CONTENTS

Fast-Forward and Rewind

SOUND

Sounds are vibrations of the air caused by vibrating objects. Take a simple musical example - the string on a guitar. When it is plucked, it is pulled in one direction and released. Because it was under tension from the pulling, it snaps back to its original position and, because of its momentum, it keeps going through its at-rest position to an opposite state of tension.

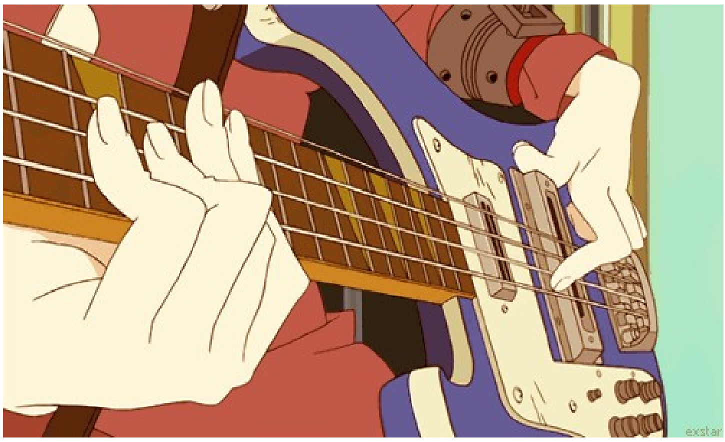


Figure 3.1- String Vibration - Click on the image for animation

It proceeds to move back and forth, each time with a little less power, until it comes to rest in its original position.

Figure 3.2 - Vibration Decay - Click on the image for animation

Almost all struck or plucked instruments vibrate in some variation of this action. When the string is released it pushes the air in front of it causing a slight extra compression of the air molecules or, put another way, slightly higher pressure. This is called "compression". When the string flicks back, it causes a slight vacuum, or low pressure area. This is called "rarefaction". As

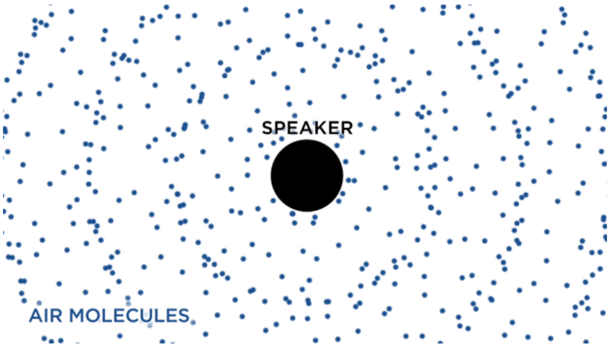


Figure 3.3 - Compression wave -Click on the image for animation

The string vibrates back and forth more and more of these compression and rarefaction areas are created. They act like ripples in a pond, spreading out quickly and always at the same speed, the speed of sound.

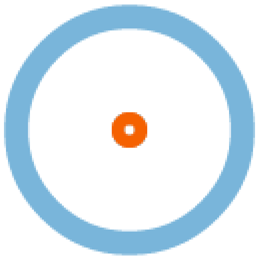


Figure 3.4 - Waves - Click on the image for animation

If you are standing some distance away from the vibrating string when these ripples reach you, if there were some way of counting how many waves occur per second, many things could be told about the string itself! For one thing, because the speed of sound is constant, you would know how many times the string vibrates in a second. This number is called the FREQUENCY of a sound. The second thing you would want to determine is how strong the ripples are, and that is, how compressed the compression wave is and how vacuous the rarefaction wave is. This strength is called the AMPLITUDE of the wave. When working with sound it can also be called the VOLUME or LOUDNESS of the sound. The amplitude can tell you one or both of two things: how strong the source of vibrations was (i.e. how powerfully it could push air around) and/or how far away the source of the vibration is, because the amplitude of the ripples decreases with distance.

There are a number of other things we wish to detect about the sound waves that reach us. No object vibrates simply. Each has a characteristic 'waveform' that, when perceived, can identify that object. This is called the TIMBRE or quality of the sound and is how we distinguish a piano from a violin. We would want to detect these variations and have a sense of where the sound is coming from.

We perceive these complex waves with our ears. We hear different frequencies as different PITCHES and we can hear over the range of about 20 to 20,000 cycles (vibrations) per second.

We perceive loudness, and remarkably, we can sense the amplitudes of rustling leaves or those of a jet plane. The jet produces compressions and rarefactions nearly one million times greater than leaves!

Without going in to much detail, this is the way the ear works: the pressure inside the human head remains constant (though adjusted to normal pressure of the atmosphere of the air). When there are no sound waves in the air, the eardrum is at rest between two areas of equal pressure. However, when a sound wave ripples past, with its fluctuating bands of high and low pressure, the eardrum is pulled slightly outward during a rarefaction wave and pushed slightly in by the high pressure part of the wave. This means that the eardrum is going in and out at the same rate (with the same frequency) as the original sound source. The eardrum's vibrations are transmitted be means of small bones to the cochlea, a spiral organ in the inner ear filled with a liquid and coated on the inside with millions of small hairs. Each of these hairs is connected to a nerve ending through which these signals are sent to the brain.

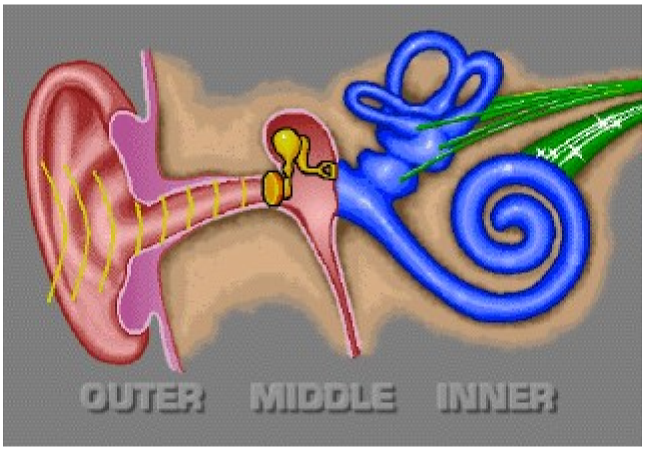


Figure 3.5 - How the ear works - Click on the image for animation

If we could take a picture of a small section of air through which a sound wave is moving, it might look like this:-

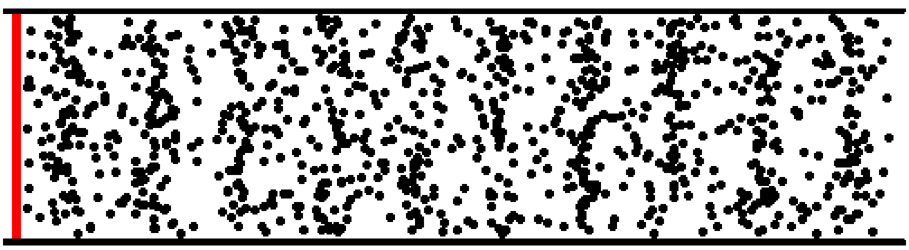


Figure 3.6 - Air molecules - Click on the image for animation

In this image each dot represents a few million air molecules, but even with this simplification it is a rather clumsy way of describing how a wave 'looks'. Here is a better way to describe the "pressure" at each point of the wave:-

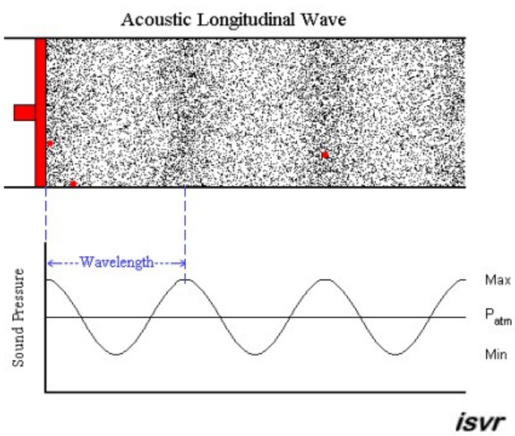


Figure 3.7 - Pressure wave - Click on the image for animation

The line P*atm* is the normal pressure while the wavy line is a graph of the pressure of the wave. When the wavy line is above P*atm*, the pressure is greater than normal air pressure, when below P*atm*, it is less than air pressure.

Figure 3.8 shows two sound waves drawn using pressure graphs:-

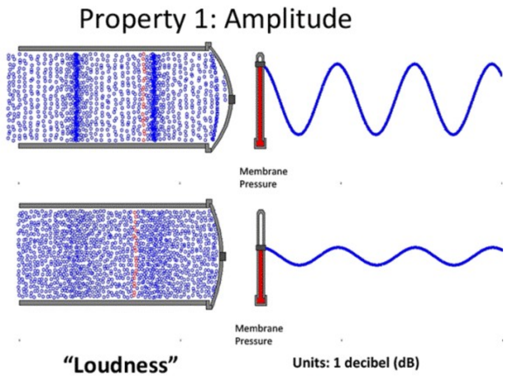


Figure 3.8

The difference between the two waves is that the top one goes further above and below the mid-point than the bottom wave. This indicates that its amplitude or loudness is greater and is measured from "peak to peak", from the top of the highest peak to the bottom of the lowest trough. Below are two more waves:

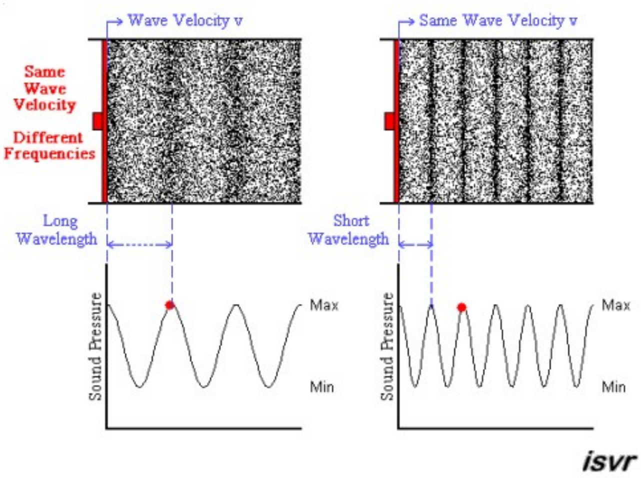


Figure 3.9 Click on the image for animation

Notice that in this case the amplitude of the two waves is the same, but that in the same length of time there are more excursions up and down in the right wave as in the left - that is the right wave has a higher frequency than the left wave. If a wave has twice the frequency of another wave, we hear it one octave higher. Notice that if the first octave starts out at 80Hz (Hz is the symbol for Hertz which is the same as cycles per second), then the next octave starts at 160Hz (twice the first), the third octave will start at 320Hz, the next at 640Hz, then 1280Hz, 2560Hz and 5120Hz. Whereas the first octave had a range of only 160Hz, the top octave had a range of 2560Hz! but to our ear/brain both sound like a single octave.

Figure 3.10 shows some standard wave shapes:-

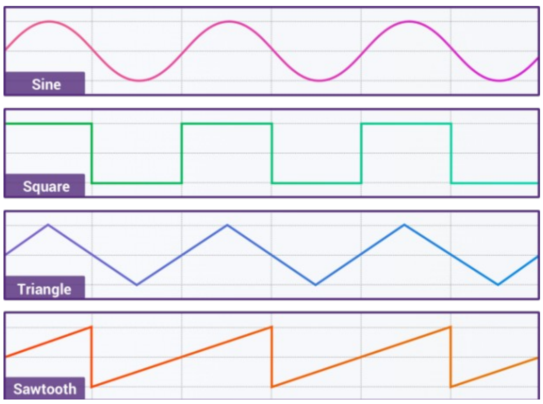


Figure 3.10

The SINE and SAWTOOTH are two wave types that you will find on most synthesizers. The waves in this drawing have the same frequency and amplitude but a different SHAPE. The shape of a wave affects its TIMBRE or sound quality. Picture your eardrums being pulled in and out by the waves shown above to see the difference in the kind of motion the liquid in the cochlea would have. In the real world, of course, nothing can vibrate in quite these shapes and if it could, the air cannot ripple in quite this fashion, and if it could, the eardrum cannot be moved in precisely this way. But it can all come remarkably close.

Below is what the sound waves of a guitar and a cymbal might look like:

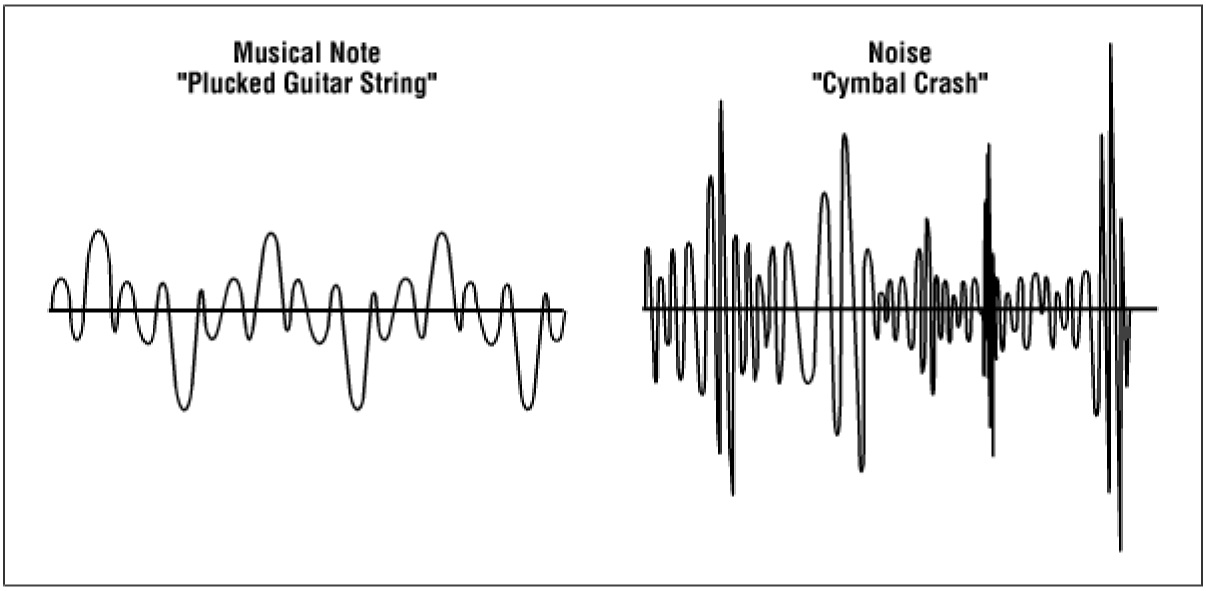


Figure 3.11- Guitar - Cymbal

VOLTAGE

Voltage can be considered to be electric pressure. By the middle of the 19th century, many of the advantages of converting sound waves (rapidly changing atmospheric pressure) into voltage were discerned. Primary amongst them was that while sound waves died out relatively rapidly, voltage waves could be sent thousands of miles over wires, around corners and through walls. The main problem was how to convert sound waves in to voltage waves and then, after a journey of perhaps a hundred miles, convert the voltage waves more or less accurately, back in to sound waves. In other words, the problem was the invention of the telephone.

A microphone is a device for converting sound waves in to voltage waves, or atmospheric pressure into electric pressure. The simplest microphones have a diaphragm which acts much like the eardrum in its response to sound waves. It is pushed inwards by a compression wave and pulled outwards by a rarefaction wave. The diaphragm is attached to a device which, when it is pushed inward creates a positive voltage and when it is pulled outward creates a negative voltage. When the diaphragm is at rest, its output is 0 volts.

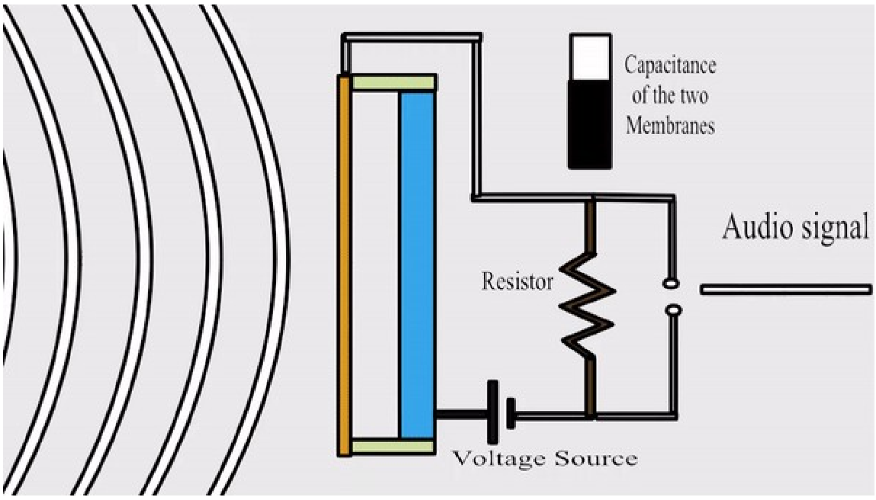


Figure 3.12 - The Microphone - Click on the image for animation

Because of this one-to-one correspondence the voltage output of a microphone is said to be isomorphic with the sound wave input.

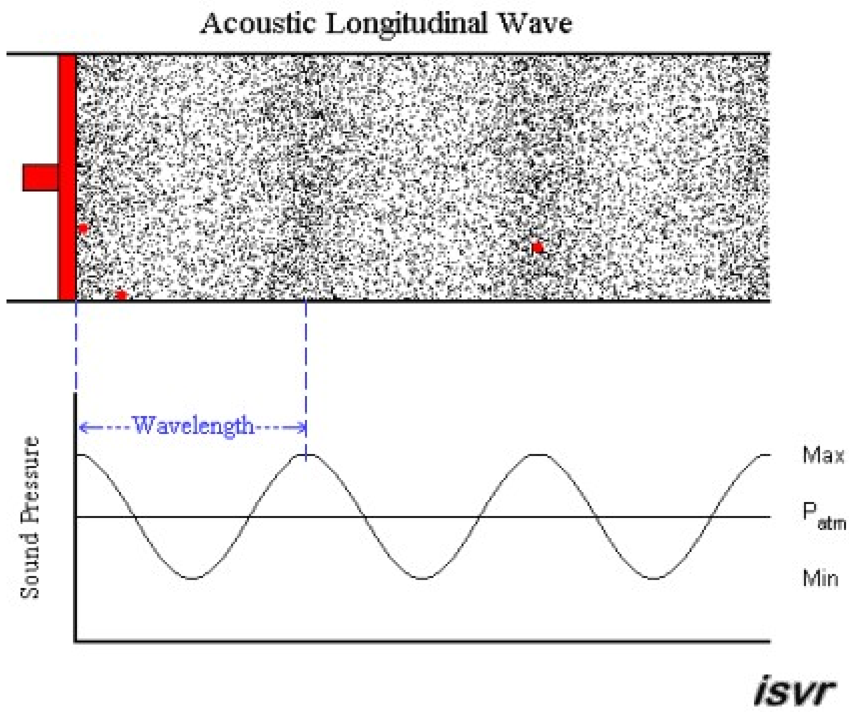


Figure 3.13 - Click on the image for animation

A speaker is a device that takes a voltage wave and converts it into a sound wave. Though there are many kinds of speakers the most common ones work by moving a speaker "cone" with an electro-magnet.

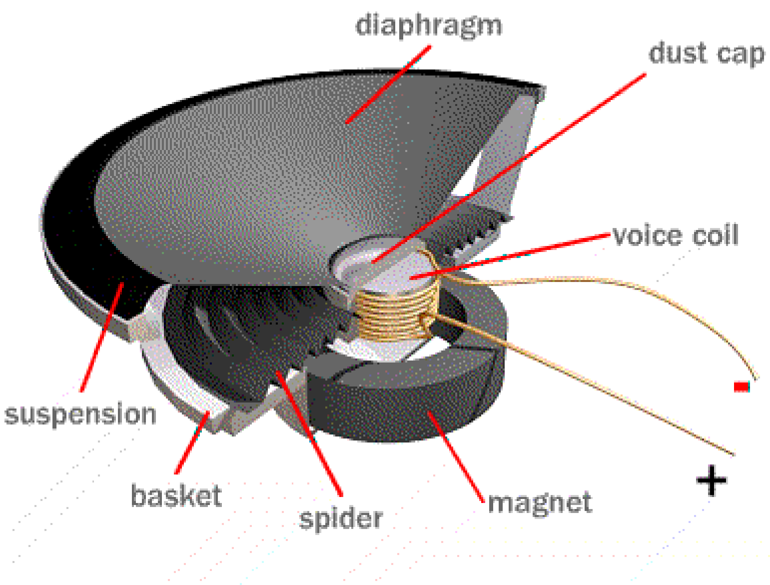


Figure 3.14 - Click on the image for animation

In this kind of speaker the coil wire attached to the speaker cone sets up magnetic fields which push and pull itself in and out from the magnet as the voltage changes, thereby pushing and pulling the cone in and out. This creates rarefaction and compression waves in front of the cone. The speaker cone, therefore, reproduces the movement of the diaphragm of the microphone and in so doing reproduces the original sound wave.

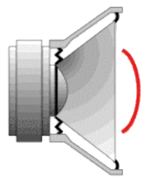


Figure 3.15 - Click on the image for animation

It was the ability of such a system to transmit sound over long distances that first attracted the attention. It soon became clear that there were other advantages. Once the sound wave was converted into a voltage, it was far more malleable. It could be amplified, for instance, so that when the speaker re-created the sound it could be louder than the sound originally picked up by the microphone.

A speaker doesn't know where the voltages it is receiving are coming from. Its cone will move in response to any varying voltage. A SYNTHESIZER is a device which creates and sculpts voltages of various shapes that, when directed to a speaker, create sound that can be used in musical settings.

THE DEVELOPMENT OF THE SYNTHESIZER

From the earliest days of electronics, there have been various devices to create and alter voltages of audio frequency. We've already discussed the amplifier which takes an input of a varying voltage and puts out that same varying voltage magnified in amplitude. Another device is an oscillator, which simply puts out a varying voltage in a number of simple shapes:-

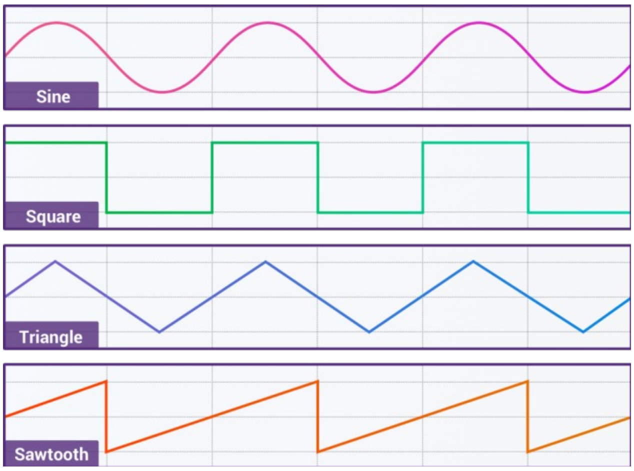


Figure 3.16

A knob, or pot (short for potentiometer, which is the device the knob turns) on the front of the oscillator would determine the frequency of these waves, that is how often in one second the wave would rise and fall.

The first step towards electronic music was taken when the OUTPUT of the oscillator was connected, or PATCHED to the INPUT of the amplifier. The OUTPUT of the amplifier was sent to the speaker.

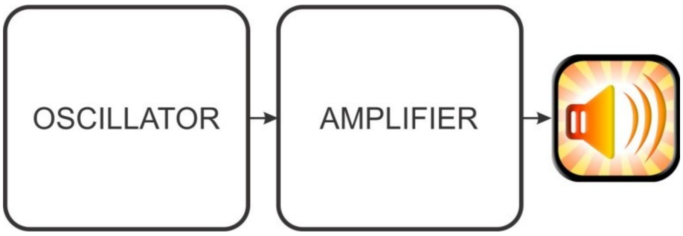


Figure 3.17

Note the "block diagram" used above. In this form of notation a block indicates an electronic device. The arrow coming out of a device is its output, while an arrow going in to a device is its input. An output of one device is always the input to another device. The output of a speaker goes to the input of the ear. What outputs from your mouth inputs in to someone else's ear.

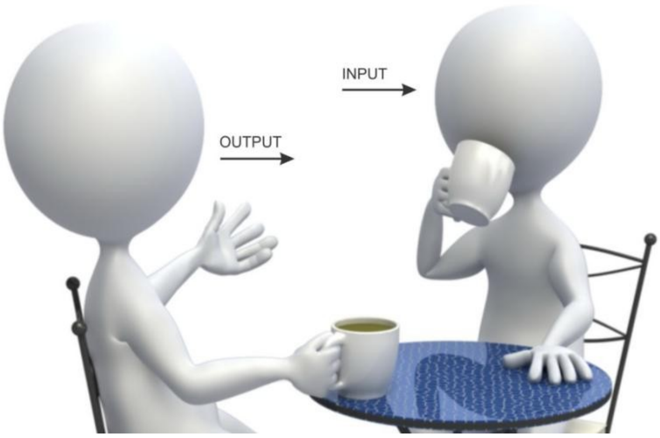


Figure 3.18 – You can't beat a good 'chin wag', people talking face-face

Another device was the mixer, which takes inputs and adds them together to produce a single output. Unlike the amplifier the mixer has more than one input.

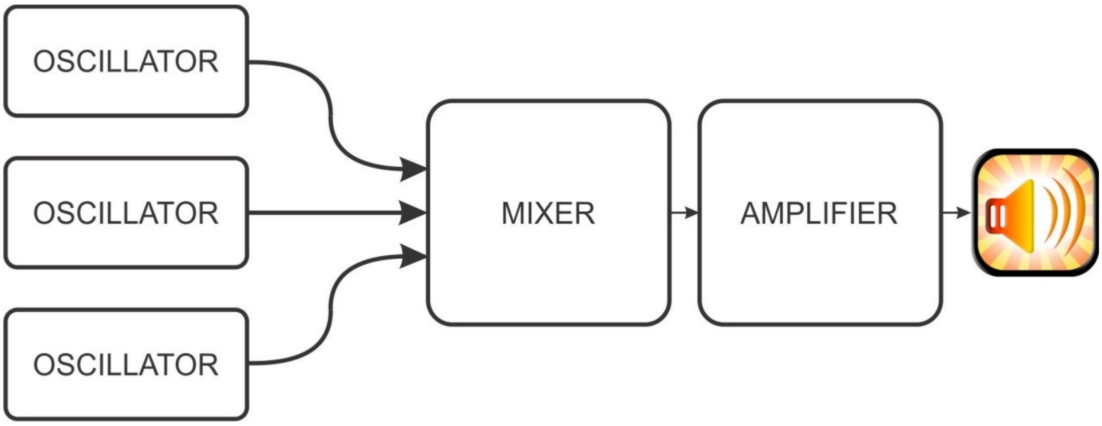


Figure 3.19

Still another important device was the filter. A filter is a device that can eliminate or accentuate various frequency components of a complex sound. For instance it can be used to eliminate all the very high frequency components (the hiss) in a sound, by only allowing those frequencies in the range of the human voice to pass. A pot on the front of the filter controls which frequencies will be attenuated or eliminated.

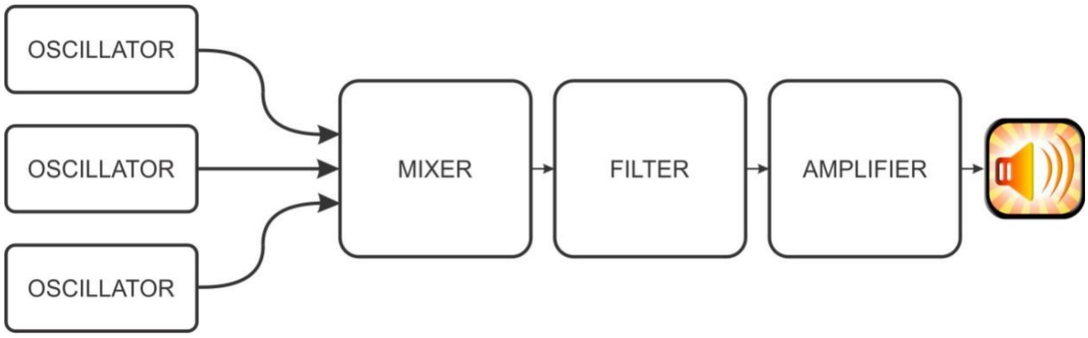


Figure 3.20

There are two problems with this procedure of adding device after device. The first was that very quickly there were just physically too many knobs to fiddle. The second problem was that knobs couldn't be turned quickly or precisely enough. The amplifier could not be turned up and then quickly down again fast enough to make the "sound envelope" of a single whack of a drum.

The invention of the tape recorder, just after World War II, solved some of these problems. A single sound could be produced electronically, recorded on to a short piece of tape, and spliced into another previously made sound and so on until a string of sounds had been made. Two of these tapes could be mixed together through a mixer and recorded on to a third tape. The speed of the tape machines could be varied, and the segments could be reversed or even cut to form spliced "envelopes". This was (and still is) a very tedious process, but it is a very rich and flexible one. A studio built to be able to produce electronic tapes in this way is called a Classical Electronic music studio.

The first major improvement in the classical studio came from Columbia University where they devised a controller which could set all the dials instantaneously from the instructions given on a punched paper tape.

It wasn't until the sixties that the synthesizer as we now know it was designed by Don Buchla and Robert Moog by adding Voltage Control to the classical studio.

The Voltage Controlled Electronic Music Synthesizer solved both of the two major problems of the classical studio by employing voltage Control which works in the following manner:

Each device is given a special input called a Control Voltage Input (CV or sometimes VC for Voltage Control). This input accepts a voltage such that as this voltage increases it is JUST LIKE TURNING UP THE KNOB ON THE FRONT OF THE DEVICE. That is, a voltage can be used to CONTROL the device. For instance, in a voltage controlled amplifier, if the voltage at the CV input increases, it turns the amplifier up and makes it louder.

NOTE that in these block diagrams, as a matter of convention, the control voltage input is on the bottom of the device, the "signal" is on the left side and the output is on the right side.

In a voltage controlled oscillator, a rising voltage at its control voltage input would make its frequency rise. For each device the control voltage affects only the function of that device.

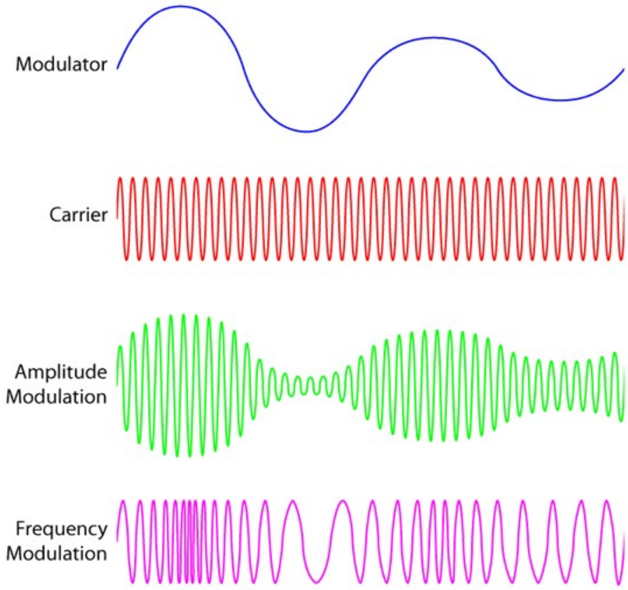


Figure 3.21 Amplitude and Frequency modulation

Control voltages solved both problems of the classical music studio. With enough control voltages you could change all the settings of all your devices. And secondly you could change these settings so rapidly as to seem instantaneous. You could change the settings very, very slowly, or you could change them at audio frequencies, for instance 500 times per second. When a device's settings are changed at those rates, some very strange things begin to happen, many of which can be musical.

The only problem left, of course, is where to get all these control voltages. This problem is not as great as it seems for a control voltage is identical to any other kind of voltage. For instance, we could us an oscillator to control an amplifier since the output of that oscillator is a voltage!

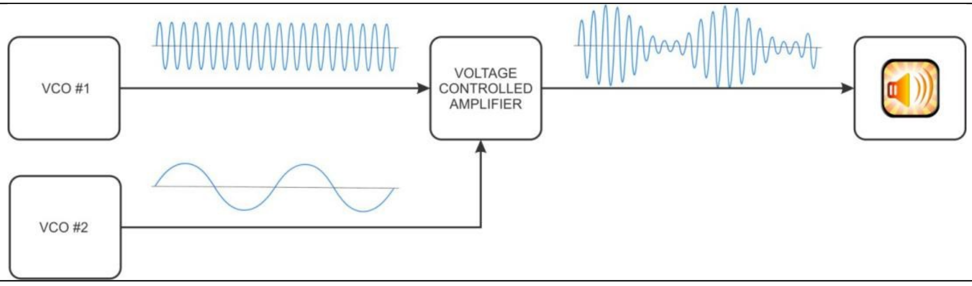


Figure 3.22 Click on the images for animation and audio

In the above example VCO #2 is controlling the amplifier, making the signal from VCO #1 louder and softer.

Most of the early synthesizers have two different sets of patch cords, one for the control voltages and one for the signals, even though the voltages themselves are indistinguishable. The Euro-Serge does not make this distinction.

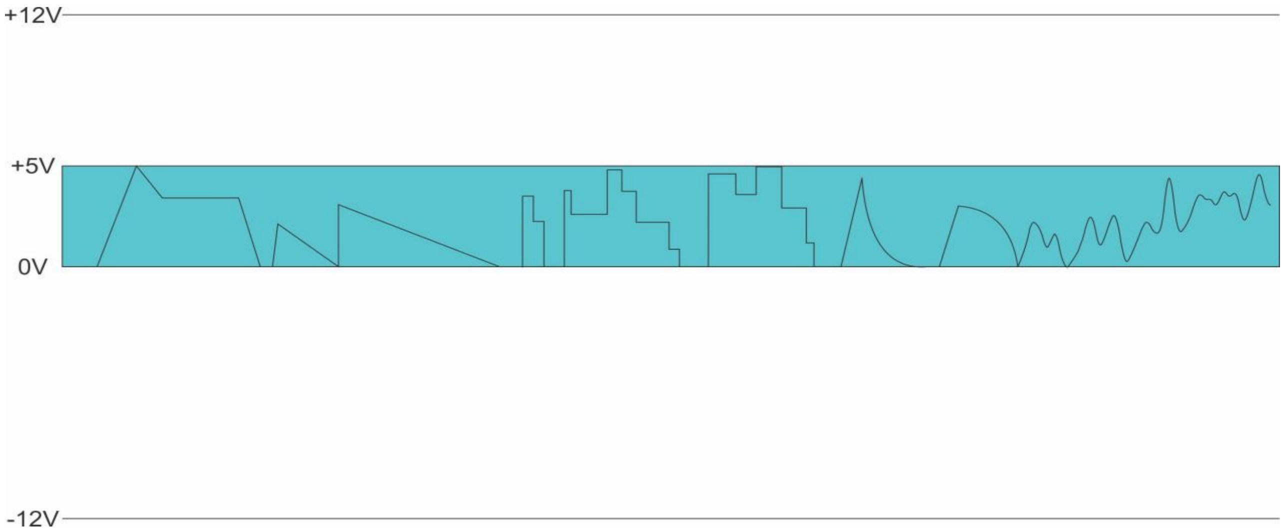
THE EURO-SERGE SYSTEM

The Euro-Serge Synthesizer is a Voltage Controlled Modular Music System. MODULAR means it is composed of separate devices of modules which must be patched together to produce complex sound. Voltage Controlled means that almost all of these devices can be controlled by a voltage as well as by their own pots. MUSIC means that the Euro-Serge can be used to create complex, ordered sound, and Synthesizer means that it needs no other input (though it is able to accept one) and that it can create, or synthesize, sound.

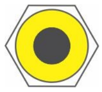
There are four principal types of signal in the EURO-SERGE: DC control, logic control, bi-polar control, and audio signals.

DC CONTROL VOLTAGES: BLUE/GREEN.

Blue and Green are the colours of the jacks which handle signals in the DC control voltage range. DC is the abbreviation used in electronics ("direct current") meaning that a voltage is of one polarity only. The polarity for DC control voltages in the EURO-SERGE is positive. Their range falls typically from 0V to +5V, with a maximum voltage range of +/-12V. This is the way (typical) DC control voltages look within the maximum range of the system.



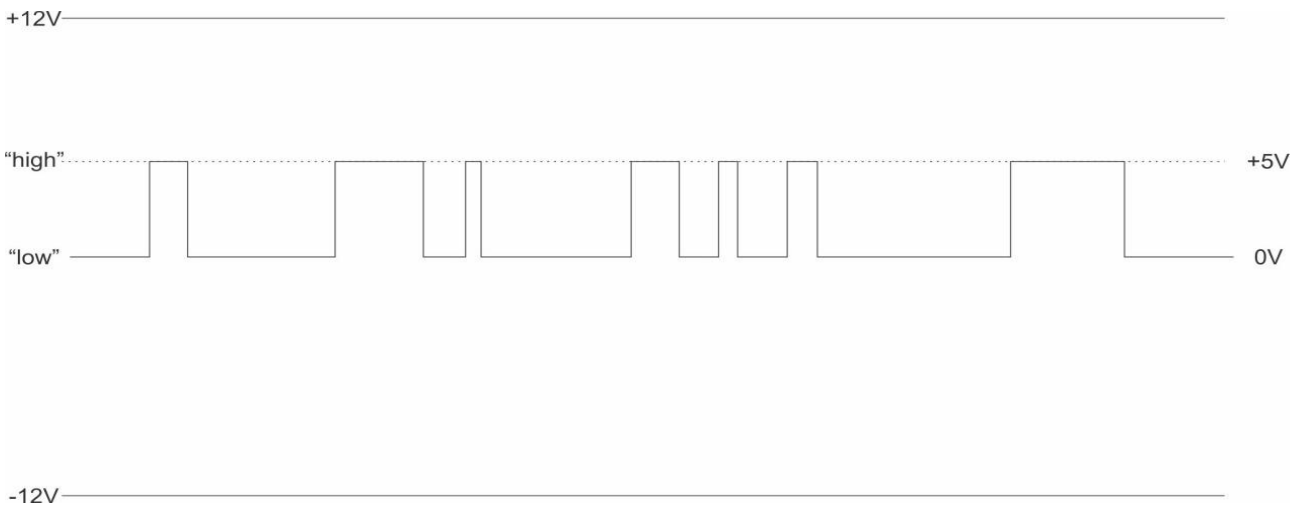
LOGIC CONTROL VOLTAGES: RED/YELLOW.



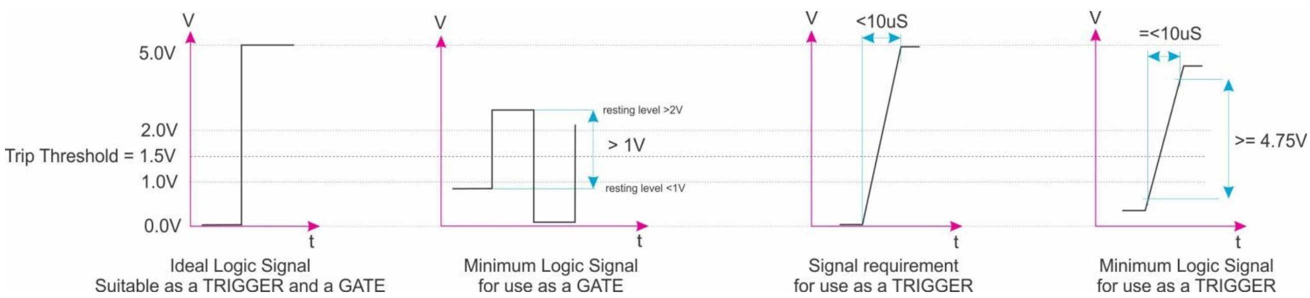
Red and Yellow are the colours of the jacks which handle logic control which are, typically, 'triggers' and 'gates'. Logic signals fall into the same voltage range as DC control voltages though there are modules which produce outputs of more than +5V. Logic signals are either "high" or "low". The (very fast) transition from "low" to "high" defines the point in time something can be "triggered". The inverse transition, from "high" to "low" is ignored: it cannot be used to trigger anything….

A second use of logic voltages is to define how long something should be sustained. This is usually defined by how long a logic pulse stays "high".

Logic pulses look like this:



While logic signals normally only have the 2 states of 'lo' (0V) and 'hi' (+5V) and are usually associated with pulse-type waveforms, other waveshapes may be used as long as they meet the specific requirements:-

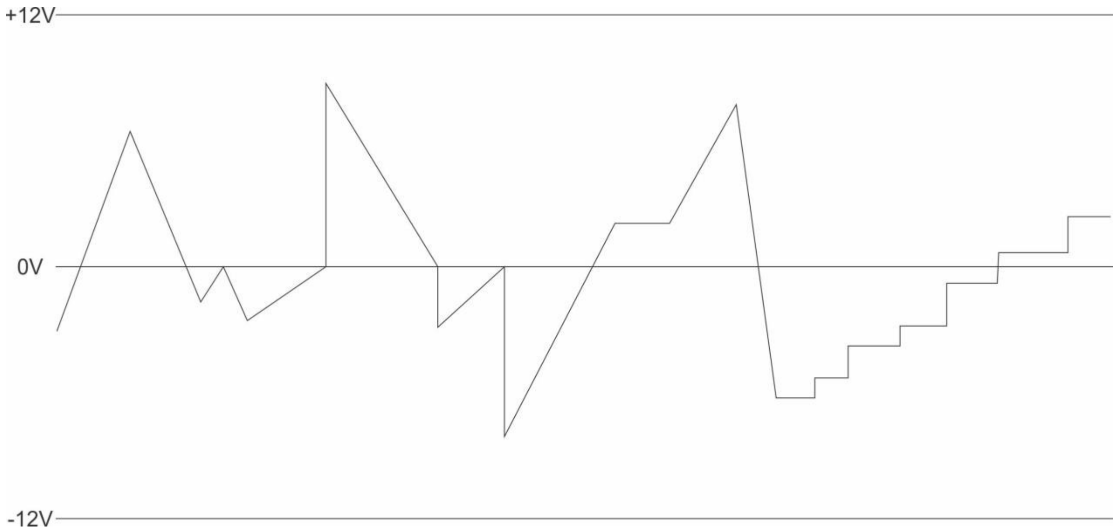


1. For a GATE the waveshape must have a range of greater than 1V and swing from below the "'lo boundary" of 1V to above the "hi boundary" of 2V

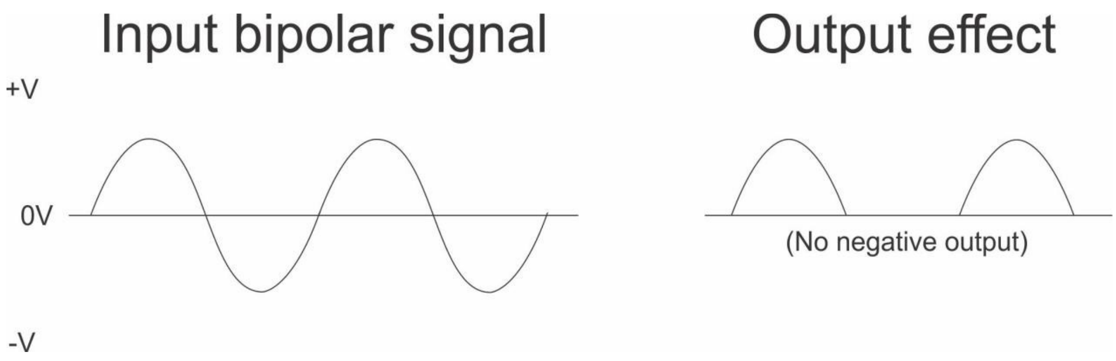
2. For a TRIGGER the waveshape must have a range of greater than 4.7V and swing from below the "'lo boundary" of 1V to above the "hi boundary" of 4V, AND
3. Have a slew time of less than 0.3V/uS (maximum rise time of less than 10uS)

AC CONTROL VOLTAGES: BLACK/WHITE.

Black and white are the colours of the jacks which handle bipolar or AC control signals. The word bipolar denotes the ability of a control voltage to be negative as as well as positive (+/-). AC is the abbreviation used in electronics ("alternating current"). AC control voltages in the EURO-SERGE may fall anywhere within the entire voltage range of the system (+/-12V). AC control voltages typically look like the following:



NB: although many of the (blue) inputs that handle DC control voltages will accurately respond to AC control voltages, others will not, and will cut out the negative part of the AC input signal. A graphic example of this effect is shown below, along with a list of the modules affected.

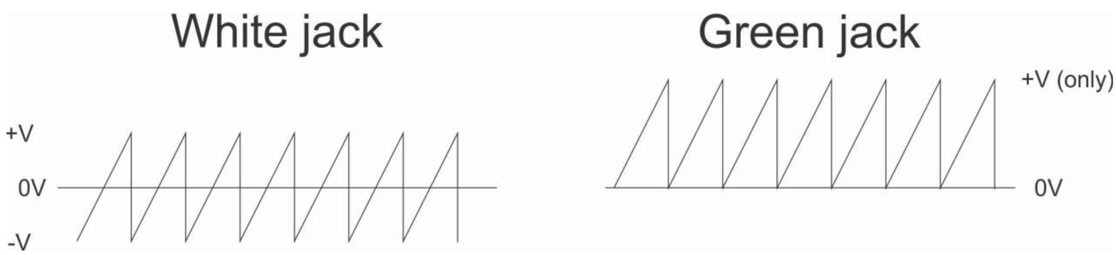


Affected modules:
PEAK & TROUGH
POSITIVE & NEGATIVE SLEW
WAVESHAPER
Etc…

AUDIO SIGNALS: BLACK/WHITE.

Audio and AC signals share the use of the same black and white jacks of the EURO-SERGE. This is done because both share the same bipolar range of +/-12V. The main differences between the types is (1) audio is always bi-polar, (2) audio always falls in to the audible portion of the frequency spectrum (from about 16Hz to 16kHz). In practise, modules designed to process audio signals are easily differentiated because they will start filtering out frequencies below about 16Hz. Moreover, audio modules will generally restore the average DC voltage level of the signal to zero volts.

A graphic example of this effect is shown below, through a comparison of white (AC) and green (DC from 0V to +5V) outputs of an OSCILLATOR:



There are four basic kinds of modules on the Euro-Serge. Many modules can serve more than one of these functions:-

1. SOUND SOURCES. The basic sound source is the oscillator though there are others such as white noise. Sounds from the external world, as long as the have been converted into appropriate voltages (by the use of microphones or pickups for example) can also be used as sound sources. Oscillators are completely voltage controllable.
2. SOUND PROCESSORS. Processors are devices that input one or more signals, operate on these signals, and then output a different but related signal. Mixers, filters, envelope shapers, amplifiers are all processors. Almost all of these devices are voltage controllable.
3. CONTROL VOLTAGE SOURCES. Control voltage sources are devices that are used to create the control voltages which are used to control other devices. The keyboard, for instance, puts out a voltage which can be used to control the setting of an oscillator. Other devices are envelope generators, sequencers, sample/hold devices and envelope followers. These devices are voltage controlled themselves, making possible complex levels of control.
4. CONTROL VOLTAGE PROCESSORS. These devices input a control voltage, operate on it, and output a related but different voltage. Processors and portamentos are examples of these modules.

- Every module has at least one output
- All processor type modules have at least one input as well as an output
- Most module share control voltage inputs which control the function of the module. These inputs are of two basic types:-

  PROCESSED INPUTS which have a pot associated with the input jack that can attenuate, amplify and/or invert the control voltage

  UNPROCESSED CONTROL VOLTAGE INPUTS affect the given module in a predetermined way.

	Full Range		
	Expanded IN-OUT		
	ORIGINAL SERGE		
	INPUT	OUTPUT	SPECIAL
AC/Audio	AC IN	AC OUT	AC SPECIAL
DC	DC IN	DC OUT	DC SPECIAL
Logic	LOGIC IN	LOGIC OUT	LOGIC SPECIAL

Figure 3.23 - Input/Output Colour Coding Scheme

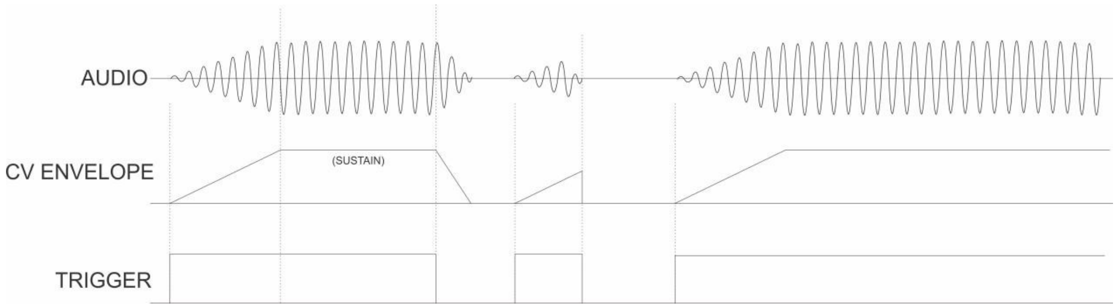
This scheme is an expansion of the original Serge 3-colour scheme which used the 3-colours in the left column and didn't differentiate between input and output.

Euro-Serge has added the 2nd column to give this differentiation between inputs and outputs within each signal type.

A 3rd column provides for identifying a signal that is 'special' for example 'DC SPECIAL' could indicate a CV that has a negative voltage extent, or that the signals are 'hotter' than specified in the EuroSynth Specification. Examples of such modules that use these special jacks are the 'SYNC' input on the OSCILLATOR, and the 'COUPLER' function of the SMOOTH & STEPPED.

How are the various signals used?

The usual logic of synthesizers is that LOGIC PULSES are used to start and define the length of sustain of CONTROL VOLTAGE ENVELOPES. Whereas CONTROL VOLTAGES serve to specify and control the frequency, timbre or loudness of an AUDIO VOLTAGE. Thus, for example:



One of the notable features of the EURO-SERGE SYSTEM is that only one system of patchcords is used. This is in contrast with a number of synthesizer which use tow or more patchcord systems to handle the various types of signals, phone type jacks, for example, to handle audio, and cinch-jones to handle triggers. The advantages of a one patchcord system is that it allows signals to be used wherever useful, for example using control voltage envelopes as audio signals, etc..
This is often done in EURO-SERGE, especially since most modules in the system are extremely wide-range, and overlap the sub-audio and audio ranges of frequencies.

Where are the LOGIC PULSE to be found on the EURO-SERGE?

LOGIC PULSES may be initiated externally through the use of manual controllers, such as the push-buttons of the PROGRAMMERS, or from keyboards, or internally from repetitive sources of pulses such as the NEGATIVE POSITIVE SLEWS, ENVELOPE GENERATORS, RANDOM, etc… LOGIC PULSES may also be gotten by using the COMPARATOR to sense the amplitude of the signal from external sources such as microphones, tape recorders, foot pedals or sensors attached to instruments such as drums etc.

Where are the CONTROL VOLTAGES to be found on the EURO-SERGE?

There are a wide variety of CONTROL VOLTAGES on the EURO-SERGE. These include triangular or trapezoidal envelope shapes from the wide variety of envelope generators available (NEGATIVE and POSITIVE SLEWS, ENVELOPE GENERATOR, SMOOTH FUNCTION, etc). These may be triggered through the use of an external LOGIC PULSE, or be used in a self-recycling mode where the modules provides its own TRIGGER. The way this works is shown in the following pages.

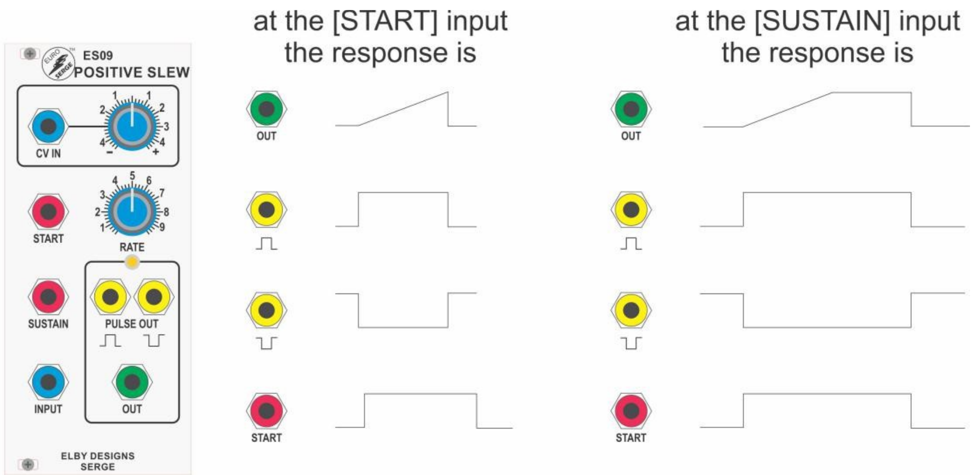
EXAMPLES OF MODULES WHICH CAN BE TRIGGERED TO PRODUCE ENVELOPES

Triggering modules is usually done by putting a pulse source into a pulse input (red). A pulse into a “start” input triggers an envelope through one cycle. A pulse in to a “sustain” input will trigger and envelope AND determine the length of time it remains at its ‘sustain’ level.

The following diagrams show how this operates for the POSITIVE SLEW, the ENVELOPE GENERATOR, and the POSITIVE + NEGATIVE SLEWS linked together to form an envelope generator.

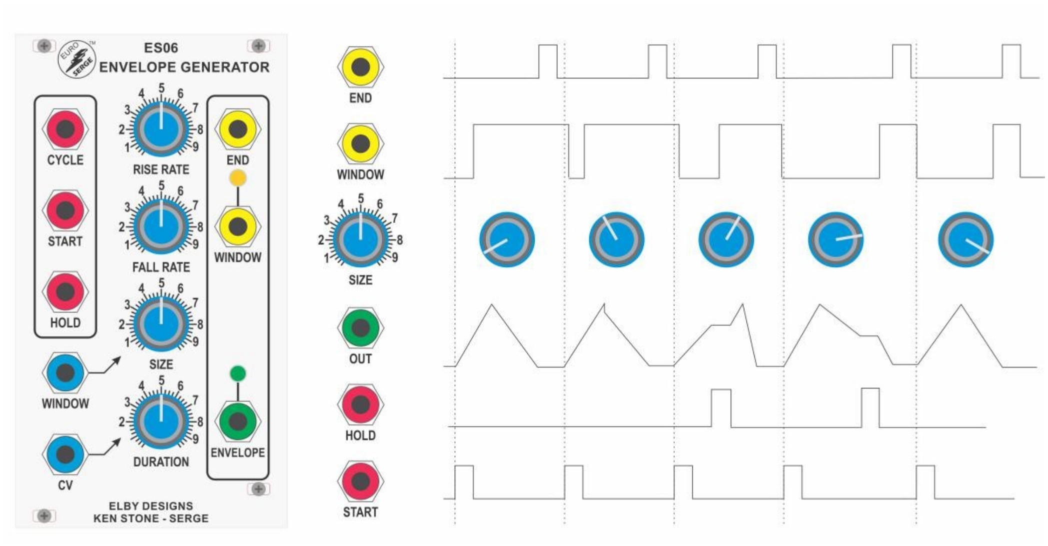
POSITIVE SLEW

The additional two output pulses are useful in a variety of triggering functions, delay, duration and self-triggering (as shown in later pages).



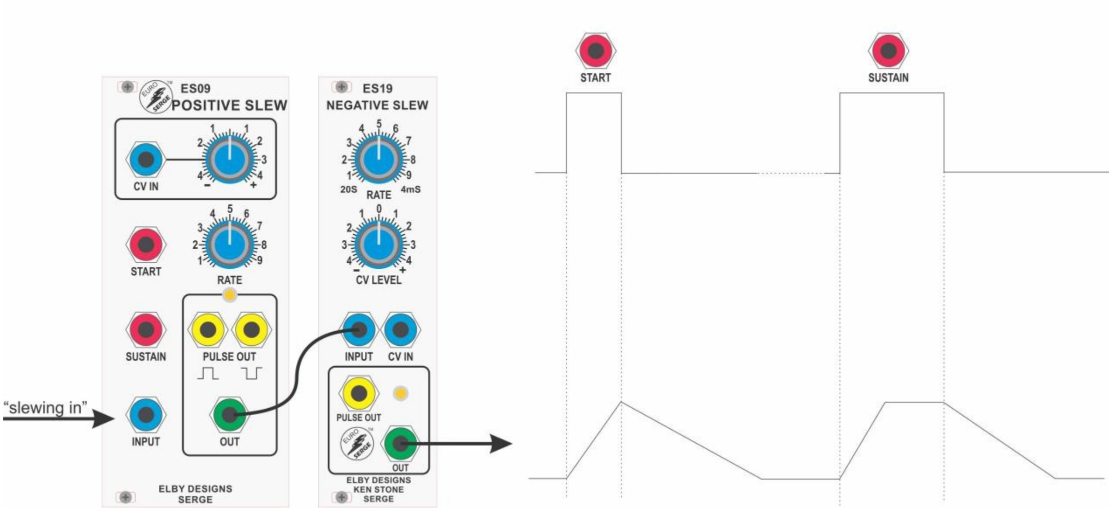
ENVELOPE GENERATOR

NB: Putting a pulse (or a control voltage above +2.5V) into the [HOLD] input is also shown below..

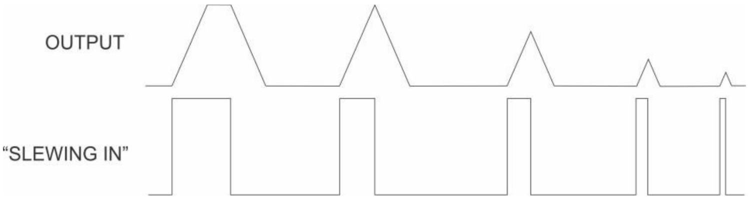


A more intricate function is also shown here: the [WINDOW SIZE]. This is a pulse trigger output which may be set to occur at any point in a cycle according to the position of the [WINDOW SIZE] knob (as shown) or the level of a control voltage at the [WINDOW SIZE] input (not shown). This is a very useful function in obtaining a variable time delay between different envelope generators.

<u>POSITIVE & NEGATIVE SLEWS</u> (connected as envelope generators)



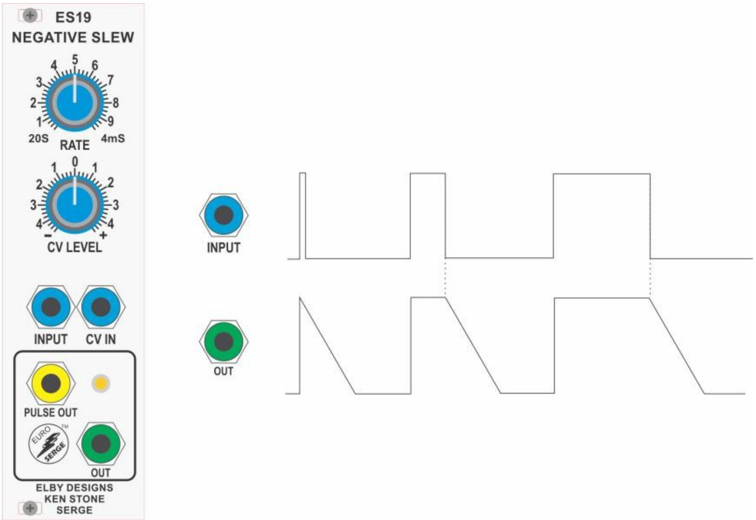
Another manner in which a pulse input may be used with the combination shown above, is through the main "slewing" input. While this is not really a true example of 'triggering' since an envelope does not occur irrespective of the pulse length, nevertheless this is a very useful manner of generating envelopes for keyboard performance.
What is generally wanted in keyboard work is making sure that the sound will enter its "decay" period (ie will die down) the moment that a finger is lifted.



NB: ”slewing” will be explained in later pages.

NEGATIVE SLEW

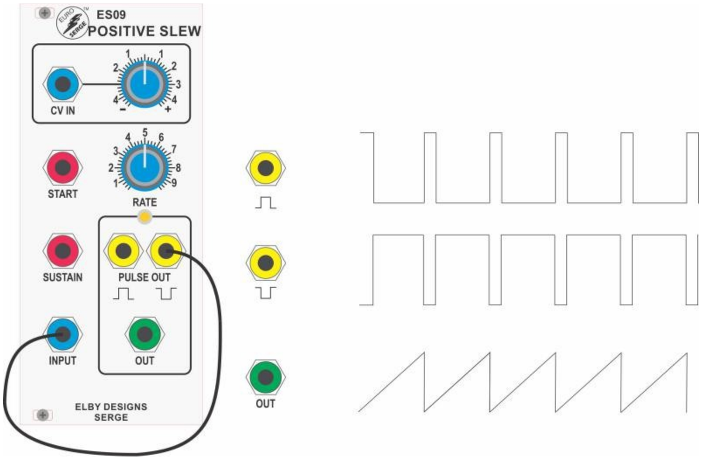
As in the envelope generator connection of POSTIVE + NEGATIVE SLEWS, the following is not properly speaking “triggering” since in this case triggering depends on how fast an input moves. However, the following use of the NEGATIVE SLEW is often useful:



The previous examples of triggering are all performed through the use of pulses external to the module, as derived from keyboards, the PROGRAMMER, or other pulse sources. The following examples show how it is possible to feed a pulse back within a module so that it triggers itself repetitively. This is an extremely useful mode of operation which yields voltage controllable trigger pulse generators, repetitive envelopes, and even, whenever the need arises, to obtain additional audio oscillators. The process is called “self-triggering”.

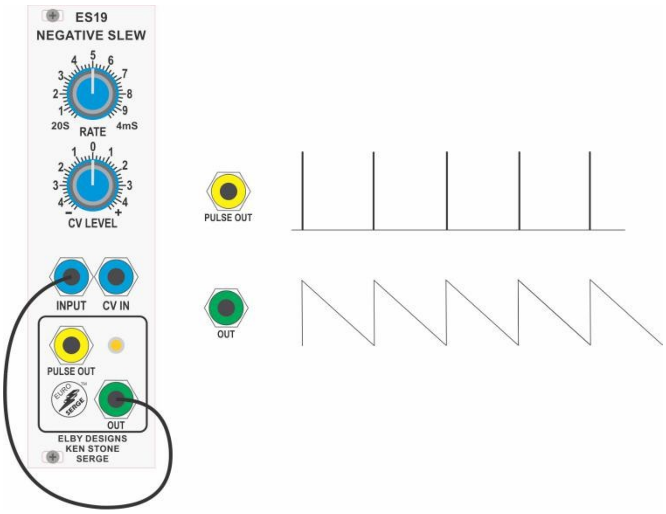
EXAMPLES OF SELF-TRIGGERING

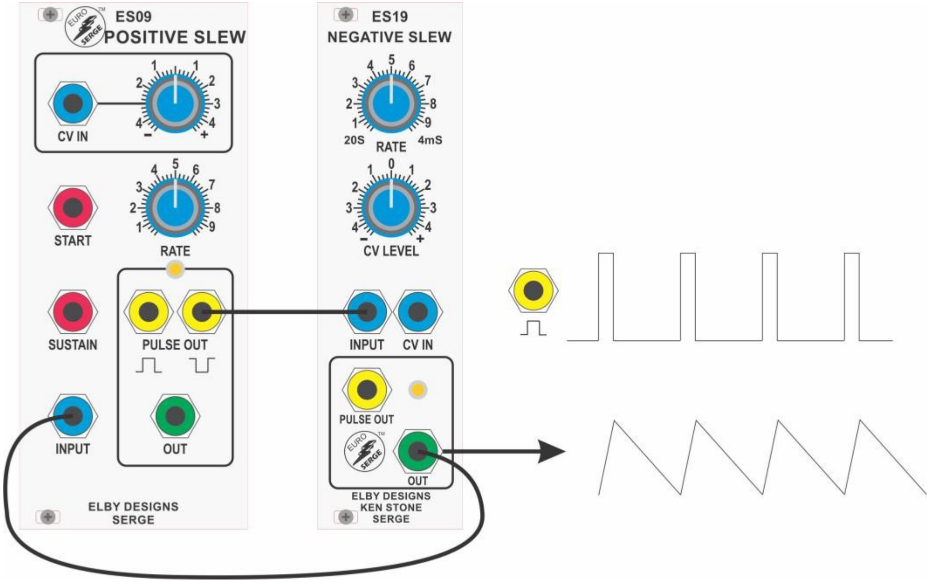
POSITIVE SLEW

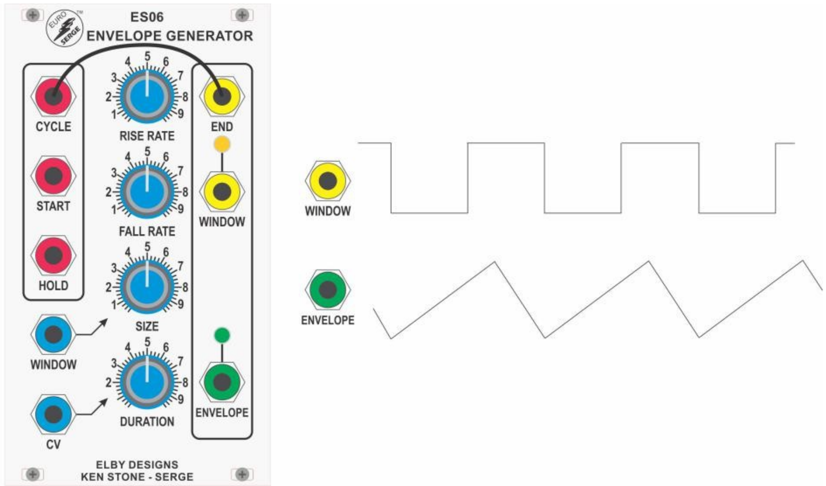


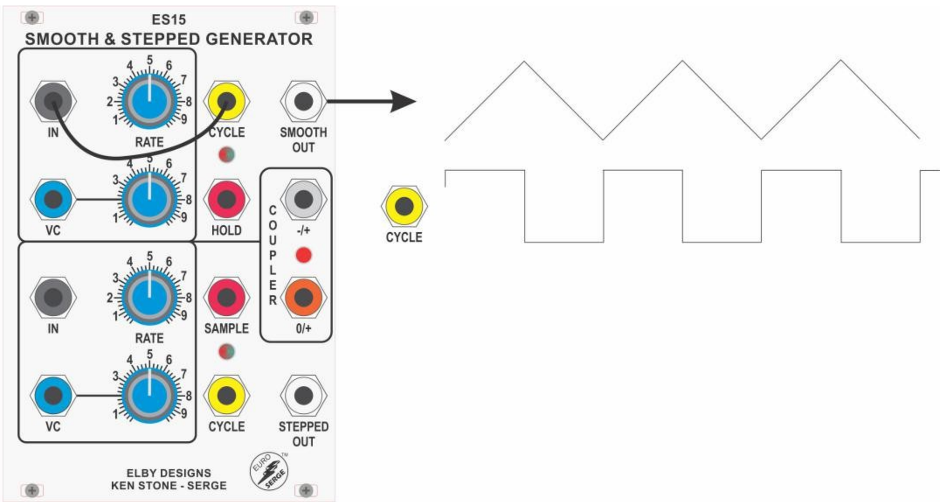
In this patch, the pulse output marked “ “ may be used to trigger other functions, while the sawtooth output is useful to over 3kHz as an audio source. Using a WAVESHAPER, furthermore, the sawtooth may be shaped into a sine-wave. With a COMPARATOR, a pulse-width modulation may be gotten. Explanations are forthcoming in later pages…

This patch is useful one of the most useful of the EURO-SERGE system, for use as a pulse source, as percussive attack-type sawtooth for the FILTER, and sometimes as an audio generator.



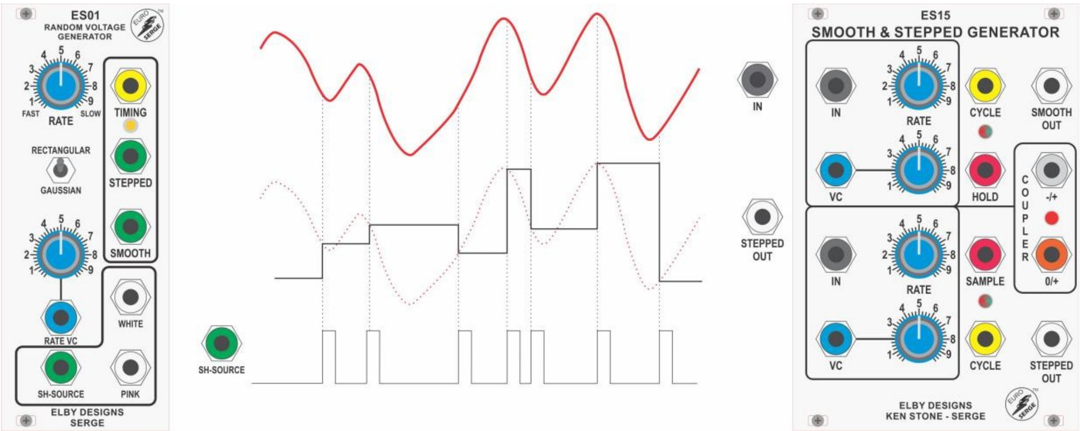

ES09
POSITIVE SLEW
CV IN
START
RATE
SUSTAIN
PULSE OUT
INPUT
OUT
ELBY DESIGNS
SERGE
ES19
NEGATIVE SLEW
20S
RATE
4mS
CV LEVEL
INPUT
CV IN
PULSE OUT
OUT
ELBY DESIGNS
KEN STONE
SERGE


ES06
ENVELOPE GENERATOR
CYCLE
RISE RATE
END
START
FALL RATE
WINDOW
HOLD
SIZE
WINDOW
DURATION
CV
ENVELOPE
ELBY DESIGNS
KEN STONE - SERGE
WINDOW
ENVELOPE


ES15
SMOOTH & STEPPED GENERATOR
IN
RATE
CYCLE
SMOOTH OUT
VC
HOLD
COUPLER
-/+
0/+
IN
RATE
SAMPLE
VC
CYCLE
STEPPED OUT
ELBY DESIGNS
KEN STONE - SERGE
CYCLE

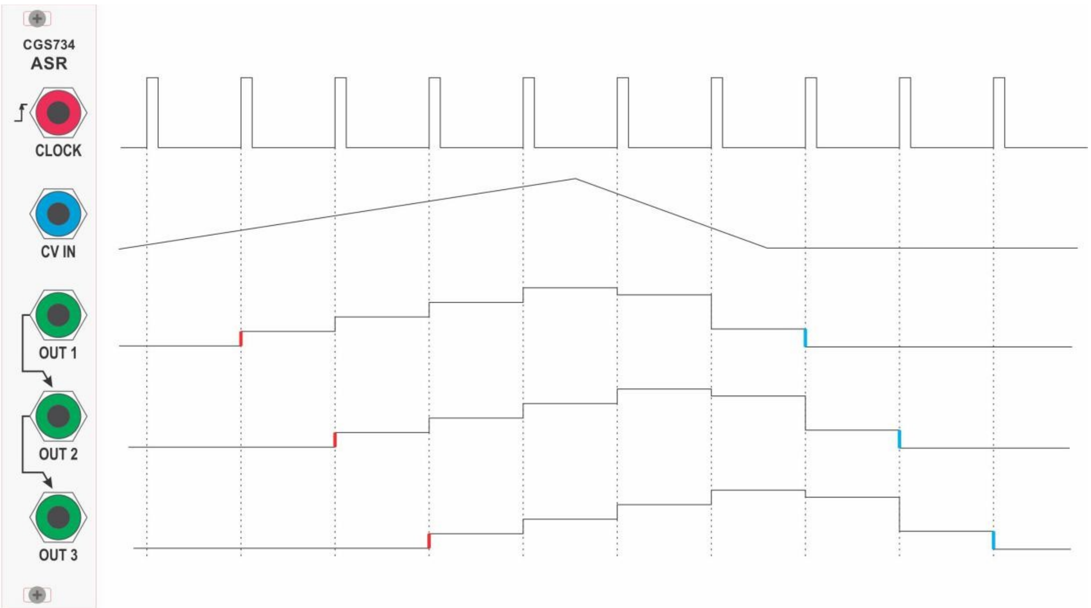
Apart from envelope generating functions, there are several additional functions in the EURO-SERGE that use triggering pulses. These include: sampling, sequencing, and selecting.

SAMPLING:

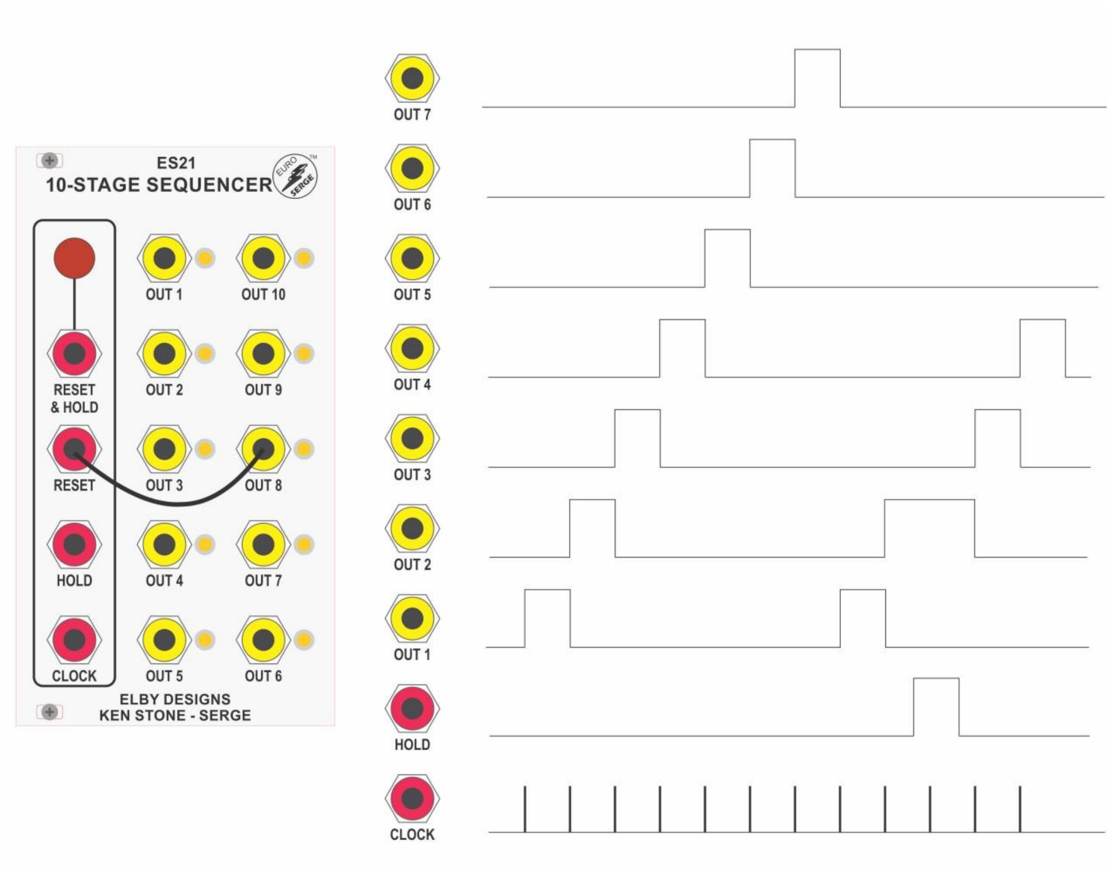


The SAMPLE & HOLD (also called STEPPED FUNCTION, on the SMOOTH & STEPPED GENERATOR) will “sample” whatever voltage is present at its input at the moment it receives a trigger at the [SAMPLE] input. Thereafter, the modules holds that voltage, until another pulse is received:

The ANALOG SHIFT REGISTER is a Sample & Hold with a twist, since at every pulse it samples the input voltage as above, but also moves whatever voltage was previously held at a stage down to its second and third stages:



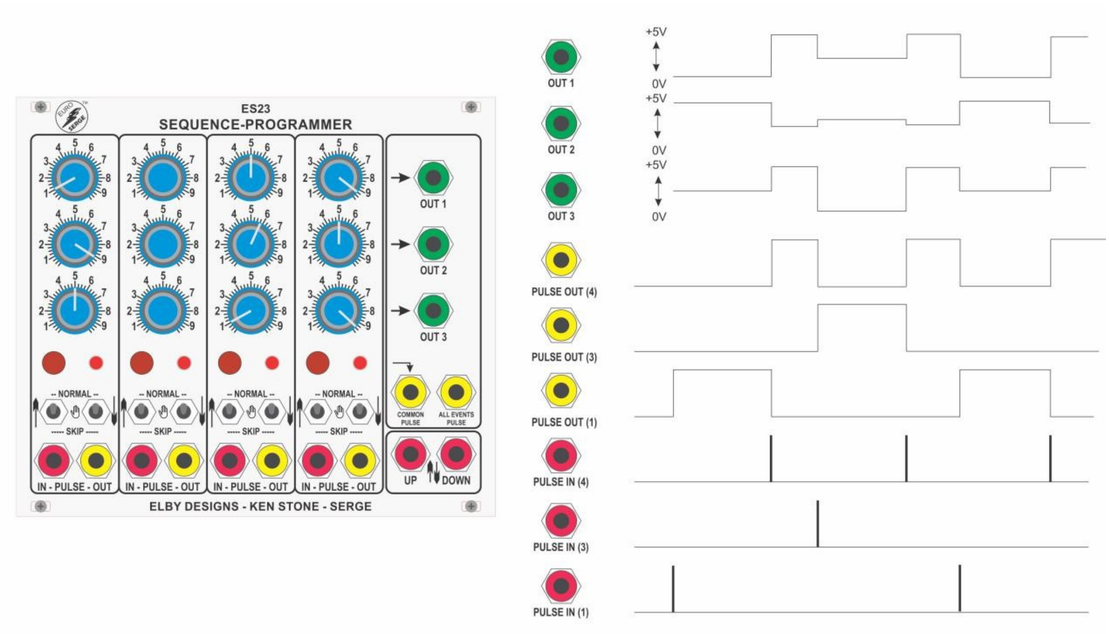
SEQUENCING:



Triggering the [CLOCK] input with a repetitive pulse source, sequences pulses one at a time from the ten outputs of the sequencer. A pulse at the [HOLD] input stops the sequencer. A pulse (or pressing the pushbutton) of the [RESET & HOLD] function immediately breaks the sequence and moves the output pulse back to stage 1. By feeding a pulse from a stage, from stage 8 in the example below, back into the [RESET], the sequencer can be made to sequence through shorter sequences.

The SEQUENCER is excellent for frequency sub-division of audio, for rhythm generation, and for sequencing through a selection of stages on the PROGRAMMER

SELECTING:



Stages on the PROGRAMMER(s) can be selected through the application of trigger pulses at their pulse inputs. Once selected, a stage will stay “on” until another stage gets selected. The stage’s pulse output will stay “high”, and its preset voltage levels will remain available at the common outputs, until the stage is turned “off”.

HOW ARE THE CONTROL VOLTAGES USED, AND WHAT CAN THEY DO?

Control voltages are at the heart of synthesizer use. They are used to vary nearly all aspects of musical sound (audio). These aspects include frequency, timbre, amplitude, phase, modulation, blend (of one signal with another). Control voltages are also used to vary the amplitude, repetition rate, and shape of other control voltages.

Control is achieved by patching voltages in the VC (voltage control) inputs of various modules. These inputs are, on the EURO-SERGE, generally associated with knobs which determine the depth and direction of the effects being controlled. Note however that there are many VC inputs which do not have input knobs.

- VC inputs with full processing. This knob sets the level at which an effect starts, for example the initial amplitude, initial frequency, phase, waveshape etc.
- VC inputs with no processing. This type of input allows a 0V to +5V voltage to control an effect through its entire range. Examples of this type of VC input may found on the VCA, the WAVESHAPER (VC1 & VC2) the RATE CONTROLLED WSAMPLE & HOLD etc. A 0V to +5V input in to the “waveshape” input of the OSCILLATOR will move the output waveshape through a continuous transition between sine wave to sawtooth, for example.
- Calibrated VC inputs. This type of input may be found on the keyboard or computer orientated EURO-SERGE modules. In these modules the VC inputs are accurately scaled at 1V per octave. This means that a change of one volt at a VC input effects a change in frequency of one octave (ie a change in frequency of 2:1). here again, the VC input(s) are associated with knobs which affect the initial level of an effect. Examples of this of module are the OSCILLATORS.

NB: calibration is left open to be adjusted by the user on VC inputs with processing. This can easily be accomplished by following the rules set out in the accompanying page called “PROCEDURE FOR ADJUSTING THE TRACKING OF TWO OR MORE MODULES”.

SOME EXAMPLES OF THE WAY CONTROL VOLTAGES WORK

In this list of examples, we are limited by the fact that many of the voltage controllable functions on the EURO-SERGE are irreducible to a graphic example. Phasing, modulation and timbre are best heard rather than seen. In fact, the same may be said about all of the functions in a synthesizer. We therefore encourage the reader to try the following examples themselves, extending the principles here, described to all of those modules for which we can no obvious example.

VC control of an OSCILLATOR's frequency

VC control of the waveshape of an OSCILLATOR

ANOTHER EXAMPLE OF VC WAVESHAPING (using WAVESHAPER VC2)

VARIABLE PULSE-WIDTH (using the COMPARATOR)

AMPLITUDE (LOUDNESS) CONTROL (using a VCA)

This is the standard manner of controlling loudness with a VCA, by using the "log" input for the control voltage. The resulting loudness contour shape is perfectly suited to the way we hear sound, since human perception is 'exponential". As in the perception of frequency, we hear an octave whether the actual frequencies are 100Hz - 200Hz, or 1kHz - 2kHz, our perception of loudness is such that a doubling of a loudness level is heard to be the same change in loudness, whether from *p* to *pp*, or from *double forte* to *forte*. Hence the contour in the diagram, which increases as an exponential function of the control voltage. The "lin" voltage control input provides for a linear function as shown in the next diagram.

Here the slope is linear. Note that on the EURO-SERGE, the "lin" control voltage input affects the audio signal in the inverse manner to the "log" input. That is: 0V into the [LOG] is minimum amplitude; into the [LIN] input it engenders the maximum level.

The [LIN] input of the VCA is useful in several ways. It simplifies the generation of "tremoloes" while the total effect is being controlled in the normal manner, since both [LOG] and [LIN] inputs can be used simultaneously. Additional effects that can be gotten is gain controlled amplitude modulation (with an OSCILLATOR into the "lin" input), and controlling the amplitude of another VC with a VC. An example of this is shown below:

AMPLITUDE CONTROL OF A VC BY A VC
This process is called two-quadrant multiplication, since one VC multiplies the other. In the EURO-SERGE, the transfer function is DC input X LIN input / 5.

This is about as afar as we can go with graphic examples to describe the use and effects of control voltages. We simply cannot give graphics examples of the way the FILTER, PHASER, RING MODUALTOR etc work and make any sense. The basic principles of operation remain the same as in the previous pages: a suitable audio input is patched into the main function input of a module; a control voltage is patched into the VC input of the module; and the output is monitored through a loudspeaker. We recommend that the user of the EURO-SERGE go through all the modules one by one, following this procedure:-

(1) patch a suitable audio voltage into the main input of the module and monitor the output through speakers while varying the module's knobs manually,
(2) patch a suitable control voltage into the VC input of the module and adjust the VC processing knob (if any) to get a feeling for the module. Of course, different control voltage types will affect the module differently, so that it is advisable to try several different types of control voltages, smooth, stepped, envelopes with fast rises, slow falls and vice versa, random voltages, audio control voltages, etc.

ABOUT SLEWING

Among the features unique to the EURO-SERGE, none are as useful and versatile as the modules that perform “slewing”. Indeed, “slewing” makes “programmability” possible. Programmability is the feature which permits a number of EURO-SERGE modules to emulate the functions which in more traditional systems would take several separate modules to perform. The savings in cost and space which result, set the EURO-SERGE apart from all others.

What is slewing?

The word is the technical word used in electronics to describe the inability of an amplifier to follow, at its output, the changes presented to its input. All amplifiers suffer from this effect, some more than others. The effect depends on how fast an amplifier is able to respond. The illustration below shows the response typical of slewing of two amplifiers, one faster than the other, to a square wave.

In the EURO-SERGE, we have incorporated this effect and have made it voltage controllable as to its speed over a very wide range (log-linearly). For example, the responses of the VC SLOPE GENERATOR and the SMOOTH FUNCTION (from the SMOOTH & STEPPED VC GENERATOR) may be voltage controlled to respond in the following manner:

The uses of the SMOOTH FUNCTION and the VC SLOPE are manifold. They may be patch-programmed to cycle, yielding a very wide range log-linear range triangle wave generator. They can be used as non-linear filters, in that decreasing their slew rates decreases the throughput of the faster moving input waves, while retaining whatever slower moving waves are present at the input. One interesting application of the modules has been to remove the clicks found on old phonograph records, since the clicks are very fast waves riding on slower moving audio:

Another use of the VC SLOPE and the SMOOTH FUNCTION is for linear portamento between voltage steps. This results in an effect directly related to musical portamento when a VC SLOPE or SMOOTH FUNCTION is used to control an OSCILLATOR.

There are several variants of the slewing principles in the EURO-SERGE. These are found in the POSITIVE and NEGATIVE SLEWS, the STEPPED FUNCTION and the RATE CONTROLLED SAMPLE & HOLD.

The characteristic of the NEGATIVE SLEW is that it is able to acquire the input waves at a very fast slew rate whenever the input voltage is more positive than the output, but it is constrained to slew downwards (negatively) whenever the input voltage drops below the output. The slew rate, again, is voltage controllable over a wide range.

The basic accuracy of the NEGATIVE SLEW allows it to be used to follow keyboard voltages used to control OSCILLATOR's pitch. Another use of the NEGATIVE SLEW is as an envelope follower. In this function, the NEGATIVE SLEW rectifies the incoming audio (from a microphone for example) and provides a voltage that is proportional to the audio signal's amplitude. Thus:

The PSOITIVE SLEW functions in a manner inverse to that of the NEGATIVE SLEW. It is constrained to slew upward (positively) whenever the input exceeds the output, but is able to follow the input at whatever rate whenever the latter falls below the output. Thus:

Linking POSITIVE and NEGATIVE SLEWS together produces a combined slewing function that has adjustable and separately controllable up and down slopes:

Both the POSTIVE SLEW and the NEGATIVE SLEW have pulse-type auxiliary functions which allow them to be used in a variety of ways already described in previous pages (VC envelope generator, pulser, sawtooth oscillators, pulse delay etc). An interesting set of applications of the POSITIVE SLEW arises because its slewing input is independent of the "start" and "sustain" auxiliary functions. One manner of using this multiple input is to have the POSITIVE SLEW follow and externally applied voltage envelope while, every so often, pulsing it into triggerable cycles. This process yields complex envelopes with interesting possibilities. Another use of the multiple input is in this patch for obtaining sub-harmonic waves to an OSCILLATOR's frequency:

Another set of modules which uses the slewing concept are the RATE CONTROLLED SAMPLE & HOLD, and the STEPPED FUNCTION from the SMOOTH & STEPPED VC GENERATOR. Everytime these modules receive a trigger pulse at their "sample" inputs, they attempt to sample the voltages present at their main inputs. This action was demonstrated in earlier pages. However, the rate at which they are able to acquire the input is limited and controllable in a manner analogous to slewing. In this way they are able to produce a type of stepped slewing very useful in making staircase-type waveforms and portamenti.

The STEPPED FUNCTION has the added capacity of being patch programmable to function as a self-cycling triangular wave staircase generator: (see the page devoted to the SMOOTH & STEPPED GENERATOR for the uniquely varied ways this unusual generator may be patch-programmed).

A FEW WORDS ABOUT MODULATION

Modulation in synthesizers is an amazingly powerful means of creating very rich and varied timbres. Modulation is basically a word meaning voltage control that is happening at an audio rate ie where the control voltage is of an audible frequency. There are, therefore, as many forms of modulation as there are different types of voltage controllable modules. Pulse-width, waveshape, frequency, amplitude, ring modulation, can all be modulated in the EURO-SERGE. Exploration of these different forms will be richly rewarded with unique sounds.

In general, modulation of one signal by another results in the generation of added frequencies (called “sidebands”) which are the sum and/or difference of the frequencies present in the original signals. The ‘cleanest” forms of modulation are types which are (1) linear, and (2) where the signals involved are clean of rich harmonic spectra. Pulse-width, waveshape, and other forms of modulation such as switching modulation (as available through the use of the BI-DIRECTIONAL ROUTER and the PEAK & TROUGH modules) are non-linear and/or involve signals already rich in harmonics. These are forms of modulation with limited usefulness, since the harmonic spectra they produce are often times too crowded to be fit for human musical consumption. The cleanest types of modulation available in the EURO-SERGE are (1) amplitude modulation, (2) ring modulation, and (3) frequency modulation.

(1) AMPLITUDE MODULATION: This is a modulation type best performed by the VCA or the RING MODULATOR. The following patch is best suite for modulation , and offers the advantage of keeping the “log” input free to be available for normal amplitude control:

NB: to be effective, the signal patched into the [LIN] input must be in the DC control voltage range of 0V to +5V as is available from the green jack outputs of the OSCILLATOR, POSTIVE & NEGATIVE SLEWS, and ENVELOPE GENERATOR.

The output signal in this form of modulation features the sum and difference frequencies plus the audio signal present at the main function input. The signal at the [LIN] input does not appear at the outputs, and is said to be “suppressed”.

(2) RING MODULATION. The RING MODULATOR performs this type of modulation with a number of voltage controllable options not normally found in synthesizer equipment. Typically, as a simple ring modulator, the two signals are patched in to the [X] and [Y] inputs, and the knob, set as shown, is

adjusted to provide maximum suppression of the input signal at [X] (this is best performed by patching the [X] signal alone and adjusting the knob for an audible null before patching in the [Y] input). The response typical of ring modulation are the sum and difference frequencies resulting from the two input signals bereft however of either of the input signals. Hence this form of modulation is also known as doubly suppressed modulation. The [VC X] and [VC Y] inputs offer the possibility of providing two unique and sonorously valuable voltage controllable transitions: a voltage input from 0V to +5V at the [VC X] input moves the output from full ring modulation through amplitude modulation (wherein the signal at [X] starts being heard) through non-modulation (wherein the only output heard is the signal at [X]). A VC of 0V to +5V at [VC Y] performs the same effect vis a vis the signal at [Y]. In the diagram below, the left illustrates the typical manner of using the RING MODULATOR while to the right is a patch which is useful whenever an additional VCA might be needed: in this patch [VC X] is equivalent to the [LOG] input on a VCA, and the signal at [X] is functionally similar to the [AC] input. Note however that a null must be adjusted at the knob, and that there will be some (inevitable) feedthrough of the gated audio in this patch:

(3) FREQUENCY MODULATION

This is an exceptionally rich modulation type. It can be used wherever there is a voltage controllable frequency function. On the EURO-SERGE, these are legion: the OSCILLATORS, SLEWS, FILTERS etc can all be modulated. Two types of frequency modulation may be gotten by using the green or the white outputs. Using the green outputs (whose characteristic output will be in the DC control voltage range of 0V to +5V) into the VC processing input of an OSCILLATOR, for example, will result in a form of unidirectional frequency modulation, where the apparent centre frequency will shift along with the setting of the processing knob. Using a white output to frequency modulate an OSCILLATOR will have a steadier effect, since the voltages from typical audio outputs on the EURO-SERGE are bi-polar audio, and modulation will occur equally upward and downward in frequency. There is, however, still a small shift in frequency as the depth of the modulation increases. This has been shown in the work of several musician scientists such as John Chowning of Stanford university, to be an unavoidable result of the mathematics of frequency modulating a log-linear OSCILLATOR input. With a linear VC input, the small shift in frequency does not occur; and therefore the rich timbres made available through frequency modulation can be used in a musically coherent manner in conjunction with keyboards etc.

PROCEDURE FOR ADJUSTING THE TRACKING OF TWO OR MORE MODULES

The procedure which follows uses two OSCILLATORS for the sake of an example. It can also be used for tracking POSITIVE & NEGATIVE SLEWS, VC SLOPE & SMOOTH, ENVELOPE GENERATORS, FILTERS etc.

1. Without a voltage into the VC inputs, adjust very carefully the two OSCILLATORS for perfect unisson at a given frequency. If the processing is to be positive, it is best to use a relatively low frequency such as 100Hz (low A on the F clef). If the processing is to be negative, it is best to pick a higher frequency such as 1kHz (C two octaves above middle C). Use sawtooth outputs mixed in to a single mixer for ease of listening for beats in adjusting for the unisson.
2. Use a steady voltage such as that from the PROGRAMMER, PROCESSOR, or a keyboard, and patch into the VC input of only one of the OSCILLATORS. Adjust the resultant shift in frequency for the desired interval.
3. Patch the same voltage into the VC input of the second OSCILLATOR and adjust the VC input processing knob to obtain a unisson at the higher (or lower) frequency.
4. Unplug the voltage from both OSCILLATORS and test for the accuracy of the initial unisson. This may have to be re-adjusted, and steps (2) and (3) performed once again to attain maximum accuracy.

NOTES:
(1) Tracking of FILTERS is best down while listening to the FILTERS set at high "Q" (resonance), and pulsing the inputs with the sawtooth of a NEGATIVE SLEW. The NOISE SOURCE is an alternate sound source that can be used to render the FILTERS frequencies apparent. Adjustment may then be performed as above.

(2) Adjustment of the SLEWS and other ENVELOPE GENERATING modules is best down while re-cycling them in the audio frequency range. After adjustment, the internal rate control knobs may be returned to a sub-sonic range. The basic accuracy of the adjustment will remain good in that range. Do not, however, use the top most two octaves of audio in these modules, as their accuracy is somewhat degraded by the fact that they are operating at the very extreme of their range.

Chapter 4
Self-Teaching Patches #2