WAVES SERIES

Synthesizers and Subtractive Synthesis 2

Application and Practice

Jean-Michel Réveillac

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Contents

Preface

If you want to know if this book is for you, how it is constructed and organized, what is in it, and what conventions will be used, you have come to the right place, this is the place to start.

Target audience and prerequisites

This book is intended for all those who are interested in sound synthesis and synthesizers, whether they are amateurs or professionals, or even musicians, performers or composers.

The information presented in some sections requires basic knowledge of general computing and digital audio.

For some work on microcomputers, you will need to have good knowledge of the operating system (paths, folders and directories, files, names, extensions, copies, moves, etc.).

For exercises based on the VCV Rack and Native Instruments Reaktor Blocks software synthesizers, you will need to know their philosophy, general principles of design and use in order to build a VCV or Reaktor Software Modular Rack.

For exercises related to the visual programming languages Max/MSP and Pure Data, basic knowledge of their interface and the commands of their editors will be necessary.

If you do not feel comfortable with these prerequisites, a set of books and tutorials are mentioned in the reference section of this book, which will help develop your knowledge.

Possession of a synthesizer based on subtractive synthesis will be a plus, especially if it is an ARP2600, a Minimoog, a Novation Bass Station II, a Behringer Neutron or an Arturia MatrixBrute. Software or hardware clones of these machines are also welcome.

Software such as Pure Data or VCV Rack can be downloaded easily and for free, as can software clones of some synthesizers (Minimoog, ARP 2600). Consult the links in the reference section of this book for this purpose.

Organization and contents of the book

This book consists of two volumes:

1) *Synthesizers and Subtractive Synthesis 1: Theory and Overview*.

2) *Synthesizers and Subtractive Synthesis 2: Application and Practice*.

Volume 1 successively presents a preface, specifying the contents and the writing conventions used, and then an introduction followed by five chapters, a conclusion and two appendices:

– sound synthesis;

– different types of synthesis;

– components, processing and tools;

– work environment;

– CV/Gate and MIDI.

The conclusion, as its name suggests, attempts to assess the current state of subtractive synthesis and synthesizers.

Appendices 1 and 2 provide some additional elements and some reminders. You will find information in the following order:

– General MIDI 1 and 2 instruments;

– MIDI boxes, mergers and patchers.

Volume 2 presents a preface identical to that of Volume 1, followed by five chapters, a conclusion and four appendices:

– subtractive synthesis, the beginnings;

– subtractive synthesis, the fundamentals;

– advanced subtractive synthesis;

– duophony, paraphony and polyphony;

– sequencer and arpeggiator.

Appendices 1– 4 provide some additional information in the following order:

– USB connectivity;

– Pure Data extensions;

– keyboards and interface;

– MIDI notes, numbers and frequencies.

The conclusion sheds light on the contents of the book and a brief overview of the future evolution of sound synthesis systems and software.

At the end of this book, you will find references and a list of internet links.

A glossary is also present, and it will explain certain acronyms and terminology very specific to sound synthesis and synthesizers.

Each of the chapters can be read separately. If concepts that are dependent on another chapter are present, the references to the relevant sections are indicated. However, Chapter 1, devoted to sound synthesis, provides the necessary foundations for understanding the subsequent chapters.

If you are a new reader on the subject, I strongly advise you to read Chapter 1 first; the following chapters will then be clearer.

For everyone else, I hope you will discover new notions that will enrich your knowledge.

Conventions

This book uses the following typographical conventions:

– *Italics*: reserved for important terms used for the first time in the text, which may be present in the glossary at the end of the book, mathematical terms, comments, equations, expressions or variables.

– UPPER CASE: reserved for command names, entry, exit, or connection points, specific functions, modules belonging to the different hardware or software synthesizers used in the exercises. It can also be elements, options or choices within menus present in the interface of a program.

– `Courier` font: reserved for objects manipulated within the visual programming software Max/MSP and Pure Data.

Notes are indicated by the presence of the keyword:

NOTE.– These notes complete the explanations already provided.

Figures and tables all have a description which is often useful for understanding.

Vocabulary and definitions

As with all techniques, subtractive sound synthesis and synthesizers have their own vocabulary, with words, acronyms, abbreviations, initials and proper nouns not always familiar. This is the role of the glossary already mentioned above.

Acknowledgments

I would particularly like to thank the ISTE team, and my editor Chantal Ménascé, who trusted me.

Finally, I would like to thank my wife, Vanna, and my friends, passionate about the subject, who supported me throughout the writing of this book.

January 2024

Introduction

Where volume one gathered information and theoretical knowledge, this volume brings together practical exercises carried out on hardware or software synthesizers of several categories: wired, semi-modular, or modular.

The equipment chosen is the Behringer 2600 or the ARP 2600, the Minimoog, the Novation Bass Station II, the Behringer Neutron and the Arturia MatrixBrute, for hardware synthesizers. On the software side, the modular VCV Rack and Native Instruments Reaktor complete the list. A large part of the exercises is reserved for the Max/MSP and Pure Data visual programming environments.

Figure I.1. *The five machines covered in this book. For a color version of this figure, see www.iste.co.uk/reveillac/synthesizers2.zip*

I wanted to put my exercises within the reach of as many people as possible by choosing some affordable machines (Neutron, Bass Station II) in terms of cost and two free open-source software (VCV Rack, Pure Data).

As far as software is concerned, this book is not a learning tutorial. I believe the reader will already know the fundamental bases to carry out each of the examples.

As for the equipment, the user manuals for each machine will provide you with the necessary elements.

If you have no experience, refer to the reference section at the end of the book, where you will find various links to access all the documentation and downloadable tutorials.

The exercises are ordered with increasing difficulty, but there is nothing to prevent you from completing them in the order you want. However, the elements already covered are not recalled for each exercise; they are assumed, so you may need to go back to Volume 1 to review some of them.

Depending on their specificities, some exercises do not need to be presented for all synthesizers, hardware, software or languages covered in this book.

Chapters 1 and 2 focus on the key elements of a monodic subtractive synthesizer, oscillator, filter, envelope generator, low-frequency generator and noise generator.

Chapter 3 covers more advanced features, available only on some synthesizers: ring modulation, sample and hold, and sound effects.

Chapter 4 responds to a subject that has long inconvenienced synthesizer manufacturers because its implementation, until the mid-1980s, required sophisticated and expensive electronics, that of polyphony.

Chapter 5 is not really related to subtractive synthesis, but rather to shaping and manipulation tools: sequencers and arpeggiators.

For all exercises, when equipment is used, this is indicated (in cyan for controls and red for everything else) on each of the figures depicting the synthesizer front panel.

To visualize what each parameter does, the user-editable controls are shown in cyan, and controls that the user must position exactly as indicated are in red. The uncolored commands have no influence on the sound reproduction for the given exercise.

For exercises using hardware or software without an integrated keyboard, a MIDI keyboard and an audio interface or a virtual keyboard can be used. Be sure to set them correctly (MIDI channel, port, type of interface, etc.). Appendices 2 and 3 will provide some explanations to novices in this field.

The exercises will sometimes be followed by more advanced work, interspersed with examples using Max/MSP, Pure Data and VCV Rack software. They complement and enrich the exercises by giving you new avenues of research and development.

With these remarks, it is time to get hands-on with the machines, put together modular synthesizers, and open our minds and especially our ears!

1

Subtractive Synthesis: The Beginning

To simplify the search, I have summarized in Table 1.1, for each of the exercises in this chapter, the hardware and software chosen and the sections where you can find them.

Exercise	Hardware/software	Section
No. 1. 1 VCO, 1 VCA	Behringer Neutron	1.1.1
	Behringer 2600 (ARP2600)	1.1.2
	Max/MSP	1.1.3
	Pure Data	1.1.4
	VCV Rack	1.1.4
No. 2. 1 VCO, 1 VCA, 1 EG	Behringer Neutron	1.2.1
	Behringer 2600 (ARP2600)	1.2.2
	Max/MSP	1.2.3
	Pure Data	1.2.4
	VCV Rack	1.2.5
No. 3. 1 VCO, 1 VCA, 1 EG, 1 VCF	Behringer Neutron	1.3.1
	Max/MSP	1.3.2
	Pure Data	1.3.3
	VCV Rack	1.3.4

Table 1.1. *Summary of the different exercises*

Before starting, it seems appropriate to clarify that the objective of the exercises, in all chapters, is to learn about subtractive sound synthesis in order to understand it better and master it, but also to allow your ears to discover the sensations and the sounds reproduced by each of the signals that you are going to create. What is the point of doing sound synthesis if not to discover new sounds or understand what it means to reproduce a sound, a timbre, or an already existing tone such as that of a musical instrument or a familiar noise? We need to remember to listen rather than hear, pay attention and discover the richness of the sound universe surrounding us by synthesizing our main constituents.

NOTE.– As the exercises are presented, specific comments will not be repeated to avoid overloading the explanations. In case of doubt or misunderstanding, I advise the reader to go back and read the previous exercises to find the explanatory elements that may be missing.

1.1. Exercise 1 – generate sound with a single oscillator

The basics of sound synthesis are to generate sound from an oscillator. A classic configuration contains an oscillator (VCO) and an amplifier (VCA), which can be preceded by an input controller, often a keyboard.

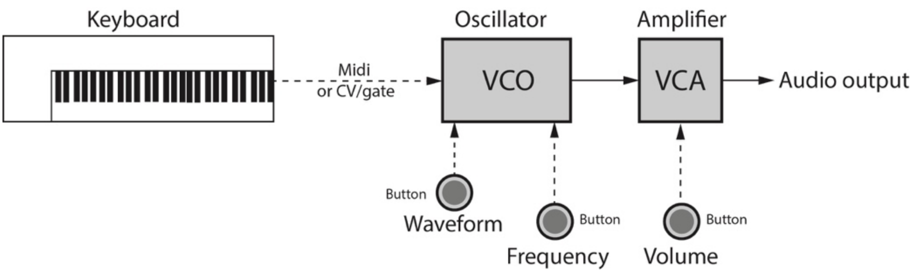

Figure 1.1. *Subtractive sound synthesis with an oscillator. The command signals are represented with dotted lines*

1.1.1. *Behringer Neutron*

The Behringer Neutron semi-modular synthesizer (see Volume 1, section 4.1.3) has two oscillators whose signals can be mixed. For this exercise, we will use Oscillator 1 (Oscillator 2 would have worked the same way, as these two oscillators are identical) and a patch cable, on the matrix, to route it to the VCA. The oscillator has five waveforms, available over three octaves.

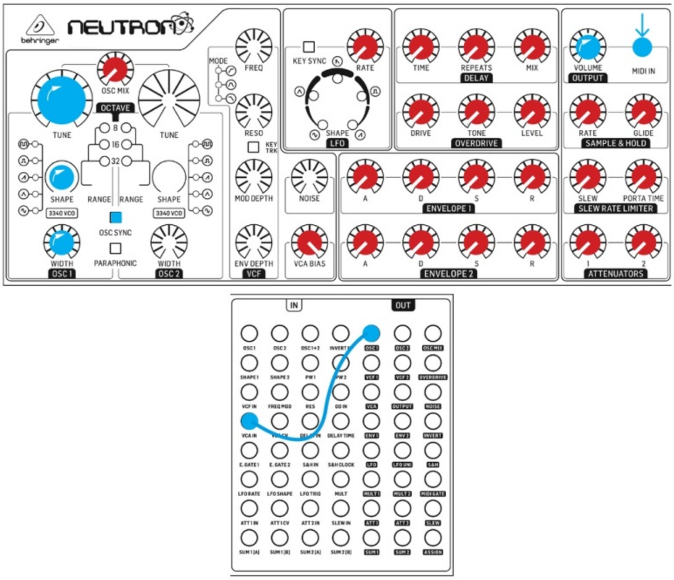

Figure 1.2. *Exercise 1 for the Behringer Neutron. For a color version of this figure, see www.iste.co.uk/reveillac/synthesizers2.zip*

Instructions and comments are as follows:

– connect a MIDI keyboard to the MIDI IN input (on the front panel) and switch it on. Check that the keyboard and the Neutron are placed on the same MIDI channel number (1–16). On the Neutron, the adjustment is made with the DIP switches located on the back;

– connect the audio output (OUTPUT) on the back to an amplification system;

– switch on the Neutron;

– connect the output (OUT) of oscillator 1 (OSC1) with a patch cable to the input (IN) of the VCA (VCA IN) on the input–output matrix to the right; this will route the signal produced by the oscillator directly to the amplifier input;

– the controls of oscillator 1 (OSC1) are all accessible. We find the agreement (TUNE), the waveform (SHAPE: mode-tonal, square-pulse, sawtooth, triangle, sinusoid) and the width (WIDTH), which modifies the width of the pulse or the tonal mode when chosen as the waveform and the octave (RANGE – 8’, 16’ or 32’);

– the oscillator mix control knob (OSC MIX) must be turned all the way to the left;

– the VC BIAS button (influence of the VCA) must be turned all the way to the right to open the VCA to the maximum;

– the VOLUME OUTPUT knob can be adjusted to adjust the overall audio output volume to your liking;

– the GATE knob of the LFO must be turned all the way to the left; otherwise, it modifies the signal of the mode-tonal and impulse waveforms;

– all DELAY, OVERDRIVE, ENVELOPE 1 and 2, SAMPLE & HOLD, SLEW RATE LIMITER and ATTENUATORS knobs should be turned all the way to the left.

NOTE.– Instead of connecting a MIDI keyboard, it is possible to use a virtual MIDI keyboard or the one in some DAWs (digital audio workstations). In this case, the connection is made via the USB-MIDI ports of the microcomputer and the Neutron. For the latter, it is located at the back of the device. Again, the MIDI channel numbers must be identical.

1.1.2. *Behringer 2600 (ARP 2600)*

The Behringer 2600 is one of the ARP 2600 clones (see Volume 1, section 4.1.1) and has similar, if not superior, functionality to today's synthesizers. It is semi-modular but has no separate matrix, and the connection points are distributed on each front panel module.

For this exercise, we will need a patch cable connected to the VCA, the other end of which can be moved to obtain the various signals generated by the oscillator since the equipment does not have a waveform selector.

Oscillator 2 was chosen because it has four waveforms; oscillator 3 would have provided the same results, with these two oscillators being equivalent.

The audio output of the 2600 is stereophonic by default, so you can choose to use both channels or just one. The slide control, PAN, manages the left–right balance.

NOTE.– The names of the commands are not always specified on the serigraphy of the front panel of the ARP 600, Behringer 2600, Korg 2600 or other clones. You can refer to these in the figures for each exercise.

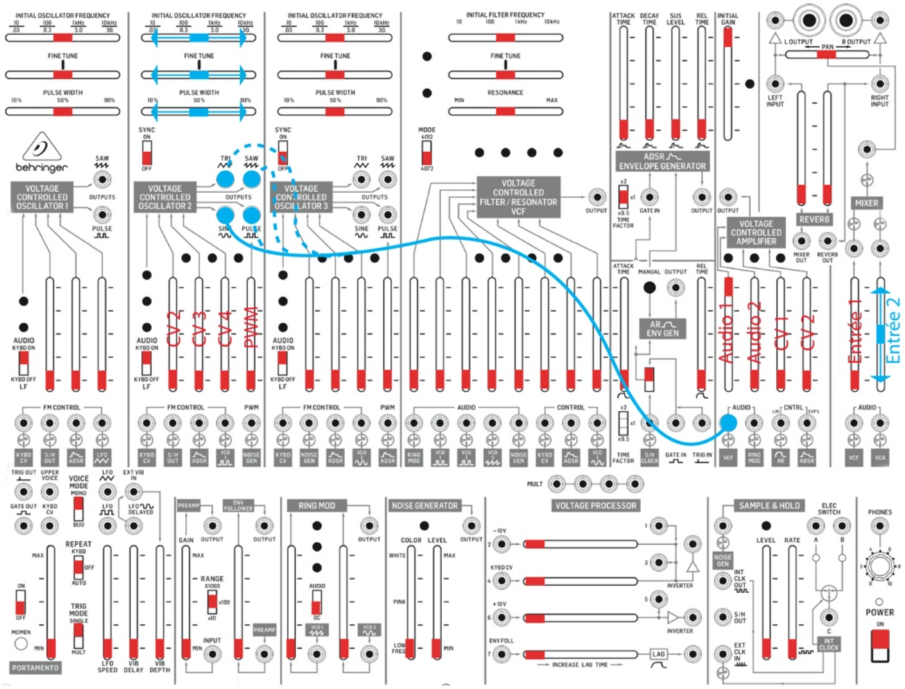

Figure 1.3. *Exercise 1 for Behringer 2600 (ARP 2600). For a color version of this figure, see www.iste.co.uk/reveillac/synthesizers2.zip*

Instructions and comments are as follows:

– connect a MIDI keyboard to the MIDI IN input on the back and switch it on. Check that the keyboard and the 2600 are set to the same MIDI channel number (1–16). On the Behringer 2600, the adjustment is made using the DIP switches on the back. If you are on an ARP 2600, a KORG 2600, or another clone, use the appropriate keyboard;

– connect the one or two audio outputs (L OUTPUT – R OUTPUT) located at the front to an amplification system;

– switch on the 2600;

– connect, using a patch cable, one of the four outputs, TRI, SAW, SINE, or PULSE to input 1 of the VCA;

– the INITIAL OSCILLATOR FREQUENCY, FINE TUNE and PULSE WIDTH controls are active and modify the audio signal. The level 2 control of the MIXER module input controls the output volume. The PULSE WIDTH control, which defines the width of the waveform square, is active if you have chosen the PULSE output of the oscillator;

– the LFO SPEED, VIB DELAY, VIB DEPTH and REVERB controls must be set to zero (lower position of the slider);

– all oscillator 2 input level controls must be set to zero;

– the AUDIO switch of oscillator 2 must be placed on KEYB ON so that the keyboard is active;

– the SYNC switch of oscillator 2 must be set to OFF;

– the INITIAL GAIN control must be placed at its maximum (uppermost position of the slider) to obtain the optimal gain of the VCA;

– the audio signal level control 1 entering the VCA must be placed at its maximum (uppermost position of the slider) to obtain a maximum incoming level;

– the PAN control can be placed in the center position to obtain an audio signal of equal intensity on the right and left outputs.

1.1.3. *Max/MSP*

The Max/MSP exercises in this book have been tested and designed with version 8.5.4, they may also work on different versions but noticeable differences may occur in some cases[1].

You will find in this exercise some of the main Max/MSP functions.

NOTE.– In all Max/MSP exercises, we will not use Live objects[2] (Ableton) to allow all users to carry out the work.

1 Available at: www.cycling74.com/.

2 Live is a software music sequencer developed by Ableton that has been available since 1999. Since 2009, Ableton and Cycling ’74, the distributor of Max/MSP, have been working together and have developed “Max for Live”, a version of Max, integrated with Live. In 2017, Ableton acquired Cycling ’74.

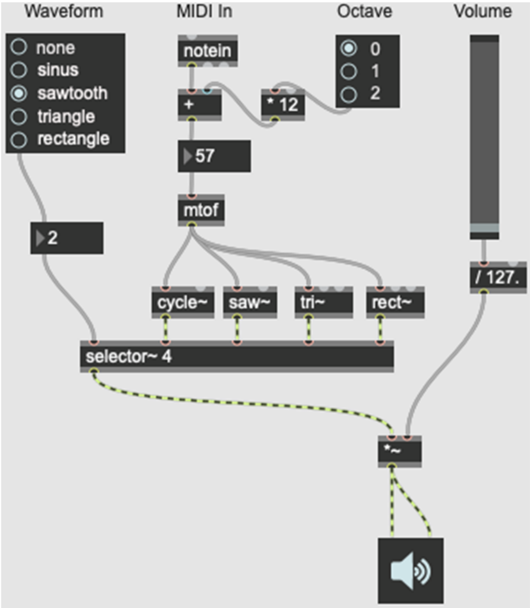

Figure 1.4. *Exercise 1 with Max/MSP*

Instructions and comments are as follows:

– `Waveform`: `radiogroup` object outputting 0, 1, 2, 3, or 4 based on user choice (0 for no signal, 1 for sine signal, 2 for sawtooth signal, 3 for triangle signal, 4 for square wave signal);

– `notein`: MIDI IN acquisition of MIDI notes and information from the keyboard;

– `+`; `* 12`, `Octave`: allows you to increase or decrease the notes by +/– 2 octaves by multiplying the output of the vertical object `radiogroup` by 12 and adding it to the note number[3] received, visualized by the object `number` connected to the output of the object `+`;

– `mtof`: converts the MIDI note number to a frequency in hertz;

– `cycle~`: oscillator that outputs a sine waveform;

– `saw~`: oscillator that outputs a sawtooth waveform;

3 In Appendix 4, you will find the different correspondences of the MIDI note numbers (piano note, frequency, name, etc.).

– `tri~`: an oscillator that outputs a triangular waveform;

– `rect~`: an oscillator that outputs a rectangular waveform;

– `Selector~ 4`: it routes the waveform chosen by the user to the volume control and then the output;

– `*~`: audio operator combining two signals, here a frequency signal and a floating number between 0 and 1 for volume management (`0` by default);

– `Volume`: vertical slider to adjust the volume. By default, it generates values between `0` and 127. Its size is 128, and its minimum output value is 0;

– `/127.`: divides the value of the slider by 127 so that the volume varies between 0 and 1;

– two whole `number` objects and one floating number `flonum` object are present to display the choice of the waveform, the note number and the volume value;

– `Ezdac~` (icon: speaker): it generates an audio signal as output by default on two channels (right and left);

– the texts (waveform, MIDI IN Octave, etc.) are present as comments (`Comment`).

NOTE.– In the event of a malfunction, remember to check the MIDI and audio configuration of Max/MSP in the "Options" menu, "MIDI Setup" sub-menu and "Audio Status". Also, do not forget to click on the "Audio On/Off" icon to the bottom right of the patcher window to activate the sound, and check that the sound is activated on your computer if this is the output you have chosen by default.

1.1.4. *Pure Data*

This exercise covers the main functions in creating a Pure Data patch (see Volume 1, section 4.2.3): object, selector, slider, number, message, etc.

All of these functions will be used throughout the exercises. In Appendix 2, you will find some patches intended to improve or modify the exercises: oscilloscope, keyboard, etc.

NOTE.– You may have seen previously, in section 1.1.3, the term "patcher" for a new project in Max/MSP, whereas here we call it "patch". The terminology is different, but the meaning is the same. It may be an evolution of the language of the developers over time or a problem of rights after the departure of Miller Puckette from the Max/MSP project in 1996 (see Volume 1, sections 4.2.2 and 4.2.3).

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