ACTIVE PRESERVATION OF ELECTROPHONE MUSICAL INSTRUMENTS. THE CASE OF THE “LIETTIZZATORE” OF “STUDIO DI FONOLOGIA MUSICALE” (RAI, MILANO)

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ABSTRACT

This paper presents first results of an ongoing project devoted to the analysis and virtualization of the analog electronic devices of the “Studio di Fonologia Musicale”, one of the European centres of reference for the production of electroacoustic music in the 1950’s and 1960’s. After a brief summary of the history of the Studio, the paper discusses a particularly representative musical work produced at the Studio, *Scambi* by Henri Pousseur, and it presents initial results on the analysis and simulation of the electronic device used by Pousseur in this composition, and the ongoing work finalized at developing an installation that re-creates such electronic lutherie.

1. INTRODUCTION

Despite the fact that electroacoustic music is a young form of art, it is necessary to take care of its preservation, due to the limited life of the supports where electroacoustic music works are preserved, of the reading systems of the data, and of the instruments. Moreover, preservation and restoration of this works raises peculiar technical and philological issues. With particular regard to electrophone instruments, many technological generations have passed since the appearance of the first instruments, and many electronic components used in their construction do not exist anymore or are only available with difficulty. [1]

The potential damages produced by a bad conservation or an inadequate restoration are irreversible.

The aim of this paper is to report on initial results of an ongoing project devoted to the preservation, analysis and virtualization of the analog electronic devices of the Studio di Fonologia Musicale. The final goal is to develop an installation consisting of a SW-HW system that re-creates the electronic lutherie of the Studio, allowing users to interact with such lutherie. In particular, the production setup originally employed to compose *Scambi* is considered as a relevant case study. Achieving the goal of the project implies *(i)* analyzing the original devices through both project schemes and direct inspection; *(ii)* validating the analysis through simulations with *ad-hoc* tools (particularly Spice – Simulation Program with Integrated Circuit Emphasis, a software especially designed to simulate analog electronic circuits [3]); *(iii)* developing physical models of the analog devices, which allow efficient simulation of their functioning (according to the *virtual analog* paradigm [4]); *(iv)* designing appropriate interfaces to interact with the virtual devices. The paper is organized as follows. Section 2 discusses the issues posed by preservation and restoration of electrophone instruments. Section 3 briefly summarizes the history of the Studio di Fonologia and of *Scambi*. Finally, Sec. 4 presents initial results on the analysis and simulation of the electronic lutherie used by Pousseur for the composition of *Scambi*.

2. PRESERVATION AND RESTORATION

In most cases, the electroacoustic musical piece, as the author has produced it, is made of various elements like a score, recorded music, suggestions for interpretation, and other materials which are often important for understanding the making of the piece itself. This lead to the need of preserving both graphics and textual materials (score, schemes, suggestions) and audio materials (musical parts or the whole piece), software (for sound synthesis, live electronics, etc.), and electrophone instruments. The first materials are usually on paper and are thus concerned with the more general problem of paper materials preservation. Audio materials are recorded on various supports in which a rapid degradation of the information occurs. A new interesting field is the preservation of electrophone musical instruments.

Preservation can be categorized into *passive* preservation, meant to defend the original instruments from external agents without altering the electronic components, and *active* preservation, which involves a new design of the instruments using new electronic components. Active preservation is

[1] Electrophones are considered to be the only musical instruments which produce sound primarily by electrical means. Electrophones are one of the five main categories in the Hornbostel-Sachs scheme of musical instrument classification [1]. Although this category is not present in the original scheme published in 1914, it was added by Sachs in 1940 [2], to describe instruments involving electricity.

needed to prevent the equipments from disappearing, and it is desirable because it allows to access them on a wide scale (e.g. active preservation may allow to access the instrument in virtual spaces that can be accessed even remotely by large communities of users). Collaboration between technical and scientific competences (informatics as well as electronic engineering) and historical-philological competences is also essential.

In the field of audio documents preservation some relevant guidelines have been sketches along the years [5, 6], but most questions regarding the safeguard and the preservation of electrophone instruments remain unanswered, as the regulations in force do not provide for specific care or legislative obligations.

2.1 The instruments

Electroacoustic music instruments differ from traditional ones in many respects: the use of electric energy as the main sound producing mechanism, rapid obsolescence, the dependence on scientific research and available technology. Unlike Sachs [2], we prefer (from the standpoint of preservation) to cluster electrophone instruments in three categories: electroacoustic, electromechanical, and electronic (analogic or digital).

In an electroacoustic instrument, transductors transform acoustic vibrations into a voltage variation representing the acoustic pressure signal. Sound is produced through an amplification system, while the original acoustic sound is hardly perceivable. Examples are the microphone, the electromagnetic pick-up of the electric guitar, the piezoelectric pick-up of the turntable.

In electromechanical instruments, voltage variations are caused by sound storage on a rotating disk or a tape according to electromechanical, electrostatic, or photoelectric principles. The main electromechanical generator is the audio-wheel first used by Thaddeus Cahill in the early 1900's, for his Telharmonium. Successful electromechanical instruments include the Hammond organ (audio-wheel) and the Mellotron (magnetic tape). Unlike the electroacoustic case, in electromechanical instruments sound could be heard only through the amplification.

In electronic instruments, sound is synthesized by one or more electronic generators without any acoustic or mechanical vibrations. Electronic components used for synthesis range from valves and semiconductors to VLSI circuits, with analogue technologies being replaced by digital ones. Sound is synthesized through combination and interconnection of "primitive" components like oscillators, noise generators, filters, modulators, etc. Examples of electronic instruments are electronic organs and synthesizers.

Preservation of these instruments poses several problems. First of all, "today, probably, more electronic than acoustic instruments are produced and, within short time, it is likely that more electronic instruments will be produced than all the acoustic instruments made in the human history" [7]. Secondly, these instruments should be preserved not only for museal purpose, but also to preserve their functionality. In our opinion, it is necessary to keep alive the music in the present time independently from its original instruments, whose careful preservation protects a cultural heritage useful to historical and musicological research.

It is also necessary to make a distinction between commercial instruments, produced on a large scale, and experimental prototypes realized in musical research labs. The former are typically closed and compact instruments whose operational aspects are well documented and often protected by patents. Large-scale production makes less problematic their preservation, in terms of availability of replacement components. On the contrary, experimental prototypes are harder to preserve, because of lacking technical documentation, as well as "cannibalism", i.e. the practice of reusing some components for the assemblage of new devices. This phenomenon also makes difficult to date prototypes, and to know their characteristics at the time when the musical work was realized.

Often, electroacoustic music production is not linked to a particular instrument, but to a *system* composed of several instruments. This requires preservation of the laboratories where all the steps of the musical work production process were performed. As an example, the study of electronic music in Köln has been reconstructed in the same configuration used in the 1950's. A similar approach has been followed for the Institute of Sonology of the Utrecht University, active in the 1960's. The exhibition at the Cité de la Musique in Paris includes a section dedicated to electrophone instruments related to the experience of real-time computer music in the 1980's.

3. THE *STUDIO DI FONOLOGIA MUSICALE*

3.1 History

The Studio di Fonologia Musicale [8] was founded in 1955 at the Milan offices of the Italian Radio-Television (RAI), under the initiative of the italian composers Luciano Berio and Bruno Maderna. In a few years, the Studio became one of the European centres of reference for the production of electroacoustic music, by deploying cutting-edge devices for the generation and processing of sound. Often these devices were especially designed and crafted by Alfredo Lietti: oscillators, noise generators, filters, dynamic and frequency modulators. These were unique pieces, created with great care to meet the needs of the composers who attended the Studio.

In 1967 the Studio underwent a partial renovation. As a consequence, much of the older equipment was dismantled and has been lost. However, thanks to records kept in archives (photographs, schemas, drawings and articles) it is possible, in many cases, to know the characteristics and the functionality of most equipments that no longer exist. The Studio was closed in 1983 and the devices were disassembled and transported to Turin, where they remained packed in storage until 2003, when they were returned in the RAI headquarters in Milan.

The electronic lutherie of the Studio di Fonologia Musicale has recently been transferred to the Milan Museum of musical instruments: this inestimable technological and cultural heritage is now accessible to the general public in a permanent museum exhibition. However the electronic devices and sound generators are not currently functioning, they are exhibited as mute instruments and visitors can only listen to recordings of musical compositions that made use of these devices. As a consequence, it is not possible to fully appreciate the variety of timbral and expressive possibilities of these instruments, which could be experienced only by directly interacting with them. The museum is thus seeking for solutions that allow visitor to experience such an interaction, possibly by a virtual recreation of the devices.

The cultural value of the electronic lutherie of the Milan Studio is testified by the efforts devoted jointly by RAI and the Milan Museum of musical instruments, in order to set-up the current exhibit. In fact the Milan Studio, together with its counterparts in Paris and Cologne, was one of the topical places of early electronic music, and during the 1950's and 1960's was able to attract composers of international stature. The Belgian composer Henry Pousseur was among them.

3.2 *Scambi*

Analyzing the analogue tape work *Scambi*, composed and realized in 1957 by Pousseur at the Studio di Fonologia, allows to identify some characteristics of the open-form [9]: the interchange of sections within certain constraints, and the possibility of combining sections. In particular Pousseur specified "connecting rules", according to which only certain sequences beginning with the same character could be rearranged.

Writing about *Scambi* in 1959, Pousseur ended by envisaging the day when technology would allow listeners to make their own realizations of the work (either following his connecting rules or not) and to give the, now active, listener the experience of a temporal event open to his intervention and which could therefore be elevated in type, as vital, creative freedom [10]. The active listener becomes, in effect, a composer; reception and interpretation are expressed as (musical) production. In fact several versions of *Scambi* exist. Among them, two were realized by Pousseur himself, one by Marc Wilkinson [11], and two by Luciano Berio (who seems to have disregarded the connecting rules suggested by Pousseur).

Pousseur's conception of open form can be summarized in the definition of 'music bar' given by the composer himself:

> "(...) I can easily imagine that in the not too distant future the possibility of doing such work will become generally available. All one needs at home is some splicing tape and leader tape and a simple tape recorder, or preferably two or three (and with several amateurs this should not be too difficult), which need not be perfectly synchronized, the small errors here leading to constantly new figures; else, the whole material could be made available to amateurs in some kind of 'music bar'. The joy of turning the volume control – maybe in company – or even of a little spatial distribution, requiring no expensive apparatus, would help to give the now active listener the experience of how the course of an event can be influenced and raised to the form of a vital, creative freedom." ([10, p. 54])

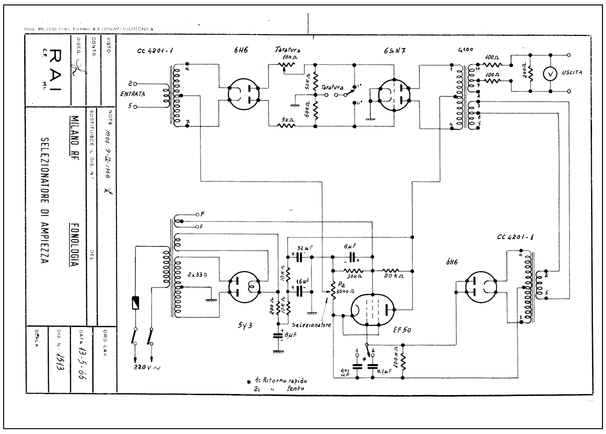

Figure 1. Original project scheme of the Selezionatore di Ampiezza.

A "contemporary" recreation of *Scambi*, which uses a collaborative tangible interfaces, is presented in [12].

4. VIRTUALIZATION OF THE ELECTRONIC LUTHERIE

This section presents the ongoing work finalized at realizing an installation consisting of a *music bar* [10, pag. 54], i.e. a SW-HW system that re-creates the electronic lutherie and the production setup that were originally used to compose *Scambi*: an equivalent of the concept of the *access copy* in the field of audio document preservation [5, 6]. The installation will be at disposal of users, who will have the possibility to directly interact with the virtual versions of the electronic instruments (sound generators, filtering devices, etc.) in the same way as electronic musicians did in the 1950's and 1960's, and will, therefore, be able to better understand the functioning and the possibilities of this kind of equipment. In particular, users will be able to compose their own versions of *Scambi* using the virtual equivalents of the original equipment and material employed by the composer, eventually realizing Pousseur's vision after more than 50 years.

4.1 Analysis and reverse engineering

Analysis of the analogue electronic devices is being conducted using the original projects of the devices, which are nowadays part of a permanent exhibition at the Milan Museum of Musical Instruments. Preliminary inspections indicate that the original project schemes are generally well documented in terms of characteristics of the basic components and of circuitry. In some cases where the documentation is not detailed enough, it is necessary to inspect directly the original instruments through *ad-hoc* measurements on some components. Finally, in order to assess the accuracy of the analysis, the behavior of the devices has

Figure 2. The front panel of the *Selezionatore di ampiezza* (photo courtesy of M. Novati [8]).

Figure 3. Rear view of the *Selezionatore di ampiezza* (photo courtesy of M. Novati [8]).

to be simulated using electronic engineering tools (particularly Spice [3]).

The circuit of the *Selezionatore di ampiezza* utilized by Pousseur for *Scambi* is depicted in Figure 1. The figure reproduces the RAI project schemes, which are slightly different from the ones originally presented by Lietti in [13]. The circuit has two operating modes, which depend on the activation status of the EF50 pentode.

1. When the pentode is off, no current flows through the potentiometer P2, so that the secondary of the input transformer CC4201 is connected to ground. In this case, the input signal, scaled by the input transformer, passes unchanged through the twin diode 6H6. The following bridge, composed by three resistances and the potentiometer P1, renders the signal symmetric: by means of the connectors and the switch positioned in the rear of the device (see Figure 3) it is possibe to tune the potentiometer P1 until the amplitudes in the upper and in the lower side of the bridge are equal. Finally, the dual triode 6SN7 amplifies the signal to drive the output stage.
2. When the pentode is on, the current flowing through the potentiometer P2 polarizes the secondary of the input transformer to the voltage V_p (depending on the position of the potentiometer). As a result, the current will flow through one of the diodes of the 6H6 tube only when the voltage of the input signal is, in absolute value, greater than the bias voltage V_p. If on the other hand the amplitude of the input voltage is less than V_p, the twin diode 6H6 is off and the output voltage will be zero. The knob at the bottom left of the front panel of the device (see Figure 2) lets the operator control the resistance value of P2 and the V_p threshold.

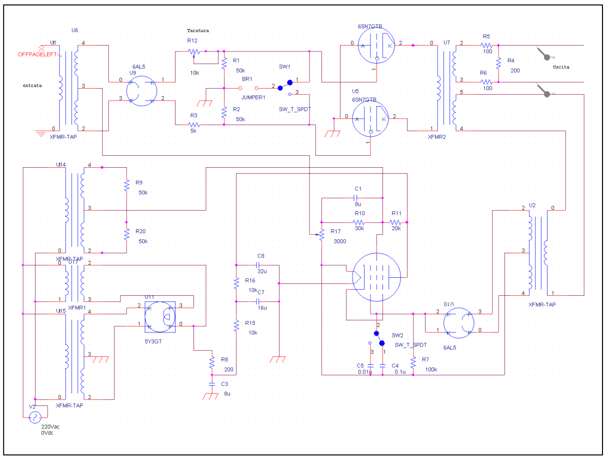

Figure 4. Electrical scheme designed to simulate the device.

The activation status of the pentode EF50 depends by the feedback circuit: the output signal is drown from the connectors 6 and 7 of output transformer G100, it is rectified by the twin diode 6H6, it is filtered by the RC circuit and, finally, is applied to the suppression grid of the pentode EF50.

If a signal is present in the output stage, the twin diode 6H6 is on and the current flows through the RC circuit, biasing the suppression grid to a negative potential, in respect to the cathode. In this condition, the flow of current is inhibited and the pentode is off. Conversely, when there is no signal in the output stage, no current flows through the RC circuit and then the grid will be at the same potential of the cathode. Under these conditions, the pentode is on. The biasing of the pentode is provided by the power supply circuit, that rectified the alternate power supply through the tube 5Y3. The speed at which changes the pentode is switched on and off depends on the speed at which the RC circuit responds to changes in the feedback signal, i.e. on the time constant of the circuit $\tau = RC$. The switch at the bottom right of the front panel (see Figure 2) lets the operator select between two time constants: $\tau_1 = 0.001s$ and $\tau_2 = 0.01s$.

4.2 Simulations

The circuit of the *Selezionatore di ampiezza* has been replicated in Spice. To this end, datasheets and libraries for all the circuit components have been found. Figure 4 shows a snapshot of the resulting Spice replica of the original circuit.

The output of the circuit was simulated in response to

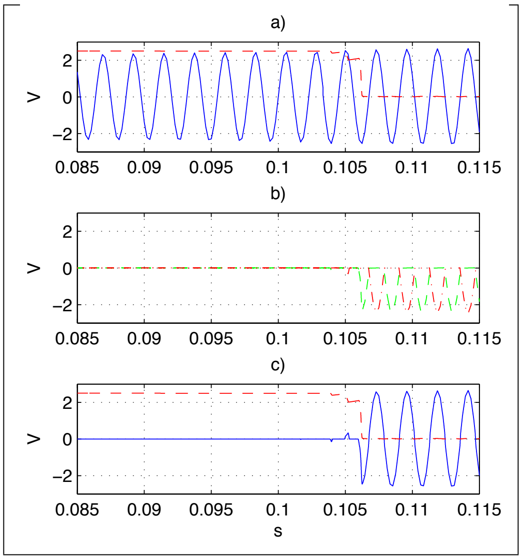

Figure 5. Spice simulation of the circuit excited with a sinusoidal signal with slowly increasing amplitude. a) input signal (blue solid line) and the voltage V_p (red dotted line); b) voltages at the two anodes of the twin diode 6H6; c) output signal (blue solid line) and the voltage V_p (red dotted line). The selector is turned on $C_2 = 0.1\mu F$.

- sinusoidal voltage signals with slowly increasing amplitude;
- stochastic voltage signals with zero mean.

Figure 5 shows the results of a Spice simulation. The input sinusoidal signal V_i is plotted in the upper frame (blue solid line), together with the voltage V_p (red dotted line), i.e. the bias voltage of the input transformer. As long as the input signal is below the voltage V_p, the twin diode 6H6 is off and the voltage at both its anodes is zero (see Figure 5 b). Therefore, the output voltage is also zero (see Figure 5 c) and the pentode EF50 is on. When the peak amplitude of the input voltage exceeds V_p, as at time $t = 0.103s$, the diode 6H6 begins to conduct (at least when $|V_i| > V_p$). Therefore, the output voltage is equal to the portion of the input waveform with amplitude greater (in absolute value) than V_p, the pentode EF50 starts to shut down, and the voltage V_p starts to decrease. This transition phase takes about 4 ms. After the transition, the twin diode 6H6 is always on (the two parts of the diode conduct either in correspondence of the positive and negative half-wave respectively), the output signal is approximately equal to the input, the pentode EF50 is powered off completely and the voltage Vp is close to zero.

Figure 6 shows the behavior of the circuit in response to a stochastic signal with a brownian spectral density. Initially, the input signal (a) is maintained below the voltage V_p and the output (b) is zero. At $t = 0.014s$ the stochastic signal exceeds, in absolute value, the threshold V_p and this causes the switching off of the pentode and the lowering of V_p. Until the input signal has a high average amplitude the pentode is off. When the input amplitude decreases, around t = 0.05s, the pentode starts to turn on, the voltage

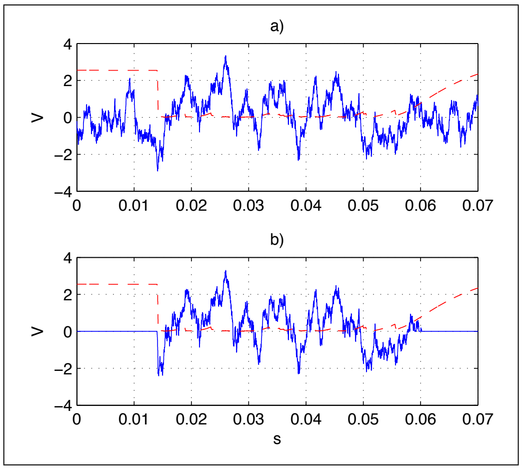

Figure 6. Spice simulation of the circuit excited with a stochastic signal. a) input signal (blue solid line) and the voltage V_p (red dotted line); b) output signal (blue solid line) and the voltage V_p (red dotted line). The selector is turned on $C_1 = 0.01\mu F$.

grows and the V_p signal output changes gradually to zero.

The speed with which the pentode turns on, as a result of a lower input voltage, depends on the time constant of the RC circuit connected to the pentode grid. A selector on the front panel of the amplitude selector allows you to choose between two capacitor values, $C_1 = 0.01\mu F$ and $C_2 = 0.1\mu F$, which correspond to the time constants $\tau_1 = 1ms$ and $\tau_2 = 10ms$. The results of Figure 6 are obtained with the selector on C_2 and it can be seen that the rise time of V_p is, as expected, about $2 \cdot \tau_2$.

Figure 7 compares the device responses to the same input signal as a function of the time constant of the RC circuit. Frames (a) and (b) are related to the time constant $\tau_1 = 1ms$ (selector on $C_1 = 0.01\mu F$): the rise time of V_p is faster than in the case showed in Figure 6. Moreover, it can be seen that the circuit reacts differently if the time constant is changed (see frames (c) and (d)). Unfortunately, no audio comparison and assessment of the end-result with respect to original signals is possible: as it is well known, no recordings of this device exist (we have only the complete sequences, where the Liettizzatore's outputs are processed).

5. CONCLUSION

The advent of digital technologies allowed to overcome many of the technical limitations of analog electroacoustic devices. However the question is whether the electroacoustic community is exploiting these digital resources for new experiments in form. The authors strongly believe that now the composers are able to explore in exhaustive way the potential of open forms using new media and new Human Computer Interfaces But, in order not to constantly "re-invent the wheel", works such as *Scambi* must be regarded as being more important now than fifty years ago.

In this sense, the authors are developing the *Music Bar* for active listeners. starting from the original project and

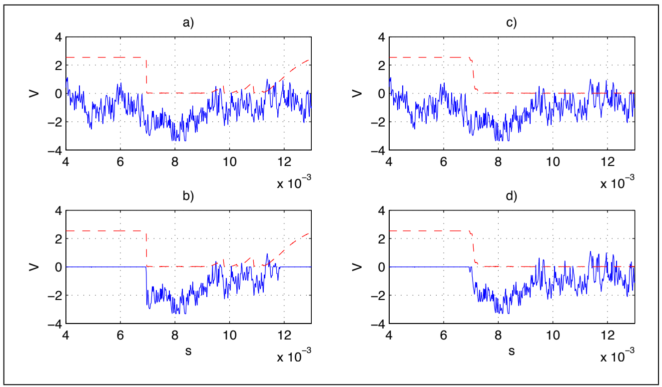

Figure 7. Spice simulation of the circuit excited with a stochastic signal. a) input signal (blue solid line) and the voltage V_p (red dotted line), selector on $C_2 = 0.1\mu F$; b) output signal (blue solid line) and the voltage V_p (red dotted line), selector on $C_2 = 0.1\mu F$; c) input signal (blue continuos line) and the voltage V_p (red dotted line), selector on $C_1 = 0.01\mu F$; d) output signal (blue solid line) and the voltage V_p (red dotted line), selector on $C_1 = 0.01\mu F$.

schemas of *Selezionatore di ampiezza*, the authors developed a system that allows the user-performer-composer to surf among the existing performances of *Scambi* and to create his own. Specifically, the installation will allow users to creatively interact with (i) virtual counterparts of the electronic devices of the Studio di Fonologia, and (ii) the production system of *Scambi* realized by Pousseur. The user-performer-composer will be able to surf among the existing performances of *Scambi* (e.g. by Luciano Berio and others), and to create his own, by selecting the original audio sequences used by Pousseur, and following (or not) the connecting rules proposed by the composer.

Future work will be devoted to the development of accurate and efficient virtual analog models of the original devices. Recently proposed techniques for the efficient simulation of nonlinear electric systems will be employed [14], and results from spice simulations of the circuits will be used to evaluate the accuracy of the virtual analog models.

A second key point for the effectiveness of the final installation is the design of the user interface. As future work, the authors intend to develop a tangible interface, able to recreate the corporeity, the materiality of the original interfaces: the inherent latencies between the user gestures and the corresponding effects on sound generation; the resistance and viscosity of the tape, which was slowed by hand by the composer-performer; and so on. All these physical characteristics influenced the composer and his way of interacting with the devices, and need to be preserved in their virtual counterparts.

6. ACKNOWLEDGEMENT

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