ELECTRONIC MUSIC COMPOSITION - PERFORMANCE EQUIPMENT

SHORT FORM CATALOG — 1967

R. A. MOOG CO.
TRUMANSBURG, N. Y. 14886, U. S. A.

COMMENT

The Moog components for electronic music composition are noteworthy for their flexibility and for their method of direct voltage control. They go far to reduce the lag between the composer's intentions and the end result.

Wayne Barlow, Associate Dean, Eastman School of Music

The Moog instrumentation offers versatility, flexibility, and economy. Mr. Moog's personal interest in the entire development of electronic music assures the composer of an ear sympathetic to his problems and needs and will undoubtedly result in additions and further sophistication in equipment.

Will Gay Bottje, Director, Electronic Music Studio, Southern Illinois University

The Moog 900 System is a remarkable synthesis of the best features of the classical electronic music technique, the R.C.A. Sound Synthesizer, and computer-generated sound programming, with great convenience and "cybernetic engineering." Each module responds like a small building block to almost any logical musical construction.

Walter Carlos, Composer, New York City

Considering the electronic excellence of each individual item, the ease with which they are combined, the skill and originality in the design of new instruments, and the basic flexibility of the use of voltage control, the Moog electronic instruments are oustanding.

Joel Chadabe, Director, Electronic Music Studio, State University of New York at Albany

The Moog line lends itself to all aspects of electronic music. It performs admirably under all varieties of voltage control, from simple keyboard to computer programming.

Gustav Ciamaga, Director, Electronic Music Studio, University of Toronto

R.A. Moog equipment has been invaluable to my work with electronic composition. I have twice used modules of his design as parts of a live concert instrument. The studio equipment is compact, lightweight, and has proven to be quite free from technical malfunctions.

Herbert Deutsch, Composer, Huntington, New York

Moog equipment has fine voice and is particularly well-designed. Two days with it saves me two weeks of work.

Tod Dockstader, Composer, Westport, Connecticut

We are most fortunate to have a creative electronic engineer such as Robert Moog dedicated to the invention and development of electronic music composition equipment. North Texas State University is using his studio synthesizer, including the linear controllers and a considerable amount of other equipment. We find it most reliable, rugged, and highly versatile. Since it is transistor equipment, it is small and easy to handle. We are most pleased with our dealings with the R.A. Moog Company.

Merrill Ellis, Director, Electronic Music Composition Lab, North Texas State University

I am enormously impressed with the versatility and operating ease of the equipment. Operations which had taken hours before could be done in a matter of minutes. Dr. Moog is undoubtedly a leader in this field, both in the quality and originality of his equipment.

Donald Erb, Composer-in-Residence, Cleveland Institute of Music

The electronic music equipment designed by the R.A. Moog Co. has been of great value to me. It performs excellently, and is versatile and reliable.

Emmanuel Ghent, Composer, Columbia-Princeton Electronic Music Center

We are thrilled — with the seemingly endless sound possibilities — with the noise-free, pop-less circuits you have built — with the overall appearance. Thank you for the obvious care you took in your planning and construction.

Frank H. Harris, President, Frank Harris Productions, Inc.

THE R.A. MOOG ELECTRONIC MUSIC EQUIPMENT

In less than two decades, electronic music has matured from an awkward and shy intruder into the realm of music to a dynamic and significant medium of musical expression. The original techniques of producing electronic music (the generation and modification of sound material by wholly electronic means and the manipulation of these sounds by tape recording) excluded live performance, use of programmed control, and the electronic processing of natural sounds. Although later methods were somewhat less restrictive, electronic music has until very recently been composed primarily by what is known as "classical studio technique." A classical studio typically consists of a collection of signal generators (audio oscillators, white noise generators, etc.), signal modifiers (filters, modulators, reverberation units, etc.), mixers, and at least two tape recorders. Tape splicing and other tape manipulations are of prime importance in classical studio technique, since these operations are employed to assemble individual tape segments into finished compositions. Classical studio technique is certainly a valid means of musical expression. However, recent developments in both programmed control and real time performance are pointing the way to more efficient, time-saving, yet musically natural procedures.

The R.A. Moog Synthesizers are integrated systems of modular, single-function generating, modifying, and controlling instruments. Each instrument is designed to perform its function over a range and with an accuracy consistent with the state of the art. The organization of single-function instruments into Synthesizers offers the composer the same flexibility as a classical studio, while the consistency of design of the various instruments allows him to think in terms of meaningful acoustic and musical operations without being encumbered by technical details.

The Moog Synthesizers are, however, much more than "packaged classical studios." Both programmed control and real time performance are made practical through voltage control, a principle first employed systematically in the design of electronic music composition instruments in 1964 by the Moog Co.

Voltage-Controlled Instruments

Voltage control is the use of an electrical voltage to determine the operating characteristics of a signal generating or modifying instrument. Classical studio instruments are not generally voltage-controlled. Their operating points must be set by manipulating dials, a procedure which limits spontaneity and the accurate, rapid variation of sound parameters. Voltage-controlled instruments also have panel controls which allow their operating points to be varied. In addition, however, a voltage-controlled instrument has one or more control inputs which allow the instrument's operating point to be varied in step with an externally applied control voltage. Rapid and precise voltage variations may be produced by a variety of means, each of which has its own characteristics and advantages. In the Moog Synthesizers, accurate, wide range voltage-controlled oscillators, amplifiers, mixers, and filters are the basic signal generating and modifying devices. Control voltages are produced by oscillators, random generators, transient (envelope) generators, and several types of manual and programmed devices.

An oscillator generates a periodically varying voltage. The rate at which the variations occur is known as the frequency. Frequencies between 20 and 20,000 vibrations per second correspond to audible tones with definite pitch. Mathematically speaking, the frequency is exponentially related to the pitch. That is, an increase in the frequency by a given ratio will result in a pitch increase

of a fixed amount, or interval. Frequencies below 20 vibrations per second do not have a definite pitch, and the effect of each cycle is heard distinctly.

The voltage-controlled oscillators used in Moog Synthesizers embody several important features. First, the relationship between the control voltage magnitude and the frequency of oscillation is exponential. Thus, equal changes in control voltage will produce equal intervals. The exponential relationship is: a one-volt increase in the control voltage raises the pitch one octave. This relationship is accurate over a six-octave range, and is useful over four additional octaves. Second, three independent control inputs are provided, and the frequency is actually proportional to the exponential of the sum of whatever voltages are applied to these three control inputs. Thus, several patterns of pitch variation can be superimposed in a single oscillator signal. Third, four output waveforms are simultaneously available: sine, triangular, sawtooth, and pulse. (The width of the pulse waveform is continuously variable from perfect symmetry (square wave) to a "narrow pulse" waveform of 10% duty cycle.) Finally, the total frequency range of the oscillator extends from one vibration every thirty seconds to 15,000 vibrations per second, and may therefore be used for timing and control functions as well as direct signal generation.

The general musical usefulness of this combination of characteristics cannot be overstated. With no control inputs whatever, these oscillators can be used as constant-frequency generators, the mainstays of the classical studio technique. By using a keyboard controller to select one of a multitude of fixed voltages, a pattern of discrete pitches may be "played." The ratios between the voltage steps are proportional to the ratios of the intervals that are generated. If the fixed voltages are equally spaced, then an equal-tempered scale will be generated, the smallest interval in the scale being equal to the octave-fraction equal to the magnitude of the control voltage differences. A manually-controlled frequency sweep can be produced with a linear potentiometer-type controller. The sweep may be as large as twelve octaves with an appropriate manual control device. A periodically varying frequency, such as a vibrato or a trill, can be generated by using the low frequency output of another oscillator as a control voltage. Random variations in the frequency of a voltage-controlled oscillator are produced by using filtered white noise as a control voltage, and transient variations are similarly produced by using non-repeating ("one-shot") control voltages. For programmed control, the output of a sequencer, the switching mechanism of a paper tape reader, or the analog output of a computer can be directly connected to the control input of the oscillator, and a simple, easily understood encoding scheme for generating the control voltage sequence can be employed.

Furthermore, any combination of the above types of oscillator control can be used simultaneously. For instance, a pattern of discrete voltages from a keyboard controller may be applied to one oscillator control input while a periodic, slowly varying voltage is applied to another control input, to give a pitch pattern with vibrato. If both the speed and intensity of the periodically varying control voltage is increased, the output of the modulated oscillator undergoes rapid, wide frequency variations. Consequently, the modulated tone becomes thick in texture and loses its purity of pitch. An enormous variety of clangorous (quasi-pitched) sounds, some of which resemble gongs, drums, and other percussion instruments, can be generated in this manner. Furthermore, if the modulating oscillator and the modulated oscillator are both controlled from the same manual control device, then patterns of clangorous tones of differing apparent pitch but identical tone quality may be produced.

Voltage-controlled amplifiers perform all of the amplitude and gain varying functions in the Moog Synthesizers. These include amplitude modulating and gating as well as envelope shaping and mixing.

A voltage-controlled amplifier has signal inputs, signal outputs, and control inputs. The amplitude of the signal output is proportional to that of the voltage applied to the signal input, the constant of proportionality being determined by the magnitude of the voltage applied to the control input. The Moog voltage-controlled amplifiers are completely balanced and direct-coupled. Two independent signal inputs are provided, one of which provides amplification with a polarity opposite the other. Two independent push-pull outputs are provided and, like the voltage-controlled oscillators, it is the sum of the control voltages applied to the three control inputs that determines the gain of the amplifier. Finally, a choice of two relationships between the control voltage sum and the gain (ratio of signal output to signal input) are available: linear and exponential. In the linear mode, the amplifier gain is directly proportional to the control voltage sum over the control voltage range 0-6 volts. In the exponential mode, the amplifier gain increases 12 db for each one-volt increase in the control voltage sum. In both modes, the gain is at its maximum of +6db when the control voltage sum is 6 volts.

Amplitude modulation (for the production of effects such as tremolo, repeated percussion, and clangorous tones) is produced by using an appropriate alternating voltage (from an oscillator, for instance) as the control voltage. Envelopes are imparted to steady signals by applying non-repeating voltages to the control input. For instance, a percussive envelope would be produced from a control voltage which rose to 6 volts within a hundredth of a second or so, then dropped back to zero in one or two seconds. Voltage-controlled mixing is achieved with two or more voltage-controlled amplifiers, the outputs of which are connected together. Complex envelopes can also be produced in this manner.

Dynamic variations in timbre, which add much aural interest and appeal to musical events, are readily produced with voltage-controlled filters. All Moog Synthesizers incorporate a voltage-controlled lowpass filter, and the larger models have a voltage-controlled highpass filter as well. Both instruments have one signal input, one signal output, and three control inputs. The lowpass filter passes all frequencies up to a variable "cutoff frequency," and attenuates frequencies above the cutoff frequency. The highpass filter performs the inverse function. In both instruments the relationship between the control voltage sum and the cutoff frequency is exactly the same as that for the voltage-controlled oscillators: a one-volt increase in the control voltage sum increases the cutoff frequency by one octave. This relationship is accurate over a 10-octave frequency range. The correspondence between the control modes of these filters and that of the voltage-controlled oscillators allows any voltage variation which produces a given pitch contour when controlling a voltage-controlled oscillator, to produce a congruent timbral contour by controlling a voltage-controlled filter. Thus, for instance, a scale of pitched noise can be "played" on a keyboard controller.

Another valuable application of the voltage-controlled filters is the imparting of rapid, non-recurring timbral variations to a steady tone. Suppose, for instance, that a tone rich in harmonics is fed through a lowpass filter. If a control voltage which starts high and decreases gradually is applied to a control input of the filter, the cutoff frequency is swept down so that first the high harmonics of the tone are attenuated, then the lower ones are attenuated as well. The aural effect is that of a plucked string. If, however, the control voltage rises instead of falls, then the harmonics become audible gradually, starting with the lowest. This produces a convincing trombone-like attack. Dynamic timbral variations of this type can be used to synthesize virtually all orchestral colors, as well as provide a vast field of experimentation in new timbres.

Other Signal Generators and Modifiers

The voltage-controlled oscillators, amplifiers, and filters described above are the central signal generating and modifying instruments of the Moog Synthesizers. Several other important instruments are also supplied. A white sound source (random voltage generator) is supplied with every system. The random voltage is either used as a signal to be subjected to filtering, or as a control voltage to impart random variations to the voltage-controlled instruments. Non-voltage-controlled signal modifiers in the Moog Synthesizers include fixed filter banks which provide half-octave filtering in up to fourteen bands, a spring-type reverberation device, and a four-channel mixer.

Control Voltage Sources

In addition to oscillators and random voltage generators, control voltages are generated by transient, or envelope generators. Upon receiving a "trigger" voltage, these instruments produce a control voltage which rises to a preset voltage level with a certain "rise time," then immediately decays with an "initial decay time" to a "sustain level" voltage. When the trigger voltage is removed, the generated control voltage falls to zero with a "final decay time." All three times are continuously variable over the range of 5 milliseconds to 10 seconds (a 2000 : 1 ratio) and the sustain level is continuously variable from 0 to the maximum voltage. With these non-recurring control voltage contours, a wide variety of pitch, amplitude, and timbral inflections can be produced — inflections which invariably impart high aural interest to the sound material.

Manual control voltage generators include a keyboard controller for discrete control voltage selection, and a linear controller for continuous manual control voltage variation. The keyboard controller incorporates a conventional 5-octave organ keyboard to select one of 61 equally spaced voltages. The spacing between the voltages can be adjusted, so that the composer is by no means confined to the 12-tone chromatic scale. Two unique features greatly enhance the utility of the keyboard controller: a "memory" circuit effectively holds the control voltage of the last key to be depressed, thus eliminating spurious end-of-note transients, and a variable "portamento" control allows the composer to glide from one fixed voltage (pitch) to another, and thus produce continuous control voltage variations on the keyboard. In addition to producing a control voltage, the keyboard controller produces a trigger voltage which initiates one or more envelope generators whenever any key is depressed, thus synchronizing non-recurring variations, such as the onset of one envelope, with the depressing of a key.

The linear controller incorporates a taut metal band. The position of the composer's finger along this band determines the magnitude of the control voltage it produces. Virtually any control voltage contour can be produced, with discrete jumps as well as continuous glides, and virtually any sound parameter can be made a direct function of hand position.

The Synthesizer Concept

The Moog Synthesizers are designed to meet the requirements of composers of all types of electronic music. The most general and important requirements, based on discussions with over 100 composers, are:

1. The Synthesizer should perform all of the basic generating and modifying operations of the classical studio, and provide additional resources consistent with the state of the art.
2. The design should contain no unnecessary inherent limitations.

3. The operation of the Synthesizer should be straightforward and easy for a musician to understand, and should not require extensive technical knowledge.
4. Features which speed up the composition process and give the composer direct control should be stressed.
5. The instruments should be stable and precisely calibrated for repeatability and ease in working with a score.
6. The complete Synthesizer should be as lightweight and portable as possible, and should present an esthetically pleasing appearance.
7. Reliability should be achieved through the use of conservative design, quality components, and rugged construction techniques.
8. By using suitable control devices, the Synthesizer should be readily adaptable to both live performance and programmed control.

All of the instruments comprising the Moog Synthesizers are designed for as general application as possible. Thus, for example, one type of oscillator produces a whole spectrum of musically useful waveforms, and over a frequency range appropriate to control and timing as well as to signal generation. Another example is that one type of voltage-controlled amplifier performs all the dynamic amplitude-varying functions in the system. Signal and control voltage levels are adjusted so that, wherever possible, logical interconnections of instruments may be set up with a minimum of patch cords, and without level adjustments. Standard two-circuit phone plugs are used for both signal and control voltage interconnections. Many voltages serve as either signal or control voltages, a feature made possible by the careful design and wide range of the modular instruments.

The Moog Synthesizers are completely compatible with standard professional audio equipment, and can be installed in an existing studio with no modification. However, an extensive studio is not necessary; only two or three tape recorders and a monitor amplifier and speakers are actually necessary, in addition to a Moog Synthesizer, to form a working composition studio. The compatibility of Moog Synthesizers with conventional audio equipment facilitates the processing of external signals (natural sounds, for instance) by the Synthesizer. Such processing can be used as part of a live performance, as can any other Synthesizer function.

All modular instruments are 8-3/4" high and integral units of 2-1/8" wide, and are mounted in one or two console cabinets. The proportions of the console, as well as the arrangement of the modular instruments, are set to provide convenient and logical interconnections of the most frequently used signal and control paths. All power supply wiring is carried through rugged cabling within the console cabinet. One precisely regulated power supply powers the entire Synthesizer.

All circuitry is solid state, with high quality components for low distortion and noise, and with high stability. Any instrument may be removed for inspection and servicing in a fraction of a minute with no tools other than a screwdriver.

By utilizing the features outlined thus far, the Moog Synthesizers are able to meet all of the basic requirements of electronic music composers. The partial list below is of institutions and composers who have acquired Moog Synthesizers and related instruments and systems, and who, through their word-of-mouth recommendations, are largely responsible for the current wide acceptance of R.A. Moog electronic music equipment.

<u>Educational Institutions</u>

State University of New York at Albany, Albany, N.Y.
University of British Columbia, Vancouver, B.C.

State University of New York at Buffalo, Buffalo, N.Y.
Catholic University of America, Washington D.C.
Colgate University, Hamilton, N.Y.
Columbia-Princeton Electronic Music Center, New York, N.Y.
University of Illinois, Urbana, Ill.
University of Indiana, Bloomington, Ind.
University of Iowa, Iowa City, Ia.
University of North Carolina, Greensboro, N.C.
North Texas State University, Denton, Tex.
Peabody Conservatory, Baltimore, Md.
University of Pennsylvania, Philadelphia, Pa.
Philadelphia Musical Academy, Philadelphia, Pa.
Simon Fraser University, Burnaby, B.C.
Southern Illinois University, Carbondale, Ill.
Syracuse University, Syracuse, N.Y.
University of Texas, Austin, Tex.
University of Toronto, Toronto, Ont.
Washington University, St. Louis, Mo.
University of Wisconsin, Madison, Wisc.

Independent Composers

Paul Beaver, Los Angeles, Calif.
Max Brand, New York, N.Y.
John Cage, Stony Point, N.Y.
Walter Carlos, New York, N.Y.
Robert Ceely, Boston, Mass.
Herbert Deutsch, Huntington, N.Y.
Emmanuel Ghent, New York, N.Y.
Alwin Nikolais, New York, N.Y.
Richard Robinson, Atlanta, Ga.
Raymond Scott, Farmingdale, N.Y.
Eric Siday, New York, N.Y.
Ralph Swickard, Los Angeles, Calif.
Edward Zajda, Cicero, Ill.

Commercial Producers

Carrol Musical Instrument Service, New York, N.Y.
Frank Harris Productions, Inc., St. Louis, Mo.
Pams Productions, Inc., Dallas, Tex.

Scientific and Technical Organizations

Bell Telephone Laboratories, Murray Hill, N.J.
Kepco, Inc., Flushing, N.Y.
New York Research Group, New York, N.Y.

The Synthesizer I

The Synthesizer I is a signal generating and modifying system of limited complexity, designed to satisfy the requirements of independent composers and to fill the need for inexpensive standardized teaching equipment. It enables the composer to perform the basic signal generating and processing operations conveniently and efficiently. In addition, its modest size and simplicity of operation make it ideal for real time performance.

Complement of the Synthesizer I

The Synthesizer I contains the following instruments:

2 - #901 Voltage-Controlled Oscillators
2 - #902 Voltage-Controlled Amplifiers
1 - #903 White Sound Source
1 - #904-A Voltage-Controlled Lowpass Filter
1 - #905 Reverberation Unit
1 - #907 Fixed Filter Bank
1 - #910 Power Supply
1 - #911 Envelope Generator
1 - #950 Keyboard Controller
1 - #955 Linear Controller

The keyboard and linear controllers are housed in their own cabinets. All of the other instruments are housed in a console cabinet 39-3/4" long, 14" high, and 13" deep. The console cabinet contains all of the instrument interconnections and two console circuit panels that provide patching, attenuating, filtering, and mixing facilities.

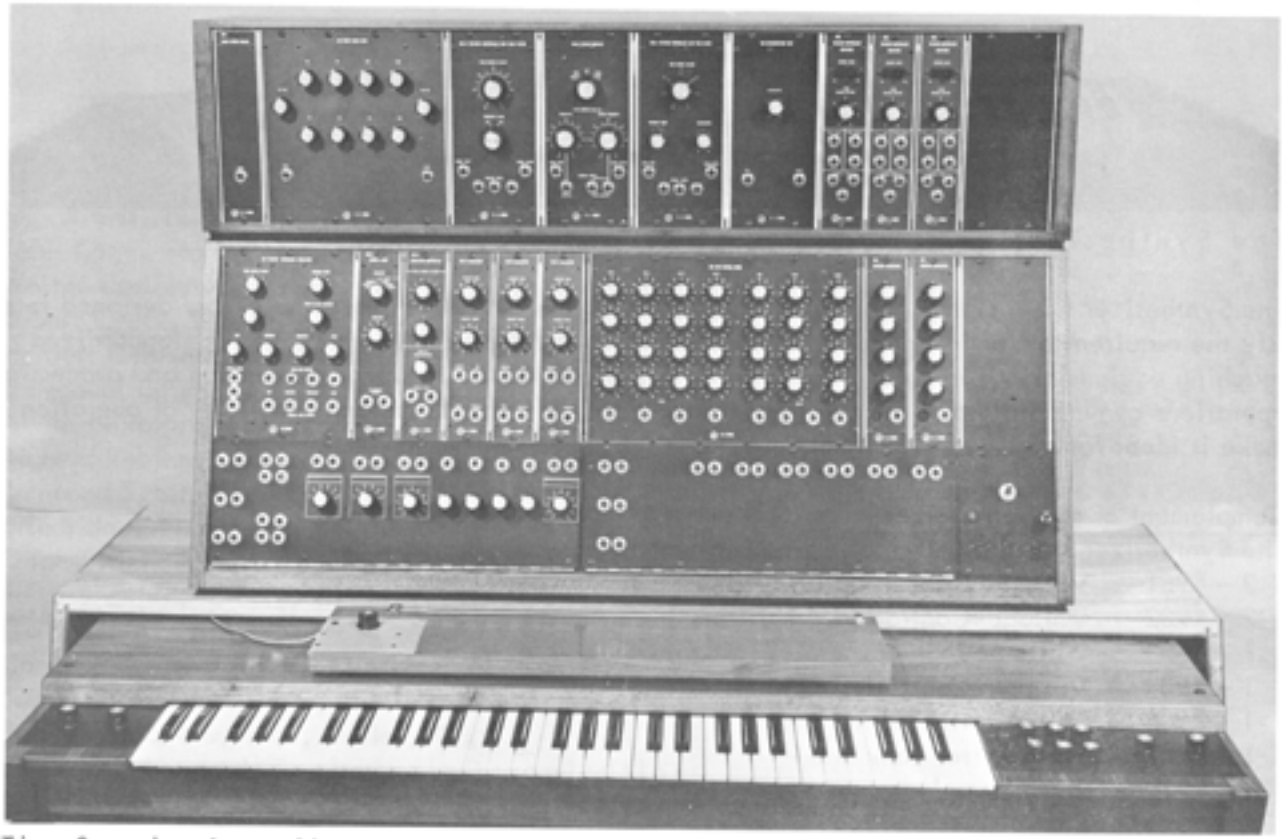
System Capabilities

The following operations, which are most of those basic to electronic music composition, can be

conveniently performed with the Synthesizer I:

1. Generation of constant frequency signals with sine, triangular, sawtooth, and pulse waveforms.
2. White sound generation.
3. Dynamic variation of frequency, amplitude, and formant through the application of repetitive, transient, or random control voltages.
4. Half-octave filtering of any signal.
5. Reverberation.
6. Discrete or continuous manual control of frequency, amplitude, and formant.

The Synthesizer I, in combination with two or more tape recorders and one or more monitor amplifiers, comprises a complete basic composition studio. It is particularly suitable for use in the teaching of electronic music composition, and is also appropriate for use as a starting point in establishing an extensive electronic composition studio. Additional 900 Series instruments can be added at any time, to expand the flexibility of the system or to meet specific compositional requirements.



The Synthesizer II

The Synthesizer II is a signal generating and modifying system of moderate complexity. It offers all of the facilities of the Synthesizer I and additional facilities for spectrum synthesis, formant control, and envelope generation.

Complement of the Synthesizer II

The Synthesizer II contains the following instruments:

1 - #901 Voltage-Controlled Oscillator
1 - #901-A Oscillator Controller

3 - #901-B Oscillators
1 - #901-C Output Stage
3 - #902 Voltage-Controlled Amplifiers
1 - #903 White Sound Source
1 - #904 Voltage-Controlled Filter
1 - #905 Reverberation Unit
1 - #907 Fixed Filter Bank
1 - #910 Power Supply
2 - #911 Envelope Generators
1 - #950 Keyboard Controller
2 - #955 Linear Controllers
1 - #984 Four-Channel Mixer

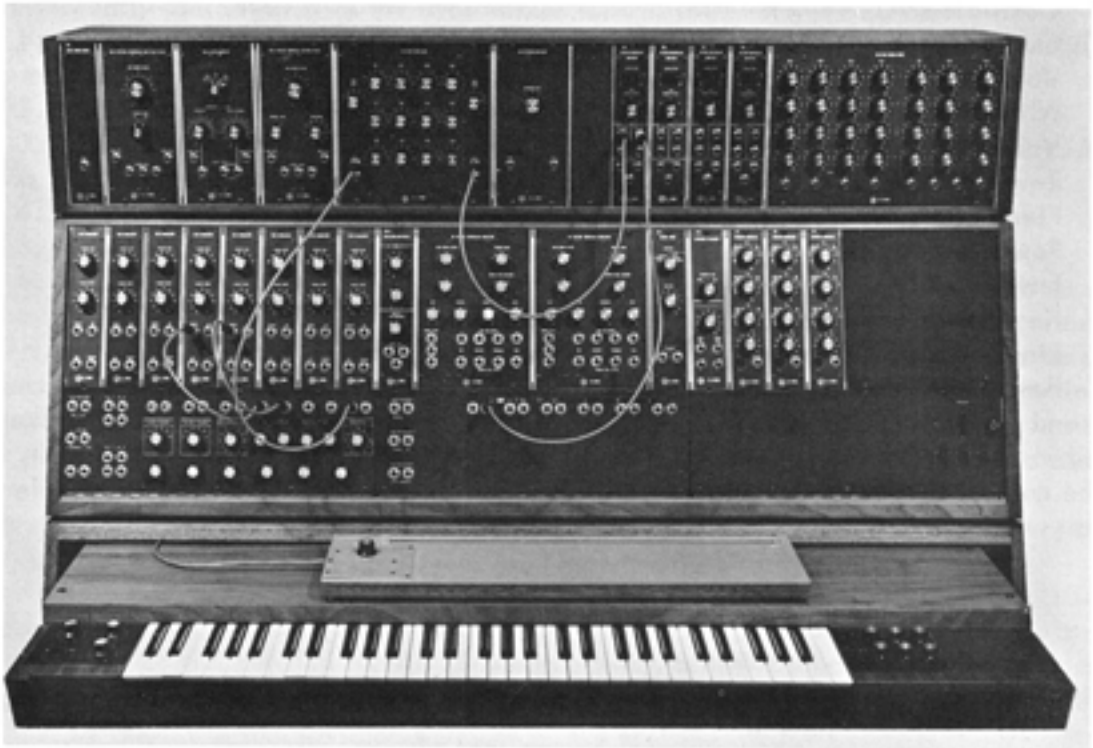
The keyboard and linear controllers are housed in their own cabinets. All of the other instruments are housed in two console cabinets, the total dimensions of which are 39-3/4" long, 24" high, and 13" deep. The console cabinet contains all of the instrument interconnections and two console circuit panels that provide patching, attenuating, filtering, and mixing facilities.

System Capabilities

Most of the basic operations of electronic music composition, as well as many sophisticated procedures, can be conveniently performed with the Synthesizer II. These include:

1. Generation of up to four constant frequency signals with sine, triangular, sawtooth, and pulse waveforms.
2. White sound generation.
3. Dynamic variation of frequency, amplitude, and formant through the application of repetitive, transient, or random control voltages.
4. Half-octave filtering of any signal.
5. Reverberation.
6. Generation of a widely variable transient control voltage.
7. Discrete or continous manual control of frequency, amplitude, and formant; control of up to four oscillator tones simultaneously with one controller.

The Synthesizer II, in combination with two or more tape recorders and one or more monitor amplifiers, comprises a complete basic composition studio, and offers some additional facilities that are usually associated with the larger institutional studios. It is appropriate for use in an extensive course in composition techniques, or as a generating and processing facility in independent or moderate-size institutional studios. Additional 900 Series instruments can be added at any time, to expand the flexibility of the system or to meet specific compositional requirements.



The Synthesizer III

The Synthesizer III is a signal generating and modifying system of considerable complexity and great flexibility. A full range of advanced as well as basic techniques is available to the composer. The component instruments are logically designed and placed to enable the composer to work in an efficient and convenient way. Yet, the system offers a range of facilities usually associated with large institutional studios.

Complement of the Synthesizer III

The Synthesizer III contains the following instruments:

2 -	#901	Voltage-Controlled Oscillators
1 -	#901-A	Oscillator Controller
8 -	#901-B	Oscillators
1 -	#901-C	Output Stage
4 -	#902	Voltage-Controlled Amplifiers
1 -	#903	White Sound Source
1 -	#904	Voltage-Controlled Filter
1 -	#905	Reverberation Unit
1 -	#910	Power Supply
3 -	#911	Envelope Generators
1 -	#912	Envelope Follower
1 -	#914	Extended Range Fixed Filter Bank
1 -	#950	Keyboard Controller
2 -	#955	Linear Controllers
1 -	#984	Four-Channel Mixer

The keyboard and linear controllers are housed in their own cabinets. All of the other instruments are housed in two console cabinets, the total dimensions of which are 52-1/2" long, 24" high, and

13" deep. The console cabinet contains all of the instrument interconnections and three console circuit panels that provide patching, attenuating, filtering, and mixing facilities. One of these panels houses an eight-channel mixer for the eight oscillators.

System Capabilities

The Synthesizer III offers the great flexibility and versatility of operation that is required in the investigation of and experimentation with new compositional techniques. The following operations can be conveniently performed with the Synthesizer III:

1. Generation of up to ten simultaneous constant frequency signals with sine, triangular, sawtooth, and pulse waveforms.
2. White sound generation.
3. Complex dynamic variation of frequency, amplitude, and formant through the combined application of repetitive, transient, and random control voltages.
4. Extended range half-octave filtering of any signal.
5. Reverberation.
6. Generation of three simultaneous, widely variable transient control voltages.
7. Discrete or continuous manual control of frequency, amplitude, and formant; control of up to ten oscillator tones simultaneously with one controller.
8. Deriving the envelopes of natural sounds and imparting them to generated sounds, and the synchronizing of electronically generated envelopes with existing tracks.

Many Synthesizer III's and similar systems have been installed as the basic signal generating and processing facilities in large institutional and private composition studios. The Synthesizer III is completely compatible with standard professional quality audio equipment and represents the current state of the art in electronic music composition equipment.

SINGLE-FUNCTION INSTRUMENTS — CONDENSED SPECIFICATIONS

All instruments listed below are standard design and in regular production. In general, each instrument is designed to perform a single generating or modifying function. Standard control voltage and signal voltage levels assure compatibility among the instruments and with standard professional audio equipment. Unless otherwise noted, the 900 Series instruments require an external regulated power supply of +12 volts and -6 volts. The 901 and 901-B oscillators require an additional voltage of -9 to -12 volts, unregulated. All other instruments are powered directly from the 110-125 volt 60 Hz AC line. (220 volt AC operation can be provided on special order.)

All 900 Series instruments, except manual controllers, have front panels 8-3/4" high and integral multiples of 2-1/8" wide, and require a suitable mounting enclosure with a front opening of 8" high and at least 7" deep. Except where noted, signal output levels are -3 db (0.5 volts RMS) and output impedances are 600 ohms. Signal input levels are also -3 db 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. Detailed specifications and application information for all instruments are available upon request.

901 Voltage-Controlled Oscillator

Provides sine, triangular, variable width pulse, and sawtooth waveforms simultaneously over the frequency range 0.03-15,000 Hz. Three control inputs are provided for precise, rapid frequency variations over a ten-octave range by external control voltage. Relationship between the control voltage sum and the frequency is exponential, accurate to within 1/2 semitone over a six-octave range. Panel features include coarse and fine fixed control-voltage controls, a six-position frequency range switch, a pulse width control, and four waveform attenuators. Panel width is 6-3/8".

901-A Oscillator Controller

Used to control the frequencies of two or more 901-B oscillators (see below) so that the ratio between the frequencies of the controlled oscillators remains constant. Like the 901, the 901-A has three control inputs, two fixed control-voltage controls, and a pulse width control. The relationship between the control voltage sum and the frequency of the controlled oscillators is exponential, accurate to within 1/2 semitone over a six-octave range. Panel width is 2-1/8".

901-B Oscillator

Provides sine, triangular, variable-width pulse, and sawtooth of fixed level simultaneously over the frequency range .03-15,000 Hz. Two or more of these can be ganged, and their frequencies controlled from a single 901-A controller. The accuracy of tracking of two or more oscillators is typically 1/4 semitone over a six-octave range. Complex spectra and note mixtures can be produced, and can be shifted over wide frequency ranges. Panel features include a frequency range switch, a frequency vernier control, and an output jack for each waveform. Panel width is 2-1/8".

901-C Output Stage

In conjunction with a 901 or 901-B oscillator, this instrument produces two outputs of equal

magnitude but opposite sign, from any of the oscillator waveforms. The outputs are variable level and are used as control voltages. Maximum peak-to-peak output voltage is 5 volts. Front panel controls include a waveform selector switch, output level control, and two output jacks. Panel width is 2-1/8".

901-D Variable Waveform Output Stage

Four independent inputs (from any sources) are mixed. The composite waveform is then subjected to clipping to reshape the waveform. The levels and degrees of clipping are variable. Complementary outputs are provided. Front panel controls include four input attenuators, top and bottom clipping level and degree, and output level. The resultant output may be used as a control voltage, or as a processed audio signal with controlled distortion. Panel width is 6-3/8".

902 Voltage-Controlled Amplifier

A universal "variable-gain black box" with balanced, direct-coupled inputs and outputs. Maximum gain is +6 db. Either linear or exponential control modes are available. The linear mode is accurate to ± 1% over a 40 db gain range. The exponential relationship is accurate to ± 2 db over an 80 db range. At maximum gain, signal-to-noise ratio is greater than 70 db and distortion is less than 2%. In conjunction with control voltage sources such as Models 901, 911, 912, or 955, this instrument will perform virtually any amplitude-varying function. Panel features include a control mode switch, a fixed control-voltage control, two signal inputs, two signal outputs, and three control inputs. Panel width is 2-1/8".

903 White Sound Source

Generates white noise over a 1-20,000 Hz bandwidth. One output jack and no panel controls.

904 Voltage-Controlled Filter

Patented circuits provide voltage-controlled filtering over a ten-octave range. Highpass, lowpass, and resonant modes are available. The highpass and lowpass modes may be combined for broad bandpass or bandreject functions. See the three listings that follow for detailed descriptions of the three sections. Total panel width is 12-3/4".

904-A Voltage-Controlled Lowpass Filter

This is the lowpass section of the 904. Frequencies up to the cutoff frequency are passed without attenuation; above the cutoff frequency, the attenuation increases 24 db/octave. The cutoff frequency is accurately voltage-controllable over a ten-octave range. The control mode is exponential: a one volt increase in the control voltage doubles the cutoff frequency. A regeneration control introduces a resonance at the cutoff frequency, thereby changing the filtering mode from lowpass to resonant. Front panel features include a fixed control-voltage control, a three-position frequency range switch, a regeneration control, one signal input, three control inputs, and one signal output. Panel width is 4-1/4".

904-B Highpass Filter

This is the highpass section of the 904. It performs the inverse function of the 904-A, but

otherwise has the same control and frequency range characteristics. No resonant mode is provided. Panel features include a fixed control-voltage control, a two-position range switch, one signal input, three control inputs, and one signal output. Panel width is 4-1/4".

904-C Filter Coupler

This is the coupler section of the 904. Both signal and control functions are coupled. In the bandpass mode, the signal paths of the two filter sections are placed in series; in the bandreject mode, they are placed in parallel. Two control voltage inputs are provided. The center frequency control inputs move the cutoff frequencies of the filter sections together so that their ratio remains constant, while the bandwidth control input changes the ratio between the cutoff frequencies. Front panel features include a function switch, bandwidth and center frequency fixed control-voltage controls, a signal input, a signal output, one bandwidth control input and two center frequency control inputs. Panel width is 4-1/4".

905 Reverberation Unit

Provides mechanical-acoustic reverberation through a spring-type reverberation unit. Reverberation time is 1.7 seconds. Provision is made for mixing the reverberated and unreverberated signals with one panel control. One signal input and one output are provided. Panel width is 4-1/4".

907 Fixed Filter Bank

Contains ten independent fixed-frequency filter sections: one lowpass section with a cutoff frequency of 210 Hz, eight half-octave bandpass sections with center frequencies at 250, 350, 500, 700, 1000, 1400, 2000, and 2800 Hz, and one highpass section with a cutoff frequency of 3360 Hz. The cutoff slopes of all sections approach 24 db/octave. Signal levels from each section are individually controllable by panel controls. One signal input and one signal output are provided. Panel width is 8-1/2".

910 Power Supply

Provides -6 and +12 volts regulated DC at 1.5 amperes. Line and load regulations are both 0.1%. A -10 volt unregulated bias is also provided. Front panel features include an on-off switch, fuse holder, pilot light, and three power output sockets. This supply is available either on a standard module (panel width is 6-3/8") or mounted on a 19" x 5-1/4" standard relay rack panel. Normal line input voltage is 117 volts 60 Hz AC. 220 volts, 50 Hz operation is also available.

911 Envelope Generator

Generates the control voltage required for producing transient variations in amplitude, timbre, and pitch. Attack time, initial decay time, and final decay time are continuously and independently adjustable over the range of 5 milliseconds to 10 seconds. External triggering may be achieved by Models 912, 950, or an external switch. Front panel controls for the three time constants and the sustaining level, a trigger input socket, and a control output jack are provided. Panel width is 2-1/8".

912 Envelope Follower

In conjunction with a voltage-controlled amplifier, this instrument produces an envelope which is

a replica of the envelope of an applied "command" signal. Replication of the command envelope is accurate to ± 3 db over a 40 db dynamic range. A trigger output, capable of initiating an envelope generator in synchronism with the command signal, is also produced. Panel features include a response time switch, a threshold control for determining at what level the trigger is initiated, a command signal input jack, a control output jack, and a trigger output jack.

914 Extended Range Fixed Filter Bank

This is an augmented version of the 907 fixed filter bank. The lowpass section cuts off at 105 Hz. Two half-octave sections at 125 and 175 Hz and two at 4000 and 5600 Hz are provided in addition to the eight half-octave sections of Model 907. The highpass section cuts off at 6720 Hz. Fourteen panel controls determine the signal levels of the filter sections. Two paralleled signal inputs and two paralleled signal outputs are provided. Panel width is 8-1/2".

950 Keyboard Controller

This manual controller uses a conventional five-octave organ keyboard. Discrete, equally spaced values of control voltage are selected by depressing the appropriate key. The difference between control voltage values is 1/12 volt, and is adjustable over a ± 10% range. A "memory" circuit holds the control voltage corresponding to the last key to be depressed. A portamento circuit introduces a time lag between the depressing of a key and the control voltage change, thereby making it possible for the control voltage to "glide" from one value to another. In addition to the control voltage, the keyboard produces a trigger which initiates the cycle of any number of 911 envelope generators. The keyboard is housed in its own attractive hardwood enclosure, 40" long, 15" deep, and 4" high. Controls for adjustment of the voltage difference between keys, for degree of portamento, and for the memory circuit are placed at the left cheek of the keyboard.

955 Linear Controller

In this controller, a taut metal band is strung over a resistance ribbon. The composer moves his finger along the band to change the point of contact between it and the ribbon. The control voltage output is precisely related and directly proportional to the position of the point of contact. Control voltage variations as large as six volts, discrete as well as continuous, can be produced by hand motion. The controller is 24" x 6" x 1" and has one control for determining the maximum voltage variation.

984 Four-Channel Mixer

Four inputs may be cross-coupled to any of four output channels in any proportion, by a matrix of sixteen input attenuators. Each of the four output channels has bass and treble controls which attentuate or boost both the low and high frequencies. Finally, there is an output level control for each of the four channels. Panel width is 12-3/4".

RM-1 Eight-Unit Rack Mount

This is a mounting frame 19" x 10-1/2" for holding 900 Series modular instruments whose total panel width is 17" or less. All power supply wiring is provided. The frame, with the instruments mounted in it, may be free-standing or placed in a standard relay rack.

1500 Series Tape Recorders

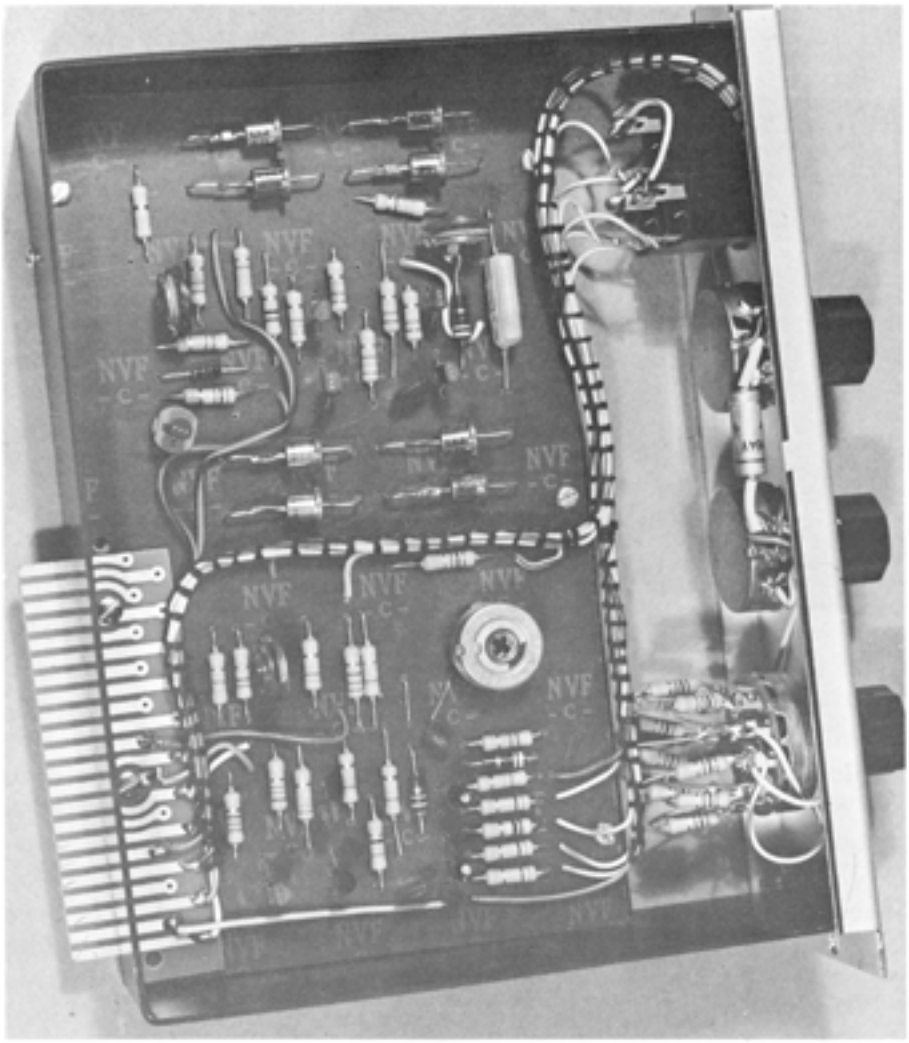
This line of equipment provides special features useful in electronic music composition, at prices well below standard professional audio recorders. The VIKING 230 solenoid-controlled tape deck is used in conjunction with specially-designed electronic circuitry. The deck specifications are:

Tape speeds:	7-1/2 and 15 ips
Flutter:	0.2% at 7-1/2 ips; 0.15% at 15 ips
Reel Size:	7"
Timing Accuracy:	0.2%
Capstan Motor:	Hysteresis Synchronous

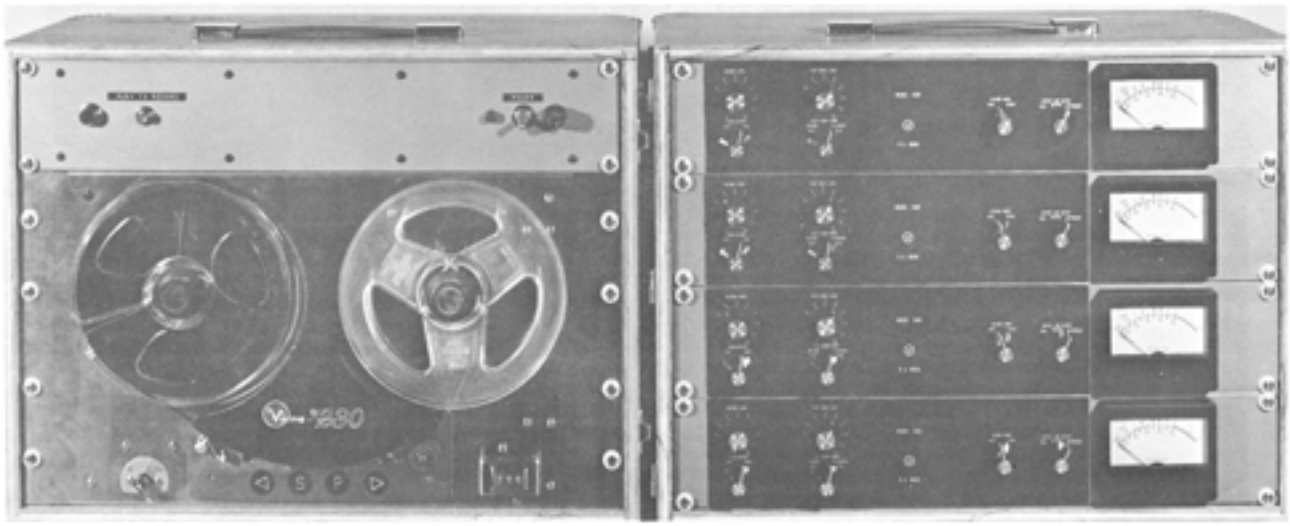
The record-playback specifications depend upon the tape speed and type of heads that are used. For instance, the Model 1502 uses half-track stereo erase, record, and playback heads. Signal-to-noise ratio is 55 db and frequency response is ± 2 db from 50 Hz to 18 KHz at a tape speed of 15 ips. Interchannel crosstalk is 55 db. The Model 1504 uses four-channel, in-line quarter-track record and playback heads. Signal-to-noise ratio is 54 db and frequency response is ± 3 db from 50 Hz to 18 KHz at a tape speed of 15 ips. Adjacent channel crosstalk is 50 db. The electronic circuitry is arranged for maximum flexibility. Each channel is completely independent and is mounted on a separate chassis. Any channel may be recorded while others are being played back. Playing back from the record head (commonly known as Sel-Sync) may be done on any channel for exact synchronization with already-recorded material. 1500 Series recorders are available in either console or portable cases. The console cabinet is 20-1/2" wide, 20-1/2" deep, and 28-1/2" high, and is designed to rest on a table of 27"-29" height. The portable cases are 20" x 15" x 10" each. A variety of head configurations and deck options are available. Further information will be supplied upon request.

1900 Power Oscillator-Amplifier

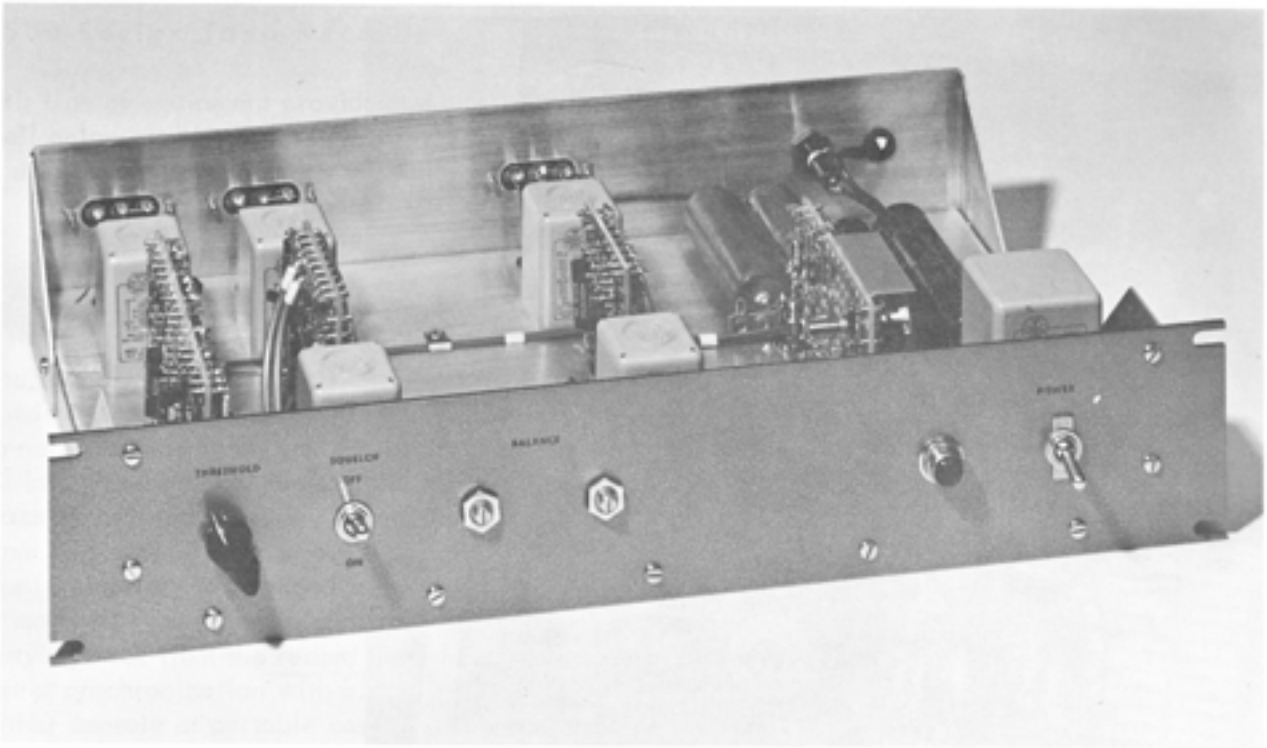
This instrument supplies variable-frequency power for driving tape recorder capstan motors. Converts any tape recorder with a synchronous capstan motor to variable speed operation. Output rating is 150 volt-amperes. Frequency range of the internal oscillator is 30-120 Hz, and is stable within 0.2% over an eight hour period. Any external oscillator may also be used as the frequency source. The panel is a standard 19" x 7" relay rack panel.



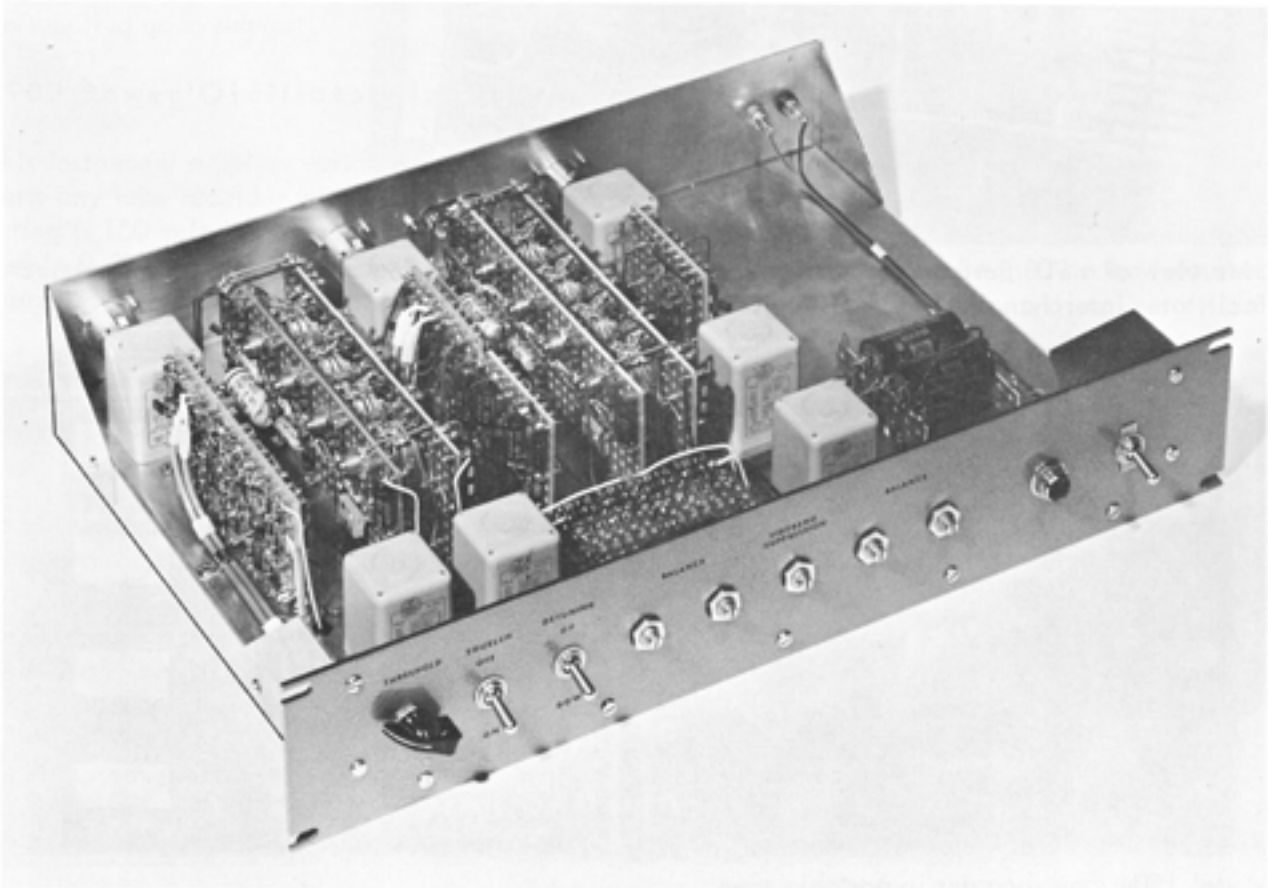
Side view of a 900 Series modular instrument. Modular construction and plug-in power connector facilitates interchanging and servicing.



Model 1504 tape recorder in portable case.



Model 6401 Bode ring modulator.



Model 6552 Bode frequency shifter.

THE BODE RING MODULATORS AND FREQUENCY SHIFTERS

Ring modulators and frequency shifters designed and built by Harald Bode have been widely used by several important studios. These versatile signal modifiers are as valuable in processing natural sounds as in transforming electronically generated material. The ring modulator is a signal modifier with two inputs and one output. The output signal contains frequencies that are the sum and difference of the frequencies fed into the two inputs. The program input uses a squelch circuit that automatically turns off the other, or carrier, input. This squelching function results in an extremely "clean" output signal, with no audible leakthrough. The frequency shifter (sometimes called a Klangumwandler) also has two inputs and one output. The output contains all of the frequency components of the program input, shifted in frequency by an amount equal to the frequency of the carrier input. Both instruments are fully solid-state, and conservatively designed for quiet, trouble-free operation. They conform to professional audio equipment standards and may either be installed as part of a conventional studio, or used in conjunction with a Moog Synthesizer or other integrated system. The R.A. Moog Co. manufactures the Bode instruments using Mr. Bode's design and technical advice.

6401 Bode Ring Modulator

The output of this device is composed of the sum and difference frequencies of the two input signals. Unwanted sidebands are better than 30 db below the desired signal output. Carrier suppression without squelch is better than 45 db; with the squelch circuit on, the carrier suppression is better than 75 db. Hum and noise are better than 60 db below maximum output level. Both inputs are high impedance. The output impedance is 600 ohms, and is floating. A signal level of one volt at each of the inputs results in a one-volt output. The frequency response of the instrument as a whole is $\pm$ 2 db from 30 Hz to 20,000 Hz. The front panel is 19" x 3-1/2", standard relay rack mounting. Front panel features include a squelch threshold control, a squelch on-off switch, two screwdriver balancing adjustments, a power switch, and a pilot light. The entire instrument is self-contained with a built-in power supply for 110 volts AC. All audio connections are made at screw-type terminal strips at the rear of the instrument.

6402 Bode Dual Ring Modulator

This is a dual channel version of the Model 6401, with completely separate channels, each with two signal inputs and one output. Aside from the duplication of circuitry, the Model 6402 has the same features and specifications as the Model 6401.

6552 Bode Frequency Shifter (Klangumwandler)

The output of this instrument contains the frequencies of the program input, shifted by an amount equal to the frequency of the carrier input. The non-harmonic partials present at the output are 20 db or more below the desired signal level, and the rejection of the carrier and the unwanted sideband is better than 40 db. The carrier frequency range is 40-10,000 Hz. Both inputs are high impedance. The output impedance is 600 ohms, and is floating. A signal level of one volt at each of the inputs results in a one-volt output. All audio connections are made at the rear of the instrument by screw-type terminal strips. The front panel is 19" x 3-1/2", standard relay rack mounting. Front panel features include a switch for either subtracting or adding the carrier frequency to the program spectrum, five screwdriver adjustments, a squelch threshold control, a squelch switch, a power switch, and a pilot light. An auxiliary power supply of 20 volts at 200 ma is required, and can be supplied on a separate chassis.

SPECIAL INSTRUMENTS AND SYSTEMS

In addition to standard Synthesizers and single-function instruments, the R.A. Moog Co. designs and manufactures special instruments to meet specific requirements. The list below is only a partial catalog of instruments which have already been made to specification, and serves as an indication of the range of our capabilities. Your inquiry regarding any special instrument or system will be answered promptly and thoroughly.

Special systems assembled from standard instruments: Many special systems, designed to meet specific requirements, have been assembled from standard Moog modular instruments. This includes live performance instruments with switchable interconnections that eliminate the need for patch cords.

Specially designed manual controllers: Touch-sensitive keyboard and linear controllers, hand-capacitance Theremin-type antennas, and multi-function foot pedals are some of the control devices that can augment the capabilities of any of the Moog Synthesizers.

Programming devices: Eight- and sixteen-channel sequencers, each channel producing three control voltages and one trigger voltage, have been built. A digital-to-analog interface for use with conventional paper tape readers has also been designed and built.

Special performance equipment: A complete system of sensitive, position-sensing antennas and related control equipment was designed and built for John Cage's "Variations V". A system for synchronizing performers during the playing of rhythmically complex music, through aural timing pulses encoded on magnetic tape, was designed and built for composer Emmanuel Ghent.

Polyphonic composing and performance instruments: A microtonal polyphonic performance instrument was designed and built for the New York Research Group. This instrument has thirty-one independent oscillators per octave, seven octaves, and a special two-dimensional keyboard with 479 keys. Another microtonal polyphonic performance instrument with a touch-sensitive keyboard with 137 keys, is being built for jazz performer Gary David.

Live signal processing systems: Systems especially for the processing of instrumental and voice sounds during performance have been designed and built. Capabilities of these systems include filtering, envelope reshaping, production of octaves, frequency modulation, and amplitude modulation.

Systems for experimental and scientific applications: Because of the high accuracy and wide range of standard Moog modular instruments, they can be used to good advantage in scientific instrumentation. Virtually all classes of function generation and audio signal processing can be performed by Moog equipment.

Design and installation of complete studios: We have designed and installed six complete composition studios to date, and have advised and worked on many more.

Mixers and mixing consoles: Mixers meeting the requirements of electronic music composers have been designed and built. Some include features such as voltage control and photocell switching.

PRICE LIST AND TERMS OF PURCHASE

Single Function Instruments

#901	Voltage-Controlled Oscillator	$ 275
#901-A	Oscillator Controller	$ 120
#901-B	Oscillator	$ 170
#901-C	Output Stage	$ 65
#901-D	Variable Waveform Output Stage	$ 125
#902	Voltage-Controlled Amplifier	$ 140
#903	White Sound Source	$ 80
#904	Voltage-Controlled Filter	$ 575
#904-A	Voltage-Controlled Lowpass Filter	$ 250
#904-B	Voltage-Controlled Highpass Filter	$ 250
#904-C	Filter Coupler	$ 100
#905	Reverberation Unit	$ 100
#907	Fixed Filter Bank	$ 360
#910	Power Supply	$ 175
#911	Envelope Generator	$ 115
#912	Envelope Follower	$ 130
#914	Extended Range Fixed Filter Bank	$ 510
#950	Keyboard Controller	$ 580
#955	Linear Controller	$ 145
#984	Four-Channel Mixer	$ 280
RM-1	Eight-Unit Rack Mount for 900 Series Modular Instruments	$ 25
#1502	Two-Channel Tape Recorder	$1050
#1504	Four-Channel Tape Recorder	$1850
#1900	Power Oscillator-Amplifier	$ 385
#6401	Bode Ring Modulator	$ 435
#6402	Bode Dual Ring Modulator	$ 650
#6552	Bode Frequency Shifter	$1400

Synthesizers

Synthesizer I (Formerly called "System A")	$2835
Synthesizer II (Formerly called "System B")	$4345
Synthesizer III (Formerly called "System C")	$6190

Ordering Information

1. Terms of sale of standard Synthesizers and single-function instruments are: 50% with order, and the balance on delivery. Purchases by rated institutions are payable within thirty days from date of invoice. Terms of payment for special instruments and systems will be arranged at the time of sale.

2. All orders will be acknowledged promptly and an estimated delivery date will be given.

3. Unless the customer provides specific shipping instructions, instruments and systems weighing fifty pounds or less will be shipped by parcel post or United Parcel Service. Larger systems will be shipped by truck for distances less than 500 miles, or by Air Express for greater

distances. All shipping costs will be assumed by the purchaser.

4. The R.A. Moog Co. guarantees all of its instruments against defects in materials and workmanship for a period of one year. During this time, instruments believed to be defective may be sent to the R.A. Moog Co. with transportation charges prepaid. The instrument will be serviced and returned, usually within 48 hours, with return transportation charges paid by the R.A. Moog Co. After the one year period, instruments will be serviced at a nominal cost, and the return transportation charges will be paid by the instrument owner.

Field service is available in certain localities. Write for details.

SPECIFICATIONS AND PRICES IN THIS CATALOG ARE SUBJECT TO CHANGE WITHOUT NOTICE.

THE R.A. MOOG CO.

The R.A. Moog Co. was founded in 1954 to engage in the design and manufacture of electronic music instruments and related products. The first standard product was the Theremin, an electronic musical instrument played by the free movement of the performer's hands in the space surrounding it. In 1964, the first voltage-controlled, modular electronic music composition instruments were introduced after several months of intensive collaboration with composer Herbert Deutsch. Further collaboration and consultation led to the development of the present line of equipment. One such occasion for collaboration was a three-week electronic music composition workshop, conducted by the R.A. Moog Co. during the summer of 1965. Twelve composers attended, half of whom now have their own studios and are active in the field. This large-scale collaboration between composers and instrument manufacturer is unique in the history of electronic music instrumentation.

A staff of ten skilled fabricators, assemblers, technicians, and engineers perform virtually all of the design, construction, and testing of the Moog Synthesizers on the premises of the R.A. Moog Co. This direct control over manufacturing is assurance that every Moog Synthesizer is built to the high standards of the R.A. Moog Co. Because of this, the R.A. Moog Co. is able to guarantee its products for one year against defects of material or workmanship. For routine servicing, maintenance instructions are provided, and the service department of the R.A. Moog Co. is prepared to repair instruments within 48 hours after receipt.

Extensive equipment demonstration and consultation is available at the electronic music studio maintained by the R.A. Moog Co. for its educational affiliate, the Independent Electronic Music Center, Inc. Interested composers are invited to write or phone (607-387-6101) for an appointment.

After close to two years experience with a considerable number of the Moog components, we find them extremely valuable and useful components of our electronic music equipment. They complement in function very well both our standard hardware and specialized items of our own design.

Lejaren Hiller, Director, Experimental Music Studio, University of Illinois

The R.A. Moog Co. equipment is in a class by itself. I would not know where to turn without it. Using Moog equipment is the only way an electronic composer can really function without the constant services of an electronic technician.

Arthur B. Hunkins, Director, Electronic Music Studio, The University of North Carolina at Greensboro

The R.A. Moog Co. equipment in our laboratory is of inestimable value. Its flexibility and capabilities delight all who use it. We would not wish to be without it. I recommend it as essential equipment in any electronic music studio or laboratory.

Emerson Meyers, Director, Electronic Music Laboratory, Catholic University of America

The compactness, flexibility, and high quality of electronic engineering of the Moog instruments are admirable. The sound variety and controllability in these instruments, occupying small space and costing relatively little, make them ideal for the composer's private sound studio.

Alwin Nikolais, Director, Alwin Nikolais Dance Company

I find the Moog equipment to be among the best conceived one could possibly imagine. It has the advantage of combining extreme precision, direct manipulation, perfect technical realization, and very useful compactness. It is a model of what I think will be developed as the "instrument of the future."

Henri Pousseur, Slee Professor of Composition, State University of New York at Buffalo

What impresses me most about Moog's equipment and design is its immediacy for the composer. I find I respond to it the way I would to an instrument I want to learn to play.

George Rochberg, Director, Electronic Music Studio, University of Pennsylvania

The instruments designed by R.A. Moog are, to my mind, the only available instruments for electronic composition which equal in subtlety and "presence" the sounds of live instruments. The flexibility and virtually unlimited possibilities of combination and recombination of the various components make these instruments unique in the field of electronic music. Dr. Moog's inventions make possible sounds and techniques of composition that are sure to move electronic music out of the realm of esoterica and into the larger world of the general concert-going public.

Andrew Rudin, Composer, Electronic Music Studio, Philadelphia Musical Academy

Even with my comparatively limited experience with the electronic equipment designed and built by R.A. Moog, I am happy to report that I found it highly responsive to my musical demands, and stimulating — yes, even inspiring — to my musical imagination. It is a fascinating instrument, the total possibilities of which won't be topped for a long time.

Albert Tepper, Acting Chairman, Department of Music, Hofstra University

In my opinion the electronic music equipment designed and built by the R.A. Moog Co. is the best available on the market; not only is the design work both original and practical but the construction is obviously of very high quality.

Raymond Wilding-White, Director, Studio for Experimental Music, Case Institute of Technology

The high quality craftsmanship of Moog electronic music composition instruments lets me concentrate on compositional problems — there are no maintenance headaches.

Edward Zajda, Composer, Chicago

Edward Koren in Saturday Review