Electronic Music - Inquiry Description

This inquiry leads students through a study of the music industry by studying the history of electric and electronic instruments and music. Today's students have grown up with ubiquitous access to music throughout the modern internet. The introduction of streaming services and social media in the early 21st century has shown a sharp decline in the manufacturing and sales of physical media like compact discs. This inquiry encourages students to think like historians about the way they and earlier generations consumed and composed music. The questions of artistic and technological innovation and consumption, invite students into the intellectual space that historians occupy by investigating the questions of what a sound is and how it is generated, how accessibility of instrumentation affects artistic trends, and how the availability of streaming publishing and listening services affect consumers.

Students will learn about the technical developments and problems of early electric sound generation, how the vacuum tube allowed electronic instruments to become commercially viable, how 1960s counterculture broadcast avant-garde and experimental sounds to a mainstream audience, and track how artistic trends shift overtime when synthesizers, recording equipment, and personal computers become less expensive over time and widely commercially available. As part of their learning about electronic music, students should practice articulating and writing various positions on the historical events and supporting these claims with evidence. The final performance task asks them to synthesize what they have learned and consider how the internet has affected music publishing.

This inquiry requires prerequisite knowledge of historical events and ideas, so teachers will want their students to have already studied the 19th c. periods of the second industrial revolution, the 20th century through both World Wars, and the Cold War to ensure that they have an understanding of ideas promulgated in that era. For instance, they should especially understand that the mathematics of electromagnetic induction and resonance were not fully understood until the late 19th century. Without the mathematical building blocks, practical electrical devices were not possible on a wide scale, and after around 1880, a great number of consumer appliances become electrified.

NOTE: Teachers are encouraged to modify and adapt the inquiry to meet the needs and interests of their students as well as themselves.

Historical Background

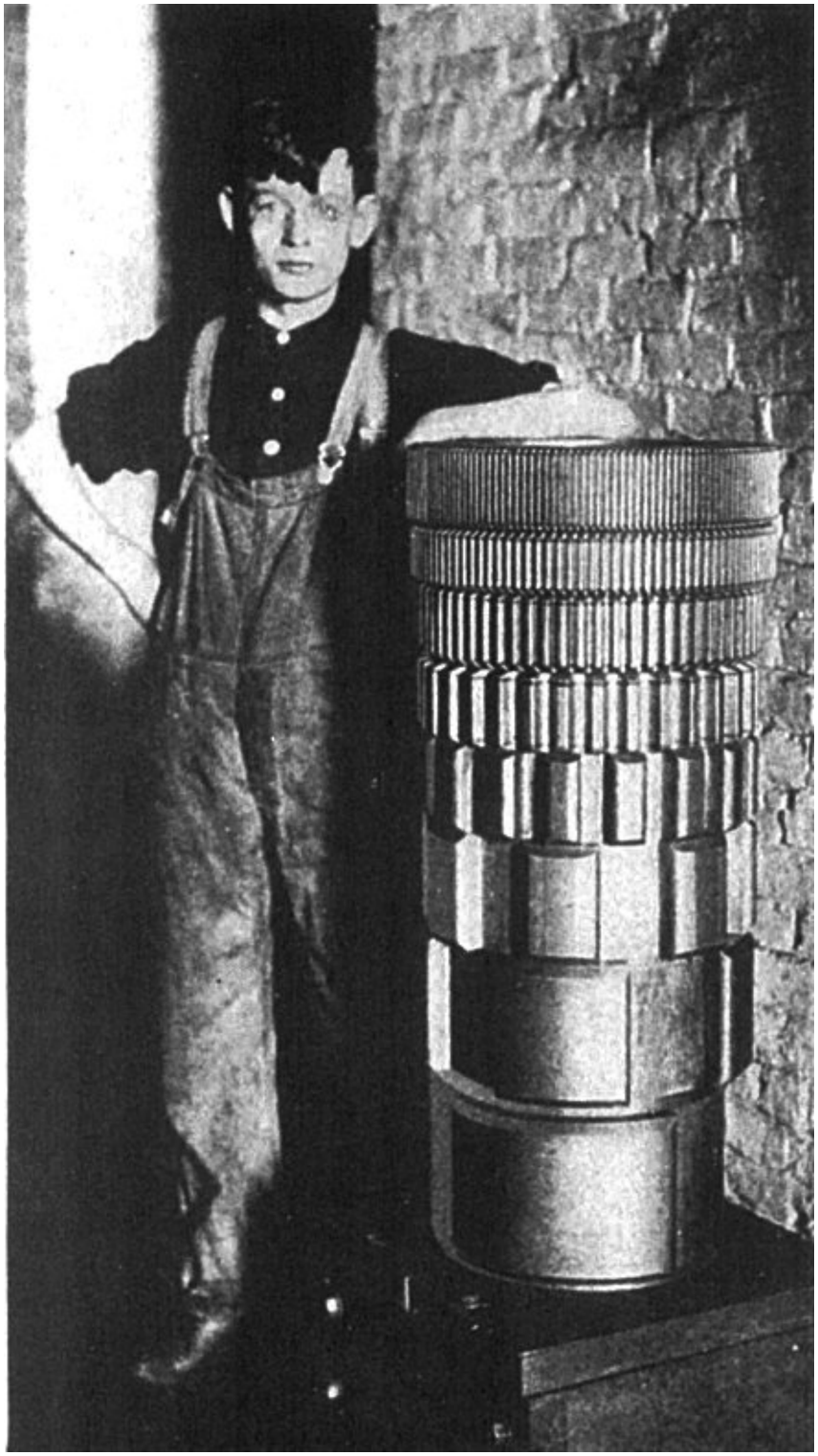
Pictorial PowerPoint that accompanies this context

Benjamin Franklin's 1751 text "Experiments and Observations on Electricity" is generally considered to be the first serious scientific work on electricity. Around this time, two early musical curiosities appeared, the Clavecin électrique (1759) and the Denis D'or (1753). Both instruments used static electricity – the Clavecin électrique would use static electricity to ring a clapper between bells, and the Denis D'or appears to be an elaborate prank, described as an instrument of near-magical properties that did nothing but shock the user.

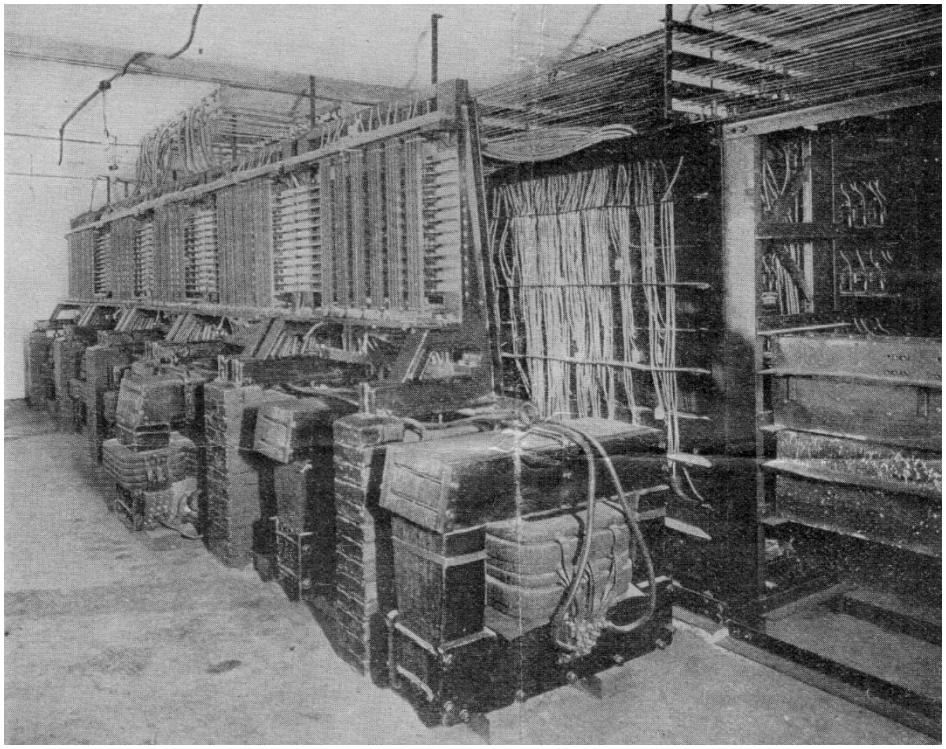
Despite Franklin's early work, and these early curiosities, the mathematics of electromagnetic induction were not understood until about a century later. Faraday's principles of electromagnetic induction (1831) and Maxwell's equations (1860-71) provided the fundamental building blocks of how electrical devices function. The earliest devices which could record and play back sound date from this period. The phonautograph (1857), recorded sound from a horn attached to a sharp point, could not play sound back. In 1877, Thomas Edison invented the phonograph, which was the first devices able to play back sound.

In 1863, Hermann von Helmholtz wrote his seminal paper "On the Sensations of Tone as a Physiological Basis for the Theory of Music", the foundation of modern acoustics. This paper states that any sound, theoretical or extant in nature, can be reproduced by adding any number of sine waves together, which has profound implications for the synthesis of sound via means of electricity. As demonstrated by the telephone, electromagnetic waves can be converted to mechanical waves that propagate through the air and are heard by the ear, via means of an electromagnet.

Late 19th century experiments into electric musical instruments were often derived from work done on the telephone. The first electric instrument that garnered successful commercial performances was the Telharmonium, invented by Thaddeus Cahill. The first model was completed in 1901, and used tone-wheels to generate sound, giant cylinders that when spun would generate an electromagnetic field, which was then converted to a sound wave. As one tonewheel was needed for each note, the machine was huge – the first model weighed seven tons, and the second two, from 1906 and 1911, weighed 200 tons and spanned 60 feet. Performances on the instrument were broadcast through telephone lines.

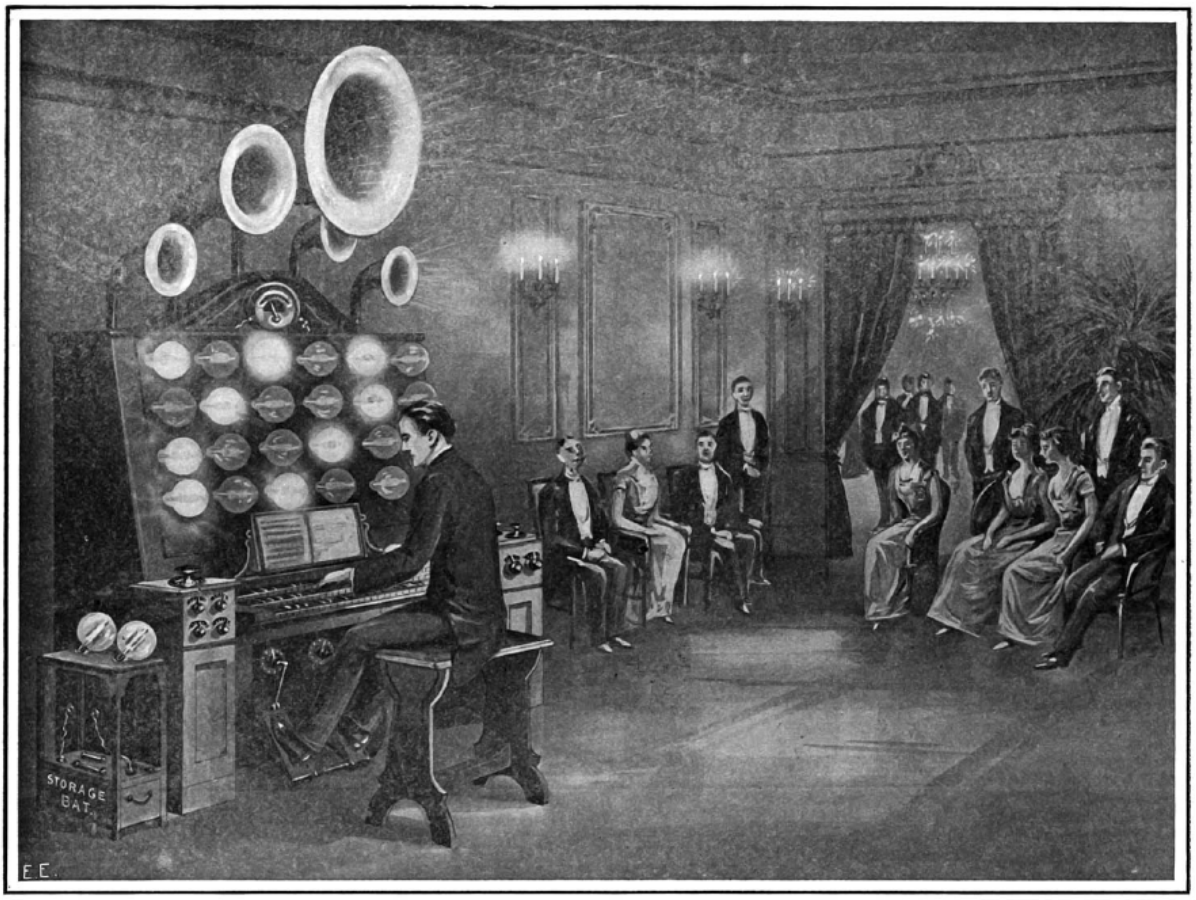


A boy with a Telharmonium tonewheel, c.1906. This was required to generate one note. Photo from McClure's magazine, 1906



Telharmonium wiring, from 1906 promotional brochure

Eventually the novelty wore off and the company went bankrupt. Around this time, vacuum tubes were developed. The diode (1904) and the triode (1907) were two of the earliest and most important tubes, which are the foundation of modern electronics. Vacuum tubes found frequent use in radio sets, but also could be applied to musical instruments. With the tubes heterodyning effect, Lee De Forest was able to construct an electronic piano in 1915, which was far smaller than a Telharmonium and could be practically sold on the commercial market.



The Audion Piano May Entertain Us in the Near Future With Music Purer Than That Obtainable With Any Instrument Now Available. Also it Will Imitate Faithfully Any Orchestral Piece.

The Audion Piano, a far more reasonably sized instrument. From "Audion Bulbs as Producers of Pure Musical Tones", 'The Electrical Experimenter', December 1915

All electronic instruments used vacuum tubes until the development of the transistor. While many used a familiar keyboard-based input model, others operated on wireless principles such as the Theremin. Many early public performances using electronic instruments were renditions of popular or classical songs. Much of the experimental and avant-garde music in the interwar period used unconventional arrangements of either traditional instruments like percussion, or construction of noisemaking mechanical instruments, such as with Italian Futurist composers. However, the promise of creating new sounds with electricity was noted as early as 1907. Early pieces composed specifically for electronic instruments include Messaien's "Oraison" (1937) and John Cage's "Imaginary Landscapes No. 1" (1939), scored with two variable-speed phonographs.

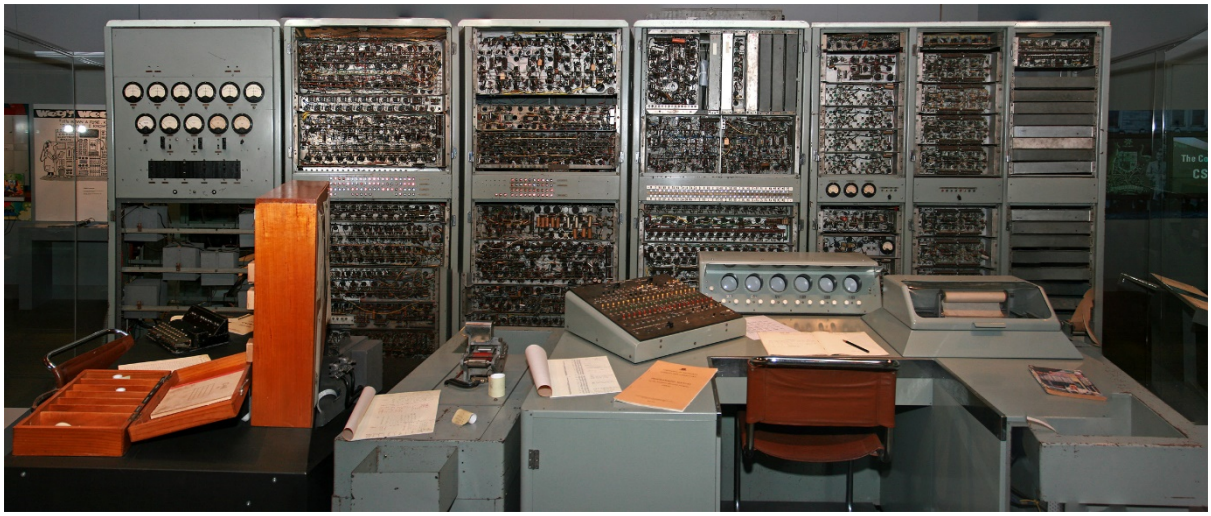
The Dolby magnetic tape recorder was demonstrated in 1946 at Institute of Radio Engineers meeting, which had profound implications for radio broadcasting and composting. Editing and splicing tape was far easier and more cost efficient than previous editing methods. Tape could be stretched or played back at different speeds to induce certain effects, or generate tones. Halim El-Dabh's 1944 "The Expression of Zaar", from a wire recorder, is an early example of this method of composition.

Jack Mullin in the old NBC control room in early 1949 with the two portable Ampex 200 recorders and the first Ampex 300 recorder. (Photo: Eve Mullin Collier, https://ethw.org/First-Hand:Bing_Crosby_and_the_Recording_Revolution)

In the 1940s, Pierre Schaeffer began experimenting with radio and 78 RPM records at Studio d'Essai de la Radiodiffusion-Télévision Française (RTF). This new style of music became known as “Musique concrete”, an early example is Schaffer and Pierre Henry’s 1950 piece “Symphonie pour un Homme Seul". The Groupe de Recherches de Musique Concrète established in 1951 at RTF, and was the first electroacoustic music studio, attracted many experimental composers including Stockhausen, Varèse, and Xenakis, as well as inspiring other radio and tv stations, such as the BBC, WDR (W. Germany) and NHK (Japan), to create their own studios operating along similar lines.

Karlheinz Stockhausen in the WDR Studio, 1991. Image courtesy Kathinka Pasveer under the GNU Free Documentation License, Version 1.2, https://commons.wikimedia.org/wiki/Commons:GNU_Free_Documentation_License,_version_1.2

Towards the end of World War II, all-purpose electronic digital computers were developed by the military for the purpose of computing ballistics tables. Similarly, to how the Telharmonium used cutting edge technology for novel purposes, it was too large to be reproduced commercially; early electronic computers like the ENIAC extensively used vacuum tubes which made them extremely large, often the size of several rooms of a house. The development of the transistor and its commercial introduction in the late 1940s and 1950s revolutionized electronics, allowing for even greater miniaturization. Computers over the course of the 1950s and 1960s, computers shrunk in size and increased in power. The earliest use of a computer to play music was in 1951, but at this time computers were not powerful enough to play music in real-time. A melody had to be preprogrammed and processed, often very time intensive taking several days to process a few seconds of music. Computers during the 1960s were often used as compositional aides by avant-garde composers like Xenakis, who used computers to calculate the mathematical placement of certain notes. One of the earliest pieces of software for real-time music performance on a computer was GROOVE, developed by Max Mathews at Bell Labs in 1970. Along with the development of transistors and computers came the development of synthesizers, allowing musicians to easily create new sounds.



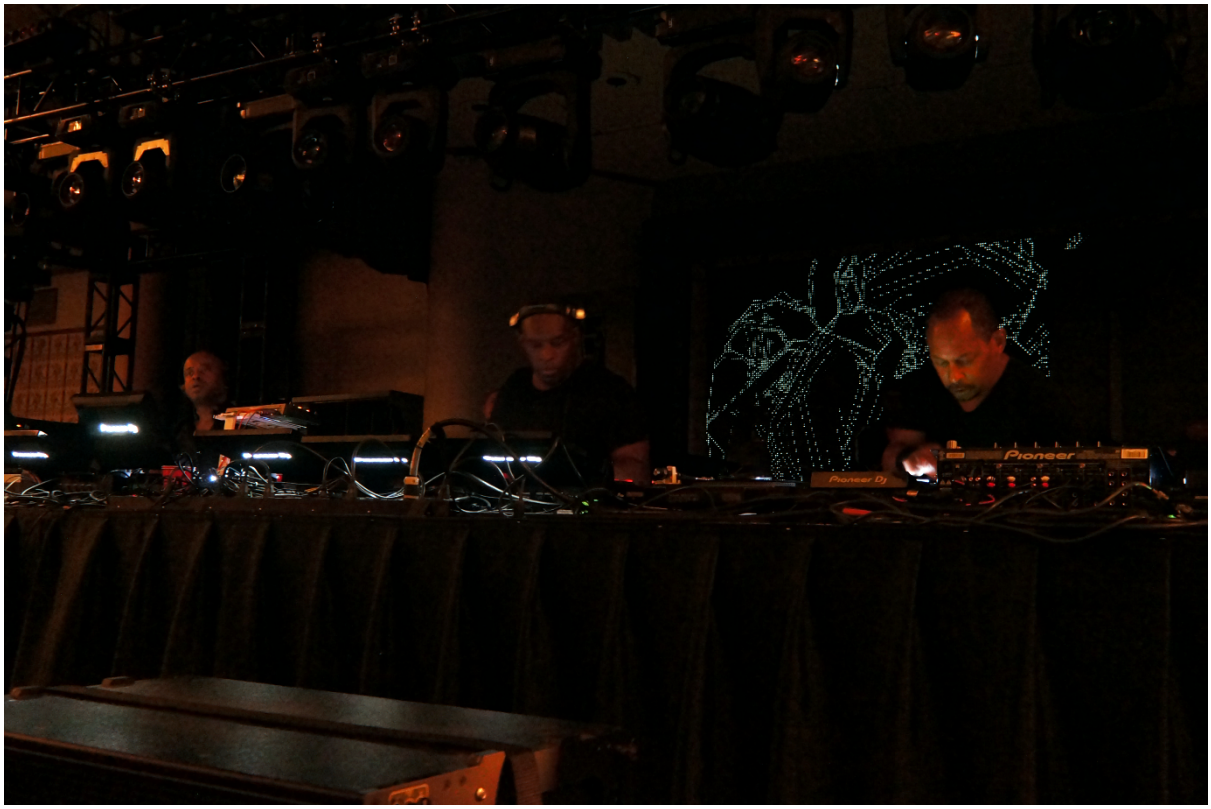
CSIRAC (Council for Scientific and Industrial Research Automatic Computer), the first computer to play digital music. Like the Telharmonium, it was enormous and not practical for everyday use. Image courtesy John O'Neill, under the GNU Free Documentation License, version 1.2 https://commons.wikimedia.org/wiki/Commons:GNU_Free_Documentation_License,_version_1.2

By the late 1960s, electronic music was typically only heard in niche areas. The vast majority of experimental composers were academics who were formally trained through music school, and often exhibited their works in high-culture performance-based areas. Many of the pioneering works from the musique concrete movement were not released on vinyl to consumers until several decades after their first performance. Much of what the average popular culture conception of electronic music was the scores and sounds in science fiction and horror film. With the growing popularity of the late 1960s counterculture movement, often emphasizing darker, noisier sounds, as well as a blossoming psychedelic and progressive rock scene that often-rewarded music experimentation, electronic sounds started to shift away from academia and more into the popular consciousness. Traditional media narratives of 1960s counterculture often focus only the American, and sometimes British artists, but the movement was largely global. In particular, the German progressive rock scene often employed heavier and more dissonant sounds than their US or UK counterparts. By the early 1970s, artists like Faust, Can, Neu or Amon Düül, incorporated tape loops, non-traditional instruments, electronic dissonance and noise, into their songs.

The most important group to come out of the German progressive rock scene was Kraftwerk, whose works from the 1970s rather resemble their contemporaries. However, starting with 1974's "Autobahn" album, Kraftwerk shifted to an all-electronic sound with homemade instruments, changing their image to match, dressing up like lifeless robots during their performances. Kraftwerk's sound throughout the mid and late 1970s greatly influenced virtually every genre of popular electronic music to follow – namely techno, industrial, disco, hip-hop, and synthpop.

Kraftwerk performing in Zurich, 1976. Image courtesy Ueli Frey, Wikimedia commons.

By the late 1970s, the price of home recording technology sharply dropped, with the widescale introduction of cassettes. It was now possible for a musician to easily record their own music and distribute it to friends or record labels without having to go through an expensive process of recording at a studio. The PC revolution of the late 1970s also brought down prices for computers, drum machines and synthesizers. The wide array of new tools combined with the availability of recording software led to the development of several new underground genres, now led by young musicians without formal training, instead of previously being led by academics steeped in formal music theory. Popular club genres like house and techno were pioneered by working class African American DJs and aspiring musicians from Chicago and Detroit, respectively, and tape trading allowed artists to bypass the traditional gatekeepers of record labels, creating an underground network of fans.



The Belleville Three, Juan Atkins, Kevin Saunderson, Derrick May, performing at the Detroit Masonic Temple on May 27th 2017. The Belleville Three are generally considered to be the most influential figures in the emerging Detroit Techno scene in the early 1980s, a major precursor to the modern techno scene. Image courtesy Wikimedia commons, user PeRshGo.

By the late 1980s and early 1990s, techno and industrial had received mainstream recognition, and the genres further fractured into countless subgenres, nearly all being pioneered from the ground up, rather than top down. As computing power increases throughout the late 1980s and early 1990s, it became possible to compose entire tracks using software like a tracker, which functions in a similar way as a sequencer, mapping out various sound samples. These files were small enough to be distributed through the large network of dial-up Bulletin Board Systems (BBS) that were prevalent throughout the 1980s and early 1990s before the popularization of the Internet.

By the mid 1990s, the Internet had rapidly eclipsed the popularity of the BBS, offering worldwide interconnectivity. Compositional software became more advanced, and the MP3 compressional algorithm offered near-CD quality in a much smaller file size. Much like how tape-trading scenes allowed independent artists to bypass record label infrastructure, the Internet greatly simplified this process, with peer-to-peer filesharing programs, websites and platforms offering the ability to instantly access and share music with anyone from around the world. This is such a profound change to how the music industry fundamentally operates that many key figures expressed reactionary ideas at first. Napster, the earliest prominent peer-to-peer filesharing program, was sued and shutdown, and similar lawsuits were filed against other filesharing platforms. As a result of Napster's popularity, CD sales rapidly declined. Innovative companies realized that sales of CDs would never return to their former levels and instead offered artists and industry players a way to monetize content

through streaming subscription services like Spotify, or ad-based monetization on platforms like YouTube. Other sites like Soundcloud and Bandcamp allow artists to directly upload and sell their works, as well as connect with fans and other people within the community.

Question 1:

Online sources:

"On the sensations of tone as a physiological basis for the theory of music", by Hermann von Helmholtz, 1877
https://books.google.com/books?id=x_A5AAAAIAAJ&printsec=frontcover&source=gbs_ge_summary_r&cad=0#v=onepage&q&f=false

The text which represents the mathematical foundation of modern acoustics.

"The Incredible Talking Machine", Randall Stross
http://content.time.com/time/specials/packages/article/0,28804,1999143_1999210,00.html

Further explores Edison's phonograph invention.

"The 'Telharmonium' or 'Dynamophone'", 120 Years of Electronic Music
http://120years.net/the-telharmonium-thaddeus-cahill-usa-1897/

More in-depth exploration on the Telharmonium.

"The Art of Noise", Luigo Russolo, 1913
http://www.artype.de/Sammlung/pdf/russolo_noise.pdf

The futurist manifesto which suggests noise should be incorporated into music.

Pieces:

Antonio Russolo – "Corale" (1921)

https://www.discogs.com/Filippo-Tommaso-Marinetti-Il-Futurismo/release/2559759

Unfortunately, due to the lack of widespread recording technologies at the time, few recordings of the Italian Futurist movement are extant. This piece by Antonio Russolo, brother to Luigi, is somewhat late in the Futurist movement, but is a good representative of soundscapes produced by the homemade Intonarumori instruments. These instruments were purely mechanical and had no electric component, but were created to produce non-traditional sounds that are described in Luigi Russolo's "The Art of Noises". When listening to this piece, think of how modern electric and electronic instruments could generate sounds that would accompany the music.

Question 2:

Online sources:

"Planar Microwave Engineering: A Practical Guide to Theory", Chapter 1.2: "The Birth of the Vacuum Tube", Thomas H. Lee
https://books.google.com/books?id=uoj3IWFxbVYC&pg=PA13&dq=Audion+triode#v=onepage&q=Audion%20triode&f=false

Further detail on the development of the vacuum tube and its impact in electronics as a whole.

"The 'Audion Piano' and Audio Oscillator", 120 Years of Electronic Music
http://120years.net/the-audion-pianolee-de-forestusa1915/

An elaboration of the significance of the Audion vacuum tube and its application to music.

https://patents.google.com/patent/US1661058A/en
https://ethw.org/Theremin

Theremin patent and ETHW article on Theremin.

https://www.engineering.com/ElectronicsDesign/ElectronicsDesignArticles/ArticleID/16337/Vacuum-Tubes-The-World-Before-Transistors.aspx
"Vacuum Tubes: The World Before Transistors", Michael Alba

An overview of electronics in the age of vacuum tubes, the switch to transistors, and how the transistor led to the miniaturization of electronics.

Pieces:

Clara Rockmore – "Nocturne in C# Minor" (1975)

https://www.discogs.com/Clara-Rockmore-Nadia-Reiseberg-Clara-Rockmores-Lost-Theremin-Album/release/1655212

Recorded late in Rockmore's life, a piece like this would have been typical of her performances during the height of her fame in the 1930s. Many public performances on emerging electronic instruments such as the Theremin, were renditions of classical pieces, such as this one, originally composed by Chopin. The Theremin, which comes in at around fifteen seconds, is accompanied by a piano. This piece highlights how the Theremin sounds and is performed, with its evocative vibrato and almost otherworldly tone. Keep this in mind as you listen to the piece. When a key on a piano is pressed, it always plays the same note, which also holds true for electronic pianos like the Audion Piano at the time. The Theremin has a different approach to sound generation as pitch is controlled by the distance the player's hand is from a radio antenna. Each subsequent key on a piano represents a half-step on the scale, but a Theremin produces an analog gradient of pitch, making it possible

to, intentionally or otherwise, play microtuned notes or unconventional scales. Rockmore's work is rarely adventurous in this sense, but the potential is there for future composers.

Pierre Schaeffer – "Symphonie pour un homme seul: Intermezzo" (1957)

https://www.discogs.com/Various-Panorama-Of-Musique-Concr%C3%A8te-No-2/release/405830

One of the first major Musique concrete pieces utilizing tape composition methods. The nature of tape allows the composer to cut and splice pieces, bend the tape to change pitch, reverse the tape, layer it onto other tapes, etc. When listening to the piece, consider the level of effort and time required to manually manipulate tape this way. Depending on the fidelity of the medium, several inches of tape could correspond with less than a second of sound. As computers were on the horizon at this point and not widely available for sound arrangements in this fashion, composing even brief pieces by tape was extraordinarily time consuming.

Question 3:

"The First Computer Musician", R. Luke Dubois, June 8, 2011
https://opinionator.blogs.nytimes.com/2011/06/08/the-first-computer-musician/
Profile of Max Mathews in New York Times.

"Mod love", Andrew Leonard, archive link from Salon, 1999
https://web.archive.org/web/20121025040018/http://www.salon.com/1999/04/29/mod_trackers/

An article on musicians using Trackers, a music composition tool which specifically creates small file sizes so they can easily be distributed through what was in the 1980s and 1990s, a limited amount of bandwidth through BBS's and the internet.

Interview: Juan Atkins, 2017
https://daily.redbullmusicacademy.com/2017/05/interview-juan-atkins

An interview with Juan Atkins, one of the Detroit techno pioneers the Belleville three, on his influences and the early techno scene.

Pieces:

Max Mathews – "Numerology" (1960)

https://www.discogs.com/Various-Music-From-Mathematics/release/1411970

Max Mathews is sometimes referred to as the "father of computer music". While not the first to compose music on a computer, his work explores the mathematical theoretical side of music and goes beyond renditions of popular songs and classical pieces. When listening to "Numerology", it feels more like a special effects demo than a deliberate piece. Shifting

from one effect to another through its length gives the listener a good idea of what sorts of mathematical functions computers can generate with respect to music. It is recommended this piece be listened to with software capable of displaying a spectrograph as the relatively basic mathematics are visually rather striking and easy to see.

Kraftwerk – "Trans-Europe Express" (1977) and "The Man Machine" (1978)

https://www.discogs.com/Kraftwerk-Trans-Europa-Express/master/2877
https://www.discogs.com/Kraftwerk-The-ManMachine/master/4010

Kraftwerk's late 1970s output is considered by many to be the foundation of modern popular electronic music, and some music critics have considered them as important, if not more so, than the Beatles to the development of late 20th century popular music. As computing technology improves throughout the 1960s and 1970s, Kraftwerk utilized sequencers, synthesizers and drum machines, most often homemade or customized by the band, to create their mechanical, futuristic, robotic pop sound. These records were highly influential to the development of disco, techno and hip-hop.

Afrika Bambaataa & the Soul Sonic Force – "Planet Rock" (1982)

https://www.discogs.com/Afrika-Bambaataa-the-Soul-Sonic-Force-Music-By-Planet-Patrol-Planet-Rock/master/19152

An early Afrofuturistic hip-hop track that recontextualizes the refrain from Kraftwerk's "Trans-Europe Express" at around 45 seconds in. Technology at the time made it far easier to sample passages of music than the manual manipulation of tape from several decades prior. As such, sampling was a prominent feature of hip-hops development through the 1980s and 1990s. On this track, the recontextualization of Kraftwerk's futuristic sound is a good example of how their influence spread to a wider audience.

Model 500 – "No UFOs" (1985)

https://www.discogs.com/Model-500-No-UFOs/master/5405

An early Detroit techno track, this piece showcases how the lowered cost of music technology reduces the gatekeeping to composing. Juan Atkins began experimenting with synthesizers when he was still in high school, and was able to compose in his bedroom. While "No UFOs" was written when Atkins was in his early 20s, it demonstrates the possibilities for aspiring musicians at the time. Using homemade studios without major label backing, the early techno artists are very "ground-up" and independent, versus composers from the 1960s who were often attached to a television or radio studio like RTF or the BBC.

Question 4:

"The Rise and Fall of Digital Music Distribution Services: a Cross-Case Comparison of MP3.com, Napster and Kazaa", K. Alves, K. Michael, Proceedings of the Collaborative

Electronic Commerce Technology and Research Conference LatAm, University of Talca, Chile, 3-5 October 2005, 1-22
https://www.researchgate.net/publication/30389522_The_Rise_and_Fall_of_Digital_Music_Distribution_Services_a_Cross-Case_Comparison_of_MP3com_Napster_and_Kazaa
An in-depth look at mp3.com and Napster, two of the earliest music sharing online distribution services, with a focus on the legal elements.

"Sales Of Physical Music Media Slump As Consumers Move To Streaming Services", Mark Sparrow, Forbes
https://www.forbes.com/sites/marksparrow/2019/01/03/sales-of-physical-music-media-slump-as-consumers-move-to-streaming-services/#4dc620602255
Article from Forbes pointing to sharp decline of CD sales in streaming environment.

“Music streaming is fueling vinyl's resurgence”
https://www.engadget.com/2018/12/04/music-streaming-is-fueling-vinyls-resurgence/
Article detailing how vinyl has been making a comeback in the age of streaming. Consider why a format like a CD would decline in sales, but a format like vinyl would increase in sales in the age of streaming.

“Now that you're here, check out my SoundCloud”, Maeve Sheehey, Daily Tar Heel
https://www.dailytarheel.com/article/2019/01/soundcloud-rappers-0120
Article detailing the popularity and current usage of Soundcloud