



FREQ FM

8-BIT GENERATIVE DIGITAL FM SYNTHESIZER

CONSTRUCTION MANUAL

HARDWARE REVISION 1.5

FIRMWARE REVISION 1.2

TL;DR

I *rarely* read the manual, so I can't expect you to either 😊. But if you read nothing else, please read this to save yourself some problems during the build.

ARDUINO NANO PINS

To enable the Arduino Nano to fit into the DIP30 socket, the legs must be shorter than a standard Nano. The best way to do this is to **insert the long-ends of the pin header into the Nano**, then trim the excess from the top-side of the Nano.

POLARISED COMPONENTS

Components with a polarity will only work if they are inserted in the correct orientation. Incorrect placement will cause them to not work correctly, and...

IN SOME CASES THIS WILL DESTROY THE COMPONENT!

Check these thoroughly **before soldering** and again before powering the unit:

- Illuminated switches SW1 – SW6
- 100uF Electrolytic capacitors C2, C4, C6
- NPN transistor Q1
- Diode D1
- Arduino Nano V3
- MAX7219/MAX7221 LED matrix driver IC
- 8x8 LED Matrix

All other components can either be inserted any orientation, or the PCB will only allow the correct orientation.

If components are damaged and require replacement, in most cases we recommend sourcing these from a local supplier as shipping costs for single components can be prohibitive.

ALIGNMENT WITH FRONT PANEL

To ensure the interface components align with the holes in the front panel, it is good practice to place them firmly into the PCB and then...

TEST-FIT THE FRONT PANEL BEFORE SOLDERING THESE COMPONENTS!

Even small misalignment of these components can make things not fit together during assembly, or can make knobs and switches not function smoothly.

- Switches SW1-SW6
- Potentiometers
- 3.5mm jacks
- LED matrix

CONTENTS

Introduction.....	4
Voices.....	4
Sequencer.....	4
Hardware.....	4
Bill of Materials.....	5
Construction Manual.....	6
Testing.....	11
Final Assembly.....	12
Troubleshooting.....	13
Specifications.....	15
Voice Architecture.....	15
Sequencer Architecture.....	15
Technical Specifications.....	16

INTRODUCTION

The Freq FM is an 8-bit digital synthesizer for your desktop featuring dual FM voices paired with a 2-track generative sequencer.

From soul-soothing sine waves to multiverse-shredding modulated distortion, slapping bass lines to soaring arp leads, the Freq FM is a powerhouse of sound design packaged with a melodic and intuitive generative sequencer inspired by the likes of Elektron, Intellijel & Music Thing.

With 2 channels of liquid FM sounds, it plays great by itself or synced with your favourite external gear.

VOICES

- 2 independent FM voices
- 2-operator FM (for old-school Prince of Persia vibes!)
- Multi-mode FM ratios – quantised, free-multiple, independent
- Multiple operator waveforms for carrier & modulator – Sine, Triangle, Saw, Square, Noise
- Attack/Decay modulation envelope per voice
- LFO per voice with multiple waveforms and selectable destination: envelope attack, decay & depth, FM ratio, note length or modulation level

SEQUENCER

- 2/1.5 track polymeric sequencer with up to 16 steps per track (Both tracks use same note sequence but can have different step-counts and clock divisions for polymeric rhythms)
- Multiple generative algorithms – (semi)random notes, (semi)random runs, arpeggio, drone
- Sequence mutates/evolves at user-defined rate & note-density
- Selectable tonic, octave & scale – Ionian (Major), Minor (Dorian), Pentatonic, Phrygian (GOA!), Octaves, Fifths
- Tap-tempo control
- Sync input & output (Eurorack and Korg Volca compatible)
- 16-step parameter-lock recording of synth parameters (**track 1 only**)

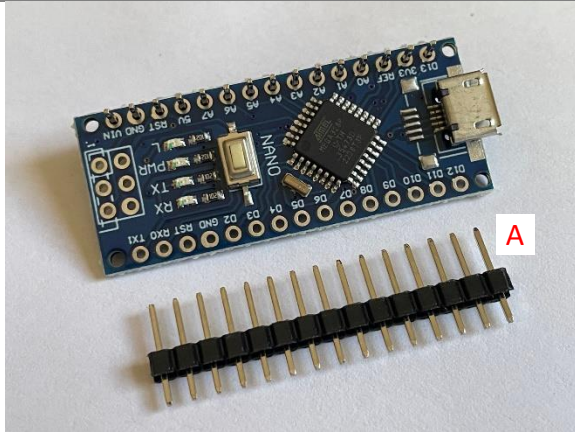
HARDWARE

- Mono audio output (16KHz 14-bit DAC)
- Sync input / output (0-5V rising-edge)
- Powered by an Arduino Nano V3
- 112mm (w) x 100mm (d) x 40mm (h)
- 7-12V DC or micro USB powered.
- Current draw 65mA @ 12VDC (v1.5 hardware)

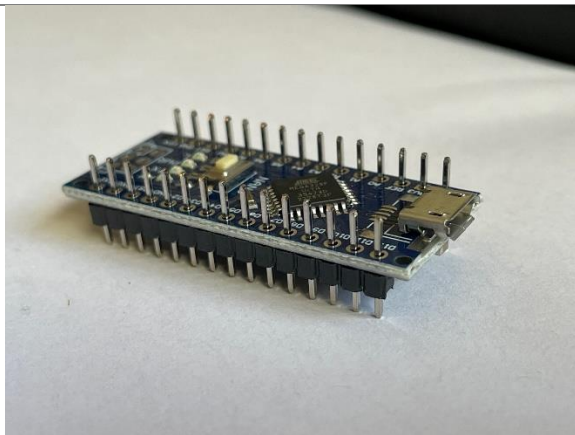
BILL OF MATERIALS

PCB Reference	Part Type	#	Description
	FREAQPCB15A	1	Main PCB Revision 1.5a
	FREAQFACE16A	1	Front panel Revision 1.6a
	FREAQREAR13	1	Rear Panel Revision 1.3
MAX7219	MAX7221	1	8-Digit LED Display Driver IC with SPI. MAX7221 and 7219 are functionally interchangeable, however the 7221 is classed as low-EMI so introduces less noise
U1	ARDNANO3	1	Arduino Nano v3.0 with micro-USB connector. Note to fit into the dip socket I have shortened the legs when soldering the pin headers.
	LED8X8	1	8x8 LED matrix display common cathode
470	R470	6	470Ω resistor If desired this value can be replaced with higher/lower resistance to reduce/increase LED button brightness (and current draw)
1M	R105	3	1MΩ resistor
1K	R102	1	1KΩ resistor
10K	R103	1	10KΩ resistor
100K	R104	2	100KΩ resistor
3k9	R392	1	3.9KΩ resistor
200K	R204	1	200KΩ resistor. If desired this value can be replaced with higher/lower resistance to reduce/increase LED matrix brightness (and current draw).
4n7	C472CER	1	4.7nF ceramic capacitor
100n	C104CER	3	100nF ceramic capacitor
1u	C106MON	1	1uF monolithic capacitor
100u	C107ELEC	3	100uF electrolytic capacitor
D1	1N4004	1	1N4004 diode
Q1	BC337TO92	1	BC337 NPN transistor
MAX7219	DIPSKT24	1	DIP socket for MAX7219/MAX7221
U1	DIPSKT30	1	DIP socket for Arduino Nano
J2, J3	IDCSKT8X1	2	1x8 pin header socket 8.5mm height
J6, J7, J8	PJ360A	3	3.5mm audio jack stereo 3-pin, unswitched
SW1, SW2, SW3, SW4, SW5	PB6149L	5	Illuminated LED tact switch (main colour)
SW6	PB6149L	1	Illuminated LED tact switch (secondary colour)
Various	PTV09A-4025U-B103	8	9mm 10k linear potentiometer (25mm shaft, 40-knurl)
7-12VDC	PWRDCSKT2.1	1	2.1mm pin DC power socket
	SCREWHEXM310	4	10mm long M3 hex-head screws (for rear panel)
	NUTHEXM3	4	M3 nut (for between the main pcb and rear panel)
	SPACEHEXM312	4	12mm M3 nylon spacer
	SCREWHEXM306	4	6mm long M3 hex-head screws (for front panel)

CONSTRUCTION MANUAL

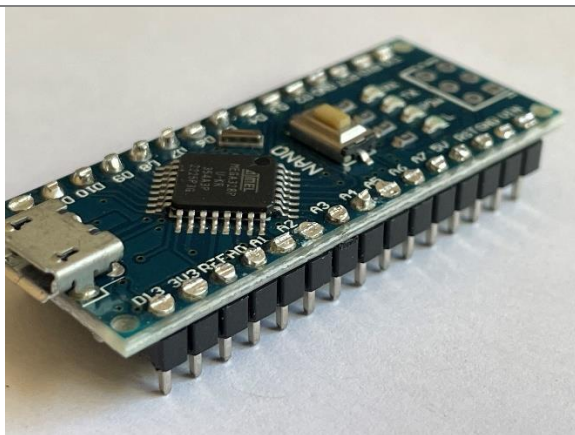


Insert the longer legs of the Arduino Nano (marked A) through the Nano's PCB holes.



The Arduino Nano should now look like this. It is good practice to rest the Nano in the unpopulated Freq PCB to ensure the pins are aligned at 90 degrees to the Arduino PCB before soldering.

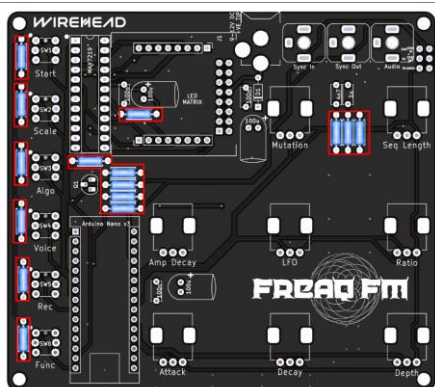
Solder all pins of the Arduino Nano.



Trim the excess from the top using side-cutters.

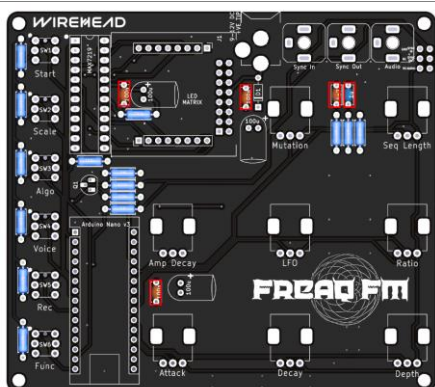
IMPORTANT: Be careful of damaging the Nano's components when trimming the pins.

CONSTRUCTION MANUAL (CONTINUED...)

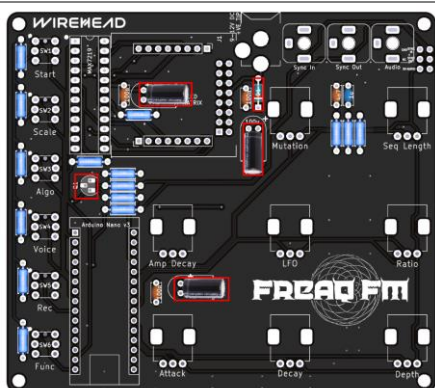


Place all resistors, solder all pins and trim all legs to 1-2mm length

(note layout may vary slightly between board revisions)



Place ceramic and monolithic capacitors, solder all pins and trim all legs to 1-2mm length

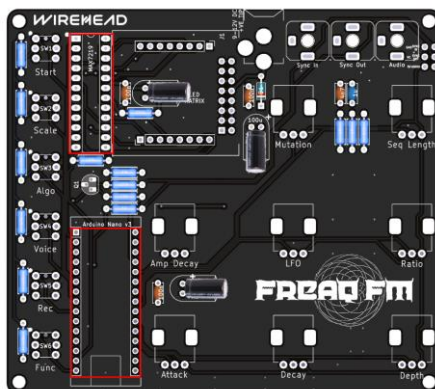


Place diode D1, NPN transistor Q1, and all 100uF electrolytic capacitors & solder all pins

IMPORTANT: note correct orientation of these components indicated by the silkscreen – incorrect placement will damage or destroy these components.

IMPORTANT: To fit the LED matrix and the front panel the capacitors must all be mounted **flat** against the PCB (C2 & C6 folded to the right, C4 folded down).

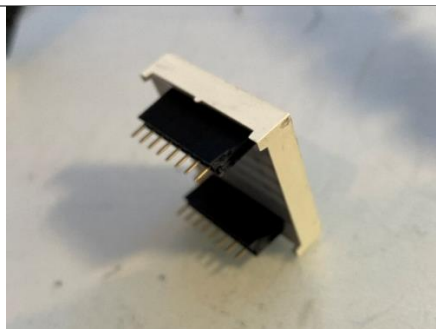
IMPORTANT: Fold the capacitor legs **BEFORE** soldering.



Place DIP IC sockets for the MAX7219 and Arduino & solder all pins.

IMPORTANT: It is best to solder 1 pin of each socket and ensure it sits flush against the PCB – reflowing the joint if necessary, then solder the remaining pins.

CONSTRUCTION MANUAL (CONTINUED...)



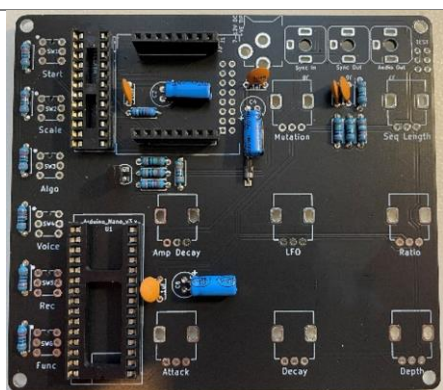
Insert the LED matrix into the 1x8 headers then loosely place into the J1/J2 sockets on the PCB

IMPORTANT: DO NOT SOLDER THESE YET!!

Place the potentiometers SEQ LENGTH and ATTACK to act as guides.

IMPORTANT: DO NOT SOLDER THESE YET EITHER!!

Using the front panel, align the LED cutout with the LED matrix at the same time as aligning the potentiometer shafts with their corresponding holes. The LED matrix should fit snugly through the cut-out.



Keeping the front panel in place, solder pins 1 and 8 of both header sockets.

Once in place, remove the front panel and LED matrix, then solder all remaining pins of the header sockets



Place all 8 potentiometers and 3 audio jacks.

IMPORTANT: DO NOT SOLDER THESE YET!!



Using the front panel, align all potentiometer shafts audio jacks with their corresponding holes. Keeping the front panel in place, solder 1 pin of each component.

IMPORTANT: Depending on the component supplier, the jacks may be a very tight fit in the faceplate. Apply firm pressure to get them through the holes.

Once in place, remove the front panel (being careful not to pull out the jacks!) then solder all remaining pins

CONSTRUCTION MANUAL (CONTINUED...)

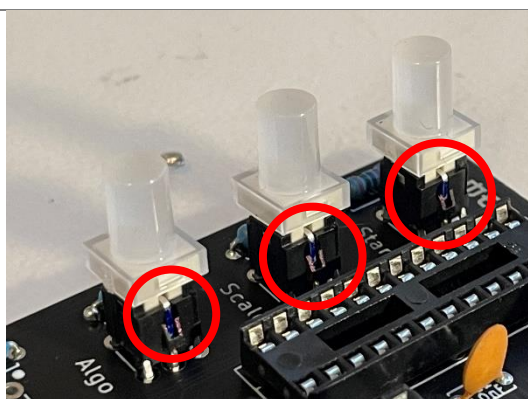


Place all switches SW1-SW6.

IMPORTANT: DO NOT SOLDER THESE YET!!

SUPER IMPORTANT: these components have a polarity. Check to make sure the small guiding pin on the underside of the switch is aligned with the guide hole in the PCB (towards the top of the PCB). The switches also have a coloured stripe which indicates the LED colour.

IMPORTANT: If you have multiple colours in your kit, use one colour for the FUNC button (bottom left) the other colour for the remaining switches

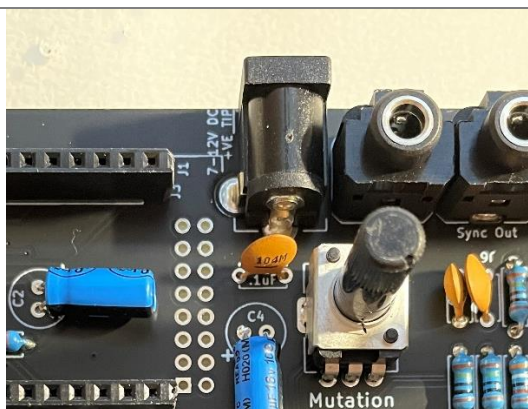


The coloured stripe on each switch which indicates **the LED colour must be facing the INSIDE** of the synth.



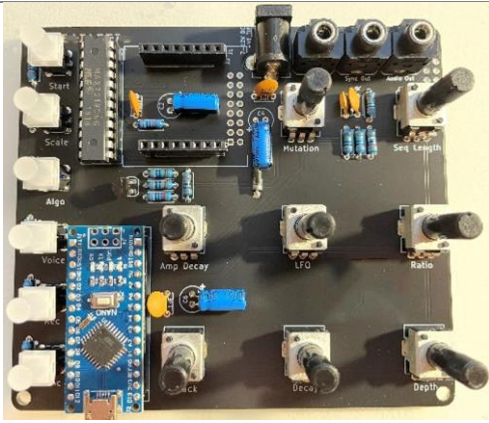
Using the front panel, align all switch button caps with their corresponding holes. Keeping the front panel in place, solder 1 pin of each component.

Once in place, remove the front panel then solder all remaining pins



Place the DC power jack and solder all pins

CONSTRUCTION MANUAL (CONTINUED...)



Insert the MAX7219/7221 IC, the Arduino Nano V3 into their respective sockets.

IMPORTANT: note the orientation of the max7219 IC – the notch should be at the top of the board

IMPORTANT: note the orientation of the Arduino – the USB port should be at the bottom of the board



Insert the LED matrix into the sockets J1/J2.

IMPORTANT: note the orientation of the LED matrix – the side with the small tab in the centre of the plastic enclosure should be towards the Arduino Nano

Ensure all component legs are trimmed to less than 2mm in length

Clean flux from the board using isopropyl alcohol or similar cleaning fluid

NOW TEST IT BEFORE YOU POWER IT ON!

TESTING

Visually inspect all solder joints and ensure they are solid and have good connection between the PCB pad and the component leg.

Using a multimeter with continuity mode, ensure there are no shorts between the 5V and GND or between the DC Power input and ground.

IMPORTANT: if you find any shorts you must locate the fault and fix it before applying power to the unit!

Connect a micro USB cable to the USB port on the Arduino Nano.

All switch LEDs should light up.

The LED matrix should display the firmware version followed by the Wirehead logo.

Turn the [SEQ LEN] control fully clockwise, then press [START].

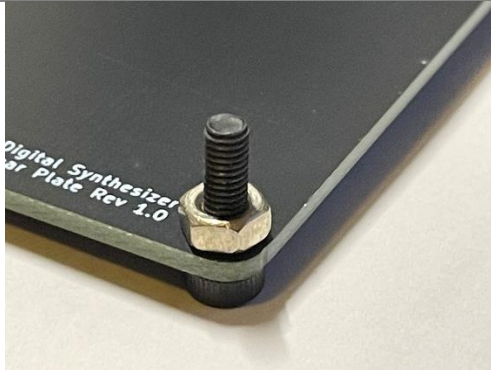
The sequencer should start running with the default sequence.

Connect an amplifier or mixer to the [AUDIO] output jack and twist some knobs.

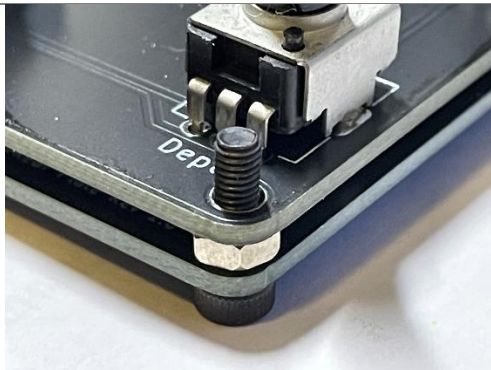
Congratulations – the Freq FM should be outputting sweet FM chimes or nasty noises, depending on knob positions!

NOW WE CAN COMPLETE THE CONSTRUCTION...

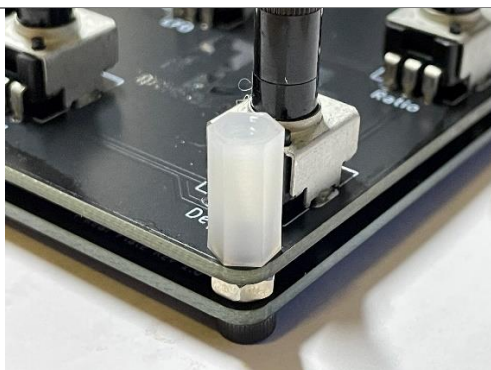
FINAL ASSEMBLY



For each mounting hole in the rear panel insert a 10mm-long hex screw through from the underside of the rear panel then attach an M3 hex nut



Place the main PCB onto the rear panel.



Once in place, attach a 12mm M3 nylon spacer to each screw



Place the front panel over all components, being careful to ensure the potentiometer, audio jacks, switches and LED matrix all fit through their respective holes

Once the front panel is in place, insert the 6mm hex screws through the front panel and screw into the nylon spacers.

The LED Matrix is covered with a plastic protection sticker. This can be left on or removed depending on your preference. It looks glossier with the plastic left on, or more matt if removed.

TROUBLESHOOTING

Problem	Possible Causes	Recommended Action
No LED switches light up when powered on	Diode D1 inserted incorrectly	Check that the stripe on diode D1 orientation of diode D1. If incorrect, desolder and orientate correctly. If problem persists, diode may have been damaged – replace component
	Power supply or cable cannot provide adequate voltage or current (7-12V, at least 320mA at 12VDC)	Replace power supply Replace power cable Replace USB cable
	Power supply incorrect polarity	Replace/configure power supply to ensure positive tip
Some LED switches light up but not others	Some switches inserted incorrectly	Check that switch orientation is as per construction manual. If incorrect desolder (these are tricky!) and orientate correctly
Display does not show anything when powered on	Matrix inserted incorrectly	Check that orientation is as per construction manual. If incorrect remove and orientate correctly.
	MAX7219/7221 IC inserted incorrectly	Check that the orientation is as per construction manual. If incorrect, remove and orientate correctly. If problem persists, IC may have been damaged – replace component
	Power supply unstable or power cable plugged in	Replace power supply / cable Replace power cable Replace USB cable
Display is 100% lit up	Power supply unstable or insufficient current	Replace power supply / cable Replace USB cable
	Poor solder-joints on MAX7221 IC	Check all solder joints
Controls don't work or unreliable	Pins not fully soldered	Check all solder joints and rework as required
Sync input not working as expected	Transistor Q1 inserted incorrectly	Check that the orientation is as per construction manual. If incorrect, desolder and orientate correctly. If problem persists, component may have been damaged – replace component
	Input signal is insufficient voltage to trigger the sync	Check voltage output by sending device

TROUBLESHOOTING (CONTINUED...)

Problem	Possible Causes	Recommended Action
Display works but no sound	Current control settings are making synth output inaudible frequencies	Move knobs to make audible sounds – especially turn [FM RATIO] clockwise and hold [FUNC] and turn [AMP DECAY/OCTAVE] clockwise
	Sequence contains no notes	Turn [SEQ LEN] fully clockwise, turn [MUTATION] fully clockwise and hold [FUNC] and turn [MUTATION/DENSITY] fully clockwise
	Sequencer not running	Press [START]
	Carrier is set to Null waveform	Hold [FUNC] and turn [ATTACK/CARRIER] fully anti-clockwise
	Audio cable not plugged in	This happened yesterday 😊 plug it in!
Sequencer stops or accelerates randomly	Interference received on sync input	Hold [FUNC] and tap [START/TEMPO] to reset tempo control
	Unusual tap-tempo input	Replace sync cable
Control components don't align with front panel holes	Components soldered at an angle	Rework solder joints to re-align component to be 100% vertical. This can be tricky!
Front panel hits the top of the Arduino nano and doesn't fit properly	Arduino Nano not seated correctly in socket	With both thumbs, push the Nano firmly into the socket
	Different Arduino Nano used with 'standard' length pins or mini-USB connector	The Freq FM ships with a Nano with shortened pins and micro-USB connector to fit into the provided IC socket. If you have used a different Nano than the one provided, carefully shorten the pins by ~2mm with a side-cutter, ensuring all pins are the same length. Alternatively source longer spacers than those provided (which are 12mm). Up to 15mm will work without an issue, however over 14mm the 3.5mm jack sockets will start to become recessed behind the front panel.

SPECIFICATIONS

VOICE ARCHITECTURE

Voice 1		Voice 2	
Carrier	8-bit digital oscillator	Carrier	8-bit digital oscillator
Octave	0 - 6	Octave	0 - 6
Waveform	Sine, saw, reverse saw, square, noise, off	Waveform	Sine, saw, reverse saw, square, noise, off
Amp Decay	Note length ~20ms – ~16s	Amp Decay	Note length ~20ms – ~16s
Modulator	8-bit digital oscillator	Modulator	8-bit digital oscillator
FM Ratio		FM Ratio	
FM Mode	quantised, high multiple, low multiple, fixed	FM Mode	quantised, high multiple, low multiple, fixed
Waveform	Sine, triangle, distorted-tri, square, reverse saw, off	Waveform	Sine, triangle, distorted-tri, square, reverse saw, off
Mod Envelope		Mod Envelope	
Depth		Depth	
Attack time		Attack time	
Decay time		Decay time	
LFO		LFO	
Depth		Depth	
Rate		Rate	
Waveform	Sine, triangle, distorted-tri, square, reverse saw, off	Waveform	Sine, triangle, distorted-tri, square, reverse saw, off
Parameter locks		-	
Per step* parameter locks			
Note length			
LFO depth			
FM ratio			
Mod envelope attack, decay and depth			
* controls voice 1 but step based on track with longest sequence length			

SEQUENCER ARCHITECTURE

Track 1	Track 2
Sequence length	Sequence length
Current step	Current step
Note length	Note length
Sequence notes	
Sequence mutation rate	
Sequence note density	
Steps per sync pulse	

SPECIFICATIONS (CONTINUED...)

TECHNICAL SPECIFICATIONS

SPECIFICATIONS	
Synthesis	2-operator FM 8-bit digital oscillators
Polyphony	2 bi-timbral voices
Sequencer	16 step polymetric sequencer
Modulation	Attack/decay envelope per channel Multi-waveform LFO per channel Parameter locking per step (voice 1 only)
I/O	Audio out Sync in / out Power 9-12v USB (power and firmware update) Eurorack power (with modification)
External sync	Sync in & out 0-5v sync pulse 1/2/4 steps per pulse Internal clock (enabled/disabled)
Signal output	14-bit 16384Hz DAC Mono output
Microprocessor	Arduino Nano V3 (ATMEGA328P)
Power supply	Micro USB 9-12VDC 2.1mm Positive tip Can be adapted for +12V eurorack power
Display	8 x 8 LED matrix
Power consumption	65mA @ 12VDC
Dimensions	111mm (w) (~22HP) x 100mm (d) x 40mm (h)