A Brief History of Electronic Music

1: 1896-1945

> The first twenty-five years of the life of the archetypal modern artist, Pablo Picasso - who was born in 1881 - witnessed the foundation of twentieth century technology for war and peace alike: the recoil operated machine gun (1882), the first synthetic fibre (1883), the Parsons steam turbine (1884), coated photographic paper (1885), the Tesla electric motor, the Kodak box camera and the Dunlop pneumatic tyre (1888), cordite (1889), the Diesel engine (1892), the Ford car (1893), the cinematograph and the gramophone disc (1894). In 1895, Roentgen discovered X-rays, Marconi invented radio telegraphy, the Lumiere brothers developed the movie camera, the Russian Konstantin Tsiolkovsky first enunciated the principle of rocket drive, and Freud published his fundamental studies on hysteria. And so it went: the discovery of radium, the magnetic recording of sound, the first voice radio transmissions, the Wright brothers first powered flight (1903), and the annus mirabilis of theoretical physics, 1905, in which Albert Einstein formulated the Special Theory of Relativity, the photon theory of light, and ushered in the nuclear age with the climactic formula of his law of mass-energy equivalence, E = mc2. One did not need to be a scientist to sense the magnitude of such changes. They amounted to the greatest alteration of man's view of the universe since Isaac Newton.
>
> - Robert Hughes (1981)

In 1896 Thaddeus Cahill patented an electrically based sound generation system. It used the principle of additive tone synthesis, individual tones being built up from fundamentals and overtones generated by huge dynamos. Unbelievably huge: the second version of the instrument weighed 200 tons and was 60 feet in length. It had a conventional piano-type keyboard and was even polyphonic. First publicly demonstrated in 1906, this remarkable machine became known as the *Dynamophone* or *Telharmonium*. Cahill's vision was to sell production models of the machine to all the large cities in America, and to have concerts of 'Telharmony' broadcast into homes, hotels, theatres, and restaurants via the telephone networks. Needless to say cost, and the fact that it actually interfered with the normal workings of the network, meant that this grandiose scheme never came to fruition.

One of the geared shafts.

The twin-manual keyboard in a hotel lobby.

Although conceptually very advanced, the Telharmonium was already old technology: in 1907 Lee de Forest invented the vacuum tube. It primarily provided a compact means of generating continuous radio waves and of amplifying and detecting radio signals, but by extension also solved the problem of producing, amplifying, and processing all sorts of signals. 1907 also saw the publication of Busoni's influential *Sketch of a New Aesthetic of Music*, which whilst it does not specifically refer to the production of music by electronic or mechanical means, exhorts modern composers to take the next step into "abstract sound, to unhampered technique, to unlimited tonal material".

In 1910 the Futurist Balilla Pratella published *The Technical Manifesto of Futurist Music*, a clarion call to the composer as city dweller, openly embracing the machine age and all its implications. Their work, he said, should reflect "the musical soul of crowds, of great industrial plants, of trains, of transatlantic liners, of armoured warships, of automobiles, of aeroplanes". Whilst the Futurist romanticisation of war has rightly always been criticised, they nonetheless caught the spirit of the age with their frenetic and breathless art. In 1912 another Futurist Luigi Russolo published *The Art of Noises*, a somewhat more considered and technically informed text than Pratella's, following it up in 1914 with what was possibly the first successful performance of absolute 'new music' at the Teatro dal Verne in Milan.

Partly because of the influx of Europeans, and partly because it had escaped the mass destruction of the First World War, the focus of development shifted to America. In 1924, Russian physicist cum instrument designer cum virtuoso violinist Leon Theremin demonstrated his new invention, variously known as the Aetherphone, Thereminvox, or more usually, simply the Theremin. A direct result of vacuum tube technology, the instrument remains unique in that it is played without being touched! It has two antennae that propagate low-power, highfrequency electromagnetic fields. Each field may be altered by the performer moving their hands within it. These alterations are then amplified and used to control the pitch and volume of sounds generated using a beat-frequency or heterodyning oscillator. (The difference between two supersonic frequencies creates the audio). The pitch antenna is a straight rod on the right side of the console, whilst the volume antenna curves like a shepherds crook and projects horizontally on the left. From this brief description it is obvious that the instrument needs performers of extreme skill and a very good ear for pitch, as there are no physical guides like frets or keys. It is probably this factor that limited the widespread use of the Theremin, along with the lack of original material for it. Having said that, the instrument is now available again with digital control and a decent MIDI spec from Bob Moog's company, Big Briar!

Leon Theremin

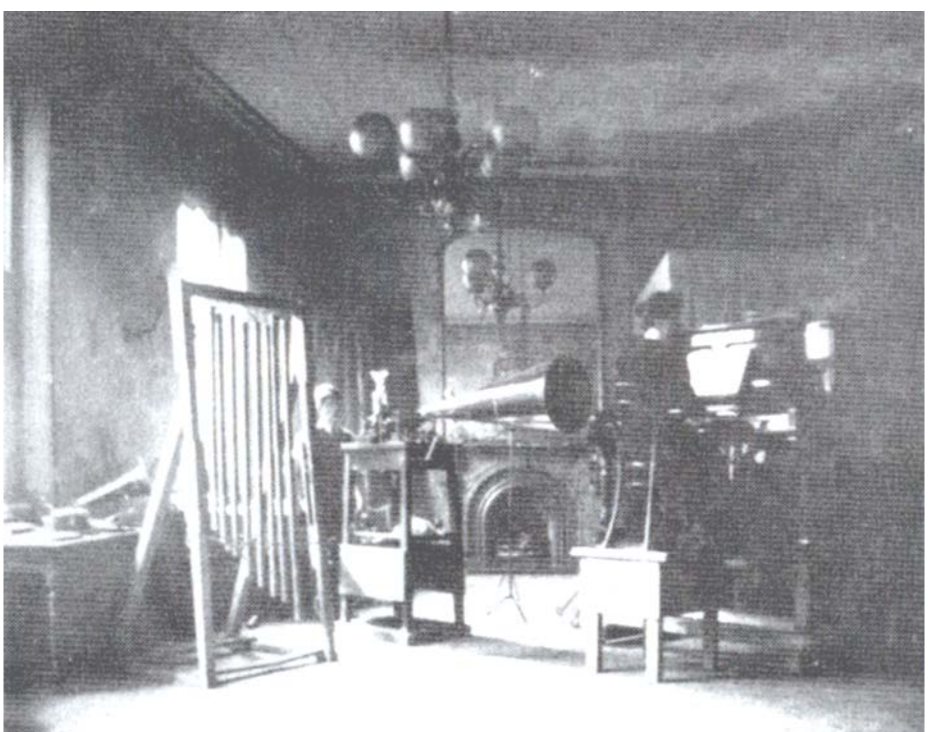
The twenties and thirties saw a number of other, largely unsuccessful, instruments being built: the Ondes Martinot, Dynaphone, Trautonium, Warbo Formant Organ, Spharophon, and Givelet. Typically these were conventional keyboard type machines with a limited tonal repertory based around additive synthesis principles via sine wave generation, although some (such as the Warbo Formant Organ) did allow for reasonably complex filtering. The Givelet was unusual in that it combined electronic sound production with control by pre-punched tape. Oscar Vierling's Electrochord and the Miessner piano used strings to produce sounds, with movable capacitor pickups allowing tonal variation.

Significant progress was being made in other quarters. Electrical recording, gramophones, and radio had all developed hand in hand. In 1935 the German company AEG produced the Magnetophon, the first modern tape recorder. Although still of relatively poor quality, it used plastic tape coated with ferrous particles as its recording medium. This was a vast improvement over the steel tape used previously: it could be cut and therefore edited, it was much lighter, and much safer. (Breakages of steel tape were notoriously hazardous.) In America Dudley Homer at Bell Labs developed the Voder, and then the Vocoder in 1936. These were offshoots from the telecommunications industry, Bell Labs being the research arm of the American Telephone and Telegraph company (AT&T). What the Vocoder did was to analyse speech sounds using an array of bandpass filters, and then generate a series of control voltages from envelope followers. The idea was that it would be these control voltages that would be transmitted, rather than the speech itself, and these would then be decoded at the receiving end. Because these control signals had a much lower bandwidth than speech, it was hoped the system would greatly increase effective channel capacity. Although of only limited use in a purely musical sense, the importance of this work lies in its relation to acoustics and psychoacoustics, information theory and sampling theory, all just around the corner...

2: Microphones and the Development of Electrical Recording

The word *microphone* first appears as early as 1827 in Wheatstone's description of an acoustic device: this type of 'loose contact' carbon microphone was used in 1877 by Berliner and 1888 by Hughes. The principle is non-magnetic: the diaphragm has a cavity behind it which is filled with conductive carbon granules, and as the diaphragm vibrates it alternately compresses and releases them. This varies their resistance and the speech signal is modulated onto a DC current supplied by a battery. It became the standard microphone type within telephones throughout the 20th Century.

Alexander Graham Bell devised another microphone type that was included in his 1876 patent for a 'speaking telegraph' (ie a telephone). This *moving armature* transducer was initially used as both a microphone and speaker, but proved to be too insensitive. An improved magnetic transducer became, in turn, the standard type of telephone earpiece.



First ever recording studio in London (31 Maiden Lane) in 1898

The sound quality of these microphones was very poor, and it was not until the spread of radio broadcasting throughout the 1920s that improvements in frequency response, dynamic range, and noise performance were considered necessary. Recording itself was done *Acoustically* (Borwick 1990):

> Sound recording in the pre-radio valve days had no use for microphones. The sounds were simply picked up acoustically by a large horn having a diaphragm at the apex to which the disc-cutting stylus was attached. The vibratory energy thus received was enough to inscribe the waveform as a spiralling groove on the rotating soft-wax master.

Although Wente had been experimenting with a type of microphone we would now call a *piezzo-electric* or *electret* device (a condenser with pre-polarised diaphragms) as early as 1917, the first electrical recordings did not appear until 1925. This was pioneered by US telephone company Western Electric. Recording pioneer Fred Gaisberg wrote (Moore 1999):

> The inadequacy of the accompaniments to the lovely vocal records made in the Acoustic Age was their great weakness. There was no pretence of using the composer's score; we had to arrange it for wind instruments largely […] and all nuances (such as *pianissimo* effects) were omitted…
> Acoustically recorded sound had reached the limit of progress. The top frequencies were C3 (2088Hz) and the low remained at E (164Hz). Voices and instruments (especially stringed instruments) were rigidly confined within these boundaries….

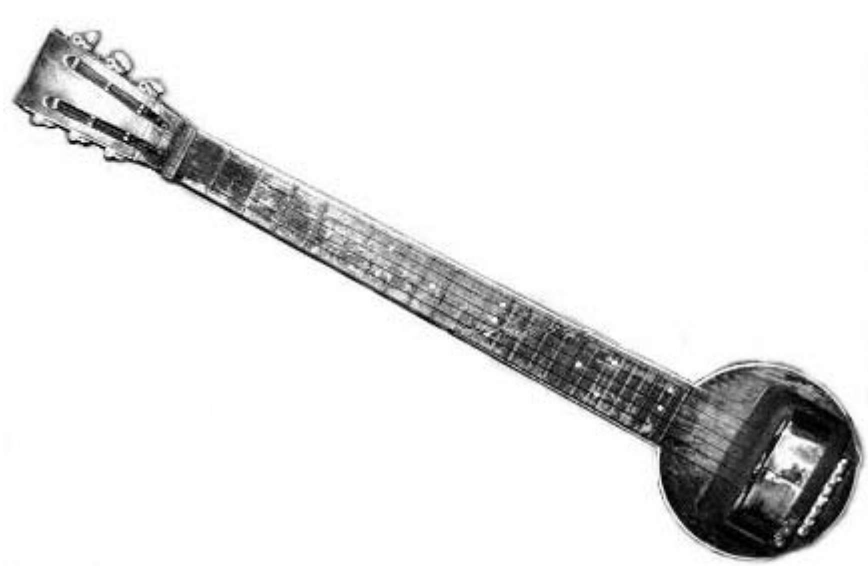
Even so, the performance of the microphones used was still quite poor by modern standards, and it was not until the 1930s that recognisable moving-coil, ribbon, and condenser microphones began to be manufactured.

No discussion of this subject can be complete without some mention of Alan Blumlein. Working for the Edison-owned Columbia in the UK during the late 1920s and early 1930s, Blumlein invented and filed the patents for many of the fundamental recording technologies used throughout the latter half of the 20th Century: advances in moving-coil microphone technologies; moving-coil cutting lathes; various types of stereo microphone techniques (Binaural, Coincident crossed pairs, and Middle-and-Side); and the invention of a working stereo cutting lathe.

3: The Electric Guitar

There are several people who claim to have invented the first electric guitar. Who you believe largely depends on your definition of what constitutes a guitar. Electric banjo's and Hawaiian guitars were already in production by the mid-1920s; Gibson had a prototype electric guitar as early as 1924; some sources claim Stromber-Voisinet had an electric guitar in production by 1928; and at around this same time Paul H. Tutmarc was building and selling hand-made electric guitars, basses, zithers, and pedal-steel guitars.

However, according to a Paul Williams article on the Museum of Making Music website the credit must go to George Beauchamp (working with Paul Barth). The reason Williams definitively attributes the invention of the guitar to them is that they invented what we would recognise today as the modern pickup with a separate pole-piece for each string. Other than that, the instrument has actually little in common with any electric guitar we know today, not least of the reasons being that the 'Frying Pan' has a banjo-like body made from cast aluminium:



The 'Frying Pan'.

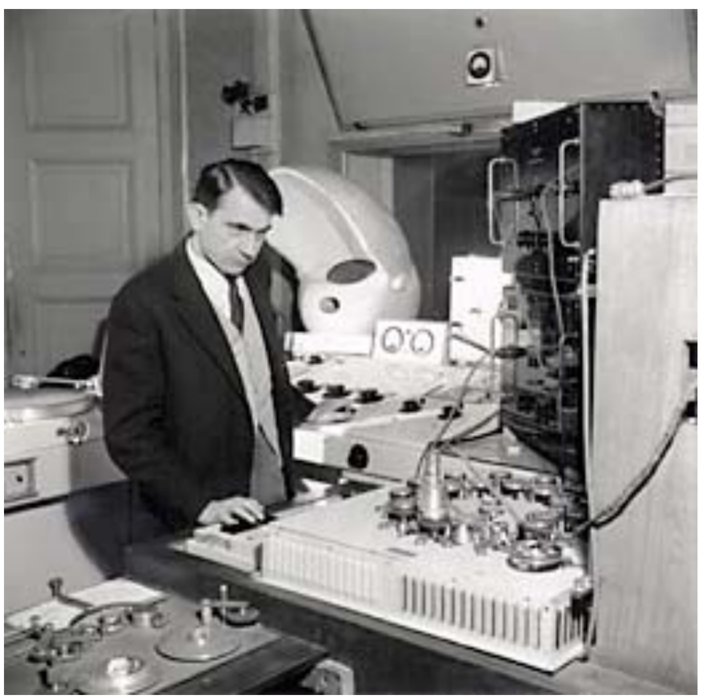
They were manufactured by the Rickenbacker company and marketed under that name. Production apparently continued into the 1950s. However, by then solid-body electric guitars (invented by Les Paul in 1941) and functional semi-acoustic guitars were being manufactured in large numbers by Gibson, Epiphone, and others.

4: Europe 1945-1958

World War II had in itself been a spur to technological innovation: much progress had been made with radio and radar, von Neumann and Turing were laying the foundations of modern computing, and of course the atomic age had been born. In Europe, rebuilding was the order of the day.

Pierre Schaeffer was an electronics engineer who had risen through the ranks at Radiodiffusion Television Francaise (RTF) in Paris. As early as 1942 he had persuaded the corporation to support research into musical acoustics. Inspired somewhat by the Futurists, Schaeffer developed the technique of recording naturally produced sound events, and in 1948 embarked upon a series of compositions using these sound events as source material. Hence the music of the 'Paris School' came to be known as *Musique Concrete,* and the recorded sounds came to be known as *Objets Sonores.* On a theoretical level, concrete can be taken to represent the opposite of abstract. To make a parallel with painting, we could say that a typical Mondrian or Kandinsky was totally abstract. A Cezanne landscape or Matisse interior, on the other hand, could be likened to *objets sonores:* whilst they do not directly represent the real world, they are nonetheless deliberately derived from it, but transformed by the painter into something unique, personal, and only 'of itself'.

Recording equipment consisted initially of direct-to-disc cutting lathes. Schaeffer experimented with removing attack portions of sounds by manually manipulating a volume control between the microphone and the recorder, simply not recording them. He played discs backwards and at differing speeds, re-recording the results onto another disc. With the arrival in 1951 of tape machines and a brand new studio, new techniques were developed. The *Morphophone* was an early tape echo machine, with a row of twelve playback heads instead of the usual one. Two other machines, called *Phonogènes*, were designed to play back pre-recorded tapes at different speeds; one had a continuously variable pitch range, the other was controlled by a conventional keyboard. Some experiments were also carried out with sound diffusion, using a sound projection aid called the *potentiometre d'éspace.* This would be used to manually control the movement of one channel of audio on a five-track tape. The other four tracks were each sent to one of four loudspeakers. It is interesting to note here that rather than providing 'surround sound' in the arrangement we know as quadraphonic, one of the speakers was placed on the ceiling, allowing the illusion of vertical as well as horizontal movement to be created.



Pierre Schaeffer in 1952 playing the *phonogène à clavier*, a tape recorder with its speed altered by playing any of twelve keys on a keyboard.

Meanwhile in 1948 Dr. Werner Meyer-Eppler, then director of the Phonetics Department at Bonn University, was visited by Homer Dudley and given a demonstration of the Vocoder. Suitably impressed, he used the machine in the creation of a tape illustrating a lecture on electronic sound production. In attendance was Robert Beyer of North-West German Radio.The pair struck up a relationship, with Meyer-Eppler the theoretician and Beyer the technician. They were joined by another influential figure in Germany at that time, Herbert Eimert, a radio producer for West German Radio (WDR) in Cologne, music critic, and composer. It was he who was instrumental in WDR broadcasting 'The Sound World of Electronic Music' in October 1951. The programme featured a discussion and tapes of sounds 'constructed' by overdubbing the simple tones generated by a Melochord (designed by American Harald Bode). On the same day WDR agreed to establish an electronic music studio for them. In 1953 Karlheinz Stockhausen joined the studio.

The whole approach to the creation of sound and of composing was radically different than the Paris School: in fact, initially, they were diametrically opposed. Whereas Schaeffer was taking complex sounds and transforming them, the Cologne studio affected a 'Year Zero' approach. Complex sounds were laboriously built up by overdubbing simple tones, initially using only the most basic equipment: tape machines; a single sine oscillator; a white noise generator; filters; and later, reverberation. Stockhausen describes one such process during the production of *Gesang der Junglinge,* quoted in Kurtz (1992):

> I invented completely different processes in which the three of us - myself and two musical and technical collaborators - each used a different piece of equipment. One of us had a pulse generator, the second a feedback filter whose width could be continuously changed and the third a volume control (potentiometer). I drew graphic representations of the processual forms. In one such form, lasting twenty seconds, for example, the first of us would alter the pulse speed, say from three to fourteen pulses per second, following a zigzag curve; the second would change the pitch curve of the feedback filter, in accordance with another graphic pattern; and the third - using yet another graphic - would change the dynamic curve. [...] So we sat down to realise one of these processual forms, one of us would count 3, 2, 1, 0, then off we went. The stopwatch was running, and at the end of twenty seconds each of us had to be finished.

This exact method of sound synthesis was also applied to composition. Eimert based his compositions on measure and number; Meyer-Eppler proposed statistical compositional techniques derived from information theory, and in his classes students were encouraged to create texts using cards, lotteries, roulette, or telephone directory numbers! Underlying it all were the serial techniques of Schoenberg and, especially influential at this time, Webern.

Although the Paris and Cologne schools started out from opposed positions, as time went on the hardline stances were softened until a 1967 piece like Stockhausen's *Hymnen* is using all available techniques regardless of their origin. From being a primarily studio bound medium many experiments were carried out with mixed live and electronic performances, sound diffusion scores, and aleatory performance scores. As the 1950's progressed many more studios were started: in 1955 the Studio di Fonologia Audizioni Italiane in Milan; in 1956

Japanese Radio (NHK) in Tokyo; 1957 saw new studios in Warsaw, Munich (Siemens), and Eindhoven (Philips). A studio in Stockholm and the BBC's Radiophonic Workshop in London followed in 1958.

A final word on French composer Edgard Varése. A unique and uncompromising personality, his work is at once typically modern and yet completely distinct from any movement or school. His work in the twenties used conventional orchestral resources (often scoring unorthodox playing techniques in order to coax new sounds from traditional instruments, and then adding sirens and a whole scrapyard of drums and percussion), culminating in *Ionisation* of 1931: percussion as pure sound. For the next twenty years he composed virtually nothing, desperately trying to find the money to build his own studio: he even approached one of the Hollywood film companies. By the 1950's everyone had caught up with him and he started composing again; *Deserts* of 1951-54 for orchestra and prepared tapes; and finally *Poéme Electronique,* an all-tape piece commissioned by Le Corbusier for the Philips Pavilion at the Brussels World Fair of 1958. One of the great men of modern music.

5: America 1945-1981

The musical climate in America was very different from that in Europe. The war years had seen another influx of intellectuals and artists into the country with Stravinsky, Schoenberg, Bartok, Hindemith, Milhaud, Krenek, Martinu, and Varése being the most prominent names amongst the composers. Perhaps the most profound effect of this was that it left a vacuum behind in Europe, which, as we have seen, sucked into it the most adventurous and forward-looking of the new composers and theoreticians, now unhindered by the weight of tradition. This European tradition now took root in the Universities of America, and it meant that for a long time the established music departments had relatively little to do with the emergent new electronic musical forms: that was left to the scientists.

Unfortunately, because America did not have a state-sponsored radio network it meant that support for electronic music studios was hard to find. The only notable exception was Louis and Bebe Barron who had opened a studio in New Yorkin 1948 where people such as John Cage and Morton Feldman became involved in a short-lived project called *Music for Magnetic Tape*. Varése re-worked the tape sections for *Deserts* here, but the studio is probably most famous for the film soundtrack to *Forbidden Planet* (1956).

The only place that had enjoyed consistently supported research into the applications of electronics in music was Bell Labs, the research arm of AT&T. The technological influence of the scientists at Bell Labs cannot be underestimated. By 1945, Harry Nyquist had already outlined sampling theory. In 1947 John Bardeen, Walter Brattain and William Shockley had invented the solid-state transistor, a contemporary 'inventing of the wheel' which would eventually allow a computer that had once been filled a room to be shrunken down to the size of a postage stamp. To put the cap on it, in 1948 Claude Shannon had published his seminal work on information theory, *The Mathematical Theory of Communication*. These developments would eventually lead to the computer becoming the primary means of communication and control across society as a whole.

Also in the late 1940s Les Paul had been busy perfecting a method of *sound on sound* overdubbing, recording direct-to-disc using home-built cutting lathes, custom-built EQ units, and of course his experimental electric guitars (an all-aluminium headless electric, for example). By 1957 he had built the first multitrack tape machine. Working with Ampex, he converted one of their 7-track military-use data recorders into an 8-track machine suitable for audio recording. Even though the Ampex 300-8 went on sale later that year at $11,000, it is interesting to note that these machines were very slow to enter into widepread use. The first album to be released that was completely recorded on 8-track was the Beach Boys *Pet Sounds* of 1967.

From 1951 through to 1959 Vladimir Ussachevsky and Otto Leuning had worked on various tape pieces without ever actually ever being able to secure enough funds to build a studio. However persistence won the day, and the Rockefeller foundation eventually provided $175,000 for the foundation of the Columbia-Princeton Electronic Music Centre. The system was to be based around the RCA synthesizer.
Started in the late 1940's, the RCA synthesizer was designed by two electronic engineers Harry F. Olson and Herbert Belar. Apparently inspired by Shannon's work, the machine was designed to generate compositions based upon statistical probability and to play them back (monophonically). The basis for the compositional system lay in the analysis of the statistical characteristics of Stephen Foster's folk songs. Based on vacuum tube technology, the machine generated sound via sets of tuned oscillators, filters, LFOs, and resonators: two control channels were available. Everything was controlled from a punched paper tape, which was manufactured via a typewriter-style keyboard. Each tape had 36 columns of information (=36 rows of holes), 18 for each control channel. Once running, electrical contacts were made between a brush and a drum through the punched holes. The machine had direct outputs to loudspeakers, and the results could be recorded onto a direct-to-disc cutting lathe. Version 2 (1959) had expanded voice facilities, now controlled by two synchronised paper tapes, and had a four-track tape machine instead of the cutting lathe:

Milton Babbitt at the RCA Mark II Electronic Music Synthesizer (1960).

As a synthesizer, the machine was very limited. As a compositional tool it was deeply flawed by the superficial level of the analysis of the songs, especially the rhythmic aspects. Inputting material was presumably laborious, definitely non-interactive: and like Cahill's Telharmonium in its own time, it was already a technological dinosaur. What is interesting about the machine is that it is the first 'music workstation', bundling sound manipulation, note (event) sequencing, and master recording, all into one centrally controlled unit. Great idea, shame about the music!

Meanwhile, back in Bell Labs, violin-playing electrical engineer Max Mathews was beginning what was to become the mainstream of the American new music. In 1957, using an IBM 704 valve computer, Mathews developed a program called MUSIC I: it generated an equilateral triangle waveform which was converted into audio by an Epsco 12-bit vacuum tube digital-to-analogue converter (DAC). The user could specify pitch, amplitude, and duration for each note. From this incredibly primitive beginning (it must have seemed amazing at the time…) Mathews quickly developed MUSIC II and then MUSIC III in 1960. MUSIC III was notable in that it was written for the first transistorised computer, the IBM 7094. It was also the first to introduce the concept of the unit generator. These were basic 'building blocks' corresponding to the functions now commonly associated with analogue synthesizers, such as oscillators, adders, noise generators, and attack generators: thus the user could build up their own 'orchestra', as Mathews termed it. The main problem associated with computer music was the vast amount of data that had to be input by the user to generate an event. In order to specify a particular sound at a sampling rate of 30kHz, for example, 30,000 numbers would have to be supplied every second to determine the pressure fluctuations alone. Multiply this by the number of other parameters that are needed for filters, LFO's, pitch changes, and the like, multiply it again for the number of voices used, and then multiply it again by the number of seconds that elapse whilst the piece plays… and all this had to be input from a QWERTY keyboard! Should there be any mistakes, or should the results not be quite what was intended, it would have to edited and re-computed. We are in deepest Truax territory: these are the ultimate in 'weak', general systems, where literally every last detail of a sound has to be determined and encoded. Unit generators were one way of alleviating the problem by having 'off the shelf' modules at the users disposal, making the system 'stronger' at the expense of some flexibility.

A whole range of other systems were developed on mainframe computers at Universities throughout America, almost all based on Mathews original model. In general the music that came out of these studios could be said to be primarily concerned with texture and timbre, having relatively few 'note-events'. Extensive research was carried out on the analysis and resynthesis of instrumental timbres, and later developments allowed the digital sampling of natural sounds using an analogue-to-digital converter (ADC), and at Stanford John Chowning developed a synthesis technique called Frequency Modulation (FM). As computer processing power increased so the systems became more sophisticated, allowing input from piano-type keyboards, graphic displays of information, cross-system portability, and easier programming.

A good example of a mature computer music piece is Mike McNabb's *Dreamsong,* realised at the Centre for Computer Research in Music and Acoustics (CCRMA) at Stanford. The piece took two years to complete, and employs techniques such as FM, sung vocal processing and resynthesis, and additive synthesis, with crowd and speech sounds processed by flanging, comb-filtering, Doppler shifting, and panning. The program used is MUS10, a descendant of Mathews' MUSIC IV, computed on a DEC KL-10 mainframe. Unit generators are still in evidence. The voice sounds were recorded digitally and analysed: in the finished piece the original recording and the resynthesised voice are both used. Stunning sonic transformation are made between bells and voices, voices and other purely synthetic sounds. There is a limited amount of harmonic material, but on the whole the piece flows organically (McNabb 1981):

> …from the real world to the dream realm of the imagination, with all that implies with regard to transitions, recurring elements, and the unexpected.

In 1964, Robert Moog presented a paper entitled *Voltage-Controlled Electronic Music Modules* at the annual convention of the Audio Engineering Society (AES). This became the blueprint for a whole new generation of relatively affordable, portable, synthesizers. The miniaturisation of the electronic components that had been made possible by transistors allowed Moog to develop the concept of a modular synthesis system. These modules could then be 'patched' together in user-determined combinations, the common link between them being control voltages (cv's). Very quickly other companies (Buchla, EMS, ARP) picked up on the idea, and for the first time electronic synthesis reached the general public. The machines were generally of two types: large systems which tended to have the keyboard and electronics separate, and modules which had to be physically patched together with leads; and much smaller machines with a hard-wired control flow and a $2\frac{1}{2}$ or 3 octave keyboard built in. An example of the former would be the Moog 3C; an example of the latter the MiniMoog. They were all monophonic, with non touch-sensitive keyboards; they tended to be unreliable; most had problems with oscillators drifting out of tune.

From a purist point of view, another problem could be that the mass production of these machines defeated the purpose of having a synthesizer. There were now studios and individuals the length and breadth of the country with identical machines: with mass production came the idea of manufacturers dictating a single design policy. In practice, the vast majority of commercial machines were subtractive synthesizers, using filters to remove harmonic material from relatively complex wave shapes such as sawtooth, square, and triangle.

Development of this type of 'analogue' synthesis, as it became commonly known, continued throughout the 1970's. The market came to be increasingly dominated by Japanese manufactured instruments. Synthesizers became polyphonic, and just as they were becoming unwieldy they developed digital control. This was primarily dependent upon multiplexing, yet another telecommunications spin-off that allowed a single processor to do lots of jobs (as opposed to lots of processors all doing one job each, which was far too costly). Digital control in its turn brought with it voice memories, stable oscillators, increased polyphony, and, eventually, digital communication: MIDI.

This is not to say that there was no common ground between the essentially academic/ scientific world of computer music and the increasingly 'pop'-oriented market of analogue synthesis. In 1970 our old friend Max Mathews developed GROOVE, a hybrid system consisting of a 'minicomputer' connected to and controlling an analogue synthesizer. What made it so interesting was that it was an attempt to solve the problems of performer interaction with a computer system. Compositions could be made in the normal way. What the system then encouraged the user to do was to play back the composition, at the same time recording performance gestures enacted via a joystick and rotary controllers. These performance gestures could then be edited if necessary, a process which was aided by a graphic display. The emphasis throughout was that of interaction.

Another interesting system was MUSYS III, developed in London by Peter Zinovieff using the profits made from his EMS company. The system used two PDP-8 computers controlling a bank of 252(!) oscillators, 64 band-pass filters, 12 tuneable filters, a white-noise generator, a percussion generator, 9 digitally controlled amps, envelope shapers, plus a whole array of manually controlled equipment like ring modulators, filters, and reverb units. Information could be input via a normal keyboard, QWERTY keyboard , or a special console with a 'spinwheel' that could be used to manipulate the sequencer register position. This incredible system was dismantled in 1979 through lack of funds, with only a handful of works having been completed on it.

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