The Cambridge Companion to Electronic Music

Musicians are always quick to adopt and explore new technologies. The fast-paced changes wrought by electrification, from the microphone via the analogue synthesiser to the laptop computer, have led to a wide range of new musical styles and techniques. Electronic music has grown to a broad field of investigation, taking in historical movements such as musique concrète and elektronische Musik, and contemporary trends such as electronic dance music and electronica. This book, winner of the 2009 Nicolas Bessaraboff Prize, brings together researchers at the forefront of the sonic explorations empowered by electronic technology to provide accessible and insightful overviews of core topics and uncover some hitherto less-publicised corners of worldwide movements. This updated and expanded second edition includes four entirely new chapters, as well as new original statements from globally renowned artists of the electronic music scene, and celebrates a diverse array of technologies, practices and music.

Nick Collins is Reader in Composition at Durham University. His research interests include live computer music, musical artificial intelligence, and computational musicology, and he is a frequent international performer as composer-programmer-pianist or codiscian, from algoraves to electronic chamber music.

Julio d’Escriván is Senior Lecturer at the University of Huddersfield. He researches in film and audiovisual music composition and is himself a composer of music for the screen. His work spans electroacoustic and orchestral music, electronica, film music, commercials, live coding and improvisation.
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The Cambridge Companion to
Electronic Music

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Amy Alexander is a digital media, audiovisual and performance artist who has also worked in film, video, music, tactical media and information technology. Alexander’s projects have been exhibited and performed internationally in festivals and museums as well as on the Internet, in clubs and on the street. She has written and lectured on software art and culture and audiovisual performance, and she has served as a reviewer for both visual media and computer music events and publications. Alexander is an Associate Professor of Visual Arts at the University of California, San Diego. http://amy-alexander.com

Natasha Barrett (UK / Norway) is a composer, performer and researcher in the field of contemporary electroacoustic art music. She received her doctoral degree in 1998 from City University in London and has since followed a career predominantly as a freelancer. Her work encompasses acousmatic and electroacoustic concert composition, sound installations, theatre music, large-scale outdoor media productions, sound-architectural works and interactive art. She regularly collaborates with designers and scientists, as well as musicians and visual artists. Her work is inspired by acousmatic sound and the aural images it can evoke, particularly in terms of the evocative implications of space. Besides her compositional activities, she has been employed as a researcher at the Department for Musicology, University of Oslo, and as a professor in electroacoustic composition at the Norwegian State Academy for Music. Barrett's works are performed and commissioned throughout the world and have received a long list of prizes. These include the Nordic Council Music Prize (Nordic Countries), Giga-Hertz Award (Germany), Edvard Prize (Norway), Jury and public first prizes in Noroit-Leonce Petitot (France), five first prizes and the Euphonic D'Or in the Bourges International Electroacoustic Music Awards (France), Musica Nova (Prague), CIMESP (Brazil), Concours Scrine
Notes on Contributors

(France), International Electroacoustic Competition Ciberart (Italy), two prizes in Concours Luigi Russolo (Italy), and two first prizes in the International Rostrum for electroacoustic music. www.natashabarrett.org

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Nicolas Collins

New York born and raised, Nicolas Collins spent most of the 1990s in Europe, where he was Visiting Artistic Director of Stichting STEIM (Amsterdam), and a DAAD composer-in-residence in Berlin. An early adopter of microcomputers for live performance, Collins also makes use of homemade electronic circuitry and conventional acoustic instruments. He is a Professor in the Department of Sound at the School of the Art Institute of Chicago, and from 1997 to 2017 was editor-in-chief of the Leonardo Music Journal. His book, Handmade Electronic Music – The Art of Hardware Hacking (Routledge), has influenced emerging electronic music worldwide. www.nicolascollins.com

Julio d’Escriván is a Venezuelan composer working in music for the screen. His work since the late 1980s spans electroacoustic and orchestral music, electronica, film music, commercials, live coding and improvisation. Although most of his career has been as a freelance in the Americas, he currently works as a Senior Lecturer at the University of Huddersfield; there he lectures and researches in film and audiovisual music composition.

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Andrew Hugill (1957) is Director of the Centre for Creative Computing at Bath Spa University. Between 1976 and 1980, he studied composition with Roger Marsh at the University of Keele. After university he earned a living as a music copyist and as musical assistant at the Opéras de Lyon and Paris, before beginning his academic career in 1986. Hugill’s compositions have been performed and broadcast worldwide. Symphony for Cornwall (1999) used the internet in a ground-breaking way. Secret Garden (2013) was experienced by 36,500 people during its two month exhibition in the Taipei Museum of Contemporary Art. Hugill’s research is trans-disciplinary, covering composition, musicology, computer science and literature.
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He is the author of *The Digital Musician* (Routledge 2008/2012) and *Pataphysics: A Useless Guide* (MIT Press 2012). He is a Principal Fellow of the Higher Education Academy.

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Adinda van ’t Klooster is an artist who works with drawing, sound, light, animation, sculpture and interactive audiovisual performance and installation. Her work has been exhibited, performed and screened in China, the USA, Australia, Slovenia, Spain, Scotland, the Netherlands, England, Norway and Ireland. Her research interests include emotion-aware artworks, biofeedback art, aesthetic experience, sound art, interactive art and graphical scores. She has been involved in multiple interdisciplinary projects that explore the links between music and art. Her work has received many awards and has been commissioned throughout the UK. Examples can be seen at www.adindavantklooster.com and www.affectformations.net

John Richards explores the idea of Dirty Electronics, which focuses on shared experiences, ritual, gesture, touch and social interaction. In Dirty Electronics process and performance are inseparably bound. The ‘performance’ begins on the workbench devising instruments and is extended onto the stage through playing and exploring these instruments. Richards is primarily concerned with the performance of large-group electronic music and DIY electronics, and the idea of composing inside electronics. His work also pushes the boundaries between music, performance art, electronics, and graphic design and is transdisciplinary as well as having a socio-political dimension. www.dirtyelectronics.org

Julian Rohrhuber is a German artist and theorist. As professor for music informatics and media theory at the Robert Schumann Hochschule in Düsseldorf, he develops the intersections between art, programming and philosophy. His art projects include compositions, installations and performances, film sound tracks, a system for interactive sound programming, and collaborative and network art pieces. He writes on topics such as philosophy of mathematics, education politics, documentary realism, distributed agency, and algorithmic time.
Margaret Anne Schedel is a composer and cellist specialising in the creation and performance of ferociously interactive media whose works have been performed internationally. Her research focuses on gesture in music, the sustainability of technology in art, and sonification of data. As an Associate Professor of Music at Stony Brook University, she serves as Co-Director of Computer Music and is the Director of cDACT, the consortium for digital arts, culture and technology. She ran SUNY’s first Coursera Massive Open Online Course (MOOC), an introduction to computational arts. Schedel holds a certificate in Deep Listening and is a joint author of Cambridge University Press’ Electronic Music. She has been commissioned by the Princeton Laptop Orchestra, the percussion ensemble Ictus, and the reACT duo. She sits on the boards of 60x60, the International Computer Music Association, is a regional editor for Organised Sound and an editor for Cogent Arts and Humanities. In her spare time she curates exhibitions focusing on the intersection of art, science, new media, and sound.

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Mary Simoni is a composer, author, teacher, pianist, consultant, arts administrator, and amateur photographer. She is currently the Dean of Humanities, Arts & Sciences at Rensselaer Polytechnic Institute and Professor Emerita, Performing Arts Technology at the University of Michigan. Her music and multimedia works have been performed in Asia, Europe, and throughout the United States and have been recorded by Centaur Records, the Leonardo Music Journal published by the MIT Press, and the International Computer Music Association. She is the recipient of the Prize in Composition by the ArtNET Virtual Museum and named semifinalist for the American Prize in Composition-Chamber Music. Her music is frequently recognised by Vox Novus. She has authored several books, Algorithmic Composition: A Guide to Composing Music with Nyquist co-authored with Roger Dannenberg and published by the University of Michigan; and Analytical Methods of Electroacoustic Music published by Routledge. She is a Medal Laureate of the Computer World Honors Award for her research in digital music information retrieval.

Ge Wang is an Assistant Professor at Stanford University’s Center for Computer Research in Music and Acoustics (CCRMA). He researches programming language and software design for music, interaction design, mobile music, laptop
orchestras, aesthetics of music technology design, and education at the intersection of engineering, art, and design. Ge is the author of the ChucK music programming language, the founding director of the Stanford Laptop Orchestra (SLOrk), the Co-founder of Smule (reaching over 125 million users), and the designer of the iPhone’s Ocarina and Magic Piano.
Acknowledgements

So begins a round of thanks to many individuals, and most especially, those we've inevitably forgotten to mention. The editors wish to thank all of the contributors to this book who've put up with our requests and editing. Without the chapter authors and the artists who have kindly provided statements, there would hardly be any book to have the honour of editing!

We also have to say a big thank you specifically to Vicki Cooper, Becky Jones, Helen Waterhouse, Jo Breeze, Michael Downes, Chloe Harries, Kate Brett, Sophie Taylor, Sharon McCann, Phil Clement, Laura Macy and all others associated with the production of the book at Cambridge University Press.

For external reviews of chapters we very much appreciate the time and effort of Robert Rowe, Chris Brown, Fredrik Olofsson, Bill Hsu, Alberto de Campo, Bob Gluck, Brian Kane, John Hawks, Michael Scroggins, Curtis Roads and Jøran Rudi. Additional proofreading and comments were provided by a number of the chapter authors.

For assistance with obtaining artists' statements, many thanks to Terumi Narushima, Joana Seguro, Daniel Klemm, Sharen Norden, Zoe Miller, Dave Griffiths, Ryoko Akama, Falk Griefenhagen, Isa Wolf, Matthew Werth, Brandon Sanchez, Kathinka Pasveer, and of course to the various chapter authors, friends and enemies who themselves suggested people and helped us to get in contact with them.

Karlheinz Essl wishes to thank Florian Cramer (Rotterdam) for his attendance to discuss the history of algorithmic thinking in philosophy and literature and Jennifer Walshe (Berlin/New York) for proofreading the manuscript.

Meg Schedel owes a debt of gratitude to her proofreading parents, Rita and Charles Schedel.

Julian Rohrhuber appreciates the immensely useful advice from, and acknowledges the inspirations of, his colleagues. He'd like to thank Anthony Moore, Alberto de Campo, Renate Wieser, Chris Brown, Julio d'Escriván and Nick Collins for their generous interest in his article. He'd also like to express gratitude to Kurd Alslleben, Antje Eske, Jin Hyun Kim, Hannes Hölzl, Alex McLean, Frank Wörler, Guy van Belle, Georg Hajdu, Maarten Bullynck and many others, who pointed out numerous interesting aspects of networks and network art.

Ge Wang wishes to extend hearty thanks to Perry Cook for his teaching and insights on the history of programming and music, to Ananya Misra for providing invaluable feedback from beginning to end, to Mark Ballora for his excellent online history of computer music, to Max Mathews for information and perspective, and to Rebecca Fiebrink, Spencer Salazar and Matt Hoffman for their support.
xv Acknowledgements

Nick Collins thanks everyone who suffered any editorial attention from him, and acknowledges with great respect and warmth his collaborators and colleagues in the field. He particularly welcomes the support and essential input of his co-editor. He also wishes to extend a special thank you to the third person.

Julio d'Escrivá wishes to thank Julian Rohrhuber for his review and suggestions. Also a special thanks to his co-editor, for roping him into this wonderful project and for his invaluable constructive criticism. A warm thanks to Sue Guilmurray from the university library at ARU, Cambridge. And … very especially he wishes to acknowledge the love, patience and support of Milly, Isa, Mari, Emi and Ana throughout this project.
### Chronology

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>569–475 BC</td>
<td>Pythagoras leads the elitist <em>mathematikoi</em> and <em>akousmatikoi</em></td>
</tr>
<tr>
<td>1026</td>
<td>Guido d’Arezzo’s vowel-to-pitch mapping procedure for composing melodies for texts</td>
</tr>
<tr>
<td>1626</td>
<td>Francis Bacon describes the ‘sound-house’ in <em>The New Atlantis</em></td>
</tr>
<tr>
<td>1734</td>
<td>Louis Bertrand Castel builds a prototype clavecin oculaire, the first light organ</td>
</tr>
<tr>
<td>1738</td>
<td>Jacques de Vaucanson’s flautist automaton is exhibited</td>
</tr>
<tr>
<td>1757</td>
<td>Johann Philipp Kirnberger’s <em>Allezeit fertiger Polonaises und Menuettencomponist</em> (<em>The always ready Polonaise and Menuet Composer</em>), a musical dice game</td>
</tr>
<tr>
<td>1761</td>
<td>Jean-Baptiste Delaborde builds the <em>Clavecin Electrique</em> in Paris</td>
</tr>
<tr>
<td>1843</td>
<td>Lady Ada Lovelace describes the possible musical applications for Charles Babbage’s machine in <em>The Sketch of the Analytical Engine</em></td>
</tr>
<tr>
<td>1857</td>
<td>A. Seebeck formulates the <em>rate theory</em> which states that neural firing patterns encode the periodic structure of auditory stimuli</td>
</tr>
<tr>
<td>1864</td>
<td>Innocenzo Manzetti invents a ‘speaking telegraph’ for his musical automaton</td>
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<tr>
<td>1876</td>
<td>Alexander Bell’s (controversial) telephone patent</td>
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<tr>
<td>1877</td>
<td>Thomas Edison invents the carbon microphone</td>
</tr>
<tr>
<td>1876</td>
<td>Co-invention by Charles Cros and Thomas Edison of the phonograph</td>
</tr>
<tr>
<td>1881</td>
<td>Ernst Werner von Siemens invents the loudspeaker</td>
</tr>
<tr>
<td>1881</td>
<td>Clément Ader demonstrates stereo broadcast with the premiere of his Théâtrophone, conveying music from the Paris Opéra to the World Expo</td>
</tr>
<tr>
<td>1897</td>
<td>Thaddeus Cahill patents the <em>Art of and Apparatus for Generating and Distributing Music Electronically</em></td>
</tr>
<tr>
<td>1898</td>
<td>Valdemar Poulsen patents a magnetic <em>Telegraphone</em>, which can both record and play back sound</td>
</tr>
<tr>
<td>1899</td>
<td>William Duddell invents the <em>Singing Arc</em></td>
</tr>
<tr>
<td>1906</td>
<td>Cahill finally builds the Telharmonium</td>
</tr>
<tr>
<td>1906</td>
<td>Lee De Forest invents the triode vacuum tube (which he calls the <em>Audion</em>), allowing controlled amplification; ironically, Cahill could have used this invention to make the Telharmonium much smaller!</td>
</tr>
<tr>
<td>1909</td>
<td>The Tel-musici Company combine a telephone exchange with a music room; they are bankrupt within a few years, just like Cahill</td>
</tr>
</tbody>
</table>
xvii Chronology

1913      Luigi Russolo writes his manifesto *The Art of Noises*
1920      Lev Termen invents the Theremin
1924      Ottorino Respighi combines a phonograph playing alongside an orchestra in *Pini di Roma*.
1928      Fritz Fleumer invents the magnetic tape recorder in Germany
1929      Maurice Martenot invents the *Ondes Martenot*
1930      Friedrich Trautwein invents the *Trautonium*
1931      Walter Ruttmann’s *Weekend* is an early precedent in juxtaposition of fragments of recorded sound,
           Paul Hindemith and Ernst Toth hold a multiple turntable concert of *Grammophonmusik* in Berlin, with young exchange student John Cage in attendance
1932      An electroacoustic montage is created by the sound department of Paramount Studios in Hollywood, for the film *Jekyll and Hyde*
1933      In Oskar Fischinger’s film, *Tönende Ornamente* (Ornament Sound), the soundtrack is created by drawing directly onto the optical soundtrack
1936      The theremin is used by composer Max Steiner to expand the timbral palette of the orchestra in the film *King Kong*
1937      Varèse publishes his manifesto *The Liberation of Sound*
1938      John Cage delivers his lecture *The Future of Music: CREDO*
1939      Orson Welles’ *War of the Worlds* radio play successfully deceives its audience into believing a Martian invasion is taking place
1939      Johanna Beyer’s *Music of the Spheres* is composed, with parts for three electrical instruments and two percussion instruments
1944      Cage begins working with live electronic sound in his piece *Imaginary Landscape No. 1*
1946      Egyptian-born Halim El-Dabh experiments by electronically processing recordings made with a wire recorder, a medium that predated tape
1946      The *Schillinger System of Musical Composition* is published posthumously
           Raymond Scott writes the patent disclosure for the ‘orchestra machine’
1948      At the French National Radio-Television (RTF), Pierre Schaeffer experiments with mixing pre-recorded sources on various turntables and creates *Etude aux Chemins de Fer*. The RTF studios eventually host the Groupe de Recherches Musicales (GRM)
           Claude Elwood Shannon publishes *A Mathematical Theory of Communication*
1951      Pierre Schaeffer and Pierre Henry compose *Symphonie pour un homme seul*, a landmark in musique concrète
           The Studio für Elektronische Musik at West German National Radio (WDR) is founded in Cologne
           Percy Grainger invents the *Kangaroo Pouch Machine*
xviii Chronology

The Columbia Tape Music Center, in New York, is started by Luenning and Ussachevsky. It would later become the Columbia–Princeton Electronic Music Center in 1959.

Louis and Bebe Barron compose Heavenly Menagerie in their studio, months before the more famous Cologne Studio is established.

Bernard Herrmann uses theremins as main instruments with the film orchestra in his score for The Day the Earth Stood Still.

Schaeffer investigates spatialisation with the potentiomètre d'espace.

1952
Schaeffer publishes a syntax for musique concrète in the treatise Esquisse d’un solfège concrete.

Monique Rollin's Étude Vocale (1952) is an early musique concrète study.

Cage is composing Williams Mix (completed by 1953); the realisation takes a team of tape splicers (in reality, Louis and Bebe Barron) many months.

1953
In Milan, the Studio di Fonologia is established. In Tokyo the Electronic Music Studio for Japan Radio (NHK) is opened.

Herbert Eimert composes Struktur 8.

1950–4
Varèse composes Déserts, which combines an ensemble of live instrumentalists with tape.

1955–9
Lejaren Hiller and Leonard Isaacson experiment with using a mainframe computer to algorithmically generate musical scores, composing the Illiac Suite for string quartet in 1956.

1955
Iannis Xenakis publishes The Crisis of Serial Music, critiquing integral serialism on psychological and statistical grounds.

1956
Louis and Bebe Barron create the first purely electronic film score for Forbidden Planet.

In the Netherlands, the Center for Electronic Music is established within the Philips Research Laboratory.

Stockhausen's Gesang der jünglinge combines concrète and elektronische.

Xenakis completes the first granular study: Analogue B.

1957
In Warsaw, the Studio Experimentalne is established at Polish National Radio.

The Bell Telephone Laboratories host the first digital music experiments: Max Mathews programs the first sounds ever generated by a digital computer and creates MUSIC I, the earliest programming environment for sound synthesis.

1958
The BBC Radiophonic Workshop is founded, after years of effort from Daphne Oram in particular.

Xenakis designs the Philips Pavilion at the Brussels World's Fair for which Varèse composes Poème électronique; Xenakis also provides Concrèt PH for the interludes between shows.
Chronology

In Santiago de Chile, the Laboratorio de Acústica is used for the earliest electronic music in South America

Raymond Scott invents and begins development of the Electronium, an algorithmic composing machine without a musical keyboard

In Toronto, the University of Toronto Electronic Music Studio is founded

1958–60  Stockhausen works on Kontakte

1960  Andrej Markowski creates, at the Experimental Studio in Warsaw, electronic music and sound design for The Silent Star, directed by Kurt Maetzig

Raymond Scott composes a completely electronic soundtrack for the Vicks: Medicated Cough Drops commercial

1961  The Norsk Rikskringkasting (NRK) in Oslo allows its studios to be used for the earliest experiments in electronic music in Norway

Kelly and Lochbaum design an algorithm to simulate the human vocal tract

James Tenney creates the plunderphonic tape piece Collage #1 (Blue Suede), sampling and manipulating a famous Elvis track

1962  In Buenos Aires, the Laboratorio de Música Electrónica associated to the Instituto Torcuato di Tella is founded; in Ghent, Belgium, the Institut vor Psychoakoestiek en Elektronische Muziek; in East Berlin, the Experimentalstudio für Kunstliche Klang und Gerauscherzeugung, Laboratorium für Akustisch-Musikalische Grenzprobleme

1963  Gottfried Michael Koenig's Projekt 1 program is devised, for automatic aleatoric serial composition

1964  Stockhausen composes Mikrophonie I for amplified and processed tam-tam

Jean-Claude Risset visits Bell Labs for the first time and uses MUSIC IV to investigate the timbre of trumpets

1965  Steve Reich creates his first phase piece: It's Gonna Rain

Alvin Lucier creates his Music for Solo Performer, the first live electronics piece to use amplified alpha brainwaves

1967  In Gordon Mumma's composition Hornpipe an analogue device analyses and amplifies the resonances of the hall in which a performer is playing the French horn, thus predating interactive machine-listening systems

John Chowning discovers Frequency Modulation sound synthesis

1968  MUSIC V becomes the first computer music programming system to be implemented in FORTRAN

David Tudor composes the first of his Rainforest pieces, featuring a multitude of objects acting as loudspeakers dangling directly from their cables
xx Chronology

Raymond Scott invents the first ‘drum machine’, *Bandito the bongo artist*

Jean-Claude Risset creates a catalogue of computer-generated sounds at Bell Labs including guidelines to synthesise different musical instruments using MUSIC V; Risset also composes *Computer Suite from Little Boy*, utilising auditory illusions

Wendy Carlos’ *Switched-On Bach* achieves popular success, promoting Robert Moog’s modular synthesisers

Lee Scratch Perry sets up his Upsetter record label – the Jamaican sound system and studio scene is a fertile backdrop for the development of dub and the remix

1969

Max Mathews builds the GROOVE system to connect a computer to an analogue synthesiser

First performance of Lejaren Hiller and John Cage’s *HPSCHD*, for massed audiovisual forces

Luc Ferrari’s *music promenade* manipulated field recording

1970

Pierre Boulez founds the Institut de Recherche et Coordination Acoustique/Musique (IRCAM)

1970–2

François Bayle’s *L’expérience acoustique*

1971

Richard Teitelbaum’s piece *Alpha Bean Lima Brain* involves the transmission of brain waves by telephone to control jumping beans

Wendy Carlos creates the electronically instrumental score for *A Clockwork Orange* by Stanley Kubrick

Hiller and Ruiz develop the first computer simulations by physical models, of instrumental sounds

John Chowning describes techniques for the computer simulation of moving sound sources that are based on the Doppler effect as well as reverberation effects

Tonto’s Expanding Head Band release the psychedelic and progressive *Zero Time*, composed with the expanded Series III Moog synthesiser

1972

Salvatore Martirano builds the *SalMar Construction*, a realtime generative electronic music instrument.

F. Richard Moore, Gareth Loy, and others at the Computer Audio Research Laboratory (CARL) at University of California at San Diego develop and distribute an open-source, portable system for signal processing and music synthesis, called the CARL System, modelled after UNIX

Eduard Artemiev produces the electronic score for *Solaris* by Andrei Tarkovsky

*Pong* by Atari becomes a mass gaming phenomenon

1973

The Composers inside Electronics collective is formed

DJ Kool Herc is experimenting with turntable mixing at parties in the Bronx
xxi Chronology

1974
Paul De Marinis builds *Parrot Pleaser*, an automatic music composing circuit intended to be played by a bird

Curtis Roads writes a program with MUSIC V implementing granular synthesis

François Bayle establishes the Acousmonium loudspeaker orchestra

1974–9
Laurie Spiegel develops the *VAMPIRE* (Video And Music Program for Interactive Realtime Exploration/Experimentation) system

1975
Michel Waisvisz unleashes the Crackbox synthesizer

1976
John Appleton produces the prototype for the Synclavier

1977
Denis Smalley writes *Darkness After Time’s Colours*

*The League of Automatic Composers* is founded by Jim Horton, John Bischoff and Rich Gold

Ben Burtt coins the term ‘sound designer’ to reflect his contribution to the film *Star Wars*

Hildegard Westerkamp creates *Lighthouse Park Soundwalk*

1978
Atari releases the Atari Video Music audio-visualiser

Brian Eno creates the ambient music installation *Music for Airports*

Kraftwerk create their *The Man-Machine* album, touring with robotic mannequins

*Space Invaders* by Toshihiro Nishikado is the first game to have continuous music throughout

Trevor Wishart composes *Red Bird: A Political Prisoner’s Dream*

1979
Merzbow starts his Lowest Music and Arts record label to release his music on cassette

1980
Fonction d’onde formantique (FOF) sound synthesis (or formant wave function synthesis), is developed at IRCAM by Xavier Rodet, Yves Potard and Jean-Baptiste Barrière

1981
The launch of Music TeleVision; MTV appropriates the existing term VJ for their presenters, starting a parallel use of this descriptor, later fully reclaimed by live club visual artists

Boulez works on *Répons*

1981–8
David Jaffe’s *Silicon Valley Breakdown* utilises an extended version of Karplus-Strong synthesis

1982
*The Musical Instruments Digital Interface* protocol (MIDI) is established

The Yamaha DX7 is released and becomes the first widely accessible digital synthesiser

Double D and Steinski win a remix competition with the first of their influential cut and paste *Lessons*

1983
Paul Lansky develops *Cmix*, later to become *RTCmix*, an extension for realtime use created by Brad Garton and David Topper

Yasunao Tone begins ‘wounding’ CDs through the application of perforated Scotch tape
xxii Chronology

First attempts at automatic accompaniment systems from Roger Dannenberg and Barry Vercoe presented at the International Computer Music Conference at IRCAM

The Wabot-2 score reading and keyboard playing robot is completed, the first of a series of musical robots produced at Waseda University

Early Chicago House recordings from Jesse Saunders, amongst others

1985
Laurie Spiegel develops Music Mouse
Paul Lansky's Idle Chatter
Detroit Techno provides one historical strand amongst many of electronic dance music: Juan Atkins had been recording in the duo Cybotron since 1981, and released his first Model 500 tracks in 1985; influences included electronic, disco and funk artists such as Kraftwerk, Giorgio Moroder and Parliament

1986
Csound is originally authored by Barry Vercoe and colleagues at the MIT Media Labs
George E. Lewis begins working on the Voyager interactive music system
The Akai S900 becomes one of the first (and possibly the most accessible) commercially available sampling modules for mass consumers

1987
The Hierarchical Music Scoring Language (HMSL) is authored by Polansky, Rosenboom and Burk

1988
Miller Puckette publishes his paper The Patcher; at IRCAM he develops this visual patching system into an interactive computer music programming environment called Max

1989
John Oswald releases the Plunderphonic EP and is later forced to 'recant', destroying all remaining copies, by the litigious music industry

1990
Max (later Max/MSP, then later still just Max again) is released commercially, becoming available to non-academic musicians
Public Enemy's album Fear of a Black Planet demonstrates the power of their sampled hip hop production, allied to strong political messages

1991
Nic Collins creates the piece Broken Light by hardware hacking CD players
Common Lisp Music (or CLM), a sound synthesis language is written by Bill Schottstaedt at Stanford University

1992
Reed Ghazala starts publishing articles on 'Circuit Bending' in the journal Experimental Musical Instruments

1993
Björk's Debut is the first example of her many collaborations with electronic dance music producers
xxiii Chronology

1994  Autechre’s *anti-EP* (particularly the third track, ‘Flutter’) is designed not to repeat in such a way as to confound recent anti-rave legislation

1995  The *Synthesis Toolkit* (STK), a collection of building blocks for realtime sound synthesis and physical modelling, for the C++ programming language, is authored by Perry Cook and Gary Scavone

1996  James McCartney develops *SuperCollider*, an environment and programming language for realtime audio synthesis

1997  Miller Puckette releases *Pure Data*, a freeware program with a similar environment to Max/MSP

1998  Coldcut release *Let Us Play*, an extended CD including the live AV sampling demo *Timber*

1999  Maurice Methot and Hector LaPlante start streaming algorithmic music live on the internet with *The Algorithmic Stream*

2000  Introduction of the *Open Sound Control* (OSC) network music connectivity protocol

2001  Ryoji Ikeda releases +/−

2002  Atau Tanaka and Kaspar Toeplitz install *Global String*, uniting space with cyberspace

2003  Chris Watson releases *Outside the circle of fire*

2007  Chris Chafe’s *Network Harp* uses network latency for sound synthesis

2008  *ChucK*, an audio synthesis programming language, is created by Ge Wang and Perry Cook

2009  The *Firebirds* installation by Paul de Marinis reignites the use of gas fire loudspeakers

2010  Ryoji Ikeda releases *Algorithmic Stream 2010*

2012  *Sonic Bloom* is used by Tame IMPACT to promote adaptive audio techniques at Coachella

2013  *Vocaloid* singing voice synthesiser software is released for Japanese speakers

2015  Nintendo and Toshio Iwai release the *Electroplankton* interactive musical video game

2016  *The Tomb Raider: Legend* game widely promotes adaptive audio techniques

2017  Daft Punk’s stage pyramid show is revealed at Coachella

2018  The iPhone is released, paving the way to low latency audio processing smartphone applications

2019  *Björk’s Biophilia* is both interactive app and music release
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2010</td>
<td>The Turner Prize is given to sound artist Susan Philipsz</td>
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<td>2011</td>
<td>Amon Tobin's ISAM stage show maps audio synchronized graphics onto a large on-stage sculpture. The <em>Oramics to Electronica</em> exhibition opens at London's Science Museum</td>
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<tr>
<td>2014</td>
<td>The HTML 5 specification is finalized; an era of realtime web browser audio applications has already begun</td>
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<tr>
<td>2016</td>
<td>Daphne Oram's <em>Still Point</em> (1949) for double orchestra, pre-recorded sound and electronic processing via microphones is finally premiered, at the <em>Deep Minimalism</em> Festival in London</td>
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