one must remember that the arts succeed where computers fail in elevating the human being in us all. The development of electronic music—itself a by-product of technology—exemplifies everything about being human that the arts can offer.

Chapter 1

WHAT IS ELECTRONIC MUSIC?

The field of music is full of uninformative labels and categories. Electronic music has not escaped this phenomenon. During the heyday of institutionalized electronic music in the '50s, even the founders of the music had difficulty agreeing on what to call it. Schaeffer and Henry called their combination of synthetic and natural sounds "musique concrète." Eimert and Stockhausen called their music of purely synthetic origins "elektronische Musik." Varèse called his combination of synthetic and processed natural sounds "organized sound." Luening and Ussachevsky called it "tape-music."

The situation is no less confusing today. Try and explain the differences between ambient, illbient, minimalism, new age, space music, electronica, techno, environmental, avant-garde, downtown (in New York), proto-techno, electro, Krautrock, world, dub, trance, house, acid house, rave, and just plain old electronic music. Most of these so-called genres exist as points on a single continuous spectrum of music that wouldn't be possible without electronics. Trying to define them any further than that is unhelpful.

I decided not to pigeonhole works of electronic music into those kinds of uninformative genres. Instead, it makes more sense to me to discuss the music from the standpoint of composition: the aesthetic and technological approaches used by a composer to work with the sound material. This requires an understanding of the technology that aids the composer, for in the field of electronic music the creative act is securely tethered to the equipment. A discussion of musique concrète must also be a part of a discussion of tape recorders, tape loops, and the kinds of sound manipulation that can take place because of tape editing. Other technology and approaches that drive the nature of a composer's work include process music, turntablism, and tools that can be used for real-time electronic music production in live performance. By discussing the music in this way I hope to acknowledge the unavoidable influence of technology on the composer while at the same time providing a framework within which different approaches to composition can be illuminated. It also allows for the easy grouping of works of similar conceptual and technical origins so that they can be compared and contrasted.

The stuff of electronic music is *electrically produced or modified sounds*. A synthesizer, sine wave generator, and a doorbell all use electrically produced sounds. An amplified violin connected to a wah-wah pedal, or a voice being embellished by electronic reverberation, are examples of ways to modify sounds.

This is perhaps as broad a definition as one can have of electronic music short of admitting that everything we listen to can be defined in this way. The lines are often blurred between sounds that originate from purely electronic sources and sounds from the real world that are synthetically modified. But I will use two basic definitions that will help put some of the historical discussion in its place: purely electronic music versus electroacoustic music.

Purely Electronic Music

Purely electronic music is created through the generation of sound waves by electrical means. This is done without the use of traditional musical instruments or of sounds found in nature, and is the domain of computers, synthesizers, and other technologies. It is the realm of programs, computer displays, and "virtual" instruments found in software.

Ensembles for Synthesizer (1961–63) by Milton Babbitt (b. 1916) is an example of purely electronic music. It is a twelve-tone piece exploring different "ensembles" of rapidly changing pitches, rhythms, and timbres. It was composed using the RCA Music Synthesizer at the Columbia-Princeton Electronic Music Center. *Switched-On Bach* (1968) by Wendy Carlos (b. 1939) is an example of purely electronic music in which Carlos performs keyboard music of Bach using only the Moog synthesizer.

Purely electronic music can be made through either *analog* or *digital* synthesis. The difference between the two merely lies in the way electricity is controlled. There are no aesthetic differences between the outcomes, and the listener will probably not be able to tell the difference.

In analog synthesis, composers work with continuous electrical current that is *analogous* to its corresponding sound waves. The sound begins as an electric current (alternating current, or AC). The vibrating pattern of the current can be controlled by the composer to create regular or irregular patterns. This current is then fed to an amplifier and loudspeakers, which convert the electrical oscillations into air pressure waves that can be detected by the ear. The resulting sound waves vibrate at the same rate as the electrical waves produced by the electrical sound source. The vibrations of the electric current are controlled by triggering devices such as rotating dials and piano-style keyboards. Analog sounds can be generated by something as simple as a buzzer or sound-wave oscillator, or by an instrument designed more specifically for musical applications such as an electric guitar or analog synthesizer.

Making sound digitally requires computer circuitry that can generate sound waves. Home computers, toys, digital synthesizers, and video games do this through the use of sound chips. Instead of working directly with the control of continuous electric current, a sound chip represents sound waves as binary information, coded into a series of "on" and "off" electrical pulses. This bitstream represents sounds using the same principles that a computer uses to represent numbers or letters of the alphabet. Different pitches are represented by different codes. Because human hearing is an analog process, digital signals must be converted to analog signals before they can be heard. To make the sound patterns audible, the computer converts the codes into an analog form of electrical current that can be amplified and used to operate a loudspeaker. This is done through what is called a digital-to-analog converter. Once the digital codes are converted into continuous electric current and fed to a speaker system, they sound the same as sounds produced through conventional analog means. The reverse process can be used to get analog sounds into a computer for digitization; they are converted using an analog-to-digital converter and then controlled by the computer.

The benefits of digitally generated sound synthesis are many. Like anything else that can be done on a computer, sounds can be controlled and organized with unprecedented ease, in comparison to the rigors of manipulating analog sounds on tape. Digital sounds can be cut and pasted, modified using special effects, made louder or softer, and structured to precise time measurements. Digital sound has the added benefit of being devoid of hiss and other audio artifacts of analog tape recording. The music that results can be copied directly to an audio CD for listening, storage, and distribution.

The term "synthesis" refers to the process of constructing sounds using electronic, or synthetic, means. The music synthesizer is a device designed to generate purely electronic sounds by analog or digital means. Prior to 1980, most commercially available synthesizers were analog.

Electroacoustic Music

Electroacoustic music uses electronics to modify sounds from the natural world. The entire spectrum of worldly sounds provides the source material for this music. This is the domain of microphones, tape recorders, and digital samplers.

The term "electroacoustic music" can be associated with live or recorded music. During live performance, natural sounds are modified in real time using electronics. The source of the sound can be anything from ambient noise to live musicians playing conventional instruments.

Cartridge Music (1960) by John Cage (1912–1992) is a work of electroacoustic music in which phono cartridges were used to amplify sounds that were otherwise nearly inaudible. *Rainforest IV* (1973) by David Tudor (1926–1996) used the amplified and processed sounds of vibrating objects freely suspended in the performing space. The sounds were amplified, filtered, mixed, and also recycled to make other objects vibrate.

The manipulation of recorded, naturally occurring sounds is the foundation of much electronic music. The classic art of composing electronic music using magnetic tape was not conceptually very different from what is called "digital sampling" today. The objective in each case is to capture sounds from the real world that can then be used, and possibly modified, by the composer.

The amplification of traditional musical instruments is a form of electroacoustic music, but for the purposes of this book such work only crosses the line into the realm of electronic music if the musician uses technology to modify the sound.

The interaction of live musicians playing electronically modified or processed acoustic instruments has been a popular approach with composers. In *Mikrophonie I* (1964) by Karlheinz Stockhausen (b. 1928), the sounds of a tam-tam are picked up by two microphones, amplified, and processed through electronic filters. *Wave Train* (1966) by David Behrman (b. 1937) which threw away all established techniques for playing the piano, consisted of controlled feedback caused by guitar pickups placed on the strings of a piano. *Superior Seven* (1992) by Robert Ashley (b. 1930) used real-time digital processing to extend and embellish the notes played by a flutist.

Electronic music exists *because* it is conceived and created with electronic instruments. Does this make it different from other kinds of music? Don't we listen to it with the same set of ears?

Aaron Copland observed that "we all listen to music, professionals and non-professional alike, in the same sort of way—in a dumb sort of way, really, because simple or sophisticated music attracts all of us, in the first instance, on the primordial level of sheer rhythmic and sonic appeal."[1]

As attractive as this observation is, I will argue that we listen to electronic music with different ears, and a different state of mind. One day this will not be the case. Our taste and perceptual constructs will evolve to the point where music of non-acoustic origins will be treated with the same objectivity as all other music, in Copland's "dumb sort of way." But today, hardly fifty years into the recorded medium of electronic music, we have barely been able to get past the technology and think only about the music. Composer-technicians are still most at home in this field. Anyone who composes with synthesizers, software, and computers knows very well that the technology of electronic music has not yet reached the "appliance" stage. When it does, the necessities of *composing* will preoccupy composers instead of the necessities of *mechanics*, the knowledge needed to push the correct buttons and plug in the correct components.

Electronic music is not entirely alien to us. It shares many characteristics with other music. It is emotionally charged and designed to absorb one's attention. Even the most colorless music, stripped of all ornamentation, is fraught with emotional implications. Charles Ives took the twelve-tone composers to task when he wrote, "Is not all music program music? Is not pure music, so called, representative in its essence? Is it not program music raised to the *n*th power, or, rather, reduced to the minus *n*th power? Where is the line to be drawn between the expression of subjective and objective emotion?"[2] The listening experience is psychological and fluid, moving forward incessantly, demanding that we take notice or miss out.

Seven Reasons Why Electronic Music Is Different

The sound resources available to electronic music are unlimited and can be constructed from scratch. One of the key differences between electronic music and music composed for traditional instruments is that *its sonic vistas are limitless and undefined.* The composer not only creates the music, but *composes* the very sounds themselves. Herbert Eimert (1897–1972), one of the founders of the Studio für Elektronische Musik in Cologne, expressed the innate potential of electronic music this way:

> The composer, in view of the fact that he is no longer operating within a strictly ordained tonal system, finds himself confronting a completely new situation. He sees himself commanding a realm of sound in which the musical material appears for the first time as a

> malleable continuum of every known and unknown, every conceivable and possible sound. This demands a way of thinking in new dimensions, a kind of mental adjustment to the thinking proper to the materials of electronic sound.[3]

Any imaginable sound is fair game. The composer can invent sounds that do not exist in nature or radically transform natural sounds into new instruments. For *Thema–Omaggio a Joyce* (1958), Luciano Berio (b. 1925) used tape manipulation to transform the spoken voice into a myriad of sound patterns eerily laced with the tonalities of human communication. In the piece *Luna* (from *Digital Moonscapes*, 1984), Wendy Carlos modeled a digital instrument whose voice could be modified in real time as it played a theme, metamorphosing from the sound of a violin to a clarinet to a trumpet and ending with a cello sound. This sound wasn't possible in the world outside of the computer, but became possible with her library of "real-world orchestral replicas" that the GDS and Synergy synthesizers allowed.[4] For *Beauty in the Beast* (1986), she took this experimentation a step further by "designing instrumental timbres that can't exist at all, extrapolated from the ones that do exist."*

Electronic music expands our perception of tonality. The accepted palette of musical sounds was extended in two directions. On one hand, the invention of new pitch systems became easier with electronic musical instruments. Microtonal music is more easily engineered by a composer who can subdivide an octave using software and a digital music keyboard than by a piano builder. On the other hand, electronic music stretched the concept of pitch in the opposite direction, toward less and less tonality and into the realm of noise. All sounds became equal, just another increment on the electromagnetic spectrum. Varèse sensed this early on and introduced controlled instances of noise in his instrumental and electronic music. Cage accepted the value of all sounds without question and let them be themselves:

> Noises are as useful to new music as so-called musical tones, for the simple reason that they are sounds. This decision alters the view of history, so that one is no longer concerned with tonality or atonality, Schoenberg or Stravinsky (the twelve tones or the twelve expressed as seven plus five), nor with consonance and dissonance, but rather with Edgard Varèse (1885–1965) who fathered forth noise into twentieth-century music. But it is clear that ways must be discovered that allow noises and tones to be just noises and tones, not exponents subservient to Varèse's imagination.[5]

Electronic music only exists in a state of actualization. Igor Stravinsky (1882–1971) wrote that "it is necessary to distinguish two moments, or rather two states of music: potential music and actual music. . . . It exists as a *score*, unrealized, and as a *performance*."[6] You will rarely find an electronic work that can be accurately transcribed and reproduced from sheet music. It does not exist as "potential music" except in the form of notes, instructions, and ideas made by the composer. Conventional musical notation is not practical for electronic music. You cannot study it as you would a piece of scored music. Experiencing electronic music is, by its nature, a part of its actualization. The term "realization" was aptly adopted by electronic music pioneers to describe the act of assembling a finished work. Even those works that are transcriptions of conventionally composed chromatic music cannot be fully described on paper, because the elements of electronic instrumentation, sound processing, and performance defy standardization. A work of electronic music is not *real*, does not exist, until a performance is *realized,* or played in real time.

Electronic music has a special relationship with the temporal nature of music. "Music presupposes before all else a certain organization in time, a chrononomy."[7] The plastic nature of electronic music allows the composer to record all of the values associated with a sound (e.g., pitch, timbre, envelope) in a form that can be shifted and reorganized in time. The ability to modify the time or duration of a sound is one of its most fundamental characteristics. Traditional instrumental music, once recorded, benefits from a similar control over the manipulation of a real-time performance. The equivalency between space and time that Cage attributed to the coming of magnetic tape recording—and which can be extended to any form of analog or digital sound recording or even MIDI control signals—has the liberating effect of allowing the composer to place a sound at any point in time at any tempo.

* Wendy Carlos, interview with Carol Wright, *New Age Voice*, <www.newagevoice.com>, November, 1999, copyright 1999 by Carol Wright (June 18, 2001).

In electronic music, sound itself becomes a theme of composition. The ability to get inside the physics of a sound and directly manipulate its characteristics provides an entirely new resource for composing music. The unifying physics behind all sounds—pitched and unpitched alike—allow a composer to treat all sounds as being materially equal.

Electronic music does not breathe: it is not affected by the limitations of human performance. As Robert Ashley learned about electronic music early on, "It can go on as long as the electricity comes out of the wall."[8] The arc and structure of the music is tolerant of extremes in the duration and flow of sounds. The ability to sustain or repeat sounds for long periods of time—much longer than would be practical for live instrumentalists—is a natural resource of electronic music. In addition to its sustainability, electronic music can play rhythms too complex and rapid for any person to perform. It can play with more than two hands at the same time. The composer is freed of the physical limitations of human performance and can construct new sounds and performances of an intricacy that can only exist as a product of the machine.

Electronic music springs from the imagination. The essence of electronic music is its disassociation with the natural world. Hearing is a "distance" sense, as opposed to the "proximal" senses of touch and taste. Listening engages the intellect and imagination to interpret what is heard, providing "only indirect knowledge of what matters—requiring interpretations from knowledge and assumptions, so you can read meaning into the object world."[9] Having little basis in the object world, electronic music becomes the pulse of an intimate and personal reality for the listener. Its source is mysterious. "It is thought, imagined and engraved in memory. It's a music of memory."[10] In these ways, the human being becomes the living modulator of the machine product, the circuitry dissolves into the spirit of humanness that envelops it.

Chapter 2

ELECTRONIC MUSIC RESOURCES

Electronic music is an art that marries technology and human imagination. While becoming an electrical engineer is not a prerequisite for making or listening to electronic music, some background on how the music is produced can improve one's appreciation for it. Anyone with the added inclination to become a soldering composer should certainly take notice of the material attributes of sound.

The Components of Sound

Sound is produced by air pressure waves that cause the eardrum to vibrate. These vibrations are converted by auditory nerves into impulses that the brain recognizes as sounds. If the wave vibrates in a regular pattern, it is perceived as a pitched sound, such as those used in music. If the wave does not vibrate in a regular pattern, it is perceived as unpitched sound or noise.

The science of musical acoustics developed during the latter half of the nineteenth century in tandem with general discoveries in the field of electricity. The scientist Hermann von Helmholtz (1821–1894) was largely responsible for this work, with his landmark 1862 paper "Sensations of Tone." In it, he demonstrated that musical sound could be analyzed according to a few basic physical principles. Using combinations of tuning forks to illustrate his point, he showed that the quality (or timbre) of a tone was reliant on the intensity, order, and number of harmonics (overtones and partials) present in the note. A single musical note was not so simple after all. Helmholtz showed that it actually consists of a base, or fundamental, tone accompanied by related vibrations (harmonics) above the pitch of the fundamental, which create tim-