PAIA ELECTRONICS, INC.

3740

USING the GNOME MICRO-SYNTHESIZER

A SHORT TUTORIAL ON SYNTHESIZERS

Before we get into the operation of the Gnome's controls, a short discussion of synthesizers in general is in order for those whose exposure has been limited.

At PAIA we think of synthesizers in terms of analog computers. Before Integrated Circuits made extremely complex digital computers a relatively low cost practical reality, analog computers were used extensively to model real life mechanical systems. Applications ranged from studying the effects of shock absorbers and springs on the suspension of automobiles to the control of military artillery by means of projecting the impact point of a shell based on the ballistics of the weapon.

Modern electronic music synthesizers are analog computers that are modeling not automobiles or guns but sound sources. More on this shortly.

Every natural sound producing system can be broken down into several separate elements. Ordinarily the first element in the chain is an energy source. A violin draws energy from the bowing action of the performer, a guitar from the deforming force of fingers or pick on the strings and wind and reed instruments from the breath of the musician.

The second element is some means of converting the energy added to the system into periodic oscillations of a pre-determined frequency. In a guitar the elasticity of the strings cause them to vibrate when deformed and released, in a saxophone the reed converts the steady breath of the musician into a series of pulses.

The last element is some means of coupling the oscillations that are occuring in the instrument into the air so that they can be heard. In a guitar the function is performed by the body of the instrument, in a piano by the sounding board, and by the horns of wind and reed instruments. The individual characteristics of each of these elements interact to determine how the instrument will sound to a listener.

DYNAMICS

If the energy is added to the system in a single pulse - as in picking a guitar string or striking the keys of a piano - the instrument is of the percussion family and all such instruments have the common characteristic of sound intensity at its highest level immediately after the striking action. The period during which the sound output of an instrument is building to its maximum is known as "attack" and this instantaneous rise to a peak is known as "percussive attack". In natural percussion instruments the attack is immediately followed by a "decay" period during which the instrument dissipates the energy that was added in the striking force. During the decay the sound falls from the peak it reached during attack back down to nothing. The decay period may be of short duration as it is in drums or long as in pianos and this is again a function of the instrument.

If the energy is added in a continuous flow, the attack and decay may be separated by a sustain interval during which time the output of the instrument can be relatively constant. As long as a violinist bows the instrument sound comes out, as long as the musicians breath holds out he can get a sustained note from his piccolo.

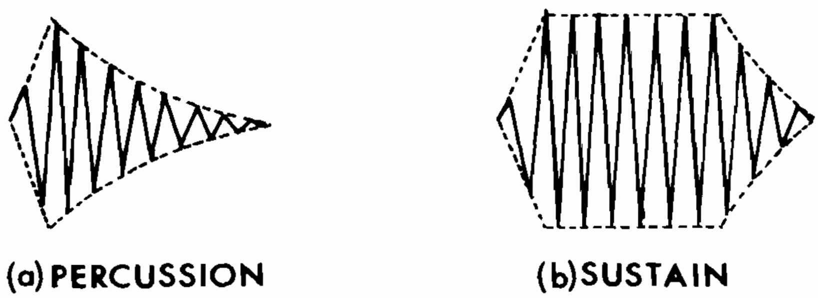


Figure 1 - Typical Envelopes

Figure 1 shows an attack/decay and an attack/sustain/decay envelope ("envelope" is a term that designates the behavior of the peak amplitude of the sound and in effect the envelope contains the sound). Figure 1 (a) would be typical of a percussion instrument while figure 1 (b) is the situation that you would expect to find in wind or brass instruments. Taken together, attack, sustain and decay are known as dynamics and the dynamics of an instrument make by far the largest contribution to how that instrument will be perceived by a listener.

TIMBRE

But, all instruments that are capable of sustain intervals don't sound alike - a trumpet doesn't sound anything like a flute - so there are obviously other differences as well. Timbre is the term ordinarily used as a label for some of these differences.

The individual timbral characteristics of instruments are the result of two interacting phenomena; first, the "waveshape" of the oscillations produced by the vibrating element and secondly, the resonant characteristics of the coupling device that transfers the energy from the vibrating element to the air.

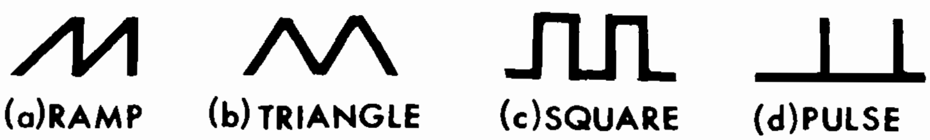


Figure 2 - Excitation Waveforms

Not everything vibrates the same way and figure 2 shows four examples of the waveforms produced by the "oscillators" in natural instruments. Figure 2 (a) is typical of the situation found in most bowed instruments. This generally is known as a "ramp" waveform and in a violin it is caused by the bow grasping a string and deflecting it until the friction of the rosin on the bow is overcome at which time the string "snaps back" and is grabbed again. Figure 2 (b) shows a "triangle" waveform which is typical of the back and forth oscillatory motion of the body of air within a flute. Figure 2 (c) is a "square" wave that is usually produced when one or more reeds alternately open and close to allow bursts of the musicians breath to pass into the instrument. Figure 2 (d) shows a "pulse" that is often the result of a performer's compressed lips on the mouthpiece of instruments in the brass family. Do not be confused and think that these waveshapes represent the sound of the instrument. These diagrams represent only the way that the vibrating element is behaving, the actual sound results from these waveforms as modified by the instrument's natural resonator - more on this shortly.

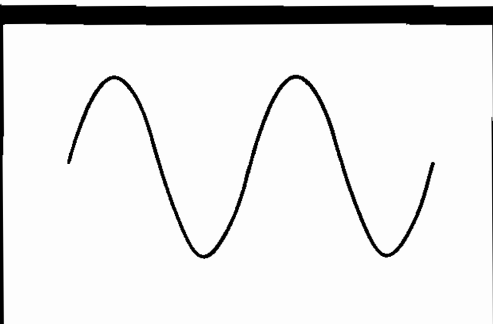


Figure 3 - Sine Wave

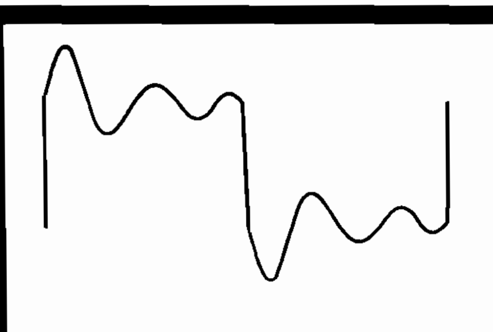


Figure 4 - "Ringing" filter response to square wave excitation waveform.

Figure 3 shows a sine wave. A sine wave is sort of a strange beast because while there are almost no natural instruments that produce it, it is the only "pure tone" and all of the waveforms shown in figure 2 (in fact any repeating or non-repeating waveform) can be broken down into sine wave components. The number, amplitude, frequency and phase of the various sine waves required to produce non-sinusoidal complex waveforms are ordinarily called the "harmonic structure" of the waveform. Harmonic structure is a concept that is critical to complete understanding of sound synthesis but in the interest of brevity cannot be covered here. Interested readers are directed to the bibliography at the end of this booklet.

Every physical thing that exists will vibrate when exposed to an energy source. Every physical thing has certain frequencies at which it "likes" to vibrate better than others. The thing - whatever it is - is said to be "resonant" at these frequencies. If the energy applied to the system is periodic (oscillatory) and the frequency of the energy source is the same as one of the resonant frequencies of the thing, then the thing will vibrate more energeticly than when the frequency of the energy source is not at one of the resonant points.

The resonant chambers of instruments have certain frequencies that they like better than others and tend to filter out the frequencies that they don't like so much. Because of this filtering property, waveshapes consisting of various sine wave harmonic content go into one end of an instrument and come out the other with the sine wave components of the waveshape accentuated if at resonance and attenuated if off resonance. Because the amplitude of the sine wave components are altered, the waveshape is altered. Square waves go into one end of a saxophone and a "ringing" waveform such as the one represented in figure 4 comes out the (Note: figure 4 is an exaggeration for illustration purposes only, the output of a saxophone is much more subtle than that shown). In some instruments the characteristics of the resonant chamber are constant, as in stringed instruments, while in others - wind and brass instruments for example - the parameters of the resonators must be altered to even closely approximate an equally tempered musical scale.

SYNTHESIZERS

Now that we have some idea how the mechanical properties of a musical instrument effect the sound produced, we will look at how electronic circuits can be used as analogs of those mechanical properties.

The electronic analog of vibrating strings, reeds, etc. is the oscillator. Just as the different types of vibrating elements in natural instruments can produce a variety of waveforms so can the electronic oscillators in synthesizers. Most oscillators are capable of producing at least ramp, triangle and pulse waveforms with the added capability of making the pulse so broad that it becomes a square wave. Many synthesizer oscillators can also produce a sine wave but just as a pure tone doesn't appear much in natural instruments, a sine wave from a single oscillator isn't terrificly interesting in electronic music. In any case, a triangle wave is very close to the same sound as a sine.

The pitch of natural instruments is determined by the length of the vibrating string, the pressure on the reeds or the configuration of the musicians lips and properties of the resonant chamber. In synthesizers the pitch (frequency) of the oscillator is determined by the magnitude of a control voltage applied to a set of input terminals. Increasing the control voltage raises the pitch of the oscillator. The common abbreviation for Voltage Controlled Oscillator is VCO.

Control voltages can be derived from a number of possible sources including strip controllers (as with the GNOME), keyboards, programmable sources of various types (sequencers, function generators, etc.) foot pedals and so on. All of these controllers have in common the fact that some action on the part of the musician produces predictable changes in the controller's output voltage. Voltage control is a concept that is essential to synthesis and interested readers are directed to the source material in the bibliography.

In the simulation of an instrument's dynamics, synthesizers diverge slightly from their counterpart mechanical systems. It would be natural to assume that the oscillator is "keyed" or "triggered" some sort of way to make its attack and decay simulate the natural instrument equivalent. In fact, the output of the oscillator is constant and the building up and dying away of the sound is implemented by varying the gain of an amplifier. As you may imagine, it would be at best cumbersome to twiddle the knob of an amplifier fast enough to simulate percussive attack but here again voltage control comes to the rescue in the form of a Voltage Controlled Amplifier (VCA).

In synthesizers, the gain of the amplifier is made proportional to the magnitude of a control voltage and in most cases this controlling signal is generated by a programmable function generator.

A function generator is simply an electronic circuit that in response to a triggering signal produces a voltage that rises to a pre-set level in an amount of time set by one control knob (attack) and then falls back to zero in an amount of time set by a second knob (decay). Sustain is ordinarily handled by keeping the triggering signal on for the desired sustain interval.

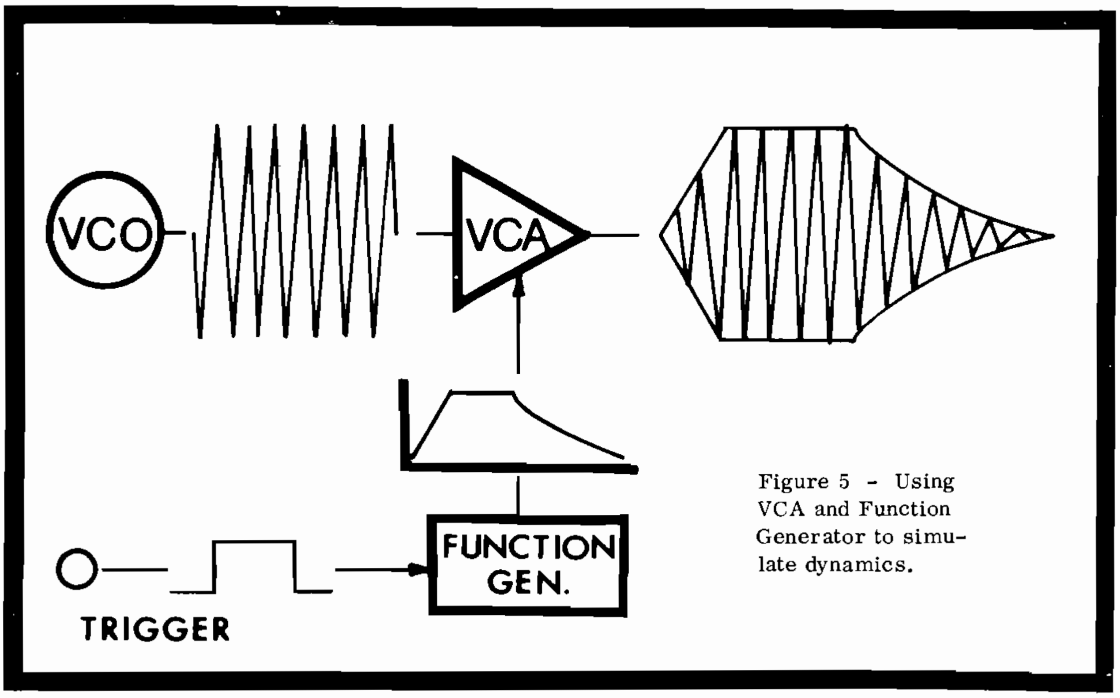


Figure 5 - Using VCA and Function Generator to simulate dynamics.

Figure 5 shows a typical example of an oscillator feeding a VCA which is being controlled by a function generator to produce the envelope shown.

This leaves us with only one of the most basic natural porperties to simulate: Timbre. As with mechanical instruments, many of the timbral properties of a sound are the result of the excitation waveform produced by the vibrating element and the remainder are the result of the characteristics of the resonator that couples those vibrations to the transmission medium (the air). Earlier we dwelt heavilly on the filtering characteristics of natural resonators because we were leading up to the use of an electronic filter as an analog for this mechanical element.

Electronic filters come in large enough variety that there are engineers who spent the bulk of their professional life designing these single elements. While most of these designs have immediate or potential use in electronic music we will concentrate on the type used in the GNOME, the band-pass filter.

Like the natural resonators that we discussed earlier, band-pass filters have one frequency that they "like" better than others and this frequency is called the resonant or "center" frequency. A sine wave applied to the input of a band-pass filter will pass through relatively unchanged if it is at this resonant frequency but will be attenuated if at some frequency other than resonance. Similarly, the sine wave components of a complex signal that are within the pass band of the filter will be unchanged while the components outside the pass band will be attenuated producing a planned and controlled "distortion" of the excitation function.

Since many natural instruments count on alterations of their resonators to produce chromatic tones there must also be some means of controlling at least the resonant frequency of a synthesizer's filter. As you might expect, voltage control is the answer.

Control voltages for a Voltage Controlled Filter (VCF) can originate from basicly the same sources as those that control the oscillators. If the center frequency of the filter is to change with changing pitch of the oscillator the same voltage that is controlling the oscillator can also be routed to the filter. For the spectacular "waa-waa's" that are characteristic of electronic music the control voltage can originate in an automatic function generator.

NOISE

To this point in our analysis we have dealt exclusively with "pitched"sound sources, sources that have a readily discernable repitition frequency and therefore an easily recognized musical pitch. There are also "unpitched" sources.

The concept of an unpitched musical sound may at first seem as esoteric as "the sound of one hand clapping" but it actually requires no meditation to understand. The "hiss" that you hear from an FM radio that is tuned between stations is an unpitched sound and most synthesizers have provisions for a "noise" source that produces just this effect. From a technical standpoint it is the result of summing together randomly varying amplitudes of all possible frequencies within a given frequency band.

The applications of noise are very broadly based; for example, the sound of the snares of a snare drum are noise with a percussive envelope. By processing noise through the proper filters the sounds of the surf and the wind are easily simulated.

So, now we know a little bit about how musical instruments work and how electronics can be used to simulate the properties of these instruments - let's look at the Gnome and begin applying some of these principles.

THE GNOME

In the early days of synthesizers each element of a system was a free-standing module and specific connections were set up using patch cords. Patch cords allow great flexibility but the laborious task of setting up patches for each voice is a disadvantage to most performing musicians. In a small system which will not be expanded beyond a specific capability, a normalized connection (one in which a specific arrangement of elements is pre-wired) is definitely the way to go.

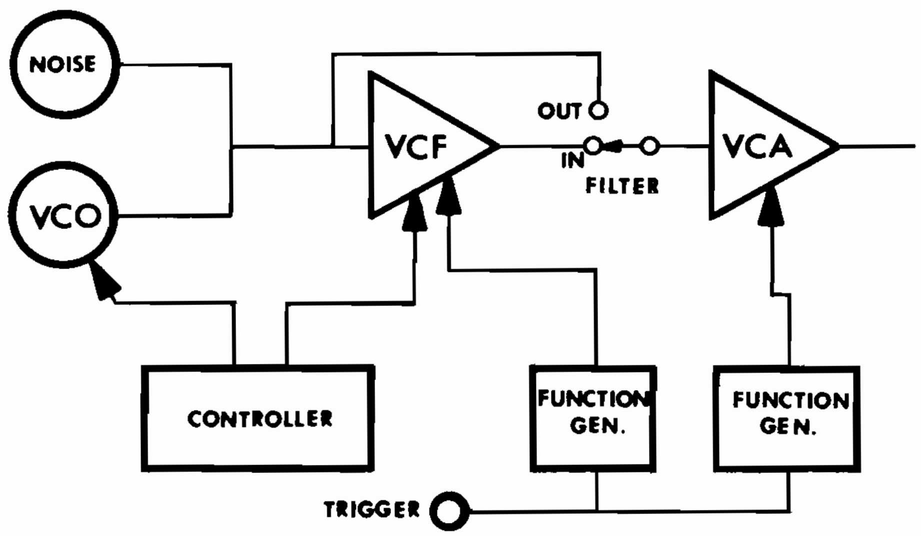


Figure 6 - GNOME normalization block diagram

Figure 6 shows the signal and control paths through the Gnome. The VCO always feeds the input of the VCF and the VCA can get its input either directly from the VCO or from the output of the VCF. The control voltage for the VCA always comes from the function generator dedicated to this element. The control voltage for the VCO can come either from the self-contained controller or the power supply and is adjustable with the VCO Range control. VCF control voltages can come either from this element's dedicated function generator or the controller or both. This is a fairly typical normalization scheme for small synthesizers and while it unquestionably limits the versatility of the machine, the limitations are minimal and entirely consistent with the inherent limitations of the simplified, low cost circuitry of the Gnome.

CONTROLS

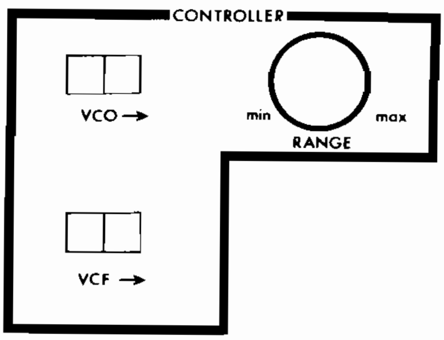
The front panel graphics of the Gnome are broken down into six sections corresponding to the six major circuit elements that make up the unit. These sections are:

1) Controller
2) Trigger
3) Noise Source
4) Voltage Controlled Oscillator
5) Voltage Controlled Filter
6) Voltage Controlled Amplifier

Taking these sections one at a time:

CONTROLLER

The built in ribbon controller is nothing more than an exposed resistance element that has its left end grounded and a positive voltage applied to the right end. The saw-tooth cuts on the resistance strip along with the paralleling resistors inside the case combine to produce a voltage distribution along the controller strip that is exponential and approximately chromatic. If it were not for this exponential voltage distribution at the controller, semi-tone intervals at the top end of the strip would seem to be bunched together while those at the low end of the strip would be spread apart. This relates back to the distribution of semi-tone intervals in the equally tempered musical scale and interested readers are referred to the sources listed in the bibliography for further information on this subject.



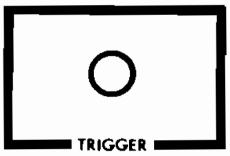
<u>RANGE</u> The CONTROLLER Range potentiometer varies the voltage that appears across the controller strip. At the max. position of this control the strip is a little less than 4 octaves long while at the min. setting it is slightly more than 1/2 octave long. As we shall see later on in this manual, the CONTROLLER and VCO Range controls interact to place the musical "length" of the controller at any desired position within the oscillator's 8 octave range.

<u>VCO and VCF switches</u> The two slide switches within the controller box allow the voltage that is picked off the controller strip by the wiper probe to be routed either to the VCO or VCF or both. Sliding the switch bat in the direction of the arrow routes the voltage to the element indicated.

NOTE: Part of the chemical composition of the vinyl that forms the controller strip is an agent known as a "plastisizer", a substance that keeps the vinyl from becoming brittle. Pressure cuases this plastisizer to form an insulating film on the surface of the strip.

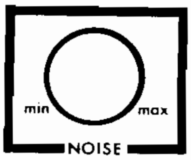
If you notice that excessive force on the controller probe is required to produce smooth glissandos from the oscillator it is an indication that this insulating film is forming. Clean the controller strip regularly (every 20 minutes or so for the first few hours of operation) with lighter fluid or iso-propyl alcohol. If not abused, the controller strip should improve with age as slight irregularities are smoothed out by constant pressure.

TRIGGER



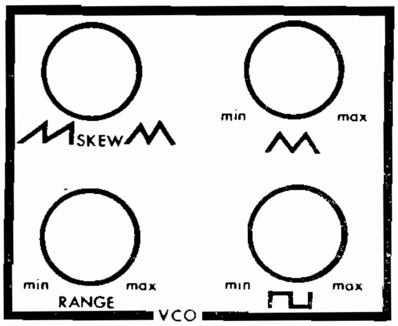
There is only one control inside the trigger box and that is the Trigger button. Whenever this button is pressed a voltage is applied to the triggering inputs of the function generators associated with the VCF and VCA. Provisions have been made internally to reduce multiple triggering caused by "noisy" switch contacts but a firm pressure on the button is needed to prevent contact bounce.

NOISE SOURCE



The single control inside the Noise box is a level control that determines the amount of white noise that will appear on the common audio buss. At the min. position of this control the noise source is isolated from the buss and the noise level increases with clockwise rotation toward max.

VCO



Range The Range control inside the VCO box is an attenuator on the control voltage input line of the oscillator and is useful in a number of different ways. When the CONTROLLER VCO switch is off, a constant voltage is applied to the VCO Range control allowing the oscillator to be set to some constant pitch that is independent of the controller action.

When the CONTROLLER VCO switch is on, the VCO Range and CONTROLLER Range controls can be used together to set the highest and lowest pitches available from the strip controller. Figure 7 illustrates this by using a bar to represent the total 8 octave range of the oscillator. The double ended arrow above the bar represents the range of the strip controller. Rotating the CONTROLLER Range control toward max. increases the length of the double ended arrow across the width of the bar. For example, with both controls set to max. the range of the controller is approximately from 600 Hz. to 6500 Hz. If the CONTROLLER Range is left at max., the controller will remain a little over three octaves long but reducing the VCO Range can cause these three octaves to run from 30 Hz. to 350 Hz. NOTE: The same slight non-linearities that in most circumstances make the GNOME oscillator incompatible with keyboards will also make the "length" of the controller strip variable depending on the setting of the VCO Range control but under normal circumstances these errors will not be noticeable or objectionable.

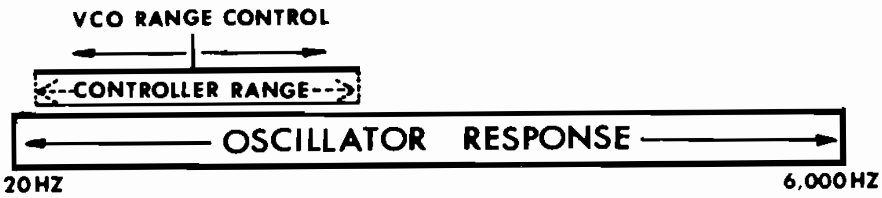


Figure 7 - Schematic representation of CONTROLLER operation

At the min. setting of this control the oscillator is off regardless of the condition of the controller or the setting of the CONTROLLER VCO switch.

SKEW The SKEW control is a little unusual for synthesizers but it allows the Gnome's simple VCO to produce 4 basic waveforms (triangle, ramp, square wave and pulse) while also making available a wide range of waveforms in between the four. Figure 8 shows the effect of this control. Clockwise rotation changes the ramp wave to a triangle and the narrow pulse to a square wave. There is some shift in oscillator pitch associated with the rotation of the control from one end of its travel to the other. This deviation is maximum toward the center of the range of the control with the two extreme ends being within a semi-tone of the same pitch.

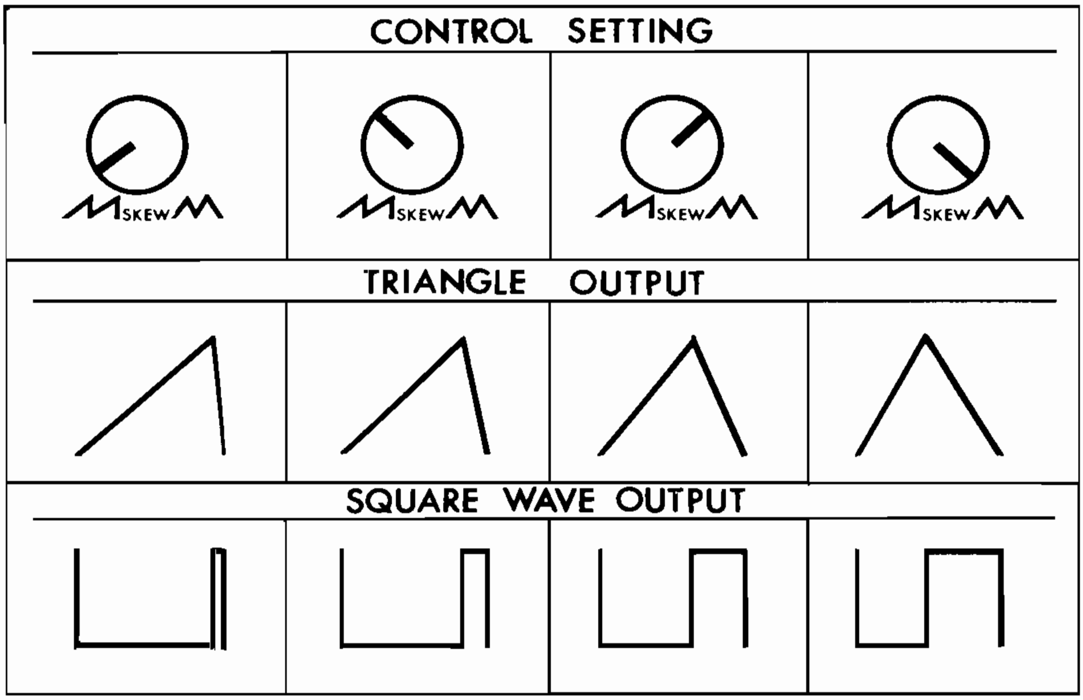
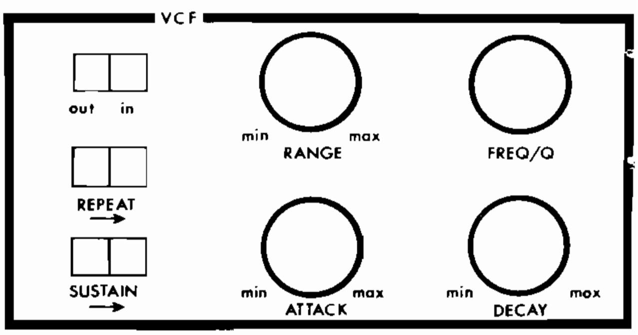


Figure 8 - VCO Skew control operation

TRIANGLE The setting of the control labeled with the triangle symbol ( ) determines the amount of ramp/triangle waveform applied to the common audio buss. Level increased with clockwise rotation of the control from min. to max.

SQUARE WAVE The setting of the control labeled with the square wave symbol ( ) determines the amount of pulse/square wave waveform applied to the common audio buss. Level increases with clockwise rotation of the control from min. to max.

VCF



IN-OUT The voltage controlled filter may be eliminated from the audio path entirely by setting the in-out switch to the out position.

FUNCTION GENERATOR CONTROLS

All but one of the controls inside the VCF box are directly related to the operation of the filter's dedicated function generator.

Repeat and Sustain switches There are four possible combinations of settings of the repeat and sustain switches and each of these combinations produces a different response. These combinations are most easily explained in tabular form as on page 9.

CONDITION	RESPONSE	COMMENTS
REPEAT, SUSTAIN	PERCUSSION	Normal percussion output. Attack and decay at the rate set by these controls.
REPEAT, SUSTAIN	SUSTAIN	Normal sustain output. Attack and decay at rate set by those controls output voltage holds high (sustains) while trigger button is held down.
REPEAT, SUSTAIN	MUTE	Similar to percussion (no sustain). Attack and decay at rate set by those controls except when trigger button is released generator by-passes decay time and re-sets to zero.
REPEAT, SUSTAIN	REPEAT	Function generator serves as its own trigger source and output oscillates from low level to high level. Rise time set by attack, fall time set by decay.

Figure 9 - VCF Function Generator Responses

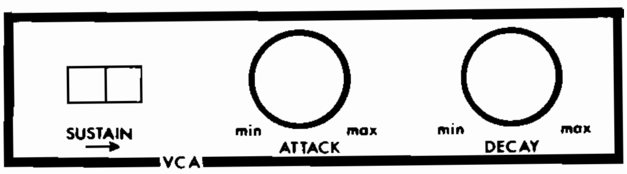
Range The range control within the VCF box is an attenuator on the output of the VCF's dedicated function generator, it varies the amount of control voltage applied to the filter from the function generator only. Since the response of the filters will vary from one unit to the next, this control is designed so that rotation fully clockwise to "max." provides a control voltage greater than the maximum range of the filter. This assures that maximum range will be available on all units. Voltages originating from the controller when the CONTROLLER VCF switch is on are not routed through this range control.

Attack The Attack control inside the VCF box determines the time required for the filter's dedicated function generator output to rise to its peak. Range of this control is from .005 seconds at the min. setting to a little over 1 second at max.

Decay The Decay control inside the VCF box determines the time required for the output of the filter's dedicated function generator to fall from the attack peak back down to no output. Range of this control is the same as Attack.

Freq./Q This is the only control inside the VCF box that actually makes some change to the filter itself. Clockwise rotation of this control raises the frequency of the filter while simultaneously decreasing the Q and increasing the loss of the filter. It is normal for the volume of the sound to decrease as the Freq./Q control is rotated in a clockwise direction.

VCA



Sustain The sustain switch within the VCA box serves roughly the same function as does the sustain switch in the VCF. With the sustain off (switch to the left) pressing the trigger button will cause the VCA's dedicated function generator to attack and then immediately decay. As long as the trigger button is held down the attack and decay times will be as set by these controls but when the trigger is released a "muting" function takes over that quickly turns the VCA off.

Turning the sustain switch on (to the right) causes the function generator to hold at the peak level as long as the trigger button is held down. Releasing the trigger now causes the envelope to decay at the rate set by the Decay control. These responses are tabulated in figure 10.

CONDITION	RESPONSE	COMMENTS
		Hold Trigger for standard percussion response.
		Percussion with muting when Trigger released. Attack cycle need not finish before muting.
		Normal sustain response. Attack cycle will always finish before decay begins.

Figure 10 - VCA Function Generator Responses

Attack The Attack control within the VCA box determines the amount of time required for the output of the amplifier to build to a peak. Range of this control is from .002 seconds at min. to slightly more than one second at max.

Decay The Decay control within the VCA box determines the amount of time required for the amplifier to turn off. Range of the control is from .005 seconds at min. to slightly more than one second at max.

There are two jacks on the back of the Gnome case. The miniature phone jack is the output that requires a standard miniature phone plug for connections. Co-axial cable should always be used to connect the Gnome output to the input of the amplifier being used.

The black pin jack on the rear edge of the case is an external trigger input. For best operation the trigger voltage applied to this jack should exceed 8 volts but trigger voltages greater than 4 volts will produce a triggering action (triggers less than 8 volts will not allow the function generators to go to their maximum level). External triggering voltages must be referenced to the Gnome case ground.

ILLUSTRATION PATCHES

AND

TECHNICAL ANALYSIS

In the early modular synthesizers, "patch" cords were used to connect together processing elements to produce the effect desired. The charts that early electronic musicians used to keep records of the interconnections they had used quite naturally became known as patch charts, or simply "patches". Like most slang, the term remains even through in many cases the patch cords have gone. The settings of knobs and switches that cause a synthesizer to produce a specific effect are still referred to as patches.

In these illustrations the positions of switches are indicated by darkening the position occupied by the switch bat (the plastic slide that changes the setting of the switch). Settings of knobs and controls are shown by drawing a line from the center of the knob to its perimeter representing the pointer of the knob. An asterick (*) on any control means that there is special information on the setting of the control contained in the comments section that accompanies each patch.

It would be impossible to list all of the possible patches for the GNOME because almost every possible setting of the switches and controls produces some sort of sound (exceptions are listed at the end of this section). These patches have been selected because each illustrates some particular facet of the GNOME's operation, they are simply the starting points for whatever journeys your imagination can conceive.

WHISTLER

COMMENTS

The whistler is simply the triangle waveform output of the VCO being turned on and off by the VCA.

In order to achieve manual control, the CONTROLLER VCO switch is turned on so that voltages picked off of the controller strip by the wiper probe are routed to the oscillator. The CONTROLLER Range and VCO Range controls are both set to max. to achieve the highest possible pitch.

The triangle output of the oscillator is selected by turning the VCO Skew control to the triangle designator and turning the triangle output control to max. The pulse/square wave output is not used in this voice so the square wave level control is set to min.

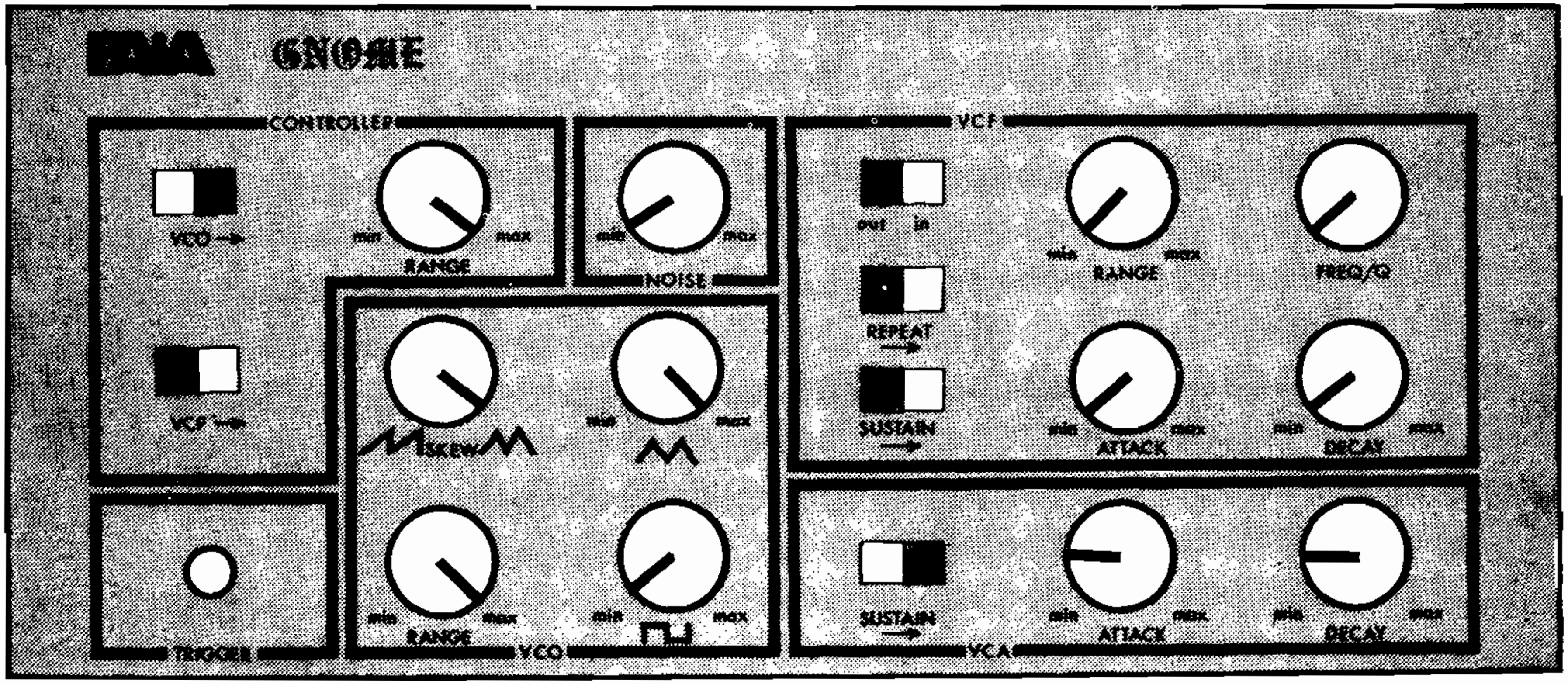
The filter is not being used so all of its controls are set fully counter-clockwise in the case of knobs or to the left in the case of switches. NOTE: As a general rule, any section of the GNOME that is not being used should be disabled with this "knobs CCW, switches to the left" rule to prevent any possible interactions between used and unused elements.

The VCA Sustain switch is turned on so that a sound will be produced as long as the trigger button is held down and Attack and Decay controls are set slightly off min.

Press the trigger button and select pitch as desired by moving the wiper probe over the surfact of the controller strip.

VARIATIONS: Substitute square wave, pulse or ramp for triangle. Juggle VCA Attack and Decay for different effects. Change pitch range by setting CONTROLLER Range to min.

For a very strange "gimmicky" sort of effect use the patch as originally shown, and press and hold the trigger button and quickly and repeatedly bounce the wiper probe up and down on the far right hand end of the controller strip. This effect, that some have called a "ray gun", is produced by the VCO very quickly sweeping up and down over the audio spectrum.


GNOME
CONTROLLER
VCO
RANGE
min
max
VCF
NOISE
out
in
REPEAT
SUSTAIN
FREQ/Q
SKEW
ATTACK
DECAY
TRIGGER
VCO
VCA

DYNA-MUTE

COMMENTS

The Dyna-mute voice automaticly sweeps the center frequency of the filter up and down over a harmonic rich pulse excitation waveform.

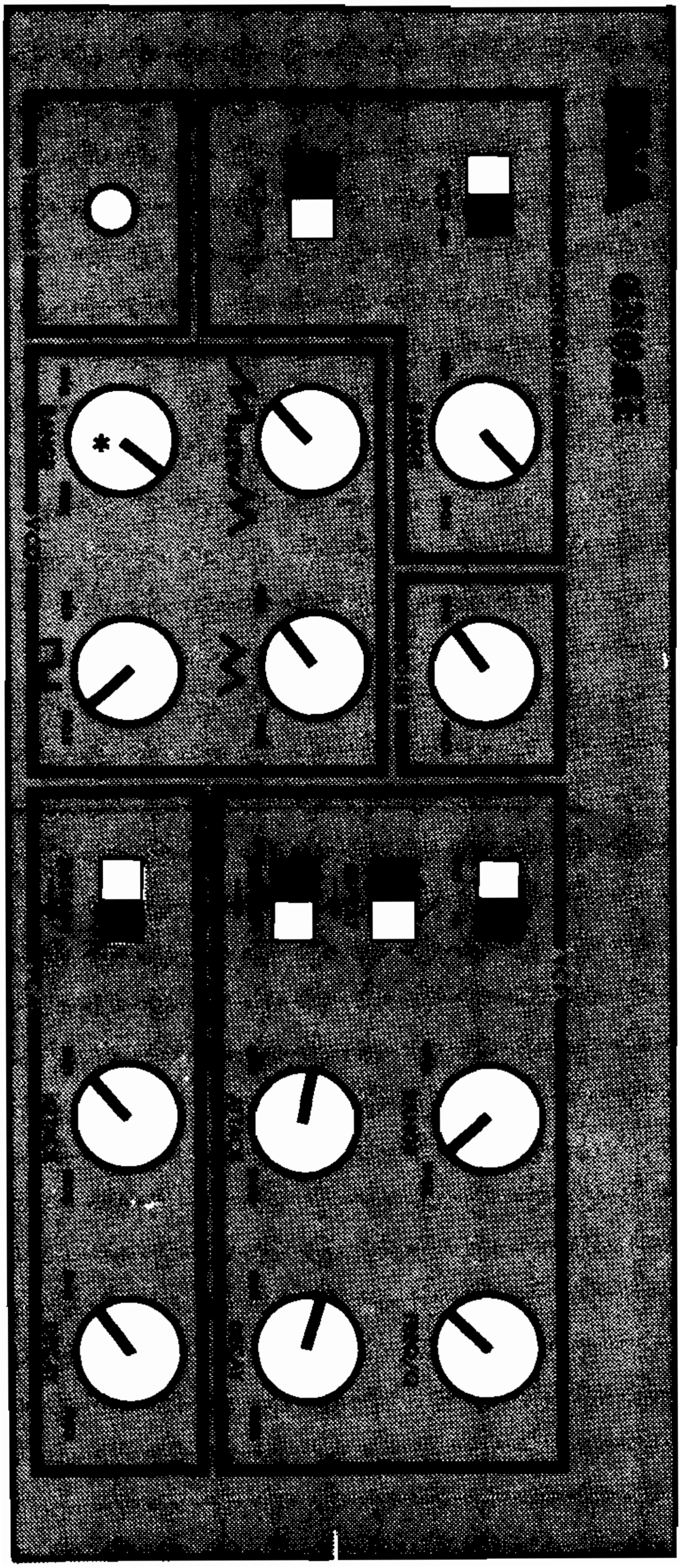
Select a narrow pulse excitation waveform by turning the VCO Skew control toward the ramp symbol and bringing up the level on the square wave output. This time the CONTROLLER Range is reduced to restrict the upper frequency of the oscillator. The pitch range of the controller strip is set to include the lowest possible frequencies by pressing the trigger button (VCA Sustain on) while holding the wiper probe down on the extreme left end of the strip. The VCO Range control is then rotated counter-clockwise until it starts again (should be about 20 to 30 Hz.).

The VCF is used this time so the VCF "in-out" switch is set to in. And since we are using the VCF's function generator as a control voltage source, the VCF Range control is advanced (start with max. setting and work back as desired). Freq./Q is left at the CCW limit of its rotation for minimum loss through the filter and the Attack and Decay controls are advanced slightly off of their min. settings.

VCA Sustain is turned on so that sound will be produced as long as the TRIGGER button is held down and VCA Attack and Decay are both set to min.

Pressing the trigger button while selecting a note with the wiper probe will now produce the waa-waa sound so familiar to electronic music buffs.

VARIATIONS: Set the VCF Repeat and Sustain switches to "on" to cause the filter to continuously cycle up and down over the pulse's harmonic content.



WIND

COMMENTS

The sound of the wind is simulated by sweeping the band pass filter over the output of a noise source.

This patch does not use the VCO, so its controls are all CCW. Noise will be used so NOISE is set to max.

The sound of the wind doesn't just immediately start or stop so the VCA Sustain is turned on and Attack and Decay controls are set toward max.

Instead of setting the pitch of the oscillator the strip controller is now going to vary the center frequency of the filter so the CONTROLLER VCF switch goes on while the CONTROLLER VCO switch goes off. Proper setting of the CONTROLLER Range will be covered shortly but for now it can be set to max.

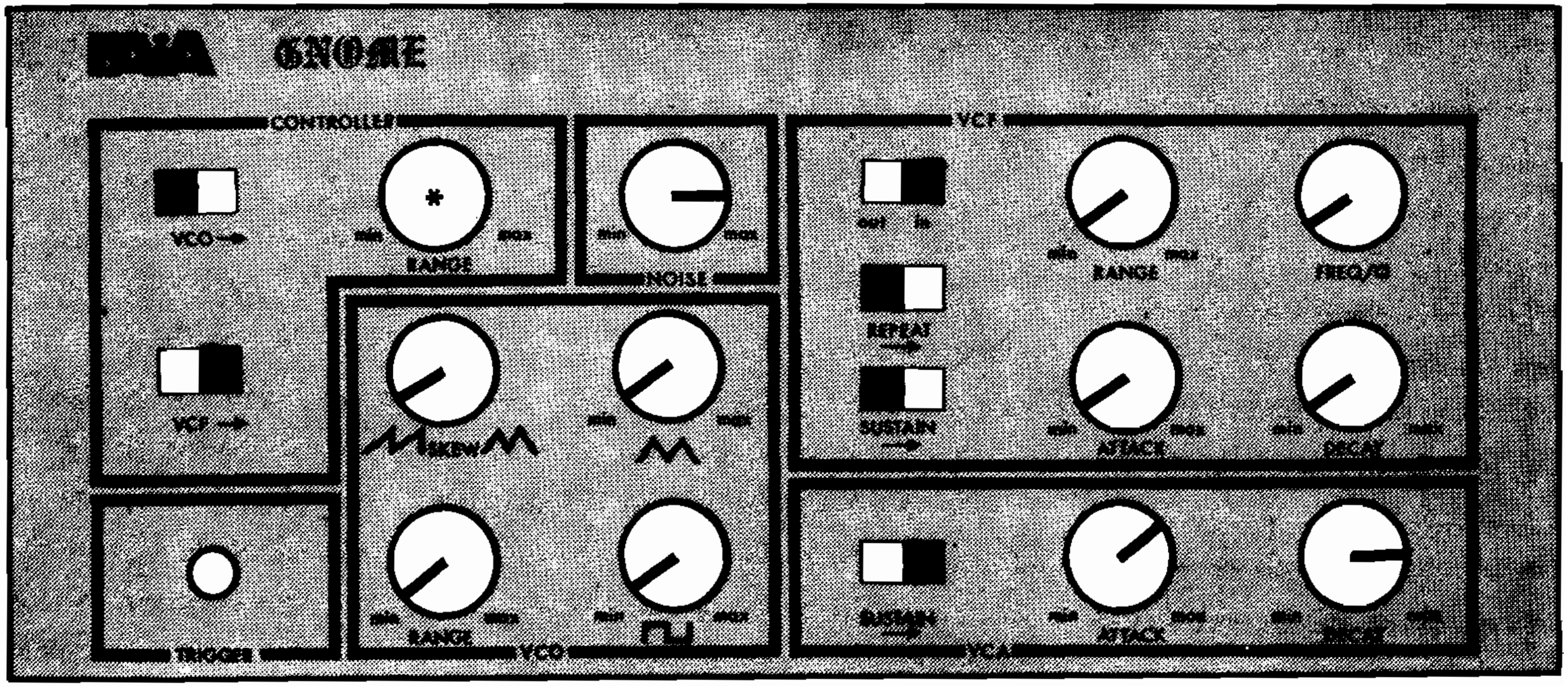
Since the filter is being used, the VCF "in-out" switch is set to in, but since the VCF's function generator is not the control voltage source it's "knobs CCW, switches left" for VCF Range, Attack, Decay, Sustain and Repeat.

Pressing the TRIGGER button while moving the wiper probe up and down over the controller strip will now produce the whistle of the wind.

You may notice that the upper portion of the controller strip produces no discernable change in the sound; if so, it is an indication that the control voltage is exceeding the range of the filter. Press the trigger button and with the wiper probe held down on the far right hand end of the controller strip rotate the CONTROLLER Range control CCW until you hear a slight change in the pitch of the noise. This procedure sets the output of the controller strip to correspond with the control voltage range of the filter.

You may also notice that the noise is not "smooth" but has some slight "popping" in the background. This is an indication that the noise source is overloading the filter input and this condition can be cured by turning down the NOISE level.

VARIATIONS: Turn VCA Sustain off and reduce Attack and Decay to form percussion envelope for sound. Sweep filter by turning VCF Repeat and Sustain switches on and advancing the Range control as desired.


GNOME
CONTROLLER
VCO
RANGE
min
max
VCF
NOISE
min
max
VCF
out
in
RANGE
FREQ/Q
REPEAT
SUSTAIN
ATTACK
DECAY
SKEW
RANGE
VCO
TRIGGER
SUSTAIN
VCA
ATTACK
DECAY

SNARE DRUM

COMMENTS

The snare drum patch mixes noise (to simulate snare sounds) with a low frequency triangle (to simulate strike tone) with VCA settings to produce percussive envelope.

The CONTROLLER is not used in this voice at all. Knobs CCW, switches left.

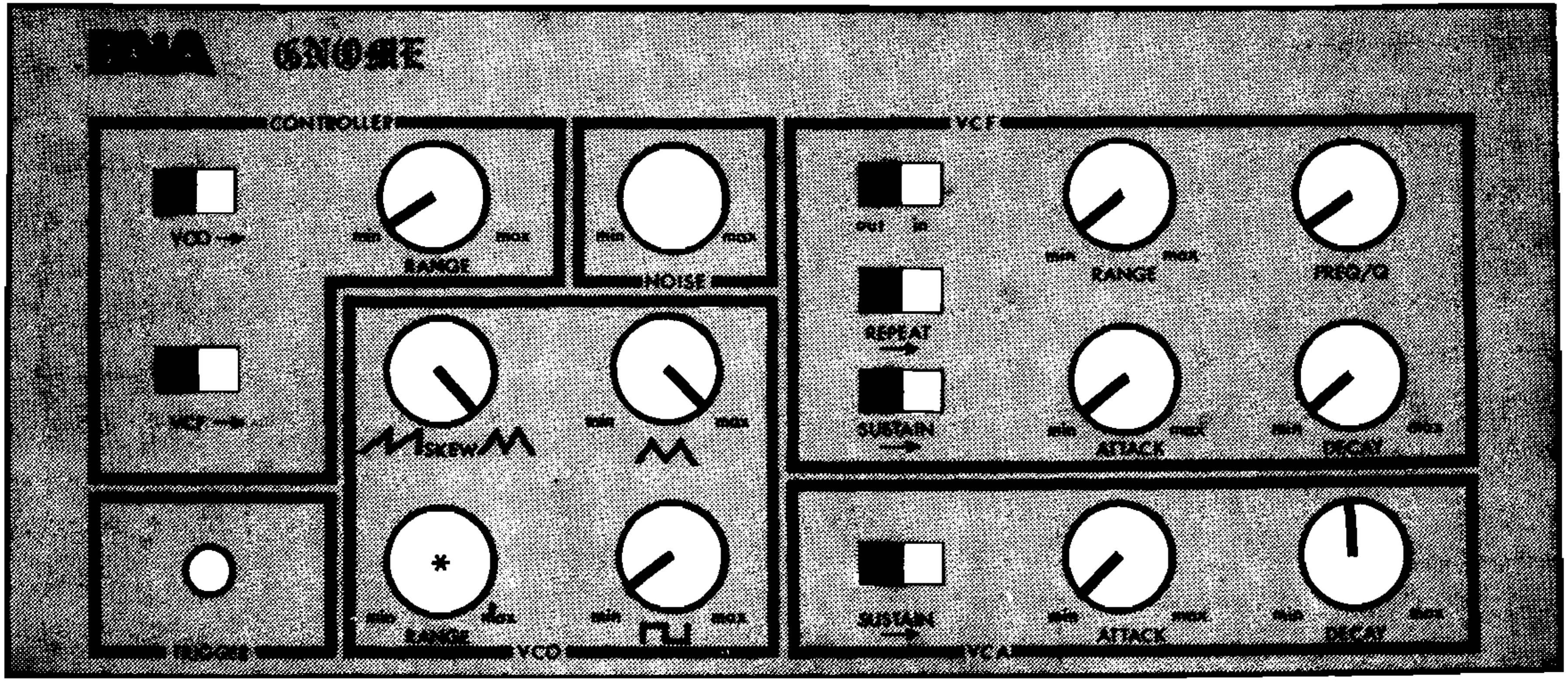
The VCO will be used but its control voltage source will be the internal reference. Turning the CONTROLLER VCO switch off automaticly switched in this reference and the pitch of the oscillator can now be set by the VCO Range control. About 1/3 of the rotation from min. is the approximate setting for this control but the final decision on pitch will be whatever sounds right to you. A Triangle is the pitched source here so the Skew goes to the triangle symbol and the triangle level goes to max. Square wave level is set to min.

The filter is not used; VCF controls CCW, switches left.

The VCA is set for a percussion envelope by turning Sustain off, Attack to min. and Decay about 1/2 of its rotation.

While pressing the TRIGGER button bring up the level of the noise source until it sounds like the proper proportion of snare sound to strike tone.

VARIATIONS: Turn CONTROLLER VCO switch on so that the oscillator is controlled by the wiper probe and use CONTROLLER Range and VCO Range to set a control range that is very heavy on the low pitched end (similar to dyna-mute comments). Presto, a chromatic snare drum (one that you can play tunes on.)


GNOME
CONTROLLER
VCO
RANGE
NOISE
VCF
out in
RANGE
FREQ/Q
REPEAT
SUSTAIN
ATTACK
DECAY
SKEW
RANGE
VCO
TRIGGER
SUSTAIN
ATTACK
DECAY
VCA

ELECTRO-SAX

COMMENTS

The GNOME is not sufficiently sophisticated to realisticly duplicate the sound of many natural instruments but this patch is roughly the equivalent of a saxophone. It is not intended to sound exactly like the natural equivalent.

In this patch we are going to control both the VCO and VCF from the strip controller. Begin with CONTROLLER VCF and VCO switches both on and Range set to max. (this setting may change).

The square wave output of the VCO will be used so set Skew to the triangle symbol (see fig. 8 page 8) and bring the square wave level control to max. Range is set mid-range for now and can be changed to suit your taste later.

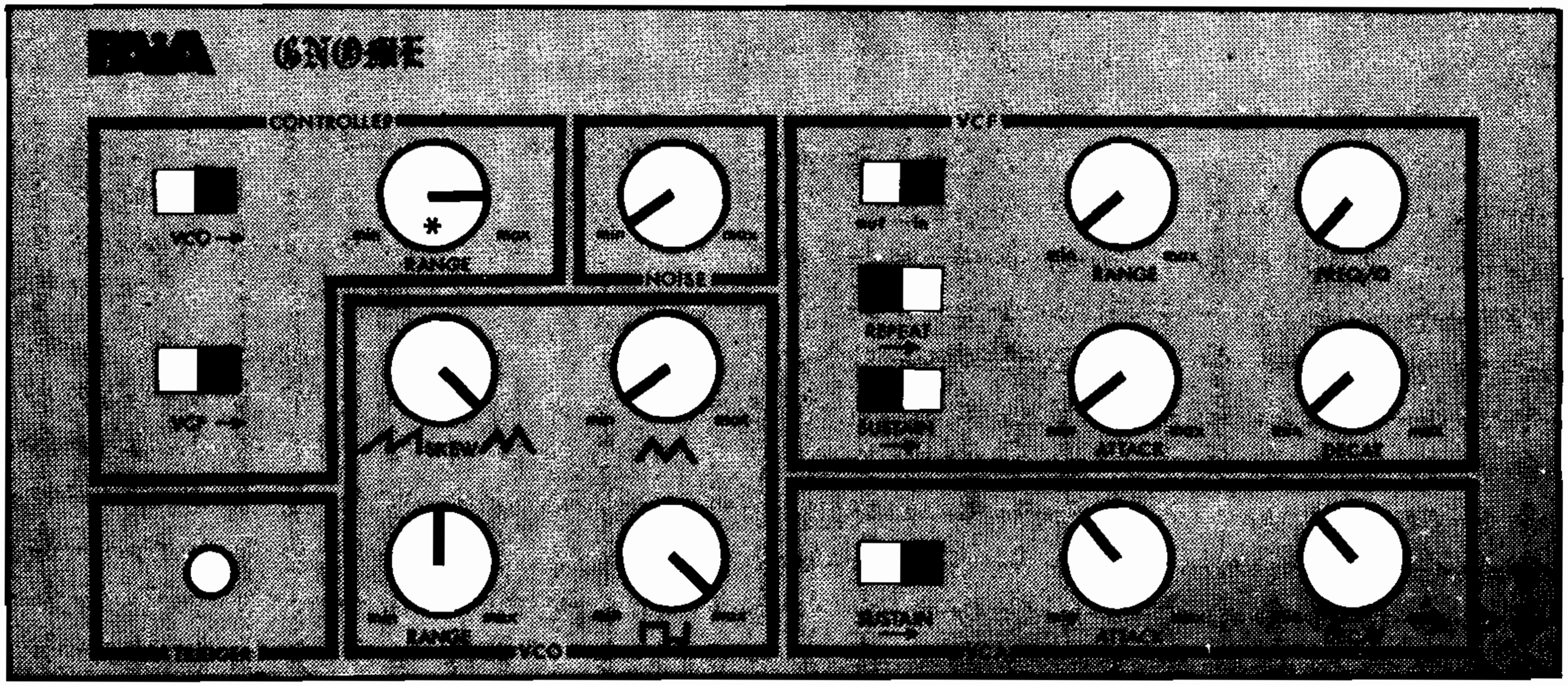
The filter is used but not the filter's function generator. Set VCF "in-out" to in, Repeat off, Sustain off, Range min., Attack min. and Decay min.

At this point you may want to set the controller range to correspond to the range of the filter. Temporarily bring the NOISE up and set the CONTROLLER Range as outlined in the wind voice comments. When finished return the NOISE to min.

VCA Sustain is turned on and Attack and Decay set just slightly off of min.

Press the trigger button and slide the wiper probe over the controller strip to change pitch.

VARIATIONS: There are no natural instruments that have a reverse percussion envelope which builds up slowly and then suddenly stops but we are used to hearing this sort of sound when it is produced by playing a tape recording backwards. This type of effect can be simulated by sliding the VCA Sustain to off, Attack to max. and Decay to min.



GNOME
CONTROLLER
VCO →
VCF →
min RANGE max
min NOISE max
VCF
REPEAT
SUSTAIN
min RANGE max
FREQ/Q
min ATTACK max
min DECAY max
SKEW
min max
min RANGE max
VCO
SUSTAIN
ATTACK

SUMMARY

The GNOME will produce some sort of sound for almost every setting of the front panel controls with the following exceptions:

1) The power switch must be turned on. (that's not as funny as it sounds, everybody forgets to turn things on from time to time)
2) One of the three sound source controls (NOISE, VCF triangle/ramp level or square/pulse level must be advanced.
3) If the VCO is being used, the VCO Range control must be advanced off of min.
4) If the CONTROLLER VCO switch is on, the wiper probe must be contacting the controller strip.
5) The TRIGGER button must be pressed to produce a sound.

BATTERIES Any good grade of 9 volt transistor battery will operate the GNOME but better performance can be expected when mercury cells are used. The GNOME drains considerable power and the less than constant voltage characteristics of common carbon-zinc cells will allow slight oscillator frequency shift corresponding to triggering of the function generators. This shift will be most noticeable at low frequencies.

If you use carbon-zinc cells you can expect battery life on the order of 15 hours or more, provided that the instrument is turned off when not being used. Turning the power switch on and leaving it on will drain the batteries in about 10 hours. Mercury cells will last considerably longer.

CONTROLLER STRIPS If properly maintained (i.e. not abused) the controller strip should last indefinitely. NEVER USE SOLVENTS OTHER THAN THOSE RECOMMENDED IN THESE INSTRUCTIONS ON THE CONTROLLER STRIP. Lighter fluid is highly recommended.

As explained earlier, the controller strip will probably need to be cleaned often (every 15 minutes or so) during the first 10 to 15 hours of use. The symptoms of a contaminated controller strip are erratic and noisy response of the oscillator.

Controller strips are available separately from PAIA for $3.50 postpaid.

Order: SP-3740-cs GNOME controller strip

From: PAIA Electronics, Inc.
1020 W. Wilshire Blvd.
Oklahoma City, OK 73116

TECHNICAL ANALYSIS

Figure 11 (on facing page) shows a comprehensive block diagram of the workings of the GNOME.

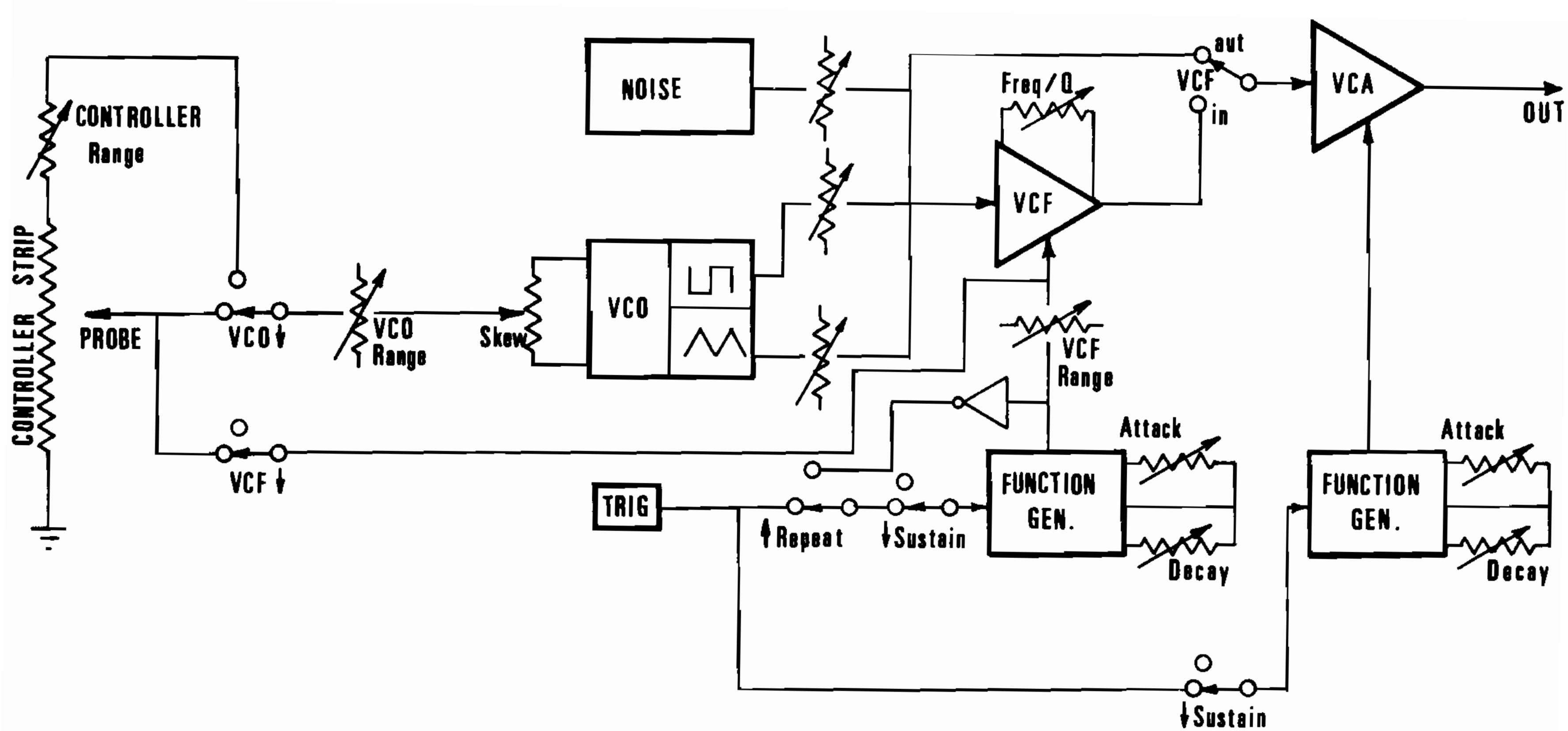

CONTROLLER
Range
CONTROLLER STRIP
PROBE
VCO
VCO
Range
Skew
VCF
NOISE
VCO
Freq/Q
VCF
aut
VCF
in
VCA
OUT
VCF
Range
TRIG
Repeat
Sustain
FUNCTION
GEN.
Attack
Decay
FUNCTION
GEN.
Attack
Decay
Sustain

Figure 11

DESIGN ANALYSIS

CONTROLLER

The "saw tooth" geometry of the conductive elastomer that forms the controller strip of the GNOME combines with the paralleling resistors R8 through R11 to produce an exponential voltage distribution along the surface of the strip. The controller range potentiometer R78 is in series with the effective resistance of the controller strip forming a voltage divider. Increasing the resistance of R78 decreases the voltage that appears across the length of the strip.

The wiper probe, which is decoupled by an emitter follower in the VCO to prevent loading of the controller, picks a voltage from the strip that is proportional to the position of the probe along the length of the strip. Switches S2 and S3 allow this voltage to be routed either to the VCO, VCF or both simultaneously.

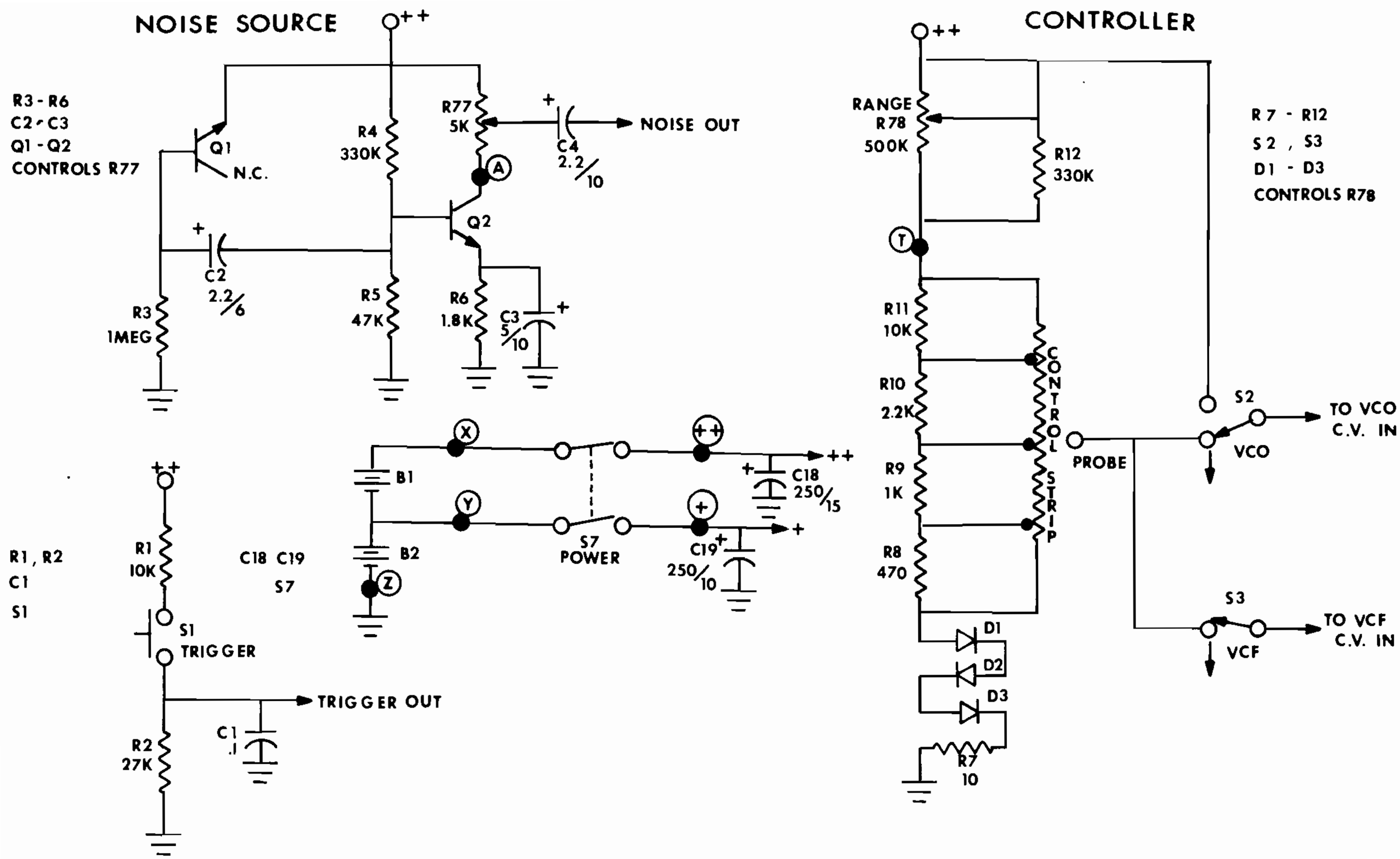
The diodes at the bottom end of the controller strip provide a constant voltage drop of approximately 1.5 volts insuring that there will be sufficient voltage on the strip to drive the VCO regardless of the setting of R78.

NOISE SOURCE

The GNOME's noise source is a standard design employing the shot noise that results from the avalanching process of the reverse biased base emitter junction of transistor Q1. The noise appears across resistor R3 and is coupled by capacitor C2 to the single stage amplifier comprising Q2, R4, R5 and R6. R77 is the level control for the noise source and as the wiper of this control is moved toward the collector of Q2 the amount of noise introduced into the common audio buss is increased.

TRIGGER

Trigger push-button S1 connects the +18 volt supply line to the trigger buss through R1. Capacitor C1 by-passes contact bounce impulses to ground.


NOISE SOURCE
CONTROLLER
R3 - R6
C2 - C3
Q1 - Q2
CONTROLS R77
Q1
N.C.
R4
330K
R77
5K
A
C4
2.2/10
NOISE OUT
Q2
C2
2.2/6
R3
1MEG
R5
47K
R6
1.8K
C3
5/10
R1, R2
C1
S1
R1
10K
S1
TRIGGER
TRIGGER OUT
R2
27K
C1
.1
C18 C19
S7
X
Y
Z
B1
B2
S7
POWER
C18
250/15
C19
250/10
RANGE
R78
500K
R12
330K
T
R11
10K
R10
2.2K
R9
1K
R8
470
CONTROL STRIP
D1
D2
D3
R7
10
PROBE
R 7 - R12
S 2 , S3
D1 - D3
CONTROLS R78
S2
VCO
TO VCO
C.V. IN
S3
VCF
TO VCF
C.V. IN

VCO

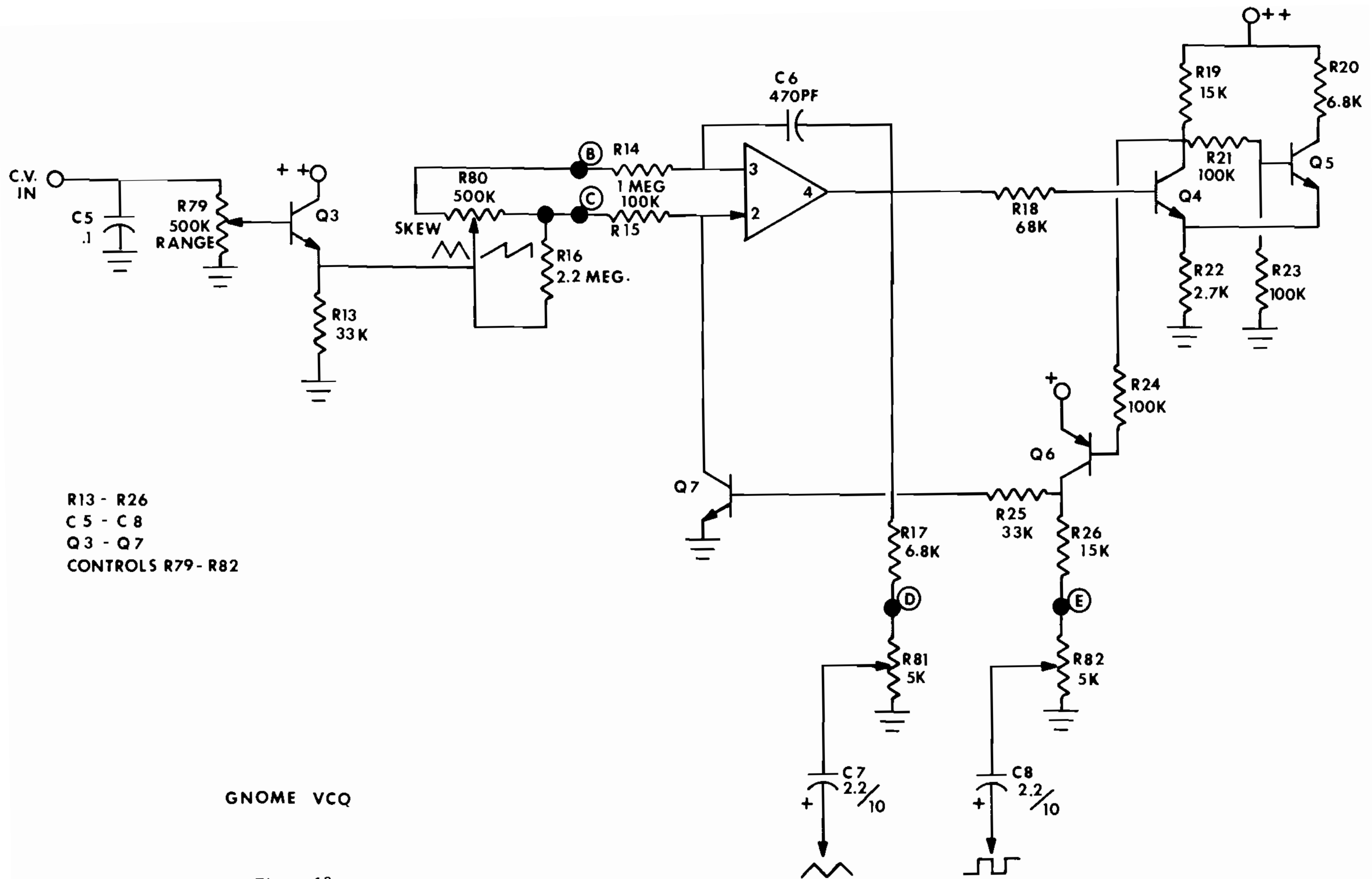
Control voltages are applied to the oscillator at the point marked "c.v. in" where C5 by-passes to ground contact noise originating at the controller strip. The control voltage is then applied to the VCO Range control R79 which serves as an attenuator on the control voltage line. The wiper of R79 connects to the base of emitter follower Q3 which serves as an impedance matching device between the control voltage input and the oscillator circuitry.

The oscillator is a relatively common type consisting of an integrator built up from one amplifier section from the LM-3900 Integrated Circuit and a Schmitt trigger comprising discrete transistors Q4 and Q5 and associated components.

The configuration of the integrator is such that the amplifier will work to make identical currents flow into its inverting (pin 3) and non-inverting (pin 2) inputs. Because of the values of resistors R14, R15 and R80, the current into the non-inverting input will always be at least twice the current into the inverting input except when transistor Q7 is turned on. To make up for this difference in current the output voltage of the amplifier rises linearly to force current through capacitor C6 into the inverting input. At some point the integrator output voltage exceeds the threshold established by the Schmitt trigger causing the collector voltage of Q4 to switch from essentially +18 volts to approximately 3 volts. Under these conditions the base emitter junction of Q6 is forward biased causing the collector of this transistor to rise to approximately 9 volts. The resulting current flow through R25 into the base of Q7 switches this transistor which in turn effectively shunts the current that was previously flowing into the non-inverting input of the integrator to ground. The integrator's amplifier now tries to make up for the surplus current flow into the inverting input by linearly decreasing its output voltage to pull current out of this input through C6. When the amplifier's output voltage falls to the level at which the Schmitt trigger re-sets, the collector voltage of Q4 goes high again which turns off Q6 and Q7 and restores the current flow into the integrator's non-inverting input so that the cycle can start over.

The cycle is identical when the SKEW control is rotated toward the ramp (/|/|) position except that the decreased resistance in the non-inverting input circuit allows a greater current flow which causes the integrators output ramp to rise more quickly. Simultaneously, the resistance taken away from the non-inverting input circuit is added to the inverting input to cause the integrator's output to fall more slowly. The combination of increasing rise time while decreasing fall time keeps the total period of the waveform approximately constant.

The ramping output of the integrator is applied to the series string or R17 and R81 with the setting of the wiper of R81 determining the amount of triangle/ramp waveform that is applied to the audio buss. Similarly, R82 is in the collector circuit of the seitching transistor Q6 and the wiper of this control sets the amount of square/pulse wave applied to the audio buss.



C.V. IN
C5 .1
R79 500K RANGE
+ +
Q3
R13 33K
SKEW
R80 500K
B
R14 1 MEG
C
100K R15
R16 2.2 MEG.
C6 470PF
3
2
4
R18 68K
Q7
R17 6.8K
D
R81 5K
C7 2.2/10
+
R25 33K
Q6
+
R24 100K
R26 15K
E
R82 5K
C8 2.2/10
+
++
R19 15K
R20 6.8K
R21 100K
Q4
Q5
R22 2.7K
R23 100K
R13 - R26
C5 - C8
Q3 - Q7
CONTROLS R79 - R82
GNOME VCQ

Figure 13

VCF

The GNOME filter is a common design built around one amplifier section of the LM-3900 and is tuned by varying the effective resistance of Field Effect Transistor Q8.

The three signals applied to the audio buss are mixed together by R34, R35 and R36 and applied to the input of the filter through R27. Slide switch S8 allows either the filtered or the unfiltered audio buss signal to be applied to the VCA.

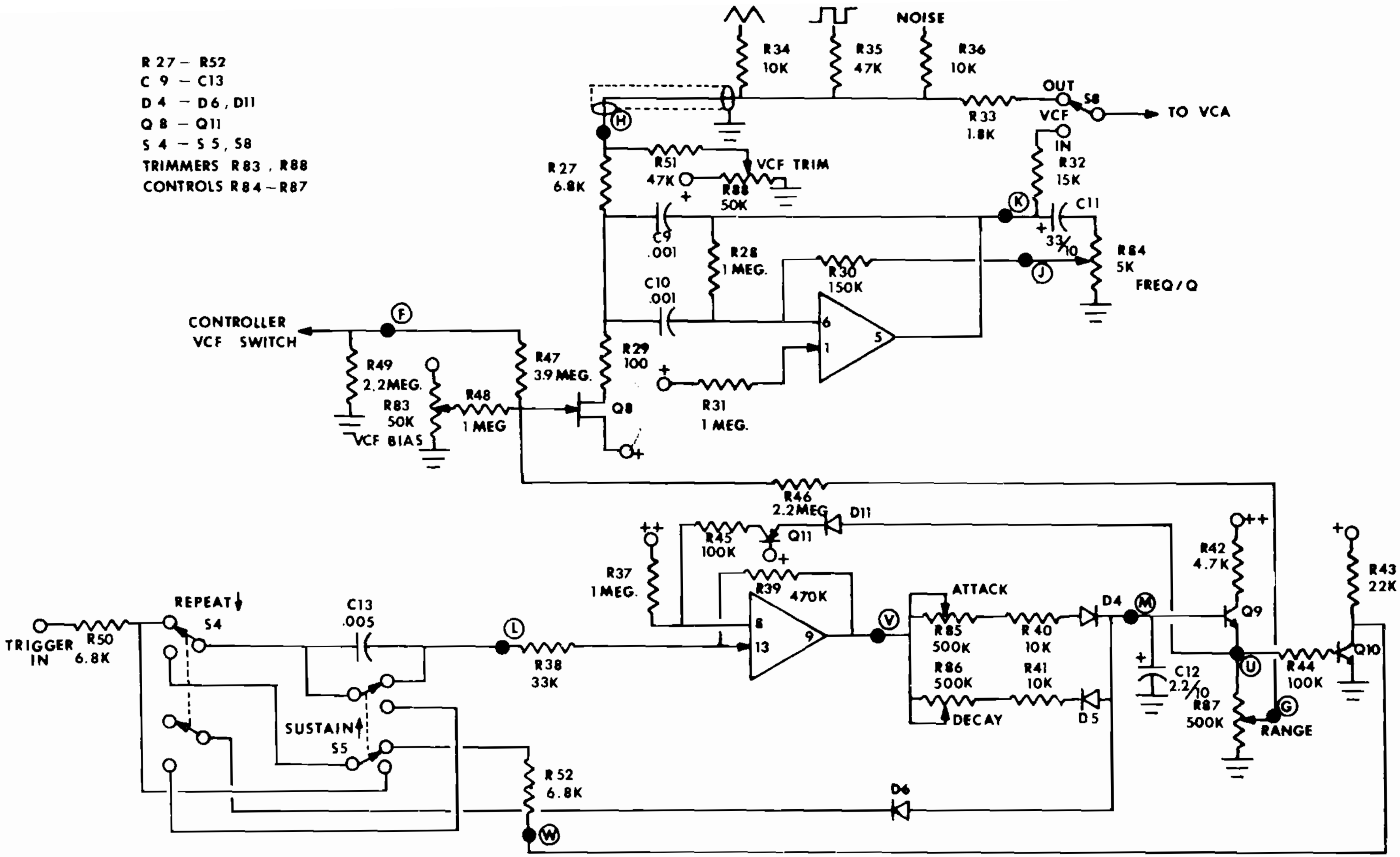
Control voltage for the filter can originate either at the controller strip or the filter's dedicated function generator. Controller voltages appear across R49 and are applied to the gate of the FET through R47 while voltages from the function generator are applied through R46.

The function generator comprises one section of the LM-3900. Trigger voltages that appear at R38 produce a current flow into the amplifier's non-inverting input that cause its output to switch to a high level. This high output voltage causes the timing capacitor C12 to charge through R40, the Attack control R85 and the forward biased diode D4. The voltage across C12 is sensed by the high impedance emitter follower Q9 with the voltage at the emitter of this transistor being a diode drop less than the voltage across the capacitor.

Once the amplifier is turned on by a trigger, it is held on by feed-back current through R39 even if the trigger is removed. As long as the voltage at the emitter of Q9 is low, Q11 is off and there is no current flow through R45 into the inverting input of the amplifier. As soon as the voltage at the emitter of Q9 exceeds two diode drops (D11 and the base-emitter junction of Q11) above the +9 volt reference at the base of Q11 this transistor starts to conduct causing a current flow through R45 into the amplifier's inverting input. If the triggering signal has been removed by this time the amplifier's output resets to a low voltage causing the charge on C12 to drain off through R41, the Decay control R86 and D5 which is forward biased under these conditions. If the triggering signal is still present it provided enough current into the amplifier's non-inverting input to hold the output high for a sustain interval.

Slide switch S5 provides for either sustained or non-sustained outputs from the function generator by allowing either a direct or capacitively coupled input for the trigger signal. Slide switch S4 provides for a repeat function by allowing the normal trigger signal from the trigger push-button to be replaced by the collector voltage of Q10. Q10 is a simple inverter stage which transitions to a high output voltage when the output of the function generator approaches its lowest output.

D6 provides a discharge path from C12 back into the triggering network when a "mute" function is desired from the function generator (Sustain off, Repeat on).



R 27 – R52
C 9 – C13
D 4 – D6, D11
Q 8 – Q11
S 4 – S 5, S8
TRIMMERS R83, R88
CONTROLS R84 – R87
R34 10K
R35 47K
NOISE
R36 10K
OUT
S8
TO VCA
VCF
R33 1.8K
IN
R32 15K
R27 6.8K
R51 47K
VCF TRIM
R88 50K
C11
C9 .001
R28 1 MEG.
33/10
R84 5K
FREQ/Q
R30 150K
C10 .001
CONTROLLER VCF SWITCH
R49 2.2MEG.
R83 50K
VCF BIAS
R47 3.9 MEG.
R48 1 MEG
R29 100
Q8
R31 1 MEG.
R46 2.2MEG
D11
R45 100K
Q11
R37 1 MEG.
R39 470K
ATTACK
R85 500K
R40 10K
D4
R86 500K
R41 10K
DECAY
D5
R42 4.7K
Q9
C12 2.2/10
R87 500K
RANGE
R43 22K
R44 100K
Q10
REPEAT
S4
TRIGGER IN
R50 6.8K
C13 .005
R38 33K
SUSTAIN
S5
R52 6.8K
D6

Figure 14

VCA

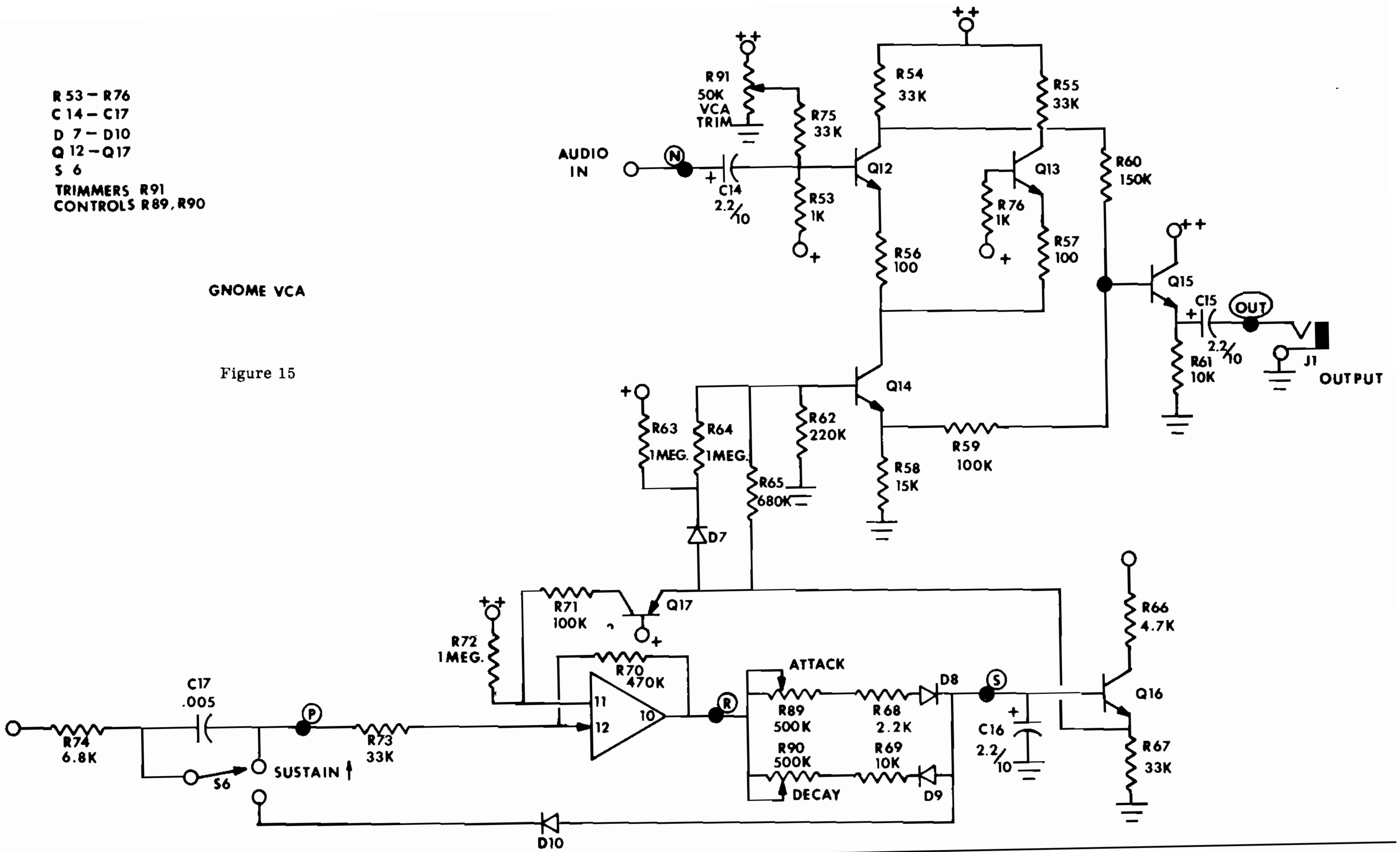
With the deletion of the components that provide for repeat, the operation of the function generator associated with the VCA is identical to that of the VCF's function generator.

The VCA is a common design employing a differential pair (Q12 and Q13) sharing a common constant current sink in their emitter circuits. Since the gain of a transistor is proportional to its collector to emitter current, more current flow through the current sink (Q14) increases the gain of the transistors in the differential stage.

In more expensive VCA's the differential outputs from the collectors of Q12 and Q13 would be applied to the inverting and non-inverting inputs of an operational amplifier so that the DC voltage level changes associated with increasing and decreasing the gain of the pair would be rejected as common mode voltage. In this circuit the DC voltage shifts are cancelled out in R59 and R60 and this is based on the fact that as the voltage at the collector Q12 drops with increased gain, the voltage at the emitter of Q14 rises by a proportional amount because of current flow through R58. The ratio of R59 to R60 cancels the DC level shifts while acting only as an attenuator on the audio signal present at the collector of Q12.

Emitter follower Q15 provides a high input impedance to the output of the VCA while presenting a desirable low output impedance to drive the power amplifier being used with the GNOME.

R 53 – R 76
C 14 – C 17
D 7 – D 10
Q 12 – Q 17
S 6
TRIMMERS R91
CONTROLS R89, R90



GNOME VCA

Figure 15

BIBLIOGRAPHY

MAGAZINE ARTICLES

"The Synthesizer"
Morton Subotnick
Recording Engineer/Producer
Vol. I no. 1 April/May 1970

"Live Electronic Music Equipment"
Robert D. Ehle
db
Vol. 5 no. 12 December 1971

"The Fine Art of Voltage Control"
David Kirk
Studio Sound
Vol. 13 no. 4 April 1971

"A New Look"
Bernard L. Krause
Down Beat
Vol. 41 no. 1 17 Jan. 1974

"Electronic Music - Its Composition and Performance"
Robert A. Moog
Electronics World
Vol. 77 no. 2 Feb. 1967

"Compositional Limitations of Electronic Music Synthesizers"
Hubert S. Howe, Jr.
Journal of the Audio Engineering Society
Vol. 19 no. 6 June 1971

"Vladimr Ussachevsky"
Profile
Down Beat
Vol. 41 no. 1 17 Jan. 1974

BOOKS

Horns, Strings and Harmony
Arther H. Benade 1960
Doubleday & Co.

New Directions in Music
David Cope 1971
Wm. C. Brown Co.

Electronic Music, Systems, Techniques and Controls
Allen Strange
Wm. C. Brown Co.

Learning Music with Synthesizers
David Friend
Alan R. Pearlman 1974
Thomas D. Piggott
Hal Leonard Pub. Co.

Electronic Music Production
Alan Doublas 1974
TAB Books

Electronic Musical Instruments
Norman A. Crowhurst 1971
TAB Books

Notations
John Cage

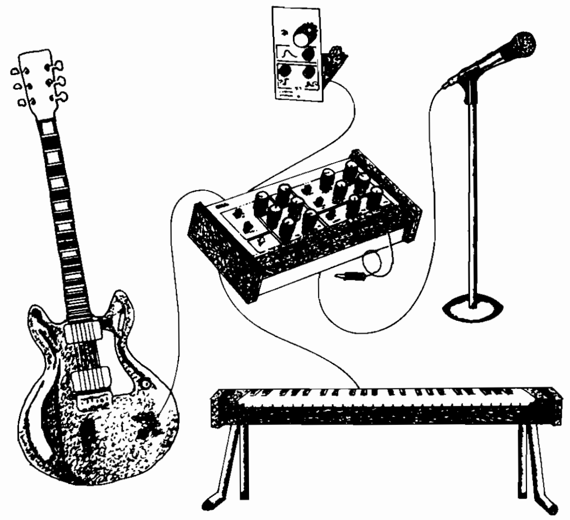
Music Notation and Terminology
K. W. Gehrkens

Modern Music Notation
Laszlo Boehm 1961
G. Schirmer

Toward a New Music
Carlos Chavez 1937
W. W. Norton

On the Sensations of Tone as a Physiological Basis for the Theory of Music
Hermann L. F. Hermann 1948
Peter Smith Co.

Interfacing External Signals with the Gnome Micro-Synthesizer



Many people are interested in low cost methods of processing signals from standard musical instruments, microphones or recorded signals. As well as serving as a low cost introduction to the principles of synthesizers, the Gnome can easily be modified to become a versatile processing center for external signals. Here are some ways to accomplish this type of interface, each suited to slightly different circumstances. Perhaps you'll find one here that is just what you've been looking for.

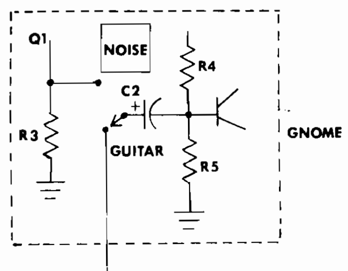
ed.

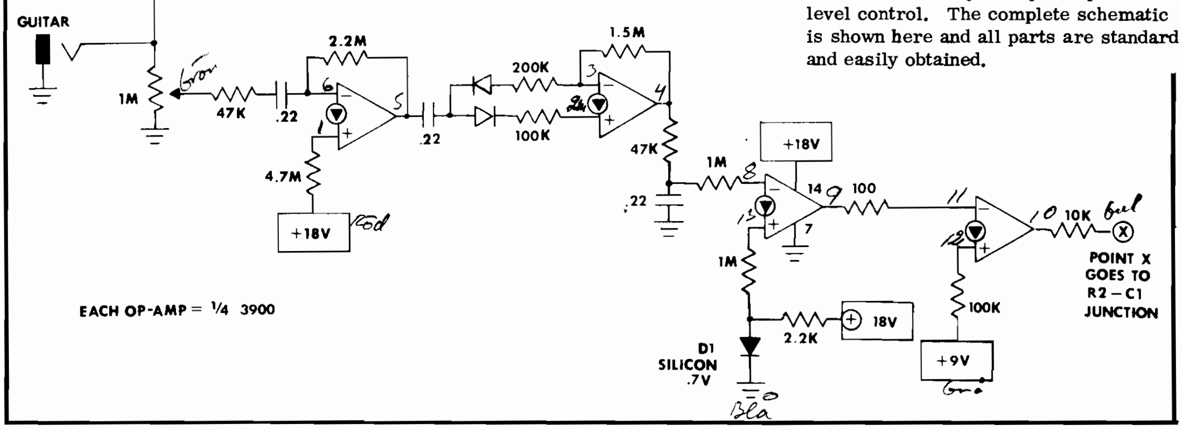
Guitar/Gnome Interface

by: Craig Anderton

This circuit serves as an automatic trigger for the GNOME. A suitable jack for an external signal input can be mounted on the rear panel. The external signal is applied to a 1 meg sensitivity control which can also be mounted on the rear panel. The first stage of the LM3900 is a high gain audio amp. The output from this stage is then fed to a rectifier built around the second amp of the IC. The rectified signal is filtered by the 47K/.22 mfd. combination. The voltage across this capacitor is present only when an input signal is present. Thus, the comparator output is connected to the point which will cause both of the Gnome's envelope generators to begin sweeping. In other words, the applied external signal will produce the same effect as pressing the trigger button. The original input signal is simultaneously applied to one side of a SPDT switch mounted on the GNOME case. The positive side of C2 in the Gnome is lifted from the circuit board, and an extention wire connects it to the wiper of the switch. The remaining side of the switch is connected by a wire to the unused positive mounting hole for C2. This switch will allow the user to select noise generation or external signal generation.

Another nice feature of this circuit is that your external signal will now use the noise circuitry as a preamp and level control. The complete schematic is shown here and all parts are standard and easily obtained.





Gnome/Instrument Interface

Using the 2720-11 Envelope Follower

by: Marvin Jones

For those of you who like to avoid making your own circuit boards and tracking down the parts for your projects, we present an alternative. You will still need to install an external input jack, and this can be connected to the Gnome's noise circuit as shown in Craig's circuit or it can be connected directly to the Gnome's audio buss (Ts-2, lug 3) through a 2.2 mfd. electrolytic capacitor as shown in figure B. Note that the positive lead of the capacitor will go to the audio buss, while the negative lead goes to the tip connection of the external input jack.

To provide the signal detection and triggering function, you can use the PAIA 2720-11 Envelope Follower module. The external signal source will be fed to both the 2720-11 and to the Gnome external input. The desired trigger (step or pulse) output of the 2720-11 is then patched to the external input of the Gnome (the black pin jack on the rear apron of the case).

Be sure to have a common ground ~~between the Envelope Follower and the~~ Gnome in order for the trigger signal to have effect.

As an extra bonus, the 2720-11 has an envelope control voltage output. The voltage at this jack is a DC voltage which varies from 0 to 7 volts and is directly proportional to the amplitude of the signal applied to the input of the 2720-11. The wiper probe of the Gnome can be inserted into this envelope output and you can sweep the frequency of the Gnome's VCO or VCF each time a signal is generated by your external source. This particular set up can yield a great variety of effects.

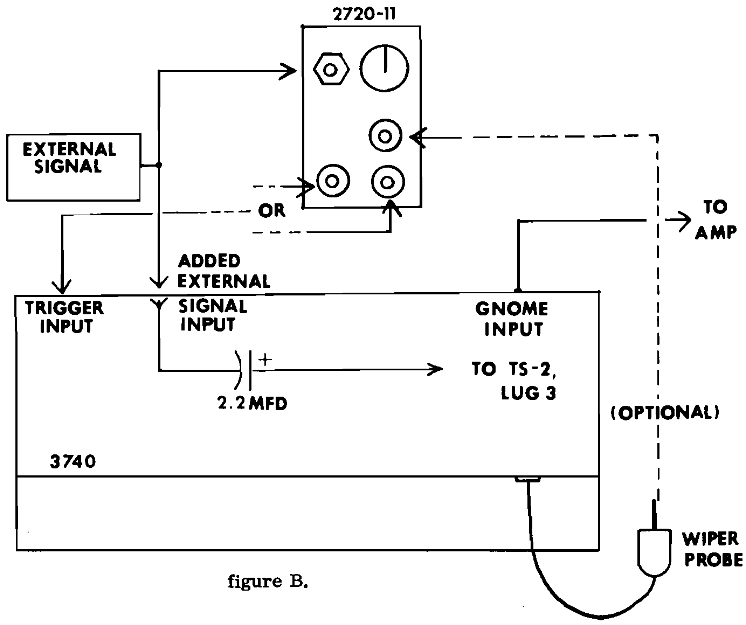


figure B.

Electronic Piano/Gnome Interface

by: Dana Lee

Recently I've done some slightly different things with the Gnome Micro-Synthesizer. It involved modification of the trigger jack and the addition of the external input jack for the Gnome.

The black pin jack for the trigger was removed and in its place a stereo phone jack was inserted. The tip and ring were connected to each side of the trigger button on the front panel - the shield was automatically connected to ground. This means that if I wish to plug in an external trigger footswitch, it can be done using the tip and ring connections. If I want to use an external trigger voltage, I use the tip connection and ground with the ring connection unused (see figure C).

For some time I wanted to interface my electronic piano with the Gnome.

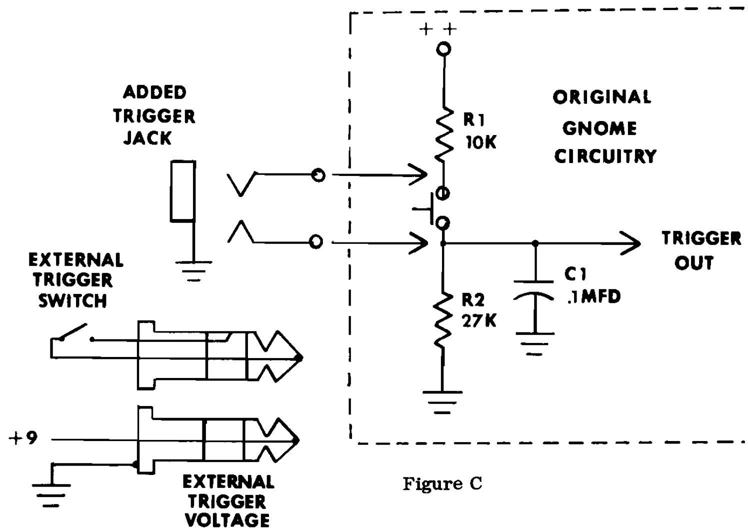


Figure C

continued......

INTERFACING THE GNOME

..... continued

This was not difficult, as I merely installed a regular mono phone jack with the shaft connection automatically to ground and the tip connection to where the outputs of the VCO are bussed. (Evidently, Dana's piano is capacitively coupled at the output. To be safe, you should install a coupling capacitor as described earlier. Once again, the audio bus is at TS-2, lug 3. -- ed.)

This now means that I can use the VCF and VCA for my electronic piano. Some of the effects are weird, such as when the Gnome's VCF is set for the fastest possible repeated sweep. This will give the most spectacular effects, but pleasant effects are obtained by adjustment of any of the filter controls. Also, I have found that I can add slower attacks to my piano using the VCA and the external footswitch trigger that I've made.

That's about it, but it allows for a phenomenal amount of experimenting. Just a few cents worth of jacks, and it's done. Just thought I'd pass the idea along to share with others in case they're into this type of thing.

Our thanks to Craig Anderton and Dana Lee for their contributions. We've had many requests from our readers concerning external inputs for the Gnome. Perhaps you can find the answer to your special needs here. Good luck to all you wire freaks out in Gnome Mans Land!

— ed. —