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 diversity 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. A fascinating array of composers and inventors have contributed to a diverse set of technologies, practices and music. This book brings together some novel threads through this scene, from the viewpoint of researchers at the forefront of the sonic explorations empowered by electronic technology. The chapters provide accessible and insightful overviews of core topic areas and uncover some hitherto less publicised corners of worldwide movements. Recent areas of intense activity such as audiovisuals, live electronic music, interactivity and network music are actively promoted.

The Cambridge Companion to

Electronic Music

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Nick Collins (1975) is a lecturer in computer music at the University of Sussex, and has indulged in both mathematics and instrumental composition in the past. His interests run the gamut of topics in electronic music, but particular specialisms include algorithmic composition, live electronica, machine listening and interactive music systems. He occasionally tours the world as the non-Swedish half of the Swedish audiovisual laptop duo klipp av.

Nicolas Collins studied composition with Alvin Lucier, worked for many years with David Tudor, and has collaborated with soloists and ensembles around the world. He lived most of the 1990s in Europe, where he was Visiting Artistic Director of Stichting STEIM (Amsterdam), and a DAAD composer-in-residence in Berlin. He is a Professor in the Department of Sound at the School of the Art Institute of Chicago, and Editor-in-Chief of the Leonardo Music Journal. Recent recordings are available on PlateLunch, Periplum and Apestaartje. His book, *Handmade Electronic Music – The Art of Hardware Hacking*, was published by Routledge in 2006.

Julio d'Escriván is a composer who uses music technology, both for concert music, and in its applications to the moving image. He has twice won prizes at the International Electroacoustic Music Competition of Bourges, France. His electroacoustic music has been recorded, broadcast and performed in Europe and the Americas. He has worked extensively in music for TV advertising, documentaries and film with

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Karlheinz Essl was born in 1960 in Vienna. Austrian composer, improviser and performer. He studied composition with Friedrich Čerha and musicology at the University of Vienna (doctorate 1989, with a thesis on Anton Webern). Besides writing experimental instrumental music, he performs on his own computer-based electronic instrument, develops algorithmic composition software and creates generative sound and video environments. From 1990–4 he was composer-in-residence at the Darmstadt summer courses, and from 1992–3 he worked as a commissioned composer at IRCAM/Paris. In the period 1995–2006 he taught 'algorithmic composition' at the Bruckner-University in Linz. In 2007 he will become professor of composition at the University of Music and Performing Arts in Vienna.

Andrew Hugill (1957) is Director of the Institute Of Creative Technologies (IOCT) at De Montfort University, Leicester. 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. Hugill's compositions have been performed and broadcast worldwide. *Symphony for Cornwall* (1999) used the internet in a ground-breaking way. Hugill's research is wide ranging and includes 'pataphysics, which is rooted in French literature. He is an Associate Researcher of the Université de Paris, Sorbonne, and his 2006 CD and booklet entitled *'Pataphysics* has received rave reviews in almost every European language.

Sergi Jordà (1961), digital luthier (*FMOL*, *reacTable* . . .) and improviser, likes to invent new digital musical instruments without forgetting to make music with them. His music has been released on various labels and compilations (Hazard Records, SGAE, MIT Press . . .), he has composed for different instrumental setups (including a brass band) and for films, but he prefers the immediacy and volatility of free improvisation. During the 1990s, he worked extensively in performances and installations in collaboration with other artists (La Fura dels Baus, Marcel.lí Antúnez . . .). He holds a Ph.D. in digital communication and is a researcher of the Music Technology Group of the Pompeu Fabra University, where he teaches computer music, audio programming, HCI and interactive media arts. He has written many articles and two books, and has given workshops, lectured and performed though Europe, Asia and America.

Julian Rohrhuber is a German artist and theorist, working in the fields of cultural theory, philosophy and media art. His art projects include installations and performances, film sound tracks, a system for interactive sound programming, and various collaborative and network art pieces. He currently works in a research project at the University of Cologne, and at the Academy of Media Arts Cologne, where he teaches algorithmic acoustics and works on art theory, programming and philosophy.

Margaret Anne Schedel is a composer and cellist specialising in the creation and performance of ferociously interactive media. While working towards a DMA in music composition at the University of Cincinnati, her thesis, an interactive multimedia opera, *A King Listens*, premiered at the Cincinnati Contemporary Arts Center. She is working towards a certificate in Deep Listening and serves as the

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Stefania Serafin is currently associate professor in sound modelling at Aalborg University in Copenhagen. She holds a Ph.D. in Computer Based Music Theory and Acoustics from CCRMA, Stanford University, and a Master in Acoustics, Signal Processing and Computer Science from IRCAM in Paris. She has been visiting researcher at Cambridge University, Stanford University and KTH in Stockholm, and visiting professor at the University of Virginia. Stefania has published her research on sound synthesis by physical models in the *Computer Music Journal*, the *Journal of New Music Research*, *Organised Sound*, and *IEEE Transactions of Speech and Audio Processing*, and she presents regularly at the International Computer Music Conference (ICMC), New Interfaces for Musical Expression (NIME), Digital Audio Effects (DAFX), and musical acoustics conferences.

Petri Toiviainen is a professor of music at the University of Jyväskylä, Finland, with a specialisation in music cognition. He has published numerous articles on computational modelling of music perception and cognition. Currently his research focuses on computational music analysis, music and movement, and modelling of musical emotions. He is the head of the Finnish Centre of Excellence in Interdisciplinary Music Research, located at the Universities of Jyväskylä and Helsinki.

Ge Wang received his B.Sc. in computer science from Duke University in 2000 and is a Ph.D. candidate studying with Perry Cook in Computer Science at Princeton University. Ge conducts research in computer music languages, interactive systems for sound synthesis/analysis and musical composition/performance, visualisation of sound, interface design, new performance ensembles (e.g. the Princeton Laptop Orchestra), live coding, and methodologies for education in computer science, computer music, and new media. Ge also composes and performs via various electroacoustic and computer-mediated means.

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Chronology

569–475 BC	Pythagoras leads the elitist *mathematikoi* and *akousmatikoi*
1026	Guido d'Arezzo's vowel-to-pitch mapping procedure for composing melodies for texts
1626	Francis Bacon describes the 'sound-house' in *The New Atlantis*
1734	Louis Bertrand Castel builds a prototype *clavecin oculaire*, the first light organ
1738	Jacques de Vaucanson's flautist automaton is exhibited
1757	Johann Philipp Kirnberger's *Allezeit fertiger Polonoisen und Menuettencomponist* ('The always ready Polonaise and Menuet Composer'), a musical dice game
1761	Jean-Baptiste Delaborde builds the *Claveçin Electrique* in Paris
1843	Lady Lovelace describes the possible musical applications for Charles Babbage's machine in *The Sketch of the Analytical Engine* A. Seebeck formulates the *rate theory* which states that neural firing patterns encode the periodic structure of auditory stimuli
1857	Leon Scott invents the *phonoautograph*
1864	Innocenzo Manzetti invents a 'speaking telegraph' for his musical automaton
1876	Alexander Bell's (controversial) telephone patent Thomas Edison invents the carbon microphone
1877	Co-invention by Charles Cros and Thomas Edison of the phonograph Ernst Werner von Siemens invents the loudspeaker
1898	Valdemar Poulson patents a magnetic *Telegraphone*, which can both record and play back sound
1899	William Duddell invents the *Singing Arc*
1897	Thaddeus Cahill patents the *Art of and Apparatus for Generating and Distributing Music Electronically*
1906	Cahill finally builds the Telharmonium Lee De Forest invents the triode vacuum tube (which he calls the *Audion*), allowing controlled amplification; ironically, Cahill could have used this invention to make the Telharmonium much smaller!
1909	The Tel-musici Company combine a telephone exchange with a music room; they are bankrupt within a few years, just like Cahill
1913	Luigi Russolo writes his manifesto *The Art of Noises*
1919	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
	Maurice Martenot invents the *Ondes Martenot*
1929	Friedrich Trautwein invents the *Trautonium*
1931	First electroacoustic montage is created by the sound department of Paramount Studios in Hollywood, for the film *Jekyll and Hyde*
1932	In Oskar Fischinger's film, *Tönende Ornamente* (Ornament Sound), the soundtrack is created by drawing directly onto the optical soundtrack
1933	The theremin is used by composer Max Steiner to expand the timbral palette of the orchestra in the film *King Kong*
1936	Varèse publishes his manifesto *The Liberation of Sound*
1937	John Cage delivers his lecture *The Future of Music: CREDO*
1938	Orson Welles' *War of the Worlds* radio play successfully deceives its audience into believing a Martian invasion is taking place
1939	Cage begins working with live electronic sound in his piece *Imaginary Landscape No. 1*
1944	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 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 seule*, a landmark in musique concrète
	The Studio für Elektronische Musik at West German National Radio (WDR) is founded
	Percy Grainger invents the *Kangaroo Pouch Machine*
	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 concrète*
	Cage composes *Williams Mix*; 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 1957
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
	The BBC Radiophonic Workshop is founded
	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 1*, the earliest programming environment for sound synthesis
1958	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
	In Santiago de Chile, the Laboratorio de Acústica is used for the earliest electronic music work done in South America
	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	Andreij 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* (1967) 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 Tudor composes the first of his *Rainforest* pieces, featuring a multitude of objects acting as loudspeakers dangling directly from their cables 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's *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 synthesiser, being the first 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
	Walter 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
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
	DJ Kool Herc is experimenting with turntable mixing at parties in the Bronx
1974–9	Laurie Spiegel develops the *VAMPIRE* (Video And Music Program for Interactive Realtime Exploration/Experimentation) system
1975	Michel Waisvisz unleashes the Cracklebox synthesiser
	John Appleton produces the prototype for the Synclavier
1976	Denis Smalley writes *Darkness After Time's Colours*
1977	*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*
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
1981–8	Boulez works on *Répons*
1982	David Jaffe's *Silicon Valley Breakdown* utilises an extended version of Karplus-Strong synthesis
1983	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*
	Detroit Techno provides one historical strand amongst many of electronic dance music: Juan Atkins had been recording in the duo Cybotron since 1981, and influences included electronic, disco and funk artists such as Kraftwerk, Giorgio Moroder and Parliament
1984	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
	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
1985	Laurie Spiegel develops *Music Mouse*
	Paul Lansky's *Idle Chatter*
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	Public Enemy's album *Fear of a Black Planet* demonstrates the power of their sampled hiphop production allied to strong political messages
	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) is released commercially, becoming available to non-academic musicians
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
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
	Miller Puckette releases *Pure Data*, a freeware program with a similar environment to Max/MSP
1997	Coldcut release *Let Us Play*, an extended CD including the live AV sampling demo *Timber*
	Maurice Methot and Hector LaPlante start streaming algorithmic music live on the internet with *The Algorithmic Stream*
	Introduction of the *Open Sound Control* (OSC) network music connectivity protocol
	Ryoji Ikeda releases +/−
1998	Atau Tanaka and Kaspar Toeplitz install *Global String*, uniting space with cyberspace
	The gameboy *Nanoloop* sequencer is created by Oliver Wittchow
	Chris Watson releases *Outside the circle of fire*
2000	Tabletop tangible musical controllers such as *SmallFish* and *Jam-O-Drum* begin to develop; they would be followed by others such as the *reacTable* and the *Audiopad*
	Radiohead's *Kid A* openly assimilates electronica influences
2000–3000	Jem Finer's *LongPlayer* installation intends to run for a thousand years
2001	Chris Chafe's *Network Harp* uses network latency for sound synthesis

2002	*ChucK*, an audio synthesis programming language, is created by Ge Wang and Perry Cook The *Shazam* mobile phone-based automatic music track recognition service is launched
2004	The *Firebirds* installation by Paul de Marinis reignites the use of gas fire loudspeakers
2005	Nintendo and Toshio Iwai release the *Electroplankton* interactive musical video game
2006	The *Lara Croft: Tomb Raider Legend* game widely promotes adaptive audio techniques