62 Years and Counting: MUSIC N and the Modular Revolution

By Brian Lindgren

MUSC 7660X - History of Electronic and Computer Music

Fall 2019

24 December 2019

Abstract. MUSIC N by Max Mathews had two profound impacts in the world of music synthesis. The first was the implementation of modularity to ensure a flexibility as a tool for the user; with the introduction of the unit generator, the instrument and the compiler, composers had the building blocks to create an unlimited range of sounds. The second was the impact of this implementation in the modular analog synthesizers developed a few years later. While Jean-Claude Risset, a well known Mathews associate, asserts this, Mathews actually denies it. They both are correct in their perspectives.

Introduction

Over 76 years have passed since the invention of the first electronic general purpose computer,[1] the ENIAC. Today, we carry computers in our pockets that can perform millions of times more calculations per second.[2] With the amazing rate of change in computer technology, it's hard to imagine that any development of yesteryear could maintain a semblance of relevance today. However, in the world of music synthesis, the foundations that were laid six decades ago not only spawned a breadth of multifaceted innovation but continue to function as the bedrock of important digital applications used around the world today. Not only did a new modular approach implemented by its creator, Max Mathews, ensure that the MUSIC N lineage would continue to be useful in today’s world (in one of its descendents, Csound) but this approach also likely inspired the analog synthesizer engineers of the day, impacting their designs.

[1] Wikipedia. “ENIAC,” found at https://en.wikipedia.org/wiki/ENIAC, accessed on 17 December 2019
[2] Hines, Nickolaus. “Then And Now: The World’s Very First Computer vs. Today’s Supercomputers,” https://allthatsinteresting.com/first-computer

What is MUSIC N and how did it come about? What came before it and after it? How did it function as a modular design and why was that so pivotal at that time? How did it influence the world of analog synthesis? Lastly, how are its impacts still reverberating today? Let's begin with the origins of MUSIC N.

Background

MUSIC I was a software program developed by engineer Max V. Mathews in 1957 while working at Bell Telephone Laboratories (Bell Labs). In terms of music, Mathews was a self-taught amateur violinist, and as an engineer, worked in "the Audio Research Department to study new and better ways of compressing and encoding speech."[3] The story goes[4] that Mathews and his boss, John Pierce (known for working on the ECHO and Telstar communications satellites and coining the name 'transistor'[5]), attended a local concert featuring music by Arnold Schoenberg and Karl Schnabel. While they enjoyed the former, they did not enjoy the latter. Pierce suggested that perhaps the computer (the IBM 704 mainframe at Bell Labs[6]) could write better music than Schnabel and that Mathews should try his hand on coding it to do so. Mathews got to work and in 1957 his efforts bore fruit. He writes:

> Computer performance of music was born in 1957 when an IBM 704 in NYC played a 17 second composition on the Music I program which I wrote. The timbres and notes were not inspiring, but the technical breakthrough is still reverberating. Music I led me to Music II through V. A host of others wrote Music 10, Music 360, Music 15, CSound, Cmix. Many exciting pieces are now performed digitally.[7]

---

[3] Park, T. H. "An Interview with Max Mathews," *Computer Music Journal* 33 (Fall 2009) p. 10.
[4] Ibid.
[5] Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music* (Upper Saddle River, NJ: Prentice-Hall: 1997). p 114.
[6] Wikipedia. "ENIAC," modified 17 December 2019 https://en.wikipedia.org/wiki/ENIAC
[7] Haas, Jeffrey. 2018 "Chapter Five: Digital Audio" in Introduction to Computer Music: Volume One https://cecm.indiana.edu/etext/digital_audio/chapter5_ref.shtml, accessed on 21 December 2019

Chronologically, there was little accomplished in the development of software-based music creation prior to Mathews' work. By his account there had been interest in various spheres; however, the most notable development was in hacking a printer to play *Mary Had A Little Lamb.*[8]

Following on the heels of the first iteration of the MUSIC platform was MUSIC II in 1958 and MUSIC III in 1960. Mathews and Pierce both felt that to gain traction in the music community the MUSIC platform would have to be introduced to serious composers. In *Electric Sound,* Joel Chadabe writes:

> Mathews and Pierce, both scientists, had early on felt the need to have musicians involved, and they had begun an outreach effort, reading papers at conferences and publishing articles in a variety of magazines. In New York, at an Audio Engineering Society conference in 1959, they had met Milton Babbitt, Vladimir Ussachevsky, Otto Luening, and eventually, Edgard Varèse. In 1960, the publications department at Bell Labs produced a recording called Music from Mathematics, a copy of which was sent to Leonard Bernstein, whose secretary acknowledged its receipt with thanks.[9]

As stated in the comment from Mathews quoted earlier, MUSIC I was rudimentary; however, by the time MUSIC III was developed the program became a robust tool that implemented several powerful features, attractive to the palates of curious composers. MUSIC finally caught the attention of the acclaimed Edgar Varèse. In the Foreword to *Csound: A Sound and Music Computing System,* Risset (one of the most well-known Bell Labs composers) writes:

> Edgard Varèse was intrigued by the advent of digital synthesis: he hoped it would afford the composer more musical control than the analog devices of electronic music. On April 26, 1959, Varèse decided to present Pitch Study to the public in a carte blanche he gave at the Village Gate in New York City, as a sort of manifesto encouraging the continuation of the development of computer sound synthesis at Bell Laboratories.

[8] Park, T. H. "An Interview with Max Mathews," p. 11

[9] Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music*. p. 109

With the endorsement from Varèse, Mathews and Pierce had their sought-after foot in the door.

A Powerful Modular System

One of the new features in MUSIC III allowed composers to build their own instruments (or sound generators) from the ground up. Considering that every musical instrument that preceded this moment had a somewhat defined sonic identity, this opened a radical new realm of possibility. Instruments were built using MUSIC III's parameters, which were in essence small building blocks. Why did Mathews chose this approach? Risset continues:

> Clearly, programming permits us to synthesise sounds in many different ways: but Mathews realised that he would have to spend his life writing different programs to implement musical ideas and fulfill the desires of various composers. So he undertook to design a really flexible program, as general as possible – a music compiler, that is, a program that could generate a multiplicity of different music programs.
>
> To attain flexibility, Mathews resorted to the concept of modularity. By selecting from among a collection of modules and connecting them in various ways, one can implement a large number of possibilities, as in construction sets such as Meccano or Lego.[10]

It was a blockbuster moment for the world of music synthesis for two reasons. The first reason was that MUSIC III had bumped the MUSIC N platform from being a simple digital sound generator into a powerful compositional tool. The second reason, we will cover shortly. From Hubert Howe (who authored some of the first MUSIC N derivatives):

> The power lay, first of all, in the ability to construct the sound wave. Because all sounds are waves, if you can generate any wave, you can generate any sound. The other important point was that, by representing all of the devices used in constructing the sound

[10] Risset, Jean-Claude. "Foreword." In *Csound: A Sound and Music Computing System,* by Victor Lazzarini et al. (Switzerland: Springer International Publishing, 2016) p. viii

> in little computer modules called unit generators (an invention by Max Mathews), you could have virtually an unlimited amount of equipment...[11]

This new paradigm in music synthesis would meet the needs of composers for decades to come, first through a slew of similarly named MUSIC N derivatives and finally culminating in Csound, coded by Barry Vercoe. The concept of the unit generator, the instrument and the compiler were introduced in MUSIC III and continue to serve as "essential elements that are still central to systems such as Csound."[12]

It is an astounding fact that a software design implemented 60 years ago could still maintain function and relevance today. I began to study Csound in 2004 with Alan Schindler as an undergraduate at the Eastman School of Music. Although I found its command line interface initially intimidating, I discovered it to be a versatile program that could produce impressive results with minimal fuss. I didn't know anything about the history of the program[13] at the time,[14] but when I learned of MUSIC N in my *History of Electronic and Computer Music* course at Brooklyn College, the architecture of the software reminded me distinctly of Csound. I immediately sought clarification regarding the connection and my professor, Dr. Douglas Geers, confirmed that Csound was a direct descendent of MUSIC N.

Since 1960 certain aspects of society and technology have dramatically changed. That the underlying structure of one of today's significant music creation software platforms still retains its basic design is remarkable. In his textbook, *Electronic and Computer Music,* Peter Manning also describes the longevity of Mathews' design:

---

[11] Howe, Hubert. "My Experiences with Max Mathews in the Early Days of Computer Music," *Computer Music Journal* 33 (Fall 2009) p. 42.
[12] Lazzarini, Victor, et al. Csound: A Sound and Music Computing System (Switzerland: Springer International Publishing, 2016) p. 4
[13] maybe Alan did say something, but it maybe went in one ear and out the other
[14] as I was studying viola performance and our focus wasn't on the history of electronic music

> With a lineage stretching almost to the midpoint of the previous century, these MUSIC N programs have undergone extensive development over the intervening years, taking full advantage of the quantum increases in processing power and versatility of the underlying technology. Despite these changes, many of the original features employed in their design have been retained…[15]

Returning to 1959, this noteworthy development in MUSIC III began to attract the attention that was sought by Mathews and Pierce. During the next few years, many composers were included in the development of MUSIC N, such as James Tenney, the first trained composer-in-residence to work at Bell Labs from 1961-1964;[16] John Chowning, a graduate student, who in 1964 brought the MUSIC IV program back to Stanford and eventually developed FM synthesis;[17] and Risset, who initially came in 1964-1965, composed music that experimented in timbre,[18] and became arguably the most famous composer of this sphere. By 1965 the growing popularity of high level language allowed composers outside the world of the IBM 7094 to port the software to their own systems.[19] MUSIC N had garnered the attention of trained composers and was on its way to shaping the next six decades of computer music.

Digital and Analog: Modular Misconceptions?

The second reason MUSIC III was a gamechanger in the world of music synthesis is detailed in the subsequent section of Risset's Foreword to *Csound: A Sound and Music Computing System.*

> ...contrary to common belief, Mathews' modular conception did not copy that of synthesisers: on the contrary, it inspired the analog devices built by Moog, Buchla, or Ketoff using voltage control, which only appeared after 1964, while MUSIC III was

[15] Manning, Peter. 2004. *Electronic and Computer Music*. (New York: Oxford University Press, 2004) p. 190
[16] Wikipedia. 2019 "James Tenney" modified 1 July 2019. https://en.wikipedia.org/wiki/James_Tenney
[17] Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music.* p. 115
[18] Chowning, John. "Fifty Years of Computer Music: Ideas of the Past Speak to the Future." In *Computer Music Modeling and Retrieval. Sense of Sounds (*Switzerland: Springer International Publishing, 2007) p. 5
[19] Chadabe 112

> written in 1959.[20] In fact, Mathews' modular concept has influenced most of the synthesis programs – the next versions MUSIC IV and MUSIC V, but also MUSIC 10, MUSIC 360, MUSIC 11, Cmusic, Csound – and also most analog or digital synthesisers – such as Arp, DX7, 4A, 4B, 4C, 4X, SYTER, compilers for physical modeling such as CORDIS-ANIMA, Genesis, Mimesis, Modalys, and real-time programs such as MaxMSP and Pure Data, much used today and more widely flow-based and object-oriented programming used in languages for electronic circuit simulation or computing software such as MATLAB.[21]

That it was actually the digital system that motivated the modularity of analog synthesizers is a powerful statement by Risset. Furthermore, there is ample documentation to back up his claim. His allegation is thought-provoking because the mutual influence of the era's analog and digital technologies is murky. If anything, what's often assumed, as Risset alludes to, is that analog came first and that digital replicated it. Let's examine evidence to support Risset's claim. The most obvious is the timeline.

It was composer Herb Deutsch who convinced Robert Moog to investigate the world of electronic music. They met at a New York State School Music Association educators conference in Rochester, NY at the Eastman School of Music in the winter of 1963.[22] This encounter, which culminated in the first Moog synthesizer sale in 1964,[23] occurred three years after the development of MUSIC III. In the case of Don Buchla, another well-known modular analog synthesizer designer, his first prototype, the Buchla Box, was completed in late 1965.[24] This was five years after MUSIC III. The timeline alone seems to indicate that if one were to have been

[20] Risset claims that MUSIC III was written in 1959, however, in this paper we will pin 1960 as the date based on an interview with Max Mathews by C. Roads in the *Computer Music Journal*, (Winter 1980, Volume 4. No. 4), p. 16
[21] Risset, Jean-Claude "Foreword," p. viii-ix
[22] Pinch, Trevor, and Trocco, Frank. *Analog Days* (Cambridge, MA: Harvard University Press, 2002) p. 21
[23] Ibid, p. 30
[24] Ibid, p. 40

the influence of another, it was the digital work of Mathews that inspired Moog and Buchla, rather than the other way around.

A parallel source of evidence comes from an earlier statement by Risset, in 2009. The following is an editor's note from Tae Hong Park, excerpted from the 2009 *Computer Music Journal*:

> According to Jean-Claude Risset (in an e-mail exchange dated 20 April 2009), diagrams, modularity concepts, and their implementations were already included in Music III (1961),[25] which was clearly earlier than when Donald Buchla and Robert Moog built their first voltage-controlled patchable analog synthesizer boxes, and earlier than when Paolo Ketoff in Italy built what became the Synket. It is often assumed that synthesizers inspired Max Mathews's design of Music III, Music IV, and Music V. However, it seems that it is the other way around. Even though the digital domain was seemingly not Robert Moog's forte and inclination at the time, he knew of the developments of Mr. Mathews's work at Bell Labs. In the winter of 1964, while Jean-Claude Risset was working at Bell Labs, Robert Moog and Jean-Claude Risset had exchanges and correspondences about these topics.[26]

This is another strong claim in favor of Risset. It is hard to argue the authority of Risset in this context: he was living in the United States and working at Bell Labs in the winter of 1964. The direct exchanges between Moog and Mathews, lessened the likelihood of their modular systems being coincidental. They had other interactions as well.

Analog Days by Pinch and Trocco retells the story of Moog collaborating with John Cage and Merce Cunningham at Lincoln Center in 1965 for the premiere of "Variations V." Mathews had loaned Moog a special mixer that he had built for an earlier collaboration with Cage.[27] Although there were serious technical challenges with the performance, it was a significant

[25] This also appears to be an erroneous date.
[26] Park, T. H. "An Interview with Max Mathews," p. 20
[27] Dayal, Geeta. "Max Mathews (1926–2011)," *Frieze* (1926–2011)" https://frieze.com/article/max-mathews-1926%E2%80%932011 09 May 2011

milestone in Moog's career. The authors portray Moog's sentiments at the time: "He was thrilled to meet Leonard Bernstein at the concert and work with the legendary Max Mathews."[28] It's a brief statement but it does lend credence to a relationship of admiration from Moog toward Mathews.

Finally, in support of Risset's comments, I sought to verify their veracity with someone who had worked closely with Mathews and knew of the general dynamics of that day. I contacted Hubert Howe, who, in 1967, co-wrote the first high-level language implementation of MUSIC N in FORTRAN, MUSIC IV-BF. In response to my question to verify Risset's comments, he replied: "Risset's comments about this are absolutely right."[29]

Max Mathews had a different viewpoint. A 14 December 2004 panel discussion with Mathews and John Chowning and moderated by composer Curtis Roads contains this exchange:

> Roads: Max, you were developing this modular unit generator concept, the idea of taking individual modules and putting them together to create sound synthesis in the early 60s, and as I recall somewhat contemporaneous with that there was another type of modular system being developed using a completely different type of technology which was the Moog synthesizer developed by Robert Moog, of course, which was analog. Can you tell us a little bit about that period and did you two influence each other or was it was it really more of an independent development?
>
> Mathews: Well no, modular synthesis was the zeitgeist at that time, and both Moog and Buchla and myself all three of us proceeded independently in two different media and came out I think with systems that were very popular because the musician could then construct his own instruments from them.[30]

---

[28] Pinch, Trevor, and Trocco, Frank. *Analog Days* p. 78

[29] Howe, Hubert to Brian Lindgren, e-mail correspondence, 18 December 2019.

[30] Roads, Curtis. "Music Meets the Computer" Youtube interview with John Chowning and Max Mathews. Recorded 14 December 2004 by Computer History Museum. Timestamp: 1:44:27. https://www.youtube.com/watch?v=Hloic1oBfug

Mathews is essentially refuting Risset's claim. "Mathews' modular conception did not copy that of synthesisers: on the contrary, it inspired the analog devices."[31] His perspective is that the implementation of modular systems was the 'zeitgeist' of the time and that Moog and Buchla did not need to be exposed to Mathews' work to realize their systems. Although it is difficult to know if Moog and Buchla were, in fact, influenced by Mathews (since they did not explicitly say so), there is one clear conclusion: Mathews did develop his modular system before Moog and Buchla.

Based on previous comments from Park, Moog and Mathews did meet. To answer the question of whether Moog's modular system was influenced by Mathews, logic stipulates two possible answers. Either Mathews is right (this was a popular concept at the time and Moog didn't need his influence) or Risset is right and Moog was influenced by Mathews. I'd like to posit a third possibility, the 'grey-area' perspective. As Mathews claimed, there was a trend towards modular systems at the time that likely inspired Moog, and Mathews' work inspired him as well. Based on accounts of Mathews, he was a humble man, who wasn't interested in laying claim to other's work, even if his accomplishments were an inspiration for that person.

A Modest Spirit

In creative spheres there is a good deal of overlapping influence. This was likely Mathews' experience at Bell Labs, where many historic innovations were born. In Risset's words:

> I was amazed when I got there. It was a fantastic atmosphere. There was an incredible group of researchers, in mathematics, computer science, psychology, acoustics, communications, biology, and they were mixed and woven together: Even the offices

31 Risset, Jean-Claude "Foreword," p. viii

> were intertwined. There was a lot of openness and generosity and less arrogance and sense of territory than in Europe.[32]

In the world of creativity, it can be hard to pinpoint sources of inspiration or to say that something was or wasn't influenced by a similar creation. Music copyright is an example. How does one determine if or how much one song inspired another composed at a later date? There may be court cases and evidence, but in many situations, arguments can be made convincingly from both sides of the table. Surely Mathews would have experienced this dynamic at Bell Labs, with the open environment described by Risset. If this were the case, accounts of Mathews' character might support the argument that, despite his influence on Moog, he would credit the trends of the times, rather than his own work, as shaping Moog's innovations.

First, a piece of evidence in support of this theory appeared in a review by James Harley of the book *Institut National de l'Audiovisuel Portraits Polychromes: Max Mathews.* Harley wrote: "It should be noted that Max is the first non-composer to be included in this series, again underscoring his importance to the field (and some would call him a composer anyway, even while his modesty compels him to deny it)."[33]

A second instance of Mathews being described as modest can be found in another editor's note in the Fall 2009 *Computer Music Journal* interview with Mathews. While noting efforts that predated his MUSIC, he recounts the time that a computer was programmed to play *Mary Had A Little Lamb* through its printer. The editor appended the printed interview: "Mr. Mathews is being modest here; there is no evidence of any previous program with such a

---

[32] Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music* p. 111
[33] Harley, James. "Review of *Institut National de l'Audiovisuel Portraits Polychromes: Max Mathews," Computer Music Journal* 32 (Spring 2008)

capability."[34] Conceivably, Mathews exhibited a 'modest' character, as Park claimed, and, at least in this case, Mathews would be generous in giving credit to others when it perhaps wasn't due. If so, perhaps it could also be the case when Curtis Roads asked if Moog's modular implementation had been inspired by Mathews.

To add a third insight, when asked by an interviewer about the Australian researchers' computer music from the early 1950s, Mathews responded: "They may be the first. Well, it's always impossible and dangerous to claim the first."[35] Why impossible and dangerous? I believe it is because he understood that his work was the extension of those who came before him and that laying claim to things that weren't directly his was not only ungracious but poisoning in a collaborative and fluidly creative environment. In the words of Isaac Newton: "If I have seen further than others, it is by standing upon the shoulders of giants."[36]

I would like to propose the paradoxical answer: both Risset and Mathews are right. Risset was present and witnessed first-hand the interaction between Moog and Mathews.[37] He knew the timeline (what was developed and when) and could see that Moog's ideas were inspired, in some part at least, by Mathews. He and others were indebted to Mathews, their mentor,[38] and in repaying that debt, was candid in his account of the influence Mathews had on those around him.

At the same time, Mathews was correct -- the use of modular systems was the zeitgeist at that time. Ideas were flowing every which way in Mathews' world, such that when asked for a

[34] Park, T. H. "An Interview with Max Mathews," P. 11
[35] Dayal, Geeta. "Max Mathews (1926–2011)"
[36] Wikipedia. "Standing on the shoulders of giants" edited on 18 November 2019. https://en.wikipedia.org/wiki/Standing_on_the_shoulders_of_giants
[37] Park, T. H. "An Interview with Max Mathews," p. 20
[38] Risset, Jean-Claude. "Max Mathews's Influence on (My) Music," *Computer Music Journal* 33 (Fall, 2009), p. 26

name for a new invention in the hallway by a colleague, Pierce spontaneously coined the word 'transistor'. Mathews was probably aware that Moog, himself, could have received inspiration from somewhere besides himself. Additionally, Mathews welcomed the reimplementation of his own ideas, hence all the MUSIC N derivatives. It was his nature to be open and generous with his ideas and nurturing of others. It would have been beneath him to claim his influence in the work of someone else's, especially in a neighboring field, like Moog's.

Ultimately, it was this commendable character of Mathews' that was perhaps the most important factor in navigating the difficulties of pioneering software development. Working on early mainframe computers was incredibly arduous. In addition, two machines would be needed to realize a composition: the machine running MUSIC N and a second machine to receive the digital output (via magnetic tape) and convert it to an analog signal. In many cases the composer would have to travel miles from one to the other. R. F. Moore describes Mathews' leadership through this pioneering time:

> Operating under those conditions was incredibly difficult. A simple test could take weeks. Max was a great inspiration to everybody. He was unflappable in these incredibly difficult circumstances of working. He was like a sailor in mid-Atlantic who didn't know how far it was to the other side but knew what to keep doing to get us there.[39]

Finally, it's clear that Mathews' system came first. From the perspective of their respective roles, as a mentee and mentor (to many people), I believe both Risset and Mathews were correct and dutiful in their statements. Regarding the scope of this paper, as an investigation into the ramifications of MUSIC N into today's world, a significant portion has

[39] Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music*, p. 113

been dedicated to querying the nature and veracity of Risset and Mathews' claims. I feel that the historical significance of the topic warranted at least as much of an inquiry.

Clarifying the Narrative

Despite the clear sequence of events, (MUSIC N being developed three years before the Moog synthesizer and five years before the Buchla) the sequence of events is often misconstrued. Worse, there's an assumption (as Risset had stated earlier) that digital systems were designed in the shadow of the modular analog synthesizers. If anything, the opposite is true. Let's take the case of a popular electronic music history textbook. In the following citation, there is no explicit falsity put forth; however, the description of events is misleading. In *Electronic and Experimental Music, 3rd Edition,* Thom Holmes writes:

> Voltage-controlled technology was responsible for the commercial boom of electronic musical instruments during the 1960s and 1970s, leading to the adoption of control principles that continue to be applied, without the need for the control voltages themselves, in the algorithms used to drive digital synthesizers and software synthesizer. [40]

While it is true that voltage-controlled technology in the 1960s and 1970s analog synthesisers was important, it is not true that this "lead to the adoption of control principals … in the algorithms used to drive digital synthesizer and software synthesizers." Considering this text is a well-known source in electronic music history education, this is disconcerting. It is important to set the record straight, not only for posterity, but in order to correctly understand the thinking of the time: that digital music creation was an engaging pursuit in its own right, with a vision

---

[40] Holmes, Thom. 2008 *Electronic and Experimental Music. Technology, Music, and Culture. 3rd ed.* (New York: Routledge, 2008) p. 188

completely independent of the analog synthesizer designers. In my exchange with Hubert Howe, he paints a vibrant image of Mathews aspirations for digital music creation:

> Max Mathews had the vision to see, in the late 1950s, that the computer was the most versatile sound generating machine possible, and he spent a good deal of his time trying to carry that out, not just in the software, but also in the construction of the first D to A converters. The data storage and transmission speeds were not really adequate to do everything at that point in time, but he knew that they would be in the future. Perhaps it was the realization from the Fast Fourier Transform, which was only developed a bit before he started, that any sound could be analyzed into a sum of sine waves where the only variables were amplitude, frequency and phase (and phase really isn't that important for music). Max turned his attention to figuring out how we could specify the parameters of the sounds that we wanted to produce. He later, as you probably know, spent a good deal of effort in analyzing sounds so that we could understand better how to produce them. This led immediately to the unit generator concept and the use of oscillators and envelope generators. Later, especially at Princeton, other methods of sound production such as digital filtering and other things were developed. John Chowning, however, deserves the credit for developing FM synthesis.[41]

Conclusion

Sixty-two years after its first iteration, the primary structural components of Max Mathew's MUSIC N are alive and well in its modern-day descendent, Csound. The reason his tools have found continued utility was that Mathews gave the composers of his day a powerful platform: building blocks to compose the music of their imagination. Their longevity is a powerful testament to the ingenuity of their design, so masterfully conceived that it is probable that Robert Moog modeled his famous modular synthesisers on Mathews' work. Although Mathews did deny this, in understanding his character, it becomes clear that his perspective was wisely chosen. He was a mentor and source of inspiration to many. His ability to nurture others, acknowledging their accomplishments when he may have had an important role in inspiring

[41] Howe, Hubert. Personal communication. 18 December 2019

them, is a testament to his great character, even surpassing the distinction of his pioneering designs. The world of computer music synthesis of today is due to their arduous efforts, and for that we owe them our debt of gratitude.

Bibliography

Books

Chadabe, Joel. *Electric Sound: The Past and Promise of Electronic Music* (Upper Saddle River, NJ: Prentice-Hall: 1997).

Holmes, Thom. *Electronic and Experimental Music: Technology, Music, and Culture. 3rd ed.* (New York: Routledge, 2008).

Lazzarini, Victor, et al. *Csound: A Sound and Music Computing System* (Switzerland: Springer International Publishing, 2016).

Manning, Peter. *Electronic and Computer Music.* (New York: Oxford University Press, 2004).

Pinch, Trevor, and Trocco, Frank. *Analog Days* (Cambridge, MA: Harvard University Press, 2002).

Risset, Jean-Claude. "Foreword." In *Csound: A Sound and Music Computing System,* by Victor Lazzarini et al. (Switzerland: Springer International Publishing, 2016).

Articles

Harley, James. "Review of *Institut National de l'Audiovisuel Portraits Polychromes: Max Mathews," Computer Music Journal* 32 (Spring 2008): 95-97.

Howe, Hubert. "My Experiences with Max Mathews in the Early Days of Computer Music," *Computer Music Journal* 33 (Fall 2009): 41-44.

Park, T. H. "An Interview with Max Mathews," *Computer Music Journal* 33 (Fall 2009): 9-22.

Risset, Jean-Claude. "Max Mathews's Influence on (My) Music," *Computer Music Journal* 33 (Fall, 2009): 26-34.

Articles in an Edited Volume

Chowning, John. "Fifty Years of Computer Music: Ideas of the Past Speak to the Future." In *Computer Music Modeling and Retrieval. Sense of Sounds (*Switzerland: Springer International Publishing, 2007)

Internet sources

Dayal, Geeta. “Max Mathews (1926–2011)” *Frieze* https://frieze.com/article/max-mathews-1926%E2%80%932011 09 May 2011

Hines, Nickolaus. “Then And Now: The World’s Very First Computer vs. Today’s Supercomputers,” https://allthatsinteresting.com/first-computer

Roads, Curtis. “Music Meets the Computer” Youtube interview with John Chowning and Max Mathews. Recorded 14 December 2004 by Computer History Museum. https://www.youtube.com/watch?v=Hloic1oBfug

Other sources

Howe, Hubert to Brian Lindgren, e-mail correspondence, 18 December 2019.