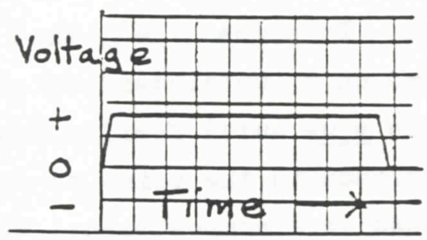
Moog Synthesizer: Concept of Voltage Control

A basic understanding of the operational principles involved in the functional characteristics of voltage-controlled equipment can be highly advantageous for a number of reasons. In the first place, one will more quickly grasp the significant role that each module plays in the total synthesizing operation. Of course, it is possible to achieve a certain understanding of the equipment solely by empirical methods, i.e., by employing and recording by ear or otherwise the gamut of dial and switch settings and of patching combinations. It seems likely that a systematic approach to the equipment based on an understanding of its theoretical operational principles plus aural familiarity would result in a reasonable, quick approach to the point at which the synthesizing equipment could be used as a compositional tool rather than an intriguing toy. This is not to say that one should not thoroughly enjoy the discovery of heretofore unknown sounds but that the novelty of such discoveries is bound to wear thin and in its place there should be a purpose for using the materials in a musical composition.

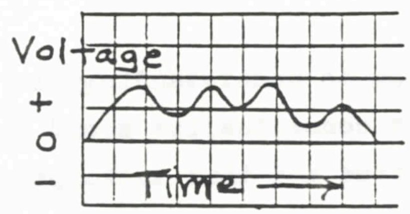
Another advantage to understanding the modules on a theoretical level is that one can conceptualize sound materials outside of precious laboratory time and then anticipate what operational setup would produce those sounds. Personal experience has proven to me that the more completely I understood the theoretical bases of the equipment the more interesting sounds I was able to produce. There are so many possible setups that a simple trial and error method is wholly inadequate to the task of comprehending this equipment.

Theoretical understanding also enables one quickly to spot an error in the setup or even a malfunctioning module. It can be terribly frustrating to patch a complex circuit which one knows should produce a fascinating sound event and then have absolutely nothing or perhaps only a shadow of the intended sound event emerge from the monitor system. Often the "error" can be corrected by a slight turn of a control dial. The problem is knowing which dial to turn and what effect it will have on the total operation.

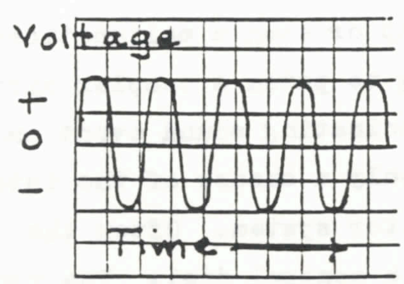
To grasp the concept of voltage-control one must first understand a few basic facts concerning voltage. Voltage is an electromotive force that can be constant in magnitude (steady direct current), varying above a zero magnitude (fluctuating direct current) or varying around zero magnitude (alternating current). In the following example the voltage level remains at one volt; it illustrates steady direct current.



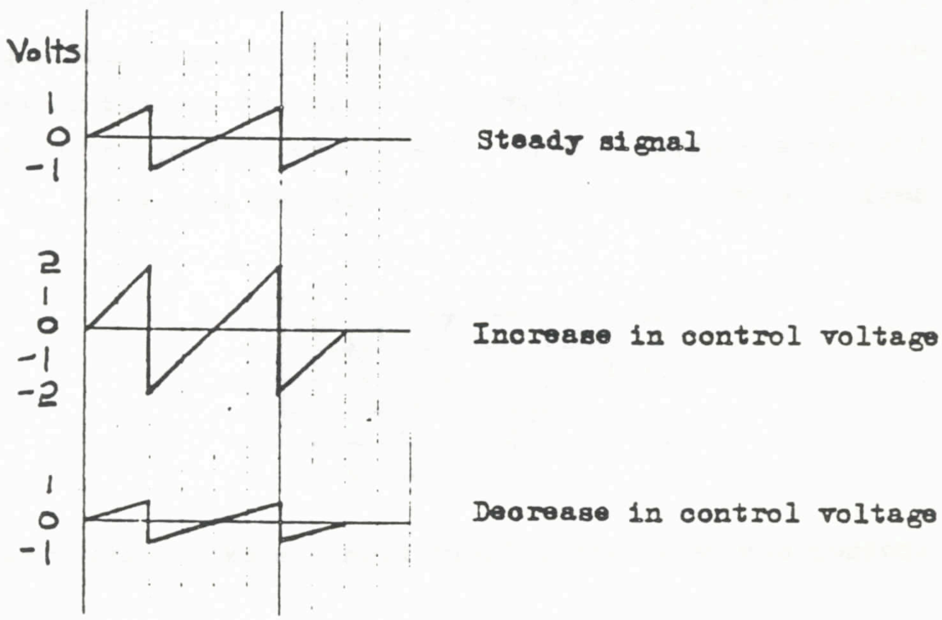
The next example illustrates the nature of fluctuating direct current.



The last example illustrates the nature of alternating current. Notice that there is a negative as well as positive voltage level involved.



The basic principle of the control voltage system is not at all complicated. An increase in the control voltage level will be reflected by an increase in frequency if it is controlling an oscillator, by an increase in amplitude if it is controlling an amplifier, or by an increase in filtering function, etc. A decrease in the control voltage level will be reflected by a decrease in frequency, amplitude or filtering function. The following simple graph taken from an oscilloscope reading illustrates this important principle as it is applied to a 902 Voltage-Controlled Amplifier.

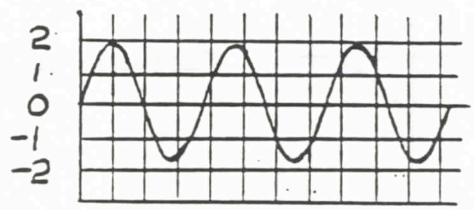


Much of Moog's equipment is designed so that some of the operating parameters are determined by the magnitude of applied control voltage. The applied control voltage can be of either class, direct or alternating current, or it can be a combination of either or both depending upon the number of control inputs. The control inputs accept voltage contours produced by external sources and impart those contours to the characteristic product of the controlled module, whether it be an oscillator, filter, or amplifier.

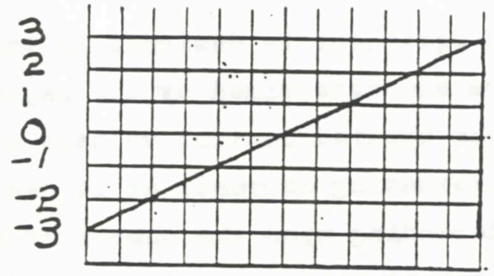
Control inputs are found on seven of the modules under consideration in this manual. They are as follows:

1. 902 Voltage-Controlled Amplifier
2. 901 Voltage-Controlled Oscillator
3. 901-A Oscillator Controller
4. 904-A Voltage-Controlled Low Pass Filter
5. 904-B Voltage-Controlled High Pass Filter
6. 904-C Filter Coupler
7. 912 Envelope Follower (Schmidt trigger circuit)

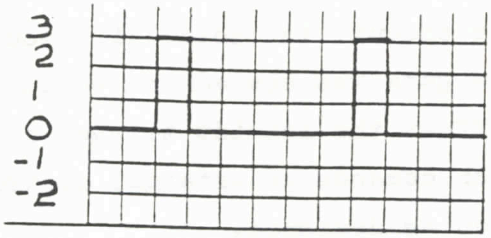
The first six modules on the above list react similarly to applied control voltage in the sense that final voltage contour which manifests itself on the parameter of the specific module is the <u>sum total</u> of applied control voltages. For example, examine what happens when a 902 Voltage-Controlled Amplifier accepts a control voltage of a different contour in each one of its three control inputs. One of the control voltages may be an amplitude vibrato from a slowly beating sine wave.



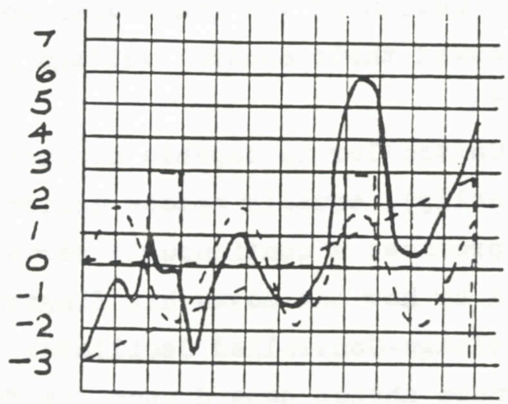
Another may be a ramp voltage from a slowly beating sawtooth.



The third may be a percussive attack produced by a keyboard-triggered Envelope Generator.



The following diagram illustrates the combined effects of these controls as applied to a 902 Voltage-Controlled Amplifier as it processes an incoming signal. Notice that all the control voltages act upon the signal being processed simultaneously; however, if they are sufficiently differentiated their individual characters emerge intact, albeit as part of the total voltage contour.



It should be remembered that if the above illustration were applied to an oscillator, it would result in frequency modulation, or if it were applied to a filter, it would result in formant modulation.

The control input found on the Schmidt trigger circuit section of the 912 Envelope Follower does not function as those discussed in the preceding pages. Instead, it controls a gate, that is, a switching circuit that passes or shuts off a signal in response to a threshold control setting. For example the threshold control may be set to "open the gate" whenever the voltage level exceeds 2 volts and to "close the gate" when it falls below that mark. This would mean that the module which the Schmidt trigger circuit is controlling would not begin its operation until the gate was opened and would cease when the gate closed. In effect the Schmidt trigger circuit is a voltage-control device which demands an external control voltage generator in order to function as designed.

Five of the modules discussed in this manual can be considered control voltage generators. They are as follows:

1. Keyboard Controller
2. Linear Controller
3. 901 Voltage-Controlled Oscillator
4. 911 Envelope Generator
5. 903 White Sound Source

Although they will be discussed in greater detail in the section devoted to the explication of the individual modules, a few remarks directed toward their control voltage functions are in order at this point.

The Keyboard Controller is capable of providing sixty-one discrete (theoretically), equally spaced control voltages. The Linear Controller produces a continuously variable control voltage which is determined by how one moves his finger along a control ribbon. The 901 Voltage-Controlled Oscillator can produce periodic control voltages whose shapes depend upon the frequency and wave-form selected. The 911 Envelope Generator's value lies in its ability to produce extremely rapid and predetermined control voltages. It contains three time controls: rise, initial decay, and final decay, and a control for sustained voltage level. The 903 White Sound Source generates random control voltages.

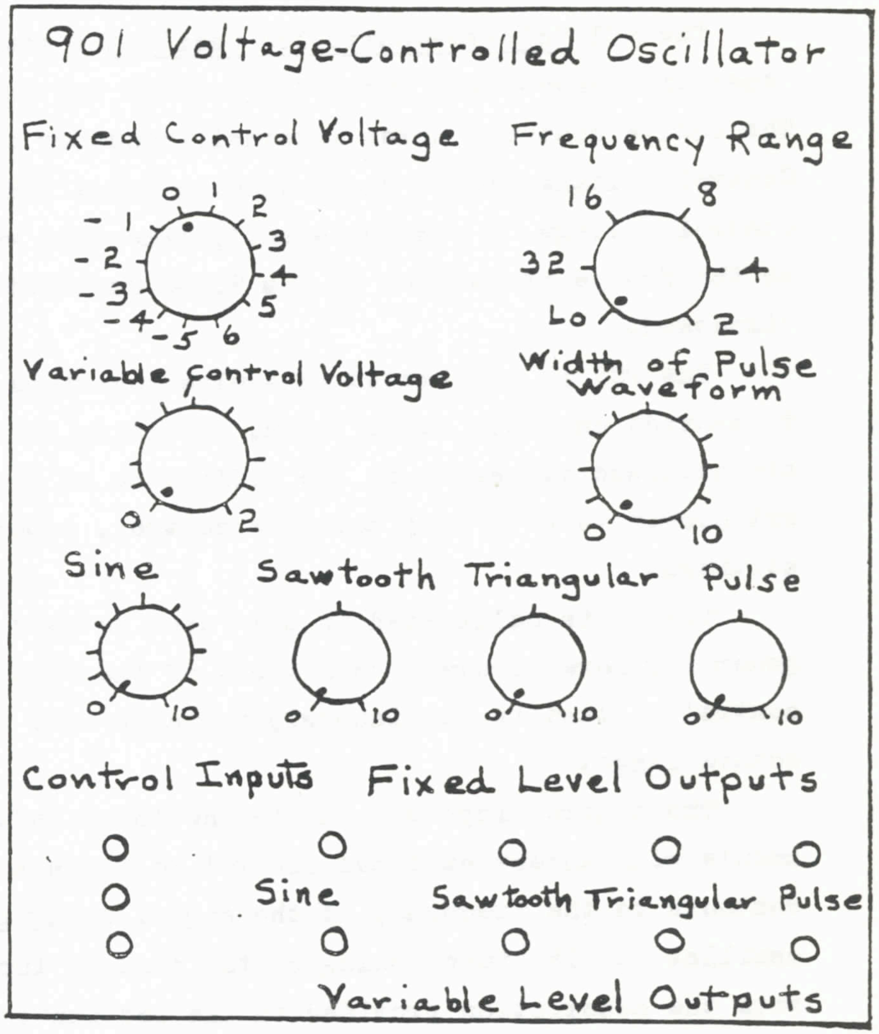
The outputs of the control voltage generators can be subjected to extensive modification before they are applied to voltage-controlled modules. These modifications can be induced by signal processing devices such as the 901-D Variable Wave-form Output Stage, attenuators, filters, or amplifiers. The potential modification processes greatly augment the versatility of control voltage generators.

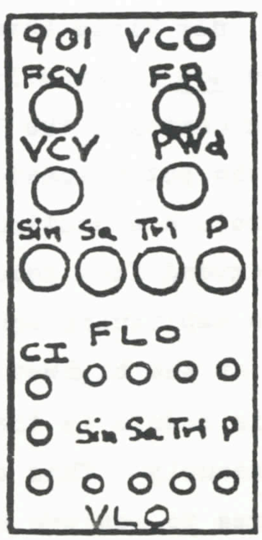
Control voltage generators are external to the modules which they control. There is another class of voltage controls which is characterized by panel-mounted internal control devices. They are the fixed control voltage, the variable control voltage, and the frequency range. The fixed control voltage and frequency range controls on the oscillators are rotary switches which are calibrated in somewhere near one volt steps. In fact any panel-mounted control which is calibrated in discrete steps is in the fixed control voltage class. Notice that several of the controls such as the frequency range settings on filters are calibrated in two or three volt steps. The fixed control voltage controls on the amplifiers and filters are actually variable control voltages because they are continuously variable over their entire ranges. Although not labeled as such, any panel-mounted control which is not calibrated is in the variable control voltage class. This includes the frequency vernier, fixed filter bank controls, mixer level controls, etc.

There is no doubt that the invention of voltage-controlled instruments has liberated the composer from the tedious linear electronic compositional techniques which were so much a part of the craft in the early days of electronic music. These instruments have simplified the generation and compositional arrangement of electronically synthesized sound so that the field is now open to composers who are not only interested in the gadgetry and philosophical problems involved in electronic music, but who also wish to use the materials in a creative whole.

The Individual Modules

Plate 5





Note: Throughout this section on the individual modules the complete drawing of the module will be accompanied by its abbreviated form which will be used exclusively in the section dealing with the circuit diagrams.

The 901 <u>Voltage-Controlled</u> <u>Oscillator</u> generates four repetitive wave-forms whose frequencies are voltage-controlled. The module contains three internal frequency controls, the Fixed Control Voltage (FCV), the Frequency Range (FR) and a variable control voltage, a control exactly like that which Moog designates as the frequency vernier in his 901-B Oscillator, which is later discussed.

The FCV is calibrated in twelve positions which are supposed to provide one volt steps which, according to the design system, are supposed to result in the difference of one octave. It has not proven to be a very accurate control, especially in the extreme settings.

The FR is calibrated in six "near octave" positions which are generally more accurate than those of the FCV. The variable control voltage is continuously variable over its entire two-octave range.

The control inputs found in the lower left hand corner of the module will accept external control voltages and impart their contours to the frequency of the signal being generated by the oscillator. The functioning of the control inputs is consistent with the description provided in the section on voltage control.

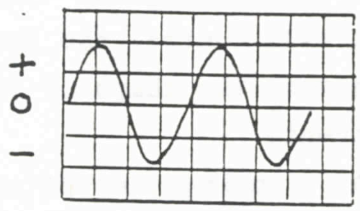
Two banks of signal outputs are found at the bottom of the module. The upper bank contains only Fixed Level Outputs, i.e., the amplitudes of the signals are <u>not</u> internally controllable, they are "fixed". The lower bank contains the Variable Level Outputs which are controlled by the potentiometers found on the center of the panel. These controls are continuously variable over their entire ranges, which extend from zero (no audible signal) at the lowest settings to amplitudes equal to the levels found at the Fixed Level Outputs at the highest settings.

One of the advantages of this module is that all of the wave-forms are available simultaneously. This allows one with little effort to mix the wave-forms to achieve unusual and musically valuable timbral effects. The same effects would be much more difficult to obtain if one had to tune a number of generators which were only able to produce a single wave-form each.

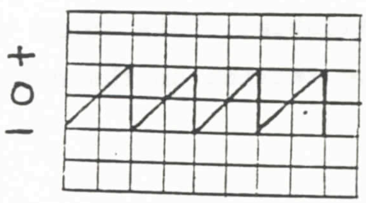
The four wave-forms which are generated by the 901 VCO are the sine, sawtooth, triangular and pulse. The sine wave-form contains no harmonics other than its fundamental. The sawtooth wave-form is extremely valuable because it contains all the harmonics. In many of the sounds which are later discussed in this manual, the sawtooth is used as the basic wave-form because it most noticeably responds to processing. The triangular wave-form contains as upper partials twelve percent of the total energy and consists of only odd-numbered harmonics.

The following diagrams represent the four wave-forms.

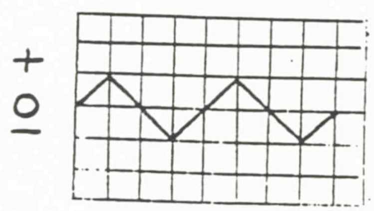
Sine



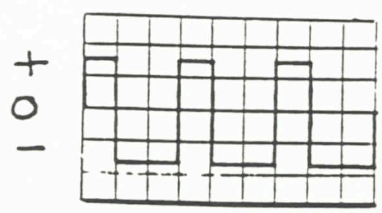
Sawtooth



Triangular



Pulse



The harmonic content of the pulse wave-form depends upon the relative widths of the positive and negative portions of the wave.

According to Moog's specification sheet on this module, the pulse wave-form can be varied from complete symmetry (square wave) to 8:1 asymmetry. This is accomplished internally by means of a continuously variable potentiometer found below the FR on the panel. This variability allows one to imitate conventional instruments such as orchestral woodwinds and strings.

If one has access to two VCO's, it is a simple matter to patch a circuit which will allow one to hear the shape of the various wave-forms. This can provide a valuable conceptualizing experience. The first oscillator should be set to generate a sub-sonic signal. A selected wave-form should then be patched to a control input on the second VCO, whose potentiometers should be set to produce an audible signal. The voltage contour of the slow periodic signal will control the frequency of the audible signal in such a way that the shape of the controlling wave-form will make itself evident.

The potentiality of using the VCO as a control voltage generator to periodically modulate other voltage-controlled devices is indeed valuable. This topic will be discussed in greater detail in the section on the combinatory functions of the modules.

The four basic waveshapes (sine, square, triangle, sawtooth) each have their own characteristics due to their different harmonic structures. More important than the actual shapes of the waves are the spectrums of the waves, in other words, their harmonic content.

The sine wave is unique among all waveforms in that it contains only one frequency. We can tell this by running it through a filter. By adjusting the frequency cutoff of the filter, the volume of the sine wave goes up and down, but the tone quality remains the same. (This may not be the case with the Moog, as the sine waves are only close approximations and may have some residual harmonics. An undistorted sine wave will behave properly.) With any other waveform, the tone quality will change as the filter's frequency is adjusted, because the harmonics are selectively filtered as the filter is turned up and down.

These other waveforms actually consist of many sine waves added together. If the fundamental is 100Hz, the second harmonic is 200Hz, the third is 300Hz, and so on.

The following illustration shows the spectrums of the basic waveforms.

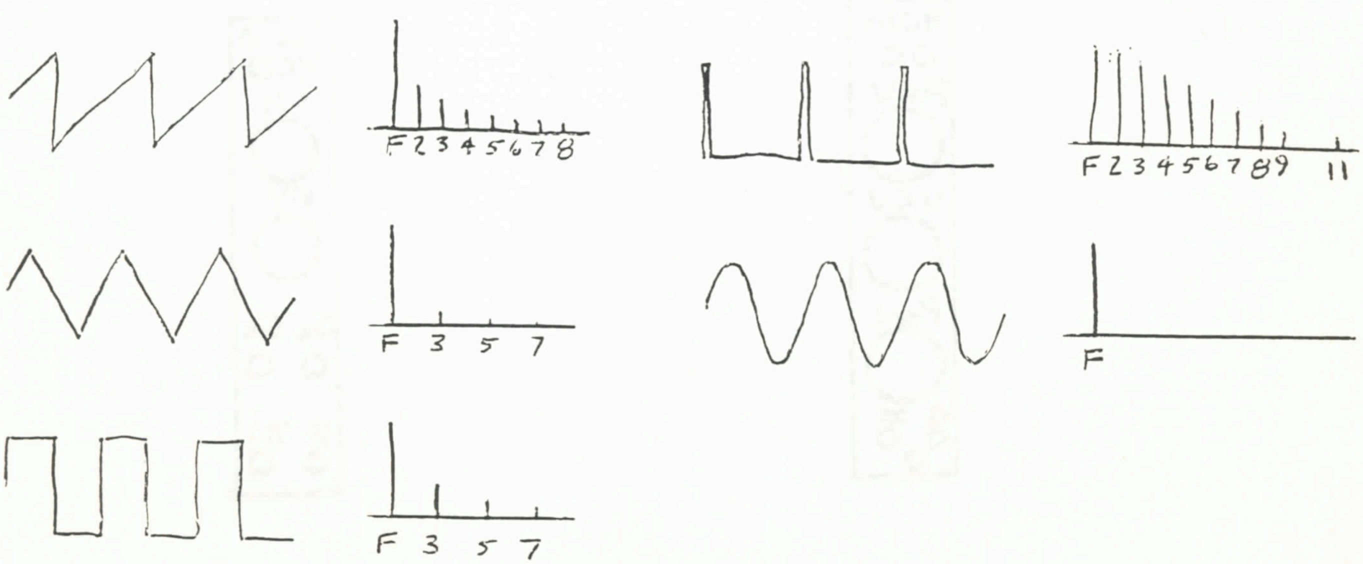


Plate 6

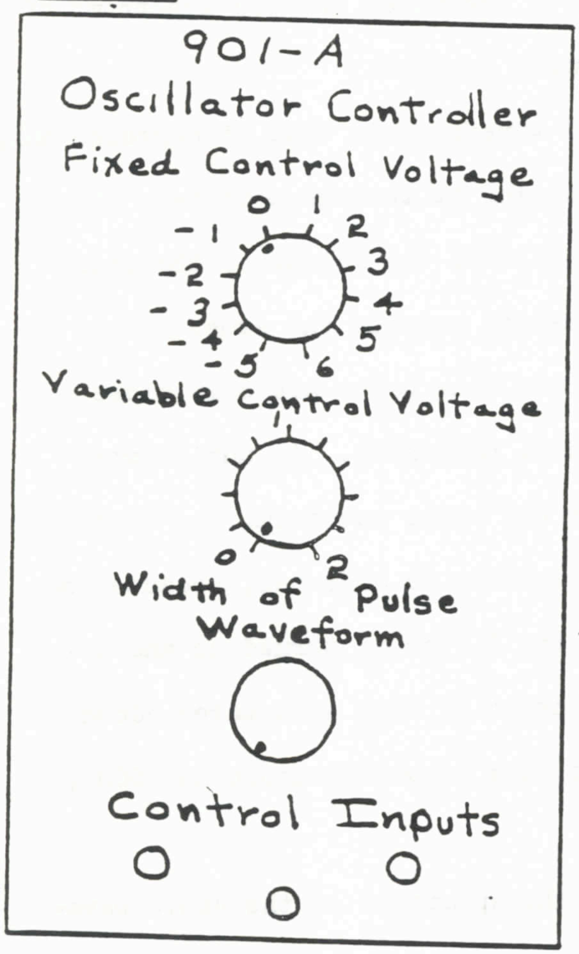
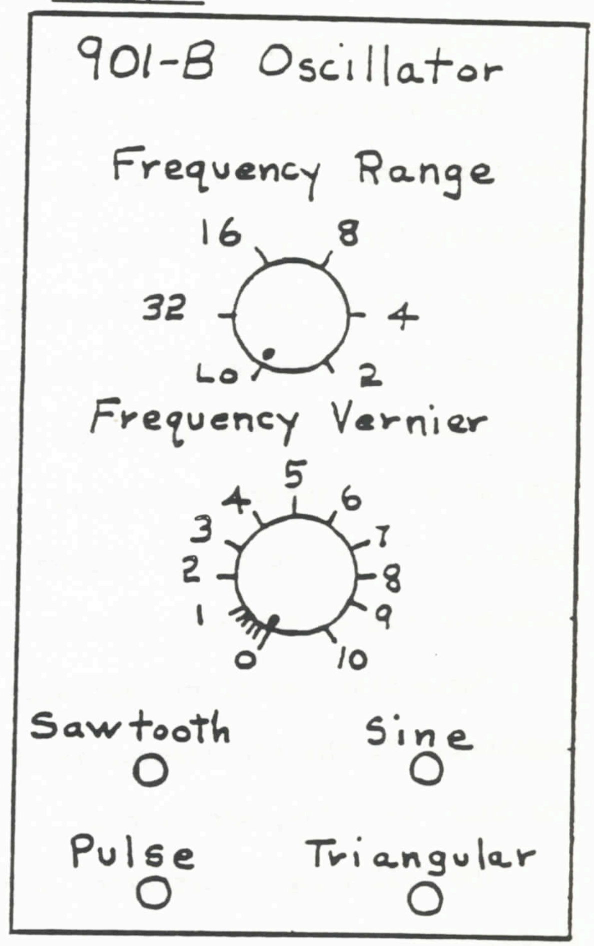
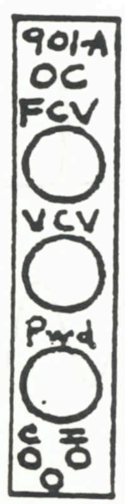
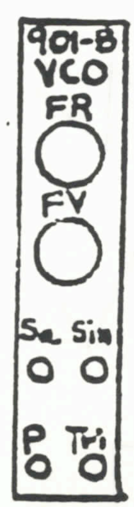


Plate 7







The 901-A Oscillator Controller is the controlling section of the 901 VCO. Its mate, the 901-B Oscillator, is the oscillating and wave-shaping section of the 901 VCO. The main advantage gained from their separation is that the 901-A can simultaneously control a bank of 901-Bs. To better understand the possibilities born of their separation, the individual modules should be examined first.

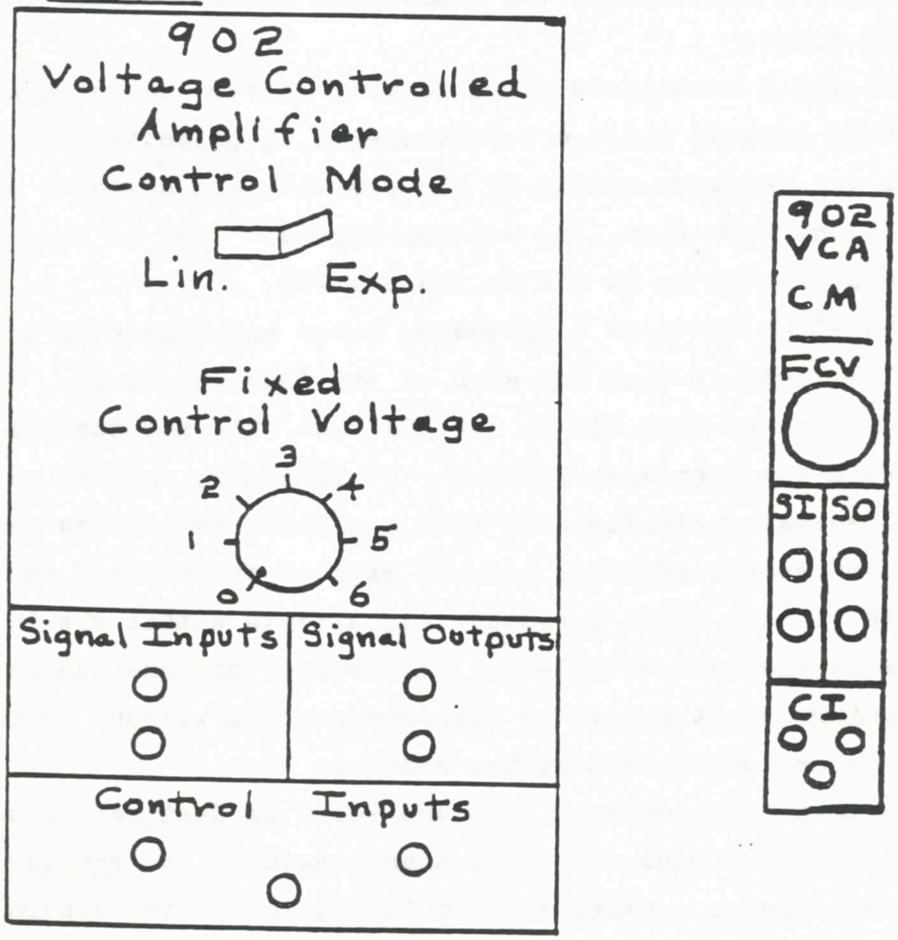
The 901-A contains a Fixed Control Voltage potentiometer, a variable control voltage potentiometer, a potentiometer to control the relative widths of the positive and negative portions of the pulse wave-form, and control inputs. Each of these controls functions exactly as it did in the 901 VCO.

The 901-B contains a Frequency Range potentiometer and a fixed level output jack for each of the four waveforms. These also function as they did in the 901 VCO. The new control is what Moog calls the Frequency Vernier. It is simply another variable control voltage potentiometer with a similar two-octave range. It is a necessary addition because without it it would not be possible to make small frequency adjustments within the individual modules in the bank of 901-Bs. This means that one can make a fine tuning adjustment in an harmonic complex without having to resort to re-tuning each of the modules.

It must be remembered that the 901-A is designed to control each module in a bank of 901-Bs simultaneously and equally. This means that when a control voltage is applied to the control inputs of the 901-A, the frequency of the signal at every output jack in the bank will be effected in exactly the same way, i.e., it will vary as the contour of the control voltage. Similarly, the pulse width potentiometer on the 901-A controls all the pulse widths in the bank simultaneously and equally.

In Moog's specification sheet concerning this module, he contends that the one controller can control up to twelve oscillators. Theoretically it is possible to preset the intervals between from two to twelve oscillators and then control this harmonic complex in a parallel manner. The intervals are set by the appropriate potentiometer readings on the individual oscillators and they will remain constant while the frequencies of the oscillators are modulated by the 901-A.

Plate 8



In his specification sheet, Moog refers to his <u>902 Voltage-Controlled Amplifier</u> (VCA) as "a signal processing instrument whose amplification (gain) is determined by the magnitude of the applied control voltages". The main function of this module is to produce some form of amplitude modulation; an increase in voltage will act upon an incoming signal by increasing its amplitude and a decrease in voltage will in turn decrease its amplitude.

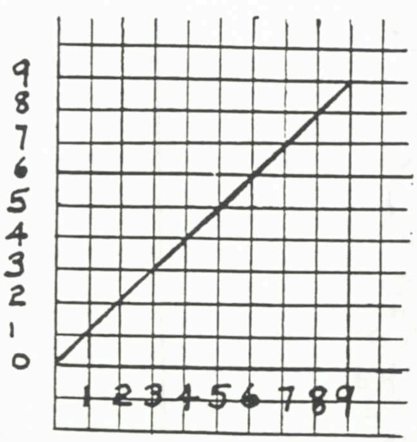
The 902 VCA has its internal voltage control in the form of a

Fixed Control Voltage potentiometer found on the center of the panel. The designation, Fixed Control Voltage, may be somewhat of a misnomer because rather than being calibrated in six fixed positions, the potentiometer is continuously variable over the entire voltage range which is from 0 to +6 volts. Naturally the fact that it is a variable control adds to the versatility of the module.

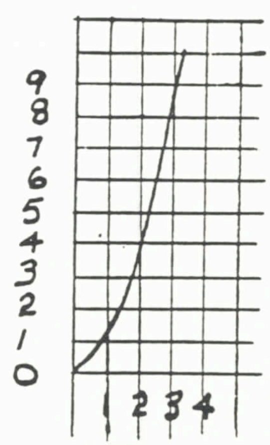
The control inputs found at the bottom of the module will accept external control voltages and their effect will be consistent with the description found in the section on control voltage.

A switch for two available control modes is found at the top of the module. The designation Lin./Exp. refers to how the signal being processed will react to the applied control voltage. When the switch is on Linear, there will be a direct algebraic correspondence between the amplitude of the signal being processed and the shape of the control voltage <u>at the control input</u>. When the switch is on Exponential, the components within the module change the shape of the control voltage so that it imparts a "logarithmic" correspondence to the amplitude of the signal being processed. The following graphs illustrate the difference between an algebraic and logarithmic correspondence:

Linear (Algebraic)



Exponential (logarithmic)

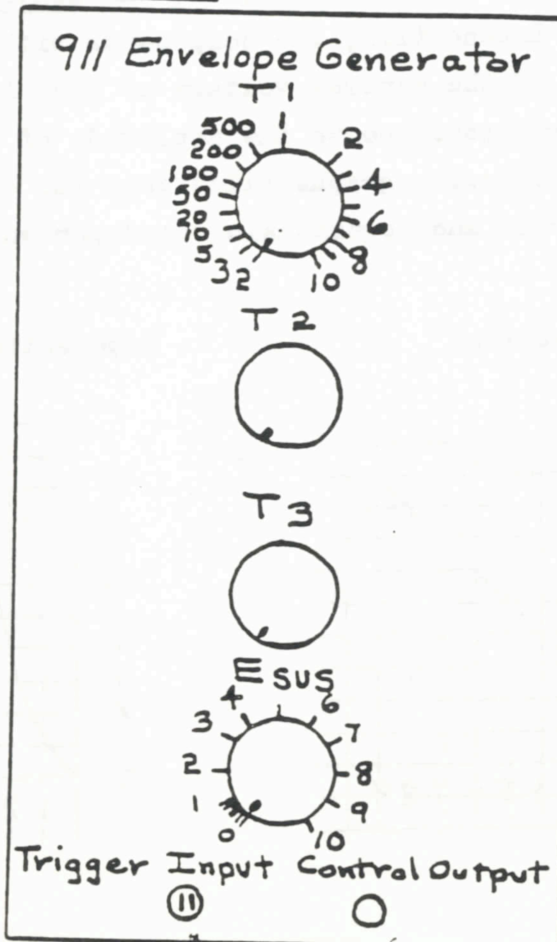


The linear control mode allows one to have a predictably gradual amplitude control and the exponential mode allows one to have a predictably <u>abrupt</u> amplitude control. The exponential mode is particularly advantageous for the production of percussive envelopes.

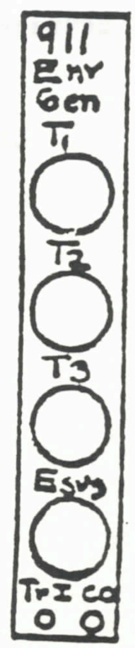
The two signal inputs found in the center of the module can function as a primitive sort of mixer. When two different signals enter the VCA they are automatically mixed, so that the amplitude of the <u>mix</u> is being controlled by the controls of the VCA. If one wishes to control the amplitude of the individual signals, he must make the accommodations before they enter the VCA.

The two signal outputs have a special feature, that is, they provide signals of slope opposite to the signal inputs which are directly across from them, and signals of similar slope to the signal inputs which are diagonally across from them.

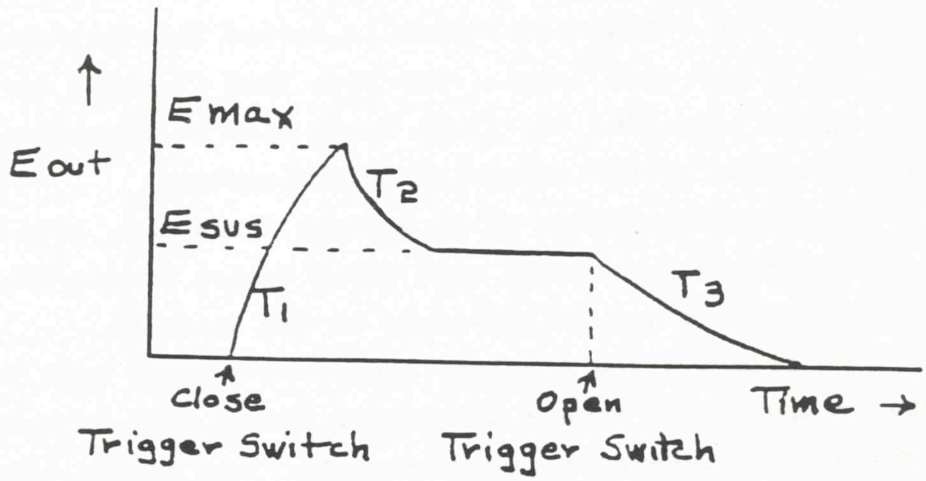
Plate 10



KBD



— The function of the 911 Envelope Generator is to generate single voltage contours which may be applied to voltage-controlled modules. The following illustration is found in Moog's specification sheet concerning this device:



To begin the voltage contour, an external "triggering switch" must be closed. A depressed key on the keyboard is the most common form of triggering switch. Once the voltage contour is initiated or "triggered" the output voltage (E out) rises to a set maximum voltage level (E max). The time that it takes for the output voltage to reach the maximum voltage is what is called the rise time or time-one (T1). The rise time is controlled by the topmost potentiometer on the panel.

When the output voltage reaches the maximum voltage level, it immediately begins its descent to the sustained voltage level (E sus). The time that it takes to get from the maximum voltage to the sustained voltage is called the initial decay time or time-two (T2). The initial decay time is controlled by the second potentiometer. The sustained voltage level is controlled by the last potentiometer. Note that the sustained level is, in effect, another temporal parameter. It differs from times one, two, and three in that the time element is controlled manually within the single voltage contour instead of by potentiometer settings. This means that as long as one keeps the triggering switch closed (e.g., depresses the key on the keyboard) the sustained voltage level will be maintained. Only after the triggering switch has been opened (or key released) will this temporal parameter come to an end.

When the triggering switch is opened the voltage begins its descent to the zero level. The time that it takes to reach the zero level is called the final decay time or time-three and it is controlled by the remaining potentiometer.

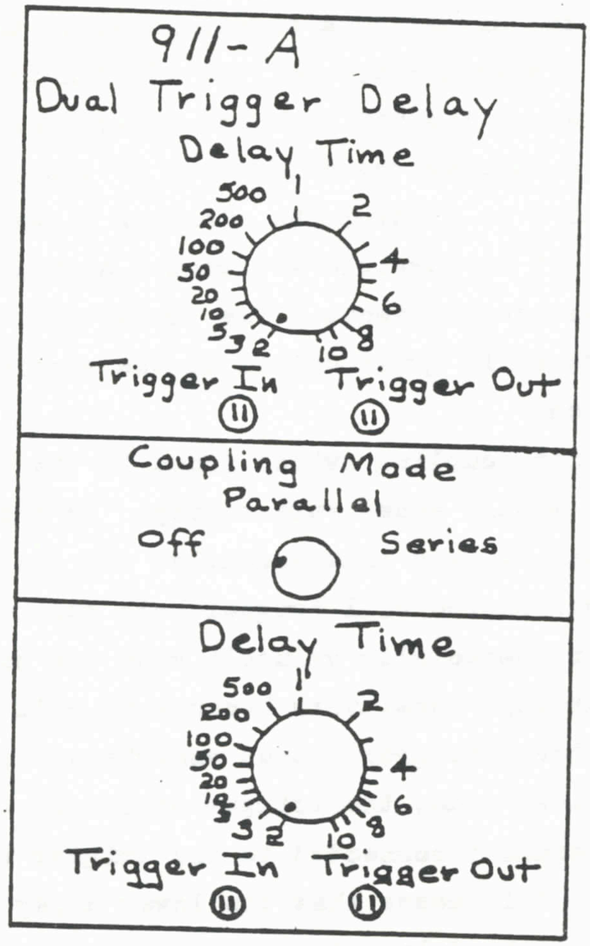
The potentiometers which control times-one, -two and -three are continuously variable over their entire ranges which encompass everything from two milliseconds to ten seconds.

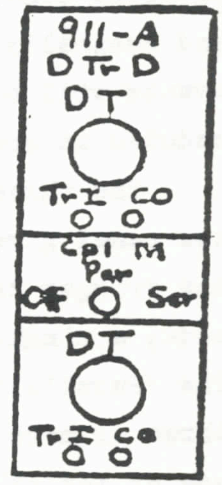
To activate the envelope generator a patch must be made to the trigger input from a triggering device such as a keyboard trigger or a Schmidt trigger circuit. This module allows one to impart a predetermined voltage contour on any voltage-controlled device simply by patching from the control output of the 911 to the control input of the device to be controlled.

— The 911-A Dual Trigger Delay (Plate 11) is designed to control the starting times of two 911 Envelope Generators. The 911-A consists of two identical delay devices which are separated on the panel of the module by their coupling device.

To function as designed the delay device must be triggered by a "switch closing". This simply means that the triggering can be done by a 950 Keyboard Controller or the trigger output of the Schmidt trigger circuit. A patch made from the output of either of these modules to the trigger input (two-pronged socket) of a 911-A Trigger Delay is the first step. The next step is setting the delay time on the potentiometer which allows a continuously variable sweep from two milliseconds to ten seconds. Actually, fine adjustments in milliseconds are only feasible up to the one second marking which constitutes the halfway mark in the turning capability of the dial. From that point on, the panel is marked in full second readings.

Plate 11





After the delay time has been set, a patch should be made from the trigger output (two-pronged plug) of the 911-A to the trigger input of a 911 Envelope Generator, which in turn will control some other voltage-controlled module. At this point, if the steps outlined below have been taken, the 911-A should perform as designed.

1. Patch from the 950 Keyboard Controller trigger output to the trigger input of a 911-A Trigger Delay.

2. Set the delay time of the 911-A.

3. Patch from the trigger output of the 911-A to the trigger input of the 911 Envelope Generator.

4. Patch from the control output of the 911 Envelope Generator to the control input of a 902 VCA with the FCV set at zero.

5. Apply an audio signal to a signal input of the 902 VCA.

6. Patch from a signal output of the 902 VCA to a monitor.

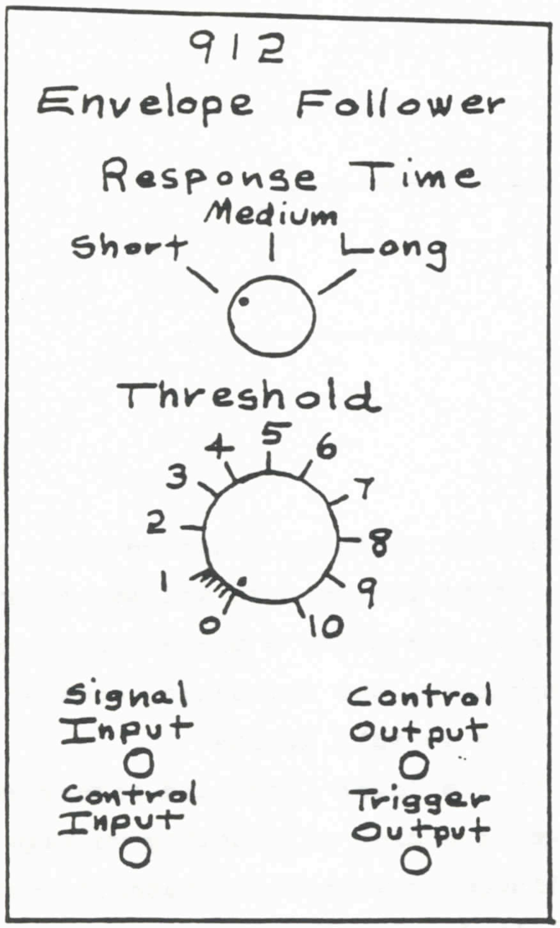
7. Depress a key on the 950 Keyboard Controller and keep it depressed at least as long as the delay time of the 911 is set.

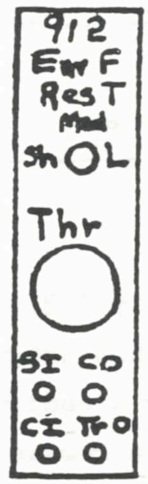
By using the 911-A to control the starting times on two 911 Envelope Generators, it is possible to produce highly complicated and musically valuable sound events. The production of such events will be discussed in great detail in the section on the modules in combination.

The three-position coupling switch found in the center of the panel gives this module added versatility. In the "Off" mode the trigger delays can be used independently. In the "Parallel" mode, a single trigger source will trigger both delay circuits. The "Parallel" mode is especially valuable when one has access to three or more 911 Envelope Generators because it will allow the use of the other keyboard trigger output somewhere else in the system. In the "Series" mode, the trigger output of the upper delay circuit is internally connected to the trigger input of the lower delay circuit. This means that the lower delay circuit will not be triggered until the delay time of the upper delay circuit is completed. It also holds true that only a single trigger source is required for the "series" mode.

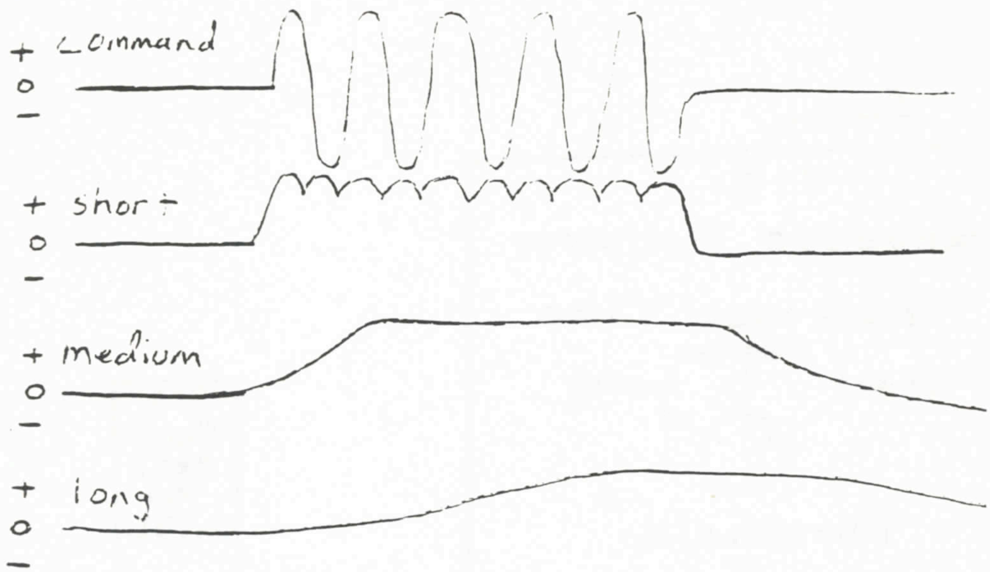
In its specification sheet, Moog describes the <u>912 Envelope Follower</u> (Plate 12) as a device which "produces a direct voltage output which is proportional to the logarithm of the average magnitude of an alternating input (command) voltage." This simply means that this module will predictably convert an alternating current, which is applied to the signal input, into a direct current control voltage which is available at the control output. The direct current which emerges from the control output will have the contour of the command signal applied at the signal input, only it will be more or less exaggerated, depending upon the Response Time setting.

Plate 12



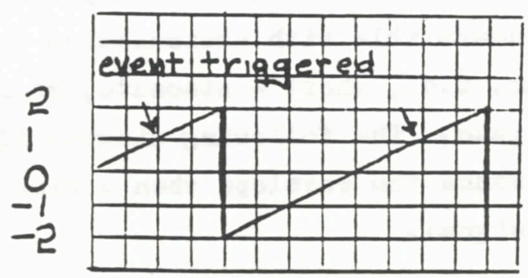


The panel control for how the envelope follower responds to the command signal is a three-position switch with short, medium and long settings. The aural effects produced by the various settings are compatible with articulation concepts familiar to every musician, i.e., short - staccato, medium - normal attack, and long - legato. The following diagram illustrates how the settings influence the envelope when a sine wave-form is used as a command signal.



The 912 Envelope Follower also contains a device known as the Schmidt trigger circuit. It is designed to trigger an event whenever a control input voltage goes above a preset magnitude. The three remaining panel components, the threshold, control input, and trigger output, belong to this device.

The control input found in the lower left-hand corner will accept either a direct voltage or a slow alternating voltage from an oscillator. The continuously variable threshold control selects the input voltage magnitude at which the trigger will respond. The following diagram illustrates this principle when a slow sawtooth is applied to the control input and the threshold is set at one volt.



Notice that the event is triggered each time the voltage reaches the preset magnitude.

The Schmidt trigger circuit also offers solutions for certain kinds of synchronization problems. For example, in a composition for electronic and vocal sounds the composer might want a complicated electronic event to begin at the peak of a vocal climax. This can be accomplished by using the voice, via the Schmidt trigger circuit, to trigger the electronic event. The following is one possible setup to achieve that end.

1. Patch the microphone to a microphone preamplifier whose gain is set fairly high.

2. Patch from the microphone preamplifier to an amplifier with a moderate gain setting.

3. Patch from the amplifier to the control input of the Schmidt trigger circuit whose threshold is set high enough so as not to respond before the peak of the vocal climax.

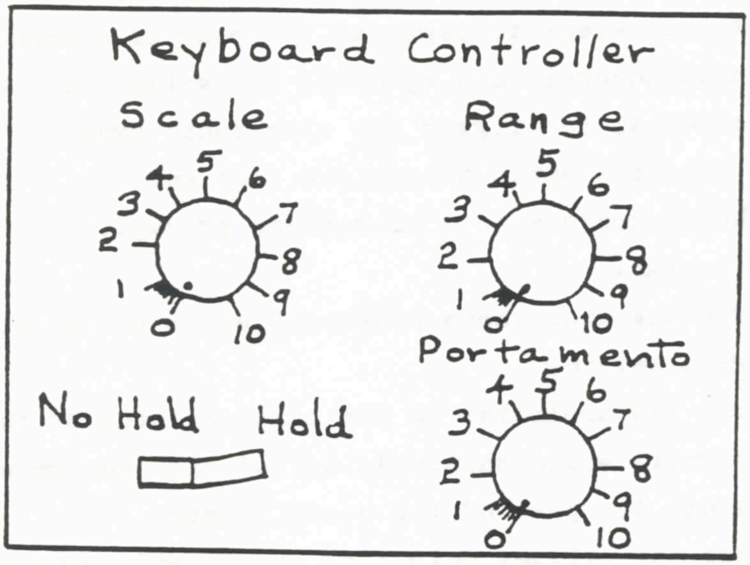
4. Patch from the trigger output of the Schmidt trigger circuit to the 911 Envelope Generator which is controlling the envelope of the electronic event.

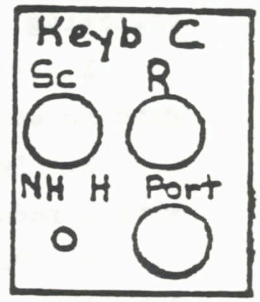
The same general procedure as outlined above can be followed using instrumental sounds or, in fact, any sound which is capable of being transformed into the voltage level required to exceed the threshold level of the Schmidt trigger circuit.

Two more observations should be made at this point. The Response Time switch does not function as part of the Schmidt Trigger circuit. The output of the Schmidt trigger circuit should only be connected to the trigger input of the 911 Envelope Generator.

The Keyboard Controller is a modified five-octave electric organ keyboard which provides sixty-one equally spaced control voltages. These may be applied to any of the voltage-controlled modules. The Keyboard Controller's operating characteristics are determined by a control panel located at its lower-left hand corner.

Plate 13





The Scale potentiometer determines what the voltage relationship is to be between "keyed octaves" on the keyboard. (One would play a "keyed octave" if he were to depress a "D" and then its counterpart twelve keys above it.) At this point it must be remembered that Moog's oscillators are designed to react to a change of one volt with a frequency change of one octave. This means that in order to have an equal-tempered scale, the difference between adjacent keys on the keyboard must be one-twelfth of a volt. A reading of 3.6 or thereabouts on the Scale potentiometer will produce that relationship between adjacent keys. Its lowest reading will produce an equal-tempered major seventh interval between "keyed octaves", and its highest reading will produce a major ninth. The control is continuously variable over its entire range. An additional characteristic of this control is that as the settings increase numerically there is also a corresponding increase in range. The difference in range between the lowest and highest settings is about a major third.

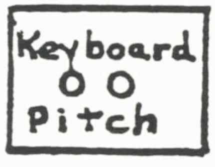
The continuously variable Range potentiometer determines at what voltage level the far left (the lowest) key will be. This, in turn, controls the relative voltage level of the keyboard.

This is true because this device is designed so the voltage at any point on the keyboard is the sum total of all the points below it. The difference between the highest and lowest settings on this control result in five-sixths of a volt which, in terms of frequency, is a minor seventh.

To understand how the No Hold/Hold switch functions one must understand some of the design principles of the Keyboard Controller. Whenever a key is depressed, it switches in one tap on a divider string. The voltage at the tap charges a capacitor which holds its charge until the next key is depressed and recharges it to another voltage level. The No Hold/Hold switch simply determines whether or not the capacitor will hold the charge after the key has been released. If the switch is on "No Hold" the voltage level will rapidly drop to near zero after the key is released. With the switch on "Hold" the voltage will remain at a level determined by the last depressed key for a considerable length of time.

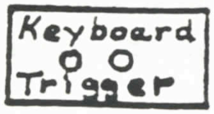
The Portamento potentiometer controls how long it takes to get to a new voltage level from the previous level. The time lengths are continuously variable from several milliseconds at the lowest setting to about four seconds at the highest setting. There is a continuous slide (portamento) in either direction depending upon the directional relationship of the depressed keys. If the Portamento setting remains constant, the time it takes to span a small "keyed" interval equals that which it takes to span a large "keyed" interval. The Portamento potentiometer functions only when the No Hold/Hold switch is in the "Hold" position.

Plate 14



The Keyboard Pitch output jacks are the output sources for the Keyboard Controller when it is to be used as a control voltage on voltage-controlled modules such as the filters, amplifiers, and oscillators.

Plate 15



The Keyboard Trigger output jacks are the output sources for the Keyboard Controller when it is used to trigger the 911 Envelope Generators.

The Keyboard Trigger and Keyboard Pitch output jacks are available simultaneously.

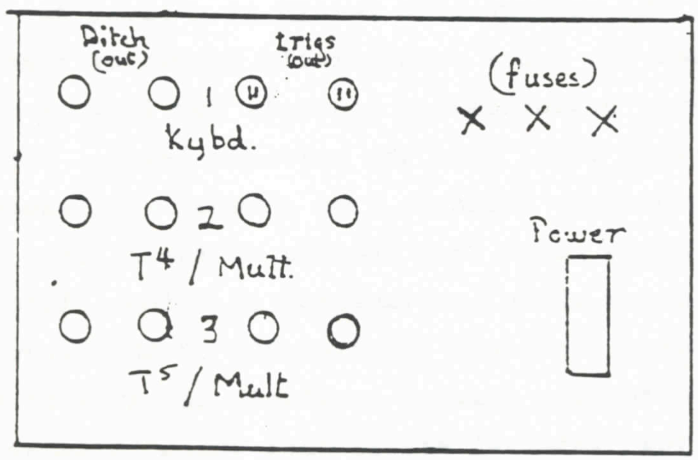
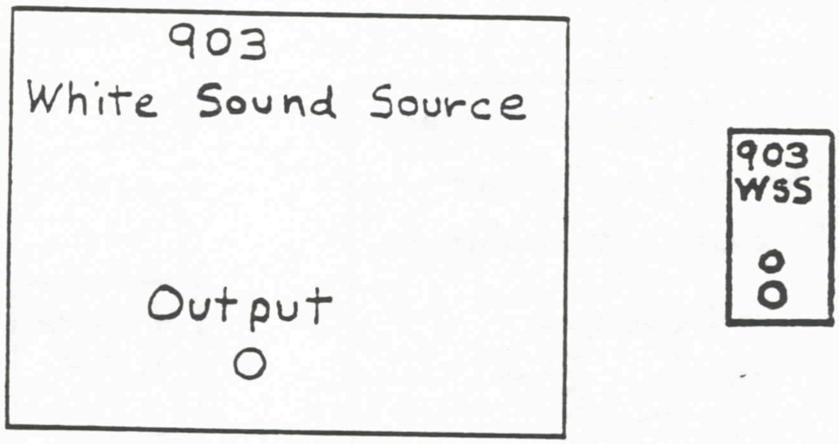


Plate16

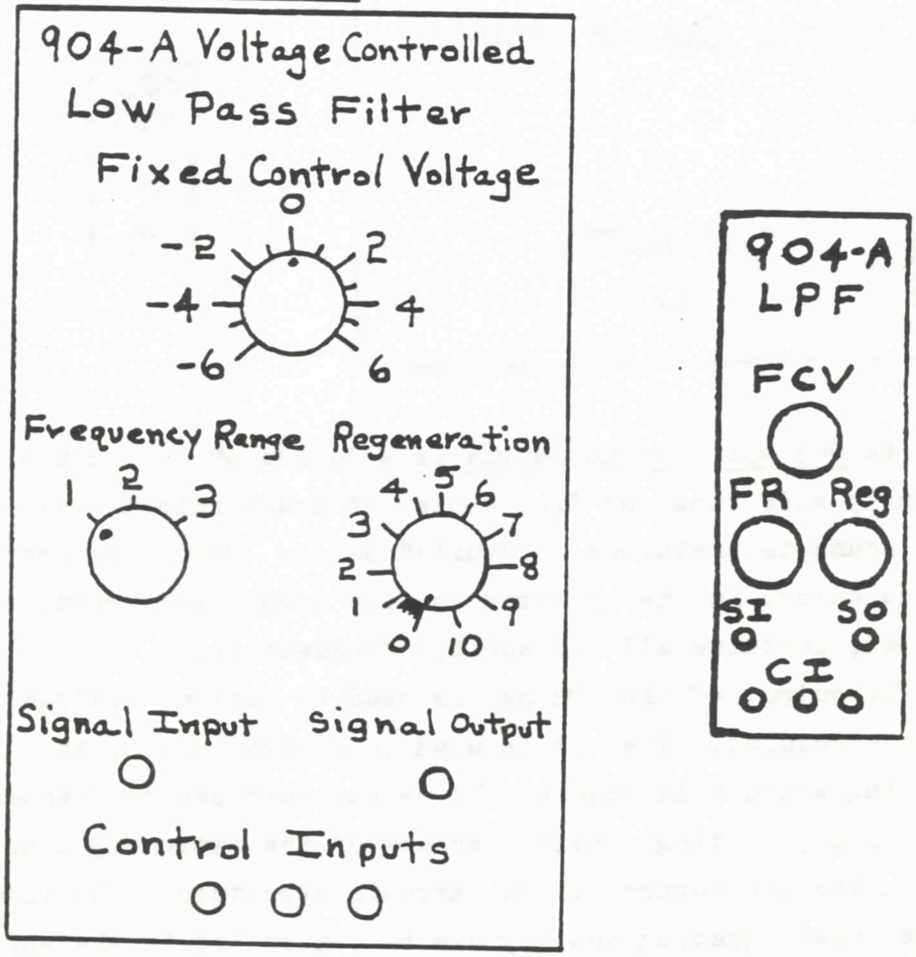


The 903 White Sound Source is a device which produces an extremely wide range of frequencies of indeterminate wave-length. White sound is analogous to "white" color. The color contains all the colors in the spectrum and the sound, for practical purposes, contains all the audible frequencies.

The output of the 903 can be used to control voltage-variable modules. When it is used to control a VCO, the resulting sound will have a well-established center frequency and a harsh, grating quality because of the extremely complicated and conflicting nature of its harmonic structure. The intensity of the harsh, grating quality can be controlled if the white sound is processed by an amplifier before it is used to control the VCO. When the amplifier is used in its attenuating capacity the quality of the sound issuing from the VCO will become relatively mellow. When it is used in its amplifying capacity the sound will become increasingly harsh as the amplitude is increased.

White sound can be filtered so that only selected frequencies or bands of frequencies are available at the output jacks of the filters. It can also be subjected to regeneration so that selected frequencies or bands of frequencies become more prominent as a frequency focal point. These processes will be discussed in greater detail in the section dealing with the combinatory functions of the modules.

Plate 17



The 904 Voltage-Controlled Low Pass Filter is designed to pass only frequencies below its cutoff frequency; those above the cutoff point are thoroughly attenuated. The cutoff frequency is the voltage-controlled parameter. The two internal control voltage potentiometers are the Fixed Control Voltage (FCV)

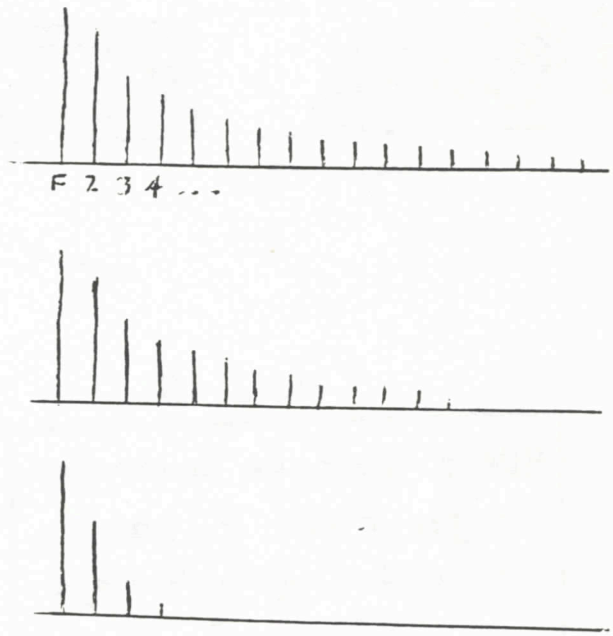
and the Frequency Range (FR). The FCV is continuously variable over a nine-octave range, while the FR is calibrated in three positions which move the cutoff frequency in two-octave steps.

The following diagram illustrates what happens to a sawtooth wave-form as the high frequencies are filtered out of it.

unfiltered

partially filtered

very much filtered



External voltages may be applied to the control inputs. Their effect will be consistent with the description found in the section on voltage-control.

The highly valuable regeneration potentiometer allows one to produce a resonant peak at the cutoff frequency. This effect is achieved by a feedback resistor which focuses its feedback in a narrow band at the cutoff frequency. The regeneration potentiometer controls the output of regenerated frequencies (feedback). Various settings of this control allow one to produce a wealth of sonorous material ranging from delicate human and animal-like sounds to nerve-racking whistles and screeches. This control also allows one to give a semblance of a pitch center to filtered white sound or, in fact, any other complex or noisy sound. The diagram illustrates what happens to filtered white noise when the regeneration potentiometer is moved from 0 - 10.

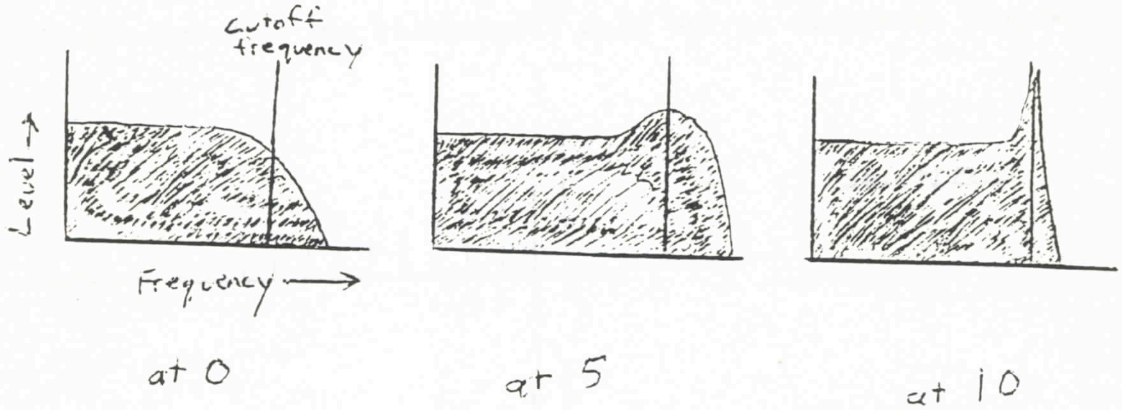


Plate 18