Electronic Music Instruments

THE NATIONAL MUSEUM OF SCIENCE AND TECHNOLOGY is a place where visitors may take pleasure from observing and learning about the impact of technology and science on everyday life. The Museum's mandate is to reflect both the history and recent advances in the fields of physical science, communications, space, transportation, energy, industrial technology, agriculture and renewable resources, as well as the links between technology and society. It pursues this mandate through collecting, recording, researching and preserving a wide range of artifacts and information. This guide has been published in order to heighten the reader's appreciation of the Museum's collection of electronic music instruments, as well as to provide information on the Museum's purpose in collecting such materials.

COLLECTION PROFILE
NATIONAL MUSEUM OF SCIENCE & TECHNOLOGY

Overture, Themes and Variations

A large number of the electronic music instruments in the Museum's collection are the work of Hugh Le Caine, Canadian physicist, inventor, composer and pioneer in the design of electronic instruments. The collection also represents the work of other inventors, and instruments that were commercially manufactured. Together they show the changing context of music instruments from the early twentieth century.

Player Piano: Many electrical devices were developed as musical instruments, beginning in the 1890s when electricity became widely available for residential use. The player piano (820394)* and reproducing piano (690699), were among the first, and soon became popular in homes and entertainment establishments. They used electric motors with rolls of paper in which holes were punched to control the piano's keyboard. When a hole passed the sensing mechanism, the corresponding key of the piano was depressed. Each roll contained the information needed for one piece of music. Well-known musicians recorded their performances on these instruments and made their piano rolls available for sale. These instruments were among the first recording devices. Later designers built large groups of mechanically activated instruments, including stringed and percussion instruments. Although most piano rolls contained versions of popular songs, the instrument has also been used to facilitate original compositions in which the piano plays more notes, more quickly than would be possible for human players. The best known composer to use the player piano in this way is Conlon Nancarrow.

The player piano was not electronic, however. It simply controlled the action of a standard acoustic piano

*NOTE TO READERS: the numbers in brackets are the accession numbers of artifacts held by the Museum.

Hugh Le Caine demonstrating the prototype Touch-Sensitive Organ in 1954 (NRC photo)

mechanism. The sound was caused by the vibration of the piano strings producing sound waves which travelled through the air to the listeners' ears. When sound is generated electronically, similar sound waves are produced by vibrations of the loud speaker cones, which are created by electric currents and magnets. The current can come from a radio receiver, a playback device such as a tape player, compact disc (CD) player or phonograph, or from an electronic music instrument.

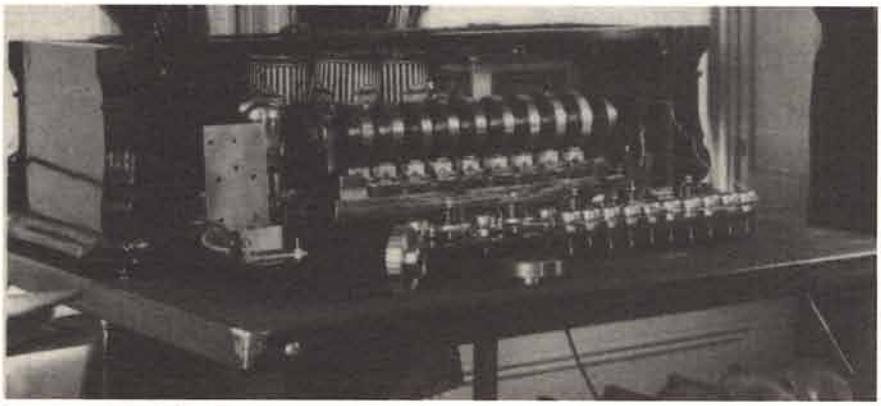
Telharmonium: Thaddeus Cahill's Telharmonium, which became operational in New York City in 1906, used early techniques for sound generation. It was a huge electromechanical installation operated by a musician playing piano-like keyboards and it required 1500 sound generators to be heard. With the invention of vacuum tubes a few years later, amplifiers and tone generators (or oscillators) were built. They were much simpler and smaller, and used much less electric power. They also produced louder sounds. These were the first devices to generate sound electronically and many inventors used them to produce new instruments.

Kanabe Ampico A reproducing piano, ca 1924 (690699)

Theremin: The best known instruments invented in the 1920s were the Ondes Martenot and the Theremin (710502), both of which are still in use. The Theremin has no keyboard. It is operated by changing the distance between the player's hands and two rods, without the musician touching the instrument. The positions of the musician's hands in space control pitch and volume. It is an exciting instrument, which requires great skill and produces an ethereal visual effect as the performer waves and flutters his or her hands in the air around the rods. The instrument was successfully manufactured by RCA in the U.S.A. This was an exciting period of exploration into new methods of sound generation and control.

Novachord: Closely following this period of innovation came the development of the electronic organ. It took advantage of new methods for producing sound, but it was designed to imitate the pipe organ, mainly used in larger churches, and the reed organ, which was found in many homes. In the mid 1930s the Hammond Organ Company began distribution of their electronic organ in Canada, and the instrument found a market in churches which lacked pipe organs, even though it was limited in its musical versatility. It soon also became popular in homes. The Hammond Novachord (770258, ca 1939) became the most common electronic organ and remained so for many years. Like earlier instruments its sound was generated by rotating tone wheels, amplified electronically.

The Theremin, manufactured by RCA, ca 1931 (710502)



Prototype of the Robb Wave Organ showing rotary sound wheels, ca 1927 (910484)

Robb Wave Organ: During this period other inventors were working on electronic keyboard instruments, including Morse Robb of Belleville, Ontario. The Robb Wave Organ (910484) was reputed to be musically superior to the Hammond Organ. This instrument was designed to reproduce the sound of a cathedral pipe organ by amplifying sounds generated by a series of rotating metal cylinders. The Robb Wave Organ came on the market in 1936 and remained available until 1941. A newspaper article on the organ — printed almost ten years before it became available — was headlined: "Young Canadian Invents Pipeless Ethereal Organ" (*Toronto Star*, 1927). The Robb Wave Organ was more expensive than other electronic organs, and sales failed to increase during the depression and the Second World War. The company ceased operation in 1941 with only thirteen units sold; none survive except for those parts preserved by the Museum from Mr. Robb's workshop.

Solovox: Production of the Solovox keyboard (850547) by Hammond began in 1940. It was manufactured in Canada under licence by the Northern Electric Company of Belleville, Ontario. The Solovox is a three-octave monophonic keyboard which produced only one note at a time, using one of twelve pre-set timbres, or tone colours. It was designed specifically to be attached beneath the keyboard of a standard piano, providing the piano with a second manual, like an organ. A musician could play one keyboard with each hand, using the Solovox to produce sustained sounds, in contrast to those of the piano which rapidly fade in volume.

The last model of the Touch-Sensitive Organ, 1956 (940105)

Le Caine: Allegro Con brio

The synthesizer has become known as a fairly small electronic keyboard instrument that can be used in performance or in an electronic music studio. In the late 1960s and throughout the 1970s the voltage-controlled analogue synthesizer was standard; now the digital synthesizer has taken its place. But the history of the synthesizer begins before this.

Sackbut: In 1945, Hugh Le Caine, of Ottawa, began developing another electronic keyboard instrument, the Electronic Sackbut (750336). Le Caine was familiar with Morse Robb's Wave Organ and the Hammond Organ, and had earlier built a touch-sensitive electronic reed organ while at Queen's University in Kingston. In the 1950s he built a touch-sensitive electronic organ (940105). Le Caine's Sackbut, however, used an entirely different method of sound generation and control, a method that later became the standard approach in electronic music—voltage control. This technique provides an automatic background voltage that can remain stable or change according to the needs of the user. The performer's physical actions, in changing the positions of keys or knobs, are translated into changes in the pre-existing voltage, and in turn are used to affect many different aspects of the sound produced by the instrument. This technique provides a wider range of possibilities to both the instrument designer and the performer. Because it was the first to incorporate this technique, the Sackbut is considered to have been the first synthesizer, even though in some ways earlier instruments, including the electronic organ, could be considered to be synthesizers. The term "synthesize," was first used in 1959 in relation

to the RCA Synthesizer, a room-sized studio installation in New York.

In designing the Sackbut, Le Caine adapted technologies already familiar in atomic physics, radar, and radio technology, all areas in which he had worked at Queen's University and at the National Research Council (NRC) in Ottawa where he was a scientist. Le Caine used devices such as waveform generators, signal filters, frequency modulators, and amplitude modulators, to transpose waveforms into auditable sound.

The Sackbut was a monophonic instrument, producing only one note at a time, but its systems for control of that one sound were extraordinary. The keyboard was sensitive to vertical pressure, so that alterations in pressure produced changes in volume. It was also laterally sensitive, so that side-to-side motion produced changes in the pitch of the sound. The Sackbut also had an innovative waveform control device that could be operated by one hand while the other played the keyboard. Using this device a musician could continuously change four different aspects of the timbre or texture of the sound. This ability to gradually change from one sound to another was an important feature of the instrument. It enabled the player to avoid the sudden switching between separate types of sound that characterized electronic organs. For Le Caine, these controls contributed to the "expressivity" of the instrument, something he felt other electronic instruments lacked.

The first Sackbut was operational by 1945, and completed in 1948. In 1954, when Le Caine first began to work on electronic music at NRC, it was brought there for further development. This is the only model that survives of the four versions of the Sackbut. A second model was built at the NRC labs between 1954 and 1960; two more models were built there between 1969 and 1973 in an attempt to make the instrument available commercially as a synthesizer. Even though the instrument was never manufactured, due to circumstances not that different from those affecting the Robb Wave Organ, it did pioneer several techniques later used in the voltage-controlled (now called analogue) synthesizer.

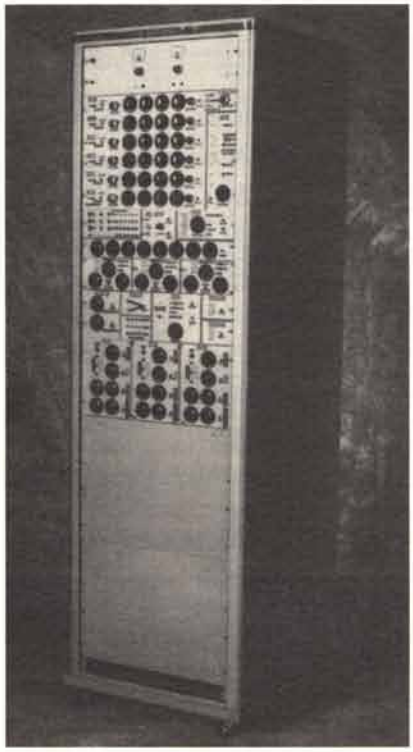
Polyphone: The Polyphone (860004), an analogue polyphonic synthesizer, was built by Le Caine's NRC lab in 1970, at the same time as the last two Sackbuts were being completed, and ten years before polyphonic synthesizers became a profitable component of the synthesizer market. It was built in consultation with Paul Pedersen of McGill University and was able to produce many sounds simultaneously. It had a touch-sensitive keyboard, each key with its own separate oscillator, pitch control, and wave form control. Essentially, it was a bank of 37 key-operated oscillators, able to produce 37 separately defined tones.

The instrument incorporated a pressure-sensitive pedal keyboard which controlled other aspects of the overall sound. However it was difficult to learn to play, a problem it shared with most synthesizers.

Work also began in another lab at NRC on one of the first computer music systems. John Chong was working with Le Caine on a new instrument, the Paramus (870023), that combined digital and analogue technology. These hybrid synthesizers became commercially available in the early 1980s. It combined the best of analogue and digital techniques, providing the more pleasant tone colour, stability and adaptability of the analogue technology and the memory and computation speed of the digital technology. The computer was used to control all the rhythmic and durational aspects to organize pitch material, and to control by graphic means the changing volumes and tone colours of the sounds. By 1973 when work stopped on the Paramus, one of its designers, Dave Rocheleau, had completed the design of a digital oscillator which could provide a high degree of stability and waveform flexibility.

Studio Études

Le Caine's keyboard synthesizers were intended for live performance and for studio composition in "electronic music." With the advent in the late 1940s of acetate-backed magnetic tape for recording, a new approach to the composition of music began to develop. Recorded sounds could now be altered by cutting the tape and re-attaching it in different configurations. Sounds could be layered, and electronically altered and then rerecorded. Compositions were produced by these techniques, and then played over speaker systems in concert without the involvement of performers. The site for this activity, resembling a laboratory because of the large amount of electronic equipment, became known as the Electronic Music Studio.



The Paramus, ca 1973 (870023)

There were two trends in this music in the 1950s: *electronic music*, in which sounds were generated by electronic devices such as oscillators, predominated in Germany, while *musique concrète*, which used sounds recorded on tape by microphones, predominated in France. Composers of both styles adapted the sounds for various contexts, using remarkably similar means, such as reverberation, mixing, changed playback speeds, and filtering. The end result, was always pre-recorded, and became known as "tape" music. In North America, composers tended to combine both methods.

Multi-track: The first instrument built by Le Caine for the studio was the special purpose tape recorder or "Multi-track" of 1955 (910219). Its sole purpose was to facilitate the *musique concrète* technique of changing the playback speed of recorded sound. Le Caine composed his landmark composition *Dripsody* in 1955 using the new Multi-track, and several other compositions followed. The studio instrument used keyboards which included many features of the Sackbut. One was used to control the changes in playback speed of the six reels (or loops) of two-channel tape which were playing simultaneously, and another to combine the resulting sounds into a single stereo output. Keyboards provided convenient and immediate methods of controlling the instrument as they could easily be operated by musicians and the pitch changes produced in the pre-recorded sounds exactly matched those of the standard keyboard; playing an octave on the keyboard would double (or halve) the playback speed and the sound would rise (or fall) by an octave.

The first Multi-track remained in Le Caine's lab at NRC until 1959 when it became the feature instrument of a new electronic music studio at the University of Toronto. This was the first such studio in Canada, and the second in North America. The new studio made the Multi-track available for use by many composers and had a broad impact on the development of electronic music because composers came from all over the world to work with it.

Later versions of the instrument added features such as improved mixers (operated by touch-sensitive keys), filters, lighted panels to show operation modes, and the ability to play up to ten stereo tapes; the instruments also became increasingly slick-looking and easier to operate. One (860005) was sent to a new studio at McGill University in Montreal in 1964; others were sent to Queen's University (870022), the University of Toronto (910220), and to a studio in Jerusalem. Requests for Multi-tracks were received from England and the U.S.A. but, again, the commercial manufacture of the instrument failed.

After the Electronic Music Studio opened at the University of Toronto, some elements of the Sackbut's control system were built (1962–65) as separate modules for use by composers in the studio. These included sine-wave generators (860003), ring modulators (860007), oscillators with adjustable filters (860011), envelope shapers (860012), function generators (860013), level control amplifiers, tone shifters and oscillator banks (910218). These facilitated the use of the *electronic music* method of sound generation. Most of the studio instruments could be used in combination with one another.

All of these instruments, or modules, were made available to composers at the university studios, and in some cases their presence directly influenced other designers of electronic instruments. One of these was Robert Moog, who often visited the Toronto studio and later designed the first commercially successful voltage-controlled synthesizer. It quickly became famous when Walter Carlos's *Switched-On Bach* recording was released in 1968.

Le Caine's Sackbut was "pre-patched," meaning that the electrical connections within the instrument could not be changed. Later voltage-controlled synthesizers were organized so that wires (or patch

cords) could be used to link the voltages to various modules within the instrument. This approach, which required some technical expertise, is less common today. It was related to the techniques used in electronic music studios where composers could experiment, for the first time, with the basic elements of sound and try new ideas. A great deal of excitement was generated by the studios, stimulating design of new equipment for this environment.

Hamograph: The hamograph (910217) was built at the University of Toronto studio in 1960 by its first director, Myron Schaeffer, in consultation with Le Caine. It was intended to automate the mixing of the six stereo output channels of the Multi-track.

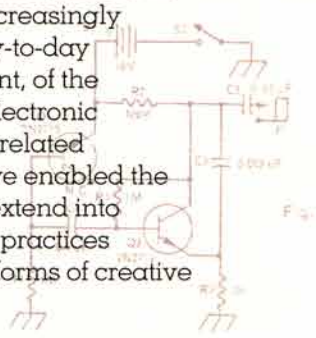
Spectrogram: The spectrogram (860006), built between 1959 and 1962, used a moving roll of graph paper to control a bank of oscillators. Sections of the paper which had been darkened by ink would trigger a photosensitive switch, and turn on the related sound generator automatically. It could be used to control several different instruments in the studio, such as a bank of tone generators, or the output of the Multi-track.

Sonde: The Sonde (860154) of 1968 used a relatively small number of electronic sound generators to produce 200 separate pitches, which were turned on and off by mechanical sliders. A second version of the sonde (910216) was built at the University of Toronto Electronic Music Studio between 1968 and 1970 following Le Caine's design, but this instrument was controlled by 200 printed circuit keys, also designed by Le Caine's lab, which activated each sound when the conductivity of the performer's finger completed the circuit.

The serial sound structure generator (e.g. 860008) was built between 1965 and 1970. It was a precursor of the sequencers which first became popular on analogue synthesizers, then on digital synthesizers. This instrument offered a much more comprehensive range of options than did smaller versions provided with synthesizers. It was able to repeat interlocking series of up to 13 pitches, and up to 13 durations, using varying timbres. It could be used in conjunction with other serial structure generators and with other instruments in the studio, including the Multi-track, and was intended to facilitate the serial, or twelve-tone, method of composition.

Electronic Continuo

Today many of the techniques used by these instruments have become commonplace. Equipment is very compact and affordable, and is used by musicians across a broad range of styles. The historical distinction between instruments for performance or studio use is now less important, yet large electronic music studios continue to stimulate a great deal of innovative activity in music composition and production, in teaching, and in research, making important contributions that have expanded our understanding of sound and music. We hear the results of this daily in the creative uses of sound on radio, TV, theatre, film and in concert, as sounds are sampled, altered electronically and played in new contexts and relationships. As our concepts of music expand to include sounds from many different sources, we are becoming increasingly aware of our day-to-day sonic environment, of the "soundscape." Electronic instruments and related technologies have enabled the role of sound to extend into interdisciplinary practices involving many forms of creative activity.



Gayle Young
Composer and author of The Sackbut Blues: Hugh Le Caine, Pioneer in Electronic Music.

Aussi en français sous le titre *Aperçu d'une collection : les instruments de musique électroniques.*

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