VOLTAGE CONTROL

by Pauline Oliveros

The concept, synthesizer has pervaded the limited existing electronic music technology since the middle of the 1960's. Most of the equipment in the first electronic music studios was not manufactured specifically for electronic music. The equipment was modified in various ways or used as it was manufactured, often awkwardly. Mostelectronic music systems were influenced by the techniques in use during the early days of the Cologne studio. Electronic music was considered ideal for serial techniques and the work done in the Cologne studio under the direction of Herbert Eirnert was dogmatically ruled by serial techniques. Along with "absolute" control of pitch, volume and durations, a young composer named Karlheinz Stockhausen, who worked at the Cologne studio, wished to achieve any sound imaginable by working backwards with Fourier Anaylsis. The Fourier theories proposes that all sounds in nautre consist of simple harmonic motions or single frequencies called sine waves in

various complex relationships; that any sound in nature could be analyzed into its constituent sine waves in their proper phase and amplitude relationships.

All sounds consist of more than one frequency. The frequency of the fundamental or lowest partial determines the pitch. A single frequency can be represented graphically as follows; if a pen were attached to a string vibrating, in a single mode, which was being moved forward in time at a constant rate, the following picture would be drawn representing the back and forth motions of the string through its normal resting point.[1] 1. Amplitude means the height of the motion or the maximum excursion of the string from its resting point or axis. If two strings were vibrating in single modes simultaneously at the same frequency with exactly the same starting time, the vibrations would be in phase[2]. Phase is any point during a complete cycle.

Stockhausen reasoned that he could arrive at a synthesis of any sound imaginable by the combination of sine waves in the electronic

music studio.

Stockhausen soon found that his working hypothesis was a tedious and not altogether satisfactory means of achieving the desired ends. (Although any sound imaginable may be theoretically possible to synthesize electronically, the sound will always be tempored by the loud speakers and how the speakers are coupled to the space which contains them). As reflected in his 1956 work Gesang der Junglinge, modulation and musique * concrete were new techniques incorporated in his music. Modulation in the broad sense means to effect or vary one parameter in sympathy with another parameter. Parameter means any variable characteristic of a system. In this case modulation was of the ring type. Ring modulation, because of circuit changes, is now commonly referred to as balanced modulation. Ring or balanced modulation means to sound two frequencies together in a circuit which produces sum and difference frequencies while

*Musique concrete is derived from pre recorded acoustic sounds, which are manipulated electronically and by various tape techniques. Musique concrete was named so by Pierre Schaeffer, a Parisian eigineer who began to work with it in 1948.

suppressing the original two frequencies. This technique immediately produces more complex sounds which, with addition by mixing or subtraction by filtering, can produce further changes in quality without the longer process of synthesis.

The introduction of acoustic material ended the notion of pure electronic music. Today, the term electronic ~~mus~~ music includes the ~~amplifi~~ amplification and manipulation of acoustic material with electronic circuits as well as electronically generated material. However, the influence of the early studio techniques and dogma have greatly affected the design of today's voltage controlled electronic music systems. These are commonly referred to as synthesizers although synthesis is only one aspect of voltage controlled electronic music systems. Voltage control is the great innovation in these electronic music systems, and will be discussed in depth later in this article.

Voltage controlled electronic music systems consist of sound sources (generators or oscillators), sound modifiers, (mixers, filters,

modulators, amplifiers and reverberators) and controllers or voltage sources (keyboards, sequencers, random voltage sources, pulse generators and voltage or envelope generators). Circuits for sound sources external to the system are sometimes provided for in the form of pre-ampe to admit the external source from a microphone or other transducer. Usually, system inputs will accept outputs from hi-level sources such as a tape recorder or radio; however, modification and control circuits are more specifically designed for the systmm sound sources or electronic wave forms (acoustic* wave forms are inevitably more complex) since usually only a limited amount of modification and control will apply effectively to external sources. This situation reflects the early interest in so-called pure electronic music and serial technique. Research and inclusion of circuitory for the amplifcation, modification and control of acoustic sound sources would enhance the palette these systems offer, especially, for instance, the control of acoustic material by circuitory for converting acoustic signals to control voltages and their transpositions. The

* wave form refers to a graphic representation of amplitude variations plotted against time.

electronic reconstitution of acoustic signals would offer such possibilitiies as frequency modulation.*

The concentration on control of pitch, durations and amplitude has retarded developments in the control of other parameters of composition; for instance: timbre changing by voltage controlled wave shaping and sound location control. The serial technician and pitch oriented composers are well served, but composers who are timbre oriented are not. The tendency to consider voltage controlled electronic music systems as replacements for older tape techniques involving the ~~xxx~~ shaping of single events has resulted in monophonic (or one sound at a time) devices. Control of many devices (not sure of word) and simultaneous events from a single sources will be an important new development, allowing the composer more extensive performing technique in the studio or on stage. The idea that tape storage of musical events could replace performers entirely is preposterous. Not only is tape an imperfect medium, but it is also, after recording, in ~~xxxxx~~ a state of continual deterioration.

* Frequency modulation means to change frequency in sympathy with another signal.

Tape is only a temporary buffer until performance technology is made available.

Some other influences in the design of voltage controlled electronic music systems are the following:

1. The practicing technicians' and composers' adaptation to awkward manuevers with equipment not primarily packaged for musical purposes has not encouraged research toward human musical engineering; in other words, a better arrangement of knobs, switches and patching facility* (external interconnection of circuits) or entirely different devices would permit a more musical control of sound events.

The musician is bound to centuries of muscular control of sound events. The kinetic impulse and action is of course extremely satisfying. Replacement or supplement of these impulses with more appropriate neurophysiological input devices, which utilize neurological rather than muscular signals, will require

* Although patching on two of the newest systems has been virtually replaced by a matrix of switches or Pen Jacks, the musical problem is not solved. It is just as difficult to develop reflexes for matrix switching as for patching. The advantage of no patch cord mess is followed by the disvantage of switch sizes and arrangements more suitable for the metric measurements of the hardware than for human digits.

extensive re-education of musicians and designers not to mention audiences. The keyboard as used with electronic music systems is no longer a transducer of muscular energy to mechanical energy, but is a switching device which sends voltage to circuits which perform various selected tasks. The re-education of old reflexes, inherent in presenting this device as a familiar item in an unfamiliar context, really calls for a new device which is more compatible with the system. This could lead the musician or technician into a more satisfactory relationship with a new kind of instrument which is essentially dealing with sound material much more related to neurological than muscular functions.

2. The designers have acted upon biased advice from a few composers. Bias is certainly not bad in itself. Some clearly defined operating characteristics are present because of it; however, the systems are marketed to persons representing a wide range of idfferent interests. Eventually systems could reflect

more inclusive ideas when more composers learn how to communicate with designers and vice versa.* A universal electronic music system will probably remain in the realm of the ideal since no system can ever be entirely inclusive, and composers' problems are diverse andchange continually as well. Also, the comprehension of a system often reveals its weaknesses and finally lead to the derive for a different one.

3. Cost is the key concept in design practice. Many excellent designs have not been produced because of economics. If a system is too expensive then the market is too limited. The economic limitation also discourages human engineering because too many standard parts and devices would have to be thrown out.

Fundamentals of Voltage Control

In order to understand the concept of voltage control a summary knowledge of electronic fundamentals, wave forms and modulation is necessary and can be an aid leading to refinements in the generation and manipulation

* A symposium sponsored by Synthesis on compositional problems, which are alien to the available systems for composers, and on design problems, which limit systems for engineers, would be valuable.

of electronic sound. The operation of any of these systems can be learned by rote, by following the manual, or through experimentation. Some of all these methods is valuable but much trial and error can be eliminated by study of the following:

Keypoints are that 1. sound is produced by variations in voltage. 2. Electronic sound sources can be manipulated by variations in voltage. 3. Waveforms are variations in voltage plotted against time. 4. Modulation is the ability to vary one voltage in sympathy with another voltage.

All matter is composed of atoms. Electricity is possible because of the structure of atoms.[3] Atoms have a nucleus surrounded by orbiting particles called electrons. Electrons have a negative charge. The nucleus of the atom is made up of neutrons. Neutrons have an equal but opposite charge called positive. Unlike charges attract and like charges repel. Electrons are attracted to the nucleus but the centrifugal force due to the speed of the orbit prveents the electrons from joining the nucleus.

The attraction between the nucleus and the electrons is so great that a force is required to separate them. In electricity this force is known as voltage.

Voltage is the difference in potential electrical force or pressure capable of producing current flow which is controlled by resistance. Current consists of electrons flowing from a negative source to a positive source or from a point having many electrons. When current flows work is performed when a resistance is present. Resistance is opposition to electron flow. Resistance is a property of all materials in varying degrees. Materials with high resistance such as rubber are known as insulation. Electrons in the atomic structure of rubber are more tightly bound than in a material such as copper. Copper has very low resistance and is a good conductor of electrons. Electrons in the atomic structure of copper are more loosely bound because there are more electrons than neutrons making them more susceptible to attraction away from the nucleus. Resistance controls the amount of work to be performed.

Voltage is analogous to the potential energy a musician can store. When the musician releases his energy, for instance as a vocalist, his energy in the form of air flow causes his vocal cords to vibrate. The outer air is a voltage source. The ability to store air in his lungs creates the difference in potential. If he releases all of his energy at once he might produce an inarticulate shout depending on the amount of air stored in his lungs and the compliance of his glottis which releases short puffs of air like a valve opening and closing. The shout would be the result of work performed by the air flow through the vocal cords.[4]

Air flow is analogous to current flow. The form of the shout would roughly be determined by the relationship of the capacity of his lungs to his vocal cords, lips, oral cavities and body resonance, and how his vocal cords respond to the amount of air flow released by the glottis which caused them to vibrate. The total opposition of the larynx which contains the glottis and vocal cords plus the pathway for the air flow from lungs to outer air is analogous to electrical resistance or the load.

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A vocal sound represents work performed by a complete circuit bdtween the air and the vocal appartus. Lung action creates the difference in potential necessary to cause air flow. Then work is performed and energy is returned to the original source. (outer air). In an electric circuit, voltage, current and resistance must be present in order for the ~~air~~ circuit to function.

The relationship of voltage, current and resistance is expressed by Ohm's law for electric circiuts. Ohm's law states that current varies directly with voltage and inversely with resistance. The following equation expresses this relatinnship: $I = \frac{E}{R}$ where I is the current or intensity, E is the voltage or electromotive force and R is the resistance. Current is measured in amperes, the rate of electron flow past a point. Voltage is measured in volts, the amount of energy available. Resistance is measured in Ohms, the amount of ϕ opposition to current flow. (Ohm is symbolized by Ω). The work performed by an electric circuit is measured in watts. The rate at which the work is done is known as power. Power

can be determined by multiplying the voltage times the current or P = EI.

There are two kinds of voltage: d-c and a-c. D-c refers to direct durrent or current which is produced by electrons traveling in one direction only.[6] If a source of electrons such as a battery[7] is connected so that current flows from its negative terminals to its positive terminals through a resistance, for example a flashlight lamp, the lamp will glow steadily from the point in time that the connection is made until the source of voltage is depleted or disconnected.[8]

When the connection is made current rises instantaneously from zero to a constant value[9] which is determined by Ohm's law and remains at that value until the circuit is disconnected. With a fixed voltage and resistance the only variable characteristic of this circuit is the duration of the current which can be controlled by the insertion of a switch.[10] This ability to start and stop d-c is extremely important in electronic circuits. With a variable resistance the amplitude or intensity of d-c can be made to vary[11] which caused d-c to behave like

a-c and to be considered as such.

A-c refers to alternating current[12] or current which is produced by electrons which periodically reverse direction of travel. This periodic reversal of direction is analogous to a vibrating string.[13] The reversal of direction causes a-c to have a characteristic which is not part of a constant value d-c or straight line d-c. The all important eharacteristic for a-c[14] is frequency which like the vibrating string under the proper resonant conditions can produce sound or pitch.

Returning to the flashlight lamp circuit, if the battery terminals were periodically reversed in the circuit a-c would result. The lamp would flick on and off periodically. Household current is a-c at 60 hz.* and household lamps flicker at that rate.

A-c is produced by generators at power stations. A-c is more economical than d-c where large amounts of power are required because it is easier to transmit. D-c can be obtained from a-c by special circuitry. Most electronic circuits use d-c to supply power to other parts of the circuit but a-c is necessary for all but the simplest circuits like the flashlight circuit.

*hz. is an abbreviation for hertz which means cycles per second.

The use for constant value d-c is analogous to the musician placing his finger at a certain point on a string to influence the number of vibrations per second and thus the pitch. Simply placing a finger on a string will not produce sound if the action is gentle and the finger remains constant in place.[15] However if enough force is applied as the finger contacts the string a sound will be heard, if resonance is present in the form of a sounding board, as the string is induced to vibrate. If the finger could move fast enough with the proper force like a piston[16], a pitch would be heard. The pitch would be determined by the frequency of the finger action modulated by its position on the string and the resonance of the oscillating system.

If a battery is connected to a loud speaker a similar phenomena can be observed. When the connection is made a sharp pulse occurs as the current rises from zero to a constant magnitude. The initial pulse caused by the connection induces the speaker cone to vibrate. After the initial pulse, no further sound will be heard since electrons traveling in one direction at a constant magnitude cannot be heard. However if the connection between the battery and speaker was switched on and off

at 440 times per second the pitch A would be perceived. In this way d-c can be made to behave like a-c and have the variable characteristic of frequency without reversing the direction of electron travel. This is the function of the glottis in the example of the vocalist. Although air flow from the lungs is in one direction only, pitch of the voice is determined primarily by the frequency of the air pulses released by the glottis. Resonance of the oral and body cavities and partials introduced by the vocal cords also have some influence on pitch perception.

In order to have sound from electricity then, a-c, pulsating or fluctuating d-c or the interruption of straight line or constant value d-c must be present. These electrical voltages are termed signals when some characteristic of voltage or current is being changed or varied. The sizes of electronic signals as sound and control sources can best be studied by analyzing the wave forms commonly used in electronic music systems.

August 5, 1972

R.A. Cutter
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Dear Mr. Cutter,

Please remove my name from your Advisory Board, all Synthesis stationery and from Synthesis Magazine in any connection. This letter will also serve as an authorization for Erick Stokes to personally retrieve my original longhand manuscript on Voltage Controll which you commissioned. If my name appears again in connection with your magazine or my manuscript is not surrendered, I shall certainly file suit against you through my attourney.

You use the word commission very carelessly. Your mishandling of me and my so called commissioned manuscript has been one of the most inconsiderate acts which I have encountered in my professional career.

Sincerely yours,

Pauline Oliveros

~~Pauline Oliveros~~

cc; Ted Bumer, Attourney

Erick Stokes

All Colleagues at UCSD