header socket.
- LEDs are soldered before the pots jack and switch. Closer to the pcb the better.
- Vactrols are placed horizontally. On the diode side the shorter legs - cathode - goes into the squared hole.
- On the board there is a JST male header footprint. It is not necessary to place it but it could be useful to use BE2N as a standalone unit. Experiment with this.

Have fun,
Federico Intrisano
Jolin