Electronic Instruments for the Musician

R-A-MOOG CO-

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MODULAR ELECTRONIC INSTRUMENTS FOR GENERATING AND PROCESSING AUDIO SIGNALS

The instruments to be described are the first group of a system of compatible signal generating and processing modules, designed to perform basic functions required in electronic music composition, and in many other audio signal processing applications. The value of these modules is attributable to this unique combination of the features:

1. Many of the instruments are voltage-controlled. The relation between the magnitude of the controlling voltage and the controlled variable of the instrument (e.g. frequency of the oscillator or gain of the ampifier) is mathematically simple (usually linear or exponential) and accurate within specified narrow limits over a wide range.

2. The input and output levels of the instruments are arranged so that the instruments may be connected in tandem with a minimum of gain or impedance adjustment.

3. The entire system of modules utilizes solid state circuitry and is powered from a common regulated power supply.

4. The panels of all instruments are 9-1/2" wide (one-half the width of a standard 19" relay rack) and integral multiples of 1-7/8" high.

VOLTAGE CONTROL

In much electronic signal processing equipment, the functional variables are determined by passive electronic components. For instance, the frequency of a typical audio test oscillator is determined almost entirely by the value of two resistors and two capacitors. As another example, the gain of a typical amplifier is stabilized by a feedback network consisting primarily of resistors. Such instruments are useful where stability of performance over long periods of time is important. However, in the production of electronic music, and in other application involving the rapid changing of signal variables, instruments whose functions are controlled by the effect of an applied voltage upon the characteristics of non-linear (usually active) components within the instrument, are generally of greater value.

The usefulness of a voltage-controlled instrument is further enhanced if the voltage controls the instrument variable in a simple, predictable way. As an illustration, consider a relaxation oscillator in Figure 1, which consists of a charging capacitor, a discharging element such as a neon bulb or a unijunction transistor, and a source of constant current. The constant current charges the capacitor until the capacitor voltage reaches the breakdown voltage of the discharging element. The discharging element abruptly conducts away a portion of the capacitor charge, then switches off. The process repeats, giving rise to a sawtooth waveform across the capacitor. The frequency of the oscillation is directly proportional to the total charging current. Thus, adding a given current will increase the frequency a fixed amount, regardless of the magnitude of the "standing current" to which the given current is added. Stated more precisely, the frequency is a linear function of total charging current.

In the production of music, however, constant frequency differences are of little value. The fundamental subjective concept of frequency change in music is the INTERVAL, which is a ratio of two frequencies. In order to be musically valuable therefore, a voltage-controlled oscillator should generate a fixed frequency ratio (percentage change in frequency) for a given control voltage change. In mathematical language, what is desired is that the frequency be an exponential function of the control current.

To appreciate the great utility of a voltage-controlled oscillator in which the frequency is exponentially related to the control voltage, consider the circuit arrangement shown in Figure 2. In addition to the relaxation oscillator itself (c), the voltage control consists of (a) a linear adder which produces a voltage proportional to the sum of all the input voltages and (b) an exponential operator that produces a current proportional to the exponential of its input voltage. The oscillator frequency is then proportional to the exponential of the sum of the input (control) voltages.

By using one control voltage input, the above oscillator can be used as a monophonic pitch generator. Taking the control voltage from a series of equally spaced taps on a potentiometer divider, produces an equally tempered scale. This arrangement is shown in Figure 3. To produce vibrato or other periodic variations in frequency, an alternating control voltage is applied to another control input. The width of vibrato (i.e. the ratio of frequency change to center frequency) remains constant as the center frequency (perceived pitch) is varied. The arrangement for producing vibrato is shown in Figure 4. The third control input may be used to transpose a frequency pattern. Thus,

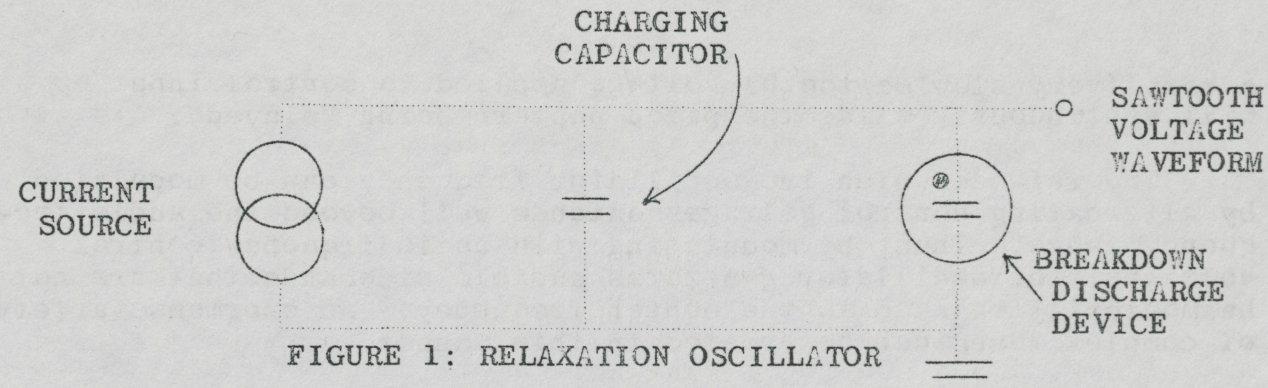

FIGURE 1: RELAXATION OSCILLATOR

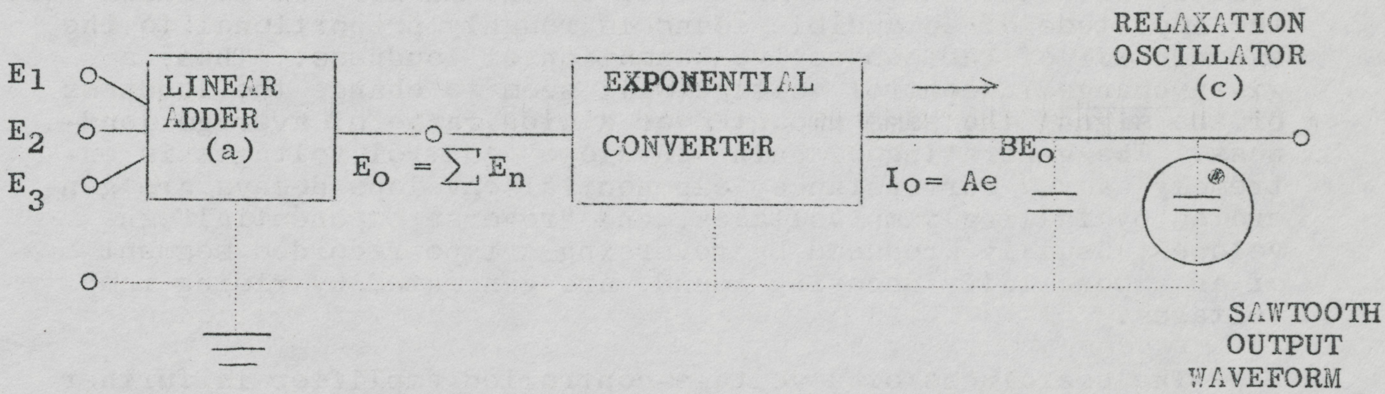

FIGURE 2: ADDITION OF LINEAR ADDER AND EXPONENTIAL CONVERTER

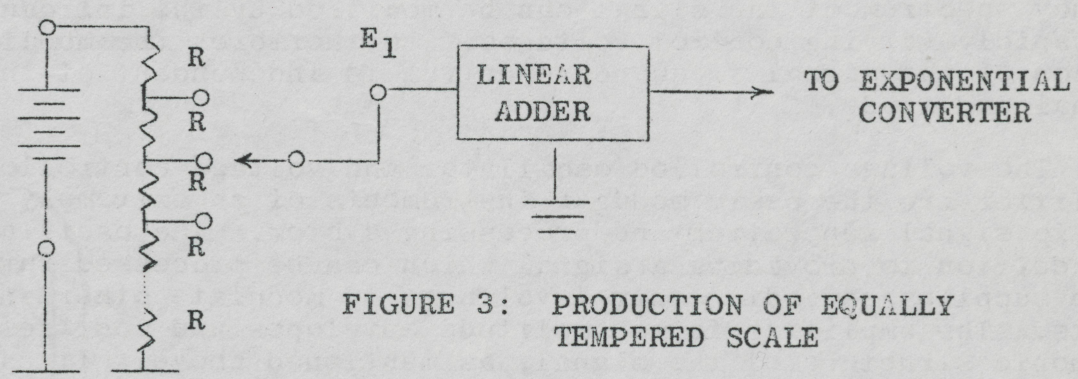

FIGURE 3: PRODUCTION OF EQUALLY TEMPERED SCALE

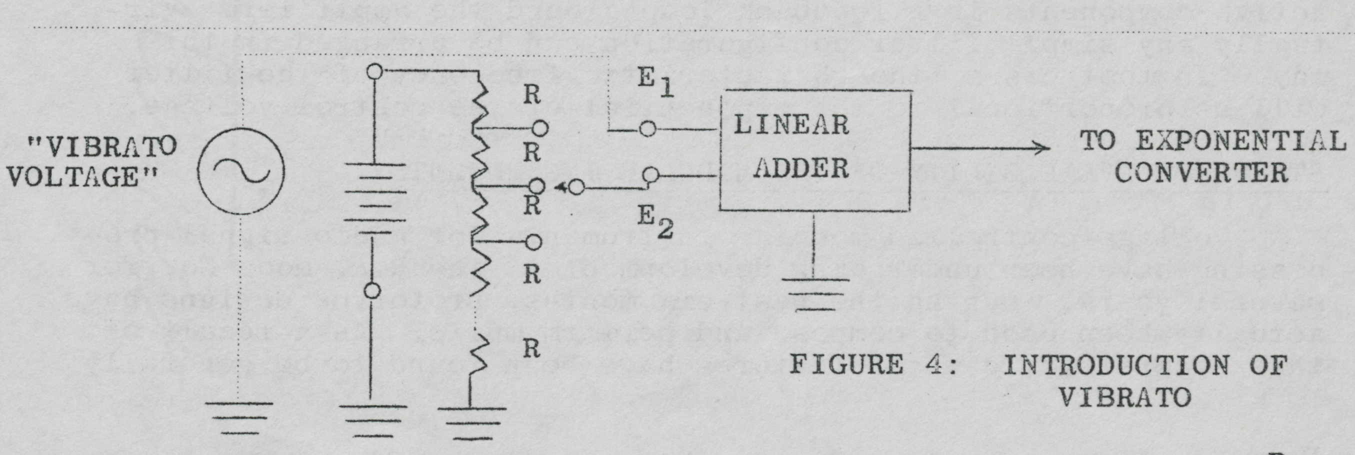

FIGURE 4: INTRODUCTION OF VIBRATO

a ramp (very slow sawtooth) voltage applied to control input #3 will continuously slide the pitch paptern being "played".

The rate at which the occillator frequency can be modulated by alternating control voltages **extends well beyond the audio frequency range**. Thus, by modulating with audio frquency control voltages, the oscillator generates audible sidebands that are not harmonically related to the center frequency. An enormous variety of complex tones can be created in this manner.

A voltage-controlled amplifier in which the gain is proportional to the exponential of the sum of the control voltages is equally valuable in the composition of the music. It is known that the amplitude of an audible sound is roughly proportional to the exponential of the subjective sensation of loudness. Thus, a given change in control voltage will seem to change the loudness of the signal the same amount over a wide range of average loudness. The generating of gain "envelope" control voltages is extremely easy. For instance, exponential envelope decays are generated by falling ramp voltages, and "reverse exponential" envelopes, usually produced by reversing a tape-recorded segment of an exponetially decaying sound, are generated by rising ramp voltages.

The usefulness of a voltage-controlled amplifier is further enhanced by balancing the amplifier so that control voltages variations do not feed through to the output. With this feature, the amplifier can perform as an ideal amplitude-modulator. The frequency spectrum of the signal can be modified by the introduction of rapidly-varying control voltages. Furthermore, the modification of the signal frequency spectrum is independent of the signal amplitude.

The voltage-controlled oscillator and voltage-controlled amplifier are the basic moduaar instruments of an extremely versatile signal generating and processing system. The oscillator, in addition to providing a signal which can be processed further, also supplies periodic control voltages to modulate other instruments. The amplifier forms amplitude envelopes and modifies the harmonic structure of the signal, as mentioned above. It can also be connected as a voltage-controlled filter by placing passive reactive components in a feedback loop around the amplifier. Virtually any simple filter configuration can be arranged in this way. In most cases, the characteristic frequency of the filter will be proportional to the exponential of the control voltage.

STATUS OF AVAILABILITY OF THE MODULAR INSTRUMENTS

Voltage-controlled modular instruments for audio signal processing have been undergoing development at the R.A. Moog Co. for several years. During the past six months, prototype designs have actually been used to compose and perform music. As a result of this experience, certain features have been found to be generally valuable, and have been incorporated in the instruments listed below. These instruments are now in pilot production. In the near future, more modular instruments will be placed in pilot production, and extensive data will be gathered on instruments currently being produced.

In a few months, a comprehensive catalog will be prepared. In the meantime, R.A. Moog Co. invites communications from those who are interested in the generating and processing of audio signals, and who wish to submit suggestions or problems for our consideration.

TENTATIVE SPECIFICATIONS OF CURRENTLY AVAILABLE EQUIPMENT

All instrument panels are 9-1/2" wide and integral multiples of 1-7/8" high. Mounting holes conform to standard relay-rack dimensions. Power supply requirements are +12 volts and -6 volts regulated DC.

MODEL 901 VOLTAGE- CONTROLLED OSCILLATOR

Relation between Control Voltage and Oscillator Frequency: Control voltage increase of 0.75 volts will double Oscillator Frequency.

Frequency range: One of six frequency ranges is selected by a charging capacitor selector switch. The total range, and the range of greatest accuracy are listed below:

Range	Total Frequency Range	Range in which Frequency is proportional to exponential of control voltage to within ± 1%
LO	0 - 50 cps	1-0 cps - 25 cps
32'	0 - 1 KC	15 cps - 500 cps
16'	0 - 2 KC	30 cps - 1 KC
8'	0 - .4 KC	60 cps - 2 KC
4'	0 - 8 KC	120 cps - 4 KC
2'	0 - 15KC	240 cps - 6KC

Output Waveforms: Sawtooth, sine-like, and rectangular pulse. Width of pulse is variable by a panel control.

Size: Panel size is 9-1/2" X 3-1/2 . Depth in back of panel is 6".

Price: $ 145.00

MODEL 902 VOLTAGE- CONTROLLED AMPLIFIER

Input Impedance:	8,000 ohms
Output Impedance:	6,000 ohms
Maximum Voltage Gain:	100
Range of Voltage Gain:	Greater than 80 db
Gain Range in which gain is proportional to exponential of control voltage to within 1%:	.1 - 100 (60 db)
Signal-Noise ratio at voltage gain of 50 and input voltage of 5mv:	better than 70 db
Maximum signal voltage input:	10 mv
Total harmonic distortion at maximum gain and input voltage of 10 mv:	1.6%
Frequency response:	D.C. - 20 KC

Size: $125.00

MODEL 910 POWER SUPPLY

Output Voltages:	+12 volts and -6 volts
Maximum Oıtput Current:	2 amperes

Regulation: ± .1 % for loads of 0-2 amps and line voltages of 105-130V

Size: Panel size 9-1/2" X 7". Depth behind panel is 6".

Price: $120.00

MODEL 950 FIVE OCTAVE KEYBOARD

Supplies control voltage to an oscillator or bandpass filter for equal temperament tuning. Also generates two independently adjustable envelope control voltages when any key is pressed. Keyboard is housed in hand-finished natural walnut case.

Price: $220.00

MODEL 955 "SLIDE-WIRE" CONTROLLER

Supplies continuously-variable control voltage to any voltage-controlled instrument. Consists of two-foot long gold-plated taut band which is strung over a high-resistance wire. The resistance wire is connected to the power supply, thus forming a long potentiometer. The taut band is pressed down at a point determined by the control voltage desired.

Price: $35.00