random

modular quad true random voltage generator
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Contents

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1 Introduction

The transistorkreis random module is a quad true random voltage generator for modular synthesizers. Each of its four voltage outputs can be switched to

- uniform or normal distribution,
- unipolar or bipolar polarity and
- an amplitude of 5 Vpp or 10 Vpp (via a DIP switch on the main PCB).

There are two inputs to trigger new random voltages for output 1 to 3 and for output 4, which accept clock signals up to audio range frequencies. The true randomness of the generated voltages is ensured by using the RNG[1] module of an STM32 microcontroller based on an unpredictable physical noise source.

Modules from transistorkreis for modular synthesizers are available as DIY kits for the Moog format (MU) and the Eurorack format. Their design is generic and also allows for building any other format. Figure 1 shows the front panel layout of the Moog and Eurorack version of the random module. The design of modules from transistorkreis is partially published and licensed as open source, see section 4 for the open-source firmware of the random module.

Modules from transistorkreis feature:

- skiff-friendly Eurorack modules,
- no tantalum electrolytic capacitors due to ecological reasons,
- only high-quality electronic and electromechanical components.

DIY kits from transistorkreis are compliant to European regulations. Modules from transistorkreis or their components must be disposed separately.

[1]See application note AN4230 from STMicroelectronics.

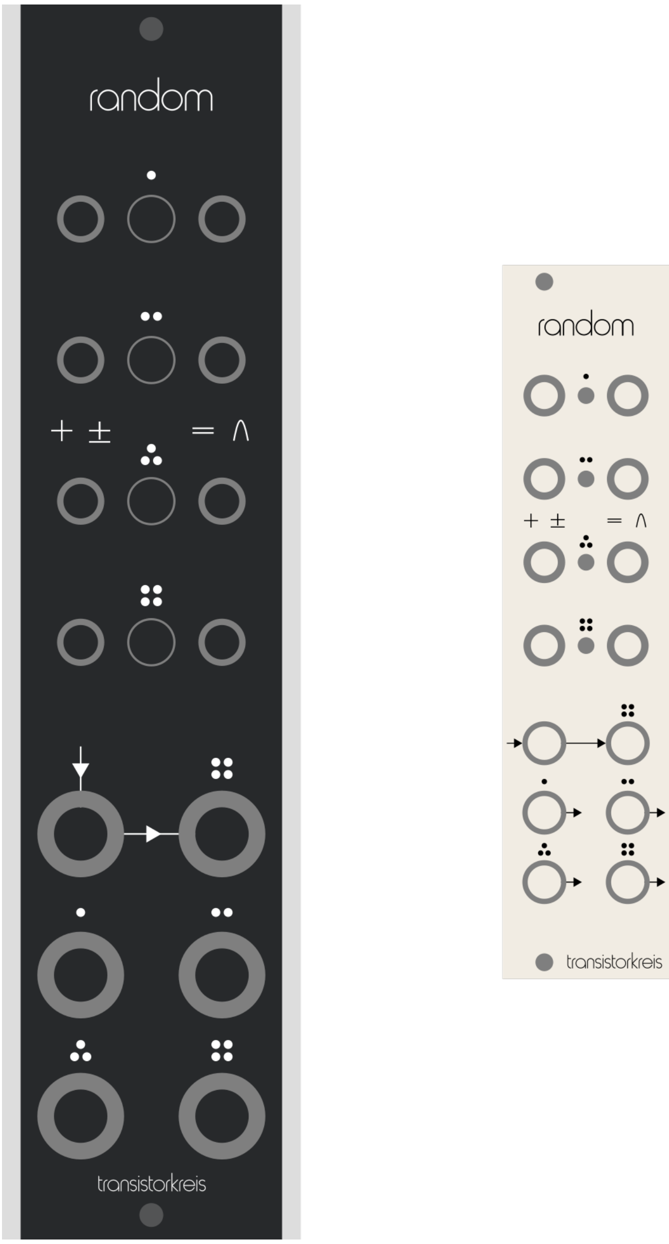

Figure 1: Front panel layout of the Moog and Eurorack version.

2 Operation

Only install and operate completely ready-made modules. Follow the instructions in section 3 on how to build your random module.

2.1 Installation

Always switch off the power supply of your modular synth before installing a new module in order to avoid serious damage!

Make sure that the power supply of your modular synth has sufficient capacity to power all modules. Therefore, sum up the specified positive current draw of all modules, including your random module. This should be the +12 V or +15 V current draw depending on your modular synth. Do the same for the negative current draw, i.e. the −12 V or −15 V current draw. The current draw should be specified in the manufacturer's technical specification for each module. And the current draw of your random module is listed in table 4 in section 5. Only proceed with the installation of your transistorkreis module if none of the values exceeds the specification of the power supply of your modular synth.

Use washers to avoid damaging the surface of the front panel.

Installation of the Moog version

A ±15 V power supply and 6-pin MTA-100 connectors are used to power your system. See figure 2 on how to connect the power supply to your transistorkreis module. Make sure that the male and female connector are aligned and correctly orientated. Never use any violence to plug or unplug connectors. You should see a short front panel LED running light when your transistorkreis random module is powered up.

Installation of the Eurorack version

A ±12 V power supply and IDC connectors are used to power your system. Only use the Eurorack power cable from transistorkreis to connect the power supply of your modular synth to your transistorkreis random module. This power cable has a small and a large IDC connector: 2 rows each with 10 and 16 pins. Connect the small IDC connector to the Eurorack power connector of the main PCB of your random module. The male connector on the PCB is shrouded to ensure a correct orientation and alignment of the

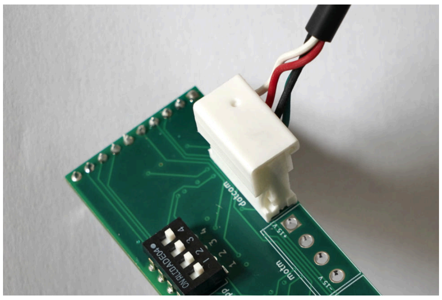

Figure 2: MTA-100 power connector

connection. Respectively, the red wire of the power cable is located at the side of the connector that is marked with “-12 V”. See figure 3 on how the Eurorack power cable is connected to your transistorkreis module.

Connect the large IDC connector of the Eurorack power cable to the power supply of your modular synth. Never use any violence to plug or unplug connectors and double check

- that the female connector of the power cable and the male connector of the power supply are aligned (no open pins) and correctly orientated,
- that the red wire of the power cable is located at the -12 V side of the male connector to avoid serious damage!

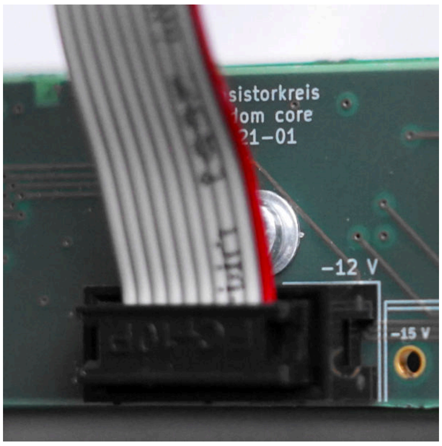

Figure 3: Eurorack power connector

You should see a short front panel LED running light when your transistorkreis random module is powered up.

2.2 Usage

There are two inputs to trigger new random voltages:

- one input to trigger new random voltages for output 1 to 3 and
- a second input to trigger a new random voltage for output 4.

The first input is normalised to the second one, i.e. the first input triggers all four outputs if the second input is left unplugged. Both inputs accept clock signals up to audio range frequencies.

There are three settings for each of the four outputs:

- Use one of the left-handed switches to set an output to unipolar polarity (+) for only positive voltage values or to bipolar polarity (±) for positive and negative voltage values.
- Use one of the right-handed switches to set the voltage distribution of an output to uniform (=) or normal ($\frown$). With uniform distribution all possible voltage values are of equal probability, whereas high positive or negative voltage values are less likely with normal distribution.
- Use the DIP switch on the main PCB to set the peak-to-peak amplitude of an output, i.e. the difference between the lowest and highest possible voltage value. It can be set to 5 Vpp or 10 Vpp. Therefore, refer to the PCB marking of the DIP switch. This can only be done if the module is not installed into the case of your modular synth. Always switch off the power supply of your modular synth before removing your module!

Refer to table 1 for the resulting output voltage range depending on the polarity and peak-to-peak amplitude setting. Those voltage ranges fit both Moog and Eurorack requirements depending on the purpose of your transistorkreis random module within your patch.

Table 1: Output voltage range depending on polarity and amplitude.

	unipolar (+)	bipolar (±)
5 Vpp	0 V to 5 V	−2.5 V to +2.5 V
10 Vpp	0 V to 10 V	−5 V to +5 V

2.3 Patch examples

This section presents some ideas of what you can do with your random module. There is also a demo video clip on the transistorkreis homepage that presents the following patch examples.

CV source

Connect the gate signal, that is used to trigger a sound, to your transistorkreis random in order to trigger new random voltages when the sound is triggered. Use those voltages to modulate parameters of the sound, e.g. VCF cutoff frequency and resonance, square wave pulse width, VCA gain, fader balance etc. This will add brio to the sound and is especially useful with periodic sounds and sequences. Figure 4 shows an example.

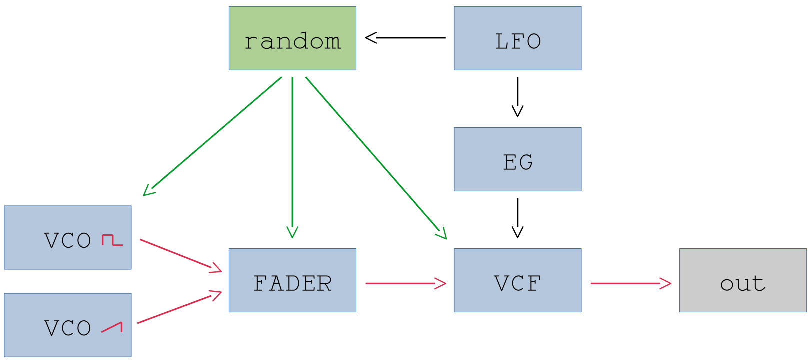

Figure 4: The random module as CV source.

The recommended peak-to-peak amplitude of an output is depended on its modulation destination, but 5 Vpp should be sufficient. The polarity of an output should be unipolar if the random module shall only increase the modulated parameter, e.g. negative values do not make sense for a filter resonance that is set to Zero. Switch an output to bipolar if your random module shall increase as well as decrease the modulated parameter depending on the current random value, e.g. a filter cutoff frequency shall vary around a certain value. Switch the distribution of an output to uniform if all possible values are equally desirable. And switch it to normal distribution if extreme values, i.e. very high and very low values, are less desirable.

Digital noise oscillator

Connect a VCO to the random input in order to trigger new random voltages with frequencies in the audio range. Switch the distribution to uniform, the polarity to bipolar and the peak-to-peak amplitude should be 10 Vpp. Your random module serves as a digital noise oscillator now and you may modulate the frequency of the VCO, e.g. with an LFO or an envelope generator, to reach certain effects. You may try to use a self-oscillating filter instead of a VCO to increase the maximally possible frequency your random module is triggered with. Figure 5 visualize this patch idea.

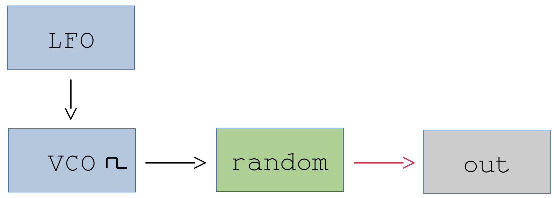

Figure 5: The random module as digital noise oscillator.

Digital noise modulator

A digital noise modulator is similar to the digital noise oscillator in the previous subsection and your random module is also triggered with frequencies in the audio range. But for modulating purposes and in contrast to the digital noise oscillator the polarity of an output is depended on the modulation destination and a peak-to-peak amplitude of 5 Vpp should be sufficient. For instance, you may use the output of your random module to modulate the frequency and the pulse width of a square wave VCO in order to generate interesting timbres. In addition, the frequency of the triggering VCO might be modulated to reach certain effects. Figure 6 shows an example patch.

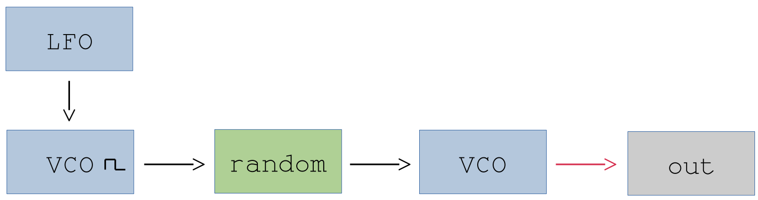

Figure 6: The random module as digital noise modulator.

3 Building the module

Being experienced in electronics and soldering is mandatory!
Always use ESD prevention measures when touching the Core PCB!

The electronics of the random module is placed onto only one main PCB, which is called the Core PCB. Its electronics is ESD[2]-sensitive. You should at least use a grounded wrist strap and an anti-static mat when touching its electronics in order to avoid serious damage. There are auxiliary PCBs, which carry front panel components. Core PCB and auxiliary PCBs are connected via pin strips or ribbon cables.

3.1 Bill of material

Table 2 lists all components that are required to build the random module for the Moog (MU) and Eurorack (ER) format. All available PCB references are listed if a component is used for more than one PCB.

3.2 Preparing the Core PCB

The Core PCB is almost complete: All SMD[3] components have already been soldered and the firmware for the STM32 has already been flashed and tested. You still have to solder the remaining components:

- the DIP switch SW1,
- the MTA-100 power connector J1 for the Moog version or the Eurorack power connector J3 for the Eurorack version,
- the male pin strips J5 and J6.

Make sure

- that you solder all components onto the PCB side where the outline of the respective component is marked, see figure 7 and 8,
- that the pin strips are soldered completely rectangular to the PCB surface,
- that the orientation of the power connectors J1 and J3 is correct, see their component outline on the PCB and figure 7.

[2] electrostatic discharge
[3] surface-mount device

Table 2: Bill of material.

num	MU	ER	denomination	value or annotation	PCB ref
1	✓	✓	Core PCB	all SMD components placed	–
1	✓	✓	DIP switch	4 pos, 2.54 mm	SW1
2	✓	✓	male pin strip	1 row, 10 pos, 2.54 mm	J5-6
2	✓	✓	female pin strip	1 row, 10 pos, 2.54 mm	J1-2/J7-8
1	✓	✓	spacer	M3, 11 mm	–
2	✓	✓	screw M3	DIN 7985, 6 mm	–
3	✓	✓	washer M3	DIN 125 (0.5 mm thick)	–
1	✓	–	Control PCB	no components placed	–
1	✓	–	Jack PCB	no components placed	–
1	✓	–	power connector	MTA-100, 6-pin (Dotcom)	J1
8	✓	–	switch & 2 nuts	SPDT, on-none-on	SW1-8
8	✓	–	toothed washer	suitable for the switch	–
8	✓	–	notched washer	suitable for the switch	–
4	✓	–	LED	5 mm, red, 1.7 V, 2 mA	D1-4
2	✓	–	IDC connector	2 rows, 8 pos, 2.54 mm, male	J3, J7
2	✓	–	IDC connector	2 rows, 8 pos, 2.54 mm, female	–
1	✓	–	ribbon cable	8 conductors, 28 AWG	–
4	✓	–	LED holder	VCC CMC_441_CTP	–
4	✓	–	toothed washer	suitable for the LED holder	–
4	✓	–	plastic nut	suitable for the LED holder	–
6	✓	–	mono jack & nut	Switchcraft 112APCX	J1-6
6	✓	–	washer	suitable for the jack	J1-6
6	✓	–	washer M10	DIN 125 (2.0 mm thick)	–
1	–	✓	ER PCB	no components placed	–
1	–	✓	power cable	Eurorack power cable	–
1	–	✓	power connector	2 rows, 10 pos, 2.54 mm, male	J3
6	–	✓	mono jack & nut	Thonkiconn PJ398SM	J1-6
4	–	✓	LED	3 mm, red, 1.7 V, 2 mA	D1-4
8	–	✓	switch & nut	SPDT, on-none-on	SW1-8
8	–	✓	toothed washer	suitable for the switch	–
8	–	✓	washer M5	DIN 125 (1.0 mm thick)	–

Pin 2 of the Moog power connector J1 must be cut off with a small side cutter. This pin is marked on the PCB and in figure 7.

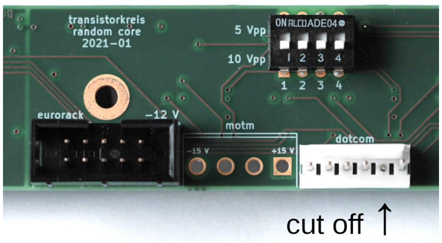

Figure 7: DIP switch and power connectors.

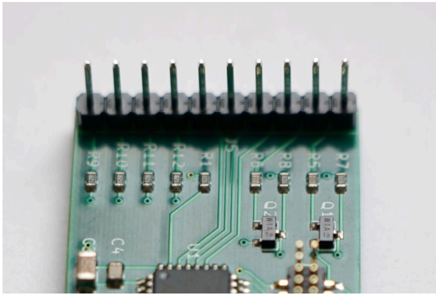

Figure 8: Male pin strips.

3.3 Building the Eurorack version

There is one auxiliary PCB holding the front panel components. Make sure that you solder each component onto the PCB side where the outline of the respective component is marked.

At first you need to solder the female pin strips J7 and J8. You may form a sandwich with the Core PCB before you solder them in order to make them properly fit into their male counterparts on the Core PCB, see figure 9. Remove the Core PCB after you soldered the pin strips.

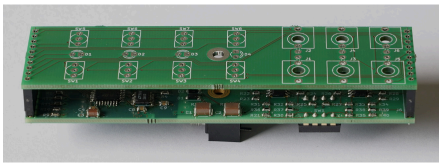

Figure 9: Forming a sandwich before soldering J7 and J8.

Fix the spaceholder onto the PCB with a screw and a washer (M3) on each side of the PCB as shown in figure 10. Fix the spaceholder onto the PCB side where the pin strips are as shown in figure 11.

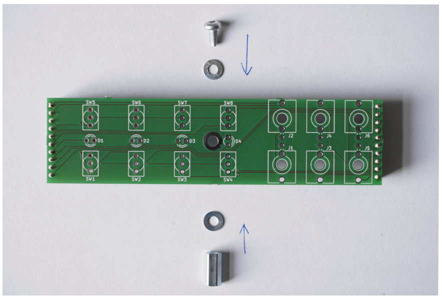

Figure 10: The spaceholder fixation.

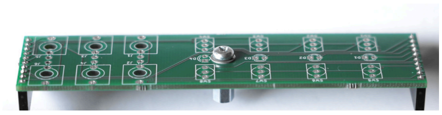

Figure 11: The fixed spaceholder and its orientation.

Put the leads of LED1 to LED4 through their solder pins. Make sure that the shorter leads, i.e. the cathode leads, are put through the rectangular solder pins, see figure 12. Do not solder them yet!

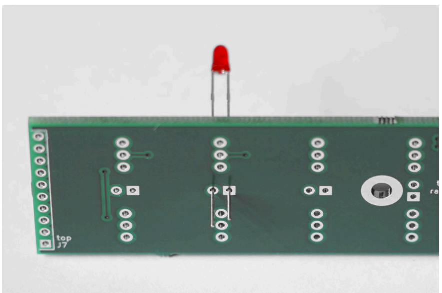

Figure 12: The rectangular solder pins for the LED cathode leads.

Put the switches SW1 to SW8 and the jacks J1 to J6 onto the PCB. Do not solder them yet! Put a washer (M5) and a toothed washer onto the switches, see figure 13 for the order of the washers. Put the front panel onto the switches and the jacks. Use their nuts to fix the front panel loosely; only use your fingers to tighten the nuts. Solder the switches and jacks and tighten their nuts properly now. Be very careful not to damage the front panel surface if you use a wrench or a pair of pincers to tighten the nuts.

Figure 13: Switch with its washer and toothed washer.

Push the LEDs through their front panel holes, shorten their leads and solder them. Keep in mind that LEDs are heat-sensitive. Plug the Core PCB onto the auxiliary PCB. Double check the orientation of the PCBs and the alignment of the male and female pin strips in order to avoid serious damage: top to top, bottom to bottom and no open pins! Use the remaining screw and washer (M3) to fix the PCB to the spaceholder. The module is now ready-built. See figure 14 on how it should look like.

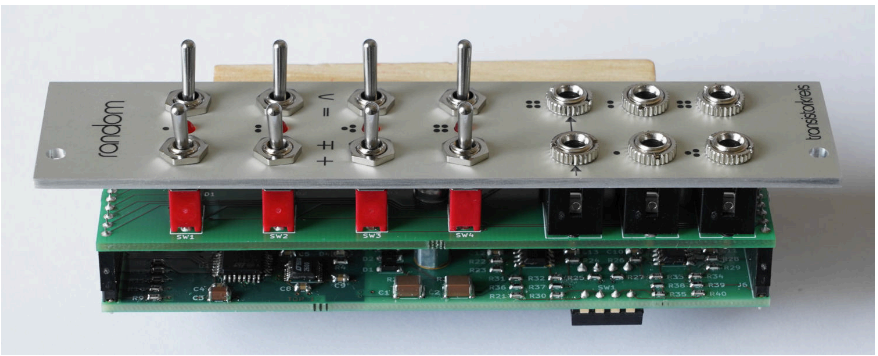

Figure 14: The ready-built Eurorack module.

3.4 Building the Moog version

There are two auxiliary PCBs holding the front panel components: one for the switches and LEDs and one for the jacks. They are called Control PCB and Jack PCB. Control and Jack PCB are connected with a ribbon cable with IDC connectors. And Control

PCB and Core PCB are connected via female and male pin strips. Make sure that you solder each component onto the PCB side where the outline of the respective component is marked.

Control PCB

Fix the spaceholder onto the PCB with a screw and a washer (M3) on each side of the PCB as shown in figure 15. Fix the spaceholder onto the PCB side with the marked outline of J1, J2 and J3.

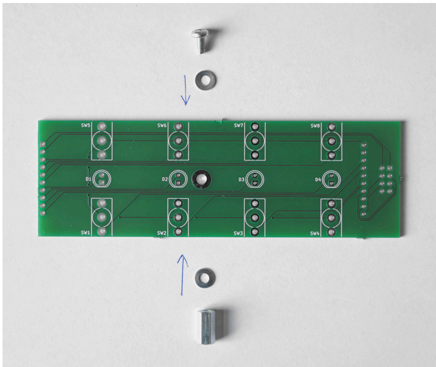

Figure 15: The spaceholder fixation.

Solder the female pin strips J1 and J2. You may form a sandwich with the Core PCB before you solder them in order to make them properly fit into their male counterparts on the Core PCB, see figure 16 for details. Remove the Core PCB after you soldered the pin strips.

Figure 16: Forming a sandwich before soldering J1 and J2.

Solder the male IDC connector J3. Make sure that its orientation is correct in order to avoid serious damage. Therefore, have a look at the outline of J3, that is marked on the PCB: The notch of J3 points outwards as shown in figure 17.

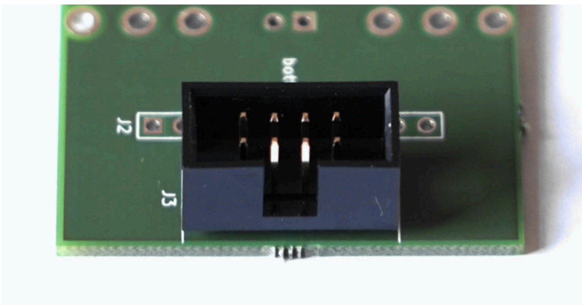

Figure 17: Orientation of J3.

Put the four LED holders into their front panel holes and fix them each with a toothed washer and a plastic nut, see figure 18.

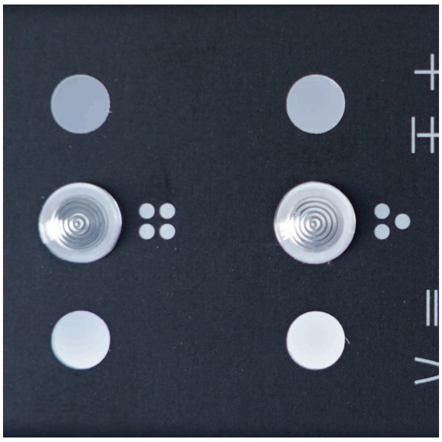

Figure 18: Front panel LED holders.

Put the leads of LED1 to LED4 through their solder pins. Make sure that the shorter leads, i.e. the cathode leads, are put through the rectangular solder pins, see figure 19. Do not solder them yet!

Put the switches SW1 to SW8 onto the PCB. Do not solder them yet! Screw a nut onto the switches and carefully tighten them with a wrench. Add a notched washer and a toothed washer onto the switches, see figure 20 for the order of nut and washers and figure 21 on how it should look like.

Put the front panel onto the switches and make sure that its orientation is correct: J3, i.e. the bottom side of the Control PCB, points downwards. Use an additional nut for each switch to fix the front panel loosely; only use your fingers to tighten the nuts.

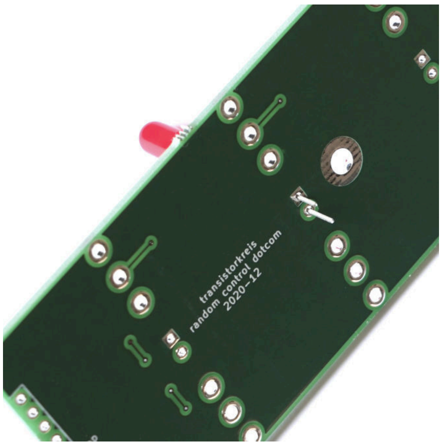

Figure 19: The rectangular solder pins for the LED cathode leads.

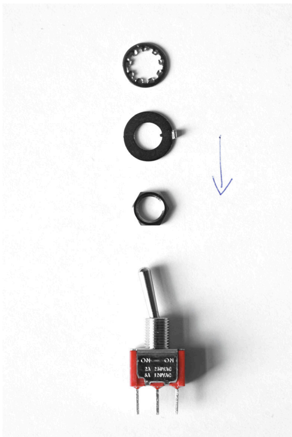

Figure 20: Switch with its nut as well as notched and toothed washer.

Solder the switches and tighten their nuts properly now. Be very careful not to damage the front panel surface if you use a wrench or a pair of pincers to tighten the nuts.

Push the LEDs into their LED holders, shorten the LED leads and solder them. Keep in mind that LEDs are heat-sensitive.

Jack PCB

Solder the male IDC connector J7 onto the Jack PCB. Pay attention to the correct orientation of J7 to avoid serious damage: The notch of J7 points to the PCB center,

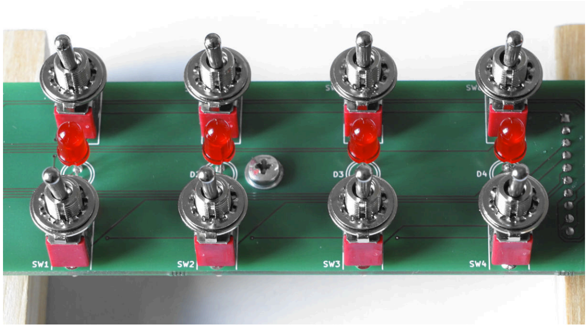

Figure 21: LEDs and switches placed onto the Control PCB.

which is also indicated by its marked outline.

Put the jacks J1 to J6 onto the PCB. Do not solder them yet! Add a washer (M10) onto each jack as shown infigure 22.

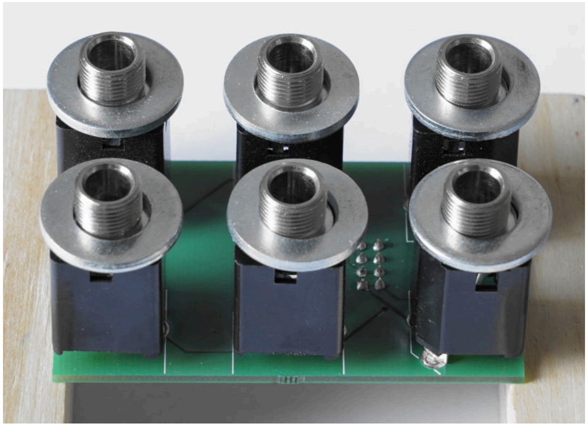

Figure 22: Washers placed onto the jacks.

Put the front panel onto the switches. Make sure that its orientation is correct, i.e. J1 and J2 are the inputs and IDC connector J3 points upwards respectively. Add a washer and a nut to each jack and use the nuts to fix the front panel loosely; only use your fingers to tighten the nuts. Solder the jacks and tighten their nuts properly now. Be very careful not to damage the front panel surface if you use a wrench to tighten the nuts. See figure 23 on how it should look like.

Plug the Core PCB onto the Control PCB. Double check the orientation of the PCBs and the alignment of the male and female pin strips in order to avoid serious damage: top to top, bottom to bottom and no open pins! Use the remaining screw and washer

Figure 23: The fixed front panel jacks.

(M3) to fix the Core PCB to the spaceholder.

Connecting the Control PCB and the Jack PCB

A ribbon cable with IDC connectors is used to connect the Control and Jack PCB. Put the 8-pin female IDC connectors onto the outer ends of the ribbon cable as shown in figure 24. Double check the orientation of the connectors to avoid serious damage: Their notches must point into the same direction.

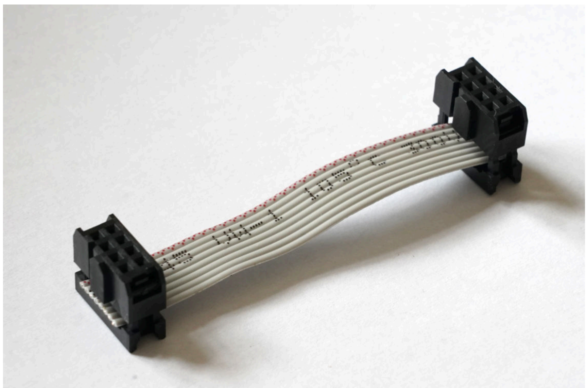

Figure 24: Orientation of the IDC connectors.

Add the connector clips to fix the connectors to the ribbon cable. Check the proper alignment of connectors and ribbon cable and use a pair of pincers to carefully push the clips into the connectors. Pay attention that the clips properly latch. See figure 25 for details.

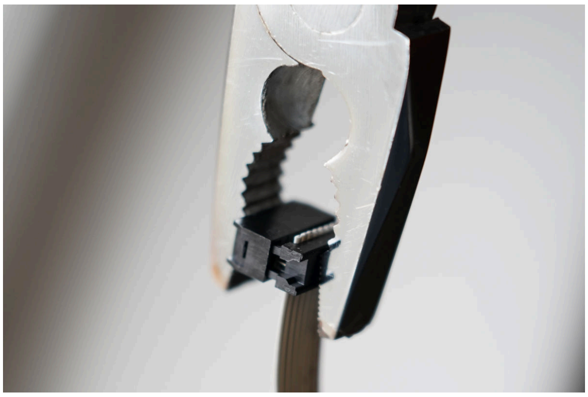

Figure 25: Fixation of the IDC connectors to the ribbon cable.

Turn the ribbon cable around the top of the connectors and use the larger clips for an additional fixation of the ribbon cable as shown in figure 26. The ribbon cable is now ready-built, see figure 27 on how it should look like. Plug the cable into the respective male IDC connectors in order to connect the Control and Jack PCB, i.e. plug the cable into J3 of the Control PCB and J7 of the Jack PCB.

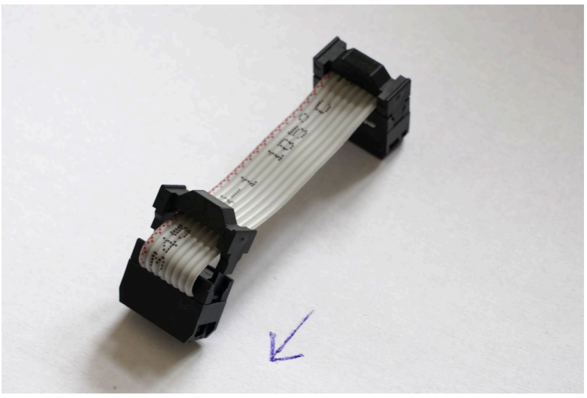

Figure 26: Additional fixation of the ribbon cable.

The module is now ready-built. See figure 28 on how it should look like.

Figure 27: The ready-built ribbon cable.

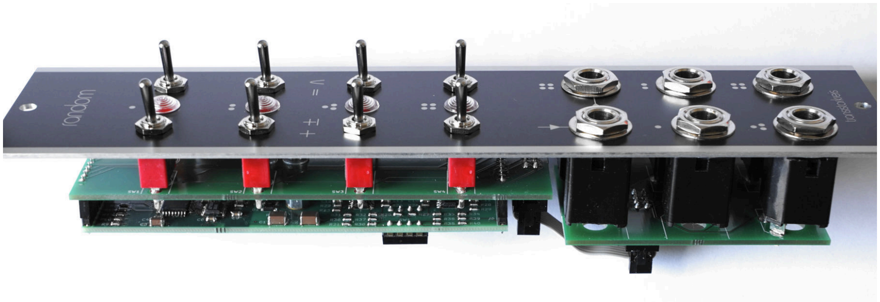

Figure 28: The ready-built Moog module.

3.5 Support for other formats

You are solely responsible for any damages to your module or hardware when you try to build a customized version!

Other formats in gerneral

The electronics of the random module is placed onto the Core PCB, that is equal for all formats. You may design auxiliary PCBs that carry the front panel components and connect them to the pin strips of the Core PCB. Therefore, breadboard-style PCBs can be used since the pin strips of the Core PCB are aligned to 0.1 inch, respectively 2.54 mm. Table 3 lists the pin assignment of the male pin strips J5 and J6 of the Core PCB. Their first pin is marked each with a rectangular solder pin.

The polarity of an output is set to bipolar if the respective polarity pin is connected to

VDD and set to unipolar if it is unconnected. The distribution of an output is set to normal if the respective distribution pin is connected to VDD and set to uniform if it is unconnected. All LED cathode terminals have to be connected to GND.

Table 3: Pin assignment of the Core PCB pin strips.

pin	J5 (top)	J6 (bottom)
1	input 1	VDD
2	input 2	GND
3	distribution 1	polarity 1
4	distribution 2	polarity 2
5	distribution 3	polarity 3
6	distribution 4	polarity 4
7	LED 1 anode	output 1
8	LED 2 anode	output 2
9	LED 3 anode	output 3
10	LED 4 anode	output 4

MOTM

The Core PCB offers solder pins for an optional 4-pin MTA-156[4] MOTM[5] power connector. You might also use the Control and Jack PCB of the Moog version, but create a slimmer front panel that fits the MOTM format.

4 Firmware

You are solely responsible for any damages to your module or hardware when you try to modify the firmware of your module!

The firmware of the transistorkreis random module is written in C++ for an STM32L412 microcontroller and you may modify it in order to adapt it to your needs. For instance, you could implement an alternative random distribution or use the second input to switch any parameter instead of triggering a new random voltage for the fourth output.

The Firmware is published under the GNU GPLv3 license[6] and provided as git[7] repos-

[4]TE Connectivity 640445-4
[5]Mother Of The Modulars, originally by Synthesis Technology
[6]See https://choosealicense.com/licenses/gpl-3.0/.
[7]See https://git-scm.com/.

itory on github[8] The firmware is organized as an STM32CubeIDE[9] project. Use the serial wire debug port J4 on the Core PCB to flash and debug the firmware.

Figure 29 shows an UML[10] class diagram of the firmware and all relevant classes and software units are listed below. Further details are documented in the source code with Doxygen[11].

- Eventhandler: Processes state machine events, e.g. input triggers and timer events.
- Animation: Realizes the front panel LED running light via a state machine.
- Generator: Generates uniformly or normally distributed random numbers.
- PcbStatusLed: Realizes the flashing of the SMD LED on the Core PCB.
- RngHandler: Manages the random number buffers.
- Transmitter: Controls the front panel outputs and LEDs via SPI[12].
- TIMER, GPIO, SPI, RNG: low-level HAL[13] drivers.

5 Technical Data

Table 4 lists the most important technical data of the transistorkreis random module.

Table 4: Technical data of the random module.

quantity	value
supply voltage	$\pm 12\,\mathrm{V}$ to $\pm 15\,\mathrm{V}$
current draw (pos. and neg. draw)	$+32\,\mathrm{mA}$ and $-15\,\mathrm{mA}$
front panel dimensions	5 U/1 HP (Moog), 3 U/6 HP (Eurorack)
depth (from front panel)	45 mm (Moog), 38 mm (Eurorack)
weight	227 g (Moog), 78 g (Eurorack)
input trigger threshold	800 mV
max. operating ambient temperature	40 °C

[8] The repository can be cloned from https://github.com/transistorkreis/random.
[9] See https://www.st.com/en/development-tools/stm32cubeide.html.
[10] Unified Modeling Language
[11] See https://www.doxygen.nl/.
[12] Serial Peripheral Interface
[13] Hardware Abstraction Layer

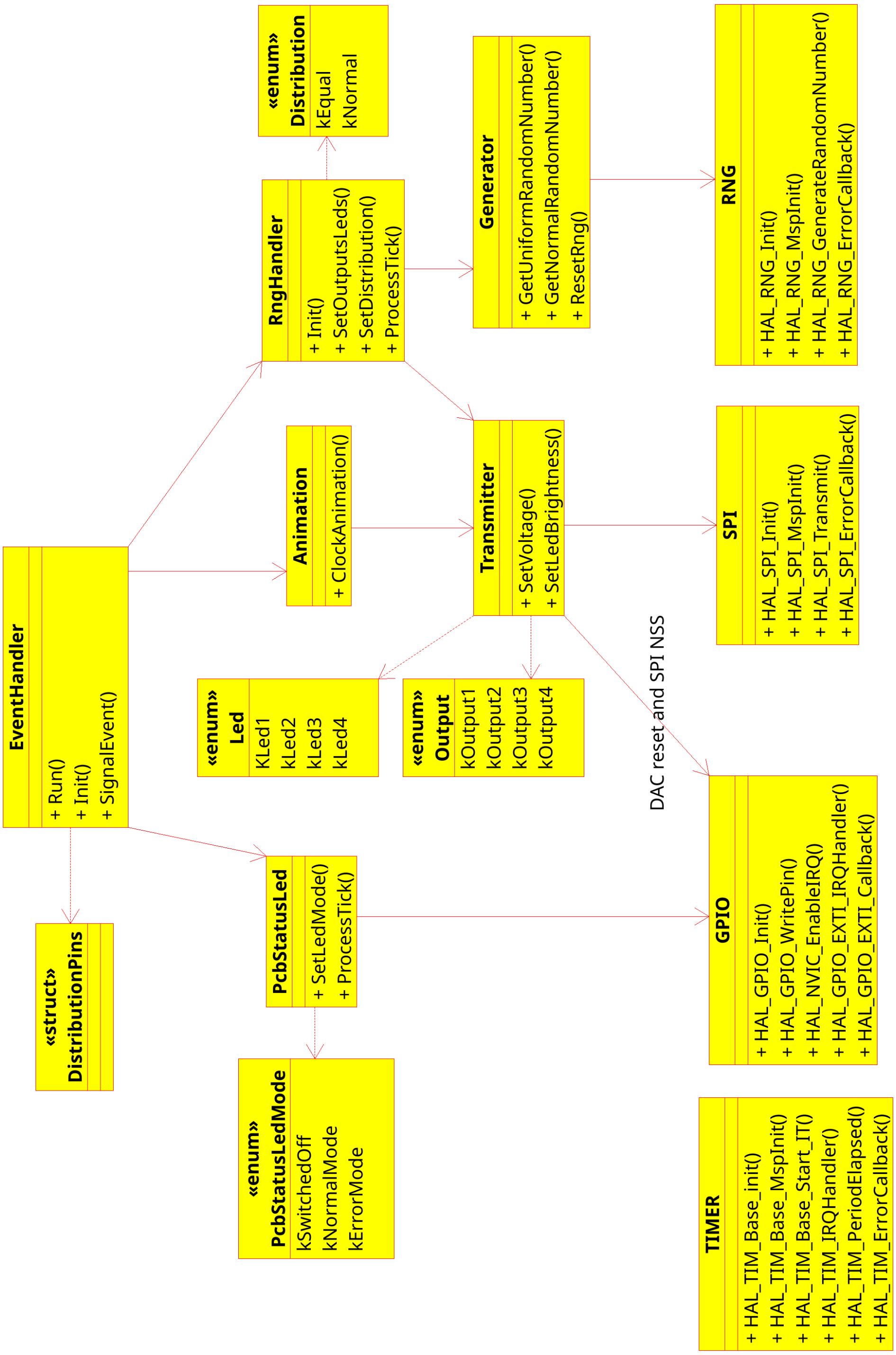

Figure 29: UML class diagram of the firmware