Rediscovering an Analogue Heritage: Digitally Driven Voltage-Controlled Synthesizer Modules

André Gonçalves
Research Center for Science and Technology of the Arts (CITAR)
Portuguese Catholic University - School of the Arts
hello@andregoncalves.info

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With this paper I intend to report the latest developments in what was previously defined as The Voltage-Controlled Computer (VCC)[1]. This new paradigm is a hardware based system locating itself in a specific spectrum of Embedded Computing that also complies to the standards and tradition of the Voltage-Controlled Synthesizer (VCS) as in[2][3][4]. This solution allows it's users to rethink and setup new models for analog and digital integration and interaction within a Modular Synthesizer system. A report on the latest hardware developments and a full description of it's actual software library illustrates how the VCS can be augmented through this particular device.
Based on my own research and development of commercial VCS Modules, emphasis is directed towards developments beyond the VCC and the different implementation methods used for both software and hardware. Described modules bring new and powerful tools to the use of the Voltage-Controlled Synthesizer and are now in use by hundreds of user's all over the world.

Keywords Voltage-controlled synthesizer, voltage-controlled computer, embedded system

1. Introduction

As described by Chadabe, *The voltage-controlled synthesizer is not a simple object. It is a hardware system that is different in many ways from computers and from many other devices or systems that are also referred to as synthesizers* [3].

Beyond what would be expected, voltage-controlled synthesizers are stronger today than they ever were. Many brands are creating new hardware that integrates both digital and analogue features in order to achieve hybrid systems that take advantage of both world's best features. There are several commercial products that illustrates this very effectively, the best example would be Moog Music teaming up with Spectrasonics to create the OMG-1 custom synthesizer[1] where two iPads and two iPod Touch are integrated with an analogue synthesizer where any parameter can be crossed between any of the interfaces. One last example is Korg's new Monotron [2] and Monotribe [3] analogue synthesizers, these very small and cheap synthesizers are totally analogue and illustrate how modern technology and surface mount components allow smaller circuit designs, another curiosity of these products is that Korg made their schematics public so that DIY enthusiasts can either circuit bent or build them themselves.

2. The Voltage-Controlled Computer

Since December 2010, I made a new prototype of the Voltage-Controlled Computer (Version 3) this version has new features that come to fill my latest definition of a VCC while at the same time also respond to feedback from present users.

2.1. Recent Hardware Developments

The main hardware improvement is the use of bipolar output voltages. It is now possible to choose, through a switch on the front panel, between positive (0 to +5v) or bipolar (-5v to +5v) outputs. This allows the VCC to behave like any standard VCS module that has bipolar output.

Furthermore the MCU used was upgraded from ATmega1280 to an ATmega2560, which provides more space for all the new algorithms included in the new library update.

Figure 1. ADDAC001 - The Voltage-Controlled Computer

2.2. Recent Software Developments

In the last months several improvements have been made in the C++ Library[4].

A list of all the classes that are now implemented in the ADDAC Library:

◦ Complex Random - This class features a random algorithm with gaussian or brownian modes, it offers controls over maximum and minimum amplitude, maximum and minimum time between steps, internal or external clock trigger and a quantized mode.

◦ Lissajous Curves - This class allows the generation of Lissajous Curves with parameters for X and Y amplitude, speed and offset.

◦ Physics - This class features a physics engine with control over gravity, acceleration, elasticity and simulation speed.

◦ Quadraphonic Spatializer - This class features the standard algorithm for quadraphonic spatialization featuring polar or cartesian modes with controls over angle/x and radius/y for the sound source location.

◦ CV Looper - This class allows to record and overdub CV playing it back in a loop, controls for playback speed and decay when in overdub mode.

◦ Quantizer - This class features an algorithm for quantizing incoming CV signals into it's closest note voltage be it in the 1v per octave or 1.25v per octave standards (Moog and Buchla standards). It also offers the possibility of quantizing incoming signals to any type of scale including micro-tunning scales.

◦ Complex ADSR - This class features a complex ADSR with controls for each envelope step time and amplitude. It also features a variable curve (exponential to logarithmic) for all steps.

◦ Complex LFO - This class features an LFO with controls over frequency, maximum and minimum wave amplitude, and X and Y offset.

◦ Logic Operations - This class features all logic operations, i.e., And, Or, Not, Nand, Nor, Xor and Xnor.

◦ Clock Operations - This class is a clock divider and multiplier, it can divide incoming clock signals by any number as well as multiply it by any interval. The multiply function offers control over the number of steps and the multiplication for the defined steps.

◦ Also implemented a connection to the IANNIX Software[5] as well as a Iannix example file with optimized Serial communication parameters. Tests running 8 channels of data registered consistent speeds of approximately 10ms per code loop.

Examples for all these new classes were added in the, extensively commented, main code example file.

3. ADDAC SYSTEM

ADDAC System[6] is the brand name under which I commercialize VCS modules.

3.1. Brief History

It all started about two years ago and since then it has been establishing itself in the market and getting a renowned reputation. The acronym ADDAC comes from Analog to Digital and Digital to Analog Converters. The word System was added to illustrate the idea of an expandable system where different expansion modules could be put together in order to customize and convey each user's needs.

Although this name came as a necessity when I was making the website to promote and share information about what I now refer to as the VCC, the brand grew more than I ever expected and extended itself to other VCS areas that I could never predict at that initial time. However due to marketing reasons I always kept the initial name.

Furthermore I never had the intention of commercializing these modules, all initial developments started as a necessity I had in my own VCS and my own particular use of such a system. Through some advice of Tom Bugs[7] a good friend with whom I started sharing details of what I was developing, he recommended me to share my developments in a couple specialized forums. Instantly after my first posts I started receiving all these encouraging posts that were very enthusiastic about my developments. It didn't take long until I understood that many other people felt this same necessity and that my developments were getting some serious attention from many other users. This led me to develop everything in a more professional and careful way.

3.2. Beyond the VCC

Several months after the initial forum feedbacks, I understood that although many VCS users were receptive to the VCC possibilities the method developed for operating such system was not compatible with the standard VCS user knowledge. The programming skills needed to operate such system and customize it's code library was most of the time inexistent in such users. At that point I started thinking in new methods to make it more user friendly, trying to achieve an easier way to operate it and bring it closer to the standard plug and play VCS modules. This proved to be an enormous task that I couldn't afford to develop by myself since it would take me months of intense development.

At that point in time I started to think in an alternative way to resolve this problem. The solution was to create dedicated modules that would encapsulate a particular algorithm that I had developed for the VCC, developing standalone plug and play modules with a dedicated front panel. This way I would have a module for each of the VCC featured classes while, at the same time, it would allow to develop new modules with new functions that the VCC could not respond to due to the specificity of it's own hardware.

In March 2010 I announced the first of these standalone modules, i.e, ADDAC101 .WAV Player. This module was the keystone in my developing process and it's immediate popularity was the factor that made me take ADDAC System one step further and look at it as a proper brand.

4. STANDALONE VCS MODULES

During the course of the last eighteen months I've developed more than fifteen standalone modules, these fall into three categories:

◦ Modules that integrate specific hardware not featured in the VCC, i.e., Wav Player, Digital FM Radio, Dual Oscilloscope.

◦ Modules that use one of the VCC's featured classes and encloses it in a dedicated front panel allowing no programming to be done by the user, i.e., Complex Random, Lissajous Curves, Marble Physics, Quadraphonic Spatializer.

◦ Standard analogue modules, i.e., Filterbank, Audio Mixers, CV Mapping, CV Inverter, Multiples.

All these modules feature both analogue inputs and outputs, these are converted to and from digital signals at standardized Control Voltages (CV). These Control Voltages operate at standardized VCS bipolar ranges. The modules are mountable on standard Eurorack synthesizer cabinets and connected to standard Bus Boards, powering themselves from any standard VCS bipolar power supply.

4.1. ADDAC101 .WAV Player

This module illustrates the first aforementioned method where the hardware of the VCC had to be changed as the SD card slot does not exist in the VCC hardware. The popularity of this module mainly relates to it's state of the art features. A SD Card slot allows the user to load wav files into a SD card from a computer and then, loading it into the module front panel, access and playback, in a loop, those wav files through it's panel controls. As of today, there's no other VCS module in the commercial market that allows the playback of digital files.

Figure 2. ADDAC101 .WAV Player 100th unit commemorative edition

4.1.1. Features

SD cards can be swapped at any point in time. After which the Reset button, located under the SD card slot, needs to be pressed in order for the MCU to update the SD card new file directory.
The module front panel features:

◦ One SD Card slot.

◦ One Reset momentary push switch, located below the SD Card slot.

◦ Four variable settings, Loop Size, Initial Position, Sample Rate and VCA controlled either manually through the front panel knob or externally from a CV input, these are the four top right sections seen on Figure 2, the first three are used in the code running on the MCU through it's own ADC inputs while the fourth is a totally analogue circuit.

◦ Three SPDT switches located in the bottom right corner.

◦ One Gate/Digital input located in the bottom left corner, this feature serves various purposes depending on the two first aforementioned SPDT switches and can be triggered either through a momentary push switch or through an external Gate input.

◦ Two sound outputs, one pre-VCA, located on the top left corner with a pre-volume knob, and one post-VCA located in the VCA section.

◦ An Envelope Follower CV output section, located above the SPDT switches.

4.1.2. Dynamic controls

◦ Loop Size - this allows to dynamically control the size of the loop being played, trimming down the file total duration to a smaller size.

◦ Initial Position - this allows to dynamically control the initial point of the loop being played, also allowing to scroll through the file duration.

◦ Sample Rate - this allows to dynamically control the sample rate resolution, creating a pitch like effect on the file being played.

◦ Voltage Controlled Amplifier - this is a totally analogue VCA circuit that allows to dynamically control the overall volume of the sound output.

The first three inputs also feature one led to monitor it's current state.

4.1.3. SPDT switches

◦ Skip / Loop - This switch set the Gate/Digital input to either a file access mode or a playback mode.

◦ Loop / One Shot | Forward / Random - This switch operates depending on the previous switch setting. If set to Skip mode then the switch is used to define how the files are being accessed. Files will then be played either consequently, one after the other or in a random mode.

If set to Loop mode then the file will be played either in a constant loop or as a one shot playback, playing just once and stopping when reaching the end point defined by the Loop Size setting.

◦ Sample Rate On/Off - This switch is used to activate or deactivate the Sample Rate setting.

4.1.4. Gate/Digital input

◦ if Skip and Forward modes are selected a positive input advances to the next file.

◦ if Skip and Random modes are selected a positive input randomly chooses the next file to be played.

◦ if Loop and Loop modes are selected a positive input re-triggers the file playback to the Initial Position setting.

◦ if Loop and One Shot modes are selected a positive input triggers the file playback starting from the Initial Position setting.

4.1.5. Envelope Follower

This CV output is related to the amplitude of the post-VCA sound. It has controls for level and decay. A led is also present to monitor the voltage output.

4.2. ADDAC501 Complex Random

This module illustrates the second aforementioned method where one of the VCC's featured classes is enclosed in a dedicated front panel so that no programming is required to be done by the user.

4.2.1. Features

The module front panel features:

◦ Four variable settings, Voltage Maximum, Voltage Minimum, Frequency Maximum and Frequency Minimum, controlled either manually through the front panel knob or externally from a CV input, these are the top four sections seen on the left module of Figure 3. Each of these sections features a SPDT switch to choose if it is controlled manually or externally. The last of these sections features a second SPDT switch.

◦ Three SPDT switches located at the bottom of the panel.

◦ Three independent CV outputs, located above the bottom SPDT switches each with a monitor led.

Figure 3. ADDAC501 Complex Random & ADDAC501B Complex Random Expansion

4.2.2. Dynamic controls

◦ Voltage Maximum - this allows to dynamically control the maximum random voltage output, between zero and five volts.

◦ Voltage Minimum - this allows to dynamically control the minimum random voltage output, between zero and five volts. If the Minimum value is bigger than the Maximum value the module behaves like a constant voltage source defined by the Minimum value setting.

- ◦ Frequency Maximum - this allows to dynamically control the maximum clock interval time between each step.
- ◦ Frequency Minimum - this allows to dynamically control the minimum clock interval time between each step. If the Minimum value is bigger than the Maximum value setting than the module behaves at a constant clock source defined by the Minimum value. The second SPDT switch in this section allows to select between internal or external clock source.

4.2.3. SPDT switches

- ◦ Standard / Brownian - selects the type of random algorithm used.
- ◦ Quantization On / Off - allows to quantize the zero to five volts range to a Major Pentatonic scale using Moog's 1v per octave standard.
- ◦ Standard / Brownian Time - selects the type of random algorithm used for the clock timing.

4.2.4. ADDAC501B Complex Random Expansion

The module on the right of Figure 3 is an expansion module with two extra features. A jumper on the back of the main module activates / de-activates this expansion.

- ◦ Smooth - This knob allows to define the amount of legato between each clock step.
- ◦ Gate outputs - these six outputs are grouped two by two, positive and inverted, and are related to each of the main module's CV outputs. The behavior of these outputs are dependent of the Voltage Maximum and Minimum settings, if the random step is above the average between Maximum and Minimum settings then the positive Gate output goes High and the inverted output goes Low and vice-versa.

4.2.5. Java Simulator App

In order to better illustrate the behavior of this module, a Java application[8] built in Processing[9] was developed for potential users to test and better understand the module's inherent features.

This application is cross compatible with the three main operating systems and, besides all the functions of the real hardware module, it features a graphical display that resembles an oscilloscope like monitor and a very simple sound engine as if the module output was plugged straight into the CV input of a VCO. This way the audiovisual experience of using this application makes it a very effective demonstration of the module's potential.

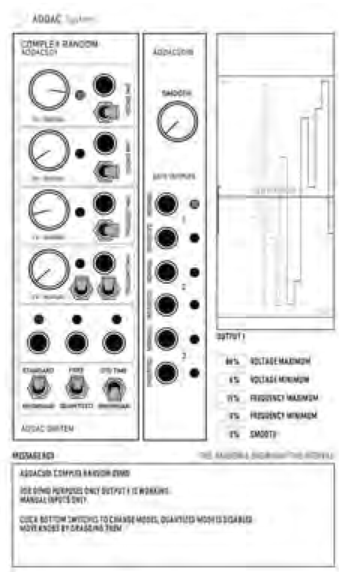

Figure 4. ADDAC501 Complex Random Java Simulator

5. CURRENT AND FUTURE DEVELOPMENTS

My current research is focused in developing an hybrid system that can take advantage of the analogue sound generation and the computational power of mobile devices such as the iPad. This will allow to develop digital applications that can be integrated with Pure Data[10] through the LibPD[1] DSP library and directly interface them with analogue physical hardware. This will allow to include Pure Data patches in the VCS chain through dedicated hardware and software while at the same time taking advantage of all the expressivity allowed by multi-touch technology.

Another crucial part of my actual research is to develop an analogue circuit that is versatile enough to efficiently digitize the voltage ranges of different modules keeping precision at all times, i.e., LFO's range between -5v and +5v, ADSR's between 0v and +5v or 0v and +10v, envelope followers between 0 and +11v. This problem has been identified for several months and although the CV inputs circuit already covers some of this concern I believe that more precision can be achieved making better use of the ADC's integrated circuit range.

6. REFERENCES

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[3] http://www.korg.com/monotribe

[4] Library now available at github: https://github.com/barnone/ADDAC_Library

[5] http://www.iannix.org

[6] http://www.addacsystem.org

[7] Tom Bugs is the creator behind the renowned Bug Brand Company, http://www.bugbrand.co.uk

[8] Available at: http://addacsystem.org/ADDACjava/addac501

[9] http://www.processing.org

[10] http://puredata.info

[Abstract in Korean | 국문 요약]

아날로그 유산의 재발견: 디지털 방식으로 제어되는 전압 제어 신시사이저 모듈

안드레 곤살베스

디지털 신시사이저의 출현 이래로 아날로그 세대의 구식의 제어 방식은 이제 새로운 기술의 발전에 힘입어 새롭게 융합된 방식을 보이고 있다. 이러한 방법은 아날로그와 디지털 두 가지 방식에 있어서 모두 최상의 결과를 보여 준다. 이 글을 통해 필자는 과거 전압 제어 컴퓨터 계열 장비들의 가장 최근의 개발 상황을 소개하고자 한다. 이러한 새로운 패러다임은 내장형 컴퓨팅의 스펙트럼에 속하는 하드웨어를 기반으로 하고 있으며, 표준 전통 방식의 전압 제어 신시사이저와 호환된다. 필자의 연구와 상업적 전압제어 신시사이저 모듈의 개발에 근거하여, 어떻게 전압 제어 컴퓨터를 뛰어넘을 것인지, 그리고 하드웨어와 소프트웨어에 모두 적용되는 또 다른 실행 방법을 개발할 수 있을지에 초점을 맞추고자 한다. 아울러 이 글에 설명된 모듈은 전압 제어 신시사이저의 사용을 위한 새롭고 강력한 도구를 만들어낸다.