Introduction

Sound wave analysis

In order to synthesize sounds successfully, you should understand some of the basic concepts of acoustics relating to sound waves.

Sine waves

A sound wave is a periodic waveform, or shape of sound, that repeats itself over time. The simplest waveform, the sine wave, is represented graphically as shown on the opposite page.

A sine wave can also be represented on a graph called a frequency spectrum. The single component of the sine wave, called the fundamental frequency, is placed at the frequency of the note played. It is also called the first harmonic. In the case of a sine wave, no other harmonics are present.

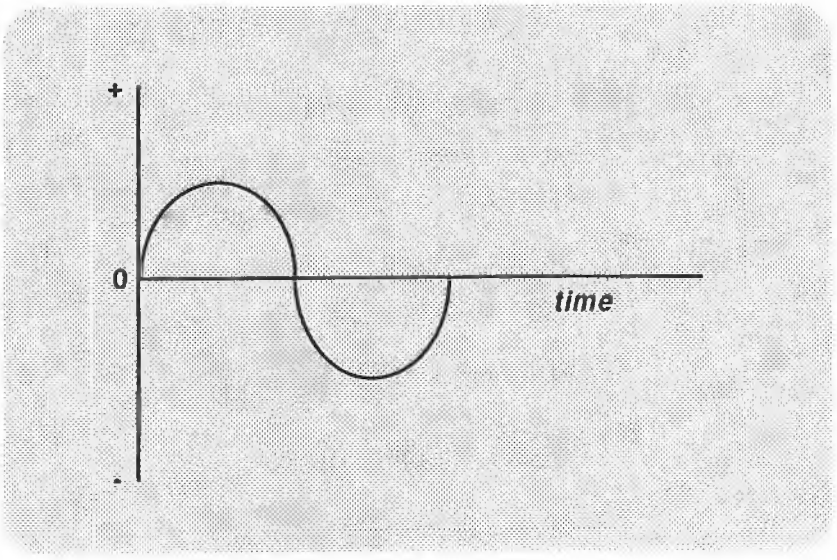


figure 1.1
Sine wave

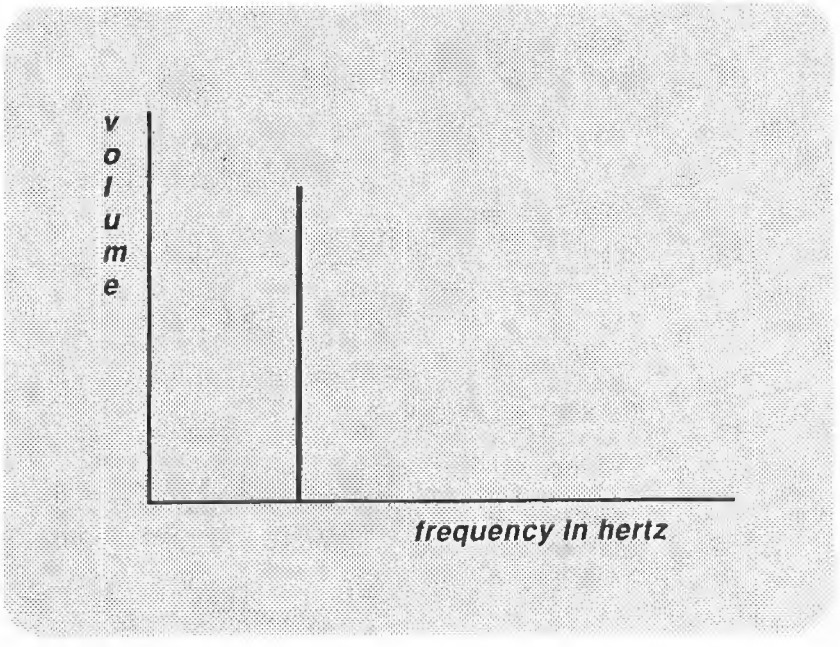


figure 1.2
Harmonic spectrum

Sound wave analysis (con't)

Complex sound waves

Complex waves are created when sine waves are superimposed one upon another. Joseph Fourier, the nineteenth century French mathematician, observed that all periodic waves, no matter how complex, are in fact sine waves of different amplitudes and phases with frequencies at the harmonics of the fundamental, all superimposed one upon another.

A complex wave, like the sawtooth wave sounding at 440 hertz shown in figure 1.3, can be broken down into four sine waves, each with its own volume and period, as shown in figure 1.4

Placed on the frequency spectrum, this wave has four harmonics. The first harmonic, at 440 hertz, with a coefficient of 100, sounds at 100 percent relative volume. The second harmonic at twice the fundamental frequency, or 880 hertz, has a coefficient of 50. The third is at three times the fundamental, or 1320 hertz, and has a coefficient of 33.3. And the fourth is at four times the fundamental, or 1760 hertz, and has a coefficient of 25.

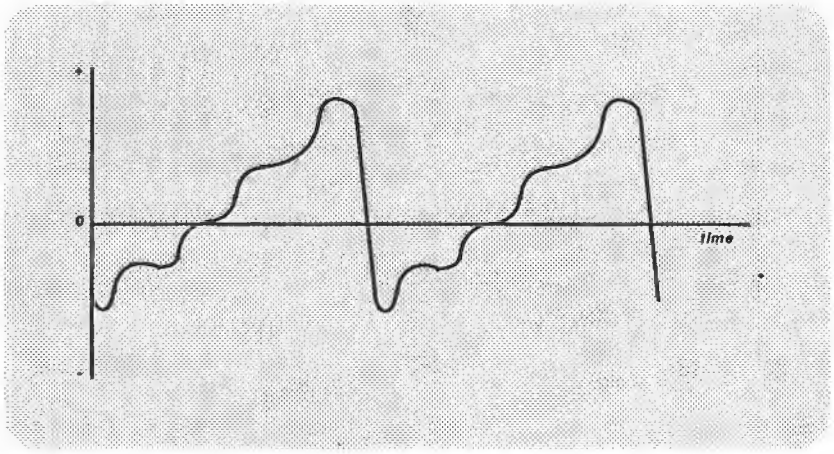


figure 1.3
Sawtooth wave

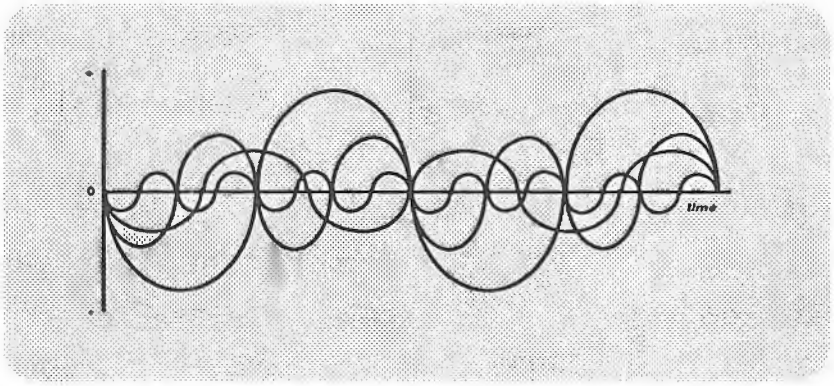


figure 1.4
Four sine waves

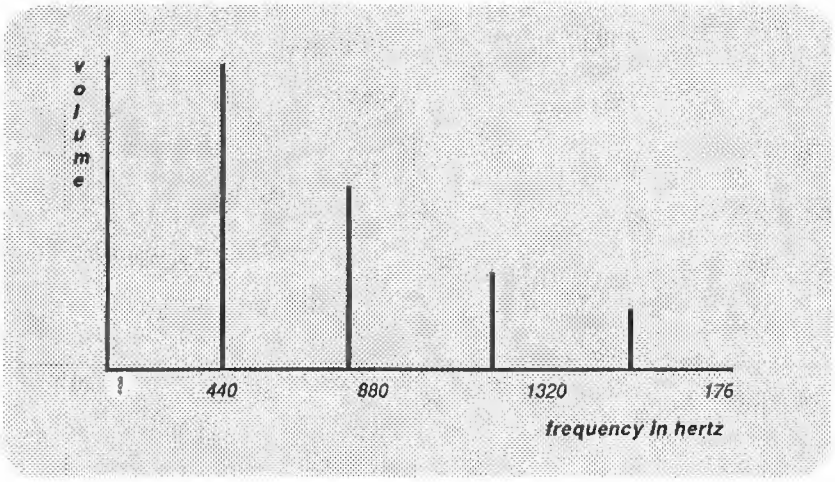


figure 1.5
Harmonic spectrum

Sound wave analysis (con't)

Sound waves of acoustic instruments

The sounds produced by musical instruments are usually much more complex than the above single complex waveform.* Analysis of sounds produced by acoustic instruments shows that not only does each instrument have its own harmonic structure, but also that this structure can vary according to a note's duration, volume and pitch.

For example, when a note is sounded on the piano, the full range of harmonics is present at the attack. After that moment, however, each harmonic has its own rate of decay, so that as the note fades, its harmonic structure is constantly changing.

A clarinet played mezzo forte has the first four odd harmonics present. Yet a note played double forte on a clarinet may have the first seven odd harmonics plus additional even-numbered harmonics, while one played pianissimo may have only the first three odd harmonics.

Sounds produced by an oboe emphasize harmonic frequencies near 1000 hertz and 3000 hertz while frequencies near 2000 hertz are attenuated. Thus, a middle C played on an oboe has louder fourth and twelfth harmonics while a C an octave higher has louder second and sixth harmonics.

---

* A classic textbook on musical acoustics is John Backus, *The Acoustical Foundations of Music* (W.W. Norton and Company, New York, 1969).

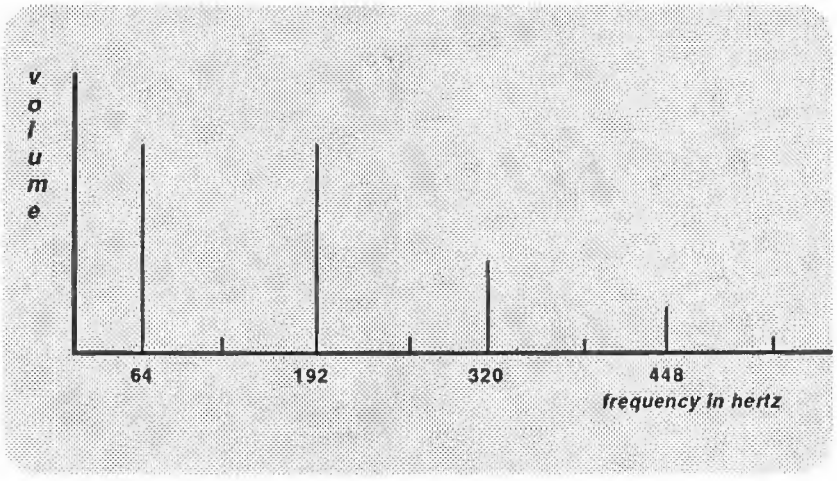


figure 1.6
Clarinet harmonics

Designing sounds for the Synclavier

The Synclavier Digital Audio System provides several techniques for sound design.

Creating the basic waveform

On the Synclavier, you can create a basic waveform using any one of three methods:

- **Additive synthesis** is a process in which simple sine waves are superimposed one on another to create a complex waveform.

  Once a synthesized waveform is created, its harmonic structure can be modified further byadding frequency modulation.

- A **sampled sound** is created by digitally processing a recorded sound. The harmonic structure of a sampled sound cannot be changed by manipulating its harmonics or adding frequency modulation. You can, however, assign different sampled sounds to different parts of the keyboard to create a "keyboard patch."

- **Resynthesized sounds** are created by first analyzing and then synthesizing sampled sounds. They can be developed further using additive synthesis and frequency modulation.

Layering sounds

You can layer up to four synthesized, resynthesized or sampled sounds to create a whole timbre (pronounced tam-ber). Each layer, called a **partial timbre,** is a separate sound with its own harmonic structure and waveform, overall volume level, tuning, and so on.

You can create very complex and dynamic timbres by choosing different sounds for two or more of these partial timbres and controlling them in different ways.

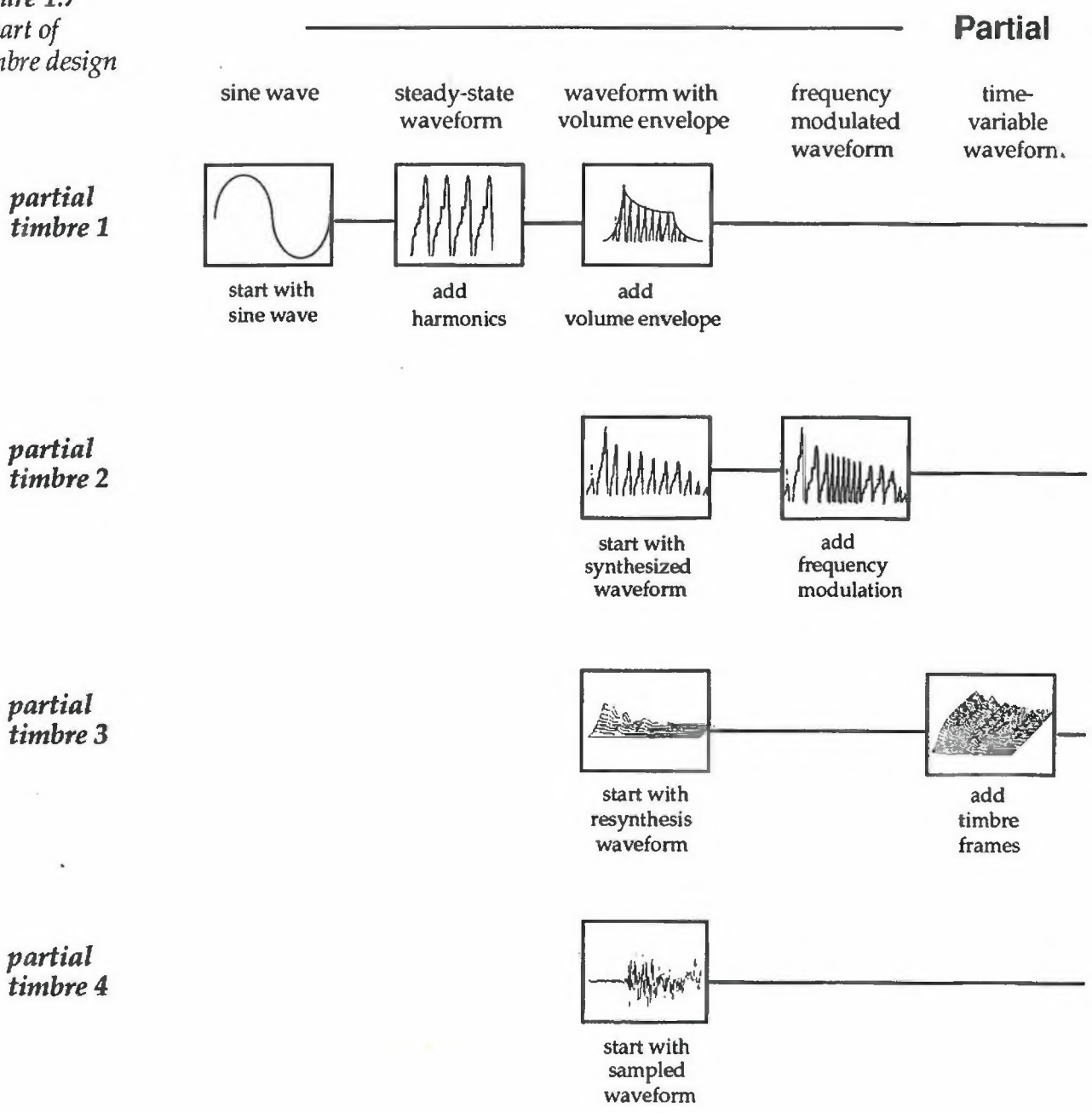
For example, to strengthen the attack of a brass timbre, you might put a percussive sound on one partial timbre. You could also put a very brassy timbre controlled by keyboard pressure on another partial timbre so that the tone could be made more "brassy" by your keyboard touch.

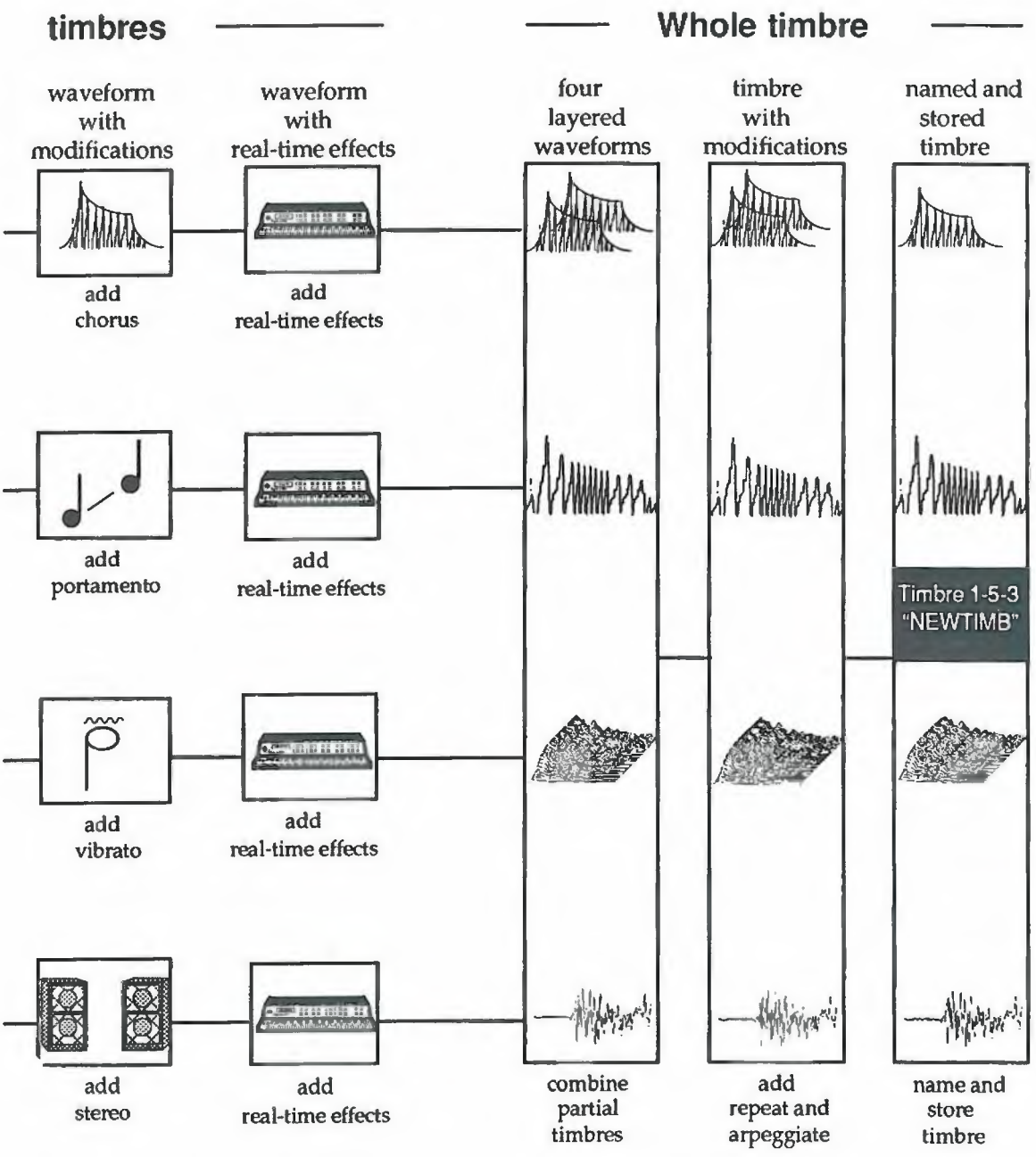
You can also combine two completely different sounds. Listen, for example, to the **flute/vibes** or **guitar/clar** instructional timbres stored in the top-level catalog of

The process of programming a Synclavier timbre is straightforward, yet the result is a complex multifaceted sound. You can start with a single sine wave, an already programmed synthesized waveform, a sampled sound or a resynthesized waveform. Once you have your beginning waveform, you shape it using different techniques.

There are ten basic stages of timbre construction. Each is a separate procedure. None has a predetermined order in the timbre construction process. The sound you choose to begin with and the extent and type of modifications to be made determine the order of construction. The flow chart on the following pages shows only a few of the many possible procedures for designing and constructing a Synclavier timbre.

figure 1.7
Chart of timbre design




timbres
Whole timbre
waveform with modifications
waveform with real-time effects
four layered waveforms
timbre with modifications
named and stored timbre
add chorus
add real-time effects
add portamento
add real-time effects
add vibrato
add real-time effects
add stereo
add real-time effects
Timbre 1-5-3 "NEWTIMB"
combine partial timbres
add repeat and arpeggiate
name and store timbre

Designing sounds for the Synclavier (con't)

Stages of timbre construction

The sine wave. The fundamental unit of any synthesized sound is the sine wave. If you want to start with a sine wave, select the timbre named **sine wave** from the **timbre directory** in the top-level catalog of your Winchester.

The steady-state waveform. A steady-state waveform is a periodic wave with a set number of harmonics. You synthesize such a waveform on the Synclavier using the knob and buttons to dial in the relative volume of up to 24 harmonics.

Waveform with volume envelope. A **volume envelope** shapes a waveform by giving it an **attack, an initial decay, a sustain period** and a **final decay.** You program a volume envelope by setting peak and sustain volume levels and by setting the times for the attack, initial decay and final decay.

Frequency modulated waveform. Frequency modulation adds harmonic components to a synthesized waveform by introducing a modulating frequency into the wave. You can program frequency modulation by setting the times and volume levels of a harmonic envelope.

Time-variable waveform. A time-variable waveform changes its harmonic structure over time. You create such a wave on the Synclavier either by starting with a **resynthesis** sound or by programming the harmonic content and splice times of timbre frames.

Waveform with modifications. A waveform with a steady or varying harmonic structure and volume envelope can be further modified by adding **vibrato, portamento, stereo, chorus** and other effects.

Stages of timbre construction (con't)

Waveform with real-time effects. A waveform with **real-time effects** can have many aspects of its programming varied in real time by the way you play the Synclavier. Any of the parameters set previously can be controlled by your keyboard touch or by the use of one or two pedals, a mod wheel, a ribbon controller or a breath controller.

The layered timbre. Up to four sounds can be combined into a single Synclavier timbre by placing them on selected partial timbres of the keyboard timbre.

Whole timbre modifications. The whole Synclavier timbre can be further modified by adding **chorus** or **repeat/arpeggiate** effects.

Timbre storage. When a Synclavier timbre is complete, you can give it an identifying **name** and place it in a special **storage area** for later recall.

Designing sounds for the Synclavier (con't)

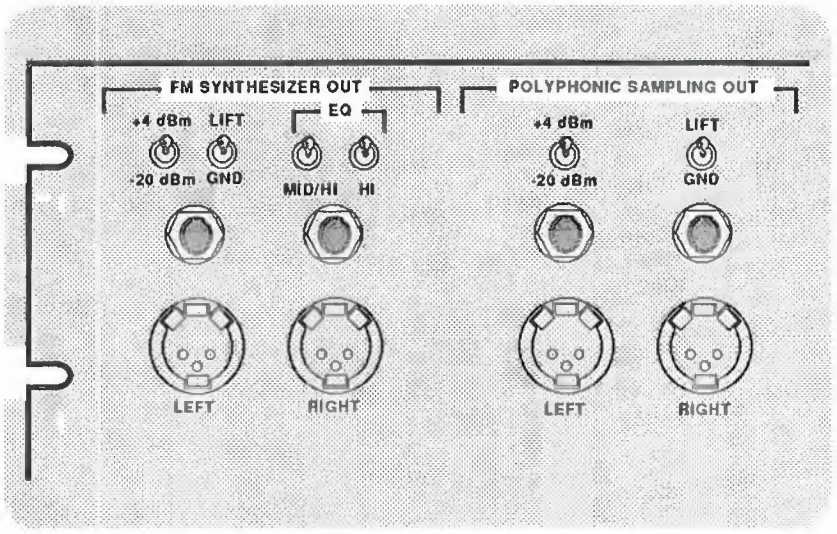
Sound output

The final output of a synthesized sound comes from the Synclavier FM synthesizer voices and is fed through the **FM synthesizer out** jacks on the control unit to your sound system.

The final output of a sampled sound comes from the polyphonic sampling voices and is fed through the **polyphonic sampling out** jacks to your system.

Output from both sources is a composite of the sounds produced by the keyboard, guitar and memory recorder. It is available through both 1/4-inch phone jacks and XLR jacks.

figure 1.8
Output jacks



Recalling sounds to the keyboard

Timbres are brought to the keyboard using either the **timbre directory** on the terminal screen or the **timbre library, bank, entry** and numbered buttons under **timbre/ sequence storage** on the keyboard control panel.

Recalling a timbre from the terminal

To recall a timbre from the terminal, follow these instructions:

1. Select the **timbre directory** from the **welcome** or **main menu** by typing the letter next to **timbre directory.**

2. If the timbre file containing the desired timbre is on another device, choose that device from those shown at the top of the screen by typing the appropriate number.

3. Select the timbre from those listed using the arrow keys and press **<return>**.

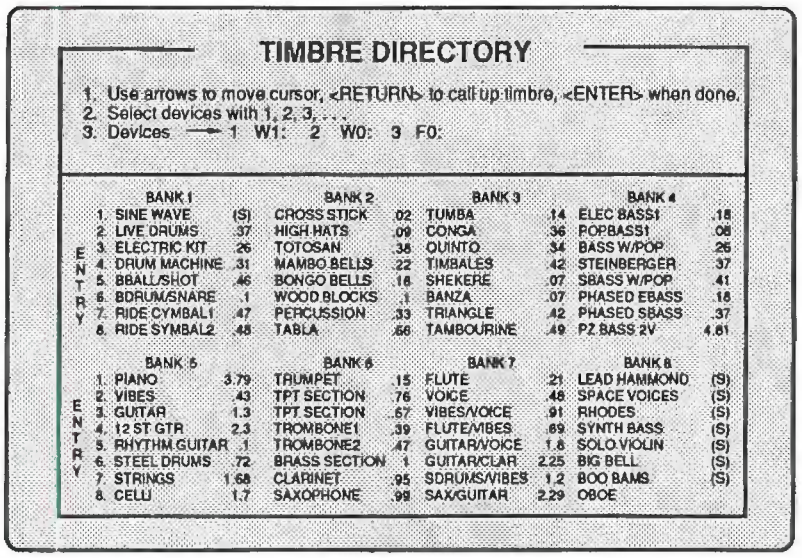


figure 1.9
Timbre directory

Recalling sounds to the keyboard (con't)

Timbre files

The **timbre directory** represents a special timbre storage space called a **timbre file.** Each timbre is ready for immediate recall at any time and always sounds exactly the same.

A timbre file consists of up to eight banks with up to eight timbre entries in each bank. Since some timbres take up more space than others, a bank may have fewer than eight timbres and a timbre file may have fewer than eight banks.

One timbre file is located on your Winchester in the top-level catalog; that is, the storage area of your Winchester that is immediately available when you start the system. Other timbre files can be located in subcatalogs and on floppy disks, one in each storage area.

Timbre identification

When you recall a timbre to the keyboard, the display window shows information about that timbre. The timbre number identifies the library, bank and entry numbers that define the location of the timbre in the timbre file.

Timbres that have been factory preset have been given identifying names. You can use the timbre name function to rename the preset timbres and to name your own timbres.

Following the timbre name in the display window are the expressions

[number] V and [number] F

showing the number of voices and frames in a synthesized timbre. The voices are the number of FM synthesizer channels required to play a single note in that timbre. Frames are the number of spliced-in waveforms in a synthesized or resynthesized timbre. Voices and frames are explained in the section "Resynthesis."

Recalling sounds to the keyboard (con't)

Recalling timbres on floppy disks

If the timbre you want to recall is not in the **timbre directory**, it may be located in a timbre file in a subcatalog on the Winchester or on one of the floppy disks of the *Timbre Library*.

If the timbre you want to recall is on a floppy disk, you can recall it by changing the **timbre directory.**

1. Place the appropriate disk into a floppy drive.

2. Select **F0:** (for **floppy drive 0**) or **F1:** (for **floppy drive 1**) from the list of storage devices across the top of the **timbre directory** by typing the number preceding it.

   The selected **timbre directory** appears on the screen.

Recalling timbres from a subcatalog

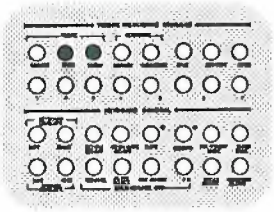
If the timbre you want to recall is stored in a subcatalog of the Winchester, you can recall it using the following procedure:

1. Return to the **welcome menu** by pressing **<enter>**.
2. Select the **subcatalog directory.**
3. Select the desired subcatalog.
4. Return to the **welcome menu.**
5. Select the **timbre directory** again.

   The directory from the selected subcatalog appears on the screen.

Note: Subcatalogs are described in the manual *Organizing and Storing Sounds.*

Recalling sounds to the keyboard (con't)



bank, entry panel 4

Recalling a timbre using the keyboard control panel

When you use the keyboard button panel, you can only recall a timbre from a timbre file in the **current catalog** or from a disk placed in **floppy drive 0.**

To recall a timbre from the current catalog:

1. Press **bank** and then a numbered button to select timbre bank.

2. Press **entry** and then a numbered button to select a timbre entry.

   The timbre is placed on the keyboard, and its data appears in the display window.

Recalling timbres on floppy disks

You can recall a timbre from a floppy disk by following these instructions:

1. Place the disk containing the desired timbre file into the **F0:** drive.

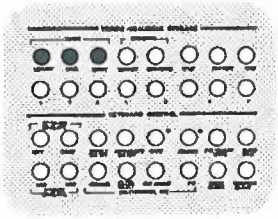
2. Press and hold **timbre library.**

3. Press **bank** and a numbered button for the bank you want to recall.

4. Continue to hold down **library** while you press **entry** and the numbered button for the timbre you want to recall.

   The timbre is placed on the keyboard, and its data appears in the display window.

If the timbre you want is in a subcatalog on the floppy disk, use the **subcatalog directory** on the terminal screen to enter that subcatalog. Then use the buttons as usual.



timbre library, bank, entry