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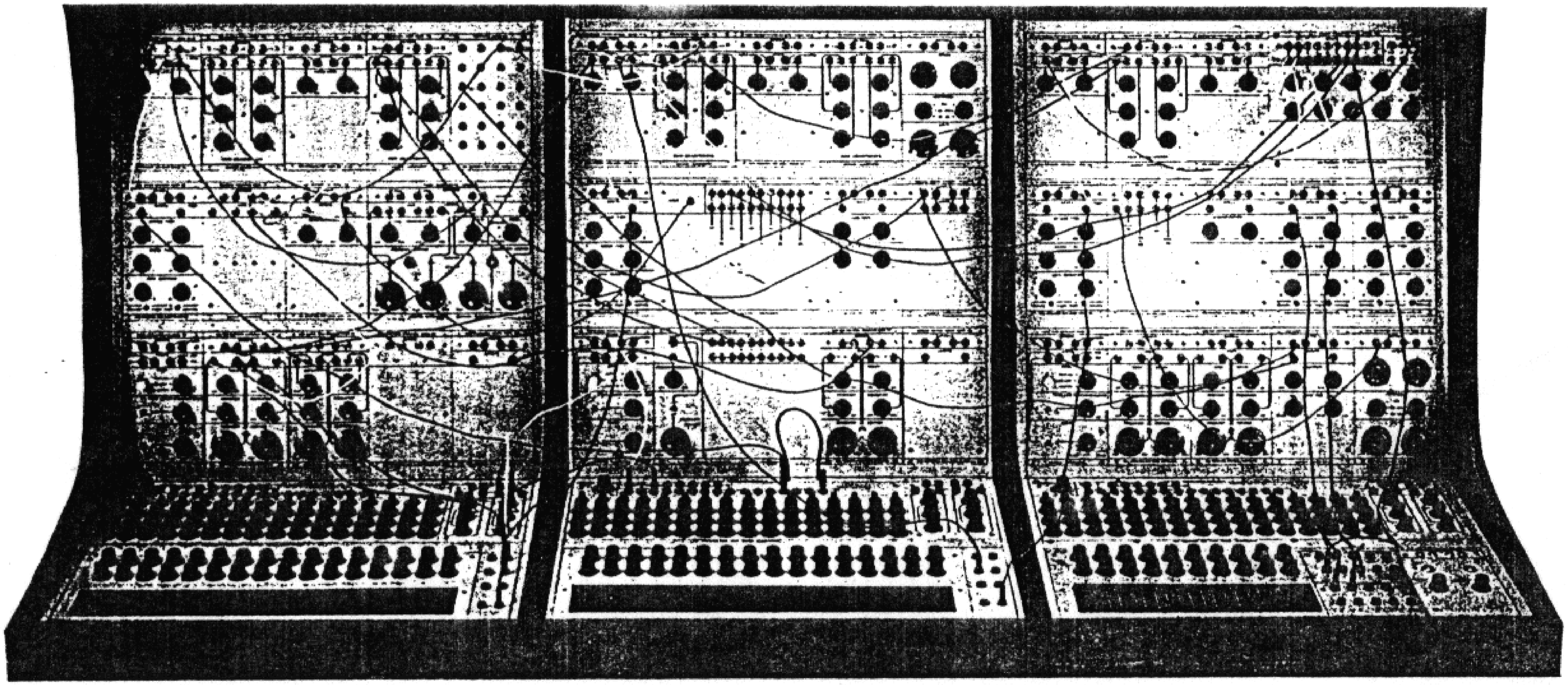
Buchla Electronic Music System Users Manual written for CBS Musical Instruments by Dr. Hubert Howe, Queens College, New York.

Buchla Electronic Music System



USER'S GUIDE TO THE BUCHLA MODULAR ELECTRONIC MUSIC SYSTEM

INTRODUCTION

1. Modules

The first thing you will probably notice about your equipment is that each unit assembled in the cabinet is of the same basic size, 7 inches high and 4 ¼ inches wide or a multiple thereof. These individual units are called **modules,** and they are each designed to perform various specific functions, which are described in detail below. On most modules, there are a number of **jacks** at the top of the unit and various **dials** and switches below. Usually the top row of jacks is for **outputs** and the row underneath for **inputs,** although there are some modules that have no inputs, and some modules have the jacks located at the right end. Most outputs are available at **multiple** jacks, in order that they may be connected to more than one input. When there are dials which determine some aspect of an input at a particular jack, there is a line drawn from the dial to the jack in question. The functions of all jacks, dials and switches are clearly labelled on each module. At the very top of the module is printed its name and model number.

Many **dual** modules are included in the Buchla System. A dual module is actually two independent modules within one panel. Sometimes they are totally independent (such as the Model 165 Dual Random Voltage Source) and sometimes they are capable of being either independent or interconnected (such as the Model 106 Six-Channel Mixer).

2. Signals

After you have examined the individual modules in your cabinet, the next thing that you will probably notice is that there are different kinds of jacks and patch cords for the system. A **patch cord** is a wire with a plug connected at each end, which is used to carry signals from one module to another. Patch cords are of several colors, which are used to distinguish different lengths. The system employs three basic varieties of signals, each with a distinctly different function:

(1) **Audio Signals** are simply **sounds.** They may be **generated** internally by various modules such as oscillators or harmonic generators, or they may come from external sources such as a tape recorder or microphone. Audio signals may be **processed** by further devices in the system, such as filters, frequency shifters, reverberation units, etc. until they are finally taken in some form and passed to a tape recorder or speaker. The final sound which is played or recorded is called the **system output.** (The synthesizer can produce several system outputs at one time.) The patch cords carrying audio signals within the system terminate with grey **miniature phone plugs** at each end. A standard level of 0 db (ref. 600 ohms) is employed for audio signals. (Sometimes audio signals will be referred to simply as "signals".)

(2) **Control Voltages** are signals which are used to determine the **operating characteristics** of various modules in the system. For example, the frequency of an oscillator may be determined either by a dial on the front panel or by a control voltage coming from another module. Control voltages may determine practically any aspect of a sound, and the use and significance of this principle is explained in detail below. Control voltages are processed at **Black** jacks on the front panels of the modules, and they are carried by patch cords terminating in black **banana plugs.** Timing pulses, as explained below, also use patch cords ending in banana plugs, but you have been provided with two sets of these patch cords, one with red plugs and one with black plugs. To avoid confusion, it is suggested that you use the **black** patch cords for control voltages, though the color of the plugs, of course, makes no difference. Control voltages range from .5 to 15 volts.

(3) **Timing Pulses** are signals which **initiate** or **trigger** events on other modules. The events initiated may be a single note or entire series of events. Timing Pulses are produced by touch controlled voltage sources, sequencers, or timing pulse generators. They are processed at **red** jacks on the modules, and they are carried by patch cords terminating in red **banana plugs.** Timing pulses are approximately 10 volts in amplitude.

There are two rules which must be followed in connecting signals from one module to another: (1) The path of flow must always be from the **outputs** of one module to the **inputs** of other modules, and (2) the jacks at each end of the connection must be the same. That is, audio signals must be connected to audio signals, control voltages to control voltages, and timing pulses to timing pulses.

3. The Concept of Voltage Control

Voltage Control is the principle which allows the operating characteristics of various modules to be determined by other modules. In such a way, the settings on various instruments can be dynamically varied without the composer having to intervene manually, and the compositional magnitude of the system is greatly increased. Voltage control is one of the most important characteristics of the system, which makes the equip-

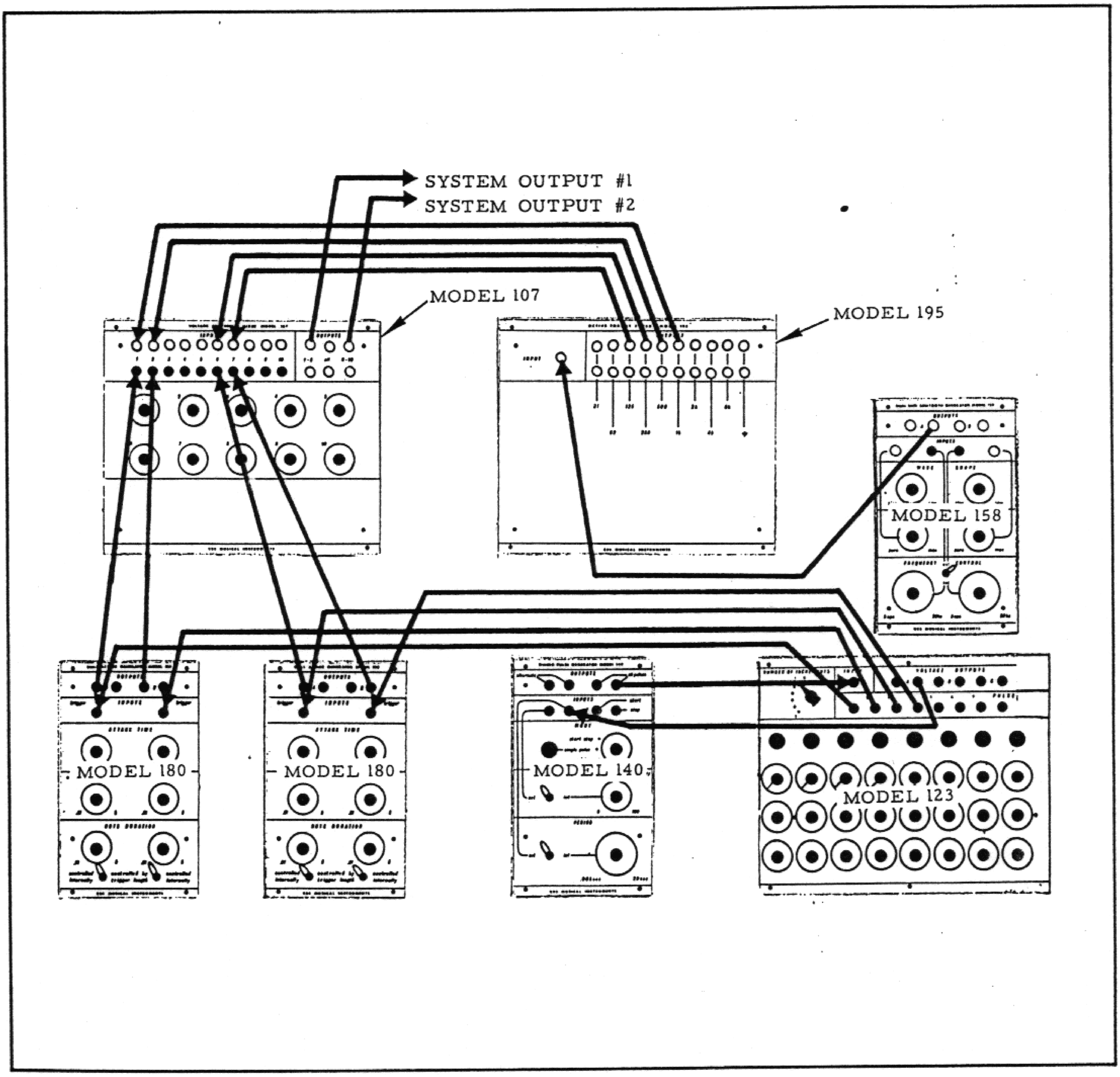

SYSTEM OUTPUT #1
SYSTEM OUTPUT #2
MODEL 107
MODEL 195
MODEL 158
MODEL 180
MODEL 180
MODEL 140
MODEL 123

Figure 4

ment much more powerful and flexible than any of the devices in older "classical" electronic music studios.

In the Buchla System, there are several modules whose purpose is solely to generate and process control voltages. There are other modules which generate or process audio signals only, and there are further modules which combine control voltages and audio signals in such a way that some characteristic of the audio signal is determined by the control voltage.

Modules which generate or process control voltages or timing pulses only are referred to as **compositional** (or semi-compositional) modules, for they can be used to determine various aspects of a piece of music such as the pitch, amplitude, or duration of a sequence of notes. These characteristics can be entirely predetermined, by setting various dials before running through the composition, or entirely random, or these two extremes can be combined to any desired degree. Under certain circumstances, the equipment can actually be made to "compose" music all by itself, in a manner that will be described in detail below (see Example 2).

On the other hand, modules which generate or process audio signals only are referred to as **performance** modules, for the actual sounds they produce must be determined either by the composer (who chose the settings on the dials) or by control voltages determined by compositional modules. A major part of learning how to use the system involves learning how to use the principle of voltage control in such a way that the composer's hands are not tied up in too many operations at one time.

On modules that have external-internal switches to allow some characteristics of a signal to be determined either by a dial on the front panel or by an external control voltage, there is generally an approximate relationship between the dial on the panel and the dials on the external devices such as that when both dials are pointing in the same direction, they should produce the same result. This relationship is only approximate, however, and must always be checked by ear. In general, the accuracy with which modules can be controlled is only to within certain broad limitations. The dials are usually marked only within the upper and lower limits of their capabilities, and intermittent values must be determined by approximation. Any predetermined series of pitches or other frequency characteristics must be tuned by ear.

It is important to remember that all control voltages within the system are completely compatible, so that any module which has a control voltage output can be used to control any other module with a control voltage input. Therefore, the same control voltage can determine more than one property of a sequence of notes, so that, for example, the rhythm of a passage can correspond precisely to a succession of pitches or amplitudes, or the envelope generator can be used to produce a change in frequency as well as amplitude. The use of control voltages in ways that might not be suggested by the most ordinary interconections is encouraged, and further demonstrates the versatility and imagination of the system.

A SEQUENCE OF TUTORIAL EXAMPLES

Example 1

Let us start with the simplest possible example, that of a single tone. Take the system output* from any output jack on the Model 158 Dual Sine-Sawtooth Oscillator, and make sure that the external-internal switch is set to "internal". By manipulating the bottom dial, you can vary the frequency of the tone from 5 to 20,000 cycles per second, and by moving the top dial you can change the timbre of the tone from a pure sine wave, which contains all harmonic partials (theoretically) in a descending amplitude series. The middle dial, marked "frequency modulation", has a line connected to an audio signal input jack, and has no effect on the tone unless another audio signal is patched into it. This signal may be taken either from another oscillator or from the other side of the dual oscillator in this panel. When connected, the frequency of frequency modulation is determined by the frequency of the input signal and the amplitude of frequency modulation by the middle dial.

*The manner in which the system output may be taken depends upon the provisions made at your particular installation. In some cases the Model 124 Patchboard may be directly wired as a central patch panel in a studio, where all tape recorders, microphones, and other devices may be interconnected. In other cases a special patch may be made from the system output jack to a tape recorder input or power ampilfier and speaker. In all examples described here, it will be assumed that the system output can be immediately accessible to the user, so that anyone going through these steps exactly will be able to stop and hear the result at any intermediate stage.

Suppose now that you want to determine the frequency of the oscillator by some other means, in order to run through a series of notes, for example. Make a connection from either of the top two rows of jacks in the Model 112 Touch Controlled Voltage Source to the control voltage input on the oscillator, and set the external-internal switch to "external". Now the frequency of the oscillator is determined by one of the dials on the Model 112 Touch Controlled Voltage Source—the dial which is directly above the last key to be touched and to the left of the row of jacks from which the connection to the oscillator is made. Moving your finger from one key to the next causes the dial which determines the frequency to be changed, except that when you remove your finger entirely the last value simply holds. The different positions on the dial which is used to control frequency from the Touch Controlled Voltage Source have aproximately the same value as the internal frequency dial on the oscillator itself, so that when both are pointing in the same direction they should produce the same frequency. (This important relationship between internal and external control voltage dials is maintained on all modules with external-internal switches similar to that on the Model 158 Dual Sine-Sawtooth Oscillator.) Now a succession of frequencies may be tuned individually on the dials on the Model 112 Touch Controlled Voltage Source, and played through in any rhythm. (The Model 112 Touch Controlled Voltage Source can also produce a control voltage proportional to finger pressure on any key, but this provides such a wide range of voltages that it is usually necessary to use it in conjunction with a Model 156 Dual Control Voltage Processor.)

At this point, however, we notice that all of the attacks of the notes are instantaneous, and they never cut off unless the system output is unplugged; the tones have no envelope. To correct this problem, it is necessary to use a Model 180 Dual Attack Generator and Model 110 Dual Voltage-Controlled Gate (or a Model 107 Voltage-Controlled Mixer). The Model 180 Dual Attack Generator produces a control voltage which has an attack, duration, and decay of determinable times. In order to apply this control voltage to the amplitude of a tone, it is necessary to use the Model 110 Dual Voltage-Controlled Gate.

The Model 180 Dual Attack Generator produces its envelope when it receives a timing pulse input from another module. In order to have it produce an envelope at the same time that a key on the Model 112 Touch Controlled Voltage Source is touched, it is necessary to patch from the timing pulse output on the Model 112 Touch Controlled Voltage Source is touched, it is necessary to patch from the timing pulse output on the Model 112 keyboard to the timing pulse input on the Model 180 Attack Generator, to connect the control voltage output on the Model 180 Attack Generator to the control voltage input of the Model 110 Dual Voltage-Controlled Gate, and to patch the audio signal output from the Model 158 Oscillator to the audio signal input on the Model 110 Gate. The system output is then available at the audio signal output of the Model 110 Gate (see Figure 1A).

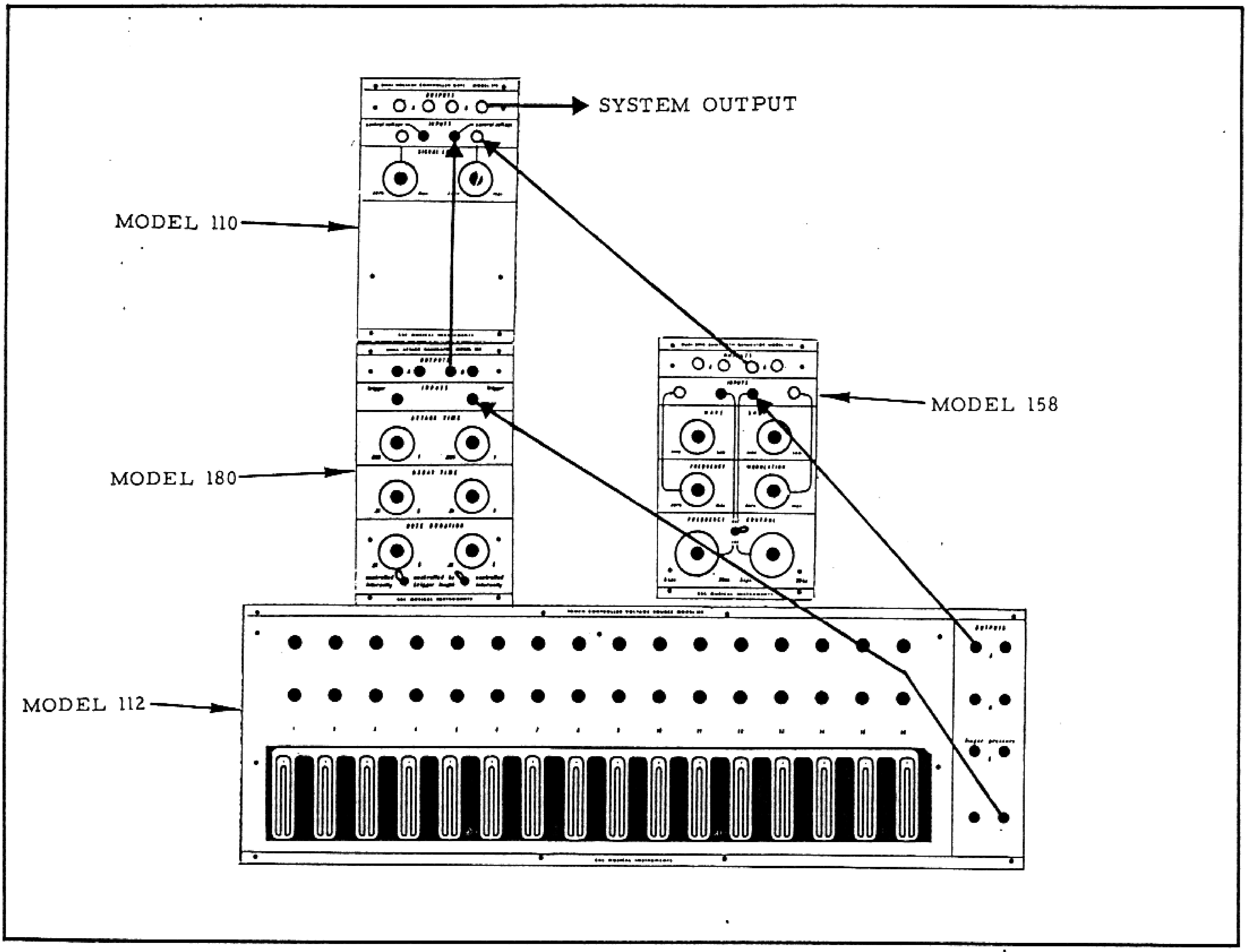


Figure 1A

The attack and decay characteristics of the tones may now be controlled by the dials on the Model 180 Dual Attack Generator. The top dial controls the attack time, which may be varied from .002 to 1 seconds; the decay time is controlled by the middle dial, and may be varied from .002 to 5 seconds. By moving the external-internal switch to the "external" position, it is possible to make the note duration be determined by the trigger length, which in this case is the length of time you leave your finger on the keyboard. The dial on the Model 110 Dual Voltage-Controlled Gate allows a further seting of the final amplitude level of the tone. Now it is posible to run through an entire series of tones of predetermined frequencies in a rhythm which will be determined by the way you touch the keys on the Model 112 Touch Controlled Voltage Source.

At this point we may consider various additional signal modifications that we may wish to make to the series of tones produced by the above example. For instance, if we would like to add frequency modulation to the tones, it is necessary to patch another audio signal into the jack connected by a line to the middle dial on the Model 158 Dual Sine-Sawtooth Oscillator. The amplitude of frequency modulation is controlled by the middle dial, and turning the amplitude all the way down can eliminate the frequency modulation entirely. The frequency and "shape" of frequency modulation are determined by the characteristics of the input signal, which for this reason is called the "modulating" tone. To judge this effect precisely, compare the frequency-modulated tone to the modulating tone as separate audio signals by taking the system output from each side of the Model 158 Dual Sine-Sawtooth Oscillator.

If we wish to take both the modulating tone and the basic tone from both sides of the Model 158 Dual Sine-Sawtooth Oscillator, we must use an additional control voltage to determine the frequency of the modulating tone, for the external-internal switch controls both oscillators in this case. (We are assuming that the other side of the oscillator is still connected as in Figure 1A.) This control voltage could be taken from the other row of dials on the Model 112 Touch Controlled Voltage Souce, in which case we could preset the frequencies of both oscillators and go through an entire series of frequency-modulated tones (see Figure 1B).

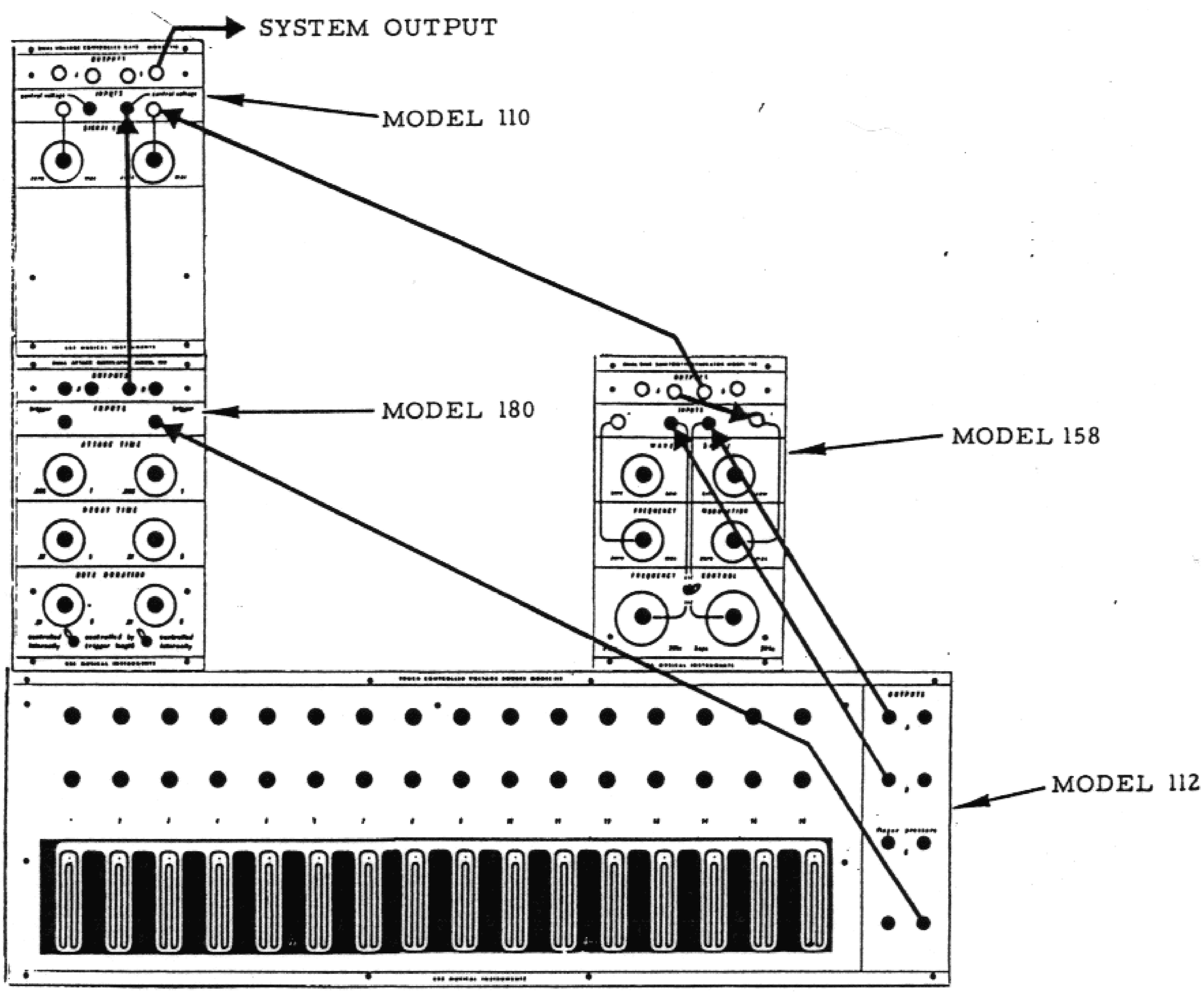


Figure 1B

Instead of using one tone to frequency-modulate another in this manner, we may chose simply to mix the two tones together into one sound. This could be accomplished by using the Model 106 Six-Channel Mixer. We need to patch simply from the two outputs on the Model 158 Dual Sine-Sawtooth Oscillator to any of the inputs on the Model 106 Mixer, and from one of the center outputs on the Model 106 Mixer (marked "all") to the audio signal input on the Model 110 Gate. The amplitude of each of the tones is now controlled separately by the dials leading to each of the input jacks on the Model 106 Mixer. The Model 106 Mixer has six inputs, so that up to six separate tones can be combined at one time. The left and right sides of the mixer can also be used separately as two three-channel mixers, and the corresponding output jacks are on the outside of the top row of jacks (marked "1-3" and "4-6"). Although in this example the amplitudes of each of the tones is controlled separately by the dials on the front panel of the Model 106 Mixer, it is important to remember that the pair of tones will have the same envelope and total amplitude, for they are being combined into one signal (see Figure 1C).

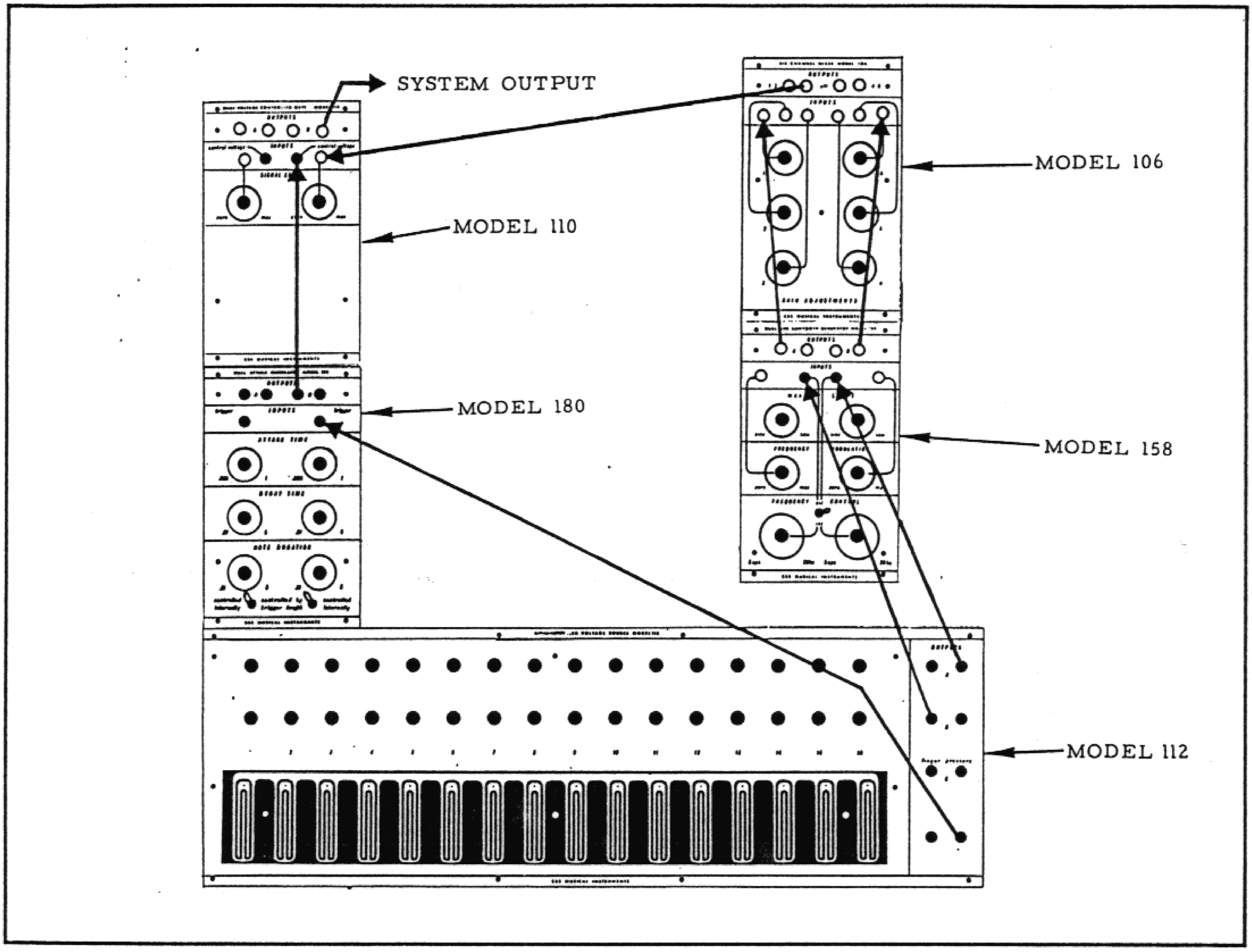


Figure 1C

Example 2

Now we are ready to consider a more complicated example. Suppose we would like to generate a sequence of partly predetermined, partly random tones differentiated by pitch, rhythm, and amplitude. It is actually very easy to solve problems of this kind with the Buchla System, because of the versatility of compositional devices and the complete compatibility of control voltages.

It is clear that we will have to use the Model 165 Dual Random Voltage Source in this example, but we will also need a module which can combine the random voltage with a predetermined voltage. Such a module would be the Model 156 Dual Control Voltage Processor. We will also use the Model 140 Timing Pulse Generator and the Model 123 Sequential Voltage Source as compositional modules in this example.

First, if you have moved to this example after finishing Example 1, it would be helpful to remove all the patches from the modules and start from scratch. Then follow these directions:

- Patch from the "all pulses" output on the Model 140 Timing Pulse Generator to the timing pulse input on the Model 123 (or Model 146) Sequential Voltage Source.
- Patch from the "all pulses" output on the Model 140 Timing Pulse Generator to the trigger input on a Model 180 Attack Generator.
- Check the three-position rotary switch on the Model 140 Timing Pulse Generator to see that it is pointing toward "repetitive".
- Patch from any timing pulse output on the Model 123 Sequential Voltage Source to the timing pulse input on a Model 165 Dual Random Voltage Source.

(This completes the patching network for timing pulses in Example 2)

- Patch from a control voltage output on the Model 165 Dual Random Voltage Source to one of the inputs on the left side of a Model 156 Dual Control Voltage Processor.
- Patch one of the three pairs of outputs on the Model 123 Sequential Voltage Source to the other input on the left side of the Model 156 Dual Control Voltage Processor.
- Patch the output of the Model 156 Control Voltage Processor to the control voltage input connected to the "period" control on the Model 140 Timing Pulse Generator, and turn the external-internal switch to "external".
- Patch from another control voltage output of the Model 123 Sequential Voltage Source to the control voltage input on a Model 158 Dual Sine-Sawtooth Oscilator, and turn the external-internal switch to "external".
- Patch from the third control voltage output of the Model 123 Sequential Voltage Source to the control voltage input on the left side of a Model 110 Dual Voltage Controlled Gate.
- Patch from the output of the Model 180 Attack Generator to the control voltage input on the right side of the Model 110 Dual Voltage Controlled Gate.

(This completes the patching network for control voltages in Example 2)

- Patch the audio signal output of the Model 158 Dual Sine-Sawtooth Oscillator to the audio signal input on the right side of the Model 110 Dual Voltage Controlled Gate.
- Patch the output of the right side of the Model 110 Dual Voltage Controlled Gate to the audio signal input on the left side of the same Model 110 Dual Voltage Controlled Gate.
- The system output is now available as the output of the left side of the Model 110 Dual Voltage Controlled Gate. This entire network of patches is illustrated in Figure 2.

In this set-up, the pitch and amplitude of the tones will be repetitive and controlled by the associated dials on the Model 123 Sequential Voltage Source. The ryhthm of the tones wil be partly random and partly repetitive, and since the timing pulse input to the Model 165 Random Voltage Source comes from the Model 123 Sequencer, there will be an eight-note rhythmic pattern which will be repeated in various degrees of augmentation and diminution. This will be most noticeable if the bottom dial on the Model 156 Control Voltage Processor is pointing straight up; the more it is pointed toward either side, the more the rhythm of the tones will be either totally random or totally repetitive. Note that if the right side of the Model 156 Dual Control Voltage Processor is used, the same basic pattern will emerge, but the value of the input in the right jack will be inverted.

If we would like the pitches and not the rhythms in this example to be partly random, we could merely exchange the output of the sequencer which controls the oscillator and the output of the control voltage processor. Similarly, if we would like the amplitudes to be partly random, we could exchange the output of the sequencer which controls the gate and the control voltage processor; or we could simply use the output of the control voltage processor to control both the timing pulse generator and either the gate or the oscillator.

Various controls which have not been mentioned to this point may now be tampered with in such a way as to change the total effect of this patching network. The attack time on the Model 180 Dual Attack Generator should be fairly fast if the notes are moving in a fast rhythm. (It might be easier to test this out with the external-internal switch for the "period" on the Model 140 Timing Pulse Generator set to "internal".) If the attack times of the notes are greater than their total duration, the notes will never reach their full amplitude

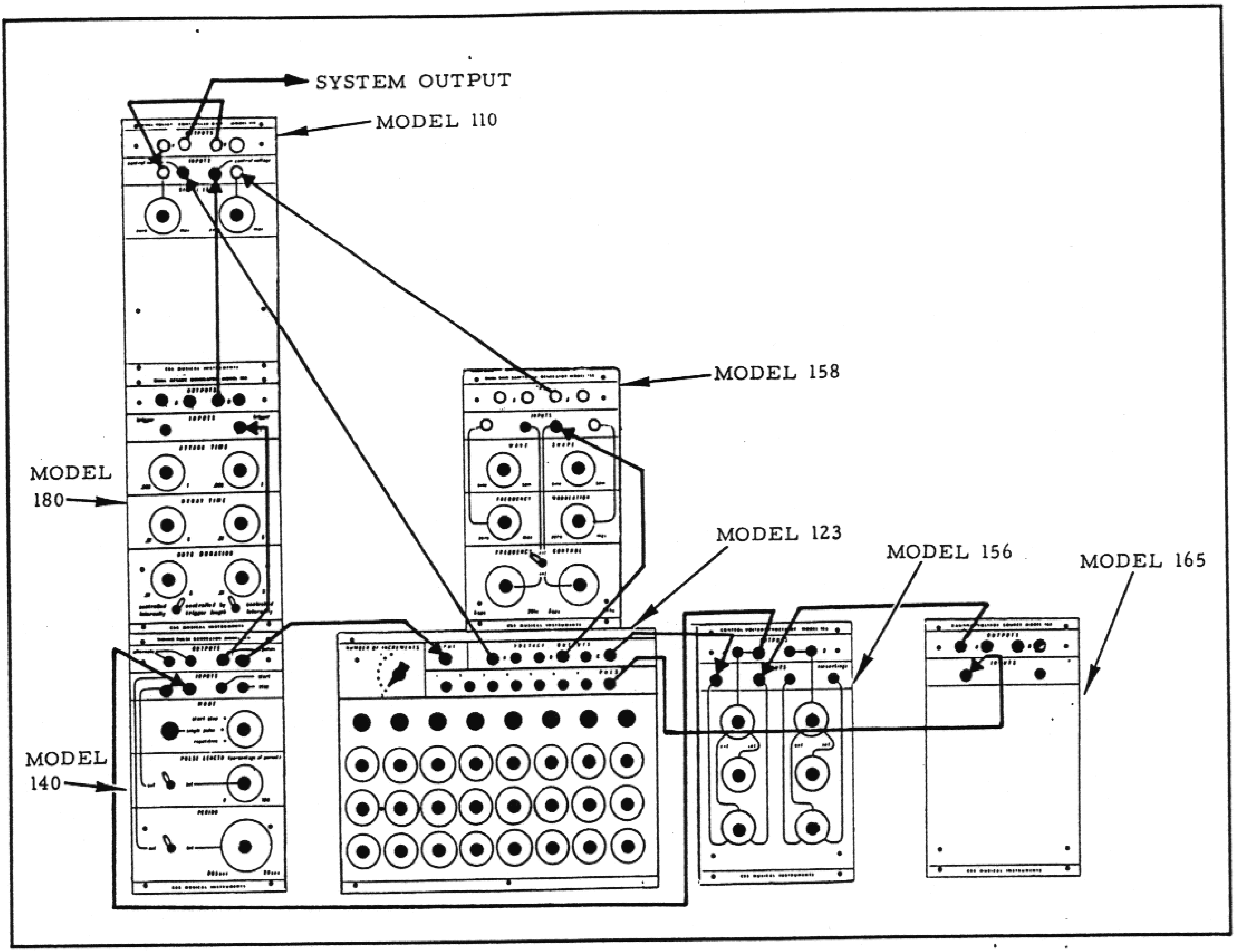


Figure 2

and the result will be either silence or a series of "muf fled crescendos." Similarly, the duration of the tones can be either constant or determined by the pulse length, which in this case is controlled by the middle dial on the Model 140 Timing Pulse Generator. If the duration of the tones is constant, it should be less than the amount of time between successive attacks, which is controlled by the "period" control (either internally or externally) on the Model 140 Timing Pulse Generator; otherwise the tones will have no decay times. Any of these possible permutations still give comprehensible results, and could be used compositionally.

There are two controls on the Model 140 Timing Pulse Generator which have external-internal switches: The "pulse length" and the "period". For purposes of demonstration, let us use the "internal position" for the time being, though for compositional purposes both could be determined by external control voltages. The period control determines the duration between successive timing pulse outputs, and the pulse length control determines the duration of each timing pulse. With the duration switch on the Model 180 Attack Generator set such that it is determined by the trigger length, these controls can be used to determine the total rhythmic structure of a sequence of tones, which can be dynamically varied since the values can be determined by external control voltages. In the example shown, it is interesting to note that the timing pulse generator controls the sequencer and is in turn controlled by the sequencer.

The controls on the Model 156 Dual Control Voltage Processor allow a great variety of means to determine the result. The bottom dial determines a mixture of the two inputs: if it is pointing straight up, the two inputs are mixed in equal amplitudes; if it is pointing more toward either input, more of that input is sent to the output, until finally the other input is cut out entirely. The middle dial is an internal voltage source. If the control voltage processor is used to control pitch, it can be used to transpose the pitches up or down uniformly. In this example it can be used to make the total rhythm of the "period" control on the Model 140 Timing Pulse Generator produce a generally fast or slow result, within the limitations of the settings of the dials on the

Model 123 Sequential Voltage Source. The final dial is similar to the bottom dial, and determines a mixture of the inputs and the internal voltage source: the different positions have the same meaning as with the bottom dial. Thus, several levels of control are possible with the control voltage processor, and the user is encouraged to experiment with it to determine its full range of effectiveness.

Example 3

Now we are ready to consider an even more complicated example, one that might be used in an actual musical composition. There will be two system outputs in this example though, of course, both of them could be mixed together to form one sound. One output will be a series of frequency-modulated tones of partly predetermined and partly random frequencies. The other output will be a more complicated sound, which will involve mixing together the two outputs of the frequency shifter and applying a glissando to one of the inputs to the frequency shifter which is proportional to the envelope of the sound. Both sounds will be given independent reverberation, and their total rhythm will be such that there will be a whole series of frequency-modulated sounds for each of the frequency-shifted sounds, which will decay slowly while the other sounds continue to be attacked. The remaining aspects of this example are best described by the actual details of the patching network itself.

As in Example 2, it is suggested that you start with all patches removed from the system then follow these instructions:

- Patch a timing pulse from the "all pulses" output of a Model 140 Timing Pulse Generator to the input on a Model 123 (or Model 146) Sequential Voltage Source.
- Patch from the "all pulses" output of a Model 140 Timing Pulse Generator to the trigger input on a Model 180 Attack Generator.
- Patch from two adjacent timing pulse outputs of the Model 123 Sequential Voltage Source to the timing pulse inputs on a Model 180 Attack Generator and on a Model 165 Random Voltage Source, in that order.
- Patch a control voltage from one of the three outputs of the Model 123 Sequential Voltage Source to one of the inputs on the left side of a Model 156 Control Voltage Processor.
- Patch the control voltage output from the Model 165 Random Voltage Source into the remaining input on the left side of the Model 156 Control Voltage Processor.
- Patch the output of the left side of the Model 156 Control Voltage Processor to both the "period" input on the Model 140 Timing Pulse Generator and to the left side of a Model 158 Dual Sine-Sawtooth Oscillator.
- Patch a control voltage from one of the other outputs of the Model 123 Sequential Voltage Source to the right side of the Model 158 Dual Sine-Sawtooth Oscillator.
- Patch the remaining control voltage output of the Model 123 Sequential Voltage Source to the "pulse length" input on the Model 140 Timing Pulse Generator.
- Patch the output of the Model 180 Dual Attack Generator which is triggered by the Model 140 Timing Pulse Generator to the control voltage input on a Model 110 Dual Voltage-Controlled Gate.
- Patch the audio signal output of the right side of the Model 158 Dual Sine-Sawtooth Oscillator, which is controlled by the Model 123 Sequential Voltage Source, to the Frequency Modulation input on the left side of the Model 158 Dual Sine-Sawtooth Oscillator.
- Patch the audio signal output of the left side of the Model 158 Dual Sine-Sawtooth Oscillator to the audio signal input on the Model 110 Dual Voltage-Controlled Gate.
- Patch the output of the Model 110 Dual Voltage Controlled Gate into a Model 190 Dual Reverberation Unit.
- Turn the external-internal switches for the "pulse length" and "period" on the Model 140 Timing Pulse Generator and the external-internal switch on the Model 158 Dual Sine Sawtooth Oscillator to "external".
- The system output for the series of frequency-modulated tones is now available as the output of the Model 190 Reverberation Unit.

The basic frequencies of the frequency-modulated tones are partly random, and are directly correlated to their rhythm. The modulation frequencies are repetitive. The entire character of the music can be changed by simply moving the dial on the Model 123 Sequential Voltage Source on the Model 156 Control Voltage Processor.

To set up the other half of this example, follow these directions:

- Patch control voltages from the Model 180 Dual Attack Generator which is triggered by the Model 123 Sequential Voltage Source to both a Model 110 Dual Voltage-Controlled Gate and to the left input on the right side of the Model 156 Dual Control Voltage Processor. Since this will be the only input to the right side of the Model 156, the bottom dial can be turned all the way in this direction.
- Patch the output of the right side of the Model 156 Dual Control Voltage Processor to the control voltage input on a Model 158 Dual Sine-Sawtooth Oscillator.
- Patch a control voltage from the Model 165 Random Voltage Source to the control voltage input on a Model 144 Dual Square Wave Oscillator.

- Turn the external-internal switches on both of the Model 144 and Model 158 Oscillators to "external".
- Patch the audio signal output of the Model 158 Sine-Sawtooth Oscillator to the left input of a Model 185 Frequency Shifter.
- Patch the audio signal output of the Model 144 Square Wave Oscillator into the right input of the Model 185 Frequency Shifter.
- Patch both the sum and difference outputs of the Model 185 Frequency Shifter into two inputs on a Model 106 Six-Channel Mixer.
- Patch the output of the Model 106 Six-Channel Mixer into the Model 110 Voltage Controlled Gate.
- Patch the output of the Model 110 Voltage Controlled Gate into a Model 190 Dual Reverberation Unit.
- The system output is now available as the output of the Model 190 Dual Reverberation Unit.

The entire patching network for Example 3 is illustrated in Figure 3.

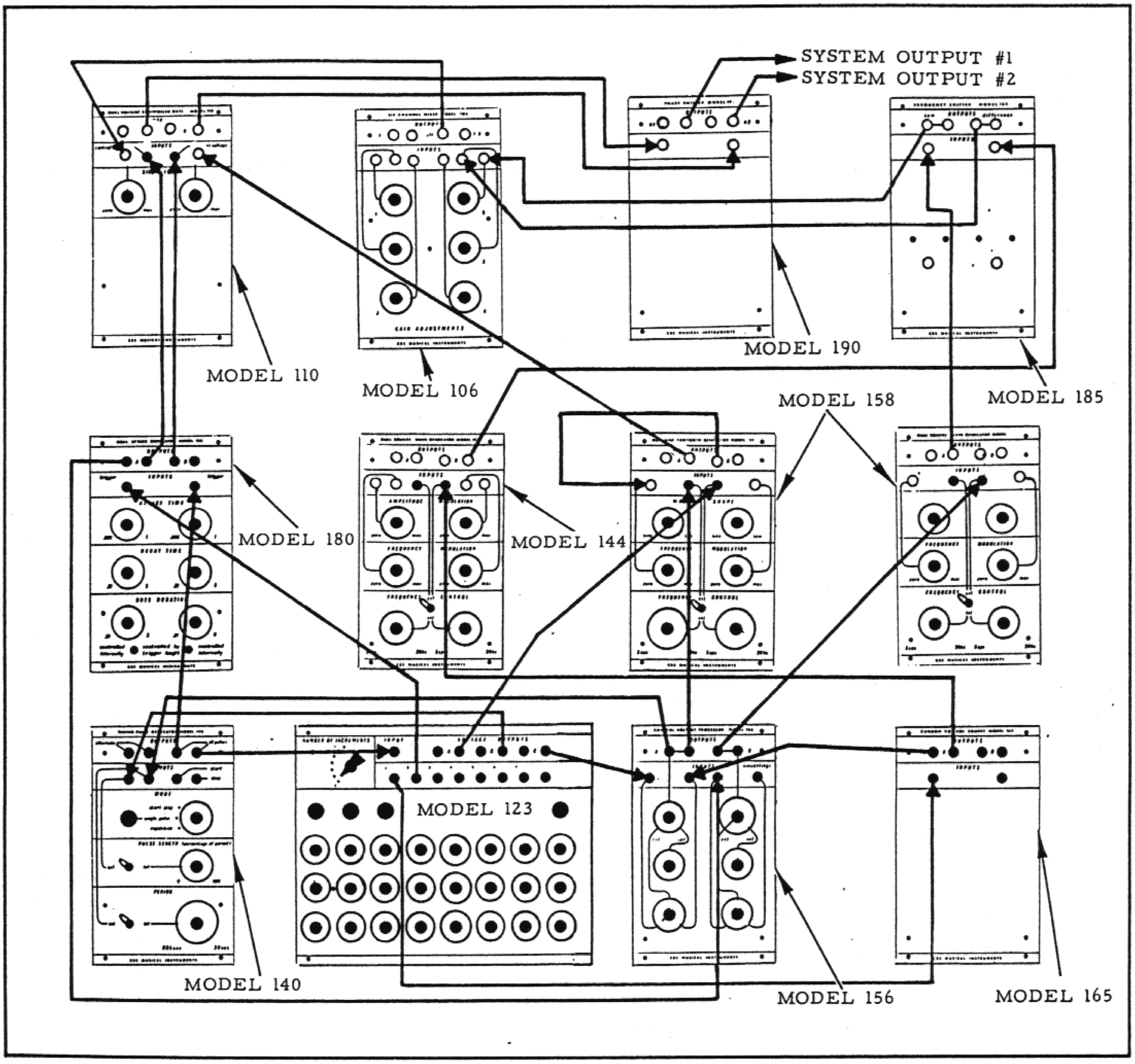


Figure 3

In order to realize the full effectivenes of this set-up, the decay time of the Model 180 Attack Generator should be quite long and the duration fairly short. In that way the frequency glide controlling the Model 185 Frequency Shifter will be quite long, and the manner in which the sound dies out will be more noticeable. It would also be possible to use the same timing pulse output of the Model 123 Sequencer to control both the attack generator and the Model 165 Dual Random Voltage Source, but this is not necessary if the timing pulse for the attack generator is taken immediately after that for the random voltage source; in that way the same value of the random voltage source can be maintained for nearly the whole duration of the sound, which will be at the end of its decay when the random voltage changes.

It is interesting to make slight changes in this set-up and compare the results: patch the output of the envelope generator into the "inverting" jack on the control voltage processor; the envelope of the sound will be just the same, but the frequency glides will be in the opposite direction. It is also interesting to switch the two inputs on the frequency shifter, or to experiment with different amounts of reverberation.

The total rhythm of both outputs in this example is correlated so that there will be one slowly changing frequency-shifted sound against eight (or less) frequency-modulated tones, which will be recurring in varied rhythmic patterns. Slight changes on the dials on the control voltage processors, attack generators, or the sequencer will produce a great variety of interesting musical effects,

Example 4

This example is called the "complex envelope". It was invented by Morton Subotnick who used it extensively in his album "The Wild Bull". The entire patch uses only one oscillator and one basic sound, and in combining it with other sounds it can be thought of as just a single tone. To set it up, follow these directions:

- Patch a timing pulse from the "all pulses" output of a Model 140 Timing Pulse Generator to the input on a Model 123 (or 146) Sequential Voltage Source.
- Patch the time pulse outputs 1-4 on the Model 123 Sequential Voltage Source to the trigger inputs on four Model 180 Attack Generators (that is, **two** dual modules).
- Turn the rotary switch in the upper left corner of the Model 123 Sequential Voltage Source to position 5.
- Patch a control voltage from output "A" of the Model 123 Sequential Voltage Source to the "period" input on the Model 140 Timing Pulse Generator, and turn the external-internal switch to "external".
- Turn the first four control voltage dials for row "A" of the Model 123 Sequential Voltage Source all the way to the left, and set the fifth approximately in the middle.
- Patch the control voltage outputs of the four Model 180 Attack Generator to control voltage inputs number 1, 2, 6, and 7 on a Model 107 Voltage Controlled Mixer.
- Patch the audio signal output of a Model 158 Dual Sine-Sawtooth Oscillator to the input on a Model 195 Format Filter, and turn the wave shape control to "sawtooth".
- Patch any four outputs of the Model 195 Octave Format Filter into the audio signal inputs number 1, 2, 6 and 7 on the Model 107 Voltage Controlled Mixer.
- The system output is now available as the output of the Model 107 Voltage Controlled Mixer. If one system output is desired, the middle output marked "all" can be taken. If two outputs are desired, the outputs marked "1-5" and "6-10" are available separately. The latter situation affords opportunity for interesting spatial effects. This entire patching network is illustrated in Figure 4.

In its most basic form, the complex envelope patch works best with the durations of the four Model 180 Attack Generators controlled internally. The attack and decay controls on the four attack generators control the envelope characteristics of different sets of harmonic partials of the basic tone. They can be arranged to fade in and out at many different rates, but the effect is always perceived as different qualities of one basic sound.

Row "A" on the Model 123 Sequential Voltage Source controls the total rhythm of the complex envelope. However, since the first four dials are set all the way to the left, their attacks are effectively instantaneous. The fifth dial, then, functions as a master rhythmic control, which determines the rate at which the entire sequence progresses.

The whole patch as shown, uses just one oscillator, It is also possible to frequency-modulate one oscillator with another, which produces an entire new range of sounds. Since the basic tone in the latter case contains combination tones, it can be a sine wave. In the former case it is necessary to use a tone with many harmonics in order to give the filter a range to operate over.

The Entire complex envelope, nevertheless, still operates as a single (monophonic or stereophonic) sound, and can be combined with other sounds as a single event.

Now suppose we would like to set up a series of tones of different predetermined and correlated amplitudes and frequencies. In this case it would be convenient to use one row of dials on the Model 112 Touch Controlled Voltage Source to control frequency and the other to control amplitude, and so we must find a module which applies a control voltage to amplitude. Such a module would be either the Model 107 Voltage-Controlled Mixer or the Model 110 Dual Voltage Controlled Gate. Since we are already using one side of the Model 110 Gate for envelope control, it would be convenient to use the other side to control amplitude. It is necessary to patch from the desired control voltage output on the Model 112 keyboard to the control voltage input on the unused side of the Model 110 gate, and from the audio signal output of the envelope side of the Model 110 gate (which was the system output in Figure 1A) to the audio signal input on the opposite side, and the system output is now available at the output of this side of the Model 110 gate. The settings on the dials of the Model 112 keyboard bear the same relationship to the amplitudes of the tones as the corresponding settings of the dial on the front panel of the Model 110 gate, so that this dial can be used as a "master volume control" for the entire series of tones produced by this patching set-up (see Figure 1D).

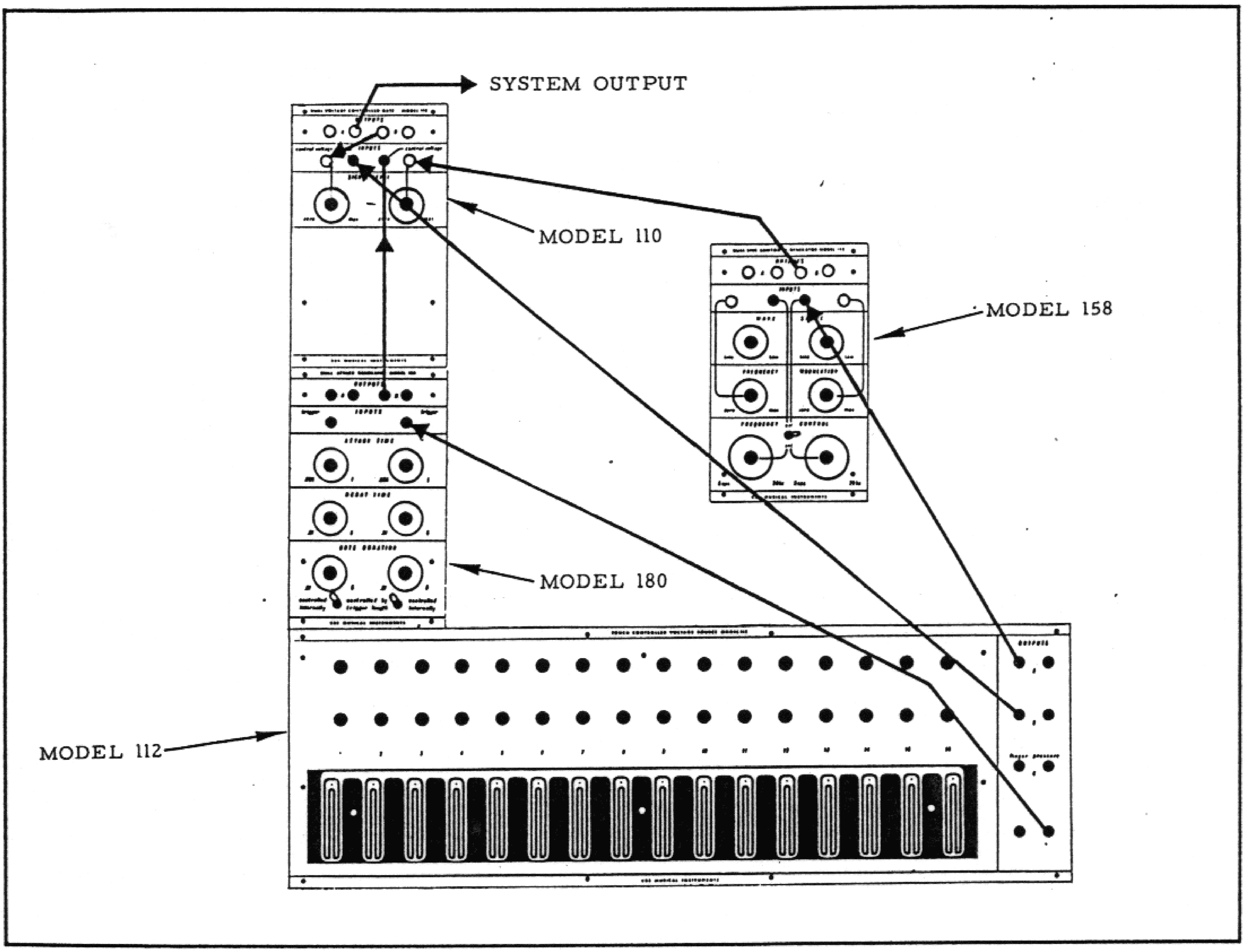


Figure 1D

Now we are in a position to consider how any general signal modification could be added to a tone which has already been generated and processed to some degree: we need to patch simply from the signal output (which up to know has been taken as the system output) to the signal input on a new device, and then take the system output from the new device. This process can be repeated until any desired degree of signal modification is achieved. For example, suppose we would like to add reverberation to a signal output from Example 1A. We need to patch only from the audio signal output of the Model 110 gate in Example 1A to the signal input on either side of a Model 190 Dual Reverberation Unit, and take the system output from one of the two output jacks immediately above the input we selected (see Figure 1E). The dial in this case controls the amount of reverberation in the final sound.

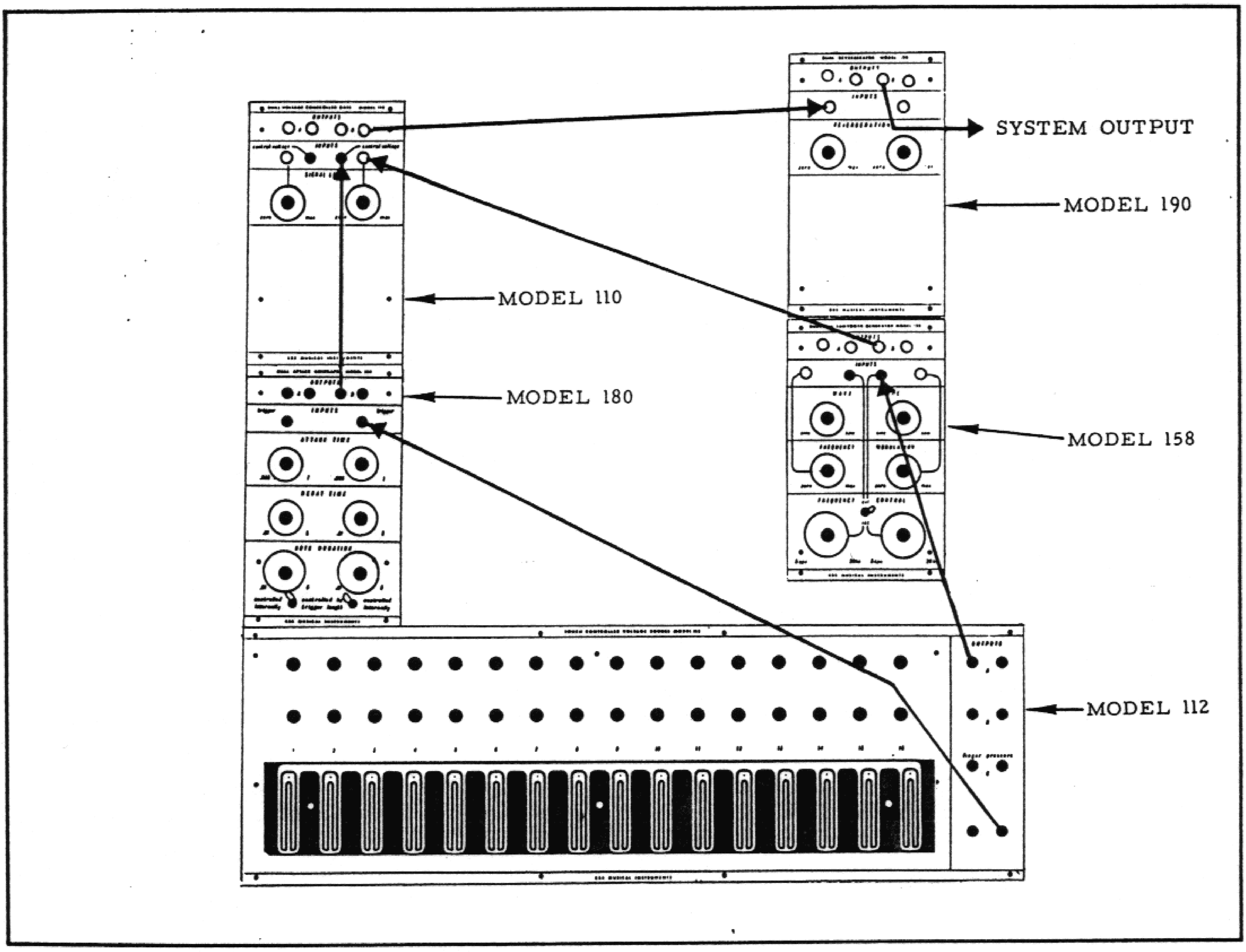


Figure 1E

Now suppose we wish to add a low filter to the sound just produced in Example 1E. All we need to do is patch the output of the reverberation unit in Example 1E to the input on either side of a Model 192 Dual Lo-pass Filter, and take the system output from the filter (see Figure 1F). The dial on the Model 192 Filter now controls the on/off frequency of the lowpass filter. Note that it makes no difference whether we patch the reverberation unit or the filter in first, as long as the final sound passes through all of these modules before being taken as the system output. This is a general rule which holds for any signal processing; extensive modifications can be compounded one onto another, and as long as the system output is taken after all of the modifications, the results will be the same, regardless of the order in which they are applied.

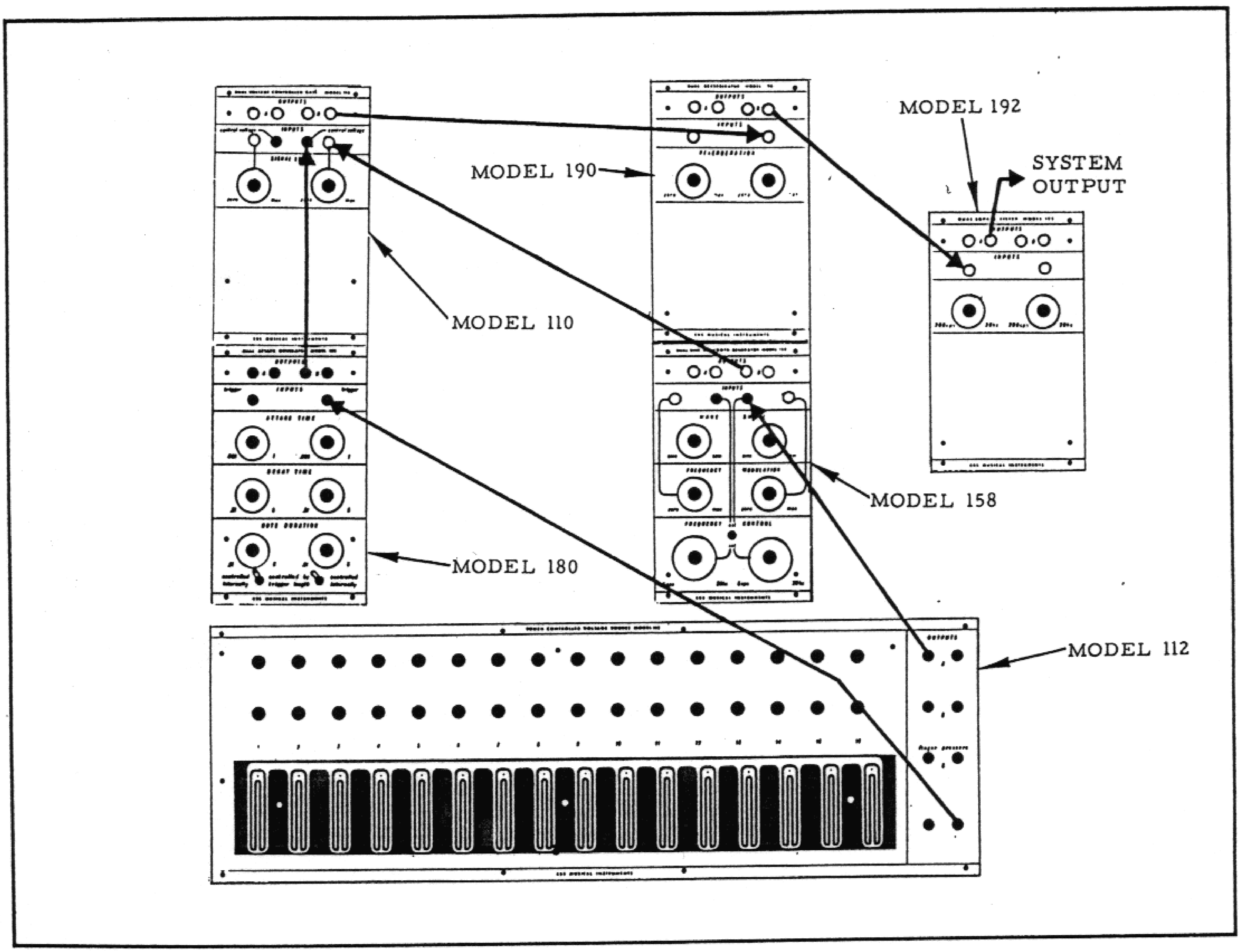


Figure 1F

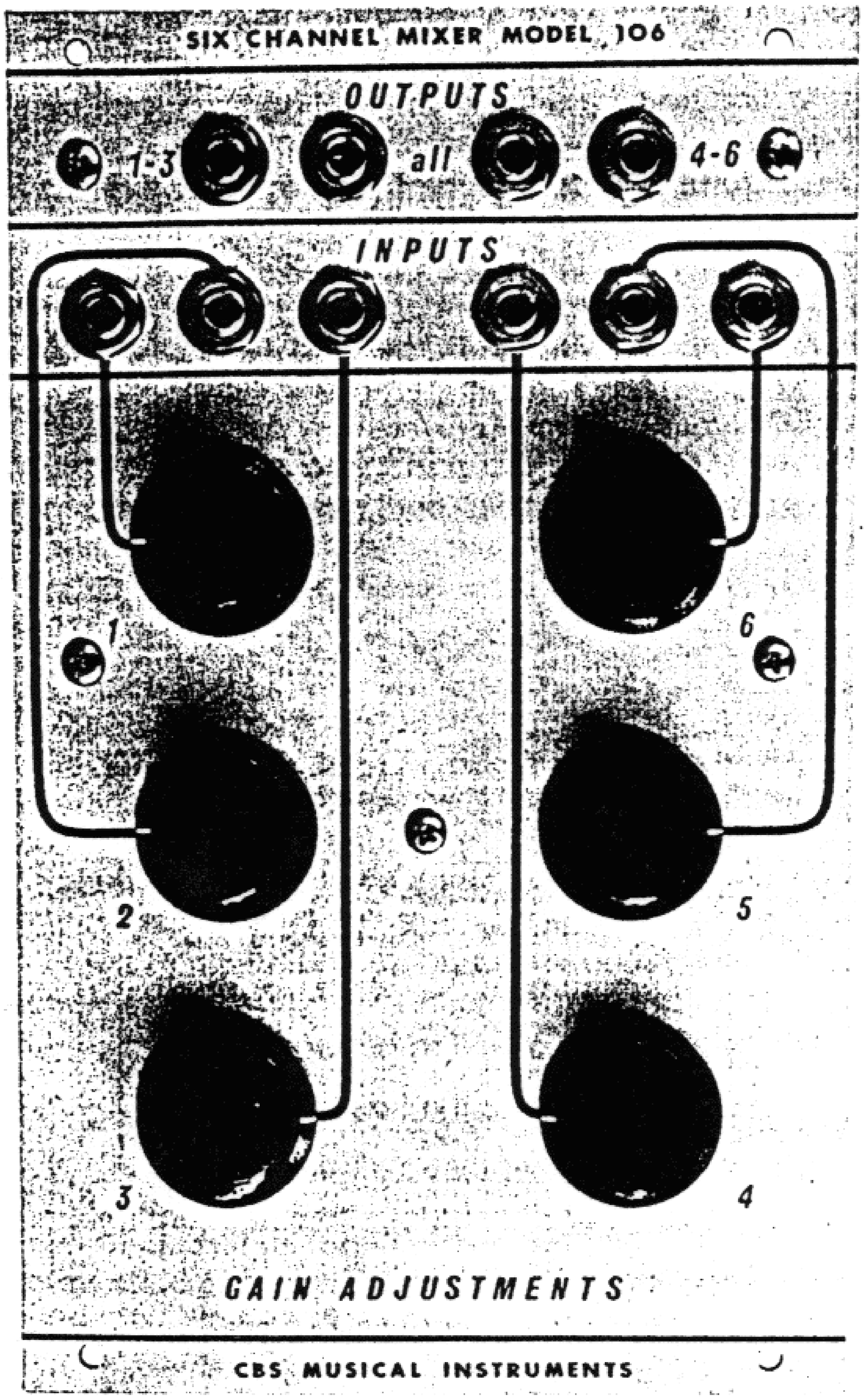
DESCRIPTION OF INDIVIDUAL MODULES

Model 106 Six-Channel Mixer

The Model 106 Six Channel Mixer contains six **signal inputs** and four **signal outputs** and six **volume controls** for the inputs on its front panel.

Lines are drawn on the panel between the **input jacks** and the associated **volume controls.** The volume level of each of the inputs may be separately set by these controls, but there is no master gain control for the output.

The Model 106 Six-Channel Mixer is really three-channel mixers with separate and common outputs. The middle two outputs are for the sum of the six inputs, and the other two jacks for channels 1-3 and 4-6, respectively.



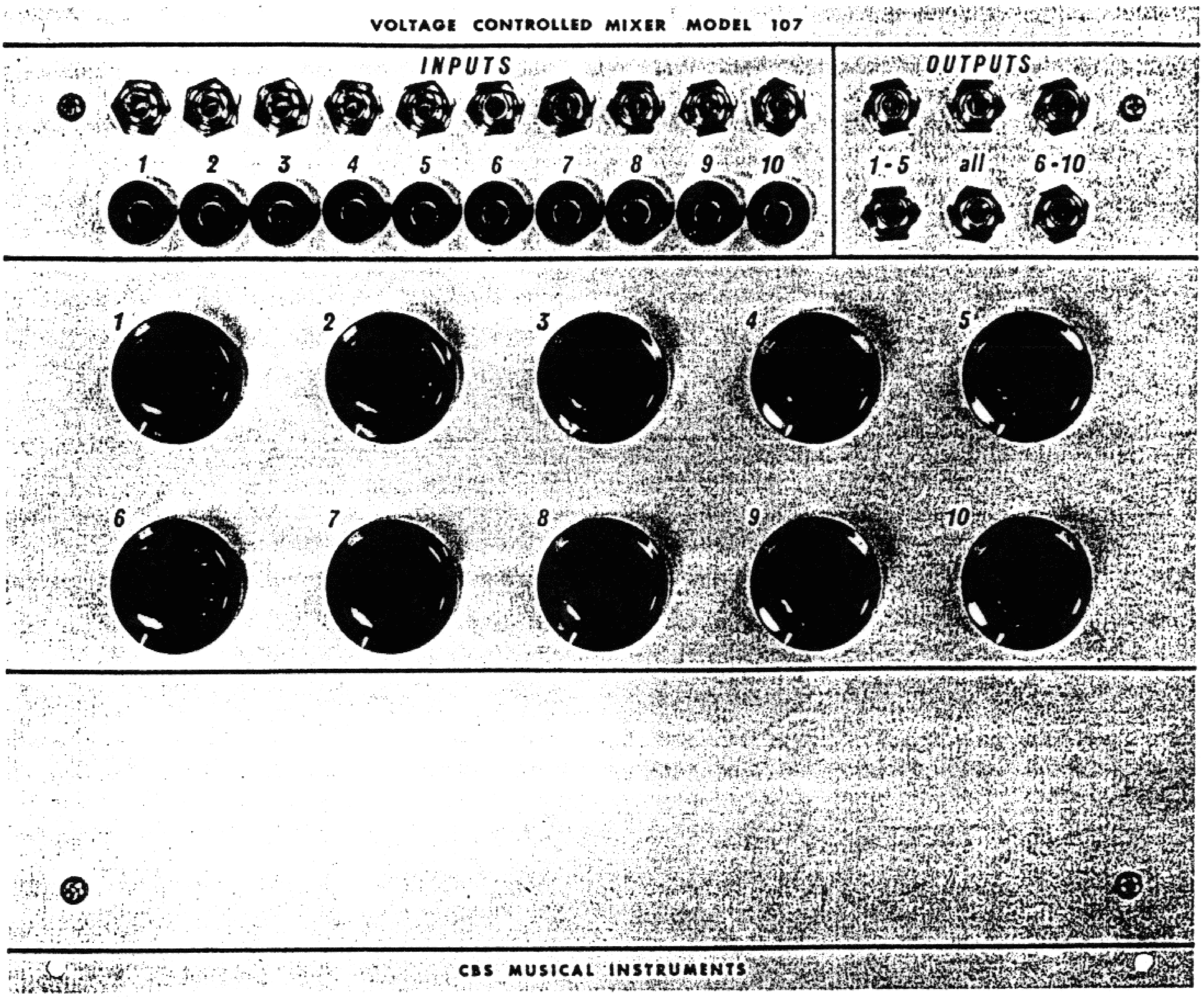
Model 106 Six-Channel Mixer

Model 107 Voltage-Controlled Mixer

The Model 107 Voltage-Controlled Mixer provides a way of applying a control voltage to the amplitudes of ten audio signals and mixing the result into one or two separate complex signals. Its front panel has ten associated **signal inputs, control voltage inputs,** and **volume control dials,** and three pairs of vertically aligned **signal outputs.**

The associated **signal** and **control voltage inputs** are vertically aligned and are numbered 1-10. The **volume control dials** are also numbered to indicate their correspondence to the inputs. The final amplitudes of the audio signal inputs are a result of the control voltage input and the setting on the dial, so that two levels of control are provided. The control voltage input might be taken either from an envelope generator, in which case the envelope is applied to the amplitude of the input signal, or from some programmable voltage source, such as the Model 146 Sequential Voltage Source or the Model 112 Touch Controlled Voltage Source, in which case the control voltage determines the loudness level of the input signal.

The three pairs of **signal outputs** provide a mixture of inputs 1-5, 6-10, or all of the inputs, so that the unit can be used as two separate five-input mixers or one ten-input mixer.



Model 107 Voltage-Controlled Mixer

Model 110 Dual Voltage Controlled Gate

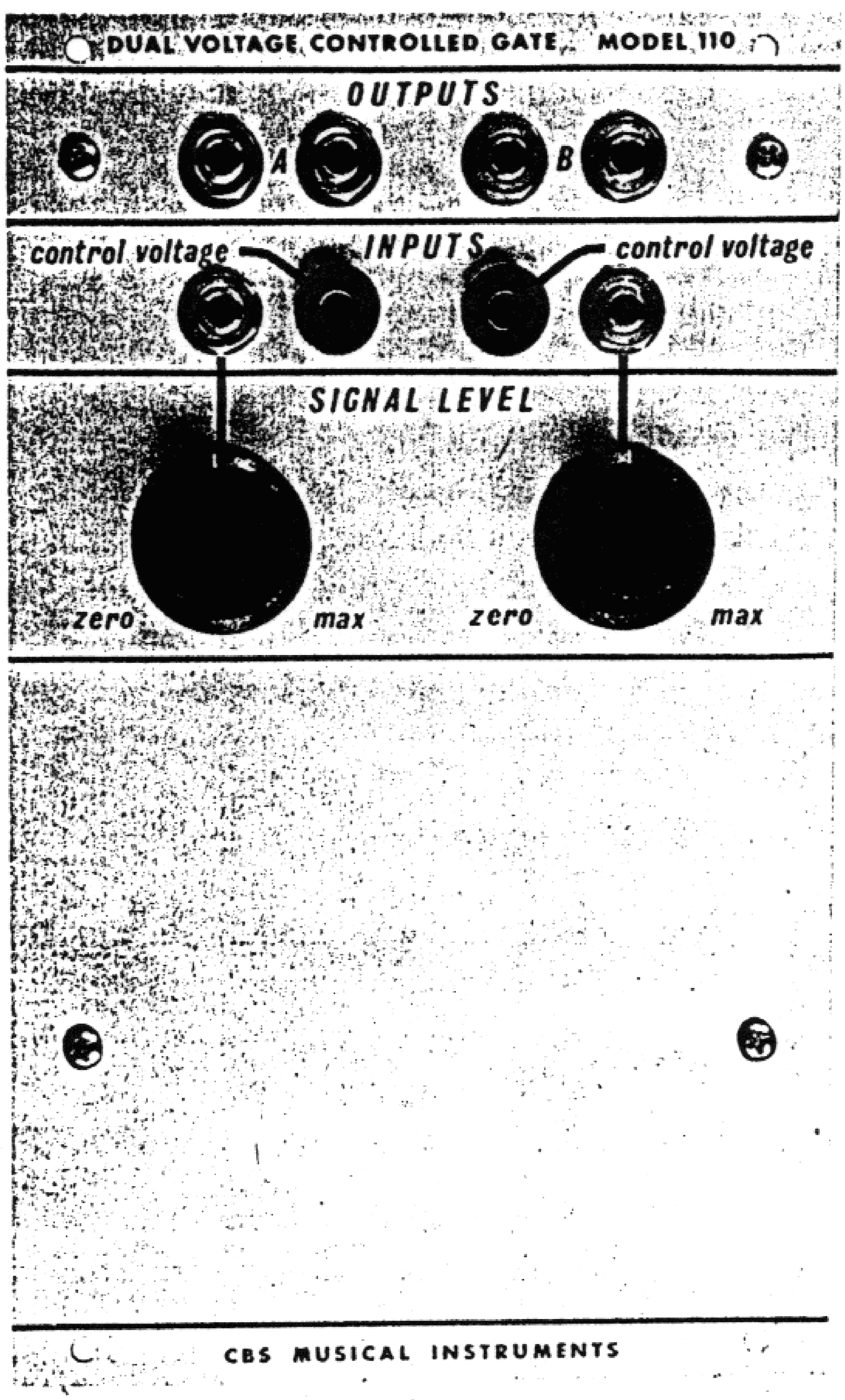
The Model 110 Dual Voltage Controlled Gate is necessary for amplifying **audio signals** according to an externally determined **control voltage.** It has two pairs of **signal inputs** with an associated **control input** and **signal level control** and two **signal outputs.**

The **control input** to the Model 110 Dual Voltage Controlled gate generally comes from a **Model 180 Dual Attack Generator,** in which case the gate is used to process **envelopes.** (See section 7-180.) However, the control input may come from any external device with a control output, and the gate is capable of processing any amplitude-modifying function.

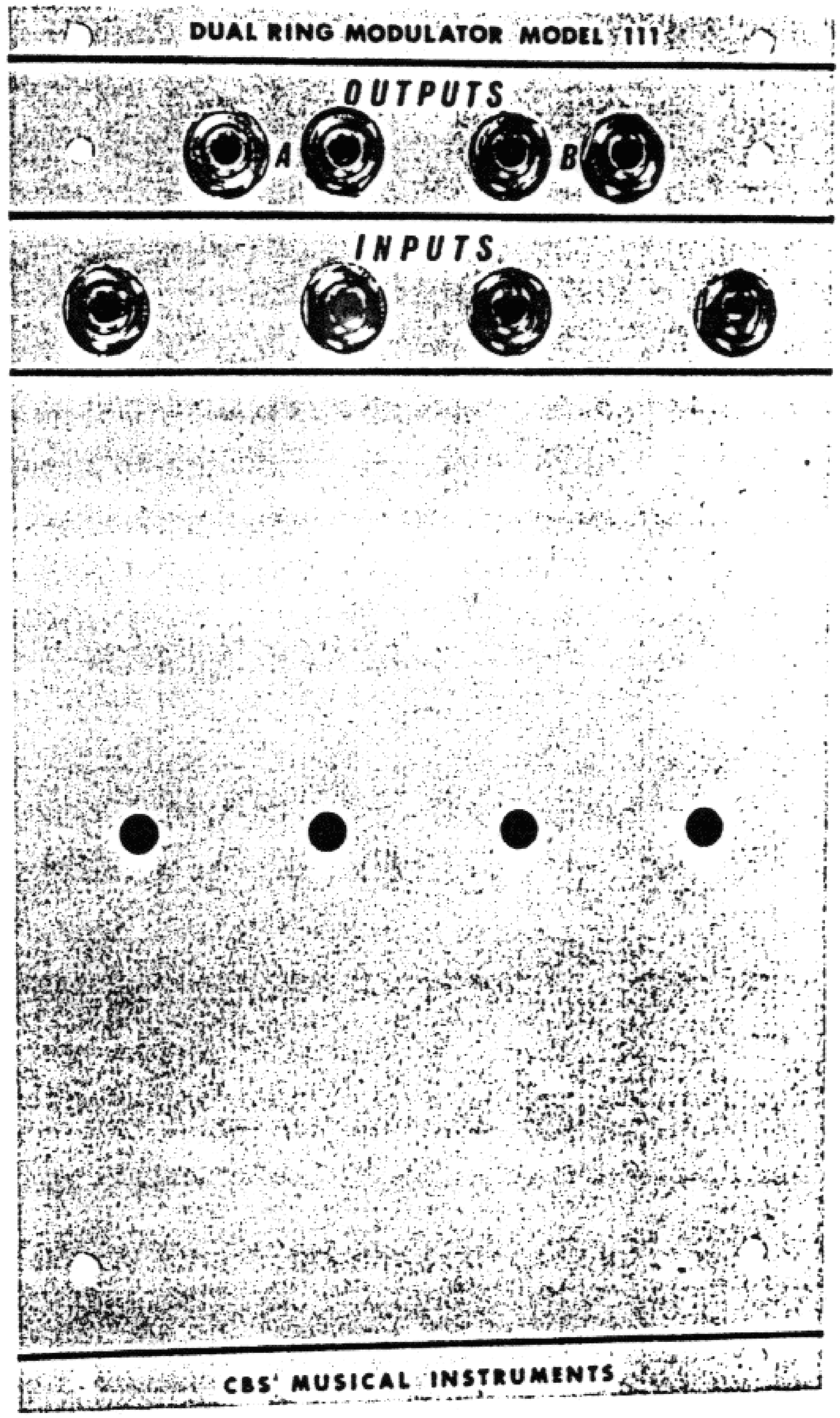
The **signal level control** determines the amplitude of of the output which is processed by the control input.

Model 111 Dual Ring Modulator

Ring modulation is a special kind of amplitude modulation which contains both the same and different frequencies of two input signals. The Model 111 Dual Ring Modulator consists of two independent ring modulators in one panel. Each ring modulator has two **signal inputs** and a pair of **signal outputs.** There are no other controls. It makes no difference which of the two input signals is patched into which input on the panel, as long as both inputs are connected; switching the inputs will result in the same output.



Model 110 Dual Voltage Controlled Gate



Model 111 Dual Ring Modulator

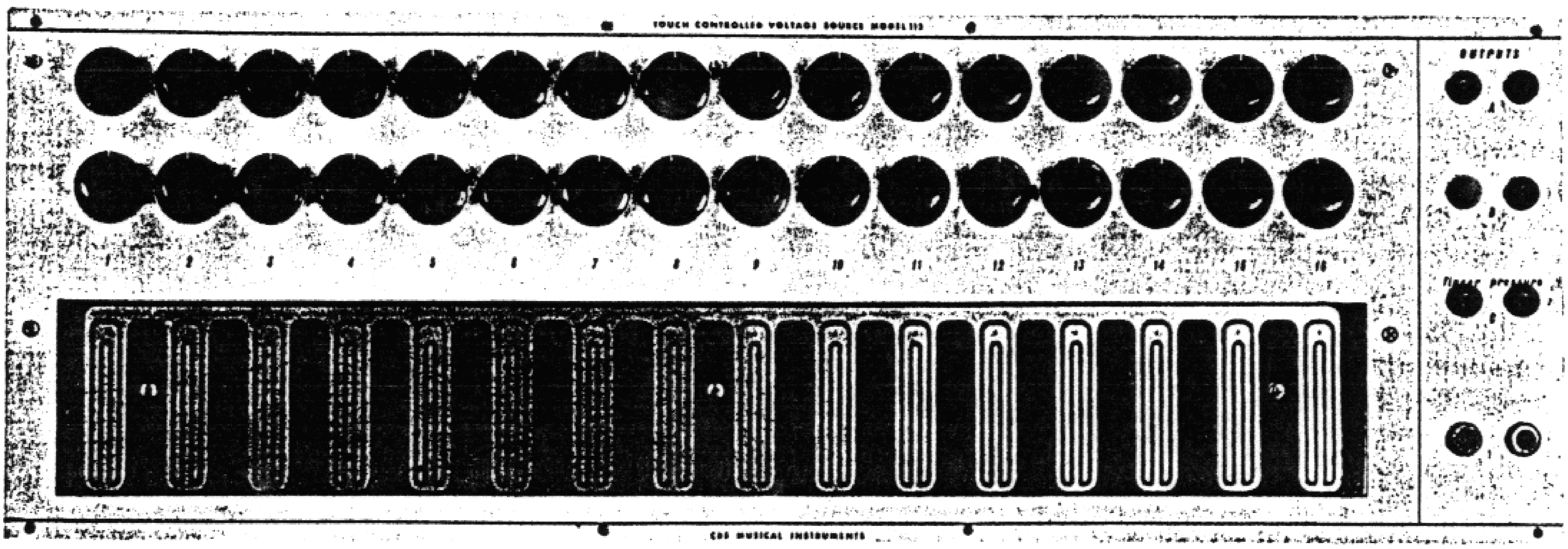
Model 112 Touch Controlled Voltage Source

The Model 112 Touch Controlled Voltage Source is used to initiate **timing pulses** and **control voltages** by manual means. It consists of 16 touch-activated, pressure-sensitive **keys** together with two rows of 16 associated **fixed control voltage dials** and two **control outputs** for each row. There is also a third pair of **control outputs** whose output voltage is proportional to the **finger pressure** on any key, and a fourth pair of **timing pulse outputs.**

The fixed control voltage associated with any key may be determined by the setting on the coresponding dial in either row. Touching a key merely **selects** one of the control voltages in this case.

The value of the control voltage at the third pair of control outputs is proportional to the **finger pressure** on any key. This provides a means of manual dynamic variation of control voltage.

The **timing pulse output** is activated whenever a key is touched. Thus the Model 112 Touch Controlled Voltage Source may be used manually to initiate a note or series of notes with both predetermined and dynamically variable control voltage parameters.

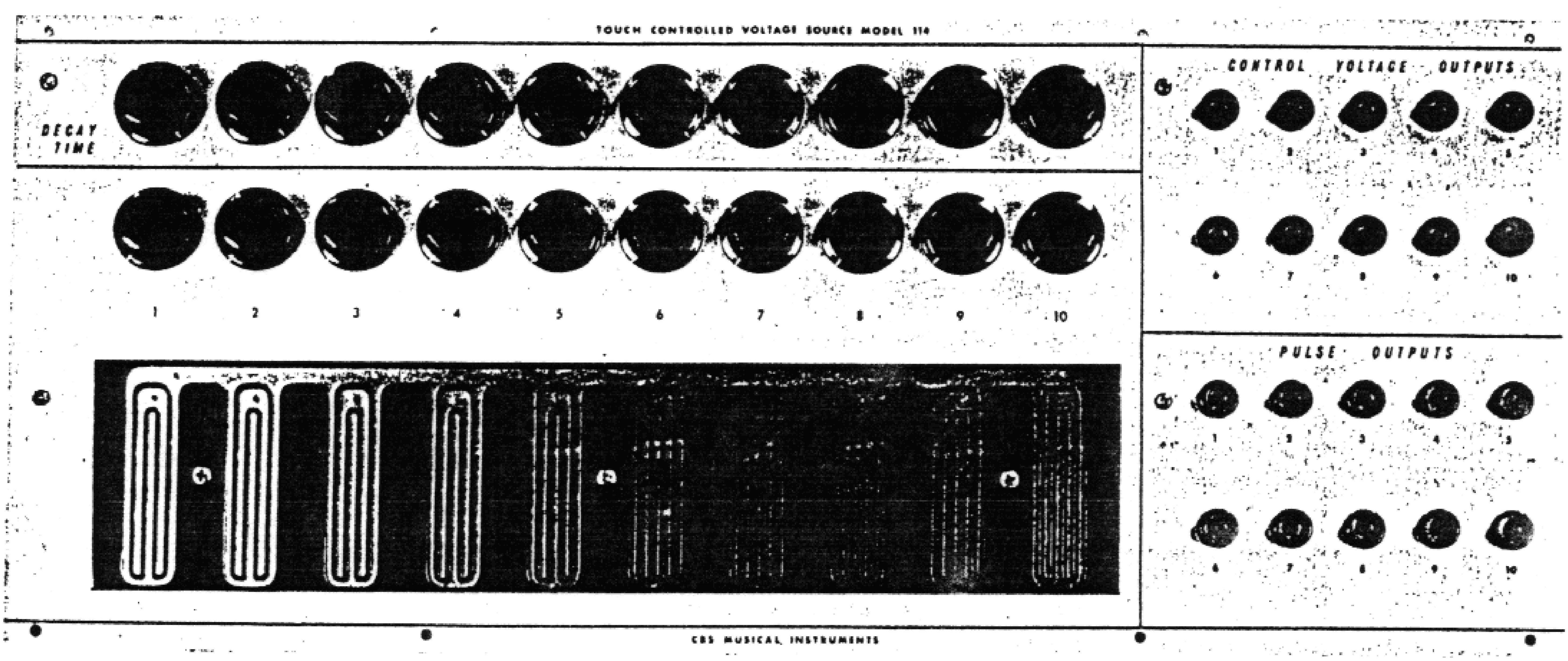


Model 112 Touch Controlled Voltage Source

Model 114 Touch Controlled Voltage Source

The Model 114 Touch Controlled Voltage Source is similar in appearance to the Model 112 Touch Controlled Voltage Source, but it is actually used for very different purposes. It consists of ten pressure-sensitive touch activated **keys** with ten associated **control voltage dials, decay time dials, control voltage outputs,** and **timing pulse outputs.** There are separate control voltage and timing pulse outputs for each key, and each is numbered to indicate the correspondence.

The ten **timing pulse outputs** are activated only when the corresponding key is touched, unlike the Model 112, where the timing pulses are activated when any key is touched. Timing pulses can be used to initiate Model 123 or 146 Sequential Voltage Sources, Model 180 Attack Generators, Model 165 Random Voltage Sources, or Model 140 Timing Pulse Generators.



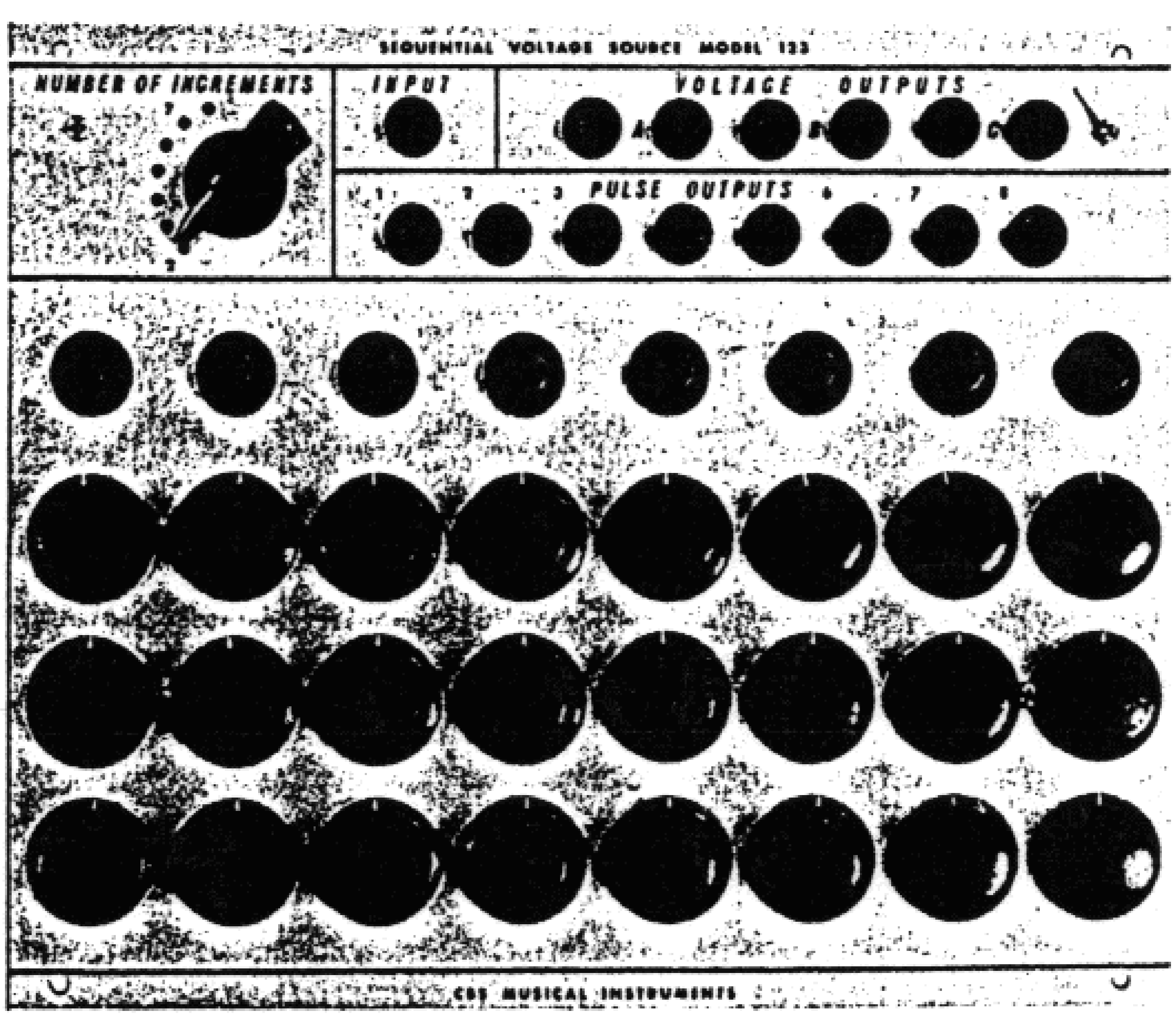
Model 114 Touch Controlled Voltage Source

When the **control voltage dial** for a given key is turned all the way to the left, the control voltage output for that key is determined entirely by finger pressure. When the dial is all the way to the right, the control voltage output is a constant maximum value. At intermediate stages, the control voltage output is a combination of the setting on the dial and finger pressure. This feature of the Model 114 Touch Controlled Voltage Source is particularly useful for controlling Model 110 Voltage Controlled Gates or Model 107 Voltage Controlled Mixers. The keys can then be used to control the amplitudes of a combination of tones which are being mixed into a single output. The correspondence of ten control voltage outputs on the Model 114 Touch Controlled Voltage Source and ten control voltage inputs on the Model 107 Voltage Controlled Mixer is especially convenient.

The **decay time dials** provide an additional level of control that makes possible cross-fading between several tones in a mixture. When the dials are all the way to the left, the control voltage output is released as soon as the finger is taken off the key. As the dials are turned more toward the right, there is an increasing decay time over which the control voltage output drops to zero after the finger is released. Thus, one tone can fade away while another is brought in by slowly increasing finger pressure, or several touch-activated tones can be made to fade away at different rates.

Model 123 Sequential Voltage Source

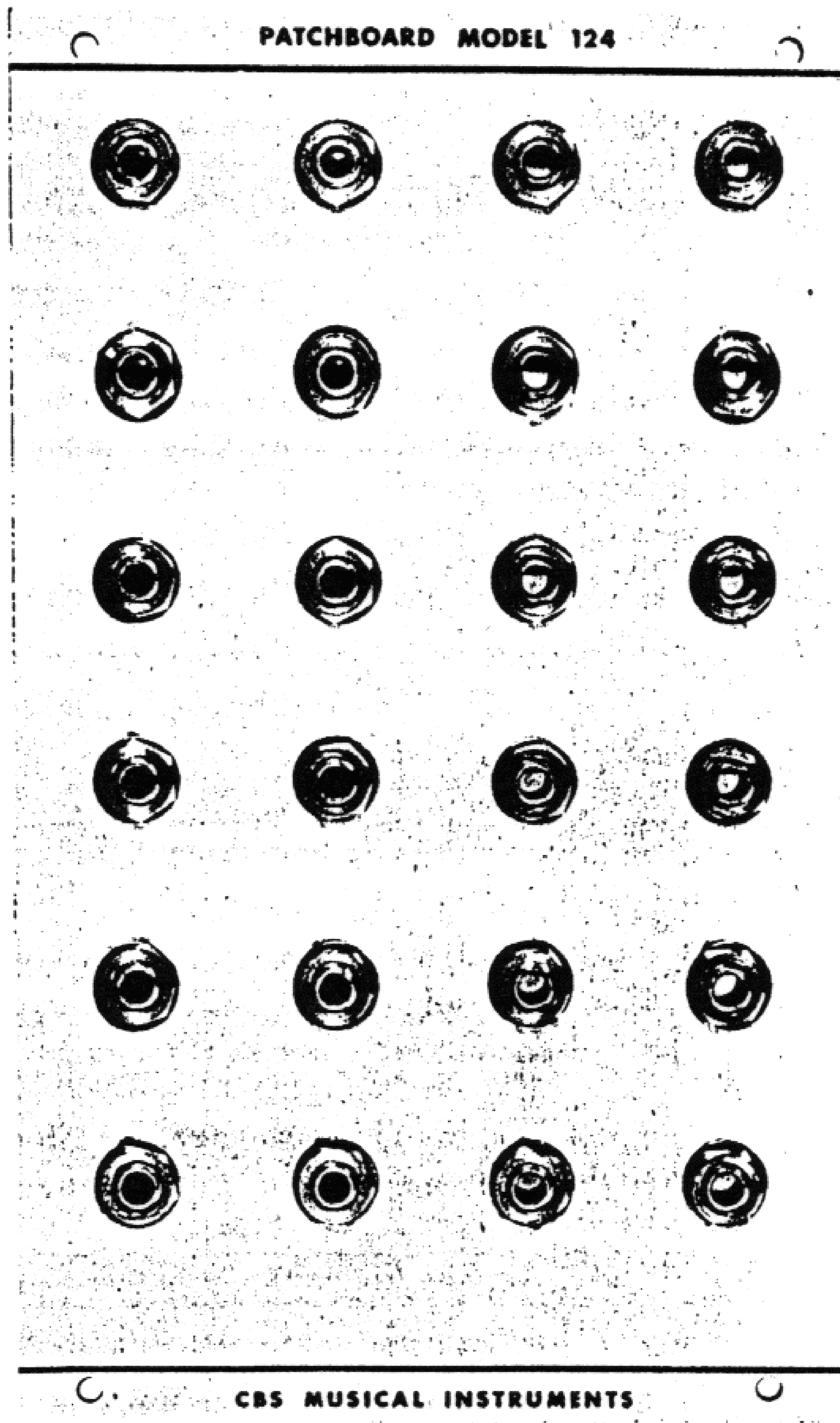
The Model 123 Sequential Voltage Source, one of the most important modules of the Buchla System, produces a repetitive sequence of from two to eight **programmed control voltages** at each of three outputs. Its front panel includes a **timing pulse input,** an **output rotary switch,** three pairs of **control voltage outputs,** eight **timing pulse outputs,** eight red **indicator lamps,** and three rows of eight **control voltage potentiometers.**



Model 123 Sequential Voltage Source

The **timing pulse** input usually comes from a **Model 140 Timing Pulse Generator,** but it may also come from a Touch Controlled Voltage Source. The timing pulse determines **switching** between a **sequence** of between two and eight groups of three **programmed control voltages.** The number of events in the sequence is determined by the **output rotary switch.** Upon receiving a timing pulse, the unit moves to the next group of programmed control voltages. The switching is sequential, so that when it reaches the end of the sequence it returns to the beginning.

The eight red **indicator lamps** show which group of three associated **control voltage potentiometers** are currently in control. The potentiometers are arranged in a 3 x 8 matrix. Each column is associated with a single event, with the corresponding indicator lamp located immediately above. Each row is associated with the same **control voltage output jacks:** the top row feeds jacks "A", the middle row jacks "B" and the bottom row jacks "C". The eight **pulse outputs** are energized as the corresponding segments are switched.



Model 124 Patchboard

Thus, up to three parameters of a repetitive sequence of up to eight notes may be separately and simultaneously controlled. These parameters may correspond, for example, to pitch, amplitude, and duration.

Model 124 Patchboard

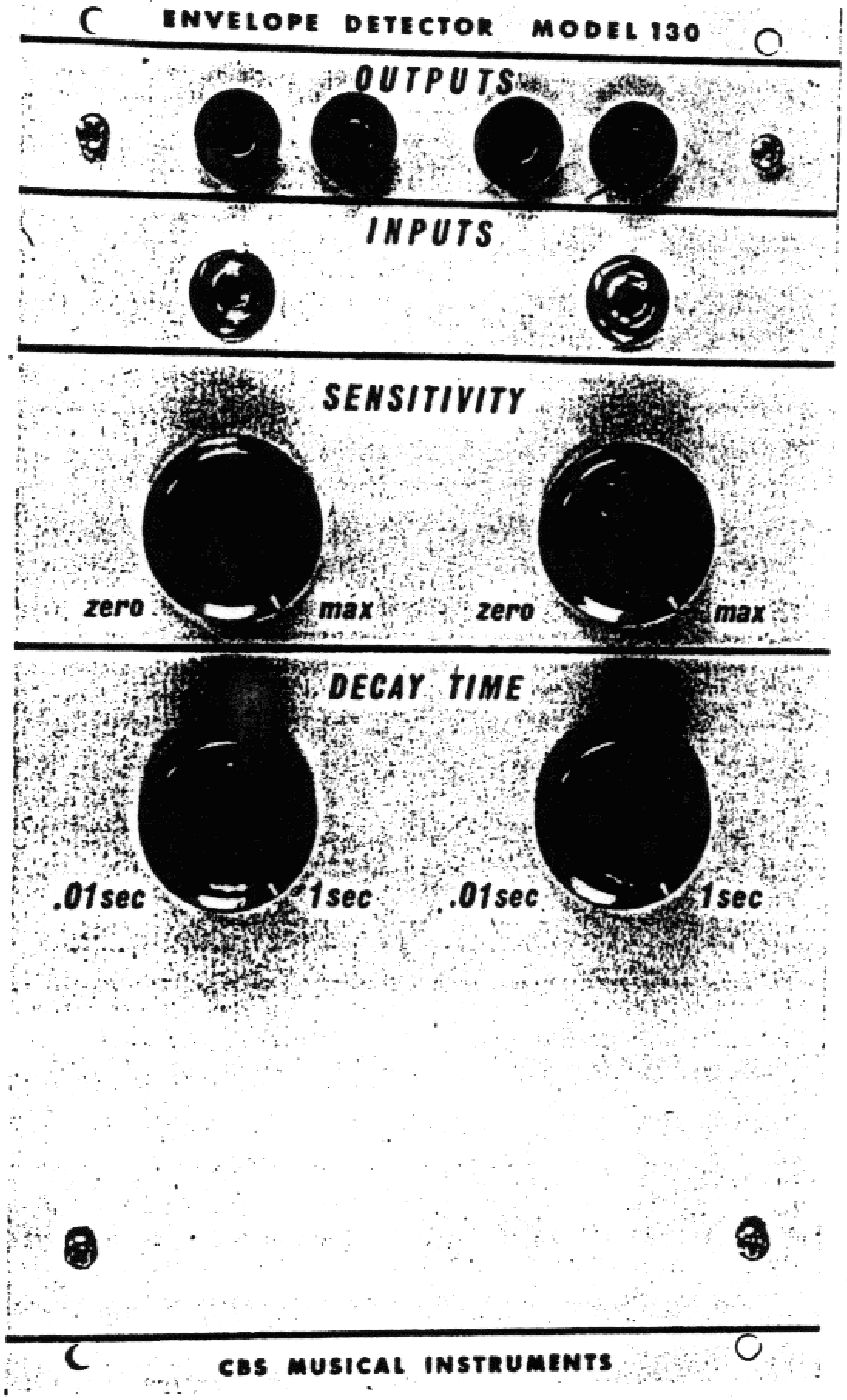
Consists of 24 miniature audio jacks mounted on a panel. Used in studio installations to facilitate connection to tape recorders, narrators, and other auxiliary equipment.

Model 130 Dual Envelope Detector

The Model 130 Dual Envelope Detector produces a control voltage proportional to the instantaneous amplitude of an applied signal. In such a way it can reproduce the envelope of an applied "command" signal or perform other general-purpose functions that involve converting an audio signal into a control voltage.

The side of the front panel of the Model 130 Dual Envelope Detector contains an **audio signal input,** a pair of **control voltage outputs,** and dials for the **sensitivity** and **decay time.** The **sensitivity** control determines the proportion of the input signal which the envelope detector will respond to. When it is set at zero, all the way to the left, it will not respond regardless of the amplitude of the input signal. As it is turned more toward the right, the envelope detector will respond to an increasingly softer input signal until, when it is all the way to the right, it will respond to any level input signal. (It is important to remember, however, that its output is still proportional to the input signal, so that a very soft signal will produce a very small value.) Thus, the sensitivity control acts as a threshold device.

The **decay time dial** provides an additional level of control over the rate at which the control voltage output fades out. When it is all the way to the left, the control voltage is released in exact correspondence with the amplitude of the input signal. When it is moved more toward the right, the release is not instantaneous, but is allowed to fade out over a longer time. The decay time can be varied from .01 to 1 second.



Model 130 Dual Envelope Detector

Model 140 Timing Pulse Generator

The Model 140 Timing Pulse Generator is used to initiate **timing pulses** in various ways. Its front panel has two **timing pulse outputs** for **all pulses** and two for **alternate pulses,** two **control voltage inputs** for the **pulse length** and **period,** two **timing pulse inputs** for the **start-stop mode,** a three-position **rotary switch,** a **push button, pulse length** and **period** (tempo) controls, and **external-internal switches** for the **pulse length** and **period.**

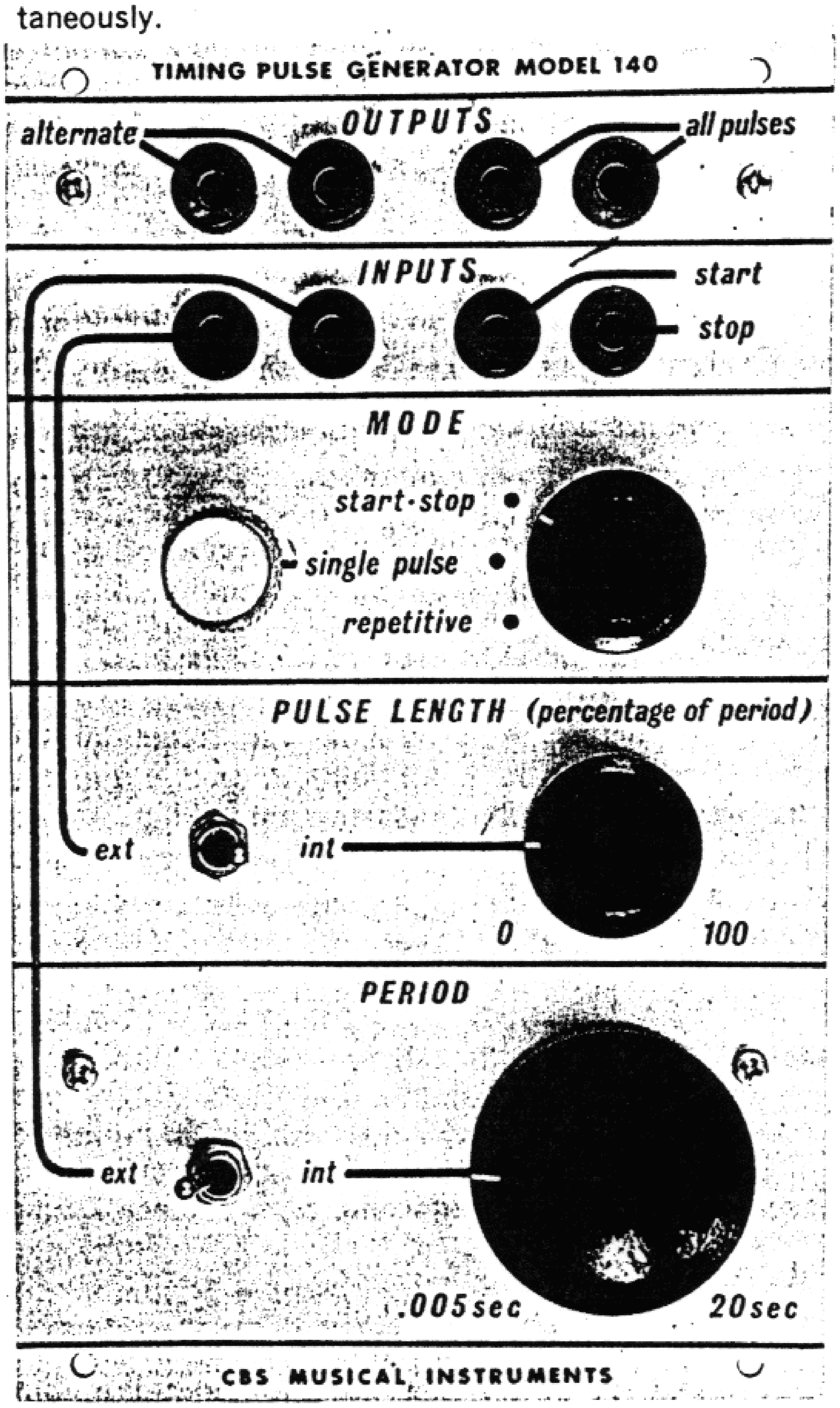
The **timing pulse outputs** are available at the top jacks. The right jacks output all pulses and the left jacks alternate pulses only.

The **mode switch** has three positions: start-stop, **single pulse,** and **repetitive.** In the **start-stop mode,** the action of the Timing Pulse Generator is controlled by **external** timing pulses, which may come from another Timing Pulse Generator or a Touch Controlled Voltage Source. In the single pulse mode, a new pulse is generated only when the **push button** is depressed. In the **repetitive mode,** new pulses are generated at a rate determined by the **period** (tempo) control.

The **period** (tempo) control, if determined internally, will generate a new pulse at a regularly repeating **tempo** between .005 seconds (200 cycles per second) and 20 seconds. The period may also be controlled **externally** by a **control voltage.** If it is desired to use, for example, one of the control voltage outputs of the **Model 123 Sequential Voltage Source** to determine **duration between successive attacks,** it must be patched into this control input. Thus, the Timing Pulse Generator controls and is controlled by the Sequential Voltage Source.

The **pulse length** is always determined as a **percentage** of the **period,** and may be used to control the duration on a **Model 180 Dual Attack Generator.** (See section 7-180.) If determined **internally,** the pulse length may be set to a constant between 0 and 100 per cent. It may also be determined **externally** by a **control voltage.**

The Model 140 Timing Pulse Generator is usually used to control either a Model 123 Sequential Voltage Source or a Model 165 Dual Random Voltage Source, or both, and a Model 180 Dual Attack Generator simultaneously.



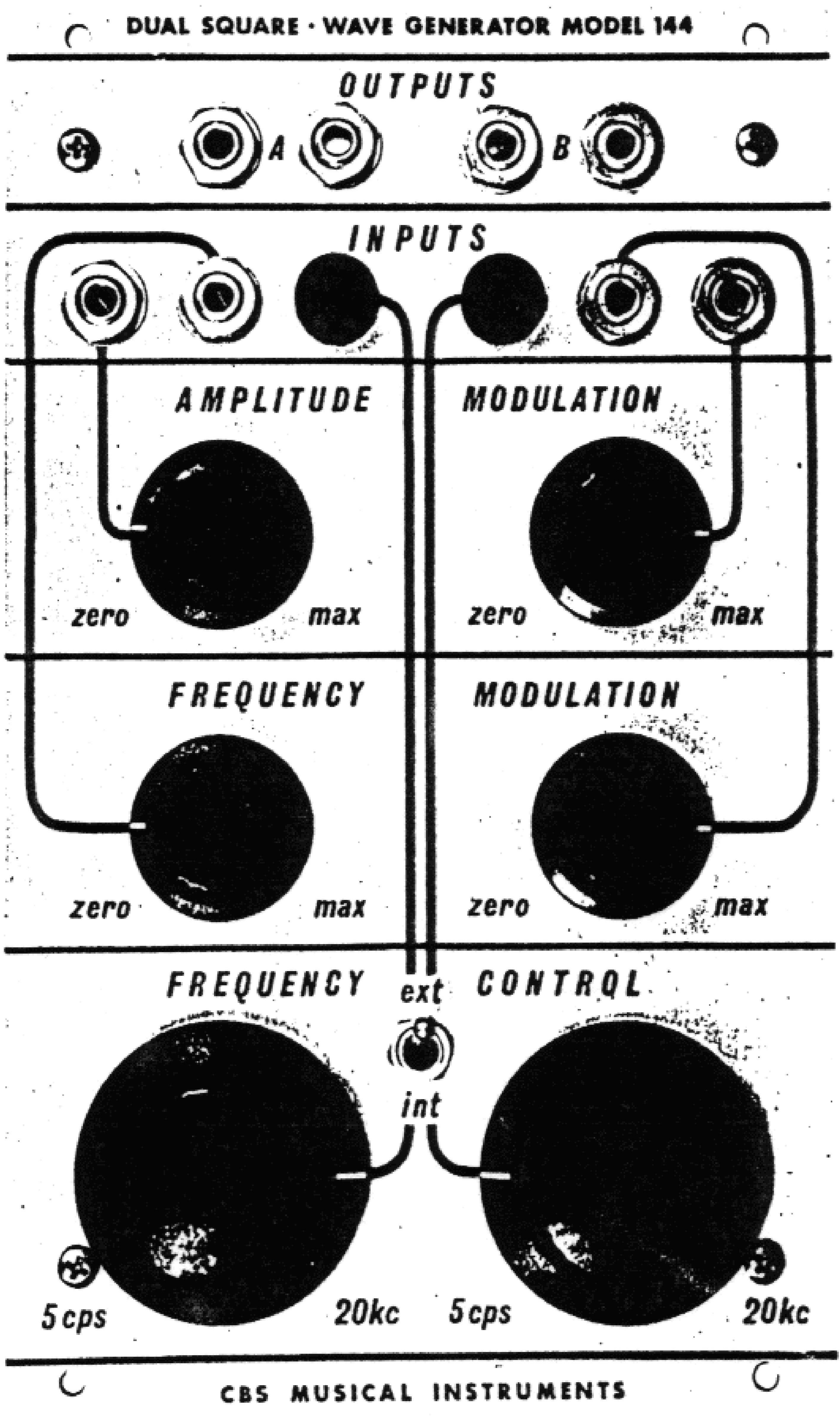
Model 140 Timing Pulse Generator

Model 144 Dual Square Wave Oscillator

The Model 144 Dual Square Wave Oscillator is a basic signal generating module of the Buchla System. Each oscillator contains two **signal outputs,** a **control voltage input,** an **amplitude modulation control** with an associated **signal input,** a **frequency modulation control** with an associated **signal input,** and a **frequency control** dial. There is also an **internal-external switch** which allows the frequencies of both oscillators to be determined by external **control voltages.** Frequencies are continuously variable between 5 and 20,000 cycles per second.

The **frequency modulation** (vibrato) and **amplitude modulation** (tremolo) controls allow the signal output to be varied. Both controls require an external **signal input** (usually from another oscillator), which determines the **rate** (speed) of modulation. The control dial determines the **bandwidth** (amplitude of the modulation, and is continuously variable between zero and the maximum amount of the input signal. This is one of the few cases in the Buchla System where a **signal** is used to determine an aspect of an instrument's operating characteristics.

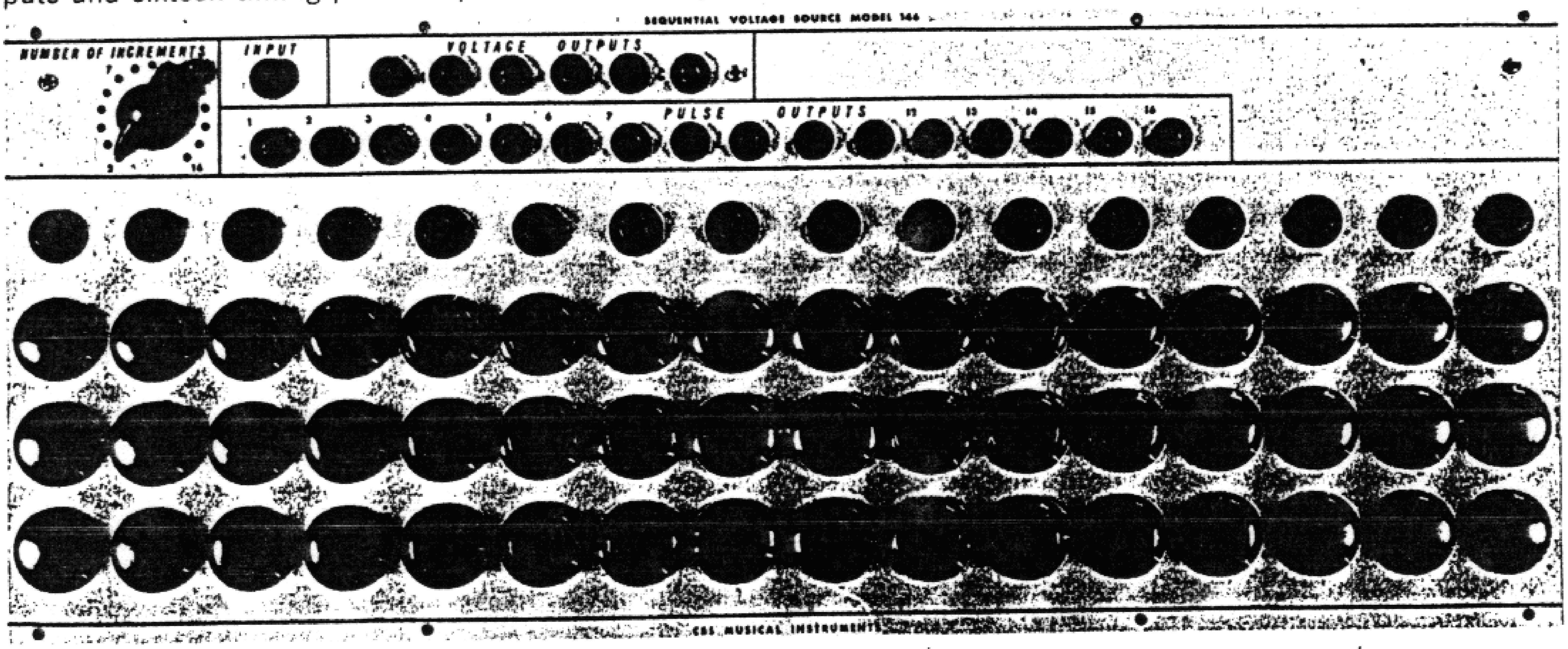
It is a curious feature of the Buchla System that only the square wave oscillators have amplitude modulation controls (cf. section 7-158).



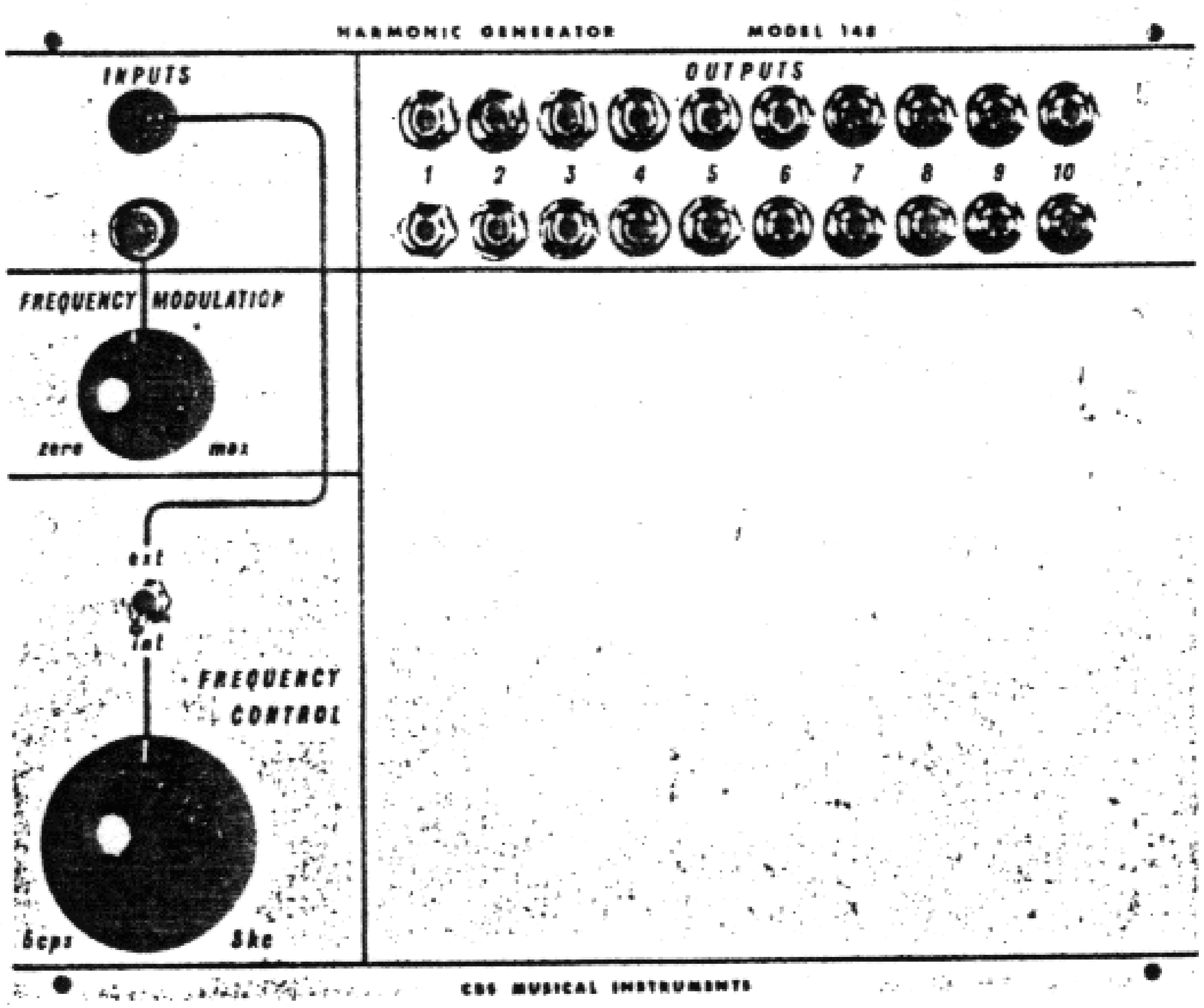
Model 144 Dual Square Wave Oscillator

Model 146 Sequential Voltage Source

The Model 146 Sequential Voltage Source is identical to the Model 123 Sequential Voltage Source, except that it has sixteen groups of three control voltage outputs and sixteen timing pulse outputs instead of eight. For this reason it takes up twice as much panel space as the Model 123 Sequential Voltage Source, but in all other respects it is identical.



Model 146 Sequential Voltage Source



Model 148—Harmonic Generator

Model 156 Dual Control Voltage Processor

The Model 156 Dual Control Voltage Processor is used to combine, transpose, compress and invert control voltages. Each channel has two **control voltage inputs,** two **control voltage outputs,** two **voltage selector dials** and an **internal voltage source.** The left and right sides of the module have distinctly different functions, unlike most dual units.

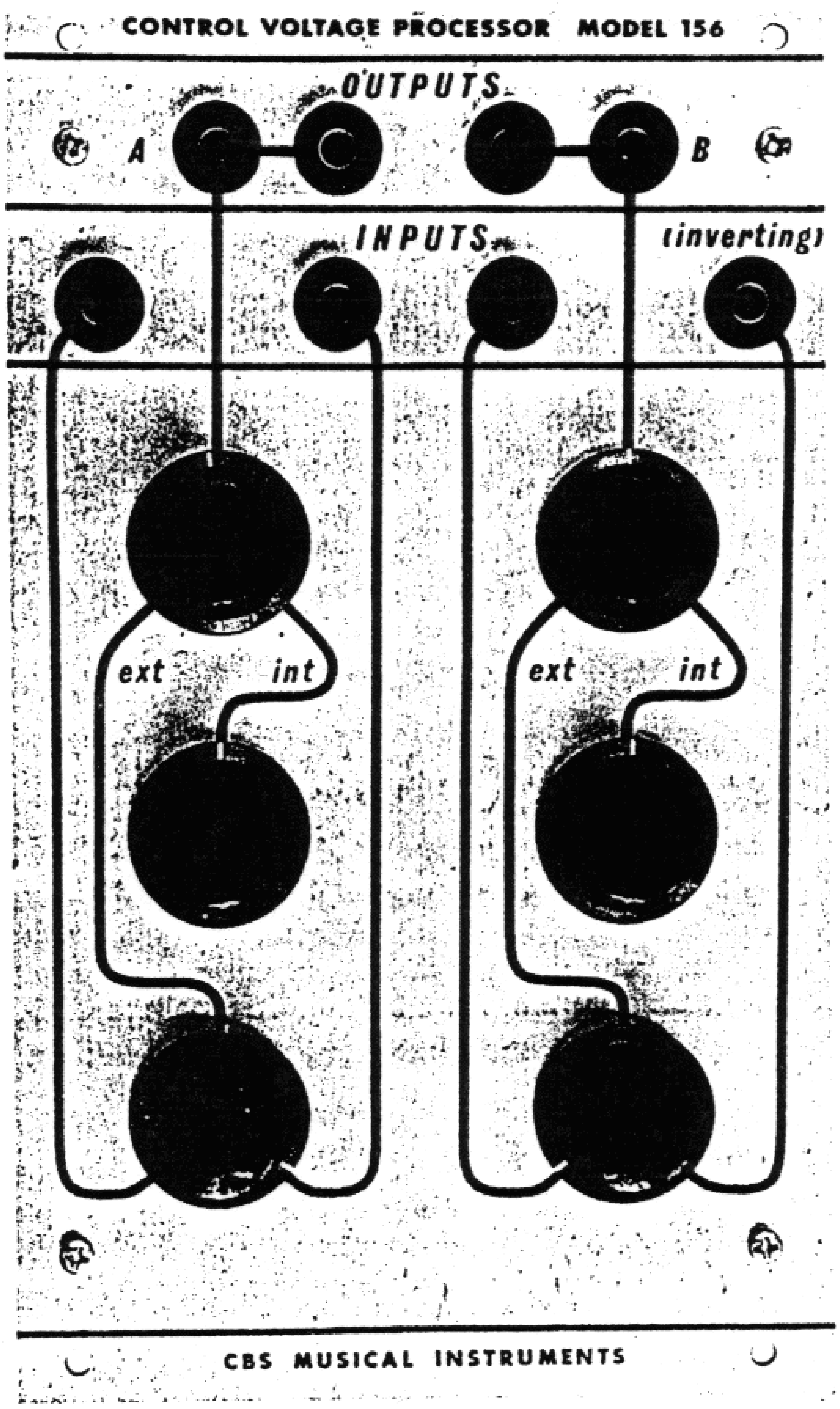
Both of the **control voltage inputs** (in each channel) are connected to the bottom **voltage selector dial.** In the **left** unit, the voltage selector dial simply **combines** the two voltages, whereas in the **right** unit it **inverts** the voltage at the **right** input, such that the maximum voltage (15 volts) is transformed into the minimum (.5 volts) and vice-versa. Intermediate values are inverted modulo 14.5 (+.5) volts. (E. g., 6 volts would be inverted into 14.5 (+.5) —6 (—.5) = 9.5 volts.) Thus, frequency is inverted modulo 20,000 (—5) c.p.s.

The bottom **voltage selector dial** simply **combines** a proportion of the left and right control voltage inputs and feeds the result to the top dial. When the bottom dial is all the way to the left, only the left input is fed to the top dial, and when it is all the way to right, only the right input is fed to the top dial. When it is set at some intermediate value, some proportion of each input is fed to the top dial, so that the maximum voltage that it could ever put out would be 15 volts. (Thus, setting the dial exactly half way in the middle will cause **half** the voltage of each input to be combined (or inverted) and fed to the top dial.)

The **middle** dial sets the value of the **internal voltage source.** If no inputs are patched into the unit, the output will simply be this value, so that the unit may be used as a separate fixed voltage source.

The top **voltage selector dial** determines what proportion of the combined inputs and the internal voltage source is fed to the outputs. When it is set all the way to the left, only the inputs are fed to the ouput, and when it is set all the way to the right, only the internal voltage source is fed to the output. Intermediate values determine what **proportion** of these two sources is fed to the output, so that when it is more to the right, a greater proportion of the internal voltage source is fed to the output, and when it is more to the left, a greater proportion of the inputs is fed to the output. Thus, turning the dial toward the right gradually **compresses the** voltages until they are equal to the internal voltage source. When the top dial is set at some intermediate value, the **internal voltage source** can be used to **transpose** the combined inputs up or down uniformly.

Thus, both units can be used to **transpose, compress,** and **combine** control voltages, and the right unit can be used to **invert** control voltages as well.



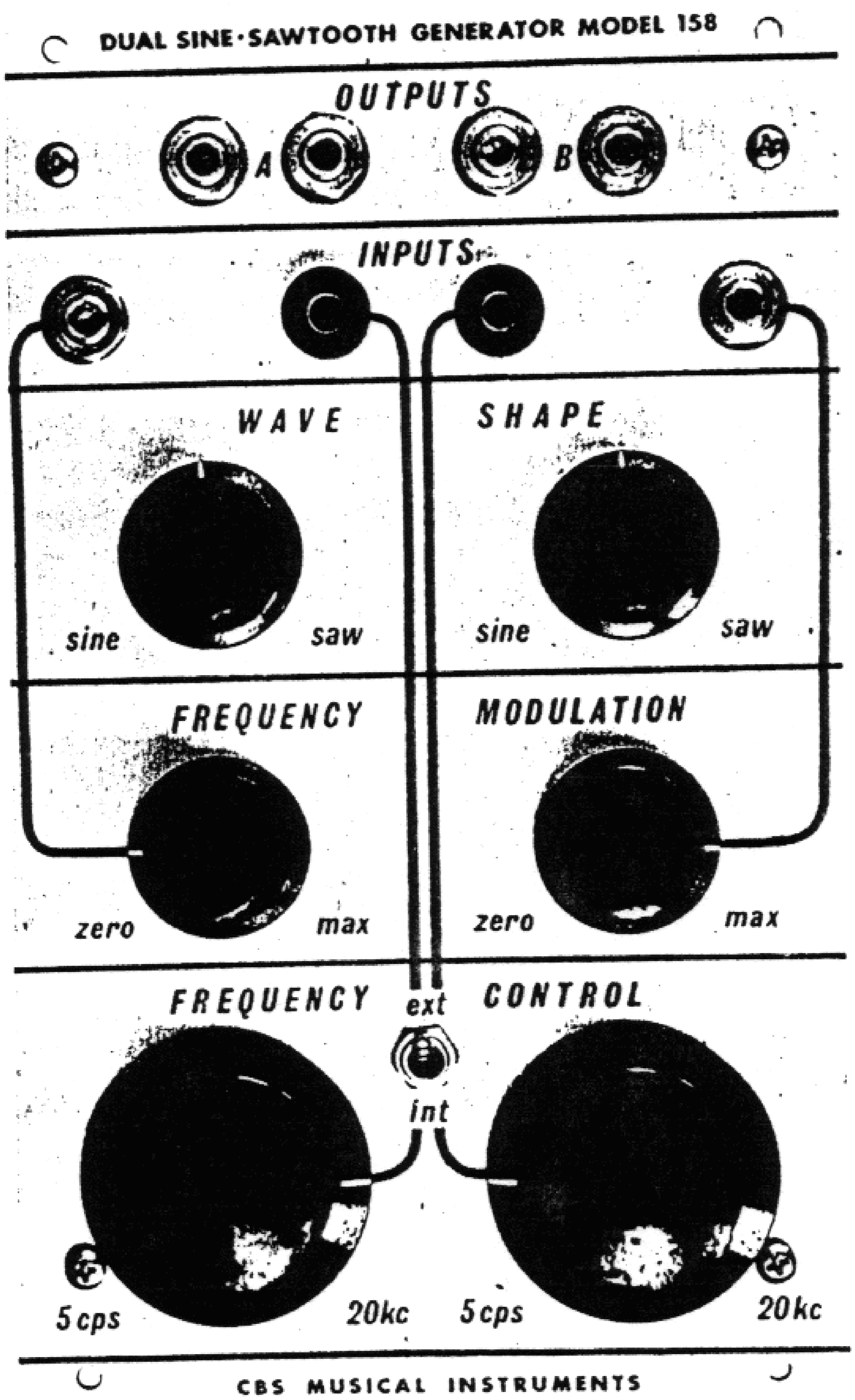
Model 156 Dual Control Voltage Processor

Model 158 Dual Sine-Sawtooth Oscillator

The Model 158 Dual Sine-Sowtooth Oscillator is similar in appearance to the Model 144 Dual Square Wave Oscillator. Each oscillator contains two **signal outputs,** a **control voltage input,** a **wave shape control,** a **frequency modulation control** with an associated signal input, and a **frequency control dial.** There is also an **internal-external switch** which affects both oscillators, allowing their frequencies to be determined by an external control voltage. Frequencies are continuously variable between 5 and 20,000 cycles per second.

The **wave shape control** allows the **waveform** of the output to be continuously varied between a **sine** wave and a **sawtooth** wave. When it is all the way to the left, the oscillator produces a sine wave, and turning it to the right gradually introduces upper partials until the full sawtooth wave is reached.

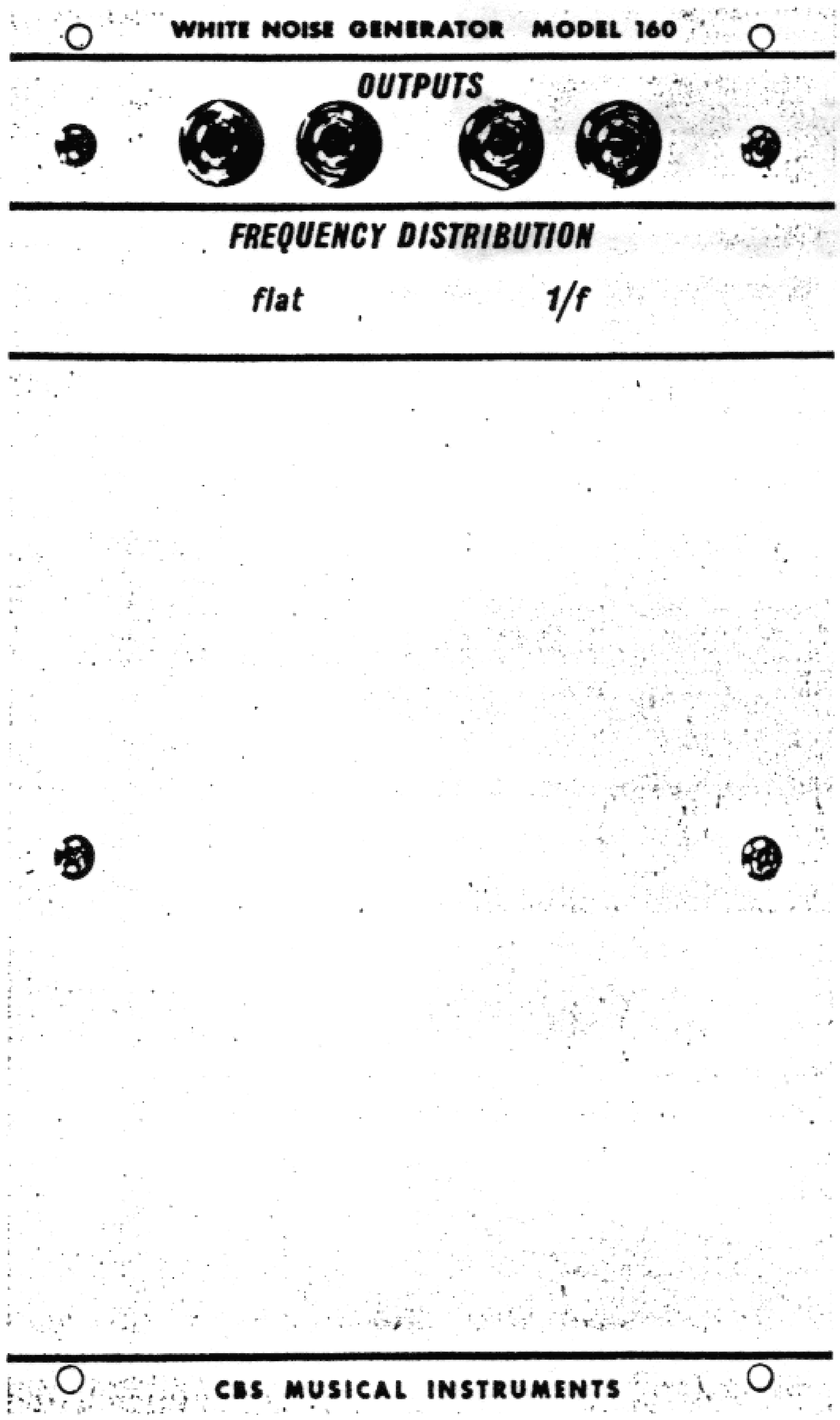
The frequency modulation control requires an external **signal input,** which determines the **rate** (speed) of frequency modulation (vibrato), while the control itself determines the **bandwidth** (amplitude), and may be continuously varied between zero and the full frequency value of the signal input (cf. section 7-144.).



Model 158 Dual Sine-Sawtooth Oscillator

Model 160 White Noise Generator

The Model 160 White Noise Generator produces **white noise** with a flat frequency distribution from 5 to 20,000 cycles per second and weighted noise with a constant power per octave distribution. Its front panel contains two **signal outputs.**

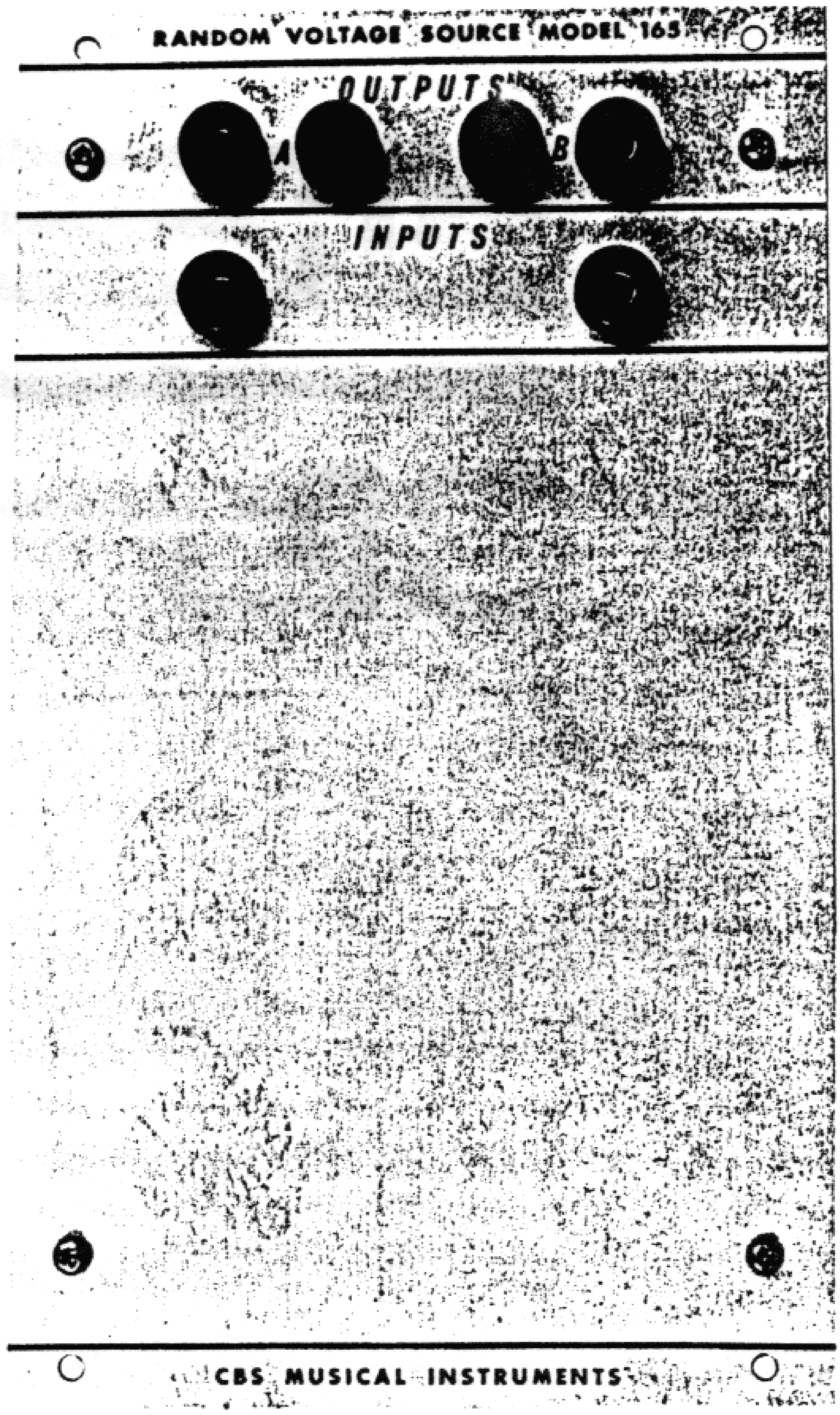


Model 160 White Noise Generator

Model 165 Dual Random Voltage Source

The Model 165 Dual Random Voltage Source produces two uncorrelated, random **control voltage** outputs whenever it receives a **timing pulse** trigger. Its panel contains two separate **timing pulse inputs** and two **control outputs** for each channel. The module can be used to randomize frequency, amplitude, time, or any other parameter determined by a control voltage.

(Note: this unit produces a "click" whenever it receives the timing pulse trigger, which signifies that it has generated a new random voltage. This click is not part of the output and does not affect the signal in any way.)



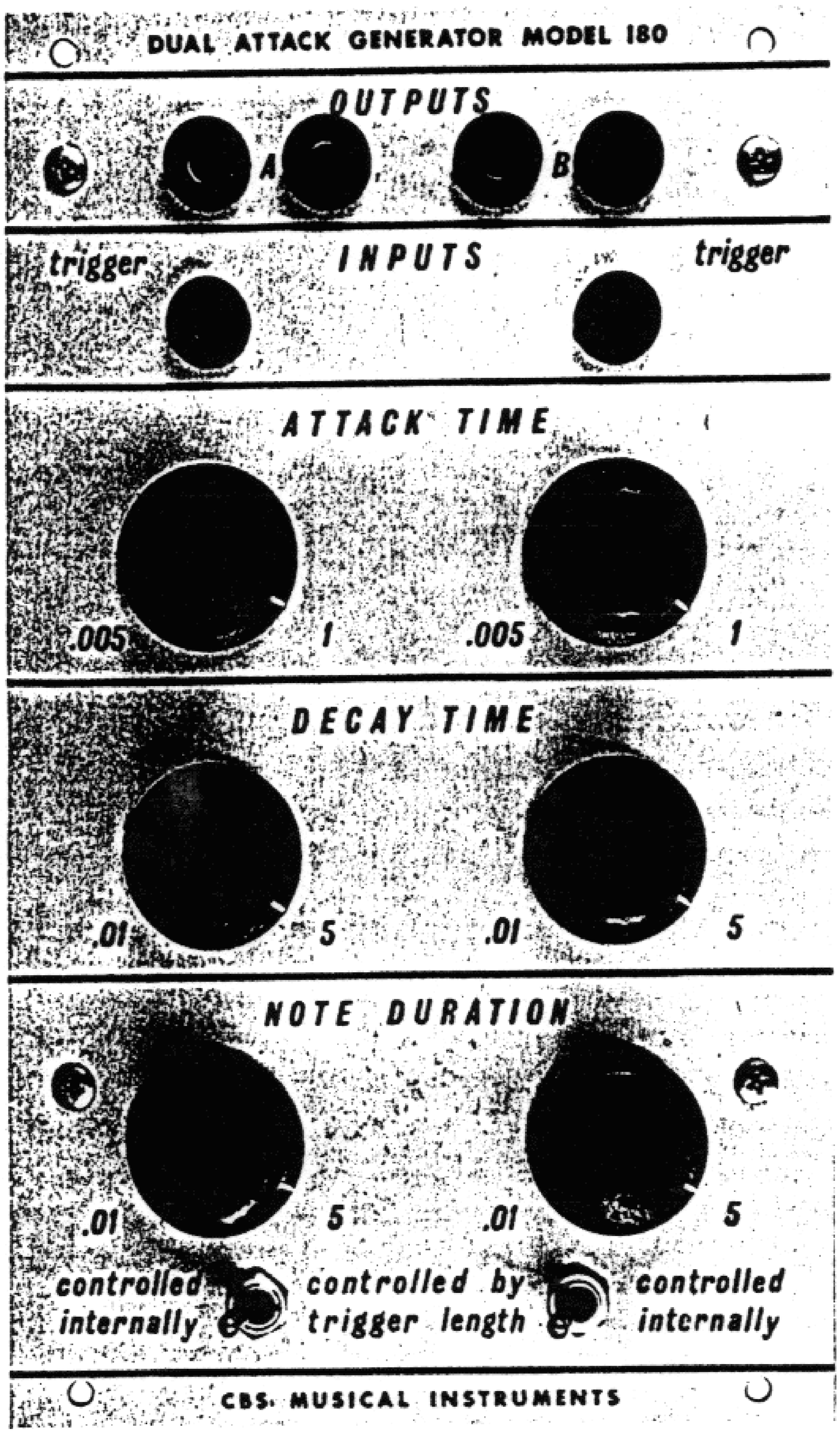
Model 165 Dual Random Voltage Source

Model 180 Dual Attack Generator

The Model 180 Dual Attack Generator produces an **envelope control voltage** initiated by a **timing pulse.** The two units in its panel are entirely separate. Each Attack Generator has two **control voltage** outputs, a **trigger** (timing pulse) **input,** separate controls for **attack time, decay time,** and **note duration,** and an **external-internal** switch which allows the **note duration** to be determined by the **trigger length.**

The **timing pulse** is initiated either by a Model 140 Timing Pulse Generator or a Touch Controlled Voltage Source. The **attack time** is variable from .002 to 1 second; **decay time** from .002 to 5 seconds; **duration** from .002 to 5 seconds. The **mode** of attack and decay is assumed to be **exponential.**

Since the output of the Model 180 Dual Attack Generator is a **control voltage,** it must be used together with a Model 110 Dual Voltage Controlled Gate to apply the envelope to a **signal.** Of course, the unit can also be used to control any parameter, such as frequency, directly.



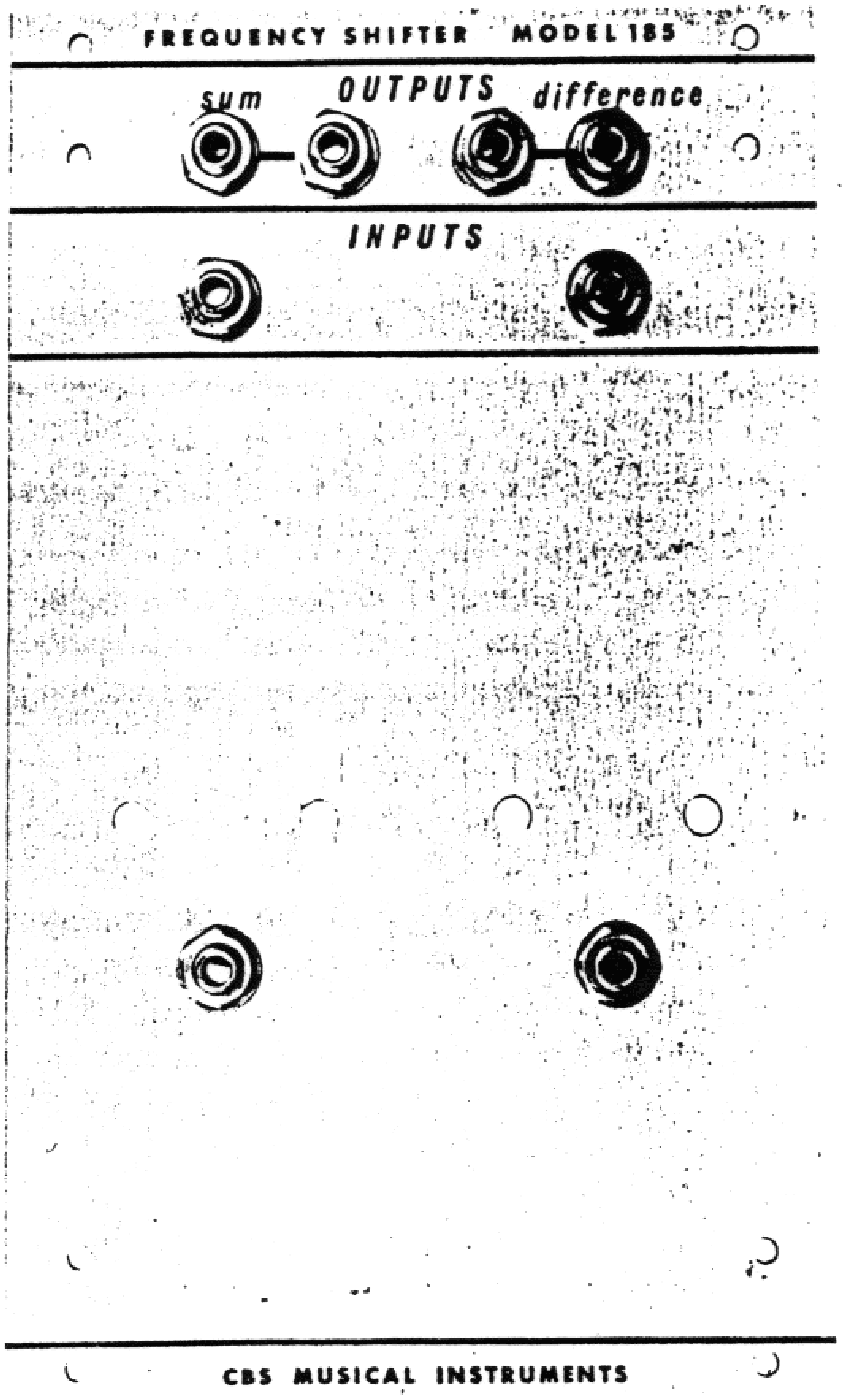
Model 180 Dual Attack Generator

Model 185 Frequency Shifter

The Model 185 Frequency Shifter is used to shift frequencies of an input signal by an amount determined by another applied carrier frequency. The shifting is applied uniformly to all frequencies in the input signal, so that the unit is not a **transposing** device, but a device for obtaining new **timbres,** usually containing **non-harmonic partials.**

The front panel of the Model 185 Frequency Shifter contains two **signal inputs** and four **signal outputs,** two of which are marked "sum" and two of which are marked " difference". The left signal input is for the **signal** and the right is for the **carrier frequency.** In the **sum outputs** the carrier frequency is **added** to the frequencies of the input signal, and in the **difference outputs** the carrier frequency is **subtracted** from the input signal. In the case of the difference outputs only, **negative frequencies** may be present and audible. In the case of sum outputs, frequencies shifted above the limits of audibility will simply be lost.

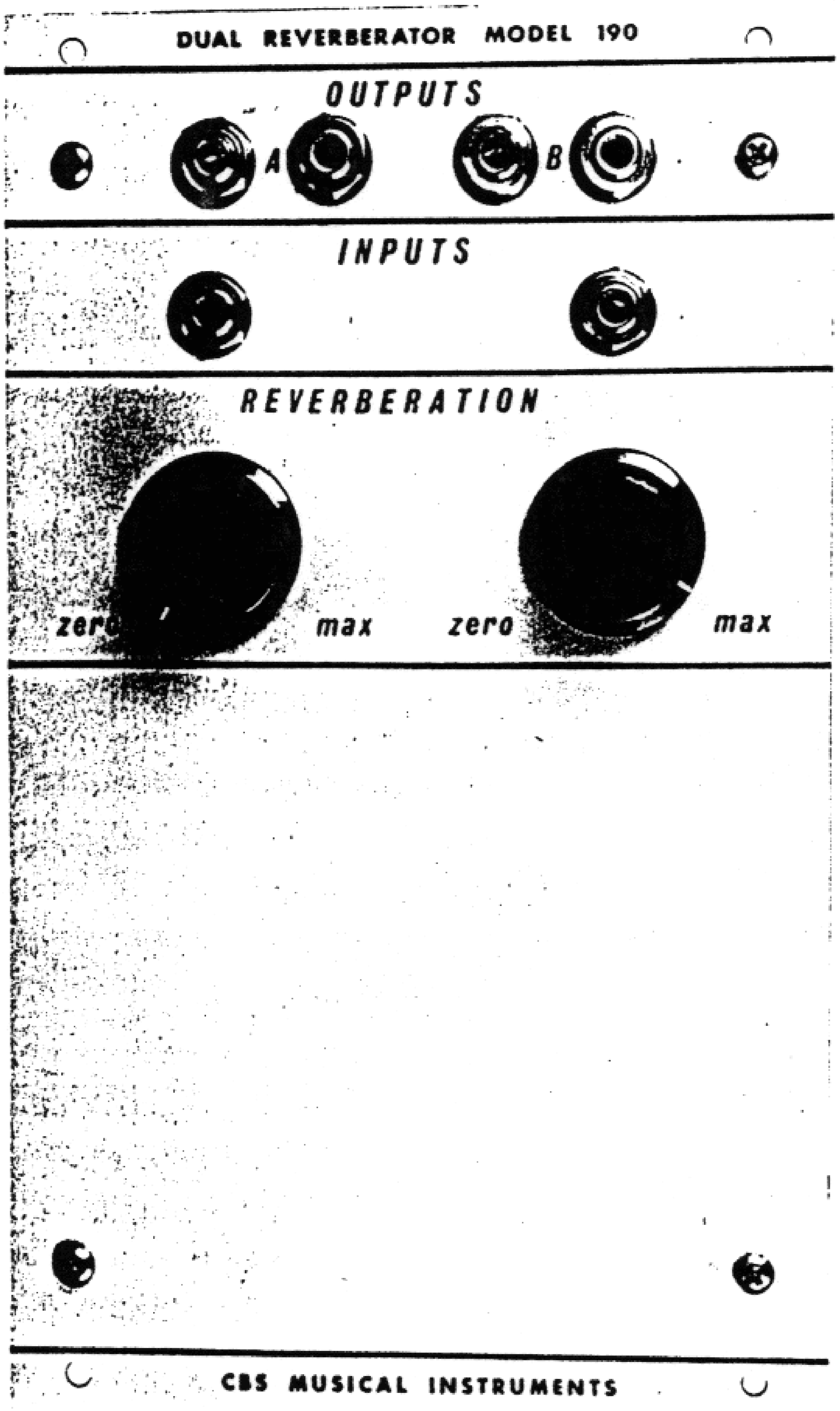
If the **sum** and **difference** outputs are **mixed** into one signal, the Model 185 Frequency Shifter produces **ring modulation.**



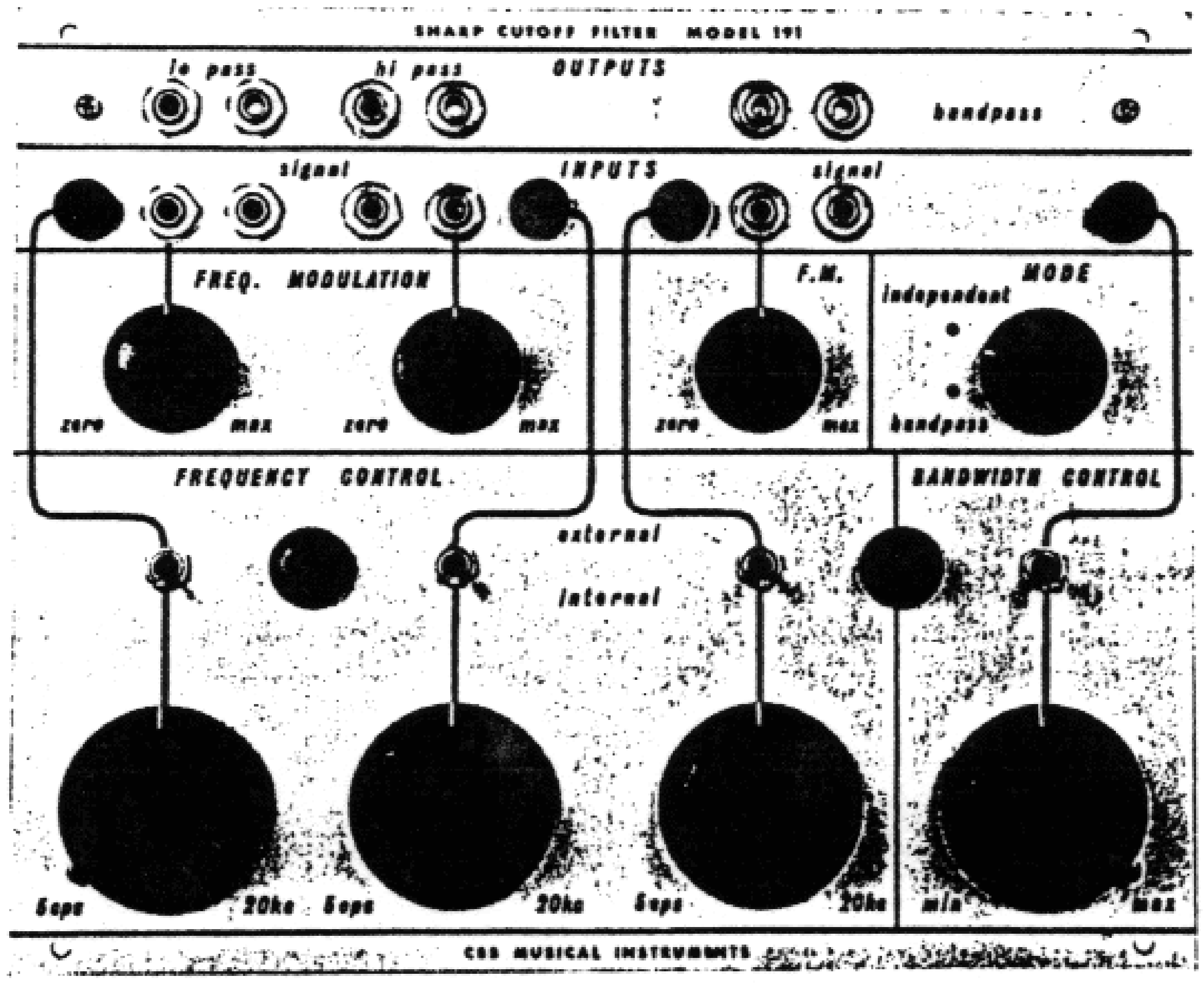
Model 185 Frequency Shifter

Model 190 Dual Reverberation Unit

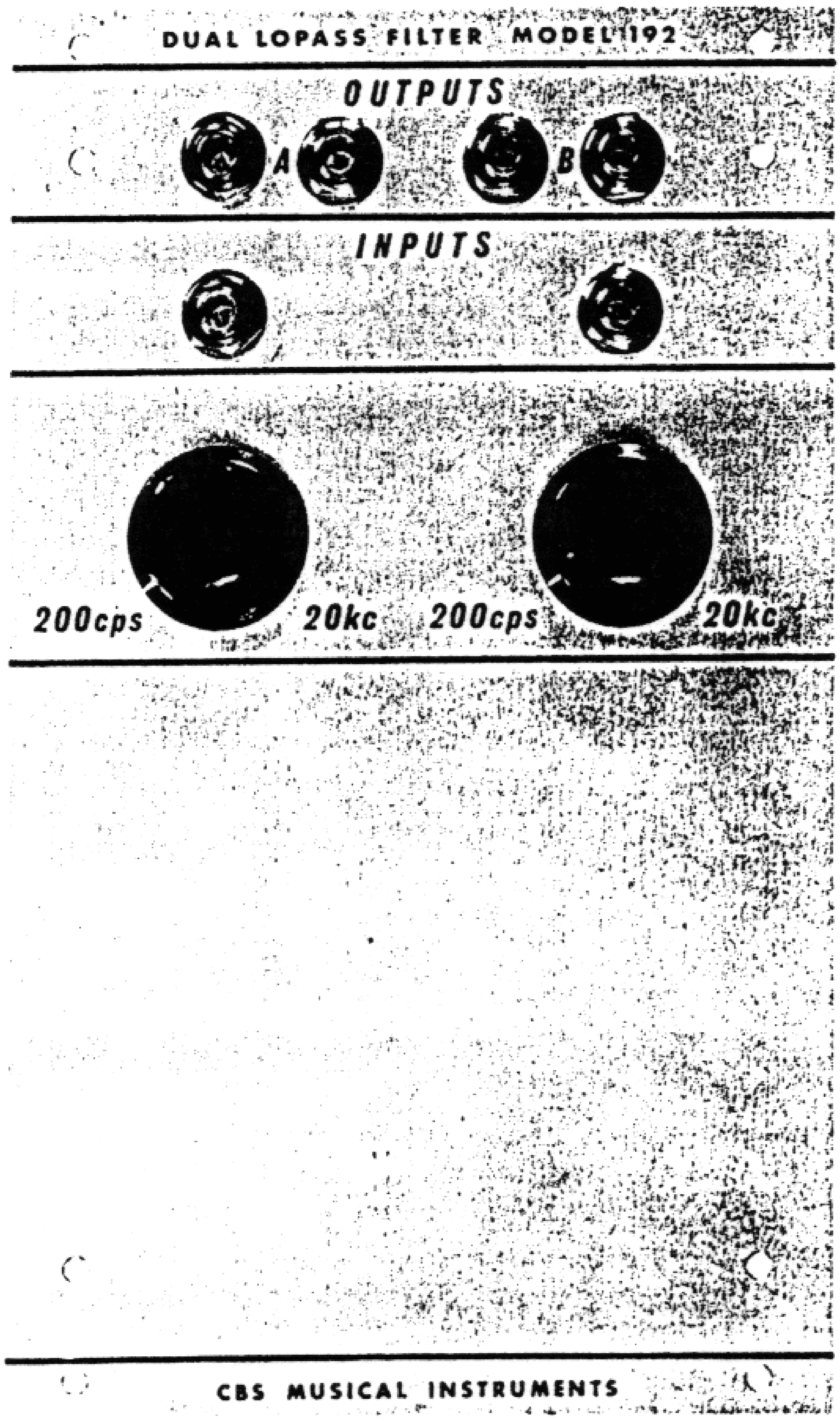
The Model 190 Dual Reverberation Unit contains two independent spring type reverberators. Each reverberator contains a **signal input,** two **signal outputs,** and a **reverberation control dial.** The degree of reverberation is continuously variable by the reverberation control dial.



Model 190 Dual Reverberation Unit

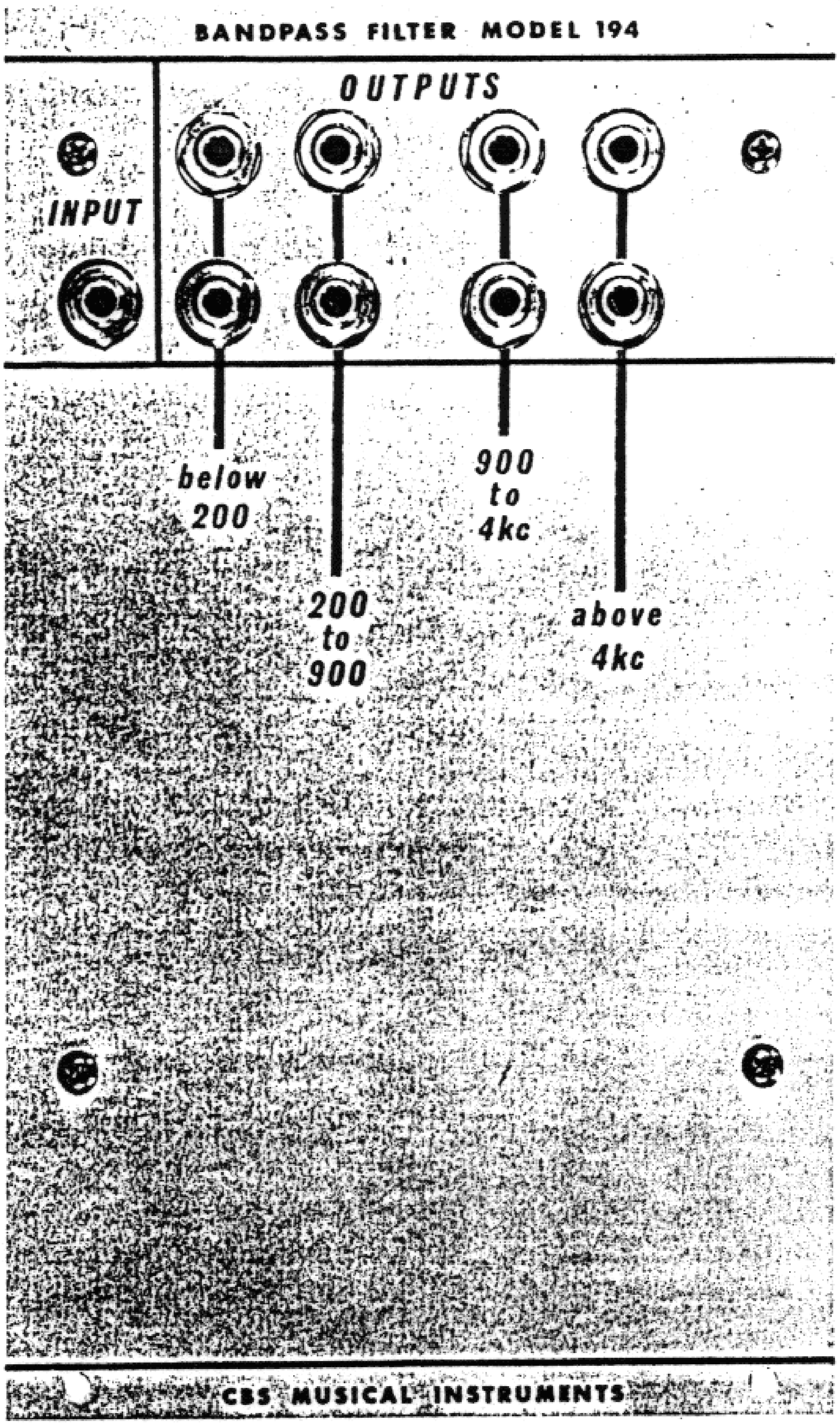


Model 191 — Sharp Cutoff Filter



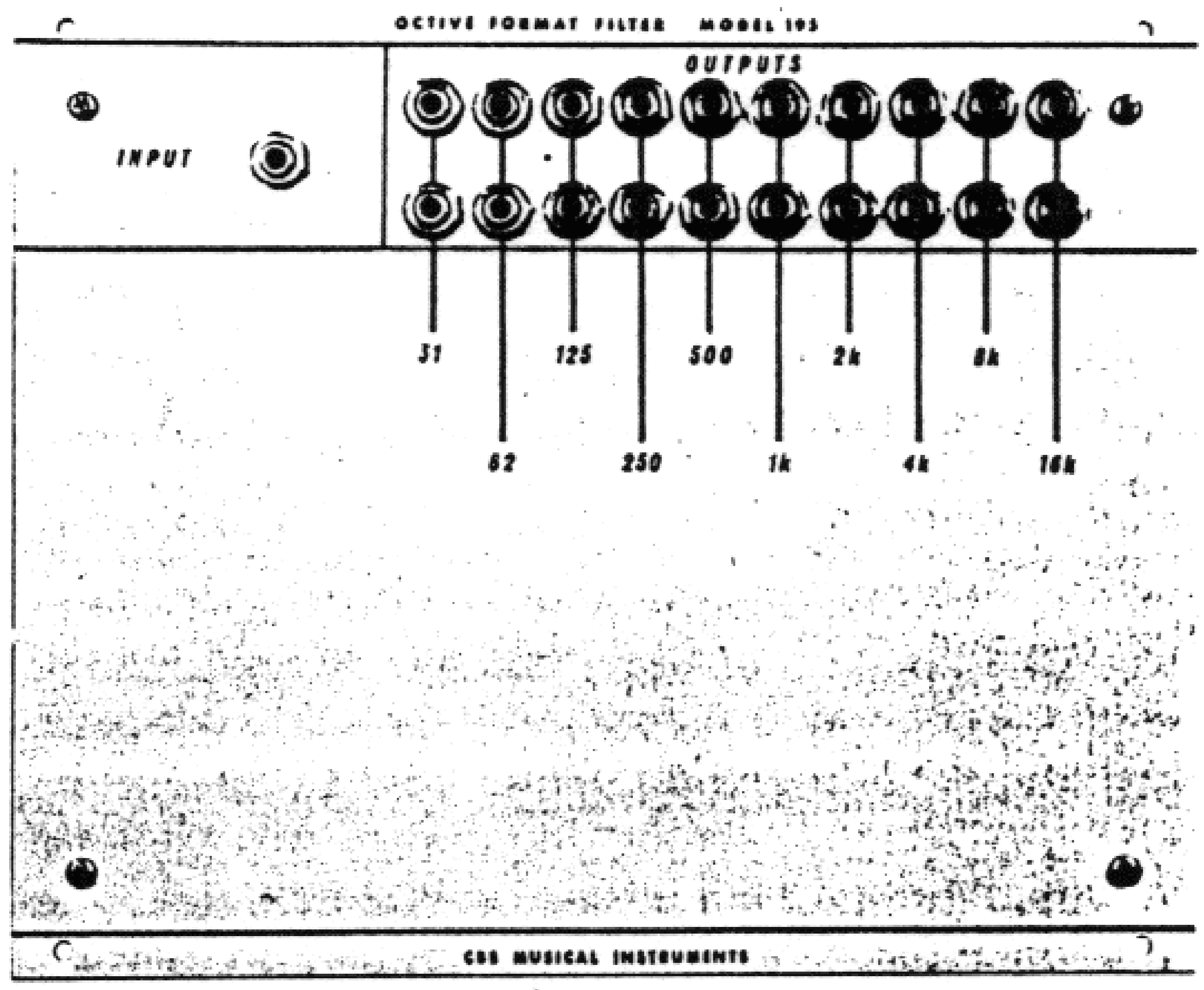
Model 192—Dual Lopass Filter

Model 194 — Band Pass Filter

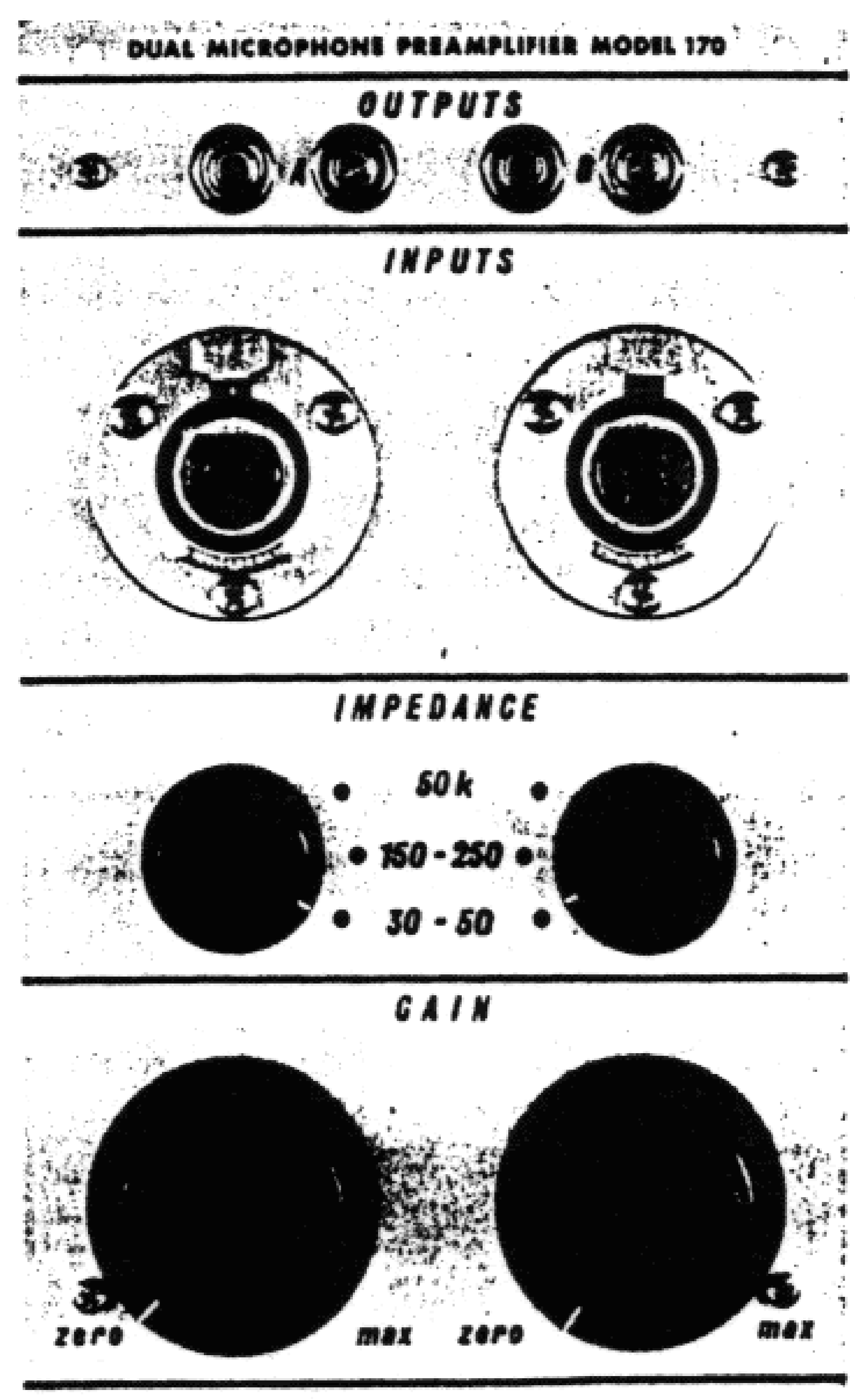


Model 195 Octave Format Filter

The Model 195 Octave Format Filter divides one input signal into ten frequency bands centered at octave intervals from 31 cps to 16 kc. Its front panel contains one **audio signal input** and ten pairs of **audio signal** outputs of frequency bands centered at 31, 62, 125, 250, 500, 1k, 2k, 4k, 8k, and 16k cycles per second. The associated pairs of output jacks are vertically aligned in this case, and lines are drawn between the two jacks extending down to the frequency label.



Model 195 Octave Format Filter



Model 170 — Dual Microphone Preamplifier

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