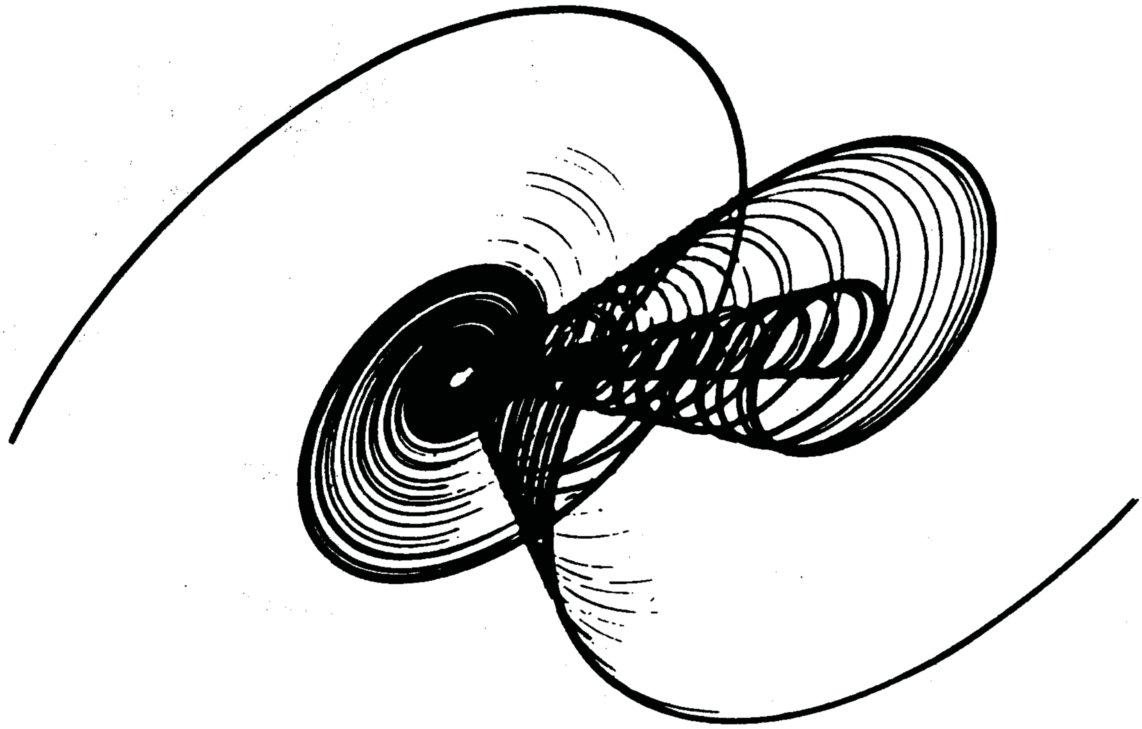

OWNER'S MANUAL

THE ARP SYNTHESIZER
SERIES 2500

OWNER'S MANUAL

THE ARP ELECTRONIC MUSIC
SYNTHESIZER
SERIES 2500

ARP INSTRUMENTS, INC., 320 Needham Street, Newton, Mass 02164

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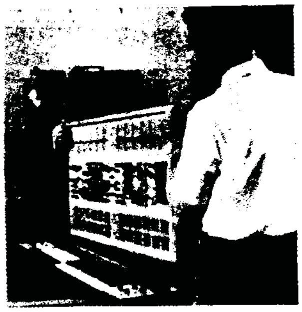
Cover design generated on oscilloscope by ARP synthesizer

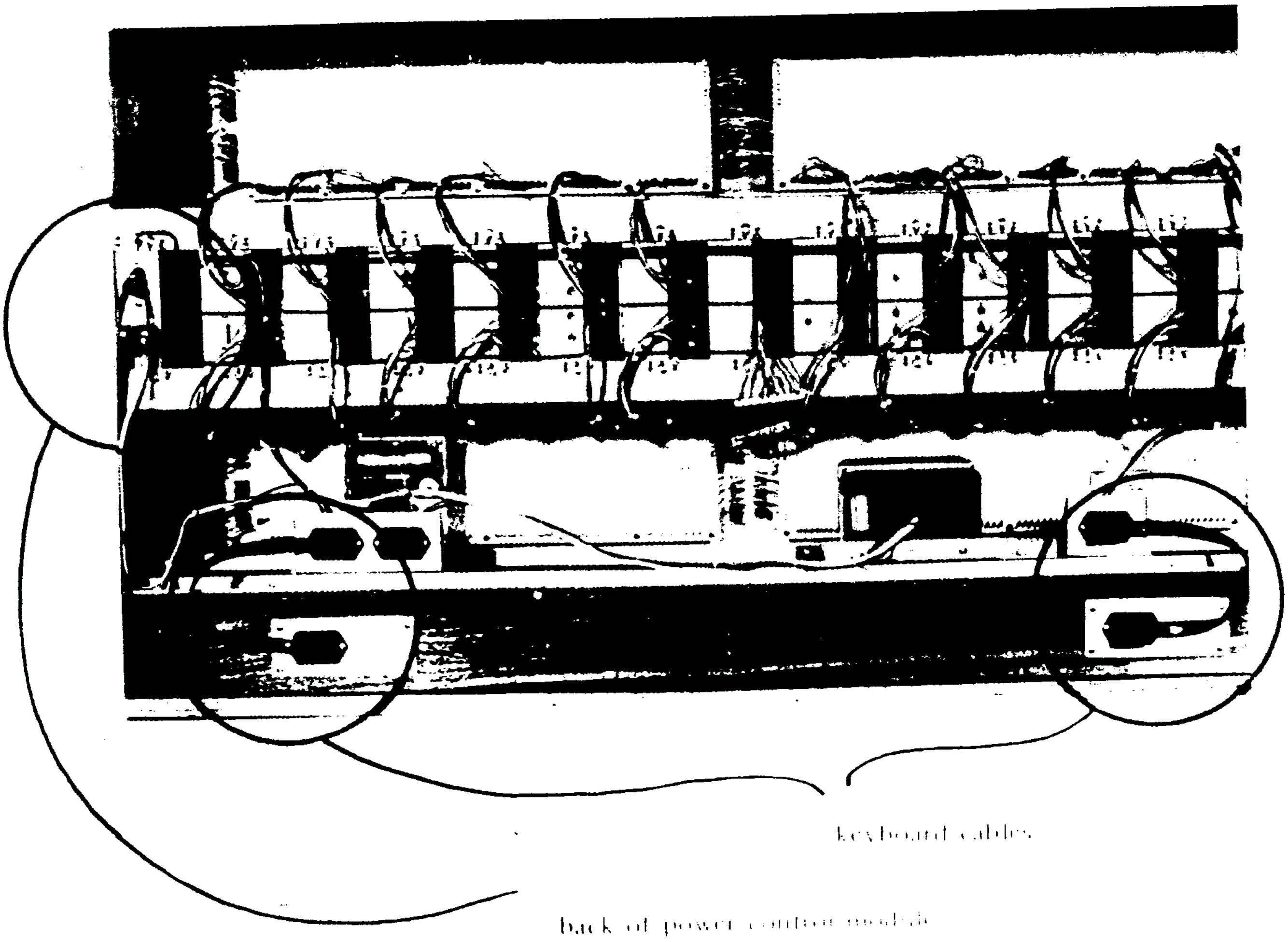
UNPACKING AND INSTALLING YOUR ARP 2500 SYNTHESIZER

Unpack the keyboard unit first by removing the top of the crate. Remove the padding from the top and sides of the keyboard and lift the keyboard from the crate. Set the keyboard on a sturdy desk or table of suitable size. Be sure to check the keyboard and crate for cables which may have been packed with the keyboard.

Unpack the main console by removing the front and top of the crate. Remove padding from sides and lift the console from the crate. Place the console on top of the keyboard as shown below, resting the back edge in place first with the cabinet tilted slightly backward. The cabinet should seat tightly as shown in the bottom picture.



The keyboard should now be connected to the console using the supplied cables. When inserting the cable connectors, be sure to check the pin spacings to make sure that the male and female connectors match. The power cord plugs into the back of the 1002 Power Control Module, which is usually located at the left end of the rear of the console. When connecting the power cable, it is important that the third wire ground connection be used. If the wall sockets in your studio have only two holes, consult an electrician for advice on using an appropriate adapter.



1.0 THIS SECTION of the ARP OWNER'S MANUAL is designed to serve two purposes.

1.01 THE FIRST is to serve as an introduction to the operation instructions for the Series 2500 Synthesizers and the Series 1000 Function Modules,

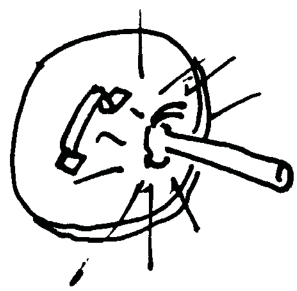
1.02 THE SECOND is to serve as a general introduction to the terms, concepts, and practices involved in electronic sound synthesis. We have designed it to serve this purpose because, first of all, there is at present no such general introduction available, and second because the owner of a new ARP Synthesizer has had statistically very little previous experience with synthesizers.

1.1 THE PARAGRAPHS in this section of the manual are numbered decimally to correspond with the structure of topics. The most important general headings are numbered with a single digit; subtopics under each heading will follow the digit with a decimal point and another digit, and so on. This system facilitates cross referencing within the text, and makes it easier to use as a standard reference.

2. TWO BASIC IDEAS ARE INVOLVED in all electronic music synthesizers.

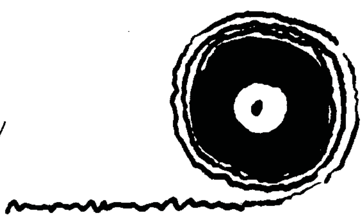
2.1 THE FIRST is that ACOUSTICAL WAVEFORMS CAN BE GENERATED AND MODIFIED PURELY BY ELECTRONIC MEANS.

2.11 Banging on a garbage can lid generates a horrible racket by mechanical means. The racket is a very complicated sound; but no matter how complicated it gets, it can be reproduced by a single long and complicated wiggle in a phonograph record. So can a symphony. From a certain point of view all the sounds you've ever heard, ever will hear, and ever could imagine, must be reducible to one (or at most two—one for each ear) complicated wiggle of your eardrums.



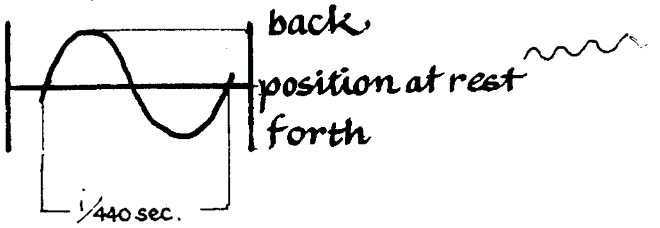
2.111 Edison's phonograph recorded by mechanical means the vibrations he fed into it. The cylinder—and later the disc—stored them as mechanical wiggles in a groove; on playback, running this groove past a needle made the needle wiggle, the needle made a diaphragm vibrate, and the diaphragm passed it on to the air in the form of pressure vibrations, and the air transmitted the sound waves to somebody's ears.

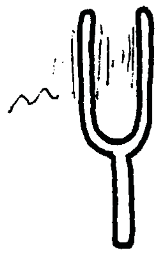
2.112 Nobody has done it that way for quite a while now. Today, a microphone turns sound waves into electrical signals. In other words, rapid and periodic fluctuations in air pressure are transformed into rapid and periodic fluctuations in some electrical phenomenon—usually a voltage. In this form the wave can be electrically amplified, equalized, filtered, and subjected to various other indignities before being sent to a recording lathe that turns it back again into a mechanical waveform in a groove. Likewise, when the record is played, the stylus wiggles the way it did in Edison's player, but its vibrations are immediately turned into electrical signals. They don't become mechanical again until they reach the loudspeaker.



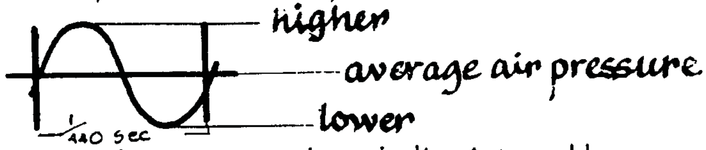
2.12 IN ALL THIS, THE ONLY THING THAT DOESN'T CHANGE IS THE SHAPE OF THE WAVE, i.e. THE WAVEFORM.

2.121 Suppose you bang an A-440 tuning fork on the corner of the table. In 1/440th of a second, then, the fork makes one complete vibration back and forth:

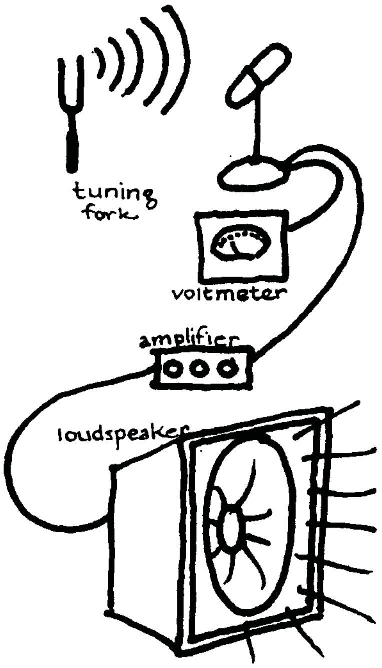


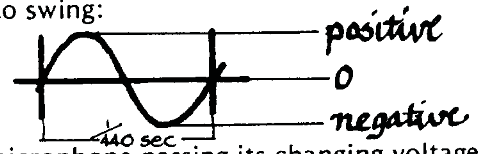


2.122 If you had an exceedingly precise barometer around, it would register during that same 1/440th of a second, a variation in air pressure:

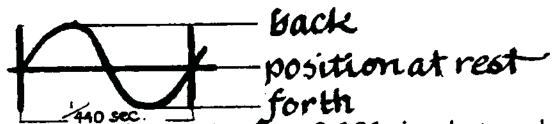


2.123 And a nearby microphone connected to a voltmeter would cause the pointer to swing:





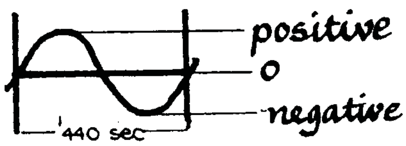
2.124 The same microphone passing its changing voltages on to an amplifier, and the amplifier feeding its output to a loudspeaker, would make the loudspeaker cone move back and forth:



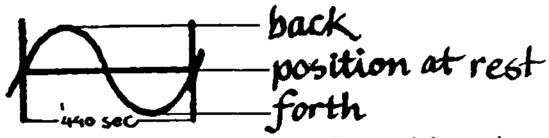
. . . which you will see, by referring back to 2.121, is what we began with.

2.1241 We have used an extremely simple waveform for these examples; but remember that the process of translating waveforms we have just outlined holds for any waveform whatsoever. In our graphs, the only change from one example to the next has been in the meaning of the vertical dimension of the graph; the horizontal dimension always represents some period of time, while the vertical one changes from representing physical position (the "back and forth" of the tuning fork or the loudspeaker cone) to a physical quantity (air pressure) to an electrical quantity (positive or negative voltage). But the waveform is unchanged.

2.125 Take another look at what we said in 2.123 and ask yourself what the voltmeter would do if instead of being connected to the microphone it were connected to some kind of electrical circuit that could generate smoothly changing voltages at the rate of 440 times each second. The pointer would swing positive and then negative like this:



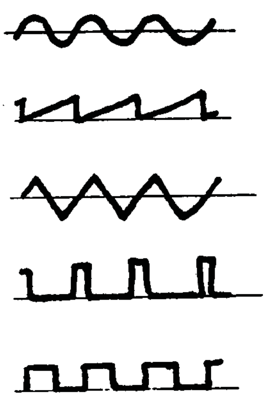
2.126 And the same generating circuit hooked up to the amplifier hooked up to the speaker would cause the same back-and-forth movement as in 2.124:



. . . which amounts to getting the sound of a tuning fork without having a tuning fork. Or, by the same principle, the sound of somebody banging on a garbage can lid without either a garbage can lid or somebody to bang on it. Or any sound at all: if you can generate the right waveform electronically, then you can generate the sound.

2.127 The generators we talked about in 2.125 are not imaginary; they exist, and they are called OSCILLATORS, and every synthesizer has at least a few of them; a really big synthesizer might have several dozen. So do electronic organs.

2.13 IF THE SHAPE OF THE WAVEFORM IS MODIFIED, SO IS THE SOUND, and vice versa. Take this for the time being as an iron-clad law; there are exceptions but they don't matter just now.

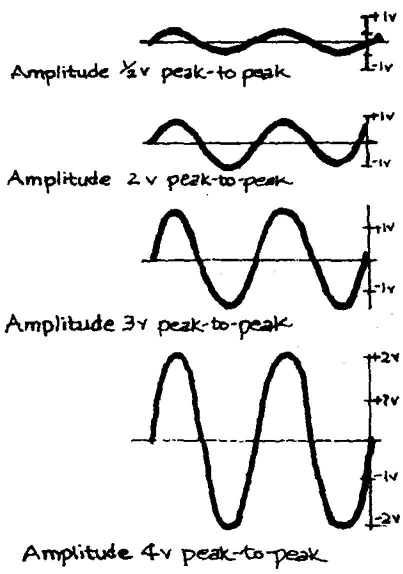


2.131 Wrapping an old army blanket around the garbage can lid muffles the sound. Carrying it, wrapped or unwrapped, into a tiled bathroom while you're banging on it changes the sound again; and so on. Anything you can do mechanically to modify the sound is going to show up as a modification in the pattern of air pressure variations and therefore in the pattern of the changing voltages produced by the microphone. Turn the can lid into a shoebox and kick it across the room—a different waveform. Turn it into a kettledrum—another waveform. Spread rubber cement over the drumhead—another waveform. Fill it with water—for every pint, another waveform; not by much, maybe, but still different.

2.132 By the same principle, any modification in an electrical waveform will modify the sound it makes through an amplifier and loudspeaker. The tone controls on a phonograph change the electrical waveforms that pass through them; changing stops on an electronic organ or drawbars on a Hammond changes the electrical waveform produced; and EVERY SINGLE CONTROL ON A SYNTHESIZER has some effect on an electrical waveform.

2.14 THE TWO SIMPLEST RELATIONSHIPS BETWEEN WAVE-FORM-CHANGES AND SOUND-CHANGES are these:

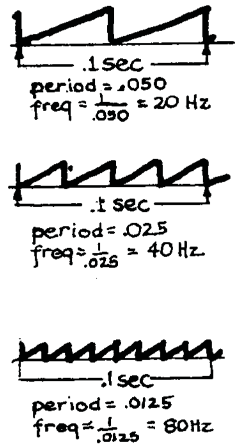
2.141 Increasing the AMPLITUDE of an audio waveform increases the VOLUME of the sound it makes. (But it might make no sound at all—the amplifier might be turned off or the loudspeaker disconnected. The point of this joke is to remind you that electrical vibrations and sound waves are not, after all, the same kind of activity; there is no sound inside electronic organs, or synthesizers either. Sound doesn't enter into the picture at all until the rapidly fluctuating voltages which the organ or synthesizer generates are amplified and fed to a loud-speaker.) (YOU are interested only in the sounds—but the synthesizer doesn't know that.)



2.1411 The AMPLITUDE of a waveform is the amount of maximum deviation from its "center". In a loudspeaker this "center" is the position of the loudspeaker cone at rest; in an electrical circuit it might be a condition of zero voltage. The amplitude of a loudspeaker cone's motion would be measured in inches or more likely in fractions of an inch back and forth. The amplitude of a fluctuating or alternating voltage would be measured in volts positive and negative. Thus a voltage waveform that reached a peak of +1 V and then of –1 V would have an amplitude of 2 V "peak-to-peak".

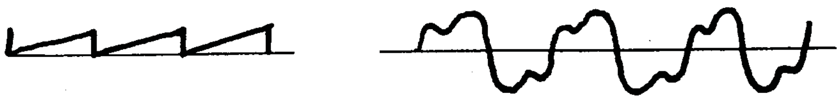
2.1412 You'll save yourself a lot of confusion by thinking of AMPLITUDE only in connection with waveforms and of VOLUME only in connection with sounds. For example: because there are no sounds inside a synthesizer (see 2.141), there cannot logically be any volume controls; but there are a great many amplitude controls. The point of our putting so much emphasis on this distinction will become clearer as you read on.

2.142 Increasing the FREQUENCY of an audio waveform increases the PITCH of the sound it makes. But it is important here, just as with AMPLITUDE and VOLUME, to keep the two notions distinct. FREQUENCY is a characteristic of PHYSICAL VIBRATIONS (whether mechanical, electrical, or otherwise), but PITCH is a peculiar characteristic of THE WAY HUMAN BEINGS PERCEIVE physical vibrations between approximately 20Hz and 20KHz. And of course the whole point of human perception anyway is to register and take note of changes in one's surroundings. So a change in an audio frequency registers as a change in pitch, but frequency and pitch are not the same.



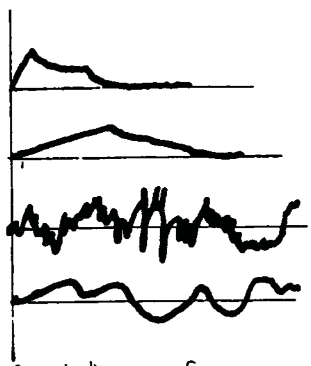
2.1421 For example: every pitch is produced by some frequency, but many frequencies produce no sense of pitch at all—because they're not audio frequencies. Middle C on a piano corresponds with a frequency of about 261 cycles per second—but a frequency of 2.61 cycles per second corresponds to no pitch at all—it is far below audibility.

2.14211 Here is some useful terminology. Some kinds of vibration have a repeating pattern;



and if they do they are called PERIODIC. One segment of a periodic vibration, from any point in its waveform to the beginning of its repetition, is a CYCLE. The length of one cycle (usually stated in seconds or in fractions of a second) is the PERIOD of the waveform; but the number of cycles occurring in a given length of time is the FREQUENCY of the vibration. There is an international standard unit of frequency: it is the HERTZ (abbreviated as "Hz") and it is defined as ONE CYCLE PER SECOND. As usual, the prefix "Kilo-" means "one thousand" and so a vibration or oscillation of one thousand cycles per second will be spoken of as "One KiloHertz" or "1KHz".

2.14212 NOT ALL WAVEFORMS are PERIODIC. Some waveforms happen only once; and some waveforms are so complicated that your chances of finding any kind of repetition are nil regardless of what frequency you look for. In this case the waveform as a whole will show no particular repeating pattern but only an apparently random motion. For whatever reason, a waveform that does not demonstrate any repeating patterns is called APERIODIC.



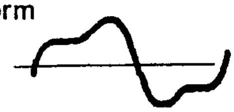
Aperiodic waveforms

2.14213 We will use these terms throughout the rest of this manual. Frequencies of less than 1Hz will generally be referred to by their period to save you the labor of, say, translating ".05Hz" into "one cycle every 20 seconds".

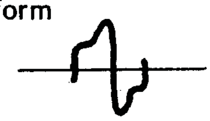
2.15 CHANGES IN THE AMPLITUDE OR FREQUENCY OF A PERIODIC WAVEFORM ARE, INDEED, SO COMMON, AND THEIR RELATIONSHIP TO PERCEIVED SOUND SO CLEAR, THAT THEY ARE NOT COMMONLY THOUGHT OF AS INVOLVING CHANGES IN THE SHAPE OF A WAVEFORM AT ALL.

2.151 From now on we will follow this convention. Changing the frequency or amplitude of a wave will not count as a change in its shape.

2.1511 There is a more subtle reason than mere convenience for this practice. Graphically, this waveform



can become this waveform



by a mere change of coordinates; and likewise for turning this waveform  into this one 

But no amount of graphical transformation will turn something like this

into this  ; no change in mere amplitude or frequency or both or change in units of measurement. (The latter is what we mean by a "change in coordinates".)

2.152 CHANGES IN THE SHAPE of an audio waveform are generally associated with CHANGES IN THE TONE QUALITY, or TIMBRE,* of the sound produced. (See 2.131). Since human perception has limits, there are possible changes in the shape of a waveform that might not be perceived by even the most practiced ear; but anything that is perceived as a change in timbre must be reflected in the waveform being perceived.

"Timbre" is the subjective quality of a tone which enables the listener to distinguish between it and other tones which may have the same pitch or loudness. (e.g. trumpets and clarinets produce sounds of different timbres.)

2.1521 Summarizing 2.141, 2.142, and 2.152 gives us these approximate relationships:

subjective changes in perceived...	correspond to physical changes in the...
VOLUME	AMPLITUDE
PITCH	FREQUENCY
TIMBRE or	WAVESHAPE or
TONE COLOR	FREQUENCY-SPECTRUM

. . . of the perceived vibration.

This is worth remembering because, as we have emphasized elsewhere, synthesizers work with the qualities listed in the right-hand column for the sake of our perception of those listed in the left-hand column; anyone who uses a synthesizer regularly must be able to translate easily from the language of volume, pitch, and timbre, to the language of amplitude, frequency, and waveshapes. This section of the manual is intended to get you started on this sort of translation back and forth.

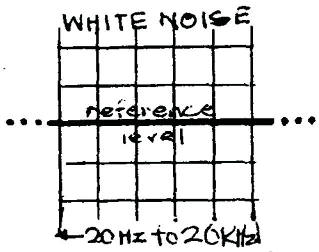
2.153 The OSCILLATORS in any synthesizer generate one or more of these simple periodic waveforms: SINE  , SAWTOOTH  , SQUARE  , TRIANGLE  , and PULSE  .

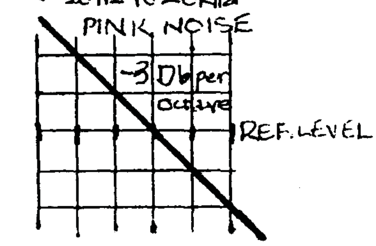
2.154 A NOISE GENERATOR produces an APERIODIC waveform (see section 2.14212) of completely RANDOM pattern.

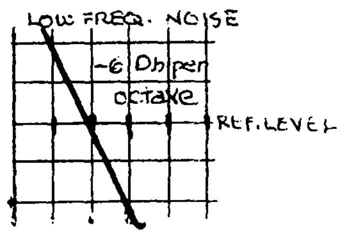
2.1541 A random voltage has very interesting properties. You can think of it statistically as a waveform in which your chances of finding any particular frequency are equal to your chances of finding any other frequency. Strictly speaking this sort of a waveform is called WHITE NOISE, by analogy with white light: it contains all frequencies just as white light contains all colors.

2.1542 Human ears tend to give undue prominence (for reasons we needn't go into here) to the higher frequencies in a WHITE NOISE signal, so that it sounds like steam escaping from a radiator. If a white noise signal is slightly FILTERED to produce a noise whose frequency content SOUNDS MORE EQUAL TO HUMAN EARS, it is called PINK NOISE. Pink noise sounds like NIAGARA FALLS.

2.1543 From the statistical point of view, what happens when white noise is FILTERED is simply that the odds on finding any particular frequency in the noise waveform become heavily weighted in favor of some certain RANGE OF FREQUENCIES. This range is called the BANDWIDTH of the filtered noise. Thus we can talk about wideband





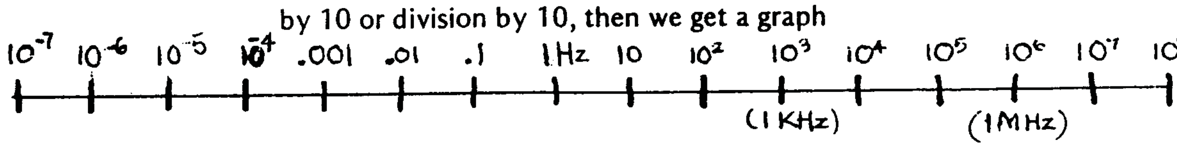


noise, narrowband noise, noise centered around 2KHz, and so on. (See also 2.182)

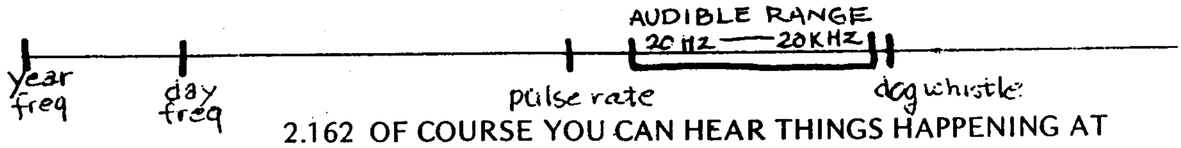
2.155 Each of these waveforms, at audio frequencies, has its own characteristic sound (see 2.13). We will not try to describe here the sound of each waveform; that will come into your own experience in sections 4 and 5.

2.16 We will call any periodic waveform with a basic frequency between 20Hz and 20KHz an AUDIO WAVEFORM. Frequencies between these two extremes are AUDIO FREQUENCIES. Higher frequencies are ULTRA-SONIC and lower frequencies are SUB-SONIC, or simply LOW.

2.161 Our reason for calling some frequencies "audio" is of course simply that only vibrations in this range can produce SOUNDS. If we draw a line and put "1Hz" in the center of it, and let the two ends run off to infinity, and let every half-inch or so represent a multiplication by 10 or division by 10, then we get a graph

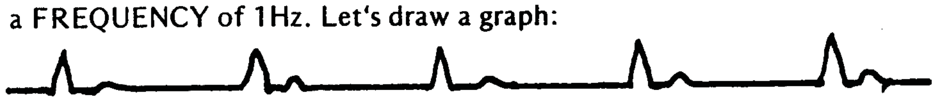


in which the range of human hearing is



2.162 OF COURSE YOU CAN HEAR THINGS HAPPENING AT LOWER FREQUENCIES than 20 Hz. BUT YOU HEAR THEM AS SEPARATE AND REPEATING SOUNDS, not as continuing tones or noises.

2.1621 Your heart is beating, let us say, 60 times per minute. (This is rather low for a pulse rate but keeps the numbers simple.) That's the same as saying it beats once every second and so we can say it beats at a FREQUENCY of 1Hz. Let's draw a graph:

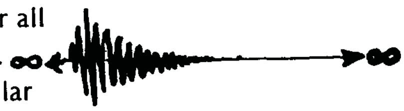


Now imagine your pulse gradually increasing to 120 per minute, or 2Hz:

And now to something like 20Hz (that's 1200 times a minute—a lot of adrenalin):

And finally to say 60Hz:

Somewhere just above 20Hz you would lose your sense of individual EVENTS happening very rapidly. Instead you would begin to hear a very low PITCH gradually rising with the rising frequency of your heartbeat. And the opposite would happen if your heart began to slow down again—first a descending PITCH, then the gradually growing sense of no pitch at all but rather of separate and countable EVENTS.
2.163 A SYNTHESIZER CAN GENERATE AND MODIFY both AUDIO-FREQUENCIES (i.e. PITCHES and NOISE) and LOW-FREQUENCIES (i.e. EVENTS).
2.1631 You may think of an event that happens only once as having an infinitely low frequency—like picking a guitar string once for all eternity, or beating a drum just once and then travelling on . . .



2.1632 Playing a note on a piano and repeating it at some regular interval produces a series of EVENTS at a low frequency. The events have a certain PITCH because each event is the occurrence of an AUDIO—FREQUENCY vibration. Here's a graph of everything that happens:

and here's a graph of the LOW-FREQUENCY waveform involved

and the audio-frequency that produces the pitch looks, all by itself, like this

2.1633 Note that in any graph of an event or a series of events such as the first one in 2.1631 above, you can derive the SHAPE of the LOW-FREQUENCY WAVEFORM involved by simply connecting the highest points on the higher-frequency waveform.

2.1634 Thus we come to the very important notion that EVENTS have SHAPES. And the SHAPE of any event is the SHAPE OF THE LOW-FREQUENCY WAVEFORM that can "produce" the event. Thus, for example, playing a staccato tune on an organ would produce a series of pitches

and a series of events of this shape

Playing the same tune on a guitar would produce, perhaps, the same pitches

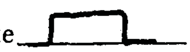
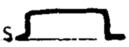
but the events would have a different shape altogether.

2.164 THE SHAPE of an EVENT is called its ENVELOPE or CONTOUR. In the example given above, we could say that the notes played on the organ have a different ENVELOPE from the same notes played on the guitar.

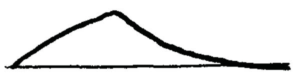
2.1641 Here are some possible envelopes:

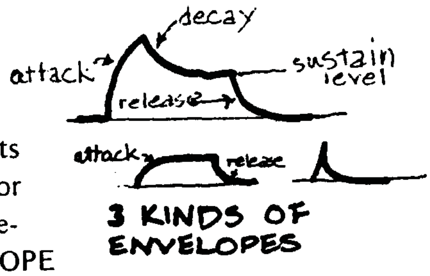
banjo  distant thunder 

piano note fortissimo  piano note soft and staccato 

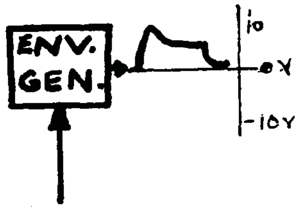
organ note  organ note taped and played backwards 

banjo taped and played backwards 

Chinese gong 

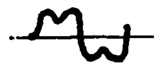


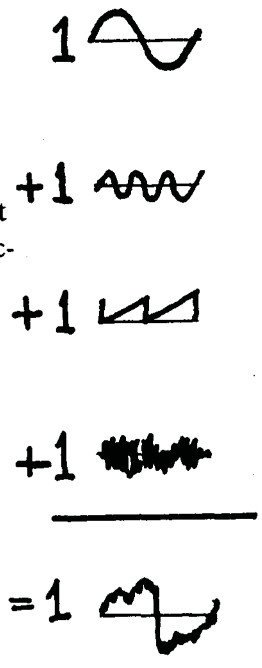
2.17 Any low-frequency waveform may be used to produce events and to give them a shape. But usually a synthesizer will have one or more devices designed specifically to generate low-frequency waveshapes suitable for giving events a shape. These are called ENVELOPE GENERATORS or ENVELOPE TRANSIENT GENERATORS. Their output is APERIODIC (see 2.1422); instead of appearing over and over again spontaneously it appears only when the envelope generator is TRIGGERED.



2.18 OTHER CIRCUITRY in any synthesizer MODIFIES waveforms by MIXING them, FILTERING them, or MODULATING them.

2.181 Two waveforms can be added together by simply adding their values at every instant. This is easier to show than to talk about:

This  added to this  makes this . Once they are mixed it's practically impossible, except in simple cases, to untangle them again.

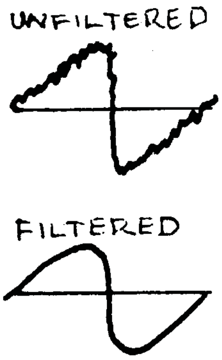


2.1811 IT MAY SEEM ODD that when you have mixed together say the sound of a violin and the sound of a piano (or any two or more instruments) it is all but impossible to separate them again. But remember what is going on: in electrical terms, a particular sound is not represented simply by "a voltage" but by a PATTERN of voltage fluctuations. So when two or more signals are electronically mixed into one, two or more patterns have been added together to form a more complicated pattern. And the problem of separating them is not a simple problem of dividing a voltage into little voltages, but the much more complicated one of separating patterns, i.e. waveforms, out of one complicated pattern.

It is as if you were to copy a page of this manual onto one line by writing each line directly on top of the preceding line:
ltnis bsy ifwyoitingvexehtdinoepdyraqpalgeooftdhpisofmtheuplrecectdingline:
all the letters would be there, but the copy would be illegible. Your ears, from long practice perhaps, generally have no difficulty in recognizing familiar patterns in the 24-hour-a-day waveform the world presents to them; no other instrument can even begin to approach the ease with which, say, you disentangle the voice of a friend in a crowd from all the other voices in the crowd. This is a problem in

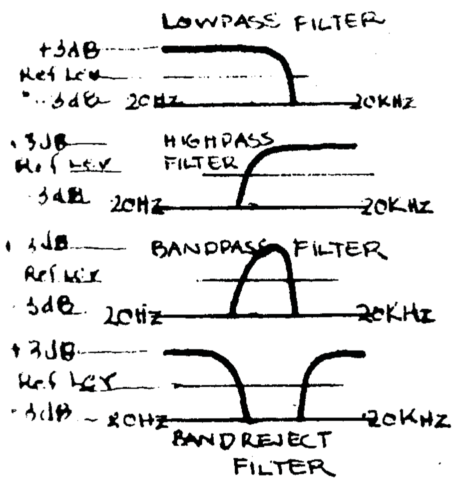
PATTERN RECOGNITION, and has for many years been the subject of intense research by computer-program designers. But the best they have done so far falls considerably short of what your ears and brain do all the time.

2.1812 In very simple cases, frequencies may be removed from a waveform by FILTERING (see 2.182 following), but a filter circuit is a perfect idiot: it knows nothing of what the frequencies it is blocking or boosting mean, and can do nothing to separate two sounds of the same pitch. The scratch filter in a stereo amplifier cuts out some of the noise from a dirty or scratched record; but it also removes any musical sound that falls in the same frequency range as the scratches. On a good pair of speakers this is quite audible as a loss of sparkle and airiness in the recording—a slight muffling of the sound.



2.1813 So one way of making more complicated waveforms out of simple ones is by MIXING simple ones together. This is also sometimes called additive synthesis. The drawbars of a Hammond work by additive synthesis.

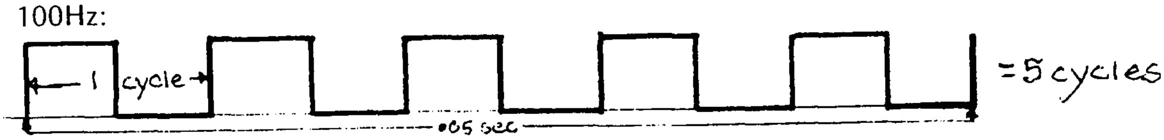
2.182 In a complex waveform representing many frequencies simultaneously, some frequencies may be weakened, strengthened, or removed almost entirely by FILTERING. The treble and bass controls on a stereo amplifier are simple filters that boost or cut high and low audio frequencies respectively. A filter may operate over a broad or narrow range of frequencies; it may pass all signals up a certain frequency, in which case it is called a LOW-PASS filter; it may pass only frequencies above a certain frequency, in which case it is called a HIGH-PASS filter. Or it may pass only a narrow band of frequencies; then it is a BAND-PASS filter. If it does just the opposite, i.e. passes all frequencies except a certain band of frequencies, it is a BAND-REJECT, or NOTCH filter.



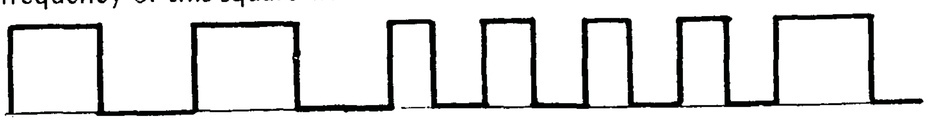
2.1821 Simplifying a complex sound by filtering is called subtractive synthesis.

2.183 To MODULATE a waveform is to change it systematically, following the pattern of another waveform. If the change is in frequency, then the result is FREQUENCY MODULATION (FM); if the change is in amplitude, then the result is AMPLITUDE MODULATION (AM). Other kinds of modulation exist and will be discussed later.

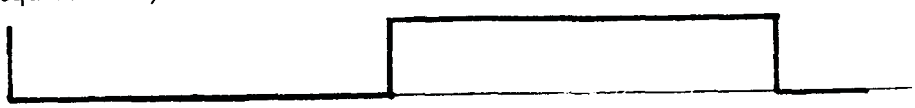
2.1831 Here is a simple example of frequency modulation. Suppose we begin with a simple oscillation, say a square wave at a frequency of 100Hz:



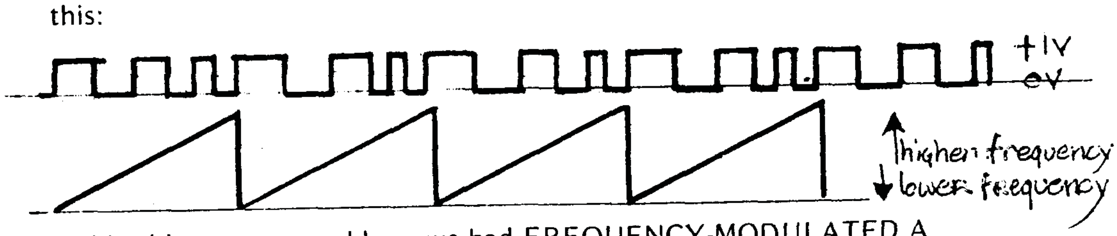
Now, at the rate of 25Hz, let's alternately double and halve again the frequency of this square wave:



If we draw a graph in which up means higher frequency and down means lower frequency, and graph the changes in frequency of our 100Hz square wave, it looks like this:

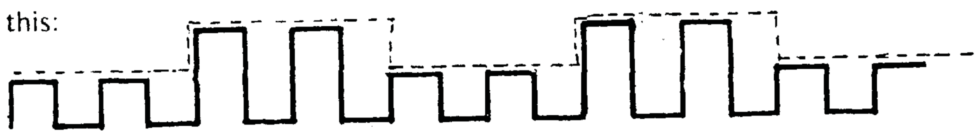


A look at the first and last graphs, and at their "result" in the second graph, shows what we mean if we say that we have FREQUENCY-MODULATED A 100Hz SQUARE WAVE by A 25 Hz SQUARE WAVE. If, instead of shifting suddenly up and suddenly down again, we start from 100Hz and moved gradually up to say 200Hz and then started suddenly again from 100Hz, a graph of the changes in frequency would look like this:

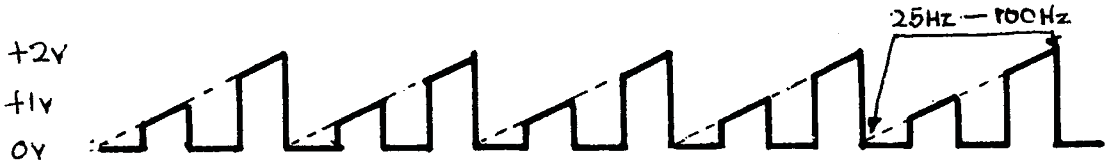


and in this case we would say we had FREQUENCY-MODULATED A 100Hz SQUARE WAVE WITH A 25Hz SAWTOOTH.

2.1832 AMPLITUDE MODULATION, on the other hand, of a 100Hz square wave by a 25Hz square wave would produce something like this:

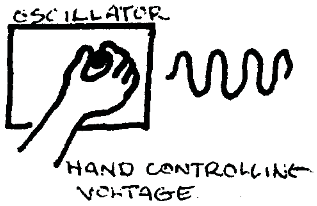


and by a 25Hz sawtooth might look like this:

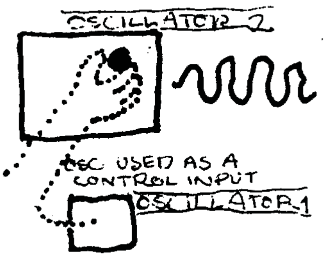


2.2 THE SECOND BASIC IDEA on which electronic synthesis is based is that WAVE-GENERATING and WAVE-MODIFYING equipment MAY BE CONTROLLED ELECTRONICALLY. You may think of this to begin with as a kind of "remote control", in which one piece of equipment may control the frequency or gain of another piece of equipment by an electrical signal.

2.201 Other instruments such as electronic organs, electronic pianos, theremins, and so on, generate and/or modify their sounds electronically, just as synthesizers do. But other instruments are designed only for manual control through keys, pedals, stop tabs or knobs, and couplers.

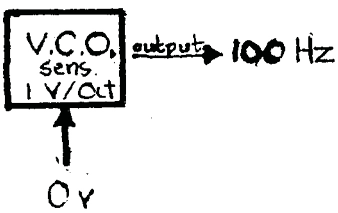


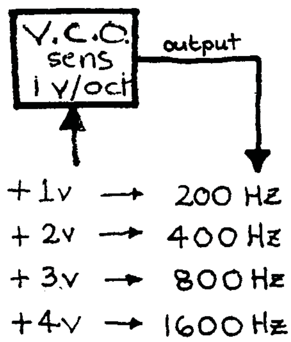
OR

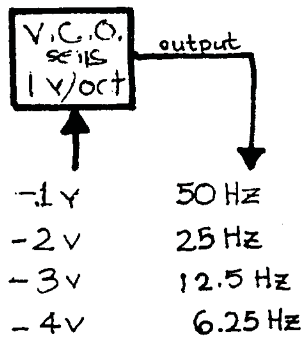


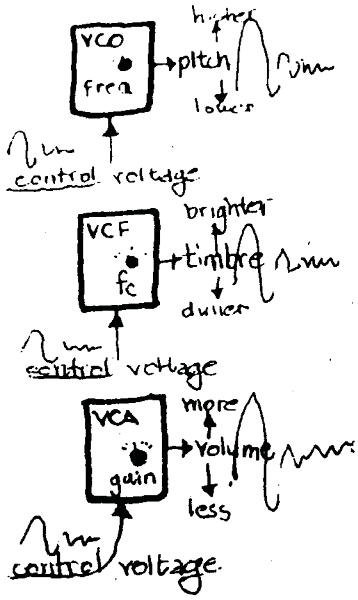
2.21 The oscillators, filters, and amplifiers in a synthesizer, however, are designed to be controlled both manually and by voltages. A vibrato effect, for example, may be obtained by manually varying the frequency of an oscillator rapidly over a small range; but a much smoother and more flexible vibrato is created by using a low-frequency sine wave to control the pitch of the oscillator output.

2.211 In any oscillator, filter, or amplifier that is designed to be VOLTAGE CONTROLLED, a voltage applied to a control input will have exactly the same effect as a manual adjustment of one of the controls on the unit. (Which characteristic of the unit is affected is usually indicated at the input to it; some units may be designed so that more than one of their operating characteristics may be VOLTAGE CONTROLLED.) A voltage controlled oscillator, for example, may commonly have a sensitivity of ONE OCTAVE per VOLT. Such an oscillator would double its frequency, i.e. rise one octave, for every increase of one volt in the signal applied to its control input. And a negative one-volt signal at the input would drive the oscillator frequency down by one octave. A continuously fluctuating voltage would cause the oscillator frequency to continuously fluctuate. And so on.

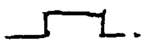


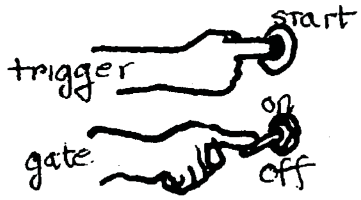




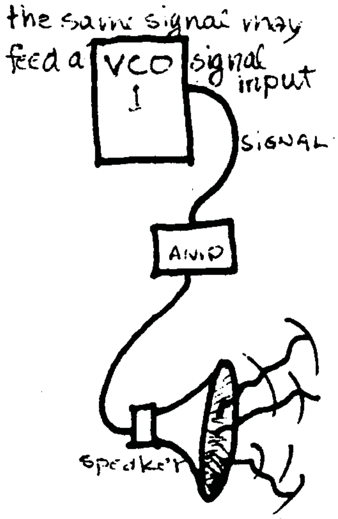


2.212 It is important to remember that VOLTAGE CONTROL is an extension of manual control; in theory anything you can do with a voltage you should be able to do with a knob, manually. IN FACT, your hands cannot move fast enough, or accurately enough, to come within miles of what a voltage signal can do with a voltage-controlled device.
2.22 Continuously variable characteristics such as the frequency of an oscillator, the cutoff frequency of a filter, or the gain of an amplifier, may be controlled by continuously variable voltages.
2.23 Other functions that may be controlled by electrical signals are START functions and ON-OFF functions. Signals used for these purposes are called TRIGGERS and GATES respectively.
2.231 An electronically TRIGGERED device will begin to operate when a voltage at the proper input goes from zero to some positive voltage and immediately comes back to zero. On a graph such a TRIGGER SIGNAL might look like this  .
2.232 An electronically GATED device will begin to operate when a voltage at the proper input goes from zero to some positive value AND WILL CONTINUE to operate ONLY AS LONG AS the voltage stays at or above that value. Thus a GATE SIGNAL might look like this

 .



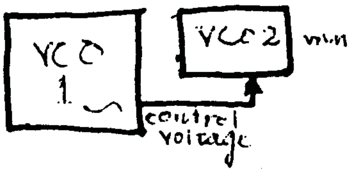
2.24 A keyboard controller for a synthesizer usually works by some combination of CONTROL VOLTAGES to signal which key is pressed down, GATES to signal the length of time a key is down, and TRIGGERS to signal the exact instant at which a key is pressed down.
2.25 USING A SIGNAL TO CONTROL something in this fashion DOES NOT MAKE A DIFFERENCE to the SIGNAL. A voltage is a voltage is a voltage; there are control voltages only where there is equipment designed to be voltage controlled. Calling a signal a control signal is only saying what, in some particular case, its FUNCTION is; namely, that it is being fed to the control input of a voltage-controllable device.



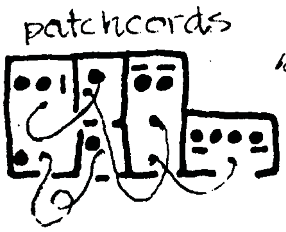
2.251 It is EXTREMELY IMPORTANT to be clear about this because of the OTHER FUNCTION that a voltage signal may serve: i.e. simply to provide an AUDIO SIGNAL (pitched tone or noise) for modification and ultimately for listening. Between these two functions there is all the difference in the world; but there is no intrinsic difference BETWEEN THE SIGNALS THEMSELVES. The same output from the same oscillator may be used either as an AUDIO SIGNAL or as a CONTROL SIGNAL; it makes no difference to the oscillator. To find out whether a signal is audio or control, don't look to where it comes from but rather to where it goes.

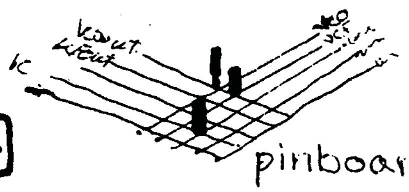
2.3 A SYNTHESIZER, then, consists of SIGNAL-GENERATING and SIGNAL-MODIFYING equipment; and some of this equipment is VOLTAGE-CONTROLLED by signals which usually are generated, and may also be modified, within the synthesizer.

2.31 EACH DEVICE in a synthesizer IS COMPLETELY SEPARATE from the others. It is electrically independent of them and has its own separate INPUT and OUTPUT points, usually readily available to the user.



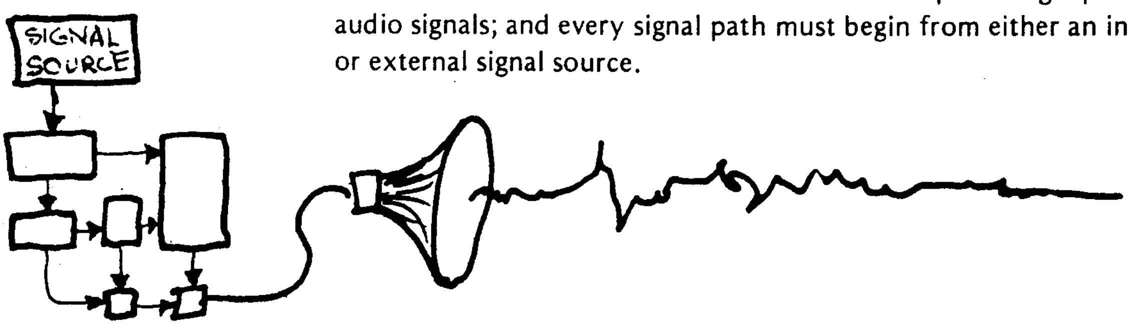
2.32 EVERY SYNTHESIZER has some provision for CONNECTING its internal devices to each other. These may take the form of patch-cords; matrix boards with pins, or matrix switches. The devices are connected to each other BY THE USER, who may connect them in MANY DIFFERENT CONFIGURATIONS depending on what sounds and sound-patterns he wants to produce.





2.33 OPERATING A SYNTHESIZER means doing two different things: one is CONNECTING to each other the devices to be used, or "setting up the patch" as it is called, and the other is SETTING UP, ADJUSTING, AND USING the controls on the devices in the patch.

2.331 SETTING UP A PATCH involves at least providing a path for audio signals; and every signal path must begin from either an internal or external signal source.



2.3311 Any signal from any device in a synthesizer may be fed directly to an external amplifier or recorder. More commonly it will be routed through other devices before reaching the synthesizer's main output channels. Several signals may be combined in a mixer, or one signal may be split to follow two different paths, which, modifying it in different ways, may later recombine.

2.3312 Likewise, externally generated signals (from tape recorders, preamplifiers, etc.) may be fed directly into the signal input of any device in a synthesizer, provided only that the signal source output has the proper electrical characteristics (i.e. impedance and amplitude; See Section 4).

2.332 Setting up a patch may also involve providing control paths; but not necessarily.

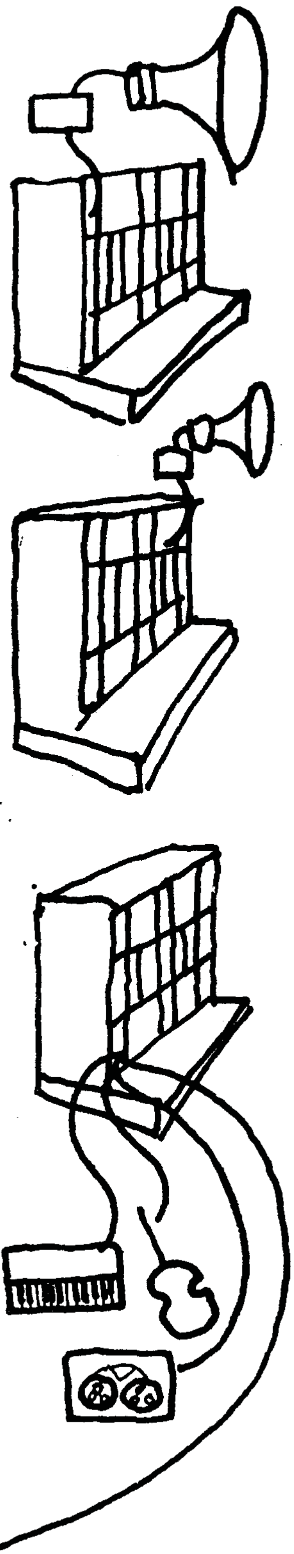
2.3321 It is possible to generate many interesting sounds without ever using voltage control; but it's tedious work, particularly if you're trying to get something like "Mary Had a Little Lamb" or something similar. In the early days of electronic synthesis the only way you could get a tune was either by "playing" an oscillator by hand, as if it were a penny-whistle, or by recording separately each note on tape and then splicing all the notes together. Then for controlling the volume you had to run the completed tape through an amplifier, with one hand on the volume control, while rerecording the result on another recorder. Likewise for controlling the timbre, or tone, of the melody.

2.333 EVERY CONNECTION IN A PATCH IS EITHER A SIGNAL PATH OR A CONTROL PATH.

2.334 NO CONNECTION IN A PATCH CAN BE BOTH A SIGNAL AND A CONTROL PATH AT THE SAME TIME.

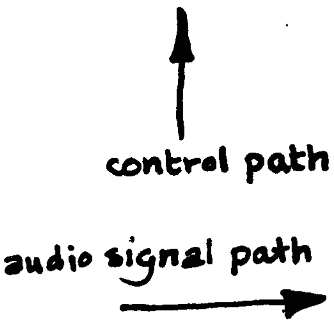
2.335 THE AUDIBLE EFFECT OF MANIPULATING ANY MANUAL CONTROL DEPENDS ON THE PARTICULAR PATCH BEING USED.

2.3351 Thus, for example, if the audio output from an oscillator is part of a signal path, then changing the frequency of the oscillator will in some way change the pitch of a sound in the synthesizer's main output; but if the same oscillator is controlling another oscillator whose output is part of a signal path, then changing the first oscillator's frequency might change the rate of a vibrato or, at a higher frequency, the timbre of a frequency-modulation or amplitude-modulation effect.



2.34 ALL OF THE CONNECTIONS involved in any particular patch can be diagrammed with blocks (to symbolize individual devices) and arrows (to indicate signal and control paths). Such a diagram is called a BLOCK DIAGRAM.

2.341 SIGNAL PATHS in a block diagram are indicated by HORIZONTAL LINES. OUTPUTS leave from the right side of a block, and INPUTS enter from the left.



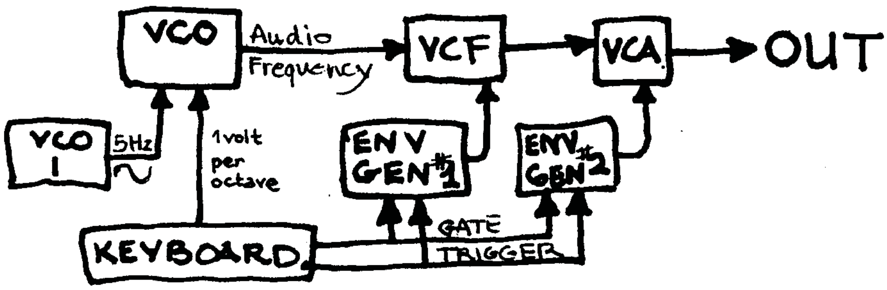
2.342 CONTROL PATHS are indicated by VERTICAL LINES. OUTPUTS leave from the right side of the block and INPUTS enter from the bottom.

2.343 Inside each block may be specified, if desired, a set of control values for the unit represented by that block:

2.3431 For an oscillator you may want to specify its frequency, or you may want to specify which of several waveforms is being used; for a filter the specification might concern frequency and/or resonance; for a triggered function, the rate of repetition, and so on.

2.344 A simple block diagram might look like this.

2.345 A more complicated one might look like this.



2.35 BLOCK DIAGRAMS are EXTREMELY USEFUL.