BRÜN, KENNETH GABURO, and SALVATORE MARTIRANO along with the engineer James Beauchamp whose Harmonic Tone Generator was one of the most interesting special sound generating instruments of the period.

By the end of the decade PIERRE SCHAEFFER had reorganized the Paris studio into the Groupe de Recherches de Musicales and had abandoned the term musique concrète. His staff was joined at this time by LUC FERRARI and François-Bernard Mache, and later by François Bayle and Bernard Parmegiani. The Greek composer, architect and mathematician YANNIS XENAKIS was also working at the Paris facility as was LUCIANO BERIO. Xenakis produced his classic composition *DIAMORPHOSES* in 1957 in which he formulated a theory of density change which introduced a new category of sounds and structure into musique concrète.

In addition to the major technical developments and burgeoning studios just outlined there was also a dramatic increase in the actual composition of substantial works. From 1950 to 1960 the vocabulary of tape music shifted from the fairly pure experimental works which characterized the classic Paris and Cologne schools to more complex and expressive works which explored a wide range of compositional styles. More and more works began to appear by the mid-1950's which addressed the concept of combining taped sounds with live instruments and voices. There was also a tentative interest, and a few attempts, at incorporating taped electronic sounds into theatrical works. While the range of issues being explored was extremely broad, much of the work in the various tape studios was an extension of the Serialism which dominated instrumental music. By the end of the decade new structural concepts began to emerge from working with the new electronic sound sources that influenced instrumental music. This expansion of timbral and organizational resources brought strict Serialism into question.

In order to summarize the activity of the classic tape studio period a brief survey of some of the major works of the 1950's is called for. This list is not intended to be exhaustive but only to provide a few points of reference:

1949) Schaeffer and Henry: *SYMPHONIE POUR UN HOMME SEUL*

1951) Grainger: *FREE MUSIC*

1952) Maderna: *Musica su due Dimensioni*; Cage: *William's Mix*; Leuning: *Fantasy in Space*; Ussachevsky: *Sonic Contours*; Brau: *Concerto de Janvier*

1953) Schaeffer and Henry: *ORPHÉE*; Stockhausen: *Studie I*

1954) Varèse: *DÉSERTS*; Stockhausen: *Studie II*; Leuning and Ussachevsky: *A Poem in Cycles and Bells*

1955) B. & L. Barron: soundtrack to *Forbidden Planet*

1956) Krenek: *Spiritus Intelligentiae Sanctus*; Stockhausen: *GESANG DER JÜNGLINGE*; Berio: *Mutazioni*; Maderna: *Notturno*; Hiller: *ILLIAC SUITE FOR STRING QUARTET*

1957) Xenakis: *DIAMORPHOSES;* Pousseur: *Scambi*; Badings: *Evolutionen*

1958) Varèse: *POÈME ÉLECTRONIQUE;* Ligeti: *ARTIKULATION*; Kagel: *Transición I*; Cage: *FONTANA MIX*; Berio: *THEMA—OMAGGIO A JOYCE*; Xenakis: *Concret P-H II*; Pousseur: *RIMES POUR DIFFÉRENTES SOURCES SONORES*

1959) Kagel: *Transición II*; Cage: *INDETERMINACY*

1960) Berio: *Differences*; Gerhard: *Collages*; Maxfield: *NIGHT MUSIC*; Ashley: *The Fourth of July*; Takemitsu: *Water Music*; Xenakis: *Orient-Occident III*

By 1960 the evolution of the tape studio was progressing dramatically. In Europe the institutional support only increased and saw a mutual interest arise from both the broadcast centers and from academia. For instance it was in 1960 that the electronic music studio at the Philips research labs was transferred to the INSTITUTE OF SONOLOGY at the University of Utrecht. While in the United States it was always the universities that established serious electronic music facilities, that situation was problematic for certain composers who resisted the institutional mileau. Composers such as Gordon MUMMA and ROBERT ASHLEY had been working independently with tape music since 1956 by gathering together their own technical resources. Other composers who were interested in using electronics found that the tape medium was unsuited to their ideas. JOHN CAGE, for instance, came to reject the whole aesthetic that accompanied tape composition as incompatible with his philosophy of indeterminacy and live performance. Some composers began to seek out other technical solutions in order to specify more precise compositional control than the tape studio could provide them. It was into this climate of shifting needs that a variety of new electronic devices emerged.

The coming of the 1960's saw a gradual cultural revolution which was co-synchronous with a distinct acceleration of new media technologies. While the invention of the transistor in 1948 at Bell Laboratories had begun to impact electronic manufacturing, it was during the early 1960's that major advances in electronic design took shape. The subsequent innovations and their impact upon electronic music were multifold and any understanding of them must be couched in separate categories for the sake of convenience. The categories to be delineated are 1) the emergence of the voltage-controlled analog synthesizer; 2) the evolution of computer music; 3) live electronic performance practice; and 4) the explosion of multi-media. However, it is important that the reader appreciate that the technical categories under discussion were never exclusive but in fact interpenetrated freely in the compositional and performance styles of musicians. It is also necessary to point out that any characterization of one form of technical means as superior to another (i.e. computers versus synthesizers) is not intentional. It is the author's contention that the very nature of the symbiosis between machine and artist is such that each instrument, studio facility, or computer program yields its own working method and unique artistic produce. Preferences between technological resources emerge from a match between a certain machine and the imaginative intent of an artist, and not from qualities that are hierarchically germane to the history of technological innovation. Claims for technological efficiency may be relevant to a very limited context but are ultimately absurd when viewed from a broader perspective of actual creative achievement.

1) THE VOLTAGE-CONTROLLED ANALOG SYNTHESIZER

A definition: Unfortunately the term "synthesizer" is a gross misnomer. Since there is nothing synthetic about the sounds generated from this class of analog electronic instruments, and since they do not "synthesize" other sounds, the term is more the result of a conceptual confusion emanating from industrial nonsense about how these instruments "imitate" traditional acoustic ones. However, since the term has stuck, becoming progressively more ingrained over the years, I will use the term for the sake of convenience. In reality the analog voltage-controlled synthesizer is a collection of waveform and noise generators, modifiers (such as filters, ring modulators, amplifiers), mixers and control devices packaged in modular or integrated form. The generators produce an electronic signal which can be patched through the modifiers and into a mixer or amplifier where it is made audible through loudspeakers. This sequence of interconnections constitutes a signal path which is determined by means of patch cords, switches, or matrix pinboards. Changes in the behaviors of the devices (such as pitch or loudness) along the signal path are controlled from other devices which produce control voltages. These control voltage sources can be a keyboard, a ribbon controller, a random voltage source, an envelope generator or any other compatible voltage source.

The story of the analog "synthesizer" has no single beginning. In fact, its genesis is an excellent example of how a good idea often emerges simultaneously in different geographic locations to fulfill a generalized need. In this case the need was to consolidate the various electronic sound generators, modifiers and control devices distributed in fairly bulky form throughout the classic tape studio. The reason for doing this was quite straight forward: to provide a personal electronic system to individual composers that was specifically designed for music composition and/or live performance, and which had the approximate technical capability of the classic tape studio at a lower cost. The geographic locales where this simultaneously occurred were the east coast of the United States, San Francisco, Rome and Australia.

The concept of modularity usually associated with the analog synthesizer must be credited to Harald Bode who in 1960 completed the construction of his MODULAR SOUND MODIFICATION SYSTEM. In many ways this device predicted the more concise and powerful modular synthesizers that began to be designed in the early 1960's and consisted of a ring modulator, envelope follower, tone-burst-responsive envelope generator, voltage-controlled amplifier, filters, mixers, pitch extractor, comparator and frequency divider, and a tape loop repeater. This device may have had some indirect influence on Robert Moog but the idea for his modular synthesizer appears to have evolved from another set of circumstances.

In 1963, MOOG was selling transistorized Theremins in kit form from his home in Ithaca, New York. Early in 1964 the composer Herbert Deutsch was using one of these instruments and the two began to discuss the application of solid-state technology to the design of new instruments and systems. These discussions led Moog to complete his first prototype of a modular electronic music synthesizer later that year. By 1966 the first production model was available from the new company he had formed to produce this instrument. The first systems which Moog produced were principally designed for studio applications and were generally large modular assemblages that contained voltage-controlled oscillators, filters, voltage-controlled amplifiers, envelope generators, and a traditional style keyboard for voltage-control of the other modules. Interconnection between the modules was achieved through patch cords. By 1969 Moog saw the necessity for a smaller portable instrument and began to manufacture the Mini Moog, a concise version of the studio system that contained an oscillator bank, filter, mixer, VCA and keyboard. As an instrument designer Moog was always a practical engineer. His basically commercial but egalitarian philosophy is best exemplified by some of the advertising copy which accompanied the Mini Moog in 1969 and resulted in its becoming the most widely used synthesizer in the "music industry":

"R.A. Moog, Inc. built its first synthesizer components in 1964. At that time, the electronic music synthesizer was a cumbersome laboratory curiosity, virtually unknown to the listening public. Today, the Moog synthesizer has proven its indispensability through its widespread acceptance. Moog synthesizers are in use in hundreds of studios maintained by universities, recording companies, and private composers throughout the world. Dozens of successful recordings, film scores, and concert pieces have been realized on Moog synthesizers. The basic synthesizer concept as developed by R.A. Moog, Inc., as well as a large number of technological innovations, have literally revolutionized the contemporary musical scene, and have been instrumental in bringing electronic music into the mainstream of popular listening.

In designing the Mini Moog, R. A. Moog engineers talked with hundreds of musicians to find out what they wanted in a performance synthesizer. Many prototypes were built over the past two years, and tried out by musicians in actual live-performance situations. Mini Moog circuitry is a combination of our time-proven and reliable designs with the latest developments in technology and electronic components.

The result is an instrument which is applicable to studio composition as much as to live performance, to elementary and high school music education as much as to university instruction, to the demands of commercial music as much as to the needs of the experimental avant garde. The Mini Moog offers a truly unique combination of versatility, playability, convenience, and reliability at an eminently reasonable price."

In contrast to Moog's industrial stance, the rather countercultural design philosophy of DONALD BUCHLA and his voltage-controlled synthesizers can partially be attributed to the geographic locale and cultural circumstances of their genesis. In 1961 San Francisco was beginning to emerge as a major cultural center with several vanguard composers organizing concerts and other performance events. MORTON SUBOTNICK was starting his career in electronic music experimentation, as were PAULINE OLIVEROS, Ramon Sender and TERRY RILEY. A primitive studio had been started at the San Francisco Conservatory of Music by Sender where he and Oliveros had begun a series of experimental music concerts. In 1962 this equipment and other resources from electronic surplus sources were pooled together by Sender and Subotnick to form the San Francisco Tape Music Center which was later moved to Mills College in 1966. Because of the severe limitations of the equipment, Subotnick and Sender sought out the help of a competent engineer in 1962 to realize a design they had concocted for an optically based sound generating instrument. After a few failures at hiring an engineer they met DONALD BUCHLA who realized their design but subsequently convinced them that this was the wrong approach for solving their equipment needs. Their subsequent discussions resulted in the concept of a modular system. Subotnick describes their idea in the following terms:

"Our idea was to build the black box that would be a palette for composers in their homes. It would be their studio. The idea was to design it so that it was like an analog computer. It was not a musical instrument but it was modular...It was a collection of modules of voltage-controlled envelope generators and it had sequencers in it right off the bat...It was a collection of modules that you would put together. There were no two systems the same until CBS bought it...Our goal was that it should be under $400 for the entire instrument and we came very close. That's why the original instrument I fundraised for was under $500."

Buchla's design approach differed markedly from Moog. Right from the start Buchla rejected the idea of a "synthesizer" and has resisted the word ever since. He never wanted to "synthesize" familiar sounds but rather emphasized new timbral possibilities. He stressed the complexity that could arise out of randomness and was intrigued with the design of new control devices other than the standard keyboard. He summarizes his philosophy and distinguishes it from Moog's in the following statement:

"I would say that philosophically the prime difference in our approaches was that I separated sound and structure and he didn't. Control voltages were interchangeable with audio. The advantage of that is that he required only one kind of connector and that modules could serve more than one purpose. There were several drawbacks to that kind of general approach, one of them being that a module designed to work in the structural domain at the same time as the audio domain has to make compromises. DC offset doesn't make any difference in the sound domain but it makes a big difference in the structural domain, whereas harmonic distortion makes very little difference in the control area but it can be very significant in the audio areas. You also have a matter of just being able to discern what's happening in a system by looking at it. If you have a very complex patch, it's nice to be able to tell what

aspect of the patch is the structural part of the music versus what is the signal path and so on. There's a big difference in whether you deal with linear versus exponential functions at the control level and that was a very inhibiting factor in Moog's more general approach.

Uncertainty is the basis for alot of my work. One always operates somewhere between the totally predictable and the totally unpredictable and to me the "source of uncertainty," as we called it, was a way of aiding the composer. The predictabilities could be highly defined or you could have a sequence of totally random numbers. We had voltage control of the randomness and of the rate of change so that you could randomize the rate of change. In this way you could make patterns that were of more interest than patterns that are totally random."

While the early Buchla instruments contained many of the same modular functions as the Moog, it also contained a number of unique devices such as its random control voltage sources, sequencers and voltage-controlled spatial panners. Buchla has maintained his unique design philosphy over the intervening years producing a series of highly advanced instruments often incorporating hybrid digital circuitry and unique control interfaces.

The other major voltage-controlled synthesizers to arise at this time (1964) were the Synket, a highly portable instrument built by Paul Ketoff, and a unique machine designed by Tony Furse in Australia. According to composer Joel Chadabe, the SYNKET resulted from discussions between himself, Otto Leuning and JOHN EATON while these composers were in residence in Rome.

Don Buchla in his Berkeley, California studio with several of his creations, late 1970's. Coutesy of Don Buchla.

Chadabe had recently inspected the developmental work of Robert Moog and conveyed this to Eaton and Leuning. The engineer Paul Ketoff was enlisted to build a performance oriented instrument for Eaton who subsequently became the virtuoso on this small synthesizer, using it extensively in subsequent years. The machine built by Furse was the initial foray into electronic instrument design by this brilliant Australian engineer. He later became the principal figure in the design of some of the earliest and most sophisticated digital synthesizers of the 1970's.

After these initial efforts a number of other American designers and manufacturers followed the lead of Buchla and Moog. One of the most successful was the ARP SYNTHESIZER built by Tonus, Inc. with design innovations by the team of Dennis Colin and David Friend. The studio version of the ARP was introduced in 1970 and basically imitated modular features of the Moog and Buchla instruments. A year later they introduced a smaller portable version which included a preset patching scheme that simplified the instrument's function for the average pop-oriented performing musician. Other manufacturers included EML, makers of the ELECTRO-COMP, a small synthesizer oriented to the educational market; OBERHIEM, one of the earliest polyphonic synthesizers; muSonics' SONIC V SYNTHESIZER; PAIA, makers of a synthesizer in kit form; Roland; Korg; and the highly sophisticated line of modular analog synthesizer systems designed and manufactured by Serge Tcherepnin and referred to as Serge Modular Music Systems.

In Europe the major manufacturer was undoubtedly EMS, a British company founded by its chief designer Peter Zinovieff. EMS built the Synthi 100, a large integrated system which introduced a matrix-pinboard patching system, and a small portable synthesizer based on similar design principles initially called the Putney but later modified into the SYNTHI A or Portabella. This later instrument became very popular with a number of composers who used it in live performance situations.

One of the more interesting footnotes to this history of the analog synthesizer is the rather problematic relationship that many of the designers have had with commercialization and the subsequent solution of manufacturing problems. While the commercial potential for these instruments became evident very early on in the 1960's, the different aesthetic and design philosophies of the engineers demanded that they deal with this realization in different ways. Buchla, who early on got burnt by larger corporate interests, has dealt with the burden of marketing by essentially remaining a cottage industry, assembling and marketing his instruments from his home in Berkeley, California. In the case of MOOG, who as a fairly competent businessman grew a small business in his home into a distinctly commercial endeavor, even he ultimately left Moog Music in 1977, after the company had been acquired by two larger corporations, to pursue his own design interests.

It is important to remember that the advent of the analog voltage-controlled synthesizer occurred within the context of the continued development of the tape studio which now included the synthesizer as an essential part of its new identity as the electronic music studio. It was estimated in 1968 that 556 non-private electronic music studios had been established in 39 countries. An estimated 5,140 compositions existed in the medium by that time.

Some of the landmark voltage-controlled "synthesizer" compositions of the 1960's include works created with the "manufactured" machines of Buchla and Moog but other devices were certainly also used extensively. Most of these works were tape compositions that used the synthesizer as resource. The following list includes a few of the representative tape compositions and works for tape with live performers made during the 1960's with synthesizers and other sound sources.

1960) Stockhausen: *KONTAKTE*; Mache: *Volumes*;

1961) Berio: *VISAGE*; Dockstader: *TWO FRAGMENTS FROM APOCALYPSE*

1962) Xenakis: *BOHOR I*; Philippot: *Étude III*; Parmegiani: *DANSE;*

1963) Bayle: *PORTRAITS DE L'OISEAU-QUI-N'EXISTE-PAS*; Nordheim: *EPITAFFIO*

1964) Babbitt: *Ensembles for Synthesizer*; Brün: *Futility*; Nono: *LA FABBRICA ILLUMINATA*

1965) Gaburo: *LEMON DROPS*, Mimaroglu: *Agony*; Davidovsky: *Synchronisms No. 3*;

1966) Oliveros: *I OF IV*; Druckman: *Animus I*;

1967) Subotnick: *SILVER APPLES OF THE MOON*; Eaton: *CONCERT PIECE FOR SYN-KET AND SYMPHONY ORCHESTRA*; Koenig: *Terminus X*; Smiley: *ECLIPSE*;

1968) Carlos: *Switched-On Bach*; Gaburo: *DANTE'S JOYNTE*; Nono: *CONTRAPPUNTO DIALETTICO ALLA MENTE*

1969) Wuorinen: *TIME'S ENCOMIUM*; Ferrari: *MUSIC PROMENADE*

1970) Arel: *Stereo Electronic Music No. 2*; Lucier: *I AM SITTING IN A ROOM*

2) COMPUTER MUSIC

A distinction: *Analog* refers to systems where a physical quantity is represented by an analogous physical quantity. The traditional audio recording chain demonstrates this quite well since each stage of translation throughout constitutes a physical system that is analogous to the previous one in the chain. The fluctuations of air molecules which constitute sound are translated into fluctuations of electrons by a microphone diaphram. These electrons are then converted via a bias current of a tape recorder into patterns of magnetic particles on a piece of tape. Upon playback the process can be reversed resulting in these fluctuations of electrons being amplified into fluctuations of a loudspeaker cone in space. The final displacement of air molecules results in an analogous representation of the original sounds that were recorded. Digital refers to systems where a physical quantity is represented through a counting process. In digital computers this counting process consists of a two-digit binary coding of electrical on-off switching states. In computer music the resultant digital code represents the various parameters of sound and its organization.

As early as 1954, the composer YANNIS XENAKIS had used a computer to aid in calculating the velocity trajectories of glissandi for his orchestral composition *Metastasis*. Since his background included a strong mathematical education, this was a natural development in keeping with his formal interest in combining mathematics and music. The search that had begun earlier in the century for new sounds and organizing principles that could be mathematically rationalized had become a dominant issue by the mid-1950's. Serial composers like MILTON BABBIT had been dreaming of an appropriate machine to assist in complex compositional organization. While the RCA Music Synthesizer fulfilled much of this need for Babbitt, other composers desired even more machine-assisted control. LEJAREN HILLER, a former student of Babbitt, saw the compositional potential in the early generation of digital computers and generated the Illiac Suite for string quartet as a demonstration of this promise in 1956.

Xenakis continued to develop, in a much more sophisticated manner, his unique approach to computer-assisted instrumental composition. Between 1956 and 1962 he composed a number of works such as *Morisma-Amorisma* using the computer as a mathematical aid for finalizing calculations that were applied to instrumental scores. Xenakis stated that his use of probabilistic theories and the IBM 7090 computer enabled him to advance "...a form of composition which is not the object in itelf, but an idea in itself, that is to say, the beginnings of a family of compositions."

The early vision of why computers should be applied to music was elegantly expressed by the scientist Heinz Von Foerster:

"Accepting the possibilities of extensions in sounds and scales, how do we determine the new rules of synchronism and succession?

It is at this point, where the complexity of the problem appears to get out of hand, that computers come to our assistance, not merely as ancillary tools but as essential components in the complex process of generating auditory signals that fulfill a variety of new principles of a generalized aesthetics and are not confined to conventional methods of sound generation by a given set of musical instruments or scales nor to a given set of rules of synchronism and succession based upon these very instruments and scales. The search for those new principles, algorithms, and values is, of course, in itself symbolic for our times."

The actual use of the computer to generate sound first occurred at Bell Labs where Max Mathews used a primitive digital to analog converter to demonstrate this possibility in 1957. Mathews became the central figure at Bell Labs in the technical evolution of computer generated sound research and compositional programming with computer over the next decade. In 1961 he was joined by the composer JAMES TENNEY who had recently graduated from the University of Illinois where he had worked with Hiller and Gaburo to finish a major theoretical thesis entitled *Meta + Hodos* For Tenney, the Bell Lab residency was a significant opportunity to apply his advanced theoretical thinking (involving the application of theories from Gestalt Psychology to music and sound perception) into the compositional domain. From 1961 to 1964 he completed a series of works which include what are probably the first serious compositions using the MUSIC IV program of Max Mathews and Joan Miller and therefore the first serious compositions using computer-generated sounds: *Noise Study, Four Stochastic Studies, Dialogue, Stochastic String Quartet, Ergodos I, Ergodos II, and PHASES.*

In the following extraordinarily candid statement, Tenney describes his pioneering efforts at Bell Labs:

"I arrived at the Bell Telephone Laboratories in September, 1961, with the following musical and intellectual baggage:

1. numerous instrumental compositions reflecting the influence of

Webern and Varèse;
2. two tape-pieces, produced in the Electronic Music Laboratory at the University of Illinois - both employing familiar, 'concrete' sounds, modified in various ways;
3. a long paper ("Meta+Hodos , A Phenomenology of 20th Century Music and an Approach to the Study of Form", June, 1961), in which a descriptive terminology and certain structural principles were developed, borrowing heavily from Gestalt psychology. The central point of the paper involves the ***clang****, or primary aural Gestalt, and basic laws of perceptual organization of clangs, clang-elements, and sequences (a high-order Gestalt-unit consisting of several clangs).*
4. A dissatisfaction with all the purely synthetic electronic music that I had heard up to that time, particularly with respect to ***timbre****;*
5. ideas stemming from my studies of acoustics, electronics and - especially - information theory, begun in Hiller's class at the University of Illinois; and finally
6. a growing interest in the work and ideas of John Cage.
I leave in March, 1964, with:
1. six tape-compositions of computer-generated sounds - of which all but the first were also composed by means of the computer, and several instrumental pieces whose composition involved the computer in one way or another;
2. a far better understanding of the physical basis of ***timbre****, and a sense of having achieved a significant extension of the range of timbres possible by synthetic means;*
3. a curious history of renunciations of one after another of the traditional attitudes about music, due primarily to gradually more thorough assimilation of the insights of John Cage.
In my two-and-a-half years here I have begun many more compositions than I have completed, asked more questions than I could find answers for, and perhaps failed more often than I have succeeded. But I think it could not have been much different. The medium is new and requires new ways of thinking and feeling. Two years are hardly enough to have become thoroughly acclimated to it, but the process has at least begun."

In 1965 the research at Bell Labs resulted in the successful reproduction of an instrumental timbre: a trumpet waveform was recorded and then converted into a numerical representation and when converted back into analog form was deemed virtually indistinguisable from its source. This accomplishment by Mathews, Miller and the French composer JEAN-CLAUDE RISSET marks the beginning of the recapitulation of the traditional representationist versus modernist dialectic in the new context of digital computing. When contrasted against Tenney's use of the computer to obtain entirely novel waveforms and structural complexities, the use of such immense technological resources to reproduce the sound of a trumpet, appeared to many composers to be a gigantic exercise in misplaced concreteness. When seen in the subsequent historical light of the recent breakthroughs of digital recording and sampling technologies that can be traced back to this initial experiment, the original computing expense certainly appears to have been vindicated. However, the dialectic of representationism and modernism has only become more problematic in the intervening years.

The development of computer music has from its inception been so critically linked to advances in hardware and software that its practitioners have, until recently, constituted a distinct class of specialized enthusiasts within the larger context of electronic music. The challenge that early computers and computing environments presented to creative musical work was immense. In retrospect, the task of learning to program and pit one's musical intelligence against the machine constraints of those early days now takes on an almost heroic aire. In fact, the development of computer music composition is definitely linked to the evolution of greater interface transparency such that the task of composition could be freed up from the other arduous tasks associated with programming. The first stage in this evolution was the design of specific music-oriented programs such as MUSIC IV. The 1960's saw gradual additions to these languages such as MUSIC IVB (a greatly expanded assembly language version by Godfrey Winham and Hubert S. Howe); MUSIC IVBF (a fortran version of MUSIC IVB); and MUSIC360 (a music program written for the IBM 360 computer by Barry Vercoe). The composer Charles Dodge wrote during this time about the intent of these music programs for sound synthesis:

*"It is through simulating the operations of an ideal electronic music studio with an unlimited amount of equipment that a digital computer synthesizes sound. The first computer sound synthesis program that was truly general purpose (i.e., one that could, in theory, produce any sound) was created at the Bell Telephone Laboratories in the late 1950's. A composer using such a program must typically provide: (1) Stored functions which will reside in the computer's memory representing waveforms to be used by the **unit generators** of the program. (2) "Instruments" of his own design which logically interconnect these **unit generators**. (**Unit generators** are subprograms that simulate all the sound generation, modification, and storage devices of the ideal electronic music studio.) The computer "instruments" **play** the notes of the composition. (3) **Notes** may correspond to the familiar "pitch in time" or, alternatively, may represent some convenient way of dividing the time continuum."*

By the end of the 1960's computer sound synthesis research saw a large number of new programs in operation at a variety of academic and private institutions. The demands of the medium however were still quite tedious and, regardless of the increased sophistication in control, remained a tape medium as its final product. Some composers had taken the initial steps towards using the computer for realtime performance by linking the powerful control functions of the digital computer to the sound generators and modifiers of the analog synthesizer. We will deal with the specifics of this development in the next section. From its earliest days the use of the computer in music can be divided into two fairly distinct categories even though these categories have been blurred in some compositions: 1) those composers interested in using the computer predominantly as a compositional device to generate structural relationships that could not be imagined otherwise and 2) the use of the computer to generate new synthetic waveforms and timbres.

A few of the pioneering works of computer music from 1961 to 1971 are the following:

1961) Tenney: *Noise Study*

1962) Tenney: *Four Stochastic Studies*

1963) Tenney: *PHASES*

1964) Randall: *QUARTETS IN PAIRS*

1965) Randall: *MUDGETT*

1966) Randall: *Lyric Variations*

1967) Hiller: *Cosahedron*

1968) Brün: *INDEFRAUDIBLES*; Risset: *COMPUTER SUITE FROM LITTLE BOY*

1969) Dodge: *CHANGES*; Risset: *Mutations I*

1970) Dodge: *EARTH'S MAGNETIC FIELD*

1971) Chowning: *SABELITHE*

3) LIVE ELECTRONIC PERFORMANCE PRACTICE

A Definition: For the sake of convenience I will define live electronic music as that in which electronic sound generation, processing and control predominantly occurs in realtime during