CHAPTER 5

Tape Composition and Fundamental Concepts of Electronic Music

I think of the delay system as a time machine, because first you have to be present to make a sound and play it. Then it's recorded and played back in the future, so that what the future is essentially dealing with is really the past. So it sort of expands your sense of time.[1]
—Pauline Oliveros

Seven Fundamental Traits of Electronic Music

Tape Composition Methods and Techniques

- Composing with Tape
- *Listen: Classic Tape Composition Techniques*
- *Innovation: From Tape Recorders to Laptops—The Evolution of* Fontana Mix

Summary

Pauline Oliveros at the San Francisco Tape Music Center, 1965.
(John Bischoff, Mills College Center for Contemporary Music)

In 1966 the magnetic tape studio still represented the leading edge in electronic music technology. Just 18 short years after the establishment of the first major electronic music studio in Paris, there were at least 560 documented institutional and private tape studios in the world.[2] Of these, only 40 percent were sponsored by institutions and corporations, the rest being privately equipped and operated as a result of the increasing affordability of tape recorders, mixers, microphones, oscillators, and other basic tools of the trade. The year 1966 was pivotal because it marked the point at which the earliest analog music synthesizers were becoming known—a new trend in musical technology that would temporarily drive electronic musicians back to the confines of institutional studios, which were among the earliest adopters of the new and expensive equipment. The first synthesizers were not designed as performance instruments for making live music but rather as sophisticated, modular alternatives for producing electronic sounds for the tape studio. The development of analog synthesizers is the topic of the next chapter. Before leaping into the history of yet another episode in the evolution of music technology, this chapter pauses to assess the imprint made by early tape composition on the development of the electronic music field even to this day.

In spite of the numerous successive waves of music technology development, many of the basic aesthetic concepts and artistic choices that were invented by early composers of tape music remain at the core of electronic music still being produced today. These traits of electronic music can be traced not only to the exigencies of the tape medium itself, but also to the underlying principles that make electronic music different from music composed and performed for acoustic instruments. This chapter explores the characteristics that differentiate electronic music from other kinds of music and examines the roots of the aesthetic choices, effects, and techniques of electronic music that are descended from the early days of tape composition.

SEVEN FUNDAMENTAL TRAITS OF ELECTRONIC MUSIC

The emergence of electronic music in the 1950s was yet another example of the ability of musical culture to reinvent itself through new approaches to instrumentation, style, and structure. Writing in the first issue of the contemporary music journal *die Reihe*, musicologist H. H. Stuckenschmidt (1901–88) characterized electronic music as the Third Stage in the aesthetic history of music, the first two being the invention of vocal music and instrumental music:

> Music has developed further and further away from its human origins; now, at what we define as its Third Stage, the Electronic, we are astonished and not without pride, to have before us an art, totally controlled by the spirit of man, in a way not previously imaginable.[3]

Early practitioners of electronic music, regardless of their school of thought toward composing music, uniformly recognized several key aspects of electronic music that distinguished it from making music in a traditional way. These guiding principles can be divided into seven traits:

1 **The sound resources available to electronic music are unlimited**. New sounds can be constructed from the raw material of electronic waveforms. The composer not only creates the music, but composes the very sounds themselves. Eimert explained the innate potential of electronic music in the following 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.[4]

The composer can invent sounds that do not exist in nature or radically transform natural sounds into new instruments. For *Thema–Omaggio a Joyce*, Berio 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* (1984), Wendy Carlos (b. 1939) modeled a digital instrument, the voice of which 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.[5] For *Beauty in the Beast* (1986), Carlos took this experimentation a step further by "designing instrumental timbres that can't exist at all, extrapolated from the ones that do exist."[6]

2 **Electronic music can expand the perception of tonality**. On one hand, the invention of new pitch systems is made 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 also stretches the concept of pitch in the opposite direction, toward less defined tonality into the realm of noise. All sounds may be considered equally important increments 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 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.[7]

3 **Electronic music 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."[8]

In the world of electronic music there are many works that cannot be accurately transcribed and reproduced from a printed score. The underlying reason for this is that electronic music is a medium in which the composer directly creates the performance either as a recording or a live performance. There is rarely a need for somebody else to interpret or read a score other than the composer. Many works are realized directly only one time using electronic media for the purpose of creating a recording. This is not to deny attempts made by composers to score electronic music. But scoring often results in a composer devising a unique form of notation to define the elements of a work that is especially suited to whatever sound-generating technology is available to them. For *Studie II*, Stockhausen developed a graphical score using geometric shapes representing the pitch and dynamic components of the sine waves used to create the piece. In this case, specific pitches and dynamics were determined with such precision that an accurate reproduction is possible using other media. One such faithful realization of *Studie II* was completed 52 years after the original in 2006 by German composer Georg Hajdu using the graphical programming language *Max/MSP* for laptop computer. The work *Game* (1975) by Carl Michaelson was written for two flutes and ring modulator; the flutists perform notes prescribed using a conventional score and their output is miked and modulated using a ring modulator with settings noted by the composer. There is no standardization for the creation of a score for electronic music. The scores for many electronic works consist of written instructions and vary widely depending on the needs of the composer. *I Am Sitting in a Room* (1969) by Alvin Lucier (b. 1931) was an experiment in the degenerative effects of recording and re-recording the same sound using a microphone and two tape recorders. The basic sound material was a written text passage provided by the composer. The instructions consisted of the procedural steps needed to record and re-record the sound "through many generations" and instructions for splicing them "together in chronological order" to "make a tape composition the length of which is determined by the length of the original statement and the number of generations recorded."[9] But even such a seemingly straightforward set of instructions will have widely varying results depending on the acoustical properties of the room in which the piece is recorded, the fidelity of the tape recording equipment, and the number of generations of the passage recorded. Originally intended as a recorded tape piece, a live, real-time realization was performed in 2000 by Christopher Burns using a program called *Pure Data* (*Pd*) for the creation of interactive computer music. In his interpretation, Burns chose not to fix the duration of the performance ahead of time because he was "unsure of how quickly the process would unfold when the intended performance space was filled with an audience."[10]

Experiencing electronic music is a part of its actualization. The term **realization** was adopted by electronic music pioneers to describe the act of assembling a finished work. A work of electronic music is not real—does not exist—until a performance is realized, or played in real time.

Other than assisting the composer in making notes for the realization of a work, reasons for creating or publishing a score include providing an example that might be instructional for others, copyrighting a work, and providing instructions for instrumentalists when a work can be performed live.

4 **Electronic music has a special relationship with the temporal nature of music.** "Music presupposes before all else a certain organization in time, a chronomony."[11]

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, MIDI control signals, or even a performance sequence outlined in *Max/MSP*—has the liberating effect of allowing the composer to place a sound at any point in time at any tempo.

5 **In electronic music, sound itself becomes the material 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.

6 **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."[12] 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 contrast to its sustainability, electronic music can play rhythms too complex and rapid for any person to perform. The composer is freed from the physical limitations of human performance and can construct new sounds and performances of an intricacy that can only exist when played by a machine.

7 **Electronic music often lacks a point of comparison with the natural world of sounds, providing a largely mental and imaginative experience.** Hearing is a "distance" sense, as opposed to the "proximal" senses of touch and taste. The essence of electronic music is its disassociation with the natural world. 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."[13] 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."[14] 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.

TAPE COMPOSITION METHODS AND TECHNIQUES

Until the arrival of the magnetic **reel-to-reel tape recorder**, electronic music had only been a live performance medium using instruments such as the Theremin, *Ondes Martenot*, or the humble turntable. The tape recorder transformed the field of electronic music overnight by making it a composer's medium. Most classical music composition for the Theremin and *Ondes Martenot* came to a halt during the 1950s as composers turned to the tape medium to explore new sonic possibilities. The early practitioners of tape music sought new sounds, structures, and tonalities by working directly with the raw materials of sound.

Composing with Tape

For the early adapters of magnetic tape composition—Schaeffer, Henry, Cage, Luening, Ussachevsky, and Varèse—the medium had the liberating effect of separating the creation of music from the traditional practice of scoring and notating parts. John Cage put it plainly when he told the author:

> It made one aware that there was an equivalence between space and time, because the tape you could see existed in space, whereas the sounds existed in time. That immediately changed the notation of music. We didn't have to bother with counting one-two-three-four anymore. We could if we wanted to, but we didn't have to. We could put a sound at any point in time.[15]

To understand what Cage meant you may have had to visit an electronic music studio. There was usually a rack from which hung pieces of tape that had not yet been spliced together. Holding a strip of magnetic tape in one's hand was equivalent to seeing and touching sound. You could manipulate this normally elusive phenomenon in ways that were previously unavailable to composers. It was a technological, psychological, and social breakthrough without parallel for music.

Karlheinz Stockhausen had a similar revelation about the materiality of time when using the magnetic tape medium. By speeding up or slowing down a sound—even a conventionally musical sound—all of the characteristics comprising the physics of a sound could be leveled by the hammer of technology. Rhythm once organized in familiar meters could be sped up or slowed down beyond the point of recognition. Such elements as the timbre of chosen instruments, harmony, and melody could each be transformed uniformly and unequivocally by so many inches-per-second of tape running on a variable-speed tape recorder. Chords could be sped up to become beats and rhythms. Rhythms could be slowed down to become drones. The components of a musical work were all reduced to the common denominator of vibration. This was the unified field theory of serialism "in which duration, pitch and color were aspects of the same thing."[16] Stockhausen called it the "unified time domain."[17] These insights were shared by many other composers who first worked with magnetic tape in Paris, Cologne, Milan, New York, and other early studios.

Even though the practice of composing with magnetic tape is obsolete today, many of the most fundamental effects associated with electronic music originated with the pioneers who learned how to push the limitations of this fragile medium. The state of the art may have shifted from magnetic tape to digital media but the basic concepts of sound manipulation born over 50 years ago still apply. Most of these techniques are still fundamental to the recording and manipulation of sounds using digital media and software. In fact, most software designed for the editing and processing of sounds continues to borrow its lexicon of terms and controls from the world of magnetic tape, where the concepts of Record, Play, Fast Forward, Rewind, and Pause were first applied.

Tape Splicing

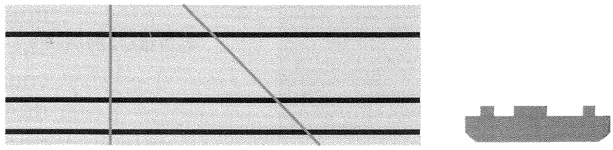

Figure 5.1 Splicing block.

The cutting and splicing of magnetic tape is, in effect, no different from moving sound around in time and space. A magnetic tape recording is linear in that the signal is recorded from the start of the tape to its end as it passes across the recording head of the tape recorder. The recording head instills an electromagnetic imprint of the audio signal onto the iron oxide coating of the tape. This imprint is not permanently fixed and can be recorded over or disturbed by bringing it into close proximity with any strong magnetic field such as that of a loudspeaker. A recorded sound is played by passing the taped signal across a playback head that translates the magnetic imprint into an audible sound. The magnetic tape recording process is **analog**, meaning that no digitization of the signal is used to record or playback sounds.

Tape editing or **splicing** allows a sound that occurred at one time or location in a recording to be moved to another, changing the linear sequence of the original recording. Conceptually, splicing relies on the linear nature of the tape medium in which one sound follows another, unlike the random access nature of digital media other than digital tape.

The mechanics of magnetic tape splicing are simple. Tape is placed on open reels, mounted on a tape recorder, and manually moved across the playback head to locate a point in the sound where an edit is to occur. Locating a sound on tape can be likened to the manual spinning of a vinyl record by a DJ to cue up a particular point in a recording. The composer's only other tools are a ruler to "measure" time in inches or centimeters of tape, a razor blade, a **splicing block** (see Figure 5.1), and splicing tape or glue to join two ends of tape to form a permanent edit. The splicing block is a rectangular aluminum block with a slot to securely hold a length of magnetic tape. It is made of aluminum to avoid magnetization of the block that could add noise to the splice. The splicing block has two narrow channels across the width of the tape to guide a razor blade while the tape is cut. One slot is perpendicular to the tape and the other angled to provide a diagonal cut. A diagonal cut is potentially stronger because the joint between the two pieces of tape is longer and more gradual than a simple vertical cut. A vertical cut is also more likely to cause an audible popping sound when the edit is played back. To splice magnetic tape together, the end of each piece of tape is mounted on the splicing block and then trimmed with a razor blade using one of the cutting channels as a guide. Using the cutting channels ensures that the two lengths of tape to be joined are trimmed at precisely the same angle. The ends of tapes are then inserted into the splicing block channel and butted up against each other in the track of the splicing block and joined with splicing tape.

From this limited technology arose various philosophies about splicing tape. The object was first and foremost to create an absolutely silent cut. The slightest misadventure with matching up the two ends of tape, a bubble in the splicing tape, or dust in the adhesive of the splicing tape could result in an audible pop in the edited sound. Various tricks of the trade came about because of this, including the "hourglass" splice, which reduced the width of the tape at the point of a splice, providing less surface area for

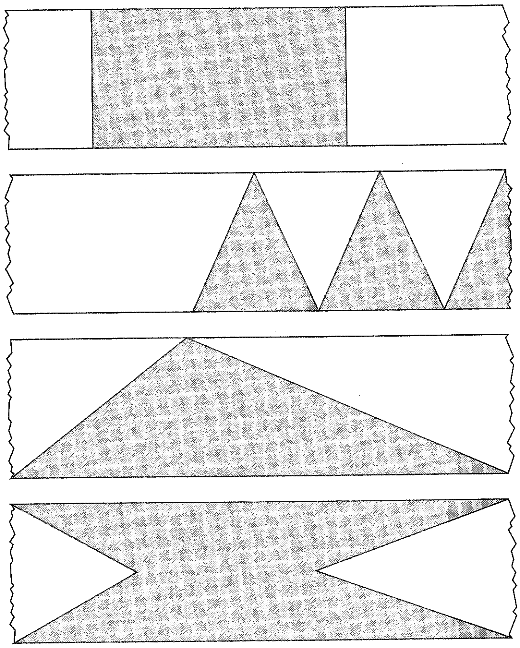

Figure 5.2 Examples of tape splicing techniques, each having a different effect on the transition of one sound to another.

noise during the transition from one piece of tape to the next. Unfortunately, this method could momentarily reduce the amplitude of the signal at the point of the splice—an effect that was sometimes audible.

Splicing could be used in a limited way to change the attack and decay patterns of recorded sounds (see Figure 5.2). A long, angled splice of several inches would create a perceptible dissolve from one sound to the next. Cutting periodic segments of blank tape—or **leader tape**, the non-magnetic protective tape at the beginning or end of a reel—into a passage of continuous sound could induce a rhythmic or pulsing effect. Cuts made at right angles created a sharper, percussive jump from sound to sound. Cage experimented with radically extreme splices when he produced *Williams Mix* (1952), using the shape and angle of splices to alter the slope of attack and decay of recorded sounds. Morton Feldman used leader tape to space the sequence of sounds that he pre-recorded for assembling *Intersection* (1953).

In practice, composers in the classic tape studio followed a three-step process for composing with tape. The first step involved *the recording of raw material*—sounds developed by whatever means and recorded onto magnetic tape. The second step involved listening to the tapes and *extracting sections of sound to be used in the final assembly* of the piece. These sounds were literally spliced out of the original tape, labeled, and stored for easy access, often on a wall rack where the pieces of tape could be hung. The third step was *assembling the chosen segments of tape into the desired sequence* using a splicing block and splicing tape. Barring any additional remixing or modification, the final edited sequence comprised the master tape of the work.

Degeneration of a Recorded Signal

The fidelity of a magnetic tape recording will degenerate with each successive copy of the original or master. This is due to noise introduced in the recording process and the inability of the tape machine and tape medium to respond equally well to all frequencies of sound. Master or first-generation tapes include the least amount of noise. All other factors being equal, recordings made at a higher tape transport speed with have improved fidelity because the denseness of the incoming signal will be extended over a longer length of tape, raising the threshold of frequency and dynamic response at the point where the tape meets the record head. While high-speed recording and dubbing can improve the fidelity of copies, some level of noise is always going to creep into a copy of a tape. Until the introduction of digital recording—which allows for the making of copies that are as good as the master—composers needed to be mindful of noise as a necessary evil of the magnetic tape composition process.

CLASSIC TAPE COMPOSITION TECHNIQUES

LISTEN

1. *Intersection* (1953) by Morton Feldman
   Feldman used leader tape to add patches of silence required by his piece
2. *I Am Sitting in a Room* (1969) by Alvin Lucier
   An experiment in the degeneration of magnetic tape sounds
3. *Discreet Music* (1975) by Brian Eno
   Used tape delay with multiple tape recorders
4. *Invention in Twelve Tones* (1952) by Otto Luening
   Used tape echo
5. *Beautiful Soop* (1967) by Pauline Oliveros
   Used multiple tape echo signals
6. *Le Microphone bien tempéré* (1950–52) by Pierre Henry
   Used reverberation
7. *Music for the Gift* (1963) by Terry Riley
   One of the first uses of tape delay with multiple tape recorders
8. *I of IV* (1966) by Pauline Oliveros
   Combined multiple tape delay system with the gradual degeneration of the audio signal
9. *Cinq études de bruits: Étude violette* (1948) by Pierre Schaeffer
   Early application of backwards sounds using a turntable
10. *Glissandi* (1957) by György Ligeti
    Extensive use of tape speed variation and backwards sounds

Some composers have used the degenerating effect of tape copying as an element in their compositions. This effect was the underlying idea behind Brian Eno's (b. 1948) *Discreet Music* (1975), in which two short melodic lines played on a synthesizer were recorded onto a long loop of tape that was channeled through two tape recorders. The recording made on the first machine was then played on the second machine, the output of which was then played back into the recording input of the first machine. In this way the first tape recorder continued to make successively degenerating copies of the original recording. Once set in motion, Eno did little to modify the sound other than "occasionally altering the timbre of the synthesizer's output by means of a graphic equalizer."[18]

The crowning achievement in the use of tape degeneration in electronic music was *I Am Sitting in a Room* (1970) by Alvin Lucier, completed five years prior to *Discreet Music*. The score for the piece, described earlier in this chapter, was devised after an evening of acoustical experimentation by the composer. Lucier explained the genesis of the piece as follows:

> I had heard that Bose had tested his loudspeakers by doing some kind of a cycling process to see where the frequencies were. I tried it out in *I Am Sitting in*

> *a Room*. I did it one night in an apartment that I was in. I thought up that text right there that night. I wrote it down, without much editing, and then with a pair of tape recorders, a KLH loudspeaker, and an amplifier I just made that piece. I set up the two tape recorders outside the apartment so there wouldn't be any noise from the machinery. I sat inside with a microphone and spoke the text two or three times to get the volume right. Then I put the loudspeaker up where I had been sitting so that the speaker became my voice. The evening was spent with these machines and I would play back the original text recording through the speaker into the microphone to a second machine. I would check that to make sure that the volume was all right. Then I rewound that, spliced it onto the first machine, and played that back. I spliced it 16 times. It took me all night. So the final product is that tape.[19]

In this work, the acoustics of the room provided a natural filter for the sound that was being "heard" by the microphone, accentuating certain frequencies and dampening others. As the piece progressed, only the sharpest characteristics of the sound continued to propagate during each successive generation of recordings, eventually disintegrating into an unintelligible, pulsating set of modulations. It was the aural equivalent of the visual degeneration that takes place when you make successive photocopies of photocopies.

Tape Echo, Reverberation, Loops, and Delay

The tape recorder made possible several basic techniques for repeating sounds that have been popular since the earliest experiments with tape composition. Echo, delay, and tape loops are among the effects that persist conceptually in the manipulation of sound by digital systems today.

Echo is the repetition of a single sound that gradually decays in amplitude and clarity with each successive repetition until it fades away. This was first achieved using tape recorders equipped with three "heads"—the erase, recording, and playback heads—across which magnetic tape was transported to erase, record, or play sounds.

To create echo with a tape recorder, the playback output signal of the machine was fed back into the input, or record head, of the same machine (see Figure 5.3). In this configuration, the tape recorder was simultaneously recording and then playing back the sound just recorded. The distance that the tape must travel from the record head to the playback head, and the speed of the tape transport, determined the length of the delay. Continuing in this manner without interruption created the echo effect and the signal degenerated in strength, or amplitude, with each successive echo. The strength or persistence of the echo—how many repetitions were possible—was determined by the amplitude of the playback signal being fed back into the recorder. The stronger the signal, the longer the sequence of repeats. Turning up the playback to the point of distortion produced echo "frizz"—echoes that eventually became stronger than the source signal and produced a **white noise** effect.

Tape echo quickly became a staple effect of electronic music composition. While the French and German schools used echo only sparingly in their earliest works, perhaps because they had so many other audio resources at their disposal, the effect was popular with composers working in America who had little more than tape recorders with which

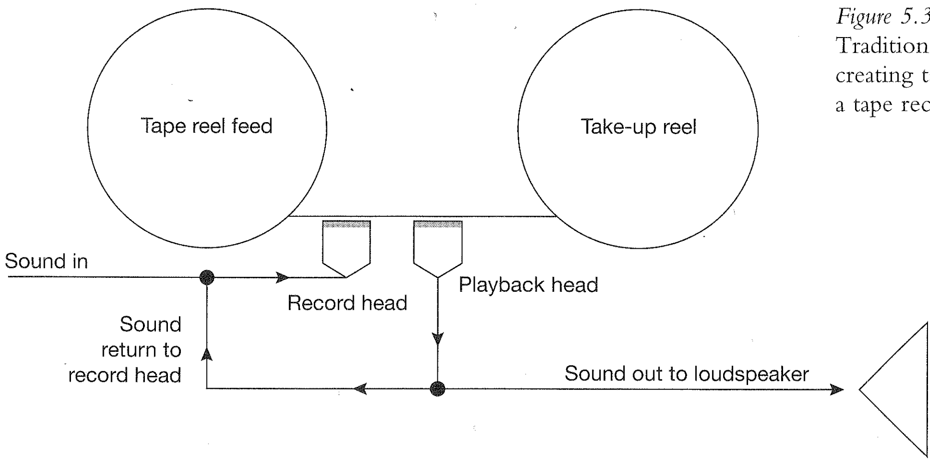

Figure 5.3
Traditional method of creating tape echo using a tape recorder.

to work. In New York, Otto Luening utilized echo as an important structural element in his early works that modified the sound of the flute, such as *Low Speed* (1952) and *Invention in Twelve Tones* (1952).

By the 1960s, a variety of dedicated black box devices were manufactured to produce echo. Designed primarily for use by performing musicians such as rock artists, products such as the Echoplex were essentially tape recorders dedicated to the creation of echo. Inside such a device was a loop of magnetic tape along with the requisite erase, record, and playback heads. The sound to be enhanced with echo was patched in using a guitar cable. One advantage of these dedicated devices was that the distance between the record and playback heads could be adjusted to increase the length of time between echoes.

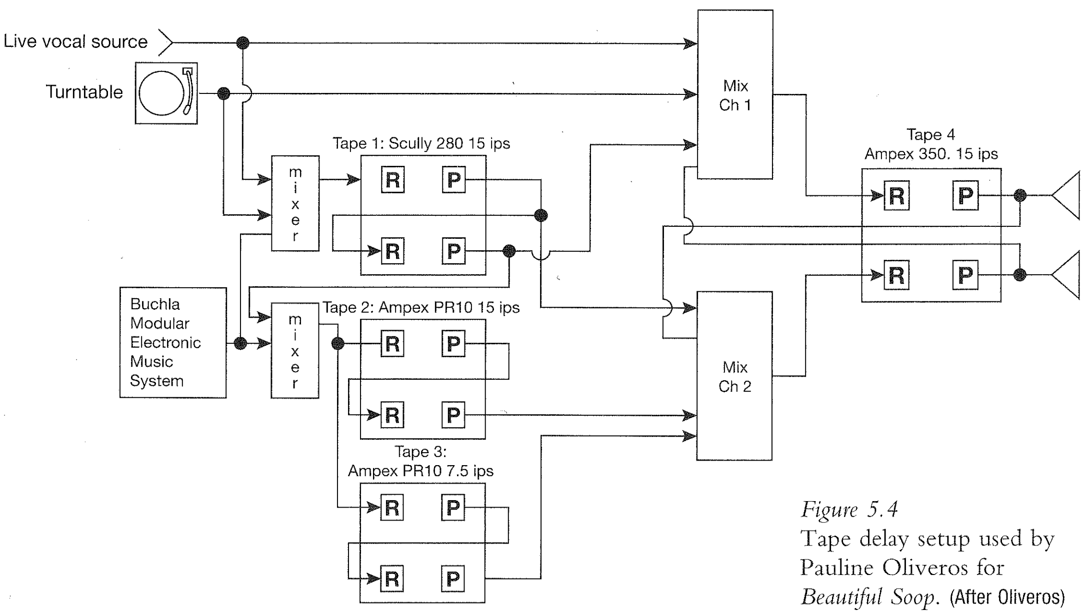

Figure 5.4
Tape delay setup used by Pauline Oliveros for *Beautiful Soop*. (After Oliveros)

Such analog echo devices have since been replaced by software programs and digital effects units that model their audio processing after the most familiar and interesting tape echo boxes of the past.

Composer Pauline Oliveros used tape echo as the structural process behind many of her groundbreaking works. In *Beautiful Soop* (1967), she used three different brands of tape recorders to create multiple echo effects simultaneously from the same input signal, exploiting the different distances between the record and playback heads of the different machines (see Figure 5.4). She described this complex circuit:

> With all the feedback loops in operation there is a shimmering effect on attacks, and interesting timbre changes on sustained sounds. Because every delay line was controlled by a separate mixing pot, as much or as little feedback [echo] as designed was introduced, and each delay line could be treated as a separate source. By sending delay lines to various modifying devices, a large number of variations could occur.[20]

The work combined fragments of Lewis Carroll verse recited by several people with synthesized tones, creating a dialog between the spoken word and synthetically produced music. Echo was liberally applied simultaneously to all of the material using three tape recorders, resulting in echo effects that were at times distinct but also multilayered and complex.

Reverberation is sometimes confused with echo and, although technically the two effects are based on a similar psychoacoustic phenomenon, reverberation is generally defined as minute or fractional time delays in the perception of sound waves as they bounce back from reflective surfaces of varying distances in the listening environment. Reverberation occurs naturally in any environment and is most obvious when experiencing the ambient characteristics of concert halls, sports arenas, and outdoor stadiums. Reverberation effects were created in the classic tape studio by mixing the source signal with ghost frequencies of itself. Before the advent of digital delay systems, this was commonly done using a simple physical device known as *spring reverberation*. The source signal was run through a metal coil and detected by a **pickup** at the other end. In traveling through the coil, the sound signal was delayed just slightly enough to create an artificially produced ghost sound when recombined with the undelayed source signal. The thickness of the wire and tightness of the coil affected the degree of reverberation that could be generated and the more sophisticated units had several options depending on the degree of reflectiveness desired.

Reverb was one of the most-used audio processing effects during the formative years of the Paris and Cologne studios. It was used in many early disc and tape works by Pierre Schaeffer and Pierre Henry in Paris, including their collaboration *Symphonie pour un homme seul* (1950) and Henry's first solo work of *musique concrète*, *Le Microphone bien tempéré* (1950–52), in which the composer used reverb and other effects to modify the sound of a piano in 16 short movements.

A length of tape can be spliced end to end to form a **tape loop**. The idea of tape loops pre-dated the use of magnetic tape and was borrowed from the lock grooves created by early turntablists, including Paul Hindemith and Pierre Schaeffer. Unlike echo, in which each repetition of an initial sound becomes weaker until it diminishes entirely, the sound repeated by a tape loop does not weaken.

Figure 5.5
Vladimir Ussachevsky with a specially designed tape loop feeding device for a tape recorder, 1965. (Columbia University Computer Music Center)

The rate at which a tape loop repeats is determined by the length of the loop and the playback speed of the tape machine. Digital **sampling** essentially mimics the creation of a loop, resulting in a sound that can be played by itself or "looped" in a repeating pattern. Digital samplers can be set to repeat a sound at the same volume in a looping cycle or allow it to diminish for an echo effect, blurring the line between what once were separate techniques in the analog world of tape machines.

Tape delay is an extended form of tape echo in which the time between repetitions is lengthened well beyond what can be normally achieved on a single tape recorder. This was most often done by using two or more widely spaced tape recorders through which a single length of magnetic tape was threaded. A sound was recorded on the first machine and played-back on the second, creating a long delay between the first occurrence of the sound and its repetition on the second machine. If the sound being played back on the second machine was simultaneously recorded by the first machine, an extended echo effect was created with long delays between successive, degenerating repetitions.

Tape delay has been used extensively by several composers. Its origins go back to the composers associated with the San Francisco Tape Music Center in 1960.[21] Terry Riley may have been the very first to compose a piece using this technique when he created *Music for the Gift* in 1963, possibly the first work to use the technique of a long tape loop fed through two widely separated tape machines. Riley was in Paris working with jazz musician Chet Baker's group when he got the idea:

> The accumulation technique hadn't been invented yet and it got invented during this session. I was asking the engineer, describing to him the kind of sound I had worked with in *Mescalin Mix* [an earlier tape composition]. I wanted this kind of long, repeated loop and I said "can you create something like that?" He got it by stringing the tape between two tape recorders and feeding the signal from

> the second machine back to the first to recycle along with the new incoming signals. By varying the intensity of the feedback you could form the sound either into a single image without delay or increase the intensity until it became a dense chaotic kind of sound . . . The engineer was the first to create this technique that I know of. This began my obsession with time-lag accumulation feed-back.[22]

Oliveros's piece *I of IV* (1966) made extensive use of accumulative tape delay and degeneration of the repeating signal. Like Riley, Oliveros did this by threading one reel of tape through two tape recorders. The sound was recorded on the first machine, played back on the second, and fed back to the first machine to be recorded again. The distance between the two machines caused a lag of about eight seconds, a fairly long delay. The music was further layered by splitting the output signal and playing one version of the output directly, without delay, and then applying echo to the other output.

I of IV was made in July 1966, at the University of Toronto Electronic Music Studio. It was produced in real time, without edits, using a sound processing technique that Oliveros called the amplification of "combination tones and tape repetition." She explained:

> The combination tone technique was one which I developed in 1965 at the San Francisco Tape Music Center. The equipment consisted of 12 sine tone square wave generators connected to an organ keyboard, 2 line amplifiers, mixer, Hammond spring-type reverb and 2 stereo tape recorders. 11 generators were set to operate above 20,000 Hz, and one generator at below 1 Hz. The keyboard output was routed to the line amplifiers, reverb, and then to channel A of recorder 1. The tape was threaded from recorder 1 to recorder 2. Recorder 2 was on playback only. Recorder 2 provided playback repetition approximately 8 seconds later. Recorder 1 channel A was routed to recorder 1 channel B and recorder 1 channel B to recorder 1 channel A in a double feedback loop. Recorder 2 channel A was routed to recorder 1 channel A, and recorder 2 channel B was routed to recorder 1 channel B. The tape repetition contributed timbre and dynamic changes to steady state sounds. The combination tones produced by the 11 generators and the bias frequencies of the tape recorders were pulse modulated by the sub-audio generator.[23]

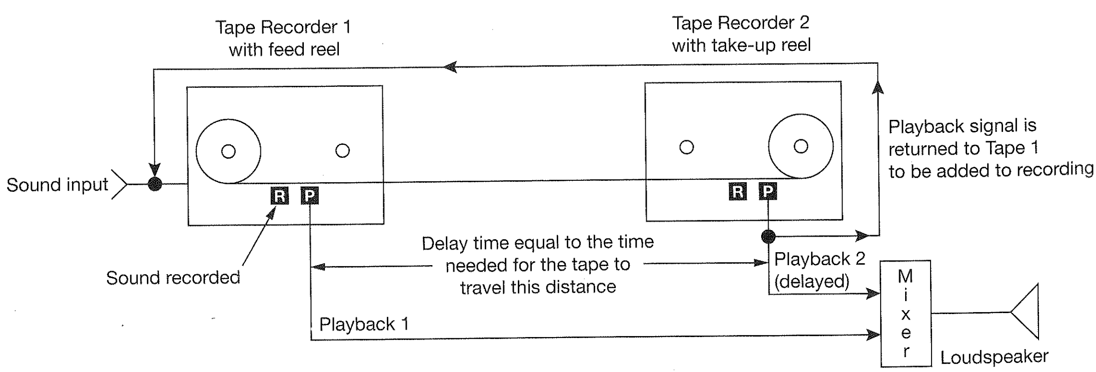

Figure 5.6 Simple tape delay setup using tape recorders.

LISTENING GUIDE 5.1

Title: *I of IV* (excerpt)

Artist: Pauline Oliveros **Year**: 1966 **Duration**: 3:00

Genre: Tape composition using real-time tape delay

Electronic Instrumentation: Twelve sine wave oscillators (keyboard controlled), two tape recorders, two line amplifiers, mixer, spring-reverberation.

Background: This piece is built around a performance process that is conducted in real time. Therefore, the technique for creating this work is essentially that of live electronic music. Realized in the studios of the University of Toronto, where Oliveros was visiting, it is based on real-time tape manipulation and audio processing techniques first developed at the composer's home base, the San Francisco Tape Music Center. The main text of this chapter includes a detailed description of the composer's step-by-step process. In short, the work was created by recording a mix of 12 sine tones using the first tape machine and playing the sounds back on the second machine using a long tape loop and a time lag of about eight seconds. In addition, another version of the tones bypassed the delay entirely and is heard using echo effects. These outputs—tape delay and echo-treated sine waves—are combined by the composer in a real-time mix.

	Listen For: Accumulative tape delay and gradual degeneration of a repeating audio signal. Imagine the process of creating this work in real time.
0:00–1:20	The piece begins with an intense buzzing of multi-layered sound waves; after eight seconds you can hear a slight bump in the sound indicating that the tape delay system has begun. From this point onward, the composer continually adjusts the modulation, filtering, and mixing of the sine tones as the sound is recorded on a tape loop and fed to the playback head of the second machine. Oliveros is mixing the results to produce the sound that you hear, all in real time. For about the first minute, the buzzing sound dominates the mix. At about 60 seconds, Oliveros begins to adjust the sine wave tones to higher, more harmonic pitches and the buzzing sound gradually diminishes. She creates a mix of wavering, continuous tones accented by short, fuzzy bursts. The long, continuous tones blend into the background of the tape delay sequence, providing a droning effect that effectively masks the eight-second cycle of repetition. The long tones blend and interfere with one another, creating interesting beat frequency effects. The short, fuzzy bursts provide accents to the droning sounds, giving the music intermittent rhythmic moments. Notice how the composer selectively builds layers of new sounds on sounds that are repeating, forming complex rhythms and textures.
1:21–3:00	Beginning at about 1:21, you can hear the entrance of sine tones that bypass the tape delay and are being played by the composer using tape echo. These echoing tones, at first very clear and distinct, become a part of the tape delay mix and gradually diminish. For the remainder of the work beyond this excerpt, the composer continues to explore various combinations of sine tones, tape delay, and echo effects, gradually shifting the nature of the mix and fully exploring the timbral changes introduced by the effects of sound accumulation and degeneration.

Compare and Contrast

Discreet Music (1975) by Brian Eno
Erosphere (1981) by François Bayle
Live Echo (2007) by Susumu Yokota

INNOVATION

FROM TAPE RECORDERS TO LAPTOPS—THE EVOLUTION OF *FONTANA MIX*

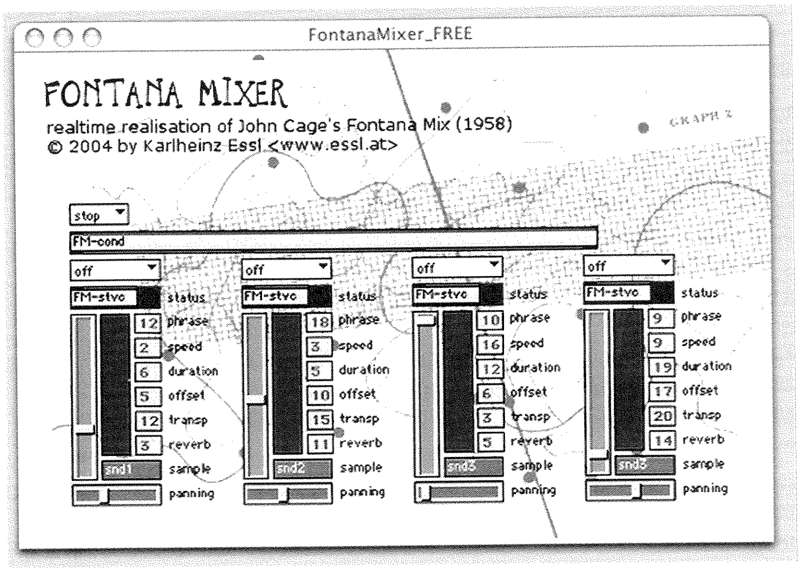

Figure 5.7 *FontanaMixer*, a real-time software performance program based on John Cage's score for *Fontana Mix*. (Karlheinz Essl)

The 1958 tape piece *Fontana Mix* by John Cage was a work whose composition was indeterminate—unfixed—in relationship to its performance. Cage accomplished this by introducing a randomization process to formulate each performance from a set of provided compositional materials. The score consisted of 10 sheets of paper and 12 transparencies. The sheets of paper had drawings of six curved lines differentiated by thickness and texture. Ten of the transparencies had randomly distributed points, the number of points per transparency being 7, 12, 13, 17, 18, 19, 22, 26, 29, and 30. Another transparency had a grid measuring two by ten inches and the tenth transparency contained a 10¾-inch straight line. The work was intended to be performed by "any kind and number of instruments."[24] The score materials were used to determine the parameters of each available instrumental part through a set of instructions: "Place a sheet with points over a drawing with curves (in any position). Over these place the graph. Use the straight line to connect a point within the graph with one outside."[25] Among Cage's additional instructions, all originally dictated by chance operations, was the selection of six elements (e.g. sound sources or a dynamic element such as amplitude) and up to 20 values that could be assigned to each of the six elements. Cage expressly stated that the composition was not "limited to tape music but may be used freely for instrumental, vocal, and theatrical purposes."[26] The composer also encouraged others to consider as an option the distribution of the sound in space.

For his first realization of the work, Cage created four monophonic tracks of magnetic tape music. Each of the four parts required a separate interpretation of the score and he drew from a variety of concrete sound sources for the audio material as he had been done for the earlier *Williams Mix*. The selection, duration, and editing sequence for each tape was based on the pattern of intersecting dots and lines rendered by each interpretation of the score.

Cage's imaginative graphical score for *Fontana Mix* has been interpreted by many artists over the years. Most recently, two composers working independently have created computer versions of *Fontana Mix*. Canadian Matt Rogalsky (b. 1966) created *FontanaMixer* in 2002, an application for electronically generating a graphical score for *Fontana Mix* using a digital representation of Cage's graphical score (see Figures 5.7 and 5.8). Anyone can download the program and make up their own version of the work (http://royallyvague.com/fontananet). Rogalsky also developed *FontanaNet* (2002), a shared laptop version of the work that can be performed in real time by several interacting performers. Several players interact with a central computer that serves as the server for the work. Developed using the software tool *SuperCollider*, 20 different sampled sound sources are shared by the performers who then make changes to audio parameters as they each interpret a version of the score.

Performers act by (1) using the top two rows of keys on the laptop to select a sound sample; (2) pressing the spacebar to start the selected sound sample; and (3) pressing one of the z, x, c, v, or b keys to activate one of five dynamic settings including amplitude, pan speed, sample playback speed, high-pass filter cutoff frequency, or amplitude modulation depth, and then using a Wacom tablet to modify the values for the chosen dynamic parameter. Rogalsky also took into consideration the distribution of the sounds in space, explaining that "Each version of the sound travels independently around the circle of loudspeakers. They kind of wander around."[27]

Yet another laptop version of *Fontana Mix* was developed by Austrian composer Karlheinz Essl (b. 1960) in 2004. Essl's version, also called *FontanaMixer*, is a completely self-generating sound environment that the composer programmed using *Max/MSP*. Adhering to Cage's instructions, and providing four sound channels as in Cage's four-track tape version, Essl's program uses chance-based operations to assign values to each of six possible parameters affecting the sound source. The audio sources become highly modified using granular synthesis techniques. Essl's *FontanaMixer* (www.essl.at/works/fontana-mixer.html#english) is provided with four sound sources including the voice of John Cage and nature sounds, but the user is invited to replace any of the given sources with audio tracks of their own.

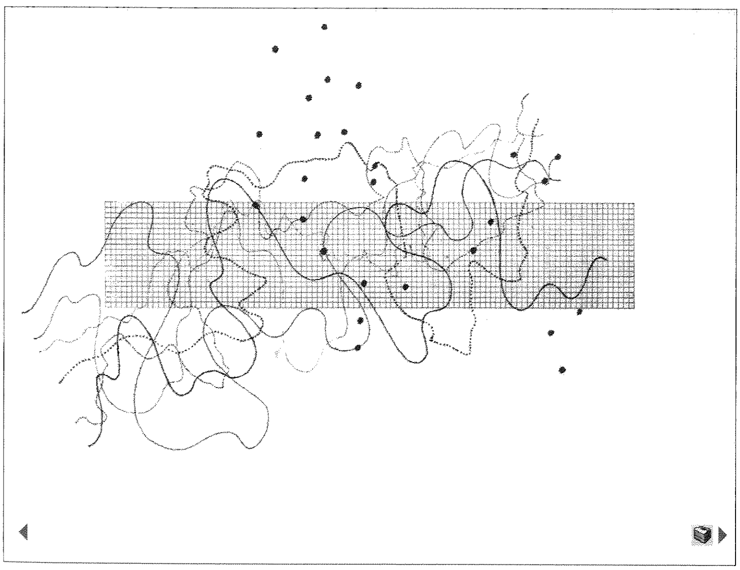

Figure 5.8 Matt Rogalsky's *FontanaMixer* program generates individualized scores for the performance of Cage's *Fontana Mix*. (Matt Rogalsky)

Oliveros's widely heard recording of *I of IV* in 1967 occupied the entire side of a CBS-Odyssey record album of electronic music. This recording can be credited with seeding the musical world with the idea of tape delay (see Figure 5.6) and has been often repeated by experimental composers, including Eno on *Discreet Music* and some related work for guitar by Robert Fripp. Fripp's real-time performances using dual tape recorders and a feedback delay system—dubbed *Frippertronics* by his friends—led Fripp and Eno to collaborate on the recordings *No Pussyfooting* (1972) and *Evening Star* (1974), each of which combined elements of rock music with Fripp's distinctive tape delay style of guitar playing.

Another Oliveros piece—*C(s) for Once* (1966)—used three tape recorders with one tape threaded through all three to affect the sounds being played of live voices, flutes, trumpets, and organ. Another notable work whose performance depended on a tape recorder was *Mugic* (1973), by Charles Amirkhanian. In this piece, the composer threaded a single reel of magnetic tape through the record and playback heads of three tape recorders. Spoken words were recorded on tape machine 1 and played back as a delayed signal on machines 2 and 3. Then, taking a page from Lucier's book, Amirkhanian also used a microphone to pick up the acoustic resonance of the sounds being played in the room so that the clarity of the dialog and playback signal gradually deteriorated as the piece continued.

Tape Reversal: Playing Sounds Backwards

The idea of playing recorded sounds in reverse—**tape reversal**—was another technique borrowed from turntablism. Pierre Schaeffer was one of the first composers to record a turntable piece that included an extended section of backwards sounds. About one minute into the short *Cinq études de bruits: Étude violette* (1948) there was a 35-second section consisting primarily of slowly advancing piano notes and chords played in reverse. This type of effect was evidently unwieldy to achieve with a turntable, for reverse sounds were not used in very many of the early *musique concrète* works created with discs. The introduction of the tape recorder greatly simplified the ability to play recorded sounds backwards while also extending the duration of a reversed sound to virtually the entire length of a tape if desired. On a monophonic, **full-track**, tape recorder capable of recording only one track in one direction across the entire width of the magnetic tape, playing a sound in reverse was as simple as flipping the tape over and playing the tape upside down. Later recorders that were capable of recording two tracks—**half-track stereo**—in one direction could also play sounds in reverse if the tape was flipped over, but tracks would be transposed from the left to the right and vice versa. The most common commercially available tape recorders of the 1960s and 1970s recorded stereo tracks on both sides of a tape, therefore having two quarter tracks running in either direction. Although trickier to play sounds in reverse on such a machine, it could be accomplished by changing the way that the tape was threaded around the capstan. That trick only worked if the tape recorder was equipped with three drive motors—one for the supply reel, one for the take-up reel, and one for the capstan. Threading the tape behind the capstan and pinch roller had the effect of reversing the direction of the tension-activated supply and take-up reel motors, causing the supply reel to take up the tape, the result being that the recording traveled backward across the playback head. Of course, the most manageable method of working with reversed sounds was simply to snip out a length of recorded tape and splice it back into the piece backwards.

The most distinctive change to a sound when it is reversed is that its envelope characteristics also become reversed. Whereas a sound may have previously ramped up from a low volume and concluded with a bang, it did the opposite when reversed, beginning with a bang and subsiding as a fade-out. Playing the sound of the voice in reverse has the effect of turning something familiar into the unfamiliar and has been the source of much experimentation in electronic music. Reversing sounds quickly became a popular technique in tape composition and an indispensable tool for the composer who wanted to modify sounds without quite changing them altogether. Early works from all of the major electronic music studios of Europe, the United States, and Japan all made use of this technique. Playing sounds in reverse, like echo and reverberation, became one of the most familiar electronic music techniques and persists as a valued resource today of digital sound editing systems.

Tape Speed Manipulation

Another classic tape music technique was the effect of playing a sound at a speed other than that at which it was recorded, or **tape speed manipulation**. Tape recorders usually had two or three standard tape transport speeds: 7.5 inches (19 cm) per second, 15 inches (38 cm) per second, and 30 inches (76 cm) per second on professional machines. Using a faster tape speed resulted in higher fidelity because more magnetic particles were being devoted to recording a given sound than if the tape was running more slowly. Tape transport speed was controlled by a **capstan**—a tiny rotating, motor-driven spindle that pinched the tape against a rubber roller and pulled it from the supply reel to the take-up reel. Changing the diameter of the capstan would change the transport speed.

The setting for the fixed speeds used on tape recorders were not arrived at by accident. Note that each of the speeds was twice as fast as the speed before it. In musical terms, these speeds were exactly one octave apart. If a note recorded at 15 inches per second (ips) was played at 30 ips, it would have been one octave higher. Greater extremes in octave ranges could be achieved by re-recording sounds multiple times at different speeds to multiply the effect of octave changes. Composers purposefully recorded sounds at speeds other than the final playback speed of the master so that they could transpose the sounds up or down in the frequency range.

Changing the playback speed of a sound modified its pitch and duration. While the dominant pitch of a sound would change by an octave if the speed were shifted up or down, the tempo of the sound and its timbre were also transformed, often with unexpected results.

While most tape machines had specific speed settings, it was sometimes desirable to provide variable speed control through a continuous range of speeds without graduated increments. Some special purpose tape recorders were capable of varying the speed on a sliding scale between the standard settings, allowing one to gradually shift speed in smaller increments than simple octave steps. If working without a variable-speed tape recorder, a makeshift method of adding slight increases in transport speed and pitch could be accomplished by wrapping the capstan with one or more layers of splicing tape. By the 1970s, some commercially available reel-to-reel tape recorders came equipped with variable-speed capstans, or *varispeed*, which allowed speed to be varied over a continuous range.

Glissandi (1957) by György Ligeti was a short work of electronic music that used the techniques of tape reversal and variable speed changes as its chief structural guideposts. This work and *Artikulation* (1958) comprise the composer's only completed electronic works. As a young composer, Ligeti had little first-hand knowledge of contemporary music outside of Soviet-controlled Hungary where he lived. After reportedly hearing a radio concert of Stockhausen's *Gesang der Jünglinge* (1956), he began a correspondence with Stockhausen that led to his invitation to work at the studios of the WDR, which he did in 1957.[28] *Glissandi* was Ligeti's first completed electronic music composition and for many years he was reluctant to release it publicly because he considered it to be more of a test piece than a fully realized work. "*Glissandi* is a weak piece, concerning both the sound and form," declared Ligeti many years later. "It has a primitive, almost schematic, form."[29] Ligeti is known for his highly organized and mathematical approach to composition, an instinct that he shared with the Cologne school of electronic music. Although *Glissandi* did not embody the fully-formed serialism of Stockhausen's *Studie I* and *Studie II*, it is clear from analyzing the work and Ligeti's notes that he gave much thought to its structural plan.

Ligeti made use of several key pieces of equipment at the Cologne studio when composing *Glissandi*. Chief among these was a sine wave generator with a rotary dial for varying the pitch manually, reverberation, a variable-speed tape recorder, and filter banks. The audio filters found at the Cologne studio were some of the most advanced in any electronic music studio of the time and provided the composer with a fine degree of control over audio frequencies across the spectrum.

Glissandi had a planned structure that was more well-defined than might be evident upon first hearing the recording. The entire piece was 7′ 44″ long. Consisting of a sequence of rising and falling sine waves, glissandi made up the major tonal material of the piece. Some of the glissandi were created by manually adjusting the dial of a sine wave generator, while others appear to have been created using variable speed changes on a tape recorder. The basic sound material lasted 3′ 52″, after which, at the precise middle of the work, the first half of the piece was played entirely in reverse. In addition to playing the material in reverse, the second half of the piece also included an overdub of the first half played normally, but highly filtered so that only small particles of the sound were audible. The mirror-like structure of the work was carefully timed and added to the listening experience. For example, one could listen to a sound that occurred 25 seconds from the beginning of the work and then hear the same passage in reverse precisely 25 seconds before the end of the work. Ligeti did not evidently apply serial techniques to select the tones for the piece, but his organizational scheme was clearly symmetrical. The composer's sketches for the first half of the piece consisted of several sections of approximate durations labeled with Roman numerals (Table 5.1).

Table 5.1 **A sketch from the first section of Ligeti's *Glissandi*[30]**

Section	I	II	IIIA	IIIB	IIIC	IIID
Duration (seconds)	40–50	40–45	24	20	17	15

Detailed analysis of the recording by musicologist Benjamin Robert Levy revealed subsections within Ligeti's major sections (Table 5.2).

Table 5.2 **A sketch from Ligeti's *Glissandi* showing subsections**[31]

Subsection	IIIe	IIIf	IIIg	IIIh	IIIi	IIIj	IIIk	IIIl	IIIm	IIIn	IIIo
Duration (seconds)	12	11	9.5	8	7	6	5	4	3	2	1

Furthermore, Levy discovered that the succession of durations for some of the sections closely corresponded to a **Fibonacci series** of numbers—a sequence in which each new value in a series is simply the sum of the two before it. "Beginning with Roman numeral III, the subdivisions steadily decrease in length, and the rate at which they do so is determined by a Fibonacci-like series. Examining the differences in duration between sections yields the following arrangement" (see Figure 5.9).[32]

Note how the Fibonacci series is revealed if, reading Levy's diagram from right to left, one adds the duration of a sequence and the difference between it and the successive sequence, the result being equal to the duration of the next sequence in the row.

Aesthetically, *Glissandi* was an exercise in the exponential concretion and expansion of sonic textures. Using only pure sine waves as source material, the rich overtones and brushes of noise were the result of Ligeti's methodical combinations of groups of sliding tones. It was an atmospheric music of sweeping sonic textures, a characteristic that Ligeti would further explore in his long history as a composer of instrumental music. His experience in Cologne made an indelible impression on Ligeti, so much so that he has often been described as a composer who brought the textures of electronic music to works for orchestra. The influence of his experience with electronic music fundamentally changed Ligeti's approach to composing music for orchestra.

The methods and techniques associated with composing music for tape laid the groundwork for the development of all future electronic music. When digital media and sound editing software began to replace the tape recorder and splicing block during the 1980s, many familiar techniques associated with tape editing were transferred to the toolkits of computer programs designed for organizing, synthesizing, and editing music. Part III, Digital Synthesis and Computer Music, discusses the evolution of digital music development and the extension of traditional analog audio processing techniques to the computer electronic music studio.

Grouping				1		1						3				2
Difference		4		3		2		2		2		1.5		1.5		
Duration	24		20		17		15		13		11		9.5		8	

																8
1		1		1		1		1		1		1		1		
	7		6		5		4		3		2		1		0	

Figure 5.9 A sketch from Ligeti's *Glissandi* showing Fibonacci-like series. (After Levy, 2006)

SUMMARY

- Many of the basic aesthetic concepts and artistic choices invented by early composers of tape music remain at the core of electronic music still being produced today.
- The seven fundamental traits of electronic music are:
  1. The sound resources available to electronic music are unlimited.
  2. Electronic music can expand the perception of tonality.
  3. Electronic music exists in a state of actualization.
  4. Electronic music has a special relationship with the temporal nature of music.
  5. In electronic music, sound itself becomes the material of composition.
  6. Electronic music does not breathe—it is not affected by the limitations of human performance.
  7. Electronic music often lacks a point of comparison with the natural world of sounds, providing a largely mental and imaginative experience.
- Many modern practices and techniques found in modern electronic music had their origins in the classic tape studio.
- Classic tape techniques that have successfully transferred to the tapeless digital domain include editing (cutting and pasting of sounds), tape echo, reverberation, sound loops, delay, reversal of sounds, and tape speed manipulation.

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