rossum
electro-music

EVOLUTION

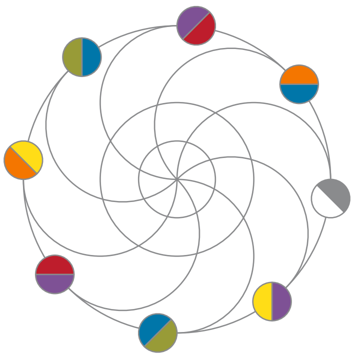
Variable Character Ladder Filter

Operation Manual

www.rossum-electro.com

Contents

1. Introduction



Thanks for purchasing (or otherwise acquiring) the Rossum Electro-Music Evolution Variable Character Ladder Filter.

This manual will give you the information you need to get the most out of Evolution. However, the manual assumes you already have a basic understanding of synthesis and synthesizers. If you're just starting out, there are a number of good reference and tutorial resources available to get you up to speed. One that we highly recommend is:

Power Tools for Synthesizer Programming (2nd Edition)
By Jim Aikin
Published by Hal Leonard
HL00131064

Additionally, for the technically and/or historically minded among you, check out Section 10, The Evolution of EVOLUTION, for Dave's account of how Evolution came to be.

Support

In the unlikely event that you have a problem with your Evolution, tell us about it here:

http://www.rossum-electro.com/support/support-request-form/

... and we'll get you sorted out.

If you have any questions, comments, or just want to say "Hi!," you can always get in touch here:

http://www.rossum-electro.com/contact-us/

... and we'll get back to you.

Happy music making!

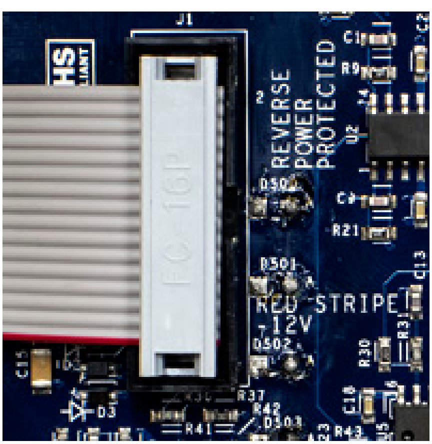
2. Installation

As you will have no doubt noticed, the rear of Evolution is a circuit board with exposed parts and connections. When handling Evolution, it's best that you hold it by the edges of the front panel or circuit board. It's not particularly easy to blow up, but why take chances?

More specifically, the biggest risk (to the extent that there's a risk), is damage by static electricity. Particularly on dry, cold days (or if you've just shuffled across your shag carpet in fuzzy slippers), make a point of touching the metal panel first, before touching any other part of the module.

While all Rossum Electro-Music modules are protected against reverse polarity damage, both to your module and your system, care should still be taken to connect the power cable correctly. (For more detail on our unique protection method, check out Dave's discussion of Circuit Protection in Section 10.)

Plug the included 16-pin connector into the header on the rear of the module such that the red stripe on the cable (the -12V side) is on the same end of the header as the "Red Stripe `-12V" text on the PCB.



Evolution requires, at most, 85mA of +12V and 75mA of -12V.

We have included both M3 and M2.5 (for vector rails) mounting screws. Use what fits your system.

If rack rash is of concern to you, use the included nylon washers when mounting Evolution in your case.


EVOLUTION
Variable Character Ladder Filter
FREQUENCY
Q
GENUS
SPECIES
3 POLES
4 POLES
5 POLES
6 POLES
Q LEVEL
COMPENSATION
FREQ CV3
0
0
0
FREQ CV 2
Q CV 2
GENUS CV 2
SPECIES CV 2
1V/OCT
Q CV 1
GENUS CV 1
SPECIES CV 1
INPUT
OUTPUT
rossum electro-music

3. Overview

Evolution is a pure analog lowpass filter that offers — in a single module — the characteristics of a wide variety of synthesizer filter types.

At the core of Evolution is Dave's unique implementation of Bob Moog's iconic ladder filter from the original E-mu Systems 2100 LPF module (which, incidentally, Dave counts as his favorite sounding of all of the filters he designed). Check Section 10 to learn what made the 2100 (and, consequently, Evolution) so special.

For Evolution, Dave has designed new capabilities that not only allow you to dial in all of the outstanding qualities of the original 2100, but combine to let you create the sonic characters of other synth filters that are not otherwise possible with traditional ladder filters.

They include:

- A Genus control that allows voltage control of the number of filter poles, allowing a range of entirely new and striking audio effects.
- A Species control that allows voltage control of the signal level into the ladder, letting you control the intensity of the filter's characteristic distortion.
- Voltage controlled resonance with a variable Q Level Compensation control that lets you control the balance of the resonant signal and the frequencies below the cutoff frequency (which would otherwise be attenuated as the resonance is increased).
- An extremely accurate and temperature stable frequency control exponential generator, rivaling the specifications of the best analog VCOs

Taken together, Evolution gives you everything from the platonic ideal of the pure classic ladder filter to an almost unlimited selection of alternative filter characteristics.

In the following sections, we'll look at each of Evolution's functions in turn.

4. Input and Output

The Input and Output jacks let you get audio into and out of Evolution.

Evolution is DC coupled throughout, so you can use Evolution to process CVs as well as audio.

The Input expects a signal level up to 20Vp-p

Depending on the Input level and the settings of the various controls, the Output provides a signal level of up to 20Vp-p without clipping.

5. Frequency

Evolution's Frequency section provides manual and CV control of Evolution's cutoff frequency (i.e., the frequency above which the amplitude of the signal is attenuated).

FREQUENCY Knob

The FREQUENCY knob allows you to set Evolution's initial cutoff frequency (I.e., the cutoff frequency when no CVs are present). The actual cutoff frequency is controlled by the sum of this knob and all present control voltages.

Without CVs present, the range of the control is from approximately 22Hz to 22kHz. With CVs, the available range is from .02Hz to 40kHz.

When Evolution is in self-oscillation mode (see the Q section below), this control sets the initial frequency of oscillation.

NOTE: *Refer to the Genus section below to understand how the Poles setting affects the oscillation and resonant frequencies.*

1V/OCT CV Input

The 1V/OCT CV Input is a calibrated full level control voltage input that is summed with the value of the FREQUENCY knob and the FREQ CV2 and FREQ CV3 inputs. When properly calibrated (as it will be when delivered), Evolution's 1V/Octave tracking is accurate over a 10 octave range (better than many Eurorack VCO modules). When in self-oscillation mode, Evolution serves as an extremely high quality sine wave oscillator.

FREQ CV2 Input

The FREQ CV2 Input is a control voltage input that is modified by its associated attenuverter and then summed with the value of the FREQUENCY knob and the FREQ CV3 and 1V/OCT inputs.

When the attenuverter knob is set to its "0" position, no control voltage is passed to the filter. As the knob is turned clockwise from 0, the amplitude of the control voltage increases until, at maximum clockwise rotation, the full amplitude of the signal at the FREQ CV2 Input is passed through and results in a nominal 1V/Oct response.

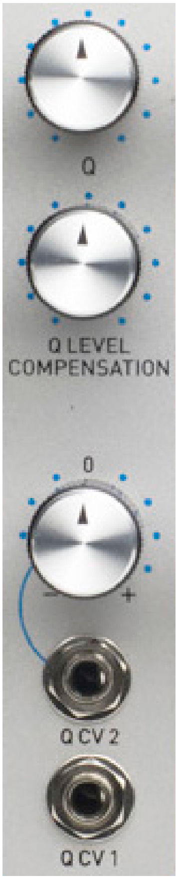
As the knob is turned counter-clockwise from 0, the signal at the FREQ CV2 Input is inverted (e.g., a CV of +2.5V becomes -2.5V). The farther counterclockwise the knob is turned, the less the attenuation of the inverted signal, until, at maximum counter-clockwise rotation, the full amplitude of the inverse of the signal at the FREQ CV2 Input is passed through, also at a nominal 1V/Oct response.

FREQ CV3 Input

The FREQ CV3 Input is a control voltage input that is modified by its associated conventional attenuator and then summed with the value of the FREQUENCY knob and the FREQ CV2 and 1V/OCT inputs.

When the attenuator knob is set to its maximum counter-clockwise position, no control voltage is passed to the filter. As the knob is turned clockwise, the amplitude of the control voltage increases until, at maximum clockwise rotation, the full amplitude of the signal at the FREQ CV3 Input is passed through at a nominal 1V/Oct response.

6. Q (Resonance)



Evolution's Q section provides manual and CV control of the height of the resonant peak at (or near) Evolution's cutoff frequency, as well as the level of the frequencies below the resonant peak. (See the discussion of the effect of the Genus setting on the frequency of the resonant peak below.)

Q Knob

The Q knob allows you to set the initial height of Evolution's resonant peak (I.e. the height of the peak when no CVs are present). The actual height of the resonant peak is controlled by the sum of this knob and all present control voltages. This control produces a voltage range of between 0V and 7V.

When the Q knob is turned clockwise to about 4V, the filter will enter self-oscillation mode, producing a pure sine wave. In this mode, Evolution acts as a very high-quality sine wave oscillator.

NOTE: *The purest sine wave and the most accurate tracking occur when the filter is just barely into oscillation and the Genus control is set to 4 poles.*

ANOTHER NOTE: *Refer to the Genus Section to understand how the Poles setting affects the oscillation and resonant frequencies.*

YET ANOTHER NOTE: *Also refer to the Genus Section to understand how the Q setting affects oscillation during transitions from one pole setting to another.*

Q LEVEL COMPENSATION

In a traditional resonant ladder filter, as the height of the resonant peak is increased, the levels of the frequencies below the resonant peak are attenuated. When the cutoff frequency is swept manually or by a control voltage, the result is the familiar classic "wah" we're all familiar with.

In many cases, that's exactly what you want, as at high Q, you can hear the filter pick out each overtone (or "frequency" of noise) as you sweep through the audio spectrum.

However, if what you want is to add some resonant spice to a pad or fat bass sound, the lower frequency attenuation that results from turning up the Q results in sucking some (or most) of the guts out of the sound, leaving it sounding thin.

Luckily, Evolution gives you a choice with the Q LEVEL COMPENSATION control.

With the control turned fully counter-clockwise, there is no compensation and the filter acts exactly like a traditional ladder filter.

As you turn the control clockwise, the amplitudes of the frequencies below the cutoff frequency are progressively boosted until, at full clockwise rotation, they are at their full (pre-attenuation) level.

Simply dial in the exact level of compensation you want for each particular patch and you're good.

Q CV2 Input

The Q CV2 Input is a control voltage input that is modified by its associated attenuverter and then summed with the value of the Q knob and the Q CV1 Input. (If you haven't already read the explanation of how the attenuverters work back up in the FREQ CV2 Input section, you can check that out now.)

Q CV1 Input

The Q CV1 Input is a full level control voltage input that is summed with the value of the Q knob and the Q CV2 Input.

7. Genus

Evolution's Genus control gives you real-time manual and CV control of the number of poles in the ladder. It is is, as far as we're aware, unique among all implementations of the classic ladder filter.

The number of poles defines the slope at which Evolution attenuates frequencies at increasing distance from the cutoff frequency. This parameter is expressed in dBs of attenuation per octave.

For example, a lowpass filter with a slope of 24dB per octave (the most common slope of classic Moog-style ladder filters) means that a signal one octave above the cutoff frequency will be attenuated by 24dBs, a signal two octaves above the cutoff frequency will be attenuated by 48dBs, at 3 octaves 72dBs, etc.

Expressed as filter poles, each pole provides 6bB of attenuation.

The slopes available in Evolution are:

3 poles = 18dB/oct

4 poles = 24dB/oct

5 poles = 30dB/oct

6 poles = 36dB/oct

Not only does being able to select the number of poles give Evolution a variety of filter characteristics, the ability to modulate the number of poles in real time (including at audio rates) opens up entirely new sonic vistas.

Pole Selection and Resonant and Self-Oscillation Frequencies

For technical reasons that you'll find explained in Section 10 (if you're so inclined), different pole selections result in different resonant frequencies relative to the cutoff frequency.

The resonant and oscillation frequencies at the various pole settings are:

3 poles: resonant frequency is 10 semitones above the cutoff frequency

4 poles: resonant frequency is equal to the cutoff frequency

5 poles: resonant frequency is 6 semitones below the cutoff frequency

6 poles: resonant frequency is 10.5 semitones below the cutoff frequency

Consequently, with Q turned up, modulating the number of poles results in a dynamic shifting of the resonant frequency. This provides unique and striking effects, both at moderate LFO-like rates and at audio frequencies.

The same principle governs Evolution's oscillation frequency when in self-oscillation mode. Modulating the Genus parameter while in self-oscillation mode will result in various arpeggiator-like patterns (defined by the amplitude and speed of the modulation).

GENUS Knob

The GENUS knob allows you to set the initial number of poles in the ladder. The actual number of poles is controlled by the sum of this knob and all present control voltages.

A swing of 5 volts (either from the Genus knob or via the CV inputs) will cause Evolution to cover the entire range of poles.

NOTE: *The selection of poles is not a discrete four-step process, but offers a continuous transition between settings (as indicated by the LEDs described next).*

ANOTHER NOTE: With Q set just at the point of self-oscillation, slowly moving from one pole setting to another will result in Evolution ceasing to oscillate when the setting is between poles (i.e., when two adjacent LEDs are lit).

However, with Q set to maximum, oscillation is continuous during transitions between pole settings.

If you're modulating Genus during self-oscillation, choose the Q setting that results in whichever of these options you want for your patch.

Or modulate Q as well for even more complex effects.

GENUS LEDs

The four LEDs indicate in real time the current number of effective poles as defined by the sum of the GENUS knob and the two CVs. Any time two adjacent LEDs are lit simultaneously, it is an indication that the Genus parameter is between those two pole settings.

GENUS CV2 Input

The GENUS CV2 Input is a control voltage input that is modified by its associated attenuverter and then summed with the value of the GENUS knob and the GENUS CV1 Input. (We're pretty sure you know how the attenuverters work by now.)

GENUS CV1 Input

The GENUS CV1 Input is a full level control voltage input that is summed with the value of the GENUS knob and the GENUS CV2 Input.

8. Species

Evolution's Species section provides manual and CV control of the level of the signal into Evolution's distortion circuitry.

As Dave explains it:

> *"The ladder design, as I implemented it, has no inherent distortion for signals far below the cutoff frequency. The characteristic timbre of the ladder filter comes primarily from distortions of frequencies near and above the cutoff frequency. The degree of distortion depends on the signal amplitude. Consequently, it is sonically interesting to modulate the signal amplitude going into the ladder, and modulate the output signal with the precise inverse gain. This is the function of the Species control. A high voltage into the Species input will cause the filter to distort more audibly."*

So, briefly, the Species section gives you control over the ladder's "good" distortion.

NOTE: *Because of the way Species is implemented, with Q feedback within the VCAs that control the Species function, Evolution's resonance is unaffected by the Species setting (I.e., the higher the Q setting, the less obvious the Species setting). However, the amplitude of any self-oscillation will be inversely proportional to the Species setting. Consequently, when using the Evolution as an oscillator, the Species control can be used to amplitude modulate the output. If oscillation is combined with an input signal, the results become even more interesting.*

SPECIES Knob

The SPECIES knob allows you to set the initial level of the signal going into the ladder and provides a range of 10 volts. The actual signal level is controlled by the sum of this knob and all present control voltages.

With no CVs present, the range of the knob from full counterclockwise up until the 12:00 o'clock position results in subtle distortion. The range past the 12:00 o'clock position results in more pronounced distortion.

SPECIES CV2 Input

The SPECIES CV2 Input is a control voltage input that is modified by its associated attenuverter and then summed with the value of the SPECIES knob and the SPECIES CV1 Input. (Attenuverters, blah, blah, blah.)

SPECIES CV1 Input

The SPECIES CV1 Input is a full level control voltage input that is summed with the value of the SPECIES knob and the SPECIES CV2 Input.

9. Specifications

Controls
Initial Frequency
Initial Q
Q Level Compensation
Initial Genus (# of Poles)
Initial Species (Distortion Input Level)

Signal Input
1x 3.5mm mono socket - 100K Impedance

Signal Output
1x 3.5mm mono socket - 1K Impedance

Frequency CV Inputs
1x Attenuated - min 50k Impedance
1x w/Attenuverter - 100K Impedance
1x 1V/OCT Full Level - 100K Impedance

Q CV Inputs
1x Full Level - 100k Impedance
1x w/Attenuverter - 100k Impedance

Genus CV Inputs
1x Full Level - 100k Impedance
1x w/Attenuverter - 100k Impedance

Species CV Inputs
1x Full Level - 100k Impedance
1x w/Attenuverter - 100k Impedance

Power Requirements
+/-12V via 16-pin, Doepfer-style connector

Current Draw
85mA +12V, 75mA -12V (maximum)

Dimensions
16HP (W); Rear of panel to the top of the
power connector: 25 mm (D)

Supplied Accessories
1x 16-pin, Doepfer-style cable
4x M3 screws
4x M2.5 screws
4x Nylon washers
1x Quickstart Guide

10. From Dave's Lab: The Evolution of EVOLUTION

The fundamental core of the Rossum Electro-Music EVOLUTION Variable Character Filter is Bob Moog's famous "ladder" filter, which was described in US Patent 3,475,623. This circuit uses the variation of the Bipolar Junction Transistor's emitter resistance with current as the voltage variable element in an RC filter. In the Moog implementation, four identical stages each implemented a single real lowpass pole. The Moog 904A module included a "Regeneration" control that created a negative feedback path around the four poles. Since each pole provided 45 degrees of phase shift at its -3dB point, increasing this feedback produced a resonant peak at cutoff. The musical utility of the Moog filter is, of course, famous.

In 1973, E-mu Systems introduced their 1100 submodule, which was the heart of their 2100 lowpass filter module. The 1100 used a Moog ladder as its core element, but I wanted to isolate the innate audio characteristics of the filter ladder from those colorations resulting from the input level-shifters and output amplifier used in the Moog 904A. I also envisioned a DC-coupled design with a cutoff frequency range well beyond 10 octaves, as well as eliminating variations of the height of the resonant peak or oscillation amplitude with frequency control voltage.

I level-shifted the exponential generator to allow the filter signal input to be directly applied to the ladder base. I then designed a completely new output stage for the ladder; this circuit has never (to my knowledge) been used outside my designs. The entire signal path was DC coupled and the resonant feedback path phase compensated.
The 1100 was my favorite sounding filter (I liked it more than the SSM2040 I later invented, and kept the 1100 as E-mu's modular lowpass in preference to a cheaper 2040 design). The operational range of the cutoff frequency was from about 0.1Hz to 25kHz, with stable Q's throughout.

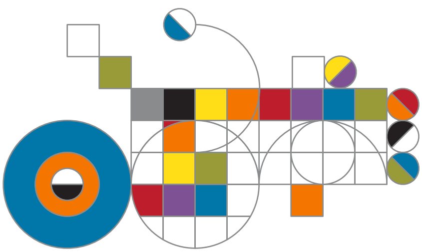
In launching Rossum Electro-Music, I chose a new implementation of the 1100 filter as the first all-analog module for our Eurorack offering, based on its unique and outstanding audio characteristics.

I re-engineered the basic 1100 core using modern available surface-mount components and then added a number of features to the original 1100 design:

Ladder filters self-oscillate, and can be used as VCOs. I was able to design the Rossum Electro EVOLUTION's frequency control exponential generator to be extremely accurate and temperature stable, rivaling the specifications of the best analog VCOs. I also added a novel temperature compensation circuit for the ladder emitter resistance. The actual measured specs surprised and delighted me.

The resonance ("Q") of the original 1100 was not voltage controlled. I implemented voltage controlled Q using one cell of an

SSM2164 VCA. Since the SSM2164 is based on my 1979 design of the SSM2010, this is an apt choice. (Sadly, the original 2164 is no longer produced, so a replica source was needed.) The phase compensation has been maintained, but I added a "Q Compensation" control. The negative feedback resonance path in the 1100, like the Moog 904A, caused



the amplitude of signals in the passband to be attenuated as the Q increased, which some users found undesirable. If instead the signal is inserted into the Q VCA, this effect is eliminated. In EVOLUTION, the Q Compensation control allows insertion of the signal with an arbitrary mix into either of these inputs, allowing the ratio of direct to resonant amplitude to be arbitrarily selected.

There is no inherently desirable taper for Q control. In highly resonant, but oscillation-proof filters such as state variable designs, it makes sense to exponentially control Q. But in ladder filters, oscillation is expected, and high Q's without oscillation are not practically achievable. The Rossum Electro EVOLUTION implements approximately linear control of the Q VCA.

The ladder design, as I implemented it, has no inherent distortion for signals far below the cutoff frequency. The characteristic timbre of the filter comes primarily from distortions of frequencies near and above the cutoff frequency. The degree of distortion depends on the signal amplitude. Consequently, it is sonically interesting to modulate the signal amplitude going into the ladder, and modulate the output signal with the precise inverse gain. This is the function of the Species control. A high voltage into the Species input will go well beyond the linear region of the ladder and cause the filter to distort much more audibly.

Because ladder filters produce their resonance by feedback, the relationship of that feedback to the drive VCAs is critical. The Rossum Electro EVOLUTION places the Q feedback within the drive VCAs. This means that the filter's resonance is unaffected by the Species setting, but that the amplitude of any self-oscillation will be inversely proportional to the Species level. When using the filter as an oscillator, the Species control can be used to amplitude modulate the output. If oscillation is combined with an input signal, the results become even more interesting. Like the Q circuit, SSM 2164 cells are used for the drive VCAs.

With these additions, the preliminary design of EVOLUTION looked pretty complete. Then Marco asked if it would be possible to add voltage controlled slope (those marketing guys are never satisfied). My first take was that this would not be practical, because varying the slope usually involves controlling complex pole pairs, and the ladder comprises only real poles.

Then I realized that I could steer the current around individual ladder stages in an analog manner, controlling the number of poles rather than the slope. A prototype proved this was both practical and audibly pleasing.

Since the resonant frequency of a ladder filter is determined by the 180 degree phase shift point, it changes with the number of poles: 60 degrees for three poles, 45 for four, 36 for five, and 30 degrees for six poles. Modulating the number of poles produces a unique "bubbly" sound.

Two more tweaks were needed to complete the circuit. Because the number of poles not only affects the phase shift for resonance, it also changes the amount of feedback required for oscillation, the pole control circuit needs to control the Q VCA in a manner such that the same Q control voltage produces the onset of oscillation for each pole setting. And since it's useful but difficult to tune the initial pole setting to be in the center of the range (exactly steering the current to the desired ladder poles), I added analog controlled LEDs to indicate the activation of the poles.

We then sent development versions of Evolution to a number of collaborating musicians who responded with some excellent suggestions. These resulted in a few more circuit tweaks to finalize the product.

Circuit Protection

Eurorack suffers from the problem of power connector reversal. When 10 pin connectors are used, mis-insertion results in a swap of +12V and -12 V, and protection is easily accomplished using various techniques such as series diodes.

But more systems are providing the +5V supply and thus use the full 16 pin connector. When this is reversed, a diode-protected module is still safe, but the six connected ground pins in the module will short together the system's +5V and +12V supplies, potentially damaging the power supply and any modules that use +5V.

To prevent this, Rossum Electro-Music modules deviate from the standard Eurorack power connector by leaving power connector pins 9 and 10 open, rather than connecting them to ground. When plugged in backwards, this leaves the system +12V supply disconnected. Since ground is still supplied by four pins as well the chassis and any patch cords connected to the module, the dropping of these two pins has no measurable effect on circuit performance, but it means that if a Rossum Electro module is accidentally plugged in backwards, no stress is placed on the +5V supply or modules that use it.

11. Acknowledgements

A number of wonderful people generously provided help, advice, encouragement, and inspiration during the development of Evolution.

Many thanks from the Rossum Electro-Music team to:

Bob Moog, for his inspiring filter design

Jim Aikin

Patrick Brede

Nancy Enge

Josh Holley

Mihai Ionescu

Kurt Kurasaki

Michael Logue

William Mathewson

Gur Milstein

Kevin and Denise Monahan

Trish Neilsen

David Phipps

Bill Putnum

Allan Shaffer

Dan Snazelle

Kirk Southwell

Tomio Ueda

Andy Zenczak (and the crew at Gadgetbox Studios)

And, it goes without saying, but we'll say it anyway, our families for understanding all the late nights and weekends spent not having fun (or doing chores) with them.