# Memo

TO: Mr. John Johnson, Department Head

FROM: Charles Finn, Research Assistant

DATE: March 13th, 2022

SUBJECT: Direct Digital Synthesis Research

Dear Mr. Johnson, this memo is in regards to the historical research you asked me to provide on direct digital synthesis. After concluding my research on the topic, I have prepared and attached a select overview for you to review.

**Direct Digital Synthesis**

In the following report I will discuss and summarize direct digital synthesis with an expanded definition and include a concise summary of its process, history and modern implications. The overview will include:

- A brief history of the first theoretical direct digital synthesis networking model
- An expanded definition of direct digital synthesis
- A step by step description of how direct digital synthesis works
- A brief explanation of how direct digital synthesis has impacted modern music

If you have any questions for me regarding this report, or would like more information on any of the following research presented, please do not hesitate to contact me at Charles.Finn@mail.citytech.cuny.edu.

Attachments: Expanded definition & report on direct digital synthesis

Charles Finn

March 20th, 2022

Direct Digital Synthesis Expanded Definition & Report

In 1957 at Bell Labs Max Matthews, the first innovator of computer generated music, developed a program called MUSIC-N, a computer program that used direct synthesis to produce digital audio waveforms. MUSIC-N was the first program ever with the ability to create sound in a digital format opening up the world to an entirely new form of music production and altering the course of modern music forever.

Six years later Matthews published an article in Science magazine observing the future promise of computer generated music. He wrote:

> There are no theoretical limitations to the performance of the computer as a source of musical sounds, in contrast to the performance of ordinary instruments. At present, the range of computer music is limited principally by cost and by our knowledge of psycho-acoustics. These limits are rapidly receding. (Matthews, 1963, p. 553)

At present day, the "receding limits" that Matthews spoke of have turned into a reality. With the rise of the synthesizer in popular music, MIDI, and more recently, the at-home digital audio workstation (DAW), the power to alter and create sound has become one of the most accessible creative devices for amateur and professional musicians alike. This evolution can all be attributed to Matthews' idea of direct digital synthesis. In this essay, I will define direct digital synthesis, explain how it is achieved in a step by step process and discuss its impact on modern music.

Direct digital synthesis is the process of manufacturing an analog waveform by producing a time-varying signal in digital form and then executing a digital-to-analog conversion. Matthews wrote that "the direct conversion of numbers to sound is only one of the ways in which a computer can generate sound. An alternative procedure is to use the number from the computer to control electronic apparatus such as oscillators and filters which, in turn, generate the sounds." (1963, p. 553) In simpler terms, direct digital synthesis is the operation of constructing a real sound from a digital source. This process can be achieved with a networking model made up of three different components: a unit generator, a converter, and a filter.

The first part of the process is accomplished with a unit generator, or in uncomplicated terms, a computer itself. Numerical data is submitted to the computer, which in turn is used to create an acoustic signal. In his article "Current Perspectives In the Digital Synthesis of Musical Sounds" Xavier Serra wrote:

> A unit generator accepts numerical control entries and generates a signal, which is also numerical, which can be used as an entry to another unit generator or it can be a sound. Examples of unit generators are: oscillators, filters, adders, multipliers, envelope generators, and random number generators. From the combination of these elements, synthetic sounds can be created similar to those obtained with the voltage-controlled modules of analog synthesizers, but with a more precise control. (Serra, 1997, p. 2)

The next part of the process is accomplished using a converter. The converter takes the digital signal captured and transforms it into an analog sound (real sound). Matthews stated that a digital converter "generates a sequence of numbers from the computer" and "generates a sequence of electric pulses whose amplitudes are proportional to the numbers." (1963, p. 553) Essentially, every number or chain of numbers entered in a sequence is responsible for a particular signal that will then be converted into actual sound. It works by assessing the particular features of a real sound and applying the constraints to the created signal from the generator. Serra wrote:

> To generate the sound of a string, we must consider its length, thickness, density, etc. Once we introduce these physical measurements, the model allows us to reproduce the movement of the string numerically inside the computer and, at the same time, convert this movement into sound. (Serra, 1997, p. 5)

The last part of the model is a filter, which smooths the pulses. (Matthews, 1963, p. 553) Essentially filtering is the process of taking away unnecessary sound or dissonant sound, and readying the sound for human ears. Serra wrote:

> Analysis detects partials by studying spectral characteristics of a sound and represents them as sinusoids. These partials are subtracted from the original sound and the "residue" left over is represented as filtered white noise (Serra, 1997, p. 7)

To review, the three step networking model works by inputting numerical data into a computer, transforming that data into analog sound with a converter, and then subtracting the unnecessary parts of the sound, readying it for the human ear using a filter.

Although direct digital synthesis has proven complications, such as redundancy and the difficult creation of "musically desirable sound," (Comerford, 2007, p. 35) its benefits reside in its unlimited capacity for creative control. In their article "Music's Measure: using digital synthesis to create an instrument tone" Peter and Lucy Comerford wrote:

> Digital sound synthesis creates musical sound by mixing together different simple sound components in the right blend to produce the sound required. Change the blend and you change the result, like an artist who mixes paint colours on a palette or a chef who varies the proportions in a recipe. This is what makes synthesis such fun to work with! The creative possibilities are almost endless. (Comerford, 2007, p. 35)

For musicians and producers direct digital synthesis has created a way to shape and alter sound in unimaginable ways. And while most musicians and producers are not directly responsible for the synthesis of a sound, direct digital synthesis has led to an inexhaustible database of sounds for personal use, and the ability to edit those sounds. The result is, like Peter and Lucy Comerford mentioned, the ability to design and construct any soundscape one wishes to.

Direct digital synthesis, the process of taking a digital sound and creating an analog sound, has come a long way since Max Matthews first theoretical networking model was created in Bell Labs in 1957. The three part networking model, consisting of a unit generator, converter, and filter, have altered the way sounds and compositions are created. Because of direct digital synthesis, music production no longer relies on real instruments but a mixture of real and synthesized sounds. Users, amateur or professional, now have the ability to select and choose from an endless amount of sounds for composition at the touch of a button. And this metamorphosis of the music industry goes hand in hand with the evolution of direct digital synthesis.

## References

Serra, X. (1997). Current Perspectives in the Digital Synthesis of Musical Sounds. pp. 1-10.

Comerford, Peter & Lucy. "Music's measure": using digital synthesis to create instrument tone. Organist's Review. *May Edition. pp. 35-41.*

*Mathews, M.V. (1963). The Digital Computer as a Musical Instrument. Science, 142 3592, 553-7*
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