University of Iowa

ELECTRONIC MUSIC STUDIO

Composer's Manual

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Chapter 1

INTRODUCTION AND RULES

Introduction

The University of Iowa Electronic Music Studio was founded in 1964 as an "experimental" studio, and was originally equipped with various kinds of testing devices and more or less homemade instruments. Over the years, the studio's capabilities have changed, and with the fairly recent acquisition of professional quality tape recorders and a Moog "super-module", development of the studio as a "composing" facility has increased.

The Studio is located in Eastlawn 207. Facilities are presently made available to all qualified faculty and students. These may include: faculty composers, graduate and, on occasion, undergraduate students taking Electronic Studio I/II and Special Studies, individuals pursuing compositional projects, and visiting composers. Keys to the Studio may be obtained from the School of Music Office upon receipt of written authorization from the Director of the Studio.

Because the Studio's expensive and specialized equipment is used without supervision, it is necessary to ask users to observe the following simple rules:

1. Please consider your Studio key a privilege: it must not be copied or lent to unauthorized persons.

2. Every Friday, a sign-up sheet will be posted outside the Studio door. Authorized users may sign up for no more than 4 hours of studio time per week. (Free time would thus be available on a first-come first-served basis.) If additional time is required, please see the Director.

3. The Studio will be closed regularly during certain hours each week for technical maintenance and repairs. Should you observe

malfunctions of the equipment, please make a note of same as accurately as possible, and bring it to the attention of the Director or the Studio Technician.

4. During non-class hours, kindly knock for admittance to the Studio. There may be a composer at work! If no reply is forthcoming, <u>then</u> use your key. This is a matter of consideration.

5. Upon leaving the Studio: remove all patch cords; remove tape from recorders; turn off 1) the main power supply, 2) the air-conditioner, and 3) the light.

6. Be sure you are thoroughly familiar with the contents of this manual.

The Studio Manual describes (nearly) every piece of equipment in the Studio regarding its basic operating characteristics. Although many useful operations are detailed herein, the Manual is in no sense a composing guide. In preparing this booklet, I have relied a great deal on the <u>Composer's Manual</u> by Hubert H. Howe, Jr., written for the Electronic Music Studio at Queens College. Many of the descriptions of Moog instruments are quoted extensively — with occasional changes suitable to our particular system.

The Manual is, by its very nature, temporary and incomplete. As new equipment is received and incorporated into the Studio, as older equipment becomes obsolete, the manual will change. Therefore, it is advisable to bind these pages in loose-leaf fashion.

Needless to say, suggestions for improvement or correction are welcome.

Peter Tod Lewis
Director
Summer 1970

Chapter 2

EQUIPMENT LIST

Equipment List

~~1 Scott Type-1812 Random~~ Noise Source

1 Ampex 354 Stereophonic Tape Recorder

1 Martin Audio Varispeed

1 Ampex AG-350 Stereophonic Tape Recorder

~~2 Heath~~ IG-82 Sine-Square Generators

~~1 Allison~~ Model 2BR Variable Filter

~~1 Balanced~~ Modulator

~~1 Beckman~~ Model-7050 Frequency Counter

Custom 20-input Quad Mixer

~~1 Six-input~~ Two-output Mixer

Patch Panel

2 Three-input One-output Unity Gain Mixers

~~1 Dual-Sawtooth~~ Generator

~~1 McIntosh~~ Model MA-230 Preamp-Amplifier

~~1 Koss~~ Stereo Headphones

~~1 UD Reverberator~~

Moog Synthesizer:

- 3 ~~1~~ Four-input One-output Mixer
- 1 Multi-Purpose Unit
- Pitch and Trigger Panel
- 1 901 Controller Connector
- 2 901 Voltage-Controlled Oscillators
- 1 901A Oscillator Controller
- 6 901B Oscillators
- 4 902 Voltage-Controlled Amplifiers
- 2 904 Voltage-Controlled Filter
- 1 904 Controller Connecter
- 1 905 Reverberation Unit
- 1 910 Power Supply
- 2 911 Envelope Generators
- 1 911-A Dual Trigger Delay
- 1 912 Envelope Follower
- 1 914 Extended Range Fixed Filter Bank
- 1 950 Keyboard Controller

1 Scully 180-2 Stereophonic Tape Recorder

1 Dyna Model-PAS Stereo Preamplifier

1 Garrard Model-40B Automatic Turntable

1 Bulk Eraser

2 Heath AS-2U Speakers

8 Magitran P-20 Polyplanar Speakers

~~1 Tektronix Type~~-531 Oscilloscope

1 Multi-Purpose Patch-Box

Chapter 3

THE PATCH PANEL

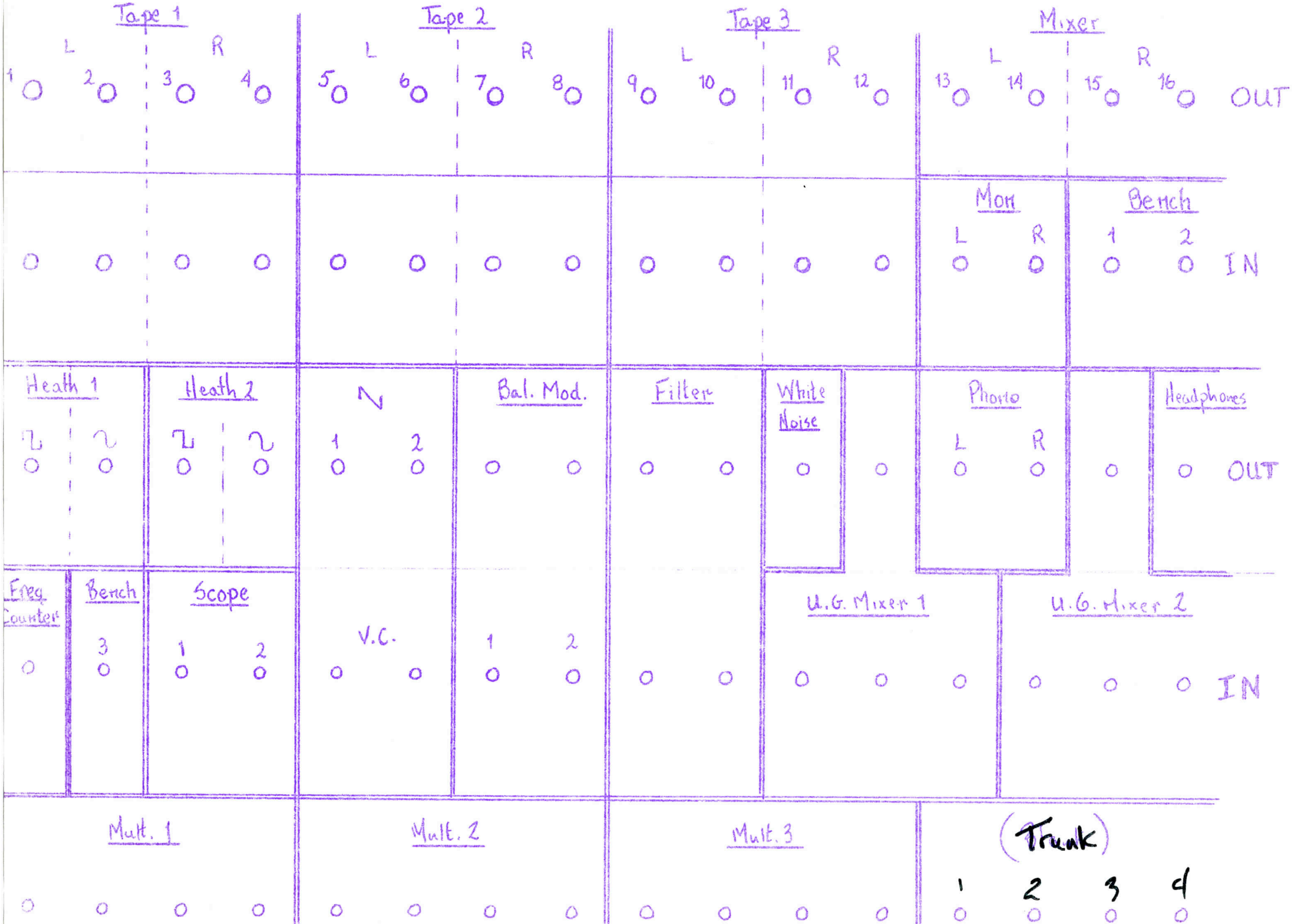
The Patch Panel

The Patch Panel is the central interface between all equipment in the studio. It consists of five rows of 16 jacks each, mounted in Rack 3 below the Six-Input Two-Output Mixer. (N.B. Don't confuse the Mixer input jacks with the top row of the Patch Panel.) The 80 jacks of the Patch Panel are connected as shown in Figure 3-1. Note that rows A and C consist entirely of outputs, rows B and D of inputs. Row E consists of three multiples, each multiple comprising four two-way jacks (meaning that they may be used as either inputs or outputs) which are interconnected, and four Trunk lines to (and from) the Moog. (See section 5-2.51.)

It will be noted that some units have both inputs and outputs, whereas other units have only outputs. The output from any unit may be patched directly to the input of any other (providing it has an input) by means of the patch cords with two-conductor phone plugs on either end.

In order to hear a sound, some connection must be made into the Monitor inputs or the Mixer inputs. These inputs connect directly to the speaker amplifiers. The Mixer, located directly above the Patch Panel, contains volume controls for each input, thus enabling suitable listening levels for monitoring sounds without effecting the signal level in any of the other units.

Patch Panel - Summer 70



Chapter 5

THE MOOG SYNTHESIZER

THE MOOG SYNTHESIZER

1. General Considerations: Voltage Control

The Moog Synthesizer is a self-contained modular electronic music generating and modifying system, containing all of the components listed in the equipment list in Chapter 2. Basic to the system is the concept of voltage control and the principle that any output can be used either as a signal or a control voltage. Therefore, any generating device may be used either for timing and control functions or for direct signal production.

Voltage control is the use of an electrical voltage to determine the operating characteristics of a signal generating or processing instrument. A control voltage is the value used for this purpose. Since frequency is exponentially related to pitch –– such that, for example, a doubling of frequency produces a rise of one octave in pitch –– the Moog voltage-controlled instruments have been designed to embody an exponential relationship between the control voltage magnitude and the frequency of oscillation. Thus, equal changes in control voltage produce equal musical intervals. The exponential relationship is one volt per octave, 1/12 volt per half-step.

On the Moog Synthesizer, oscillators and amplifiers have two kinds of inputs/outputs: one for signals and the other for controls. The signal input/output is for a sound which is being generated or processed. The control input determines some aspects of the instrument's operating points. Several control inputs may be in effect at the same time. This is much different from "classical" electronic studio devices, where all the operating points of the instrument can be controlled only by turning dials.

In addition to the signal generating and processing instruments, there is a keyboard controller attached to the Synthesizer. Controllers differ from other units in that they put out both a control voltage, for determining some characteristic of an instrument's operating points, and a trigger, for initiating events. Further details concerning the operation of the Synthesizer are contained in the descriptions of individual components.

All patch cords for the Moog Synthesizer have two-wire conductor phone plugs on either end, except for patch cords for the trigger inputs on the 911 Envelope Generators. The patch cords are usually marked with two colored bands on either end, which help in tracing patch connections in complicated set-ups. The colors have no other significance.

The Synthesizer has no "trunk lines", so connections must be made directly to the Patch Panel.

(All Moog 900 Series instruments require an external regulated power supply of +12 volts and -6 volts. The 901 and 901B oscillators require an additional voltage of -9 to -12 volts, unregulated.
Signal output levels are 0db (0.8 volts RMS) and output impedances are 600 ohms. Signal input levels are also -3db and signal input impedances are 10,000 ohms. Control input impedances are 100,000 ohms, and control voltages range from -6 to +6 volts DC.)

2. The Synthesizer Console

The instruments in the Moog Synthesizer are mounted in the console cabinet as shown in Figure 5-1. In addition to the numbered modular instruments explained on the following pages, the Synthesizer console contains several units mounted on the bottom row of the cabinet, and also the two right-hand units in the middle row, which are used for normalling connections between the controller and signal generator and for other functions. These devices include: one 901 Controller Connector, one 904 Controller Connector, two Four-Input One-Output Mixers, a panel containing pitch and trigger jacks from the Controller, a Multi-Purpose unit containing a Low Pass and High Pass Filter and an Attenuator, and a panel of two multiples.

Additional Moog units not mounted in the console cabinet are also described in the following pages.

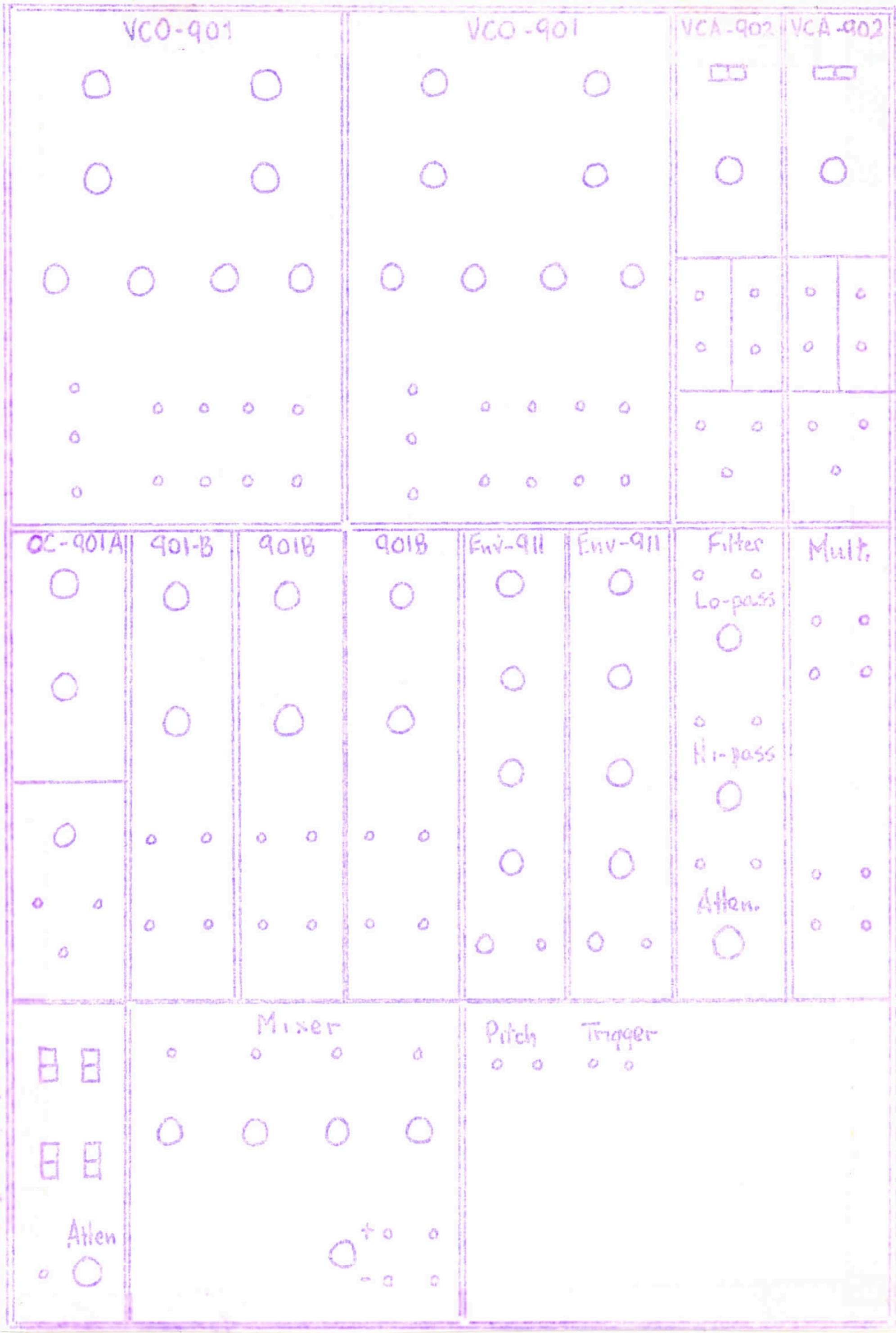


Figure 5-1: The Moog Synthesizer Console

1. <u>901 and 904 Controller Connectors</u>

These devices are similar in appearance and are mounted to the left of the 4-1 Mixers. They consist of three control switches which are color-coded in red and a fourth switch color-coded in blue which illuminate when turned on, a jack for an external input and an attenuator control. The difference between the 901 and 904 Connectors is that the 901 Connector controls the 901A Oscillator Controller directly above it, while the 904 controls the 904 Voltage-Controlled Filter.

Turning on switch #1 connects the 950 Keyboard Controller to the particular module above. Switches #2 and #3 are currently not connected to anything. These devices thus eliminate patching from the Keyboard Controller to the designated modules.

In the case of the 901 Controller Connector, connection of the controller switch will cause the frequency of the oscillator bank to be determined directly by the Keyboard (as well as the dials on the units themselves, and any additional control inputs). The 904 Controller Connector is connected to all three sections of the 904 Voltage-Controlled Filter, and must be used in conjuction with another signal generating device. For example, white noise can be filtered for a definite pitch, the pitch being determined by a control voltage from the keyboard.

The fourth switch on the 901 and 904 Controller Connectors is for an attenuator. When this switch is turned on, illuminating a blue light, and an external signal is fed into the jack, it is possible to attenuate the control voltage produced by the controller. For examplp, to obtain frequency modulation, an oscillator may be patched into the external input and switched on and off by the blue switch. The attenuator would control the amplitude of the modulating signal, in this case the modulating bandwidth.

It is also possible to obtain equal-tempered scales with other than

12 notes to the octave by using the attenuator control. Normally the keyboard is set to 12-tone equal temperament, within the range of the "scale" control on the keyboard itself. By patching from the pitch jack on the Pitch and Trigger Panel into the external input jack on the Controller Connector, one can vary the size of the control voltage produced by the Controller. To obtain a microtonal scale with more then twelve notes to the octave, turn off the switch connecting the Controller to the oscillator or filter bank (switch #1), and turn on the attenuator switch #4. The attenuator can then be set for any scale between 12-tone equal temperament and a scale so small that there is no difference between the highest and lowest keys on the keyboard. To get a macrotonal scale with fewer than twelve notes to the octave, the same set-up can be used, with switch #1 also turned on in addition to the attenuator switch.

In order to obtain other types of tunings, such as meantone temperament, one must have a 950-B Scale Programmer.

2. Four-Input Complementary Output Mixer

Any signal(s) may be patched into the mixer's top row of four jacks, marked mixer inputs. The "pots" (short for potentiometers) directly below each of these jacks attenuate the amplitude of the input. In the lower right corner of the unit are four output jacks and an output control marked master gain, which attenuates the volume level of the output, the sum of each of the four inputs.

Note that the top two output jacks are marked "+" and the bottom two "-", positive and negative respectively. The negative output is identical to the positive output, except that it is 180 degrees out of phase. These are called complementary outputs. Thus, a signal mixing the positive and negative outputs in equal proportion will exactly cancel itself out, producing silence.

The click filter, if switched toward the top, will apply a "hi-fi" filter to the output signal, cutting down the amplitude of the signal's high harmonics. (This filter should normally be kept in the "off" position.)

The four jacks on the lower left of the unit are not connected.

3. Multi-Purpose Unit
Multiples
Pitch and Trigger Panel

The Multi-Purpose Unit contains a Low Pass and HIgh Pass Filter and an Attenuator. A low pass filter cuts off high frequencies, thus "passing" low frequencies. A high pass filter performs the opposite function. The frequency at which the attenuation begins for low and high pass filters is called the cutoff frequency. The Low Pass and High Pass Filters on this unit can be controlled in only six discreet steps each, and have no control inputs.

The Attenuator is often useful as an additional potentiometer which can modify the magnitude of any signal through attenuation (rather than amplification).

The Multiples, mounted in the unit adjacent to the Multi-Purpose Unit, comprise two groups of four jacks, each group connected integrally, each jack permitting either input or output. Thus, a multiple is used to make one output available at more than one jack location, enabling the distribution of one signal to more than one input. A multiple is not used to combine signals, however. (The multiples on the Synthesizer function in exactly the same way as those on the Patch Panel.)

The pitch and trigger jacks are simply the locations on the console panel at which the outputs of the Keyboard Controller appear. While the Keyboard Controller may be connected to the "oscillator bank" by raising Switch No. 1 of the 901 Controller Connector, no such switch control is available for the other units. Thus, to connect the Keyboard Controller to the 901 Voltage Controlled Oscillators, it is necessary to patch directly from a pitch jack to one of the Control Inputs on the 901.

The trigger jacks are essential for any operations involving the 911 Envelope Generators. Note the special plugs necessary to connect to these units. Once the trigger is connected, the Keyboard Controller trigger voltage is operative.

5. Trunk Lines

Four sets of two jacks connected to trunk lines 1 through 4 are provided on the Synthesizer consoles in the lower left corner of the 4-Input Complementary-Output Mixers. Each set of two jacks is connected together as a multiple. If more than one source is to be fed into a single line, a mixer should be used. (See section 5-2.3.) The Synthesizer trunk line jacks provide direct connection to the corresponding numbered trunk line jacks on the Patch Panel.

3. Individual Units

901 Voltage Controlled Oscillator
901A Oscillator Controller
901B Oscillator

The basic function of an oscillator is that of signal generation, whether the signal is used as an audio tone itself or as a control input to another unit. Out of the total frequency continuum, only sounds with a frequency between approximately 16 and 16,000 cps (cycles per second; also called Hz.) are audible to the human ear. Frequencies below this value, however, may be used as control signals.

The Moog oscillators generate four different wave-forms — sine, sawtooth, pulse (square), and triangular — over a frequency range from .1 to 15,000 cps. A sine wave contains only one fundamental frequency with no harmonic partials, while sawtooth, pulse, and triangular waves contain, theoretically, an infinite series of partials. Their differences may be explained as follows:

> A sawtooth wave contains an infinite series of harmonic partials, but in a certain amplitude ratio, such that the higher the harmonics, the lower the amplitude.
>
> A square wave contains an infinite series of odd-numbered harmonic partials in the same amplitude ratio as the sawtooth wave.
>
> A triangular wave contains an infinite series of only odd partials, like the square wave, but the amplitude ratio is different, and also the phase of every other odd partial is 180 degrees.

The 901 Voltage Controlled Oscillator contains a fixed control voltage rotary switch with twelve positions labelled -5 to +6, a frequency range rotary switch with 6 positions labelled "LO" followed by powers of 2 from 2 to 32, a frequency vernier control, a width of pulse waveform control, four variable level output amplitude controls, three control input jacks, four fixed level output jacks, and four variable level output jacks.

Patching a connection from one of the output jacks to either the Six-Input Two-Output Mixer or to the Amp Monitor will produce a steady frequency of the waveform specified by the jack. The amplitude of the fixed level outputs is constant, while that of the variable level outputs may be attenuated by the appropriate amplitude control.

The frequency of the oscillator is controlled by the combination of the fixed control voltage, the frequency range control, and the frequency vernier. Adjacent steps on the frequency range control are an octave apart, with a fairly high accuracy, except that the "LO" position is considerably lower than the other positions. Adjacent steps on the fixed control voltage switch are approximately an octave apart, but this control is less accurate than the frequency range switch. The frequency vernier provides continuous adjustment of the frequency over a range slightly greater than an octave. Note that the frequencies of each of the output waveforms are identical.

Connecting a controller (e.g., the 950 Keyboard Controller) to the oscillator by patching from the pitch jack on the Pitch and Trigger Panel to a control input will cause the frequency of the oscillator to be determined by a combination of each of the above congrols and the controller, which can cover only five octaves. This "combination" is called the CONTROL SUM, defined as: the algebraic sum of all the input control voltages, plus whatever is set on the fixed control voltage knob(s) on the face of the module.

> A word of caution: oscillators can produce accurate musical scales only when the control sum lies between 0 and +5 volts. Beyond this range the oscillators will either be out of tune or will cease generating output signals. The keyboard control voltage output ranges from 0 to +5 volts. Thus, you can exceed the control sum range if the algebraic sum of the two fixed control voltage knobs does not equal approximately zero.

The width of pulse waveform control changes the waveform of the pulse output from a square wave to an alternating long and short pulse, and is a powerful way of changing the harmonic spectrum of the pulse output. It is also especially useful when the oscillator is used as timing control rather than as a signal generator.

A 901A Oscillator Controller with several 901B Oscillators to its right constitute an oscillator bank. The 901A drives all 901B's in the bank simultaneously. The 901A contains a fixed control voltage rotary switch, a frequency vernier, a width of pulse waveform control and three control input jacks. These controls performs exactly the same functions as those on the 901, except in this case they affect all of the 901B's.

The 901B Oscillator contains a frequency range control, a frequency vernier, and four output jacks for the sine, sawtooth, pulse, and triangular waveforms. These are all fixed level outputs.

> N.B. Tuning between 901B's in the same bank will remain accurate over a large frequency range as long as the frequency vernier is set between 3 and 7.

GENERAL DESCRIPTION:

The 901 Voltage-Controlled Oscillator is a wide-range generator of repetitive waveforms, the frequency of which is controlled by the sum of applied control voltages. The relationship between the control voltage change and the frequency change is accurately exponential over a wide range. The total frequency span of the oscillator is 0.1 to 15,000 Hertz (cycles per second) in six overlapping ranges. Four waveform outputs are available: sawtooth, triangular, sine, and pulse. The width of the pulse waveform is continuously variable, by means of a front panel potentiometer, from complete symmetry (square wave) to 8:1 asymmetry. One fixed and one variable output are available for each waveform.

The 901-A Oscillator Controller and the 901-B Oscillator are, respectively, the controlling and the oscillating/waveshaping sections of the 901 Voltage-Controlled Oscillator. The separation of the functions of the 901 into two modular instruments allows the assembly of a bank of oscillators, all of which are controllable from one (or more) controllers. The 901-A panel contains the control voltage input jacks and potentiometers which vary the frequencies of all the controlled oscillators simultaneously. The 901-B panel contains frequency range controls and fixed level output jacks for each waveform. One controller may control up to twelve oscillators. The ratios between the frequencies of the oscillators are set on the frequency range controls. All of the oscillator frequencies are then controlled simultaneously by the application of the control voltages at the control inputs of the controller. The oscillator frequencies are controlled so that the ratios (intervals) between the frequencies of the various oscillators remain constant while the frequencies of all the oscillators are varied by the control voltages. A bank of oscillators in which the intervals between the frequencies remain constant as the frequencies themselves are varied obviously has great musical value.

ELECTRICAL SPECIFICATIONS: 901 VOLTAGE-CONTROLLED OSCILLATOR

Number of control inputs:	3
Impedance of control input:	100K ± 1%
Relationship between control input voltage change and output frequency change:	An increase of one volt in the sum of the control inputs doubles the oscillator frequency.

Impedance of the fixed level outputs:	600 Ohms
Level of the fixed level outputs:	0.5 volts RMS (-4 db)
Impedance of the variable level outputs:	1500 Ohms maximum
Range of levels of the variable level outputs:	0-0.5 volts
Dependence of frequency of oscillation upon the magnitude of the control voltage sum:	A one volt increase in the sum of the control voltages doubles the frequency. This relationship is accurate to ± 1% within the control voltage span of 0 to +5 volts, and is accurate to ± 5% within the control voltage span of -4 to +6 volts.
Span of voltage control of the frequency:	Ten octaves. Frequencies at three control voltage sums for each of the six ranges are shown in the chart below.

TYPICAL FREQUENCIES OF OSCILLATION AT THREE VALUES OF THE CONTROL VOLTAGE SUM, FOR ALL SIX RANGES

	Range					
	1	2	3	4	5	6
+6V	80	1040	2016	3930	10550	14060
0	1.2	16	16	61	123	265
-4V	.08	1.0	1.0	3.9	8.0	16

Waveform:	Sawtooth, triangular, sine and pulse waveforms are available simultaneously.
Power supply requirements:	-6 volts and +12 volts regulated and -10 volts unregulated with respect to ground. Maximum current is 40 ma.

MECHANICAL SPECIFICATIONS: 901 VOLTAGE CONTROLLED OSCILLATOR

Panel size:	8-3/4" high x 6-3/8" wide
Depth behind panel:	6"
Panel components:	1 - 12-position "Fixed Control Voltage" switch which provides one volt steps in the control voltage sum. 1 - "Fixed Control Voltage" potentiometer which provides a two-volt continuous control voltage change. 1 - 6-position "Frequency Range" switch 1 - "Pulse Width" potentiometer 4 - "Output Level" potentiometers, one for the variable level output of each waveform. 4 - "Variable Level Output" jack, one for each waveform. 3 - "Control Input" jacks
Rear Connector:	Printed circuit board (mates with standard 22-pin connector) Standard connectors are: #1 +12 volts #2 Ground #3 -6 volts #9 sine output #11 triangular output #12 pulse output #14 -10 volts #16 sawtooth output

ELECTRICAL SPECIFICATIONS: 901-A OSCILLATOR CONTROLLER

Number of control inputs, impedance of control inputs, relationship between control input change and output frequency change, and span of voltage control of the frequency:	Same as for 901 Voltage Controlled Oscillator above.

Maximum number of 901B oscillators that can be driven with one 901A controller:	12
Power supply requirements:	-6 volts and +12 volts regulated. Maximum current is 25 ma.

MECHANICAL SPECIFICATIONS: 901-A OSCILLATOR CONTROLLER

Panel size:	8-3/4" high x 2-1/8" wide
Depth behind panel:	6"
Panel components:	1 - 12 position "Fixed Control Voltage" switch which provides one volt steps in the control voltage sum. 1 - "Fixed Control Voltage" potentiometer which provides a two-volt continuous control voltage change. 1 - "Pulse Width" potentiometer 3 - Control Input jacks
Rear connector:	Printed circuit board (mates with standard 22-pin connector). Standard connections are: #1 +12 volts #2 Ground #3 -6 volts #5, #6, #7 To corresponding numbers on 901-B connectors.

ELECTRICAL SPECIFICATIONS: 901-B OSCILLATOR

Amplitude of each output:	0.5 volt RMS
Impedance of each output:	600 Ohm nominal
Output waveforms:	Sawtooth, triangular, sine and pulse waveforms are available simultaneously.
Span of voltage-control of the frequency:	Same as that of the 901 Voltage Controlled Oscillator. See chart above.

902 Voltage Controlled Amplifier

The 902 performs a variety of amplification functions, corresponding to loudness or volume.
On the face of the module is a control mode switch, a fixed control voltage pot, two complementary ("positive" and "negative") signal inputs, two complementary signal outputs, and three control inputs. The 902 increases the volume of the signal passing from the input jacks to the output jacks as the control sum increases. When the control sum equals 6 volts the 902 signal output reaches a maximum and when the control sum equals 0 volts there is no signal output.

In conjunction with other control voltage sources, particularly the 911 Envelope Generator, the 902 VCA will perform other amplitude-varying functions. The 911 is connected to the VCA by patching from the former's control output jack to a control input on the latter. In this case the fixed control voltage should be set at 0, so that the output of the VCA will be determined entirely by the control voltage from the 911. The control mode switch determines the shape of the attack and decay times of the 911. (See Section 5-3.911.)

The VCA may also be controlled by an oscillator in order to produce amplitude modulation.
A special kind of amplitude modulation, referred to as ring modulation, may be produced by the VCA in conjunction with a mixer in the following arrangement: signal 1 must be patched into both the signal input on the 902 and an input on the mixer. (This may necessitate the use of a multiple.) The output of the 902 is patched into another mixer input, and signal 2 is patched into a control input on the 902. The 902 must be set to the linear mode, and the fixed control voltage should be about halfway up. The two mixer inputs should be balanced carefully at a fairly low level, and the master gain of the mixer should be all the way up. The mixer output is then the ring modulated signal, which contains both the sum and difference frequencies of the input signals.

GENERAL DESCRIPTION

The Moog Model 902 Voltage-Controlled Amplifier is a signal-processing instrument whose amplification (gain) is determined by the magnitude of the applied control voltages. Any amplitude varying operation can be performed on an audio signal by applying the appropriate control voltage contour to the control inputs of the Model 902. These operations include loudness control, gating, production of percussive envelopes, amplitude modulation, and balanced modulation. The Model 902 is also well suited for use as the variable gain element in certain types of voltage-controlled filters. For instance, a combination of the Model 902-A Bandpass Filter Adaptor and the Model 902 form a simple voltage-controlled bandpass filter.

The Model 902 is completely balanced and direct-coupled. Two independent signal inputs and two independent signal outputs are provided. Both the signal inputs and the signal outputs are push-pull. That is, unblanced signals may be introduced into or taken from either side of the balanced circuit, or balanced signals may be processed directly. When the Model 902 is used in an unbalanced system, the two independent inputs allow two signals to be mixed, while the two outputs provide signals of opposite sign. These features, plus the direct-coupled feature which allows the Model 902 to process arbitrarily slow signals, are extremely useful in modifying slowly-varying voltages as well as rapidly-varying audible signals.

ELECTRICAL SPECIFICATIONS

Nominal impedance of each of the two signal inputs:	10,000 ohms
Nominal impedance of each of the two signal outputs:	600 ohms
Impedance of each of the three control inputs:	100,000 ohms
Maximum voltage gain:	6 db.
Range of voltage gain:	Greater than 80 db.

Relationship between the magnitude of the control voltages and the gain:	Two control modes are available. The "exponential" mode produces a gain ratio change of 12± 1 db for a change of 1 volt in the magnitude of the sum of the control voltages. The "linear" mode produces a linear control voltage gain relationship. The complete gain range from 0 to 2 is covered by varying the control voltage sum from 0 to +6 volts.
Signal-Noise Ratio at unity gain and 0.5 volts input:	Better than 70 db
Maximum signal input voltage:	2 volts RMS
Total Harmonic Distortion at unity gain and maximum signal input voltage:	2.0%
Frequency response:	D.C. - 50 kc
Power supply requirements:	-6 volts and +12 volts with respect to ground. Maximum current is 40 ma.

MECHANICAL SPECIFICATIONS

Panel size:	8-3/4" high x 2-1/8" wide
Depth behind panel:	6"
Panel components:	1 - Control Mode switch 1 - "Fixed Control Voltage" potentiometer 2 - Signal input jacks 2 - Signal output jacks 3 - Control input jacks (Phone jacks are standard. Other connectors are available.)
Rear connector:	Printed Circuit Board. (Mates with standard 22-pin connector.)

REQUIRED ACCESSORIES

A. Power supply for supplying -6 volts and +12 volts. Either a regulated A.C. supply (e.g. Moog Model 910) or dry batteries is satisfactory.

B. Enclosure for mounting instruments with 8-3/4" vertical panels.

OPTIONAL ACCESSORIES

A. Oscillator for producing amplitude modulation (e.g. Moog Model 910)

B. Envelope Control Voltage Generator for producing percussive and sustained envelopes. Simple circuits can be readily constructed. More elaborate instruments (e.g. Moog Model 911) are available.

C. Manual Control Device for producing control voltage contours (e.g. Moog Model 955).

904 Voltage Controlled Filter

A filter is a basic kind of signal processing device, whose operation is to resonate (increase the amplitude of) or to attenuate (decrease the amplitude of) or to pass or reject in entirety some particular area or areas of the frequency continuum. A filter response curve is a plot of frequency against gain (the ratio between input and output amplitude), showing the amount by which a filter resonates or attenuates frequencies in each region.

Generally the input to a filter is some kind of basic waveform containing many harmonic partials. In this case the filter will affect the timbre of the sound, resonating certain partials and attenuating others. Filters are also used with noise inputs to generate percussive effects.

A low pass filter cuts off high frequencies, thus passing low frequencies. A high pass filter is the inverse, cutting off low frequencies and passing highs. The frequency at which the attenuation begins for both low and high pass filters is called the cutoff frequency.

A band pass filter resonates only one particular area of the frequency continuum, which is called the center frequency. The bandwidth specifies how great an area on each side of the center frequency is resonated, and changing the bandwidth usually affects the damping (roughly, the shape) of the resonance curve. A band reject filter is the inverse of a band pass filter. It rejects one particular frequency area and passes frequencies on either side of that area.

The Moog 904 filters provide extremely flexible control over all of these filtering characteristics, and are comprised by the 904A VoltageControlled Low Pass Filter, the 904B Voltage Controlled High Pass Filter, and the 904C Filter Coupler. These units are referred to as filter sections.

The 904A Voltage Controlled Low Pass Filter contains one signal input, one signal output, three control inputs, a fixed control voltage control, a three-position frequency range switch, and a regeneration control.

The frequency range switch is analogous to the same control on the 901 oscillators and selects a basic area of the frequency continuum which is then further determined by the fixed control voltage control. The frequency range switch moves the cutoff frequency in two-octave steps (a frequency factor of four), while the fixed control voltage pot provides continuous "fine tuning" adjustment. These two controls determine the cutoff frequency, which is the voltage-controllable parameter, doubling for each one volt increase in the applied control sum. (This relationship holds over a 500:1 (9 octave) cutoff frequency range and is the same frequency/control voltage relationship found in the 901 oscillators.) Above the sutoff frequency, the gain decreases at a rate approaching 24 db/octave.

The regeneration control is a unique feature of the 904A. This control varies the amount of internal feedback, introducing a resonant peak in the response of the filter at the cutoff frequency.

The 904B Voltage Controlled High Pass Filter passes only those frequencies above the cutoff frequency. Its characteristics, functions, and modes of operation directly correspond to those of the lowpass filter, with one exception: it has no regeneration control.

The 904C Filter Coupler does no actual filtering, but connects the filters either in series (signal to be filtered first passes through one filter and then the other) or in parallel (signal to be filtered passes through both filters simultaneously, and the two outputs are then mixed). When the two filters are in series, only frequencies below the lowpass cutoff and above the highpass cutoff are passed, the filters thus comprising a bandpass device. Conversely, when the two are in parallel, all frequencies are passed, except for those above the lowpass cutoff and below the highpass cutoff, the filters thus comprising a bandreject device. The coupler also accepts two control inputs. One of these (called the center frequency control input) ~~may be~~ is automatically applied to both filters so that the low frequency and high frequency cutoff move together. The other control input (called the bandwidth input) is applied directly to the control input of one filter and, through a polarity-reversing circuit, to the control input of the other filter. This produces changes in the bandwidth without affecting the mean, or center, frequency of the passband.

Because of its wide range, accurate control, and fast response, the 904 Voltage Controlled Filter is widely used in electronic music composition. In its bandpass mode, the 904 imparts a broad resonant spectrum to timbres of periodic signals or a sense of pitch to non-periodic signals. Transient (short-lived) control voltage variations are transformed into timbres characterized by dynamic spectrum variations. Periodic control voltages produce aural effects which generally cannot be acheived by the more familiar frequency or amplitude modulations. Control voltages created by keyboards or linear controllers, or other programming devices, produce instantaneous, predictable formant changes over wide ranges.

#904 VOLTAGE-CONTROLLED FILTER

GENERAL DESCRIPTION:

The 904 voltage-controlled filter is a lowpass-highpass filter made up of three sections: a lowpass filter (904-A), a highpass filter (904-B), and a coupler (904-C) which connects the two filters in either the "bandpass" or "bandreject" mode. When the coupler is disconnected, the two filters may be used independently.

The lowpass filter passes only those frequencies below the cutoff frequency. Above the cutoff frequency, the gain (ratio of output amplitude to input amplitude) decreases at a rate approaching 24 db/octave. The cutoff frequency is the voltage-controllable parameter, and doubles for each one volt increase in the sum of the applied control voltages. This relationship holds over a 500:1 (9 octave) cutoff frequency range (and is the same frequency/control voltage relationship found in the 901 oscillator). Panel features include a signal input, a signal output, three control inputs, a fixed control voltage potentiometer (-6 to +6 volt range), a three-position switch which moves the cutoff frequency range in two-octave steps (a frequency factor of four), and a regeneration potentiometer. This latter control varies the amount of internal feedback, introducing a resonant peak in the response of the filter at the cutoff frequency.

The highpass filter passes only those frequencies above the cutoff frequency. Its characteristics, functions, and modes of operation directly correspond to those of the lowpass filter, with one exception: it has no regeneration control.

The coupler itself does no actual filtering, but connects the filters either in series (signal to be filtered first passes through one filter and then the other) or in parallel (signal to be filtered passes through both filters simultaneously; the two outputs are then mixed). When the two filters are in series, only frequencies below the lowpass cutoff and above the highpass cutoff are passed. The filters in series thus comprise a bandpass device. Conversely, when the two are in parallel, all frequencies are passed, except for those frequencies above the lowpass cutoff and below the highpass cutoff. The filters in parallel thus comprise a bandreject device. The coupler also accepts two control inputs. One of these (called the center frequency control input) is automatically applied to both filters so that the low frequency and high frequency cutoff move together. The other control input (called the bandwidth input) is applied directly to the control input of one filter and, through a polarity-reversing circuit, to the control input of the other filter. This produces changes in the bandwidth without affecting the mean, or center frequency of the passband.

Because of its wide range, accurate control, and fast response, the 904 Voltage-Controlled Filter is widely used in electronic music composition and other audio signal processing applications. In its bandpass mode, the 904 imparts a broad resonant spectrum to timbres of periodic signals or a sense of pitch to non-periodic signals. Transient (short-lived) control voltage variations are transformed into timbres characterized by dynamic spectrum variations. Periodic control voltages produce aural effects which generally cannot be achieved by the more familiar frequency or amplitude modulations. Control voltages created by keyboards or linear controllers, or other programming devices, produce instantaneous, predictable formant changes over wide ranges.

<u>ELECTRICAL SPECIFICATIONS</u> 904-A LOW PASS FILTER
904-B HIGH PASS FILTER

Nominal signal input impedance:	10,000 Ohms
Nominal signal output impedance:	600 Ohms
Impedance of each of the three control inputs:	100,000 Ohms
Maximum voltage gain:	0 db
Range of cutoff frequencies:	20 Hz - 30 Khz in two overlapping ranges
Range of voltage control of cutoff frequency within a given range:	9 octaves (500:1)
Relationship between the cutoff frequency and the magnitude of the control voltages:	A one volt increase in the sum of the control voltages will double the cutoff frequency.
Signal-noise ratio at maximum cutoff frequency and 0.5 volts input:	Better than 60 db
Maximum signal input voltage:	2.0 volts RMS

Power supply requirements: -6 volts and +12 volts with respect to ground. Maximum current is 50 ma.

MECHANICAL SPECIFICATIONS

904-A LOW PASS FILTER
904-B HIGH PASS FILTER

Panel size: 8-3/4" high x 4-1/4" wide

Depth behind Panel: 6"

Panel components: 1 - "Fixed Control Voltage" potentiometer; 1 - 2-position "Range" switch; 1 - "Regeneration" potentiometer (904-A only); 1 - Signal Input Jack: 1 - Signal Output Jack; 3- Control Input Jacks; (Phone jacks are standard. Other connectors are available)
Rear Connector: Printed circuit board (mates with standard 22-pin connector)

ELECTRICAL SPECIFICATIONS

904-C FILTER COUPLER (Used with one 904-A lowpass filter, and one 904-B highpass filter)

Nominal signal input impedance:	10,000 Ohms
Nominal signal output impedance:	600 Ohms
Impedance of each of the two "center frequency" control inputs:	100,000 Ohms
Impedance of the "bandwidth" control input:	100,000 Ohms
Maximum voltage gain:	0 db
Relationship between the center frequency and the magnitude of the center frequency control voltage.	A one volt increase in the sum of the center frequency control voltages will double the center frequency of the pass or reject band.

Relationship between the bandwidth and the magnitude of the bandwidth control voltages:	A one volt increase in the sum of the bandwidth control voltages will increase the bandwidth of the pass or reject band by one octave.
Signal-noise ratio with composite filter "wide open" and 0.5 volts input:	Better than 60 db
Maximum signal input voltage:	2.0 volts RMS
Power supply requirements:	-6 volts and +12 volts with respect to ground. Maximum current is 20 ma.

MECHANICAL SPECIFICATIONS: 904-C FILTER COUPLER

Panel size:	8-3/4" high x 4-1/4" wide
Depth behind panel:	6"
Panel components:	1 - 3-position "MODE" switch
	1 - "Center Frequency" fixed control voltage potentiometer
	1 - "Bandwidth" fixed control voltage potentiometer
	1 - Signal Input jack
	1 - Signal Output jack
	1 - Bandwidth control input jack
	2 - Center Frequency control input jacks
	Printed circuit board (mates with standard 22-pin connector)

REQUIRED ACCESSORIES:

A. Power supply for supplying -6 volts and +12 volts. Either a regulated A. C. supply (e.g. Moog Model 910) or dry batteries are satisfactory.

B. Enclosure for mounting instruments with 8-3/4" vertical panels.

OPTIONAL ACCESSORIES:

A. Oscillator for producing formant modulation (e.g. Moog Model 901)

B. Envelope Control Voltage Generator for producing dynamic formant variations. Simple circuits can be readily constructed. More elaborate instruments (e.g. Moog Model 911) are available.

C. Manual Control Device for producing control voltage contours (e.g. Moog Model 955).

Using the 904 Voltage Controlled Filter

The 904-A voltage controlled low pass filter and the 904-B voltage controlled high pass filter may either be used separately or coupled to form a band pass or band reject filter.

To use the A and B independently be sure that the mode switch on the 904-C coupler is in the OFF position.

To couple the A and B together to form a band pass or band reject filter, select the appropriate position on the COUPLING MODE switch on the filter coupler. The signal to be filtered is applied to the SIGNAL INPUT of the 904-C and taken from the SIGNAL OUTPUT of the 904-C. Signal inputs and outputs of the 904-A and 904-B are not used.

Maximum effectiveness of the filter coupler will be achieved with the controls of the low pass and high pass sections at the following settings:

904A	FIXED CONTROL VOLTAGE	+6
	RANGE	"2"
904B	FIXED CONTROL VOLTAGE	-1
	RANGE	low

The REGENERATION control on the 904A may be set at any position.

905 Reverberation Unit

Reverberation, or echo, is a kind of signal modification which is produced mechanically when a sound bounces off the walls of a room or other objects and returns to mix with the original signal. Its only variable characteristic is the reverberation time(which is actually not a variable on the 905 Reverberation Unit), which is the time it takes the sound to die out in a given environment.

The 905 provides mechanical-acoustic reverberation through a spring-type mechanism. Its front panel contains a signal input and signal output jack, and a knob which determines the ratio of the reverberated signal which is mixed with the unreverberated signal. Reverberation time is 1.7 seconds.

GENERAL DESCRIPTION

The Moog Model 910 Power Supply produces regulated -6 and +12 volts for powering most of the Moog "900 series" instruments. Conservatively designed and ruggedly built, this supply can furnish power for all but the most elaborate and extensive systems.

ELECTRICAL SPECIFICATIONS:

Output Voltages:	-6 and +12 ±1% with respect to ground
Output Current:	2 amperes maximum
Load regulation:	0.5%
Line regulation:	0.05%
Input voltage:	105-130 volts 60 cycle A.C.
Output ripple:	1 millivolt maximum

MECHANICAL SPECIFICATIONS:

Panel size:	8-3/4" high x 6-3/8" wide
Depth behind panel:	7"
Panel Components:	1 - Off-On Switch 1 - Pilot light 1 - Fuse holder 3 - Power outlet sockets (Jones S-303)
Rear Connectors:	3-Power outlet sockets (Jones S-303)

10/65 Specifications subject to change.

911 Envelope Generator

Envelope is a general name for the attack and decay characteristics of a sound, roughly corresponding to what is usually referred to as the articulation qualities of musical instruments. Strictly speaking, the envelope includes all dynamic changes of a sound, including any crescendo, diminuendo, or more complex variations in amplitude, but usually the components of an envelope are broken down into the rise or attack time, initial decay time, steady state amplitude, and final decay time, and any other changes in amplitude are specified separately (and controlled by different devices).

The attack time of a sound is the time in which the sound grows from silence to some peak amplitude. Attack times on conventional musical instruments tend to be very fast, measured in milliseconds. The initial decay time of a sound is the time in which the amplitude falls from the peak of the attack to the steady state amplitude, which is the level at which the sound is sustained for most of its duration. The initial decay, if present, is usually fast, like the attack, and is recognized because often the attack amplitude overshoots the steady state value before the note levels off. The final decay time is the time it takes the sound to fall from its steady state amplitude to silence.

The shape of attacks and decays on conventional instruments tends to be complex. Two simple mathematical relationships can be described, nevertheless: a linear rise or decay in amplitude is one which changes by equal values over equal time segments, corresponding to a straight line graphically; an exponential rise or decay changes by an equal ratio over equal time segments, corresponding to an exponential curve graphically (and, incidentally, to a linear change in decibels). An exponential curve approaches zero asymptotically, but theoretically never reaches it.

Conventional instruments are not capable of controlling envelope characteristics very precisely. The rise times of wind instruments tend to be faster than those of stringed instruments. A plucked string has a fast rise and an exponential decay, with no initial decay time or steady state amplitude. Furthermore, empirically speaking, the envelope of each partial on notes with complex timbres is different, so that applying the summation envelope to the same partials would produce a different timbre. It is also known that conventional instruments often produce transients, which include partials (sometimes not harmonically related) which are present during the attack only.

Electronic instruments, by providing precise control over each of the envelope variables, can produce all kinds of effects impossible with conventional instruments. At the same time, it must be recognized that the main difficulty in synthesizing the sounds of conventional instruments is due mainly to the necessity of specifying a separate envelope for each partial.

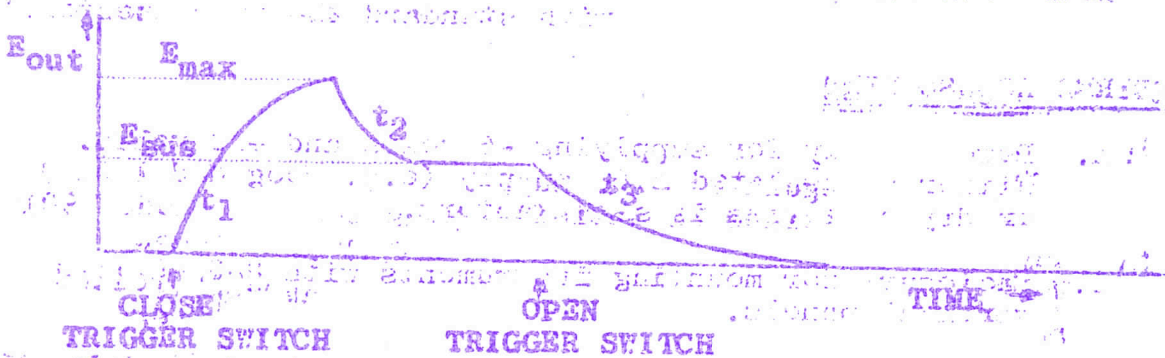
The Moog 911 Envelope Generator, upon receiving a trigger from a controller or 912 Envelope Follower or 960 Sequential Programmer, produces a control voltage envelope. Its front panel includes a trigger input socket, a control output jack, and four controls labelled T_1 (attack time), T_2 (initial decay time), T_3 (final decay time, and E_{sus} (sustain-level.

The trigger input socket receives the trigger from a controller via a special patch cord from the trigger output jack on the Pitch and Trigger Panel. The control voltage is available at the control output jack. Although envelope is usually considered a characteristic of amplitude, the control voltage output may also be used to control pitch or timbre by being patched to the control input of a 901 Oscillator or a 904 Filter.

The attack time, initial decay time, and final decay time controls may be adjusted over the range of 5 milliseconds to 10 seconds. The sustaining level control sets the amplitude to which the initial decay returns, and should be turned up approximately half way to have effect. The final decay time then begins as soon as the trigger control is released.

GENERAL DESCRIPTION

The Moog Model 911 Envelope Control Voltage Generator is a device for generating single voltage contours of the type illustrated below:



When the triggering switch (external to the Model 911) is closed, the output voltage E_{out} rises with a characteristic time t_1. When E_{out} reaches a set level E_{max}, it immediately begins to fall with a characteristic time t_2, and to approach and level off at E_{sus}. The output voltage remains at E_{sus} until the triggering switch is opened, at which time it falls to zero with a characteristic time t_3. The voltage-time contour is thus characterized by four variables: the <u>rise time</u> (t_1), the <u>initial decay time</u> (t_2), the <u>sustain level</u> (E_{sus}), and the <u>final decay time</u> (t_3). t_1, t_2, t_3, and E_{sus} are all continuously variable over wide ranges by means of panel controls.

The output voltage E_{out} may be applied to the control input of any voltage-variable device. In particular, the use of the Model 911 in conjunction with a voltage-controlled amplifier such as the Moog Model 902 enables the composer to impart an extremely wide variety of amplitude envelopes to steady signals. Similarly, voltage-controlled oscillators and filters produce musically useful sounds when used in conjunction with the Model 911.

ELECTRICAL SPECIFICATIONS

Range of t_1:	10 milliseconds - 10 seconds
Range of t_2:	10 milliseconds - 10 seconds
Range of t_3:	10 milliseconds - 10 seconds
E_{max} (Voltage at which t_2 begins):	5.5 volts ± 10%
Range of E_{sus}:	0 to E_{max}
Nominal Output Impedance:	10,000 ohms.
Power Supply requirements:	-6 volts and +12 volts with respect to ground. Maximum current is 50 milliamperes.
Method of triggering:	Closing of an external switch.

MECHANICAL SPECIFICATIONS

Panel Size:	8-3/4" high x 2-1/8"wide
Depth behind panel:	6"
Panel Components	4-Potentiometer knobs for t_1, t_2, t_3, and E_{sus}. 1-Output phone jack 1-Socket for external triggering switch (Jones S-302)
Rear Connector:	Printed Circuit Board (Mates with standard 22-pin connector.)

REQUIRED ACCESSORIES

A. Power supply for supplying -6 volts and +12 volts. Either a regulated A.C. supply (e.g. Moog Model 910) or dry batteries is satisfactory.

B. Enclosure for mounting instruments with 8-3/4" vertical panels.

C. Any voltage-variable device, such as the Moog Model 901 Voltage-Controlled Oscillator, Model 902 Voltage-Controlled Amplifier, or Model 904 Voltage-Controlled Filter.

Specifications subject to change.

914 Fixed Filter Bank

The 914 Fixed Filter Bank is actually a series of 14 separate fixed-frequency filters. Its panel contains two signal inputs and two signal outputs and fourteen fixed-frequency filter sections of the bandpass type whose knobs attenuate particular narrow bands identified by their center frequencies. The cutoff frequencies for each section remain constant and there are no control inputs. (See Section 5-3.904.)

950 Keyboard Controller

The Moog 950 Keyboard Controller is the most important controller for the synthesizer. It contains a five-octave organ keyboard with 61 keys, a scale program selector switch, scale, range, and portamento controls, and a hold-no hold switch.

The scale program selector switch should always be left in the internal position; using the external position requires a 950-B Scale Programmer. The internal position insures that control voltages produced by adjacent keys on the keyboard will be equally spaced in voltage, which will produce equal changes in pitch.

The scale control allows the size of the interval between adjacent keys to be varied. When the control is approximately "5", the interval is a half-step. Turning the knob up or down will change both the size of the interval between adjacent keys and the pitch produced by a particular key, but this amount cannot be varied by greater than 10%. Further gradations require using the attenuator on a 901 Controller Connector. (See section 5-2.1.)

The range control is simply a transposing device. It allows the pitch produced by a particular key to be tuned up or down without changing the size of the interval between adjacent keys.

The hold position on the hold-no hold switch introduces a "memory" circuit which retains the control voltage corresponding to the last key depressed. The portamento control is in effect only when the hold position is used, and may be used to introduce a glissando between one key and another. The portamento circuit controls the time lag between the beginning and end of the glissando. The time lag is instantaneous when the portamento control is at zero, and may be set or varied up to several seconds. The memory circuit is disconnected when the no hold position is used. When no hold is in effect, the control voltage produced by the keyboard drops very low when the keys are released. No hold is a position used only for special effects, and this switch should normally be kept on hold.

In addition to the control voltage, the keyboard also produces a trigger, which can initiate the cycle of any number of 911 Envelope Generators. The trigger is sustained as long as any key remains depressed. (See section 5-3.911.)